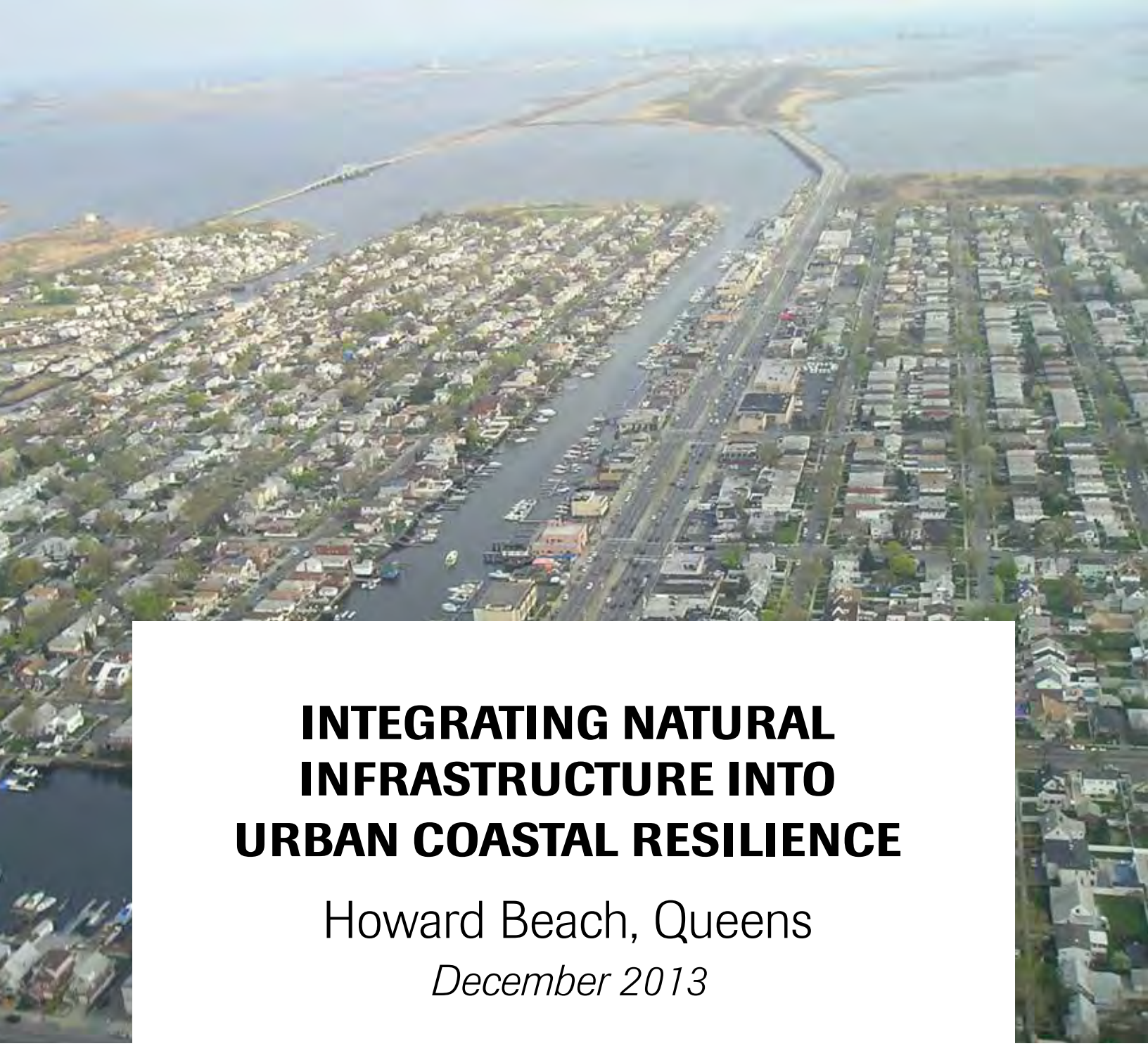

INTEGRATING NATURAL INFRASTRUCTURE INTO URBAN COASTAL RESILIENCE

Howard Beach, Queens

December 2013

The Nature Conservancy

Protecting nature. Preserving life.®

The contents of this report were developed by The Nature Conservancy, with technical support from CH2M Hill and Davey Resource Group. Primary funding was provided by the JPB Foundation, with additional support from The Rockefeller Foundation and TD Bank.

In preparing this report the Conservancy and CH2M Hill relied, in whole or in part, on data and information provided by third parties and on publicly available data and information that has not been independently verified by the Conservancy or CH2M Hill and is assumed to be accurate, complete, reliable and current. Therefore, while the Conservancy and CH2M Hill have utilized best efforts in preparing this report, the Conservancy and CH2M Hill do not warrant or guarantee the conclusions set forth in the report and shall not be liable for any reliance thereon by any third parties.

Front and Back Cover Image | Source: Aerial View of Howard Beach © *Adrian Madlener*

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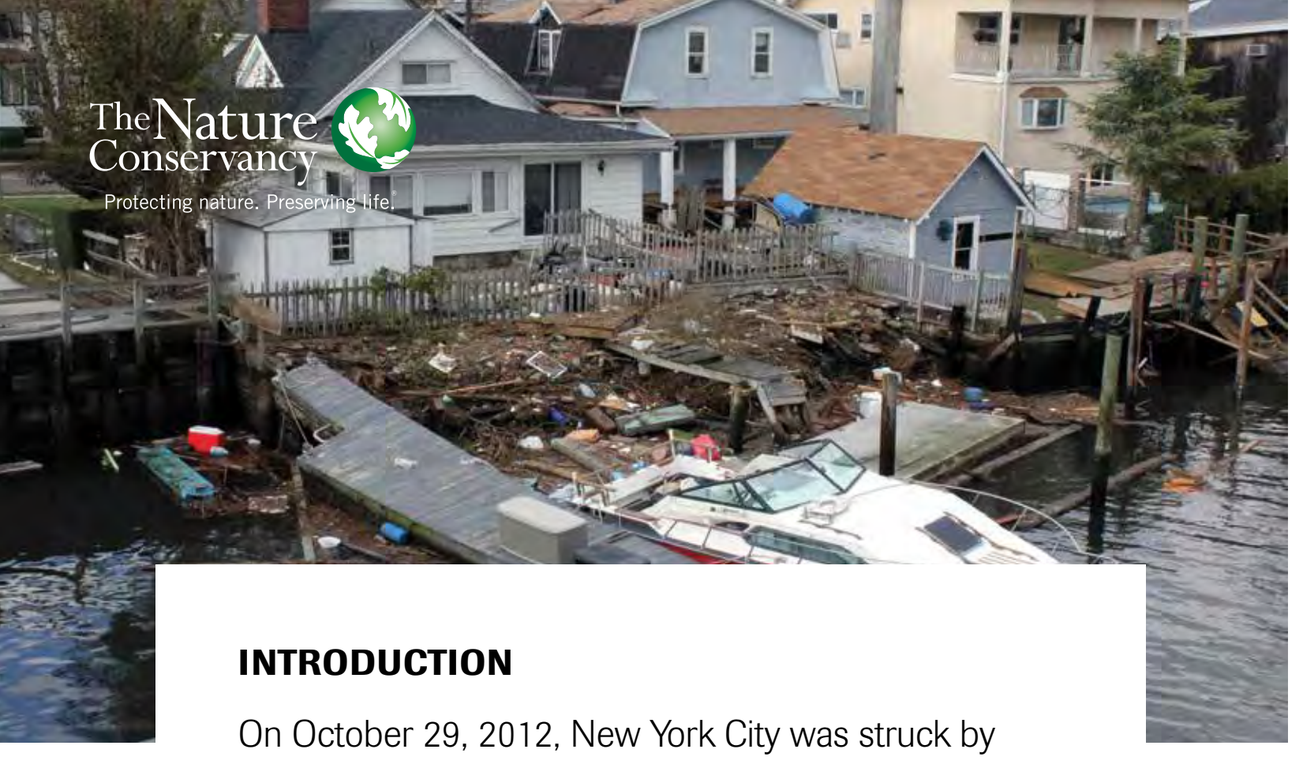


INTRODUCTION

On October 29, 2012, New York City was struck by Superstorm Sandy, which brought storm surges over 13 feet and caused more than $19 billion in damages to the City. Across the region, more than 125 people died as a result of Sandy, including 48 NYC residents. As fires raged in some city neighborhoods, water destroyed homes in others. While climate change predictions indicated that a catastrophic storm could happen someday, for most people, the destruction was beyond imagination. This was a loud, stark wake-up call to the reality of our changing climate.

Source: Hurricane Sandy Aftermath © *Pamela Andrade*

This case study provides a first of its kind look at how natural defenses, in conjunction with built infrastructure, can help protect our communities from the impacts of climate change. Given New York City's density, in many parts of the City it is more cost-effective to protect people and property from climate risks at the neighborhood or regional scale than home by home or through relocation. This case study is focused on neighborhood scale protection alternatives and offers a methodology that could be replicated and applied to other coastal communities to evaluate the efficacy and relative costs and benefits of potential coastal resilience strategies.

This report evaluates potential strategies for one neighborhood to illustrate how the methodology works and how integrated natural and built infrastructure can mitigate flood risks, but our interest is much broader than one community. We aim to provide the information, analysis and tools needed to protect coastal communities across New York City, New York State, the nation and the globe that are vulnerable to climate risks. In addition to providing a robust and replicable methodology for evaluating both natural and built infrastructure's ability to protect communities from climate change risks, **the ultimate findings of the report are:**

- Howard Beach, our sample NYC community, currently faces significant climate risks, particularly from coastal flooding, which will increase over time;
- In this type of dense urban community it is cheaper to address flood risks at the neighborhood scale than to elevate each individual home above the FEMA base flood elevation plus the recommended two feet of free boarding;
- Hybrid approaches that combine natural and built infrastructure could provide a cost-effective way to reduce flood risks at the neighborhood scale;
- Innovative financing options are available to bring these hybrid approaches to reality;
- Mitigating flood risks provides significant public and private benefits to the City and homeowners, which offers opportunities for monetizing benefits for different groups to offset construction and maintenance costs.

Natural defenses have the added benefits of enhancing both the environment—including water quality, air quality, and habitat—and the quality of life in surrounding communities. Both environmental and quality of life improvements have tangible economic benefits for the City and for property owners. Natural defenses, including wetlands, dunes, seagrass and ribbed mussel beds, are important, effective tools in protecting lands and waters for people and nature, which is The Nature Conservancy's core mission. This study advances the discussion of how natural defenses can be utilized in urban coastal resilience strategies moving forward.

