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Buzzards Bay Risk Assessment

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This report presents the results of the USCG Buzzards Bay Risk Assessment conducted under: USCG Buzzards Bay HSHQDC-12-J-00325 of SEDI's Fiscal Year 2009 Research Plan. The purpose of the task is to produce a technical risk study and evaluation of measures that may reduce the level of potential risk of an oil spill in Buzzards Bay and the Cape Cod Canal. The agencies are interested in evaluating the risk reduction benefits and any associated environmental, economic, or other quantitative or qualitative costs of the use of marine pilots and tugboat escorts for *all* towing vessels. The USCG and MassDEP hope to use the results of this study to evaluate the current level of federal and state regulation for Buzzards Bay and the Canal and to determine whether the USCG should make changes to the pilot and escort system requirements.

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Abstract

This is a technical risk study and evaluation of measures that may reduce the level of potential risk of an oil spill in Buzzards Bay and the Cape Cod Canal. The report evaluates the risk reduction benefits and any associated environmental, economic, or other quantitative or qualitative costs of the use of marine pilots and tugboat escorts for *all* towing vessels with laden tank barges, regardless of whether they are single-hulled or double-hulled, by addressing:

- Analysis of oil spill probabilities from double-hull tank barges
- Analysis of potential consequences of oil spills
- Evaluation of risk mitigation costs and benefits associated with a requirement for federally-licensed pilots
- Evaluation of risk mitigation costs and benefits associated with a requirement for escort vessels

Key Words

- Oil spill
- Risk assessment
- Escort tugs
- Maritime risk mitigation
- Buzzards Bay

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Executive Summary

The United States Coast Guard (USCG) and Massachusetts Department of Environmental Protection (MassDEP) contracted with the Systems Engineering Development Institute (SEDI) to provide a technical risk study and evaluation of measures that may reduce the level of potential risk of an oil spill in Buzzards Bay and the Cape Cod Canal. In particular, the agencies are interested in evaluating the risk reduction benefits and any associated environmental, economic, or other quantitative or qualitative costs of the use of marine pilots and tugboat escorts for *all* towing vessels with laden tank barges, regardless of whether they are single-hulled or double-hulled. The study was required to focus on single-hull/double-hull tank barges operating in the Buzzards Bay Regulated Navigation Area (RNA) and address:

- Analysis of oil spill probabilities from double-hull tank barges
- Analysis of potential consequences of oil spills, with regard to:
  - Environmentally-sensitive habitats, resources at risk, and threatened and endangered species
  - Seasonality associated with vulnerabilities
  - Limits to available oil spill containment
- Evaluation of risk mitigation costs and benefits associated with a requirement for federally-licensed pilots
- Evaluation of risk mitigation costs and benefits associated with a requirement for escort vessels

Oil Spill Probability

Oil spills as a result of an incident are typically caused by human factors, equipment failures, or environmental conditions that result in groundings, collisions, or allisions. The oil spill probability is a function of vessel transits and traffic density, and of the preventative nature and enforcement of regulatory requirements including tug crewing, qualifications, and barge design and construction. Significant oil spills are serious but fortunately rare events. The clearest summary of oil spill probability during our research was provided in a Nuka Report[1] that stated: "…a 1998 study by the National Research Council (NRC)[2] confirmed that advances in vessel technology, such as double hulls and redundant systems, do not erase the need for additional prevention measures.…The NRC considered the results of outflow analyses following the implementation of double-hull requirements showed that four out of every five oil spills attributable to collisions and groundings would be eliminated, and a two-thirds reduction would be realized in the total volume of oil spilled from collisions and groundings. These predictions validate the popular belief that double hulls have a significant and positive effect on reducing the risk and the severity of oil spills; however, they also show that double hulls are not a perfect prevention measure, thus enforcing the need to continue with other prevention programs."

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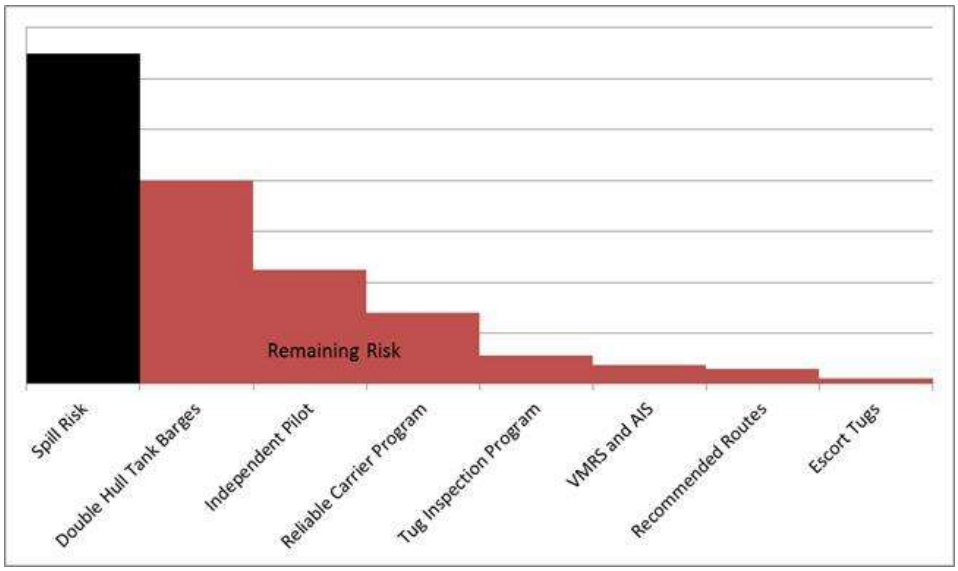
[1] Nuka Research and Planning Group, LLC, *Importance of Maintaining the PWS Escort System for Double-Hulled Tankers*, Report to Prince William Sound Regional Citizens' Advisory Council. December 2004.

[2] NRC, *Double Hull Tanker Legislation: An Assessment of the Oil Pollution Act of 1990*. National Academy Press, Washington, DC. 1998.

While the risk of oil spills was not quantitatively determined for Buzzards Bay, the relative contributions of preventive policies, programs, and services implemented in Buzzards Bay were assessed along with proposed regulations including the requirement for an independent pilot on board, and an escort or response tug to accompany the tug/barge during transits or high-risk periods. The difficulty in assessing the double-hull barge oil spill risk is due to a limited number of incidents, perhaps due in part to prevention programs. Nationwide, there has been a significant reduction in the number of spill incidents since the Oil Pollution Act of 1990 (OPA 90) was implemented. However, incidents occur, and, as a result, some spills still occur. Causal factors such as human error (45 percent) and material failures (45 percent) account for the majority of reported incidents. Although these factors are mitigated through inspection, certification, and operational programs, the probability of an oil spill remains due to unforeseen events, willful neglect, weather-related issues, accidents, or multiple other issues.

The impact of the layered programs, policies, and services addressed in this report reduce the probability of an oil spill as shown in the conceptual figure below. There is no scale on this figure as it represents the combined, layered activities that mitigate the risk of an oil spill. Double-hull tank barge requirements, effective in January 2015, will provide a significant reduction in oil spills through the reduction of the probability of a spill after an incident that resulted in a collision, allision, or grounding. The independent pilotage requirement proposed, whether federal or state pilots, provides additional decision support and experience on the tug when transiting Buzzards Bay, and reduces the probability of a human factor-induced incident. The American Waterways Operators (AWO) Responsible Carrier Program (RCP) and developing USCG Tug Inspection Program reduce the likelihood of a material and human factor-related incident through vessel design and equipment standards, maintenance programs, staffing and certification programs, and compliance programs. These programs also support the capability to respond to an incident once it occurs, reducing the risk or lessening the impact of a spill.



Consequences of Oil Spills

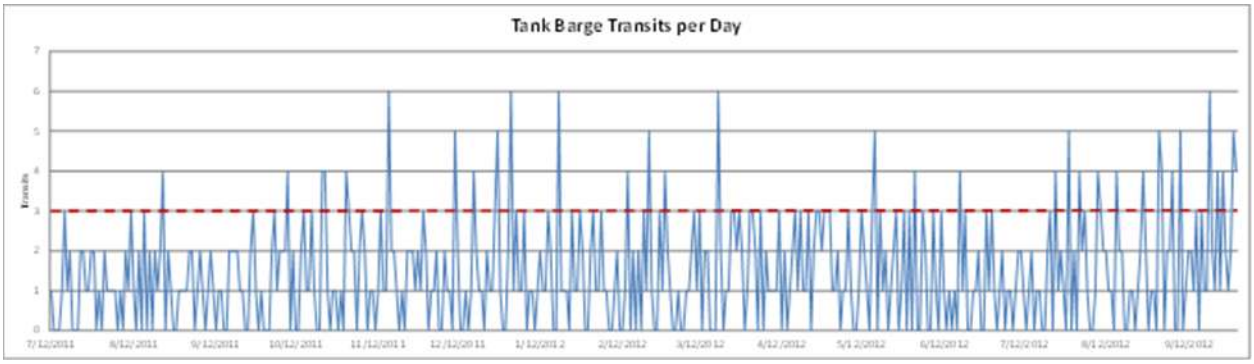
Consequences of oil spills are addressed in the *Draft Environmental Assessment for Implementation of Revisions to the RNA Governing Maritime Transport of Petroleum Products and Other Hazardous Materials on Buzzards Bay, Massachusetts*, with regard to the impacts on the environment, tourism, and wildlife. No additional research was developed for this report. However, the cost of oil spills was estimated using the model developed by Dagmar Schmidt Etkin, Modeling Oil Spill Response and Damage Costs, and the estimated costs were compared to the 2003 Barge B-120 spill for validation of the estimates.

The following table summarizes the costs of spills of both light and heavy oils for different spill amounts based on Etkin's model, and are shown in millions of dollars. The scenario amounts were selected based on the typical 100,000 bbl barge with multiple, segregated tanks.

Scenario/Volume	Mechanical Cleanup		Socioeconomic		Environmental		Total	
	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy
Scenario 1 – 1,000 bbl	$4	$22	$7	$19	$7	$8	$19	$50
Scenario 2 – 10,000 bbl	$38	$95	$77	$154	$33	$44	$148	$293
Scenario 3 – 50,000 bbl	$80	$237	$347	$675	$137	$192	$565	$1,105
Scenario 4 – 100,000 bbl	$160	$475	$695	$1,350	$275	$385	$1,130	$2,210
B-120 Spill – 3,100 bbl	--	$24	--	$39	--	$11	--	$74

Seasonality of Incident Probabilities

Seasonal variability affecting the number of vessel transits and the limits of response equipment in harsh environmental conditions were expected to factor into the vulnerability of an oil spill. The seasonality of oil transports was expected to show a marked change during the fall and winter as the home heating season begins. A review of the transits showed a minor increase in multiple barge movements in early fall and midwinter, however high-transit days were typically followed by low transit days. The average of 3 transits per day, upbound and downbound, is consistent with the approximately 1,200 annual transits of tug barges, of which 50 percent are laden.



Limits of Available Spill Containment

The state of Massachusetts also compiled an inventory of response equipment within Massachusetts and New England that may be available in the event of a release of oil within state

waters. This inventory listed equipment available but the report noted that the process of evaluating the capabilities for on-water recovery and other response tactics was not undertaken, and was limited by the scope of the report. The report noted there were limited skimmers in Massachusetts, and the closest major on-water response resources are located in Portland, Maine.

The 2010 massive release of oil from the Macondo exploratory well aboard the drilling rig *Deepwater Horizon* has challenged the planning factors for response resource capabilities. The Incident Specific Preparedness Review (ISPR) conducted following the Deepwater Horizon incident found that the amount of response resources used on scene vastly exceeded the amount planned/required by regulation and that they were ineffective in recovering the amount of oil anticipated by planners. The implications of this for oil spill response on Buzzards Bay are substantial. Until the planning requirements for oil spill response resources are rationalized with the anticipated actual performance during an oil spill, it must be assumed that current on-water response, at least, will not meet expectations. This is an area for further research.

Evaluation of Risk Mitigations and Costs of Federal Pilots and Escort Tugs

The results of change analyses conducted identify the requirement for an independent pilot (either state or federal) as providing the greatest reduction to a risk of an oil spill. The additional qualified navigation individual effectively decreases the probability of a human-factor incident and has a per-trip cost of approximately $4,000 per transit, or $2.4M per year based on an average of 600 laden transits per year. This mitigates Human Factor-influenced risks of oil spills.

The requirement for double-hull barges is the second significant contributor to the reduction of oil spills. The double hull provides a high probability that oil outflow will not occur if a collision, allision or grounding incident occurs. The benefits of a double hull are realized only after the occurrence of a collision, allision or grounding and would have resulted in a breakdown in the preventive policies, programs, and services, including the independent pilot, recommended routes, vessel transit monitoring, training and certification programs, vessel inspection programs. The requirement for double hull barges is described as an expected condition after full implementation in January 2015.

The availability of escort tugs, whether full escorts or sentinel tugs on call to respond to an incident, are similar in some respects to the double-hull requirement in that they provide a service should a breakdown occur in the preventive policies, programs, and services, resulting in a high-risk situation. The availability of an escort tug provides a preventive service to reduce the risk of an oil spill from collision, allision, or grounding, and the master on the escort tug provides an added level of review of developing situations similar to the additional pilot. Escort tug costs were estimated for ABS Firefighting or FiFi1 tugs ($13,000 per transit, $7.8M per year), non-FiFi1 tugs ($9,000 per transit, $5.4M per year), or sentinel tugs (average cost of $24,000 per transit but reduced instances per year based on extreme weather conditions, for an annual cost of $3.4M per year). An increase in risk is also noted in the event of collision if escort tugs and/or sentinel tugs were entirely eliminated, even for double-hull tank barges. Reducing the firefighting capability on escort tugs has limited effect either positively or negatively. A lesser decrease in risk was noted if the Vessel Movement Reporting System (VMRS) were to upgrade to a Vessel Traffic Management System.

The operation of the VMRS also has a positive impact on risk reduction through the monitoring of vessel transits and the identification and communication of potential hazards and risk areas

within the waterway. The VMRS, coupled with the recommended transit routes, reinforces the environmental criticality of the waterway and focuses tug/barge operations during the transit.

The change analysis could not identify significant differences between full escorts and weather-based escort requirements, primarily because of the construct of the change analysis that considers the impact of the capability in response to an event. The weather-based escort alternative does provide the added level of risk mitigation during high-risk periods, resulting in a reduction in the cost of the mitigation service by approximately 80 percent, based on the occurrence of extreme weather conditions 20 percent of the year. The relative value of each of the change measures is shown in the figure below and sorted by the highest-to-lowest contribution. The color indicates the scale of the highest (green) and lowest (red) contribution.

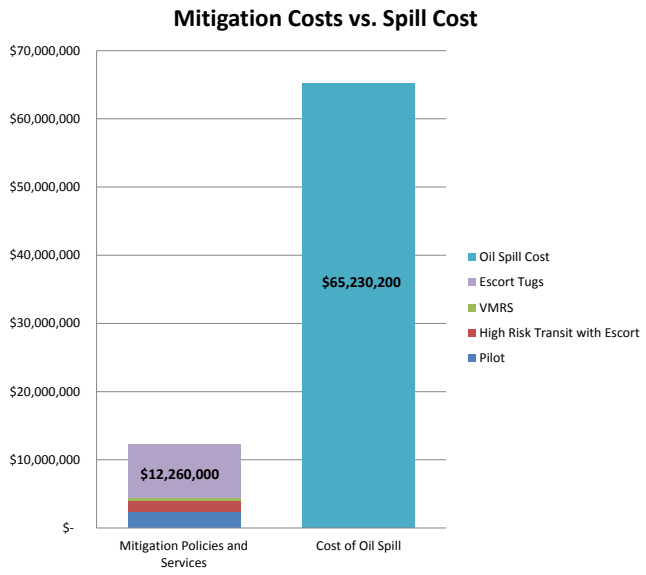
Activity	Risk Score for Each Category of Casualty				Overall Risk Score
	Drifted Grounding	Powered Grounding	Collision	Allision	
Require a pilot (federal or state) on all towing vessels with barges carrying more than 5,000 barrels of oil or hazardous substances					
Change barge configuration from single hull to 100% double hull					
Require escort tug					
Require escort tug in adverse weather or when determined necessary					
Active management of vessel traffic (upgrade VMRS)					
Require FiFi1 firefighting capability for escort or sentinel tug					
Require sentinel or response tug in lieu of escort tug					

Legend

	Change contributes most to risk mitigation
	50th percentile
	Change contributes least to risk mitigation

The “What If” Analysis was conducted for scenarios describing reactive and proactive responses to potential oil spill incidents. Reactive responses are those activities that are undertaken after an incident has occurred. Proactive activities are those activities taken to reduce the likelihood of an incident or to position resources for immediate response to mitigate the effects of an oil spill. Contributions to oil spill reduction were identified for the requirement for an independent pilot and escort tug requirements in each “what if” scenario.

Although insufficient information was available to attribute the expected volume of oil outflow, the potential costs of spills are adequately offset by the costs of the mitigation activities. The mitigation program costs are contrasted to the reported cost of the B-120 spill, resulting in the following diagram.



Further mitigation alternatives from the review of larger Risk Analysis Studies were also reviewed. Potential additional mitigation alternatives are presented in Section 8.

1 Introduction

The United States Coast Guard (USCG) is responsible for developing and implementing policies and procedures that facilitate commerce, improve safety and efficiency (including preventing and responding to oil spills in the marine environment), and inspire dialogue within the maritime community with the primary goal of making waterways as safe, efficient, and commercially viable as possible. The Oil Pollution Act of 1990 (OPA 90), which established the principles under which oil spills in the United States would be handled, specifically did not preempt states from imposing additional liability or other requirements with respect to oil spills or from taking action with respect to removal actions involving oil spills. The Massachusetts Department of Environmental Protection (MassDEP) is responsible for implementing laws and regulations regarding the prevention and remediation of oil spills in Massachusetts.

The USCG and MassDEP require a technical risk study and evaluation of measures that may reduce the level of potential risk of an oil spill in Buzzards Bay and the Cape Cod Canal. In particular, the agencies are interested in evaluating the risk reduction benefits and any associated environmental, economic, or other quantitative or qualitative costs of the use of marine pilots and tugboat escorts for *all* towing vessels with laden tank barges, regardless of whether they are single-hulled or double-hulled. The USCG and MassDEP plan to use the results of this study to evaluate the current level of federal and state regulation for Buzzards Bay and the Canal and to determine whether the USCG should make changes to the pilot and escort system requirements codified at 33 C.F.R. § 165.100 (including the "Special Buzzards Bay Regulations" [33 C.F.R. § 165.100(d)]) when it proceeds with a new rulemaking. **Figure 1** shows a map of Buzzards Bay and the Cape Cod Canal (marked by the red point).

Figure 1. Buzzards Bay and Cape Cod Canal

1.1 Background

OPA 90 introduced oil spill requirements and funds, and launched prevention programs with the purpose of reducing the number and volume of spills. Regulations from the USCG and other federal agencies implementing OPA 90 have included mandates for double-hull tank vessels, crewing studies, oil spill response plans, and an Incident Command System to manage the

coordination of spill response and cleanup activities. Since OPA 90, the volume of oil spilled into U.S. waterways and the numbers of those spills have been reduced; however, spills still occur. Casualties resulting in oil spills in U.S. waters have similarly been reduced through the imposition and enforcement of regulations and industry-led programs designed to improve vessel safety, including tank barge safety.

Other legislation has created special regulations for protected areas, rivers, and waterways. Regulated Navigation Areas (RNA) designated by the USCG under the Ports and Waterways Safety Act provide for additional measures to control the shipment of hazardous materials and petroleum products. The Commonwealth of Massachusetts established "Areas of Special Interest" with additional operating requirements for certain vessels operating in these areas to prevent casualties resulting in oil spills.

Although proactive in intent, these regulated areas are typically established after a significant or potential incident. For example, the Buzzards Bay Special Area of Interest and the Buzzards Bay RNA were established in response to a major oil spill in Buzzards Bay caused by the grounding of the Bouchard Barge B-120. On Sunday, April 27, 2003, the Tank Barge Bouchard B-120 struck rocks south of Westport, Massachusetts, when it passed on the wrong side of a navigational marker at the entrance of Buzzards Bay. The resulting 12-foot gash on the bottom of the hull released an estimated 98,000 gallons of Number 6 fuel oil into Buzzards Bay. The vessel was en route to deliver oil at the Mirant electricity generation facility located on the Cape Cod Canal.[3] In the wake of the April 27, 2003, barge B-120 oil spill into Buzzards Bay, the Massachusetts Legislature passed Massachusetts Oil Spill Prevention and Response Act (MOSPRA). The purpose of the Act was to strengthen several statutes that govern Massachusetts' ability to prevent and respond to oil spills in the coastal waters of the Commonwealth. The Act was amended in 2008 and 2009. MOSPRA is codified at Mass. General Laws c. 21M.

MOSPRA originally established state pilotage requirements, personnel and manning requirements, tank vessel design requirements, drug and alcohol testing provisions, tugboat escort provisions, mandatory vessel routing requirements, and the certificate of financial assurance requirement.

On March 29, 2006, the USCG published a Notice of Proposed Rulemaking (NPRM) to implement revisions to the existing RNA that was applicable to First Coast Guard District waters. The NPRM proposed to establish additional federal navigation, safety, and waterways management improvements on Buzzards Bay.

On August 30, 2007, the USCG published a Final Rule to implement the revisions that were proposed in the 2006 NPRM to amend the existing RNA for navigable waterways within the First Coast Guard District. Navigation safety measures required by these regulations can be found at 33 C.F.R. § 165.100. The Special Buzzards Bay Regulations are codified in 33 C.F.R. § 165.100(d)(5). The amended regulations established a Vessel Movement Reporting System (VMRS) that required a federally-licensed pilot who is not a member of the crew be onboard all single-hull barges transporting oil or hazardous materials through Buzzards Bay and the Canal, and mandated the use of tugboat escorts for all single-hull barges transporting oil and hazardous

[3] Buzzards Bay Estuary Program, http://buzzardsbay.org/oilspill-4-28-03.htm, downloaded October 30, 2010.

materials through the Bay and the Canal. The USCG prepared a Categorical Exclusion Determination, as defined in its Agency Procedures for Implementing the National Environmental Policy Act (NEPA), for the Final Rule. In subsequent litigation, the U.S. Circuit Court of Appeals for the First Circuit found that this level of NEPA analysis and documentation was insufficient. A draft Environmental Assessment (EA) was completed on July 18, 2012, and advertised for public comment in the Federal Register announcement published in Vol. 77, No. 149 on August 2, 2012. Comments and related material to the Federal Register announcement were required to be submitted to an online docket or to the First Coast Guard District Docket Management Facility by September 4, 2012. This study did not include a review of any of the comments received by the First Coast Guard District regarding the draft EA.

1.2 Purpose and Need for Risk Assessment

The Buzzards Bay/Cape Cod Canal navigation route is a major throughway for tank barges transporting oil to parts of northeastern United States and Canada. The primary traffic in the Bay are tugs and barges moving between the ports of Philadelphia and New York heading to the northern New England ports of Boston, Portsmouth, and Portland via the Cape Cod Canal. Other traffic includes large oceangoing ships coming from Portsmouth and Boston headed to Long Island Sound and New York via the Cape Cod Canal. Well over 20,000 commercial cargo, tanker, tug/tow, passenger, and commercial fishing vessels pass through Buzzards Bay each year, as well as thousands of smaller vessels, including recreational fishing and pleasure boats. Since 1969, there have been several tank barge groundings that resulted in the discharge of oil into Buzzards Bay. Discharges of oil or other hazardous materials can adversely impact people, property, the marine environment, and the economy. In 1985, Congress designated Buzzards Bay an Estuary of National Significance. Buzzards Bay also contains ecologically-significant habitats for threatened and endangered species, serves as the location for sport and commercial fin and shell fishing, and provides valuable recreational uses that, among other things, promote tourism.

2 Methodology

Risk assessments that rely exclusively on spill probability models tend to result in higher levels of uncertainty than those that use multiple methodologies. Oil spills, and events leading to them, tend to be low-probability, high-impact events. An examination of historical spill data has shown that these incidents also tend to be highly random both in location and in timing. A preliminary literature review indicates that past efforts at quantifying spill probability and risk solely on the basis of historical spill data have resulted in high levels of uncertainty.

The funding and period of performance for this risk assessment were constraints that limited the methodology to the following sources:

- Published studies and reports.
- Safety data and incident reports from tank barges and tank ships operating in Buzzards Bay since 2006. The review was limited to safety data and incident reports since 2006, although the historical spills in Buzzards Bay, including the 2003 B-120 spill, were included in the analyses.
- A review of other vessel escort systems in place in the United States and of risk reduction measures identified through other risk assessments, including Puget Sound, Prince William Sound, and various California ports.
- Interviews with USCG First District and MassDEP representatives.

Publicly-available data were reviewed and discussed with USCG and MassDEP sponsors. The sponsors also provided data, reports, and other information.

2.1 Review of Geographic and Weather Conditions

The geographic review of Buzzards Bay summarizes information from multiple sources including the USCG Pilot and navigation charts. Weather data were assessed from the National Data Buoy Center for wind speeds in Buzzards Bay using the BUZM3 data buoy, located at the mouth of Buzzards Bay in position 41°23'48" N 71°2'0" W. Visibility information was not available from this National Oceanic and Atmospheric Administration (NOAA) site, therefore the nearest available data set at the New Bedford Regional Airport was used. Sea ice data were extracted from USCG annual Domestic Ice Operations reports prepared by the First Coast Guard District to report on activities during the ice season. Specific assessments were completed for the frequency of adverse weather conditions that have typically hindered safe navigation, specifically expected periods of low visibility, high winds, and sea ice.

2.2 Vessel and Tank Barge Operations

Vessel operations in Buzzards Bay were analyzed to identify trends in vessel transits through the area from multiple data sources including:

- Automated Information System (AIS) data for all reporting vessels in Buzzards Bay from January 2011 through December 2011 (at 5-minute intervals).
- Cape Cod Canal transits from the U.S. Army Corps of Engineers, direct report from Canal Staff (includes transits through the Canal only).

- U.S. Army Corps of Engineers Waterborne Commerce of the U.S., excerpts for the Cape Cod Canal waterway (includes data on nationwide transits; New England transits were used in analysis).
- Interviews with USCG and MassDEP representatives regarding tank barge operations.

2.3 Oil Spill Probabilities

In analyzing oil spill probabilities, multiple data sources were examined, including:

- USCG Marine Information System Law Enforcement (MISLE) data call for incidents in Buzzards Bay and the Cape Cod Canal, 2006–2011
- MISLE data call for incidents nationwide, 2006–2011
- Publicly-available data on oil spills in Buzzards Bay, primarily from the Buzzards Bay National Estuary Program (http://www.buzzardsbay.org/)
- Escort tug incidents and request forms provided by MassDEP, 2011–2012

Historical data were used to compute an expected value for oil spills in Buzzards Bay. Data were limited by the task order to information after 2006, although during the course of the report significant events prior to that date were summarized due to the limited number of events involving tug/barge oil spills.

2.4 Oil Spill Costs and Consequences

Data sources reviewed in estimating oil spill consequences included:

- Northeast National Estuary Program Coastal Condition Report, Buzzards Bay National Estuary
- USCG Buzzards Bay Draft Environmental Assessment

The cost analysis includes the cost of both an oil spill and the cost of mitigation efforts. The oil spill costs were estimated using Etkin's oil spill response and damage cost model.[4] The cost model incorporates a cost per gallon spilled for overall cleanup, socioeconomic impact, and environmental impact. The estimation uses modifying factors, explained in detail in Section 7, for each of these three cost bins to tailor the cost model to Buzzards Bay.

The costs of mitigation efforts were estimated using cost data provided by MassDEP[5, 6] and the U.S. Bureau of Labor and Statistics. Once the risk mitigation costs were developed, the cost of each mitigation measure was compared to the cost of the B-120 oil spill by examining the return on investment and the payback in years of the various risk mitigations.

2.5 Identification of Risk Factors

Risk is commonly defined as the product of the probability or frequency of an adverse event and the consequences of the event. Risk factors are those actions or commissions that increase the chance of an adverse event.

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[4] D.S. Etkin, "*Modeling Oil Spill Response and Damage Costs*," Freshwater Spills Symposium, April 8, 2004. Environmental Research Consulting, New York.

[5] R. Packard, MassDEP, "MassDEP Rescue Tug Cost Estimates," email received November 9, 2012.

[6] S. Mahoney, Summary of BB Rescue Tug Response.xls, January 22, 2009.

Causal factors have been classified and grouped into the following areas:

- Human Factors – Includes errors of commission (inappropriate actions), commissions (lack of required action), slips (correct intention by inappropriate action), and mistakes (inappropriate inattention).
- Equipment Casualty – Equipment that has been badly affected and cannot operate as intended; equipment failure.
- Adverse Weather – Includes environmental factors such as periods of high winds, waves, low or restricted visibility, or sea ice that impairs navigation.

For the purposes of this risk assessment, an adverse event includes the following incidents:

- Collision – A moving vessel striking one or more other moving vessels.
- Allision – A moving vessel striking a stationary object (such as a bridge).
- Drifted Grounding – A vessel moving without power into a shallow area such that the vessel comes in contact with the sea bed (also referred to as a low energy grounding).
- Powered Grounding – A vessel under power strikes a submerged object or sea bed (also referred to as a high energy grounding).
- Near Miss – Any reportable marine casualty that did not result in a discharge into the water. These instances include releases that were contained on the vessel in some manner, as well as collisions, allisions, and groundings where there was a potential for discharge (i.e., near miss pollution incidents).

2.6 Risk Mitigation Options

The primary objective of this task is to review the risk mitigation from the implementation of an additional, independent pilot and the use of escort tugs during double-hull tank barge transits in Buzzards Bay. Besides these options, proposed risk mitigation alternatives were extracted from the following available sources:

- Ports and Waterways Safety Assessment (PAWSA) report for Buzzards Bay, 2003
- USCG Buzzards Bay Draft Environmental Assessment, July 2012
- Risk Assessments from
  - Aleutian Islands - Transportation Research Board Special Report 293: Risk of Vessel Accidents and Spills in the Aleutian Islands: Designing a Comprehensive Risk Assessment, 2008[7]
  - Puget Sound - Study of Tug Escorts in Puget Sound, December 2004[8]
  - Prince William Sound - North Puget Sound Long-Term Oil Spill Risk Management Panel July 2000[9]

[7] Transportation Research Board Special Report 293: Risk of Vessel Accidents and Spills in the Aleutian Islands: Designing a Comprehensive Risk Assessment, 2008, http://onlinepubs.trb.org/Onlinepubs/sr/sr293.pdf

[8] State of Washington: Dept. of Ecology, Glosten Associates, Inc. Study of Tug Escorts in Puget Sound , 30 December 2004 http://www.ecy.wa.gov/programs/spills/hottopics/pipeline/pipelinephotos/tug/tugstudystuff/FinalReport.pdf

[9] Washington State Department of Ecology, North Puget Sound Long-Term Oil Spill Risk Management Panel, July 2000, https://fortress.wa.gov/ecy/publications/publications/0008024.pdf

Although the study was intended to focus on escort tugs and pilots, the ongoing and developing prevention programs through federal, state, and industry collaboration have resulted in a reduction in reported vessel incidents. These programs include:

- American Waterways Operators Responsible Carrier Program
- USCG Tug Inspection Programs
- Double-Hull Barge Requirements
- Buzzards Bay Vessel Movement Reporting System (VMRS)

The mitigation options were compared to the current operations of tank barges, including pilotage, regulations, and infrastructure, to determine if the PAWSA-recommended alternatives or practices from the other waterway systems were either applicable, valid, and/or implemented within Buzzards Bay.

Three previous risk assessments and the Buzzards Bay PAWSA were reviewed to identify applicable recommendations for the Buzzards Bay area. The risk assessments were significant efforts involving collaboration with multiple stakeholders, and were focused on the conditions of the areas under study. However, similarities exist within the operations of vessels and within waterways. A subjective assessment of the applicability of the Risk Analyses was completed by the authors of this report based on their experience in waterway management, vessel inspections, and incident investigations.

A total of 13 recommendations were identified from the area risk assessments from Puget Sound, the Aleutian Islands, and Prince William Sound as being applicable to Buzzards Bay, and another 12 recommendations were identified as potentially being applicable. In the authors' opinions, 32 other recommendations from these studies were identified as focused on local geographic, weather, or other conditions and were not directly applicable to Buzzards Bay tank barge operations. Some of the applicable recommendations from the previous studies are being pursued in Buzzards Bay, such as requiring double-hull tank barges (which are mandated for phase-in by 2015 under federal law), and others are addressed in the Change Analysis of this report. The recommendations from the PAWSA Workshop Report on Buzzards Bay, Massachusetts (September 2003) are not included in this summary because they have previously been presented and reviewed.

Tables 1, 2, and **3** are summaries of the recommendations provided by each area's risk assessment. The recommendations are categorized into seven grouped categories and the applicability to Buzzards Bay is indicated in the table description. The status of the recommendation is indicated in the "Status" column and includes an assessment of the recommendations which is currently in place or being developed (**Table 1**), potential future program based on further study (**Table 2**), or which is not recommended for Buzzards Bay (**Table 3**). Additionally, programs that may have applicability to Buzzards Bay are highlighted in gray-scale within the tables. Reviewing and identifying commonalities among the risk assessments that support the risk mitigations identified in this report have been suggested in other areas as well. For example, both the Aleutian Islands and Prince William Sound reports recommend implementing weather-based restrictions. The restrictions may vary between these two areas, but the fundamental idea is that risks during transits in severe weather conditions could be mitigated with the support of escort tugs.

Additionally, the development of a near-miss reporting system would enable the collection of information on incidents that could be used to identify trends from the compilation of potential incidents. This capability would enable the assessment of current programs in order to develop changes to the layers of preventive and response programs, capabilities, and services to prevent the occurrence of an oil spill.

