ENVIRONMENTAL
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OIL SPILL PROBABILITY ANALYSIS FOR THE CAPE WIND ENERGY PROJECT IN NANTUCKET SOUND

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**OIL SPILL PROBABILITY ANALYSIS
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1 INTRODUCTION

1.1 Synopsis

Minerals Management Service (MMS) and Cape Wind Associates LLC (CWA) have requested an analysis of the probability that an oil spill might occur at the Cape Wind Energy Project in Nantucket Sound, Massachusetts. This analysis has been prepared as part of an Environmental Impact Study (EIS) of the Cape Wind Energy Project.

The worst-case discharge would be an instantaneous and simultaneous release of 40,000 gallons of electric insulating oil[1,2] and 2,000 gallons of diesel and other oils from the ESP and up to 200 gallons of turbine and other lubricating oils from the gearboxes of each of the 130 wind turbine generators (WTG) for a total release of 68,000 gallons of oil in the entire complex – an extremely unlikely scenario. Such a worst-case discharge event would only occur if something damaged the ESP *and* all 130 of the WTGs to the extent that the entire contents of all four electrical transformer insulating oil tanks, as well as the oil in each of the WTGs, would be released almost instantaneously. There is the possibility of spillage of some lesser portion of the oil from one or more components of the Cape Wind complex. Additional potential sources of oil spillage for the Cape Wind Energy Project would include the 500 maintenance vessel trips that would occur annually[3], as well as vessels that transit the area and may impact one of the structures. Unlike many other electricity-transmitting cables, there is no oil in the cables that connect the turbines and ESP, and ESP and the land-based facility. There is no chance of a spill from these cables.

1.2 Analytical Approach

The determination of the probability of the theoretical occurrence of an instantaneous release of 40,000 gallons of electric insulating oil and 2,000 gallons of diesel and other oils from the ESP and up to 200 gallons of turbine and other lubricating oils from each of the 130 wind turbine generators (WTG) for a total of 68,000 gallons of oil from the Cape Wind Energy Project involves two major components: determining the probability that any spill might occur from the ESP and WTGs; and analyzing the range of spill sizes (and associated probabilities) that might be expected if a spill were to occur from the ESP and WTGs.

ERC determined that this analysis should involve a four-step process for both the ESP and WTG components of the wind turbine farm.

1) Evaluate and describe the events that might cause damage to the ESP and/or WTGs.

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[1] Electric insulating oil as would be found in the Cape Winds project would be a form of mineral oil (similar to that used in pharmaceutical applications). Electric insulating oil (with a specific gravity of 0.882) is a light oil that floats on water. This type of oil is relatively non-persistent in that it rapidly disperses (breaks into small droplets in the water column, which facilitates natural biodegradation) with a small degree of evaporation so that by 36 hours after the spill only about 12 percent of the original spilled amount would still be present on the water surface. The cleanup of this type of oil would be considerably less complex than the cleanup of a heavy fuel oil spill such as the oil that spilled from the Bouchard No. 120 barge spill due to the lower persistence of the electric insulating oil on shorelines and the inability of this oil to sink below the water surface.

[2] Note that while electric insulating oils that were used in the past in transformers contained PCBs (polychlorinated biphenyls), these substances are not permitted in newly installed transformers and would not be present in the Cape Winds components.

[3] There would be, on average, two crew boat trips per day over about 250 days of each year for maintenance activities.

2) Estimate or qualitatively analyze the probability of each of these events occurring.
3) Estimate or qualitatively analyze the probability that for each of these events that damage occurs to the ESP and/or WTGs.
4) Estimate or qualitatively analyze the probability for each of these events to cause damage sufficient to cause an oil spill from the ESP and/or WTGs.

Given the scope of this evaluation, ERC performed quantitative analyses for those events for which data exists in the form of previous spill/accident data records, and for other events to the extent possible. Where quantitative analyses are not possible or practicable, ERC performed qualitative evaluations. Once these probabilities were analyzed, the potential spill sizes that might occur given that a spill *does* occur would then be analyzed using data in ERC's comprehensive oil spill databases, including: analysis of potential spill volumes (development of a probability frequency distribution function) given that a spill has occurred (from previous spill records); aggregation of data for all spill causes to determine the overall probability distribution function of spill volumes, given that a spill has occurred; and coupling of the probability size distributions for all spill causes with the probability of spill occurrence to provide an overall probability distribution function that will predict the probability of a particular spill of a certain volume occurring over some period of time (5, 10, or 30 years). From this analysis, the probability that a worst-case discharge from the ESP and WTGs would occur would be determined, as well as the probability of the smaller spill volumes. The series of steps are diagrammed in Figure 1.

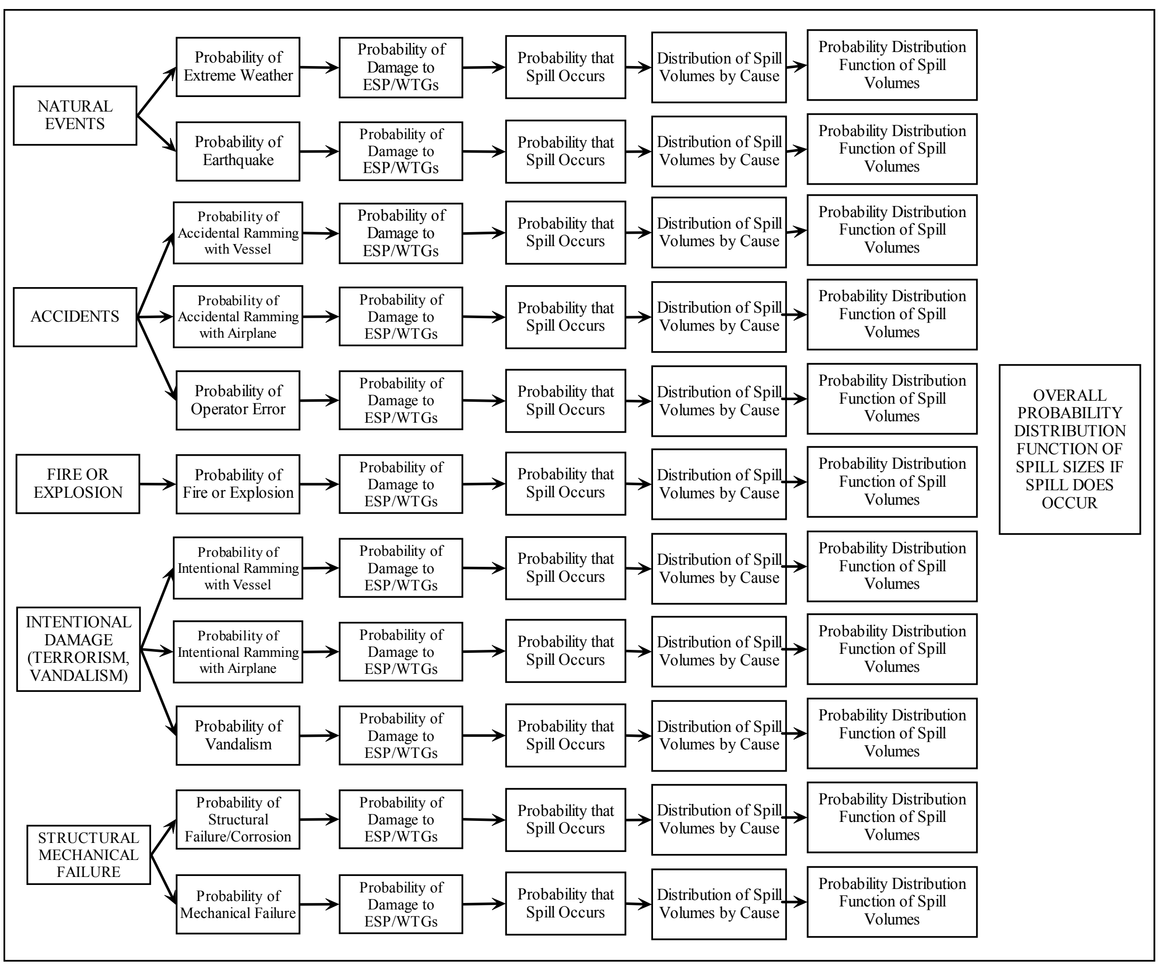

Figure 1: Series of Steps for Determining Probability Distribution Function of Spills

1.3 Description of Cape Wind Energy Project[4]

The proposed wind energy project is to be located on Horseshoe Shoal in Nantucket Sound (Figure 2). The Sound lies south of the southern coast of Cape Cod and northeast of Martha's Vineyard, north of Nantucket and southwest of Monomoy Island. It is approximately 1,430 km^2 (550 mi^2) in area with depths to 21.3 m (70 ft) below Mean Lower Low Water (MLLW). The depths relative to MLLW are as shallow as 0.6 m (2 ft) on Horseshoe Shoal. The area around Horseshoe Shoal is a dynamic system with strong tidal currents (0.5 to 1.0 m/s [1.6 to 3.1 ft/s]) and shifting bed forms consisting primarily of sand. The tide range is approximately 0.9 m (3 ft).

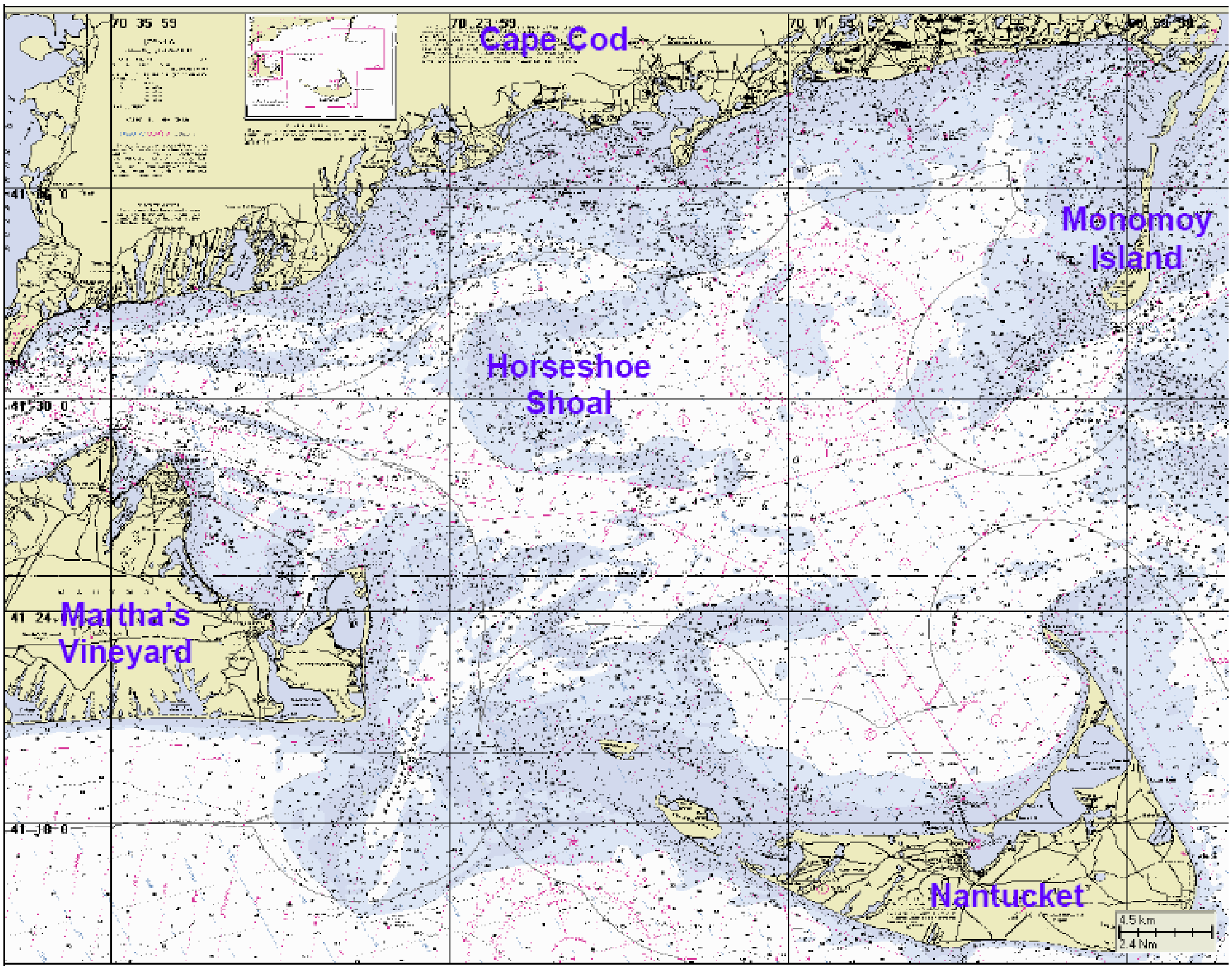

Figure 2: Nantucket Sound shown bounded by Cape Cod to the North, Martha's Vineyard to the west, Nantucket to the southeast, and Monomoy Island to the northeast. (From Knee, *et al.* 2005)

The Wind Park will consist of 130 wind turbine generators (WTG), an electric service platform (ESP), and a series of cables connecting the WTGs to the ESP and two cable circuits from the ESP to a landfall in Yarmouth (Figure 3). The turbines will be located in an array designed to maximize energy production. Each WTG will be mounted on a monopile driven into the seabed that is between 5.1 and 5.5 m (16.75 and 18 ft) in diameter at the MLLW water line. The smaller diameter will be used in water depths from 3.6 to 12. m (12 to 39 ft) MLLW while the larger diameter will be used between depths of 12.2 to 15.2 m (40 to 50 ft). The spacing between the WTGs is approximately 0.63 km (0.34 nm) in the northwest / southeast direction and 1 km (0.54 nm) in the east / west direction.

