Risk Assessment Methodology DRAFT Technical Memorandum

New Jersey Fostering Regional Adaptation through Municipal Economic Scenarios - March 2019

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Overview

This technical memorandum summarizes the methodology for the risk assessment and cost-benefit analysis to be implemented in Task 2 to evaluate the risk of coastal flooding in the Two Rivers region under current and potential future climate conditions and the efficacy of resilience and adaptation measures. The methodology follows the procedures outlined in '*What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure*' ("NOAA handbook"), published by NOAA in June 2013. While the methodology will be similar, this technical memo reflects the uses of updated data since the Handbook was released including, the 1-in-20 change estimates developed by Kopp et al, 2014 and in Kopp et al, 2016. This Technical Memorandum is to be provided at the conclusion of the risk assessment (Task 2C.4) and benefit-cost analysis (Task 3A.2) in conjunction with the findings of the respective tasks. This technical memorandum focuses on the risk assessment methodology.

Both the risk assessment and cost-benefit processes take into account the impacts and probability of hazard events, enabling the comparison of coastal flood events of varying degrees of magnitude within the common framework of annualized loss. The types of impacts and methods of assessment are discussed in detail later in this document and presented in Figure 2. Risk scenarios are 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. The initial year for which the risk assessment is conducted – and which is the subject of a subsequent technical memo - is 2020. This year was selected for the Baseline Risk Assessment as it is 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 changes between 2017 and 2020 are considered 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 will be expressed in 2017 dollars.

The output of the risk assessment (i.e. the part of the risk assessment that can be expressed in monetary terms) can be expressed in terms of "annualized loss". Annualized loss is defined as the expected annual loss over the long term (UNISDR, 2017). A term also used is Annualized Loss Exposure (ALE)[1]. Risk is the probable frequency and magnitude of future loss, or *Frequency x Magnitude = Loss*. The combination of both of these elements (not just a single one) is what can be called *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

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

ALE allows the prioritization or comparison of separate risk issues which often have different frequencies and per-event impacts. However Annualized Loss Exposure is not a prediction. Understanding the probability of something is not the same as prediction (example: rolling dice).

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. This process is summarized below.

Workflow Overview of Risk Assessment and Cost-Benefit Analysis

The risk assessment and cost-benefit analysis are part of an overall workflow in developing resilience and adaptation measures for the Two Rivers region. The general workflow is outlined in Figure 1. The methodology for the tasks in the orange boxes (i.e., the tasks associated with the risk assessment and cost-benefit analysis) are detailed in this document. The methodology and results of the Baseline Risk Assessment in Year 2020, which is one of the tasks in the orange boxes (i.e., the tasks associated with the risk assessment and cost-benefit analysis) will be described in a subsequent Technical Memorandum. 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 the 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 Technical Memoranda to provide a comprehensive methodology description.

Define High Water Level Event Scenarios

As described in the *NJ FRAMES Planning Inundation Levels – Technical Memo Summary* (http://www.nj.gov/dep/oclup/docs/njframes-tech-memo-summary.pdf) provided by Rutgers University, three high water level event scenarios have been selected to take into account a range of coastal flood hazards: 3, 7, and 12 ft. above Mean High Higher 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 be representative of permanent inundation, coastal flooding, and coastal storm flooding as detailed in Table 1 below. The full water levels memo is available at the following location: http://www.nj.gov/dep/oclup/docs/njframes-tech-memo.pdf. Further refinement of the permanent inundation methodology will be conducted as part of the No Action Risk Assessment in coordination with NOAA.

Extreme water level values come from NOAA’s Extreme Water Levels statistics for the Sandy Hook, NJ tide gauge. The team uses the "Exceedance Probability Levels and Tidal Datums" at the gauge for our tidal datum and water level references. Although both NOAA and 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). 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).

These extreme water level values were specifically selected to reflect what the entire region would experience "at a minimum." This still water approach to assessing current and future flood exposure allows projection of 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). As wave heights cannot be predicted into the future without a substantive local modeling effort, this approach does not account for wave heights associated with 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, the selected water levels represent the minimum levels of exposure and areas adjacent to the coastline that may experience additional impact from run-up and wave action.

The use of still water levels enables utilization of mapping visualization tools like the NJ FloodMapper.org, the NJ Coastal Flood Exposure Profiler and NOAA’s Sea Level Rise viewer for planning and communication purposes.

The Risk Assessment methodology includes the baseline scenario in 2020 for 3, 7 and 12 ft. water levels, as well as for future No Action scenarios for years 2030, 2050 and 2100. For these scenarios a High Emissions 1-in-20 chance estimate for sea level rise is used. This high emission scenario estimates a sea level rise of 5.3 feet by 2100, which is higher than lower emission scenarios. This high emission scenario is used to capture the earliest instance in which assets in the study area experience risk. A sensitivity analysis will be conducted for this assumption using the high-emissions middle estimate (3.4 feet by 2100) and the low-emissions estimate (2.3 feet by 2100).

Table 1: Water Levels Above Current MHHW Assessed for NJ FRAMES Analyses

			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% AEP) 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 approximately 2.8 feet above MHHW.
		Coastal Storm Flooding	7 ft.	• A 100-Year (1% AEP) Flood today • A 10-Year (10% AEP) Flood under a High Emission Scenario in 2100 • 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.
			12 ft.	• 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 historical record for this tide gauge (i.e. since 1910) has never recorded a water level this high.

Note: Hurricane Sandy under High Emission Scenario in 2100 projected at 11.2’