Table 1. Alignment of Previous Risk Analyses to Potential Buzzards Bay Alternatives – Current Programs

Grouped Category	Waterway	Recommendation	Justification	Status in Buzzards Bay
Enhance oil spill response/ capabilities and training	Puget Sound	Review oil spill response issues.	Current Drills, after action report system	Current Programs evaluate oil spill response
Inspection and Enforcement	Aleutians	Increase inspection/enforcement on vessels (especially older vessels) calling at U.S. and Canadian ports and transiting the Aleutians.	American Waterways Operators (AWO) Compliance Program, Tug/Barge Inspection Programs	Developing Program
	Puget Sound	Improve scope and effectiveness of inspection programs.		
	Prince William Sound	Implement long-term plans for quality assurance and safety management programs.		
Vessel Personnel and Pilotage	Aleutians	Enhance requirements for vessel safety equipment and crew training, and enforce existing requirements.	AWO Responsible Carrier Program (RCP), Tug/Barge Inspection Program	Developing Program
	Aleutians	Establish an incident and near-miss reporting system with safeguards for mariners.	Would help identify trends in potential casualties	Recommended Initiative
	Puget Sound	Establish a near-miss reporting system.		
	Puget Sound	Develop a Standard of Care (SOC) for planned maintenance.	AWO RCP, Tug/Barge Inspection Programs	Developing Program
Waterways Management and Traffic Control	Aleutians	Enhance or expand vessel tracking and communication systems.	VMRS, AIS	Current Program
	Prince William Sound	Implement weather-based closure restrictions to stop transits during periods of high winds.	Recommended Alternative	Recommended Initiative to establish weather based escort requirements
	Prince William Sound	Have escort tugs accompany oil-laden tankers in their transit out of Prince William Sound.	Potential Alternative	Potential Alternative

Table 2. Alignment of Previous Risk Analyses and Potential Buzzards Bay Alternatives

Grouped Category	Waterway	Recommendation Summary	Discussion
Emergency Operations and Procedures	Aleutian Islands	Enhance the tug-of-opportunity network.	Depending on escort requirements
	Aleutian Islands	Finalize USCG salvage and firefighting requirements.	No sufficient evidence that this is an issue
	Aleutian Islands	Provide standby rescue tugs to respond to vessels in distress (large enough for prevailing conditions and ships in trade).	Depending on Escort Requirements
	Aleutian Islands	Require all large vessels to have emergency tow packages.	Potential for future requirement based on frequency of mishaps.
Enhance Oil Spill Response	Aleutian Islands	Conduct emergency training and salvage drills.	May be included in AWO RCP/Inspection programs
Vessel Equipment and Design	Puget Sound	Develop a SOC for anchor use.	No sufficient evidence that this is an issue
	Puget Sound	Develop a SOC for firefighting capability.	
	Puget Sound	Develop a SOC for steering gear testing.	
	Aleutian Islands	Require redundant steering and propulsion for tankers.	No sufficient evidence that this is an issue
Vessel Personnel and Pilotage	Puget Sound	Develop a SOC for vessel-towing arrangements.	No sufficient evidence that this is an issue
	Puget Sound	Establish an education program for small vessels.	Limited interference indicated in escort vessel logs

Other recommendations from these reviewed Risk Assessments were subjectively categorized as not applicable are included for reference in **Table 3**. These items reflect specific conditions to the other waterways and were therefore considered not applicable to Buzzards Bay.

Table 3. Alignment of Previous Risk Analyses and Non-Applicable Recommendations

Grouped Category	Waterway	Recommendation Summary	Justification
Communication	Puget Sound	Ensure effective communications with local Marine Resource Committees.	Current systems adequate
	Prince William Sound	Vessel Traffic Service (VTS) to manage interactions between fishing vessels and tankers.	Local Issue
Emergency Operations and Procedures	Aleutian Islands	Station adequate salvage/lightering equipment /capabilities at key locations.	Managed in response plans
		Enhance and expand USCG response capabilities for vessels in distress (e.g., response teams, rescue vessels, and helicopters).	Current systems adequate
		Require pollution response plans for all large vessels transiting sensitive areas, similar to requirements for vessels calling at Alaska ports.	Current systems adequate
Vessel Equipment and Design	Aleutian Islands	Require redundant steering and propulsion for all vessels.	Not applicable
Vessel Personnel and Pilotage	Aleutian Islands	Expand pilotage areas and pilot services to Unimak Pass and other possible locations.	Current systems adequate

The risk mitigation analysis consisted of two steps.

Step 1. The Change Analysis is a risk assessment methodology that is used for systematically evaluating risk associated with changes in conditions. For example, establishing a requirement for tug escorts for double-hull tank barges in Buzzards Bay results in a new configuration for the system already in place and affects risk, either positively or negatively. The impact of that change is evaluated in the Change Analysis using factors such as spill probability, vessel traffic density, channel configuration, weather anomalies, and other factors that may influence or be influenced by the change in operational requirements. Other changes put in place over time will also affect risk, such as the implementation of the VMRS in Buzzards Bay. The Change Analysis provides an examination of the impact those changes have had on the risk of an incident and future risk. The Change Analysis also allows for identifying measures that may be useful in mitigating any adverse effects from the change in the system to reduce risk to an acceptable level.

Step 2. The "What-If" analysis provides an assessment of risk if an incident occurs, regardless of the probability of that incident occurring. It emphasizes consequence (one of the main components of risk) and is useful for determining the outcomes of a decision. It is also useful in identifying potential mitigation measures that may be taken to reduce consequences. Proactive (or Risk Mitigation Measures) and Reactive Scenarios are described to reflect activities that are unplanned and planned.

Mitigation Measures to Be Evaluated

- Double-Hull Tank Barges (as a baseline) – Approximately 98 percent implemented based on current transit data, with full implementation by January 1, 2015
- Escort tugs for all barge transits
- Escort tugs in adverse weather or when determined necessary
- Sentinel tug in lieu of escort tug
- Independent pilot on board tug/barges carrying petroleum products
- Active management of vessel traffic through VMRS
- Require Firefighting (FiFi1) capability for escort or sentinel tug

3 Geographic Review of Buzzards Bay

Buzzards Bay is designated as an estuary of national significance by the Environmental Protection Agency National Estuary Program. This designation indicates an estuary whose waters, natural ecosystems, and economic activities were deemed by Congress to be critical to the environmental health and economic well-being of the nation.[10]

The Bay, shown in **Figure 2**, is approximately 28 miles long and 8 miles wide at its widest point and encompasses an area of 228 square miles. Buzzards Bay interacts with three different marine systems: the Atlantic Ocean, Vineyard Sound, and Cape Cod Bay. The Cape Cod Canal, a 17.2-mile sea-level waterway operated by the U.S. Army Corps of Engineers, provides the hydrologic and navigational connection between Buzzards Bay and Cape Cod Bay. Together, Buzzards Bay, the Cape Cod Canal, and Cape Cod Bay provide the shortest deep-draft route between New York and Boston. In addition to barges passing through the Bay to northern New England and Canadian ports, a number of fishing vessels, ferries, and recreational boaters frequent Buzzards Bay.[11, 12]

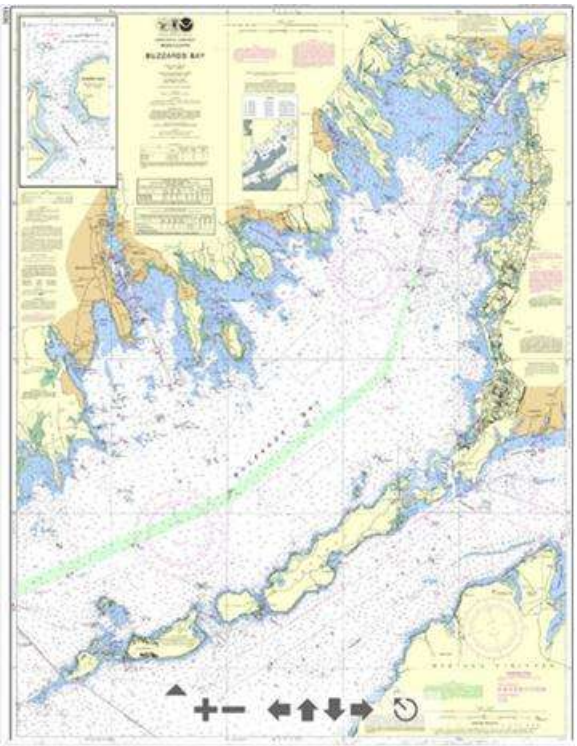


Figure 2: Buzzards Bay Chart

[10] U.S. Environmental Protection Agency, Estuaries and Coastal Watersheds, http://water.epa.gov/type/oceb/nep/index.cfm, downloaded October 30, 2012.

[11] U.S. Department of Homeland Security, U.S. Coast Guard, *Ports and Waterways Safety Assessment: Buzzards Bay Profile*, September 9, 2003.

[12] M. Pirnie, Arcadis, *Draft Environmental Assessment for Implementation of Revisions to the RNA Governing Maritime Transport of Petroleum Products and Other Hazardous Materials on Buzzards Bay, Massachusetts,* submitted to U.S. Coast Guard, July 18, 2012.

3.1 Buzzards Bay Topography and Bathymetry

The 280 miles of coastline surrounding Buzzards Bay include numerous points and bights, many of which form smaller bays and rivers on the northwestern extent of the Bay, the largest of which is the Acushnet River located just to the east of New Bedford, Massachusetts. The shoreline of Buzzards Bay is generally rocky. Large boulders are common adjacent to the shorelines, making close approaches to the shore potentially dangerous for mariners. The depth of the Bay ranges from 16 to 33 feet near the head to over 65 feet near the mouth. The depth of the Cape Cod Canal is 32 feet at mean low water. The water level between the Cape Cod Bay and Buzzards Bay differs by 5 to 9 feet,[13] which has the effect of creating tidal currents of approximately 4.5 knots. The tides throughout Buzzards Bay are generally diurnal in nature (i.e., there are two high tides and two low tides per 24-hour period). The tidal range is approximately 3 feet. Mid-bay currents are relatively weak, with minimum velocity of about 0.2 knots and a maximum of about 0.5 knots.

The bottom of the Bay is very broken with boulder reefs, wrecks, obstructed ledges, and shoals, making navigation in some areas of the Bay potentially dangerous. Dangerous reefs in Buzzards Bay (marked on **Figure 3** in red) include Hen and Chickens Reef by Gooseberry Neck, Sow and Pigs Reef by Cuttyhunk Island, Ribbon Reef, north of Cuttyhunk Light, Coxens Ledge, north of Ribbon Reef, and Mishaum Ledge, south of Mishaum Point. The entrance to New Bedford Harbor is obstructed by ledges and shoals. Also, lobster fishing gear is common throughout the entire bay.

Figure 3: Dangerous Reefs in Buzzards Bay

The shoreline of Buzzards Bay is primarily a rocky bottom inside and around the 30-foot contour, with two exceptions. On the southern shoreline of the Bay near Woods Hole there is a 3-mile stretch of shoreline from Uncatena Island northeast to Quisset Harbor where the bottom is a mixture of sticky sand and mud. Additionally, on the northern shoreline of the Bay there is a 3-

[13] NOAA, Coast Pilot 2, 42nd Edition, 2013.

mile stretch of shoreline from the Bird Island Light Tower southwest to Point Connett where the bottom is a mixture of mud, hard bottom, and rocks. Overall, approximately 90 percent of the Buzzards Bay shoreline inside and around the 30-foot contour has a rocky bottom.[14]

Buzzards Bay has two principal anchorages, which are located on either side of the recommended route for vessels transiting Buzzards Bay. Both anchorages afford 20 to 30 feet of draft and have a rocky bottom. These anchorages are designated "L" and "M" on the navigation charts for Buzzards Bay.

3.2 Wind and Weather

Buzzards Bay is located in a relatively temperate climate. Average summer high temperatures are in the mid-70s Fahrenheit and average winter lows are in the mid-20s Fahrenheit. **Figure 4** shows the range of wind speed from 1985 to 2008 in the bay area averaged between 10 and 20 knots with greater wind speeds observed in the winter months. From spring to fall winds out of the south and southwest are common. Due to the northeast-southwest orientation of the Bay, these winds strengthen as they move up the Bay. The highest winds and, subsequently, the most significant beach erosion are caused by winter storms. Winter storms come west from the continental United States. The Gulf Stream coming from the south generally tracks winter storms directly over Buzzards Bay and the Cape Cod Canal. Hurricane force winds have been associated with these types of winter storms.[15]

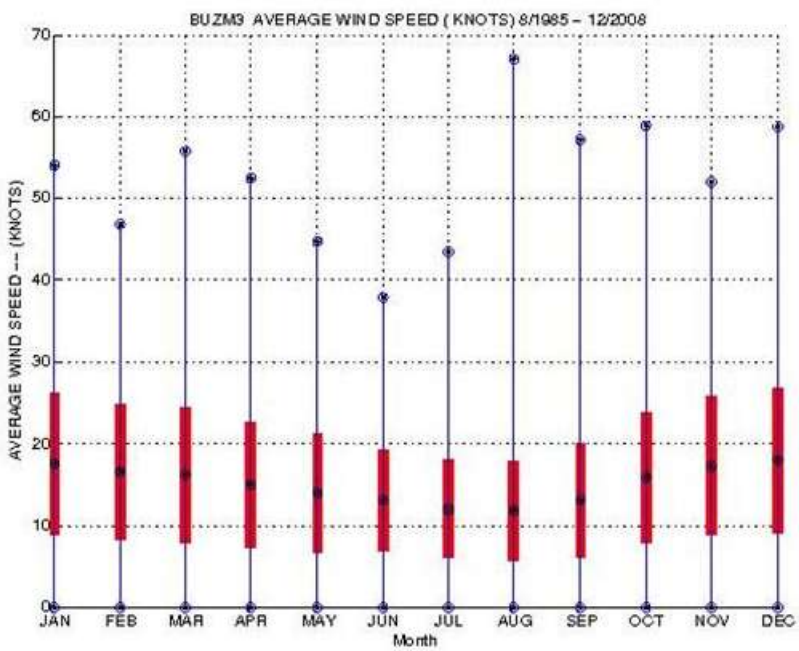


Figure 4: Average Wind Speeds in Knots by Month (NOAA 2012)

The frequency of sustained winds were analyzed at 25 through 45 knots at 5-knot intervals from the weather data for the BUZM3 station at the mouth of Buzzards Bay. Average wind speed

[14] NOAA, Office of Coast Survey, Chart 13230, Edition 50, http://www.charts.noaa.gov/OnLineViewer/13230.shtml, August 2010.

[15] NOAA, National Data Buoy Center, http://www.ndbc.noaa.gov/station_page.php?station=buzm3, 2012.

(m/s) and gusts (m/s) were available at 1-hour intervals for the period from January 2002 through October 2012 to cover at least a 10-year period and most current available wind information. Some minor gaps were evident in the data: there were 92,830 observations out of an expected 94,896 records (10 years + 10 months at 24 reports/day for a 97.8 percent reporting rate), and 1,708 wind records and 1,876 gust records were entered as "99" or "no data." These missing and invalid records were excluded from the summaries, primarily to determine the denominator for the frequency percentage calculation. The occurrences of reported winds were counted for analysis thresholds of 25 to 45 knots at 5-knot intervals, and then divided by the total reported records to determine the frequency of winds at the threshold speeds. Additionally, the average and mode (the most frequently occurring) wind gusts were calculated. The result of this analysis shows the historical frequency of wind speeds greater than these threshold values and the associated wind gusts, to inform on the expected periods of high winds for potential use as a metric for determining severe weather risk mitigation requirements. A high-wind condition is one of the reasons why tank barges request tug escort assistance, based on the Tug Escort Request Log provided by MassDEP. These data will be incorporated into the frequency of hazardous weather conditions used in the Cost Analysis. From this analysis, as reported in **Table 4**, average wind speeds in excess of 25 knots have occurred approximately 9.5 percent of the time over the last 10 years.

Table 4: Wind Speed Summary, January 2002–October 2012

Wind Speed Threshold (kts)	25	30	35	40	45
% Reports > Threshold	9.49%	3.28%	0.96%	0.24%	0.05%
Reported Periods (hours)	8,651	2,992	874	218	44
Average Wind Gusts	32.95	38.15	43.46	48.88	54.75
Mode Wind Gusts	28.77	34.02	40.82	45.87	52.68

Significant Storms: Over the past 100 years, 11 hurricanes or tropical storms have passed within 65 miles of Buzzards Bay, as shown in **Figure 5**. Of these 11 storms, the strongest when passing near Buzzards Bay were Hurricane Bob in 1991 (Category 2) and Hurricane Edna in 1964 (Category 2), shown in orange below. Hurricanes and tropical storms have the potential to cause damaging winds and storm surges in the Buzzards Bay area.[16] **Figure 6** summarizes potential damages due to hurricane winds.

[16] NOAA, National Hurricane Center, http://www.nhc.noaa.gov/, 2012.

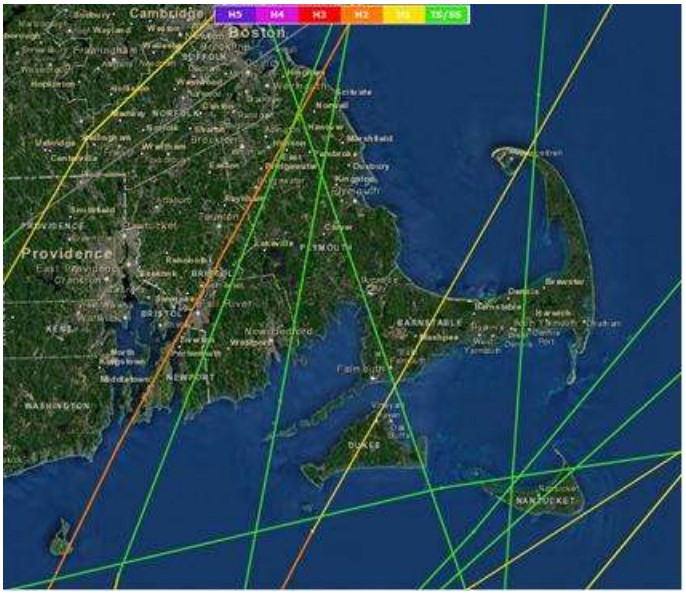


Figure 5: Hurricanes and Tropical Storm Tracks Near Buzzards Bay, 1912–2012

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74-95 mph 64-82 kt 119-153 km/h	**Very dangerous winds will produce some damage:** Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph 83-95 kt 154-177 km/h	**Extremely dangerous winds will cause extensive damage:** Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111-129 mph 96-112 kt 178-208 km/h	**Devastating damage will occur:** Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130-156 mph 113-136 kt 209-251 km/h	**Catastrophic damage will occur:** Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	157 mph or higher 137 kt or higher 252 km/h or higher	**Catastrophic damage will occur:** A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Figure 6: NOAA Hurricane Classification System with Descriptions of Wind Damage

The recent October Hurricane/Storm Sandy caused considerable damage along the eastern seaboard, and severely hampered the marine transportation system, dislocating many aids to navigation in the northeast United States, including Buzzards Bay. However, despite the damage from winds, storm surge, and other factors, there were no reported tug and barge incidents in Buzzards Bay in part due to preparations and heavy weather planning as the storm had sufficient and adequate advance notice of arrival. The periods of high winds during Sandy were listed for the period October 28–31, 2012, to show the potential impact of a major storm should wind criteria be considered for the Buzzards Bay RNA, and shown in **Figure 7.** Maximum sustained

speeds of 56.2 knots were recorded with maximum gusts of 64.7 knots during the height of the storm on October 29, 2012.

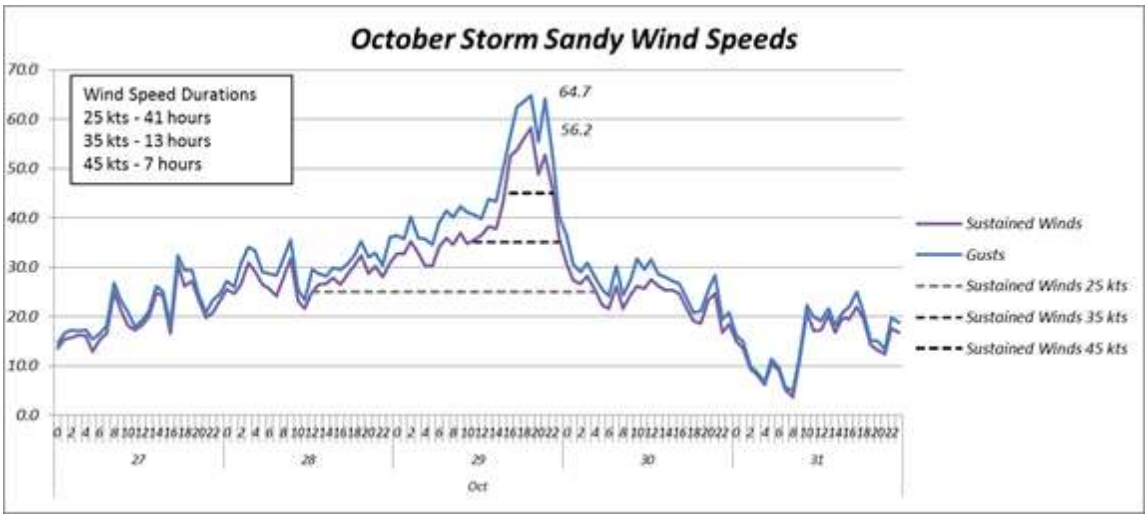


Figure 7: Hurricane/Storm Sandy Wind Speeds, Gusts, and Sustained Speeds

3.3 Visibility

During April and November areas of dense fog reduce visibility for periods of 24 to 48 hours due to the changing seasons. Summer months produce frequent haze, reducing visibility below 5 miles. Dense fog or haze generally lasts less than 12 hours. The Army Corps of Engineers, operators of the Cape Cod Canal, requires a minimum of 0.5 miles of visibility for marine traffic movements.

Limited data regarding visibility in Buzzards Bay were available for this report. Neither the Buzzards Bay (station BUZM3) nor Woods Hole (station BZBM3) NOAA data buoys record visibility data. The most comprehensive set of data regarding visibility in the area is Meteorological Terminal Air Report (METAR) data recorded at the New Bedford Regional Airport, approximately 12 miles NNW from the center of Buzzards Bay. The data were acquired from the National Climatic Data Center.[17] METAR data typically contain information for temperature, dew point, wind speed, wind direction, precipitation, cloud cover, visibility, and barometric pressure. METARs are observations, not forecasts, and are recorded approximately once every hour at or slightly above ground level. METARs are generally used by the aviation community for flight planning purposes; however, in the case of this study they provide the most comprehensive source of readily-available data regarding visibility near Buzzards Bay.

Table 5 and **Figure 8** show the number of days for each year of the acquired data (October 2006–October 2012) in which a METAR observation recorded the visibility at or below 1 mile and 0.5 miles for any period of time, and the average number of days per year in which the visibility was at or below 1.0 mile and 0.5 miles for any period of time. The data show that the average number of days per year in which the visibility was below 1.0 mile is 76. On average, there are 49 days per year in which the visibility is below 0.5 miles.

[17] NOAA, National Climatic Data Center, http://www.ncdc.noaa.gov/, October 30, 2012.

Table 5: Number of Days with Low Visibility

Reporting Year	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	Average
<= 0.5 Miles	46	50	46	33	54	67	49
<=1.0 Miles	76	71	75	50	83	100	76

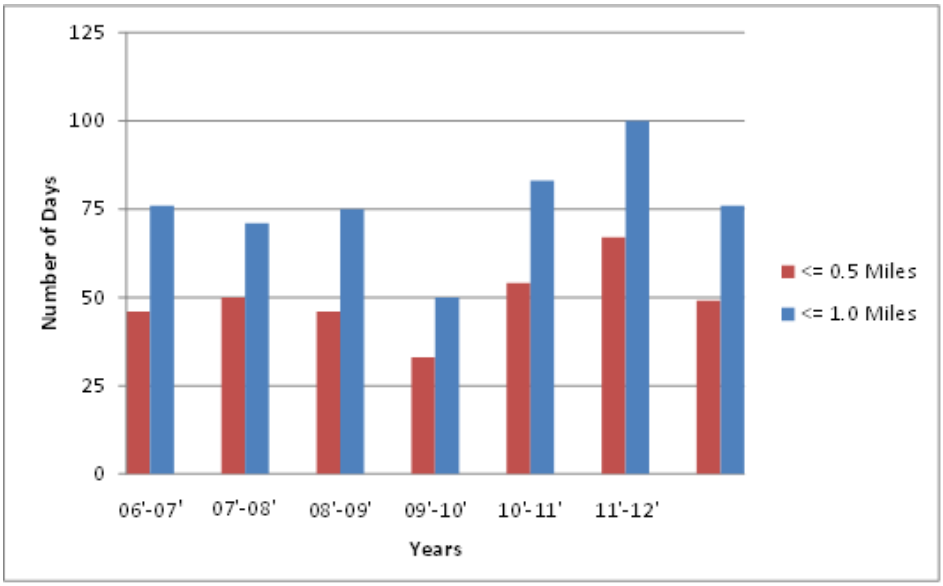


Figure 8: Number of Days with Low Visibility

Adverse Weather Summary: The number of days with low visibility is of importance because in the escort tug activity logs provided by MassDEP, about 50 percent of the escort requests were associated with low visibility or other inclement weather conditions (developed further in Section 5). The data show that, on average, 20 percent of the days in a year can expect visibility conditions under 1 mile. These periods of low visibility typically do not last an entire day, but last rather a few hours. For planning purposes a notional value of 10 percent will be designated as days with sustained low visibility to account for trip-scheduling opportunities to avoid low-visibility periods.

Low-visibility conditions (fog) and high winds do not occur at the same time, therefore the number of days with each of these conditions can be added together to determine a total frequency of hazardous weather conditions. With a notional value of sustained low-visibility conditions occurring 6 percent of the year (49 days/365 x 50 percent to account for less than a full day) and winds greater than 25 knots occurring 9.5 percent of the days in a year, we can expect that there are hazardous weather conditions 15.5 percent, rounded to 16 percent, of the days in a year.

4 Buzzards Bay Current Operations and Oil Spill History

This section describes the current operations regarding oil transported through Buzzards Bay. **Figure 9** summarizes the tug, pilot, and communication requirements in recent years for the area. Oil spills and vessel incidents (groundings and collisions) are displayed in the timeline to show how the legislation has evolved (especially state regulations) as local incidents have occurred. Full descriptions of federal and state tug and pilotage requirements are provided in Appendix A.

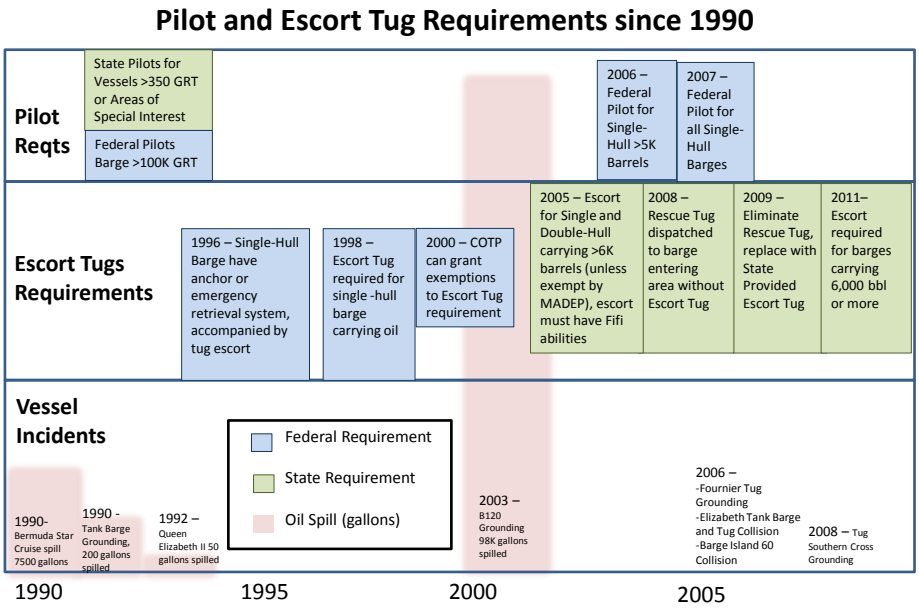


Figure 9: Requirements Timeline

4.1 Current Buzzards Bay Operations

Buzzards Bay is an RNA with federal regulations issued by the USCG establishing recommended routes to be taken through Buzzards Bay, requiring participation in a VMRS, and requiring single-hull tank barges carrying 5,000 barrels or more of oil or other hazardous materials to be accompanied by an escort tug and to be under the direction of a federally-licensed first class pilot who is not a member of the crew.

Similarly, the Commonwealth of Massachusetts has established regulations for Buzzards Bay requiring single-hull and double-hull tank vessels carrying more than 6,000 barrels of oil to be accompanied by a tug escort in addition to the towing vessel, to provide a voluntary notification to the state prior to entering Buzzards Bay, and in the case of single-hulled tank barges to have at least two crew members on the tank barge, if the barge is capable of housing crew, and the towing vessel for single-hulled tank barges must have a licensed deck officer serving solely as a lookout.

Tugboats towing tank barges traveling through Buzzards Bay will typically arrive with a long tow wire and shorten the tow, maneuver the tug into the “notch” at the stern of the barge, or

bring the barge alongside for transit through Buzzards Bay and the Cape Cod Canal. In most instances, the tug will separate from the barge to maneuver into position, leaving the barge untethered for a short period of time. In high winds or low visibility, this operation could increase the risk of a drifted grounding. This situation may have been ameliorated in some instances by the use of an assist tug.[18]

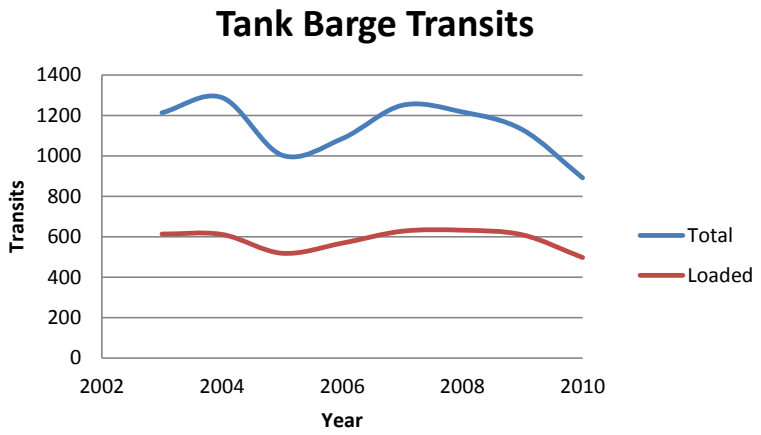
The federal or state pilot will board the towing vessel and conduct a radio conference with the escort tug regarding communications and other pertinent information concerning the transit. The escort tug will typically proceed about ¼-mile astern of the tow. Under some circumstances, such as high winds, the escort tug will tie up alongside the tow to provide additional maneuverability to the tow.

4.1.1 Buzzards Bay Traffic

Tugs and barges make up the majority of traffic in Buzzards Bay as they move between New York and Philadelphia to northern New England ports. More than 20,000 commercial cargo, tanker, tug, passenger, and commercial fishing vessels pass through the Bay each year, along with thousands of smaller recreational boats. Freight traffic travels across the Bay from New Bedford toward Martha's Vineyard and Nantucket.[19]

Passenger vessels traveling between New Bedford and Martha's Vineyard regularly run, carrying passengers and cars. There are also high-speed ferry operations between these two harbors. The frequent commodity transiting Buzzards Bay is petroleum. Manufactured goods and other crude materials (with the exception of petroleum) consist of about 10 percent each of total freight through the Bay. Other materials include chemicals, coal, food, and farm products. The New Bedford fishing fleet consists of about 300 fishing vessels.

Information provided from the Cape Cod Canal indicates approximately 50 percent of barge transits were loaded, as shown in **Figure 10**.



[18] Letter from the Commissioner of MassDEP to the Chairs of the Joint Committee on Natural Resources, Environment, and Agriculture, "*Massachusetts Oil Spill Prevention Act, MGL Chapter 21 M Section 9 Report on Exigent Circumstances Waiver Requests and Vessels Requesting Escort Tugboat Assistance in 2011*," June 20, 2012.

[19] U.S. Department of Homeland Security, U.S. Coast Guard. *Ports and Waterways Safety Assessment: Workshop Report – Buzzards Bay, Massachusetts*, September 9, 2003.

Figure 10: Cape Cod Canal Data – Canal Transits

To validate these data, vessel transit data were extracted from the USACE Waterway Commerce of the United States data, and also compared to the previous Buzzards Bay PAWSA Report, Draft EA, Sector Southeastern New England (SENE)-provided information, and data from the Cape Cod Canal. Some differences may be expected from the Cape Cod Canal data as the Waterborne Commerce of the United States (WCUS) includes all vessel transits in the Cape Cod Canal Waterway, which is described as the following:

> **Cape Cod Canal Waterway**: Extending from the outer end of the northerly breakwater in Cape Cod Bay to a point in Buzzards Bay near Cleveland Ledge about 5 miles southwest of Wings Neck Light. Controlling Depth: 32 feet in the Land Cut; 30.8 feet in Hog Island Channel; 32 feet in Cleveland Ledge Channel; 24.1 feet in East Mooring Basin; and 29.4 feet in West Mooring Basin. Project Channel Depth: 32 feet at mean low water. Entire length: 17.4 miles.[20]

WCUS data included vessel transits, direction, and vessel type, and are shown in **Figure 11.**

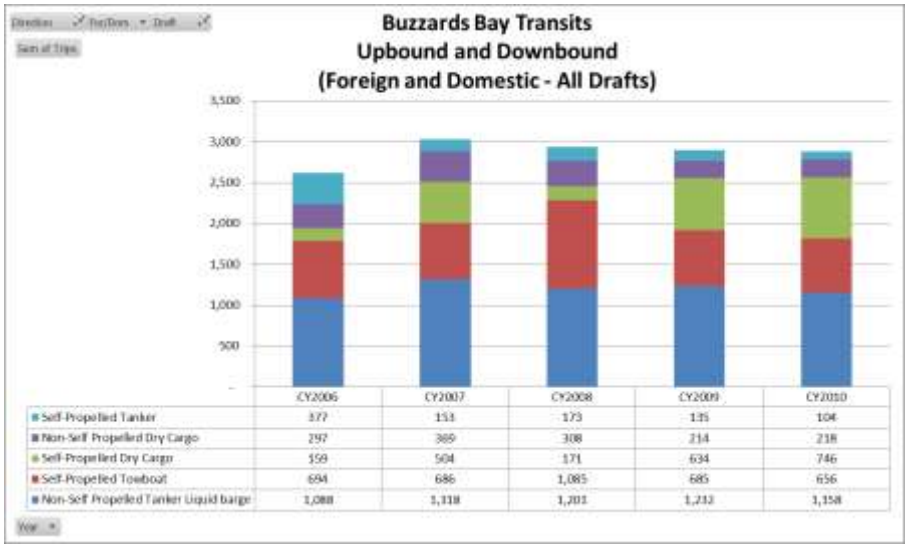


Figure 11: Buzzards Bay Transit Totals

From July 2011 to July 2012, 45,000,000 bbl of oil passed through Buzzards Bay. **Figure 12** shows the number of tank barges passing through the Bay by barge capacity.