[4] From Knee, *et al*. 2005.

The ESP will be located near the center of the WTG array and will be the termination point of all the 33kV cables from the WTGs and the two 115kV cables from shore. It will be a fixed platform on six 107 cm (42 in) diameter piles driven into the seabed. It will be approximately 30.5 m (100 ft) wide by 61 m (200 ft) long and elevated approximately 12 m (39 ft) above the MLLW water line. Water depth at the site is 8.5 m (28 ft) MLLW. The platform will include 4 electrical transformers, each containing approximately 10,000 gallons of electrical insulating oil, electrical equipment, fire protection, emergency backup generators, and emergency living accommodations.

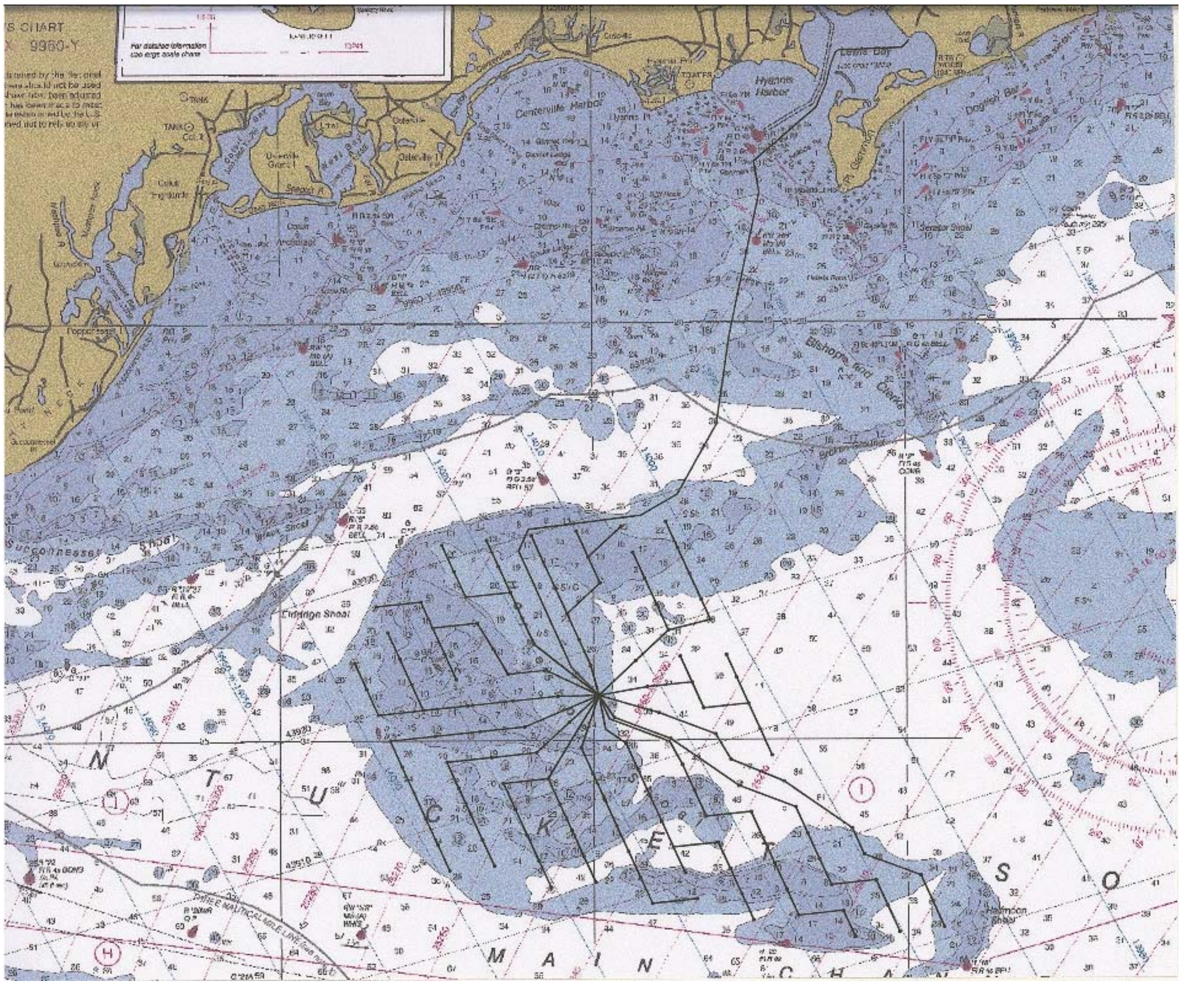

Figure 3: Location of wind farm on Horseshoe Shoal in Nantucket Sound showing WTGs as dots, WTG connecting cables and main power cable to shore as thin black lines.

The cables connecting the WTGs to the ESP will vary in diameter from 132 mm (5.2 in) to 164 mm (6.5 in) depending on the number of WTGs to which they are connected (up to 10) and are rated at 33kV.The cables running from the ESP to shore in Lewis Bay will be 197 mm (7.75 in) in diameter and rated at 115kV. Four cables will be installed as two circuits with a separation distance of 6.1 m (20 ft) between the circuits. Each circuit will be 20.1 km (12.5 mi) long. The cables are to be buried to a minimum depth of 1.8 m (6 ft) below present bottom using a jetting technique whereby pressurized seawater is jetted into the seabed to fluidize the sediments along the cable route. The cable then sinks of its own weight through the fluidized sediments and is buried as the sediment returns to its pre-jetted condition. It is estimated that the fluidized trench created by the jetting process will be approximately 1.8 m (6 ft) wide at the seabed, 2.4 m (8 ft) deep and 0.6 m (2 ft) wide at the bottom. The jetting equipment moves at approximately 91 m/hr (300 ft/hr). Horizontal directional drilling will be used to bring the 115kV cable circuits onto land in Lewis Bay.

2 POTENTIAL CAUSES OF OIL SPILLS FROM THE WIND ENERGY COMPLEX

2.1 Events that May Have the Potential to Damage the ESP or the WTGs

The types of events that might cause damage to the ESP or the WTGs to such an extent as to potentially cause oil spillage include natural events, accidents, fires, explosions, or intentional damage. These types of events could potentially damage the energy project components even if they are in excellent condition and properly maintained and operating.

2.1.1 Natural Events That Exceed Project Design Standards

Although the structures would be designed to withstand the 100 year return storm event, in theory extreme weather events, such as hurricanes, tropical storms, northeaster blizzards or storms, with the ensuing winds and sea states beyond the engineered design limits could potentially damage the ESP and/or one or more WTGs by toppling the platform or the turbines. In addition to these extreme meteorological events, seismic events, including earthquakes, tremors, and tsunamis could also cause damage to the ESP or WTGs.

2.1.2 Accidents

Casualty events involving vessels, airplanes, or helicopters unintentionally crashing into, ramming, grounding upon, or colliding with the ESP and/or WTGs might cause sufficient damage to cause oil spillage from either the vessel itself or from the facility.

2.1.3 Fires or Explosions

A fire or explosion originating in one of the components of the energy project might cause sufficient damage to cause oil to spill from the ESP and/or the WTGs.

2.1.4 Intentional Damage

Intentional damage could take the form of vandalism, such as intentionally breaking a component of the wind energy complex or damaging or manipulating the controls or mechanics of the ESP and/or WTGs. There is also the possibility of intentional damage from a terrorist attack involving an airplane or vessel ramming into one of the components. Bombs or other incendiary devices could be dropped from an airplane or launched from a vessel as part of a terrorist attack or as an act of war.

2.1.5 Unintentional Damage During Maintenance or Repairs

There is the possibility that a vital component of the ESP or WTGs could be unintentionally damaged during routine maintenance operations or during repairs.

2.2 Other Situations that Might Cause Oil Spillage

In addition to the events described above that may cause damage to one or more of the components of the wind energy complex, there are several other situations that might cause oil to spill.

2.2.1 Structural Failures

Corrosion, cracking, wind or water erosion, or breakage of any of the components of the wind energy complex that hold or transport oil could potentially cause oil to spill.

2.2.2 Mechanical or Equipment Failures

Failure in one of the mechanical, electrical, or computerized components of the ESP or WTGs due to lack of necessary maintenance or replacement, negligence, or some unforeseen problem could also potentially cause an oil spill.

2.2.3 Operations Errors

As a result of negligence or unintentional operator error, oil could leak from one of the components holding oil.

2.2.4 Oil Transfers

Any transfer of oil that occurs during replenishing, exchanging, or refueling could potentially cause the release of oil from either the delivery vessel or from the facility side.

3 PROBABILITIES OF OIL SPILL-CAUSING EVENTS

3.1 Hurricanes

In the last 154 years[5], there have been 10 hurricanes that have impacted Massachusetts. Five of these hurricanes were Category One hurricanes[6] on the Saffir-Simpson Hurricane Scale[7], two were Category Two hurricanes[8], and three were Category Three hurricanes[9]. There have been no Category Four[10] or Category Five[11] hurricanes in Massachusetts in 154 years. The possible future numbers of hurricanes in Massachusetts are shown in Table 1. Increases in hurricanes due to natural cycles of activity or climate change are possibilities, but are not included in this analysis.

Table 1: Potential Numbers of Hurricanes in Massachusetts

Saffir-Simpson Scale Hurricane Category	Annual Probability of Occurrence	Potential Numbers of Hurricanes in Time Period			
		1 Year	5 Years	10 Years	30 Years
Category One	0.032	0.032	0.162	0.325	0.974
Category Two	0.013	0.013	0.065	0.130	0.390
Category Three	0.019	0.019	0.097	0.195	0.584
Category Four	**0.006**	**0.006**	**0.032**	**0.065**	**0.195**
All Categories	**0.070**	**0.070**	**0.356**	**0.715**	**2.143**

Over 30 years, there are likely to be two hurricanes that impact the waters of Massachusetts, potentially including Nantucket Sound[12]. If a hurricane did occur, there is a 46 percent probability that, it would be a Category One hurricane, a 19 percent chance that the hurricane will be a

[5] Data for 1851 through 2004 from the National Oceanic and Atmospheric Administration National Weather Service National Hurricane Center (http://www.nhc.noaa.gov/paststate.shtml)

[6] Category One Hurricane: Winds 74-95 mph (64-82 kt or 119-153 km/hr). Storm surge generally 4-5 ft above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs. Also, some coastal road flooding and minor pier damage.

[7] The Saffir-Simpson Hurricane Scale is a 1-5 rating based on the hurricane's present intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline, in the landfall region. Note that all winds are using the U.S. 1-minute average.

[8] Category Two Hurricane: Winds 96-110 mph (83-95 kt or 154-177 km/hr). Storm surge generally 6-8 feet above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center. Small craft in unprotected anchorages break moorings.

[9] Category Three Hurricane: Winds 111-130 mph (96-113 kt or 178-209 km/hr). Storm surge generally 9-12 ft above normal. Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Damage to shrubbery and trees with foliage blown off trees and large trees blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the center of the hurricane. Flooding near the coast destroys smaller structures with larger structures damaged by battering from floating debris. Terrain continuously lower than 5 ft above mean sea level may be flooded inland 8 miles (13 km) or more. Evacuation of low-lying residences with several blocks of the shoreline may be required.

[10] Category Four Hurricane: Winds 131-155 mph (114-135 kt or 210-249 km/hr). Storm surge generally 13-18 ft above normal. More extensive curtainwall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of structures near the shore. Terrain lower than 10 ft above sea level may be flooded requiring massive evacuation of residential areas as far inland as 6 miles (10 km).

[11] Category Five Hurricane: Winds greater than 155 mph (135 kt or 249 km/hr). Storm surge generally greater than 18 ft above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of all structures located less than 15 ft above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5-10 miles (8-16 km) of the shoreline may be required. Only 3 Category Five Hurricanes have made landfall in the United States since records began:

[12] These hurricanes may not be *direct* hits to Nantucket Sound.

Category Two hurricane, and a 27 percent chance[13] that one of these hurricanes will be a major hurricane of Category Three. Since the Cape Wind structures have been designed to withstand a "100-year storm"[14] and Category Three hurricanes, it is likely that only a Category Four or greater hurricane could potentially cause some level of damage to the structures. As shown in Table 1, it is extremely unlikely (less than one – 0.2 – hurricane) with this potential for damage (Category Four or greater) would occur over the course of 30 years.

3.2 Earthquakes and Tsunamis

Between 1990 and 2001, there were 284 earthquakes recorded in the northeastern United States and eastern Canada. The distribution of magnitudes[15] of these earthquakes is shown in Figure 4.

