Estimated Costs of Inaction

Financial District and Seaport Climate Resilience Master Plan

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1. Overview & Objectives

This appendix supplements the Financial District and Seaport Climate Resilience Master Plan – Chapter 4: The Impact of Climate Change, specifically pages 60 to 62.

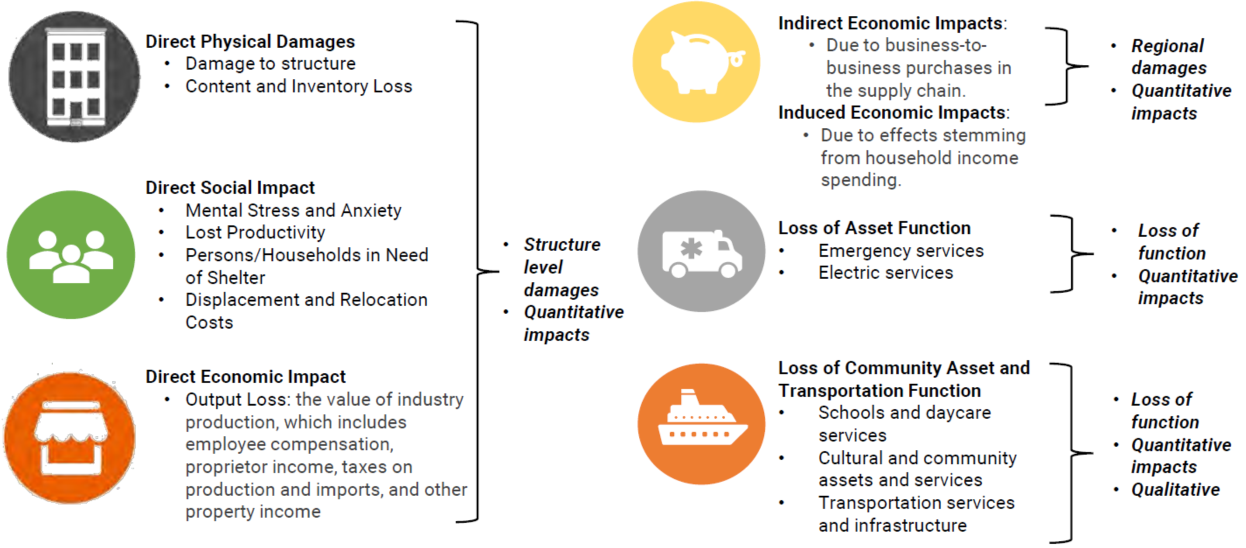
Failure to address the potential impacts of climate change in Lower Manhattan bears a steep cost and impacts all of New York City. Inaction is not an option. The Financial District and Seaport waterfront is critical to the economic development and identity of Lower Manhattan and damage to the area would have negative ripple effects throughout the city, the metropolitan region, and the nation. From now through 2100, flooding is projected to cause up to $20.3 billion in estimated cumulative total losses to area and region, if no action is taken. In addition to these tremendous economic impacts, flooding would create costs that are challenging to quantify, such as losses to citywide services like transit.

To assess the potential impacts of no action and the benefits of coastal protection, the project team conducted a losses avoided analysis using both quantitative and qualitative methods. The overarching goals of the losses avoided analysis were to:

1. Make the case for the need for the project by assessing the impact of flood damage if no flood protection infrastructure was built,
2. Understand the geographic distribution of flood losses to inform development of phasing and implementation plans,
3. Inform the funding and financing analysis by refining the scale of project benefits and identifying the share of benefits to specific stakeholders, including the City of New York (the City),
4. Develop an understanding of the impacts related to community assets and service losses, and
5. Incorporate implementation timelines to understand the implications of phasing decisions.

The losses avoided analysis was used to evaluate and communicate the potential benefits in terms of avoided potential costs related to direct physical damage to buildings and contents, economic impacts, social impacts, and loss of community, transportation, and asset function. Benefits were allocated based on impacts to residents, and economic losses to workers, businesses, and the City. The analysis also examined the distribution of losses by geography and stakeholders.

Figure 1: Overview of Analyzed Damages



This appendix first covers the sources, methodology, and results for the quantitative analysis of cumulative losses from now through 2100. Quantitative cumulative analyses include direct economic impact, indirect/induced economic impact, building damage, relocation, contents damage, and social disruption. The appendix then covers the same topics for supplemental qualitative and quantitative analyses of specific flood events. These analyses include roads, transit, and community services. Finally, the benefits-share allocation process and its results are discussed. A list of primary data sources, abbreviations, and additional potential losses screened is available at the end of the appendix.

2. Quantitative Summary Analysis of No Action and Losses Avoided

The project team undertook a multi-step, detailed process to estimate the quantifiable costs of inaction and the losses avoided if the proposed project is implemented. The quantifiable losses include:

- Direct economic benefits to businesses in the study area
- Indirect and induced impacts to businesses in the New York City Metropolitan Statistical Area (MSA)
- Damages to buildings and their contents
- Costs of relocation during a flood event
- Social disruption costs including health costs from injuries and mental stress and lost income due to health issues
- Loss of emergency response services

3. Overview of Approach

The project team used best available data in its analysis to establish existing conditions including land use, structure types, and population, and to model the probability and severity of flooding over time. The no action scenario, or what the flood losses would be if no flood risk reduction project was implemented, was analyzed separately from the benefits of the proposed project.

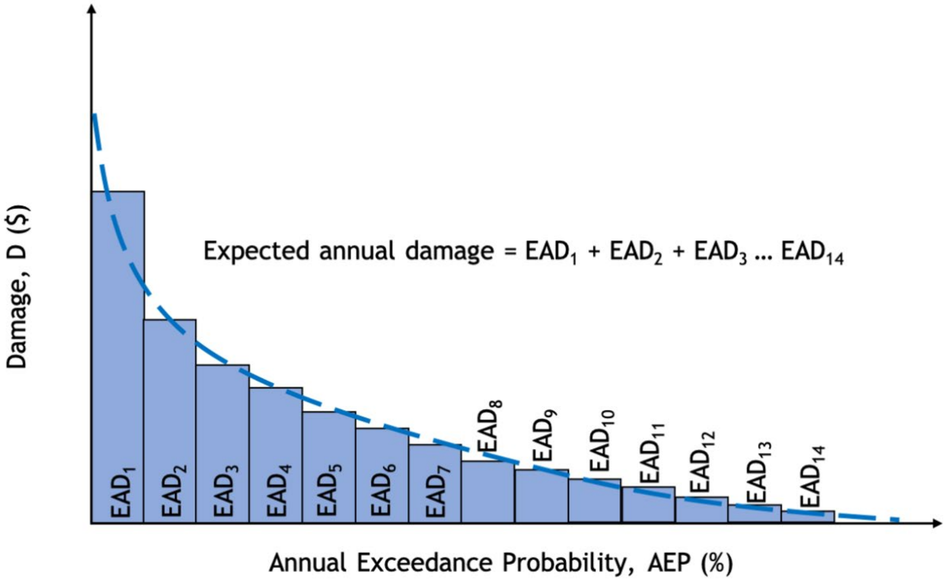
Avoided losses and the cost of inaction are analyzed in a variety of ways, including:

- **Annualized Losses** are the aggregate of high-impact, low-frequency events with low-impact, high-frequency events to present risk. It is the probable loss that may occur within any given year.
- **Present Value Losses** represent cumulative future loss projected over a specified period, discounted back to values in the starting year.
- **Event-Based Losses** are the losses that occur during one event only, such as during the 1% annual exceedance probability event in the 2050s.

The avoided losses analysis started by examining the impacts on the area under a range of flood events. The modeling considered six flood events in four different time periods, for a total of 24 flood events. The assessment is based on the best available flood hazard data available for the area, which includes the 1-year, 2-year, 10-year, 50-year, 100-year and 500-year flood events for the 2020s, 2050s, 2080s, and 2100; additional detail is included in **Section 3.1 Collect Flood Data**. The first step in the process was to calculate the expected damage from each of these flood events.

Then, annualized losses were calculated by using the four flood events from the same year and conducting trapezoidal integration, similar to what is shown in *Figure 2*. Once annualized losses for 2020, 2050, 2080, and 2100 were calculated, the expected annual losses between those years were estimated. For the present value losses, all annualized losses from 2020-2100 were summarized and discounted to get a representative value of expected damages due to coastal flooding in the study area.

Figure 2: Expected Annual Damage (Source: Colorado Water Conservation Board)



The following sections discuss the steps of this analysis. The methodologies reflect industry best practices and standards consistent with federal guidelines from Federal Emergency Management Agency (FEMA) and/or the Department of Housing and Urban Development (HUD) for use in benefit-cost analyses required for federal funding, with exceptions and limitations noted below. The steps include:

- 3.1. Collect Flood Data
- 3.2. Develop Building Inventory
- 3.3. Identify Buildings Impacted by Flood Scenarios
- 3.4. Identify Depth Damage Functions to be Used
- 3.5. Calculate Physical Damage to Structures and Contents
- 3.6. Calculate Relocation Costs
- 3.7. Assess Human Impacts
- 3.8. Calculate Economic Losses

3.1. Collect Flood Data

One of the primary flood data sources was the Preliminary Flood Insurance Study (PFIS) and accompanying Preliminary Flood Insurance Rate Maps (PFIRMs) for New York City which were released by FEMA in December 2013. While FEMA is currently working on an update to these maps following a successful appeal by the City in 2016, the PFIRMs are currently considered the best available current flood hazard information for the study area.

The PFIS Transects represent locations where overland wave height analysis was modeled. Transect locations are selected based on topography, land use, shoreline features and available fetch distance. They capture the dominant wave direction, which is typically perpendicular to the shoreline, and extend inland to the point where coastal flooding ceases. Spacing distance for the transects is based on development density (FEMA, 2013). Each transect contains a series of stillwater recurrence intervals, which represent the probability that the given event will be equaled or exceeded in any given year. The PFIS identifies stillwater elevations at the 10, 50, 100, and 500-year recurrence intervals (10%, 2%, 1%, and 0.2% annual chance). Stillwater elevation surface rasters were created from the transects applicable to the study area. Stillwater elevations from one of those transects can be found in *Table 1* below; all are similar and the below is representative.

Table 1. FEMA PFIS Stillwater Elevations, Transect NY-16

Flood Source	**Location**	**Starting Stillwater Elevations (-ft NAVD88)**			
		10%	2%	1%	0.2%
		10-year	50-year	100-year	500-year
East River	**NY-16**	6.8	9.8	11.2	14.7

Source: New York City Flood Insurance Study, 2013

The project team incorporated additional higher frequency recurrence intervals in order to quantify storms smaller than the 10-year that cause damages in the study area. Because the FEMA PFIS does not provide flood elevations below the 10-year recurrence interval, the team incorporated additional data from the National Oceanic and Atmospheric Administration (NOAA). *Figure 3* provides the available high and low annual exceedance probability levels relative to the tidal datums and the geodetic North American Vertical Datum (NAVD88) for the nearest tide gauge, The Battery, NY - Station ID: 8518750[1]. On the left are the exceedance probability levels for the mid-year of the tidal epoch currently in effect for the station. On the right are projected exceedance probability levels and tidal datums based on historic trends[2]. The team used the exceedance probability levels for the tidal epoch (1983-2001) as the basis for analysis because New York City Panel on Climate Change (NPCC) sea level rise projections used in this assessment are based on a 2000-2004 baseline[3]. The team incorporated the 1-year and 2-year (99% and 50% annual chance) events, which have stillwater elevations of 1.22 and 1.49 meters respectively. As identified in the graphic below, the 0.06 must be subtracted from the provided height to convert to NAVD88. Once converted into feet to be in the same units as the FEMA PFIS values, the values are 3.8 feet and 4.7 feet respectively. Sea level rise is added to these values to get the values in the 99% and 50% AEP rows of Table 2.

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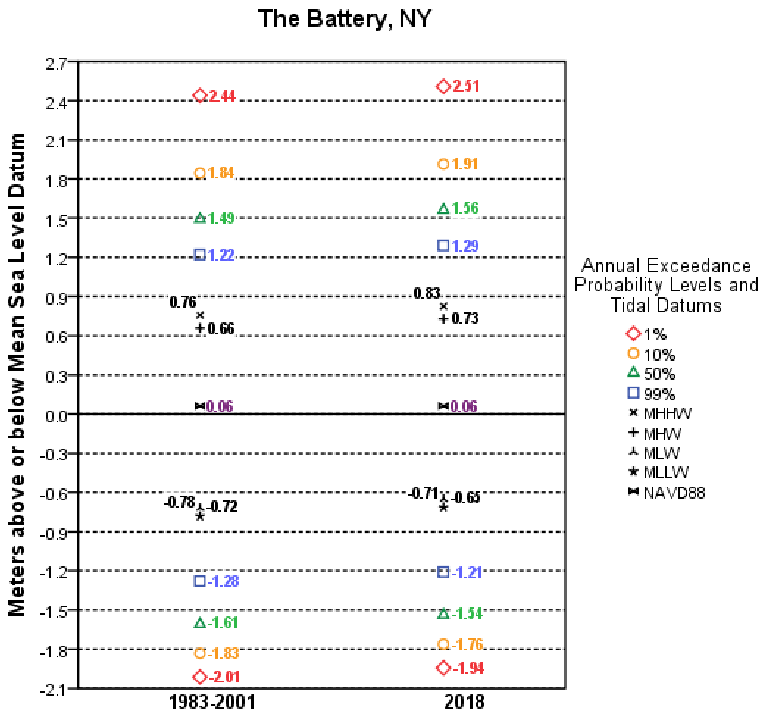
[1] The levels are in meters relative to the National Tidal Datum Epoch (1983-2001) Mean Sea Level datum.

[2] The values from 2018 are not used in this analysis; the graph is simply explained for completeness.

