HURRICANE SANDY IN NEW JERSEY AND NEW YORK

H Facility-Specific Descriptions of Critical Facilities and Key Assets

This appendix provides material supplementary to Chapter 5. The Mitigation Assessment Team (MAT) visited eight hospitals: Bayonne, Hoboken, Jersey City, and Palisades in New Jersey; and Bellevue, Coney Island, Long Beach, and New York University (NYU) Langone in New York.

H.1 Overview of Hospital Performance

Healthcare facilities are regulated by New York State, the State Department of Health, and the City Department of Health and Mental Hygiene. These agencies worked together in the Healthcare Evacuation Center at the New York City (NYC) Office of Emergency Management (OEM) to prepare healthcare facilities for anticipated storm impacts. State regulations require that hospitals and nursing homes have a backup power source to allow them to shelter in place and continue services in the event of an outage. The decision to order a general evacuation of healthcare facilities to protect against the potential risks of an approaching storm must be balanced against the inherent risks of the evacuation itself to vulnerable populations, as evacuating hospital patients and elderly and infirm populations can exacerbate existing conditions and increase mortality rates. As Sandy approached, the City instructed hospitals in Zone A to discharge those patients who could safely be discharged and to reschedule elective surgeries. Patients at hospitals in Zone A who could not be safely discharged were instructed to shelter in place, as were those in residential healthcare facilities (New York City 2013a).

The following tables summarize the damage the MAT observed in hospitals and the time it took to bring services and critical infrastructure back after Hurricane Sandy. Table H-1 summarizes the areas that were damaged at each hospital. Table H-2 presents the number of days hospital services were unavailable because of damage from Hurricane Sandy. Table H-3 shows the number of days critical infrastructure was not available to hospitals because it was damaged during Hurricane Sandy.

As shown in Table H-1, Long Beach Medical Center and Hoboken University Medical Center carried out evacuations before damage occurred in those facilities. The other hospitals the MAT visited tried to shelter in place and lost critical services during the storm event, leading to conditions that required these hospitals to evacuate patients from facilities without utilities.

As shown in Table H-2, Bellevue, Long Beach, and NYU Langone suffered the longest periods without services due to damaged medical equipment and hospital areas. Table H-3 presents the length of time it took to repair critical utility systems. Though these systems were repaired relatively quickly, until the hospitals repaired damage to medical equipment and hospital rooms, they could not open to provide medical services.

Table H-1: Physical Damage to Hospital Service Areas

	New Jersey				New York			
	Bayonne	Hoboken	Jersey City	Palisades	Bellevue	Coney Island	Long Beach	NYU Langone
Evacuation	None	Before Sandy	None	1 Day After Sandy	After Sandy	After Sandy	Before Sandy	After Sandy
Hospital Treatment Areas and Non-Intensive Care Unit (ICU) Floor Beds								
Adult medical	N	N	N	N	N	N	N	N
Adult surgical	N	N	N	N	N	N	N	N
Pediatric beds	N	N	N	N	N	N	N	N
Other non-ICU	N	N	N	N	N	N	N	N
Psychiatric beds	N	N	N	N	N	N	N	N
ICU Beds								
Adult medical ICU	N	N	N	N	N	N	N	N
Adult surgical ICU	N	N	N	N	N	N	N	N
Pediatric ICU	N	N	N	N	N	N	N	N
Other ICU beds	N	N	N	N	N	N	N	N
Operating/Procedure Rooms								
Major/in-patient	N	N	N	N	N	N	N	N
Minor/out-patient	N	N	N	N	N	N	N	N
Labor and delivery	N	**Y**	N	NA	N	N	N	N
Pharmacy	N	Not Known	N	N	N	**Y**	**Y**	**Y**
Laboratory	N	N	N	**Y**	N	**Y**	N	N
Radiology	N	**Y**	N	**Y**	N	**Y**	N	**Y**
Out-Patient Areas								
Emergency department	N	**Y**	**Y**	**Y**	N	**Y**	N	**Y**
Out-patient clinics	N	**Y**	**Y**	NA	N	N	**Y**	**Y**
Dialysis	N	N	N	NA	N	N	N	N
Non-Clinical Areas								
Kitchen	N	**Y**	Not Known	Not Known	N	N	**Y**	**Y**
Laundry	N	NA	Not Known	Not Known	N	N	**Y**	**Y**
Administration	N	**Y**	Not Known	**Y**	N	**Y**	N	**Y**
Medical records	N	N	Not Known	**Y**	N	N	N	N

NA = Not Applicable

Table H-2: Days of Hospital Services Lost

Hospital Services	New Jersey				New York			
	Bayonne[a]	Hoboken[b]	Jersey City	Palisades	Bellevue	Coney Island	Long Beach	NYU Langone
	Approximate Days of Service Lost							
Emergency Department Services	0	14	0	1	40-100	14	>60	>60
Out-Patient Clinics								
Medical/primary care	0	7	7	1	20-34	16	30	7+
Surgical clinics	0	NA	7	1	20-34	5	>60	7+
Ob/gyn clinics	0	7	7	NA	20-34	5	>60	7+
Pediatric clinics	0	7	7	NA	20-34	5	>60	7+
Surgical Services								
Major operative procedures	0	14	7	1	100	>30	>60	60
Minor procedures	0	14	7	1	100	>30	>60	49
Endoscopic procedures	0	14	7	1	100	>30	>60	60
Other specialty procedures	0	14	NA	1	100	>30	>60	60
Obstetric/delivery Services	NA	14	0	NA	100	>30	NA	>60
Rehab/physical therapy	0	14	0	1	100	21	>60	>60
Laboratory services	0	14	0	1	5	3	>60	49
Radiology Services								
Plain radiographs/x-rays	0	3	0	1	40	3	>60	49
Computed tomography (CT) scans	3	3	0	3	40	3	>60	49
Magnetic resonance imaging (MRI)	0	3	0	1	100	>30	>60	60
Ultrasound	0	3	0	1	40	3	>60	49
Interventional procedures	0	NA	0	7	100	>30	NA	49
Blood Bank	0	NA	NA	1	40	>30	NA	49
Non-Clinical Services								
Kitchen	0	NA	0	1	60	0	>60	>60
Laundry	0	NA	0	1	60	0	>60	>60
Administrative	0	7	0	0	5	0	0	moved
Medical records	0	0	0	0	NA	0	0[c]	0

NA = Not available at that facility

a. Took patients transferred from Hoboken Hospital

b. Hospital closed for 14 days

c. Lost records in the out-patient clinic only

Table H-3: Days of Critical Infrastructure Loss

Logistic Support/Infrastructure	New Jersey				New York			
	Bayonne	Hoboken	Jersey City	Palisades	Bellevue	Coney Island	Long Beach	NYU Langone
	Approximate Days of Service Lost							
Electrical Power								
Municipal power service	**7**	**5**	**4**	**1**	**5**	**3**	**14**	**>30**
Hospital backup power	0	**<1**	0	0	0	**<0.5**	NA	**3**
Water								
Municipal water – all	0	0	0	0	**7**	0	**9**	**1**
Municipal water drinking	0	0	0	0	**7**	0	**9**	**1**
Hospital backup – all	NA	NA	NA	NA	**3**	NA	NA	NA
Hospital backup drinking	NA	NA	NA	NA	**3**	NA	NA	NA
Medical Gases								
Oxygen	0	0	0	0	**40-100**	**3**	NA	NA
Other gases	0	0	0	0	**40-100**	**3**	NA	NA
Suction	0	0	0	0	**40-100**	**3**	NA	NA
HVAC								
Heating system	0	**1**	0	0	**600**	**7**	**>30**	**1**
Cooling/air conditioning	0	**1**	0	0	**100**	**7**	**>30**	**1**
Information Systems								
Computer system	0	0	0	0	0	NA	0	**3**
Medical records	0	0	0	0	0	NA	0	**3**
Communications								
Telephones (land lines – internal)	0	**10**	0	0	**5**	**3**	**>30**	**7**
Telephones (land lines – external)	**1.5**	**10**	0	0	**5**	**3**	**21**	**7**
Telephones (cellular)	**1**	**5**	**2**	**2**	**30**	**3**	**5**	**3**
Elevators	0	**1**	0	0	**7**	**7**	**>30**	**2**

NA = Not applicable because hospital closed

HVAC = Heating, Ventilation, and Air Conditioning

H.2 Healthcare Facilities – Hospitals

Of the eight hospitals visited by the MAT, five are described in detail in this report: Hoboken University Medical Center, NJ; the Palisades Medical Center and associated long-term care facility (The Harborage), NJ; Bellevue Hospital, NY; Long Beach Medical Center, NY; and NYU Langone Medical Center, NY. These five complexes were selected as representative examples of the types of issues faced by hospitals during and after Hurricane Sandy. See Chapter 5, Figure 5-1 for locations of the healthcare facilities visited by the MAT.

H.2.1 Hoboken University Medical Center (Hoboken, NJ)

Facility Description. The hospital, shown in Figure H-1, is approximately 0.5 mile from the Hudson River at 308 Willow Ave in Hoboken, NJ. The main hospital is a single facility with four buildings that have been constructed over time with their relative locations shown in Figure H-2. Table H-4 lists the building names with the date of construction and the type of services and major equipment that are located on their first floors.

Figure H-1:
Hoboken University Medical Center entrance (Hoboken, NJ)

Table H-4: Hoboken University Medical Center Main Campus Facilities

Building	Date of Construction	First Floor Services and Equipment
Assumption Hall	1890	Conference room, old emergency room, physician offices
West Tower	1962	Admissions, ambulatory clinics, radiology, magnetic resonance imaging (MRI) suite, computed tomography (CT) scan, nuclear medicine, cardiology and cardiac rehabilitation
South Building	1971	Boiler room, carpenter shop, maternal / fetal medicine, gift shop, cafeteria, patient financial services, main lobby
North Building	2009	Emergency department

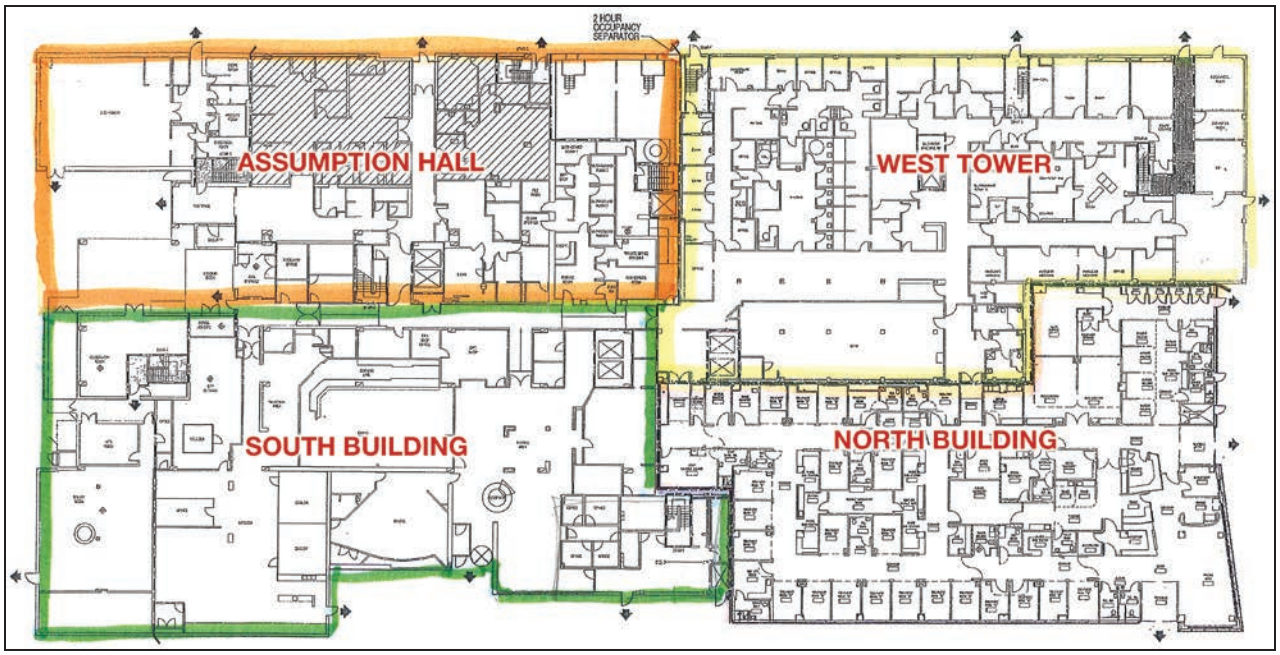


Figure H-2: Hoboken University Medical Center layout (Hoboken, NJ)
SOURCE: HOBOKEN UNIVERSITY MEDICAL CENTER

The hospital's main campus is 8 feet below mean sea level, and the first floor elevations vary between buildings (see discussion on the City of Hoboken below). A small basement area houses mechanical equipment, including potable water pumps; fire pumps; heating, ventilation, and air conditioning (HVAC) equipment for maternal and fetal services; and chillers. The hospital also owns two other properties in the area, including a three-story townhouse (with a basement) that is used as a clinic and a building located one block from the hospital that serves as a family health center. The hospital is located in Zone AE with a base flood elevation (BFE) of 9 feet.

The hospital receives electric power and natural gas from Public Service Enterprise Group (PSEG). A 10,000-gallon fuel oil tank is part of the heating system. The hospital has two emergency generators that operate at a 350-gallons-per-hour fuel consumption rate and draw fuel from a 2,000-gallon fuel tank. Both fuel tanks are located above ground.

Because some areas of Hoboken lie near or below sea level, the City of Hoboken provides information on flooding risks and flood mitigation activities on its Web site,[1] including the location of frequent flooding and barricades used to close streets, tide charts for the Hudson River, and Federal Emergency Management Agency (FEMA) BFEs. When heavy rain coincides with a high tide of the Hudson River, water cannot drain into the river, causing some streets to flood. A flood pump was installed by the North Hudson Sewerage Authority to pump water into the river, but it did not eliminate the flooding. The North Hudson Sewerage Authority has a combined sewer and wastewater treatment system that is gravity fed.

Pre-Event Planning and Flood Mitigation Measures. Patients at Hoboken University Medical Center were transferred to four other hospitals based on pre-established arrangements.

1 http://www.hobokennj.org/departments/environmental-services/storm-flood-zones.

Hoboken University Medical Center prepared for Hurricane Sandy by installing plywood over doors, sandbagging walls, and covering low-level openings, as shown in Figures H-3 and H-4. The Center had an emergency generator tied to a switchgear that was located at a lower elevation and subject to flooding, so the hospital de-energized the switchgear to minimize damage.

Figure H-3: Wall opening that was protected with mastic and plywood (Hoboken, NJ)

Figure H-4: Flood levels through an entrance doorway on Monday, October 29, 2012, while the streets remained flooded
PHOTO COURTESY OF HOBOKEN UNIVERSITY MEDICAL CENTER (HOBOKEN, NJ)

Severity of Flooding and Damage to Facility. The hospital lost power around 9 p.m. on Monday, October 29. Elevator equipment for two of the eight elevators were flooded. The fuel tanks and the elevated fuel oil pump were not damaged during the flood event. The generators were operating again by Wednesday. Floodwater also inundated the disaster response equipment housed in four trailers located near the Medical Center.

Hoboken University Medical Center has a combined sewer and wastewater treatment system that is gravity fed. The sewer system did not have backflow controls; therefore, water shot out of the drains and toilets. The staff estimated that 95 percent of the water entered the building through pipe conduits. Flood levels varied inside the buildings from 6 inches to 4 feet (Figure H-5). The small basement area flooded, damaging the potable water booster pumps, fire pumps, HVAC systems for the Maternal/Fetal Medicine Department, and chillers (Figure H-6). Diagnostic equipment and supplies on the first floor were also damaged by floodwater.

The townhouse property basement where the main electric service and a hot water heater are located was flooded. The family health center was flooded with approximately 5 feet of water.

The hospital has a seven-story smoke stack that was stabilized with guy wires, as shown in Figure H-7. One of the guy wires snapped in the wind gusts, which were reported as 70 to 80 miles per hour.

Figure H-5:
Deeper flood levels in other parts of the hospital
PHOTO COURTESY OF HOBOKEN UNIVERSITY MEDICAL CENTER (HOBOKEN, NJ)

Figure H-6:
Basement area with flood-damaged mechanical equipment (Hoboken, NJ)

Because of concern the stack might topple onto a boiler and a 10,000-gallon liquid oxygen tank, which has a cryogenic radius of 185 yards, the fire department helped set new guy wires during the storm event.

Effect on Operations and Recovery Actions. Hoboken University Medical Center was extensively damaged by the flooding, but reopened its Emergency Room as an urgent care center for 12 hours a day approximately 5 days after Hurricane Sandy. Hospital in-patient services were fully restored and reopened after 2 weeks.

Figure H-7:
Smoke stack and supporting guy wire (red arrow) (Hoboken, NJ)

As a result of Hurricane Sandy, Hoboken University Medical Center intends to:

- Relocate radiology equipment to a higher floor (after a structural review of floor capacity)
- Move "soft" offices (offices related to tasks such as customer services, office support, etc., that do not require expensive or specialized equipment) to the first floor
- Elevate the electrical switchgear
- Install backflow valves to avoid floodwater infiltration through the sewer lines and floor drains
- Install engineered door barriers to replace the use of plywood as a flood barrier

Because of the low elevation of the city, the emergency operation plans for Hoboken University Medical Center will be modified to assume an "island mode," where road access is cut off for a period of time. The facility also plans to develop an improved communications plan for staff and for the public.

H.2.2 Palisades Medical Center (North Bergen, NJ)

Facility Description. The Palisades Medical Center complex contains three sections: the hospital, the Pavilion building, and The Harborage long-term care facility. The site layout is shown in Figure H-8. The hospital has 180 beds and the long-term care facility has 240 residents. The site is on the west shore of the Hudson River, approximately opposite mid-town Manhattan. The hospital is the oldest of the three sections and was constructed in 1978. The Pavilion, which connects the hospital to the long-term care facility, was constructed in 1995.

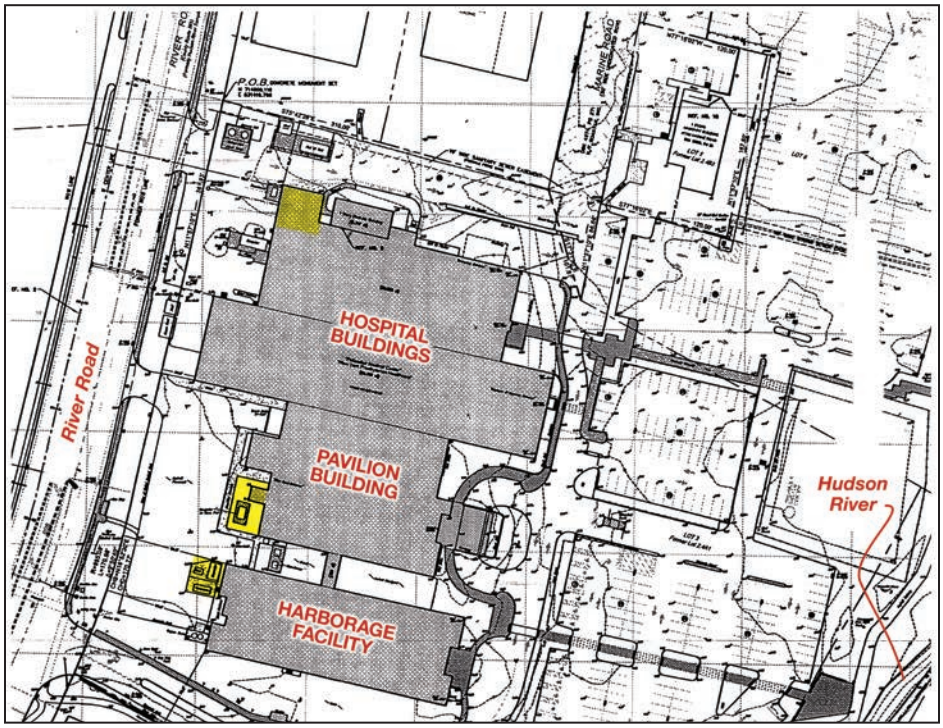


Figure H-8: Site plan for the Palisades Medical Center (yellow highlighted areas indicate locations of emergency generators) in North Bergen, NJ

SOURCE: PALISADES MEDICAL CENTER

The buildings are constructed on fill material. Staff reported that ground levels have settled several feet since the original construction and that the parking area at the east end of the site has been elevated to reduce the frequency of nuisance flooding. All buildings are steel-framed structures constructed with reinforced concrete floors and supported by pilings. The buildings are constructed over crawlspaces that contain piping and utilities. The crawlspaces are typically about 4 feet high and reportedly are contiguous between the buildings.