[20] http://www.ndc.iwr.usace.army.mil//wcsc/webpub10/Part1_WWYs_Trips_VessType_Dir_YR_Draft_CY2010_CY2006.HTM.

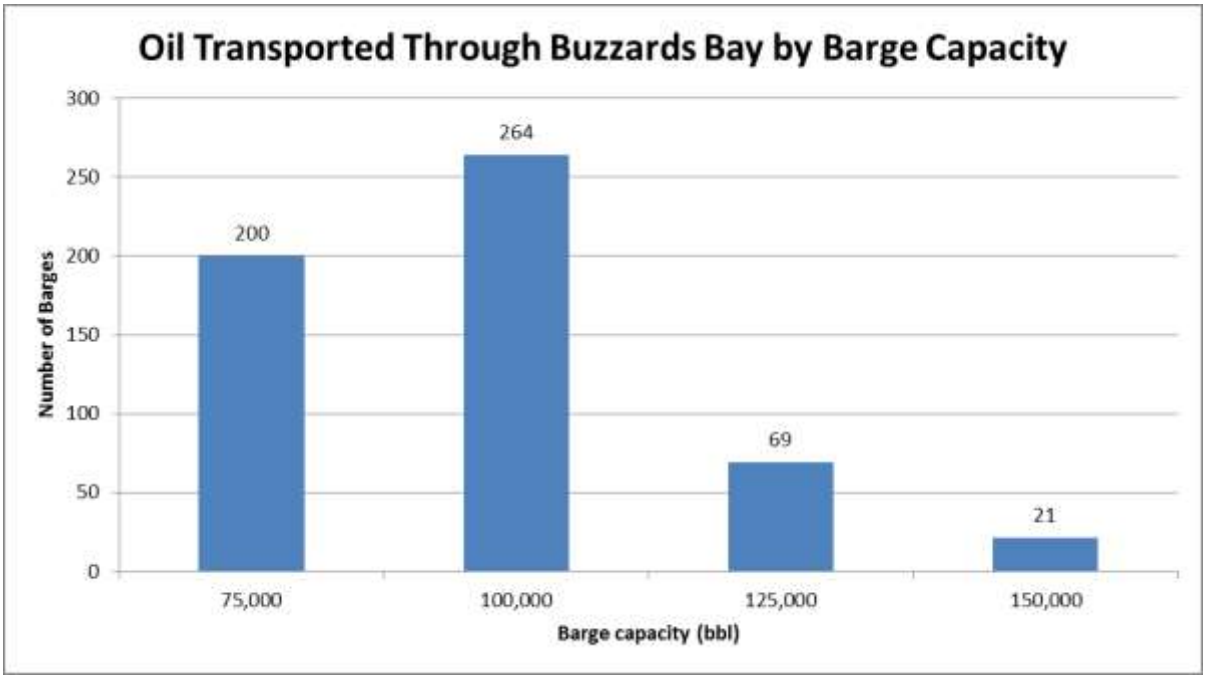


Figure 12: Oil Transported Through Buzzards Bay by Barge Size[21]

The vast majority of barges operating in Buzzards Bay today have double hulls (as seen in **Figure 13**) and by 2015 all tank barges operating in U.S. waters are required to be double-hulled.[22]

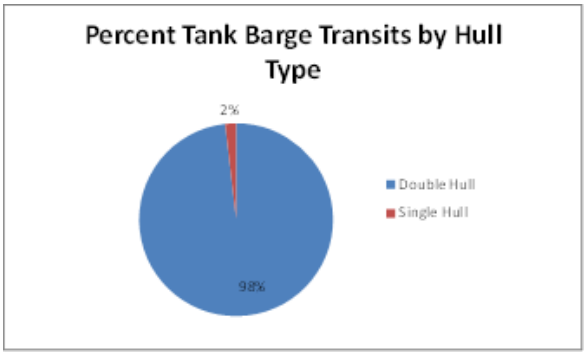


Figure 13: Percentage of Tank Barge Transits by Hull Type[23]

Similarly, discussions with the two major tugboat operators in the area, McAllister and Boston Towing and Transportation, indicated that virtually all tugs operating in the area have twin propulsion and twin screws.[24]

Articulated tug barges (ATB), in which the tank barge is propelled by a tug positioned in a notch in the stern of the barge, are also in use in Buzzards Bay. This configuration of tug and barge,

[21] MassDEP, Tugboat Escort Reporting Forms 2011–2012.

[22] OPA 90.

[23] MassDEP, Tugboat Escort Reporting Forms July 2011–September 2012.

[24] Personal communication between M. Power, Boston Towing and Transportation, and G. Oliviera, McAllister Towing, October 22, 2012.

with a hinged connection, provides better maneuverability than a barge on a tow wire and eliminates the need to disconnect the tow wire to bring the barge alongside in confined areas.

Double-hull barges that operated in Buzzards Bay from 2007 to 2011 ranged in length from about 245 feet to about 580 feet. The double-hull barges in Buzzards Bay have 10 to 16 tanks with total capacity ranging from 19,000 barrels to about 400,000 barrels, with an average capacity of 98,910 barrels.

Single-hull barges that operated in Buzzards Bay from 2007 to 2011 ranged in length from 230 feet to 460 feet with similar drafts and an average capacity of about 70,000 barrels. The drafts of barges operating in Buzzards Bay are controlled by the depth of Cape Cod Canal. The published depth is 32 feet at mean low water but shoaling in the Canal can sometimes reduce depth to 30 feet at mean low water. Vessels are notified to contact Buzzards Bay Control if they are lower than a prescribed draft.[25]

4.1.2 Vessel Information and Monitoring Systems

Vessel information systems include the Automated Information System (AIS) which is an International Maritime Organization (IMO) standard for certain vessels, and a Vessel Movement Reporting System (VMRS), which is a manual, call-in system operated at the Cape Cod Canal.

Automatic Identification Systems

AIS provides information about the ship to other ships and to coastal authorities automatically.

- AIS provides information about the ship's identity, type, position, course, speed, navigational status, and other safety-related information. This information is automatically sent to appropriately-equipped shore stations, other ships, and aircraft.
- AIS provides the capability for ships to receive this information from similarly-fitted ships.

Data provided by the AIS were used to determine the frequency with which vessels are in close proximity to one or more other vessels. **Figure 14** shows vessel positions in Buzzards Bay and the Cape Cod Canal. The darker orange the area is, the more vessels are reporting from that location. This map includes recreational vessels, but only those reporting through AIS. In **Figure 14** the recommended route is clearly shown in orange moving from west to east through the Canal. New Bedford and Woods Hole are also clearly marked by dark orange spots. Traffic between Martha's Vineyard and Woods Hole appears very dark, most likely due to ferry traffic. A distinct path across Buzzards Bay from New Bedford to Woods Hole is clear; this path crosses the recommended route through the Bay. Congestion is also evident approaching the Cape Cod Canal from the west. These crossing areas represent a potential high-risk area, which is mitigated by the additional pilot on board to monitor traffic and other vessel activities.

[25] U.S. Coast Guard Navigation Center, Local Notice to Mariners, http://www.navcen.uscg.gov/?pageName=lnmDistrict&region=1, various dates.

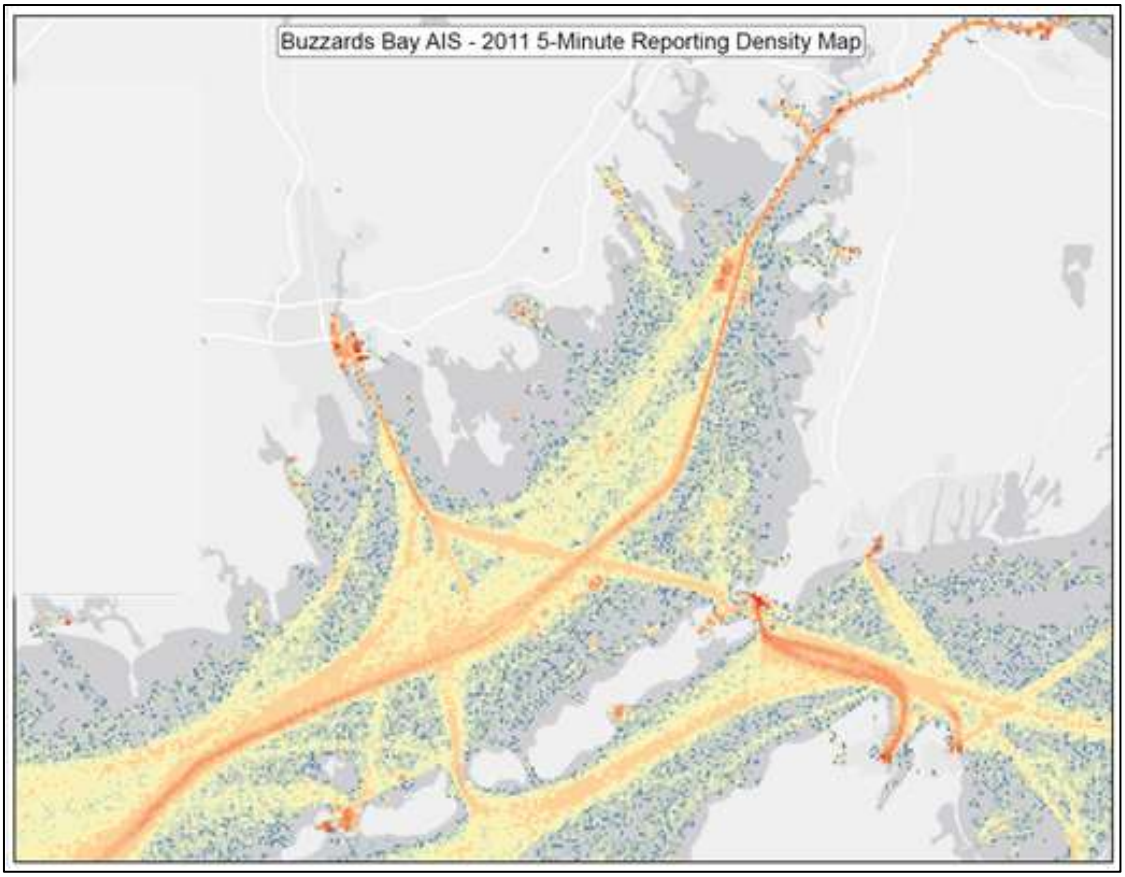


Figure 14: Buzzards Bay AIS Density Map

Vessel Movement Reporting System

In November 2007, the USCG and the U.S. Army Corps of Engineers implemented a VMRS in Buzzards Bay for vessels transiting Buzzards Bay and Cape Cod Canal as part of the regulatory scheme for enhancing vessel safety and environmental protection.

The VMRS is made up of two areas, shown in **Figure 15.** The Buzzards Bay Control area extends from the western entrance of Buzzards Bay to the vicinity of Cleveland Ledge (shown in blue), and the Cape Cod Canal Control area includes waters from Cleveland Ledge to Cape Cod Bay (shown in red). Vessels transiting these areas are required to notify the Army Corps of Engineers Control Center as they enter and exit the area and provide specific information about their transits and their vessels. The USCG enforces reporting requirements for vessels operating in the Buzzards Bay Control area, while the Army Corps of Engineers enforces reporting requirements for vessels operating in the Cape Cod Canal Control area.

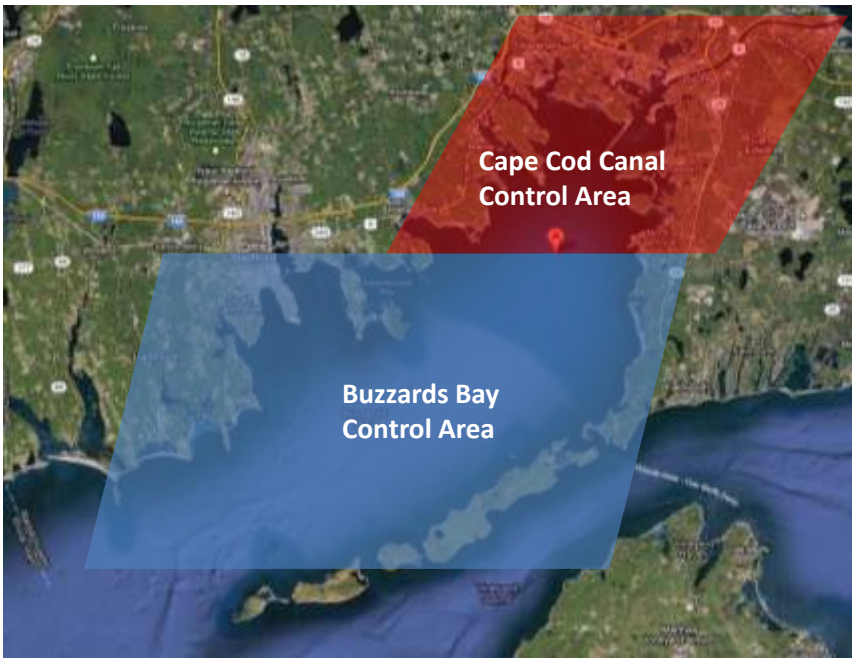


Figure 15: VMRS Areas in Buzzards Bay

The Cape Cod Canal Control Center, working in conjunction with the Coast Guard Sector Southeastern New England Command Center, coordinates and provides marine traffic reports, waterway status, other information, and recommendations that could affect safe navigation within the VMRS areas.

To avoid congested radio frequencies associated with the VMRS, vessels participating in the VMRS are divided into two categories: "Active" participants and "Passive" participants. Active users, which are generally larger vessels, vessels engaged in towing operations, or vessels with 50 or more passengers, are required to actively communicate with controllers during the vessel transit. Passive participants are required to monitor assigned radio frequencies and, when called, respond promptly to control personnel. Even though towing vessels are described as active participants, the VMRS is a passive system compared to some other traffic management systems, or Vessel Traffic Systems, used around the United States.[26]

In contrast to a VMRS, the purpose of a VTS is to provide active monitoring and navigational advice for vessels in particularly confined and busy waterways. Among other things, a VTS has the authority to issue directions to control and supervise vessel movement within its area of responsibility.

4.2 Vessel Compliance and Assist Programs

Vessel compliance programs include the USCG/AWO Responsible Carrier Program and the Towing Vessel Inspection Program. Vessel Assist Programs include the Escort Tug Program, which may include direct escorts of tank barges (escort tugs), or immediate response tugs (sentinel tugs) which would be available to respond to a developing incident, and the

[26] U.S. Coast Guard, Navigation Center, http://www.navcen.uscg.gov/?pageName=vtsMain, November 2012.

requirement to carry a pilot in addition to the vessel crew. These programs are described in the following sections.

4.2.1 Responsible Carrier Program

In 1997, the AWO, a trade association representing about 80 percent of the tugboats, towboats, and barges operating in U.S. waterborne trade,[27] established the RCP that seeks to improve safety and environmental protection in the towing industry by incorporating identified best industry practices in three primary areas: company management policies, vessel equipment, and human factors. In 1998, AWO member companies voted to require participation in the RCP as a condition of membership in AWO. The RCP addresses the need for each participating member to establish safety and environmental protection programs, including vessel operating and inspection policies; vessel and equipment maintenance, including towing gear and machinery; and human factors, including watch-standing hours and training. The RCP also requires companies to obtain a third-party audit by an AWO-certified auditor to verify compliance every 3 years. The AWO provides a summary of tank barge company membership in the RCP in **Figure 16.**

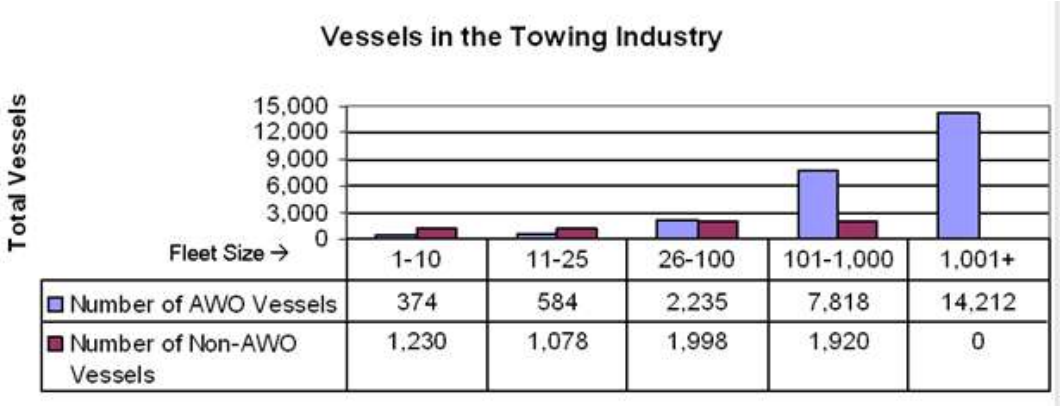


Figure 16: AWO: Vessels in the Towing Industry and RCP Compliance

In a Report to Congress in 2012, the USCG noted that a "downward shift in spill volume occurred about 1997, which corresponds to the implementation of voluntary industry standards, known as the Responsible Carrier Program, applicable to member companies of the American Waterways Operators Association (AWO). Though a voluntary program, most of the U.S. tank barge population belongs to member companies of AWO."[28]

4.2.2 Towing Vessel Inspection Program

Requirements regarding safety and firefighting equipment, towing gear, manning, and licensing for towing vessels have been in place for many years; however, prior to 2004, towing vessels were uninspected. Section 415 of the Coast Guard and Maritime Transportation Act of 2004,

[27] American Waterways Operators, "*Fleet Data by Number of Vessels and AWO Membership*," http://www.americanwaterways.com/industry_stats/fleet_data/index.html, November 2012.

[28] U.S. Coast Guard, "*Improvements to Reduce Human Error and Near-Miss Incidents, 2012 Report to Congress*," Washington, DC, May 7, 2012.

Pub. L. 108-293, authorized the USCG to establish regulations for a safety management system appropriate for the characteristics, methods of operation, and nature of service of towing vessels.

In 2011, the USCG published a Proposed Rule to establish requirements for inspection of these vessels.[29] As part of the implementation of the inspection program for towing vessels, the USCG established a Towing Vessel Bridging Program (TVBP) to ensure that both the Coast Guard and the towing vessel industry were prepared to meet the new requirements. Phase 1 of the TVBP began in June 2009 and was intended to prepare the towing industry for the impending inspection regulations through Industry-Initiated Examinations (IIE) to verify compliance with existing regulations. The USCG estimates that of the approximately 5,800 towing vessels, the Coast Guard conducted 4,200 examinations.[30] Phase 2 of the TVBP commenced on July 1, 2012, and is a risk-based examination program that will emphasize vessels not subject to the IIEs conducted during Phase 1.

When the Proposed Rule is finalized, it is intended by the USCG to require either annual inspections by the Coast Guard to verify compliance with minimum standards for safety or document compliance with an approved Towing Safety Management System (TSMS) that includes the requirements contained in the final rule.[31] It may be anticipated that an approved program under AWO's RCP will be acceptable to the Coast Guard as an approved TSMS.

4.2.3 Escort Tug Program

Under the current Buzzards Bay escort tug program, escort tugs are dispatched from New Bedford, Massachusetts, in the case of McAllister Towing, or from Boston, Massachusetts, in the case of Boston Towing and Transportation. Escort tugs may also remain in the area following an escort and would likely find a berth at the Massachusetts Maritime Academy or other convenient location on the western end of the Cape Cod Canal.

Prior to entry into the Buzzards Bay RNA, tugboats will have made arrangements to bring aboard a federal or state pilot (as applicable), secure a tug escort, in accordance with federal and state regulations, notify the VMRS, and provide an intent to transit notification to MassDEP through the Massachusetts Emergency Management Agency. If a MOSPRA-compliant escort tug is not available, the towing company may request the use of a non-compliant tug escort. Escort tug providers self-certify that they meet MOSPRA requirements. Non-compliant tugs generally lack the ABS-Class 1 FiFi1 capability. **Table 6** lists the escort tugs made available under the state program and whether or not they are state-compliant.[32] State-compliant is defined as meeting the requirements in Chapter 21M and 314 CMR 19.00.

[29] U.S. Coast Guard, "Inspection of Towing Vessels, Proposed Rule," Federal Register, Vol. 76, No. 155, August 11, 2011.

[30] https://www.workboat.com/blogpost.aspx?id=13517.

[31] U.S. Coast Guard, "Inspection of Towing Vessels, Proposed Rule," Federal Register, Vol. 76, No. 155, August 11, 2011.

[32] MassDEP.

Table 6: Self-Certified Escort Tugboat Vessels

Date	Tug Name	Owner/Operator	Bollard Pull	Horsepower	Twin Screw/ Tractor	Fire Fighting	Line Handling	VHF Radio	Towin g Winch	Braking Force	Fully Compliant
Compliant Tugs											
7/19/2011	Justice	Boston Towing	> 50,000	5,400	Tractor	ABS Class 1	Yes	Yes	Yes	Yes	Yes
7/20/2011	Independence	Boston Towing	> 73,000	5,400	Tractor	ABS Class 1	Yes	Yes	Yes	Yes	Yes
7/21/2011	A.J. McAllister	McAllister Towing	> 83,000	6,000	Tractor	ABS Class 1	Yes	Yes	Yes	Yes	Yes
11/2/2011	Sabine	McAllister Towing	> 50,000	5,000	Z drive Tractor	ABS Class 1	Yes	Yes	Yes	Yes	Yes
Non-Compliant Tugs											
7/14/2011	Andrew McAllister	McAllister Towing	> 50,000	6000	Tractor	ABS Class 1	No	Yes	Yes	Yes	No
7/20/2011	Fournier Boys	Canal Towing & Assist	> 50,000	5,000	Twin Screw	No	Yes	Yes	Yes	Yes	No
7/20/2011	Freedom	Boston Towing	> 50,000	4,400	Tractor	No	Yes	Yes	Yes	Yes	No
7/21/2011	McAllister Sisters	McAllister Towing	> 50,000	4,000	Tractor	No	Yes	Yes	Yes	Yes	No
8/2/2011	Liberty	Boston Towing	> 50,000	4,400	Tractor	No	Yes	Yes	Yes	Yes	No
10/6/2011	Reliance	McAllister Towing	< 50,000	3,000	Twin Screw	No	Yes	Yes	Yes	Yes	No
11/11/2011	Iona McAllister	McAllister Towing	> 50,000	4,000	Twin Screw	No	Yes	Yes	Yes	Yes	No
12/31/2011	Nancy McAllister	McAllister Towing	> 50,000	4,000	Twin Screw	4.2.3.1.1	4.2.3.1.2	4.2.3.1.3	4.2.3.1.4	4.2.3.1.5	No
12/31/2011	Rainbow	McAllister Towing	> 60,000	5,000	Z drive Tractor	No	Yes	Yes	Yes	Yes	No

4.2.3.2 Tug Escort Requirements in Other States

California Ports

The State of California enacted the Oil Spill Prevention and Response Act of 1990 that established Harbor Safety Committees for five ports and required these ports to develop tug escort standards. Exemption from tug escort requirements applies only to tankers, defined as any self-propelled, waterborne vessel, constructed or adapted to transport oil in bulk or in commercial quantities as cargo. California regulations provide for exemptions from the escort tug requirements for double-hull tankers in the identified ports with redundant systems. Additionally, the Administrator may require exempt tankers to periodically demonstrate the tanker and crew's ability to maneuver in response to a partial or total loss of propulsion and/or steering at a level of safety at least equal to that of an escorted tanker. The specific exemption does not apply to tank barges and such an exemption is not being considered, according to the San Francisco Marine Exchange.

The following is a summary of escort requirements in California ports where escort tugs have been required.

- San Francisco – Tug escorts are required for all tank vessels carrying more than 5,000 tons of oil, except for double-hull tankers that have fully-redundant steering and propulsion systems, independent propellers and rudders, a bow thruster, and other navigational equipment.
- Port Hueneme – Tug escorts are required for all tank barges entering, departing, or shifting greater than 150 feet in length to be escorted by a tug of varying horsepower depending on the length, in addition to the towing vessel.
- Humboldt Bay – A tug escort is required for all tank barges transiting the waters of Humboldt Bay, carrying as cargo a total volume of oil greater than or equal to 5,000 long tons or 5 percent of the vessel's deadweight tonnage.
- San Diego – Tug escorts are required for all tank vessels carrying more than 5,000 tons of oil, except for double-hull tankers that have fully-redundant steering and propulsion systems, independent propellers and rudders, a bow thruster, and other navigational equipment.
- Los Angeles/Long Beach – Tug escorts are required for all tank vessels carrying more than 5,000 tons of oil, except for double-hull tankers that also have fully-redundant steering and propulsion systems, independent propellers and rudders, a bow thruster, and other navigational equipment.

Alaska Ports

- Prince William Sound, Alaska – The escort tug requirements for Prince William Sound were established by OPA 90. Section 4116 of that Act required two escort towing vessels to accompany each single-hull tank vessel over 5,000 Gross Registered Tons (GRT) transporting oil in bulk. In 2010, an amendment to OPA 90 included in the Coast Guard Authorization Act extended this requirement to double-hull tank vessels over 5,000 GRT.

Washington Ports

- Puget Sound – OPA 90 required a similar regulation for vessels transiting the Rosario Straits and Puget Sound, however the 2010 Coast Guard Authorization Act did not extend the requirement for tug escorts to double-hull vessels operating on Puget Sound.

Table 7: Summary of Tug Escort Requirements in Other States

Location	Applicability	Authority	Double-Hull Exception	Escort/ Sentinel/ Response	Tug Specifications	Additional Pilot Requirement
Humboldt Bay, CA	Tank vessels carrying more than 5,000 tons or 5% of DWT	State law implemented by local regulation	No	Escort	Bollard pull equal to or greater than DWT of tank vessel	No
Los Angeles/Long Beach, CA	Tank vessels carrying more than 5,000 tons	State law implemented by local regulation	Double-hull tank ships with redundant systems	Escort	"Tug Matching Criteria" established in regulations	No
Port Hueneme, CA	Tank barges longer than 150 feet and all tank ships	State law implemented by local regulation	No	Escort	500 horsepower (HP) minimum, barges greater than 250 feet require escort of 1,500 HP	No
Prince William Sound, AK (Valdez Narrows)	All tankers > 5,000 GRT	OPA 90, as amended	No	2 escorts	Towing and turning specifications	Federal pilot
Puget Sound, WA	Single-hull tankers > 5,000 GRT (OPA 90), all laden tankers > 40,000 DWT	OPA 90 and state law	Yes	2 escorts	Tug HP > 5% of ship's DWT	Tankers > 5,000 gross tons must have state pilot
San Diego, CA	Single-hull tank ships and all tank barges designed to carry > 5,000 long tons of oil and carrying more than 5% DWT of cargo	State law implemented by local regulation	Double-hull tank ships with redundant systems	Escort	Bollard pull and assist lines	No
San Francisco, CA	Tank vessels carrying > 5,000 long tons of oil	State law implemented by local regulation	Double-hull tank ships with redundant systems	Escort	"Tug Matching Criteria" established in regulations	No

4.2.4 Pilotage Requirements

Pilots for vessels required to carry them are typically dispatched from Fairhaven, Massachusetts, in the Port of New Bedford or from Newport, Rhode Island, as shown in red on the map in **Figure 17**. Massachusetts requires that every foreign vessel and every U.S. flag vessel sailing "on register," that is engaged in international trade, of 350 GRT or greater that is entering, departing, in transit, or shifting berths in the waters of the Commonwealth must employ a state-licensed pilot, and other U.S. flag vessels carrying oil, hazardous material, or hazardous waste in bulk as cargo in or operating on "Areas of Special Interest" must employ a pilot as well. Even though MOSPRA contains language requiring a state-qualified pilot be placed on board towing vessels when towing barges carrying more than 5,000 barrels of oil, whether double-hulled or not, MassDEP has not enforced that requirement since July 2011.[33]

Figure 17: Pilot Dispatch Locations for Buzzards Bay

4.3 Ice Operations

Buzzards Bay is infrequently impacted by ice; however, at the head of the Bay and on the eastern shore drift ice can create difficulties when approaching harbors. In severe winters the drift ice can extend across the Bay and form a barrier. Winds from the northwest cause ice to form more rapidly. When ice extends out toward the channel, the outer edges are broken off and carried south creating drift ice. According to the Buzzards Bay Ports and Waterway Safety Assessment, ice in the Cape Cod Canal and Buzzards Bay impacts the marine traffic once every 10 years. When buoys are carried out of position to the western entrance of the canal, traffic is suspended. This condition could last as long as 7 to 10 days.[34]

Operations in severe ice conditions increase the risk of spills because vessels may be limited in their maneuverability due to the ice, visual aids to navigation may not be available or reliable due to effects of ice and movement of ice floes, and potential damage to the operating and emergency equipment may occur due to extreme temperatures. Sector Southeastern New England has established an Ice Operations Plan[35] to establish policy, guidance, and procedures for icebreaking activities in the area. The Sector uses its Captain of the Port (COTP) authority

[33] R. Packard, personal communication, November 2012.

[34] U.S. Department of Homeland Security, U.S. Coast Guard, *Ports and Waterways Safety Assessment: Workshop Report – Buzzards Bay, Massachusetts*, September 9, 2003.

[35] Sector SENE INST 3020.1A, February 28, 2008.

and available assets to promote the safe transit of vessels, and to facilitate the continuation of waterborne commerce. The Sector coordinates ice operations with the U.S. Army Corps of Engineers (USACE), which controls traffic within the Cape Cod Canal. The Ice Operations Plan prioritizes mission response during ice operations to allocate resources most effectively. During ice conditions, the Sector may impose any or all of the following Navigation Restriction Options, as well as other actions.

- Daylight-only navigation
- Minimum visibility parameters (e.g., 1 to 2 miles)
- One-way traffic on selected waterway segments
- Operational differential global positioning system (DGPS) and radar during transits
- Steel hull restrictions
- Shaft HP restrictions
- Towing restrictions – requiring vessels to push ahead or alongside
- Cargo restrictions – may be imposed when ice conditions and/or Coast Guard icebreaking operations are such that only a limited number of vessels can be accommodated
- Scheduled convoys
- Broadcast ice conditions and safety zones

Ice Operations Assessment

Safe tank barge operations in ice conditions appear to be managed by the Sector. Operations in ice are difficult, and the availability of an additional pilot or escort tug would support safe transits.

4.4 National Oil Spill History

In 2012 the USCG prepared a report to Congress on the "Improvements to Reduce Human Error and Near-Miss Incidents"[36] that contained a detailed breakdown of vessel casualty causes and resultant oil spills. In the 10 years covered by the report (2001 through 2010), oil barges accounted for the majority of spills by volume, although tank ship spills result in a higher average volume per incident, as shown in **Table 8**. The data are sorted by the number of incidents in the left columns, and the total gallons spilled in the right columns. **Figure 18** and **Figure 19** present the data in a graphical format.

[36] U.S. Coast Guard, *"Improvements to Reduce Human Error and Near-Miss Incidents,"* 2012 Report to Congress, May 7, 2012.

