NEW YORK STATE GOVERNOR'S OFFICE OF STORM RECOVERY

LIVING BREAKWATERS

BENEFIT COST ANALYSIS

MARCH 24, 2021

wsp

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NEW YORK STATE GOVERNOR’S OFFICE OF STORM RECOVERY

PROJECT NO.: LSC2043436.07LSC2043436.07LSC2043436.07
DATE: MARCH 2021

WSP USA SOLUTIONS, INC.

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1 EXECUTIVE SUMMARY

This benefit cost analysis (BCA) was prepared for the Living Breakwaters: Tottenville Pilot Rebuild by Design Project (Living Breakwaters or the Project) by WSP USA Solutions, Inc (WSP) on behalf of the Gove
of Storm Recovery (GOSR). The Project is located in the waters of Raritan Bay (Lower New York Harbor) along the shoreline of Staten Island, extending from Tottenville and Conference House Park, from Wards Point in the Southwest to Butler Manor Woods in the Northeast (**Figure ES-1**).

The BCA is an update of the original BCA report prepared by WSP (formerly Louis Berger, U.S.), dated January 17, 2017. This update reflects the most recent infomation about the Project elements and design, costs, and benefits. As the previous BCA, this BCA was prepared following US Department of Housing and Urban Development (HUD) BCA Guidance for Action Plan Amendments (APA) for Rebuild by Design (RBD) Projects (HUD CPD-16-06). The analysis uses generally accepted economic and financial principles for BCA as articulated in the federal Office of Management and Budget (OMB) Circular A-94.

The Project has the following elements:

- A system of specially designed breakwaters and physical habitat enhancements on the breakwater system, including shellfish (oyster) restoration on the breakwaters, along with a short segment of shoreline restoration (one-time sand placement at the existing beach).
- Oyster cultivation and activities supporting oyster restoration, including: oyster cultivation (hatchery expansion, remote setting facility, etc.), shell collection and curing, and the installation of oysters on the breakwaters in addition to oyster nurseries in Lemon Creek and Great Kills Harbor that create and enhance ecological connectivity across sites for oyster larvae and mobile species (fish, crabs, etc.) that inhabit them.
- Programming including educational, stewardship, and capacity-building activities related to the breakwaters.

The Project is designed to (1) reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville, Staten Island; (2) enhance habitat functions and values supporting local ecosystems through the creation and improvement of nearshore and coastal habitat; and (3) foster stewardship and recreational and educational use of the coast and near shore, through increased awareness, access, and participation.

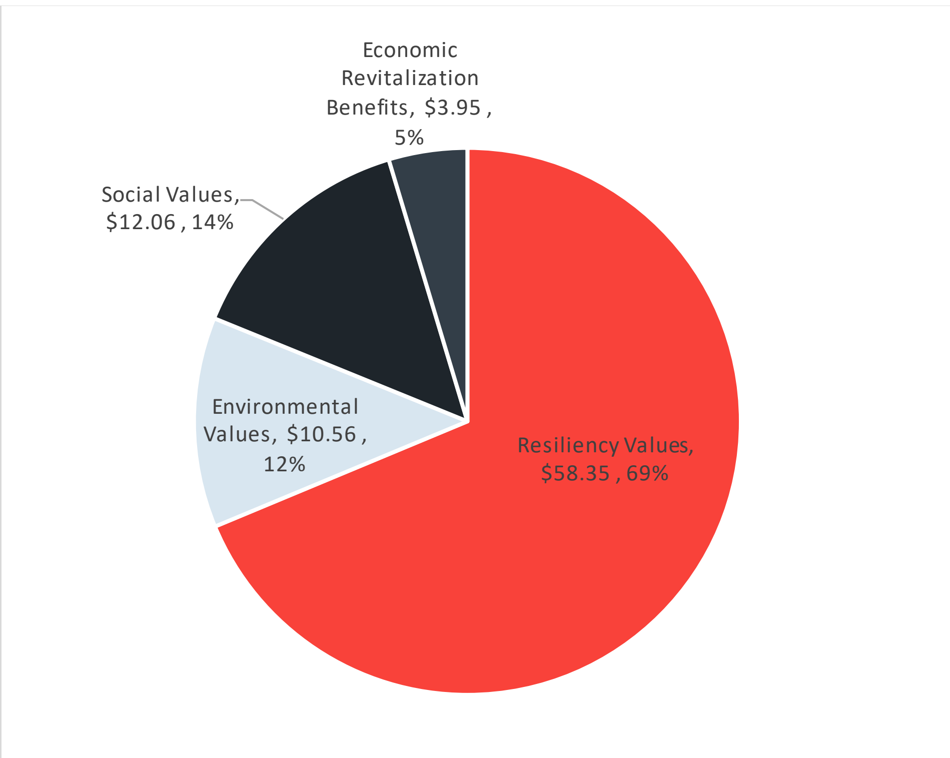
The BCA indicates that the Project will generate substantial net benefits (i.e., the benefits exceed the costs over the life of the Project) to the shoreline community of Tottenville, Staten Island, New York, as well as other beneficiaries from the New York metropolitan region.

Figure ES-1: Living Breakwaters: Tottenville Pilot Rebuild by Design Project Illustration

The BCA considers the Project cost and benefits that are expected to occur during the 50-year evaluation period. Following HUD guidance, the BCA applies a 7 percent discount rate to determine the present value of future cost and benefit streams. The present value of the Project's lifecycle cost, which includes upfront capital cost and annual operation and monitoring cost during the evaluation period, was estimated as $82.7 million. The present value of the Project's benefits over the evaluation period was estimated as $84.9 million. As shown in Figure **ES-2**, the benefits include:

- $58.3 million resiliency values;
- $10.6 million environmental values;
- $12.1 million social values; and
- $3.9 million economic revitalization benefits.

Figure ES-2: Project Benefits: Cumulative Present Values (2020-2070, 7 percent discount rate)



Based on a 7 percent discount rate, the present value of the Project's net benefits (benefits minus costs) is $2.2 million, and the benefit cost ratio (BCR) (benefits divided by costs) is 1.03 (**Table ES-1**). These net benefits demonstrate that the Project has merit and would add value to the community of Tottenville and provide benefits to other beneficiaries throughout the New York metropolitan region.

The Project's future annual benefit and cost streams [illegible] tested how changes in assumptions would alter the economic feasibility of the Project, measured by the BCR and the net present value. The sensitivity analysis shows that, with a 3 percent discount rate, the present value of the Project's [illegible] $5[illegible]0 million, and the BCR is 1.54. The sensitivity analysis also examined potential construction cost overruns and changes in operation and maintenance (O&M) cost as well as substantial reductions in the largest benefit category [illegible] present value of benefits. The Project is robust with a 3 [illegible] percent discount rate and can withstand these standard stress factors given the uncertainties that may arise, and it would remain economically viable over this period.

Table ES-1: Living Breakwaters—Benefit Cost Analysis Summary

	7%	3%
LIFECYCLE COSTS		
Project Investment Costs	$78,280,740	$85,608,660
Operations & Maintenance	$4,379,303	$7,428,897
Total Costs	**$82,660,043**	**$93,037,558**
BENEFITS		
Resiliency Values	**$58,345,852**	**$89,841,035**
Avoided Property Damages	$3,446,874	$7,277,180
Avoided Casualties (Mortality & Injuries)	$3,262,364	$6,567,390
Avoided Mental Health Treatment Costs	$561,915	$1,131,178
Avoided Lost Productivity Costs	$1,259,875	$2,536,225
Avoided shoreline erosion/dune reconstruction costs	$47,450,148	$67,555,200
Avoided displacement/disruption costs	$266,448	$542,491
Avoided Road Closure/Travel Disruption costs	$323,207	$650,640
Avoided Cost of Power Outages	$1,159,383	$2,333,927
Avoided Automobile Damages	$77,179	$167,266
Avoided Debris	$6,850	$14,512
Avoided Emergency Repairs	$22,078	$47,813
Avoided Damages to Parks and Utilities	$509,532	$1,017,212
Environmental Values	**$10,557,255**	**$21,481,453**
Total Gross Ecosystem Annual Service Gains (+)	$10,723,747	$21,809,222
Total Ecosystem Annual Services Displaced (-)	$166,492	$327,769
Net Ecosystem Annual Service Gains	$10,557,255	$21,481,453
Social Values	**$12,057,887**	**$23,832,401**
Educational/Environmental Stewardship	$322,966	$405,211
Recreation	$11,734,921	$23,427,190
Economic Revitalization Benefits	**$3,946,572**	**$7,878,799**
Property Value Impacts (∫[Distance and Beach Width])	$3,946,572	$7,878,799
Total Benefits	**$84,907,565**	**$143,033,689**
NET BENEFITS	**$2,247,522**	**$49,996,131**
Benefit-Cost Ratio	**1.03**	**1.54**

2 INTRODUCTION

The Rebuild by Design Living Breakwaters Project (Living Breakwaters or the Project) benefit cost analysis (BCA) was completed by applying procedures described in the US Department of Housing and Urban Development (HUD) guidance document CPD-16-06 for Rebuild by Design (RBD) projects. The analysis is also consistent with procedures and principles found in OMB Circular A-94. The analysis follows the "with and without project" evaluation framework that is used to isolate the net benefits of the intervention.

2.1 FUTURE "WITH PROJECT" SCENARIO

In the Future "With Project," the Project would be constructed, consisting of the following elements:

- A system of specially designed breakwaters and physical habitat enhancements on the breakwater system, including shellfish (oyster) restoration on the breakwaters, along with a short segment of shoreline restoration (one-time sand placement at the existing beach).
- Oyster cultivation and activities supporting oyster restoration, including: oyster cultivation (hatchery expansion, remote setting facility, etc.), shell collection and curing, and the installation of oysters on the breakwaters in addition to oyster nurseries in Lemon Creek and Great Kills Harbor that create and enhance ecological connectivity across sites for oyster larvae and mobile species (fish, crabs, etc.) that inhabit them.
- Additional programming including educational, stewardship, and capacity-building activities related to the above through the Billion Oysters Project.

Components of the Project include a system of off-shore breakwaters engineered to provide maximum habitat and ecological restoration opportunities. In this scenario, the Project will:

- Reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville;
- Enhance habitat functions and values supporting local ecosystems through the creation and improvement of nearshore and coastal habitat; and
- Foster stewardship and recreational and educational use of the coast and nearshore through increased awareness, access, and participation.

2.2 FUTURE "WITHOUT PROJECT" SCENARIO

In the Future "Without Project" Scenario, the Project would not be built. If the Project is not constructed, the Tottenville shoreline would continue to be at increased risk of continued erosion, and shoreline communities would face the risk of damaging storm waves, as experienced during Superstorm Sandy. Without the construction of the Project, the community may continue to lose parkland and other open spaces and natural resources, and residents will continue to face the risk of bodily injury, loss of life, loss of property and damage to public infrastructure. These cumulative impacts would have a negative effect on the health and productivity of residents and the economy.

The aquatic habitat of the bay adjacent to Tottenville would remain in its current state, characterized by a sand/gravel bottom condition with limited structured habitat to support the variety of fish, crustaceans, bivalves, and other benthic invertebrates identified as a priority in the Hudson Raritan Estuary comprehensive restoration plan. Shoreline habitat would remain subject to the disturbance and erosion effects of high-energy wave action during severe storms not attenuated by the Project.

Educational programming in Conference House Park and the Billion Oyster Project programming in Staten Island would remain.

2.3 KEY ANALYSIS ASPECTS

The BCA quantifies lifecycle cost and risk reduction benefits (resiliency values), environmental values, social values, and economic revitalization values that would be generated by the Project per HUD guidelines. Details on these categories of benefits are provided in the following section. An overview of wave impact and attenuation performance data used for the BCA is included in Appendix A.

The BCA uses a 50-year evaluation time horizon and a 7 percent discount rate as recommended by HUD and per OMB guidelines. The BCA also includes a sensitivity analysis that assesses the effect of changes in key assumptions on the Project. As part of the sensitivity analysis, the net benefits were calculated using the 3 percent discount rate that is often applied in studies valuing environmental and ecosystem benefits (Freeman, 1999).

The analysis includes valuations based on physical point estimate quantities for projected habitats that provide ecosystem services and values obtained from peer-reviewed literature that have been applied to value these resources using benefits-transfer techniques. The Federal Emergency Management Agency (FEMA) has applied similar methods to value ecosystem services for environmental infrastructure projects or projects that remove obstructions to watersheds and floodplains to restore ecosystem services (FEMA, 2013).

2.4 PROCESS FOR PREPARING BENEFIT COST ANALYSIS

The BCA was prepared by WSP. This BCA is an update of the 2017 BCA, which was also prepared by WSP, and uses the methodologies and assumptions from the 2017 BCA as applicable. As with the 2017 BCA, this BCA relied on inputs, data, and information from GOSR; the Living Breakwaters design team, including SCAPE Landscape Architecture, Ocean and Coastal Consultants COWI, WSP, the NY Harbor Foundation, MFS Engineers & Surveyors, and Arcadis; and GOSRôs consultant preparing the environ In addition, WSP applied its own research findings, collective multidisciplinary expertise, experience, and professional judgment in completing the BCA on behalf of the State of New York.

2.5 PROPOSED FUNDED PROJECT

The integrated purposes of the Living Breakwaters Project are threefold:

(1) to reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville;
(2) to enhance habitat functions and values supporting local ecosystems through the creation and improvement of nearshore and coastal habitat; and
(3) to foster stewardship and recreational and educational use of the coast and nearshore through increased awareness, access, and participation.

The Project is an innovative coastal green infrastructure project that aims to increase physical, ecological, and social resilience. The Project is located in the waters of Raritan Bay (Lower New York Harbor) along the shoreline of Staten Island. The affected shoreline extends from Tottenville and Conference House Park, from Wards Point in the Southwest to Butler Manor Woods in the Northeast. The Project area is a shallow estuary that has historically supported commercial fisheries and shell fisheries, and it consists of the following main elements (Final Design Drawings, SCAPE, 2020, Modeling Report, SCAPE, 2016):

(1) A system of engineered breakwaters and physical habitat enhancements on the breakwater system, including shellfish (oyster) restoration on the breakwaters, along with a short segment of shoreline restoration (one-time sand placement at the existing beach);
(2) Oyster cultivation and activities supporting oyster restoration including: oyster cultivation (hatchery expansion, remote setting facility, etc.), shell collection and curing, and the installation of oysters on the breakwaters in addition to oyster nurseries in Lemon Creek and Great Kills Harbor that create and

enhance ecological connectivity across sites for oyster larvae and mobile species (fish, crabs, etc.) that inhabit them; and

(3) Programming including educational, stewardship, and capacity-building activities related to the above.

2.6 PROJECT SCHEDULE

Project construction is anticipated to start during the third quarter of 2021 and to be complete between the end of 2023 and the end of 2024. For the BCA, it was assumed that construction would be completed mid-2024. This period factors in fish and crab spawning months that may prevent certain construction activities from occurring during specific times of the year and is consistent with conservative economic modelling principles applied in BCA.

2.7 FULL PROJECT COST

The upfront Project costs are estimated to be $92 million (in 2020$). This includes the engineer's cost estimate developed as part of the 100 percent design for the breakwater construction and shoreline restoration and a construction contingency as well as the most up-to-date estimates of the following costs provided by GOSR: design, environmental review, program administration, construction management, oyster restoration, and educational programming. In addition, monitoring of the structural performance, functional performance, and biological function will occur throughout the Project life.

2.8 CURRENT SITUATION AND PROBLEM TO BE SOLVED

The need for enhanced erosion protection, wave attenuation, and social resiliency was demonstrated during the severe storm events of 2011 and 2012 (including Superstorm Sandy in 2012) when the Tottenville community experienced severe damage from storm waves. In addition to storm events, the shoreline has experienced ongoing erosion over the last 35 years. While shoreline change patterns oscillate between erosion and accretion, most of the shoreline in the Project area has experienced erosion. In many locations, erosion rates average over 1 foot per year and, in one section of the Conference House Park shoreline, the average rate of erosion is 3 feet per year. To put these rates into context, **Figure 2-1** depicts the historic shoreline change in part of the Project area over the past 35 years.

Figure 2-1: Historic long-term shoreline change

Source: Modeling Report SCAPE 2016

The need for habitat enhancement within Raritan Bay has been well documented through ecological assessments and reports including *National Marine Fisheries Service Raritan Bay* habitat evaluations and the *New York State Department of Environmental Conservation Shellfish Assessments* developed for the Food and Drug Administration in support of their northern quahog (*Mercenaria mercenaria*) fishery and the *New York ï New Jersey Comprehensive Restoration Plan for New York Harbor* (HRE-CRP).

The Project is taking a thematically and spatially layered approach to reducing coastal risk, restoring and enhancing habitats important to local ecosystems, improving water access, and engaging with residents through community and educational programs directly related to the Projectôs coastal and ecological resilie Project is consistent with New York Cityôs Coastal Protection In as well as the HRE-CRP. The efforts and objectives were guided by the harbor-wide assessment of habitats and their functions and values used in the drafting of the *Comprehensive Restoration Plan* (Modeling Report, SCAPE, 2016; Bain et al., 2006: USACE, 2009).

2.9 RISKS FACING PROJECT AREA COMMUNITY

Without the Project, the Tottenville community would continue to face risks associated with the ongoing erosion of shoreline, vulnerability to unbridled wave action and destructive wave energy, and ongoing susceptibility to future damages and social dislocations. These types of impacts were experienced and most noticeable during the severe storm events of 2011 and 2012 (including Superstorm Sandy) when the Tottenville community experienced severe damage from storm waves. However, it is apparent that, without the Project, ongoing ch shoreline will affect quality of life going forward. In addition to storm events, the shoreline has experienced ongoing erosion over the last 35 years at rates depicted in **Figure 2-1**. While shoreline change patterns oscillate between erosion and accretion, most of the shoreline in the Project area has experienced erosion. If unaddressed, these erosion patterns can alter the character of the community and generate ongoing costly maintenance and restoration activities in the future. Narrower beaches mean decreased protection from wave action, greater exposure of shoreline features such as dunes to erosion, and loss of important shoreline public space. In fact, some segments of the Tottenville beach are not accessible at high tide, and with the current rates of erosion and sea level rise (SLR), the extent of these zones will only increase.

3 BENEFITS AND COSTS

3.1 LIFECYCLE COSTS

The Project's lifecycle costs include Project investment costs (upfront capital construction costs), periodic monitoring costs, and annually recurring operating costs for educational programs.

The total Project investment costs are estimated to be $92 million (in 2020$). **Table 3-1** shows the breakdown of the investment costs into construction cost, which includes breakwater construction, shoreline restoration, and general conditions; construction contingency; design; environmental review; program administration; construction management; oyster restoration; and educational programming.

Project construction costs are obtained from the engineer estimate for the value engineering, which took place after the 100 percent design was complete (2020) and the construction contractor bid. A contingency of 3 percent of the total construction cost was included. Project investment costs for the oyster restoration were obtained from the Billion Oyster Project (2020). Costs for other items are current estimates based on project stage and budget expended to date and were obtained from GOSR.

Table 3-1: Project Investment Cost (in 2020$)

	COST
Design	$8,300,000
Environmental Review	$2,911,424
General Construction Bid	$67,497,131
Construction Contingency	$2,024,914
Construction Management	$3,900,000
Oyster Installation	$3,000,000
Education	$2,147,965
Program Administration	$2,100,000
Total	**$91,881,434**

Source: Living Breakwaters Engineer's Estimate (2020); Billion Oyster Project (2020); GOSR (2021)

Once installed, the breakwaters will require periodic monitoring. Project monitoring costs include the costs associated with functional, structural, and biological monitoring. Periodic monitoring cost estimates by year were obtained from the design team (SCAPE) and permitting team (AKRF). NYSDEC, per the Project's operation and maintenance manual (COWI, 2020) approved by the permitting agencies, may elect to reassess the inspection frequency and associated costs after 15 years of routine monitoring, based on the inspection findings to date and industry-accepted practice at that time. For the purpose of the BCA, an equivalent annual cost of $317,000 was assumed. The Billion Oyster Project (BOP), which is a citywide initiative to restore oysters in the New York Harbor that considers education key to long-term success, conducts educational activities. To date, educational activities have included the development of a Living Breakwaters curriculum for grades 4 to 10, during which students investigate the ecosystems supported by the different habitats in Raritan Bay, teachers undertake professional development activities, and researchers undertake field work.

In addition to continuing the educational activities conducted to date, additional educational programming will start during the breakwater construction and oyster restoration. Additional educational programming will include an annual walking tour, an annual shoreline event, and enhancements to an exhibit about oyster restoration. The cost and description of the educational program was obtained from BOP (BOP Memorandum dated 2/20/21).

The annual public event and annual walking tour will take place along the shoreline at Conference House Park, from which most of the living breakwaters will be visible during the falling tide and at low tide. The oyster restoration exhibit enhancement will also be located in Conference House Park. The targeted audience for the public event is students and teachers. Activities at the event may include oyster monitoring, seining, and exercises from a Living

Breakwaters lesson plan. The audience for the walking tour is schools, community groups, and the general public. Walking tour topics may include an introduction to the breakwaters and their importance and stories from the local community and how they interact with the site. The exhibit enhancements may include language, signage, examples of oyster installations, and video display.

For the BCA, the breakwater construction and oyster restoration are assumed to be complete mid-2024. The breakwater monitoring costs were assumed to start upon completion of the breakwaters and occur throughout the 50-year evaluation period. The additional educational programming related to the oyster restoration is assumed to start in 2022 and continue through 2029. The Living Breakwaters curriculum is assumed to continue to benefit students after the completion of the Project.

Based on a 7 percent discount rate, the present value of the cost stream throughout the 50-year evaluation period equals $82.7 million.

3.2 BENEFITS

3.2.1 RESILIENCY BENEFITS

Resiliency values are the benefits that capture risk reduction and the risk avoidance and property and infrastructure protection values offered by the Project. Under the Future "With Project" Scenario, these values are the avoided costs that would have been incurred under the Future "Without Project" Scenario. An avoided cost that would no longer be incurred under the Future "With Project" Scenario was counted as an annual benefit in the BCA.