Superstorm Sandy not only revealed the harsh realities of increasingly severe weather, it also forced a critical conversation about how we best protect communities from the impacts of climate change. To further that conversation, The New York City Special Initiative for Rebuilding and Resiliency asked The Nature Conservancy to evaluate the role of nature and natural infrastructure in protecting communities from some of the impacts of climate change—particularly sea level rise, storm surges and coastal flooding.

The City of New York asked the Conservancy to prepare this case study using the community of Howard Beach, a low-lying, densely populated neighborhood on Jamaica Bay. The City asked us to use this community to evaluate the potential to develop integrated natural and built infrastructure strategies to protect coastal communities, model what these strategies could look like, perform a preliminary cost benefit analysis based on avoided losses, and identify potential funding mechanisms to finance infrastructure, construction and operation.

Howard Beach, Queens, was selected by the City as the demonstration neighborhood for this pilot due to the amount of damage it suffered during Sandy, the difficulty of protecting the neighborhood due to its canals, its vulnerability to high frequency, low-impact flooding due to sea level rise, and its location on Jamaica Bay, where it does not face ocean waves. This study presented an important opportunity to objectively assess the role of natural defenses in protecting densely populated, coastal urban communities that was well aligned with the Conservancy's science-based approach to public policy and management challenges and expertise in coastal resilience and climate change impacts.

To conduct this analysis we retained CH2M Hill, a global engineering firm with expertise in coastal engineering, to complement our expertise in natural infrastructure. This study demonstrates that natural infrastructure is a crucial part of addressing climate change impacts on coastal communities—including those in urban areas. It also provides a foundation for additional work.

The resilience strategies evaluated in this report do not represent the only strategies that could be utilized to increase the resilience of Howard Beach or other coastal communities. Rather, they represent an initial attempt to create a suite of representative coastal protection options for an urban neighborhood to help the City and the Conservancy understand the costs and benefits of neighborhood-scale coastal protection utilizing natural and conventional defenses.

It should be noted that since we conducted the analysis, new information and flood maps were produced by FEMA, which may have an impact on our final cost-benefit calculations. Our methodology was created to further assessment and evaluation as updated information and data becomes available in this rapidly evolving field. Additionally, while this report explores a set of alternatives, it does not recommend a specific course of action. Any specific actions would require further analysis in accordance with applicable funding and other requirements and need to be compatible with the region's other restoration and redevelopment plans.

In this study we offer possible infrastructure solutions that address the challenges that Howard Beach faces in order to (a) further the dialogue around coastal resilience and finance, and (b) ultimately advance better management practices, risk reduction initiatives and policy choices for similar communities. This report details the background on the study and its connection to City initiatives, the scope of work, our methods, the solution suites, analyses of the efficacy of the alternatives and their cost/benefit ratios, and potential financing options. Our estimates of the benefits of both natural and hybrid approaches are conservative and should be viewed as a starting point, as we do not fully quantify all the benefits. Ultimately, we see these alternatives providing more value than indicated in this preliminary report.

We do recommend further study and action steps, some of which we are conducting as part of our ongoing work on coastal resilience and urban conservation, and others that will need to be conducted by the appropriate agencies and community organizations.

Recommended next steps include:

- Evaluate the efficacy and benefits of the proposed strategies during more frequent, less intense storms and other climate change scenarios;
- Evaluate water quality and other ecological impacts of the proposed strategies;
- Conduct a robust ecosystem services analysis of the options to create a more complete picture of benefits;
- Consider an analysis of built infrastructure only strategies;
- Evaluate the social impacts of the proposed strategies;
- Analyze the benefits of the proposed strategies for neighboring communities and upland areas;
- Conduct a robust community information and input process to inform comprehensive decisions about resilience solutions, planning, policies and practices;
- Conduct a 30 year return on investment analysis on the proposed strategies.

Using nature and natural infrastructure in conjunction with built infrastructure to make the City more resilient in the face of climate change is critical to the future of people living in its 520 miles of coastal communities. Protecting, rebuilding and restoring wetlands, dunes, seagrass and trees can help safeguard coastal communities by slowing waves, reducing storm surges, preventing erosion and absorbing rain, while providing other important quality of life and environmental benefits. These natural assets create an insurance policy for the future—they are nature's cushion against rising sea levels and storm surge, and they remove pollution from the millions of gallons of freshwater that flow into our oceans each minute.

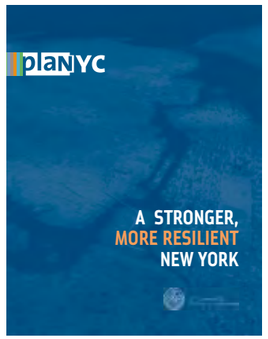
The Conservancy's coastal restoration and protection strategy aims to preserve and enhance these natural-systems and ensure they continue to deliver critical protection for our coastal cities. The Conservancy's urban strategy advances natural infrastructure as a critical asset for coastal defense. This report demonstrates that natural infrastructure can and should be considered side by side with built infrastructure in evaluating sustainable solutions for protecting our coastal cities from the impacts of climate change.

SCOPE OF WORK

While Superstorm Sandy was the impetus for this report, our charge was not to model the impacts of Sandy or to develop strategies to mitigate the damage caused by a similar storm. Rather, our goal was to evaluate the current and future climate risks facing Howard Beach as a sample community, with an emphasis on coastal flooding, and demonstrate the potential role and value of an integrated suite of strategies that include natural and built infrastructure.

To accomplish this, we developed four suites of strategies ("Alternatives") containing natural and built infrastructure elements, and modeled their ability to mitigate damage caused by a 1-in-10, 1-in-25, and 1-in-100 year storm. Two of these alternatives were further modeled for risk reduction capacity using sea level rise projections (12 and 32 inches), to determine how their protective capacity would change over the next 40 years. Flood levels and sea level rise projections were based on analysis conducted by FEMA and the New York City Panel on Climate Change. These strategies do not represent the entire universe of potential options. Rather, they were selected to illustrate how a hybrid approach could be appropriately evaluated and analyzed.

Estimated losses were calculated using HAZUS, a software tool developed by FEMA that does not include infrastructure damage in its projections.



Source: *PlaNYC - A Stronger, More Resilient New York*

As a result, economic loss estimates are limited to building damage, vehicle losses and business interruption—outputs that are calculated by HAZUS. Impacts to public infrastructure are likely to be significant during 1-in-100 year storms, which would increase the cost benefit ratio for many of the scenarios analyzed in this report.

In addition, only limited operation and maintenance costs for our proposed coastal resilience strategies were used for this analysis. More robust annual costs need to be factored into each scenario to develop a complete return on investment (ROI) analysis over the lifespan of the infrastructure.

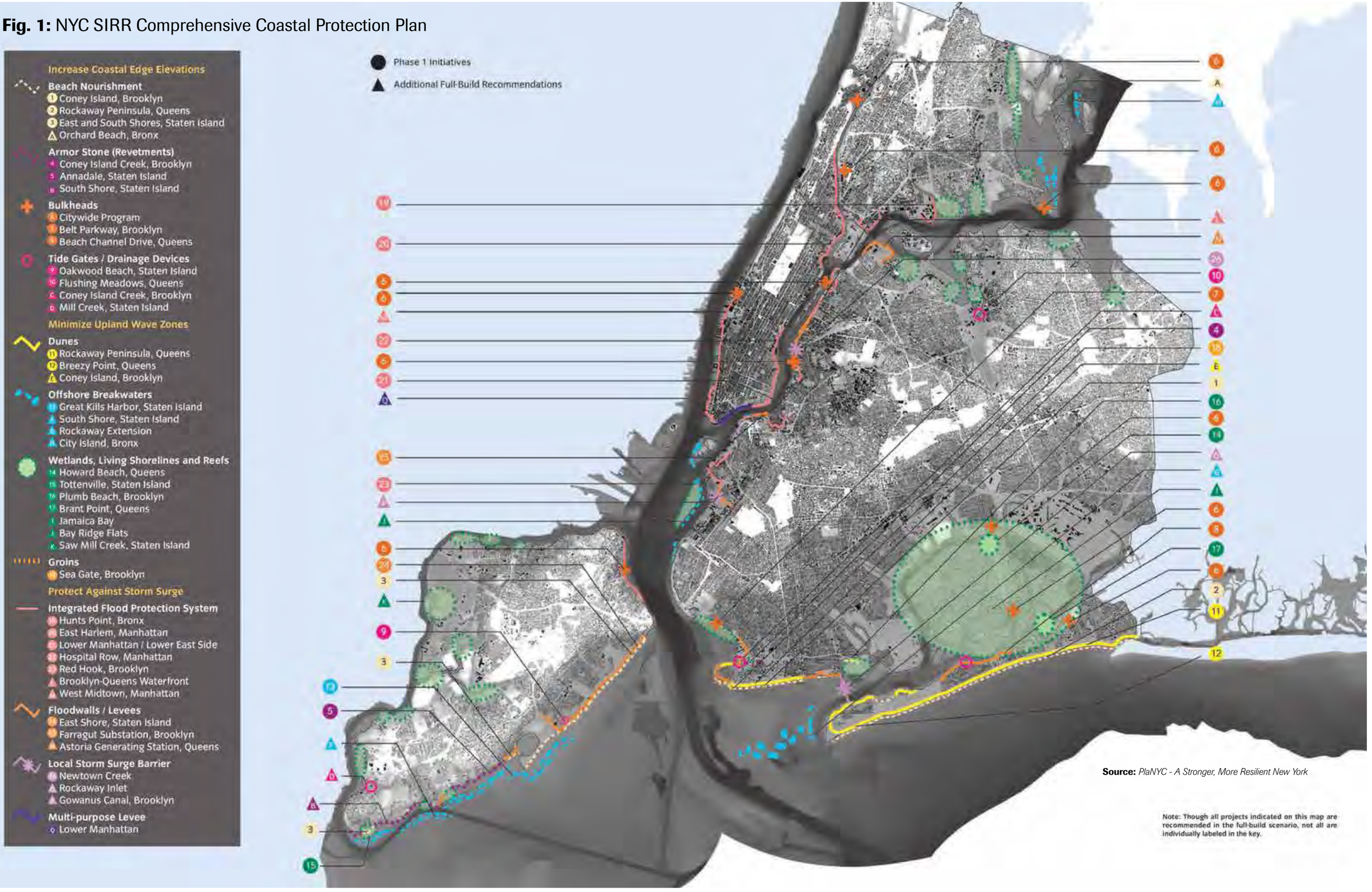
SPECIAL INITIATIVE FOR REBUILDING AND RESILIENCE

On June 12, Mayor Bloomberg released the SIRR report, which detailed more than 250 initiatives to create a stronger, more resilient New York. Several specific actions were included for Howard Beach and Jamaica Bay. The analysis and potential coastal resilience strategies developed by the Conservancy were created on a parallel track to the work completed by the SIRR; however, there are many similarities in the City and Conservancy's findings and strategies.