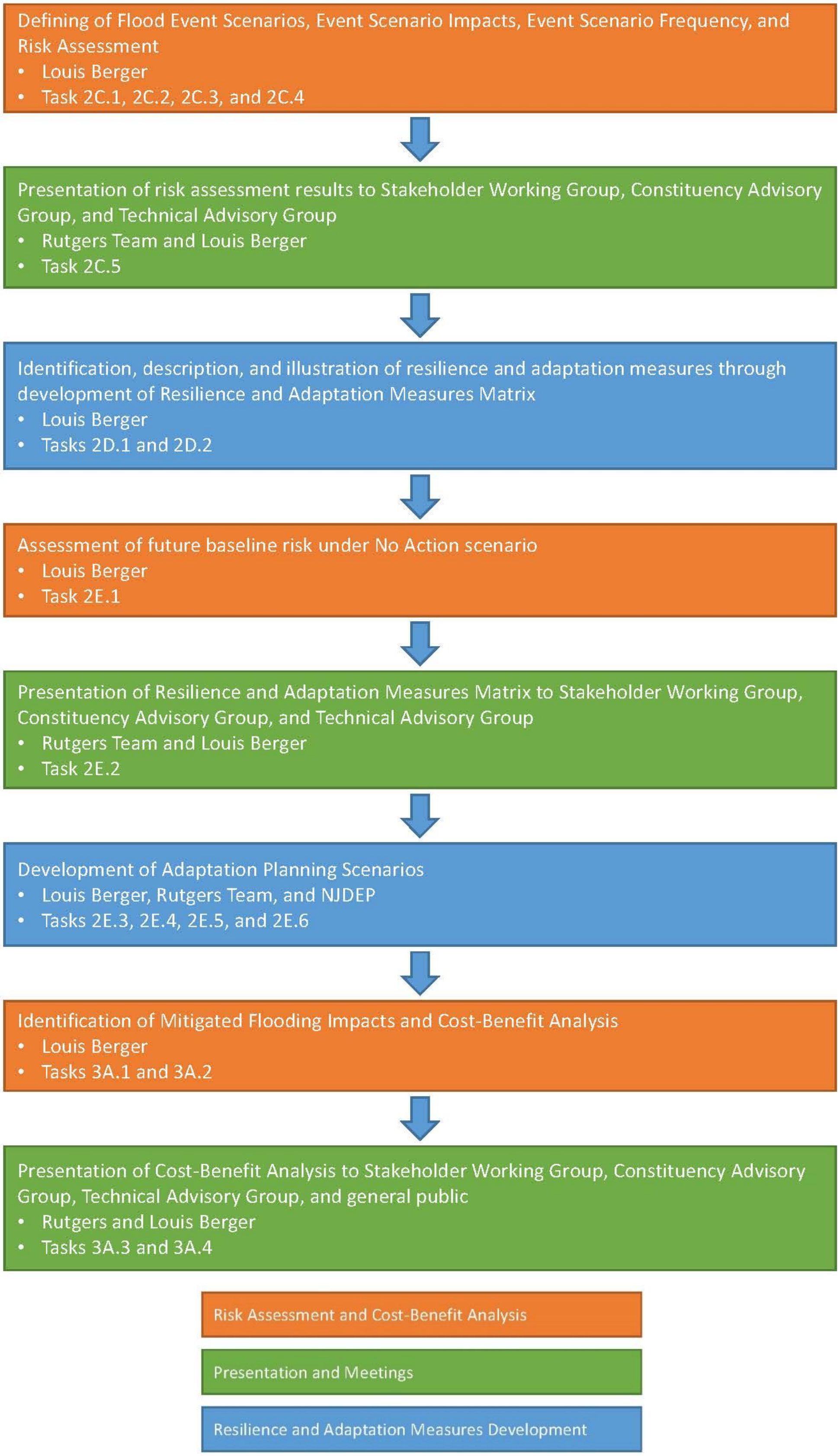


Figure 1: Workflow for the Development of Resilience and Adaptation Measures

Identify Event Scenario Impacts

As suggested in *'What Will Adaptation Cost?'* The impacts of each event scenario will be identified in terms of monetized impacts (Economic Impacts, Socio-Economic Impacts) and non-monetized impacts (Natural Resource Impacts, Social Impacts). The evaluation of these impacts is described below. Figure 2 provides an overview of the different impacts and methods of assessment. The methods to asses these impacts are discussed further below as well as in Technical Memorandum No. 4: Baseline Risk Assessment Technical Memo.

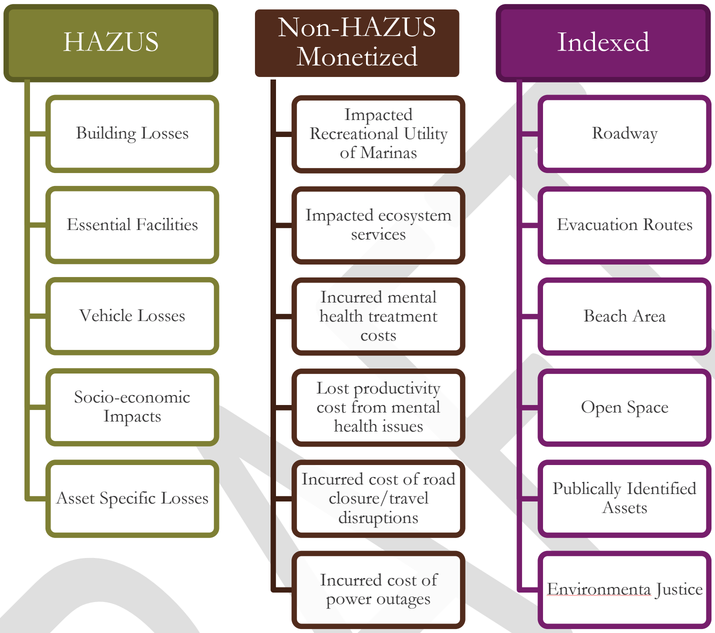


Figure 2: Overview of Risk Assessment Methods for Monetized and Non-Monetized Impacts

Monetized Impacts in HAZUS

HAZUS is a flood modeling and loss estimation software tool developed by FEMA and recommended by NOAA in 'What Will Adaptation Cost?', which was employed to measure economic and socio-economic impacts resulting from the flood event scenarios. 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, taking into account 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, map data, and general building stock (GBS) data. In addition, HAZUS contains national data on critical facilities (e.g., hospitals, schools), high potential loss facilities (HPL) (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 discrete analysis was conducted on specific assets identified as part of Task 2B.

To provide area specific information, results of inundation modeling completed by NJDEP were imported into HAZUS to establish the spatial extent of inundation, including height of inundation, for each of the three water level event scenarios.

Additional impacts that HAZUS-MH is unable to process due to data characteristics outside the HAZUS-MH modeling capabilities, will be measured separately as Monetized Asset Impacts, Indexed Asset Impacts, and Qualitative Asset Impacts. Steps for capturing these impacts are shown in the section, *Characterization of Impacts Outside of HAZUS: Monetized, Indexed, and Qualitative Asset Impacts*.

Economic and Socio-Economic Impacts will be evaluated in terms of dollars and are defined as follows:

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

These impacts will be monetized for each event scenario using HAZUS-MH. HAZUS-MH is based in a Geographic Information System (GIS), and contains spatial data on the population and physical structures within a region. Flood event scenarios are modeled spatially across the study area. Given the expected flood depth at a physical location, HAZUS-MH calculates the corresponding losses due to flood damage to a structure, taking into account the structure's building value, first floor elevation, structure type, and other parameters. The effects of permanent inundation cannot be assessed directly through HAZUS and the specific methodology will be developed as part of the No-Action scenario assessment in coordination with NOAA.

To estimate the economic impacts of each flood event scenario for the NJ FRAMES risk assessment, the HAZUS-MH default data will serve as a basis for the existing building stock. As described further below, a Hazus Level 1 analysis will be conducted region-wide to provide a high-level estimate of the damages from the water level events. A Hazus Level 2 analysis will be conducted on the applicable assets identified through the Map What Matters and Getting to Resilience processes using up-to-date newly researched data on building values, first floor heights, etc. The results of the Level 2 analysis will be summarized separately from the Level 1 analysis.

