ECONOMICS
APPENDIX

NEW JERSEY BACK BAYS
COASTAL STORM RISK MANAGEMENT
FEASIBILITY STUDY

PHILADELPHIA, PENNSYLVANIA

APPENDIX C

March 2019

NJBB
NEW JERSEY BACK BAYS STUDY

U.S. Army Corps of Engineers
Philadelphia District

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C-1) INTRODUCTION

This appendix presents the economics methodology, assumptions, and resulting analysis for managing coastal storm risk within the New Jersey Back Bays system. This report will detail each step of the analytical process and describe relevant inputs and results for each region of the study area. The assessment is conducted at a Feasibility level and covers 950 square miles within New Jersey.

Spanning over five counties, the study area captures approximately 183,000 structures with over $90 billion in damageable assets, critical infrastructure, utilities, and other benefit categories. The study area is delineated into the possible maximum study area extent and the 0.2% Annual Chance Exceedance (ACE) Event Floodplain for FY2080 with Intermediate Relative Sea Level Change.

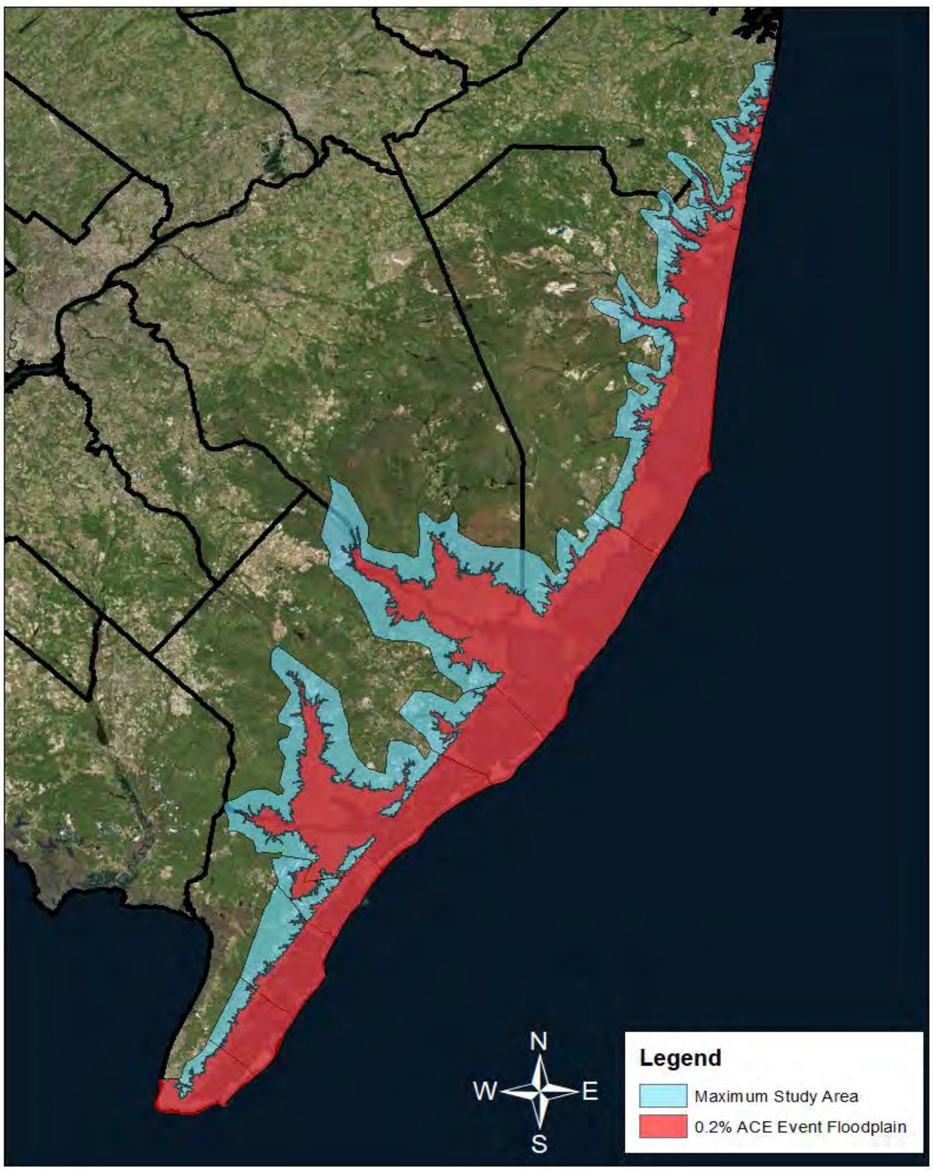

Figure 1: New Jersey Back Bays – Study Area Extent

C-2) HEC-FDA MODEL SOFTWARE DESCRIPTION

The Hydrologic Engineering Center – Flood Damage Reduction Analysis (HEC-FDA) software version 1.4.2 is used to model Future Without-Project Conditions and a variety of scenarios for Future With-Project Conditions.

HEC-FDA ver. 1.4.2 provides integrated hydrologic engineering and economic risk analysis during the formulation and evaluation of flood damage reduction plans in compliance with policy regulations ER 1105-2-100 *Planning Guidance Notebook* and ER 1105-2-101 *Risk Analysis for Flood Damage Reduction Studies*. Uncertainty in discharge-exceedance probability, stage-discharge, and damage-stage functions are quantified and incorporated into economic and engineering performance analyses of alternatives. The process applies Monte Carlo simulation, a numerical-analysis procedure that computes the expected value of damage while explicitly accounting for uncertainty in the basic parameters used to determine flood inundation damage.

Data on historic storms, water surface profiles, depth-percent damage functions, and residential, commercial, and public structures within the study area will be used as input for the HEC-FDA software. In conjunction with Hydrologic modeling, HEC-FDA will also incorporate Historic (Low), Intermediate, and High Relative Sea Level Change (RSLC) analysis in compliance with ER 1100-2-8162 *Incorporating Sea Level Change in Civil Works Programs* and ER 1110-2-1619 *Risk-Based Analysis for Flood Damage Reduction Studies.*

Future Without Project Conditions are used as the base condition over the 50-year period of analysis and are compared against potential alternatives to determine potential with-project National Economic Development (NED) benefits. The model will use the FY2018 Project Evaluation and Formulation Rate (Discount Rate) of 2.75%.

Model Elements

HEC-FDA requires a significant amount of data to properly project damages over a 50 year period of analysis. These data are acquired or created from a variety of different sources and are used to create the potential damage pool (structure inventory) and integrate that inventory with a range of potential storm events to calculate Average Annual Damages for each individual structure for each With- and Without-Project Condition scenario.

C-3) STRUCTURE INVENTORY DEVELOPMENT

This section will cover the creation of the structure inventory and describe the final hydrologic engineering inputs for HEC-FDA known as Water Surface Profiles (more detail can be found in the Engineering Appendix).

Structure Identification and Valuation

The structure inventory for the study area was created using materials supplied by the New Jersey Department of Environmental Protection (NJDEP), New Jersey Department of Transportation (NJDOT), New Jersey Geographic Information Network (NJGIN), and the Tax Assessor's Office for each of the five New Jersey counties included in the study.

Development of the structure inventory involves surveying existing floodplain structures to collect the data necessary to determine expected coastal storm damages. The purpose for collecting this information is to determine what structures are located in the floodplain, the depreciated replacement value of the structures and their associated contents, and the zero-damage elevation at which they are initially susceptible to flooding.

County tax parcel and assessment records provide the basis for Depreciated Replacement Value (DRV) in compliance with EM 1110-2-1619 *Risk Based Analysis for Flood Damage Reduction Studies*. Specifically, tax assessor records offer information on structure location (Northing & Easting Coordinates), structure address and municipality, category type, occupancy type, parcel ID number, and county tax assessment value.

Only structures within the 0.2% Annual Chance Exceedance Event (500YR) floodplain are included in the HEC-FDA model inventory as structures with ground elevations above that threshold experience damages so infrequently that their exclusion does not affect the calculated Average Annual Damages for the study area.

Figure 2 shows the tax parcel overlay for the area directly around Manasquan Inlet. This includes a partial view of Point Pleasant Borough and Point Pleasant Beach Borough in Ocean County and Brielle Borough and Manasquan Borough in Monmouth County. The tax parcel overlay with associated tax record values are not yet clipped to the 0.2% ACE Event floodplain.

Figure 3 shows the same area with the FY2080 0.2% ACE Event floodplain with Intermediate Relative Sea Level Change (RSLC) shaded in blue. This shaded area is the model extent of the economic analysis.

Figure 4 shows the inventory after the tax parcel polygons are converted to a singular data point, or centroid, and then clipped to the 0.2% ACE event floodplain. The markers shown have GPS coordinates, tax assessor values, and information on structure use and design. This same process was completed for all 950 square miles of study area to build the foundation of the structure inventory.

Figure 2: Manasquan Inlet Example – Tax Parcel Overlay

Figure 3: Manasquan Inlet Example – 0.2% Annual Chance Exceedance (ACE) Event Floodplain

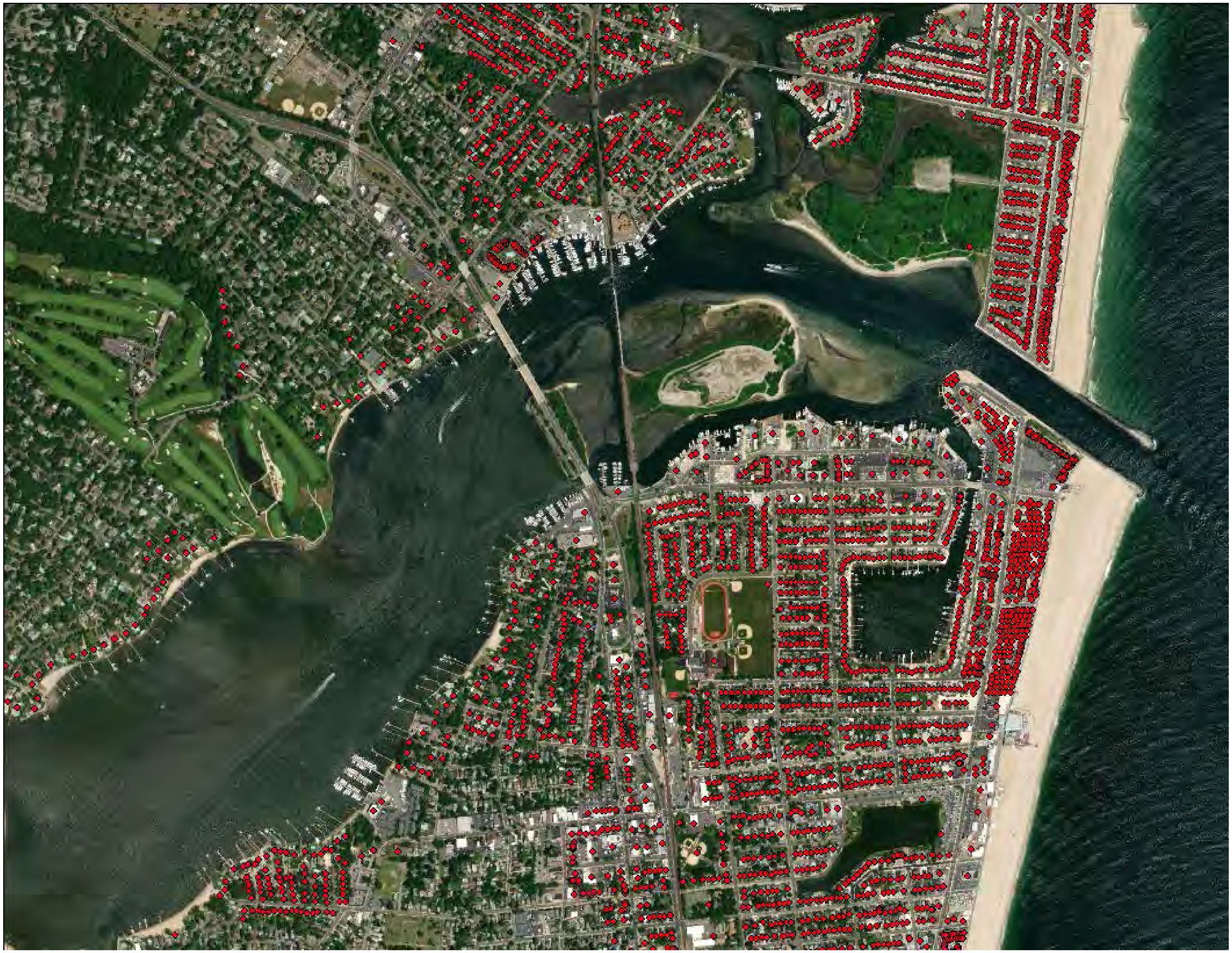

Figure 4: Manasquan Inlet Example – Structure Inventory

In total, structures are located in 84 separate municipalities across five counties. Table 1 shows the 25 municipalities with the largest volume of structures within the study area and a summary row detailing the structure category breakdown for all 182,930 structures in all 84 municipalities.

Table 1: Structure Count by Category Type by Municipality

Municipality	TOTAL	RES	COM	PUB	IND	HIGH	% TOTAL
Ocean City	17882	17192	573	115	1	1	9.78%
Toms River	13689	13332	262	83	12	0	7.48%
Brick	9772	9519	160	92	1	0	5.34%
Long Beach	8217	8036	151	30	0	0	4.49%
Atlantic City	7782	6098	1136	476	9	63	4.25%
Sea Isle City	6330	6146	143	41	0	0	3.46%
Brigantine	6285	6095	120	60	0	10	3.44%
North Wildwood	5681	5441	198	40	0	2	3.11%
Margate City	5510	5350	119	41	0	0	3.01%
Avalon	5304	5153	121	30	0	0	2.90%
Wildwood Crest	5098	4930	124	30	0	14	2.79%
Little Egg Harbor	4964	4871	51	42	0	0	2.71%
Stafford	4864	4801	36	27	0	0	2.66%
Point Pleasant	4818	4586	197	35	0	0	2.63%
Lacey	4772	4673	58	40	1	0	2.61%
Ventnor	4574	4392	135	41	1	5	2.50%
Berkeley	4374	4290	48	35	1	0	2.39%
Cape May	3788	3480	240	63	0	5	2.07%
Stone Harbor	3114	2878	192	44	0	0	1.70%
Wildwood	3078	2534	478	57	5	4	1.68%
Pt Pleasant Beach	2869	2627	214	28	0	0	1.57%
Lavallette	2551	2480	53	18	0	0	1.39%
Beach Haven	2384	2251	107	26	0	0	1.30%
Surf City	2248	2131	94	23	0	0	1.23%
Belmar	2169	2041	98	30	0	0	1.19%
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Remaining	40813	38518	1683	572	34	6	22.31%
TOTAL	**182930**	**173845**	**6791**	**2119**	**65**	**110**	**100.00%**
PERCENT TOTAL	**-**	**95.03%**	**3.71%**	**1.16%**	**0.04%**	**0.06%**	**100.00%**

Residential structures comprise the overwhelming majority of structure in the study area with over 95% of total inventory by volume. Non high-rise commercial or public structures comprise most of the remaining 5% of structures by volume. For this study, structures with six or more floors are considered high-rises and are separated into their own category due to their unique damage mechanisms.

Tax assessor structure values, noted as *Improvement Value*, provide a base for determining depreciated replacement value of structures, but need to be adjusted to account for deviations between assessed value and replacement value while also accounting for discrepancy between the date of the assessment and the date of the study. Further information on this technique can be found in EM 1110-2-1619 *Risk Based Analysis for Flood Damage Reduction Studies.*

For this study, the value adjustment is completed by developing a stratified random sample of structures and independently estimating their depreciated replacement value using Marshall & Swift Residential Estimator 7 and then comparing the stated tax assessor value against M&S depreciated replacement value. Assuming the stratified random sample is representative of the entire population, the average percent difference between the two values can then be applied to the entire inventory of structures to adjust the individual assessor value for each structure to a unique depreciated replacement value.

Figure 5 provides the M&S Standard Report output for a structure in Cape May City. Random structures were selected both along the barrier islands and on the mainland.

Standard Report

Estimate ID:	CapeMay_140
Property Owner:	[redacted]
Address:	
City:	Cape May
State/Province:	New Jersey
ZIP/Postal Code:	08204
Surveyed By:	[redacted]
Survey Date:	

Single-family Residence		Floor Area:	4,000 Square Feet
Effective Age:	10	Quality:	3 Average
Cost as of:	March, 2017	Condition:	3 Average
Style:	2 1/2 Story Finished		
Exterior Wall:	Frame, Hardboard Sheets 100%		
Plumbing Fixtures:	11		

	Units	Cost	Total
Base Cost	4,000	66.46	265,840
Plumbing Fixtures	11	1,822.40	20,046
Wood Shingle	4,000	2.97	11,880
Raised Subfloor	4,000	11.39	45,560
Floor Cover Allowance	4,000	5.27	21,080
Forced Air Furnace	4,000	4.92	19,680
Plumbing Rough-ins	1	737.00	737
Appliance Allowance	1	4,355.00	4,355
Basic Structure Total Cost	4,000	97.29	389,178
Replacement Cost New	4,000	97.29	389,178
Physical + Functional Depreciation 9.0%			35,025
Total Depreciated Cost			354,153
Total			$354,153

Cost data by Marshall & Swift/Boeckh, LLC and its licensors.

Figure 5: Marshall & Swift Residential Estimator 7 – Standard Report

Content values are established using a Content-to-Structure Value Ratio (CSVR) with the implicit assumption that the content values of a structure are directly related to the value of the structure itself. The exact CSVR utilized is determined by the category type of the structure and are pulled from EM 1110-2-1619 *Risk-Based Analysis for Flood Damage Reduction Studies*.

Table 2 shows the Structure and Content value for each County isolated by category type.

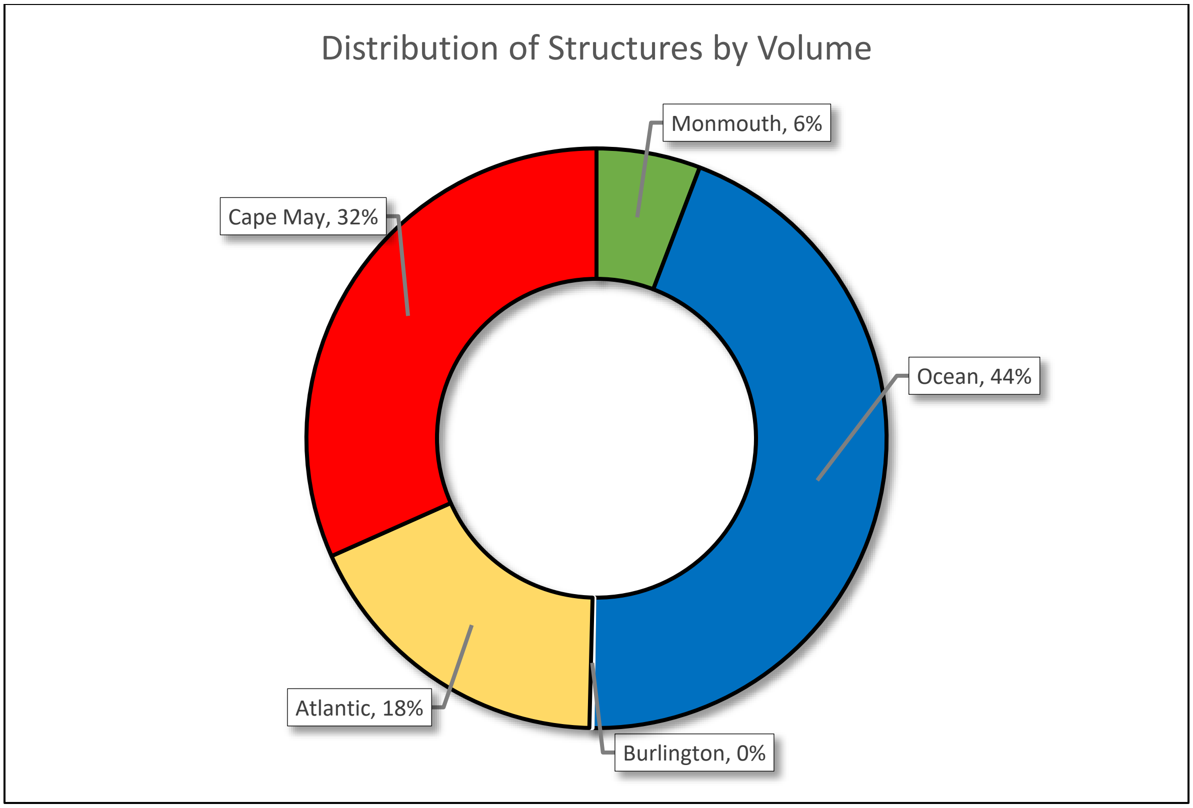
Table 2: Total Structure and Content Value by County by Category Type ($1000s)

County	Count	TOTAL	RES	COM	PUB	IND	HIGH
Monmouth	10598	$4,357,499	$3,932,765	$228,731	$179,399	$16,604	$0
Ocean	81262	$25,034,179	$23,030,635	$1,514,747	$475,772	$13,025	$0
Burlington	322	$99,498	$63,088	$31,755	$4,655	$0	$0
Atlantic	32825	$20,842,858	$9,405,230	$2,712,856	$3,724,643	$16,936	$4,983,192
Cape May	57923	$21,890,206	$19,168,233	$1,761,709	$773,244	$39,455	$147,565
TOTAL	**182930**	**$72,224,240**	**$55,599,951**	**$6,249,799**	**$5,157,714**	**$86,020**	**$5,130,757**
AVERAGE	**-**	**$394**	**$319**	**$920**	**$2,434**	**$1,323**	**$46,643**

Residential properties, with 95% of structures by volume, still contribute the majority of structure and content value with 77% of total value, but have the lowest average structure and content value of the five categories. High-rise structures, particularly the high value structures in Atlantic City, have the highest average structure and content value and contribute over 7% of total value though only representing .06% of structures by volume.

Figure 6 on the following page shows a comparison between the structure volume by County and the structure value by County. Atlantic County has the largest divergence between structure volume and structure value with 18% of structures contributing 29% of total value. This discrepancy is directly correlated with the presence of high value structures on Absecon Island, primarily Atlantic City.

Together, Atlantic County and Ocean County contribute 62% of total structures by volume with 64% of total structure and content value.



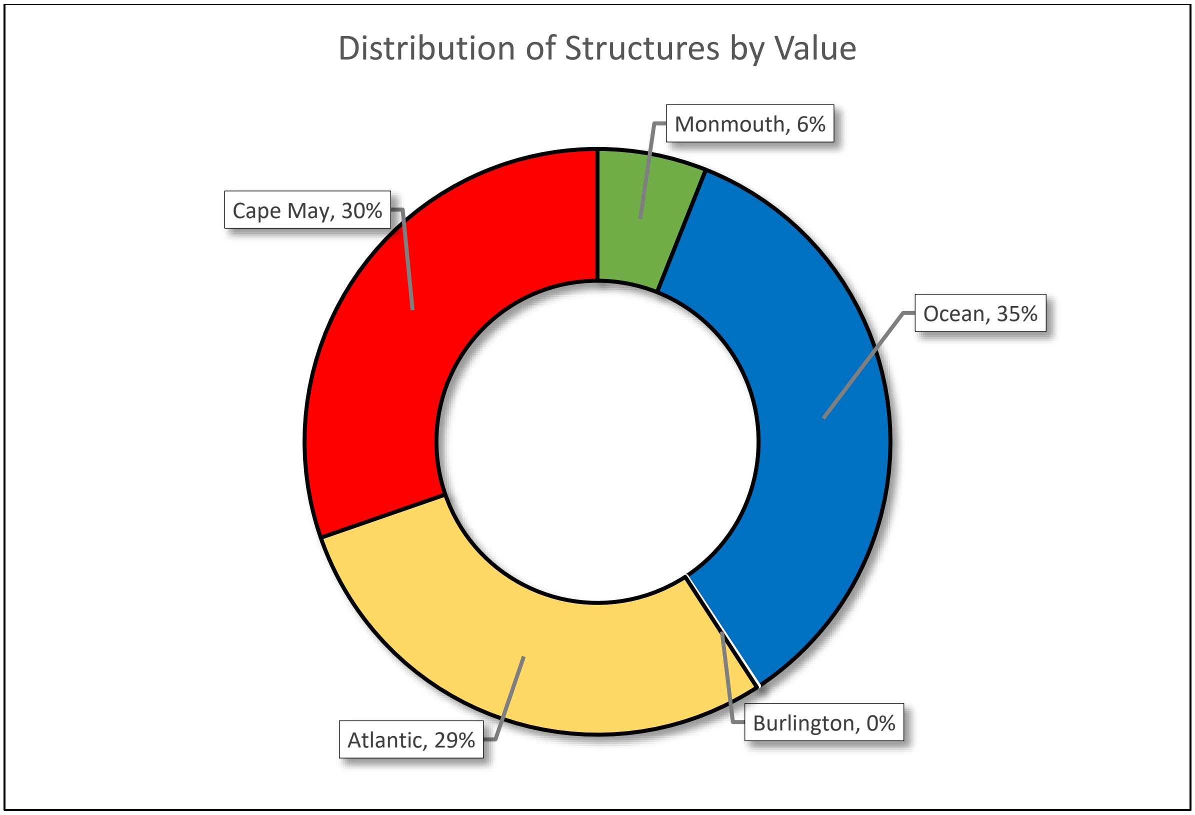


Figure 6: Structure Volume and Depreciated Replacement Value by County

While HEC-FDA does have the capacity for other damageable asset inputs, the remaining benefit categories at this point of the study were calculated outside of the model due to limitations in available valuation data and Depth-Percent Damage Curves. These benefit categories include Vehicle Damages, Critical Infrastructure, Transportation Delays costs, and Emergency costs. Currently, these benefit categories are calculated as percentages of the HEC-FDA derived values though eventually these benefit types will be estimated as HEC-FDA outputs or using reliable historic damage data.

Other benefit categories such as Recreation benefits or Income Loss prevention are not quantified nor included in the final NED benefit numbers.

Life Loss or Persons at Risk (PAR) are not considered NED benefits and are not yet quantified in this study, but will be calculated for the final Recommended Plan.

Structure First Floor Elevation

First Floor Elevation (FFE) is the addition of Ground Elevation and Foundation Height to measure the absolute elevation of the main floor of the structure. For this study, all structures in the inventory are assumed to have a pile foundation without basements and a damage point of zero. In other terms, HEC-FDA only begins to quantify damages at that individual structure when the flood stage height reaches the main flood elevation.

Ground Elevation is the height of the land at the inventory marker location; typically at the central point of the structure. Ground Elevation is calculated at a population level with the availability of a National Oceanic and Atmospheric Administration (NOAA) Digital Coast Bare Earth Light Detection and Ranging (LiDAR)-derived Digital Elevation Model (DEM). As the LiDAR-derived DEM is available for the entire study area, each individual structure is provided a unique, calculated Ground Elevation with a high degree of certainty.

Figure 7 on the following page shows an example Digital Elevation Model for a section of Atlantic City in Atlantic County. The areas shaded in red have the lowest elevation with areas shaded in green or blue having the highest. The structure inventory is overlaid as red markers. Each structure Ground Elevation is calculated at the intersection of their marker and the underlying Digital Elevation Model. This process is repeated for all 182,930 structures.

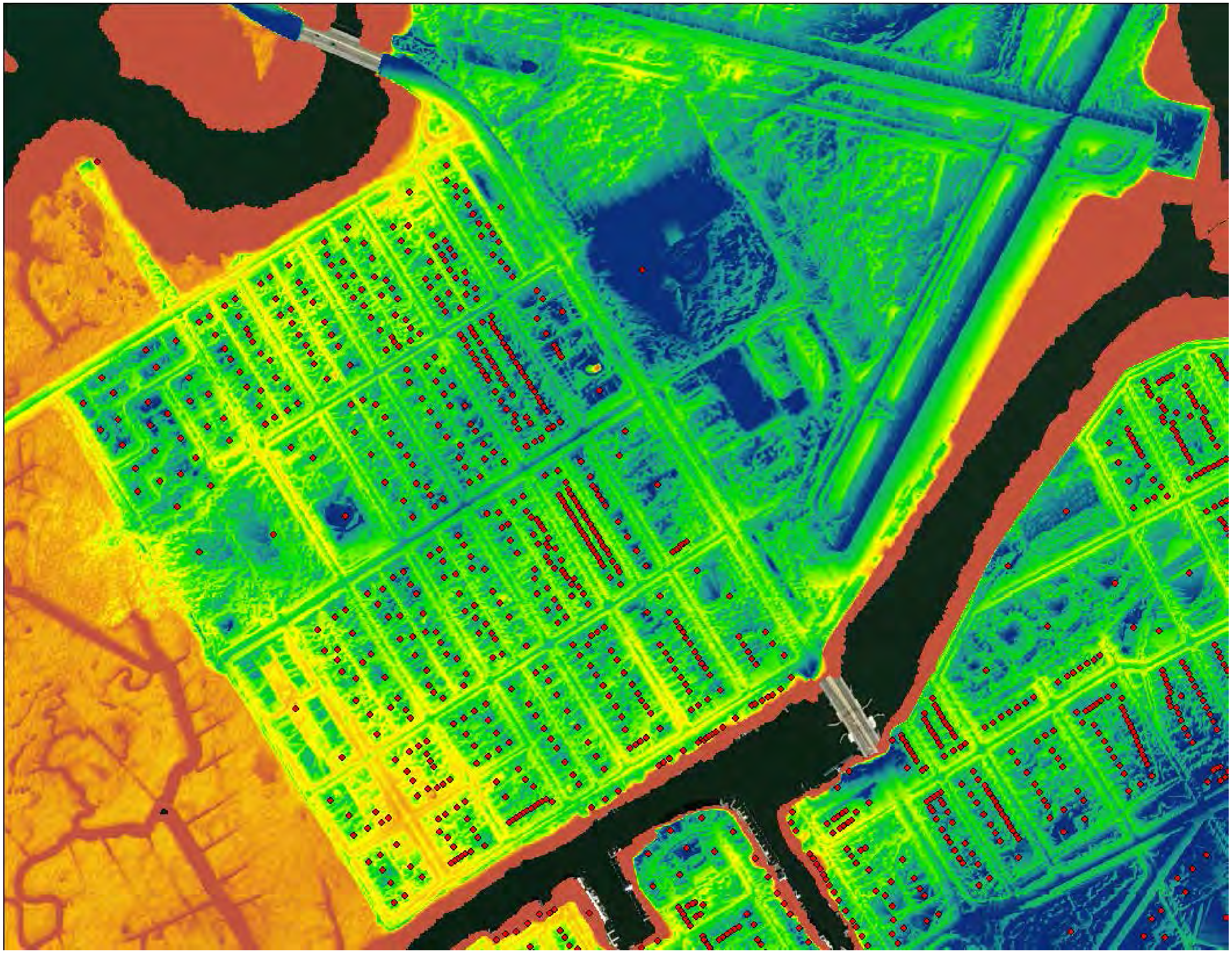


Figure 7: LiDAR-derived Digital Elevation Model – Atlantic City Example

Foundation Height is more difficult to attribute to every structure. While techniques such as field surveys or mobile LiDAR can theoretically calculate Foundation Height for every structure with a high degree of certainty, the size of the inventory makes these methods prohibitively time and resource consuming. To individually measure all 182,930 structures would require years of intense resource allocation. Additionally, population level data such as New Jersey tax records do not offer a measurement for Foundation Height nor can available aerial imagery provide insight on main floor height above Ground Elevation.

To calculate the First Floor Elevation for structures within the model inventory, a stratified random sample is collected of structures within each occupancy type, from both the barrier islands and mainland, to assign a typical foundation height per structure type. The average foundation height for a given occupancy type is then added to the structure's unique Ground Elevation to calculate final FFE.

Foundation Height samples were collected using Google Earth Pro street view for 2,430 structures, or 1.3% of the total inventory. Table 3 provides the assigned Foundation Height results of that effort.

Table 3: Foundation Height by Occupancy Type

CATEGORY	OCCUPANCY	FOUNDATION
RES	Single Family Residential One Story (SFR1) Single Family Residential Multi Story (SFRM) Apartment Complex	1.5ft 2.5ft 0.5ft
COM	Commercial	0.5ft
PUB	Public	0.5ft
IND	Industrial	0.5ft
HIGH	High-Rise	0.5ft

Non single family residential structures were predominantly constructed at grade to comply with Americans with Disabilities Act (ADA) requirements or due to limitations in elevating structures of certain sizes or uses. To account for some non-single family residential structures having elevated foundations, a Foundation Height of 0.5ft is applied across the population in lieu of 0.0ft.

For single family residential structures, buildings with multi stories were more likely to have elevations at least 2ft above ground level while structures with only one story were typically at grade or elevated only 1ft above ground level. Foundation Heights of 1.5ft and 2.5ft for SFR1 and SFRM occupancy types were assigned, respectively.

The final piece for assigning the First Floor Elevation of residential structures is to estimate the probability of structures already elevated outside the 1% Annual Chance Exceedance (ACE) event floodplain, or the 100YR event. Especially along the barrier islands, many residential structures are elevated 7ft-10ft above ground to prevent inundation from high to moderate frequency storm events.

From the same 2,430 structure sample, 1,630 structures were sampled from the barrier islands while 400 were sampled from the mainland and a further 400 were sampled from "finger canal" communities along the mainland such as Mystic Islands or Beach Haven West. Figure 8 provides aerial imagery of an example finger canal community.

Figure 8: Finger Canal Community Example – Beach Haven West (Stafford Township)

As shown in Figure 8, these communities are unique along the mainland due to the presence of inland canals adjacent to almost all structures within the society. A result of this type of community planning is that the structure types and probabilities are more closely related to communities along the barrier island than closer communities on the mainland.

From the Foundation Height sample, structures on the barrier islands or within finger canal communities had an approximate 33% probability of being elevated outside the 1% ACE event floodplain while mainland communities experienced only a 5% probability of elevation above the 1% ACE event floodplain.

To account for this probability, one third of all structures located on the barrier islands or in finger canal communities were elevated to 13ft NAVD88 within the HEC-FDA model inventory to prevent these structures from experiencing damage from any high or moderate frequency storm event. Similarly, one twentieth of all structures on the mainland were raised to 13ft NAVD88 within the inventory. The structures designated as "elevated" were selected based on a true random method within their respective community types.

For modeling purposes, the maximum FFE allowed in the inventory is 40ft NAVD88. At this stage, damages are impossible for any storm event.

While this method of assigning average foundation height by occupancy type and selecting a certain volume of residential structures as “elevated” provides a reasonable accuracy for estimating First Floor Elevation across a large population, it does not allow for knowing the true FFE for each individual structure within the inventory; only the assigned FFE for a typical structure of a given occupancy type at that location.

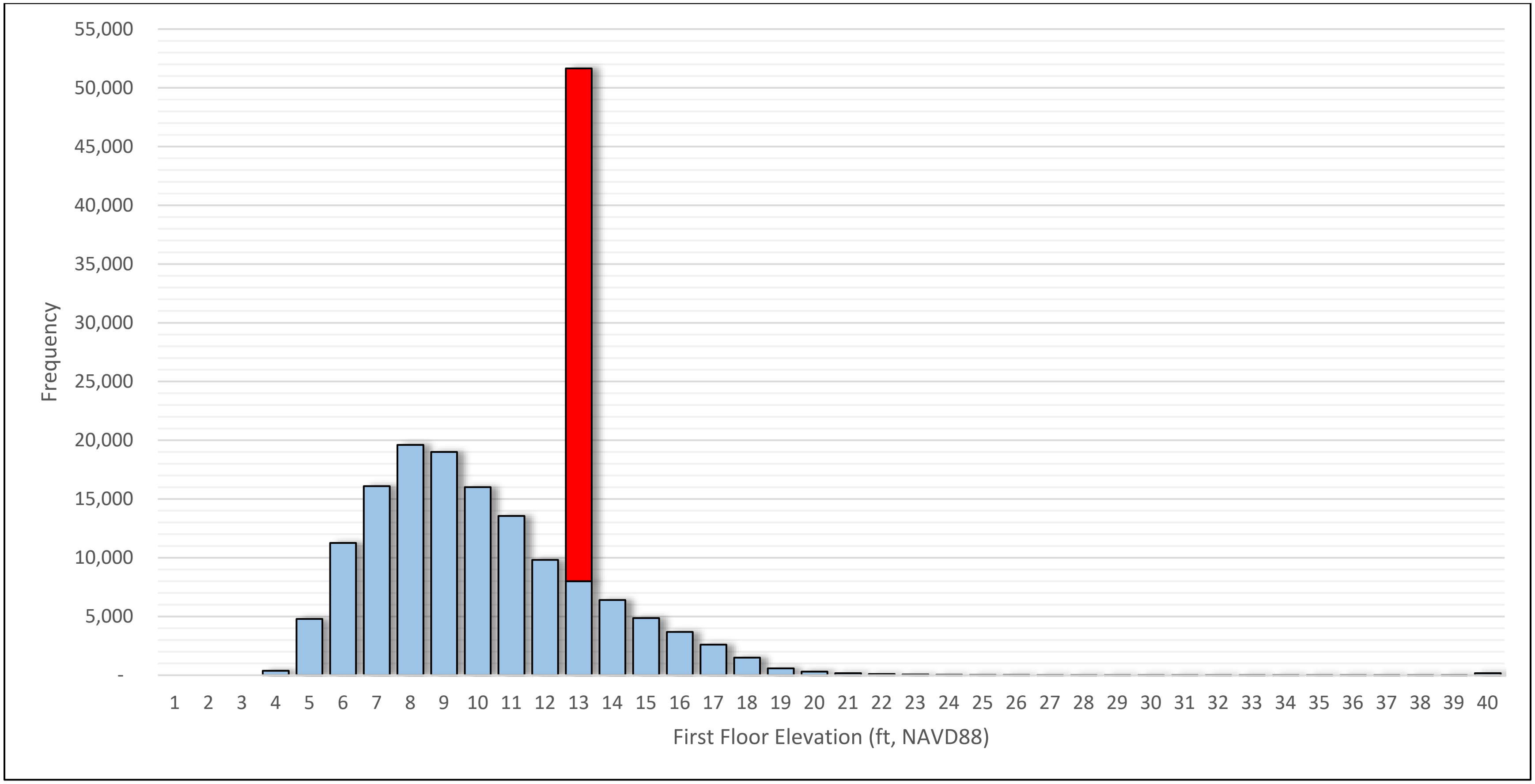


Figure 9: First Floor Elevation Distribution

As shown in Figure 9 above, the First Floor Elevation assignment follows a normal distribution with a slight right-tailed skew. The outlier at 13ft NAVD88 is due to the “elevation” assignment methodology discussed earlier with the randomly assigned structures shaded in red.

Depth-Percent Damage Functions

Damage functions are user-defined curves applied within the model to determine the extent of storm-induced damages attributable to inundation. Depth-percent damage curves are created for both structures and contents and for all structure occupancy types.

Damage is determined as a percentage of overall structure or content value using a triangle distribution of values: Minimum, Most Likely (ML), and Maximum. For inundation, damage is determined by the storm-surge heights in excess of the first floor elevation. While depth-percent damage curves provide the option for quantifying damages at thresholds below the First Floor Elevation, the beginning damage point for all occupancy types is set to 0ft.

The depth-percent damage functions utilized in this study (Table 4) are developed by the North Atlantic Coast Comprehensive Study (NACCS) - Resilient Adaptation to Increasing Risk: Physical Depth Damage Function Summary Report. Due to the limited availability of damage curves as well as the similarity in foundation height, foundation type, and risk levels, the same depth-percent damage function is repurposed for commercial, public, and industrial structures.

Table 4: Depth-Percent Damage Functions by Structure Occupancy Type

Single Family Residential One Story (SFR1)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-1.0	0	0	0	0	0	0
-0.5	0	0	5	0	0	0
0.0	0	1	10	0	0	5
0.5	6	10	20	5	20	30
1.0	10	18	30	18	40	60
2.0	16	28	40	34	60	84
3.0	20	33	45	60	80	100
5.0	30	42	60	80	90	100
7.0	42	55	94	100	100	100
10.0	55	65	100	100	100	100

Single Family Residential Multi Story (SFRM)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-2.0	0	0	0	0	0	0
-1.0	0	0	2	0	0	0
-0.5	0	1	3	0	0	3
0.0	0	5	8	0	5	8
0.5	5	10	10	5	12	20
1.0	9	15	20	15	25	30
2.0	15	20	25	25	35	40
3.0	20	25	30	32	45	60
5.0	25	30	40	40	55	80
7.0	40	50	55	50	70	100
10.0	50	60	70	60	80	100

Commercial (COM) / Public (PUB) / Industrial (IND)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-1.0	0	0	0	0	0	0
-0.5	0	0	0	0	0	0
0.0	0	5	9	0	5	8
0.5	5	10	17	5	18	28
1.0	12	20	27	17	35	50
2.0	18	30	36	28	39	58
3.0	28	35	43	37	43	65
5.0	33	40	48	43	47	65
7.0	43	53	60	50	70	90
10.0	48	58	69	50	75	90

Apartment Complex (APT)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-1.0	0	0	0	0	0	0
-0.5	0	0	0	0	0	0
0.0	0	5	8	1	2	8
0.5	5	8	12	5	10	15
1.0	7	20	25	8	15	20
2.0	10	28	29	15	20	25
3.0	18	28	30	20	25	30
5.0	20	38	44	25	30	32
7.0	35	46	50	30	35	40
10.0	35	50	60	37	45	50

High-Rise (HIGH)

Stage	Structure			Contents		
	Min	ML	Max	Min	ML	Max
-8.0	0	0	0	0	0	0
-5.0	0.5	6.5	10	0	0.25	0.5
-3.0	1.75	9	12.5	0	0.25	1.25
-1.0	3.5	13	16	0	0.5	2.5
-0.5	3.5	13.25	17.75	0	1.5	3.5
0.0	5.5	13.75	18.5	0	4	5
0.5	6.75	14.25	19.25	1.5	5	6
1.0	8	15.5	20	2.6	5	8
2.0	8.75	17.5	22.5	4	7	11
3.0	9.5	19	24	5.5	7.5	13.5
5.0	10.25	21.5	25	6.5	10	16
7.0	11.15	22.5	25.5	8	11	20
10.0	12.5	23.5	26.5	9	12	20

Reach Delineation

Damage reaches are specific geographical areas within a floodplain. They are used to define consistent data for plan evaluations and to aggregate structure and other potential flood inundation damage information by stage of flooding. Reaches are drawn according to hydrologic or municipal boundaries and can be aggregated as necessary to present damages by municipality, proposed alternative, or any other required grouping.

Due to the size of the study area extent and the variability in water conditions as well as the presence of 83 municipal boundaries, the study area is divided into 226 unique, independent reaches. All 182,930 structures fall into exactly one reach.

Figure 10 shows the reach delineation breakdown for the entire study area.