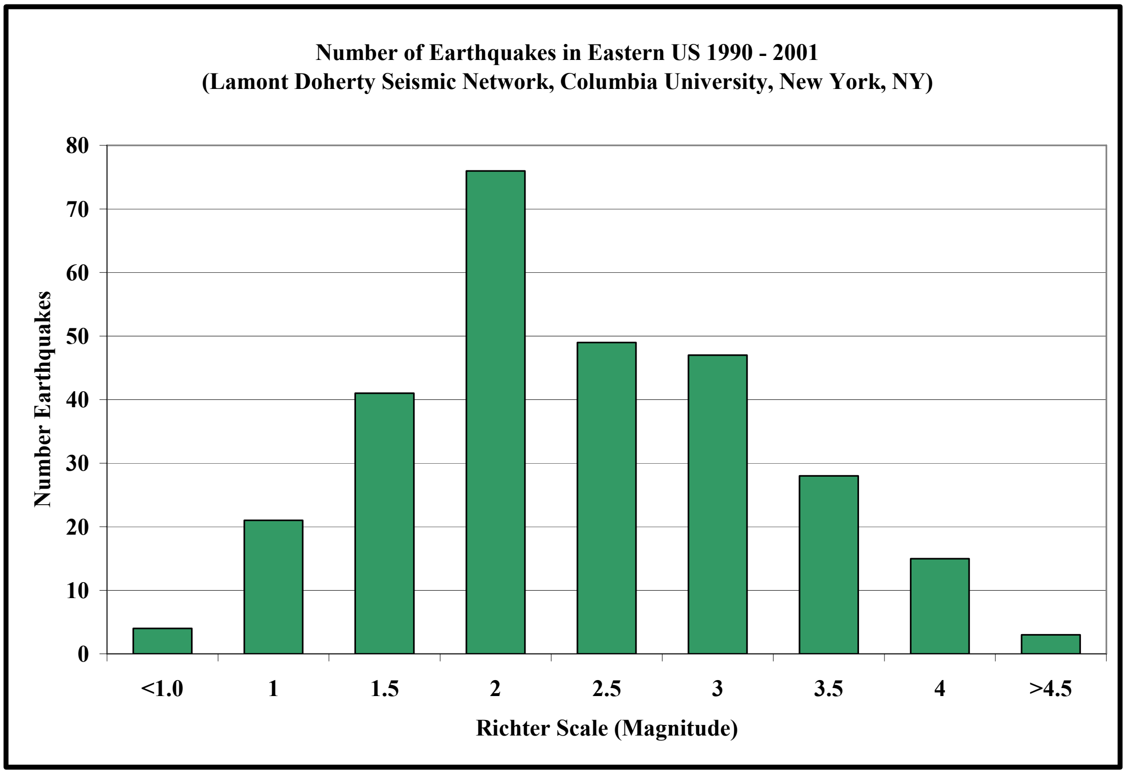

Figure 4: Number of Earthquakes in Eastern US and Canada during 1990 – 2001 (Data from Lamont Doherty Seismic Network, Columbia University)

Nearly 94 percent of the earthquakes were *below* 3.5 in magnitude, which are generally inconsequential with regard to structural damage. There were three events of 4.7 to 4.8 in magnitude. These earthquakes are generally felt but cause little damage. The probability of an earthquake greater than this for the area surrounding the Cape Wind Energy Project over 5 years, 10 years, and 30 years are shown in Figures 5 through 7.

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[13] These probabilities are rough estimates based on the relative annual probability of occurrence for each hurricane type in Table 1.

[14] A "100-year storm" is an event that statistically has a one percent chance of occurring in any one given year. Over the course of 30 years, there would be a one percent chance in any one year that such a storm would occur. The fact that a severe storm occurred in one year has no impact on whether it might occur in the following year. Thus, there is the possibility of having two "100 year storms" two years in a row.

[15] Richter magnitudes and effects: Less than 3.5: generally not felt, but recorded; 3.5-5.4: often felt, but rarely causes damage; under 6.0: at most slight damage to well-designed buildings, can cause major damage to poorly constructed buildings over small regions; 6.1-6.9: can be destructive in areas up to about 100 kilometers across where people live; 7.0-7.9: major earthquake, can cause serious damage over larger areas; 8 or greater: great earthquake, can cause serious damage in areas several hundred kilometers across. Because of the logarithmic basis of the Richter scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value (US Geological Survey).

The probability that there would be an earthquake of at least 4.75 magnitude in the immediate area around the Cape Wind Energy Project or within 50 kilometers of the Project is 0.002 in five years, 0.003 in 10 years, and 0.015 in 30 years. The probability of a major earthquake of 7.0 or greater is less than 0.001 in 30 years, based on US Geological Survey earthquake probability models.

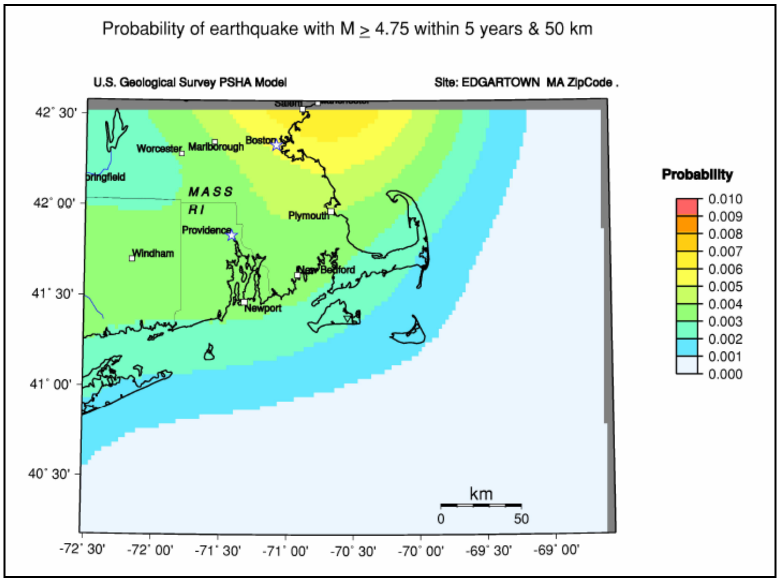

Figure 5: Probability of earthquake over 4.75 in Nantucket Sound area over 5 years. Source: US Geological Survey (http://earthquake.usgs.gov)

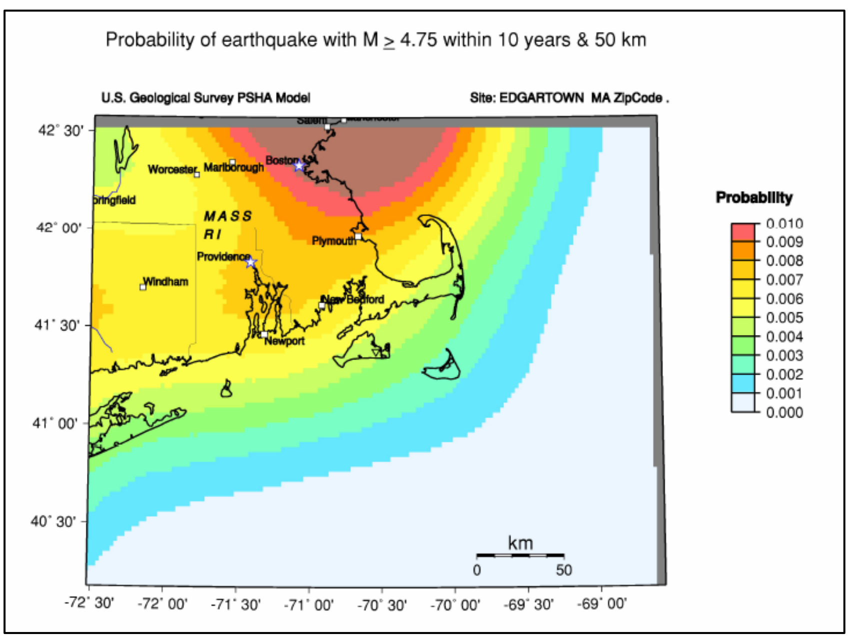

Figure 6: Probability of earthquake over 4.75 in Nantucket Sound area over 10 years. Source: US Geological Survey (http://earthquake.usgs.gov)

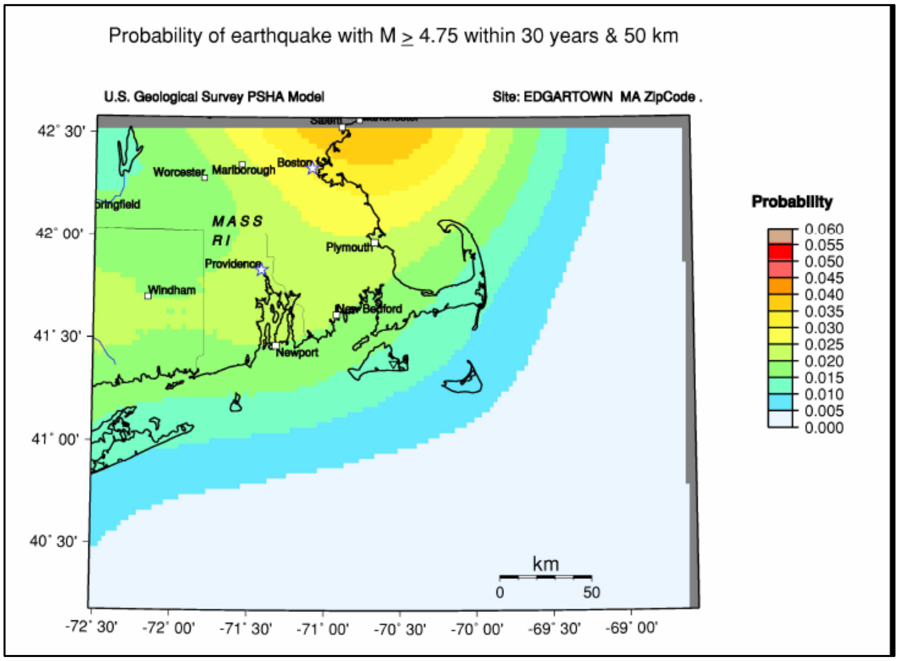

Figure 7: Probability of earthquake over 4.75 in Nantucket Sound area over 30 years. Source: US Geological Survey (http://earthquake.usgs.gov)

Tsunamis (also called "seismic sea waves") occur when there are undersea earthquakes of at least 7.5 on the Richter scale[16].The recent massively destructive tsunami in Southern Asia followed a 10.0-Richter scale earthquake. Tsunamis are most common in the Pacific Ocean, according to NOAA, but have occurred in the North Atlantic Ocean, including one that followed the 1775 Lisbon earthquake. This tsunami was 23 feet (seven meters) high in the Caribbean Sea. The probability that there would be an earthquake of a magnitude severe enough to cause a tsunami in the Nantucket Sound over the course of 30 years is, for all practical purposes, zero. Tsunamis also rarely occur after extraterrestrial collisions from asteroids or meteors, or as a result of massive underwater landslides, which are often related to or caused by earthquakes. The probability of this occurring in Nantucket Sound or near enough to the Cape Wind location to impact the Sound in 30 years is also exceedingly small[17].

3.2.1 Oil Spillage from Natural Phenomena – Earthquakes, Tsunamis, Hurricanes

The probability of a hurricane, earthquake, or tsunami with sufficient force to topple or otherwise break the Cape Wind offshore structures is exceedingly small. But, with the recent unprecedented experiences of Hurricanes Katrina and Rita in the Gulf of Mexico and the impacts on offshore oil facilities, there is naturally concern that such events might affect offshore structures in other parts of US waters. If the entire ESP and several, if not all, of the WTGs were to be completely destroyed in an unprecedented storm or seismic event, it is possible that the entire 68,000 gallons of oil in the offshore Cape Wind

[16] Tsunamis can also rarely occur after volcanic eruptions, landslides, or extraterrestrial collisions (*e.g.*, meteors). On the US east coast, a massive underwater landslide on the continental shelf could cause a tsunami. To estimate the probability of this type of event occurring would require a geological analysis beyond the scope of this study.

[17] In over 300 years, there has been one report of a possible tsunami that affected the waters off Nantucket, Massachusetts (41.28N; 70.08W), based on information from the National Geophysical Data Center (National Oceanic and Atmospheric Administration). The *New York Times* (1924) published an account (letter to the editor) of a sailing party that traveled through the channel between Nantucket and Tuckernuck Islands onto the ocean to the south. The men witnessed "a vast, huge wave stretching shore to shore approaching the vessel. This huge wave was topped by a white foaming crest which curled and threw off white froth, and yet did not curl over frontward." Lockridge *et. al* (2002) surmised that an earthquake on Oct 24, [1879], and an aftershock Oct 26, [1879] may have disturbed sediments causing a landslide tsunami. This earthquake information is not verified as of 2006. NGDC classifies this tsunami report as a "very doubtful tsunami".

structures could be released. The degree to which these structures could withstand hurricane force winds and associated sea states, or the force of a tsunami or earthquake would need to be analyzed by a structural engineering team to definitively determine what the potential damage might be.

According to an ERC study conducted for the US EPA (Etkin 2004 and ERC database), in the 24 years ending in 2003, there have been 161 incidents of natural phenomena, including typhoons, tornadoes, floods, and high winds, that have caused oil spillage from land-based electric-generating facilities and/or transformers[18] regulated by the US Environmental Protection Agency (EPA). Only six percent of facility spills were attributable to natural phenomena. The average spill volume in these events was 1,100 gallons, but ranged from 50 gallons to as much as 105,000 gallons.

3.3 Vessel Accidents

Oil spills from vessels occur for a variety of reasons – due to intentional discharges (legal[19] and illegal), errors in fuel or cargo tranfers to or from a vessel, mechanical or structural failures, or accidents (casualties). The continuous vessel traffic in Nantucket Sound means that there is *always* a potential for a spill in this location *even without the presence of the Cape Wind structures*. According to US Army Corps of Engineers data on waterborne commerce for 2000 through 2003, there are an average of 1,097 vessel trips (for vessels of at least 300 GRT) passing Cross Rip Shoal, south of Horseshoe Shoal and the Main Channel (USACE 2000 – 2003) (Table 2). Note that there is some variation in vessel traffic from year to year (Figures 8 and 9). The standard deviation was computed and provided in Table 2.