The HAZUS model includes a set of standardized asset types and associated data. Where applicable, additional assets are added to HAZUS from the asset database developed by the Project Team as a part of Task 2B. These assets will be incorporated in the model and any missing parameters necessary for those assets to be processed by the HAZUS model will be provided by the Risk Assessment Team (consisting of Louis Berger and Binera).

This workflow maximizes both the use of the FEMA-developed HAZUS methodology and datasets in addition to the asset database developed by the Project Team. In addition, this workflow ensures the methodology is replicable, while also incorporating site- and region-specific data.

The asset database specified above includes assets collected from publicly available datasets, such as geospatial datasets provided by the New Jersey Geographic Information Network. In addition, because the HAZUS method does not capture all assets relevant to this project, additional assets were collected through a public engagement process. This process included reaching out to public stakeholders through the following ways:

- Getting to Resilience (GTR) Meetings
- Stakeholder Meetings
- Public Outreach Meetings
- Map What Matters Events (JC NERR, 2017)

Results of inundation modeling completed by the NJDEP will be imported into HAZUS to define the spatial extent of inundation. A hypothetical example of HAZUS Flood Modeling results for critical assets is shown below in Figure 3 for illustration:

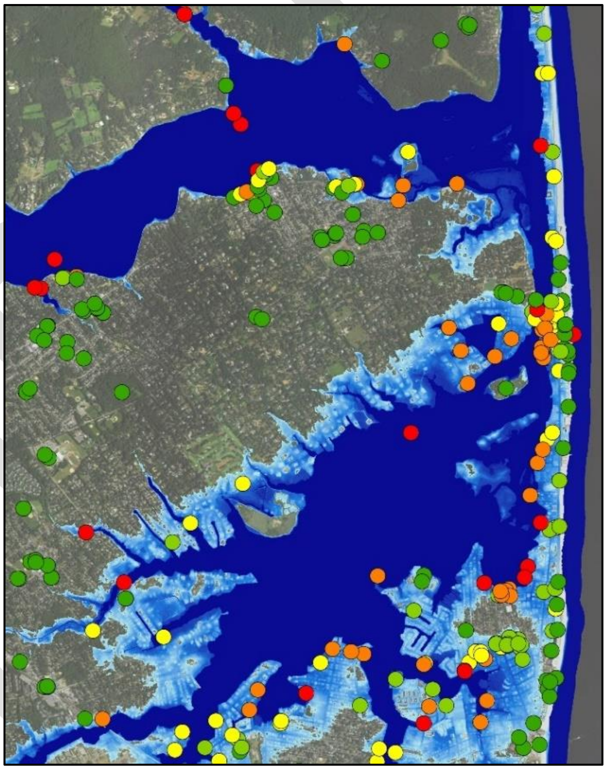


Figure 3: Example map of HAZUS damage estimates for a high water level event scenario ranging from low damage (green) to total damage (red). Data for illustration only.

The HAZUS database is, in general, developed from Census 2010 data and residential structures from Dun & Bradstreet market analysis profiles projected for 2010. More specifically, the general building stock inventory in HAZUS is developed from the following sources (FEMA, 2017):

- Census of Population and Housing, 2010.
- Dun & Bradstreet, Market Analysis Profile aggregated by Standard Industrial Classification (SIC) Code Clusters, July 2006. Projected for 2010.
- Department of Energy, Housing Characteristics 1993. Office of Energy Markets and End Use, DOE/EIA-0314 (93), June 1995.
- Department of Energy, A Look at Residential Energy Consumption in 1997, DOE/EIA-0632(97), November 1999.
- Department of Energy, A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures, DOE/EIA-0625(95), October 1998.

In addition to the data sets above, Homeland Security Infrastructure Program (HSIP) data will be included to assess impacts to critical assets. More recent detailed information for assets will be developed and applied as described in Technical Memo No. 4: Baseline Risk Assessment Technical Memo. . A “Level 1” analysis, based on the most recently available 2010 Census data (included in HAZUS), will be used to establish estimates of *region-wide* losses in terms of economic and socio-economic impacts. Considering the scope of the study updating HAZUS data to current conditions is considered not practicable. However, assets identified as part of Task 2B will be 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 will be done for other assets, such as vehicles. For example, HAZUS estimates of vehicle damage from inundation are based on water depths reaching a certain height of a vehicle by type. For each vehicle type (car, light truck, heavy truck), the program applies a Depth Damage Function (DDF) measuring the percentage of damage with regard to the flood level, and this amount of damage varies based on whether the flood is below carpet, between carpet and dashboard, or above dashboard. The methodology for incorporating these new assets into the HAZUS impact analysis is described below.

Characterization of Impacts Outside of HAZUS

Impacts to assets that do not have the appropriate characteristics to enable processing through the HAZUS model will be identified separately. Additional impacts will be captured separately outside of HAZUS as Monetized Asset Impacts, Indexed Asset Impacted, and Qualitative Asset Impacts.

Example metrics that could be used to assess these impacts include those listed in Table 2. The table also includes benefits that may occur as a result of projects, which will be calculated as part of the cost-benefit analysis. The final list of impacts characterized outside of HAZUS will depend on the data available in the study area. The table below also details if an impact is monetized or indexed and previous studies in which each benefit/impact was quantified. The methodology for monetizing impacts are described in the studies referenced. The referenced studies are for projects in the New York / New Jersey Region and while generally applicable also are a relatively close match to reflect the context of the project, consistent with the approach to leverage local/regional data and methods when possible to augment more general data sets. Local data will be used in applying the methodologies to the study area to ensure applicability of the parameters in the assessment. The methodology for indexing and qualitatively assessing impacts are described in the sections below.

Monetized Asset Impacts

Additional impacts will be monetized where possible. Although not included in the project (limits effort to an index based analysis only), the Risk Assessment Team will consider monetization of such values through methods that have been previously applied and accepted by government agencies, such as ecosystem services values calculated for Benefit Cost Analysis in support of HUD CDBG-DR grants (including the HUD Rebuild by Design and HUD National Disaster Resilience Competition).

These may include impacts to assets such as a riverfront, a beach, a "Main Street" or other such assets that have been identified by the public as important but are not defined in a format that can be processed through HAZUS (e.g., because they are not a structure). In cases where the impact can be monetized, such will be done. For example, if an entire beachfront would be impacted by flooding such that the economic viability of the beach would be impacted, the monetized impact of this effect would be reflected in the loss to the extent possible.

