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SECTION 16. TSUNAMI

A tsunami is a devastating onshore surge of water that can be triggered from geologic activity. This phenomenon can be defined as a string of waves created by an underwater disturbance such as an earthquake, landslide, volcanic eruption, or impact from a meteorite. A tsunami is a series of water waves that can move hundreds of miles per hour in the open ocean and can come ashore with waves as high as 100 feet or more. The height of a tsunami wave that comes onshore is related to the strength of the source that generated the tsunami and to the configuration of the ocean bottom along the shore affected by the tsunami.

DEFINITIONS

Tsunami—A series of traveling ocean waves of extremely long wavelength usually caused by displacement of the ocean floor and typically generated by seismic or volcanic activity or by underwater landslides.

An earthquake can also generate a tsunami if the earthquake causes a major landslide into a water body or if it causes a major slumping of submarine sediments:

- An earthquake results from a sudden shift in the subduction zone between continental and oceanic crusts. This abrupt motion displaces the overlying water upward and downward, which initiates a tsunami (Diagram A in Figure 16-1).
- The initial tsunami splits into a deep ocean and coastal tsunami, headed in opposite directions (Diagram B in Figure 16-1). The distant tsunami travels through deeper waters; therefore, it moves much faster.
- The local tsunami is amplified as it passes over the continental slope, due to the tsunami encountering shallower water (Diagram C in Figure 16-1). As it continues toward land, should the trough of the tsunami reach the coastline first, the water level along the coastline appears to fall rapidly, as if the tide is ebbing. This is called drawdown.

16.1 HAZARD PROFILE

16.1.1 Location

All of the coastal areas of Massachusetts are exposed to the threat of tsunamis. However, at the present time it is unknown what the probability is of a damaging tsunami along the Massachusetts coast.

According to a document titled *U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves*, the U.S. Atlantic coast and the Gulf Coast states have experienced very few tsunamis in the last 200 years. The states of Louisiana, Mississippi, Alabama, the Florida Gulf Coast, Georgia, Virginia, North Carolina, Pennsylvania, and Delaware have no known historical tsunami records. Only a total of six tsunamis have been recorded in the other Gulf and East Coast states. Three of these tsunamis were generated in the Caribbean – two were related to a magnitude 7+ earthquake along the Atlantic coast and one reported tsunami in the Mid-Atlantic states that may be related to an underwater explosion or landslide.

Unlike the Atlantic and Gulf Coasts, the Pacific Basin, Puerto Rico, and the U.S. Virgin Islands have a moderate to very high tsunami hazard. The Pacific territories including Guam, American Samoa, and the Northern Marianas all experience tsunamis, mostly a moderate hazard for these areas. For Washington, Oregon, California, Puerto Rico, and the Virgin Islands, studies show that these areas have a high hazard.

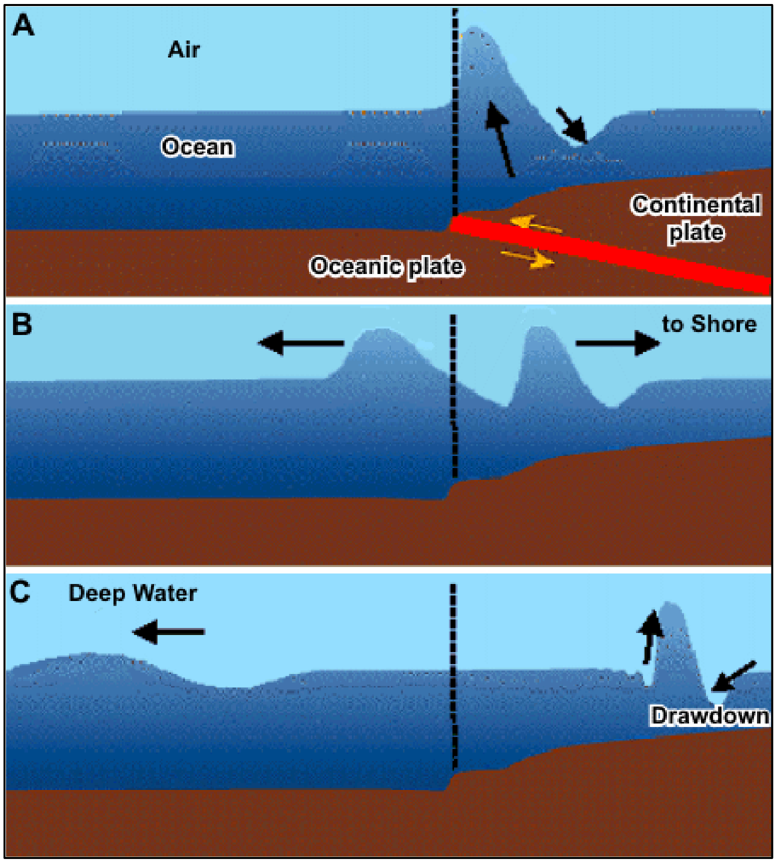

Figure 16-1. Generation of a Tsunami from an Earthquake

Tsunami and tsunami-like waves that have impacted the east coast of the U.S. were analyzed by Lockridge. The National Geophysical Data Center (NGDC) of NOAA compiled a listing of all tsunamis and tsunami-like waves of the eastern U.S. and Canada. Forty-nine potential tsunami events have been identified as possibly impacting the east coast of the U.S. between 1668 and 2008. Of these events, eight were categorized as definite or probable tsunamis.

