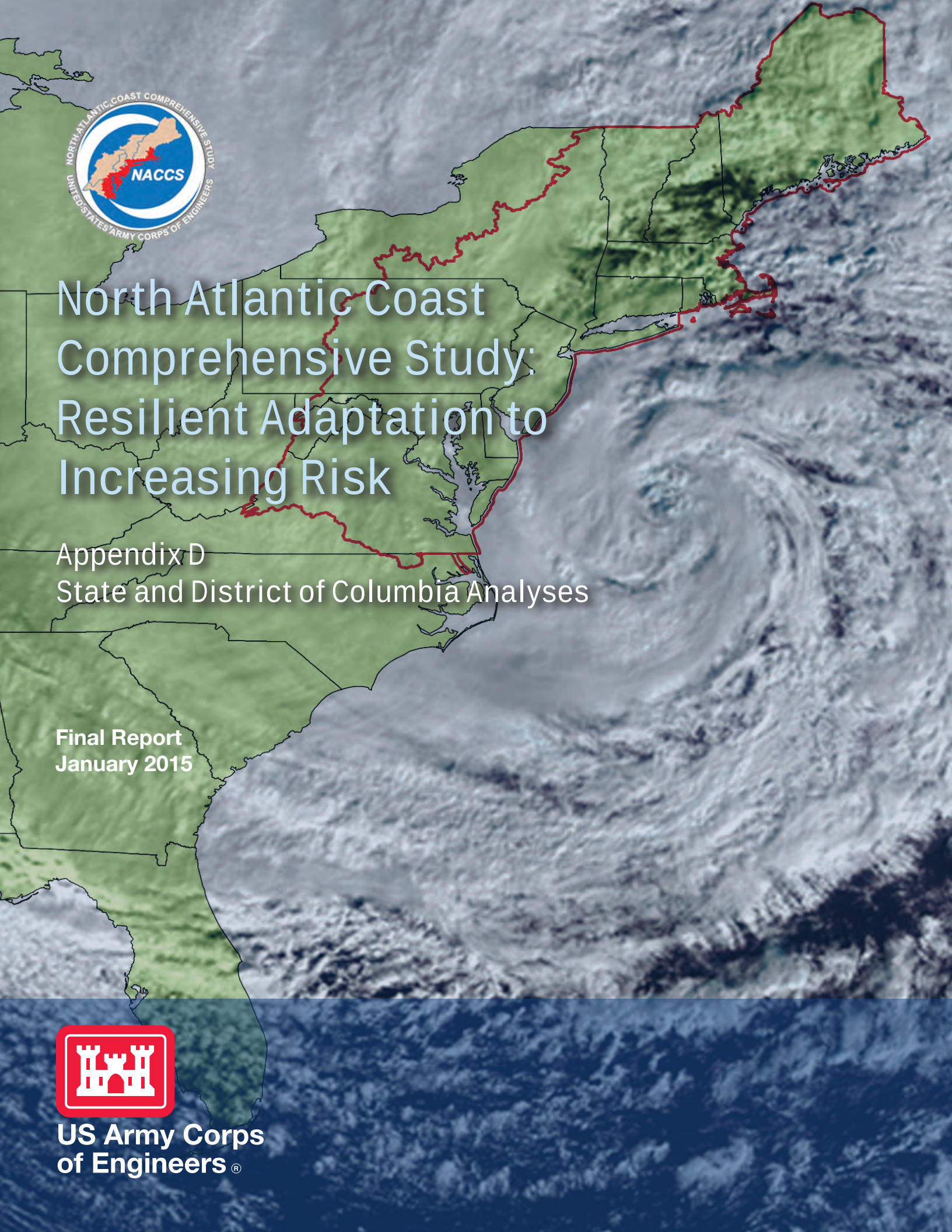

North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk

Appendix D
State and District of Columbia Analyses

Final Report
January 2015

US Army Corps of Engineers®

APPENDIX D: STATE AND DISTRICT OF COLUMBIA ANALYSES

NORTH ATLANTIC COAST COMPREHENSIVE STUDY: RESILIENT ADAPTATION TO INCREASING RISK

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I. Introduction

On October 29, 2012, Hurricane Sandy made landfall near Brigantine, NJ. Because of its tremendous size, Hurricane Sandy drove a catastrophic storm surge into the New Jersey and New York coastlines. For example, a storm surge of 12.65 feet and 9.4 feet above normal high tide was reported at Kings Point on the western end of Long Island Sound and the Battery at the southern tip of Manhattan, respectively. This surge was accompanied by powerful and damaging waves especially along the coast of central and northern New Jersey, Staten Island, and southern-facing shores of Long Island. Flood depths due to the storm tide were as much as nine feet in Manhattan, Staten Island, and other low-lying areas within the New York Metropolitan Area (Blake et al., 2013).

With estimated damages of $65 billion, Hurricane Sandy was the second costliest hurricane in the Nation's history and the largest storm of its kind to hit the U.S. east coast. Twenty-six States were impacted by Hurricane Sandy, with disaster declarations issued in 13. New York and New Jersey were the most seriously impacted States, with the greatest damage and the most fatalities in the New York Metropolitan Area. New York had 48 direct fatalities, followed by 12 in New Jersey, five in Connecticut, two each in Pennsylvania and Virginia, and one each in New Hampshire, West Virginia, and Maryland.

The purpose of the North Atlantic Coast Comprehensive Study (NACCS): Resilient Adaptation to Increasing Risk 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 relative 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 the 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 manage 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 and District of Columbia Analyses Appendix*** considers State-specific conditions, risk analyses and areas, and comprehensive coastal storm risk management (CSRM) strategies in order to provide a more tailored Framework for each of the nine states and the District of Columbia within the study area.

This State Appendix is composed of the following sections:

- Overview presenting analyses and findings applicable to all states within the NACCS study area.
- Nine individual State and District of Columbia Chapters.

The NACCS study area includes the North Atlantic Ocean coastline affected by Hurricane Sandy (Figure 1). The Federal Emergency Management Agency (FEMA) Modeling Task Force (MOTF) Hurricane Sandy

Total Damage (Composite Surge/Precipitation/Wind Map) County Impact Analysis documents widespread economic impacts related to storm surge, intense rainfall, and high winds and identifies areas in purple with counties with more than 10,000 people exposed to the surge[1]. Also, areas in red identify counties with 500 to 10,000 people exposed to surge, experienced wind damages greater than $100 million, or precipitation greater than 8 inches; areas in yellow identify counties with 100 to 500 people exposed to surge, wind damages of $10 to $100 million or precipitation of 4 to 8 inches; and areas in green had no surge impacts, wind damages less than $10 million, or precipitation less than 4 inches.