Table 2: Non-HAZUS Avoided Impacts / Benefits (Quantified)

Avoided Impacts/Benefits	Type	Source
Property value increases	Monetized	Living with the Bay. Living Breakwaters.
Job creation—including from construction and from protection of assets	Monetized	Living with the Bay. Living Breakwaters.
Avoided event interruption costs	Monetized	Living with the Bay
Recreational utility value (e.g., boats, parks, fishing)	Monetized	Living with the Bay. Living Breakwaters.
Improvement of air and water quality	Monetized	Living with the Bay. Living Breakwaters.
Added ecosystem services	Monetized	Living with the Bay. Living Breakwaters.
Avoided mental health treatment costs	Monetized	Living Breakwaters
Avoided lost productivity from mental health issues	Monetized	Living Breakwaters
Avoided road closure/travel disruption costs	Monetized	Living Breakwaters
Avoided cost of power outages	Monetized	Living Breakwaters
Education and environmental stewardship	Monetized	Living Breakwaters
Protected roads by Annual Average Daily Traffic	Indexed	Raise Shorelines Citywide Study
Protected environmental justice area	Indexed	Raise Shorelines Citywide Study
Protected number of elderly individuals	Indexed	Raise Shorelines Citywide Study
Protected number of non-English speaking individuals	Indexed	Raise Shorelines Citywide Study
Protected number of households under poverty	Indexed	Raise Shorelines Citywide Study
Protected number of households with disabled individuals	Indexed	Raise Shorelines Citywide Study
Protected areas with high Social Vulnerability Index	Indexed	Raise Shorelines Citywide Study

Indexed Asset Impacts

In cases where an asset has impacts that cannot be monetized with standard methodologies, values for such impacts will be indexed.

For the purposes of this project, an index is a quantity that acts as a proxy for the magnitude of impacts or benefits. An index usually is defined on an interpretable scale, such as a scale of 1 – 10 or Low/Medium/High. As previously described, a proxy is used in the case where an impact or benefit cannot be monetized. Examples of metrics that can be converted to indices include population count, traffic counts, and square footage of protected area. The table below provides an example of an index that quantifies the magnitude of impacts from displaced individuals.

For indexed impacts, metrics such as roadway length, beach area, park area, SVI, evacuation routes, and publically-identified assets (see Figure 2 above). Will be used to quantify the magnitude. A detailed discussion of the application of these metrics is provided in Technical Memo No. 4: Baseline Risk Assessment Technical Memo. Next, risk index scales (e.g., rating from 1 to 5) or other measures consistent with the framework outlined in '*What Will Adaptation Cost*' will be developed and used to evaluate the expected impacts. The use of index scales allows the assessment of non-monetary impacts in a consistent manner such that the benefits of adaptation planning scenarios can be identified and taken into account in the final BCA. Development of these index scales will be conducted in collaboration with the Project Team and subject matter expert input.

Table 3: Example Index for Displaced Individuals

Scale Value	Impact Duration	Impact Description
1	1 – 2 days	Short-term displacement of affected population (1-7 days) resulting in minimal impact on community wellbeing.
2	3 – 5 days	
3	6 – 7 days	
4	2 weeks	Moderate displacement of affected population (2-4 weeks) resulting in a moderate impact on community wellbeing.
5	3 weeks	
6	4 weeks	
7	1 month	Significant displacement of affected population (1-3 months) resulting in severe impact on community wellbeing.
8	2 months	
9	3 months	
10	>3 months	Long-term displacement of affected population (3+ months) resulting in widespread impact on community wellbeing.

Qualitative Asset Impacts

Some asset impacts may not lend themselves to either monetization or indexing due to the scale of the analysis and the absence of compatible methodologies conducted by other studies that assess risk for the purposes of resilience or data requirements that are beyond the scope of this study. For example the FEMA DFIRMS (V-Zone) delineation for areas impacted by 3FT waves for 1% chance event was reviewed but determined to be non-compatible. Another example of this are the effects of wave action on natural systems, which would require substantial granularity of site specific natural resource information and dynamics and detailed modeling and may not be suitable for a regional level of analysis within the scope the FRAMES project. However to acknowledge such potential impacts, the risk assessment will reference literature (and, where applicable, case studies) that describe the mechanisms of wave action and erosion and their potential effect on natural systems and how such mechanisms and trends can exacerbate impacts on natural systems, including aspects of habitat fragmentation. Where flood levels lead to patterns similar to those referenced in literature, this will be identified as a special risk. In such a case, a planning scenario that reduces such fragmentation will make note of such potential landscape-level regional benefits and reference applicable literature.

For example, to the extent feasible, ecosystem functions that are impacted by fragmentation would be identified. Where regional studies are available (e.g., a study on the effects of sea level rise on coastal wetland systems along the Jersey shore), such studies will be referenced to contextualize the (avoided) loss and any additional benefits. An example of such a study is a recent study that indicates the benefits of wetland systems in reducing certain flood impacts. In a case like this, the study will be cited for context and reference purposes but will not be translated into regional program-specific risks and benefits as such would be outside the scope of the FRAMES project.

Assets with multiple types of impacts

For assets that incur multiple types of impacts, such as is the case for a beach which represents open space, ecological, and other values, and their values will be monetized as practicable, considering accepted methodologies. Because the nature of impacted assets and the current uncertainty of their characteristics (as this draft is issued prior to the actual analysis), the methodology will be presented once the impacted assets have been identified. Appropriate references will be included to established methodologies. For example the “Map What Matters” (MWM) process (see below) may have revealed for a hospital certain values that are not captured by the standard HAZUS-based value. In such case those additional (non-HAZUS determined) values will be made explicit and will be acknowledged through an index or qualitative reference.

Getting to Resilience (GR) / Map What Matters (MWM) Assets

The GTR/MWM process provides important insight in the identification of assets, values of assets or types of assets important to the community respondents and not always captured through the HAZUS model data sets or established databases. An overview of the MWM process is provided in JC NERR, 2017. The GTR/MWM process reflects the input generated by those community members who participated in the public engagement process. To ensure a transparent understanding of the results the analysis will represent these assets and values as generated through the GTR/MWM process as separate from the HAZUS output. The results of the incorporation of the GTR/MWM assets into the risk assessment will be communicated to the various participants in the NJ FRAMES engagement process, indicating how their engagement and asset mapping input is reflected in the risk assessment.

Flood Scenario Risk Profiles

The combination of monetized risk, indexed risk and qualitative risk components represents the overall risk profile of a specific flood scenario.

This profile can then be used for purposes of developing regional action scenarios that eliminate or reduce such risks and create additional benefits. The action scenarios can then also be represented in terms of monetized risk reduction, indexed risk reduction, and qualitative risk reduction.

