Regulatory Assessment
Use of Tugs to Protect Against Oil Spills in the Puget Sound Area

Prepared for:

The United States Coast Guard

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EXECUTIVE SUMMARY

Background:

Title IV of the Alaska Power Administration Asset Sale and Termination Act (P.L. 104-58) required the Coast Guard to report on the most cost-effective means of implementing an international, private-sector tug of opportunity system (ITOS). ITOS uses existing towing vessels to aid vessels in distress operating in the area of the Olympic Coast National Marine Sanctuary and the Strait of Juan de Fuca. This tasking derived from long-standing public concerns over the risk of drift grounding in the region. The Presidential Determination of April 28, 1996 expanded upon this legislation, requiring the Secretary of Transportation to determine the adequacy of all vessel safety and environmental protection measures in effect in Puget Sound area waters. After appropriate notice and opportunity for public comment, the Secretary is required to propose such additional measures as he deems necessary. The Volpe National Transportation Systems Center, under contract to the Coast Guard, undertook the task of assessing the adequacy of current measures. Their report, Protection Against Oil Spills in the Marine Waters of Northwest Washington State, evaluated spill risks for the Puget Sound region and listed some 200 potential risk reduction measures. Coast Guard Headquarters' staff identified eleven measures as worthy of further consideration. This Regulatory Assessment addresses three of these measures.

This assessment focuses on the risk due to underway accidents leading to large oil spills, involving crude oil and petroleum products from tankers and tank barges, as well as bunker fuels from commercial vessels. Eight alternatives for mitigating oil spillage in the study region are evaluated:

ALT. 1: International Tug of Opportunity System (ITOS)
ALT. 2: Extend two tug escort requirement for laden single-hull tankers westward to "J" Buoy
ALT. 3: Provide single tug escort for laden single-hull tankers westward to "J" Buoy
ALT. 4: Provide single tug escorts east of "J" Buoy for all *Priority 1* vessels
ALT. 5: Provide single tug escorts east of "J" Buoy for all vessels greater than 300 GT
ALT. 6: Provide single tug escorts east of "J" Buoy for all vessels greater than 3,000 GT
ALT. 7: Dedicated rescue tug, to meet response times for all vessels throughout the region
ALT. 8: Dedicated rescue tug, to meet response times for tank vessels throughout the region

ITOS has been implemented within the region by the private sector. ALT. 2 through ALT. 6 are extensions to the existing escort regulations, that require a two tugboat escort for all single hull tankers larger than 5,000 GT transporting oil in U.S. waters east of New Dungeness Point Light. ALT. 7 and ALT. 8 involve the stationing of a rescue tug at the western end of the Strait of Juan de Fuca.

Approach

The study region encompasses the Strait of Juan de Fuca and its offshore approaches, Puget Sound south to Olympia, and the waters in and around the San Juan Islands. The primary focus is on the Strait and coastal waters within a 60 nm radius of "J" Buoy, which are considered within reach of a pre-positioned rescue tug. A projected baseline for oil spillage is established for the period 2000-2025 that represents the hypothetical future, without the benefit of any of the alternative measures under review. The baseline incorporates projected changes in cargo movements and fleet make-up, as well as the projected impact on oil spills of existing regulations including the double hull provisions of OPA90.

Historical spill data is used as the basis for establishing the current spill risk level for tankers, tank barges, and freighters. The sparseness of spill data for the Puget Sound region makes it necessary to utilize national statistics to determine the frequency and size of spills, and then project these values to the study area. Probabilistic oil outflow calculations were carried out to assess the relative effectiveness of double hull tankers, as there is insufficient statistical information to evaluate their performance.

The relative effectiveness of each alternative in averting collisions, powered groundings, and drift groundings was developed from analysis and, when appropriate, expert opinion. These factors are applied against the baseline spill rates to forecast spillage in barrels of oil on an annual basis for the period 2000-2025. To assess net cost effectiveness, compliance costs and avoided costs are determined. Avoided costs include vessel and cargo damage, injuries, and loss of life. Clean up costs and environmental damage assessment are considered separately, and not included in the net cost effectiveness calculation.

The qualitative environmental impact assessment section provides the decision-makers with a characterization of the likely effects of oil spills. This provides insight into the possible benefits of the measures under consideration. The qualitative study evaluates three size spills in two locations. The assessment evaluates environmental impacts, response conditions and capabilities, as well as effects on trade, fishing and recreation.

Finally, a Small Business Assessment was performed to determine if the proposed regulations would have a significant impact on a substantial number of small entities.

Findings

During the period 2000-2025, crude oil receipts are projected to remain constant, whereas steady growth is forecast for movements of petroleum products and containers. The number of vessels greater than 300 GT in size transiting the Strait of Juan de Fuca is projected to grow from about 11,000 transits in year 2000 to over 17,000 transits in year 2025, an increase of 50%. Petroleum movements, including cargo oils and ship bunkers, are forecast to grow from about 360 million barrels in year 2000 to 457 million barrels in year 2025.

For the Puget Sound region, the return period between spills greater than 10,000 gallons in size from collisions and groundings of commercial vessels is estimated at 5.0 years for year 2000 (see Table E1). If no new measures for mitigating spillage are adopted, the expected return period in year 2025 is 3.6 years. The return period between spills from tankers increases during this period due to OPA90 and STCW effects, from 66.8 years in year 2000 to 201.3 years in year 2025. However, the growth in transits of dry cargo vessels more than offsets improvements from ISM and STCW, accounting for the overall increase in projected spill frequency over the study period.

Year	2000	2005	2010	2015	2020	2025
Tankers (laden)	66.8	95.8	138.4	230.4	215.3	201.3
Tank Barges (laden)	27.9	34.2	42.3	115.2	99.5	84.8
Others	6.6	6.3	5.8	5.1	4.4	3.8
All commercial vessels	5.0	5.0	4.9	4.8	4.1	3.6

Table E1 Projected Return Period Between Spills in the Study Region (for spill greater than 10,000 gallons in size from collisions and groundings)

Although the number of spills will increase, a net reduction in oil outflow from collisions and groundings of about 27% is projected. This is primarily attributable to the phase out of single hull tank vessels. In the year 2000 petroleum carriers pose the greatest risk, as tankers and tank barges are responsible for 75% of the total projected outflow. By the year 2025, with dry cargo vessels are responsible for 66% of the total projected outflow (see Figure E1).