Three emergency generators serve the Palisades Medical Center complex. One of the generators, a 675-kilowatt (kW) unit that supplies the hospital, is located inside (Figure H-9). The other generators, a 250 kW unit that supplies the Pavilion and a 300 kW unit that supplies The Harborage long-term care facility, are in exterior enclosures (Figure H-10). The base of the interior unit is at an approximate elevation of 9 feet, or 1 foot above the BFE; the bases of the Pavilion and The Harborage units are located approximately at the BFE.

Figure H-9:
675 kW generator supplying the hospital (North Bergen, NJ)

Figure H-10:
300 kW generator supplying The Harborage long-term care facility (North Bergen, NJ)

The site is located in Zone AE, with BFEs of 8 and 10 feet. Construction drawings indicate that the finished floor of most of the hospital is at an elevation of 9.7 feet North American Vertical Datum of 1988 (NAVD88). The boiler room and generator room, which contain the major mechanical, electrical, and plumbing (MEP) components for the hospital and the Pavilion have a lower elevation of 8.5 feet NAVD88. The major MEP components for The Harborage long-term care facility are located on the fifth floor.

The Advisory Base Flood Elevation (ABFE) maps place most of the facility in Zone A with an ABFE of 12 feet. The east edge of the facility is near Zone V, with an ABFE of 14 feet.

Pre-Event Planning and Flood Mitigation Measures. The Palisades Medical Center complex reduced its patient population to 80 patients before Hurricane Sandy arrived by transferring patients to the Hackensack University Medical Center located approximately 10 miles to the northwest. The Palisades Medical Center did not fully evacuate because they planned to shelter the remaining patients in place as they had for Hurricane Irene in 2011. This decision was based on expected flood levels. Truck-mounted generators were brought to the facility to back up the emergency generators.

To prevent potential damage, the furnace and boilers were manually shut down before the flooding event. The computed tomography (CT) scan and the radiology equipment were also intentionally shut down to help prevent damage.

Severity of Flooding and Damage to Facility. Floodwater flowed into crawlspaces beneath the three buildings via crawlspace ventilation louvers mounted near grade (Figure H-11). Floodwater also entered the crawlspace by flowing through the backfilled soils under and around the buildings. Flow rates through the soils were sufficient to develop what staff called "sinkholes" around the buildings (Figure H-11). Floodwater completely filled the crawlspaces and entered the buildings through numerous floor penetrations (related to piping, conduits, etc.) in the concrete slab (Figure H-12). Staff reported that the floodwater did not overtop the sandbags or the temporary flood barriers. Water depths within the buildings reached approximately 2 to 4 inches, and were below the top of the cove base molding.

In the boiler and generator rooms, which are lower than the rest of the facility, water depths reached approximately 16 to 18 inches above the finished floor and came within inches of the boilers, the chiller units, and the hospital's generator. Flooding also damaged utility systems on the first floor of the hospital, including the electrical system, humidifiers, pumps, HVAC equipment, communications systems, and information technology (IT)/data systems.

Figure H-11: Crawlspaces under the buildings were filled when water entered through ventilation louvers (left); floodwater created sinkholes as soil eroded along the building perimeter and the flow continued into adjacent building crawlspaces (right) (North Bergen, NJ)

Figure H-12: Floodwater filled the crawlspaces under the buildings (North Bergen, NJ)

The floodwater reached River Road around 6 p.m. and cut off vehicle access. Flooding also damaged elevator equipment below the first floor level. Outage times for each elevator depended on its location and equipment type.

Utility power was lost between 8 p.m. and 10 p.m. on Monday, October 29, when the local electric power and gas supplier, PSEG, turned off power. Floodwater inundated two of the three onsite emergency generators that serve the Pavilion and The Harborage long-term care facility and interrupted power to the fire pump. The third emergency generator was intentionally shut down before it flooded to help minimize damage. Although temporary truck-mounted generators had been brought to the facility to provide backup emergency power, these generators were also damaged by flooding.

Table H-5 lists the major equipment affected by floodwater at the Palisades Medical Center, the primary effect of the flooding, and the approximate elevation of the major equipment.

Effect on Operations and Recovery Actions. The hospital had intended to shelter-in-place the remaining 80 patients in the hospital, but after generator power was lost, the hospital transferred them to four other hospitals in accordance with pre-established agreements. The transfers occurred between 6 a.m. and 9 a.m., on Monday, October 29, prior to the storm surge event, when the tide receded and River Road became accessible. Palisades Medical Center remained closed for 36 hours (McDonald 2012). Power was restored by 8 a.m. on Tuesday, October 30, from a different substation. Palisade Medical Center reopened its emergency room and brought all evacuated patients back to the hospital within 36 hours. The original substation that supplied power to the facility was still not functioning as of the site visit on December 10, 2012.

Based on interviews, the Palisades Medical Center staff realized that such a multi-event outage had not been anticipated or addressed in their emergency response plans; they intend to modify the plans to include increasing coordination at all staffing levels, training staff in evacuation procedures,

increasing the capacity of emergency generators, and creating redundancy between generators. Staff reported that Hurricane Sandy resulted in both a power outage and flooding that cut off road access and reduced ambulance availability.

Table H-5: Flood Effects on Palisades Medical Center Equipment

Equipment	Effects	Approximate Elevation of Equipment (NAVD88, feet)
675-kilowatt (kW) emergency generator that serves the hospital	Generator was shut down when flood levels approached the base of the unit	9
250 kW emergency generator that serves the Pavilion building	Generator was damaged by inundation	9
Elevators	Elevator pits were inundated	2
Chiller unit	Water levels reached the bottom of the water-cooled chiller but did not disrupt the unit	8
Boilers	Water levels reached the bottom of the boiler but did not disrupt the unit	8
Temporary generator	The trailer-mounted temporary generator was shut down when floodwater reached the unit	9
Electric power	Water reached the bottom of the power transformer for the hospital, long-term care facility, and office building	10
Secondary power conductors	Secondary conductors that run from the pad-mounted utility transformer to the electric room and switchgear failed approximately 4 weeks after the event, when a short circuit developed between Phase A and Phase C	7
Information technology (IT) and telephone	IT and telephone service was lost when floodwater flowed under the raised floor of the IT room	10
Computed tomography (CT) scanner and magnetic resonance imaging (MRI)	CT scanner and MRI were damaged by a power surge caused by floodwater	7

NAVD88 = North American Vertical Datum of 1988

H.2.3 Bellevue Hospital (Manhattan, NY)

Facility Description. Bellevue Hospital, which was established in 1847, is located on 1st Avenue in New York, NY. The full service hospital has 900 beds and a Level I trauma center. It also has 320 psychiatric beds and 100 prisoner beds. The facility has five buildings with interconnected basements (Figure H-13):

- Main hospital (1973) (Figure H-14)
- Ambulatory care (ER) building (2005)
- Administration building (1954)
- C and D buildings (1938)
- F and G buildings (not indicated)

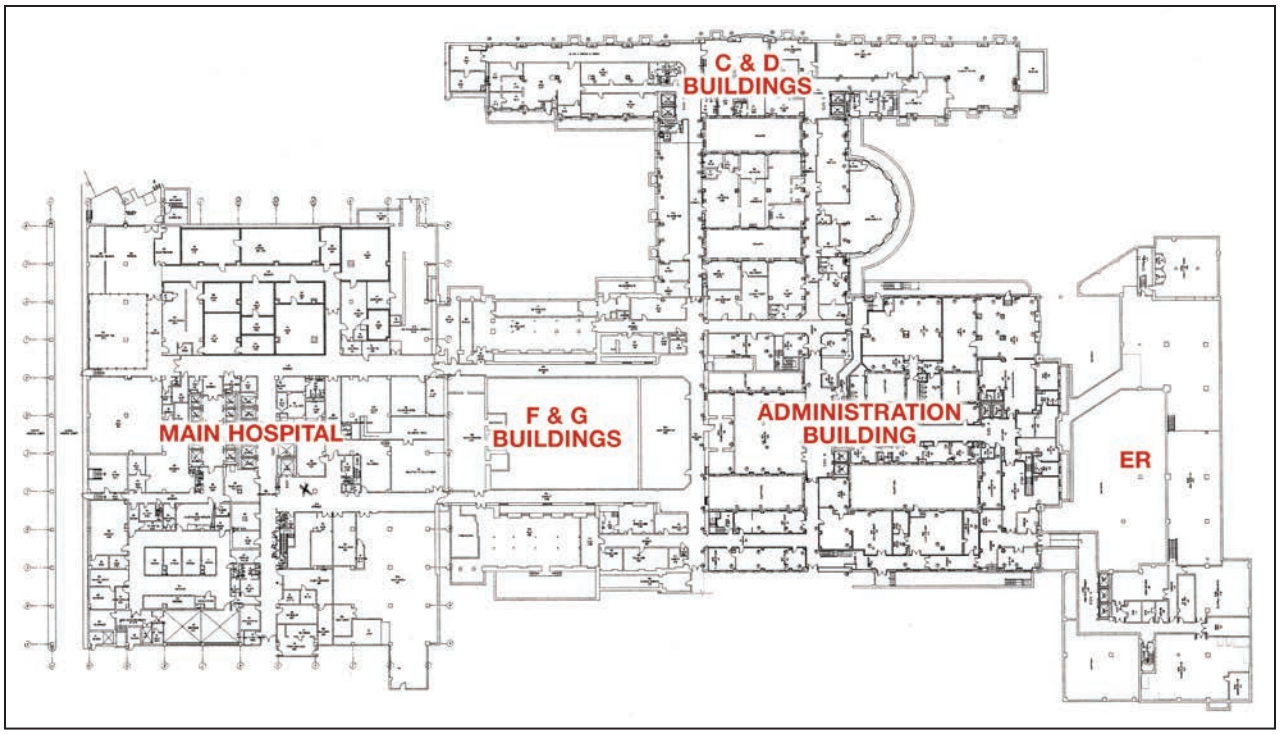


Figure H-13: Bellevue Hospital building layout (Manhattan, NY)
SOURCE: BELLEVUE HOSPITAL

Figure H-14: Bellevue Hospital entrance (left) and Ambulatory Care lobby (right) (Manhattan, NY)

In 1973, construction was completed on Bellevue's 25-story main hospital building. In 2005, an ambulatory care and combined multidisciplinary intensive care unit (ICU) were opened.

The main hospital had many of its utilities and equipment in the basement, including the IT systems, electric power and high-voltage lines, air handling units, water pumps for roof tanks, municipal steam pipes, medical vacuum and medical air systems, and a natural gas distribution system. The facility is partly located in flood Zone AE with a BFE of 9 feet and partly in a flood Zone X.

Pre-Event Planning and Flood Mitigation Measures. Bellevue Hospital stopped routine services and discharged patients before the storm and expected to shelter the remaining patients in place. Bellevue Hospital had 725 patients that it planned to shelter in place. Oxygen tanks and fuel pumps were protected using dry floodproofing measures (submarine doors) and emergency generators were elevated.

After the Northeast Blackout in 2003, in which a surge of electricity caused power failures across the Northeast and Midwest United States and into Canada, a new electric power plant and 1,500 kW emergency generators were installed on the 13th floor of the main hospital. However, one emergency generator and the fuel oil pumps remained in the basement. After Hurricane Irene, Bellevue Hospital installed a submarine door to protect the fuel oil pump system, but the seal around the door failed during Hurricane Sandy.

Severity of Flooding and Damage to Facility. Flooding first occurred around 9 to 10 p.m. on Monday, October 29, 2012. Water flooded FDR Drive and swept down a loading ramp (Figure H-15) flooding the basement and utility systems. The basements filled with 3 to 15 feet of water, depending on the basement floor elevation, within an hour or so. Hospital personnel had hoped to have continuous pumping during the flood event to keep the basement dry, but the pumps were inadequate for the inundation that occurred.

Fifteen Con Edison power feeds enter Bellevue Hospital at the basement level. All utilities and services in the basement were lost, including electrical power, steam, communications, HVAC equipment, IT, computers, fire protection systems, and elevators. Mechanical systems lost or damaged included pumps, electrical switchgear, and a combined domestic water and fire pump system (pumps, motors, and controllers were damaged).

Some air intakes on the basement level were located below floodwater levels. Only one tank for fire protection was available after the flood event.

Figure H-15: Access drive (left) to utility tunnel below Bellevue Hospital (right). High water mark (HWM) is shown in left photograph (Manhattan, NY).

The emergency generator and day tank provided power until the fuel was consumed. Although the fuel pumps and the large fuel tank in the basement had flooded, the below-grade fuel oil tanks were not compromised. Generator power was maintained and supplied at 30 percent of the normal load to power emergency lighting and power systems. New York Police Department (NYPD) brought a fuel tanker to the site, and hospital staff spent 13 hours carrying 5-gallon containers of fuel up 13 flights of stairs so the generators could continue to operate using fuel from the day tank.

Effect on Operations and Recovery Actions. Based on its experience with Hurricane Irene, the hospital staff thought it was well prepared for Hurricane Sandy. However, storm surge overwhelmed the hospital and flooded the basement. Bellevue Hospital used 3,000 gallon-per-hour pumps that the Fire Department of New York (FDNY) brought to the facility to pump out the basements and tunnels over 5 days.

Because the generators on elevated floors were operating, the staff sheltered patients in place until the potable water in roof tanks was depleted. Patients on ventilators were transferred on Tuesday, October 30, and all but two remaining patients were transferred the following day. The last two patients were transferred on Saturday, November 3.

Bellevue reopened its outpatient care building in mid-November 2012. By mid-December 2012, the emergency department re-opened for walk-ins and averaged 180 patients per day. The radiology and laboratory were also re-opened, with the exception of the magnetic resonance imaging (MRI) facility. Bellevue re-opened its Level I trauma center, which treats 120,000 patients per year and the rest of its clinical operations in early February 2013.

Bellevue Hospital recovery plans include moving selected elevator equipment up to the ground floor so the elevators can function during an emergency. Also, the emergency power distribution system is being expanded to bring emergency generator power to key areas of the hospital, including sections that house CT scanners and MRI machines, pharmaceutical and chemotherapy facilities, and research laboratories. Options for water pumps include moving them to a higher floor or bringing in additional pumps at street level that can be used as a backup system. Engineering experts are looking for ways to improve protection for the fuel oil pumps and medical gas tanks. The hospital is also adding connections for mobile boilers that can be brought in to provide heat and hot water if necessary.

H.2.4 Long Beach Medical Center (Long Beach, NY)

Facility Description. The Long Beach Medical Center is a four-story, 162-bed facility on the north shore of Long Beach, NY, south of Reynolds Channel, the strait that separates Long Beach from Long Island. The hospital provides medical and surgical services, behavioral health services, physical rehabilitation, alcoholism and chemical abuse counseling, and treatment services, as well as outpatient programs. The hospital was constructed in several phases. The most recent addition, the west wing, was constructed in 1990 to National Flood Insurance Program criteria. The east wing and west wing have a basement that is approximately two-thirds below grade, with windows in the upper portion of the wall. In addition to the hospital, the Komanoff Center for Geriatric and Rehabilitative Medicine is located at the site and provides senior care.

The Long Beach Medical Center is in Zone AE with a BFE of 8 feet. The Long Beach Medical Center and Komanoff Center are located in Nassau County, which did not issue ABFEs because their Flood Insurance Rate Maps (FIRMs) were recently revised and adopted on September 11, 2009.

Pre-Event Planning and Flood Mitigation Measures. Some passive flood mitigation efforts were in place. However, the 3-foot-high bulkhead along the Long Beach Medical Center waterfront at Jamaica Bay did not continue past the hospital property lines and, therefore, was not effective in keeping floodwater from entering the hospital property (Figure H-16). The west wing was elevated to 6 feet above grade, and waterproof "submarine" doors were installed at the basement level, but they had not been used in 22 years. Additionally, plywood covers were installed on vents to the boiler room.

Nassau County Executive Mr. Mangano declared a State of Emergency and ordered the mandatory evacuation of Long Beach Hospital and all nursing homes on Saturday, October 27, 2012. The Long Beach Medical Center followed the mandatory evacuation ordered by local officials. The evacuation involved moving 55 patients from the hospital and 161 residents from the senior care center. Patients and residents were evacuated to hospitals and nursing homes with assistance from the OEM, NYPD, wheelchair-accessible Metropolitan Transportation Authority (MTA) buses, and municipal and private ambulances. The evacuation took 12 hours and was completed by 7 p.m. on Sunday, October 28, 2012. The OEM was kept active until all patients were transferred, and then the hospital was closed. Non-critical personnel were released; engineering and management staff remained on site to respond to the event.

Figure H-16: Long Beach Medical Center (red arrow shows end of bulkhead) (Long Beach, NY)

Severity of Flooding and Damage to Facility. Floodwater fully inundated the basement floor of the Long Beach Medical Center. Staff reported that the maximum flooding coincided with high tide, which occurred at 8:45 p.m. on October 29. Floodwater reached depths of approximately 4 feet at the main entrance to the hospital (Figure H-17). Five hydraulic elevators in the hospital and their mechanical equipment were inundated. However, the two elevators in the west wing were unaffected because the mechanical equipment was on the fourth floor.

Power from Long Island Power Authority was lost at 7:20 p.m. on October 29, when the Island Park substation (located about 4 miles from hospital) was damaged. The hospital and surrounding community lost power, potable water, and sewer service. Water service was out for 8 to 9 days, sewer service was out for 10 to 12 days, and power service was out for 2 weeks.

Floodwater entered the main facility through near-grade ventilation louvers, doors, windows, and window-mounted air conditioning units (Figure H-18), flooding the partial subgrade basement at Long Beach Medical Center up to the first floor. Inundation caused nearly all of the storm damage; widespread damage from moving floodwater or breaking waves was not observed. Along the north side of the building, which faces Reynolds Channel, the MAT observed damaged wall sheathing and damaged skirting to a construction trailer and broken windows leading to the basement level (Figure H-19).

Floodwater flowed through the basement level. The submarine door that separates the older east wing from the newer west wing failed and allowed floodwater to flow into the newer, more flood-resistant section of the building (Figure H-20). Staff reported that the submarine door had not been routinely operated and tested. The MAT could not determine if the failure of the submarine door was the single cause of flooding in the newer west wing or if the flood levels were high enough at the site to allow floodwater to enter the west wing from other entrance points.

Figure H-17: Floodwater rose to the top of the second step down from the emergency room entrance. The basement level below the emergency room contains critical equipment and critical functional spaces (Long Beach, NY).

Figure H-18: Low points of entry for floodwater at louvers (left) and doors (right) (Long Beach, NY)

Figure H-19:
Damaged sheathing and skirting to a construction trailer (left) and broken windows to basement level adjacent to the trailer (inset shows detail)
(Long Beach, NY)

Figure H-20:
Submarine door that failed to prevent floodwater from flowing from the older, more vulnerable east wing into the newer west wing (Long Beach, NY)

Floodwater fully inundated the lowest floor of the hospital. The electrical distribution system, boiler plant, generators, fire alarms, communications equipment, chillers, and HVAC systems were all inundated. The boiler room was situated at the lowest grade in the facility. The plywood covers on the vents to the boiler room failed at the connections to the frames. Floodwater inundation damage included:

- Four boilers in the heating plant (Figure H-21)

Figure H-21:
Heating plant damaged from inundation (Long Beach, NY)

- Electrical switchgear (Figure H-22)
- Communications and IT equipment
- One of the hospital's emergency generators

Figure H-22: Damaged electrical switchgear (Long Beach, NY)

Long Beach Medical Center had three emergency generators, one in the basement and one at grade level (both of which flooded), and another 400 kW generator elevated 4 to 5 feet above grade in a detached building south of the hospital that was not flooded. Floodwater rose 22 inches above the floor level of the detached building and inundated the utility company pad-mounted transformer located outside the building (Figure H-23). Floodwater approached the bottom of the generator, but did not reach it, its main power connections, or its diesel engine. However, the duplex fuel oil pumps and pump controls that draw fuel oil from the underground fuel tank were mounted at a lower level on the generator chassis and were inundated. Inundation of the pumps and their controls prevented the generator from operating (Figure H-24).