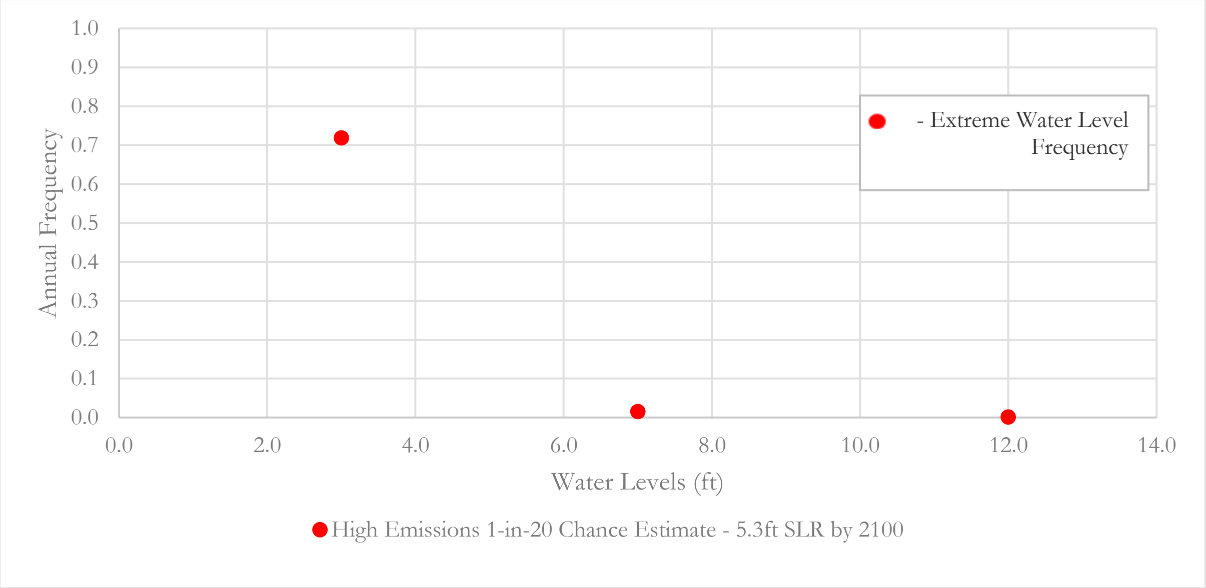
In characterizing the solution, reference will then be made to the MWM and public engagement process. For example, if a scenario reduces the risk to an asset not picked up by the HAZUS model, then the fact that this regional asset was important in the MWM process will be explicitly referenced as an important regional community value identified though the public engagement process. Note that the avoided economic loss of this asset not being eliminated would be included in the second category of assets that may not be captured through the HAZUS model (which focuses on structures) but through the economic benefit analysis.

As the Risk Assessment Team works through the three risk assessment components the more detailed methodologies will be shared with the NJ FRAMES Project Team, experts from NOAA and other relevant parties in accordance with the SOW.

Estimation of Event Scenario Frequency

The probability of each event scenario is required to assess risk in terms of annualized impacts. The estimation for the baseline event scenario frequencies as well as succeeding no-action risk assessment years (2030, 2050, 2100) were calculated using an Extreme Value Theory (i.e., generalized extreme value distribution (GEV)) or an Empirical Distribution application.

Figure 2: Water Level Frequencies – 2020 Baseline



Baseline Risk Assessment

To form a basis for comparison against future conditions with and without adaptation planning scenarios implemented, baseline coastal flood risk under current climate conditions must first be assessed. For monetized impacts, risk is assessed in terms of average annualized losses by multiplying the average annual probability and expected losses of each event scenario. This method of calculated average annualized losses is based off of Equation 4.4 from the NOAA handbook, reproduced below. The average annualized losses describe the magnitude of losses adjusted for the probability of the event(s) that cause those losses. An example risk calculation is shown below for illustration purposes.

$$ED_X = P(X) * AD_X$$

Where:

ED_{XYN} = expected damage of storm type X

$P(X)$ = annual probability of storm type X

AD_X = average annualized damage of storm type X

Table 4: Example Baseline Monetized Risk Calculation under current climate conditions. Data for illustration purposes only.

Event Scenario	Average Annual Probability	Total Losses ($M)	Risk: Annualized Losses ($M)
A	0.1	$1,000	$100
B	0.01	$15,000	$150
C	0.005	$55,000	$275

For non-monetized impacts, risk is assessed as the event scenario probability multiplied by the index scale ratings developed for natural resources and social impacts of each event scenario. Shown below is an example risk calculation for Natural Resource Impacts.

Table 5: Example baseline monetized risk calculation under current climate conditions.

Data for illustration purposes only – event scenarios, impacts and probabilities are hypothetical and non-specific.

Event Scenario	Average Annual Probability	Natural Resource Impact	Risk: Annualized Impact Index
A	0.1	2 - Low	0.2
B	0.01	4 - Severe	0.04
C	0.005	5 - Extreme	0.025

Note that the probabilities of 3, 7, and 12 foot water levels under the baseline scenario have not been calculated. The calculation of these probabilities will be conducted based off of the probabilities of water levels calculated in preceding Technical Memos. The methodology for establishing the water levels and associated probabilities are described in detail in Technical Memo No. 1: NJ FRAMES Water Level Proposals Project Team Deliberation Memo and Technical Memo No. 2: NJ FRAMES Planning Inundation Levels – Technical Memo Summary by Rutgers University.

Upon completion of the baseline risk assessment, the results will be presented as part of the Stakeholder Working Group, Constituency Advisory Group, and Technical Advisory Group as a part of Task 2C.5.

No-Action Scenario Assessment

Due to the impacts of sea level rise, the likelihood of each event scenario occurring will increase over time. The impacts of each scenario will also increase due to projected population growth and development in the study region, leading to an increase in future risk. Future population growth and land use patterns will be coordinated with regional forecasting by agencies such as the North Jersey Transportation Planning Authority, which is the Metropolitan Planning Organization for the region in which the study area is located, as well as municipal and county projections where applicable and available. To re-establish baseline risk under these future conditions, assuming no adaptation planning scenarios are implemented (i.e., the No Action scenario), the impact assessment as described in steps 2 – 4 is repeated under these new conditions. An example is shown below for illustration purposes:

Table 6: Example risk calculation comparing baseline risk to a single future No-Action scenario. Data for illustration only.

Event Scenario	Average Annual Probability		Total Losses ($M)		Risk: Annualized Losses ($M)	
	Baseline	**2100 – No Action**	**Baseline**	**2100 – No Action**	**Baseline**	**2100 – No Action**
A	0.1	0.5	$1,000	$2,000	$100	$1,000
B	0.01	0.1	$15,000	$21,000	$150	$2,100
C	0.005	0.01	$55,000	$80,000	$275	$800

Impacts to natural resources and social impacts are evaluated similarly using the index scales established during the baseline risk assessment.

Interpolation of No-Action Scenario Assessment to Additional Years in the Time Horizon

The No-Action Scenario Assessment will be initially performed for the 2100 year. To interpolate the results of the No-Action Scenario Assessment, the probability of each of the water levels during the additional time periods (2030 and 2050) was interpolated using an exponential function. These two years were chosen due to their prevalence in sea level rise research (Kopp et al., 2014; Kopp et al., 2016). The interpolations of the assessed water levels for 2030 and 2050 are depicted in the figures 5 and 6 below.