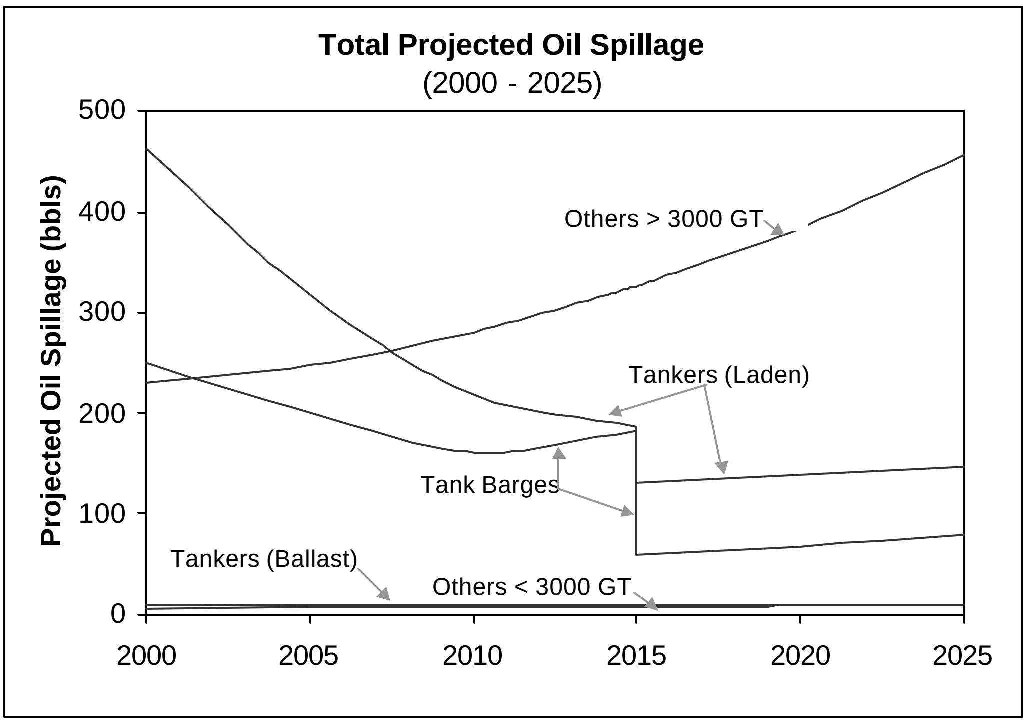


Figure E1 Baseline Oil Spillage

The relative effectiveness of each alternative in averting collisions, powered groundings, and drift groundings was determined and applied against the baseline oil spillage to project the barrels of oil spillage averted for the period 2000-2025. The present value of the averted spillage is displayed in Figure E2. These benefits divided by the present value net costs (the compliance costs less certain avoided costs such as injuries, fatalities, and vessel damage) gives the net cost effectiveness. The net cost effectiveness for the eight alternatives, expressed in terms of dollars per barrel of oil not spilled, is presented in Table E2 and Figure E2.

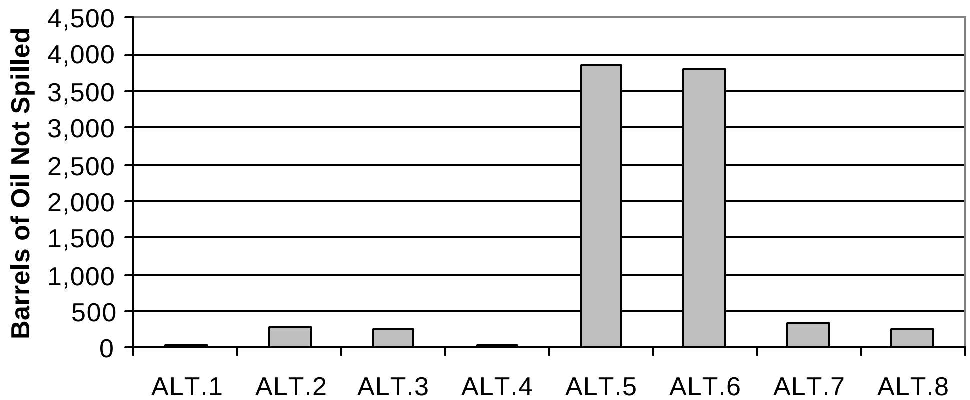


Figure E2 Present Value of Pollution Averted

Type of Benefits & Costs	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	ALT 7	ALT 8
Net Costs (million US$)	$1.1	$52.4	$26.2	$9.5	$2,252.5	$1,996.4	$63.6	$64.7
Pollution Averted (barrels)	26	285	243	39	3856	3789	338	264
Net Cost-Effectiveness (US$ Per Bbl not Spilled)	$42,382	$183,964	$107,798	$242,466	$584,190	$526,846	$188,461	$245,131

Table E2 Calculation of Net Cost Effectiveness

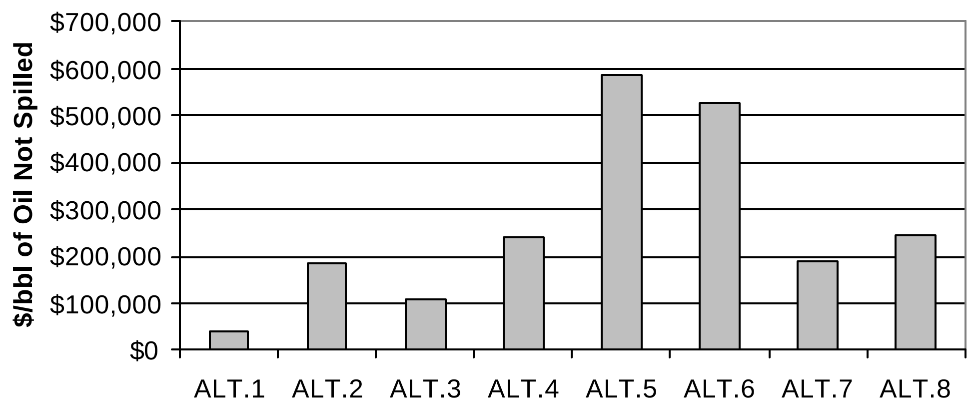


Figure E3 Net Cost Effectiveness

The pollution averted by ITOS (ALT. 1) is significantly less than most of the other alternatives. However, because of its relatively low costs, it offers the lowest cost per barrel of oil spillage averted.

Current legislation requires escorts for laden single hull tankers east of Pt. Dungeness. Requiring a single tug to accompany laden single hull tankers between the offshore entrance of the Strait of Juan de Fuca and Dungeness (ALT. 3) is the most cost effective of the escort options. Extending escort requirements to double-hull tank vessels and freighters (ALT 5, and ALT. 6) is less cost effective. Double hulls on tank vessels significantly reduce the risk of spills from collision and grounding accidents for those vessels, and freighters have comparatively smaller spills as they carry less oil in smaller tanks. There are also significant compliance costs associated with slowing down containerships and other higher speed vessels to match the speed of the escort tugs.

The rescue tug options (ALT. 7 and ALT. 8) call for a tug permanently stationed at the entrance to the Strait of Juan de Fuca. The primary purpose of the rescue tug is to assist vessels with power or steering failures, but it also is assumed that the tug will escort laden tank vessels through the congested traffic zone around “J” Buoy. The low probability of drift groundings compared to other types of accident limits the effectiveness of rescue tugs. In fact, a substantial portion of the pollution averted by the rescue tug is attributable to its assumed use as an escort for laden tank vessels.