The 20,000-gallon fuel tank was below grade, but did not flood because its fill pipe was sealed and its vent was elevated 18 feet above grade. Although the tank was under several feet of floodwater, no water entered the tank to contaminate or displace the fuel (Figure H-25).

In contrast to the Long Beach Medical Center, the lowest floor of the Komanoff Center is near grade (approximately 6 feet higher than the basement floor of the hospital). Although flooding depths inside the Komanoff Center were significantly lower than those in the hospital, damage to equipment and services was still significant. Floodwater damaged heating equipment, electrical service and distribution equipment, the emergency generator and emergency power systems, plumbing systems, HVAC equipment, and other critical infrastructure. However, because the flood depths were significantly lower than in the hospital, the required cleanup and recovery efforts were reduced. At the time of the MAT visit, staff reported that the senior care facility was scheduled to

re-open within 2 months of the event and would be heated with portable boilers and powered by portable generators. As of October 2013, Long Beach Hospital has not reopened, but the Komanoff Center reopened in February 2013.

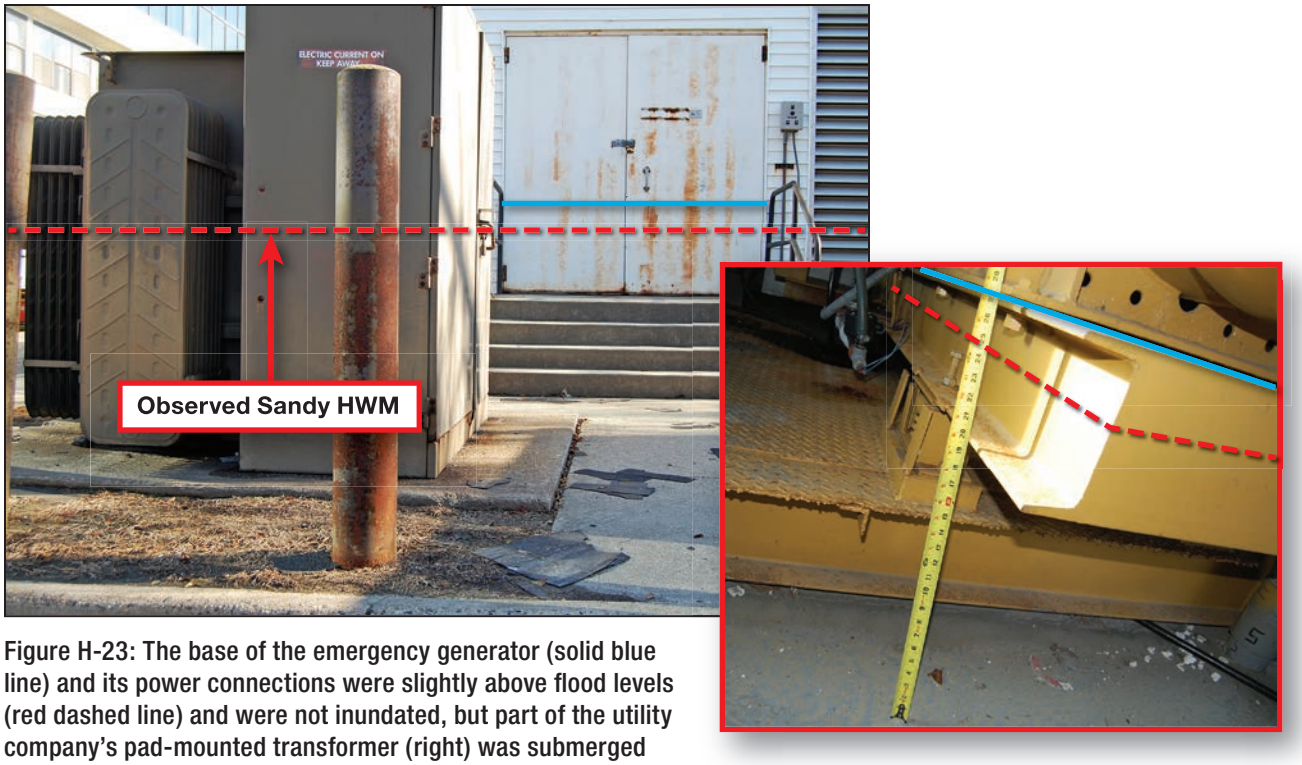


Figure H-23: The base of the emergency generator (solid blue line) and its power connections were slightly above flood levels (red dashed line) and were not inundated, but part of the utility company's pad-mounted transformer (right) was submerged (Long Beach, NY)

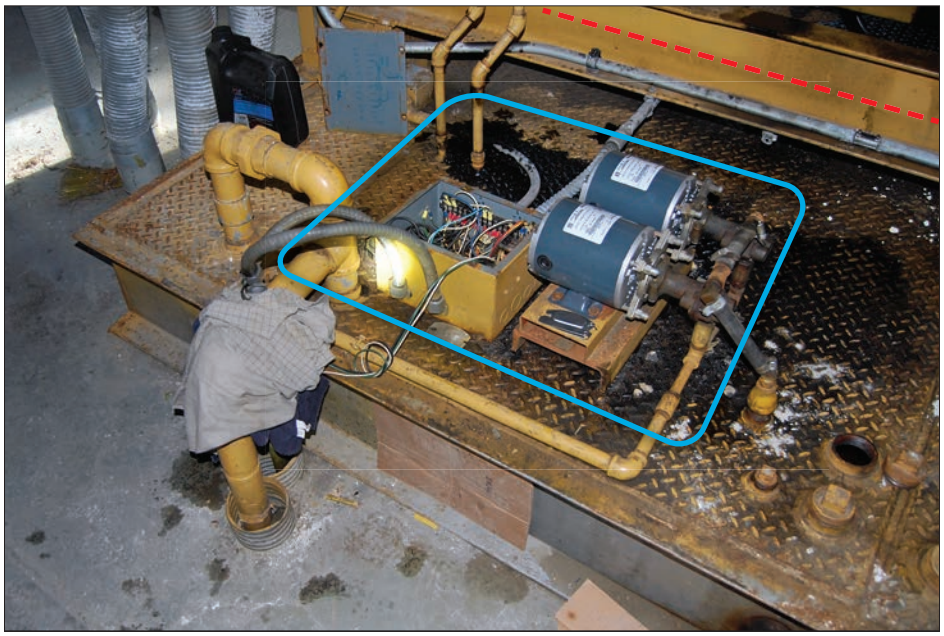


Figure H-24: Floodwater (red dashed line) submerged fuel oil pumps and their controls (circled in blue), which prevented the generator from operating (Long Beach, NY)

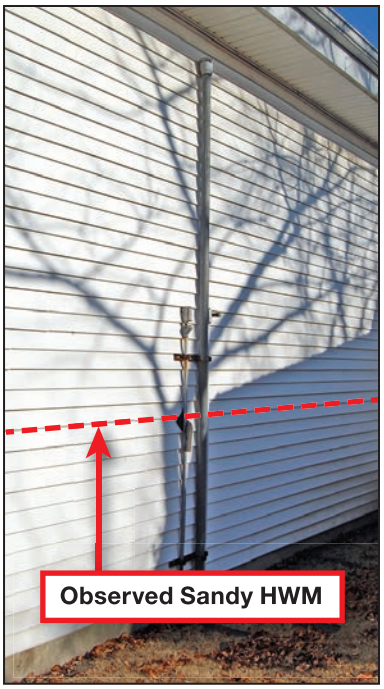


Figure H-25: Fill pipe for underground fuel tank (under access cover) was sealed, and vent pipe extended well above the flood level (shown at right in red). The tank was not damaged, and fuel was not contaminated or released (Long Beach, NY).

Effect on Operations and Recovery Actions. Both the medical center and the senior care facility remained closed for months after Hurricane Sandy while repairs were made. The Long Beach Medical Center plans to elevate the boiler plant and electrical distribution systems above the design flood level and to floodproof other sections of the hospital that cannot be elevated. Some departments, such as the pharmacy, purchasing/stock room, and communications, are being relocated to higher floors.

H.2.5 New York University Langone Medical Center (Manhattan, NY)

Facility Description. NYU Langone Medical Center comprises a number of facilities that conduct teaching, research, and patient care. Several of the facilities are located in New York City between East 30th and East 34th Streets, between First Avenue and FDR Drive, adjacent to the East River. Figures H-26 and H-27 depict these facilities, which include:

- Rusk Institute of Rehabilitation Medicine (1948)
- Perelman Research Building (1948)
- Medical Science Building (1950s)
- Tisch Hospital (1962)
- Schwartz Health Care Center (1970s)
- Skirball Institute (1994)
- Smilow Research Center (2005)

The buildings are generally steel-frame construction with steel piles. A tunnel underneath the facility connects the buildings, except for the Skirball Institute and Alumni Hall. The tunnel system

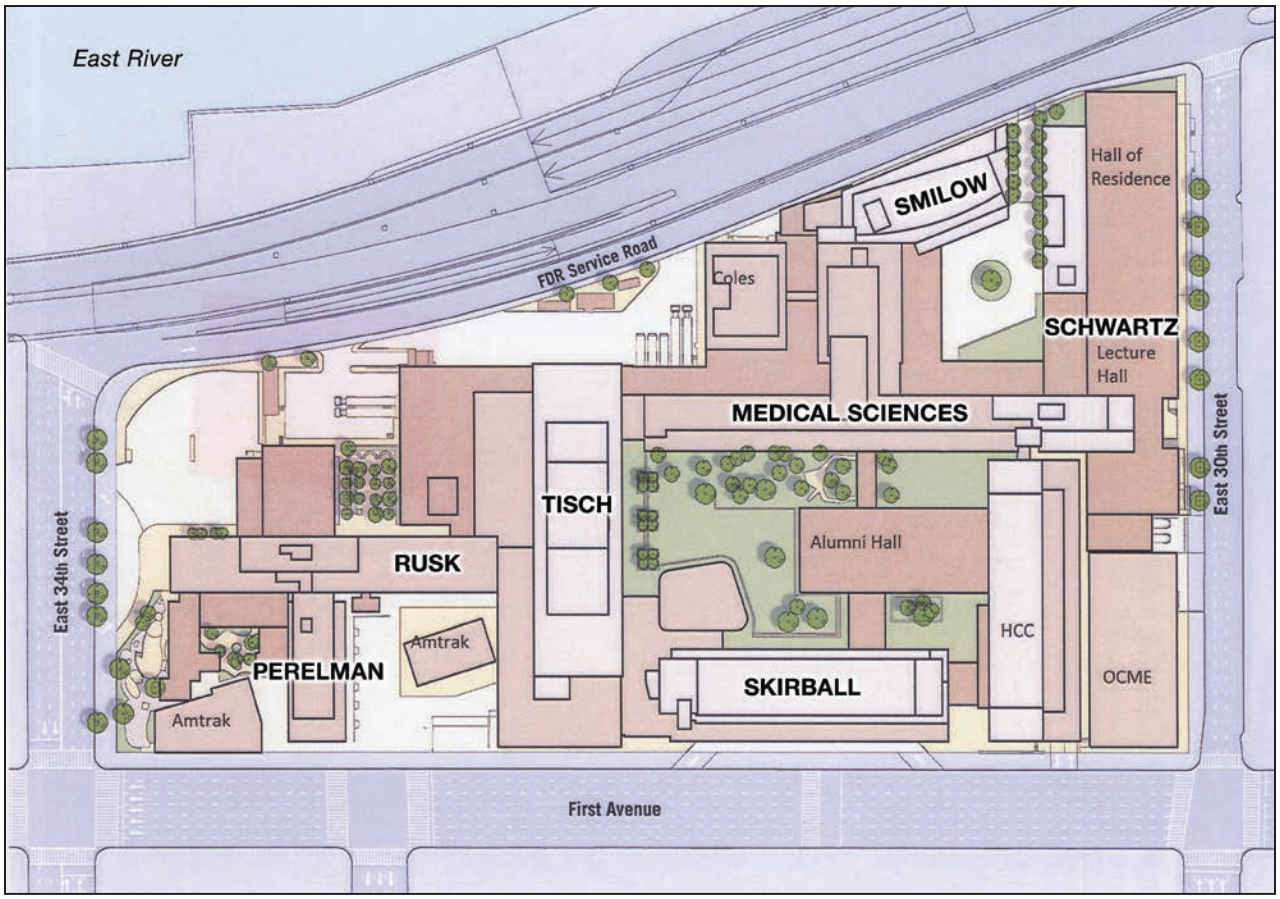


Figure H-26: NYU Langone Medical Center site layout (Manhattan, NY)

SOURCE: NYU LANGONE MEDICAL CENTER

Figure H-27: NYU Langone Medical Center with Tisch Hospital at left (Manhattan, NY)

has two basement levels, referred to as the ground floor and the cellar. Steel doors were installed in the 1960s to create fire barriers along the tunnel system. The emergency generators for the Medical Center are located on the Rusk Building roof with a 250-gallon day tank that was expected to provide power for up to 3 hours. A 20,000-gallon fuel tank is in a below-grade vault near a pump house, with a dry-floodproofed fuel pump for longer-term emergency power needs. The ground floor level is at 8 feet by Manhattan datum, which is about 9.65 feet in NAVD88. Some of the facility is located in Zone AE with a BFE of 9 feet.

Pre-Event Planning and Flood Mitigation Measures. NYU Langone Medical Center stopped routine services and discharged over 250 patients by Sunday, October, 28, 2012, leaving 322 patients to shelter in place. Preventive measures included dry floodproofing of vents subject to flooding, sandbagging doorways, and stationing pumps and staff inside the facility to handle seepage. The emergency department was closed to patients on Sunday evening, October 28, 2012.

Severity of Flooding and Damage to Facility. By 6:30 p.m. on Monday, October 29, 2012, the East River began to flood the area east of the medical center. Water had breached walls along FDR Drive and was travelling down East 34th Street toward Second Avenue. The Medical Science Building cellar water level went from ankle to waist deep in minutes and lost primary and backup power to the command center, data center, and telecom room. The Smilow Building was flooded and water filled the cellar level to the top of doorways. Floodwater filled the tunnels and rose to 2 feet on the ground floor in places. There were multiple points of water entry. Basement areas also had air intakes located below the rising water levels. The steel fire doors installed in the 1960s were damaged by either buckling or by pushing the door frames out of the walls. The fuel oil pumps for the emergency generators on the Rusk Building roof shut down as a result of an electric short circuit in the pump safety shut-off circuitry caused by water infiltration. The pump house was surrounded by about 6 feet of floodwater and was not accessible until water receded the next morning, when the fuel pump was restarted.

At about 7 p.m. on Monday, October 29, a second command center was established on the third floor of the Skirball Building, but the lights went out when Con Edison proactively powered down the electrical and steam systems. The emergency generator and day tank for Tisch Hospital provided lights. However, communication systems were not functioning. An evacuation plan for the remaining patients was subsequently developed.

At about 8 p.m. on Monday, October 29, a third command center was set up on the first floor of the Skirball building. Hospital staff contacted the OEM, NYPD, and the FDNY for assistance in transporting patients to other facilities. The ambulances would not move patients without orders from a hospital willing to accept the patients. Consequently, every patient transported by ambulance was taken to a facility that NYU Langone Medical Center had contacted and confirmed the availability of the appropriate level of inpatient bed. FDNY was on every other floor to aid communication between staff. Medical staff set up lighting in stairwells and evacuated patients down two stairwells in the Tisch Hospital and two stairwells in the Schwartz Health Care Center, as the elevators were not functioning. Staff evacuated 322 patients over 13 hours.

Flooding resulted in loss of the emergency department and kitchen on the ground floor, as well as a large amount of radiology equipment in the basement levels. All utilities and services in the subgrade level and ground floor basement levels were lost, including communications, HVAC, IT, computers, and fire protection systems. Equipment for electric power and steam systems in

the basement tunnels was damaged. Mechanical systems that were lost or damaged include steam distribution, pumps, electrical switchgear, and elevators. The pipes of the combined domestic water and fire protection system were also damaged. Only one tank for potable water and fire protection remained operational after the flood event.

Effect on Operations and Recovery Actions. Although staff thought they were well prepared for Hurricane Sandy based on their experience with Hurricane Irene, storm surge overwhelmed the hospital and flooded the basement.

The hospital planned to use its sump pumps during the flood event to keep the basement dry, but the pumps were inadequate for the amount of inundation. Portable boilers were brought to the site to replace those damaged by floodwater inundation in the basement (Figure H-28).

Figure H-28: NYU Langone portable boilers to replace those damaged by basement flooding (Manhattan, NY)

NYU Langone Medical Center experienced long-lasting effects of Hurricane Sandy damage. After Hurricane Sandy, the hospital had to relocate some teaching activities to other facilities. Its research activities have been hindered by the loss of facilities, experiments, data, and a vivarium. The NYU Langone Medical Center Emergency Department is renovating and expanding its facilities as part of a 3-year, multi-phased project to increase the size and capacity of the department. Outpatient procedures resumed at Schwartz Health Care Center on December 17, 2012, and Tisch Hospital inpatient services resumed on December 27, 2012. NYU Langone Medical Center opened an urgent care center and resumed pediatric and obstetric services on January 14, 2013.

Although NYU Langone Medical Center was prepared and its faculty and staff were trained for the storm, Hurricane Sandy was an unprecedented, multi-impact event in which all utilities were lost and transportation to and from the facility was affected. The loss of communications and

telecommunications (cell towers and batteries) was a serious impediment to the event response. NYU Langone Medical Center also identified the following long-term policy issues that need to be addressed: 1) evacuation practices, 2) public health issues, and 3) regional planning. Hospital staff believe patient evacuation should be coordinated across New York City, as not all hospitals went into shelter mode, and advance agreements for aid and transfers across the medical system would help in disaster situations.

H.3 Healthcare Facilities – Senior Care Centers

The MAT briefly visited the following senior care facilities in New Jersey and New York after Hurricane Sandy:

1. The Harborage (long-term care facility), North Bergen, NJ

2. Beach Terrace Care Center, Long Beach, NY

3. Komanoff Center for Geriatric and Rehabilitative Medicine, Long Beach, NY

4. Sea Crest Health Care Center, Brooklyn, NY

The most significant issue faced by the four senior care centers visited by the MAT was the loss of electrical power. Utility power was lost Monday, October 29, 2012, between 7 p.m. to 9 p.m. for all facilities when regional electric power companies de-energized their systems prior to the arrival of the storm. Power and emergency generator systems were located on the first floor or basement levels at all four facilities. Most of the observed emergency generators used fuel oil, but one system used natural gas. Each of the facilities made a soft switch to generator power, but all of them lost generator power when inundated by storm surge. Emergency system power failure was due to inundation of some component of the emergency power system, such as the generator or fuel oil pump. See Chapter 5, Figure 5-1 for locations of the healthcare facilities visited by the MAT.

Two of the senior care facilities are located adjacent to hospitals, and two are located near local hospitals. The Harborage long-term care facility is adjacent to Palisades Medical Center. The Komanoff Center for Geriatric and Rehabilitative Medicine is next to the Long Beach Medical Center. These two facilities had similar flooding conditions, damages, and effects as the respective adjacent hospitals. Observations of these two facilities are provided with the hospitals in Chapter 5, Section 5.2. Therefore, only specific observations of Park Avenue Extended Care Center, Beach Terrace Care Center, and Sea Crest Health Care Center are included here.

H.3.1 Beach Terrace Care Center (Long Beach, NY)

Facility Description. Beach Terrace Care Center is a three-story long-term care facility with 182 beds, constructed in 1947 and expanded in 1967 and 2000. The site is on the south edge of Long Beach immediately landward of the city's boardwalk (Figures H-29 and H-30). It is within the Effective Special Flood Hazard Area (SFHA) in Zone VE with a BFE of 16 feet according to the September 11, 2009, FIRM. ABFEs have not been published for the area.

Figure H-29: Street views of the Beach Terrace Care Center looking south (Long Beach, NY)

Figure H-30: Rear view of the Beach Terrace Care Center looking north; the city's boardwalk is in the foreground (Long Beach, NY)

Severity of Flooding and Damage to Facility. Flood depths near the facility were approximately 2 feet. Floodwater reached depths of approximately 4 feet inside the building. Waves destroyed lower portions of the walls and windows in the south wall and moving floodwater deposited approximately 2 to 3 inches of sand within the building. Moving floodwater also undermined the pad-mounted transformer that serves the facility (Figure H-31) and inundated the electrical service switchgear. Flood depths reached approximately 16 inches in the boiler room (Figure H-32).