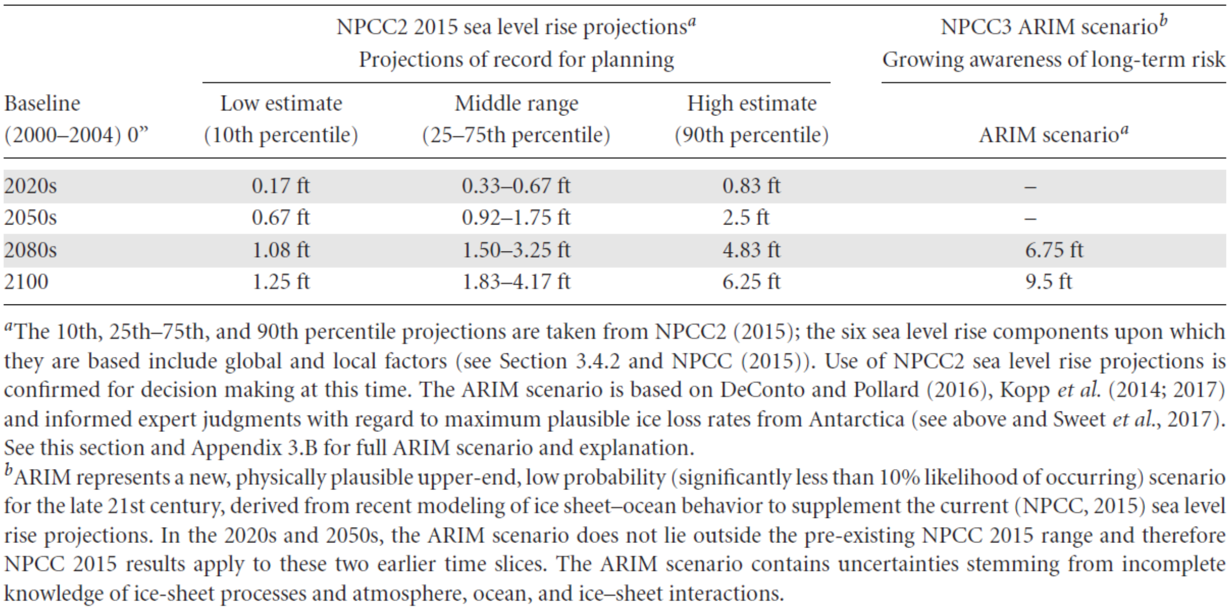
[3] The mid-year data from the current tidal epoch is the best available data for the 1 year and 2 year events.

Figure 3: Exceedance Probability Levels and Tidal Datums (8518750 The Battery, NY)



After establishing the current elevations for the recurrence intervals used in the analysis, the next step is to add a factor for sea level rise (SLR) to assess flood impacts from now through 2100. The team used SLR projections from the 2019 report developed by the NPCC. According to the high (90th percentile) estimates, sea levels are expected to rise by approximately 10 inches by the 2020s, 30 inches by the 2050s, 58 inches by the 2080s, and 75 inches by 2100. The team added each increment of sea level rise to the stillwater elevations to model the storms appropriately over time.

Figure 4: New York City SLR Projections, NPCC 2019



	NPCC2 2015 sea level rise projections[a] Projections of record for planning			NPCC3 ARIM scenario[b] Growing awareness of long-term risk
Baseline (2000–2004) 0”	Low estimate (10th percentile)	Middle range (25–75th percentile)	High estimate (90th percentile)	ARIM scenario[a]
2020s	0.17 ft	0.33–0.67 ft	0.83 ft	–
2050s	0.67 ft	0.92–1.75 ft	2.5 ft	–
2080s	1.08 ft	1.50–3.25 ft	4.83 ft	6.75 ft
2100	1.25 ft	1.83–4.17 ft	6.25 ft	9.5 ft

[a] The 10th, 25th–75th, and 90th percentile projections are taken from NPCC2 (2015); the six sea level rise components upon which they are based include global and local factors (see Section 3.4.2 and NPCC (2015)). Use of NPCC2 sea level rise projections is confirmed for decision making at this time. The ARIM scenario is based on DeConto and Pollard (2016), Kopp *et al.* (2014; 2017) and informed expert judgments with regard to maximum plausible ice loss rates from Antarctica (see above and Sweet *et al.*, 2017). See this section and Appendix 3.B for full ARIM scenario and explanation.

[b] ARIM represents a new, physically plausible upper-end, low probability (significantly less than 10% likelihood of occurring) scenario for the late 21st century, derived from recent modeling of ice sheet–ocean behavior to supplement the current (NPCC, 2015) sea level rise projections. In the 2020s and 2050s, the ARIM scenario does not lie outside the pre-existing NPCC 2015 range and therefore NPCC 2015 results apply to these two earlier time slices. The ARIM scenario contains uncertainties stemming from incomplete knowledge of ice-sheet processes and atmosphere, ocean, and ice–sheet interactions.

All six return periods examined across all four time periods (24 flood events total) were used to extrapolate future annual exceedance probabilities for a range of flood events. For instance, today's 10% annual chance flood may happen several times a year in the future. Properties that are flooded so frequently that they may be unusable if mitigations are not taken were also identified, and the impact of the loss of those properties was incorporated into the analysis, as described in more detail below. The 24 events that served as the basis of the analysis are noted in *Table 2*.

Table 2: Approximate Stillwater Elevations Used as the Basis of Analysis

Approximate Stillwater Elevations (feet NAVD88)		**Sea Level Rise Time Period**			
		2020s (10 inches SLR)	2050s (30 inches SLR)	2080s (58 inches SLR)	2100 (75 inches SLR)
Annual Exceedance Probability	99%	4.6	6.3	8.6	10.1
	50%	5.5	7.2	9.5	10.9
	10%	7.7	9.4	11.7	13.1
	2%	10.6	12.3	14.6	16.0
	1%	11.9	13.6	15.9	17.3
	0.1%	15.6	17.3	19.6	21.0

3.2. Develop Building Inventory

The project team developed a building inventory for the study area, incorporating data from the following sources:

- **City of New York Primary Land Use Tax Lot Output (PLUTO) Data (2020):** PLUTO data are developed by the New York City Department of City Planning. Attributes from this dataset used in the direct physical damage analysis include gross building square footage, number of stories, basement type, and land use.
- **Department of Information Technology and Telecommunications (DoITT) Building Footprints (2019):** Building footprints represent the perimeter extent of buildings and provide the building height above grade and the number of stories.
- **NYC Topo bathymetric 2017 Digital Elevation Model (DEM):** This DEM provides data on ground elevation as collected by LiDAR.
- **RS Means Building Construction Cost Data (2020):** This publication provides location-specific building replacement square foot costs for a wide range of building occupancy types. The team determined building and contents replacement costs for residential buildings and garages using the 2020 RS Means standard replacement cost values, adjusted using RS Means location factors.
- **USACE NAACS Depth Damage Functions:** US Army Corps of Engineers (USACE) Generic Depth Damage Functions (DDFs) for residential and non-residential buildings were used to determine the amount of damage to buildings and contents for each flood scenario. The DDFs were chosen based on the hazard and structure type of each building.
- **FEMA Contents-to-Structure Ratio Values (CSRVs):** The 2009 FEMA BCA Reference Guide provides CSRVs based on building type, in the form of a percentage of building replacement value (BRV). This guidance states that when generic DDFs from USACE are used, 100% of the BRV can be used for residential buildings.
- **HAZUS Occupancy Classes:** FEMA's HAZUS program is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes and is used for structure occupancy classes for applying appropriate DDFs and replacement values.

In order to identify which buildings within the study area would flood in the future, and benefit from the flood protection project, the team incorporated relevant building attributes to building footprints data. Attributes included number of stories, total area (gross building square footage), first floor footprint, basement type, and structure use, which were from the City of New York's PLUTO data. As PLUTO data is provided at the lot-level, the data for each lot was allocated to individual building footprints proportionally based on the estimated volume of each building using DOITT data on height and footprint of each building on the lot.[4]

Table 3 below summarizes the primary data source for each of the structure information inputs necessary for the analysis.

Table 3. Building Inventory Data Sources

Structure Attribute	Source
Structure Use	The primary source of the structure use description was the City of New York PLUTO Data. This data was updated to be as accurate as possible by identifying buildings under construction, pending construction, or pending demolition through reviewing the latest Google Streetview. New building characteristics from building permits were identified using NYC Department of Buildings Building Information Search as needed. Buildings with scheduled demolishment were removed from the analysis.
Building Type	Building Type was used to assign depth damage functions to structures. The building type classification follows the HAZUS Occupancy model, which distinguishes between residential, commercial, industrial, government, and education uses, and was assigned based on the structure use. Upper and lower floors of buildings were considered separately to account for mixed-use buildings.
First Floor Area	Building floor area data was drawn from City of New York PLUTO Data. The values were compared to the shape area in the DOITT Building Footprint shapefile to ensure that it was reasonable. If it was not reasonable, the value from the DOITT shapefile replaced the value from the database.
Number of Stories	Number of stories was drawn from PLUTO. If unavailable, the roof height of the buildings was available in the DOITT Building Footprint data. This height was divided by 10 feet (approximate floor height) to get the number of floors.
First Floor Elevation (FFE)	The first floor elevation (FFE) in North American Vertical Datum of 1988 (NAVD88) of each building was estimated using a variety of sources and methods: • Initially, the first-floor elevation for all buildings was based on the ground elevation for the study area, which was taken from the NYC Topo Bathymetric 2017 Digital Elevation Model. • For buildings built after 1983, elevations were verified against building code standards applicable at the time of the building's construction and its location in the floodplain. Data was updated as needed. • Interviews conducted by the City as part of the Lower Manhattan Coastal Resiliency Property Owners Assessment Tool on the heights of flood protection measures implemented at the time of the analysis were incorporated into the analysis. • Google Streetview was used to ground truth first floor elevations as necessary.
Building Replacement Value	The team identified per square-foot replacement value estimates using RSMeans Square Foot Costs for New York, New York (in 2021 dollars) based on structure use and size. To ensure these costs were properly valued, all RSMeans costs were adjusted for inflation using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator.[5] Due to the number of buildings analyzed, the project team determined the average gross square footage for each structure type and applied the cost per square foot closest to this determined square footage area. Additionally, to ensure a conservative approach in analysis, the project team applied the lowest cost materials option.

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[4] One limitation of this approach is that when there are multiple buildings on one lot, the dominant structure use of the whole lot is applied to each building.

[5] CPI Inflation Calculator. Located at: http://www.bls.gov/data/inflation_calculator.htm

Structure Attribute	Source
Contents Replacement Value	Contents replacement value was estimated as a percent of the entire building replacement value using Contents-to-Structure Ratio Values. The contents values for benefitting structures were identified using the applicable USACE Depth Damage Functions. Content values were assigned based on the identified Building Type and Contents Value based on Percentage of Structure Value provided by HAZUS.

3.3. Identify Buildings Impacted by Flood Scenarios

For each flood scenario—the 99%, 50%, 10%, 2%, 1%, and 0.2% annual chance storm in each timeframe—the project team used the mapped extent of the floodplain to identify buildings that would be flooded. Flooded buildings are identified as those footprints that are within or intersect the floodplain extent. Flood elevations and corresponding flood depths, from the events outlined in **Section 3.1 Collect Flood Data**, are calculated for each building flooded.

3.4. Identify Depth Damage Functions to be Used

There are depth damage functions (DDFs) for direct physical damage (structure and contents damage) and displacement time. Data on land use, building classification, housing units, basements, and number of floors was used to classify all the buildings in the inventory as specific typologies. The typologies used for direct physical damage are from the U.S. Army Corps of Engineers North Atlantic Coast Comprehensive Study (USACE NACCS), and include "urban high rise" and "commercial, engineered" among others. Each DDF determines what percent of a building will be damaged based on the projected flood depth and type of building it represents. Multiplying the percent damage by damageable building and content replacement values results in the total building damage and contents damage in dollar values.

The percent damage identified through a DDF must be applied to the *damageable value* of the building, which is not always the total building replacement cost. Damageable value is based on the DDF, which provides a maximum number of stories considered "damageable" for the corresponding building type; NACCS explicitly says "the damage to high rise buildings should be calculated as a percent of the first 10 stories". The number of stories analyzed by the function is related to the structure type and the expected location of mechanical, electrical, and plumbing (MEP) assets in buildings. For example, urban high-rise depth-damage functions from the NACCS report recommend that only the first 10 floors are considered the damageable value of the building, assuming that mechanical and electrical assets are located within the basement or first floor of the building.

Furthermore, the HAZUS Flood Technical Manual provides expected restoration time curves by the 33 standard HAZUS occupancy classes, in addition to national one-time relocation costs per square foot.[6] Restoration time is the time needed for physical restoration of building damage, including time for cleanup, inspections, permits, and delays due to contractor availability. Restoration times are estimated based on structure use and flood depth. The team uses data inputs from PLUTO to map each building to its best fit according to HAZUS occupancy class and NACCS typologies.

Throughout the process, the lower and upper floors of impacted buildings are examined separately, as it is quite possible that the lower floors of the building serve a different purpose than the upper floors. In high rise buildings, lower floors are the first two floors; in all other buildings, the first floor alone is taken as the lower floor. For

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[6] Values provided by HAZUS have been adjusted by an inflation factor. The inflation factor comes from the U.S. Bureau of Labor Statistics Consumer Price Index.

example, take a building that is eight floors tall with a bodega on the first floor and apartments above. The single lower floor with the bodega would be assigned one depth damage function while the seven upper floors with apartments would be assigned another depth damage function. Results are calculated for lower and upper floors based on their respective depth damage functions and then combined to produce a value for the whole building.

3.5. Calculate Physical Damage to Structures and Contents

For each typology, USACE provides DDFs, which identify the percent of damage to structures and contents expected for intervals of flood heights. There are additional depth damage functions for the same typologies to assess damage to building contents. For this analysis, the building replacement values were taken from RS Means for New York City in 2020.

3.6. Calculate Relocation Costs

The HAZUS Flood Technical Manual provides guidance to calculate relocation costs based on occupancy type. Relocation costs consist of one-time relocation costs, lost income experienced by property owners who lease their buildings, and rental costs for tenants in their buildings. These costs are a function of monthly rent and building restoration time. All square footage areas are based off gross square footage values from PLUTO.