To put the net cost effectiveness of each alternative into perspective, one must consider the environmental effects of a spill in this region. The Washington outer coast and the Strait of Juan de Fuca are unique environments that contain a wide diversity of shorelines and marine habitats. The qualitative environmental impact assessment indicated significant environmental impacts occur in the Strait of Juan de Fuca and along the outer coast of Washington State following a large oil spill. A spill in the vicinity of the “J” buoy would spread oil down the outer coast of the State. A similar spill off Port Angeles would spread oil along the coast of the Strait of Juan de Fuca out to Neah Bay. The larger the quantity of oil spilled, the greater the impact to natural resources. Birds, fish, mammals and plants would be impacted. The greatest threat to wildlife occurred during the larger spill near Port Angeles. Both large spills however produce significant animal fatalities and injuries. The spills also disrupt the fishing, tourism, recreation and waterway movements in the spill area.

DEFINITIONS

Marine Accident Terminology

Allision: The impact of a vessel with a fixed object other than the bottom (e.g. impact with a bridge, pier, or offshore platform).

Collision: The impact of a vessel underway with another vessel underway.

Powered Grounding: The impact of a vessel with the ground or shoreline while the vessel is under power.

Drift Grounding: The impact of a vessel with the ground when the vessel loses its ability to navigate (e.g. though loss of propulsion, steering, or towline separation), and is blown aground before it can get underway or is taken under tow.

Risk Assessment Terminology

Incident: An event in which the vessel is put at risk. Examples include loss of propulsion, loss of steering, and navigational errors.

Accident: A marine incident which could lead to the release of petroleum product into the environment. Examples include collisions, powered groundings, drift groundings, fire and explosion, and founderings.

Causality: The precursor event to an accident. Examples include failure to take appropriate precautions, inattention, or component failures.

Spill Event: An accident resulting in oil outflow into the environment.

Spill Frequency: The measure of how often a spill event occurs (e.g. oil spills per year, oil spills per 1000 transits, or oil spills per mile traveled).

Consequence: As used herein, the oil outflow from a spill event. The oil outflow from a given spill event will depend on many factors, including the energy at impact, the location of damage, and the vessel configuration (e.g. single hull or double hull).

Risk: The product of the likelihood of a hazard and its consequence. As used herein, risk is taken as the product of the frequency of spill events and the mean or expected outflow (i.e. the integral of the spill probability distribution), and is therefore a measure of the expected oil outflow.

Conditional Probability: A conditional probability, Pr(A|B), is the probability of event A given that event B has occurred. For instance, the likelihood that a vessel will spill oil given an accident is a conditional probability. Probabilities are dimensionless, and expressed in numbers between 0 and 1.

Other Definitions

Oil: As used herein, oil is defined as all petroleum oils, such as crude oils, fuel and residual oils, and waste oils. Non-petroleum oils such as animal and vegetable oils are not considered in this study.

Persistent Oil: Crude oils and residual oils, which tend towards more widespread contamination when spilled, and are more difficult to clean-up.

Non-Persistent Oil: As used herein, No. 2 Diesel Oil and other light refined products, which tend to evaporate and more readily disperse when spilled.

Bollard Pull: The maximum static pull which a tug can exert without forward tug movement, measured in tons force.

Deadweight (DWT): The difference between the displacement of a ship in water at a specific gravity of 1.025 at the assigned summer load waterline and the lightship weight, measured in metric tons. The lightship is the displacement of a ship without cargo, consumables (fuel, fresh water, etc.), ballast water, passengers and crew.

Gross Registered Ton (GRT): GRT is admeasured in accordance with international conventions and national requirements, and is a function of the a vessel's space within the hull and of enclosed spaces above deck with certain exceptions.

Area to be Avoided (ATBA): Areas with defined limits where either navigation is particularly hazardous or it is exceptionally important to avoid casualties. All ships, or certain classes of ships, may be instructed to avoid these areas.

Traffic Separation Scheme (TSS): A vessel routing scheme separating opposing streams of traffic by separation zones. Within international waters, traffic separation schemes are established by the International Maritime Organization (IMO).

Vessel Traffic System (VTS): A vessel traffic management system, where authorities monitor vessel movements within a waterway by radar surveillance, and disseminate navigational information regarding potential hazards.

Young-of-the-year (YOY): Eggs, larvae, and juveniles less than one year old for fish and shellfish.

ABBREVIATIONS

ACOE	United States Army Corps of Engineers
ADIOS	Automated Data Inquiry for Oil Spills
CCG	Canadian Coast Guard
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMAN	Coastal-Marine Automated Network
COTP	Captain-Of-The-Port
DOE	Washington Department of Ecology
DWT	Deadweight Tonnage (measured in metric tons)
EDRC	Effective Daily Recovery Capacity
EIA	Environmental Impact Assessment
GT	Gross Registered Tonnage
ISM	International Ship Management Code
IMO	International Maritime Organization
ITOS	International Tug of Opportunity System
MMS	Mineral Management Service
MSIS	U.S. Coast Guard Marine Safety Information System
NDBC	National Data Buoy Center
NOAA	National Oceanic and Atmospheric Administration
NRDAM/CME	Natural Resource Damage Assessment Model for Coastal and Marine Environment
OCMS	Olympic Coast Marine Sanctuary
OMS	Washington Office of Marine Safety
OPA90	Oil Pollution Act of 1990

OSCS	Oil Spill Compensation Schedule
OSRO	Oil Spill Removal Organization
RA	Regulatory Assessment
STCW	Standards for Training and Certification of Watchkeepers
TAPS	Trans Alaska Pipeline Service
TSC	Temporary Storage Capacity
TSS	Traffic Separation Scheme
UNESCO	United Nations Educational Scientific and Cultural Organization
USCG	United States Coast Guard
VTS	Vessel Traffic System

Other Abbreviations

nm	nautical miles
MT	metric tons

1 INTRODUCTION

1.1 Objective

This report is a regulatory assessment (RA) that considers various alternatives intended to mitigate the risks of vessel oil spills in the Puget Sound area, were they codified into the Code of Federal Regulations (CFR). The purpose of the RA is to:

- Assess the costs and benefits of a range of alternatives,
- Qualitatively assess the environmental and economic impact of various spill scenarios, and
- Assess the impact of alternatives on small business.

1.2 Background

Title IV of the Alaska Power Administration Asset Sale and Termination Act (P.L. 104-58) required the Coast Guard to report on the most cost-effective means of implementing an international, private-sector tug of opportunity system (ITOS). ITOS uses existing towing vessels to aid vessels in distress operating in the area of the Olympic Coast National Marine Sanctuary and the Strait of Juan de Fuca. This tasking derived from long-standing public concerns over the risk of drift grounding in the region. Prior attempts to position a dedicated rescue tug in the western waters of the Strait of Juan de Fuca were unsuccessful in both the regulatory and legislative approaches taken.

The Presidential determination of April 28, 1996 subsequently expanded upon the requirement of P.L. 104-58 to, among other taskings, require the Secretary of Transportation to determine the adequacy of all vessel safety and environmental protection measures that are in effect in Puget Sound area waters. This tasking requires that the Secretary, after appropriate notice and opportunity for public comment, propose such additional measures as he deems necessary to provide such protection.