Pre-Event Planning and Flood Mitigation Measures. The facility's 182 residents were evacuated on Sunday October 28, 2012, the day before Hurricane Sandy struck the area.

Effect on Operations and Recovery Actions. During the December 13, 2012, MAT site visit, the facility was back in operation.

Figure H-31:
Floodwater undermined soils supporting the pad-mounted transformer that serves the building (Long Beach, NY)

Figure H-32:
Flood depths reached approximately 16 inches in the boiler room (Long Beach, NY)

H.3.2 Sea Crest Health Care Center (Brooklyn, NY)

Facility Description. The Sea Crest Health Care Center is a nursing home facility on Coney Island, NY. The five-story building was built in 1973 and has a 320-certified-bed capacity. The nursing home is in the Effective SFHA in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 13 feet and a 0.2-percent-annual-chance advisory flood elevation of 17 feet.

Most of the MEP equipment for the building is located on the lowest floor, along with the elevator control room, laundry room, kitchen, and a common area. The emergency generator is elevated on high ground outside the building; but the transfer switch is in the lower level with the other MEP equipment.

Pre-Event Planning and Flood Mitigation Measures. Based on an interview with staff during the site visit, the facility was evacuated during Hurricane Irene in 2011. Prior to Hurricane Sandy, the staff prepared to evacuate all 320 beds, but because New York City public health officials did not mandate the evacuation of long-term care facilities, the Sea Crest Health Care Center sheltered in place. The facility installed plywood over windows and openings, placed sandbags, and installed expanding foam to common area openings located on the lowest floor prior to Hurricane Sandy as emergency protective measures (Figure H-33).

Figure H-33: View of the facility and sand deposited during the flooding (left) with close-up view (right); approximately 10 feet of sand was deposited at the facility during Hurricane Sandy (Brooklyn, NY)

Severity of Flooding and Damage to Facility. After losing utility power during the storm, Sea Crest Health Care Center switched to emergency power, and within 15 minutes completely lost power when water breached a door adjacent to the boardwalk, removing the door from the frame, inundating all the MEP equipment and shutting down the building's critical building systems (Figures H-34 and H-35).

Effect on Operations and Recovery Actions. During Hurricane Sandy, staff relocated patients to the second floor, which initially had power and the use of elevators; however, the facility lost emergency power as the storm made landfall. The hydraulic elevators were damaged by flooding (Figure H-36) and staff had to move patients down stairs. After the storm, on Monday, October 29, staff provided three meals, changed linens, and provided limited services. On Tuesday, they began evacuating patients, and by 5 p.m. on Wednesday, October 31, the facility was completely evacuated. Approximately 45 days after the storm, the facility remained without power, and only minimal repairs were underway.

Figure H-34:
This vent grating was an initial point of entry for floodwater (Brooklyn, NY)

Figure H-35:
MEP equipment was inundated with more than 6 feet of water during Hurricane Sandy (Brooklyn, NY)

Figure H-36:
The hydraulic elevators were flooded, forcing staff to move patients without elevator services (Brooklyn, NY)

H.4 Fire and Police

The performance observations of 12 specific first responder facilities described in this section are representative of damage observed by the MAT at the 38 police, fire, and emergency medical services (EMS) facilities visited across the impacted area. This section provides a general description of each facility, its location in the floodplain, the flood damages, the effects of the damages, and the planned recovery actions. See Figure 5-7 for locations of the first responder facilities visited by the MAT.

H.4.1 Bay Head Fire Company No. 1 Station 14 (Bay Head, NJ)

Facility Description. The one-story firehouse for Bay Head Fire Company No. 1 Station 14 was built in 1963 (Figure H-37) and is parallel to Scow Ditch Creek, which runs between Bay Head Harbor and Twilight Lake. The site is in Zone AE with a BFE of 5 feet according to the September 29, 2009, FIRM. The Advisory Flood Zone for the property is Zone V with an ABFE of 10 feet and an advisory elevation of 14 feet for the 0.2-percent-annual-chance event. The building was constructed 6 to 12 inches above the previous flood of record (a flood event in 1950). The station has a generator sitting at grade in an exterior room adjacent to the creek. The station's boilers and water heater are partially elevated in a room in the apparatus bay.

Damage to Facility. Emergency power systems and mechanical and electrical equipment at Bay Head Fire Company No. 1 Station 14 were damaged when Hurricane Sandy storm surge inundated the ground floor of the firehouse with approximately 32 inches of water. Floodwater entered the generator room through the exterior doorway and generator exhaust vent, damaging the at-grade generator (Figure H-38). The truck bay was also damaged, including one of the partially elevated boilers (Figure H-39) and equipment and contents (records). The living space, which is elevated slightly above the truck bay, was inundated with about 4 inches of water, which caused damage to the interior finishes and kitchen equipment.

Figure H-37:
Bay Head Fire Company No. 1 is housed in a one-story station built in 1963 (Bay Head, NJ)

Figure H-38:
At-grade generator inundated with approximately 32 inches of floodwater that entered the room through the doorway and generator vent (inset) (Bay Head, NJ)

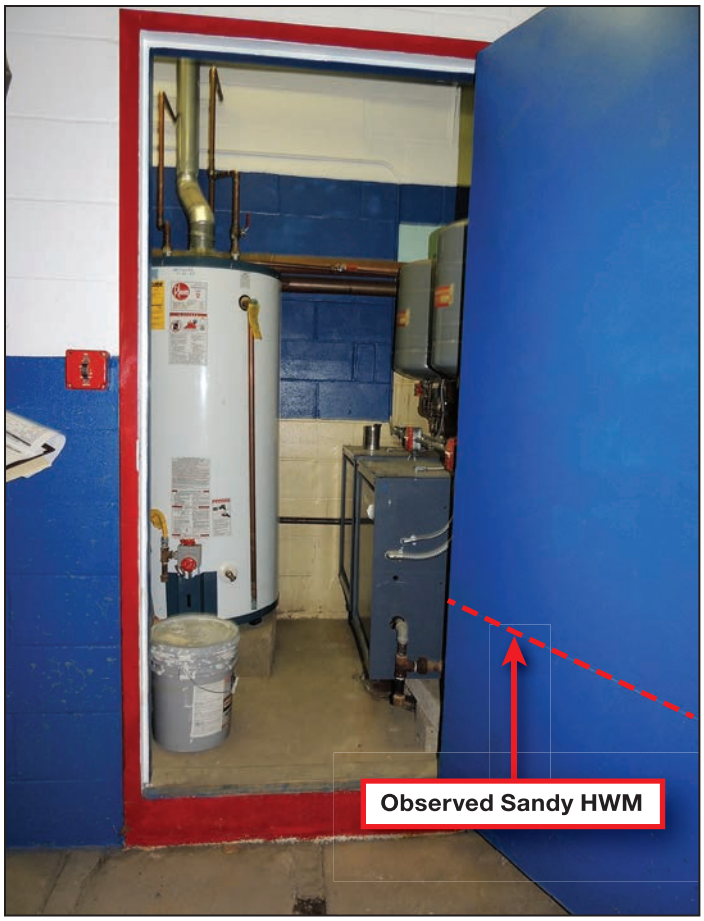


Figure H-39: Damaged boiler in room with partially elevated boiler and water heaters; HWM is visible on the door (red dashed line) (Bay Head, NJ)

Effect on Operations and Recovery Actions. Firefighters were forced to abandon the station during Hurricane Sandy when storm surge inundated the ground floor. The station had only limited functionality after the floodwater receded until a temporary generator was installed. During the MAT site visit, the station was fully operational and was used as a FEMA Disaster Recovery Center.

H.4.2 Beach Haven Volunteer Fire Company No. 1 (Beach Haven, NJ)

Facility Description. The two-story firehouse (without a basement) for Beach Haven Volunteer Fire Company No. 1 was built in 1915, with major renovations in 1976 (Figure H-40). The firehouse is adjacent to the Beach Haven Boroughs Hall, EMS, Beach Haven Police Department, and Public Works. The site is centered between the bayside and oceanside of Long Beach Island and is in Zone AE with a BFE of 9 feet according to on the September 29, 2006, FIRM. The Advisory Flood Zone and ABFE for the property are the same as the BFE; the advisory flood elevation for the 0.2-percent-annual-chance event is 13 feet. The station's emergency generator and boiler are located in at-grade rooms and are not elevated. The generator room is at the rear of the facility and has an exterior louvered door (Figure H-41).

Damage to Facility. The location of the Beach Haven Volunteer Fire Company No. 1 generator and boiler room left the equipment vulnerable. Flood inundation from Hurricane Sandy was

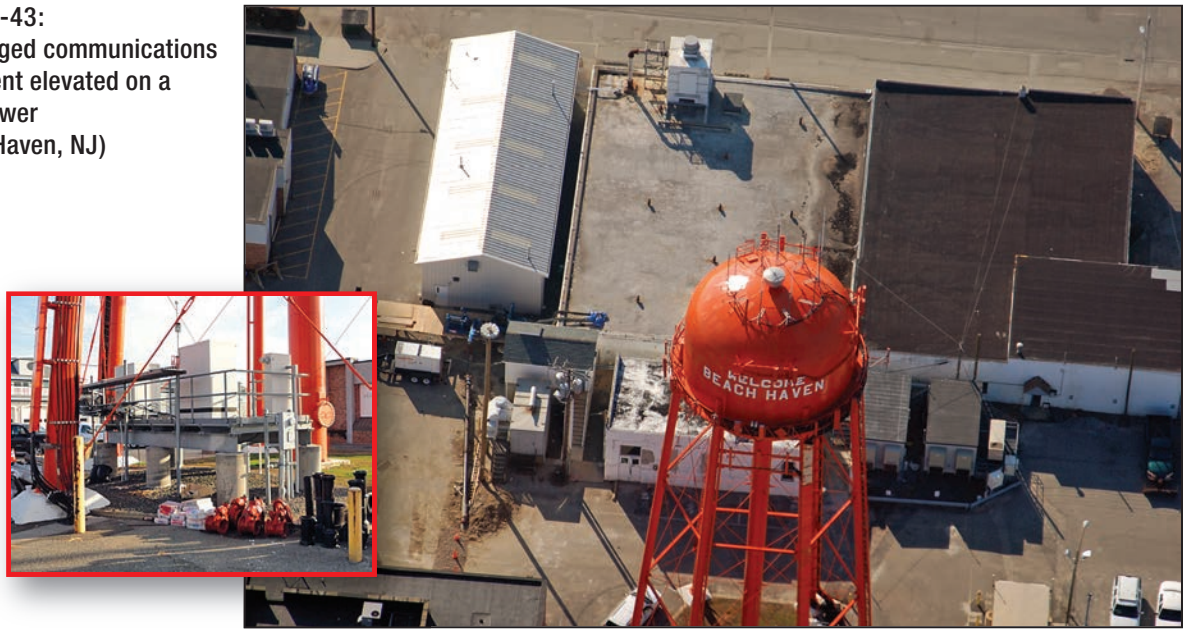
Figure H-40: Beach Haven Volunteer Fire Company No. 1 (Beach Haven, NJ)

Figure H-41: Louvered door to the generator room (Beach Haven, NJ)

approximately 4 feet deep inside the first floor of the facility (Figure H-42). Both the generator and boiler were damaged, along with equipment, contents, and interior finishes. The communications equipment for the station was undamaged, as it was elevated on a water tower behind the facility (Figure H-43).

Figure H-42:
Ground floor was inundated with approximately 4 feet of water (Beach Haven, NJ)

Figure H-43:
Undamaged communications equipment elevated on a water tower (Beach Haven, NJ)



Effect on Operations and Recovery Actions. Firefighters worked remotely from a local motel for 2 weeks following the storm before moving operations back to the firehouse.

H.4.3 Jersey City Fire Department Engine Two (Jersey City, NJ)

Facility Description. The Jersey City Fire Department (JCFD) Engine Two station is a two-story building (with a basement) built over 100 years ago and is approximately 0.5 mile west of the Hudson River in the Paulus Hook neighborhood (Figure H-44). The site is in Zone AE with a BFE of 9 feet according to the August 16, 2006, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 12 feet and an advisory elevation of 18 feet for the 0.2-percent-annual-chance event.

Figure H-44: JCFD Engine Two is housed in a two-story station (with a basement) built over 100 years ago (Jersey City, NJ)

Damage to Facility. The JCFD Engine Two station incurred extensive flood damage to mechanical and electrical equipment. Hurricane Sandy storm surge flooded the basement to the ceiling and the first floor of the building to about 2 to 3 feet, damaging contents. Floodwater entered the facility through doorways and then entered the basement through the stairway. In addition, floodwater entered the basement through a louvered at-grade vent located in the sidewalk adjacent to the building (Figure H-45). The basement inundation damaged the boiler, hot water heater, and electrical distribution service panel (Figure H-46).

Effect on Operations and Recovery Actions. JCFD Engine Two was unable to continue operations because of extensive damage to mechanical and electrical equipment. The facility does not have an emergency generator and was unable to function during and after the storm. During the MAT site visit (approximately 45 days after Hurricane Sandy), the station was still unoccupied, and the repairs remained incomplete. Mitigation was being integrated into the repairs, including relocating the electrical distribution service panel from the basement to the first floor (Figure H-47).

Figure H-45: Floodwater entered the basement through a louvered at-grade vent in the outside sidewalk, which leads to an exhaust vent in the basement (inset) (Jersey City, NJ)

Figure H-46: Equipment damaged by flood inundation in the basement was replaced by this new furnace and hot water heater. Best practice would be to relocate the equipment above the BFE (Jersey City, NJ).

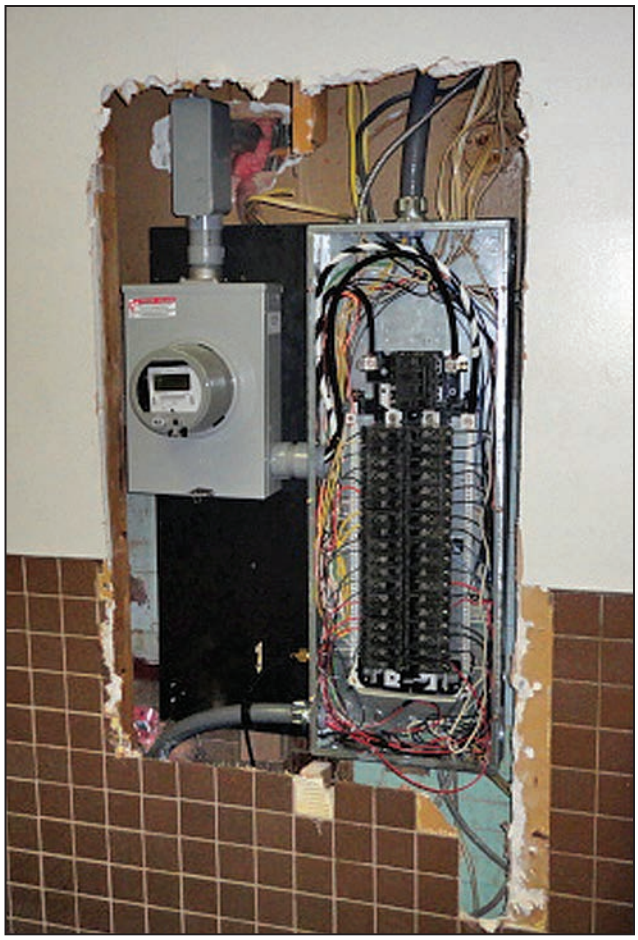


Figure H-47:
New electrical service panel relocated from the basement to the first floor. The previous panel was damaged by floodwater inundation in the basement (Jersey City, NJ).

H.4.4 Seaside Heights Volunteer Fire Department Station 44 (Seaside Heights, NJ)

Facility Description. The Seaside Heights Volunteer Fire Department Station 44 is a two-story station built in 1950. It has no basement, and is adjacent to the Seaside Heights Police Department and Township Hall (Figure H-48). The site is in Zone AE with a BFE of 8 feet according to the August 29, 2006, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 7 feet and an advisory flood elevation of 11 feet for the 0.2-percent-annual-chance event. The station is centered on Barnegat Peninsula between Barnegat Bay and the Atlantic Ocean. The station has an exterior generator shared with the Police Department and Township Hall. The generator is elevated approximately 43 inches and fueled by a belly tank built into the frame of a generator support (Figure H-49). The transfer switch and electrical service panel are on an exterior wall in a covered alley (Figure H-50).

The fire department took precautionary measures the day before the storm's arrival by moving its fire engines away from the coast to higher ground in Toms River, NJ. Based on interviews with a representative from the fire station, an off-road four-wheeler and 5-ton, military 6x6 truck were the only vehicles that remained at the station to be used for critical response operations during the storm. The fire engines were returned to the station (undamaged) and used immediately after the floodwater had receded.

Figure H-48:
Seaside Heights Volunteer Fire Department Station 44 (Seaside Heights, NJ)

Figure H-49:
The exterior generator, elevated approximately 43 inches, is fueled by a belly tank (Seaside Heights, NJ).

Figure H-50: The transfer switch and electrical service panel on an exterior wall in a covered alley (Seaside Heights, NJ)

Damage to Facility. The facility was inundated with approximately 2 to 3 inches of water and sustained minimal damage. Although the facility lost utility service power, the elevated generator allowed the facility to continue providing critical response operations during and after Hurricane Sandy.

Effect on Operations and Recovery Actions. The station sustained minimal damage and was fully operational during and after the storm. Minor cleanup was required.

H.4.5 Ship Bottom Police Station (Ship Bottom, NJ)

Facility Description. The Ship Bottom Police Station is a one-story building (Figure H-51) approximately 300 yards from the oceanfront in Ship Bottom, NJ. The site is in Zone AE with a BFE of 7 feet according to the September 29, 2006, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 9 feet and an advisory elevation of 13 feet for the 0.2-percent-annual-chance event. Prior to the storm, the police station did not have a permanent generator.

Damage to Facility. The facility was inundated with 6 to 12 inches of floodwater throughout the ground floor and lost utility power (Figure H-52). The outside air condensers were also damaged during the storm (see Figure H-53).

Effect on Operations and Recovery Actions. The facility is currently being renovated and will have a propane generator installed. During the MAT site visit (approximately 45 days after Sandy), the police department was running limited operations from a command trailer adjacent to the building.

Figure H-51:
Exterior view of Ship Bottom Police Station (Ship Bottom, NJ)

Figure H-52:
Interior damage to Ship Bottom Police Station (Ship Bottom, NJ)

H.4.6 Ship Bottom Volunteer Fire Company 1 (Ship Bottom, NJ)

Facility Description. The Ship Bottom Volunteer Fire Company 1 two-story firehouse (without a basement) was built in 1934 and has been modified over the years. The site is in Zone AE with a BFE of 7 feet according to the September 9, 2006, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 9 feet and an advisory flood elevation of 13 feet for the 0.2-percent-annual-chance event. The station's furnace, hot water heater, and emergency generator are in a mechanical room on the ground floor. A diesel tank fueling the generator is located outside the facility adjacent to the mechanical room.

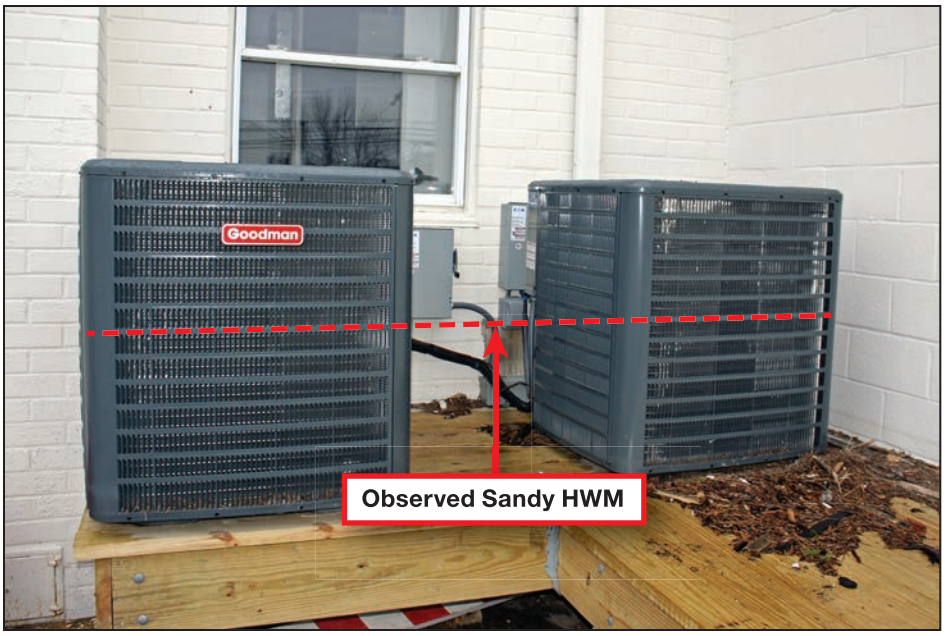


Figure H-53:
Air condensers damaged during the storm (Ship Bottom, NJ)

Damage to Facility. Ship Bottom Volunteer Fire Company 1 was without municipal power for 3 days, but because its generator continued functioning, operations were only slightly affected by the storm. Flood inundation inside the firehouse damaged equipment, contents, and interior finishes. In the mechanical room, 18 to 20 inches of floodwater damaged the grade-level boiler. Although the emergency generator was surrounded by water, its elevation of approximately 20 inches above the floor slab prevented damage (Figure H-54). Prior to the storm, the firefighters moved most of the fire engines off Long Beach Island to higher ground to avoid damage to response vehicles.

