APPENDIX D: STATE AND DISTRICT OF COLUMBIA ANALYSES

NORTH ATLANTIC COAST COMPREHENSIVE STUDY:
RESILIENT ADAPTATION TO INCREASING RISK

STATE CHAPTER

D-7: State of Delaware

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I. Introduction

The purpose of the North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk (NACCS) is to catalyze and spearhead innovation and action by all to implement comprehensive coastal storm risk management strategies. Action is imperative to increase resilience and reduce risk from, and make the North Atlantic region more resilient to, future storms and impacts of sea level change (SLC). Resilience is defined by the U.S. Army Corps of Engineers (USACE) and National Oceanic and Atmospheric Administration's (NOAA) Infrastructure Systems Rebuilding Principles as the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.

The goals of the NACCS are to:

- Provide a risk management framework, consistent with NOAA/USACE Infrastructure Systems Rebuilding Principles; and
- Support resilient coastal communities and robust, sustainable coastal landscape systems, considering future sea level and climate change scenarios, to reduce risk to vulnerable populations, property, ecosystems, and infrastructure.

The NACCS Main Report addresses the entire study area at a regional scale and explains the development and application of the NACCS Coastal Storm Risk Management Framework from a broad perspective. This State Coastal Risk Framework Appendix discusses state specific conditions, risk analyses and areas, and comprehensive coastal storm risk management (CSRM) strategies in order to provide a more tailored Framework for the State of Delaware. Attachments include the Delaware Inland Bays and Delaware Bay Coast Focus Area Analyses (FAA) Report, as well as the State of Delaware response to the USACE State Problems, Needs, and Opportunities correspondence.

II. Planning Reaches

Planning reaches for Delaware have been developed to offer smaller units than state boundaries from which coastal storm risk management (CSRM) coastal resilient community decisions can be made. These planning reaches are based on natural and manmade coastal features including shoreline type, USACE CSRM projects, and the 1 percent floodplain (Figure 1).

Included in Delaware are 3 planning reaches; DE1-3. DE1 includes areas of northern DE and southeastern PA. The reach begins at the confluence of Darby Creek and the Delaware River in Delaware County, PA southwest to the Christina River in New Castle, DE. Major cities/towns include Wilmington, Marcus Hook, and Chester. DE2 includes areas of north central DE. The reach begins at the Christina River and extends to the southern border of Kent County. Major cities/towns include New Castle and Delaware City. DE3 includes the entire coastal shoreline of Sussex County north to south as well as the shorelines of the Delaware Inland Bays. Major cities/towns include Lewes, Rehoboth Beach, Dewey Beach, Bethany Beach, South Bethany Beach, and Fenwick Island.

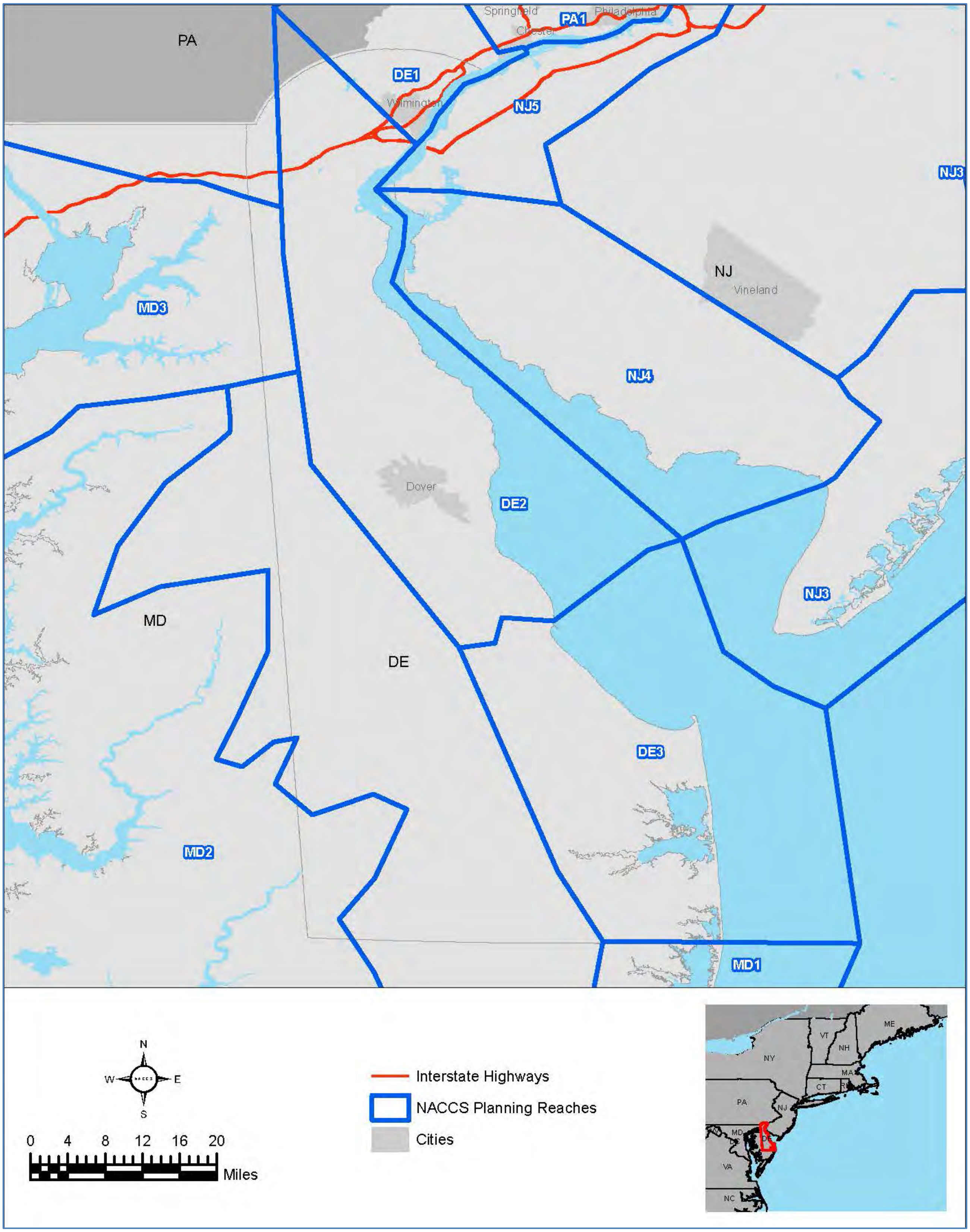

Figure 1. Planning Reaches for the State of Delaware

III. Existing and Post-Sandy Landscape Conditions

III.1. Existing Conditions

The existing conditions are the conditions immediately after the landfall of Hurricane Sandy. This existing conditions analysis includes consideration of the population, supporting critical infrastructure, environmental conditions, inventory of existing coastal storm risk management projects and associated project performance during Hurricane Sandy, the Federal Emergency Management Agency (FEMA) and Small Business Administration response and recovery efforts, FEMA flood insurance claims, and shoreline characteristics that were vulnerable to coastal flood risk associated with Hurricane Sandy. Development of detailed existing conditions across the study area illuminates the vulnerabilities to storm damage that exist. This process helps to identify coastal risk reduction and resilience opportunities. The existing condition serves as the base against which all proposed risk reduction and resilience are compared. Further discussion of the existing conditions is provided in Appendix C – Planning Analyses.

The existing conditions for the State of Delaware are summarized in that while the Atlantic Ocean coast is well protected owing to a significant number of Federal coastal storm risk management projects, the Delaware Inland Bays and Delaware Bay coasts are not well protected due to the limited number of Federal coastal storm risk management projects. The existing conditions are further discussed herein through an analysis of the population and supporting critical infrastructure affected by Hurricane Sandy within the study area. Figure 2 and Table 1 summarize pertinent information regarding population affected by Hurricane Sandy.

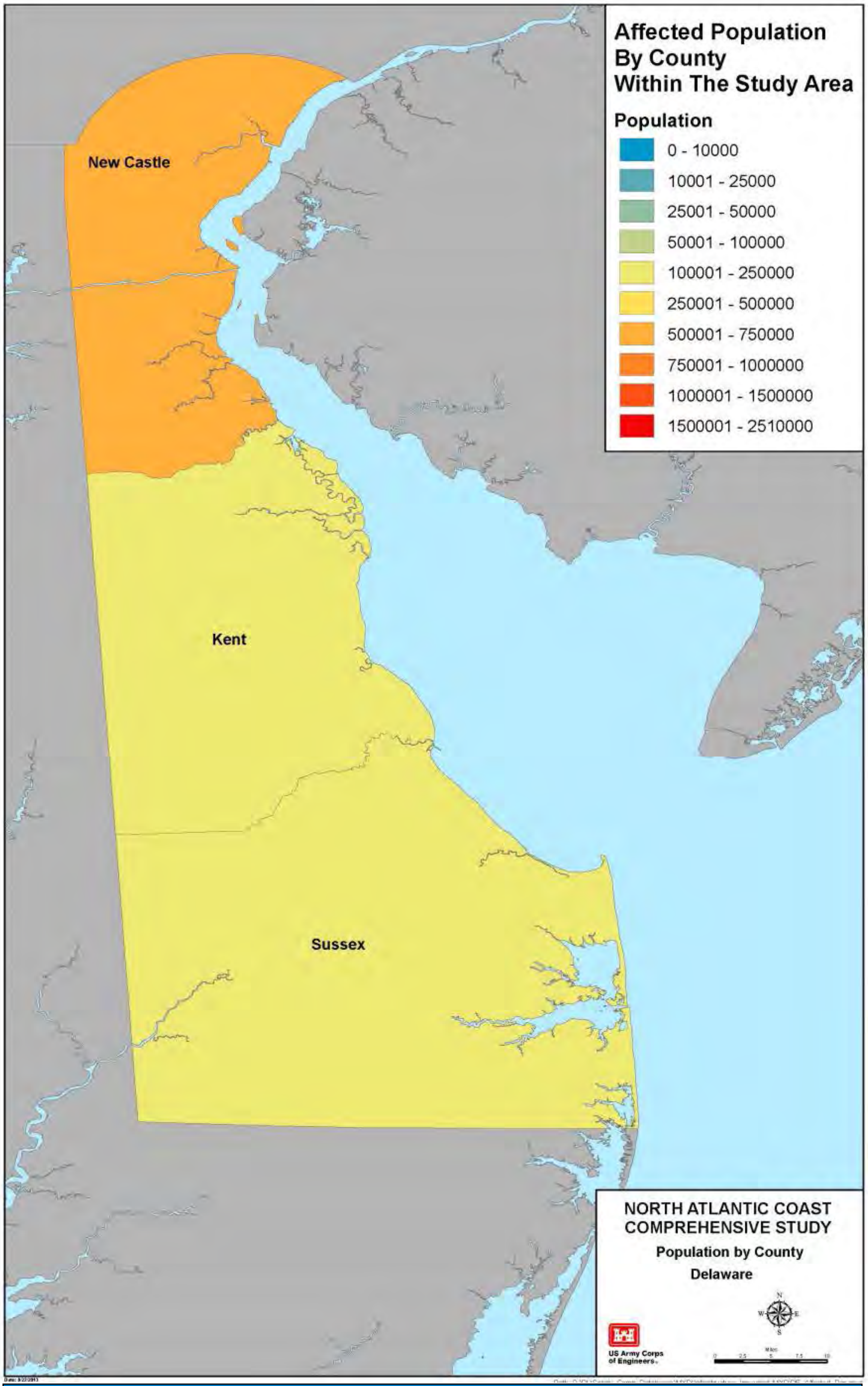

Figure 2. Affected Population by Hurricane Sandy for the State of Delaware (U.S. Census Data, 2010)

Table 1. Affected Population by Hurricane Sandy for the State of Delaware

County	Population
Kent	162,310
New Castle	538,479
Sussex	197,145
Total Population Affected	**897,934**

Figure 3 and Table 2 summarize pertinent information regarding infrastructure affected by Hurricane Sandy. Critical infrastructure elements include sewage, water, electricity, academics, trash, medical, and safety.

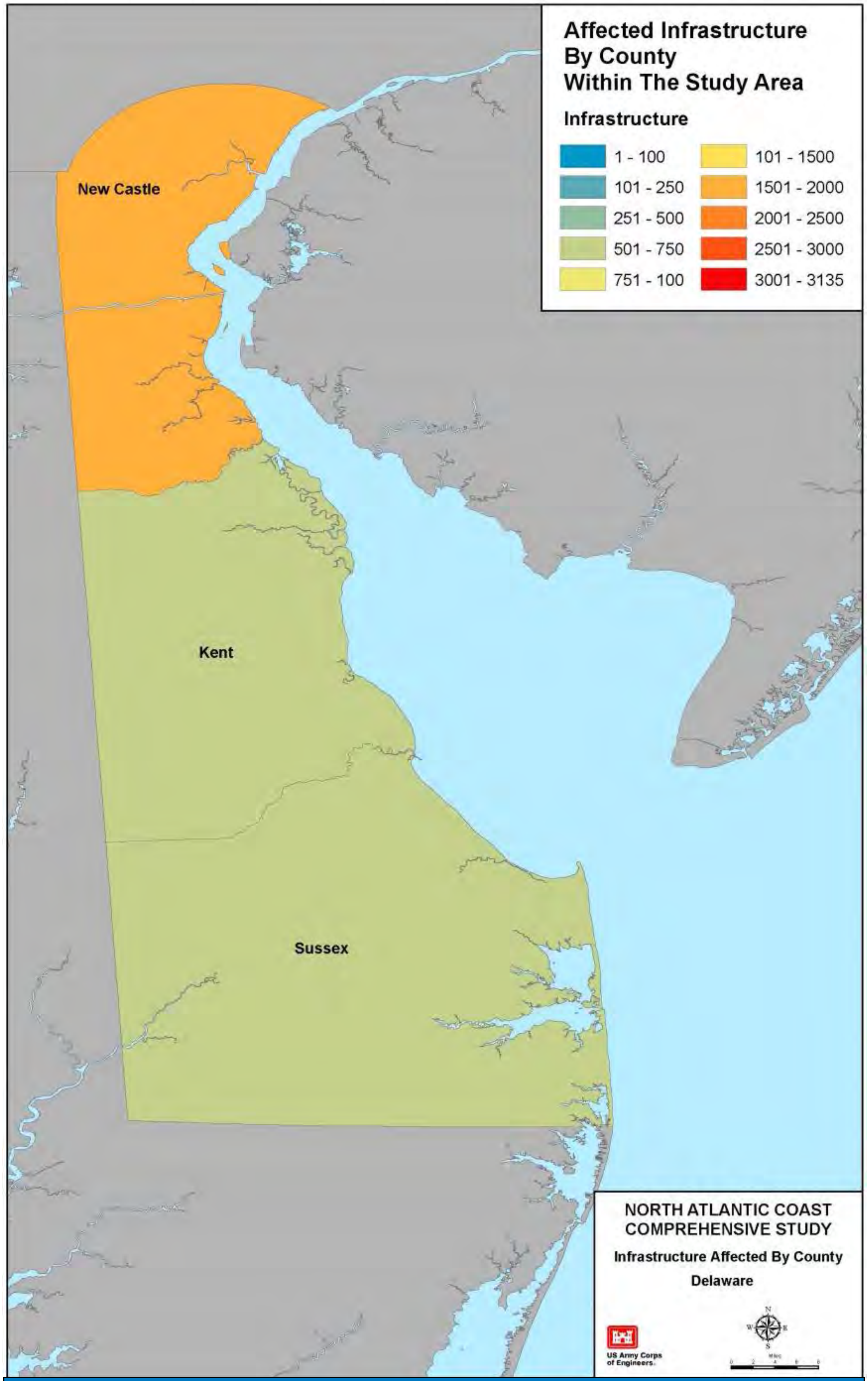

Figure 3. Affected Infrastructure by Hurricane Sandy for the State of Delaware

Table 2. Affected Infrastructure Elements by Hurricane Sandy

County	Infrastructure
Kent	598
New Castle	1,611
Sussex	661
Total Infrastructure Affected	**2,870**

A detailed discussion of the environmental existing conditions is provided in the Environmental and Cultural Resources Conditions Report.

III.2. Post-Sandy Landscape

The post-Sandy landscape condition is defined as the forecasted scenario or most likely future condition if no NACCS CSRM action is taken, and is characterized by CSRM projects and features, and socio-economic, environmental, and cultural conditions. This condition is considered as the baseline from which future measures will be evaluated with regard to reducing coastal storm risk and promoting resilience. A base year of 2018 has been identified when USACE projects discussed below will be implemented/constructed.

A total of 10 USACE projects in Delaware are included in the post-Sandy landscape condition. Seven of these projects are CSRM projects and three are navigation (NAV) projects (Figure 4). A complete list of existing USACE projects within the entire study area is presented in the Planning Analyses Appendix.

The post-Sandy landscape condition also includes active (at the time of the landfall of Hurricane Sandy) state and local/community CSRM projects in the State of Delaware. Some of these projects may have been damaged during Hurricane Sandy. USACE understands that the State of Delaware and the local communities have or are currently rebuilding and restoring the shoreline and damaged infrastructure and property to pre-Sandy conditions under emergency authorities and programs. Given this priority and the apparent lack of resources to commence new CSRM efforts at this time, the USACE has made the assumption that the states' most likely future condition will be the pre-Sandy condition. The State of Delaware was queried with regards to the statement's accuracy in a May 23, 2013 letter, and there was no disagreement as to the statement's accuracy.

Active State of Delaware CSRM projects (at the time of the landfall of Hurricane Sandy) were inventoried and mapped as shown in Figure 4. A detailed discussion of the environmental existing conditions is provided in the Environmental and Cultural Resources Conditions Report.

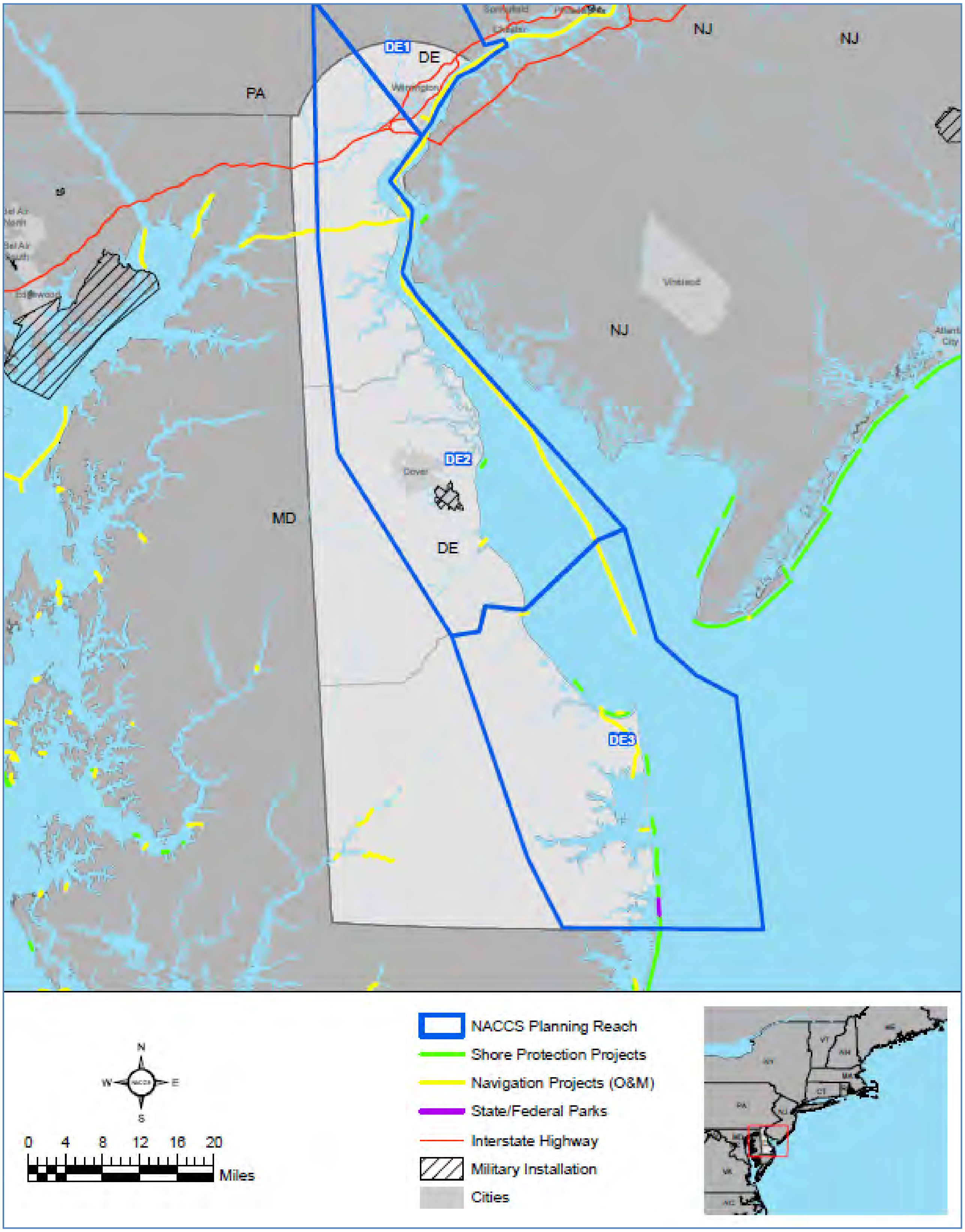

Figure 4. Federal Projects Included in the Post-Sandy Landscape Condition

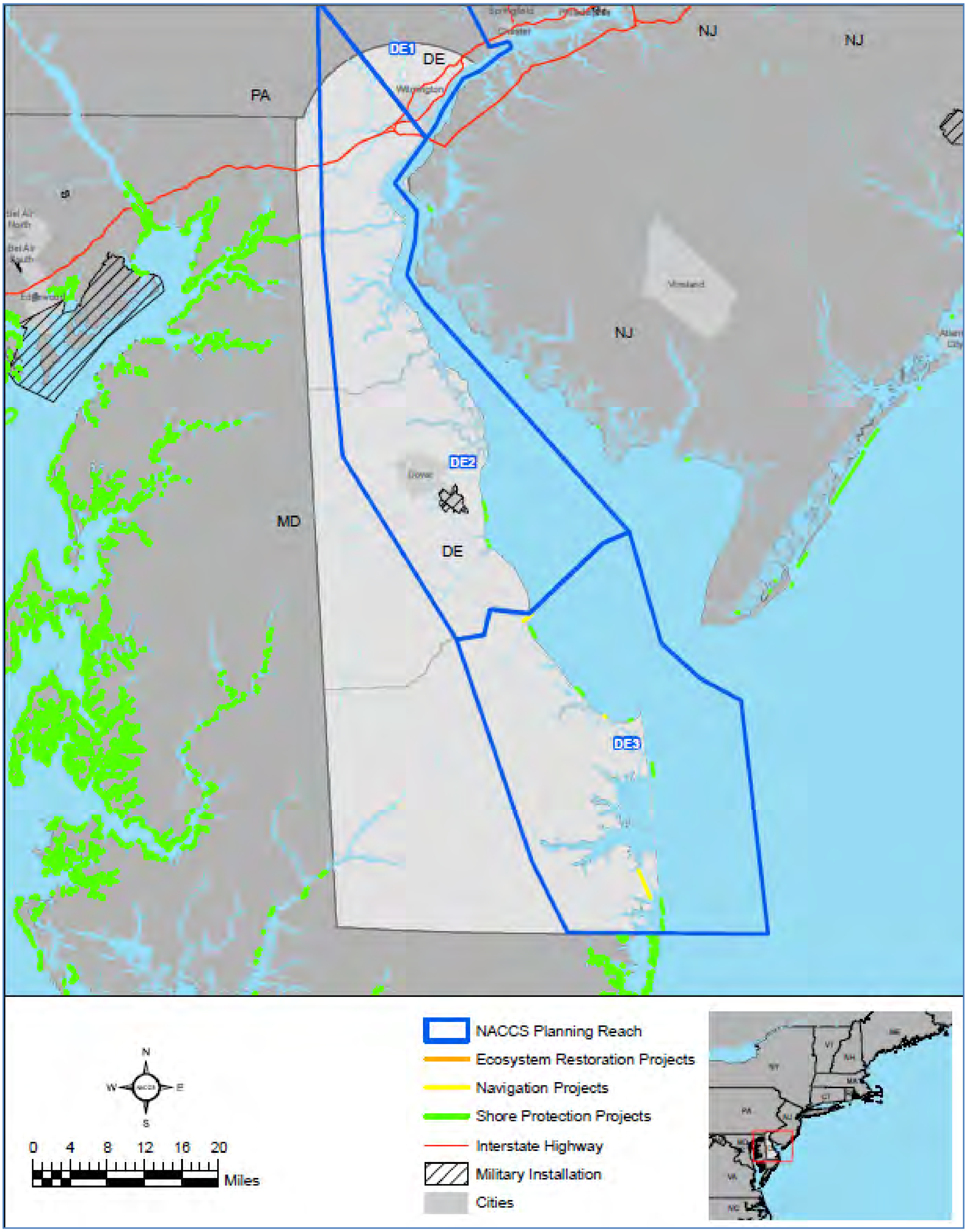

Figure 5. State Projects Included in the Post-Sandy Landscape Condition

Sea Level Change

The current USACE guidance on development of sea level change (USACE, 2013) outlines the development of three scenarios: Low, Intermediate, and High (Figure 6). The NOAA High scenario (NOAA, 2012) is also plotted in Figure 6. The details of different scenarios and their application to the development of future local, relative sea level elevations for the NACCS study area are discussed in greater detail in the Main Report.

These USACE and NOAA future sea level change scenarios have been compared to state or region specific sea level change scenarios. The scenario presented in the Delaware SLR Advisory Committee's "Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment for the State of Delaware, June 2012", is frequently referenced, if unofficially, by various bureaus within the State of Delaware (Figure 6). Comparison of the USACE Low, Intermediate, and High and NOAA High relative sea level change scenarios (for the Lewes, DE NOAA tide gauge) with the Delaware SLR Advisory Committee scenarios for the State of Delaware indicate similar trends but some uncertainty in future water levels. Thus, importance should be placed on scenario planning rather than on specific, deterministic single values for future sea level change. Such sea level change scenario planning efforts will help to provide additional context for state and local planning and assessment activities.

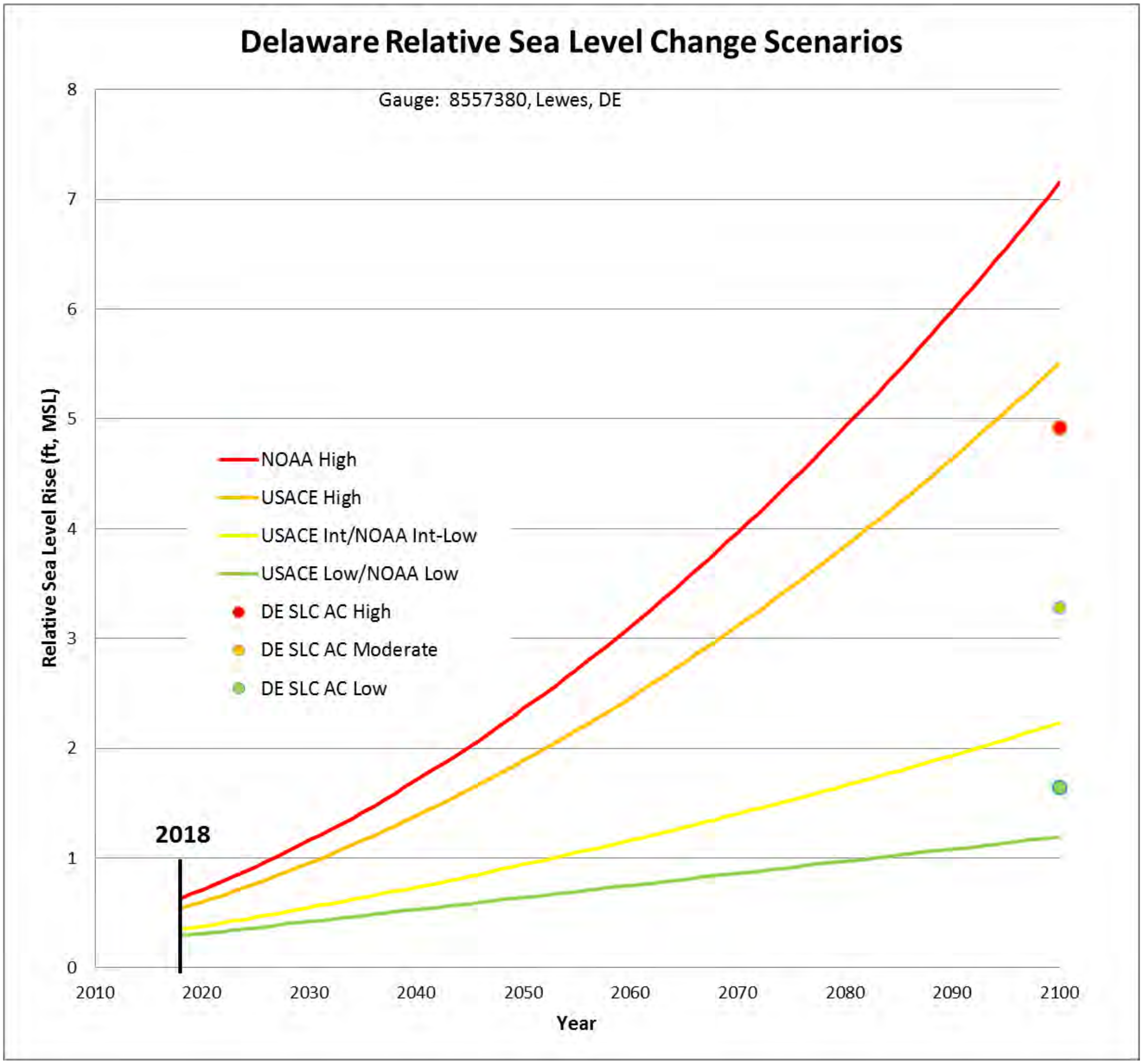

Figure 6. Relative Sea Level Change for Delaware (Delaware SLR Advisory Committee, 2012) and for Lewes,DE for USACE and NOAA Scenarios.

To consider the effects of sea level change on the future landscape change, future sea level change scenarios have been developed by the USACE (ER 1100-2-8162, 2013) and NOAA (2012). Figure 7 shows areas that would be below mean sea level at three future times (2018, 2068, 2100) based on the USACE “High” Scenario. A detailed discussion of mapping basis and technique for this and other mapping is provided in Appendix C – Planning Analyses.

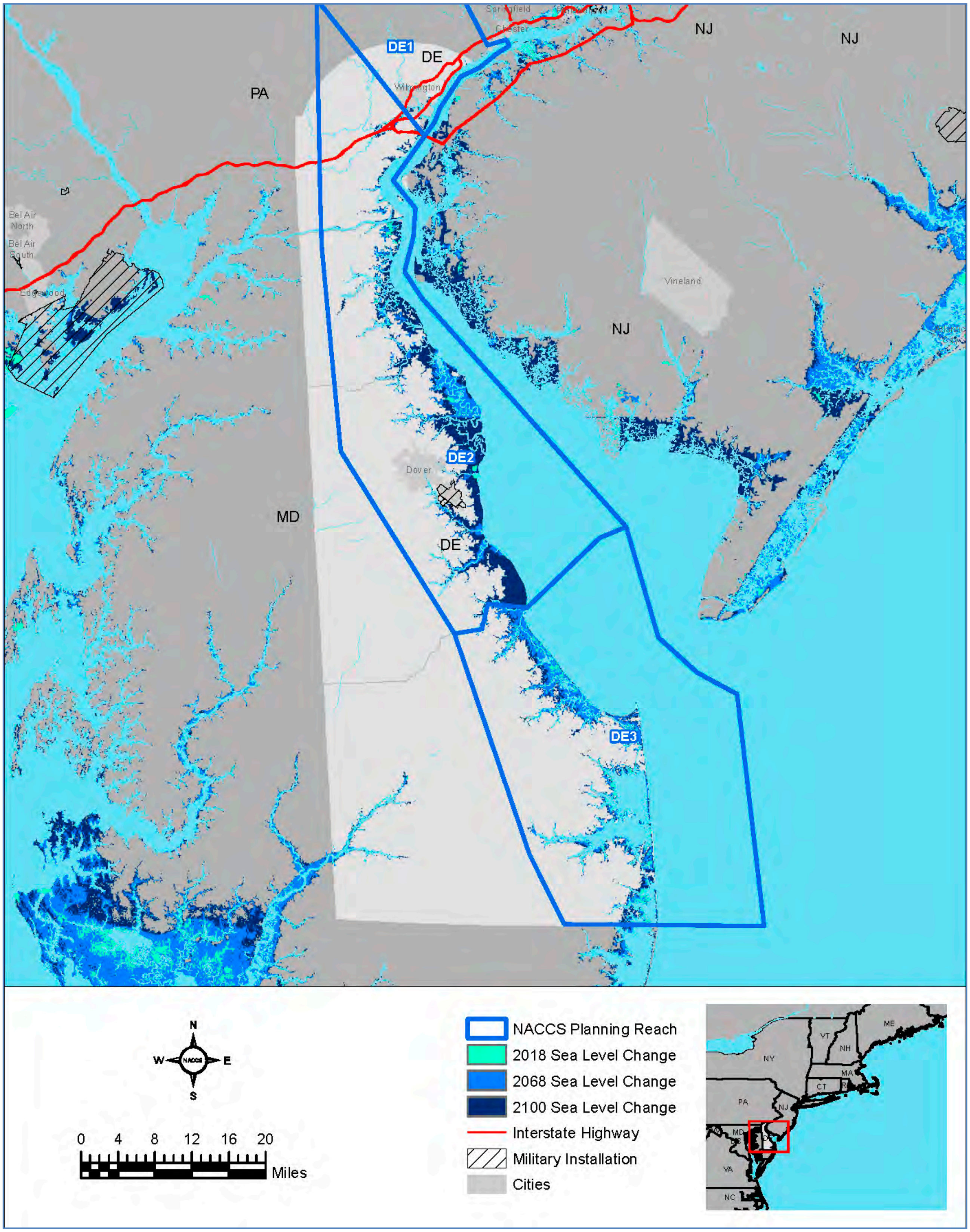

Figure 7. USACE High Scenario Future Mean Sea Level Mapping for the State of Delaware

Forecasted Population and Development Density

Using information and datasets generated as part of the U.S. Environmental Protection Agency's (EPA) Integrated Climate and Land Use Scenarios (ICLUS), inferences to future population and residential development increases by 2070 were evaluated (USEPA, 2009). Figure 8 presents the USACE High scenario inundation and the forecasted increase in residential development density derived from ICLUS data for Delaware. Changes to environmental and cultural resources and social vulnerability characteristics will not be considered as part of the overall forecasted exposure index assessment. Discussions of likely future impacts with respect to sea level change on environmental and cultural resources will be considered in the Environmental and Cultural Resources Conditions Report. Additional information related to the forecasted population and development density is included in Appendix C – Planning Analyses.