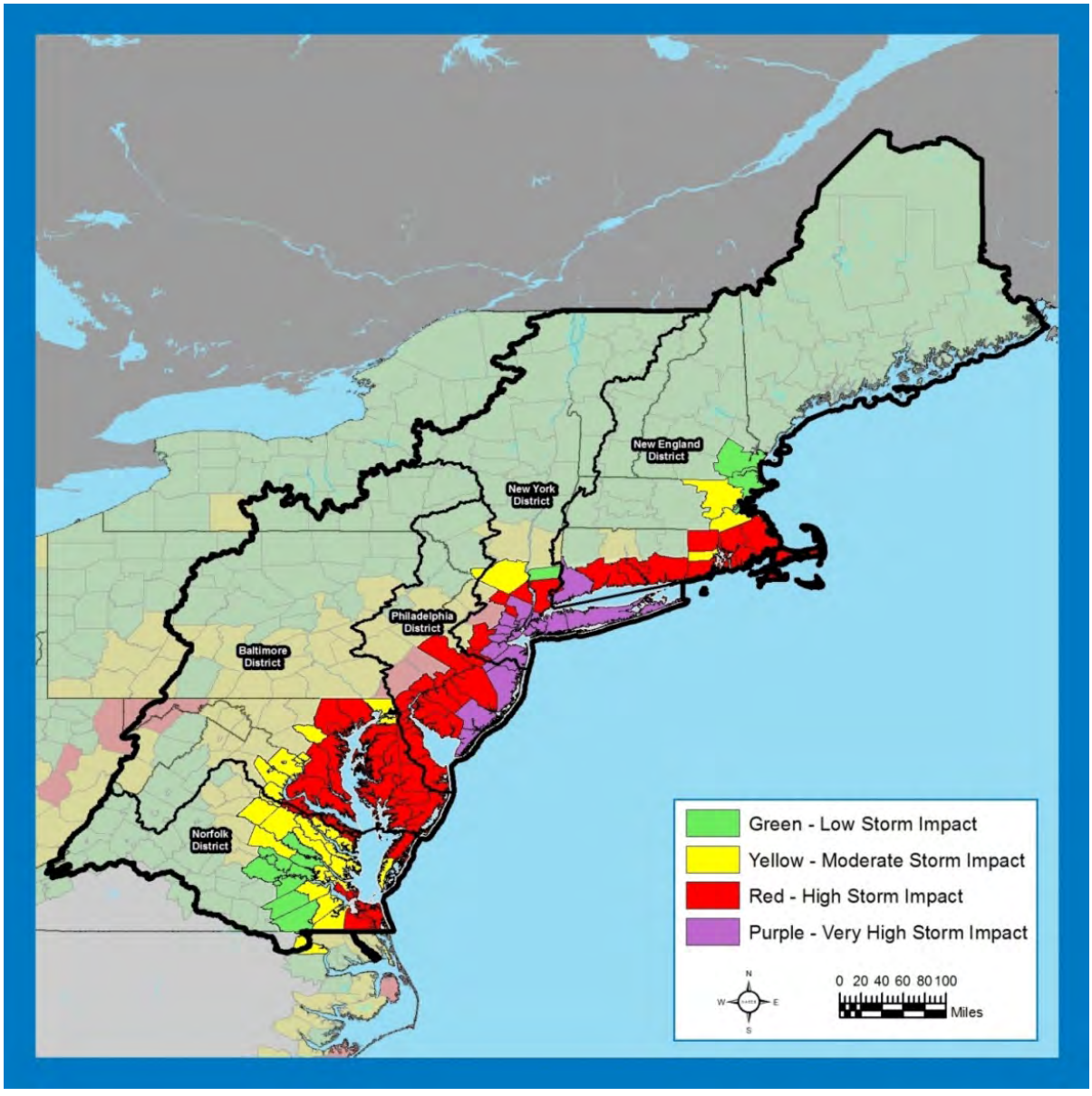

Figure 1. Areas Impacted by Hurricane Sandy with highlighted counties included in the NACCS Study Area (FEMA MOTF, 2013)

[1] Available online at https://content.femadata.com/GISData/MOTF/Hurricane%20Sandy/

In order to conduct more detailed analyses, planning reaches were developed for each state in the study area based on natural and manmade coastal features including shoreline type, USACE CSRM projects, and the 1-percent-annual-chance floodplain (Figure 2). Maps depicting individual planning reaches for each state are included in the respective State and District of Columbia chapters within this appendix. Planning reaches offer smaller, more manageable units for analysis and decision making.

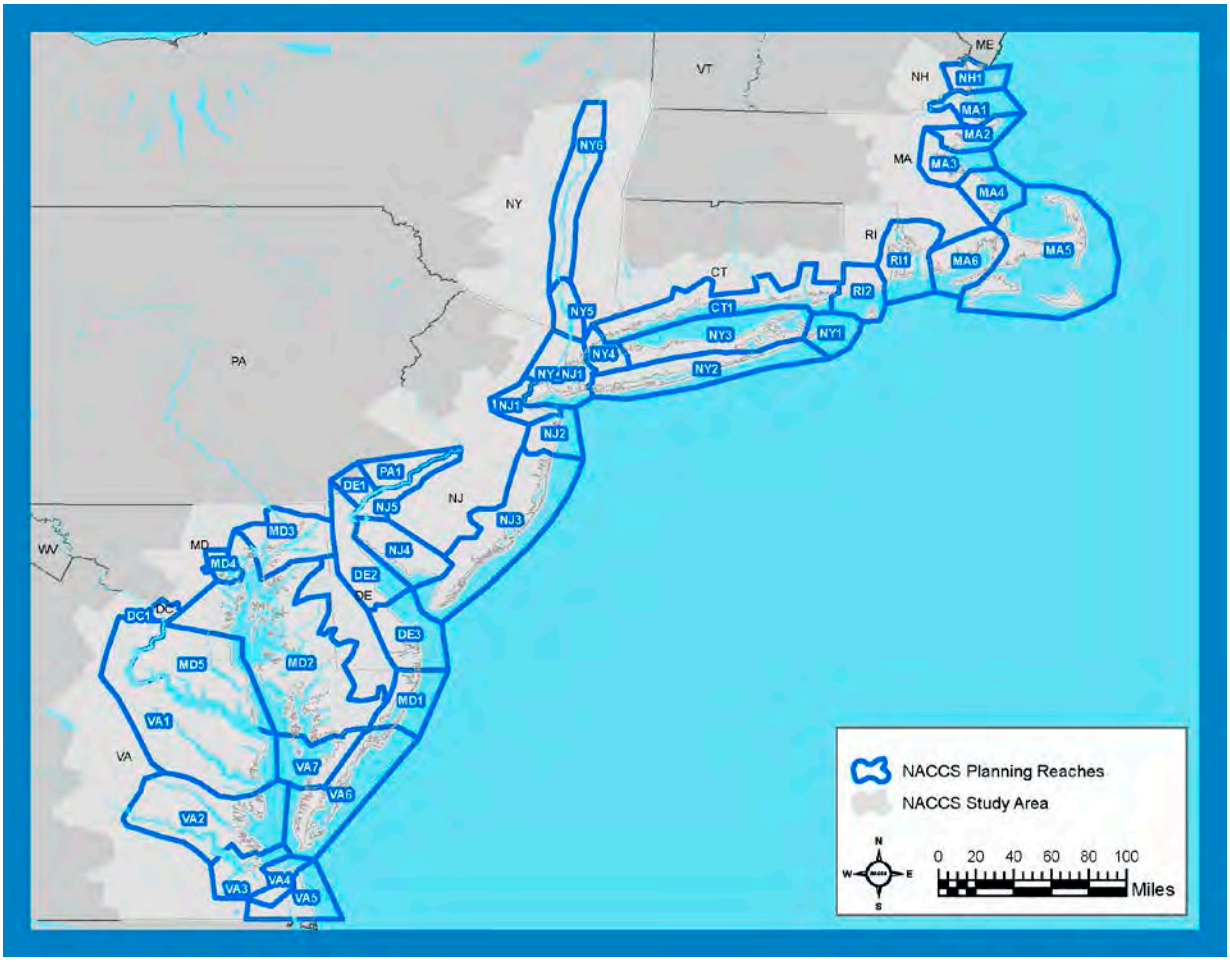

Figure 2.NACCS Planning Reaches

II. Existing and Post-Sandy Landscape Conditions

II.1. Existing Conditions

For the purposes of the NACCS, the existing conditions are the conditions immediately after the landfall of Hurricane Sandy. The existing conditions for each State and the District of Columbia include consideration of the population, supporting critical infrastructure, environmental conditions, inventory of existing coastal storm risk management projects, and associated project performance during Hurricane Sandy, 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.