Table 2: Annual Large Vessel Trips Passing Cross Rip Shoal 2000 – 2003 (US Army Corps of Engineers Data)

Vessel Type	Average Annual Number of Vessel Trips (Standard Deviation[20])
Passenger[21] & Dry Cargo[22]	892.25 (581.18)
Tank Ship	22.00 (4.32)
Tow/Tug	81.50 (2.08)
Dry Cargo Barge	94.50 (23.07)
Tank Barge	6.75 (4.79)
Total	**1,097 (560.47)**

In addition to the traffic from larger vessels south of Horseshoe Shoal, there is also considerable traffic from smaller vessels in the vicinity and north of the proposed Cape Wind site. Based on schedules for ferries to and from Nantucket operating out of Woods Hole and Hyannis[23], Massachusetts, there are 5,700 ferry trips (one-way) each year, with the majority of the trips occurring during the months of late March through mid-October. Smaller numbers of ferries operate in the off-season for island residents and businesses. Sixty-two charter fishing vessels, 19 commercial fishing vessels, and 36 touring vessels, all of which are under 200 GRT also are known to operate in this area, based on data in the *Revised Navigational Risk Assessment* (ESS Group, Inc., 2006). The number of vessel trips associated with these vessels is unknown. If each commercial fishing vessel operates for 250 days per year, there would be an average of 4,750 commercial fishing trips per year. If each charter fishing vessel and touring vessel operates once

[18] These do not include the smaller, 50-gallon pole-mounted transformers on electric utility lines.
[19] Under the International Convention for the Prevention of Pollution from Ships 1973 and its 1978 Protocol (MARPOL 73/78), to which the US is a party, oil tankers can legally discharge up to 15 parts per million (ppm) of oil while enroute . Non-tank vessels can discharge oil at distances of at least 12 nautical miles from the nearest land.
[20] Statistical measure of spread or variation of actual amounts (*e.g.*, 892 ± 581, represents a range of 311 – 1,473.)
[21] Does not include passenger or passenger/vehicle ferries.
[22] Categories of passenger vessels and dry cargo vessels combined in USACE data.
[23] Steamship Authority, Woodshole, MA: http://web2.steamshipauthority.com/ssa/

per day during the months of June through September, there could be an average of 11,760 additional trips per year from these types of vessels. These data are summarized in Table 3.

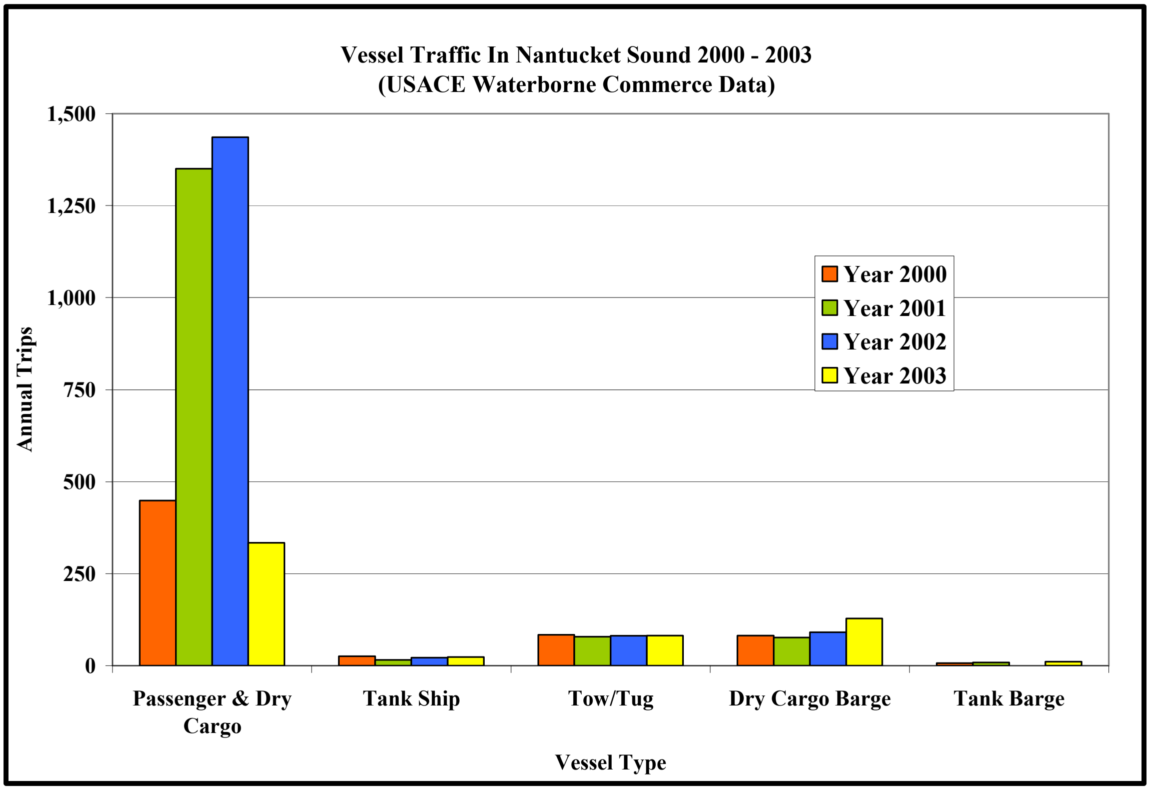

Figure 8: Nantucket Sound Annual Vessel Traffic (US Army Corps Engineers Data)

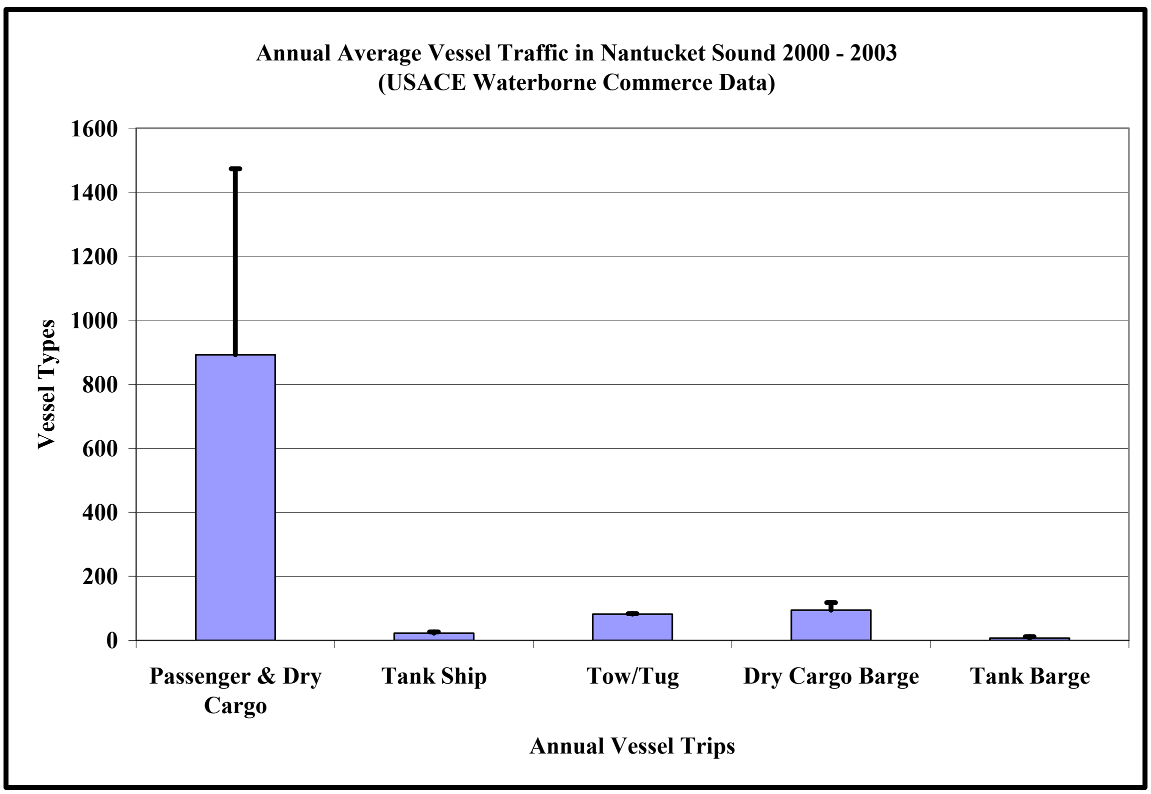

Figure 9: Annual Average Nantucket Sound Vessel Traffic (error bars indicating one standard deviation)

Table 3: Annual Smaller Vessel Trips Passing Through Nantucket Sound					
Vessel Type	**Average GRT**	**Length (ft)**	**Beam (ft)**	**Draft (ft)**	**Estimated Average Annual Number of Vessel Trips**
Ferries	516	197	45	11	5,700
Commercial Fishing	77	59	18	9	4,750
Charter Fishing	23	44	15	5	7,440
Touring	85	61	15	7	4,320
Total	-	-	-	-	**22,210**

The addition of the Cape Wind components changes the potential for vessel-sourced oil spills in two potential ways – adding structures that might be struck by a vessel or contribute to the collision between two vessels or adding vessel trips for oil deliveries to the WTGs increasing the potential for spills from that type of vessel. At the same time, the installation and activation of the Cape Wind Energy Project will also *reduce* the number of vessel trips of tank barges with heavy fuel oil headed for facilities that burn oil to generate electricity[24]. This would *reduce* the risk of spills from these vessels. The *Revised Navigational Risk Assessment* states that lighted Private Aids to Navigation (ATON) that will be added to each of the WTGs will add to the existing network of USCG maintained ATONs and will provide more navigational references for mariners. The addition of these private ATONs has the potential to help in reducing vessel accidents in this area overall.

3.3.1 Vessel Accidents in Waters Near Nantucket Sound

In the waters near Nantucket Sound (the "Study Area" as depicted in Figure 10), there are on average 140 vessel casualties each year[25], including 41 collisions[26], 38 groundings, 9 allisions[27], and 52 incidents of loss of vessel control[28]. Twenty three percent of these incidents involved vessels of 300 gross registered tons (GRT) or larger (Table 4).

Figure 10: Waters Near Nantucket Sound as Applied in Analysis of Vessel Casualties

[24] The 27 April 2003 spill of 98,000 gallons of No. 6 fuel oil in Buzzards Bay, Massachusetts, from the tank barge Bouchard No. 120 is an example of a spill that originated from a fuel oil barge. (See http://www.buzzardsbay.org/oilspill-4-28-03.htm#updates)
[25] ERC vessel casualty databases derived from US Coast Guard vessel casualty data.
[26] One vessel hitting another vessel.
[27] A vessel hitting a stationary object, such as a dock.
[28] Vessel casualties involving sinking, flooding, abandonment, non-accident related pollution, or capsizing were not considered here as these incidents would not likely impact structures such as the Cape Wind Energy complex.

Table 4: Average Annual Vessel Casualties in Waters Near Nantucket Sound (ERC Vessel Casualty Databases)						
Casualty Type	Vessels < 300 GRT		Vessels ≥ 300 GRT		All Vessels	
	Incidents	% Incidents	Incidents	% Incidents	Number Incidents	% Incidents
Allision	1	1%	8	25%	9	6%
Collision	32	30%	9	28%	41	29%
Grounding	27	25%	11	34%	38	27%
Loss of Control	48	44%	4	13%	52	37%
Total	**108**	**100%**	**32**	**100%**	**140**	**100%**

Based on average numbers of annual vessel trips in the Study Area shown in Figure 10 (Tables 2 and 3), the probabilities of casualties per vessel trip in the waters near Nantucket Sound are shown in Table 5. Note that these vessel casualties would occur in the *absence* of the Cape Wind structures in Nantucket Sound, as well as in the presence of the structures.

Table 5: Average Annual Vessel Casualties Per Vessel Trip in Waters Near Nantucket Sound (ERC Vessel Casualty Data and USACE Vessel Trip Data)			
Casualty Type	Vessels < 300 GRT	Vessels ≥ 300 GRT	All Vessels
Allision	0.00005	0.00729	0.00039
Collision	0.00144	0.00820	0.00176
Grounding	0.00122	0.01003	0.00163
Loss of Control	0.00216	0.00365	0.00223
Total	**0.00486**	**0.02917**	**0.00601**

3.3.2 Oil Spills from Vessels Due to Casualties in Nantucket Sound Area

It is important to note that a vessel casualty *does not necessarily result in an oil spill* from the vessel (s) involved in the collision, allision, grounding, or other casualty. In fact, according to ERC oil spill data, there are, on average, only 54 oil spills annually in US marine waters attributable to the 10,683 average annual vessel casualties in US waters. This would come to an average of 0.005 spills *per vessel casualty* or 0.000025 spills due to vessel casualties *per vessel trip in the US*. The spills that result from these casualties do tend to be of greater volume than spills due to other causes, such as errors during lightering or bilging operations. The average allision- or collision-related spill involves 8,000 gallons of spilled oil. The average grounding spill involves 4,200 gallons.

The population of vessels involved in these spills across US waterways includes tankers and barges that carry considerably more oil than the largest oil tank vessel that transits Nantucket Sound. That tank ship, the T/V GREAT GULL (3,800 DWT, 1,720 GRT) would carry about 1.17 million gallons of oil *fully* loaded, but generally no more than one million gallons. The largest tank ships that travel through US waters carry 80 million gallons of oil. The potential for a larger spill would tend to be lower in Nantucket Sound with smaller vessels in transit.