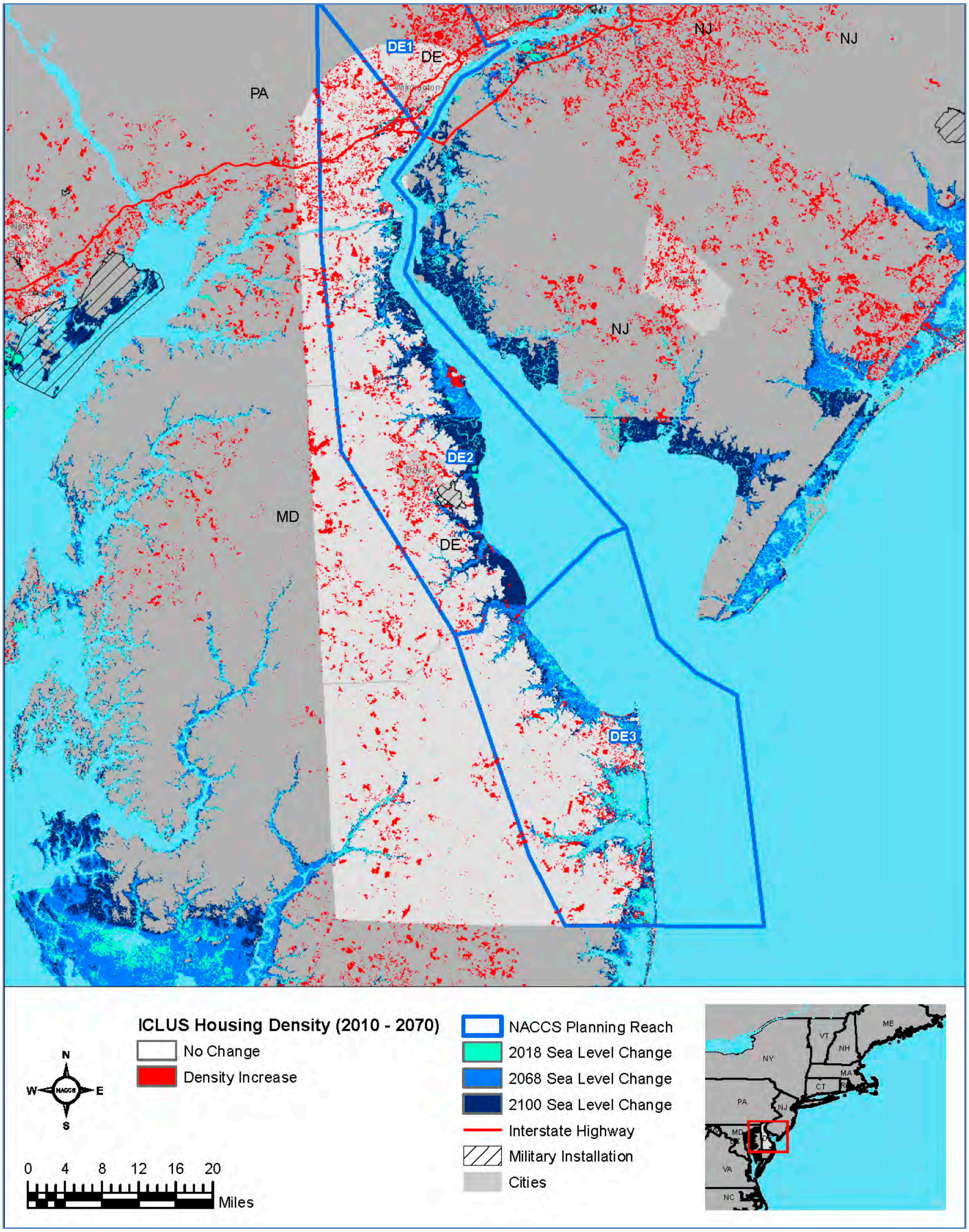

Figure 8. USACE High Scenario Future Mean Sea Level Inundation and Forecasted Residential Development Density Increase for the State of Delaware

Extreme Water Levels

As part of the Coastal Storm Risk Management Framework, the extent of coastal flood hazard was completed by using readily available 1 percent flood mapping from FEMA, preliminary 10 percent flood values from the Engineer Research and Development Center (ERDC) extreme water level analysis, and the Sea, Lake, and Overland Surge from Hurricanes (SLOSH) modeling conducted by NOAA. The inundation zones identified by the SLOSH model depict areas of possible flooding from the maximum of maximum (MOM) event within the five categories of hurricanes by estimating the potential surge inundation during a high tide landfall. Although the SLOSH inundation mapping is not referenced to a specific probability of occurrence (unlike FEMA flood mapping, which presents the 0.2 percent and 1 percent flood elevation zones), a Category 4 hurricane making landfall during high tide represents an extremely low probability of occurrence but high magnitude event. In most cases, it is only possible to provide risk reduction to some lower level like the 1 percent flood. Figure 9 presents the SLOSH hydrodynamic modeling inundation mapping associated with Category 1 through 4 hurricanes.

Figure 10 presents the approximate 1 percent floodplain plus 3 feet for the same area to illustrate areas exposed projected inundation levels which are closely aligned with the USACE high scenario for projected sea level change by year 2068. Areas between the Category 4 and 1 percent plus 3-foot floodplain represent the residual risk for those areas included in the NACCS study area and Category 4 MOM floodplain.

Figure 11 presents the limit of the current 10 percent floodplain (an area with a 10 percent or greater chance of being flooded in any given year). The purpose of the 10 percent floodplain is to consider the possibility of surge reduction related to some natural and nature-based features (NNBF) management measures such as wetland, living shorelines, and reefs.

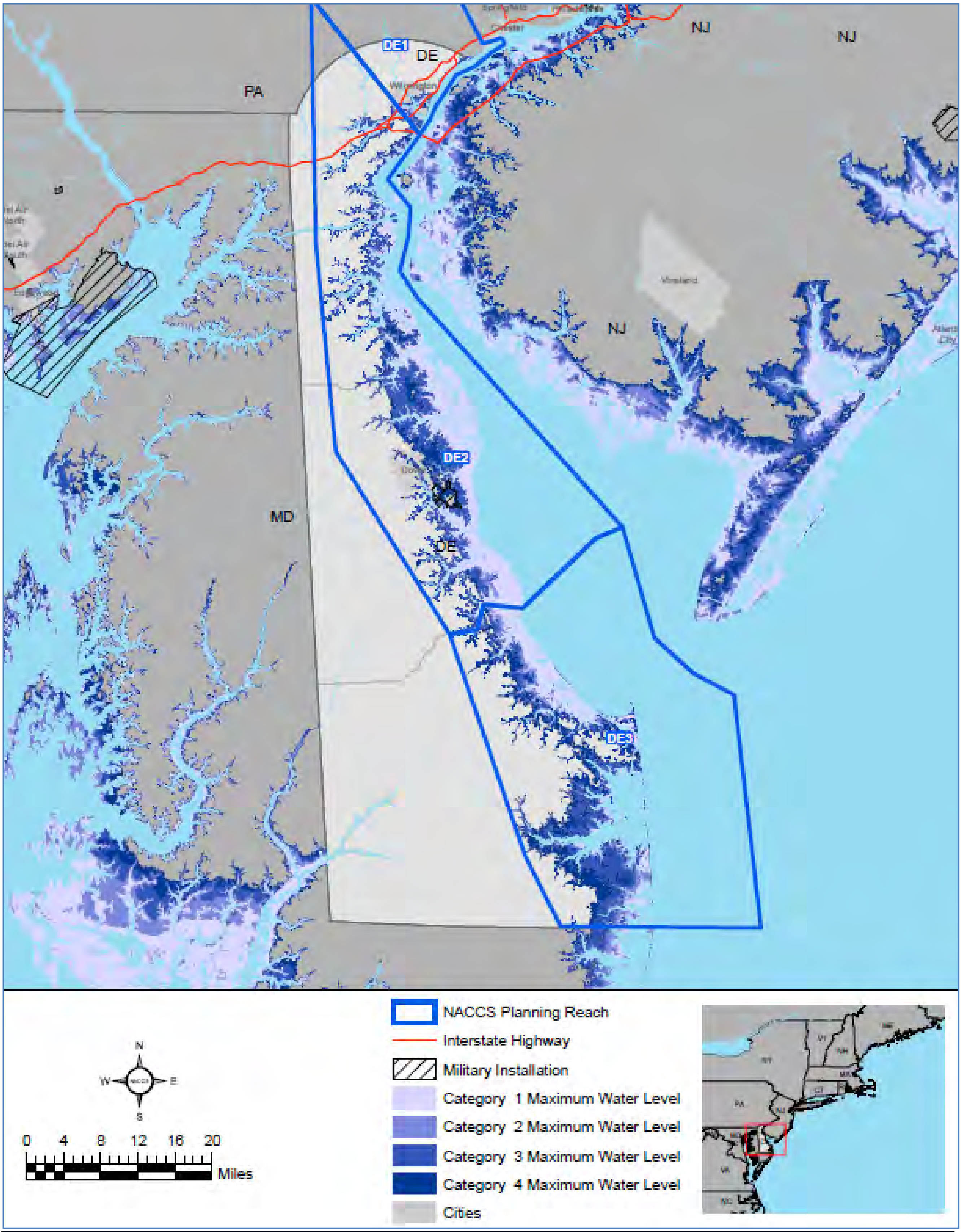

Figure 9. Impacted Area Category 1-4 Water Levels for the State of Delaware

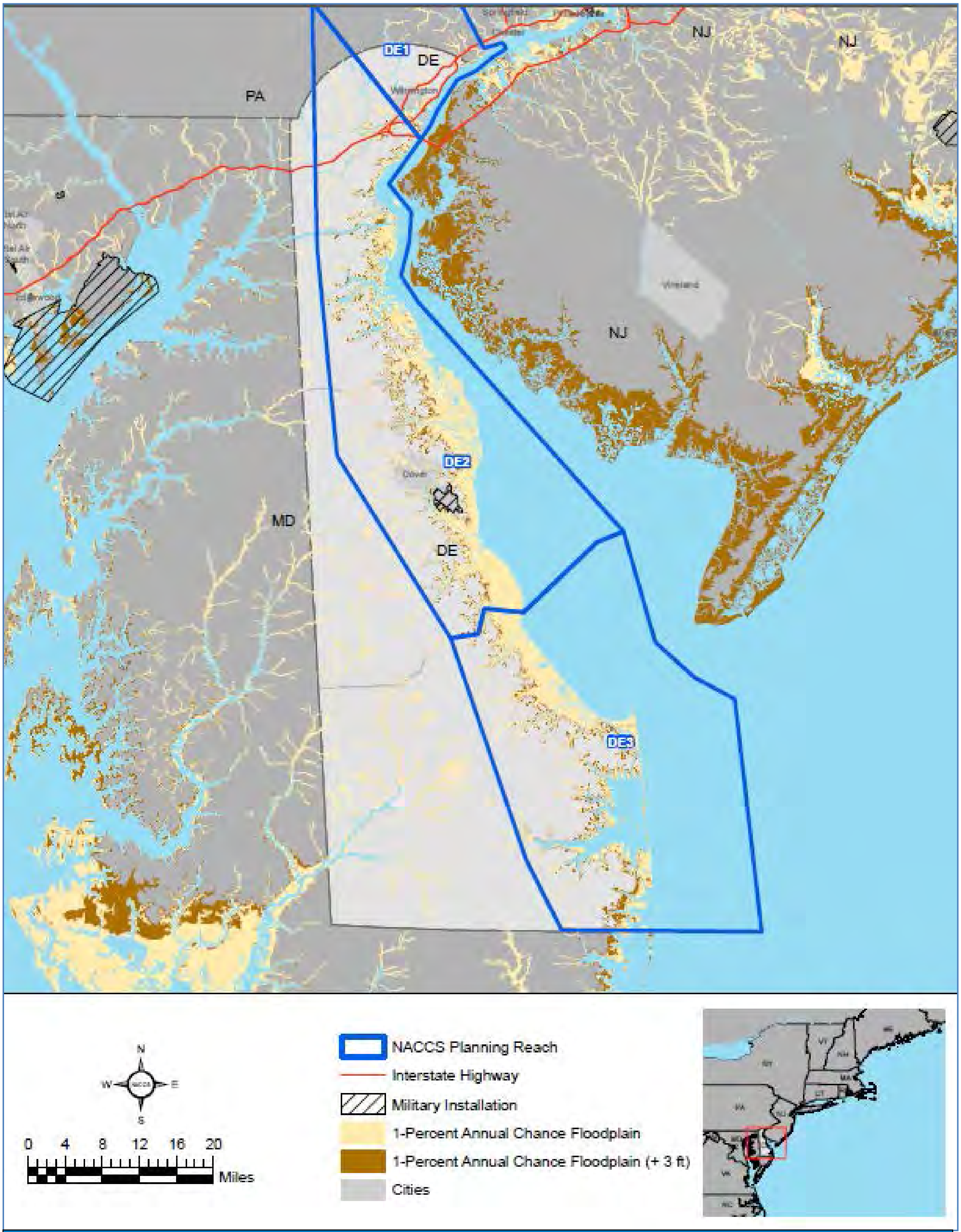

Figure 10. Impacted Area 1 Percent + 3 feet Water Surface for the State of Delaware

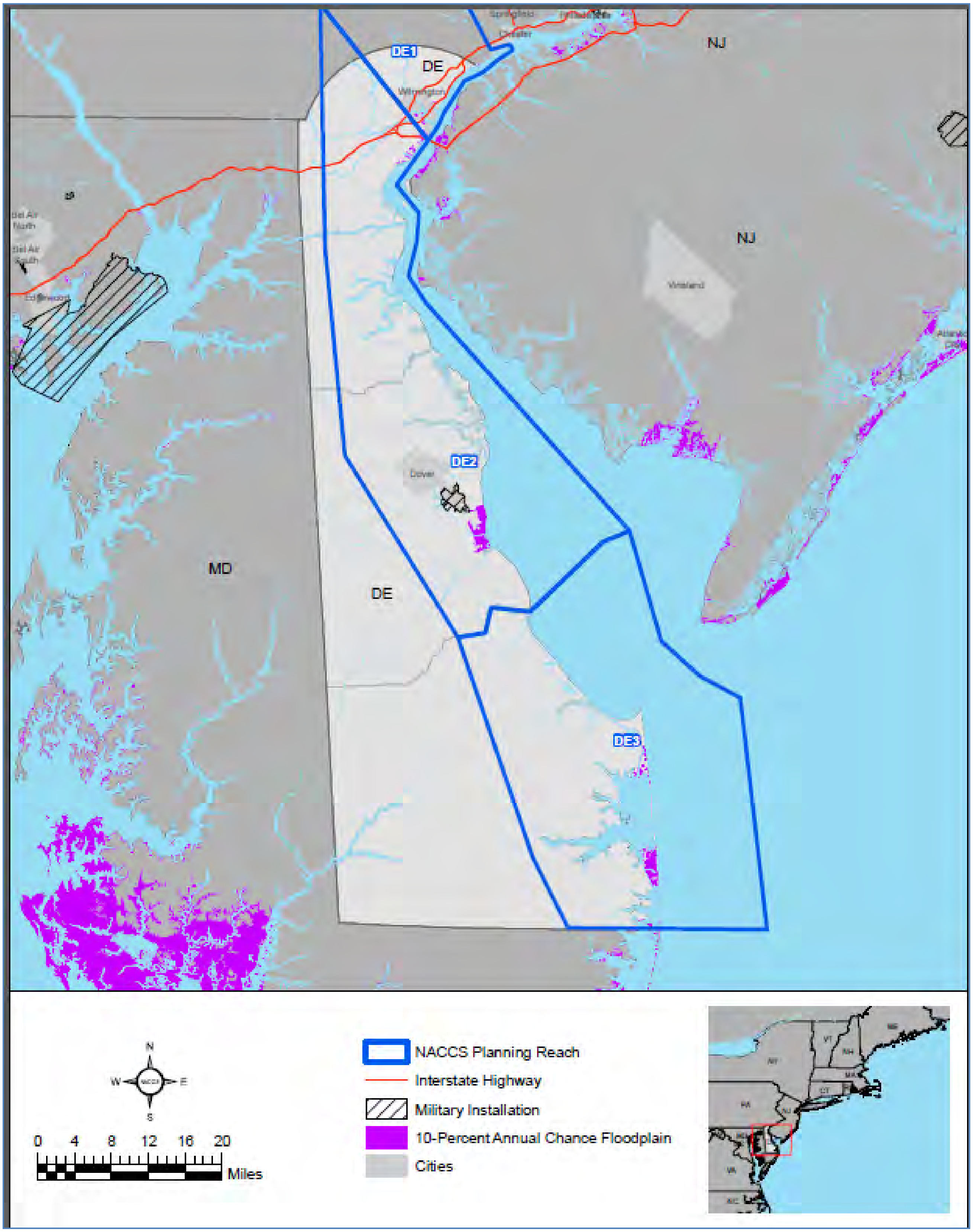

Figure 11. Impacted Area 10 Percent Water Surface for the State of Delaware

Environmental Resources

Delaware's beaches include a berm and dune system that naturally migrates landward, but infrastructure built on areas along the coast block that process. Sand beaches and vegetated dunes provide an important buffer between coastal waters and infrastructure. Sea level change and climate change can have significant impacts to this buffer if nothing is done to protect this habitat, as more frequent periods of sustained high water as a result of sea level change in combination with high wave energy associated with storms contribute to erosion and overwash of natural beaches.

It is expected that CSRM projects constructed by USACE would continue to receive renourishment for 50 years after initial construction. The remaining beaches and dunes that are not maintained by the state and local communities are at risk of damage from sea level change. If beaches are armored, adjacent beaches will erode and sediments will not be available for natural replenishment of sand in areas that are not supplemented with beach nourishment projects. In many areas this will eliminate beach nesting habitat for terrapins and horseshoe crabs and foraging habitat for birds by small beach organisms found within or on the sandy substrate or beach wrack.

Millions of birds migrating along the mid-Atlantic flyway depend on horseshoe crab (*Limulus polyphemus*) eggs laid on sandy beaches along the Delaware Bay. The loss of these sandy beaches to sea level change could be devastating to horseshoe crabs, birds, including the red knot, coastal birds, nesting terrapins, and other wildlife.

Delaware's estuarine barriers and beach strands naturally migrate landward as the shoreline retreats due to erosion. Development along the coast can inhibit the migration process. If there is no room for migration, unprotected areas will erode. When subject to sea level change, narrow, low elevation barrier island communities will become more susceptible to storm overwash, barrier segmentation, and the creation of new tidal inlets. This could lead to a decrease in habitat availability.

Coastal wetlands have the potential adapt and keep pace with sea level change through vertical accretion and inland migration if there is space available at the same elevation relative to the tidal range and a stable source of sediment. Sea level change forces coastal wetlands to migrate inland causing upslope transitional brackish wetlands to convert to saline marshes and the saline marshes on the coastline to drown or erode. Delaware coastal wetlands that are adjacent to human development or seawalls that block natural wetland migration paths will be inundated and will likely convert to open water or intertidal mud flats. In addition, these wetlands will generally be unable to accrete at a pace greater or equal to relative sea level change, so a change in sea level will cause a net loss of marsh acreage. Tidal marshes in the Delaware Estuary are particularly vulnerable to sea level change because excess nutrients have promoted top heavy vegetation highly susceptible to erosion. This habitat is critical for numerous nesting birds, birds migrating along the Atlantic Flyway, diamondback terrapin, marsh dwelling fish, shellfish, and other species. The loss of these wetlands could also lead to the loss of secondary ecosystem services, such as flood risk management, nutrient storage, and water filtration.

Coastal freshwater wetlands in Delaware are particularly sensitive to extreme high tides resulting from an increase in storm frequency or magnitude; these high tides can carry salts inland to salt-intolerant vegetation and soils. If these coastal freshwater wetland communities are unable to shift inland due to lack of space, freshwater flora and fauna could be displaced by salt-tolerant species, likely leading to a loss of biodiversity. Freshwater and brackish impoundments are also at risk of breaching and saltwater intrusion as a result of sea level change, resulting in conversion to open water and the loss of breeding, resting, and wintering habitat for a variety of resident waterfowl, shorebirds, wading birds, and various bird species migrating along the Atlantic Flyway.

Sea level change could result in the inundation of tidal mud flats and this would eliminate critical foraging opportunities for birds. The tidal flats of Delaware's back bays are especially vulnerable, as these are critical foraging areas for hundreds of species of shorebirds, passerines, raptors, waterfowl, and finfish.

Freshwater swamps, such as those dominated by red maple, seaside alder, and Atlantic white cedar will not survive permanent saltwater intrusion and are thus at very high risk from sea level change. This habitat will be lost if nothing is done and there is no room to migrate landward.

Sea level change could also have an impact on large bird populations are found on marsh islands and islands created with dredged material in the back bays. Loss of marsh area as a result of sea level change would have negative implications for the hundreds of thousands of shorebirds that stop in marshes along the Atlantic Flyway to feed and rest during their annual migrations.

Although there is generally more room for wetlands to migrate in parks and refuges, these areas will still lose salt and freshwater marshes and dry land to open water as a result of the effects of sea level change.

A more detailed explanation of these effects can be found in the Environmental and Cultural Resources Conditions Report.

IV. NACCS Coastal Storm Exposure and Risk Assessments

The extent of flooding, as presented in Figures 9 to 11, was used to delineate the areas included in the coastal storm risk and exposure assessments. An exposure index was created for population density and infrastructure, social vulnerability characterization, and environmental and cultural resources. In addition, the three individual indices were combined to create a composite exposure index. The purpose of combining individual exposure indices into a composite index was to provide an illustration of example values for features of the system, with population density and infrastructure weighted at 80 percent of the total index, and social vulnerability characterization and environmental and cultural resources weighted at 10 percent each. To meet the legislative direction to focus on vulnerable coastal populations, the weighting of 80 percent for population and infrastructure for illustrative purposes reflects this intent. For the purpose of the Framework, the overall composite exposure assessment identified areas with the potential for relative higher vulnerability considering collectively the natural, social, and built components of the system. Additional information related to the development of the NACCS risk and exposure assessments is presented in Appendices B – Economics and Social Analyses, and C – Planning Analyses.

IV.1. NACCS Exposure Assessment

The Tier 1 assessment first required identifying the various categories to best characterize exposure. Although a myriad of factors or criteria can be used to identify exposure, the NACCS focused on the following categories and criteria, as emphasized in Public Law (PL) 113-2.

Population Density and Infrastructure Index

Population density includes identification of the number of persons within an areal extent across the study area; infrastructure includes critical infrastructure that supports the population and communities. These factors were combined to reflect overall exposure of the built environment. Figure 12 presents the population density and infrastructure exposure index. Figure 13 presents the percentages of infrastructure included within the population density and infrastructure exposure index.

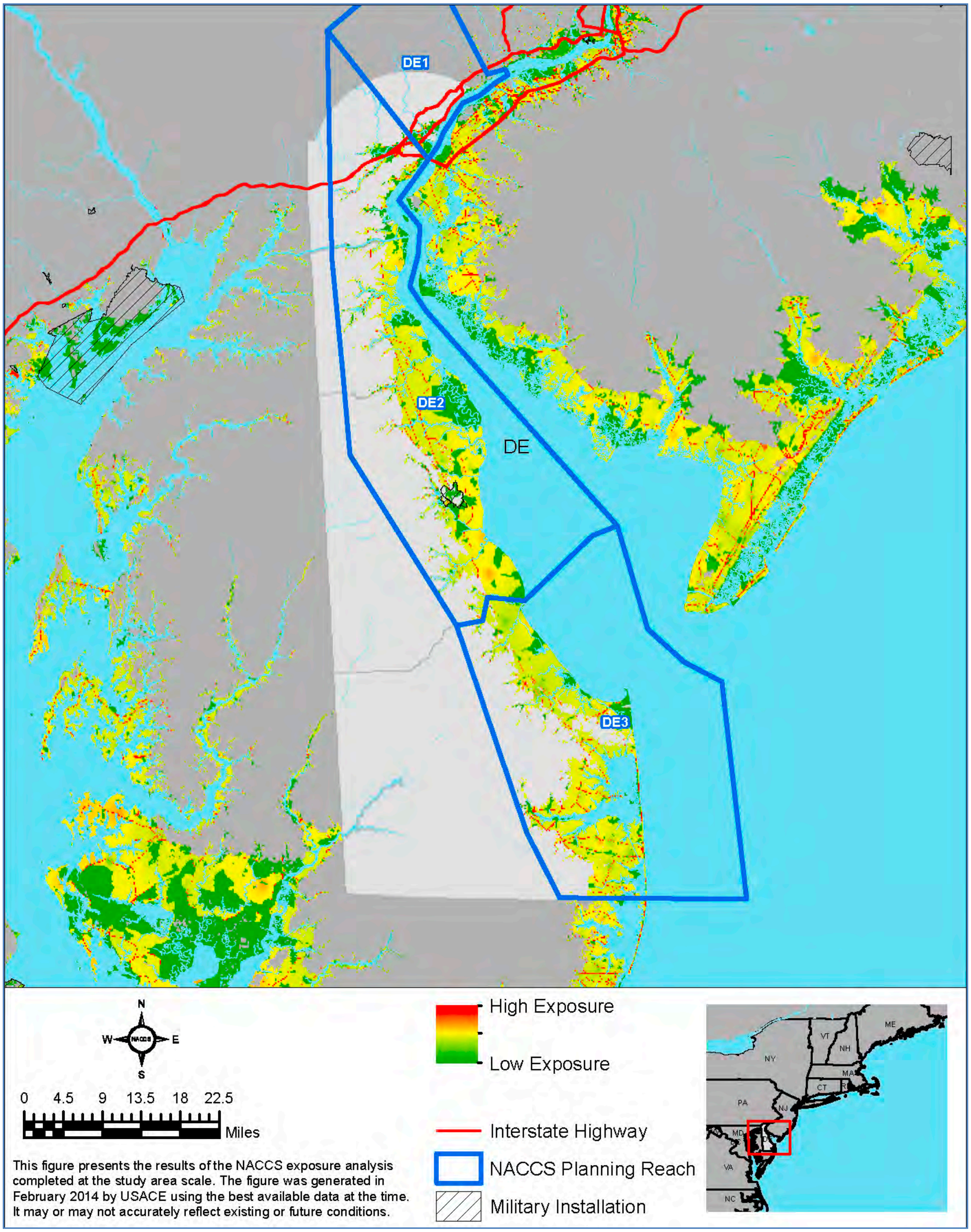

Figure 12. Population and Infrastructure Exposure Index for the State Delaware

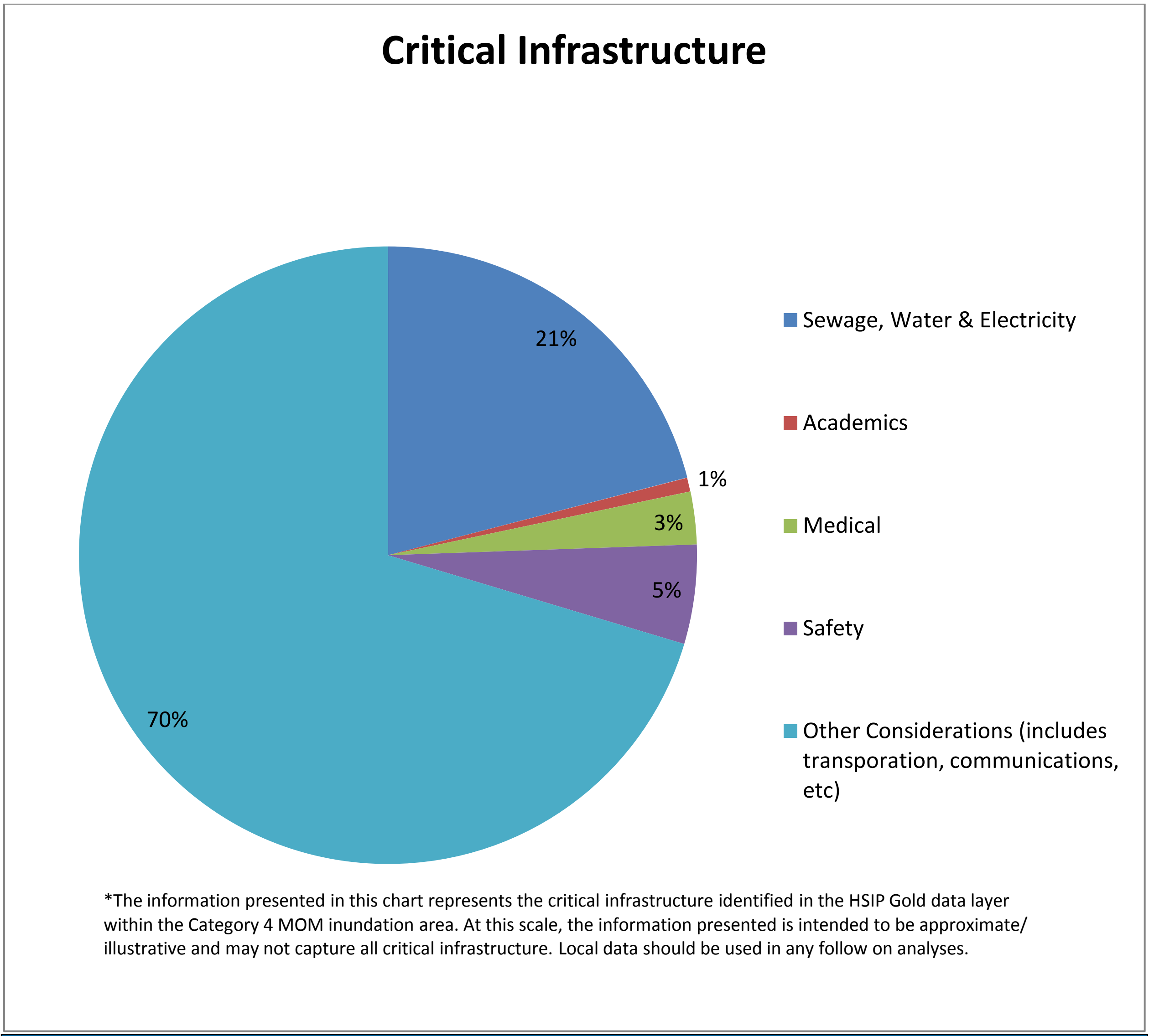

Figure 13. Vulnerable Infrastructure Elements within the Category 4 MOM Inundation Area in the State of Delaware

Social Vulnerability Characterization Index

The social vulnerability characterization captures certain segments of the population that may have more difficulty preparing for and responding to natural disasters and was completed using the U.S. Census Bureau 2010 Census data. Important factors in social vulnerability include age, income, and inability to speak English.

Figure 14 presents the social vulnerability characterization exposure Index for the State of Delaware. Areas with relatively higher concentrations of vulnerable segments of the population are identified from this analysis.

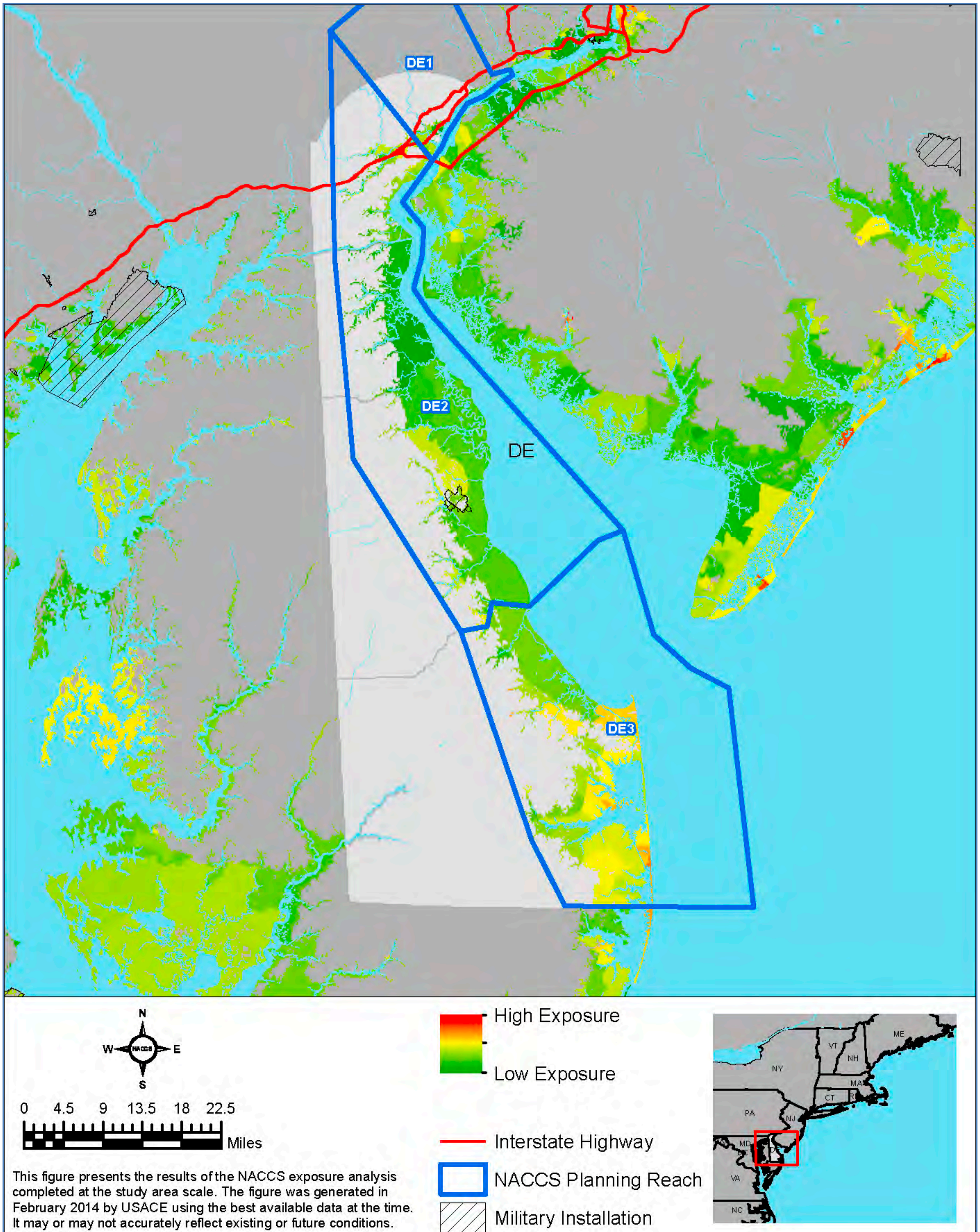

Figure 14. Social Vulnerability Exposure Index for the State of Delaware

The identification of risk areas based on the social exposure analysis is also shown below on a reach-by-reach basis for each of the planning reaches in the State of Delaware.

Reach: DE1

Based on the social vulnerability analysis, five areas were identified within this reach as areas with relatively high social vulnerability. These areas were located within census tracts 30.02, 22, and 29 (New Castle County, DE), 4054 and 4064.02 (Delaware County, PA). These areas were identified as vulnerable mainly due to a large percent of the population being under the poverty level.

Reach: DE2

Based on the social vulnerability analysis, two areas were identified within this reach as areas with relatively high social vulnerability. These areas were located within census tracts 145.02 and 145.01 (New Castle County, DE). These areas were identified as vulnerable mainly due to a large percent of the population being under the poverty level.