The Coast Guard has been actively engaged since the Presidential determination to carry out the first phase of this tasking and to facilitate and report on ITOS. Two reports to Congress have been filed outlining the criteria for a private-sector ITOS, and reviewing the industry proposal. The Coast Guard was also the lead agency for the second phase, the determination of adequacy of all vessel safety and environmental protection measures, which was performed under contract with the Volpe National Transportation Systems Center. The report Protection Against Oil Spills in the Marine Waters of Northwest Washington State, Ref. (1), outlines the risks associated with commercial vessels underway in the subject area. In particular, that report indicates that this waterway system is a safe one, although room for improvement does exist. Specifically, the report notes that the highest risks are those due to collisions, followed by powered grounding and drift grounding, with the remainder of the risk distributed amongst the remaining accident types. This report also identified human and organizational error as the dominant cause, followed by physical environment and conflicting vessel operations. Geographically, the risk was highest in central Puget Sound, followed by the San Juan Islands region and the Olympic Coast.

In addition to the risk assessment, the report includes a listing of potential risk reduction measures, which were culled from a series of Public Meetings, Public Workshops, Dockets, the two Expert Panels, and a literature review. This list of over 200 potential additional measures was not evaluated in the Volpe analysis, although they were categorized by functional area. Based upon a Coast Guard Headquarters staff distillation of that unfiltered list of measures, eleven measures were identified as worthy of further consideration. This RA addresses three of these measures.

This study focuses on the risk due to underway accidents leading to large oil spills, involving cargo oils from tankers and tank barges, as well as bunker fuels from commercial vessels. Three potential uses of tugs to reduce the risks of oil spillage are evaluated: (1) ITOS, (2) the expansion of existing escort tugs requirements, and, (3) the stationing of a rescue tug at the western end of the Strait of Juan de Fuca. Altogether, eight alternative measures are evaluated, including five escort tug alternatives, and two rescue tug alternatives.

The study then investigates the impact of oil spills on the environment and the impact on natural resources. Large, medium and small size spills were simulated at the eastern and western ends of the Strait. The spills simulated the impact of collisions occurring near the "J" buoy and groundings near Port Angeles. The impacts of these incidents were evaluated qualitatively.

Finally, a small business analysis was conducted to determine the impacts the proposed regulations would have on small business.

1.3 Scope of Study

The analysis is restricted to commercial vessels of 300 GT and above. The study does not address spills from U.S. or foreign government vessels. It is recognized that spills from vessels under 300 GT, particularly towing vessels and fishing boats, have accounted for a significant portion of the oil spilled in the Puget Sound area in recent years. Although not included in the benefit-cost analysis, the relative contributions of smaller vessels to the spill statistics are annotated.

The principal area of study is the Strait of Juan de Fuca, and the approaches to the entrance of the strait. The offshore area includes the Olympic Coast National Marine Sanctuary, the International Maritime Organization (IMO) designated *Area to be Avoided*, and the northern and southern approaches to the Strait of Juan de Fuca. Only for the alternatives involving the use of escort tugs for vessels other than laden single hull tankers is the analysis extended eastward of Dungeness. For these alternatives, the escorts are assumed to accompany the vessels to their final destinations within U.S. waters.

Available data for vessel traffic, oil and dry cargo movements, and accidents and spills are applied in this study. Standard statistical analysis techniques are applied to assess the completeness of data and, when these data are too sparse or too inconsistently maintained to be used with a reasonable level of confidence, expert opinion is used to supplement the statistics.

2 ALTERNATIVES AND METHODOLOGY

2.1 Alternatives Analyzed

Eight alternatives for mitigating oil spillage in the study region were evaluated. Each alternative was taken independently, and compared to a baseline condition. The baseline condition represents the hypothetical future, without any of the alternative measures in effect.

ALT. 1: International Tug of Opportunity System (ITOS)
ITOS is a system implemented and funded by the private sector, that coordinates the response of tugs of opportunity with disabled vessels in the Strait of Juan de Fuca and along the north coast of Washington. Transponders installed on tugs operating in the waterway enable the vessel traffic system (VTS) operators to quickly identify the location of suitable tugs when the need arises.

ALT. 2: Extend two tug escort requirement for laden single-hull tankers westward to "J" Buoy
OPA90 requires a two tugboat escort for all single hulled tankers larger than 5,000 GT transporting oil in U.S. waters east of New Dungeness Point Light. This alternative assumes the two tug escort is extended to the start of the traffic lanes, approximately 8 miles to the West of "J" Buoy. Extensions of the escort requirements for tankers would be implemented under Port and Waterway Safety Act authority.

ALT. 3: Single tug escort requirement for laden single-hull tankers between "J" Buoy and Dungeness
This alternative is similar to ALT. 2, except that only one tug is required when escorting the laden single-hull tankers between "J" Buoy and Dungeness.

ALT. 4: Single tug escort requirements east of "J" Buoy for all *Priority 1* vessels
Implementation of single tug escort requirements for all *Priority 1* vessels, escorting the vessels between the initiation of the traffic lanes west of "J" Buoy and their origination/destination ports within the Puget Sound region. *Priority 1* vessels are certain foreign flag vessels greater than 300GT determined by the Coast Guard to pose high risks. During 1998, 11 vessels categorized as *Priority 1* made a total of 60 transits through the Strait of Juan de Fuca. These were primarily fish factory vessels, but also included containerships and bulk carriers.

ALT. 5: Single tug escort requirements east of "J" Buoy for all vessels greater than 300 GT
Implementation of single tug escort requirements for all vessels greater than 300 GT, escorting the vessels between the initiation of the traffic lanes west of "J" Buoy and their origination/destination ports within the Puget Sound region.

ALT. 6: Single tug escort requirements east of "J" Buoy for all vessels greater than 3,000 GT
This alternative is similar to ALT. 5, except that only vessels greater than 3,000 GT are required to have an escort.

ALT. 7: Dedicated rescue tug, to meet response times for all vessels
A dedicated rescue tug is pre-positioned near "J" Buoy, to provide response to stricken vessels

within the Strait of Juan de Fuca and the offshore approaches. The effectiveness of both 5,500 HP and 10,000 HP tugs were assessed.

ALT. 8: Dedicated rescue tug, to meet response times for tank vessels
This alternative is similar to ALT. 7, except that the rescue tug is only required to be maintained in ready condition off "J" Buoy when tankers and tank barges are transiting the Strait of Juan de Fuca and the western approaches to the Strait.

ITOS (ALT. 1) reduces the risk of drift groundings by shortening the time required to initiate response. The pre-positioned rescue tug (ALT. 7 and ALT. 8) is primarily effective against drift groundings, but its effectiveness in averting collisions by escorting tankers through the traffic convergence zones just west of "J" Buoy are also considered. The escort tug options (ALT. 2 through ALT. 6) reduce the likelihood of collisions, powered groundings, and drift groundings.

2.2 Study Region

The study region encompasses the Strait of Juan de Fuca and its offshore approaches, Puget Sound south to Olympia, and the waters in and around the San Juan Islands. The primary focus is on the Strait and coastal waters within a 60 nm radius of "J" Buoy, which are considered within reach of a pre-positioned rescue tug.