The SIRR report calls for the U.S. Army Corps of Engineers (USACE), subject to funding, to implement a wetlands restoration project designed to attenuate waves for Howard Beach. This project would build upon the existing work of the Hudson-Raritan Estuary Comprehensive Restoration Plan and leverage the work contained in this report, which was cited by the City in the SIRR report. The goal is to complete this project within four years of completing the USACE study.

Subject to available funding, the City will also call upon the USACE, simultaneous with the Howard Beach wetlands restoration, to restart studies of the Rockaway Peninsula and of Jamaica Bay. Following completion of these studies, the reports call on the USACE to implement coastal protection projects to provide flood protection and reconstitute some of the City's most important protective wetlands and marsh islands. If restarted now, this study could be completed by 2016 and would expedite restoration of Jamaica Bay wetlands, improvements to bulkheads in low-lying

Fig. 1: NYC SIRR Comprehensive Coastal Protection Plan



Source: *PlaNYC - A Stronger, More Resilient New York*

Note: Though all projects indicated on this map are recommended in the full-build scenario, not all are individually labeled in the key.

neighborhoods and implementation of a local storm surge barrier for Rockaway Inlet.

In addition to restoring wetlands, the SIRR Report recommends that the City, subject to funding, raise bulkheads and other shoreline structures to minimize the risk of regular flooding in targeted neighborhoods including Howard Beach and the bayside of the Rockaway Peninsula, Broad Channel in Queens, West Midtown in Manhattan, Locust Point in the Bronx, Greenpoint in Brooklyn, the North Shore of Staten Island, and other low-lying locations.

As this report was going to press, New York State announced an ambitious Jamaica Bay restoration plan designed to provide natural protective functions to Howard Beach by implementing an innovative resiliency project on a 150 acre span along Spring Creek and Jamaica Bay. This commitment goes well beyond the natural infrastructure options evaluated in this report, and represents a significant and valuable investment by the state in using natural systems effectively to protect communities and provide other benefits.

The Conservancy has been asked to continue to work with the City to increase the resilience of coastal communities, with a near-term focus on Jamaica Bay.

KEY FINDINGS

Howard Beach currently faces significant climate risks, particularly from coastal flooding, which will increase over time.

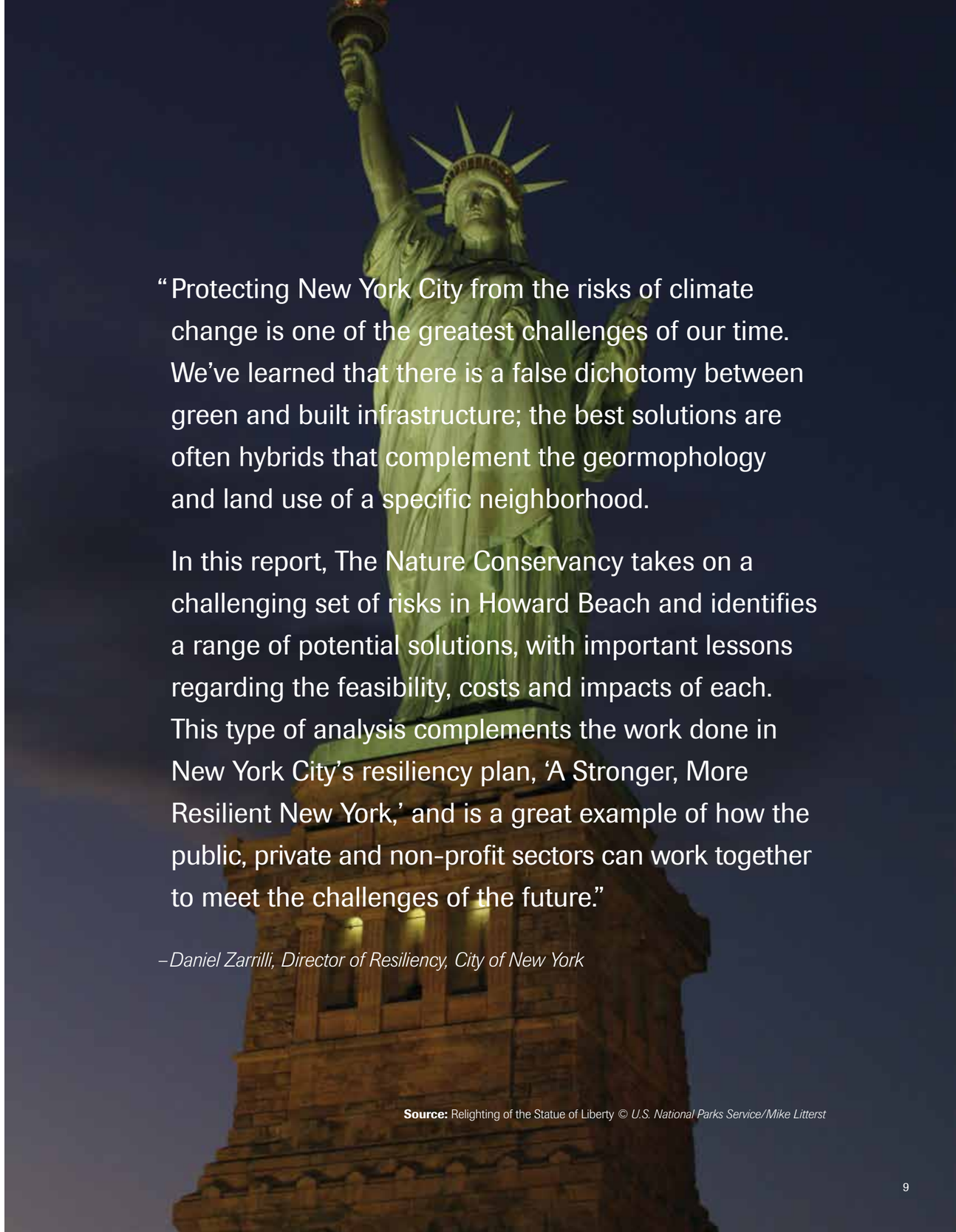
- Howard Beach faces significant flood risks. The current 1-in-25 year storm causes $30 million in losses. The current 1-in-100 year storm is estimated to result in $494 million in losses.
- An increase in sea levels of 32 inches will double the estimated losses associated with a 1-in-100 year storm to $1 billion.

Preliminary analyses indicate that integrated natural and built infrastructure could be a cost-effective solution for reducing flood risks.

- In this area, it is more cost-effective to address flood risks at the neighborhood scale than to elevate each individual home above the FEMA base flood elevation plus the recommended 2 feet of free boarding. The total estimated cost of elevating each individual home is more than $700 million (approximately $125,000 per home)—a figure 2.5 times greater than the most expensive alternative identified in this report.
- The natural infrastructure options alone (Alternatives 1 and 2) that are evaluated in this report cannot protect Howard Beach from major flood events given the existing urban conditions and flood risks.
- Hybrid strategies (Alternatives 3 and 4) that integrate natural and built infrastructure (e.g., sea walls and sea gates) can offer significant protection from high frequency, low impact flood events and the current 1-in-100 year storm.
- Alternatives 3 and 4 result in anticipated avoided losses from the current 1-in-100 year storm of $348 million and $466 million, respectively. This includes between $300-$400 million in avoided building damage.
- The natural infrastructure elements of Alternatives 3 and 4 likely lengthen the life and reduce annual maintenance costs of Spring Creek Park and its protective berms through the reduction of wave energy and erosion. In addition, having properties adjacent to parkland as opposed to sea walls is likely to result in an increase in property values.

Opportunities exist to spread the cost of adaptation actions among those who benefit from increased resilience and avoided losses.

- Mitigating flood risks provides significant public and private benefits to the City and homeowners, offering opportunities to monetize benefits for different groups to offset construction and maintenance costs.
- Several types of financing mechanisms could be used to offset portions of the construction and maintenance costs associated with resilience strategies.



"Protecting New York City from the risks of climate change is one of the greatest challenges of our time. We've learned that there is a false dichotomy between green and built infrastructure; the best solutions are often hybrids that complement the geormophology and land use of a specific neighborhood.

In this report, The Nature Conservancy takes on a challenging set of risks in Howard Beach and identifies a range of potential solutions, with important lessons regarding the feasibility, costs and impacts of each. This type of analysis complements the work done in New York City's resiliency plan, 'A Stronger, More Resilient New York,' and is a great example of how the public, private and non-profit sectors can work together to meet the challenges of the future."