Mid-Atlantic Ridge

The closest tectonic boundary to the U.S. east coast is the spreading Mid-Atlantic Ridge, which contains numerous faults and earthquakes that take place. However, according to the Maine Geological Survey, tsunamis are more likely to occur at convergent margins. In the Caribbean Sea, there is a convergent plate boundary and a region with a higher probability of generating earthquakes that could produce tsunamis. Tsunamis could potentially travel to New England from the Caribbean, the Mid-Atlantic Ridge, or from the Canary Islands.

Tsunami Threat to the East Coast of the U.S. and New England

Caribbean Islands

The Caribbean is home to some of the most geologically active areas outside of the Pacific Ocean. Similar to the Indonesian Islands, this area has a subduction zone that is located just north of Puerto Rico, where the North American plate is being subducted beneath the Caribbean Plate at the Puerto Rico Trench. This area includes other troughs and areas of plate tectonics that have produced numerous earthquakes, submarine landslides, volcanic eruptions, and resulting tsunami activity.

North Carolina/Virginia Continental Shelf

Although the U.S. east coast is much less likely to be affected by a tsunami than the west coast, tsunami threats do exist. Evidence has been found of a large submarine landslide 18,000 years ago off the coasts of Virginia and North Carolina, called the Albemarle-Currituck Slide, in which over 33 cubic miles of material slid seaward from the edge of the continental shelf, most likely causing a tsunami.

Canary Islands

The Canary Islands are a volcanic island-arc chain located in the eastern Atlantic Ocean, just west of the Moroccan coastline. La Palma is the western-most and the youngest of the Canary Islands and is volcanically active with three large volcanoes. It is also the location of the most active volcano of the Canary Islands, Cumbre Vieja, which last erupted in 1949 and 1971. Some researchers point to this volcano as the source of creating a large tsunami in the Atlantic Ocean.

Based on a study of past landslide deposits and existing geology of the volcano, it is suggested that the west flank of the Cumbre Vieja may experience failure during a future eruption, resulting in a landslide into the depths of the Atlantic Ocean of a block 15 to 20 kilometers wide and 15 to 25 kilometers long.

Although the flank instability of Cumbre Vieja is noted, many scientists disagree with massive failure of the western flank of the volcano. These scientists think it would happen in smaller, separate events that would not be capable of triggering a mega-tsunami. The International Tsunami Information Center stated the following in regards to the creation of a mega-tsunami by massive flank failure:

- While the active volcano of Cumbre Vieja on Las Palma is expected to erupt again, it will not send a large part of the island into the ocean, though small landslides could occur
- No mega tsunamis have occurred in the Atlantic or Pacific Oceans in recorded history
- The colossal collapses of Krakatau or Santorin generated catastrophic waves in the immediate area but hazardous waves did not propagate to distant shores. Numerical and experimental models of such events and of the Las Palma event verify that the relatively short waves from these small occurrences do not travel as tsunami waves from a major earthquake do.

16.1.2 Previous Occurrences

On April 13, 1668, an earthquake of intensity IV struck the Boston and Salem area. It was said that an unknown river was swallowed up and its course was altered. According to NOAA, two run-ups were associated with this event. (http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=70&d=7; ftp://ftp.ngdc.noaa.gov/hazards/publications/ref0541_lockridge.pdf)

On November 18, 1755, a Magnitude-6.0 earthquake threw down chimneys and walls in Boston. Gabled ends of buildings collapsed and stone walls were shaken down. Shaking due to this earthquake was experienced by a ship located near the epicenter of Cape Ann, Massachusetts. The shock was felt over a 300,000 square mile area from the Chesapeake Bay to Nova Scotia. Aftershocks were felt for a month. This event was reported to have produced a noticeable sea wave.

In 1755, a major earthquake in Lisbon, Portugal caused a major tsunami along the Portuguese coast. Historical reports indicate that a small tsunami was observed across the Atlantic Ocean in the Caribbean from this Portuguese earthquake. Thus, history suggests that there is some tsunami hazard to Massachusetts, both from a strong, local offshore earthquake and from a major earthquake across the Atlantic Ocean. Some scientists have also suggested that a tsunami could be generated if a major landslide were to take place on Canary Islands in the eastern Atlantic Ocean. There is no specific information on previous occurrences.