Figure 10: HEC-FDA Reaches – Study Wide

Figure 11 on the following page provides a close-up example at Wildwood Island and West Wildwood Island. From the 15,593 structures (Figure 12) across seven reaches, damages can be presented for each individual reach, each municipality, the entire island, or as part of a regional or study wide alternative.

Figure 11: HEC-FDA Reaches – Wildwood Island and West Wildwood Island – Boundary

Figure 12: HEC-FDA Reaches – Wildwood Island and West Wildwood Island – Inventory

Water Surface Profiles

Each damage reach has a single Water Surface Profile (WSP). A Water Surface Profile is the water surface stage at that location associated with thirteen separate flood events. While a reach may not have more than one associated WSP, several reaches may have the same WSP if they share similar hydrologic conditions but are divided due to political boundaries.

Water Surface Profiles are developed for the Without-Project Condition for the Base Year and Future Year, with each Relative Sea Level Change (RSLC) scenario (Low, Intermediate, High), for all 226 reaches as well as for each With-Project Condition for the Base year and Future Year, with each RSLC scenario, for all 226 reaches. Detailed information on the development and application of Water Surface Profiles for all HEC-FDA scenarios and reaches can be found in the Engineering Appendix.

Figure 12 shows an example Water Surface Profile for North Wildwood City on the northeast corner of Wildwood Island (Reach 26) for the Without-Project Condition scenario with Intermediate RLSC in the Base Year (FY2030).

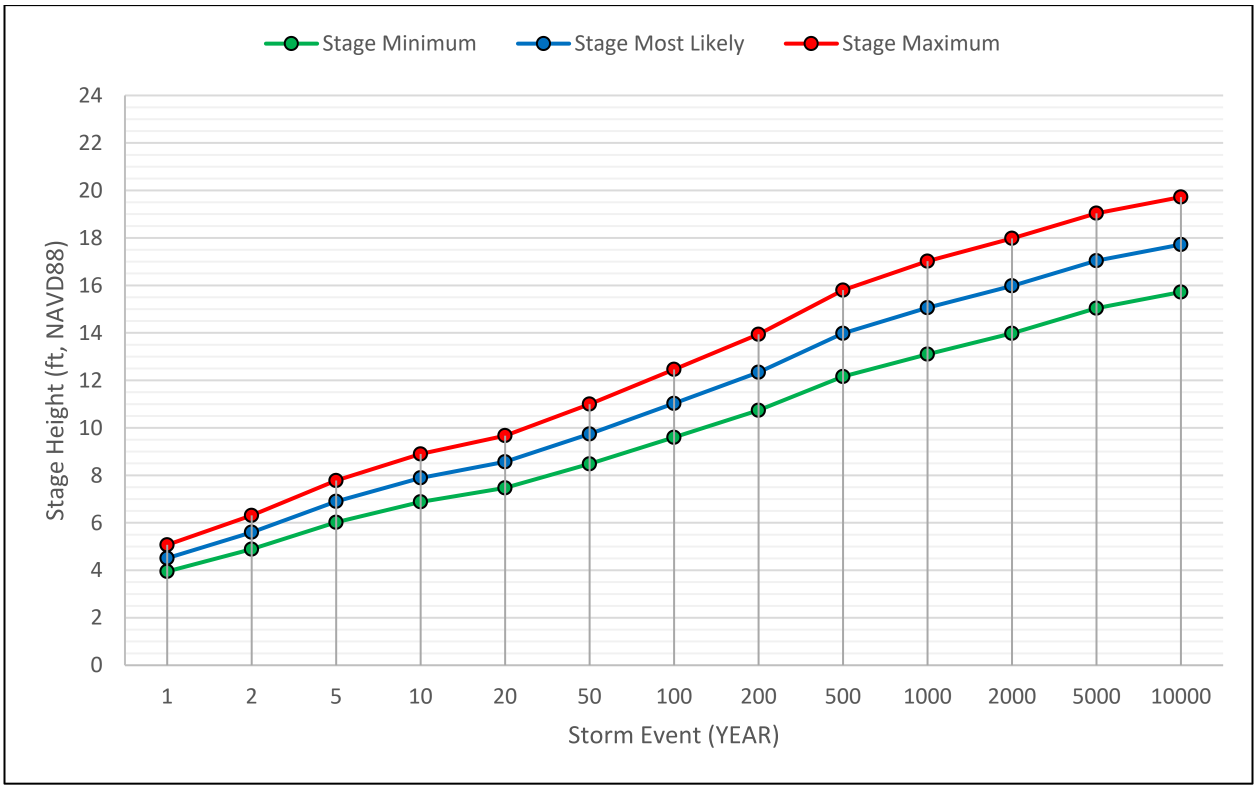


Figure 13: Water Surface Profile Example – North Wildwood City (Reach 26)

It is important to note that Water Surface Profiles are also developed with a triangle distribution of values. The “Stage Maximum,” or upper extent, of the Intermediate RSLC curve is not the same as the High RSLC curve. Each RSLC scenario has a unique set of 13 data points per reach and its own Minimum, Most Likely, and Maximum extent.

C-4) FUTURE WITHOUT-PROJECT CONDITION

HEC-FDA links the predictive capability of hydraulic and hydrologic modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the total damages under various proposed alternatives while accounting for risk and uncertainty. The model output is then used to determine the net National Economic Development (NED) benefits of each project alternative in comparison with the No-Action Plan, or Future Without-Project Condition.

Storm damage is defined as the monetary loss to contents and structures incurred as a direct result of inundation caused by a storm of a given magnitude and probability.

For the Future Without-Project Condition (FWOP) and Future With-Project Conditions (FWP), the structure inventory and assigned values are considered static throughout the 50 year period of analysis. Though this approach may ignore future condemnations of repeatedly damaged structures or increases in the number or value of structures in the inventory due to future development, the variability and limitations of projecting future inventory changes over 50 years across such a wide study area are too significant to assign any reasonable level of certainty to the predicted inventory alterations.

As mentioned earlier Future Without-Project Condition damages are used as the base condition and potential project alternatives are measured against this base to evaluate the project effectiveness and cost efficiency. Future Without-Project Condition damages are presented as Average Annual Damages (AAD) over a 50 year period of analysis with an FY2018 Project Evaluation and Formulation Rate (Discount Rate) of 2.75%.

The following model results for Future Without-Project Condition analysis are based on estimated structure and content damages with additional damages such as vehicles, critical infrastructure, emergency costs, and transportation delays accounted for using a percentage increase at the reach level. As the study progresses, this percentage allocation for additional benefit categories will be replaced by more specific and more detailed data at the reach level.

Current data reflects primary, or direct, damage values and future analysis will incorporate secondary, or indirect, damage from disruptions to critical infrastructure. This includes interruptions to power plants, wastewater treatment facilities, and communication centers.

Model Results

The New Jersey Back Bays study area experiences a total of $1,571,616,000 in Without-Project Average Annual Damages (AAD) over a 50 year period of analysis with Intermediate RSLC. Table 5 shows the breakdown in Average Annual Damages across all 84 municipalities. It is important to note the values in Table 5 only reflect the AAD of the sections of the municipality that intersect with the study area. AAD within the municipality that are outside the study area are not included nor quantified.

While Average Annual Damages per Structure fluctuates by municipality, Atlantic City has the highest mean AAD per Structure at $41,605 followed by Ocean City at $12,292. The total study area has a mean AAD per Structure at $8,591.

Figures 14 and 15 shows the relative contribution to Average Annual Damages by Reach. The generated heat map shows high damage areas in red and lower damage areas in green.

Table 5: Without-Project Average Annual Damages by Municipality

Municipality	AAD	Municipality	AAD
Atlantic City	$323,774,000	Absecon	$4,393,000
Ocean City	$219,809,000	Eagleswood	$4,217,000
Toms River	$69,526,000	Mantoloking	$3,778,000
Sea Isle City	$62,714,000	Bass River	$3,656,000
North Wildwood	$59,807,000	West Cape May	$3,545,000
Long Beach	$54,554,000	Hamilton	$3,329,000
Brick	$53,293,000	South Toms River	$3,168,000
Brigantine	$37,997,000	Mullica	$3,090,000
Avalon	$37,841,000	Galloway	$2,906,000
Wildwood	$36,102,000	Cape May Point	$2,720,000
Little Egg Harbor	$33,981,000	Linwood	$2,573,000
Margate City	$28,530,000	Wall	$2,474,000
Point Pleasant	$28,009,000	Brielle	$2,333,000
Bay Head	$27,066,000	Belmar	$1,989,000
Manasquan	$26,571,000	Avon-by-the-Sea	$1,969,000
Stone Harbor	$25,008,000	Neptune	$1,902,000
Ship Bottom	$24,660,000	Barnegat	$1,786,000
Stafford	$24,308,000	Island Heights	$1,711,000
Pt Pleasant Beach	$23,860,000	Port Republic	$1,534,000
Egg Harbor	$23,113,000	Spring Lake	$1,436,000
Ventnor City	$21,304,000	Corbin City	$1,268,000
Lavallette	$21,111,000	Dennis	$1,103,000
Surf City	$20,869,000	Sea Girt	$621,000
Cape May	$20,732,000	Weymouth	$483,000
Beach Haven	$19,537,000	Beachwood	$392,000
Berkeley	$17,259,000	Pine Beach	$303,000
West Wildwood	$17,177,000	Northfield	$235,000
Middle	$16,636,000	Estell Manor	$210,000
Tuckerton	$15,354,000	Lake Como	$188,000
Somers Point	$13,650,000	Washington	$167,000
Harvey Cedars	$11,974,000	Asbury Park	$162,000
Lower	$11,906,000	Neptune City	$132,000
Wildwood Crest	$11,189,000	Spring Lake Heights	$128,000
Seaside Heights	$10,706,000	Bradley Beach	$125,000
Upper	$10,666,000	Loch Arbour	$93,000
Longport	$10,400,000	Allenhurst	$35,000
Lacey	$8,760,000	Ocean (Monmouth)	$21,000
Seaside Park	$8,238,000	Interlaken	$21,000
Ocean Gate	$7,566,000	Lakewood	$18,000
Barnegat Light	$5,733,000	Egg Harbor City	$18,000
Pleasantville	$5,100,000	Deal	$8,000
Ocean Township	$4,981,000	Long Branch	$5,000
		TOTAL	**$1,571,616,000**

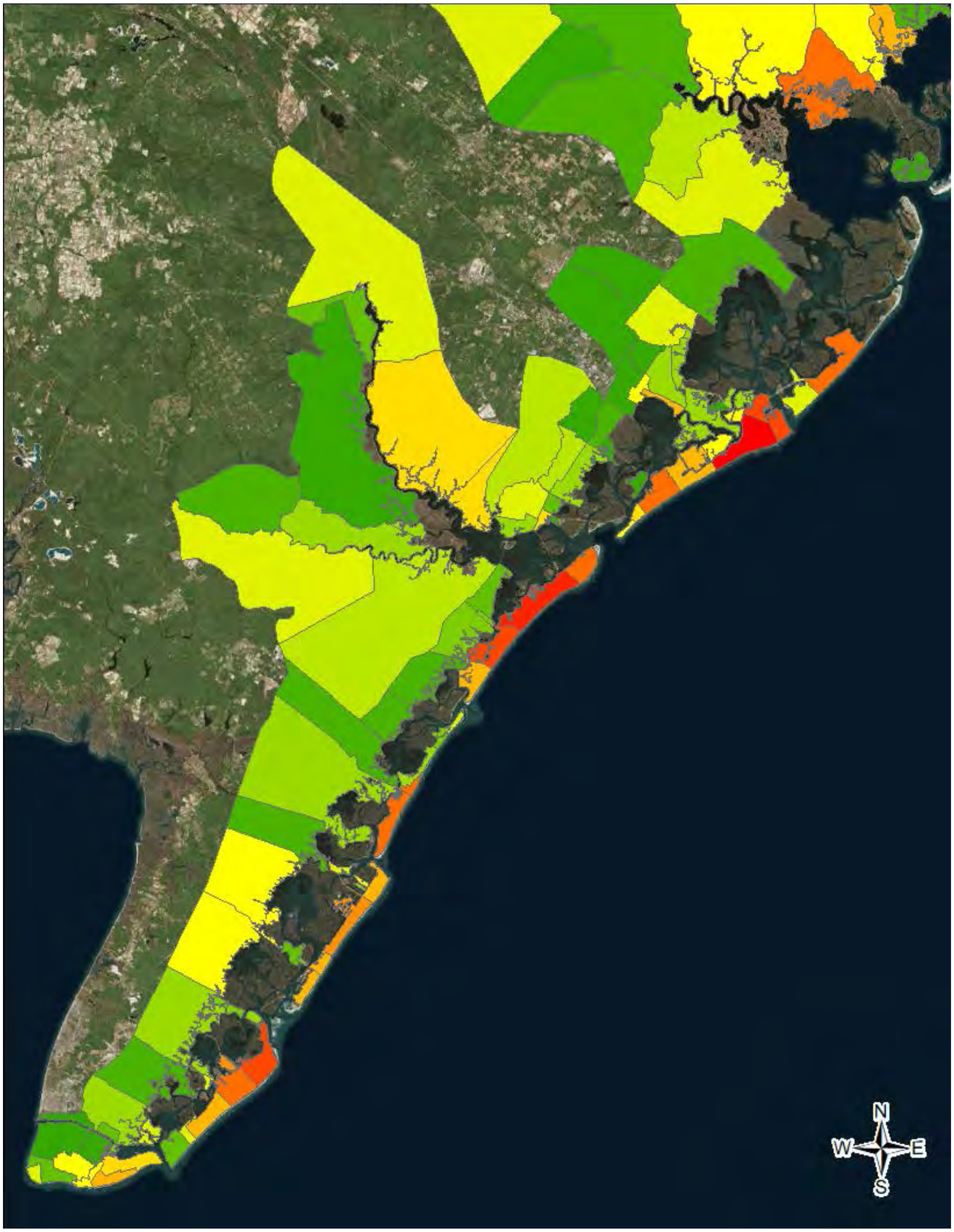


Figure 14: FWOP Damages – Heat Map (Cape May + Atlantic)

For Cape May County and Atlantic County, the majority of estimated Future Without-Project Condition damages are focused on the southern tip of New Jersey and along the barrier islands. These areas typically have a higher density of structures, higher average value per structure, and increased inundation risk due to lower ground elevations.

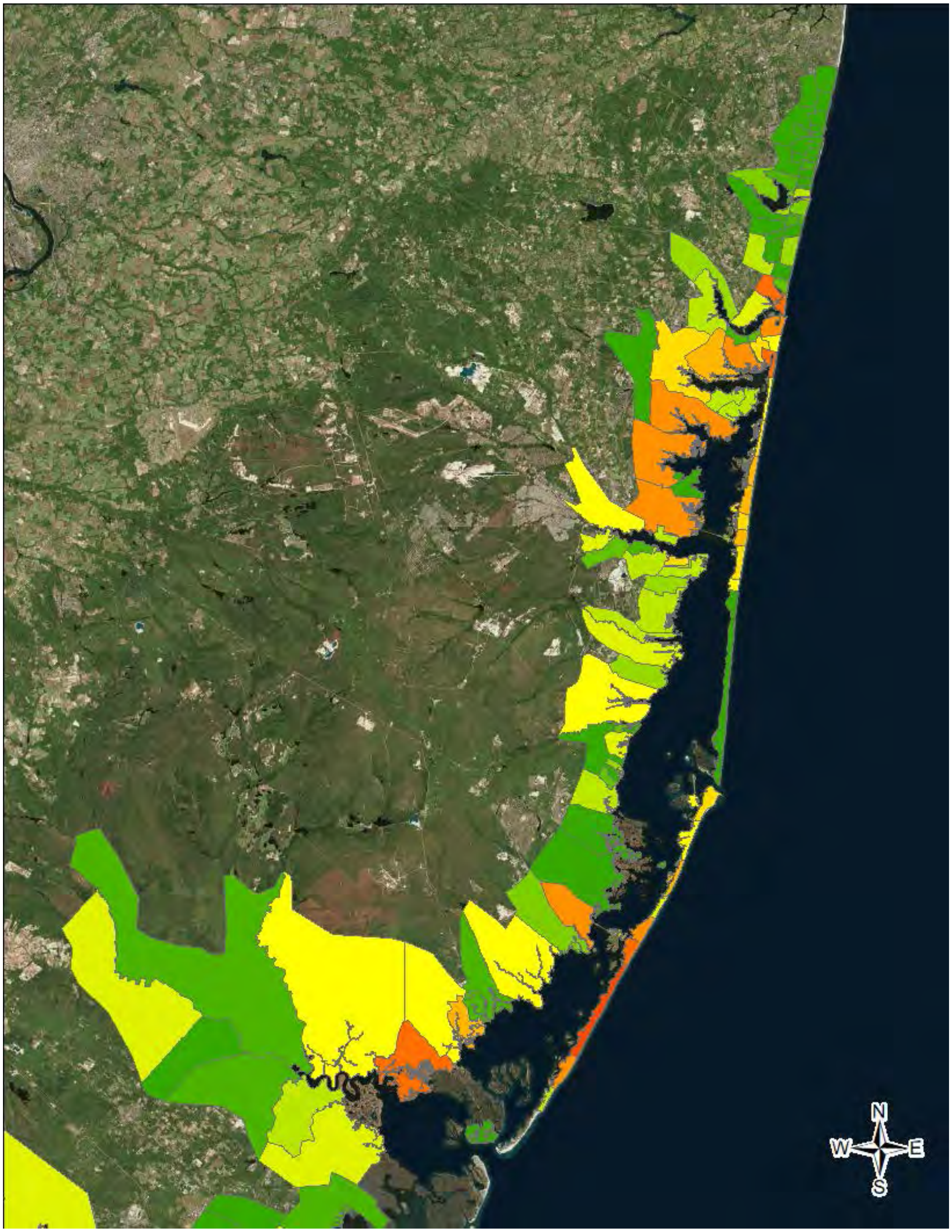


Figure 15: FWOP Damages – Heat Map (Burlington + Ocean + Monmouth)

For Burlington, Ocean, and Monmouth counties, damages are focused along the barrier islands, within the "finger canal" communities, and at the northern extent of Barnegat Bay. These areas share the same high density, high value, low elevation conditions.

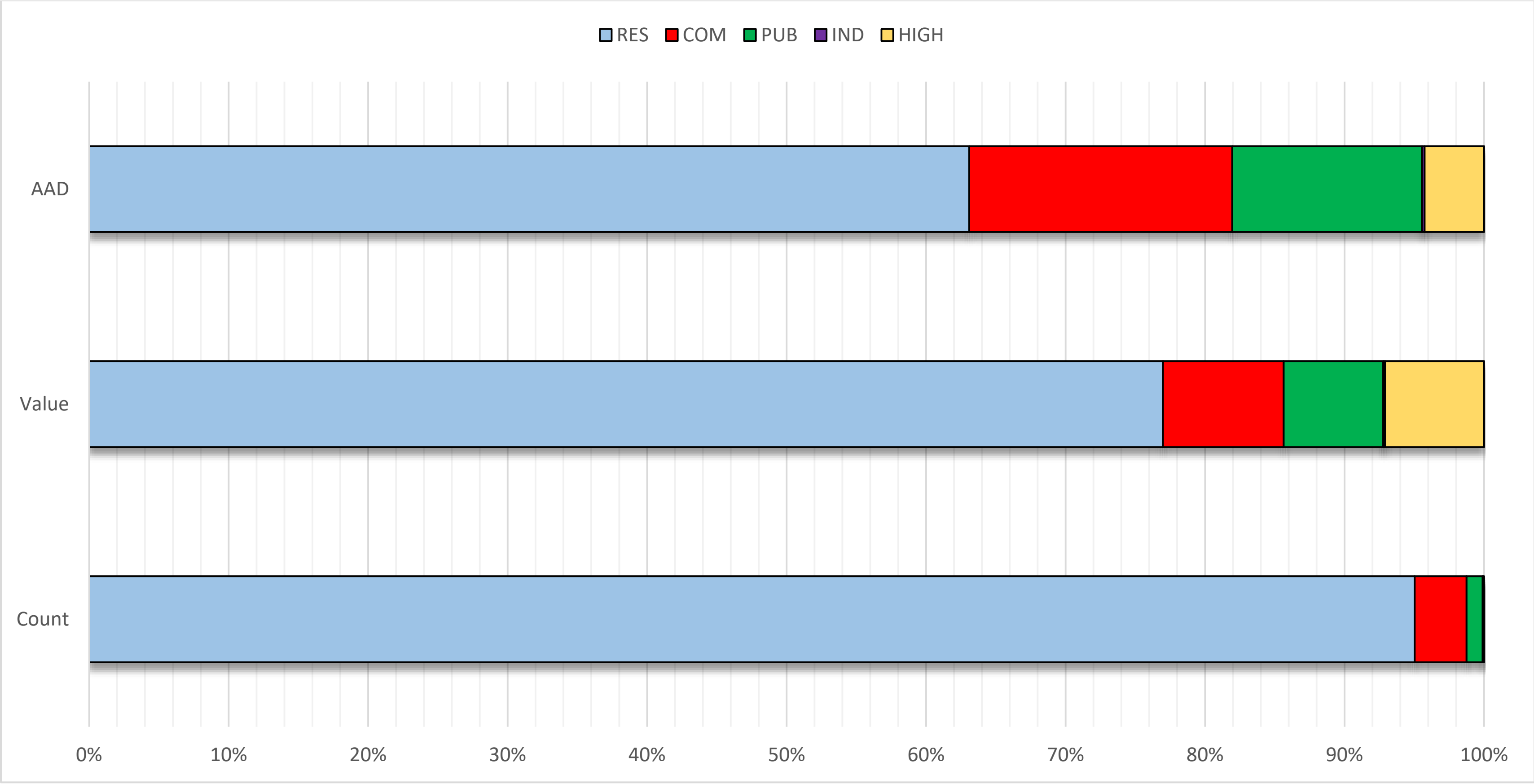


Figure 16: Comparison of Structure Count, Value, and Average Annual Damage by Type

Figure 16 shows a comparison between structure volume, structure/content value, and contribution to Average Annual Damages (AAD).

Residential structures represent over 95.0% of total structure by count, but only contribute 77.0% of total value by occupancy type and only 63.1% of total Average Annual Damages. Commercial and Public structures represent 3.7% and 1.2% of total structures by volume, respectively, but contribute 18.9% and 13.6% of total AAD. Higher AAD estimates for Commercial and Public structures stem from their higher average structure/content value as well as greater risk to inundation due to lower foundation heights.

High-rise structures represent 7.1% of total inventory value, but only 4.3% of total AAD due to a relatively flat inundation damage curve.

C-5) FUTURE WITH-PROJECT CONDITION

Performing economic analysis on proposed alternatives within the study area was an iterative process with complex interdependence between study reaches and between certain measure combinations. Additional details can be found in the Plan Formulation Appendix, but economic analysis centered on three possible measure types: Perimeter (floodwalls and levees), Non-structural (building elevations), and Storm Surge Barriers (inlet gates). Each measure was first evaluated independently for all relevant study area locations and then combined with other measure types to create NED optimizing and comprehensive "hybrid" alternatives.

This section will detail the methodology and results of investigating each measure type in isolation and the following Hybrid NED (Multi-Measure) Alternative Section will combine these measures into implementable and complete proposed alternatives.

Perimeter Measures Analysis

Economic evaluation of perimeter measures was completed using three iterative cycles of analysis. The investigative cycles include an initial comprehensive qualitative analysis, an excel-based quantitative analysis, and a final HEC-FDA based quantitative analysis.

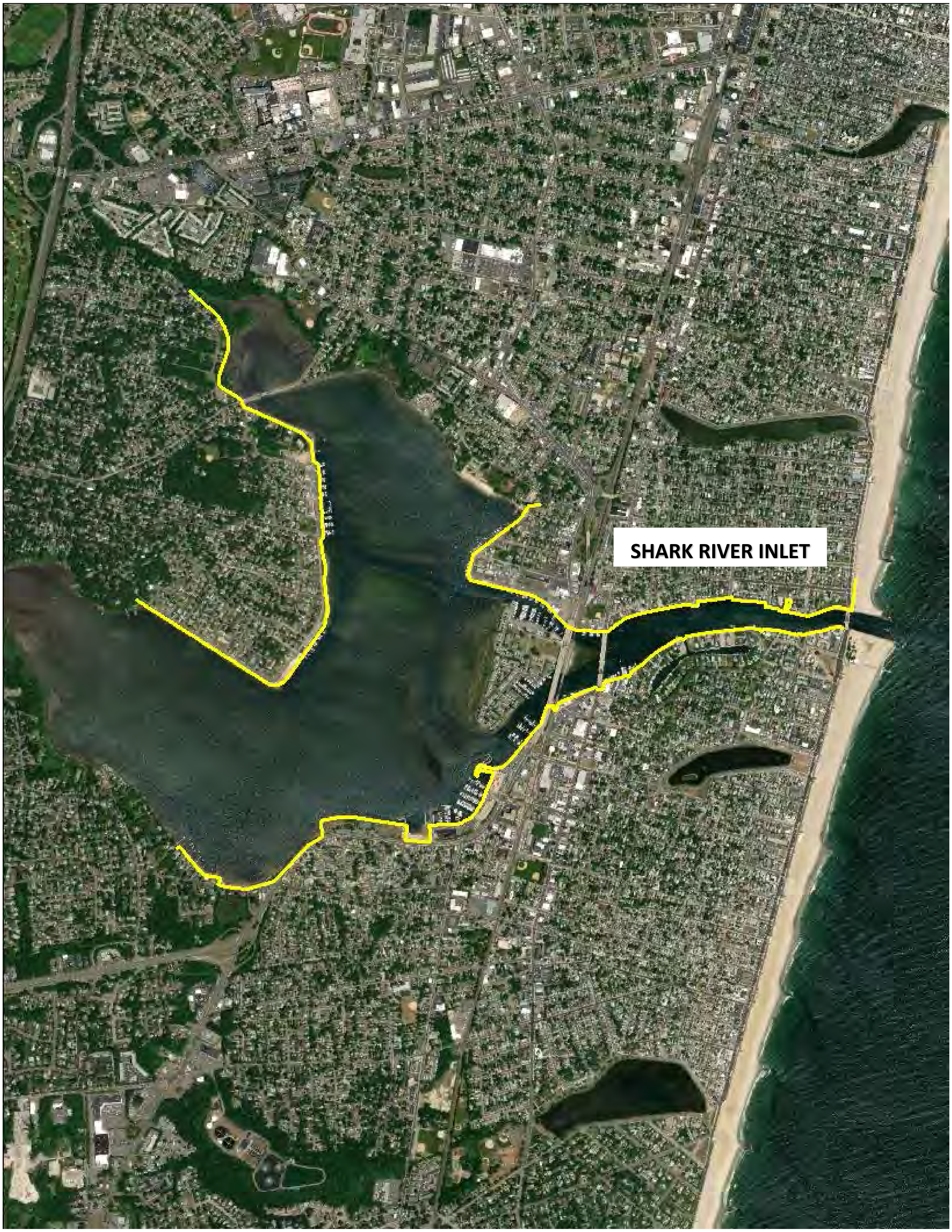
Cycle 0

The initial analysis effort was to create a comprehensive qualitative screening of potential perimeter measure locations across the entire study area. The analysis completed in Cycle 0 did not assign refined costs nor benefits to identified perimeter locations, but merely identified areas where a perimeter solution was physically implementable and then only screened out areas where a theoretically possible perimeter solution was massively more expensive than even the highest conceivable value of the inventory landward of the measure.

Cycle 0 identified 49 remotely possible perimeter locations across the barrier islands, mainland, and finger canal communities. These locations represent the widest possible base for future analysis and all successive cycles of analysis worked to refine cost and benefit inputs to screen these identified locations to only the economically justified alternatives.

Figure 17 shows all 49 identified perimeter locations. Due to the size of the study area, the locations are shown in sections moving South to North. Measures include floodwalls and/or levees depending on ground conditions. In total, Cycle 0 presents 1.8 million feet of perimeter length.

Figure 17: Perimeter Measure Analysis – Cycle 0


SHARK RIVER INLET

Cycle 1

Using the results of Cycle 0 as the widest possible number of potentially justified alternatives, Cycle 1 introduced more refined cost inputs and benefit estimates to assign preliminary Benefit-Cost Ratios to each of the 49 identified locations. The most promising locations would then continue further into the analysis while less promising locations would be screened from further study. At this stage of the analysis, the decision was made to use lower than anticipated cost estimates and higher than expected benefit assessments to capture the largest number of theoretically justified perimeter locations.

Perimeter costs were adapted from the North Atlantic Coast Comprehensive Study (NACCS) and benefits were calculated using an excel-based model with preliminary structure inventory data and a simplified depth-percent damage curve. Cost estimates included $8,000 per linear foot of floodwall with additional costs added for miter gates, sluice gates, or road closures where applicable. Analysis was completed using the FY2018 Federal Discount Rate of 2.75% with a 50 year period of analysis.

Table 6 shows the 13 perimeter locations (including Strathmere) that displayed a BCR above 1.0.

Table 6: Perimeter Measure Analysis – Cycle 1 Results

ID	Location	Length	Initial Const.	AAC	AAD	AANB	BCR
1	Cape May City	15,757	$133,361,310	$6,273,439	$16,961,371	$10,687,932	2.7
2	Wildwood Island	54,070	$491,161,680	$23,104,697	$93,958,647	$70,853,950	4.1
4	West Wildwood	11,727	$100,154,110	$4,711,341	$11,938,657	$7,227,316	2.5
5	Stone Harbor / Avalon	96,936	$858,289,730	$40,374,738	$63,320,119	$22,945,381	1.6
10	Sea Isle City	34,954	$329,939,900	$15,520,676	$38,710,939	$23,190,263	2.5
11	Strathmere	8,165	$77,850,490	$3,662,159	$2,777,660	-$884,499	0.8
12	Ocean City	78,573	$703,272,670	$33,082,593	$186,282,803	$153,200,210	5.6
18	Absecon Island	97,409	$977,008,560	$45,959,381	$400,981,475	$355,022,094	8.7
23	Brigantine	48,590	$431,911,960	$20,317,536	$52,970,720	$32,653,184	2.6
26	Long Beach Island	206,561	$1,883,468,300	$88,600,081	$145,286,947	$56,686,867	1.6
42	Island Beach	186,140	$1,784,578,000	$83,948,190	$160,691,242	$76,743,052	1.9
45	Manasquan Inlet (North)	22,642	$235,353,970	$11,071,267	$32,182,394	$21,111,127	2.9
52	West Cape May	4,481	$57,882,910	$2,722,865	$15,923,307	$13,200,441	5.8
TOTAL ESTIMATED		**866,005**	**$8,064,233,590**	**$379,348,963**	**$1,221,986,280**	**$842,637,317**	**3.2**
ROUNDED		**866,000**	**$8,064,234,000**	**$379,349,000**	**$1,221,986,000**	**$842,637,000**	**3.2**

In Table 6 above, Average Annual Cost includes Operations & Maintenance (O&M) and Average Annual Damages includes estimates for vehicle damages, infrastructure damages, transportation delays, and emergency costs.

All 13 of the locations identified in the chart above were evaluated further using HEC-FDA in Cycle 2. This includes Strathmere with a 0.76 Benefit-Cost Ratio as this was the only community on the barrier islands without an initial BCR above 1.0.

Several mainland communities such as Somers Point and West Atlantic City had BCRs above 0.9, but were ultimately excluded from further perimeter measure analysis as costs were expected to rise substantially while benefits were not expected to greatly fluctuate. In other words, though Cycle 1 analysis operated with a high degree of uncertainty, none of the 36 screened locations could reasonably be expected to attain future economic justification with perimeter measures and their exclusion presents no risk to final study results.

Figure 18 shows the 13 remaining perimeter measure locations. Again, due to the size of the study area, the locations are shown in sections moving South to North. In total, Cycle 1 presents 840,000ft of perimeter length.

Figure 18: Perimeter Measure Analysis – Cycle 1

Cycle 2

The final analysis cycle for perimeter measures transferred modeling from preliminary excel-based tools to USACE certified HEC-FDA modeling. Evaluation with HEC-FDA allows for significantly greater complexity and accuracy than possible with excel-based methods.

Cost estimates were also updated with modifications to perimeter measure placement and lengths as well as efforts to improve accuracy with changes to cost per linear foot and applied contingencies.

Table 7: Perimeter Measure Analysis – Cycle 2 Results

ID	Location	Length	Initial Const.	AAC	AAD	AANB	BCR
1	Cape May City	15,825	$249,540,895	$11,738,633	$9,887,438	-$1,851,196	0.8
2	Wildwood Island	54,171	$810,770,180	$38,139,375	$84,907,400	$46,768,025	2.2
4	West Wildwood	11,726	$170,039,200	$7,998,800	$15,864,050	$7,865,250	2.0
5	Stone Harbor / Avalon	97,225	$1,443,894,068	$67,922,105	$46,650,575	-$21,271,530	0.7
10	Sea Isle City	35,166	$544,084,466	$25,594,234	$31,810,925	$6,216,691	1.2
11	Strathmere	8,187	$117,797,150	$5,541,286	$2,472,163	-$3,069,124	0.4
12	Ocean City	78,732	$1,149,394,269	$54,068,563	$182,588,238	$128,519,674	3.4
18	Absecon Island	111,114	$1,755,389,808	$82,575,151	$320,230,675	$237,655,524	3.9
23	Brigantine	48,699	$714,920,468	$33,630,516	$30,157,550	-$3,472,966	0.9
26	Long Beach Island	209,124	$3,172,187,591	$149,222,621	$118,660,075	-$30,562,546	0.8
42	Island Beach	186,871	$3,092,467,435	$145,472,512	$107,272,863	-$38,199,649	0.7
45	Manasquan Inlet (North)	22,820	$461,553,732	$21,711,912	$30,560,638	$8,848,726	1.4
52	West Cape May	4,480	$88,265,089	$4,152,071	$8,890,325	$4,738,254	2.1
TOTAL ESTIMATED		**884,140**	**$13,770,304,352**	**$647,767,779**	**$989,952,913**	**$342,185,134**	**1.5**
ROUNDED		**884,000**	**$13,770,304,000**	**$647,768,000**	**$989,953,000**	**$342,185,000**	**1.5**

In comparison with the data shown in Table 6, estimated Average Annual Costs increased 71% over their Cycle 1 values. Average Annual Benefits decreased 19% when transferring from excel-based Cycle 1 to HEC-FDA based Cycle 2 analysis. This results in a total 59% decrease in Average Annual Net Benefits.

Of the 13 identified locations, 7 remain economically justified and a further 3 sites (shaded yellow) could realistically attain justification with optimizations to measure placement or type. However, Strathmere does not have the inventory to remain economically feasible and the sheer length of floodwall necessary to protect Long Beach Island or Island Beach creates an insurmountable cost hurdle.

Figure 19 shows the locations of the 7 to 10 economically feasible perimeter locations.

Figure 19: Perimeter Measure Analysis – Cycle 2

Non-Structural Measures Analysis

Non-structural measures fall into four broad groups resulting from the inventory and screening process previously discussed in Chapter 10.1 Coastal Storm Risk Management Inventory and Screening: Managed Coastal Retreat, including Acquisition / Relocation, Building Retrofit (floodproofing, elevations, ring levees), Land Use Management (zoning changes, undeveloped land preservation), and Early Flood Warnings (evacuation planning, emergency response systems). Refinements to the National Flood Insurance Program (including increasing homeowner participation and increasing municipal protection in the Community Rating System) also represent a non-structural opportunity at an agency level. Each measure type has a varying level of storm damage reduction function / adaptive capacity and a complete non-structural alternative would include each of the four measures as necessary to optimize CSRM benefits.

At this stage of the analysis, non-structural economic analysis incorporates only building retrofits (elevations) to Residential structures. Future analysis will include floodproofing and ring levees for Commercial, Public, and Industrial structures, as well as acquisition / relocation.

Building retrofits, while effective in reducing the potential risk for storm damage to that specific structure, has no positive impact on reducing storm damage risk to surrounding property, vehicles, or infrastructure. Furthermore, emergency access and evacuation is not improved solely with the implementation of building retrofits and property owners should still evacuate vulnerable properties during storm events lest they become trapped by rising storm surge. While this section details the cost and benefits analysis for implementing only non-structural measures, the most likely optimal alternative will ultimately incorporate non-structural as a supplemental measure to either perimeter measures, storm surge barriers, or both.

Cost Estimates

Building elevation costs are adapted from the North Atlantic Coast Comprehensive Study (NACCS) and are centered on quantifying the cost for elevating a typical (median) Single Family Residential One-Story (SFR1) structure and the cost for elevating a typical Single Family Residential Multi-Story (SFRM) structure.

A true building elevation cost is developed on a house-by-house basis and includes a number of factors including foundation type, wall type, size of structure, condition, available work space, local labor rates, and many additional variables. Given the size of the study area and the limitations of the structure inventory, building elevation costs are based on the sampled median foundation size per occupancy type (SFR1 vs. SFRM). Total initial construction costs are then based on the estimated number of structures that require elevation in a given reach multiplied by the typical elevation cost per occupancy type. This method does not allow the identification of the exact structures that require elevation, but provides an estimate for overall cost and benefit quantification per reach.

NACCS building elevation costs incorporate values for engineering and design, administrative fees, temporary housing for inhabitants, and other inputs. Table 8 provides the full cost breakdown for elevating a typical SFR1 structure and Table 9 provides the full cost breakdown for a typical SFRM structure. Both tables use an FY18 price level.

Table 8: Building Retrofit Costs – Single Family Residential One Story

Item	Number	Unit	Unit Cost	Total Cost
Elevation	1,559	SQFT	$87.57	$136,483
Temporary rehousing	1	ea	$10,000	$10,000
Subtotal				***$146,483***
Contingency	25%			$36,621
Total Construction				***$183,104***
E&D	$10,000			$10,000
S&A	10%			$18,310
TOTAL ESTIMATED INTITAL CONSTRUCTION				**$211,414**

Median square footage for a typical SFR1 structure in the study area was quantified using a sample of 48,287 building footprint GIS files (provided by New Jersey Department of Environmental Protection) that intersected with SFR1 inventory markers, or a 63.9% sample of SFR1 structures. The median structure base was calculated at 1,559 square feet. All other cost inputs, including unit cost and contingency, are pulled from the NACCS.

Table 9: Building Retrofit Costs – Single Family Residential Multi Story

Item	Number	Unit	Unit Cost	Total Cost
Elevation	1,839	SQFT	$87.57	$161,016
Temporary rehousing	1	ea	$10,000	$10,000
Subtotal				***$171,016***
Contingency	25%			$42,754
Total Construction				***$213,770***
E&D	$10,000			$10,000
S&A	10%			$21,377
TOTAL ESTIMATED INTITAL CONSTRUCTION				**$245,147**

Similar to SFR1 structures, the typical SFRM structure square footage base was quantified using a sample of 59,852 building footprint shapefiles provided by NJDEP, or a 61.4% sample. The median structure base was calculated at 1,839 square feet.

Structures are elevated to a Design Flood Elevation (DFE). This is the Base Flood Elevation (BFE) + 3ft. The additional height is added to mitigate risk from sea level rise.

Structure Identification

Selecting structures eligible for building elevation focused on identifying structures with the highest coastal storm damage risk levels. Residential structures in high risk areas or with lower first floor elevations are more vulnerable to coastal storm damage and considered prime candidates for building retrofits.

Non-structural analysis focused on structures within the 20% Annual Chance Exceedance (ACE) floodplain (05YR Storm Event), the 10% ACE floodplain (10YR Storm Event), and the 5% ACE floodplain (20YR Storm Event). Each of the 226 study reaches has a unique water surface profile with a set stage height for the 20% ACE, 10% ACE, and 5% ACE events. All structures with first floor elevations equal to or below any of the three storm event stage heights (FY2030 Intermediate RSLC curve) is considered high risk and eligible for building retrofit evaluation.

Figure 20 shows the number of structures contained within each layer as determined by first floor elevation in comparison to the storm event return frequency.

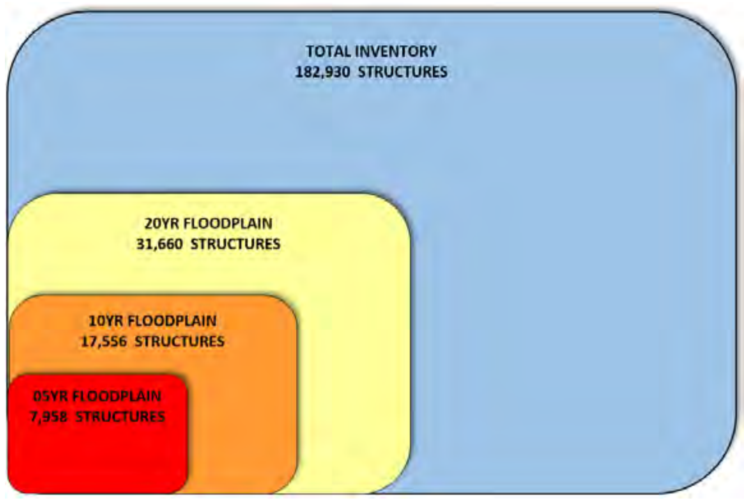


Figure 20: Non-structural Building Retrofit Volume

Of the 182,930 structures captured in the study inventory (including 172,971 SFR1 / SFRM structures), only 4.6% of SFR1 and SFRM structures fall within the 20% ACE event floodplain (05YR Storm Event). 10.1% of total SFR1 or SFRM structures fall within the 10% ACE event floodplain (10YR Storm Event) and a final 18.3% fall within the 5% ACE event floodplain (20YR Storm Event).

Benefit Analysis

Non-structural economic analysis is conducted using HEC-FDA with an FY18 Federal Discount Rate of 2.75% over a 50 year period of analysis. All SFR1 and SFRM structures with first floor elevations below the 5% ACE event stage height were "elevated" to 15ft NAVD88 within the model. This elevation height was selected only to remove any possibility of damage for these structures for any storm more frequent than the 1% ACE event. In reality, the exact elevation necessary for each structure (Design Flood Elevation) will fluctuate depending on the municipality and specific area conditions.

One limitation of HEC-FDA is the requirement of a static inventory for the entirety of the period of analysis. Structures cannot be added, removed, nor elevated within the model. To circumvent this limitation for non-structural analysis, two separate HEC-FDA models are developed. One model has the Without-Project Condition from FY2030 to FY2080 (results shown in Table 5) and a separate model has the With-Project Condition (updated inventory) from FY2030 to FY2080. The difference in calculated average annual damages between the model results is the coastal storm damage reduction benefits of retrofitting 31,660 of the 182,930 structures in the inventory.

Additional damage categories such as infrastructure, vehicle damage, emergency costs, and transportation delays are not mitigated through non-structural measures and are included in the residual damage category.