–Daniel Zarrilli, Director of Resiliency, City of New York

Source: Relighting of the Statue of Liberty © *U.S. National Parks Service/Mike Litterst*

Alternative 1:

Natural infrastructure (shoreline)

Capital Cost: $40 M
Annual O&M: $373 K
1-in-100 yr. damage: $465 M
Avoided damage: $29 M
Annual Ecosystem Services Benefit: $662 K
B/C Ratio: **0.73**

Elements: *+14' NAVD berms, restored marsh, and ribbed mussel hard toe in Spring Creek Park; rock groin at Charles Memorial Park; breakwater at entrance to Shellbank Basin.*

Source: *CH2M Hill*

Source: *CH2M Hill*

Alternative 2:

Natural infrastructure (wetlands)

Capital Cost: $88 M
Annual O&M: $772 K
1-in-100 yr. damage: $462 M
Avoided damage: $32 M
Annual Ecosystem Services Benefit: $279 K
B/C Ratio: **0.36**

Elements: *+14' NAVD berms, restored marsh and ribbed mussel hard toe in Spring Creek Park; restored and new marsh in Jamaica Bay.*

Alternative 3:

Hybrid with removable walls

Capital Cost: $249 M
Annual O&M: $913 K
1-in-100 yr. damage: $146 M
Avoided damage: $348 M
Annual Ecosystem Services Benefit: $662 K
B/C Ratio: **1.39**

Elements: *+14' NAVD berms, restored marsh and ribbed mussel hard toe in Spring Creek Park; berm and rock groins at Charles Memorial Park; removable flood walls along Crossbay Boulevard, Shellbank Basin, west side of Hawtree Basin and portions of the Belt Parkway.*

Source: *CH2M Hill*

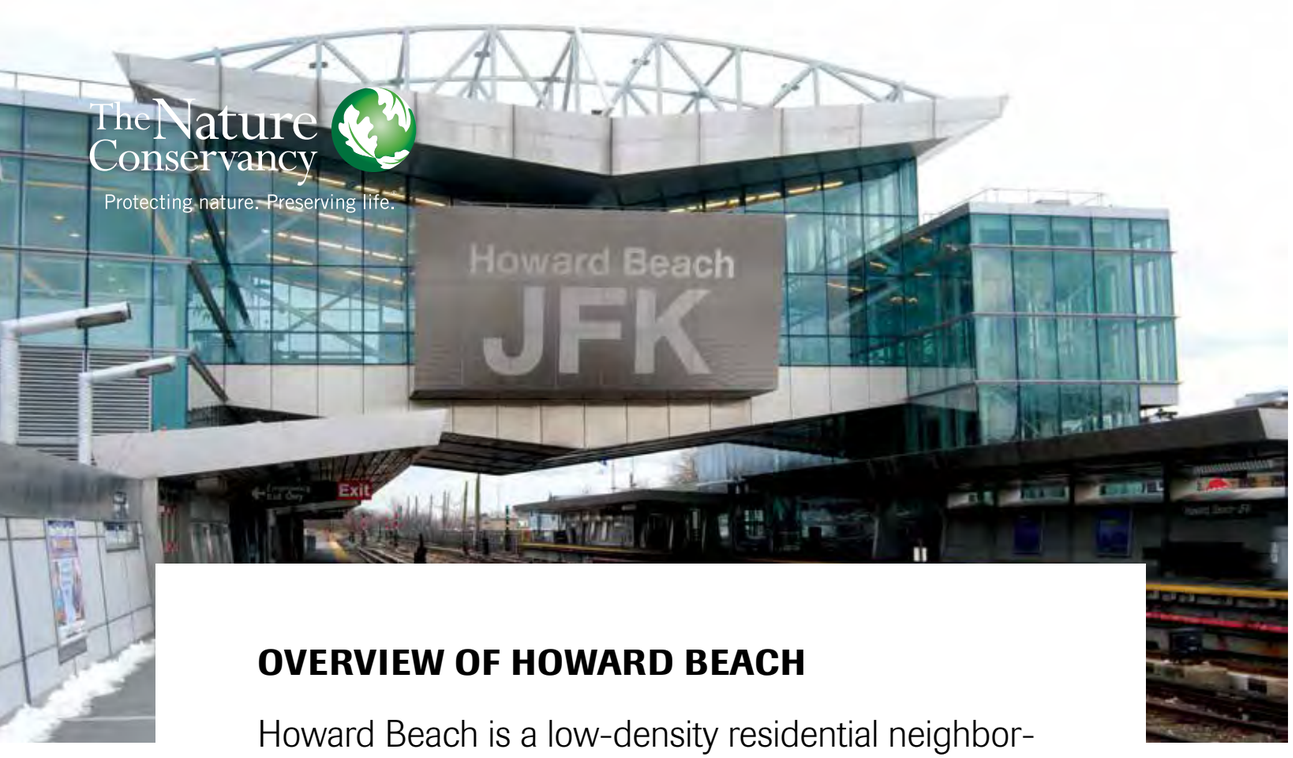
Source: *CH2M Hill*

Alternative 4:

Hybrid with operable flood gates

Capital Cost: $76 M
Annual O&M: $895 K
1-in-100 yr. damage: $28 M
Avoided damage: $466 M
Annual Ecosystem Services Benefit: $662 K
B/C Ratio: **6.08**

Elements: *+14' NAVD berms, restored marsh and ribbed mussel hard toe in Spring Creek Park; berm and rock groins at Charles Memorial Park; movable flood gates at entrances to Shellbank and Hawtree Basins; berm at parkland in Hamilton Beach.*



OVERVIEW OF HOWARD BEACH

Howard Beach is a low-density residential neighborhood located on Jamaica Bay in the southwestern portion of Queens. The community covers approximately 1,530 acres (2.4 square miles) and is bordered to the north by the Belt Parkway and South Conduit Avenue, to the south by Jamaica Bay, to the east by 102nd–104th streets, and to the west by 78th Street. Howard Beach contains two canals—Hawtree Creek and Shellbank Basin—that are used for recreational activities.

Source: Howard Beach/JFK © *Paul Lowry*

POPULATION

Howard Beach is home to approximately 14,700 residents. The neighborhood's population is generally older (35% are over 55 years of age), wealthier (median household income is approximately $80,000) and less heterogeneous (86% of residents are White, non-Hispanic) than the rest of the City (see Fig. 2). Over 90% of the population speaks English as a first language or "very well".

Residents have generally lived in Howard Beach for a long time. Only 2% of residents moved into the area within the past 4 years, and over 80% have lived in Howard Beach over 20 years.

Compared to other neighborhoods along Jamaica Bay—and the as a whole—Howard Beach has a relatively high employment rate, with 93% of the population over 16-years-old in the labor force. The neighborhood also has a low poverty rate (only 8% of residents are below the poverty line) and a high level of education attainment. Approximately 44% of residents over 25 years of age have attended some college or have an Associates or Bachelors degree (23% have a Bachelors degree).

HOUSING

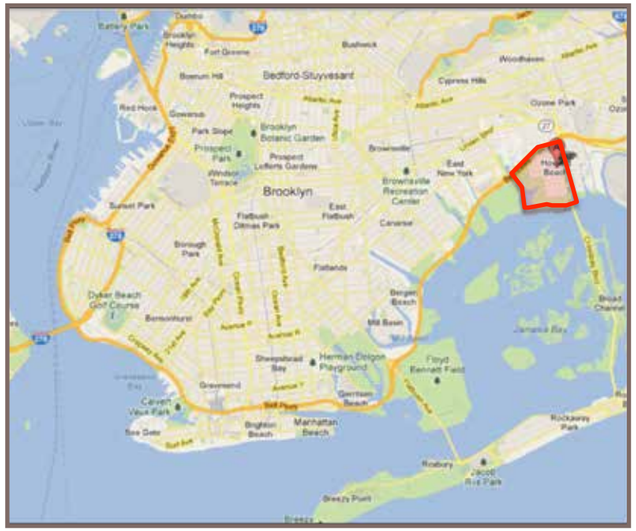
71% of residences in Howard Beach are single family detached homes—including over 93% of the homes in western portion of Howard Beach. 24% of homes are buildings with two apartment units, with a majority of these buildings in the eastern section (Old Howard Beach).

More than 90% of the residential buildings were built before 1980, before national flood protection standards were put in place, with a majority constructed between 1940–1979. As a result, many buildings are below the recommended base flood elevation (BFE) and have basements.

Approximately 85% of housing units in Howard Beach are owner-occupied—a level significantly higher than the city-wide average. Only 44% of these units have mortgages, which require owners to have flood insurance. (This is perhaps explained, in part, by the long length of tenure of many residents.) As a result, many homes may not have flood insurance.

Howard Beach's residential units have a relatively high median home value of approximately $550,000, which is slightly higher than the city-wide median value.

Howard Beach, Queens, New York



Source: Map Data © *2013 Google*

SOCIAL VULNERABILITY

Critical factors of a community's resilience include the economic, social and physical status of its population, as well as population characteristics (e.g., race, age, ethnicity). A community with little connectivity or few community-based organizations and networks (e.g., churches, civic groups, non-profits), high rates of health issues (e.g., asthma or limited mobility), linguistic or physical isolation, poor building stocks, low incomes or high unemployment is generally more vulnerable to climate risks and other shocks.

Howard Beach's relatively high median income, homeownership rate, education attainment, employment rate and concentration of English-speakers and ethnic make-up are indicators of high community resilience; however, there are factors that could heighten portions of the population's vulnerability to climate risks.

Elderly residents are more susceptible to heat-related illnesses, which are likely to increase as temperatures rise and the city faces more days over 90˚F each year. In addition, elderly residents are more likely to have mobility issues or need assistance, which could complicate evacuations in advance of a storm event.

Consistent with the age demographics of the neighborhood, almost half of Howard Beach households (49%) receive Social Security income and 30% received retirement income. In cases where this is the sole source of income, residents could have a limited ability to handle economic shocks (e.g., climate events).

Fig. 2: Howard Beach Demographics

	HOWARD BEACH		CITYWIDE
Demographic Indicators			
Population	14,700	---	8,175,133
Over 55 years old		35%	23%
White, non-Hispanic		86%	44%
Tenure of 20 years or more		80%	---
English-speaking		90%	71%
Economic Indicators			
Median household income	~$80,000	---	~$51,270
Households receiving Social Security Income		49%	
Employed (active labor force 16+ years old)		93%	
Post-high school education		44%	
Housing Indicators			
Housing units	5.679	---	3,371,062
Median home value	$550,000	---	$514,900
Owner-occupied homes		85%	29%
with mortgages		44%	64%

Source: *American Community Survey (2007-2011), City of New York*

INFRASTRUCTURE

Howard Beach has limited major infrastructure. The A-train stops at the Howard Beach elevated subway station, which connects to the Port Authority's Air Train to JFK Airport. The Belt Parkway, a state-owned major thoroughfare, encompasses the northern boundary of the neighborhood.

In addition, the northern terminus of the Marine Bridge is in Howard Beach—connecting Crossbay Boulevard, the commercial heart of Howard Beach, to the Rockaways. Crossbay Boulevard includes a number of restaurants, event halls, retail stores, hotels and car dealerships. Additional commercial activities are located along 103rd Street and 159th Avenue in Old Howard Beach.

NATURAL ENVIRONMENT

Howard Beach includes a number of natural features. The community is on Jamaica Bay, an 18,000-acre wetland estuary comprising an area almost equal to that of Manhattan. The bay consists of numerous islands, waterways, meadowlands and freshwater ponds and contains parkland managed by the City, the State and the National Park Service. This includes Spring Creek Park and Frank M. Charles Memorial Park, which are located in Howard Beach.