Figure 1 Chartlet of Study Region

2.2.1 Geography

The Strait of Juan de Fuca is a long, narrow submarine valley that originates along a depression between the lava flows and metamorphic rocks of southern Vancouver Island to the north and the Olympic Peninsula mountains to the south, Ref. (2). It extends approximately 55 nm eastward from its entrance at Cape Flattery, and is approximately 12–15 nm wide for most of this distance. At its narrowest point between Race Rocks and Angeles Point, the Strait is 10 nm wide. It widens to about 21 nm for the eastern portions which extend to Whidbey Island. The depth of the Strait decreases gradually to the east from around 245 meters (about 800 feet) at mid-channel near the western end to about 180 meters (about 600 feet) at a distance of 43 nm east of Cape Flattery. This eastward shoaling continues to the cross-channel sill that cuts across the Strait south of Victoria. The sill is relatively shallow, 55 meters (about 80 feet). East of this submarine ridge there are several shallow banks through which the deepest channels lead into Haro Strait, Rosario Strait, Admiralty Inlet and Deception Passage. The Strait and its western approaches represent a relatively unrestricted waterway in contrast to the narrow passages at its eastern end.

The coastline of the Strait and its approaches is relatively uniform with a low rocky shoreline abutted against cliffs up to 20 meter (65 feet) in height. Centuries of wave action have turned much of the shore into rocky intertidal platforms that are often engulfed in kelp in summer.

The offshore portion of the study area includes the waters northwest, west and south of “J” Buoy. “J” Buoy, located at the entrance of the Strait, marks the center of the Vessel Traffic System (VTS) separation zone north of Cape Flattery. To the west lies the ocean coastal areas of the Olympic Peninsula and Vancouver Island. The Olympic Coast National Marine Sanctuary lies off the west coast of the Olympic Peninsula and includes a portion of the western end of the Strait. It extends from Koitlah Point near Neah Bay, Washington due north to the international border, seaward in a generally southwest direction to the 100 fathom line, and then south to a point due west of the mouth of the Copalis River. The Copalis River cuts across the heads of the Nitnat, Juan de Fuca and Quinault submarine canyons, Ref. (3). The sanctuary encompasses roughly 3300 square miles.

The International Maritime Organization (IMO) has adopted the waters of the Washington Coast as a voluntary area to be avoided (ATBA) to mitigate the risk of pollution in the marine sanctuary. The voluntary scheme applies to all ships bound to and from the Strait engaged in the trade of carrying hazardous cargo, including but not limited to tankers and other bulk carriers and barges. It is roughly coincident with the marine sanctuary, but does not extend as far offshore, being bounded by the eastern edge of the VTS southwestern approach lanes. Canada has designated a Tanker Exclusion Zone of about 50 miles width along the coast of Vancouver Island.

The coast of the Pacific Northwest and its adjacent waters are an environmentally rich and sensitive area known for an abundance of flora and fauna. Commercial uses include fishing, crabbing, shrimping and shellfish industries, and the waters provide recreational opportunities for both tourists and residents.

2.2.2 Environmental Data

Prevailing oceanic winds off the outer British Columbia and Washington coasts are from the northwest in summer and southwest in winter, Ref. (2). These are derived from the seasonal variation in the position of two atmospheric pressure cells, the North Pacific high and the Aleutian low. Inside the Strait of Juan de Fuca the flow of air is strongly influenced by the adjoining mountainous terrain. The prevailing winds are parallel to the Strait, westerly in summer and easterly in winter. Wind speeds generally decrease from west to east, and comparatively weak and variable winds prevail off the eastern portions. Winds greater than 30 knots occur during 10-15 days per month in winter, compared to only 1-2 days per month in summer. Two important features not associated with the large scale circulation pattern are the Arctic air outbreaks in winter and the sea breeze in summer. Arctic outbreaks result from the dense cold air driven seaward by high pressure to produce strong easterly winds at the entrance of the Strait and northerly winds over Puget Sound. During summer, a moderately strong sea breeze builds along the Strait as daytime heating of the land draws cooler marine air inward.

Wave heights in the Strait are constrained by the total fetch along the Strait of about 85 nm and to a lesser extent by the duration and strength of the wind. This also applies to seas generated by westerlies in the Strait where the associated offshore winds blow parallel to the outer coast rather than parallel to the axis of the channel. Strong winds along the coast are generally linked to rapidly moving frontal systems of limited duration and extent. Sustained Arctic outbreaks and stationary fronts associated with intense low pressure cells produce the largest seas. Wave records for the waters off Tofino on the west coast of Vancouver Island suggest that wave heights will exceed 5.5 meters (18 feet) at least 10% of the time in the winter and 3 meters (10 feet) about 10% of the time in the summer. Dispersion, refraction and dissipation will continually diminish wave heights towards the eastern end of the Strait.

Currents in the Strait of Juan de Fuca are dominated by tidal influences and the net outward flow due to discharge from the Fraser and other rivers. In the main body of the Strait the currents tend to parallel the shoreline; however, the islands and channels in the eastern portions of the waterway cause significant local departures from this norm.

Archived data from the National Climatic Data Center and Environment Canada were utilized for developing the impact of wind and waves in the simulations of groundings performed in this study. These are implemented as joint probability density tables for wind speed and wind direction. Where wave heights are important in the evaluation of tug operations and drift rates they have been referenced back to equivalent wind speeds utilizing established relationships, Ref. (4). Details of the environmental data are included in the discussion of the simulations.

2.2.3 Traffic Patterns and Vessel Traffic Management

The Strait of Juan de Fuca is the principal waterway through which international and regional commerce moves to and from the Canadian ports of Victoria, Vancouver and Roberts Banks, the Washington State ports of Port Angeles, Bellingham, Everett, Seattle, Tacoma and Olympia, and the oil terminal facilities. Annually, there are currently over 10,500 inbound and outbound transits of non-government vessels above 300 GT through the Strait of Juan de Fuca.

Inbound tankers deliver crude oil to the refineries at Anacortes, Cherry Point, and Ferndale. Petroleum products primarily move within the Sound, between the refineries and southern ports, although there is a growing movement of finished product, both shipment and receipts, through the Strait of Juan de Fuca. In recent years, over 65% of the vessels above 300 GT transiting the Strait have been containerships and bulk carriers. Commercial cargo traffic into the Puget Sound ports is increasingly dominated by container movements, whereas large quantities of dry bulk cargoes are exported from Vancouver and other British Columbia ports.

Several U.S. and Canadian naval operating/exercise areas are to be found in the region.

Fishing vessel traffic is heavy in the region, especially during the period June through September. Smaller recreational vessels also add to the congestion, particularly during the summer months.

An IMO sanctioned traffic separation scheme has been established in the Strait of Juan de Fuca. Another system, the Haro Strait and Strait of Georgia Traffic Separation Scheme, was established by the U.S. Coast Guard and Transport Canada. These schemes connect with each other and, although not a part of the mandatory VTS system, both schemes are monitored by the Cooperative Vessel Traffic Management System (CVTMS). In practice, these separation schemes are observed by most deep draft vessels, including government vessels transiting the Strait. Laden tank barges generally transit within the traffic lanes, whereas empty barges and freight barges tend to move outside of the lanes.

