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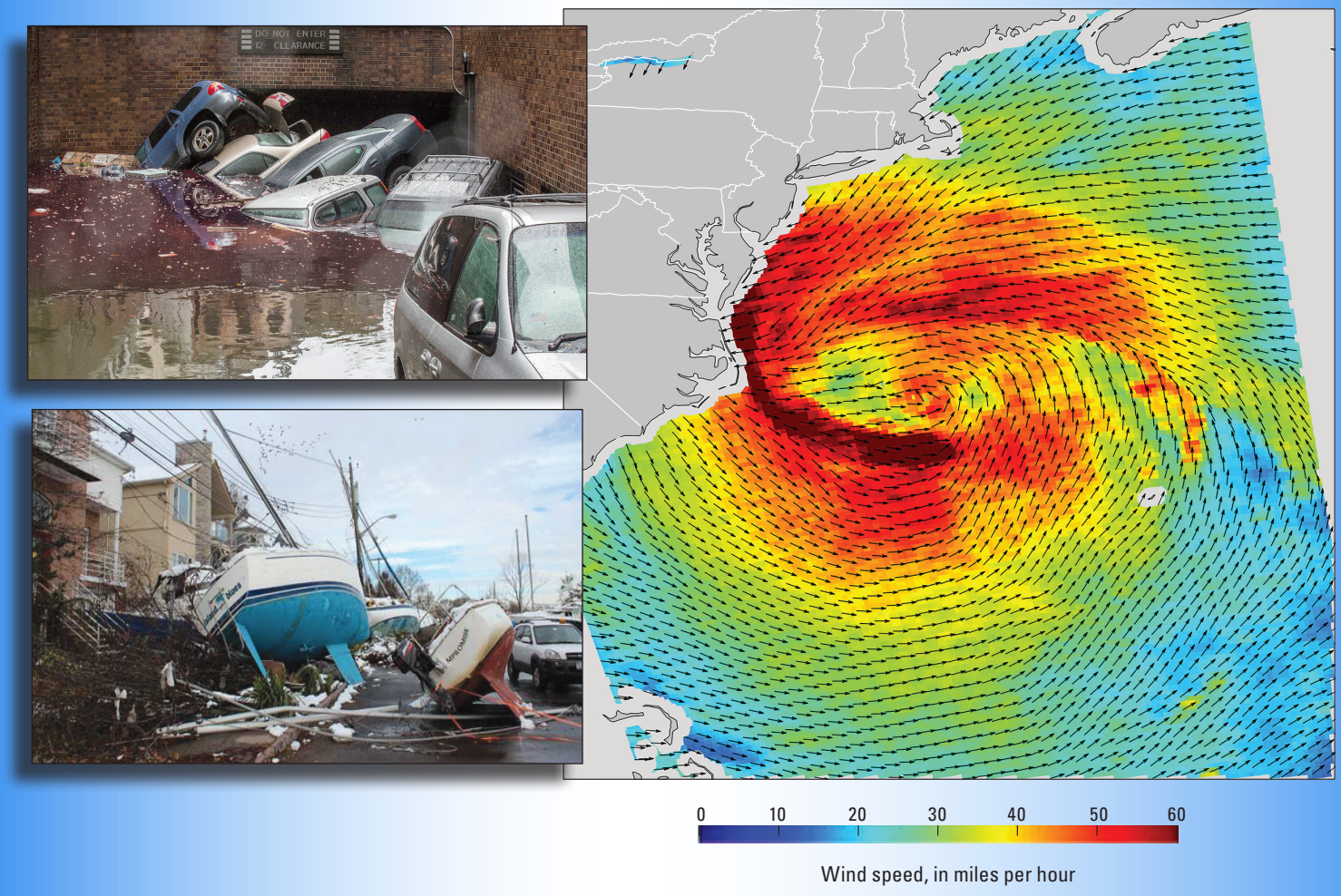
Analysis of Storm-Tide Impacts From Hurricane Sandy in New York



Scientific Investigations Report 2015–5036

U.S. Department of the Interior
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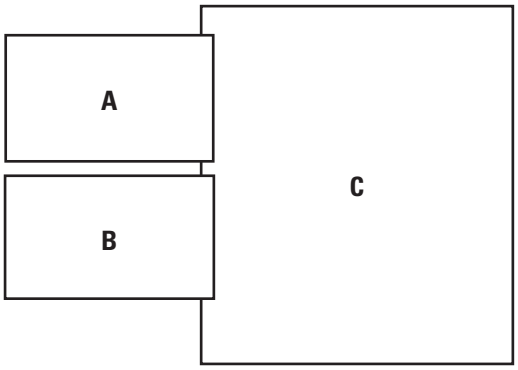
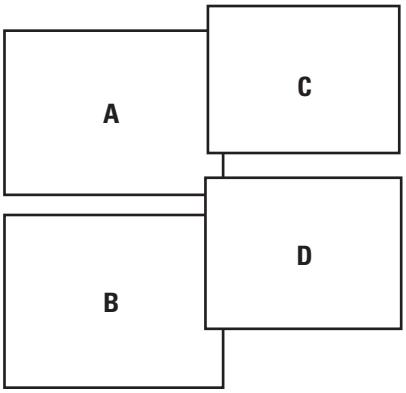


Front cover. *A,* Vehicles partly submerged at an entrance to a flooded parking garage in the Financial District of Manhattan; photograph courtesy of Frankie Torres / Flickr. *B,* Sailboats stranded in a street in Great Kills, Staten Island; photograph courtesy of the BoatUS Marine Insurance Program. *C,* Strength and direction of Hurricane Sandy's ocean surface winds on October 28, 2012. Wind speeds above 40 miles per hour (mi/hr) are depicted in yellow, above 50 mi/hr are in orange, and above 60 mi/hr are in red; wind directions are indicated by black arrows. Map is modified from National Aeronautics and Space Administration (2013) produced with data from a radar scatterometer on the Indian Space Research Organization's Oceansat-2.



Back cover. *A,* A boardwalk swept off its pilings in Rockaway, Queens; photograph courtesy of John Huntington / Shutterstock. *B,* The 168-foot *John B. Caddell* water tanker aground in a parking lot in Stapleton, Staten Island; photograph courtesy of Sean Sweeney. *C,* A vehicle swept off a street in Great Kills, Staten Island; photograph courtesy of Rob Gross / Flickr. *D,* A boat stranded on the railroad tracks at Metro North's Ossining Station on the Hudson Line; photograph courtesy of the Metropolitan Transportation Authority of the State of New York / Flickr.

Analysis of Storm-Tide Impacts From Hurricane Sandy in New York

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Conversion Factors

[Inch/Pound to International System of Units]

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
mile per hour (mi/h)	1.609	kilometer per hour (km/h)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations

BFE	base flood elevation
FEMA	Federal Emergency Management Agency
HWM	high-water mark
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
USGS	U.S. Geological Survey

Analysis of Storm-Tide Impacts From Hurricane Sandy in New York

By Christopher E. Schubert,[1] Ronald Busciolano,[1] Paul P. Hearn, Jr.,[1] Ami N. Rahav,[2] Riley Behrens,[1] Jason Finkelstein,[1] Jack Monti, Jr.,[1] and Amy E. Simonson[1]

Abstract

The hybrid cyclone-**nor'easter**[3] known as Hurricane Sandy affected the mid-Atlantic and northeastern United States during October 28–30, 2012, causing extensive coastal flooding. Prior to storm landfall, the U.S. Geological Survey (USGS) deployed a temporary monitoring network from Virginia to Maine to record the **storm tide** and coastal flooding generated by Hurricane Sandy. This sensor network augmented USGS and National Oceanic and Atmospheric Administration (NOAA) networks of permanent monitoring sites that also documented **storm surge**. Continuous data from these networks were supplemented by an extensive post-storm high-water-mark (HWM) flagging and surveying campaign. The sensor deployment and HWM campaign were conducted under a directed mission assignment by the Federal Emergency Management Agency (FEMA). The need for hydrologic interpretation of monitoring data to assist in flood-damage analysis and future flood mitigation prompted the current analysis of Hurricane Sandy by the USGS under this FEMA mission assignment.

The analysis of storm-tide impacts focused on three distinct but related aspects of coastal flooding from Hurricane Sandy, including flooding inland along the tidal reach of the Hudson River. These aspects are (1) comparisons of peak storm-tide elevations to those of historical storms and to **annual exceedance probabilities**, (2) assessments of storm-surge characteristics, and (3) comparisons of maps of inundation extent that were derived from differing amounts of available storm-tide data. Most peak storm-tide elevations from Hurricane Sandy were greater than about 9.5 feet (ft) above North American Vertical Datum of 1988.

Peak storm-tide elevations from Hurricane Sandy were compared with data for the intense nor'easter of December 11–13, 1992, and Hurricane Irene (August 27–28, 2011), which weakened to a tropical storm before arriving in New York. Peak storm-tide elevations from Hurricane Sandy were higher than those from the December 1992 nor'easter at 24 of 27 sites; most differences were greater than about 0.7 ft or 9 percent (above the historical storm tide). Peak storm-tide elevations from Hurricane Sandy were higher than those from Tropical Storm Irene at all sites; most differences were greater than about 2.5 ft or 48 percent. Data from permanent and temporary monitoring sites and HWM sites were compared with corresponding FEMA flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities in New York. Peak storm-tide elevations from Hurricane Sandy had annual exceedance probabilities less than or equal to 1 percent and (or) greater than 0.2 percent at a plurality of sites—184 of 413. Peak storm-tide elevations greater than or equal to the 0.2-percent flood elevation accounted for 81 of 413 sites. Peak storm-tide elevations less than the 10-percent flood elevation accounted for only 10 of 413 sites.

Data from selected permanent monitoring sites in the USGS and NOAA networks were used to assess storm-surge magnitude associated with the peak storm tide, and magnitude and timing of the peak storm surge. Most magnitudes of the peak storm surge were greater than about 8.3 ft, and most magnitudes of the storm surge component of the peak storm tide were greater than about 7.8 ft. Timing of peak storm surge arrival with respect to local phase of tide controlled where the most extreme peak storm-tide levels and coastal flooding occurred. This finding has bearing not only for locations impacted by the highest storm tides from Hurricane Sandy, but also for those that had the greatest storm surges yet were spared the worst flooding because of fortuitous timing during this storm.

Results of FEMA Hazus Program (HAZUS) flood loss analyses performed for New York counties were compared for extents of storm-tide inundation from Hurricane Sandy mapped (1) pre-storm, (2) on November 11, 2012, and (3) on February 14, 2013. The resulting depictions of estimated total building stock losses document how differing amounts of available USGS data affect the resolution and accuracy of storm-tide inundation extents. Using the most accurate results from the final (February 14, 2013) inundation extent, estimated losses range from $380 million to $5.9 billion for individual New York counties; total estimated aggregate losses are about $23 billion for all New York counties. Quality of the inundation extents used in HAZUS analyses has a substantial effect on final results. These findings can be used to inform future post-storm reconstruction planning and estimation of insurance claims.

[1]U.S. Geological Survey

[2]Harris IT Contracting

[3]Bold text is defined in the glossary.

Introduction

The hybrid cyclone nor'easter known as Hurricane Sandy affected the mid-Atlantic and northeastern coastline of the United States during October 28–30, 2012 (fig. 1), producing northeast-to-southeast winds of tropical-storm strength (39 to 73 miles per hour [mi/hr]) that gusted to greater than hurricane strength (greater than 73 mi/hr) and causing extensive coastal flooding and beach erosion. Severe tidal flooding occurred along coastal areas of southeastern New York, northern New Jersey, and southern Connecticut during the afternoon of October 29 and continued through the early morning of October 30. Although peak storm-tide levels occurred near the times of normal tidal high water during October 29–30, widespread tidal flooding that began during the morning of October 29 did not subside in some coastal areas until October 31.

Prior to storm landfall, the U.S. Geological Survey (USGS) deployed a temporary monitoring network of water-level and barometric pressure sensors to continuously record the timing, areal extent, and magnitude of the storm tide and coastal flooding generated by Hurricane Sandy (McCallum and others, 2013). Sensors were deployed at 224 locations along the Atlantic coast from Virginia to Maine, including 59 in New York alone (fig. 2). The temporary monitoring network augmented USGS and National Oceanic and Atmospheric Administration (NOAA) networks of permanent monitoring sites (fig. 2) that also documented storm surge—the difference (when positive) between the observed water level and the normal (predicted astronomical) tide level. Continuous data from these networks were greatly supplemented by an extensive post-storm high-water-mark (HWM) flagging and surveying campaign from November to December 2012. More than 950 HWMs were measured along the mid-Atlantic and northeastern coastline; roughly one-third of these were measured in southeastern New York and north along the Hudson River to the head-of-tide at the Federal Dam in Troy (fig. 2).

The temporary monitoring network deployment and HWM flagging and surveying campaign were undertaken as part of a coordinated Federal emergency response as outlined by the Stafford Act (Robert T. Stafford Disaster Relief and Emergency Management Act, Public Law 93–288, as amended, 42 U.S.C. 5121 et seq.) under a directed mission assignment by the Federal Emergency Management Agency (FEMA). The methods and data associated with these activities are described in a rapid-delivery report that provides a quantitative historical record of Hurricane Sandy (McCallum and others, 2013). The need for hydrologic interpretation of monitoring data to assist in the analysis of flood damages and future flood-mitigation efforts in New York prompted the current analysis of Hurricane Sandy under this mission assignment with FEMA. This interpretation was conducted by the USGS in cooperation with FEMA.

Purpose and Scope

This report presents the results of an analysis of storm-tide impacts from Hurricane Sandy in New York that was done as part of the FEMA mission assignment. Specifically, the report presents (1) comparisons of peak storm-tide elevations to selected historical storms and annual exceedance probabilities; (2) the storm-surge magnitude associated with the peak storm tide, and magnitude and timing of the peak storm surge; and (3) comparisons of selected maps of inundation extent that were derived from differing amounts of available sensor and HWM data.

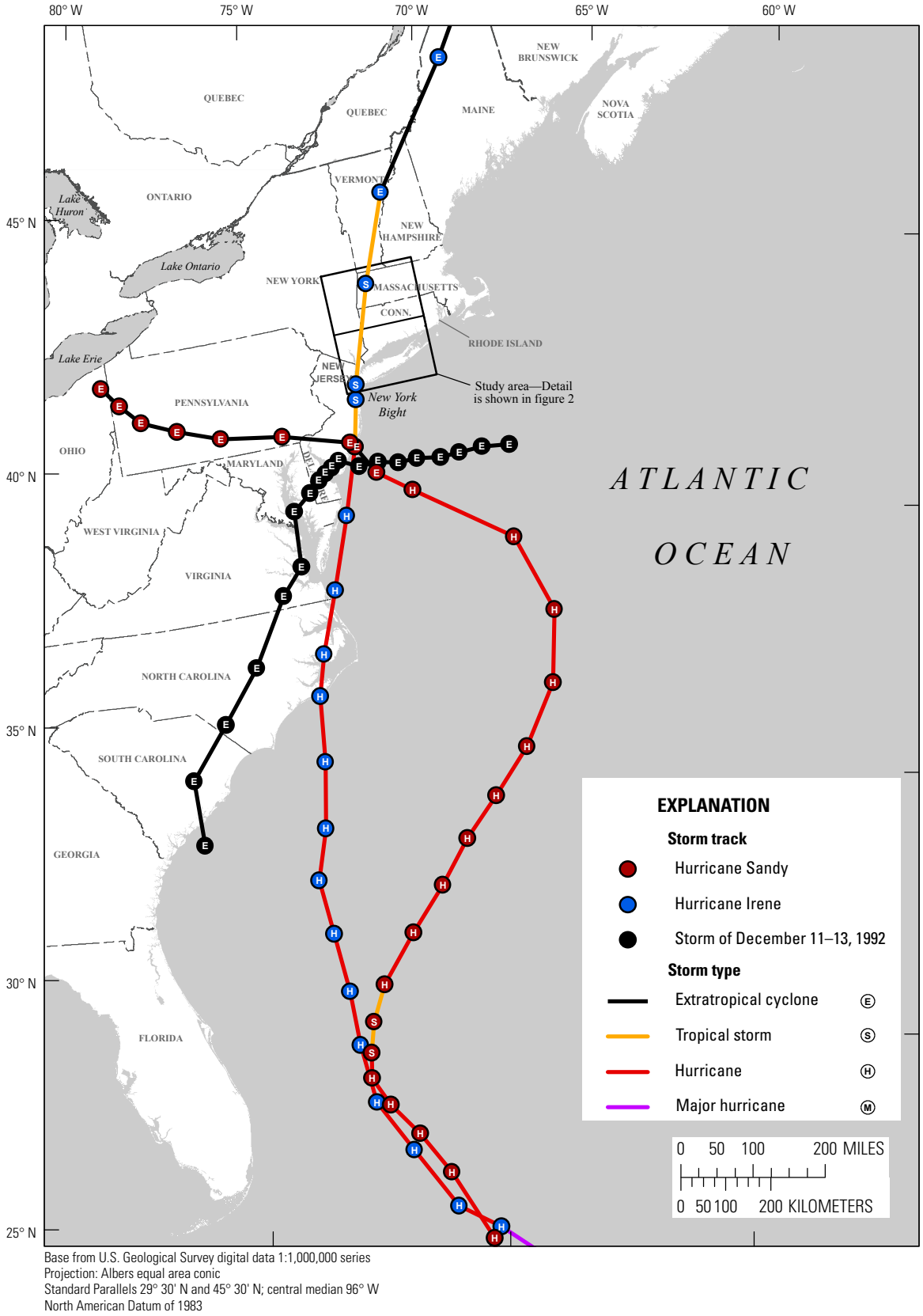
Meteorological History of Hurricane Sandy

Hurricane Sandy was the 18th named storm and 10th hurricane of the 2012 Atlantic hurricane season. Sandy developed from a low pressure system in the Caribbean Sea. Hurricane Sandy was first classified by the National Hurricane Center (NHC) as a tropical depression and then as a tropical storm south of the island of Jamaica on October 22, 2012. After drifting slowly southwest on October 23, on October 24 Sandy turned to the north and intensified into a Category 1 hurricane on the Saffir-Simpson hurricane scale (National Hurricane Center, 2013b) just before making landfall in Jamaica.

Hurricane Sandy continued to the north, intensified into a strong Category 2 hurricane before making landfall in Cuba, and then emerged on the north side of Cuba during the morning of October 25. The storm proceeded to drift northwest as a Category 1 or 2 hurricane as it moved through the Bahamas on October 25 and 26. Hurricane Sandy then began a north-northeast track on October 26 as a Category 1 hurricane (fig. 1). This track continued into the evening of October 28, when Hurricane Sandy turned to the north. Sandy turned northwest on October 29. Hurricane Sandy made landfall near Atlantic City, New Jersey, as an extratropical cyclone at 7:30 p.m. eastern daylight time on October 29 with a minimum central pressure of 945 millibars. The storm moved inland over New Jersey and weakened into a remnant trough in western Pennsylvania on October 31.

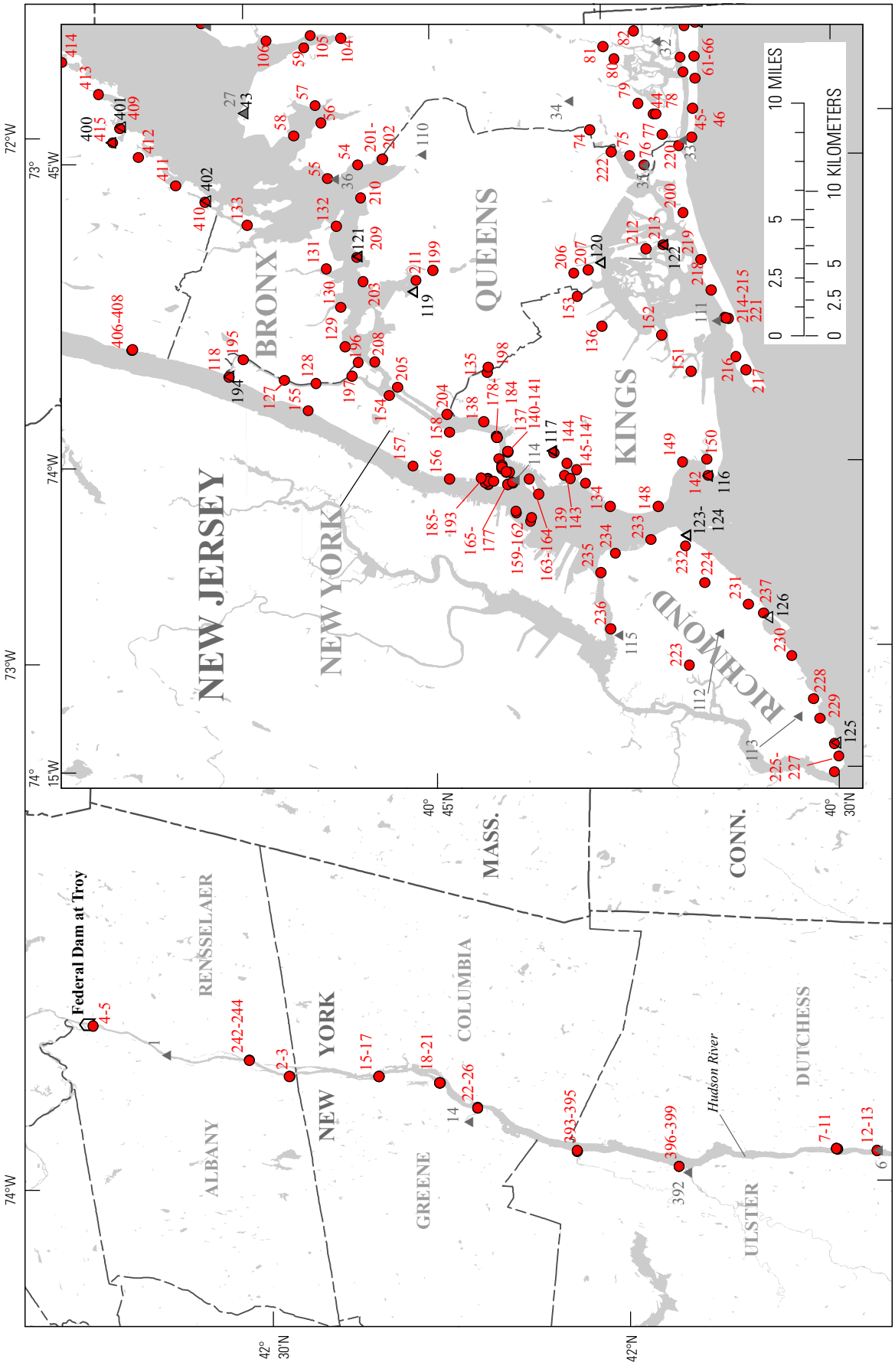
The unusual north-to-northwest motion of the storm that began on October 28 was caused by two factors: (1) an anomalously strong, blocking high-pressure system situated over the Canadian Maritimes and (2) an approaching and deepening midlatitude trough to the west over the eastern United States. These factors caused the storm to curve toward the coast south of New York City and Long Island. Hurricane Sandy's interaction with these two weather systems also caused the storm's transition from a tropical to a post-tropical system, which created an outward expansion of the storm's wind field. Just prior to United States landfall, this wind field or fetch was estimated to be about 1,000 miles (mi) wide (fig. 3), making Sandy the largest Atlantic Hurricane on record (Blake and others, 2013).

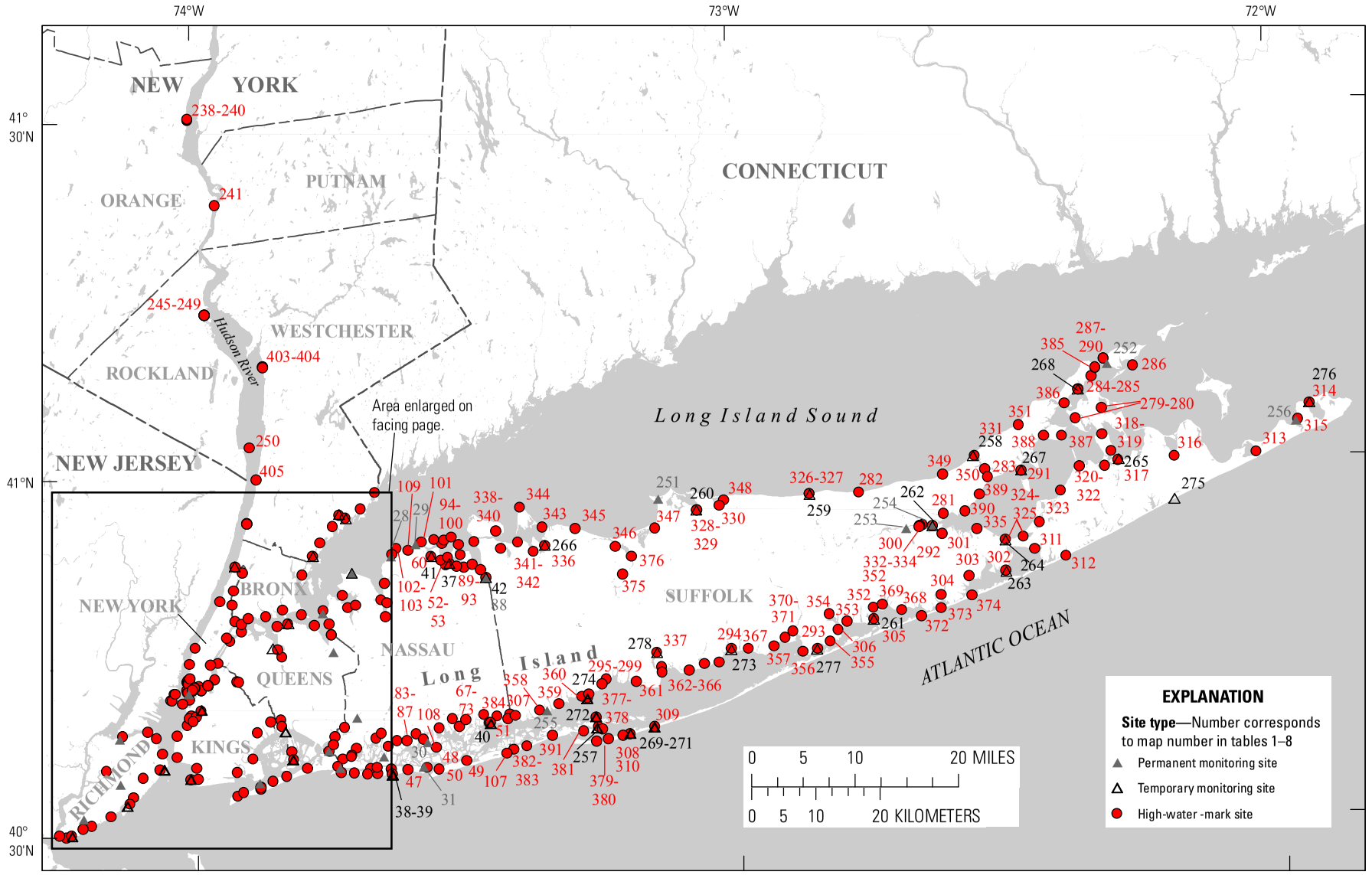
The extremely large fetch of tropical-storm force winds circulating around Hurricane Sandy, combined with its



Base from U.S. Geological Survey digital data 1:1,000,000 series
Projection: Albers equal area conic
Standard Parallels 29° 30' N and 45° 30' N; central median 96° W
North American Datum of 1983

Figure 1. Location of study area in New York and tracks of Hurricane Sandy, Tropical Storm Irene, and the storm of December 11–13, 1992, in the North Atlantic region. Storm position and intensity values for Hurricane Sandy and Tropical Storm Irene are from National Hurricane Center (2013a). Position values for storm of December 11–13, 1992, are from Andrew Cox (Oceanweather, Inc., written commun., 2013).


NEW JERSEY
NEW YORK
BRONX
QUEENS
KINGS
RICHMOND
Federal Dam at Troy
RENSSELAER
ALBANY
NEW YORK
COLUMBIA
GREENE
ULSTER
DUTCHESS
MASS.
CONN.
Hudson River
0 2.5 5 10 MILES
0 2.5 5 10 KILOMETERS
72°W
73°W
74°W
73° 45'W
74° 15'W
42° 30'N
42°N
40° 45'N
40° 30'N



Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 2. Locations of permanent and temporary monitoring sites and high-water-mark sites that documented the storm tide of Hurricane Sandy in New York counties. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.

anomalous track, piled large amounts of ocean water over multiple tidal cycles north and west of the center of counter-clockwise circulation. This onshore flow was funneled into the New York Bight—the large embayment formed by the Atlantic coastline of Long Island and northern New Jersey—and inland through the many interconnected estuaries, propagating more than 100 mi north along the Hudson River to the head-of-tide at the Federal Dam in Troy. These are the primary reasons why Hurricane Sandy caused historic coastal flooding in these areas, producing a storm surge much greater than that expected for a Category 1 hurricane taking a more normal north-to-northeast track up the Atlantic seaboard.

Winds in the southeastern New York region began to increase well in advance of Hurricane Sandy. By the afternoon of October 27, as Hurricane Sandy was moving northeast along the southeastern United States coast, winds in the region began to increase from an east to northeast direction. This was primarily due to the pressure gradient between the hurricane well to the south and the blocking high to the northeast of the region. As the storm approached Cape Hatteras, North Carolina, on the afternoon of October 28, winds began to shift to a more northeast direction; winds shifted to the north-northeast by the end of the day, as the hurricane continued moving northeastward well east of Cape Hatteras. During the day on October 29, the storm began its sharp turn towards the southern New Jersey coast and transitioned to a post-tropical system with winds rapidly increasing over the region and shifting back to the northeast. Maximum winds occurred from late in the afternoon to around midnight on October 29. As the storm approached and then made landfall south of the region, the strong winds quickly switched to an easterly direction by late afternoon and then to a southeasterly direction just after landfall. As the storm continued moving inland through southern New Jersey and then into Pennsylvania, strong winds from the southeast to south continued for a few hours and then gradually decreased during the day on October 30.

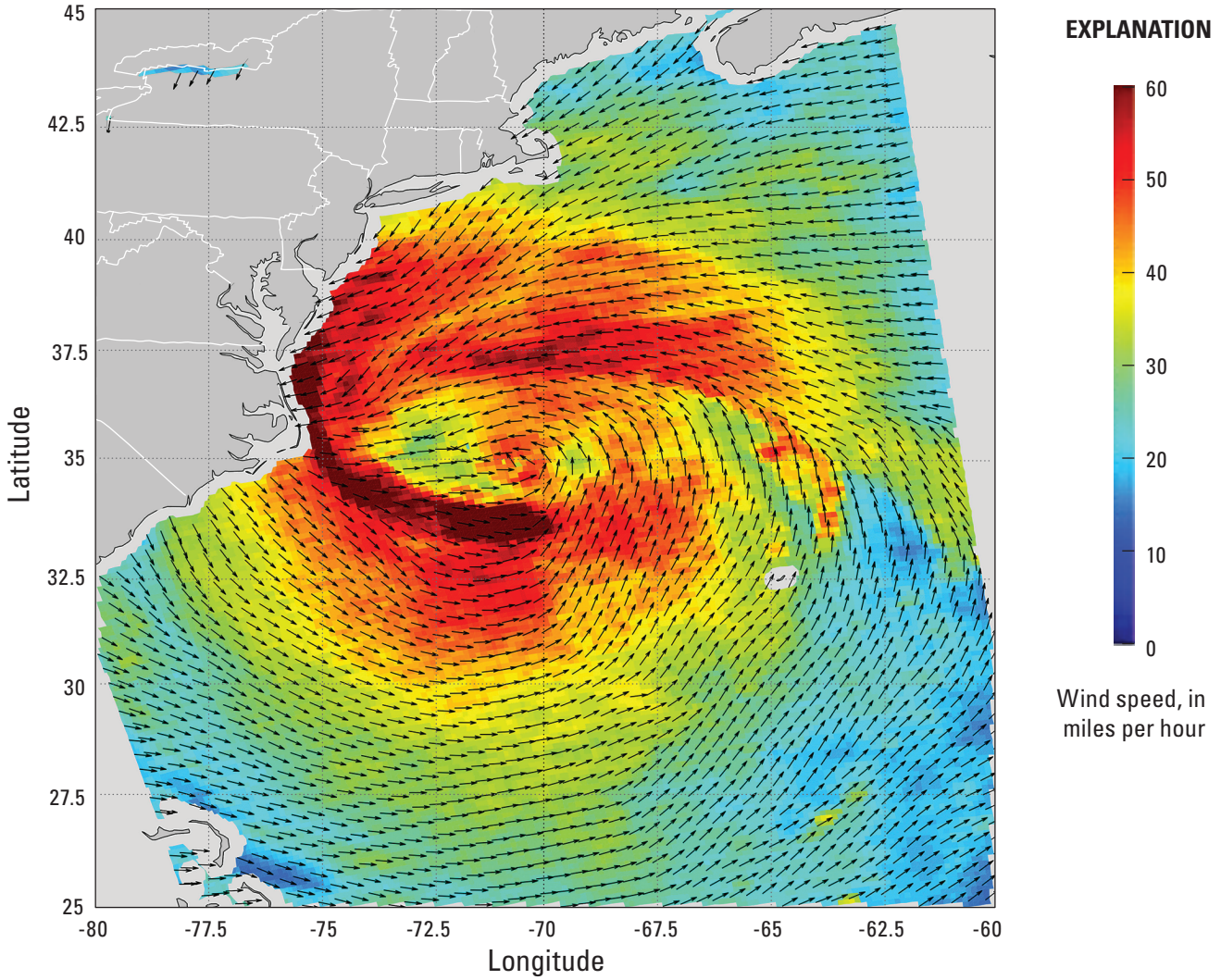


Figure 3. Strength and direction of Hurricane Sandy's ocean surface winds on October 28, 2012. Wind speeds above 40 miles per hour are depicted in yellow, above 50 are in orange, and above 60 are in red; wind directions are indicated by black arrows. Map is modified from National Aeronautics and Space Administration (2013) produced with data from a radar scatterometer on the Indian Space Research Organization's Oceansat-2.

Analysis of Storm-Tide Impacts From Hurricane Sandy

The analysis of storm-tide impacts focused on three distinct but related aspects of coastal flooding produced by Hurricane Sandy—(1) comparisons of peak storm-tide elevations to historical storms and annual exceedance probabilities, (2) identification of the storm-surge magnitude associated with the peak storm tide, and magnitude and timing of the peak storm surge, and (3) comparisons of selected maps of inundation extent that were derived from differing amounts of available sensor and HWM data.

Peak Storm-Tide Elevation

Peak storm-tide elevations at the permanent and temporary monitoring sites and HWM sites shown in figure 4 provide a comprehensive depiction of the coastal flooding from Hurricane Sandy in New York. The data for these sites are also available from a USGS interactive storm-tide mapper at http://water.usgs.gov/floods/events/2012/sandy/sandymapper.html. The storm-tide elevations have been affected by wave action to varying degrees, depending on the measurement techniques and site conditions under which the data were collected. A diagram of FEMA coastal **flood hazard zones** and the manner in which wave heights affect **base flood elevation**s (BFEs), particularly at locations in **VE** zones (Federal Emergency Management Agency, 2013a) is shown in figure 5. Specifically, these locations are likely to have flooding with wave heights of 3 feet (ft) or greater, whereas those in **AE** zones will have flooding with wave heights less than 3 ft.

As a result, records from permanent and temporary monitoring sites in VE zones likely were affected by wave heights of 3 ft or greater, the effects of which were removed using a 3-minute mean to obtain a peak elevation comparable with **stillwater elevation**s; monitoring records from sites in other coastal flood hazard zones likely were affected by wave heights less than 3 ft and, thus, provide a peak elevation generally comparable with the corresponding stillwater elevations. Similarly, HWMs at sites in VE zones likely were affected by wave heights of 3 ft or greater and, therefore, are comparable only with the BFEs. HWMs at sites in other coastal flood hazard zones likely were affected by wave heights less than 3 ft and, thus, are generally comparable with the corresponding stillwater elevations.

Most peak storm-tide elevations from Hurricane Sandy (fig. 4) were greater than about 9.5 ft above North American Vertical Datum of 1988 (NAVD 88); this level was exceeded at most of the sites in Albany, Nassau, Rensselaer, and Westchester Counties and New York City (Bronx, Kings, New York, Queens, and Richmond Counties). In the remaining counties with Hurricane Sandy data—Dutchess, Greene, Orange, Rockland, Suffolk, and Ulster, peak storm-tide elevations were greater than about 7.2 ft above NAVD 88 at most sites. The maximum peak storm-tide elevation was 16.9 ft above NAVD 88 at HWM site HWM–NY–RIC–717 (map number 230) in New York City. The minimum peak storm-tide elevation was 3.5 ft above NAVD 88 at HWM site HWM–NY–SUF–638 (map number 373) in Suffolk County. Data were not obtained along the east shore of the Hudson River in Columbia and Putnam counties; HWMs obtained along the west shore in Greene and Orange counties represent peak storm-tide elevations in these reaches.