1. **Identify impacted buildings.** Relocation costs are estimated under the assumption that a building is damaged and unusable, not just exposed to flood hazards. For this reason, displacement costs are only applied to buildings that experience at least 1 foot of flooding. It is assumed that damage incurred by flood depths below 1 foot can be repaired while the building is still in use.
2. **Identify impacted square footage.** For many buildings, the analysis assumes that displacement is applicable only on damaged floors. However, some of the area consists of urban high-rise buildings, where structure type and height may be a greater contributing factor to restoration time than occupancy. The structure damage methodology assumes that buildings with more than three stories likely have complex mechanical, electrical, and plumbing equipment located in basements or lower floors (that is, elevators, and heating, ventilation, and air conditioning [HVAC]) that would prohibit access to higher floors regardless of flood depth. Therefore, for high-rise buildings, relocation costs are calculated for the whole building for time it takes to restore the first floor. All other buildings assume that restoration only impacts the first floor.
3. **Estimate displacement time.** The displacement time for each flood event is correlated to estimated flood depth within each building. Displacement time estimates are specific to different structure occupancies and flood depth intervals.
4. **Identify and apply percent owner-occupancy rate:** The owner-occupancy rate is used to distinguish between lost income experienced by property owners and rental costs for displaced tenants. Owner occupancy rates are provided by HAZUS for each occupancy class.
5. **Calculate one-time disruption costs.** FEMA HAZUS methodology assumes that every building with flood depths of 1 foot incurs one-time disruption costs for accommodating the interruption and potentially moving to a new location when the building is damaged. Estimated disruption costs are calculated based on a cost per square foot and the square footage of disrupted space.
6. **Identify rental costs.** Expected daily rental costs were calculated per building, regardless of owner occupancy. Daily rental costs were used to represent both the rental income a property owner can lose if

a tenant is displaced, and the amount a tenant would spend to rent comparable space while repairing their building. Sources included the Elliman rent report and LoopNet, which include cost per square foot estimates that were modified to a daily value.

7. **Process relocation costs.** The HAZUS Flood Technical Manual provides guidance to calculate relocation costs to building occupants based on occupancy type (FEMA, 2015). If buildings experienced physical damage and had over 1 foot of flood depth, relocation costs are the sum of one-time damage loss, rental income loss for property owners, and temporary rental costs for tenants.

3.7. Assess Human Impacts

FEMA provides guidance and standard methodologies to quantify human impacts of flooding, including injuries, mental stress, and lost productivity. Standard values were updated and scaled to reflect New York City costs and conditions where applicable. Data on the number of residents and workers from the U.S Census American Community Survey were used to derive these results. The assessed human impact was performed pursuant to established methodologies for the purposes of the avoided losses analysis. There are additional meaningful and diverse impacts that are expected from flooding that are not able to be accounted for in these methodologies.

3.7.1. Injuries

The economic value of injuries is calculated based on research from federal agencies on expected injuries from a flood event and their economic valuation. The Center for Disease Control and Prevention (CDC) estimated that 10.4 percent of residents in the Hurricane Sandy inundation zone were injured within the first week of the storm.[7] This percentage is applied to the number of residents in impacted buildings for each flood scenario. The economic value of injuries is calculated based on Willingness to Pay (WTP) values from the Federal Aviation Administration (FAA), which are based on the severity of injuries.

3.7.2. Mental Stress

Natural disasters threaten or cause loss of health, social, and economic resources, which leads to psychological distress. Mental stress and anxiety impacts are evaluated as the cost of treatment for expected psychological distress that would occur because of property damage or displacement. Impacts are estimated based on cost, prevalence, and course. Cost is the cost of treatment for those who seek it. Prevalence is the percentage of people who struggle with their mental health after a disaster event. Course is the rate at which mental health symptoms reduce or increase over time.

FEMA uses cost and prevalence to establish a standard per capita value for mental stress and anxiety costs. The standard per capita value assumes mild to moderate impacts will reduce over time as treatment is provided while severe mental health problems persist. According to the FEMA Benefit-Cost Analysis Toolkit, Version 6.0, $2,443 is the standard per capita cost of mental stress treatment after a disaster; this value is modified to $2,891 to account for appropriate inflation from the original value. This value assumes that only forty-one percent of the impacted population seeks mental health support. The value does not capture the social impact that results from people who do not seek mental health support. The quantification of this distress is based on the cost of treatment for post-disaster mental health impacts. The final mental stress cost of a flood event is the product of the number of affected residents and the standard cost of treatment for thirty months.

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[7] Center for Disease Control, "Nonfatal Injuries 1 Week After Hurricane Sandy — New York City Metropolitan Area, October 2012" Available at https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6342a4.htm

3.7.3. Lost Productivity

Work productivity can be lost due to mental illness, as described in research on the impact of psychiatric disorders on work loss days. The historical impacts indicate that mental health issues will increase after a disaster, and this, paired with research related to lost productivity due to mental illness, indicates that economic productivity can be impacted by an increase in mental health issues post-disaster.[8] The impact of mental health on work productivity is calculated based on research into the impact of mental health on earnings. Research from the World Health Organization found that individuals in the United States with mental health illnesses experience as much as a 25.5 percent reduction in earnings. [9] The lost productivity value provided by the FEMA BCA Toolkit Version 6.0 is $8,736 per worker per household; this value is modified to $10,887 to account for appropriate inflation from the original value. The lost productivity value is multiplied by the number of wage earners in the household. Census inputs identify the number of workers per tract; this value is distributed to structures through the same process as population distribution.

3.8. Calculate Economic Losses

This portion of the methodology models existing economic relationships within New York City and expected impacts to those relationships in a post-disaster situation. Damage to buildings can have direct impacts on the economy, including loss of sales and revenues due to business closure. In the context of this analysis, direct economic losses refer to economic activity that is lost because of functional disruption of a building's use. The analysis measures lost economic activity as lost output, in accordance with FEMA HAZUS methodologies. This approach operates on the assumption that extensive flood damage to buildings affects the ability of businesses to operate because of unsafe working environments or the inability to provide goods and services. While this category of losses and approach have been accepted by HUD, they have not been commonly used in FEMA benefit cost analyses for funding applications. Therefore, the use of this analysis in future funding applications should be evaluated with guidance from FEMA, New York State Department of Homeland Security, and New York City Emergency Management.

Analysis steps used to estimate output losses are as follows:

1. **Identify impacted buildings**

Output losses are estimated only where a building is damaged and unusable, not just exposed to flood hazards. For this reason, output losses are only applied to buildings that experience at least 1 foot of flooding. It is assumed that damage incurred by flood depths below 1 foot can be repaired while the building is still in use.

2. **Identify impacted square footage**

For many buildings, the analysis assumes that restoration and subsequent disruption of building use is applicable only to damaged floors, which does not reach higher than the first floor. However, access to upper levels may be compromised in urban high-rise buildings when only the first floor is flooded. In this study, any building with more than six stories is classified as urban high-rise, and output loss is assessed for the whole building. For buildings six or fewer stories, output loss is only calculated for the first floor. The values are modified by service interruption multipliers, as described below.

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[8] Insel, Thomas. Assessing the Economic Costs of Serious Mental Illness. American Journal of Psychiatry. 165:6 June 2008. / Kessler et al. Individual and Societal Effects of Mental Disorders on Earnings on the United States: Results from the National Comorbidity Survey Replication. American Journal of Psychiatry. 165:6. June 2008.

[9] 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

3. Estimate restoration time

As outlined in **3.4. Identify Depth Damage Functions to be Used**, depth damage functions are used to identify the estimated restoration times for the impacted structures.

4. Apply Service Interruption Multipliers to Restoration Time

Restoration time is adjusted for businesses that can rent alternative space or use spare industrial/commercial capacity elsewhere using service interruption multipliers. For example, churches and membership organizations are typically able to quickly find alternative space, and government functions also resume operating almost right away. Service interruption multipliers, which come from the HAZUS technical manual, convert restoration time to economic functional downtime for the business interruption calculation and are assigned to a specific building based on its assigned HAZUS occupancy class and damage state. For buildings, where the revenue or continued service depends on the existence and continued operation of the facility, the duration of business or service interruption more closely relates to the repair time; these buildings include residential areas and entertainment venues.[10]

According to FEMA (HAZUS Earthquake Technical Manual), the time modifiers represent median values for the probability of business interruption across occupancy classes and for various states of structure damage. These median values consider that a portion of the businesses impacted will suffer longer outages and even fail completely under extensive and complete damage states. A few of the service interruption modifiers have trends that indicate a reduction of economic functional downtime with higher damage states, meaning occupants may decide to relocate while the space is restored.

5. Identify output per building.

Output data from IMPLAN zip code-level data was used in the assessment. IMPLAN is an economic impact assessment modeling software that brings in economic data from many sources, including the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, and the U.S. Census Bureau. IMPLAN has over 500 individual economic industries and logs industry production value (output), regional gross domestic product (value added), labor income (employee and proprietor compensation), and employment data (jobs).

IMPLAN data at the zip code level was used to extract output specific to the study area, which is then further distributed to buildings. This was done using an aggregation and grouping method that links structure use with an economic industry. Structure uses and IMPLAN industries were aggregated into “sectors” that represent related building uses and economic activity. Total building areas within the study area were then summed by sector and used to identify average output per square foot. These average values were then applied to the disrupted area of flood-damaged buildings to identify the amount of economic activity (in output) in each building.

6. Calculate output loss.

Output loss is equal to the impacted square footage *multiplied by* the restoration time in days *multiplied by* the service interruption multiplier *multiplied by* the average output loss per day per square foot.

I. Identify Repetitively Flooded Buildings and Related Losses

Over time with sea level rise, some buildings in the study area are flooded so repetitively that they are considered fully lost and removed from the analysis to avoid overestimating the physical damage losses. This avoids the assumption that buildings that are repetitively damaged are repetitively rebuilt and reinhabited without flood risk

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[10] The research and development of service interruption multipliers pre-dates current COVID-19 related practices of work-from-home.

mitigation and therefore continue to have their unmitigated losses accounted for. The criterion that triggers the effective full loss of a building is when the expected annual damage is more than 50% of the building replacement value. This threshold is derived from the FEMA requirement to bring structures up to existing floodplain management standards when more than 50% damaged.

Buildings meeting this criterion are removed from the analysis of losses from the point they meet the criteria onward; for example, if the period of analysis is 2020-2100 and a criteria is met in 2070, the structure's losses accrue until 2070, when full loss is incurred and the structure is subsequently removed from consideration. To quantify the loss of the building the team assesses the annual economic value of the building in terms of output and jobs (based on analysis above), the value of the first-floor contents (assuming they would be damaged by flooding)[11], and the replacement value of the total building's structure.

II. Assess Regional Indirect and Induced Losses

Results from the direct business interruption calculations were used in conjunction with IMPLAN input-output program, which measures economic change within a given study area, to generate regional indirect and induced losses. Input-output modeling is based on interdependencies between economic sectors and analyzes the ripple effect of direct changes in an economy. IMPLAN estimates these interdependencies using IMPLAN Group, LLC's proprietary social accounting matrices (SAMs) and multipliers integrated with publicly available economic data from the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, and the U.S. Census Bureau.

Inputs to the IMPLAN model represent the direct business interruption losses outlined in *3.8 Calculate Economic Losses*. The direct effect inputs are the initial change in the economy for which regional losses are modeled. IMPLAN considers the effects of these direct impacts and measures the cascading economic impacts.

Indirect losses represent impacts on business-to-business purchases in the supply chain, while induced losses stem from changes in household income spending. Economic disruption caused by coastal flood hazards in the study area can have cascading impacts through the supply chain and how people choose to spend money. Estimating indirect and induced losses seeks to capture the reverberating impacts of loss that may occur throughout the New York-Newark-Jersey City, NY-NJ-PA Metropolitan Statistical Area.

Of note, the indirect and induced IMPLAN model outputs are reported as impacts to specific economic sectors and industries, thereby losing their building-specific identity and spatial orientation.

III. Tax Revenue

Tax revenue is included in the direct, indirect, and induced economic impacts outlined above, but it is important to consider separately as taxes can represent a large share of operating budgets. Tax losses may be felt at the federal, state, and local levels. If residents or businesses relocate from the study area due to coastal flood impacts, personal and income tax revenues collected at the state and local level may decline. Tax losses to the government may mean less money spent on roads, schools, and other key community interests. IMPLAN does not separate out tax impacts from direct, indirect, and induced losses, but instead represents total tax impacts.

Indirect and induced economic losses and tax losses estimated through this approach have been accepted by HUD. However, they have not been commonly used in FEMA benefit cost analysis for funding applications. Therefore, future funding applications should evaluate the use of analysis in future funding applications with guidance from FEMA, New York State Department of Homeland Security, and New York City Emergency Management.

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[11] Repetitive loss will likely occur due to a low depth of flooding at a high frequency, so it is assumed that only the contents of the first floor are lost, while the contents on other floors can be removed from the structure.