AVOIDED PROPERTY DAMAGES

INTRODUCTION

The breakwaters provide wave attenuation benefits. The avoided wave damage to structures and building contents was quantified using a methodology that compared damages and costs of various storm events in the "With Project" Scenario with the "Without Project" Scenario. In the Future "Without Project" Scenario, the Project would not be constructed, but the existing dune would provide some level of protection against property damages during storm events. The storm intervals analyzed as part of the BCA include 10-year, 25-year, 50-year, and 100-year storm events; their anticipated flood levels; and waves for both current and projected 21-inch SLR.

Within the BCA, the avoided damages from storm events were calculated using the Expected Annual Damages (EAD) framework. The EAD framework takes a weighted average sum of multiple storm events (of differing magnitudes and annual chance occurrences) and depicts these values as one annual-avoided-damages figure within the **Project Resource Statement** applied to calculate the BCR.

The results of the 100 percent design FUNWAVE analysis by Arcadis were used to estimate the benefits of the Project based on a reduction of wave energy (Memo to GOSR from SCAPE and Arcadis, 11/25/2020). The FUNWAVE analysis results included maps and geographic information systems (GIS) data that showed the different wave heights with and without the Project throughout the shoreline and coastal areas of Tottenville.

The Project attenuates wave energy and lowers incoming wave heights up to a 100-year storm event. The existing dune, which is assumed to be 9 feet, offers protection from frequent and small storm events. The Project enhances the existing dune's benefits by lowering incoming wav… more effectively protect against more severe storms and slowing or preventing erosion of the dune itself. In addition, the Project mitigates the impacts of waves on the shoreline, preventing its erosion. The analysis assumed that the dune and shoreline would be maintained in the Future "Without Project" Scenario. The avoided dune and shoreline maintenance costs under the "With Project" Scenario were counted as a separate resiliency benefit of the Project.

METHODS & DATA APPLIED

An approach using GIS was utilized to quantify the benefits. The approach utilized ArcGIS and GIS layers to determine real properties affected by storm events. The resulting data was used to quantify the avoided damages.

The approach is similar to FEMA's sized methodology for estimating potential losses. While compatible with the aforementioned approaches, the approach used for this study provides for greater specificity as it relates to the data used to quantify the damages. The data sets used for this BCA are described below:

NYC BUILDING FOOTPRINTS

New York City maintains a GIS layer showing the footprint of existing buildings with the city limits. This was used to determine the location and footprint of the buildings within the study area in relation to ground elevation and wave height shown in the FUNWAVE wave height model data. It was updated based on Google Street View and real estate data to account for recent building demolitions and new construction.

USACE NORTH ATLANTIC COAST COMPREHENSIVE STUDY DEPTH-DAMAGE FUNCTIONS

The USACE North Atlantic Coast Comprehensive Study included a Physical Depth Damage Function Summary Report Appendix. The appended analyses were the result of a workshop that developed depth-damage relationships by soliciting opinions from expert panelists including coastal and structural engineers, appraisers, restorers, and catastrophe modelers from the insurance industry (NACCS, 2015). In the workshops, the panelists utilized their experience and expert knowledge on recent storm events to quantity the depth-damage relationships. The quantified depth-damage relationships, called depth damage functions (DDFs), are used in USACE implementation studies and help reduce the stu DDFs quantify the physical damages to building structures and The contents caused by various storm events. The DDFs provide damages as a percentage of the property value, dependent on the inundation depth or wave height. The curves estimate a structure and contents damage value as a percentage of the building replacement value based on the depth of inundation or wave height. As a simplifying assumption, the DDFs do not consider the following to be factors in the damage analysis: age of building; basement use; construction quality; city codes; dune or seawall presence; lobby layout; backwater valves; and layout of mechanical, electrical, and plumbing systems.

NYC DEPARTMENT OF CITY PLANNING MAPPLUTO

The NYC Department of City Planning's MapPLUTO is a G location of each property and records detailed information on the lot and buildings located on it. Data from Map PLUTO was applied to the buildings located on each lot and includes the building gross square feet, number of units and building use (residential or commercial). As with the building footprints, data from Google Street View and online real estate sites were used to update and correct any errors in the original MapPLUTO data.

LIDAR

A NYC Topobathymetric Digital Elevation Model (DEM) with 1 foot resolution was used to determine the ground elevation within the study area. This DEM was based on LIDAR flown during 2017 and is the most recent ground elevation data in Tottenville. It was used to determine ground elevation of each building in the BCA as well as any other ground elevation needed, such as the location and height of the dunes.

BUILDING ANALYSIS

A GIS Building Analysis layer was created specifically for this BCA utilizing a mix of the New York City Building Footprints Layer, NYC MapPLUTO, NYC LIDAR data, Google Street View, and online real estate data. After extracting all relevant spatial and table data for each building from the NYC data sets, the Building Analysis layer was updated and enhanced using more detailed and recent data from recent Google Street View, recent ortho imagery, and online real estate data. This allowed it to correct inaccuracies and missing data from the NYC data sets, as well as account for recently demolished buildings and new construction. Importantly, all the data brought together in the Building Analysis layer was used to determine the residential property type and first floor elevation, number of units, and basement type (finished or unfinished) which were critical to the BCA analysis.

100 PERCENT DESIGN FUNWAVE ANALYSIS BY ARCADIS

The FUNWAVE analysis performed by Arcadis was completed in November of 2020 and shows the 100-year storm water levels and wave heights for the 100-year storm along the coastal areas of Tottenville in existing conditions and with 21 inches of SLR with and without the Project (Memo to GOSR from SCAPE and ARCADIS, 11/25/2020). These GIS raster layers were used in conjunction with the Building Analysis layer to determine the study area for the BCA and the wave impacts and attenuation on each building within the study area (**Figure 3-1** and **Appendix B**).

Figure 3-1: Affected Buildings

SOURCE: WSP ANALYSIS BASED ON NYC BUILDINGS, MAP PLUTO, NYC 2017 LIDAR, GOOGLE STREET VIEW, REAL ESTATE DATA AND ARCADIS FUNWAVE ANALYSIS

METHODOLOGY

STORM EVENTS AND WAVE IMPACTS

The BCA has quantified damages to structures and contents for properties mitigated by the Project. As stated above, mitigated damages for the 10-year, 25-year, 50-year, and 100-year storm events, and their related flood and wave impacts for both current and projected 21-inch SLR scenarios, were quantified. Water levels and wave heights assumed for each event are depicted in **Table 3-2**.

Table 3-2: Stillwater Elevation and Wave Heights for Storm Events

RETURN PERIOD	ANNUAL CHANCE	"TODAY"		WITH 21-INCH SEA LEVEL RISE	
		Stillwater Elevation (feet, NAVD88)	Significant Wave Height (feet)	Stillwater Elevation (feet, NAVD88)	Significant Wave Height (feet)
10 year	10%	8.1	3.9	9.8	3.9
25 year	4%	9.3	4.3	11.0	4.3
50 year	2%	11.3	4.9	13.0	4.9
100 year	1%	12.9	5.3	14.6	5.3

Depth-damage functions USACE North Atlantic Coast Comprehensive Study (NACCS) were used. Separate depth-damage functions were used for wave damages to residential and commercial properties. For residential properties, the analysis utilized the depth damage functions for six residential property types: single-story without basement; single-story with basement; multi-story without basement, multi-story with basement, elevated open, and elevated closed. For commercial properties, the analysis used the damage function for two property types: engineered and non-engineered commercial properties. The values in the depth damage Likely scenario was used. **Tables 3-3 through 3-6** depict these depth-damage functions for residential and commercial structures and contents. For each building, the depth damage functions were applied to the wave crest relative to the building first floor elevation to estimate the damage to structures and building contents under the "With Project" and "Without Project" scenarios.

Table 3-3: Structural Damages Residential Buildings, Depth Damage Functions by Building Type

WAVE CREST	SINGLE STORY NO BASEMENT	TWO STORY NO BASEMENT	SINGLE STORY WITH BASEMENT	MULTI STORY WITH BASEMENT	PILE FOUNDATION OPEN	PILE FOUNDATION ENCLOSED
-5	0%	0%	0%	0%	0%	6%
-3	0%	0%	0%	0%	4%	14%
-2	0%	0%	4%	2%	0%	0%
-1	3%	10%	10%	10%	10%	40%
0	5%	20%	20%	20%	50%	60%
1	35%	36%	35%	35%	70%	85%
2	60%	50%	60%	60%	100%	100%
3	90%	86%	88%	80%	100%	100%
5	100%	100%	100%	100%	100%	100%

Source: USACE (2015)

Table 3-4: Content Damages Residential Buildings, Depth Damage Functions by Building Type

WAVE CREST	SINGLE STORY NO BASEMENT	TWO STORY NO BASEMENT	SINGLE STORY WITH BASEMENT	MULTI STORY WITH BASEMENT	PILE FOUNDATION OPEN	PILE FOUNDATION ENCLOSED
-5	0%	0%	0%	0%	5%	5%
-3	0%	0%	0%	0%	5%	10%
-2	0%	0%	0%	0%	0%	0%
-1	0%	5%	15%	12%	20%	40%
0	10%	20%	35%	35%	50%	50%
1	30%	35%	50%	55%	75%	75%
2	60%	45%	80%	75%	100%	100%
3	100%	94%	100%	100%	100%	100%
5	100%	100%	100%	100%	100%	100%

Source: USACE (2015)

Table 3-5: Structural Damages Commercial Buildings, Depth Damage Functions by Building Type

WAVE CREST	COMMERCIAL ENGINEERED	COMMERCIAL PRE-ENGINEERED
-1	0%	0%
0	0%	0%
1	9%	12.5%
2	20%	30%
3	33%	49%
5	55%	75%
7	65%	100%
10	82%	100%

Source: USACE (2015)

Table 3-6: Content Damages Commercial Buildings, Depth Damage Functions by Building Type

WAVE CREST	COMMERCIAL ENGINEERED	COMMERCIAL PRE-ENGINEERED
-1	0%	0%
0	0%	2.50%
1	18%	20%
2	30%	40%
3	41%	60%
5	75%	95%
7	95%	100%
10	95%	100%

Source: USACE (2015)

The mitigated damages for the Project were quantified as the difference between the damages under the Future – Without Project” Scenario and the Future – With Project” scenario. For the Living Breakwaters Project, the wave reduction scenario as modeled with FUNWAVE model based on the 100 percent design were used to estimate the effect of the breakwaters and the dune on wave height during a 100-year storm. The existing dunes were assumed to

have a crest elevation of 9 feet NAVD88, which was the average elevation along the dune alignment. The dunes, which are part of the both the "With Project" and "Without Project" scenarios, also provide wave reduction, since we can assume that the maximum height of a wave is reduced to 78% of the water depth above any feature based on FEMA's Guidance for Coastal Flood Risk Analysis and Mapping (FEMA, 2005).

RESULTS

The mitigated damages for each event as described above are shown in **Table 3-7**. Mitigated damages would be incurred for 100-year and 50-year storm events today and with 21-inch SLR. For the 50-year storm event without SLR, the dune would protect against most waves, but some damage would still occur to properties near the shore under the "With Project" scenario. For all other storm events, the existing dune would provide sufficient wave attenuation to prevent wave damage to buildings, and there would be no difference in the "With Project" and "Without Project" scenarios.

Without the breakwaters, the dune could be lost due to wave damage and erosion, however for the purposes of the BCA, it is assumed that the dune will be maintained in good condition. The avoided costs of this maintenance under the "With Project" scenario were included as a separate benefit, discussed in the section below on avoided shore erosion/dune reconstruction cost.

As the severity of the storm event increases, the mitigated damage increases due to the prevented geographic extent and inundation and wave depth. This is because as the geographic extent and inundation depth of properties increase with the severity of the storm depth, more properties are affected, and each property is affected more for high severity events. Thus, mitigation of higher severity storm events would result in the mitigation of both a higher count of properties and extent of damages for each property.

Table 3-7: Avoided Damages to Structures and Contents

	AVOIDED DAMAGES PER EVENT	AVOIDED EXPECTED ANNUAL DAMAGES (EAD)
100 Year Storm—Today		
Avoided Damages to Structures	$6,358,106	$63,581
Avoided Damages to Contents	$4,527,085	$45,271
Total Avoided Property Damages	$10,885,191	$108,852
100 Year Storm—With SLR		
Avoided Damages to Structures	$7,046,047	$70,460
Avoided Damages to Contents	$4,513,973	$45,140
Total Avoided Property Damages	$11,560,020	$115,600
50 Year Storm—Today		
Avoided Damages to Structures	$4,339,594	$86,792
Avoided Damages to Contents	$2,709,763	$54,195
Total Avoided Property Damages	$7,049,357	$140,987
50 Year Storm—With SLR		
Avoided Damages to Structures	$8,522,629	$170,453
Avoided Damages to Contents	$5,786,368	$115,727
Total Avoided Property Damages	$14,308,997	$286,180

The EAD converts the total mitigated damages (MD) per storm event to the annual chance equivalent. EAD were calculated for today and for 21 inches of SLR. For intermediate years, the EAD were estimated using linear interpolation.

The sum total per year (t) for EAD_t damages would be equal to the following combination of risk adjusted damages ([MD] x [1/Return Period]) shown in **Equation 1**.

$$EAD_t = \Sigma\ ([MD_t \times 1\%] + [MD_t \times 2\%] \qquad \textbf{(Equation 1)}$$

Based on a 7 percent discount rate, the present value of the avoided building and building content damages throughout the 50-year evaluation period equals $3.4 million.

AVOIDED DISPLACEMENT COSTS

During storm events, tenants of both residential and commercial properties are forced to evacuate their homes and businesses. Displacement costs consist of the damages associated with this forced-evacuation. The displacement cost consist stime disruption cost along with a recurring monthly rental cost for the duration of the displacement).ò (FEMA, 2011

METHODOLOGY

The BCA quantified displacement costs that would be mitigated by the Project. Mitigated damages for each storm event outlined in the Property Structure and Contents section above were quantified. The FEMA BCA methodology for quantifying displacement costs was applied for this task. As described above, displacement costs represent the sum of a one-time disruption cost and a recurring displacement cost for the duration of displacement. This relationship is shown in **Equation 2** below.

$$\begin{aligned} Displacement\ Cost &= (Disruption\ Cost * \ Floor\ Area) \\ &+ (Rental\ Cost * Floor\ Area * Duration\ of\ Displacement) \end{aligned} \qquad \textbf{(Equation 2)}$$

Based on the FEMA methodology, displacement costs are assumed to be proportional to the rental cost of the building. Both rental costs and disruption costs were estimated as a per-square-foot value dependent on the occupancy type: single-family residential, multi-family residential, or commercial. These per-square-foot values were obtained from the FEMA benefit cost analysis re-engineering document and are shown in **Table 3-8** (FEMA, 2011). The values were adjusted to 2020 dollars using the Consumer Price Index (CPI) for New York-Newark-Jersey City from the Bureau of Labor Statistics (BLS). The duration of displacement is assumed to be dependent on both occupancy type and inundation depth and is shown in **Table 3-9**. Displacement duration increases significantly when the structure exceeds the demolition threshold of 50 percent damage, especially for building located within the 100 year floodplain.

Table 3-8: Rental Costs and Disruption Costs by Occupancy Type

OCCUPANCY TYPE	RENTAL COST (2008, $/SQ. FT./MONTH)	DISRUPTION COSTS (2008, $/SQ. FT.)	RENTAL COST (2020, $/SQ. FT./MONTH)	DISRUPTION COSTS (2020, $/SQ. FT.)
Single Family	0.73	0.88	0.88	1.06
Multi Family	0.65	0.88	0.78	1.06
Retail Trade	1.25	1.16	1.50	1.40
School	1.09	1.01	1.31	1.22

Source: FEMA (2012)

Table 3-9: Duration of Displacement by Occupancy Type and Inundation Depth

OCCUPANCY TYPE	DISPLACEMENT FOR 0' - 4'	DISPLACEMENT FOR 4' - 8'	DISPLACEMENT FOR 8' + (INSIDE FP)	DISPLACEMENT FOR 8' + (OUTSIDE FP)
Single Family	12	15	24	18
Multi Family	14	15	18	24
Retail Trade	14	15	18	24

Source: FEMA (2012)

The avoided displacement was estimated based on the s Project” Scenario and “Without Project”. The square foot floor area of each benefitting building was obtained from NYC Department of City Planning’s Map information used to determine the occupancy type of each building. The methodology outlined in the Property Structure and Content section above was used to determine the water levels at each property in each storm event scenario.

RESULTS

The avoided damages for each storm event shown in **Table 3-10** are the difference between the damages under the “With Project” Scenario and “Without Project” Sce The table shows the avoided displacement cost in case of a 50-year and a 100-year storm event and the corresponding Expected Annual Damages. Similar to the mitigated property structure and content damages, mitigated displacement costs were incurred only for the 50-year and 100-year storm events. In these storm events, the Project provided wave energy reductions that resulted in a quantifiable reduction in building damage and associated displacement and disruption time.

Table 3-10: Avoided Displacement Costs

	AVOIDED DAMAGES PER EVENT	AVOIDED EXPECTED ANNUAL DAMAGES (EAD)
100 Year Storm - Today	$887,668	$8,877
100 Year Storm - With SLR	$583,318	$5,833
50 Year Storm - Today	$622,327	$12,447
50 Year Storm - With SLR	$973,861	$19,477

Based on a 7 percent discount rate, the present value of the avoided displacement cost throughout the 50-year evaluation period equals $0.3 million.

AVOIDED MORTALITY AND INJURIES

Mortality estimates were developed assuming impacts would be comparable to those for a Superstorm Sandy type event. The historical record was examined, and two individual deaths were reported for the Tottenville section of Staten Island (Annese, 2012). These Sandy deaths were related to individuals being carried away by the storm due to wave damage to the structures they occupied. Drowning deaths can result from high velocity of destabilizing moving water enhanced by wave action. Furthermore, injuries such as lacerations can result as storm victims are pushed into sharp objects by moving water enhanced by waves. Therefore, the BCA includes likely avoided mortality benefits and associated injuries that would be attributed to the wave attenuation properties of the Living Breakwater Project. The EAD calculation applied for this BCA over the 50-year project evaluation horizon is based on the 1% annual chance event. The adjustment factor calculation adjusts the total Value of Statistical Lives (VSL) monetary estimate for two expected deaths by a 1% factor (return period reciprocal: 1/100) each and every year over the projection period. The 1% factor is also applied to the estimated projected injuries.

Analysis of the population at risk was based on the historical record and the base population for the number of households located within the FEMA at risk zone for the Tottenville, Staten Island project area. The population growth rates applied to the base population at risk in the projections were sourced from New York Metropolitan Transportation Councilôs (NYMTC) popula.tion projectio

The fatality rate, was calculated as the number of reported deaths divided by the estimated population at risk. This fatality rate was applied to the projected population at risk over the projection period time horizon.

The injury rate was sourced from a Centers for Disease Control (CDC) report released post-Superstorm Sandy. This study entitled Nonfatal Injuries 1 Week after Hurricane Sandy ð New York City Metropolitan Area, October 2012 examined reported injuries one week after Sandy, by area (CDC, 2014). The study found that of the at-risk population, 10.4% sustained an injury in the first week after Sandy (CDC, 2014).

The injury rate was applied to the projected population at risk over the project evaluation period to calculate the expected number of non-fatal injuries adjusted by the number of multiple injuries sustained by 70% of the impacted population at risk. From Table 2 of the CDC Study, the severity of injuries reported were mostly arm cuts, leg cuts, hand cuts and back, leg and foot strains. These types of injuries were cross-referenced to the most likely Abbreviated Injury Scale (AIS) suggested for use under the HUD Guidance for Benefit Cost Analysis (HUD CDP 16-06). The estimated injuries corresponded to AIS 1.

To estimate the avoided monetary cost of projected deaths and injuries, the HUD Guidance Source, Table 2-2: Relative Disutility Factors by Injury Severity Level, (for Use with 3% or 7% Discount Rates) (HUD CPD-16-06) was applied. The cumulative number of deaths and injuries were valued by applying the 2020 Dollar values to these injury estimates by year.

Based on a 7 percent discount rate, the present value of the avoided mortality and injuries throughout the 50-year evaluation period equals $3.2 million.

AVOIDED MENTAL HEALTH COSTS

After Superstorm Sandy, researchers quantified the incidence of depression, anxiety, and Post Traumatic Stress Disorder (PTSD) on the impacted populations in the New York metropolitan region. In a study titled, *The Impact of Hurricane Sandy on the Mental Health of New York Area Residents*, Schwartz et al. (2015) applied multivariable logistic regression models to examine the relationships between Superstorm Sandy exposure and depression, anxiety, and PTSD. The probable depression was reported in 33.4 percent of the participants, probable anxiety in 46 percent, and PTSD in 21.1 percent. Increased exposure to Superstorm Sandy was associated with a greater likelihood of depression even after controlling for demographic factors known to increase susceptibility to mental health issues (Schwartz et al., 2015).

To quantify the monetary cost of the avoided mental health treatment for depression and anxiety, this BCA uses the same methodology as the 2017 BCA. The BCA applies the results of the incidence rate for PTSD of 21 percent to the estimate of the exposed population in case of a 100-year storm event. From this depression-affected sub-set of area residents, the BCA then applied the updated total per person treatment cost for mental health care that is used by FEMA (FEMA, 2012), adjusted to 2020 dollars using the BLS CPI for the NY-NJ region. This mental health treatment cost value was then adjusted for the expected annual chances of the storm events modelled in the avoided property damages estimates.

Based on a 7 percent discount rate, the present value of the avoided mental health treatment cost throughout the 50-year evaluation period equals $0.6 million.