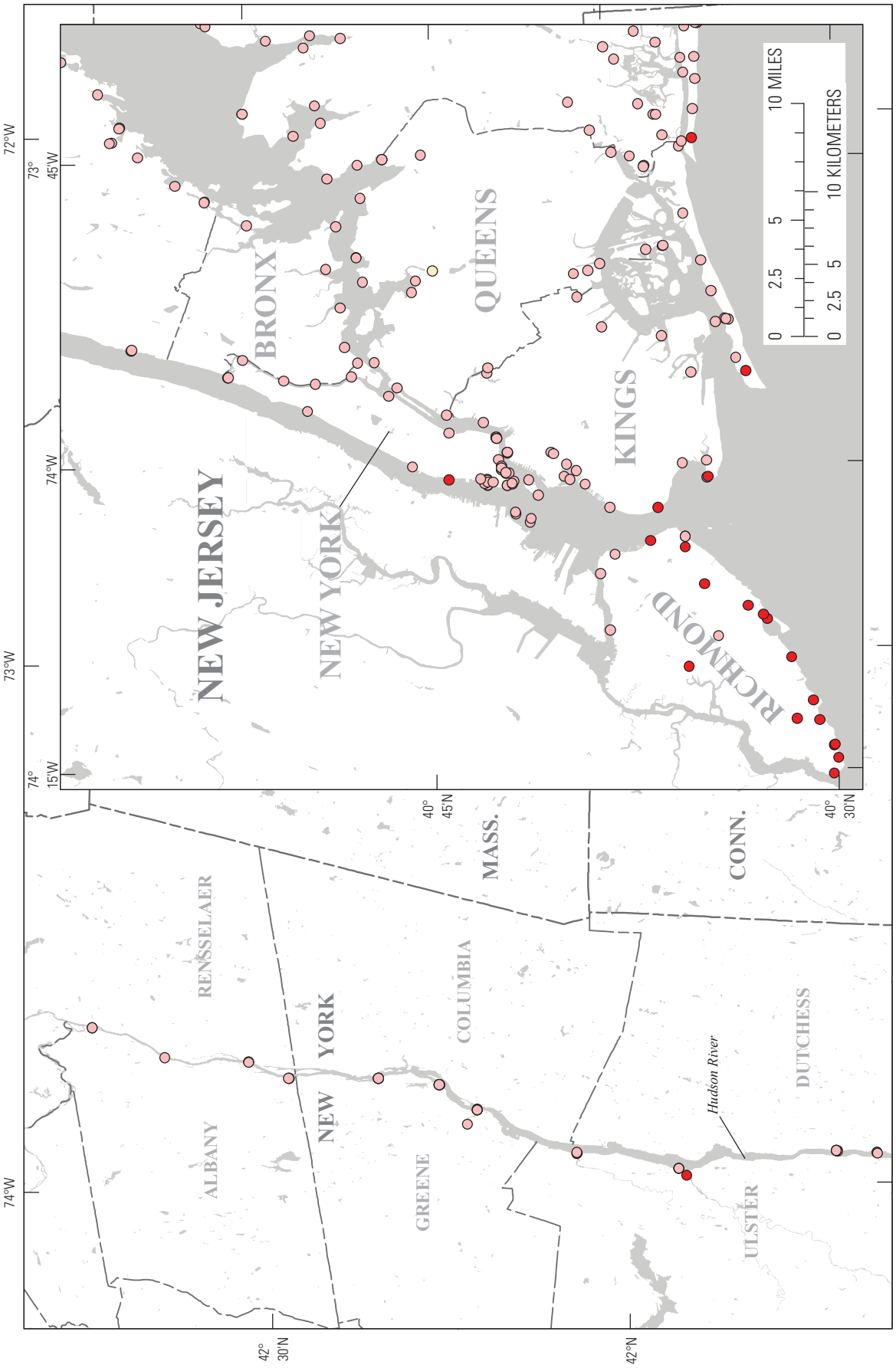
Comparison With Historical Storms

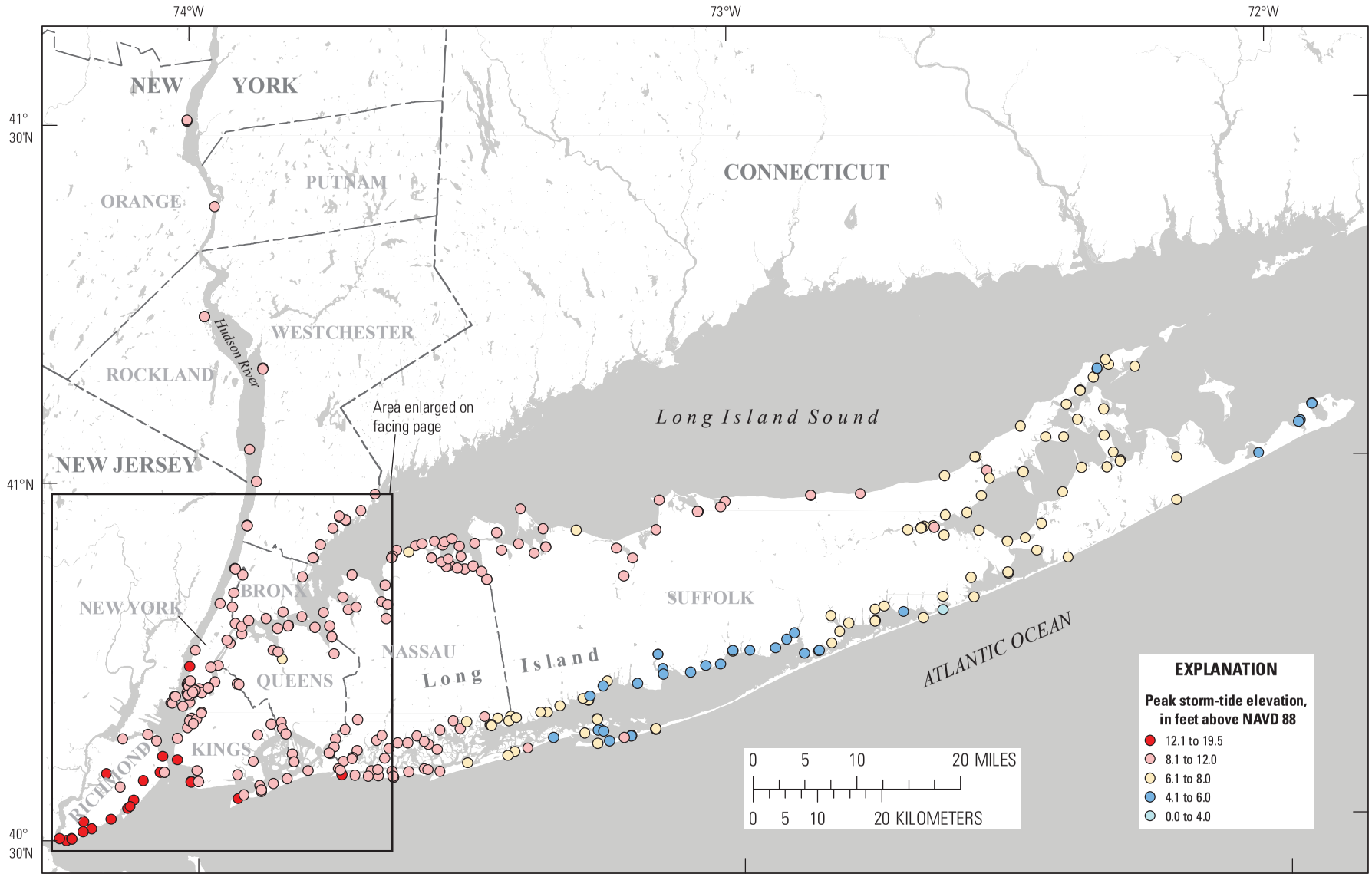
Peak storm-tide elevations produced by Hurricane Sandy were compared with those of historical storms for which data on substantial coastal flooding are available. These storms include the intense nor'easter of December 11–13, 1992, and Hurricane Irene (August 27–28, 2011), which weakened to a tropical storm before arriving in New York.

December 1992 Nor'easter

The intense nor'easter that affected the mid-Atlantic and northeastern coastline of the United States during December 10–14, 1992 (fig. 1), produced east-to-northeast winds of gale-force strength (39 to 54 mi/hr) that gusted to greater than hurricane strength and caused heavy rain, extensive coastal flooding, and severe beach erosion (Schubert and Busciolano, 1994). Severe tidal flooding occurred during the morning of December 11 and continued through the early afternoon of December 12 along coastal areas of southeastern New York, northern New Jersey, and southern Connecticut. Although peak storm-tide levels occurred near the times of normal tidal high water during December 11–12, widespread tidal flooding did not subside in many coastal areas until December 14.

Peak storm-tide elevations produced by the storm of December 11–13, 1992, at 27 HWM sites and peak storm-tide elevations produced by Hurricane Sandy at nearby sites in New York are listed in table 1. Calculations of the differences between their peak storm-tide elevations are included in table 1, and the differences are depicted in units of feet and percent (above the historical storm tide) in figure 6*A* and 6*B*, respectively. These differences indicate that peak storm-tide elevations from Hurricane Sandy were higher than those from the December 1992 nor'easter at 24 of 27 sites (89 percent). Most differences were greater than about 0.7 ft or 9 percent, with most of these from sites along the Atlantic Ocean shores of Nassau and Suffolk Counties and New York City. The maximum absolute difference was 4.5 ft at HWM site HWM–NY–QUE–505 (Hunters Point) in New York City, and the maximum relative difference was 110 percent at HWM sites HWM–NY–SUF–407 (Bay Shore), HWM–NY–SUF–600 (Oakdale), and HWM–NY–SUF–620 (Bellport) along the Atlantic Ocean shore of Suffolk County. The minimum absolute and relative differences were –0.5 ft and –4 percent, respectively, at HWM site HWM–NY–NAS–936 (Bayville) along the Long Island Sound shore of Nassau County.


74°W
73°W
72°W
42° 30'N
42°N
40° 45'N
40° 30'N
74° 15'W
74°W
73° 45'W
NEW JERSEY
NEW YORK
BRONX
QUEENS
KINGS
RICHMOND
0 2.5 5 10 MILES
0 2.5 5 10 KILOMETERS
ALBANY
RENSSELAER
NEW YORK
COLUMBIA
GREENE
MASS.
CONN.
DUTCHESS
ULSTER
Hudson River



Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 4. Peak storm-tide elevations produced by Hurricane Sandy in New York counties. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.

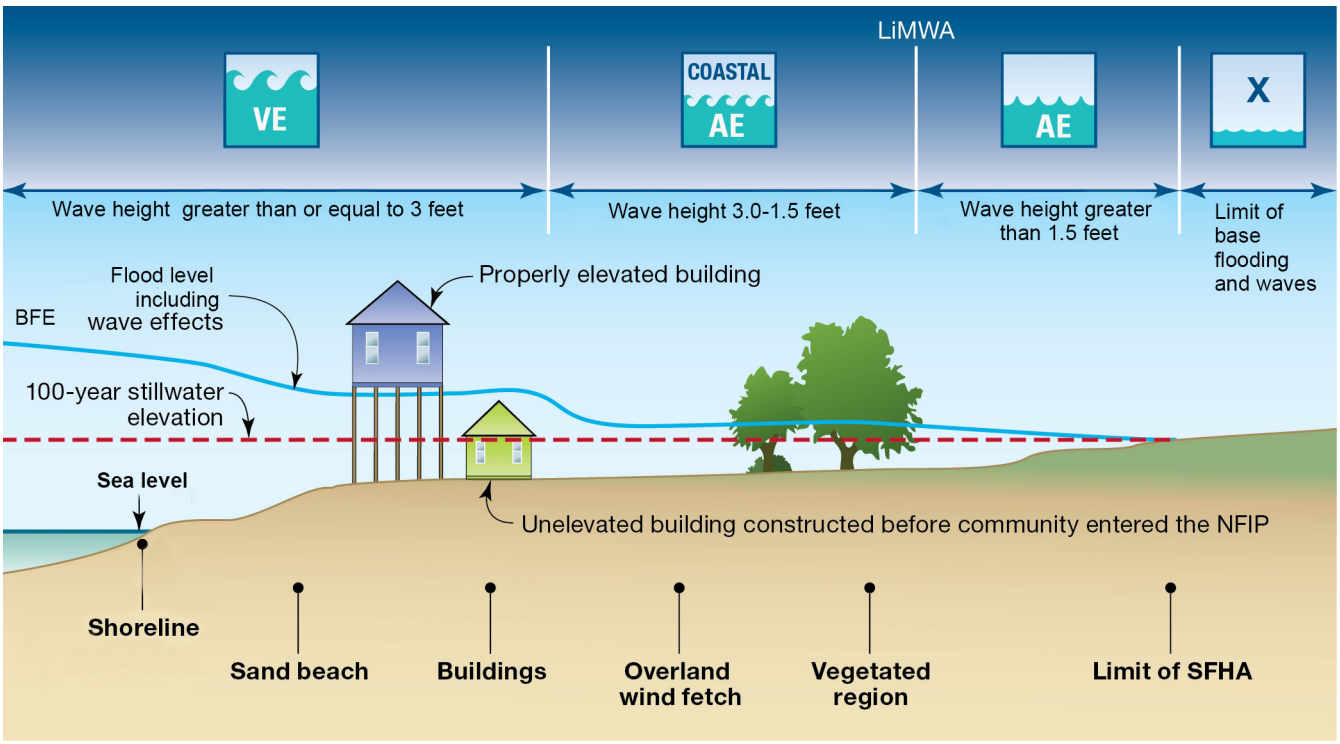
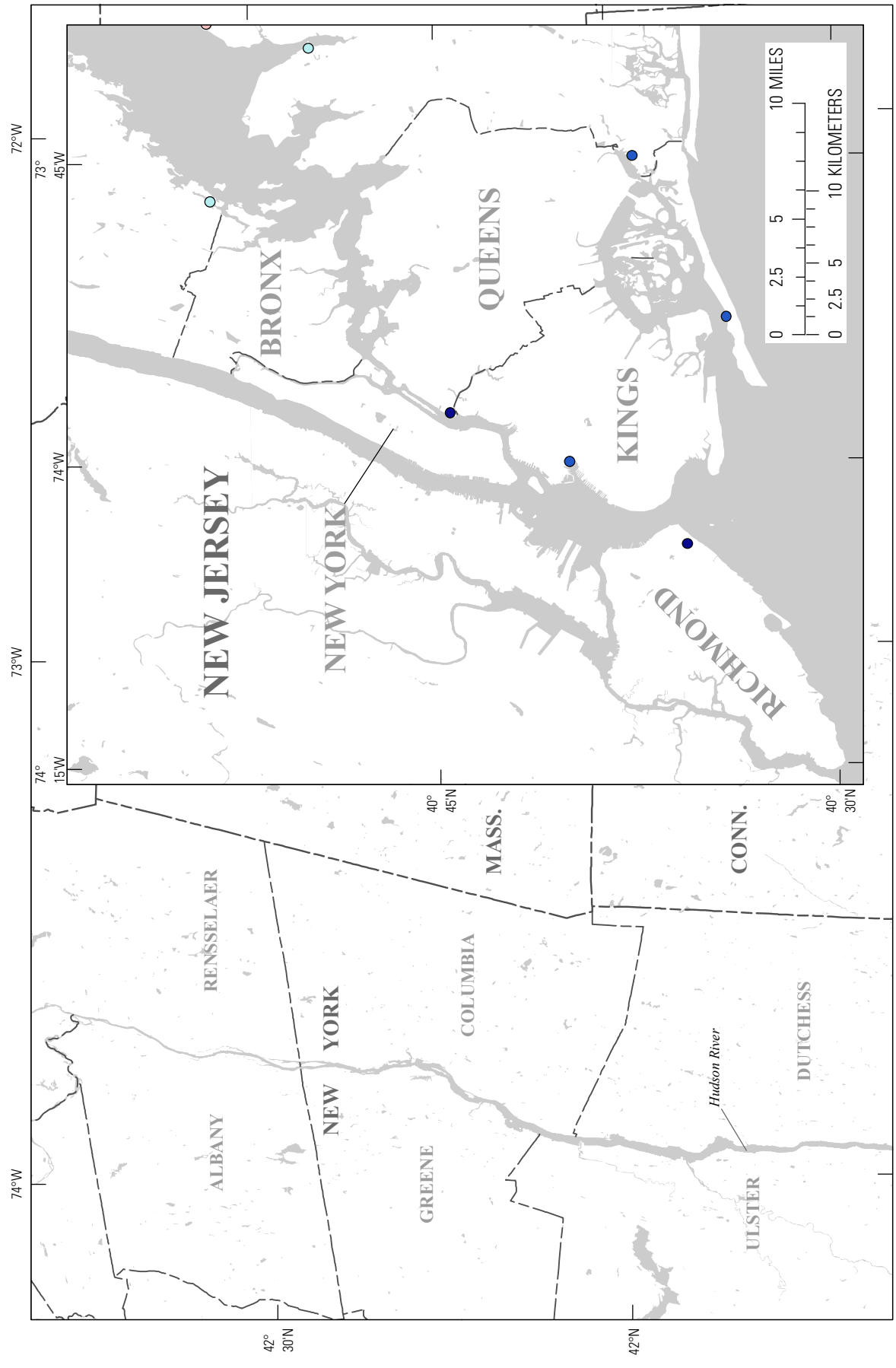


Figure 5. Federal Emergency Management Agency coastal flood hazard zones and effects of wave heights on base flood elevations (BFEs), particularly at locations in the VE zone; from Federal Emergency Management Agency, 2013a. VE zone is the area subject to high velocity wave action (a 3-foot breaking wave) from the 1-percent annual chance coastal flood. AE zone is the area subject to inundation from the 1-percent annual chance flood; these areas are not subject to high velocity wave action but are still considered high risk flooding areas. X zone is the area of moderate coastal flood risk outside the regulatory 1-percent annual chance flood up to the 0.2-percent annual chance flood level. LiMWA, limit of moderate wave action; NFIP, National Flood Insurance Program; SFHA, special flood hazard area.

Table 1. Peak storm-tide elevations produced by storm of December 11–13, 1992, at 27 high-water-mark sites, and peak storm-tide elevations produced by Hurricane Sandy at nearby sites in New York.

[High-water-mark (HWM) site locations are shown in figure 2. GMT, Grenwich Mean Time; NAVD 88, North American Vertical Datum of 1988]

Hurricane Sandy						Storm of December 11–13, 1992					Difference		
Site				Peak storm tide		Site			Peak storm tide			Peak storm-tide	
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	Estimated date (GMT)	Elevation, in feet above NAVD 88	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	Estimated date (GMT)	Elevation, in feet above NAVD 88	Site location, in miles	Feet	Percent
						Nassau County							
59	HWM–NY–NAS–519	40.82775	-73.65676	10/30/2012	10.4	Port Washington	40.82796	-73.65748	12/11/1992	9.8	0.041	0.6	6
60	HWM–NY–NAS–700	40.88750	-73.56361	10/30/2012	10.2	Mill Neck	40.88741	-73.56318	12/11/1992	9.7	0.023	0.5	5
75	HWM–NY–NAS–910	40.62586	-73.74889	10/30/2012	10.4	Inwood	40.62731	-73.74650	12/11/1992	7.2	0.161	3.2	44
88	HWM–NY–NAS–923	40.85722	-73.46333	10/30/2012	9.7	Cold Spring Harbor	40.85734	-73.46367	12/11/1992	9.5	0.019	0.2	2
90	HWM–NY–NAS–925	40.87199	-73.50356	10/30/2012	10.2	Cove Neck	40.87402	-73.50255	12/11/1992	9.3	0.150	0.9	10
96	HWM–NY–NAS–931	40.91413	-73.52602	10/30/2012	9.8	Centre Island	40.91474	-73.52758	12/11/1992	9.0	0.092	0.8	9
101	HWM–NY–NAS–936	40.90816	-73.58157	10/30/2012	10.4	Bayville	40.90825	-73.58389	12/11/1992	10.8	0.121	-0.4	-4
102	HWM–NY–NAS–938	40.89152	-73.63566	10/30/2012	10.0	Glen Cove 2	40.89046	-73.63409	12/11/1992	10.2	0.110	-0.2	-2
						New York City							
145	HWM–NY–KIN–900	40.66725	-74.00001	10/30/2012	11.0	Greenwood	40.66713	-73.99991	12/11/1992	7.3	0.008	3.7	51
204	HWM–NY–QUE–505	40.74169	-73.95904	10/30/2012	10.7	Hunters Point	40.74075	-73.95945	12/11/1992	6.2	0.069	4.5	73
214	HWM–NY–QUE–726	40.56779	-73.88247	10/30/2012	10.5	Roxbury	40.56819	-73.88263	12/11/1992	7.8	0.029	2.7	35
232	HWM–NY–RIC–719	40.59386	-74.06829	10/30/2012	12.7	Arrochar	40.59314	-74.06260	12/11/1992	8.9	0.051	3.8	43
						Suffolk County							
281	HWM–NY–SUF–003	40.93250	-72.61556	10/30/2012	7.2	Aquebogue	40.93255	-72.61545	12/11/1992	7.2	0.006	0.0	0
282	HWM–NY–SUF–005	40.96522	-72.77187	10/29/2012	9.1	Baiting Hollow	40.96524	-72.77184	12/11/1992	8.4	0.002	0.7	8
288	HWM–NY–SUF–304	41.14331	-72.31243	10/29/2012	6.4	Orient	41.14330	-72.31249	12/11/1992	5.4	0.003	1.0	19
299	HWM–NY–SUF–407	40.71159	-73.24435	10/29/2012	6.1	Bay Shore	40.71169	-73.24341	12/11/1992	2.9	0.050	3.2	110
301	HWM–NY–SUF–409	40.90420	-72.61990	10/30/2012	7.7	Flanders	40.90428	-72.62006	12/11/1992	7.5	0.010	0.2	3
302	HWM–NY–SUF–410	40.85040	-72.50380	10/29/2012	6.6	Hampton Bays 1	40.85005	-72.50617	12/11/1992	3.7	0.127	2.9	78
322	HWM–NY–SUF–433	40.95980	-72.39820	10/30/2012	6.5	North Sea	40.95962	-72.39808	12/11/1992	6.3	0.014	0.2	3
329	HWM–NY–SUF–509	40.94574	-73.07198	10/30/2012	8.8	Port Jefferson	40.94489	-73.07146	12/11/1992	8.3	0.065	0.5	6
331	HWM–NY–SUF–511	41.01220	-72.55640	10/30/2012	7.8	Mattituck	41.01283	-72.55873	12/11/1992	7.0	0.129	0.8	11
336	HWM–NY–SUF–517	40.90030	-73.35303	10/30/2012	9.5	Northport 1	40.89908	-73.35296	12/11/1992	9.1	0.084	0.4	4
337	HWM–NY–SUF–600	40.74760	-73.15039	10/29/2012	6.1	Oakdale	40.74759	-73.15049	12/11/1992	2.9	0.005	3.2	110
344	HWM–NY–SUF–607	40.95410	-73.39812	10/30/2012	10.0	Asharoken	40.95401	-73.39813	12/11/1992	9.0	0.007	1.0	11
357	HWM–NY–SUF–620	40.75282	-72.93438	10/29/2012	5.6	Bellport	40.75363	-72.93348	12/11/1992	2.7	0.073	2.9	107
391	HWM–NY–SUF–965	40.63417	-73.34526	10/29/2012	5.2	Gilgo State Park	40.63510	-73.34252	12/11/1992	4.7	0.158	0.5	11
						Westchester County							
410	HWM–NY–WES–801	40.89064	-73.78236	10/30/2012	10.2	New Rochelle	40.89094	-73.78416	12/11/1992	10.1	0.096	0.1	1


A
74°W
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NEW JERSEY
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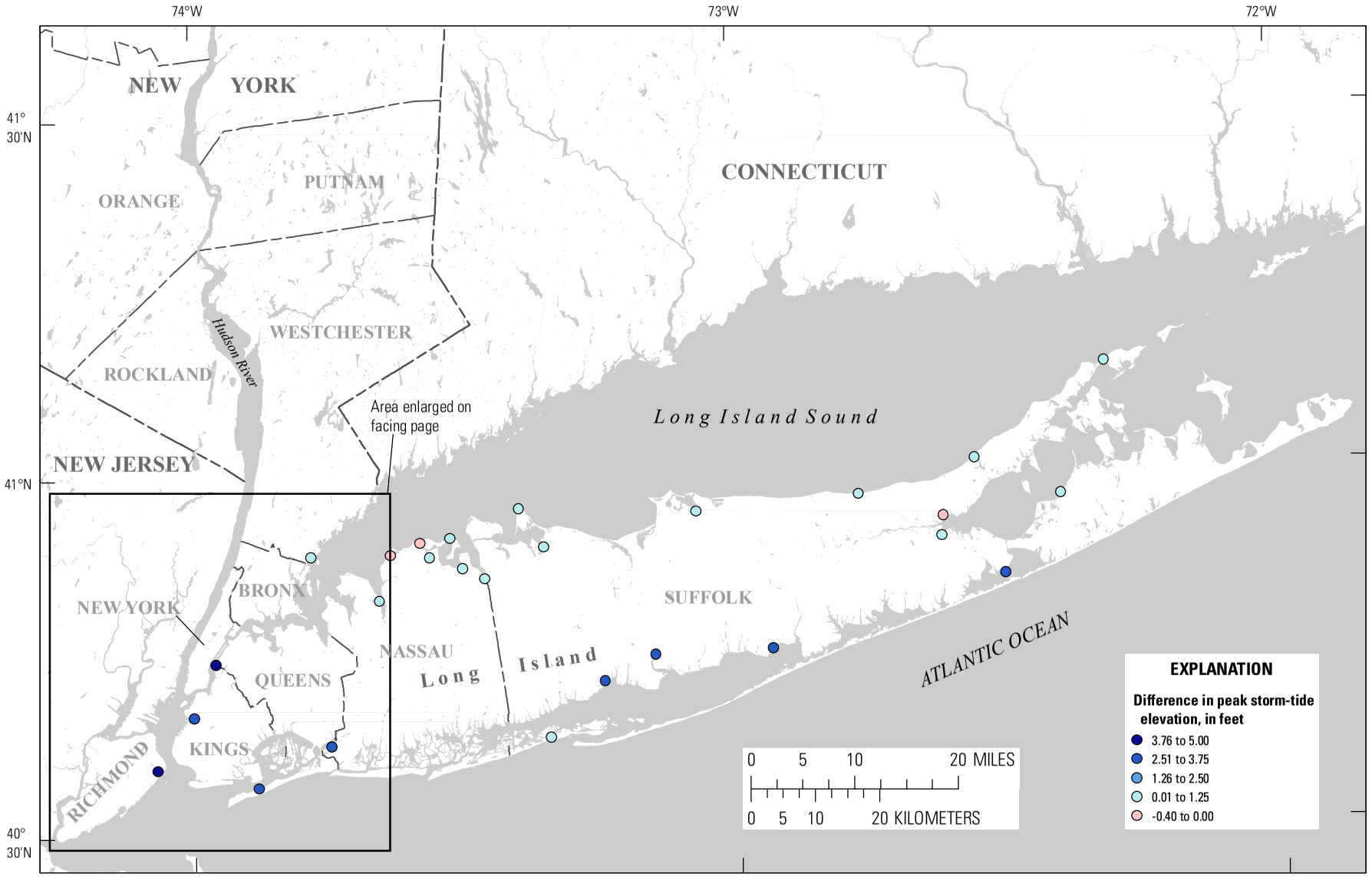
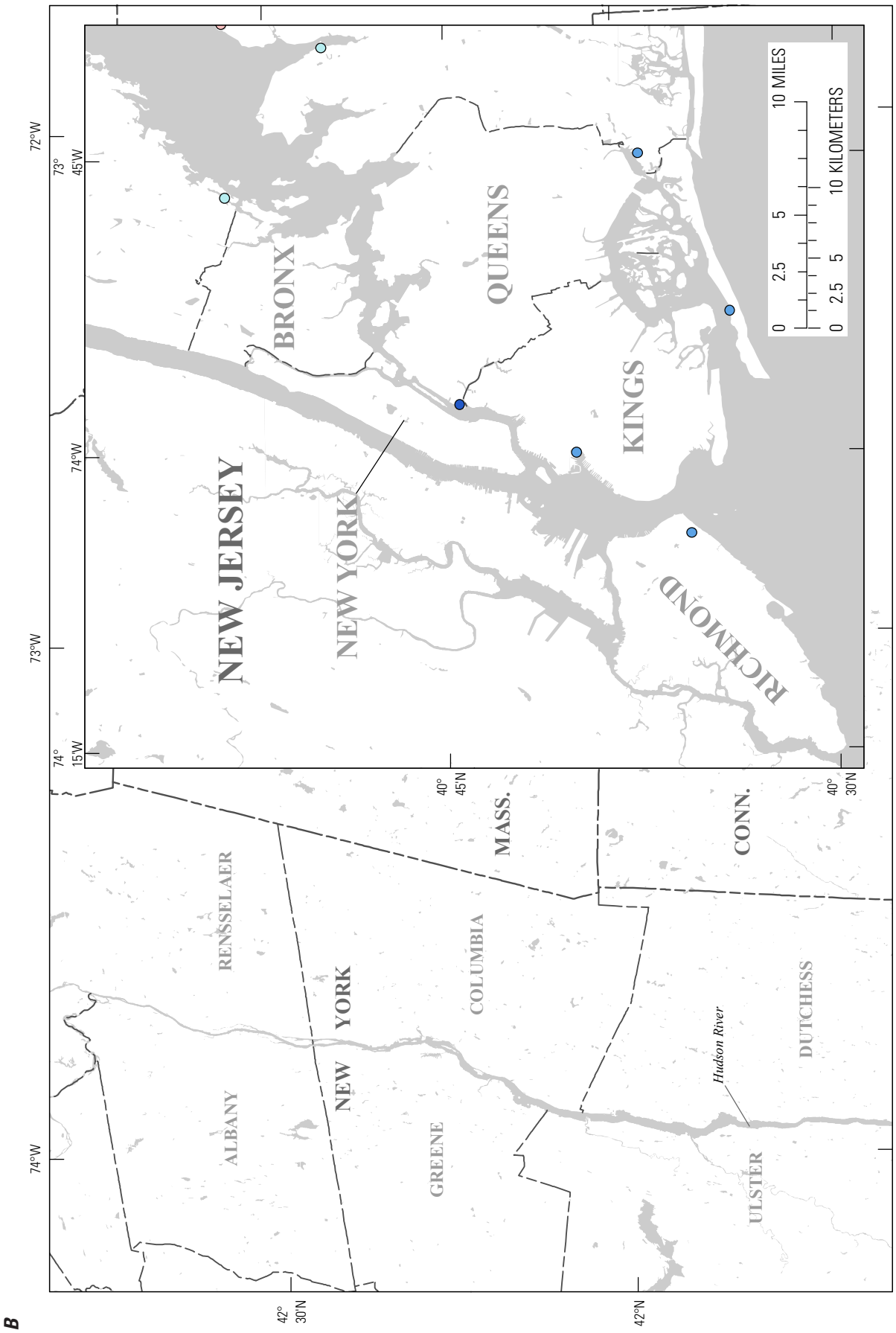
QUEENS
KINGS
RICHMOND
0 2.5 5 10 MILES
0 2.5 5 10 KILOMETERS
RENSSELAER
ALBANY
NEW YORK
COLUMBIA
GREENE
MASS.
CONN.
Hudson River
DUTCHESS
ULSTER



Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 6. *A,* Differences in feet between peak storm-tide elevations produced by Hurricane Sandy and the storm of December 11–13, 1992, in New York. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.


B
72°W
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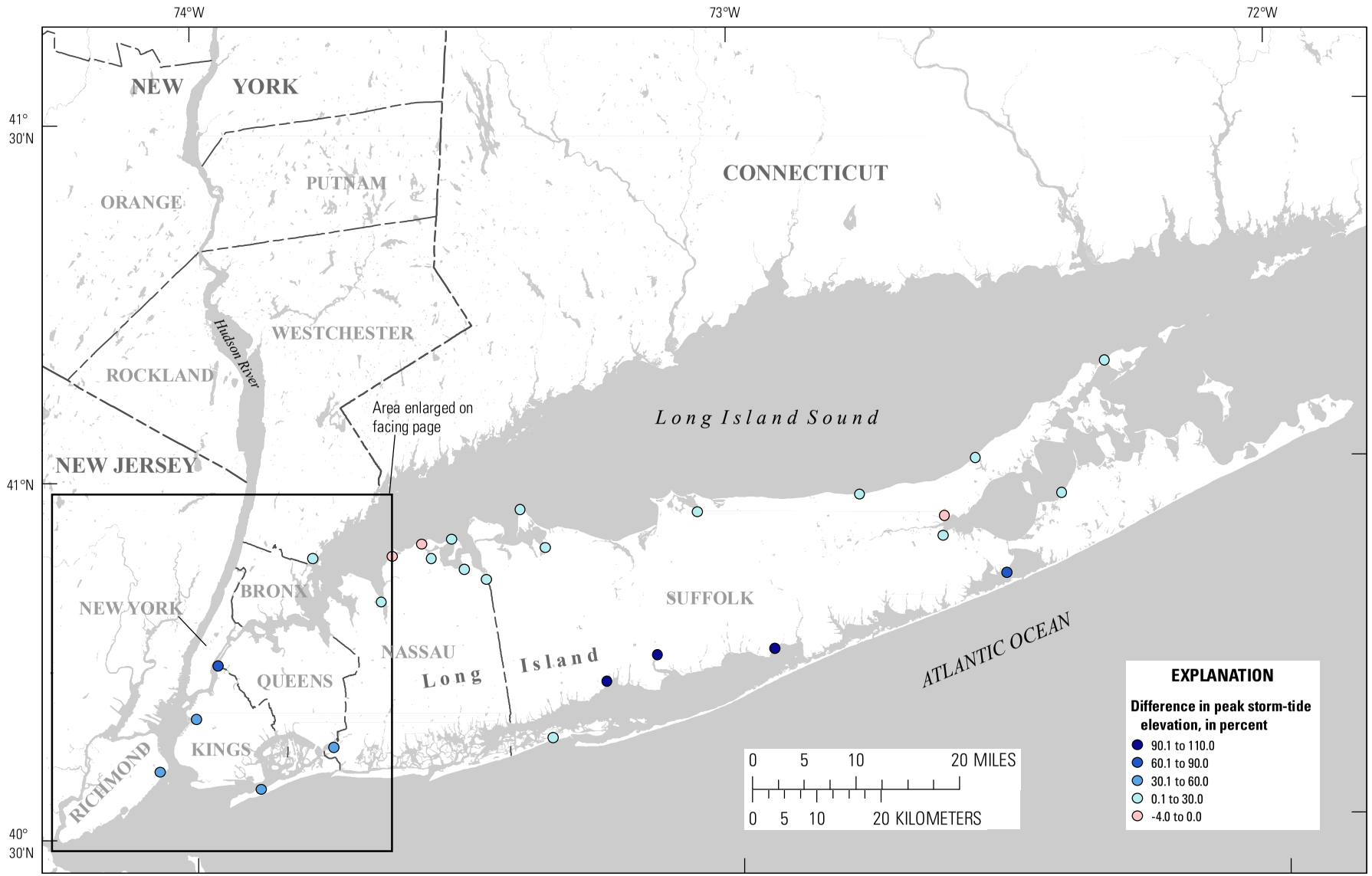
NEW JERSEY
NEW YORK
BRONX
QUEENS
KINGS
RICHMOND
0 2.5 5 10 MILES
0 2.5 5 10 KILOMETERS
RENSSELAER
ALBANY
NEW YORK
COLUMBIA
GREENE
MASS.
CONN.
DUTCHESS
ULSTER
Hudson River



Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 6. *B,* Differences in percent between peak storm-tide elevations produced by Hurricane Sandy and the storm of December 11–13, 1992, in New York. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.—Continued.

Tropical Storm Irene

Tropical Storm Irene initially made landfall as a Category 1 hurricane on the North Carolina coast near Beaufort on August 27, 2011 (fig. 1); after traversing the coast and Outer Banks of North Carolina, the storm went back out to sea and made a second landfall as a Category 1 hurricane near Atlantic City, New Jersey, on August 28 (McCallum and others, 2012). The resulting storm tide reached National Weather Service moderate to major flood thresholds in coastal areas of Long Island and New York City as Irene crossed western Long Island on August 28 as a tropical storm (Busciolano and Schubert, 2012).

Peak storm-tide elevations produced by Hurricane Sandy and Tropical Storm Irene at 19 permanent monitoring sites, 23 temporary monitoring sites, and 10 HWM sites in New York are given in tables 2, 3, and 4, respectively. The data in tables 2 through 4 include the differences between their peak storm-tide elevations for the two storms; differences in elevations are depicted in units of feet and percent in figure 7*A* and 7*B*, respectively. These differences indicate that peak storm-tide elevations from Hurricane Sandy were higher than those from Tropical Storm Irene at all sites. Most differences were greater than about 2.5 ft or 48 percent, with most of these from sites along the Atlantic Ocean shores of Nassau and Suffolk Counties, in New York City, and in Rockland County. The maximum absolute difference was 6.5 ft at HWM site HWM–NY–RIC–719 (005–CNY–01–006) in New York City (table 4), and the maximum relative difference was 111 percent at HWM site HWM–NY–KIN–908 (005–CNY–02–003), also in New York City. The minimum absolute and relative differences were 0.14 ft and 1.7 percent, respectively, at temporary monitoring site SSS–NY–SUF–002WL (table 3) along the Long Island Sound shore of Suffolk County.

Historical Peak Water-Level Elevations

Peak storm-tide elevations produced by Hurricane Sandy, historical peak water-level elevations, estimated dates of occurrence, and periods of record at 19 permanent monitoring sites in New York are presented in table 2. Of the 19 permanent monitoring sites, the peak storm-tide elevation from Hurricane Sandy exceeded the historical peak water-level elevation at 16 sites (84 percent) and was very close to the historical peak at 1 site (5 percent). One of the two sites where the historical peak was greater than the peak from Hurricane Sandy—USGS site 01302050—is a **streamgage** in New York City that historically may have been affected by high streamflow. The other site—NOAA site 8510560—is a **tide gage** in Suffolk County near the extreme eastern tip of Long Island, where the storm-tide impacts from Hurricane Sandy were less than those at sites farther westward. The one site where the peak from Hurricane Sandy was very close to, but did not exceed, the historical peak—USGS streamgage 01303000—is along the Long Island Sound shore of Nassau County. This historical peak is from the unnamed, major hurricane of September 21, 1938; however, it was only 0.06 ft higher than the peak from Hurricane Sandy.

Comparison With Annual Exceedance Probabilities

Peak storm-tide elevations at the permanent and temporary monitoring sites and the HWM sites were compared with the corresponding FEMA flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year recurrence intervals). The comparison relied on stillwater flood elevations, and on coastal flood hazard zones and base flood elevations, which were generally derived from the most recently published FEMA Flood Insurance Study (FIS) and Flood Insurance Rate Map (FIRM) products, respectively, that were in effect for New York localities affected by the storm tide of Hurricane Sandy. One exception to this was in New York City, where the comparison relied primarily on coastal flood hazard zones and flood elevations derived from preliminary work map data (Federal Emergency Management Agency, 2013e), which represent the best available information at the time of this study. A comparison of peak storm-tide elevations to annual exceedance probabilities for New York City was also performed using the most recently published FEMA FIS and FIRM products for this locality; the data are listed in tables 5 through 7. However, this comparison with legacy products is not discussed in the text or shown in the figures.

Peak storm-tide elevations produced by Hurricane Sandy and the corresponding FEMA flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year recurrence intervals) at 24 permanent monitoring sites, 43 temporary monitoring sites, and 346 HWM sites in New York are listed in tables 5, 6, and 7, respectively. The comparisons between Hurricane Sandy peak storm-tide elevations and FEMA flood elevations for sites in tables 5 through 7 also include the annual exceedance probabilities (and recurrence intervals) for these sites; annual exceedance probabilities are shown in figure 8. These comparisons indicate that peak storm-tide elevations from Hurricane Sandy had annual exceedance probabilities of less than or equal to 1 percent and (or) greater than 0.2 percent (recurrence intervals greater than or equal to 100 years and (or) less than 500 years) at a plurality of sites—184 of 413 (45 percent).

Most of the peak storm-tide elevations greater than or equal to the FEMA 1-percent (100-year) flood elevation and (or) less than the 0.2-percent (500-year) flood elevation were from sites in Dutchess, Nassau, Orange, Rockland, Suffolk, and Ulster Counties; New York City; and along the Hudson River shore of Westchester County (fig. 8). Peak storm-tide elevations associated with the minimum annual exceedance probabilities (maximum recurrence intervals)—elevations higher than or equal to the FEMA 0.2-percent (500-year) flood elevation—accounted for 81 of 413 sites (20 percent); most of these were along the Atlantic Ocean shores of Nassau and western Suffolk Counties, in Orange and Rockland Counties, and along the Hudson River shore of Westchester County. Peak storm-tide elevations associated with the maximum annual exceedance probability (minimum recurrence interval)—elevations lower than the FEMA 10-percent (10-year) flood elevation—accounted for only 10 of 413 sites (2 percent); most of these were in Albany and Rensselaer Counties.

Table 2. Peak storm-tide elevations produced by Hurricane Sandy, Tropical Storm Irene, and historical peak water-level elevations, dates of occurrence, and periods of record at 19 permanent monitoring sites in New York.

[Permanent monitoring site locations are shown in figure 2. Peak storm-tide records for Tropical Storm Irene at National Oceanic and Atmospheric Administration (NOAA) sites from Fanelli and Fanelli, 2011; records for Hurricane Sandy at NOAA sites from Fanelli and others, 2013. Historical peak water-level records and periods of record at NOAA sites from National Ocean Service, 2013. GMT, Grenwich Mean Time; NAVD 88, North American Vertical Datum of 1988]

Hurricane Sandy						Tropical Storm Irene peak storm tide		Difference in peak storm-tide elevation		Historical peak water level		Period of record
Site				Peak storm tide								
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	Estimated date (GMT)	Elevation, in feet above NAVD 88	Estimated date (GMT)	Elevation, in feet above NAVD 88	Feet	Percent	Estimated date	Elevation, in feet above NAVD 88	
Dutchess County												
6	01372058	41.65093	-73.94458	10/30/2012	8.66	8/28/2011	7.08	1.58	22	8/28/2011	7.08	1992–2013
Nassau County												
27	01302250	40.86622	-73.71019	10/30/2012	10.31	8/28/2011	8.39	1.92	23	3/15/2010	8.50	2007–2013
28	01302600	40.88856	-73.63800	10/30/2012	9.87	8/28/2011	8.21	1.66	20	8/28/2011	8.21	2009–2013
29	01302845	40.90511	-73.59319	10/30/2012	10.06	8/28/2011	8.04	2.02	25	8/28/2011	8.04	2007–2013
60	[1,2]01303000	40.88750	-73.56361	10/30/2012	10.2	8/28/2011	8.4	1.8	21	9/21/1938	10.26	1937–2000, 2005–2012
88	[3]01303500	40.85722	-73.46333	10/30/2012	9.7	8/28/2011	9.14	0.6	7	8/31/1954	9.67	1950–2013
30	01310521	40.62760	-73.57541	10/30/2012	8.98	8/28/2011	6.22	2.76	44	8/28/2011	6.22	1999–2013
31	01310740	40.59344	-73.58374	10/30/2012	8.97	8/28/2011	5.94	3.03	51	8/28/2011	5.94	1997–2013
32	01311143	40.60883	-73.65611	10/30/2012	9.77	8/28/2011	6.63	3.14	47	8/28/2011	6.63	2010–2013
33	01311145	40.59316	-73.73735	10/30/2012	9.70	8/28/2011	6.33	3.37	53	8/28/2011	6.33	2002–2013
35	01311850	40.61733	-73.75791	10/30/2012	10.55	8/28/2011	6.42	4.13	64	8/28/2011	6.42	2002–2013
New York City												
110	01302050	40.75583	-73.74583	10/30/2012	9.69	8/28/2011	9.46	0.23	2	10/19/1996	10.35	1993–2013
111	01311875	40.57372	-73.88514	10/30/2012	10.65	8/28/2011	6.48	4.17	64	8/28/2011	6.48	2002–2013
114	8518750–NOAA	40.70000	-74.01333	10/30/2012	11.28	8/28/2011	6.72	4.56	68	12/11/1992	6.93	1920–2013
Orange County												
241	[4]01374019	41.38620	-73.95510	10/30/2012	8.6	8/28/2011	6.69	1.9	28	8/28/2011	6.69	1991–2013
Rockland County												
250	[5]01376269	41.04319	-73.89610	10/30/2012	9.7	8/28/2011	6.56	3.1	47	8/28/2011	6.56	2010–2013
Suffolk County												
251	01304057	40.96286	-73.14317	10/30/2012	9.35	8/28/2011	7.81	1.54	20	8/28/2011	7.81	2007–2013
255	01309225	40.66927	-73.35568	10/30/2012	6.54	8/28/2011	4.08	2.46	60	8/28/2011	4.08	2002–2013
256	8510560–NOAA	41.04833	-71.96000	10/30/2012	5.55	8/28/2011	4.08	1.47	36	8/31/1954	6.87	1947–2013

[1]Permanent monitoring site 01303000 was discontinued in February 2011; peak elevation for Hurricane Sandy uses value from high-water-mark site HWM–NY–NAS–700 at same location.