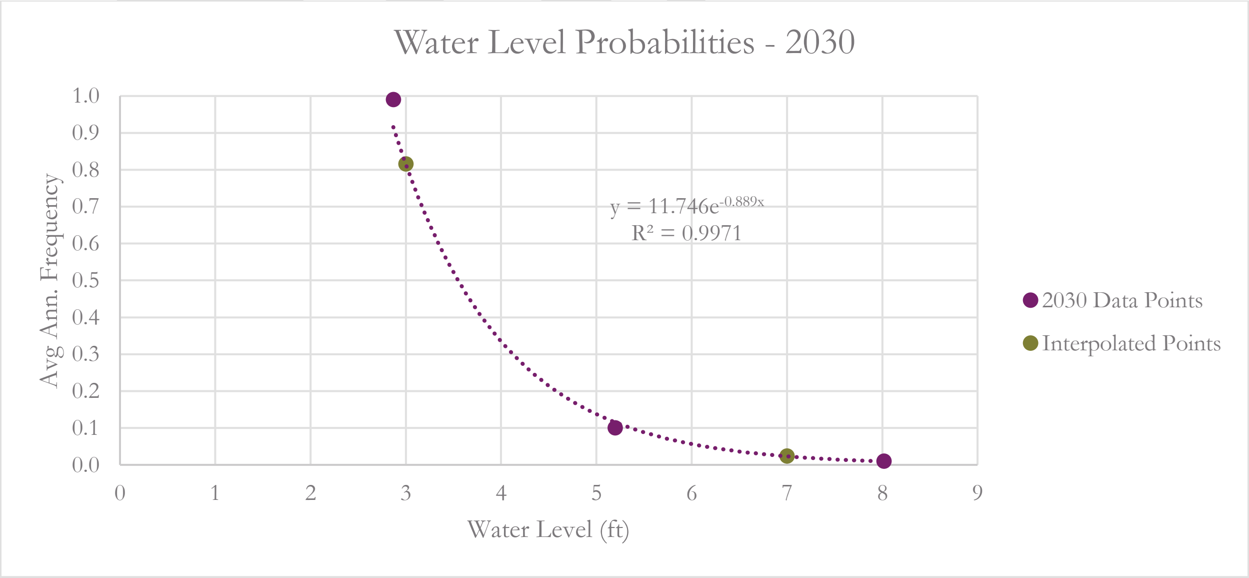


Figure 5: Interpolation of water levels for 2030

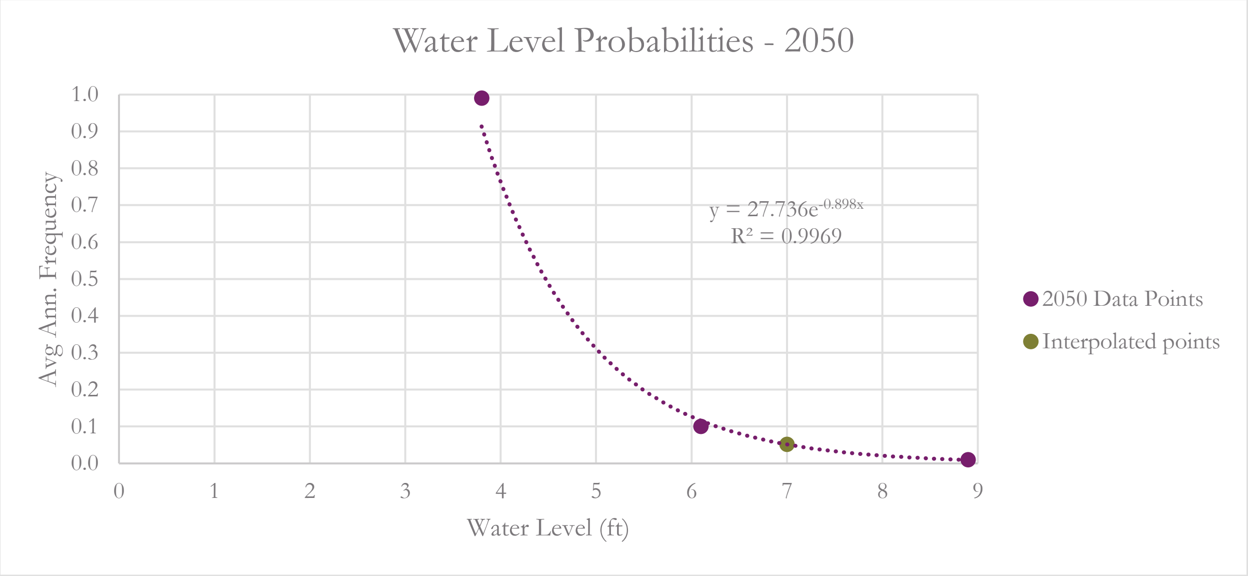


Figure 6: Interpolation of water levels for 2050

As suggested by the R^2 values in the figures above (0.9971 for 2030 and 0.9969 for 2050), an exponential function is appropriate for interpolating the probabilities of water levels. The probabilities for the assessed water levels are shown below.

Table 7: Probabilities of water levels for 2030 under the High Emissions 1-in-20 Chance Estimate

Water Level (ft)	Average Annual Frequency
3.0	0.9048
7.0	0.0180
12.0	.0012

Table 8: Probabilities of water levels for 2050 under the High Emissions 1-in-20 Chance Estimate

Water Level (ft)	Average Annual Frequency
3.0	Permanent Inundation
7.0	0.0516
12.0	High Uncertainty

Note that the 12 foot water level for 2030 and 2050 was estimated to have extremely low probabilities (less probably than a 1000-year event), resulting in a high uncertainty. Because the probabilities of these events are extremely low, the results of the assessment are not expected to materially affect the results of the assessment. These two events are excluded from the analysis in the 2030 and 2050 timeframes.

The 12 foot water level event will be included in the analysis for the 2100 timeframe, as the probability of this event increases due to the impacts of sea level rise.

The interpolation is possible because each water level (or event scenario) has a probability of occurring in each of the time periods. Note that this interpolation method assumes that the losses from each water level is the same at various time periods. For example, while the probability of event scenario A may be 50% in 2100, the same event scenario may have a probability of 25% in 2050. Figure 6 below illustrates this phenomenon.

The *probabilities* of each water level will then be applied to the *losses* associated with each water level to calculate the average annualized losses from that water level for the specified time period. An example of this calculation is shown in table 7 below. Note that example values are used and do not reflect actual probabilities.