AVOIDED LOST PRODUCTIVITY COSTS

As done in the 2017 BCA, this BCA applied the established FEMA methodology to calculate the avoided lost productivity costs for the cohort that would most likely experience mental health problems, anxiety, and depression calculated above. FEMA also published suggested lost productivity losses per worker per day in their supplementary guidance (FEMA, 2012). The productivity values were converted to 2020 dollars based on the CPI for the New York-Newark-Jersey City region from the Bureau of Labor Statistics. To calculate the number of wage earners who would most likely be unproductive because of mental health problems, the labor force participation rate of 62.7% from the 2015-2019 American Community Survey was applied to the exposed population. This lost productivity

avoided cost estimate value was then adjusted for (annualized) the expected annual chances of the storm events modelled in the avoided property damages estimates.

Based on a 7 percent discount rate, the present value of the avoided lost productivity throughout the 50-year evaluation period equals $1.3 million.

AVOIDED SHORE EROSION/DUNE RECONSTRUCTION COSTS

Shoreline erosion benefits were based on the cost of restoring and replacing the cubic yards of shoreline that would have been lost annually over the 50-year evaluation period under the “Without Project” Scenario. This measure is a way of estimating the economic value of lost land that would occur in the absence of the Project, without any interventions that arrest erosion. The Living Breakwaters Project would avoid these maintenance and restoration costs over time. Because of the increased interest in beach restoration and nourishment projects in the New York and New Jersey area, the demand and supply market balance for fill materials has led to higher premium prices (SCAPE Appendix D, 2016). From this perspective, the Project offers substantial economic benefits as the up-front investment costs would result in substantial periodic maintenance cost savings over the 50-year evaluation period.

The avoided cost estimate is based on the volume (cubic yards) of materials that would be replaced at various intervals over time. Under the “Without Project” Scenario, modelling results have indicated that the projected shoreline change with erosion would amount to 12,940 cubic yards per year over the 50-year planning horizon. The avoided total volume of sand placement from the Project was estimated to be 647,000 cubic yards. The cost per cubic yard ($123/cy in 2020$) was sourced from the 100 percent design Opinion of Probable Cost analysis and reflects current local market conditions as described above. The design team characterized this process based on an analysis with the GENESIS shoreline change model, calibrated to historical erosion rates occurring over the period spanning 1978-2012 (**Figure 3-2**). Without the Project, this erosion is expected to occur over the entire shoreline affected by the Project, within a 5,000-6,000 linear foot range (Arcadis, December 9, 2016).

In addition, the Project area is susceptible to the ocean-like shoreline conditions of Staten Island under storm/erosion conditions due to the regional funnel/surge effect that makes it comparable to ocean environments in terms of storm-induced erosion. The New York Bight Apex always experiences abnormally high surge levels attributable to the right angle made by Long Island and New Jersey coastlines that significantly increases storm surge levels wherever a hurricane has made landfall in the New York Bight Apex (Coch, 2015).

The estimates of avoided shoreline restoration costs and nourishment project interventions are supported by a review of case studies examined for the purposes of assessing the actual historic volumes of fill materials that would be mobilized (per project) for shoreline protection. These case studies were reviewed to get a sense of the volume of materials associated with actual projects in the New York coastal zone per linear foot of shore protection project. Select beach locations were available for the New York shoreline and they provided an indication of the volume of materials mobilized for these projects (BND, 2016).

Figure 3-2: Illustrative Shoreline Dynamics—Observed Historic Shoreline Change, 1978- Spring 2012 (Pre-Sandy)

Source: Modeling Report, SCAPE, 2016

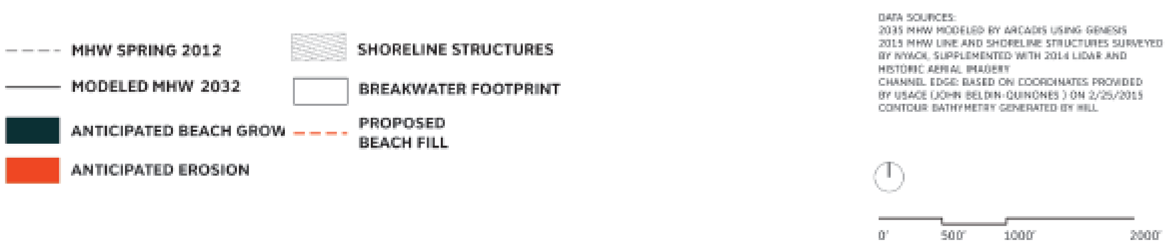


Figure 3-3 shows a bi-modal distribution of projects and the average volumes of material per linear foot (LF) of shore. At least 10 projects show fill volumes between 51-101 cubic yards per LF of shoreline protected. A scatter plot was also prepared for shorelines that were close in length to the Project alignment area. **Figure 3-4** shows the scatter plot of LF of shore protection projects versus the cubic yards per LF of materials mobilized. Projects with shore lengths between 4,000 and 7,000 LF were characterized by CY/LF amounts of between 50 and 75 cubic yards/LF.

Figure 3-3: Frequency Distribution of New York Shore Protection Projects

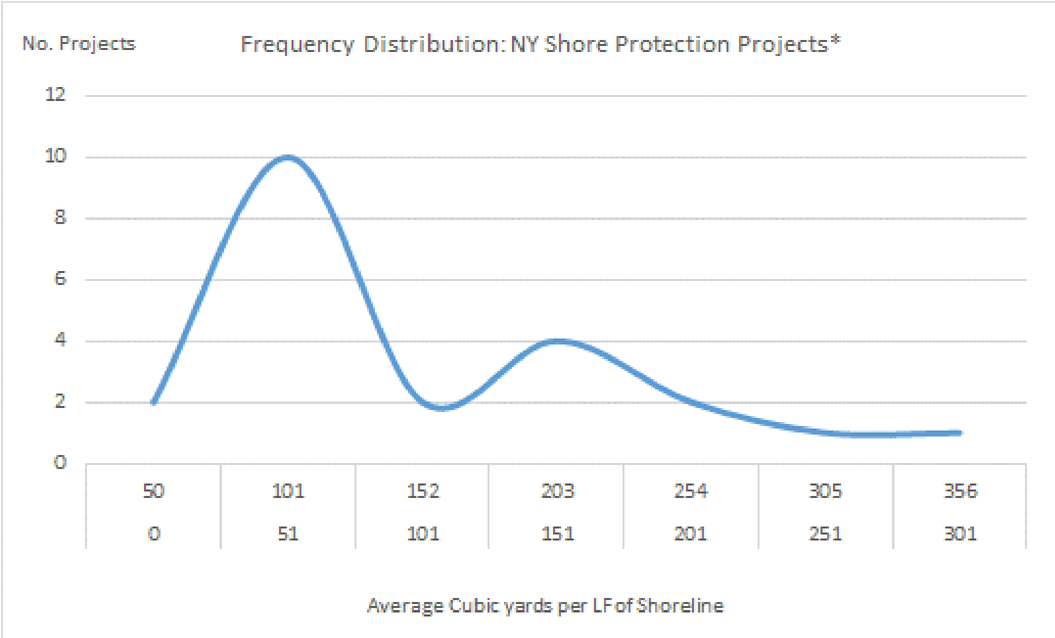
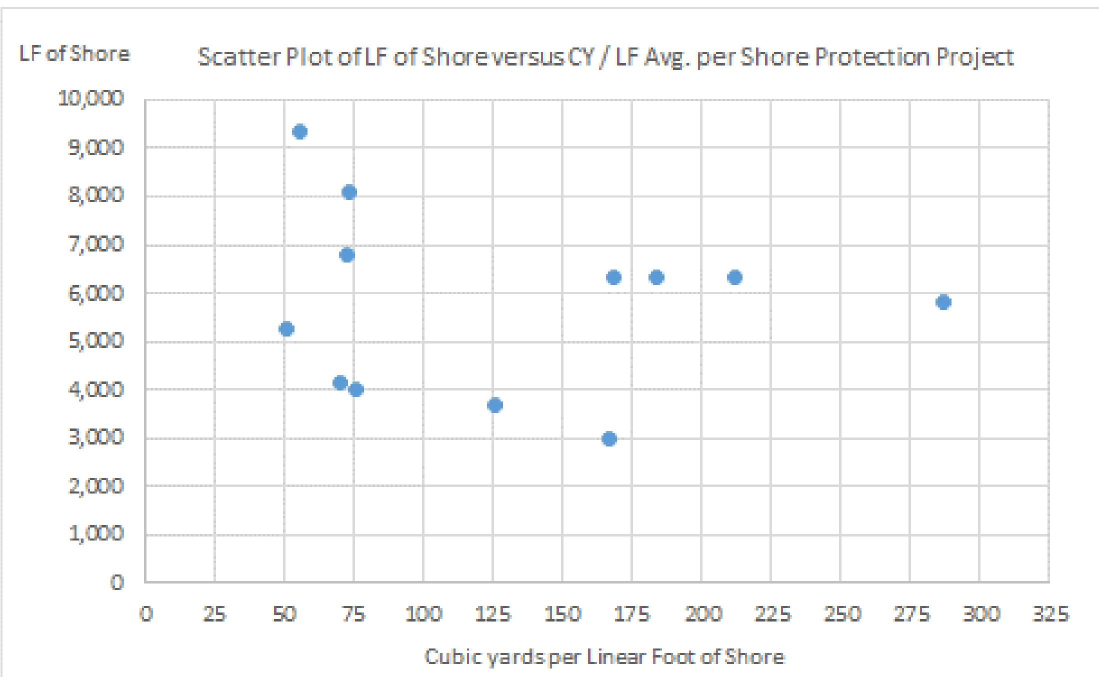


Figure 3-4: Average Cubic Yard per Linear Foot of Sand for Shore Protection Projects



This above data was referenced to inform and simulate the likely size of shoreline nourishment events (projects), given the total volumes estimated from the modelling exercise.

The avoided cost estimate was based on replacing fill along the shoreline erosion area at periodic intervals (every four years), as well as periodically reconstructing the dune based on a dune reconstruction cost estimate provided by NYC Department of Parks & Recreation (NYC Parks, 12/12/16). The BCA also simulates a total dune replacement

construction cost that would occur after a 50- or 100-year storm. This latter cost was also sourced from NYC Parks and was escalated to 2020 dollars from the original 2013 dollar cost using the BLS CPI for the region (NYC Parks, 01/03/17). In addition, the BCA also takes into account that the breakwaters will reduce damages to the dunes from smaller storms.

It was assumed that under the ñWith sustained erosion would continue, punctuated by storms (and their impacts). For purposes of BCA, it was assumed that ï absent the Project - this would require more frequent reconstruction efforts every few years. The the Living Breakwaters Project. The avoided cost of shoreline nourishment and dune reconstruction addresses this value over time because it is linked to rates of erosion.

Based on a 7 percent discount rate, the present value of the avoided shoreline erosion and dune reconstruction cost throughout the 50-year evaluation period equals $47.5 million.

AVOIDED ROAD CLOSURE/TRAVEL DISRUPTION COSTS

Superstorm Sandy resulted in substantial travel time delays for commuters due to closed roads, poor road conditions, and damages sustained from debris carried onto roads from wave surges and strong winds (PlaNYC, 2013). Following Sandy, commuters who did not have the option to telecommute experienced increased frustration levels and substantial increases in commute times from traffic congestion and detours, with commute times sometimes spanning two to three times as long as their normal pre-Sandy daily commute. Since Staten Island is geographically separated from the major centers of employment in Manhattan, the frustration levels (measured by an index out of 10, with 10 being the highest) were relatively high (7 out of 10). For Staten Island residents the average pre-Sandy commute time was 84 minutes. The average post-Sandy commute time (Nov. 1-2) was 240 minutes (Kaufman et al., 2012).

The BCA applies the FEMA methodology to value the cost of avoided road closures based on the value of time. This method recognizes that individuals who experience increased travel time due to bridge or road closures attach an economic value to the lost time incurred (FEMA, 2011).

To value the avoided travel time delays associated with avoided road closures and disruptions, the working age population was estimated from the Traffic Analysis Zone (TAZ 2206) population for the Tottenville shoreline community based on the labor force participation rate. It was assumed that an average two-hour delay would be incurred over a two-week period for this group of estimated commu was converted to 2020 dollars using the BLS CPI for the region. The resulting travel time disruption value was then converted to an EAD amount. The EAD amount was based on the 1% chance annual storm event factor for the 100-year storm per the Project assumptions noted in **Table 3-2**.

Based on a 7 percent discount rate, the present value of the avoided road closure and travel disruption cost throughout the 50-year evaluation period equals $0.3 million.

AVOIDED COST OF POWER OUTAGES

Power outages caused considerable disruptions following Sandy. It has been estimated that 120,000 customers lost power on Staten Island, and repairing damage to the aboveground electrical power network took approximately two weeks (PlaNYC, 2013).

As under the 2017 BCA, this BCA applies the FEMA method to value power outages under the 100-year design storm event (FEMA, 2011). Application of the FEMA method involved first estimating the functional downtime (measured as the system days of lost service). Using this approach, a two-week functional electrical service disruption estimate was assumed for the Tottenville community under a 100-year storm event. This corresponds to the likely impacts from a 100-year storm event. The population for the Traffic Analysis Zone (TAZ 2206) applicable to the study area was used as a proxy for the number of people served by the electric power utility. The economic impacts of lost electric power service were then calculated using the per capita economic impacts and the affected population. FEMA has developed per capita values to calculate the economic impacts, and these values were updated to 2020 using the New York-Newark-Jersey City CPI. **Table 3-11** shows the value applied in the BCA.

Table 3-11: Economic Impacts of Loss of Electric Power (per capita per day)

CATEGORY	ECONOMIC IMPACT (2010 DOLLARS)	ECONOMIC IMPACT (2020 DOLLARS)
Impact on Economic Activity	$106	$124
Impact on Residential Customers	$25	$29
Total Economic Impact	$131	$154

Source: FEMA (2011)

The resulting avoided annual cost of lost power was then converted to an EAD amount based on the 1% chance annual storm event factor for the 100-year storm.

Based on a 7 percent discount rate, the present value of the avoided loss of electric power throughout the 50-year evaluation period equals $1.2 million.

AVOIDED DAMAGES TO VEHICLES

Inundation would damage motor vehiclesð including cars, small trucks, and heavy-duty trucks. The damage incurred to vehicles depends on the vehicle type. Automobiles, which are closer to the ground than small trucks or heavy-duty trucks, are more susceptible to water damage than larger vehicles. Vehicles parked at residences are at risk. However, unlike other assets, motor vehicles could be moved away from potential inundation zones, avoiding damage from inundation.

The number of vehicles at risk was estimated based on the average number of the vehicles per housing unit in Tottenville, which is 1.78 according to the 2015-2019 American Community Survey. Based on USACEô Economic Guidance Memorandum 09-04 (USACE, 2019), we assumed that 49.5 percent of vehicles would not be moved in advance of the storm and would be at risk for damage with a storm.

The number of vehicles that would benefit from the Project are the vehicles that would not be moved and that would experience less damageen aurni doe rt ht ahne uñnWdi et rh t PhrTeo jdãem Wagiet t òh oSuct P r was estimated based on the flood depth at the residence as estimated during the impact analysis, vehicle depth damage functions reported in USACE Economic Guidance Memorandum 09-04 (USACE, 2019), and an estimated average value per vehicle. The average value per vehicle was estimated as 50 percent of the average vehicle sales price in 2020 of $40,107, which is $20,053.

Table 3-12 shows the avoided damages to vehicles for the 50- and 100-year storm events. The mitigated event based damages were converted to EAD in the benefit cost analysis by applying Equation 1 above.

Table 3-12: Avoided Damages to Vehicles

	AVOIDED DAMAGES PER EVENT	AVOIDED EXPECTED ANNUAL DAMAGES (EAD)
100 Year Storm - Today	$205,409	$2,054
100 Year Storm - With SLR	$199,616	$1,996
50 Year Storm - Today	$157,689	$3,154
50 Year Storm - With SLR	$417,061	$8,341

Based on a 7 percent discount rate, the present value of the avoided loss damages to vehicles throughout the 50-year evaluation period equals $0.1 million.

AVOIDED DAMAGES TO PARKS AND UTILITIES

Superstorm Sandy caused extensive damage to parks on Staten Island. According to the NYC Department of Parks and Recreation this amounted to $3,892,046 at Conference House Park due to inundation and wave damage to buildings and park structures.

Damage to public utilities from inundation and waves can cause further interruption to the lives of residents and significant expense to government and utilities in repair costs for downed wires, broken pipes, and clogged drains. Damages to utilities were estimated based on determining the potentially impacted population that would be protected by the breakwaters and comparing that to the size of the population in Community District 503 of 159,853, which had known utility damage costs during Superstorm Sandy of $64,151,261 (Stantec, 2021). The population that would be protected was determined by finding the number of housing units protected (496) and multiplying them by the average household size (2.84) to determine a population of 1,409. Thus, given the utility damages per person in Community District 503 of $401.31, the total damages in case of a Sandy-type event in the area protected by the breakwaters would be $565,307.

The Living Breakwaters would avoid a portion of these damages to parks and utilities in case of a 100-year and a 50-year storm. The Living Breakwaters would not provide additional benefits for smaller storms over and above those provided by the dunes. The avoided damages were estimated using data and assumptions from the Tottenville Shoreline Project BCA (Stantec, 2021). The total and annual damages avoided by the Living Breakwaters are presented in **Table 3-13.**

Table 3-13: Avoided Damages to Parks and Utilities

	RECURRENCE INTERVAL	AVOIDED DAMAGES PER EVENT	AVOIDED EXPECTED ANNUAL DAMAGES (EAD)
Parks	100	$1,668,530	$16,685
	50	$1,044,436	$20,889
Utilities	100	$242,349	$2,423
	50	$151,701	$3,034
Total		$3,107,015	$43,032

Based on a 7 percent discount rate, the present value of the avoided damages to parks and utilities throughout the 50-year evaluation period equals $0.5 million.

AVOIDED DEBRIS REMOVAL

Debris removal is a significant costs after storms and must be conducted quickly to clear roads for emergency vehicles and allow people to move back into their residences. Much of the debris generated by storms is generated when inundation and waves break off sections and materials from buildings and spread them around the area.

Damages buildings are the origin of debris. Therefore, the amount of debris needed to be removed can be calculated based on the amount of damage to buildings in cubic yards and how much it would take to dispose of that material based on the tipping fee (for disposal) in landfills. USACE estimates that, for each house with more than 50 percent damage, disposal costs would be $530 if it did not have a basement and $915 if it did have a basement (NACCS, 2015). These costs could be avoided with the breakwaters in place and were calculated based on the avoided damages to buildings, as shown in **Table 3-14**.

Table 3-14: Avoided Debris Removal

	AVOIDED DAMAGES PER EVENT	AVOIDED EXPECTED ANNUAL DAMAGES (EAD)
100 Year Storm - Today	$20,214	$202
100 Year Storm - With SLR	$19,030	$190
50 Year Storm - Today	$14,488	$290
50 Year Storm - With SLR	$31,158	$623

Based on a 7 percent discount rate, the present value of the avoided debris removal throughout the 50-year evaluation period equals about $7,000.

AVOIDED EMERGENCY REPAIRS

After major storms, some homes require immediate repairs to ensure that residents can stay in their homes while waiting for permanent repairs to be completed. In the aftermath of Sandy, the NYC Rapid Repairs program was a critical first step in helping residents rebuild their communities (NYC, 2013). The program restored essential heat, power, and hot water to 11,773 buildings, 140 of which in Tottenville. On the busier days, the program employed 2,300 skilled tradespeople to provide repairs to more than 200 homes in a single day. The citywide program cost was $116.15 million.

The Project will reduce wave damages to buildings in Tottenville and therefore reduce the need for emergency repairs in the case of major storms. The estimated avoided building emergency repair cost is based on the avoided building damages for the 50-year and 100-year storms (**Table 3-15**).

Table 3-15: Avoided Emergency Repairs

	AVOIDED DAMAGES PER EVENT	AVOIDED EXPECTED ANNUAL DAMAGES (EAD)
100 Year Storm – Today	$77,736	$777
100 Year Storm - With SLR	$86,147	$861
50 Year Storm - Today	$35,778	$716
50 Year Storm - With SLR	$104,200	$2,084

Based on a 7 percent discount rate, the present value of the avoided emergency repairs throughout the 50-year evaluation period equals about $22,000.

3.2.2 ENVIRONMENTAL VALUE

The environmental value of the Project was estimated through the evaluation of ecosystem service provisioning provided by the Project and subtracting negative effects of the Project on ecosystem services. The ecosystem services for the Project were derived from a combination of the estimated habitat area (in sq. ft./acres), and from habitat values per acre obtained from published literature sources (Grabowski et al., 2012). The SCAPE team provided the estimates of the habitat sizes in acres for the Project that would be both gained and displaced based on the 100year storm based on the 100 percent design. The ecosystems services valuation for the BCA was limited to the value of net acres gained by ecological service type. In this section [illegible] the terminology used in the source material for the ecosystem service valuations. Living breakwaters are artificial reefs that provide the same ecosystem services as reefs.

Table 3-16 shows the ecosystem service types valued and the original values per hectare per year from Grabowski et al. (2012). The 2011 values were converted to 2020 dollars using the CPI for the region from the BLS.

Changes in the intertidal and subtidal habitat areas related to shoreline restoration activities were not addressed since the net change in area is insignificant and thus a change in ecosystem service value would not be appreciable.

Table 3-16: Summary of Ecosystem Services Values

SERVICE TYPE	MEASUREMENT	AVERAGE VALUE/HECTARE /YEAR (2011)	AVERAGE VALUE/ACRE /YEAR (2020)
Oyster habitat/reef sustainability	density (ind./m^{-2})	$880	$2,472

SERVICE TYPE	MEASUREMENT	AVERAGE VALUE/HECTARE /YEAR (2011)	AVERAGE VALUE/ACRE /YEAR (2020)
Production Augmentation Finfish and Crustaceans-			
Commercial	$4.12/10m^{-2} of reef area	$4,123	$11,580
Water quality			
Nitrogen removal	246 micromoles/h^{-1}/m^{-22} of reef below MHW occupied by filter feeders	$4,050	$11,375
SAV enhancement	1 ha reef = 0.0 05 ha SAV	$1,292	$3,629

Source: Grabowski et al. (2012)

TOTAL GROSS ECOSYSTEM ANNUAL SERVICE GAINS (+)

Ecosystem services annual gains were assessed for the proposed ecologically enhanced breakwater system and oyster restoration using the services of habitat/reef sustainability, commercial finfish, water quality, habitat, and recreation. Monetary values were derived from Grabowski et al. (2012), Costanza et al. (2006), and Kaval and Loomis (2003). The monetary values from the literature were adjusted to 2020 values using the CPI for the NY-NJ region from the BLS (**Table 3-17**).