[2]Permanent monitoring site 01303000 was discontinued in February 2011; peak elevation for Tropical Storm Irene uses value from high-water-mark site HWM–NY–NAS–003 at same location.

[3]Measurement limit at permanent monitoring site 01303500 was exceeded during Hurricane Sandy; peak elevation for this storm uses value from high-water-mark site HWM–NY–NAS–923 at same location.

[4]Measurement limit at permanent monitoring site 01374019 was exceeded during Hurricane Sandy; peak elevation for this storm uses value from high-water-mark site HWM–NY–ORA–004 at same location.

[5]Measurement limit at permanent monitoring site 01376269 was exceeded during Hurricane Sandy; peak elevation for this storm uses value from high-water-mark site HWM–NY–ROC–006 at same location.

Table 3. Peak storm-tide elevations produced by Hurricane Sandy and Tropical Storm Irene at 23 temporary monitoring sites in New York.

[Temporary monitoring site locations are shown in figure 2. GMT, Grenwich Mean Time; NAVD 88, North American Vertical Datum of 1988]

Hurricane Sandy							Tropical Storm Irene						Difference		
Site					Peak storm tide		Site				Peak storm tide		Site location, in miles	Peak storm-tide elevation	
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	Estimated date (GMT)	Elevation, in feet above NAVD 88	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	Estimated date (GMT)	Elevation, in feet above NAVD 88		Feet	Percent
							[2]Nassau County								
37	SSS–NY–NAS–001WL	40.87791	-73.53057	VE	10/30/2012	10.09	SSS–NY–NAS–001WL	40.87791	-73.53057	VE	8/28/2011	8.19	0.000	1.90	23
38	SSS–NY–NAS–004WL	40.58275	-73.64068	VE	10/30/2012	11.69	SSS–NY–NAS–004WL	40.58275	-73.64068	VE	8/28/2011	7.73	0.000	3.96	51
							[2,3]New York City								
116	SSS–NY–KIN–001WL	40.58000	-74.01161	VE	10/30/2012	11.57	SSS–NY–KIN–001WL	40.58000	-74.01161	VE	8/28/2011	6.83	0.000	4.74	69
119	SSS–NY–QUE–001WL	40.76229	-73.85828	AE	10/30/2012	10.35	SSS–NY–QUE–001WL	40.76229	-73.85828	AE	8/28/2011	8.03	0.000	2.32	29
120	SSS–NY–QUE–002WL	40.64533	-73.83638	VE	10/30/2012	10.84	SSS–NY–QUE–002WL	40.64533	-73.83638	VE	8/28/2011	6.79	0.000	4.05	60
123	SSS–NY–RIC–001WL	40.59388	-74.05985	VE	10/30/2012	12.43	SSS–NY–RIC–001WL	40.59388	-74.05985	VE	8/28/2011	7.33	0.000	5.10	70
125	SSS–NY–RIC–003WL	40.50188	-74.23034	VE	10/30/2012	13.81	SSS–NY–RIC–003WL	40.50188	-74.23034	VE	8/28/2011	7.35	0.000	6.46	88
							[4]New York City								
116	SSS–NY–KIN–001WL	40.58000	-74.01161	VE	10/30/2012	11.57	SSS–NY–KIN–001WL	40.58000	-74.01161	VE	8/28/2011	6.83	0.000	4.74	69
119	SSS–NY–QUE–001WL	40.76229	-73.85828	VE	10/30/2012	10.32	SSS–NY–QUE–001WL	40.76229	-73.85828	VE	8/28/2011	8.02	0.000	2.30	29
120	SSS–NY–QUE–002WL	40.64533	-73.83638	VE	10/30/2012	10.84	SSS–NY–QUE–002WL	40.64533	-73.83638	VE	8/28/2011	6.79	0.000	4.05	60
123	SSS–NY–RIC–001WL	40.59388	-74.05985	VE	10/30/2012	12.43	SSS–NY–RIC–001WL	40.59388	-74.05985	VE	8/28/2011	7.33	0.000	5.10	70
125	SSS–NY–RIC–003WL	40.50188	-74.23034	VE	10/30/2012	13.81	SSS–NY–RIC–003WL	40.50188	-74.23034	VE	8/28/2011	7.35	0.000	6.46	88
							[2]Suffolk County								
257	[5]403836073154775	40.64333	-73.26306	AE	10/30/2012	5.16	403836073154801	40.64328	-73.26334	AE	8/28/2011	3.43	0.015	1.73	50
258	SSS–NY–SUF–001WL	41.01259	-72.55828	AE	10/30/2012	7.86	SSS–NY–SUF–001WL	41.01259	-72.55828	AE	8/28/2011	6.94	0.000	0.92	13
259	SSS–NY–SUF–002WL	40.96438	-72.86320	AE	10/30/2012	8.19	SSS–NY–SUF–002WL	40.96438	-72.86320	AE	8/28/2011	8.05	0.000	0.14	2
260	SSS–NY–SUF–003WL	40.94617	-73.07227	VE	10/30/2012	8.79	SSS–NY–SUF–003WL	40.94617	-73.07227	VE	8/28/2011	7.50	0.000	1.29	17
261	SSS–NY–SUF–004WL	40.78712	-72.75025	VE	10/30/2012	6.41	SSS–NY–SUF–004WL	40.78712	-72.75025	VE	8/28/2011	4.82	0.000	1.59	33
262	SSS–NY–SUF–005WL	40.91608	-72.63774	VE	10/29/2012	7.73	SSS–NY–SUF–005WL	40.91608	-72.63774	VE	8/28/2011	4.08	0.000	3.65	89
263	SSS–NY–SUF–006WL	40.84887	-72.50285	VE	10/30/2012	6.88	SSS–NY–SUF–006WL	40.84887	-72.50285	VE	8/28/2011	5.59	0.000	1.29	23
264	SSS–NY–SUF–008WL	40.89331	-72.50300	AE	10/30/2012	6.53	SSS–NY–SUF–008WL	40.89331	-72.50300	AE	8/28/2011	3.94	0.000	2.59	66
265	SSS–NY–SUF–009WL	41.00197	-72.29030	VE	10/30/2012	6.28	SSS–NY–SUF–009WL	41.00197	-72.29030	VE	8/28/2011	3.69	0.000	2.59	70
266	SSS–NY–SUF–011WL	40.90048	-73.35304	VE	10/30/2012	9.46	SSS–NY–SUF–011WL	40.90048	-73.35304	VE	8/28/2011	8.07	0.000	1.39	17
267	SSS–NY–SUF–014WL	40.99070	-72.47074	VE	10/30/2012	6.88	SSS–NY–SUF–014WL	40.99070	-72.47074	VE	8/28/2011	4.61	0.000	2.27	49
268	SSS–NY–SUF–015WL	41.10104	-72.36144	VE	10/30/2012	6.37	SSS–NY–SUF–015WL	41.10104	-72.36144	VE	8/28/2011	4.29	0.000	2.08	48
269	SSS–NY–SUF–017WL	40.64316	-73.15750	VE	10/30/2012	10.60	SSS–NY–SUF–017WL	40.64316	-73.15750	VE	8/28/2011	7.21	0.000	3.39	47
272	SSS–NY–SUF–019WL	40.65932	-73.26486	VE	10/30/2012	5.29	SSS–NY–SUF–019WL	40.65932	-73.26486	VE	8/28/2011	3.08	0.000	2.21	72
273	SSS–NY–SUF–021WL	40.74918	-73.01338	VE	10/30/2012	6.07	SSS–NY–SUF–021WL	40.74918	-73.01338	VE	8/28/2011	3.96	0.000	2.11	53
274	SSS–NY–SUF–022WL	40.68523	-73.27990	VE	10/30/2012	6.38	SSS–NY–SUF–022WL	40.68523	-73.27990	VE	8/28/2011	3.86	0.000	2.52	65

[1]Records from temporary monitoring sites in VE zones are likely to have been affected by wave heights of 3 feet or greater, the effects of which were removed using a 3-minute running mean to obtain a peak elevation comparable to stillwater elevations; monitoring records from sites in other coastal flood hazard zones will have been affected by wave heights less than 3 feet and, thus, provide a peak elevation generally comparable to the corresponding stillwater elevations.

[2]Coastal flood hazard zones from Federal Emergency Management Agency (2013b).

[3]Results not discussed in text or shown in figures.

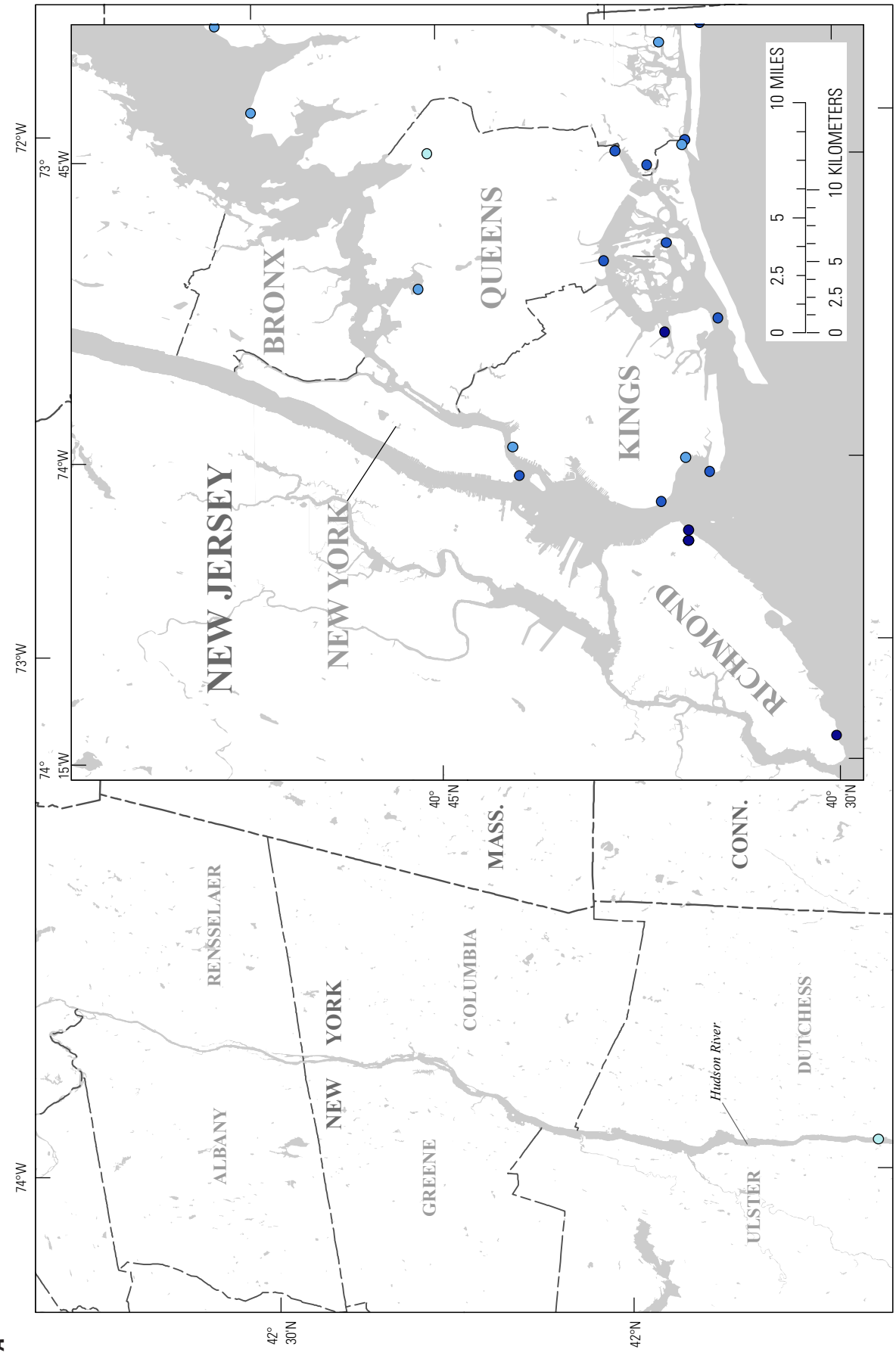
[4]Coastal flood hazard zones from Federal Emergency Management Agency (2013e).

[5]Temporary monitoring site 403836073154801 was not reoccupied during Hurricane Sandy; peak elevation for this storm uses value from temporary monitoring site 403836073154775 at nearby location.

Table 4. Peak storm-tide elevations produced by Tropical Storm Irene at 10 high-water-mark sites, and peak storm-tide elevations produced by Hurricane Sandy at nearby sites in New York.

[High-water-mark site locations are shown in figure 2. High-water marks that documented the storm tide of Tropical Storm Irene were collected by the Federal Emergency Management Agency. no., number; GMT, Grenwich Mean Time; NAVD 88, North American Vertical Datum of 1988]

Hurricane Sandy						Tropical Storm Irene					Difference		
Site				Peak storm tide		Site			Peak storm tide		Site location, in miles	Peak storm-tide elevation	
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	Estimated date (GMT)	Elevation, in feet above NAVD 88	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	Estimated date (GMT)	Elevation, in feet above NAVD 88		Feet	Percent
140	HWM–NY–KIN–604	40.70400	-73.98944	10/30/2012	11.0	005–CNY–03–012	40.70453	-73.98950	8/28–29/2011	8.0	0.037	3.0	38
148	HWM–NY–KIN–903	40.61089	-74.03629	10/30/2012	12.9	005–CNY–03–009	40.61060	-74.03650	8/28–29/2011	8.5	0.023	4.4	52
149	HWM–NY–KIN–904	40.59519	-74.00007	10/30/2012	11.5	005–CNY–03–007	40.59414	-74.00169	8/28–29/2011	9.6	0.112	1.9	20
152	HWM–NY–KIN–908	40.60743	-73.89626	10/30/2012	11.2	005–CNY–02–003	40.60536	-73.89844	8/28–29/2011	5.3	0.183	5.9	111
213	HWM–NY–QUE–714	40.60587	-73.82204	10/29/2012	10.3	005–CNY–02–006	40.60524	-73.82235	8/28–29/2011	6.0	0.046	4.3	72
220	HWM–NY–QUE–732	40.59512	-73.74139	10/30/2012	9.0	005–CNY–02–020	40.59514	-73.74402	8/28–29/2011	6.9	0.138	2.1	30
222	HWM–NY–QUE–910	40.63739	-73.74588	10/30/2012	10.6	005–CNY–02–019	40.63697	-73.74214	8/28–29/2011	6.7	0.199	3.9	58
232	HWM–NY–RIC–719	40.59386	-74.06829	10/30/2012	12.7	005–CNY–01–004	40.59407	-74.06039	8/28–29/2011	9.0	0.129	3.7	41
232	HWM–NY–RIC–719	40.59386	-74.06829	10/30/2012	12.7	005–CNY–01–005	40.59432	-74.06004	8/28–29/2011	8.9	0.150	3.8	43
232	HWM–NY–RIC–719	40.59386	-74.06829	10/30/2012	12.7	005–CNY–01–006	40.59416	-74.05983	8/28–29/2011	6.2	0.159	6.5	105


A
74°W
73°W
72°W
42° 30'N
42°N
40° 45'N
40° 30'N
74° 15'W
73° 45'W
NEW JERSEY
NEW YORK
BRONX
QUEENS
KINGS
RICHMOND
0 2.5 5 10 MILES
0 2.5 5 10 KILOMETERS
RENSSELAER
ALBANY
NEW YORK
GREENE
COLUMBIA
MASS.
CONN.
Hudson River
DUTCHESS
ULSTER

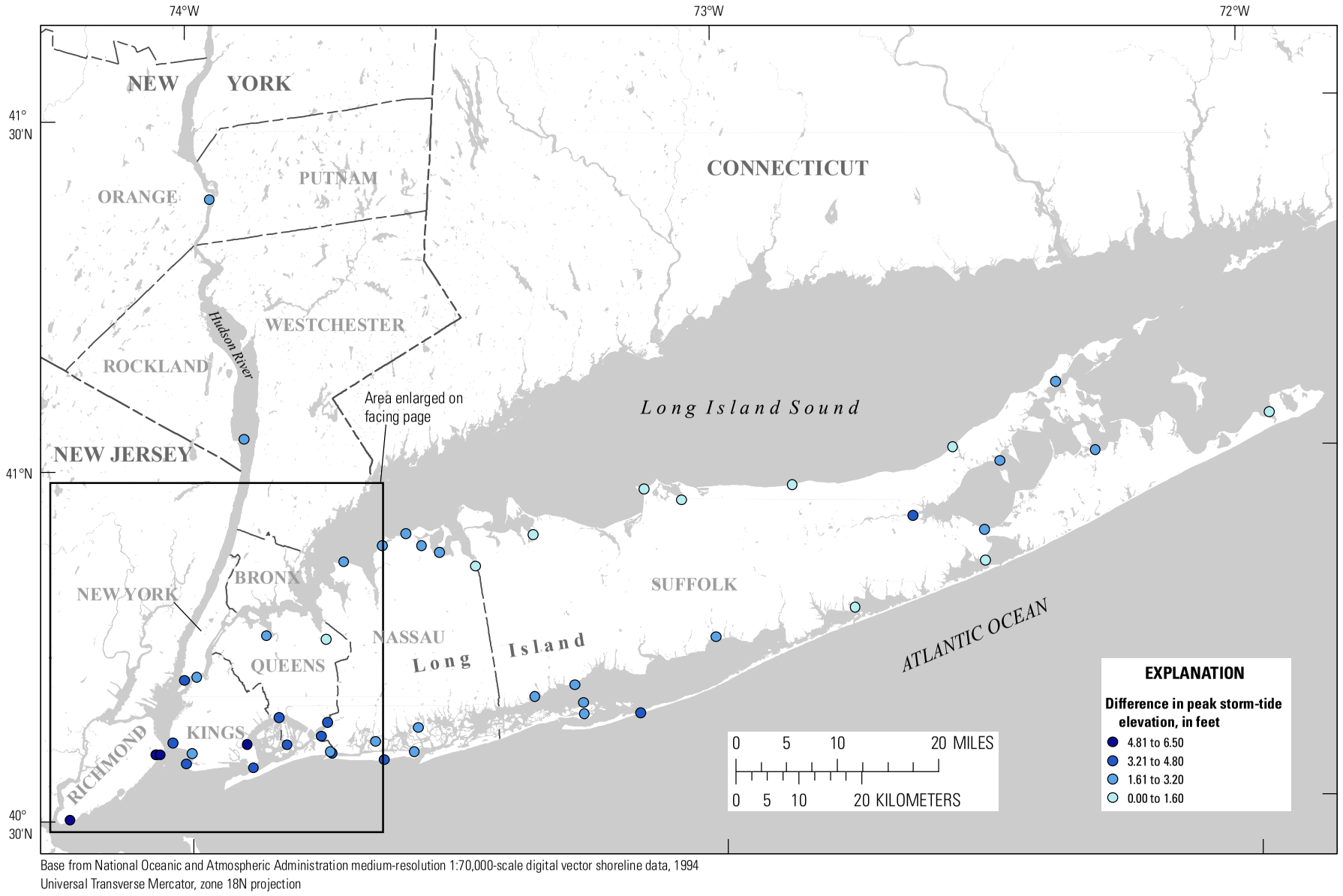
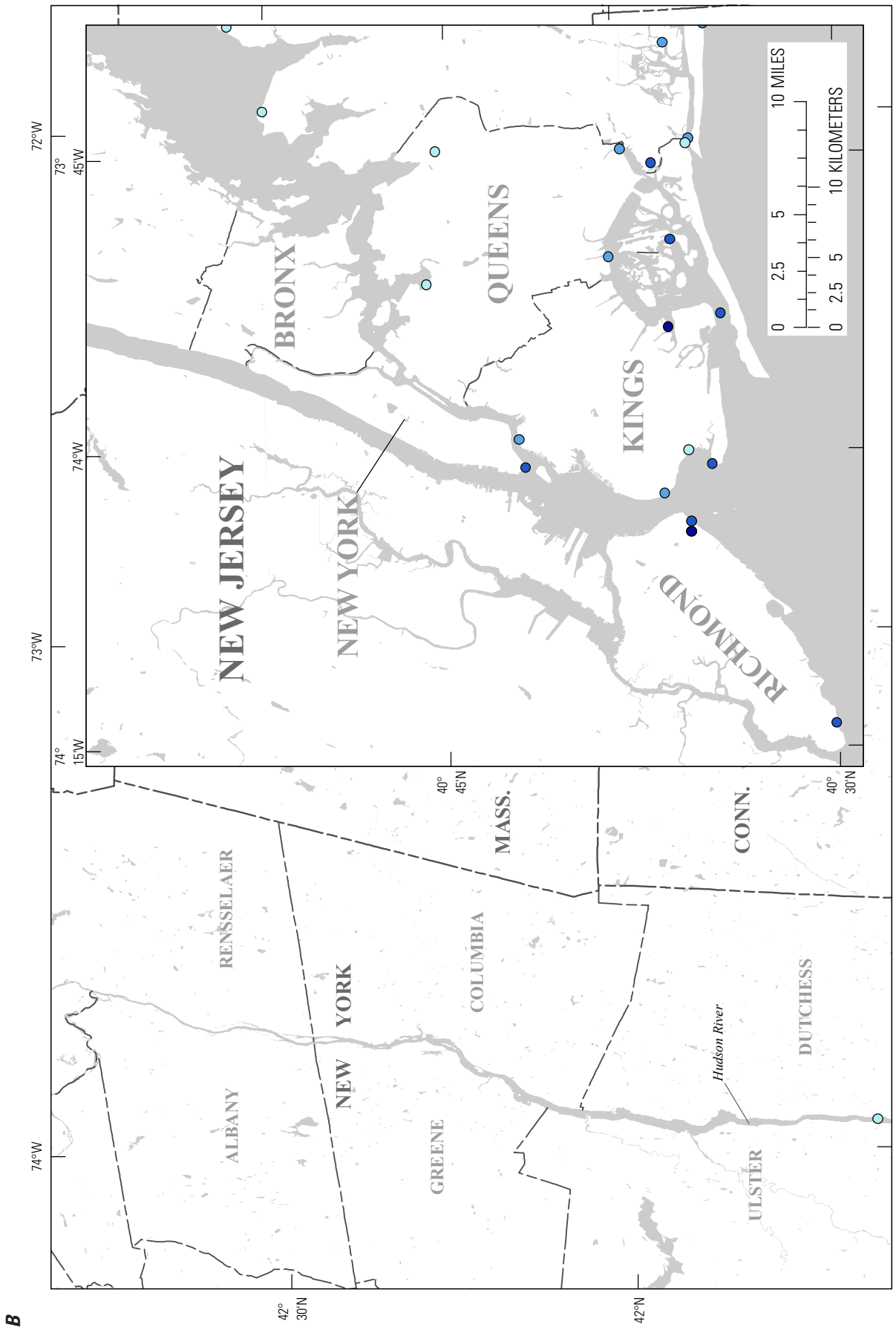
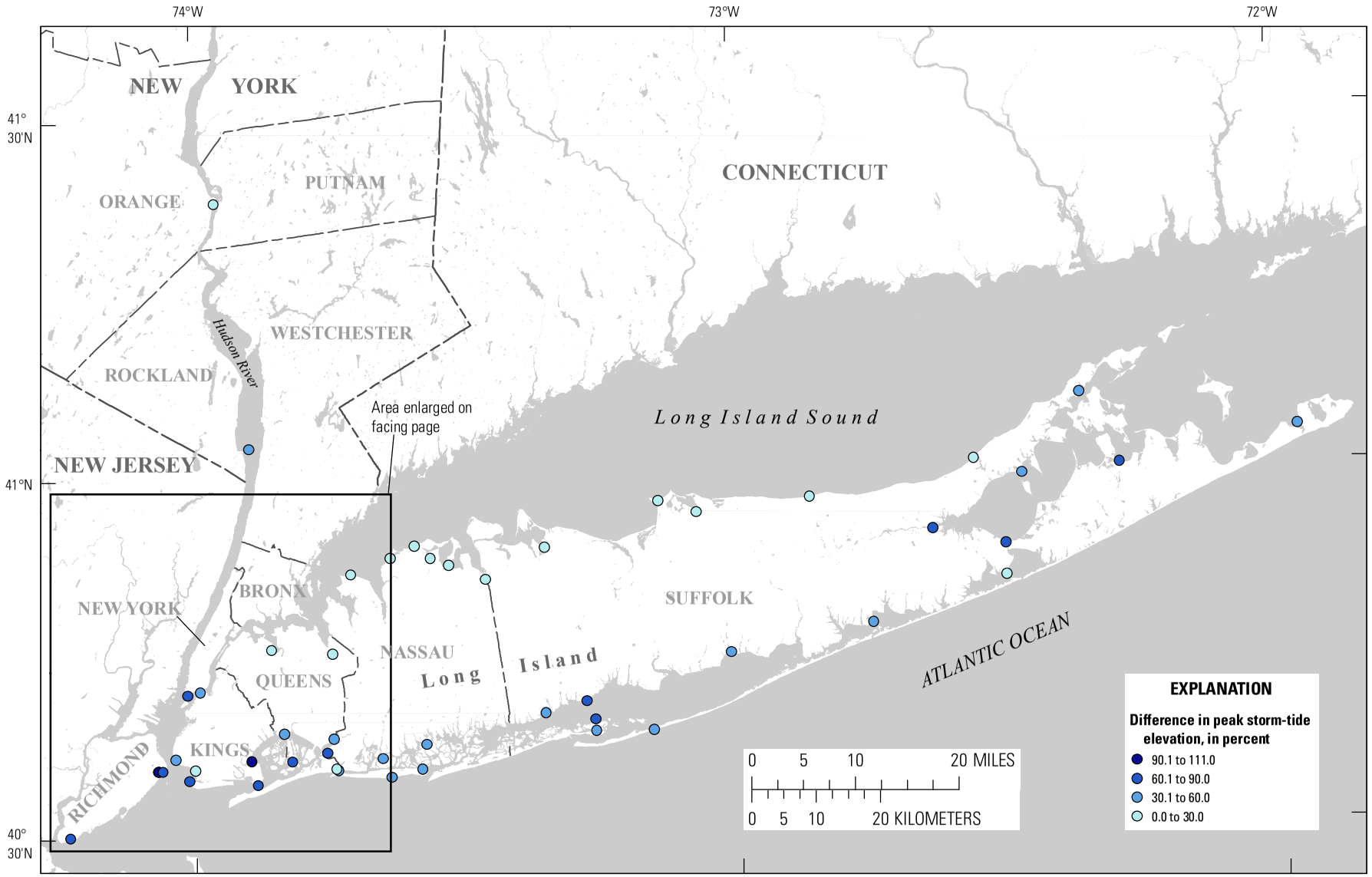


Figure 7. *A,* Differences in feet between peak storm-tide elevations produced by Hurricane Sandy and Tropical Storm Irene in New York. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.


B
74°W
73°W
72°W
42° 30'N
42°N
40° 45'N
40° 30'N
74° 15'W
73° 45'W
74°W
NEW JERSEY
NEW YORK
BRONX
QUEENS
KINGS
RICHMOND
0 2.5 5 10 MILES
0 2.5 5 10 KILOMETERS
RENSSELAER
ALBANY
NEW YORK
COLUMBIA
GREENE
MASS.
CONN.
Hudson River
DUTCHESS
ULSTER



Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 7. *B,* Differences in percent between peak storm-tide elevations produced by Hurricane Sandy and Tropical Storm Irene in New York. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.—Continued.

Table 5. Peak storm-tide elevations produced by Hurricane Sandy at 24 permanent monitoring sites, and the corresponding Federal Emergency Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year recurrence intervals) in New York.

[Permanent monitoring site locations are shown in figure 2. Peak storm-tide records for Hurricane Sandy at National Oceanic and Atmospheric Administration (NOAA) sites from Fanelli and others, 2013. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number; GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value]

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				1-percent (100-year) base flood elevation	Hurricane Sandy peak storm tide			
					Stillwater flood elevation								
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)		Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent
					[2,3]Albany County								
1	01359139	42.64611	-73.74750	A12	10.2	13.8	15.6	19.6	20.2	10/30/2012	10.57	10	10
					[4,5]Dutchess County								
6	01372058	41.65093	-73.94458	AE	5.9	7.1	8.0	9.7	8	10/30/2012	8.66	>100 & <500	<1 & >0.2
					[6,7]Greene County								
14	01362090	42.22417	-73.88089	AE	6.3	8.0	8.6	10.9	21	10/30/2012	9.80	>100 & <500	<1 & >0.2
					[5,8]Nassau County								
27	[15]01302250	40.86622	-73.71019	AE	7.3	9.9	12.8	13.5	13	10/30/2012	10.31	60	1.7
28	[15]01302600	40.88856	-73.63800	AE	6.7	8.9	11.4	13.0	13	10/30/2012	9.87	70	1.4
29	01302845	40.90511	-73.59319	VE	6.3	8.7	9.7	12.1	12	10/30/2012	10.06	>100 & <500	<1 & >0.2
30	01310521	40.62760	-73.57541	AE	6.4	7.5	7.9	8.6	10	10/30/2012	8.98	>500	<0.2
31	01310740	40.59344	-73.58374	AE	6.4	7.5	7.9	8.6	9	10/30/2012	8.97	>500	<0.2
32	01311143	40.60883	-73.65611	AE	6.7	8.0	8.4	9.1	9	10/30/2012	9.77	>500	<0.2
33	01311145	40.59316	-73.73735	AE	6.7	8.6	9.6	11.3	10	10/30/2012	9.70	>100 & <500	<1 & >0.2
34	[6]01311500	40.66361	-73.70444	AE	4.9	6.1	6.8	8.6	15	10/30/2012	9.33	>500	<0.2
35	01311850	40.61733	-73.75791	AE	4.9	6.1	6.8	8.6	11	10/30/2012	10.55	>500	<0.2
					[9,10,11]New York City								
110	01302050	40.75583	-73.74583	X	--	--	--	15.6	--	10/30/2012	9.69	<500	>0.2
111	01311875	40.57372	-73.88514	--	5.5	7.0	7.8	9.9	--	10/30/2012	10.65	>500	<0.2
112	01376534	40.57372	-74.14131	AE	5.4	6.9	7.5	9.3	--	10/30/2012	11.82	>500	<0.2
113	01376558	40.52542	-74.20939	AE	6.7	8.4	9.2	11.3	--	10/30/2012	12.76	>500	<0.2
114	8518750–NOAA	40.70000	-74.01333	VE	6.4	7.9	8.6	10.8	12.9	10/30/2012	11.28	>500	<0.2
					[12]New York City								
110	01302050	40.75583	-73.74583	AE	9.3	11.5	12.5	14.2	13	10/30/2012	9.69	20	5.0
111	01311875	40.57372	-73.88514	--	6.6	9.0	10.0	12.6	--	10/30/2012	10.65	>100 & <500	<1 & >0.2
112	01376534	40.57372	-74.14131	X	--	--	--	13.8	--	10/30/2012	11.82	<500	>0.2
113	01376558	40.52542	-74.20939	X	--	--	--	16.2	--	10/30/2012	12.76	<500	>0.2
114	8518750–NOAA	40.70000	-74.01333	VE	6.9	9.9	11.3	14.9	15	10/30/2012	11.28	100	1.0

Table 5. Peak storm-tide elevations produced by Hurricane Sandy at 24 permanent monitoring sites, and the corresponding Federal Emergency Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year recurrence intervals) in New York.—Continued.

[Permanent monitoring site locations are shown in figure 2. Peak storm-tide records for Hurricane Sandy at National Oceanic and Atmospheric Administration (NOAA) sites from Fanelli and others, 2013. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number; GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value]

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				1-percent (100-year) base flood elevation	Hurricane Sandy peak storm tide			
					Stillwater flood elevation								
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)		Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent
[5,13]Suffolk County													
251	01304057	40.96286	-73.14317	AE	6.9	8.3	8.7	10.3	11	10/30/2012	9.35	>100 & <500	<1 & >0.2
252	01304200	41.13664	-72.30675	VE	4.2	5.4	5.8	6.7	9	10/30/2012	6.43	>100 & <500	<1 & >0.2
253	01304500	40.91361	-72.68667	X	--	--	--	9.6	--	10/30/2012	6.76	<500	>0.2
254	01304562	40.91778	-72.63867	VE	4.8	6.1	6.5	9.6	9	10/29/2012	7.65	>100 & <500	<1 & >0.2
255	01309225	40.66927	-73.35568	VE	4.4	5.0	5.3	5.8	8	10/30/2012	6.54	>500	<0.2
256	[14]8510560–NOAA	41.04833	-71.96000	VE	3.5	4.9	8.7	7.2	13	10/30/2012	5.55	60	1.7
[6,15]Ulster County													
392	01372007	41.91814	-73.98172	AE	6.0	7.5	8.9	10.4	8	10/30/2012	13.50	>500	<0.2

[1]Records from permanent monitoring sites in VE zones are likely to have been affected by wave heights of 3 feet (ft) or greater, the effects of which were removed using a 3-minute mean to obtain a peak elevation comparable to stillwater elevations; monitoring records from sites in other coastal flood hazard zones will have been affected by wave heights less than 3 ft and, thus, provide a peak elevation generally comparable to the corresponding stillwater elevations.

[2]Stillwater flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (1979, 1989).

[3]Coastal flood hazard zones from Federal Emergency Management Agency (2013c); base flood elevations converted from units of feet above National Geodetic Vertical Datum of 1929 (NGVD 29) as reported in Federal Emergency Management Agency (2013c).

[4]Stillwater flood elevations from Federal Emergency Management Agency (2012).

[5]Coastal flood hazard zones and base flood elevations from Federal Emergency Management Agency (2013b).

[6]Coastal flood hazard zones and base flood elevations from Federal Emergency Management Agency (2013c).

[7]Stillwater flood elevations from Federal Emergency Management Agency (2008).

[8]Stillwater flood elevations from Federal Emergency Management Agency (2009a).

[9]Stillwater flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (2007a).

[10]Coastal flood hazard zones from Federal Emergency Management Agency (2013b); base flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (2013b).

[11]Results not discussed in text or shown in figures.

[12]Coastal flood hazard zones and flood elevations from Federal Emergency Management Agency (2013e).

[13]Stillwater flood elevations from Federal Emergency Management Agency (2009c).

[14]Stillwater flood elevation for 1-percent annual exceedance probability (100-year recurrence interval) includes wave setup.

[15]Stillwater flood elevations from Federal Emergency Management Agency (2011).

Table 6. Peak storm-tide elevations produced by Hurricane Sandy at 43 temporary monitoring sites, and the corresponding Federal Emergency Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year recurrence intervals) in New York.

