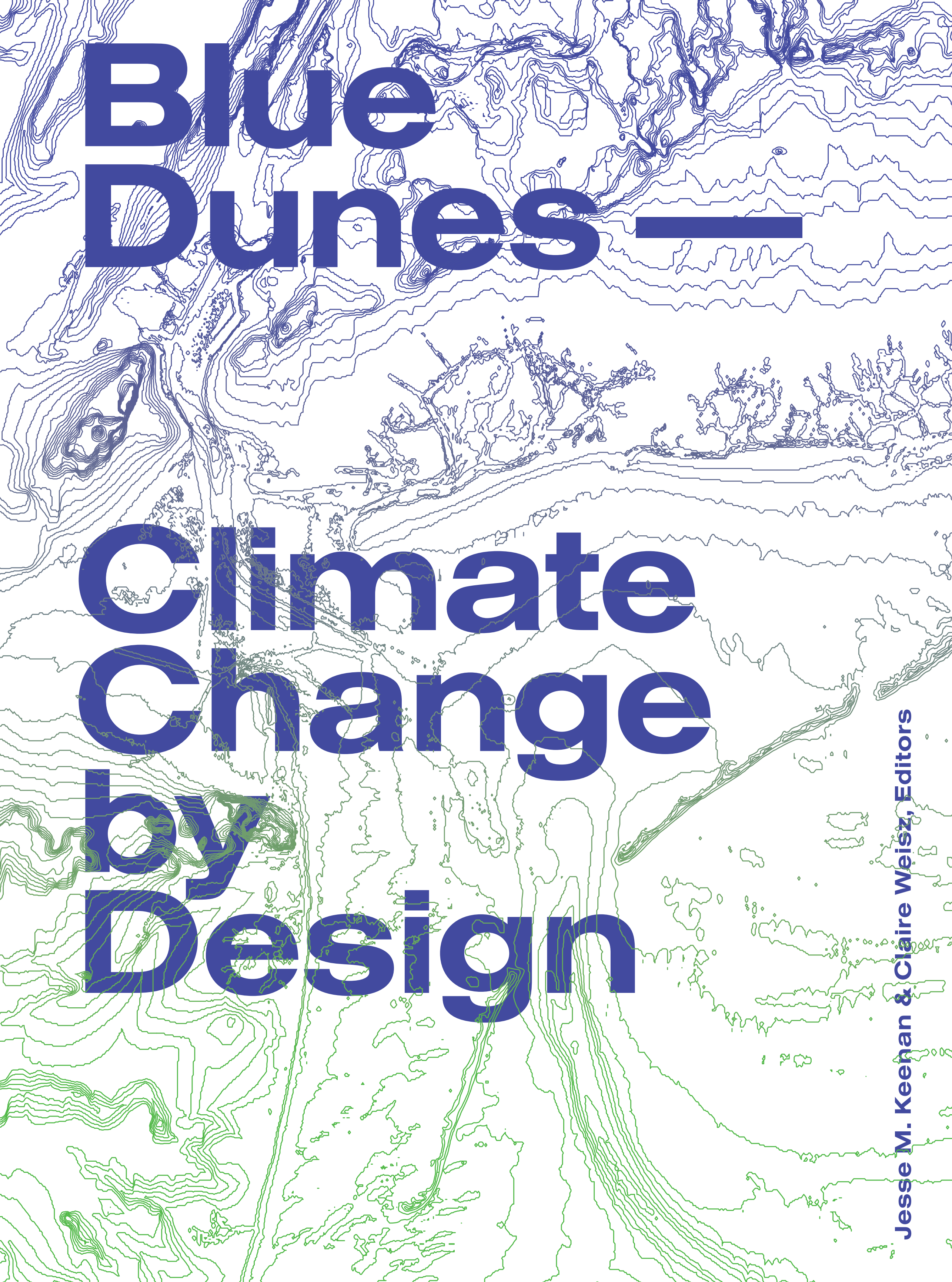
Blue Dunes—

Climate Change by Design



Jesse M. Keenan & Claire Weisz, Editors

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Blue Dunes —
Climate Change by Design

I

INTRO-
DUCTION

While the scientific abstractions of climate change are often difficult to translate, the occurrence of extreme weather events are very real in the consciousness of the public. As extreme weather proliferates in its occurrence and intensity with climate change, there is an emerging awareness of not only the wide ranging impacts of climate change, but also the necessity to mitigate environmental risks; to develop a resiliency to the occurrence of those risks; and, to ultimately adapt our social, economic, and dependent environmental systems. This book provides a narrative for how the role of designers, and the inherently synthetic process of design, can be utilized in tandem with science, social science, and engineering to plan for and respond to extreme weather and climate change.

As a proposal to construct an artificial archipelago of barrier islands to partially mitigate the impact of storm surge and sea level rise in the New York metropolitan region, Blue Dunes serves as a model for process innovation in transdisciplinary practices seeking regional connections beyond the boundaries of projects and programs. Through the case study of a high-profile public project, this narrative also includes the realities shaping the disagreements among relevant actors in terms of the path forward for defining the object of resilience and the nature of who bears the costs and the benefits of adaptation. The point and counterpoint between positivism and post-positivism, and between art and science, give life to the nature of the complexity of adaptation in the built environment. These professional and disciplinary frictions shaped a design process that is the central tenet of this book. With the occurrence of Hurricane Sandy (Sandy), a new era in the American discourse for evaluating and preparing for extreme weather and climate change was ushered in. As such, Blue Dunes is merely a snapshot of a larger movement for seeking innovation, which cuts across the conventional boundaries of knowledge in the built and natural environments.

HYDRODYNAMICS AND COASTAL ECOLOGIES

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Alan F. Blumberg & Sergey V. Vinogradov

Coastal Ocean Modeling: The Central Evidence

This research was supported, in part, by a grant of computer time from the City University of New York High Performance Computing Center under NSF Grants CNS-0855217, CNS-0958379 and ACI-1126113.

COMPUTATIONAL MODELING OF BARRIER ISLANDS

Given the nature of existing and future technologies, it was hypothesized that a set of offshore landscapes—barrier islands—in the coastal waters of the Mid-Atlantic region could be constructed in such a way that they would decrease the height of storm surges, and, therefore, could save lives, reduce damage, and safeguard the built environment. To test this hypothesis, a series of hydrodynamic simulations were conducted to look at new landscapes by using historical storm data in a storm-surge flood.

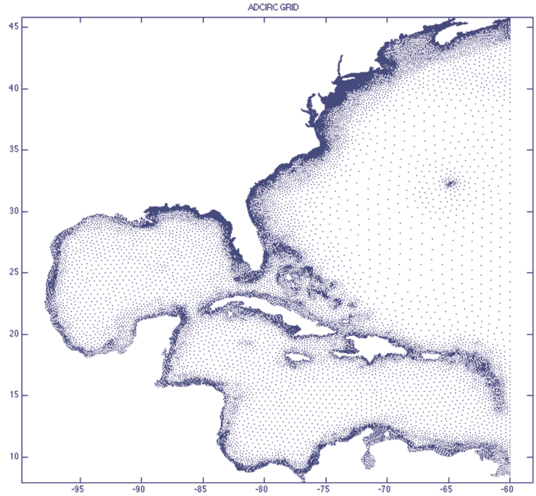
Stevens Institute of Technology's Davidson Laboratory (the Laboratory) created and maintains the New York Harbor Observing and Prediction System (NYHOPS), a vital forecasting resource for emergency preparedness in the metro New York City area and coastal New Jersey. The Laboratory operates in two primary areas: marine monitoring and forecasting and experimental and numerical marine hydrodynamics (i.e., ship design and evaluation). In October 2012, the Laboratory's Sandy predictions proved accurate and vital, attracting the attention of CNN, The Weather Channel, and other national media. Research from the Laboratory has regularly been referenced for the development, innovative infrastructure and coastline rebuilding solutions and assessments of the effectiveness of municipal shore protection initiatives, beach erosion mitigation plans, and zoning laws designed to prepare for future natural disasters. The Laboratory also works closely with the U.S. Department of Homeland Security (DHS), the Port Authority of NY and NJ, NJ Transit, and the National Oceanic and Atmospheric Administration (NOAA) on projects including modeling and forecasting of wind, tide, current, and wave conditions to better assist preparation for and response to storms, floods, accidents, and other emergencies on water.