Table 10: Non-structural Measure Evaluation – 5% ACE Event Floodplain

Item	Number	Unit Cost	Total Cost
SFR1 Elevations	20,338	$211,414	$4,299,737,932
SFRM Elevations	11,322	$245,147	$2,775,554,334
Total Initial Const.	***31,660***		***$7,075,292,266***
Period of Analysis			50
FY18 Discount Rate			2.75%
Capital Recovery Factor			0.037041
Total AAC			***$262,075,331***
Without AAD			$1,571,616,063
With AAD			$1,119,950,393
Reduced AAD			***$451,665,670***
AANB			***$189,590,339***
BCR			***1.72***
Residual Damage			***71.3%***

The non-structural alternative is economically justified, however, the alternative has an exceptionally high residual damage percentage. As stated earlier, these residual damages stem from damage to non-elevated surrounding property, vehicle damage, infrastructure damage, emergency costs, and transportation delays.

Storm Surge Barrier Measure Analysis

Storm Surge Barrier analysis was an iterative process with greater complexities due to the interdependence of some inlets throughout the study area. Additional modeling was completed by the Engineering Research and Design Center (ERDC) and more information on the exact nature of the hydrologic modeling efforts can be found in the Engineering Appendix. This section will cover the economic analysis of the final suite of proposed storm surge barrier and inland bay closure alternatives.

Unlike perimeter measure analysis in HEC-FDA, where water surface profiles are unchanged and “floodwalls” are added to the model to estimate damage reduction, or non-structural measure analysis, where water surface profiles are unchanged and the inventory is altered to account for building elevations, storm surge barrier analysis involves with- and without-project water surface profiles with differing stage heights to measure the benefits of reduced inundation levels.

Study Regions

The New Jersey Back Bay area can be divided into five regions of relative independence. Within each region, all of the inlets are interdependent, with project performance requiring the closure of all inlets to maintain any reasonable level of stage height reduction during coastal storm events. Figure 21 on the following page shows the five study regions. Though not shown, all 226 HEC-FDA reaches are contained within one of the five regions and each HEC-FDA reach is restricted to exactly one Region with no overlaps. This allows for HEC-FDA reach outputs to be aggregated at the Region level and then Region level results to be aggregated (if necessary) to calculate a study wide proposed alternative combination.

The South Region extends from Cape May City up north of Corson’s Inlet. The Central Region extends from Corson’s Inlet to Little Egg / Brigantine Inlets. The North Region extends from Little Egg / Brigantine Inlets to just north of Manasquan Inlet. Shark River Region is the area directly affected by Shark River Inlet and the Coastal Lakes Region includes all of the coastal lakes not already covered by the North or Shark River Regions.

Storm Surge Barrier and bay closure alternatives are presented by each Region with determination that the alternatives proposed within each Region have no impact on the project performance of an alternative proposed at a different Region.

All storm surge barrier alternatives are calculated using the FY2018 Federal Discount Rate of 2.75% with a 50 year period of analysis and Intermediate RSLC.

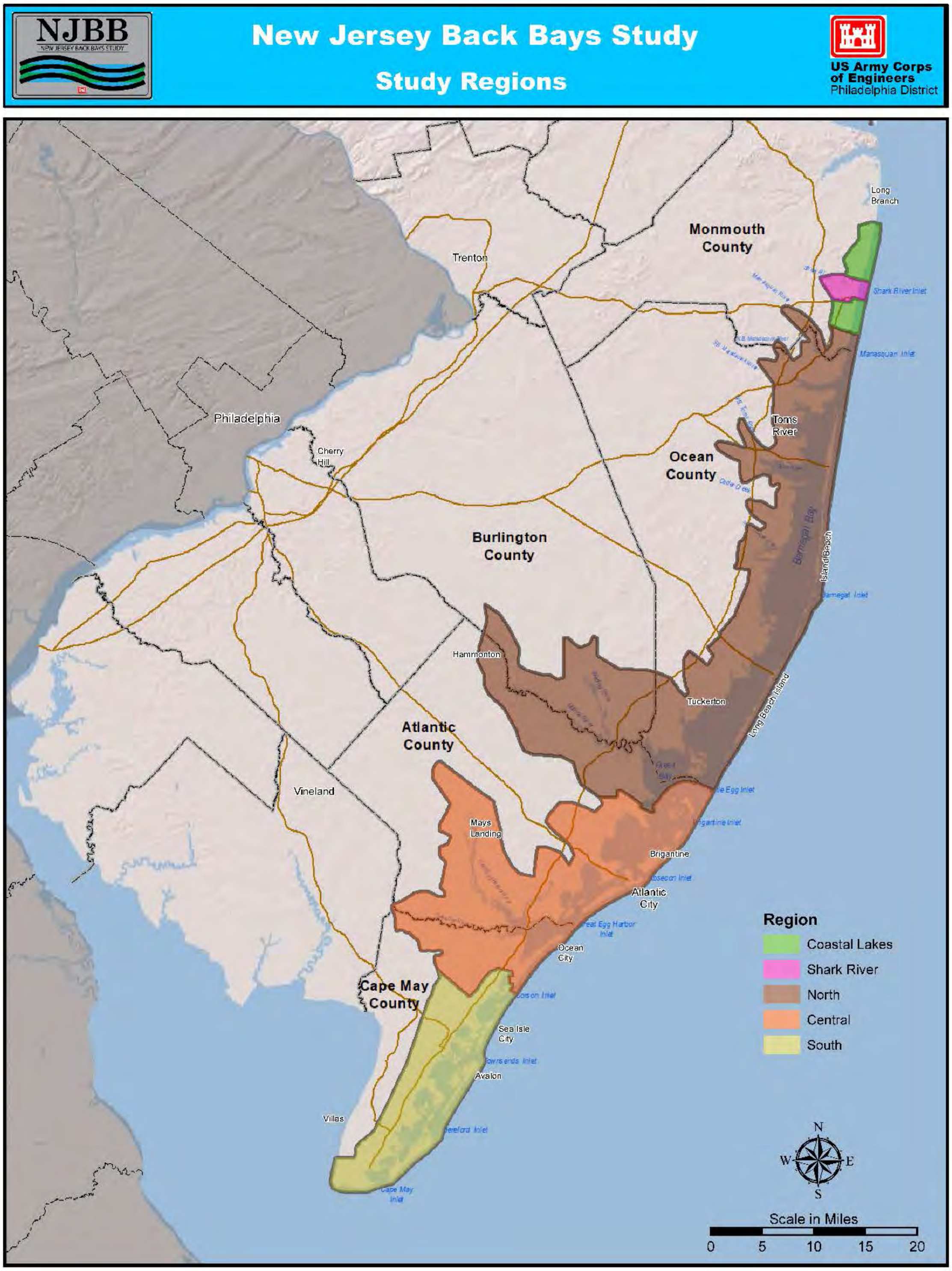


Figure 21: Study Area Regions

Cost Estimates

Detailed storm surge barrier designs and cost estimation methodology can be found in the Engineering Appendix, but this section will cover the final cost estimates used for the economic analysis.

Detailed cost estimates were calculated for eleven possible inlet closures and eight possible bay closures. Estimates are based on barriers with navigable sector gates and vertical life gates to allow tidal flow outside of storm events. Figure 22 shows an example barrier diagram for Barnegat Inlet.

Figure 22: Storm Surge Barrier Example Design – Barnegat Inlet

Cost estimates are shown in Table 11 and Table 12 with values for initial construction, contingency, interest during construction, and OMRR&R.

Table 11: Storm Surge Barrier Cost Estimates ($1000s)

Region	Barrier	Init. Const.	Contingency	Total Const.	Duration (Month)	IDC	Subtotal AAC	OMRR&R	Total AAC
South	Cape May Canal	$389,412	$145,232	***$534,644***	55	$67,387	$22,300	$8,250	***$30,549***
South	Cape May Inlet	$1,203,163	$448,721	***$1,651,884***	113	$427,769	$77,032	$25,500	***$102,532***
South	Hereford Inlet	$1,001,373	$373,463	***$1,374,836***	66	$207,944	$58,628	$21,222	***$79,850***
South	Townsends Inlet	$785,109	$292,807	***$1,077,916***	56	$138,333	$45,051	$16,638	***$61,689***
Boundary	Corson Inlet	$686,898	$256,179	***$943,077***	61	$131,834	$39,816	$14,556	***$54,372***
Central	Great Egg Harbor	$2,838,878	$1,058,762	***$3,897,641***	126	$1,125,444	$186,060	$60,175	***$246,235***
Central	Absecon Inlet	$2,065,920	$770,487	***$2,836,407***	127	$825,513	$135,641	$43,789	***$179,430***
Boundary	Brigantine to Little Egg Inlet	$4,390,448	$1,637,421	***$6,027,869***	143	$1,975,383	$296,448	$93,066	***$389,514***
North	Barnegat Inlet	$1,251,230	$466,647	***$1,717,878***	105	$413,364	$78,943	$26,519	***$105,462***
North	Manasquan Inlet	$605,604	$225,861	***$831,465***	81	$154,341	$36,515	$12,833	***$49,348***
Shark	Shark River Inlet	$430,712	$160,635	***$591,347***	48	$65,048	$24,313	$9,125	***$33,439***
TOTAL ESTIMATED AMOUNT		**$15,648,749**	**$5,836,214**	***$21,484,962***	**-**	**$5,532,359**	**$1,000,746**	**$331,673**	***$1,332,419***

Table 12: Bay Closure Cost Estimates ($1000s)

Region	Barrier	Init. Const.	Contingency	***Total Const.***	Duration	IDC	Subtotal AAC	OMRR&R	Total AAC
South	Wildwood Blvd	$641,899	$238,183	***$880,082***	55	$110,927	$36,708	$13,248	***$49,956***
South	Stone Harbor Blvd	$828,572	$306,461	***$1,135,034***	56	$145,663	$47,438	$16,782	***$64,220***
South	Sea Isle Blvd	$426,966	$158,037	***$585,003***	50	$67,032	$24,152	$8,692	***$32,844***
Central	52nd Street	$307,798	$113,822	***$421,620***	49	$47,344	$17,371	$6,234	***$23,605***
Central	Absecon Blvd	$720,765	$265,805	***$986,570***	50	$113,045	$40,731	$14,381	***$55,112***
Central	North Point	$2,256,894	$840,313	***$3,097,206***	133	$944,003	$149,690	$47,431	***$197,121***
North	Holgate	$2,459,847	$915,349	***$3,375,197***	125	$966,853	$160,834	$51,543	***$212,376***
North	Point Pleasant Canal	$233,064	$86,919	***$319,984***	49	$35,932	$13,183	$4,934	***$18,117***
TOTAL ESTIMATED AMOUNT		**$7,875,807**	**$2,924,890**	***$10,800,696***	**-**	**$2,430,798**	**$490,107**	**$163,245**	***$653,351***

Benefit Analysis

Storm Surge Barriers provide coastal storm risk management benefits by lowering flood stage heights during storm events. The effectiveness of the storm surge barrier alternative is dependent upon the combination of storm surge barriers and bay closures as well as hydrologic conditions in the study Region.

SHARK RIVER REGION

Shark River Inlet is the only inlet in the study area with full independence from all other inlet systems. The Region experiences $9,828,750 in average annual damages, or just 0.6% of all damages in the study area. Due to local conditions around the inlet, the Shark River Storm Surge Barrier requires a coastal structure, either dune or floodwall, along the ocean front to provide high ground for the storm surge barrier to tie into.

Figure 23 shows the extent of the Shark River Region as well as the outline of the potential storm surge barrier measure.

The Shark River Storm Surge Barrier has a projected $33,349,000 average annual cost (AAC) with $6,149,000 in average annual benefits (AAB) for -$27,289,000 in average annual net benefits (AANB) with a 0.18 benefit-cost ratio (BCR). The storm surge barrier does prevent 62.6% of storm damage in the Region, but the potential damage pool is too small to support the barrier cost.

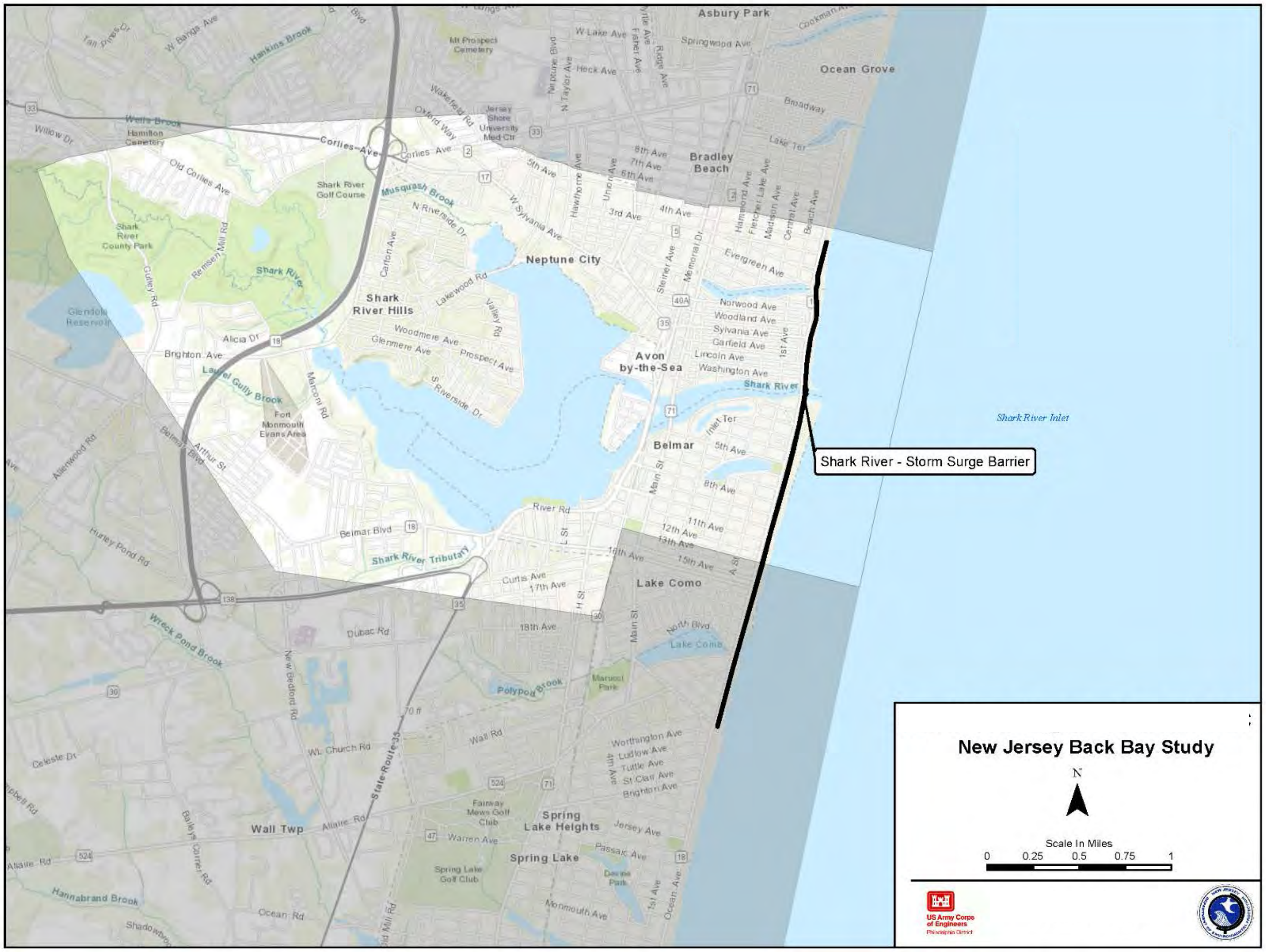


Figure 23: Shark River Region Storm Surge Barrier Alternatives

NORTH REGION

North Region includes the possibility of two storm surge barriers, Barnegat Inlet SSB and Manasquan Inlet SSB, as well as two bay closures, Point Pleasant Canal BC and Holgate BC. The combination of these measures creates the three alternatives shown in Figure 24.

Table 13 displays the AANB and BCR results for the three storm surge barrier and bay closure combination alternatives.

Table 13: North Region Storm Surge Barrier Alternatives

ITEM	Manasquan SSB + Barnegat SSB	Manasquan SSB + Barnegat SSB + Holgate BC	Manasquan SSB + Pt. Pleasant BC
Initial Construction	$2,549,342,000	$5,924,539,000	$1,151,448,000
AAC	***$154,810,000***	***$367,186,000***	***$67,465,000***
AAD Without	$548,225,000	$548,225,000	$548,225,000
AAD With	$239,397,000	$113,711,000	$505,723,000
AAB	***$308,828,000***	***$434,515,000***	***$42,502,000***
AANB	***$154,018,000***	***$67,329,000***	***-$24,963,000***
BCR	***1.99***	***1.18***	***0.63***
Residual Damage	43.7%	20.7%	92.2%
O&M	$39,351,000	$90,894,000	$17,766,000

Closing Manasquan Inlet and Barnegat Inlet with storm surge barriers has the highest NED AANB of the three SSB and BC alternatives. Adding a bay closure at Holgate does reduce residual damages by approximately 23%, but has 56.3% fewer AANB and a considerably higher AAC and O&M cost.

The final alternative, constructing only the Manasquan storm surge barrier and the Point Pleasant Canal closure, is not economically justified and does nothing to mitigate damages for over 92% of the Region.

It is important to note that any of the alternatives discussed so far can be combined with other measure types to further drive down residual damages and boost AANB. The combination of perimeter, non-structural, and storm surge barrier alternative is discussed later in the Appendix.

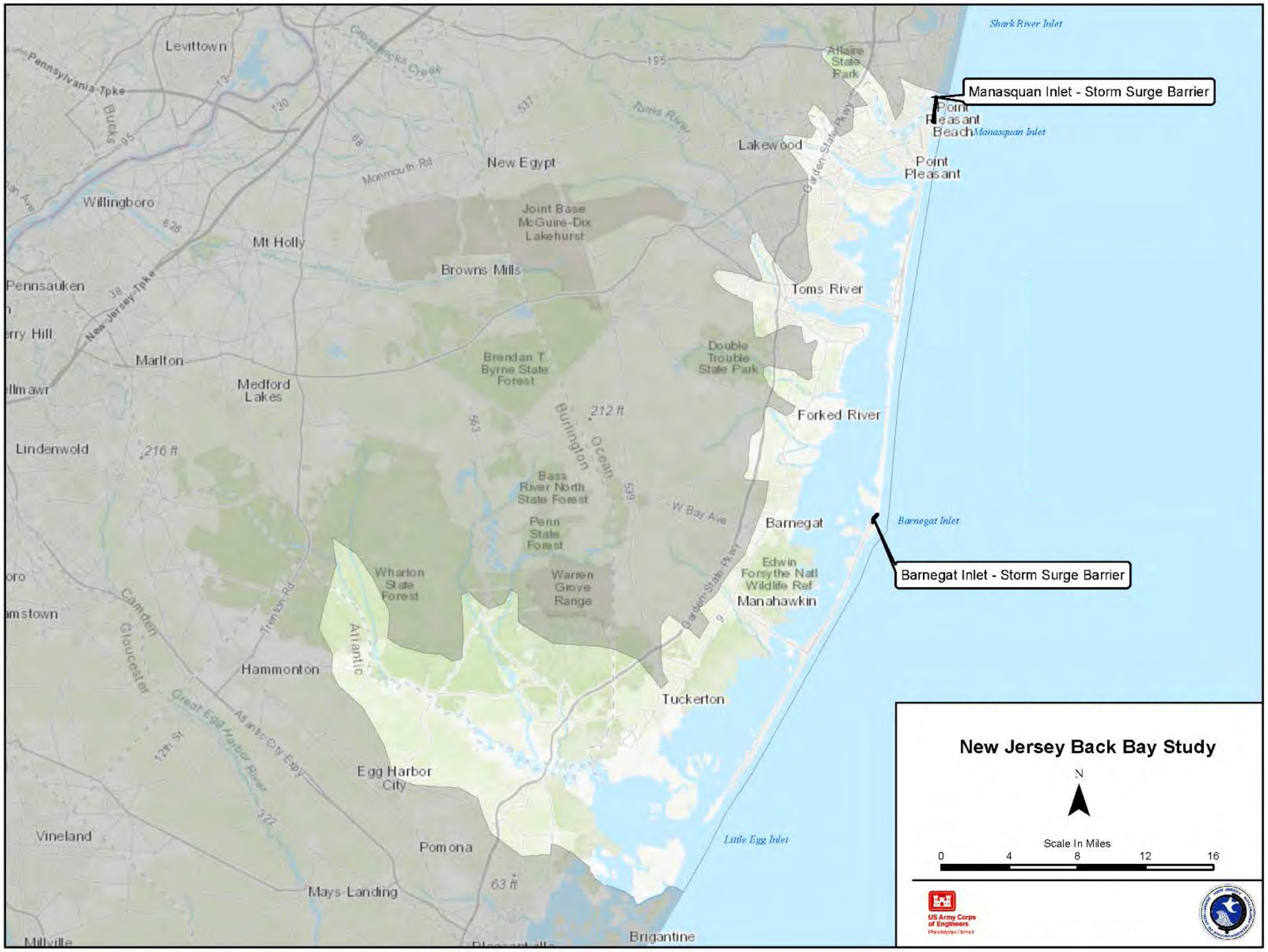
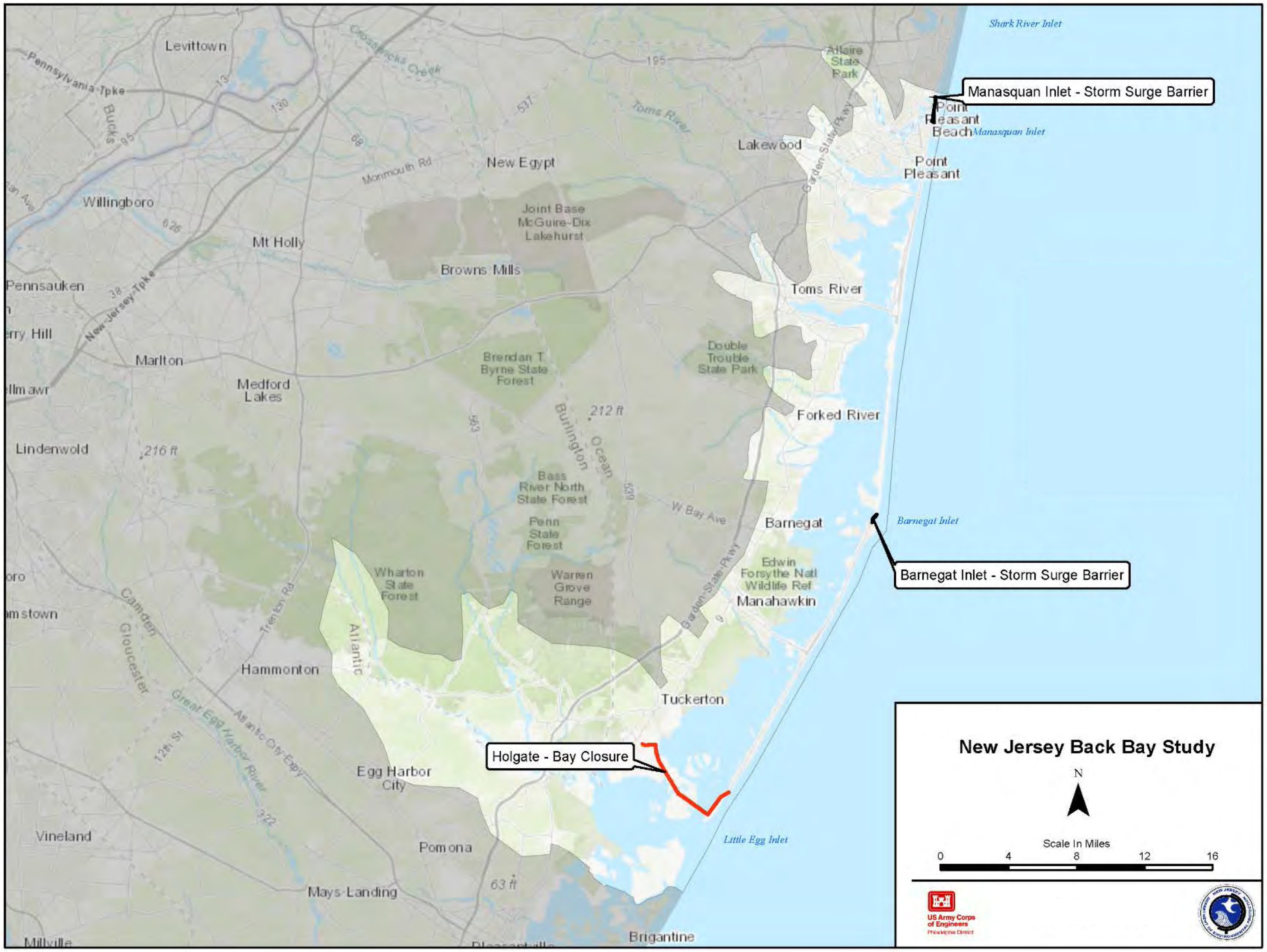
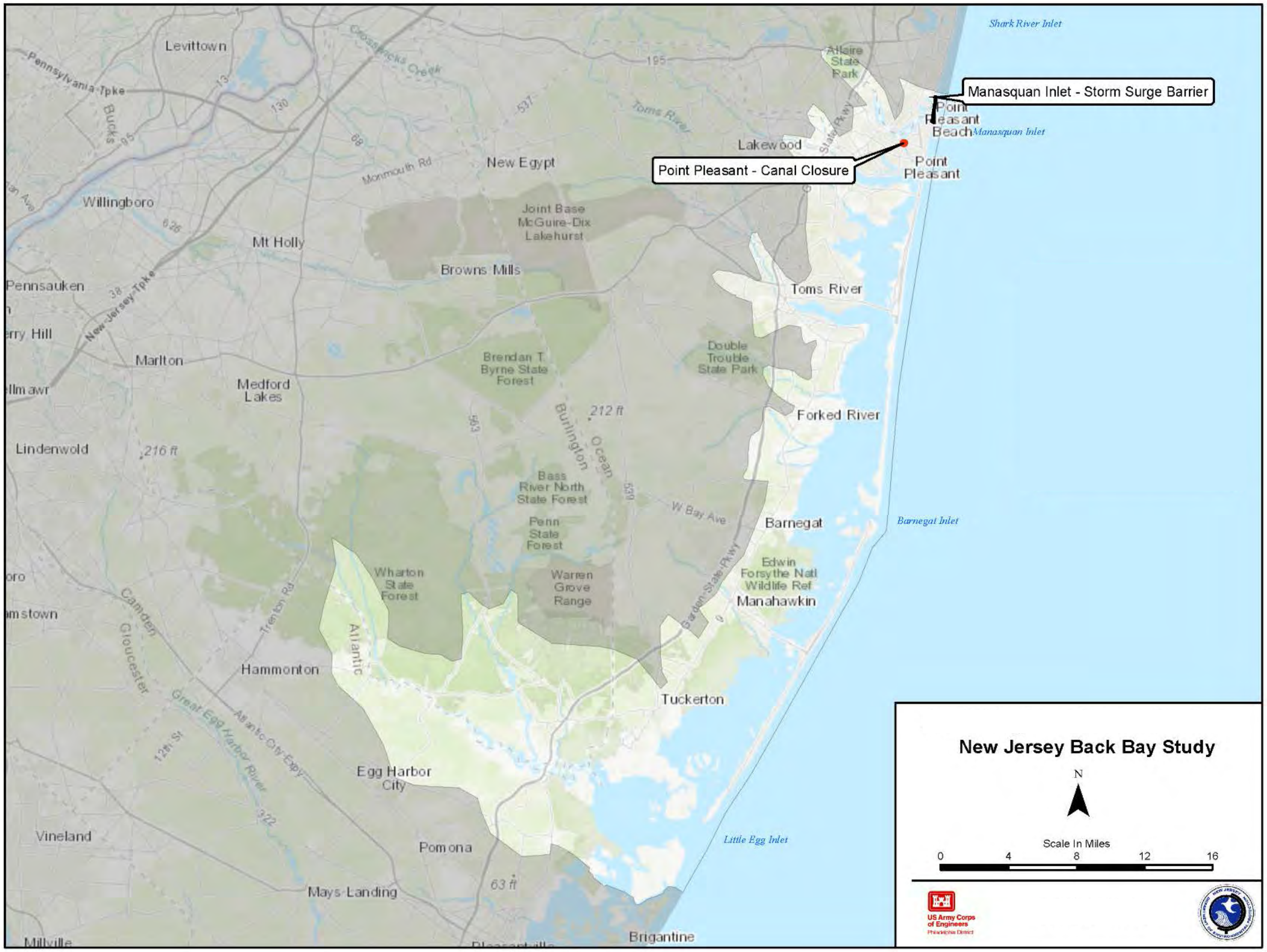


Figure 24: North Region Storm Surge Barrier Alternatives


Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Holgate - Bay Closure
New Jersey Back Bay Study
N
Scale In Miles
0 4 8 12 16
US Army Corps of Engineers
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant Beach
Point Pleasant
Joint Base McGuire-Dix Lakehurst
Browns Mills
Pennsauken
Toms River
Marlton
Medford Lakes
Brendan T. Byrne State Forest
Double Trouble State Park
Forked River
Lindenwold
Bass River North State Forest
Penn State Forest
Barnegat
Wharton State Forest
Warren Grove Range
Edwin Forsythe Natl Wildlife Ref
Manahawkin
Hammonton
Tuckerton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine
Allaire State Park


Manasquan Inlet - Storm Surge Barrier
Point Pleasant - Canal Closure
New Jersey Back Bay Study
N
Scale In Miles
0 4 8 12 16
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Point Pleasant Beach
Point Pleasant
Lakewood
Toms River
Forked River
Barnegat
Manahawkin
Tuckerton
Brigantine
Egg Harbor City
Hammonton
Pomona
Mays Landing
Vineland
Levittown
Willingboro
Mt Holly
Pennsauken
Marlton
Medford Lakes
Lindenwold
New Egypt
Browns Mills
Joint Base McGuire-Dix Lakehurst
Brendan T Byrne State Forest
Bass River North State Forest
Penn State Forest
Warren Grove Range
Wharton State Forest
Double Trouble State Park
Edwin Forsythe Natl Wildlife Ref
Allaire State Park
US Army Corps of Engineers

CENTRAL REGION

Initial analysis of the Central Region includes the possibility for two storm surge barriers, Absecon Inlet SSB and Great Egg Harbor SSB, and two bay closures, North Point BC and Absecon Blvd BC. The combination of these measures creates the three alternatives shown in Figure 25.

During further analysis, a third bay closure was modeled at South Ocean City (north of Corson's Inlet). That bay closure is not presented here, but is included in the "hybrid" alternative analysis later in the Appendix.

Table 14 displays the AANB and BCR results for the three storm surge barrier and bay closure combination alternatives.

Table 14: Central Region Storm Surge Barrier Alternatives

ITEM	Absecon SSB + Great Egg Harbor SSB	Absecon SSB + Great Egg Harbor SSB + North Point BC	Great Egg Harbor SSB + Absecon Blvd. BC
Initial Construction	$6,734,047,000	$9,831,254,000	$4,884,211,000
AAC	***$425,665,000***	***$622,785,000***	***$301,347,000***
AAD Without	$702,936,000	$702,936,000	$702,936,000
AAD With	$132,766,000	$50,016,000	$108,652,000
AAB	***$570,170,000***	***$652,920,000***	***$594,284,000***
AANB	***$144,506,000***	***$30,135,000***	***$292,937,000***
BCR	***1.34***	***1.05***	***1.97***
Residual Damage	18.9%	7.1%	15.5%
O&M	$103,964,000	$151,395,000	$74,556,000

Closing Absecon Inlet and Great Egg Harbor Inlet is economically justified with over $144,000,000 in AANB. Adding North Point bay closure does reduce residual damages down to 7.1%, but results in $114,371,000 in lost AANB due to the estimated $3 billion initial construction cost (Table 12).

Construction of a bay closure at Absecon Blvd (southwest of Brigantine Island) slightly increases residual damages in comparison to the North Point BC, but is considerably less expensive than either the Absecon SSB or North Point BC and maximizes NED AANB at $292,937,000 with a BCR of 1.97. The addition of the South Ocean City bay closure during additional analysis further reduced residual damages and increased AANB.

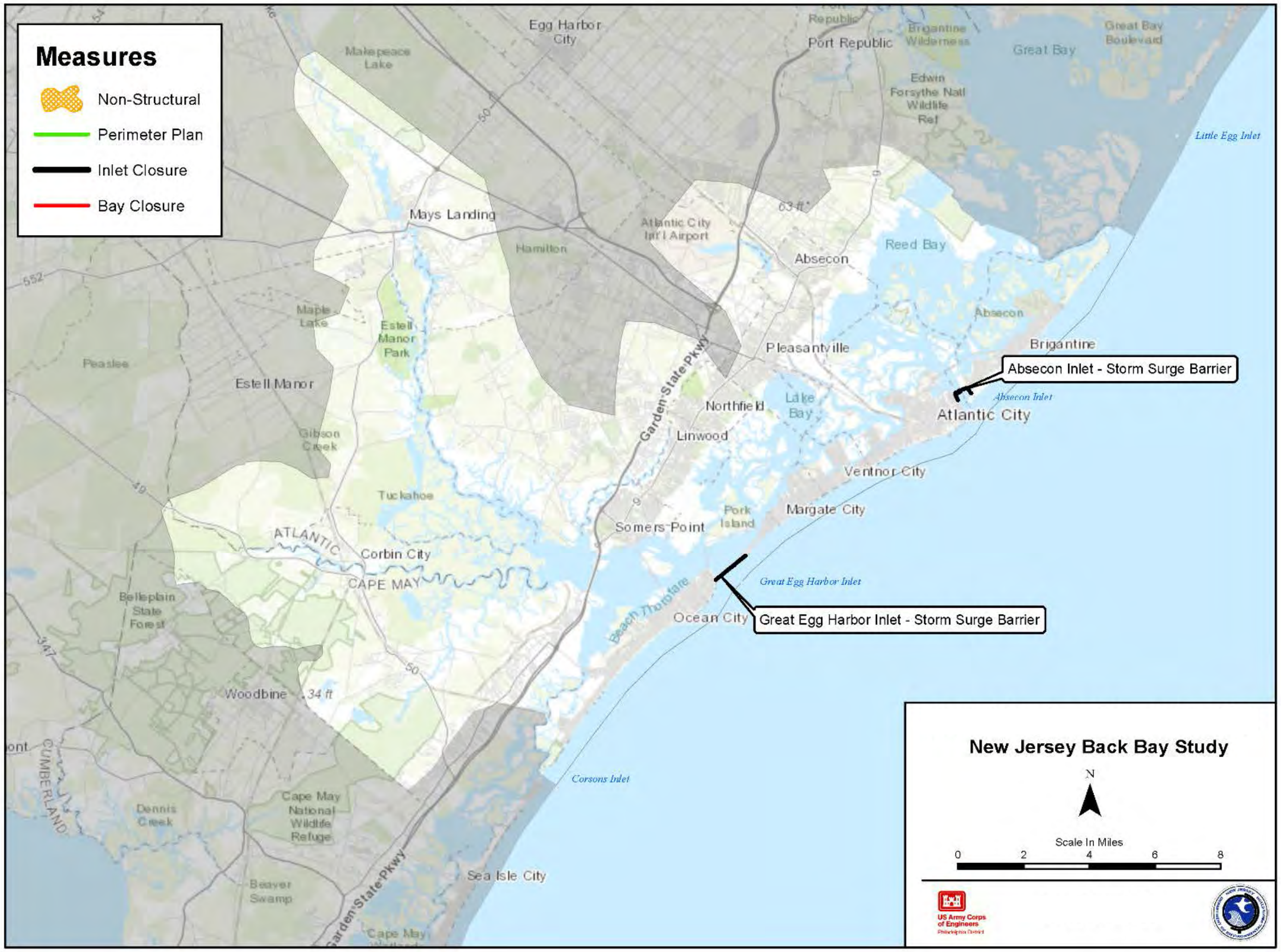
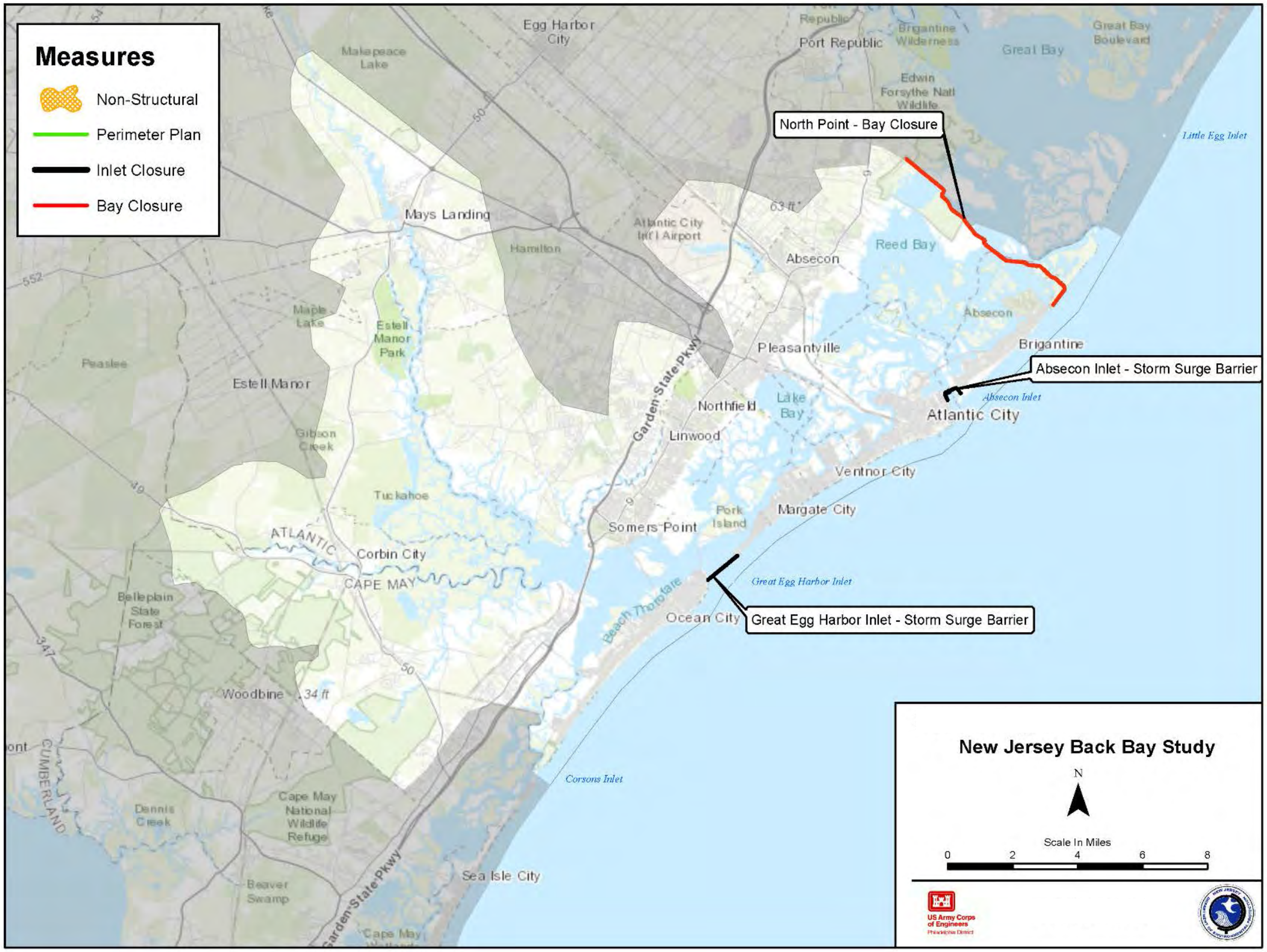
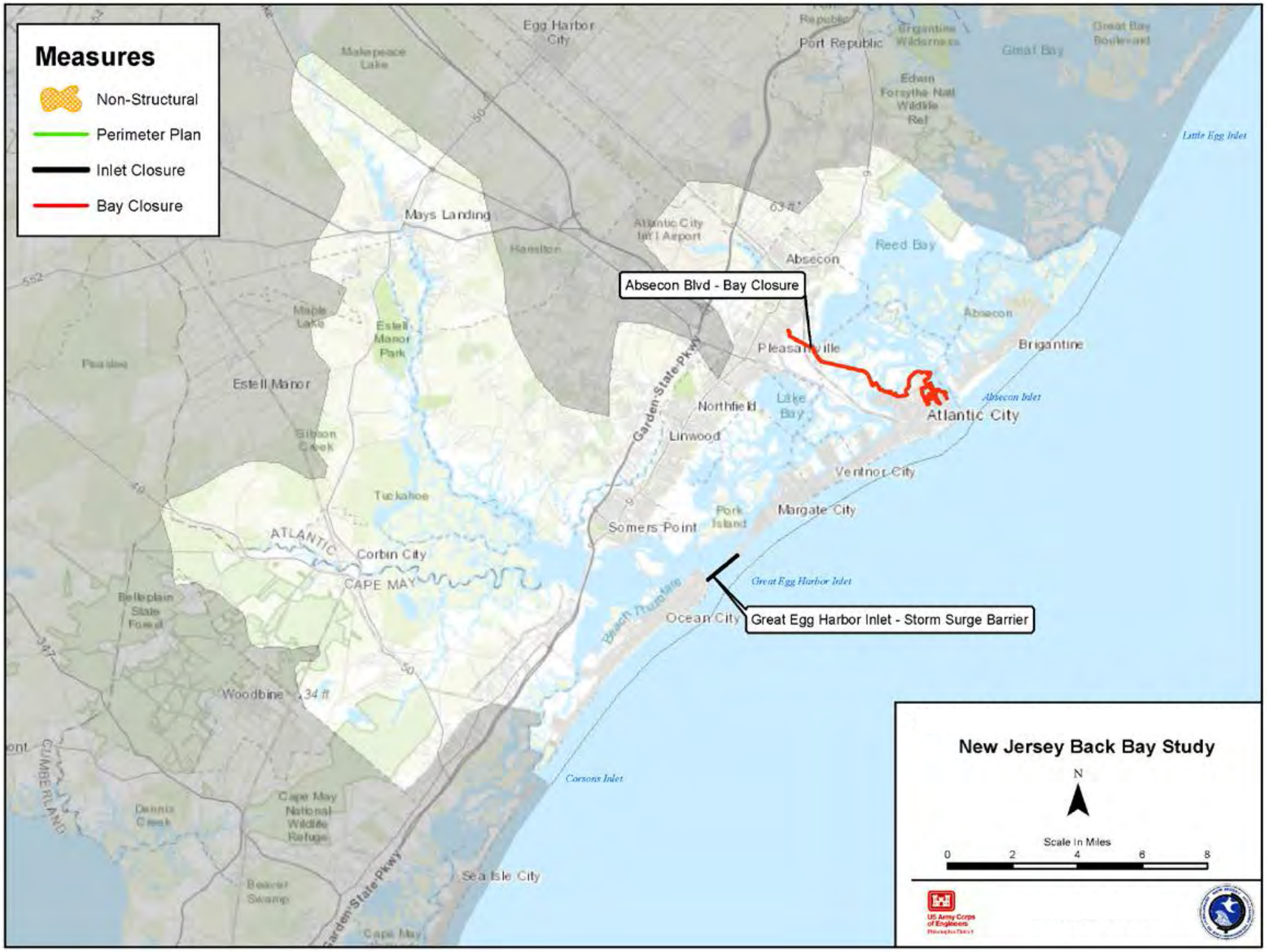


Figure 25: Central Region Storm Surge Barrier Alternatives


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Point - Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
New Jersey Back Bay Study
N
Scale In Miles
0 2 4 6 8
US Army Corps of Engineers
Egg Harbor City
Port Republic
Great Bay
Little Egg Inlet
Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Estell Manor
Northfield
Linwood
Atlantic City
Absecon Inlet
Ventnor City
Margate City
Somers Point
Corbin City
Great Egg Harbor Inlet
Ocean City
Woodbine
Corsons Inlet
Sea Isle City
Garden State Pkwy



Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Absecon Blvd - Bay Closure
Great Egg Harbor Inlet - Storm Surge Barrier
New Jersey Back Bay Study
N
Scale In Miles
0 2 4 6 8
Egg Harbor City
Port Republic
Mays Landing
Absecon
Reed Bay
Pleasantville
Brigantine
Northfield
Linwood
Atlantic City
Absecon Inlet
Ventnor City
Margate City
Somers Point
Corbin City
Ocean City
Great Egg Harbor Inlet
Estell Manor
Tuckahoe
Woodbine
Sea Isle City
Corsons Inlet
Little Egg Inlet
Garden State Pkwy

SOUTH REGION

Analysis of the South Region includes four storm surge barriers, Cape May Canal SSB, Cape May Inlet SSB, Hereford Inlet SSB, and Townsends Inlet, and three bay closures, Wildwood Blvd BC, Stone Harbor Blvd BC, and Sea Isle Blvd BC. The combination of these measures creates the three alternatives shown in Figure 26.