[Temporary monitoring site locations are shown in figure 2. no., number; FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; GMT, Grenwich Mean Time; >, greater than; <, less than; &, and; --, no value]

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), feet above NAVD 88				1-percent (100-year) base flood elevation	Hurricane Sandy peak storm tide			
					Stillwater flood elevation								
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)		Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent
				[2,3]Nassau County									
37	[10]SSS–NY–NAS–001WL	40.87791	-73.53057	VE	6.3	8.7	9.9	12.0	13	10/30/2012	10.09	>100 & <500	<1 & >0.2
38	[10]SSS–NY–NAS–004WL	40.58275	-73.64068	VE	6.7	8.9	13.8	12.4	19	10/30/2012	11.69	80	1.3
39	[10]SSS-NY-NAS-004WV	40.58275	-73.64068	VE	6.7	8.9	13.8	12.4	19	10/29/2012	9.91	60	1.7
40	SSS–NY–NAS–005WL	40.65238	-73.45850	AE	5.2	6.2	6.5	7.2	7	10/30/2012	7.98	>500	<0.2
41	SSS–NY–NAS–006WL	40.88750	-73.56361	AE	6.3	8.7	9.4	12.0	11	10/30/2012	10.22	>100 & <500	<1 & >0.2
42	[10]SSS–NY–NAS–007WL	40.85722	-73.46333	AE	6.3	8.7	10.4	12.0	10	10/30/2012	9.98	90	1.1
43	[10]SSS–NY–NAS–008WL	40.86622	-73.71019	AE	7.3	9.9	12.8	13.5	13	10/30/2012	10.29	60	1.7
				[4,5,6]New York City									
116	SSS–NY–KIN–001WL	40.58000	-74.01161	VE	6.3	7.9	8.6	10.8	11.9	10/30/2012	11.57	>500	<0.2
117	SSS–NY–KIN–003WL	40.67688	-73.98984	AE	6.3	7.8	8.6	10.7	8.9	10/30/2012	11.08	>500	<0.2
118	SSS–NY–NEW–001WL	40.87757	-73.92633	AE	6.1	7.6	8.4	10.7	8.0	10/30/2012	9.50	>100 & <500	<1 & >0.2
119	SSS–NY–QUE–001WL	40.76229	-73.85828	AE	8.1	10.2	11.4	14.5	12.9	10/30/2012	10.35	60	1.7
120	SSS–NY–QUE–002WL	40.64533	-73.83638	VE	4.9	6.1	6.8	8.6	8.9	10/30/2012	10.84	>500	<0.2
121	SSS–NY–QUE–004WL	40.79651	-73.82879	VE	8.6	10.9	12.1	15.1	14.9	10/30/2012	10.50	40	2.5
122	SSS–NY–QUE–005WL	40.60615	-73.82265	AE	4.9	6.1	6.8	8.6	7.9	10/30/2012	10.38	>500	<0.2
123	SSS–NY–RIC–001WL	40.59388	-74.05985	VE	6.3	7.9	8.6	10.8	12.9	10/30/2012	12.43	>500	<0.2
124	SSS–NY–RIC–001WV	40.59388	-74.05985	VE	6.3	7.9	8.6	10.8	12.9	10/30/2012	11.11	>500	<0.2
125	SSS–NY–RIC–003WL	40.50188	-74.23034	VE	6.7	8.4	9.2	11.3	13.0	10/30/2012	13.81	>500	<0.2
126	SSS–NY–RIC–004WL	40.54345	-74.12768	VE	6.4	8.0	8.8	10.9	12.9	10/30/2012	13.17	>500	<0.2
				[7]New York City									
116	SSS–NY–KIN–001WL	40.58000	-74.01161	VE	7.1	9.9	11.2	14.5	17	10/30/2012	11.57	>100 & <500	<1 & >0.2
117	SSS–NY–KIN–003WL	40.67688	-73.98984	AE	6.6	8.8	10.3	14.0	10	10/30/2012	11.08	>100 & <500	<1 & >0.2
118	SSS–NY–NEW–001WL	40.87757	-73.92633	VE	5.6	8.2	9.3	12.7	13	10/30/2012	9.41	>100 & <500	<1 & >0.2
119	SSS–NY–QUE–001WL	40.76229	-73.85828	VE	9.7	12.1	13.1	15.1	15	10/30/2012	10.32	20	5.0
120	SSS–NY–QUE–002WL	40.64533	-73.83638	VE	6.4	8.8	9.9	12.5	14	10/30/2012	10.84	>100 & <500	<1 & >0.2
121	SSS–NY–QUE–004WL	40.79651	-73.82879	VE	9.7	11.9	12.8	14.7	16	10/30/2012	10.50	30	3.3
122	SSS–NY–QUE–005WL	40.60615	-73.82265	VE	6.3	8.7	9.7	12.0	13	10/30/2012	10.37	>100 & <500	<1 & >0.2
123	SSS–NY–RIC–001WL	40.59388	-74.05985	VE	7.1	10.1	11.4	14.8	17	10/30/2012	12.43	>100 & <500	<1 & >0.2
124	SSS–NY–RIC–001WV	40.59388	-74.05985	VE	7.1	10.1	11.4	14.8	17	10/30/2012	11.11	90	1.1
125	SSS–NY–RIC–003WL	40.50188	-74.23034	VE	8.1	11.3	12.7	16.3	16	10/30/2012	13.81	>100 & <500	<1 & >0.2
126	SSS–NY–RIC–004WL	40.54345	-74.12768	AE	7.4	10.5	12.0	15.7	14	10/30/2012	13.22	>100 & <500	<1 & >0.2
				[3,8]Suffolk County									
257	403836073154775	40.64333	-73.26306	AE	3.7	4.3	4.5	4.8	5	10/30/2012	5.16	>500	<0.2
258	[10]SSS–NY–SUF–001WL	41.01259	-72.55828	AE	6.2	7.5	10.8	9.4	12	10/30/2012	7.86	60	1.7
259	[10]SSS–NY–SUF–002WL	40.96438	-72.86320	AE	5.9	7.4	10.5	10.8	12	10/30/2012	8.19	60	1.7
259	[10]SSS–NY–SUF–002WL	40.96438	-72.86320	AE	5.9	7.4	10.5	10.8	12	10/30/2012	8.19	60	1.7

Table 6. Peak storm-tide elevations produced by Hurricane Sandy at 43 temporary monitoring sites, and the corresponding Federal Emergency Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year recurrence intervals) in New York.—Continued

[Temporary monitoring site locations are shown in figure 2. no., number; FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; GMT, Grenwich Mean Time; >, greater than; <, less than; &, and; --, no value]

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), feet above NAVD 88				1-percent (100-year) base flood elevation	Hurricane Sandy peak storm tide			
					Stillwater flood elevation								
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)		Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent
					[3,8]Suffolk County—Continued								
260	SSS–NY–SUF–003WL	40.94617	-73.07227	VE	6.8	7.7	8.2	9.0	13	10/30/2012	8.79	>100 & <500	<1 & >0.2
261	SSS–NY–SUF–004WL	40.78712	-72.75025	VE	5.0	6.2	6.8	7.8	10	10/30/2012	6.41	70	1.4
262	SSS–NY–SUF–005WL	40.91608	-72.63774	VE	4.8	6.1	6.5	9.6	9	10/29/2012	7.73	>100 & <500	<1 & >0.2
263	SSS–NY–SUF–006WL	40.84887	-72.50285	VE	5.5	7.1	8.0	9.3	12	10/30/2012	6.88	40	2.5
264	SSS–NY–SUF–008WL	40.89331	-72.50300	AE	4.0	5.2	5.5	9.6	7	10/30/2012	6.53	>100 & <500	<1 & >0.2
265	SSS–NY–SUF–009WL	41.00197	-72.29030	VE	5.2	6.2	6.5	9.8	9	10/30/2012	6.28	60	1.7
266	SSS–NY–SUF–011WL	40.90048	-73.35304	VE	7.1	8.2	8.9	10.5	12	10/30/2012	9.46	>100 & <500	<1 & >0.2
267	SSS–NY–SUF–014WL	40.99070	-72.47074	VE	4.0	5.2	5.5	9.6	8	10/30/2012	6.88	>100 & <500	<1 & >0.2
268	SSS–NY–SUF–015WL	41.10104	-72.36144	VE	4.2	5.4	5.8	6.7	9	10/30/2012	6.37	>100 & <500	<1 & >0.2
269	[10]SSS–NY–SUF–017WL	40.64316	-73.15750	VE	6.5	8.5	14.1	11.5	22	10/30/2012	10.60	70	1.4
270	[10]SSS–NY–SUF–017WV	40.64316	-73.15750	VE	6.5	8.5	14.1	11.5	22	10/29/2012	10.34	70	1.4
271	[10]SSS–NY–SUF–018WL	40.63473	-73.20216	AE	4.3	4.8	8.0	5.2	10	10/30/2012	4.09	<10	>10
272	SSS–NY–SUF–019WL	40.65932	-73.26486	VE	3.7	4.3	4.5	4.8	7	10/30/2012	5.29	>500	<0.2
273	SSS–NY–SUF–021WL	40.74918	-73.01338	VE	4.2	4.7	4.9	5.4	7	10/30/2012	6.07	>500	<0.2
274	SSS–NY–SUF–022WL	40.68523	-73.27990	VE	3.7	4.3	4.5	4.8	7	10/30/2012	6.38	>500	<0.2
275	10SSS–NY–SUF–023WV	40.94428	-72.18910	VE	5.7	8.5	14.8	13.4	23	10/29/2012	7.94	40	2.5
276	SSS–NY–SUF–024WL	41.07319	-71.93438	VE	3.5	4.9	5.3	7.2	8	10/29/2012	5.70	>100 & <500	<1 & >0.2
277	SSS–NY–SUF–026WL	40.74687	-72.85550	AE	4.8	6.0	6.4	7.0	8	10/30/2012	5.68	40	2.5
278	SSS–NY–SUF–027WL	40.74760	-73.15039	AE	4.2	4.6	4.8	5.2	5	10/30/2012	5.30	>500	<0.2
					[3,9]Westchester County								
400	405658073433147	40.94889	-73.73278	AE	8.8	10.7	11.6	13.9	12	10/30/2012	10.16	40	2.5
401	SSS-NY-WES-001WL	40.94276	-73.71983	VE	8.7	11.3	12.5	16.8	15	10/30/2012	10.44	40	2.5
402	SSS-NY-WES-003WL	40.89039	-73.78172	AE	8.5	11.1	12.8	16.1	12	10/30/2012	10.44	40	2.5

[1]Records from temporary monitoring sites in VE zones are likely to have been affected by wave heights of 3 feet (ft) or greater, the effects of which were removed using a 3-minute running mean to obtain a peak elevation comparable to stillwater elevations; monitoring records from sites in other coastal flood hazard zones will have been affected by wave heights less than 3 ft and, thus, provide a peak elevation generally comparable to the corresponding stillwater elevations.

[2]FEMA stillwater flood elevations from Federal Emergency Management Agency (2009a).

[3]Coastal flood hazard zones and base flood elevations from Federal Emergency Management Agency (2013b).

[4]Stillwater flood elevations converted from units of feet above the National Geodetic Vertical Datum of 1929 (NGVD 29) as reported in Federal Emergency Management Agency (2007a).

[5]Coastal flood hazard zones from Federal Emergency Management Agency (2013b); base flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (2013b).

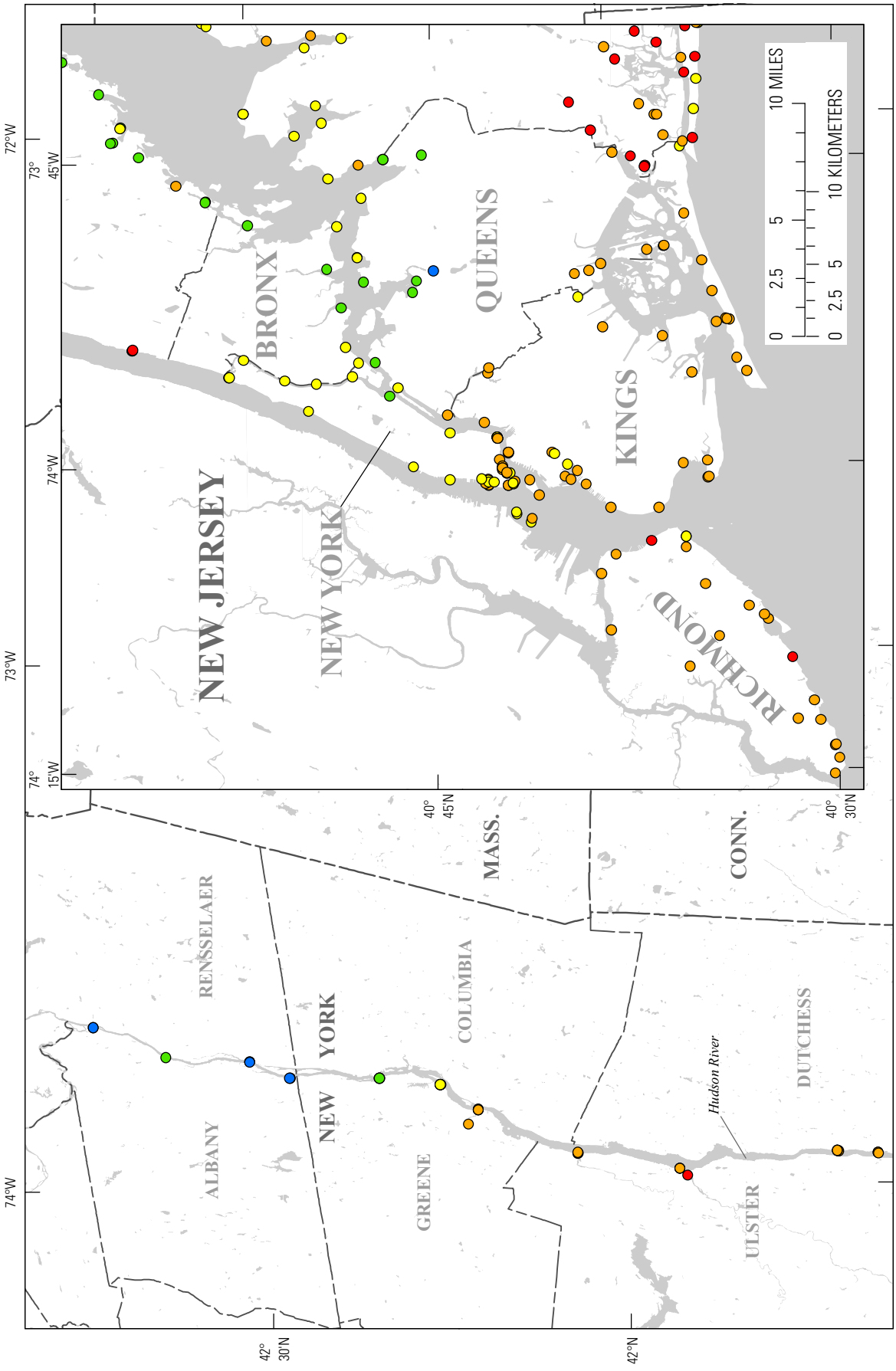
[6]Results not discussed in text or shown in figures.

[7]Coastal flood hazard zones and flood elevations from Federal Emergency Management Agency (2013e).

[8]Stillwater flood elevations from Federal Emergency Management Agency (2009c).

[9]Stillwater flood elevations from Federal Emergency Management Agency (2007b).

[10]Stillwater flood elevation for 1-percent annual exceedance probability (100-year recurrence interval) includes wave setup.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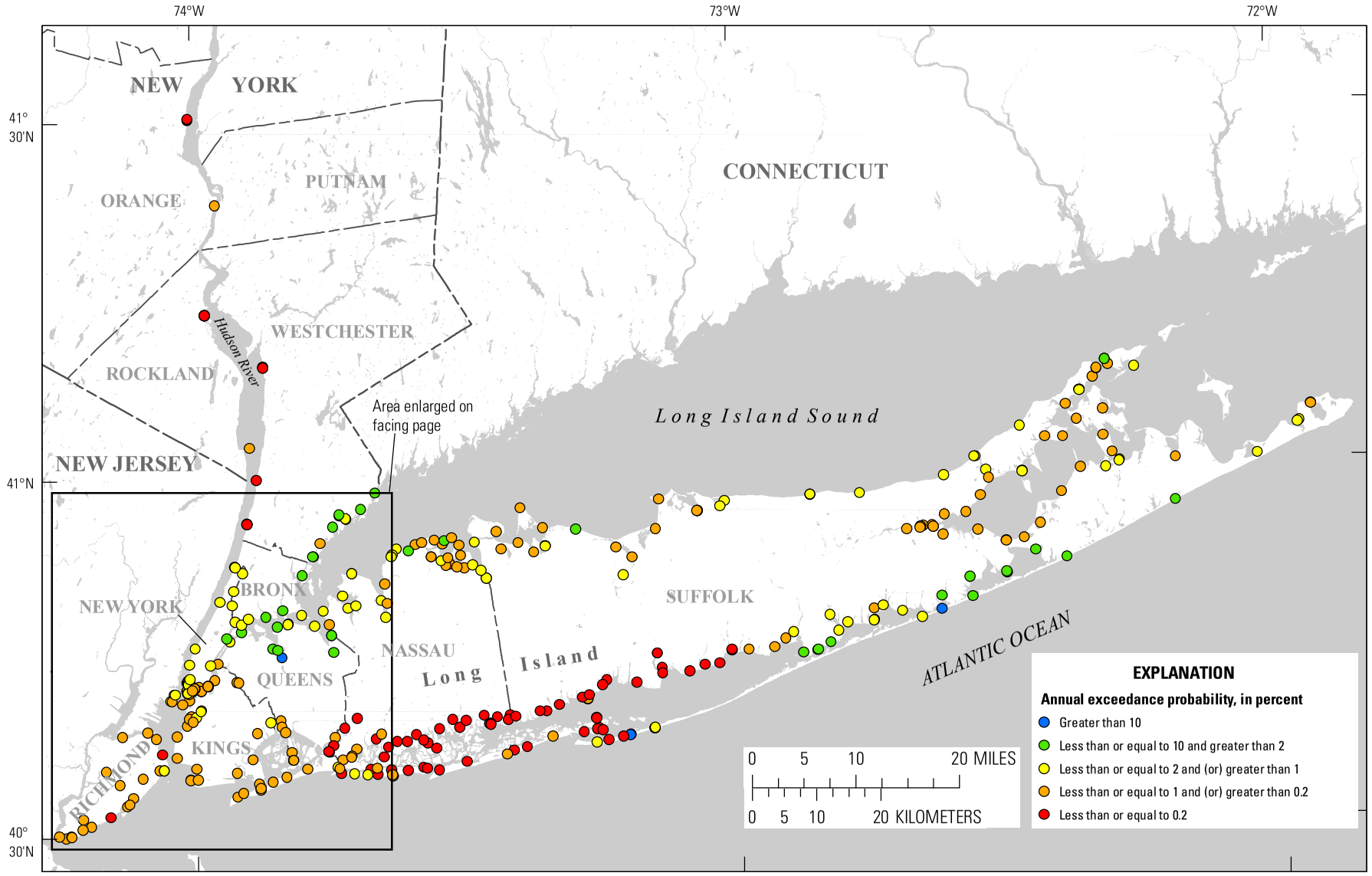


Figure 8. Selected annual exceedance probabilities for peak storm-tide elevations produced by Hurricane Sandy in New York counties. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.

Storm Surge

Data from selected permanent monitoring sites in the USGS network and from sites in the NOAA network document Hurricane Sandy's storm surge, calculated as the difference between the observed water level and normal (predicted astronomical) tide level. Calculations of this residual water level were performed to assess the storm-surge magnitude associated with the peak storm tide, and the magnitude and timing of the peak storm surge, for these sites in the two networks.

Storm-Surge Magnitude Associated With Peak Storm Tide

The storm-surge magnitudes associated with the peak storm tides produced by Hurricane Sandy at 18 permanent monitoring sites in New York are provided in table 8 and figure 9*A*. Most magnitudes of the storm surge associated with the peak storm tide were greater than about 7.8 ft; most of these are from sites in Albany County, along the Atlantic Ocean shore of Nassau County, and in New York City. The maximum storm-surge magnitude associated with the peak storm tide was 9.43 ft at permanent monitoring site 8519483 (map number 115) in New York City. The minimum storm-surge magnitude associated with the peak storm tide was 5.24 ft at permanent monitoring site 8510560 (map number 256) in Suffolk County near the extreme eastern tip of Long Island.

Magnitude and Timing of Peak Storm Surge

The magnitude and timing of the peak storm surge produced by Hurricane Sandy at 18 permanent monitoring sites in New York are listed in table 8; the magnitudes of the peak storm-surge from this storm at these sites are shown in figure 9*B*. Most magnitudes of the peak storm surge were greater than about 8.3 ft; nearly of these are from sites along the Long Island Sound shores of Nassau and Suffolk Counties and in New York City. The maximum magnitude of the peak storm surge was 12.65 ft at permanent monitoring site 8516945 (map number 36) along the Long Island Sound shore of Nassau County. The minimum magnitude of the peak storm surge was 5.89 ft at permanent monitoring site 8510560 (map number 256) in Suffolk County near the extreme eastern tip of Long Island.

Of the 18 permanent monitoring sites in table 8, the peak storm surge arrived within 36 minutes of the time of peak storm tide at 8 sites (44 percent), all of which are along the Atlantic Ocean shore of Nassau County and in New York City; this condition resulted from the peak storm surge arriving in phase with the astronomical tide—generally coinciding with normal high tide—at these locations (Schubert and Busciolano, 2013). In contrast, the peak storm surge preceded the time of peak storm tide by 90 minutes or more at 9 of 18 sites (50 percent); these sites are all in Albany County, along the Long Island Sound shore of Nassau County, and in Suffolk County. The peak storm surge followed the time of peak storm tide by 114 minutes at the one remaining site, which is in Suffolk County at the head of an estuary on eastern Long Island. In the two latter cases, the condition resulted from peak storm surges arriving out of phase with the astronomical tide—nearly coinciding with normal low tide locally—at these sites (Schubert and Busciolano, 2013), all of which are inland of the New York Bight.

Extent of Storm-Tide Inundation

Comparisons were made between selected maps of the extents of storm-tide inundation from Hurricane Sandy that were derived from differing amounts of available USGS data from the permanent and temporary monitoring sites and HWM sites. The comparisons were made using the results of FEMA HAZUS (Federal Emergency Management Agency, 2013d) flood loss analyses depicted for three different extents of storm-tide inundation from Hurricane Sandy. These depictions include a (1) pre-storm mapping of inundation extent; (2) November 11, 2012, mapping of inundation extent; and (3) February 14, 2013, mapping of inundation extent (Austen K. Cutrell, Federal Emergency Management Agency, written commun., 2013).

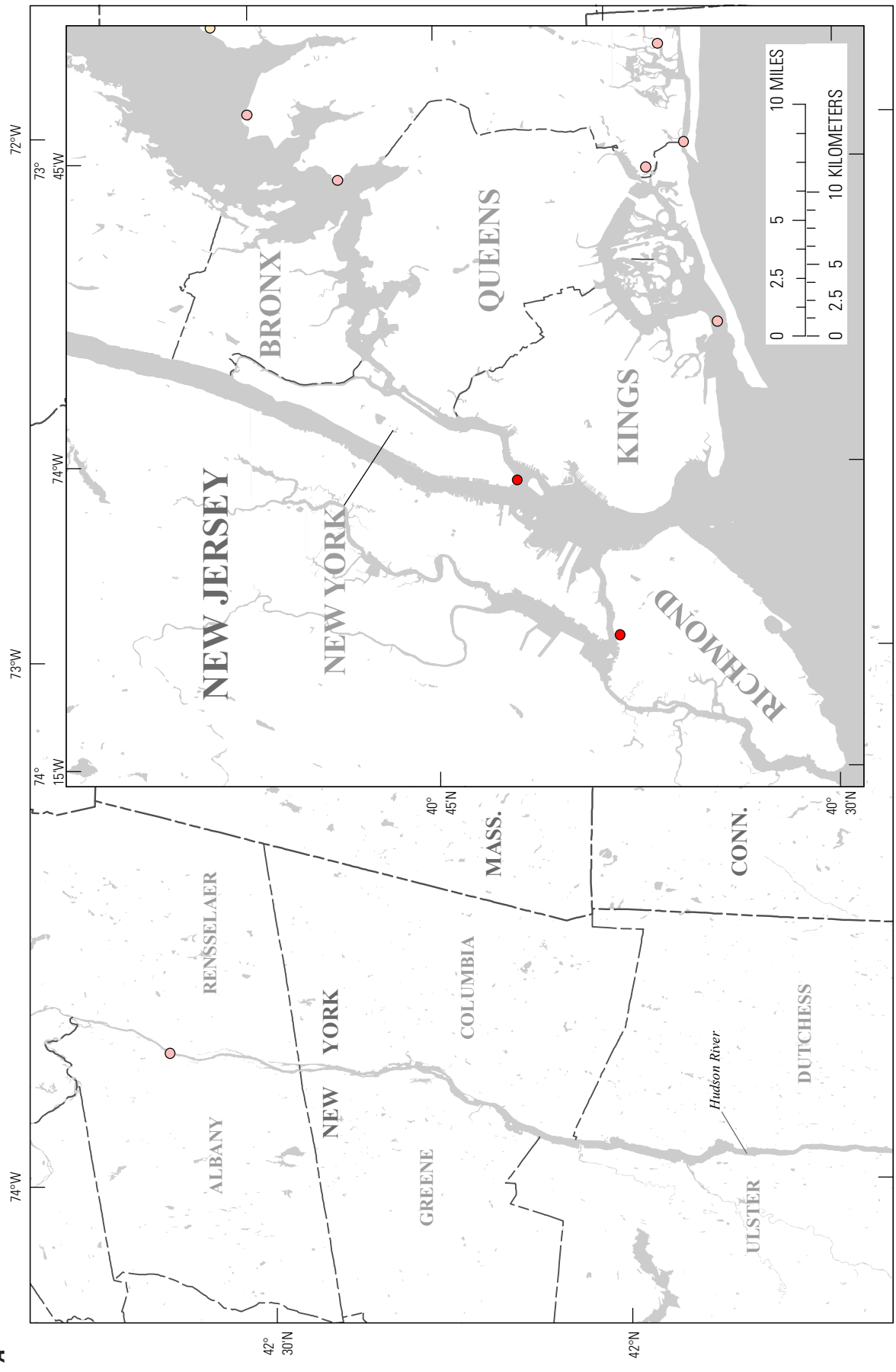
Mapping of Inundation Extent

The final, pre-storm mapping of inundation extent from Hurricane Sandy, as indicated in a 30-meter (m) resolution NHC Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model (National Hurricane Center, 2013c) hindcast product dated October 31, 2012, is shown in figure 10*A*. Figure 10*B* shows the November 11, 2012, mapping of inundation extent from Hurricane Sandy, as indicated in a FEMA interim high-resolution (3-m) product that was based on USGS data available from storm landfall through November 11, 2012. The February 14, 2013, mapping of inundation extent from Hurricane Sandy, as indicated in a FEMA final high-resolution (3-m) product based on USGS data available from storm landfall through February 14, 2013, is shown in figure 10*C*. A visual comparison of the three maps (fig. 10) shows that small differences in inundation extent are locally apparent; however, more meaningful comparisons may be made using the results of HAZUS flood loss analyses for the mapped inundation extents.

Table 8. Storm-surge magnitude associated with the peak storm tide, and magnitude and timing of the peak storm surge, produced by Hurricane Sandy at 18 permanent monitoring sites in New York.

[Negative time difference denotes a peak storm surge that preceded the peak storm tide. Permanent monitoring site locations are shown in figure 2. Peak storm-tide and surge records for Hurricane Sandy at National Oceanic and Atmospheric Administration (NOAA) sites from Fanelli and others (2013). Storm-tide elevation associated with the peak storm surge at NOAA sites from National Ocean Service (2013). No., number; GMT, Grenwich Mean Time; NAVD 88, North American Vertical Datum of 1988; --, no value]

Site				Peak storm tide				Peak storm surge				
Map no.	Identifier	Latitude, in decmal degrees	Longitude, in decmal degrees	Date (GMT)	Time (GMT)	Elevation, in feet above NAVD 88	Storm-surge magnitude, in feet	Date (GMT)	Time (GMT)	Magnitude, in feet	Storm-tide elevation, in feet above NAVD 88	Time difference, in minutes
						Albany County						
1	01359139	42.64611	-73.74750	10/30/2012	09:45	10.57	8.03	10/30/2012	08:15	8.15	9.79	-90
						Nassau County						
27	01302250	40.86622	-73.71019	10/30/2012	02:00	10.31	8.24	10/29/2012	23:06	11.84	7.86	-174
28	01302600	40.88856	-73.63800	10/30/2012	02:30	9.87	7.26	10/29/2012	22:48	11.52	7.21	-222
29	01302845	40.90511	-73.59319	10/30/2012	02:18	10.06	7.59	10/29/2012	23:06	10.76	6.80	-192
30	01310521	40.62760	-73.57541	10/30/2012	01:12	8.98	7.85	10/30/2012	01:36	7.92	8.98	24
31	01310740	40.59344	-73.58374	10/30/2012	01:06	8.97	7.66	10/30/2012	01:36	7.78	8.75	30
32	01311143	40.60883	-73.65611	10/30/2012	01:12	9.77	8.14	10/30/2012	01:48	8.32	9.61	36
33	01311145	40.59316	-73.73735	10/30/2012	00:42	9.70	8.08	10/30/2012	01:12	8.21	9.60	30
35	01311850	40.61733	-73.75791	10/30/2012	01:36	10.55	8.38	10/30/2012	02:00	8.47	10.37	24
36	8516945–NOAA	40.81030	-73.76490	10/30/2012	02:06	--	8.54	10/29/2012	23:00	12.65	--	-186
						New York City						
110	01311875	40.57372	-73.88514	10/30/2012	01:06	10.65	8.72	10/30/2012	01:42	9.13	10.58	36
114	8518750–NOAA	40.70000	-74.01333	10/30/2012	01:24	11.28	9.40	10/30/2012	01:24	9.40	11.28	0
115	8519483–NOAA	40.63670	-74.14170	10/30/2012	01:24	--	9.43	10/30/2012	01:48	9.56	--	24
						Suffolk County						
251	01304057	40.96286	-73.14317	10/30/2012	02:06	9.35	7.99	10/30/2012	00:24	9.56	8.09	-102
252	01304200	41.13664	-72.30675	10/30/2012	01:24	6.43	6.00	10/29/2012	22:00	7.18	5.70	-204
254	01304562	40.91778	-72.63867	10/29/2012	20:18	7.65	8.31	10/29/2012	22:12	9.16	7.29	114
255	01309225	40.66927	-73.35568	10/30/2012	02:00	6.54	6.27	10/29/2012	23:54	6.38	6.02	-126
256	8510560–NOAA	41.04833	-71.96000	10/30/2012	00:12	5.55	5.24	10/29/2012	22:12	5.89	5.22	-120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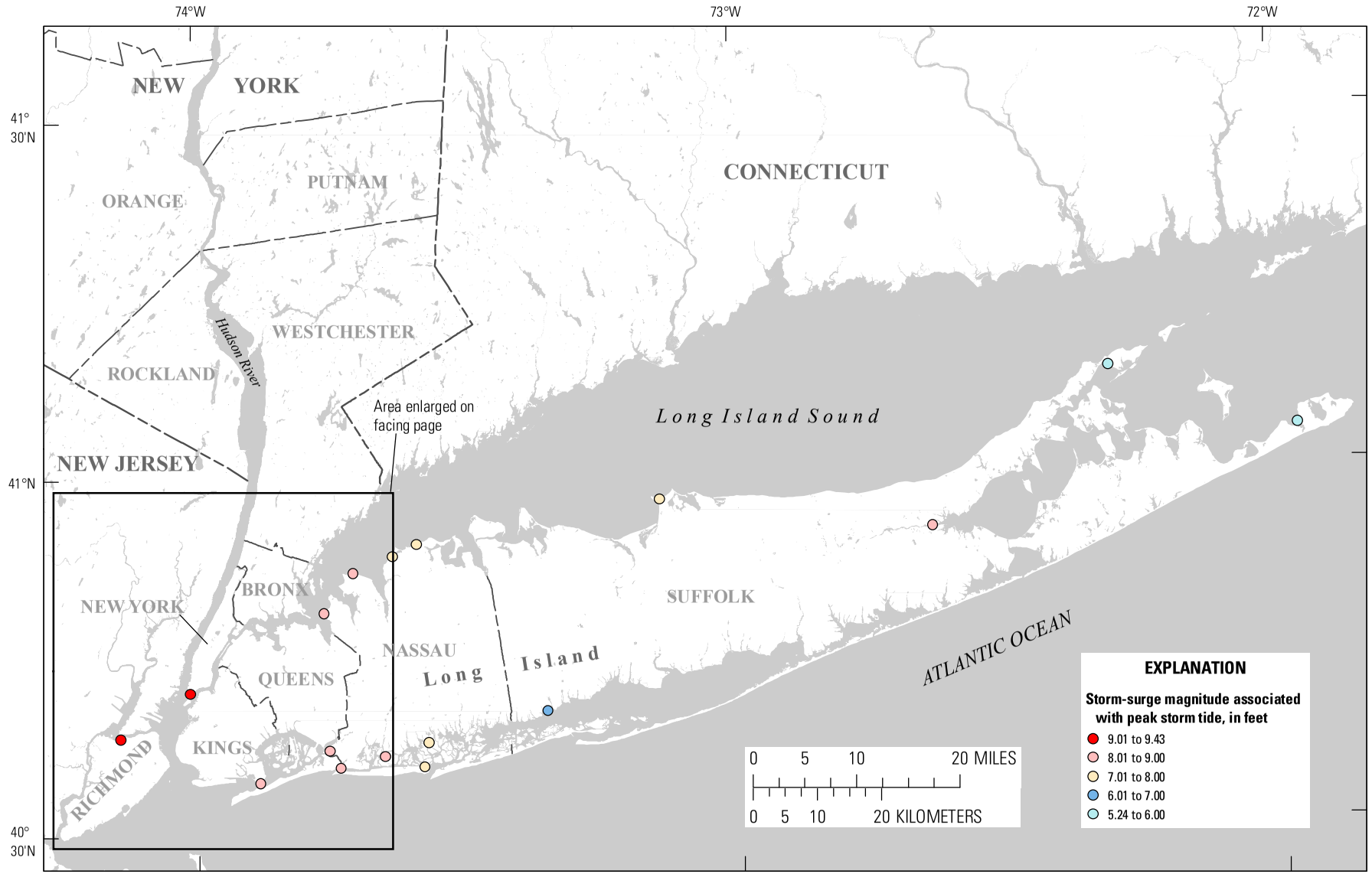
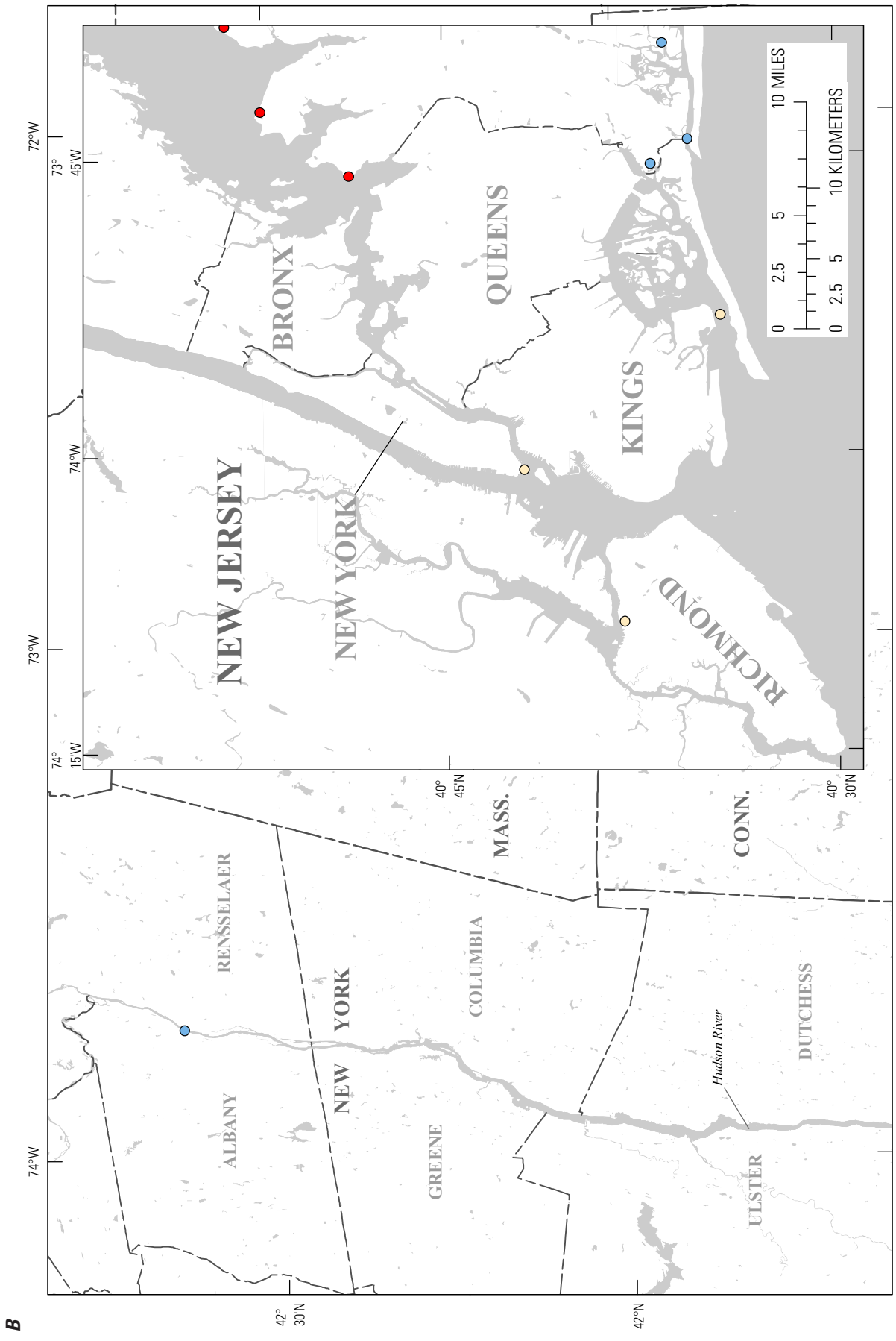


Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 9. *A,* Storm-surge magnitude associated with the peak storm tide produced by Hurricane Sandy in New York counties. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.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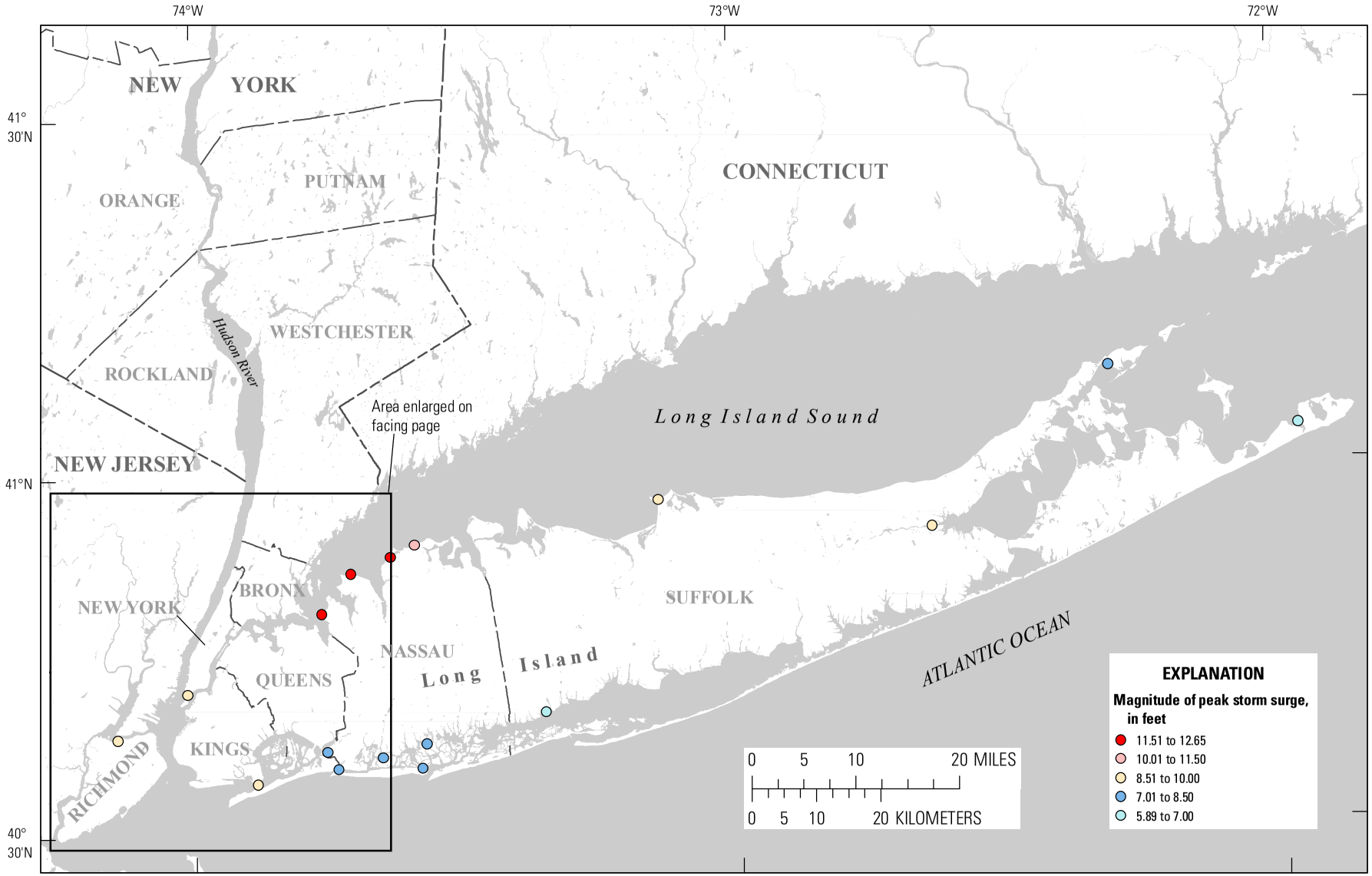
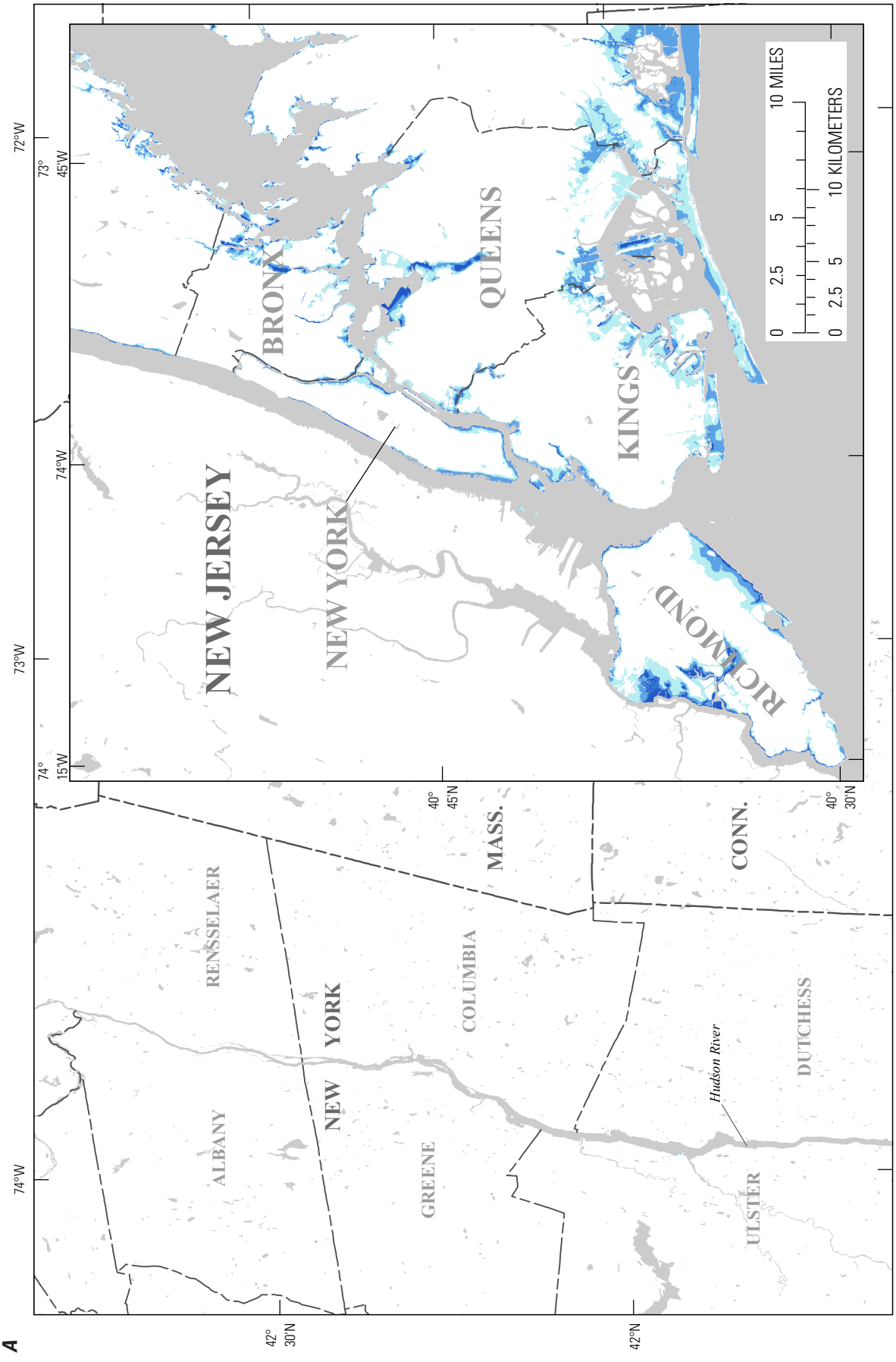


Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 9. *B,* Magnitude of the peak storm surge produced by Hurricane Sandy in New York counties. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond.—Continued.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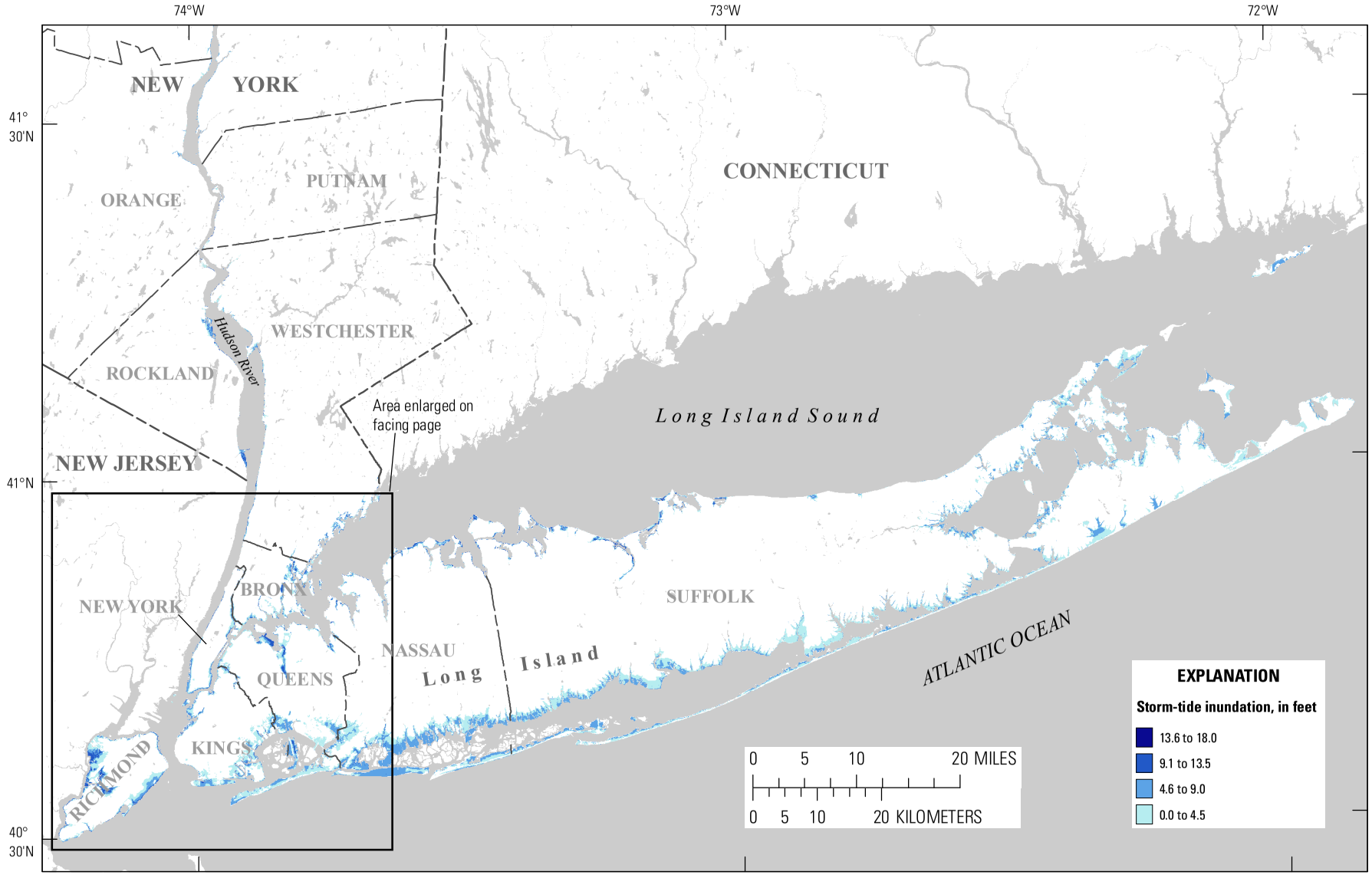
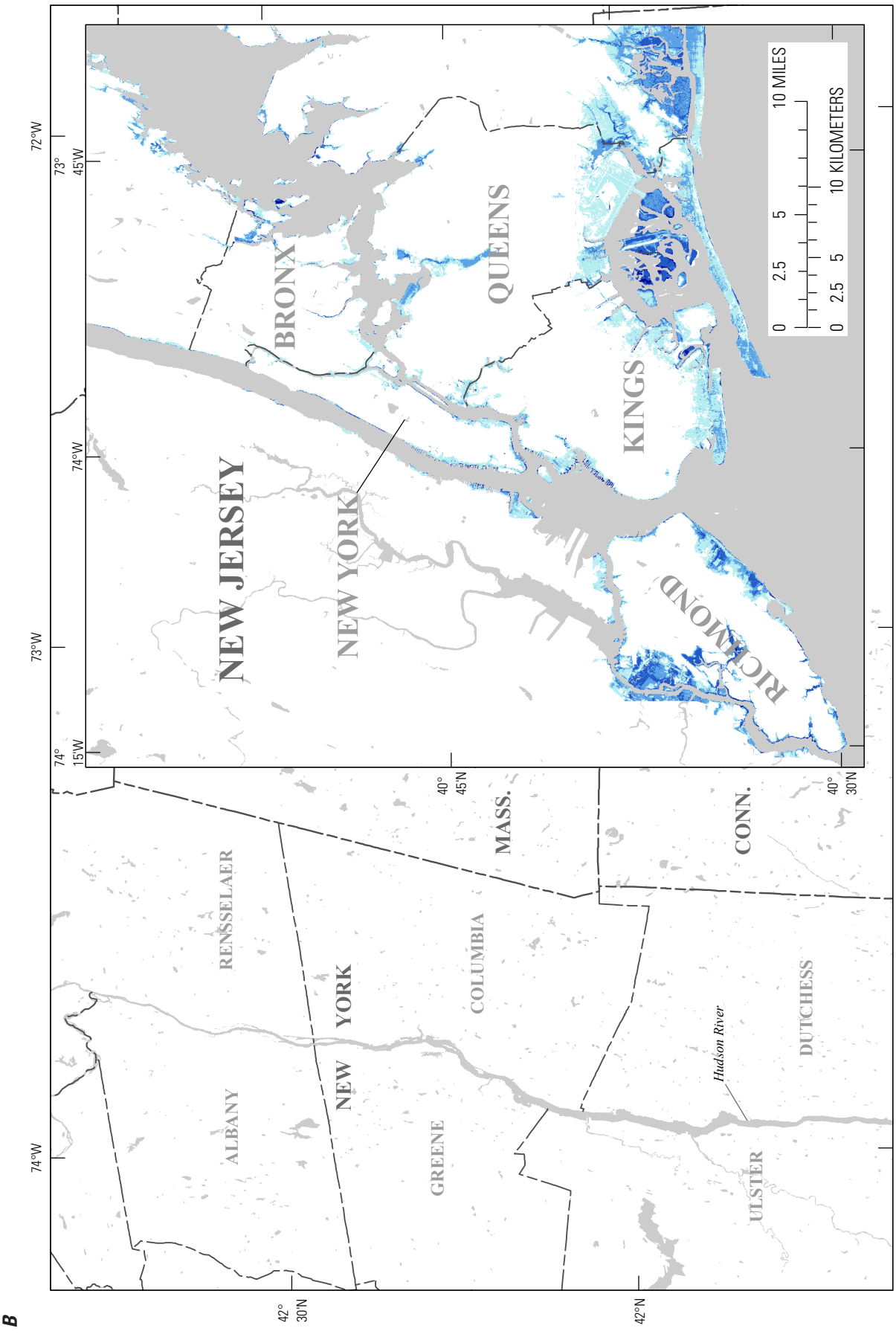


Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 10. *A*, Extent of storm-tide inundation from Hurricane Sandy in New York counties that was derived from U.S. Geological Survey (USGS) storm-tide data available for National Hurricane Center Sea, Lake, and Overland Surges from Hurricanes model hindcast product dated October 31, 2012. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond. Extent of storm-tide inundation is from Austen K. Cutrell (Federal Emergency Management Agency, written commun., 2013).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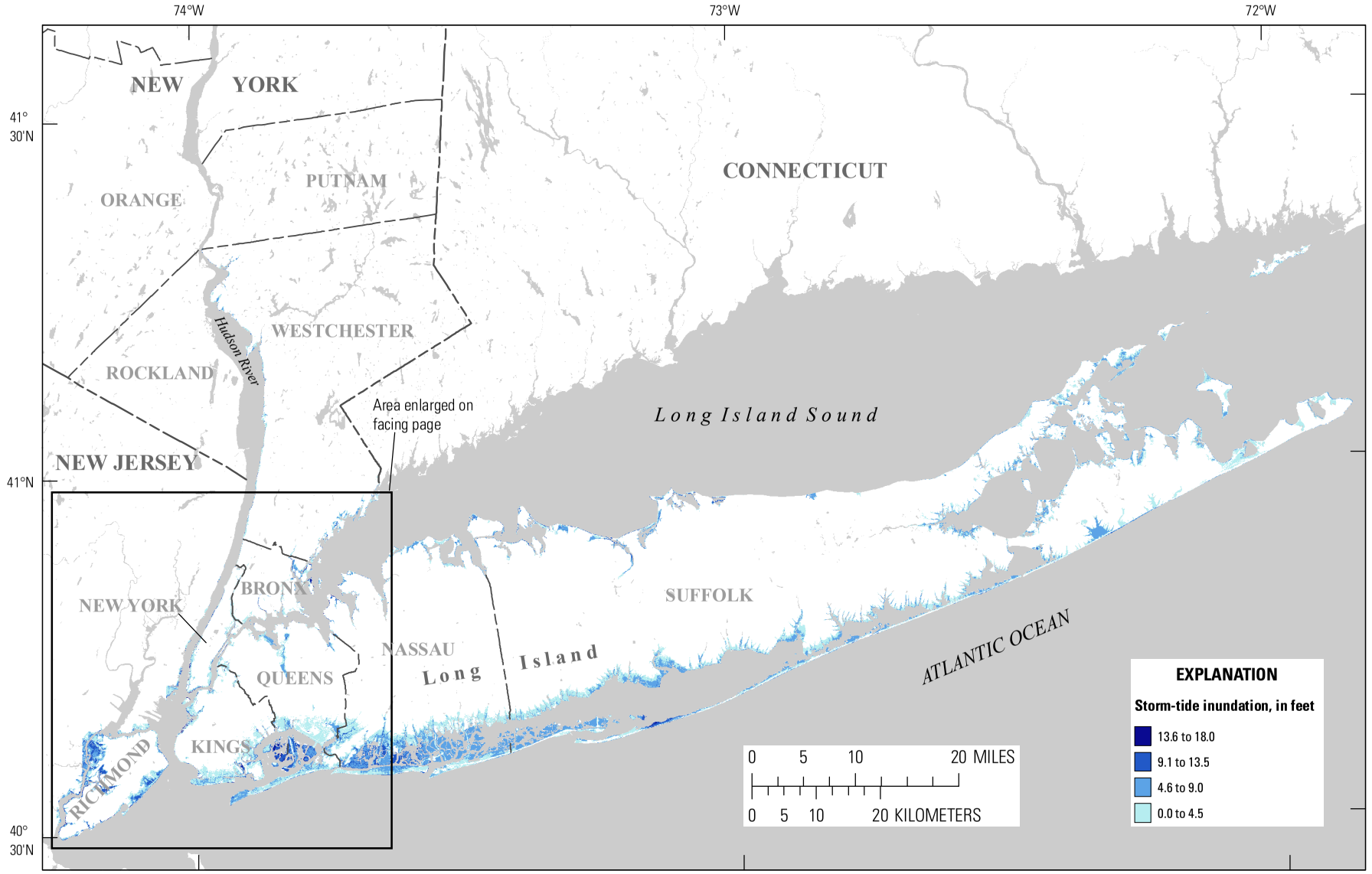
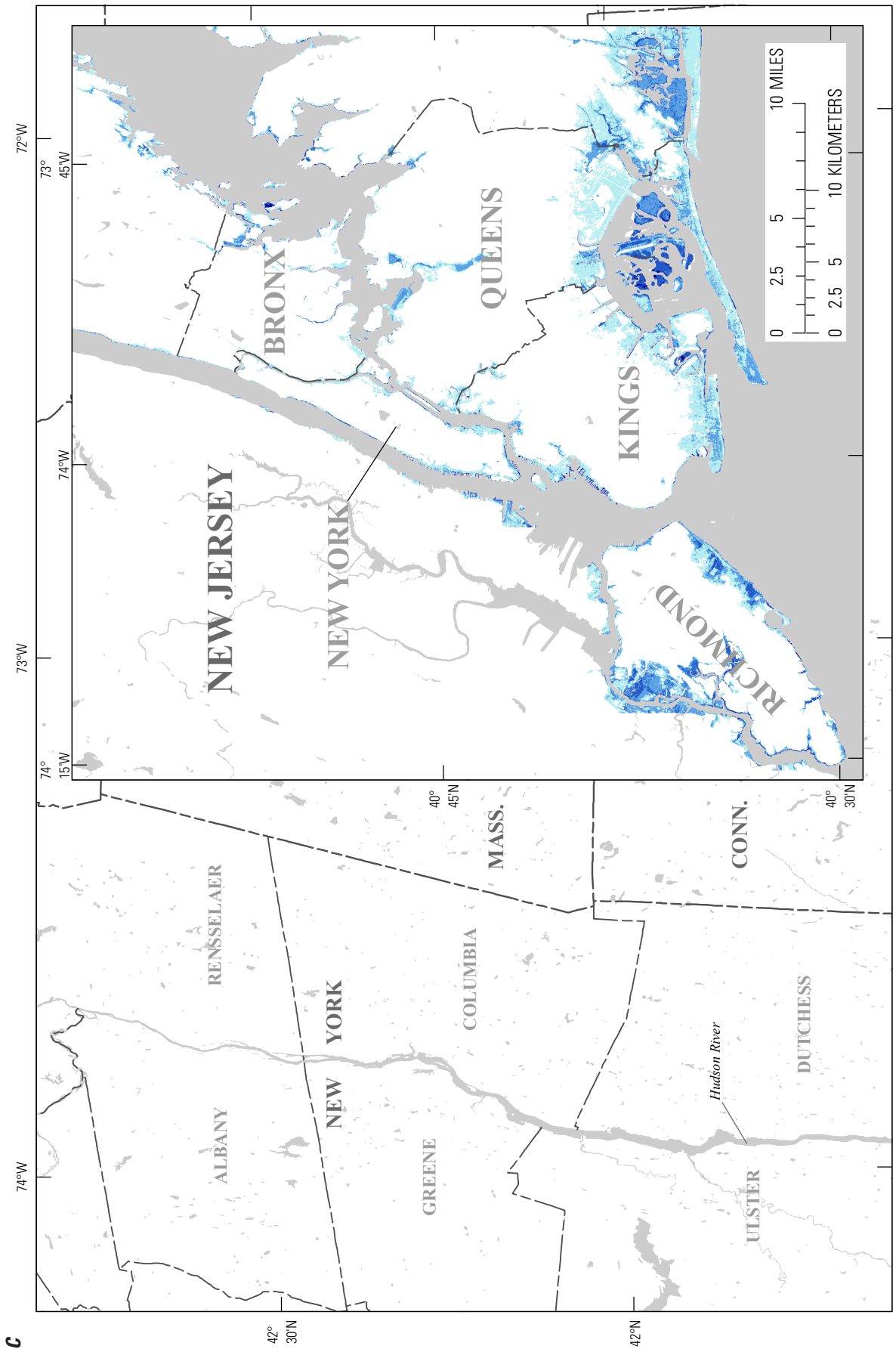


Figure 10. *B*, Extent of storm-tide inundation from Hurricane Sandy in New York counties that was derived from U.S. Geological Survey (USGS) storm-tide data available for Federal Emergency Management Agency (FEMA) interim high-resolution product based on USGS data available from storm landfall through November 11, 2012. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond. Extent of storm-tide inundation is from Austen K. Cutrell (Federal Emergency Management Agency, written commun., 2013).—Continued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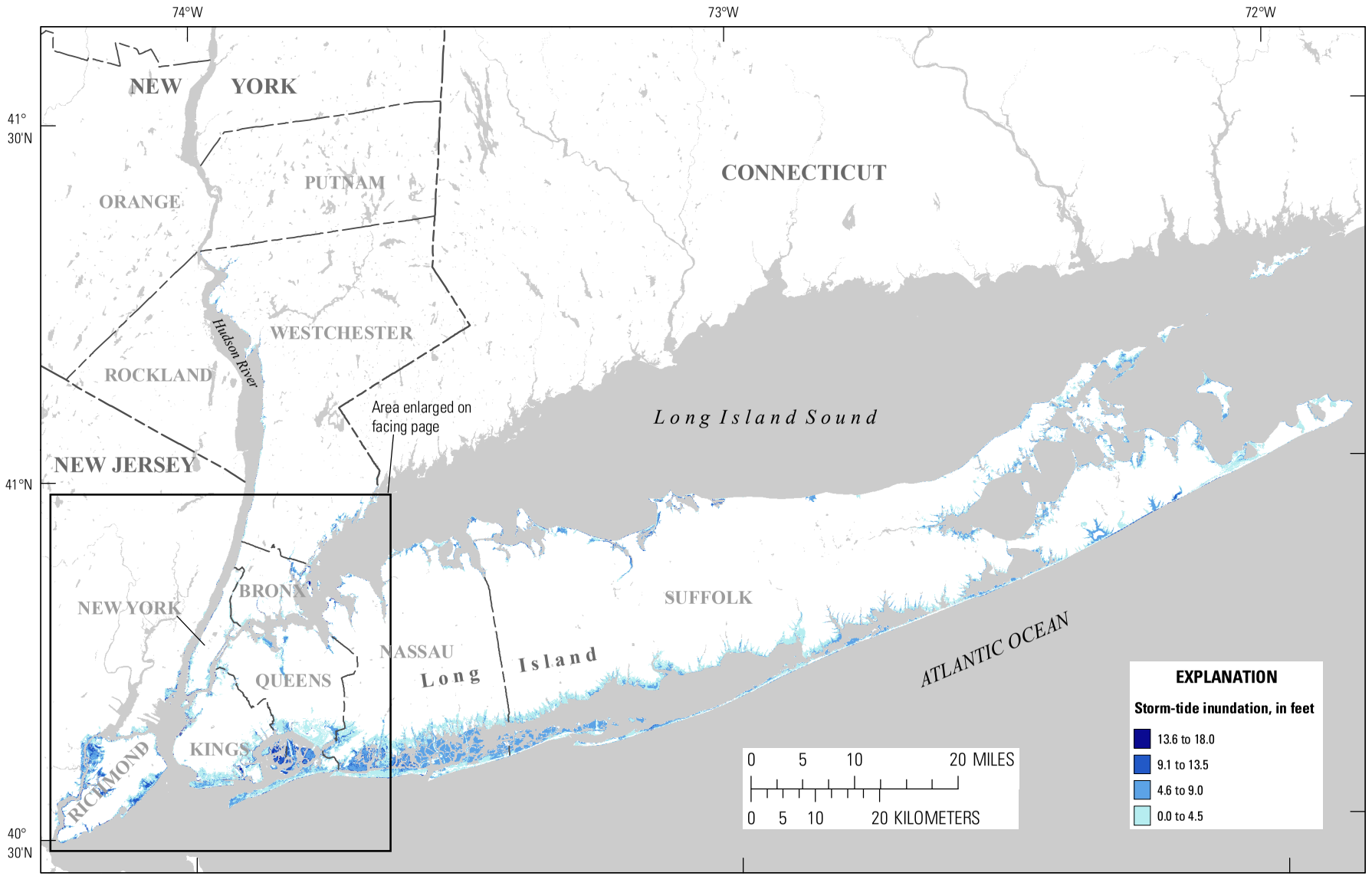


Figure 10. *C*, Extent of storm-tide inundation from Hurricane Sandy in New York counties that was derived from U.S. Geological Survey (USGS) storm-tide data available for Federal Emergency Management Agency (FEMA) final high-resolution product based on USGS data available from storm landfall through February 14, 2013. Inset shows enlargement of the five counties that comprise New York City—Bronx, Kings, New York, Queens, and Richmond. Extent of storm-tide inundation is from Austen K. Cutrell (FEMA, written commun., 2013).—Continued

HAZUS Flood Loss Analyses

HAZUS is FEMA's "nationally applicable standardized methodology that contains models for estimating potential losses" from floods and other disasters; through use of geographic information system (GIS) technology, HAZUS enables the physical, economic, and social effects of disasters to be estimated (Federal Emergency Management Agency, 2013d). Results of HAZUS building stock flood loss analyses performed for New York counties are mapped for the three extents of inundation from Hurricane Sandy in figure 11; the losses for the three different storm-tide inundation extents are graphed by date in figure 12. The results consist of depictions of estimated total building stock losses for the pre-storm (October 31, 2012) mapping of inundation extent; November 11, 2012, mapping of inundation extent; and February 14, 2013, mapping of inundation extent (fig. 10*A*, 10*B*, and 10*C*, respectively, and fig. 12).

The depictions of estimated total building stock losses document how differing amounts of available USGS data affect the resolution and accuracy of storm-tide inundation extents. Estimated losses for October 31, 2012, (fig. 11*A*) were derived from an inundation extent (fig. 10*A*) that was based on essentially no data from the temporary monitoring sites or HWM sites. Estimated losses for November 11, 2012, (fig. 11*B*) were derived from an inundation extent (fig. 10*B*) produced after most of the temporary sensor data became available but before most of the HWM sites were surveyed. Estimated losses for February 14, 2013, (fig. 11*C*) were derived from an inundation extent (fig. 10*C*) produced after all data from the temporary monitoring sites and HWM sites had become available.

Overall, the depictions indicate that estimated losses from Hurricane Sandy for all building stock are consistently higher for coastal counties, particularly those along the Atlantic Ocean shore (fig. 11), than for the rest of New York. Using the most accurate results from the final (February 14, 2013) extent of storm-tide inundation, estimated total building stock losses range from $380 million to $5.9 billion for New York counties; total estimated aggregate losses are about $23 billion for all New York counties (fig. 12). The aggregate HAZUS loss assessments for all New York counties are highest for the analyses made using the October 31, 2012, inundation data; substantially lower for the analyses made using the November 11, 2012, inundation data; and lower still for the analyses made using the February 14, 2013, inundation data. This trend also appears in the results for Nassau and New York counties; however, the results for other counties show mixed trends.

Estimated total building stock losses from Hurricane Sandy for the three storm-tide inundation extents were subtracted from one another to create graphs from datasets of differences, which are shown in figure 13. The differences datasets are referred to by the dates of the inundation extents used in the HAZUS analyses—November 11, 2012, minus October 31, 2012 (fig. 13*A*), February 14, 2013, minus October 31, 2012 (fig. 13*B*), and February 14, 2013, minus November 11, 2012 (fig. 13*C*). These datasets indicate there are substantial differences between HAZUS loss estimates for analyses done using the three inundation extents. Figure 13 clearly shows the differences resulting from the quality of the inundation extent, which, in turn, is largely determined by the availability of USGS storm-tide data. The differences (expressed using absolute values) are as high as $4.6 billion for individual counties, while aggregate total differences for all New York counties approached $8 billion (fig. 12). These results demonstrate the significant effect that the resolution and accuracy of the inundation extent data have on the HAZUS analyses. In that the improved resolution and accuracy are largely due to the data from the temporary monitoring network deployment and HWM flagging and surveying campaign, the cost of this deployment and campaign seems more than justified by the substantial improvement in final loss estimates. The value of these findings for informing future post-storm reconstruction planning and estimation of insurance claims are considerable.

Summary and Conclusions

The hybrid cyclone nor'easter known as Hurricane Sandy affected the mid-Atlantic and northeastern coastline of the United States during October 28–30, 2012, producing northeast-to-southeast winds of tropical-storm strength (39 to 73 miles per hour [mi/hr]) that gusted to greater than hurricane strength (greater than 73 mi/hr) and caused extensive coastal flooding and beach erosion. Prior to storm landfall, the U.S. Geological Survey (USGS) deployed a temporary monitoring network from Virginia to Maine of water-level and barometric pressure sensors to continuously record the timing, areal extent, and magnitude of the storm tide and coastal flooding generated by Hurricane Sandy. The temporary monitoring network augmented USGS and National Oceanic and Atmospheric Administration (NOAA) networks of permanent monitoring sites that also documented storm surge—the difference (when positive) between the observed water level and normal (predicted astronomical) tide level. Continuous data from these networks were greatly supplemented by an extensive post-storm high-water-mark (HWM) flagging and surveying campaign from November to December 2012. The temporary monitoring network deployment and HWM flagging and surveying campaign were undertaken as part of a coordinated Federal emergency response as outlined by the Stafford Act (42 U.S.C. 5121 et seq.) under a directed mission assignment by the Federal Emergency Management Agency (FEMA). The need for information that assists in the analysis of flood damages and future flood mitigation efforts in New York prompted the current analysis of Hurricane Sandy by the USGS under this FEMA mission assignment.

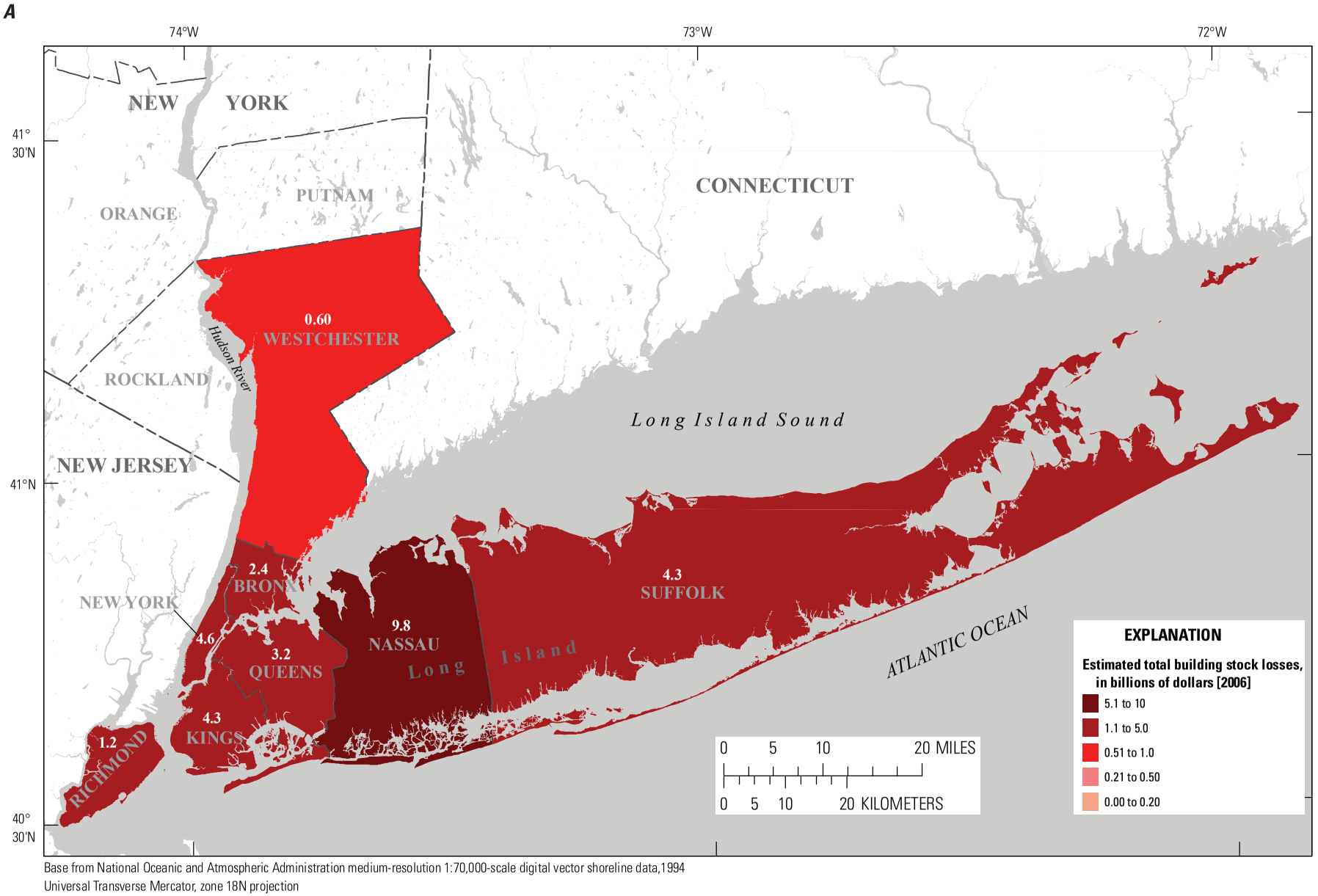
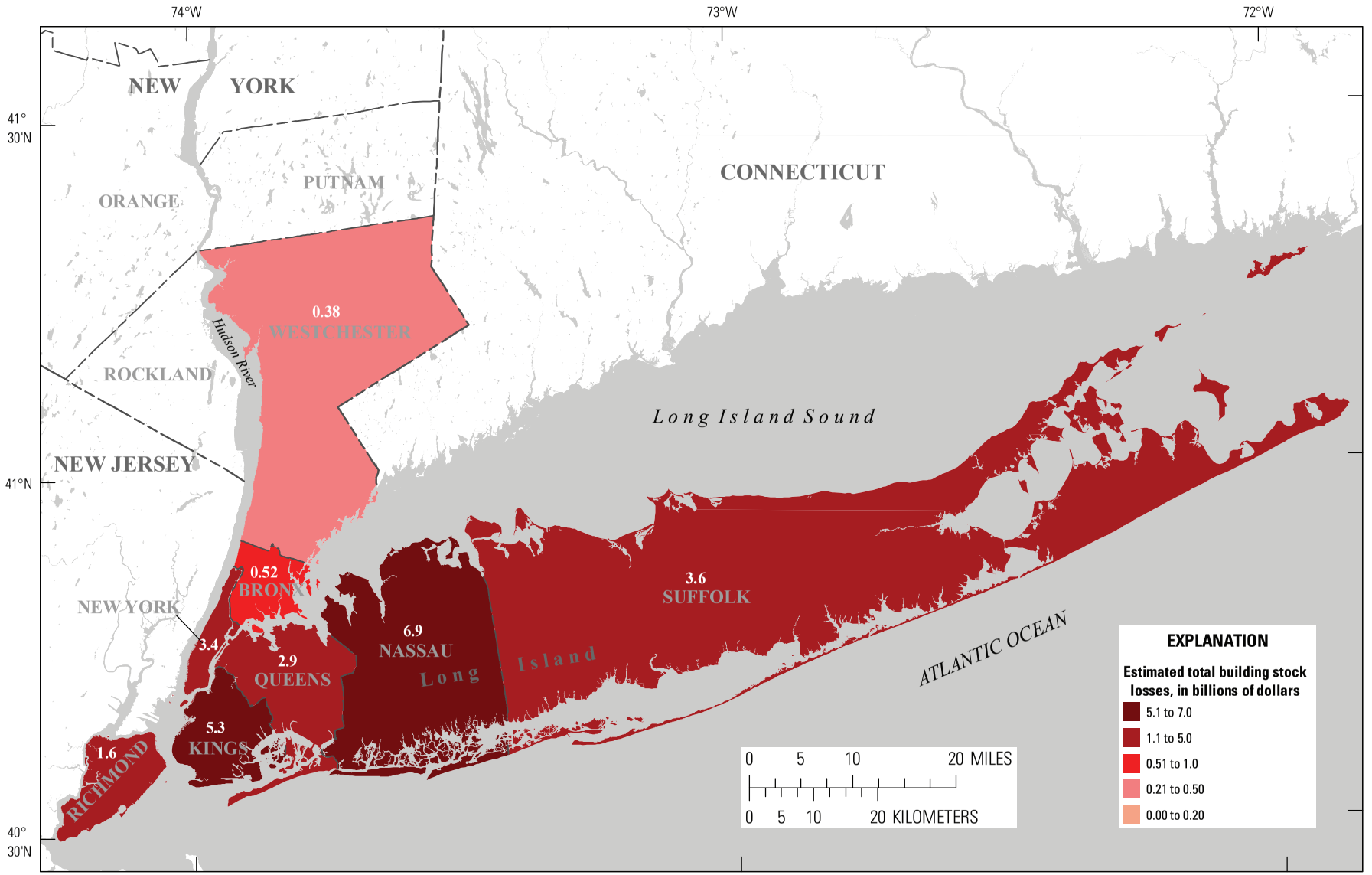


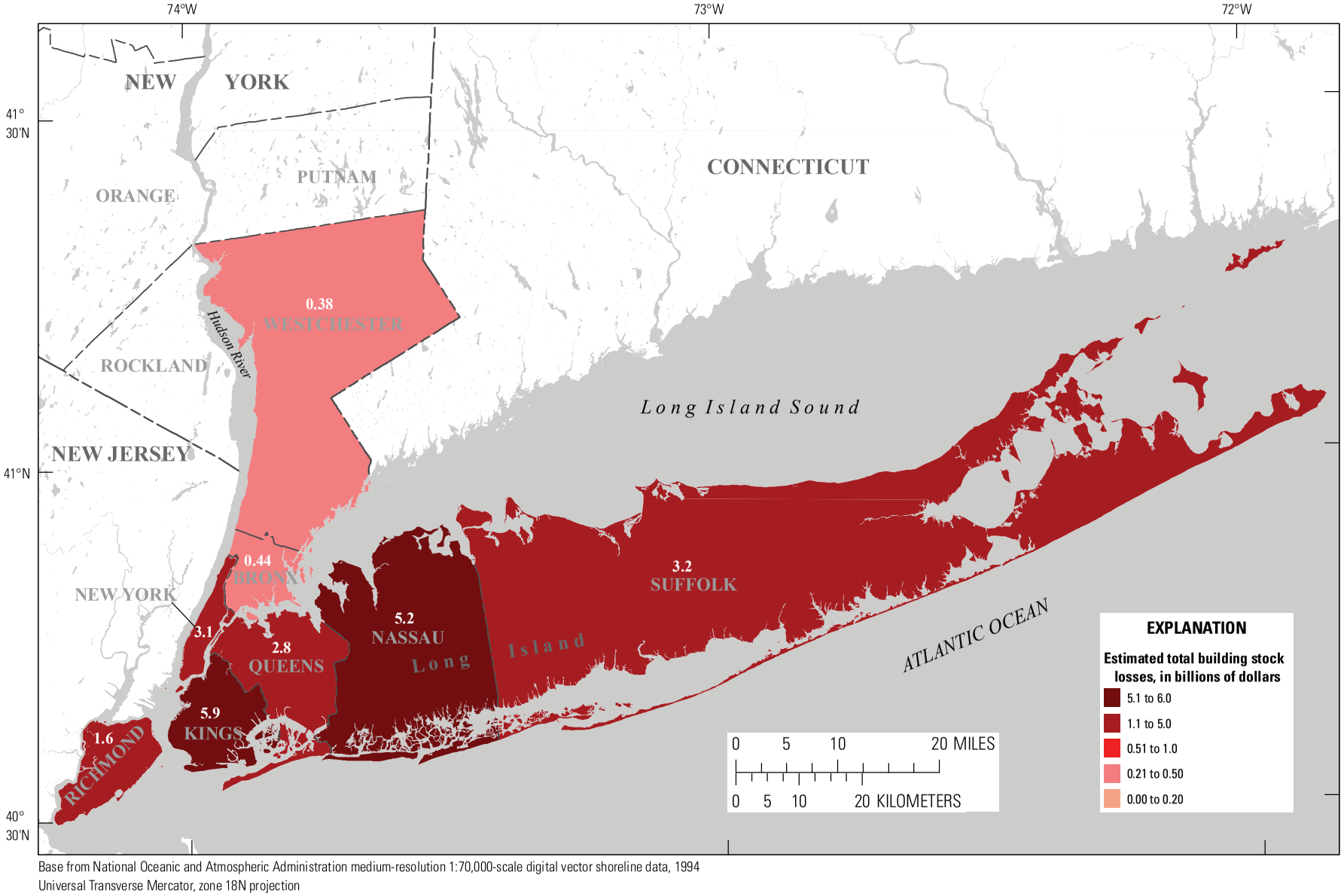
Figure 11. *A*, Federal Emergency Management Agency (FEMA) Hazus Program (HAZUS) estimated total building stock losses due to storm-tide inundation from Hurricane Sandy in selected New York counties for inundation depicted in National Hurricane Center Sea, Lake, and Overland Surges from Hurricanes model hindcast product dated October 31, 2012.



Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 11. *B*, Federal Emergency Management Agency (FEMA) Hazus Program (HAZUS) estimated total building stock losses due to storm-tide inundation from Hurricane Sandy in selected New York counties for inundation depicted in FEMA interim high-resolution product based on U.S. Geological Survey (USGS) data available from storm landfall through November 11, 2012.—Continued

C



Base from National Oceanic and Atmospheric Administration medium-resolution 1:70,000-scale digital vector shoreline data, 1994
Universal Transverse Mercator, zone 18N projection

Figure 11. *C*, Federal Emergency Management Agency (FEMA) Hazus Program (HAZUS) estimated total building stock losses due to storm-tide inundation from Hurricane Sandy in selected New York counties for inundation depicted in FEMA final high-resolution product based on USGS data available from storm landfall through February 14, 2013.—Continued

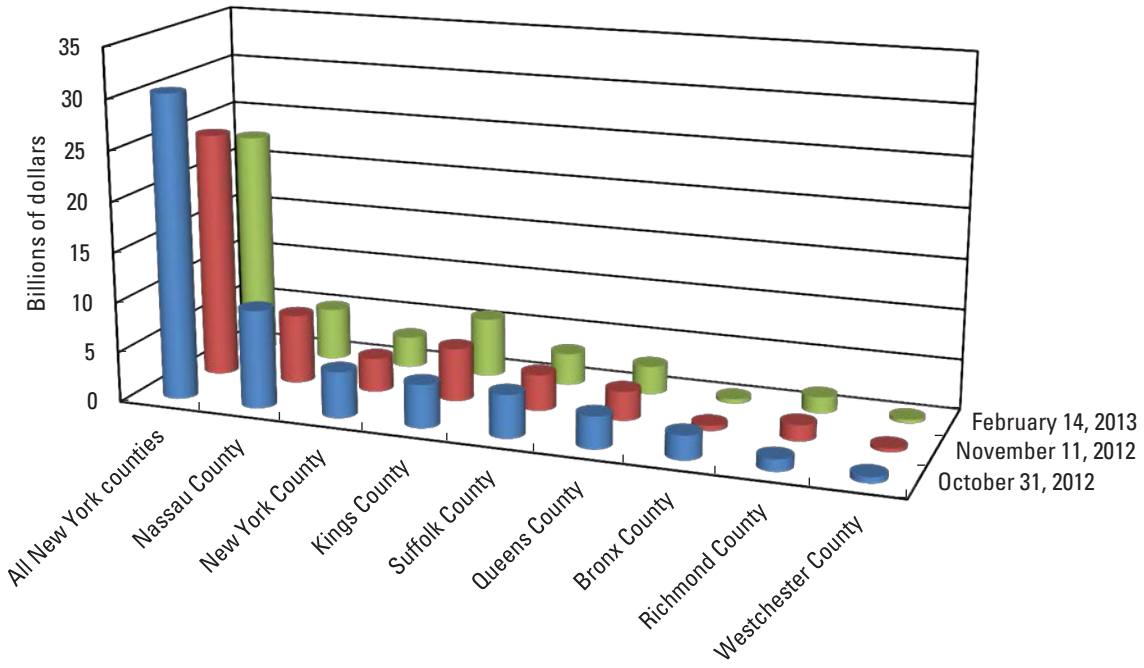
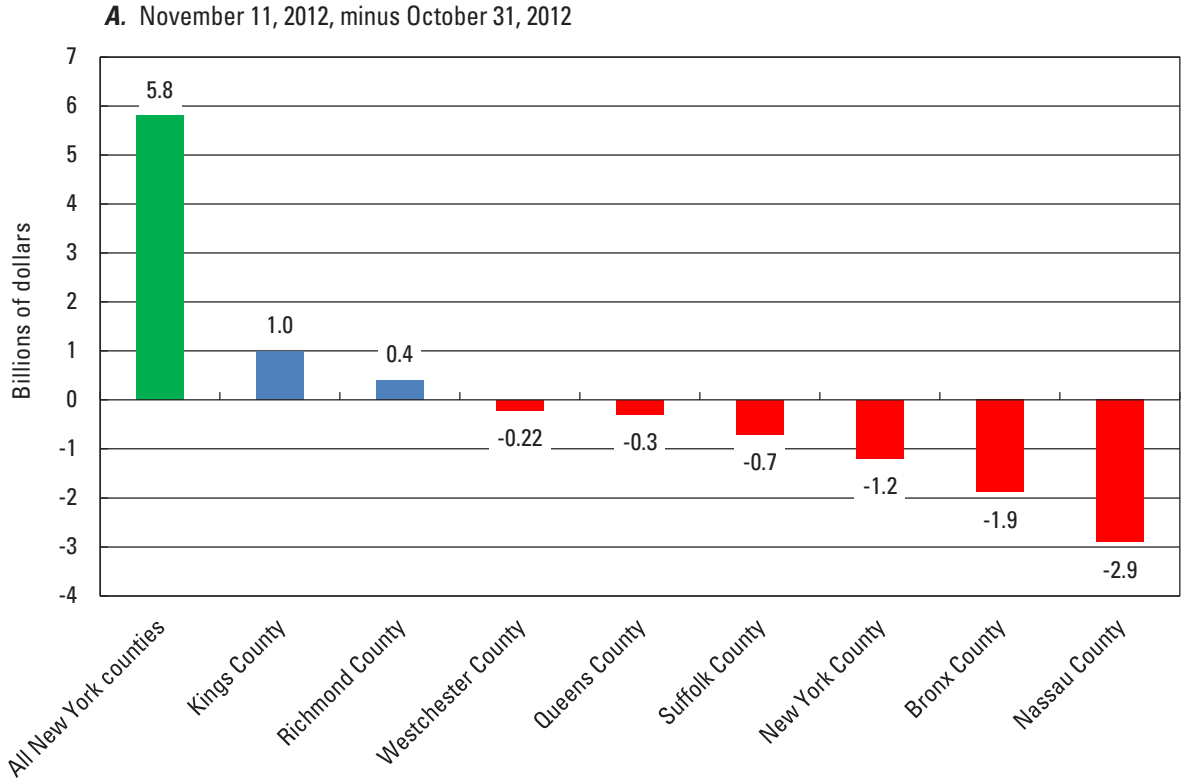


Figure 12. Federal Emergency Management Agency (FEMA) Hazus Program (HAZUS) estimated total building stock losses due to storm-tide inundation from Hurricane Sandy in selected New York counties for inundation depicted in National Hurricane Center Sea, Lake, and Overland Surges from Hurricanes model hindcast product dated October 31, 2012, FEMA interim high-resolution product based on U.S. Geological Survey (USGS) data available from storm landfall through November 11, 2012, and FEMA final high-resolution product based on USGS data available from storm landfall through February 14, 2013.



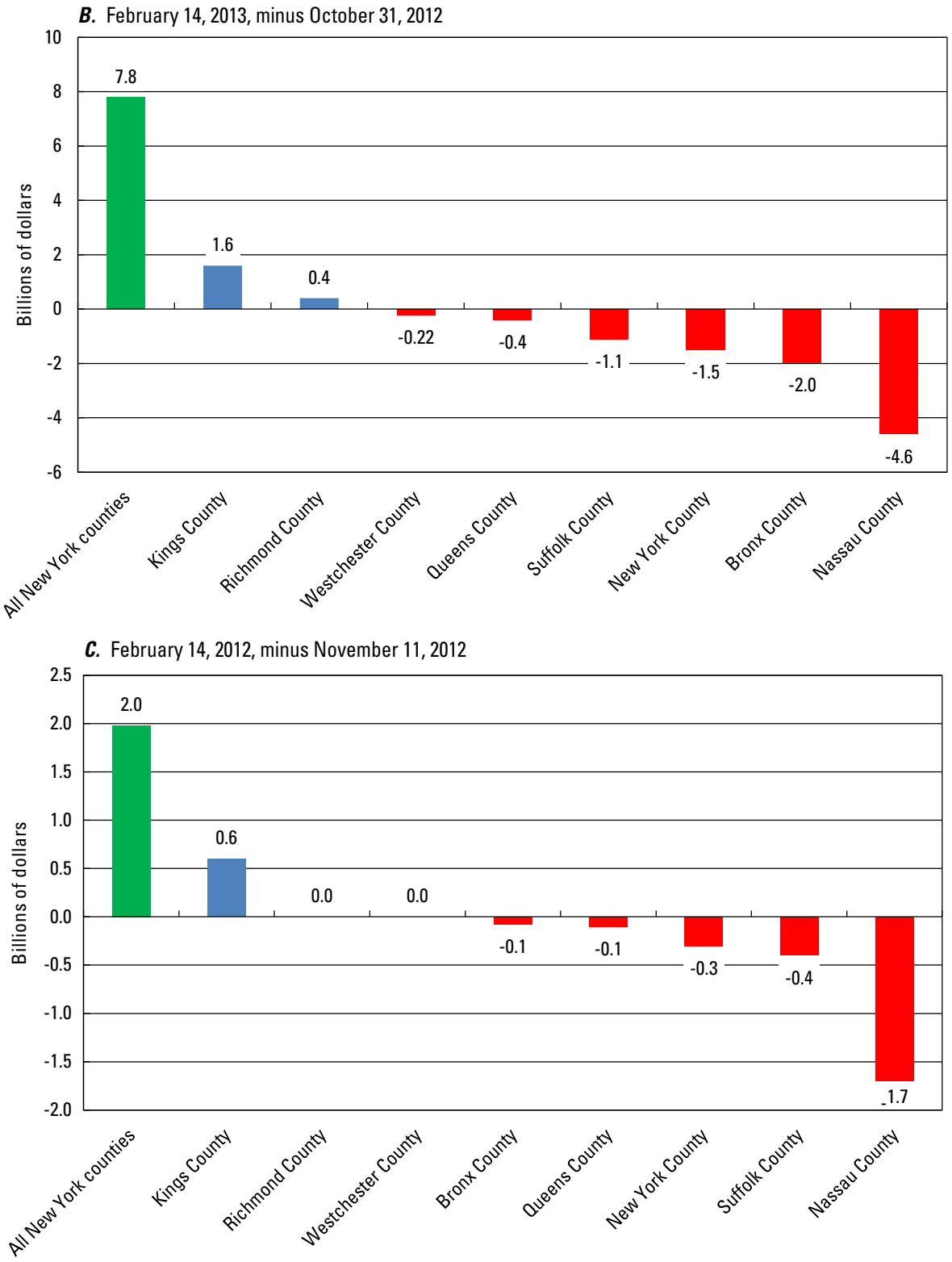


Figure 13. Differences between Federal Emergency Management Agency (FEMA) Hazus Program (HAZUS) estimated total building stock losses due to storm-tide inundation from Hurricane Sandy in selected New York counties for inundation depicted in National Hurricane Center National Hurricane Center Sea, Lake, and Overland Surges from Hurricanes model hindcast product dated October 31, 2012, FEMA interim high-resolution product based on U.S. Geological Survey (USGS) storm-tide data available through November 11, 2012, and FEMA final high-resolution product based on USGS storm-tide data available through February 14, 2013. *A,* November 11, 2012, minus October 31, 2012, *B,* February 14, 2013, minus October 31, 2012, and *C,* February 14, 2013, minus November 11, 2012. Blue and red shading denotes positive and negative values, respectively. Green shading denotes absolute values.

Hurricane Sandy was the 18th named storm and 10th hurricane of the 2012 Atlantic hurricane season. The extremely large fetch of tropical-storm force winds circulating around Hurricane Sandy, combined with its anomalous track, piled large amounts of ocean water, over multiple tidal cycles, north and west of the center of counterclockwise circulation. This onshore flow was funneled into the New York Bight—the large embayment formed by the Atlantic coastline of Long Island and northern New Jersey—and inland through the many interconnected estuaries, propagating over 100 miles north along the Hudson River to the head-of-tide at the Federal Dam in Troy.

The analysis of storm-tide impacts focused on three distinct but related aspects of coastal flooding produced by Hurricane Sandy, including flooding inland along the tidal reach of the Hudson River. These aspects are (1) comparisons of Hurricane Sandy peak storm-tide elevations with those of historical storms and to annual exceedance probabilities; (2) identification of the storm-surge magnitude associated with the peak storm tide, and magnitude and timing of the peak storm surge; and (3) comparisons of maps of inundation extent that were derived from differing amounts of available sensor and HWM data. Most peak storm-tide elevations from Hurricane Sandy were greater than about 9.5 feet (ft) above North American Vertical Datum of 1988; this level was exceeded at most of the sites in Albany, Nassau, Rensselaer, and Westchester Counties and New York City.

Peak storm-tide elevations produced by Hurricane Sandy were compared with those of historical storms for which data on substantial coastal flooding are available. These storms include the intense nor'easter of December 11–13, 1992, and Hurricane Irene (August 27–28, 2011), which weakened to a tropical storm before arriving in New York. Peak storm-tide elevations from Hurricane Sandy were higher than those from the December 1992 nor'easter at 24 of 27 sites (89 percent) overall. Most differences were greater than about 0.7 ft or 9 percent (above the historical storm tide), with most of these from sites along the Atlantic Ocean shores of Nassau and Suffolk Counties and in New York City. Peak storm-tide elevations from Hurricane Sandy were higher than those from Tropical Storm Irene at all sites. Most differences were greater than about 2.5 ft or 48 percent, with most of these from sites along the Atlantic Ocean shores of Nassau and Suffolk Counties, in New York City, and in Rockland County.

Peak storm-tide elevations at the permanent and temporary monitoring sites and the HWM sites were compared with the corresponding FEMA flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year recurrence intervals). Peak storm-tide elevations from Hurricane Sandy had annual exceedance probabilities of less than or equal to 1 percent and (or) greater than 0.2 percent [recurrence intervals greater than or equal to 100 years and (or) less than 500 years] at a plurality of sites—184 of 413 (45 percent); most of these were from sites in Dutchess, Nassau, Orange, Rockland, Suffolk, and Ulster Counties; New York City; and along the Hudson River shore of Westchester County. Peak storm-tide elevations associated with the minimum annual exceedance probabilities (maximum recurrence intervals)—elevations higher than or equal to the FEMA 0.2-percent (500-year) flood elevation—accounted for 81 of 413 sites (20 percent); most of these were along the Atlantic Ocean shore of Nassau and western Suffolk Counties, in Orange and Rockland Counties, and along the Hudson River shore of Westchester County. Peak storm-tide elevations associated with the maximum annual exceedance probability (minimum recurrence interval)—elevations lower than the FEMA 10-percent (10-year) flood elevation—accounted for only 10 of 413 sites (2 percent); most of these were in Albany and Rensselaer Counties.

Data from selected permanent monitoring sites in the USGS network and from sites in the NOAA network were used to assess the storm-surge magnitude associated with the peak storm tide and the magnitude and timing of the peak storm surge. Most magnitudes of the storm surge associated with the peak storm tide were greater than about 7.8 ft; most of these are from sites in Albany County, along the Atlantic Ocean shore of Nassau County, and in New York City. Most magnitudes of the peak storm surge were greater than about 8.3 ft; nearly all of these are from sites along the Long Island Sound shores of Nassau and Suffolk Counties and in New York City. Of the 18 permanent monitoring sites, the peak storm surge arrived within 36 minutes of the time of peak storm tide at 8 sites (44 percent), all of which are along the Atlantic Ocean shore of Nassau County and in New York City; this condition resulted from the peak storm surge arriving in phase with the astronomical tide—generally coinciding with normal high tide—at these locations. In contrast, the peak storm surge preceded the time of peak storm tide by 90 minutes or more at 9 of 18 sites (50 percent); these sites are all in Albany County, along the Long Island Sound shore of Nassau County, and in Suffolk County. In this latter case, the condition resulted from peak storm surges arriving out of phase with the astronomical tide—nearly coinciding with normal low tide locally—at these sites, all of which are inland of the New York Bight. Understandably, the timing of peak storm surge arrival with respect to local phase of tide ultimately controlled where the most extreme storm-tide levels and coastal flooding occurred. This finding has bearing not only for sites impacted by the highest storm tides from Hurricane Sandy, but also for those sites that had the greatest storm surges yet were spared the worst flooding because of fortuitous timing during this storm.

Comparisons were made between selected maps of the extent of storm-tide inundation from Hurricane Sandy that were derived from differing amounts of available USGS data from the permanent and temporary monitoring sites and HWM sites. The comparisons were made using the results of FEMA Hazus Program (HAZUS) flood loss analyses depicted for three different extents of storm-tide inundation from Hurricane Sandy. Depictions of estimated total building stock losses document how differing amounts of available USGS data affect the resolution and accuracy of storm-tide inundation extents.

Overall, these depictions indicate that estimated losses from Hurricane Sandy for all building stock are consistently higher for coastal counties, particularly those along the Atlantic Ocean shore, than for other New York counties. Using the most accurate results from the final (February 14, 2013) extent of storm-tide inundation, estimated total building stock losses range from $380 million to $5.9 billion for New York counties; total estimated aggregate losses are about $23 billion for all New York counties. Clearly, the quality of the inundation extents used in HAZUS analyses has a significant effect on final results. In that the improved resolution and accuracy are largely due to the data from the temporary monitoring network deployment and HWM flagging and surveying campaign, the cost of this deployment and campaign seems more than justified by the substantial improvement in final loss estimates. The value of these findings for informing future post-storm reconstruction planning and estimation of insurance claims are considerable.

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Table 7

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	1-percent (100-year) base flood elevation
									[2,3]Albany County
2	HWM–NY–ALB–006	42.47331	-73.79050	AE	10.2	13.8	15.6	19.6	15.2
3	HWM–NY–ALB–007	42.47344	-73.79050	AE	10.2	13.8	15.6	19.6	15.2
4	HWM–NY–ALB–009	42.74684	-73.68936	A12	21.3	25.9	27.6	31.3	27.3
5	HWM–NY–ALB–010	42.74740	-73.68924	A12	21.3	25.9	27.6	31.3	27.3
									[4,5]Dutchess County
7	HWM–NY–DUT–001	41.70667	-73.94013	AE	5.9	7.1	8.0	9.7	8
8	HWM–NY–DUT–002	41.70699	-73.94000	X	--	--	--	9.7	--
9	HWM–NY–DUT–003	41.70874	-73.93926	AE	5.9	7.1	8.0	9.7	8
10	HWM–NY–DUT–004	41.70865	-73.93920	AE	5.9	7.1	8.0	9.7	8
11	HWM–NY–DUT–005	41.70853	-73.93947	AE	5.9	7.1	8.0	9.7	8
12	HWM–NY–DUT–006	41.65165	-73.94353	AE	5.9	7.1	8.0	9.7	8
13	HWM–NY–DUT–007	41.65172	-73.94363	AE	5.9	7.1	8.0	9.7	8
									[5,6]Greene County
15	HWM–NY–GRE–001	42.34817	-73.79239	AE	8.5	11.5	12.9	16.1	14
16	HWM–NY–GRE–002	42.34814	-73.79247	AE	8.5	11.5	12.9	16.1	14
17	HWM–NY–GRE–003	42.34786	-73.79256	AE	8.5	11.5	12.9	16.1	14
18	HWM–NY–GRE–004	42.26305	-73.80639	AE	7.4	9.8	10.9	13.6	11
19	HWM–NY–GRE–005	42.26287	-73.80664	AE	7.4	9.8	10.9	13.6	11
20	HWM–NY–GRE–006	42.26246	-73.80628	AE	7.4	9.8	10.9	13.6	11
21	HWM–NY–GRE–007	42.26333	-73.80640	AE	7.4	9.8	10.9	13.6	11
22	HWM–NY–GRE–008	42.21036	-73.85409	AE	6.3	8.0	8.6	10.9	10
23	HWM–NY–GRE–009	42.21034	-73.85379	AE	6.3	8.0	8.6	10.9	10
24	HWM–NY–GRE–010	42.21027	-73.85436	AE	6.3	8.0	8.6	10.9	10
25	HWM–NY–GRE–011	42.21043	-73.85438	AE	6.3	8.0	8.6	10.9	10
26	HWM–NY–GRE–012	42.21046	-73.85430	AE	6.3	8.0	8.6	10.9	10
									[5,7]Nassau County
44	HWM–NY–NAS–001	40.61083	-73.71500	AE	6.7	8.4	9.3	10.4	9
45	[19]HWM–NY–NAS–220	40.58705	-73.73468	AE	6.7	8.8	11.1	12.0	15
46	[19]HWM–NY–NAS–221	40.58619	-73.71098	AE	6.7	8.9	14.0	12.4	14
47	[19]HWM–NY–NAS–222	40.58958	-73.61233	AE	6.5	8.1	9.5	10.0	13
48	HWM–NY–NAS–223	40.59228	-73.57712	AE	6.4	7.5	7.9	8.6	9
49	HWM–NY–NAS–224	40.60113	-73.50374	AE	5.7	6.7	7.1	7.7	8
50	HWM–NY–NAS–225	40.58967	-73.55444	AE	6.4	7.5	7.9	8.6	8
51	HWM–NY–NAS–416	40.65380	-73.45880	AE	5.2	6.2	6.5	7.2	7
52	[19]HWM–NY–NAS–501	40.87750	-73.53017	AE	6.3	8.7	9.9	12.0	11
53	[19]HWM–NY–NAS–502	40.87593	-73.53659	AE	6.3	8.7	9.9	12.0	11
54	HWM–NY–NAS–512	40.79520	-73.75320	X	--	--	--	12.8	--
55	[19]HWM–NY–NAS–513	40.81418	-73.76414	VE	6.8	9.9	11.3	12.8	17
56	[19]HWM–NY–NAS–516	40.81764	-73.71872	AE	7.3	9.9	11.3	13.5	14
57	[19]HWM–NY–NAS–517	40.82108	-73.70426	AE	7.3	10.2	11.5	13.5	13
58	[19]HWM–NY–NAS–518	40.83497	-73.72870	AE	7.3	9.9	11.5	13.5	13
59	[19]HWM–NY–NAS–519	40.82775	-73.65676	AE	7.3	10.2	11.2	13.5	12

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	10.2	10	10	0.0	Fair	Fair debris line across field in park
10/30/2012	10.0	<10	>10	0.0	Poor	Poor debris line along field in park
10/30/2012	10.6	<10	>10	0.0	Poor	Poor debris line on right bank rip-rap
10/30/2012	10.7	<10	>10	0.0	Poor	Poor debris line on right bank rip-rap
10/30/2012	9.0	>100 & <500	<1 & >0.2	4.0	Good	Good seed line on back door of restaurant
10/30/2012	9.0	<500	>0.2	0.0	Good	Good debris line on grass
10/30/2012	9.1	>100 & <500	<1 & >0.2	2.9	Good	Good seed line on downstream exterior wall of Children's Museum
10/30/2012	9.0	>100 & <500	<1 & >0.2	2.4	Good	Good seed line on streamward side of outbuilding
10/30/2012	9.0	>100 & <500	<1 & >0.2	2.7	Good	Good seed line on upstream side of green power shed
10/30/2012	9.1	>100 & <500	<1 & >0.2	4.1	Good	Good seed line on outside of USGS streamgage—01372058—Hudson River below Poughkeepsie, NY
10/30/2012	9.0	>100 & <500	<1 & >0.2	5.1	Good	Good mud line inside USGS streamgage—01372058—Hudson River below Poughkeepsie, NY
10/30/2012	9.6	20	5.0	1.9	Good	Good seed line on white vinyl fence on Franklin Street
10/30/2012	9.7	30	3.3	4.0	Good	Good seed and mud line on sliding glass door on Franklin Street
10/30/2012	9.2	20	5.0	0.0	Good	Good debris line on lawn
10/30/2012	9.5	50	2.0	--	Excellent	Excellent seed line on Athens wastewater treatment plant sign
10/30/2012	9.5	50	2.0	--	Excellent	Excellent seed line on outside of blue house
10/30/2012	9.5	50	2.0	--	Excellent	Excellent seed line on white house
10/30/2012	9.5	50	2.0	--	Excellent	Excellent seed line on outside of red garage on wastewater treatment plant property
10/30/2012	8.5	90	1.1	3.1	Good	Good seed line on cinder block wall behind dumpster
10/30/2012	9.6	>100 & <500	<1 & >0.2	3.9	Good	Good seed/mud line on window of "Historic Catskill Point" building
10/30/2012	9.5	>100 & <500	<1 & >0.2	3.1	Fair	Fair seed line on "Catskill Historical marker" sign on "Port of Call" restaurant
10/30/2012	9.6	>100 & <500	<1 & >0.2	3.4	Good	Good seed line on gate for "Port of Call" restaurant
10/30/2012	9.6	>100 & <500	<1 & >0.2	3.5	Good	Good mud line on "Port of Call" restaurant door
10/30/2012	9.8	>100 & <500	<1 & >0.2	0.0	Fair	Fair debris line on back lawn on house
10/30/2012	12.7	>500	<0.2	3.0	Excellent	Excellent mud line inside the service entrance on inside wall at Ocean Boulevard
10/30/2012	10.6	70	1.4	0.6	Good	Good mud line inside maintenance shed to west of main entrance to Atlantic Beach Club on Beach Street
10/30/2012	10.2	>500	<0.2	0.8	Good	Good mud line inside small room and under air-conditioning unit
10/30/2012	9.3	>500	<0.2	0.6	Fair	Fair seed line on field manager shed by mower shelter
10/30/2012	8.0	>500	<0.2	3.6	Excellent	Excellent seed line on inside of pump station door
10/30/2012	8.7	>500	<0.2	1.5	Excellent	Excellent seed and mud line on inside of concession stand building
10/29/2012	7.9	>500	<0.2	3.5	Excellent	Excellent seed line on outside of shed
10/30/2012	9.8	100	1.0	1.0	Good	Good seed line inside of building
10/30/2012	10.1	>100 & <500	<1 & >0.2	0.8	Good	Good seed line inside of building
10/30/2012	10.2	<500	>0.2	0.0	Good	Good debris line in yard on Candy Lane
10/30/2012	10.8	<100	>1	0.0	Fair	Fair debris line in yard on Steamboat Road
10/30/2012	9.7	50	2.0	0.0	Fair	Fair debris line in yard on Pheasant Run Road
10/30/2012	10.0	50	2.0	2.5	Good	Good seed line inside garage
10/30/2012	10.8	80	1.3	0.0	Fair	Fair wash line in yard
10/30/2012	10.4	60	1.7	0.0	Fair	Fair wash line in recreation park

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[5,7]Nassau County—Continued
60	HWM–NY–NAS–700	40.88750	-73.56361	AE	6.3	8.7	9.4	12.0	11
61	[19]HWM–NY–NAS–707	40.58398	-73.64081	AE	6.7	8.4	10.1	10.9	15
62	HWM–NY–NAS–708	40.59076	-73.64328	AE	6.6	8.0	8.4	9.1	9
63	HWM–NY–NAS–709	40.59328	-73.66889	AE	6.7	8.1	8.6	9.2	9
64	[19]HWM–NY–NAS–710	40.58501	-73.66842	AE	6.7	8.4	10.1	10.8	14
65	[19]HWM–NY–NAS–711	40.58437	-73.68644	AE	6.7	8.4	10.1	10.7	15
66	HWM–NY–NAS–712	40.59185	-73.68087	AE	6.7	8.1	8.6	9.4	9
67	HWM–NY–NAS–901	40.65905	-73.42680	AE	5.2	6.2	6.5	7.2	7
68	HWM–NY–NAS–902	40.66249	-73.44657	AE	5.2	6.2	6.5	7.2	7
69	HWM–NY–NAS–903	40.65387	-73.46098	AE	5.2	6.2	6.5	7.2	7
70	HWM–NY–NAS–904	40.66478	-73.47136	X	--	--	--	7.5	--
71	HWM–NY–NAS–906	40.65828	-73.50484	X	--	--	--	7.7	--
72	HWM–NY–NAS–907	40.64879	-73.51624	X	--	--	--	7.7	--
73	HWM–NY–NAS–908	40.66016	-73.52912	AE	6.0	7.1	7.5	8.1	8
74	HWM–NY–NAS–909	40.65054	-73.72746	AE	4.9	6.1	6.8	8.6	11
75	HWM–NY–NAS–910	40.62586	-73.74889	AE	4.9	6.1	6.8	8.6	11
76	HWM–NY–NAS–911	40.61710	-73.75665	AE	4.9	6.1	6.8	8.6	11
77	HWM–NY–NAS–912	40.60548	-73.73197	AE	6.7	8.6	9.6	11.3	10
78	HWM–NY–NAS–913	40.60913	-73.71528	X	--	--	--	10.4	--
79	HWM–NY–NAS–914	40.62015	-73.70643	AE	6.7	8.4	9.3	10.4	10
80	HWM–NY–NAS–915	40.63459	-73.66964	AE	6.7	8.0	8.4	9.1	9
81	HWM–NY–NAS–916	40.64152	-73.65965	AE	6.7	8.0	8.4	9.1	9
82	HWM–NY–NAS–917	40.62223	-73.64732	X	--	--	--	9.1	--
83	HWM–NY–NAS–918	40.63071	-73.63131	X	--	--	--	8.9	--
84	HWM–NY–NAS–919	40.63021	-73.61309	X	--	--	--	8.7	--
85	HWM–NY–NAS–920	40.64001	-73.59571	AE	6.4	7.5	7.9	8.6	8
86	HWM–NY–NAS–921	40.63229	-73.58286	AE	6.4	7.5	7.9	8.6	8
87	HWM–NY–NAS–922	40.64760	-73.55389	AE	6.0	7.1	7.5	8.1	8
88	[19]HWM–NY–NAS–923	40.85722	-73.46333	AE	6.3	8.7	10.4	12.0	10
89	[19]HWM–NY–NAS–924	40.86783	-73.47280	VE	6.3	8.7	10.4	12.0	24
90	[19]HWM–NY–NAS–925	40.87199	-73.50356	AE	6.3	8.8	9.8	12.0	11
91	HWM–NY–NAS–926	40.88895	-73.50922	X	--	--	--	12.0	--
92	[19]HWM–NY–NAS–927	40.87615	-73.48767	VE	6.3	8.7	10.4	12.0	17
93	[19]HWM–NY–NAS–928	40.87341	-73.51669	AE	6.3	8.8	9.9	12.0	10
94	[19]HWM–NY–NAS–929	40.88239	-73.54598	AE	6.3	8.7	9.9	12.0	10
95	HWM–NY–NAS–930	40.90515	-73.54333	X	--	--	--	12.0	--
96	[19]HWM–NY–NAS–931	40.91413	-73.52602	AE	6.3	8.7	9.8	12.0	10
97	HWM–NY–NAS–932	40.90336	-73.51229	X	--	--	--	12.0	--
98	HWM–NY–NAS–933	40.88625	-73.53246	AE	6.3	8.7	9.4	12.0	11
99	HWM–NY–NAS–934	40.91038	-73.53987	AE	6.3	8.7	9.4	12.0	10
100	HWM–NY–NAS–935	40.91084	-73.55811	X	--	--	--	12.0	--
101	[8]HWM–NY–NAS–936	40.90816	-73.58157	AO	6.3	8.7	9.4	12.0	10
102	[19]HWM–NY–NAS–938	40.89152	-73.63566	AE	6.7	8.9	11.4	13.0	11
103	[19]HWM–NY–NAS–939	40.89939	-73.62746	AE	6.4	8.8	12.7	13.0	15

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	10.2	>100 & <500	<1 & >0.2	2.2	Excellent	Excellent seed line inside USGS streamgage—01303000—Mill Neck Creek at Mill Neck, NY
10/30/2012	10.7	>100 & <500	<1 & >0.2	1.1	Good	Good mud line on beach wall
10/30/2012	9.3	>500	<0.2	1.3	Excellent	Excellent mud line on inside wall of house
10/30/2012	8.7	>100 & <500	<1 & >0.2	0.8	Excellent	Excellent mud line on inside wall of house
10/30/2012	11.6	>500	<0.2	1.7	Excellent	Excellent mud line on back of building
10/30/2012	9.7	90	1.1	0.4	Good	Good mud line on front of building
10/30/2012	9.5	>500	<0.2	--	Good	Good mud line on side of fence
10/29/2012	7.5	>500	<0.2	3.5	Excellent	Excellent seed line on side of house
10/29/2012	7.7	>500	<0.2	1.3	Excellent	Excellent seed line on inside wall of building
10/30/2012	8.0	>500	<0.2	3.3	Good	Good seed line on side of house
10/30/2012	8.4	>500	<0.2	0.8	Good	Good seed line on side of fence
10/30/2012	7.9	>500	<0.2	0.0	Good	Good debris line on grassy hill
10/29/2012	8.5	>500	<0.2	0.9	Good	Good seed line on side of fence
10/29/2012	8.6	>500	<0.2	2.5	Excellent	Excellent seed line on side of fence
10/30/2012	8.8	>500	<0.2	1.0	Excellent	Excellent seed line on side of house
10/30/2012	10.4	>500	<0.2	1.3	Excellent	Excellent seed line on front of house
10/30/2012	10.2	>500	<0.2	4.3	Excellent	Excellent seed line on front of house
10/29/2012	9.8	>100 & <500	<1 & >0.2	2.8	Excellent	Excellent seed line on side of house
10/29/2012	10.0	<500	>0.2	0.0	Poor	Poor debris line on grass lawn
10/29/2012	10.1	>100 & <500	<1 & >0.2	1.9	Excellent	Excellent seed line on front of house
10/29/2012	9.6	>500	<0.2	1.2	Excellent	Excellent seed line on side of house
10/29/2012	8.5	>100 & <500	<1 & >0.2	1.8	Good	Good seed line on front of building
10/29/2012	9.4	>500	<0.2	1.1	Excellent	Excellent seed line on side of building
10/29/2012	9.4	>500	<0.2	1.6	Excellent	Excellent seed line on front of house
10/29/2012	9.3	>500	<0.2	2.5	Excellent	Excellent seed line on side of fence
10/29/2012	9.2	>500	<0.2	3.3	Excellent	Excellent seed line on front of house
10/29/2012	9.0	>500	<0.2	4.6	Good	Good seed line on front of house
10/29/2012	8.4	>500	<0.2	2.8	Excellent	Excellent seed line on side of fence
10/30/2012	9.7	80	1.3	3.7	Excellent	Excellent cork line inside USGS streamgage—01303500—Cold Spring Brook at Cold Spring Harbor, NY
10/30/2012	10.0	<100	>1	0.0	Fair	Fair debris line on grass
10/30/2012	10.2	>100 & <500	<1 & >0.2	1.9	Excellent	Excellent seed line on back of house
10/30/2012	9.8	<500	>0.2	0.0	Good	Good debris line on lawn
10/29/2012	9.5	<100	>1	2.0	Excellent	Excellent seed line on shed
10/30/2012	10.0	>100 & <500	<1 & >0.2	1.2	Excellent	Excellent seed line on side of fence
10/30/2012	9.6	90	1.1	3.1	Excellent	Excellent seed line on tree
10/30/2012	10.0	<500	>0.2	0.0	Good	Good debris line
10/30/2012	9.8	100	1.0	0.0	Good	Good debris line on lawn
10/30/2012	9.7	<500	>0.2	1.1	Excellent	Excellent seed line on back of building
10/30/2012	10.0	>100 & <500	<1 & >0.2	2.3	Excellent	Excellent seed line on side of garage
10/30/2012	8.1	40	2.5	0.7	Good	Good seed line on side of fence
10/30/2012	11.1	<500	>0.2	1.7	Excellent	Excellent seed line on side of fence
10/30/2012	10.4	>100 & <500	<1 & >0.2	1.3	Excellent	Excellent seed line on fence
10/30/2012	10.0	70	1.4	1.8	Excellent	Excellent seed line on door
10/30/2012	9.9	60	1.7	0.8	Good	Good seed line on tree

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	1-percent (100-year) base flood elevation
									[5,7]Nassau County—Continued
104	[19]HWM–NY–NAS–940	40.80471	-73.64963	AE	7.3	10.2	11.2	13.5	13
105	HWM–NY–NAS–941	40.82358	-73.64658	X	--	--	--	13.5	--
106	HWM–NY–NAS–942	40.85112	-73.65046	X	--	--	--	13.5	--
107	HWM–NY–NAS–954	40.61020	-73.43005	X	--	--	--	12.6	--
108	HWM–NY–NAS–955	40.62021	-73.55973	X	--	--	--	8.6	--
109	[19]HWM–NY–NAS–964	40.89678	-73.60560	AE	6.3	8.7	11.3	12.4	12
									[9,10,11]New York City
127	HWM–NY–BRO–804	40.84280	-73.92900	AE	5.8	8.1	8.9	11.4	8.9
128	HWM–NY–BRO–805	40.82300	-73.93220	AE	7.7	9.3	10.2	13.0	9.9
129	HWM–NY–BRO–807	40.80470	-73.90230	VE	7.4	9.3	10.3	13.0	13.9
130	HWM–NY–BRO–808	40.80700	-73.87000	VE	8.7	11.0	12.2	15.6	14.9
131	HWM–NY–BRO–809	40.81540	-73.83860	AE	8.6	10.9	12.1	15.1	13.9
132	HWM–NY–BRO–810	40.80920	-73.80370	AE	8.7	11.1	12.4	15.4	13.9
133	HWM–NY–BRO–811	40.86470	-73.80200	AE	8.8	11.3	12.6	15.7	12.9
134	HWM–NY–KIN–001	40.64076	-74.03564	X	--	--	--	10.7	--
135	HWM–NY–KIN–002	40.71637	-73.92492	AE	6.1	7.7	8.5	10.9	8.9
136	HWM–NY–KIN–003	40.64454	-73.88815	X	--	--	--	8.6	--
137	HWM–NY–KIN–504	40.70396	-73.99049	AE	6.2	7.8	8.5	10.7	8.9
138	HWM–NY–KIN–510	40.71887	-73.96524	AE	6.2	7.8	8.5	10.7	8.9
139	HWM–NY–KIN–511	40.66879	-74.00956	AE	6.3	7.8	8.6	10.7	9.9
140	HWM–NY–KIN–604	40.70400	-73.98944	AE	6.2	7.8	8.5	10.7	8.9
141	HWM–NY–KIN–605	40.70400	-73.98944	AE	6.2	7.8	8.5	10.7	8.9
142	HWM–NY–KIN–715	40.57941	-74.01118	X	--	--	--	10.8	--
143	HWM–NY–KIN–724	40.66524	-74.01270	AE	6.3	7.8	8.6	10.7	9.9
144	HWM–NY–KIN–725	40.67541	-73.99099	AE	6.3	7.8	8.6	10.7	8.9
145	HWM–NY–KIN–900	40.66725	-74.00001	X	--	--	--	10.7	--
146	HWM–NY–KIN–901	40.66111	-74.00556	AE	6.3	7.8	8.6	10.7	8.9
147	HWM–NY–KIN–902	40.65583	-74.01619	AE	6.3	7.8	8.6	10.7	9.9
148	HWM–NY–KIN–903	40.61089	-74.03629	X	--	--	--	10.7	--
149	HWM–NY–KIN–904	40.59519	-74.00007	X	--	--	--	10.8	--
150	HWM–NY–KIN–905	40.58019	-73.99792	AE	6.3	7.9	8.6	10.8	8.9
151	HWM–NY–KIN–906	40.58940	-73.92607	AE	4.9	6.1	6.8	8.6	7.9
152	HWM–NY–KIN–908	40.60743	-73.89626	AE	4.9	6.1	6.8	8.6	8.9
153	HWM–NY–KIN–909	40.65948	-73.86370	X	--	--	--	8.6	--
154	HWM–NY–NEW–001	40.77760	-73.94250	AE	7.0	8.0	9.7	12.3	9.9
155	HWM–NY–NEW–002	40.82800	-73.95420	AE	6.2	7.7	8.5	10.6	8.9
156	HWM–NY–NEW–003	40.74070	-74.01170	AE	6.3	7.9	8.6	10.8	8.9
157	HWM–NY–NEW–004	40.76312	-74.00047	AE	6.3	7.9	8.6	10.8	8.9
158	HWM–NY–NEW–005	40.74013	-73.97328	AE	6.1	7.7	8.5	10.9	8.9
159	HWM–NY–NEW–008	40.69035	-74.04692	--	6.3	7.9	8.6	10.8	--
160	HWM–NY–NEW–009	40.68971	-74.04387	--	6.3	7.9	8.6	10.8	--
161	HWM–NY–NEW–010	40.69912	-74.03992	--	6.3	7.9	8.6	10.8	--
162	HWM–NY–NEW–011	40.69938	-74.03867	--	6.3	7.9	8.6	10.8	--
163	HWM–NY–NEW–012	40.69086	-74.01246	AE	6.4	7.9	8.7	10.7	8.9
164	HWM–NY–NEW–013	40.68527	-74.02489	AE	6.4	7.9	8.7	10.7	8.9
165	HWM–NY–NEW–100	40.70110	-74.01560	VE	6.4	7.9	8.6	10.8	12.9