Reach: DE3

Based on the social vulnerability analysis, one area was identified within this reach as an area with relatively high social vulnerability. This area was located within census tract 505.03 (Sussex County, DE). This area was identified as vulnerable mainly due to a large percent of the population being non-English speakers.

Environmental and Cultural Resources Index

Environmental and cultural resources were also evaluated as they relate to exposure to the Cat 4 maximum inundation. Data from national databases, such as the National Wetlands Inventory and The Nature Conservancy Ecoregional Assessments; data provided from USFWS, including threatened and endangered species habitat and important sites for bird nesting and feeding areas; shoreline types; and historic sites and national monuments, among others were used in this analysis to assess environmental and cultural resource exposure. It should be noted that properties with restricted locations, typically archaeological sites, and certain other properties were omitted from the analysis due to site sensitivity issues.

Figure 15 depicts the environmental and cultural resources exposure index for the State of Delaware. This exposure analysis is intended to capture important habitat, and environmental and cultural resources that would be vulnerable to storm surge, winds, and erosion. It should be noted though, that mapped areas displaying high exposure index scores (shown in red and orange) may not include all critical or significant environmental or cultural resources, as indexed scores are additive; the higher the index score, the greater number of resources present at the site. Impacts and recovery opportunity would vary across areas and depending on the resource affected.

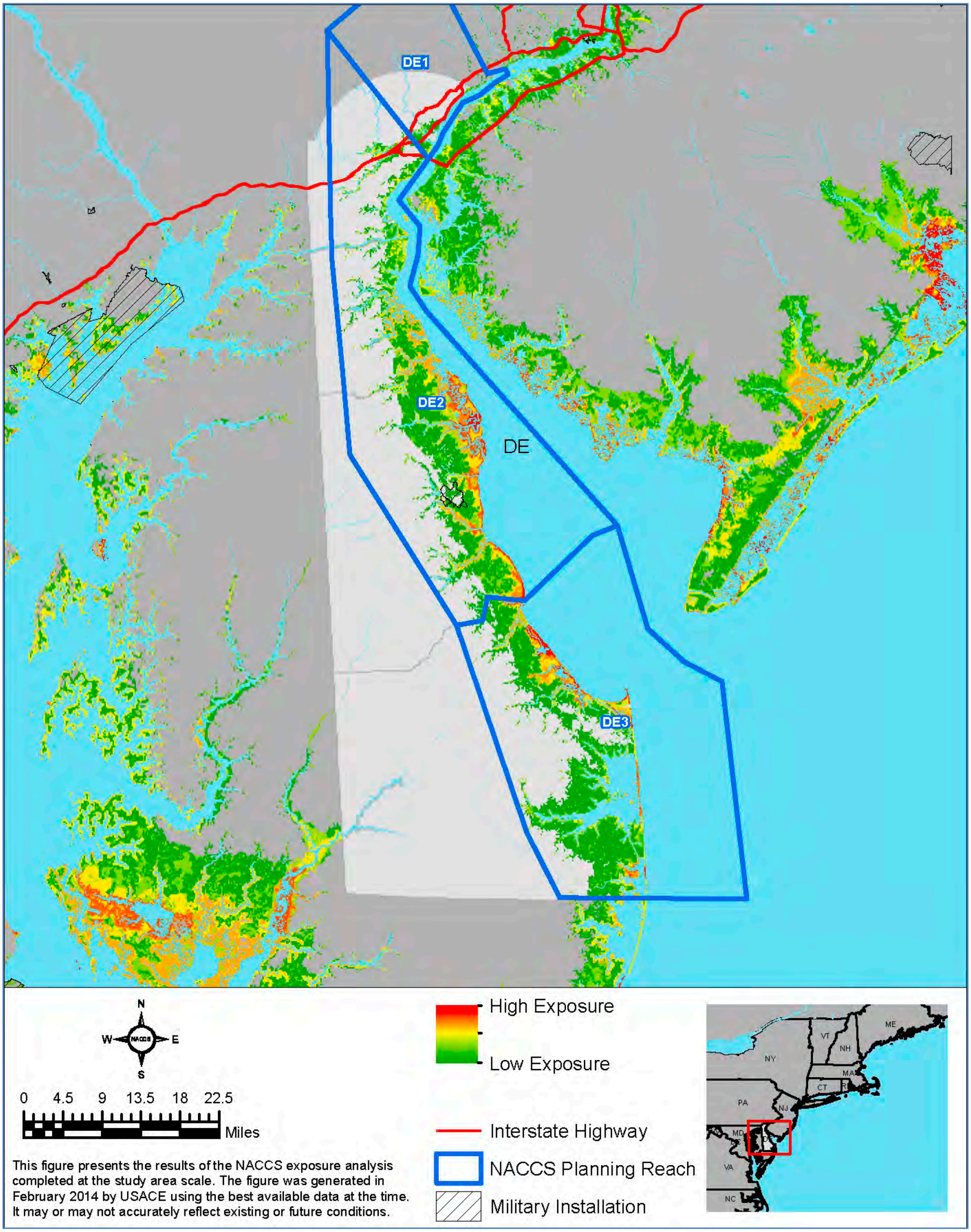

Figure 15. Environmental and Cultural Resources Exposure Index for the State of Delaware

It should be noted that some regions that may be recognized as important in one category or another may not show up on the maps as a location identified as a High (red and orange) Environmental and Cultural Resource Exposure area. These areas may have met only one or just a few of the criteria used in the evaluation. Further, due to the minority contribution of cultural resources in the analysis (40 percent) and their general lack of proximity to key natural resource areas, historic properties may not be strongly represented.

A description of the environmental and cultural resource exposure areas for each planning reach is described below.

Reach: DE1

There are no high environmental and cultural resources exposure index areas in DE1.

Reach: DE2

Priority areas (as defined by others) within the high environmental and cultural resources exposure index area in DE2 include Coastal Barrier Islands as defined under the Coastal Barrier Resources Act (~1,385 acres); USFWS protected areas (~3,640 acres); Rare, threatened, and endangered species (~2,560 acres); and TNC priority conservation areas (~3,310 acres). The Coastal Barrier Islands within the high environmental and cultural resources exposure index area in DE2 include: Little Creek (~410 acres) and Broadkill Beach (~980 acres). The USFWS protected area within the high environmental and cultural resources exposure index area in DE2 includes roughly 4,500 acres of Bombay Hook National Wildlife Refuge. Rare, threatened, and endangered species within the high environmental and cultural resources exposure index area in DE2 includes approximately 2,560 acres of Red Knot (Proposed Threatened species) designated habitat.

Habitat within the high environmental and cultural resources exposure index area in DE2 is primarily emergent marsh (~2,840 acres), but also includes Unconsolidated Shore (sand, gravel, cobble) (~135 acres), Unconsolidated Shore (mud, organic, flat) (~220 acres), and Freshwater Forested/Shrub Wetland (~4 acres).

Cultural Resources within the high environmental and cultural resources exposure index area in DE2 includes the Port Mahon Lighthouse historic site, Fleming House, the Little Creek Methodist Church, Old Brick Store, Saxton United Methodist Church, Stubbs Elizabeth House, Sutton Thomas House, Town Point, and Woodley Jonathan House. Additionally, there is a cultural resources buffer area of approximately 2,660 acres.

Reach: DE3

This analysis resulted in approximately 5,650 acres of high environmental and cultural resources exposure index area (red and orange) in DE3.

Priority areas (as defined by others) within the high environmental and cultural resources exposure index area in DE2 include Coastal Barrier Islands as defined under the Coastal Barrier Resources Act; USFWS protected areas; Rare, threatened, and endangered species; TNC priority conservation areas; and City, County, and State parks. The Coastal Barrier Islands within the high environmental and cultural resources exposure index area in DE3 include: Broadkill Beach (~3,771 acres), Cape Henlopen (~1,180 acres), Delaware Seashore (~215 acres), Fenwick Island (~220 acres), and Plum Beach Island (~210 acres). The USFWS protected areas within the high environmental and cultural resources exposure index area in DE3 include over 840 acres of Prime Hook National Wildlife Refuge. Rare, threatened, and endangered species within the high environmental and cultural resources exposure index area in DE3 includes roughly 1,180.acres of Red Knot (Proposed Threatened species) designated habitat, 1000 acres of Piping Plover (Threatened species) designated habitat, and 1,050 acres of seabeach amaranth (Threatened species) designated habitat. City, County, and State parks (each greater than 10 acres) within the high environmental and cultural resources exposure index area in DE3 include approximately 1,410 acres of State Parks.

Habitat within the high environmental and cultural resources exposure index area in DE3 is primarily emergent marsh (~3550 acres), but also includes Unconsolidated Shore (sand, gravel, cobble) (~690 acres), Scrub-Shrub, Unconsolidated Shore (mud, organic, flat) (~160 acres), Freshwater Forested/Shrub Wetland (~130 acres), Freshwater Emergent Wetland (~30 acres), and Riverine (~1 acre).

Cultural Resources within the high environmental and cultural resources exposure index area in DE3 includes the Indian River Life Saving Service Station historic site. Additionally, there is a cultural resources buffer of approximately 5,550 acres.

Composite Exposure Index

All three of the exposure indices were summed together to develop one composite index that displays overall exposure. Figure 16 depicts the Composite Exposure Index for the State of Delaware.

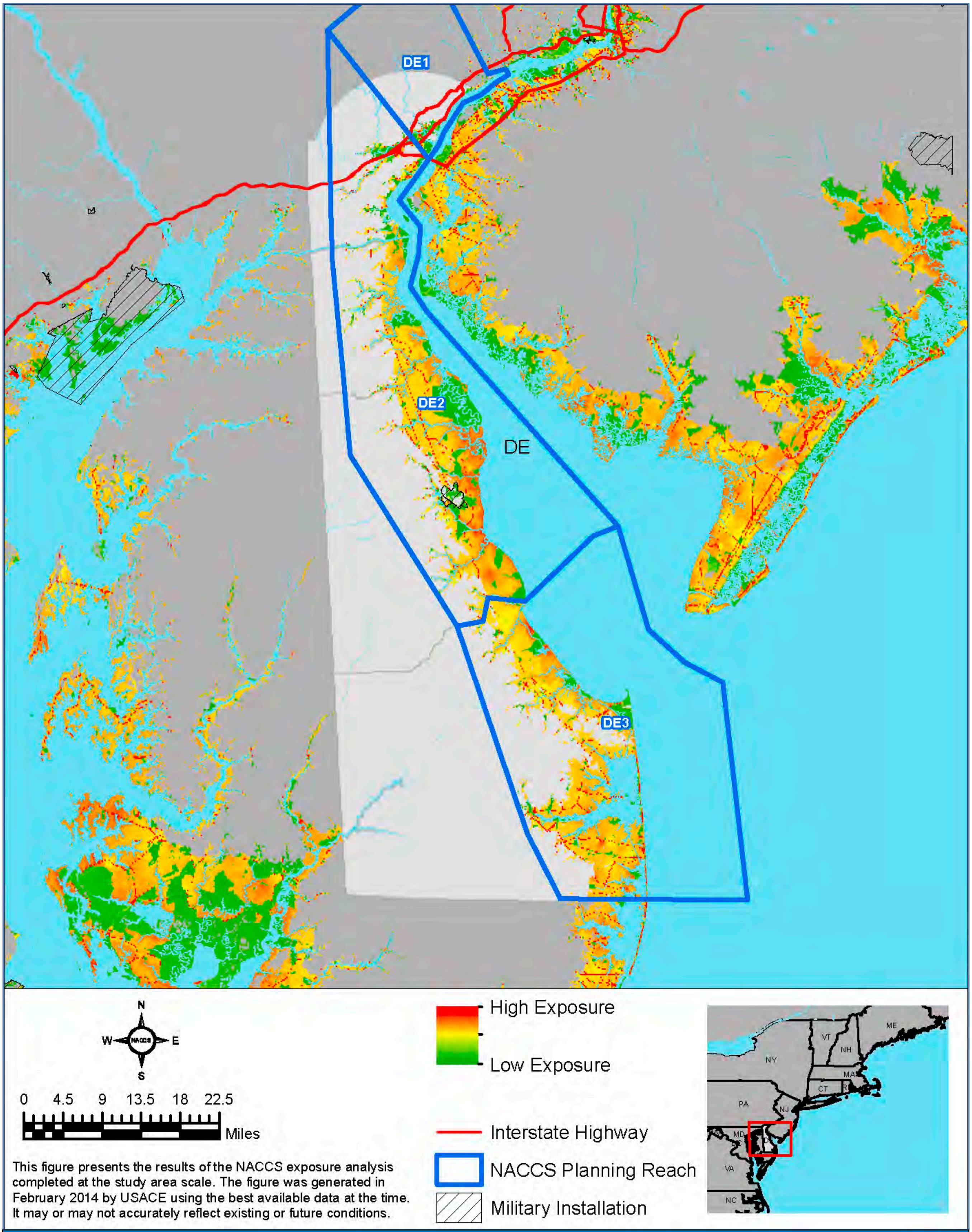

Figure 16. Composite Exposure Index for the State of Delaware

IV.2. NACCS Risk Assessment

Exposure and coastal flood inundation mapping is used to identify the specific areas at risk. Once the exposure to flood peril of any area has been identified, the next step is to better define the flood risk. The Framework defines risk as a function of exposure and probability of occurrence. For each of the floodplain inundation scenarios, Category 4 MOM, 1 percent flood plus three feet, and the 10 percent flood, three bands of inundation were created. The bands correspond with the flooding source to the 10-percent inundation extent, the 10-percent to the 1-percent plus three feet extent, and the 1-percent plus three feet to the CAT4 MOM inundation extent. The 1-percent plus three feet extent was defined as the CAT2 MOM because at the study area scale there were areas that did not include FEMA 1-percent flood mapping. This process was completed for the composite exposure assessment in order to generate the NACCS risk assessment. The data was symbolized to present areas of relatively higher risk, which based on the analysis, corresponds with the three bands that were used in the analysis. Subsequent analyses could incorporate additional bands, which would present additional variation in the range of values symbolized in the figure. Figure 17 depicts the results of this risk assessment using the composite exposure data for the State of Delaware.

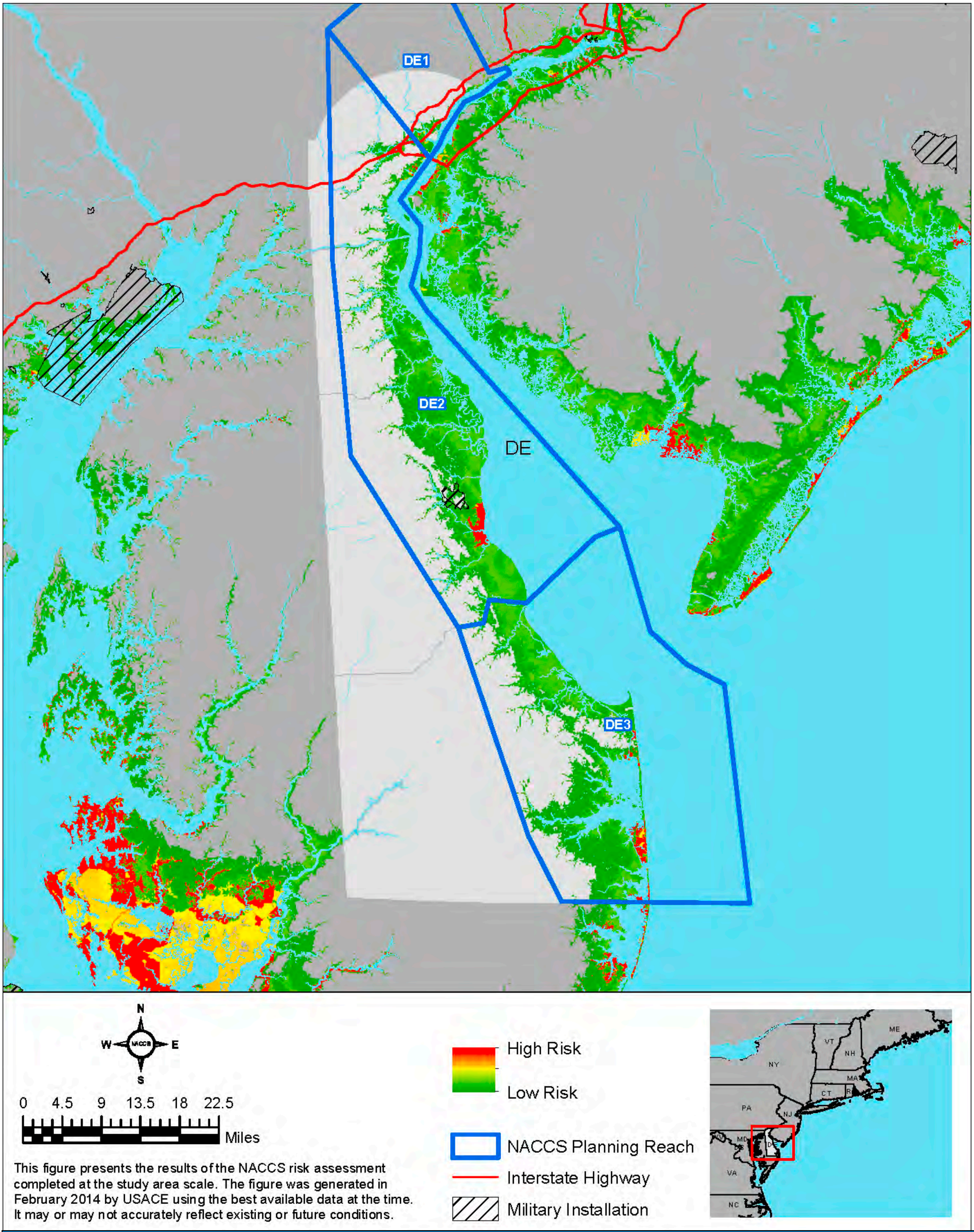

Figure 17. Risk Assessment for the State of Delaware

IV.3. NACCS Risk Areas Identification

Applying the risk assessment to the State of Delaware identified 8 areas for further analysis (Figure 18). These locations are identified by reach in Figures 19 through 21 and are described in more detail below.

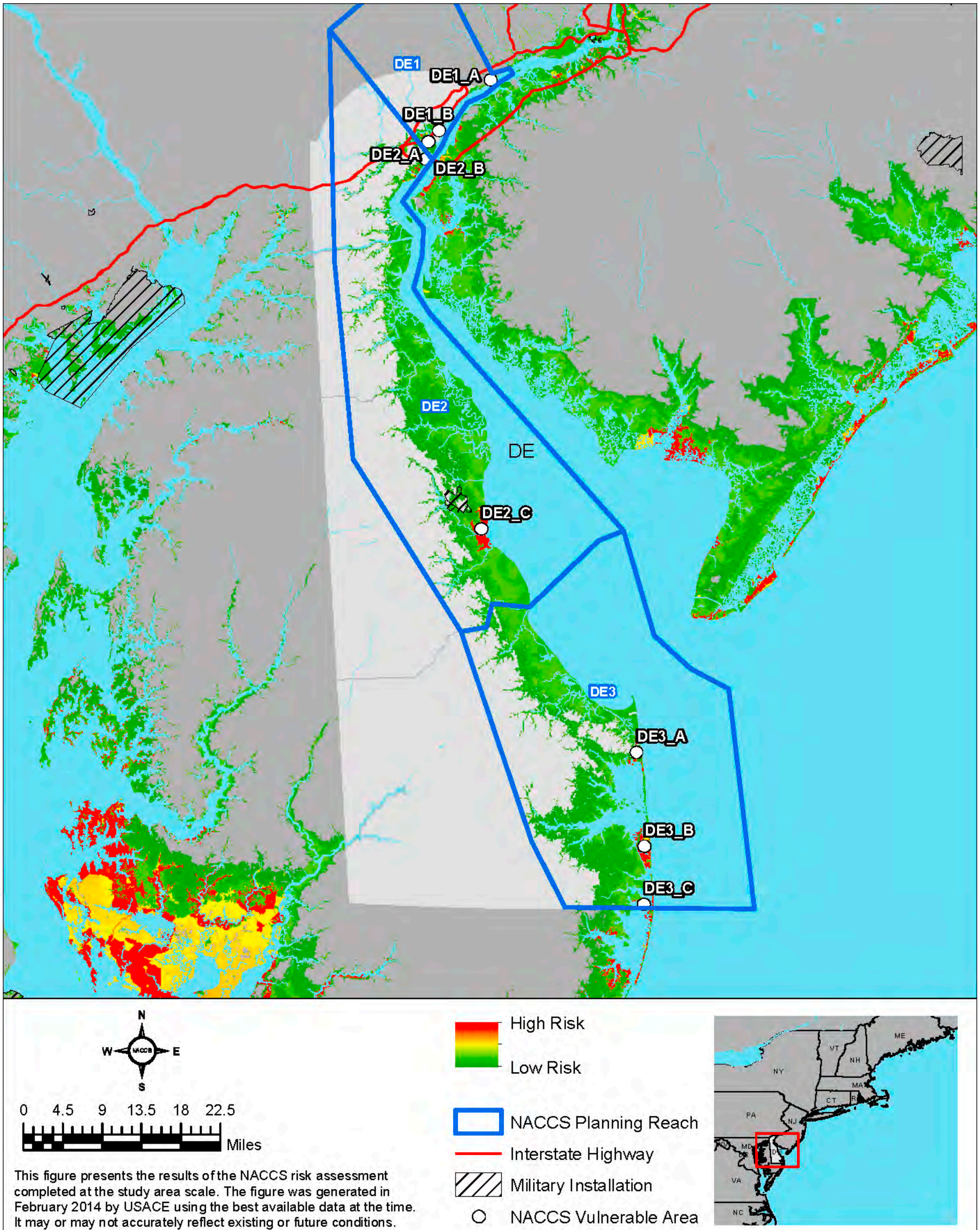

Figure 18. Risk Areas in the State of Delaware

Reach: DE1

The shoreline of Delaware Reach 1 (Figure 19) is classified as mostly urban. Two areas of high exposure were identified in this reach and are described below.

DE1_A: Chester Creek and Delaware River

Chester Creek is a tributary of the Delaware River. Cities and townships in this area include Marcus Hook and Claymont. This area is characterized by mixed industrial and commercial use and urban residential development. Major roads include Interstate 95, 495, and the Commodore Barry Bridge. There are two oil refineries, four power plants, thirteen ports, and three rail road bridges.

DE1_B: Brandywine Creek and Delaware River

Brandywine Creek is a tributary of the Delaware River. Bellevue Lake and Edgemoor Reservoir are also within this reach. Cities and townships include Bellefonte, Edgemoor, and Wilmington. This area is characterized by a mixed industrial and commercial use and urban residential development. Major roads include Interstate 495. There are two power plants, three ports, and ten rail bridges.

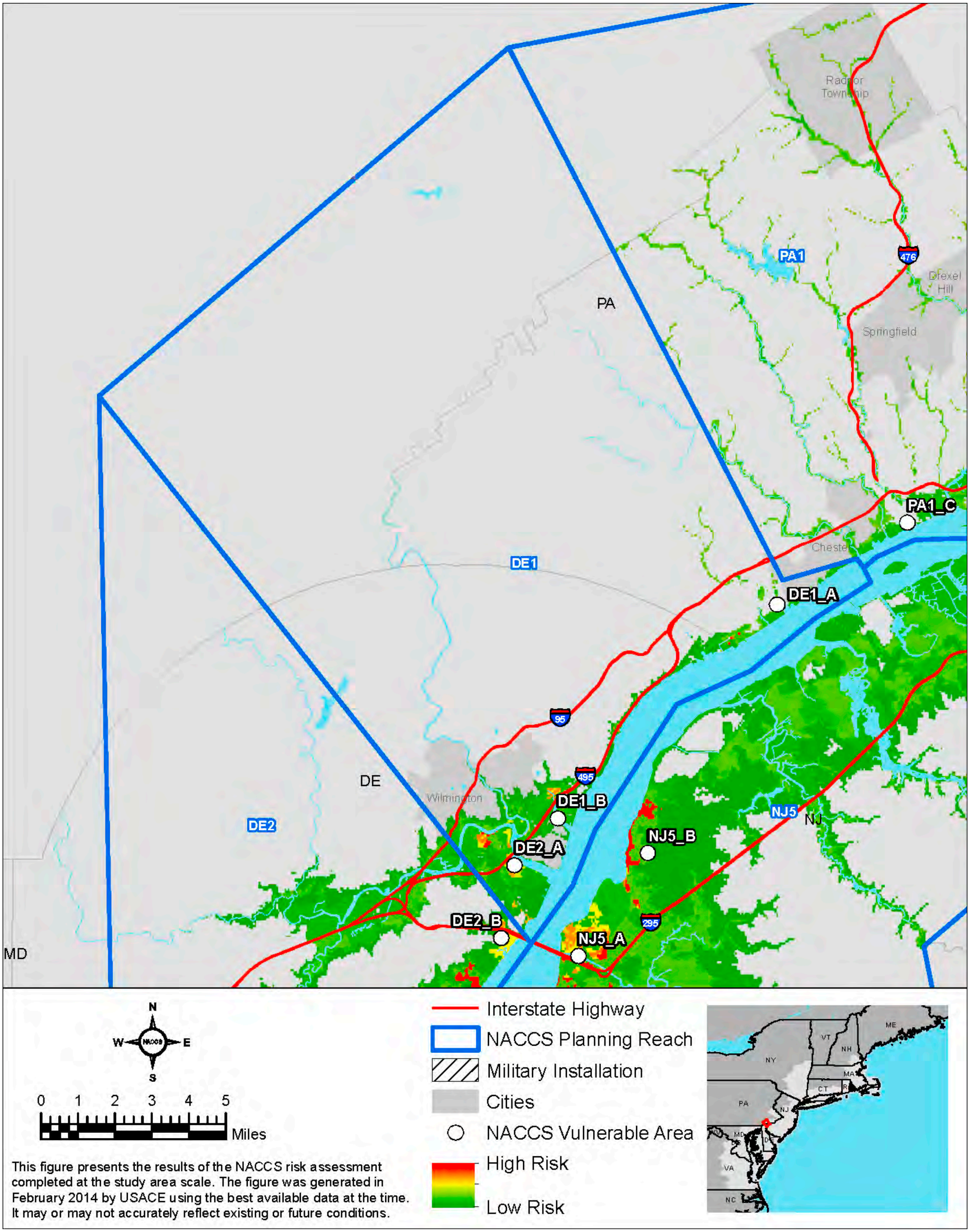

Figure 19. DE1 Risk Areas

Reach: DE2

The shoreline of Delaware Reach 2 (Figure 20) is classified as mostly wetland with periodic regions of urban influence. Three problems areas were identified in this reach and are described below.

DE2_A: Brandywine Creek, Christina River, and Delaware River

Brandywine Creek and the Christina River are tributaries of the Delaware River. Cities and townships include Eden Park and Wilmington. This area is characterized by a mixed industrial and commercial use and urban residential development. Major roads include Interstate 495. There is one power plant, seven ports, and three rail bridges.

DE2_B: Delaware River Vicinity

The Delaware River borders this risk area. Cities and townships include New Castle. This area is characterized by a mixed industrial and commercial use and urban residential development with extended areas of wetland shoreline. Major roads include the Delaware Memorial Bridge (Interstate 295). There are two rail bridges.

DE2_C: Jones, Murderkill, and Delaware Rivers

Jones and Murderkill Rivers are tributaries of the Delaware River. This area includes the Town of Bowers Beach. This area is characterized by rural residential and beach community development. No major roads to account for. There are no major infrastructures within this risk area.

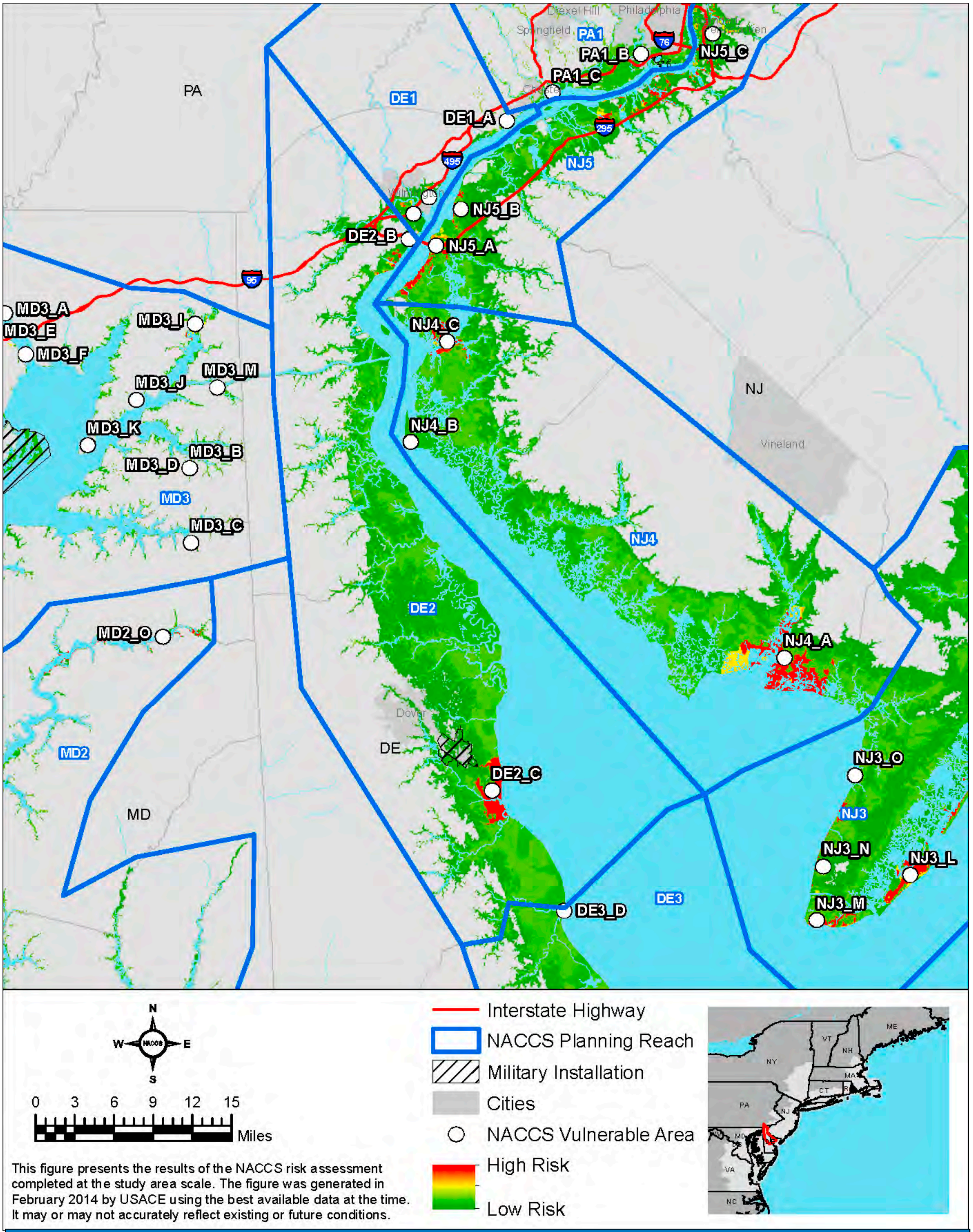

Figure 20. DE2 Risk Areas

Reach: DE3

The shoreline of Delaware Reach 3 (Figure 21) is classified as mostly beach and wetland with minimal urban influence. Three areas of high exposure were identified in this reach and described below.

DE3_A: Rehoboth Bay, Lewes and Rehoboth Canal, Silver Lake, and the Atlantic Ocean

Rehoboth Bay, Lewes and Rehoboth Canal, Silver Lake, and the Atlantic Ocean are the present bodies of water influencing this area. Cities and townships include Henlopen Acres, Rehoboth Beach, and Dewey Beach. This area is characterized by medium density urban residential and beach community development. The shoreline for this area is constructed of beach, bluffs, wetlands, and a low amount of urban. Major roads include Delaware State Hwy 1. There’s one airport present in this risk area.

DE3_B: Indian River Bay, Salt Pond, Assawoman Canal, and the Atlantic Ocean

Indian River Bay, Salt Pond, Assawoman Canal, and the Atlantic Ocean are the present bodies of water influencing this area. This area includes the Towns of Bethany Beach and South Bethany. This area is characterized by medium density urban residential and beach community development. The shoreline for this area is constructed of beach, bluffs, wetlands, and a low amount of urban development. Major roads include Delaware State Highway 1.

DE3_C: Little Assawoman Bay, Montego Bay, and the Atlantic Ocean

Little Assawoman Bay, Montego Bay, and the Atlantic Ocean are the present bodies of water influencing this area. This area includes the Town of Fenwick Island. This area is characterized by medium density urban residential and beach community development. The Shoreline for this area is constructed of beach, bluffs, wetland, and urban. Major roads include Delaware State Highway 1.

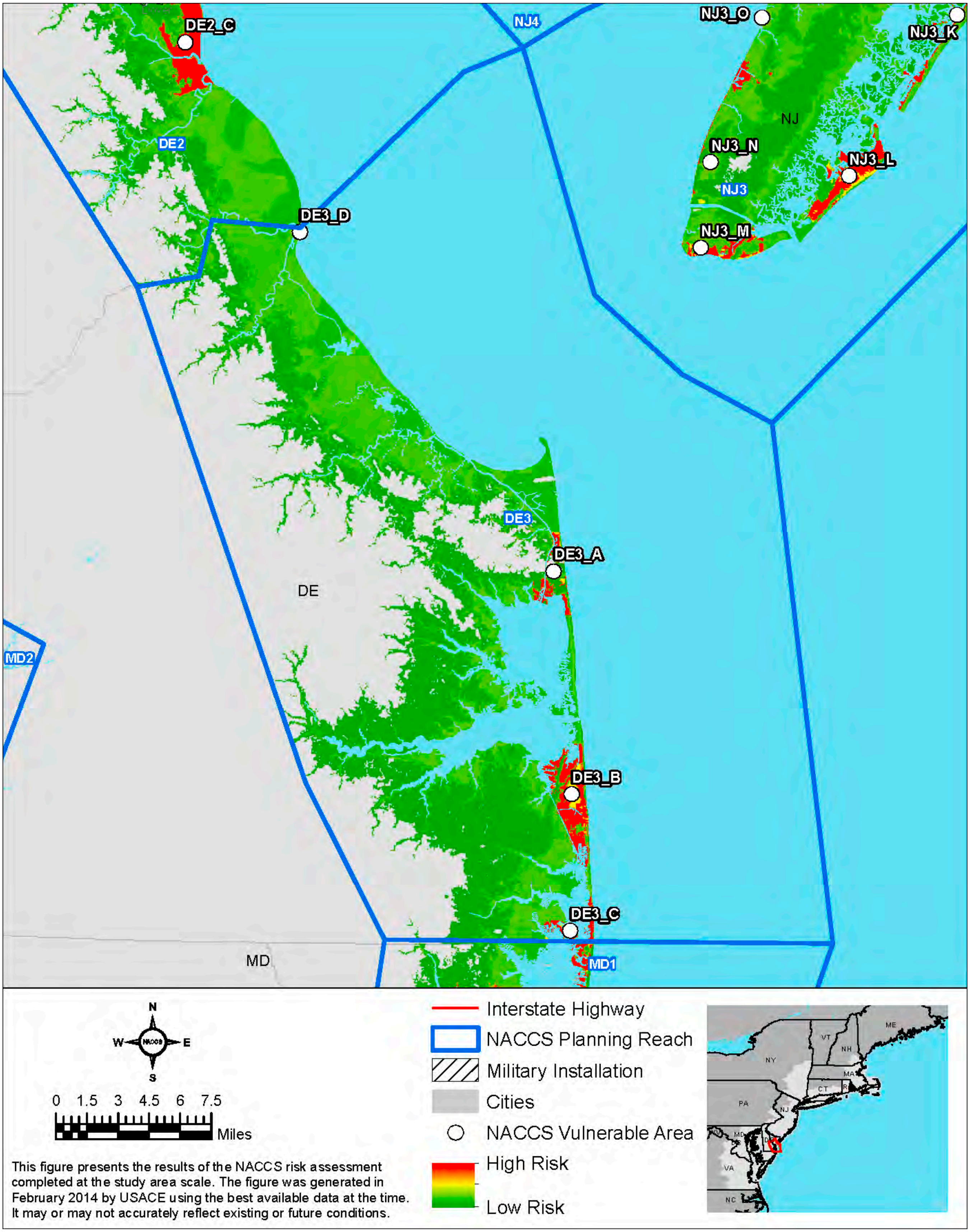

Figure 21. DE3 Risk Areas

V. Coastal Storm Risk Management Strategies and Measures

V.1. Measures and Applicability by Shoreline Type

The structural and NNBF measures were further categorized based on shoreline type for where they are best suited according to typical application opportunities and constraints and best professional judgment (Dronkers et. al, 1990; USACE 2014). Shoreline types were derived from the NOAA Environmental Sensitivity Index Shoreline Classification dataset (NOAA, n.d.). Figure 22 presents the location and extent of each shoreline type in the State of Delaware. Table 4 summarizes the measures applicability based on shoreline type. It is assumed non-structural measures could be considered in all geographic contexts, subject to further evaluation at a smaller scale.