MODELING APPROACH

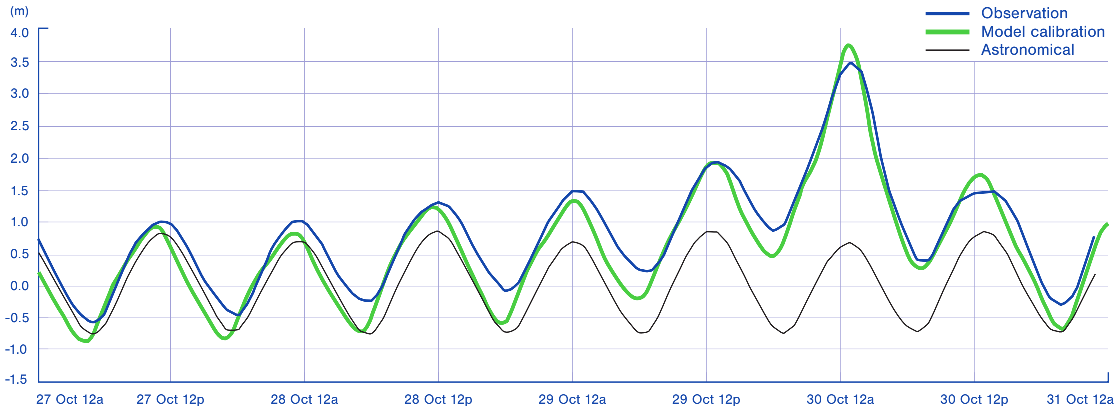
The Laboratory uses a sophisticated set of three-dimensional and two-dimensional hydrodynamic models that are capable of producing the hydrodynamic estimates of the flood zones, peak flood levels, and wave heights for given scenarios, as well as flood exceedance statistics for coastal locations based on a large set of tropical and extra-tropical storms. Models solve the system of hydrodynamic equations on a numerical grid (Blumberg & Mellor, 1987). Every experiment, such as a combination of a coastal modification scenario and a storm, consists of tidal spin-up phase, which computes the proper tidal motion of the water, and the storm run, which adds atmospheric pressure and winds on top of the tide. The model computes the advancement and buildup of a storm tide and the inland propagation of water over the floodplain. At every grid node of the model, the maximal water level, or a peak flood, is computed over the course of numerical integration. This serves as a quantitative estimate of the extent of inland flooding, its horizontal spread, and vertical inundation. A comparison of the peak flood computed for a modified coastal scenario to the results of a base scenario provide an impact estimate of that modification and the capability of it to reduce and stop inundation in particular areas. An example of such an application is the flooding along the NJ Hudson River waterfront (Blumberg, et al., 2015). A new, high-resolution, hydrodynamic model that encompasses the Hudson River waterfront cities of Hoboken, Jersey City, Weehawken, and Bayonne has been developed and validated. Robust wetting and drying of land in the model physics provides for the dynamic prediction of flood elevations and velocities across land features during inundation events. Validation for Hurricane Sandy conditions against 56 water marks and 16 edgemarks shows that the model is capable of computing overland water elevations quite accurately. Because the model was able to capture the spatial and temporal variation of water levels in the region observed during Hurricane Sandy, it was used to identify the flood pathways and suggest where flood preventing interventions could be built.

MODEL SETUP

The model experiments in this study introducing various sets of barrier islands in the New York Bight utilized a vertically-integrated, two-dimensional, coupled modeling system based on ADCIRC (ADvanced CIRCulation model) and SWAN (Simulating Waves Nearshore) models (ADCIRC + SWAN). The model uses the FEMA Region II unstructured numerical grid with 604,790 nodes over the northwestern part of the Atlantic. Spatial resolution is variable and it is enhanced in the coastal New York / New Jersey regions where the distance between nodes can be as fine as 70 m. ■ Figure 54 Floodplains (i.e., grid nodes on land that can be flooded) are incorporated with spatially varying bottom friction based on land use. Tidal forcing is defined by eight



■ **Figure 54:** ADCIRC Grid; FEMA setup ADCIRC + SWAN domain.



■ **Figure 55:** Modeled and observed water level at The Battery, NY, during the 2012 Superstorm Sandy (Stevens Institute of Technology, Davidson Laboratory, 2013; NOAA, 2012).

major short-period tidal constituents (K1, K2, M2, N2, O1, Q1, S2, and P1). Neither rainfall nor river runoff is included.

ADCIRC + SWAN (Version 49) is run on the Cray system Salk at the High-Performance Computing Center (HPCC) at the College of Staten Island, City University of New York (CUNY). On average, one tropical storm experiment takes about 20 hours of CPU time (including tidal spin-up) using 256 cores available for this study. About 200,000 CPU-hours were used to complete this study. Data for atmospheric pressure and winds was provided by Oceanweather, Inc. Model setup including base bathymetry, bottom friction, and all subgrid parameterizations is taken from FEMA Region II study by Risk Assessment, Mapping and Planning Partners **(RAMPP, 2013)**.

MODEL VALIDATION

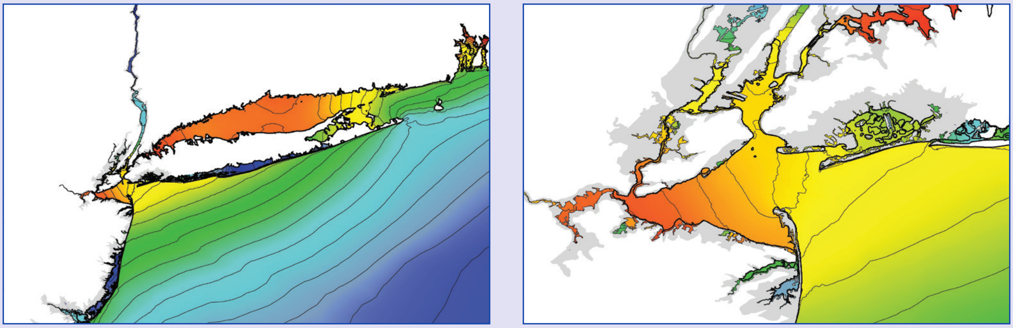
The FEMA Region II study has compiled a comprehensive model validation for a set of historical storms **(RAMPP, 2013)**, including four tropical storms and three extra-tropical storms (nor'easters). These experiments, reproduced in this study, agreed for the most part with the FEMA results to the order of computer precision. An additional validation was conducted for Hurricane Sandy using atmospheric winds and pressure produced by Oceanweather, Inc. These fields come from Oceanweather's proprietary atmospheric boundary layer model, which assimilates meteorological data. For this project, there was no separate validation study of atmospheric fields. Instead, the modeled sea levels were compared with existing data. The exact spatial distribution of land flooding from Sandy was not available at the time of this study, so the validation focused on sea level time series at NOAA recording buoys. In particular, The Battery location shows generally excellent consistency in timing, amplitude, and phase of the surge between the model (i.e., green curve) and historical data (i.e., black curve) on all stages of the storm (i.e., advance, peak, and retreat) ■ **Figure 55**. The model overestimates the 3.5 m flood peak at The Battery by 5%, which can be attributed to the up-scaling wind factor of 1.04 inherited from earlier modeling work. These discrepancies are clearly not important for this particular research, which focuses on the differences in flooding due to new barrier island construction.