Additional discussion of existing conditions is provided in the Appendix C- Planning Analyses and the Environmental and Cultural Resources Conditions Report, and is included in the respective State and District of Columbia chapters within this appendix.

II.2. Post-Sandy Landscape

Overview

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 coastal storm risk management and promoting resilience. A baseline of 2018 has been identified when USACE CSRM projects will be implemented/constructed.

Details of the post-Sandy landscape condition, as well as maps including Federal and non-Federal projects for each state and the District of Columbia, are included in the respective chapters of this appendix. A complete list of existing USACE projects within the entire study area is presented in the Appendix C - Planning Analyses.

Some of the future changes considered in the post-Sandy landscape include:

- Relative sea level is increasing throughout the study area, and this will increase the areas exposed to storm surge and frequency of flooding.
- Shorelines are changing in response to relative SLC and sediment surpluses/deficits. Historic erosion patterns are likely to continue or accelerate.
- The population in the study area is increasing, and this will increase the number of people and extent of infrastructure at risk during a storm.
- The population in the study area is getting older. As Hurricane Sandy revealed, older populations are more vulnerable during a storm.
- The extent and character of CSRM projects will increase. In response to the increased risk, many communities will implement projects and programs to reduce vulnerability and reduce risk to developed areas through a combination of traditional engineered storm risk management projects, nature-based solutions, and strategic retreat and/or elevation of vulnerable structures.

Coastal Storm Risk Management Projects

For purposes of forecasting future scenarios, it is assumed that:

- All existing USACE CSRM projects identified in the First Interim Report will be both repaired to pre-Sandy conditions through the USACE Flood Control and Coastal Emergencies (FCCE) program and also returned to authorized design dimensions through funding provided under Public Law (P.L.) 113-2;
- All authorized but unconstructed USACE CSRM projects identified in the Second Interim Report will be constructed to authorized design dimensions through funding provided under P.L. 113-2;
- All studies identified in the Second Interim Report with a high (>75 percent) probability of construction will be constructed to authorized design dimensions through funding provided under P.L. 113-2;
- Other Federal agency/non-governmental organization (NGO) projects and State or District of Columbia projects will be repaired to their pre-Sandy condition unless otherwise communicated by individual agencies.

The post-Sandy landscape identified those projects applicable to receive construction funds as a part of the Second Interim Report. They were identified based on the assumption that Federal funds were available and after coordination with non-Federal sponsors. Many of these projects are already underway or were in receipt of funding appropriated as part of P.L. 113-2. In early 2013, once the scoping and existing and future conditions forecasts for the NACCS were being developed, the study adopted a general assumption of five years to complete construction of those projects identified in the Second Interim Report. In parallel to the NACCS, the post-Sandy construction program was established. Further coordination resulted in refined schedules leading to some projects expected to be fully constructed before 2018 as well as many after 2018. Clarification of the situation will be made and reflect further consideration of forecasting future conditions as part of subsequent analyses to account for studies or projects within a more refined study area.

Relative Sea Level Change and Climate Change

Climate change, including relative SLC over the planning horizon, is expected to have a profound effect on the coastal region. Planning horizons considered in the NACCS include 2068, 2100 and 2118, which account for USACE and NOAA policies on future SLC for long range planning. These horizons assume a baseline of 2018 when the majority of USACE projects included in the previously discussed post-Sandy landscape condition will be implemented. To consider the effects of SLC on the future landscape, scenarios have been developed by USACE (documented in Engineer Regulations (ER) 1100-2-8162, USACE, 2013a) and by NOAA (2012). The details of different scenarios and their application to the development of future local, relative sea level elevations are discussed in Chapter IV of the Main Report. Maps depicting areas that would be below mean sea level at three future times (2018, 2068, and 2100) based on the USACE "High" Scenario are included in the state and District of Columbia chapters.

Climate change impacts may include, but are not limited to, shoreline retreat from erosion and inundation, increased frequency and magnitude of storm related flooding, increased frequency of minor local flooding during high tide (NOAA, 2014), and saltwater intrusion into the estuaries and aquifers. Relative SLC will not only inundate the landscape, but will also be a driver of change in habitat and species distribution. Additionally, the presence of developed shorelines behind many of these habitats will prevent migration of those habitats landward and limit their capacity for adaptation. Habitat changes may be structural or functional; species that depend on coastal habitats for feeding, nesting, spawning, protection, and other

activities could be severely impacted if this critical habitat is converted or lost. Additional ecosystem services provided by coastal habitats would also be affected.

Extreme Water Levels

Coastal flooding is primarily caused by rainfall, storm surge, and waves. For the North Atlantic coastline, tides can have a significant influence on the degree of flooding. For the region from Virginia to Maine, both tropical cyclones (hurricanes) and extratropical storms (nor'easters) have caused significant coastal flooding.

The NACCS is quantifying existing and future storm conditions for use in assessing potential vulnerability and measures to increase resilience from coastal flooding. As part of the NACCS, rigorous regional statistical analysis and detailed high-fidelity numerical hydrodynamic modeling is being conducted for the North Atlantic coastal region to quantify coastal storm wave, wind and water level extremes. The inclusion of potential future climate change will be included in the analysis. However, in the interim, future storm water level elevation extremes are being quantified for use in determining areas exposed to flooding and relative vulnerability. A discussion of the methodology to identify extreme water levels is provided in Appendix A - Engineering.

The extent of flooding from coastal storms was estimated using readily available 1-percent storm mapping from FEMA, preliminary 10-year storm values from the NACCS extreme water level analysis, and the Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model inundation mapping prepared by NOAA. The purpose of the various inundation datasets was to be able to evaluate changes in vulnerability at the study area scale, which represent varying levels of probability and corresponds with other agencies' regulatory and planning efforts.

The SLOSH model inundation mapping prepared by NOAA corresponds to hurricane intensities categorized by the Saffir-Simpson hurricane wind scale, but also other characteristics of hurricanes that can vary considerably along the coast, including angle of approach to the shoreline, width and slope of the continental shelf, astronomical high tide level, and local geographic features (FEMA, 2011). The inundation zones identified by the SLOSH model depict areas of possible flooding from the maximum of maximum event within the five categories of hurricanes by estimating the potential surge inundation during a high tide landfall. The results of the SLOSH inundation mapping are used to prepare hurricane evacuation studies. Although the SLOSH inundation mapping is not referenced to a specific probability of occurrence (unlike inundation mapping presents on a flood insurance rate map (FIRM), which references the inundation to the 1-percent and 0.2-percent storm event), a Category 4 hurricane making landfall during high tide represents an extremely low probability of occurrence, but a high magnitude event.

The intent of the NACCS was to generate a spatially comprehensive, but first-order approximation of flooding vulnerability across the entire northeastern Atlantic coastal region. The use of NOAA's Maximum of Maximums (MOM) from the SLOSH Model was necessary based on the very large spatial extent of the study area and the fact that it is currently the most advanced storm surge modeling available for the entire study area. The extent of the Category 4 (CAT4) MOM represents the maximum storm tide levels caused by extreme hurricane scenarios across the study area and, therefore, provides a reasonable approximation of the most extreme flooding extent. Hydrodynamic modeling inundation mapping associated with Category 1 through 4 hurricanes used for evacuation modeling is presented in the respective state and District of Columbia chapters within this appendix.