Table 8: Oil Spills from Vessels 2001–2010

Sorted By Count of Spills		
Vessel Type	**Spills**	**Gallons**
Recreational	5,058	71,227
Fishing Vessel	3,619	367,322
Tow/Tugboat	2,965	292,143
Unclassified Vessel	2,479	63,461
Tank Barge	1,318	3,151,868
Passenger	1,100	36,360
Freight Ship	893	725,930
Offshore Support Vessel (OSV)/Oil Recovery	883	98,027
Industrial Vessel	604	28,342
Public Vessels	486	129,225
Tank Ship	426	1,262,927
Freight Barge	407	17,412
Modu	259	413,368
Research Vessel	162	4,500
Other	51	483
Totals	**20,710**	**6,662,594**

Sorted By Volume of Spills		
Vessel Type	**Spills**	**Gallons**
Tank Barge	1,318	3,151,868
Tank Ship	426	1,262,927
Freight Ship	893	725,930
Modu	259	413,368
Fishing Vessel	3,619	367,322
Tow/Tugboat	2,965	292,143
Public Vessels	486	129,225
OSV/Oil Recovery	883	98,027
Recreational	5,058	71,227
Unclassified Vessel	2,479	63,461
Passenger	1,100	36,360
Industrial Vessel	604	28,342
Freight Barge	407	17,412
Research Vessel	162	4,500
Other	51	483
Totals	**20,710**	**6,662,594**

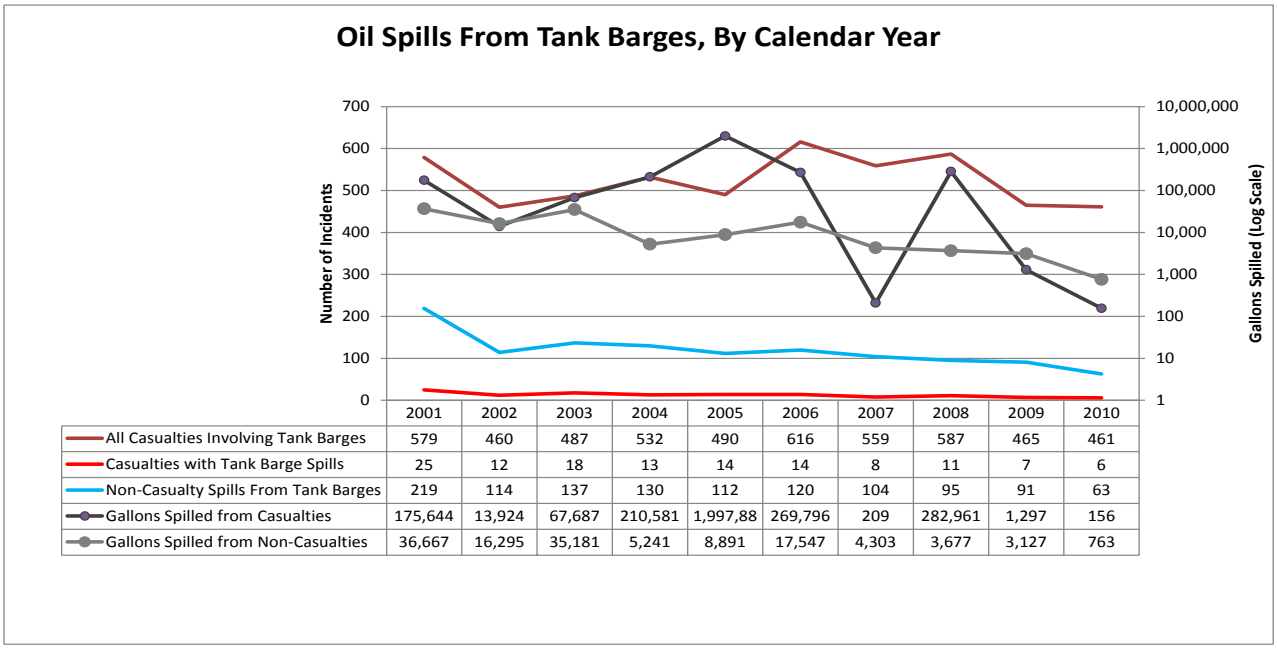
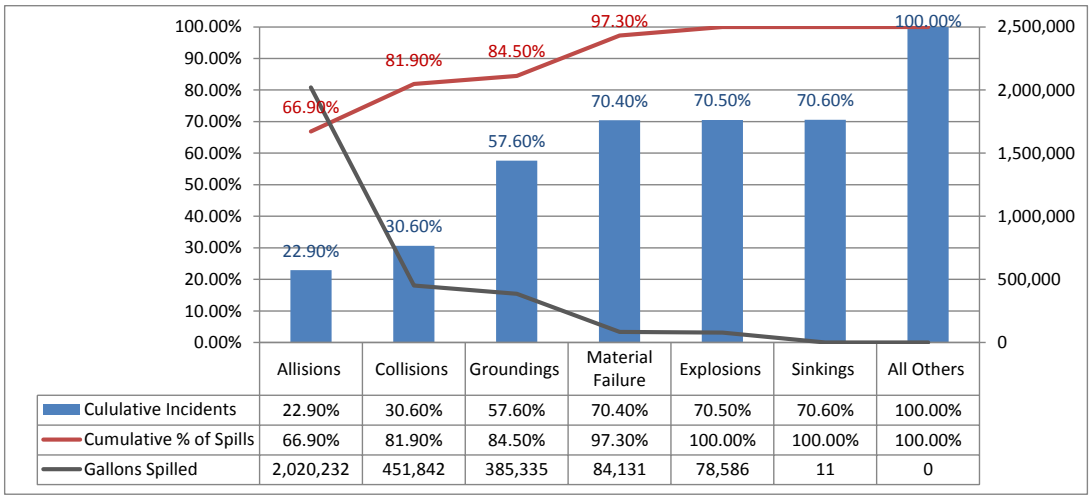


Figure 18: Oil Spills from Tank Barges by Calendar Year



	Allisions	Collisions	Groundings	Material Failure	Explosions	Sinkings	All Others
Cululative Incidents	22.90%	30.60%	57.60%	70.40%	70.50%	70.60%	100.00%
Cumulative % of Spills	66.90%	81.90%	84.50%	97.30%	100.00%	100.00%	100.00%
Gallons Spilled	2,020,232	451,842	385,335	84,131	78,586	11	0

Figure 19: Cumulative Barge Incidents, Percent of Oil Spilled, and Gallons Spilled

The AWO has done extensive analyses on tug and barge safety. The AWO states, "For 2010, the Corps of Engineers reported that 236.8 million short tons or approximately 64.9 *billion* gallons of oil was transported by barge on U.S. waterways. That amount represents 75 percent of all oil carriage on domestic waterways. When compared to the amount transported, the spill rate for 2011 is approximately 1 gallon per 4.1 million gallons transported (projected)."[37]

The trend in oil spills shows a definite decline since 1996 and is attributed to the prevention programs developed under OPA 90, including public/private partnerships to increase maritime safety and environmental stewardships. Despite the program efforts, accidents happen, as shown by the impacts of the barge DBL-152 incident oil spill in **Figure 20.**

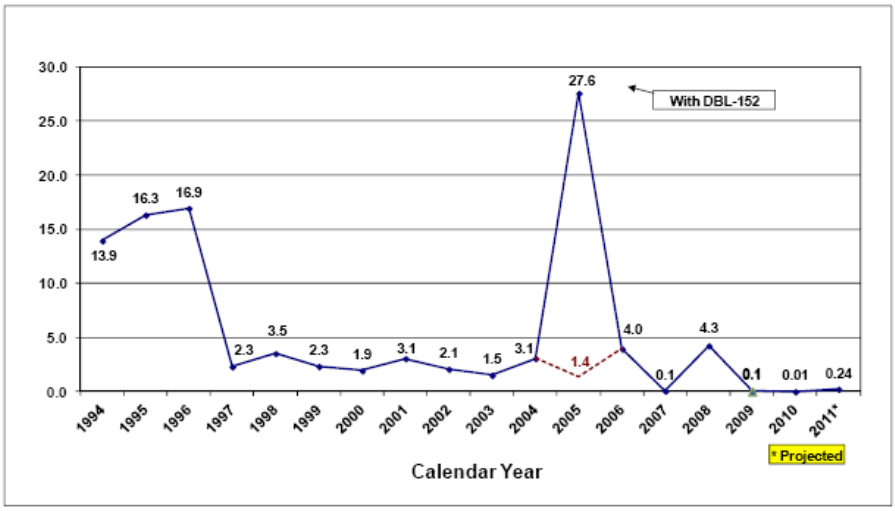


Figure 20: AWO – Gallons of Oil Spilled From Tank Barges, Per Million Transported

Also in **Figure 21,** the majority of medium- and high-severity incidents are from allisions, material failure, collisions, or groundings. First event in the AWO analysis refers to the primary

[37] http://www.americanwaterways.com/commitment_safety/Stats_Report_1Aug12.pdf.

causal factor that led to the incident based on the reported investigation. Although the national oil spill prevention programs are showing positive results in terms of reducing the volume and number of spills, catastrophic events, when they occur, involve significant costs for response and remediation, particularly in protected areas. The AWO study examined all reported incidents with tugs and barges, while the USCG fatigue report to Congress was limited to incidents that resulted in an oil spill. Although the incident counts are not traceable to validate the causal factors between the two studies, the frequency of the occurrence of vessel incidents shows that incidents do occur.

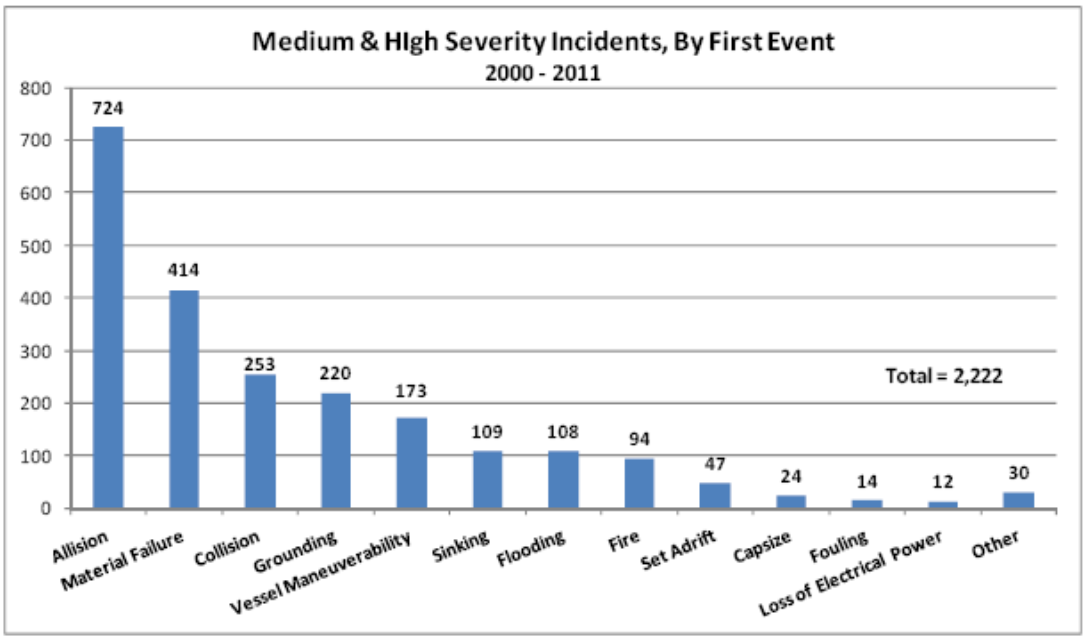


Figure 21: AWO Analysis – Medium-Severity and High-Severity Incidents, by First Event

4.4.1 Buzzards Bay Oil Spill History

Table 9 lists all major oil spills in Buzzards Bay since 1963 which was extracted from the Buzzards Bay National Estuary Program website.[38]

Table 9: Buzzards Bay Oil Spill History

Date	Location	Type	Volume (gallons)	Comments
1940s	Western Buzzards Bay, Westport (at Hen and Chickens)	No. 2 fuel oil	unknown	
1963	Near Nyes Neck, North Falmouth	No. 2 fuel oil	unknown	Came ashore during the winter.
September 16, 1969	Fassets Point, West Falmouth	No. 2 fuel oil	189,000	Florida Fuel Barge. Final estimate was 4,500 barrels spilled.
October 9, 1974	Cleveland Ledge (near canal	No. 2 fuel oil	11,000–37,000 (under review)	Bouchard 65 barge grounded. Was towed to an anchorage off Wings Neck.

[38] Buzzards Bay National Estuary Program, http://buzzardsbay.org/pastspills.htm, retrieved 30 October 30, 2012.

Date	Location	Type	Volume (gallons)	Comments
	entrance)			Oil came ashore in North Falmouth and Bourne.
January 28, 1977	Cleveland Ledge	No. 2 fuel oil	81,144	Bouchard 65 barge grounded, oil on iced-over bay, some burned. Final estimate was 1,932 barrels spilled.
June 10, 1990	Cleveland Ledge	No. 6 fuel oil	7,500	Bermuda Star cruise ship went aground, impacts to Naushon.
June 18, 1990	Cleveland Ledge	Diesel oil or heating oil	100 or 200	Bouchard 145 fuel barge.
August 7, 1992	Sow and Pigs Reef, Cuttyhunk	No. 6? fuel oil	50	Queen Elizabeth II cruise ship. Residual from empty fuel tank that was ruptured.
April 27, 2003	Hen and Chickens Reef, Westport	No. 6 fuel oil	98,000 (estimate)	Bouchard B-120 fuel barge.

Recent vessel casualties (2006–2011) extracted from USCG MISLE data for vessel incidents in Buzzards Bay include two collisions and three grounding events; however, these events did not result in an oil spill.[39] **Table 10** summarizes these incidents.

Table 10: Buzzards Bay and Cape Cod Canal Recent Incidents[40]

Date	Vessel Name	Vessel Type	Event Type	MISLE Case ID
January 6, 2006	Coastal Express	Towing Vessel	Grounding	272773
March 12, 2006	Norman Mcleod, Everlast	Barge, Towing Vessel	Collision	279306
March 24, 2006	Fournier Boys	Towing Vessel	Grounding	280769
May 20, 2006	Island 60, Vernon C, Canal Deluge	Towing Vessel/Barge, Towing Vessel	Collision	296836
June 5, 2006	Canal Deluge	Towing Vessel	Damage to Environment	292743
February 6, 2008	Columbia Baltimore, Turecamo Boys	Barge, Towing Vessel	Grounding	393340
November 9, 2008	Southern Cross	Towing Vessel	Grounding	3360443
May 4, 2009	Lincoln Sea, Jessica & Susan	Towing Vessel, Commercial Fishing Vessel	Collision	3467621
November 8, 2012*	Lori Anne	Fishing Vessel	Grounding	N/A
*Information on most recent incident provided by MassDEP and not included in MISLE data				

4.5 Double-Hull Barge Incidents in the United States

The following summaries were included to describe the only recorded incidents involving double-hull barges resulting in an oil spill.

[39] USCG MISLE data, Incidents for Buzzards Bay and Cape Cod Canal, obtained September 19, 2012.

[40] USCG MISLE data, Incidents for Buzzards Bay and Cape Cod Canal, obtained September 19, 2012.

Barge DBL 152 – Slurry Oil

The Barge DBL 152 incident has been widely reported as involving a double-hull barge; however, further investigation has shown that the barge was designed with double sides and a single bottom. This design, while not often used on the Atlantic Coast, is used on the Gulf Coast and Mississippi River.[41] Interviews with the NOAA Scientific Support Coordinator during the incident and the Operations Officer for the Coast Guard's Deployable Operations Group who oversaw salvage operations confirmed that the barge was constructed with double sides but had a single bottom.[42, 43] Even though the incident resulted in the puncturing of the single bottom, it is recorded here in the interest of completeness.

On November 11, 2005, while en route from Houston, Texas, to Tampa, Florida, the integrated tug barge unit of the tugboat *Rebel* and the double-sided, single-bottom Barge DBL 152 collided with the submerged remains of a pipeline service platform that collapsed during Hurricane Rita. The barge capsized, and an estimated 1,925,532 gallons were discharged into federal waters of the Gulf of Mexico. The majority of the released heavy oil sank to the seafloor.[44]

The cleanup costs amounted to $66,346,000 or approximately $34.50/gallon released, reflective of the nature of the spill (sinking oil) and the inability to recover or remove much of the oil.

Barge DM 932 – No. 6 Fuel Oil

Early in the morning on July 23, 2008, the chemical tank ship *Tintomara* collided with the American Commercial Lines barge DM 932, which was being pushed by the tug boat *Mel Oliver* near downtown New Orleans, Louisiana. The collision resulted in a spill initially reported as over 9,000 barrels (380,000 gallons) of Number 6 fuel oil. That volume estimate was later reduced to about 6,500 barrels or 270,000 gallons when one tank was found substantially intact during the wreck removal process. Following the release of the fuel oil, the USCG closed the Lower Mississippi River to all vessel traffic, and traffic restrictions persisted for several weeks to accommodate cleanup operations and to prevent passing vessels from being contaminated. Cleanup of the incident took several months, with most of the response effort demobilized by early October.

The total cost, including response costs and damages, was approximately $102,019,000 in 2011 dollars, or $387/gallon released.[45]

4.5.1 Double-Hull Mitigation

As mandated by OPA 90, all single-hull tank vessels, including barges, will be phased out by 2015. The study of oil outflow from tank ships yields results that provide some standard of

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[41] J. Elliott, CDR, Operations Officer, U.S. Coast Guard, Deployable Operations Group, personal communication, October 31, 2012.

[42] S. Lehman, NOAA Scientific Support Coordinator for DBL-152 incident, personal communications, October 31, 2012.

[43] J. Elliott, CDR, Operations Officer, U.S. Coast Guard, Deployable Operations Group, personal communication, October 31, 2012.

[44] NOAA Damage Assessment, Remediation, and Restoration Program (DARRP) Tank Barge DBL 152, Federal Waters of the Gulf of Mexico retrieved from http://www.darrp.noaa.gov/southeast/dbl152/.

[45] U.S. Coast Guard, National Pollution Funds Center, "*Oil Pollution Act Liability Limits in 2011: Fiscal Year 2011*," Annual Report to Congress, Washington, DC, May 3, 2012.

comparison with tank barges. The probability of zero outflow of oil as a result of a grounding involving a double-hull tank ship ranges from 0.801 to 0.844, depending on tidal conditions. The mean oil outflow from an incident in which oil is released ranges from 0.8 percent to 1.5 percent of the cargo on board. The extreme oil outflow from such incidents is predicted to range from 6.7 percent to 12 percent of the cargo on board. These numbers are applied to a typical barge traversing Buzzards Bay, in the Cost Analysis, Section 7, of this report.

4.6 Adverse Events, Risk Factors, and Mitigating Measures Addressed in this Study

Risk is commonly defined as the product of the probability of an adverse event and the consequences of the event. For the purposes of this risk assessment, an adverse event includes the following incidents:

- Collision – A moving vessel striking one or more other moving vessels.
- Allision – A moving vessel striking a stationary object (such as a bridge).
- Grounding – A vessel moving, powered or adrift, into a shallow area and coming in contact with the sea bed.
- Near-Miss – A condition that could result in a collision or allision or grounding.
- Equipment Casualty – Equipment that cannot operate as intended; equipment failure.
- Adverse Weather – Includes periods of high winds, waves, low or restricted visibility, or sea ice that impair navigation.

4.6.1 Causal Factors for Tank Barge Casualties

The USCG Study, "*Improvements to Reduce Human Error and Near-Miss Incidents*," lists the following causal factors for tank vessel casualties. These causal factors are aligned to existing mitigation measures in place and being considered for Buzzards Bay, and other measures recommended in risk analyses for other areas.

- Human factors – fatigue, inattention errors, mistiming errors, willful violations, procedural errors
- Material factors – material failure
- Environmental factors – waterway hazard, struck by another vessel, severe weather, other

These factors are discussed with regard to their mitigating capabilities to the adverse events noted in **Table 11**.

Table 11: Summary of Causal Factors, Mitigating Policies, and Developing Programs

Causal Factors	Mitigating Policies					Developing Programs	
	Double-Hull Tank Barges	Independent Pilot	VMRS and AIS	Recommended Routes	Escort Tugs	Responsible Carrier Program	Tug Inspection Program
Human Factors							
Fatigue	Reduction of spill should an incident occur	Secondary responsible operator	Remote monitoring of tug barge position	N/A	N/A	Operating standards	N/A
Inattention errors				Provides route selection	Immediate response	N/A	
Mistiming errors				N/A		N/A	
Willful violations				N/A		N/A	
Procedural error				N/A		Operator certification	
Material Factors							
Material failure	Reduction of spill should an incident occur	Response decision support	N/A	N/A	Immediate response	Equipment and maintenance standards	Vessel and equipment inspection program
Environmental Factors							
Waterway hazard	Reduction of spill should an incident occur	Response decision support	Alert of hazardous conditions	Reduces transits near hazards	Immediate response	N/A	N/A
Struck by another vessel			Alert of other traffic	N/A			
Severe weather			Alert of hazardous conditions	Waterway closures in extreme conditions	Maneuvering assistance		
Other			Alert of hazardous conditions and traffic	N/A	Immediate response		

5 Oil Spill Probability Analysis

Oil spills are, fortunately, rare events. However, the consequences of an oil spill may be devastating to the environment, marine species, and the local economy. Oil spill probabilities are developed considering the frequency of tank barge transits through Buzzards Bay. Using historical data, the probability of an oil spill is derived and discussed. A previous study regarding vessel groundings is discussed and applied to Buzzards Bay.[46] Other data sources and scenarios are analyzed and discussed. Lastly, the analysis section discusses trends in oil consumption that may relate to future transits of oil products.

5.1 Buzzards Bay and Nationwide Incidents

A MISLE data call on incidents in Buzzards Bay and the Cape Cod Canal and nationwide incidents from 2006 to 2011 provided the number of reported incidents; however, the data call is limited and causal factors are not included. Over this 5-year period, Buzzards Bay and the Canal saw two collisions and two groundings. Both groundings occurred outside of the marked channel. Collisions and groundings are low-frequency events. Due to the lack of data received, an expected value for the probability of a collision or grounding in the Bay cannot be determined from the MISLE data call. The sample size (5 years of MISLE data, limited by the scope of this report) is too small to report an accurate expected value.[47] A second caution to using the MISLE data to report an expected value of oil spills is that the MISLE data did not include whether the incident resulted in oil spilling or not.

To gain a more realistic probability of an oil spill, more historic data were identified. **Table 9** (see **Section 4.4.1**) summarizes all major oil spills in Buzzards Bay since 1963.[48]

There were 8 major oil spills over the last 72 years, or an average of 1 spill every 9 years, compared to the nationwide prediction of 1 spill every 13 years. With 600 laden transits per year we can say the expected value of an oil spill is 0.000185 or 1/5400. This probability of an oil spill calculation is based on historical data dating back to the 1940s. As noted in previous sections, there have been many changes to oil transportation, especially over the past 10 years. It is difficult to state a definitive probability of an oil spill in Buzzards Bay for these reasons. The frequency of an oil spill at 1 spill every 9 years is based on historical data and is a historical probability, but this does not necessarily mean that Buzzards Bay is due for an oil spill this year.

Trends were identified while examining nationwide incidents (but not necessarily oil spills) for tank barges. **Figure 22** shows that tank barge groundings have decreased over the past 6 years. Collisions and allisions remained somewhat stable, except during the final year (2011) both saw a decrease in reported incidents. **Figure 22** supports the observation that vessel groundings may be the largest risk to oil spills.[49]

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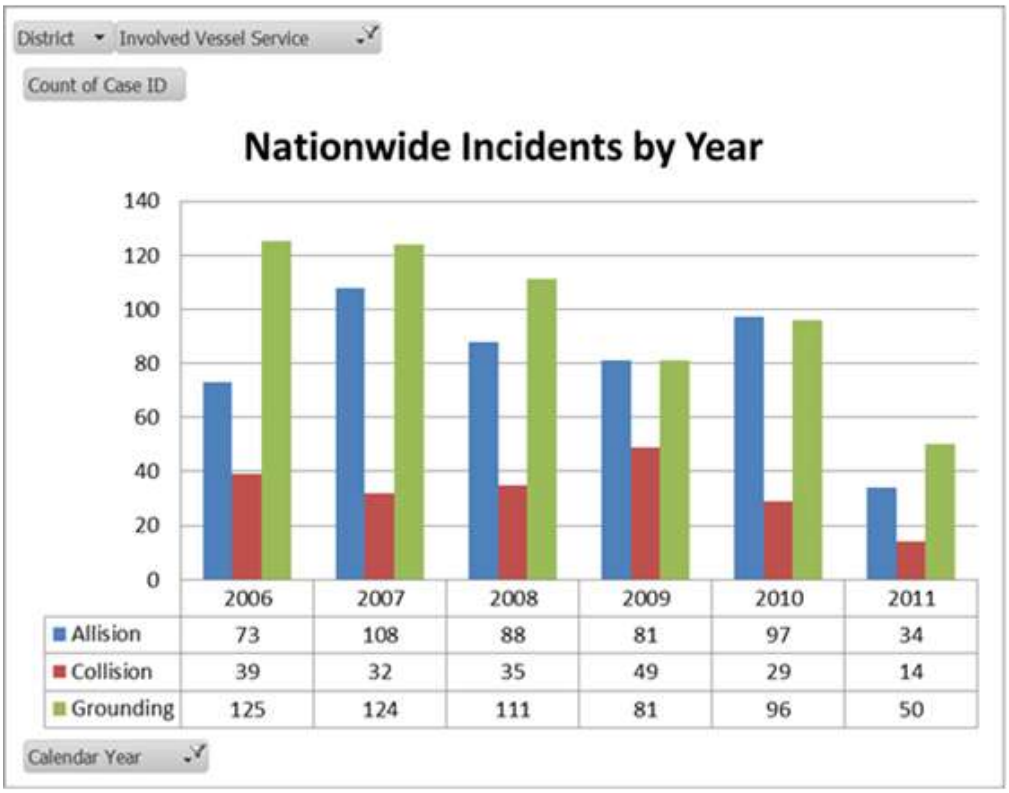
[46] M. Amrozowicz, A.J. Brown, and M. Golay, "*A Probabilistic Analysis of Tanker Groundings*," 7th International Offshore and Polar Engineering Conference, Honolulu, Hawaii, May 1997.

[47] U.S. Coast Guard, MISLE, Buzzards Bay and Cape Cod Canal Incidents, September 19, 2012.

[48] Buzzards Bay National Estuary Program, http://buzzardsbay.org/pastspills.htm, retrieved October 30, 2012.

[49] U.S. Coast Guard, MISLE, Nationwide Incidents, September 19, 2012.



	2006	2007	2008	2009	2010	2011
Allision	73	108	88	81	97	34
Collision	39	32	35	49	29	14
Grounding	125	124	111	81	96	50

Figure 22: Nationwide Incidents by Year[50]

5.2 Powered Grounding Fault Tree

A previous study, "*A Probabilistic Analysis of Tanker Groundings*," provides a fault tree analysis for both powered and drifted groundings. The powered groundings take into account failure probabilities for a faulty passage plan, faulty planning information, and piloting error. The computation for drifted groundings takes into account the wind-current assistance failure, anchor failure, and lost way.[51]

Interpretation of the powered grounding probability calculation reveals that the authors used two levels of verification in their calculations. They specify a mate and conning officer assisting the captain. It can be assumed then that this would be consistent with the Buzzards Bay requirements for an additional pilot who is not a member of the crew. It is safe to apply this analysis of powered groundings to the possibility of a powered grounding in Buzzards Bay. This analysis provides the probability of the events that would lead to a powered grounding, but does not take into account the geophysical properties of Buzzards Bay. For example, the human error that leads to a powered grounding may occur, but the vessel may be in a location where there is ample deep water surrounding the vessel and the vessel is recovered before it enters a risky area.

A powered grounding occurs due to human error in planning or pilotage when a vessel is able to follow a safe route, but instead it proceeds along an unsafe route. The combination of an event

[50] U.S. Coast Guard, MISLE, Data Call on Nationwide Incidents 2006-2011, received September 19, 2012.

[51] M. Amrozowicz, A.J. Brown, and M. Golay, "*A Probabilistic Analysis of Tanker Groundings*," 7th International Offshore and Polar Engineering Conference, Honolulu, Hawaii, May 1997.

tree and fault tree provides discrete logic diagrams to show the causal relationships and determine the probability of the accident scenarios. The study assigns human error probabilities for each piloting error in the event tree. **Figure 23** shows the event tree and fault tree for powered groundings as a result of faulty vessel plans.

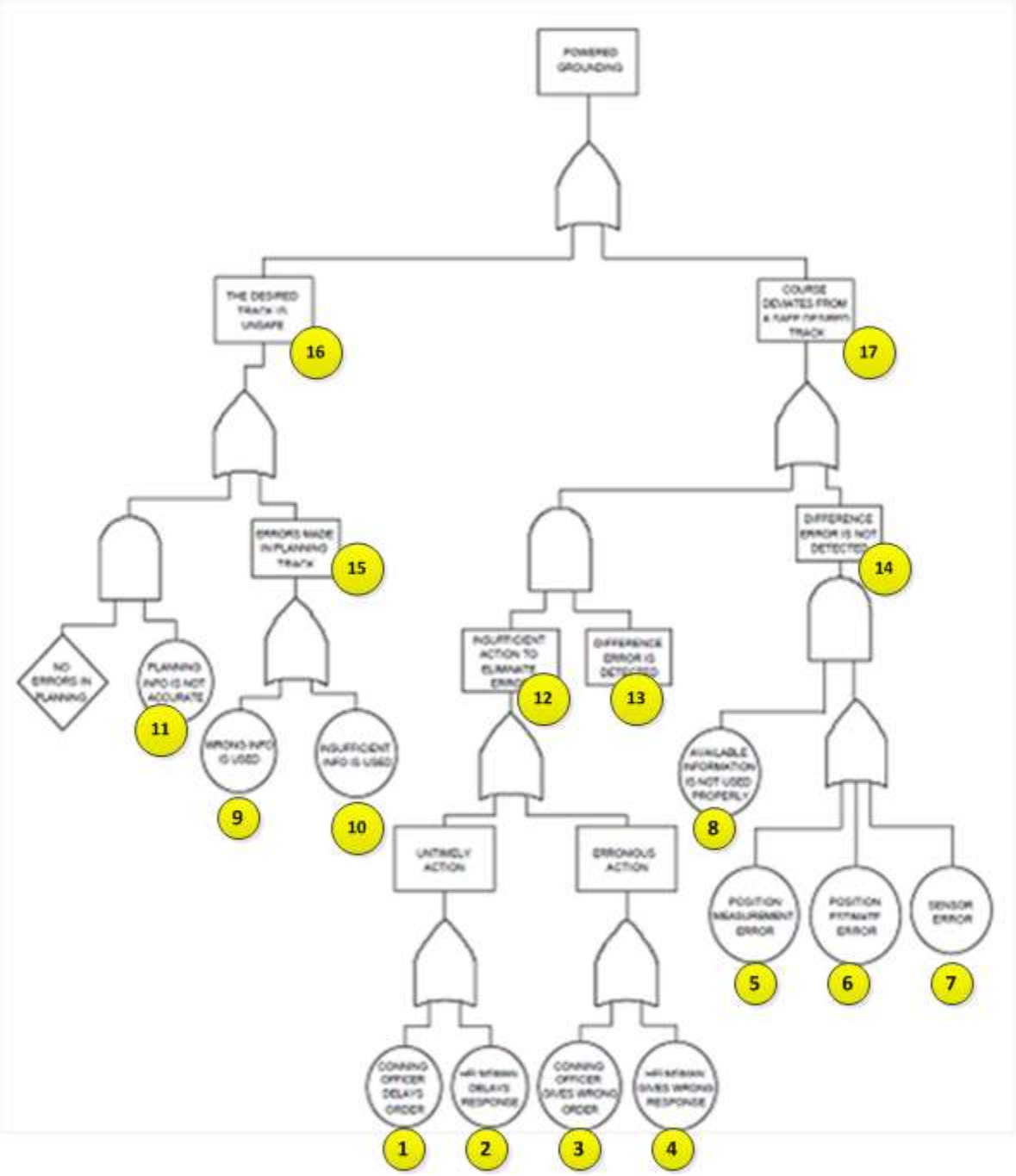


Figure 23: Powered Grounding Fault Tree

5.2.1 Assessment of Fault Tree

Although a simple representation of the decisions made during a route selection, the fault tree shows the number of decisions made by the master during the route selection process. Each of these decisions could introduce an error, resulting in an unsafe condition. This limited sampling of the decision points identifies 17 instances of potential error. Within Buzzards Bay there are current mitigating policies to reduce risk of error in the route selection process, including the following:

- Recommended routes – reduce the tug master's need to select a safe course
- VMRS – mandates the reporting of position and intention, potentially increasing the diligence toward navigation

The addition of an independent pilot further reduces risk of any error in decision making. As an independent variable, the probability of simultaneous errors by the master and pilot are multiplicative. If the decision fault tree represented all decisions during a transit (which it obviously does not), the probability of error from a single operator is 1/17. When the independent pilot is inserted, the probability of both operators committing the same error is 1/17*1/17, or 1/289. This results in a risk probability reduction from 5.9 percent to 0.35 percent.

5.3 Escort Activities

Table 12 shows an escort tug activity log provided by MassDEP for January through September 2012, a period when industry was funding escort tugs. It shows 38 instances where escort tugs were requested to provide assistance. From January through June 2011, Massachusetts-provided tug escorts provided one assist, and from July through December 2011 the industry-provided escort tug provided assistance 16 times. The activity log was assessed to develop the activity type (e.g., assist) and causal factor (e.g., weather) to review the types of assistances and reasons.

Table 12: Escort Activity Log

Date	Tug Barge	Description	Activity Type	Causal Factor
1/4/2012	Morton Bouchard B-210	Made up to barge while Morton broke tow, weather/fog.	Assist	Visibility
1/6/2012	Endeavor VB-38	Made up to VB-38 @ Cleve Ledge as tail boat, weather/fog.	Assist	Visibility
1/19/2012	Christine McAllister RTC-502	Sabine made up to the oil barge in Anch L, to steady while making tow, weather.	Assist	Weather
1/19/2012	Marion Moran Adelade	Cement barge, requested a tug to act as a tail boat to assist steering through the canal, weather.	Assist	Weather
1/21/2012	Ruth Reinauer RTC-102	Gave the Ruth an assist into and out of Sprague terminal, New Bedford.	Assist	Maneuvering
1/25/2012	Susquehanna DS-506	Made up to the barge while the transit tug broke tow and made up in push gear, weather.	Assist	Weather
2/2/2012	Gulf Service Energy 11104	Tug asked the Sabine to make up to the barge to steady it while they broke tow and went to push gear.	Assist	Weather
2/3/2012	Mary Turecamo Portland	Captain had Sabine make up to the barge as a tail boat through the canal.	Assist	Maneuvering
2/13/2012	Frederick Bouchard	Made up to barge to keep it in the channel as the	Assist	Current

Date	Tug Barge	Description	Activity Type	Causal Factor
	B-210	Frederick went from towing to push gear, strong current.		
2/21/2012	Liberty Service Energy 11105	Escort requested through the canal for barge carrying ethanol, tug called Prov and stated they had "mechanical issues."	Assist	Casualty
2/21/2012	Choptank DS-53	Made up alongside barge and standby in Anch C for weather.	Assist	Weather
2/24/2012	Penn#4 Penn-92	Assist the Penn#4/Penn-92 into the west end stakes for weather.	Assist	Weather
2/26/2012	Penn#4 Penn-92	Assist the Penn#4/Penn-92 off of the west end stakes for weather.	Assist	Weather
2/26/2012	Weddell Sea DBL-83	Captain had Sabine make up in the notch to assist unit through the canal.	Assist	Maneuvering
3/4/2012	Mary Turecamo Portland	Captain had Sabine make up alongside barge Portland to assist from Cleve Ledge to east end.	Assist	Maneuvering
3/9/2012	Jennifer Turecamo Maria T	Captain ordered tug to assist cement barge from Cleve Ledge to East End, high winds.	Assist	Weather
3/10/2012	Mary Turecamo Portland	Captain had the Sabine make up alongside the barge with 3 lines, high winds.	Assist	Weather
3/10/2012	Quenames Portland	Sabine assisted the barge into the Sandwich Terminal.	Assist	Maneuvering
3/19/2012	Christine McAllister RTC-502	Sabine assisted the barge into the west stakes due to zero visibility fog.	Assist	Weather
4/16/2012	Brendan Turecamo Portland	Sabine made up to the barge at Anch C waiting for visibility and current.	Assist	Weather
4/19/2012	Endeavor VB-38	Sabine made up as a tail boat for an assist and boost, from BB #4 to the East End.	Assist	Maneuvering
4/22/2012	Jane Bouchard B-225	Sabine made up to the barge at Anch C waiting, zero visibility.	Assist	Weather
4/26/2012	Stephen Scott RTC-61	Sabine assisted in search for mariner overboard 0430 until 1430.	Assist	SAR
4/27/2012	Patuxent DS-508	Sabine made up to the barge at Cleve Ledge to give assist through canal due to wind and visibility.	Assist	Weather
5/5/2012	Gulf Service Energy 11105	Carrying ethanol but requested the Sabine to make up to the starboard bow of the barge, from Cleve Ledge to the EE due to weather and wind.	Assist	Weather
5/12/2012	Rhea Bouchard B-280	Ordered by Rhea to go ahead and clear small recreational boat traffic on Saturday morning, at Hog 1 & 2.	Other Vessel	Traffic
5/27/2012	Siberian Sea Columbia	Sabine made up to barge for steering and power help bucking tide through the canal.	Assist	Current
5/28/2012	Bohemia DS-59	Sabine made up in notch to assist tow through the canal.	Assist	Maneuvering
6/9/2012	Siberian Sea Columbia	They had the Sabine make up 3 lines in the notch, the Siberian Sea kept the barge on the tow.	Assist	Maneuvering
6/11/2012	North Sea Pacific	Sabine made up to the barge in rough seas while the North Sea went from push gear to tow.	Assist	Weather

Date	Tug Barge	Description	Activity Type	Causal Factor
7/7/2012	Pocomoke DS-53	Stand by to assist with a broken (push gear) tow wire @0615, then push on barge as they adjusted push gear @0745.	Equip	Casualty
7/11/2012	Arabian Sea DBL-102	Made up to the barge to assist it through Buzzards Bay and the CCC.	Assist	Maneuvering
7/31/2012	Morton Bouchard Jr. B-220	S/V Lulu Belle of Martha's Vineyard Doc. 1129330 sailed over wire between tug and barge despite repeated attempts to contact on VHF and evasive actions taken by the Morton Jr. When all other actions failed, the Morton Jr. took all way off and dipped their tow wire allowing the other vessel to pass over without incident.	Other Vessel	Operator
8/2/2012	Brendan Turecamo Adelaide	Requesting an assist from the Sabine, using Sabine as a tail boat to go through the CCC.	Assist	Maneuvering
9/4/2012	North Sea Columbia	Sabine made up in the notch to assist in steering the barge through the canal.	Assist	Maneuvering
9/21/2012	Siberian Sea Columbia	Andrew McA made up in the notch to assist and steer through the canal.	Assist	Maneuvering
9/21/2012	Zachary Reinauer RTC-26	Nancy gave assist from stream into the East End Stakes.	Assist	Maneuvering
9/21/2012	Zachary Reinauer RTC-26	Iona gave assist from the East End Stakes into stream.	Assist	Maneuvering

Figure 24 shows all reported escort activities by type of activity. The Change Analysis (Section 6) discusses how different risk mitigations may help to reduce these occurrences.