Table 9: No-Action Scenario Assessment to Additional Years

Event Scenario	**Average Annual Probability**		**Total Losses ($M)**		**Risk: Annualized Losses ($M)**	
	2100 – No Action	**2050 – No Action**	**2100 – No Action**	**2050 – No Action**	**2100 – No Action**	**2050 – No Action**
A	0.5	0.25	$2,000	$2,000	$1,000	$500
B	0.1	0.05	$21,000	$21,000	$2,100	$1,050
C	0.01	0.005	$80,000	$80,000	$800	$400

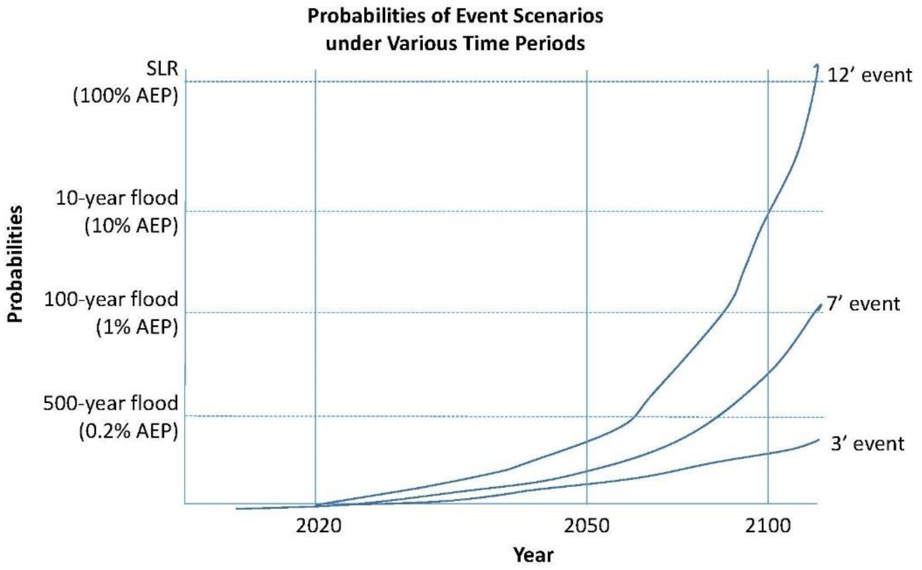


Figure 7: Demonstration of Event Scenario Probabilities for Various Time Periods (Figure is for illustrative purposes only and does not reflect actual values)

Adaptation Planning Scenario Development and Assessment

Adaptation planning scenarios (APS) will be defined by the Project Team in collaboration with stakeholders. Once the adaptation planning scenarios are identified, the reduction in flooding under these scenarios given future sea level rise conditions at specified points in time will be assessed. As the sea level rise conditions in both the No Action scenario and under APS implementation at a given time threshold are the same, the probability of the event scenario does not change.

The impact assessment as described in steps 2 – 4 is repeated under these new conditions, taking into account both the reduction in flood extent due to APS implementation and increased development in the study area. An example risk calculation comparing the baseline risk, risk under the No-Action scenario, and risk under the implementation of a single APS is show in Table 10. These calculations are repeated for all identified APS.

Table 10: Example risk calculation comparing baseline risk, a single future No-Action scenario, and a single Adaptation Planning Scenario (APS). Data for illustration purposes only.

Event Scenario	**Average Annual Probability**		**Total Losses ($M)**			**Risk: Annualized Losses ($M)**		
	Baseline	**2100**	**Baseline**	**2100 - No Action**	**2100 - APS 1**	**Baseline**	**2100 - No Action**	**2100 - APS 1**
A	0.1	0.5	$1,000	$2,000	$1,200	$100	$1,000	$600
B	0.01	0.1	$15,000	$21,000	$18,000	$150	$2,100	$1,800
C	0.005	0.01	$55,000	$80,000	$62,000	$275	$800	$620

Impacts to natural resources and social impacts are evaluated similarly using the index scales established during the baseline risk assessment.

Benefit-Cost Analysis

Finally, the change in risk from the baseline calculations to future conditions where no adaptation planning scenarios have been implemented (i.e., the No-Action scenario) and future conditions that include adaptation planning scenarios will be compared to the cost of APS implementation in a benefit-cost analysis. This requires the assessment of the total cost of each APS, including a discounting of future costs to a comparable net present cost. Initially the FEMA 7% discount rate will be applied followed by the 3% discount rate used in HUD and OMB studies/guidance for consistency and comparative analysis to other BCAs. A sensitivity test will be applied to the discount rate to determine the effect on the BCR of the selected APS. Although APS will be implemented in the future, estimation of benefits will not include future projections of inflation and will be calculated in terms of present dollar value.

An example cost-benefit calculation of monetized impacts and benefits for a single adaptation planning scenario is shown in Table 11 below. This calculation will be repeated for all APS that have been selected for analysis.

Table 11: Example Monetized Benefit-Cost Analysis calculation for a single APS. Data for illustration only.

Event Scenario	Risk Under No-Action Scenario ($M)	Risk Under APS 1 ($M)	Benefit ($M)
A	$1,000	$600	$400
B	$2,100	$1,800	$300
C	$800	$620	$180
		Total Benefit ($M):	$880
		Cost of APS 1 Implementation ($M):	$750
		Benefit/Cost Ratio:	1.17

The monetized benefit-cost ratio for all APS can then be compared to inform future decision-making.

Non-monetized impacts and benefits will also be calculated and compared to the cost of APS implementation in a similar manner. An example calculation of a non-monetized benefit is shown below:

Table 12: Example Benefit-Cost Analysis calculation for a single APS. Data for illustration only.

Event Scenario	Natural Resource Risk Under No-Action Scenario	Natural Resource Risk Under APS 1	Benefit
A	1.5	0.5	1
B	0.3	0.2	0.1
C	0.05	0.04	0.01
		Total Benefit ($M):	1.11
		Cost of APS 1 Implementation ($M):	$750

Since the non-monetized benefits calculated using the index scales will not be in the same units as the monetized benefits, a monetized BCA ratio cannot be directly compared to an assessment of non-monetized benefits. Non-monetized benefits can be compared to the costs of APS implementation, and these benefits will be reported separately to provide input to stakeholders on both monetized and non-monetized benefits. For example an APS can substantially improve the index value of a particular non monetized resource or reduce the indexed impacts. This provides a comprehensive view of coastal flood risk and the benefits and costs of all adaptation planning scenarios, while maintaining full transparency.

Sea Level Rise

The initial screening of potential impacts to assets as a result of flood scenarios will be conducted using the highest sea level rise projection for all flood scenarios. This conservative approach ensures that all assets potentially affected are included in the initial impact screening. It also ensures that potential relationships among assets can be fully explored and is not limited to assets that fall within the medium or low SLR projection. This may be particularly relevant for regional systems such as wetlands that may incur fragmentation effects under a high SLR projection but not or much later under medium or low SLR projections. The results of this analysis will be used to develop planning scenarios that seek to improve regional resilience. In the development of Action Planning Scenarios (APS), there will be short-, medium-, and long-term scenarios. This will develop an understanding of how the study area is impacted over multiple time periods until 2100. This understanding will convey how assets/impact areas are subjected to continuous inundation vs. inundation on an incidental basis. For example, Asset A may be affected by permanent inundation in 2050 while Asset B is affected by 100-year floods in 2050. Mitigation solutions for Asset A and B will be different due to the nature of the flooding that impacts them. Solutions that address both risks and/or provide opportunities to further enhance adaptation in the future may be most preferable.