The approximate 1-percent floodplain (plus 3 feet) is presented for each state and the District of Columbia to illustrate areas exposed to projected inundation levels and is closely aligned with the USACE high scenario for projected relative SLC by year 2068. FEMA's National Flood Insurance Program (NFIP)

bases the availability of flood insurance on communities' adoption and enforcement of floodplain management ordinances relative to the Special Flood Hazard Area (SFHA), which is defined as the area that will be inundated by the 1-percent flood. Flood insurance and building ordinances for communities participating in the NFIP reference the 1-percent flood elevation as first floor elevation requirements for new or substantial renovations, or new mortgages on home sales. Local jurisdictions can adopt more stringent building codes. USACE optimizes CSRM projects to maximize economic benefits greater than or equal to the costs to construct the project. However, for the purposes of the NACCS, considerations using the 1-percent flood inundation mapping were made to evaluate risk management measures.

The current 10-percent floodplain (an area with a 10-percent or greater chance of being flooded in any given year) is presented for each State and the District of Columbia. This analysis is based on the 10-year return period frequency water levels from NOAA gages. The purpose of the 10-percent floodplain is to consider the flood risk reduction performance of various natural and nature-based features (NNBF) management measures. Relative SLC was not considered as part of the 10-percent floodplain because adaptive management would be used to adjust to sea level conditions.

Detailed environmental resources discussions are included in the respective State and District of Columbia chapters within this appendix.

Climate Change Adaptation

Adaptive capacity describes a system's ability to evolve, either naturally or through engineered maintenance activities, in such a way as to preserve or enhance the system's valued functions. In the future coastal landscape, adaption and adaptive capacity of risk reduction measures, communities, and the population will become more and more prominent over time. Specifically, with current literature documenting increases in storm intensity and frequency, and impacts from relative SLC, the coastal landscape can be expected to change considerably in the future (IPPC, 2007; 2013). The NACCS SLC analyses presented three potential scenarios of SLC 2068, 2100, and 2118 (based on a baseline of 2018) which reinforces the concept of coastline migration and inundation over time.

The NACCS CSRM Framework includes evaluations of strategies in response to increased risk from coastal storms and relative SLC. Subsequent analyses at community-specific scales should incorporate climate change adaptation planning when considering projected future vulnerabilities. The effects of climate change may result in relative SLC as well as increase in extreme water levels, storm surge, and rainfall/runoff. The combination of extreme water levels and relative SLC (some areas of the NACCS study area will likely experience variations in the effects of relative SLC due to relative effects of land subsidence and tidal processes) will vary across the study area. Flood frequency, erosion/sedimentation, and environmental responses will depend on site and regional characteristics. By using a long-term planning horizon, communities will be able to consider the appropriate short-term response to address existing levels of exposure and vulnerability and reduce the need to reinvest in a different solution based on the rate of relative SLC over time. The NACCS CSRM Framework includes an evaluation of the various risk management measures and presents how adaptation and adaptive capacity could be incorporated into their design. Development of coastal vulnerability metrics, which incorporate adaptive capacity concepts, are available in the Use of Natural and Nature-Based Features in Coastal Systems report (Bridges et. al. 2015).

III. Coastal Storm Exposure and Risk Assessments

Risk is an overarching concept that includes the components of hazard, exposure, performance of a system of flood risk management features, subsequent consequences, and vulnerability. Exposure and risk assessments represent an approach to evaluating risk from flood hazard along the North Atlantic Coast as a system, incorporating the natural, social, and built systems as referenced in the NOAA/USACE Infrastructure Systems Rebuilding Principles. As such, the exposure and risk assessments make use of the planning process that allows stakeholders to highlight vulnerable areas by evaluating three criteria: population and infrastructure, social vulnerability factors of the population, and environmental and cultural sensitivities. The Framework has been applied on a macro-level covering a large geographic area. The Framework presents an illustrative example and assessment of risk to assist in identifying coastal flood hazards.

For the NACCS, risk to coastal flood hazard was defined using flood inundation mapping in combination with the exposure. Vulnerability is defined as the degree to which a system's receptors or assets are susceptible to, and unable to cope with, the adverse effects of coastal flooding over a period of time or temporal reference. It is a function of character and magnitude of a hazard (here, coastal storm flooding) to which the community is exposed, the sensitivity of the population, infrastructure, environmental and cultural resources in the community, and the capacity of the community to bounce back and regain functional performance.

NACCS Exposure Assessment

The assessment first required identifying various categories to best characterize exposure, where exposure is defined as the presence of people, infrastructure, and/or environmental and cultural resources (receptors of the hazard) affected by coastal storm risk hazard. The higher density of people, infrastructure, and/or environmental and cultural resources produces relatively higher exposure to coastal storm risk hazard.

Although a myriad of factors or criteria/on can be used to identify exposure, the NACCS focused on the following categories and criteria/on:

1. **Population Density and Infrastructure:** Population density includes identification of the number of persons within an areal extent across the study area; infrastructure includes critical infrastructure that supports population and communities. These factors have been combined to reflect overall vulnerability to the built environment.

2. **Social Vulnerability Characterization:** Social vulnerability characterization includes certain segments of the population that may have more difficulty preparing for and responding to coastal flood events.

3. **Environmental and Cultural Resources:** The environmental and cultural resources exposure analysis captures important habitat, and environmental and cultural resources that would be affected by storm surge, winds, and erosion. These resources have been combined to reflect an overall vulnerability of the natural and cultural environments. Impacts and recovery opportunity would vary across areas and depend on the resource(s) affected.

Population Density and Infrastructure Index

The affected population and population density were identified as a measure of the coastal flood exposure. In addition to reducing risk to coastal populations, an objective of the NACCS is to identify risk to critical infrastructure. The Homeland Security Infrastructure Program was used to identify critical infrastructure using principles associated with an engineering reconnaissance process described in the Department of the Army Field Manual 3-34.170, *Engineer Reconnaissance* (U.S. Army, 2008). The sewage, water, electricity, academics, trash, medical, safety, and other considerations (SWEAT-MSO) assessment process was developed to provide immediate feedback concerning the status of the basic services necessary to sustain a population. The post-hurricane recovery time is directly proportional to time it takes to restore interruptions in basic services. These services are necessary to provide more resilient communities, and identifying the exposure and vulnerability of these assets is an important step in developing a CSRM Framework.

Appendix C – Planning Analyses provides a discussion of how these different indices were weighted in the analysis and the exposure indices are included in the respective State and District of Columbia chapters within this appendix. Because the NACCS was conducted at a regional scale, the population density and infrastructure index was applied consistently across the entire study area and was weighted more heavily than the social vulnerability and environmental and cultural resources indices to address the study goals set by PL 113-2. In applying the Framework at a State or local level, the indices and weights should be adjusted to more accurately reflect the conditions and priorities of the user.

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 data. The overarching goal was to quantify areas where the population was more vulnerable to storm impacts due to social factors such as age, income, and non-proficient English speakers. The following equation, including data categories available in the U.S. Census data at the block-group level, was used to define the social vulnerability exposure index:

% Population 65 and over + % Population under 5 + % Population w/ Income below poverty +

% Population Non-proficient English speakers

Figures depicting the social vulnerability exposure index are included in the respective State and District of Columbia chapters within this appendix.

Environmental and Cultural Resources Exposure Index

The environmental and cultural resource exposure index captures important habitat, and cultural and environmental resources, including those defined by others, that would be vulnerable to storm surge, winds, and erosion. Impacts and recovery opportunity would vary across each planning reach and depending on the resource affected. Data used for this analysis is listed below but additional data could be utilized depending on the user's mission, priorities, and required level of detail.