4. Assumptions

As a modeling exercise, many uncertainties are inherently part of the losses avoided analysis. These uncertainties largely come from assumptions that are made during the analytic process. The assumptions are in line with best practices for methodologies throughout the industry and the results presented herein reflect those best practices. However, results presented herein should be taken as estimates of the cause of no action and the value of losses avoided. Assumptions include:

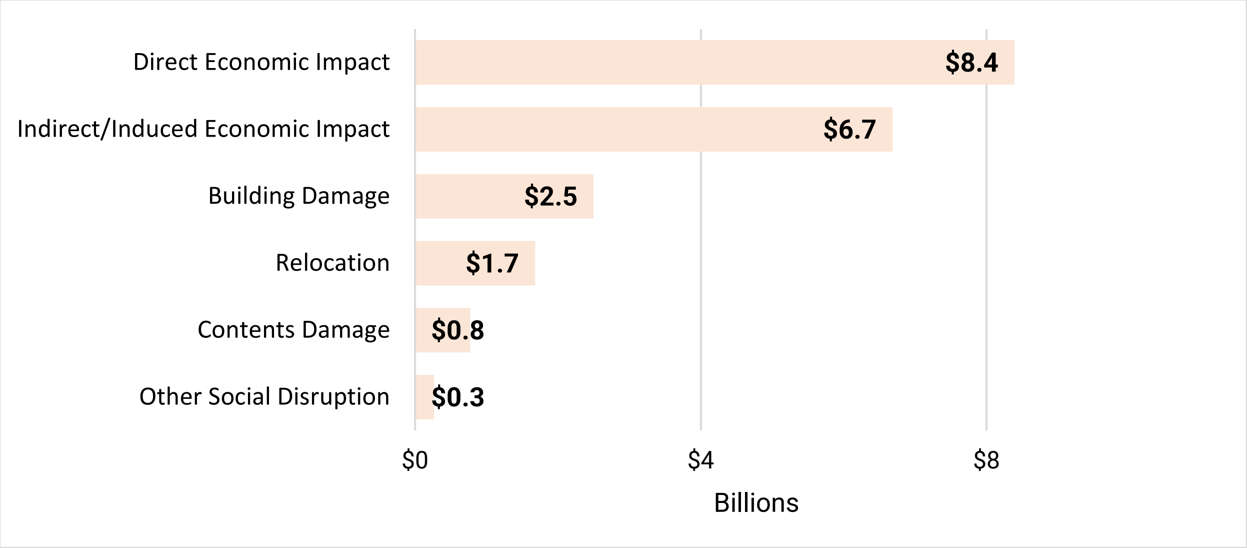
1. No losses are avoided until an entire section of flood protection with tie backs is in place.
2. Escalation is not considered; losses are discounted if they are in the future, but they are not escalated to reflect the potential impacts of inflation. The impact of the discount rate on future losses is significant; making numbers that are growing over time seem much smaller.
3. Changes to present-day demographics are not considered; future demographics are taken as reflective of current demographics.
4. The phasing and implementation timeline of the flood protection measures impacts on the losses avoided. The later the protection is in place, the longer losses incurred remain unmitigated.
5. First floor elevations are taken as the ground elevation except where other information, such as building codes and known mitigation projects, allowed for more specific values. First floor elevations are the basis for flood exposure and flood depth.
6. Building replacement values are derived from HAZUS, a FEMA tool, and RS Means, a construction cost-estimating resource published yearly, and are scaled to New York City values, as appropriate. These tools represent the industry standard for replacement value estimation but do correlate precisely to the costs of repairs for any specific building in the study area.
7. The NACCS depth-damage functions used to link damage percentages to flood depths represent the best available data for the project area, but do not correlate precisely to the damage percentages experienced by any specific buildings in the study area.
8. Economic data for many sectors are aggregated and then distributed to buildings based on size and structure use type of the building. Because the building use types are not perfectly matched to economic sector, there is inherent error associated with this methodology. Results for any specific building may over- or under-represent the actual economic activity impacted but are more accurate when aggregated at the scale of the study area. Additionally, this method captures average annual estimates of economic impacts for sectors present in the study area but does not capture the seasonal variation in sales and activity that may occur. Direct economic losses are assumed to be a loss to the region and are assumed not to be recaptured elsewhere. This methodology represents an industry standard and best practice for economic impact estimation.

5. Summary of Results

5.1. Costs of Inaction

From now through 2100, if no action is taken, flooding is projected to cause up to $20.3 billion in estimated cumulative total losses to the study area and region. A break-down of these losses is summarized in *Figure 5*.

Figure 5: Present Value Cost of Inaction, 2020-2100, 6.25% Discount Rate



Included within the economic impacts outlined above are **$2.2B**[12] in local, state, and federal **tax impacts**[13]. While the other costs noted are costs that would accrue to private businesses and individuals, the tax impacts are costs for the City and state and federal governments.

5.1.1. Repetitively Flooded Buildings

For this analysis, a building is deemed repetitively lost when it's expected annual damage is greater than 50% of the building replacement value. When this threshold is reached, it is assumed that the building is taken out of commission. Therefore, risk stops being accrued on these buildings once the threshold is reached. The analysis accounts for the value of this loss through a one-time loss of one year of economic output loss and the value of the total building replacement.

125 buildings in the study area are vulnerable to repetitive losses while some of these buildings are large waterfront assets, many are smaller buildings with smaller building replacement values, and reaching the threshold sooner.

The figure below shows the number of buildings that meet the repetitive loss threshold during a specified time period. These properties are all also within the area that will be flooded by Mean Monthly High Water (MMHW) by 2100.

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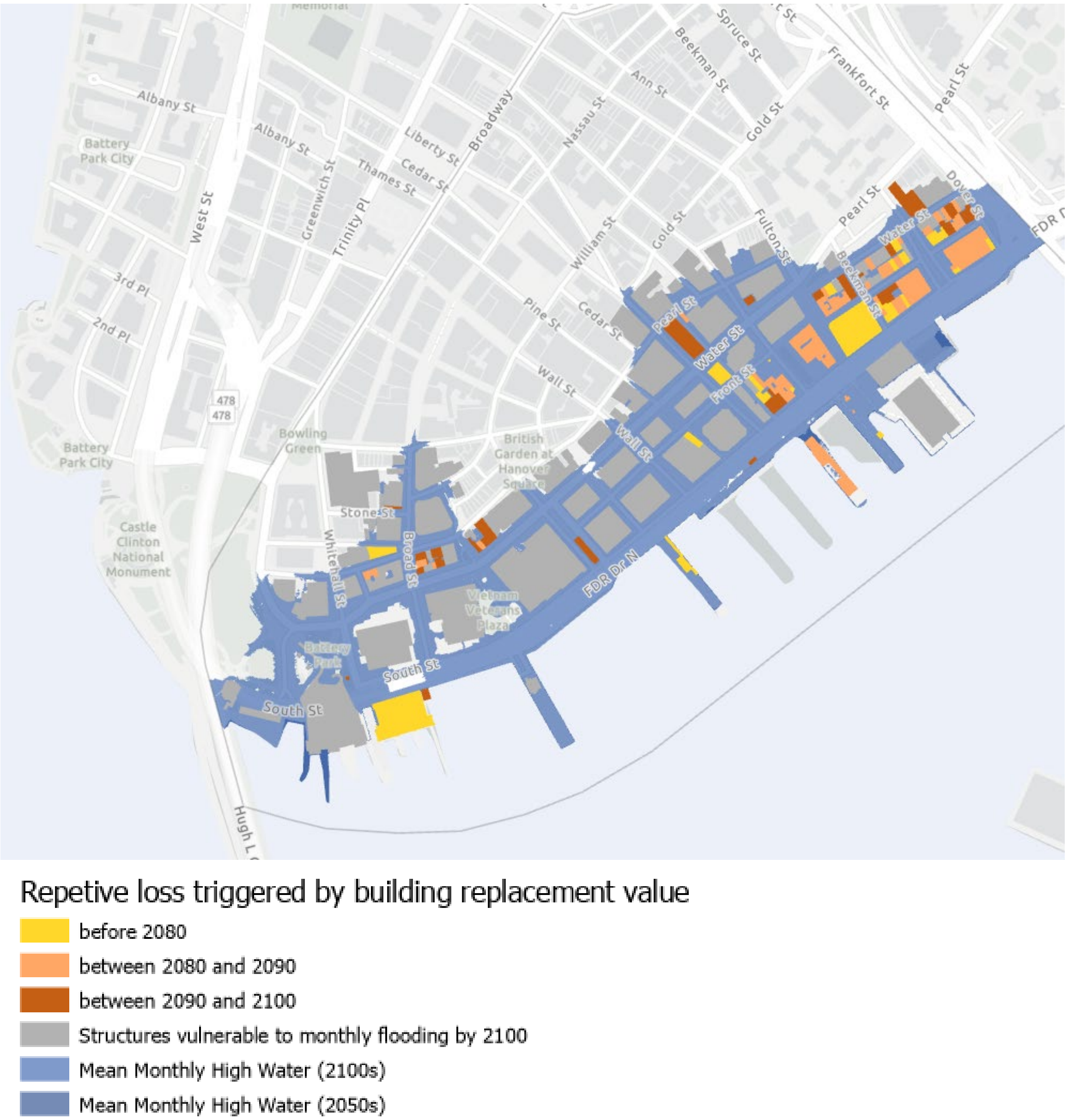
[12] Taxes are spread across direct losses avoided and indirect/induced losses avoided. Tax results cannot be added to any summary or detailed results as they are already included as a portion of the reported economic impacts.

[13] Due to methodology limitations, tax impacts cannot be separated from economic impacts.

Figure 6: Repetitively Flooded Buildings



5.2. Avoided Losses

If implemented, this project would avoid about **$11.1 billion** in losses from now through 2100.[14] A breakdown is included in Figure 7.

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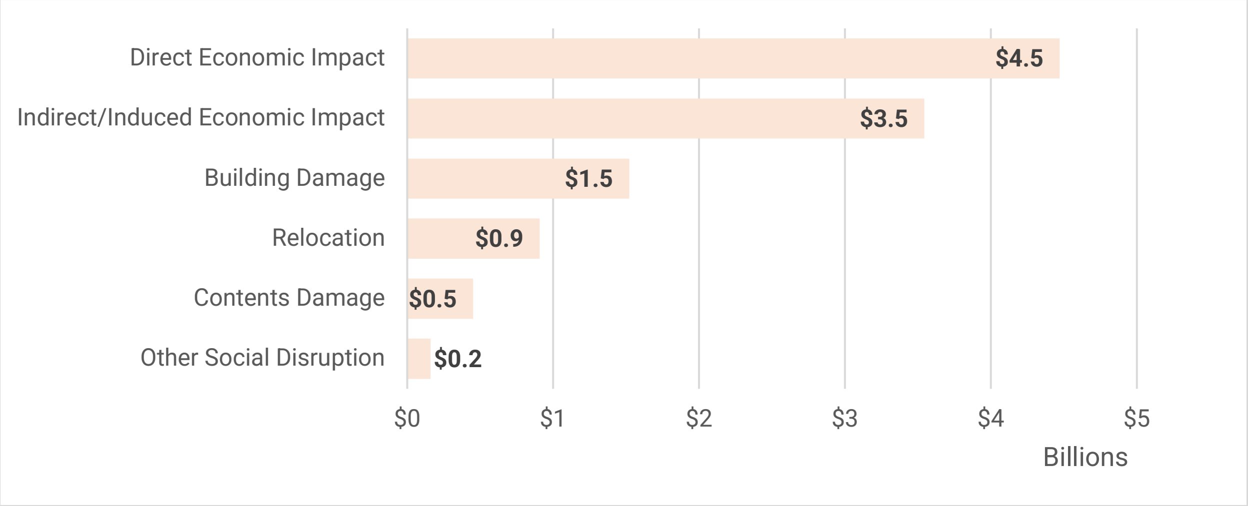
[14] Represents present value of direct, indirect, and induced losses with 6.25% discount rate.

Figure 7: Present Value Losses Avoided, 2020-2100, 6.25% Discount Rate



Included within the economic impacts above are **$1.15B** in federal, state, and local **tax losses avoided.**[15]

The following industries are likely the primary contributors to the direct, indirect, and induced economic impacts:[16]

- Banking
- Securities and commodity contracts brokerage
- Insurance agencies
- Legal services
- Financial investment activities
- Internet publishing and broadcasting
- Real estate
- Management consulting services
- Data processing & hosting
- Architectural and engineering services

5.2.1. Loss of Tax Revenue

Present value avoided tax losses in New York-Newark-Jersey City MSA and across all tax levels are expected to be approximately $1.15B. Local taxes account for approximately 19% of these expected tax losses avoided, or $220M, while state taxes account for approximately 18% of expected tax losses avoided. The remaining 63% of tax losses avoided are expected to be suffered by the federal government. [17]

Flooding over time could result in a reduction in property values and therefore additional tax losses. However, there is very little research applicable to the study area on this subject, so it would be difficult to currently support any quantification of this phenomenon. As such, this analysis does not reflect the impact of potential reductions in property values on taxes.

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[15] Taxes are spread across direct losses avoided and indirect/induced losses avoided. Tax results cannot be added to any summary or detailed results as they are already included as a portion of the reported economic impacts.

[16] Due to aggregation methods in the methodology, there is inherent uncertainty at this level of detail; these industries are examples of the contributors to the impact.

[17] Percentages calculated based on numbers using a 6.25% discount rate and assume that tax rates and the relative split between federal, state and local taxes remains constant over time.

Of note: the information in this section simply provides more detail to the economic impact estimates. Tax results cannot be added to any summary or detailed results as they are already included as a portion of the reported economic impacts.

Table 4: Loss of Tax Revenue

	Type of Tax			
	Local ($ millions)	State ($ millions)	Federal ($ millions)	Total ($ millions)
Corporate Tax	25	24	65	113
Personal Tax	23	99	304	426
Social Insurance Tax	-	8	340	348
Tax on Production and Imports	175	70	16	261
TOTAL	**223**	**202**	**724**	**1,150**

5.3. Benefit Cost Ratio

To assess the cost-effectiveness of the master plan, the project team compared expected losses avoided to estimated costs and calculated an estimated Benefit Cost Ratio (BCR). A BCR in excess of 1 means the project benefits exceed the project costs. As shown below the BCR for the master plan is 3.12 when using a 6.25% discount rate. This is based on the un-escalated project costs, since the losses avoided do not include cost escalation.

BCRs are used by federal agencies when evaluating projects for federal funding opportunities. For future funding applications, project costs and project benefits will need to be refined as more detail is known about specific project elements and to ensure that benefits are calculated using methodologies accepted by the funding agency, such as FEMA. As described in more detail in the Project Costs appendix, the project costs estimates available at this time are high level and are intended to present an understanding of the cost implications of different project features to inform further refinement in future phases of the project.

Table 5: Benefit Cost Ratio

Discount Rate	Total Direct Losses Avoided ($ billions)	Indirect Economic Losses Avoided ($ billions)	Total Losses Avoided ($ billions)	Estimated Project Cost ($ billions)	Benefit Cost Ratio
6.25%	7.51	3.54	11.05	3.54	**3.12**

6. Discount Rate Sensitivity Analysis

The choice of discount rate used for the losses avoided analysis greatly impacts the value of potential losses avoided of the project. Since yearly expected losses increase over time due to the impact of sea level rise, the choice of discount rate has a very strong impact on direct losses avoided. A sensitivity test was conducted across four discount rates.