Additionally, a conceptual analysis of geographic applicability of NNBF measures presented in Table 3 was completed, including beach restoration, beach restoration with breakwaters/groins, living shorelines, reefs, submerged aquatic vegetation, and wetlands. The GIS operations that were used for the NNBF screening analysis are described in the Use of Natural and Nature-Based Features for Coastal Resilience Report (Bridges et. al., 2015). In addition to the NOAA Environmental Sensitivity Index Shoreline Classification dataset (NOAA, n.d.), other criteria that was considered was habitat type, impervious cover, water quality, and topography/bathymetry. Consistent with the theme of the Framework, further evaluation of the results would be required at a smaller scale and with finer data sets. Figure 23 presents the location and extent of NNBF measures based on additional screening criteria. Additional information associated with the methodology and results of the analysis is presented in Appendix C – Planning Analyses.

The lengths of shoreline type on an individual reach basis are provided in Figures 24 to 26 and Table 4.

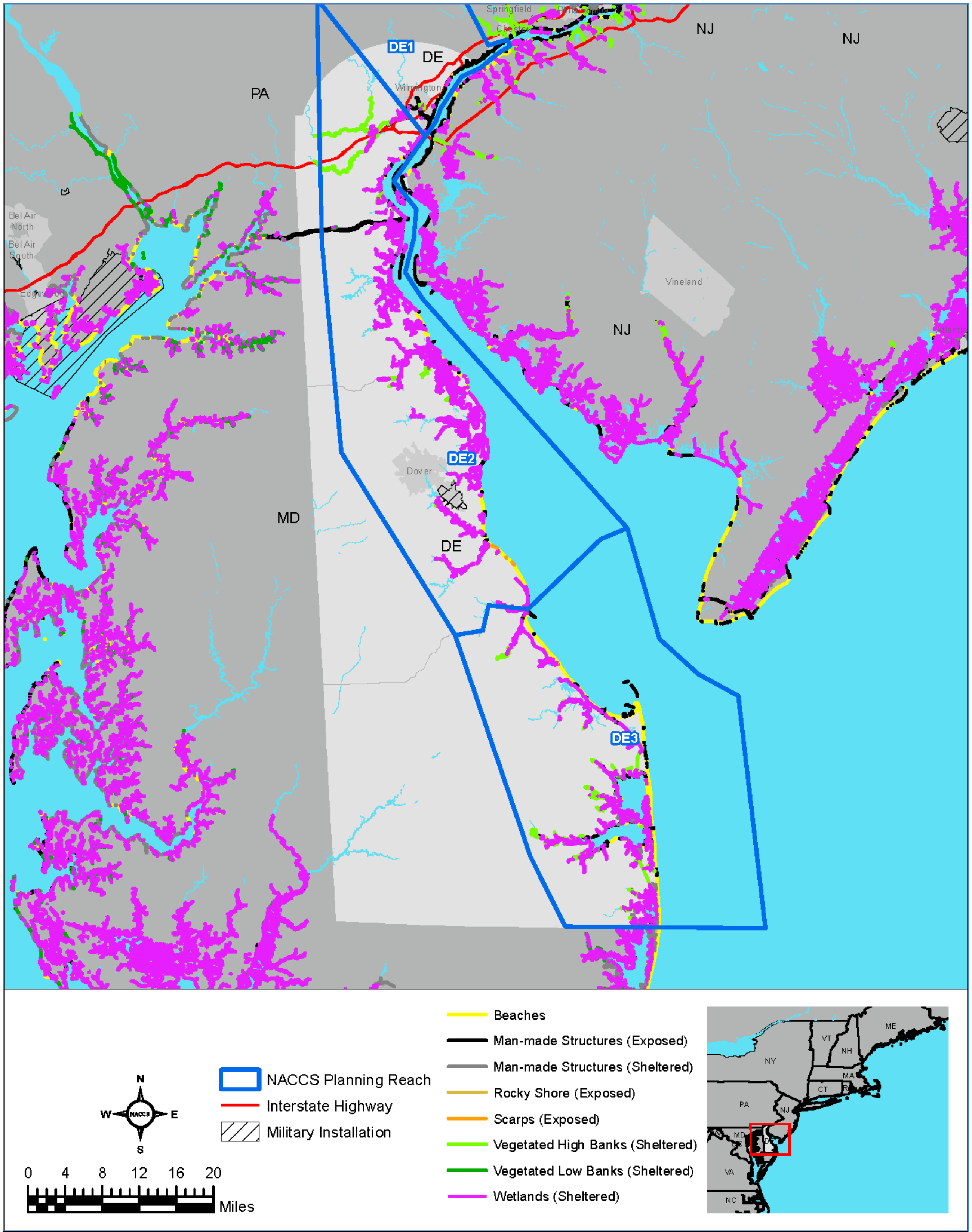

Figure 22. Shoreline Types for the State of Delaware

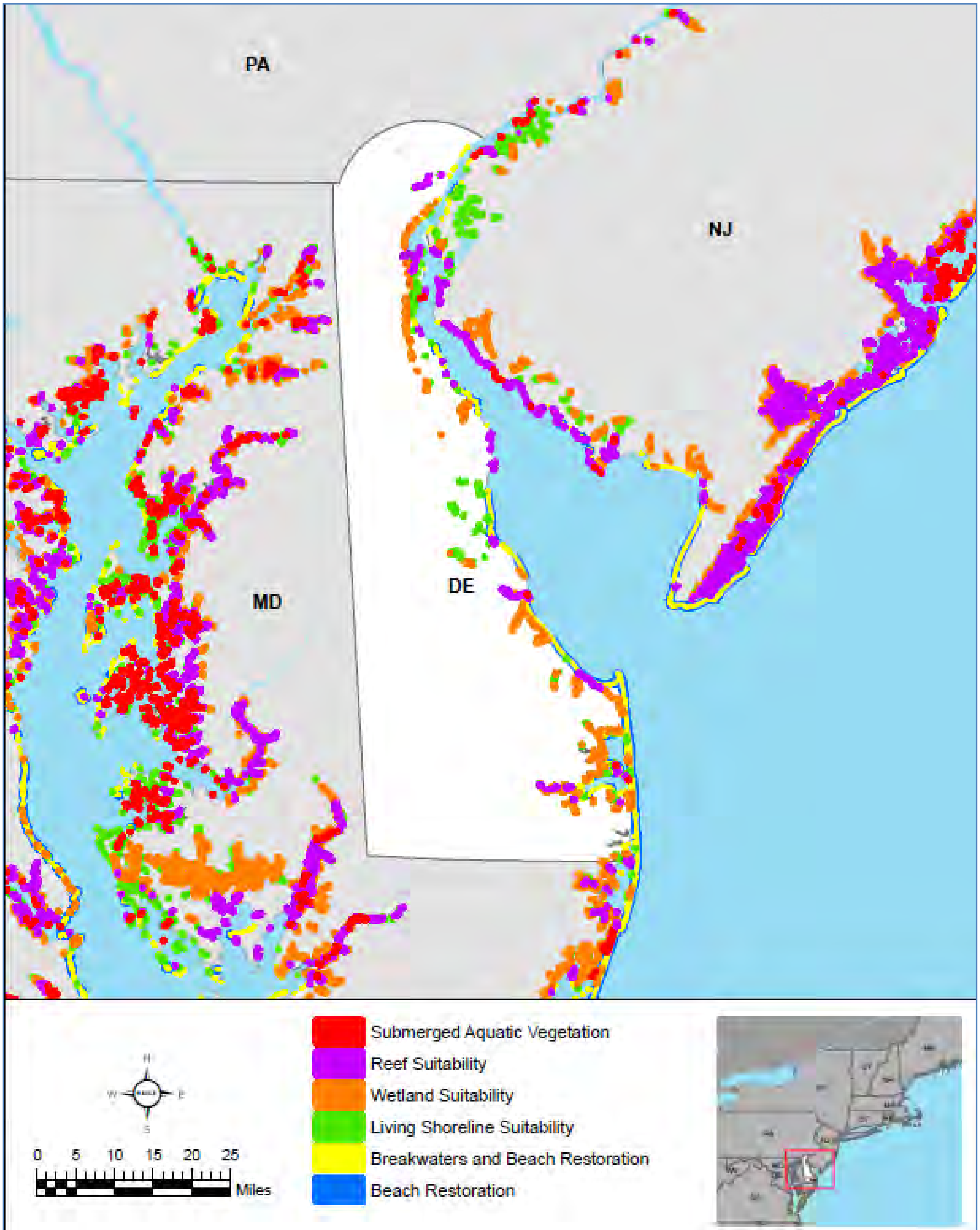

Figure 23. NNBF Measures Screening for the State of Delaware

Table 3. Structural and NNB Measure Applicability by NOAA-ESI Shoreline Type

Measures	Rocky shores (Exposed)	Rocky shores (Sheltered)	Beaches (Exposed)	Manmade structures (Exposed)	Manmade structures (Sheltered)	Scarps (Exposed)	Scarps (Sheltered)	Vegetated low banks (Sheltered)	Wetlands/Marshes/ Swamps (Sheltered)
Structural									
Storm Surge Barrier[1]									
Barrier Island Preservation and Beach Restoration (beach fill, dune creation)[2]			x						
Beach Restoration and Breakwaters[2]			x						
Beach Restoration and Groins[2]			x						
Shoreline Stabilization						x	x	x	
Deployable Floodwalls					x				
Floodwalls and Levees		x			x			x	
Drainage Improvements	x	x	x	x	x	x	x	x	x
Natural and Nature-Based Features									
Living Shoreline						x	x	x	x
Wetlands							x		x
Reefs	x	x				x			x
Submerged Aquatic Vegetation[3]									x
Overwash Fans[4]									
Drainage Improvements	x	x	x	x	x	x	x	x	x

[1] *The applicability of storm surge barriers cannot be determined based on shoreline type. It depends on other factors such as coastal geography.*
[2]*Beaches and dunes are also considered Natural and Nature-Based Features*
[3]*Submerged aquatic vegetation is not associated with any particular shoreline type. Initially, it is assumed to apply to wetland shorelines.*
[4]*Overwash fans may apply to the back side of barrier islands which are not explicitly identified in the NOAA-ESI shoreline database.*

Table 4. Shoreline Types by Length (feet) by Reach

Row Labels	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes / Swamps / Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
DE1	**4,170**	**92,035**		**8,977**		**4,989**		**110,171**
DE1_A		55,443						55,443
DE1_B	4,170	36,592		8,977		4,989		54,728
DE2	**28,192**	**62,748**		**127,488**	**1,070**	**865**		**220,363**
DE2_A		46,086		3,658		865		50,609

DE2_B	4,480	7,527		39,058				51,065
DE2_C	23,712	9,135		84,772	1,070			118,689
DE3	**132,046**	**59,247**	**181,398**	**219,685**	**1,124**	**73,507**	**253,420**	**920,427**
DE3_A	23,782	11,388	8,623	38,331	1,124	21,787		105,035
DE3_B	37,231	13,336	98,445	103,184		23,053		275,249
DE3_C	14,526	16,713	74,330	78,170				183,739
DE3_D	56,507	17,810				28,667	253,420	356,404
Grand Total	**164,408**	**214,030**	**181,398**	**356,150**	**2,194**	**79,361**	**253,420**	**1,250,961**

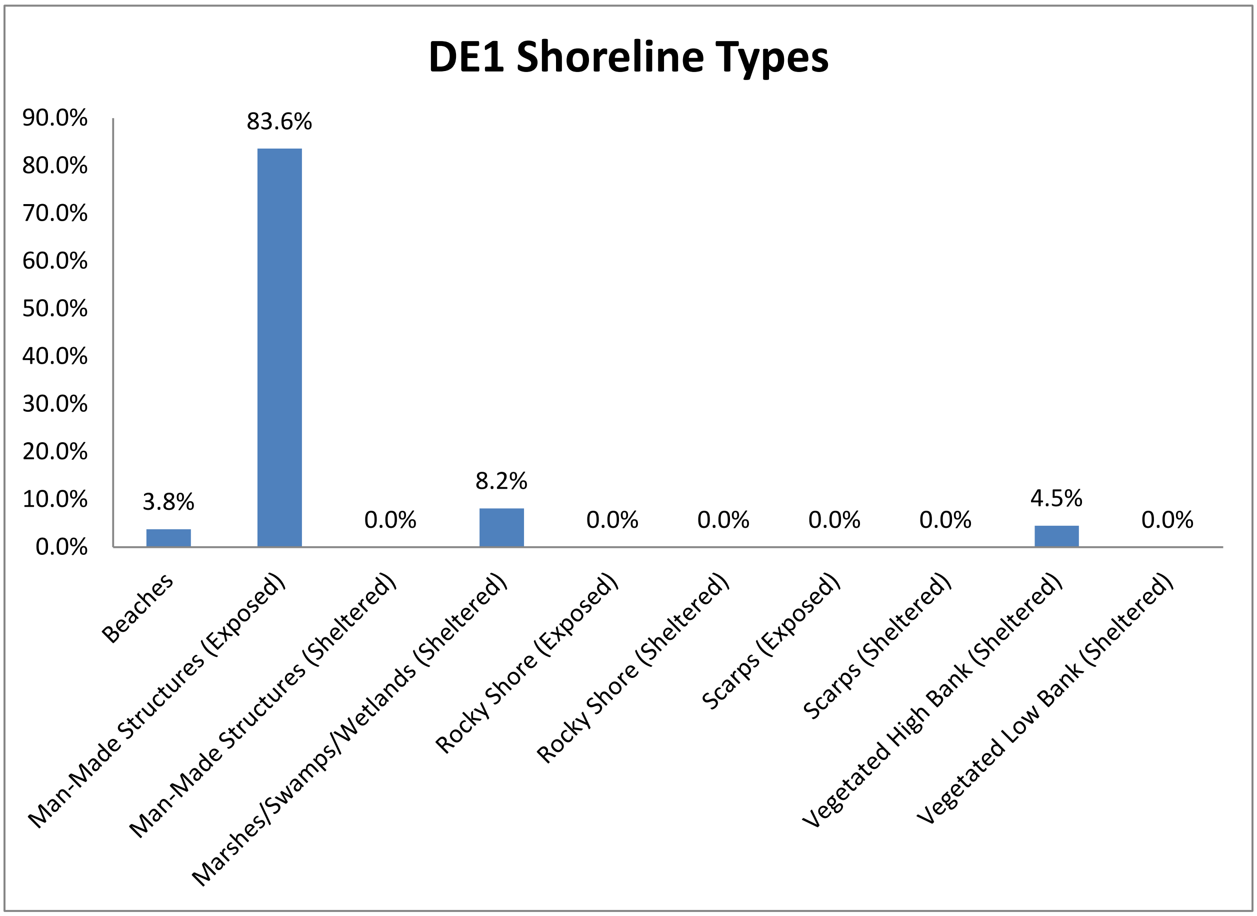

Figure 24. DE-1 Shoreline Types

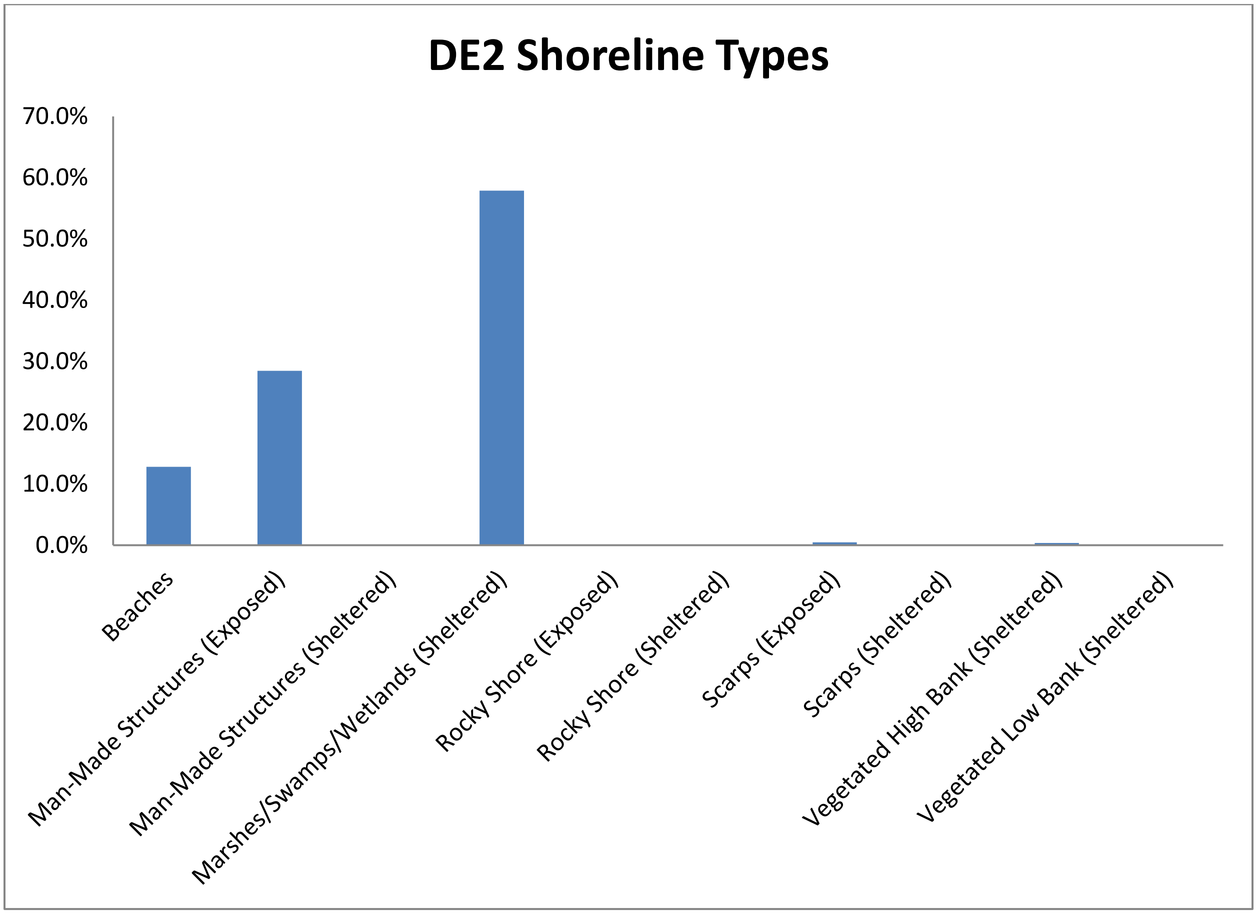

Figure 25. DE-2 Shoreline Types

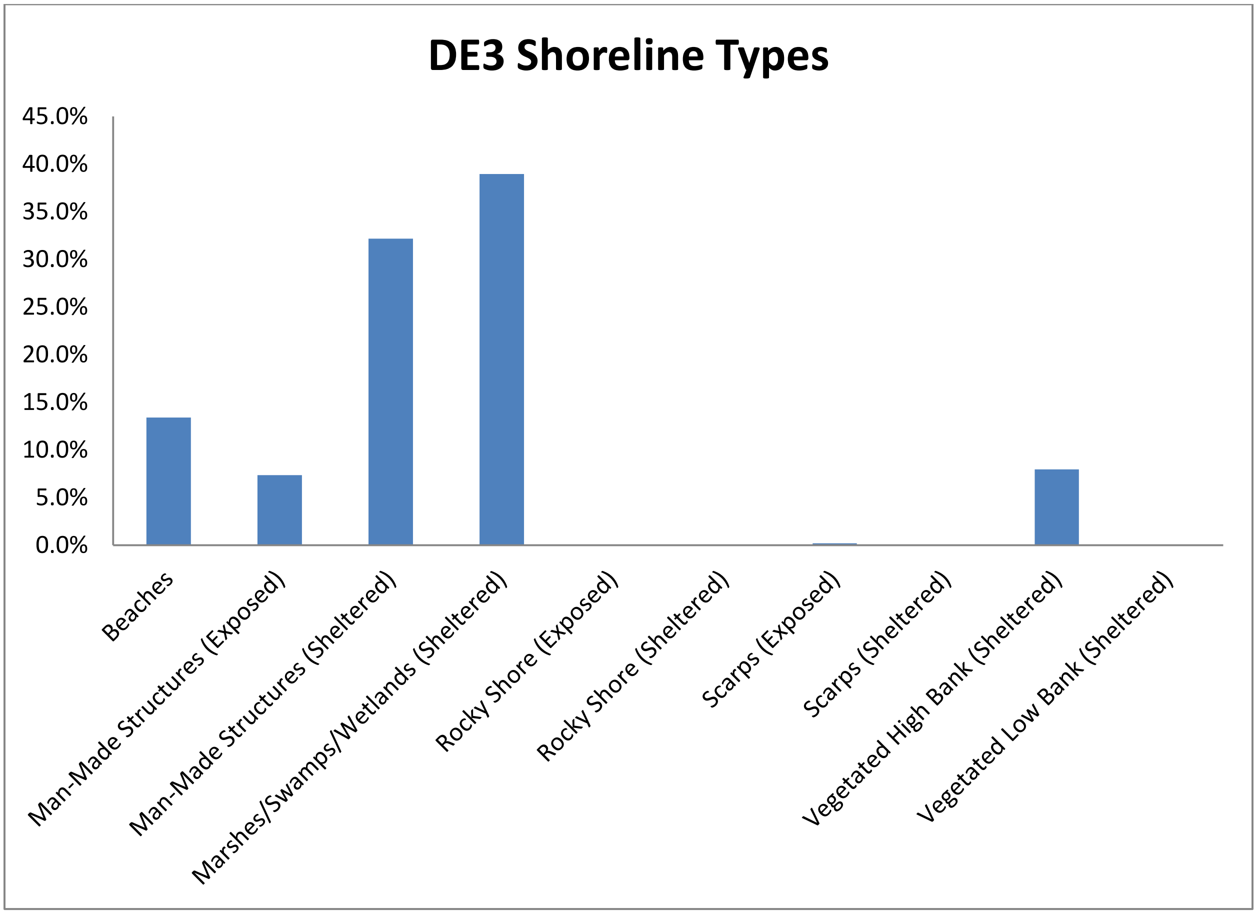

Figure 26. DE-3 Shoreline Types

V.2. Cost Considerations

Conceptual design and parametric cost estimates were developed for the various coastal storm risk management measures were representative, concept designs were developed for each measure together with quantities and parametric costs (typically per linear foot of shoreline) based on a combination of available cost information for existing projects and representative unit costs for all construction items (e.g., excavation, fill, rock, plantings) based on historical observations. Additional information on the various measures is included in Appendix C – Planning Analyses.

VI. Tier 1 Assessment Results

Table 5 presents the results of the State of Delaware risk areas and the comparison of management measures. The reference to the level of risk reduction in the table relates to the flooding attribute of the storm damage reduction and resilience storm damage reduction function presented in Table 1 of the overview section. The level of risk reduction (High or Low) is based on a 1 percent chance flood plus three feet (High) or 10 percent chance flood (Low) level. For each shoreline type within the risk area presented in Table 5, the numerical sequence of the measures for each shoreline type within the respective risk area relates to the change in risk and the parametric unit cost estimates for the applicable measures. Nonstructural measures could be considered in all geographic contexts, subject to further evaluation at a smaller scale. As a result, Table 5 only presents the change in risk and the parametric unit cost estimates for structural measures, including NNBF.

Table 5. Comparison of Measures within NACCS Risk Areas in the State of Delaware

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
DE1_B	**Beaches**	**H**	**3**	**2**	**1**									
DE1_B	Wetlands (Sheltered)	L									1	3	4	2
DE2_A	**Wetlands (Sheltered)**	**L**									**1**	**3**	**4**	**2**
DE2_B	Wetlands (Sheltered)	L									1	3	4	2
DE2_B	Beaches	H	3	2	1									
DE2_B	Wetlands (Sheltered)	L									1	3	4	2
DE2_C	Beaches	H	3	2	1									
DE2_C	Scarps (Exposed)	L				3					1		2	
DE2_C	Wetlands (Sheltered)	L									1	3	4	2
DE3_A	Beaches	H	3	2	1									
DE3_A	Manmade Structures (Sheltered)	H					3	2	1					
DE3_A	Scarps (Exposed)	L				3					1		2	
DE3_A	Wetlands (Sheltered)	L									1	3	4	2
DE3_B	Beaches	H	3	2	1									
DE3_B	Manmade Structures (Sheltered)	H					3	2	1					
DE3_B	Wetlands (Sheltered)	L									1	3	4	2
DE3_C	Beaches	H	3	2	1									

VII. Tier 2 Assessment of Conceptual Measures

As part of the NACCS Tier 2 analysis for the State of Delaware and in coordination with the Delaware Department of Natural Resources and Environmental Control (DNREC), the Mispillion Inlet/River Complex was selected as an example area to further evaluate flood risk as part of the CSRM Framework. Defined as Area DE3_D, the Mispillion Inlet/River Complex includes Milford and Slaughter Beach. The example area represents an area within the State of Delaware at risk to coastal flooding. This area was selected for additional analysis due to the lack of existing projects as well as the overall need for enhanced coastal resilience to surrounding communities (Slaughter Beach and Milford) and the surrounding environmentally sensitive areas. Also, the significantly eroded nature of the beach in the vicinity specifically to the north of the inlet is environmentally sensitive horseshoe/shorebird crab habitat. The inlet/river complex is also hydraulically connected to surrounding environmentally sensitive areas including Prime Hook National Wildlife Refuge.

As demonstrated in Table 6, this area of high risk was subdivided into six sub regions. Each sub region offers a unique set of CSRM measures which may act as an example for similar geomorphic settings in the State of Delaware by state and local agencies, and non-profit organizations. This analysis referenced CSRM discussions in existing literature including the ‘Coastal Engineering Assessment of Habitation Restoration Alternatives at Mispillion Inlet’ Report (DNREC, 2008) and the ‘Management Plan for the Delaware Bay Beaches’ (DNREC, 2010), as well as the US Fish and Wildlife Service (USFWS) ‘Prime Hook National Wildlife Refuge Comprehensive Conservation Plan’ (USFWS, 2013).

Table 6. Tier 2 Analysis Example Area Relative Cost/Management Measure Matrix for the DE3_D Risk Area

DE3_D Risk Area Strategy														
					Risk Management Strategies (DE)									
					Preserve				***Accommodate***				***Avoid***	
Existing Coastal Flood Risk Management Projects					Structural Measures (100-yr plus 3')		Regional/ Gates (500-yr)		NNBF (10yr)		Non-Structural (10yr)		Acquisition (10-year floodplain)	
Sub Risk Area	Description	Reference/Note	Existing Project - 2018 Post-Sandy	Estimated Design	Description	Cost Index	Description	Cost Index	Description	Cost Index	Description	Cost Index	Description	Cost Index
1	Narrow sandy beach backed by low dune and wetlands, limited development		None	N/A	N/A	N/A	N/A	N/A	Beach restoration with narrow berm and low dune	1.00	N/A	N/A	N/A	N/A
2	Inlet with jetties	DNREC (2008)	USACE NAV: O&M with 2 jetties	N/A	N/A	N/A	N/A	N/A	1) Hybrid living shoreline along eastern river bank landward of beach	1.00	N/A	N/A	N/A	N/A
					N/A	N/A	N/A	N/A	2) Hybrid living shoreline along interior southern shoreline	1.00	N/A	N/A	N/A	N/A

					N/A	N/A	N/A	N/A	3) Hybrid living shoreline adjacent to Dupont Nature Center revetment/ bulkhead	1.00	N/A	N/A	N/A	N/A
					N/A	N/A	N/A	N/A	4) Living shoreline along eastern river bank from inlet entrance up Mispillion River	1.00	N/A	N/A	N/A	N/A
					N/A	N/A	N/A	N/A	5) Living shoreline along western river bank from inlet entrance up Mispillion River	1.00	N/A	N/A	N/A	N/A
3	Slaughter Beach municipality	DNREC (2010); Southern part of sub region included in Prime Hook NWR	None	N/A	1) Beach restoration on Bayshore	0.55	N/A	N/A	No NNBF along tidal creeks	N/A	Building retrofit (elevate structures)	0.63	Acquisition and Relocation	1.00

					2) Elevation of CR 204 (Bay Ave.)	1.00	N/A	N/A	No NNBF along tidal creeks	N/A	N/A	N/A	N/A	N/A
4	Narrow sandy beach backed by low dune and wetlands, limited development with intertidal wetland with overwash fans		None	N/A	N/A	N/A	N/A	N/A	Beach restoration with narrow berm and low dune	1.00	N/A	N/A	N/A	N/A
					Tidal floodgate	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
					Tidal floodgate	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	Upland farms/forest with some development, includes part of Prime Hook NWR		None	N/A	N/A	N/A	N/A	N/A	No NNBF along tidal creeks	N/A	N/A	N/A	Acquisition and Relocation	1.00

6	Developed areas including the City of Milford		Local	25-year	Shoreline stabilization (bulkhead/revetment addition/improvements) along Milford Waterfront, north bank	1.00	N/A	N/A	No NNBF along tidal creeks	N/A	Building retrofit (elevate structures and floodproof)	0.26	Acquisition and Relocation	0.43
			Local	25-year	Shoreline stabilization (bulkhead/revetment addition/improvements) along Milford Waterfront, south river bank	1.00	N/A	N/A	No NNBF along tidal creeks	N/A	N/A	N/A	N/A	N/A
					Tidal floodgate under Route 1	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 6 presents the results of the Tier 2 analysis. The Tier 2 analysis evaluates the relative costs associated with the three primary strategies: avoid, accommodate, and preserve for CSRM for this particular area. For each of the areas identified, management measures were selected based on knowledge of the area and available data and analyses including shoreline type, topography, extent of development from aerial photography, sea level change inundation, extreme water levels, and flood inundation mapping. Other information considered in the identification of measures includes existing CSRM projects, conceptual costs and the change in vulnerability associated with a combination of measures.

Risk management strategies considered for the Mispillion Inlet/River Complex risk area in the NACCS Tier 2 analysis include a combination of structural, NNBF, and non-structural measures. This combination of measures covers the full range of flood risk management strategies and illustrates an integrated approach to risk reduction and increased resilience.

Structural measures include beach restoration with revetments along the adjacent bay and riverside shorelines of Mispillion Inlet, as well as revetment along the DuPont Nature Center. Shoreline stabilization (bulkhead/revetment addition/improvements) along Milford Waterfront was also included in the analysis. Regional risk management strategies including three tidal flood gates were considered at potential bayshore breach locations as well as at Route 1 to the east of Milford.

NNBF measures within this Mispillion Inlet/River Complex were considered to mitigate the effects of frequent flooding locally. These NNBF measures are consistent with the aforementioned references and include beach restoration with a low dune and oyster reefs along the bayshore as well as hybrid living shorelines at several locations along the interior shorelines and river banks

Finally, non-structural measures such as acquisition, elevation, and floodproofing of structures in areas subject to very frequent flooding (more than a 10 percent annual chance) for the municipalities of Slaughter Beach and Milford as well as surrounding developed areas was considered as part of an adaptation strategy.

The risk management associated with the management measures corresponds to the qualitative evaluation of measures presented in Table 6, such as high for a 1 percent flood plus 3 feet and low for a 10 percent flood. The cost index was derived from parametric unit cost estimates divided by the highest parametric unit cost of all the management measures in the area. The higher the cost index the greater the relative costs. This enables the users to compare the measures associated with the risk management strategy in order to evaluate affordability and ultimately lead to an acceptable level of risk tolerance. The combination of measures leading to a selection of a plan as described in the NACCS Framework would further quantify risk management, and evaluate and compare the change in the risk based on the total cost of the plan. This would be completed at a smaller scale, Tier 3 analysis, which would be able to incorporate refined exposure and risk, evaluation of other risk management measures, as well as refined costs.

VIII. Focus Area Analysis Summary

The Delaware Inland Bays and Delaware Bay Coast Focus Area Analysis (FAA) has been developed for the State of Delaware. The purpose of the FAA is to determine if there is an interest in conducting further study to identify structural, non-structural, NNBF, and policy/programmatic CSRM strategies and opportunities. The complete FAA is provided as an attachment to this Delaware State Chapter. A summary discussion of the content of this analysis for the FAA is provided below.

The purpose of the FAA is to:

- Examine the Delaware Inland Bays and Delaware Bay Coast to identify problems, needs, and opportunities for improvements relating to CSRM, flood risk management, and related purposes.
- Identify non-Federal sponsor(s) willing to cost share potential future investigations.

The study region includes the Atlantic Ocean, Inland Bays, and Delaware Bay coastlines of the State of Delaware in New Castle, Kent and Sussex Counties. The Atlantic Ocean coast line area under study is approximately 77 square miles and the Delaware Bay area to be studied is approximately 145 square miles. A map of the study area is included as Figure 27.