Habitat (as defined by The Nature Conservancy [TNC] and the U.S. Fish and Wildlife Service [USFWS])

Seagrass

Estuarine Emergent Marsh

Forested Wetland

Scrub-Shrub Wetland

Freshwater Emergent Marsh

Freshwater Forested/Scrub Wetland

Riverine Wetland

Rocky Shoreline

Unconsolidated Shore - mud, organic, flat

Unconsolidated Shore - sand, gravel, cobble

Cultural Resources

Cultural Resource Buffer (1000 feet)

National Monuments and National Historical Parks

National Register of Historic Places (NRHP) listed properties

Priority Areas (as defined by others)

Coastal Barrier Islands under Coastal Barrier Resources Act (CBRA), Estuarine Barriers, Barrier Spits, Bay Barriers

USFWS Protected Areas

Federal Threatened, Endangered, or Proposed Species (USFWS)

Waterbird Nesting Colony, Shorebird Stopover, or Special Interest Species (USFWS)

The Natural Conservancy's regionally significant coastal conservation target areas

City, County, State and Federal Parks >10 acres

In this example, each of the three categories (Habitat, Cultural Resources, and Priority Areas) were given consideration, with Habitat and Priority Areas contributing 30% of the total environmental and cultural resource exposure score, and Cultural Resources contributing 40%. Again, this is just an example to demonstrate the exposure index and weighting can/should be modified depending on the user's mission and priorities.

It should be noted that some regions that may be recognized as important in one category or another, may not appear 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. Additional information on important habitat, environmental, and cultural resources can be found in the Environmental and Cultural Resources Conditions Report.

Composite Exposure Index

All three of the exposure indices were combined to develop one composite index that displays overall exposure. Each index was multiplied by a relative weight and the results were summed to develop the total 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. For the purpose of the Framework, the overall composite exposure assessment identified areas with the potential for relative higher exposure to flood peril considering collectively the natural, social, and built components of the system. . Figures depicting the Composite Exposure Index for each State and District of Columbia are included in the respective chapters within this appendix.

Forecasted Population Density and Infrastructure Index

It is likely that the population will increase in the NACCS study area. Using information and datasets generated as part of the U.S Environmental Protection Agency's (USEPA) Integrated Climate and Land Use Scenarios (USEPA, 2009), inferences related to the future population and land use changes have been incorporated into the sea level change analyses mapping. Additional information is included in the Planning Analyses appendix, with the results presented in the corresponding state chapter of this appendix. 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 relative SLC on environmental and cultural resources are presented in the Environmental and Cultural Resources Conditions Report.

NACCS Risk Assessment

For the NACCS, 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. Figures depicting the results of this risk assessment using the composite exposure data are included in the respective State and District of Columbia chapters within this appendix.

NACCS Risk Areas Identification

Areas of high risk have been identified in each State and are discussed on a reach-by-reach basis in the respective State and District of Columbia chapters within this appendix.

IV. NACCS Coastal Storm Risk Management Strategies and Measures

Coastal systems provide important social, economic, and ecological benefits to the Nation. However, our coasts are vulnerable to the influence of a combination of factors, including storms, changing climate, geological processes, and the pressures of ongoing development and urbanization. In addition to policy and programmatic efforts to reduce risk, three primary strategies were considered under the NACCS Coastal Storm Risk Management Framework to address the flood risk to vulnerable coastal populations (Dronkers et. al., 1990; USACE, 2014):

1. **Avoid** – Sometimes termed "retreat," this option seeks to avoid increasing impacts through traditional nonstructural activities, such as acquisition, to convert land to open space, providing natural infrastructure risk reduction benefits, but it also could include other strategies, such as NNBF measures.
2. **Accommodate** – This option allows individuals and communities to adapt to sea level changes and other impacts as they occur over time. This strategy could include traditional nonstructural measures, such as elevation, floodproofing, and ring walls, along with improved implementation of NNBF measures consistent with NACCS Opportunities in Section II.
3. **Preserve** – Sometimes termed "protect," this option focuses on preserving the function or reliability of the given economic, social, and/or environmental system that is adversely affected by climate change (e.g., navigation channels continue to function reliably, flood risk reduction measures continue to reduce risk), and may include structural, nonstructural, NNBF, and combinations of each as appropriate.

Risk management measures were then organized by three categories: structural, nonstructural, and NNBF. Some NNBF were identified for both the NNBF and structural categories because of their storm surge reduction potential. Additionally, policy measures were organized under the nonstructural category.

To that end, risk management measures were characterized by the degree to which they could contribute to: 1) reduction of coastal storm damages (through reductions in flooding, waves, or erosion); 2) production of multiple benefits; and 3) the promotion of resilience and adaptive capacity (Table 1). Appendix C – Planning Analyses includes additional information on the description of risk management measures, including benefits, impacts, and other considerations.

Table 1. Storm Risk Management and Resilience Attributes Associated with the Full Array of Measures

Aggregated Measure Type[1]	**Category**[2]	**Storm Damage Reduction Function**			**Multi-Benefits**[3]	**Resilience**
		Flooding	Wave Attenuation	Erosion		Adaptive Capacity[4]
Acquisition (building removal) and relocation[5]	Non-STR	High	High	High	High	High
Building retrofit (e.g., Floodproofing, elevating structures, relocating structures, ringwalls)	Non-STR	High	Low	Low	Low	Low
Enhanced flood warning & evacuation planning (Early warning systems, emergency response systems, emergency access routes)	Non-STR	Low	None	None	Low	High

Land use management/conservation and preservation of undeveloped land, zoning and flood insurance	Non-STR	Medium	None	None	High	Medium
Deployable floodwalls	STR	Medium	None	None	None	Low
Floodwalls and levees	STR	High	Low	None	Low	Low
Shoreline stabilization (Seawalls, revetments, bulkheads)	STR	Low	High	High	Low	Low
Storm surge barriers	STR	High	Medium	None	Low	Low
Barrier island preservation and beach restoration (Beach fill, dune creation)	STR/NNBF	High	High	Medium	High	High
Beach restoration and breakwaters	STR/NNBF	High	High	High	High	Medium
Beach restoration and groins	STR/NNBF	High	High	High	High	Medium
Drainage improvements (e.g., Channel restoration, water storage/retention features)	STR/NNBF	Medium	Low	Medium	Medium	Low
Living shorelines	STR/NNBF	Low	Medium	Medium	High	High
Overwash Fans (e.g., Back bay tidal flats/fans)	NNBF	Low	Medium	High	Medium	High
Reefs	NNBF	Low	Medium	Medium	High	High
Submerged aquatic vegetation	NNBF	Low	Low	Low	High	Medium
Wetlands	NNBF	Low	Medium	Medium	High	High

[1] *An extensive list of management measures was compiled as part of the NACCS Measures Working Meeting in June 2013. The Measures presented here represent an aggregated list of the categories of measures and corresponding conceptual parametric unit cost estimates.*

[2] *STR = structural measure, Non-STR = nonstructural measure, and NNBF = natural and nature-based features measure. Multiple measures are listed if the aggregated measure type is made up of a combination of measures.*

[3] *Multi-benefits focus on socioeconomic contributions to human health and welfare above and beyond the risk reduction benefits already highlighted in this table (e.g., flooding, wave attenuation, etc). These benefits could include increased recreational opportunities, development of fish and wildlife habitat, provisioning of clean water, production of harvestable fish or other materials, etc.*

[4] *Adaptive capacity is the assessment of a measure's ability to adjust with change conditions and forces (including sea level change) through natural processes, operation and maintenance activities, or adaptive management, to preserve the measure's function.*

[5] *Acquisition, relocation, and buyouts do not actually prevent flooding and erosion, but removes the population from its effects.*

IV.2. 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. Shoreline types were derived from the NOAA Environmental Sensitivity Index (ESI) Shoreline Classification dataset (NOAA, n.d.). Table 2 summarizes the measures applicability based on shoreline type. It is assumed nonstructural measures could be considered in all geographic contexts, subject to further evaluation at a smaller scale.