Figure H-54:
The emergency generator is elevated approximately 20 inches above the floor slab, which prevented damage from the Hurricane Sandy floodwater inundation (Ship Bottom, NJ)

Effect on Operations and Recovery Actions. The generator provided the station with power for 3 days following Hurricane Sandy until power service was restored by the utility provider. Operations continued at the firehouse immediately following the storm. A new elevated boiler had been installed at the time of the MAT visit.

H.4.7 Toms River Fire Company No. 2 (Toms River, NJ)

Facility Description. The Toms River Fire Company No. 2 is housed in a two-story (no basement) steel-frame station built in 1958. The firehouse is a little more than 400 feet north of Toms Rivers (leading from Barnegat Bay). The site is in Zone AE with a BFE of 5 feet according to the September 29, 2006, FIRM. The Advisory Flood Zone for the site is Zone A with an ABFE of 8 feet and an advisory elevation of 12 feet for the 0.2-percent-annual-chance event.

The station has an exterior emergency generator in a shed towards the rear of the property, which is on slightly higher ground (Figure H-55). Prior to Hurricane Sandy, Toms River Fire Company No. 2 had modernized its mechanical equipment, including installing new boilers elevated above the floor slab on concrete blocks (Figure H-56).

Damage to Facility. The storm surge inundated the ground floor of the firehouse with approximately 38 inches of water (Figure H-57). The generator was not inundated and kept the station powered until service was restored by the utility provider. Damage was primarily limited to interior finishes.

Effect on Operations and Recovery Actions. The firehouse was fully functional immediately following the storm.

Figure H-55: Exterior generator in a shed located on slightly higher ground that was not inundated and provided power to the station during the storm (Toms River, NJ)

Figure H-56:
Prior to Hurricane Sandy, the station modernized the mechanical equipment, including installing new boilers elevated above the floor slab on concrete blocks (Toms River, NJ)

Figure H-57:
The ground floor was inundated with approximately 38 inches of water (Toms River, NJ)

H.4.8 43rd Battalion, Engine 245, FDNY Ladder 161, and NYPD 60th Precinct (Brooklyn, NY)

Facility Description. The 43rd Battalion, Engine 245, and Ladder 161 of the FDNY and the NYPD's 60th Precinct share a combined fire and police station built in 1971. The facility is approximately 0.25 mile north of Lower New York Bay and 0.25 mile south of Coney Island Creek. The site is in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 12 feet and an advisory flood elevation of 17 feet for the 0.2-percent-annual-chance event. The fire station is located in the north end of the facility and has two stories and a basement. The police station is in the south end and has three stories, with two levels below ground. Prior to the storm, the two stations were separated by a masonry wall. The mechanical and electrical room is located two stories below grade in the police station. The police station has a generator on the first floor, with the transfer switch located in the basement. The facility also has a fuel service station.

Damage to Facility. The facility lost functionality during Hurricane Sandy because of significant damage to MEP equipment. Flood inundation was approximately 5 feet above grade and damaged interior finishes, contents, and equipment throughout the first floor (Figure H-58). Floodwater entered the facility through windows, doorways, and ventilation wells, then spread to the basement through stairways, and collapsed the basement wall separating the fire station and police station (Figures H-59 to H-61). The floodwater inundation reached the basement ceiling and damaged the MEP equipment (furnace, hot water heater, switchgear, etc.; Figure H-62) for both stations. Although the police station generator was on the first floor, the transfer switch was located in the lower basement and was inundated. Both the FDNY and NYPD evacuated most vehicles prior to and during Sandy to prevent damage, but most equipment within the stations was destroyed.

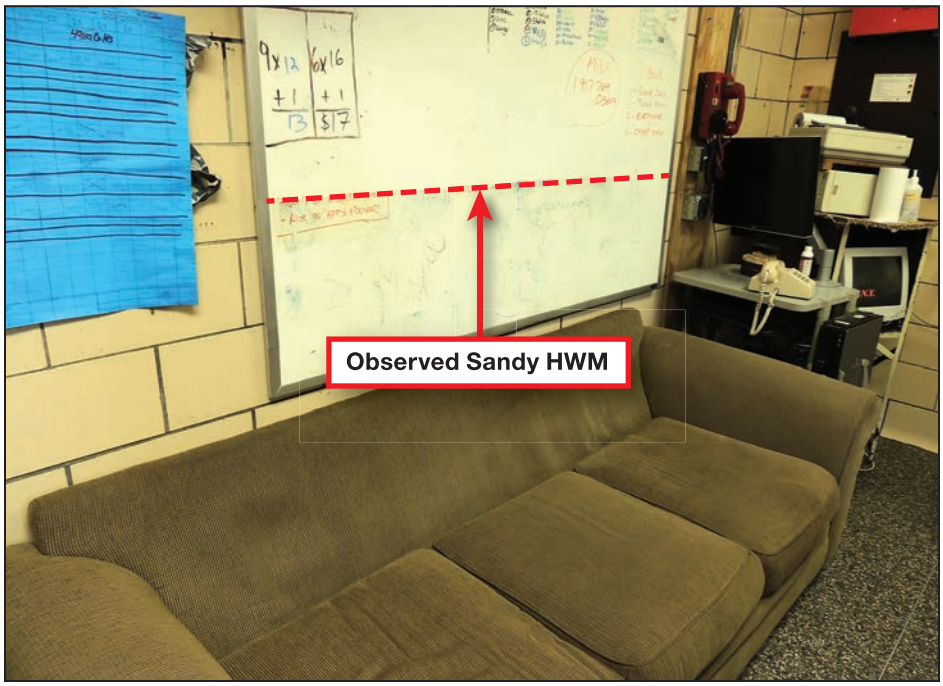


Figure H-58: HWM on the fire station's dry-erase board (Brooklyn, NY)

Figure H-59:
Floodwater entered the fire station's basement through this interior stairway as well as the collapsed wall (see Figure H-60) separating the fire and police stations (Brooklyn, NY)

Figure H-60:
Damage to the masonry wall (indicated by dashed red lines) separating the fire and police stations. The wall collapsed as a result of floodwater inundation (Brooklyn, NY).

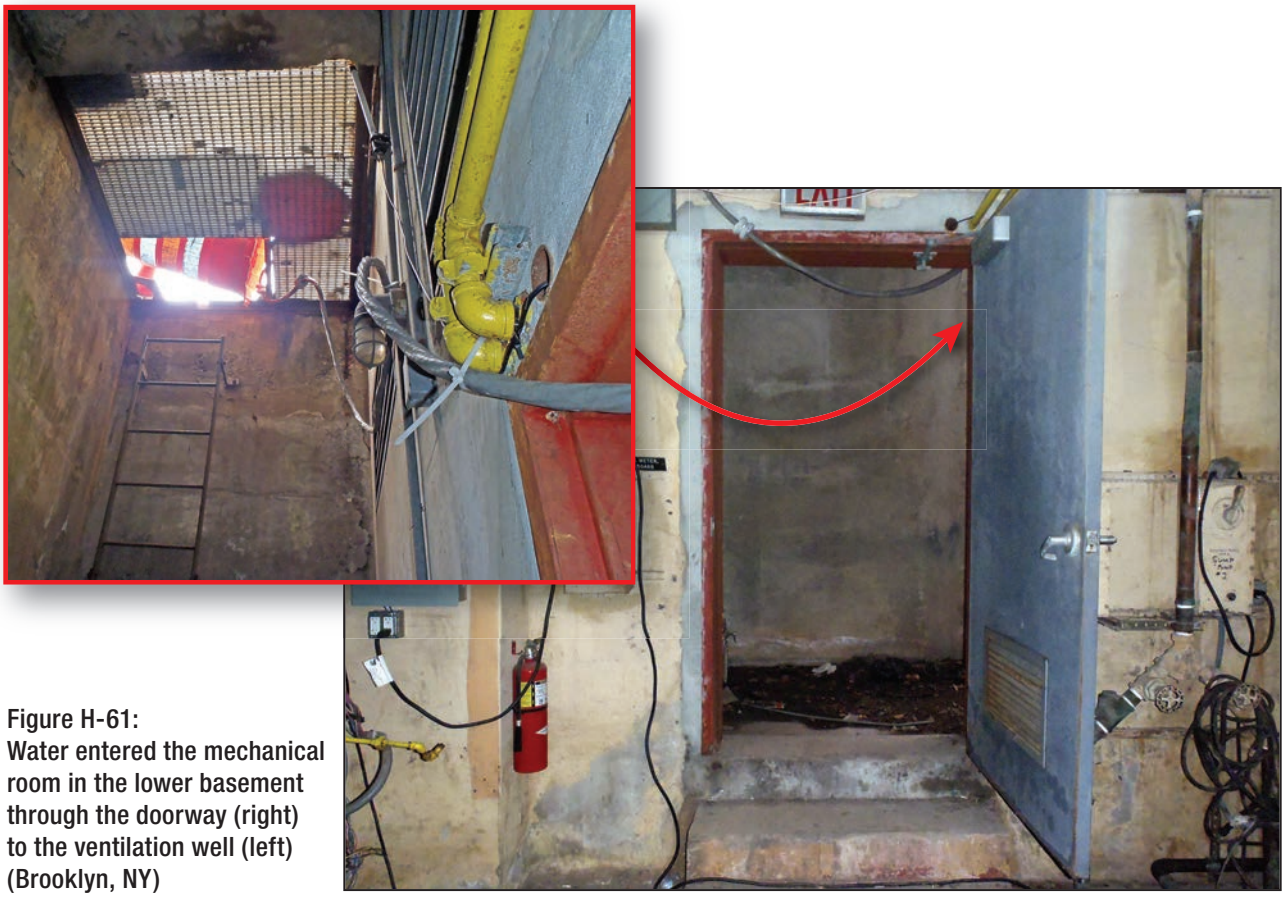


Figure H-61:
Water entered the mechanical room in the lower basement through the doorway (right) to the ventilation well (left) (Brooklyn, NY)

Figure H-62:
The floodwater in the lower basement reached the pipes along the ceiling (Brooklyn, NY)

Effect on Operations and Recovery Actions. During the MAT site visit (approximately 45 days after Sandy), the FDNY was operating from the station on generator power. The fuel service station was still inoperable because they lacked power to pump fuel to vehicles (Figure H-63). The NYPD was running limited operations from a command trailer adjacent to the building with most personnel relocated to an adjacent precinct's facility (Figure H-64). Telecommunications equipment that had been located on the first floor prior to Hurricane Sandy was being elevated to the second floor.

Figure H-63:
The facility fuel service station was not in service at the time of the MAT visit because of the lack of power (Brooklyn, NY)

Figure H-64:
The NYPD had to operate from an adjacent mobile command center for months (Brooklyn, NY)

H.4.9 FDNY Engine Company 168 and Emergency Medical Service 23 (Rossville, NY)

Facility Description. The Staten Island fire station housing FDNY Engine Company 168 and Emergency Medical Service 23 is outside the SFHA on high ground in Rossville, NY, just east of the West Short Expressway. The two-story steel-frame fire station was built in 2002 (Figure H-65) and suffered minimal damage from Hurricane Sandy. The station has an exterior generator at ground level, which kept the building powered for several days following Hurricane Sandy until power was restored by the utility provider.

Damage to Facility. The fire station did not sustain any significant damage from Hurricane Sandy.

Effect on Operations and Recovery Actions. The fully functioning site with power, communications, fuel, water, heat, and accessibility was critical to response operations as it became a command and control center for several Staten Island FDNY units that were inundated.

Figure H-65: FDNY Engine Company 168 and Emergency Medical Service 23 (Rossville, NY)

H.4.10 Lower Manhattan Fire Station Housing FDNY Engine Company 4 and Ladder Company 15 (New York, NY)

Facility Description. The Lower Manhattan fire station housing FDNY Engine Company 4 and Ladder Company 15 was built in 1987 at the bottom of a 36-story commercial office building along the East River near the South Street Seaport across from Pier 11 (Figure H-66). The site is in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the site is Zone V with an ABFE of 15 feet and an advisory elevation of 18 feet for the 0.2-percent-annual-chance flood event.

A dispatch office is partially elevated on the first floor. The living area, along with most of the MEP equipment, is on the second floor. The fire station's generator is on the third floor (Figure H-67).

Figure H-66:
Partially elevated dispatch center on the first floor (New York, NY)

Figure H-67:
The fire station's generator is on the third floor; the generator vent is shown in the inset (New York, NY)

Damage to Facility. Flood inundation from Hurricane Sandy was approximately 6 feet above street level (the HWM at Pier 11 was 11.3 feet based on U.S. Geological Survey HWM-NY-NEW-104). Damage incurred at the station was primarily to equipment and contents on the first floor. The dispatch office, which was flooded with about 1 to 2 feet of water, also incurred some damage.

Effect on Operations and Recovery Actions. The facility was still operating on generator power during the MAT site visit (approximately 45 days after Hurricane Sandy) and was using cellular and radio communications because it still did not have an active phone line.

H.4.11 Sea Gate Police Station (Brooklyn, NY)

Facility Description. The Sea Gate Police Station is a two-story wood-frame building on Surf Avenue along Coney Island Beach in Brooklyn and was built in 1935. The site is in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the site is Zone A with an ABFE of 12 feet and an advisory elevation of 17 feet for the 0.2-percent-annual-chance event.

Damage to Facility. Flood inundation from Hurricane Sandy was approximately 5 feet on the first floor (Figure H-68) and significantly damaged the building structure, mechanical and electrical equipment, and building contents.

Figure H-68: High water was approximately 5 feet throughout the first floor (dashed red line) (Brooklyn, NY)

Effect on Operations and Recovery Actions. Temporary shoring was put in place following Hurricane Sandy to support the second story because of damage to the wood-frame load-bearing walls. The facility ran limited operations from a command trailer adjacent to the building for months after Hurricane Sandy.

H.5 Schools

The observations of performance of four specific schools described in this section of the report are representative of damage observed by the MAT at the schools visited across the impacted area. This section provides a general description of the facility, its location in the floodplain, damages to the facility, and the effects of the damages and recovery actions. See Figure 5-9 for locations of the schools visited by the MAT.

H.5.1 Long Beach Island Grade School (Ship Bottom, NJ)

Facility Description. The Long Beach Island Grade School, constructed in 1951, is a one-story building with a subgrade mechanical room. The school is in Zone AE with a BFE of 7 feet according to the September 29, 2006, FIRM. The Advisory Flood Zone for the site is Zone AE with an ABFE of 9 feet and an advisory elevation of 13 feet for the 0.2-percent-annual-chance event.

Damage to Facility. Floodwater came within 10 to 12 inches of the main floor. The mechanical room under the school was inundated by 29 inches of floodwater that entered through utility and ventilation penetrations. Floodwater damaged furnaces, water heaters, switchgear, and other equipment (Figure H-69).

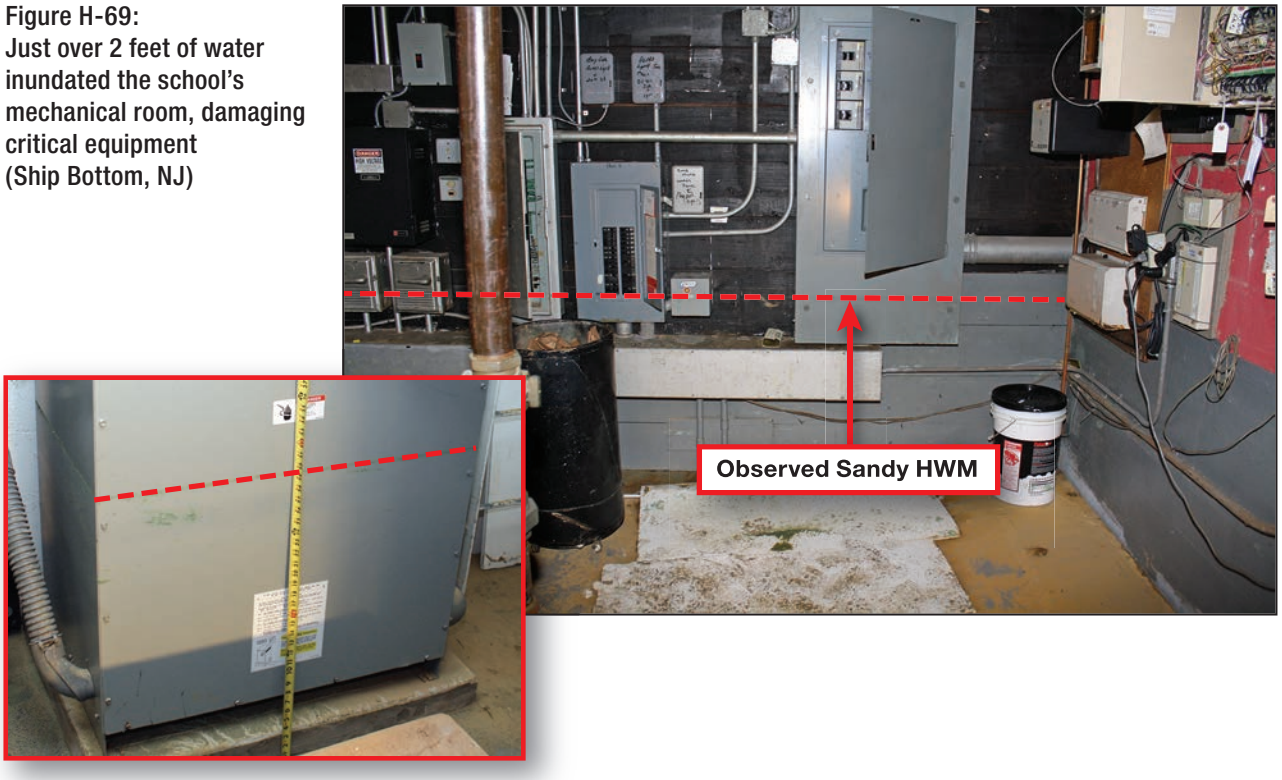


Figure H-69:
Just over 2 feet of water inundated the school's mechanical room, damaging critical equipment (Ship Bottom, NJ)

Effect on Operations and Recovery Actions. The school could not re-open following the storm because of flood damage to mechanical and electrical equipment. It is expected to re-open in February 2014. Students were temporarily relocated to Ethel A. Jacobsen Elementary School until repairs are complete.

H.5.2 Battery Park City School (Manhattan, NY)

Facility Description. The Battery Park City School (Primary School/Intermediate School 276 – PS/IS 276) building is an eight-story, steel-frame structure that opened in 2009 (Figures H-70 and H-71). The school is in Lower-Manhattan Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 12 feet.

The school, which has a capacity of 1,000 students, includes a library, cafeteria, auditorium, and gymnasium, each with a capacity of over 300 people. With the exception of electrical switchgear (Figure H-72), fire service pumps, and a 250-gallon fuel tank, most of the building's MEP equipment is in a mechanical penthouse on the ninth floor. The school has several pieces of anchored rooftop equipment, primarily remote terminal units, associated with its solar panel system (Figure H-73). According to the building architects' Web site, the roof-mounted photovoltaic panels can generate 50 kW of energy, roughly one-third of the energy needed to light the school. The architect estimates the building's high-efficiency boilers, insulation, and solar panels reduce the school's energy costs by 25 percent.

The facility manager took precautionary measures prior to Hurricane Sandy, including placing sand bags at each entrance and locking the elevators on the third floor.