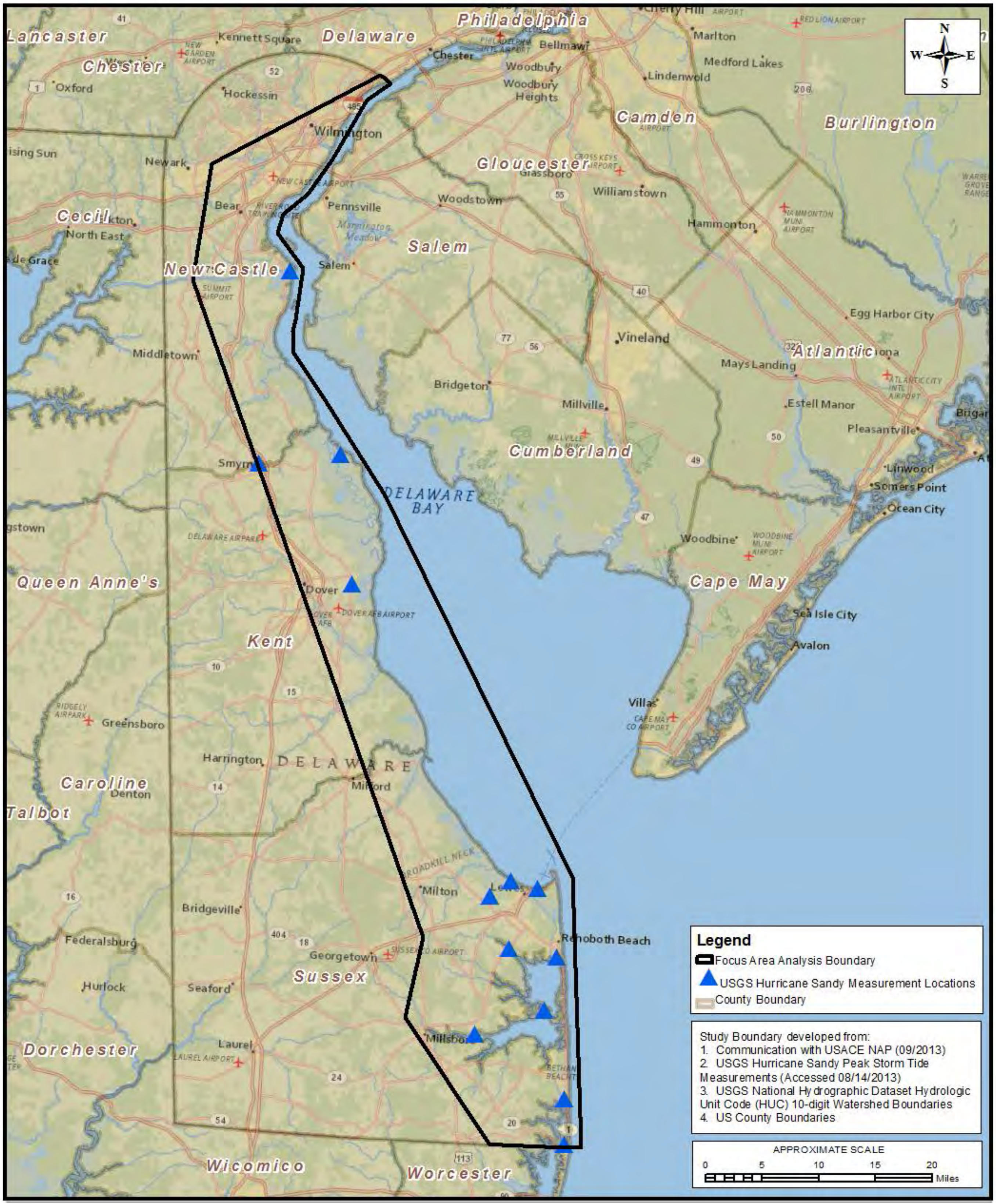

Figure 27. Delaware Inland Bays and Delaware Bay Coast Focus Area Analysis Boundary

IX. Agency Coordination and Collaboration

IX.1 Visioning Meeting Summary

A visioning meeting conducted by the USACE Philadelphia District was held at the St. Jones Reserve in Dover, DE on Tuesday, February 4, 2014. Attendees included representatives from state, county, and local community agencies and representatives and non-profit organizations.

Dialogue centered around the Delaware Inland Bays and Delaware Bay Coast, specifically how information was being both coordinated with stakeholders and incorporated into the NACCS. Specific discussion topics included identifying coastal storm risk at the community level, solutions to that risk, and identifying pertinent policy changes and legislative solutions that could improve coastal resilience.

Correspondence was also received from the Town of South Bethany associated with the Visioning Meeting. More information is included in the NACCS Agency Collaboration and Coordination Report.

IX.2 Coordination

As part of PL 113-2, Federal agencies received appropriations for various purposes within the agencies' mission areas in response to Hurricane Sandy. As part of the NACCS authorizing language, the NACCS was conducted in coordination with other Federal agencies, and state, local, and tribal officials to ensure consistency with other plans to be developed, as appropriate. Extensive collaboration occurred as part of the NACCS, which is presented in the Agency Coordination and Collaboration Report.

Interagency points of contact and subject matter experts were asked in early 2013 to assist in preparing the scope for the NACCS and to be engaged in data gathering and development of analyses as part of the NACCS. This coordination complements the NACCS website located at http://www.nad.usace.army.mil/CompStudy.aspx and webinars for several coastal resilience topics.

Several letters to the DNREC in September through October, 2013 requested feedback with respect to the preliminary problem identification, the post-Sandy most-likely future conditions, vulnerability mapping, and problems, needs and opportunities for future planning initiatives. In response to the April 2014 USACE request letter regarding problems, needs and opportunities, DNREC responded by letter in June 2014 (Attachment B of this State Chapter) stating that there is significant interest in the development of more specific coastal storm risk management and resilience solutions in the State of Delaware. Mispillion River/Inlet is the most vulnerable area and should be the focus of such comprehensive and cooperative solutions. DNREC also conducted a review of a previous draft of this appendix for the State of Delaware in April of 2014.

USACE received several comments from DNREC. These comments have been documented elsewhere and have been incorporated into the current version of this appendix.

IX.3 Related Activities, Projects and Grants

Specific Federal, state, and private non-profit organization efforts that have been prepared in response to PL 113-2 are discussed below specifically for the State of Delaware. Additional information regarding Federal, state, and private, non-profit organization projects and plans applicable to all of the states in the NACCS Study Area are discussed in Appendix D: State and District of Columbia Analyses, while additional information regarding the alignment of interagency plans and strategies is discussed in the Agency Collaboration and Coordination Report.

Federal Efforts

The U.S. Department of the Interior (DOI) received $360 million in appropriations for mitigation actions to restore and rebuild national parks, national wildlife refuges, and other Federal public assets through resilient coastal habitat and infrastructure. The full list of funded projects can be found at: http://www.nfwf.org/hurricanesandy/Documents/doi-projects.pdf.

In August 2013, the Department of the Interior announced that USFWS and the National Fish and Wildlife Foundation (NFWF) would assist in administering the Hurricane Sandy Coastal Resiliency Competitive Grants Program. This program will support projects that reduce communities' vulnerability to the growing risks from coastal storms, sea level change, flooding, erosion and associated threats through strengthening natural ecosystems that also benefit fish and wildlife (NFWF, 2013). The Hurricane Sandy Coastal Resiliency Competitive Grants Program will provide approximately $100 million in grants for over 50 proposals to those states that were affected by Hurricane Sandy. States affected is defined as those states with disaster declarations as a result of the storm event. The grants range from $100,000 to over $5 million and were announced on June 16, 2014. More information on the program can be found at www.nfwf.org/HurricaneSandy, and the full list of projects can be found at: http://www.doi.gov/news/upload/Hurricane-Sandy-2014-Grants-List.pdf. Three NFWF Hurricane Sandy Competitive funded grants include: DE Bayshore Coastal Resiliency: Mispillion to Milford Neck; Creating a Three Dimensional Wetland Model for the Bombay Hook National Wildlife Refuge; and Repairing Infrastructure and Restoring Wetlands and Beaches along the Central Delaware Bayshore (NFWF, 2013) (Figure 28).

Table 7 presents the list of specific Federal projects and plans that have been funded for the State of New Jersey that have been identified to date. Figure 28 presents proposed projects (including DOI grant projects that were not selected to receive grant funding because those that were not selected to receive grant funding represent an opportunity to potentially receive funding in the future) and other ongoing Federal actions using PL 113-2 funding.

Table 7. Post-Sandy Delaware Federal and State Projects and Plans

Agency	State	Funded Projects	Cost
USFWS/DOI	DE	Prime Hook National Wildlife Refuge Coastal Tidal Marsh /Barrier Beach Restoration	$19,805,000
USFWS/DOI	DE	Building a predictive model for submerged aquatic vegetation prevalence and salt marsh resilience in the face of Hurricane Sandy and sea level risk	$217,000
USGS/DOI	DE	GS2-3B: Storm Surge Science Evaluations to Improve Models, Risk Assessments, and Storm Surge Predictions	$1,500,000
USGS/DOI	DE	Estuarine physical response to storms (GS2-2D Estuarine Physical Response)	$2,200,000

Table 7. Post-Sandy Delaware Federal and State Projects and Plans

Agency	State	Funded Projects	Cost
USFWS/DOI	DE	Decision Support for Hurricane Sandy Restoration and Future Conservation to Increase Resiliency of Tidal Wetland Habitats and Species in the Face of Storms and Sea Level Rise	$2,200,000
USGS/DOI	DE	Barrier Island and Estuarine Wetland Physical Change Assessment (GS2-2A Wetland Physical Assessment)	$1,350,000
USGS/DOI	DE	GS2-5D Forecasting Biological Vulnerabilities: Building and delivering data visualization, multi-scale datasets, and models of reduced biological systems resilience to future storms in support of informed natural-resource decision making	$1,025,000
USFWS/DOI	DE	A Stronger Coast: Three USFWS Region 5 multi-National Wildlife Refuge projects to increase coastal resilience and preparedness	$2,060,000
USFWS/DOI	DE	Resilience of the Tidal Marsh Bird Community to Hurricane Sandy and Assessment of Restoration Efforts	$1,573,950
USGS/DOI	DE	Linking Coastal Processes and Vulnerability – Assateague Island Regional Study (GS2-2C Assateague)	$4,000,000
USFWS/DOI	DE	Coastal Barrier Resources System Comprehensive Map Modernization Supporting Coastal Resiliency and Sustainability following Hurricane Sandy	$5,000,000
USFWS/DOI	DE	Decision Support for Hurricane Sandy Restoration and Future Conservation to Increase Resiliency of Beach Habitats and Beach-Dependent Species in the Face of Storms and Sea Level Rise	$1,750,000
USGS/DOI	DE	GS2-3A: Enhance Storm Tide Monitoring, Data Recovery, and Data Display Capabilities	$2,200,000
USGS/DOI	DE	Topographic Surveys: Lidar Elevation Data	$4,050,000
USGS/DOI	DE	GS2-5A Evaluating Ecosystem Resilience: Assessing wetland ecosystem functions and processes in response to Hurricane Sandy impacts	$1,240,000

Table 7. Post-Sandy Delaware Federal and State Projects and Plans

Agency	State	Funded Projects	Cost
DOI NFWF Grant/DNREC	DE	Restoring Delaware Bay's Wetlands and Beaches in Mispillion Harbor Reserve and Milford Neck	$6,187,683
DOI NFWF Grant/University of Delaware	DE	Creating a Three Dimensional Wetland Model for the Bombay Hook National Wildlife Refuge	$427,000
DOI NFWF Grant/DNREC	DE	Repairing Infrastructure and Restoring Wetlands along the Central Delaware Bayshore	$4,910,270

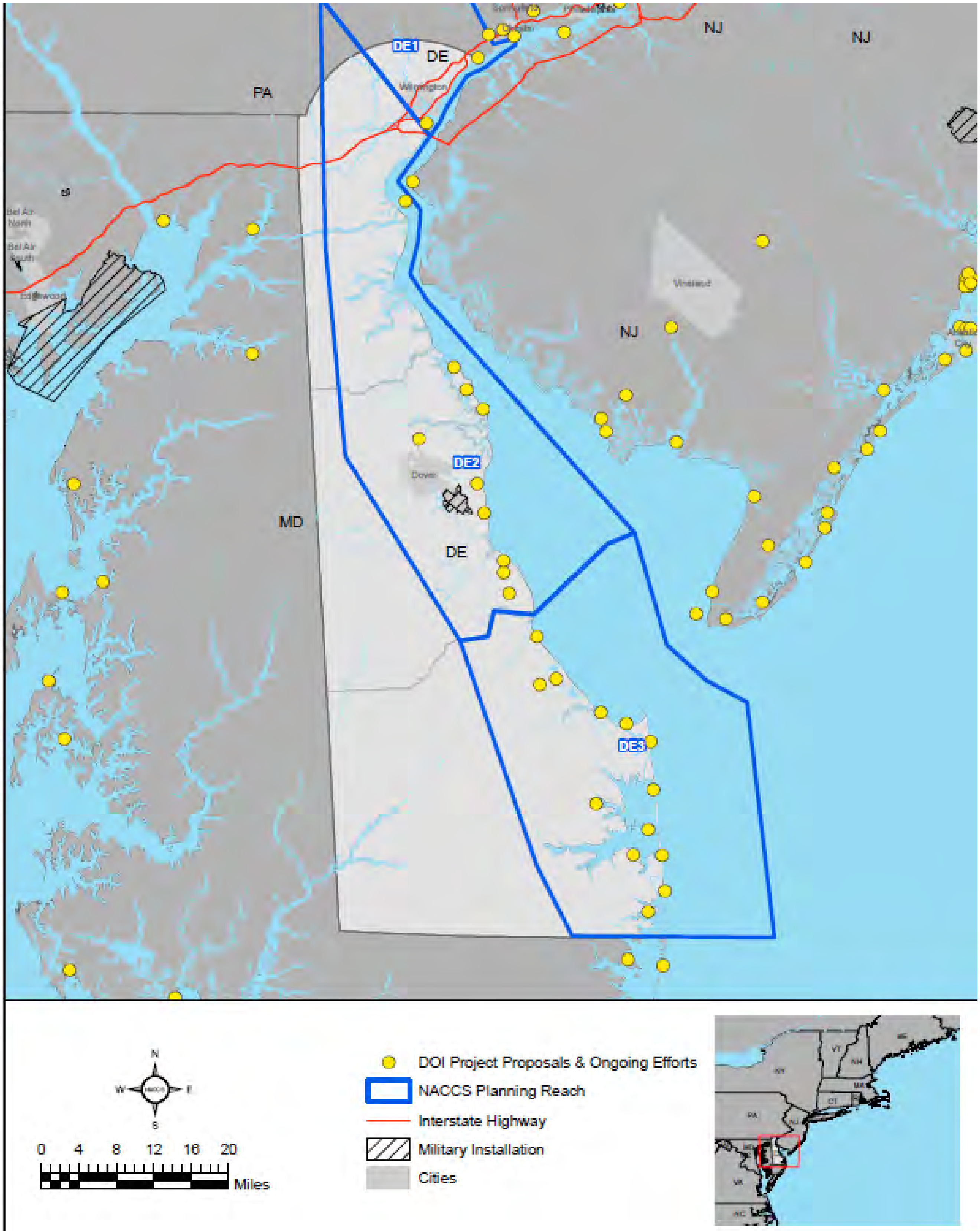

Figure 28. DOI Project Proposals and Ongoing Efforts.

Other grant opportunities included in the Hurricane Sandy Coastal Resiliency Competitive Grants Program include other topographic surveys, storm tide monitoring, and other resources to assess habitat and opportunities to increase resilience along the North Atlantic Coast.

State and Local Efforts

Hazard Mitigation Plans have been developed by both New Castle County and Sussex County. These plans detail the risk to population and infrastructure from flooding, coastal storm damage, sea level change and other factors towards the development of a comprehensive pre- and post-disaster hazard mitigation program. In addition, the City of Lewes has developed a Mitigation and Climate Adaptation Action Plan to further the city's hazard mitigation work by incorporating climate adaptation to improve community sustainability and resilience.

Private Non-Profit Organization Efforts

The Partnership for the Delaware Estuary continues to advance the principles of the Delaware Estuary Living Shoreline Initiative by inventorying living shoreline opportunities towards building coastal wetland resilience for the Delaware Estuary.

IX.4 Sources of Information

A review of Federal, state, municipal, and academic literature was conducted and various reports covering topics related to coastal resilience and risk reduction in Delaware were considered in the development of this state narrative and are listed in Table 8.

Table 8. Federal and State of Delaware Sources of Information

Resource	Source/Reference	Subject
New Castle County Hazard Mitigation Plan	http://www2.nccde.org/EmergencyManagement/Accomplishments/default.aspx	
Sussex County Hazard Mitigation Plan	http://www.sussexcountyde.gov/all-hazard-mitigation-plan	
City of Lewes Mitigation and Climate Adaptation Action Plan	http://www.ci.lewes.de.us/pdfs/Lewes_Hazard_Mitigation_and_CLimate_Adaptation_Action_Plan_FinalDraft_8-2011.pdf	
Barnett, J., Dobshinsky, A. 2008. Climate Change: Impacts and Responses in the Delaware River Basin. Prepared for the Delaware River Basin Commission by the City Planning 702 Urban Design Studio at the University of Pennsylvania.		

Resource	Source/Reference	Subject
Carey, W.L., Maurmeyer, E.M., and Pratt, A.P. (2004). Striking a Balance: A Guide to Coastal Dynamics and Beach Management in Delaware. 2nd edition, Delaware Department of Natural Resources and Environmental Control, Dover, Delaware, Document No. 40-07-01/04/08/06, 47 p. Retrieved from http://www.dnrec.delaware.gov/swc/Pages/CoastalConsBeachPres.aspx		
Kreeger D., J. Adkins, P. Cole, R. Najjar, D. Velinsky, P. Conolly, and J. Kraeuter. May 2010. Climate Change and the Delaware Estuary: Three Case Studies in Vulnerability Assessment and Adaptation Planning. Partnership for the Delaware Estuary, PDE Report No. 10-01. 1 –117 pp.		
FEMA's Coastal Flood Loss Estimating tool	http://fema.maps.arcgis.com/home/webmap/viewer.html?webmap=b4ae0b42789447b18c4b919682b848ad&extent=-98.0694,26.3156,-61.2872,42.2143	
	http://fema.maps.arcgis.com/home/item.html?id=b4ae0b42789447b18c4b919682b848ad	
Model projections of rapid sea level change on the northeast coast of the United States	\\nab-netapp1\CENAB\Projects\Civil-Projects\North Atlantic Coast Comp Study\References\Reports\Yin_2009_Model Projections of Rapid Sea Level Rise on the Northeast Coast of US.pdf	

Resource	Source/Reference	Subject
National Oceanic and Atmospheric Administration (NOAA) 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers. NOAA Office of Ocean and Coastal Resource Management.		
The New Orleans Hurricane Protection System: Assessing Pre-Katrina Vulnerability and Improving Mitigation and Preparedness, NAE/NRC	http://www7.nationalacademies.org/ocga/testimony/New_Orleans_Hurricane_Protection_System.asp	Mitigation & Preparedness
Performance Evaluation of the New Orleans and SE Louisiana Hurricane Protection System, IPET, USACE	http://biotech.law.lsu.edu/katrina/ipet/ipet.html is the final report of a series concerning the in-depth analysis of the New Orleans and Southeast Louisiana Hurricane Protection System (HPS) conducted by the Interagency Performance Evaluation Task Force (IPET). The analyses conducted by the IPET and the information presented in this report are designed to answer five principal questions that comprised the IPET mission: 1. The System: What were the pre-Katrina characteristics of the HPS components; how did they compare to the original design intent? 2. The Storm: What was the surge and wave environment created by Katrina and the forces incident on the levees and floodwalls? 3. The Performance: How did the levees and floodwalls perform, what insights can be gained for the effective repair of the system, and what is the residual capability of the undamaged portions? What was the	The prototype risk assessment for New Orleans identified the areas most vulnerable to future flooding and with the highest residual risk. Residual risk is the vulnerability that remains after all risk reduction measures are considered. Risk assessment provides a new and more comprehensive method to understand the inherent vulnerability of areas protected by complex protection systems and subjected to uncertain natural hazards. It provides a direct view into the sources of vulnerability, providing a valuable tool for public officials at all levels to focus resources and attention on the most serious problems and to seek solutions that reduce risk through both strengthening physical structures and reducing exposure of people and property to losses by non-structural means. Given a relatively uniform level of reliability of the protection system, the relative risk values are largely related to elevation (below sea level) and the value of property or number of people who occupy those areas. The emergency response preparedness and efficiency of evacuation prior to a storm is a key component to reducing risk to life and human safety. This is especially important for those who need assistance to evacuate.

Resource	Source/Reference	Subject
	performance of the interior drainage system and pump stations and their role in flooding and unwatering of the area? 4. The Consequences: What were the societal-related consequences of the flooding from Katrina (including economic, life and safety, environmental, and historical and cultural losses)? 5. The Risk: What were the risk and reliability of the HPS prior to Katrina, and what will they be following the planned repairs and improvements (June 2007)?	
The New Orleans Hurricane Protection System: What Went Wrong and Why, ASCE	http://www.asce.org/uploadedFiles/Publications/ASCE_News/2009/04_April/ERPreport.pdf The members of the ASCE Hurricane Katrina External Review Panel have conducted an in-depth review of the comprehensive work of the USACE Interagency Performance Evaluation Taskforce (IPET). Dedicated efforts of more than 150 engineers and scientists, have, in the year and a half following Hurricane Katrina, evaluated the causes of the New Orleans area hurricane protection system failures. As a result of this excellent work, there is now better understand what went wrong and why. The ASCE Hurricane Katrina External Review Panel has an obligation to share its findings and insights, which go beyond the scope of the IPET review, so that others may learn from this tragedy and prevent similar disasters from happening again, not only in New Orleans, but in other communities throughout the United States that are also vulnerable to hurricanes and flooding.	The American Society of Civil Engineers, Hurricane Katrina External Review Panel has identified 10 critical actions they believe are critical to help minimize the risks of another "Katrina" in the future. These include 1. Keep safety at the forefront of public priorities, 2. Quantify the risks, 3. Communicate the risks to the public and decide how much risk is acceptable, 4. Rethink the whole system, including land use in New Orleans, 5. Correct the deficiencies, 6. Put someone in charge, 7. Improve interagency coordination, 8. Upgrade engineering design procedures, 9. Bring in independent experts, and 10. Place safety first
The New Orleans Hurricane Protection System: Assessing Pre-Katrina Vulnerability and Improving Mitigation and Preparedness, NAE/NRC	Jeffrey Jacobs, a Scholar with the Water Science and Technology Board of the National Research Council served as the study director for the National Academy of Engineering and National Research Council's Committee on New Orleans Regional Hurricane Protection Projects. The Council is the operating arm of the National Academy of Sciences, the National	There were several lessons learned as a result of hurricane Katrina discussed within the document. There were as follows: 1.There are many inherent hydrologic vulnerabilities of living in the greater New Orleans metropolitan region, especially in areas below sea level. Post-Katrina repairs and strengthening have reduced some of these vulnerabilities. Nevertheless, because of the possibility of

Resource	Source/Reference	Subject
	Academy of Engineering, and the Institute of Medicine of The National Academies. The Academies operate under an 1863 charter from Congress to provide independent advice to the Federal government on scientific and technical matters. Their committee was convened in December 2005 at the request of then-Assistant Secretary of the Army for Civil Works, Mr. J.P. Woodley, to provide an independent review of the work of the Interagency Performance Evaluation Task Force, or IPET. The IPET group was assembled by the U.S. Army Corps of Engineers to evaluate the performance of the New Orleans hurricane protection system during Hurricane Katrina and to provide advice in repairing the system. During its 3.5-year tenure our committee issued five reports, all of which reviewed draft reports issued by the IPET. Their committee's fifth and final report was issued in April 2009 and it reviewed the IPET draft final report and commented on important "lessons learned" during Hurricane Katrina and its aftermath. The document was a summary of those lesson learned as identified in their final report.	levee/floodwall overtopping or more importantly, levee/floodwall failure the risks of inundation and flooding never can be fully eliminated by protective structures no matter how large or sturdy those structures may be. 2. The pre-Katrina footprint of the New Orleans hurricane protection system consisted of roughly 350 miles of protective structures including levees, I-walls, and T-walls. There was undue optimism about the ability of this extensive network of protective structures to provide reliable flood risk management. Future construction of protective structures for the region should proceed with these lessons firmly in mind and in the context of a more comprehensive and resilient hurricane protection plan. 3. The planning and design for upgrading the current hurricane protection system should discourage settlement in areas that are most vulnerable to flooding due to hurricane storm surge. The voluntary relocation of people and neighborhoods out of particularly vulnerable areas with adequate resources designed to improve their safety in less vulnerable areas should be considered as a viable public policy option. 4. When voluntary relocations are not viable, floodproofing measures will be an essential complement to protective structures such as levees and floodwalls in improving public safety in the New Orleans region from hurricanes and induced storm surge. This committee especially endorses the practice of elevating the first floor of buildings to at least the 1 percent flood level, and preferably to a more conservative elevation. The more conservative elevation reflects a subsequent finding in this report regarding the inadequacy of the 1 percent flood as a flood risk management standard for a large urban center such as New Orleans. Critical public and private infrastructure electric power, water, gas, telecommunications, and flood water collection and pumping facilities should be strengthened through reliable construction, ensuring reliable interdependencies among critical infrastructure systems.5.The disaster response plan for New Orleans, although extensive and instrumental in

Resource	Source/Reference	Subject
		successfully evacuating a very large portion of the New Orleans metropolitan area population, was inadequate for the Katrina event. Thus, there is a need for more extensive and systematic evacuation studies, plans, and communication of evacuation plans. A comprehensive evacuation program should include not only well designed and tested evacuation plans, protocols, and criteria for evacuation warnings, but also alternatives such as improved local and regional shelters that could make evacuations less imposing. It also should consider longer-term strategies that can enhance the efficiency of evacuations, such as locating facilities for the ill and elderly away from more vulnerable areas that may be subject to frequent evacuations.

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ATTACHMENT A

Focus Area Analyses Report

ATTACHMENT A

Delaware Inland Bays and Delaware Bay Coast Focus Area Report

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1. APPENDIX A – Stakeholder Inquiry Letter and List of Contacts
2. APPENDIX B – Meeting Documentation from Stakeholder Meetings
3. APPENDIX C – Stakeholder Responses to Information Inquiry

1. Study Authority

The focus area analysis presented in this report is being conducted as part of the North Atlantic Coast Comprehensive Study (NACCS) authorized by the Disaster Relief Appropriations Act of 2013 (Public Law [PL] 113-2), Title X, Chapter approved 29 January 2013.

Specific language within PL 113-2 states, "…as a part of the study, the Secretary shall identify those activities warranting additional analysis by the Corps." This report identifies coastal storm risk management activities warranting additional analysis that could be pursued for the Delaware Inland Bays and Delaware Bay Coast study area. Public Law 84-71 is a plausible method for further investigation, as well as existing study resolutions for the area, the Floodplain Management Services Program, Planning Assistance to the States, Continuing Authorities Program (CAP), and other relevant authorities.

2. Study Purpose

The purpose of the focus area report is to capture and present information regarding possible cost-shared, future phases of study to provide structural and/or non-structural coastal storm risk management, flood risk management, ecosystem restoration, and other related purposes for the Delaware Inland Bays and Delaware Bay Coast study area.

The focus area report will:

- Examine the Delaware Inland Bays and Delaware Bay Coast study area to identify problems, needs, and opportunities for improvements relating to coastal storm risk management and related purposes.
- Identify a non-Federal sponsor(s) willing to cost-share the potential future investigation.

3. Location of Study Area / Congressional District

The study area includes the Delaware Inland Bays, the set of interconnected bodies of water that are separated from the Atlantic Ocean by a spit of land, and the Delaware Bay coastline of the State of Delaware in New Castle, Kent, and Sussex Counties. A map of the study area is included as **Figure 1**. The Inland Bays coastline area is approximately 77 square miles and the Delaware Bay coastline is approximately 145 square miles.

Congressional interest in the Delaware Inland Bays and Delaware Bay Coast has been expressed by John C. Carney, Jr., Delaware's at-large Representative in the House. In addition, Congressional interest in the study area lies with Delaware Senators Tom Carper and Christopher Coons.

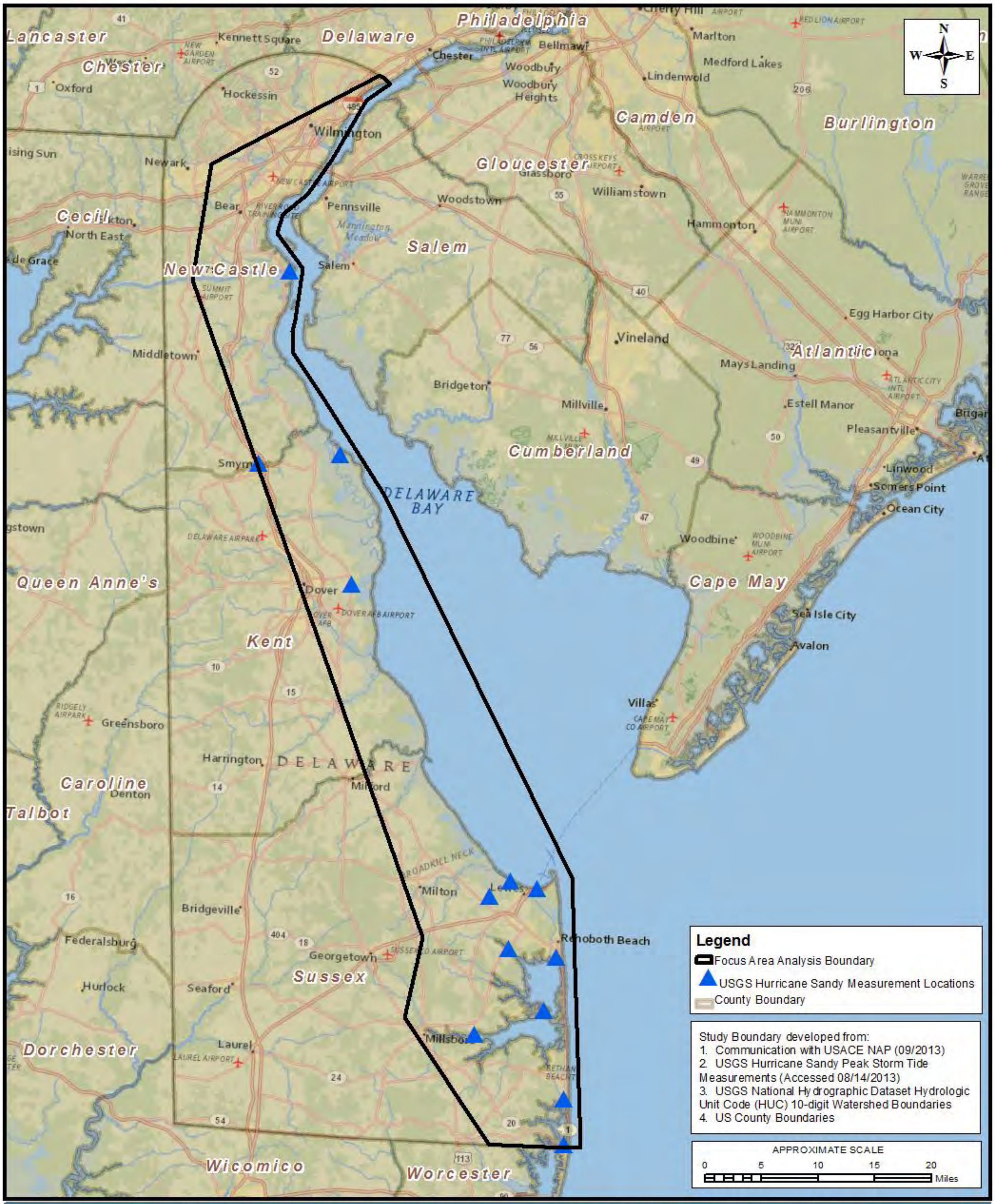

Figure 1. Delaware Inland Bays and Delaware Bay Coast Focus Area Analysis Boundary

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4. Prior Studies and Existing Projects

This focus area report will identify problems and opportunities within the study area as they relate to coastal storm risk management and related purposes. The occurrence of flooding within the study area has been well documented and a number of prior studies in the study area were reviewed for relevancy to this study. Types of projects and studies include those related to navigation, coastal storm and flood risk management, ecosystem restoration, and water resource management. Community resilience is also an increasingly relevant topic included for consideration in projects and studies. The intent of including community resilience is to consider past, present, and future exposure to hazards such as coastal flooding, and to influence and improve the capacity to withstand and recover from adverse situations.

Table 1 summarizes various studies and projects undertaken by Federal, state, and local agencies. Report Sections 4.1 through 4.2 provide brief descriptions of studies and projects.

4.1 Federal

USACE has several ongoing studies and projects in the study area related to coastal storm risk management, ecosystem restoration, and navigation. The Delaware Bay Coastline, Port Mahon Coastal Storm Damage Reduction, Broadkill Beach Coastal Storm Damage Reduction, Delaware River Dredged Material Utilization, and Restoration of Grassdale and the Delaware River Deepening all focus on coastal storm risk management and may also address restoration of nearshore environments, contribution to improved water quality, and habitat recovery at specific locations within the Delaware Bay coastline.

USACE also operates and maintains by dredging several Federally authorized navigation channels in the study area, including the Indian River Inlet, Inland Waterway from Rehoboth Bay to Delaware Bay, the Chesapeake and Delaware (C&D) Canal, Mispillion River, Murderkill River, Christina River (Wilmington Harbor), and Roosevelt Inlet. Material dredged from the navigation channels is often utilized beneficially for placement at coastal restoration sites to build land and/or create functional habitat.

4.2 State

PBS&J developed the 2010 Management Plan for the Delaware Bay Beaches for the Delaware Department of Natural Resources and Environmental Control (DNREC) Shoreline and Waterway Management Section which provides guidance for long-term management for several beaches located along the Delaware Bay (DNREC, 2010). The study incorporates existing literature and data, previous historical analysis, coastal processes modeling, conceptual beach nourishment designs, and cost estimates and schedules.

The State of Delaware prepared a 2012 report entitled “Preparing for Tomorrow’s High Tide – Sea Level Rise Vulnerability Assessment for the State of Delaware” (DNREC, 2012). It contains background information about relative sea level change, methods used to determine vulnerability, and a comprehensive accounting of the extent and impacts that relative sea level change will have on resources within the state. The information contained within the document will be used by the Delaware Sea Level Rise Advisory Committee and other stakeholders to guide development of relative sea level change adaptation strategies.