DESCRIPTION OF EXPERIMENTAL RESULTS

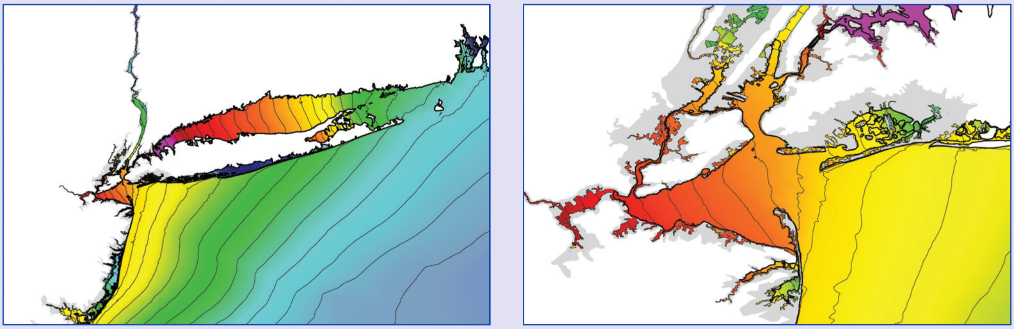
New artificial barrier islands are introduced by replacing the depths at corresponding ocean grid nodes in the model with +10 m elevation. Three storms were used in this analysis: (i) Hurricane Donna (September 11–13, 1960); (ii) the 1992 Nor'easter (December 6–14, 1992); and (iii) Hurricane Sandy (October 25 – November 1, 2012).

■ **Figures 56, 57, 58:** Peak flood maps resulting from Hurricane Donna (top); the 1992 Nor'easter (middle); and Hurricane Sandy (bottom) (Stevens Institute of Technology, Davidson Laboratory, 2013).

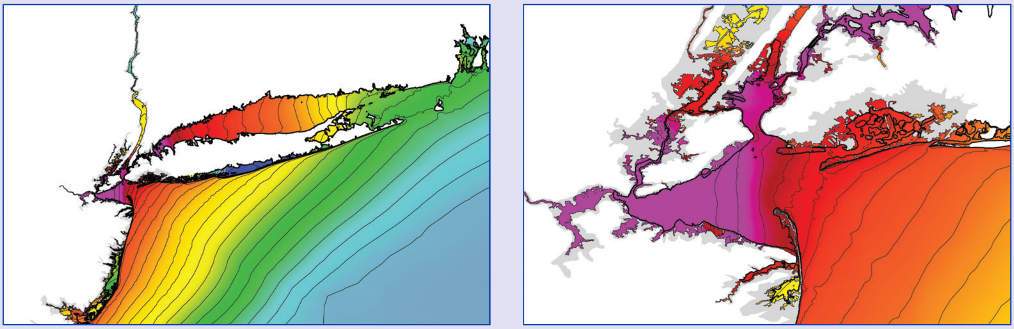
1960 DONNA (September 11–13) PEAK FLOOD



1992 NOR'EASTER (December 6–14) PEAK FLOOD



2012 SANDY (October 25 – November 1) PEAK FLOOD



Mid-Atlantic Bight Area

New York Harbor Area

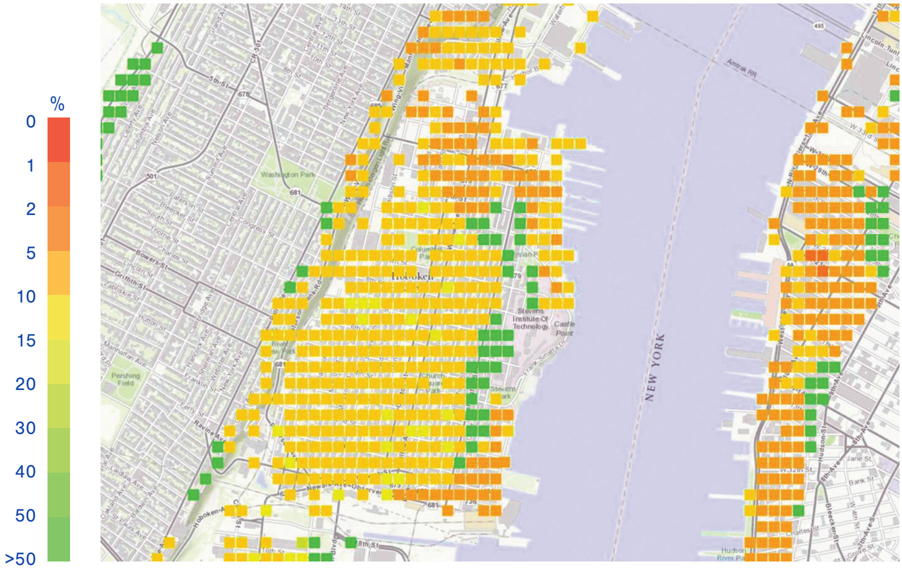
These three storms all had significant flooding in the study area and represent tropical, extra-tropical, and hybrid systems. As a result, these storms were a good surrogate for a diverse range of future storms. The results from each of these storm events are shown in ■ **Figures 56, 57, 58**.

A series of different barrier island configurations were investigated in the search for the most effective configuration for reducing storm surge. The hypothetical configurations were as follows:

- × MODEL 1: This configuration completely closed the Sandy Hook to Rockaway transect. The model run allowed the team to study how much of the storm surge would be reflected back into the Atlantic Ocean, as well as the nature of flooding via the Long Island Sound.
- × MODEL 2: This configuration closed Long Island Sound. This model run allowed the team to study how much of the storm surge comes in via the Sandy Hook to Rockaway transect.
- × MODEL 3: This configuration refined the NY Harbor protection and examined the blocking features along the NJ shore surge pathway.
- × MODEL 4: This configuration further refined the NY Harbor protection and examined the blocking features along the NJ shore surge pathway, as well as the islands' capacity for reducing the exposure to the open ocean at the Sandy Hook-Rockaway Transect.
- × MODEL 5: This configuration further refined the NY Harbor protection and examined a reduction in exposure to the open ocean
- × MODEL 6: This configuration evaluated the effect of blocking existing maritime transportation links along the NJ coast.
- × MODEL 7: This configuration evaluated the effect of blocking existing maritime transportation links along the Long Island coast.
- × MODEL 8: This configuration evaluated the performance of small block islands for deflecting storm surge.
- × MODEL 9: This configuration evaluated the performance of long slender islands along the coast in conjunction with small block islands.
- × MODEL 10: This configuration built on Model 9 and added dunes perpendicular to the Rockaway Peninsula and to Sandy Hook, in a north-south direction.
- × MODEL 11: This configuration evaluated a series of slender dunes along the coast of New Jersey with short curvature 'hooks' added at the entrance to the NY Harbor.
- × MODEL 12: This configuration evaluated long slender dunes along the coast from central Long Island to the entrance to the NY Harbor and at the entrance of the Long Island Sound. It removed the 'hooks' from the dunes in Model 11.

