No Action Risk Assessment DRAFT Technical Memorandum

New Jersey Fostering Regional Adaptation through Municipal Economic Scenarios (NJFRAMES) – March 2019

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I. Overview

This technical memorandum summarizes the methodology and results of the No Action Risk Assessment conducted to evaluate the risk of coastal flooding in the Two Rivers region under current climate conditions. The term "No Action" risk assessment reflects the future flood risk conditions (assessed for 2030, 2050 and 2100) in the project area if actions to be identified by the FRAMES project are not implemented. At a later stage in the project comparison of risk *without* Action (No Action) to risk *with* Action (as reflected in the Adaptation Planning Scenarios) will then indicate the risk reduction that may result from the Adaptation Planning Scenarios. The methodology follows the methods applied in the Baseline Risk Assessment and based on general procedures outlined in 'What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure' published by the National Oceanic and Atmospheric Administration ("NOAA Framework") in June 2013 and more specifically the Risk Assessment Methodology Technical Memorandum previously developed on December 14, 2017 (NJFRAMES, Dec 2017).

The No Action Risk Assessment considers the anticipated impacts and probability of flood hazard events, enabling the comparison of coastal flood events of varying degrees of magnitude. As described in the Risk Assessment Methodology Technical Memorandum (December 2017) risk scenarios were characterized through establishing water levels (3, 7 and 12 feet above MHHW) and then assigning probabilities to those water levels in key decadal analysis years (2020, 2030, 2050, 2100), so as to generate an understanding of how risks would evolve in the future. A discussion of this methodology is summarized below under "Inundation Levels Selected for Risk Assessment".

The *initial* year for which the risk assessment was conducted was 2020. This year was selected for the Baseline Risk Assessment as it was the year closest to the current year (2018), among the decadal years for which extreme water levels were established through 2100. For purposes of analysis it was assumed that changes between 2017 and 2020 would be de minimis in terms of their effect on the results of the Baseline Risk Assessment. However, to enable comparison across all decadal risk assessment years (2020, 2030, 2050 and 2100) all monetary valuations in the risk assessment, including the No Action Risk Assessments are expressed in 2017 dollars. The Baseline Risk Assessment originally conducted in June 2018 was revised in August 2018 to be consistent with a revised methodology to establish extreme water level frequencies used for the No Action Risk Assessment, pursuant to discussions with NOAA between June and August 2018.

The monetary output of the No Action Risk Assessment can be expressed in terms of "annualized loss". Annualized loss is defined as the expected annual loss over the long term (UNISDR, 2017). Another term commonly used in risk assessments is Annualized Loss Exposure (ALE)[1] or the probable frequency and magnitude of future loss. The combination of both elements (not just one) is what can be called *Loss Exposure* or *Risk*.

$$Risk = Frequency \times Magnitude$$

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[1] https://www.risklens.com/blog/what-exactly-is-annualized-loss-exposure

Examples:

- 6 events per year x $10,000 per event loss equals an ALE of $60,000
- 1 event every 4 years x $800,000 per event equals an ALE of $200,000
- 1 event every 100 years x $10,000,000 per event equals an ALE of $100,000

ALE allows comparison and prioritization of dissimilar risks or separate risk issues having difference frequencies and pre-event impacts and is especially useful for risk communication. The results of the risk assessment serve as indicators of risk, as trends of risk over time, and as input in the development of adaptation planning strategies and supporting analyses such as cost-benefit analysis.

The Baseline (2020) Risk Assessment (see Attachment 1) and the No Action Risk Assessment (2030, 2050, 2100); along with information obtained from community engagement efforts, will inform the development of a Resilience and Adaptation Measures Matrix. The Resilience and Adaptation Measures Matrix will include potential measures to increase the resilience of the study area. The No Action Risk Assessment will be used to refine and evaluate the effectiveness of proposed solutions in the Resilience and Adaptation Measures Matrix.

II. Methodology

A. Overall Methodology

The No Action Risk Assessment is part of an overall workflow in developing resilience and adaptation measures for the Two Rivers region. See Figure II-1 for a diagram of the workflow of technical memoranda leading up to this Assessment. The methodology and results of the No Action Risk Assessment, which is one of the tasks in the orange boxes (i.e., the tasks associated with the risk assessment and cost-benefit analysis) is detailed in this document. The full methodology report, as published in December 2016 is included as Attachment 2. Other tasks have been described in previous Technical Memoranda or will be the subject of future Technical Memoranda. The compendium of Technical Memoranda will be synthesized and finalized at the end of planning process, to reflect any adjustments and refinements made through stakeholder and technical input to the various methodologies developed and deployed. The full methodology to be completed at the end of the process will thus incorporate and update preceding Draft Technical Memoranda to provide a comprehensive methodology description.

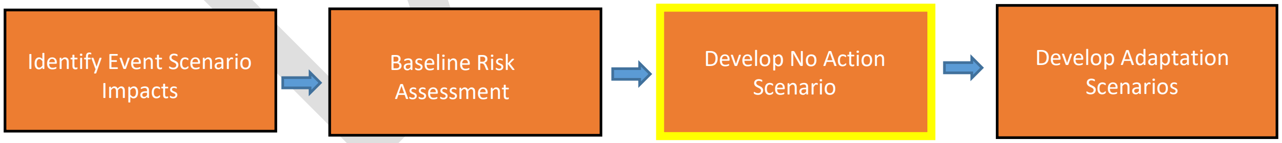

Figure II-1. Risk Assessment Workflow

As described in the NJ FRAMES Planning Inundation Levels – Technical Memo Summary (NJFRAMES, Feb 2017), three high water level event scenarios were selected to take into account a range of coastal flood hazards: 3, 7, and 12 ft. above Mean Higher High Water (MHHW). These high-water level event scenarios (referred to hereafter as “event scenarios”) were developed by the NJ FRAMES project team (i.e., “project team”) to reflect different levels of permanent inundation, coastal flooding, and coastal storm flooding as detailed in **Figure 1** below.

Extreme water level values come from NOAA's Extreme Water Levels statistics for the Sandy Hook, NJ tide gauge. The team used the "Exceedance Probability Levels and Tidal Datums" at the gauge for tidal datum and water level references. Although both NOAA and the Federal Emergency Management Administration (FEMA) communicate events regarding a probability of exceeding a specific water level height (e.g., a 1% or 100-year event), the NOAA 1% Annual Exceedance Probability (AEP) is different from the FEMA Base Flood Elevation (BFE).[2] More specifically, the NOAA AEP does not reflect additional height from run-up and wave action as considered in FEMA Flood Insurance Rate Map (FIRM) modeling. The NOAA AEP values also do not reflect hydrodynamic effects modeled in the US Army Corps of Engineers' (USACE) most recent risk analysis in the North Atlantic Coast Comprehensive Study (NACCS).

The project team explicitly chose these extreme water level values so that the approach would reflect what the entire region would see "at a minimum." This still water approach to assessing current and future flood exposure allows the project team to project water levels into the future without making spatial adjustments in wave heights associated with extreme storms between coastal and inland areas (such as tidal rivers, bays, and estuaries). Also note, that since wave heights cannot be predicted into the future without a substantive local modeling effort, this approach does not account for wave heights from weaker storms or tidal fluctuations but would still result in higher water levels in the future due to sea-level rise under various scenarios. As a result, these water levels represent minimum levels of exposure and areas adjacent to the coastline may experience additional impact from run-up and wave action.

Additionally, the use of still water levels allows the project team, practitioners and stakeholders to utilize mapping visualization tools like the NJ FloodMapper.org, the NJ Coastal Flood Exposure Profiler and NOAA's Sea Level Rise (SLR) viewer for planning and communication purposes.

This Technical Memo describes the risk for 3, 7 and 12 ft. water levels in future years 2030, 2050, and 2100, using a High Emissions 1-in-20 chance estimate for SLR. This SLR assumption results in the project team accounting for a 5.3-foot increase in sea level by 2100. The project team chose to plan for 5.3 feet of sea level rise as a precautionary approach to developing project needs and implementation timing.

In contrast to event-based impacts (such as a water level associated with a 50-year storm), parts of the Two Rivers region will experience a condition characterized as "permanent inundation." This permanent inundation is caused specifically by sea level rise under a High Emissions 1-in-20 chance scenario.[3] To adequately characterize permanent inundation, a review of recent publications concerning permanent inundation as well as a statistical analysis of daily highest water levels at the Sandy Hook tidal gauge over

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[2] "The extreme levels measured by the CO-OPS tide gauges during storms are called storm tides, which are a combination of the astronomical tide, the storm surge, and limited wave setup caused by breaking waves. They do not include wave runup, the movement of water up a slope. Therefore, the 1% annual exceedance probability levels shown on this website do not necessarily correspond to the Base Flood Elevations (BFE) defined by the Federal Emergency Management Administration (FEMA), which are the basis for the National Flood Insurance Program. The 1% annual exceedance probability levels on this website more closely correspond to FEMA's Still Water Flood Elevations (SWEL). The peak levels from tsunamis, which can cause high-frequency fluctuations at some locations, have not been included in this statistical analysis due to their infrequency during the periods of historic record." Source: https://tidesandcurrents.noaa.gov/est/stickdiagram.shtml?stnid=8531680

[3] Permanent inundation is classified as MHHW.

a 19-year period (1998-2016) was completed (see Attachment 4).[4] For the purposes of assessment, the project team assumes that areas where the ground would be wet at Mean Higher High Water (MHHW) in a given analysis year are given a "total loss" designation (i.e., 100% loss of the asset value seaward of the inundation line).

Application of HAZUS to Assess Impacts from Flooding and Permanent Inundation

The first step in a flood risk assessment is to identify the impacts that flood events and permanent inundation will have on the area, in terms of economic impacts, socio-economic impacts, and impacts to communities (monetized and otherwise).

As described in the Risk Assessment Methodology Technical Memorandum, one of the tools used to assess impacts is the FEMA HAZUS 4.0[5] flood loss-modeling tool. HAZUS is a nationally applicable standardized Earthquake, Wind, Flood methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes. HAZUS uses Geographic Information Systems (GIS) technology to estimate physical, economic, and social impacts of disasters. It graphically illustrates the limits of identified high-risk locations due to earthquake, hurricane, flood, and tsunami.

Figure II-2: Water Levels above Current MHHW for NJ FRAMES (Updated from NJFRAMES, Feb 2017)

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[4] In the report *When Rising Seas Hit Home,* the Union of Concerned Scientists define permanent inundation at various locations, using tide gauges that exceeded 26 inundation events a year as their definition and where 10% of land area is impacted. https://www.ucsusa.org/sites/default/files/attach/2017/07/when-rising-seas-hit-home-full-report.pdf

[5] https://www.fema.gov/hazus

			Water Level	What High Water Level Condition Does This Height Represent?	How does this water level relate to recent events at Sandy Hook?
Permanent Inundation	Coastal Flooding		3 ft.	- An Annual (99%) Flood in 2050 - Permanent Inundation (MHHW) under a High Emission Scenario in 2100	In January 2017, a water level associated with a Nor'easter reached approximaely 2.8 feet above MHHW.
		Coastal Storm Flooding	7ft	- A 100-Year (1%AEP) Flood today, a 50-Year Flood in 2030 - An Annual (99% AEP) Flood under a low probability, high consequence High Emission Scenario in 2100	Hurricane Sandy reached a water level of 8.3 feet above MHHW, slightly above this assessment
			12ft	- A 1000-Year (.1% AEP) Flood today, a 500-year (.2% AEP) flood in 2050 - A 100-Year (1% AEP) Flood under a low probability, high consequence High Emission Scenario in 2100 - Hurricane Sandy under a High Emission Scenario in 2100	The historcial record for this tide gauge (i.e. since 1910) has never recorded a water level this high

For the No Action risk assessment, the HAZUS Flood Model tool was utilized. This model enables visualization of the spatial relationships between populations and other more permanently fixed geographic assets or resources for the specific hazard being modeled, which is a crucial function in the pre-disaster planning process[6]. A more detailed discussion of HAZUS and its application to this project is provided below in Section B.1 and additional guidance on flood risk assessment can be found on FEMA's web site[7]. The impacts estimated by HAZUS include economic impacts and socio-economics impacts. More information is provided in Section II.B.

In addition to HAZUS, other methodologies developed during the Baseline Risk Assessment to gauge flood-related impacts not captured by HAZUS were used in the No Action Risk Assessment to estimate both flood and permanent inundation-related impacts. These include

> (1) methodologies to monetize flooding and permanent inundation-related impact types not included in HAZUS
>
> (2) methodologies to capture flooding and permanent inundation impacts that are not included in HAZUS and could not be monetized but were instead addressed through an index value

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[6] https://www.fema.gov/hazus

[7] https://www.fema.gov/media-library-data/1469146645661-31ad3f73def7066084e7ac5bfa145949/Flood_Risk_Assessment_Guidance_May_2016.pdf

Flood and permanent inundation impacts not in either one of the above categories, but relevant to include from an awareness perspective are included through reference to other studies. These methodologies are explained in detail in Sections B and C. The identification of relevant assets to which the impacts could occur was based on established databases, additional datasets provided by other projects or entities, as well as through an extensive engagement process including the *Getting to Resilience* (GTR) component of the project and the Map What Matters campaign, which enlisted the Constituency Advisory Group and the public to identify social, natural, economic, and other public and private assets that had importance to the community .

Once flood event and permanent inundation impacts had been assessed through HAZUS, the probability of a *singular* flood event in each of the future year periods – 2030, 2050, & 2100, as previously calculated in the Event Scenario Frequencies Technical Memorandum (NJFRAMES 2018) was multiplied by the resulting total losses to establish a risk metric of annualized loss as shown in the equation below. These frequencies are shown in Attachment 4.

$$Risk\ for\ event\ i = Annualized\ Loss\ for\ event\ i = Impact\ of\ event\ i * Probability\ of\ event\ i$$

As noted above, the probability associated with a specific water level (3, 7 or 12 ft.) was determined by a specific event probability associated with such water level.

All probabilities for specific flood events in future years – 2030, 2050, & 2100 – were calculated using an Extreme Value Theory (i.e., generalized extreme value distribution (GEV)) or an Empirical Distribution application. The statistical application used was dependent on the expected SLR in the decadal analysis year. Permanent inundation was classified as MHHW in the future year periods with an assumed absolute probability of 1.0 (i.e., 100% frequency of occurrence), with losses resulting in a “total loss” designation (i.e., 100% loss of inundated asset). Note, the projected SLR conditions (5.3ft.) for 2100 are expected to exceed the 3 feet planning event No Action Scenario in 2100. The expected frequency of this event is thus 1.0, with losses resulting in a “total loss” designation. The risk outputs for permanent inundation cannot be compared directly to those associated with probability-based events and the “total loss” value is only an *indicator* of the effects of permanent inundation risks. High risks not captured by this analysis would also be occurring in these same areas, but by other (lower) water levels occurring with high frequencies. For the purpose of the regional assessment, a general understanding of when and where permanent inundation would occur within the Two Rivers Region was considered most relevant for the development of Action Scenarios. This approach is further explained in the Event Scenario Technical Memorandum of August 14th, 2018 (see Attachment 4).

Following is a description of the methodology used to assess event scenario *impacts*.

1. Summary of HAZUS Methodology to Assess Impacts

HAZUS is a flood modeling and loss estimation software tool developed by FEMA and recommended by NOAA in ‘What Will Adaptation Cost?’. HAZUS is based on a Geographic Information System (GIS), and contains spatial data on the population and physical structures within a region. Given the expected flood depth at a physical location, the HAZUS software program calculates the corresponding losses due to flood damage to a structure, considering the structure’s building value, first floor elevation, structure type, and other parameters. Losses due to flood damage to vehicles were similarly calculated, with the vehicle’s value and the number of vehicles present within the impacted area taken into consideration. Vehicle inventory is a function of parking supply and occupancy, parking generation rates (i.e., vehicle distributions based on time of day and structure type), and vehicle population by age group and type.

HAZUS contains a multitude of data including boundary map data and general building stock (GBS) data. In addition, HAZUS contains national data on critical facilities (e.g., hospitals, schools), high potential loss (HPL) facilities (e.g., nuclear power plants, military and industrial facilities), transportation and lifeline systems (e.g., highway, railway, bus transportation, ferry transportation), agriculture, vehicles, and population demographics. Data sources include but are not limited to United States Army Corps of Engineers, RS Means, and the U.S. Department of Labor, Bureau of Labor Statistics as well as several nationally applied surveys. Population demographics data is based on the most recent U.S. Census data (i.e., 2010 Census data). Due to HAZUS only containing national aggregated data (i.e., default data), a similar discrete analysis performed for the Baseline Risk Assessment (Task 2B) was conducted on specific assets identified.

a) Summary of HAZUS Methodology for Flood Scenario Events

As with the HAZUS analysis conducted for the Baseline Risk Assessment, area specific information based on the results of the flood inundation modeling completed by the New Jersey Department of Environmental Protection (DEP), was imported into HAZUS to establish the spatial extent of inundation, including height of inundation, for each of the three water level event scenarios in the future periods under a High Emissions 1-in-20 chance estimate for SLR (i.e., 5.3ft. by 2100).

Economic and Socio-Economic Impacts were expressed in terms of dollars and defined as follows:

- Economic Impacts: Building damage, building content loss, essential facility damage, and vehicle damage; and,
- Socio-Economic Impacts: Business interruption costs, rental income loss, wage loss, and relocation costs.

Both a “Level 1” and “Level 2” analysis, as conducted in the Baseline Risk Assessment, were completed for the No Action Risk Assessment. A “Level 1” analysis, based on the most recently available 2010 Census data (included in HAZUS), was used to establish estimates of *region-wide* losses in terms of economic and socio-economic impacts. Assets collected through public and stakeholder engagement (Task 2B) were imported into HAZUS to perform a “Level 2” analysis, providing estimates of building loss and content loss using updated data *customized to each asset* within the study region for which the required data on building value, first floor height, etc. was available. The same loss estimation methodology (i.e., application of Depth Damage Function (DDF) to measure extent of damage) was applied for vehicle loss estimation.