The offshore approaches to the Strait consist of two inbound and two outbound traffic lanes, which initiate approximately 8 nm to the west and southwest of “J” Buoy. These lanes transition into inbound and outbound lanes within the Strait, such that southbound traffic crosses the route of traffic inbound from the eastern approach. The lanes within the Strait extend from “J” Buoy eastward to the precautionary zone north of Port Angeles. Vessels transit through a “rotary” at the convergence of the traffic lanes from the Strait, and inbound and outbound lanes direct traffic to and from the pilot stations at Ediz Hook and Victoria. Again, crossing of routes is unavoidable.

The traffic lanes are typically about 1 nm wide in the offshore approach and through the Strait to the precautionary zone north of Port Angeles. Exiting the precautionary area the lanes are more typically about 0.5 nm wide. The separation zone between traffic lanes within the Strait and the offshore approaches to “J” Buoy vary in width, but are typically at least 1 nm wide. Correspondingly, the separation between lanes reduces in the eastern areas to about 0.5 nm.

2.2.4 Vessel Traffic Management and Regional Regulations

Vessel traffic in the region is monitored by the Cooperative Vessel Traffic Management System (CVTMS), operated jointly by the Canadian and U.S. Coast Guards. The Canadian Marine Communications and Traffic Services (MCTS) operates Tofino VTS, with responsibility for the waters west of “J” Buoy north to Triangle Island and south to Cape Alava, Washington. The Vessel Traffic Service (Puget Sound), operated by the U.S. Coast Guard in Seattle, covers the waters in the Strait of Juan de Fuca east of Longitude 124°-40’W (east of Port Angeles), and in the waters of Rosario Strait, Admiralty Inlet, Puget Sound, and navigable waters adjacent to these areas. Vancouver VTS (currently relocating to Patricia Bay) controls the waters east of Vancouver Island from Victoria to Cape Caution. Participation in the system is mandatory throughout the waterway, with the exception of several classes of smaller vessels whose length limits vary from 20 to 30 meters. These smaller classes include many tugs and fishing vessels.

All vessels 30 meters or greater, including tugs and tows, are required to contact Tofino VTS when inbound and crossing longitude 127°W, latitude 48°N, or within 50 miles of Vancouver Island. CVTS monitors the vessels until they are formally “handed-off” to Seattle VTS. Vessels continuing north through Haro Strait are then handed-off to Vancouver VTS. A similar procedure occurs for outbound voyages.

Pilotage is compulsory for all foreign vessels and U.S. vessels above 1600 GT engaged in foreign trade, and transiting east of Port Angeles. Pilotage is optional for U.S. vessels engaged in the coastwise trade with a federally licensed pilot on board. Puget Sound pilots serve all U.S. ports and places east of 123°24’W. Canadian pilots serve Victoria, Vancouver and other vessels transiting Haro Strait. The pilot station for Puget Sound pilots is about 0.5 nm north of the east end of Ediz Hook. The Canadian pilot station is approximately 2 nm south of Clover Point.

In addition to the routing, traffic management, and pilotage requirements, there are a number of state and federal regulations specific to the Puget Sound region. Regulations directly applicable to this study include federal and state law limiting the size of tankers entering Puget Sound to 125,000 tons deadweight, and a requirement for two tug escorts for all laden single hull, self-propelled tank vessels of 5,000 GT and above transiting the Puget Sound area east of Dungeness. In addition to the USCG port state control initiatives, the State of Washington also screens vessels through advance notice of entry, conducts inspections, and prepares safety reports. The state also maintains its own list of “high risk” vessels.

2.3 Overview of the Benefit-Cost Framework

In this study, the cost effectiveness of each alternative is presented in terms of the net cost per barrel of spilled oil averted.

2.3.1 Benefits

Benefits are defined as the number of barrels of averted oil spillage. A projected baseline for oil spillage was established for the period 2000-2025, that represents the hypothetical future, without the benefit of ITOS or any of the other alternative measures listed in Section 2.1. The baseline incorporates projected changes in cargo movements and the fleet make-up, as well as the projected impact on oil spills of existing regulations including the double hull provisions of OPA90, the International Ship Management Code (ISM) and Standards for Training and Certification of Watchkeepers (STCW). It does not account for any contemplated regulatory changes, such as possible changes to the traffic separation scheme.

The relative effectiveness of each alternative in averting collisions, powered groundings, and drift groundings is developed from analysis and, when appropriate, expert opinion. These factors are applied against the baseline spill rates to forecast spillage in barrels of oil on an annual basis for the period 2000-2025. The difference between these values and the baseline spill volumes is the barrels of oil not spilled, which is discounted at 7 percent and expressed in 1999 barrels. Each alternative measure is analyzed independently (i.e. each analysis assumes only one of the alternatives is implemented). Due to the overlapping effects of the various alternatives, this independent analysis of alternatives will produce an overestimation of benefits should more than one alternative be implemented.

2.3.2 Costs

Cost of Compliance and Enforcement: The cost of each alternative includes the cost to implement the alternative (capital and recurring costs), costs of industry compliance including those related to changes in transit times, and the government cost of enforcement. The stream of yearly costs for the period 2000-2025 is discounted at 7% per year to a present value in 1999 for each alternative.

Avoided Costs: When an alternative is effective in avoiding accidents and consequently reducing vessel damage, cargo loss, time loss, human injuries and/or loss of life, these avoided losses are benefits that should be accounted for. Because these benefits can not readily be expressed in terms of barrels of oil, a monetary value is assigned. The stream of yearly avoided costs for the period 2000-2025 is discounted at 7% per year to a present value in 1999 for each alternative. Avoided costs related to cleanup and containment are not included in this benefit-cost assessment.

MSIS data from USCG G-MOA and the USCG "1995 Prevention Through People – Quality Action Team Report" are used to develop fatality and serious injury rates in the event of an accident. The avoided costs are based on DOT's estimate of society's willingness to pay to avert fatalities and serious injuries. The benefit analysis concentrates on collision and grounding accidents that produced major spills, whereas the cost analysis must also account for averted collision and grounding accidents that did not spill oil. The accident rates are derived from the USCG CASMAIN accident database for the period 1992-1997, considering all reported collision and grounding accidents for the study region.

2.3.3 Combining Costs and Benefits

As described above, all costs are taken to present value in 1999. The *Avoided Costs* are subtracted from the *Cost of Compliance and Enforcement* to obtain the *Net Costs.* The *Net Cost-Effectiveness* equals the *Benefits* (present value of the number of barrels of oil not spilled) divided by the *Net Cost*.

2.4 Data Sources and Limitations

Data were gathered from a wide variety of sources. When necessary, expert opinion was used to fill in gaps where historical data and/or theoretical analysis were considered too unreliable.

2.4.1 Public Input

The Coast Guard sought public opinion on the alternatives and the framework of the benefit-cost analysis, and a public meeting was also held on the Advance Notice of Proposed Rulemaking. Numerous responses were received. The contents of the public docket were reviewed and, when appropriate, incorporated into this analysis. For example, one commentator suggested that a rescue tug pre-positioned at the entrance to the Strait of Juan de Fuca should be utilized to escort tankers through the transition zone west of "J" Buoy. Another commentator expressed concern over the costs related to slowing down vessels in the Strait, should a tug escort requirement be implemented. These are representative of the type of suggestions put forth in the public commentary and then addressed in this analysis.