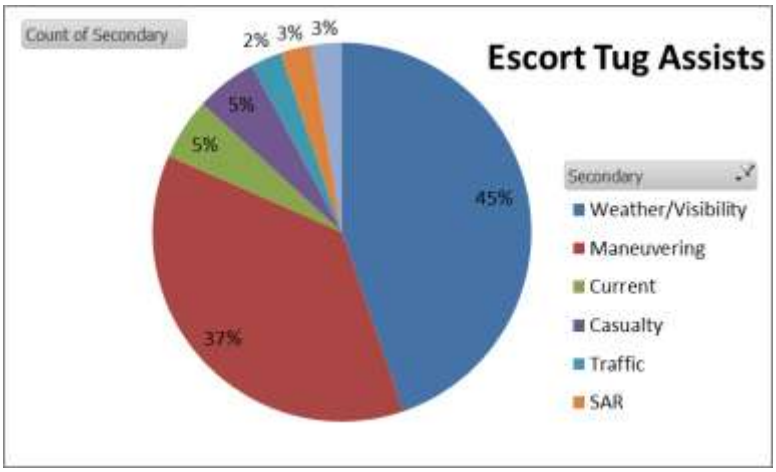


Figure 24: Reported Escort Activities Chart

5.3.1 Assessment of Escort Tug Use

The limited sampling of 38 uses of escort tugs provided by MassDEP is constrained by the cost factors for the use of the escort tug. Logically, where the escort tug was funded by the state, the availability and use of the tug was considered necessary or useful; where the escort tug was funded by the towing vessel, the use of the tug may definitely be considered as necessary. Nonetheless, use of the escort tug in weather, visibility, and maneuvering situations represents 82

percent of the reported usage, and indicates a potential benefit to the reduction of risk from an adverse situation. Other reported instances of escort tug assistance include assists during the making up of the tug/barge from towing to pushing when entering the Buzzards Bay RNA or Cape Cod Canal. Most operations are performed in the lower bay to avoid traffic.

5.4 Response Tug Analysis

A quick-look analysis was conducted to assess the response time for sentinel tugs at different locations within Buzzards Bay. Locations were identified along the typical transit route, beginning at the entrance of Hog Island Channel to the entrance of Buzzards Bay. Sentinel tug locations were estimated at Woods Hole, New Bedford, and Cuttyhunk Island. The nearest hazards were plotted for each position and the wind drift leeway was calculated for the nearest hazard both east and west of the track. **Figure 25** is a chart of Buzzards Bay indicating study points, routes, and response window (area where a response tug would intercept prior to a grounding). Wind speeds were assessed at 20, 30, and 40 knots at a direction perpendicular from the survey point to the nearest hazard to model the most severe conditions.

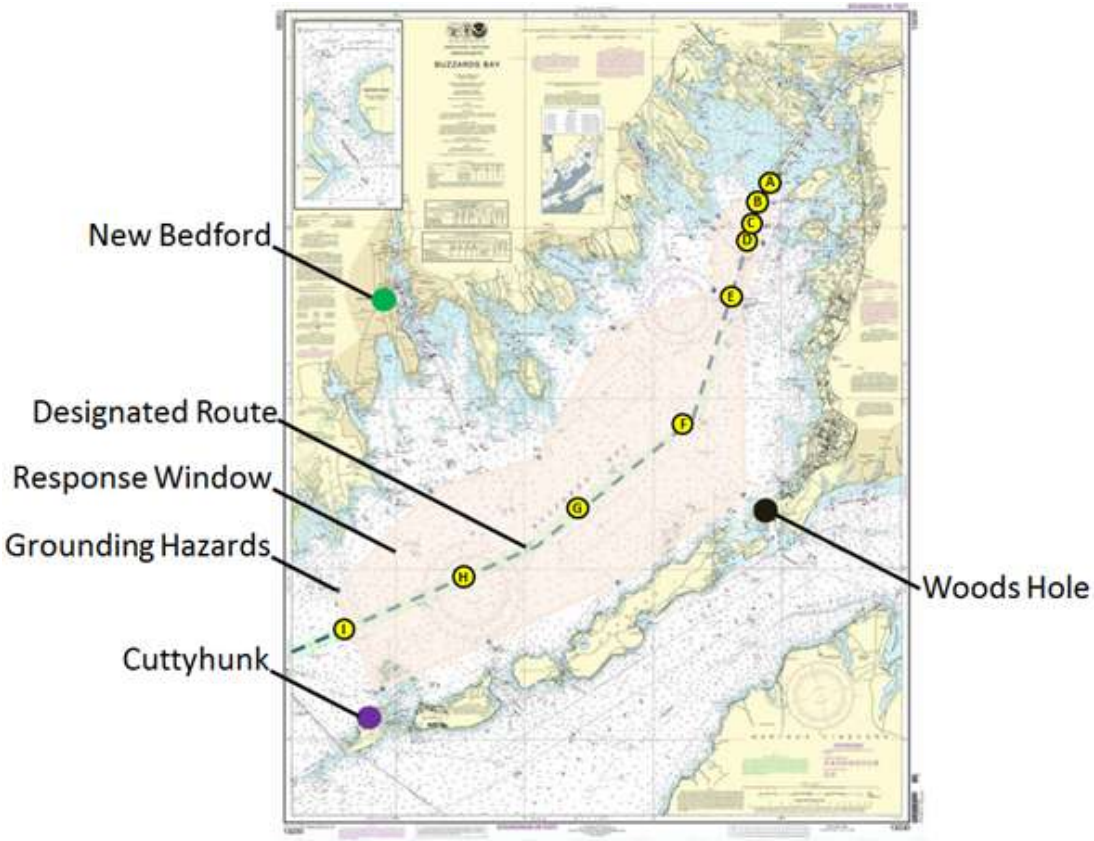


Figure 25: Response Tug Ports and Transit Route Analysis Points

5.4.1 Assumptions

The following assumptions were used in this analysis.

- No tidal current information or effect on drift was calculated in this quick-look analysis. A worst-case drift to the nearest hazard was developed based on leeway calculations per

the USCG National Search and Rescue Manual. This calculation, used for search and rescue datum development, considers vessel size and drift in different wind conditions. The leeway calculation is used to estimate the drift speed of an unpowered tug/barge to the nearest navigational hazard to determine whether or not a response (sentinel) tug would arrive on the scene prior to the disabled vessel drifting into a hazard.

- This assumed the response tugs were in a high-readiness status, were fully crewed, and could depart upon notification of an incident at the maximum speed indicated. Response tug speeds were set at 15 knots. The time to transit to the point was calculated on the distance and the 15-knot speed.
- Leeway drift was calculated as the distance to the closest hazard, with the assumption that the wind direction would be the worst case to drive the unpowered barge to that hazard.
- Tug/barge mitigating activities (anchoring, etc.) were not considered for this leeway model; in other words, the vessel is completely disabled and drifts to the nearest navigational hazard without benefit of anchoring. This assumption presents the worst-case scenario.

5.4.2 Response Results

The resultant response windows representing the time from the incident where the barge became unpowered/uncontrolled and adrift to the nearest hazard were plotted for each route analysis point. Response tug transit times to the analysis points were also plotted for each port location. The resultant graph clearly depicts those locations on the Buzzards Bay transit route where, based on these assumptions, the barge would drift into a hazard prior to the arrival of the sentinel tug, especially near the mouth of the Cape Cod Canal (points A–E). A New Bedford-based response tug may not be adequate for a response in the entrance to Buzzards Bay in wind conditions greater than 20 knots, although the Cuttyhunk and Woods Hole ports could respond in those areas. The response times and response windows are shown in **Figure 26**.

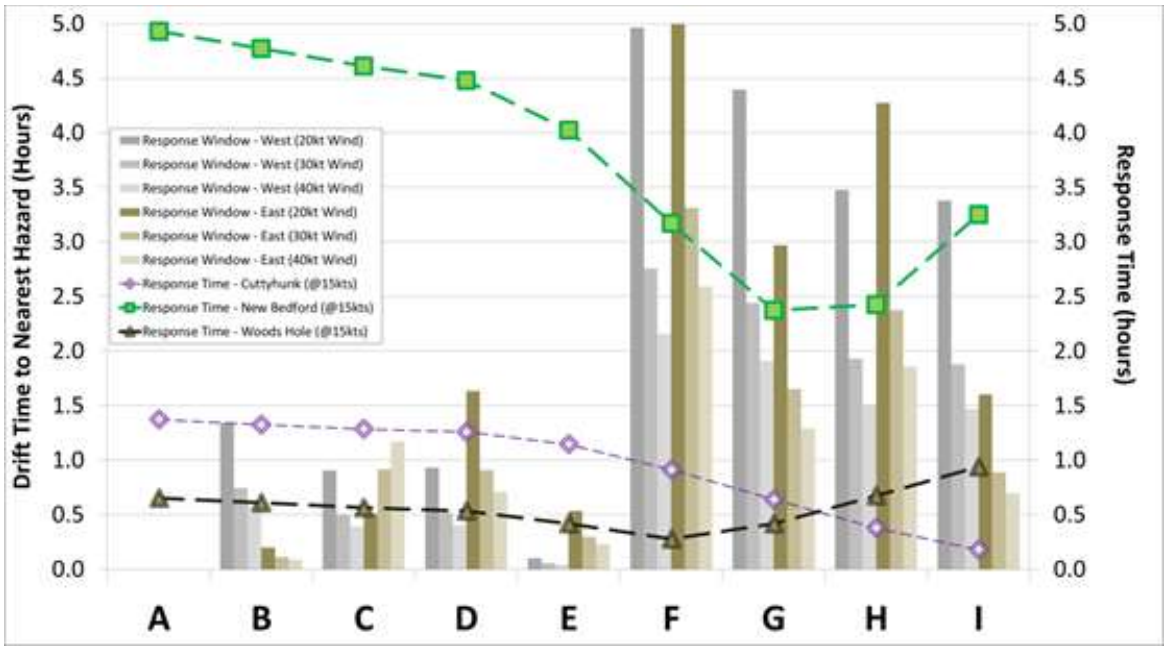


Figure 26: Time to Drift to Hazard and Response Tug Arrival Time by Port

5.4.3 Assessment of Response (Sentinel) Tug

This analysis may be interpreted in several ways.

- During high-wind conditions the expected arrival time for a response tug may not be sufficient to respond prior to a barge drifting to a hazard with a direct wind direction. This could indicate the need for an escort tug during the periods of high winds.
- The response requirements could be positively impacted by an additional location near the entrance to the Canal.
- The use of a response tug and an escort tug to cover the separate areas identified in this quick-look analysis is not reasonable. The cost of the high-readiness response tug would not be offset by the 2-hour transit from basically point F to the entrance of Buzzards Bay by an escort tug.

5.5 Operator Fatigue

As many as 80 percent of all marine accidents can be attributed to human factor causes.[52] Of those factors the most cited is fatigue among vessel crewmembers, particularly those working the watch-standing positions. The USCG Office of Marine Safety, Security, and Environmental Protection, and the Office of Navigation Safety and Waterway Protection found, in a recent human factors study, that fatigue was among the top three causes of marine accidents.

A study performed by the USCG Research and Development Center studied the contributions of human factors and fatigue on maritime vessel causalities.[53] The study surveyed 279 personal

[52] E. DeCola, S. Fletcher, "*An Assessment of the Role of Human Factors in Oil Spills from Vessels*." Nuka Research and Planning Group, LLC, 2006.

[53] A.M. Rothblum, "*Procedures for Investigating and Reporting Human Factors and Fatigue Contributions to Marine Casualties*." U.S. Coast Guard Research and Development Center, 1996.

injuries and major vessel casualties to determine if crewmember fatigue was a contributor to the incidents. **Figure 27** is taken directly from Rothblum's study and shows the frequency of vessel casualty types caused by human factors, both with and without a crewmember fatigue contribution, for 40 incidents. The data show that over 50 percent of vessel grounding and 30 percent of the of the total vessel casualty incidents can be attributed, in part, to crewmember fatigue. The study concludes that fatigue is a leading factor contributing to maritime vessel casualties.

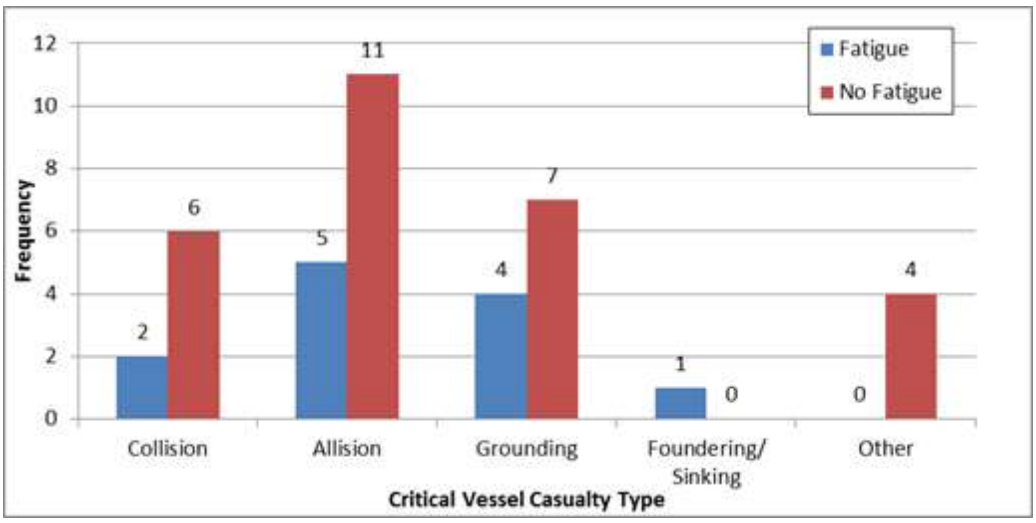


Figure 27: Critical Vessel Casualty by Human Factor

5.5.1 Assessment of Fatigue

Overall, multiple credible sources have cited the high contribution that crewmember fatigue plays in maritime accidents. The causes and potential solutions to crewmember fatigue are outside the scope of this study; however, the contributions that fatigue imparts on vessel incidents, especially grounding incidents, should be noted. Policies for mitigation of fatigue include:

- The Responsible Carrier Program – Sets standards for watch cycles and periods. Operators agree to comply with the standards as part of certification.
- Additional Pilot – The presence of another independent operator on board provides a direct observation of the tug crew. An unsafe condition would be expected to be reported and corrective action taken, including anchoring. The pilot is definitely not intended as a relief master.
- VMRS – Vessel operators reporting to the VMRS may be late or may forget to report. The VMRS operator, identifying non-reporting vessel movements through AIS, may identify potential high-risk situations and forward information to response agencies.

5.6 Oil Spill Consequence Analysis

Buzzards Bay has various economic and environmental resources that have been harmed by oil spills in the past and may be expected to be harmed in the event of a future oil spill. Consequences of oil spills are addressed in the Draft Environmental Assessment for

Implementation of Revisions to the RNA *Governing Maritime Transport of Petroleum Products and Other Hazardous Materials on Buzzards Bay, Massachusetts*.

The National Response System (NRS) for oil spills in the United States was established by OPA 90 and implemented by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).[54] In addition to the NCP, the NRS requires that each Regional Response Team (RRT) prepare a Regional Contingency Plan (RCP), generally corresponding to each Standard Federal Region in the United States, and that each Area Committee in the United States prepare an Area Contingency Plan (ACP).[55]

The Commonwealth of Massachusetts fully participates in the Area Committee for Sector Southeastern New England and has some parallel oil spill contingency planning and response requirements.[56] Additionally, MassDEP has prepared Geographic Response Plans (GRP) for regions within the state, including Buzzards Bay.[57] The GRPs are further subdivided into specific areas that identify critical resources, response tactics, equipment requirements, and other special considerations.

The state of Massachusetts has also compiled an inventory of response equipment within Massachusetts and New England that is available in the event of a release of oil within state waters.[58] This inventory listed equipment available but the report noted that the process of evaluating the capabilities for on-water recovery and other response tactics was not undertaken.[59] The report did note, however, that there were a limited number of oil skimmers in Massachusetts. The closest major on-water response resources are located in Portland, Maine.[60]

The provision of oil spill response resources in the United States generally falls to the private sector. General. Since the enactment of OPA 90, these resources have been provided by Oil Spill Removal Organizations (OSRO) that maintain equipment in preparation for and use during an oil spill. OSROs are contracted by vessel and facility owners and operators and are identified in Vessel Response Plans (VRP) or Facility Response Plans (FRP) required by regulation and approved by the federal agency assigned the responsibility by Executive Order of the President.

The location and capabilities of OSROs' oil spill response resources are determined by planning factors in the VRP and FRP regulations. For example, the Effective Daily Recovery Capacity (EDRC) of an open-water oil spill skimming unit is specified in USCG regulations. Vessel and facility owners and operators are required to ensure that the oil spill response resources that they identify in the VRP or FRP for response to various categories of spill sizes are sufficient to deal

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[54] Title 40 U.S. Code of Federal Regulations, Part 300.

[55] Areas in the United States correspond to U.S. Coast Guard Sectors for coastal and marine waters and to U.S. EPA Regions for inland waters.

[56] MassDEP, "*Massachusetts Contingency Plan*," 2008, and Rhode Island and Southeastern Massachusetts Area Committee "*Area Contingency Plan*," December 2010.

[57] Nuka Research and Planning Group, LLC, "*Massachusetts Geographic Response Plans*," http://grp.nukaresearch.com, July 2011.

[58] Nuka Research and Planning Group, LLC, "*Inventory and Assessment of Marine Oil Spill Response Resources in Massachusetts and New England States*," Prepared for Massachusetts Department of Environmental Protection, December 2009.

[59] Nuka Research, Ibid.

[60] Nuka Research, Ibid.

with the spills. The approval process for VRPs and FRPs confirms the match of requirements and capabilities.

The 2010 massive release of oil from the Macondo exploratory well following the fire and explosion aboard the drilling rig *Deepwater Horizon*, however, challenged the assumptions underlying the planning factors for determining response resources. The Incident Specific Preparedness Review (ISPR) conducted following the incident found that, among other things, the amount of response resources used at the scene of the oil spill vastly exceeded the amount required by regulation and that they were ineffective in recovering the amount of oil anticipated by planners.[61]

The implications of this for oil spill response on Buzzards Bay are substantial. Until such time as the planning requirements for oil spill response resources is rationalized with the anticipated actual performance during an oil spill, it must be assumed that on-water response, at least, will not meet expectations.

5.6.1 Environmental Concerns

The most significant impacts to Buzzards Bay from an oil spill include toxic contamination of the ecosystem, closures of shellfish beds due to pollution, habitat loss, nitrogen loading, and resulting coastal eutrophication. Buzzards Bay has 350 miles of coastline that host many habitats: salt marshes, tidal flats, barrier beaches, eelgrass beds, and sub-tidal zones. The Bay is home to a $4 million annual shellfish industry. Commercial species harvested include soft-shell clams, quahogs, scallops, oysters, and lobsters. There are more than 500 commercial shell fishing permits and 12,800 recreational permits sold annually.[62]

River herring and bay scallops are important natural resources in Buzzards Bay that would be negatively impacted by an oil spill. The river herring population has declined to a fraction of historic levels. Similarly, pollution has hindered scallop colonization. Buzzards Bay National Estuary Program is supporting physical restoration efforts to help restore these important marine resources. Additional information on important populations of birds, fish, and other protected species can be found in the *Draft Buzzards Bay Environmental Assessment*.

5.6.2 Socioeconomic Concerns

Four counties surround the Bay. These counties have substantial year-round residential populations, but in addition each area also experiences a substantial increase in seasonal visitors during the summer. Some towns' populations double during the summer months. Eight of the 11 towns bordering the Bay contain over 70 percent seasonal or recreational housing. Visitors support local businesses and the local economy. Additionally, Buzzards Bay is a popular recreational boating area. More than 12,000 boats can be found on Buzzards Bay during peak

[61] U.S. Coast Guard, "*BP Deepwater Horizon Oil Spill Incident Specific Preparedness Review, Final Report*," Washington, DC, January 2011.

[62] U.S. Environmental Protection Agency, National Estuary Program Coastal Condition Report, Chapter 3, Northeast National Estuary Program Coastal Condition, Buzzards Bay National Estuary Program, June 2007.

summertime holidays. Regattas and recreational fishing events also draw large numbers of visitors to the waterways.[63]

As mentioned, the Cape Cod Canal provides access between New York and Boston and other northern ports. Traffic is not solely limited to tank barges carrying oil; if the Cape Cod Canal were to close due to an oil spill the economic burden would be significant. The cost of closing the canal is not estimated, but it is expected to be a significant loss.

5.6.3 Consequences of B-120 Oil Spill of 2003

After the B-120 spill of 2003, NOAA and other federal and state agencies (the Trustees) evaluated the environmental and cultural impacts of the spill.[64] Natural resource damages were divided into four categories: shoreline habitat, birds and wildlife, recreational uses, and aquatic resources. The natural resource damages caused by the B-120 spill are summarized below. Similar consequences could be expected in the event of another spill in Buzzards Bay.

- Shoreline habitat – The Trustees estimated that 98 miles of shoreline were oiled. The shoreline included coarse substrate habitats, sand beach habitats, and marsh habitats.
- Birds and wildlife – About 450 birds were immediately killed by the spill including loons, scoters, mergansers, oyster catches, terns, eiders, and piping plovers. The plovers and terns are two federally-protected species. The wildlife assessment also includes future lost productivity and delayed mortality.
- Recreational uses – Substantial parts of Buzzards Bay were closed to shell fishing for several months after the spill. There was limited access to portions of the Bay for boating and to some shorelines after the spill.
- Aquatic resources – It was determined that several aquatic habitats and resources were potentially impacted from the spill. These resources included finfish, shellfish, and other invertebrates.

[63] *Draft Environmental Assessment for Implementation of Revisions to the RNA Governing Maritime Transport of Petroleum Products and Other Hazardous Materials on Buzzards Bay, Massachusetts*. Submitted to U.S. Coast Guard. Prepared by Malcolm Pirnie, Arcadis, July 18, 2012.

[64] NOAA, Northeast Region, *Damages Assessment, Remediation, and Restoration*, retrieved from http://www.darrp.noaa.gov/northeast/buzzard/injury.html.

6 Analysis of Risk Mitigation Options

6.1 Risk Mitigation Options

Mitigation activities address expected risk. **Figure 28** shows a notional relationship among the event factors, policies, and services that mitigate the risk, the resultant potential for an oil spill from these unmitigated risks, and the impact of the double-hull requirement. This figure is complicated because it represents a system with interdependent, random, and causal relationships among the risk factors, the mitigation policies and services, and the potential for an oil spill. Each of these areas is described below to illustrate the relationships, and is shown graphically in **Figure 28**. The effects of the mitigation policies and services and double-hull requirements are also included in the Change and What-If analyses in Section 6.3 of this report.

- **Adverse Event Factors** – These categories of causal factors are identified in the USCG report on *Improvements to Reduce Human Error and Near-Miss Incidents*. From the limited sampling of tug and barge incidents, the percentages of occurrence of these factors were used to identify the factors that could result in a spill. The results of these risk factors are collisions, allisions, groundings, and near-misses. The underlying causes of these events include human factor-related errors by the operator or by the operator of another vessel that place the tug and barge at risk; equipment failures that degrade tow vessel performance, capabilities, or ability to control the barge; or factors such as weather and accidents that place the tug and barge at risk. The distribution of the column represents 100 percent of adverse event factors scaled by their historical occurrence.
- **Mitigation Policies, Programs and Services** – These are preventive measures instituted by the USCG, Massachusetts, and the towing industry to mitigate adverse effects. Each of the applicable policies, programs, and services is shown associated with the adverse risk events that are mitigated by the activities. These are defined below.
  - Policies
    - *Recommended Routes* – These provide routes away from known hazards and separate inbound and outbound transits. The recommended routes also reduce route selection decision making by the tug operators. Furthermore, recreational boater traffic may be more aware of tug/barge transits within the routes, although anecdotally, the marking of the recommended route may influence vessels to transit in the lanes, increasing traffic density and therefore the risk of adverse effects.
  - Programs
    - *Responsible Carrier Program* – This policy provides certification of vessel, crew, and operations. This stringent independently-audited voluntary initiative has a goal of improving the safety and environmental performance of the towing industry. The RCP initiative supplements existing regulations and requirements.
    - *Tug Inspection Program* – This developing USCG program will verify compliance with minimum standards for tug boats, and will involve inspecting currently uninspected vessels.
  - Services
    - *VMRS* – This system requires notification at entrance, designated points, and exit, and AIS reporting. Information is monitored at the Cape Cod Canal Operations

Center. Vessels transiting Buzzards Bay are more aware of intended transits and potential issues within the waterway. Operators are constantly reminded of the sensitive waterway through the required call-in locations, possibly increasing their vigilance during navigation.

- *Additional Independent Pilot* – This service requires the presence of an independent pilot on the towing vessel to support the vessel movement through Buzzards Bay. This policy provides support for navigation and special operations execution, reducing the probability of human error in decision making. The independent pilot is a major risk reduction factor.
- *Escort Tugs* – Escort tugs accompany a tug/barge during a transit. Current federal requirements are for single-hulled barges to be escorted in Buzzards Bay. Current state requirements require both double-hull and single-hull barges to be escorted in Buzzards Bay. The escort tug is an immediately-available failsafe for any incident with the tug or barge.
- *Sentinel Tugs* – These tugs support the tug/barge in response to an incident or high-risk situation. Sentinel tugs are maintained in a high-readiness status for immediate response to an incident. Sentinel tugs provide a guaranteed service response level to address any developing high-risk situation.

- **Remaining Risk** – Remaining Risk presents a summary of the risk after the mitigating actions have been applied. The presence of risk along with each of the mitigation policies, programs, and services in response to the Adverse Event Factors acknowledges that some risk remains after these activities. The quantification of this risk was not possible due to the complex interactions of the activities, random events, and even willful actions. This simply shows that some risk exists after all mitigations. Remaining risk items are shown in **Figure 28** as contributing to either near misses or potential oil spills.
- **Potential Oil Spill** – The potential oil spill column represents the notion that the potential risk factors result in either no incident, an incident with no spill, or, in the worst case, an incident with a spill. The relative sizes of these boxes are not relevant, and they are shown of similar sizes.
- **Double-Hull Requirement** – The Double-Hull Requirement stack shows the impact of double-hull barges on a potential oil spill. Data from the National Academy of Science Double-Hull Barge Study indicated a 75 to 83 percent reduction in the probability of a spill, should a grounding, collision, or allision occur. This reflects the probability that, despite the mitigating policies and services, escorts, and double-hull barges, there is still a slight risk of some event that could cause a spill and that the double hull could breach, causing a release of oil.

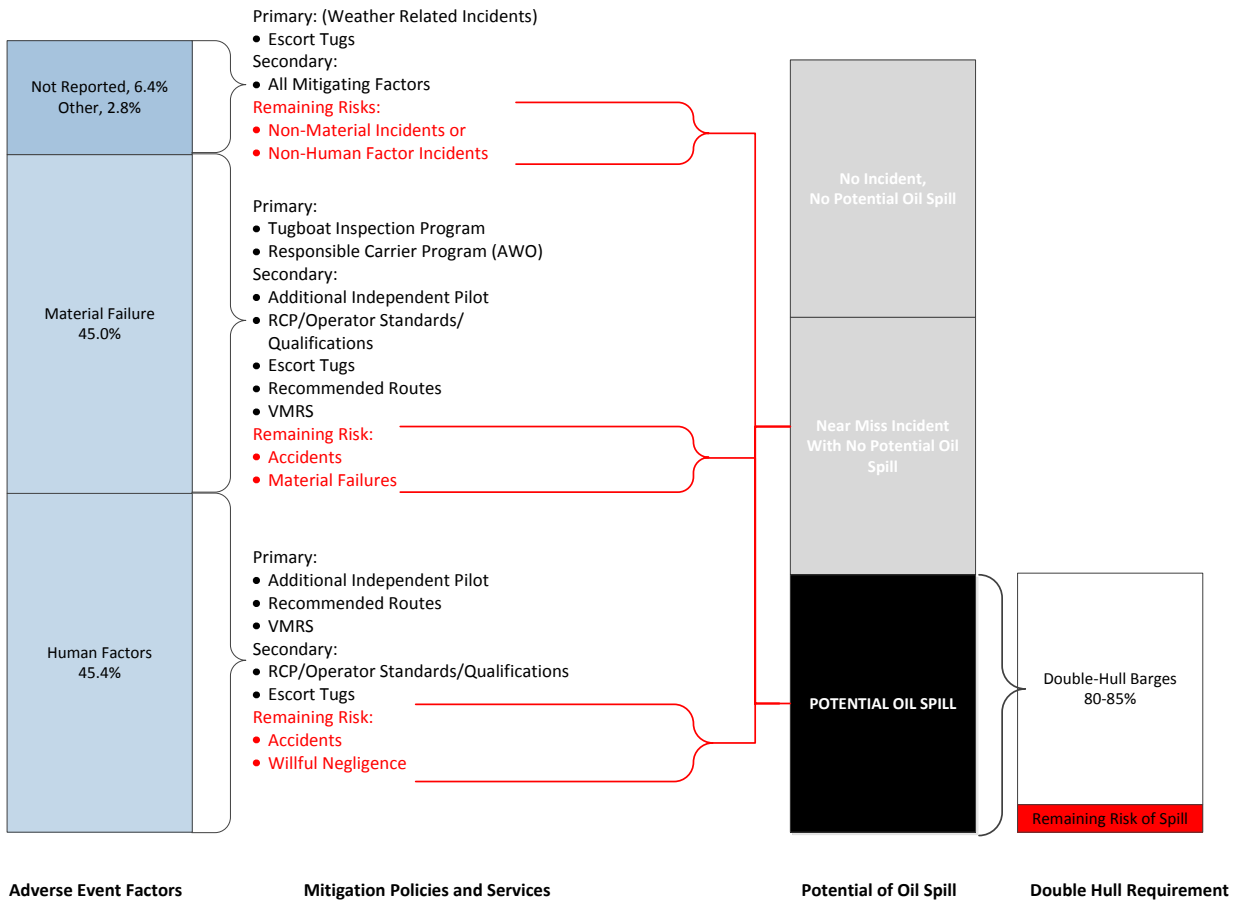

Figure 28: Event Factor, Mitigations, and Risk Flow

The complex **Figure 28** is represented in a style view to demonstrate the impact of the layers of mitigation policies, programs, and services to reduce risk, and that there is some residual risk remaining. This step function view does not, however, imply unique contributions to risk reduction as many of the activities are closely related. The activities are sorted by the relative contributions to risk reduction in the following order, and the contributions they provide for either response or prevention:

- Double-Hull Barges – reduce risk after an event – Mitigation
- Independent Pilots – reduce human factor-caused events – Prevention
- Reliable Carrier Program – reduces human factor-caused and material-caused events – Prevention
- Tug Inspection Program – reduces human factor-caused and material-caused events – Prevention
- VMRS/AIS – reduce human factor-caused events – Prevention and Response Alerts
- Recommended Routes – reduce human factor-caused events – Prevention
- Escort Tugs – reduce human factor-caused, environmental-caused, and material-caused events, and reduce risk after an event – Prevention and Response
- Sentinel (Response) Tugs – reduce risk after an event – Response

Figure 29 shows there is remaining risk after all mitigating activities are applied. Program managers identify the remaining risk as the acceptable or affordable risk.