Table 2. Structural and NNBF Measure Applicability by NOAA-ESI Shoreline Type

Measures	Rocky shores (Exposed)	Rocky shores (Sheltered)	Beaches (Exposed)	Man-made structures (Exposed)	Man-made structures (Sheltered)	Scarps (Exposed)	Scarps (Sheltered)	Vegetated low banks (Sheltered)	Wetlands/Marshes/ Swamps (Sheltered)
Structural									
Storm Surge Barriers[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 (NNBF)									
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 NNBF.*

[3] *Submerged aquatic vegetation is not associated with any particular shoreline type. It is initially 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.*

IV.3. General Design and Cost Considerations

Conceptual designs and parametric cost estimates (typically per linear foot of shoreline) were developed for the various CSRM measures 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.

Design Criteria

A Design Standards and Criteria Team was formed to examine existing coastal engineering design standards and criteria as required by P.L. 113-2:

"…that efforts using these funds shall incorporate current science and engineering standards in constructing previously authorized Corps projects designed to reduce flood and storm damage risks and modifying existing Corps projects that do not meet these standards, with such modifications as the Secretary determines are necessary to incorporate these standards or to meet the goal of providing sustainable reduction to flooding and storm damage risks."

Table 3 presents the post-Hurricane Sandy design criteria identified by the Design Standards and Criteria Team. These criteria informed the coastal storm risk management levels assigned to measures. Table 4 presents suggested levels of coastal storm risk management. Actual risk management levels may vary depending on site-specific conditions.

Table 3. Post-Sandy Design Criteria of Other Agencies

Agency	Criteria
NYC Special Initiative for Rebuilding and Resilience (2013)	FEMA Base Flood Elevation (BFE) + 3 ft
U.S. Housing and Urban Development (HUD) Hurricane Sandy Rebuilding Task (2013)	FEMA Base Flood Elevation (BFE) +1 ft

Table 4 summarizes the conceptual design criteria that were used in evaluating costs and risk management for the various coastal storm risk management measures. The design criteria included a "+3 feet" allowance for the structural measures to account for uncertainty associated with future sea level change forecasts. This 3-foot allowance is consistent with the USACE High scenario for projected sea level change by year 2068, as well as post-Hurricane Sandy design guidance developed by other agencies. Most structural measures and NNBF features such as beach fill and dune creation were assumed to be designed to a 1 percent flood elevation plus a 3-foot allowance for future sea level change. Storm surge barriers were assumed to be designed to a 0.2 percent flood elevation with the same 3-foot sea level change allowance.

Table 4. Criteria for Conceptual Design of NACCS Risk Management Measures	
Measure Type	**Criteria[1]**
Structural (not barriers)[2]	1-percent storm tide level + 3 ft SLC allowance
Storm Surge Barriers	0.2-percent storm tide level + 3 ft SLC allowance
Natural and Nature-Based Features	10-percent storm tide level
Nonstructural (Floodproofing and Buyouts)	1-percent storm tide level + 3 ft SLC allowance

[1] *Criteria are for conceptual NACCS design only, and may not be consistent with existing USACE or other Agency analysis or design guidance.*

[2] *Beaches and dunes are also considered NNBF.*

For other NNBF measures (not including beach restoration [beach fill, dune creation] measures presented in Table 1), the design criteria of the 10 percent flood was assumed for risk management potential. This design criteria was assumed for concept design purposes, although the opportunity for surge reduction would ultimately be dependent on site-specific criteria, such as geographical location, local tide variance, geomorphological conditions, etc. In addition, the allowance for future sea level change increase was not considered for the 10 percent floodplain because NNBF risk management measures would depend on tidal influences to maintain their functionality (e.g., wetlands and living shorelines). Adaptive management considerations with respect to sea level and climate change would be required for NNBF management measures.

Buildings are typically elevated (nonstructural measure) one foot above the 1 percent flood to account for risk and uncertainty. However, as part of floodplain ordinances and building codes, some coastal communities have, or are enacting, more stringent elevation requirements of up to three feet above the 1 percent flood as a result of the magnitude and impact of Hurricane Sandy, and the uncertainty regarding the rate of sea level change. Therefore, for the purposes of this analysis, the more conservative requirement of three feet above the 1 percent flood was used as the nonstructural design elevation.

IV.4. Comprehensive CSRM and Resilience

The NACCS provides a general understanding of the areas of exposure and risk to coastal storm risk (including relative SLC), an array of potential opportunities to address coastal storm risk, including parametric unit costs, specific state and District of Columbia analyses for ease of identifying additional analysis, and an illustrative characterization of exposure and risk.

The Framework identifies a combination of structural and NNB, nonstructural, and policy/programmatic measures that could provide a defined level of risk management with a relative range of costs offering adaption to future conditions. The Framework would help state and local entities to make risk reduction decisions, plan for coastal resilience, as well as conduct follow-on technical analyses and studies.

Decision makers can use the Framework to identify management measures for further exploration and evaluation based on the area or community-specific needs, priorities, and conditions. Additionally, the Framework is applicable to all areas and communities, with a range of exposures, and not only those

areas at highest risk. With more detailed data and criteria, coastal communities could tailor the Framework to more accurately evaluate their existing level of flood risk and resilience, and consider the appropriate management measures to address more specific problems, needs, and opportunities.

A more detailed discussion of the Framework is provided in the Main Report and Planning Analyses Appendix while the application of the Framework is provided in the respective state and District of Columbia chapters of this appendix.

Tier 1 Assessment Results

The NACCS Tier 1 assessment is the application of the CSRM Framework at the study or regional scale to evaluate and compare solutions to address coastal flood risk. The assumptions and data requirements are broader and coarser. By completing a tiered analysis, the assumptions and data requirements become more refined at a smaller scale. The NACCS Tier 1 assessment incorporates the various components as part of the steps presented in the Framework, including analyzing risk and vulnerability, identifying possible solutions, and developing cost estimates. Results of this analysis for the each state's risk areas and the comparison of management measures is provided in the respective state and District of Columbia chapters of this appendix.

Tier 2 Assessment Results

The Tier 2 analysis evaluates the relative costs associated with management measures included in the three primary strategies: avoid, accommodate, and preserve for coastal storm risk management 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 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.

Tier 3 Assessment

The detailed Tier 3 evaluation would consider combinations of measures for comparison of alternative plans and could incorporate a benefit-cost analysis. Additional characteristics or metrics beyond risk assessment and parametric cost estimates should be explicitly considered at this level of analysis and the best available data should be used. Tier 3 evaluation should also consider other metrics associated with risk, vulnerability, and exposure, including more refined site-specific datasets addressing sensitivity and adaptive capacity. In addition, the evaluation should consider the resilience, including rapid recovery, of critical infrastructure, focusing more protection on infrastructure that is slow to recover (e.g., hospitals) compared to those that rapidly recover (e.g., portions of airports without buildings). Various metrics associated with evaluation of management measures objectives, such as risk reduction (life safety), damage reduction, feasibility, and impacts should also be incorporated.