Table 1. Prior Studies and Existing Projects

Study / Report	Focus Area	Structural / Non-Structural	Time Frame [Ongoing / Proposed Short Term / Proposed Long Term]	Status	Navigation	Coastal Storm Risk Management	Flood Risk Management	Ecosystem Restoration	Water Resource Management	Community Resilience
USACE										
Indian River Inlet and Bay, Inland Waterway from Rehoboth Beach to Delaware Bay, Broadkill River, C&D Canal, Mispillion River, Murderkill River Federal Navigation Projects	Navigation Channels	S	LT	O&M	X					
Delaware River Main Channel Deepening	Navigation Channel	S	LT	Construction	X					
Port Mahon, Coastal Storm Damage Reduction	Delaware Bay, Kent County, Beachfill	S	LT	Plan		X	X			
Broadkill Beach, Coastal Storm Damage Reduction	Delaware Bay Coastline	S	LT	Ongoing		X	X			
Lewes Beach, Coastal Storm Damage Reduction	Delaware Bay Coastline	S	LT	Ongoing		X	X			
Delaware Bay Coastline Feasibility Study (including the Broadkill Beach, Lewes and Port Mahon Feasibility Studies)	Delaware Bay Coastline	S	LT	Ongoing		X	X	X		
Delaware River Dredge Material Utilization Feasibility Study	Delaware River Coastline	S	LT	Ongoing	X	X	X	X		
Restoration of Grassdale	Ecosystem Restoration	S	ST	Ongoing				X		

Study / Report	Focus Area	Structural / Non-Structural	Time Frame [Ongoing / Proposed Short Term / Proposed Long Term]	Status	Navigation	Coastal Storm Risk Management	Flood Risk Management	Ecosystem Restoration	Water Resource Management	Community Resilience
State of Delaware										
Management Plan for the Delaware Bay Beaches	State-wide	S/N	LT	Plan		X	X		X	X
Preparing for Tomorrow's High Tide – Sea Level Rise Vulnerability Assessment for the State of Delaware	State-wide	S/N	LT	Plan					X	X
DNREC Shoreline and Waterway Management Section Beach Fill/Nourishment	State-wide	S/N	Ongoing	Project		X	X	X		X
Coastal Engineering Assessment of Habitation Restoration Alternatives at Mispillion Inlet (-Moffatt & Nichol, 2008),	Mispillion Inlet	S/N	LT	Plan	X	X	X	X		
Local										
2010 New Castle County All Hazard Mitigation Plan	County-wide	S/N	LT	Plan		X	X		X	X
2010 Multi-jurisdictional All Hazard Mitigation Plan Update – Sussex County, DE	County-wide	S/N	LT	Plan		X	X		X	X
The City of Lewes Hazard Mitigation and Climate Adaptation Action Plan (2011)	Lewes, DE	N	LT	Plan					X	X

5. Plan Formulation

Six planning steps in the Water Resource Council's Principles and Guidelines are followed to focus the planning effort and recommend a plan for potential future investigation. The six steps are:

- Identify problems and opportunities
- Inventory and forecast conditions
- Formulate alternative plans
- Evaluate effects of alternative plans
- Compare alternative plans
- Select a recommended plan

The iterations of the planning steps typically differ in the emphasis that is placed on each of the steps.

This focus area report emphasizes identification of problems and opportunities. The following sections present the results of the initial iterations of the planning steps conducted during the focus area analysis. This information will be refined in future iterations of the planning process that will be accomplished during the future study phases.

5.1 Problems and Opportunities

The shorelines of the Delaware Inland Bays and the Delaware Bay Coast are characterized by flat, low-lying coastal plains that are subject to tidal flooding during storms. The shoreline consists of either undeveloped coastal beach and marsh, or developed residential and commercial infrastructure. Historic relative sea level change has exacerbated the problem over the past century, and the potential for accelerated relative sea level change in the future will only increase the magnitude and frequency of the problem (DNREC, 2012).

Public and private property at risk involves densely populated sections of the barrier coastline and also mainland portions of the areas bordering the bays and tidal tributaries of the study area. It includes densely developed urban areas, private residences, businesses, including refineries, chemical plants, schools, infrastructure, roads, and evacuation routes for coastal emergencies. Inundation of sites identified through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), otherwise referred to as Superfund sites, or other hazardous waste sites may severely impact water quality. Plan formulation will focus on managing risk, improving resilience to future coastal storm damage, and ensuring that robust designs can account for a wide range of potential storm scenarios. Additionally, the Delaware Inland Bay and Delaware Bay Coast regions include undeveloped areas that provide ecological, fisheries, and recreational benefits. These areas are subject to erosion, loss, and alteration due to coastal storms. Dunes, beaches, marshes, and estuarine ecosystems are quite fragile in some locations and are threatened by sea level change.

The southern half of Delaware is highly vulnerable to flooding as evidenced by the number of reported flood events in recent years, particularly the Ash Wednesday storm in March of 1962, which had a storm surge of 9.5 feet above mean lower low water (MLLW) and Hurricane Floyd in September 1999 which caused more than $8 million in damages (Sussex County, 2010). According to the National Climatic Data Center (NCDC), 57 flood events were reported in Sussex County between March 13, 1993 and November 30, 2009, resulting in more than $45 million in property damage in Sussex County alone, compared to approximately $24 million in damages for New Castle County for the same time period (NOAA NCDC, 2012). The vulnerability of this area to future flooding events and storm damage is effectively increased, considering the combined effects of climate change and sea level change on the frequency and intensity of coastal flooding events. Hurricane Sandy caused minor damage along the Delaware Inland Bays and Delaware Bay Coast, damaging property through flooding and erosion. A maximum storm surge of 5.0 feet North Atlantic Vertical Datum of 1988 (NAVD88) was recorded at Lewes, DE (Delaware Geological Survey, 2012). Nearly 11 inches of rain fell in several parts of Delaware coupled with winds that increased water levels in the bays (Delaware State Climatologist, 2012).

As part of this focus area analysis, plan formulation will include identification of potential measures to help these vulnerable areas become more resilient to coastal storm damage.

In order to collect data on problems and opportunites for Delaware Inland Bays and Delaware Bay Coast, stakeholder meetings and webinars were conducted with USACE, state, and local agencies. **Appendix A** includes a list of points of contact (POCs) invited to participate in meetings and webinars, meeting materials and questionnaires. **Appendix B** includes meeting minutes with a list of participants, and **Appendix C** includes comments received from agencies and stakeholders that were unable to attend meetings and/or webinars or from attendees who provided additional feedback following meetings and webinars. Stakeholder input was incorporated into the development and analysis of potential measures for this focus area report. A summary of stakeholder input is included in **Table 2.**

Table 2. Summary of Stakeholder Input - Problems

Problem Area	Problems Identified	Reference
Canals extending to Little Assawoman Bay	Flooding due to storm surge, wind direction, and rain. Flood damage to homes.	Letter response, dated 9/9/2013
Delaware River and Bay, other bays	Flooding due to storm surge, wind direction and rain. Beach erosion, flooding, overtopping dikes.	Response to survey
Mispillion River and Inlet.	Flooding due to storm surge, wind direction, and rain. Beach erosion, habitat loss, flooding, overtopping of inlet structures.	Letter response dated 6/19/2014

5.1.1 Problems and Opportunities by Region

Delaware River Region

The Delaware River region of the Delaware Bay study area includes the Christina River floodplain, the City of New Castle, Pea Patch Island, Delaware City, and Bay View Beach. The shoreline of this region is classified as mostly wetland with periodic regions of urban influence. Problem areas were identified in this reach and are described below.

The Christina River empties into the Delaware River at the Port of Wilmington. Cities and unincorporated areas include Claymont, Wilmington and Edgemoor. This area is characterized by a mixed industrial and commercial use and urban residential development. Major roads include Interstate 495. There are seven ports, one power plant, and three rail bridges.

Further south, New Castle, with its system of dikes, borders the Delaware River. This area is characterized by a mixed industrial and commercial use and urban residential development with extended areas of wetland shoreline. Major roads include the Delaware Memorial Bridge (Interstate 295). There are two rail bridges.

An example of the type of storm causing coastal flooding encountered in this region is Hurricane Floyd which battered New Castle County on September 16, 1999. This storm brought torrential rains and damaging winds. The hurricane caused widespread flash flooding as rain totals averaged around nine inches, most of which fell in a 12-hour period from the early morning through the afternoon on the 16th. Approximately 300 residents of New Castle and Sussex counties were evacuated to shelters. The combination of winds funneling into Delaware Bay and the runoff from inland waterways produced minor tidal flooding at the times of high tide in New Castle County. The hardest hit community within the county was Glenville (near Stanton) along the White Clay Creek. About 100 homes were flooded with up to six feet of water. During the height of the storm, 40 roads and bridges were closed including sections of Delaware State Routes 1 and 9.

During Hurricane Sandy several of the dikes in New Castle were overtopped and weakened. This allowed more damage to occur in subsequent smaller events. State funds have been appropriated to reconstruct and raise the five dikes.

Bay View Beach and Augustine Beach experienced flooding of homes and erosion of beaches during Hurricane Sandy. A concrete seawall in Bay View Beach is currently constructed to an insufficient crest elevation and a series of concrete groins no longer functions as designed.

Delaware Bay Region

The Delaware Bay region of the study area extends from Woodland Beach to Lewes. This region includes the communities of Woodland Beach, Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach, Prime Hook Beach, Broadkill Beach, and Lewes. While dominated by the Delaware Bay, the region is also influenced by the Mahon River, Little Creek, the Murderkill River, and Mispillion River. There are several notable wildlife areas and refuges that are experiencing erosion and breaching including the Prime Hook National Wildlife Refuge. Climate change is resulting in more frequent periods of sustained high water as a result of relative sea level change in combination with high wave energy associated with storms that contribute to erosion and overwash of natural beaches. Relative sea level change impacts will be more obvious on the bay/wetland side of barrier beaches because without replenishment projects, as the water rises, more land is lost. Relative sea level change could lead to changes in location of the sandy beach, overwash, and dune grassland habitats, adversely impacting rare beetles, horseshoe crabs, diamondback terrapins, and shorebird nesting and foraging habitats (DNREC, 2012).

When subject to elevated water levels, narrow, low-elevation estuarine barrier communities, such as those in Prime Hook National Wildlife Refuge, will become more susceptible to storm overwash, barrier segmentation, the formation of new tidal inlets, and closing of previous inlets.

Both the Mispillion and Murderkill Rivers tidal inlet entrances are important for navigation and can impact the hydrodynamics of adjacent wetlands. Inlet structures at both inlets were damaged during Hurricane Sandy, thus resulting in reated severe impacts including the instability of the functions and values of adjacent wetlands. In the case of Murderkill, the State-owned and maintained jetties are constructed from large grout-filled bags. Flooding and erosion of adjacent beaches occurred in these areas. Milford, situated approximately 7 miles inland on the Mispillion River, experienced storm surge coupled with stormwater runoff which flooded homes and roadways. The beaches, dunes, and intertidal flats and marshes surrounding Mispillion Harbor and the Federally-maintained jetties are invaluable habitat for significant populations of migratory and nesting shorebirds and other fauna.

Inland Bays Region

The Inland Bays region of the study area includes Rehoboth Bay, Indian River Bay, and Little Assawoman Bay. This region includes bays that are connected to the Atlantic Ocean by Indian River Inlet. Bayside communities experiencing coastal flooding include Dewey Beach, Joy Beach, Old Landing, Long Neck, Oak Orchard, Bethany, South Bethany and Fenwick Island.

The Dewey Beach, Bethany Beach, and South Bethany areas are characterized as a medium density urban residential and beach community development. The shoreline for this area is constructed of beaches, bluffs, and wetlands. The major road in this region is Delaware State Route 1 which intersects other local arteries such as State Routes 9 and 13 near the Dover Air Force Base. South Bethany is an example of a town that experienced flooding during Hurricane Sandy that resulted from a combination of tidal surge, heavy rainfall and winds from the west that pushed water into the town. Existing bulkhead heights were too low (for example, York Road was reported to be at an elevation of 1.7 feet NAVD88).

Further south on Little Assawoman Bay lies Fenwick Island. This area is characterized by medium density urban residential and beach community development. The shoreline for this area varies with beaches, bluffs, wetlands, and urban development. Delaware State Route 1 is the major artery.

5.2 Objectives

The national or Federal objective of water and related land resources planning is to contribute to National Economic Development (NED) consistent with protecting the nation’s environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation. USACE also has a National Ecosystem Restoration (NER) objective in response to legislation and administration policy. This objective is to contribute to the nation’s ecosystems through ecosystem restoration, with contributions measured by changes in the amounts and values of habitat. Projects which produce both NED benefits and NER benefits will result in a “best” recommended plan so that no alternative plan or scale has a higher excess of NED benefits plus NER benefits over total project costs. This plan shall attempt to maximize the sum of net NED and NER benefits, and to offer the best balance between two Federal objectives. Recommendations for multipurpose projects will be based on a combination of NED benefit-cost analysis, and NER benefits analysis, including cost effectiveness and incremental cost analysis.

In addition to Federal water resources planning objectives, the main goals of the NACCS, under which this focus area analysis is being conducted, are to:

1) Reduce risk to which vulnerable coastal populations are subject.
2) Ensure a sustainable and robust coastal landscape system, considering future sea level change and climate change scenarios, to reduce risk to vulnerable populations, property, ecosystems, and infrastructure.

Specific objectives for this focus area analysis are to:

1) Manage risk from storm surge.

2) Manage flood risk.
3) Provide adaptive and sustainable solutions for future development that account for future changes such as relative sea level change, land subsidence and climate change.
4) Maintain or improve ecosystem goods and services provided (social, economic and ecological balance).
5) Incorporate opportunities for nature-based infrastructure, alone and in combination with traditional measures.
6) Maintain economic viability of the working coastline.
7) Improve emergency response and evacuations by improving the transportation systems before and during flood events.
8) Incorporate problems, needs, and opportunities identified by stakeholders to manage flood risk.
9) Manage erosion occurring along the bay beaches.
10) Manage risk to National Register of Historic Places and other cultural resources
11) Better incorporation of regional sediment management (RSM) into non-Federal projects, continuation of RSM practices in place, and identification of new opportunities.

5.3 Planning Constraints

Planning constraints are both institutional (policy/programmatic, legislative, and funding-related) and physical (such as sensitive ecosystem areas, land use, etc.).

5.3.1 Institutional Constraints

1) Comply with all Federal laws and executive orders, such as the National Environmental Policy Act (NEPA), the Clean Water Act, the Endangered Species Act, and Executive Order 11988.
2) Avoid increasing the flood risk to surrounding communities and facilities.
3) Avoid solutions that cannot be maintained by the non-Federal sponsors, whether due to expense or complicated technologies.
4) Comply with local land use plans and regulations.
5) Difficulty in funding long-term operation and maintenance costs.
6) Permitting with Federal, state, and local agencies.
7) Many of the beaches within the study area are recognized as a recreational resource. It is important that this resource not be compromised.
8) Acquisition of real estate and easements.
9) Limited Federal funding for maintenance of projects.

5.3.2 Physical Constraints

1) Some areas within this study area are highly developed.
2) Avoid additional degradation of water quality, which would put additional stress on aquatic ecosystems.

3) Avoid impacting or exacerbating existing hazardous, toxic, and radioactive wastes (HTRW) that have been identified within the project area.

4) Minimize the impact to authorized navigation projects.

5) Minimize the impact to other projects and areas where risk has been managed, such as sensitive wetlands, wildlife management areas, etc.

6) Minimize effects on cultural resources and historic structures, sites, and features.

7) Loss of streetscape character and potential economic losses from elevation of structures or placement of floodwall/levee.

8) Lack of sand borrow areas for projects.

5.4 Future Without Project Condition

The future without project (FWOP) condition is the most likely condition expected to exist in the future in the absence of proposed projects. The FWOP condition is the baseline against which all project plans are evaluated. FWOP conditions, including sea level change considerations, will be developed along with the no-action alternative during the future phases of study.

5.5 Measures

This section identifies a broad range of potential solutions (measures) to address the study area objectives. Many of these measures are outlined in “Coastal Risk Reduction and Resilience: Using the Full Area of Measures” (USACE, 2013). Any of these potential measures will be weighed against a “No-action Plan” in the future phases of study.

5.5.1 Structural Measures

Structural measures are used to control floodwaters. Broad-based structural measures identified include:

1) <u>Seawall/Revetment</u>: Seawalls are built parallel to the shoreline with the purpose of reducing overtopping and consequent flooding of areas behind the seawall due to storm surge and waves. Revetments are onshore sloping structures which manage shoreline erosion. Areas immediately seaward of a seawalls or revetments may be impacted because of isolation from an inland sediment source.

2) <u>Groins</u>: Groins are narrow structures, built perpendicular to the shoreline, that stabilize a beach experiencing longshore erosion. Beach material will accumulate on the updrift side of a groin, but the downdrift side will experience erosion caused by isolation from the longshore sediment transport source. Both the accretional and erosional effects extend some distance alongshore away from the groin.

3) <u>Detached Breakwaters</u>: The primary function of a detached breakwater is to reduce beach erosion by reducing wave heights in the lee of the structure. The reduction in wave heights reduces longshore and cross-shore sediment transport. Detached breakwaters are built nearshore, in shallow water, and generally parallel to the shoreline. They are low-crested structures which decrease wave energy and help promote an even distribution of material along the coastline. Since detached breakwaters can impact the transport of beach material, there can be erosional impacts in downdrift areas. In addition, detached breakwaters, when submerged, can cause a non-visible hazard to boats and swimmers.

4) Berms / Levees: Berms, levees, or dunes can be constructed along the shoreline, tying into high ground or surrounding an area entirely, to manage risk of storm surge and wave run-up, and erosion to the landward shoreline. These measures have a large footprint since their stability is partially dependent on a maximum side slope from the top to the toe, and are often composed of earthen materials. Levees or berms also need to be constructed to prevent or control underseepage of floodwaters through the existing soils. They may need to include pumping stations to remove interior stormwater drainage. Roads sometimes need to be ramped to cross these features.

5) Multipurpose Berms/Levees: Berm and levee features require a large footprint to remain stable. However, it is possible to incorporate features in the design of the levees, such as parking areas/garages, commercial or residential development, recreational greenways, etc. to take advantage of the increased elevation.

6) Floodwalls and Bulkheads: Floodwalls or bulkheads can be constructed along the shoreline, tying into high ground or surrounding an area entirely, to manage risk of storm surge, wave run-up, and erosion to the landward shoreline. These measures have smaller footprints than berms and levees; but require concrete or steel pilings for stability to withstand force from floodwaters, including waves. Floodwalls must also be designed to prevent or control under seepage in the existing soils. Floodwalls may need to include pumping stations to remove interior stormwater drainage, and often include floodgates to allow for access roads to any waterside property. Floodwalls may not be applicable in areas that are subjected to severe wave activity.

7) Flood/Tide Gates: A flood or tide gate can be constructed across a tributary to provide for risk reduction from coastal inundation upstream of the gate. Flood and tide gates are constructed with openings to allow for recreational or industrial uses of a tributary to continue, and also allow for some connectivity of the ecosystem. There are several types of flood gates; two types include an Obermeyer Gate and a Steel Gate. The Obermeyer gate lifts a steel gate flap to close the gate, whereas a Steel gate slides horizontally into closing position. Inflatable dams can also be used as a gate, as they can be filled with air or water to inflate and act as a closed gate.

   If the watershed upstream of the flood or tide gate does not have enough natural floodplain storage to hold increases in water level due to precipitation runoff, then either additional storage space will need to be created and/or pumping stations will need to be added to handle interior drainage upstream of a flood or tide gate.

8) Portable Floodwalls: Portable floodwalls are a potentially viable measure when complete portability is necessary and no permanent fixings or structures are desired. Portable floodwalls are typically constructed of lightweight aluminum and rely on the weight of the water to press down and stabilize the wall to create a water tight seal. Temporary floodwalls can vary in height to accommodate the change in existing elevation and optimize cost. However, installation of a system of portable floodwalls may need to begin several days depending on available resources. Therefore, portable floodwalls may not be suitable for some events and areas when installation time exceeds event warning time. Additionally, portable floodwalls are not applicable where subject to storm wave action.

9) Portable Berms/Cofferdams: Portable coffer dams are another rapidly deployable, temporary method that can be used for flood risk management. The coffer dam, made of commercial grade vinyl coated polyester, is a water inflated dam which consists of a self-contained single tube with

an inner restraint baffle/diaphragm system for stability. The dam has ability to stand alone as a positive water barrier without any additional external stabilization devices. The system can be installed easily in the field when needed and removed when the threat is over. Once laid out, it can be inflated using any available water source. Each unit is up to 100 feet long and 8 feet high. Portable coffer dam units can be joined together by overlapping end to end at any angle to manage flood risk to large areas.

Temporary pumps are required to fill the cofferdam units; however, the pumps can used as temporary pump stations to pump trapped water on the "dry" side of the cofferdam and discharging the water into the "wet" side.

10) Storm Surge Barriers: Storm surge barriers are often coupled with levees to prevent storm surge from propagating up waterways. Storm surge barriers generally consist of a series of movable gates that are normally open to let flow pass, but will close when storm surge exceeds a certain water level.

11) Road, Rail, or Light Rail Raises: Roads can be raised on berms or levees. The advantage of raising a road is two-fold. First, to raise main evacuation routes so they will not be flooded during a coastal and heavy precipitation event. Secondly, existing easements can provide some of the property needed for the footprint for building a berm or levee. However, main routes in the Delaware Inland Bays and Delaware Bay Coast area are heavily developed. In order to raise existing main routes, a large amount of property along the roadways will likely need to be acquired and this could have a major impact for the main business corridors. Additionally, the side roads leading to these main roads would need to be ramped for access.

    Another option is raising existing rail or light rail lines on berms or levees. A road, rail, or light rail line raise may create interior drainage problems if stormwater storage is insufficient. Additional storage space and/or pumping stations may be required to remove interior stormwater drainage.

12) Beach and Dune Restoration: Shoreline restoration by sand nourishment or replenishment of beaches subject to erosion. Restoration often includes include dune restoration/enhancement to provide additional risk reduction for flooding and wave action.

13) Stormwater System Improvements: Existing stormwater systems can be improved by increasing capacity, through additional piping and stream channelization, increasing pipe sizes and inlets and adding more storage areas, adding gates to outfall pipes to prevent storm surge from entering the storm sewer system, and pumping water from the storm system.

14) Bridge Trash Racks: Trash racks can be installed upstream of critical bridges to collect debris during a flood event to help preserve the structural integrity of the bridge support structure.

5.5.2 Non-Structural Measures

Broad-based non-structural measures identified include:

1) Acquisition / Buyouts: Homes that are subject to repetitive loss from flooding and are outside of an area proposed for a structural flood risk management project are viable candidates for buyouts or relocations. A buyout occurs when the homeowner is paid fair market value for the property, and moves to a new location. Relocations can occur when the homeowner has a parcel large enough that a home can be moved to higher ground on the existing parcel or a

home can be relocated to a different parcel entirely. Acquisitions and buyouts restore the natural floodplain in the location of previous development.

2) Early Warning Systems: Flood warning systems are important to notify citizens of a flooding event. Coastal storms typically have a several-day timeframe where the community is aware of the possibility of impact, but last minute changes in speed and direction can alter the level of impact dramatically, and evacuations need to be planned well in advance for these types of storms in flat coastal areas. It is important for the community to have the means to reach out to their citizens before and during a large storm event. Large precipitation events from storms other than coastal storms may develop with little notice. Road signs that indicate flooded areas using real-time communications from citizens are one way to alert the community of these issues.

3) Elevating Structures: This involves raising the building in place so that the lowest floor is above the flood level for which floodproofing is provided. The building is jacked up and set on a new or extended foundation.

4) Floodproofing: There are two types of floodproofing techniques: dry floodproofing and wet floodproofing. Dry floodproofing keeps the floodwaters from entering the structure while wet floodproofing allows the floodwaters to enter the building but minimizes the damages.

   Dry floodproofing involves sealing the walls of structures such as buildings with waterproofing compounds, impermeable sheeting, or other materials and using closures for covering openings from floodwaters. Dry floodproofing is most applicable in areas of shallow, low-velocity flooding.

   Wet floodproofing allows the structure to flood inside while ensuring minimal damage to the building and any contents. By allowing the force of the water to pass through a building, the interior flooding allows hydrostatic force on the inside of the building walls to equally counteract the hydrostatic force on the outside, thus eliminating the chance of structural failure. Wet flooding practices include installation of flood vents in the ground floor or crawl space to allow floodwater to flow through the building without causing structural damage or conversion of ground floor living space to uninhabitable space such as a carport or open garage.

5) Increase Storage: In order to reduce flooding from precipitation events, natural storage of the watershed can be restored or additional storage can be added. Restoration of natural storage includes restoring wetlands and returning floodplains to undeveloped states in riverine areas. Increasing natural storage in stormwater systems includes reducing impervious areas to allow infiltration of runoff from precipitation events. Additional storage can be added through detention ponds and on a more localized basis through rain barrels or cisterns. A major component of increasing natural infiltration in stormwater management includes the use of green stormwater management.

6) Public Engagement and Education: A community can aid in flood risk management by educating its citizens about the existing flooding hazards and what can be done to reduce risk to their property. Additionally, if a flood risk project is constructed, educating the community on residual project risk must occur.

7) Relocating Utilities and Critical Infrastructure: A community can protect its own public infrastructure by relocating utilities underground and moving critical infrastructure out of floodplain areas. Examples of critical infrastructure include hospitals and shelters.

8) Preservation: Land preservation programs should be developed to place environmentally sensitive land in permanent easements to better manage watersheds and their interrelated systems.

9) Resilience Performance Standards: Develop resilience performance standards for infrastructure to be used when making investment decisions. These standards may include information such as the recurrence interval of a storm that infrastructure should be designed to withstand, how long different end users can be without power, or how and when to include climate change or relative sea level change into design standards.

10) Emergency Response Systems: Emergency response systems include preparation for floods in anticipation of the flood event and flood-fighting plans to assist after the fact. The plans should include contingency and emergency floodproofing and must be properly integrated with emergency evacuation plans.

11) Modify/Remove Structures for Better Channel Function: Channel alterations such as modifying or removing features or widening/deepening channels can help manage flooding by improving channel function.

12) Design or Redesign and Location of Services and Utilities: Services and utilities can be relocated to areas of low risk or to higher areas not subject to flooding. Additionally, existing services/features can be elevated above the flood elevation or can include floodproofing features in the design.

13) Surface Water/Stormwater Management: Management of stormwater and surface water systems can improve water quality, decrease erosion, and increase storage in the event of a storm which minimizes flood risks. The development of a surface water or stormwater management plan can help facilitate best management practices of the systems.

14) Building Codes and Zoning: Climate change and coastal hazard considerations should be incorporated into building and zoning codes. Building codes can promote construction techniques that minimize damages to future construction or to areas of redevelopment. Some examples include requiring new structures to be raised above flooding elevations and structures to be built on pier foundations in areas of wave action. Zoning can be used to avoid activities on the floodplain other than those compatible with periodic flooding.

15) Strategic Acquisition: Purchase of undeveloped land for flood risk management.

16) Emergency Plans/Hazard Mitigation Plans: Emergency planning allows a community to be prepared for storm events, such as flood inundation from coastal storms. Hazard mitigation plans are developed to document hazards a community is exposed to and determine mitigation measures a community would like to implement to manage risk from these hazards. It is important for both of these plans to be kept up to date with local issues in order to prepare and recover after a flooding event.

17) Retreat: Consider managed retreat, allowing wetlands and beaches to take over land that is dry. Include land use and zoning appropriate for coastal storm risk management.

18) Wetland Migration: Adjust zoning laws for wetland migration.

19) Coastal Zone Management: Coastal Zone Management regulates activities within the “Coastal Zone” to ensure that development is accomplished with the least amount of damage to the coastline. In Delaware, the management of coastal resources is shared by a number of entities

within DNREC, specifically the Division of Watershed Stewardship (Shoreline and Waterway Management Section), the Division of Fish and Wildlife, and the Division of Water, Office of the Secretary (Delaware Coastal Programs), as well as the Delaware National Estuarine Research Reserve.

5.5.3 Natural and Nature-Based Infrastructure

Nature-Based Infrastructure (NBI) refers to the planned use of natural and engineered features to produce engineering functions in combination with ecosystem services and social benefits. Natural and nature-based features include a spectrum of features, ranging from those that exist due exclusively to the work of natural process to those that are the result of human engineering and construction. The built components of the system include nature-based and engineered structures that support a range of objectives, including storm risk management (e.g., seawalls, levees), as well as infrastructure providing economic and social functions (e.g., navigation channels, ports, harbors, residential housing). Natural coastal features take a variety of forms, including reefs (e.g., coral and oyster), barrier islands, dunes, beaches, wetlands, and maritime forests. The relationships and interactions among the natural and built features comprising the coastal system are important variables determining coastal vulnerability, reliability, risk and resilience.

1) Green Stormwater Management: Management practices can be used to reduce impervious areas and increasing storage on a localized basis for stormwater. Some examples include bio-swales, rain gardens, green roofs, rain barrels or cisterns. Green stormwater management practices that involve plantings also allow for evapotranspiration of stormwater, and provide for a pleasing aesthetic component. Reducing impervious areas allows for infiltration of stormwater which manages runoff quantity and improves runoff quality. Green stormwater management can also allow for opportunities to add public recreational features and provide for ecosystem restoration, while providing for wave attenuation and stormwater storage.
2) Constructed or Rehabilitated Reefs: Reefs can act as a natural barrier to dampen storm wave activity.
3) Salt Marshes: Salt marshes can provide sediment stabilization to an area, and can dissipate and/or attenuate oncoming wave action. Depending on the cross-shore width of a salt marsh, it has the potential to manage storm surge effects. The traditional rule of thumb (USACE, 1963) was that for every 2.7 miles of marsh, storm surge is reduced by one foot; however, the degree of protection that wetlands provide from storm surge is extremely complicated.
4) Freshwater Wetlands: Freshwater wetlands can provide flood management by detention and/or storage for floodwaters. Infiltration through a freshwater wetland to an aquifer below can assist in groundwater recharge and provide water quality benefits. Freshwater wetlands also provide sediment stabilization benefits.
5) Vegetated Dunes and Beaches: Vegetation helps to stabilize dunes and beaches from erosion due to wind and wave action.
6) Vegetated Submerged Aquatic Vegetation (SAV), Salt Marshes and Wetlands: Vegetated features help to break offshore waves, attenuate wave energy, slow the inland transfer of stormwater and increase infiltration.
7) Oyster and Coral Reefs: Reefs can act as a natural barrier to dampen wave action, while providing essential habitat to marine organisms.

8) Barrier Island Restoration: Barrier islands act as the first line of defense in reducing risk to the mainland from storm surge and wave action. Restoration includes increasing barrier island elevation or plan form (length/width) and can include vegetation components such as dune/beach grass to stabilize sediments and increase wave dissipation.

9) Maritime Forests / Shrub Communities: The dense vegetation of maritime forests and shrub communities helps to stabilize soils while dissipating wave action and slowing the inland transfer of stormwater.

The broad measures identified herein, structural, non-structural, and nature-based, have the potential for further development to target specific areas for coastal storm risk management. The goal of measures development is to achieve the objectives by combining one or more measures while avoiding constraints. Measures identified will be further evaluated, screened and used in combination (as appropriate) in future phases of study to determine area-specific project viability to meet the planning objectives.

5.5.4 Area-Focused Measures

The previously described broad-based measures (structural, non-structural and natural/nature-based) are applicable to most areas within the study area. Specific area-focused measures provided through stakeholder input and/or otherwise derived from previous studies, particularly any existing hazard mitigation plans, are listed below. This comprehensive list includes some measures that are beyond the purview of USACE. Potential measures that could be evaluated as part of future study phases are included herein.

Delaware River Region:

1) Flood-prone urban areas - New Castle and Delaware City (Delaware City Hazard Mitigation and Climate Adaptation Action Plan, 2014) along the Delaware River, and Wilmington along the Christina River:
   - Raise, replace or add to bulkheads and dikes along the shoreline.
   - Stabilize and armor unprotected eroding shorelines with vegetation or stone.
   - Develop integrated flood risk management systems using structural (engineering) and non-structural (wetlands) measures.
   - Review and enhance coastal area design guidelines to better mitigate the impacts of flooding.
   - Enhance and strengthen waterfront zoning and permitting.
   - Evaluate green corridors and parks for possible improvements for flood risk management.
   - Incorporate regional sediment management practices.
   - Acquisition, elevation or floodproofing of existing structures to better mitigate the impacts of flooding.

2) Design or redesign and relocation of services and utilities. Delaware River shoreline communities - Bay View and Augustine Beach
   - Raise, replace or add to seawalls along the shoreline.
   - Beach nourishment and dune construction.

- Review the functioning of the groins.
- Review and enhance coastal area design guidelines to better mitigate the impacts of flooding.
- Enhance and strengthen waterfront zoning and permitting.
- Evaluate green corridors and parks for possible improvements for flood risk management.
- Incorporate regional sediment management practices.
- Acquisition, elevation or floodproofing of existing structures to better mitigate the impacts of flooding.

Design or redesign and relocate services and utilities.

3) Dikes (New Castle County) - Buttonwood Dike, Broad Marsh Dike, Gambacorta Marsh Dike, Army Creek Dike, Red Lion Creek Dike
4) Federal holdings - Reedy Island
5) State holdings - Pea Patch Island
6) State impoundments – Lang Impoundment at the Augustine Wildlife Area

In January 2010, New Castle County updated the All Hazard Mitigation Plan (New Castle County, 2010). The specific mitigation strategies and actions listed in the plan for the multiple communities within New Castle County were:

- Retrofit the Genderwood stormwater management facility.
- Implement Phase II of channel improvements to reduce the identified flooding problems in Little Mill Creek and in the Shellpot Creek Watershed.
- Identify properties from the New Castle Flood Mitigation Plan for possible acquisition.
- Floodproof Shore Lumber in the Stanton area, the Openlander property on Barney Mill Road, Delaware City Community shelter, sewer lift stations at Cooch's Bridge and Rodel, the South Well field pump station, and the Northwest booster station.
- Conduct a vulnerability assessment of Perkins Run, a flood vulnerability assessment for Delaware City, City of New Castle, and the Town of Newport, and a stormwater study for Elsmere.
- Encourage multiple communities to join the Community Rating System.
- Establish a coastal flood warning and notification system in certain communities.
- Construct a flood barrier, drainage improvements, and wetlands enhancement for Dragon Run and along the C&D Canal.
- Evaluate solutions for flooding of Route 9 at Dragon Run, Route 72, Route 13 in Delaware City, and other evacuation routes.
- Replace the tide gate and re-engineer the outfall into Delaware River at Washington and Harbor Streets, the tidal flushing pipe and valve at Old Locks, and other conduits that may lack conveyance capacity.
- Increase storage capacity of Little Mill, Chestnut Run, Silverbrook, Derrickson Run, and other waterbodies.