To account for losses specifically resulting from the flood event (Level 1 and Level 2) in the future year periods, permanent inundation losses relative to expected SLR were removed from the estimated flood event losses to eliminate the possibility of potential double counting of losses.[8] Level 1 reconciled flood event losses are thereafter adjusted to account for census population changes based on NJTPA population projections in the future analysis years (see section II.C.).[9] A description of the coordination with NJTPA and methodology developed to create demographic projections to 2100 for application in the HAZUS model is included with this Technical Memorandum as Attachment 3.

b) Summary of HAZUS Methodology for Permanent Inundation

In a similar manner as the HAZUS methodology applied for estimating flood event impacts, area specific information was imported into HAZUS to establish the spatial extent of inundation, including height (depth) of inundation, for each of the three SLR extents (1.1ft. by 2030, 2.0ft. by 2050, and 5.3ft. by 2100) in the future years under a High Emissions 1-in-20 chance estimate for SLR. The HAZUS flood model is currently not designed to account for SLR within a flood event simulation, thus to adequately account for exclusively the areas inundated due to SLR, the study region's Digital Elevation Model (DEM) as determined by the HAZUS flood model is lowered. The lowered DEM allows HAZUS to estimate losses resulting from permanently inundated areas that would otherwise not be possible. Inundated areas are assumed to be wholly lost with all losses and damages resulting in a "total loss" designation (i.e., 100% loss of asset). Level 1 permanent inundation losses are adjusted to account for census population changes based on NJTPA population projections in the future analysis years (see section II.C).[10]

It should be noted that the risk outputs for permanent inundation cannot be compared directly to those associated with probability based singular (incidental) events and that the "total loss" value is only an *indicator* of the effects of permanent inundation risks insofar as an area or assets permanently inundated are impacted in a fundamentally different way compared to incidental loss. High risks not captured by the risk analysis would also be occurring in these areas by other (lower) water levels occurring with high frequencies, i.e., lower level flood events capable of damaging infrastructure are equally plausible; however, there is currently no way to reasonably distinguish between these events and "permanent inundation" in a macro-level assessment. For purpose of regional assessment, a general understanding of when and where permanent inundation would occur within the Two Rivers Region was considered most relevant for the development of Action Scenarios, as this would indicate both temporal and spatial patterns of a different type of risk, relevant to the development of strategies with regional applicability. Areas subject to permanent inundation would then be addressed in detail as part of the development of specific solutions where the nature and specific effects of permanent inundation are then most appropriately evaluated.

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[8] Permanent inundation relative to flood level were removed from flood event losses at the census block level and occupancy building type or vehicle type categorical levels to account for variation in flood depth throughout the study region.

[9] Population changes are assumed to specifically correlated with residential building stock within the study region, therefore, flood event residential losses are adjusted proportionally based on projected population changes at the census block level in the future analysis year periods (2030, 2050, and 2100).

[10] Population changes are assumed to specifically correlated with residential building stock within the study region, therefore, permanent inundation residential losses are adjusted proportionally based on projected population changes at the census block level in the future analysis year periods (2030, 2050, and 2100).

2. Incorporating Assets Collected Through Public and Stakeholder Engagement

The assets collected through public and stakeholder engagement and used for the HAZUS Level 2 analysis in the Baseline Risk Assessment were used in the HAZUS Level 2 analysis in the No Action Risk Assessment. The data collection and importing of the identified assets is explained in the Baseline Risk Technical Memorandum (NJ Frames, 2018; Attachment 1).

B. Methodology for Non-HAZUS Quantified and Indexed Impacts

a) Impacted recreational utility of marinas

Superstorm Sandy resulted in $6 billion in damages for marina and boat owners and 500 damaged marinas (Meeco Sullivan, 2014) across the impacted region. In New Jersey, marinas provide recreational utility, the value of which can be quantified by the cost that visitors and users are willing to incur in return for its services. In general, this quantification considers the number of slips at each marina, an estimate of the usage of the slips throughout the year, and the recreational utility per slip usage as defined per New York's Governor's Office of Storm Recovery GOSR's Living Breakwaters project (GOSR 2017), and depicted in the equation below.

$$Total\ Recreational\ Utility = Number\ of\ Slips * Slip\ Usage\ per\ Year$$
$$* Recreational\ Utility\ Per\ Slip$$

First, the marinas at-risk in the study area were identified. This was done by filtering through assets within each of the flood extents from the asset database. Through this method, 18 marinas were identified to be at-risk from MHHW + 12' flooding in the study area. The number of slips at each marina was identified through a desktop search in Google Earth. The total number of slips in the 18 marinas was 1,408 slips, as seen in Table 1.

Table II-1: Marinas At-Risk in the Study Area for the MHHW 12' Flood Scenario

Marina Name	Number of Slips
Wharfside Marina	59
Monmouth Sailing Center	30
Pleasure Bay Yacht Basin Inc	57
Channel Club Marina	63
Navesink Yacht Sales & Marina	127
Irwins Yacht Works Inc	237
Surfside Marina	37
Covesail Marina	48
Carriage House Marina	42
Fair Haven Yacht Works	85

Marina Name	Number of Slips
Oceanic Marina	92
Anglers Marina	35
Gateway Marina Inc	92
Twin Lights Marina	10
Leonardo State Marina	176
Shrewsbury Sailing & Yacht Club	48
Belford Ferry Terminal	19
Monmouth Cove Marina	151
Total	**1,408**

Next, the total slip usage was estimated by applying the total number of slips to an estimated slip usage rate. To start, the slip usage rate was assumed to be 4 visitations per slip per year per GOSR 2017. By applying this estimated slip usage rate to the total number of slips, an annual total slip usage value of 5,632 visitations was calculated for marinas at-risk from MHHW + 12’ flooding.

Finally, a recreational utility rate was applied to the annual slip usage rate to quantify the annual recreational value of the marinas in the study area. The recreational utility rate was estimated to be $30.13 in 1995 dollars and $47.84 in 2017 dollars. This estimate of the recreational utility rate was developed through data collected from a survey of recreational users and is an average of the added recreational value of fishing and boating (Johnston et. al., 2002). The recreational usage rate represents the willingness to pay (WTP) for users for this experience. The willingness to pay value captures the consumer surplus value, as opposed to the gate fee or nominal price of storing the boat at the marina. So for example, boaters may travel several hours on a trip and expend gas and time to reach a destination for a day trip. The time devoted to this trip also has an opportunity cost that should be reflected in the willingness to pay value. This willingness to pay value, captures these other economic values and is the preferred value to apply in a social welfare benefit cost analysis.

The recreational utility at-risk values from flooding from each of the water levels at the impacted marinas are shown in Table 2.

Table II-2: At-Risk Recreational Utility of Marinas by Flood Scenario – 2020 Baseline Condition

Scenario	Total Marinas	Total slips	Total Slip Usage	Value per Slip Usage ($ 2017)	Value of boat trips ($ 2017/yr.)
Marinas in MHHW + 3’	11	619	2,476	$47.84	$118,449
Marinas in MHHW + 7’	17	1067	4,268	$47.84	$204,177
Marinas in MHHW + 12’	20	1408	5,632	$47.84	$269,429

b) *Impacted ecosystem services*

The natural environment (i.e., ecosystem) in the study area provides ecosystem services to the community that can be quantified. These ecosystem services include temporary storage of flood waters by wetlands and storage of greenhouse gases in forests. The Risk Assessment considers the economic value of these ecosystem services by leveraging the acreage of various ecosystem types and a per acre value estimate of each ecosystem type from Costanza, 2006. Costanza, 2006 assesses the economic value of New Jersey's natural capital for the purposes of policy, planning, and regulatory decisions and is analogous to the ecosystem service values provided in FEMA's *Final Sustainability Benefits Methodology Report* (FEMA 2012). These per acre value estimates are shown in Table 3 below.

To get $2017 levels, we adjusted the 2004 values for inflation using the Consumer Price Index. The CPI increased from 188.9 in 2004 to 245.12 in 2017, for a cumulative inflation rate of 29.8%, or 2.0% per year.

Table II-3: Ecosystem Service Values

Land Use/Land Cover Type	Total Service Values per Acre (2004 USD)	Total Service Values per Acre (2017 USD)
Beach	$42,147.00	$54,695.43
Coastal Shelf	$1,299.00	$1,685.75
Cropland	$866.00	$1,123.83
Forest	$1,476.00	$1,915.45
Freshwater Wetland	$11,568.00	$15,012.14
Grass/Rangelands	$78.00	$101.22
Riparian Buffer	$3,383.00	$4,390.22
Saltwater Wetland	$6,130.00	$7,955.09
Urban Greenspace	$2,473.00	$3,209.29

First, the acreage of impacted ecosystem types was calculated, using geospatial data developed by DEP for land use/land cover (DEP, 2012). The relevant land use/land cover types were identified in the data and then matched to the ecosystem types utilized in Costanza, 2006. A relevant land use/land cover type is defined as land use/land cover types likely to lose ecosystem service values from inundation. Next, the acreage of each ecosystem type in each of the flood scenarios was calculated using ArcGIS. These acreages are shown in **Table 4.**

Table II-4: Acreages of Ecosystem Types At-Risk

Land Use/Land Cover Type	Acreage within MHHW + 3'	Acreage within MHHW + 7'	Acreage within MHHW + 12'
Beach	164.12	298.80	427.70
Coastal Shelf	969.17	1364.27	1,605.17
Cropland	3.10	7.11	12.18
Forest	168.65	397.78	553.81
Freshwater Wetland	367.97	734.18	1,074.65

Grass/Rangelands	103.58	200.63	239.68
Riparian Buffer	20.44	20.59	20.61
Saltwater Wetland	431.19	441.71	442.99
Urban Greenspace	139.30	413.07	641.69
Total	**8,912.21**	**13,174.67**	**16,853.41**

For further detail the coastal shelf classification includes: saline marsh (low and high) and vegetated dune communities. The beach is classified as is.

The per acreage utility values from Costanza, 2006 were then applied to the acreages to calculate the ecosystem service values at-risk for each of the water levels. The ecosystem service value at-risk for each Land Use/Land cover type at the baseline year is shown in **Table 5.**

Table II-5: Ecosystem Service Values At-Risk for Each Land Use/Land Cover Type – 2020 Baseline Condition

Land Use/Land Cover Type	Value At-Risk within MHHW + 3' (2017 USD)	Value At-Risk within MHHW + 7' (2017 USD)	Value At-Risk within MHHW + 12' (2017 USD)
Beach	$8,976,570	$16,342,872	$23,393,452
Coastal Shelf	$1,633,782	$2,299,823	$2,705,914
Cropland	$3,483	$7,986	$13,692
Forest	$323,048	$761,936	$1,060,793
Freshwater Wetland	$5,524,012	$11,021,556	$16,132,768
Grass/Rangelands	$10,485	$20,308	$24,261
Riparian Buffer	$89,724	$90,374	$90,480
Saltwater Wetland	$3,430,166	$3,513,814	$3,523,991
Urban Greenspace	$447,061	$1,325,647	$2,059,364
Total	**$20,438,334**	**$35,384,320**	**$49,004,719**

c) Incurred mental health treatment costs

After natural disasters, the potential for mental health illnesses pose a risk to affected victims. The Risk Assessment considers the impact to potential victims by considering the treatment costs that are incurred by those that develop the need for mental health-related assistance and the lost productivity caused by mental health illness. This section describes the methodology conducted to quantify impacts due to treatment costs, followed by a discussion of the methodology used to quantify impacts associated with productivity costs. The methodologies follow the guidelines detailed in FEMA, 2012

To quantify impacts due to treatment costs, the size of the population affected by the disaster is estimated by multiplying the percentage of residential square footage with substantial damage (over 50% building damage) to the residential population. This method for calculating the affected population assumes that the fraction of residential square footage with substantial damage is an indicator for the fraction of affected population. The methodology specified above is represented by the equation below.

$$Incurred\ Mental\ Health\ Treatment\ Costs = \sum_{i}^{Census\ Tracts} (Population * \%\ residential\ sq.ft.substantial\ damage * treatment\ cost)$$

Next, a per person mental health treatment cost was applied to the population affected by the disaster. The per person mental health treatment costs considers the incidence rate of mild/moderate and severe mental illnesses and the treatment cost of both types of mental illnesses for up to 30 months. Because the incidence rate is already embedded in the per person mental health treatment cost, the incidence rate is applied to the entire population affected by the disaster rather than only the population estimated to be affected by disaster-induced illnesses. The per person treatment cost is $2,443.10 in 2012 dollars and $2,608.31 in 2017 dollars. As stated above, this per person treatment cost already considers the incidence rate of various degrees of mental illness. These incidence rates are shown in Table 6 (FEMA, 2012). The values show incidence rates for mental health illnesses because of Hurricane Katrina and Rita (Schoenbaum, 2009) and are recommended incidence rates in FEMA, 2012. As defined in Schoenbaum, 2009, mild/moderate cases are those that “meet (the) criteria for a mental disorder, plus serious role impairment” while severe cases are those that are classified as a disorder plus severe/multiple role impairment.

Table II-6: Mental Health Incidence Rates (FEMA, 2012)

Time after Disaster	Severe	Mild/Moderate
7 – 12 months	6%	26%
13 – 18 months	7%	19%
19 – 24 months	7%	14%
25 – 30 months	6%	9%

The size of the population affected by each water level and the total treatment cost incurred for each water level is shown in Table 7. As stated above, the cost of mental health treatment costs includes the consideration of the incidence rates for severe and moderate mental health incidences.

Table II-7: Treatment Costs for Disaster-Induced Mental Health Illnesses – 2020 Baseline Condition

Scenario	Population Affected With "Substantial" (>50%) Damage	Cost of Mental Health Treatment Costs (2017 dollars)
MHHW + 3’	2,434	$6,348,621.72
MHHW + 7’	6,809	$17,759,969.30
MHHW + 12’	19,635	$51,214,127.96

d) Lost productivity from mental health issues

As described above, mental health illnesses affect productivity for affected individuals. In two studies (Insel, 2009 and Levinson, et al., 2010), individuals affected with mental health illnesses incurred reduced earnings. The Risk Assessment considers this reduction in earnings by assuming that individuals with disaster-induced severe mental illnesses incur reduced earnings.

To do so, the population affected with "substantial damage" (as described in the section above) is applied to a productivity loss value. Similar to the per person treatment cost value described in the section above, this productivity loss value considers prevalence rate and is applied to the population directly affected by the disaster (flooding). The productivity loss value considers lost productivity up to 30 months after the disaster. The productivity loss value is \$8,736.00 in 2012 dollars and \$9,327.00 in 2017 dollars (FEMA, 2012).

The calculation of the lost productivity cost from mental health issues is depicted by the equation below. Note that the estimation of the population affected by the flood event is approximated by the percentage of residential square footage with substantial damage multiplied by the population in a census tract.

$$Lost\ Productivity\ Costs = \sum_{i}^{Census\ Tracts} (Population * \%\ residential\ sq.ft.substantial\ damage * Cost\ of\ Lost\ Productivity)$$

The cost of lost productivity estimated using this methodology is shown in **Table 8.**

Table II-8: Lost Productivity Costs due to Disaster-Induced Mental Health Illnesses

Scenario	Population Affected With "Substantial" (>50%) Damage	Cost of Lost Productivity (2017 dollars)
MHHW + 3'	2,434	\$22,701,305
MHHW + 7'	6,809	\$63,505,829
MHHW + 12'	19,635	\$183,130,703

e) Lost Value of Time from road closure/travel disruptions

After Superstorm Sandy, New Jersey residents experienced increased commuting times and increased frustration levels while commuting (Kaufman, 2012). The Risk Assessment considers the lost Value of Time due to a longer commute caused by a disaster and the value of that lost time. To do so, the Risk Assessment followed the methodology detailed in GOSR, 2017.

First, the number of commuters affected by the disaster was estimated. This was accomplished by obtaining the number of commuters residing in each census tract from the American Community Survey. Similar to the calculation for incurred costs from mental health treatments, the fraction of residential square footage with substantial damage is assumed to be an indicator for the fraction of affected population/commuters in a census tract. From this data set, the number of affected commuters was determined by applying the percentage of residential square footage with substantial damage to the number of commuters. In addition, 20% of regular commuters were assumed to opt to stay home (FHWA, 2017).

Next, the total amount of lost time was estimated. To do so, a travel time increase of 17 minutes per direction (34 minutes per day) was assumed based on survey data (Kaufman, 2012). In addition, this travel time increase was assumed to last 7 days.

Finally, to calculate the value of the lost time, FEMA's Value for Lost Time was used. The Value for Lost Time is based on employer costs for employee compensation provided by Bureau of Labor Statistics' *Employer Costs for Employee Compensation Historical Listing* (BLS 2017). For 2017, this value is $35.28 per hour in 2017 dollars.

The number of commuters affected by the disaster, the total amount of lost time, and lost Value of Time for each water level is shown in **Table 9.**

Table II-9: Value of Lost Time due to Travel Time Increases for Commuters – 2020 Baseline Condition

Scenario	Affected Commuters	Lost Time (hours)	Lost Value of Time (2017 dollars)
MHHW + 3'	28,814	114,296	$4,032,346
MHHW + 7'	81,481	323,208	$11,402,777
MHHW + 12'	246,289	976,946	$34,466,667

f) Lost productivity from power outages

After Superstorm Sandy made landfall, 2,615,291 customers in New Jersey experienced power outages according to the U.S. Department of Energy (DOE, 2012). Power outages from storms cause lost productivity for both residents and employers. The Risk Assessment considers this by estimating the time of lost productivity for residents and workers and then applying the FEMA Value of Lost Time (FEMA, 2012). Note that the lost productivity from power outages is separate from the lost Value of Time from road closure/travel disruptions due to the causes of the losses.

The Value of Lost Time for residents is $25.00 per day in 2010 dollars and $106.00 per day for workers in 2010 dollars, which is $28.10 and $119.16, respectively, in 2017 dollars (FEMA, 2011).

The total number of residents affected was calculated by multiplying the number of residents in a census tract by the percentage of residential square footage with substantial damage in the census tract. Again, the fraction of residential square footage with substantial damage is assumed to be an indicator for the fraction of affected population. The number of workers affected was calculated by multiplying the number of employed individuals in a census tract by the percentage of residential square footage with substantial damage in the census tract. Average functional downtime for employments was 10 days and for residents was 14 days. We take the affected residents and workers and multiply to these two parameters respectively.

The number of affected residents and employed individuals and the lost productivity due to power outages is shown in Table 10.

Table II-10. Lost productivity from Incurred cost of power outages – 2020 Baseline Condition

Scenario	Affected Residents	Affected Workers	Cost of Affected Population (2017 USD)	Cost of Affected Employment (2017 USD)	Total Loss (2017 USD)
MHHW + 3’	2,432	764	$956,981	$2,898,287	$3,855,268
MHHW + 7’	6,810	2,164	$2,679,167	$8,114,048	$10,793,215
MHHW + 12’	19,637	6,366	$7,726,075	$23,398,970	$31,125,046

g) *Summary of Methodology to Forecast Non-HAZUS Monetized Assets in Future Year Scenarios*

In a similar manner as the HAZUS methodology applied for estimating flood event impacts, Louis Berger used population projections and permanent inundation datasets to understand how assets will be impacted in future out years. After separating the absolute loss of permanent inundation from the frequency-based risk-of-loss from the water levels, Berger annualized the risk for each of the assets. The results can be found in the Monetized Impacts section (III.A.2), and the full methodology can be found in Attachment 3.