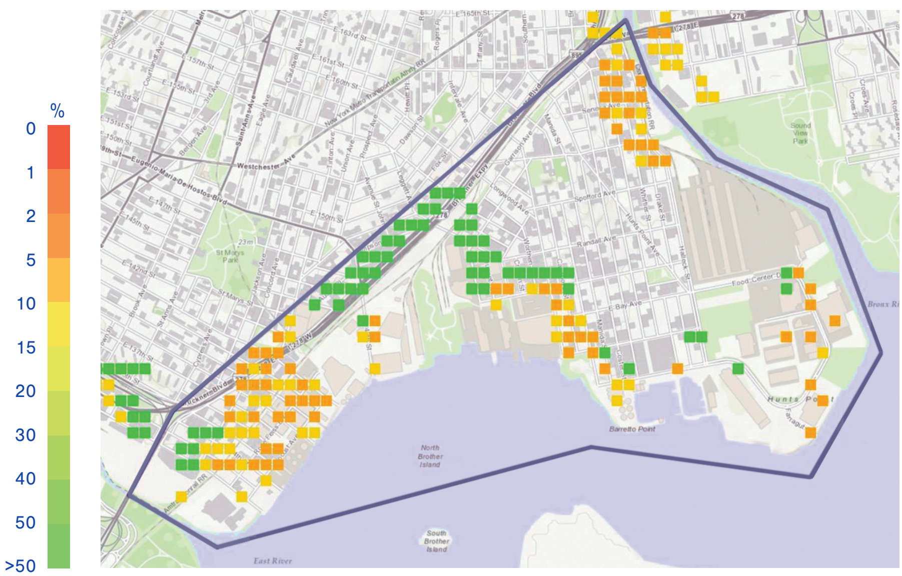
Of the configurations referenced above, four were chosen for further analysis: Model 8, Model 9, Model 10, and Model 11 ■ **Figures 59–62**. Graphical sets of outputs were created for each dune and island configuration. For each storm that ran on a modified bathymetry, the following outcomes were plotted: (i) peak flood maps from the base run; (ii) peak flood maps from the modified run; and (iii) the reduction of storm peak flooding due to modification. Peak flood maps show maximal sea surface elevation at each wet/flooded grid node during the storm. Peak reduction plots show the difference with the base run. Positive reduction (i.e., decrease in peak flood due to new islands) is shown in red colors and negative reduction is shown in blue colors. Plotted ranges are -0.5/+0.5 m except for -1/+1 m for final configuration run with Hurricanes Sandy and Donna.

■ **Figure 82:** Hoboken estimated loss reduction (AIR, 2014).



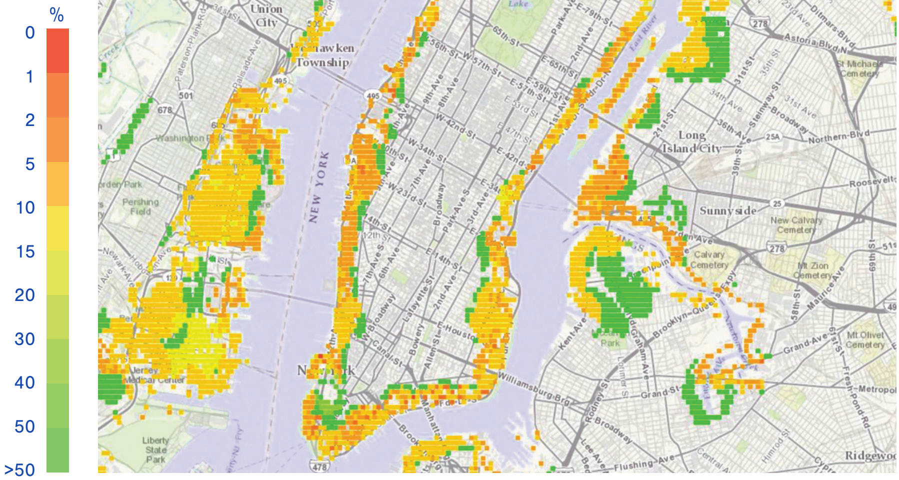
	GROUND LOSS ($M)	INSURED LOSS ($M)
Before Mitigation	1,355	855
After Mitigation	967	619

■ **Figure 83:** Hunts Point estimated loss reduction (AIR, 2014).



	GROUND LOSS ($M)	INSURED LOSS ($M)
Before Mitigation	124	27
After Mitigation	56	13

■ Figure 84: Lower Manhattan estimated loss reduction (AIR, 2014).



	GROUND LOSS ($M)	INSURED LOSS ($M)
Before Mitigation	11,436	3,085
After Mitigation	5,469	1,272

■ Figure 85: Red Hook estimated loss reduction (AIR, 2014).

	GROUND LOSS ($M)	INSURED LOSS ($M)
Before Mitigation	469	199
After Mitigation	257	102