An overview of the benefit-cost analysis and environmental impact study was presented at a public meeting held in Seattle on May 12th, 1999. At this meeting, stakeholders expressed their concerns with respect to the risks to the environment, the size of rescue tugs being assessed in the study, and the potential impact high cost solutions could have on shipping into the Puget Sound area.

2.4.2 Expert Panel

The scarcity of accident and spill data necessitated reliance on subjective technical judgements in a number of areas. To assist in making these decisions, a panel with expertise in navigation through the waters of the Puget Sound and the operation of escort and rescue/salvage tugs was assembled. The panel participated in a structured workshop, providing input on relative risks within the waterway and expert opinion on the effectiveness of escort and rescue tugs in various conditions.

The panel consisted of experts in a wide range of marine operations, and the discussion items similarly ranged widely. Expert judgements were sought and recorded on a number of items. However, the pool of experts on any specific issue was not large. The use of the panel was primarily to educate the investigators about the specifics of the marine operations in the study region, raise issues of concern, and to provide guidance for sensitivity analyses to conduct around the base set of assumptions. The impact of this guidance is discussed as applied throughout the report.

In addition, the analytic approaches taken in this study required evaluation of several operational aspects of tug operations. Expert opinion was sought both during the expert panel workshop, and throughout the course of the investigation.

The makeup of the panel of experts and the conduct of the expert panel workshop are documented in Appendix 1 – Panel of Experts.

2.4.3 Traffic Data Sources

Historical cargo movements in the study region for 1995-1997 were derived from data obtained from the Army Corps of Engineering (ACOE), Statistics Canada, and directly from the Canadian ports. The crude oil and product flows from the ACOE data were also compared to data obtained from the Western States Petroleum Association (WSPA). Projections for growth in the trade of the various commodities through the year 2025 was developed from the *1999 Marine Cargo Forecast*, Ref. (5), and from discussions with shipping companies.

The identification of vessels transiting the Strait of Juan de Fuca during 1997-1998 was determined from Canadian (Tofino) and USCG (Seattle) VTS summary data. These databases provided the types, names, and registry of each vessel. The Register of Ships, Ref. (6), was cross-referenced for information on vessel size (DWT and GT), speed, and fuel capacity.

The distribution of vessels within the Strait of Juan de Fuca was obtained from the Seattle VTS radar data. This information was used to determine which types of vessels utilize the traffic lanes and which vessels (e.g. freight barges) typically stay clear of the lanes. The Seattle VTS data were also used to map the distribution of vessels across the lanes. Similarly, Tofino VTS radar data provided the routing of inbound and outbound vessels in the offshore approaches to the Strait, as well as the frequency and routing of coastal voyages that pass through the offshore portion of the study region.

2.4.4 Accident and Spill Data Sources

Oil spills are low probability event. This is particularly true for the very large spills, which are responsible for a majority of the spillage from collisions and groundings. The frequency of these large spills cannot be calculated on a first-principles approach with sufficient accuracy for a benefit-cost analysis, and therefore the frequency of oil spills and the projected oil outflow were derived from historical spill statistics. Within the Puget Sound region and offshore approaches, there have been only four spills greater than 10,000 gallons in size initiating from collisions or groundings during the last 20 years. Due to this sparseness of spill data, spill frequencies and outflows were derived from national statistics, and then these data were projected to the study region.

The Coast Guard CASMAIN and MINMOD databases covering the period 1986-1997 were the primary sources of accident and spill data. These spill data were compared to Minerals Management Service (MMS) database of spills over 1,000 barrels in size, to search out missing records. Canadian spill and accident data was not applied, as it has not been consistently collected in the Pacific region in recent years. The accident data were also compared to State of Washington data for validation purposes.

The causality listed in the Coast Guard databases do not always identify collision and grounding events. Therefore, the narrative description associated with each major spill event in the USCG database during 1986-1997 was reviewed to determine if the oil outflow was the direct result of a collision or grounding incident. ACOE cargo and vessel movement data for U.S. coastal ports were used to develop national spill rates as a function of tons of cargo moved. These spill rates were then projected to the study region based on the movements of cargo through the Strait of Juan de Fuca, which were derived from the data sources described in Section 2.4.3.

Avoided fatality, injury, and damage costs are not limited to spill events, but apply to any accident that is averted through implementation of an alternative measure. Therefore, the frequency of significant collision and grounding accidents in the Puget Sound region was determined from the CASMAIN accident data, and compared to State of Washington data. Although there are concerns about the consistency and completeness of these accident databases, the associated avoided costs are small compared to the compliance costs and have minimal impact on the overall benefit-cost analysis.

2.4.5 Cost Data Sources

Industry Compliance Costs: In this assessment the compliance costs include the costs of the escort or rescue tug, and the costs associated with reduced transit speed for escorted ships. Data for the development of the tug acquisition and operating costs were obtained from previous studies on escort and rescue tugs, Refs. (7), (8), & (9), and from a matrix of existing and proposed tugs developed by the Glosten Associates. Containership and car carrier costs for the reduced transit speed are based on hourly costs developed from Herbert Engineering Corp.'s in-house database of ship construction and operating costs, and verified using Ref (10). Cargo costs for these ships are generally based on Ref. (11).

Avoided Costs: The cost of avoided fatalities and injuries are based on Ref. (6) adjusted to 1999 dollars. The ship damage, cargo damage, and ship lost service were developed using the methodology presented in Ref. (5) adjusted for the mix of vessel types and also adjusted to 1999 dollars.

2.4.6 Data Limitations

Based upon comparisons to some limited data on crude oil and product movement obtained from the Western States Petroleum Association (WSPA), it appears that ACOE has not fully captured the movements of petroleum products. To provide a conservative bound on the analysis, the assumed product flow was increased to reflect the WSPA data and be consistent with the number and sizes of the inbound and outbound tankers and tank barges. The transit data for laden tankers and tank barges were gleaned from radar data and vessel "arrival report" summary data obtained from Tofino VTS.

VTS is considered a reliable source for transit data, as it is rigorously applied throughout the study region and also collects vessel information through the advance reporting procedures. Washington State data for transits through the Strait of Juan de Fuca are in reasonable agreement with the VTS figures applied in this report.

Historical data on spill frequencies and spill volumes form the cornerstone of the benefit analysis, as the effectiveness factors for the alternative measures are applied against the baseline spill volumes to compute the barrels of oil not spilled. A relative strength of the spill data set is that major spills (spills greater than 10,000 gallons in size) from collisions and groundings in U.S. waters have been consistently reported over the last 12 years. The spill data were carefully reviewed and validated as far as practical with the other data sources described previously, and are considered reliable and complete.

The sharp downturn in the frequency of collision and grounding spill events since 1990 presents some challenges. To incorporate this improvement in accident rates, data from1992-1997 is applied for the "probable" case, although from a statistical perspective a larger sample is preferred. Statistical analysis demonstrated that there are an insufficient number of events since 1990 to reliably estimate expected spill sizes, and therefore mean spill sizes for the very large spills are derived from spills over a 25 year period (1973-1997).