2. Indexed Impacts

The index scales developed during the Baseline Risk Assessment and used to evaluate the severity of the impacts to community resources such as transportation infrastructure, recreational areas, and socially vulnerable populations are similarly applied in the No Action Risk Assessment to evaluate impacts resulting from both the flood event scenario and permanent inundation. The indexed impacts, summarized in Table II-11, should not be considered an exact measurement and more so a quantitative method that provides a non-monetized proxy value for the degree of impacts to the transportation infrastructure, recreational areas, and socially vulnerable populations. These index scales allow for relative comparison among areas and populations affected, among the No-Action scenarios. In this manner, it can be used to identify areas or populations with relative high risk and the relative risk reduction achieved by Action Scenarios, once developed. Because they are index scales, they are not additive to the quantified risks. Indexed results should be considered as separate indicators of risk and potential risk reduction. This section describes the methodology and data sources that contributed to the development of the index scales for the No Action Risk Assessment.

Table II-11. Summary of Indexed Impacts

Index	Description	Formula
Roads	% of roadways in the project area that would be impacted given a certain water level	Impact % = (miles of roadway inundated – miles of roadway permanently inundated) ÷ miles of roadway in project area
Evacuation Routes	% of evacuation routes in the project area that would be impacted given a certain water level	Impact % = (miles of evacuation route-roadway inundated – miles of evacuation routes permanently inundated) ÷ miles of evacuation route-roadway in project area

Index	Description	Formula
Beach Area	% of beaches in the project area that would be impacted given a certain water level	Impact % = (acres of beach inundated – acres of beach permanently inundated) ÷ acres of beach in project area, per NJ Land Use-Land Cover data
Park Area	% of open space in the project area that would be impacted given a certain water level	Impact % = (acres of open space inundated – acres of beach inundated – acres of marinas inundated – acres of open space permanently inundated) ÷ acres of open space in project area
Social Vulnerability (Social Impact Scale Rating)	The quantified degree to which a community exhibits certain social conditions that may affect that community's ability to prevent human suffering and financial loss in the event of disaster	Social Impact Scale Rating = SoVI x Population x % Residential SqFt Damage

a) Roads

Roadway access is critical following a flood event for emergency services and to provide residents access to homes after evacuation orders have been lifted. To capture the degree of impact to roadways in each No Action Scenario, roadway impacts resulting from both the flood event and expected SLR in terms of permanent inundation were evaluated. In both evaluations, the percent of roadway mileage inundated within the study area was calculated in a GIS environment using a shapefile of roadways developed by the State of NJ and polygons of the flood and permanent inundation extent as provided by the Rutgers team and generated by the HAZUS flood model, respectively. To isolate the degree of impact to roadways resulting from the flood event, permanently inundated roadways were removed to eliminate the possibility of the double counting of impacts.

b) Evacuation Routes

In addition to providing a planned route for evacuation (prior to the emergency event), evacuation routes represent critical paths of travel for communities. Thus, the risk to evacuation routes was assessed to highlight this importance. First, evacuation routes were extracted from the asset database developed in Task 2B. Evacuation routes were collected from the New Jersey Geographic Information Network. Next, the total length of evacuation routes in the study area was calculated and found to be 90.5 miles. The percentage of the evacuation routes inundated within the study area was then calculated in GIS.

c) Beach Area

The integrity of beaches and dunes is critical, not just for recreational and tourism opportunities, but for protection from future storm surges. Inundated beaches and dunes experience erosion, which degrades the value of the natural assets. To capture the degree of impact to beaches in each No Action Scenario, beach impacts resulting from both the flood event and expected SLR in terms of permanent inundation were evaluated. In both evaluations, the percent of beach area inundated within the study area was calculated in a GIS environment using Land Use-Land Cover data (available from the State of NJ) that identifies beach areas, and polygons of the flood and permanent inundation extent as provided by the Rutgers team and generated by the HAZUS flood model, respectively. To isolate the degree of impact to beaches resulting from the flood event, permanent inundation beach impacts were removed from the estimated beach flood impacts to eliminate the possibility of potential double counting of impacts.

d) Park Areas

Access to recreational areas is an important community and economic resource. Flood events and permanent inundation have the potential to inundate park land, reducing access to these open spaces. Open space areas were identified using a GIS dataset developed by the Open Space and Preservation Resources Inventory of NJ. To avoid duplication with the monetized impact of Marinas as described above, marinas were excluded from the Open Space and Preservation Resources Inventory data set and index scale. Additionally, it should be noted that although there is minimal overlap between beaches and recreational areas, overlap areas were only included in the Beach Area index to avoid any potential double counting. This open space layer was compared to the flood inundation and permanent inundation polygons provided by the Rutgers team for each flood event and generated by the HAZUS flood model, respectively. These polygons were used to calculate the percent of open space areas impacted in both the flood event scenario and SLR extent. The inundated area is considered the area within the flood extent or permanently inundated area. To isolate the degree of impact to park areas resulting from the flood event, permanent inundation park area impacts were removed from the estimated park area flood impacts to eliminate the possibility of potential double counting of impacts. For example, if 2 acres of a 10-acre park is within the flood extent and 1 acre of the same 10-acre park is within the permanent inundation extent, 1 acre is considered inundated.

e) Social Vulnerability

Social vulnerability is defined as "the degree to which a community exhibits certain social conditions, including high poverty, low percentage of vehicle access, or crowded households, may affect that community's ability to prevent human suffering and financial loss in the event of disaster" (CDC, 2018). Factors such as poverty rates, vehicle access, crowding in households, and other variables, may impact a population's overall recovery rate following a flood event. To evaluate the impact of each No Action Scenario in future years – 2030, 2050, & 2100 – on socially vulnerable populations, the Social Impact scale developed during the Baseline Risk Assessment – based on the Social Vulnerability Index[11], a HAZUS-based estimate of damages to housing in each flood event and permanent inundation extent, and population counts from the 2016 American Community Survey, were considered. The permanent inundation social impact rating is calculated separately to eliminate possibility of double counting of impacted populations. A detailed process description of the Social Impact scale as well as a summary description of the Social Vulnerability Index (SVI) is provided in Baseline Risk Assessment (June 2017). Additionally, note that the social vulnerability index limitations outlined in the Baseline Risk Assessment still hold for the No Action Risk Assessment.

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[11] Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. Social Vulnerability 2016 Database NJ. http://svi.cdc.gov/SVIDataToolsDownload.html. Accessed on March 2018.

f) Publicly Identified Assets

As part of the community engagement process, 257 assets in the study area were identified and labeled as publicly identified assets. The impact of each water level event scenario on these publicly identified assets were also assessed. This assessment on Publicly Identified Assets was performed to conduct an assessment beyond assets identified by the NJFRAMES team and to highlight the importance of publicly identified assets to the community.

The impact to Publicly Identified Assets was quantified by identifying the percentage of publicly identified assets that are inundated or touching the flood extent. The number of impacted assets was obtained by calculating the number of assets inundated by each water level. Then, the number of inundated assets was divided by the total number of publicly identified assets identified (257) to result in an index. This calculation is depicted by the equation below.

$$Index\ Value\ for\ Publicly\ Identified\ Assets = \frac{Number\ of\ Assets\ Inundated}{Total\ Number\ of\ Publicly\ Identified\ Assets}$$

The resulting index for publicly identified assets are shown in Table 10.

Table II-12: Impacted Publicly Identified Assets

Flood Event	Percentage of Impacted Assets
MHHW + 3’	**13%**
MHHW + 7’	**17%**
MHHW + 12’	**21%**

C. Population Projection Methodology

To estimate population growth in the future year scenarios, Louis Berger distributed NJTPA’s original population projections from the MPO’s (TAZ) grouping levels into the Census Block levels, whose population projections are extended to 2100. From NJTPA TAZs, Louis Berger distributed the population projections to 2045 to Census Block levels. To forecast to 2100, Louis Berger utilized a logistic growth curve for this particular area projection to account for growth constraints such as land scarcity and population/housing unit full buildout. The process is summarized in Figure II-3.

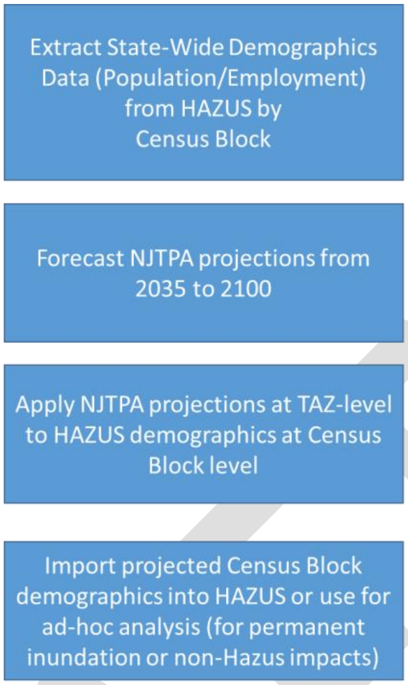

Figure II-3. Summary of Population Projection Methodology

For each TAZ, there are five parameters that were used to determine the shape of this curve:

1. The start value (base year population)
2. Target value (a carrying capacity that the projection is approaching, but never exceeds
3. A starting period value where the growth will accelerate
4. An inflection point value where the growth reaches its maximum rate and starts to level off
5. Hill's slope parameter to modify for the steepness of the growth curve.

The reason for selecting the 5-parameter logistic curve model over other logistic model was its ability to model asymmetrical patterns beyond the inflection point, which is usually the case when a region has reached its maximal build-up capabilities. For further details on the population projection, see Attachment 3.

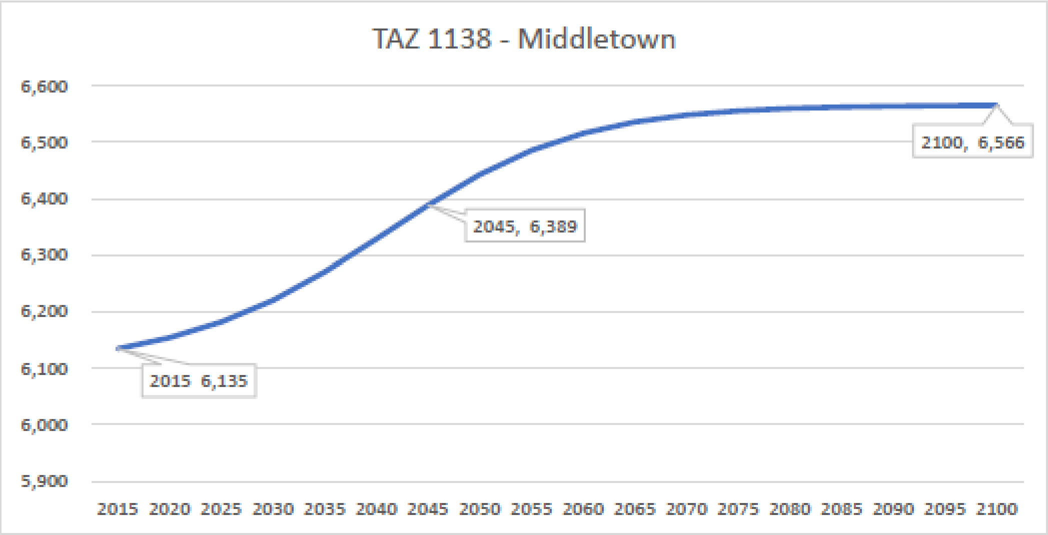

Figure-II-4. Example population projection for a TAZ in Middletown. The tapering growth in later years is consistent across most TAZ projections.

III. Summary of Results – No Action Risk Assessment

A. Event Scenario Impacts

1. Impacts Assessed using HAZUS

“Level 1” analysis results include economic losses to buildings (building loss, content loss, inventory loss), vehicle losses, losses due to damaged essential facilities, and socio-economic loss (business interruption costs, rental income loss, wage loss, and relocation costs). The flood event and permanent inundation results of the Level 1 analysis are shown below. *The flood event losses do not include the losses associated with permanent inundation and both types of losses are shown in separate tables.* The results in Tables 11 - 25 show the total impact estimates incurred for each water level *event* scenario and *permanent* inundation level in base year 2020 and future years 2030, 2050, and 2100.[12] Note that for all essential facility estimates, losses do not include monetary impacts to Fire Stations, as cost information was not available in the default HAZUS data for the study region.

Table III-1: HAZUS Level 1 Analysis - Building Losses in the Project Area – Flood Event Loss by Future Year

Flood Event	Building Loss	Building Content Loss	Building Inventory Loss	Total
2020 (Baseline)				
MHHW + 3’	$66,090,181	$89,443,164	$757,519	**$156,290,864**

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[12] Note: Event-based impacts (e.g. Table 12) may decrease over time as a greater portion of impacts shift to permanent inundation impacts (e.g. Table 13). Although both types of impacts are different in nature and should not be added mathematically the overall impact increases over time.

Flood Event	Building Loss	Building Content Loss	Building Inventory Loss	Total
MHHW + 7’	$543,473,008	$633,082,753	$6,772,681	**$1,183,328,442**
MHHW + 12’	$1,762,414,567	$1,873,807,540	$20,629,319	**$3,656,851,426**
2030				
MHHW + 3’	$46,194,586	$60,017,269	$573,915	**$106,785,769**
MHHW + 7’	$556,384,102	$630,944,105	$6,589,077	**$1,193,917,284**
MHHW + 12’	$1,850,482,000	$1,932,021,450	$20,445,715	**$3,802,949,166**
2050				
MHHW + 3’	$24,630,321	$32,375,258	$387,879	**$57,393,458**
MHHW + 7’	$551,504,276	$618,189,675	$6,403,041	**$1,176,096,992**
MHHW + 12’	$1,828,363,901	$1,903,964,963	$20,259,679	**$3,752,588,543**
2100				
MHHW + 3’	See **Table 13**: *5.3’ SLR (2100)*			
MHHW + 7’	$242,247,489	$270,868,153	$3,504,285	**$516,619,927**
MHHW + 12’	$1,600,689,469	$1,623,544,437	$17,360,923	**$3,241,594,828**

Table III-2: HAZUS Level 1 Analysis - Building Losses in the Project Area – Permanent Inundation Loss by Future Year

Permanent Inundation	Building Loss	Building Content Loss	Building Inventory Loss	Total
1.1' SLR (2030)	$78,167,980	$79,997,385	$254,303	**$158,419,668**
2.0' SLR (2050)	$164,299,153	$156,663,923	$485,425	**$321,448,501**
5.3' SLR (2100)	$863,806,329	$870,787,802	$6,498,205	**$1,741,092,336**

Table III-3: HAZUS Level 1 Analysis - Building Losses in the Project Area – 3’ Permanent Inundation Loss in 2100[13]

Permanent Inundation	Building Loss	Building Content Loss	Building Inventory Loss	Total
3' Permanent Inundation	$263,599,897	$268,384,242	$1,280,412	**$533,264,551**

Table III-4: HAZUS Level 1 Analysis - Count of Essential Facilities Damaged in the Project Area – Flood Event by Future Year

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[13] The projected SLR conditions (5.3ft.) are expected to exceed the MHHW +3’ No Action event scenario in 2100, therefore, losses resulting from inundated area are designated as a “total loss” (i.e., 100% loss of assets). Although both types of events are assumed to occur at the same frequency of 1.0 (see Section A. Overall Methodology), losses are calculated with respect to the flooding or inundation level so as to not conflate flood losses to permanent inundation losses. Thus, the losses for the MHHW +3’ and not the 5.3’ SLR level (i.e., permanent inundation). The purpose of this method is to allow for an accurate comparison across planning events in future years (2030, 2050, 2100). Therefore, it was necessary to show flood and permanent inundation losses separately.

Essential Facility Type	MHHW + 3'	MHHW + 7'	MHHW + 12'
2020			
Emergency Operations Centers	1	1	2
Fire Stations	2	3	5
Hospitals	0	0	0
Police Station	3	4	5
Schools	0	0	9
2030			
Emergency Operations Centers	1	1	2
Fire Stations	2	3	5
Hospitals	0	0	0
Police Station	3	4	5
Schools	0	0	9
2050			
Emergency Operations Centers	1	1	2
Fire Stations	1	2	4
Hospitals	0	0	0
Police Station	2	3	4
Schools	0	0	9
2100			
Emergency Operations Centers	0	0	1
Fire Stations	0	0	2
Hospitals	0	0	0
Police Station	0	0	1
Schools	0	0	9

Table III-5: HAZUS Level 1 Analysis - Count of Essential Facilities Damaged in the Project Area – Permanent Inundation by Future Year

Essential Facility Type	1.1' SLR (2030)	2.0' SLR (2050)	5.3' SLR (2100)
Emergency Operations Centers	0	0	1
Fire Stations	0	1	3
Hospitals	0	0	0
Police Station	0	1	4
Schools	0	0	0

Table III-6: HAZUS Level 1 Analysis - Count of Essential Facilities Damaged in the Project Area – 3' Permanent Inundation in 2100[14]

Essential Facility Type	3.0' Perm. Ind.
Emergency Operations Centers	1
Fire Stations	2
Hospitals	0
Police Station	3
Schools	0

Table III-7: HAZUS Level 1 Analysis - Essential Facility Losses in the Project Area – Flood Event by Future Year

Flood Event	Count of Damaged Facilities	Essential Facility Loss
2020 (Baseline)		
MHHW + 3'	6	$1,363,789
MHHW + 7'	8	$10,607,441
MHHW + 12'	21	$80,979,672
2030		
MHHW + 3'	6	$1,363,789
MHHW + 7'	8	$10,607,441
MHHW + 12'	21	$80,979,672
2050		
MHHW + 3'	4	$1,124,156
MHHW + 7'	6	$10,367,808
MHHW + 12'	19	$80,733,958
2100		
MHHW + 3'	0	$0
MHHW + 7'	0	$0
MHHW + 12'	13	$75,031,166

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[14] The projected SLR conditions (5.3ft.) are expected to exceed the 3' No Action event scenario in 2100, therefore, losses resulting from inundated area are designated as a "total loss" (i.e., 100% loss of assets).