In 1879, a wall of water was observed by small craft in channel between Nantucket and Tuckernuck Islands. There was one injury associated with this event

On November 18, 1929, a magnitude 7.3 earthquake and submarine slump along the Grand Banks of Newfoundland caused a significant tsunami that came ashore along the Newfoundland coast, inundating coastal villages and causing major damage. Twenty-eight persons died in Newfoundland, and one person drowned in Nova Scotia. The earthquake was felt as far south as Washington, D.C., and Baltimore, Maryland. Twelve trans-Atlantic cables were broken, all more than once for a total of 28 breaks over a large area, indicating a turbidity current. This event was recognized as the first documented turbidity current. The tsunami moved at 400 kilometers per hour south and east to Bermuda and Portugal, and impinged at 140 kilometers per hour on southern Newfoundland and Nova Scotia. Minor damage was reported in Bermuda and was seen on tide gages down the east coast of the U.S. and in the Azores in Portugal. In New England, records were complicated by waves produced by a severe storm. In Barnstable, Massachusetts, high tides were reported.

According to the 2008 NOAA study (*U.S. States and Territories National Tsunami Hazard Assessment: Historical Record and Sources for Waves*) tsunami events and losses were summarized for the Atlantic region. Table 16-1 is a summary of their findings for the Atlantic Region. Figure 16-2 shows the number of tsunami events and total number of events causing run-up heights from 0.1 meters to greater than 3.0 meters for the U.S. and its territories in the Atlantic, Gulf Coast, Puerto Rico, and the Virgin Islands.