For the 2017 BCA, the estimated square feet of each habitat type was derived from the calculations provided by the design team in a December 13, 2016, memorandum entitled *Calculation of Available Surface Area and Marine Habitat Generated for Living Breakwaters* (SCAPE, December 13, 2016). The current calculations for this BCA update were developed by SCAPE in February 2020 based on the methodology of a memorandum (SCAPE, October 3, 2017), which is an update from previous memos dated November 28, 2016, and July 17, 2017. The calculations include the amount of marine habitat generated and displaced by the Project, taking into consideration both the breakwater structures and the potential beach fill proposed.

Based on a 7 percent discount rate, the present value of the ecosystem services gains throughout the 50-year evaluation period equals $10.7 million.

Table 3-17: Summary of 2016 annual ecosystem service values for breakwater/oyster reef system

SERVICE TYPE	ACCESSIBLE SURFACE AREA (ACRE)	PLANAR REEF AREA (ACRE)	AVERAGE VALUE / ACRE PER YEAR (IN 2020$)	TOTAL VALUE PER YEAR (IN 2020$)
Oyster habitat/reef sustainability	16.6		$2,513	$41,609
Finfish and Crustaceans				
Commercial	41.4		$11,772	$487,371
Water Quality				
Nitrogen removal	33.1		$11,564	$382,994
SAV enhancement		9.7	$3,629	$35,020
Habitat				
Refugia	29.0		$469	$13,579
Total				$945,696

To account for a lag time in the establishment of reef habitat and benefits, percentages (out of 100% of full annual ecosystem service delivery) were applied to specific services during the first three years post-construction. **Table 3-18** lists the modifiers used in this analysis. The values applied were based on references reporting on monitoring observations for constructed reefs and breakwaters.

Table 3-18: Ecosystem Habitat Extended Value/Time Lag Modifiers

BREAKWATER/OYSTER REEF	EXTENDED VALUE/TIME LAG MODIFIERS		
Service Type	**Year 1**	**Year 2**	**Year 3**
Oyster habitat / reef sustainability	0.50	0.75	1.0
Finfish and Crustaceans			
Commercial	0.90	1.0	1.0
Water Quality			
Nitrogen removal	0.50	0.75	1.0
SAV enhancement	0.50	0.75	1.0
Habitat			
Refugia	0.9	1	1

Based on a 7 percent discount rate, the present value of the gross ecosystem services gains throughout the 50-year evaluation period equals $10.7 million

TOTAL ECOSYSTEM ANNUAL SERVICES DISPLACED (-)

The construction of the breakwaters would displace approximately 9.7 acres of subtidal small and large grained bottom habitat. For subtidal sandy bottom, service areas and monetary values were derived from Costanza et al. (2006) and include water supply, biological control, nutrient regulation, and cultural and spiritual values (**Table 3-19**). Costanza et al. (2006) referred to the subtidal coastal zones as "Shelf," which was defined as the subtidal zone below the beach elevation.

Table 3-19: Summary of Ecosystem Services Applied to the Displaced Subtidal Habitat: Subtidal small and large grained bottom habitat

SERVICE TYPE	MEASUREMENT	AVG. VALUE/ ACRE /YEAR 2004	AVG. VALUE/ ACRE/YEAR 2020
Water supply	acre/year	$521	$564
Biological Control	acre/year	$20	$22
Nutrient Regulation	acre/year	$723	$783

Source: Costanza et al. (2006)

Based on a 7 percent discount rate, the present value of the displaced ecosystem services throughout the 50-year evaluation period equals $0.2 million.

NET ECOSYSTEM ANNUAL SERVICE GAINS (-)

The total calculated value for the displaced subtidal habitat was subtracted or netted from the breakwater/oyster reef total values. Based on a 7 percent discount rate, the present value of the net ecosystem service gains throughout the 50-year evaluation period equals $10.6 million.

There is some uncertainty associated with the source of the ecosystem service values and their direct application to the New Ecosystem Annual Service Gains, which may experience lower oyster densities and growth rates of filter feeders, and the ability of the breakwater/oyster reef in achieving full functionality. To account for this uncertainty, a three-year lag time for some services was built into annual valuation based on literature sources (La Peyre et al., 2013).

To better visualize the types of ecosystem services that will be supported by the Project in the future, **Figure 3-5** is reproduced below.

Figure 3-5: Schematic of Living Breakwaters Underwater View

Source: SCAPE Press packet images.

3.2.3 SOCIAL VALUE

To estimate the social values that would arise from the Project, a combination of comparable usage at similar educational and environmental stewardship facilities and area park recreational visitation patterns was combined with benefits transfer. Benefits transfer is the process of adapting an existing value estimate (such as the willingness to pay for an amenity or park service) and transferring it to a new application that is in another location but is similar. There are two types of benefit transfers: value transfers and function transfers. A value transfer takes a single point estimate or an average of point estimates from multiple studies, to transfer to a new policy application. A function transfer uses an estimated equation to predict a customized value for a new policy application. Social values for the Project were estimated by applying a ñ the willingness to pay for recreational and specific types of environmental education among potential users.

EDUCATION AND ENVIRONMENTAL STEWARDSHIP

Living Breakwatersô education conduc a citywide initiative to restore oysters in the New York Harbor that considers education key to long-term success.

The Project will continue to provide educational opportunities for area residents and others through the environmental education and stewardship programs that are organized through BOP. In addition, from 2022 to 2029, BOP will provide an annual walking tour, an annual shoreline event, and enhancements to an exhibit about oyster restoration (BOP Memorandum dated 2/20/21). The targeted audience for the public event is students and teachers and the audience for the walking tour is schools, community groups, and the general public. BOP also holds two annual professional development events (PDE) for teachers as part of the Oyster Research Station and Oyster Research Tank Programs and fieldwork events.

It is anticipated that most educational users would be area residents from the immediate area and less so from the region, as well as nearby school systems. The augmentation of the beach and surrounding open areas by the Living

Breakwaters Project will provide enhanced outdoor educational opportunities as well. The Project offers a unique opportunity for marine-based education within an urban setting.

Many studies have found educational benefits of environmental education programs for children in kindergarten to 12th grade. Studies found positive effects of environmental education including increased confidence, increased interest in school, and improved test scores (Volk and Cheak, 2003; Schneller et al., 2015; Blatt, 2013). The educational programs also have the potential to change future behavior. Several studies have linked environmental education and environmental quality (Dietz, 2004; Johnson, 2012; Purnell, 2004). Cordero (2020) conducted a study that quantifies the effect of the environmental education on environmental quality. The study shows that climate change education affects behavior and reduces carbon emissions. The study findings are based on a survey of 104 students who participated in a one semester climate change course five or more years prior. The survey showed that the majority of course graduates reported that they made pro-environmental decisions at least partly because of what they learned during the course. The survey also showed that, for the average course graduate, these decisions reduced their individual carbon emissions by 2.86 tons of CO2 per year.

Education in a recreational and outdoor setting is typically geared towards specific extracurricular environmental activities. It was determined that the educational benefits associated with the Project represented a quantifiable value. BOP estimated the number of participants. For PDE for teachers, the average class size of NYCDOE was used to estimate the total number of beneficiaries of the events. To determine the overall education value, a per-visit utility value of $37 per visit was applied. This visitor utility value was based on a study conducted by Economic Planning and Systems for the East Bay Regional Park District (2017). A previous version of the work by Economic Planning and Systems that was citied in a Texas A&M University (Harnik and Crompton, 2014) was used in the 2017 BCA. The visitor utility value from the 2017 study was converted to 2020 dollars using the BLS CPI and was applied to an estimate of the total number of participants per year.

Based on a 7 percent discount rate, the present value of the educational benefits throughout the 50-year evaluation period equals $0.3 million.

RECREATION

The completion of the Project will enhance recreation opportunities along the shoreline as well as just offshore. The additional beach area (beach width) and calmer waters resulting from the breakwaters will provide opportunities for the community to fish, view the waterfront, boat, and perform other beach and water activities. These recreational opportunities represent a tangible direct use benefit that the Project would provide. It is anticipated that the majority of recreational users will be local area residents and some residents from the greater region.

Several approaches were considered for obtaining an estimated recreational benefit value, including applying a value per acre value as well as a per visit utility figure. An approach using a value per visit utility figure was used, as obtainable data supported this approach best. To obtain an estimated value, three separate per-visit utility values were applied: one for walking, hiking, biking, and fishing. Kayaking was assigned the boating value. As for the utility of educational programs, the visitor utility value were obtained from a study conducted by Economic Planning and Systems in 2017 for the East Bay Regional Park District of which a previous version was citied in a Texas A&M University (Harnik and Crompton, 2014) that was used in the 2017 BCA. In addition, an estimate of the overall annual visitation was derived using visitation figures from a nearby State park, Clay Pit Ponds State Park Preserve on Staten Island. The 2018 visitation data, which is the most recent year available, was used to estimate the 2020 visitation using the annual growth rate between 2017 and 2018 (http://lohud.nydatabases.com/database/new-york-parks-attendance).

The percent of annual visitors that would engage in each activity was estimated and is shown in **Table 3-20**.

Table 3-20: Recreational Users

TYPE OF RECREATION	PERCENT OF ANNUAL VISITORS
Walking, hiking, biking, and fishing	70%
Kayaking and boating	30%

The per-visit utility figure was applied to each estimated number of recreation users to arrive at an estimated annual benefit for each type of recreation. These were then added together to arrive at a total annual figure for all recreation. Other types of recreation may occur at the Project site, such as seashell collecting or bird watching. As utility figures for such activities would be quite difficult to find, and considering these types of activities could be grouped as walking or hiking, it is assumed such activities fall into the categories for walking and hiking.

Given the novel feature that the Living Breakwaters will represent to local boating enthusiasts, additional research was conducted on the number of small boat slips at marinas on Staten Island that could access the Project. From the total number of slips, an estimate of potential visitation associated with these small boats was completed. The number of potential visitors who would likely visit the Project area by small boat was then valued by applying the above per visit utility figure. **Table 3-21** shows the estimate of marina slip capacity.

Table 3-21: Staten Island Marinas

NAME	SLIP CAPACITY
Atlantis Marina	170
Captains Marine Mercury	160
Great Kills Yacht club	250
Mansion Marina	217
Marina Café	270
Nichols Great Kills Marine	350
Port Atlantic Marina	240
Richmond County Yacht Club	40
Staten Island Yacht Sales	50
Tottenville Marina	240
Unnamed Marina	166
\a Estimated Total:	2,153

Note: \a Select marina capacities were estimated from aerial photographs.
Source: http://marinas.com/search/?search=1&category=marina&country=US&region=NY&city=Staten+Island

The estimate of small boat total visitors was based on assuming a boat party size of three persons. It was assumed that two-thirds of the slip capacity boats would visit the Project area three times over the course of a year. Based on these assumptions, approximately 13,000 annual boat trips could be generated from the available marine slip capacities estimated.

Based on a 7 percent discount rate, the present value of the educational benefits throughout the 50-year evaluation period equals $11.7 million.

COMMUNITY COHESION

Parks and beaches offer an opportunity for community members to meet, interact, strengthen the community, and build social capital. Several studies on the value of parks and open space include community cohesion as one of the benefits of parks (NPRA, 2010; Harnik, 2014). In neighborhood parks, residents of all ages have the opportunity to interact, which improves the quality of life in the neighborhood. Furthermore, the social capital that is created through parksð especially when neighbors work together to create, save, or renew a park or open spaceð not only benefits resident quality of life but wards off anti-social problems, reducing the need for police, prisons, and rehabilitation (Harnik, 2014).

The benefit of community cohesion was not quantified. The magnitude of the benefit will be affected by the level of community involvement during the planning and development of the Project as well as by the use of the Project area and facilities by residents upon the Projectô s completion.

3.2.4 ECONOMIC REVITALIZATION

Economic revitalization benefits from the near-term construction phase impacts on jobs, earnings, and regional output, and will accrue to local adjacent property owners from anticipated positive property value impacts beyond those provided by the coastal risk reduction function of the Project.

ECONOMIC IMPACTS

During the construction phase, the Project will support jobs in construction and related industries. Upon its completion, the Project will support jobs related to the O&M of the programming activities, breakwater, oyster restoration efforts, and beach. While typically not a net benefit to society, job creation constitutes a positive contribution to the New York City and New York State economies. Due to the unique character of the Project, it may attract local and out-of-state visitors whose spending would further increase the economic contribution of the Project to the New York City and State economy, respectively.

CONSTRUCTION PHASE

In the 2017 BCA, the economic impact of the Project construction was obtained from the Draft Environmental Impact Statement (DEIS). Using an input-output model, the DEIS estimated the total economic impact of the construction of the Project, which includes jobs in the construction and related industries (i.e., direct effect), jobs supported by spending on construction materials and other inputs at the supplying industries (i.e., indirect effect), and jobs supported by household spending by persons directly or indirectly working on the Project construction (i.e., induced effect). They found that the construction of the Project (Alternative 3 in the DEIS) would support a total of 419 person-years[1] of employment in New York State, 411 of which would be in New York City based on a construction cost of $66.5 million (in 2016$). Based on the 100 percent design construction cost estimate of $74 million assessed in this BCA, the Project would support a total of 434 person-years of employment in New York State, 426 of which would be in New York City. The construction of the Project would support 292 person-years of employment in the construction and related industries. Considering the indirect and induced jobs that would be generated through the multiplier effect, the Project would support an additional 134 person-years of employment in New York City and an additional 8 person-years of employment in the rest of New York State.

OPERATIONS

Upon completion of the construction, ongoing monitoring, maintenance, and educational programming spending will support additional jobs in Staten Island with multiplier effects in the rest of New York City and New York State. As explained in the Project lifecycle section, monitoring cost will average $0.6 million per year during the first five years of operation and an average of $0.3 million per year during the remainder of the Project lifetime. During the first five years of operation, spending on educational programming will be $55 thousand per year. In total, there will be an average of $0.4 million to $0.7 million of spending on Project operation and maintenance spending per year throughout the Project's lifecycle. This spending will support full and part-time jobs in education, monitoring of the performance and function of the breakwaters. These annually recurring expenditures will also generate additional indirect and induced economic impacts within the community and region.

VISITORS

Should the Living Breakwater Project attract visitors from outside New York City, or outside New York State, spending by these visitors (i.e., food, retail, transportation, and other recreation) would generate a positive impact on the New York City and New York State economies. For example, it can be expected that a portion of the visitors attending the family and adult education programs and/or persons traveling to the area for recreational purposes (e.g., kayaking) may reside outside of New York City, especially from neighboring New Jersey. The potential impact of visitor spending was not quantified due to the difficulty of anticipating the number of regional visitors, but it is expected to add some value in the future.

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[1] A person-year of employment is the equivalent of one person working full-time for one-year.

PROPERTY VALUE IMPACTS

Economists have applied hedonic property price based statistical (regression based) methods to isolate the effects of various attributes or amenities that can influence property values. Hedonic methods analyze how the different characteristics of a marketed good, including environmental quality, might affect the price people pay for the good or factor. This type of analysis provides estimates of the implicit prices paid for each characteristic, such as the number of rooms, and the quality of the adjacent host environment. A hedonic price function for residential property sales might decompose sale prices into implicit prices for the characteristics of the lot (e.g., acreage), characteristics of the house (e.g., structural attributes such as square footage of living area), and neighborhood and environmental quality characteristics. In terms of aquatic ecosystems, properties with closer proximity to these systems may sell for more than similar properties that do not have this adjacency or proximity (NRC, 2005).

The hedonic analysis method is a statistical procedure for accounting and disentangling estimates of the market price premium that residents pay for ocean frontage or having access to higher quality recreational amenities and ecological services. The BCA applied a hedonic market study that quantified the property value premium associated with the width of the beach itself. This study was particularly relevant to the Projectôs objec
erosion and providing for a contiguous beachfront and improved utility and access along the Project alignment.

The BCA applied a particular study that examined the increase in residential property values associated with a one-foot increase in beach width (Gopalakrishnan et al, 2010). The study included a functional determination or elasticity of (distance to x beach width) with respect to home prices. According to the study, a one-foot increase in beach width was associated with a 0.5% increase in home prices for those homes located within 32.8 feet from the Limit of Moderate Wave Action (LiMWA). To apply the results of this study through benefits transfer techniques, the BCA used GIS to isolate those homes within the Project area that were within 10 meters (32.8 feet) from the LiMWA. The market premium was based on holding the current market value of these properties constant in 2016 dollars as per HUD BCA Guidance (HUD CPD-16-06).

Based on a 7 percent discount rate, the present value of the property value benefits throughout the 50-year evaluation period equals 3.9 million.

4 PROJECT RISKS

4.1 DESCRIPTION OF PROJECT RISKS

As identified in the 2017 BCA, project risks generally relate to issues that could influence both the cost and timing of construction (SCAPE Appendix D, 2016), as follows:

Availability of Construction Materialsð Other factors relate to sourcing and availability of raw materials used in construction. This risk relates to contracting with the lowest cost suppliers of stones in sufficient quantities, with the appropriate rock sizes and qualities, having the needed surface textures to support and grow habitats. In addition, there is some risk related to sourcing sand quantities that meet quality and suitability criteria for shoreline restoration. Given high demand for beach nourishment fill in the New York/New Jersey region, unit prices may be higher for these materials that could influence Project construction costs.

Localized Unfavorable Construction Conditionsð In addition, some Project aspects could influence the estimated construction costs such as unanticipated soft soils/sediments that may be encountered in certain locations. These soils could lead to remedial procedures that could raise costs.

Extreme Weather Conditionsð The storm/hurricane season in New York has the potential to influence the construction schedule.

Stakeholder Concernsð Other risks relate to the possibility that certain stakeholders have concerns about the Project that could affect its construction schedule and cost. It is noted that the project team has performed outreach activities to inform stakeholders about the goals, objectives and benefits of the Living Breakwaters Project and received regular feedback from stakeholders throughout the design process, and will continue to perform these activities during construction.

4.2 SENSITIVITY ANALYSIS

A sensitivity analysis was comp cost-effectiveness of potential assessed th changes in Project costs and benefits. **Table 4-1** shows the results of the sensitivity analysis. The base present value of net benefits is $2.2 million using a 7 percent discount rate and $50 million using a 3 percent discount rate. The base BCR is 1.03 using a 7 percent discount rate and 1.54 using a 3 percent discount rate.

Table 4-1: Sensitivity Analysis

SENSITIVITY TEST	PRESENT VALUE OF NET BENEFITS	BCR
Increase in Capital Costs (10%), 7 % discount rate	($5,580,552)	0.94
Increase in Capital Costs (10%), 3 % discount rate	$41,435,265	1.41
Increase in Annual O&M (30%), 7 % discount rate	$933,732	1.01
Increase in Annual O&M (30%), 3 % discount rate	$47,767,462	1.50
Decrease in Annual O&M (30%), 7 % discount rate	$3,561,313	1.04
Decrease in Annual O&M (30%), 3 % discount rate	$52,224,800	1.58
Decrease in Resiliency Benefits (Percent of Baseline Estimates):		
90% of Baseline, 7 % discount rate	($3,587,063)	0.96

SENSITIVITY TEST	PRESENT VALUE OF NET BENEFITS	BCR
90% of Baseline, 3 % discount rate	$41,012,027	1.44
70% of Baseline, 3 % discount rate	$23,043,820	1.25
50% of Baseline, 3 % discount rate	$5,075,614	1.05
Decrease in Environmental Values (Percent of Baseline Estimates):		
90% of Baseline, 7 % discount rate	$1,202,548	1.01
80% of Baseline, 7 % discount rate	$157,574	1.00
90% of Baseline, 3 % discount rate	$47,859,588	1.51
50% of Baseline, 3 % discount rate	$39,313,418	1.42

The sensitivity analysis assesses the effect of an increase in construction cost on With a 7 percent discount rate, a 10 percent increase in capital costs would lower the BCR from 1.03 to 0.94 and erase the positive cumulative net present value of the Project. With a 3 percent discount rate, a 10 percent increase in capital costs would lower the BCR from 1.54 to 1.41. The O&M cost for future years is uncertain because changes in technologies, industry practices, and regulations may decrease or increase the cost. A 30 percent increase in annual O&M would lower the baseline BCR from 1.03 to 1.01, holding all other variables constant and a 7 percent discount rate. A 30 percent decrease in the O&M cost, on the other hand, would increase the baseline BCR from 1.03 to 1.04 based on a 7 percent discount rate. With a 3 percent discount rate, a 30 percent increase in O&M cost would reduce the BCR from 1.54 to 1.50, while a 30 percent decrease in O&M cost would increase the BCR to 1.58.