The South Region has four inlets with a high level of interdependency plus environmental concerns at Hereford Inlet. For any proposed alternative to have a noticeable impact on stage height reductions, all four inlets need to be closed. In Table 15 and Figure 26, the last two alternatives have some non-structural measures included due to concerns about induced damages, but the additional AAB and AAC from these components is minor and does not affect the economic justification of the alternatives.

Table 15 displays the AANB and BCR results for the three storm surge barrier and bay closure combination alternatives.

Table 15: South Region Storm Surge Barrier Alternatives

ITEM	**Cape May Canal + Cape May Inlet + Hereford Inlet + Townsends Inlet**	**Cape May Canal + Cape May Inlet + Hereford Inlet + Townsends Inlet + Sea Isle Blvd BC**	**Cape May Canal + Cape May Inlet + Wildwood Blvd BC + Stone Harbor Blvd BC + Townsends Inlet + Sea Isle Blvd BC**
Initial Construction	$4,639,279,000	$5,265,569,000	$5,924,476,000
AAC	***$274,620,000***	***$308,994,000***	***$344,010,000***
AAD Without	$310,626,000	$310,626,000	$310,626,000
AAD With	$19,772,000	$12,431,000	$16,702,000
AAB	***$290,854,000***	***$298,195,000***	***$293,924,000***
AANB	***$16,233,000***	***-$10,799,000***	***-$50,086,000***
BCR	***1.06***	***0.97***	***0.85***
Residual Damage	6.4%	4.0%	5.4%
O&M	$71,610,000	$80,302,000	$89,110,000

Closing all four of the inlets in the South Region is economically justified, but ignores serious environmental concerns and potential mitigation costs at Herford Inlet.

Adding a bay closure at Sea Isle Blvd does drive down residual damages, but decreases overall AANB and drives the BCR below 1.0. Replacing the storm surge barrier at Hereford Inlet with two bay closure avoids some of the potential mitigation costs, but adds significant construction costs to the alternatives and drives the BCR further below 1.0.

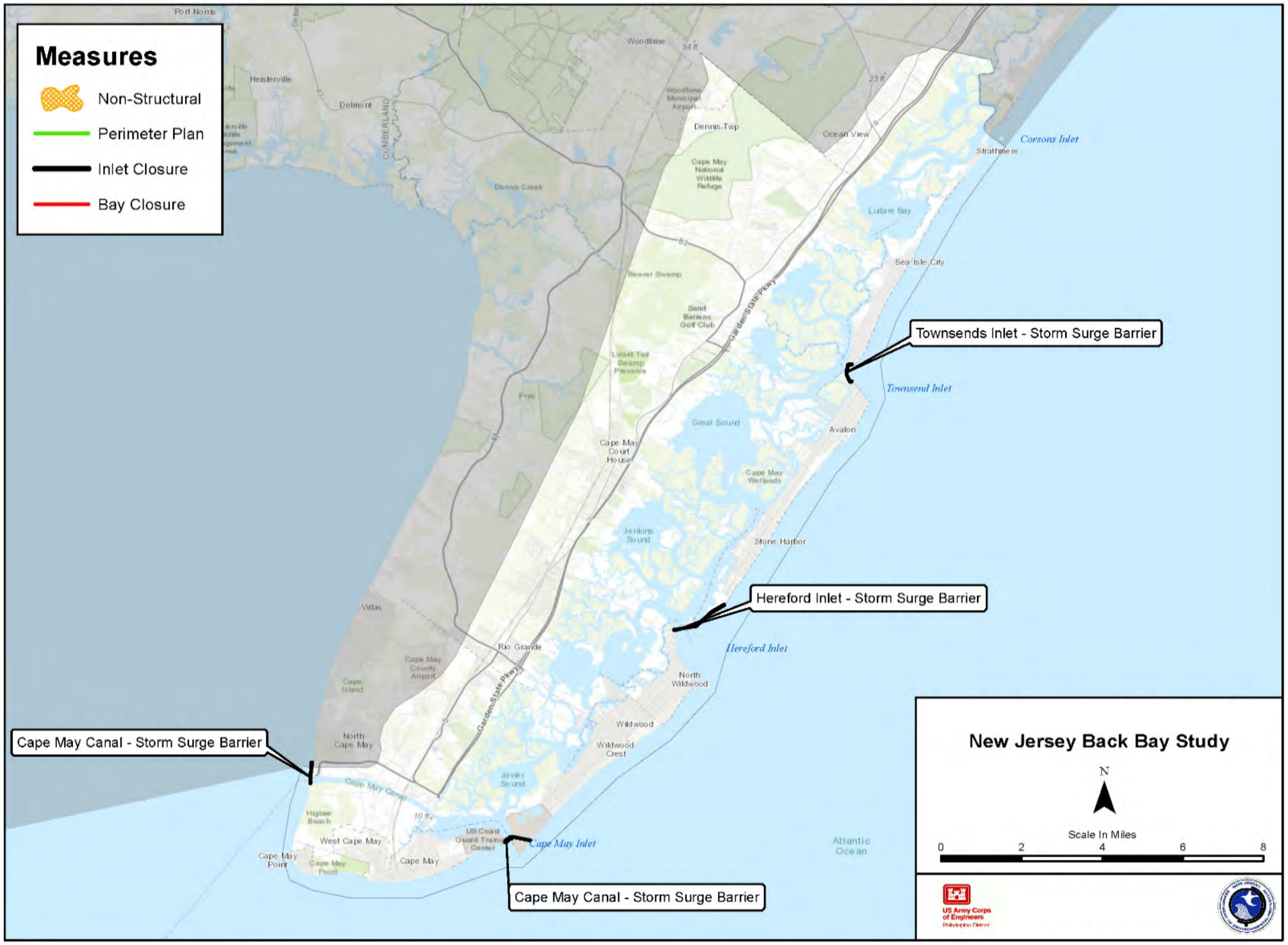
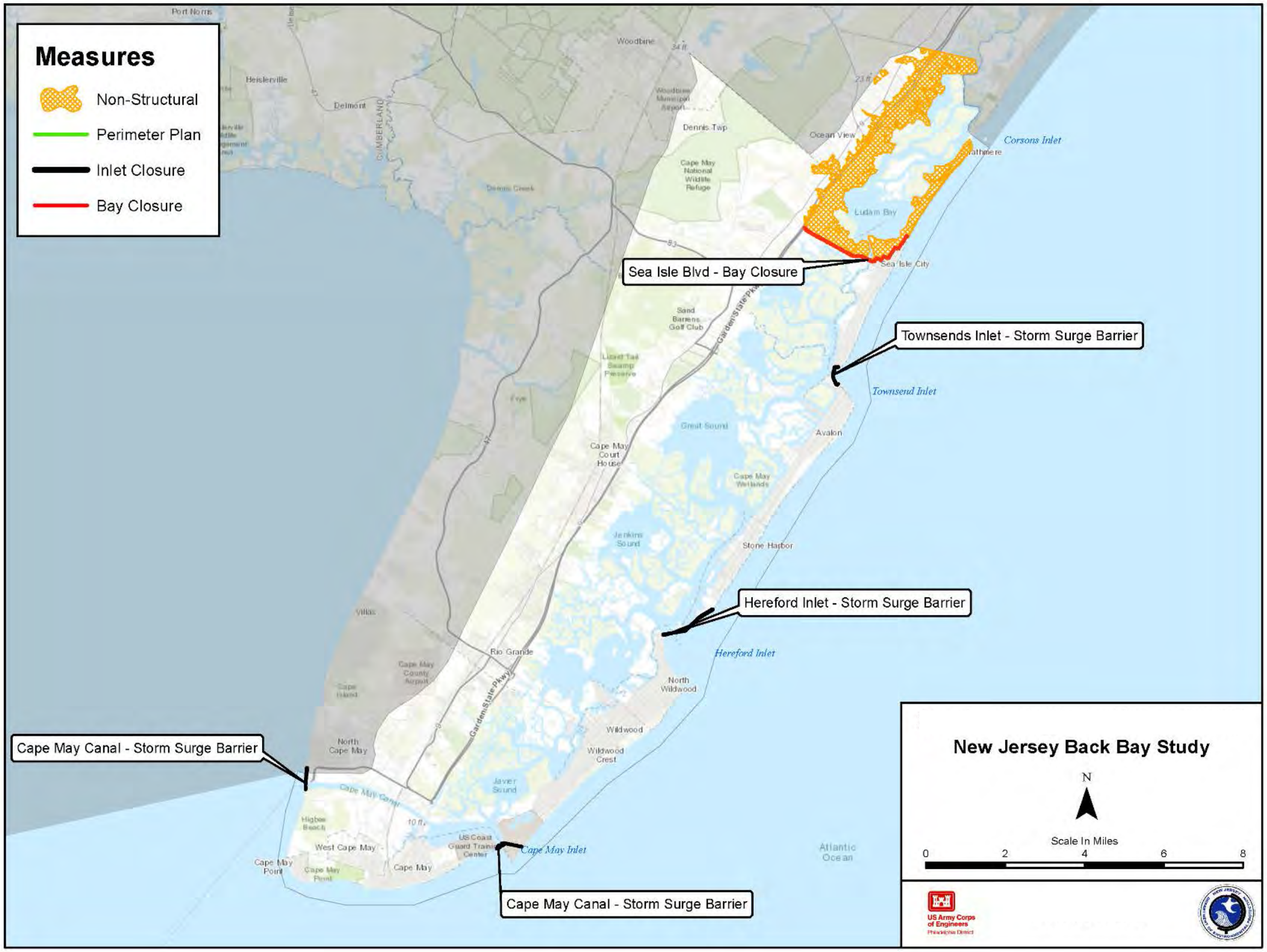
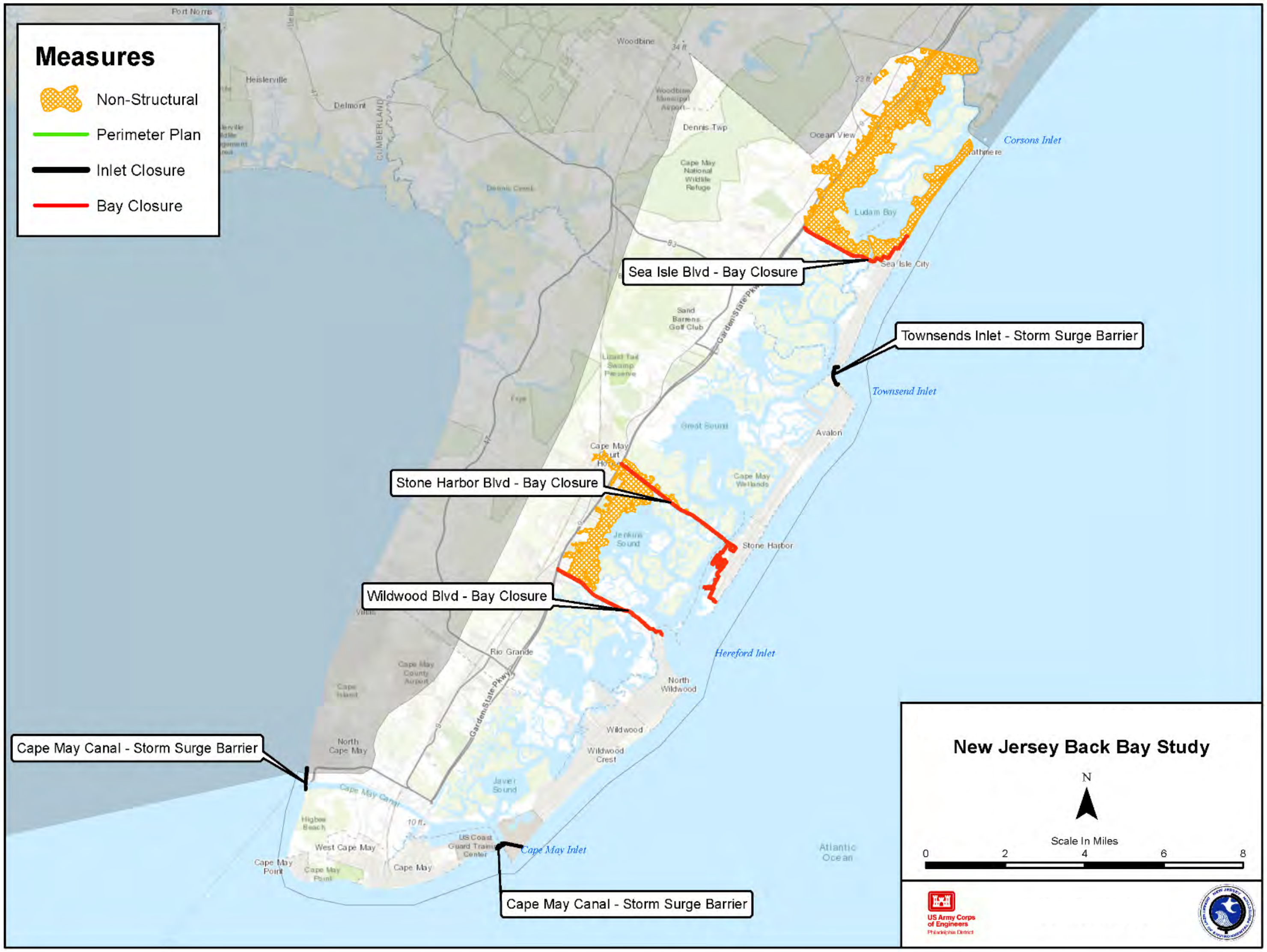


Figure 26: South Region Storm Surge Barrier Alternatives


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle Blvd - Bay Closure
Townsends Inlet - Storm Surge Barrier
Hereford Inlet - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
New Jersey Back Bay Study
N
Scale In Miles
0 2 4 6 8
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Avalon
Stone Harbor
North Wildwood
Wildwood
Sea Isle City
Rio Grande
North Cape May
West Cape May
Cape May
Atlantic Ocean


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle Blvd - Bay Closure
Townsends Inlet - Storm Surge Barrier
Stone Harbor Blvd - Bay Closure
Wildwood Blvd - Bay Closure
Cape May Canal - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Sea Isle City
Avalon
Stone Harbor
North Wildwood
Wildwood
Wildwood Crest
Cape May
West Cape May
Rio Grande
Atlantic Ocean
New Jersey Back Bay Study
N
Scale In Miles
0 2 4 6 8
US Army Corps of Engineers

C-6) HYBRID NED (MULTI-MEASURE) ALTERNATIVES

Following the evaluation of each potential measure type in isolation, potential CSRM solutions are combined into hybrid, or multi-measure, alternatives. Combining the highest reasonable NED AANB measure from each Region into a single, comprehensive alternative maximizes NED benefits and optimizes CSRM performance.

Description

The following tables show 51 potential measure combinations though not all hybrid alternatives are considered complete nor environmentally acceptable. All 51 alternatives are shown to provide transparency on the transition from isolated single-measure alternatives to a final Focused Array of complete and implementable hybrid multi-measure plans.

The Focused Array of Alternatives is presented in the following section and is displayed at a Region level.

The 51 alternatives display the incremental combination of measures starting with (A) non-structural only, (B) perimeter only (including non-incrementally justified perimeter measures), (C) justified perimeter only, (D) justified perimeter with non-structural (plus permutations for reasonably marginal perimeter measure locations), (E) storm surge barriers with non-structural and/or perimeter, (F) storm surge barriers with non-structural and/or perimeter and bay closures, and finally (G) storm surge barriers with non-structural and/or perimeter and a different combination of bay closures.

Table 16 provides a brief description of each alternative and Figure 27 provides the visual map for each of the 51 alternatives. Table 17 provides economic data on each measure combination.

It is important to note that the first four alternatives presented are not shown by Region, but displayed as study wide single-measure alternatives. These four alternatives do not consider completeness nor environmental acceptability and should only be viewed as a rough baseline for which NED optimizing hybrid alternatives can improve upon.

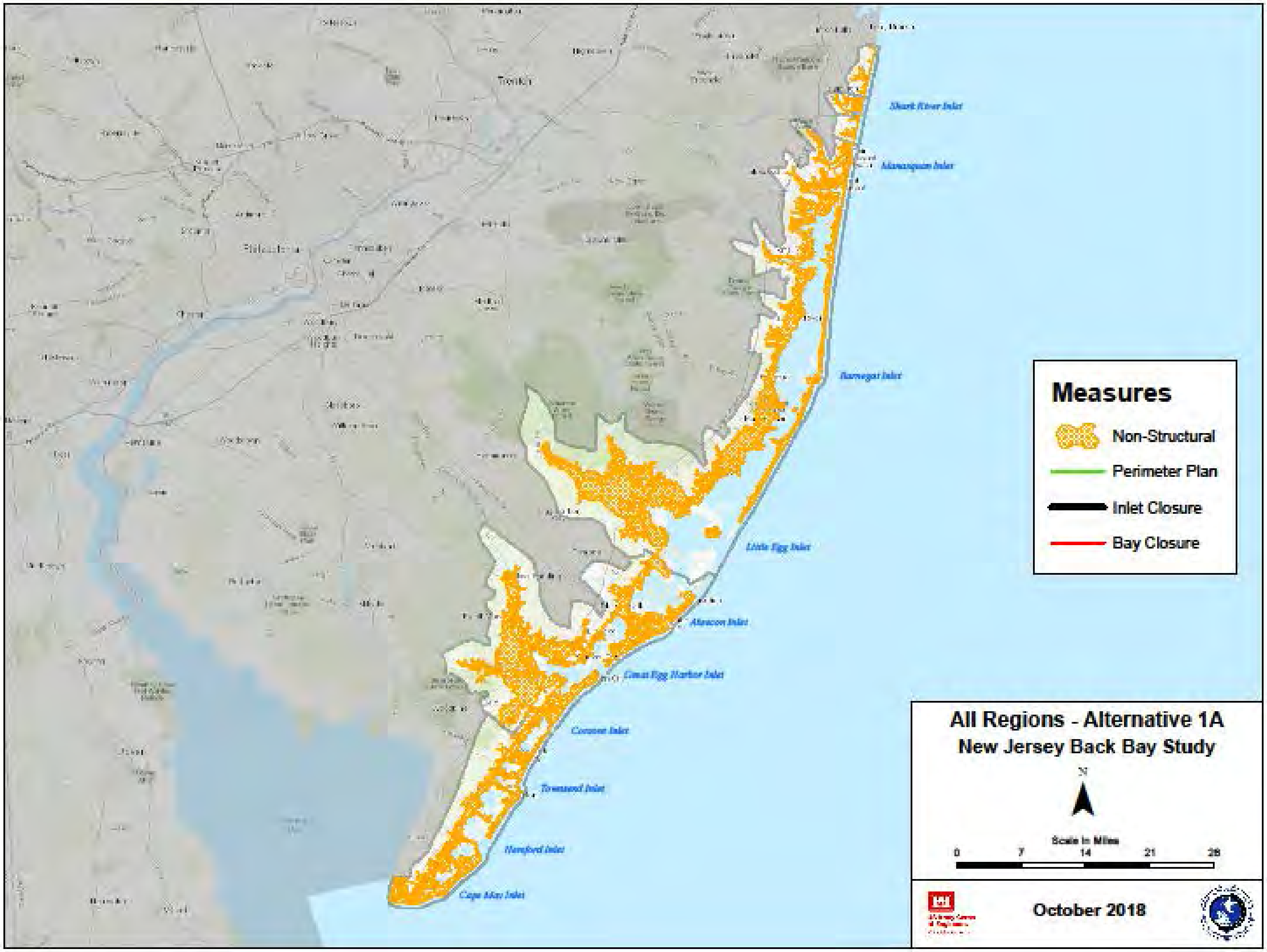
Table 16: Comprehensive List of 51 Regional Alternatives

REGION	PLAN	DESCRIPTION
STUDY WIDE	1A	Non-Structural ONLY
	1B	Perimeter (justified) ONLY
	1C	Storm Surge Barrier ALL INLETS
	1D	Storm Surge Barrier ALL INLETS minus Little Egg Harbor Inlet
SHARK RIVER	2A	Non-Structural ONLY
	2B	Perimeter ONLY
	2C	Storm Surge Barrier ONLY
NORTH REGION	3A	Non-Structural ONLY
	3B	Perimeter ONLY
	3C	Perimeter (justified) ONLY
	3D	Perimeter (justified) + Non-Structural
	3E(1)	Storm Surge Barrier ONLY
	3E(2)	Storm Surge Barrier + Non-Structural
	3E(3)	Storm Surge Barrier + Non-Structural + Perimeter
	3F(1)	Storm Surge Barrier + Bay Closure (Holgate)
	3F(2)	Storm Surge Barrier + Bay Closure (Holgate) + Non-Structural
	3G	Storm Surge Barrier + Bay Closure (Point Pleasant Canal)
CENTRAL REGION	4A	Non-Structural ONLY
	4B	Perimeter ONLY
	4C	Perimeter (justified) ONLY
	4D(1)	Perimeter (justified) + Non-Structural
	4D(2)	Perimeter (justified and non-justified) + Non-Structural
	4E(1)	Storm Surge Barrier ONLY
	4E(2)	Storm Surge Barrier + Non-Structural
	4E(3)	Storm Surge Barrier + Non-Structural + South Ocean City Perimeter
	4E(4)	Storm Surge Barrier + Non-Structural + South Ocean City Bay Closure
	4F(1)	Storm Surge Barrier + Bay Closure (North Point)
	4F(2)	Storm Surge Barrier + Bay Closure (North Point) + Non-Structural
	4F(3)	Storm Surge Barrier + Bay Closure (North Point) + Non-Structural + South Ocean City Perimeter
	4F(4)	Storm Surge Barrier + Bay Closure (North Point) + Non-Structural + South Ocean City Bay Closure
	4G(1)	Storm Surge Barrier + Bay Closure (Absecon Blvd)
	4G(2)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + Non-Structural
	4G(3)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + Non-Structural + South Ocean City Perimeter
	4G(4)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + Non-Structural + South Ocean City Bay Closure
	4G(5)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + NS Brigantine + South Ocean City No-Action
	4G(6)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + NS Brigantine + South Ocean City Non-Structural
	4G(7)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + NS Brigantine + South Ocean City Perimeter
	4G(8)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + NS Brigantine + South Ocean City Bay Closure
	4G(9)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + PM Brigantine + South Ocean City No-Action
	4G(10)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + PM Brigantine + South Ocean City Non-Structural
	4G(11)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + PM Brigantine + South Ocean City Perimeter
	4G(12)	Storm Surge Barrier + Bay Closure (Absecon Blvd) + PM Brigantine + South Ocean City Bay Closure
SOUTH REGION	5A	Non-Structural ONLY
	5B	Perimeter ONLY
	5C	Perimeter (justified) ONLY
	5D(1)	Perimeter (justified) + Non-Structural
	5D(2)	Perimeter (justified and non-justified) + Non-Structural
	5E(1)	Storm Surge Barrier ONLY
	5E(2)	Storm Surge Barrier + Non-Structural
	5F	Storm Surge Barrier + Non-Structural + Bay Closure (Sea Isle Blvd)
	5G	Storm Surge Barrier + Non-Structural + Bay Closure (Sea Isle Blvd, Wildwood Blvd, Stone Harbor Blvd)

*NS = Non-Structural, PM = Perimeter Measure

Figure 27: Comprehensive List of Figures for 51 Regional Alternatives

See Following Maps: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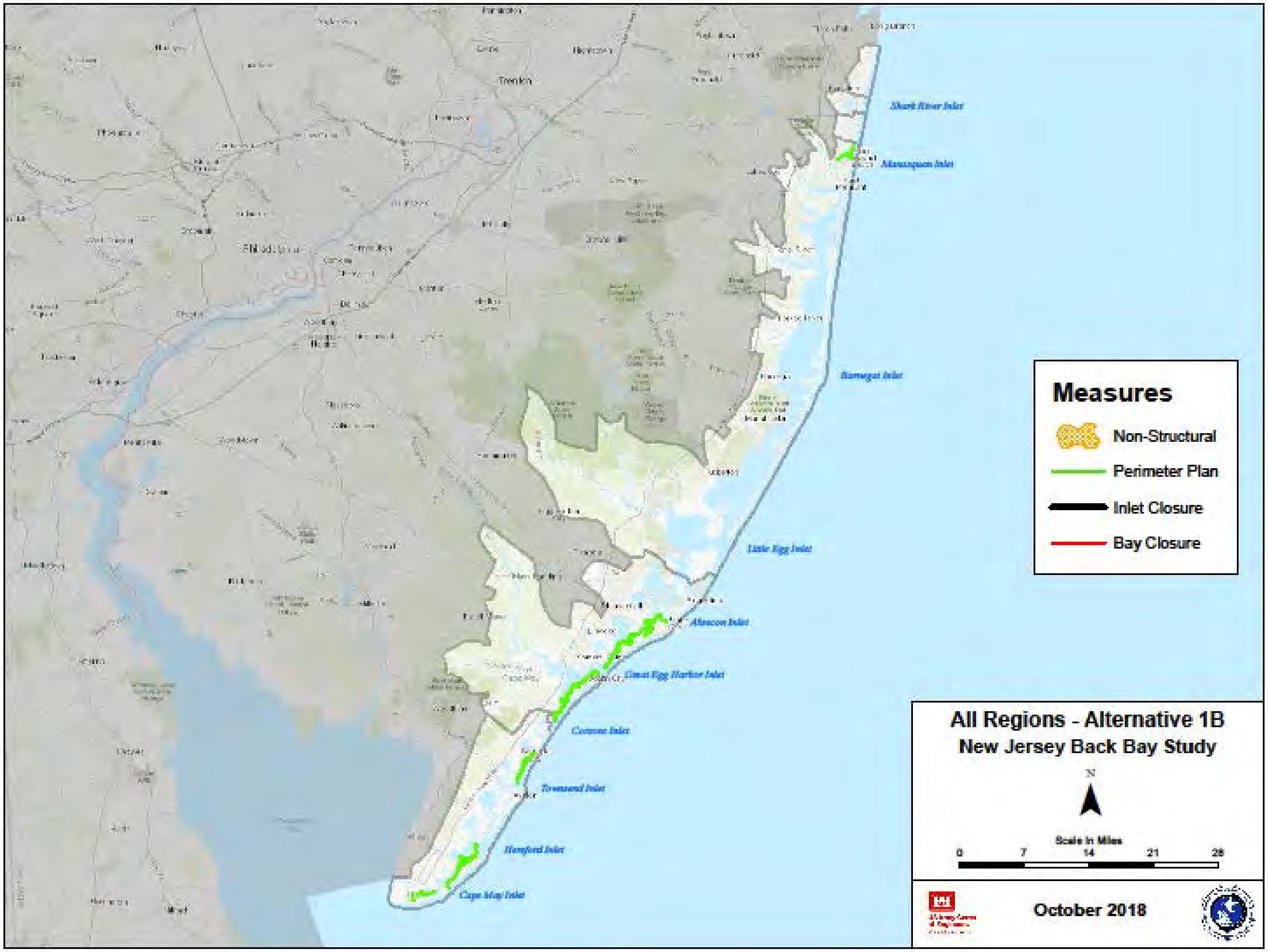
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corson Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Trenton
Philadelphia
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
All Regions - Alternative 1A
New Jersey Back Bay Study
N
Scale in Miles
0
7
14
21
28
October 2018


Measures
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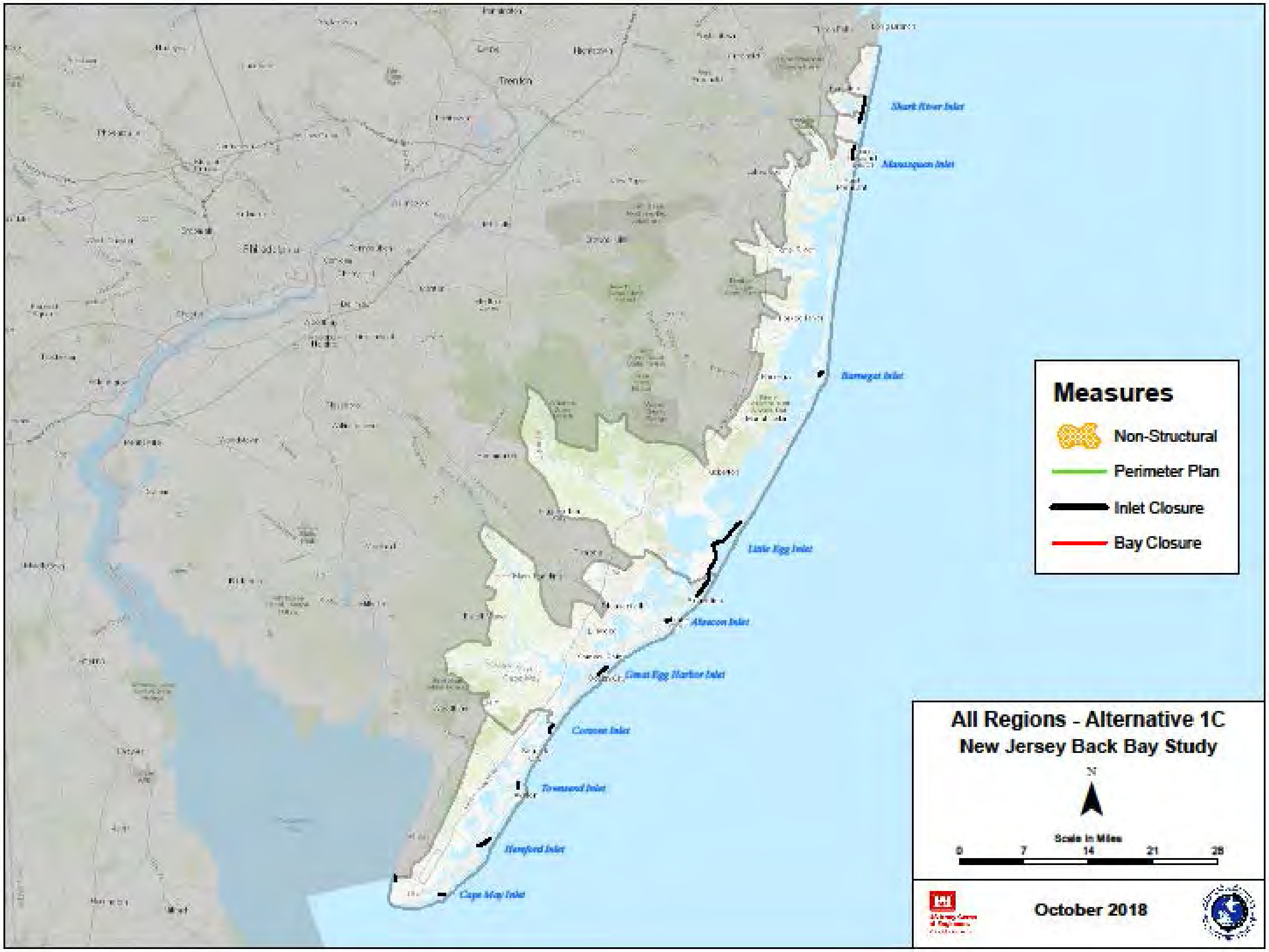
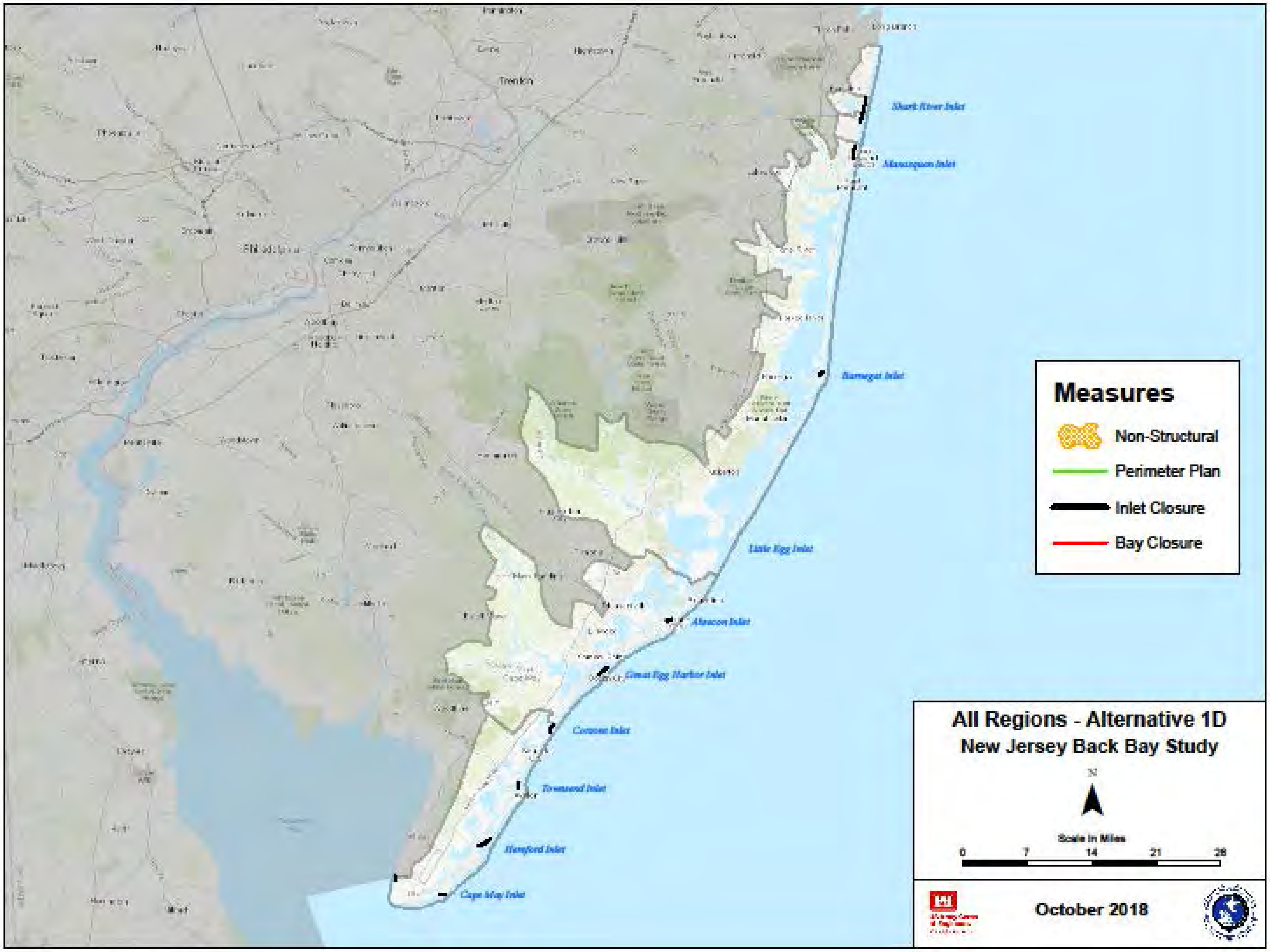
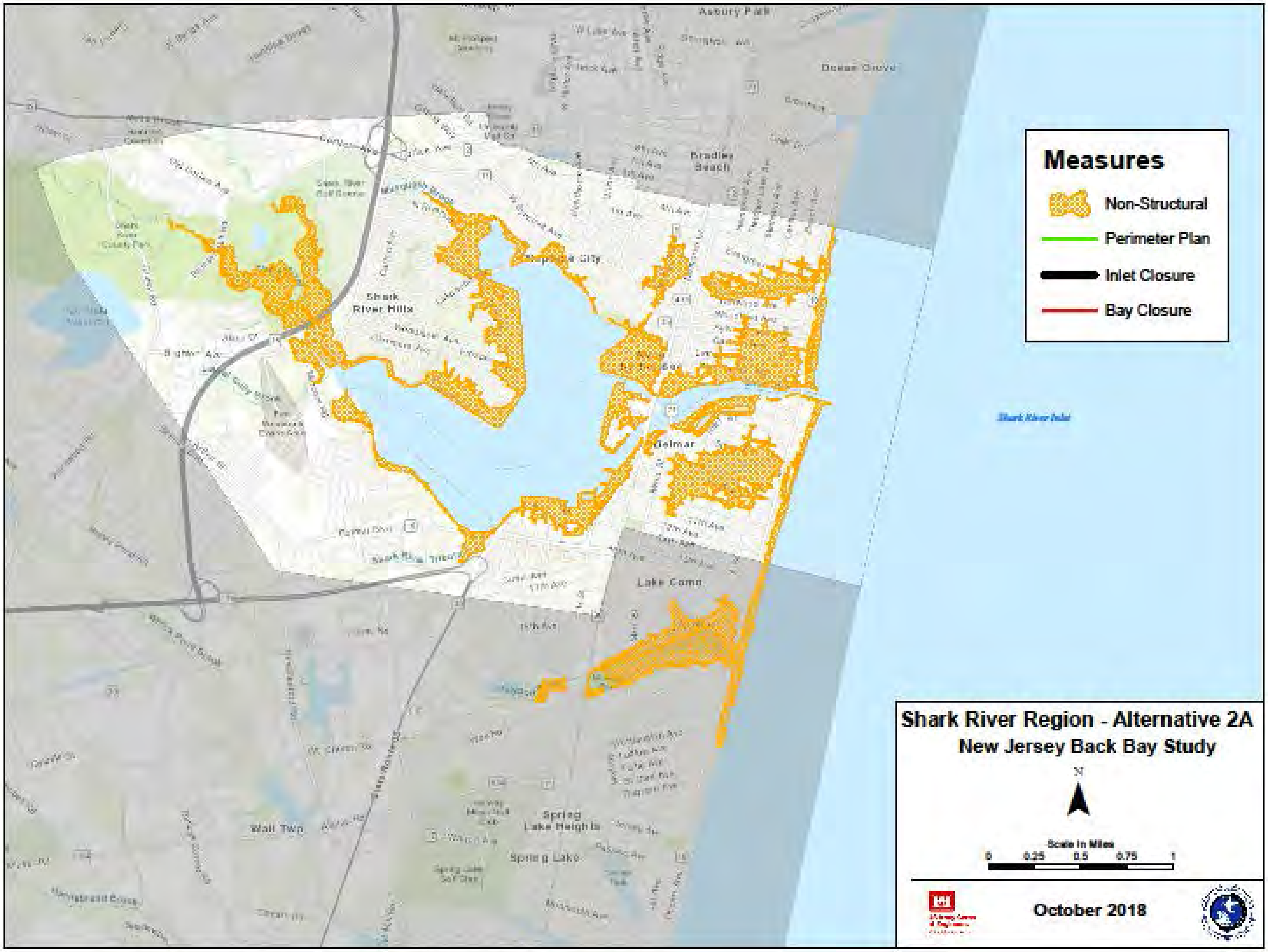
Perimeter Plan
Inlet Closure
Bay Closure
All Regions - Alternative 1B
New Jersey Back Bay Study
N
Scale in Miles
0 7 14 21 28
October 2018
Trenton
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corson Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet


Trenton
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corson Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
All Regions - Alternative 1C
New Jersey Back Bay Study
N
Scale in Miles
0
7
14
21
28
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
All Regions - Alternative 1D
New Jersey Back Bay Study
N
Scale In Miles
0
7
14
21
28
October 2018
Trenton
Philadelphia
Shark River Inlet
Manasquan Inlet
Barnegat Inlet
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corson Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet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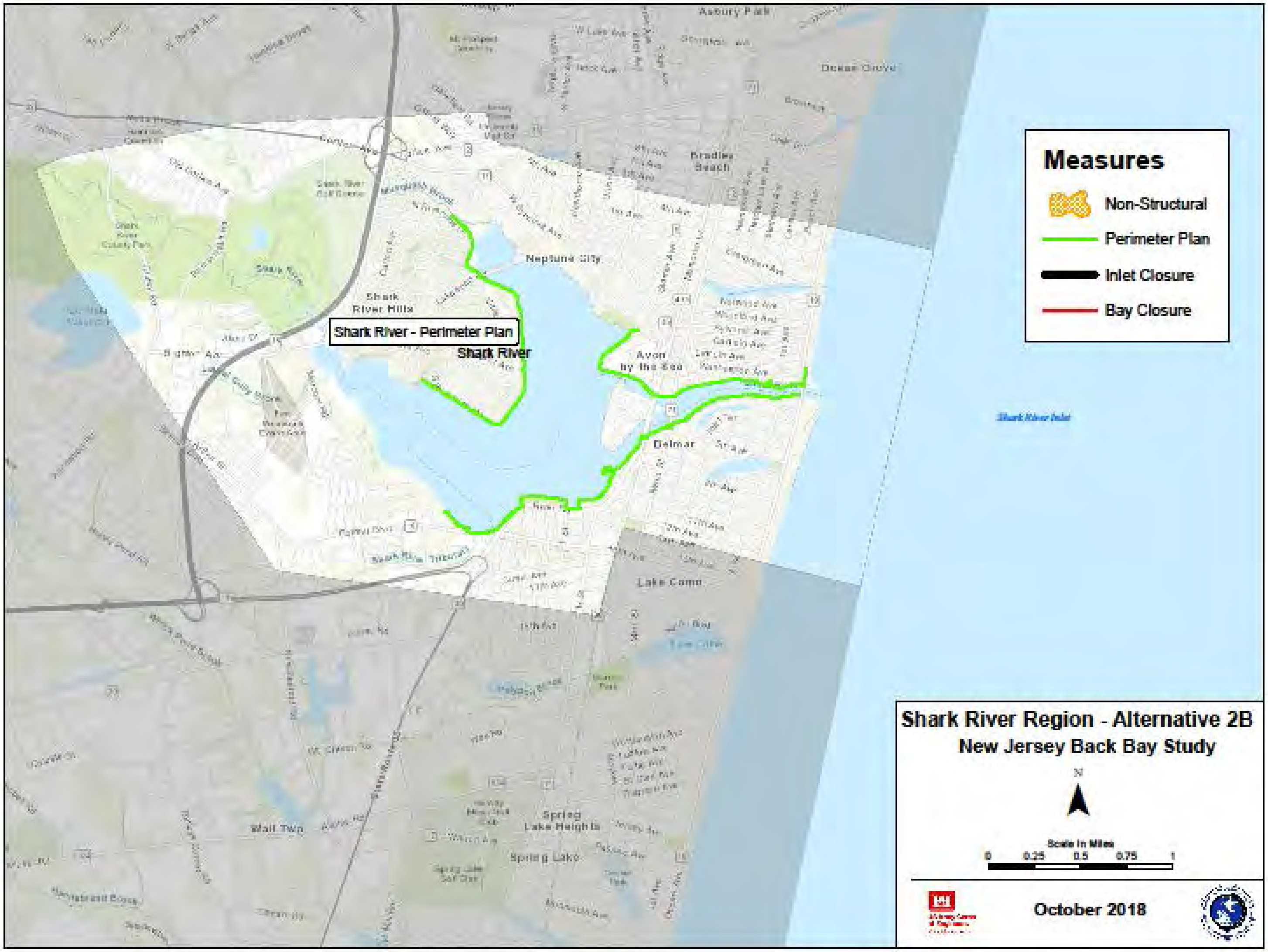
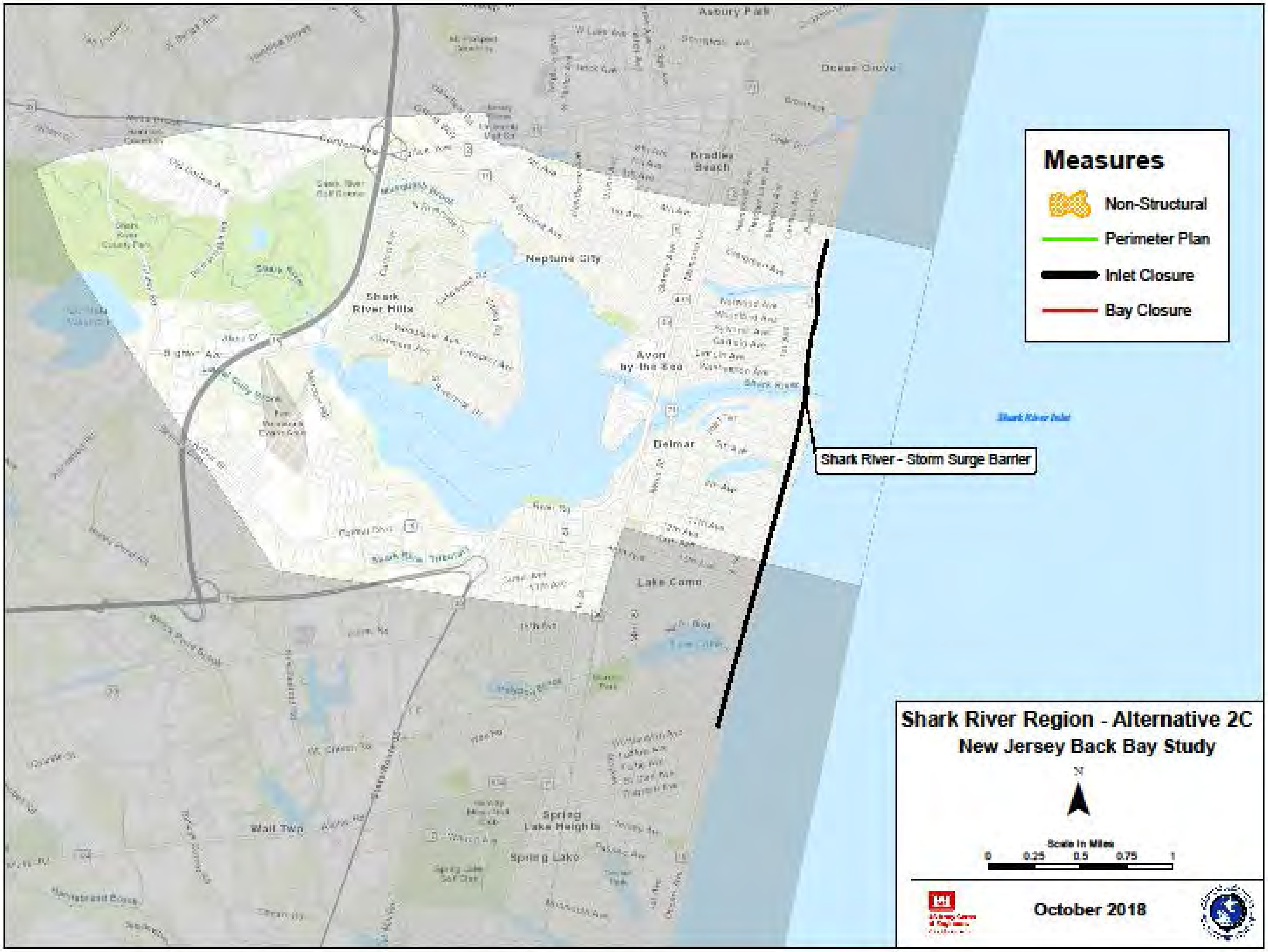
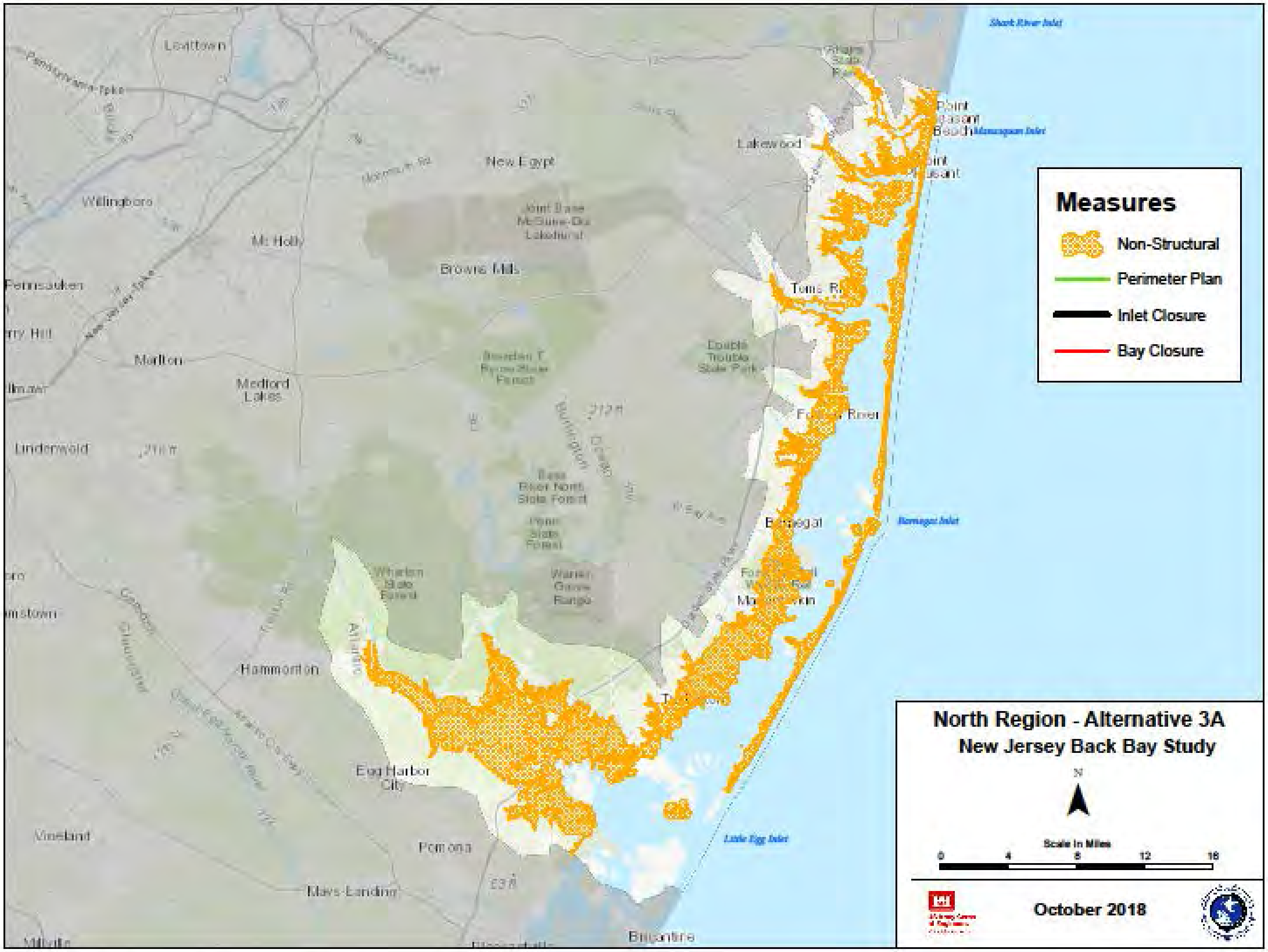
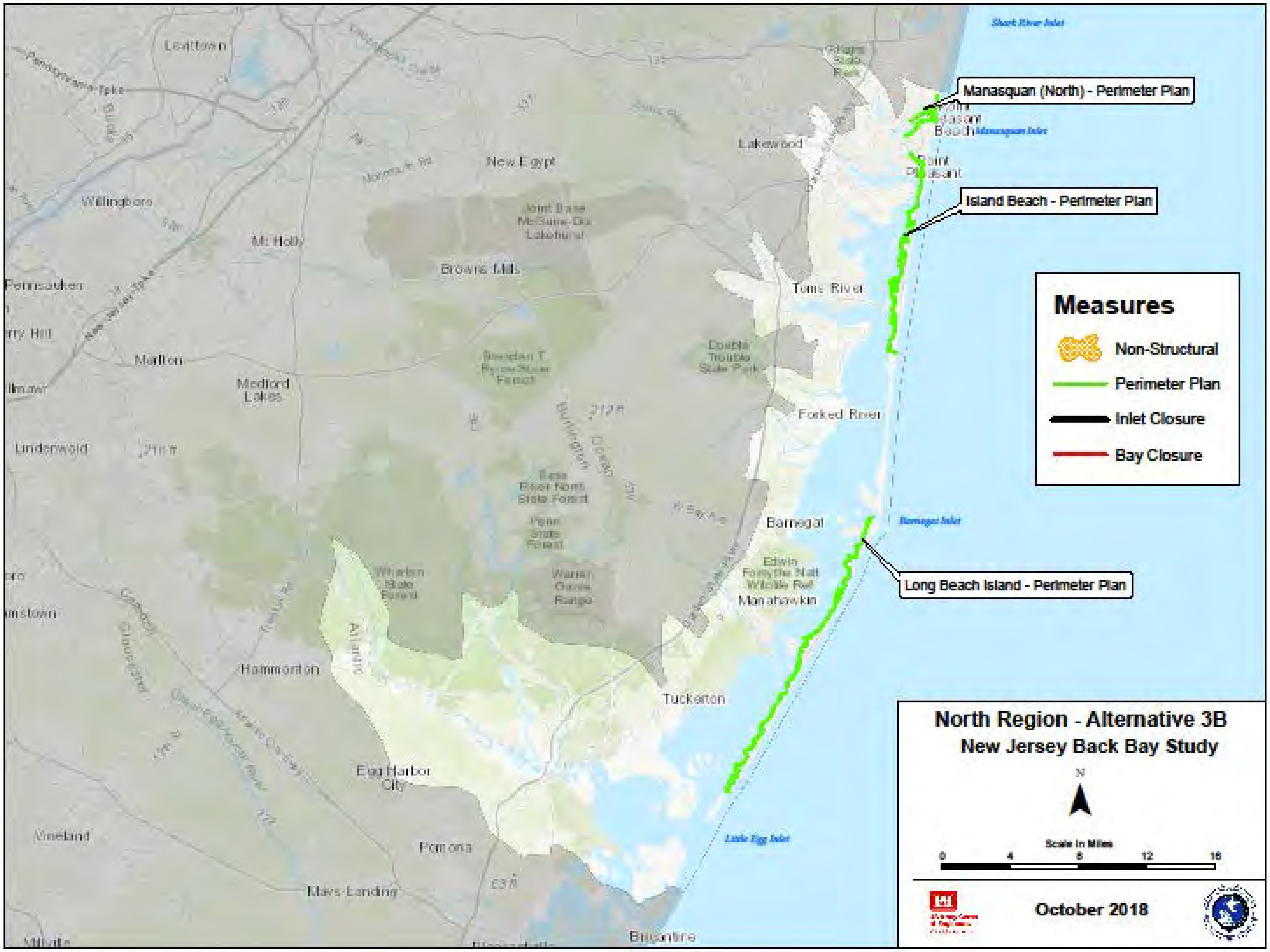
Perimeter Plan
Inlet Closure
Bay Closure
Shark River Region - Alternative 2A
New Jersey Back Bay Study
October 2018



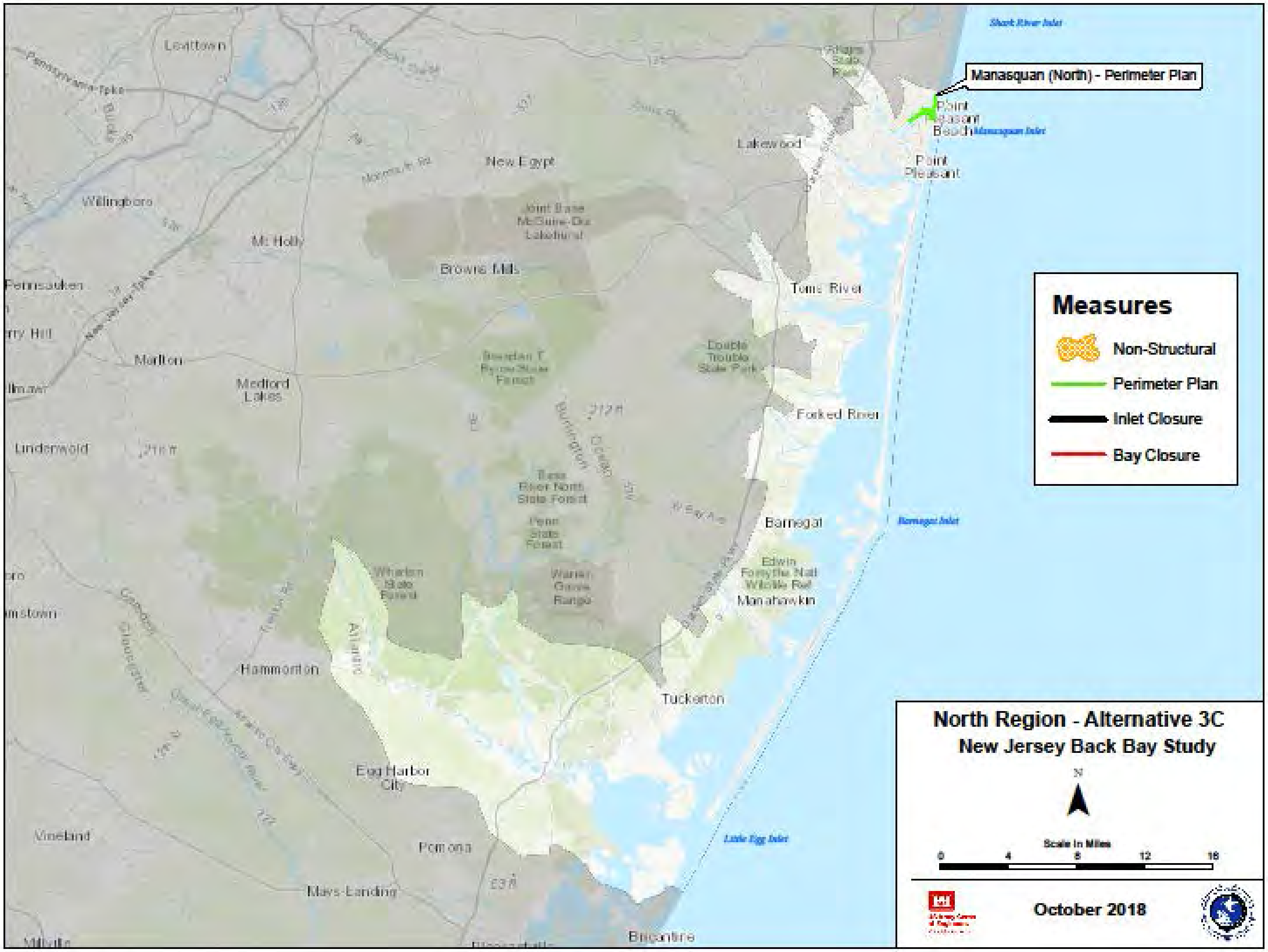
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Shark River - Perimeter Plan
Shark River
Shark River Inlet
Shark River Region - Alternative 2B
New Jersey Back Bay Study
N
Scale in Miles
0 0.25 0.5 0.75 1
October 2018

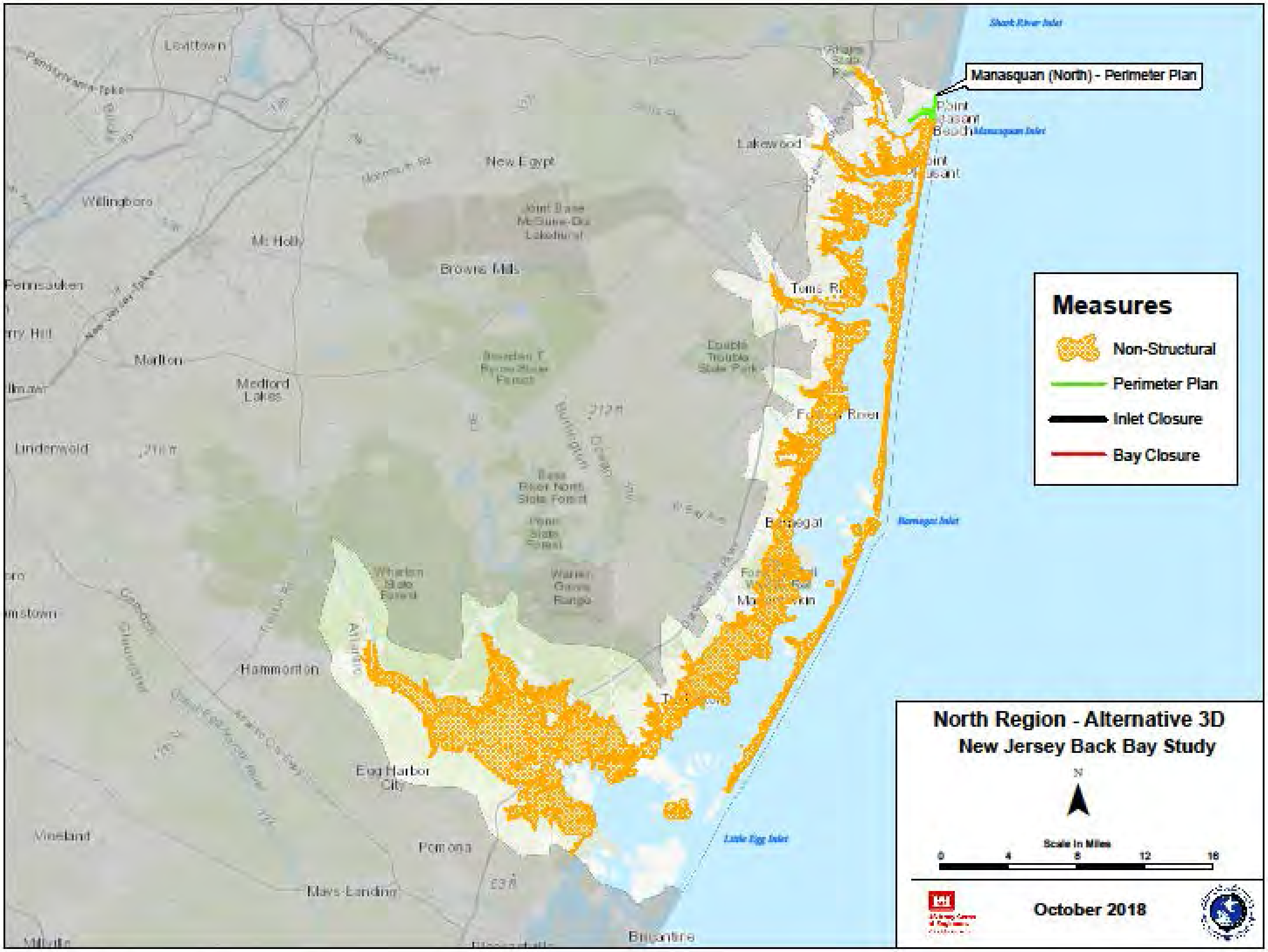

Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Shark River - Storm Surge Barrier
Shark River Inlet
Shark River Region - Alternative 2C
New Jersey Back Bay Study
N
Scale in Miles
0 0.25 0.5 0.75 1
October 2018
Neptune City
Shark River Hills
Avon by the Sea
Belmar
Lake Como
Bradley Beach
Asbury Park
Ocean Grove
Spring Lake Heights
Spring Lake
Wall Twp

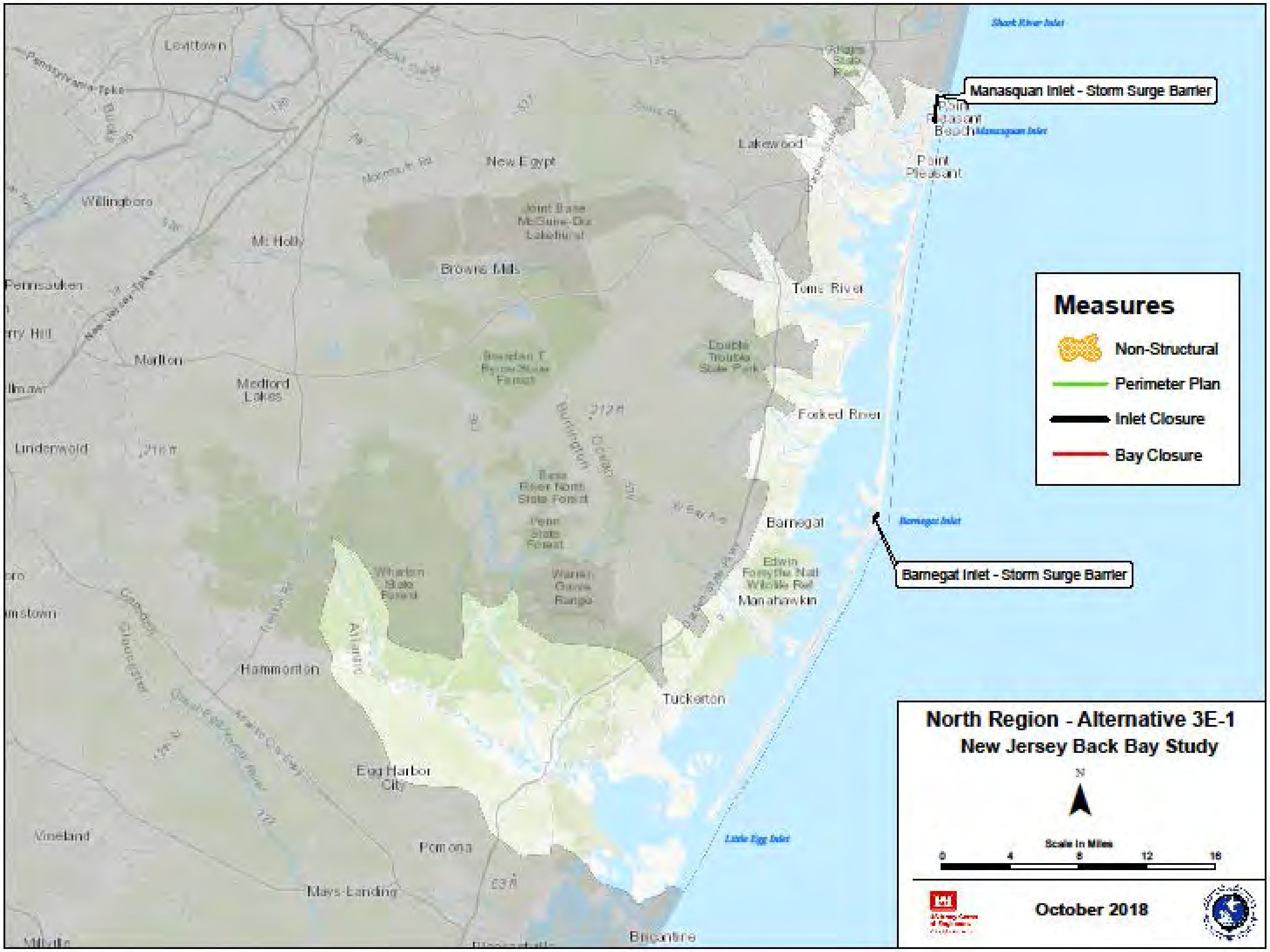

Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3A
New Jersey Back Bay Study
October 2018

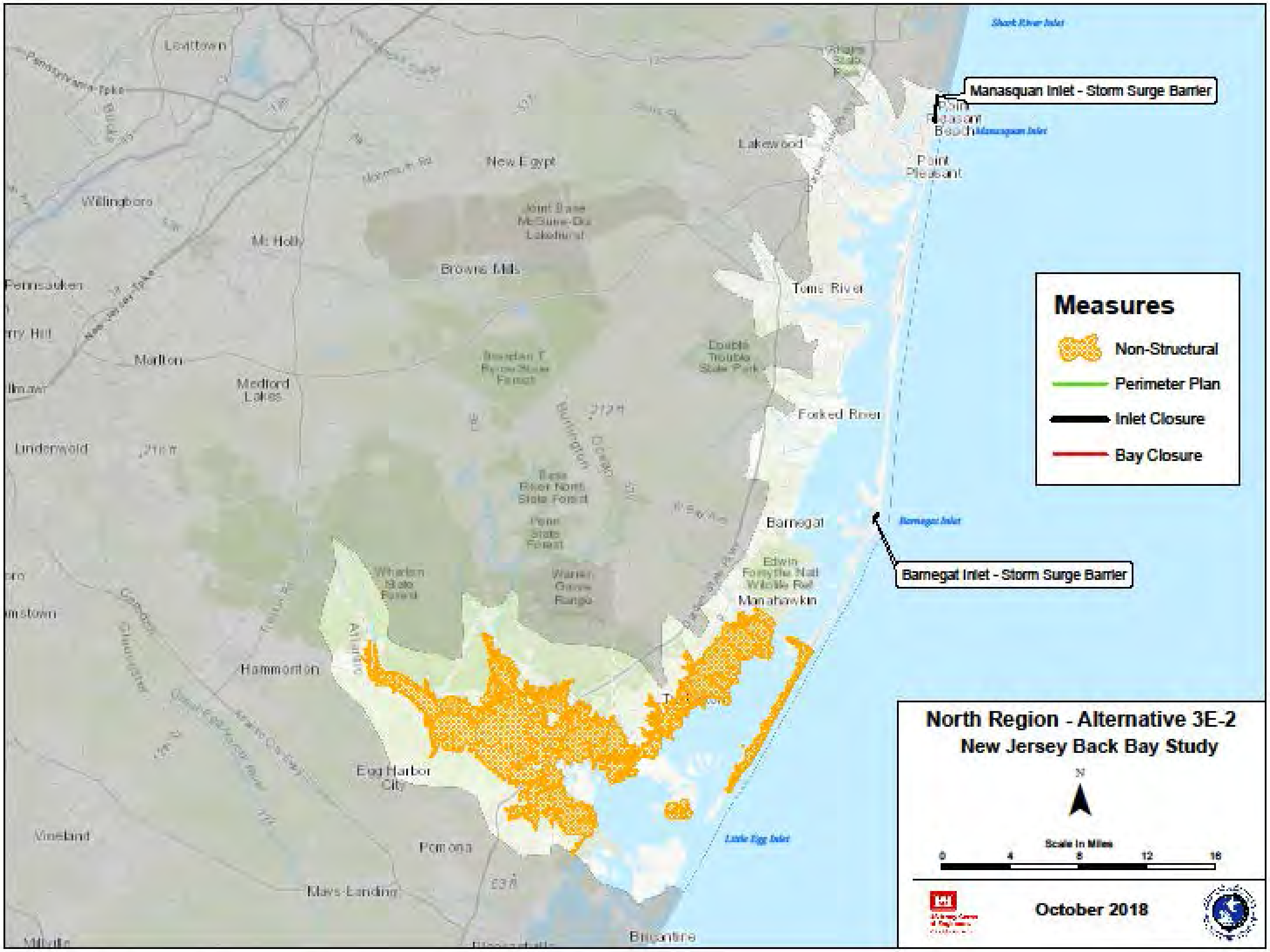


Manasquan (North) - Perimeter Plan
Island Beach - Perimeter Plan
Long Beach Island - Perimeter Plan
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3B
New Jersey Back Bay Study
N
Scale In Miles
0
4
8
12
16
October 2018
Lakewood
New Egypt
Willingboro
Mt Holly
Browns Mills
Toms River
Forked River
Barnegat
Manahawkin
Tuckerton
Hammonton
Egg Harbor City
Pomona
Mays Landing
Brigantine
Vineland
Marlton
Medford Lakes
Levittown


Manasquan (North) - Perimeter Plan
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3C
New Jersey Back Bay Study
N
Scale In Miles
0 4 8 12 16
October 2018
Levittown
Willingboro
Mt Holly
New Egypt
Browns Mills
Lakewood
Point Pleasant Beach
Point Pleasant
Toms River
Forked River
Barnegat
Manahawkin
Tuckerton
Marlton
Medford Lakes
Pennsauken
Lindenwold
Hammonton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine


Manasquan (North) - Perimeter Plan
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3D
New Jersey Back Bay Study
October 2018
Lakewood
New Egypt
Browns Mills
Toms River
Hammonton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine
Willingboro
Mt Holly
Marlton
Medford Lakes
Levittown
Pennsauken
Lindenwold


Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3E-1
New Jersey Back Bay Study
Scale In Miles
0
4
8
12
16
October 2018
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant
Browns Mills
Toms River
Marlton
Medford Lakes
Forked River
Barnegat
Manahawkin
Hammonton
Tuckerton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine


Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3E-2
New Jersey Back Bay Study
N
Scale In Miles
0
4
8
12
16
October 2018
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant
Browns Mills
Toms River
Marlton
Medford Lakes
Forked River
Barnegat
Manahawkin
Hammonton
Egg Harbor City
Pomona
Vineland
Mays Landing
Brigantine
Lindenwold

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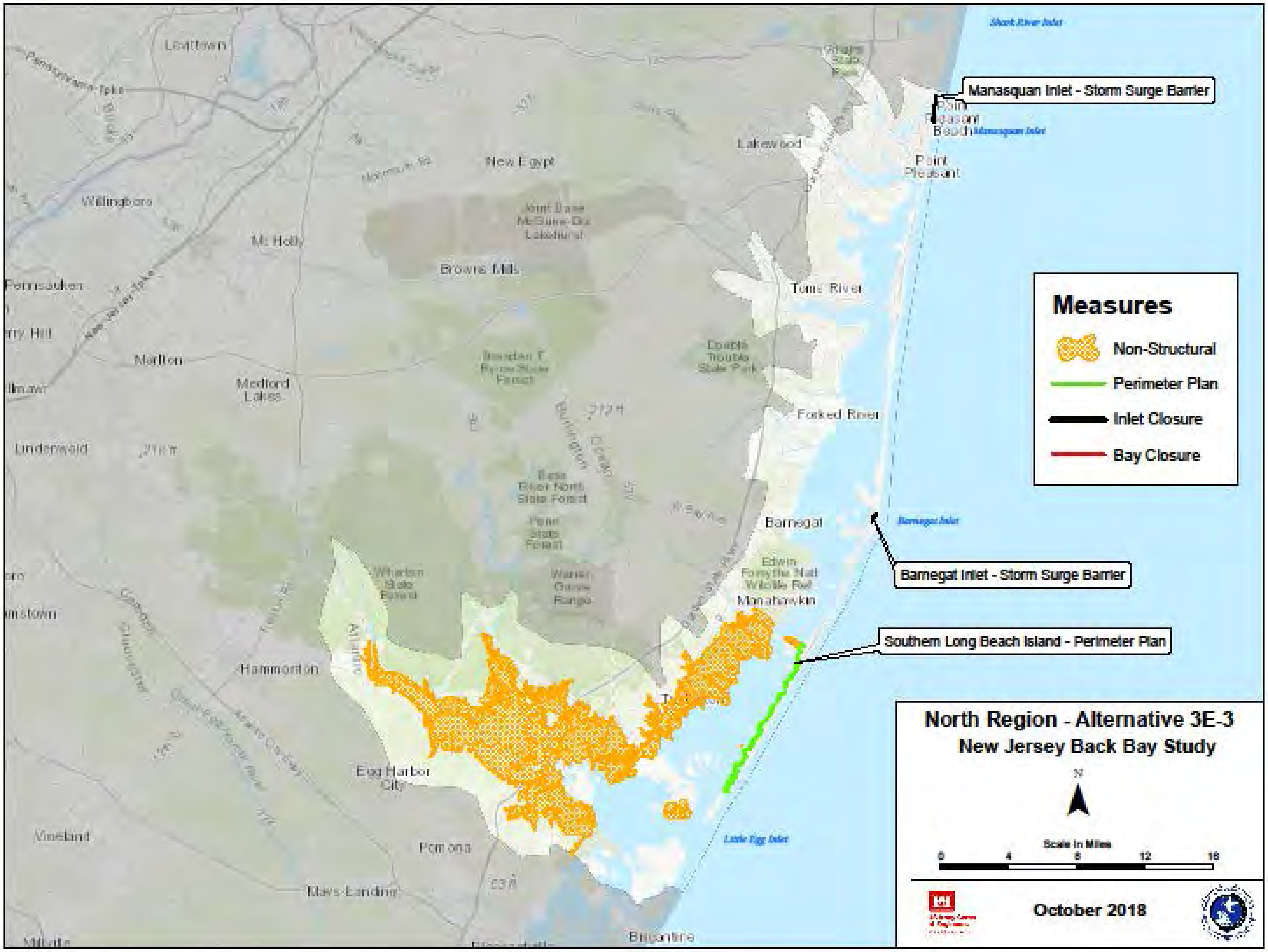
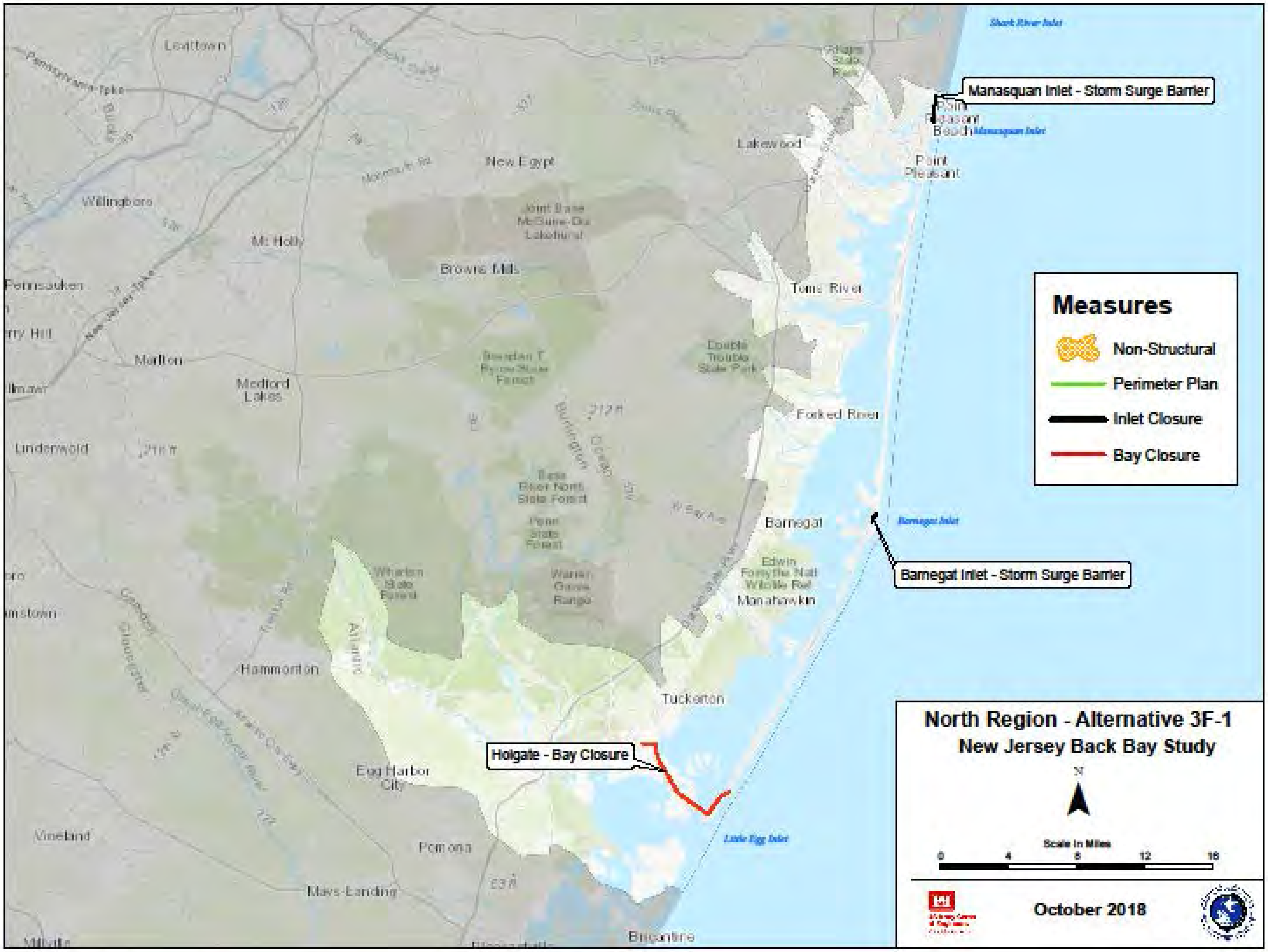
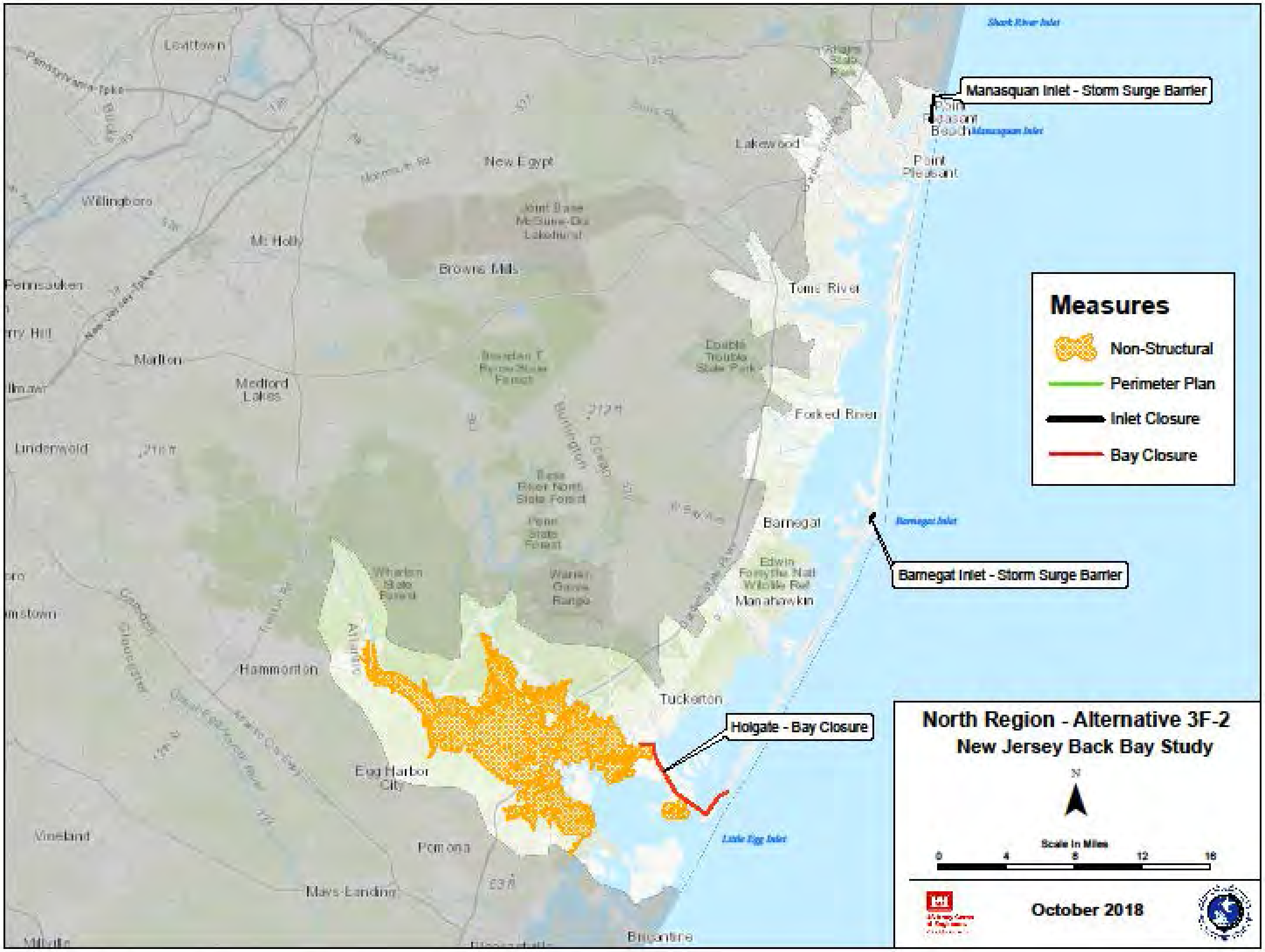

Manasquan Inlet - Storm Surge Barrier
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Barnegat Inlet - Storm Surge Barrier
Southern Long Beach Island - Perimeter Plan
North Region - Alternative 3E-3
New Jersey Back Bay Study
N
Scale In Miles
0
4
8
12
16
October 2018
Levittown
Willingboro
New Egypt
Lakewood
Point Pleasant
Browns Mills
Toms River
Marlton
Medford Lakes
Forked River
Barnegat
Manahawkin
Hammonton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine


Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Holgate - Bay Closure
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3F-1
New Jersey Back Bay Study
N
Scale In Miles
0
4
8
12
16
October 2018
Levittown
Willingboro
Mt Holly
New Egypt
Browns Mills
Lakewood
Point Pleasant
Point Pleasant Beach
Toms River
Forked River
Barnegat
Manahawkin
Tuckerton
Marlton
Medford Lakes
Hammonton
Egg Harbor City
Pomona
Vineland
Mays Landing
Brigantine
Pennsauken
Lindenwold