Source: Dunbar and Weaver, 2008

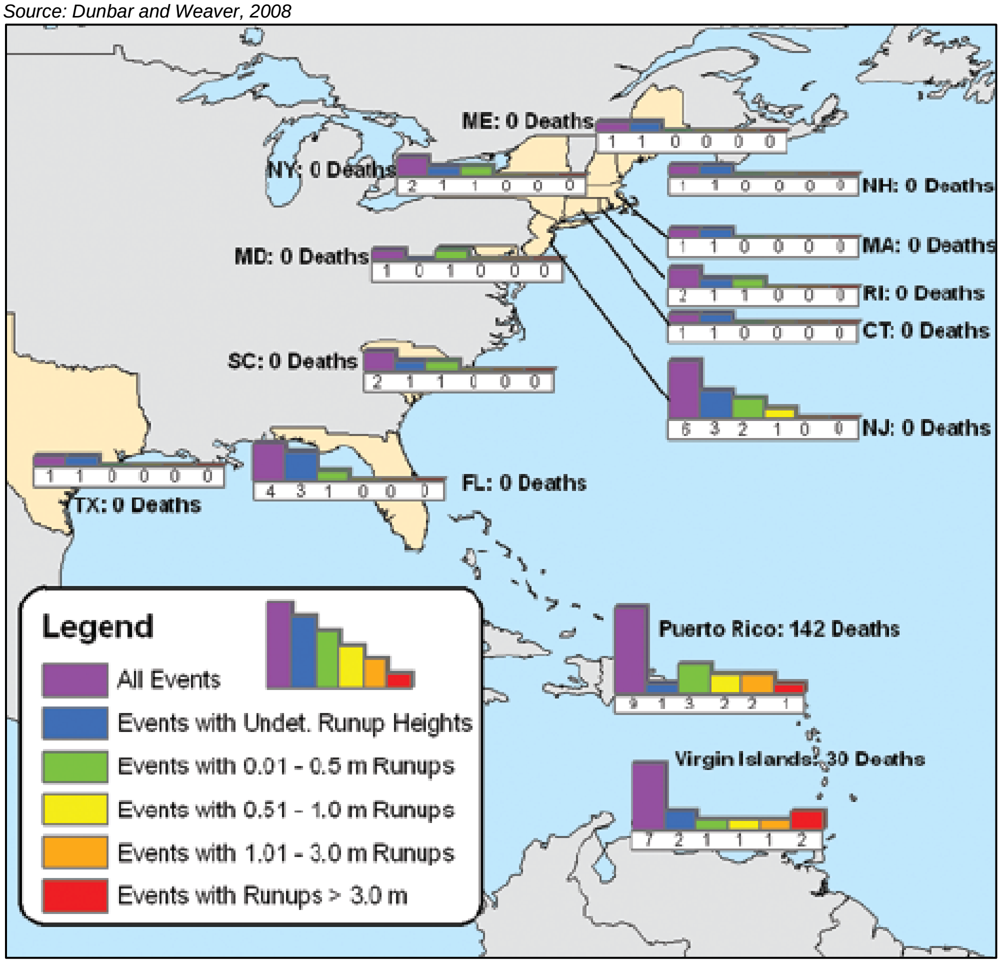

Figure 16-2. Total Number of Tsunami Events for the U.S. and its Territories

TABLE 16-1.
SUMMARY OF TSUNAMI EVENTS AND LOSSES IN THE ATLANTIC REGION

U.S. Atlantic Coast

Location (and year of first confirmed report)	Total number of tsunami events with any observed runup	Events with undetermined runup heights	Events with runups 0.01 to 0.5 m	Events with runups 0.51 to 1.0 m	Events with runups 1.01 to 3.0 m	Events with runups > 3.0 m	Total number of runups for all tsunami events	Reported deaths	Million dollars damage reported
Maine (1929)	1	1					3		
New Hampshire (1929)	1	1					1		
Massachusetts (1929)	1	1					2		
Rhode Island (1929)	2	1	1				3		
Connecticut (1964)	1	1					1		
New York (1895)	2	1	1				7		
New Jersey (1918)	6	3	2	1			8		
Pennsylvania									
Delaware									
Maryland (1929)	1		1				1		
Virginia									
North Carolina									
South Carolina (1886)	2	1	1				2		
Georgia									
Florida (1886)	4	3	1				5		
Atlantic Coast Totals	**21**	**13**	**7**	**1**	**0**	**0**	**33**	**0**	**$0**

Source: Dunbar and Weaver, 2008

16.1.3 Frequency

The frequency of tsunamis is related to the frequency of the events that cause them, so it is similar to the frequency of seismic or volcanic activities or landslides.

In the U.S. coastal areas, the frequency of damaging tsunamis is low compared to many other natural hazards; however, the impacts can be extremely high.

16.1.4 Severity

Tsunamis are a threat to life and property to anyone living near the ocean. From 1950 to 2007, 478 tsunamis were recorded globally. Fifty-one of these events caused fatalities, to a total of over 308,000 coastal residents. The overwhelming majority of these events occurred in the Pacific basin. Recent tsunamis have struck Nicaragua, Indonesia, and Japan, killing several thousand people. Property damage due to these waves was nearly $1 billion.

The West Coast and Alaska Tsunami Warning Center is one of two tsunami-warning centers that are operated by NOAA in the United States. The Warning Center is part of an international tsunami warning system program and serves as the operational center for all coastal regions of Canada, the United States (expect Hawaii), the Caribbean, and the Gulf of Mexico (NOAA, 2013). In addition, the USGS operates the U.S. National Seismograph Network, which is part of the Global Seismic Network that monitors seismic activity around the world. These networks are able to detect seismic events that are capable of resulting in a tsunami. Soon after an earthquake occurs, seismic activity is recorded by seismographs and sent to a satellite and to the U.S. National Seismograph Network in Colorado. There, it is analyzed and warnings, if needed, are issued.

16.1.5 Warning Time

The National Tsunami Hazard Mitigation Program was formed in 1995 by Congressional action which directed NOAA to form and lead a federal/state working group. The program is a partnership between NOAA, the USGS, FEMA, the National Science Foundation, and the 28 U.S. coastal states, territories, and commonwealths.

One of the actions outlined by the plan was the development of a tsunami monitoring system to monitor the ocean's activity and make citizens aware of a possible tsunami approaching land. In response, NOAA developed the DART tsunami monitoring buoys. To ensure early detection of tsunamis and to acquire data critical to real-time forecasts, NOAA has placed Deep-ocean Assessment and Reporting of Tsunami (DART) stations at sites in regions with a history of generating destructive tsunamis. NOAA completed the original 6-buoy operational array in 2001 and expanded to a full network of 39 stations in March 2008. The information collected by a network of DART™ buoys positioned at strategic locations throughout the ocean plays a critical role in tsunami forecasting.

When a tsunami event occurs, the first information available about the source of the tsunami is the seismic information for the earthquake. As the tsunami wave propagates across the ocean and successively reaches the DART systems, the systems report sea level measurements to the Tsunami Warning Centers, where the information is processed to produce a new and more refined estimate of the tsunami. The result is an increasingly accurate forecast of the tsunami that can be used to issue watches, warnings, or evacuations.

16.2 SECONDARY HAZARDS

Aside from the tremendous hydraulic force of the tsunami waves themselves, floating debris carried by a tsunami can endanger human lives and batter inland structures. Ships moored at piers and in harbors often are swamped and sunk or are left battered and stranded high on the shore. Breakwaters and piers collapse, sometimes because of scouring actions that sweep away their foundation material and sometimes because of the sheer impact of the waves. Railroad yards and oil tanks situated near the waterfront are particularly vulnerable. Oil fires frequently result and are spread by the waves.