The expected frequency distributions of spill volumes due to vessel allisions, collisions, and groundings in Nantucket Sound (based on Nantucket Sound vessel traffic) *without* the presence of the Cape Wind structures are shown in Figures 11 – 13 and Table 6. These spill volumes are the amount that would be expected to be spilled *if* there were a spill associated with a vessel casualty (allision, collision, or grounding). As shown in Table 6, 60 percent of tanker spills would involve less than 600 gallons. Eighty percent of tank barge spills would involve less than 400 gallons. Smaller vessel incidents would involve less than 100 gallons in over 50 percent of cases, as shown in figure 13. It is important to note that these hypothetical spills are *unrelated* to the presence of the Cape Winds structures. These spills make up the *baseline* of spills.

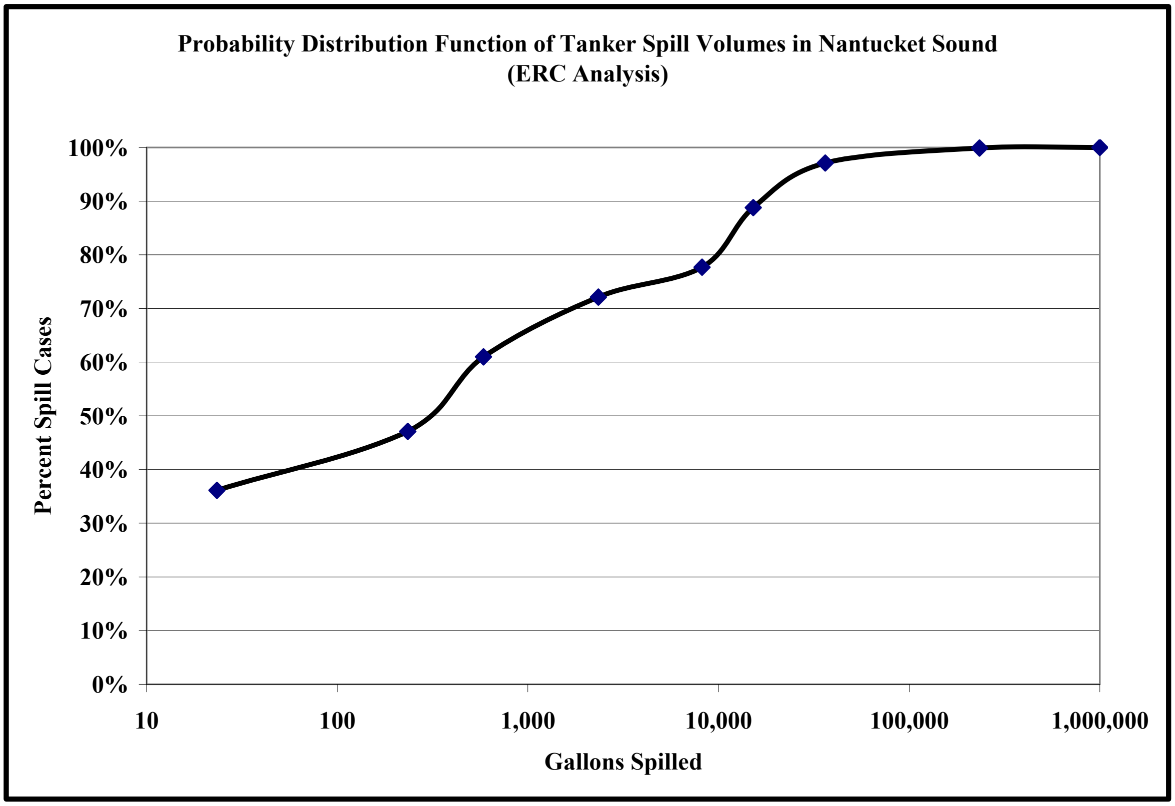

Figure 11: Probability Distribution Function of Hypothetical Oil Tanker Spill Volumes in Nantucket Sound (without Cape Wind).

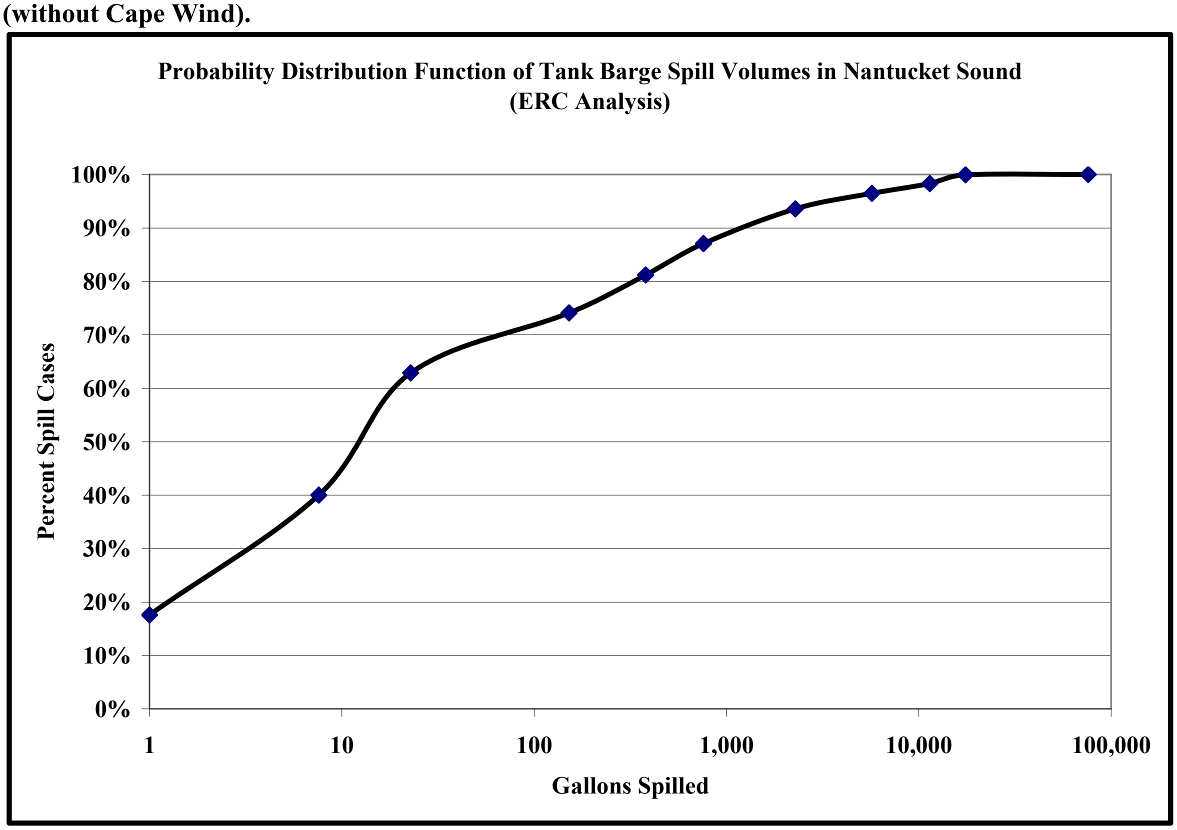

Figure 12: Probability Distribution Function of Hypothetical Tank Barge Spill Volumes in Nantucket Sound (Without Cape Wind)

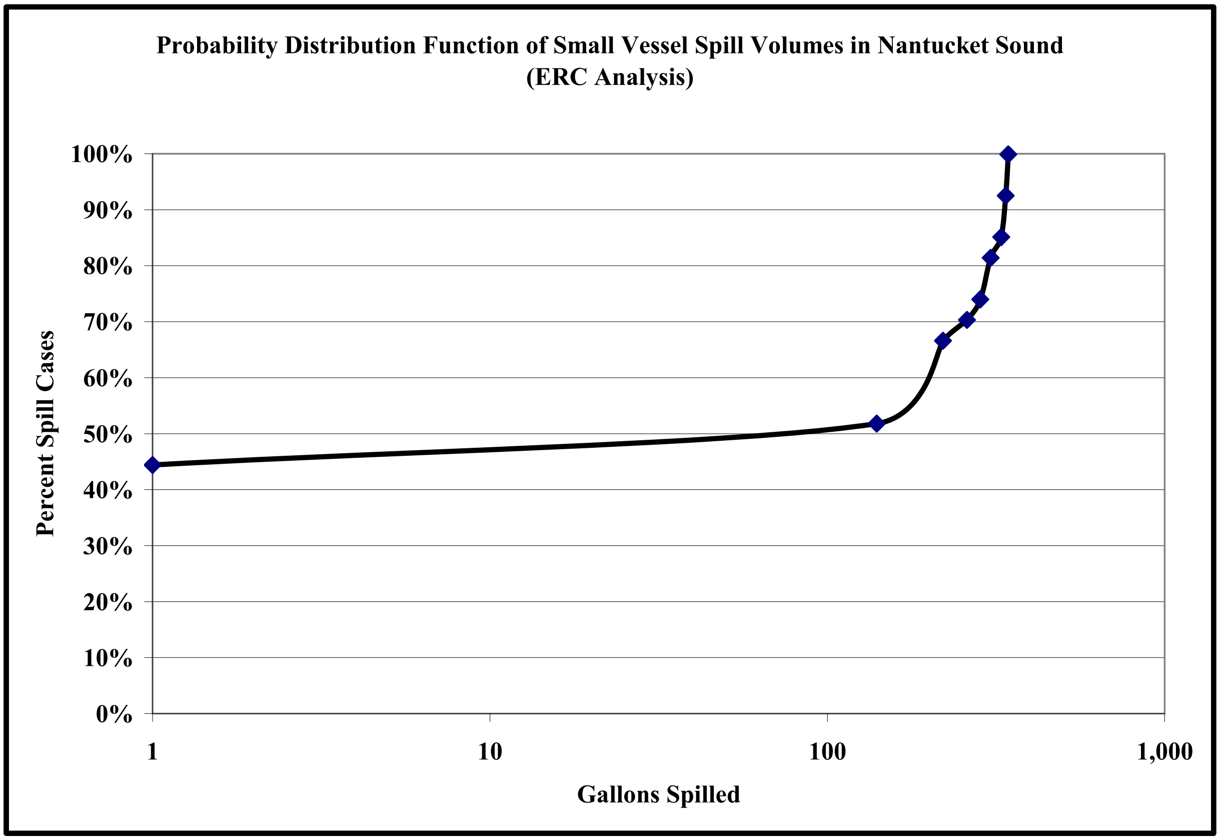

Figure 13: Probability Distribution Function of Hypothetical Small Vessel Spills in Nantucket Sound (Without Cape Wind)

Table 6: Probability Distributions of Hypothetical Vessel Spills in Nantucket Sound (Without Cape Wind)								
Tankers (see Figure 11)			**Tank Barges (see Figure 12)**			**Small Vessels (see Figure 13)**		
Volume Spilled (gallons)	**Percent Cases**	**Cumulative Percent[29]**	**Volume Spilled (gallons)**	**Percent Cases**	**Cumulative Percent**	**Volume Spilled (gallons)**	**Percent Cases**	**Cumulative Percent**
23	36.1%	36.1%	1	17.6%	17.6%	1	44.4%	44.4%
234	11.0%	47.1%	8	22.4%	40.0%	140	7.4%	51.8%
585	13.9%	61.0%	23	22.9%	62.9%	220	14.9%	66.7%
2,340	11.1%	72.1%	152	11.2%	74.1%	259	3.7%	70.4%
8,190	5.6%	77.7%	380	7.1%	81.2%	284	3.7%	74.1%
15,210	11.1%	88.8%	760	5.9%	87.1%	305	7.4%	81.5%
36,270	8.3%	97.1%	2,280	6.5%	93.6%	328	3.7%	85.2%
234,000	2.8%	99.9%	5,700	2.9%	96.5%	338	7.4%	92.6%
1,000,000[30]	0.1%	100.0%	11,400	1.8%	98.3%	344	7.4%	100.0%
			17,480	1.7%	100.0%			

Applying the average of casualties per vessel trip for the Study Area near Nantucket Sound[31] and spills per casualty to the vessel trips estimated for the Nantucket Sound area, the estimated casualties for this area are estimated to be those shown in Table 7. These spills are ones that might occur from oil contained in the vessels themselves after alliding

[29] Cumulative percent means that for any volume in the table that percentage of spills is equal to or smaller than that volume, *e.g.*, for tankers, 61 percent of spills are 585 gallons or less.
[30] The maximum spillage from an oil tanker would be the total release of 1.17 million gallons of oil (the total cargo capacity in the largest tanker to transit Nantucket Sound). Most tankers are only filled to about 80 – 85 percent capacity, in this case that would be one million gallons.
[31] Smaller vessels (including commercial fishing, charter fishing, and touring vessels) were assumed to have the 0.00486 casualties per trip, and larger vessels (>300 GRT) were assumed to have the 0.02917 casualties per trip).

with a shoreline structure (*e.g.*, pier) navigational hazard, colliding with another vessel, or grounding on a submerged object. These are casualties and spills unrelated to the presence of the Cape Wind offshore facility.