Discount rates were chosen for the following reasons:

- **0%:** As a baseline comparison for the sensitivity analysis
- **2.75%:** Discount rate from USACE Civil Works Direct Program Development Policy Guidance
- **6.25%**: Discount rate used by NYC Office of Management and Budget (OMB)
- **7%:** U.S. OMB discount rate used by FEMA for funding applications

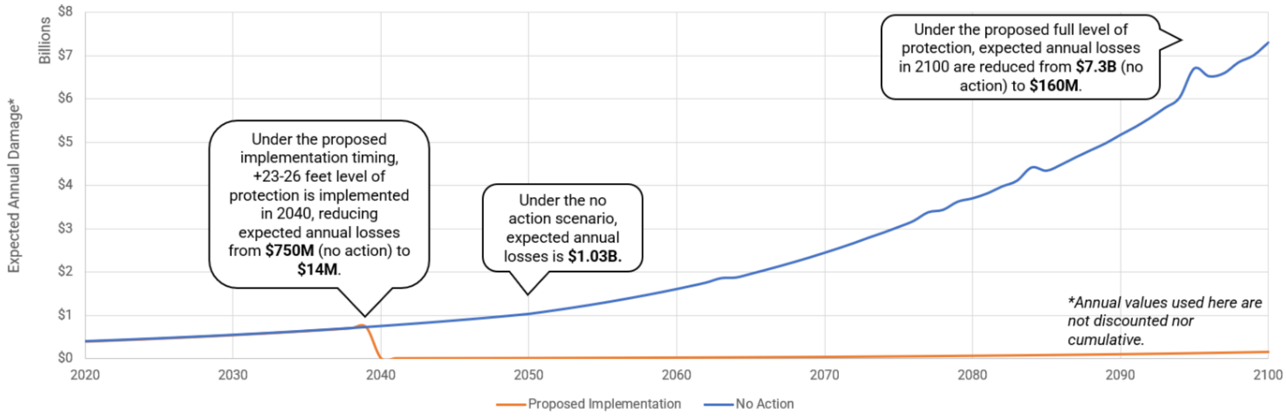
Table 6: Discount Rate Sensitivity Analysis

Discount Rate	Total Direct Losses Avoided ($ billions)	Estimated Indirect Economic Losses Avoided ($ billions)	Estimated Total Losses Avoided ($ billions)
0%	178	84	261
2.75%	38	11	55
6.25%	7.5	3.5	11.1
7%	5.6	2.7	8.3

6.1. Avoided Losses Over Time

Losses from flooding for the no action scenario increase over time as sea levels rise. However, avoided losses only begin to accrue once the project is implemented. *Figure 8* below shows how losses accrue over time, reaching approximately $1 billion annually by 2050, and how implementation of the project reduces potential losses.

Figure 8: Avoided Losses over Time (2021 dollars)



Under the proposed implementation timing, +23-26 feet level of protection is implemented in 2040, reducing expected annual losses from **$750M** (no action) to **$14M**.

Under the no action scenario, expected annual losses is **$1.03B.**

Under the proposed full level of protection, expected annual losses in 2100 are reduced from **$7.3B** (no action) to **$160M**.

**Annual values used here are not discounted nor cumulative.*

7. Supplemental Quantitative and Qualitative and Event-Based Analyses

In addition to the losses described above, the team conducted a qualitative assessment of the impacts of flooding and sea level rise over time in the study area, and how the proposed project would avoid those impacts. This analysis also includes additional losses that were quantified for specific flood events and are not able to be incorporated into the annualized or cumulative losses described above.

7.1. Roads, Highways, and Ferries

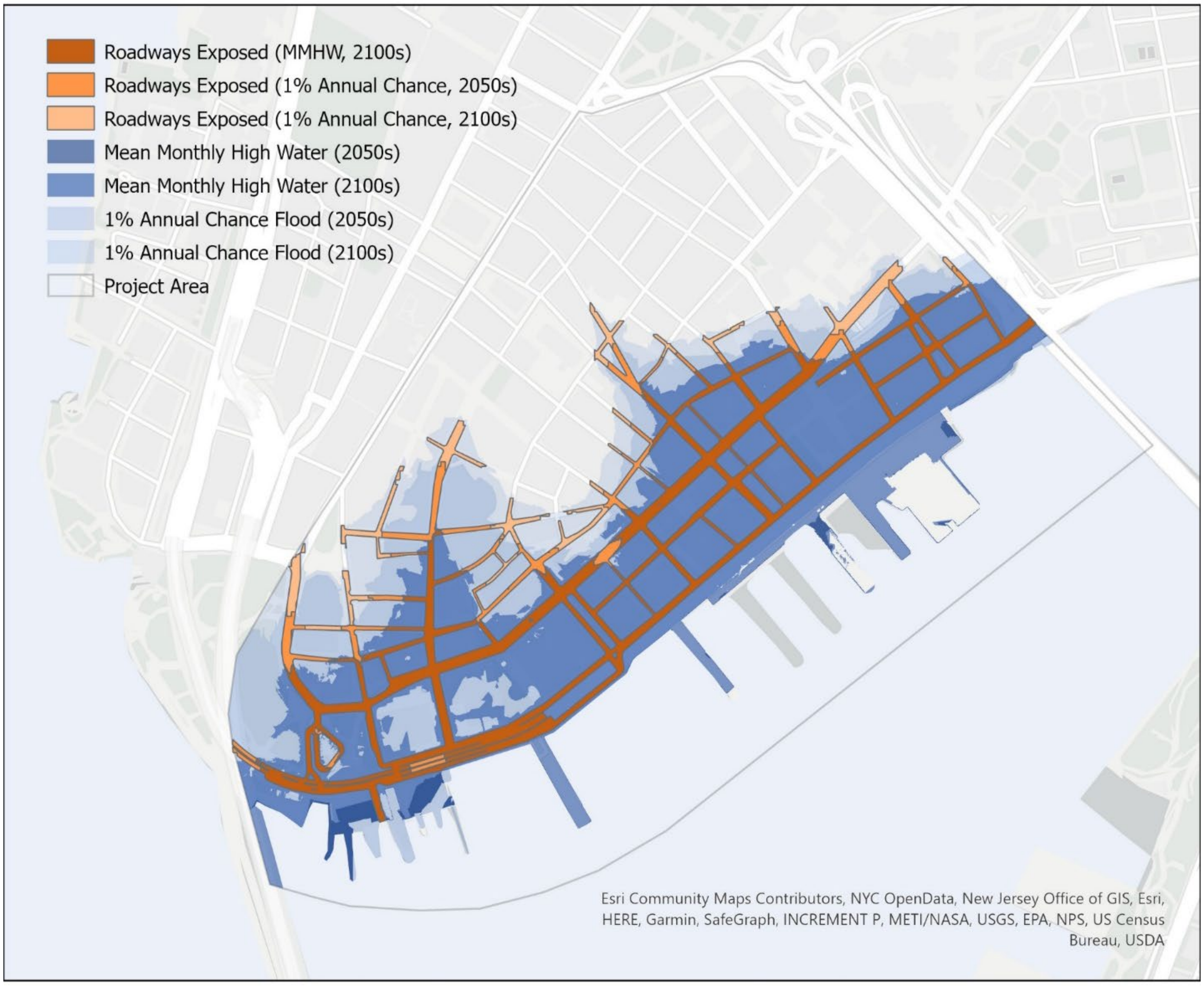
7.1.1. Roads

The team mapped roads in the study area that will be flooded by either MMHW or the 1% annual chance storm, in 2050 and 2100. Roadways are considered exposed to inundation at a flood depth of 6 inches or higher; this is the depth of water which reaches the undercarriage of cars and poses safety concerns. Impacts from flooding include disruption of traffic, damage to electrical devices (e.g., used in streetlights, traffic signals, MuniMeters, SBS ticketing machines, and bus shelters), disruption to parking and damage to parked vehicles, damage to some trees and plantings due to saltwater inundation, and potential scour and erosion, leading to increased maintenance costs and reduced lifespans for the roads.

Key findings include:

- Approximately **24 acres** of surface roads will be exposed to a 1% annual chance flood by the 2050s
- The area of exposed surface roads will increase to approximately **29 acres** by the 2100s for a 1% annual chance flood
- Additionally, **1.4 acres** of the **Battery Park Underpass** in the study area will be exposed by the 2050s 1% annual chance flood scenario and will serve as a flood pathway to the rest of the Underpass
- Approximately **21 acres** of roadways are expected to be exposed to MMHW in the 2100s. The impact of the 2050s is expected to be minimal.

Figure 9: Impacted Roadways



Esri Community Maps Contributors, NYC OpenData, New Jersey Office of GIS, Esri, HERE, Garmin, SafeGraph, INCREMENT P, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA

7.1.2. Bus Service

Lost transportation service can be estimated as a function of the lost time to travelers due to disrupted transportation networks. The basic economic concept is that personal time has value, regardless of formal employment compensation. To estimate the value of time lost due to loss of transportation service, the project team used the methodology detailed in the federal Department of Transportation's (DOT) 2016 Guidance on the Value of Time as a basis on which to derive a value of travel time savings (VTTS) for all-purpose local (as opposed to intercity) travel and apply values (e.g., median hourly wages) localized to the New York-Newark, NY-NJ-CT-PA combined statistical area (CSA). This regionalized VTTS value of $0.35/minute was used to assign a dollar value for each increased minute of expected travel time. The MMHW and the 1% annual chance storms in the 2050s and 2100 scenarios were assessed.

The project team calculated the expected cost of affected bus service to bus passengers in terms of increased travel time due to increased traffic congestion as a function of lost time in dollar value. The project team first identified any bus routes in the study area expected to be inundated to any depth during each flood event. The project team assumed the entire daily ridership of each bus route affected would be impacted in the event of flooding to any depth and subject to increased travel time due to congestion for 2 days (based on documented experiences during Hurricane Sandy), in order to capture the full impact to riders of increased congestion along the entirety of the bus route in question.

To estimate the additional travel time expected due to increased flood-induced congestion on bus routes, the team drew on existing studies to identify an average normal commute time on public transit in NYC—specifically, 53 minutes.[18] This is considered best-available data and served as a proxy baseline bus travel time per rider under normal conditions, as similar data on all-purpose travel using bus transit specifically is not publicly available. The team used this baseline to calculate a congestion factor based on a post-Sandy survey performed by the NYU Wagner School of Public Policy, which found that Manhattan residents' commute time increased by approximately 56% in the days following the storm.[19] Therefore, if one rider rides on the bus for an average of 53 minutes in a single day, the project team assumed the same rider spends an additional 29.7 minutes riding when the bus route is inundated due to flooding–a 56% increase. Using this congestion factor, the team used the average daily ridership[20] for each bus route as well as the regionalized value of travel time saving (VTTS) per minute, described above, to calculate the total rider time lost for all affected bus riders as a dollar value, per day. The team assumed these effects would last 2 days immediately following a flooding event, based on the number of days of "emergency-level gridlock" that followed Hurricane Sandy.

Additionally, analysts projected lost farebox revenue for MTA due to free fares on buses, as transit fares were suspended for five days following Hurricane Sandy, although buses continued to provide service to the public. The team used 2019 final estimates of farebox revenue for NY City Transit and the MTA Bus Company,[21] assuming pre-COVID-19 levels of bus ridership. The team estimated lost farebox revenue by proportionally dividing 2019 farebox revenue estimates from fare collection on buses by route according to share of overall ridership.

The project team found that the following bus lines[22] will all inundated be in the MMHW 2100 and 1% annual chance flood scenarios (2050s and 2100s). No bus lines are expected to be impacted in the MMHW 2050s scenario:

- New York City Transit (NYCT) bus lines: M15, M20, M55
- MTA Bus Company (express) bus lines: BM1, BM2, BM3, BM4, QM7, QM8, QM11, QM25

A MMHW (2100) or 1% annual chance (2050s or later) flood event is therefore expected to disrupt travel for up to 59,000 daily passengers for approximately two days, resulting in a cumulative $1.15M in lost value of travel time per flooding event. Impacts on these bus lines are also expected to result in $393K in lost farebox revenue to the MTA per event. These results are summarized in *Table 7*.

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[18] Time to Commute. 2021. Retrieved 15 September 2021, from https://www.geotab.com/time-to-commute/

[19] Kaufman, S., C. Qing, N. Levenson, and M. Hanson. 2012. *Transportation During and After Hurricane Sandy*. Rudin Center of Transportation, NYU Wagner Graduate School of Public Service. Available online at: https://wagner.nyu.edu/files/faculty/publications/sandytransportation.pdf.

[20] Weighted average of weekday and weekend daily ridership (2019), assuming pre-COVID-19 levels of bus ridership. Obtained from Metropolitan Transportation Authority. 2020. Subway and bus ridership for 2019. Available online at: https://new.mta.info/agency/new-york-city-transit/subway-bus-ridership-2019.

[21] Metropolitan Transportation Authority. 2020. MTA 2020 Adopted Budget. Available online at: https://new.mta.info/document/15221.

[22] Bus lines occasionally overlap

Table 7. Event-Based Losses Avoided for Loss of Bus Service

Losses Avoided	NYCT Bus Lines	MTA Bus Company (Express) Bus Lines	Total
	Impacted Average Daily Ridership:[23] 55,790	Impacted Average Daily Ridership: 3,550	Impacted Average Daily Ridership: 59,340
Lost Value of Travel Time ($)	1,080,000	73,700	1,150,000
Lost Farebox Revenue ($)	361,500	31,200	392,700
Total ($)	**1,440,000**	**104,900**	**1,540,000**

7.1.3. Bike Ridership

Bike ridership in the study area is split between commuters and tourists. The Greenway following the waterfront is predominantly used by visitors to the city, as commuters coming over the Brooklyn Bridge or from uptown would most likely cut into Lower Manhattan, which provides a more direct route, rather than follow the greenway.

If the Greenway or other nearby streets are flooded tourists would not bike in the area, which could bring concern of economic loss to local buildings. However, in this scenario, nearby buildings would be flooded as well, so lack of access to them via biking should not increase the economic losses already being experienced. Commuters may choose an alternate route or an alternate mode of transportation to arrive at their destination. However, if their destination is also flooded, commuters may not complete their trip at all.

The team mapped bike lanes flooded by at least 6 inches under Mean Monthly High Water (MMHW) or the 1% annual chance storm, in 2050 and 2100. In addition to disruption of movement through the area and potential increased maintenance costs for the bike lanes, inundated bike lanes pose a major life safety issue for cyclists through the area. Key findings include:

- Approximately **2.3 miles** of bicycle lanes will be exposed to a 1% annual chance flood by the 2050s.
- The length of exposed bicycle lanes will increase to approximately **2.6 miles** by the 2100s for a 1% annual chance flood.
- Approximately **1.6 miles** of bicycle lanes are expected to be exposed to MMHW in the 2100s. The impact in the 2050s is expected to be minimal.
- This would significantly affect the approximately **1,340 daily weekday cyclists** and **1,880 daily weekend cyclists** using the East River Greenway, in addition to any other cyclists commuting or passing through the study area.