Table III-8: HAZUS Level 1 Analysis - Essential Facility Losses in the Project Area – Permanent Inundation

Permanent Inundation	Count of Damaged Facilities	Essential Facility Loss
1.1' SLR (2030)	0	$0
2.0' SLR (2050)	2	$2,605,719
5.3' SLR (2100)	8	$12,449,817

Table III-9: HAZUS Level 1 Analysis - Essential Facility Losses in the Project Area – 3’ Permanent Inundation in 2100[15]

Flood Event	Count of Damaged Facilities	Essential Facility Loss
3' Permanent Inundation	6	$9,844,098

Table III-10: HAZUS Level 1 Analysis - Vehicle Losses in the Project Area – Flood Event by Future Year

Flood Event	Vehicle Losses			
	2020	2030	2050	2100
MHHW + 3'	$30,078,270	$16,837,170	$9,802,897	$0
MHHW + 7'	$222,179,793	$208,938,693	$201,904,420	$107,308,799
MHHW + 12'	$464,887,210	$451,646,110	$444,611,837	$350,016,217

Table III-11: HAZUS Level 1 Analysis - Vehicle Losses in the Project Area – Permanent Inundation by Future Year

Permanent Inundation	Vehicle Losses
1.1' SLR (2030)	$24,744,286
2.0' SLR (2050)	$41,643,158
5.3' SLR (2100)	$229,665,598

Table III-12: HAZUS Level 1 Analysis - Vehicle Losses in the Project Area – Permanent Inundation by Future Year

Permanent Inundation	Vehicle Losses
3.0' Permanent Inundation	$85,413,310

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[15] The projected SLR conditions (5.3ft.) are expected to exceed the 3’ No Action event scenario in 2100, therefore, losses resulting from inundated area are designated as a “total loss” (i.e., 100% loss of assets)

Table III-13: HAZUS Level 1 Analysis - Socio-Economic Impacts in the Project Area – Flood Event by Future Year

Flood Event	Relocation Loss	Capital-Related Loss	Wage Losses	Rental Income Loss	Total
2020					
MHHW + 3'	$251,696	$426,788	$1,133,239	$41,341	**$1,853,064**
MHHW + 7'	$1,208,626	$1,477,344	$3,669,650	$294,253	**$6,649,873**
MHHW + 12'	$2,690,834	$2,854,983	$7,787,975	$710,098	**$14,043,890**
2030					
MHHW + 3'	$224,795	$296,704	$894,957	$35,733	**$1,452,189**
MHHW + 7'	$1,224,213	$1,347,427	$3,432,725	$299,712	**$6,304,078**
MHHW + 12'	$2,774,037	$2,726,025	$7,554,003	$745,498	**$13,799,563**
2050					
MHHW + 3'	$154,296	$181,241	$567,904	$22,501	**$925,942**
MHHW + 7'	$1,180,644	$1,232,206	$3,108,097	$293,871	**$5,814,818**
MHHW + 12'	$2,699,591	$2,610,513	$7,226,901	$731,950	**$13,268,954**
2100					
MHHW + 3'	$0	$0	$0	$0	**$0**
MHHW + 7'	$505,061	$484,260	$1,112,233	$144,923	**$2,246,477**
MHHW + 12'	$2,125,376	$1,864,932	$5,239,729	$622,042	**$9,852,079**

Table III-14: HAZUS Level 1 Analysis - Socio-Economic Impacts in the Project Area – Permanent Inundation by Future Year

Permanent Inundation	Relocation Loss	Capital-Related Loss	Wage Losses	Rental Income Loss	Total
1.1' SLR (2030)	$162,909	$359,416	$1,226,029	$19,114	**$1,767,469**
2.0' SLR (2050)	$454,937	$400,809	$3,281,822	$39,323	**$4,176,891**
5.3' SLR (2100)	$2,222,078	$2,209,484	$7,282,744	$410,911	**$12,125,217**

Table III-15: HAZUS Level 1 Analysis - Socio-Economic Impacts in the Project Area – 3' Permanent Inundation in 2100[16]

Permanent Inundation	Relocation Loss	Capital-Related Loss	Wage Losses	Rental Income Loss	Total
3.0' Perm. Ind.	$1,211,147	$1,545,698	$6,713,013	$135,188	**$9,605,046**

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[16] The projected SLR conditions (5.3ft.) are expected to exceed the 3' No Action event scenario in 2100, therefore, losses resulting from inundated area are designated as a "total loss" (i.e., 100% loss of assets).

The Level 2 Analysis, which included an assessment of damage to buildings and contents of assets collected in Task 2B, is also shown below. The Level 2 Analysis differs from a Level 1 Analysis in that additional data beyond the default HAZUS database is used.

Table III-16: HAZUS Level 2 Analysis - Asset-Specific Building and Content Losses in the Project Area – Flood Event Loss by Future Year

Flood Event	Asset-Specific Building Loss	Asset-Specific Content Loss	Total
2020			
MHHW + 3'	$251,696	$426,788	**$1,133,239**
MHHW + 7'	$1,208,626	$1,477,344	**$3,669,650**
MHHW + 12'	$2,690,834	$2,854,983	**$7,787,975**
2030			
MHHW + 3'	$4,172,689	$2,382,221	**$6,554,910**
MHHW + 7'	$49,319,868	$36,092,980	**$85,412,847**
MHHW + 12'	$306,219,324	$109,025,040	**$415,244,365**
2050			
MHHW + 3'	$3,267,071	$1,871,485	**$5,138,556**
MHHW + 7'	$48,414,250	$35,943,762	**$84,358,012**
MHHW + 12'	$305,313,706	$108,875,822	**$414,189,529**
2100			
MHHW + 3'	$0	$0	**$0**
MHHW + 7'	$24,187,020	$17,977,480	**$42,164,500**
MHHW + 12'	$281,086,476	$90,909,541	**$371,996,017**

Table III-17: HAZUS Level 2 Analysis - Asset-Specific Building and Content Losses in the Project Area – Permanent Inundation Loss by Future Year

Permanent Inundation	Asset-Specific Building Loss	Asset-Specific Content Loss	Total
1.1' SLR (2030)	$8,158,710	$4,079,355	**$12,238,065**
2.0' SLR (2050)	$15,744,599	$7,872,299	**$23,616,898**
5.3' SLR (2100)	$196,718,421	$98,359,210	**$295,077,631**

Table III-18: HAZUS Level 2 Analysis - Asset-Specific Building and Content Losses in the Project Area – 3' Permanent Inundation in 2100[17]

Permanent Inundation	Asset-Specific Building Loss	Asset-Specific Content Loss	Total
3.0' Perm. Ind.	$82,622,454	$41,311,227	**$123,933,681**

A summary of all HAZUS-derived impacts is shown in the table below:

Table III-19: Summary of Impacts estimated using HAZUS in the Project Area – Flood Event Loss by Future Year

Flood Event	Level 1 Analysis		Level 2 Analysis
	Economic Impacts	Socio-Economic Impacts	Asset-Specific Impacts
2020			
MHHW + 3'	$195,639,342	$1,853,064	$9,270,208
MHHW + 7'	$1,493,997,898	$6,649,873	$88,489,663
MHHW + 12'	$4,621,039,488	$14,043,890	$418,321,180
2030			
MHHW + 3'	$106,785,769	$1,452,189	$6,554,910
MHHW + 7'	$1,193,917,284	$6,304,078	$85,412,847
MHHW + 12'	$3,802,949,166	$13,799,563	$415,244,365
2050			
MHHW + 3'	$57,393,458	$925,942	$5,138,556
MHHW + 7'	$1,176,096,992	$5,814,818	$84,358,012
MHHW + 12'	$3,752,588,543	$13,268,954	$414,189,529
2100			
MHHW + 3'	$0	$0	$0
MHHW + 7'	$516,619,927	$2,246,477	$42,164,500
MHHW + 12'	$3,241,594,828	$9,852,079	$371,996,017

Table III-20: Summary of Impacts estimated using HAZUS in the Project Area – Permanent Inundation Loss by Future Year

Permanent Inundation Losses	Level 1 Analysis		Level 2 Analysis
	Economic Impacts	Socio-Economic Impacts	Asset-Specific Impacts
1.1' SLR (2030)	$158,419,668	$1,767,469	$12,238,065

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[17] The projected SLR conditions (5.3ft.) are expected to exceed the 3' No Action event scenario in 2100, therefore, losses resulting from inundated area are designated as a "total loss" (i.e., 100% loss of assets).

2.0' SLR (2050)	$321,448,501	$4,176,891	$23,616,898
5.3' SLR (2100)	$1,741,092,336	$12,125,217	$295,077,631

Table III-21: Summary of Impacts estimated using HAZUS in the Project Area – 3' Permanent Inundation in 2100[18]

Permanent Inundation Losses	Level 1 Analysis		Level 2 Analysis
	Economic Impacts	Socio-Economic Impacts	Asset-Specific Impacts
3' Perm. Ind.	$533,264,551	$9,605,046	$123,933,681

2. Monetized Impacts

The monetized impacts for each of the monetized, non-hazus assets for each flood event and SLR are shown in Table 32

Table III-22: Non-HAZUS Monetized Impacts by Flood Scenario – 2020 Baseline Condition

Monetized Asset	MHHW + 3'	MHHW +7'	MHHW + 12'
2020 (Baseline)			
Impacted Recreational Utility of Marinas	$118,449	$204,177	$204,177
Impacted ecosystem services	$20,438,334	$35,384,320	$49,004,719
Incurred mental health treatment costs	$6,348,622	$17,759,969	$51,214,128
Lost productivity from mental health issues	$22,701,305	$63,505,829	$183,130,704
Lost Value of Time from road closure/travel disruptions	$4,032,346	$11,402,777	$34,466,668
Lost productivity from Incurred	$3,855,268	$10,793,215	$31,125,046

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[18] The projected SLR conditions (5.3ft.) are expected to exceed the 3' No Action event scenario in 2100, therefore, losses resulting from inundated area are designated as a "total loss" (i.e., 100% loss of assets).

Monetized Asset	MHHW + 3’	MHHW +7’	MHHW + 12’
cost of power outages			
2030			
Recreational Utility of Marinas	$ 74,437	$ 160,165	$ 225,417
Impacted Ecosystem Services	$9,963,045	$26,839,041	$40,084,025
Incurred Mental Health Treatment Costs	$173,965	$2,777,348	$12,471,842
Lost Productivity (Mental Health Issues)	$622,060	$9,931,198	$44,596,624
Lost Value of Time	$128,748	$1,994,902	$8,709,555
Lost Productivity (Power Outages)	$80,307	$1,272,917	$5,673,122
2050			
Recreational Utility of Marinas	$ 44,777	$ 130,505	$ 195,757
Impacted Ecosystem Services	$5,278,531	$22,154,527	$35,399,510
Incurred Mental Health Treatment Costs	$90,544	$2,693,968	$12,388,462
Lost Productivity (Mental Health Issues)	$323,767	$9,633,049	$44,298,476

Monetized Asset	MHHW + 3’	MHHW +7’	MHHW + 12’
Lost Value of Time	$75,150	$2,116,373	$9,377,647
Lost Productivity (Power Outages)	$42,801	$1,268,511	$5,794,252
2100			
Recreational Utility of Marinas	$0	$ 17,605	$ 82,857
Impacted Ecosystem Services	$0	$4,905,559	$18,150,542
Incurred Mental Health Treatment Costs	$0	$1,710,700	$11,405,195
Lost Productivity (Mental Health Issues)	$0	$6,117,096	$40,782,523
Lost Value of Time	$0	$1,509,716	$9,536,764
Lost Productivity (Power Outages)	$0	$815,062	$5,390,441

Table III-23: Non-HAZUS Monetized Analysis – Permanent Inundation by Future Year

Monetized Asset	1.1' SLR (2030)	2.0' SLR (2050)	5.3' SLR (2100)
Recreational Utility of Marinas	**$44,012**	**$73,672**	**$186,572**
Impacted Ecosystem Services	**$12,004,062**	**$16,688,576**	**$33,937,545**
Incurred Mental Health Treatment Costs	**$3,991,898**	**$8,192,970**	**$46,207,022**

Lost Productivity (Mental Health Issues)	**$14,274,170**	**$29,296,299**	**$165,226,369**
Lost Value of Time	**$2,813,014**	**$6,479,967**	**$40,037,139**
Lost Productivity (Power Outages)	$1,824,380	$3,826,169	$21,852,865

Table III-24: Non-HAZUS Monetized Analysis – 3.0’ Permanent Inundation in 2100

Calculation Type	Loss Type	2100
		3.0' Permanent Inundation
Monetized	Impacted Recreational Utility of Marinas	$186,572
Monetized	Impacted ecosystem services	$11,970,437
Monetized	Incurred mental health treatment costs	$20,444,177
Monetized	Lost productivity from mental health issues	$73,103,979
Monetized	Lost Value of Time from road closure/travel disruptions	$18,348,338
Monetized	Lost productivity from Incurred cost of power outages	$9,701,521

3. Indexed Impacts

The following table summarizes the indexed impacts of each flood event and SLR in future analysis years 2030, 2050, and 2100. The percentages below represent the index values for each respective impact type.

Table III-25: Index Analysis – Flood Event by Future Year

Index	MHHW + 3'	MHHW + 7'	MHHW + 12'
2020 Baseline			
Roads	4%	10%	16%

Index	MHHW + 3'	MHHW + 7'	MHHW + 12'
Park Area	7%	11%	16%
Beach Area	24%	55%	85%
Publicly Identified Assets	17%	35%	43%
Social Impact	10.1	27.5	69.1
2030			
Roads	3%	9%	15%
Park Area	2%	6%	10%
Beach Area	16%	54%	80%
Publicly Identified Assets	4%	8%	12%
Social Impact	0.3	4.6	20.5
2050			
Roads	2%	8%	14%
Park Area	1%	5%	9%
Beach Area	5%	42%	69%
Publicly Identified Assets	0%	4%	8%
Social Impact	0.1	4.6	20.4
2100			
Roads	0%	3%	8%
Park Area	0%	1%	6%
Beach Area	0%	11%	38%
Publicly Identified Assets	0%	0%	4%
Social Impact	0.0	3.0	19.6

Table III-26: Index Analysis – Permanent Inundation by Future Year

Index	1.1' SLR (2030)	2.0' SLR (2050)	5.3' SLR (2100)
Roads	1%	2%	7%
Park Area	4%	6%	9%
Beach Area	14%	24%	56%
Publicly Identified Assets	10%	13%	17%
Social Impact	5.8	12.5	81.0

Table III-27: Index Analysis – 3' Permanent Inundation in 2100[19]

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[19] The projected SLR conditions (5.3ft.) are expected to exceed the 3' No Action event scenario in 2100, therefore, losses resulting from inundated area are designated as a "total loss" (i.e., 100% loss of assets).

Index	3.0' Perm. Ind.
Roads	4%
Park Area	7%
Beach Area	29%
Publicly Identified Assets	8%
Social Impact	34.4

4. Total Impacts for Each Event

The impacts resulting from each flood event and permanent inundation in future years 2030, 2050, and 2100 by loss type are shown in Table 39.. The table also includes the total monetized losses for each event.

Table III-28: Summary of Impacts – Flood Event by Future Year

Calculation Type	Loss Type	MHHW + 3’	MHHW + 7’	MHHW + 12’
2020 (Baseline)				
HAZUS	Building Losses	$156,290,864	$1,183,328,442	$3,656,851,426
HAZUS	Essential Facilities (Count)	6	8	21
HAZUS	Essential Facility Loss	$1,363,789	$10,607,441	$80,979,672
HAZUS	Vehicle Losses	$30,078,270	$222,179,793	$464,887,210
HAZUS	Socio-economic Impacts	$1,853,064	$6,649,873	$14,043,890
HAZUS	Asset Specific Losses	$9,270,208	$88,489,663	$418,321,180
Monetized	Impacted Recreational Utility of Marinas	$118,449	$204,177	$204,177
Monetized	Impacted ecosystem services	$20,438,334	$35,384,320	$49,004,719
Monetized	Incurred mental health treatment costs	$6,348,622	$17,759,969	$51,214,128
Monetized	Lost productivity from mental health issues	$22,701,305	$63,505,829	$183,130,704
Monetized	Lost Value of Time from road closure/travel disruptions	$4,032,346	$11,402,777	$34,466,668
Monetized	Lost productivity from Incurred cost of power outages	$3,855,268	$10,793,215	$31,125,046
Indexed	Roadway Percent	4%	10%	16%
Indexed	Evacuation Route Percent	3%	8%	16%
Indexed	Beach Area Percent	29%	66%	93%
Indexed	Open Space Percent	7%	10%	15%
Indexed	Publicly Identified Assets Index	17%	35%	43%
Indexed	Social Impacts Index	10.1	27.5	69.1
Total Monetized Losses	N/A	$261,575,771	$1,660,484,854	$4,996,376,655
2030				
HAZUS	Building Losses	$106,785,769	$1,193,917,284	$3,802,949,166
HAZUS	Essential Facilities (Count)	6	8	21
HAZUS	Essential Facility Loss	$1,363,789	$10,607,441	$80,979,672
HAZUS	Vehicle Losses	$16,837,170	$208,938,693	$451,646,110
HAZUS	Socio-economic Impacts	$1,452,189	$6,304,078	$13,268,954
HAZUS	Asset Specific Losses	$6,554,910	$85,412,847	$415,244,365
Monetized	Impacted Recreational Utility of Marinas	$ 74,437	$ 160,165	$ 225,417

Calculation Type	Loss Type	MHHW + 3’	MHHW + 7’	MHHW + 12’
Monetized	Impacted ecosystem services	$9,963,045	$26,839,041	$40,084,025
Monetized	Incurred mental health treatment costs	$173,965	$2,777,348	$12,471,842
Monetized	Lost productivity from mental health issues	$622,060	$9,931,198	$44,596,624
Monetized	Lost Value of Time from road closure/travel disruptions	$128,748	$1,994,902	$8,709,555
Monetized	Lost productivity from Incurred cost of power outages	$80,307.11	$1,272,917.67	$5,673,122.22
Indexed	Roadway Percent	3%	9%	15%
Indexed	Evacuation Route Percent	4%	9%	16%
Indexed	Beach Area Percent	16%	54%	80%
Indexed	Open Space Percent	2%	6%	10%
Indexed	Publicly Identified Assets Index	4%	8%	12%
Indexed	Social Impacts Index	0.3	4.6	20.5
Total Monetized Losses	N/A	$144,036,395	$1,548,155,923	$4,875,848,873
2050				
HAZUS	Building Losses	$57,393,458	$1,176,096,992	$3,752,588,543
HAZUS	Essential Facilities (Count)	4	6	19
HAZUS	Essential Facility Loss	$1,124,156	$10,367,808	$80,733,958
HAZUS	Vehicle Losses	$9,802,897	$201,904,420	$444,611,837
HAZUS	Socio-economic Impacts	$925,942	$5,814,818	$13,268,954
HAZUS	Asset Specific Losses	$5,138,556	$84,358,012	$414,189,529
Monetized	Impacted Recreational Utility of Marinas	$ 44,777	$ 130,505	$ 195,757
Monetized	Impacted ecosystem services	$5,278,531	$22,154,527	$35,399,510
Monetized	Incurred mental health treatment costs	$90,544	$2,693,968	$12,388,462
Monetized	Lost productivity from mental health issues	$323,767	$9,633,049	$44,298,476
Monetized	Lost Value of Time from road closure/travel disruptions	$75,150	$2,116,373	$9,377,647