Table 7: Estimated Annual Casualties and Spills for Vessel Traffic in Nantucket Sound (Casualties Unrelated to Cape Wind Facility)									
Vessel Type	**Vessel Trips**	**Casualties[32]**				**Spills[33]**			
		1 yr	**5 yrs**	**10 yrs**	**30 yrs**	**1 yr**	**5 yrs**	**10 yrs**	**30 yrs**
Passenger & Dry Cargo	892	26.0	130.1	260.2	780.6	0.1301	0.6505	1.3010	3.9029
Tank Ship	22	0.6	3.2	6.4	19.3	0.0032	0.0160	0.0321	0.0963
Tow/Tug	82	2.4	12.0	23.9	71.8	0.0120	0.0598	0.1196	0.3588
Tank Barge	7	0.2	1.0	2.0	6.1	0.0010	0.0051	0.0102	0.0306
Ferries	5,700	27.7	138.5	277.0	831.1	0.1385	0.6926	1.3851	4.1553
Commercial Fishing	4,750	23.1	115.4	230.9	692.6	0.1154	0.5771	1.1543	3.4628
Charter Fishing	7,440	36.2	180.8	361.6	1,084.8	0.1808	0.9040	1.8079	5.4238
Touring	4,320	21.0	105.0	210.0	629.9	0.1050	0.5249	1.0498	3.1493
Total	**23,213**	**137.2**	**686.0**	**1,372.0**	**4,116.2**	**0.6860**	**3.4300**	**6.8600**	**20.5798**

It is important to note that the estimates of annual casualties and spills are very conservative. This is due to the fact that the casualty rate used was derived from vessel casualty occurrence data for a Study Area stretching between New Haven, Connecticut and the north end of the Great South Channel (a distance of approximately 190 NM). This area includes commercial ports, such as New Bedford, Fall River, Providence, New London, and New Haven. Data provided to ESS Group by the USCG indicate that only 33 casualties occurred in Nantucket Sound between 2001 and 2003. Therefore, the casualty estimates in this report likely dramatically overestimate the potential for casualties and spills in Nantucket Sound.

The potential for spillage from tank ships and tank barges will *decrease* with the greater use of double-hulled vessels, mandated by the Oil Pollution Act of 1990 by 2015. Double hulls on tank vessels decrease the likelihood that oil will spill upon impact and to decrease the volume of spillage by about 50% if the hulls are breached. With the increasing presence of double-hulled vessels in the nation’s and world’s fleet of tank vessels, the probability for large spills from these vessels is continuously decreasing and will continue to decrease until 2015.

3.3.3 Increase or Decrease in Vessel Spills in Presence of Cape Wind Facility

The vessel spills described in the previous section would be expected to occur *with or without* the presence of the Cape Wind facility. These potential spills would be the result of the inherent navigational risks and other factors that contribute to vessel spills that are already present in this area and are already present in the vessels themselves (*e.g.*, structural or mechanical factors) or in the operation of the vessels (*e.g.*, crew training).

To determine the potential impact of the Cape Wind facility on spill risk from vessels, one would need to consider the probability that a vessel would allide with one of the structures associated with the facility or collide with another vessel as a result of the presence of the structures.

According to the analyses in the *Revised Navigational Risk Assessment* prepared by ESS Group, Inc., commercial vessels are unlikely to transit through the wind park area given the natural draft limitations and the presence of charted channels around Horseshoe

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[32] Casualty rates for Nantucket Sound area.

[33] US national spill rates per casualty.

Shoal. Given this, it would be unlikely that the structures would pose an unusual navigational hazard.

If there were to be an accident involving a vessel alliding with one of the Cape Wind structures or colliding with another vessel as a result of the presence of the offshore facility, the expected vessel spill volumes would be the same as those shown in Table 6 and Figures 11 – 13.

The other potential change in oil spill risk with the installation of the Cape Wind facility is the possibility of spills that might result from vessel trips specifically associated with the facility. These are vessel trips that would not be necessary in the absence of the facility. The maintenance work boats used to service the Project components make two trips to the facility each day over 250 days of the year for a total of 500 vessel trips annually. Included in these maintenance trips are deliveries of oil made to each of the WTGs every two years[34]. On 13 percent of the maintenance boat trips (or 65 trips annually), there would be deliveries of oil to one of the WTGs. Each oil delivery would involve 200 gallons of oil carried in 55-gallon drums. The vessel type involved is under 300 GRT in size. The casualty rate of 0.00486 casualties per trip is therefore applied. The expected casualty and spill rates for these work boats are shown in Table 8.

Table 8: Estimated Annual Casualties and Spills for Maintenance Work Boats for Cape Wind Project

Vessel Type	Annual Vessel Trips	Casualties				Spills			
		1 yr	5 yrs	10 yrs	30 yrs	1 yr	5 yrs	10 yrs	30 yrs
Work Boats	500	2.4	12	24	72	0.00006	0.00030	0.00060	0.00180

The volume of oil that might be expected in the *very unlikely* event[35] that there would be a spill from one of the work boats would be less than 350 gallons of fuel only and for 13 percent of the trips there would be an additional 200 gallons in transformer oil. The most likely spill volume would be the leakage of one of the 55-gallon drums[36]. It is unlikely that all of the drums would simultaneously leak a total of 200 gallons. If the vessel were to capsize or sink, all of the filled drums would be released into the water intact, but would likely be salvaged before releasing their contents. The maximum fuel release from the vessel itself would be about 350 gallons in fuel.

The results in Tables 7 and 8 indicate that in the unlikely event there were to be a spill in Nantucket Sound from vessels transiting the area for commercial purposes unrelated to the Cape Wind Project, or from vessels involved in maintenance or oil deliveries to the Cape Wind facility structures, the largest possible spill would be a total worst-case discharge from the tank ship, which would total one million gallons of oil. Over the course of thirty years, there is unlikely to be a spill of *any magnitude* from a tank ship located in Nantucket Sound, let alone of this magnitude. There is a very small risk of a tank barge spill over the course of 30 years. The most likely spill would be one of less than 100 gallons. The largest potential tank barge spill would be about 76,000 gallons. *The risk for these types of spill would remain regardless of whether the Cape Wind Project was constructed or not. These spills are the baseline. The risk of a tank barge spill in the region could be reduced with the construction and use of the Cape Wind Project for generating electricity because there may be fewer transits of heavy fuel oil*

[34] The oil in the 10,000-gallon tanks in the ESP would not be replaced under normal conditions.
[35] Fewer than 0.002 spills from work boats in 30 years or one spill in 16,667 years, and fewer than 0.000002 spills from the oil delivery boats in 30 years or one spill in 500,000 years.
[36] There are no data or models to estimate the potential for leaks from oil drums from a maintenance boat delivering oil.

barges through Buzzards Bay/Canal to power-generating stations using heavy fuel oil rather than wind.

Over any one year, there is likely to be less than one spill due to a vessel casualty in the Nantucket Sound area *unrelated to the presence of the Cape Wind Project*[37]. Over five years, there are likely to be three spills from all vessel types, most likely from a ferry or charter fishing vessel. Over 10 years, there are likely to be seven spills. Over 30 years, there are likely to be a total of 21 spills – four from passenger and dry cargo vessels (> 300 GRT), four from ferries, three from commercial fishing vessels, five from charter fishing vessels, and three from touring vessels. Of these spills, 90 percent will be less than 10 gallons. *There are unlikely to be any spills associated with maintenance and oil delivery boats for the Cape Wind Project*. As stated above, these estimates are conservative.

Table 9 shows the combined incidence of spillage and probabilities of spill volumes for all vessel categories in Nantucket Sound.

3.3.4 Oil Spills from Offshore Facilities due to Allisions from Vessels

The other type of casualty-related oil spill that might occur might be from an allision of a vessel and the ESP or one of the WTGs. A drifting vessel of the size that frequents the wind park area is unlikely to cause significant damage to a WTG. A cruising vessel of 1,200 GRT or larger might cause some damage to a WTG causing it to collapse after impact. A collapse of a WTG might cause a spill of up to 200 gallons of turbine oil.

Due to the distance between the WTGs, it would not be possible for a single vessel to impact more than one WTG in an allision. The oil within the WTG is contained within the gearbox in the nacelle portion of the turbine. If the nacelle is damaged or begins to leak, oil would fall into the contained tower. This will reduce the likelihood that oil would leak out if the outer containment were to be breached by contact with a vessel or after having been toppled over by a vessel. If a spill did occur due to the impact of a vessel, it would be limited to 200 gallons of turbine and other oils from a WTG.

The ESP is likewise protected by secondary containment, as is required of all facilities that contain at least 1,320 gallons of oil[38] in an above-ground tank. If the ESP were to be impacted by a vessel to the extent that the outer containment would be breached, one or more of the four transformers that contain 10,000 gallons of turbine oil each might spill oil, though this is highly unlikely. Whether any oil would spill at all[39], or the amount of oil that would spill if oil *were* released, would depend on the degree and location of vessel impact, and the level of damage to oil-containing components. It is highly unlikely that oil would spill at all and the release of the entire 42,000 gallons of oil in the ESP is even more unlikely. If only one of the four transformers were to release oil, the maximum spillage would be 10,000 gallons. With an effective oil spill detection system, it is possible to stem the spillage of the entire contents of the transformer through a spill control and/or salvage operation in which the remaining contents of the oil tank would be

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[37] The probability of a vessel alliding with one of the Cape Wind structures or colliding with another vessel as a result of the presence of the Cape Wind structures is outside of the scope of this study

[38] Oil storage facilities that contain over 1,320 gallons of oil in an above-ground tank of any kind are regulated by the US Environmental Protection Agency under the Spill Prevention, Control, and Countermeasure Plan Rule (40 CFR 112), which requires secondary containment.

[39] There are no studies on the probability of oil release from an oil storage tank with secondary containment after an impact from a moving vessel. An analogous situation, the probability of spillage from secondarily contained oil tanks in a tank vessel, a study by ERC indicates that in a hard collision, allision, or grounding for a double-hulled tank vessel, there is only 3 percent chance that there will be any oil spilled. Outflow modeling indicates that the presence of the secondary containment reduces the amount of spillage by 50 percent when there is a release of oil.

removed after the spill were detected. However, it may take several hours for an effective spill response to be mounted at an offshore facility. The US Coast Guard requires that the initial spill response at an offshore facility begin within one hour of discovery of a spill, with additional resources arriving within 24 hours. Cape Wind will have a Spill Response Plan that will require that spill response efforts begin immediately upon discovery of a spill. The amount of oil that leaked out could vary from very little (a few gallons for a small leak) to the entire contained volume of the transformer (or more than one transformer), depending upon the leakage rate, and the length of time required for responders to get on-site. Increasing the size of the hole allowing the leak results in increasing the rate at which oil would be lost (Figure 14).

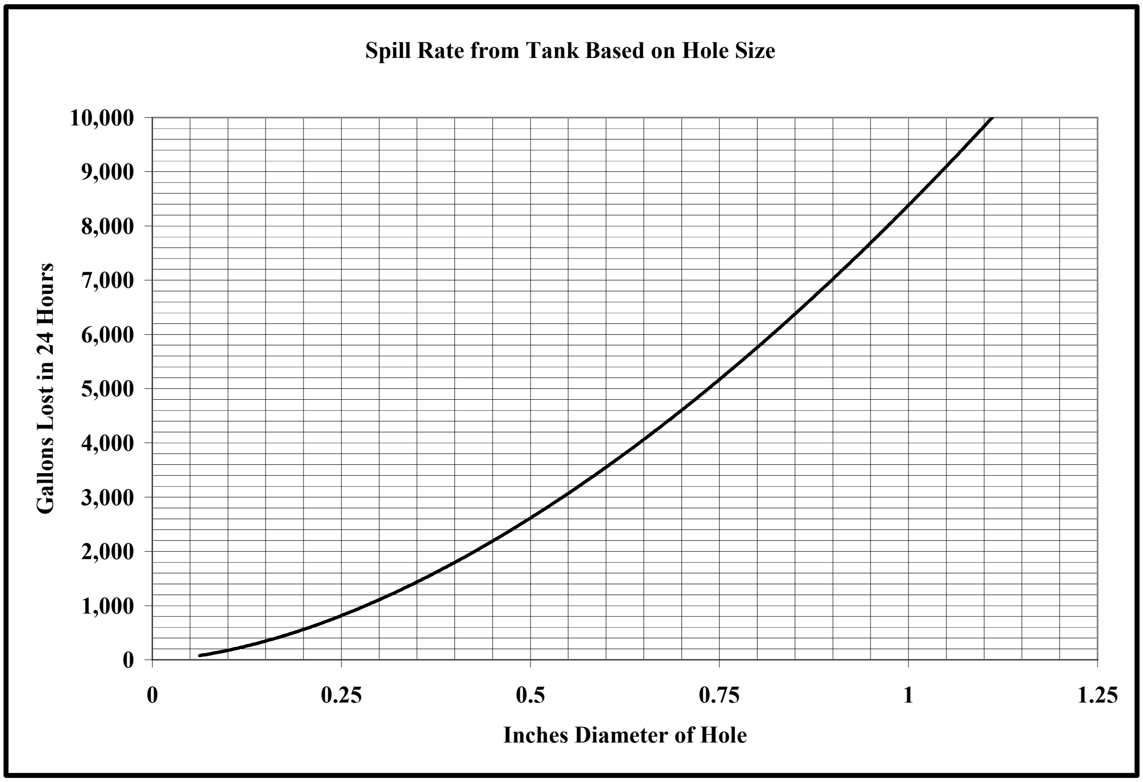

Figure 14 Spill Rate in 24 Hours Based on Diameter of Hole in Tank (at practically nil pressure head)

Table 9: Expected Number of Spills and Spill Volume Probabilities for Vessels in Nantucket Sound Area