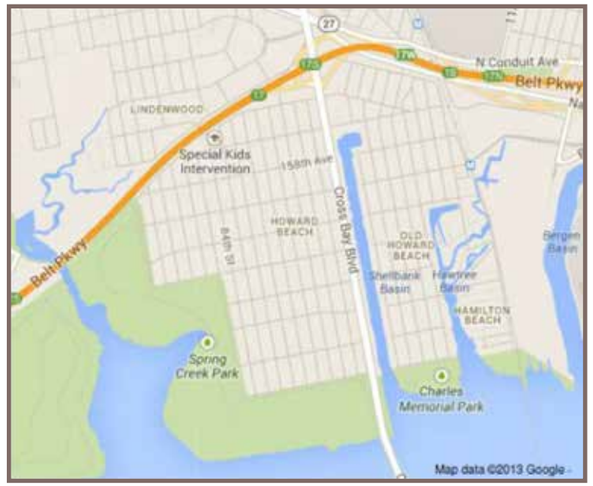
In addition, the neighborhood is intersected by two waterways—Shellbank and Hawtree Basins, which abut numerous commercial and residential properties and are used for recreational boating. These basins, which are defining characteristics of Howard Beach, also present significant flood risks.

As part of this report, the Conservancy evaluated the benefits of existing trees and potential to expand the tree canopy cover in Howard Beach. Trees and vegetated areas can capture stormwater, provide air quality benefits, and help reduce the urban heat island effect.

Almost half of Howard Beach (42%) is covered with impervious surfaces, including roadways, parking lots, buildings, sidewalks and other hard surfaces. This can exacerbate surface flooding from rainfall.

Based on a 2013 Urban Tree Canopy analysis conducted by Davey Resource Group, approximately 8.45% of Howard Beach is covered with tree canopy. Howard Beach's trees are estimated to intercept 13.5 ft3 of stormwater runoff a year (a benefit valued at $380,804).

Shellbank and Hawtree Basins, Howard Beach



Source: Map Data © *2013 Google*

Fig. 3: Tree canopy cover in Howard Beach

Source: *Davey Resource Group*

Land Cover Classification	Urban Tree Canopy Assessment (%)		
	2010	2113	% Change
Tree Canopy	8.81	8.45	-4.09
Impervious Surface	41.76	41.77	0.02
Grass/Open Space	21.73	22.08	1.61
Bare Soils	5.97	5.97	0
Open Water	21.72	21.72	0

Source: *Davey Resource Group*

Fig. 4: Surface conditions in Howard Beach

Opportunities for further planting and recommended species that can tolerate the climate risks facing Howard Beach are discussed in the Appendix. While significant opportunities exist to increase Howard Beach's tree canopy cover—particularly on manufacturing and commercial sites and along residential sidewalks—increasing the neighborhood's tree canopy cover to 10% would have a limited benefit for stormwater management.

Source: *Davey Resource Group*

CLIMATE RISKS

Given its waterfront location, flat topography and existing canals, the most significant climate risks to Howard Beach are coastal flooding and storm surges. A large majority of the neighborhood is located in the FEMA designated 1-in-100 year flood zone (see page 29), and Howard Beach experienced significant damage from Hurricane Irene and Superstorm Sandy (see Fig. 5). During Superstorm Sandy, Howard Beach experienced a peak surge height of 11.2 feet (NAVD).

Source: Howard Beach © *David Shankbone*

According to the Advisory Base Flood Elevation (BFE) Maps (see Fig. 6) issued by FEMA after Sandy, the entire neighborhood—including all buildings and public infrastructure—is likely to be in the 1-in-100 year flood zone when FEMA updates its flood maps for the City (issued in draft form this year). Flood heights associated with the 1-in-100 year event range between 14 feet at the coastline to 10 to 11 feet further inland.

Building codes require new structures built within the 1-in-100 year flood zone to be elevated at least 2 feet above the FEMA designated BFE. This does not apply to existing structures.

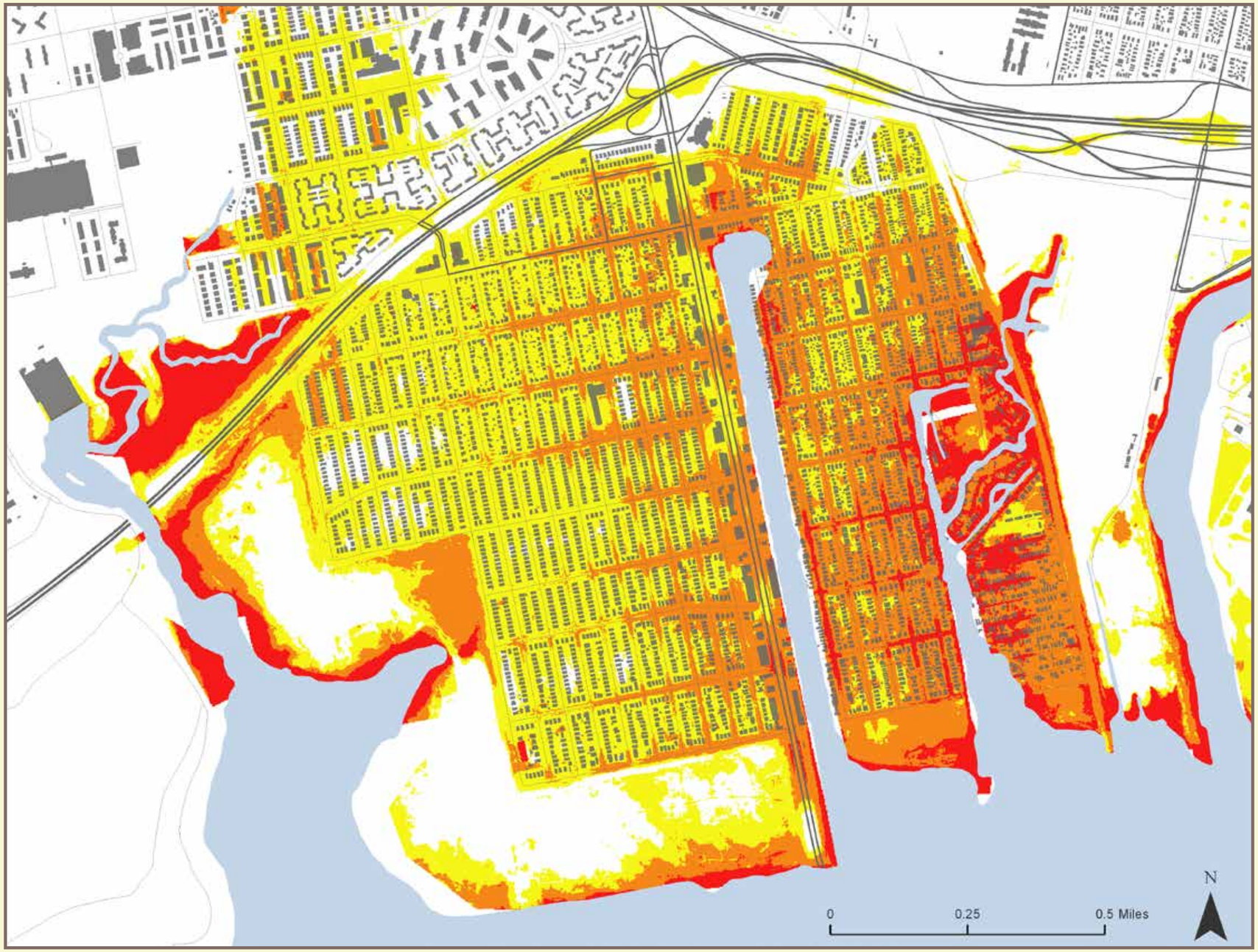
In addition, like many neighborhoods in the city, Howard Beach can experience surface and basement flooding during intense rainfall events.

The neighborhood also faces public health risks from heat waves, which disproportionately impact elderly residents and people with existing health conditions. The NYC Department of Health and Mental Hygiene estimates that the City's mortality and morbidity rates increase 8% on the second consecutive day with temperatures over 90˚F.

Source: Hurricane Sandy Aftermath © *Pamela Andrade*

Source: Hurricane Sandy Aftermath © *Pamela Andrade*

Fig. 5: Water depth at buildings during Superstorm Sandy



Source: *The Nature Conservancy using FEMA Modeling Task Force based on USGS gauge high water marks*

Fig. 6: FEMA Advisory Base Flood Elevation Maps Post-Sandy

Legend

Advisory Base Flood Evaluation Layers

Advisory Zone V-A Boundary
(zoom in to make visible)

Limit of Moderate Wave Action
(LiMWA) (zoom in to make visible)

Advisory Shaded Zone X
(zoom in to make visible)

Advisory Base Flood Evaluation Zones
(zoom in to make visible)

Advisory Zones V and A
(Zoom in to make visible)

A

V

Source: *Federal Emergency Management Agency*

CLIMATE CHANGE

According to the New York City Panel on Climate Change, New York is likely to experience 2 to 3 times more days over 90°F and more frequent and intense rainstorms by the 2050s. Sea levels are projected to rise by 11 to 31 inches (the higher end of the projections representing a "rapid ice melt" scenario)—a critical factor for Howard Beach and other coastal neighborhoods.

If sea levels rise as projected, by the 2050s Howard Beach could be at risk of daily or weekly tidal inundation during non-storm conditions.

As sea levels rise, the probability of a flood event with heights associated with the current 1-in-100 year storm (approximately 10 to 13 feet in Howard Beach) will increase. Thus, the flooding associated with the current 1-in-100 year storm is likely to reoccur, on average, once every 35 to 50 years by the 2050s.

The flood heights associated with a 1-in-100 year storm will also increase as sea levels rise and less intense flooding will occur more frequently as well.