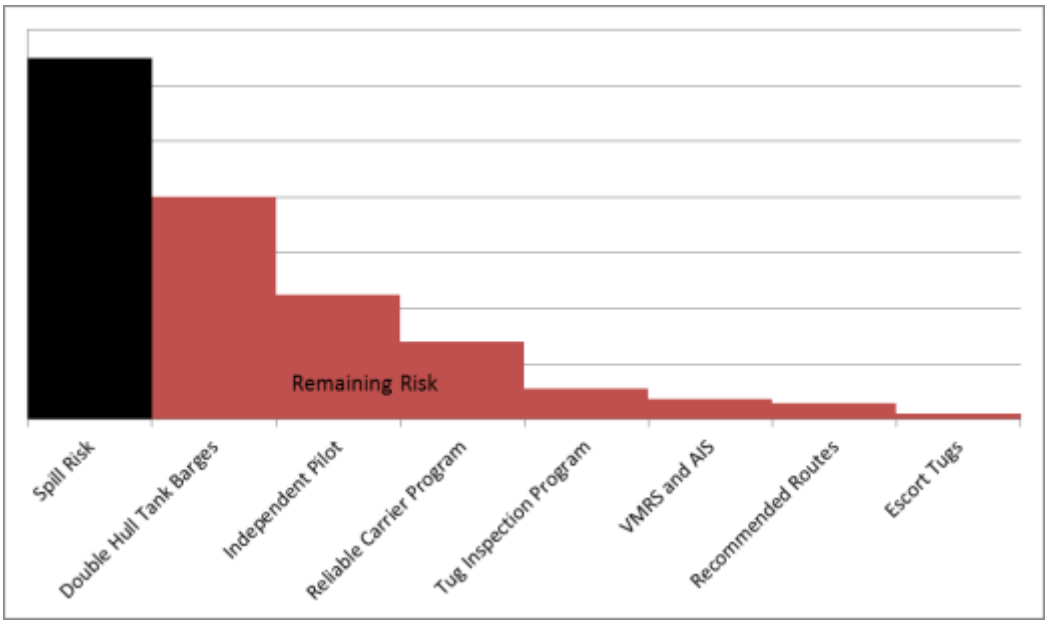

Figure 29: Summary View – Spill Risk, Mitigation, and Acceptable Risk

6.2 Change Analysis

Table 13 is a summary of the anticipated effects of various changes to the current requirements for towing vessels and tank barges carrying more than 5,000 barrels of oil while operating in Buzzards Bay.[65] It is a qualitative assessment using information developed during interviews with pilots, towboat operators, and government officials, and represents the opinions of the study authors.

For purposes of this Change Analysis, the following assumptions are made regarding the base conditions for towing vessels and barges operating in the Buzzards Bay RNA and Buzzards Bay Area of Special Interest:

1. All tank barges transiting Buzzards Bay are double-hulled. Currently, approximately 2 percent of the barges operating in Buzzards Bay are single-hulled (down from 25 percent in 2003). The trend toward double-hull construction will continue until January 1, 2015, when all tank barges operating in U.S. waters are required to be of double-hull construction.[66, 67]

[65] U.S. Coast Guard regulations for Buzzards Bay RNA apply to tank vessels carrying more than 5,000 barrels of oil or hazardous materials. The Commonwealth of Massachusetts's requirements for the Buzzards Bay Area of Special Interest apply to tank vessels carrying more than 6,000 barrels of oil. For purposes of this analysis, the smaller size vessel was selected but only oil-carrying tankers were included.

[66] U.S. Army Corps of Engineers, 2003–2011 Tank Barge Transit Data for the Cape Cod Canal. Data developed by personal request of the U.S. Army Corps of Engineers Cape Cod Canal operating staff.

[67] OPA 90 and U.S. Coast Guard implementing regulations require all tank barges (and tank ships) over a certain size to be of double-hull construction by January 1, 2015.

2. In addition to the transition to double-hull, all design, construction, and operations of tank barges transiting Buzzards Bay are assumed to remain unchanged.
3. Escort tugs are not required to accompany towing vessels and tank barges (now all double-hulled under these assumptions).
4. All towing vessels have undergone a voluntary examination under the Coast Guard's Towing Vessel Inspection Bridging program (33 CFR Subchapter M) or are subject to a Towing Vessel Safety Management System, such as the AWO Responsible Carrier Program, that is audited by a third party. This change analysis has not assessed the potential impact of the Towing Vessel Inspection program on safety and environmental protection in Buzzards Bay.
5. No navigating pilot in addition to the regular crew, either federal or state, is required to be aboard towing vessels transiting Buzzards Bay since all barges are assumed to be double-hulled.
6. Firefighting capability on towing vessels and other tugs that may be available to support response to an incident are equipped with a National Fire Protection Association (NFPA) V firefighting capability.
7. Buzzards Bay is a RNA with requirements for vessels operating there, including navigational equipment designed to prevent certain types of incidents.
8. Buzzards Bay is an Estuary of National Significance designated by the U.S. Environmental Protection Agency in 1987.
9. The Buzzards Bay VMRS, operated by the U.S. Army Corps of Engineers in conjunction with the USCG, is a passive vessel-monitoring program that does not directly control vessel movements but requires active users to transmit positions using identified checkpoints. It provides broadcast navigational information to vessels operating in Buzzards Bay.

Table 13 lists the types of events that may result in an oil spill from a tank barge operating on Buzzards Bay. The events that have been identified are (1) drifted or low-energy grounding, (2) powered or high-energy grounding, (3) collision, and (4) allision. These categories of events have been identified by the USCG as causing the greatest number of casualties from 2001 to 2010.[68]

Change activities are those situations that may alter the probability of an event occurring or reduce the magnitude of such an event. The change activities identified for this analysis are included in **Table 13**: (1) require an escort tug for all vessels towing a tank barge carrying more than 5,000 barrels of oil or hazardous substances, (2) require an escort tug during periods of adverse weather or when determined necessary, (3) require a sentinel, or response, tug in lieu of an escort tug to be available on demand for vessels and tank barges operating on Buzzards Bay, (4) require a pilot in addition to the crew on all vessels towing a tank barge carrying more than

[68] U.S. Coast Guard, "*Improvement to Reduce Human Error and Near-Miss Incidents, 2012 Report to Congress*," Washington DC, May 7, 2012. "Material failure" was identified as a cause of an oil spill in 72 percent of the casualties in the Coast Guard Study but resulted in 13 percent of the oil spilled. The report further notes that 62 percent of the reported "material failure" incidents were the result of "hull plating" and another 20 percent were the result of cargo handling equipment (pumps, piping, etc.). This report assumes that there will be no change in design or construction of tank barges, so means to reduce the number of "material failure" incidents (e.g., increase hull plate thickness) are not included in the analysis. To the extent that a "material failure" incident would ultimately lead to grounding, collision, or allision, it has been taken into consideration.

5,000 barrels of oil or hazardous substances, (5) upgrade the current VMRS for Buzzards Bay to an active Vessel Traffic Management System with authority to control vessel movements, and (6) require that sentinel or escort tugs be equipped with firefighting capability that meets the American Bureau of Shipping (ABS) standards for Firefighting vessel Type 1 (FiFi1).[69]

These risk mitigation measures are taken from the current federal requirements for single-hull barges operating in Buzzards Bay, from Massachusetts state requirements for all barges operating in Buzzards Bay, from the Ports and Waterways Safety Assessment report for Buzzards Bay, and from an analysis of other measures used in selected ports around the United States.

Even though the base condition for this report assumes that all barges will be double-hulled, the impact of double hulls is included in this analysis to show the overall effect that the change from single hulls to double hulls has on the risk of barges operating in the United States generally and in Buzzards Bay. It establishes that the singular action of changing to all double hulls has and will continue to have a dramatic effect on the potential for an oil spill from the types of events identified as the causes of oil spills from tank barges, particularly since the B-120 incident in 2003.

[69] The differences between the two classifications are provided in Appendix A, Section A 1.2 of this report.

Table 13: Summary of Potential Effects for Changes on Current Conditions in Buzzards Bay

Base Condition	Overall Potential Effect	Potential Effect on Drifted Grounding	Potential Effect on Powered Grounding	Potential Effect on Collision	Potential Effect on Allision
Change of barge configuration from single hull to 100% double hull	Substantially reduces probability of oil outflow in 2015 when all tank barges will be double-hulled. Probability of oil outflow will reduce as more single-hull barges are retired and replaced.	Minimizes potential for any oil outflow.	Reduces potential for oil outflow depending on momentum, draft, water depth, and whether grounded on ledges or shoals.	Debatable impact on oil outflow caused by collisions if barge is struck in way of the amidships area.	Reduces potential for oil outflow.
Difference from Current Condition					
Require escort tug	Secondary control is immediately available in the event of power or steering loss. Immediate assistance is available in the event of an incident. Other assistance as may be required by the Towing Vessel Master would be available. Escort tug masters are familiar with Buzzards Bay and would provide navigation, hazard avoidance warning, and advice.	Drifted groundings will be prevented. This is especially notable in high winds. But the probability of loss of oil in this type of event is very low with double-hull barges.	Powered groundings may be prevented depending on positioning of escort tug and the ability to detect a potential grounding situation. Escort tug would be available to assist grounded barge. Potential additional notification of a hazardous situation.	Escort tug has limited value in collision if positioned astern of towing vessel but escort tug radar may observe potential collision situation developing. Escort tug would be available to tow damaged vessels. Potential additional notification of a hazardous situation.	Minimal decrease in frequency of allision unless escort tug is made up alongside. Escort tug has limited value in allision if positioned astern or ahead of towing vessel. Potential additional notification of a hazardous situation.
Require escort tug in adverse weather or when determined necessary	Escort tugs would reduce risk in most situations if escort tug is positioned to maximize its utility. Adverse weather thresholds need to be determined. Other appropriate conditions could be associated with loss of redundant systems or other condition adversely affecting the towing vessel and barge.	Drifted grounding in high winds would be prevented. Additional redundant systems available.	Risk of powered groundings will be reduced depending on positioning of escort tug and the ability to detect a potential grounding situation. Potential additional notification of a hazardous situation.	Escort tug has limited value in collision if positioned astern of towing vessel but escort tug radar may observe potential collision situation developing. Potential additional notification of a hazardous situation.	If escort tug is made up alongside, risk of allision is reduced due to additional maneuvering capability. Potential additional notification of a hazardous situation.

Base Condition	Overall Potential Effect	Potential Effect on Drifted Grounding	Potential Effect on Powered Grounding	Potential Effect on Collision	Potential Effect on Allision
Require sentinel or response tug in lieu of escort tug	No secondary control is available for incidents unless sentinel tug is called out during adverse weather. Assistance to a barge involved in an incident would be available but response time would depend on location and readiness condition of sentinel tug and crew.	Sentinel tug would not be available to prevent a drifted grounding. Sentinel tug can respond to assist grounded barge and potentially minimize the impact of the casualty.	Sentinel tug would not be available to prevent a powered grounding. Sentinel tug can respond to assist grounded barge and potentially reduce the impact of the casualty.	Sentinel tug would not be available to prevent a collision. Sentinel tug can respond to assist barge in a collision and potentially reduce the impact of the casualty.	Sentinel tug would not be available to prevent an allision. Sentinel tug can respond to assist grounded barge and potentially reduce the impact of the casualty.
Require a pilot (federal or state) on all towing vessels with barges carrying more than 5,000 barrels of oil or hazardous substances.	Reduced risk of an incident due to human error. Some impact on an incident resulting from an equipment failure, such as loss of steering or power, due to the availability of additional licensed person on board. Direct and independent notification of a hazardous situation.	Decreased risk of drifted grounding caused by human error due to additional navigating crew. Limited impact on powered grounding as a result of steering gear or loss of power.	Decreased risk of powered grounding caused by human error. Limited impact on powered grounding as a result of steering gear or loss of power. Direct and independent notification of a hazardous situation.	Decreased risk of collision caused by human error. Limited impact on collision as a result of steering gear failure or loss of power. Direct and independent notification of a hazardous situation.	Decreased risk of allision caused by human error. Limited impact on allision as a result of steering gear failure or loss of power. Direct and independent notification of a hazardous situation.
Active management of vessel traffic (upgrade VMRS)	Would require increased resources (personnel and equipment) to operate. Towing vessels would receive navigation information and information about other vessels in the area from a Vessel Traffic Center (VTC). VTC would monitor and maintain track of all vessel movements while in the VMRS area. Towing vessel Master would remain in charge of tow but could be subject to controls from the VTC. Sentinel or response tug could be dispatched by VTC when needed during adverse weather or following an incident.	Some positive effect on drifted grounding caused by steering gear failure or loss of power. Drifted grounding as a result of human error is reduced.	Reduced risk of powered grounding by tracking vessel route. Some reduction in probability of a powered grounding as a result of steering gear failure. VTC can warn other vessels of the situation.	Reduced risk of collision caused by human error. Some reduction in probability of a collision as a result of steering gear failure or loss of power. VTC can warn other vessels of the situation.	Reduced risk of allision caused by human error. Limited impact on allision as a result of steering gear failure or loss of power.

Base Condition	Overall Potential Effect	Potential Effect on Drifted Grounding	Potential Effect on Powered Grounding	Potential Effect on Collision	Potential Effect on Allision
Require FiFi1 firefighting capability for escort or sentinel tug	FiFi1 capability provides substantial firefighting capability in the event of a fire or explosion, but will require supplementary capability for any significant event. Collision would be the type of incident that may benefit most from a FiFi1 tug. Without a requirement for FiFi1, there are no major offshore firefighting resources available in Buzzards Bay. It is unknown if industry would provide FiFi1 capability without a regulatory requirement.	No impact from drifted grounding incident.	Minimal impact in the event of a powered grounding. Any potential fire may be controlled by NFPA Type V systems.	Positive effect in a full-powered collision with another tank vessel. Escort tug firefighting capability would need to be supplemented by additional firefighting assets to remain effective.	Minimal effect. NFPA Type V-equipped tug should be able to control a fire or potential fire from an allision. Shore-side firefighting resources could be available to support water-side firefighting.

6.2.1 Quantifying Change

Table 14 provides a frequency score that qualitatively assesses the impact of the change activity on an oil spill event resulting from a casualty. Because there are gradations in the potential impact of change action on the frequency of a casualty, a range of scores is provided for each impact. For example, an anticipated reduction in the frequency of an event as a result of the implementation of a change action is assigned a score range from -3 to -5. If there is no anticipated change in the frequency of an event as a result of the implementation of a change action, the change action is assigned a score of 1. An anticipated increase in the frequency of an event as a result of the implementation of a change action is assigned a score range of 3 to 5.

Table 14: Impact Scores

Impact Score Description	Impact Score
Decreased Frequency of an Event	-3 to -5
No Anticipated Change in Frequency of an Event	1
Increased Frequency of an Event	3 to 5

The USCG Report to Congress on means of reducing casualties involving human error and near-miss incidents recorded that 128 incidents involving tank barges resulted in spills totaling 3 million gallons of oil from 2001 to 2010.[70] Of the 128 incidents over that 10-year period, "material failure" accounted for 92 incidents and 76 of those 92 were attributed to "hull-plating failure" or "cargo pumps, piping, and fittings." These incidents indicate a need to manage material failures. Finally, three "explosions" occurred while the barges were moored and have also been eliminated from this analysis since they did not involve vessels underway.

The resulting 47 incidents from 2001 to 2010 included 17 allisions, 8 collisions, 6 powered groundings, and 16 "material failure-other" which this analysis assumes to have resulted in drifted groundings.

The volume of 2.5 million gallons of oil spilled from those 47 incidents includes 2 million gallons attributed to allision, of which one incident accounted for 1.8 million gallons, the sinking of the double-sided, single-bottom barge DBL-152. In that incident, the barge struck a submerged oil platform previously sunk in Hurricane Rita.[71] In the opinion of the analysts for this project, this incident does not reflect a typical allision and may have otherwise been classified as a capsizing and sinking.[72]

The other two "sinking" incidents in the data resulted in minor spills (11 gallons) and were attributed to improper maintenance. The impact of classifying the DBL 152 incident as a sinking, grounding, or allision was analyzed. It was determined that it is an anomalous situation in any of the other casualties but has the least effect on this analysis if classified as a "sinking." It represents the loss of the entire cargo on board the vessel, a condition that has not been found in any of the other incidents examined. None of the sinking incidents is included in this analysis.

[70] U.S. Coast Guard, Ibid.

[71] U.S. Coast Guard, Ibid.

[72] The AWO defines allision as a "collision with fixed objects such as bridges, locks, or docks," http://www.americanwaterways.com/commitment_safety/stats.pdf, November 2012.

The 46 remaining incidents reported released a total of 730,000 gallons of oil during that 10-year period. While this is a precariously small population from which to make a quantitative assessment, it is useful in qualitatively assigning relative probabilities and relative severity of the types of casualties to assist in the measure of "riskiness" of an event.

Table 15 shows the relative frequency scores that have been assigned for the casualty types identified in this analysis. The probability of a casualty being a certain type is calculated from the frequency of the 46 casualties by type as noted previously.

Table 15: Frequency Score

Casualty Type	Historical % of Incidents	Frequency Score
Drifted Grounding	34.8	3
Powered Grounding	13.0	2
Collision	17.4	2
Allision	34.8	3

Using the Impact Score in connection with the Frequency Score will provide the relative effect of various change actions on each casualty type. **Table 16** shows the Frequency Impact score for each type of casualty.

Table 16: Frequency Impact Score

Casualty Type	Impact Score			Frequency Score	Frequency Impact Score		
	Decreased Frequency	No Change	Increased Frequency		Decreased Frequency	No Change	Increased Frequency
Drifted Grounding	-3 to -5	1	3 to 5	3	-9 to -15	3	9 to 15
Powered Grounding				2	-6 to -10	2	6 to 10
Collision				2	-6 to -10	2	6 to 10
Allision				3	-9 to -15	3	9 to 15

Table 17 provides the basis for assigning a Severity Score to an incident that may be prevented by the implementation of the various activities.[73] These values are derived from the Coast Guard Risk-Based Decision Guidelines. For example, an activity that prevents a major spill resulting from a powered grounding is assigned a score of 5. An activity that prevents a minor spill, such as preventing drifted groundings, is assigned a score of 1.

Table 17: Incident Severity by Impact Area[74]

Severity	Score	Economic Impact	Environmental Impact	Safety Impact
Major	5	> $3 million	Releases that result in long-term disruption of the ecosystem or long-term exposure to chronic health risks (major oil spill)	One or more deaths or permanent disability

[73] U.S. Coast Guard, "*Risk-Based Decision-Making Guidelines, Change Analysis*," Volume 3, Chapter 7, 2nd Edition, Washington, DC.

[74] http://www.americanwaterways.com/commitment_safety/Stats_Report_1Aug12.pdf.

Severity	Score	Economic Impact	Environmental Impact	Safety Impact
Moderate	3	$10K to < $3 million	Releases that result in short-term disruption of the ecosystem (medium oil spill)	Injury that requires hospitalization or lost work days
Minor	1	$100 to < $10K	Pollution with minimal acute environmental or public health impact (minor oil spill)	Injury that requires first aid

The analysis of the USCG's tank barge casualty data referenced above allows a measure of the relative severity of the types of casualties experienced.[75] **Table 18** shows the relative severity of each type of casualty as measured by the average volume of oil spilled in those casualties. The Incident Severity was then applied to each casualty type to obtain a Severity Score.

Table 18: Severity Score

Type of Casualty	Spill Volume by Casualty Type	Severity Score by Casualty Type
Drifted Grounding	0.0005	1
Powered Grounding	0.1080	3
Collision	0.6180	5
Allision	0.2735	3

A Total Risk Score has been established for each casualty type to represent the change in the frequency of a casualty as a result of a change activity and the severity of the event prevented. It is derivative of the equation for risk (TRS) as the frequency of an event (F) times the consequence of that event (C).

$$TRS=F \times C$$

The greater a negative TRS for a particular change action indicates the greater the reduced risk of an event. Conversely, a higher TRS indicates a greater risk of an event from the change that may result in an oil spill. The Frequency Impact Score taken from **Table 13** is used to measure F while the Severity Score within the range of those indicated in **Table 14** has been assigned as a measure of Consequence (C).

6.2.2 Drifted Grounding

Table 19 shows the Total Risk Score for changes to the current situation in Buzzards Bay in the event of a drifted or low-energy grounding. This type of incident is typified by an unpowered event in which the movement of the barge is generated by wind or tidal currents with little momentum. The USCG classifies groundings as "high-frequency/low-consequence" events based on historical data.[76] That categorization should continue with the transition to all double-hull tank barges.

[75] U.S. Coast Guard, Ibid.

[76] U.S. Coast Guard, Ibid.

Table 19: Drifted Grounding Change Analysis

Activity	Potential Effect	Frequency Impact Score	Severity Score	Total Risk Score
Change of barge configuration from single hull to 100% double hull	Minimizes potential for any oil outflow.	-15	1	-15
Require escort tug	Drifted groundings will be prevented. This is especially notable in high winds. But the probability of loss of oil in this type of event is very low with double-hull barges.	-15	1	-15
Require escort tug in adverse weather or when determined necessary	Drifted grounding in high winds would be prevented. Additional redundant systems available.	-15	1	-15
Require sentinel or response tug in lieu of escort tug	Sentinel tug would not be available to prevent a drifted grounding. Sentinel tug can respond to assist a grounded barge and potentially minimize the impact of the casualty.	3	1	3
Require a pilot (federal or state) on all towing vessels with barges carrying more than 5,000 barrels of oil or hazardous substances	Decreased risk of drifted grounding caused by human error due to additional navigating, providing validation or collaboration for the response. Limited impact on powered grounding as a result of steering gear or loss of power.	-9	1	-9
Active management of vessel traffic (upgrade VMRS)	Some positive effect on drifted grounding caused by steering gear failure or loss of power. Drifted grounding as a result of human error is reduced.	-9	1	-9
Require FiFi1 firefighting capability for escort or sentinel tug	No impact from drifted grounding incident.	3	1	3

Since drifted or low-energy groundings do not typically result in large-scale spill incidents, it is not surprising that changes to the current condition or situation would have limited impact. The greatest potential for preventing an incident related to a drifted grounding will come as a result of the change from single-hull tank barges to double-hull tank barges and requiring escort tugs, especially in adverse weather.

6.2.3 Powered Grounding

Table 20 provides the Total Risk Score for the impact of changes to the current situation in Buzzards Bay in the event of a powered or high-energy grounding. This type of incident is typified by a powered event in which the movement of the barge is generated by the towing vessel, configured for either pushing or towing. Momentum in these incidents may be high as a result of the mass of a laden tank barge and speed of the tow, depending on the bottom configuration of the surface on which the barge grounds. Momentum may be sufficient to rupture the hull of a single-hull tank barge but, in most instances, would not be sufficient to rupture both hulls of double-hull tank vessels.[77]

[77] The Glosten Associates, "*Study of Tug Escorts in Puget Sound*," prepared for the State of Washington, Department of Ecology, December 2004. The study found that double hulls increase the probability of "zero outflow" of oil as a result of grounding to about 80% compared with 10–20% for single-hull tank vessels.

Table 20: Powered Grounding Change Analysis

Activity	Potential Effect	Frequency Impact Score	Severity Score	Total Risk Score
Change of barge configuration from single hull to 100% double hull	Reduces potential for oil outflow depending on momentum, draft, water depth, and whether grounded on ledges or shoals.	-10	3	-30
Require escort tug	Powered groundings may be prevented depending on positioning of escort tug and the ability to detect a potential grounding situation. Escort tug would be available to assist grounded barge.	-10	3	-30
Require escort tug in adverse weather or when determined necessary	Risk of powered groundings will be reduced depending on positioning of escort tug and the ability to detect a potential grounding situation.	-10	3	-30
Require sentinel or response tug in lieu of escort tug	Sentinel tug would not be available to prevent a powered grounding. Sentinel tug can respond to assist grounded barge and potentially reduce the impact of the casualty.	-6	3	-18
Require a pilot (federal or state) on all tow vessels for barges carrying more than 5,000 barrels of oil or hazardous substances	Decreased risk of powered grounding caused by human error. Limited impact on powered grounding as a result of steering gear or loss of power.	-10	3	-30
Active management of vessel traffic (upgrade VMRS)	Reduced risk of powered grounding by tracking vessel route. Some reduction in probability of a powered grounding as a result of steering gear failure. VTC can warn other vessels of the situation.	-6	3	-18
Require FiFi1 firefighting capability for escort or sentinel tug	Minimal impact in the event of a powered grounding. Any potential fire may be controlled by NFPA Type V systems.	2	3	6

Unlike drifted grounding, the potential consequences of a powered or high-energy grounding are substantial. Major spills from single-hull tank barges have occurred and the ability to limit the risk of such events reflects the higher severity score for each of the change elements.

Table 21 is the Collision Change Analysis. Collisions occur when a meeting, crossing vessel, or an overtaking vessel maintains a constant bearing with decreasing range on another vessel. Unless action is taken by one vessel or the other in accordance with established "Rules of the Road" in sufficient time to avoid the collision situation, both vessels will find themselves "in extremis" and be forced to take immediate action or run the risk of colliding with each other. The ability to prevent a collision situation from developing requires vigilance of vessel traffic in the vicinity and an understanding of the track and intentions of vessels in the area. The emergence of Collision Avoidance Radar, Automatic Plotting Aids (ARPA), and Automated Identification Systems (AIS) has substantially reduced, but not eliminated, the risk of collision.[78]

[78] N. Ward and S. Leighton, "*Collision Avoidance in the e-Navigation Environment*," General Lighthouse Authorities of the United Kingdom and Ireland, The Research and Radio Navigation Directorate, http://www.gla-rrnav.org, November 2012.

Table 21: Collision Change Analysis

Activity	Potential Impact	Frequency Impact Score	Severity Score	Total Risk Score
Change of barge configuration from single hull to 100% double hull	Debatable impact on oil outflow caused by collisions if barge is struck in way of the amidships area but oil outflow may be reduced in many collisions.	-6	5	-30
Require escort tug	Escort tug has limited value in collision if positioned astern of towing vessel but escort tug radar may observe potential collision situation developing. Escort tug would be available to assist grounded barge.	-6	5	-30
Require escort tug in adverse weather or when determined necessary	Escort tug has limited value in collision if positioned astern of towing vessel but escort tug radar may observe potential collision situation developing.	-6	5	-30
Require sentinel or response tug in lieu of escort tug	Sentinel tug would not be available to prevent a collision. Sentinel tug can respond to assist barge in a collision and potentially reduce the impact of the casualty.	2	5	10
Require a pilot (federal or state) on all tow vessels for barges carrying more than 5,000 barrels of oil or hazardous substances	Decreased risk of collision caused by human error. Limited impact on collision as a result of steering gear failure or loss of power.	-10	5	-50
Active management of vessel traffic (upgrade VMRS)	Reduced risk of collision caused by human error. Some reduction in probability of a collision as a result of steering gear failure or loss of power. VTC can warn other vessels of the situation.	-6	5	-30
Require FiFi1 firefighting capability for escort or sentinel tug	Positive effect in a full-powered collision with another tank vessel. Escort tug firefighting capability would need to be supplemented by additional firefighting assets to remain effective.	-6	5	-30

As with powered groundings, the severity of an incident caused by a collision is substantial. Collisions may be high-energy events, unless both vessels are not under power. The addition of a pilot provides the greatest reduction in the risk of collision. The availability of an additional navigating capability appears to provide the greatest opportunity to prevent a collision situation from developing in the first instance.

6.2.4 Allision

Allisions occur when a vessel strikes a fixed or stationary object.[79] The greatest risk of allision occurs when a towing vessel is in a pushing configuration, sometime referred to as being "in the

[79] AWO, "*Report of the U.S. Coast Guard-American Waterways Operators Bridge Allision Work Group*," http://www.uscg.mil/hq/cg5/cg5211/docs/BAWGfinal_report.pdf, May 2003.

notch." Allisions can be high-energy events but they are infrequent.[80] A 2003 study of allisions by the USCG and the AWO found that 61 bridge allisions occurred between 1992 and 2001 that resulted in damage of $500,000 or more.[81]

Table 22: Allision Change Analysis

Activity	Potential Impact	Frequency Impact Score	Severity Score	Total Risk Score
Change of barge configuration from single hull to 100% double hull	Reduces potential for oil outflow.	-15	3	-45
Require escort tug	Minimal decrease in frequency of allision unless escort tug is made up alongside. Escort tug has limited value in allision if positioned astern or ahead of towing vessel.	-9	3	-27
Require escort tug in adverse weather or when determined necessary	If escort tug is made up alongside, risk of allision is reduced due to additional maneuvering capability.	-9	3	-27
Require sentinel or response tug in lieu of escort tug	Sentinel tug would not be available to prevent an allision. Sentinel tug can respond to assist grounded barge and potentially reduce the impact of the casualty.	3	3	9
Require pilot (federal or state) on all tow vessels for barges carrying more than 5,000 barrels of oil or hazardous substances.	Decreased risk of allision caused by human error. Limited impact on allision as a result of steering gear failure or loss of power.	-15	3	-45
Active management of vessel traffic (upgrade VMRS)	Reduced risk of allision caused by human error. Limited impact on allision as a result of steering gear failure or loss of power.	-9	3	-27
Require FiFi1 firefighting capability for escort or sentinel tug	Minimal effect. NFPA Type V-equipped tug should be able to control a fire or potential fire from an allision. Shore-side firefighting resources could be available to support water-side firefighting.	3	3	9

The severity score reflects the historical spill volumes from incidents involving allisions and the value of damage that may be prevented through various measures (releases that result in short-term disruption of the ecosystem or economic damages of $10K to less than $3 million). The analysis shows that an additional pilot will result in the greatest improvement on the situation in Buzzards Bay, while an escort tug and active VMRS will provide positive impact as well.

6.2.5 Summary Risk Score Legend

The individual TRSs for each change action have been added together to reach an Overall Risk Score for each change action for all categories of casualties, shown in **Table 23**. The scores are

[80] U.S. Coast Guard, Ibid. The study found that less than 10% of tank barge casualties were the result of allision and one incident involving the tank barge DBL-152 accounted for about 90% of the oil spilled as a result of allision between 2001 and 2010.

[81] AWO, May 2003. The report noted that the level of confidence for these statistics is substantially affected by the relative dearth of incidents. This study also included a substantial number of bridge allisions on the Western Rivers of the United States.

highlighted according to the legend below. Green is a positive change; red represents a change that increases risk. The actual colors in the table are scaled to the overall risk score summaries to the scale shown in the legend. **Table 24** is the same data sorted from lowest to highest TRS.

Table 23: Overall Risk Score, Sorted by TRS

Activity	Risk Score for Each Category of Casualty				Overall Risk Score
	Drifted Grounding	Powered Grounding	Collision	Allision	
Change of barge configuration from single hull to 100% double hull	-15	-36	-30	-45	-120
Require escort tug	-15	-30	-30	-27	-102
Require sentinel or response tug in lieu of escort tug	3	-18	10	9	4
Require a pilot (federal or state) on all towing vessels with barges carrying more than 5,000 barrels of oil or hazardous substances	-9	-30	-50	-45	-134
Active management of vessel traffic (upgrade VMRS)	-9	-18	-30	-27	-84
Require FiFi1 firefighting capability for escort or sentinel tug	3	6	-30	9	-12

Legend:	
	Change contributes most to risk mitigation
	50th Percentile
	Change contributes least to risk mitigation

Table 24: Overall Risk Score, Sorted by Change Impact

Activity	Risk Score for Each Category of Casualty				Overall Risk Score
	Drifted Grounding	Powered Grounding	Collision	Allision	
Require a pilot (federal or state) on all towing vessels with barges carrying more than 5,000 barrels of oil or hazardous substances	-9	-30	-50	-45	-134
Change of barge configuration from single hull to 100% double hull	-15	-36	-30	-45	-120
Require escort tug	-15	-30	-30	-27	-102
Active management of vessel traffic (upgrade VMRS)	-9	-18	-30	-27	-84
Require FiFi1 firefighting capability for escort or sentinel tug	3	6	-30	9	-12
Require sentinel or response tug in lieu of escort tug	3	-18	10	9	4

The results of this analysis indicate that the greatest decrease in risk for tank barges operating in Buzzards Bay occurs with the addition of a pilot in addition to the crew, followed by the change to double hulls and then by the addition of escort tugs.

6.3 "What-If" Analysis

The "What-If" analysis provides an assessment of risk if an incident occurs, regardless of the probability of the incident occurring, and mitigation measures that may be available to reduce consequences. It emphasizes consequence and is useful for determining the outcomes of a decision.

Scenarios have been selected to conduct the "What-If" analysis based on the conditions that are likely to be present or not that may lead to an incident. For example, the "Change Analysis" in this report evaluated four types of incidents that may occur: drifted or low-energy grounding, powered or high-energy grounding, collision between a tank barge and another vessel, and an allision by a tank barge with a fixed object. As with the Change Analysis, the barges involved in the incidents are assumed to be of double-hull construction. Scenarios have been developed for two separate constructs: Reactive and Proactive. Reactive Scenarios identify activities in response to a vessel casualty or human factor error. Proactive scenarios describe activities in response to forecast conditions or expected events.

6.3.1 Reactive Scenarios

The conditions that would or would not exist associated with the transit of a barge are (1) presence of an escort tug, (2) absence of an escort tug, (3) pilot on board the towing vessel in addition to the crew, and (4) no additional pilot on board the towing vessel. All other assumptions used for the Change Analysis are used here.

Scenario 1 – Drifted Loaded Barge Grounding: A towing vessel with a fully-laden double-hull tank barge carrying Number 6 fuel oil is moving east through Buzzards Bay in 35-knot winds. The towing cable parts in the vicinity of Gong Buoy No. 10. The barge drifts out of the channel and strikes a ledge just west of the buoy. The barge sits on the northern edge of the ledge at low tide.

Scenario 2 – Powered Loaded Barge Grounding: A towing vessel pushing a fully-laden double-hull tank barge carrying Number 6 fuel oil leaves the channel near Cleveland East Ledge Light traveling at 6 knots. The barge strikes the ledge, opening the outer hull. The barge is firmly fixed on the ledge.

Scenario 3 – Collision between Loaded Tank Barge and Tanker: A fully-laden double-hull tank barge carrying Number 6 fuel oil being towed astern is struck amidships by a small coastal tanker crossing the Recommended Route.

Scenario 4 – Allision between Loaded Tank Barge and Southern Tower of Railroad Lift Bridge: A fully-laden double-hull tank barge carrying Number 6 fuel oil being pushed by a towing vessel strikes the southern tower of the Cape Cod Canal Railroad Lift Bridge.