Calculation Type	Loss Type	MHHW + 3’	MHHW + 7’	MHHW + 12’
Monetized	Lost productivity from Incurred cost of power outages	$42,801	$1,268,511	$5,794,252
Indexed	Roadway Percent	2%	8%	14%
Indexed	Evacuation Route Percent	4%	9%	16%
Indexed	Beach Area Percent	5%	42%	69%
Indexed	Open Space Percent	1%	5%	9%
Indexed	Publicly Identified Assets Index	0%	4%	8%
Indexed	Social Impacts Index	0.1	4.6	20.4
Total Monetized Losses	N/A	$80,240,583	$1,516,538,989	$4,812,846,944
2100				
HAZUS	Building Losses	$0	$516,619,927	$3,241,594,828
HAZUS	Essential Facilities (Count)	0	0	13
HAZUS	Essential Facility Loss	$0	$0	$75,031,166
HAZUS	Vehicle Losses	$0	$107,308,799	$350,016,217
HAZUS	Socio-economic Impacts	$0	$2,246,477	$9,852,079
HAZUS	Asset Specific Losses	$0	$42,164,500	$371,996,017
Monetized	Impacted Recreational Utility of Marinas	N/A	$ 17,605	$ 82,857
Monetized	Impacted ecosystem services	$0	$4,905,559	$18,150,542
Monetized	Incurred mental health treatment costs	$0	$1,710,700	$11,405,195
Monetized	Lost productivity from mental health issues	$0	$6,117,096	$40,782,523
Monetized	Lost Value of Time from road closure/travel disruptions	$0	$1,509,716	$9,536,764
Monetized	Lost productivity from Incurred cost of power outages	$0	$815,062	$5,390,441
Indexed	Roadway Percent	0%	3%	8%
Indexed	Evacuation Route Percent	0%	14%	20%

Calculation Type	Loss Type	MHHW + 3’	MHHW + 7’	MHHW + 12’
Indexed	Beach Area Percent	0%	11%	38%
Indexed	Open Space Percent	0%	1%	6%
Indexed	Publicly Identified Assets Index	0%	0%	4%
Indexed	Social Impacts Index	0.0	3.0	19.6
Total Monetized Losses	N/A	$0	$683,415,441	$4,133,838,642

Table III-29: Summary of Impacts – Permanent Inundation by Future Year

Calculation Type	Loss Type	2030 1.1' SLR	2050 2.0' SLR	2100 5.3' SLR
HAZUS	Building Losses	$158,419,668	$321,448,501	$1,741,092,336
HAZUS	Essential Facilities (Count)	0	2	8
HAZUS	Essential Facility Loss	$0	$2,605,719	$12,449,817
HAZUS	Vehicle Losses	$24,744,286	$41,643,158	$229,665,598
HAZUS	Socio-economic Impacts	$1,767,469	$4,176,891	$12,125,217
HAZUS	Asset Specific Losses	$12,238,065	$23,616,898	$295,077,631
Monetized	Impacted Recreational Utility of Marinas	$ 44,012	$ 73,672	$ 186,572
Monetized	Impacted ecosystem services	$12,004,062	$16,688,576	$33,937,545
Monetized	Incurred mental health treatment costs	$3,991,898	$8,192,970	$46,207,022
Monetized	Lost productivity from mental health issues	$14,274,170	$29,296,299	$165,226,369
Monetized	Lost Value of Time from road closure/travel disruptions	$2,813,014	$6,479,967	$40,037,139
Monetized	Lost productivity from Incurred cost of power outages	$1,824,380	$3,826,169	$21,852,865
Indexed	Roadway Percent	1%	2%	7%
Indexed	Evacuation Route Percent	1%	1%	6%
Indexed	Beach Area Percent	14%	24%	56%
Indexed	Open Space Percent	4%	6%	9%

Indexed	Publicly Identified Assets Index	10%	13%	17%
Indexed	Social Impacts Index	5.8	12.5	81.0
Total Monetized Losses	N/A	$232,121,024	$458,048,822	$2,597,858,119

Table III-30: Summary of Impacts – 3.0' Permanent Inundation in 2100[20]

Calculation Type	Loss Type	2100 3.0' Permanent Inundation
HAZUS	Building Losses	$533,264,551
HAZUS	Essential Facilities (Count)	6
HAZUS	Essential Facility Loss	$9,844,098
HAZUS	Vehicle Losses	$85,413,310
HAZUS	Socio-economic Impacts	$9,605,046
HAZUS	Asset Specific Losses	$123,933,681
Monetized	Impacted Recreational Utility of Marinas	$186,572
Monetized	Impacted ecosystem services	$11,970,437
Monetized	Incurred mental health treatment costs	$20,444,177
Monetized	Lost productivity from mental health issues	$73,103,979
Monetized	Lost Value of Time from road closure/travel disruptions	$18,348,338

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[20] The projected SLR conditions (5.3ft.) are expected to exceed the 3' No Action event scenario in 2100, therefore, losses resulting from inundated area are designated as a "total loss" (i.e., 100% loss of assets).

Monetized	Lost productivity from Incurred cost of power outages	$9,701,521
Indexed	Roadway Percent	4%
Indexed	Evacuation Route Percent	6%
Indexed	Beach Area Percent	29%
Indexed	Open Space Percent	7%
Indexed	Publicly Identified Assets Index	11%
Indexed	Social Impacts Index	34.4

B. Event Scenario Risk

The monetized impacts for each scenario shown in Tables 39 and 40 are estimated total losses for each flood scenario, otherwise known as “Event Scenario Impacts”. Event Scenario Impacts are then multiplied by the probability of each event occurring to result in “annualized loss values”. The final annualized loss values characterize the risk that the community faces each year from a specific flood level. This method is described in the Risk Assessment Methodology Memorandum.

As described in the Risk Assessment Methodology Memorandum, the study team used GEV curves provided by NOAA to estimate the probabilities of each flood event occurring in the current (2020) scenario. The probability of each flood event occurring under the high emissions 1-in-20 chance estimate is shown in **Figure 1**. In addition, the annualized loss values for each flood event is also shown.

Table III-31: Probabilities in 2030, 2050, and 2100 for Flood Events under High-Emissions 1-in-20 Estimate

Flood Event	Average Annual Frequency	Total Impacts (2017 USD)	Annualized Losses (2017 USD)	Permanent Loss (Absolute Loss)
2020				
MHHW + 3'	72%	$256,350,519	$184,572,374	N/A
MHHW + 7'	1.5%	$1,650,305,499	$24,754,582	N/A
MHHW + 12'	.10%	$4,984,228,820	$4,984,229	N/A
2030				
MHHW + 3'	90%	$144,036,395	$129,632,755	$232,121,024
MHHW + 7'	2%	$1,548,155,923	$30,963,118	$232,121,024
MHHW + 12'	.10%	$4,875,848,873	$4,875,848	$232,121,024
2050				
MHHW + 3'	100%	$80,240,583	$80,240,583	$458,048,822

Flood Event	Average Annual Frequency	Total Impacts (2017 USD)	Annualized Losses	Permanent Loss (Absolute Loss)
MHHW + 7'	4%	$1,516,538,989	$60,661,560	$458,048,822
MHHW + 12'	.20%	$4,812,846,944	$9,625,694	$458,048,822
2100				
MHHW + 3' [21]	100%	$0	$0	$886,114,195
MHHW + 7'	100%	$683,415,441	$683,415,441	$2,597,858,119
MHHW + 12'	1%	$4,133,838,642	$41,338,386	$2,597,858,119

As shown in the table above, in any given year the communities in the Two Rivers region have the potential risk exposure of $185 million in annualized losses from the baseline and three future analyzed events. In addition, Table 42 shows that the communities face the highest annualized loss risk from the 3’ flood event in years 2030 and 2050 due to the high probability of the event occurring, even though the flood impacts from the 3 foot flood are lower than those associated with higher flood levels. It should be noted that the above Annualized Loss Expectancies are associated with discrete events and associated probabilities and do not reflect the aggregate loss expectancy. However, they do provide an indication of the distribution of risk at different extreme water levels in the Baseline Condition in 2020 and subsequent No Action analysis years out to 2100.

Besides the MHHW +3’ event in 2100, permanent inundation remains the same for each water level event in the given years. In the near term, sea level rise has a sizable economic impact; by 2030, there could be $232 million worth of permanent inundation loss, assuming 1.1’ SLR; much of this coming from building loss. By 2050, which is roughly the end-year of a 30-year mortgage signed today, permanent inundation could rise to as much as $458 million in economic losses.

IV. Conclusion

1. General Assessment

This assessment systematically maps out potential losses that could be faced by each community reflecting how different assets could be impacted by the three scenarios. This assessment, combined with other efforts, will serve as input into the development of Adaptation Planning Scenarios.

In the baseline, the majority of losses are building losses (60% to 73% of all monetized losses). The next highest losses are vehicle losses (9% to 11%), lost productivity (4% to 9%), ecosystem services (1% to 10%), and asset specific losses (4% to 8%). The percentage of monetized losses is shown in **Table 43.**

Table IV-1: Monetized Losses in Percentages – Baseline 2020

Loss Type	MHHW + 3’ (%)	MHHW + 7’ (%)	MHHW + 12’ (%)
Building Losses	59.7%	71.3%	73.2%
Essential Facility Loss	0.5%	0.6%	1.6%

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[21] The MHHW + 3’ is calculated from the summation of damage to 3’ permanently inundated assets, per Table 41

Loss Type	MHHW + 3’ (%)	MHHW + 7’ (%)	MHHW + 12’ (%)
Vehicle Losses	11.5%	13.4%	9.3%
Socio-economic Impacts	0.7%	0.4%	0.3%
Asset Specific Losses	3.5%	5.3%	8.4%
Impacted ecosystem services	9.9%	2.8%	1.3%
Incurred mental health treatment costs	2.4%	1.1%	1.0%
Lost productivity from mental health issues	8.7%	3.8%	3.7%
Lost Value of Time from road closure/travel disruptions	1.5%	0.7%	0.7%
Lost productivity from power outages	1.5%	0.7%	0.6%

Table IV-2: Monetized Losses in Percentages – Future Years

Loss Type	MHHW + 3’ (%)	MHHW + 7’ (%)	MHHW + 12’ (%)
2030			
Building Losses	74.1%	77.1%	78.0%
Essential Facility Loss	0.9%	0.7%	1.7%
Vehicle Losses	11.7%	13.5%	9.3%
Socio-economic Impacts	1.0%	0.4%	0.3%
Asset Specific Losses	4.6%	5.5%	8.5%
Impacted Recreational Utility of Marinas	0.1%	0.0%	0.0%
Impacted ecosystem services	6.9%	1.7%	0.8%
Incurred mental health treatment costs	0.1%	0.2%	0.3%
Lost productivity from mental health issues	0.4%	0.6%	0.9%
Lost Value of Time from road closure/travel disruptions	0.1%	0.1%	0.2%
Lost productivity from power outages	0.1%	0.1%	0.1%
2050			
Building Losses	71.5%	77.6%	78.0%
Essential Facility Loss	1.4%	0.7%	1.7%
Vehicle Losses	12.2%	13.3%	9.2%
Socio-economic Impacts	1.2%	0.4%	0.3%
Asset Specific Losses	6.4%	5.6%	8.6%
Impacted Recreational Utility of Marinas	0.1%	0.0%	0.0%
Impacted ecosystem services	6.6%	1.5%	0.7%
Incurred mental health treatment costs	0.1%	0.2%	0.3%
Lost productivity from mental health issues	0.4%	0.6%	0.9%
Lost Value of Time from road closure/travel disruptions	0.1%	0.1%	0.2%
Lost productivity from power outages	0.1%	0.1%	0.1%
2100			

Loss Type	MHHW + 3’ (%)	MHHW + 7’ (%)	MHHW + 12’ (%)
Building Losses	N/A	75.6%	78.4%
Essential Facility Loss	N/A	0.0%	1.8%
Vehicle Losses	N/A	15.7%	8.5%
Socio-economic Impacts	N/A	0.3%	0.2%
Asset Specific Losses	N/A	6.2%	9.0%
Impacted Recreational Utility of Marinas	N/A	0.0%	0.0%
Impacted ecosystem services	N/A	0.7%	0.4%
Incurred mental health treatment costs	N/A	0.3%	0.3%
Lost productivity from mental health issues	N/A	0.9%	1.0%
Lost Value of Time from road closure/travel disruptions	N/A	0.2%	0.2%
Lost productivity from power outages	N/A	0.1%	0.1%

Table IV-3: Monetized Losses in Percentages – Permanent Inundation

Loss Type	2030 1.1’ SLR	2050 2.0’ SLR	2100 5.3’ SLR
Building Losses	68.2%	70.2%	67.0%
Essential Facility Loss	0.0%	0.6%	0.5%
Vehicle Losses	10.7%	9.1%	8.8%
Socio-economic Impacts	0.8%	0.9%	0.5%
Asset Specific Losses	5.3%	5.2%	11.4%
Impacted Recreational Utility of Marinas	0.0%	0.0%	0.0%
Impacted ecosystem services	5.2%	3.6%	1.3%
Incurred mental health treatment costs	1.7%	1.8%	1.8%
Lost productivity from mental health issues	6.1%	6.4%	6.4%
Lost Value of Time from road closure/travel disruptions	1.2%	1.4%	1.5%
Lost productivity from power outages	0.8%	0.8%	0.8%

2. Case Study: MHHW +12’ in 2100

Recognizing the trend of increasingly severe impacts due to the effects sea level rise, the impacts and risks associated with the 12’ extreme water level in 2100 (SLR 5.3’) were evaluated in greater detail for both event-based and permanent flooding conditions. Total monetized losses resulting from the 12’ water level flood event is $4.13 billion (see Table 39), while permanent inundation monetized losses resulting from 5.3’ of SLR amounted to $2.59 billion (see Table 40). A total of 1,585 (32% of total region) census blocks within the region are affected as a result of the flood event, and two-thirds of those, 1,049 (21.3% of total region) census blocks are affected by permanent inundation.[22] In terms of population,

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[22] Due to variability within the elevation in the region, census blocks may be impacted by both the flood event and the sea level rise (permanent inundation).

23% of the population within the region is impacted by the flood event while 21% of the population is affected by permanent inundation. The majority of losses for both the flood event and the permanent inundation are building losses, 78% and 67% respectively. Residential losses are the greatest contributor to building losses in both cases, with residential losses comprising 74.63% of total building losses resulting from the flood event and 79.57% resulting from permanent inundation. Single family homes are considerably impacted, resulting in 82.31% (flood event) and 85.22% (permanent inundation) of total residential losses. Non-residential losses comprised 25.37% and 20.43% of total building losses, respectively.[23] Figures 2-3 show residential losses as a percentage of total building losses (i.e., direct economic loss) and for comparison, Figures 4-5 show non-residential losses a percentage of total building losses (i.e., direct economic loss).

Figure IV-1: MHHW +12' Residential Loss as a Percentage of Direct Economic Loss, 2100

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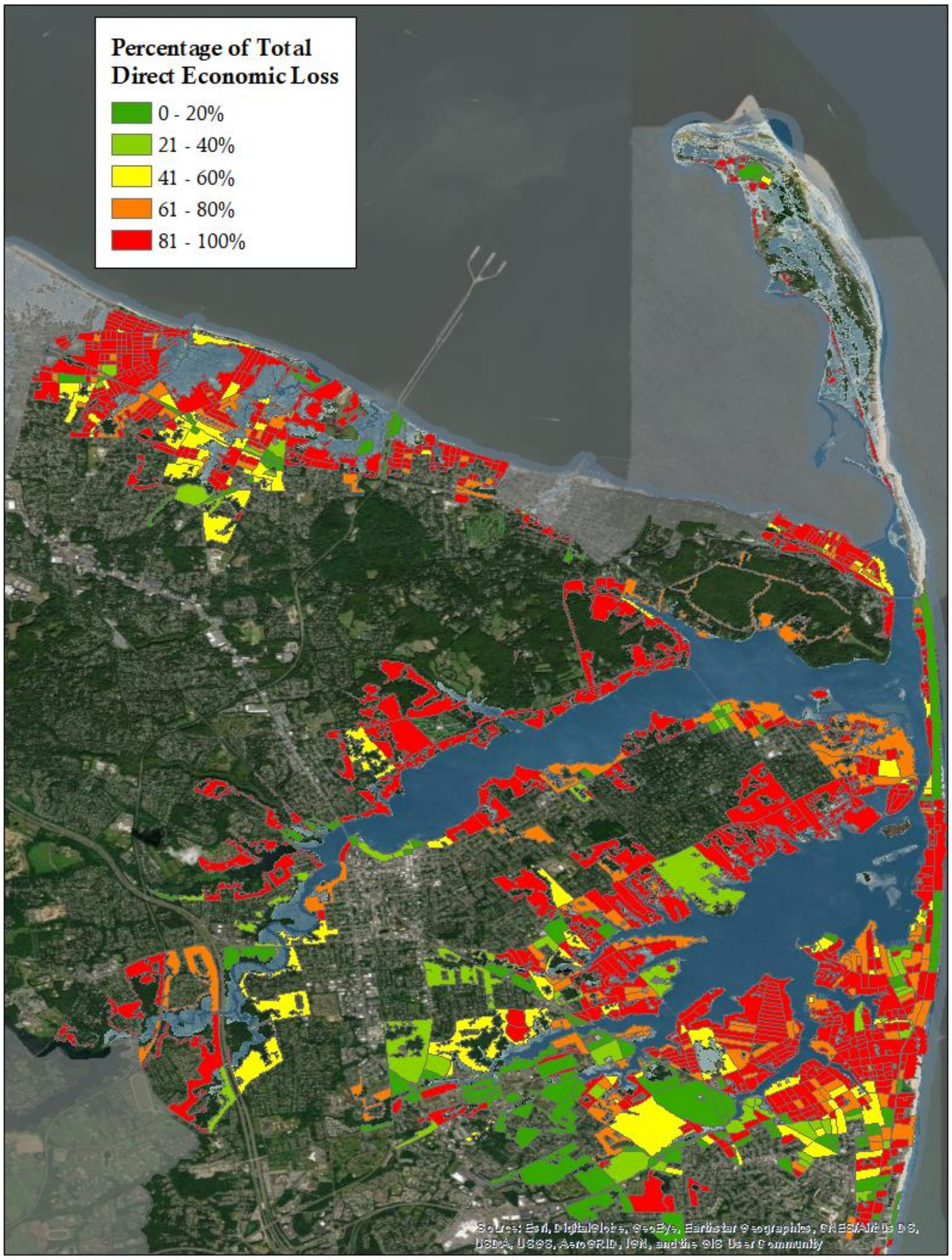
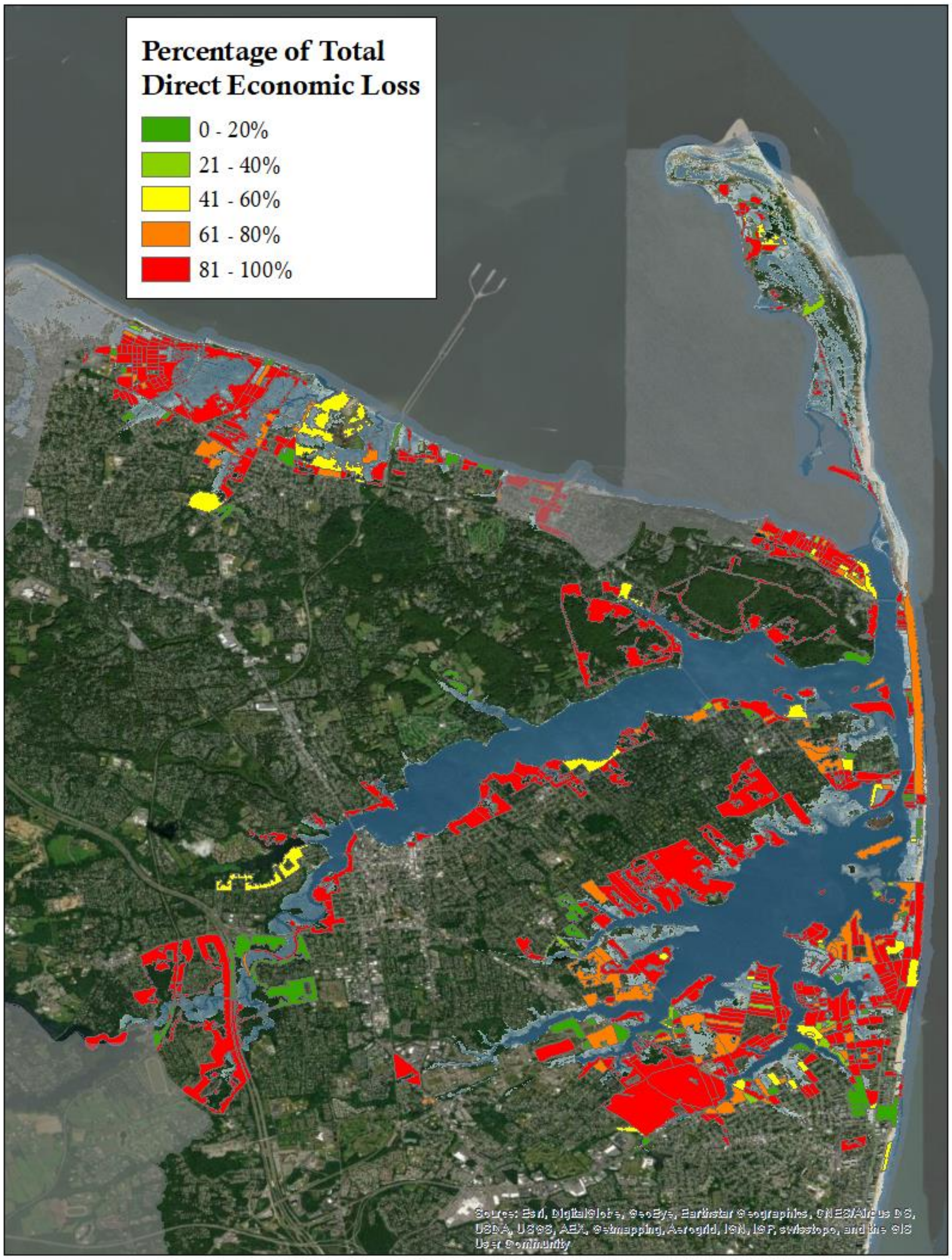
[23] Non-residential building losses include the following building types: agriculture, commercial, education, government, industrial, and religious. Building occupancy classification was developed by FEMA and is a component of the HAZUS modeling software.