7.1.4. Ferry Service

The project team looked at avoided losses for the Whitehall Ferry Terminal, which provides Staten Island Ferry service to approximately 70,000 daily passengers. Assuming operations of the Whitehall Ferry Terminal would be interrupted if water reaches a depth higher than the first-floor elevation (7' NAVD), the following events will impact services to the Staten Island Ferry with no intervention:

- 2020s: 10% annual exceedance probability storm and more severe events
- 2050s: MMHW[24] and more severe events
- 2080s: MHHW[25] and more severe events
- 2100s: MHW[26] and more severe events

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[23] Weighted average of weekday and weekend daily ridership (2019)

[24] Mean Monthly High Water, expected to be exceeded 20-30 times per year

[25] Mean Higher High Water, expected to be exceeded each day

[26] Mean High Water, expected to be exceeded twice a day

To estimate losses to be expected from any one of these events, the project team used a similar methodology to that used for loss of bus service, detailed in **Section 7.1.2**. Losses avoided can be estimated as a function of the avoided lost time to passengers due to disrupted ferry service.

The project team determined that, if service to the Staten Island Ferry were to be interrupted, the alternate public transit route from the St. George Ferry Terminal to Whitehall Ferry Terminal would likely be via express bus. Although an alternate route also exists via the NYC Ferry route, it is likely that if the Staten Island Ferry service is down due to the storm event, so is the NYC Ferry. Therefore, the alternate route analyzed here is via land, in the form of bus transit. Express buses from the stop nearest the Verrazzano Bridge take about 46 minutes to get to Water Street in Lower Manhattan during rush hour; an additional 13 minutes would be needed to get from St. George Ferry Terminal down to the Verrazzano Bridge. In all, about 33 minutes of extra time are needed to connect the two locations, were ferry service at Whitehall Ferry Terminal to be compromised.

Using a value of $0.35/minute derived from a regionalized application of DOT's VTTS methodology (as detailed in **Section 7.1.2**), the cost of lost time is $11.55 per rider per trip. With an average of 70,000 passengers serviced on a weekday, the total value of lost time is estimated to be approximately $810K per day. Assuming three days of ferry service interruption based on service disruption following Hurricane Sandy, the project team estimated a value of lost time due to loss of ferry service of about $2.43M per event.

7.2. Critical Community Services and Assets

7.2.1. Loss of Fire Station and Emergency Medical Services

Loss of function for the following assets in the study area and within the floodplain were analyzed with methodology adapted from the Benefit-Cost Analysis Sustainment and Enhancements Standard Economic Value Methodology Report (FEMA 2020).

FDNY Engine 4, located at 42 South St., provides the study area with fire-fighting services and emergency medical services (EMS). The team calculated how the potential temporary loss of function of FDNY Engine 4 due to flooding could lead to slower response times in the event of a fire or other emergency, and subsequent increased property loss, mortality, and injuries. This analysis assumes that if FDNY Engine 4 is out of service, the next closest station will serve the area with fire and EMS services. In this case, the next closest station is FDNY Engine 6 located at 49 Beekman Street. Because this station is about one mile away, the increased response time is very short and the resulting value of the loss of service is quite small, only $19,450.

7.2.2. Loss of School and Daycare Services

The team assessed lost school and daycare services using both quantitative and qualitative methods. The team quantified lost wages as well as the cost of social reproductive labor due to caretaking of children and school-aged students. These costs can be estimated by primarily using American Community Survey (ACS) data to identify families likely to miss work or undertake additional social reproductive labor to provide childcare due to school and/or daycare closures. The team used relocation times associated with each specific building combined with existing post-Hurricane Sandy studies to generate assumptions about the expected period and extent of school closures due to flood events.

The team first estimated the number of families expected to be impacted by loss of school and daycare services by dividing the estimated number of enrolled students and children by the average number of children per family in the study area, the latter value derived from ACS estimates for the five census tracts in the study area. For loss of school services, the team estimated student enrollment on a building-specific basis, using publicly available data on enrollment for each of the impacted schools. Owing to data limitations on daycare enrollment, the team relied on national childcare arrangement statistics from the 2011 Survey of Income and Program Participation (SIPP) in conjunction with selected economic characteristics of mothers in the study area to determine an area-based estimate of children in various childcare arrangements.

To account for gender disparities in caretaking, the team also used employment characteristics to generate assumptions based on desktop research about the gender most likely to be impacted in various family scenarios. Impacts to wages were based on median earnings by gender. Drawing from a wealth of existing literature, the team also calculated the cost to caretakers not in the labor force as a social reproductive cost equal to median earning in the study area. The team did not adjust the final cost to account for potentially telecommuting-capable workers given existing data limitations and assumptions that telecommuting will not be feasible, on average, in a flood scenario. Further adjustments were based on national SIPP statistics of the percentage of families that use informal childcare through grandparents, other relatives, or friends, in which case cost was estimated as a function of additional reproductive labor as opposed to lost wages.

This analysis was conducted for the following schools and daycare centers that will incur direct flood impacts:

- Blue School
- Léman Manhattan Preparatory School
- Lower Manhattan Community Middle School
- Millennium High School
- New York City Charter School of the Arts
- The Peck Slip School
- The Quad Preparatory School (Upper School Campus)
- Richard R. Green High School of Teaching
- Urban Assembly School of Business for Young Women

Loss of school services due to flooding is expected to impact the families of up to approximately 3,660 enrolled students,[27] or an estimated **2,390 families** in the study area today.[28]

The team evaluated impacts as either **value of work missed** or **value of additional caretaking burden** (or social reproductive labor) for parents due to caretaking of school-aged children, based on ACS employment characteristics of families in the study area, assuming 5 days of school closure based on Hurricane Sandy.

The team accounted for well-known **gender disparities** in caretaking[29] by sub-allocating impacts to women for families in which a male partner is employed, neither partner is employed, or no male householder is present.[30] The following schools are subject to loss of service.[31]

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[27] Search for Public Schools. 2021. National Center for Education Statistics. Available online at: https://nces.ed.gov/ccd/schoolsearch/

[28] Estimated using ACS 2019 5-year estimates, including data on relationship to householder for children in households and employment characteristics of families. Assumes the majority of students attending public schools in the area live near their schools, as NYC school zones align closely with the study area boundaries. Although there may be exceptions, the project team relied on best-available data on student enrollment and study area demographics.

[29] Sadique, M.Z., Adams, E.J. & Edmunds, W.J. 2008. Estimating the costs of school closure for mitigating an influenza pandemic. BMC Public Health 8, 135. Collins, C et al. COVID-19 and the gender gap in work hours. Gender, Work, & Organization, Supplement: Feminist Frontiers 28, 51 (2021).

[30] ACS' omission of same sex couples as well as nonbinary and gender-nonconforming categories introduces limitations

[31] Some schools are co-located in the same building

7.2.3. Value of Work Missed for Caretakers[32]

Today, there are approximately 950 employed parents who act as weekday caretakers of schoolchildren in the area that are expected to be impacted by a 1% annual chance flood event in 2050. This would result in a loss of **$1.58M** in value of work missed for this population. There are approximately 1,500 employed parents who act as weekday caretakers of schoolchildren expected to be impacted in a comparable 2100 event, corresponding to **$2.5M** in potential work missed. 92% ($1.46M and $2.31M) of these impacts are expected to be incurred by women, and approximately 8% ($120K and $190K) by men. A similar gender disparity is expected for the estimated 590 employed caretakers currently in the area that would be exposed to a MMHW event in 2100.

Table 8: Value of Missed Work for Caretakers

Losses Avoided	MMHW (2100)	1% Annual Chance (2050s)	1% Annual Chance (2100)
Value of Work Missed (Women)($)	910,000	1,500,000	2,300,000
Value of Work Missed (Men)($)	75,000	120,000	190,000
Women Affected	550	880	1,400
Men Affected	50	70	110

7.2.4. Value of Additional Burden on Caretakers[33]

Today, there are approximately 570 non-employed parents who act as weekday caretakers of schoolchildren in the area that are expected to be impacted by a 1% annual chance flood event in 2050. This would result in a loss of **$341K** in value of additional caretaking burden for this population. There are approximately 890 non-employed parents who act as weekday caretakers of schoolchildren in a comparable 2100 event, corresponding to **$535K** in additional burden. 92% ($324K and $509K) of these impacts are expected to be incurred by women, and approximately 8% ($17K and $26K) by men. A similar gender disparity is expected for the approximately 350 non-employed caretakers currently in the area that would be exposed to a MMHW event in 2100.

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[32] Value of work missed is based on the study area's weighted median hourly earnings and applies to families with employed married women with husbands who also work (thereby assuming the women will miss work to take on the role of caretaker), or families with employed single parents (men or women)

[33] Based on value of social reproductive labor which applies to families with a non-employed parent (thereby assuming they take on the role of caretaker) and is conservatively estimated based on minimum wage, with precedent from Oxfam (2020, https://www.oxfamamerica.org/explore/research-publications/time-care/)

Table 9: Value of Additional Burden on Caretakers

Losses Avoided	MMHW (2100)	1% Annual Chance (2050s)	1% Annual Chance (2100)
Value of Additional Caretaking Burden (Women) ($)	200,000	320,000	510,000
Value of Additional Caretaking Burden (Men) ($)	10,000	17,000	26,000
Women Affected	330	540	850
Men Affected	20	30	40

7.2.5. Exposed Value of Work Missed of Labor for Caretaking

The project team also evaluated loss of daycare services as value of work missed or value of social reproductive labor for parents due to caretaking of children under 5. Due to a lack of available data on children enrolled in daycare centers, the project team used ACS employment characteristics for the study area combined with 2011 national-scale data from the Survey of Income and Program Participation (SIPP) on the percentage of children in daycare centers based on the mothers' employment status as best-available data. Given these data limitations, the results of this analysis are presented as the number of families with present mothers currently residing in the study area and consequent value of work missed or labor potentially exposed across the entire study area (assuming 5 days of daycare closure, based on schools during Sandy).

Table 10: Potential Impact of Loss of Daycare Services by Flood Event

Impacts of Loss of Daycare Services to:	Potentially Exposed (Entire Study Area):
Estimated Families with Mother Present and with Children in Daycare Center	110
Value of Work Missed (Women) ($)	160,000
Value of Work Missed (Men) ($)	0
Value of Social Reproductive Labor (Women) ($)	6,600
Value of Social Reproductive Labor (Men) ($)	1,800
Total Value of Work and Social Reproductive Labor ($)	**168,400**

7.2.6. Value of Lost Free School Meals

In addition to lost wages and the cost of reproductive labor, the team calculated the cost to families of lost school meals per enrolled public-school student, as the NYC Department of Education (DOE) provides free school breakfast, lunches, and after-school snacks to all public-school students. The team used a daily value of $5.86 per student for combined breakfast and lunch meals, based on the amount distributed to families to compensate for school meals in New York State as part of the federal COVID-19 relief effort (P-EBT). This value is preferred over the federal National School Lunch Program (NSLP) and School Breakfast Program (SBP) reimbursement values, as they are reimbursed to states and school food authorities, whereas the P-EBT program distributes to households directly. However, as the P-EBT does not account for after-school snacks, which are also provided as a public-school service by NYC DOE, the team used the NSLP/SBP-assigned value of $0.96 per meal for after-school snacks on top of the value of combined breakfast and lunch meals.

Today, there are approximately **1,150 public school students**, or more than 750 families, that are expected to be affected by a 1% annual chance flooding occurring at 2050s levels or MMHW at 2100 levels, leading to a total value of **$39K** in lost free school meals. Under 2100 1% annual chance flood conditions, this increases **to approximately**

2,420 public school students, or up to 1.58K families, currently in the area who would lose a total value of **$82K** in free school meals.

Table 11: Potential Impact of Loss of School Services by Flood Event

Losses Avoided	MMHW (2100)	1% Annual Chance (2050s)	1% Annual Chance (2100)
Public School Students Affected	1,150	1,150	2,420
Value of Lost Free School Meals ($)	39,300	39,300	82,400

7.2.7. Additional Qualitative Impacts due to Loss of School Services

Further, the project team also found that the expected qualitative impacts of loss of school services could include socio-emotional and motivational development impacts to students, student learning loss, missed nutritious meals with impacts to health, as well as the disproportionate impacts to low-income and food-insecure households.[34]

7.3. Loss of Other Community Services and Cultural Assets

The team qualitatively assessed loss of other community services and cultural and recreational assets. The team developed a community and cultural asset inventory. For community services, the team focused on identifying facilities and services which are likely to provide services to socially vulnerable populations, such as human services, legal and intervention services, child nutrition services, child services and welfare, soup kitchens and food pantries, places of worship, vocational and proprietary schools, and workforce development. The team also identified cultural assets in the study area which will be impacted by flooding, such as the New York Vietnam Veterans Memorial, the National Museum of the American Indian, and others. The types of support community facilities and services may provide to their communities, and the situated meaning and significance of cultural assets, are both highly context-specific and variable. As such, it is not considered feasible to assign a dollar value to these types of losses avoided. Instead, the team developed a comprehensive and representative narrative of the qualitative impacts likely to be incurred and experienced by the communities benefitting from, drawing meaning from, and in some cases dependent on, these facilities, services, and assets in order to capture impacts as lived experience.