Figure H-70: The Battery Park City School building is an eight-story building opened in 2009 (New York, NY)

Damage to Facility. Storm surge approached the building, but did not exceed a depth of 6 inches above the lowest floor. The school sustained minimal damage during Hurricane Sandy and operated on generator power immediately following the storm until electrical service was restored. The school required only minor cleanup.

Figure H-71: View of Battery Park City School (outlined in red) during post-Hurricane Sandy aerial reconnaissance (New York, NY)

Figure H-72: Switchgear and electrical distribution equipment on the first floor of the school (New York, NY)

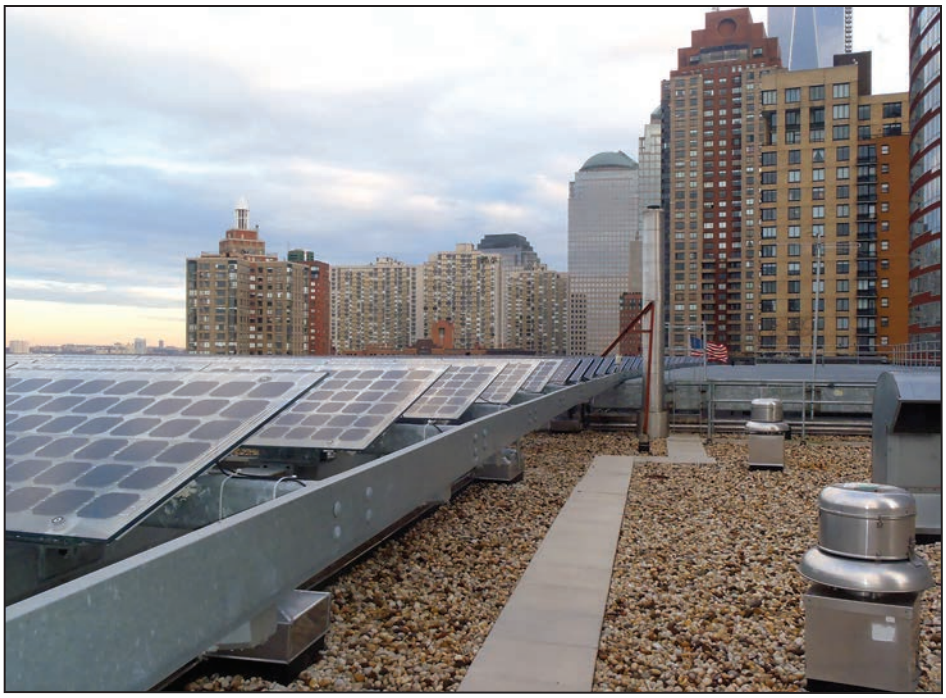


Figure H-73: Photovoltaic cells on the roof of Battery Park City School (New York, NY)

H.5.3 Jim Thorpe School (Brooklyn, NY)

Facility Description. The Jim Thorpe School (PS 370), a four-story building built in 1920 with major renovations in 2011 (Figure H-74), is in the Coney Island neighborhood of Brooklyn. The site is in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 11 feet and an advisory elevation of 15 feet for the 0.2-percent-annual-chance event.

For the 2012–2013 school year, the school has 93 students and 100 staff members. The school building has 17 classrooms, a cafeteria, an auditorium, and a gymnasium. The school's 2011 upgrades included waterproofing the foundation (Figure H-75), replacing the brick envelope, installing new windows, and improving drainage. Prior to the upgrades, the school had a problem with water seeping through exterior walls during significant rainfall events. The school's mechanical and electrical equipment, including an emergency generator, fuel tanks, pumps, boilers, and electrical switchgear are located on the ground floor.

In preparation for Hurricane Sandy, the facility manager placed sandbags and applied foam at the base of each exterior doorway to create a water barrier (Figure H-76).

Damage to Facility. The school was surrounded by more than 4 feet of floodwater; however, less than 6 inches of water infiltrated the ground floor of the school building. The floodwater entered through louvers and doorways where the flood levels exceeded the level to which the expanding foam was applied. Equipment on the ground floor was slightly elevated and was undamaged (Figure H-77).

Effect on Operations and Recovery Actions. The school did not lose utility power. Its backup generator remained functional but was not needed. The school was fully functional when the city re-opened schools the week following the storm.

Figure H-74:
Jim Thorpe PS370 is a four-story building constructed in 1920 with major renovations completed in 2011 (Brooklyn, NY)

Figure H-75:
A water barrier coating was applied to the exterior foundation walls (Brooklyn, NY)

Figure H-76: Expanding foam (shown in the inset) was applied at each doorway before Hurricane Sandy (Brooklyn, NY)

Figure H-77: Mechanical and electrical equipment on the ground floor was undamaged because only inches of water infiltrated the building (Brooklyn, NY)

H.5.4 Primary Schools 43 and 43A (Queens, NY)

Facility Description. PS43 is a four-story public elementary school built in 1993 with approximately 1,600 students, 200 staff, and 81 classrooms. PS43A is a two-story public early childhood center (pre-Kindergarten) built in 2004 with 80 students, 15 staff, and 6 classrooms. PS43 and PS43A are near each other but were constructed to different standards because of the building codes in force at the time of their constructions. See Chapter 2 and Appendices H and I for information on building codes and regulations in New York City. The schools, built just over 10 years apart, are in Far Rockaway, Queens, NY. Both facilities are in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the sites is Zone A with an ABFE of 11 feet and an advisory elevation of 15 feet for the 0.2-percent-annual-chance flood event.

Damage to Facility. The surrounding area experienced approximately 2 feet of flooding during Hurricane Sandy. Despite the similar flooding levels, the adjacent facilities (Figure H-78) incurred much different damage, primarily because of the placement of their utility systems. PS43A, the newer facility whose first floor is about 18 inches above grade, had a few inches of water in the hallway and in some classrooms. Mechanical equipment on the roof and electrical service equipment on the first floor were undamaged. The primary flood damage at PS43A was limited to two hot water heaters on the first floor.

PS43 had extensive damage to its boiler, hot water heater, pumps, and other mechanical equipment, which were at the basement and sub-basement levels. Electrical equipment in the basement sustained some minor damage, but equipment in the sub-basement mechanical room, which was inundated with more than 5 feet of water, was severely damaged (Figures H-79 and H-80). The sub-basement mechanical room has been inundated at least three other times since the school was built in the early 1990s.

Figure H-78: The two schools built almost 10 years apart performed much differently (Queens, NY)

Effect on Operations and Recovery Actions. Following Hurricane Sandy, PS43 relied on a temporary boiler for months. PS43A was able to continue normal operations when the city re-opened schools the week after the storm.

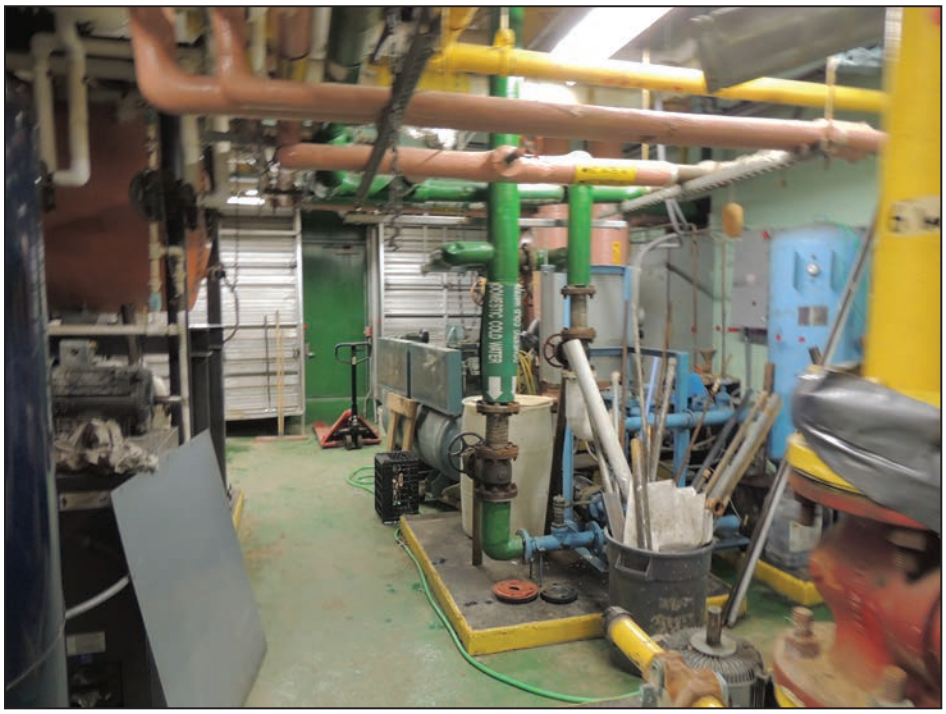


Figure H-79:
Floodwater entered the sub-basement of PS43 through ventilation openings (on each side of door on the far wall), utility conduits, and stairwells; the sub-basement of PS43 was inundated with approximately 5 feet of water (Queens, NY)

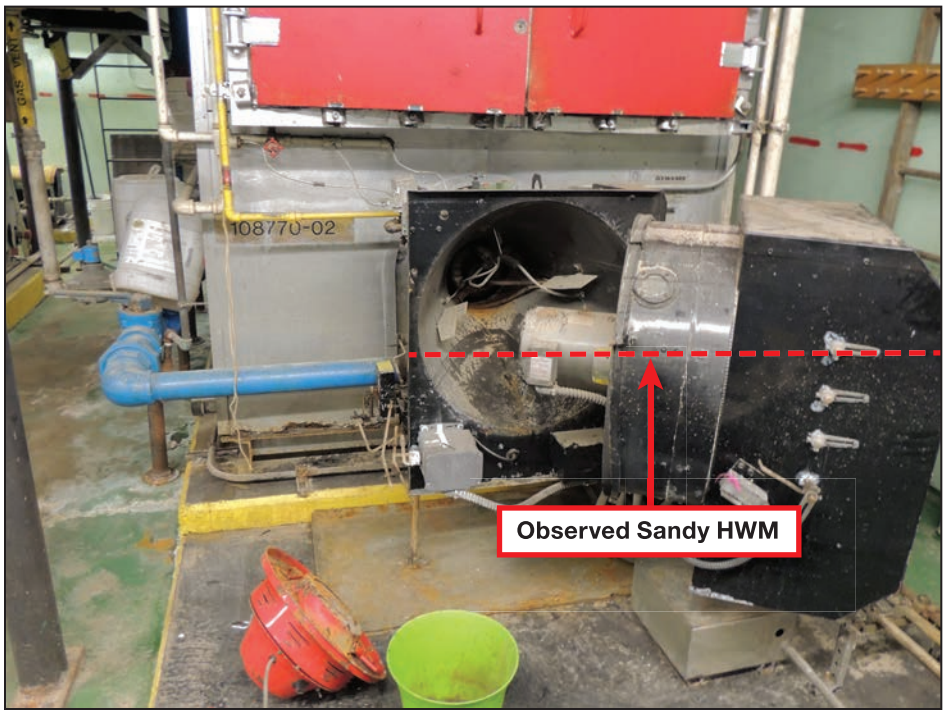


Figure H-80:
Boiler and other mechanical equipment in the sub-basement of PS43 was damaged by floodwater; HWM is indicated by the red dashed line (Queens, NY)

H.6 Data Centers

The following observations of facility performance during Hurricane Sandy are based on MAT visits to two data center facilities in Manhattan and discussions with Verizon representatives about a third facility. This section provides a description of the facility, flood damage, effects on operations, and recovery actions for each facility. See Figure 5-11 for locations of the data centers visited by the MAT.

H.6.1 Internap (Manhattan, NY)

Facility Description. Internap provides a number of network-related services including dedicated hosting, managed hosting, cloud solutions, and managed routing. Internap is located at 75 Broad Street on the 14th floor of a 33-story, steel-framed building with two basements, Basements 1 and 2. An adjacent building, 67 Broad Street, was built in 1928 and expanded in 1930 to encompass the entire block, including what is now 75 Broad Street (New York Songlines 2013).

The site is within the SFHA in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the site is Zone A with an ABFE of 12 feet and an advisory elevation of 15 feet for the 0.2-percent-annual-chance event.

Internap operates a pair of 2-megawatt generators on the second floor (Figure H-81) that can supply all the required power for their normal operations. The generation system relies on electrical switchgear and transformers located in Basements 1 and 2. The generators are fed by a 1500-gallon

Figure H-81: Location of two Internap generators on the second floor indicated by the vents on the building facade (red arrow) (Manhattan, NY)

day tank, which in turn is fed by pumps from a 10,000-gallon fuel storage tank in Basement 2. The communications infrastructure within the building is substantial, and another tenant in the building, Peer1, has a transatlantic cable (JEMB Realty 2013). The building's electric service is provided by Con Edison, who maintains a 480-volt vault in Basement 1.

Internap management executed its Emergency Action Plan. Staff members were put on 24-hour, on-call status, extra food and water were brought in, hotel accommodations were made, and conference call lines with corporate headquarters in Atlanta were secured. However, the mandatory evacuation area for New York City included the 75 Broad Street location, another Internap facility at 111 8th Avenue, and the hotel Internap booked to house its staff during the event.

Con Edison proactively shut down power to Lower Manhattan south of 14th Street at approximately 7 p.m. on October 29. Once power to the area was shut down, Internap relied on the two 2-megawatt generators on the second floor. Sandbags were placed behind the revolving doors on the second floor, but did not stop seepage under the doors.

Damage to Facility. Inundation of the basements damaged both building utility equipment and Internap's emergency power equipment. Approximately 5 feet of water was observed outside 75 Broad Street at the peak of the Sandy storm surge inundation. The floodwater pressure collapsed the building's revolving door and filled the lobby with approximately 3 feet of water.

Prior to the surge, staff noticed that a significant amount of water was entering the basement through the electrical penetrations from the sidewalk and street in the Con Edison vault. The basement where the Con Edison vault was located extends beyond the building footprint underneath the sidewalk. Once the surge compromised the exterior doors of the building, floodwater filled Basements 1 and 2 through stairwells, elevator shafts, cable penetrations, and other vents. The street remained flooded for 10 to 12 hours.

Internap's electric fuel pumps, which push fuel from the storage tank in Basement 2 to the header/day tank on the second floor were submerged and failed. The Internap 10,000-gallon fuel storage tank was submerged under approximately 20 feet of water and its structural anchorage failed (Figure H-82). The floating tank broke its supply lines and damaged fire and smoke detection and fire protection systems directly above it. Floodwater infiltrated a street vent for the fuel storage tank and forced the fuel out of the broken supply lines into the floodwater. Two other fuel storage tanks for other building occupants also broke free and/or imploded.

The building's electrical switchgear, although not energized, was fully submerged. An electrical conduit exploded when seawater and power cables interacted prior to the loss of power. Several brick infill walls failed in the lower basement areas. The control systems and pumps (in the basement levels) for the elevators service and water supply were rendered inoperable by the flooding. The stairwells were dark because the building generator was submerged and the battery backup on individual lights lasted only for a short time. Reflective strips placed on the stairs following recommendations after September 11 had worn off or were no longer reflective.

The building potable water system booster pumps—pumps that pump water to a storage tank on the roof—were submerged and failed. The holding tank on the roof only contained approximately a week's worth of water, and eventually the building was left without water for drinking and sanitation. Water was needed for drinking and sanitation purposes, but the lack of water did not affect business operations.

Figure H-82:
The 10,000-gallon Internap fuel storage tank anchors failed when the tank was submerged by approximately 20 feet of floodwater in the lower basement (left) and electric power vaults for the building that were also inundated in the basement (right) (Manhattan, NY)

Effect on Operations and Recovery Actions. Although the fuel pumps stopped operating after being inundated by floodwater, the day tank on the second floor provided generator power for approximately 8 hours after Con Edison shut down power to the area. Internap staff chose to shut the generators down once fuel levels were low, instead of running the generators dry; this step allowed for an easier restart of the engines once new fuel was obtained. Once the generators were shut down, critical equipment remained in operation on uninterruptible power supply (UPS) systems. However, mechanical systems were not supported by the UPS. Through load shedding, the UPS systems sustained operations for an additional 2 hours, instead the 20 to 30 minutes the UPS is designed for.

To continue operations, Internap staff's highest priority was to obtain fuel for the generators on the second floor. Internap had pre-existing contracts with fuel vendors to deliver fuel to its subgrade fuel tanks; however, the contract fuel vendor's trucks were not able to pump fuel from the street to the second level of the building. A fuel truck with the ability to pump to the second story was located, and with the assistance of their vendors, a consistent fuel supply to the generators was established after 9 hours of downtime for business operations (Figure H-83).

Figure H-83: Emergency generators on the mezzanine second floor with a supply hose from a fuel truck on the street (Manhattan, NY)

Basements 1 and 2 remained flooded for approximately 2 weeks. Pumping of floodwater from the basements took nearly 3 weeks, and an additional 3 weeks of cleanup were required before the basements were suitable for operations.

All structural, electrical, HVAC, and plumbing plans and as-built drawings were stored in basement level engineering offices and were lost as a result of the inundation. At the time of the MAT visit, Internap staff noted that the inability to reference plans had a significant negative impact on recovery. The City's building department maintains records, but older records are on microfiche and take time to obtain.

Internap is considering the following mitigation actions for business operations in floodprone regions:

- Strengthening fuel storage tanks and their anchorage for design-level hydrostatic submersion forces
- Elevating fuel pumps above design flood depth
- Developing contingency plans for obtaining generator fuel
- Installing a fuel filter and/or a fuel clarification system to remove debris from emergency generator fuel (Figure H-84)
- Keeping fuel hose connection to the day tank in place for rapid connection to a fuel pumper truck

Figure H-84:
Filter system placed between generator and truck-mounted fuel tanks to remove debris to ensure a continuous emergency power supply (Manhattan, NY)

- + Revising staff safety protocols to address possible injuries due to flooding, electrical hazards in a flood, navigating dark stairwells, etc.
- + Developing procedures for financial and administrative staff to make unexpected purchases, such as with new vendors or at significant costs (fuel trucks with equipment to pump to elevated levels)
- + Using satellite phones as an alternative to cell phones
- + Clarifying roles and responsibilities between tenants and building owners/operators during emergency situations
- + Installing submersible fuel pumps. However, if installed, plans must consider whether the elevation between a basement-level tank and generators several floors above the tank may be too great since many submersible pumps provide a low head for pumping
- + Locating hydraulic or pneumatic fuel pumps with compressors above design flood elevations (DFEs)
- + Installing remote cameras in basement areas to monitor flooding around electrical/power equipment to provide information without sending personnel down into potentially flooded spaces where they face the risk of electrocution, contamination, etc.
- + Keeping facility plans, drawings, and other reference documents (e.g., structural, electrical, HVAC, and plumbing plans and as-built drawings) in locations above the DFE

H.6.2 Verizon Data Center (Manhattan, NY)

Facility Description. The Verizon Data Center operates in a 17-story building at 104 Broad Street that was built in 1918 (Figure H-85). There are three subgrade levels, referred to as the Mezzanine, Basement A, and Basement B (lowest level). The site is within the SFHA in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the site is Zone A with an ABFE of 13 feet and an advisory elevation of 15 feet for the 0.2-percent-annual-chance event. The site had experienced flooding prior to the Hurricane Sandy storm surge event.

Figure H-85: Verizon Data Center (Manhattan, NY)

Con Edison provides power and steam heat to the building. Power inverters are located on above grade floors. The Con Edison cable vault is at Basements A and B. There are four electrical service entrances at Basement A, as well as a service entrance for the communication cabling. The cable vault houses approximately 500 large (> 3 inches or 76 millimeters) communication cable bundles. The communication cables have either copper/paper, copper/plastic, or fiber optic/plastic construction. Each copper bundle has several thousand copper twisted pair cables that are pressurized at 20 to 25 pounds per square inch by two large air compressors to keep moisture out.

Four generators are located on the Mezzanine and Basement A levels to provide emergency power. Three fuel tanks (25,000 gallons total) and their fuel pumps, as well as two large chillers, are in Basement B. A UPS battery service is also available to sustain power when line power is lost, but before generator power is available. The UPS battery bank takes at least 36 hours to recharge if depleted.

Because of past experience with flooding, standard operating procedures address the management of water infiltration using sandbags at doors. The facility followed these measures in preparation for Hurricane Sandy, but they were not effective.