Port facilities, naval facilities, fishing fleets, and public utilities are often the backbone of the economy of the affected areas, and these are the resources that generally receive the most severe damage. Until debris can be cleared, wharves and piers rebuilt, utilities restored, and fishing fleets reconstituted, communities may find themselves without fuel, food, and employment. Wherever water transport is a vital means of supply, disruption of coastal systems caused by tsunamis can have far-reaching economic effects.

16.3 CLIMATE CHANGE IMPACTS

The impact of climate change on the frequency and severity of tsunami events could be significant. Global sea-level rise will affect all coastal societies, especially small island states and densely populated low-lying coastal areas. *The Scientific Basis* estimates a sea level rise of 0.3 to 2.9 feet from 1990 to 2100. Currently sea level is rising at a rate of about 0.1 inches per year. This rise has two effects on low-lying coastal regions: any structures located below the new level of the sea will be flooded, and the rise in sea level may lead to coastal erosion that can further threaten coastal structures. As a rule-of-thumb, a sandy shoreline retreats about 100 feet for every 1-foot rise in sea level (IPCC, 2001).

16.4 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the tsunami hazard, a one-mile buffer from the coast of the Commonwealth of Massachusetts was used to define the area exposed and thus vulnerable. The following discusses the Commonwealth of Massachusetts' exposure to the tsunami hazard including:

- Population
- State facilities
- Critical facilities
- Economy

NOAA's NGDC is building high-resolution digital elevation models (DEMs) of select U.S. coastal regions, including Nantucket. These integrated bathymetric-topographic DEMs are used to support tsunami forecasting and modeling efforts at the NOAA Center for Tsunami Research, Pacific Marine Environmental Laboratory. The DEMs are part of the tsunami forecast system currently being developed by the Laboratory for the NOAA Tsunami Warning Centers and are used in the Method of Splitting Tsunami model developed by the Laboratory to simulate tsunami generation, propagation, and inundation.

16.4.1 In October 2008, NGDC developed a DEM of Nantucket (refer to Population

For this 2013 update, a one-mile buffer from the coast was used to determine the coastal population exposed to the tsunami hazard. **Error! Reference source not found.** summarizes the 2010 Census population exposed to this hazard.

The impact of a tsunami on life, health, and safety depends on factors including the severity of the event and whether adequate warning time was provided to residents. The USGS operates the U.S. National Seismograph Network which is part of the Global Seismic Network that monitors seismic activity around the world. These networks are able to detect seismic events that are capable of resulting in a tsunami. Soon after an earthquake occurs, seismic activity is recorded by seismographs and sent to a satellite and the U.S. National Seismograph Network in Colorado. There, it is analyzed and warnings, if needed, are issued (Maine Geological Survey, 2008).