The project would protect the following community and cultural assets from flooding:

- **3 historic districts**: South Street Seaport Historic District, Stone Street Historic District, and Wall Street Historic District
- **6 historic maritime sites**, including the Municipal Ferry Pier/Battery Maritime Building and 5 boats/ships owned by the Seaport Museum
- **13 historic buildings**, including the Fraunces Tavern and Schermerhorn Row Blocks and others
- **5 museums**, including the South Street Seaport Museum, National Museum of the American Indian, Fraunces Tavern Museum, Alexander Hamilton U.S. Custom House, and the NYC Police Museum
- Approximately **35 community facilities and services**, including immigrant services, legal intervention services, child services and welfare, senior services, programs for people with disabilities, soup kitchens and food pantries, workforce development, and vocational and proprietary schools
- Approximately 8 places of worship
- Approximately **25 other arts & cultural organizations**, including visual and performing arts, literature, and other miscellaneous multi-disciplinary organizations

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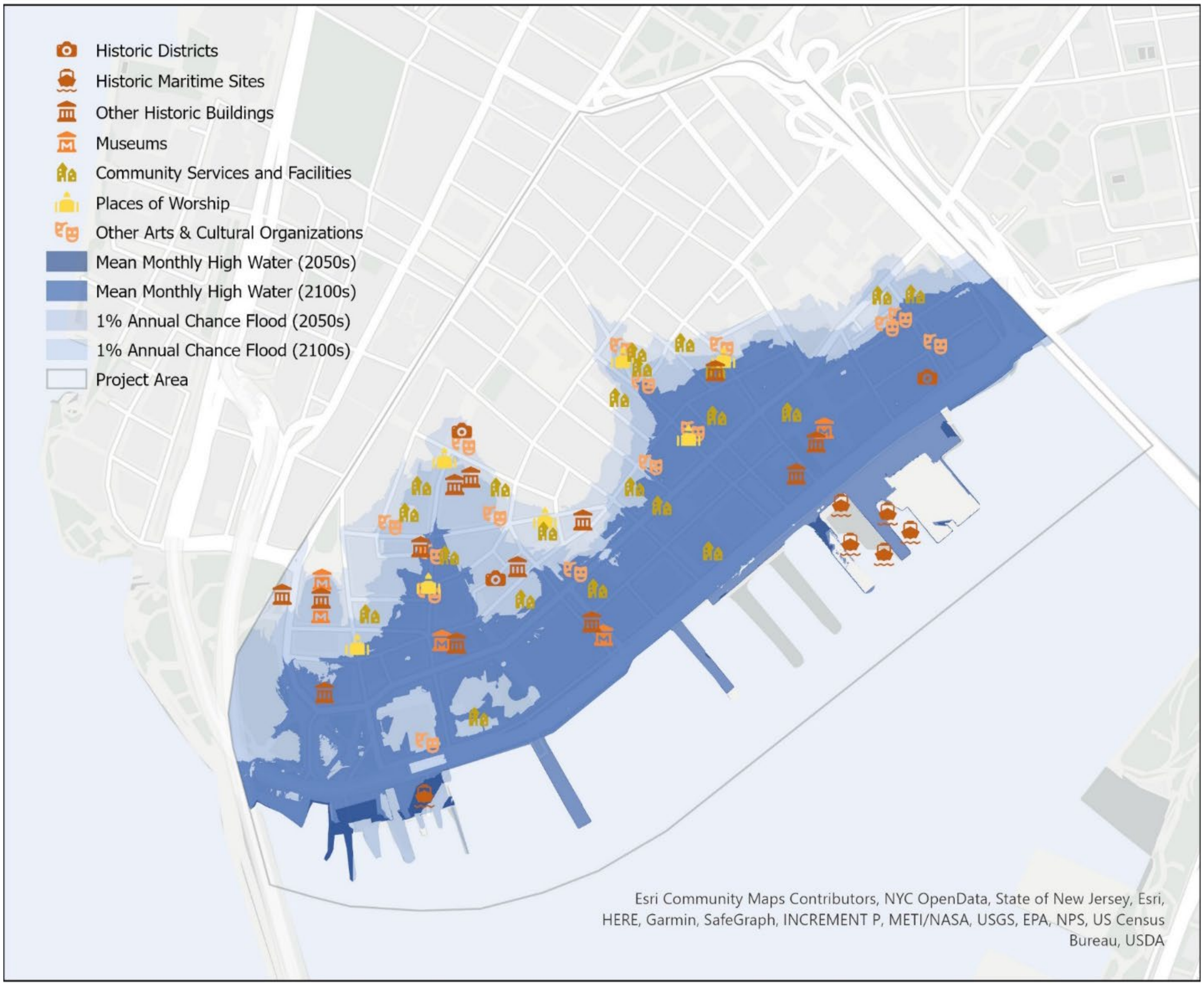
[34] Hanushek, E. A. and Woessmann, L. 2020. The Economic Impacts of Learning Losses. OECD.
Kinsey, E. W. et al. 2020. School Closures During COVID-19: Opportunities for Innovation in Meal Service. Am J Public Health. 110(11):1635-1643.

Figure 10: Community and Cultural Assets



Esri Community Maps Contributors, NYC OpenData, State of New Jersey, Esri, HERE, Garmin, SafeGraph, INCREMENT P, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA

7.4. Value of Severely At-Risk Properties

If no flood protection measures are put in place there are 219 buildings that will be flooded by Mean Monthly High Water by 2100, meaning they are projected to be flooded 25-35 times a year (more than once every two weeks). With this high flood frequency these properties would no longer be functional. Even incorporating building—scale flood mitigation measures would not address the flooded access.

These properties today account for approximately:

- 85,700 jobs
- 6,200 residents
- $116M in daily economic output
- $402M in annual property tax revenue[35]
- $38.8B in property value[36]

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[35] Tax revenue is based on NYC Department of Finance Final Tax Assessment Roll FY2022.

[36] Property value is based NYC Department of Finance Final Tax Assessment Roll FY2022.

Figure 11: Structures Vulnerable to Monthly Flooding by 2100

8. Benefits-Share Allocation

8.1. Methodology

It is important to understand the distributional effects of avoided losses in order to translate the impacts of the project to real outcomes for people, communities, and government entities. To achieve this, the project team treated avoided losses as benefits which will be variously distributed to different groups. Benefiting groups include:

- Residents
- Workers (Local and Regional)
- Business Owners (Local and Regional)
- People Who Travel through the Area
- Private Property Owners
- NYC City Government

To achieve this allocation of losses avoided to various benefitting groups, the team assigned each benefitting asset included in the avoided losses analysis to an asset category, based on the building and asset inventories. Additionally, the team specifically identified buildings or assets in the building inventory which are owned, leased by, or leased to the City to determine specific benefits to the New York City government, splitting these benefits with other benefitting groups as appropriate to the asset type in question. The team relied on two datasets to identify these City-specific buildings—City Owned and Leased Properties (COLP) and Integrated Property Information System (IPIS)—while using PLUTO data to identify other government buildings. Building categories include:

Table 12: Building Categories for Benefits-share Allocation

Building Categories	
Commercial	Privately-owned/occupied Privately-owned, City-leased City-owned, privately leased
Mixed commercial/residential	Privately-owned/occupied City-owned, privately leased
Residential	Privately-owned single family Privately-owned multifamily Privately-owned, City-leased City-owned (Department of Housing Preservation & Development)
City-owned, not leased	

Taking the losses avoided calculated as present value (6.25% discount rate), where possible, the project team allocated these avoided losses as benefits to specific groups based on the type of building benefitting and the group most likely to experience benefits due to the specific type of loss avoided for each building category. For instance, direct building damage avoided associated with privately-owned commercial buildings are allocated as benefits to private property owners. However, avoided lost wages associated with protection of the same building are allocated as benefits to workers. Similarly, for a City-owned building leased by a business, direct building damage losses avoided are allocated as benefits to the City while contents damage losses avoided are allocated as benefits to the business. Conversely, if the City leases a building from a private property owner, the City receives benefits from avoided content damage and one-time disruption cost, while the property owners receive most of the remaining benefits.

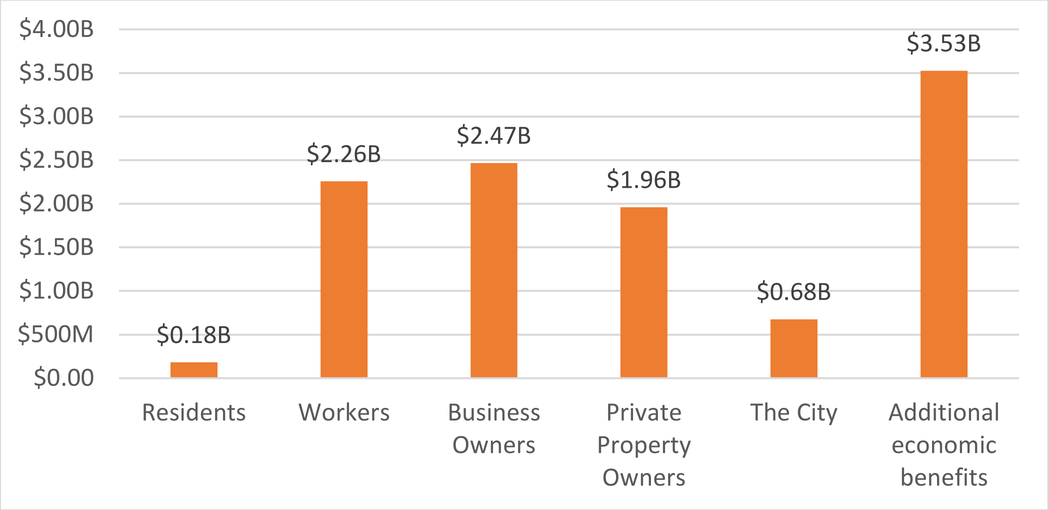
The project team also accounted for owner-occupied versus renter-occupied residential buildings to add nuance to these allocations. To achieve this, the project team estimated the percentage of owner-occupied buildings for each relevant building category based on their occupancy class, as outlined in **Section 3.2 Develop Building Inventory**. The project team then used these estimates to proportionally allocate avoided contents damage as well as disruption, injury, mental stress, and lost productivity costs as benefits to owners versus renters.

Some losses avoided, like indirect and induced economic impacts and tax revenue impacts, were not associated with any building category despite having clear benefitting groups; for example, indirect and induced avoided losses to proprietor income and other property income calculated at the regional level are allocated as benefits to regional business owners in their totality. Non-present value benefits, such as event-based estimated savings in value of lost time for avoided loss of bus service, are not included in the final benefits-share allocation but are clearly identified as benefits to specific groups, as applicable. In the case of people who travel through the area, the analysis did not support allocation of any present value benefits; however, losses avoided associated with bus services, ferry services, and roadway and bicycle lane impacts are all identified as benefits to this group.

8.2. Who Benefits?

The largest share of present value benefits due to losses avoided is to business owners and workers in the study area and region. Private property owners in the study area will also accrue substantial benefits, while the City will save approximately $676M in avoided direct impacts and lost revenue, assuming a 6.25% discount rate. While accounting for a smaller proportion of total present value benefits, the approximately $183M in benefits to residents will likely yield substantial benefits for each of the approximately 14,000 residents exposed to flooding in the area.[37] Several additional benefits due to avoided loss of emergency, community, and transportation service function will also accrue as benefits to commuters, residents, workers, and other users of the study area (however many of these benefits are not able to be calculated as present value losses).

Figure 12: Summary of Present Value Benefits, 6.25% Discount Rate



This benefit-share calculation allocates **$7.54 billion** out of the total $11.05 billion present value losses avoided as benefits to specific parties. $3.53 billion of the total present value losses avoided are not captured here due to methodology limitations in determining benefitting parties. This $3.53 billion is mostly comprised of IMPLAN (economic) intermediate inputs, direct Federal and State tax impacts, indirect/induced regional tax impacts, and

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[37] There are additional qualitative benefits that are difficult to quantify COMMENT: only include this footnote if we can elaborate on what those other qualitative benefits are

small differences in local loss of tax revenue due to limiting the region of impact for taxes to NYC for the benefits-share analysis only.

Table 13: Summary of Benefits by Group

Benefitting Group: Residents

Present Value Benefits (discount rate: 6.25%)

Approximately $183M of present value direct losses avoided will directly benefit residents in the study area,[38] including:

- Approximately $22M in avoided direct contents damage, with 61.4% of this amount benefitting renters and 38.6% benefitting residents who own their unit
- Approximately $1.5M in avoided one-time disruption/relocation costs, with 59.8% benefitting renters and 40.2% benefitting owners
- Approximately $36M in avoided mental stress costs, with 66.0% benefitting renters and 34.0% benefitting owners
- Approximately $98M in avoided lost productivity costs for employed residents, with 65.8% benefitting renters and 34.2% benefitting owners
- Approximately $25M in avoided injury costs, with 66.0% benefitting renters and 34.0% benefitting owners

Residents in the study area will benefit in the amount of a total present value of approximately $2.1K due to avoided loss of EMS function and consequently avoided loss of life.[39]

Residents in the study area will benefit in the minimal amount of a total present value of approximately $50 due to avoided loss of fire station function and consequently avoided human injuries and other damage.

Additional Benefits

By 2100, approximately 14,000 residents in the area exposed to the 1% annual chance storm will be protected, as well as approximately 4,400 in the area exposed to monthly high tides.

Approximately 2,400 families with children in school currently in the area would benefit from continued school services during a 1% annual chance storm in 2100, with some saving an average of approximately $1.7K each in value of missed work for caretaking of children and others saving an average of approximately $600 each in value of social reproductive labor. Between approximately $39K and $82K of value in free school meals will also be preserved for present-day families with children in public school during a major flood event.

Benefitting Group: Workers

Present Value Benefits (discount rate: 6.25%)

Approximately $2.26B of present value direct losses avoided will directly benefit workers, both local and regional.

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[38] Benefits to residents are sub-allocated proportional to HAZUS estimates of the percent of owner-occupied structures by occupancy class. While single- and multifamily-residential properties have their own HAZUS values, we assigned mixed commercial/residential properties multifamily residential values, commercial properties with small numbers of residents an average of all commercial values, and miscellaneous residential properties an average of all residential values.

[39] Present value of avoided emergency services losses in the total amount of $19.45K are weighted and distributed to residents and workers based on the respective number of exposed residents and workers in the project area

Benefitting Group: Workers

Approximately 111,500 exposed wage and salary workers[40] in the study area will benefit in the amount of a total present value of approximately $1.32B in avoided lost employee compensation (here inclusive of wages/salary and benefits)[41] due to business interruption caused by flooding.

- An approximate additional $98M in avoided present value lost productivity costs will benefit employed residents in the study area.
- Workers in the study area will benefit in the amount of a total present value of approximately $17K due to avoided loss of EMS function and consequent avoided loss of life.[42]
- Workers in the study area will benefit in the minimal amount of a total present value of approximately $400 due to avoided loss of fire station function and consequently avoided human injuries and other damage.

Workers across the region will similarly benefit from avoided indirect and induced employee compensation loss,[43] equal to a total present value of approximately $940M.