Vessel Type	Relation to Cape Wind Structures[40]	Expected Number of Spills				Probability of Spill Volume (gallons) Given Spill Incidence							
		In 1 Year	In 5 Years	In 10 Years	In 30 Years	90%	75%	50%	25%	10%	5%	1%	<0.0001%[41]
Passenger & Dry Cargo	Without CW	0.130	0.651	1.301	3.903	2	15	40	200	400	6,000	8,000	300,000
	With CW	0.130 + Δ[42]	0.651+ Δ	1.301+ Δ	3.903+ Δ	2	15	40	200	400	6,000	8,000	300,000
Tank Ship	Without CW	0.003	0.016	0.032	0.096	10	20	230	2,400	15,200	35,000	234,000	1,170,000[43]
	With CW	0.003 + Δ	0.016 + Δ	0.032 + Δ	0.096 + Δ	10	20	230	2,400	15,200	35,000	234,000	1,170,000[41]
Tow/Tug	Without CW	0.012	0.060	0.120	0.359	<1	<1	1	28	200	250	344	350
	With CW	0.0120 + Δ	0.060+ Δ	0.120 + Δ	0.359 + Δ	<1	<1	1	28	200	250	344	350
Tank Barge	Without CW	0.001	0.005	0.010	0.031	1	5	20	152	770	2,300	17,480	76,000
	With CW	0.001 + Δ - Δ*[44]	0.005+ Δ - Δ*	0.010 + Δ - Δ*	0.031+ Δ - Δ*	1	5	20	152	770	2,300	17,480	76,000
Ferries	Without CW	0.139	0.693	1.385	4.155	1	9	24	118	235	3,529	4,706	176,000
	With CW	0.139 + Δ	0.693 + Δ	1.385 + Δ	4.155 + Δ	1	9	24	118	235	3,529	4,706	176,000
Commercial Fishing	Without CW	0.115	0.577	1.154	3.463	<1	2	6	29	59	882	1,176	44,000
	With CW	0.115+ Δ	0.577 + Δ	1.154 + Δ	3.463 + Δ	<1	2	6	29	59	882	1,176	44,000
Charter Fishing	Without CW	0.181	0.904	1.808	5.423	<1	<1	1	28	200	250	344	350
	With CW	0.181+ Δ	0.904 + Δ	1.808 + Δ	5.423 + Δ	<1	<1	1	28	200	250	344	350
Touring	Without CW	0.105	0.525	1.050	3.149	<1	<1	1	28	200	250	344	350
	With CW	0.105 + Δ	0.525 + Δ	1.050+ Δ	3.149+ Δ	<1	<1	1	28	200	250	344	350
CW Work Boats	Without CW	0	0	0	0	0	0	0	0	0	0	0	0
	With CW	0.00006	0.0003	0.0006	0.0018	<1	<1	1	28	200	250	344	350

[40] Related to the presence of the Cape Wind structures = CW-related; not dependent on the presence of the Cape Wind structures = CW-unrelated.

[41] The worst-case discharge (the release of the entire oil content of the vessel) is the least likely event for all vessel types. The actual worst-case discharge for a particular vessel depends on its cargo and fuel capacity and actual load at the time of the accident. In each vessel type group there are different vessels that might contain different amounts of oil based on their capacities and particular loads at the time of the accident. In each vessel type group, the probability distribution function was calculated based on weighting of the vessel capacities based on the relative number of trips that each vessel would likely make through the study area in the course of one year. The probability that a particular percentage of total capacity would be released is based on studies of previous vessel casualties in US waters. The actual volume (as percentage of vessel capacity) that would be released in an accident was aggregated within each vessel type to produce the probability distribution functions shown in Figures 11 – 13. The actual worst-case discharge for a particular vessel might be somewhat less than the actual worst-case discharge amount shown under the least likely (<0.0001%) case, the volume of which represents the absolute worst-case scenario, *i.e.*, the largest discharge from the vessel with the largest capacity in that vessel type group.

[42] Δ = the unknown additional risk of a spill from an allision, collision, or grounding related to the presence of the Cape Wind structures.

[43] The spill volume would likely not exceed one million gallons as tank ships are generally not filled to 100 percent capacity.

[44] Δ* = risk reduction for tank barge spills in the region (particularly Buzzard Bay/Canal) due to the necessity for fewer tank barge trips with the offset of oil-generated energy with wind-generated energy from the Cape Wind project. This risk reduction would not likely affect the immediate area around the Cape Wind structures.

3.4 Fires and Explosions

Fires and explosions are known to occur in oil-containing transformers. The most common example of this is when a vehicle strikes a utility pole that holds a transformer. If the transformer breaks it will quickly explode and/or catch fire. A transformer that is struck by lightning or is otherwise breached will react similarly. Fires and explosions may also occur in larger transformers at electric-generating facilities. The exact cause of these incidents is not always known, though it is generally due to some kind of structural failure or electrical problem. The resulting fire or explosion usually causes the release of transformer oil.

Over the past 24 years at EPA-regulated (SPCC) power-generating facilities throughout the US, there have been a total of 34 incidents of fires and explosions resulting in the leak of transformer oil. This does not include the smaller pole-mounted transformers that generally contain about 50 gallons of mineral oil.

The number of electric utility facilities regulated by the EPA is estimated to be 2,638 nationwide (US EPA 1995). This means that 1.3 percent of facilities have had transformer fires or explosions between 1980 and 2003. This type of incident is possible for the Cape Wind facility.

The average spill volume for these incidents is 7,000 gallons, with spills ranging from 50 gallons to 100,000 gallons, depending on the type of transformer, its volume of oil, and the speed with which the fire or explosion was brought under control by response personnel. The majority of these transformers were not themselves in secondary containment of the type planned for the Cape Wind WTGs and ESP.

The probabilities of spillage and expected spill volumes for the Cape Wind facility for this incident type are summarized in Table 10. The potential number of spills resulting from fires or explosions is extremely low.

3.5 Intentional Damage (Vandalism or Terrorist Attack)

According to studies conducted by ERC for the US EPA (Etkin 2004), vandalism occurs occasionally at onshore or inland oil facilities. During the last 25 years, there have been 413 incidents involving releases of at least 50 gallons at facilities regulated by EPA between 1980 and 2003, representing three percent of spill incidents at these facilities. The average spill volume was 5,875 gallons, ranging from 50 gallons to 462,000 gallons. Sixty-two percent of the incidents involved less than 1,000 gallons.

There are an estimated 681,000 SPCC facilities[45] throughout the US. Of these, 0.06 percent has experienced vandalism incidents over the course of 24 years. Obviously, some facilities are more prone to this type of incident than others, depending on location, accessibility, and potential motivation of vandals. There are 2,638 electric-generating facilities that qualify as EPA-regulated SPCC facilities. Of these, 60 have experienced vandalism in 24 years. The average spill volume was 1,250 gallons of oil.

The land-based facilities are generally more accessible than the offshore Cape Wind structures would be. Like all SPCC-regulated facilities, there would be alarms and locks, gates, and surveillance operations to deter vandals that might approach the facilities from boats, or less likely, from airplanes or helicopters.

[45] US EPA cannot confirm the number of SPCC facilities in the US, because they are not required to register with federal or most state authorities. This figure was obtained by personal communication with EPA officials in the SPCC program. A 1995 nationwide survey of oil storage facilities conducted by EPA (US EPA 1995) estimated there to be only 387,000 facilities. EPA has since concluded that this estimate is a gross underestimate of the actual number of facilities that it regulates under the SPCC program.

Most vandalism cases involve releasing valves, tampering with control mechanisms, or puncturing pipelines or tanks. It is unlikely that a vandalism incident, if it were to occur at the Cape Wind facility, would involve the total release of the 10,000-gallon volumes from each of the four transformers from the ESP. Attempts by vandals would be unlikely to penetrate the secondary containment to release oil. The vandals would also need a concerted effort to attack all 130 WTGs. As such, vandalism to WTGs would likely be limited to a few WTGs per incident.

The possibility for a terrorist attack in the form of an intentional ramming of the facilities, most likely the ESP, with a large vessel, a torpedo, a bomb, or with an airplane as occurred in the 11 September 2001 attacks on the World Trade Center towers in New York and the US Pentagon in Washington, DC, exists. It is obviously not possible to accurately predict terrorist attacks. Logically, terrorists would want to mount an attack that would be aimed at a specific entity or to create the most damage and/or loss of life to make a "statement". Attacking the Cape Wind project would be feasible and as such this facility, like so many thousands of others in the US, would be vulnerable to damage, most likely total damage (with the release of 40,000 to 68,000 gallons of oil) in a directed terrorist attack. But, it would seem logical that there are many other more "attractive" and potentially more destructive targets, such as nuclear power plants and oil, gas, or chemical storage facilities, along the eastern or northeastern coast or inland areas, thus decreasing the likelihood of a terrorist attack directed at the Cape Wind facilities.

The probabilities of spillage and expected spill volumes for the Cape Wind facility for this incident type are summarized in Table 10. The potential number of spills resulting from intentional damage is extremely low.

3.6 Unintentional Damage during Maintenance or Repairs

According to ERC data for a study conducted for the US EPA (Etkin 2004), there were 953 incidents of mechanical damage to EPA-regulated facilities that caused oil spillage in the period of 1980 through 2003. An average of 9,200 gallons were spilled in these incidents. There were 161 incidents of this nature involving electric-generating facilities. Six percent of electric facilities had an incident related to mechanical damage during maintenance or repairs over the 24 year period. The average spill size at these facilities was 230 gallons.

The probabilities of spillage and expected spill volumes for the Cape Wind facility for this incident type are summarized in Table 10. The potential number of spills resulting from damage due to maintenance or repairs is extremely low.

3.7 Structural Failure

Structural failure[46] has been the primary cause of oil spillage in 3,400 incidents involving EPA-regulated facilities, representing nearly 13 percent of incidents between 1980 and 2003. The average spill volume was 16,000 gallons. Two hundred-twenty of these incidents involved electric-generating stations and/or transformers. Again, the average spill volume was about 16,000 gallons (ERC data and Etkin 2004). Of the 2,638 electric facilities, eight percent had spills related to structural failures over the 24 year period.

The probabilities of spillage and expected spill volumes for the Cape Wind facility for this incident type are summarized in Table 10. The potential number of spills resulting from structural failure is extremely low.

3.8 Mechanical or Equipment Failures

ERC estimated that there were 3,541 incidents of oil spills over 24 years from EPA-regulated facilities that were attributed to mechanical or equipment failure of some kind. The average spill volume was 4,700 gallons (Etkin 2004 and ERC databases). For electric-generating facilities

[46] Structural defects (in workmanship in the original construction of the facility component) were included.

alone, there were 304 incidents in 24 years. The average spill volume was 6,300 gallons. Nearly 12 percent of these facilities had incidents related to mechanical or equipment failure in that time period.

The probabilities of spillage and expected spill volumes for the Cape Wind facility for this incident type are summarized in Table 10. The potential number of spills resulting from mechanical or equipment failure is extremely low.

3.9 Operations Errors

ERC estimated that there were 3,435 incidents of oil spillage from EPA-regulated facilities due to operations errors over the course of 24 years. The average spill volume was 4,900 gallons (Etkin 2004 and ERC databases). Of these incidents, 229 involved electric-generating facilities. Nearly nine percent of electric-generating facilities had an incident related to operations errors over the 24 year period. These incidents averaged 1,400 gallons in oil volume spilled. Most of the incidents at electric-generating facilities involved overfilling of tanks or other errors during the transfer of oil from one part of the facility to another. The types of facility-based oil transfers that are generally at issue would not be occurring at the Cape Wind facility.

The probabilities of spillage and expected spill volumes for the Cape Wind facility for this incident type are summarized in Table 10.The potential number of spills resulting from operations errors is extremely low.

3.10 Oil Transfers

Oil transfer operations during deliveries of oil to the ESP and WTGs might also result in oil spillage[47]. According to a recent study conducted by ERC for the Washington State Department of Ecology (Etkin 2006), across the US there are 0.0004 oil spills per oil transfer. For each oil transfer, there is a 0.04 percent chance of an oil spill of any magnitude. For every gallon of oil transferred between vessels or between a vessel and a facility, 3.3×10^{-7} (0.00000033) gallons are spilled. With oil transfer operations occurring every two years at the Cape Winds offshore facilities, there would be a total of 130 oil transfers[48] occurring every two years. During these oil transfers, it would be expected that there would be a 0.025 spills in any one year, or 0.75 spills in 30 years. Since the oil transfers would be from 55-gallon drums, the *maximum* spill volume would likely be 55 gallons of oil.

The probabilities of spillage and expected spill volumes for the Cape Wind facility for this incident type are summarized in Table 10. The potential number of spills resulting from errors during oil transfers is very low with less than one spill occurring in the course of 30 years.

3.11 Total Oil Spill Risk

The total number of expected oil spills and expected spill volume distributions for Nantucket Sound after the Cape Wind project is in place broken down by cause and source are shown in Table 11. The total number of all expected spills (related as well as unrelated to Cape Wind) over thirty years is 19. *It is important to note that 93 percent of the potential for spills is from vessels transiting the Nantucket Sound area and is unrelated to the presence of the Cape Wind facility components(i.e., approximately 18 spills).* Over 30 years, there are likely to be fewer than two spills associated with the presence of the facility itself. There is a 90 percent chance that this spillage would involve less than 50 gallons.

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[47] The probability that the oil delivery vessels would experience an accident and spill oil prior to arriving at the Cape Wind facility is addressed in Section 3.3.2.
[48] Each of the 130 WTGs is counted as a separate oil transfer operation.