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Manasquan Inlet - Storm Surge Barrier
Barnegat Inlet - Storm Surge Barrier
Holgate - Bay Closure
North Region - Alternative 3F-2
New Jersey Back Bay Study
Scale In Miles
0
4
8
12
16
October 2018
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant
Browns Mills
Toms River
Pennsauken
Marlton
Medford Lakes
Forked River
Lindenwold
Barnegat
Manahawkin
Hammonton
Tuckerton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine

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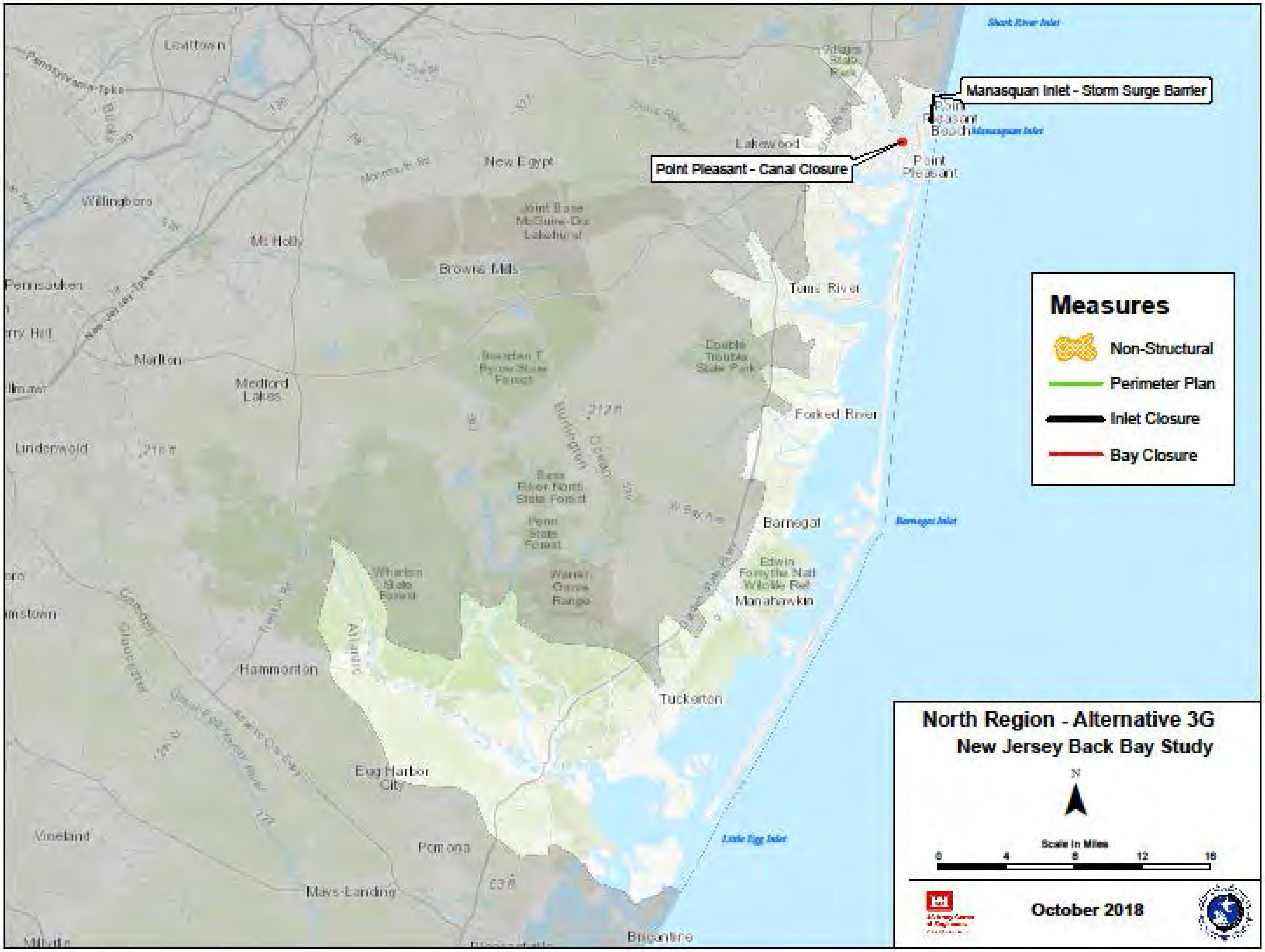
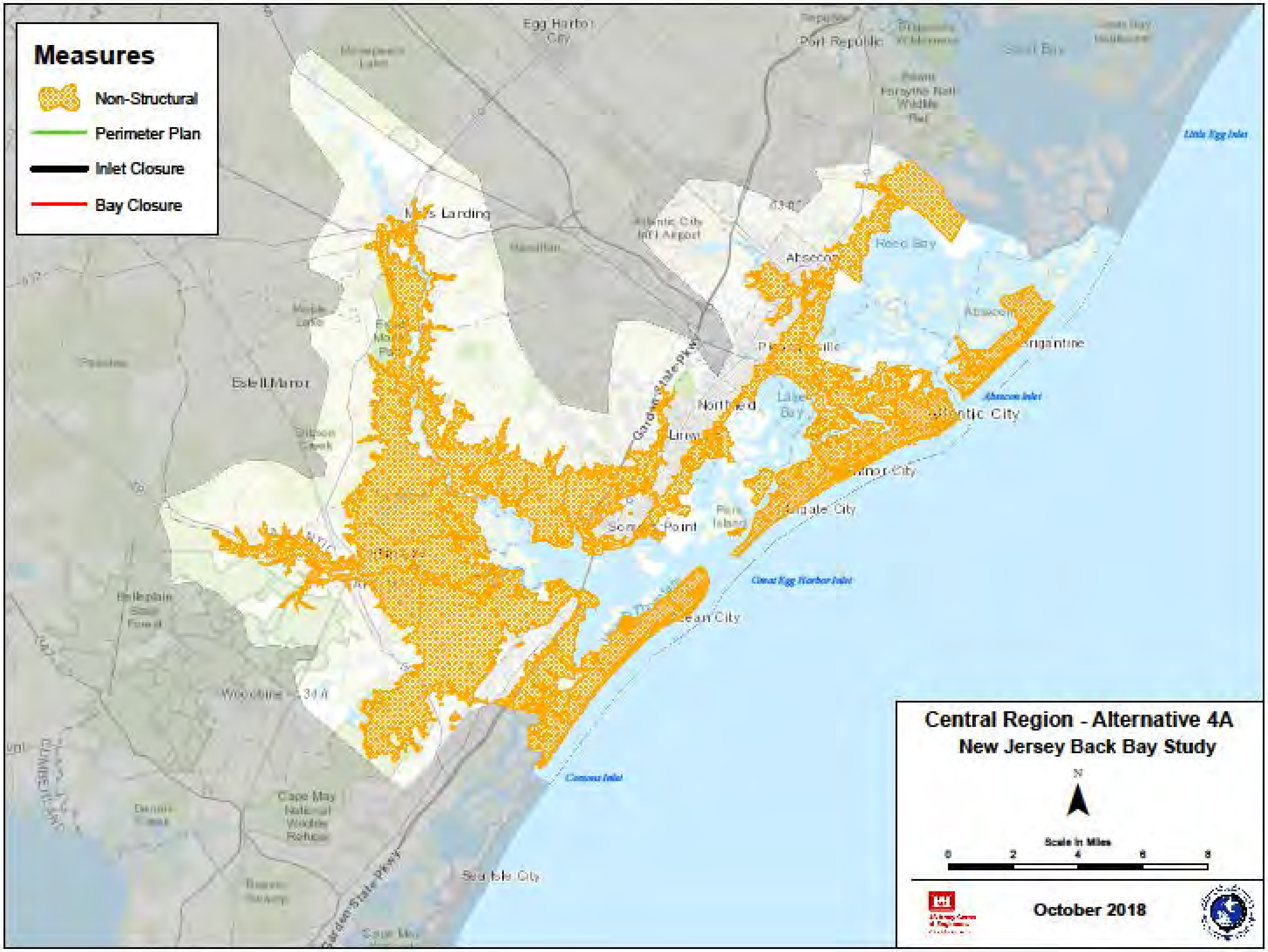
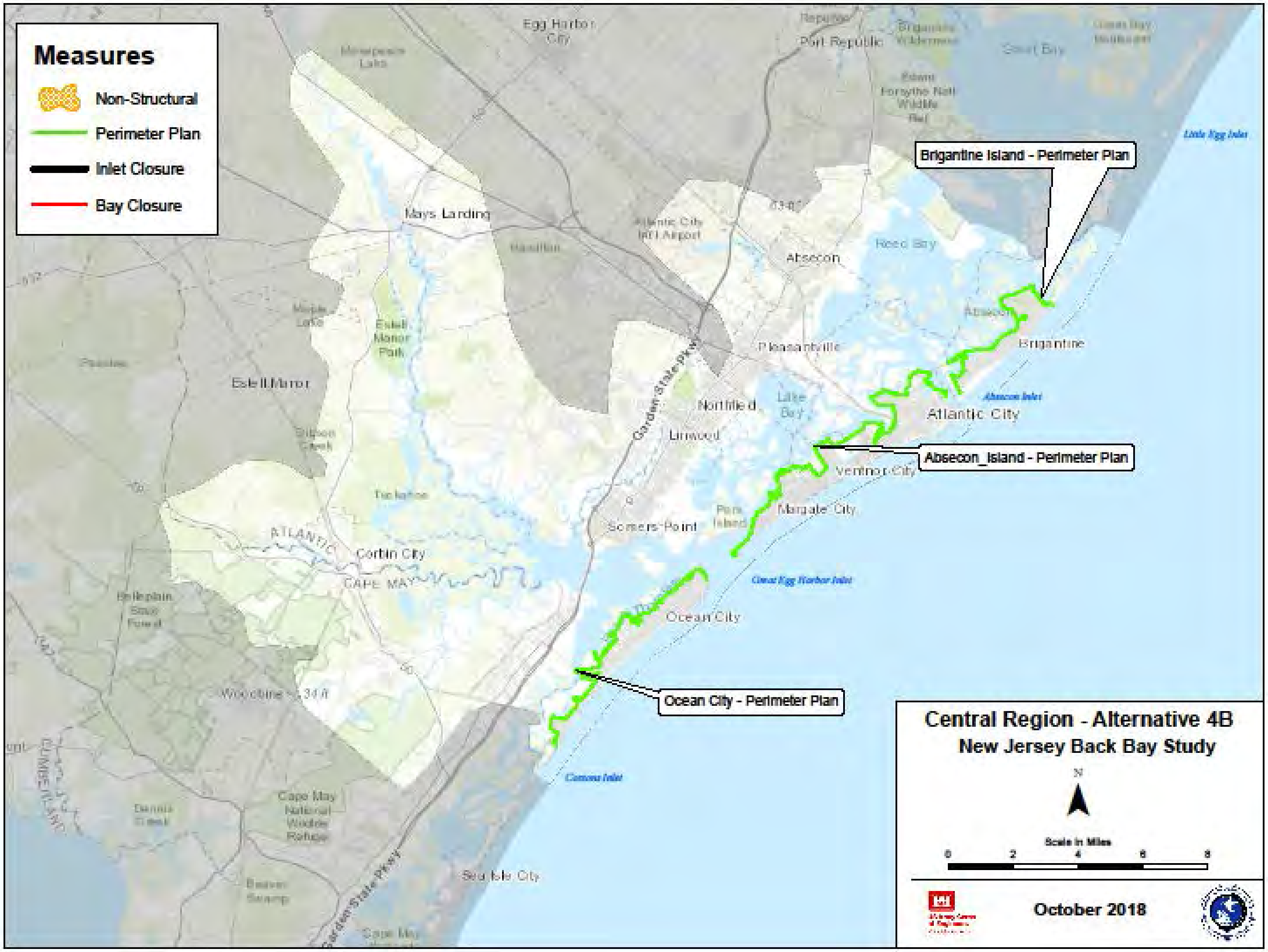
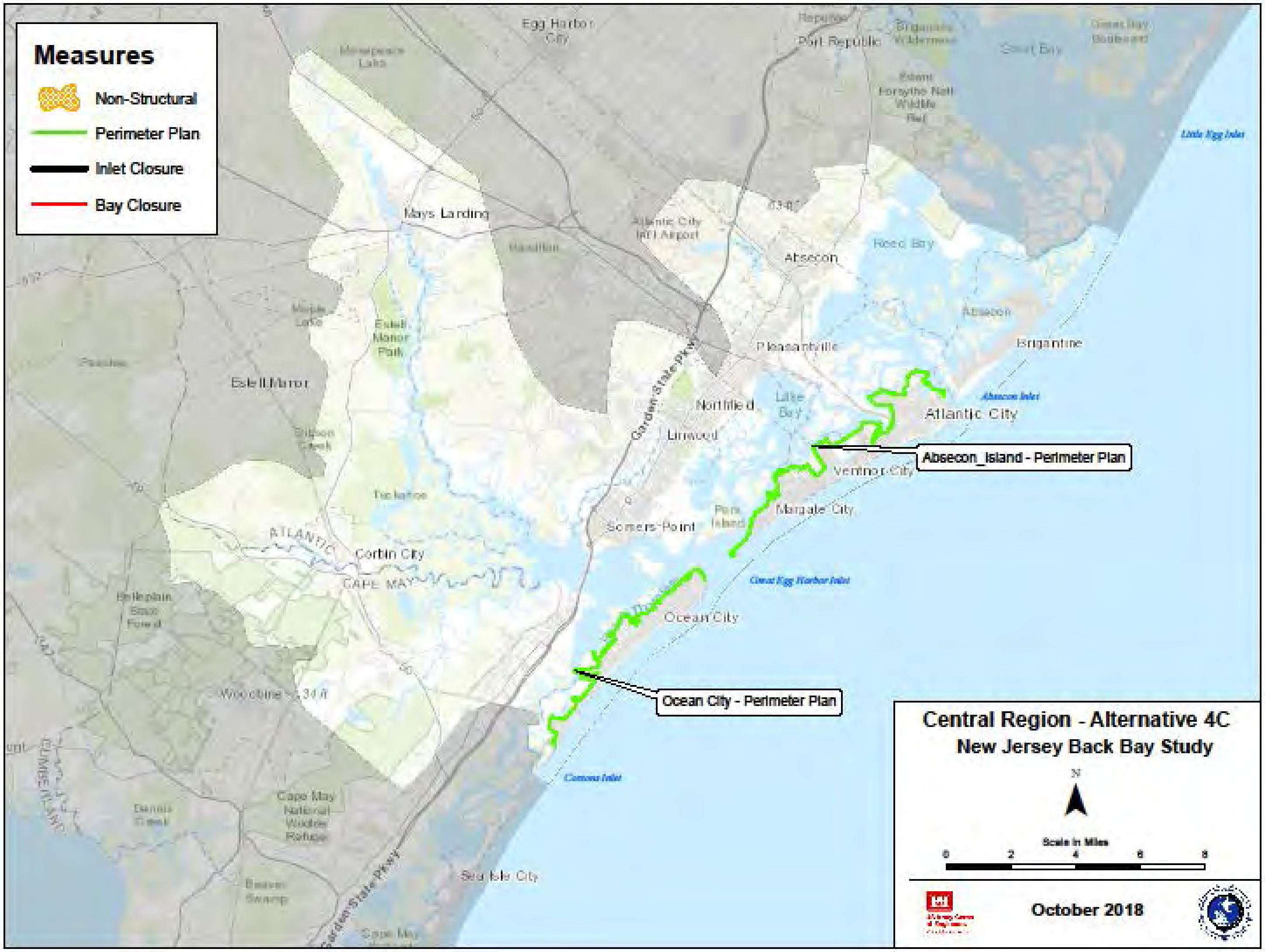

Manasquan Inlet - Storm Surge Barrier
Point Pleasant - Canal Closure
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Region - Alternative 3G
New Jersey Back Bay Study
N
Scale in Miles
0
4
8
12
16
October 2018
Levittown
Willingboro
Mt Holly
New Egypt
Lakewood
Point Pleasant Beach
Point Pleasant
Browns Mills
Toms River
Marlton
Medford Lakes
Forked River
Lindenwold
Barnegat
Manahawkin
Hammonton
Tuckerton
Egg Harbor City
Vineland
Pomona
Mays Landing
Brigantine


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Central Region - Alternative 4A
New Jersey Back Bay Study
October 2018
Atlantic City
Ocean City
Brigantine
Absecon
Northfield
Linwood
Somers Point
Sea Isle City
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corson Inlet
Port Republic
Egg Harbor City
Estell Manor
Garden State Pkwy


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Brigantine Island - Perimeter Plan
Absecon_Island - Perimeter Plan
Ocean City - Perimeter Plan
Central Region - Alternative 4B
New Jersey Back Bay Study
Scale in Miles
0 2 4 6 8
October 2018
Egg Harbor City
Port Republic
Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Northfield
Atlantic City
Linwood
Ventnor City
Margate City
Somers Point
Ocean City
Corbin City
Estell Manor
Woodbine
Sea Isle City
Garden State Pkwy
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Absecon_Island - Perimeter Plan
Ocean City - Perimeter Plan
Central Region - Alternative 4C
New Jersey Back Bay Study
October 2018
Mays Landing
Atlantic City
Ventnor City
Margate City
Ocean City
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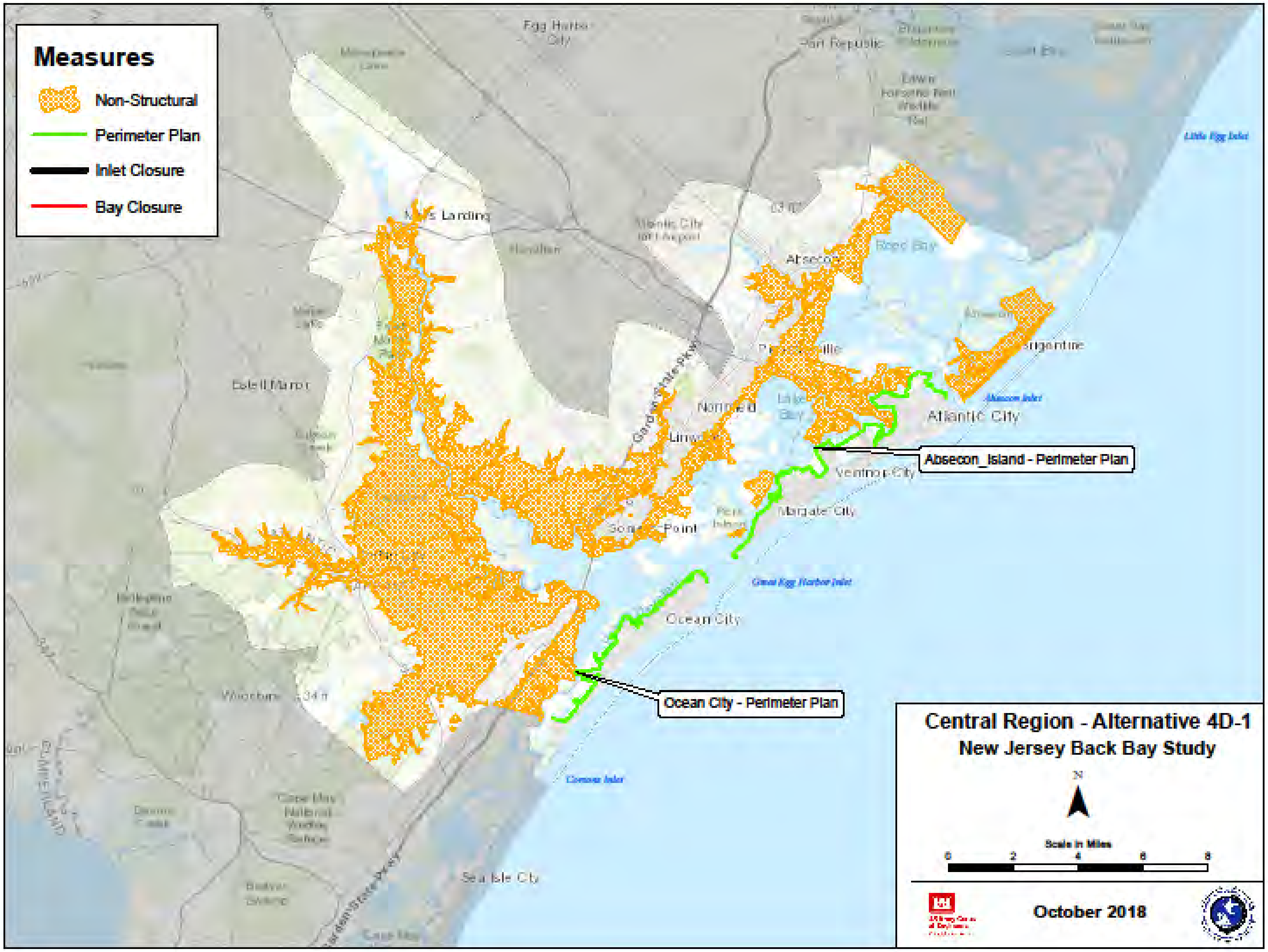
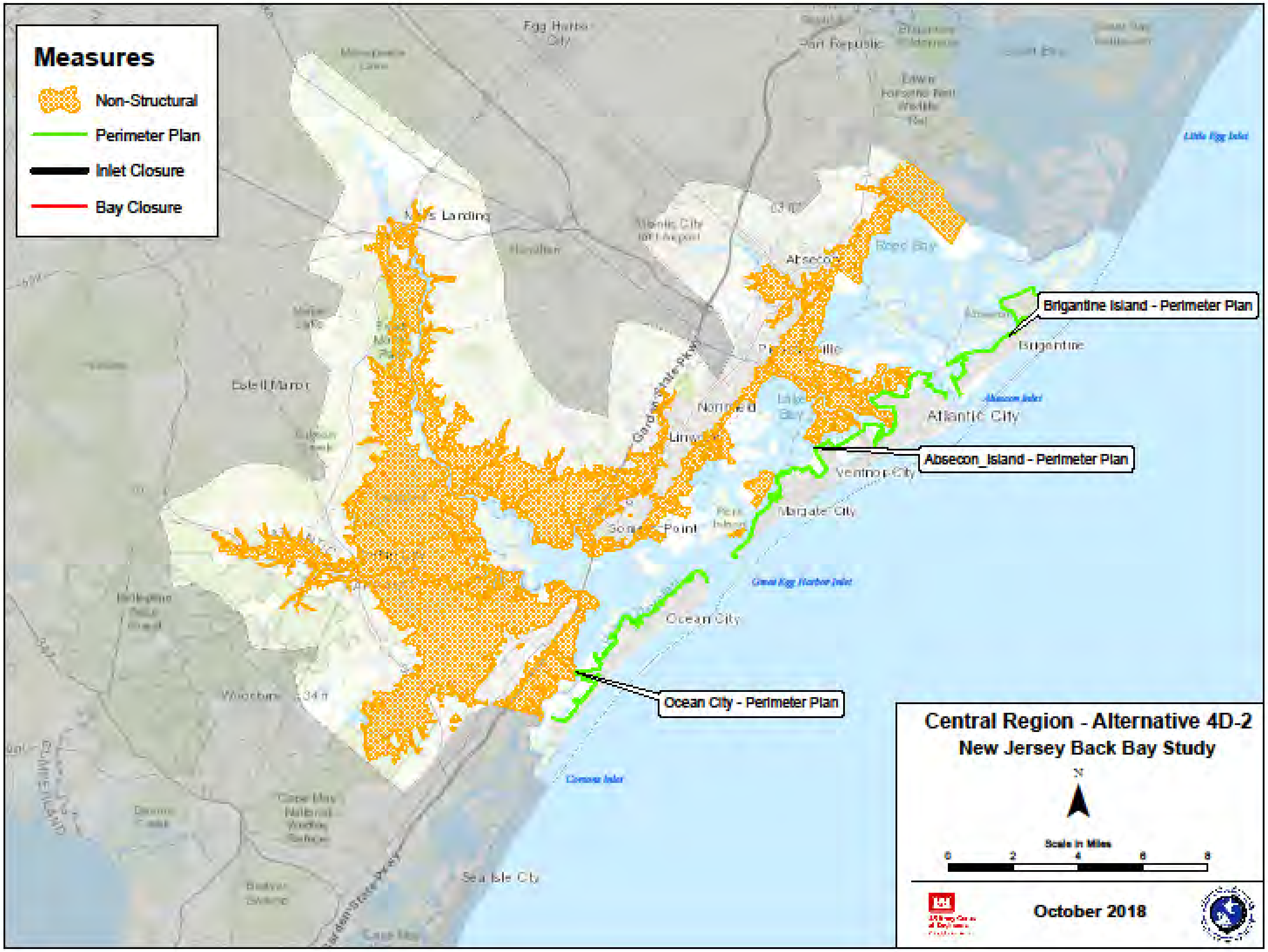
Pleasantville
Absecon
Brigantine
Corbin City
Egg Harbor City
Port Republic
Sea Isle City
Garden State Pkwy


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Absecon_Island - Perimeter Plan
Ocean City - Perimeter Plan
Atlantic City
Ocean City
Central Region - Alternative 4D-1
New Jersey Back Bay Study
Scale in Miles
0 2 4 6 8
October 2018


Measures
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Perimeter Plan
Inlet Closure
Bay Closure
Brigantine Island - Perimeter Plan
Absecon_Island - Perimeter Plan
Ocean City - Perimeter Plan
Atlantic City
Ocean City
Sea Isle City
Central Region - Alternative 4D-2
New Jersey Back Bay Study
N
Scale in Miles
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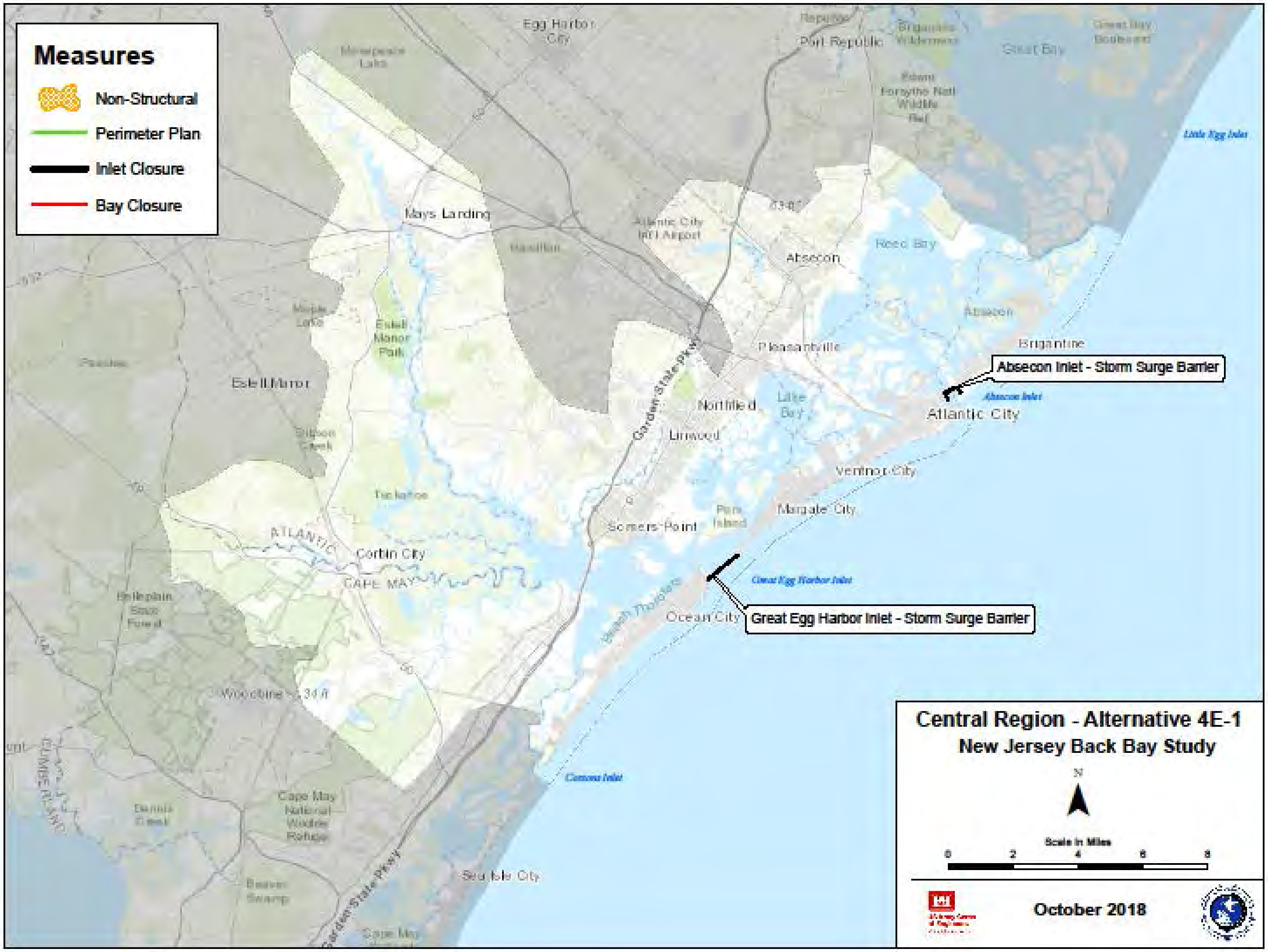
2
4
6
8
October 2018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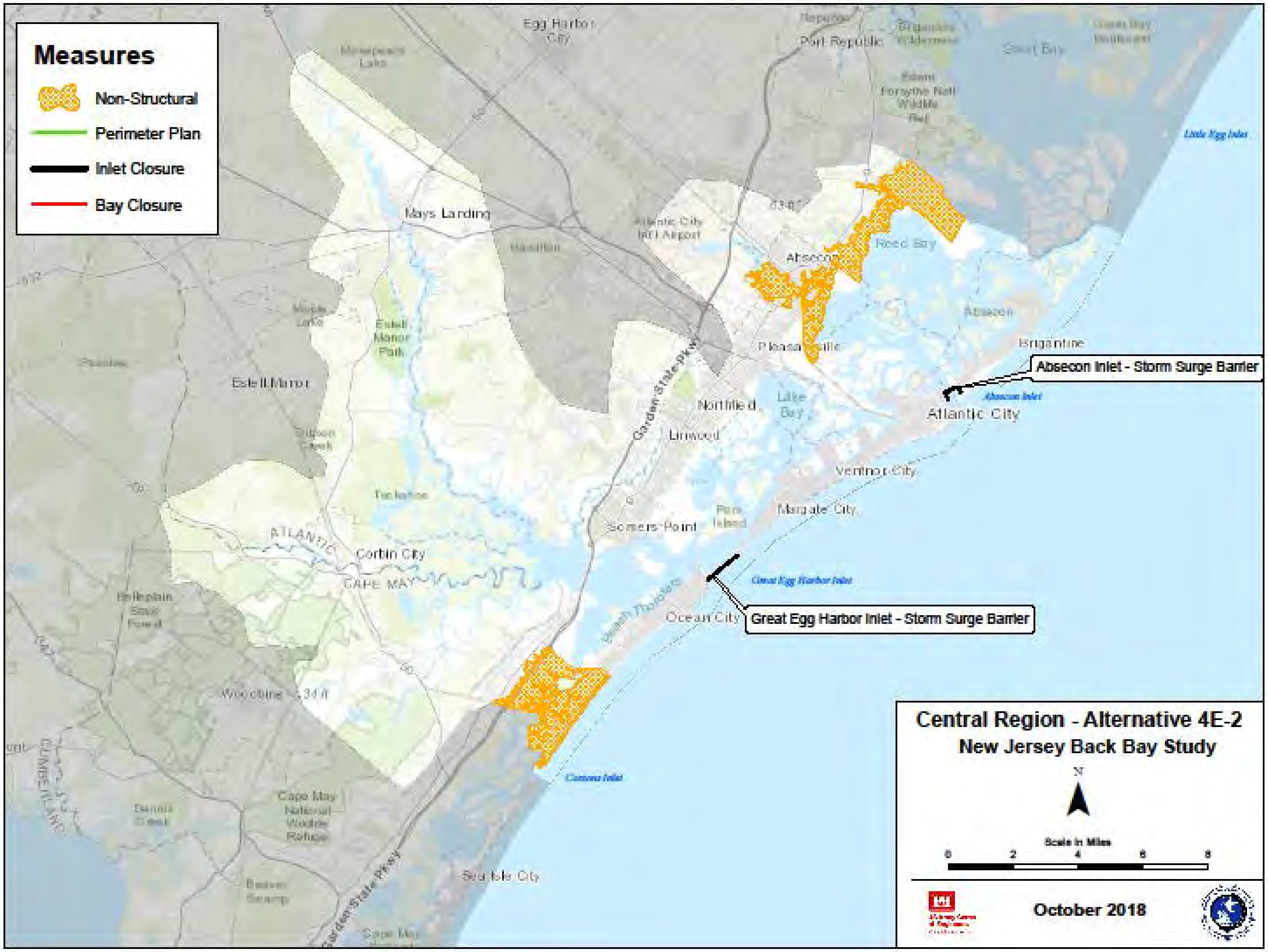
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4E-1
New Jersey Back Bay Study
Scale in Miles
0 2 4 6 8
October 2018
Mays Landing
Atlantic City
Ocean City
Brigantine
Pleasantville
Northfield
Linwood
Somers Point
Ventnor City
Margate City
Absecon
Corbin City
Estell Manor
Port Republic
Egg Harbor City
Reeds Bay
Great Bay
Sea Isle City
Garden State Pkwy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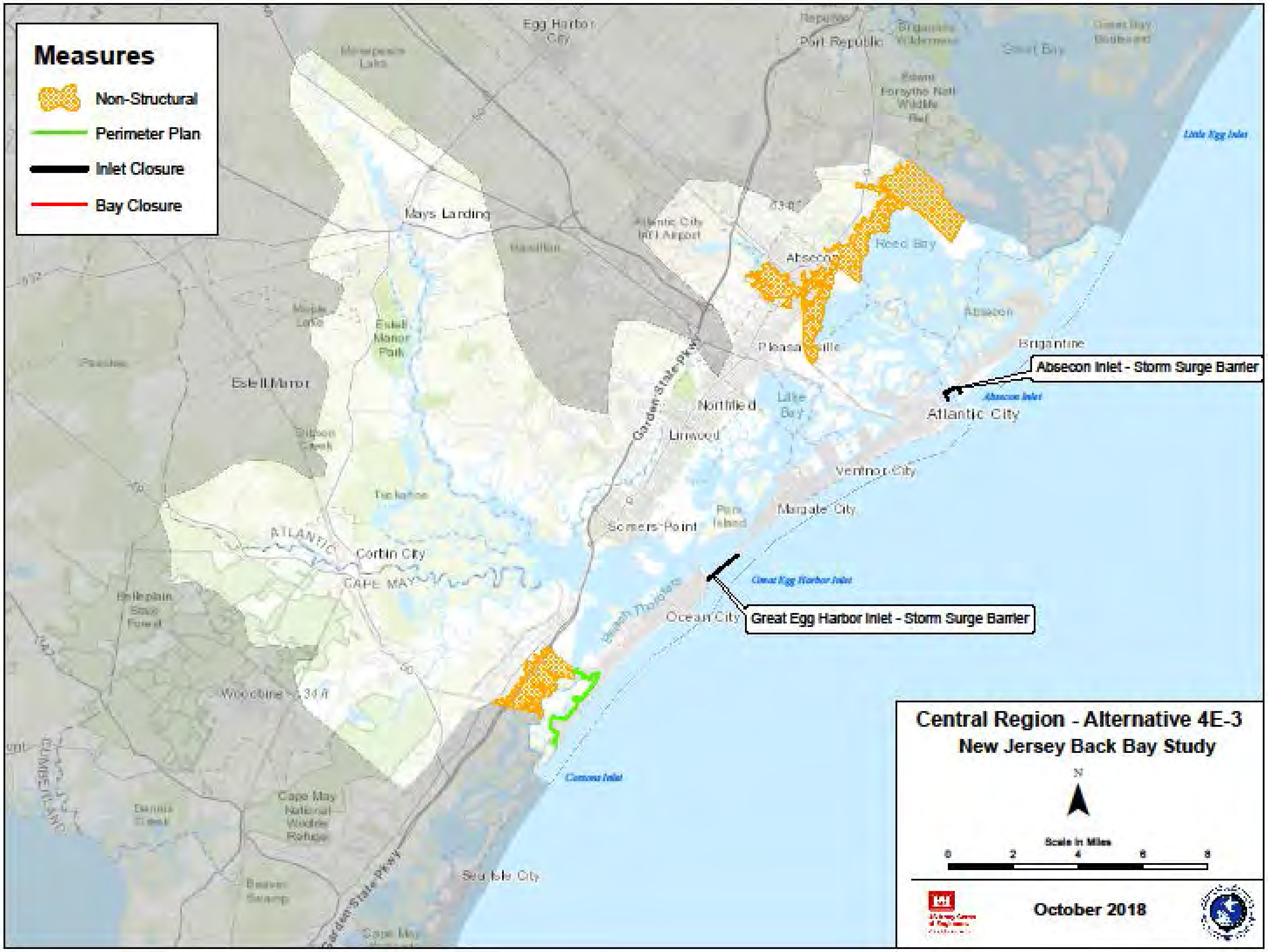
Inlet Closure
Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4E-2
New Jersey Back Bay Study
October 2018
Egg Harbor City
Port Republic
Mays Landing
Absecon
Pleasantville
Brigantine
Atlantic City
Northfield
Linwood
Ventnor City
Margate City
Somers Point
Estell Manor
Corbin City
Ocean City
Sea Isle City
Reeds Bay
Lakes Bay
Garden State Pkwy


Measures
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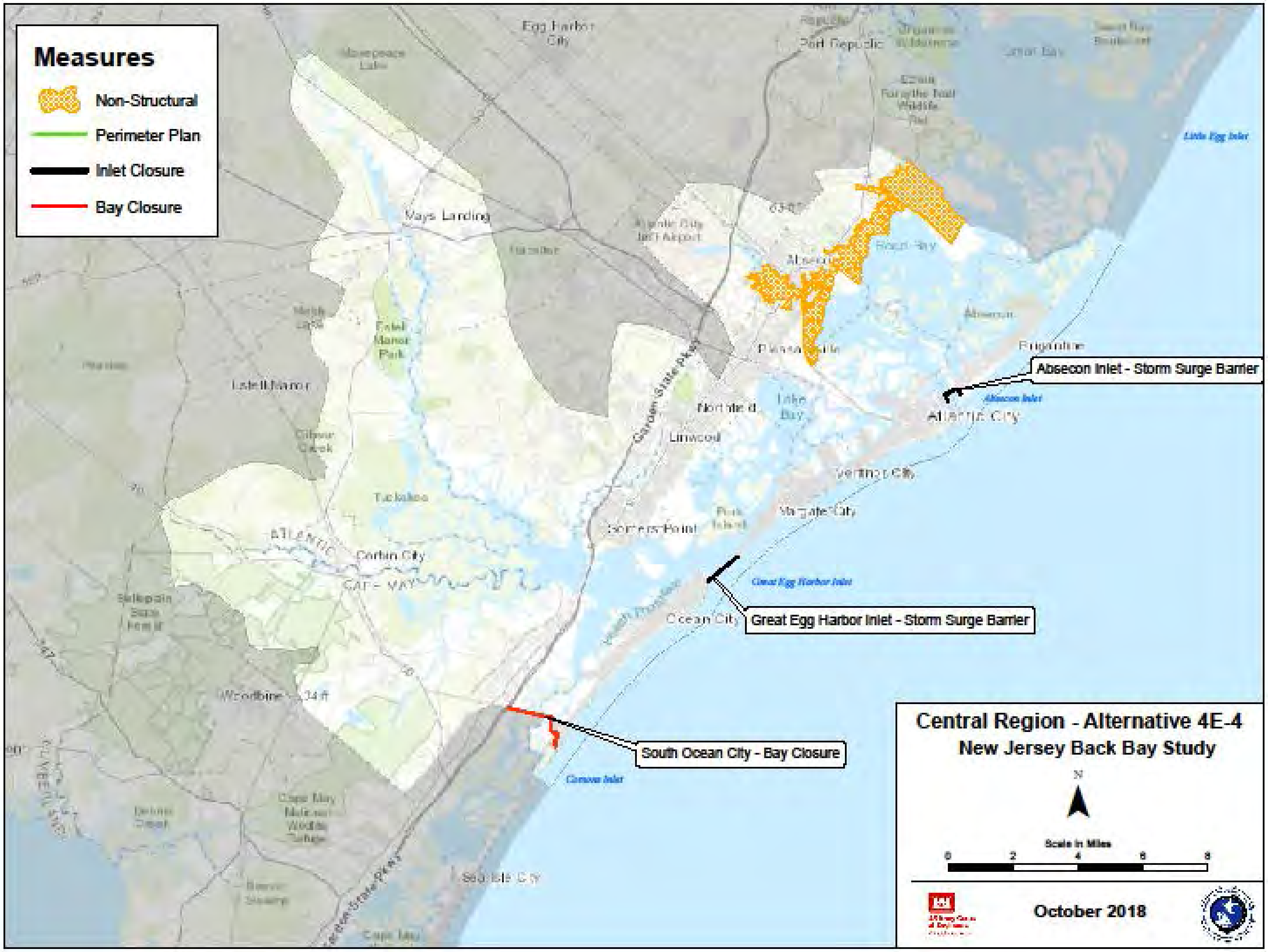
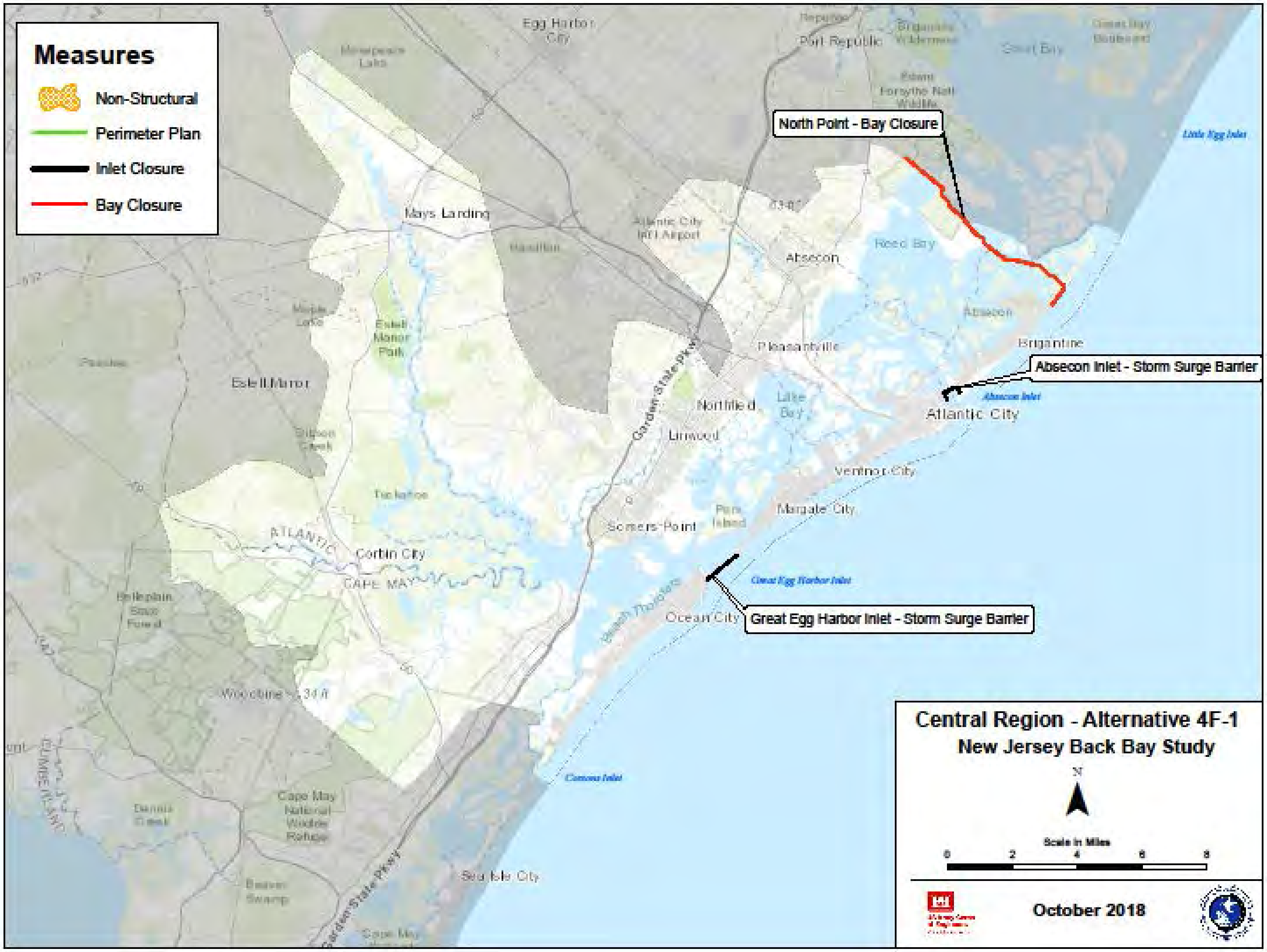
Perimeter Plan
Inlet Closure
Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4E-3
New Jersey Back Bay Study
Scale in Miles
0 2 4 6 8
October 2018
Egg Harbor City
Port Republic
Mays Landing
Estell Manor
Corbin City
Northfield
Linwood
Pleasantville
Atlantic City
Brigantine
Ventnor City
Margate City
Somers Point
Ocean City
Sea Isle City