Benefitting Group: People Who Move Through The Area

Present Value Benefits (discount rate: 6.25%)

Not calculated as part of this analysis.

Additional Benefits

Approximately 56,000 daily MTA bus riders will experience benefits from avoided lost time spent traveling caused by increased congestion along the M15, M20, and M55 bus and BM1, BM2, BM3, BM4, QM7, QM8, QM11, and QM25 express bus lines due to flooding. The time saved is almost 30 minutes per rider per trip, or $10.39 each in value of travel time savings. Assuming two days of impacted bus service following a major flood event, that amounts to approximately $1.15M saved in lost travel time for each flood event, or $577K per day of affected bus service.

Approximately 70,000 daily Staten Island Ferry passengers will experience benefits from avoided lost time spent traveling caused by loss of services at Whitehall Ferry Terminal due to flooding. The time saved is almost 33 minutes per rider per trip, or $11.55 each in value of travel time savings. Assuming three days of lost ferry service following a major flood event, that amounts to approximately $2.4M saved in lost travel time for each flood event, or $810K per day of affected ferry service.

For people who drive through the study area, approximately 23 acres of surface roads will be protected from inundation by a 1% annual chance flood in 2050, rising to 30 acres by 2100. Approximately 21 acres will be protected from MMHW flooding in the 2100s.

For people who bike through the study area, including the 1,340 daily weekday and 1,880 weekend cyclists using the East River Greenway, approximately 2.3 miles of bicycle lanes will be protected from inundation by a

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[40] IMPLAN 2018, which does not distinguish between wage and salary workers. It is nevertheless considered preferable to include salary workers in order to account for potentially lost PTO days.

[41] Net of direct social insurance (payroll) and (partial) personal income taxes, as the benefit associated with the avoided loss of these taxes accrues to the City and/or state or federal government. The remainder of direct personal income tax revenue is adjusted for under avoided loss of proprietor income (otherwise allocated as benefits to business owners).

[42] Present value of avoided emergency services losses in the total amount of $19.45K are weighted and distributed to residents and workers based on the respective number of exposed residents and workers in the project area.

[43] Net of indirect/induced social insurance (payroll) and (partial) personal income taxes, as the benefit associated with the avoided loss of these taxes accrues to federal, state, and local governments. Due to the geographic scale of the Metropolitan Statistical Area, however, it is not possible to allocate these indirect and induced benefits between the various governments.

Benefitting Group: People Who Move Through The Area

1% annual chance flood in 2050, rising to 2.6 miles by 2100. Approximately 1.6 miles will be protected from MMHW flooding in the 2100s.

Subway riders, especially those who use the 1, 4-5, R-W, and J-Z lines, may also benefit from additional protection from disruption of subway services due to flooding, slightly supplementing protections implemented by the MTA.

Benefitting Group: Business Owners

Present Value Benefits (discount rate: 6.25%)

Approximately $2.47B of present value direct losses avoided will directly benefit business owners who operate both locally and regionally.

Approximately $1.61B of present value direct losses avoided will benefit business owners operating within the study area, including:

- Approximately $1.29B of present value in avoided lost proprietor income[44] and other property income[45]
- Approximately $299M of present value in avoided direct contents damage
- Approximately $22M of present value in avoided one-time disruption/relocation costs

Businesses operating throughout the region (the New York-Newark-Jersey City, NY-NJ-PA Metropolitan Statistical Area) will similarly benefit from avoided indirect and induced proprietor income[46] and other property income losses,[47] equal to a total present value of approximately $850M.

Benefitting Group: Private Property Owners

Present Value Benefits (discount rate: 6.25%)

Approximately $1.96B of present value losses avoided will directly benefit private property owners within the study area, inclusive of commercial, residential, and non-profit property owners. Losses avoided benefiting private property owners include:

- Approximately $1.29B in avoided direct building damage
- Approximately $331M in avoided owner rental costs for relocation to replacement units
- Approximately $343M in avoided rental income loss

Approximately 78% ($1.52B) of these losses avoided will benefit property owners in primarily commercial buildings; approximately 6.5% ($127M) will benefit property owners in primarily residential (multifamily or single-family) buildings; and approximately 16% ($313M) will benefit property owners in mixed-use buildings.

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[44] Net of direct personal income taxes, as the benefits associated with the avoided loss of these taxes accrues to the City and/or state or federal government.

[45] Net of direct corporate taxes, as the benefits associated with the avoided loss of these taxes accrues to the City and/or state or federal government.

[46] Net of indirect/induced personal income taxes, as the benefit associated with the avoided loss of these taxes accrues to federal, state, and local governments. Due to the geographic scale of the Metropolitan Statistical Area, however, it is not possible to allocate these indirect and induced benefits between the various governments.

[47] Net of corporate taxes, as the benefit associated with the avoided loss of these taxes accrues to federal, state, and local governments. Due to the geographic scale of the Metropolitan Statistical Area, however, it is not possible to allocate these indirect and induced benefits between the various governments.

Benefitting Group: Private Property Owners

Residential property owners who also occupy their own units will benefit from an approximate additional $63M in avoided content damage, injury costs, lost productivity costs, mental stress costs, and one-time disruption costs as residents.

Benefitting Group: City of New York

Present Value Benefits (discount rate: 6.25%)

Approximately $676M of present value direct losses avoided will benefit City government, including:

- Approximately $205M in avoided direct building damage
- Approximately $118M in direct local tax revenue impacts[48]
- Approximately $109M in avoided direct contents damage
- Approximately $37M in avoided loss of proprietor income or other property income, understood as revenue to the City
- Approximately $15M in avoided one-time disruption/relocation costs
- Approximately $127M in avoided owner rental costs for relocation to replacement units
- Approximately $67M in avoided rental income loss
- Approximately 800 people with avoided shelter needs

The approximately $118M in direct local tax revenue impacts includes the following:

- Approximately $68M in local avoided lost tax on production and imports (TOPI) revenue due to avoided direct economic impacts across the City's five boroughs. This includes sales and excise taxes, property taxes, special assessments, and various other taxes
- Approximately $23M in direct local corporate tax revenue impacts
- Approximately $22M in direct local personal tax revenue impacts

Additional Benefits

More broadly, the City will benefit from avoided damage to critical infrastructure and essential services, including:

- EMS and fire services
- 6 public K-12 schools
- Ferry services at Whitehall Ferry Terminal servicing 25M passengers a year, the busiest commuter ferry route in the country
- NYC Ferry services at Pier 11 servicing 4M passengers a year
- Ferry services to Governor's Island at the Battery Maritime Building providing service to 767,300 riders a year, with plans for substantial growth as the island is built out.
- Up to 29 acres of roadways, and up to 2.6 miles of bike lanes.

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[48] Indirect and induced impacts are unable to be allocated due to geographic scale reported of indirect and induced tax revenue impacts (Metropolitan Statistical Area)

9. Additional Potential Losses

Additional potential losses were screened and assessed only at a high level either because they were not relevant to the study area, because losses from flooding were not considered to be substantial, or due to methodological limitations.

9.1. Loss of Service

The following potential loss of services analyses were screened but not pursued for the following reasons.

- Loss of library services: no libraries in floodplain
- Loss of police services: no police stations in floodplain
- Loss of wastewater service: no major wastewater facilities in floodplain

9.2. Maritime Infrastructure

Maritime structures, such as bulkheads, piers, and platforms, can be impacted by flooding and repetitive flood events may cause structural damage, increase maintenance costs, and decrease the lifespan of such structures. Implementation of the master plan will replace existing aging infrastructure with high maintenance costs and limited lifespans with newer, more resilient infrastructure. The condition and lifespan of these structures is documented in the Transportation and Maritime Infrastructure appendix.

9.3. Additional Subsurface Utilities

Utilities that are in the ground are generally designed to be water resistant. However, utilities in the ground generally are not designed to experience interact with salt water. Salt water is more corrosive than fresh water and continued interaction between utilities and salt water could increase maintenance costs over time. Additionally, the repeated wetting and drying of utility components could further accelerate corrosion. These factors would require more maintenance over time and may even cut short the design life of underground utility systems.

Some key findings include:

- The oil-o-static line is deep, and submersion is not likely an issue; it is unlikely to fail due to flooding or sea level rise.
- The stormwater infrastructure network is designed to be resistant to water. The only potential impact could be to electrical components at regulator components, such as those that monitor the opening and closing of sluice gates, and this cost is expected to be minimal.
- Due to the water supply network’s inherent resilience to water, no impacts to water supply systems are anticipated due to coastal flooding.

10. Primary Data Sources

Average commute time by public transit in NYC: pulled from Geotab study (https://www.geotab.com/time-to-commute/)

Bus routes: Baruch College NYC Mass Transit Spatial Layers Archive: NYC Bus Routes dataset (Nov 2020, resumption of normal services)

City-owned and -leased properties: NYC DCP City Owned and Leased Properties (COLP) (2020) and NY Integrated Property Information System (IPIS) (2019) datasets

Community and cultural assets and services: NYC Capital Planning Platform: Facilities Explorer (2020)

Department of Information Technology and Telecommunications (DoITT) Building Footprints (April 2019): Building footprints represent the perimeter extent of buildings and provide the building height above grade and the number of stories. Data also contain the Building Identification Numbers (BINs), which is a unique number assigned to specific buildings, and the Borough-Block-Lot (BBL) number, which identifies the locations of properties.; ground-truthed by comparing to area of the structure polygon in ArcGIS

Depth-damage functions: derived from USACE North Atlantic Coast Comprehensive Study (2014)

City of New York Department of Environmental Protection Digital Elevation Model (2017): The Digital Elevation Model (DEM) is derived from LiDAR collected in 2017 over New York City. A DEM models the ground surface and excludes ground features such as trees and buildings. The DEM was generated by interpolating the LiDAR ground points to create a 1-foot resolution seamless surface. Adjusted for error in LiDAR data along FDR

Demographics: Census data (2019 ACS 5-year estimates) on total population, housing units, tenure, housing by income and age, households and families, children under 18, selected economic characteristics, employment characteristics of families, and median earnings; in addition to 2011 Survey of Income and Program Participation (SIPP) data on national childcare arrangements
Direct, indirect, & induced economic output and employment: derived from IMPLAN 2018

High frequency event flood data: derived from NOAA Tides & Currents; adjusted with sea-level rise projections

Loss of emergency asset function: values and methodologies from Benefit-Cost Analysis Sustainment and Enhancements, Standard Economic Value Methodology Report, FEMA 2020

Loss of life values: DOT economic value of a statistical life (2016), FAA life safety values (2016), BRNO University of Technology fatality risk methodology

Modeled 10-, 50-, 100-, and 500-year Inundation Depth Data with Sea Level Rise (2015): Flood elevations for the 10 percent, 2 percent, 1 percent, and 0.2 percent storm events are from FEMA's Preliminary Flood Insurance Rate Maps (PFIRMs). Ten, thirty, fifty-eight, and seventy-five inches of sea level rise have been included in the PFIRM flood elevations, which is the 90th percentile sea level rise projections from the New York City Panel on Climate Change in the 2020s, 2050s, 2080s, and 2100, respectively.

MTA farebox revenue: 2019 final estimates for NYCT and MTA Bus Company, from MTA 2020 Adopted Budget

City of New York Primary Land Use Tax Lot Output (PLUTO) Data (2020): PLUTO data are developed by the City of New York Department of City Planning and contain tax lot characteristics, structure characteristics, and geographic/political/administrative districts reported at the tax lot level. PLUTO data have been merged with the Department of Finance's digital tax map to create MapPLUTO for use with Geographic Information Systems (GIS). Ground-truthed and updated where appropriate

Regionalized value of travel time savings (VTTS): derived from 2016 DOT Revised Value of Travel Time Guidance methodology, 2021 DOT BCA Guidance values, U.S. Census data (2019 ACS 5-year estimates), and BLS data on Occupational Employment and Wage Statistics (OEWS) and employer costs for employee compensation

RSMeans Building Construction Cost Data (2016): This publication provides location-specific building replacement square foot costs for 160 building occupancy types. Analysts applied those costs to each of the 27 HAZUS occupancy classes and then calculated building replacement square foot costs for structures in the project area. Costs were escalated to 2020 costs using the Consumer Price Index from the U.S. Bureau of Labor Statistics

Sea-level rise projections: New York City Panel on Climate Change, 90th percentile estimates, 2015

School enrollment data: pulled from IES National Center for Education Statistics (2020) and http://niche.com/ where needed

Value of social reproductive labor: based on precedent set by Oxfam (2020, https://www.oxfamamerica.org/explore/research-publications/time-care/)

11. List of Abbreviations

ACS: American Community Survey
BCA: Benefit Cost Analysis
BCR: Benefit Cost Ratio
BRV: Building replacement value
CDC: Center for Disease Control and Prevention
CSRV: Contents-to-Structure Ratio Values
DDF: Depth Damage Function
DEM: Digital Elevation Model
DOE: Department of Education
DOT: Department of Transportation
DoITT: Department of Information Technology and Telecommunications
EMS: Emergency Medical Services
FAA: Federal Aviation Administration
FEMA: Federal Emergency Management Agency
FFE: First Floor Elevation
FIRM: Flood Insurance Rate Map
HAZUS: Hazards United States
HUD: Department of Housing and Urban Development
HVAC: Heating, ventilation, and air conditioning
MEP: Mechanical, electrical, and plumbing
MMHW: Mean Monthly High Water, expected to be exceeded 20-30 times per year
MSA: Metropolitan Statistical Area
MTA: Metropolitan Transit Authority
NAACS: North Atlantic Coast Comprehensive Study
NAVD88: North American Vertical Datum of 1988
NOAA: National Oceanic and Atmospheric Administration
NPCC: New York City Panel on Climate Change
NSLP: National School Lunch Program
NYC: New York City
NYC OMB: New York City Mayor's Office of Management and Budget
NYCT: New York City Transit
PFIRMs: Preliminary Flood Insurance Rate Maps
PFIS: Preliminary Flood Insurance Study
PLUTO: City of New York Primary Land Use Tax Lot Output Data
SBP: School Breakfast Program
SLR: Sea level rise
TOPI: Taxes on Production and Imports
USACE: United States Army Corps of Engineers
VTTS: Value of travel time saving
WTP: Willingness to Pay