Table 25: What-If Analysis Results – Reactive Scenarios

Scenario	Consequence With Escort Tug	Consequence Without Escort Tug	Consequence With Pilot	Consequence Without Pilot
1. Drifted Loaded Barge Grounding (Low Energy)	Escort tug could have secured barge prior to grounding. No oil released.	Barge would ground but probability is low that oil would be released. Low probability that oil is released.	Barge would ground but probability is low that oil would be released. No oil released.	Barge would ground but probability is low that oil would be released. No oil released.
2. Powered Loaded Barge Grounding (High Energy)	Escort tug running astern would be available to assist towing vessel secure barge but probably not prevent incident. Oil may be released if momentum is sufficient to penetrate both barge hulls.	Barge would ground. Oil may be released if momentum is sufficient to penetrate both barge hulls.	Pilot would have observed navigational error and made correction probably preventing grounding. Oil may be released if momentum is sufficient to penetrate both barge hulls.	No additional crew to observe navigational error and barge would ground. Oil may be released if momentum is sufficient to penetrate both barge hulls.
3. Collision between Loaded Tank Barge and Tanker (High Energy)	Escort tug running astern of towed barge would allow awareness of developing collision condition and could notify crossing vessel to avoid collision.	No additional resource to provide awareness of developing collision condition. Oil may be released if colliding vessel penetrates both barge hulls.	Pilot would be available to observe developing collision condition and could notify crossing vessel to avoid collision.	No additional navigating crew to provide awareness of developing collision condition. Oil may be released if colliding vessel penetrates both barge hulls.
4. Allision between Loaded Tank Barge and Tower of Railroad Lift Bridge (Medium Energy)	Escort tug running astern is available to assist towing vessel secure barge but probably not prevent incident. Oil may be released if momentum is sufficient to penetrate both barge hulls.	Barge would allide. Oil may be released if momentum is sufficient to penetrate both barge hulls.	Pilot would have observed navigational error and made correction probably preventing grounding. Oil may be released if momentum is sufficient to penetrate both barge hulls.	No additional crew to observe navigational error and barge would allide. Oil may be released if momentum is sufficient to penetrate both barge hulls.

The results indicate that scenario 3, the high-energy collision between a tank barge and another tanker, results in the highest probability of a release of oil when there is no escort tug or additional pilot present.

6.3.2 Risk Mitigation Measures Scenarios

Proactive scenario test conditions that would or would not exist associated with the transit of a barge are (1) presence of an escort tug, (2) absence of an escort tug, (3) pilot on board the towing vessel in addition to the crew, and (4) no additional pilot on board the towing vessel. All other assumptions used for the Change Analysis are used here.

- **Scenario 1 –** A towing vessel with a fully-laden double-hull tank barge carrying Number 6 fuel oil is scheduled to transit through Buzzards Bay. The weather forecast calls for high winds exceeding 35 knot winds, with higher gusts. (Transit in hazardous weather)
- **Scenario 2 –** A towing vessel with a fully-laden double-hull tank barge carrying Number 6 fuel oil is scheduled to transit through Buzzards Bay. The tow boat company is a participant in the Responsible Carrier Program. During the approach to Buzzards Bay, the

steering system fails, but is repaired with onboard spares. (Vessel transit with a recent history of material failures)

- **Scenario 3 –** A towing vessel with a fully-laden double-hull tank barge carrying Number 6 fuel oil is scheduled to transit through Buzzards Bay. The vessel was recently inspected under a voluntary inspection program, which identified electrical connection corrosion in the main and standby generators, which could cause shorting of the electrical system. The inspector recommended servicing the generator during the next maintenance availability. (Vessel transit with a failed major system component inspection)
- **Scenario 4 –** The Acme Towing Company lost its certification in the Responsible Carrier Program after a series of near-miss incidents in New York (failure of a towing hawser), Philadelphia (a near-collision where the ACME tug had agreed to a passing situation but failed to act on the agreed-upon plan), and Jacksonville (a grounding where the ACME tug master had transited outside a marked channel and grounded on a shoal). (Company vessel transit with a history of incidents)

Table 26: What-If Analysis Results – Proactive Scenarios

Scenario	Consequence With Escort Tug	Consequence Without Escort Tug	Consequence With Pilot	Consequence Without Pilot
1. Transit in hazardous weather	Escort tug is coordinated prior to arrival to support the transit through Buzzards Bay and the Canal. No oil released.	Vessel transits in high winds and increases risk of an incident. Or Master delays trip until weather conditions improve. No oil released.	Pilot assists with navigation decisions, emergency operations, and identification of other risks, vessels, and hazards.	Master decision making during transit is reduced.
2. Vessel transit with a recent history of material failures	Risk reduced because escort tug provides redundant navigation systems and immediate towing capability.	No risk reduction. Potential for material failure exists.	Additional decision-making capability available to determine course of action if casualty occurs.	No reduction in risk of casualty.
3. Vessel transit with a failed major system component inspection	Risk reduced because escort tug provides redundant navigation systems and immediate towing capability.	No risk reduction. Potential for component failure exists.	Additional decision-making capability available to determine course of action if casualty occurs.	No reduction in risk of casualty.
4. Company vessel transit with a history of incidents	Risk reduced because escort tug provides redundant navigation systems and immediate towing capability.	No risk reduction.	Additional decision-making capability available to determine course of action if casualty occurs.	No reduction in risk of casualty.

7 Cost Analysis

The costs of oil spills are dependent on many factors such as oil type, location of the incident, shoreline impacted, and cleanup strategy selected. As noted by one researcher in the area of oil spill response costs, "Predicting the per-unit cost of a spill response is a highly imprecise science since the factors impacting cost are as complex as the factors impacting the degree of damage the spilled oil will cause. Clearly, one universal per-unit cost is meaningless in the face of these complex factors."[82]

Identifying all of the costs involved in an oil spill in the United States has been particularly difficult since the National Response System (NRS), the system of oil spill response in the United States established by OPA 90, requires the cleanup to be undertaken by the polluter or Responsible Party (generally, the owner, operator, or person in charge of the source of the spilled oil). Additionally, the Responsible Party is responsible for cleanup costs to the Limit of their Liability established in OPA 90. In many instances, these private sector costs are borne by liability insurers. As a result, most spill costs reflect the limit of liability for the Responsible Party, government expenditures in responding to the spill, and, in some instances, penalties and natural resource damage settlements between the government and the Responsible Party.

The National Pollution Funds Center (NPFC) maintains a database of oil spill costs for large spills that includes private sector costs when the Responsible Party seeks reimbursement from the Oil Spill Liability Trust Fund (OSLTF) for its expenditures in excess of the Limit of Liability. As such, it is probably the best-documented source of total oil spill response costs; however, reported costs are impacted by the "deep pockets" of corporations addressing large spills where they are among the responsible parties and the socioeconomic and public relations impact of the spill on their businesses. Monies expended in large spills may not be fully disclosed during the cleanup activities and long-term impacts, and costs may not be fully identified. Regardless, available reports on spill costs and models developed for estimating costs of oil spills have a common result: oil spills are costly.

Historical Spill Cost Summary

In a 2010 submission by the USCG to the Marine Environmental Protection Committee of the International Maritime Organizations, the USCG reported a value of $40,893.64 per metric ton spilled was given as the best estimate of the cost for response operations and $102,287.95 per metric ton for the total cost of an oil spill. This report examined spill costs from 1991 through 2011 based on NPFC data. Response costs include the costs associated with containing, recovering, and cleaning up spilled oil, while the total cost includes response costs, environmental damages after response efforts are completed, third-party damage costs, vessel repair costs, and the value of oil lost in the spill. Other costs are not captured elsewhere. These programmatic estimates result in:

- Response: Approximately $5,400 per barrel spilled or $136 per gallon spilled.
- Total Cost: Approximately $13,700 per barrel spilled or $340 per gallon spilled.

[82] D.S. Etkin, "*Estimating Cleanup Costs for Oil Spills*," Proceedings of the 1999 International Oil Spill Conference, Seattle, WA.

7.1 Cost of an Oil Spill in Buzzards Bay

Several cost models are available to estimate the cost of oil spills. The cost estimation in this report uses the model developed by Etkin, *Modeling Oil Spill Response and Damage Costs*.[83] This model was selected because of the multiple factors included in the estimation process. The estimated cost of an oil spill in Buzzards Bay includes three cost factors: a mechanical cleanup cost, a socioeconomic cost, and an environmental cost. The model provides costs for each category based on the amount and type of oil spilled. The model also incorporates environmental and socioeconomic cost modifiers to adjust the given cost per gallon for more susceptible or vulnerable areas. The derivation of each of these costs is included below.

Of the approximate 1,200 barges that were recorded as transiting Buzzards Bay, 75 percent of the barge capacities were 125,000 bbl or less. For cost estimating purposes, the 100,000 bbl barge is used for estimating the oil spill costs, which represent the most common barge size. The cost model is scalable based on oil spill volume, therefore selecting the most common occurrence of barge size is considered appropriate for the analysis. Additionally, the percentage of volume of oil spilled is considered in the analysis, which would account for a range of spills from all tank barges, with the exception of a total loss of oil from the largest operating barges. For double-hull barges, the total loss of all product would require the most catastrophic incident that would breach all holding tanks, or potentially a capsizing and failure of tank containment/sealing systems. As shown in **Figure 30**, the 100,000 bbl estimate accounts for 85 percent of barges in use.

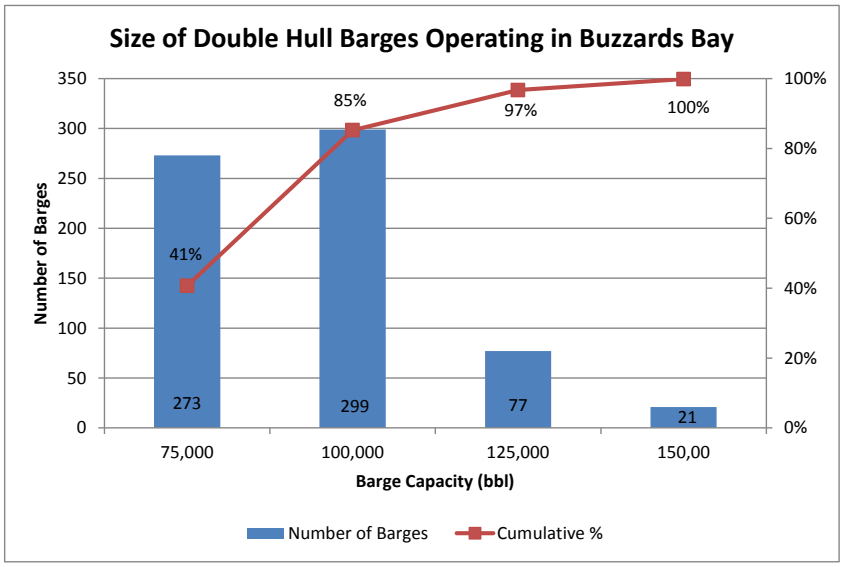

Figure 30: Tank Barges Operating in Buzzards Bay by Size

The construction of double-hull barges includes the segmenting of tanks for containment and stability considerations. Typical barge layouts are shown in **Figure 31** representing Bouchard Barge B-264 (built 2010, capacity 60,000 bbl in 10 tanks) and Barge B-242 (built 2004, capacity 141,000 bbl in 16 tanks).

[83] D.S. Etkin, *Modeling Oil Spill Response and Damage Costs*, Environmental Research Consulting. Freshwater Spills Symposium, 2004.

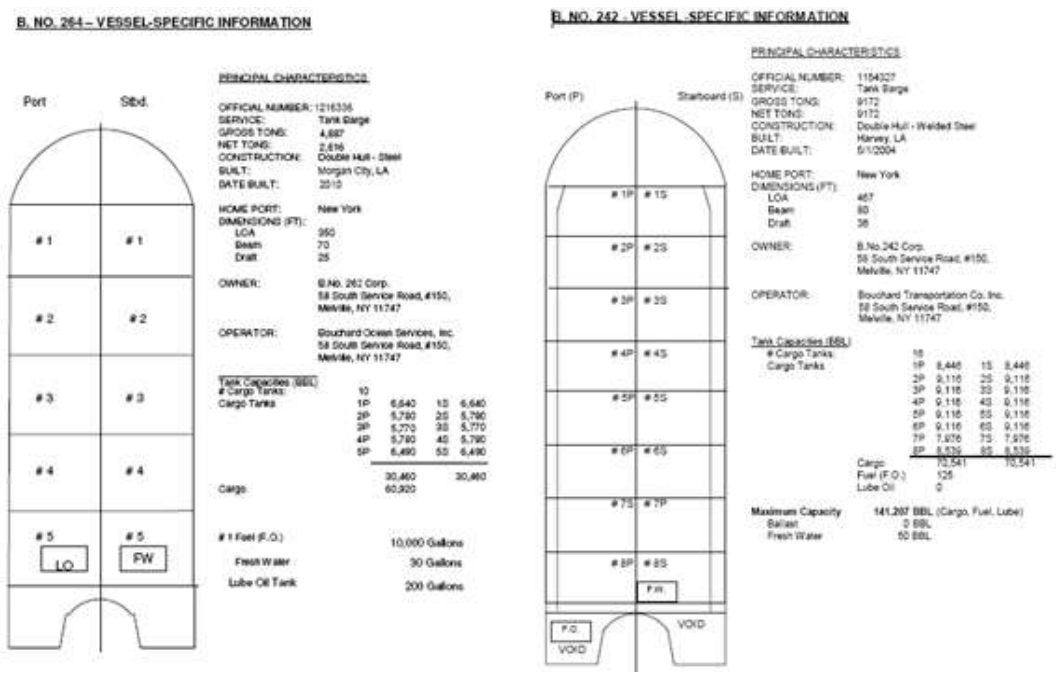

Figure 31: Double-Hull Barge Tank Layouts (Bouchard)

Four possible scenarios were derived, given that the capacity of the barge is 100,000 barrels, divided into 16 holding tanks. Scenario 1 and scenario 2 are based on a study of probable outflows from a double-hull barge. The study found the mean oil outflow from an incident in which oil is released was around 1 percent of the cargo on board, and the extreme oil outflow results in about 10 percent of the cargo on board. Scenario 3 is a spill of half the tanks on the tank barge and scenario 4 is a worst-case spill of the entire 100,000 bbl barge. The Bouchard B-120 spill of 2003 is also estimated using Etkin's cost model to provide reference.

- Scenario 1: 1 percent of the capacity is spilled – 1,000 bbl
- Scenario 2: 10 percent of the capacity is spilled – 10,000 bbl
- Scenario 3: 50 percent of the capacity is spilled – 50,000 bbl
- Scenario 4: 100 percent of the capacity if spilled – 100,000 bbl
- B-120 Spill – 3,100 bbl Number 6 oil

Etkin's cost model allows for cost estimates to be derived based on oil types. This cost estimate includes both light fuels and heavy oils; crude oils are not estimated because this type of oil is not transported through Buzzards Bay. The cleanup, socioeconomic, and environmental costs per gallon all vary based on oil type and quantity.

Cleanup Cost

The mechanical cleanup method (as opposed to using dispersants or in-situ burning) is used in Buzzards Bay. This cost estimate incorporates mechanical cleanup costs only. **Table 27** displays per gallon cleanup costs.

Table 27: Per-Gallon Cleanup Costs for Mechanical Cleanup

Per-Gallon Oil Spill Response Cost for Mechanical Cleanup		
Volume (gallons)	**Light Fuel**	**Heavy Oil**
10,000 – 100,000	$72	$359
> 100,000 – 1,000,000	$62	$154
> 1,000,000	$26	$77

The medium modifier is included in the cleanup cost to reflect the tendency for oil spread or deep penetration and how sensitive the area is to response equipment and personnel. The medium modifier of 1.6 was chosen for Buzzards Bay, as there are a large number of coastal wetlands and marshes in Buzzards Bay.

Table 28: Response Cost Modifiers for Location Medium Type

Category	Cost Modifier Value
Open Water/Shore	1.0
Soil/Sand	0.6
Pavement/Rock	0.5
Wetland	1.6
Mudflat	1.4
Grassland	0.7
Forest	0.8
Taiga	0.9
Tundra	1.3

The spill response cost is determined by multiplying the base per gallon response cost based on oil type and volume by the medium modifier by the spill amount, as shown below.

Total Response Cost = per-gallon response cost X medium modifier X spill amount

The summary in **Table 34** shows the Total Response Cost for each of the scenarios by oil type.

Socioeconomic Cost

The calculation for the socioeconomic cost portion of the total oil spill cost is similar to the calculation for the response cost. **Table 29** displays the base per-gallon cost while **Table 30** shows the Socioeconomic Cost Modifiers. Buzzards Bay is a protected area under the National Estuary Program. The Bay also provides commercial fishing; for these reasons, a modifying value of 2.0 has been chosen. Buzzards Bay would experience a large degree of long-term impact if oiled (months to years).

Table 29: Socioeconomic Base Per-Gallon Cost

Socioeconomic Base Per-Gallon Cost		
Volume (gallons)	**Light Fuel**	**Heavy Oil**
10,000 – 100,000	$200	$500
> 100,000 – 1,000,000	$100	$200
> 1,000,000	$90	$75

Table 30: Socioeconomic Cost Modifier

Socioeconomic Cost Modifier and Explanation			
Value Rank	**Spill Impact Site(s) Description**	**Examples**	**Cost Modifier Value**
Extreme	Predominated by areas with high socioeconomic value that may potentially experience a large degree of *long-term* impact if oiled.	Subsistence/commercial fishing, aquaculture areas	2.0
Very High	Predominated by areas with high socioeconomic value that may potentially experience some *long-term* impact if oiled.	National parks/reserves for ecotourism/nature viewing, historic areas	1.7
High	Predominated by areas with medium socioeconomic value that may potentially experience some *long-term* impact if oiled.	Recreational areas, sport fishing, farm/ranchland	1.0
Moderate	Predominated by areas with medium socioeconomic value that may potentially experience *short-term* impact if oiled.	Residential areas, urban/suburban parks, roadsides	0.7
Minimal	Predominated by areas with a small amount of socioeconomic value that may potentially experience *short-term* impact if oiled.	Light industrial areas, commercial zones, urban areas	0.3
None	Predominated by areas already moderately to highly polluted or contaminated or of little socioeconomic or cultural importance that would experience little short- or long-term impact if oiled.	Heavy industrial areas, designated dump sites	0.1

The spill response cost is determined by multiplying the base per-gallon socioeconomic cost based on oil type and volume by the socioeconomic cost modifier by the spill amount, as shown below.

Total Socioeconomic Damage Cost = per-gallon socioeconomic cost X socioeconomic modifier X spill amount

Table 34 shows the Total Socioeconomic Cost for each of the scenarios by type of oil product.

Environmental Cost

The Environmental Cost of the oil spill is estimated using a base per-gallon cost and modifying factors to reflect the environmental area of the spill location. **Table 31** shows the per-gallon environmental costs.[84]

Table 31: Environmental Base Per-Gallon Cost

Environmental Base Per-Gallon Cost		
Volume (gallons)	**Light Fuel**	**Heavy Oil**
10,000 – 100,000	$65	$75
> 100,000 – 1,000,000	$30	$40
> 1,000,000	$25	$35

Etkin's Environmental Cost includes two cost modifiers: a freshwater modifier (**Table 32**) and a habitat modifier (**Table 33**). Wildlife Use (1.7) was chosen for the first cost modifier, and the Wetland (4.0) category was chosen for the second. Buzzards Bay falls under other categories as

[84] Ibid.

well (e.g., recreation, estuary), but Etkin's model states that the category with the greater sensitivity, or vulnerability, should be selected.

Table 32: Freshwater Vulnerability Cost Modifier

Category	Cost Modifier Value
Wildlife Use	1.7
Drinking	1.6
Recreation	1.0
Industrial	0.4
Tributaries to Drinking/Recreation	1.2
Non-Specific	0.9

Table 33: Habitat and Wildlife Sensitivity Cost Modifier

Category	Cost Modifier Value
Urban/Industrial	0.4
Roadside/Suburb	0.7
River/Stream	1.5
Wetland	4.0
Agricultural	2.2
Dry Grassland	0.5
Lake/Pond	3.8
Estuary	1.2
Forest	2.9
Taiga	3.0
Tundra	2.5
Other Sensitive	3.2

The Environmental Cost is determined by multiplying the base per-gallon environmental cost based on oil type and volume by the environmental cost modifiers by the spill amount, as shown below.

Total Environmental Damage Cost =
per-gallon environmental cost X 0.5 (freshwater modifier + wildlife modifier) X spill amount

Table 34 shows the Total Environmental Cost for each of the scenarios by type of oil product.

The current Natural Resource Damages (NRD) estimate for the Bouchard B-120 spill of 2003 is $7.7 million dollars.[85] This includes payment for employee time and expenses related to this work, aquatic and shoreline resources, recreational uses, and some birds (for example, damages to the Piping Plover were settled for $715,000[86]), but not terns, loons, and certain other species. Therefore the above damages reflect only a partial NRD. Etkin's model does not include line item estimations for the environmental impacts of an oil spill, but rather an overall

[85] Buzzards Bay National Estuary Program, Oil Spill Cost, http://buzzardsbay.org/oilspillcosts.htm, retrieved October 31, 2012.

[86] United States of America v. Bouchard Transportation Company, Inc., et al., Case 1:10-cv-11958-NMG Document 18-2, April 15, 2011.

environmental cost that has been tailored by the above cost modifier to reflect the nature of Buzzards Bay.

Total Oil Spill Cost

The total oil spill cost was found by summing the Response Cost, Socioeconomic Cost, and Environmental Cost and applying an inflation rate of 22.5 percent to the cost in order to translate from 2004 dollars to 2012 dollars (however the cost of the B-120 cost remains in 2004 dollars to relate to the actual B-120 spill cost). **Table 34** summarizes all oil spill costs by oil type and volume spilled, and **Table 35** lists the Total Oil Spill Cost per barrel spilled. As the number of barrels spilled increases, the cost per barrel decreases. This is consistent with other disaster planning estimates in that the mobilization and demobilization costs are fixed for an event, and economies of scale relate to the efficiency of resources once on scene.

Table 34: Oil Spill Cost Factors in Million Dollars

Volume	Mechanical Cleanup			Socioeconomic			Environmental				Total	
	Light	Heavy	Cost Modifier	Light	Heavy	Cost Modifier	Light	Heavy	Cost Modifier		Light	Heavy
Scenario 1 – 1,000 bbl	$4	$22	1.6	$7	$19	2.0	$7	$8	1.7	4.0	$19	$50
Scenario 2 – 10,000 bbl	$38	$95	1.6	$77	$154	2.0	$33	$44	1.7	4.0	$148	$293
Scenario 3 – 50,000 bbl	$80	$237	1.6	$347	$675	2.0	$137	$192	1.7	4.0	$565	$1,105
Scenario 4 – 100,000 bbl	$160	$475	1.6	$695	$1,350	2.0	$275	$385	1.7	4.0	$1,130	$2,210
B-120 Spill – 3,100 bbl	--	$24	1.6	--	$39	2.0	--	$11	1.7	4.0	--	$74

Table 35: Total Oil Spill Cost Per Barrel

Total Oil Spill Cost Per Barrel Spilled		
Scenario	Light Fuel	Heavy Oil
Scenario 1 – 1,000 bbl	$19,000	$49,000
Scenario 2 – 10,000 bbl	$14,000	$29,000
Scenario 3 – 50,000 bbl	$9,000	$18,000
Scenario 4 – 100,000 bbl	$11,000	$22,000
B-120 Spill – 3,100 bbl		$23,952

According to Buzzards Bay National Estuary Program, the total cost of the B-120 spill was $24,000 per barrel which resembles Etkin's model's cost per barrel.[87] The total cost of $74.4 million compared to $74.2 million in Etkin's model is within 99 percent of the total cost (1 percent variance). For program planning purposes, this is considered acceptable.

[87] Buzzards Bay National Estuary Program, Oil Spill Cost, http://buzzardsbay.org/oilspillcosts.htm.

7.2 Oil Spill Mitigation Costs

This section estimates the cost of the mitigation options discussed in the Change Analysis (Section 6.2). The mitigations estimated in this estimation include:

- Escort tugs, both Fifi1 and non-Fifi1
- Adverse weather escort tugs, both Fifi1 and non-Fifi1
- Sentinel tugs, both Fifi1 and non-Fifi1
- Pilots
- Active VMRS monitoring

The following assumptions were made during the cost estimation process.

- The Baseline (double-hull barges) are not included in this cost estimation.
- There are 600 laden barge transits per year, considering an average of 1,200 total transits per year.[88]
- At worst case, 20 percent of barge transits will require an escort/sentinel tug because of inclement weather.
- Estimations are based on 100,000 bbl barge transits.
- Tug, pilot, and VMRS costs are consistent across all barge sizes.
- Sentinel tug cost includes standby cost and operating cost.

VMRS Costs

VMRS monitoring is currently conducted by the U.S. Army Corps of Engineers, Cape Cod Canal through a reimbursable agreement with the USCG, at a cost of $450,000 per year for one 24-hour position all year.

An enhanced VMRS system would include active AIS monitoring of traffic that could impede tank barge transits, alerting the master and pilot of potential transit issues, including traffic, wind, visibility, currents, or incidents, and monitoring the position of the tug/barge with respect to the recommended transit lanes. Costs for the enhanced VMRS include facility, utilities, equipment, maintenance, and staffing. Facility and utility costs are assumed to be managed by the host at no cost. Equipment costs (AIS receivers and radios) were estimated at a rough-order-of-magnitude level at $100,000 with a 5-year life cycle. Personnel costs were based on salary information from the Bureau of Labor Statistics, National Compensation Survey shown in **Table 36**. The watch-stander position is estimated at the “all worker” rate, and the management position is estimated at the Professional and Related rate from the following extract for the 2009 NCS. The cost factors used are highlighted in yellow in **Table 36.**No inflation of these hourly rates was conducted, due to the general nature of the survey and undefined requirements for the positions.

[88] U.S. Army Corps of Engineers, 2003–2011 Tank Barge Transit Data for the Cape Cod Canal, data developed by personal request of the U.S. Army Corps of Engineers Cape Cod Canal operating staff, U.S. Bureau of Labor and Statistics, http://www.bls.gov/ncs/ocs/sp/ncbl1708.txt, retrieved November 17, 2012.

Table 36: Personnel Costs Used in VMRS Cost Estimation[89]

Category	Civilian			Private industry			State and Local Government		
	Relative Hours			Relative Hours			Relative Hours		
	Mean	Error %	Relative Hours	Hourly Earnings	Error %	Relative Hours	Hourly Earnings	Error %	Relative Hours
All workers	$26.76	2.1	34.0	$26.27	2.3	34.0	$30.86	2.5	33.8
Management, professional, related	$39.48	2.6	36.7	$39.73	2.9	37.2	$37.89	2.7	33.8
Management, business, financial	$43.44	3.9	39.1	$43.84	4.2	39.3	$39.12	5.2	36.7
Professional and related	$37.40	1.8	35.6	$37.37	2.2	36.1	$37.56	2.5	33.1

The watch-stander and supervisory positions for a 24x7 watch position is based on the factors in **Table 37**. This analysis indicates six full-time positions are required. One supervisory position was also required to act as monitor and emergency fill-in for the watch-stander position.

Table 37: VMRS Staff Personnel Cost Factors

Cost Factor/Description			Value	Staff Costs	
Hours per year (365*24)			8,760		
Hours per staff (52*40)			2,080		
Less holidays	(13 holidays @24 hr/day)	312			
Less vacation	(15 days @8 hrs/day)	120			
Less training	(10 days @ 8hr/day)	80			
Available hours per staff			1,568	Per Hour	Per Year
Staff required	Hours/year / Available hours/staff (rounded up)		5.6 / 6	$30.86	$64,190
Supervisor			1	$37.56	$78,125
Total Personnel cost (staff # * annual cost)			**$463,258**		

Total VMRS costs are listed below. This accounts for a 10-year operation cost for the VMRS.

Table 38: VMRS Costs

Cost Factor	Description	Basis	Subtotal/ 10-Year Cost
Facility	Watch Center area with operator console	At existing USACE facility – assume no cost	$0
Utilities	Electrical, heating, etc.	At existing USACE facility – assume no cost	$0
Equipment	Radios, AIS receiver, potential remote site receivers (rough cost)	$100,000 Base cost Refresh at 5 years	$200,000
Equipment Maintenance	Maintenance at 15% acquisition	$15,000	$150,000

[89] U.S. Bureau of Labor and Statistics, http://www.bls.gov/ncs/ocs/sp/ncbl1708.txt, retrieved November 17, 2012.

Cost Factor	Description	Basis	Subtotal/ 10-Year Cost
	cost		
Watch Staff	6 watch-standers and 1 supervisor	BLS cost factors $463,258/year	$4,632,580
Total Cost			~$5,000,000

Escort Tug Costs

Escort Tug Costs were provided by MassDEP and are shown in **Table 39.**

Table 39: Escort Tug Costs

Escort Tug Type	Average Cost/Transit
FiFi1 escorts tugs	$13,000
Non-FiFi1 escort tugs (All)	$9,000

Sentinel Tug Costs

The cost of sentinel tugs includes the opportunity costs to maintain the vessels in a high-readiness status to meet a response service level, expressed in hours. The service levels in the cost proposals received by MassDEP range from 1 to 3 hours' response time. Payment of the high-readiness status is not specifically addressed in this cost estimate, but options include funding by industry, the state (from Pollution Prevention funds), or allocated per-use, which may reimburse the industry or state for the initial funding level. Added administrative costs would be expected for a complex pricing scheme, and are not included in this estimate. If sentinel tugs are a requirement, the payment process should be reviewed by a joint industry/state board.

Three sentinel tugs were suggested; however, a review of laden barge transits indicate fewer tugs may be used at a cost savings. The MassDEP data span 442 days but only 320 days have recorded tank barge traffic.[90] If the transit through Buzzards Bay and the Canal is assumed to be 4 hours, then a single tug can escort or assist three tank barge transits per day given the barge transits are coordinated. The mean number of tank barge transits per day is two; however, there are 33 instances of more than three transits per day (points above the dashed line in **Figure 32**). Therefore, more than one sentinel tug is needed less than 10 percent of the time. The number of days with no transits (points lying on the horizontal axis) leaves room for industry to coordinate barge transits in order to accommodate a sentinel tug availability and cost. It is believed that this scheduling between industry partners is possible and therefore one sentinel tug is included in this cost estimate as opposed to three sentinel tugs.

[90] MassDEP, Tugboat Escort Reporting Forms 2011–2012.

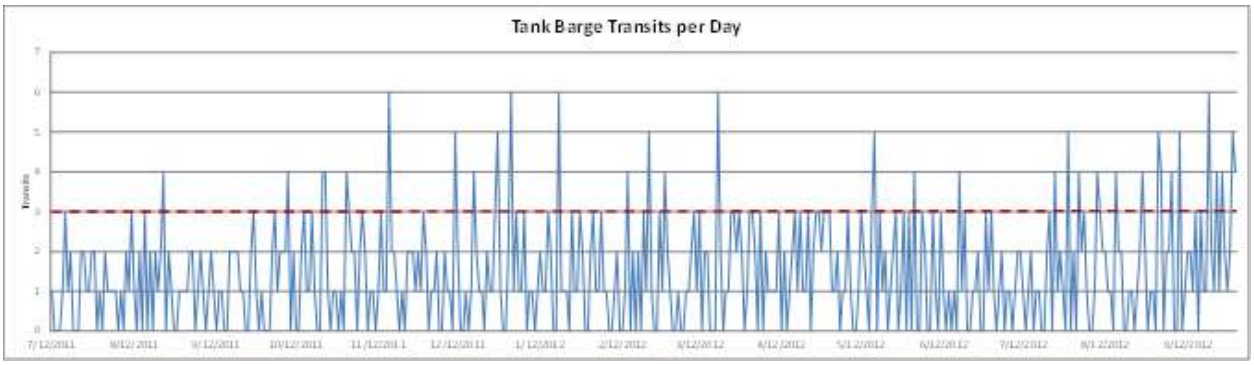

Figure 32: Tank Barge Transits per Day[91]

Total Mitigation Costs

Also, for considering the costs per transit for alternatives, the planning factors in **Table 40** were developed in order to estimate the number of transits to be supported by the mitigation programs and services. As shown in these planning factors, pilots would be required for all tug barge transits in order to address the human factor risk area. RCP-compliant tug barge transits in fair weather conditions with no major inspection issues are assumed to effectively mitigate material risks, and would either receive a waiver or not be required to use an escort tug. If the tug is not compliant, or has a major inspection issue, the assumption of managing the material risk is voided, and therefore an escort tug is recommended. Additionally, all transits in poor weather conditions, as determined by the stakeholder group recommended, and all single-hull barge transits would require a tug escort. The notional expected transits are shown for each situation. The costs listed below were provided by MassDEP on November 9, 2012.[92, 93]

Table 40: Mitigation Option Cost per bbl Shipped

Mitigation Option	Average Cost/Transit	Average Cost per Year	Average Cost per bbl ($)
Escorts for all (Fifi1)	$13,000	$7,800,000	0.1300
Escort for all (non-Fifi1)	$9,000	$5,400,000	0.0900
Sentinel tug	$24,000	$3,400,000	0.2400
Pilot	$4,000	$2,400,000	0.0400
Active VMRS monitoring*	$833	$500,000	0.0083
Escort during inclement weather (Fifi1)	$2,210	$1,300,000	0.0221
Escort during inclement weather (non-Fifi1)	$1,530	$900,000	0.0153
*VMRS costs are attributed to all tank barge transits for this study, but in the future other funding sources should be reviewed to allocate cost to a larger user base.			

The difference between the tug alternatives is that the sentinel tug is available on-call 24 hours a day, 7 days a week, and the escort tug is scheduled, with the transit and tug schedules coordinated based on weather or high tank barge traffic. The sentinel tug cost of $24,000 per transit includes the relative small operating cost and a large overhead cost ensuring the tug is

[91] MassDEP, Tugboat Escort Reporting Forms 2011–2012.

[92] R. Packard, MassDEP, "MassDEP Rescue Tug Cost Estimates," email, received November 9, 2012.