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
South Ocean City - Bay Closure
Central Region - Alternative 4E-4
New Jersey Back Bay Study
N
Scale in Miles
0
2
4
6
8
October 2018
Mays Landing
Atlantic City
Ocean City
Linwood
Northfield
Brigantine
Ventnor City
Margate City
Somers Point
Corbin City
Tuckahoe
Woodbine
Port Republic
Egg Harbor City
Sea Isle City
Cape May
Garden State Pkwy



Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Point - Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
Egg Harbor City
Port Republic
Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Northfield
Linwood
Atlantic City
Ventnor City
Margate City
Somers Point
Ocean City
Corbin City
Estell Manor
Woodbine
Sea Isle City
Garden State Pkwy
Central Region - Alternative 4F-1
New Jersey Back Bay Study
N
Scale in Miles
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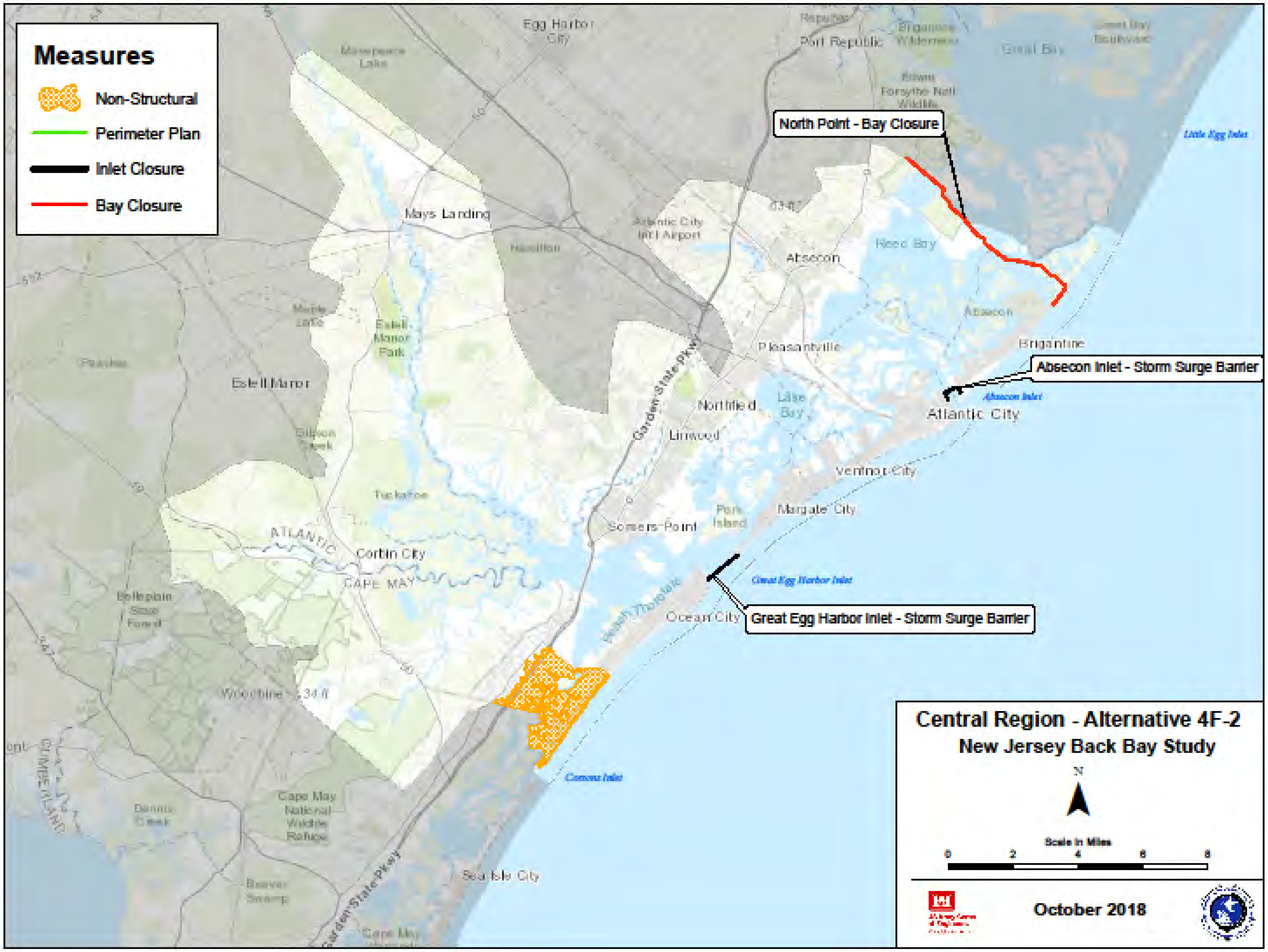
2
4
6
8
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Point - Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4F-2
New Jersey Back Bay Study
N
Scale in Miles
0 2 4 6 8
October 2018
Mays Landing
Atlantic City
Brigantine
Absecon
Pleasantville
Northfield
Linwood
Ventnor City
Margate City
Somers Point
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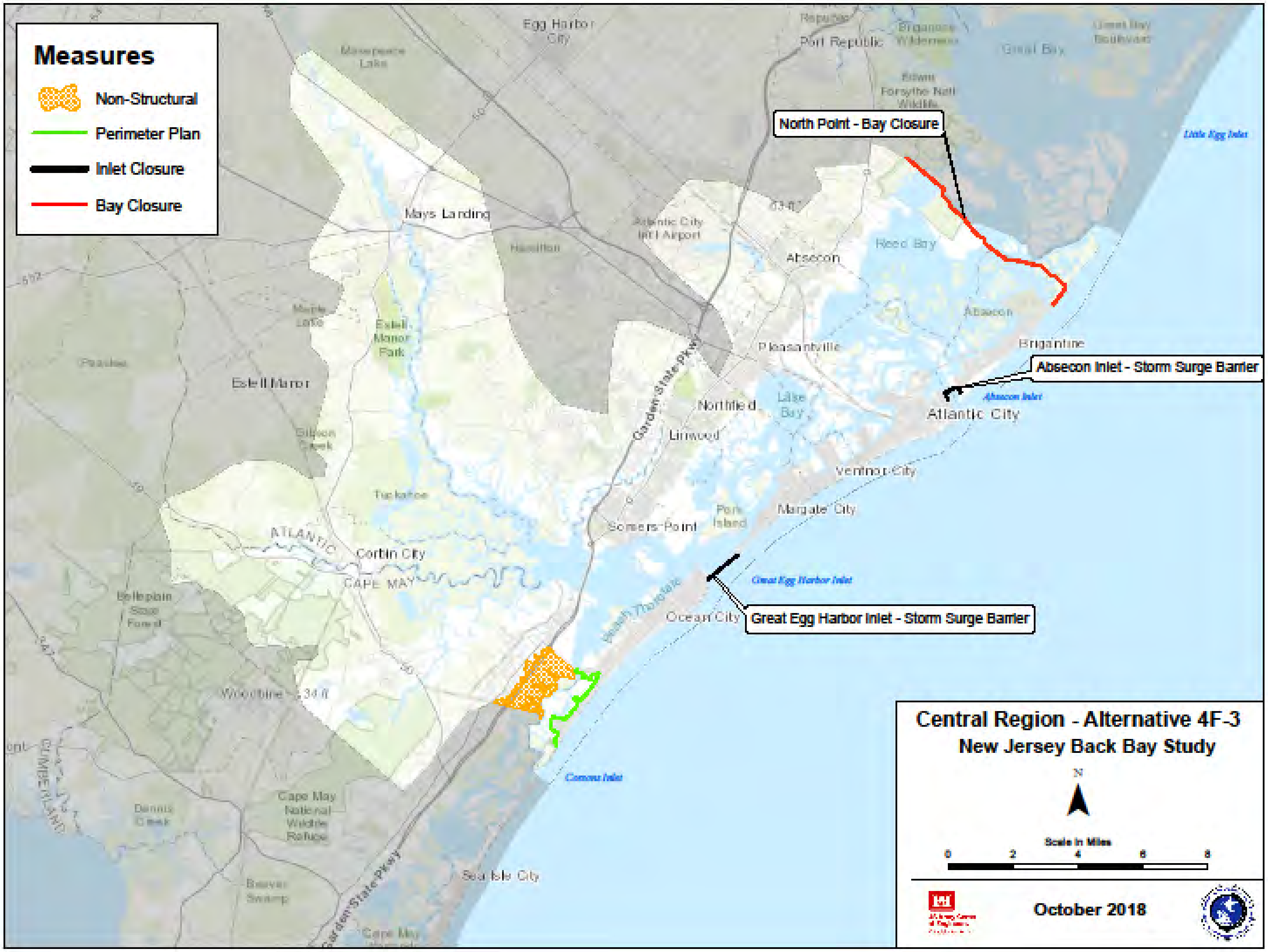
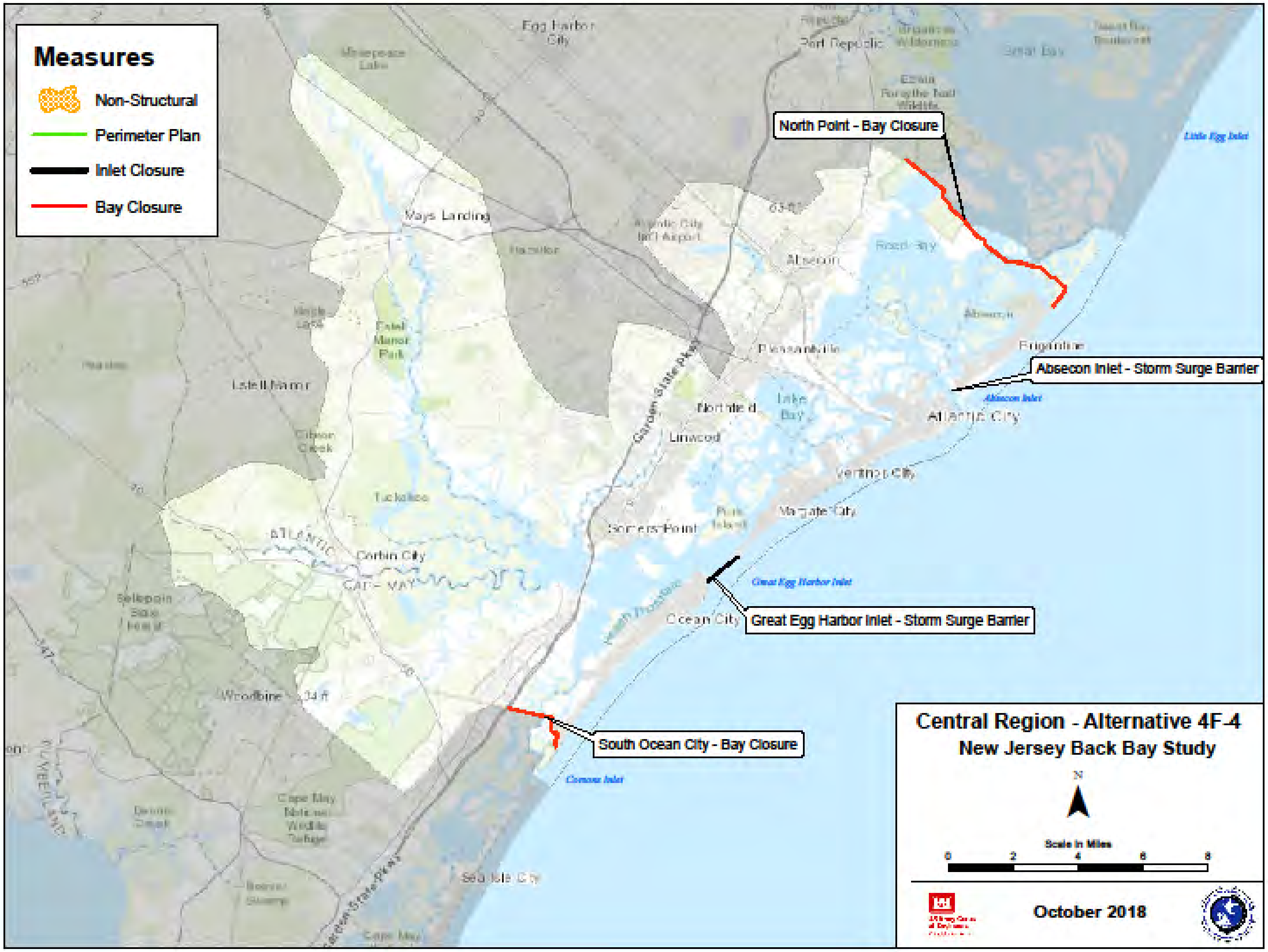
Corbin City
Estell Manor
Port Republic
Egg Harbor City
Sea Isle City
Woodbine
Reed Bay
Great Bay
Garden State Pkwy


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Point - Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4F-3
New Jersey Back Bay Study
N
Scale in Miles
0
2
4
6
8
October 2018
Egg Harbor City
Port Republic
Great Bay
Mays Landing
Absecon
Reed Bay
Brigantine
Pleasantville
Northfield
Linwood
Atlantic City
Ventnor City
Margate City
Somers Point
Ocean City
Corbin City
Estell Manor
Tuckahoe
Woodbine
Sea Isle City
Garden State Pkwy
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
North Point - Bay Closure
Absecon Inlet - Storm Surge Barrier
Great Egg Harbor Inlet - Storm Surge Barrier
South Ocean City - Bay Closure
Central Region - Alternative 4F-4
New Jersey Back Bay Study
N
Scale in Miles
0
2
4
6
8
October 2018
Egg Harbor City
Port Republic
Mays Landing
Absecon
Pleasantville
Northfield
Linwood
Atlantic City
Ventnor City
Margate City
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Corbin City
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Sea Isle City
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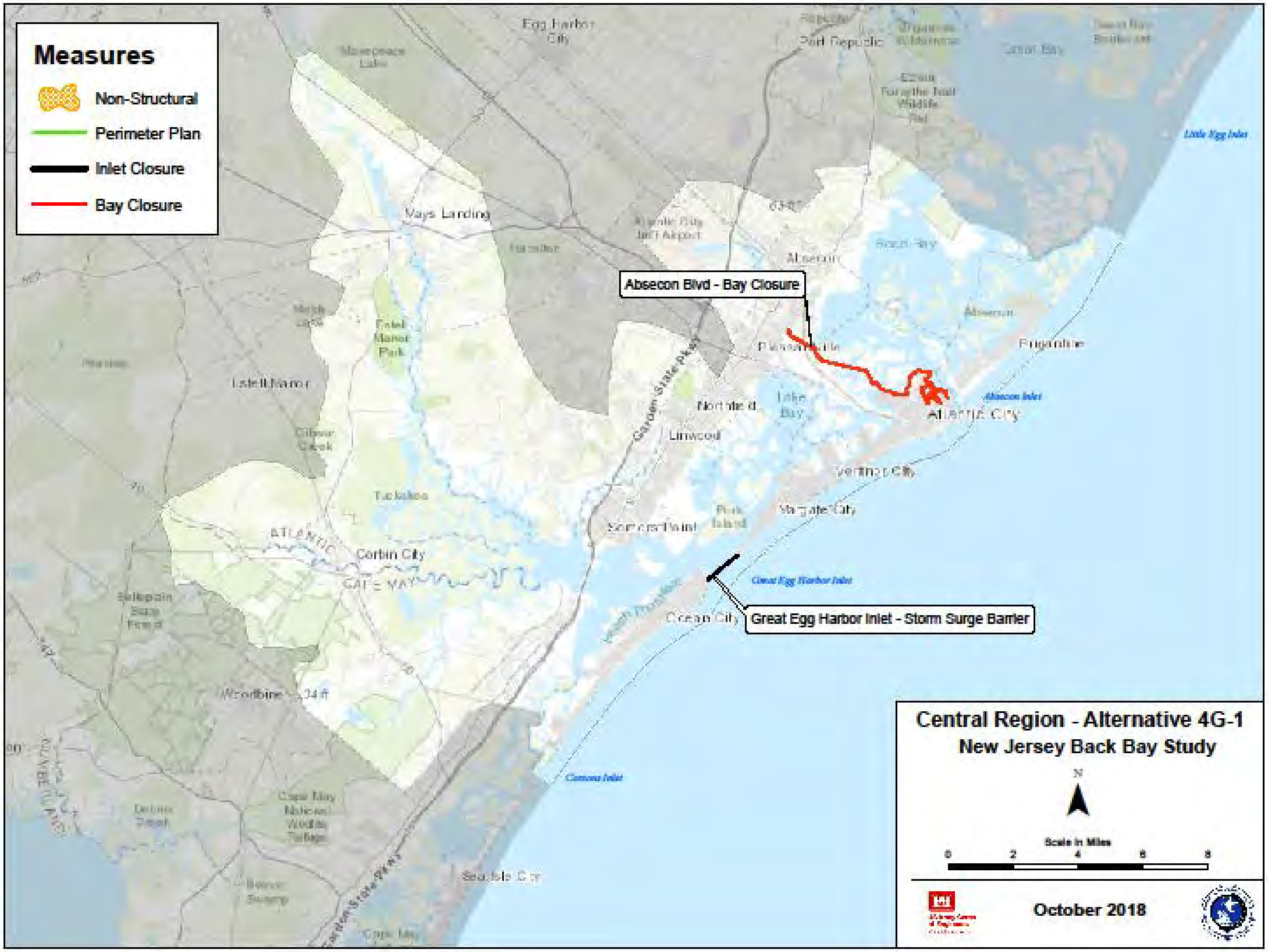
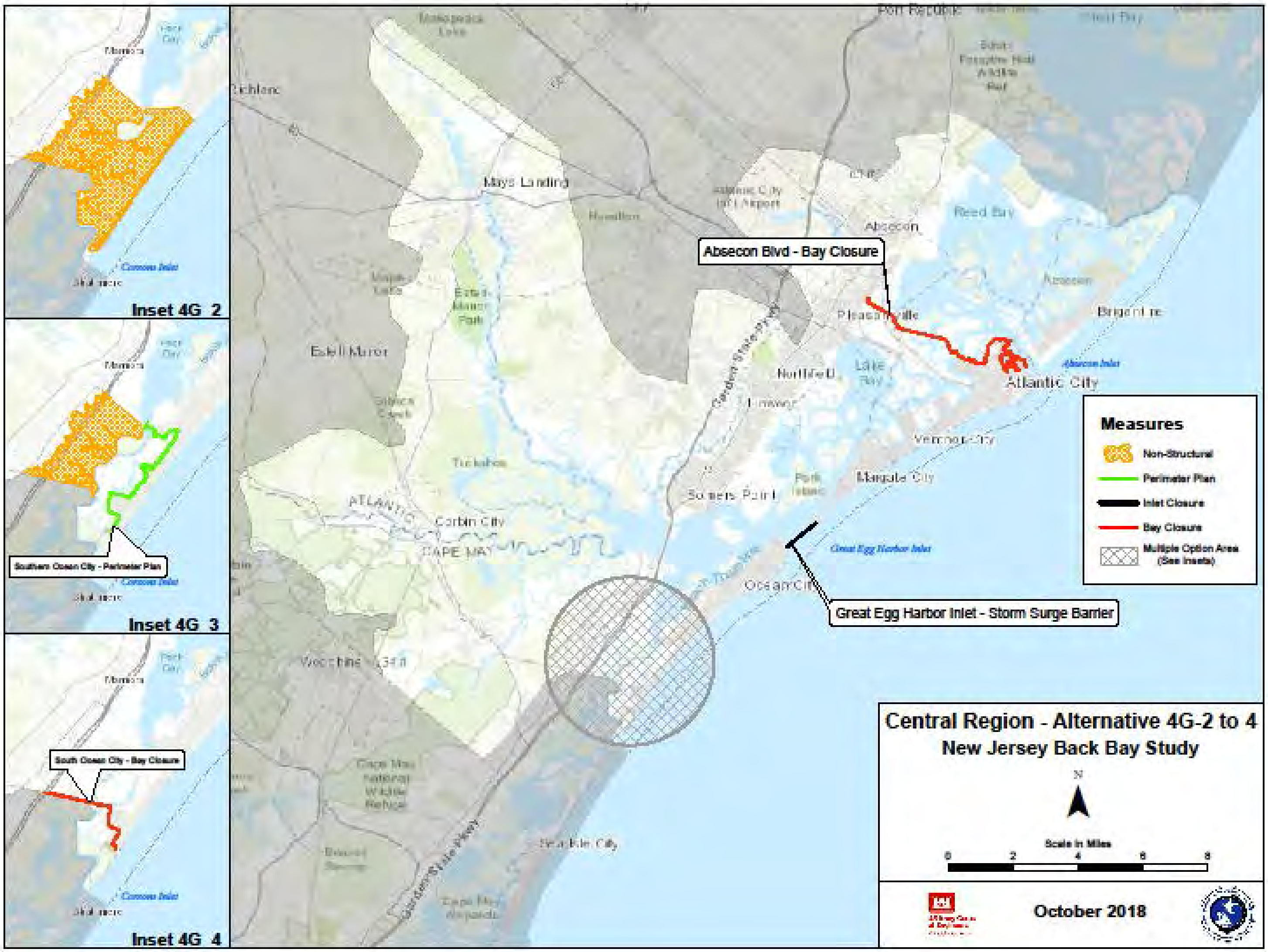
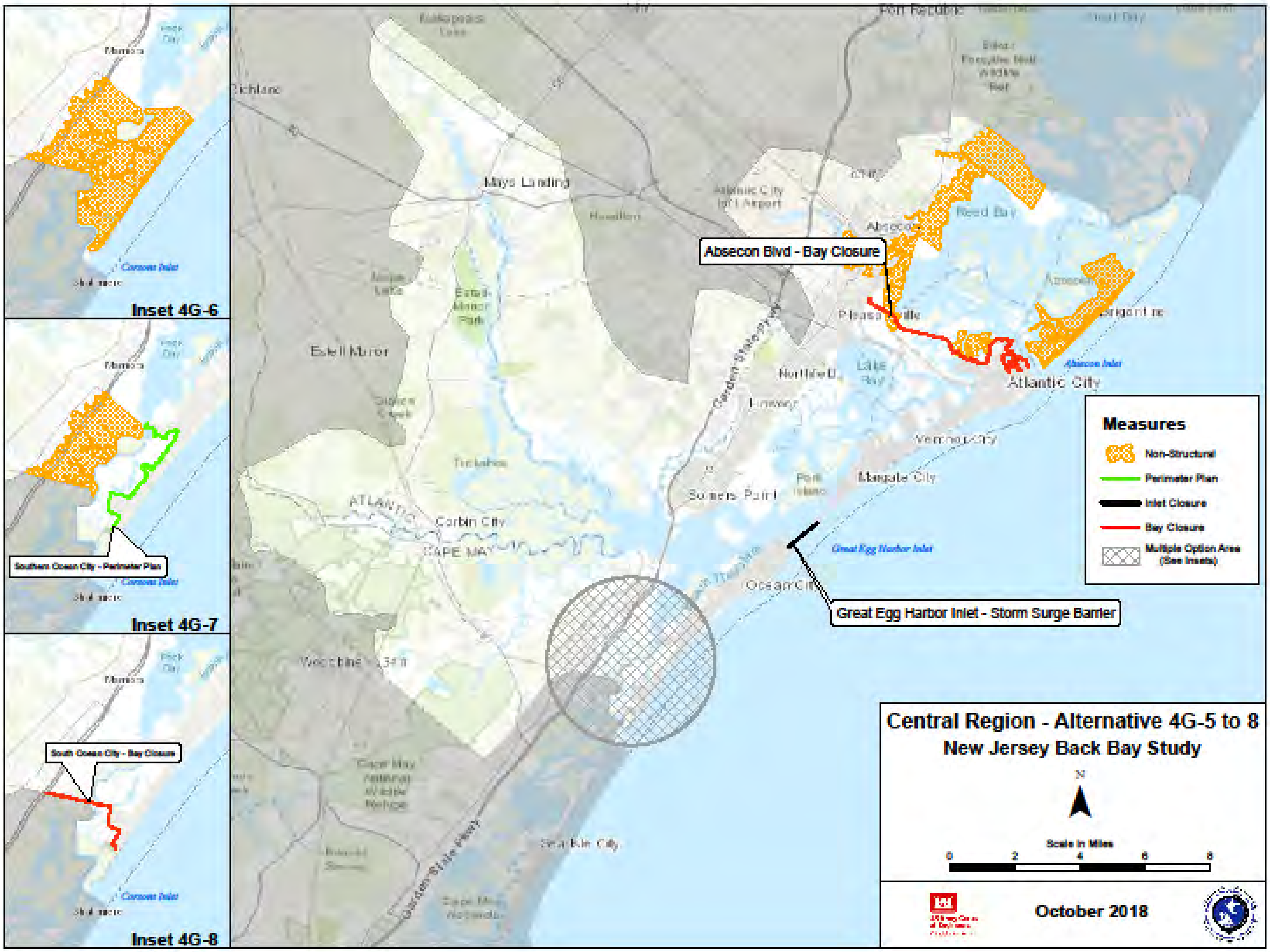
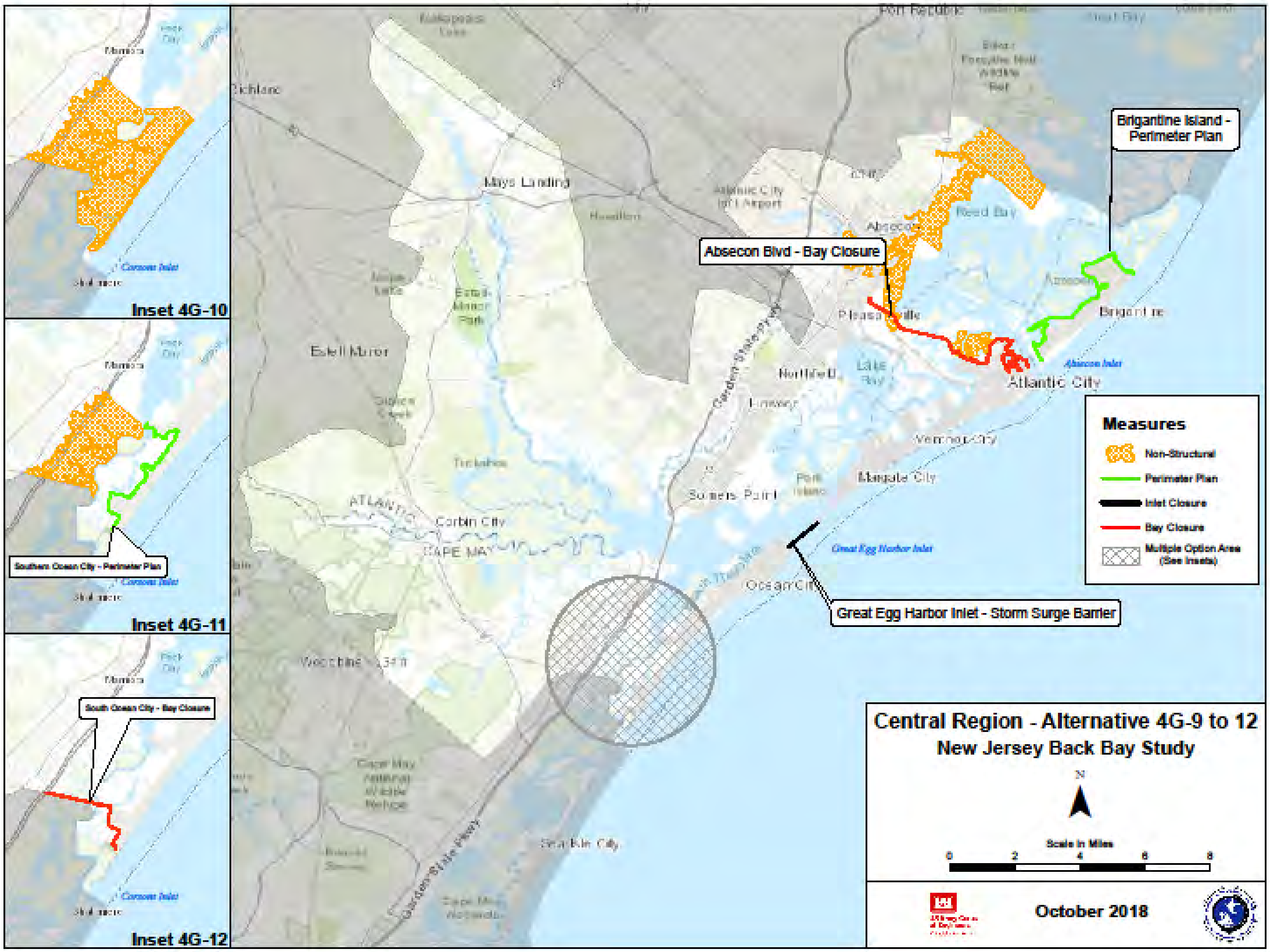
Little Egg Inlet
Absecon Inlet
Great Egg Harbor Inlet
Corsons Inlet

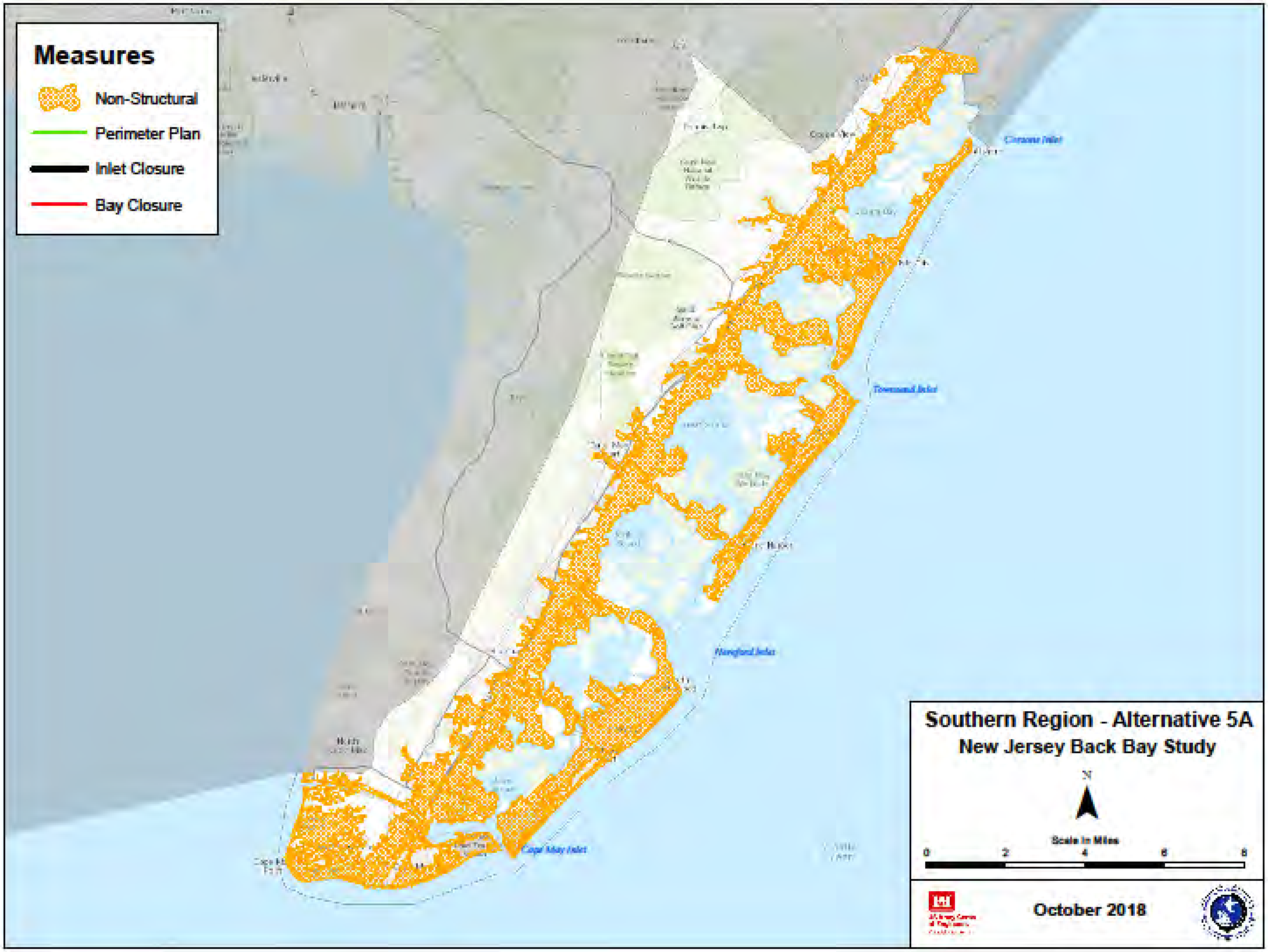


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Absecon Blvd - Bay Closure
Great Egg Harbor Inlet - Storm Surge Barrier
Central Region - Alternative 4G-1
New Jersey Back Bay Study
October 2018
Scale in Miles
0 2 4 6 8

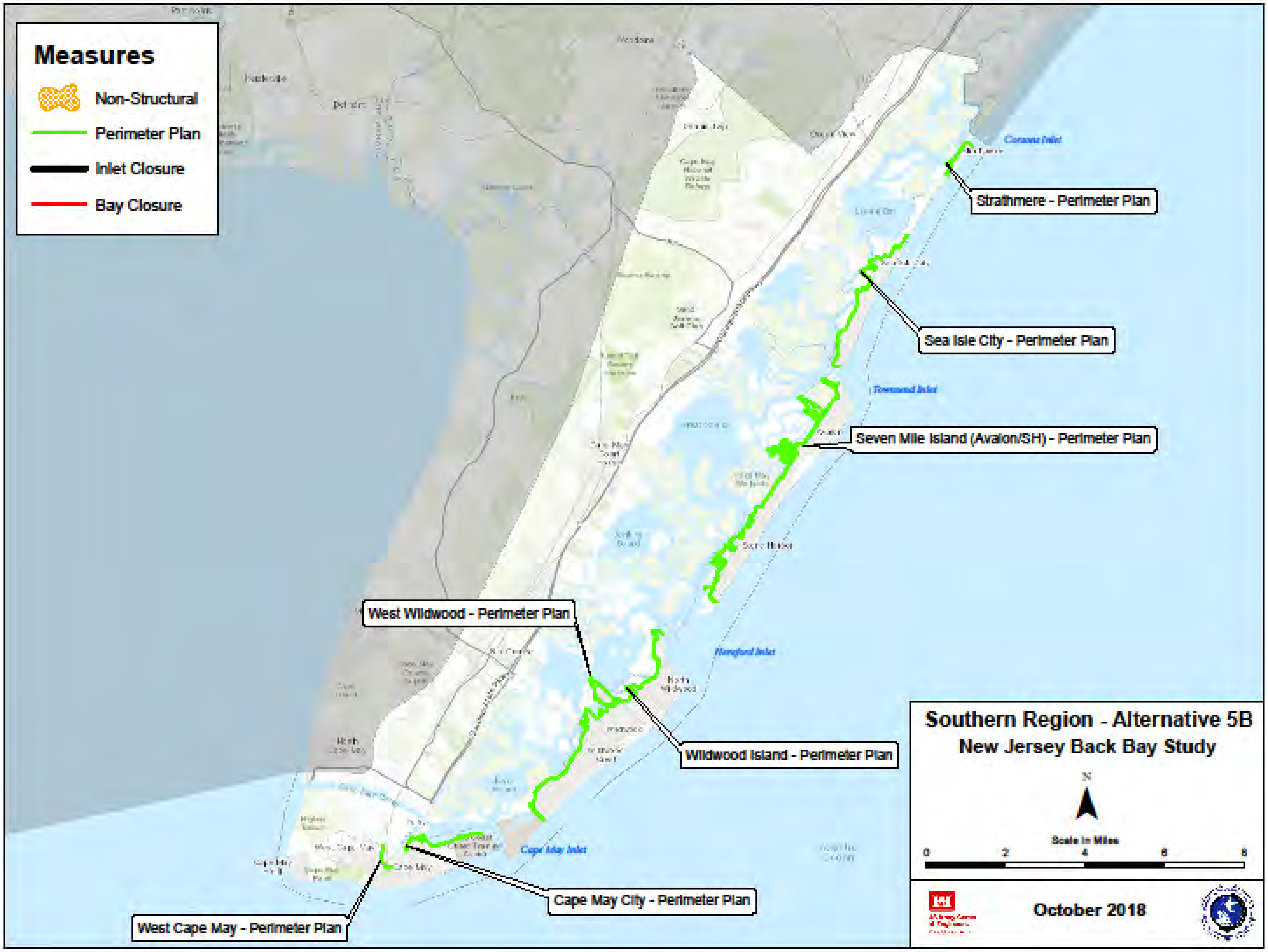

Inset 4G 2
Inset 4G 3
Southern Ocean City - Perimeter Plan
Inset 4G 4
South Ocean City - Bay Closure
Mays Landing
Absecon
Absecon Blvd - Bay Closure
Pleasantville
Atlantic City
Northfield
Somers Point
Margate City
Ocean City
Great Egg Harbor Inlet - Storm Surge Barrier
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Multiple Option Area (See Insets)
Central Region - Alternative 4G-2 to 4
New Jersey Back Bay Study
N
Scale in Miles
0 2 4 6 8
October 2018

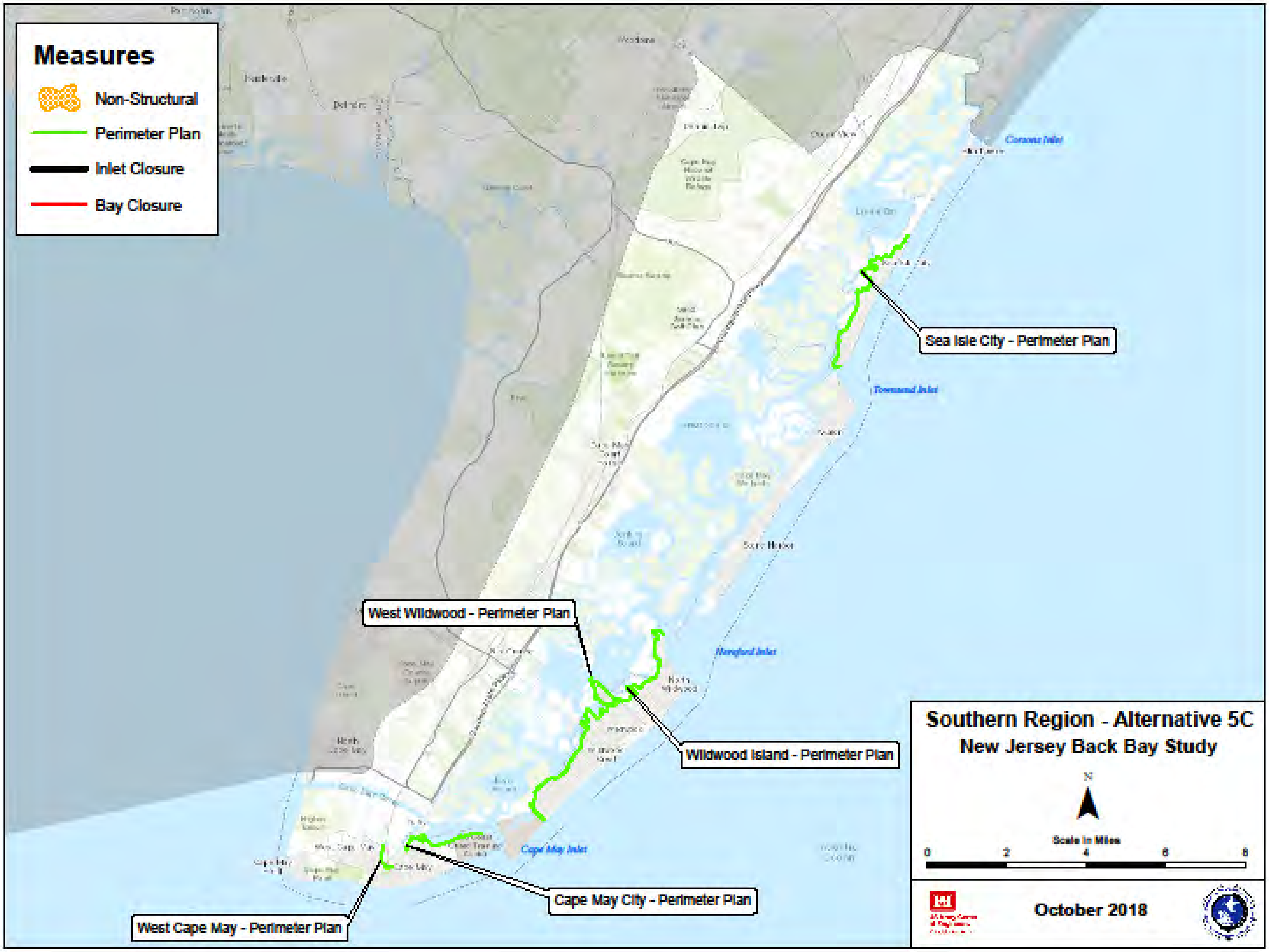

Inset 4G-6
Inset 4G-7
Southern Ocean City - Perimeter Plan
Inset 4G-8
South Ocean City - Bay Closure
Absecon Blvd - Bay Closure
Great Egg Harbor Inlet - Storm Surge Barrier
Mays Landing
Atlantic City
Ocean City
Margate City
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Multiple Option Area (See Insets)
Central Region - Alternative 4G-5 to 8
New Jersey Back Bay Study
Scale in Miles
0
2
4
6
8
October 2018