Source: Eakins et al, 2009

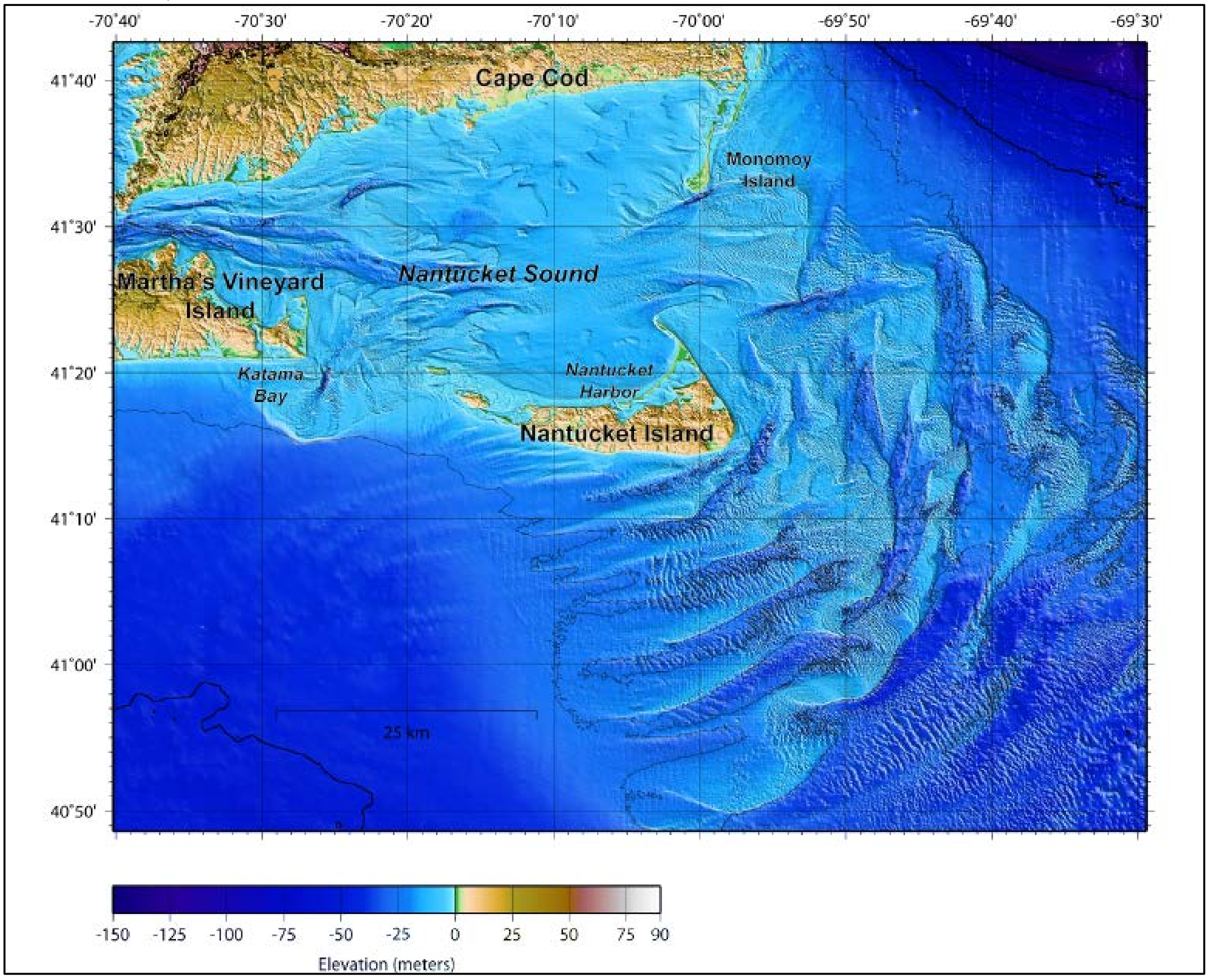

Figure 16-3) to be used as part of the tsunami forecast system. The Nantucket DEM integrates bathymetry and topography in the area spanning Nantucket Sound, from Martha's Vineyard to Nantucket Island, then north to Cape Cod, and extending into the Atlantic Ocean. The DEM has a 1/3 arc-second (approximately 10 meter) cell size, and is referenced to a vertical datum of mean high water.

Based on the research conducted for this planning process, tsunami inundation maps do not exist for the Massachusetts coast. For the purposes of the 2013 update, a one-mile buffer from the coastline was used to define the area exposed to the tsunami hazard until modeling and inundation mapping exists (portions of Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, and Suffolk). As modeling efforts continue and inundation areas are developed, additional spatial analysis will enhance the Commonwealth's exposure and vulnerability evaluation of this hazard.

16.4.2 Population

For this 2013 update, a one-mile buffer from the coast was used to determine the coastal population exposed to the tsunami hazard. **Error! Reference source not found.** summarizes the 2010 Census population exposed to this hazard.

The impact of a tsunami on life, health, and safety depends on factors including the severity of the event and whether adequate warning time was provided to residents. The USGS operates the U.S. National Seismograph Network which is part of the Global Seismic Network that monitors seismic activity around the world. These networks are able to detect seismic events that are capable of resulting in a tsunami. Soon after an earthquake occurs, seismic activity is recorded by seismographs and sent to a satellite and the U.S. National Seismograph Network in Colorado. There, it is analyzed and warnings, if needed, are issued (Maine Geological Survey, 2008).