Although not included in the project, the cost benefit analysis of the planning scenario could include a sensitivity screening to SLR scenarios. For example, the scenario will be evaluated using a medium and low SLR probability to ascertain the potential effects on the BCA results (both quantitatively and qualitatively) and/or whether a specific asset would (1) no longer be included in the planning scenario because it would not be impacted under a medium or low SLR projection or (2) should be considered but protected at a later time in the future when it would be impacted under a medium or low SLR projection. This will also inform the phasing of potential planning scenarios and the evaluation of when certain components of a planning scenario should be implemented to protect assets that may be impacted only under high SLR projections or under medium/low SLR projections at a later point in time. This will be determined as the process continues.

Risk Assessment and Cost-Benefit Analysis Methodology Review Process with NOAA

The methodology detailed in this document will undergo a review process with NOAA personnel. This review serves as a quality assurance procedure to verify that the risk assessment and cost-benefit analysis captures all impacts and benefits where possible and practicable within the scope of the project as well as verifying the accuracy of calculation methods.

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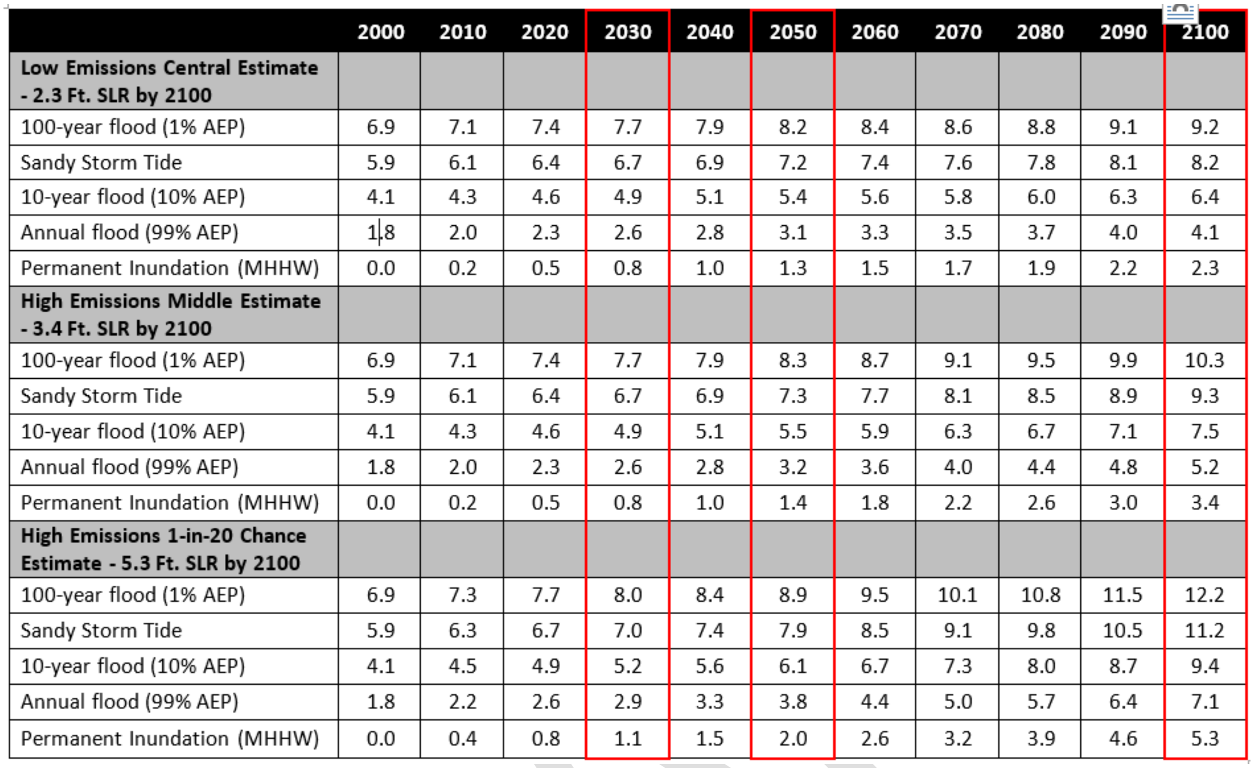
Appendix A: Water levels (in feet above MHHW) for various event scenarios[i]



	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Low Emissions Central Estimate - 2.3 Ft. SLR by 2100											
100-year flood (1% AEP)	6.9	7.1	7.4	7.7	7.9	8.2	8.4	8.6	8.8	9.1	9.2
Sandy Storm Tide	5.9	6.1	6.4	6.7	6.9	7.2	7.4	7.6	7.8	8.1	8.2
10-year flood (10% AEP)	4.1	4.3	4.6	4.9	5.1	5.4	5.6	5.8	6.0	6.3	6.4
Annual flood (99% AEP)	1.8	2.0	2.3	2.6	2.8	3.1	3.3	3.5	3.7	4.0	4.1
Permanent Inundation (MHHW)	0.0	0.2	0.5	0.8	1.0	1.3	1.5	1.7	1.9	2.2	2.3
High Emissions Middle Estimate - 3.4 Ft. SLR by 2100											
100-year flood (1% AEP)	6.9	7.1	7.4	7.7	7.9	8.3	8.7	9.1	9.5	9.9	10.3
Sandy Storm Tide	5.9	6.1	6.4	6.7	6.9	7.3	7.7	8.1	8.5	8.9	9.3
10-year flood (10% AEP)	4.1	4.3	4.6	4.9	5.1	5.5	5.9	6.3	6.7	7.1	7.5
Annual flood (99% AEP)	1.8	2.0	2.3	2.6	2.8	3.2	3.6	4.0	4.4	4.8	5.2
Permanent Inundation (MHHW)	0.0	0.2	0.5	0.8	1.0	1.4	1.8	2.2	2.6	3.0	3.4
High Emissions 1-in-20 Chance Estimate - 5.3 Ft. SLR by 2100											
100-year flood (1% AEP)	6.9	7.3	7.7	8.0	8.4	8.9	9.5	10.1	10.8	11.5	12.2
Sandy Storm Tide	5.9	6.3	6.7	7.0	7.4	7.9	8.5	9.1	9.8	10.5	11.2
10-year flood (10% AEP)	4.1	4.5	4.9	5.2	5.6	6.1	6.7	7.3	8.0	8.7	9.4
Annual flood (99% AEP)	1.8	2.2	2.6	2.9	3.3	3.8	4.4	5.0	5.7	6.4	7.1
Permanent Inundation (MHHW)	0.0	0.4	0.8	1.1	1.5	2.0	2.6	3.2	3.9	4.6	5.3

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[i] Values provided by Rutgers Team