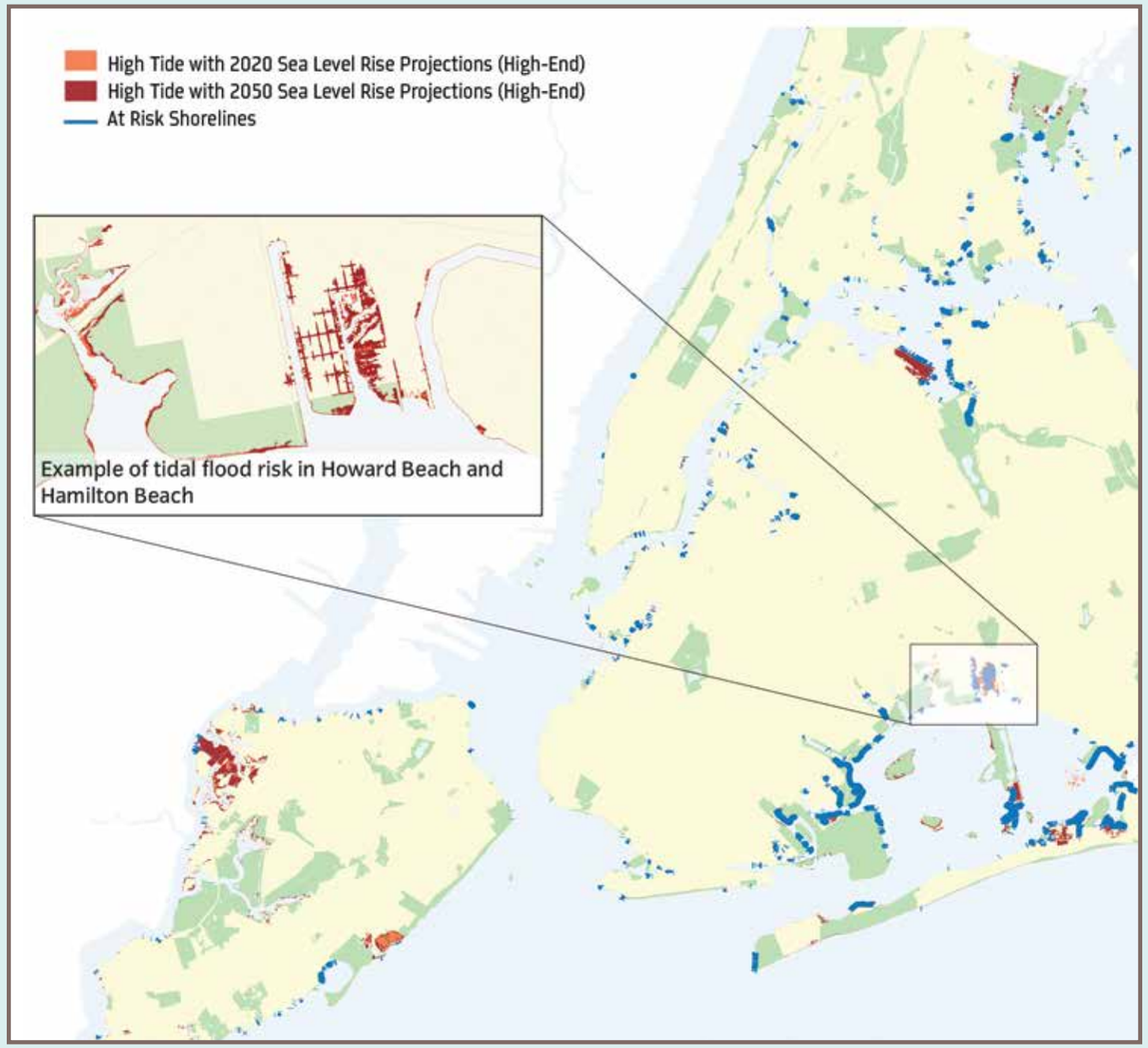
Fig. 7: *NYC Climate Change Projections*

Air temperature Baseline (1971 - 2000) 54°F	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
2020s	+ 1.5°F	+ 2.0°F to + 3.0°F	+ 3.0°F
2050s	+ 3.0°F	+ 4.0°F to + 5.5°F	+ 6.5°F
Precipitation **Baseline (1971 - 2000) 50.1 inches**	**Low-estimate** **(10th percentile)**	**Middle range** **(25th to 75th percentile)**	**High-estimate** **(90th percentile)**
2020s	-1 percent	0 to + 10 percent	+ 10 percent
2050s	1 percent	+ 5 to + 10 percent	+ 15 percent
Sea level rise **Baseline (2000-2004) 0 inches**	**Low-estimate** **(10th percentile)**	**Middle range** **(25th to 75th percentile)**	**High-estimate** **(90th percentile)**
2020s	2 inches	4 to 8 inches	11 inches
2050s	7 inches	11 to 24 inches	31 inches

Based on 35 GCMs (24 for sea level rise) and two Representative Concentration Pathways. Baseline data are from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) United States Historical Climatology Network (USHCN), Version 2 (Menne et al., 2009). Shown are the 10th percentile, 25th percentile, 75th percentile, and 90th percentile 30-year mean values from model-based outcomes.Temperature values are rounded to the nearest 0.5°F, percipitation values are rounded to the nearest 5 percent, and sea level rise values rounded to the nearest inch.

Source: *New York City Panel on Climate Change, 2013: Climate Risk Information 2013: Observations, Climate Change Projections, and Maps*

Fig. 8: Projected Impacts of Sea Level Rise on High Tides



Source: *PlaNYC - A Stronger, More Resilient New York; DCP; NOAA VDATUM for NYC*

To determine the impact of sea level rise on the boundaries and flood depths in the 1-in-25 and 1-in-100 flood zones, the Conservancy engaged CH2M Hill to model projected changes to the FEMA-designated zones.

While this study was undertaken shortly after Superstorm Sandy, the maximum design storm is the 1-in-100 year event with 32 inches of sea level rise. This study was not meant to replicate the Superstorm Sandy surge elevations.

CH2M Hill's modeling approach consisted of the following actions:

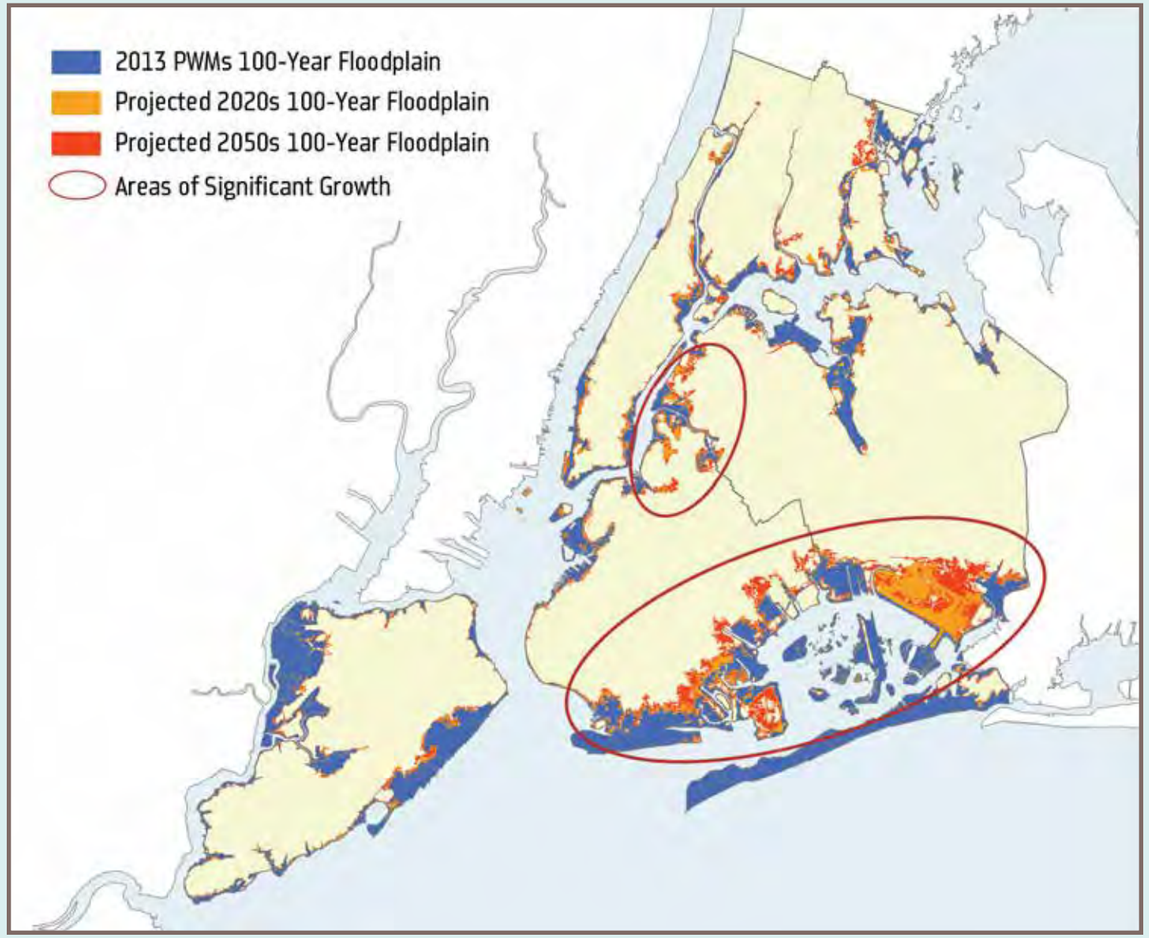
BUILDING THE MODEL (SEE FIG. 10 on pages 34-35)

1. Build a numerical model that includes New York City bathymetry (underwater contours) and Howard Beach site topography.
2. Back-calculate open water storm surge height for 1-in-100 year flood elevations using the Advisory Base Flood Elevations (ABFE) FEMA map from Jamaica Bay and excluding contributions from wind and wave setup and from wave run-up .
3. Develop open-water peak storm surge elevation based on actual storm surge measurements at the Battery and Jamaica Bay scaled to match 100-year storm surge predictions.
4. Estimate 1-in-100 year return period wind from observed wind records at nearby airport weather stations (JFK, La Guardia, Islip).
5. Run hydrodynamic model using MIKE21 HD to determine surge in Jamaica Bay and in front of Howard Beach. Compare results to FEMA surge level predictions (Item 2) to verify model accuracy.
6. Run the ISIS flood model to determine flooding extent and depths at Howard Beach.
7. Compare predicted flood elevations (Item 6) against flood levels given in the ABFE FEMA map to verify model accuracy.

TESTING FLOOD PROTECTION ALTERNATIVES

1. Develop alternatives for flood mitigation.
2. Run scenarios for the flood mitigation alternatives using various storm return periods and the following two sea level rise scenarios from the NPCC 2050 projections:
   - 12-inch sea level rise for the non-ice melt scenario
   - 32-inch sea level rise including rapid ice melt

Fig. 9: Projected 1-in-100 Year Floodplains Due to Sea Level Rise



Source: *PlaNYC - A Stronger, More Resilient New York; DCP; NOAA VDATUM for NYC*

1-IN-10 AND 1-IN-25 YEAR FLOOD EVENTS

The 1-in-10 and 1-in-25 year flood events have little to no impact on structures in Howard Beach, even with 32 inches of sea level rise.