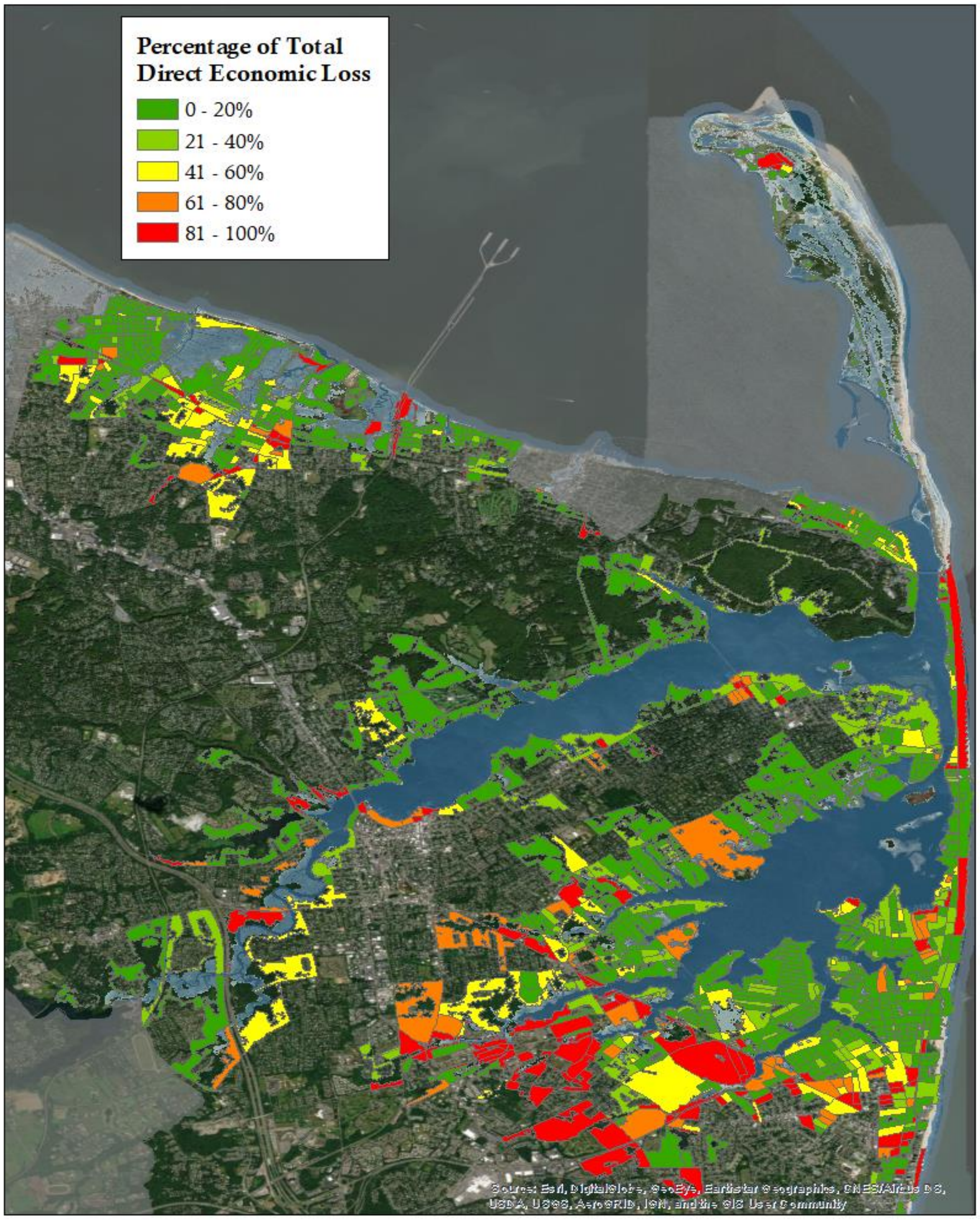
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure IV-2: Permanent Inundation (5.3’ SLR) Residential Loss as a Percentage of Direct Economic Loss, 2100



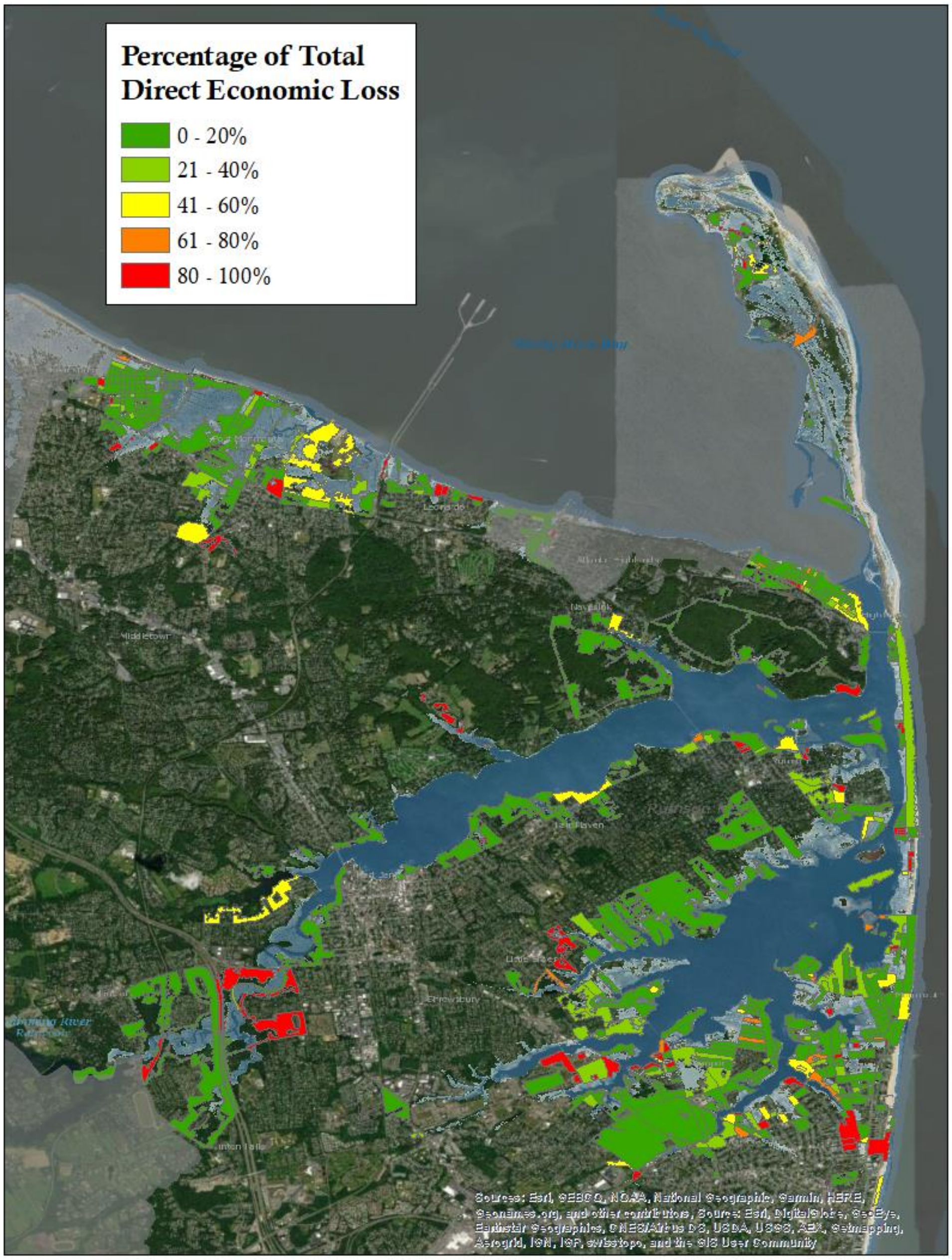
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure IV-3: MHHW +12' Non-residential Loss as a Percentage of Direct Economic Loss, 2100



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure IV-4: Permanent Inundation (5.3’ SLR) Non-residential Loss as a Percentage of Direct Economic Loss, 2100



Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

The MHHW +12’ flood event in 2100 represents the greatest loss among all No Action event scenarios. However, substantial residential losses resulting from both flood events and permanent inundation are consistently prevalent throughout all future years with increasing severity towards 2100. In the project area, socially vulnerable populations tend to live in low-lying areas. This is depicted in Figure 6 where the top five census blocks that exhibit the greatest vulnerability as indicated by the Social Impact scale also have a high risk of permanent inundation in future years due to their low-lying status. For communities like Highlands or Long Branch in the Shrewsbury estuary, this vulnerability presents an added challenge to adaptation.

Figure IV-5: Top 5 Vulnerable Census Tracts with High Residential Loss

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

B. Next steps

1. Apply risk assessment results with Contextual Analysis to evaluate appropriate resilience and adaptation measures

Using the analysis from this risk assessment and further contextual analysis, the project team will group subareas that exhibit the highest levels of risk. The team will then develop draft scenarios that incorporate structural, natural, policy, planned, and educational strategies to mitigate risk across the region based on stakeholder input from the Stakeholder Working Group #5 meeting.

2. Develop adaptation planning scenarios as part of the Regional Resiliency and Adaptation Action Plan

Once three scenarios for the Two Rivers region have been developed with specific strategies, the project team will run a Cost Benefit Analysis to understand how different strategies mitigate risk for all asset types. The No Action Risk Assessment will be used as a Base Case, from which the impacts of a planning scenario will be measured against.

V. References

Bureau of Labor Statistics. 2017. Employer Costs for Employee Compensation Historical Listing. Retrieved from: https://www.bls.gov/web/ecec/ececqrtn.pdf

Center for Disease Control (CDC). Jan 24, 2018. SVI 2016 Documentation. Retrieved at: https://svi.cdc.gov/Documents/Data/2016_SVI_Data/SVI2016Documentation.pdf

Costanza, Robert, Matther Wilsdon, Austin Troy, Alesey Voinov, Shuang Liu, John D'Agostino. 2006. The Value of New Jersey's Ecosystem Services and Natural Capital. DEP Division of Science, Research and Technology. July. 177pp.

DOE. November 2012. Hurricane Sandy Situation Report #20. Retrieved from: http://www.oe.netl.doe.gov/docs/2012_SitRep20_Sandy_11072012_1000AM.pdf

FEMA, 2011. FEMA Benefit-Cost Analysis Re-engineering (BCAR) Development of Standard Economic Values, Version 6.0 December 2011 https://www.fema.gov/media-library-data/1436988186869-3f81a0a72df11e00b8c088e8d3bd635a/TAW_Slope_Hmo_Guidance_May_2015.pdf

FEMA (2012), Final Sustainability Benefits Methodology Report, Contract #: HSFEHQ-10-D-0806; Task Order # HSFEHQ-11-J-1408.

FHWA. October 2017. Post Hurricane Sandy Transportation Resilience Study in NY, NJ, and CT. FHWA-HEP-17-097. 545pp.

Governor's Office of Storm Recovery (GOSR). Rebuild by Design Living Breakwaters Project Benefit Cost Analysis. January 17, 2017

Insel, Thomas R., MD; Schoenbaum, Michael, PhD; Wang, Phillip S., MD, DrPH. 2009. Components of the Economic Burden of Serious Mental Illness in the U.S. US Neurology Review - Touch Briefings, v. 6, Issue 1.

Johnston, R.J., Grigalunas, T. a., Opaluch, J.J., Mazzotta, M., Diamantedes, J., 2002. Valuing Estuarine Resource Services Using Economic and Ecological Models: The Peconic Estuary System Study. Coastal Management. http://www.tandfonline.com/doi/abs/10.1080/08920750252692616

Kaufman et. al., 2012. Transportation During and After Hurricane Sandy, Sarah Kaufman, Carson Qing, Nolan Levenson and Melinda Hanson, Rudin Center for Transportation, NYU Wagner Graduate School of Public Service, November 2012

Levinson, et al. 2010. Associations of Serious Mental Illness with Earnings: Results from the WHO World Mental Health Surveys. British Journal of Psychiatry. August; 197(2): 114–121. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2913273

Meeco Sullivan. Superstorm Sandy-Damaged Marinas Rebuild Fast – Press Release. Jun 1, 2014. Retrieved from http://meecosullivan.com/superstorm-sandy-damaged-marinas-rebuild-fast/

New Jersey Department of Environmental Protection (DEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information Systems (BGIS). 20150217. Land Use/Land Cover 2012 Update, Edition 20150217 Subbasin 02030104 -Sandy Hook-Staten Island (Land_lu_2012_hu02030104). Trenton, NJ.

New York Economic Development Corporation (NYCEDC). Raise Shorelines Citywide Study Final Report. Feb 16, 2016.

DEP. December 12, 2017. Environmental Justice through Public Involvement. Retrieved from: http://www.nj.gov/dep/ej/

NJFRAMES. FRAMES Municipal Asset Gathering through the Getting to Resilience (GTR) Process. Nov 2017.

NJFRAMES. Event Scenario Technical Memorandum. Aug 14, 2018

NJFRAMES. Risk Assessment Methodology Technical Memorandum. June 8, 2018

NJFRAMES. Water Level Proposals for NJ FRAMES project team deliberation. Feb 10, 2017

Pflicke, K. M., Greenberg, M., Whytlaw, J., Herb, J., & Kaplan, M. (2015). Populations Vulnerable to Climate Change in New Jersey: Update of a Statistical Analysis. 1-21. Retrieved May 30, 2018, from https://njadapt.rutgers.edu/docman-lister/conference-materials/132-populations-vulnerable-to-climate-change-report/file.United Nations Office for Disaster Risk Reduction (UNISDR). National Disaster Risk Assessment. 2017.

Louis Berger

Memorandum

DATE: August 14, 2018

TO: Kelly Pflicke (NJ DEP)

SUBJECT: Event Scenario Frequencies

During conference calls on July 10, 2018 and August 1, 2018, NOAA and the NJ Frames team discussed NOAA's feedback regarding flood event frequency estimation methods. This memo describes the proposed method to estimate the flood event scenario frequencies of planning water levels of 3, 7 and 12 feet above MHHW (as established by NJ FRAMES Planning Inundation Levels – Technical Memo Summary) for analysis years 2020 (Baseline Scenario), 2030, 2050 and 2100 (No Action Scenarios). Included with this memo is a digital spreadsheet with the projected frequencies utilizing this method.

Because of the effects of sea level rise (SLR), water levels in general rise in the later years. The lower planning water levels that are still infrequent in early years become frequent in later years. While frequent events are predicted using available historic data (empirical method), prediction of infrequent events uses a different method because very few, if any, historical data points are available for infrequent events. Because the planning water levels reflect a combination of infrequent and frequent events, both methods are used, as discussed below. The probability estimation of infrequent events is discussed first (extreme value application), followed by the probability estimation method of frequent events (empirical distribution application).

Please see the Excel file *NJFrames_Frequencies_8-13-2018*, included as electronic Attachment 1, for frequencies calculated in the analysis.

Extreme Value Application

The extreme value application and specifically, the Generalized Extreme Value (GEV) distribution function presented in the NOAA technical report *Extreme Water Levels of the United States 1983 – 2010*, was selected to characterize the distribution of the selected extreme water levels in 2020, 2030, 2050, and 2100.[1] An extreme water level is characterized as a highly infrequent event (i.e., extremely low frequency) with an expected recurrence interval > 1 year (i.e., event frequency < 1.0).