Table 10: Expected Number of Facility-Sourced Spills and Spill Volume Probabilities for Cape Wind WTGs and ESP in Nantucket Sound												
Incident Type	**Expected Number of Spills[49]**				**Probability of Spill Volume (gallons) Given Spill Incidence**							
	In 1 Year	**In 5 Years**	**In 10 Years**	**In 30 Years**	**90%**	**75%**	**50%**	**25%**	**10%**	**5%**	**1%**	**<0.0001%**
Fire/Explosion	0.001	0.003	0.005	0.016	<50	65	400	7,800	18,000	19,000	68,000[50]	68,000[49]
Intentional Damage	0.001	0.005	0.010	0.028	<50	80	400	950	1,500	3,500	10,000	32,000
Damage in Repairs	0.003	0.013	0.025	0.076	<50	58	80	145	275	840	2,600	6,000
Structural Failure	0.003	0.017	0.035	0.104	<50	60	120	500	3,800	20,000	68,000[49]	68,000[49]
Equipment Failure	0.004	0.017	0.035	0.104	<50	80	175	480	2,000	9,000	2,500	68,000[49]
Operations Errors	0.004	0.018	0.036	0.109	<50	60	115	450	2,500	8,500	17,000	56,000
Oil Transfers[51]	0.025	0.125	0.250	0.750	<1	5	10	20	55	55	55	55
Natural Phenomenon	0.003	0.013	0.025	0.076	<50	50	78	145	480	2,000	10,000	68,000[49]
TOTAL	**0.044**	**0.211**	**0.421**	**1.263**	-	-	-	-	-	-	-	-

[49] Note that the expected number of spills as presented in the table have been rounded to the nearest 0.001 (10^{-3}) for the expected number of spills in one year. The actual number of spills used for calculations of the expected number of spills in 5, 10, and 30 years is based on the number of spills rounded to the nearest 0.000001 (10^{-6}). The subsequent calculations are thus subject to round-off correction.

[50] Maximum spill volume would be 68,000 gallons for the Cape Wind facility.

[51] Oil transfer spills occur during the transfer procedure and can technically arise from the vessel end or from the facility end.

Table 11: Expected Number of Oil Spills in Nantucket Sound					
Spill Source	**Spill Cause**	**Expected Number of Spills**[52]			
		1 Year	**5 Years**	**10 Years**	**30 Years**
Pass./Dry Cargo Vessel	CW-unrelated accident[53]	0.130	0.651	1.301	3.903
Tank Ship	CW-unrelated accident[52]	0.003	0.016	0.032	0.096
Tow/Tug Boat	CW-unrelated accident[52]	0.012	0.060	0.120	0.359
Tank Barge	CW-unrelated accident[52]	0.001	0.005	0.010	0.031
Ferry	CW-unrelated accident[52]	0.139	0.693	1.385	4.155
Comm. Fishing Vessel	CW-unrelated accident[52]	0.115	0.577	1.154	3.463
Charter Fishing Vessel	CW-unrelated accident[52]	0.181	0.904	1.808	5.423
Touring Boat	CW-unrelated accident[52]	0.105	0.525	1.050	3.149
Work Boat	CW-unrelated accident[52]	0	0	0	0
Pass./Dry Cargo Vessel	Accident with CW present[54]	0.130 + Δ[55]	0.651+ Δ	1.301+ Δ	3.903+ Δ
Tank Ship	Accident with CW present[53]	0.003 + Δ	0.016 + Δ	0.032 + Δ	0.096 + Δ
Tow/Tug Boat	Accident with CW present[53]	0.0120 + Δ	0.060+ Δ	0.120 + Δ	0.359 + Δ
Tank Barge	Accident with CW present[53]	0.001 + Δ - Δ*[56]	0.005+ Δ - Δ*	0.010 + Δ - Δ*	0.031+ Δ - Δ*
Ferry	Accident with CW present[53]	0.139 + Δ	0.693 + Δ	1.385 + Δ	4.155 + Δ
Comm. Fishing Vessel	Accident with CW present[53]	0.115+ Δ	0.577 + Δ	1.154 + Δ	3.463 + Δ
Charter Fishing Vessel	Accident with CW present[53]	0.181+ Δ	0.904 + Δ	1.808 + Δ	5.423 + Δ
Touring Boat	Accident with CW present[53]	0.105 + Δ	0.525 + Δ	1.050+ Δ	3.149+ Δ
Work Boat	CW-related accident[57]	0.00006	0.0003	0.0006	0.0018
CW ESP and/or WTGs	Fire/Explosion	0.001	0.003	0.005	0.016
CW ESP and/or WTGs	Intentional Damage	0.001	0.005	0.010	0.028
CW ESP and/or WTGs	Damage in Repairs	0.003	0.013	0.025	0.076
CW ESP and/or WTGs	Structural Failure	0.003	0.017	0.035	0.104
CW ESP and/or WTGs	Equipment Failure	0.004	0.017	0.035	0.104
CW ESP and/or WTGs	Operations Errors	0.004	0.018	0.036	0.109
CW ESP and/or WTGs	Oil Transfers[58]	0.025	0.125	0.250	0.750
CW ESP and/or WTGs	Natural Phenomenon	0.003	0.013	0.025	0.076
CW ESP and/or WTGs	Hurricane[59]	**0.006**	**0.032**	**0.065**	**0.195**
CW ESP and/or WTGs	Tsunami	0.000	0.000	0.000	0.000
CW ESP and/or WTGs	Earthquake[60]	0.000	0.002	0.003	0.015
Transiting Vessels[61]	**All Causes w/o CW**	**0.686**	**3.431**	**6.860**	**20.579**
CW ESP/WTGs	**All Causes**	**0.063**	**0.310**	**0.620**	**1.862**
ALL SOURCES	**All Causes**	**0.749**	**3.741**	**7.480**	**22.443**

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52 Note that the expected number of spills as presented in the table have been rounded to the nearest 0.001 (10^{-3}) for the expected number of spills in one year. The actual number of spills used for calculations of the expected number of spills in 5, 10, and 30 years is based on the number of spills rounded to the nearest 0.00001 (10^{-5}). The subsequent calculations are thus subject to round-off correction.

53 CW-unrelated = Not dependent on presence of Cape Wind structures. CW-unrelated groundings, collisions, or allisions would occur even if Cape Wind Project were not built.

54 Accidents that occur in presence of Cape Wind structures which may or may not be related to its presence.

55 Δ = unknown additional risk of spill from accident related to presence of Cape Wind structures.

56 Δ* = risk reduction for tank barge spills due to the necessity for fewer tank barge trips with the offset of oil-generated energy with wind-generated energy from the Cape Wind project

57 Since the work boats would not be in Nantucket Sound without the presence of the Cape Wind project, any spills from these vessels would necessarily be related to the presence of the structures.

58 Oil transfer spills occur during the transfer procedure and can technically arise from the vessel end or from the facility end.

59 Category four or higher. Probabilities assume that the hurricane will cause some damage that will cause an oil spill of any magnitude. Actual probability of spillage is probably a fraction of this.

60 Earthquake of 4.75 on Richter scale. Probabilities assume that the earthquake will cause some damage that will cause an oil spill of any magnitude. Actual probability of spillage is probably a fraction of this.

61 Totals reflect spill rates in the absence of Cape Wind Project. Actual spill rates would need to be adjusted to take into account any additional risk from vessel traffic in the presence of the structures, as well as the decreased risk from tank barge spills due to the fewer vessel trips with wind-generated energy.

4.0 SUMMARY AND CONCLUSIONS

The oil spill probability analysis shows that only 7 percent of all spills expected in Nantucket Sound during a 30 year period could be attributed to the addition of the Cape Wind facility. It is possible that 2 spills attributable to the Cape Wind facility itself could occur during the same 30 year period. Of these spills, there is a 90 percent chance that they would involve volumes of 50 gallons or less, and a 1 percent chance they would involve volumes of 10,000 gallons. The probability of a spill in the same 30 year period involving the entire 68,000 gallons of oil contained within the 130 WTGs and the ESP is less than one in a million.

It is important to note that 93 percent of the spill probability in Nantucket Sound is from spills from vessels that may transit the area near the Cape Wind Facility. These spills are *unrelated to the presence of the facility and would occur whether or not the facility was in place*. The accident-related spills that might arise from the vessels are ones that would be expected in this area whether or not the Cape Wind facility were in place. The spill probabilities are based solely on the vessel traffic in the area.

The highest possibility of an oil spill occurring in the area in and around Nantucket Sound is related to vessels transiting the area, regardless of the presence of the Cape Wind structures and related work vessels:

- Over the course of any one year, transiting vessels alone may result in less than one spill.
- Over the course of any 5 year period, transiting vessels alone may result in 3 spills.
- Over the course of any 10 year period, transiting vessels alone may result in 7 spills.
- Over the course of 30 years, transiting vessels alone may result in 22 spills in and around Nantucket Sound.

The presence of the facility may very slightly increase the risk of spills from vessels alliding with one of the Cape Wind structures. The increase could be offset by the decrease in vessel trips in the region by tank barges carrying heavy fuel oil for oil-based energy-generating facilities.

- When the presence of the Cape Wind components is combined with transiting vessels, the possibility for a spill in any one year remains less than one spill.
- When the presence of the Cape Wind components is combined with transiting vessels, the possibility for a spill in any 5 year period remains approximately 4 spills.
- When the presence of the Cape Wind components is combined with transiting vessels, the possibility for a spill in any 10 year period increases slightly to less than 8 spills.
- When the presence of the Cape Wind components is combined with transiting vessels, the possibility for a spill over the 30 year period increases slightly to less than 23 spills.

Due to the large spacing between the project's components, the probability that there would be a spill of the full 68,000 gallons enclosed in the Cape Wind ESP and WTGs is negligible. There is a less than 0.0001 percent chance (*i.e.*, less than one in a million) that the spill might involve almost the entire 68,000 gallons enclosed in the Cape Wind ESP and WTGs.

4.1 Summary of Expected Spills

This section summarizes the analysis of the expected number of spills in Nantucket Sound described in Section 3.

The expected numbers of spills attributable to each potential spill cause are summarized in Table 12.

Table 12: Expected Number of Oil Spills in Nantucket Sound					
Spill Source	Spill Cause	Expected Number of Spills[62]			
		1 Year	5 Years	10 Years	30 Years
Transiting Vessels[63]	All Causes w/o CW	0.686	3.431	6.860	20.579
CW ESP/WTGs	All Causes	0.063	0.310	0.620	1.862
ALL SOURCES	All Causes	0.749	3.741	7.480	22.443

Only seven percent of the potential spills would actually come from the wind farm structures themselves. There are likely to be fewer than two spills from the Cape Wind structures themselves over the course of 30 years. The volumes of oil that would be released in any of these spill incidents are most likely going to be less than 50 gallons. Mechanical damage from a large ramming vessel, such as a tank ship or large commercial vessel, may cause spillage from one of the structures, but it is unlikely to cause the release of all of the oil, particularly from the ESP due to secondary containment. The types of incidents most likely to cause the greatest release of oil are fires and/or explosions, catastrophic earthquakes; and catastrophic ramming of the ESP and all of the WTGs in an unprecedented terrorist attack.

4.2 Summary of Probable Spill Volumes

This section summarizes the analysis of the expected volumes of spills if one were to occur in Nantucket Sound described in Section 3.

The probability distribution function of spill volumes for all causes is shown in Table 13. This function describes the potential volume of spills in the event that there actually is a spill. It does not give the probability that a spill will occur. (The probability of spill occurrence is shown in Table 12.)

Table 13: Probable Spill Volumes Given That Spill Occurs in Nantucket Sound[64] Related to the Cape Wind Energy Project								
Spill Source	Probability of Spill Volume Given Spill Incidence							
	90%	75%	50%	25%	10%	5%	1%	<0.0001%
Transiting Vessels	1 gal.	4 gal.	9 gal.	59 gal.	202 gal.	1,439 gal.	2,106 gal.	1,170,000 gal.
Cape Wind WTG/ESP	50 gal.	53 gal.	93 gal.	247 gal.	871 gal.	2,519 gal.	10,198 gal.	68,000 gal.

62 Note that the expected number of spills as presented in the table have been rounded to the nearest 0.001 (10^{-3}) for the expected number of spills in one year. The actual number of spills used for calculations of the expected number of spills in 5, 10, and 30 years is based on the number of spills rounded to the nearest 0.00001 (10^{-5}). The subsequent calculations are thus subject to round-off correction.

63 Totals reflect spill rates in the absence of Cape Wind Project. Actual spill rates would need to be adjusted to take into account any additional risk from vessel traffic in the presence of the structures, as well as the decreased risk from tank barge spills due to the fewer vessel trips with wind-generated energy.

64 The values in Table 13 are derived from a probability distribution function (PDF) (as in Figures 11 – 13) for vessel spills and for Cape Wind facility (WTG and ESP) spills as in Tables 9 and 10, respectively. The spill volumes were weighted (pro-rated) by the relative percentage of numbers of each kind of spill (the relative number of spills from different kinds of vessels in Table 9; and by cause – e.g., fire/explosion, structural failure, as in Table 10 for the CW WTGs and ESP). All of the spills for vessels were combined into one PDF and all of the spills for the CW facility were combined into another PDF. The overall percentages and spill volumes appear in Table 13. This table shows the probability and volumes of spillage that one might expect from vessels and from the CW facility over 30 years.

If a spill were to occur from the vessels transiting the Nantucket Sound area (regardless of the presence of the Cape Wind structures), there is a 90 percent chance that the spills will be one gallon or less in volume. There is a one percent chance that the spill will entail 2,100 gallons or more.

If there are 22 spills from *all* sources (*i.e*., both the Cape Wind structures and transiting vessels in spills unrelated to the presence of the Cape Wind facility, as in Table 12) over 30 years, one of the spills may involve 2,800 gallons. Twenty of the spills will involve approximately five gallons.

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