Resiliency and environmental values provide the majority of the benefits for the Project. The sensitivity analysis starts by reducing the combined value of resiliency benefits to a percentage of the baseline total values. The Projectôs total net present value will be posi 50 percent of their current estimated level if using a 3 percent discount rate

4.2.1 DISCOUNT RATE

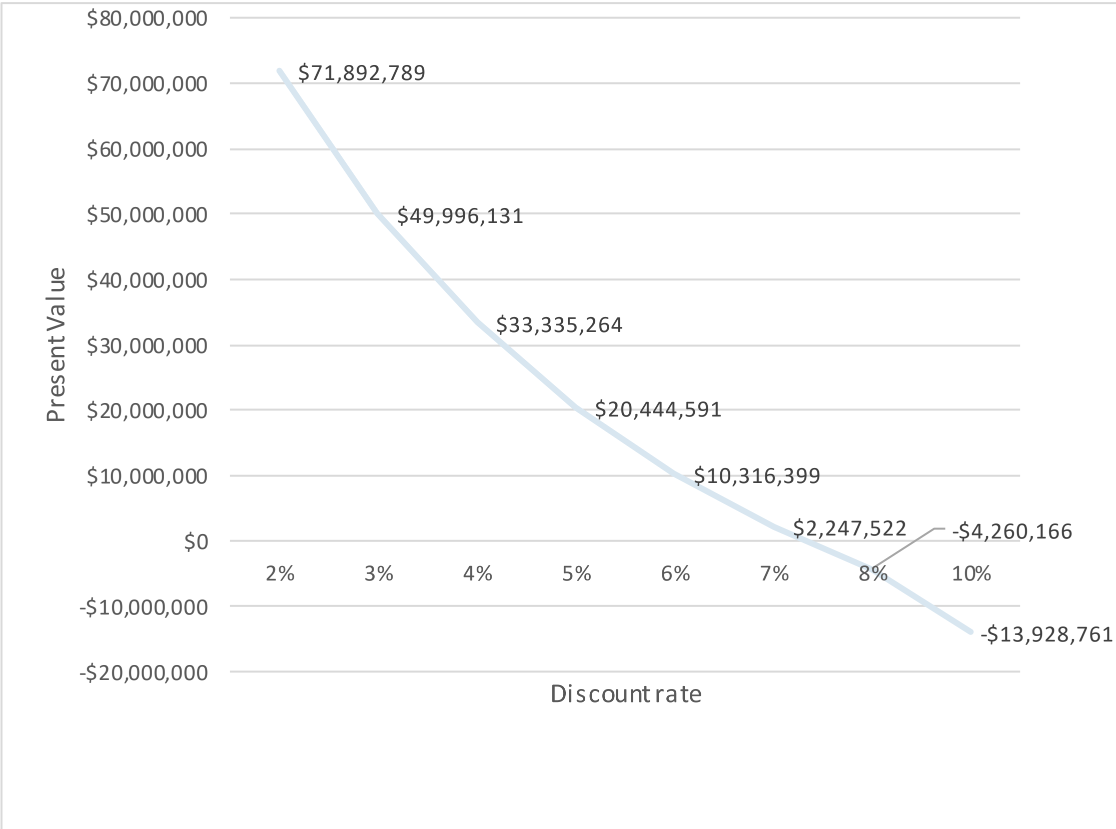
A separate analysis was conducted to assess the sensitivity net benefits (or NPV) and BCR Projectôs changes in the discount rate only. **Table 4-2** shows the Projectôs cumulative pres at various discount rates. orable The discount Project rate is up to 7 percent. NPV and BCR

Table 4-2: Discount Rate Sensitivity Analysis

DISCOUNT RATE	PRESENT VALUE OF NET BENEFITS	BCR
2%	$71,892,789	1.75
3%	$49,996,131	1.54
4%	$33,335,264	1.37
5%	$20,444,591	1.23
6%	$10,316,399	1.12
7%	$2,247,522	1.03
8%	-$4,260,166	0.95

Figure 4-1 plots the results of the sensitivity analysis of

Figure 4-1: Living Breakwaters Project Net Present Value at Varying Discount Rates



5 ASSESSMENT OF IMPLEMENTATION CHALLENGES

As outlined in the description of the Project risks noted above, the Project faces some implementation challenges. These challenges relate to coping with unforeseen factors that can affect construction costs and unanticipated delays in the construction schedule, and other uncertainties associated with offshore coastal construction and permitting. In addition, some challenges relate to effectively explaining the Project benefits to select constituencies and the overall community.

However, the sponsor and design team are effectively addressing these challenges in proactive and engaging ways that are reducing the risk to successful Project implementation. A variety of public outreach meetings have been scheduled, including the creation of the Citizenôs Advi keholders to advise GOSR on design concerns and ultimately construction impacts. These activities will continue to be hosted and promoted in the future.

6 CONCLUSION

This BCA for the Living Breakwaters Project was prepared by following the HUD BCA Guidance for APA for RBD Projects (HUD CPD-16-06). The analysis was completed using generally accepted economic and financial principles for BCA as articulated in OMB Circular A-94.

The Project is designed to (1) reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville; (2) enhance habitat functions and values supporting local ecosystems through the creation and improvement of nearshore and coastal habitat; and (3) foster stewardship and recreational and educational use of the coast and nearshore through increased awareness, access, and participation.

Using a 7 percent discount rate, and a 50-year evaluation period, the Project will generate substantial net benefits to the shoreline community of Tottenville, as well as other beneficiaries from the New York metropolitan region and regional visitors who use this community asset. **Table 6-1** and **Figure 6-1** provide more details on the categories of estimated benefits and costs.

To summarize, the lifecycle costs to build and operate the proposed Living Breakwaters Project investment (amounting to $82.7 million in constant 2020 present value dollars) would generate the following quantified benefits (and not including benefits discussed above but not quantified for various reasons):

¶ Total benefits of $84.9 million:

  - $58.3 million resiliency values;
  - $10.6 million environmental values;
  - $12.1 million social values; and
  - $3.9 million economic revitalization benefits.

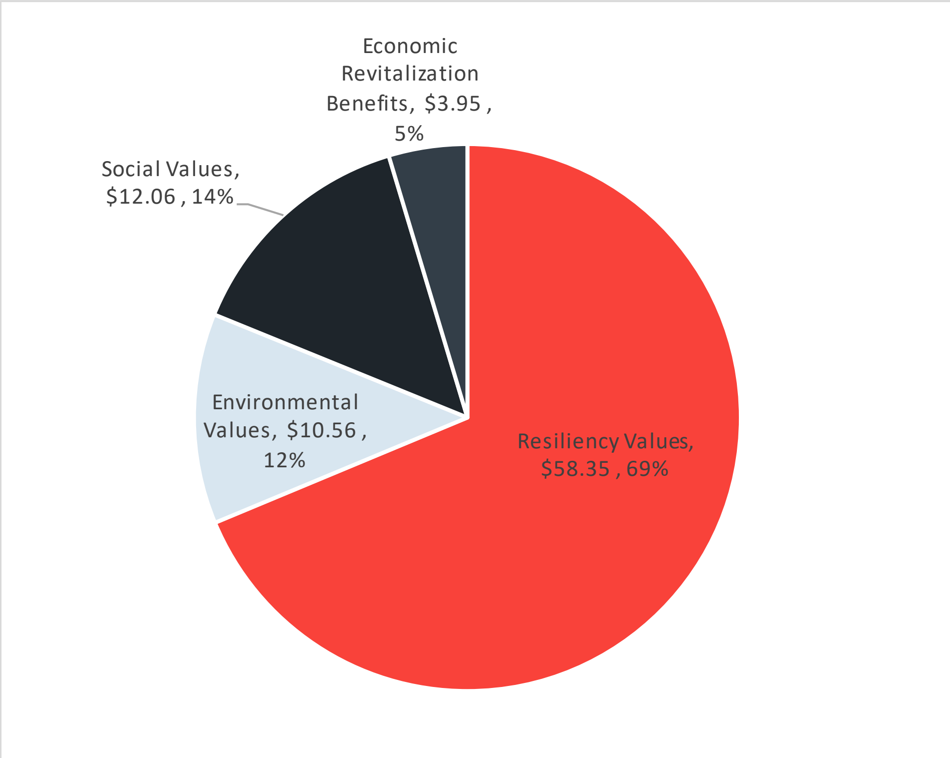
The Projectôs cum net benefits is $2.2 million and the BCR is 1.03 based on a 7 percent discount rate. These measures of project merit demonstrate that the Project is viable and would add value to the community, the environment, and the economy.

The Projectôs future annual benefit streams, year horizon, were also subjected to a sensitivity analysis examining the impacts of implementation phase and operational risks and uncertainties. The results showed that the Projectôs net present value o uncertainties that may arise and can still be economically viable over this period with a 3 percent discount rate.

Table 6-1: Living Breakwaters – Benefit Cost Analysis Summary (2020$)

	7%	3%
LIFECYCLE COSTS		
Project Investment Costs	$78,280,740	$85,608,660
Operations & Maintenance	$4,379,303	$7,428,897
Total Costs	**$82,660,043**	**$93,037,558**
BENEFITS		
Resiliency Values	**$58,345,852**	$89,841,035
Avoided Property Damages	$3,446,874	$7,277,180
Avoided Casualties (Mortality & Injuries)	$3,262,364	$6,567,390
Avoided Mental Health Treatment Costs	$561,915	$1,131,178
Avoided Lost Productivity Costs	$1,259,875	$2,536,225
Avoided shoreline erosion/dune reconstruction costs	$47,450,148	$67,555,200
Avoided displacement/disruption costs	$266,448	$542,491
Avoided Road Closure/Travel Disruption costs	$323,207	$650,640
Avoided Cost of Power Outages	$1,159,383	$2,333,927
Avoided Automobile Damages	$77,179	$167,266
Avoided Debris	$6,850	$14,512
Avoided Emergency Repairs	$22,078	$47,813
Avoided Damages to Parks and Utilities	$509,532	$1,017,212
Environmental Values	**$10,557,255**	$21,481,453
Total Gross Ecosystem Annual Service Gains (+)	$10,723,747	$21,809,222
Total Ecosystem Annual Services Displaced (-)	$166,492	$327,769
Net Ecosystem Annual Service Gains	$10,557,255	$21,481,453
Social Values	**$12,057,887**	$23,832,401
Educational/Environmental Stewardship	$322,966	$405,211
Recreation	$11,734,921	$23,427,190
Economic Revitalization Benefits	**$3,946,572**	$7,878,799
Property Value Impacts (∫[Distance and Beach Width])	$3,946,572	$7,878,799
Total Benefits	**$84,907,565**	**$143,033,689**
NET BENEFITS	**$2,247,522**	**$49,996,131**
Benefit Cost Ratio	**1.03**	**1.54**

Figure 6-1: Living Breakwaters Project–Benefit Cost Analysis Summary



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Project Resource Statement ï Year 1 - 10

Living Breakwaters Project - BCA Project Resource Statement											
constant 2020 US Dollars											
	0	1	2	3	4	5	6	7	8	9	10
	Year										
HUD Guidance Categories	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
LIFECYCLE COSTS			12	12	6						
	$ 7,816,613	$ 7,816,613	$ 30,478,084	$ 30,478,084	$ 15,239,042	$10,600	$10,600	$10,600	$10,600	$10,600	
Project Investment Costs	$7,816,613	$7,816,613	$30,478,084	$30,478,084	$15,239,042	$10,600	$10,600	$10,600	$10,600	$10,600	$0
Operations & Maintenance	$0	$0	$90,223	$472,633	$434,890	$787,721	$434,890	$581,617	$938,603	$204,843	$0
Total Costs	$7,816,613	$7,816,613	$30,568,307	$30,950,716	$15,673,932	$798,321	$445,490	$592,217	$949,203	$215,443	$0
BENEFITS											
Resiliency Values	**$0**	**$0**	**$217,064**	**$653,190**	**$1,092,007**	**$27,591,581**	**$1,260,074**	**$1,105,560**	**$1,110,700**	**$27,771,683**	**$1,121,089**
Avoided Property Damages	$0	$0	$50,926	$154,238	$259,517	$261,995	$264,496	$267,021	$269,570	$272,144	$274,742
Avoided Casualties (Mortality & Injuries)	$0	$0	$53,575	$160,943	$268,600	$268,962	$270,148	$271,339	$272,535	$273,737	$274,944
Avoided Mental Health Treatment Costs	$0	$0	$9,228	$27,721	$46,264	$46,326	$46,531	$46,736	$46,942	$47,149	$47,357
Avoided Lost Productivity Costs	$0	$0	$20,690	$62,154	$103,729	$103,869	$104,327	$104,787	$105,249	$105,713	$106,179
Avoided shoreline erosion/dune reconstruction costs	$0	$0	$43,918	$131,755	$219,592	$26,715,783	$379,209	$219,592	$219,592	$26,875,399	$219,592
Avoided displacement/disruption costs	$0	$0	$4,294	$12,926	$21,618	$21,692	$21,766	$21,841	$21,916	$21,991	$22,067
Avoided Road Closure/Travel Disruption costs	$0	$0	$5,308	$15,945	$26,611	$26,646	$26,764	$26,882	$27,000	$27,119	$27,239
Avoided Cost of Power Outages	$0	$0	$19,040	$57,196	$95,455	$95,584	$96,005	$96,429	$96,854	$97,281	$97,710
Avoided Automobile Damages	$0	$0	$1,071	$3,256	$5,501	$5,577	$5,654	$5,733	$5,812	$5,892	$5,973
Avoided Debris Removal	$0	$0	$100	$304	$512	$517	$523	$528	$533	$539	$544
Avoided Emergency Repairs	$0	$0	$307	$933	$1,576	$1,598	$1,620	$1,642	$1,664	$1,687	$1,710
Avoided damages to Parks and Utilities	$0	$0	$8,606	$25,819	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032
Environmental Values	$0	$0	$123,094	$396,571	$656,403	$818,877	$932,051	$932,051	$932,051	$932,051	$932,051
Total Gross Ecosystem Annual Service Gains (+)	$0	$0	$134,010	$402,029	$670,048	$832,522	$945,696	$945,696	$945,696	$945,696	$945,696
Total Ecosystem Annual Services Displaced (-)	$0	$0	$10,916	$5,458	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645
Net Ecosystem Annual Service Gains	$0	$0	$123,094	$396,571	$656,403	$818,877	$932,051	$932,051	$932,051	$932,051	$932,051
Social Values											
Educational/Environmental Stewardship	$31,029	$31,029	$35,452	$35,452	$35,452	$35,452	$35,452	$35,452	$35,452	$35,452	$29,187
Recreation	$0	$0	$198,210	$594,630	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050
Economic Revitalization Benefits											
Property Value Impacts (∫[Distance and Beach Width])	$0	$0	$66,660	$199,980	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300
Total Benefits	$31,029	$31,029	$640,479	$1,879,823	$3,108,212	$29,770,259	$3,551,926	$3,397,413	$3,402,553	$30,063,536	$3,406,677
Benefits less Costs	-$7,785,583	-$7,785,583	-$29,927,828	-$29,070,894	-$12,565,720	$28,971,938	$3,106,436	$2,805,196	$2,453,350	$29,848,093	$3,406,677

Project Resource Statement ï Year 11-20

Living Breakwaters Project - BCA Project Resource Statement										
constant 2020 US Dollars										
	11	12	13	14	15	16	17	18	19	20
HUD Guidance Categories	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
LIFECYCLE COSTS										
Project Investment Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operations & Maintenance	$217,318	$0	$1,205,171	$0	$244,593	$0	$259,488	$917,038	$183,528	$0
Total Costs	$217,318	$0	$1,205,171	$0	$244,593	$0	$259,488	$917,038	$183,528	$0
BENEFITS										
Resiliency Values	**$1,124,411**	**$1,287,376**	**$27,627,326**	**$1,134,539**	**$1,297,532**	**$1,141,625**	**$1,145,363**	**$1,308,747**	**$1,152,928**	**$1,156,811**
Avoided Property Damages	$277,365	$280,013	$282,686	$285,385	$288,110	$290,860	$293,637	$296,440	$299,271	$302,128
Avoided Casualties (Mortality & Injuries)	$275,198	$275,452	$275,707	$275,961	$276,189	$276,567	$276,946	$277,326	$277,706	$278,115
Avoided Mental Health Treatment Costs	$47,401	$47,444	$47,488	$47,532	$47,571	$47,636	$47,702	$47,767	$47,833	$47,903
Avoided Lost Productivity Costs	$106,277	$106,375	$106,474	$106,572	$106,660	$106,806	$106,952	$107,099	$107,246	$107,404
Avoided shoreline erosion/dune reconstruction costs	$219,592	$379,209	$26,715,783	$219,592	$379,209	$219,592	$219,592	$379,209	$219,592	$219,592
Avoided displacement/disruption costs	$22,143	$22,219	$22,295	$22,372	$22,448	$22,526	$22,603	$22,681	$22,758	$22,837
Avoided Road Closure/Travel Disruption costs	$27,264	$27,289	$27,315	$27,340	$27,362	$27,400	$27,437	$27,475	$27,513	$27,553
Avoided Cost of Power Outages	$97,800	$97,891	$97,981	$98,071	$98,152	$98,287	$98,422	$98,556	$98,692	$98,837
Avoided Automobile Damages	$6,056	$6,139	$6,224	$6,310	$6,397	$6,485	$6,575	$6,666	$6,758	$6,851
Avoided Debris Removal	$549	$555	$561	$566	$572	$578	$584	$590	$596	$602
Avoided Emergency Repairs	$1,734	$1,757	$1,781	$1,806	$1,831	$1,856	$1,881	$1,907	$1,933	$1,959
Avoided damages to Parks and Utilities	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032
Environmental Values	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051
Total Gross Ecosystem Annual Service Gains (+)	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696
Total Ecosystem Annual Services Displaced (-)	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645
Net Ecosystem Annual Service Gains	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051
Social Values										
Educational/Environmental Stewardship	$29,187	$29,187	$29,187	$29,187	$0	$0	$0	$0	$0	$0
Recreation	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050
Economic Revitalization Benefits										
Property Value Impacts (∫[Distance and Beach Width])	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300
Total Benefits	$3,409,999	$3,572,964	$29,912,914	$3,420,127	$3,553,933	$3,398,026	$3,401,764	$3,565,148	$3,409,329	$3,413,212
Benefits less Costs	$3,192,681	$3,572,964	$28,707,743	$3,420,127	$3,309,341	$3,398,026	$3,142,276	$2,648,110	$3,225,801	$3,413,212

Project Resource Statement ï Year 21 - 30

Living Breakwaters Project - BCA Project Resource Statement										
constant 2020 US Dollars										
	21	22	23	24	25	26	27	28	29	30
HUD Guidance Categories	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
LIFECYCLE COSTS										
Project Investment Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operations & Maintenance	$194,704	$0	$406,098	$0	$219,141	$0	$232,487	$478,924	$0	$416,403
Total Costs	$194,704	$0	$406,098	$0	$219,141	$0	$232,487	$478,924	$0	$416,403
BENEFITS										
Resiliency Values	**$1,320,494**	**$1,164,974**	**$1,169,103**	**$1,332,880**	**$1,177,457**	**$1,181,518**	**$1,345,227**	**$1,189,736**	**$1,193,894**	**$1,357,702**
Avoided Property Damages	$305,012	$307,924	$310,864	$313,832	$316,828	$319,853	$322,906	$325,989	$329,101	$332,243
Avoided Casualties (Mortality & Injuries)	$278,599	$279,085	$279,571	$280,059	$280,547	$280,954	$281,362	$281,770	$282,180	$282,589
Avoided Mental Health Treatment Costs	$47,986	$48,070	$48,154	$48,238	$48,322	$48,392	$48,462	$48,533	$48,603	$48,674
Avoided Lost Productivity Costs	$107,591	$107,778	$107,966	$108,154	$108,343	$108,500	$108,658	$108,815	$108,973	$109,132
Avoided shoreline erosion/dune reconstruction costs	$379,209	$219,592	$219,592	$379,209	$219,592	$219,592	$379,209	$219,592	$219,592	$379,209
Avoided displacement/disruption costs	$22,915	$22,994	$23,073	$23,152	$23,231	$23,311	$23,391	$23,472	$23,552	$23,633
Avoided Road Closure/Travel Disruption costs	$27,601	$27,649	$27,698	$27,746	$27,794	$27,834	$27,875	$27,915	$27,956	$27,996
Avoided Cost of Power Outages	$99,009	$99,182	$99,354	$99,528	$99,701	$99,846	$99,991	$100,136	$100,281	$100,427
Avoided Automobile Damages	$6,946	$7,042	$7,139	$7,237	$7,337	$7,439	$7,541	$7,645	$7,751	$7,858
Avoided Debris Removal	$608	$614	$620	$626	$633	$639	$645	$652	$659	$665
Avoided Emergency Repairs	$1,986	$2,013	$2,041	$2,069	$2,097	$2,126	$2,155	$2,184	$2,214	$2,244
Avoided damages to Parks and Utilities	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032
Environmental Values	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051
Total Gross Ecosystem Annual Service Gains (+)	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696
Total Ecosystem Annual Services Displaced (-)	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645
Net Ecosystem Annual Service Gains	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051
Social Values										
Educational/Environmental Stewardship	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Recreation	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050
Economic Revitalization Benefits										
Property Value Impacts (∫[Distance and Beach Width])	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300
Total Benefits	$3,576,895	$3,421,376	$3,425,504	$3,589,281	$3,433,858	$3,437,919	$3,601,628	$3,446,137	$3,450,295	$3,614,103
Benefits less Costs	$3,382,190	$3,421,376	$3,019,407	$3,589,281	$3,214,716	$3,437,919	$3,369,141	$2,967,213	$3,450,295	$3,197,700