Per NOAA, the GEV cumulative distribution function F was fitted to the Sandy Hook tidal gauge station's annual water level maxima (detrended) over the period, 1932 – 2012. The GEV cumulative distribution function is given as[2] [3]:

$$F(x;\ \mu;\ \sigma;\ \xi) = \ \exp\{-[1 + \ \xi(x-\mu)/\sigma]^{-1/\xi}\}$$

where μ, σ, and ξ are the location, scale, and shape parameters of the distribution.

The following parameters were estimated for the Sandy Hook tidal gauge by NOAA.

$$\text{Location } (\mu) = \ \ 0.709$$

$$\text{Scale } (\sigma) = \ \ 0.167$$

$$\text{Shape } (\xi) = \ \ 0.226$$

Using the Sandy Hook parameter estimates, probabilities were derived for the planning water levels that constituted an extreme water level event in the years 2020, 2030, 2050, and 2100.

Empirical Distribution Application

The empirical distribution presented in the NOAA technical report *Patterns and Projections of High Tide Flooding Along the U.S. Coastline Using a Common Impact Threshold* was selected to characterize the

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[1] National Oceanic and Atmospheric Administration. (2013). *Extreme Water Levels of United States 1893-2010*. Silver Spring: U.S. Department of Commerce.

[2] Due to statistically significant trends in the water level data, the annual water level maxima data is detrended linearly using mean sea level trend to remove the time dependence of the values.

[3] Coles, Stuart. (2013). *An Introduction to Statistical Modeling of Extreme Values*. New York: Springer.

distribution of frequent water levels, specifically the planning water level events of 3 feet and 7 feet above MHHW in the timeframes 2050 and 2100, respectively.[4] Due to the impacts of sea level rise, the probability of these events increases to a level of greater than 1 occurrence annually. Thus, an extreme value method would not be appropriate to estimate frequent flood events. For the purposes of this assessment, a frequent water level is characterized as an event with a recurrence interval < 1 year (i.e., event frequency > 1.0).

Using the NOAA method presented in the report as a framework, a complementary cumulative distribution function was derived using the Sandy Hook daily highest water levels (May – April) for the most recent 19-year period (1998-2016)[5]. Prior to the probability estimation, the daily highest water level data was set relative to the 2000 Sandy Hook tidal datum level and detrended to remove time dependence of the values. Additionally, missing data points were interpolated to alleviate any inconsistencies in the data. Estimated frequencies were derived for the planning water level events of 3 feet and 7 feet above MHHW in 2050 and 2100, respectively. Please note, losses resulting from planning event scenarios with a recurrence interval < 1 year are to be estimated based on an agreed upon method as defined by the NJ Frames team.

Permanent Inundation

Permanent inundation is currently classified as MHHW with an estimated frequency of 1.0. Please note, the 3 feet planning event scenario in 2100 is currently below expected sea level rise conditions (5.3 ft.). The expected frequency of the event is thus 1.0 with losses being fully captured (i.e., complete loss of inundated asset).

Event Scenario Frequency Estimates

The estimated extreme value and empirical frequencies of the planning water levels (3, 7, & 12 ft.) for 2020, 2030, 2050, and 2100 are shown in the figures below. Please see Appendix A and Appendix B for water level frequency data and comparison water levels (in feet above MHHW) for under the high emissions 1-20 chance estimate event scenario.

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[4] National Oceanic and Atmospheric Administration. (2018). *Patterns and Projections of High Tide Flooding Along the U.S. Coastline Using a Common Impact Threshold*. Silver Spring: U.S. Department of Commerce.

[5] Per the NOAA report, *Patterns and Projections of High Tide Flooding Along the U.S. Coastline Using a Common Impact Threshold,* the empirical distribution method uses a metalogical defined year (May – April) as to not divide the winter season.

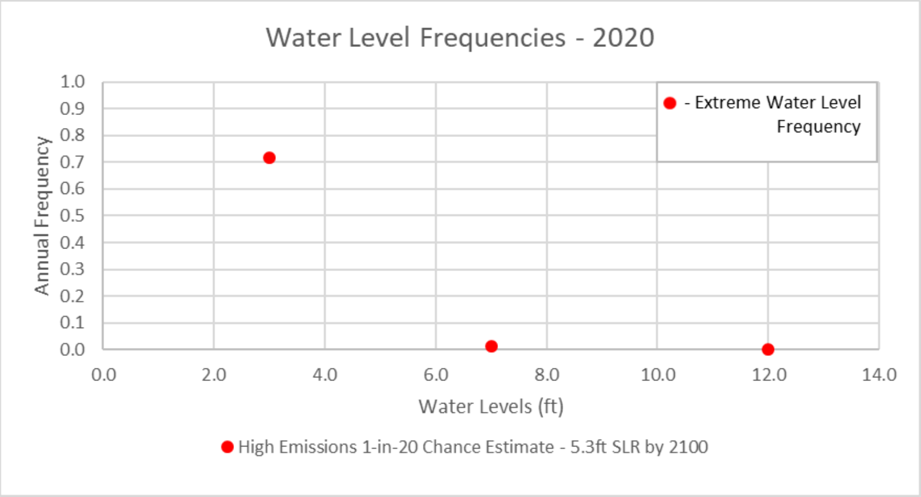

Figure 1: 2020 Water Level Frequencies.

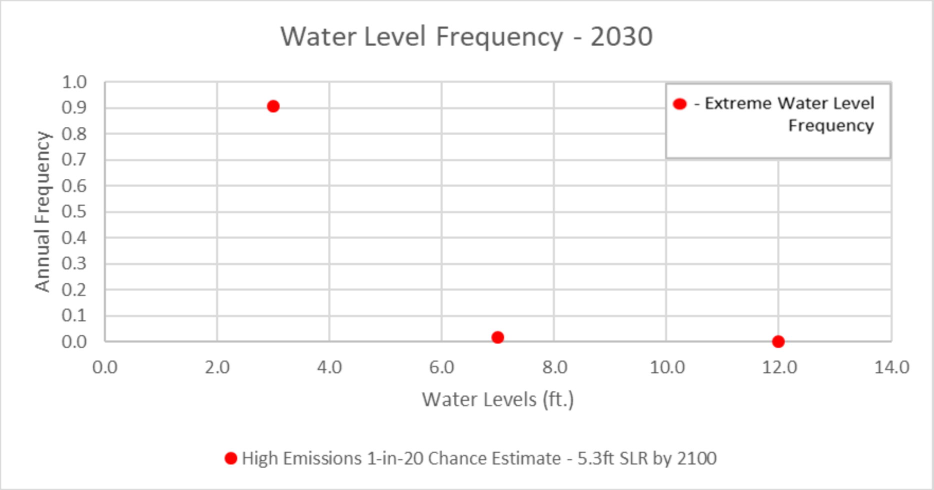

Figure 2: 2030 Water Level Frequencies.

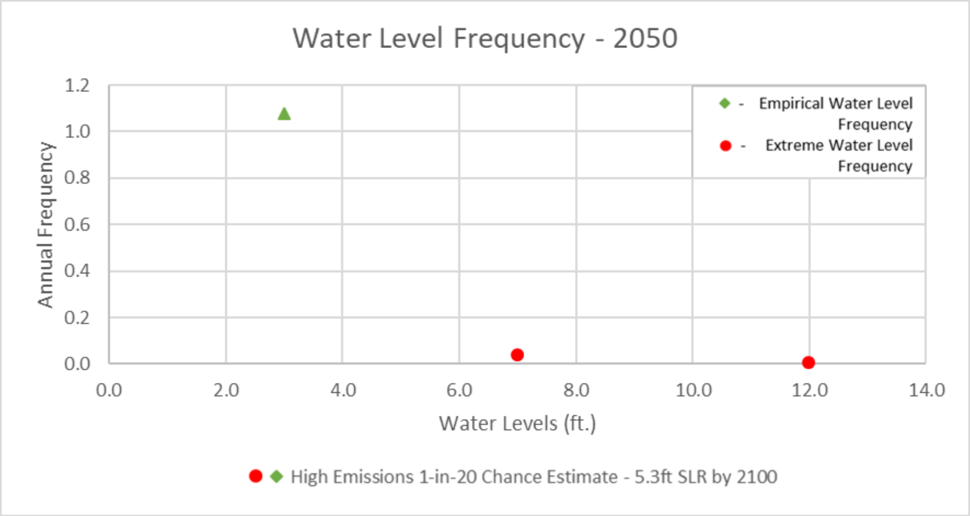

Figure 3: 2050 Water Level Frequencies.

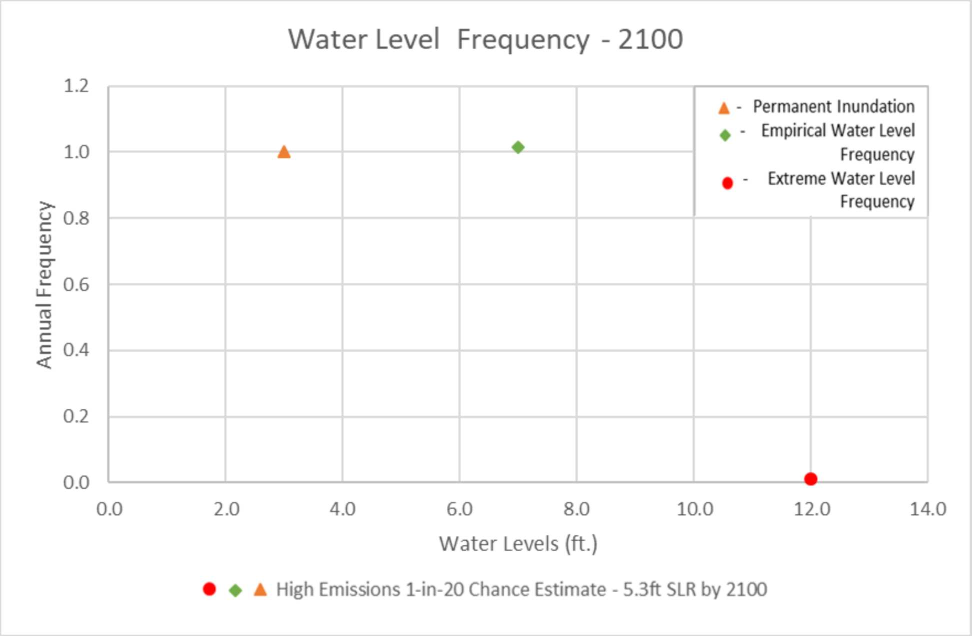

Figure 4: 2100 Water Level Frequencies.

Appendix A

The frequencies for the assessed water levels are shown below.

Table 1: Frequencies of water levels for 2020 under the High Emissions 1-20 Chance Estimate.

Water Level (ft)	Annual Frequency	Frequency Derivation Method
3.0	0.718	GEV
7.0	0.015	GEV
12.0	0.001	GEV

Table 2: Frequencies of water levels for 2030 under the High Emissions 1-20 Chance Estimate.

Water Level (ft)	Annual Frequency	Frequency Derivation Method
3.0	0.905	GEV
7.0	0.018	GEV
12.0	0.001	GEV

Table 3: Frequencies of water levels for 2050 under the High Emissions 1-20 Chance Estimate.

Water Level (ft)	Annual Frequency	Frequency Derivation Method
3.0	1.078	Empirical (see Table 4)
7.0	0.037	GEV
12.0	0.002	GEV

Table 4: Frequency of 3' water level event for 2050 under High Emissions 1-20 Chance Estimate.

Water Level (ft)	Permanent Inundation (MHHW) (5.3 ft. SLR by 2100)	SLR Adjusted Water Level Event (ft)	Annual Probability (relative to 2000)	Predicted Annual Exceedances
3.0	2.028	0.972	1.078[6]	~28

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[6] Frequent water level has a recurrence interval < 1 year (i.e., event frequency > 1.0; event occurs > 1 annually). Due to SLR in the timeframes 2050 and 2100, the 3' and 7' water level events become frequently occurring events (i.e., event occurs > 1 annually) and therefore, the water level event relative to 2000 is adjusted by the expected

Table 5: Frequencies of water levels for 2100 under the High Emissions 1-20 Chance Estimate.

Water Level (ft)	Annual Frequency	Frequency Derivation Method
3.0	1.000	Permanent Inundation[7] (see Table 5)
7.0	1.014	Empirical (see Table 6)
12.0	0.010	GEV

Water Level (ft)	Predicted Annual Exceedances
3.0	~152

Table 6: Frequency of 7' water level event for 2100 under High Emissions 1-20 Chance Estimate.

Water Level (ft)	Permanent Inundation (MHHW) (5.3 ft. SLR by 2100)	SLR Adjusted Water Level Event (ft)	Annual Probability (relative to 2000)	Predicted Annual Exceedances
7.0	5.328	1.672	1.014[6]	~5

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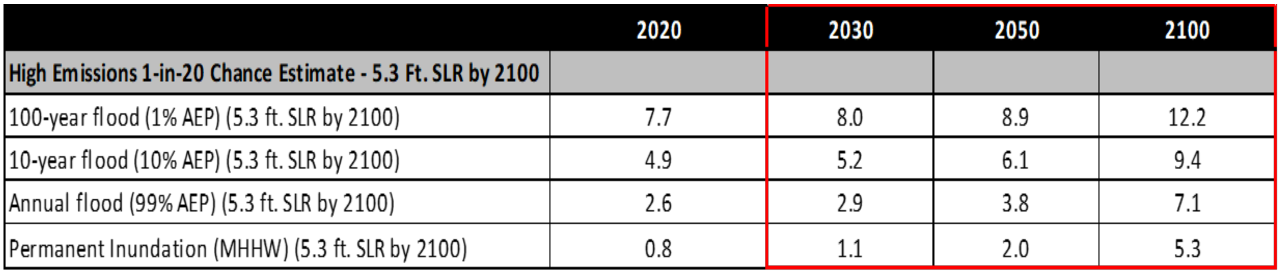
amount of SLR by 2050 and 2100, respectively, to appropriate estimate the frequency using the empirical distribution method.

[7] For the purposes of the assessment, permanent inundation has an expected frequency of 1.0 with losses being fully captured (i.e., complete loss of inundated asset).

Appendix B

Water levels (in feet above MHHW) for the high emissions 1-20 chance estimate event scenario.



	2020	2030	2050	2100
High Emissions 1-in-20 Chance Estimate - 5.3 Ft. SLR by 2100				
100-year flood (1% AEP) (5.3 ft. SLR by 2100)	7.7	8.0	8.9	12.2
10-year flood (10% AEP) (5.3 ft. SLR by 2100)	4.9	5.2	6.1	9.4
Annual flood (99% AEP) (5.3 ft. SLR by 2100)	2.6	2.9	3.8	7.1
Permanent Inundation (MHHW) (5.3 ft. SLR by 2100)	0.8	1.1	2.0	5.3

Attachment 1

<NJFrames_Frequencies_8-13-2018.xls>

(digital only)

Louis Berger

Memorandum

DATE: August 14, 2018

TO: Kelly Pflicke (NJ DEP)

SUBJECT: Population Projections through 2100

The NJ FRAMES team has coordinated with the North Jersey Transportation Planning Authority (NJTPA) to utilize NJTPA demographic data for projection of regional growth through 2100. The attached memo describes the methodology used by the Team in coordination with NJTPA

Louis Berger

Memorandum

DATE: August 9, 2018

TO: Bob Diogo (NJTPA)
CC: Bethany Bearmore, Niek Veraart, Ian Miller (Louis Berger)
FROM: Linh Nguyen (Louis Berger)

SUBJECT: **Expansion of NJTPA's population projection to 2100 for NJFRAMES Study**

Background

Louis Berger is currently working on population projections that will support the Risk Assessment phase (i.e., Future Long-term Planning Scenario (2100) Without Adaptation Measures in Place) for the New Jersey Fostering Regional Adaptation through Municipal Economic Scenarios Project (NJFRAMES) managed by the NJDEP. Since we are tasked with extending projections developed by your office we welcome your inputs and review of the proposed method to ensure that the planning level projections can be integrated within the NJFRAMES study in a timely fashion. The **Appendix** to this memo provides the Traffic Analysis Zone (TAZs) that fall within the Study Area for your reference.

Proposed Method (Extending NJTPA Population Projections for Select TAZs)

Louis Berger used the following method to distribute NJTPA's original population projections from the MPO's (TAZ) grouping levels into the Census Block levels, whose population projections are extended to 2100:

- From NJTPA TAZs, Louis Berger distributed the population projections to 2045 to Census Block levels. There are several rationales behind this distribution:
  - Census Block is the standard geographic unit used by the FEMA-HAZUS model to assess future impacts of extreme water level, including SLR and storm surge. Dissipation of population projections from TAZ down to the Census Block level provides a consistent geographic input for the HAZUS model.
  - As Census Blocks in the Study Area are completely bounded by NJTPA's TAZs, there is no need for an additional population redistribution task, as would otherwise be necessary with larger geographic groupings such as Census Tracts or Block Groups.
  - Census Blocks in the Study Area are typically granular enough to ensure that each one has their own main functional land use classification. Working with Census Block (rather than Block Groups) level negates the needs to redistribute population partially to a section of a geographic unit that is not suitable and/or zoned for residential use (i.e. protected lands, schools, etc.)

Analytical Process

Louis Berger first retrieved the 2010 Census Block Shapefile with Population and Housing Unit Counts. Each Census Block within the study area was then matched to a TAZ that it is bounded within. The percentage share of the population within that Block Group vis a vis the population in the corresponding TAZ was then calculated. This ratio was then multiplied by the population projection of the corresponding TAZ's population to derive the respective Block Group's population.

- The next step involved creating a population forecast to 2100. Louis Berger utilized a logistic growth curve for this particular area projection to account for growth constraints such as land scarcity and population/housing unit growth at full buildout. For each TAZ, five parameters are used determine the shape of this curve: (1) the start value (base year population), (2) the target value (a carrying capacity that the projection is approaching, but never exceeds), (3) a starting period value where the growth will pick up its speed, (4) an inflection point value where the growth reaches its maximum rate and starts to level off, and (5) a Hill's slope parameter to modify the trajectory for the steepness of the growth curve. The 5-parameter logistic curve model was selected over other logistic model functional forms was due to its ability to model asymmetrical patterns beyond the inflection point, which is usually the case when a region has reached its maximal build-out capacities.

- The purpose of the above step was to attempt to closely follow and incorporate growth patterns in NJTPA's projection trajectory up to 2045 with the limited amount of information available. The analysis of past projections through 2045 and observed growth rates allowed the fitted and spliced projections to incorporate the land use capacity and build out assumptions that were embodied within the original projection trajectories provided by NJTPA. The method applied to fit the growth curve in this assignment was to use the statistical software R to simulate and fit a curve from the input data. Louis Berger employed the **drc** package, an add-on package for the language and environment R, which is open source and freely available. The parameters are chosen using non-linear least squares applying the criterion of minimal sum of squared errors. More information on the theoretical aspect of fitting and estimating parameters for non-linear regression models that can be found on https://cran.r-project.org/web/packages/drc/drc.pdf.