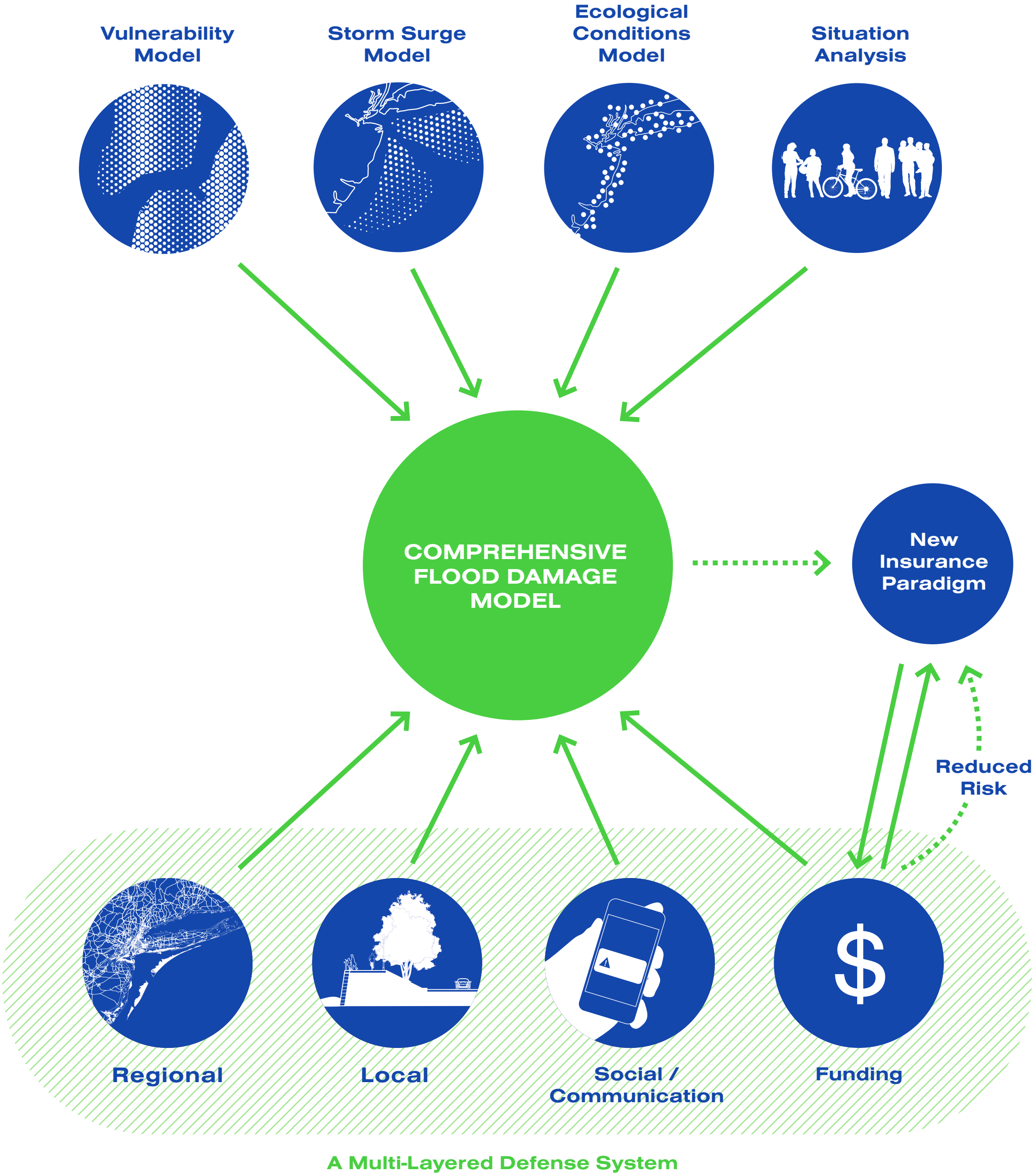
IV

DESIGN PROPOSAL

Hurricane Sandy was the costliest extreme weather event ever to hit the urban centers on the East Coast of the United States. The cost of damage due to Sandy not only reflects the severity of the storm, but also the density and patterns of settlement that are prevalent along the coast, with populations, structures, and infrastructure at low elevations and within the existing floodplain. If current land use practices continue without regard to climate projections and the anticipated increase in the frequency of extreme weather in the coming decades and centuries, the New York City metropolitan region will continue to suffer debilitating physical, financial, and social consequences with each storm event.

As a flood event, Hurricane Sandy exposed the inadequacy of existing flood defense measures and codes. It was determined that 650,000 housing units were damaged because they were built prior to the advent of flood-related building codes, and with ground floors below current base flood elevations. At the same time, financial coverage faltered because thousands of homeowners lacked insurance. The lives lost and the nearly $110 billion in physical and economic damage demonstrate the high cost of complacency.

■ **Figure 1:** Aerial view of Sandy Hook and New York Harbor (Albert Vecerka / ESTO, 2016).



■ **Figure 4:** A new conceptual model for flood defense: a multi-layered approach (WXY / West 8, 2014).

Water does not respect political boundaries. A regional approach to climate change and sea level rise is critical to the safety and well-being of local communities. Comprehensive models that share information about social and environmental risks and benefits might make it possible to reduce the impact of storms and simultaneously restore ecological strata lost over the last century. A new regional framework for systems of insurance, governance, and coastal management that utilizes pooled resources could promote a broader ambition for economic adaptation.

However, flood risk reduction cannot succeed without an understanding of individuals' experiences during and following Sandy, as well as the need for human-scale interventions. Since the hurricane, residents and business owners in the coastal floodplain have discovered a new sense of environment, and have made adjustments in preparation for the next big storm. Programs that support social networks and tangibly reduce the risks for vulnerable residents and businesses are critical to the future of the Northeast.