V. Focus Area Analyses/Visioning Meeting Summary

As part of the efforts for the NACCS, Focus Area Analyses and Visioning Meetings were performed to determine if there is an interest in conducting further study to identify structural, nonstructural, NNBF, and policy/programmatic CSRM strategies and opportunities. Focus Area Analyses Reports are included as an attachment to each respective state and District of Columbia chapter within this appendix.

A series of visioning meetings were held throughout the USACE North Atlantic Division. These meetings were conducted with representatives from Federal, state, and regional entities; NGOs; academia, business, and industry; and local governments. The purpose of these meetings was to continue dialogue with the states and other stakeholders to develop a shared vision for resilience in response to risk and exposure. These meetings reaffirmed that coastal storm risk management is a reality faced by a many stakeholders throughout the study area. A summary of the most prominent common themes identified during the visioning and partnering meetings is included:

- Coastal populations and infrastructure are vulnerable.
- Methods of coastal storm risk management strategies must be redundant, robust, and adaptable to the future uncertainty of coastal flood risk.
- Flooding from storm surge and intense precipitation events/storm water runoff threatens coastal communities.
- Interagency coordination and collaboration are quintessential to progress in making informed decisions.
- Low-lying shorelines, such as inland bays or back bays, are significantly susceptible to flooding.
- A common vision and coastal risk framework are needed to make decisions for future conditions.
- Addressing coastal storm risk is a shared responsibility borne by Federal, state, regional, local and other stakeholders.
- Emphasis on data collection, hazards and impacts prediction, support modeling, and the advancement of information and analyses are needed to provide a complete, holistic picture.

VI. Agency Coordination and Collaboration

A summary of NACCS coordination with State stakeholders, and Federal and NGO activities, projects and grants in response to P.L. 113-2 is provided below. A more detailed discussion of the Federal and NGO efforts as well as state activities, projects and grants is provided in the respective state and District of Columbia chapters within this appendix.

Coordination

As part of the NACCS authorizing language, the NACCS was conducted in coordination with other Federal agencies, and state, local, NGO and tribal officials to ensure consistency with other plans, as appropriate. Extensive collaboration occurred, 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. In addition, several correspondences with state and District of Columbia representatives commencing in mid-2013 requested feedback with respect to the preliminary problem identification, the Post-Sandy landscape, exposure mapping, and problems, needs, and opportunities for future planning initiatives. Each state and the District of Columbia identified problems, needs, opportunities and/or desired next steps for coastal resilience. Agency letters are included as part of each corresponding state chapter in Appendix D. These coorespondences reinforce postings on the NACCS website located at http://www.nad.usace.army.mil/CompStudy.aspx.

Related Activities, Projects and Grants

Specific Federal and NGO efforts applicable to all of the states in the NACCS Study Area that have been prepared in response to P.L. 113-2 are discussed below. Additional information regarding the alignment of interagency plans and strategies is discussed in the respective state and District of Columbia chapters of this appendix.

Federal Efforts

The U.S. National Climate Assessment (U.S. Global Change Research Program, 2014) assesses the science of climate change and its impacts across the United States, at present and throughout this century. It documents climate change related impacts and responses for various sectors and regions, with the goal of better informing public and private decision making at all levels. Observed and projected climate change impacts vary across regions of the United States. For the northeastern U.S., some of the impacts emphasized in the findings state that communities will be affected by heat waves, more extreme precipitation events, and coastal flooding due to relative SLC and storm surge.

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 DOI announced that USFWS and the National Fish and Wildlife Foundation (NFWF) would assist in administering the Hurricane Sandy Coastal Resiliency Competitive Grants Program, which will support projects that reduce communities' vulnerability to the growing risks from coastal storms, relative SLC, 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. The affected states are 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. Additional 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.

In recognition of the size and magnitude of Hurricane Sandy and the rebuilding challenges facing the region, President Obama signed an Executive Order on December 7, 2012 creating the Hurricane Sandy Rebuilding Task Force and designating the Secretary of U.S. Housing and Urban Development (HUD), Shaun Donovan, as Chair (HUD, 2013). More information is available at http://portal.hud.gov/hudportal/HUD?src=/sandyrebuilding. Working in tandem with the elements of the National Disaster Recovery Framework (NDRF), the Hurricane Sandy Rebuilding Task Force focused exclusively on long-term rebuilding and working to remove obstacles to resilient rebuilding while taking into account existing and future risks and promoting the long-term sustainability of communities and ecosystems in the Sandy-affected region.

The Rebuilding Strategy establishes guidelines for the investment of the Federal funds made available for recovery and sets the region on the path to being built back smarter and stronger with several outcomes in mind:

- Aligning this funding with local rebuilding visions.

- Cutting red tape and getting assistance to families, businesses, and communities efficiently and effectively, with maximum accountability.
- Coordinating the efforts of the Federal, state, and local governments and ensuring a region wide approach to rebuilding.
- Ensuring the region is rebuilt in a way that makes it more resilient – that is, better able to withstand future storms and other risks posed by a changing climate.

In addition to the Hurricane Sandy Rebuilding Task Force, HUD has also allocated approximately $10.5 billion for recovery actions to rebuild areas affected by Hurricane Sandy through the Community Development Block Grant Program (CDBG). An additional $2.5 billion has been identified for future allocation upon approval of the amendments to the state and city Disaster Recovery Plans. To be eligible to receive funds, each grantee must conduct a comprehensive risk assessment to address climate change impacts, changes in development patterns and population, and incorporate resilience performance standards identified in the Hurricane Sandy Rebuilding Strategy. Additional information can be found at http://portal.hud.gov/hudportal/HUD?src=/press/press_releases_media_advisories/2013/HUDNo.13-153.

HUD is also leading Rebuild by Design, an initiative following the Hurricane Sandy Rebuilding Task Force. The purpose of the initiative is to consider innovative and implementable solutions to address risk of future climate events (HUD, 2014). By creating a competition, the effort brings together experts from various fields to develop opportunities for resilience and innovation as part of the rebuilding process in areas with extensive impacts from Hurricane Sandy in Connecticut, New Jersey, and New York. Three geographical categories were identified: City, Shore, and Region. Ten projects were selected by HUD Secretary Shaun Donovan to proceed into a design phase. Final designs were shared with Federal and public stakeholders in April 2014, six of which were selected in June 2014. These solutions may be implemented with disaster recovery grants from HUD in addition to other sources of public and private sector funding. Additional information on the initiative and the various designs that were submitted for consideration for the competition is available at http://www.rebuildbydesign.org/.

NOAA is working to complete various data collections activities as part of the P.L. 113-2 funding allocations within the National Ocean Service, National Marine Fisheries Service, and the National Weather Service, including mapping, modeling resilience, and technical assistance (NOAA, 2013). Mapping activities include aerial photogrammetric surveys, hydrographic surveys, integrated ocean and coastal mapping LIDAR (in coordination with U.S. Geological Survey [USGS] and USACE), and fisheries survey conducted in part through the Northeast Regional Ocean Council (NROC) which serves as the regional forum for organizing, tracking, and advancing coastal marine spatial planning activities in New England. The National Weather Service also received funds to improve numerical hurricane forecast systems. Additionally, NOAA's Coastal Impact Assistance Program can provide information to support recovery and planning efforts at regional, state, and community levels. Additional information on the ongoing work can be found at http://oceanservice.noaa.gov/hazards/sandy/.

Coastal Resilience Networks (CRest) is a grant opportunity program which funds projects that help communities become more resilient to the threats posed by coastal hazards (which include storms, flooding, relative SLC, climate change, etc.). Organizations were encouraged to submit projects that will help their communities or region recover from Hurricane Sandy or other storms, as well as increase preparedness and resilience for future hazard events. Projects must fall into one of two focus areas

including hazard resilient communities or resilient communities. Additional information is available at www.csc.noaa.gov/psc/grants/crest.html.