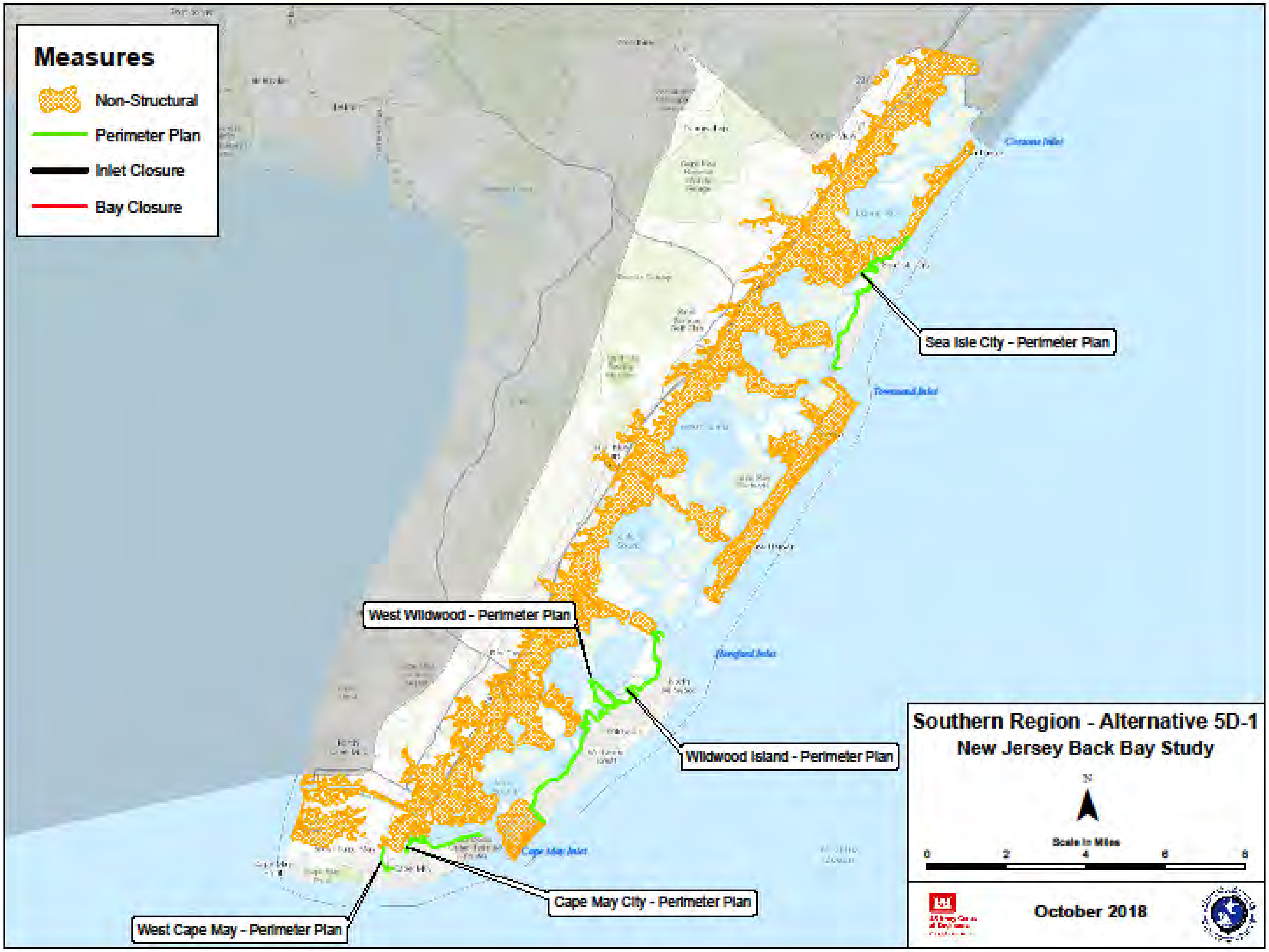

Central Region - Alternative 4G-9 to 12
New Jersey Back Bay Study
October 2018
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Multiple Option Area (See Insets)
Scale in Miles
0
2
4
6
8
Brigantine Island - Perimeter Plan
Absecon Blvd - Bay Closure
Great Egg Harbor Inlet - Storm Surge Barrier
Great Egg Harbor Inlet
Absecon Inlet
Atlantic City
Mays Landing
Estell Manor
Corbin City
Somers Point
Margate City
Ventnor City
Northfield
Pleasantville
Brigantine
Reed Bay
Lake Bay
Ocean City
Sea Isle City
Inset 4G-10
Inset 4G-11
Inset 4G-12
Southern Ocean City - Perimeter Plan
South Ocean City - Bay Closure
Corsons Inlet

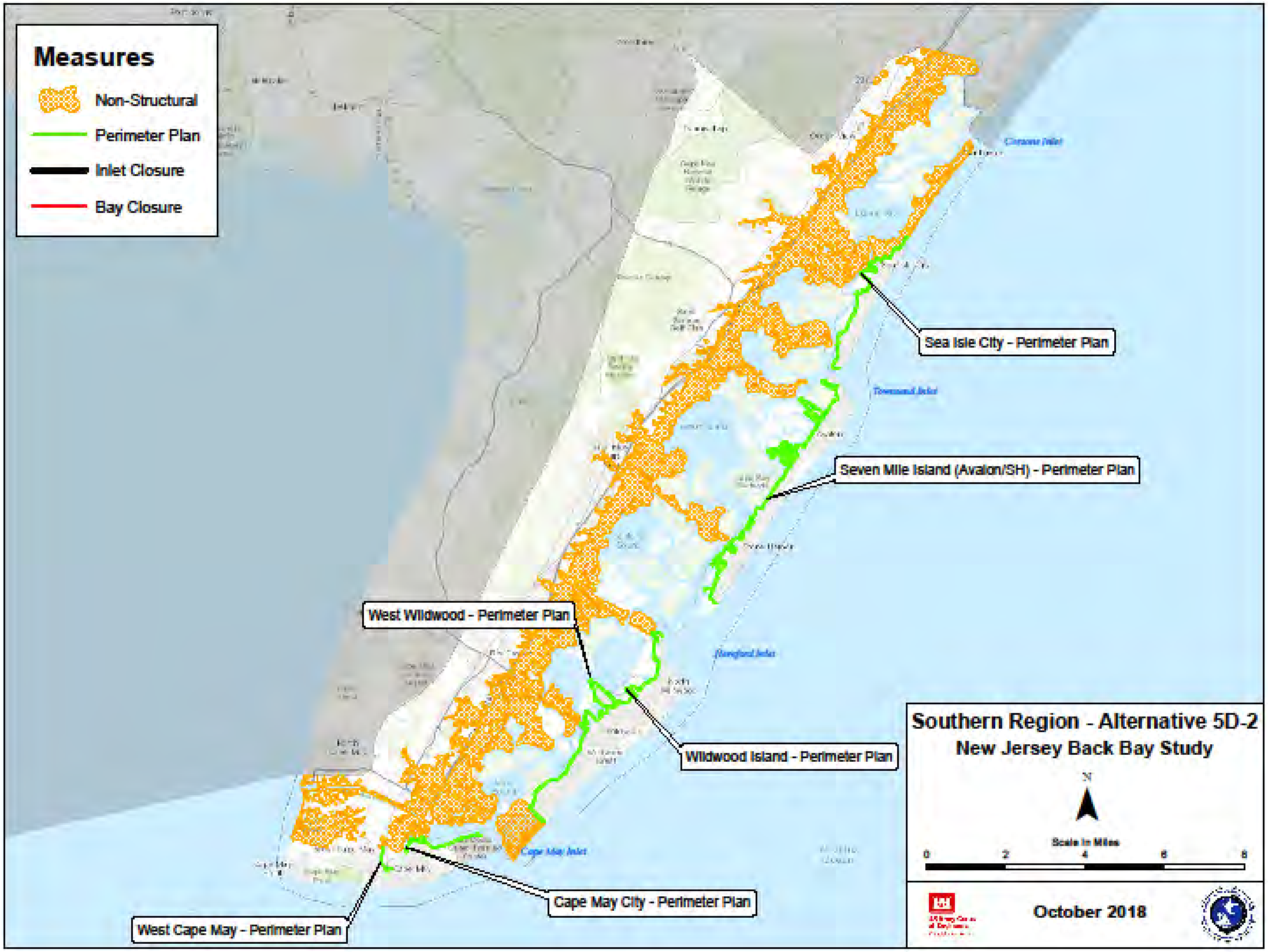


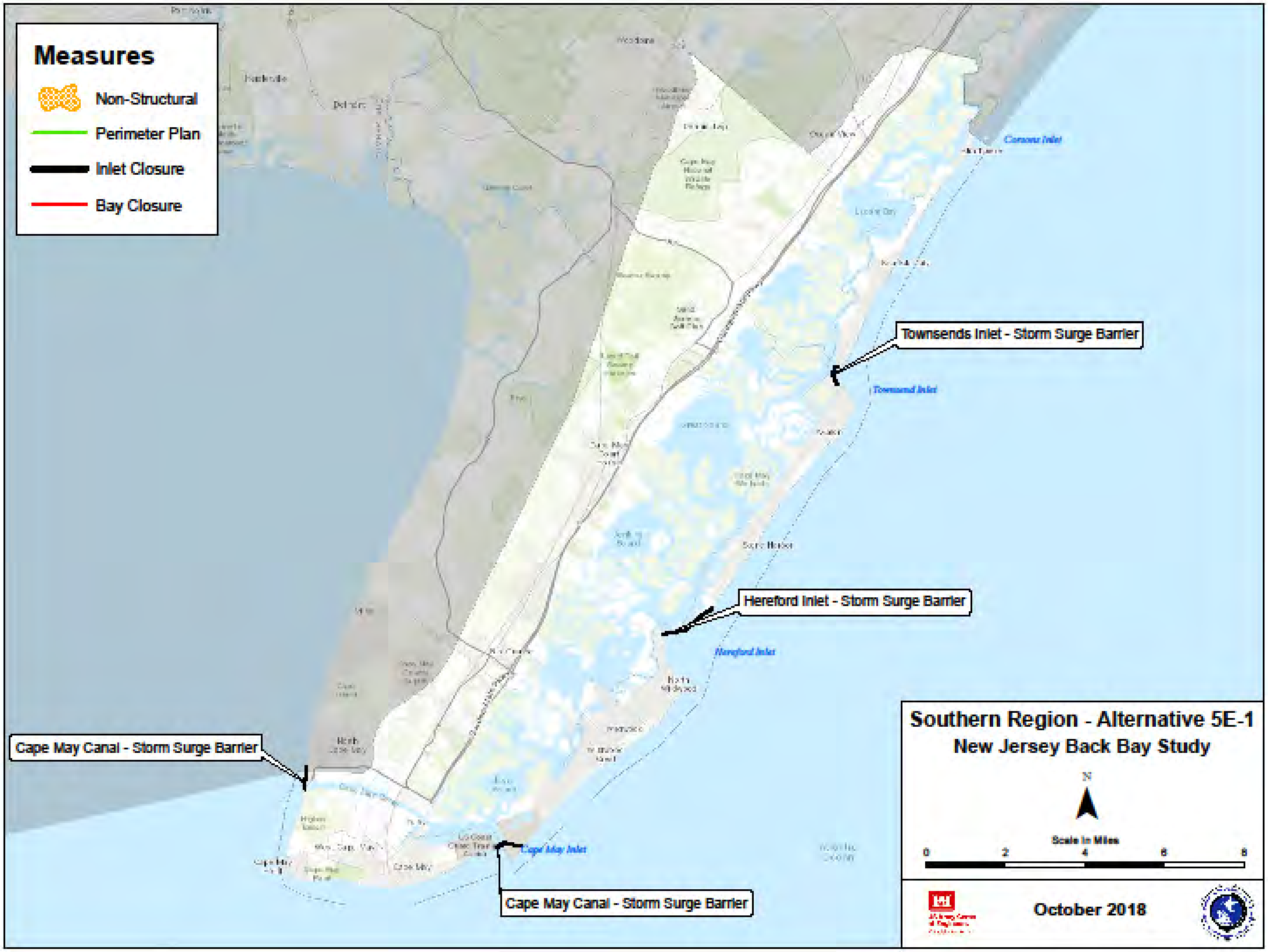
Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Southern Region - Alternative 5A
New Jersey Back Bay Study
N
Scale in Miles
0
2
4
6
8
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Strathmere - Perimeter Plan
Sea Isle City - Perimeter Plan
Seven Mile Island (Avalon/SH) - Perimeter Plan
West Wildwood - Perimeter Plan
Wildwood Island - Perimeter Plan
Cape May City - Perimeter Plan
West Cape May - Perimeter Plan
Southern Region - Alternative 5B
New Jersey Back Bay Study
N
Scale in Miles
0
2
4
6
8
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle City - Perimeter Plan
West Wildwood - Perimeter Plan
Wildwood Island - Perimeter Plan
Cape May City - Perimeter Plan
West Cape May - Perimeter Plan
Southern Region - Alternative 5C
New Jersey Back Bay Study
N
Scale in Miles
0
2
4
6
8
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle City - Perimeter Plan
West Wildwood - Perimeter Plan
Wildwood Island - Perimeter Plan
Cape May City - Perimeter Plan
West Cape May - Perimeter Plan
Southern Region - Alternative 5D-1
New Jersey Back Bay Study
Scale In Miles
0
2
4
6
8
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle City - Perimeter Plan
Seven Mile Island (Avalon/SH) - Perimeter Plan
West Wildwood - Perimeter Plan
Wildwood Island - Perimeter Plan
Cape May City - Perimeter Plan
West Cape May - Perimeter Plan
Southern Region - Alternative 5D-2
New Jersey Back Bay Study
N
Scale in Miles
0 2 4 6 8
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Townsends Inlet - Storm Surge Barrier
Hereford Inlet - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Corsons Inlet
Townsend Inlet
Hereford Inlet
Cape May Inlet
Southern Region - Alternative 5E-1
New Jersey Back Bay Study
N
Scale in Miles
0
2
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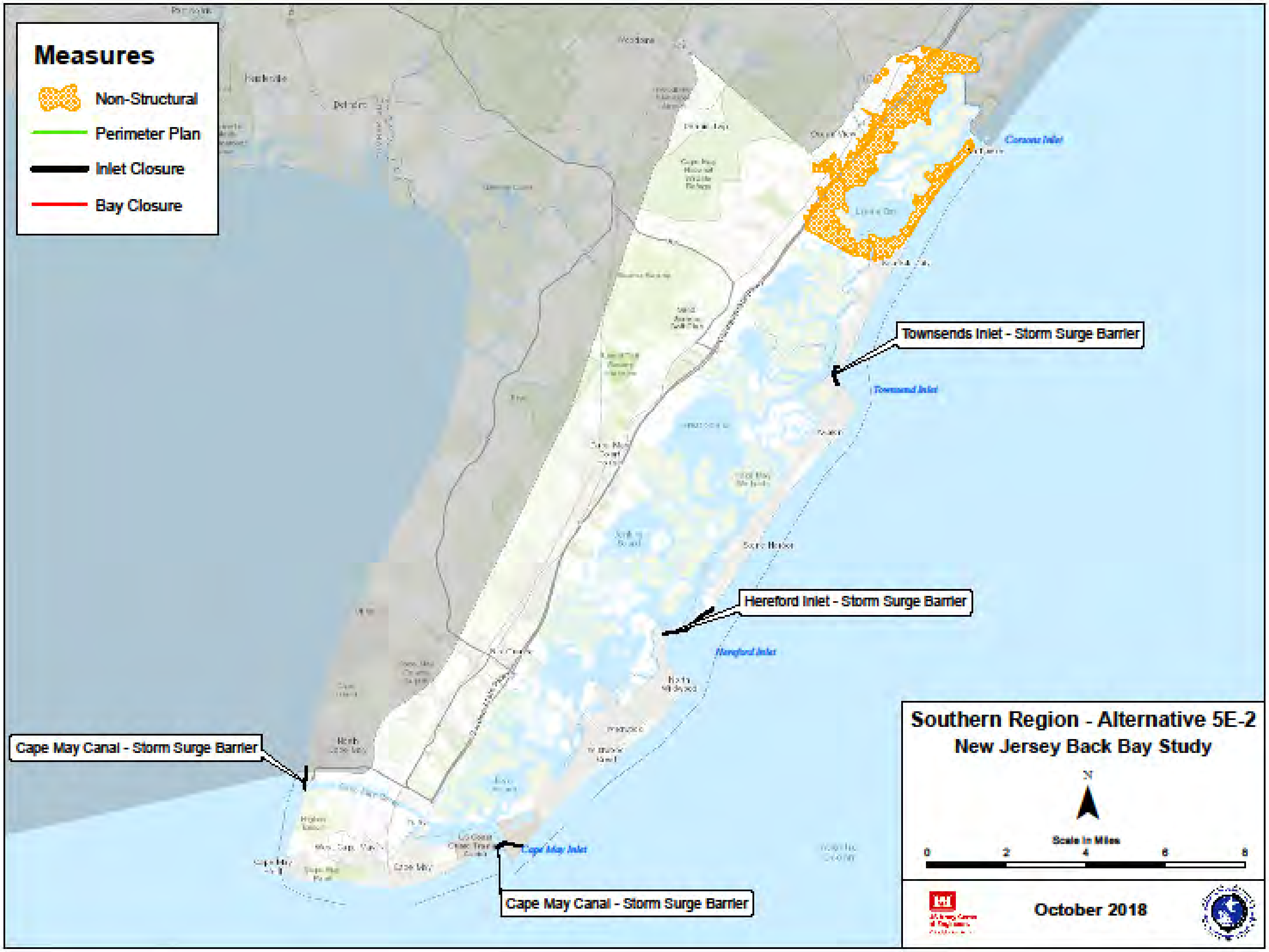
6
8
October 2018



Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Corsons Inlet
Townsends Inlet - Storm Surge Barrier
Townsend Inlet
Hereford Inlet - Storm Surge Barrier
Hereford Inlet
Cape May Canal - Storm Surge Barrier
Cape May Inlet
Cape May Canal - Storm Surge Barrier
Southern Region - Alternative 5E-2
New Jersey Back Bay Study
N
Scale in Miles
0
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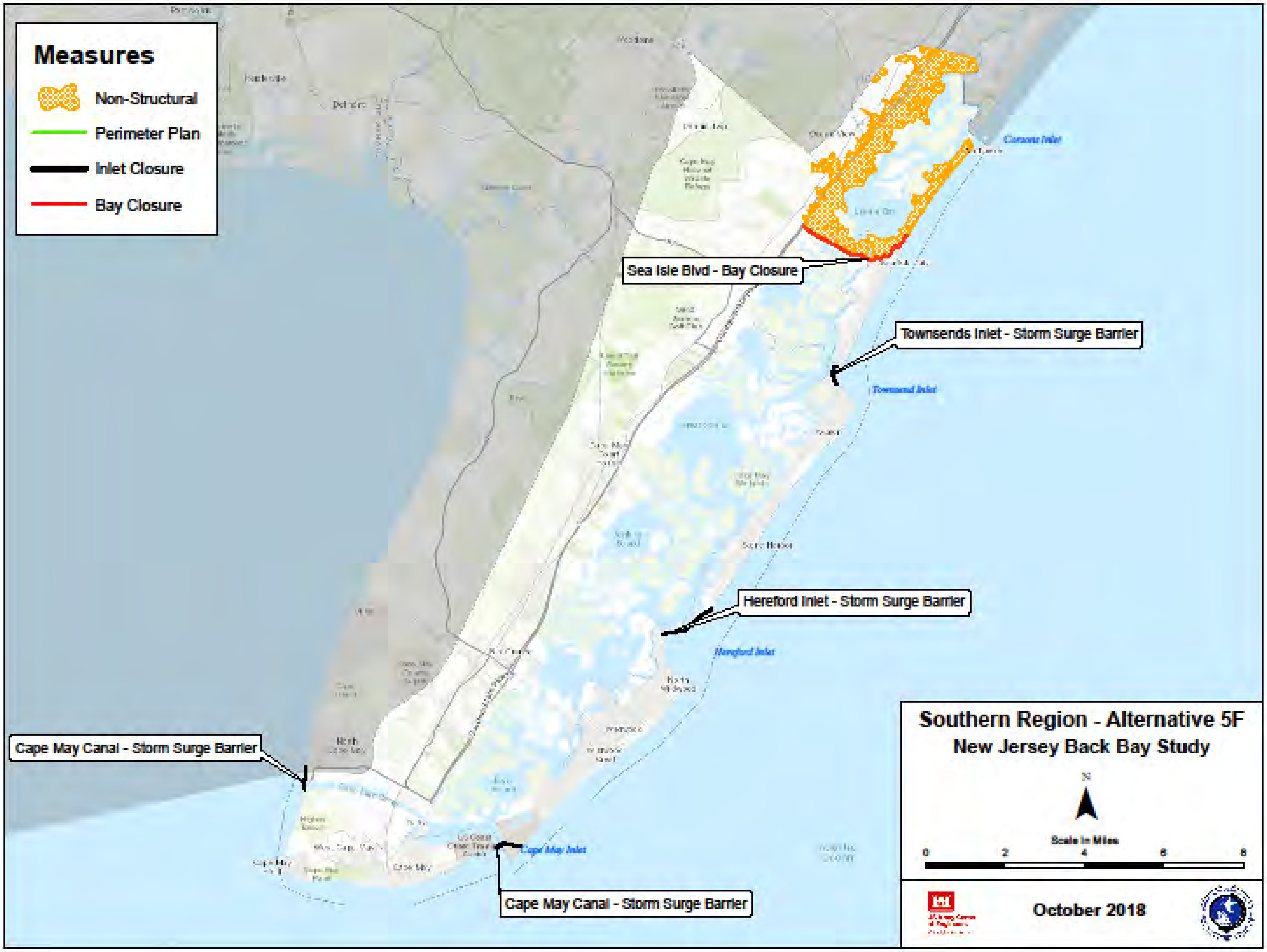
8
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle Blvd - Bay Closure
Corsons Inlet
Townsends Inlet - Storm Surge Barrier
Townsend Inlet
Hereford Inlet - Storm Surge Barrier
Hereford Inlet
Cape May Canal - Storm Surge Barrier
Cape May Inlet
Cape May Canal - Storm Surge Barrier
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New Jersey Back Bay Study
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Scale in Miles
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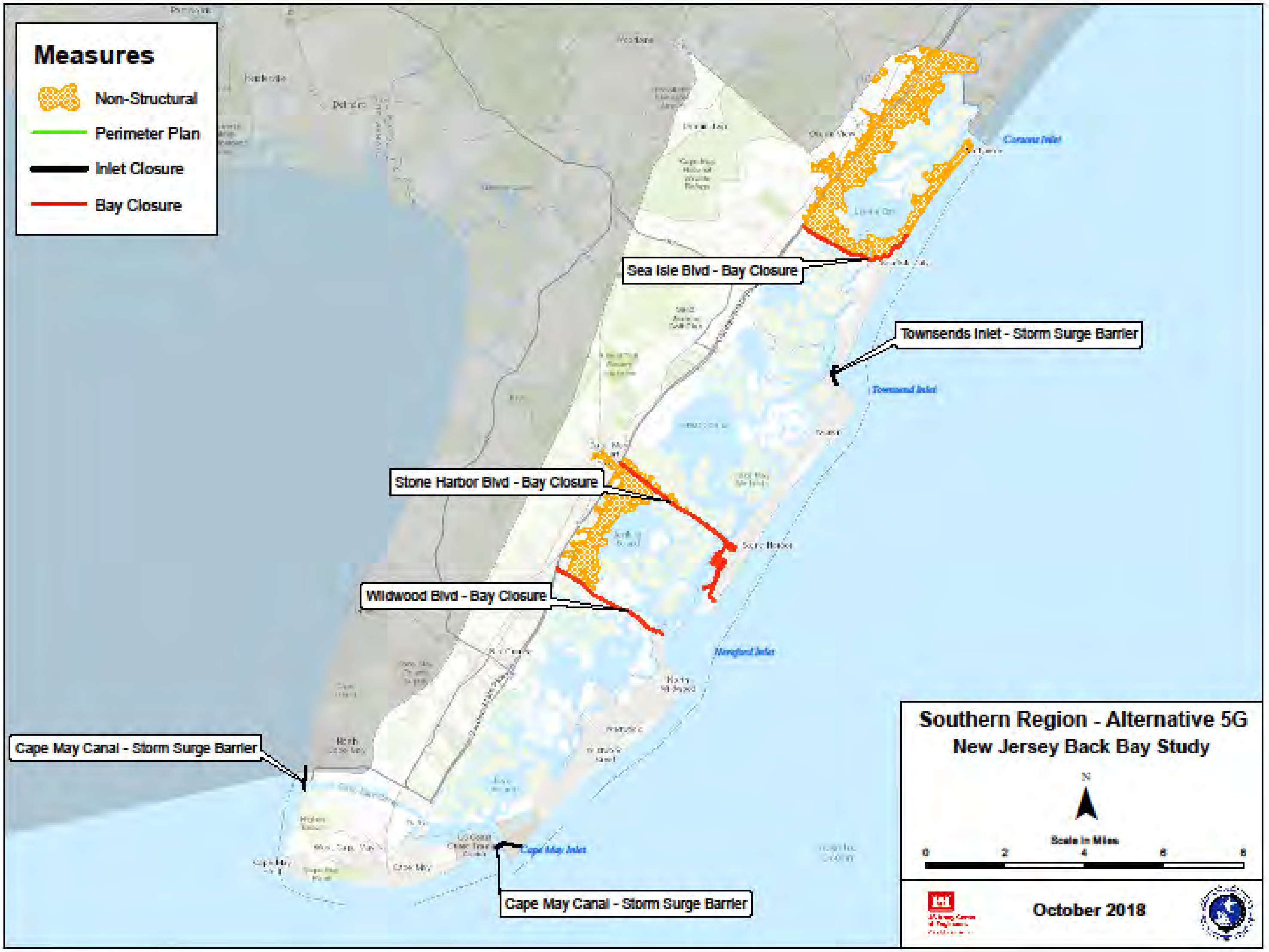
2
4
6
8
October 2018


Measures
Non-Structural
Perimeter Plan
Inlet Closure
Bay Closure
Sea Isle Blvd - Bay Closure
Townsends Inlet - Storm Surge Barrier
Stone Harbor Blvd - Bay Closure
Wildwood Blvd - Bay Closure
Cape May Canal - Storm Surge Barrier
Cape May Canal - Storm Surge Barrier
Southern Region - Alternative 5G
New Jersey Back Bay Study
Scale in Miles
0
2
4
6
8
October 2018

Evaluation

Table 17 provides the economic analysis results for the baseline study wide results and each of the Regional alternatives. Each Region is presented independently with results for Average Annual Net Benefits, Benefit-Cost Ratio, Residual Damages, and projected annual Operations & Maintenance.

All non-structural measures are evaluated using the 5% ACE (20YR) floodplain extent.

Any alternatives shaded in green denote inclusion in the Final Array of Alternatives.

Table 17: Economic Analysis Results for 51 Regional Alternatives

STUDY WIDE (BASELINE)

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
1A	$7,075,292,000	$262,075,000	$451,666,000	$189,590,000	1.72	71.26%	$0
1B	$5,229,038,000	$281,177,000	$738,568,000	$457,392,000	2.63	53.01%	$52,290,000
1C	$21,484,962,000	$1,332,419,000	$1,478,075,000	$145,656,000	1.11	5.95%	$331,673,000
1D	$15,457,093,000	$942,905,000	$1,219,060,000	$276,155,000	1.29	22.43%	$238,606,000

Each of the study wide single-measure alternatives are theoretically economically justified though the non-structural alternative only plan (1A) and incrementally justified perimeter only plan (1B) have exceedingly high residual damages at 71% and 53%, respectively. Alternative 1A does not inhibit vehicle damage, infrastructure damage, emergency costs, or transportation delays. Alternative 2A is effective at reducing CSRM damages for the communities with perimeter measures, but does nothing to mitigate damages for structures outside the perimeter locations.

The All Closed (1C) and All Closed except Little Egg Harbor Inlet (1D) are also theoretically justified, but both plans ignore serious environmental concerns at Corson's Inlet and Hereford Inlet.

As such, while these plans provide valuable context for the Region-specific evaluations, none are considered acceptable nor implementable.

SHARK RIVER AND COASTAL LAKES REGIONS

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
2A	$24,468,000	$906,000	$1,133,000	$227,000	1.25	88.47%	$0
2B	$512,216,000	$25,747,000	$3,771,000	-$21,976,000	0.15	61.63%	$5,122,000
2C	$591,347,000	$33,439,000	$6,149,000	-$27,289,000	0.18	37.44%	$9,125,000

The economic assessment presented above contains both the results for the Shark River Inlet HEC-FDA reaches and the Coastal Lakes HEC-FDA reaches (Figure 21). To reiterate, the Coastal Lakes Region covers only the coastal lakes not already included in either the North or Shark River Regions. The results are aggregated here due to the exceptionally minor influence of either Region on the overall study area.

Both the perimeter and storm surge barrier alternatives are economically unviable and only non-structural (2A) is considered an economically justified plan.

NORTH REGION

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
3A	$3,629,095,000	$134,425,000	$203,011,000	$68,586,000	1.51	62.97%	$0
3B	$6,726,209,000	$437,164,000	$276,635,000	-$160,529,000	0.63	49.54%	$67,262,000
3C	$461,554,000	$22,731,000	$26,258,000	$3,528,000	1.16	95.21%	$4,616,000
3D	$3,898,614,000	$150,042,000	$214,874,000	$64,831,000	1.43	60.81%	$4,616,000
3E(1)	$2,549,342,000	$154,810,000	$308,828,000	$154,018,000	1.99	43.67%	$39,351,000
3E(2)	$3,837,663,000	$202,530,000	$362,691,000	$160,160,000	1.79	33.84%	$39,351,000
3E(3)	$4,838,353,000	$268,041,000	$399,903,000	$131,861,000	1.49	27.06%	$53,997,000
3F(1)	$5,924,539,000	$367,186,000	$434,515,000	$67,329,000	1.18	20.74%	$90,894,000
3F(2)	$6,354,659,000	$383,118,000	$455,972,000	$72,854,000	1.19	16.83%	$90,894,000
3G	$1,151,448,000	$67,465,000	$42,502,000	-$24,963,000	0.63	92.25%	$17,766,000

Non-structural (3A) is economically justified and environmentally acceptable, though it has the same limitations as Alternative 1A with 63% in residual damages. Alternative 3B is not economically feasible due to the high cost of Long Beach Island and Island Beach. Alternative 3C includes only the justified Manasquan North perimeter measure, but the 95% residual damages are deemed too high to constitute a complete plan.

Alternative 3D has the highest NED AANB of any non-SSB plan, but shares many of the same restrictions as Alternative 3A.

Alternative 3E(1) is economically practicable, but is improved by both Alternatives 3E(2) and 3E(3). The addition of non-structural in Alternative 3E(2) maximizes AANB at $160 million while the addition of perimeter measures in Alternative 3E(3) reduces residual damages down to 27% while maintaining $132 million in AANB. At the current level of analysis, either 3E(2) or 3E(3) could be considered the alternative that reasonably maximizes NED benefits.

The inclusion of the Holgate Bay Closure in Alternatives 3F(1) and 3F(2) does not drop the storm surge barriers alternatives below 1.0, but does eliminate over $90 million in AANB, thus removing these alternatives from further consideration as the NED Plan.

Alternative 3G is not economically justified and has exceedingly high residual damages at 92%.

CENTRAL REGION

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
4A	$1,954,627,000	$72,401,000	$148,963,000	$76,562,000	2.06	78.81%	$0
4B	$3,619,705,000	$201,070,000	$562,047,000	$360,976,000	2.80	20.04%	$36,197,000
4C	$2,904,784,000	$164,102,000	$530,764,000	$366,662,000	3.23	24.49%	$29,048,000
4D(1)	$3,336,914,000	$180,109,000	$557,779,000	$377,671,000	3.10	20.65%	$29,048,000
4D(2)	$3,822,130,000	$208,568,000	$576,257,000	$367,689,000	2.76	18.02%	$36,197,000
4E(1)	$6,734,047,000	$425,665,000	$570,170,000	$144,506,000	1.34	18.89%	$103,964,000
4E(2)	$7,140,707,000	$425,665,000	$585,964,000	$160,299,000	1.38	16.64%	$103,964,000
4E(3)	$7,169,796,000	$446,873,000	$592,968,000	$146,094,000	1.33	15.64%	$107,923,000
4E(4)	$7,173,761,000	$449,940,000	$595,793,000	$145,853,000	1.32	15.24%	$110,198,000
4F(1)	$9,831,254,000	$622,785,000	$652,920,000	$30,135,000	1.05	7.12%	$151,395,000
4F(2)	$10,219,820,000	$637,178,000	$669,220,000	$32,041,000	1.05	4.80%	$151,395,000
4F(3)	$10,248,909,000	$643,324,000	$677,241,000	$33,918,000	1.05	3.66%	$155,354,000
4F(4)	$10,252,874,000	$646,390,000	$680,097,000	$33,706,000	1.05	3.25%	$157,629,000
4G(1)	$4,884,211,000	$301,347,000	$594,284,000	$292,937,000	1.97	15.46%	$74,556,000
4G(2)	$5,272,777,000	$315,740,000	$610,169,000	$294,429,000	1.93	13.20%	$74,556,000
4G(3)	$5,301,866,000	$321,885,000	$617,831,000	$295,946,000	1.92	12.11%	$78,516,000
4G(4)	$5,305,831,000	$324,952,000	$620,672,000	$295,720,000	1.91	11.70%	$80,790,000
4G(5)	$5,132,009,000	$310,526,000	$611,147,000	$300,622,000	1.97	13.06%	$74,556,000
4G(6)	$5,520,576,000	$324,918,000	$627,032,000	$302,114,000	1.93	10.80%	$74,556,000
4G(7)	$5,549,665,000	$331,064,000	$634,694,000	$303,630,000	1.92	9.71%	$78,516,000
4G(8)	$5,553,629,000	$334,130,000	$637,535,000	$303,405,000	1.91	9.30%	$80,790,000
4G(9)	$5,617,225,000	$338,985,000	$634,873,000	$295,888,000	1.87	9.68%	$81,706,000
4G(10)	$6,005,792,000	$353,378,000	$650,758,000	$297,380,000	1.84	7.42%	$81,706,000
4G(11)	$6,034,880,000	$359,524,000	$658,420,000	$298,897,000	1.83	6.33%	$85,665,000
4G(12)	$6,038,845,000	$362,590,000	$661,261,000	$298,671,000	1.82	5.93%	$87,939,000

Though limited by the same drawbacks as previously discussed non-structural only options, Alternative 4A is economically feasible with 79% residual damages. Alternatives 4B and 4C (perimeter only) are economically viable, but both are improved by Alternatives 4D(1) and 4D(2). Alternative 4D(1) adds non-structural and maximizes NED AANB benefits while Alternative 4D(2) adds non-structural and a perimeter measure to Brigantine Island. Alternative 4D(2) reduces residual damages with only a 2.6% decrease in AANB.

Alternative 4E(1) is justified yet improved with the inclusion of other measure types in 4E(2), 4E(3), 4E(4). Even though Alternative 4G has higher AANB than Alternative 4E, the 4E alternatives are also included in the Focused Array to mitigate any study risk stemming from uncertainties surrounding bay closure costs estimates and environmental impacts.

The inclusion of the North Point Bay Closure in Alternative 4F severely dropped AANB in comparison with other storm surge barrier alternative. Alternative 4F increased AAB by 14.5%, but required a 46.3% increase in AAC.

Alternative 4G(1) is economically practicable, but improved by adding either non-structural or perimeter measures to Brigantine Island and non-structural, perimeter, or bay closure measures to South Ocean City (Alternatives 4G(6) – 4G(8) and 4G(10) – 4G(12)).

At the current level of analysis, any of Alternatives 4D(1), 4D(2), 4G(7), or 4G(12) could be considered the reasonably maximizing NED alternative.

SOUTH REGION

ITEM	Initial Const.	AAC	AAB	AANB	BCR	Residual	O&M
5A	$1,467,103,000	$54,343,000	$98,558,000	$44,216,000	1.81	68.27%	$0
5B	$3,424,391,000	$181,379,000	$231,893,000	$50,514,000	1.28	25.35%	$34,244,000
5C	$1,862,700,000	$94,344,000	$181,546,000	$87,202,000	1.92	41.55%	$18,627,000
5D(1)	$2,286,822,000	$110,054,000	$206,462,000	$96,408,000	1.88	33.53%	$18,627,000
5D(2)	$3,428,552,000	$180,266,000	$237,575,000	$57,310,000	1.32	23.52%	$33,066,000
5E(1)	$4,639,279,000	$274,620,000	$290,854,000	$16,233,000	1.06	6.37%	$71,610,000
5E(2)	$4,680,566,000	$276,150,000	$292,784,000	$16,634,000	1.06	5.74%	$71,610,000
5F	$5,265,569,000	$308,994,000	$298,195,000	-$10,799,000	0.97	4.00%	$80,302,000
5G	$5,924,476,000	$344,010,000	$293,924,000	-$50,086,000	0.85	5.38%	$89,110,000

The non-structural only alternative (5A) is again economically justified though with 68% residual damages. Alternatives 5B and 5C (perimeter only) are economically viable, but both are improved by Alternatives 5D(1) and 5D(2). Alternative 5D(1) adds non-structural and maximizes NED AANB benefits while Alternative 5D(2) adds non-structural and a perimeter measure to Seven Mile Island.

Alternatives 5E(1) and 5E(2) are feasible, but with significantly fewer AANB than other alternatives and does not fully address the environmental concerns at Hereford Inlet. Adding the Sea Isle Blvd Bay Closure (5F) drops residual damages, but also drops the BCR below 1.0. Avoiding an inlet closure at Hereford Inlet with the inclusion of two bay closures (5G) even further drops the BCR below 1.0.

At the current level of analysis, Alternatives 5D(1) or 5D(2) could be considered the reasonably maximizing NED alternative.

C-7) FOCUSED ARRAY OF ALTERNATIVES

From the 51 presented Regional alternatives, 20 alternatives are still considered for further evaluation with perimeter alternatives prevalent in the South and Central Regions and storm surge barrier alternatives available in the North and Central Regions.

Table 18 provides a brief recap of the available options for each Region.

Table 18: Focused Array of Alternatives

Region	Overview	Alternative	NONSTRUC	PERIMETER	SSB	BC
SHARK RIVER	2A	2A	X			
NORTH	3A	3A	X			
	3D	3D	X	X		
	3E	3E(2)	X		X	
		3E(3)	X	X	X	
CENTRAL	4A	4A	X			
	4D	4D(1)	X	X		
		4D(2)	X	X		
	4E	4E(2)	X		X	
		4E(3)	X	X	X	
		4E(4)	X		X	X
	4G	4G(6)	X		X	X
		4G(7)	X	X	X	X
		4G(8)	X		X	X
		4G(10)	X	X	X	X
		4G(11)	X	X	X	X
		4G(12)	X	X	X	X
SOUTH	5A	5A	X			
	5D	5D(1)	X	X		
		5D(2)	X	X		

Region	Overview	Alternative	INIT. CONST.	AANB	BCR	RESIDUAL
SHARK RIVER	2A	2A	$24,468,000	$227,000	1.25	88.47%
NORTH	3A	3A	$3,629,095,000	$68,586,000	1.51	62.97%
	3D	3D	$3,898,614,000	$64,831,000	1.43	60.81%
	3E	3E(2)	$3,837,663,000	$160,160,000	1.79	33.84%
		3E(3)	$4,838,353,000	$131,861,000	1.49	27.06%
CENTRAL	4A	4A	$1,954,627,000	$76,562,000	2.06	78.81%
	4D	4D(1)	$3,336,914,000	$377,671,000	3.10	20.65%
		4D(2)	$3,822,130,000	$367,689,000	2.76	18.02%
	4E	4E(2)	$7,140,707,000	$160,299,000	1.38	16.64%
		4E(3)	$7,169,796,000	$146,094,000	1.33	15.64%
		4E(4)	$7,173,761,000	$145,853,000	1.32	15.24%
	4G	4G(6)	$5,520,576,000	$302,114,000	1.93	10.80%
		4G(7)	$5,549,665,000	$303,630,000	1.92	9.71%
		4G(8)	$5,553,629,000	$303,405,000	1.91	9.30%
		4G(10)	$6,005,792,000	$297,380,000	1.84	7.42%
		4G(11)	$6,034,880,000	$298,897,000	1.83	6.33%
		4G(12)	$6,038,845,000	$298,671,000	1.82	5.93%
SOUTH	5A	5A	$1,467,103,000	$44,216,000	1.81	68.27%
	5D	5D(1)	$2,286,822,000	$96,408,000	1.88	33.53%
		5D(2)	$3,428,552,000	$57,310,000	1.32	23.52%

The Focused Array of Alternatives is presented by Region as even just the remaining 20 alternatives have a total of 144 unique, non-repetitive combinations if they were aggregated to a study wide level. In addition, each Region (with the exception of Shark River) has multiple alternative types still under consideration with further analysis necessary to determine the NED Plan.

However, as each Region is functionally independent, it is possible to calculate the AANB and BCR for any and all of the 144 combinations. For example, the current NED maximizing study wide plan is the combination of 2A + 3E(2) + 4D(1) + 5D(1) for a total of $634,466,000 in AANB with a 2.29 BCR with 28.22% residual damages. The current damage minimization plan is 2A + 3E(3) + 4G(12) + 5D(2) with $488,069,000 in AANB with a 1.6 BCR and 17.29% in residual damages.

Combinations that minimize environmental impact or maximize social benefits or any other objective can be calculated by aggregating one alternative from each Region.

C-8) CONCLUSION

The New Jersey Back Bays CSRM Feasibility Study has identified an array of potential alternatives with additional analysis necessary to identify the true NED Plan. Each measure type has pros and cons and further investigation is necessary to determine the optimal measure combination for each Region and for the study area as a whole.