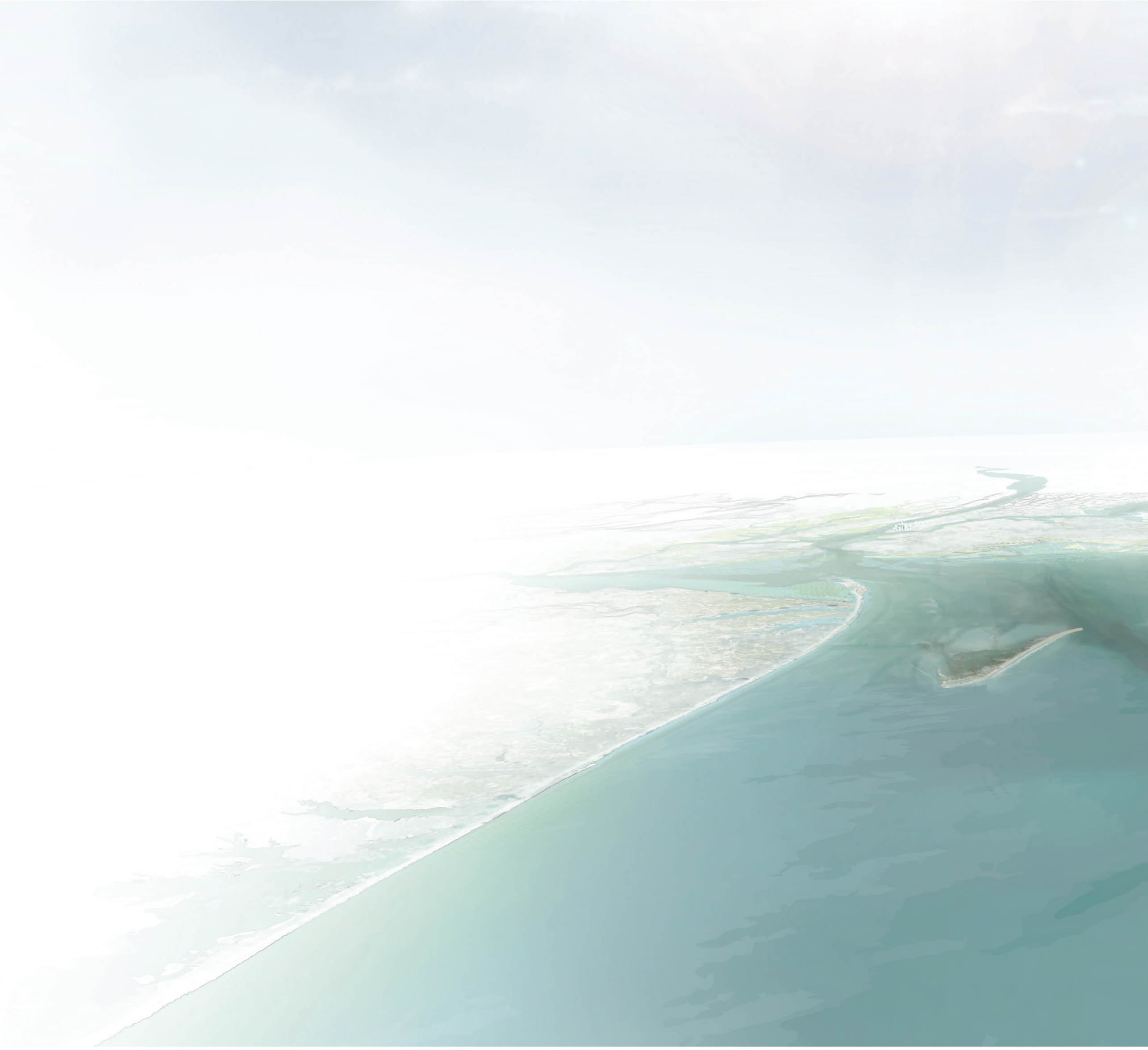
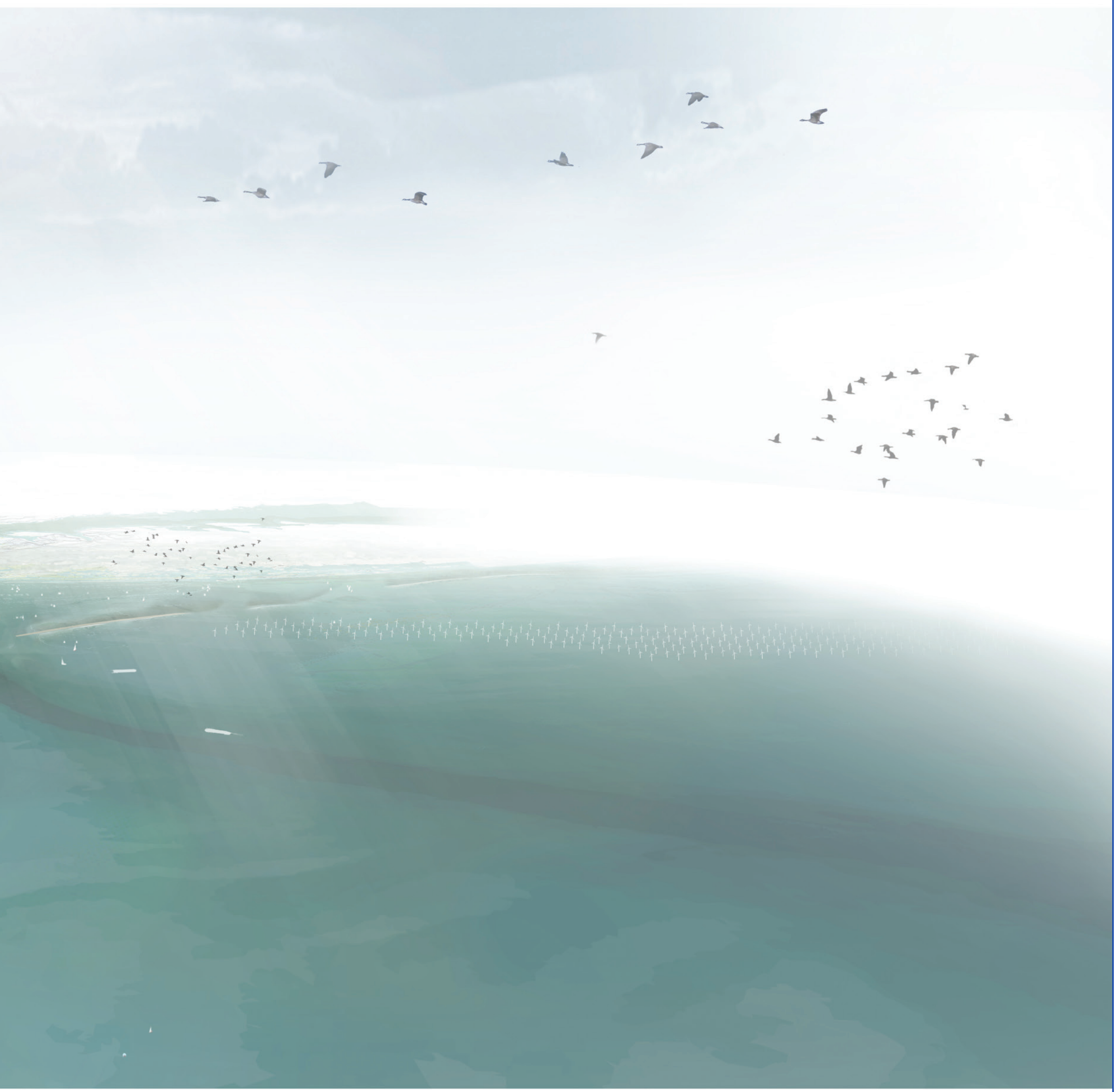
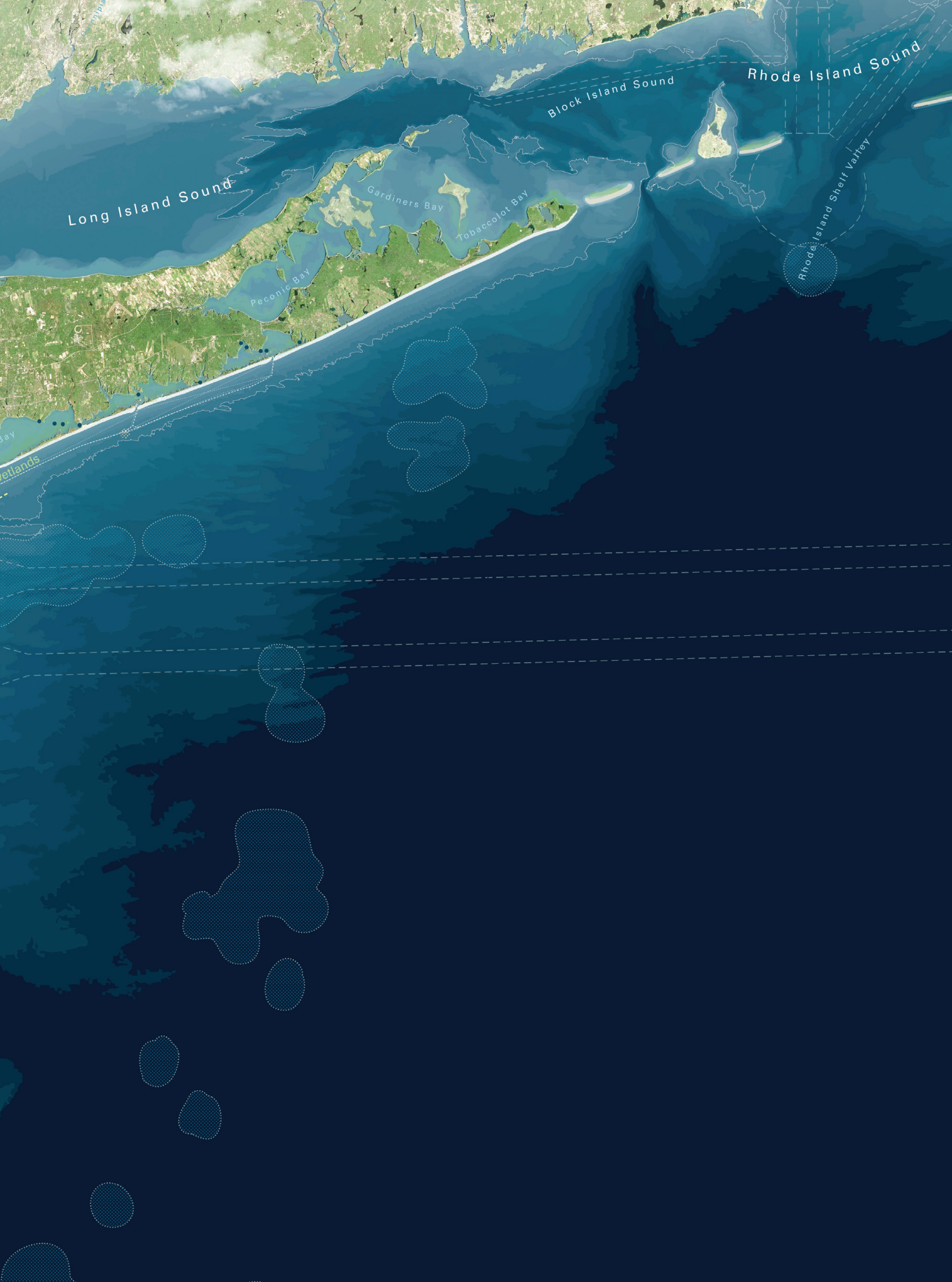


Figure 12: Aerial perspective of the New York Bight with a first phase of artificial barrier island construction (WXY / West 8, 2013).