Damage to Facility. The storm surge first entered the building at street level. As the water table rose around the basement levels, water began to enter through basement walls and openings. Once the floodwater reached a height of approximately 3 feet in the lobby level, stairwells and elevator shafts provided a path for large volumes of water to enter the basement and inundate all basement levels. In addition, part of a sidewalk above a cable vault collapsed, creating another entry point into the basement levels. Although the storm surge subsided fairly quickly, the water was present to the ceiling of Basement A for several days (Figure H-86). Pumps operated for days, but eventually burned out with little change in the water level.

Chillers in basement levels were damaged beyond repair. The MAT observed corrosion affecting a significant amount of piping, including steam pipes that will likely need to be replaced. All water-soaked pipe insulation needed to be removed and replaced. The pipe insulation includes a mix of asbestos-based insulation and non-asbestos insulation. Two of three fuel storage tanks in the

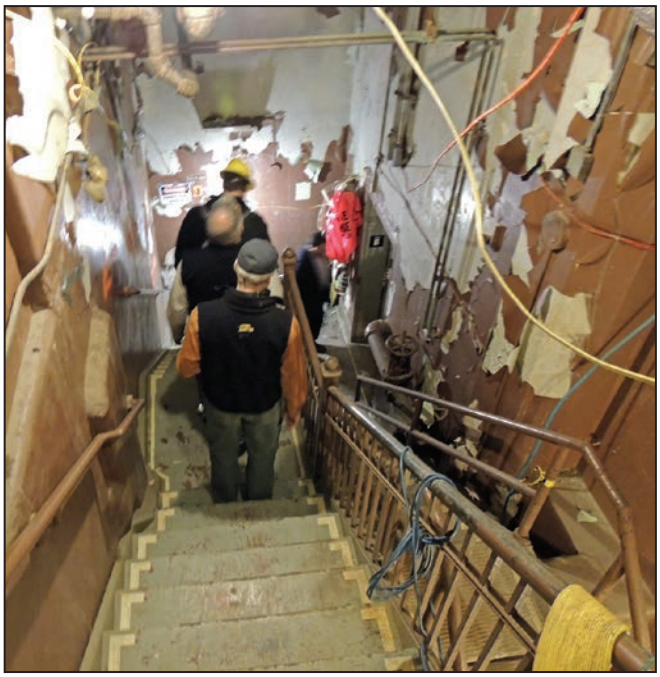


Figure H-86:
Verizon basement stairs after floodwater was drained (left); basement space was ventilated and cleaned of debris (right) (Manhattan, NY)

basement ruptured, and several inches of fuel floated on top of the floodwater. Electrical switchgear, transformers, generators, and other mechanical equipment were submerged and rendered inoperable (Figure H-87).

Cable vaults at the facility were significantly damaged by floodwater inundation. Issues that affected data and communication systems included (Figure H-88):

- The cable pressurization system was compromised and floodwater entered into the communication cables. Any hole, break, or splice in the cable served as an entry point for the floodwater, and the saltwater caused many of the communication cables to short out.

- Many of the copper communication cables had a form of paper as insulation. The paper acted like a wick and moved the water along the inside of the cable. The cable vaults held hundreds of large communication cables; most had multiple shorts and were damaged beyond (reasonable) repair. In contrast to the copper cable bundles, the fiber optic infrastructure was almost completely undamaged.

Effect on Operations and Recovery Actions. At the time of the MAT visit, the building at 104 Broad Street was operating on a mix of generator power and utility power. Temporary power was being supplied from truck-mounted generators and different substations because the original substations were damaged (Figure H-89). Replacement of the building switchgear and transformers was ongoing. Service to customers was interrupted while repairs were made to copper communication cables. Copper communication cables are being replaced with fiber optic cables, because fiber optic cables are not affected by flooding. By February 2013, all but 94 of the 1,082 businesses in Lower Manhattan had phone and internet services restored with fiber optic cables (Smith 2013).

Figure H-87: Basement transformers were completely inundated and must be replaced (Manhattan, NY)

Figure H-88: Communication cables that were damaged after floodwater penetration (Manhattan, NY)

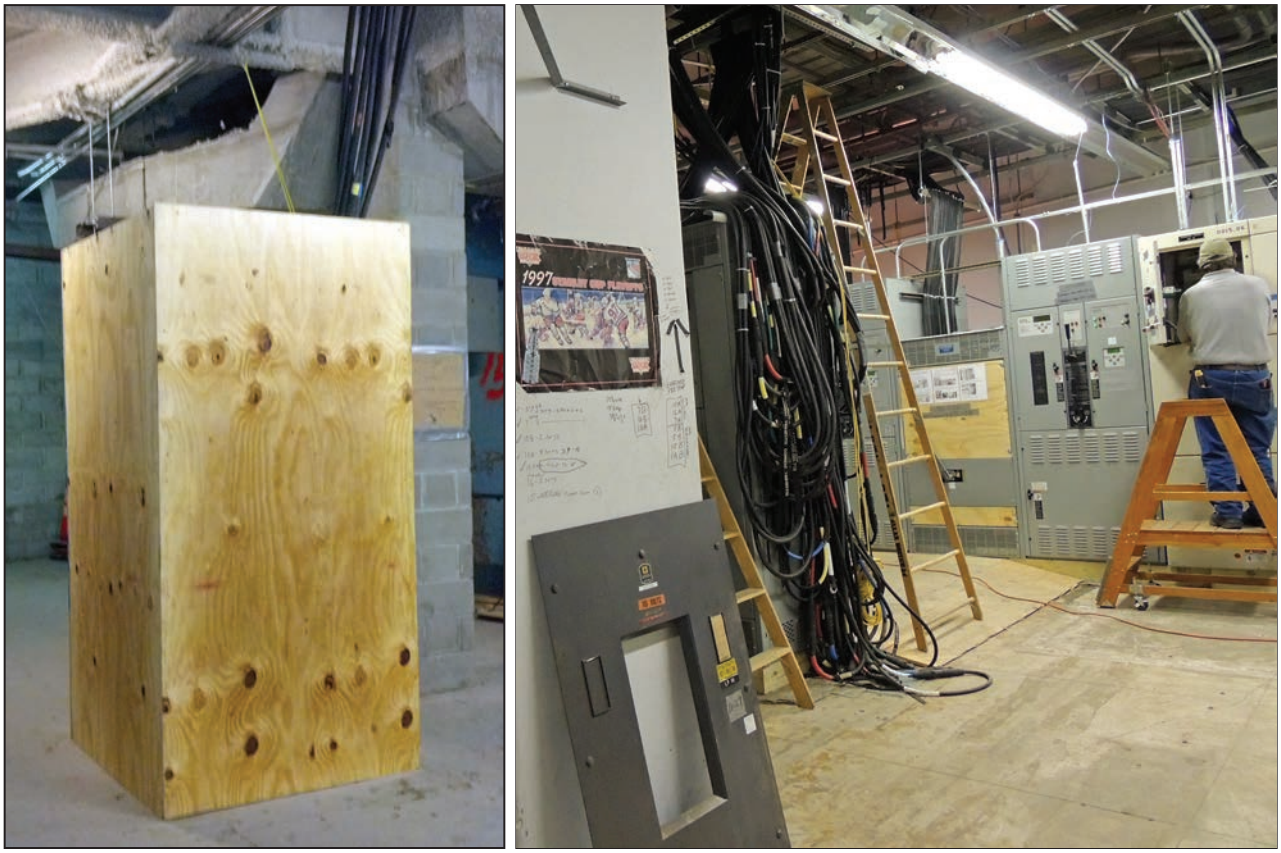


Figure H-89: Temporary utility power was provided from a secondary substation in plywood enclosure (left); flooded electrical switchgear was repaired or replaced (right) (Manhattan, NY)

The communications equipment at 104 Broad receives power through a battery float system, where electrical power is routed through a battery system before being routed to the equipment. This conditions the A/C signal and provides a permanent backup system. A full charge for these batteries is 40 Volts. Other battery float systems, like the one in place at 140 West Street, have a protective shut-off that disconnects the battery bank if the system output voltage drops below 36 Volts. The system at 104 Broad Street did not have a protection system and the battery bank was drained down to zero voltage. It takes approximately 36 hours to recharge the battery system to a minimum level. Once electric service was restored through a generator truck, and temporary electric service was routed to the battery banks, an additional 36 hours was needed to fully charge the battery system. Because the batteries were drained to such a low level, many of the batteries began to fail after Hurricane Sandy and needed to be replaced.

New York City ordinance states that large quantities of fuel stored on site must be stored in the lowest level of a building. The ordinance allows for 275 gallons of fuel to be stored on any floor in day tanks; a large generator bank might use 100 gallons per hour of fuel. The large fuel tanks in the lower basements of 104 Broad and 140 West all failed as a result of either flotation or implosion, and the fuel pumps were submerged. Verizon is considering replacing the fuel pumps with submersible hydraulic pump systems.

H.6.3 Verizon Headquarters (New York City, NY)

Facility Description. The Verizon building at 140 West Street in New York City serves as Verizon's world headquarters.[2] It covers one full city block and has more than 1.3 million square feet. The building has five basement levels referred to as A to E, with E being the lowest level. The cable vaults are located on Level A, and the fuel tanks are stored on Level E, per a New York City building code requirement that onsite fuel storage must be at the lowest level within a facility.

In 2001, 140 West Street was severely impacted by the events of September 11, 2001. Many business continuity and disaster recovery lessons were learned. Prior to September 11, all critical infrastructure at 140 West Street was in the basement levels. During repairs, many changes were made to improve the risk and disaster recovery posture of the headquarters building. Much of the critical infrastructure—generators, electrical switchgear, and chillers—was moved to higher floors. The fuel tanks were anchored in place with structural strapping.

Many electrical and network connections were rebuilt with alternate "quick connects" that could be connected to outside resources, such as temporary generators, if the building infrastructure was damaged. These connections were used during the Hurricane Sandy recovery operations.

Damage to Facility. During the storm surge, floodwater filled the basements up to mid-height on Level A, then subsided and stabilized on Level B. Because the cable vault on Level A was not fully submerged, and the inundation was temporary (hours versus days), the amount of flood damage to the cables was significantly less at 140 West Street than at 104 Broad Street, where the cable vault was submerged for days.

2 These facilities were discussed during the site visit to the Verizon facilities at 104 Broad St, New York, NY but were not visited.

Although the generators were moved to the 10th floor, the floodwater compromised the fuel pumps on Level D, and eventually compromised the fuel tanks on Level E. The depth of the floodwater caused the fuel tanks to implode, but the structural strapping kept the tanks in place.

H.7 Wastewater Treatment Plants

The MAT visited three wastewater treatment facilities. This section describes the steps taken prior to the storm surge event, situations that occurred during the event, and damage resulting from the inundation for each facility. See Chapter 5, Figure 5-15 for locations of the wastewater treatment plants (WWTPs) visited by the MAT.

H.7.1 Passaic Valley Sewerage Commissioners Wastewater Facility (Newark, NJ)

Facility Description. The Passaic Valley Sewerage Commissioners wastewater facility began operations in 1902. The 172-acre plant is located at 600 Wilson Avenue near Newark Bay and is the fifth largest modern wastewater facility in the Eastern United States (Figure H-90).

The Passaic Valley WWTP campus has numerous buildings, some with basements. All structures are on pile foundations. The first floors of the buildings are approximately 4 to 5 feet higher than surrounding ground elevation. The facility has an approximately 1-mile-long, 15-foot-wide underground utility tunnel that connects many basements and galleries. The tunnel is a conduit for power and piping systems. Sump pumps run continuously in the tunnel to manage water infiltration.

In 1924, an interceptor to relieve water accumulation by Newark Airport was added to the south side of the property. In 1980, secondary treatment facilities were added. The Passaic Valley WWTP serves a population of over 2 million residents in the 48 municipalities of Bergen, Essex, Hudson, Union, and Passaic Counties of the Passaic Valley Service District. The Passaic Valley WWTP is a gravity-fed operation that uses both primary and secondary processes to treat wastewater and stormwater discharge. The plant is capable of treating an average of 330 millions of gallons per day of wastewater with peak flows of 400 to 550 millions of gallons per day.

Figure H-90: Passaic Valley WWTP with settling tanks in the foreground (Newark, NJ)

Before Hurricane Sandy, the only power loss ever reported at the plant was for 3 hours during the Northeast blackout on August 14, 2003. The substation that provides power to the plant is on high ground (Figure H-91). Although roads and properties surrounding the facility had frequently flooded in the past, the plant had never been inundated prior to Hurricane Sandy. The flood level for Hurricane Irene just reached the docks at Newark Bay on east end of property.

Figure H-91: Substation and transformers on Passaic Valley WWTP property that avoided flood damage because of the site elevation relative to the flood depth (Newark, NJ)

The site is located within the SFHA in Zone AE with a BFE of 9 feet according to the June 4, 2007, FIRM. The Advisory Flood Zone for most of the site is Zone A with an ABFE of 12 feet and an advisory elevation of 17 feet for the 0.2-percent-annual-chance event. Portions of the site along the bay are within an Advisory Flood Zone in Zone V with an ABFE of 14 feet and an advisory elevation of 19 feet for the 0.2-percent-annual-chance event. Prior to the storm, the facility prepared for flooding by depowering systems and placing sandbags at building openings.

Damage to Facility. The area was inundated with 11 to 12 feet of storm surge during Hurricane Sandy. Floodwater overtopped the bulkhead along Newark Bay and surrounded the site from the south and southwest via Jasper Creek. Buildings flooded to the first floor levels up to 3 feet above grade during the storm surge. The storm surge flooded the sludge storage area near the river starting around 6:30 p.m. on October 29. Systematic de-energizing of facilities took place between 6:30 p.m. and 8 pm. Around 8:30 p.m., the surge flooded the entire plant from the east and southwest directions (Figure H-92). At 8:39 pm, PSEG shut off power to the primary facility substation.

Most of the damage to the Passaic Valley WWTP was caused by the flooding of the utility tunnels and operating galleries (Figure H-93), though the tunnels were not flooded immediately. The tunnels continually receive a groundwater inflow that is discharged by a sump pump system. Final clarifying tanks are approximately 13 feet deep, and occupy a large basin with 13 feet of additional height above grade level. The surge filled the basin, effectively mixing all of the tank contents. The plant has diesel fuel generators to close the influent gates, but the generator equipment was submerged. The fuel tank and fuel pump for the generators were about 6 feet above the generators and were not flooded. The influent gates were manually shut once the floodwater receded.

Basements of several service buildings not connected to the tunnel system were found to be flooded on October 30, but the tunnel system only had several inches of water and was walkable. Air vents for the tunnel system are 8 feet above the flood levels, and were not a source of flooding. On October

31, the below-grade utility tunnel system and galleries were found to be flooded up to the ceilings. The source of the flooding is not known, but seepage from overcharged soils and the loss of power to sump pumps likely played a role.

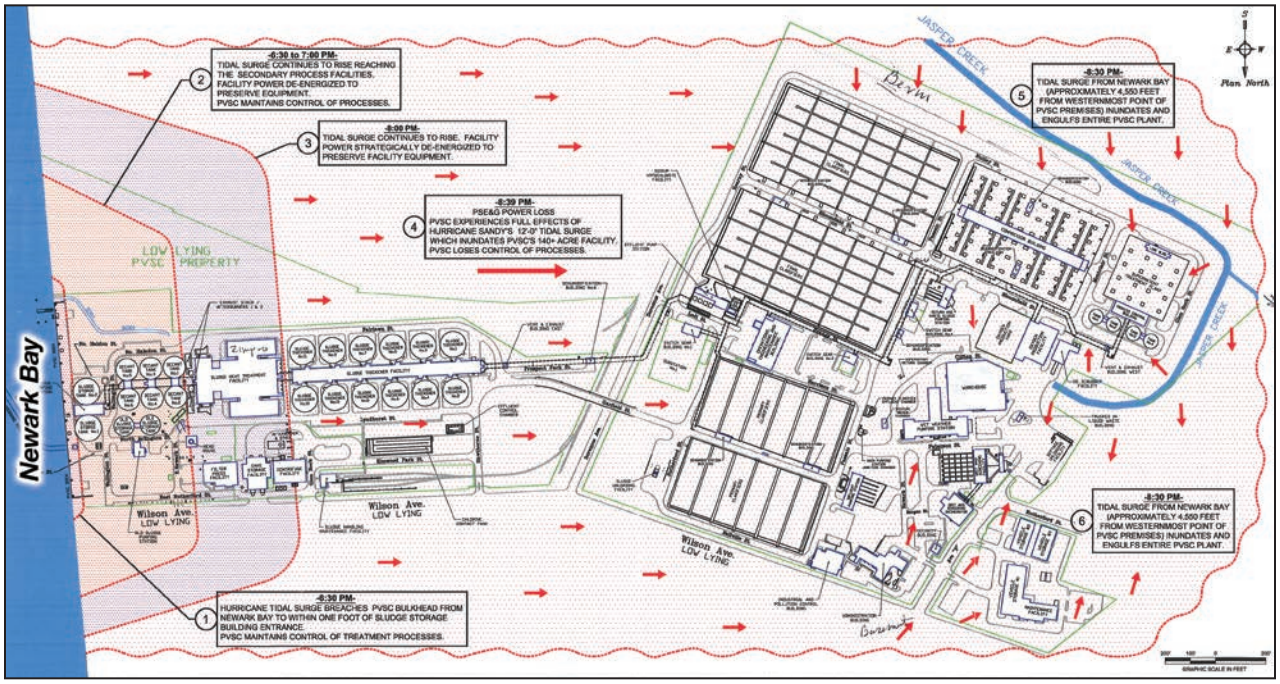


Figure H-92: Schematic of floodwater inundation starting from Newark Bay (left) around 6:30 p.m. on October 29 and moving across the site and around the facility

GRAPHIC COURTESY OF PASSAIC VALLEY SEWERAGE COMMISSION (NEWARK, NJ)

Figure H-93: Section of tunnel and basement galleries that flooded (Newark, NJ)

Effect on Operations and Recovery Actions. Equipment and systems damaged by the inundation included sump pumps for tunnel and galleries, 471 motors, biological systems for treatment, switchgear, boilers for process heaters, pumps below tanks, final clarifying tanks that were flooded with seawater (estimated at 37 million gallons), and the communication systems. Primary clarifying tanks were not flooded.

Power was restored on October 31 at 10 p.m. The local substation, which was shut down by PSEG, was not flooded, so power was restored quickly. High-volume pumps were loaned to the facility to drain the tunnels and basement galleries. The pumping operation was completed in approximately 3 days. Efforts to restore primary treatment took precedence during the recovery. Effluent pumps were started and tanks were drained. The influent pumps are elevated inside a building, but their power feeds were wetted. The effluent areas were cleaned and the gates were opened. By December 18, 2012, secondary treatment standards were being met, while repairs and replacement of equipment continued.

Passaic Valley WWTP is considering, depending on tradeoffs, the following mitigation actions:

- Providing alternate sources of power
- Building a berm or floodwall around the site
- Improving pumping capability for flood conditions
- Improving vehicle access to plant as surrounding roads are frequently flooded

H.7.2 Bay Park Sewage Treatment Plant (East Rockaway, NY)

Facility Description. The Bay Park Sewage Treatment Plant (STP) at 2 Marjorie Lane in East Rockaway is part of the Nassau County wastewater facilities (Figure H-94). The plant started operations in 1949 and was upgraded in the 1970s. The 60-acre site has facilities for primary and secondary treatment and is permitted to treat 70 million gallons per day. The plant is gravity fed and receives wastewater from sewage pumping stations throughout the county. Treated water is discharged into Reynolds Channel by gravity flow and using tide pumps, as needed. The facility has its own power plant, which is unusual.

The buildings at the Bay Park STP have up to three subgrade levels. A tunnel network connects many of the facilities and is a conduit for power and piping systems. Electrical system components are distributed across the site (transformers, switchgear, etc.). The facility had never experienced flooding before Hurricane Sandy.

The site is located within the SFHA in Zone AE with a BFE of 9 feet according to the September 11, 2009, FIRM. An Advisory Flood Zone was not issued for this site. Bay Park STP prepared for Hurricane Sandy by attaching plywood to sidewall vents to raise the protected elevation by 4 feet. Emergency generators for other STP and pumping stations were staged at Bay Park STP, because flooding was not expected. However, all of the generators at Bay Park STP were flooded and could not be used at other sites as planned.