Project Resource Statement – Year 31 - 40

Living Breakwaters Project - BCA Project Resource Statement										
constant 2020 US Dollars										
	31	32	33	34	35	36	37	38	39	40
HUD Guidance Categories	**2051**	**2052**	**2053**	**2054**	**2055**	**2056**	**2057**	**2058**	**2059**	**2060**
LIFECYCLE COSTS										
Project Investment Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operations & Maintenance	$0	$416,403	$221,028	$214,544	$0	$214,544	$0	$214,544	$0	$559,611
Total Costs	$0	$416,403	$221,028	$214,544	$0	$214,544	$0	$214,544	$0	$559,611
BENEFITS										
Resiliency Values	**$1,202,292**	**$1,206,532**	**$1,370,422**	**$1,215,113**	**$1,219,456**	**$1,382,637**	**$1,226,620**	**$1,230,254**	**$1,393,539**	**$1,237,626**
Avoided Property Damages	$335,415	$338,617	$341,850	$345,114	$348,409	$351,735	$355,093	$358,483	$361,906	$365,361
Avoided Casualties (Mortality & Injuries)	$282,990	$283,392	$283,794	$284,196	$284,599	$284,599	$284,599	$284,599	$284,599	$284,599
Avoided Mental Health Treatment Costs	$48,743	$48,812	$48,881	$48,950	$49,020	$49,020	$49,020	$49,020	$49,020	$49,020
Avoided Lost Productivity Costs	$109,286	$109,441	$109,597	$109,752	$109,908	$109,908	$109,908	$109,908	$109,908	$109,908
Avoided shoreline erosion/dune reconstruction costs	$219,592	$219,592	$379,209	$219,592	$219,592	$379,209	$219,592	$219,592	$379,209	$219,592
Avoided displacement/disruption costs	$23,714	$23,796	$23,877	$23,959	$24,042	$24,124	$24,207	$24,290	$24,374	$24,457
Avoided Road Closure/Travel Disruption costs	$28,036	$28,076	$28,116	$28,156	$28,196	$28,196	$28,196	$28,196	$28,196	$28,196
Avoided Cost of Power Outages	$100,569	$100,712	$100,855	$100,998	$101,141	$101,141	$101,141	$101,141	$101,141	$101,141
Avoided Automobile Damages	$7,966	$8,076	$8,188	$8,301	$8,416	$8,532	$8,650	$8,769	$8,890	$9,013
Avoided Debris Removal	$672	$679	$686	$693	$700	$707	$714	$721	$728	$736
Avoided Emergency Repairs	$2,275	$2,306	$2,338	$2,370	$2,402	$2,435	$2,468	$2,502	$2,536	$2,571
Avoided damages to Parks and Utilities	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032
Environmental Values	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051
Total Gross Ecosystem Annual Service Gains (+)	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696
Total Ecosystem Annual Services Displaced (-)	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645
Net Ecosystem Annual Service Gains	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051
Social Values										
Educational/Environmental Stewardship	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Recreation	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050
Economic Revitalization Benefits										
Property Value Impacts (∫[Distance and Beach Width])	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300
Total Benefits	$3,458,693	$3,462,933	$3,626,823	$3,471,514	$3,475,857	$3,639,038	$3,483,021	$3,486,655	$3,649,940	$3,494,027
Benefits less Costs	$3,458,693	$3,046,530	$3,405,795	$3,256,970	$3,475,857	$3,424,494	$3,483,021	$3,272,110	$3,649,940	$2,934,417

Project Resource Statement ï Year 41 - 50

Living Breakwaters Project - BCA Project Resource Statement										
constant 2020 US Dollars										
	41	42	43	44	45	46	47	48	49	50
HUD Guidance Categories	**2061**	**2062**	**2063**	**2064**	**2065**	**2066**	**2067**	**2068**	**2069**	**2070**
LIFECYCLE COSTS										
Project Investment Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operations & Maintenance	$0	$559,611	$297,043	$288,330	$0	$288,330	$0	$288,330	$0	$738,590
Total Costs	$0	$559,611	$297,043	$288,330	$0	$288,330	$0	$288,330	$0	$738,590
BENEFITS										
Resiliency Values	**$1,241,365**	**$1,404,757**	**$1,248,952**	**$1,252,800**	**$1,416,301**	**$1,260,606**	**$1,264,566**	**$1,428,180**	**$1,272,600**	**$1,276,675**
Avoided Property Damages	$368,849	$372,371	$375,926	$379,515	$383,138	$386,796	$390,489	$394,217	$397,981	$401,780
Avoided Casualties (Mortality & Injuries)	$284,599	$284,599	$284,599	$284,599	$284,599	$284,599	$284,599	$284,599	$284,599	$284,599
Avoided Mental Health Treatment Costs	$49,020	$49,020	$49,020	$49,020	$49,020	$49,020	$49,020	$49,020	$49,020	$49,020
Avoided Lost Productivity Costs	$109,908	$109,908	$109,908	$109,908	$109,908	$109,908	$109,908	$109,908	$109,908	$109,908
Avoided shoreline erosion/dune reconstruction costs	$219,592	$379,209	$219,592	$219,592	$379,209	$219,592	$219,592	$379,209	$219,592	$219,592
Avoided displacement/disruption costs	$24,541	$24,626	$24,710	$24,795	$24,880	$24,966	$25,051	$25,137	$25,224	$25,310
Avoided Road Closure/Travel Disruption costs	$28,196	$28,196	$28,196	$28,196	$28,196	$28,196	$28,196	$28,196	$28,196	$28,196
Avoided Cost of Power Outages	$101,141	$101,141	$101,141	$101,141	$101,141	$101,141	$101,141	$101,141	$101,141	$101,141
Avoided Automobile Damages	$9,137	$9,263	$9,391	$9,521	$9,652	$9,786	$9,921	$10,058	$10,197	$10,337
Avoided Debris Removal	$743	$751	$758	$766	$774	$781	$789	$797	$805	$813
Avoided Emergency Repairs	$2,606	$2,642	$2,678	$2,715	$2,752	$2,790	$2,828	$2,866	$2,906	$2,945
Avoided damages to Parks and Utilities	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032	$43,032
Environmental Values	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051
Total Gross Ecosystem Annual Service Gains (+)	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696	$945,696
Total Ecosystem Annual Services Displaced (-)	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645	$13,645
Net Ecosystem Annual Service Gains	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051	$932,051
Social Values										
Educational/Environmental Stewardship	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Recreation	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050	$991,050
Economic Revitalization Benefits										
Property Value Impacts (∫[Distance and Beach Width])	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300	$333,300
Total Benefits	$3,497,766	$3,661,158	$3,505,353	$3,509,201	$3,672,702	$3,517,007	$3,520,967	$3,684,581	$3,529,001	$3,533,076
Benefits less Costs	$3,497,766	$3,101,547	$3,208,310	$3,220,871	$3,672,702	$3,228,678	$3,520,967	$3,396,252	$3,529,001	$2,794,486

APPENDIX A

MEMORANDUM: WAVE ATTENUATION PERFORMANCE WITH SEA LEVEL RISE

MEMO

Date:	11/25/2020
From:	Pippa Brashear (SCAPE), Joe Marrone (ARCADIS)
To:	Scott Narod (GOSR)
Cc:	Joe Silva, John Bazzoni (COWI)
Re:	**Breakwater IFC: wave attenuation performance with sea level rise**

Dear Scott,

As requested, the design team has evaluated the Living Breakwaters Issued for Construction (IFC) layout performance with respect to the design wave conditions and several sea level rise (SLR) scenarios. The purpose of this evaluation is to determine how effective the breakwaters will be at attenuating storm waves in the future with SLR.

Storm wave reduction effectiveness was measured as the ability of the breakwaters to continue to meet the project's performance target of reducing storm waves to less than 3 feet in height at infrastructure or residential structures within the project area. It is important to note that storm wave reduction is only one of the goals of the Living Breakwaters project. Other goals include enhancing habitat functions; fostering stewardship, recreational use, and education; and reducing risk through decreasing or reversing long-term shoreline trends, all of which will continue to be met with increasing SLR. The other risk reduction component—erosion reduction or reversal—while not analyzed here, prior analysis indicates that the issued for construction design provides effective erosion reduction or reversal performance with SLR up to 2.5 feet.

Method

In order to test the wave attention performance of over the range of SLR scenarios, Arcadis utilized the FUNWAVE numerical model. The tool and model setup were consistent with previous analyses undertaken during the project's Final Design and value engineering phases. Two wave directions were considered, from the East (significant wave height of 5.3 feet) and East South East (significant wave height of 4.2 feet). For explanation of the wave directions and heights used, refer to the Final Design Modeling Report submitted on 11/15/2018. For this phase of work, the water level was varied to account for SLR (see below). For this evaluation, the model was run with the temporary dune included in the topography.

Table 1 - Water Levels

Present Day 1%-Annual-Chance Still Water Elevation (feet – NAVD88)	SLR (feet)	SLR Scenario Still Water Elevation (feet – NAVD88)
12.9	0.5	13.4
12.9	1.0	13.9
12.9	1.75	14.65

Results & Analysis

The model results were consistent with previous models, in-line with expectations and no unexpected performance areas were noted. The models indicated that the IFC breakwater alignment would meet the wave attenuation performance criteria of a reduction to less than 3-foot waves reaching infrastructure or residences during the 1%-annual-chance storm event for SLR scenarios up to 1 foot. For the 1.75-foot SLR scenario, 3-foot waves were just reaching the end of Sprague Avenue, and as such was determined to not strictly meet the performance goal. It should be noted that the breakwaters will continue to provide significant wave reduction benefits (relative to the without breakwaters scenario) when SLR exceeds 1.0 foot. The models indicate that even in the 1.75-foot SLR scenario, the breakwaters still significantly reduce wave heights in the project area. However, they will no longer strictly meet the specific performance target identified for the project design.

The New York City Panel on Climate Change (NPCC) prepares sea level rise projections for New York City. One foot of SLR is within the NPCC's middle range (25^{th}-75^{th} percentile) projection of SLR for 2050 or low estimate (10^{th} percentile) for 2080 (Vivien Gornitz, Michael Oppenheimer, Robert Kopp, Philip Orton, Maya Buchanan, Ning Lin, Radley Horton, Daniel Bader. New York City Panel on Climate Change 2019 Report Chapter 3: Sea Level Rise. Annals of the New York Academy of Sciences, March, 2019. https://doi.org/10.1111/nyas.14006).

ATTACHMENTS:

1. FUNWAVE modeling results for IFC breakwater alignment and SLR scenarios.

LIVING BREAKWATERS

Issued for Construction Breakwater Layout

Sea Level Rise Performance Evaluation

FUNWAVE Modeling Results

Assumptions / Data sources

- FUNWAVE is a phase-resolving Boussinesq wave model that solves Boussinesq-type hydrodynamic equations for waves and currents from deep water to the swash zone. It was developed at the University of Delaware and is suitable for wave modeling near breakwaters.
- FUNWAVE requires the following inputs:
  - Wave height and wave period generated by a wave maker boundary
  - Lateral boundary conditions of sponge layers
  - Computational grid and bathymetry
  - Water level
- Based on the directional frequency analysis and wave roses of the 30-year wave data hindcasted by the wave transformation model, the east (E) and east-southeast (ESE) directions are the maximum wave and dominant wave directions.

Assumptions / Data sources

- Bathymetry and topography were assigned to the computational grid based on the following sources:
  - Bathymetry/NJ Topography - FEMA PFIRM coastal study (FEMA, 2014a)
  - Bathymetry – Multibeam bathymetric survey and beach transects surveys in the vicinity of the initial Living
  - Breakwaters alignments (Hill International, 2015; MFS, 2015)
  - Topography
    - NYC 2010 1-foot LiDAR (NYCDOITT, 2012)
    - NYC 2014 1-foot LiDAR (NYCDOITT, 2014)
- For the Issued for Construction (IFC)) breakwater layout, breakwater wave performance was checked using the NYC 2014 1-foot LiDAR (NYCDOITT, 2014). The 2014 LiDAR includes the temporary dune system installed in the project area post-Superstorm Sandy.
- While using the 2010 LiDAR would provides a slightly conservative approach, using the 2014 LiDAR provides a realistic assessment given that it is likely that either the temporary dunes will remain in place or that the Tottenville Shoreline Protection Project (TSPP) will provide shoreline protection at least equivalent to the existing temporary dune system.

Assumptions / Data sources

› Please refer to the Final Design Modeling Report, November 16, 2018, for more detailed information on the modeling effort.

› The in order to evaluate future breakwater performance with sea level rise (SLR), the following water level scenarios were evaluated for the IFC breakwater layout:

Present Day 1%-Annual-Chance Still Water Elevation (feet – NAVD88)	SLR (feet)	SLR Scenario Still Water Elevation (feet – NAVD88)
12.9	0.5	13.4
12.9	1.0	13.9
12.9	1.75	14.65

FUNWAVE RESULTS:
No Action Scenario

1% Annual Chance Storm (0 SLR)

Waves from E and ESE

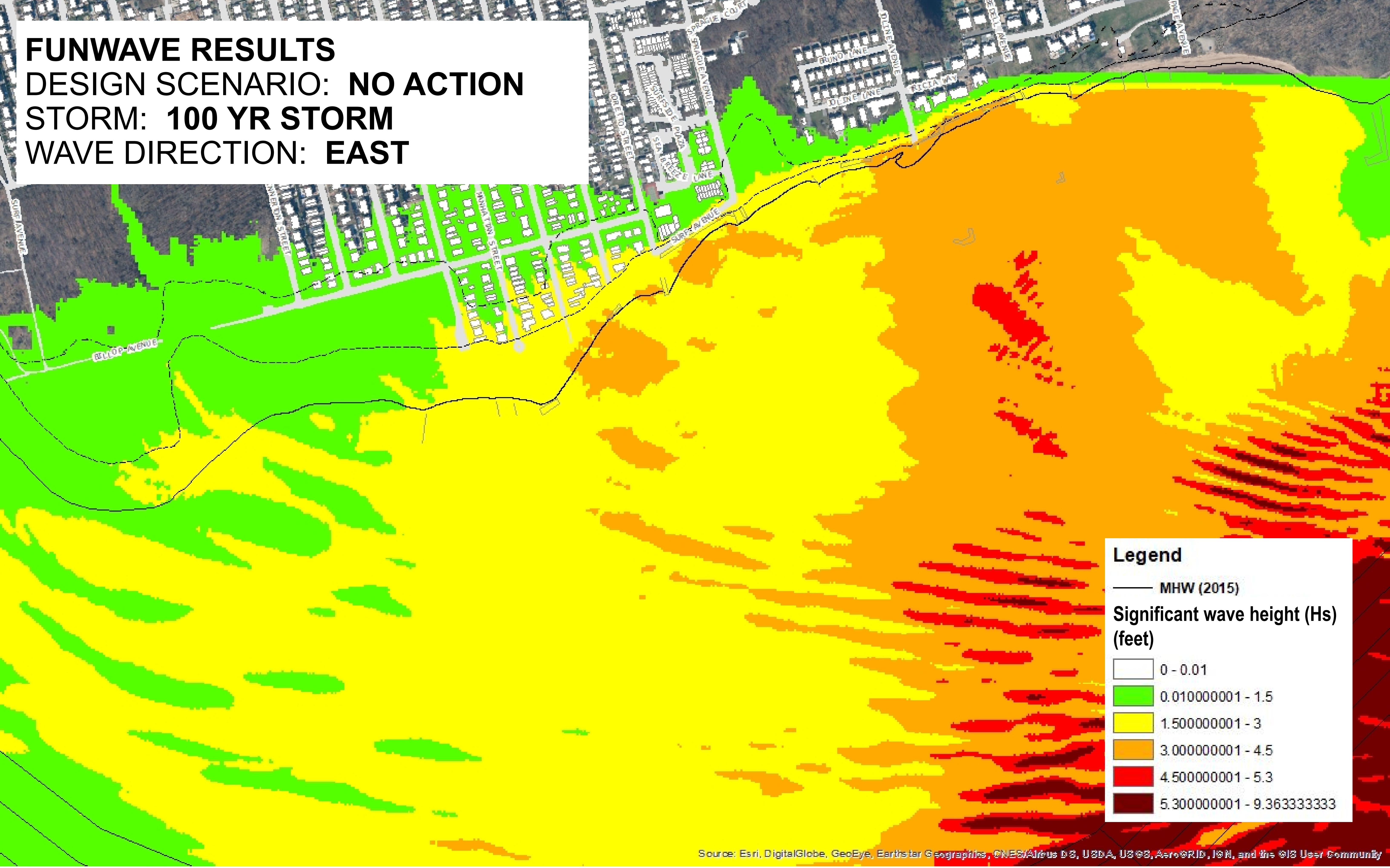
NYC 2010 1-foot LiDAR (Temporary Dunes not in place)

FUNWAVE RESULTS

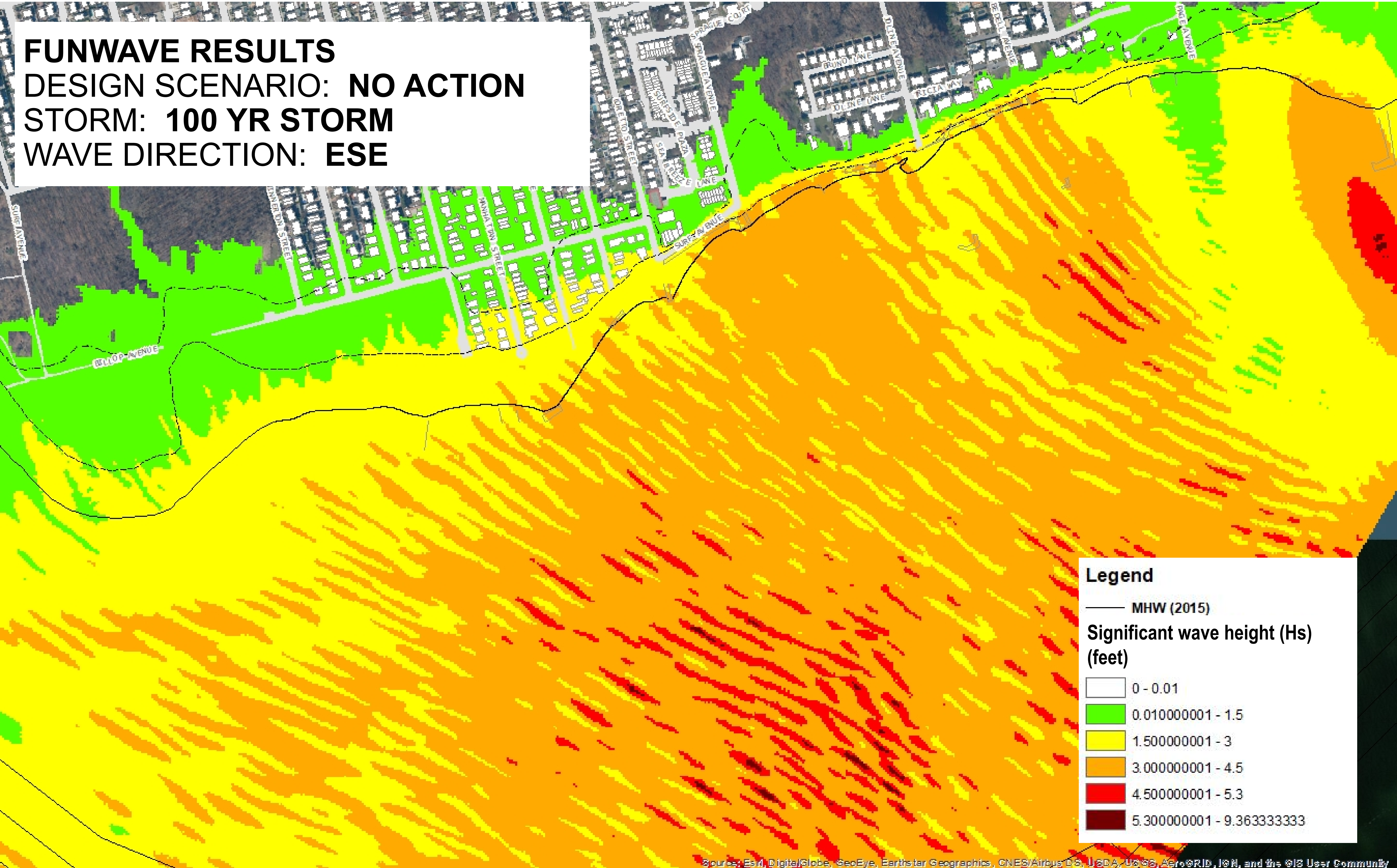
DESIGN SCENARIO: **NO ACTION**

STORM: **100 YR STORM**

WAVE DIRECTION: **EAST**



FUNWAVE RESULTS
DESIGN SCENARIO: **NO ACTION**
STORM: **100 YR STORM**
WAVE DIRECTION: **ESE**



FUNWAVE RESULTS: ISSUED FOR CONSTRUCTION (IFC) ALIGNMENT

1% Annual Chance Storm

No SLR; SLR 0.5 ft; SLR 1.00 ft; SLR 1.75 ft

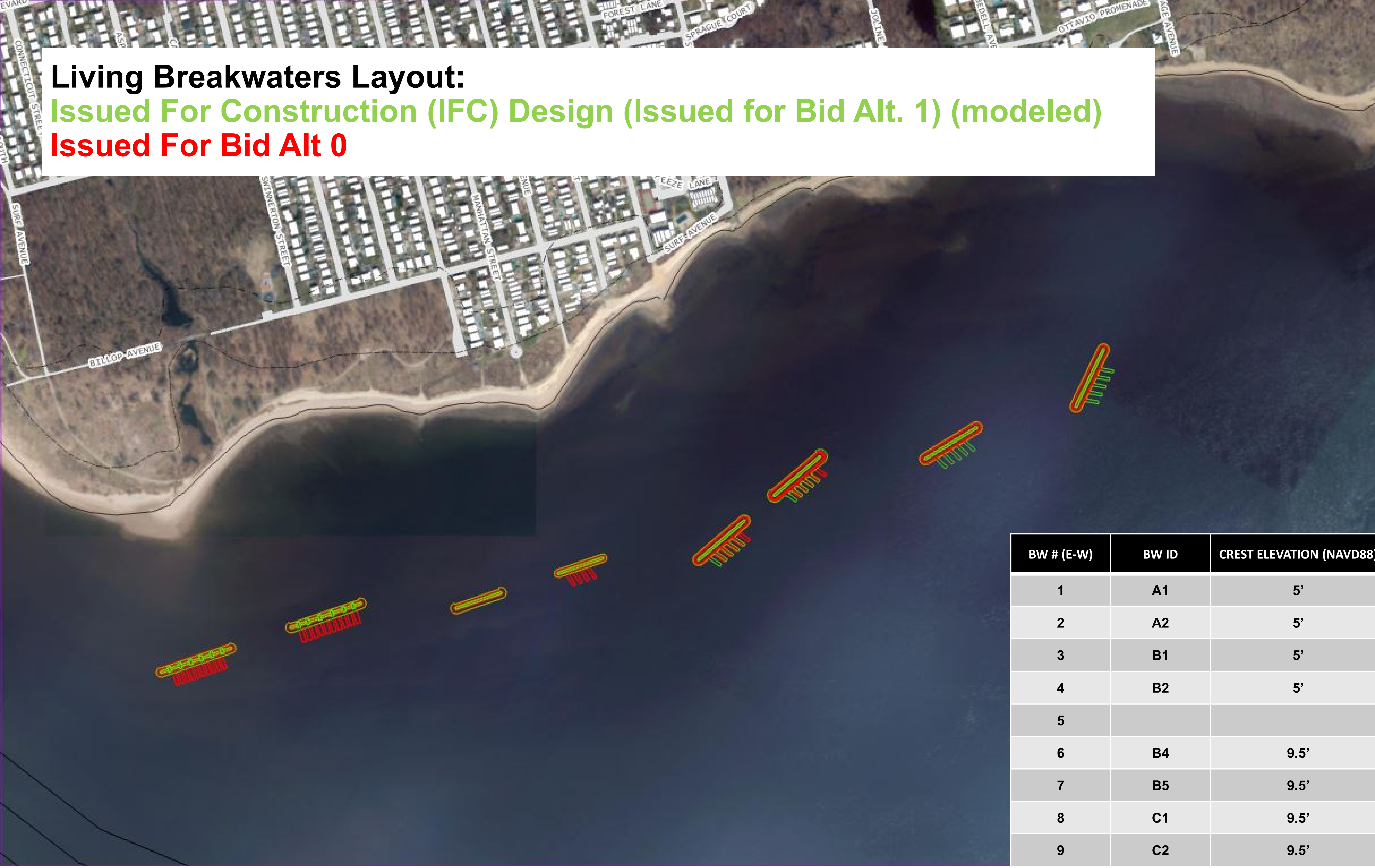
Waves from E and ESE

2014 1-foot LiDAR (Temporary Dunes in place)