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	10.2	50	2.0	0.9	Excellent	Excellent seed line on side of building
10/30/2012	10.2	<500	>0.2	0.8	Excellent	Excellent seed line
10/30/2012	10.9	<500	>0.2	0.0	Poor	Poor debris line on beach
10/29/2012	7.1	<500	>0.2	1.3	Excellent	Excellent seed line on building
10/29/2012	8.7	>500	<0.2	0.0	Good	Good debris line
10/30/2012	7.7	30	3.3	2.2	Good	Good seed line on inside corner of back of house
10/30/2012	9.7	>100 & <500	<1 & >0.2	2.1	Excellent	Excellent seed line on side of fence
10/30/2012	9.9	80	1.3	0.0	Good	Good mud line on concrete path
10/30/2012	10.6	<100	>1	1.0	Good	Good seed line inside guard booth
10/30/2012	10.3	<100	>1	0.0	Good	Good debris line in grass field
10/30/2012	10.7	50	2.0	3.4	Fair	Fair debris line on fence
10/30/2012	10.4	40	2.5	0.0	Good	Good debris line on grass
10/30/2012	10.2	30	3.3	0.0	Good	Good debris line on grass
10/30/2012	11.3	>500	<0.2	0.4	Good	Good seed line on inside door to shed
10/30/2012	10.9	500	0.2	2.2	Good	Good mud line on door of building
10/30/2012	11.0	>500	<0.2	4.1	Good	Good seed line on garage door of house
10/30/2012	11.3	>500	<0.2	4.4	Good	Good seed line in window of Bubby's Restaurant and Bar
10/30/2012	11.2	>500	<0.2	2.6	Good	Good seed line inside of office building
10/30/2012	11.2	>500	<0.2	4.1	Good	Good mud line on metal door inside concrete building
10/30/2012	11.0	>500	<0.2	1.6	Good	Good seed line on front of building
10/30/2012	10.9	>500	<0.2	--	Good	Good seed line on back of guard booth
10/29/2012	12.4	>500	<0.2	--	Excellent	Excellent mud line on outside of house
10/29/2012	11.3	>500	<0.2	3.6	Good	Good seed line on side of building
10/29/2012	9.8	>100 & <500	<1 & >0.2	3.2	Excellent	Excellent mud line on side of building
10/30/2012	11.0	>500	<0.2	--	Fair	Fair debris line on chain link fence
10/30/2012	11.2	>500	<0.2	3.0	Fair	Fair wash line in compost
10/30/2012	11.5	>500	<0.2	4.5	Fair	Fair seed line on trailer
10/30/2012	12.9	>500	<0.2	0.0	Poor	Poor debris line
10/30/2012	11.5	>500	<0.2	1.1	Excellent	Excellent seed line on wall inside building
10/30/2012	11.5	>500	<0.2	0.0	Good	Good debris line around hill side
10/30/2012	10.9	>500	<0.2	4.0	Excellent	Excellent seed line on side of house
10/30/2012	11.2	>500	<0.2	3.6	Good	Good seed line on trailer
10/30/2012	10.0	>500	<0.2	1.1	Excellent	Excellent mud line on inside of security hut
10/30/2012	10.4	>100 & <500	<1 & >0.2	2.4	Poor	Poor debris line in ornamental grass
10/30/2012	9.5	>100 & <500	<1 & >0.2	0.0	Fair	Fair debris line on lawn
10/30/2012	12.3	>500	<0.2	--	Fair	Fair mud line on interior wall of fire house
10/30/2012	10.4	>100 & <500	<1 & >0.2	2.6	Excellent	Excellent seed line on building
10/30/2012	10.8	500	0.2	2.5	Good	Good debris line on fence
10/30/2012	11.3	>500	<0.2	4.1	Excellent	Excellent seed line inside of maintenance room
10/30/2012	11.4	>500	<0.2	0.0	Fair	Fair debris line near base of Statue of Liberty
10/30/2012	11.1	>500	<0.2	--	Good	Good seed line inside door of Immigration Museum
10/30/2012	11.1	>500	<0.2	0.0	Poor	Poor debris line on grass hill
10/30/2012	11.0	>500	<0.2	2.5	Excellent	Excellent seed line on glass door inside brick building
10/30/2012	11.2	>500	<0.2	2.0	Excellent	Excellent seed line inside shed
10/30/2012	11.6	<100	>1	--	Good	Good mud line on outside window of building

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[9,10,11]New York City
166	HWM–NY–NEW–101	40.70110	-74.01500	VE	6.4	7.9	8.6	10.8	11.9
167	HWM–NY–NEW–102	40.70440	-74.01690	AE	6.3	7.9	8.6	10.8	9.9
168	HWM–NY–NEW–103	40.70440	-74.01670	AE	6.3	7.9	8.6	10.8	8.9
169	HWM–NY–NEW–104	40.70310	-74.00690	VE	6.4	7.9	8.6	10.8	11.9
170	HWM–NY–NEW–105	40.70500	-74.00670	AE	6.4	7.9	8.6	10.8	8.9
171	HWM–NY–NEW–106	40.70500	-74.00670	AE	6.4	7.9	8.6	10.8	8.9
172	HWM–NY–NEW–107	40.70500	-74.00640	AE	6.4	7.9	8.6	10.8	9.9
173	HWM–NY–NEW–108	40.70780	-74.00390	X	--	--	--	10.7	--
174	HWM–NY–NEW–109	40.70780	-74.00110	AE	6.2	7.8	8.5	10.7	9.9
175	HWM–NY–NEW–110	40.70780	-74.00220	AE	6.2	7.8	8.5	10.7	9.9
176	HWM–NY–NEW–111	40.70780	-74.00220	AE	6.2	7.8	8.5	10.7	9.9
177	HWM–NY–NEW–112	40.70970	-73.99530	AE	6.2	7.8	8.5	10.7	8.9
178	HWM–NY–NEW–113	40.71080	-73.97810	X	--	--	--	10.7	--
179	HWM–NY–NEW–114	40.71080	-73.97810	X	--	--	--	10.7	--
180	HWM–NY–NEW–115	40.71080	-73.97810	X	--	--	--	10.7	--
181	HWM–NY–NEW–116	40.71110	-73.97720	AE	6.2	7.8	8.5	10.7	8.9
182	HWM–NY–NEW–117	40.71110	-73.97720	AE	6.2	7.8	8.5	10.7	8.9
183	HWM–NY–NEW–118	40.71110	-73.97720	AE	6.2	7.8	8.5	10.7	8.9
184	HWM–NY–NEW–119	40.71110	-73.97720	AE	6.2	7.8	8.5	10.7	8.9
185	HWM–NY–NEW–120	40.71640	-74.01610	X	--	--	--	10.8	--
186	HWM–NY–NEW–121	40.71640	-74.01670	AE	6.3	7.9	8.6	10.8	8.9
187	HWM–NY–NEW–122	40.71810	-74.01470	X	--	--	--	10.8	--
188	HWM–NY–NEW–123	40.71830	-74.01500	X	--	--	--	10.8	--
189	HWM–NY–NEW–124	40.71690	-74.01190	X	--	--	--	10.8	--
190	HWM–NY–NEW–125	40.71690	-74.01250	AE	6.3	7.9	8.6	10.8	8.9
191	HWM–NY–NEW–126	40.71640	-74.01360	AE	6.3	7.9	8.6	10.8	8.9
192	HWM–NY–NEW–127	40.71310	-74.01390	AE	6.3	7.9	8.6	10.8	8.9
193	HWM–NY–NEW–128	40.72080	-74.01140	X	--	--	--	10.8	--
194	HWM–NY–NEW–802	40.87700	-73.92600	X	--	--	--	10.7	--
195	HWM–NY–NEW–803	40.86800	-73.91190	X	--	--	--	10.7	--
196	HWM–NY–NEW–806	40.79660	-73.91550	AE	8.1	10.2	11.4	14.3	12.9
197	HWM–NY–NEW–981	40.80059	-73.92647	AE	7.7	9.3	10.2	13.0	9.9
198	HWM–NY–QUE–001	40.71556	-73.92056	AE	6.1	7.7	8.5	10.9	8.9
199	HWM–NY–QUE–006	40.74922	-73.84072	AE	8.1	10.2	11.4	14.5	11.9
200	HWM–NY–QUE–007	40.59296	-73.79644	AE	4.9	6.1	6.8	8.6	6.9
201	HWM–NY–QUE–501	40.77994	-73.74918	VE	8.9	11.4	12.7	15.6	13.9
202	HWM–NY–QUE–502	40.77994	-73.74918	VE	8.9	11.4	12.7	15.6	13.9
203	HWM–NY–QUE–503	40.79284	-73.84929	AE	8.6	10.9	12.1	15.1	13.9
204	HWM–NY–QUE–505	40.74169	-73.95904	AE	6.1	7.7	8.5	10.9	8.9
205	HWM–NY–QUE–506	40.77227	-73.93600	AE	7.0	8.0	9.7	12.3	9.9
206	HWM–NY–QUE–507	40.66155	-73.84439	X	--	--	--	8.6	--
207	HWM–NY–QUE–508	40.65267	-73.84222	X	--	--	--	8.6	--
208	HWM–NY–QUE–509	40.78615	-73.91531	AE	7.4	9.3	10.3	13.0	10.9
209	HWM–NY–QUE–520	40.79645	-73.82899	VE	8.6	10.9	12.1	15.1	14.9

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	11.4	<100	>1	--	Good	Good mud line on patio of building
10/30/2012	10.0	>100 & <500	<1 & >0.2	--	Good	Good mud line inside steel storage container
10/30/2012	11.0	>500	<0.2	--	Fair	Fair seed line on wooden construction wall
10/30/2012	11.3	<100	>1	--	Good	Good seed line inside window of ferry terminal building
10/30/2012	11.1	>500	<0.2	--	Fair	Fair seed line on outside wall of building
10/30/2012	11.2	>500	<0.2	--	Fair	Fair seed line on outside wall of building
10/30/2012	11.2	>500	<0.2	--	Fair	Fair mud line on inside window of building
10/30/2012	11.1	>500	<0.2	--	Good	Good seed line on outside door of Post Office
10/30/2012	11.0	>500	<0.2	--	Good	Good seed line on outside wall of building
10/30/2012	11.1	>500	<0.2	--	Good	Good mud line on outside door of building
10/30/2012	11.1	>500	<0.2	--	Excellent	Excellent mud line on outside window of building
10/30/2012	11.2	>500	<0.2	--	Fair	Fair seed and mud line on outside wall of building
10/30/2012	11.2	>500	<0.2	0.0	Poor	Poor debris line on park lawn
10/30/2012	10.9	>500	<0.2	0.0	Poor	Poor debris line on grass hill in park
10/30/2012	10.9	>500	<0.2	--	Fair	Fair seed line on tree in park
10/30/2012	10.9	>500	<0.2	0.0	Poor	Poor debris line on grass hill in park
10/30/2012	10.9	>500	<0.2	0.0	Poor	Poor debris line on grass hill in park
10/30/2012	11.0	>500	<0.2	0.0	Poor	Poor debris line on hill in park under tree
10/30/2012	10.9	>500	<0.2	0.0	Fair	Fair debris line on park sidewalk
10/30/2012	10.9	>500	<0.2	0.0	Poor	Poor debris line on grass
10/30/2012	10.9	>500	<0.2	0.0	Poor	Poor wash line on mulch
10/30/2012	11.3	>500	<0.2	0.0	Poor	Poor debris line in garden
10/30/2012	11.1	>500	<0.2	0.0	Poor	Poor debris line in garden
10/30/2012	10.9	>500	<0.2	1.0	Excellent	Excellent seed line on loading dock
10/30/2012	10.6	500	0.2	1.5	Fair	Fair seed line on outside door of building
10/30/2012	9.8	>100 & <500	<1 & >0.2	4.3	Good	Good seed line on outside wall of building
10/30/2012	9.7	>100 & <500	<1 & >0.2	4.7	Good	Good mud line on window of building
10/30/2012	10.8	500	0.2	1.0	Excellent	Excellent mud line on outside door of building
10/30/2012	9.5	<500	>0.2	0.0	Good	Good debris line on beach
10/30/2012	9.0	<500	>0.2	2.1	Excellent	Excellent seed line on guard booth
10/30/2012	11.1	90	1.1	3.1	Fair	Fair debris line on side of fence
10/30/2012	10.3	>100 & <500	<1 & >0.2	3.8	Fair	Fair seed line inside storage container inside chain link fenced area of New York Police Department marina
10/30/2012	10.9	500	0.2	6.0	Excellent	Excellent mud line on door of storage container
10/30/2012	7.8	<10	>10	0.0	Fair	Fair debris line on lawn
10/30/2012	10.7	>500	<0.2	4.5	Good	Good debris line on fence
10/30/2012	10.3	<100	>1	3.5	Good	Good seed line on power pole in park
10/30/2012	10.3	<100	>1	2.1	Good	Good seed line on house garage
10/30/2012	10.1	40	2.5	0.0	Good	Good wash line in park
10/30/2012	10.7	500	0.2	5.0	Good	Good seed line on Amtrak facility
10/30/2012	10.9	>100 & <500	<1 & >0.2	4.0	Good	Good seed line on windows and brick of apartment building
10/30/2012	10.9	>500	<0.2	2.5	Good	Good seed line on fence
10/30/2012	10.8	>500	<0.2	2.7	Good	Good seed line on fence
10/30/2012	10.5	>100 & <500	<1 & >0.2	0.0	Poor	Poor wash line on green space in park
10/30/2012	10.8	<100	>1	0.3	Poor	Poor debris line on seawall

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[9,10,11]New York City—Continued
210	HWM–NY–QUE–521	40.79351	-73.78057	AE	8.8	11.3	12.6	15.6	12.9
211	HWM–NY–QUE–603	40.75974	-73.84864	AE	8.1	10.2	11.4	14.5	12.9
212	HWM–NY–QUE–713	40.61659	-73.82547	X	--	--	--	8.6	--
213	HWM–NY–QUE–714	40.60587	-73.82204	AE	4.9	6.1	6.8	8.6	7.9
214	HWM–NY–QUE–726	40.56779	-73.88247	X	--	--	--	9.9	--
215	HWM–NY–QUE–727	40.56537	-73.88331	X	--	--	--	9.9	--
216	HWM–NY–QUE–728	40.56111	-73.91431	AE	5.5	7.0	7.8	9.9	7.9
217	HWM–NY–QUE–729	40.55532	-73.92529	AE	5.5	7.0	7.8	9.9	8.9
218	HWM–NY–QUE–730	40.57632	-73.85982	AE	4.9	6.1	6.8	8.6	6.9
219	HWM–NY–QUE–731	40.58243	-73.83450	X	--	--	--	8.6	--
220	HWM–NY–QUE–732	40.59512	-73.74139	AE	6.3	8.0	8.7	11.1	9.9
221	HWM–NY–QUE–907	40.56704	-73.88283	X	--	--	--	9.9	--
222	HWM–NY–QUE–910	40.63739	-73.74588	AE	4.9	6.1	6.8	8.6	6.9
223	HWM–NY–RIC–001	40.59244	-74.16630	A	5.4	6.9	7.5	9.3	--
224	HWM–NY–RIC–701	40.58222	-74.09851	AE	6.3	7.9	8.6	10.8	8.9
225	HWM–NY–RIC–702	40.50242	-74.25388	X	--	--	--	11.2	--
226	HWM–NY–RIC–703	40.49965	-74.24120	AE	6.7	8.4	9.2	11.3	10.0
227	HWM–NY–RIC–704	40.50235	-74.23121	X	--	--	--	11.3	--
228	HWM–NY–RIC–705	40.51544	-74.19444	X	--	--	--	11.3	--
229	HWM–NY–RIC–716	40.51153	-74.21036	X	--	--	--	11.3	--
230	HWM–NY–RIC–717	40.52844	-74.15887	X	--	--	--	11.2	--
231	HWM–NY–RIC–718	40.55526	-74.11662	AE	6.4	8.0	8.8	10.9	9.9
232	HWM–NY–RIC–719	40.59386	-74.06829	X	--	--	--	10.8	--
233	HWM–NY–RIC–720	40.61564	-74.06305	X	--	--	--	10.7	--
234	HWM–NY–RIC–721	40.63772	-74.07386	X	--	--	--	10.7	--
235	HWM–NY–RIC–722	40.64679	-74.08955	X	--	--	--	9.8	--
236	HWM–NY–RIC–723	40.64117	-74.13595	X	--	--	--	8.4	--
237	HWM–NY–RIC–982	40.54583	-74.12383	X	--	--	--	10.9	--
									[12]New York City
127	HWM–NY–BRO–804	40.84280	-73.92900	AE	6.7	9.0	10.0	12.4	10
128	HWM–NY–BRO–805	40.82300	-73.93220	AE	7.2	9.5	10.4	12.6	10
129	HWM–NY–BRO–807	40.80470	-73.90230	VE	9.3	11.9	12.9	15.1	15
130	HWM–NY–BRO–808	40.80700	-73.87000	AE	9.6	12.0	13.0	15.2	14
131	HWM–NY–BRO–809	40.81540	-73.83860	AE	9.6	12.0	12.9	14.8	14
132	HWM–NY–BRO–810	40.80920	-73.80370	VE	9.7	12.0	12.9	14.8	16
133	HWM–NY–BRO–811	40.86470	-73.80200	AE	9.8	12.2	13.1	15.1	13
134	HWM–NY–KIN–001	40.64076	-74.03564	AE	7.0	10.0	11.4	14.8	12
135	HWM–NY–KIN–002	40.71637	-73.92492	AE	6.9	9.0	10.2	12.8	10
136	HWM–NY–KIN–003	40.64454	-73.88815	AE	6.7	9.8	10.1	13.1	10
137	HWM–NY–KIN–504	40.70396	-73.99049	AE	6.6	9.6	11.0	14.3	13
138	HWM–NY–KIN–510	40.71887	-73.96524	AE	6.8	9.5	10.8	13.9	12
139	HWM–NY–KIN–511	40.66879	-74.00956	AE	7.3	9.8	11.2	14.8	13
140	HWM–NY–KIN–604	40.70400	-73.98944	AE	6.7	9.6	10.7	14.1	12
141	HWM–NY–KIN–605	40.70400	-73.98944	AE	6.7	9.6	10.7	14.1	12
142	HWM–NY–KIN–715	40.57941	-74.01118	AE	7.0	9.9	11.4	15.0	12
143	HWM–NY–KIN–724	40.66524	-74.01270	AE	6.9	9.9	11.3	14.8	13
144	HWM–NY–KIN–725	40.67541	-73.99099	AE	6.6	8.8	10.3	13.8	11

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	10.6	40	2.5	0.0	Poor	Poor debris line on grass
10/30/2012	10.5	60	1.7	0.0	Poor	Poor debris line in parking lot
10/29/2012	10.3	>500	<0.2	0.0	Good	Good debris line
10/29/2012	10.3	>500	<0.2	1.3	Excellent	Excellent mud line on wall inside house
10/30/2012	10.5	>500	<0.2	0.0	Excellent	Excellent debris line
10/30/2012	10.8	>500	<0.2	0.0	Fair	Fair debris line in parking lot
10/29/2012	10.7	>500	<0.2	3.6	Excellent	Excellent mud line on wall inside building
10/30/2012	12.7	>500	<0.2	5.4	Excellent	Excellent mud line on side of house
10/30/2012	11.2	>500	<0.2	5.4	Excellent	Excellent wash line in front of building
10/30/2012	10.3	>500	<0.2	--	Fair	Fair mud line on wall
10/30/2012	9.0	>100 & <500	<1 & >0.2	--	Good	Good seed line on side of building
10/30/2012	11.0	>500	<0.2	4.2	Excellent	Excellent seed line on inside of doorway
10/30/2012	10.6	>500	<0.2	4.6	Good	Good seed line on inside side of concrete wall
10/30/2012	12.3	>500	<0.2	4.3	Excellent	Excellent seed line on wall of garage
10/30/2012	12.5	>500	<0.2	4.7	Fair	Fair seed line on side of fence
10/30/2012	13.1	>500	<0.2	0.0	Good	Good debris line on grass
10/29/2012	13.2	>500	<0.2	5.5	Fair	Fair seed line on side of fence
10/29/2012	13.2	>500	<0.2	0.0	Good	Good debris line on lawn
10/30/2012	13.0	>500	<0.2	0.0	Fair	Fair debris line on lawn
10/30/2012	13.1	>500	<0.2	1.0	Excellent	Excellent seed line on wooden guard rail
10/30/2012	16.9	>500	<0.2	0.0	Fair	Fair debris line on grass
10/30/2012	12.5	>500	<0.2	7.9	Excellent	Excellent seed line on door frame of house
10/30/2012	12.7	>500	<0.2	2.5	Excellent	Excellent seed line on garage door
10/30/2012	15.3	>500	<0.2	0.0	Excellent	Excellent debris line
10/30/2012	11.7	>500	<0.2	0.0	Good	Good debris line
10/30/2012	11.7	>500	<0.2	0.0	Excellent	Excellent debris line
10/30/2012	11.5	>500	<0.2	0.0	Fair	Fair debris line on lawn
10/30/2012	14.0	>500	<0.2	0.0	Poor	Poor debris line in grass
10/30/2012	9.7	90	1.1	2.1	Excellent	Excellent seed line on side of fence
10/30/2012	9.9	70	1.4	0.0	Good	Good mud line on concrete path
10/30/2012	10.6	<100	>1	1.0	Good	Good seed line inside guard booth
10/30/2012	10.3	20	5.0	0.0	Good	Good debris line in grass field
10/30/2012	10.7	30	3.3	3.4	Fair	Fair debris line on fence
10/30/2012	10.4	<100	>1	0.0	Good	Good debris line on grass
10/30/2012	10.2	20	5.0	0.0	Good	Good debris line on grass
10/30/2012	11.3	100	1.0	0.4	Good	Good seed line on inside door to shed
10/30/2012	10.9	>100 & <500	<1 & >0.2	2.2	Good	Good mud line on door of building
10/30/2012	11.0	>100 & <500	<1 & >0.2	4.1	Good	Good seed line on garage door of house
10/30/2012	11.3	>100 & <500	<1 & >0.2	4.4	Good	Good seed line in window of Bubby’s Restaurant and Bar
10/30/2012	11.2	>100 & <500	<1 & >0.2	2.6	Good	Good seed line inside of office building
10/30/2012	11.2	100	1.0	4.1	Good	Good mud line on metal door inside concrete building
10/30/2012	11.0	>100 & <500	<1 & >0.2	1.6	Good	Good seed line on front of building
10/30/2012	10.9	>100 & <500	<1 & >0.2	--	Good	Good seed line on back of guard booth
10/29/2012	12.4	>100 & <500	<1 & >0.2	--	Excellent	Excellent mud line on outside of house
10/29/2012	11.3	100	1.0	3.6	Good	Good seed line on side of building
10/29/2012	9.8	80	1.3	3.2	Excellent	Excellent mud line on side of building

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[12]New York City—Continued
145	HWM–NY–KIN–900	40.66725	-74.00001	AE	6.6	9.7	11.2	14.7	12
146	HWM–NY–KIN–901	40.66111	-74.00556	AE	6.9	9.7	11.2	14.6	12
147	HWM–NY–KIN–902	40.65583	-74.01619	AE	6.7	9.9	11.3	14.8	13
148	HWM–NY–KIN–903	40.61089	-74.03629	AE	7.1	10.0	11.3	14.7	11
149	HWM–NY–KIN–904	40.59519	-74.00007	AE	7.0	9.8	10.8	14.5	11
150	HWM–NY–KIN–905	40.58019	-73.99792	AE	7.0	9.7	11.0	14.2	12
151	HWM–NY–KIN–906	40.58940	-73.92607	AE	6.6	9.5	10.5	13.6	10
152	HWM–NY–KIN–908	40.60743	-73.89626	AE	6.7	9.1	10.2	13.0	11
153	HWM–NY–KIN–909	40.65948	-73.86370	AE	6.5	9.0	10.3	13.0	10
154	HWM–NY–NEW–001	40.77760	-73.94250	AE	8.2	10.8	11.9	14.6	15
155	HWM–NY–NEW–002	40.82800	-73.95420	AE	5.8	8.4	9.7	12.9	10
156	HWM–NY–NEW–003	40.74070	-74.01170	VE	6.6	9.4	10.9	14.3	16
157	HWM–NY–NEW–004	40.76312	-74.00047	AE	6.6	9.2	10.6	14.1	12
158	HWM–NY–NEW–005	40.74013	-73.97328	AE	7.0	9.7	10.9	14.0	12
159	HWM–NY–NEW–008	40.69035	-74.04692	VE	6.9	10.0	11.4	15.0	14
160	HWM–NY–NEW–009	40.68971	-74.04387	AE	6.9	9.9	11.3	14.7	12
161	HWM–NY–NEW–010	40.69912	-74.03992	AE	6.9	9.8	11.3	14.9	12
162	HWM–NY–NEW–011	40.69938	-74.03867	VE	6.9	10.3	11.3	14.7	13
163	HWM–NY–NEW–012	40.69086	-74.01246	AE	6.9	9.7	11.1	14.7	12
164	HWM–NY–NEW–013	40.68527	-74.02489	AE	6.9	9.8	11.2	14.8	12
165	HWM–NY–NEW–100	40.70110	-74.01560	VE	6.9	9.9	11.4	15.0	16
166	HWM–NY–NEW–101	40.70110	-74.01500	VE	6.9	9.9	11.3	14.9	14
167	HWM–NY–NEW–102	40.70440	-74.01690	AE	6.5	9.9	11.2	14.8	12
168	HWM–NY–NEW–103	40.70440	-74.01670	AE	6.5	9.9	11.1	14.8	12
169	HWM–NY–NEW–104	40.70310	-74.00690	VE	6.8	9.8	11.2	14.8	15
170	HWM–NY–NEW–105	40.70500	-74.00670	AE	6.6	9.8	11.2	14.8	12
171	HWM–NY–NEW–106	40.70500	-74.00670	AE	6.6	9.8	11.2	14.8	12
172	HWM–NY–NEW–107	40.70500	-74.00640	AE	6.6	9.8	11.2	14.8	12
173	HWM–NY–NEW–108	40.70780	-74.00390	AE	6.6	9.8	11.2	14.7	12
174	HWM–NY–NEW–109	40.70780	-74.00110	AE	6.7	9.7	11.1	14.6	12
175	HWM–NY–NEW–110	40.70780	-74.00220	AE	6.7	9.8	11.2	14.6	12
176	HWM–NY–NEW–111	40.70780	-74.00220	AE	6.7	9.8	11.2	14.6	12
177	HWM–NY–NEW–112	40.70970	-73.99530	AE	6.8	9.7	11.0	14.5	13
178	HWM–NY–NEW–113	40.71080	-73.97810	AE	6.8	9.6	10.8	13.9	12
179	HWM–NY–NEW–114	40.71080	-73.97810	AE	6.8	9.6	10.8	13.9	12
180	HWM–NY–NEW–115	40.71080	-73.97810	AE	6.8	9.6	10.8	13.9	12
181	HWM–NY–NEW–116	40.71110	-73.97720	VE	6.9	9.6	10.9	13.9	14
182	HWM–NY–NEW–117	40.71110	-73.97720	VE	6.9	9.6	10.9	13.9	14
183	HWM–NY–NEW–118	40.71110	-73.97720	VE	6.9	9.6	10.9	13.9	14
184	HWM–NY–NEW–119	40.71110	-73.97720	VE	6.9	9.6	10.9	13.9	14
185	HWM–NY–NEW–120	40.71640	-74.01610	X	--	--	--	14.5	--
186	HWM–NY–NEW–121	40.71640	-74.01670	X	--	--	--	14.5	--
187	HWM–NY–NEW–122	40.71810	-74.01470	X	--	--	--	14.4	--
188	HWM–NY–NEW–123	40.71830	-74.01500	X	--	--	--	14.4	--
189	HWM–NY–NEW–124	40.71690	-74.01190	AE	6.5	9.7	10.8	14.3	11

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	11.0	90	1.1	--	Fair	Fair debris line on chain link fence
10/30/2012	11.2	100	1.0	3.0	Fair	Fair wash line in compost
10/30/2012	11.5	>100 & <500	<1 & >0.2	4.5	Fair	Fair seed line on trailer
10/30/2012	12.9	>100 & <500	<1 & >0.2	0.0	Poor	Poor debris line
10/30/2012	11.5	>100 & <500	<1 & >0.2	1.1	Excellent	Excellent seed line on wall inside building
10/30/2012	11.5	>100 & <500	<1 & >0.2	0.0	Good	Good debris line around hill side
10/30/2012	10.9	>100 & <500	<1 & >0.2	4.0	Excellent	Excellent seed line on side of house
10/30/2012	11.2	>100 & <500	<1 & >0.2	3.6	Good	Good seed line on trailer
10/30/2012	10.0	90	1.1	1.1	Excellent	Excellent mud line on inside of security hut
10/30/2012	10.4	40	2.5	2.4	Poor	Poor debris line in ornamental grass
10/30/2012	9.5	90	1.1	0.0	Fair	Fair debris line on lawn
10/30/2012	12.3	<100	>1	--	Fair	Fair mud line on interior wall of fire house
10/30/2012	10.4	90	1.1	2.6	Excellent	Excellent seed line on building
10/30/2012	10.8	90	1.1	2.5	Good	Good debris line on fence
10/30/2012	11.3	<100	>1	4.1	Excellent	Excellent seed line inside of maintenance room
10/30/2012	11.4	>100 & <500	<1 & >0.2	0.0	Fair	Fair debris line near base of Statue of Liberty
10/30/2012	11.1	90	1.1	--	Good	Good seed line inside door of Immigration Museum
10/30/2012	11.1	<100	>1	0.0	Poor	Poor debris line on grass hill
10/30/2012	11.0	100	1.0	2.5	Excellent	Excellent seed line on glass door inside brick building
10/30/2012	11.2	100	1.0	2.0	Excellent	Excellent seed line inside shed
10/30/2012	11.6	<100	>1	--	Good	Good mud line on outside window of building
10/30/2012	11.4	<100	>1	--	Good	Good mud line on patio of building
10/30/2012	10.0	50	2.0	--	Good	Good mud line inside steel storage container
10/30/2012	11.0	100	1.0	--	Fair	Fair seed line on wooden construction wall
10/30/2012	11.3	<100	>1	--	Good	Good seed line inside window of ferry terminal building
10/30/2012	11.1	100	1.0	--	Fair	Fair seed line on outside wall of building
10/30/2012	11.2	100	1.0	--	Fair	Fair seed line on outside wall of building
10/30/2012	11.2	100	1.0	--	Fair	Fair mud line on inside window of building
10/30/2012	11.1	100	1.0	--	Good	Good seed line on outside door of Post Office
10/30/2012	11.0	100	1.0	--	Good	Good seed line on outside wall of building
10/30/2012	11.1	100	1.0	--	Good	Good mud line on outside door of building
10/30/2012	11.1	100	1.0	--	Excellent	Excellent mud line on outside window of building
10/30/2012	11.2	>100 & <500	<1 & >0.2	--	Fair	Fair seed and mud line on outside wall of building
10/30/2012	11.2	>100 & <500	<1 & >0.2	0.0	Poor	Poor debris line on park lawn
10/30/2012	10.9	>100 & <500	<1 & >0.2	0.0	Poor	Poor debris line on grass hill in park
10/30/2012	10.9	>100 & <500	<1 & >0.2	--	Fair	Fair seed line on tree in park
10/30/2012	10.9	<100	>1	0.0	Poor	Poor debris line on grass hill in park
10/30/2012	10.9	<100	>1	0.0	Poor	Poor debris line on grass hill in park
10/30/2012	11.0	<100	>1	0.0	Poor	Poor debris line on hill in park under tree
10/30/2012	10.9	<100	>1	0.0	Fair	Fair debris line on park sidewalk
10/30/2012	10.9	<500	>0.2	0.0	Poor	Poor debris line on grass
10/30/2012	10.9	<500	>0.2	0.0	Poor	Poor wash line on mulch
10/30/2012	11.3	<500	>0.2	0.0	Poor	Poor debris line in garden
10/30/2012	11.1	<500	>0.2	0.0	Poor	Poor debris line in garden
10/30/2012	10.9	>100 & <500	<1 & >0.2	1.0	Excellent	Excellent seed line on loading dock

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[12]New York City—Continued
190	HWM–NY–NEW–125	40.71690	-74.01250	AE	6.5	9.7	10.9	14.4	11
191	HWM–NY–NEW–126	40.71640	-74.01360	AE	6.7	9.7	10.8	14.4	11
192	HWM–NY–NEW–127	40.71310	-74.01390	AE	6.8	9.8	10.4	14.3	11
193	HWM–NY–NEW–128	40.72080	-74.01140	AE	7.5	9.6	11.0	14.5	11
194	HWM–NY–NEW–802	40.87700	-73.92600	VE	5.6	8.2	9.4	12.5	12
195	HWM–NY–NEW–803	40.86800	-73.91190	AE	6.0	8.7	9.5	12.5	10
196	HWM–NY–NEW–806	40.79660	-73.91550	VE	9.4	11.9	12.9	15.3	16
197	HWM–NY–NEW–981	40.80059	-73.92647	AE	7.9	10.3	11.4	13.8	12
198	HWM–NY–QUE–001	40.71556	-73.92056	AE	6.9	8.9	10.1	12.7	10
199	HWM–NY–QUE–006	40.74922	-73.84072	AE	9.2	10.9	11.5	12.6	12
200	HWM–NY–QUE–007	40.59296	-73.79644	AE	6.5	8.3	9.2	11.8	9
201	HWM–NY–QUE–501	40.77994	-73.74918	AE	9.7	11.8	12.7	14.4	14
202	HWM–NY–QUE–502	40.77994	-73.74918	AE	9.7	11.8	12.7	14.4	14
203	HWM–NY–QUE–503	40.79284	-73.84929	AE	9.7	12.0	13.0	15.0	14
204	HWM–NY–QUE–505	40.74169	-73.95904	AE	6.9	9.6	10.8	13.7	11
205	HWM–NY–QUE–506	40.77227	-73.93600	AE	8.0	10.5	11.6	14.2	12
206	HWM–NY–QUE–507	40.66155	-73.84439	AE	6.5	8.8	9.9	12.8	10
207	HWM–NY–QUE–508	40.65267	-73.84222	AE	6.5	8.7	9.8	12.5	10
208	HWM–NY–QUE–509	40.78615	-73.91531	AE	9.0	11.4	12.5	14.9	14
209	HWM–NY–QUE–520	40.79645	-73.82899	VE	9.7	11.9	12.8	14.7	15
210	HWM–NY–QUE–521	40.79351	-73.78057	VE	9.8	12.1	12.9	14.8	16
211	HWM–NY–QUE–603	40.75974	-73.84864	AE	9.7	12.0	12.9	14.9	14
212	HWM–NY–QUE–713	40.61659	-73.82547	X	--	--	--	12.0	--
213	HWM–NY–QUE–714	40.60587	-73.82204	AE	6.3	8.7	9.6	12.0	10
214	HWM–NY–QUE–726	40.56779	-73.88247	AE	6.7	8.7	9.9	12.7	11
215	HWM–NY–QUE–727	40.56537	-73.88331	X	6.7	8.7	9.8	13.0	--
216	HWM–NY–QUE–728	40.56111	-73.91431	AE	6.7	9.3	10.6	13.7	12
217	HWM–NY–QUE–729	40.55532	-73.92529	AE	6.5	9.5	11.0	14.7	11
218	HWM–NY–QUE–730	40.57632	-73.85982	AE	6.6	8.9	10.0	12.6	10
219	HWM–NY–QUE–731	40.58243	-73.83450	AE	6.5	8.6	9.6	12.1	10
220	HWM–NY–QUE–732	40.59512	-73.74139	AE	6.0	8.5	10.0	14.0	11
221	HWM–NY–QUE–907	40.56704	-73.88283	AE	6.7	8.5	9.8	12.7	11
222	HWM–NY–QUE–910	40.63739	-73.74588	AE	6.3	8.4	9.4	11.8	10
223	HWM–NY–RIC–001	40.59244	-74.16630	AE	7.3	10.2	11.6	14.7	12
224	HWM–NY–RIC–701	40.58222	-74.09851	AE	7.2	10.6	11.7	15.9	12
225	HWM–NY–RIC–702	40.50242	-74.25388	X	--	--	--	16.5	--
226	HWM–NY–RIC–703	40.49965	-74.24120	AE	8.7	11.3	13.0	16.7	14
227	HWM–NY–RIC–704	40.50235	-74.23121	X	--	--	--	16.3	--
228	HWM–NY–RIC–705	40.51544	-74.19444	X	--	--	--	16.3	--
229	HWM–NY–RIC–716	40.51153	-74.21036	X	--	--	--	16.2	--
230	HWM–NY–RIC–717	40.52844	-74.15887	X	--	--	--	15.8	--
231	HWM–NY–RIC–718	40.55526	-74.11662	AE	7.4	10.4	11.9	15.8	13
232	HWM–NY–RIC–719	40.59386	-74.06829	X	--	--	--	15.5	--
233	HWM–NY–RIC–720	40.61564	-74.06305	X	--	--	--	14.7	--

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	10.6	90	1.1	1.5	Fair	Fair seed line on outside door of building
10/30/2012	9.8	50	2.0	4.3	Good	Good seed line on outside wall of building
10/30/2012	9.7	50	2.0	4.7	Good	Good mud line on window of building
10/30/2012	10.8	90	1.1	1.0	Excellent	Excellent mud line on outside door of building
10/30/2012	9.5	<100	>1	0.0	Good	Good debris line on beach
10/30/2012	9.0	70	1.4	2.1	Excellent	Excellent seed line on guard booth
10/30/2012	11.1	<100	>1	3.1	Fair	Fair debris line on side of fence
10/30/2012	10.3	50	2.0	3.8	Fair	Fair seed line inside storage container inside chain link fenced area of New York Police Department marina
10/30/2012	10.9	>100 & <500	<1 & >0.2	6.0	Excellent	Excellent mud line on door of storage container
10/30/2012	7.8	<10	>10	0.0	Fair	Fair debris line on lawn
10/30/2012	10.7	>100 & <500	<1 & >0.2	4.5	Good	Good debris line on fence
10/30/2012	10.3	20	5.0	3.5	Good	Good seed line on power pole in park
10/30/2012	10.3	20	5.0	2.1	Good	Good seed line on house garage
10/30/2012	10.1	20	5.0	0.0	Good	Good wash line in park
10/30/2012	10.7	100	1.0	5.0	Good	Good seed line on Amtrak facility
10/30/2012	10.9	70	1.4	4.0	Good	Good seed line on windows and brick of apartment building
10/30/2012	10.9	>100 & <500	<1 & >0.2	2.5	Good	Good seed line on fence
10/30/2012	10.8	>100 & <500	<1 & >0.2	2.7	Good	Good seed line on fence
10/30/2012	10.5	30	3.3	0.0	Poor	Poor wash line on green space in park
10/30/2012	10.8	<100	>1	0.3	Poor	Poor debris line on seawall
10/30/2012	10.6	<100	>1	0.0	Poor	Poor debris line on grass
10/30/2012	10.5	20	5.0	0.0	Poor	Poor debris line in parking lot
10/29/2012	10.3	<500	>0.2	0.0	Good	Good debris line
10/29/2012	10.3	>100 & <500	<1 & >0.2	1.3	Excellent	Excellent mud line on wall inside house
10/30/2012	10.5	>100 & <500	<1 & >0.2	0.0	Excellent	Excellent debris line
10/30/2012	10.8	>100 & <500	<1 & >0.2	0.0	Fair	Fair debris line in parking lot
10/29/2012	10.7	>100 & <500	<1 & >0.2	3.6	Excellent	Excellent mud line on wall inside building
10/30/2012	12.7	>100 & <500	<1 & >0.2	5.4	Excellent	Excellent mud line on side of house
10/30/2012	11.2	>100 & <500	<1 & >0.2	5.4	Excellent	Excellent wash line in front of building
10/30/2012	10.3	>100 & <500	<1 & >0.2	--	Fair	Fair mud line on wall
10/30/2012	9.0	70	1.4	--	Good	Good seed line on side of building
10/30/2012	11.0	>100 & <500	<1 & >0.2	4.2	Excellent	Excellent seed line on inside of doorway
10/30/2012	10.6	>100 & <500	<1 & >0.2	4.6	Good	Good seed line on inside side of concrete wall
10/30/2012	12.3	>100 & <500	<1 & >0.2	4.3	Excellent	Excellent seed line on wall of garage
10/30/2012	12.5	>100 & <500	<1 & >0.2	4.7	Fair	Fair seed line on side of fence
10/30/2012	13.1	<500	>0.2	0.0	Good	Good debris line on grass
10/29/2012	13.2	>100 & <500	<1 & >0.2	5.5	Fair	Fair seed line on side of fence
10/29/2012	13.2	<500	>0.2	0.0	Good	Good debris line on lawn
10/30/2012	13.0	<500	>0.2	0.0	Fair	Fair debris line on lawn
10/30/2012	13.1	<500	>0.2	1.0	Excellent	Excellent seed line on wooden guard rail
10/30/2012	16.9	>500	<0.2	0.0	Fair	Fair debris line on grass
10/30/2012	12.5	>100 & <500	<1 & >0.2	7.9	Excellent	Excellent seed line on door frame of house
10/30/2012	12.7	<500	>0.2	2.5	Excellent	Excellent seed line on garage door
10/30/2012	15.3	>500	<0.2	0.0	Excellent	Excellent debris line