Damage to Facility. The area experienced an 11- to 12-foot storm surge, which caused flood levels of 2 to 5 feet above ground level, depending on the site elevation. Three quarters of the site was flooded by storm surge within a half hour period. Employees across the plant were contacted by radio

(cell phones were not working well) and told to go to higher floors in the administration building. Because of the sudden, unexpected flooding, site systems were not de-energized as planned. The flood elevation mark in Figure H-95 may not be the peak elevation, but a "settled" flood elevation that occurred before subgrade levels were pumped. Some buildings are slightly elevated and were not flooded by the storm surge.

Figure H-94:
Aerial view of Bay Park STP adjacent to Oyster Bay
PHOTOGRAPH COURTESY OF BAY PARK STP (EAST ROCKAWAY, NY)

Figure H-95:
Flood-damaged electric panels in a sludge dewatering facility with flood depth marked at 2 feet 7 inches (red dashed line) (East Rockaway, NY)

The plant does not rely on the local power company and its onsite power plant can operate on digester gas, natural gas, or fuel oil. The power plant itself was not inundated but the pumps that provide cooling water were flooded, and the power plant had to be shut down. Electrical equipment, including transformers, switchgears, distribution panels, branch circuits, and panel boards, was distributed across the site; equipment in flooded areas was significantly damaged by corrosion. Motors and controls for settling tanks were also damaged (Figure H-96).

In addition to its onsite power plant, the facility has backup generators for critical plant functions. Underground fuel tanks that supply the generators are in an area that storm surge did not reach. Truck-mounted generators were brought onsite prior to the storm to support recovery efforts (Figure H-97).

Effect on Operations and Recovery Actions. The STP was offline for 2.5 days. The facility resumed primary treatment of wastewater within 1 week of the storm, but in a manual mode that continued until automated systems were restored (Figures H-98 and H-99). Raw sewage pumps were submerged, but the motors were elevated above flood level, which facilitated getting pumps back on line.

Figure H-96: Settling tanks were inundated, and all motors and controls (outlined in red) that were not elevated were damaged or destroyed (East Rockaway, NY)

Figure H-97: Truck-mounted generators were brought in prior to the storm to support recovery efforts (East Rockaway, NY)

Figure H-98:
Subgrade motors for effluent pumping with power and electronic controls in conduits through the concrete slab; repairs required pulling all wires in the conduits (East Rockaway, NY)

Figure H-99:
Temporary effluent pumping system (East Rockaway, NY)

After 3 weeks, process areas were in service, emergency repairs were being completed as equipment was repaired and evaluated, and sump pumps were in place for the tunnels.

Bay Park STP is considering the flowing mitigation actions:

- Floodproofing the power plant on site
- Elevating or floodproofing motors and equipment that run the influent pumps
- Addressing backflow of drain system into building. Other buildings (outside Bay Park) with pumped drain systems for toilets did not have backflow problems.
- Addressing the water from the south and east sides entering through doors and going down stairs. Surcharged soil also caused seepage that lasted for several weeks.

H.7.3 Yonkers Wastewater Treatment Plant (Yonkers, NY)

Facility Description. The Yonkers WWTP is located at One Fernbrook Street on the Hudson River, about 20 miles north of New York City. The facility was originally constructed in 1930 and was renovated in by Dames and Moore in 1978 (Figure H-100).

Figure H-100: Yonkers WWTP with Hudson River on the left (Yonkers, NY)

The Yonkers WWTP is gravity fed, serves a population of over 500,000, and treats wastewater for a large part of Westchester County. The plant treats, on average, 95 million gallons per day using primary (screens and grit) and secondary (digesting tanks) processes. The Yonkers WWTP facility includes office spaces and a subgrade utility tunnel with motors, pumps, electronic controls, and conduit and piping systems for power, data, communications, and water (Figure H-101). The primary system has backup generator power to ensure that it is always functional.

The site is located within the SFHA in Zone AE according to the September 28, 2007, FIRM. The Advisory Flood Zone for most of the site is Zone AE with an ABFE of 10 feet and an advisory elevation of 15 feet for the 0.2-percent-annual-chance event. Portions of the site along the river are within an Advisory Flood Zone in Zone V with an ABFE of 12 feet and an advisory elevation of 17 feet for the 0.2-percent-annual-chance event. Although the facility is within the SFHA, the Plant

Figure H-101: Subgrade utility tunnel with motors, pumps, electronic controls, and conduit and piping systems for power, data, communications, and water (Yonkers, NY)

Superintendent stated that the plant had not experienced flooding during the 30+ years he had worked there. In anticipation of Hurricane Sandy, the Yonkers WWTP placed many sandbags to protect doorways and vent openings.

Damage to Facility. During Hurricane Sandy, a 12-foot storm surge traveled up the Hudson River and inundated the facility. The Superintendent requested that Con Edison de-energize the plant; this proactive action facilitated recovery and restart of the plant after floodwater receded. Equipment on the basement level—including switchgears, supervisory control and data acquisition (SCADA) systems, and elevators—was damaged. The first floor was inundated with 2 to 3 feet of water.

Effect on Operations and Recovery Actions. The plant was closed for 3 weeks after Hurricane Sandy because flooded plant equipment was non-functional. After power was restored, floodwater was pumped out of basements and tunnels, surfaces were cleaned and/or decontaminated, and equipment was dried and checked before it was restarted. All systems were evaluated for damage to determine whether they needed repair or replacement, particularly the 400 motors, pumps, and electronics. Mold was not widely reported, but is an ongoing concern that will be monitored. All permits were received to restart the plant on November 22, 2012. By the end of November, the plant was releasing fully treated effluent into the Hudson River.

Yonkers WWTP is considering the flowing mitigation actions:

- Elevating emergency generators and fuel oil
- Moving switchgear to second floor from first floor

- Labeling valves clearly to assist rapid response to events
- Grooving doorways for better flood barrier seal
- Covering air vents
- Relocating oil vats

H.8 Transportation Facilities

The MAT visited two subway stations, one rail car maintenance facility, and four gas stations. The following section provides a description of each facility and observations made by the MAT. See Chapter 5, Figure 5-9 for locations of the transportation facilities visited by the MAT.

H.8.1 PATH Harrison Maintenance Facility (Harrison, NJ)

Facility Description. The Port Authority Trans-Hudson Corporation (PATH) was established in 1962 as a subsidiary of The Port Authority of New York and New Jersey. The heavy rail rapid transit system is a key transit link between Manhattan and neighboring New Jersey urban communities and suburban commuter railroads. The system has 13 stations, including the World Trade Center Transportation Hub, and one maintenance facility. PATH carries 244,000 passenger trips each weekday (PATH 2013).

The PATH Harrison Maintenance Facility is on Cape Street along the Passaic River in Harrison, NJ, approximately 2 miles east of downtown Newark. The facility was opened in 1990 for the maintenance and repair of approximately 300 PATH system rail cars. In addition to 20 rail tracks (Figure H-102), the facility has elevated inspection and service areas with subgrade mechanical pits, storage areas and shops, an oil separator for wastewater before it is sent outside the facility, and an onsite substation. Rail cars are stored outdoors around the facility as a limited number can be serviced at a time. The site slopes upward from the Passaic River and is within the SFHA in Zone AE with a BFE of 9 feet according to the March 2, 2006, FIRM. The Advisory Flood Zone for the property is Zone AE with an ABFE of 11 feet and an advisory elevation of 15 feet for the 0.2-percent-annual-chance event.

Figure H-102: Harrison PATH Maintenance Facility looking from the south yard (Harrison, NJ)

The facility had never experienced significant flooding in its 22 years of service, nor was flooding expected for Hurricane Sandy. Other than sandbagging doorways and shutting down rail power prior to flooding, no other flood preparations were made. No emergency generators are kept onsite.

Damage to Facility. Storm surge inundated most of the site. Fences near the river had embedded debris about 5 feet above grade. The peak flood elevation was about 4 feet near the facility. The flood level above the ground floor inside the building was up to 1.5 to 2 feet (Figure H-103). Parts of the rail yard were reported to have approximately 3 to 4 feet of inundation, which damaged the undercarriage electronics and equipment of the rail cars and the electronics and power lines for the tracks. The rail car inspection area, which had a lower floor elevation with tracks for the rail cars, had water levels about half way up the rails. Water came in through the doors of the inspection facility, which were at the track level. However, floodwater did not come in through the facility floor drains, as the drains were part of a closed system that sent wastewater to an oil separator facility.

Floodwater damaged 25 percent of the PATH rail cars at the facility during the storm. The main power system (power inverters and transformers), mechanical equipment, and the boiler room sustained minimal flood damage because of siting and elevation. Most of the distribution electrical panels throughout the facility were above the flood level. However, all 110-volt and 480-volt lines below the slabs and rail tracks (Figure H-104) were damaged and had to be pulled and replaced.

Effect on Operations and Recovery Actions. A significant first step in recovery was to clear debris from the site, which took 1 to 2 weeks. Debris included cargo containers and other materials from adjacent sites along the river. The facility brought an 800 kW generator to start up the oil/water separator and initiate cleanup of floodwater, because the oily floodwater had to be treated before being pumped out of the facility.

At time of the site visit, the facility was operating at about 70 percent power and the maintenance pits were still inoperable. After the flooding event, about 85 rail cars needed undercarriage repair and were starting to corrode.

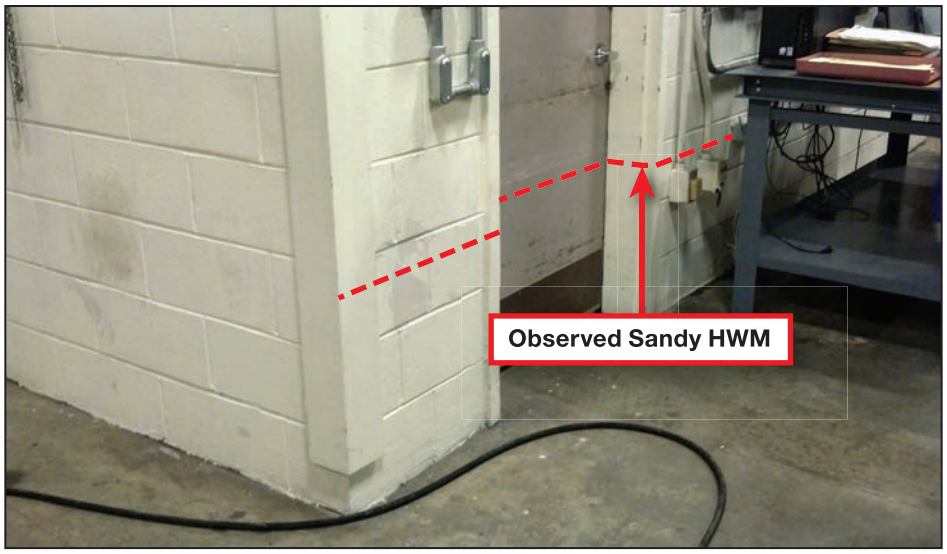


Figure H-103: Flood high water marks (about 18 inches) in supply storage area (Harrison, NJ)

Figure H-104: Outside rail tracks by the maintenance facility (left) and interior inspection facility (subgrade bay right) (Harrison, NJ)

Typically, the PATH system uses 295 of 316 rail cars per day, with remainder of the cars undergoing maintenance and repair. After Hurricane Sandy, there were 220 rail cars operating daily. When the Hoboken PATH station reopens, 295 cars will be needed. Any shortage of cars will be addressed by running 7-car trains instead of 8-car trains and temporarily deferring maintenance until additional cars are available.

Potential mitigation measures being considered by the facility include:

- Elevating the 24-hour operations office up to the second floor
- Determining needs for emergency power during flood and other disaster events
- Elevating switchgear and transformers that are below the DFE
- Improving the process for restarting the facility after power loss

H.8.2 PATH Hoboken Terminal (Hoboken, NJ)

Facility Description. The Hoboken PATH Terminal is on the Hudson River at 1 Hudson Place, just north of the Holland Tunnel and 1 mile east of Lower Manhattan. The Hoboken PATH Terminal is an intermodal facility connecting New Jersey Transit rail and bus lines, Metro-North Railroad, Bergen Light Rail, PATH, and New York Waterway ferries. It is used by more than 50,000 people daily. Parts of the facility date back to the early 1900s. The Hoboken PATH Terminal is adjacent to the New Jersey Transit station and Hoboken Bus Terminal. The top of the stairs is where the property rights of the Port Authority and New Jersey Transit meet. The terminal has steel-frame

construction with reinforced concrete and nonstructural concrete infill walls in places. The focus of this report is on the lower level platforms that are part of the PATH subway system, shown in Figure H-105.

The site is within the SFHA in Zone AE with a BFE of 9 feet according to the March 2, 2006, FIRM. The Advisory Flood Zone for the property is Zone V with an ABFE of 15 feet and an advisory elevation of 20 feet for the 0.2-percent-annual-chance event. The facility has experienced flooding in the past. In 1992, a snow storm caused flooding in the station. Between 1995 and 1997, 54-inch high floodgates were constructed for the entrances below flood elevation, based on the BFE for the site (Figure H-106). The floodgates were used during Hurricane Irene in 2011 and successfully prevented floodwater from entering the stairwells and flowing to the lower station levels. Two to three levels of sandbags were placed around elevators and two entrances, though they were overtopped.

Figure H-105: Lower platform of the PATH rail at Hoboken Terminal (Hoboken, NJ)

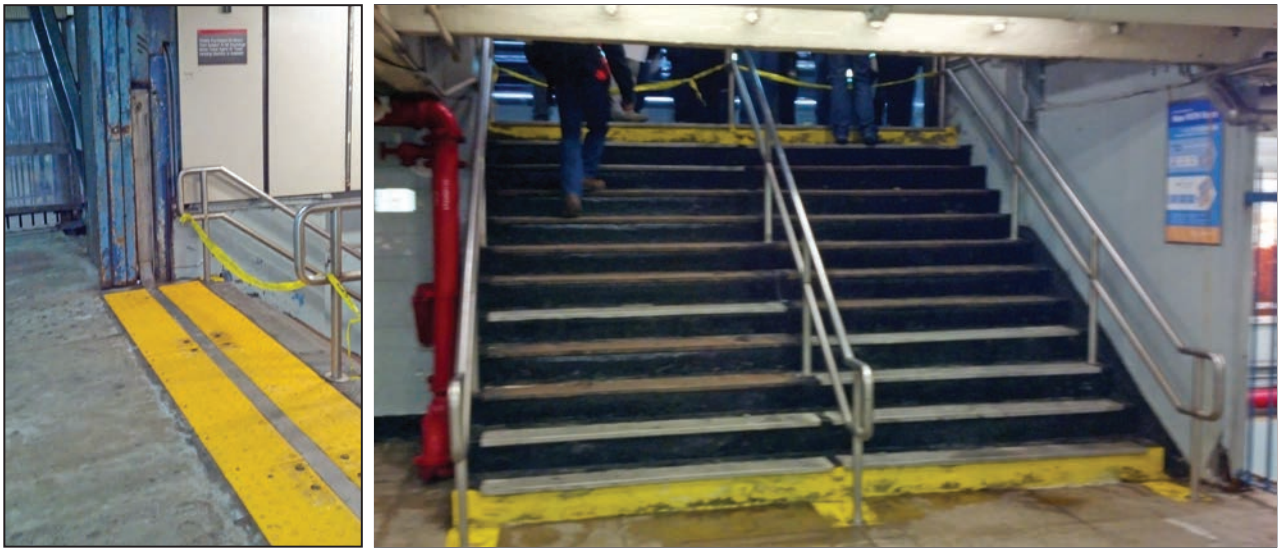


Figure H-106: Flood gate (left) at top of stairs from the New Jersey Transit station to the PATH station (right) (Hoboken, NJ)

Because the tracks are mostly below grade, submersible pumps are at low points in the system to remove water that may enter the tracks. The mechanical pumps in the tunnels are powered by 80 pounds per square inch compressed air and require no local electrical power to function. Flood gates were in place for Hurricane Sandy. Selective sand bagging was done to below-grade electrical closets. The PATH system has emergency power for air compressors that power the submersible pumps. The emergency power system and air compressors are high above the flood elevation at the Washington Street power house. The pumps at the PATH system are considered essential and are designed specifically to operate when submerged.

Damage to Facility. During Hurricane Sandy, a 9-foot storm surge traveled up the Hudson River, which is adjacent to the station. The floodgates held, but water came in through cracks and openings in the walls and foundation and around the staircases. When the floodwater was within 6 inches of overtopping the floodgates, staff in the station were told to evacuate.

Floodwater came from the New Jersey Transit side of the property with the rail tracks, overtopped the floodgate, and came down the stairs into the station. The elevator kiosk walls failed at the street level and became a significant source of water pouring into the station (Figure H-107). Floodwater also came down the wide stairway from the Lackawanna Station, another one of several stairway entrances into the subway station, overtopping the stairwell floodgate and breaching the walls around the frame supporting the floodgate. Substation entry stairs by River Street, the subway entrance by the bus terminal and the farthest from the waterfront, were not a source of water entry.

Floodwater flowed through the station into the subway tunnels at lower elevations, so water did not accumulate to a great depth in the station. Water depths on the 18 tracks varied from less than 1 foot to several feet. The tunnel pumping system operated continuously through the flood event, but at least one pump was clogged with plastic bags and other debris. Smaller capacity backup pumps were overwhelmed by the volume of water in the tunnels. Furthermore, the combined sanitary sewer system that serves the Hoboken Transit facility was overwhelmed by the storm surge and backed up in some locations.

Figure H-107: Elevator kiosk at street level (left) that failed under surge inundation loads and became a significant source of flooding (right) to the station below (Hoboken, NJ)

Pumps were brought in by both the Port Authority and the U.S. Army Corps of Engineers (USACE) to pump the floodwater out of the station. Tunnel B and Caisson 2 were pumped out by the Port Authority and Tunnels E and F were pumped out by USACE.

Effect on Operations and Recovery Actions. At the time of the MAT visit, the station was still closed and undergoing repairs, but was expected to partially reopen that week with limited service. The station reopened on December 19, 2012, and resumed services 7 days a week from 5 a.m. to 10 p.m., with the exception of service between Hoboken and the World Trade Center which was restored for weekday service on February 3, 2013. PATH resumed full normal service on March 1, 2013, including service to the World Trade Center and Exchange Place on weekends. (Lackawanna Coalition 2013).

H.8.3 MTA South Ferry Station (Manhattan, NY)

Facility Description. The MTA NYC Transit system is the largest public transportation system in North America. The system fleet of 6,300 subway cars has a daily ridership of 5 million. There are 468 subway stations, 13 maintenance shops, and two overhaul shops.

The South Ferry Station is located at Whitehall and State Streets and is the southernmost point of the MTA in Manhattan. The station serves more than 6 million people each year. The current facility was built in 2009 with reinforced concrete. The base of the rail track is approximately 50 feet below grade. The site is within the SFHA in Zone AE with a BFE of 9 feet according to the September 5, 2007, FIRM. The Advisory Flood Zone for the property is Zone A with an ABFE of 13 feet and an advisory elevation of 17 feet for the 0.2-percent-annual-chance event.

Before Hurricane Sandy, the street stairway entrances and vents were covered with plywood to an elevation of 4 feet.

Damage to Facility. During Hurricane Sandy, a 9-foot storm surge flooded most of Battery Park adjacent to the station, causing water to enter the station at station entrances, ventilation grating, and possibly through the tunnel leading to South Ferry. The main concourse for Entrance No. 1 (closest to the Staten Island Ferry and shown in Figure H-108) was flooded to approximately 3 feet above the floor level. The control area of entrance No. 2 (across State Street from Entrance No. 1) was completely submerged and the lower mezzanine of Entrance No. 3 (several hundred feet northwest of Entrance No. 2 on State Street) was flooded to approximately 8 feet above its floor level. The platform, which is below the concourse and mezzanines, was completely submerged. Flood inundation in the station submerged the electrical panels for the pumping system, rendering it inoperable.

Effect on Operations and Recovery Actions. The station has been indefinitely closed as a result of extensive flood damage with full restoration estimated to take several years to complete. The exposure of equipment and systems to seawater has caused extensive corrosion that requires replacement of the electrical equipment. Soon after South Ferry station was pumped out and drained, crews removed electrical relays and cleaned them by hand to return them to service. However, heavy corrosion is visible on the banks of relays. Throughout the subway system, metal components that were inundated by seawater began to corrode and never stopped. Even parts that still function will have a diminished lifespan (MTA.info 2013).

The old South Ferry Station, built in 1905, was re-opened on April 4, 2013, to accommodate commuters while the new station is repaired.

Figure H-108:
MTA Whitehall Station (Entrance No. 1) near the South Ferry Terminal (Manhattan, NY)