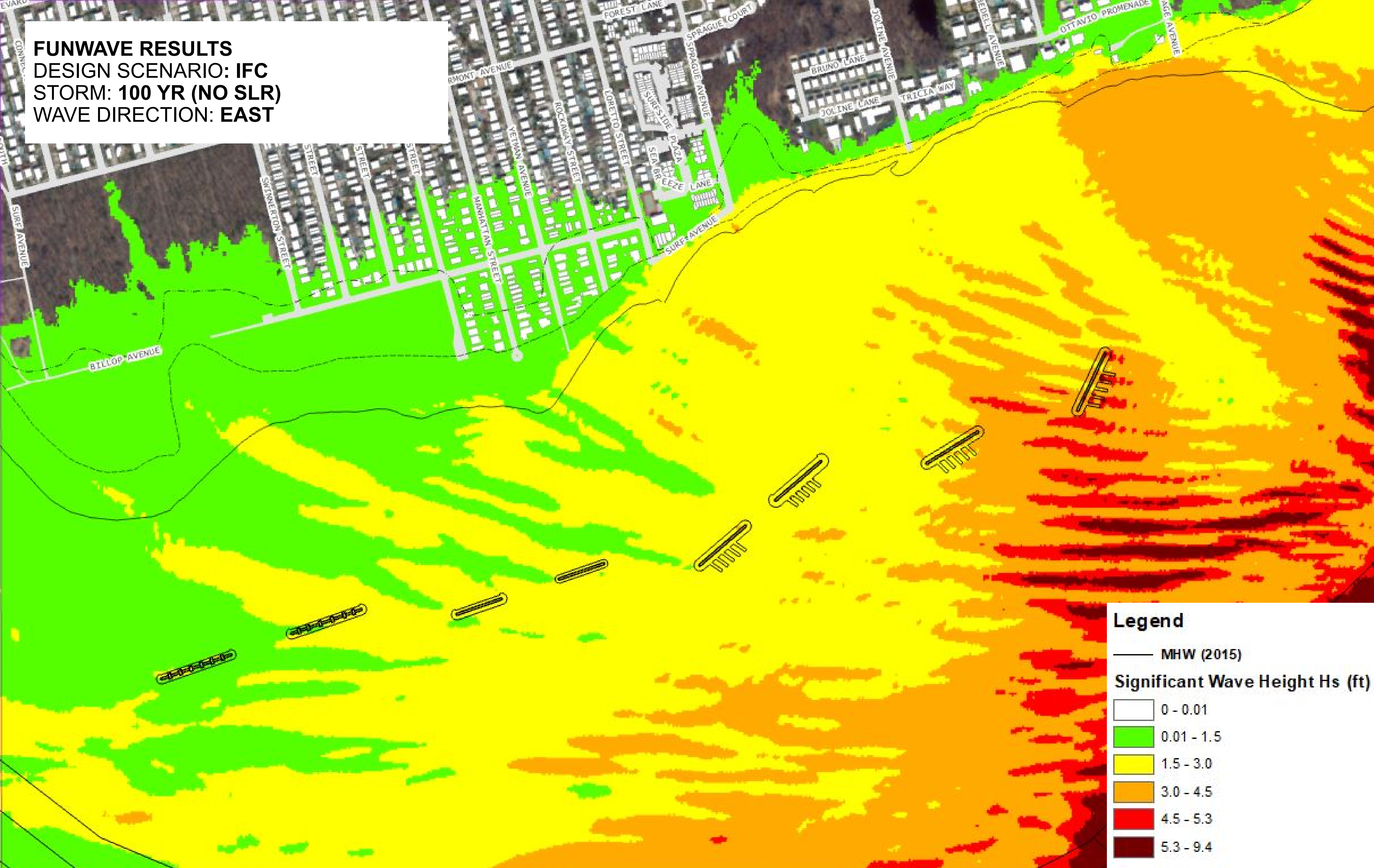
Living Breakwaters Layout:

Issued For Construction (IFC) Design (Issued for Bid Alt. 1) (modeled)

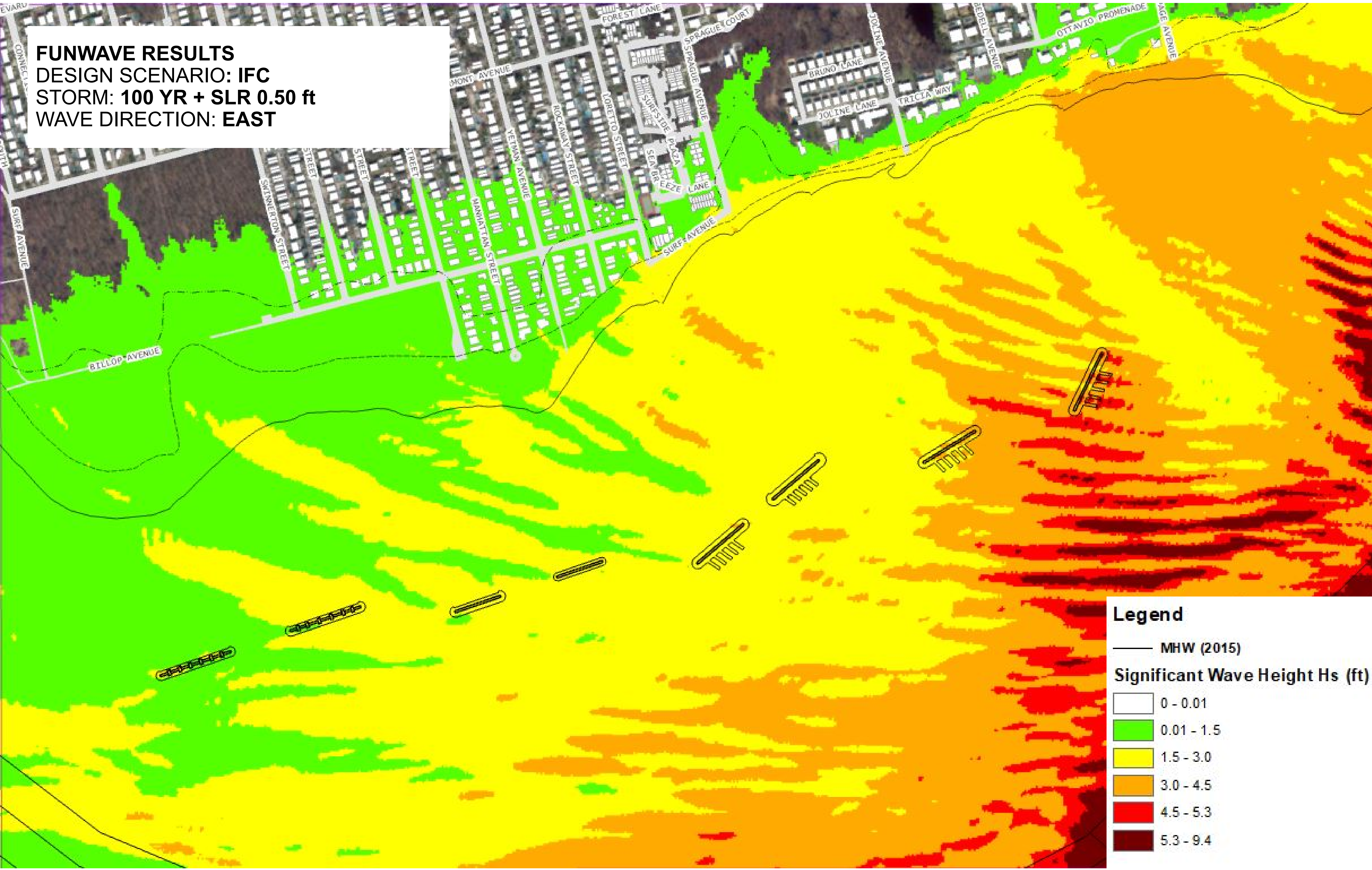
Issued For Bid Alt 0

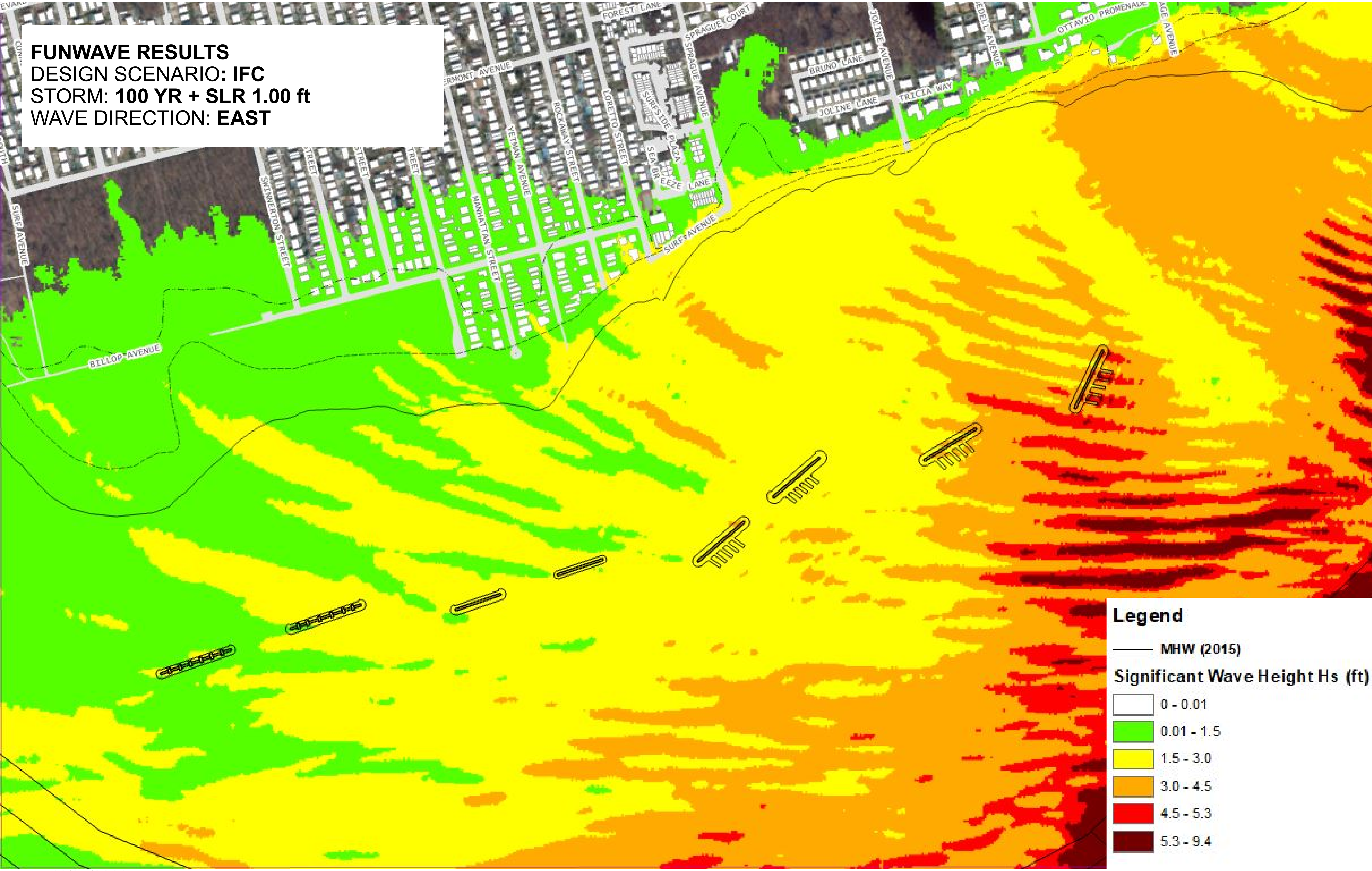


BW # (E-W)	BW ID	CREST ELEVATION (NAVD88)
1	A1	5’
2	A2	5’
3	B1	5’
4	B2	5’
5		
6	B4	9.5’
7	B5	9.5’
8	C1	9.5’
9	C2	9.5’

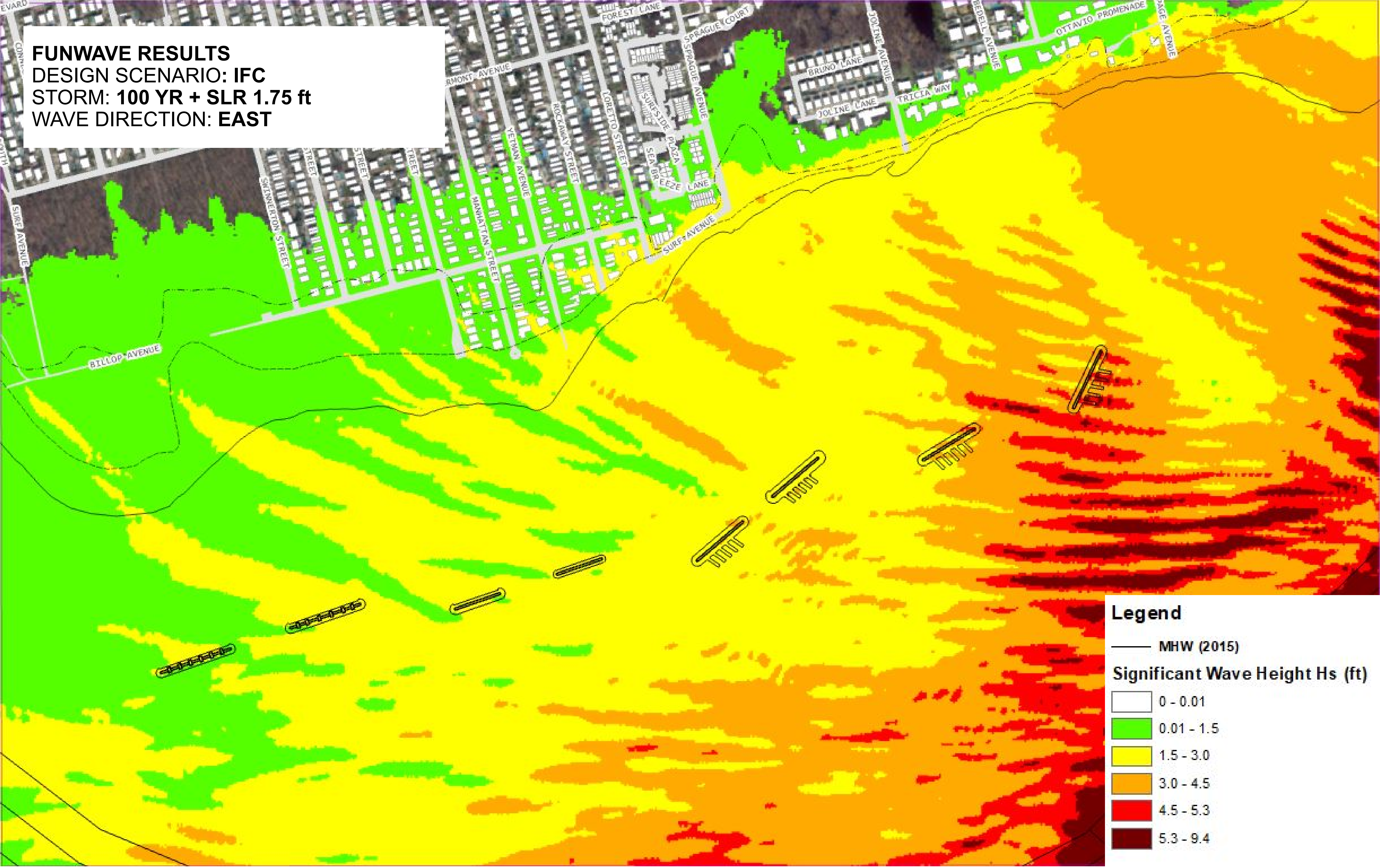

FUNWAVE RESULTS
DESIGN SCENARIO: IFC
STORM: 100 YR (NO SLR)
WAVE DIRECTION: EAST
FOREST LANE
SPRAGUE COURT
SPRAGUE AVENUE
JOLINE AVENUE
BEDELL AVENUE
OTTAVIO PROMENADE
BRUNO LANE
TRICIA WAY
JOLINE LANE
SURFSIDE PLAZA
SEA BREEZE LANE
LORETTO STREET
ROCKAWAY STREET
YETMAN AVENUE
MANHATTAN STREET
SWINNERTON STREET
SURF AVENUE
BILLOP AVENUE
Legend
MHW (2015)
Significant Wave Height Hs (ft)
0 - 0.01
0.01 - 1.5
1.5 - 3.0
3.0 - 4.5
4.5 - 5.3
5.3 - 9.4

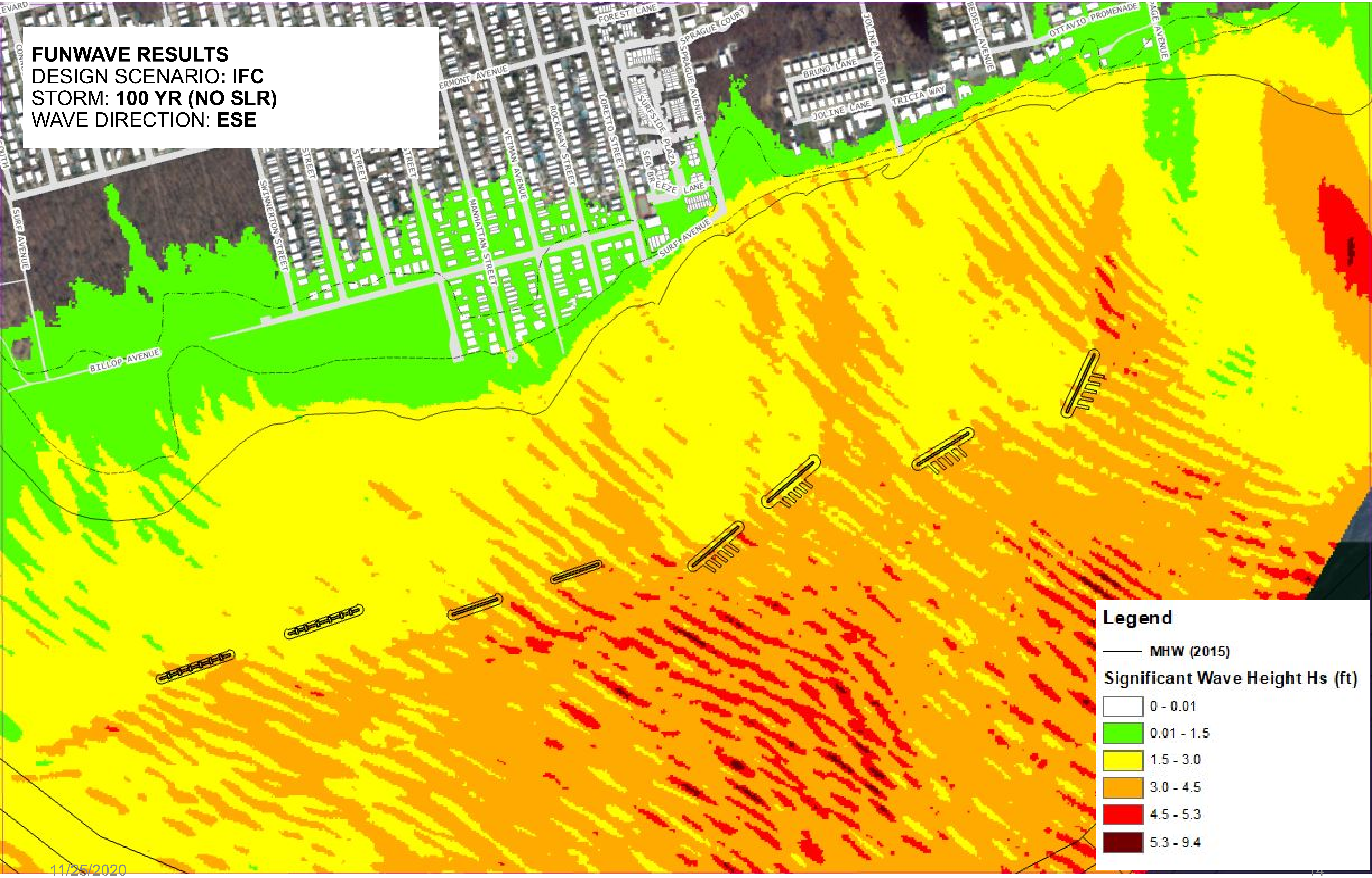
FUNWAVE RESULTS
DESIGN SCENARIO**: IFC**
STORM: **100 YR + SLR 0.50 ft**
WAVE DIRECTION: **EAST**