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[12]New York City—Continued
234	HWM–NY–RIC–721	40.63772	-74.07386	AE	7.1	10.2	11.3	14.9	12
235	HWM–NY–RIC–722	40.64679	-74.08955	AE	7.1	10.0	11.3	14.5	11
236	HWM–NY–RIC–723	40.64117	-74.13595	X	--	--	--	13.3	--
237	HWM–NY–RIC–982	40.54583	-74.12383	X	--	--	--	15.8	--
									[5,13]Orange County
238	HWM–NY–ORA–001	41.50245	-74.00505	AE	5.6	6.3	7.3	8.8	7
239	HWM–NY–ORA–002	41.50418	-74.00480	AE	5.6	6.3	7.3	8.8	7
240	HWM–NY–ORA–003	41.50464	-74.00516	X	--	--	--	8.8	--
241	HWM–NY–ORA–004	41.38333	-73.95555	AE	5.6	6.3	7.3	8.8	7
									[3,14]Rensselaer County
242	[20]HWM–NY–REN–001	42.52867	-73.75733	A13	10.2	13.8	15.6	19.6	17.2
243	[21]HWM–NY–REN–003	42.52869	-73.75786	A13	10.2	13.8	15.6	19.6	17.2
244	[22]HWM–NY–REN–004	42.52892	-73.75864	A13	10.2	13.8	15.6	19.6	17.2
									[5,15]Rockland County
245	HWM–NY–ROC–001	41.23012	-73.97685	X	--	--	--	7.9	--
246	HWM–NY–ROC–002	41.23009	-73.97685	X	--	--	--	7.9	--
247	HWM–NY–ROC–003	41.23006	-73.97678	X	--	--	--	7.9	--
248	HWM–NY–ROC–004	41.22990	-73.97688	X	--	--	--	7.9	--
249	HWM–NY–ROC–005	41.22989	-73.97697	X	--	--	--	7.9	--
250	HWM–NY–ROC–006	41.04324	-73.89656	VE	5.1	6.1	6.7	7.9	9
									[5,16]Suffolk County
279	HWM–NY–SUF–001	41.06098	-72.36782	X	--	--	--	9.0	--
280	HWM–NY–SUF–002	41.07394	-72.31890	X	--	--	--	9.8	--
281	HWM–NY–SUF–003	40.93250	-72.61556	X	--	--	--	9.6	--
282	[19]HWM–NY–SUF–005	40.96522	-72.77187	VE	5.9	7.4	10.7	10.9	13
283	HWM–NY–SUF–006	40.98249	-72.53289	X	--	--	--	9.6	--
284	HWM–NY–SUF–300	41.10103	-72.36118	VE	4.2	5.4	5.8	6.7	9
285	HWM–NY–SUF–301	41.10095	-72.36161	VE	4.2	5.4	5.8	6.7	9
286	[19]HWM–NY–SUF–302	41.13247	-72.25864	AE	4.0	5.2	8.1	9.8	8
287	HWM–NY–SUF–303	41.14333	-72.31273	AE	4.2	5.4	5.8	6.7	11
288	HWM–NY–SUF–304	41.14331	-72.31243	AE	4.2	5.4	5.8	6.7	8
289	HWM–NY–SUF–305	41.13070	-72.32822	X	--	--	--	6.7	--
290	HWM–NY–SUF–306	41.13118	-72.32848	AE	4.2	5.4	5.8	6.7	7
291	HWM–NY–SUF–307	40.98980	-72.47077	VE	4.0	5.2	5.5	9.6	8
292	HWM–NY–SUF–308	40.91593	-72.63776	X	--	--	--	9.6	--
293	HWM–NY–SUF–401	40.74750	-72.85490	AE	4.8	6.0	6.4	7.0	7
294	HWM–NY–SUF–402	40.75050	-73.01370	AE	4.2	4.7	4.9	5.4	5
295	HWM–NY–SUF–403	40.68530	-73.27990	VE	3.7	4.3	4.5	4.8	7
296	HWM–NY–SUF–404	40.65891	-73.26478	X	--	--	--	4.8	--
297	HWM–NY–SUF–405	40.69120	-73.27720	AE	3.7	4.3	4.5	4.8	4
298	HWM–NY–SUF–406	40.70527	-73.25255	AE	3.7	4.2	4.3	4.6	4
299	HWM–NY–SUF–407	40.71159	-73.24435	X	--	--	--	4.6	--
300	HWM–NY–SUF–408	40.91500	-72.66170	X	--	--	--	9.6	--
301	HWM–NY–SUF–409	40.90420	-72.61990	AE	4.8	6.1	6.7	9.6	8
302	HWM–NY–SUF–410	40.85040	-72.50380	AE	5.5	7.1	8.0	9.3	9

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	11.7	>100 & <500	<1 & >0.2	0.0	Good	Good debris line
10/30/2012	11.7	>100 & <500	<1 & >0.2	0.0	Excellent	Excellent debris line
10/30/2012	11.5	<500	>0.2	0.0	Fair	Fair debris line on lawn
10/30/2012	14.0	<500	>0.2	0.0	Poor	Poor debris line in grass
10/30/2012	8.9	>500	<0.2	1.9	Good	Good mud line on door of marina office building
10/30/2012	8.9	>500	<0.2	3.0	Good	Good seed line on inside of door to restroom of Newburgh Marina
10/30/2012	9.0	>500	<0.2	0.0	Fair	Fair wash line on ground in parking lot divider
10/30/2012	8.6	>100 & <500	<1 & >0.2	4.2	Fair	Fair seed line inside USGS streamgage—01374019—Hudson River at South Dock at West Point, NY
10/30/2012	10.0	<10	>10	2.6	Good	Good seed line on steel post
10/30/2012	10.1	<10	>10	2.2	Fair	Fair seed and mud line on small shed
10/30/2012	9.9	<10	>10	0.0	Poor	Poor debris line on grass
10/30/2012	10.3	>500	<0.2	0.0	Poor	Poor debris line on ground
10/30/2012	9.4	>500	<0.2	2.0	Fair	Fair seed line on back of house
10/30/2012	8.6	>500	<0.2	1.5	Good	Good seed line on inside of garage door
10/30/2012	9.4	>500	<0.2	--	Excellent	Excellent seed line on back of house in protected alcove
10/30/2012	11.1	>500	<0.2	0.0	Poor	Poor debris line on ground
10/30/2012	9.7	>100	<1	4.1	Good	Good seed line on interior wall of concrete instrument shelter
10/30/2012	6.6	<500	>0.2	0.0	Good	Good debris line in yard
10/30/2012	6.2	<500	>0.2	0.0	Excellent	Excellent wash line
10/30/2012	7.2	<500	>0.2	0.0	Good	Good debris line in front of house
10/29/2012	9.1	<100	>1	3.6	Excellent	Excellent mud line on garage door of house
10/29/2012	6.7	<500	>0.2	0.0	Good	Good wash line on lawn
10/29/2012	6.4	<100	>1	0.0	Good	Good debris line
10/29/2012	6.4	<100	>1	1.2	Excellent	Excellent seed line
10/29/2012	6.2	70	1.4	2.0	Excellent	Excellent seed line on wall inside building
10/29/2012	5.8	100	1.0	0.0	Good	Good debris line
10/29/2012	6.4	>100 & <500	<1 & >0.2	0.0	Good	Good debris line
10/29/2012	7.0	>500	<0.2	1.2	Excellent	Excellent seed line on outside of garage
10/29/2012	6.0	>100 & <500	<1 & >0.2	1.6	Excellent	Excellent seed line on side of house
10/29/2012	7.1	<100	>1	1.3	Excellent	Excellent seed line on back of house
10/29/2012	8.6	<500	>0.2	0.0	Fair	Fair debris line on shoulder of road
10/30/2012	5.7	40	2.5	3.9	Excellent	Excellent mud line on side of garage
10/30/2012	5.8	>500	<0.2	1.6	Excellent	Excellent mud line on side of shed
10/30/2012	7.4	>100	<1	0.0	Poor	Poor debris line on grassy embankment
10/30/2012	7.1	>500	<0.2	0.0	Poor	Poor debris line on grassy embankment
10/29/2012	5.8	>500	<0.2	2.9	Excellent	Excellent mud line on side of fence
10/29/2012	6.0	>500	<0.2	1.8	Excellent	Excellent seed line on side of fence
10/29/2012	6.1	>500	<0.2	1.1	Excellent	Excellent mud line on front of building
10/29/2012	7.8	<500	>0.2	0.8	Good	Good seed line on front of house
10/30/2012	7.7	>100 & <500	<1 & >0.2	0.5	Excellent	Excellent seed line inside building
10/29/2012	6.6	40	2.5	1.5	Excellent	Excellent seed line on outside of building

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[5,16]Suffolk County—Continued
303	HWM–NY–SUF–411	40.84480	-72.57250	AE	6.0	7.6	8.2	9.1	9
304	HWM–NY–SUF–412	40.81890	-72.62450	AE	5.6	7.2	7.7	8.7	9
305	HWM–NY–SUF–413	40.78770	-72.74950	AE	5.0	6.2	6.8	7.8	7
306	HWM–NY–SUF–415	40.77410	-72.81610	AE	5.2	6.5	6.9	7.5	8
307	HWM–NY–SUF–417	40.66300	-73.41300	AE	5.0	6.0	6.3	6.8	6
308	[19]HWM–NY–SUF–418	40.63213	-73.21621	AE	4.3	4.8	8.0	5.2	9
309	[19]HWM–NY–SUF–419	40.64400	-73.15700	VE	6.5	8.5	14.1	11.5	16
310	[19]HWM–NY–SUF–420	40.63455	-73.20305	AE	4.3	4.8	8.0	5.2	10
311	HWM–NY–SUF–421	40.87980	-72.44990	AE	5.3	7.4	8.6	10.3	9
312	[19]HWM–NY–SUF–422	40.86900	-72.39200	AE	5.9	8.4	14.4	12.7	14
313	[19]HWM–NY–SUF–424	41.00630	-72.03500	AE	3.5	4.9	8.0	7.2	10
314	HWM–NY–SUF–425	41.07223	-71.93452	X	--	--	--	7.2	--
315	[19]HWM–NY–SUF–426	41.05010	-71.95650	AE	3.5	4.9	7.9	7.2	10
316	HWM–NY–SUF–427	41.00390	-72.18660	AE	3.5	4.9	5.3	7.2	6
317	HWM–NY–SUF–428	41.00100	-72.29100	AE	5.2	6.2	6.5	9.8	7
318	HWM–NY–SUF–429	41.01360	-72.30320	AE	4.0	5.2	5.9	9.4	6
319	HWM–NY–SUF–430	41.03710	-72.31970	AE	4.0	5.2	5.9	9.4	6
320	HWM–NY–SUF–431	40.99290	-72.31550	VE	4.0	5.2	5.5	9.6	8
321	HWM–NY–SUF–432	40.99370	-72.36290	AE	4.0	5.2	5.5	9.6	7
322	HWM–NY–SUF–433	40.95980	-72.39820	AE	4.0	5.2	5.5	9.6	6
323	HWM–NY–SUF–434	40.91720	-72.43950	AE	4.0	5.2	5.5	9.6	7
324	HWM–NY–SUF–435	40.89750	-72.46950	AE	4.0	5.2	5.5	9.6	6
325	HWM–NY–SUF–436	40.89350	-72.50330	AE	4.0	5.2	5.5	9.6	6
326	[19]HWM–NY–SUF–506	40.96452	-72.86320	AE	5.9	7.4	10.5	10.8	12
327	[19]HWM–NY–SUF–507	40.96492	-72.86317	VE	5.9	7.4	10.5	10.8	13
328	HWM–NY–SUF–508	40.94574	-73.07198	AE	6.8	7.7	8.2	9.0	10
329	HWM–NY–SUF–509	40.94574	-73.07198	AE	6.8	7.7	8.2	9.0	10
330	HWM–NY–SUF–510	40.95115	-73.02948	AE	6.5	8.2	8.8	10.4	11
331	[19]HWM–NY–SUF–511	41.01220	-72.55640	AE	6.2	7.5	10.8	9.4	11
332	HWM–NY–SUF–512	40.91617	-72.66119	AE	4.8	6.1	6.7	9.6	7
333	HWM–NY–SUF–513	40.91617	-72.66119	AE	4.8	6.1	6.7	9.6	7
334	HWM–NY–SUF–514	40.91746	-72.65535	AE	4.8	6.1	6.7	9.6	8
335	HWM–NY–SUF–516	40.91010	-72.55543	X	--	--	--	9.6	--
336	HWM–NY–SUF–517	40.90030	-73.35303	VE	7.1	8.2	8.9	10.5	12
337	HWM–NY–SUF–600	40.74760	-73.15039	AE	4.2	4.6	4.8	5.2	5
338	HWM–NY–SUF–601	40.92202	-73.44324	X	--	--	--	10.5	--
339	[19]HWM–NY–SUF–602	40.90728	-73.48357	VE	7.3	8.6	10.9	11.0	13
340	HWM–NY–SUF–603	40.89717	-73.43498	AE	7.1	8.2	8.9	10.5	11
341	HWM–NY–SUF–604	40.90536	-73.40283	AE	7.1	8.2	8.9	10.5	11
342	[19]HWM–NY–SUF–605	40.89243	-73.37453	AE	7.1	8.2	9.4	10.5	10
343	HWM–NY–SUF–606	40.92593	-73.35710	AE	7.1	8.2	8.9	10.5	11
344	HWM–NY–SUF–607	40.95410	-73.39812	AE	7.1	8.2	8.9	10.5	12
345	[19]HWM–NY–SUF–608	40.92305	-73.29637	AE	7.1	8.2	11.2	10.5	11
346	HWM–NY–SUF–609	40.89697	-73.22364	AE	6.9	8.3	8.8	10.4	10
347	HWM–NY–SUF–610	40.92173	-73.14967	AE	6.8	8.2	8.7	10.3	10

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/29/2012	6.9	30	3.3	1.7	Excellent	Excellent seed line on outside of building
10/30/2012	6.4	30	3.3	2.7	Good	Good seed line on outside of garage
10/30/2012	6.3	60	1.7	1.3	Excellent	Excellent seed line on outside of building
10/29/2012	6.5	50	2.0	3.7	Good	Good seed line on side of fence
10/29/2012	7.5	>500	<0.2	3.8	Good	Good seed line on side of house
10/29/2012	9.4	>500	<0.2	5.6	Good	Good mud line inside garage
10/29/2012	8.0	<100	>1	3.7	Excellent	Excellent mud line on outside of house
10/29/2012	4.2	<10	>10	2.3	Good	Good mud line on fence
10/29/2012	6.6	30	3.3	3.7	Excellent	Excellent seed line on side of house
10/30/2012	7.9	40	2.5	0.5	Good	Good mud line on door
10/29/2012	5.2	50	2.0	1.9	Excellent	Excellent mud line on concrete wall
10/29/2012	5.8	<500	>0.2	0.0	Poor	Poor debris line in grass
10/29/2012	6.0	70	1.4	2.5	Good	Good mud line on speed limit sign
10/30/2012	6.1	>100 & <500	<1 & >0.2	1.4	Excellent	Excellent mud line on cinder block wall
10/30/2012	6.3	70	1.4	0.5	Excellent	Excellent mud line on fence
10/30/2012	6.4	>100 & <500	<1 & >0.2	2.1	Excellent	Excellent mud line on side of house
10/30/2012	6.5	>100 & <500	<1 & >0.2	1.9	Excellent	Excellent mud line on wooden post
10/30/2012	6.3	<100	>1	1.8	Excellent	Excellent mud line on post
10/30/2012	6.5	>100 & <500	<1 & >0.2	2.4	Excellent	Excellent seed line on tree
10/30/2012	6.5	>100 & <500	<1 & >0.2	--	Excellent	Excellent mud line on gate
10/30/2012	6.7	>100 & <500	<1 & >0.2	2.1	Excellent	Excellent mud line on house
10/29/2012	6.5	>100 & <500	<1 & >0.2	2.1	Excellent	Excellent seed line on shed
10/30/2012	6.3	>100 & <500	<1 & >0.2	--	Good	Good mud line on house
10/30/2012	8.3	60	1.7	4.5	Poor	Poor debris line on fence
10/30/2012	8.5	<100	>1	2.8	Excellent	Excellent seed line on back of shed
10/30/2012	8.8	>100 & <500	<1 & >0.2	1.8	Excellent	Excellent seed line on side of fence
10/30/2012	8.8	>100 & <500	<1 & >0.2	1.8	Excellent	Excellent seed line on outside of building
10/30/2012	8.6	80	1.3	2.8	Excellent	Excellent seed line on outside of garage
10/30/2012	7.8	50	2.0	1.0	Excellent	Excellent seed line on side of fence
10/30/2012	8.1	>100 & <500	<1 & >0.2	1.1	Excellent	Excellent seed line on basement door of building
10/30/2012	8.2	>100 & <500	<1 & >0.2	1.6	Poor	Poor seed line on back of building
10/30/2012	7.9	>100 & <500	<1 & >0.2	0.3	Poor	Poor seed line on door outside building
10/30/2012	7.4	<500	>0.2	2.2	Excellent	Excellent seed line on post
10/30/2012	9.5	<100	>1	0.0	Fair	High-water mark established by Seymour's Boatyard operator
10/29/2012	6.1	>500	<0.2	2.2	Excellent	Excellent seed line inside USGS streamgage—01306499—Connetquot River near North Great River, NY
10/29/2012	9.9	<500	>0.2	0.0	Good	Good wash line on grass lawn
10/29/2012	9.5	<100	>1	2.4	Fair	Fair debris line on tree
10/29/2012	9.6	>100 & <500	<1 & >0.2	0.0	Good	Good debris line
10/29/2012	9.8	>100 & <500	<1 & >0.2	3.4	Good	Good seed line on fence
10/29/2012	9.6	>100 & <500	<1 & >0.2	1.4	Excellent	Excellent seed line on outside of building
10/30/2012	9.8	>100 & <500	<1 & >0.2	2.5	Excellent	Excellent seed line on outside of building
10/30/2012	10.0	>100 & <500	<1 & >0.2	1.8	Good	Good seed line on outside of shed
10/29/2012	7.9	40	2.5	0.8	Good	Good seed line on mailbox post
10/29/2012	8.9	>100 & <500	<1 & >0.2	1.9	Excellent	Excellent seed line on side of fence
10/29/2012	9.2	>100 & <500	<1 & >0.2	1.7	Excellent	Excellent seed line on side of fence

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[5,16]Suffolk County—Continued
348	HWM–NY–SUF–611	40.95901	-73.02141	VE	6.5	8.2	8.8	10.4	12
349	[19]HWM–NY–SUF–612	40.98731	-72.61571	VE	5.9	7.4	11.0	10.9	14
350	[19]HWM–NY–SUF–613	40.99369	-72.53757	AE	6.2	7.5	9.2	9.4	8
351	[19]HWM–NY–SUF–614	41.05346	-72.47309	AE	5.8	7.2	9.2	9.3	9
352	HWM–NY–SUF–615	40.80359	-72.75011	X	--	--	--	7.9	--
353	HWM–NY–SUF–616	40.78509	-72.79888	AE	5.2	6.5	6.9	7.7	8
354	HWM–NY–SUF–617	40.79636	-72.83115	VE	5.2	6.5	6.9	7.5	10
355	HWM–NY–SUF–618	40.75787	-72.83110	AE	5.2	6.5	6.9	7.5	8
356	HWM–NY–SUF–619	40.74395	-72.88202	AE	4.4	5.5	5.4	6.6	6
357	HWM–NY–SUF–620	40.75282	-72.93438	AE	4.0	4.8	5.2	5.9	6
358	HWM–NY–SUF–621	40.66942	-73.36786	AE	4.4	5.0	5.3	5.8	5
359	HWM–NY–SUF–622	40.67828	-73.33300	AE	3.9	4.6	4.8	5.2	6
360	HWM–NY–SUF–623	40.68781	-73.29053	X	--	--	--	4.9	--
361	HWM–NY–SUF–626	40.70754	-73.18915	X	--	--	--	4.4	--
362	HWM–NY–SUF–627	40.71995	-73.14118	X	--	--	--	4.9	--
363	HWM–NY–SUF–628	40.72770	-73.14200	AE	4.2	4.6	4.8	5.2	5
364	HWM–NY–SUF–629	40.72188	-73.09145	AE	4.2	4.6	4.8	5.2	6
365	HWM–NY–SUF–630	40.72998	-73.06380	AE	4.1	4.6	4.8	5.2	5
366	HWM–NY–SUF–631	40.73158	-73.03650	AE	4.2	4.7	4.9	5.3	5
367	HWM–NY–SUF–632	40.75041	-72.98137	AE	4.1	4.7	5.0	5.5	5
368	HWM–NY–SUF–633	40.79919	-72.69754	AE	4.8	6.0	6.9	8.1	7
369	HWM–NY–SUF–634	40.80731	-72.73361	AE	4.9	6.1	6.9	7.9	8
370	HWM–NY–SUF–635	40.77322	-72.89910	AE	3.9	4.9	5.4	6.2	6
371	HWM–NY–SUF–636	40.76451	-72.91386	AE	4.0	4.8	5.3	6.0	5
372	HWM–NY–SUF–637	40.79022	-72.66212	AE	4.8	6.1	7.0	8.2	7
373	HWM–NY–SUF–638	40.80031	-72.62565	AE	5.4	6.9	7.6	8.7	8
374	[19]HWM–NY–SUF–639	40.81690	-72.56760	AE	6.0	7.6	11.0	9.1	12
375	HWM–NY–SUF–943	40.85846	-73.21036	AE	6.9	8.3	8.8	10.4	9
376	HWM–NY–SUF–944	40.88260	-73.19342	AE	6.9	8.3	8.8	10.4	9
377	HWM–NY–SUF–945	40.64552	-73.26059	AE	3.7	4.3	4.5	4.8	5
378	HWM–NY–SUF–946	40.64172	-73.25313	AE	3.7	4.3	4.5	4.8	5
379	HWM–NY–SUF–948	40.62505	-73.26518	VE	3.7	4.3	4.5	4.8	7
380	HWM–NY–SUF–949	40.62819	-73.24333	AE	3.7	4.3	4.5	4.8	5
381	HWM–NY–SUF–950	40.63977	-73.28816	AE	3.7	4.4	4.6	4.9	7
382	HWM–NY–SUF–952	40.62002	-73.39252	AE	5.0	6.0	6.3	6.8	6
383	HWM–NY–SUF–953	40.61515	-73.41682	AE	5.0	6.0	6.3	6.8	6
384	HWM–NY–SUF–956	40.66481	-73.42332	X	--	--	--	6.8	--
385	HWM–NY–SUF–957	41.11956	-72.33626	AE	4.2	5.4	5.8	6.7	6
386	HWM–NY–SUF–958	41.08202	-72.38738	X	--	--	--	9.6	--
387	HWM–NY–SUF–959	41.03709	-72.39347	X	--	--	--	9.6	--
388	HWM–NY–SUF–960	41.03756	-72.42766	AE	4.0	5.2	5.5	9.6	6
389	HWM–NY–SUF–961	40.95795	-72.54858	AE	4.0	5.2	5.5	9.6	6
390	HWM–NY–SUF–962	40.93516	-72.57569	AE	4.0	5.2	5.9	9.6	6
391	HWM–NY–SUF–965	40.63417	-73.34526	AE	4.1	4.8	5.0	5.5	5
									[8,17]Ulster County
393	HWM–NY–ULS–001	42.07166	-73.93855	AE	6.2	7.9	8.5	10.8	9
394	HWM–NY–ULS–002	42.07120	-73.93813	AE	6.2	7.9	8.5	10.8	9

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/29/2012	8.6	<100	>1	3.4	Excellent	Excellent seed line on utility pole
10/29/2012	7.3	<100	>1	1.3	Excellent	Excellent seed line on guard booth
10/29/2012	8.8	90	1.1	1.4	Excellent	Excellent seed line on side of house
10/29/2012	7.7	60	1.7	2.5	Excellent	Excellent seed line on mailbox post
10/30/2012	6.5	<500	>0.2	0.0	Excellent	Excellent debris line on lawn
10/30/2012	6.5	50	2.0	1.1	Excellent	Excellent seed line inside building
10/29/2012	6.7	<100	>1	2.3	Good	Good seed line inside shed
10/29/2012	6.2	40	2.5	3.1	Good	Good seed line on back of deck
10/29/2012	4.8	20	5.0	2.1	Good	Good seed line on side of fence
10/29/2012	5.6	>100 & <500	<1 & >0.2	1.5	Excellent	Excellent seed line on park wall
10/29/2012	6.8	>500	<0.2	2.8	Excellent	Excellent seed line on building
10/29/2012	6.6	>500	<0.2	1.8	Excellent	Excellent mud line on fence
10/29/2012	6.2	>500	<0.2	0.0	Good	Good debris line
10/29/2012	5.7	>500	<0.2	0.0	Good	Good debris line
10/29/2012	5.5	>500	<0.2	0.0	Good	Good debris line on grass
10/29/2012	5.8	>500	<0.2	2.1	Excellent	Excellent seed line on fence
10/29/2012	5.4	>500	<0.2	1.9	Excellent	Excellent mud line on building
10/29/2012	5.5	>500	<0.2	1.2	Excellent	Excellent seed line on utility pole
10/29/2012	5.6	>500	<0.2	3.1	Excellent	Excellent seed line on fence
10/29/2012	5.4	>100 & <500	<1 & >0.2	1.4	Excellent	Excellent mud line on fence
10/29/2012	5.9	50	2.0	2.4	Good	Good seed line on fence
10/29/2012	6.5	80	1.3	0.0	Good	Good wash line in front yard
10/29/2012	5.2	80	1.3	1.4	Excellent	Excellent seed line on side of house
10/29/2012	5.4	>100 & <500	<1 & >0.2	2.6	Excellent	Excellent seed line on side of house
10/29/2012	6.4	70	1.4	1.4	Excellent	Excellent seed line on fence
10/29/2012	3.5	<10	>10	1.0	Excellent	Excellent seed line on side of fence
10/29/2012	6.4	20	5.0	0.5	Excellent	Excellent seed line on fence
10/29/2012	8.6	80	1.3	0.6	Good	Good seed line on fence
10/29/2012	8.9	>100 & <500	<1 & >0.2	2.8	Excellent	Excellent seed line on door of house
10/29/2012	5.7	>500	<0.2	2.4	Excellent	Excellent seed line on electrical box
10/29/2012	5.4	>500	<0.2	1.1	Excellent	Excellent seed line on front door of building
10/29/2012	6.4	<100	>1	1.4	Excellent	Excellent seed line on inside wall of building
10/29/2012	5.6	>500	<0.2	0.0	Poor	Poor debris line on path
10/29/2012	7.8	>500	<0.2	5.5	Excellent	Excellent seed line on post under back deck
10/29/2012	8.9	>500	<0.2	4.3	Excellent	Excellent seed line on back of house
10/29/2012	7.5	>500	<0.2	1.0	Excellent	Excellent seed line on garage
10/29/2012	7.5	>500	<0.2	1.0	Excellent	Excellent seed line on side of house
10/29/2012	6.5	>100 & <500	<1 & >0.2	4.5	Excellent	Excellent seed line on front of house
10/29/2012	6.4	<500	>0.2	1.0	Good	Good seed line on side of house
10/29/2012	6.6	<500	>0.2	0.8	Good	Good seed line on garage foundation
10/29/2012	6.9	>100 & <500	<1 & >0.2	1.1	Good	Good seed line on gate
10/29/2012	6.8	>100 & <500	<1 & >0.2	3.1	Good	Good seed line on fence
10/29/2012	7.8	>100 & <500	<1 & >0.2	2.6	Good	Good mud line on shed
10/29/2012	5.2	>100 & <500	<1 & >0.2	0.8	Excellent	Excellent seed line on door inside maintenance garage
10/30/2012	9.4	>100 & <500	<1 & >0.2	3.0	Good	Good seed line on back of shed behind 145 Lighthouse Drive
10/30/2012	9.4	>100 & <500	<1 & >0.2	4.3	Good	Good seed line on landward side of 146 Lighthouse drive

Table 7. Peak storm-tide elevations produced by Hurricane Sandy at 346 high-water-mark sites, and the corresponding Federal Emergency recurrence intervals) in New York.—Continued

[High-water-mark site locations are shown in figure 2. FEMA, Federal Emergency Management Agency; NAVD 88, North American Vertical Datum of 1988; no., number;

Site					FEMA flood elevations for selected annual exceedance probabilities (recurrence intervals), in feet above NAVD 88				
					Stillwater flood elevation				1-percent (100-year) base flood elevation
Map no.	Identifier	Latitude, in decimal degrees	Longitude, in decimal degrees	[1]Coastal flood hazard zone	10 percent (10 year)	2 percent (50 year)	1 percent (100 year)	0.2 percent (500 year)	
									[8,17]Ulster County—Continued
395	HWM–NY–ULS–003	42.07149	-73.93701	AE	6.2	7.9	8.5	10.8	9
396	HWM–NY–ULS–004	41.92900	-73.96844	AE	6.0	7.5	8.9	10.4	8
397	HWM–NY–ULS–005	41.92898	-73.96849	AE	6.0	7.5	8.9	10.4	8
398	HWM–NY–ULS–006	41.92904	-73.96852	AE	6.0	7.5	8.9	10.4	8
399	HWM–NY–ULS–007	41.92899	-73.96874	AE	6.0	7.5	8.9	10.4	8
									[5,18]Westchester County
403	HWM–NY–WES–001	41.15692	-73.86997	AE	5.3	6.3	6.8	8.0	7
404	HWM–NY–WES–002	41.15573	-73.87005	AE	5.3	6.3	6.8	8.0	7
405	HWM–NY–WES–003	40.99874	-73.88460	AE	5.2	6.2	6.7	8.0	7
406	HWM–NY–WES–004	40.93719	-73.90311	AE	5.2	6.2	6.7	8.0	7
407	HWM–NY–WES–005	40.93732	-73.90304	AE	5.2	6.2	6.7	8.0	7
408	HWM–NY–WES–006	40.93713	-73.90289	AE	5.2	6.2	6.7	8.0	7
409	HWM–NY–WES–800	40.94300	-73.72090	VE	8.7	11.3	12.5	16.8	14
410	HWM–NY–WES–801	40.89064	-73.78236	AE	8.5	11.1	12.8	16.1	12
411	HWM–NY–WES–812	40.90870	-73.76860	X	--	--	--	16.1	--
412	HWM–NY–WES–813	40.93170	-73.74470	AE	8.8	10.7	11.6	13.9	12
413	HWM–NY–WES–814	40.95581	-73.69257	AE	8.7	11.3	12.5	16.8	12
414	HWM–NY–WES–815	40.97857	-73.66560	AE	8.7	11.3	12.5	16.8	13
415	HWM–NY–WES–980	40.94745	-73.73235	AE	8.8	10.7	11.6	13.9	13

[1]High-water marks (HWMs) from sites in VE zones (shaded gray) are likely to have been affected by wave heights of 3 feet (ft) or greater and, therefore, are comparable only to the base flood elevations; HWMs from sites in other coastal flood hazard zones (unshaded) will have been affected by wave heights less than 3 ft and, thus, are generally comparable to the corresponding stillwater elevations.

[2]Stillwater flood elevations converted from units of feet above the National Geodetic Vertical Datum of 1929 (NGVD 29) as reported in Federal Emergency Management Agency (1979, 1989).

[3]Coastal flood hazard zones from Federal Emergency Management Agency (2013c); base flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (2013c).

[4]Stillwater flood elevations from Federal Emergency Management Agency (2012).

[5]Coastal flood hazard zones and base flood elevations from Federal Emergency Management Agency (2013b).

[6]Stillwater flood elevations from Federal Emergency Management Agency (2008).

[7]Stillwater flood elevations from Federal Emergency Management Agency (2009a).

[8]Coastal flood hazard zones and base flood elevations from Federal Emergency Management Agency (2013c).

[9]Stillwater flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (2007a).

[10]Coastal flood hazard zones from Federal Emergency Management Agency (2013b); base flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (2013b).

Management Agency flood elevations for the 10-, 2-, 1-, and 0.2-percent annual exceedance probabilities (10-, 50-, 100-, and 500-year

GMT, Grenwich Mean Time; <, less than; >, greater than; &, and; --, no value; USGS, U.S. Geological Survey]

Hurricane Sandy peak storm tide						
				High-water mark		
Estimated date (GMT)	Elevation, in feet above NAVD 88	Recurrence interval, in years	Annual exceedance probability, in percent	Distance above ground, in feet	Rating	Description and notes
10/30/2012	9.4	>100 & <500	<1 & >0.2	3.8	Good	Good seed line on handrail of U.S. Coast Guard post
10/30/2012	9.3	>100 & <500	<1 & >0.2	4.9	Excellent	Excellent seed line on large front window of 136 Delaware Avenue
10/30/2012	9.3	>100 & <500	<1 & >0.2	4.0	Excellent	Excellent seed line on siding of south side of 138 Delaware Avenue
10/30/2012	9.2	>100 & <500	<1 & >0.2	3.1	Excellent	Excellent seed line on west side of 138 Delaware Avenue
10/30/2012	9.2	>100 & <500	<1 & >0.2	1.5	Excellent	Excellent mud line on south side of 146 Delaware Avenue
10/30/2012	9.0	>500	<0.2	0.0	Good	Good debris line on grass downstream of Metro North station
10/30/2012	9.0	>500	<0.2	2.4	Excellent	Excellent seed line inside public bathroom
10/30/2012	8.9	>500	<0.2	1.9	Excellent	Excellent seed line on upstream side of “Harvest-on-Hudson” restaurant
10/30/2012	9.0	>500	<0.2	0.0	Good	Good debris line on grass on upstream side of Hudson Park at end of Wells Avenue
10/30/2012	9.0	>500	<0.2	0.0	Good	Good debris line on grass on upstream side of Hudson Park at end of Wells Avenue
10/30/2012	9.2	>500	<0.2	1.1	Fair	Fair seed line on exterior of door on streamward side of 2 Alexander Street
10/30/2012	10.5	<100	>1	2.7	Excellent	Excellent seed line in shower stall of Mamaroneck Yacht Club
10/30/2012	10.2	40	2.5	3.1	Excellent	Excellent seed line inside steel container on dock
10/30/2012	11.8	<500	>0.2	0.0	Good	Good debris line on grass hill
10/30/2012	10.1	40	2.5	0.0	Good	Good debris line on grass berm
10/30/2012	10.2	30	3.3	2.5	Excellent	Excellent seed line on wall of utility house
10/30/2012	9.8	30	3.3	3.0	Excellent	Excellent seed line on wall inside building
10/30/2012	10.3	40	2.5	0.3	Good	Good seed line on inside of concrete water supply

[11]Results not discussed in text or shown in figures.

[12]Coastal flood hazard zones and flood elevations from Federal Emergency Management Agency (2013e).

[13]Stillwater flood elevations from Federal Emergency Management Agency (2009b).

[14]Stillwater flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (1984).

[15]Stillwater flood elevations converted from units of feet above NGVD 29 as reported in Federal Emergency Management Agency (1981a, 1981b).

[16]Stillwater flood elevations from Federal Emergency Management Agency (2009c).

[17]Stillwater flood elevations from Federal Emergency Management Agency (2011).

[18]Stillwater flood elevations from Federal Emergency Management Agency (2007b).

[19]Stillwater flood elevation for 1-percent annual exceedance probability (100-year recurrence interval) includes wave setup.

[20] High-water mark HWM–NY–REN–001 published previously as HWM–NY–COL–001.

[21] High-water mark HWM–NY–REN–003 published previously as HWM–NY–COL–003.

[22] High-water mark HWM–NY–REN–004 published previously as HWM–NY–COL–004.

Glossary

Annual exceedance probability (AEP) flood The 1-percent AEP flood has a 1 in 100 chance of being equaled or exceeded in any 1 year, and it has an average recurrence interval of 100 years (see Holmes and Dinicola, 2010). The 0.2-percent AEP flood has a 0.2 in 100 chance of being equaled or exceeded in any 1 year, and it has an average recurrence interval of 500 years.

Base flood elevation The elevation shown on the flood insurance rate map (FIRM) for zones AE, AH, A1–30, or VE that indicates the water surface elevation resulting from a flood that has a 1-percent chance of occurring in any given year. In coastal areas, BFEs are calculated using four components: (1) the storm surge stillwater elevation, (2) the amount of wave setup, (3) the wave height above the storm surge stillwater elevation, and (4) the wave runup above the storm surge stillwater elevation (where present).

Flood hazard zone Flood hazard zones are lettered based on the level and type of flood risk:

Zone VE The area subject to high velocity wave action (a 3-foot breaking wave) from the 1-percent annual chance coastal flood.

Zone A/AE The area subject to inundation from the 1-percent annual chance flood. These areas are not subject to high velocity wave action but are still considered high risk flooding areas.

Zone X Areas of moderate coastal flood risk outside the regulatory 1-percent annual chance flood up to the 0.2-percent annual chance flood level.

Nor'easter Northeastern coastal storm.

Stillwater elevation The projected elevation of floodwaters in the absence of waves resulting from wind or seismic effects. In coastal areas, stillwater elevations are determined when modeling coastal storm surge; the results of overland wave modeling are used in conjunction with the stillwater elevations to develop the coastal base flood elevations.

Storm surge Water-level rise caused by a storm over and above the predicted astronomical tide.

Storm tide Water-level rise due to the combination of storm surge and the astronomical tide.

Streamgage Instrumentation used to measure water level and corresponding streamflow.

Tide gage Instrumentation used to measure coastal water level.

Wave runup The rush of water that extends inland when waves come ashore. Wave runup effects are computed as a part of the overland wave analysis and are added to the stillwater elevations computed from the storm surge model.

Wave setup The increase in the water level caused by the onshore mass transport of water that occurs due to waves breaking during a storm. Wave setup is affected by the wave height, the speed at which waves approach shore, and the nearshore slope.

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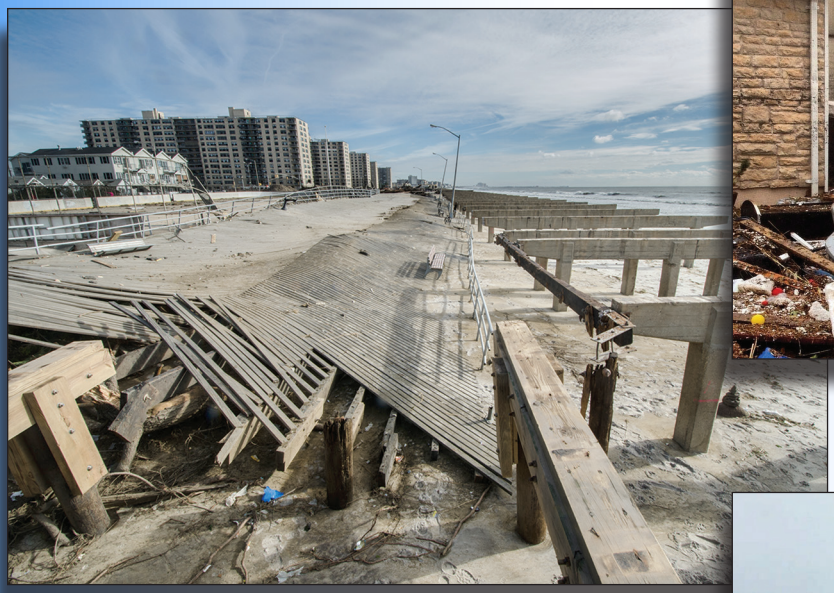

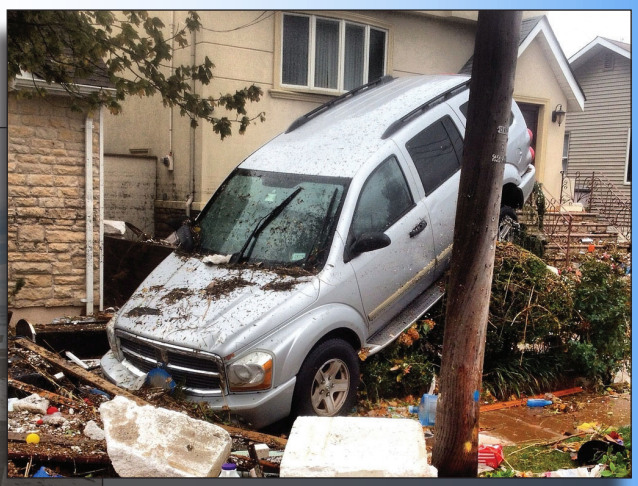

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