[93] S. Mahoney, *Summary of BB Rescue Tug Response.xls*, January 22, 2009.

readily available. The cost of having a tug readily available all the time is $10,000 per transit. The FiFi1 tug has considerable firefighting equipment and material and represents a higher cost.

As stated in **Section 5**, Buzzards Bay can expect an oil spill once every 9 years. This estimate was used to relate the cost of mitigation options to the cost of an oil spill. **Table 41** displays the per-barrel mitigation cost and the per-barrel cleanup cost by oil type and volume.

Table 41: Per bbl Mitigation Cost versus Per bbl Cleanup Costs

Mitigation Option	Average Cost per bbl ($)	Light Fuel per bbl Cleanup Cost over 9 years	Heavy Oil per bbl Cleanup Cost over 9 years
Escorts for all (Fifi1)	0.1300	< 100,000 bbl: $1,600 100,000 – 1M bbl: $1,200 > 1M bbl: $970	< 100,000 bbl: $3,800 100,000 – 1M bbl: $2,300 > 1M bbl: $1,800
Escorts for all (non-Fifi1)	0.0900		
Sentinel tugs	0.2400		
Pilots	0.0400		
Active VMRS monitoring	0.0083		
Escort during inclement weather (Fifi1)	0.0221		
Escort during inclement weather (non-Fifi1)	0.0153		

The return on investment (ROI) was calculated over a 9-year period for the Bouchard B-120 oil spill (3,100 barrels of heavy oil with cleanup cost of $24,000 per barrel spilled). ROI was calculated by dividing the cleanup cost by the cost of mitigation efforts over 9 years. The payback in years was determined for each mitigation option based on the B-120 spill size. The payback value shows how long the mitigation option can be implemented before reaching the cost of the B-120 spill. For example, the cost of escorting for all laden barges will equal the B-120 spill cost after 9 years.

Table 42: ROI and Payback by Mitigation for B-120 Spill Size

Mitigation Option	ROI based on B-120 Spill	Payback in Years
Escorts for all (Fifi1)	106%	9
Escorts for all (non-Fifi1)	153%	14
Sentinel tug	57%	21
Pilot	312%	28
Active VMRS monitoring	1653%	148
Escorts during inclement weather (Fifi1)	623%	43
Escorts during inclement weather (non-Fifi1)	901%	62

The ROI for each mitigation effort shows that for some risk mitigations (pilots, active VMRS monitoring, non-Fifi1 escort tugs) the return on investment is favorable (much greater than 100 percent). Sentinel tugs appear to be not as favorable in terms of the ROI. Providing escort tugs during inclement weather (20 percent of laden transits) would provide a more favorable ROI compared to escorts for all laden transits.

The cost of these policies and services are compared to the cost of an oil spill, based on the B-120 spill, to show the prevention costs compared to the potential avoided spill costs in **Figure 33**.

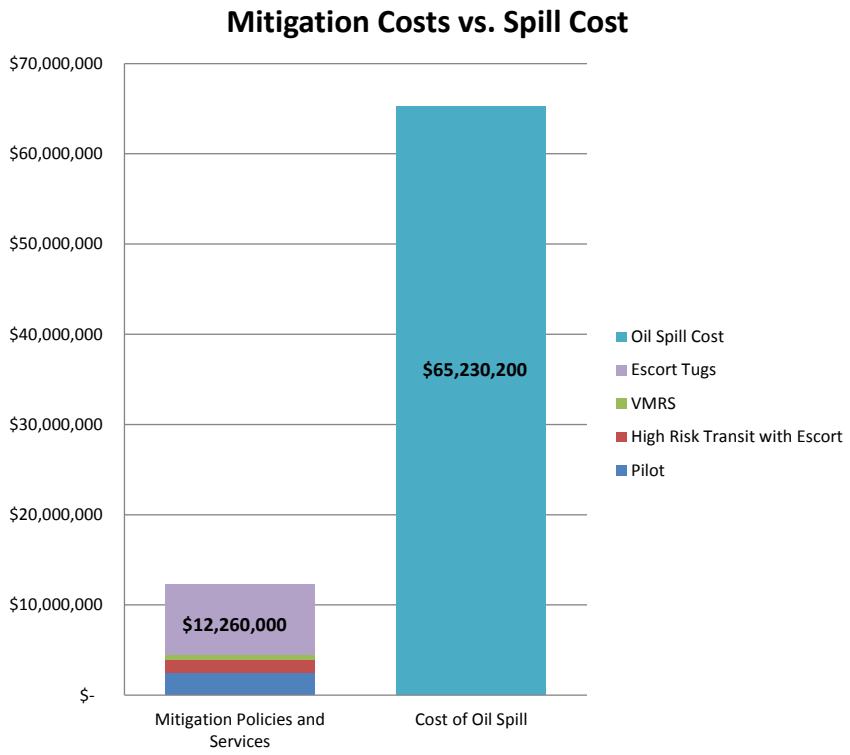

Figure 33: Mitigating Capability Costs Compared to Spill Costs

The costs for tug escorts may be reduced by instituting waivers or exemptions of escort requirements for tugs that are compliant and maintain satisfactory inspections, or requiring escorts only during adverse, high-risk weather periods, or some combination of the two alternatives. **Table 43** lists each mitigation alternative and expected escort impact, and the expected percentage of transits.

Table 43: Planning Factors for Use of Risk Reduction Item

Services		Barge	Tug	Inspection	Weather Conditions	Escort	Expected % of Transits
VMRS	Pilot						
All	All	Double Hull	Compliant	No Recent Inspection	Fair	No	> 80% of all transits
				No Major Issues		No	< 10% of Transits
				Major Issues/History of issues		Yes	< 10% of Transits
			Non-Compliant	All		Yes	< 10% of all Transits
			All	All	Poor (20%)	Yes	< 20% of all Transits
		Single Hull	All	All	All	Yes	None after 2015

Applying a factor of 40 percent of transits to account for a 20 percent severe weather factor, and a potential 20 percent of transits requiring escorts due to non-compliance or failed inspections, the annual cost of the mitigation programs including the pilots for all transits, VMRS, and three tug alternatives (escort, FiFi1, or sentinel) result in the cost table of alternatives in **Table 44**.

Table 44: Risk Mitigation Items and Costs by Alternatives

Alternative	Transits/ Year	VMRS	Pilots	Escort Tug Alternative			Total Cost
				Escort	FiFi1	Sentinel	
Full Pilots/Escort	600	$500,000	$2,400,000	$5,400,000			$8,300,600
Full Pilots/FiFi1 Escort	600				$7,800,000		$10,700,600
Full Pilots/Sentinel	240					$14,400,000	$17,300,240
Weather and Inspection/Compliance							
Full Pilots/Escort	240	$500,000	$2,400,000	$2,160,000			$5,060,240
Full Pilots/FiFi1 Escort	240				$3,120,000		$6,020,240
Full Pilots/Sentinel	240					$5,760,000	$8,660,240
7.2.1 Weather-Based Only							
Full Pilots/Escort	120	$500,000	$2,400,000	$1,080,000			$3,980,120
Full Pilots/FiFi1 Escort	120				$1,560,000		$4,460,120
Full Pilots/Sentinel	120					$2,880,000	$5,780,120

8 Additional Mitigation Measures to be Considered

In addition to an examination of escort tugs and mandatory pilotage in Buzzards Bay, other measures were identified during the study that appeared to offer additional risk reduction for towing vessels and tank barges operating in Buzzards Bay. They are identified here as potential areas for further examination.

One of the highest risk areas is the human factor-related casualties, which are mitigated through the independent pilot. Risk associated with the second-highest identified casualty type, mechanical failure, appears to be reduced through compliance with voluntary standards, such as the Responsible Carrier Program, and augmented by either the voluntary or mandatory inspection programs for towing vessels. The RCP program includes redundant systems for power, generators, and steering for compliance. These capabilities, in addition to the dual pilot recommended in this report, offer redundancy in the event of any casualty, and therefore allow a higher degree of self-sufficiency. Compliant vessels are assumed to be compliant until the inspection is conducted. If a vessel fails an inspection, or if significant issues are identified during an inspection, then an escort tug would offset any potential increase in risk due to the identified failures. Furthermore, a history of failed inspections by either the vessel or the company could indicate potential higher risks which would justify an escort tug. A stakeholder panel of operators, associations, and regulators is recommended to develop criteria for the types of inspection deficiencies and history that would lead to a requirement for an escort. Tug operators would either (1) maintain a fleet of compliant tugs, (2) select compliant tugs for operations in Buzzards Bay from their fleets, or (3) accept the higher cost of operations of an escort as an offset for the costs of compliance. Non-compliant operators would require an escort at all times.

During adverse conditions, again to be determined through consultation with stakeholders, escort tugs would be required to provide the immediate response from the effects of wind, waves, or other identified factors. Once these conditions are set, industry would determine if the need to transit during these high-risk periods is offset by the additional cost of the escort, or if a delay in transit is possible. VMRS monitoring of conditions, transits, and escorts during these high-risk periods is suggested. Transits during heavy ice conditions may not require an escort if Coast Guard or commercial icebreakers are available and convoy operations are implemented per the Sector Southeastern New England operations plan.

Although this study focused on federal pilots and escort tugs, other mitigation measures were identified during the review.

- **Incident Near-Miss System**: From the risk analyses conducted in Prince William Sound and Puget Sound, the establishment of an incident and near-miss reporting system with safeguards for mariners reporting issues would be beneficial to help identify trends in potential casualties in order to formulate mitigation measures.
- **Weather-Based Risk Management:** Weather-based risk management is another recommendation from Prince William Sound and the Aleutian Islands study. Under this concept, we recommend a joint industry/government working group identify the levels for extreme weather conditions where escorts should be conducted as a mitigation service. Establishing these thresholds will allow industry to plan transits based on forecasted conditions, and either arrange for the escort or delay transit until the weather

conditions subside. The developing Aleutian Islands Risk Assessment may have set aside the weather-based risk management. However, the traffic types (seagoing vessels), transit distances, and availability of harbors or refuges in the Aleutians are different from the semi-protected Buzzards Bay traffic and conditions.

- **Vessel-Based Risk Management**: Similar to the weather-based risk management, a vessel-based risk management program, similar to other trusted partner programs in government, may encourage the development and design of tow vessels to reduce material failures through redundant systems, maintenance programs, service life management, and personnel certification. The AWO RCP has shown substantial reductions in reported incidents, and should be encouraged and potentially rewarded with a waiver of potential escort requirements. However, with the imminent development of the tug inspection program, including periodic tests and drills for competency in managing simulated casualties, there could be penalties for non-compliant vessels, where the waiver for escorts could be revoked until the tug is either recertified or passes a follow-up inspection.
- **Structural Integrity Monitoring**: During this study, some reviews indicated structural and fatigue failures on tugs and barges. This is a potential high-risk area in the near future. The OPA 90 double-hull requirement caused barge fleet owners to upgrade or replace their fleets with compliant vessels.

One of the potential alternatives is a sentinel tug in high-readiness standby to respond to a potential incident. Although the cost per hour is higher, the potential reduced use provides some cost savings for this alternative. However, the funding for the high-readiness status to ensure that a capable vessel is available requires a funding strategy to be developed. Should the sentinel tug option be selected, we recommend a similar board of industry and government representatives to define acceptable service level response times, and potential funding options.

Appendix A Legislative Review

A.1 Tug Requirements

A.1.1 Federal Escort Tug Requirements

In 1996, following a series of major pollution incidents involving single hull tank barges in the region, the Regional Risk Assessment Team (RRAT) was established. The RRAT was jointly charted by the U.S. Coast Guard and the American Waterways Operators (AWO) and included representatives of the affected States, the Coast Guard, industry, and environmental advocacy groups.[94] The RRAT had the following objectives:

- to review industry practices for towing barges,
- to critique existing regulations, and
- to make recommendations to the Coast Guard to improve safety and reduce the risk of transporting petroleum products through the Northeastern States.

The RRAT completed its deliberations and issued a report entitled "Regional Risk Assessment of Petroleum Transportation on the Waters of the Northeast United States" in February 1997.[95]

Coincidentally, the Coast Guard Authorization Act of 1996 (P.L. 104-324) required the Coast Guard, in consultation with the Towing Safety Advisory Committee and taking into consideration the characteristics, methods of operation, and the size and nature of service of single hull non-self-propelled tank vessels and towing vessels, to prescribe regulations requiring a single hull non-self-propelled tank vessel that operates in the open ocean or coastal waters, or the vessel towing it, to have at least one of the following:

1. A crew member and an operable anchor on board the tank vessel that is capable of arresting the tank vessel without additional assistance under reasonably foreseeable sea conditions.
2. An emergency system on the tank vessel or towing vessel that without additional assistance under reasonably foreseeable sea conditions will allow the tank vessel to be retrieved by the towing vessel if the tow line ruptures.
3. Any other measure or combination of measures that the Secretary determines will provide protection against grounding of the tank vessel comparable to that provided by the measures described in paragraph (1) or (2).

In the Coast Guard authorization Act of 1998 (P.L. 105-383), the Congress made specific note of the RRAT report and provided that, not later than 31 December 1998, the Secretary of the Department in which the Coast Guard is operating shall promulgate regulations for towing vessel and barge safety for the waters of the "Northeast" that shall give full consideration to each of the recommendations for regulations contained in the report entitled ``Regional Risk Assessment of Petroleum Transportation in the Waters of the Northeast United States'' issued by the Regional

[94] National Transportation Safety Board Marine Accident Report, "Fire Aboard the Tug SCANDIA and the Subsequent Grounding of the Tug and Tank Barge NORTH CAPE on Moonstone Beach, South Kingston, Rhode Island January 19, 1996" NTSB/MAR -98/03, NTIS Number: PB98-916403, Adopted 14 July 1998, Washington, DC.

[95] The Executive Summary of the RRAT report can be found at the American Waterways Operators web site at http://www.americanwaterways.com/commitment_safety/QAT/regional_risk_assessment_petroleum_Transportation.PDF.

Risk Assessment Team for the First Coast Guard District on February 6, 1997. The Secretary shall provide a detailed explanation if any recommendation is not adopted.

On 13 October 1998, the Coast Guard published a Notice of Proposed Rulemaking, under authority of the Ports and Waterways Safety Act of 1972 (33 USC 1221 et seq.) establishing a Regulated Navigation Area (RNA) for the navigable waters of the First Coast Guard District, encompassing the waters of the Northeast identified by both the RRAT and P.L. 105-383.[96]

The Proposed Rule for the RNA required a single-hull tank barge carrying petroleum oil as cargo in bulk to be accompanied by an escort or assist tug unless towed by a tug equipped with twin-screws and two engines independent of each other and capable of maintaining control of the tank barge in the event of a loss of one of the engines. The escort or assist tug must be of sufficient capability to promptly push or tow the tank barge away from danger. It also proposed that the use of double-hull barges would preclude the use of twin-screw, twin-engine tugs.97

In March 1999, the Coast Guard issued an interim final rule for the RNA.[98] In addition to the provisions of the proposed rule, the interim final rule added the authority of the Coast Guard Captain of the Port (COTP) to grant exemptions to allow the use of single –screw and/or single engine tugs towing single-hull tank barges without tug escort upon an operator's demonstration of "equivalent measures of safety."

The interim final rule was finalized in June 2000 and became effective 1 July 2000, formalizing the proposed rule as amended by the interim final rule.[99]

On April 27, 2003, the Bouchard tank barge B-120 under tow of the Tug *Evening Tide* grounded at the entrance to Buzzards Bay while proceeding under power toward the Cape Cod Canal releasing approximately 98,000 gallons of number 6 fuel oil. Over 85 miles of shoreline in MA and 17 miles of shoreline in RI were documented as being oiled.[100] The B-120 was a single-hull tank barge built in 1975 loaded with over 4.1 million gallons of heavy fuel oil. The *Evening Tide* is a twin-screw tug with 3,900 horsepower. On 21 April 2001, the tank barge B-120 grounded in Buzzard's Bay, resulting in the report of discharge of 40,000 gallons of oil. According to the Coast Guard investigation of the incident, shortly before the grounding, the navigating officer departed the pilot house to go to an after-steering station to begin shortening the tow wire. Absent from the bridge, he failed to monitor the towing vessel's position. The mate on watch had limited experience operating on that waterway.

On 9 September 2003, the Coast Guard convened a Ports and Waterways Assessment (PAWSA) workshop in Falmouth, MA.[101] Among other things, the report recommended that the Coast

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[96] The limits of the RNA were defined as the navigable waters of the U.S., as that term is defined in 33 CFR 2.05 (a), within the geographic boundaries of the First Coast Guard District, as defined in 33 CFR 3.05-1 (b).

[97] Federal Register Volume 63, Number 197, pages 54639-54645, October 13, 1998. Other provisions included in the rulemaking are not reproduced here.

[98] Federal Register Volume 64, Number 49, pages 12746-12749, March 15, 1999.

[99] Federal Register Volume 65, Number 109, pages 35832-35838, June 6, 2000.

[100] Final Bouchard B-120 Oil Spill Shoreline Injury Assessment: Injury Quantification, Buzzards Bay, Massachusetts and Rhode Island, National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, Massachusetts Executive Office of Energy and Environmental Affairs, and the Rhode Island Department of Environmental Management, June 2008.

[101] "Ports and Waterways Assessment (PAWSA) Workshop Report for Buzzards Bay, MA, 9-10 September 2003." http://www.navcen.uscg.gov/pdf/pawsa/workshopReports/Buzzards%20Bay.pdf.

Guard consider establishing requirements for escort tugs and to formally designate the "Recommended Route" through Buzzards Bay to provide safer transit routes for commercial vessels.

In October 2004, the Coast Guard issued an Advanced Notice of Proposed Rulemaking (ANPRM) to consider amending the RNA regulations in light of the PAWSA report and to announce public meetings to obtain input on the potential amendments.[102]

A Notice of Proposed Rulemaking was issued by the Coast Guard on 29 March 2006 to amend the requirements for the Buzzards Bay RNA to provide for escort tugs for each single-hull tank barge unless the towing vessel is equipped with twin-screw propulsion and with a separate power system to each screw. In addition, each single-hull tank barge "carrying 5,000 barrels or more of oil or hazardous substances must be accompanied by an escort tug of sufficient capability to promptly push or tow the tank barge away from danger of grounding or collision…"[103]

The NPRM also provided that every single-hull tank barge must be accompanied by a pilot holding federal first class pilot's license on either the primary towing vessel or the escort tug. The pilot is in addition to the Master and crew of the primary tug.[104] The Coast Guard later clarified that a federal pilot was not required to be aboard the escort tug.[105]

On August 30, 2007, the Coast Guard finalized the regulation. The preamble to the final rule states that the Coast Guard did not "feel it is necessary to require tug escorts for double-hull tank barges at this time."

The Coast Guard also noted in this preamble that the legislative history of the Oil Pollution Act of 1990 (P.L. 101-380) and of the Ports and Waterways Safety Act (P.L. 92-340), as well as the pilotage legislation contained in Title 46, Chapter 85, did not provide the Coast Guard with authority to impose a state pilot in addition to or in lieu of a Federal pilot on the navigable waters of the U.S.

A.1.2 Commonwealth of Massachusetts Escort Tug Requirements

Following the B-120 incident in April 2003, the Commonwealth of Massachusetts legislature established an Oil Spill Commission chartered to investigate potential action to prevent future spills into Buzzards Bay. Based on legislation drafted by that commission, the legislature enacted the Massachusetts Oil Spill Prevention Act or "MOSPRA" (MA General Laws, Chapter 21M) which was signed into law by the Governor of the Commonwealth on August 4, 2004. Among other things, effective January 1, 2005, MOSPRA required both single and double-hull tank barges carrying 6,000 barrels of oil or more to be accompanied by a tug escort when entering or transiting an area of "special interest."[106] The requirement, however, does not included Hazardous Materials which is included in the Federal requirement.

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[102] Federal Register Volume 69, Number 206, pages 62427-62430, October 26, 2004.

[103] Federal Register Volume 71, number 60, pages 15649-15656, March 26, 2006.

[104] The NPRM also proposed to establish the Vessel Movement Reporting System for Buzzards Bay.

[105] Federal Register Volume 72, Number 168, page 50054, August 30, 2007.

[106] An "Area of Special Interest" is defined in the statute as any water of the commonwealth that is found by the secretary of environmental affairs to contain 1 or more immobile obstacles to navigation, abut or include areas of critical environmental concern, are designated as an estuary of national significance, abut or include habitats for endangered species, abut or include public recreation areas, support shell fishing, fin fishing or tourist industries or

MOSPRA also specified that an Escort Tug was required to be equipped with firefighting equipment, at a minimum, meeting the requirements of the following American Bureau of Shipping (ABS) classifications: Fire Fighting Vessel Class 1 and Maltese Cross A1 (Towing Vessel)[107] and have either:

- twin screws and a separate system for power to each screw, with an aggregate shaft horsepower equivalent to 4,000 horsepower or greater and a minimum bollard pull of 50 tons; or
- be a tractor tug, with an aggregate horsepower equivalent to 4,000 horsepower or greater and a minimum bollard pull of 50 tons, which is propelled by blades or screws which may be manipulated or rotated to provide propulsive thrust to any part of a 360 degree arc relative to the keel or longitudinal axis of the tug.[108]

On 30 December 2004, MOSPRA was amended to allow barges to transit the Areas of Special Interest without a tug escort under an exemption that could be granted by the Commissioner of MassDEP due to exigent circumstances. MassDEP implementing regulations established the conditions for such waivers as:

- there are no tug escorts reasonably available to accompany the tank barge in the relevant Area of Special Interest; or
- the delay in waiting for an available tug escort has or may reasonably result in a significant disruption of energy services to the public; or
- the existence or threat of a public health, safety or environmental emergency or other unique circumstances warrant the Department's exercise of its enforcement discretion.[109]

In 2008, amendments to MOSPRA provide for a State-provided Rescue Tug to be dispatched in the event a tank barge intended to enter Buzzards Bay without an escort tug. The Rescue Tug was to be manned by a state licensed pilot be equipped with: (i) twin radar displays equipped with an Electronic Chart Display and Information System (ECDIS) or Automatic Plotting Aid (ARPA) capable of integrating Automated information System (AIS); (ii) a towing winch and associated wire and gear capable of towing, at minimum, a 470 foot fully loaded tank vessel (iii) pilot disembarkation gear, and (iv) 600 feet of oil spill response boom and associated response gear.

MOSPRA was amended again in 2009 to eliminate the requirement for a "Rescue Tug" for Areas of Special interest and to provide "State-provided" Escort Tugs for Buzzards Bay.[110] In addition to the operating requirements as an "Escort Tug" generally (see above), the State-provided Escort Tugs:

- Must provide on-the-water-monitoring of these tank vessels;

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abut or include sensitive public safety areas. Such waters shall include, but not be limited to, Buzzards Bay, Vineyard Sound and Mount Hope Bay.

[107] The Fire Fighting Vessel Class I (FiFi1) is designed for early stage firefighting and rescue from a burning ship or building. Classes 2 and 3 are designed for longer duration and more extensive involvement in fighting vessel fires.

[108] Commonwealth of Massachusetts Department of Environmental Protection Web Site, http://www.mass.gov/dep/cleanup/laws/spillact.htm, October 2012.

[109] 314 Code of Massachusetts Regulations (CMR) Section 19.02.

[110] Commonwealth of Massachusetts Legislature Web Site, http://www.malegislature.gov/Laws/SessionLaws/Acts/2009/Chapter101, October 2012.

- Have the ability to warn vessels of actual or potential threats to navigation;
- Be available to assist immediately to the threat of an accident; and
- Operate within at most1/4 of a nautical mile away from a tank vessel during such escort.

State-provided Escort Tugs were also to be equipped similarly to the Rescue Tug with the addition of firefighting equipment as determined adequate by the Commissioner of MassDEP.

MassDEP regulations implementing the State-provided Escort Tug requirements provided additionally that these vessels be U.S. flag, classified by a member of the International Association of Classification Societies (IACS)[111] and meet the horsepower and bollard pull requirements from MOSPRA.

In addition, the implementing regulations provided specific operating requirements for State-provided escort tugs:

- Meet or exceed the National Fire Protection Association (NFPA) standard for Type V Marine fire-fighting vessels and special purpose fire-fighting vessels (the least stringent requirement for "fire-fighting vessels" established by NFPA) as opposed to the ABS Class 1 Firefighting vessel, previously required;
- Be able to maintain a steady minimum speed of 10 knots in a Beaufort sea state 6 (22-27 knots winds, seas up to 9½ feet) and have fuel capacity to allow for a minimum of 72 hours of continuous at sea operations;
- Meet the stability criteria established by the U.S. Coast Guard in 46 CFR 173.095 and 174.145;
- Carriage of navigational, towing and rescue equipment at a minimum to include:
  - Complete and current navigation and communication technology, including gyro and magnetic compasses, Global Positioning System (GPS), radio and telephone communications and twin radar displays equipped with ECDIS or ARPA integrated with an AIS capable of monitoring vessel movement in Buzzards Bay and its adjacent water bodies;
  - An AIS transponder;
  - A towing winch and associated wire and gear capable of towing at minimum, a 470 foot fully loaded Tank Vessel;
  - An Orville Hook device for recovery of towing bridles attached to drifting tank barges; and
  - A line-throwing gun capable of passing a suitable messenger line to a disabled vessel from a distance of at least 100 feet in 40-knot winds.

The firefighting standard revised by this rule for the State-provided Escort Tug (NFPA Type V) did not, however, extend to industry-provided Escort Tugs (ABS Class 1). The ABS Class 1 requires a total pumping capacity of 2,400 m^3/hour while the NFPA standard requires total pumping capacity of 114 m^3/hour.[112,113]

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[111] IACS is a professional organization of the major international "Classification Societies." Classification Societies are companies that provide structural and requirements for ship design and construction, propulsion systems, steering systems, etc. They additionally verify compliance with Flag-state requirements, including national laws and international treaties.

[112] National Fire Protection Association, Standard on Marine-Firefighting Vessels (NFPA 1925) 2008 ed., Quincy, MA.

MassDEP regulations implementing MOSPRA as amended continue to mandate requirements for Escort Tugs effective on January 1, 2006. Industry –provided Escort Tugs are to be equipped with:

- Primary and secondary VHF radios;
- Fendering appropriate to absorb the impact inherent in hull-to-hull operations;
- Power line handling equipment fore and aft to mechanically assist in the deployment and/or retrieval of tow lines;
- Tow lines, whether provided by the tank vessel and/or the tug escort, shall be maintained in sufficient number, length, condition and strength to assure effective control of the intended vessel maneuver, based on weather conditions, the tank vessel's size, and the tug escort's bollard pull, and have a strength of at least 1.5 times the tug escort's bollard pull; and
- Sufficient braking force to stop a tank vessel that is not self-propelled.[114]

A.1.3 Litigation

During the period of analysis, there have been several judicial decisions that have affected the regulations for tank barges transiting Buzzards Bay and the Cape Cod Canal.

The following summary is taken from the Draft Minutes of the Massachusetts Oil Spill Prevention and Response Act Advisory Committee dated June 22, 2012.[115]

- In 2005, the United States, acting on behalf of the United States Coast Guard (USCG), sued the Commonwealth, asserting that certain provisions of the MOSPRA are unconstitutional.
- In 2006, the District Court ruled that federal law "preempts" MOSPRA and enjoined Massachusetts from implementing the challenged provisions.
- In 2007, the US 1st District Court of Appeals disagreed with the District Court ruling, in part, and reinstated MOSPRA's tugboat escort, enhanced personnel, and certificate of financial assurance requirements.
- The U.S. subsequently asked the District Court to enjoin MOSPRA's escort and enhanced personnel requirements based on a 2007 USCG Final Rule for Buzzards Bay.
- In 2008, the Commonwealth sued the U. S. claiming that the USCG violated the National Environmental Policy Act (NEPA), for failing to adequately assess the environmental impact associated with the USCG Final Rule for Buzzards Bay.
- In 2010, the District Court ruled that the USCG violated NEPA by categorically exempting itself from the requirement to conduct an Environmental Assessment. The court determining that the violation was harmless, however, and ruled that the USCG's Final Rule for Buzzards Bay (33 CFR 165.100) could stand and that the federal rules invalidated MOSPRA's escort and personnel requirements.

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[113] Firefighting Systems Group web site for FiFi Classifications, http://www.fifisystems.com/home.html, October 2012.

[114] 314 CMR 19.00: Oil Spill Prevention and Response

[115] Commonwealth of Massachusetts Department of Environmental Protection Web Site, http://www.mass.gov/dep/public/committee/oswkgrp.htm, October 2012.

- In 2011, the US 1st District Court of Appeals disagreed, ruling that the USCG's violation of the NEPA was not harmless.
- In response, U.S. Court of Appeals lifted the injunction that prevented implementation of Massachusetts General Laws (M.G.L.):
  - M.G.L. c. 21M, s. 4, Manning of Towing Vessels and Barges
  - M.G.L. c. 21M, s. 6, Tugboat Escort requirements in Buzzards Bay
- The District Court also remanded the Final Rule for Buzzards Bay to the USCG for compliance with the NEPA.

A.2 Pilotage

The first Congress of the U.S. established the system of pilotage for the U.S. in 1789, giving States the right to establish pilotage rules for foreign-flag vessels and U.S. vessels engaged in international trade operating within the waters of a State. Coastwise vessels operating between US ports, on the other hand, are under the direction of a federally licensed pilot or, in certain cases, a person qualified to "serve as pilot."

Navigation of a ship in United States pilotage waters is a shared responsibility between the pilot and the master or the vessel. The pilot directs the navigation of the ship, subject to the master's overall command of the ship and the ultimate responsibility for its safety. The master has the right to intervene or to displace the pilot in circumstances where the pilot is manifestly incompetent or incapacitated or the vessel is in immediate danger (in extremis) due to the pilot's actions. International law requires the master and/or the officer in charge of the watch to "cooperate closely with the pilot and maintain an accurate check on the ship's position and movement."[116]

Pilots are required to take all reasonable actions to prevent ships under their navigational control from engaging in unsafe operations. Because of these duties, a compulsory state pilot is not a member of the bridge "team" in the context of the international Ship Management (ISM) Code. Nevertheless, a pilot is expected to develop and maintain a cooperative, mutually supportive working relationship with the master and the bridge crew in recognition of the respective responsibility of each for safe navigation.

A.2.1 Federal Rules for Pilotage

Federal pilots are mandated by Title 46, U.S. Code Chapter 85. In essence, and for purposes of this analysis, the requirement for a Federal pilot is limited to vessels in coastwise trade in the navigable waters of the U.S.[117] The Coast Guard administers federal pilotage requirements through 46 CFR 15.812.

[116] "Pilotage: One of the Oldest Yet Least-Understood Maritime Professions." Captain Michael R. Watson, U.S. Coast Guard *Proceedings of the Marine Safety Council*, Volume 68, Number 1, Spring 2011.

[117] "Coastwise" navigation is limited by statute to U.S. flag vessels.

Table A-1: Federal Pilotage Requirement Summary

Vessel Type and Size	Requirements
Inspected Coastwise Seagoing Tank Barge Greater than 10,000 GRT	A CG-licensed first class pilot is required, as per 46CFR §15.812(b)(1).
Inspected Coastwise Seagoing Tank Barge of 10,000 GRT or less	Towing vessel deck officers may "serve as pilot" if they meet the requirements specified in 46CFR § 15.812(b)(3).
Inspected Coastwise Seagoing Vessels of 1,600 GRT or less (including towing vessels)	Towing vessel deck officers may "serve as pilot" if they meet the requirements specified in 46 CFR §15.812(b)(2).
Inspected Inland Vessels of 1,600 GRT or less (including towing vessels)	No pilotage requirements.

"Acting as" pilots must complete a specified number of round trips over the route to be traversed in accordance with 46 CFR §15.812(b) (2). These individuals self-certify as to their qualifications for a route, i.e., they are not issued a pilot's license or endorsement that describes the specific waters upon which they are authorized to serve as pilot.[118]

For an original license or endorsement as First Class Pilot, an applicant must have one round trip over the route within the 6 months immediately preceding the date of application.[119] For the license or endorsement renewal one round trip over the route within the previous 5 years is required.

The "Responsible Carrier Program" developed by the American Waterways Operators provides for refresher training for Masters and Mates of Towboats in subjects such as radar and "rules of road" with a frequency to be determined by company policy but not less than every five years.[120]

A.2.2 Commonwealth of Massachusetts Rules for Pilotage

Commonwealth of Massachusetts General Laws, Chapter 103 (MA G.L. c. 103) established the state pilotage system for the State. Section 21 of MA G.L. c. 103 provides that every foreign vessel and every U.S. flag vessel sailing "on register," that is engaged in international trade, of 350 GRT or greater that is entering departing, in transit, or shifting berths in the waters of the Commonwealth must employ a State-licensed pilot. This Section also provides that other U.S. flag vessels carrying oil, hazardous material, or hazardous waste in bulk as cargo in or operating on "Areas of Special Interest" shall employ a pilot as well.

Coastwise vessels not sailing in register and not carrying oil, hazardous material, or hazardous waste in bulk as cargo are exempt from compulsory State pilotage.

Among other things, applicants for MA pilot commissions are required to show proof of first class federal pilotage for the areas in which they are applying to operate as well as evidence of 15 round trips as a pilot or pilot under instruction during the previous 3 years.[121] Applicants for pilot commissions are also required to be licensed by the Coast Guard as a mate or master of ocean vessels with unlimited tonnage.[122]

[118] NVIC 08-94

[119] 46 CFR § 10.705(e)

[120] American Waterways Operators, "Responsible Carrier Program 2012," page V-2, Arlington, VA, 2012.

[121] 995 CMR 4.06

[122] 995 CMR 4.14

Transit Pilots are the most junior pilots limited to piloting vessels less that 10,000 GRT within the geographic limitations established by their commission. Warrant Pilots are limited to serving on vessels within the confines of the geographic area or route described on their commission without size limitation. Full Branch Pilots are the most senior with substantial requirements for qualifications and may serve on any vessel within the pilotage waters of Massachusetts without limitation.[123]

State pilots are highly qualified for the services they perform. They are required to show both familiarity with an area as well as competency and recency in their qualifications.[124]

[123] 995 CMR 4.17

[124] Personal communication, Northeast Pilots Association, October 19, 2012.

Appendix B References

1. 314 Code of Massachusetts Regulations (CMR) Section 19.02.
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