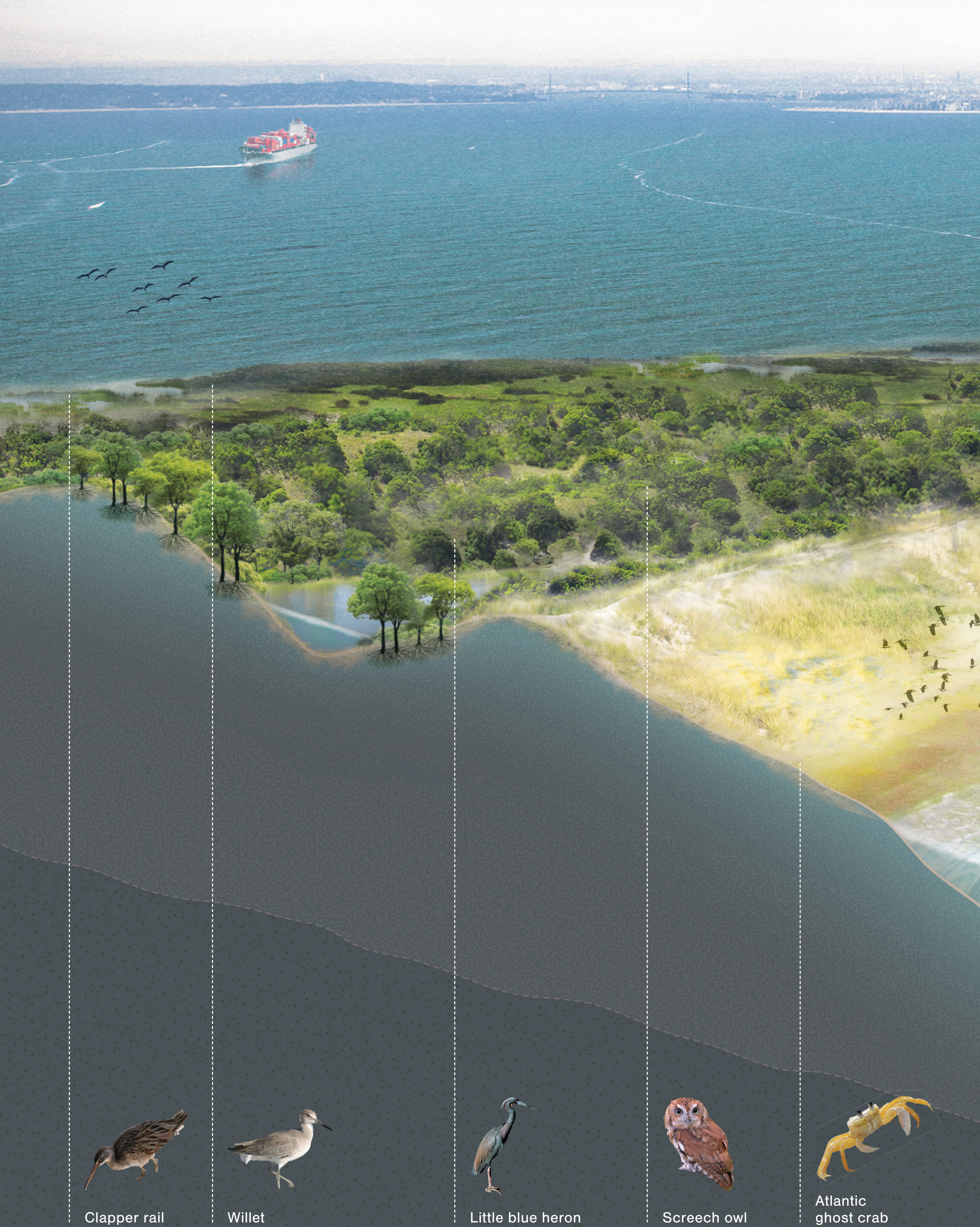
■ **Figure 13:** Aerial perspective of the New York Bight with mature artificial barrier islands; all phases of construction complete (WXY / West 8, 2013).



■ Figure 14: The Blue Dunes final concept plan, Phase 1 (WXY / West 8, 2014).



Long Island Sound
Block Island Sound
Rhode Island Sound
Gardiners Bay
Tobaccolot Bay
Peconic Bay
Rhode Island Shelf Valley

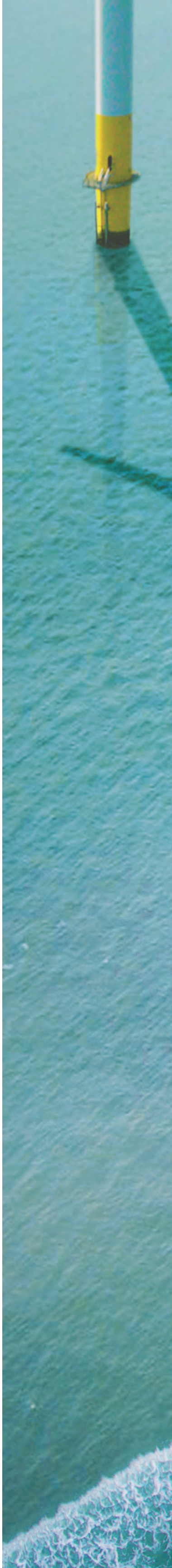


■ **Figure 24:** Section-perspective of the Blue Dunes island morphology and animal inhabitants, looking toward the New York–New Jersey Harbor (WXY, 2016; base photo: Albert Vecerka / ESTO).


Oyster catcher
Sanderlings
Short-billed dowitcher
Atlantic croaker

Coupling the construction of barrier islands with wind turbines represents one way to expand the benefits of making an unprecedented regional investment.

Jacobson, Archer, and Kempton's research suggests that offshore turbine arrays could reduce hurricane wind speeds, in addition to providing clean energy—a doubly-effective climate mitigation strategy (2014).



■ **Figure 26:** Harnessing the wind: detailed rendering of an artificial island in the context of wind turbines and surfers (WXY, 2015).

VI

APPENDIX

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

AAL	Average Annual Loss
AIANY	American Institute of Architects, New York City Chapter
AIR	AIR Worldwide
ADCIRC	Advanced CIRCulation Model
BFE	Base Flood Elevation
BOEM	Bureau of Ocean Energy Management, U.S. Department of the Interior
CAT	Catastrophic Model
CDBG-DR	Community Development Block Grant-Disaster Recovery
CFR	Code of Federal Regulations
CPU	Central Processing Unit
CSD	Cutter Suction Dredger Vessel
CUNY	City University of New York
CURE.	Center for Urban Real Estate, Columbia University
DCP	New York City Department of City Planning
DHS	U.S. Department of Homeland Security
DPR	Department of Parks and Recreation, City of New York
DUMBO	Down Under Manhattan Bridge Overpass
EAARL	Experimental Advanced Airborne Research LIDAR
EIA	Energy Information Administration, U.S. Department of Energy
EP	Exceedance Probability
FAR ROC	For A Resilient Rockaway (design competition)
FDR	Franklin D. Roosevelt East River Drive
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GAO	U.S. Government Accountability Office
GATOR	Global-to-Local Atmospheric Global Model
GCM	Global Climate Model
GCMM	General Circulation and Mesoscale Meteorological Model
GDP	Gross Domestic Product
GFDL	Geophysical Fluid Dynamic Laboratory, NOAA
HKIA	Hong Kong International Airport
HPCC	High-Performance Computing Center, CUNY
HUD	U.S. Department of Housing and Urban Development
IEA	International Energy Agency
IED	Industry Exposure Database
LIDAR	Light Detection and Ranging
LOLO	Lower-Lower Manhattan
MARCO	Mid-Atlantic Regional Council on the Ocean
MHW	Mean High Water
MLW	Mean Low Water
MoMA	Museum of Modern Art, New York
MSP	Marine Spatial Planning
MTA	Metropolitan Transportation Authority
NASA	National Aeronautical and Space Administration
NCCOS	National Centers for Coastal Ocean Science, NOAA
NFIP	National Flood Insurance Program
NJ	State of New Jersey
NJDCA	New Jersey Department of Community Affairs
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NPV	Net Present Value
NY	State of New York
NYC	New York City (geography) or City of New York (jurisdiction)
NYHOPS	New York Harbor Observation and Prediction System
OCM	Office of Coastal Management, NOAA
OEM	New York City Office of Emergency Management
OUR	Organizing and United Residents
PILOT	Payment in Lieu of Taxes
PANYNJ	Port Authority of New York and New Jersey
PV	Present Value
RAMPP	Risk Assessment, Mapping and Planning Partners, FEMA
RBD	Rebuild by Design
RFC	Reconstruction Finance Corporation
RMS	Risk Management Solutions
SIRR	Special Initiative for Rebuilding and Resiliency
SWAN	Simulating WAves Nearshore model
TEV	Total Exposed Values
USACE	U.S. Army Corps of Engineers
USC	United States Code
USGS	U.S. Geological Survey