1-in-10 year flood event
(present)

1-in-25 year flood event
(present)

1-in-25 year flood event
(2050, +32 inches of sea level rise)

Source: *CH2M Hill*

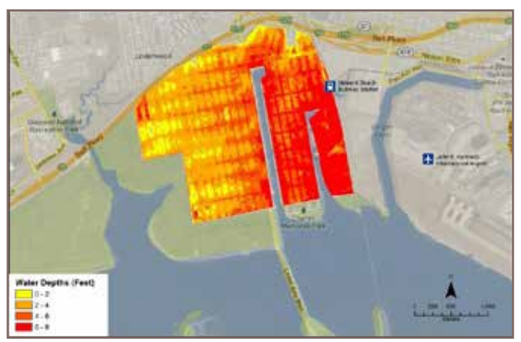
1-IN-100 YEAR FLOOD EVENTS

Under the current 1-in-100 year flood event, an overwhelming majority of Howard Beach is impacted by some level of flooding. Flooding occurs primarily by overtopping of canals and the Spring Creek Park marsh.

An addition of 12 inches of sea level rise would result in additional flooding in the southwest of Howard Beach. Thirty-two inches of sea level rise would impact the entire neighborhood as coastal flooding overtops the entire perimeter.

1-in-100 year flood event
(present)

1-in-100 year flood event
(2050, +12 inches of sea level rise)



1-in-100 year flood event
(2050, +32 inches of sea level rise)

Source: *CH2M Hill*

RESILIENCE ALTERNATIVES

The Conservancy was asked by the City to develop a suite of resilience strategies to mitigate current and future climate risks to Howard Beach, with an emphasis on coastal flooding. The Conservancy was engaged due to our experience with natural infrastructure, which was seen as having cost savings over built infrastructure and significant co-benefits to the community. In mitigating flood risks, particular attention was paid to wave action on the coastline and strategies to dampen wave action before it reaches coastal defenses or structures.

Source: Hurricane Sandy Aftermath © *Pamela Andrade*

DEVELOPING THE RESILIENCE ALTERNATIVES

To develop alternative strategies, the Conservancy hosted a charrette with CH2M Hill and various City agencies to identify flood risks and potential risk mitigation strategies. These strategies were compiled into four suites of interventions ("alternatives") to represent two natural infrastructure-only alternatives and two alternatives that include natural and built infrastructure (see page 28).

The natural infrastructure utilized in the alternatives include:

- dunes and berms
- marshes
- edges hardened with ribbed mussel toes
- rock groins and breakwaters
- artificial islands/wetlands

The alternatives integrating built infrastructure include:

- removable flood walls
- operable flood gates

Coastal protection elements were sited in Howard Beach based on site topography and geometry, direction of incoming wind and wave action, and the location of the study area within Jamaica Bay.

These alternatives do not represent the only strategies or suites of strategies that could increase the resilience of Howard Beach. Rather, they represent a first attempt to create a suite of comprehensive coastal protection options for an urban neighborhood that enables the City and the Conservancy to understand the costs and benefits of coastal protection utilizing natural and built infrastructure. Actionable strategies require further analysis and modeling and could include a mix of strategies from each alternative or other options.

The alternatives developed through the charrette were modeled against the 1-in-100 year storm to determine their ability to reduce flood risks as compared to current conditions in Howard Beach ("base case"). Alternatives 3 and 4 were further modeled to estimate how they would perform with 12 and 32 inches of sea level rise (see Fig. 13). Alternatives 1 and 2 were not modeled for sea level rise as they failed to reduce risks under current flooding conditions.

While it could be possible to reduce flood risks for Howard Beach using only built infrastructure, integrating natural infrastructure into coastal defenses can provide three types of benefits:

1. **Substitution value** where substituting natural for built infrastructure reduces capital costs (CapEx). Operating costs may increase, decrease or remain the same.
2. **Integration value** where integrating natural infrastructure into built infrastructure produces operation savings (OpEx). Capital costs may increase, decrease, or remain the same.
3. **Complementary value** where utilizing natural infrastructure produces additional, complementary benefits, e.g., increased property values (revenues). Capital and operating costs may increase, decrease, or remain the same.

Alternatives 3 and 4 include both natural and built infrastructure. The natural infrastructure elements of these alternatives (ribbed mussel hard toe and wetlands) are likely to lengthen the useful life of Spring Creek Park and its protective berms through the reduction of wave energy and erosion. This would reduce long-term capital and maintenance costs (substitution and integration value). In addition, having properties adjacent to parkland as opposed to sea walls is likely to increase in property values (complementary value).

Unfortunately, given the short duration of this project, we were unable to calculate the exact value of these benefits or to include a comparison of operating costs between natural and built infrastructure elements (e.g., maintaining a sea wall vs. a wetland). A logical next step is to complete this analysis to determine the life cycle value of an integrated approach and the difference in costs and benefits between a grey-only and a hybrid strategy.

Alternative 1:

Natural infrastructure (shoreline)

Elements:

- +14' NAVD berms, restored marsh and ribbed mussel hard toe in Spring Creek Park;
- rock groin at Charles Memorial Park;
- breakwater at entrance to Shellbank Basin.

Source: *CH2M Hill*

Source: *CH2M Hill*

Alternative 2:

Natural infrastructure (wetlands)

Elements:

- +14' NAVD berms, restored marsh and ribbed mussel hard toe in Spring Creek Park;
- restored and new marsh in Jamaica Bay.

Alternative 3:

Hybrid with removable walls

Elements:

- +14' NAVD berms, restored marsh and ribbed mussel hard toe in Spring Creek Park;
- berm and rock groins at Charles Memorial Park;
- removable flood walls along Crossbay Boulevard, Shellbank Basin, west side of Hawtree Basin and portions of the Belt Parkway.

Source: *CH2M Hill*

Source: *CH2M Hill*

Alternative 4:

Hybrid with operable flood gates

Elements:

- +14' NAVD berms, restored marsh and ribbed mussel hard toe in Spring Creek Park;
- berm and rock groins at Charles Memorial Park;
- movable flood gates at entrances to Shellbank and Hawtree Basins;
- berm at parkland in Hamilton Beach.

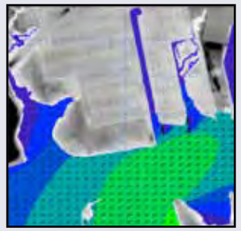
MODELING METHODOLOGIES

CH2M Hill used base maps by and produced map imagery with ESRI ArcGIS Online. Storm surge scenario results were created using USEPA HAZUS and DHI MIKE software. Each alternative was incorporated into the hydrodynamic model prepared for Howard Beach (using Mike 21 HD). Surge elevations were developed for each design storm (1-in-10, 25 and 100 year storms) to predict flood elevations within the site (using Halcrow ISIS). Based on these flood elevations, damage estimates were developed for each flood scenario (using FEMA HAZUS MH-2.1).

CH2M Hill developed construction cost estimates for each alternative and compared capital costs to avoided damage to generate an initial (and admittedly incomplete) cost/benefit ratio for each alternative.

Fig. 10

Hydrological Modeling



- Storm surge
- Wave/wind calculations
- Water depths
- Bathymetry
- Topography
- Develop hydrodynamic characteristics of 1-in-100 year storm
- Apply hydrodynamic input to alternatives

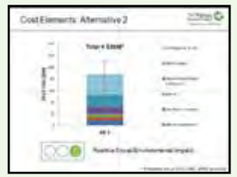
Water Depth Flood Analysis

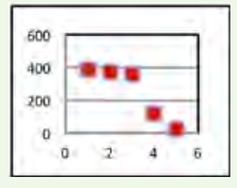
- Develop extent of coastal flooding & upland flood depths

Demographic & Economic Losses

- 2000 Census
- Building inventory
- Physical damage
- Economic loss
- Social impact

Cost/Benefit Analysis





- Cost estimates
- Cost benefits
- Avoided cost
- Economic analysis

Source: *CH2M Hill, The Nature Conservancy*

COST/BENEFIT ANALYSIS METHODOLOGY

The purpose of this cost/benefit analysis is to use the best available secondary data sources to provide a high-level assessment of the economic costs and benefits associated with prioritized scenarios.

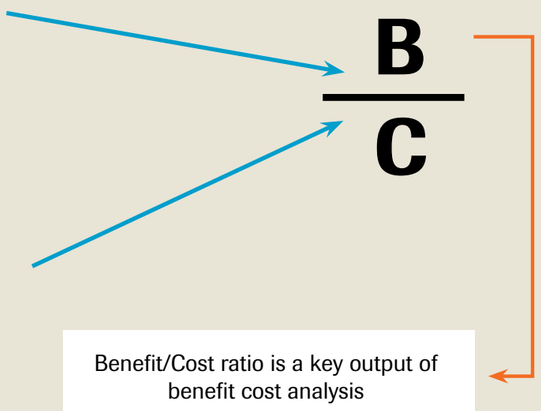
Economic cost data associated with infrastructure scenarios have been derived from industry best practices and real-world CH2M Hill project experience. Avoided costs (benefits) associated with flood damage were derived from Hazus MH-2.1—FEMA's GIS-based, Multi-hazard Risk Assessment Program for Analyzing Potential Losses due to Disasters.

This analysis contains several data limitations and assumptions, including:

- Business interruption costs are included in Hazus MH-2.1, but other indirect economic losses are not.
- Transportation and utility damages are not quantified in Hazus, but qualitative impacts have been assessed using external data.
- Limited Operations and Maintenance (O&M) costs of the alternatives are included.
- Impacts of all alternatives on JFK Airport were evaluated and have a negligible impact on the facility. Broader regional impacts of flood mitigation strategies were not considered.
- Some environmental and social costs and benefits of alternatives are not quantified, such as the environmental impacts of Alternative 4.
- Operations and Maintenance (O&M) costs were obtained from CH2M Hill and the City of New York *(see Fig. 11)*.
- Ecosystem services benefits were derived from secondary literature using benefit-transfer techniques *(see Fig. 12)*.