Source: Eakins et al, 2009

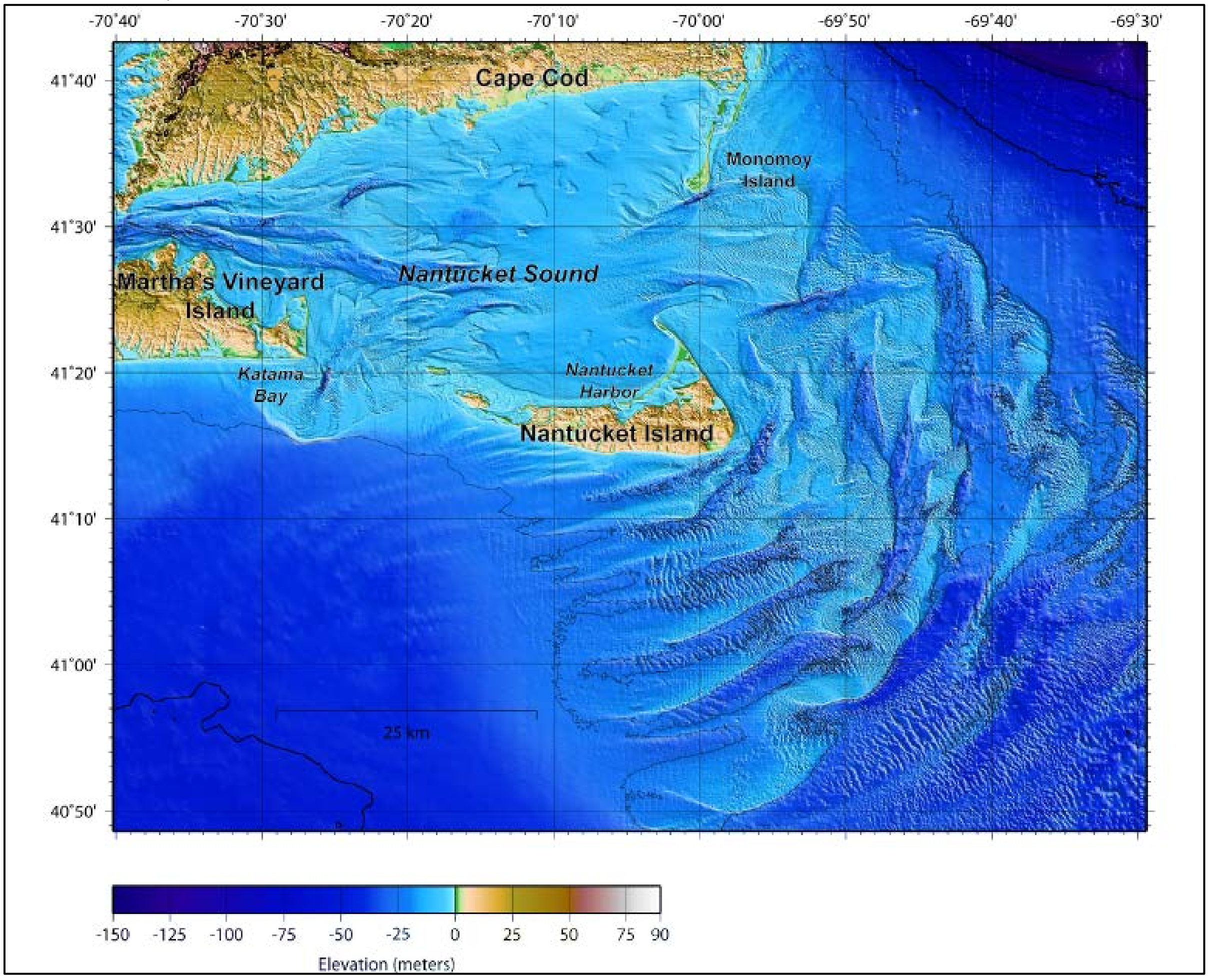

Figure 16-3. Shaded-Relief Image of the Nantucket Digital Elevation Model

TABLE 16-2.
ESTIMATED POPULATION EXPOSED TO THE TSUNAMI HAZARD

County	Population Exposed to the Tsunami Hazard
Barnstable	140,190
Bristol	221,968
Dukes	13,255
Essex	491,493
Middlesex	59,512
Nantucket	6,528
Norfolk	138,749
Plymouth	130,308
Suffolk	393,733
Total	**1,595,736**

TABLE 16-2.
ESTIMATED POPULATION EXPOSED TO THE TSUNAMI HAZARD

County	Population Exposed to the Tsunami Hazard

Source: U.S. Census 2010

As tsunami inundation or hazard areas are developed, they may be used to conduct a spatial analysis to identify the most vulnerable residents living in the tsunami hazard zone and be used to focus public education and outreach efforts on these communities. Further, tsunami inundation maps will provide information needed to create evacuation maps.

16.4.3 State Facilities

The impact of the waves and the scouring associated with debris that may be carried in the water could be very damaging to structures located in the tsunami's path. Structures that would be most vulnerable are those located in the front line of tsunami impact and those that are structurally unsound. Similar to the population exposed, all state buildings within 1-mile of the coastline are considered exposed to the tsunami hazard for the purposes of this plan. Table 16-3 summarizes the number and estimated replacement cost value (structure and contents) of state-owned and leased buildings in these coastal counties.

TABLE 16-3.
STATE-OWNED AND LEASED BUILDINGS EXPOSED TO THE TSUNAMI HAZARD

County	Number of Buildings	Replacement Cost Value (Structure and Contents)
Barnstable	239	$645,478,361
Bristol	139	$625,683,539
Dukes	6	$7,446,478
Essex	305	$3,380,458,220
Middlesex	23	$339,955,027
Nantucket	5	$31,381,244
Norfolk	115	$579,406,190
Plymouth	107	$431,990,607
Suffolk	261	$6,717,053,021
Total	**1,200**	**$12,758,852,687**

Source: DCAMM, 2012

16.4.4 Critical Facilities

All critical facilities within one-mile of the coastline are considered exposed to the tsunami hazard at this time. Table 16-4 and Table 16-5 summarize the number of critical facilities and bridges per County, respectively. Roads are the primary resource for evacuation to higher ground before and during the course of a tsunami event. Flooding caused by a tsunami will greatly impact this important component in the management of tsunami related emergencies. Bridges exposed to tsunami events can be extremely vulnerable due to the forces transmitted by the wave run up and by the impact of debris carried by the wave action. The forces of tsunami waves can also impact above ground utilities by knocking down power lines and radio/cellular communication towers. Power generation facilities can be severely impacted by both the velocity impact of the wave action and the inundation of floodwaters.