- For the purposes of this assignment, Louis Berger did not take into consideration the potential effect of SLR on the population distributions (such as potential population migration shifts away from areas subject to recurrent or permanent flooding due to Sea Level Rise), because of the regional focus of the Study and the uncertain nature of localized trends and responses especially this far into the future. The population projections are to be used as an input for the FEMA-HAZUS model where they will be combined with inundation projections to assess potential future impacts. The entire dataset will be applied to inform the Study Team about future risks by area, and subsequently to facilitate the development of future adaptation planning scenarios.

The following tables and figure show the application of the proposed first method by comparing the functional form tested to the 2045 population level. Table 1, and Figure 1 show the fitted logistic curve to project population levels for this TAZ in the study area until 2045 in orange. The blue curve represents NJTPA projections for the same period. Figure 2 shows the extension of the projections out to 2100.

We recognized and calibrated the parameters for the two noted sites in Middletown and Fort Monmouth (TAZ 1132 and TAZ 1176) that will be near their maximum build-out capacity in order to reflect the future growth observations and recommendations from Bob Diogo of NJTPA. For TAZ 1176 (Figure 3), the uncalibrated parameters had automatically flattened the curve based on the patterns presented in NJTPA's original projection. For TAZ 1132 (Figure 4), Louis Berger only slightly calibrated the top asymptote parameter to account for the maximal capacity of this TAZ.

TAZ 1138 - Middletown							
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**
NJTPA	6,134	6,156	6,181	6,218	6,280	6,321	6,390
Louis Berger's Forecast	6,135	6,154	6,182	6,221	6,271	6,329	6,389

Table 1: TAZ 1138's Population Projection – NJTPA vs Louis Berger

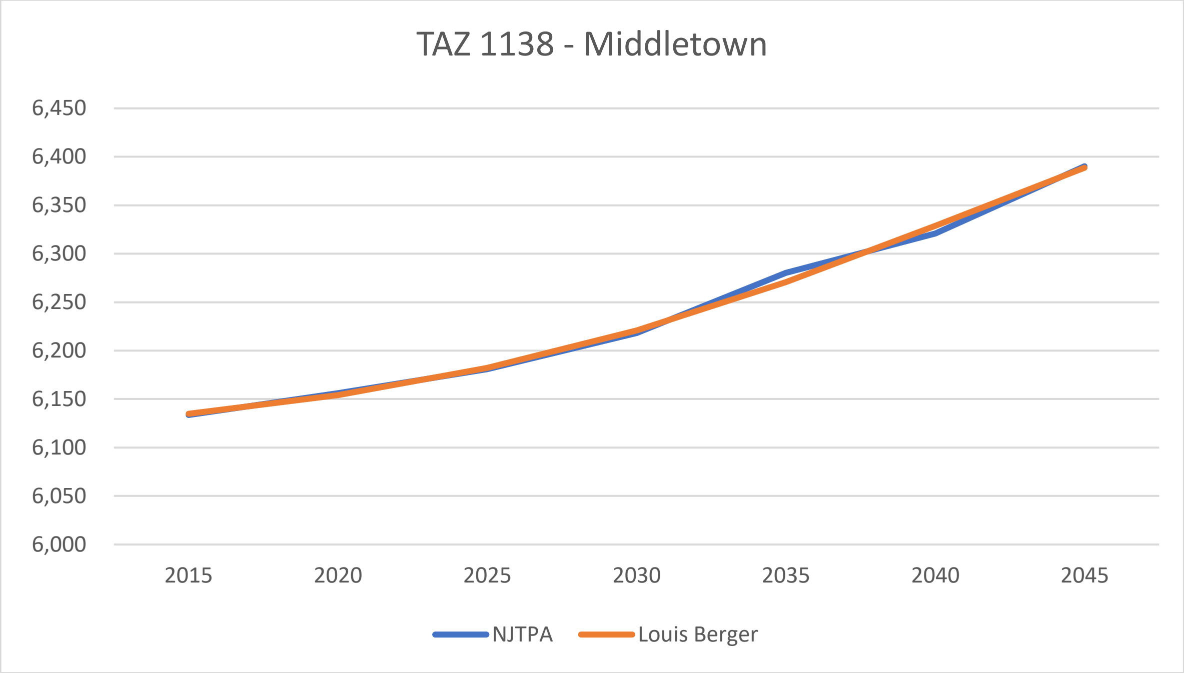


Figure 1 Comparisons of NJTPA's projection and Louis Berger's projection to 2045 for a sample TAZ

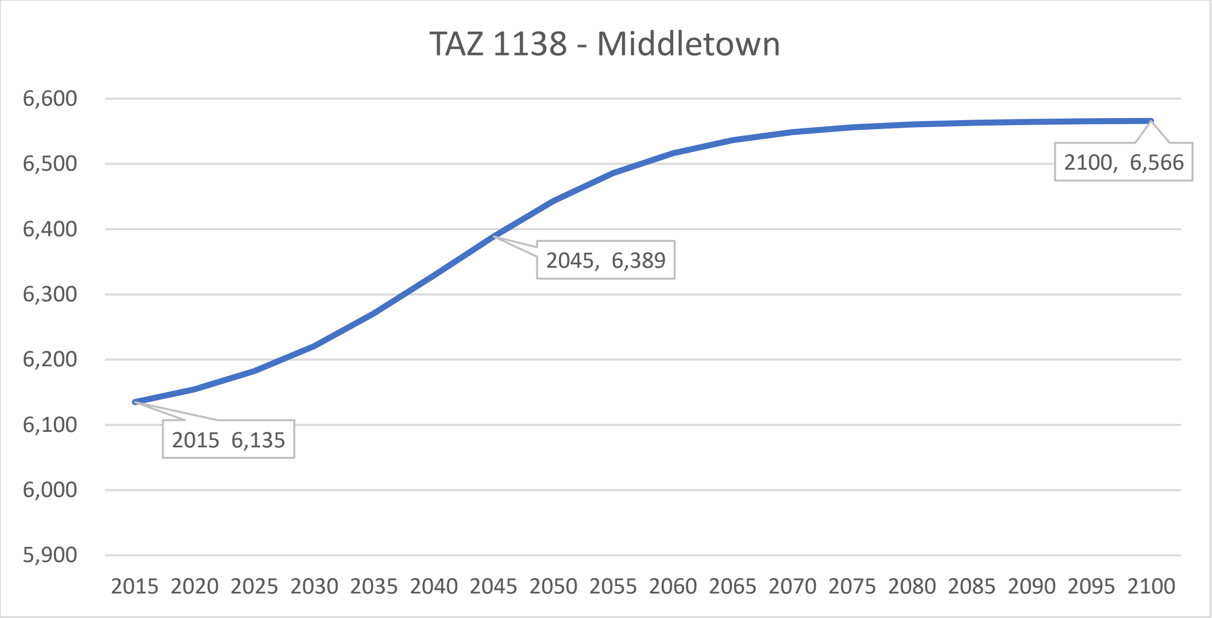


Figure 2: Extension of Louis Berger's projection until 2100 for a sample TAZ

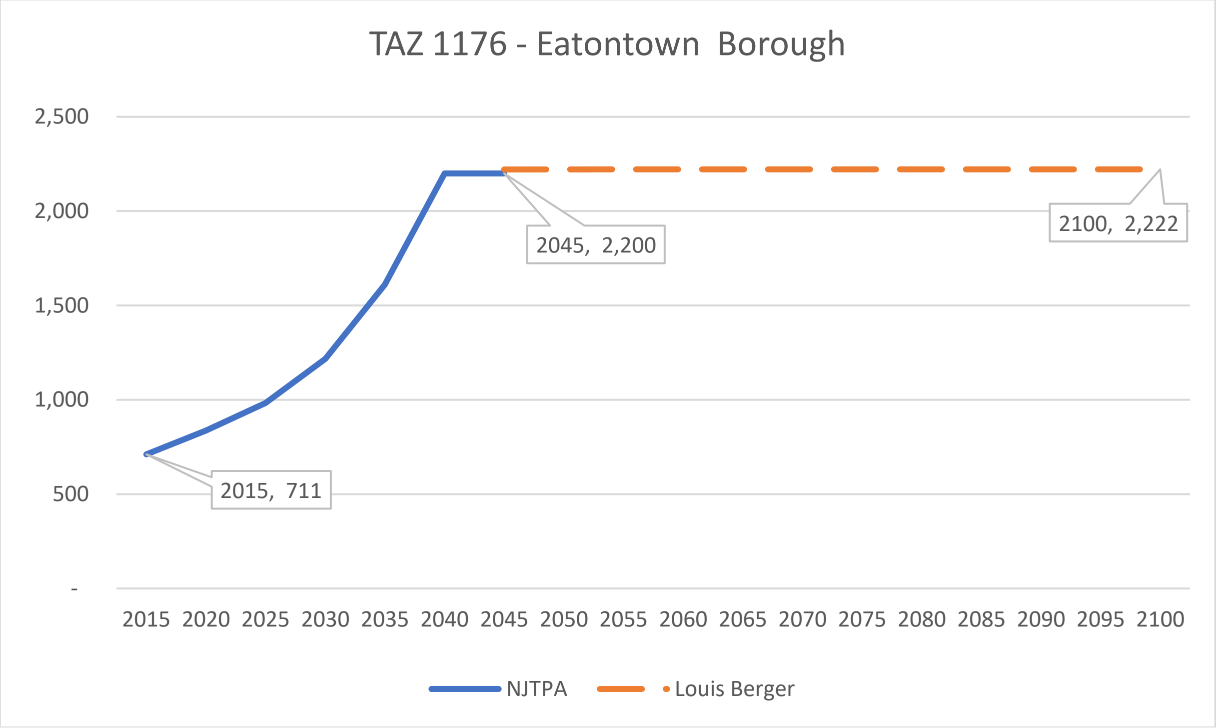


Figure 3: Extension of NJTPA's projection until 2100 for TAZ 1176

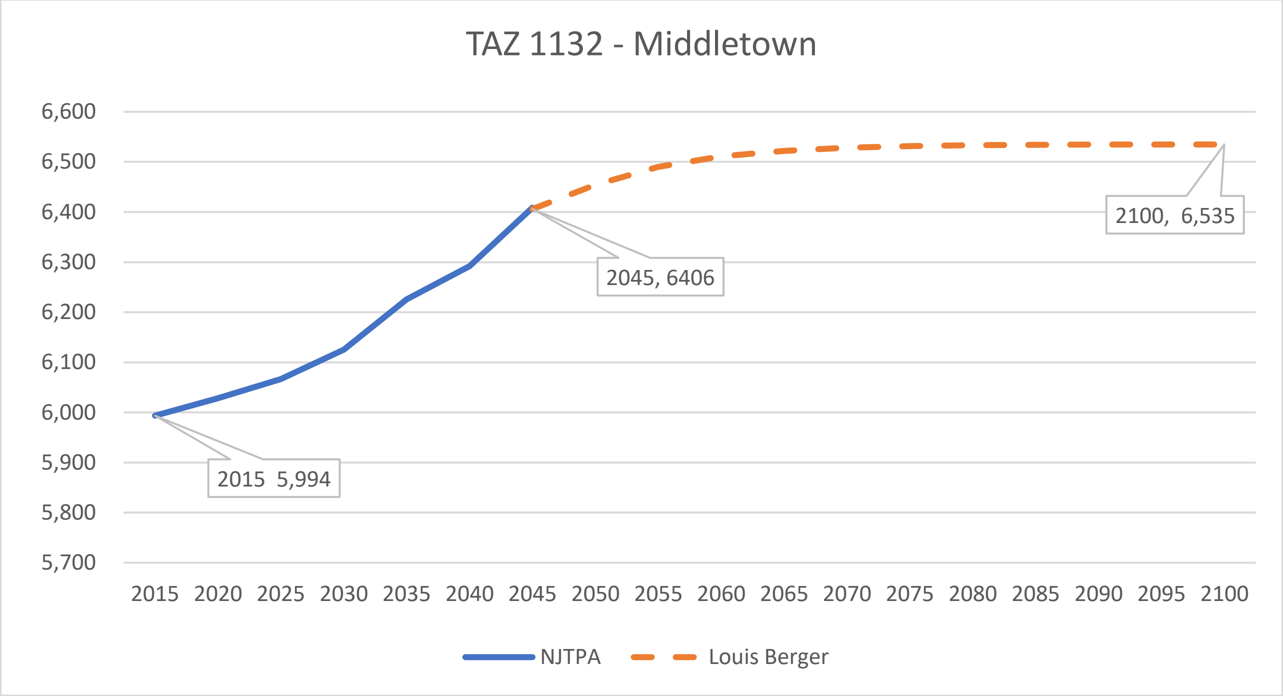


Figure 4: Extension of NJTPA's projection until 2100 for TAZ 1132

APPENDIX

Figure A-1 in the appendix shows the NJTPA's TAZs within the NJFRAMES Study Area, and Table A-1 specifies the municipalities that each TAZ belongs to.

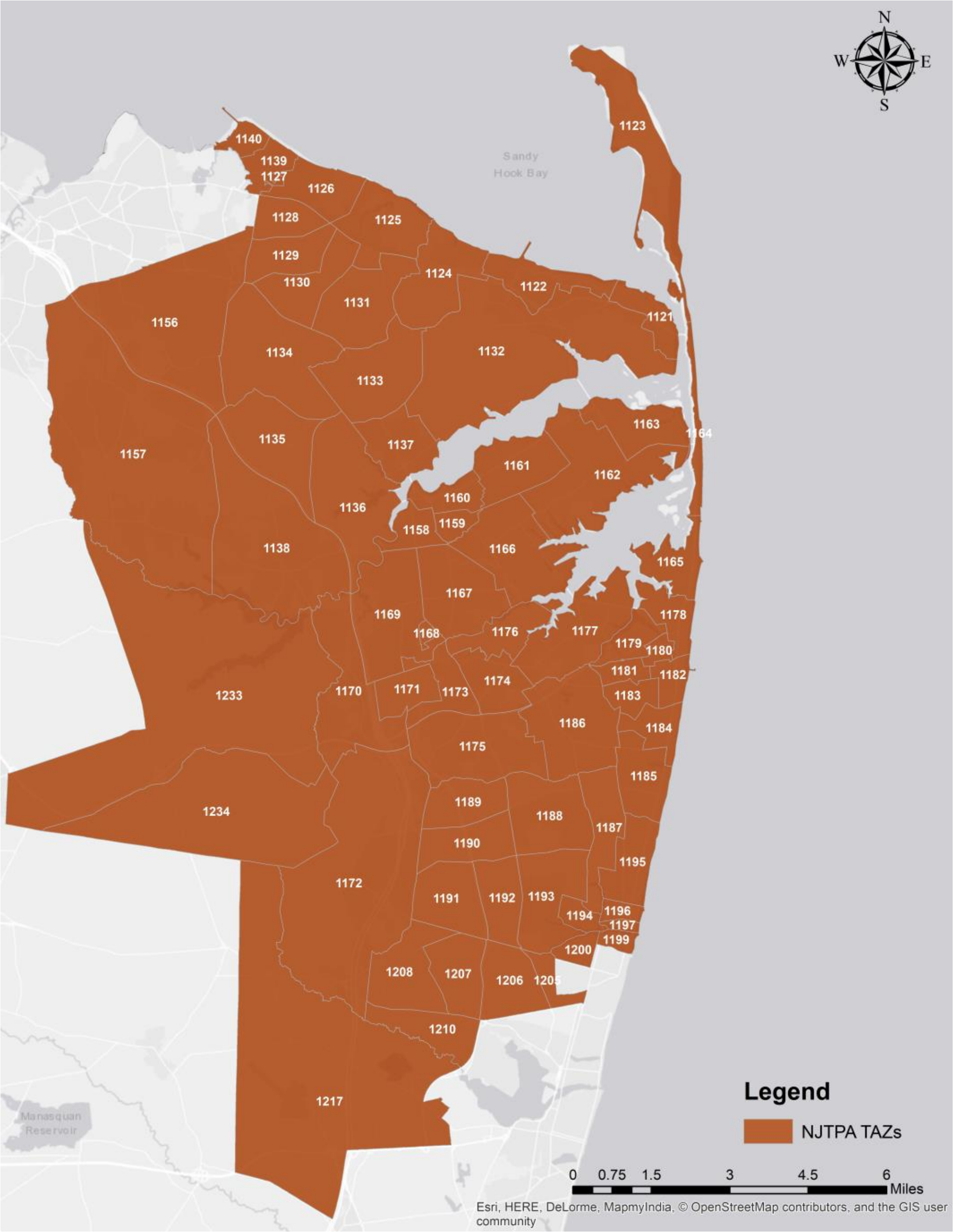


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Figure A-1: NJTPA's TAZs in the Study Area

TAZ	Municipalities	TAZ	Municipalities
1183	Long Branch city	1140	Keansburg borough
1131	Middletown township	1124	Middletown township
1139	Keansburg borough	1132	Middletown township
1175	Eatontown borough	1138	Middletown township
1174	Eatontown borough	1126	Middletown township
1128	Middletown township	1137	Middletown township
1122	Atlantic Highlands borough	1169	Tinton Falls borough
1162	Rumson borough	1129	Middletown township
1182	Long Branch city	1191	Ocean township
1167	Shrewsbury borough	1192	Ocean township
1208	Neptune township	1190	Ocean township
1185	Long Branch city	1170	Tinton Falls borough
1159	Red Bank borough	1135	Middletown township
1165	Monmouth Beach borough	1172	Tinton Falls borough
1186	West Long Branch borough	1234	Colts Neck township
1161	Fair Haven borough	1178	Long Branch city
1134	Middletown township	1233	Colts Neck township
1205	Neptune township	1145	Hazlet township
1193	Ocean township	1184	Long Branch city
1158	Red Bank borough	1157	Holmdel township
1200	Asbury Park city	1207	Neptune township
1199	Asbury Park city	1156	Holmdel township
1189	Ocean township	1123	Middletown township
1166	Little Silver borough	1164	Sea Bright borough
1127	Keansburg borough	1125	Middletown township
1179	Long Branch city	1206	Neptune township
1160	Red Bank borough	1181	Long Branch city
1136	Middletown township	1173	Eatontown borough
1121	Highlands borough	1171	Eatontown borough
1133	Middletown township	1168	Shrewsbury township
1180	Long Branch city	1196	Allenhurst borough
1187	Ocean township	1197	Loch Arbour village
1195	Deal borough	1210	Neptune township
1163	Rumson borough	1130	Middletown township
1177	Oceanport borough	1217	Wall township
1176	Eatontown borough	1188	Ocean township
1194	Interlaken borough		

Table A-2: NJTPA's TAZs and their corresponding municipalities