Delaware Bay Region:

1) Delaware Bay shoreline communities - Woodland Beach
   - Raise, replace or add to stone revetment along the shoreline.
   - Beach nourishment and dune construction.
   - Review and enhance coastal area design guidelines to better mitigate the impacts of flooding.
   - Enhance and strengthen waterfront zoning and permitting.
   - Evaluate green corridors and parks for possible improvements for flood management.
   - Incorporate regional sediment management practices.
   - Acquisition, elevation or floodproofing of existing structures to better mitigate the impacts of flooding.
2) Design or redesign and relocate services and utilities. Flood-prone urban areas – Milford, Milton and Lewes (downtown from flooding of Lewes-Rehoboth Canal)
   - Raise, replace or add to stone revetments, concrete bulkheads, and dikes along the shoreline.
   - Stabilize and armor eroding shorelines with vegetation or stone.
   - Develop integrated flood risk management systems using structural (engineering) and non-structural (wetlands) measures.
   - Review and enhance coastal area design guidelines to better mitigate the impacts of flooding.
   - Enhance and strengthen waterfront zoning and permitting.
   - Evaluate green corridors and parks for possible improvements for flood risk management.
   - Incorporate regional sediment management practices.
   - Acquisition, elevation or floodproofing of existing structures to better mitigate the impacts of flooding.
3) Design or redesign and relocate services and utilities. Other Delaware Bay shoreline beach communities - Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach, Broadkill Beach, Lewes Beach
   - Review the functioning of all shore protection treatments along the shoreline.
   - Beach nourishment and dune construction, including the beneficial use of dredged material.
   - Evaluate the impact of jetties on sediment transport, and refurbish if warranted (includes bypassing and mitigating downdrift impacts).
   - Review and enhance coastal area design guidelines to better mitigate the impacts of flooding.
   - Enhance and strengthen waterfront zoning and permitting.
   - Evaluate green corridors and parks for possible improvements for flood risk management.
   - Repair damage to impoundments and marshes at the refuges, Reedy Island and Pea Patch Island.

- Ecosystem restoration including oyster reefs, terrapin nesting habitat, horseshoe crab habitat, waterfowl and colonial nesting bird habitat.
- Incorporate regional sediment management practices.
- Consider flood risk management measures for the Mispillion River Inlet area.
- Acquisition, elevation or floodproofing of existing structures to better mitigate the impacts of flooding.

4) Design or redesign and relocation of services and utilities. Federal holdings - Bombay Hook National Wildlife Refuge, Prime Hook National Wildlife Refuge
   - Abandon intensive freshwater impoundment management in favor of restoration of natural salt marsh.
   - Import sand to enhance beach/dune habitat and to provide a marsh platform immediately behind the restored dunes to fortify the beach/barrier complex.
   - Monitoring and data collection.
5) State holdings - Mispillion River/Inlet, Murderkill River/Inlet
   - Beach restoration of beach to north of Mispillion Inlet as well as adjacent communities.
   - Living shoreline and hybrid living shorelines along Mispillion Inlet river banks.
   - Building retrofit/elevation.
6) State impoundments – Ted Harvey North and South Impoundments at the Ted Harvey Wildlife Area, Taylors Gut Impoundment at the Woodland Beach Wildlife Area, Port Mahon Impoundment at the Little Creek Wildlife Area, Little Creek South Impoundment at Little Creek Wildlife Area

The City of Lewes developed its own Hazard Mitigation and Climate Adaptation Action Plan (City of Lewes, 2011). The plan proposed the following mitigation and adaptation strategies:

- Incorporate climate change concerns into the comprehensive plan and into future reviews of the building and zoning codes.
- Improve engagement and education particularly focused on successful behavior changes related to home building and retrofits.
- Ensure that aquifer information is integrated into all planning efforts.
- Use elevation data to determine road levels and evacuation risk.
- Evaluate the City and the Board of Public Works infrastructure's flood vulnerability from direct flood impacts, as well as from indirect flood impacts to access routes.
- Improve the City's level of participation in the Community Rating System.

For Sussex County, Vision Planning & Consulting LLC updated the Multi-jurisdictional All Hazard Mitigation Plan (Sussex County, 2010). Sussex County also developed a Flood Mitigation Plan, which was further detailed in the All Hazard Mitigation Plan. The specific mitigation strategies and actions were:

- Work with the Delaware Department of Transportation (DelDOT) to improve all emergency access routes, to install storm drain/culvert on the 1100 block of South Bayshore Drive in Broadkill Beach, and to identify elevation alternatives for the rebuilding of SR 38 (Prime Hook Road).

- Improve the County's Community Rating System (CRS) rating. Review and update community plans and ordinances and incorporate updated information into the CRS update.
- Encourage residents to elevate manufactured housing located on the coast to above the base flood elevation.
- Work with homeowners to identify ways to elevate flood prone structures.
- Improve educational awareness through better notifications, training, and properly marked evacuation routes.
- Work with DNREC to endorse and finance beach restoration projects that are experiencing significant coastal erosion from rising sea levels and coastal storms.
- Conduct a study to identify stormwater management systems that need to be improved.

Inland Bays Region:

1) Flood risk management for communities along the Inland Bays including the bayside of Dewey Beach, Joy Beach/Old Landing, Long Neck, Oak Orchard, the South Side of Indian River Bay, the bayside of Fenwick Beach, Mallard Lakes, and the bayside of Bethany and South Bethany Beaches:
   - Raise, replace or add to bulkheads and dikes along the shoreline.
   - Stabilize and armor unprotected eroding shorelines with vegetation or stone.
   - Develop integrated flood risk management systems using structural (engineering, such as a storm surge barrier at Indian River Inlet and the Lighthouse Cove canal at Delaware State Route 54) and non-structural (wetlands) measures.
   - Review and enhance coastal area design guidelines to better mitigate the impacts of flooding.
   - Enhance and strengthen waterfront zoning and permitting.
   - Evaluate green corridors and parks for possible improvements for flood risk management.
   - Raise roadways.
   - Improve storm drainage and install tide valves and flood gates.
   - Acquisition, elevation or floodproofing of existing structures to better mitigate the impacts of flooding.
   - Design or redesign and relocate services and utilities.
   - Deployable water control structures such as inflatable dams within the inland bay navigation canal system including Assawoman Canal and the Loop Canal near Bethany Beach.

6. Preliminary Financial Analysis

Given the size (a combined 222 square miles) and the various jurisdictions within the study area, there could be more than one study and multiple sponsors.

A combination of all or some of the following could serve as potential non-Federal sponsor(s) for future phases of study for the the Delaware Inland Bays and Delaware Bay Coast study area: Delaware DNREC, Center for the Inland Bays, and agencies in New Castle, Kent and Sussex Counties.

The Town of Bethany Beach is the non-Federal sponsor for an ongoing feasibility study for the northern half of Bethany Beach along the inland bay area where flooding occurs numerous times per year during heavy rains and is providing their required 50 percent of the feasibility study effort (USACE, 2013).

Any non-Federal sponsor would be required to provide 50 percent of the cost of the potential future investigation. Up to 100% of the non-Federal sponsor's share can be work in-kind. The potential non-Federal sponsor is also aware of the cost sharing requirements for potential project implementation. A letter of support from the non-Federal sponsor stating a willingness to purse potential future investigation and to share in its cost, and an understanding of the cost sharing that is required for project implementation will be required.

7. Potential Future Investigation Assumptions

Based on the identified measures, potential alternative plan development, and future screening of alternatives, there appears to be an array of solutions that have the potential to be economically justified, environmentally acceptable, addressable through viable engineering solutions, and consistent with USACE policies and the Infrastructure Systems Rebuilding Principles (NOAA and USACE, 2013).

The following assumptions will provide a basis for the potential future investigation:

Policy Exception and Streamlining Initiatives: The study will be conducted in accordance with the *Principles and Guidelines* and USACE regulations. If exceptions to established guidance are identified that will streamline the study process and will not adversely impact the quality of the study, approval will be sought from U.S. Army Corps of Engineers North Atlantic Division (CENAD) to incorporate those identified initiatives.

The ongoing feasibility study for Bethany Beach, DE will continue. Other potential future investigation may result as non-Federal sponsors are identified and non-Federal funds are allocated to the effort.
Other Approvals Required. As per EC 1105-2-409 § 4(c)(3), dated April 22, 2000, any alternative plan may be selected and recommended for implementation if it has, on balance, net beneficial effects after considering all plan effects, beneficial and adverse, in the four *Principles and Guidelines* evaluation accounts:

a. National Economic Development (NED): displays changes in the economic value of the national output of goods and services;

b. Environmental Quality: displays non-monetary effects on ecological, cultural, and aesthetic resources including the positive and adverse effects of ecosystem restoration plans;

c. Regional Economic Development: displays changes in the distribution of regional economic activity (e.g., income and employment); and

d. Other Social Effects: displays plan effects on social aspects such as community impacts, health and safety, displacement, energy conservation and others.

Therefore, we propose to fully utilize these accounts to analyze a comprehensive array of benefits in the study area.

8. Views of Other Resource Agencies

Due to funding and time contraints of this focus area analysis, very limited coordination was conducted with other agencies Coordination with other resource agencies is being conducted as part of the overall comprehensive study. Additional coordination would occur during the future phases of study.

9. References

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APPENDIX A

STAKEHOLDER INQUIRY LETTER

LIST OF CONTACTS

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
WANAMAKER BUILDING, 100 PENN SQUARE EAST
PHILADELPHIA, PENNSYLVANIA 19107-3390

CENAP-PL-PS

28 August 2013

Dear Stakeholder,

The United States Army Corps of Engineers (USACE) is conducting the North Atlantic Coast Comprehensive Study (NACCS) under the authority of Public Law 113-2, the Disaster Relief Appropriations Act of 2013, Chapter 4, which authorized USACE investigations as follows:

- *"That using up to $20,000,000 of the funds provided herein, the Secretary shall conduct a* ***comprehensive study*** *to address the flood risks of* ***vulnerable coastal populations*** *in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps.*
- *"....as a part of the study, the Secretary shall* ***identify those activities warranting additional analysis by the Corps****".*

The goals of the NACCS are to:

- Promote resilient coastal communities with sustainable and robust coastal landscape systems, considering future sea level rise and climate change scenarios, to reduce risk to vulnerable populations, property, ecosystems, and infrastructure; and
- Provide a risk reduction framework (reducing risk to which vulnerable coastal populations are subject) consistent with USACE-NOAA Rebuilding Principles.

To identify those activities warranting additional analysis, USACE is conducting a Reconnaissance-Level Analysis (RLA) for the Delaware Inland bays and Delaware Bay coast. The area that will be studied as part of this RLA is shown in Figure 1 (attached).

The purpose of the RLA is to determine if there is a Federal (USACE), interest in participating in a cost-shared feasibility study to formulate and evaluate specific coastal flood risk management projects in the Delaware Inland bays and Delaware Bay coast study area. Possible coastal flood risk management measures could include: structural, non-structural, natural, nature-based, and policy and programmatic measures or a combination of them, if a feasibility study is initiated.

To conduct the RLA, **USACE requests feedback from your jurisdiction** on related problems and potential opportunities to address these issues such as those experienced during Hurricane Sandy and other storms.

Specific feedback requested is as follows:

1) **Problem identification for your area:**
    a. Did your area experience storm surge?
    b. Be specific on particular areas and water bodies within your jurisdiction that experienced storm surge.
    c. What factors, if any, exacerbated damages from storm surge?

2) **Description of damages for your area:**
    a. Provide a narrative including the types of infrastructure damaged or temporarily out of use, structure (building) damages, personal injuries/fatalities.
    b. Provide a map depicting the spatial extent of damages.

3) **Prior related studies or projects (local, state, federal) in the damaged area.**

4) **List measures that your jurisdiction has considered to address the problem** (for documentation purposes, should there be a follow-on study).

Responses should be emailed to:

Ginger Croom, croomgl@cdmsmith.com (USACE Contractor)
Or faxed to Ginger Croom at 617-452-6594

Due to the aggressive schedule to complete the RLA and to meet the Congressional mandate to complete the NACCS, please provide responses to these questions by **September 10, 2013.**

If you have any questions related to this request, please contact Ginger Croom, CDM Smith (USACE Contractor) at 617-452-6594 or me at 215-656-6599.

For more information on the NACCS, please visit:

http://www.nad.usace.army.mil/Missions/CivilWorks/HurricaneSandyCoastalRecovery/NorthAtlanticComprehensiveStudy.aspx

Sincerely,

Brian J. Mulvenna

Brian J. Mulvenna, P.E.
USACE, Philadelphia District

Encl
1. Figure 1: Study Area Map

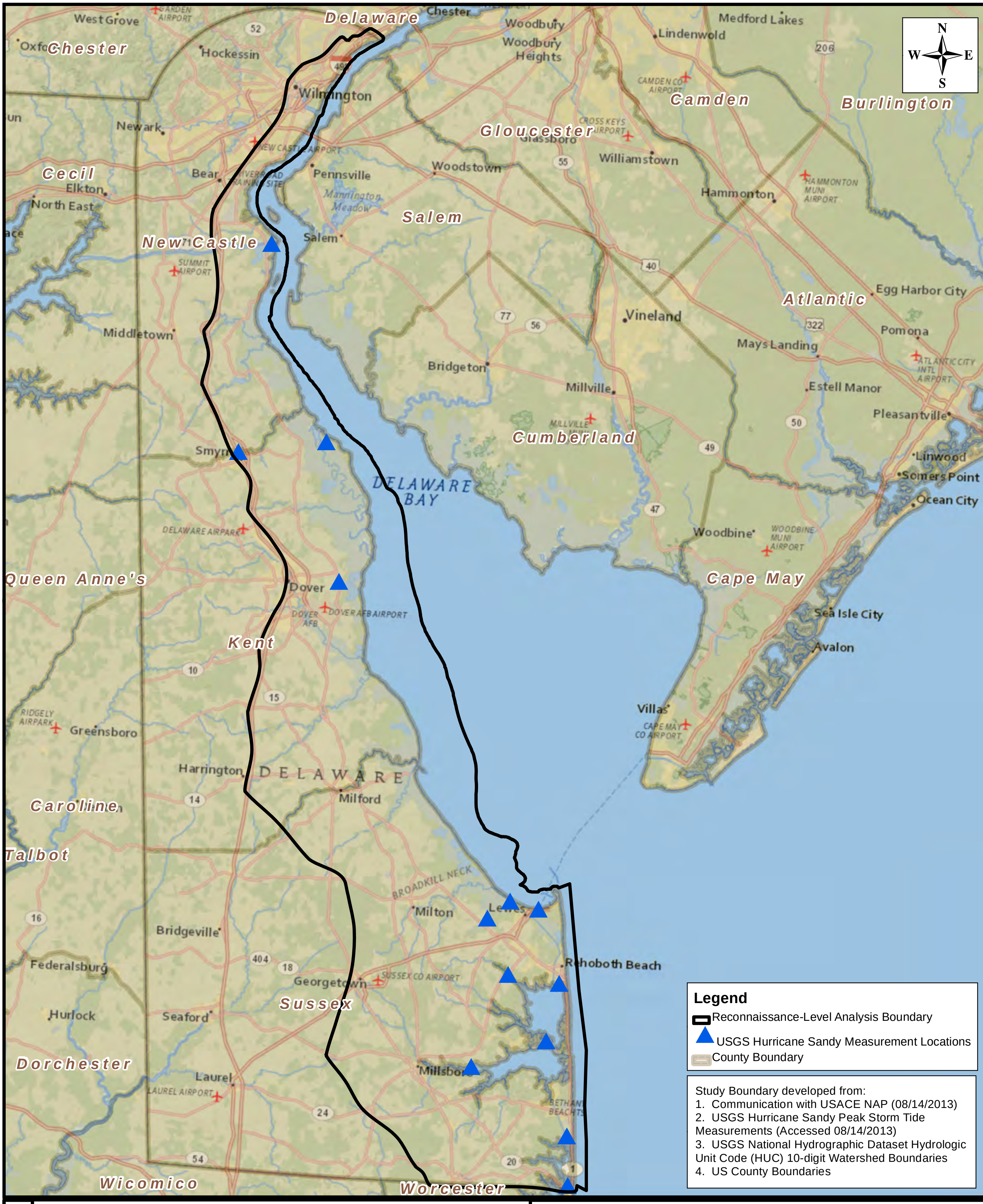


FIGURE 1

U.S. ARMY CORPS OF ENGINEERS

DELAWARE BACK-BAYS

NORTH ATLANTIC COAST COMPREHENSIVE STUDY

RECONNAISSANCE-LEVEL ANALYSIS BOUNDARY MAP

Path: C:\GIS\NACCS\MXD\DE_Back_Bays.mxd

USACE, Philadelphia District
Delaware Inland Bays and Delaware Bay Coast Focus Area Analysis
Point of Contact List

Locality	State	Title	First	Middle	Last	Address	City, State, & Zip	Phone	Email	Website
Ardencroft	Delaware	Chairman of Town	Tom		Wheeler	2119 The Highway	Arden, DE 19810	(302) 475-3516	tom.wheeler@esre.com	http://www.theardens.com/
Ardentown	Delaware	Mayor	Alison		Byer	2206 Millers Road	Ardentown, DE 19810	(302) 475-2384	ardenchair@theardens.com	http://www.theardens.com/
Bellefonte	Delaware	Commission Presiden	B. Keith		Hughes	901A Rosedale Avenue	Bellefonte, DE 19809	(302) 761-9638 Mailbox 02	Hughesk73@yahoo.com	http://www.townofbellefonte.com/
Bethany Beach	Delaware	Mayor	Tony		McClenny			(302) 539-8011	admin@townofbethanybeach.com	http://www.townofbethanybeach.com/
Bowers Beach	Delaware	City Counselor	Bob		McDevitt	3308 Main Street	Frederica, DE 19946	(302) 572-9000	Bobatbowersbeach@gmail.com	http://www.townofbowersbeach.org/
Camden	Delaware	Mayor	Wallace	G.	Edmanson, II	1783 Friends Way	Camden, DE 19934	(302) 697-2299	amanda.wooleyhand@townofcamden	http://www.townofcamden.com/
Dagsboro	Delaware	Mayor	Pattti		Adams	33134 Main Street, PO Box 420	Dagsboro, DE 19939	(302) 732-3777	staceylong@mchsi.com	http://www.townofdagsboro.com/
Delaware City	Delaware	City Manager	Richard		Cathcart	PO Box 4159	Delaware City, DE 19706	(302) 834-4573	RCathcart@ci.delaware-city.de.us	http://www.delawarecity.delaware.gov/
Dewey Beach	Delaware	Mayor	Diane		Hanson	105 Rodney Avenue	Dewey Beach, DE 19971	(302) 227-6363	Hanson@team-doctor.com	http://www.townofdeweybeach.com
Dover	Delaware	Mayor	Carleton	E	Carey, Sr.	PO Box 475	Dover, DE 19903	(302) 736-7004	ccarey@dover.de.us	http://www.cityofdover.com/
Ellendale	Delaware	Mayor	Kimberly		Hughes	PO Box 6	Ellendale, DE 19941	(302) 519-1113	kimhughes.ellendale@comcast.net	n/a
Felton	Delaware	Mayor	David	L.	Kelley	P.O. Box 239	Felton, DE 19943	(302) 284-9365	rgreene@townoffelton.com	n/a
Fenwick Island	Delaware	Mayor	Audrey		Serio	800 Coastal Highway	Fenwick Island, DE 19944	(302) 539-3011 X 203	townhall@fenwickisland.org	http://www.fenwickisland.delaware.gov
Frankford	Delaware	Mayor	Greg		Johnson	5 Main Street - PO Box 550	Frankford, DE 19945	(302) 732-9424	frankfordtownhall@mchsi.com	http://www.frankfordde.us/
Frederica	Delaware	Mayor	William	C.	Glanden	PO Box 294	Frederica, DE 19946	(302) 335-4047	mayoroffrederica@verizon.net	n/a
Georgetown	Delaware	Mayor	Michael	R.	Wyatt	39 The Circle	Georgetown, DE 19947	(302) 856-7391	mwyatt@georgetowndel.com	http://www.georgetowndel.com/
Harrington	Delaware	Mayor	Anthony	R.	Moyer	106 Dorman Street	Harrington, DE 19952	(302) 398-3530	kblanchies@cityofharrington.com	http://www.cityofharrington.com/
Henlopen Acres	Delaware	Mayor	David	L.	Hill	39 Rolling Road	Henlopen Acres, DE 19971	(302) 227-9194	townmgr@henlopenacres.com	http://henlopenacres.com/
Houston	Delaware	Mayor	Connie		Morgan	PO Box 196	Houston, DE 19954	(302) 632-0946	houstontax@comcast.net	http://www.townofhouston.com/council
Leipsic	Delaware	Mayor	Craig		Pugh	168 Main Street	Leipsic, DE 19901	(302) 736-0595	nancygoodfellow@yahoo.com	n/a
Lewes	Delaware	Mayor	James	L.	Ford, III	114 E. Third Street, PO Box 227	Lewes, DE 19958	(302) 645-7286	jimfordiii@aol.com	http://www.ci.lewes.de.us/
Little Creek	Delaware	Mayor	Glenn		Gauvry	PO Box 298	Little Creek, DE 19961	(302) 678-7656		n/a
Magnolia	Delaware	Mayor	James		Frazier	PO Box 222	Magnolia, DE 19962	(302) 943-0934 cell	dianepcahall@comcast.net	http://magnolia.delaware.gov/
Middletown	Delaware	Mayor	Kenneth	L.	Branner, Jr.	19 W. Green Street	Middletown, DE 19709	(302) 378-5670	kbranner@middletownde.org	http://www.middletownde.org/
Milford	Delaware	Mayor	Joseph		Rogers	201 S. Walnut Street	Milford, DE 19963	(302) 424-3712	citymanager@milford-de.gov	http://www.cityofmilford.com/
Millsboro	Delaware	Mayor	Robert	H	Bryan	PO Box 547	Millsboro, DE 19966	(302) 576-2100	town@millsboro.org	http://www.millsboro.org/
Millville	Delaware	Mayor	Gerald		Hockey	35207 Atlantic Ave.	Millville, DE 19967	(302) 539-0449	mvtownmgr@mchsi.com	http://millville.delaware.gov/
Milton	Delaware	Mayor	Marion		Jones	115 Federal Street	Milton, DE 19968	(302) 684-4110	mayorjones@ci.milton.de.us	http://www.ci.milton.de.us/
New Castle	Delaware	Mayor	Donald	A	Reese	112 West 7th Street	New Castle, DE 19720	(302) 322-9802	donaldreese@newcastlecity.org	http://www.ci.new-castle.de.us/
Ocean View	Delaware	Mayor	Gordon	E.	Wood, Sr.	32 West Avenue	Ocean View, DE 19970	(302) 539_9797	townmgrtov@oceanviewde.com	http://www.oceanviewde.com/
Odessa	Delaware	Mayor	Kathleen	H	Harvey	315 Main Street, P.O. Box 111	Odessa, DE 19730	(302) 378-2510	townofodessa@verizon.net	http://www.odessa.delaware.gov/
Rehoboth Beach	Delaware	Mayor	Sam		Cooper	229 Rehoboth Avenue	Rehoboth Beach, DE 19971	(302) 227-6181	information@cityofrehoboth.com	http://www.cityofrehoboth.com/
Selbyville	Delaware	Mayor	Clifton	C.	Murray	53 Lighthouse Road	Selbyville, DE 19975	(302) 436-5360	tmselbyville@mchsi.com	http://www.townofselbyville.com/
Slaughter Beach	Delaware	Mayor	Daniel		McCarthy	357 Bay Avenue	Slaughter Beach, DE 19963	(302) 424-7659	townofslaughterbeach@comcast.net	http://townofslaughterbeach.com/
Smyrna	Delaware	Mayor	H. Joanne		Masten	27 South Market Street Plaza	Smyrna, DE 19977	(302) 653-6235	jmasten@smyrna.delaware.gov	http://www.smyrnadelaware.com/
South Bethany	Delaware	Mayor	Kathy		Jankowski	310 W. 4th Street	South Bethany, DE 19930	(302) 539-8570	mayorsouthbethany@hotmail.com	http://www.southbethany.org/
Wilmington	Delaware	Mayor	Dennis	P	Williams	Louis L. Redding City/County Bldg	Wilmington, DE		dpwilliams@wilmingtonde.gov	http://www.ci.wilmington.de.us/
Woodside	Delaware	Mayor	Harold	H	Lane	PO Box 211	Woodside, DE 19980	(302) 697-1467	hallane@aol.com	n/a
Wilmington	Delaware	Water Division Direct	Sean		Duffy		Wilmington, DE	302-576-3074	SDuffy@wilmingtonde.gov	http://www.ci.wilmington.de.us/

APPENDIX B

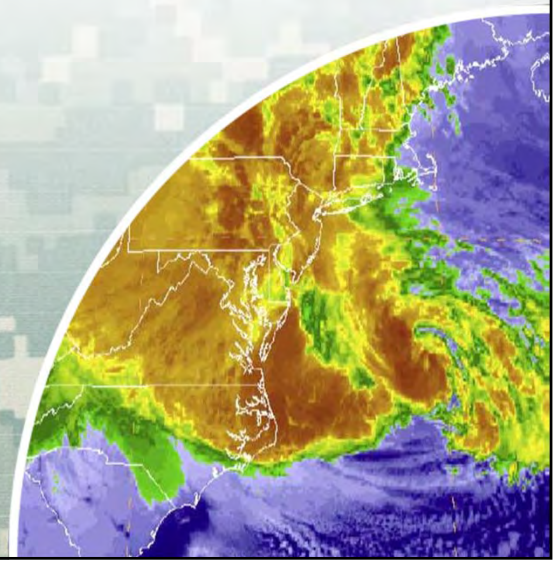
PRESENTATION

MEMORANDUM FOR RECORD

PRESENTATION

North Atlantic Coast Comprehensive Study Delaware Inland Bays and Delaware Bay Coast Reconnaissance-Level Analysis

U.S. Army Corps of Engineers
Coastal Storm Risk Management
Planning Center of Expertise
29 August 2013



Background

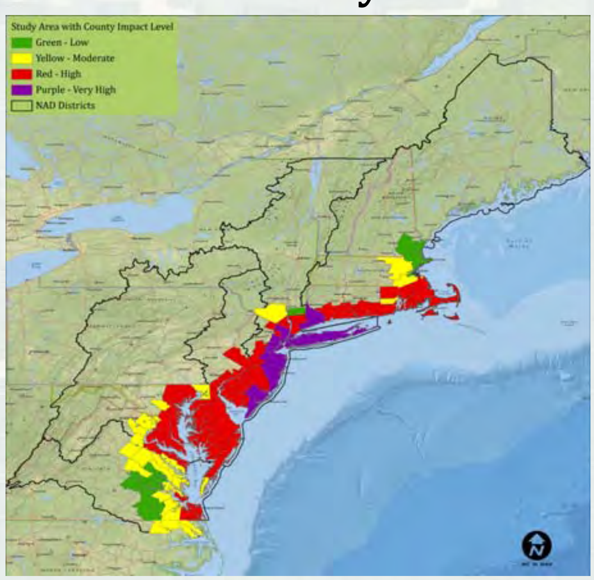
- Greatest areas of Sandy's impact: NJ, NY, CT
- Public Law 113-2
- "That using up to $20,000,000 of the funds provided herein, the Secretary shall conduct a **comprehensive study** to address the flood risks of **vulnerable coastal populations** in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps…"
- Comprehensive Study to be complete by Jan 2015

NACCS Study Goals

1. *<u>Provide Risk Reduction Framework</u>– Reduce risk to which vulnerable coastal populations are subject.*
2. *<u>Promote Resilient Coastal Communities</u> – Ensure a sustainable and robust coastal landscape system, considering future sea level rise and climate change scenarios, to reduce risk to vulnerable population, property, ecosystems, and infrastructure.*

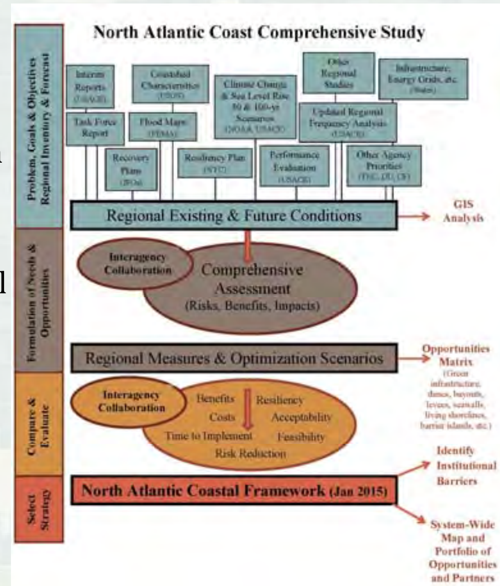
**Consistent with USACE-NOAA Rebuilding Principles*

NACCS Study Area



NACCS Scope

- **Coastal Framework**
  - ❑ Regional scale
  - ❑ Interagency collaboration
  - ❑ Opportunities by region/state
  - ❑ Identify range of potential solutions and parametric costs by region/state
  - ❑ Identify activities warranting additional analysis



Key Technical Components

- Engineering
- Environmental, Cultural, and Social
- Sea Level Rise and Climate Change (SLR & CC)
- Economics
- Plan Formulation
  - ▶ Policy & programmatic
- Coastal GIS Analysis

NACCS Schedule

- ✓ April 2013 – Existing/Future Conditions
- ✓ May – Problems/Opportunities
- ✓ June – Hydrodynamics and Measures Working Meetings
- ✓ July –Aug – Refine Analyses & Measures
- July - Dec 2013 – Interagency Collaboration Webinar Series
- Oct-Dec 2013– Reviews of analyses
- ~Jan-March 2014– Opportunities for Additional Feedback
- April-July 2014 – Alignment & Refinement
- Aug-Sept 2014 – Final Draft Report production
- Oct-Dec 2014 – NAD, HQ, ASA(CW), OMB Reviews
- Jan 2015- Submit to Congress

Reconnaissance-Level Analyses

Reconnaissance-Level Analyses

- Investigation is being conducted as a part of the North Atlantic Coast Comprehensive (NACC) Study under the authority of Public Law 113-2, the Disaster Relief Appropriation Act of 2013
- Specific language within PL 113-2 states, "…*as a part of the study, the Secretary shall identify those activities warranting additional analysis by the Corps*
- Reconnaissance-level analyses will identify activities warranting additional analysis that could be pursued

Reconnaissance-Level Analyses

- The purpose is to determine if there is a Federal, (USACE) interest in participating in a cost-shared feasibility phase study in the interest of providing potential types of projects in Delaware Inland Bays and Delaware Bay Coast
- Possible coastal flood risk management measures could include: structural, non-structural, natural, nature-based, and policy and programmatic measures or a combination of them, if a feasibility study is initiated.

Reconnaissance-Level Analyses

- What is the water resources problem to be solved?
- Is there a viable engineering solution to the problem?
- Are there potential National Economic (NED) benefits associated with a potential project?
- Is there a need/interest for Federal (USACE) participating and is there a qualified non-federal sponsor?

Reconnaissance-Level Analyses

Typically identify the following:

- Study area boundaries
- Problems and Opportunities
- Planning Objectives
- Planning Constraints
- Measures to Address Planning Objectives
- Next Steps

Feedback Requested

1. Problem identification for your area:

- ► Did your area experience storm surge?
- ► Specify particular areas and water bodies within your jurisdiction that experienced storm surge.
- ► What factors, if any, exacerbated damages from storm surge?

Feedback Requested

2. Description of damages for your area:

- ► Provide a narrative including the types of infrastructure damaged or temporarily out of use, structure (building) damages, personal injuries/fatalities.
- ► Provide a map depicting the spatial extent of damages.

Feedback Requested

3. Prior related studies or projects (local, state, federal) in the damaged area.

4. Measures that your jurisdiction has considered to address the problem

Stakeholder Outreach

- Letters emailed by USACE Philadelphia District -August 28
- Feedback requested by September 10

Next Steps

- Fall 2013 – Draft RLA
- FY 2014 – sign letters of intent with local sponsor, work towards Project Management Plan (PMP) for Feasibility Phase
- FY 2015 – Move to Feasibility phase IF:
  - Federal interest is determined during Recon-phase
  - Non-federal Sponsor is identified
  - Federal funding is available

Questions/POCs

- Brian Mulvenna – USACE Philadelphia District
  - Brian.J.Mulvenna@usace.army.mil
  - 215-656-6599 (ph)
- Ginger Croom – CDM Smith (USACE Contractor)
  - CroomGL@cdmsmith.com
  - 617-452-6594 (ph and fax)
  - 617-999-9631 (mobile)

8/29/2013 STAKEHOLDER WEBINAR MEETING MINUTES

Delaware Inland Bays and Delaware Bay Coast Study Area
Focus Area Analysis
29 Aug 2013
2 Pm
Stakeholder Meeting/Teleconference/Webinar

Attendees:
Brian Mulvenna – USACE Philadelphia District
Representative from Bethany Beach
Tony Pratt – DNREC Division of Watershed Stewardship
Kim McKenna – DNREC Shoreline and Waterway Management Section
Mike Powell – DNREC Division of Watershed Stewardship, Flood Mitigation
Frannie Bui, Ginger Croom – CDM Smith

Presentation

1. Ginger Croom presented the overview of the North Atlantic Coast Comprehensive Study (NACCS). See PowerPoint presentation.

Stakeholder Questions/Discussion

1. Kim McKenna, DNREC, requested a PDF of the presentation
2. Brian addressed Mike Powell to determine if DNREC had a similar spatial file to the FEMA MOTF Hurricane Sandy Storm Surge extent
    a. Mike Powell, DNREC, confirmed that additional, non-USGS high water marks existed, but not represented in the same manner as the FEMA MOTF layer. Mike said that he would be able to share the additional high water mark database.
3. Ginger informed the group of the additional webinar for the Delaware Inland Bays and Delaware Bay Coast study area on Tuesday 9/3 at 3PM.
4. DNREC will develop a priority list of projects/areas to be incorporated into the focus area analysis.
    a. Tony Pratt, DNREC, stated that they have general ideas for vulnerable areas. Although the study area has been expanded to include the Delaware inland bays, the inclusion of the Delaware Bay shoreline will provide another level of scrutiny. DNREC staff have an understanding of chronic problems and will be able to provide a broad range of potential solutions.
    b. Ginger commented that for the focus area analysis, specific measures will not be identified. DNREC will provide general information on vulnerable information and community feedback on specific areas (if provided) will be incorporated into the focus area analysis.
    c. Tony commented that DNREC will consider the entire Delaware shoreline inclusive of lands owned by US DOI (National Wildlife Refuges). A systems approach/analysis should be taken to incorporate ecological benefits, impacts on communities, consequences to agricultural lands, infrastructure damage from storm surge – all should be considered for the Delaware Bay shoreline in order to highlight areas of vulnerability.

Meeting adjourned 2:30 PM.

9/03/2013 STAKEHOLDER WEBINAR MEETING MINUTES

Delaware Inland Bays and Delaware Bay Coast
Focus Area Analysis
September 3, 2013
3 Pm
Stakeholder Meeting/Teleconference/Webinar

Attendees:
Brian Mulvenna – USACE Philadelphia District, Project Manager
Doug Gaffney – Gahagan & Bryant Associates
Susan Love – State of Delaware Coastal Programs Planner
Jay Smith – USACE Philadelphia District
Lauren Klonsky, Ginger Croom – CDM Smith
Bob Scarborough – State of Delaware Coastal Programs Environmental Program Manager

Presentation

1. Ginger Croom presented the overview of the North Atlantic Coast Comprehensive Study (NACCS). See PowerPoint presentation.