BENEFITS
- Avoided damages compared to base case damages
- Hazus MH-2.1 currently underestimates damages (e.g., no utilities, transportation economic impacts)
- Ecosystem services benefits from benefit-transfer of secondary literature

COSTS
- Parametric estimates based on CH2M Hill cost estimating database
- ± 30% precision (similar to Level 4, 5 estimate)
- M&O costs based on estimates from the City of New York and experts



Benefit/Cost ratio is a key output of benefit cost analysis

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Source
Inspections	$17,500	$15,750	$47,250	$29,750	CH2M Hill
Closure Actions	-	-	$510,000	$510,000	CH2M Hill
Wetland Maintenance	$227,200	$536,000	$227,200	$227,200	City of New York
Mussel Bed Maintenance	$110,193	$220,386	$110,193	$110,193	City of New York
Beach Maintenance	$18,400	-	$18,400	$18,400	City of New York
Total Annual O&M Cost	**$373,293**	**$ 772,136**	**$913,043**	**$895,543**	

Source: *CH2M Hill*

ANNUAL ECOSYSTEM SERVICES BENEFITS

To estimate annual economic benefits for ecosystem goods and services associated with each alternative, we use benefits-transfer methodology. Benefits transfer uses economic data taken from the secondary peer-reviewed literature to make inferences about the economic benefits at another similar location.

Estimates for "Restored Saltwater Wetland" (Marsh), "Beach", and "Nearshore Habitat" associated with mussel beds were drawn from 17 peer-reviewed studies reported in the 2004 technical report: *Ecological Economic Evaluation, Maury Island,* King County Washington.

Economic values were updated and converted to 2013 $USD and standardized to acres for consistency. Benefits from the natural infrastructure analyzed in this report include access to recreation and open space, water regulation and waste assimilation.

Fig. 12: *Annual Ecosystem Services Benefits (ESB)*

	Restored Marsh (acres)	ESB per Acre	ESB	Beach (acres)	ESB per Acre	ESB	Mussel Beds (acres)	ESB per Acre	ESB	Total
Alt 1	142	$755	$107,245	11.5	$47,137	$542,077	1.5	$8,701	$12,785	**$662,106**
Alt 2	335	$755	$253,006	0	$47,137	---	2.9	$8,701	$25,570	**$278,576**
Alt 3	142	$755	$107,245	11.5	$47,137	$542,077	1.5	$8,701	$12,785	**$662,106**
Alt 4	142	$755	$107,245	11.5	$47,137	$542,077	1.5	$8,701	$12,785	**$662,106**

Estimates are in 2013 USD; Adapted from *Ecological Economic Evaluation*, Maury Island, King County Washington 2004 http://your.kingcounty.gov/dnrp/library/2004/kcr982/MauryEcoReport.PDF. See appendix for further details.

Source: *CH2M Hill*

SCENARIO SELECTION

The base case (existing) scenario was analyzed for the full range of conditions: —a 10-year, 25-year and 100-year storm with no ice melt, with 12 inches of sea level rise, and with 32 inches of sea level rise.

In addition, each alternative was evaluated for the current 1-in-100 year storm (with no sea level rise). Since Alternatives 1 and 2 were found to be largely ineffectual in preventing flooding in the current condition, there was no need to evaluate them for more sea level rise. Only Alternatives 3 and 4 were analyzed with sea level rise to determine the level of protection they would provide.

Fig. 13: *Scenarios Evaluated*

	Current Conditions			No Ice Melt (NIM) +12 inches sea level rise			Rapid Ice Melt (RIM) +32 inches sea level rise		
	10yr Storm	25yr Storm	100yr Storm	10yr Storm	25yr Storm	100yr Storm	10yr Storm	25yr Storm	100yr Storm
Base Case	✔	✔	✔	✔	✔	✔	✔	✔	✔
Alt 1			✔						
Alt 2			✔						
Alt 3			✔			✔			✔
Alt 4			✔			✔			✔

Varying storm type and sea level rise allows us to begin to understand how climate change will affect choice of alternatives

Source: *CH2M Hill*

Holding storm type and sea level constant allows us to compare performance of alternatives relative to the base case

Fig. 13: Summary of direct economic losses (in millions) for each scenario*

	Current Conditions			No Ice Melt (NIM) +12 inches sea level rise			Rapid Ice Melt (RIM) +32 inches sea level rise		
	10yr Storm	25yr Storm	100yr Storm	10yr Storm	25yr Storm	100yr Storm	10yr Storm	25yr Storm	100yr Storm
Base Case	$29	$30	$494	$35	$35	$590	$41	$41	$1,000
Alt 1			$465						
Alt 2			$462						
Alt 3			$146			$162			$956
Alt 4			$28			$162			$956

Notes* *Includes losses from buildings, business interruption and vehicles* | **Source:** *HAZUS MH 2.1 in 2013 dollars*

Notes

- From a strictly economic point of view (with data limitations), Alternative 4 appears to perform best, but Alternative 3 also results in a significant net-positive economic impact.
- Internalizing broader social and environmental impacts of Alternative 4 (i.e., negative impacts on water quality) may shift this conclusion, but further research is needed.
- Pure natural infrastructure solutions—Alternative 1 and Alternative 2—do not appear to result in net-positive economic impacts at this scale.

{ BASE SCENARIO }

1-IN-100 YEAR FLOOD (PRESENT)

Source: *CH2M Hill*

Economic Losses

Building Damage	$453 M
Business Interruption	$2 M
Vehicle Losses	$39 M
Total Damage	**$494 M**

Debris

Tons	23,490
Truckloads	940

Displacement

Households displaced	4,900
Individuals displaced	14,500

{ ALTERNATIVE 1 }

Natural infrastructure (shoreline)

Costs*

Construction costs	$23.9 M
30% contingency	$9.7 M
25% profit & overhead	$6.2 M
Total Capital Cost	**$40.1 M**
Annual O&M Costs	**$373 K**

** Estimates are in 2013 USD, ±30%*

- **Restored marsh** – *onshore (142 acres)*
- **Ribbed mussel hard toe** *(2,700 cubic yards)*
- **Berms in marshland +14 ft** *(NAVD) (5,400 ft)*
  - Tie into existing high land, not continuous
- **Restored Charles Memorial Park Beach** *(11 acres)*
- **Rock breakwater** *(600 ft)*
- **2 rock groins at new beach** *(700 ft)*

Source: *CH2M Hill*

{ ALTERNATIVE 1 }

Natural infrastructure (shoreline)

Costs*

Construction costs	$23.9 M
30% contingency	$9.7 M
25% profit & overhead	$6.2 M
Total Capital Cost	**$40.1 M**
Annual O&M Costs	**$373 K**

Economic Losses

Building Damage	$426 M
Business Interruption	$1.5 M
Vehicle Losses	$37 M
Total Damage	**$465 M**
Avoided loss	**$29 M**

Debris

Tons	22,531
Truckloads	901
Avoided truckloads	29

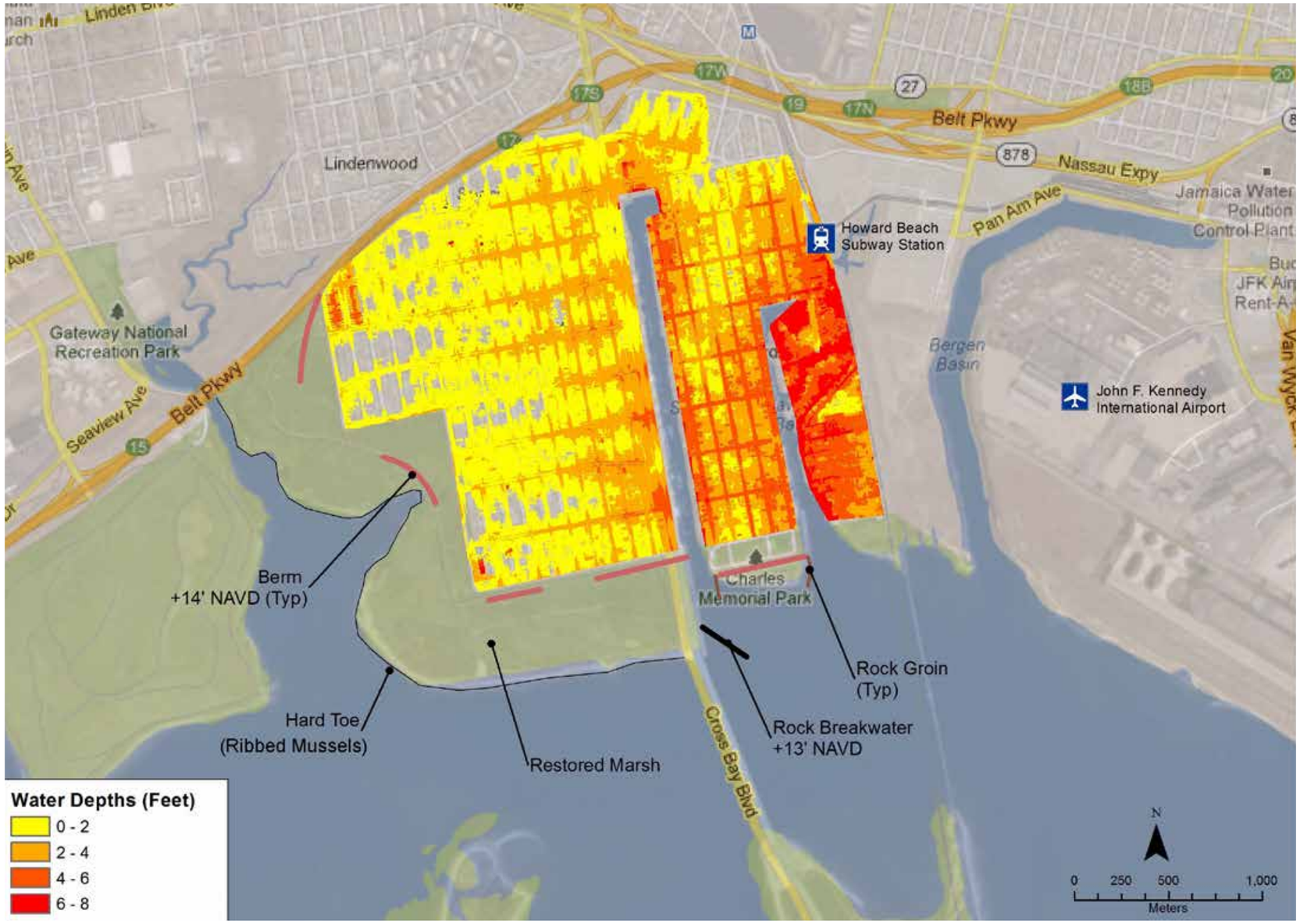
Displacement

Households displaced	4,875
Individuals displaced	14,439
Avoided displacement	25 HH
Annual Ecosystem	**$662 K**

Services Benefits

** Estimates are in 2013 USD, ±30%*

1-IN-100 YEAR FLOOD (PRESENT)



Source: *CH2M Hill*