TABLE 16-4.
NUMBER OF CRITICAL FACILITIES IN THE MASSACHUSETTS COASTAL COUNTIES

County	Police	Fire	Emergency Operation Centers	Hospitals	Schools (pre-K-grade 12)	Colleges
Barnstable	15	35	—	2	55	6
Bristol	11	27	—	3	100	3
Dukes	9	7	—	1	8	0
Essex	23	56	—	8	204	9
Middlesex	2	3	1	0	9	2
Nantucket	3	1	—	1	3	1
Norfolk	2	13	—	1	45	5
Plymouth	10	23	—	2	42	0
Suffolk	25	34	—	6	119	20
Total	**100**	**199**	**1**	**24**	**585**	**46**

Source: MassGIS, 2012

TABLE 16-5.
NUMBER OF BRIDGES IN THE MASSACHUSETTS COASTAL COUNTIES

County	Federal	State	Local
Barnstable	3	36	26
Bristol	—	97	30
Dukes	—	4	1
Essex	—	169	52
Middlesex	—	36	—
Nantucket	—	—	2
Norfolk	—	28	11
Plymouth	—	68	22
Suffolk	—	235	30
Total	**3**	**673**	**174**

Source: MassGIS, 2012

16.4.5 Economy

Economic losses from a tsunami include but are not limited to general building stock damage, business interruption/closure, closure of ports and related activities, and impacts on tourism and tax base to the Commonwealth. Tsunami waves can carry destructive debris and numerous pollutants that can have devastating impacts on all facets of the environment. Tsunamis may induce secondary hazards such as water quality and supply concerns, and public health concerns.

16.5 VULNERABILITY

Although tsunamis are infrequent events, especially in the Atlantic basin, their high impact can be devastating. The Commonwealth's vulnerability to the tsunami hazard is discussed below.

16.5.1 Population

The populations most vulnerable to the tsunami hazard are the elderly, disabled, and very young who reside near beaches, low-lying coastal areas, tidal flats, and river deltas that empty into ocean-going waters. In the event of a local tsunami generated in or near the Commonwealth, there would be little warning time, so more of the population would be vulnerable. The degree of vulnerability of the population exposed to the tsunami hazard event is based on a number of factors:

- Is there a warning system?
- What is the lead time of the warning?
- What is the method of warning dissemination?
- Will the people evacuate when warned?

For this assessment, the population vulnerable to possible tsunami inundation is considered to be the same as the exposed population.

16.5.2 State Facilities

All structures, including state-owned and leased buildings, within one-mile of the coastline are considered exposed and vulnerable for the purposes of this plan. Table 16-3 summarizes the replacement cost values for state structures within coastal counties. Structures along beaches, low lying coastal areas, tidal flats, and river deltas would be more vulnerable to a tsunami, especially in an event with little or no warning time. The impact of the waves and the scouring associated with debris that may be carried in the water could be very damaging to structures located in the tsunami's path. Those that would be most vulnerable are those located in the front line of tsunami impact and those that are structurally unsound.

16.5.3 Critical Facilities

As mentioned for state facilities, all critical facilities within one-mile of the coastline are considered exposed but those along beaches, low-lying coastal areas, tidal flats, and river deltas would be more vulnerable to a tsunami event. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed. As these data becomes available, the Commonwealth will update this section of the plan with new information. The functional down-time to restore these facilities to 100-percent of their functionality will be dependent upon the severity of the damage. The total estimated replacement cost value of the 850 bridges within one-mile of the coastline is $24 billion.

16.5.4 Economy

A tsunami's negative impact on the economy is difficult to quantify. As discussed above, losses include but are not limited to general building stock damage, business interruption/closures, port closures, utility and transportation damage, and impacts on tourism and tax base to the Commonwealth. Table 16-6 summarizes the replacement cost value (structure and contents) of the general building stock within one-mile of the coastline.

**TABLE 16-6.
GENERAL BUILDING STOCK REPLACEMENT COST VALUE
EXPOSED TO THE TSUNAMI HAZARD**

County	Total Replacement Cost Value (Structure and Contents)
Barnstable	$35,456,688
Bristol	$30,500,534,000
Dukes	$4,095,763,000
Essex	$64,522,174,000
Middlesex	$9,049,260,000
Nantucket	$3,091,334,000
Norfolk	$19,071,731,000
Plymouth	$21,827,904,000
Suffolk	$69,651,038,000
Total	**$221,845,194,688**

Source: Hazus-MH v. 2.1