Stakeholder Questions/Discussion

1. The State of NJ is currently working on a priority list of known problems that they would want to be addressed. Ginger advised Bob will coordinate with other State employees (Kim, Tony, and Mike) already working on putting feedback together to provide to CDM Smith.
2. Susan asked if we are coordinating with municipalities directly, or if we are expecting the state to reach out to towns / communities / counties. Ginger replied that CDM Smith has reached out to the communities directly.
3. Susan is concerned that the timeline is very short to get feedback from communities.
4. The state mentioned they have reached out to communities of Willmington, New Castle, and Delaware City.

Meeting adjourned 3:30 PM.

APPENDIX C

STAKEHOLDER FEEDBACK

STAKEHOLDER FEEDBACK – TOWN OF SOUTH BETHANY BEACH

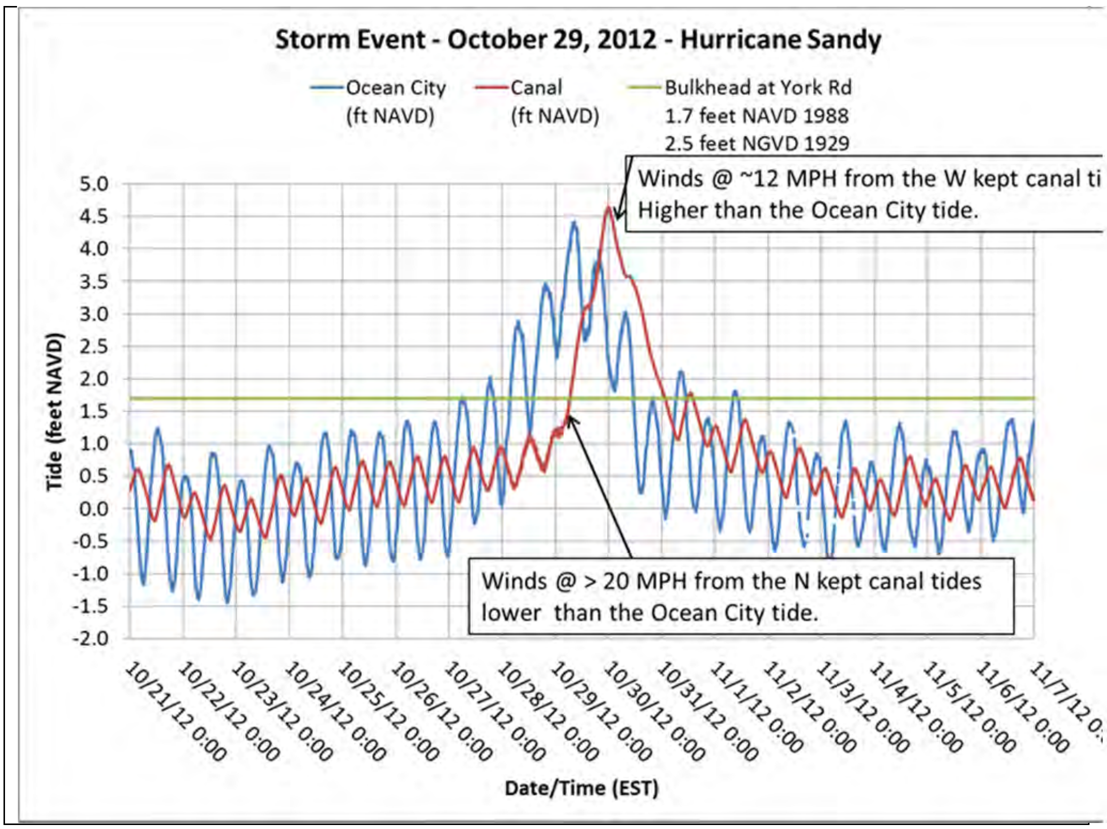
To: Ginger Croom (USACE Contractor)
From: George Junkin (Chair Town of South Bethany Sea Level Rise & Storm Surge Committee)
Date: 02 September 2013
Subject: Reconnaissance Level Analysis (RLA)

Response to Specific Feedback Requested

1) Problem identification for the Town of South Bethany (SB)
    a. Did SB experience storm surge? Yes
    b. Specifics on the SB areas and water bodies within SB jurisdiction that experience storm surge follow. SB is located on five miles of dead end canals as shown in the picture below. The canals are all west of DE Route 1. The crown of the Rt. 1 southbound lane is at 5.5 feet NGVD 1929. The water rose in the canals to 5.44 feet NGVD and flooded the areas shown in the picture below.

    c. The factors that exacerbated the damages from the storm surge follow. The level of the water in the SB canals is largely governed by the tide at the Ocean City (OC) Inlet (which is about 15 miles away from SB) and the wind. In order to reach the SB canals the OC tide must pass through the Little Assawoman Bay and then through the “Ditch” at Rt. 54 in Fenwick Island and then through the Little Assawoman Bay and then through the “Narrows” just south of SB and then through Little Bay and then it eventually gets to SB. The elapsed time for SB to see the high tide at OC is about 6 hours. If the wind is coming from the south or west the tide is amplified. If the wind is coming from the north or east the tide is mitigated. The plot on the next page shows the OC tide and the SB tide. The tide reference on this plot is NAVD 1988 which is 0.8 feet different than NGVD 1929. As can be seen from the chart, the highest tide in OC occurred at about 6 AM EST. The high tide in SB corresponding to the highest tide in OC was at about noon EST and was significantly reduced (about 1.25 feet) by the north wind. SB then did not see a corresponding low tide because the water could not flow back through the OC inlet due to the high tide at OC. The next high tide at OC, at about 6 PM EST, was still very high and by now Sandy had gone inland the wind was now coming from the west which increased the tide in SB by about 0.75 feet. This was the highest tide in SB, occurring at about midnight. Even though the high tide in SB occurs 6 hours after the high tide in OC, quite often the highest tide from storms occurs 18 hours after the highest tide in OC due to the winds.

Other factors that exacerbated damages are that the elevations of the lots are mostly less than 5 feet NGVD and many houses have living areas the ground level.



2) Description of damage for the SB area.

a. Narrative of damages follows. Houses that were at ground level saw flooding of two to three feet in their garages and living areas. See pictures on next page. The damages were in the 10s of thousands of dollars. The pictures were taken about 8 hours after the highest tide, thus the water level shown in the pictures is less than the maximum. Automobiles that were left in the flood area were "Totaled." Boats were lifted and deposited on lots and in roads. Route 1 was closed for many hours. The streets in SB were closed for 18 to 24 hours depending on the particular street. The Town incurred a total of $66,400 in cleanup expenses of which the Town was reimbursed #49,800 through FEMA. There were no injuries or fatalities except to a dog that was electrocuted when it walked into water that had flooded a vacuum cleaner that was plugged in.

b. A map depicting the special extent of damages is shown in 1) b. above. For reference SB is about ¾ mile long from north to south along Rt. 1.

3) Prior related studies or projects in the damaged area.
   a. South Bethany entered the Community Rating System (CRS) in 2007. SB is currently in CRS Class 8.
   b. SB has been attending the Delaware Sea Level Rise Advisory Committee meetings and presentations since 2010.
4) Measures that SB has considered to address the problem.
   a. The South Bethany Sea Level Rise & Storm Surge Committee was formed in June 2013 with the following Mission Statement: "Given the increasing information about future concerns that coastal communities like South Bethany may face from Sea Level Rise and Storm Surge, as demonstrated by Hurricane Sandy in October 2012, the SLR & SS Committee will:
      - Conduct a SLR & SS Vulnerability Assessment that will identify property elevations, infrastructure and public spaces that may be at risk for SRL & SS.
      - Gather relevant data and expertise to understand the possible hazards and costs associated with SLR & SS;
      - Identify potential, evaluate and recommend adaptation options;
      - Develop a response based on information and research;

      with the overall goal being the future protection of both the property owners' and the Town's assets."
   b. Based on discussions at the most recent, 8/22/2013, SLR & SS Committee meeting the focus of the committee has been defined.

Summary of Where the SLR & SS Committee Should be Focusing Their Efforts

The following selected focus areas are the product of the committee's discussions on

- The Community Rating System (CRS)
- The DE Floodplain and Drainage Standards and Recommendations and
- The Adaptation Tool Kit: Sea-Level Rise and Coastal Land Use

Selected Focus Areas

- The Comprehensive Plan – SB should update its Comprehensive Plan (CP). The SLR & SS Committee should establish an estimate for SLR (like ½ feet for every 15 years) that would be added to the CP with recommendations and schedules for adaptation implementations.
- The South Bethany Code – SB should update its code to
    - Require "freeboard". SLR & SS Committee needs to make a recommendation for required freeboard (12", 18", 24", 30", or 36".)
    - Consider raising the height limit.
    - Establish requirements relative to fill to raise the elevation of a homeowner's property. Care must be taken so that fill does not adversely affect neighbors.
    - Establish new requirements relative to bulkhead height. Allow or require higher bulkheads. (How much higher?)
- The Community Rating System (CRS) – The CRS Coordinator together with the SLR & SS Committee should strive to get more point. Suggested places are;
    - The 300 Public Information Activities, particularly 310 Elevation Certificates and 330 Outreach Projects
    - The 400 Mapping and Regulation Activities, particularly 410 Additional Flood Data (we may get points for the elevation survey we are doing in the fall) and 430 Higher Regulatory Standards (may change the code to required more "freeboard").
    - The 610 Flood Warning Program.

STAKEHOLDER FEEDBACK – DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL (DNREC)

Re: Delaware Department of Natural Resources and Environmental Control (DNREC) Stakeholder Comments Related to Issues Experienced During Hurricane Sandy for Inclusion in the US Army Corps of Engineers Delaware Inland Bays and Delaware Bay Reconnaissance Study

VULNERABLE AREAS

Bay shoreline beach communities (state managed) –

Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach, Broadkill Beach, Lewes Beach

1a. Elevated water and storm surge from Delaware Bay
1b. Delaware Bay
1c. Low elevation, limited beach widths, low or no dunes
2. Flooding of roads connecting the beach communities to US Rt 1; flooding of beach community homes; erosion of Delaware Bay beaches
3. Management Plan of the Delaware Bay Beaches (2010); State beach nourishment projects (1975 to present)

Bay shoreline communities (county managed) –

Bayview Beach, Augustine Beach, Woodland Beach

1a. Elevated water and storm surge from tidal Delaware River
1b. Delaware Bay/Delaware River
1c. Low elevation, no beach/dune, limited shore protection structures
2. Flooding of roads/homes

Dikes -

New Castle County dikes: Buttonwood Dike, Broad Marsh Dike, Gambacorta Marsh Dike, Army Creek Dike, Red Lion Creek Dike

1a. Storm surge from Sandy, elevated water levels from other coastal events
1b. Tidal Delaware River from north of C&D Canal to and including City of New Castle
1c. Improper maintenance and low elevation of dikes
2. Damages– Several dikes were overtopped causing significant structural damage (Red Lion, Army Creek, Gambacorta). Emergency repairs had to be performed but subsequent damage occurred during post-Sandy events. Flooding caused closing of Route 9 for several days, flooding of some structures and homes in the City of New Castle.
4. DNREC Coastal Programs funded evaluation of dikes and development of reconstruction plan (2010)
5. State funds have been appropriated to reconstruct and raise the 5 dikes, to be completed by 12/2013

Flood-prone urban areas (New Castle County) -

Tidal Christina River Floodplain and City of Wilmington

1a. Storm surge from Sandy, elevated water levels from other coastal events, precipitation runoff from coastal events
1b. Tidal Delaware River, Tidal Christina River
1c. Low elevation, undersize storm sewer/combined sewer system, damaged/clogged tide gates, development increasing impervious area
2. Damages – flooding of roads (evacuation routes), houses businesses, vehicles, overloading of sewer system and treatment facility, debris clogging tide gates.
3. DNREC Coastal Programs - Special Area Management Plan of Drainage and wetlands in South Wilmington. (2007)
4. Wetland creation to be used as holding basin for storm water. Engineering studies and modeling of sewer system, decoupling combined sewer, protective dikes. Repair tide gates.

City of New Castle

1a. Storm surge from Sandy, elevated water levels from other coastal events
1b. Tidal Delaware River
1c. Low land surface elevation, Improper maintenance and low elevation of dikes
2. Damages – Several dikes were overtopped causing significant structural damage (Red Lion, Army Creek, Gambacorta). Emergency repairs had to be performed but subsequent damage occurred in during post-Sandy events. Flooding caused closing of Route 9 for several days, flooding of some structures and homes in the City of New Castle. Destruction of public pier, significant debris accumulation.
3. DNREC Coastal Programs funded evaluation of dikes and development of reconstruction plan (2010)
4. State funds have been appropriated to reconstruct and raise the dikes, to be completed by 12/2013

Delaware City

1a. Storm surge from Sandy, elevated water levels from other coastal events
1b. Tidal Delaware River
1c. Low land surface elevation, poor drainage
2. Damages – houses, roadways flooded
3. UD Sea Grant Natural Hazard and Climate Change Advisory Committee developed Action Plan. DNREC Coastal Programs funded evaluation of drainage network.
4. Designs to improve drainage.

State holdings –

Little Creek Wildlife Area, Mahon River, Kelly Island

1a. Elevated water and storm surge from Delaware Bay
1b. Delaware Bay
1c. Erosion of protective berms, impoundment levees
2. Erosion of impoundment levees, marshes damaged

Murderkill River Inlet, Mispillion River Inlet

1a. Elevated water and storm surge from Delaware Bay

1b. Delaware Bay
1c. Maintenance of jetty structures and channel
2. Damages to jetty structures, shoaling within channel, erosion of adjacent shorelines

Federal holdings –
Bombay Hook National Wildlife Refuge, Pea Patch Island, Reedy Island
1a. Elevated water and storm surge from Delaware Bay/Tidal Delaware River
1b. Delaware Bay, tidal Delaware River
1c. Erosion of protective berms
2. Damages to impoundments and marshes

Prime Hook National Wildlife Refuge
1a. Elevated water and storm surge from Delaware Bay
1b. Delaware Bay
1c. Low elevation, pre-existing breaches in shoreline
2. Damages to impoundment and marshes
3. Attempted closure of breaches by State in 2011; Prime Hook NWR Comprehensive Conservation Plan (2012)

Flood-prone urban areas (Sussex County) –
Milford
1a. Elevated water and storm surge from tidal Mispillion River and storm-water runoff
1b. tidal Mispillion River
2. Roads and homes flooded

Flood-prone bayside and interior ocean community (Sussex County) –
Dewey Beach, Fenwick Island, Joy Beach, Old Landing, Long Neck, Oak Orchard, South Side Indian River Bay, Mallard Lakes
1a. Elevated water and storm surge from Rehoboth Bay, Indian River Bay, Little Assawoman Bay
1b. Rehoboth Bay, Indian River Bay, Little Assawoman Bay
1c. Construction of homes in low-lying areas
2. Flood damages to homes and roadways

Bethany Beach, South Bethany Beach interior areas
1a. Elevated water from Atlantic Ocean
1b. Elevated water from Atlantic Ocean
1c. Storm-water runoff and outfall drainage limited due to elevated ocean water
2. Flood damages to homes and roadways

AREAS WHERE STUDIES ARE COMPLETED, UNDERWAY, OR ABOUT TO BEGIN

1. Prime Hook Beach - Survey of flooded properties with engineering recommendations for flood mitigation alternatives (underway).
2. Oak Orchard - Survey of flooded properties with engineering recommendations for flood mitigation alternatives (about to begin).

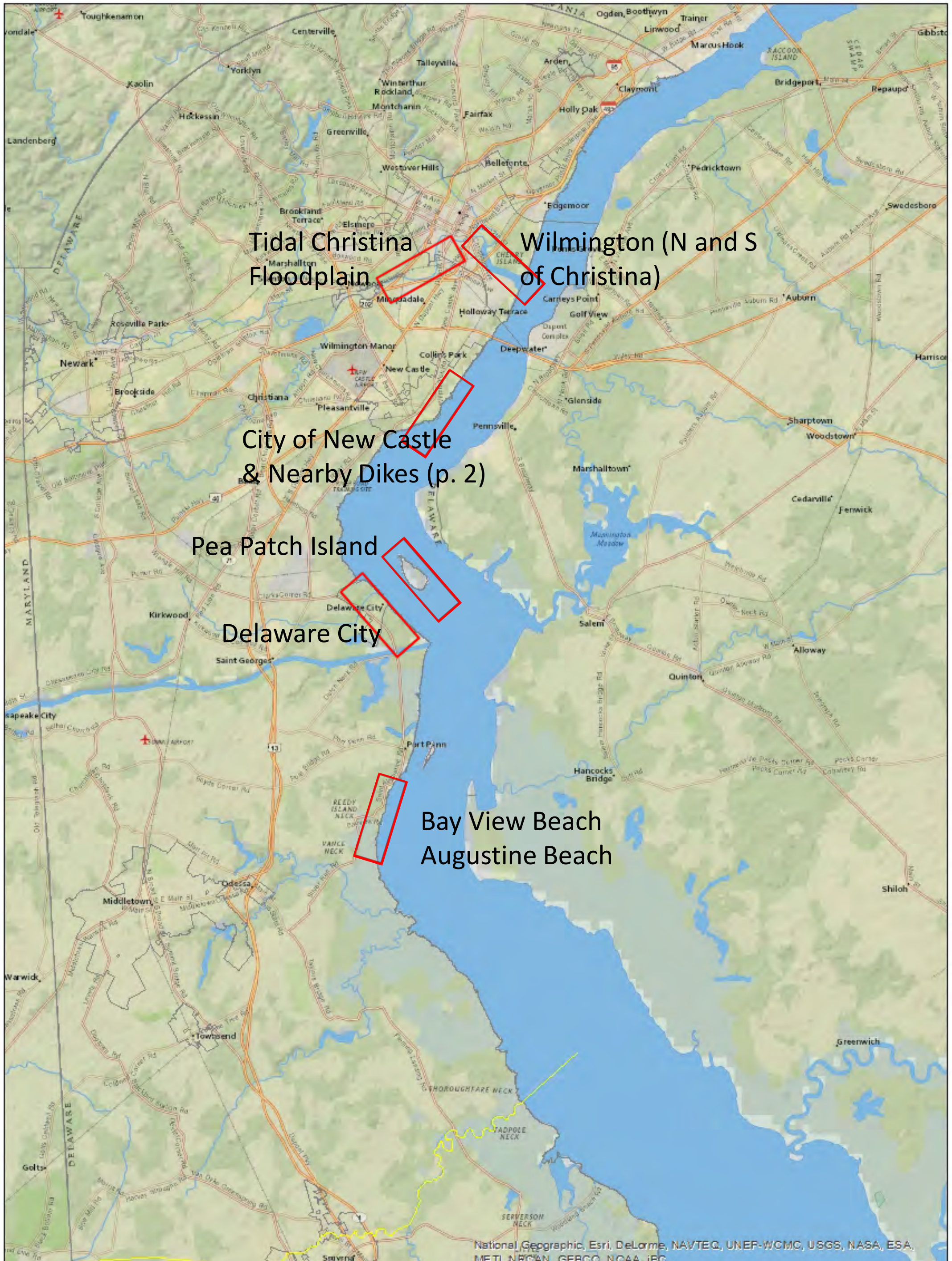
3. Slaughter Beach - Survey of flooded properties with engineering recommendations for flood mitigation alternatives (underway).
4. Bethany Beach - Evaluation of flood-prone areas with structural alternatives analysis (underway – USACE Philadelphia District lead).
5. Greater Fenwick Island area - List of properties flooded in Sandy with preliminary plans to elevate 5 houses and 4 multi-family condominiums (underway).

(With the exception of Prime Hook Beach and Bethany Beach, these are relatively informal studies but several potentially cost-effective elevation or acquisition projects have been identified.)

IMPACTS TO PIER/DOCK STRUCTURES AND INFRASTRUCTURE FROM HURRICANE SANDY

In the time period from November 1, 2012 to February 15, 2013, the DNREC Wetlands and Subaqueous Land Section (WSLS) issued 42 emergency waivers for repairs to pier/dock structures within the Inland Bays (from November 1 to February 15). In addition, WSLS estimated based on conversations with marine contractors that twice this many structures were impacted and were repaired in a manner not requiring authorization.

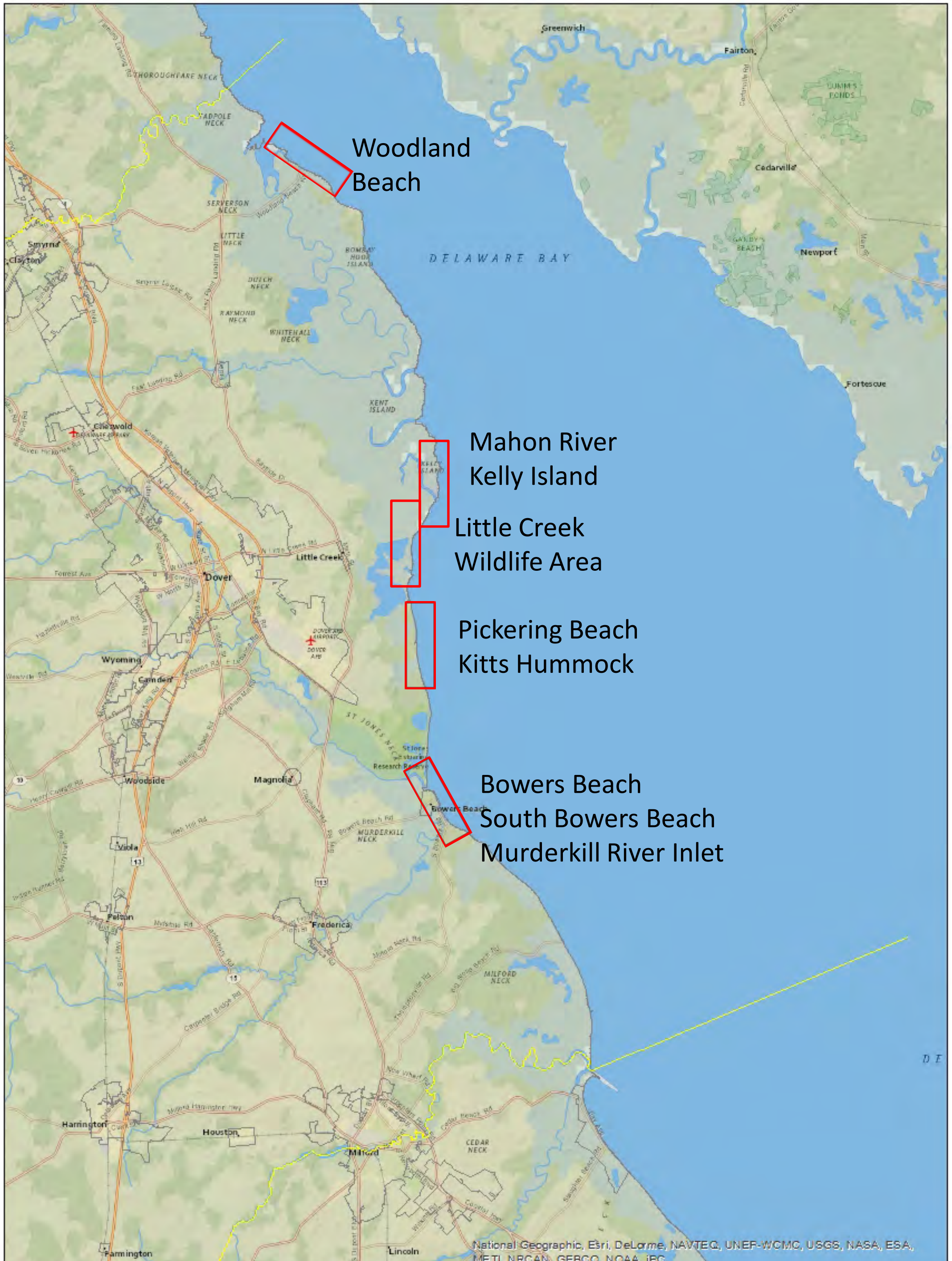
Also, the WSLS issued 10 +/- emergency waivers for repairs to roads impacted by flooding and the storm surge (including the Route 1 approach to the Indian River Inlet Bridge) and WSLS issued 10 +/- emergency waivers for repairs to beaches and earthen dikes.



Tidal Christina Floodplain
Wilmington (N and S of Christina)
City of New Castle & Nearby Dikes (p. 2)
Pea Patch Island
Delaware City
Bay View Beach Augustine Beach
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

New Castle County Flood Control Dikes

Bond Bill Restoration Project


Woodland Beach
Mahon River
Kelly Island
Little Creek Wildlife Area
Pickering Beach
Kitts Hummock
Bowers Beach
South Bowers Beach
Murderkill River Inlet
DELAWARE BAY
Dover
Little Creek
Magnolia
Frederica
Milford
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC


DELAWARE BAY
Slaughter Beach
Mispillion River Inlet
Milford
Prime Hook NWR
Prime Hook Beach
Broadkill Beach
Lewes
Dewey
Bayside
Joy Beach
Old Landing
Oak Orchard
Long Neck
South Side
IR Bay
Bethany
Interior
Interior South
Bethany
Fenwick Bayside
Mallard Lakes
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

From: McKenna, Kimberly (DNREC) [mailto:Kimberly.Mckenna@state.de.us]
Sent: Thursday, September 19, 2013 12:56 PM
To: Croom, Ginger
Cc: Powell, Michael S. (DNREC); Pratt, Tony P. (DNREC)
Subject: FW: Delaware Inland Bays and Delaware Bay Coastal Resilence Reconnaisnace Level Analysis

Hello Ginger:
See the forwarded message below. These comments are intended for inclusion in the Flood-Prone Urban Areas and Bayside/Interior Areas sections of the document that I sent to you on Sep 17. Mike is our state floodplain program manager. Please contact him if you have any questions regarding his comments (cc'd on this email exchange).
Thanks!
Kim

From: Powell, Michael S. (DNREC)
Sent: Wednesday, September 04, 2013 12:49 PM
To: McKenna, Kimberly (DNREC)
Subject: RE: Delaware Inland Bays and Delaware Bay Coastal Resilence Reconnaisnace Level Analysis

Kim,

Here are some thoughts I have regarding answers to the Corps letter:

Specific feedback requested is as follows:

1) **Problem identification for your area:**
   a. Did your area experience storm surge?
   b. Be specific on particular areas and water bodies within your jurisdiction that experienced storm surge.
   c. What factors, if any, exacerbated damages from storm surge?

2) **Description of damages for your area:**
   a. Provide a narrative including the types of infrastructure damaged or temporarily out of use, structure (building) damages, personal injuries/fatalities.
   b. Provide a map depicting the spatial extent of damages.

3) **Prior related studies or projects (local, state, federal) in the damaged area.**

4) **List measures that your jurisdiction has considered to address the problem** (for documentation purposes, should there be a follow-on study).

1) Storm surge was experienced in all of the identified areas in Hurricane Sandy, to varying degrees. In some areas, water levels reached or exceeded 50-year return frequencies while in many other areas, water levels were closer to 10-25 year return levels.

Factors that exacerbated damages to the built environment included a large building stock of older non-elevated buildings and the fact that FEMA flood levels in some areas were set far lower in the past. As recently as 1980-1995, parts of Sussex County had lower 100-year flood levels and buildings were constructed to these lower flood levels. In the Mallard Lakes community (west Fenwick) alone about

$1.5 million in flood damages during Sandy were sustained by buildings lawfully constructed in the mid 1980s to a lower regulatory 100-year flood elevation.

2) Building damages occurred mostly to residential structures where water exceeded the level of the first “living” floor of the house or condominium. Many (approximately 30-50 dwelling units) buildings were uninhabitable for several months while repairs were being made.

3) Post-Sandy high water mark surveys, building elevation surveys performed by FEMA following previous disaster declarations, Prime Hook Beach and Slaughter Beach have sent surveys to all property owners following Sandy, to collect data on the number of impacted property owners, and to identify potential flood mitigation alternatives. Ongoing USACE/Bethany Beach investigation into potential storm surge solutions for the interior basin areas in Bethany Beach.

4) Property acquisition in limited cases where that measure appears to be cost – effective, and where a public entity exists who is willing to accept ownership of the deed-restricted open space. Elevation of flooded homes where continued occupation by the owner is practical.

Michael S. Powell
Environmental Program Manager II
Flood Mitigation Program
Phone: (302) 739-9921
Fax (302) 739-6724
e-mail: michael.powell@state.de.us

From: McKenna, Kimberly (DNREC)
Sent: Thursday, August 29, 2013 11:45 AM
To: Powell, Michael S. (DNREC)
Subject: FW: Delaware Inland Bays and Delaware Bay Coastal Resilence Reconnaisnace Level Analysis

Fyi- Tony and I received this yesterday. Thought that if you had time that you may want to join the conference call today at 2pm. I am following up this email w/the USACE webinar info.
Please open the attachment because they are asking for our feedback on the problem areas from storm surge and flooding.
Thanks!
Kim

From: Mulvenna, Brian J NAP [mailto:Brian.J.Mulvenna@usace.army.mil]
Sent: Wednesday, August 28, 2013 4:57 PM
To: tom.wheeler@esre.com; ardenchair@theardens.com; Hughesk73@yahoo.com; admin@townofbethanybeach.com; Bobatbowersbeach@gmail.com; amanda.wooleyhand@townofcamden.com; staceylong@mchsi.com; RCathcart@ci.delaware-city.de.us; Hanson@team-doctor.com; ccarey@dover.de.us; kimhughes.ellendale@comcast.net; rgreene@townoffelton.com; townhall@fenwickisland.org; frankfordtownhall@mchsi.com; mayoroffrederica@verizon.net; mwyatt@georgetowndel.com; kblanchies@cityofharrington.com; Roth Tom; houstontax@comcast.net; nancygoodfellow@yahoo.com; jimfordiii@aol.com;

dianepcahall@comcast.net; kbranner@middletownde.org; citymanager@milford-de.gov; town@millsboro.org; mvtownmgr@mchsi.com; mayorjones@ci.milton.de.us; donaldreese@newcastlecity.org; townmgrtov@verizon.net; townofodessa@verizon.net; information@cityofrehoboth.com; tmselbyville@mchsi.com; townofslaughterbeach@comcast.net; jmasten@smyrna.delaware.gov; mayorsouthbethany@hotmail.com; dpwilliams@wilmingtonde.gov; hallane@aol.com; ExecutiveOffice@nccde.org; admin@co.kent.de.us; Stiller, Kathleen M. (DNREC); Scarborough, Bob W. (DNREC)
Cc: Croom, Ginger; Smith, J B NAP; McKenna, Kimberly (DNREC); Pratt, Tony P. (DNREC)
Subject: Delaware Inland Bays and Delaware Bay Coastal Resilence Reconnaisnace Level Analysis

Dear Stakeholder,

Please see attached letter regarding the North Atlantic Coast Comprehensive Study Delaware Inland bay and Delaware Bay coast Reconnaissance Level Analysis. We are looking to coordinate with you to gain input to the Study, no later than September 10, 2013.

As stated in the letter, please coordinate directly with Ginger Croom (contractor) and me.

Additionally, we plan to host conference calls/webinars related to this request. The purpose of the call/webinar will be to provide further details on the Study and answer any questions you may have. The conference calls/webinars are currently scheduled for the times below. Details on the call in information will be provided in a separate e-mail to follow.

Thursday, August 29 @ 2:00 PM
Tuesday, September 3 @ 3:00 PM

If you are not able to participate during either of the times identified above, and you have any questions on the letter, please contact our contractor, Ginger Croom, copied on this email, or me.

Brian J. Mulvenna, P.E.
Project Manager
Philadelphia District
US Army Corps of Engineers
Wanamaker Building
100 Penn Square East
Philadelphia, PA 19107
215-656-6599
215-656-6543 fax
brian.j.mulvenna@usace.army.mil

ATTACHMENT B

USACE State Problems, Needs, and Opportunities Correspondence with Individual State Responses

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
AND ENVIRONMENTAL CONTROL
DIVISION OF WATERSHED STEWARDSHIP
89 Kings Highway
DOVER, DELAWARE 19901

OFFICE OF THE
DIRECTOR

PHONE: (302) 739-9921
FAX: (302) 739-6724

June 19, 2014

Mr. Peter Blum
Chief, Planning Division
US Army Corps of Engineers
Philadelphia District
Wanamaker Building, 100 Penn Square East
Philadelphia, PA 19107-3390

Dear Mr. Blum:

Thank you for your letter (dated April 16, 2014) that provides the status of the North Atlantic Coast Comprehensive Study (NACCS) and requests feedback on the state's problems, needs and opportunities related to future planning initiatives with respect to coastal storm risk management and resilience.

The Delaware Department of Natural Resources and Environmental Control (DNREC) continues to express interest and supports various Federal, state, and local agency initiatives to communicate flood risks from coastal storms to vulnerable coastal populations and communities. In addition, DNREC supports the efforts of and is a willing collaborator with the US Army Corps of Engineers (USACE) in its development of the NACCS that addresses flood risks in vulnerable coastal areas. As part of continued collaboration with USACE and for inclusion in the NACCS documentation to be submitted to Congress, this letter serves to provide additional information related to the State of Delaware's coastal storm risk areas.

We have met with your team to discuss our priority areas and feel that the **Mispillion River/Inlet** is the most vulnerable area due to its shoreline instability, unique habitat, navigability issues, and complicated hydrodynamic structure that impact nearby State and Federal holdings. We request a comprehensive and cooperative approach to solving the issues regarding the Mispillion system and look forward to working with you to obtain the authorities and funding for project completion.

In addition, we would like the USACE to include the following areas into the NACCS. This list was sent to Ms. Ginger Croom (USACE/NACCS consultant) on September 17, 2013 and highlights the coastal storm risk (vulnerable) areas:

- *State holdings* – **Mispillion River/Inlet, Murderkill River Inlet, Pea Patch Island**
- *State impoundments* - **Lang Impoundment at the Augustine Wildlife Area, Taylors Gut Impoundment at the Woodland Beach Wildlife Area, Ted Harvey North and**

South Impoundments at the Ted Harvey Wildlife Area, Port Mahon Impoundment at Little Creek Wildlife Area, Little Creek South Impoundment at Little Creek Wildlife Area

- *Federal holdings* – **Bombay Hook National Wildlife Refuge, Reedy Island, Prime Hook National Wildlife Refuge**
- *Bay shoreline beach communities* – **Pickering Beach, Kitts Hummock, Bowers Beach, South Bowers Beach, Slaughter Beach, Broadkill Beach, Lewes Beach**
- *Delaware River/Bay shoreline communities* – **Bayview Beach, Augustine Beach, Woodland Beach**
- *Dikes* – **(New Castle County) Buttonwood Dike, Broad Marsh Dike, Gambacorta Marsh Dike, Army Creek Dike, Red Lion Creek Dike**
- *Flood-prone urban areas* - **tidal Christina River floodplain and City of Wilmington, City of New Castle, Delaware City, Milford**
- *Flood-prone Inland Bays shoreline and interior ocean community (Sussex County)* – **Dewey Beach, Fenwick Island, Joy Beach, Old Landing, Long Neck, Oak Orchard, South Side Indian River Bay, Mallard Lakes, and Bethany Beach, South Bethany interior areas**

We appreciate the opportunity to submit this list of flood risk areas to the USACE and look forward to working with you in finding solutions to reducing the risks. Please feel free to contact me if you have any questions.

Sincerely,

Anthony P. Pratt
Administrator