BIBLIOGRAPHY

Abel, N., Gorddard, R., Harman, B., Leitch, A., Langridge, J., Ryan, A. & Heyenga, S. (2011). Sea Level Rise, Coastal Development and Planned Retreat: Analytical Framework, Governance Principles and an Australian Case Study. ***Environmental Science & Policy***, 14(3), 279–288.

Aburto, M. O., de los Angeles Carvajal, M., Barr, B., Barbier, E. B., Boesch, D. F., Boyd, J. & Ganey, S. (2012). ***Ecosystem-based Management for the Oceans***. Washington, DC: Island Press.

Adger, W. N. (2006a). ***Fairness in Adaptation to Climate Change***. Cambridge, MA: MIT Press.

Adger, W. N. (2006b). Vulnerability. ***Global Environmental Change***, 16(3), 268-281.

Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S. R. & Rockström, J. (2005). Social-ecological Resilience to Coastal Disasters. ***Science***, 309, 1036–1039.

AIR Worldwide [Computer Software]. CATStation. Jersey City, NJ: Verisk Analytics, Inc.

Alberti, M., Marzluff, J. M., Shulenberger, E., Bradley, G., Ryan, C. & Zumbrunnen, C. (2003). Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems. ***BioScience***, 53(12), 1169–1179.

Albion, R. G. & Pope, J. B. (1939). ***The Rise of New York Port, 1815–1860***. New York, NY: C. Scribner's Sons.

Alexander, D. E. (2013). Resilience and Disaster Risk Reduction: An Etymological Journey. ***Natural Hazards and Earth System Science***, 13 (11), 2707–2716.

Anderson, M., Bourgeron, P., Bryer, M. T., Crawford, R., Engelking, L., Faber-Langendoen, D. & Weakley, A. S. (1998). International Classification of Ecological Communities: Terrestrial Vegetation of the United States (Vol. II). ***The National Vegetation Classification System: List of Types***. Arlington, VA: The Nature Conservancy.

Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb, Z. & Teicher, H. (2016). Equity Impacts of Urban Land Use Planning for Climate Adaptation Critical Perspectives from the Global North and South. ***Journal of Planning Education and Research***. 36(3), 333-348. First published online May 11, 2016. doi: 10.1177/0739456X16645166.

Archer, C. L. & Jacobson, M. Z. (2003). Spatial and Temporal Distributions of U.S. Winds and Wind Power at 80 m Derived from Measurements. ***Journal of Geophysical Research: Atmospheres***, 108(D9). doi: 10.1029/2002JD002076.

Archer, C. L. & Jacobson, M. Z. (2005). Evaluation of Global Wind Power. ***Journal of Geophysical Research: Atmospheres***, 110(D12). doi: 10.1029/2004JD005462.

Archer, C. L. & Jacobson, M. Z. (2013). Geographical and Seasonal Variability of the Global "Practical" Wind Resources. ***Applied Geography***, 45, 119–130.

Archer, C. L., Mirzaeisefat, S. & Lee, S. (2013). Quantifying the Sensitivity of Wind Farm Performance to Array Layout Options Using Large Eddy Simulation. ***Geophysical Research Letters***, 40(18), 4963–4970.

Barnes, J., Dove, M., Lahsen, M., Mathews, A., McElwee, P., McIntosh, R. & Weiss, H. (2013). Contribution of Anthropology to the Study of Climate Change. ***Nature Climate Change***, 3(6), 541–544.

Bazerman, M. H. (2006). Climate Change as a Predictable Surprise. ***Climatic Change***, 77(1–2), 179–193.

Bender, M. A., Ginis, I., Tuleya, R., Thomas, B. & Marchok, T. (2007). The Operational GFDL Coupled Hurricane-ocean Prediction System and a Summary of its Performance. ***Monthly Weather Review***, 135(12), 3965–3989.

Benedict, M. A. & McMahon, E. T. (2006). ***Green Infrastructure***. Washington, DC: Island Press.

Berg, R. (2013). ***Tropical Cyclone Report: Hurricane Isaac***. Miami, FL: National Hurricane Center. Retrieved November 25, 2013, from www.nhc.noaa.gov/data/tcr/AL092012_Isaac.pdf.

Bergdoll, B. (2011). ***Rising Currents: Projects for New York's Waterfront***. London, U.K.: Thames & Hudson.

Bergh, J. C., Barendregt, A. & Gilbert, A. J. (2004). ***Spatial Ecological-economic Analysis for Wetland Management: Modeling and Scenario Evaluation of Land Use***. Cambridge, U.K.: Cambridge University Press.

Berry, P. M., Brown, S., Chen, M., Kontogianni, A., Rowlands, O., Simpson, G. & Skourtos, M. (2015). Cross-sectoral Interactions of Adaptation and Mitigation Measures. ***Climatic Change***, 128(3–4), 381–393.

Besio, C. & Pronzini, A. (2014). Morality, Ethics, and Values Outside and Inside Organizations: An Example of the Discourse on Climate Change. ***Journal of Business Ethics***, 119(3), 287–300.

Bierbaum, R., Smith, J. B., Lee, A., Blair, M., Carter, L., Chapin III, F. S. & Verduzco, L. (2013). A Comprehensive Review of Climate Adaptation in the United States: More than Before, but Less than Needed. ***Mitigation and Adaptation Strategies for Global Change***, 18(3), 361–406.

Birch, K. & Siemiatycki, M. (2015). Neoliberalism and the Geographies of Marketization: the Entangling of State and Markets. ***Progress in Human Geography***, 40(2), 177–198.

Bishop, R. (2009). Chaos. In Edward N. Zalta (Ed.), ***The Stanford Encyclopedia of Philosophy***. Palo Alto, CA: Stanford University. Retrieved June 30, 2016, from http://plato.stanford.edu/archives/fall2009/entries/chaos/.

Blake, E. S. (2013). ***Tropical Cyclone Report Hurricane Sandy***. Miami, FL: National Hurricane Center. Retrieved June 30, 2016, from http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf.

Blake, E. S., Kimberlain, T. B., Berg, R. J., Cangialosi, J. P. & Beven II, J. L. (2013). ***Tropical Cyclone Report: Hurricane Sandy***. Miami, FL: National

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“Perhaps the boldest idea for how to protect New York”

— Jeff Goodell, *Rolling Stone*

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