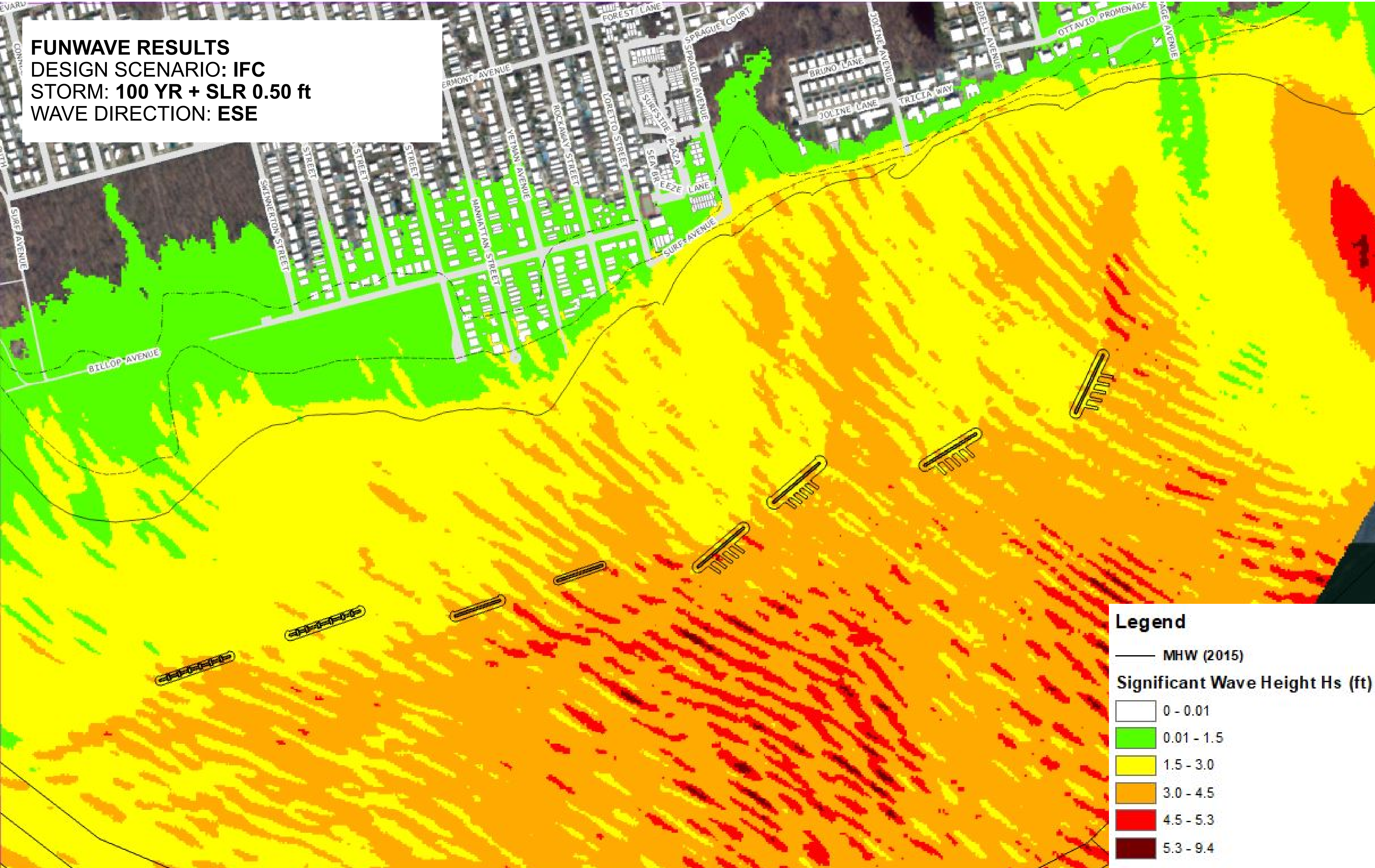

FUNWAVE RESULTS
DESIGN SCENARIO: IFC
STORM: 100 YR + SLR 1.00 ft
WAVE DIRECTION: EAST
FOREST LANE
SPRAGUE COURT
SPRAGUE AVENUE
JOLINE AVENUE
BRUNO LANE
JOLINE LANE
TRICIA WAY
OTTAVIO PROMENADE
SURFSIDE PLAZA
SEA BREEZE LANE
SURF AVENUE
LORETTO STREET
ROCKAWAY STREET
YETMAN AVENUE
MANHATTAN STREET
SWINNERTON STREET
BILLOP AVENUE
SURF AVENUE
Legend
MHW (2015)
Significant Wave Height Hs (ft)
0 - 0.01
0.01 - 1.5
1.5 - 3.0
3.0 - 4.5
4.5 - 5.3
5.3 - 9.4

FUNWAVE RESULTS
DESIGN SCENARIO**: IFC**
STORM: **100 YR + SLR 1.75 ft**
WAVE DIRECTION: **EAST**

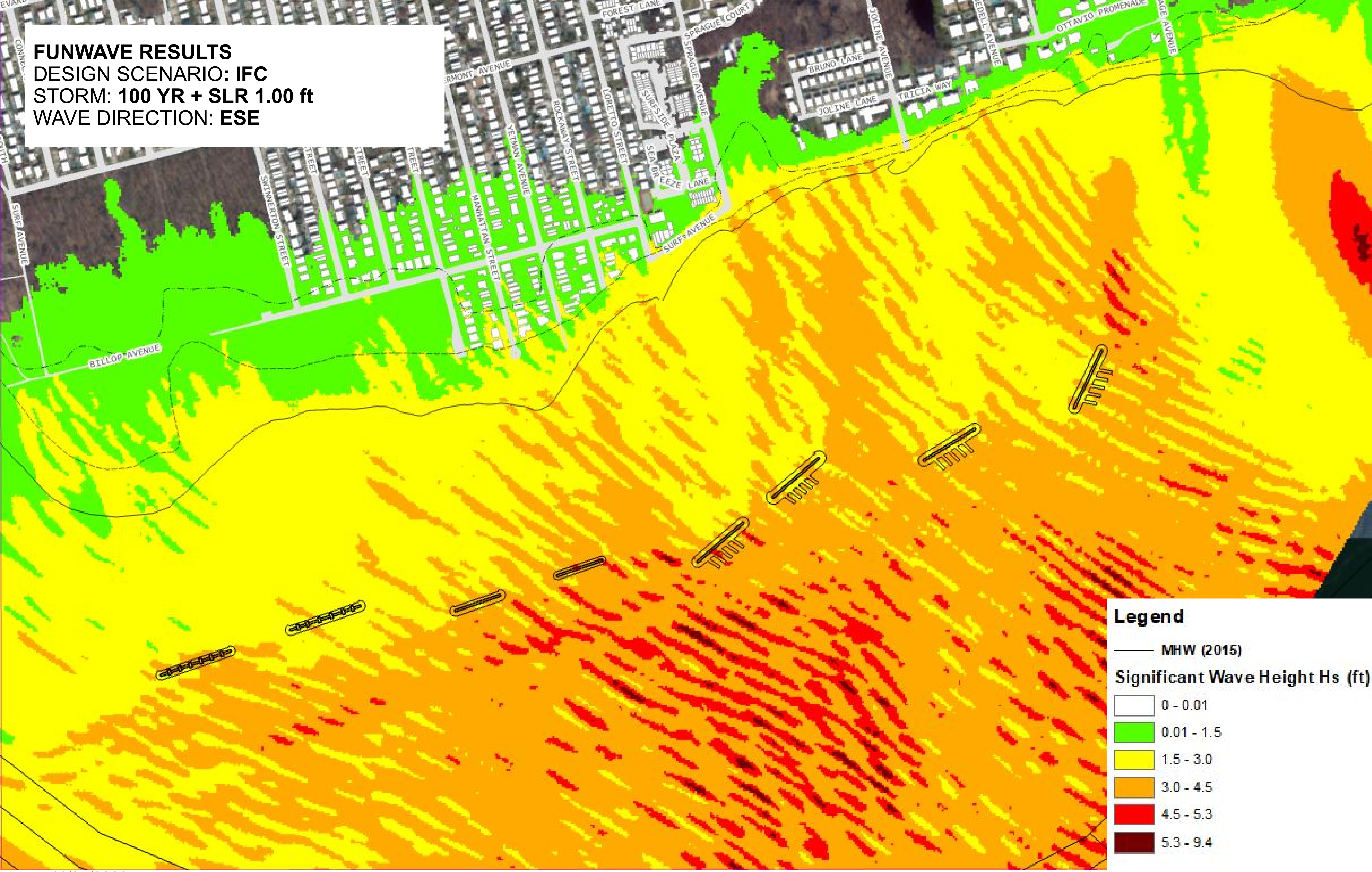



FUNWAVE RESULTS
DESIGN SCENARIO: IFC
STORM: 100 YR (NO SLR)
WAVE DIRECTION: ESE
FOREST LANE
SPRAGUE COURT
JOLINE AVENUE
BEDELL AVENUE
OTTAVIO PROMENADE
BRUNO LANE
TRICIA WAY
JOLINE LANE
SPRAGUE AVENUE
SURFSIDE PLAZA
LORETTO STREET
ROCKAWAY STREET
YETMAN AVENUE
MANHATTAN STREET
SWINNERTON STREET
SURF AVENUE
BILLOP AVENUE
Legend
MHW (2015)
Significant Wave Height Hs (ft)
0 - 0.01
0.01 - 1.5
1.5 - 3.0
3.0 - 4.5
4.5 - 5.3
5.3 - 9.4

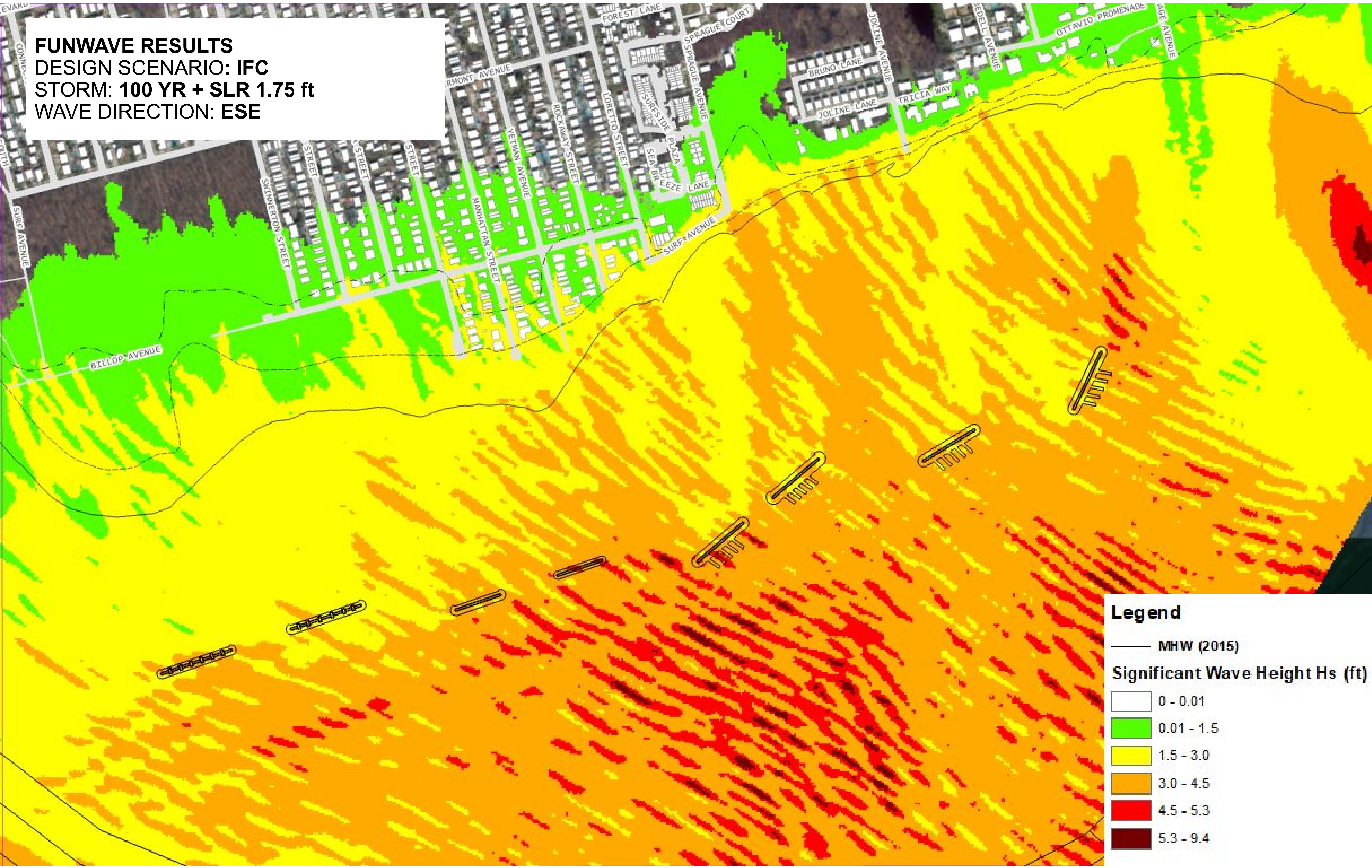
FUNWAVE RESULTS
DESIGN SCENARIO**: IFC**
STORM: **100 YR + SLR 0.50 ft**
WAVE DIRECTION: **ESE**



FUNWAVE RESULTS
DESIGN SCENARIO: **IFC**
STORM: **100 YR + SLR 1.00 ft**
WAVE DIRECTION: **ESE**



FUNWAVE RESULTS
DESIGN SCENARIO: **IFC**
STORM: **100 YR + SLR 1.75 ft**
WAVE DIRECTION: **ESE**



APPENDIX B

IMPACT ANALYSIS MAPS

Living Breakwaters
Existing Dunes
Potentially Impacted Building

Building Use
One or Two Family House
Apartment or Condominium
Restaurant
Recreation
School

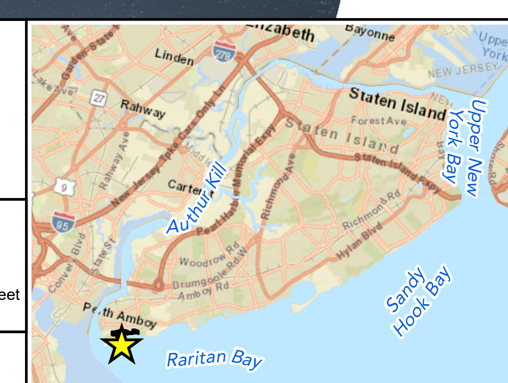
Overview

1 of 3

Sources: NYC Planning, NYC DoITT, SCAPE

Coordinate System:
NAD 1983 StatePlane New York Long Island FIPS 3104 Feet
Datum: North American 1983

March 24, 2021



Living Breakwaters Project Overview

wsp

0 200 400 600 800 1,000 Feet

- Living Breakwaters
- Existing Dunes
- Potentially Impacted Building
- New House Construction
- Demolished House

Building Use

- One or Two Family House
- Apartment or Condominium
- Restaurant
- Recreation
- School

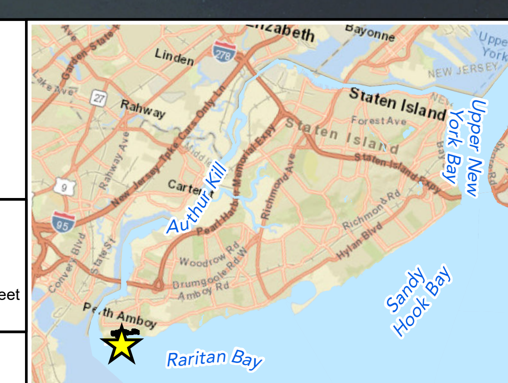
Analysis Area South

2 of 3

Sources: NYC Planning, NYC DoITT, SCAPE

Coordinate System:
NAD 1983 StatePlane New York Long Island FIPS 3104 Feet
Datum: North American 1983

March 24, 2021



Living Breakwaters
Project Overview

0 200 400 Feet

Legend	
Living Breakwaters	
Existing Dunes	
Potentially Impacted Building	
New House Construction	

Building Use

- One or Two Family House
- Apartment or Condominium
- Restaurant
- Recreation
- School

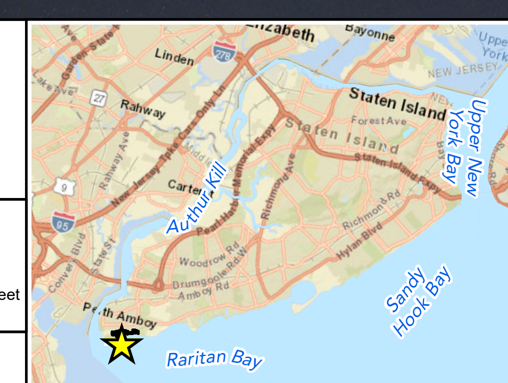
Analysis Area North

3 of 3

Sources: NYC Planning, NYC DoITT, SCAPE

Coordinate System:
NAD 1983 StatePlane New York Long Island FIPS 3104 Feet
Datum: North American 1983

March 24, 2021



Living Breakwaters Project Overview

wsp

0 200 400 Feet

Living Breakwaters
Existing Dunes
Potentially Impacted Building

Building Type

- ELEVATED ON STILTS/PILARS/WALLS
- STAIRS TO FRONT DOOR, FULL STORY
- STAIRS TO FRONT DOOR, LESS THAN 1 STORY (NO SLOPED DRIVEWAY)
- SPLIT LEVEL --STAIRS TO FRONT DOOR, LESS THAN 1 STORY, (NO SLOPED DRIVEWAY)
- FRONT DOOR AT GRADE
- SLOPED DRIVEWAY
- FIRST FLOOR BELOW GRADE

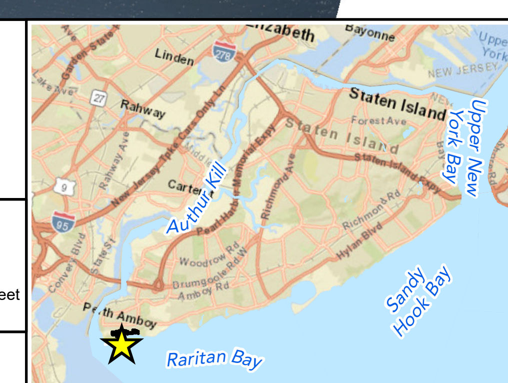
Overview

1 of 3

Sources: NYC Planning, NYC DoITT, SCAPE

Coordinate System:
NAD 1983 StatePlane New York Long Island FIPS 3104 Feet
Datum: North American 1983

March 25, 2021



Living Breakwaters
Building Type and Finished Basements

wsp

0 200 400 600 800 1,000
Feet

Living Breakwaters
Existing Dunes
Potentially Impacted Building
New House Construction
Demolished House
Known Finished Basement

Building Type

ELEVATED ON STILTS/PILARS/WALLS
STAIRS TO FRONT DOOR, FULL STORY
STAIRS TO FRONT DOOR, LESS THAN 1 STORY (NO SLOPED DRIVEWAY)
SPLIT LEVEL --STAIRS TO FRONT DOOR, LESS THAN 1 STORY, (NO SLOPED DRIVEWAY)
FRONT DOOR AT GRADE
SLOPED DRIVEWAY
FIRST FLOOR BELOW GRADE

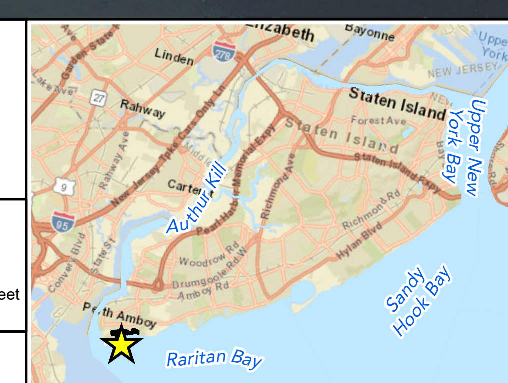
Analysis Area South

2 of 3

Sources: NYC Planning, NYC DoITT, SCAPE

Coordinate System:
NAD 1983 StatePlane New York Long Island FIPS 3104 Feet
Datum: North American 1983

March 25, 2021



Living Breakwaters
Building Type and Finished Basements

wsp

0 200 400 Feet

Living Breakwaters
Existing Dunes
Potentially Impacted Building
New House Construction
Known Finished Basement

Building Type

ELEVATED ON STILTS/PILARS/WALLS
STAIRS TO FRONT DOOR, FULL STORY
STAIRS TO FRONT DOOR, LESS THAN 1 STORY (NO SLOPED DRIVEWAY)
SPLIT LEVEL --STAIRS TO FRONT DOOR, LESS THAN 1 STORY, (NO SLOPED DRIVEWAY)
FRONT DOOR AT GRADE
SLOPED DRIVEWAY
FIRST FLOOR BELOW GRADE

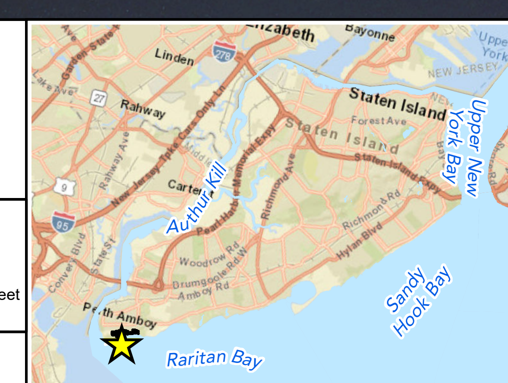
Analysis Area North

3 of 3

Sources: NYC Planning, NYC DoITT, SCAPE

Coordinate System:
NAD 1983 StatePlane New York Long Island FIPS 3104 Feet
Datum: North American 1983

March 25, 2021



Living Breakwaters
Building Type and Finished Basements

0 200 400
Feet