As part of the Natural Resources Conservation Service Emergency Watershed Protection Program, the U.S. Department of Agriculture has acquired floodplain easements for approximately 750 acres in Connecticut (Old Field Creek, West Haven), New York (New Creek/West Branch, Staten Island), and New Jersey (Bay Point). The cost was approximately $19.2 million. The easements are intended to assist victims of Hurricane Sandy and also prevent future damages in flood prone areas. Additionally, not only do the easements reduce future exposure, the floodplain easements represent habitat conservation opportunities as part of natural features for floodplain storage and wave attenuation. Additional information on the easements can be found at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1240996.pdf.

The USGS developed a science plan to support restoration and recovery following Hurricane Sandy to coordinate continuing USGS activities with other agencies and to guide continued data collection and analysis to ensure support for recovery and restoration efforts. The data, information, and analyses that are produced by implementing this plan will: (1) further characterize impacts and changes, (2) guide mitigation and restoration of impacted communities and ecosystems, (3) inform a redevelopment strategy aimed at developing resilient coastal communities and ecosystems, (4) improve preparedness and responsiveness to the next hurricane or similar coastal disaster, and (5) enable improved hazard assessment, response, and recovery for future storms along the hurricane prone shoreline of the United States. Additional information is available at http://pubs.usgs.gov/circ/1390/.

On February 4, 2013, the U.S Department of Transportation (DOT) Federal Transit Administration (FTA) announced the availability of $2 billion in emergency aid funds to transit agencies affected by Hurricane Sandy, through its new Emergency Relief Program. In the New York City metropolitan area, approximately $886 million was allocated to the New York Metropolitan Transportation Authority to rebuild and replace equipment and facilities damaged by Hurricane Sandy storm surge. Additional information on the projects is available at http://www.dot.gov/briefing-room/us-department-transportation-awards-886-million-new-york-mta-ongoing-hurricane-sandy. The projects are being implemented with resilient features so that the infrastructure will not need to be replaced when the next storm occurs.

Other Federal projects and efforts conducted within the agencies' mission areas in response to Hurricane Sandy not associated with P.L. 113-2 are discussed below.

FEMA distributes public assistance funding to states and counties within various categories, including debris removal, protective measures, public buildings, public utilities, recreational, roads and bridges, state management, and water control facilities. Detailed distribution of funding within each category can be found at http://www.recovery.gov/Sandy/whereisthemoneygoing/Pages/DisasterReliefPrograms.aspx.

USACE is working with several partners including NOAA, FEMA, The Nature Conservancy (TNC), The Conservation Fund, and academic institutions such as University of Rhode Island, Virginia Institute of Marine Sciences, and the University of New Orleans, to institute the Systems Approach to Geomorphic Engineering (SAGE) Program. The goals of this program are to pursue and advance a large-scale comprehensive view of coastal landscape change and use integrated methods for coastal landscape transformation to slow/prevent/minimize mitigate impacts to coastal communities and shorelines through an innovative approach to coastal landscape resilience. Barnegat Bay in New Jersey is one of four SAGE demonstration pilot projects. The next steps for the SAGE Program are to establish regional

communities of practice within each of the demonstration pilots, identify areas of need within the demonstration sites, and determine potential solutions for the areas of need within each of the demonstration sites.

The National Academy of Sciences have developed a report titled 'Reducing Coastal Risks on the East and Gulf Coasts' (July 2014) which offers recommendations given the challenges in managing U.S. coastal risk given the effects of climate change and increasing costs of coastal disasters. The report recommends that a strategic national vision for reducing risk is needed, as well as the development of a national coastal risk assessment. The report also states that stronger incentives should be developed to improve pre-disaster planning and mitigation efforts at the local level.

Non-Governmental Organization Efforts

The Rockefeller Foundation launched the 100 Resilient Cities Centennial Challenge to enable 100 cities to better address the increasing shocks and stresses of the 21st century. Out of the nearly 400 cities across six continents that have applied, 100 of the world's cities will be selected to receive technical support and resources for developing and implementing plans for urban resilience over the next three years. New York City, which is within the NACCS Focus Area for New York – New Jersey Harbor and Tributaries, applied for consideration to address their challenges of recurrent coastal flooding and relative SLC. The first class of cities was announced on December 3, 2013, selected by seven judges who offer unique expertise on resources and strategies that make a city better prepared to face natural and manmade disaster and New York City was one of them. Each of the selected 100 cities will work with The Rockefeller Foundation's partners to develop and implement a resilience plan and become an integrated member of the 100 Resilient Cities Network.

Structures of Coastal Resilience (SCR) is a Rockefeller Foundation-supported project dedicated to studying and proposing resilient designs for urban coastal environments in the North Atlantic region. Four design teams from Princeton University, Harvard University, the City College of New York, and University of Pennsylvania are developing both general strategies and features for coastal protection and site-specific design in the following study regions: Narragansett Bay, RI; Jamaica Bay, NY; Atlantic City, NJ; and Norfolk, VA.

TNC is working to demonstrate the role of natural infrastructure in reducing risks to people and property in the wake of Hurricane Sandy (Mathison, 2012). TNC has identified the "Hurricane Sandy Disaster Recovery Principles" (TNC, 2013) which emphasize the importance of utilizing natural infrastructure as an effective long-term solution to make people, infrastructure, and natural systems less vulnerable and valuing and protecting natural systems as a critical component of infrastructure. TNC has also developed the Coastal Resilience 2.0 Tool (available at www.coastalresilience.org), which, originally created for Long Island, New York City, and Connecticut, helps decision makers examine the social, ecological, and economic vulnerabilities from current and future risks from storm surge and relative SLC scenarios. Users can interactively identify where marshes may have the highest potential to reduce risks to people and property so they can focus conservation and restoration based on their own priorities. TNC is involved with projects considering natural infrastructure at Howard Beach, Queens, NY, as well as three localities in southern New Jersey (Jarvis Sound/Cape May, Great Bay/Mullica River, and Gandy's Beach/Money Island) through funding associated with the NFWF/US DOI Hurricane Sandy Coastal Resiliency Competitive Grants Program.

The Risk Finder is a public SLC and coastal flood risk website that provides local projections, maps, and assessments of exposure to relative SLC and coastal flooding that will eventually be tabulated for

all coastal states in the United States. As of March, 2014, the website has been launched for Connecticut, Massachusetts, New Hampshire, New Jersey, and New York. Exposure assessments cover over 100 demographic, economic, infrastructure, and environmental variables using data drawn mainly from Federal sources, including NOAA, USGS, FEMA, DOT, the U.S. Department of Energy (DOE), DOI, EPA, U.S. Federal Communications Commission (FCC), and the U.S. Census Bureau. Additional information can be found at http://sealevel.climatecentral.org.

The Mid-Atlantic Coastal Resiliency Institute is a new partnership of scientists and federal officials from Delaware to Virginia that will investigate regional sea-level change trends and how best to prepare for the impacts, including shoreline loss and increased flooding from storms. Partners of the Institute include the University of Delaware, NASA's Goddard Space Flight Center – Greenbelt Campus, Wallops Flight Facility and the Goddard Institute of Space Science; U.S. Fish and Wildlife Service; U.S. Geologic Survey; Chincoteague Bay Field Station of the Marine Science Consortium (which includes 13 Pennsylvania Colleges); College of William and Mary, Virginia Institute of Marine Science; University of Virginia, Virginia Coast Reserve Long-Term Ecological Research Program; University of Maryland, College Park; and The Nature Conservancy.

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