Historical data are also insufficient to project the frequency or size of double hull tanker spills. Therefore, double hull tanker spill estimates are based on a theoretical probabilistic-based analysis, by applying historical damage extents to the sub-division of representative double hull tankers.

Collision and grounding accidents that do not involve oil spillage are not as consistently reported as those that produce major spills. Comparison of the Coast Guard and Washington State accident data reveals many missing incidents in both data sets. Fortunately, the projection of accident rates without oil spillage is not critical to the overall benefit assessment. As compared to the averted oil spillage, the avoided costs have a relatively small impact on cost effectiveness.

3 FORECAST TRANSITS AND OIL MOVEMENTS

3.1 Analysis Approach

Cargo movements are based upon historical data up to 1997 and then extended to 2000 to establish base year projections. Projected traffic growth and fleet makeup changes are applied to forecast traffic and oil movements for the period 2000-2025. The principal steps in the development of the forecast of vessel transits and oil movements are as follows:

a) Identify the current movements of crude oil, petroleum products, and dry cargo through the study area, and forecast future quantities for the period 2000-2025.

b) Identify the current fleet serving the study area, and forecast changes in the fleet for the period 2000-2025.

c) Forecast the vessel transits through the study area for the period 2000-2025, based on the cargo projections and fleet characterization from a) and b).

d) Forecast bunker movements through the study region for the period 2000-2025. Overall exposure to oil spills is a function of these bunker movements together with the crude oil and product movements forecast in a).

3.2 Historical Traffic Data

The primary sources of data projecting vessel traffic and commodity movements were the Army Corps of Engineers (ACOE) Waterborne Commerce Statistical Data for 1995-1997, *Shipping in Canada, 1997*, Ref. (5), and direct contact with the ports in British Columbia.

3.2.1 Historical Cargo Movements through the Strait of Juan de Fuca

To project future cargo movements, it was necessary to assemble data on the tonnage of crude oil, refined petroleum product, containerized cargo, and other dry cargoes moving in deep sea vessels and barges through the Strait of Juan de Fuca. The ACOE data provide background on the types and quantities of commodities moving through the Strait inbound and outbound to U.S. ports, as well as cargo movements between Puget Sound and Canada. Certain statistics are excluded from the ACOE database, including military cargo movements in government vessels, domestic fishing vessels, and vessels passing through US waters from foreign ports bound for foreign ports. Vessels inbound and outbound to Canadian ports carrying international cargoes represent a significant portion of the traffic through the Strait of Juan de Fuca, and therefore the ACOE data were supplemented with Canadian data. Total US and Canadian inbound and outbound cargo movements through the Strait for years 1995 through 1997 are summarized in Table 1.

Puget Sound waterborne commerce is becoming increasingly dominated by container traffic –over 75% of the tonnage moved through the Port of Seattle is now in containers. Breakbulk traffic including paper and pulp are moved to Tacoma and surrounding ports. Liquid bulk movement is dominated by crude oil receipts, which are primarily delivered to refineries at Anacortes, Cherry Point, and Ferndale. There is also a small refinery in Tacoma. Petroleum products primarily move within the Sound, between the refineries and southern ports. However, there is a growing movement of finished product, both shipments and receipts, through the Strait of Juan de Fuca.

Dividing the ACOE cargo movements by the total tonnage of vessels transiting the Strait provides an indication of vessel utilization. The calculated value is under 50%, suggesting that product movement is under-reported in the ACOE data. Also, estimates of inbound and outbound product movements obtained from the Western States Petroleum Association (WSPA) for 1995 were about 40% higher than the ACOE data for that year. To account for these discrepancies, the petroleum product tonnage as shown in Table 1 and applied in this study are increased from the ACOE figures by approximately 40%. These are primarily light products – persistent oils comprise only about 20% of the product moving through the Strait.

		1995			1996			1997		
		Inbound	Outbound	Total	Inbound	Outbound	Total	Inbound	Outbound	Total
Zone (A)	Crude Oil	1,379	34	1,413	1,393	35	1,428	1,477	37	1,514
Ports in Puget Sound	Refined Products	307	585	892	269	617	886	164	472	637
located south of lat. 47°50'	Other cargoes	8,063	24,381	32,444	7,639	22,353	29,992	7,732	20,209	27,941
(Seattle, Tacoma & others)	Total Zone A	9,749	25,000	34,749	9,300	23,005	32,306	9,373	20,719	30,092
Zone (B)	Crude Oil	2	0	2	70	2	72	0	0	0
Ports in Puget Sound located	Refined Products	25	48	74	49	41	90	34	64	98
between lat. 47°50' - 48°25'	Other cargoes	523	1,500	2,024	550	1,358	1,908	322	976	1,298
(Everett, Port Angeles & others)	Total Zone B	551	1,549	2,099	669	1,401	2,069	357	1,040	1,396
Zone (C)	Crude Oil	22,066	552	22,618	21,655	541	22,196	23,609	590	24,199
U. S. Ports located	Refined Products	389	7,035	7,424	587	9,171	9,758	207	7,119	7,326
north of lat. 48°25'	Other cargoes	451	386	837	574	422	996	406	366	771
(Anacortes, Cherry Pt. & others)	Total Zone C	22,906	7,973	30,880	22,817	10,134	32,951	24,221	8,074	32,295
TOTALS for U.S. Movements	Crude Oil	23,447	586	24,033	23,119	578	23,697	25,086	627	25,713
	Refined Products	721	7,669	8,390	904	9,829	10,733	406	7,655	8,060
	Other cargoes	9,037	26,268	35,305	8,763	24,133	32,895	8,460	21,551	30,011
	Total U.S.	33,206	34,522	67,728	32,786	34,540	67,326	33,951	29,833	63,783
Zone (D)	Crude Oil	0	420	420	0	665	665	0	376	376
Canadian Ports	Refined Products	0	427	427	0	208	208	517	652	1,170
(Vancouver, Fraser ports	Other cargoes	4,051	65,893	69,944	4,425	68,211	72,636	5,333	69,407	74,739
& others)	Total Zone D	4,051	66,740	70,791	4,425	69,084	73,509	5,850	70,434	76,285
TOTALS (U.S. and Canada)	Crude Oil	23,447	1,006	24,453	23,119	1,243	24,362	25,086	1,003	26,088
	Refined Products	721	8,095	8,817	905	10,037	10,941	923	8,307	9,230
	Other cargoes	13,089	92,161	105,249	13,187	92,344	105,532	13,792	90,958	104,750
	Totals	37,257	101,262	138,519	37,211	103,624	140,835	39,801	100,267	140,068

Table 1 Cargo Movements through the Strait of Juan de Fuca (thousands of metric tons)

General data for the Canadian ports are maintained by Statistics Canada, Ref. (5). This report provides an overview of cargo movements. More specific data on routing and breakdown by commodity type were obtained through direct contact with the British Columbia ports. The bulk of the movements go through three primary ports: Vancouver, Fraser River (Fraser Port), and Nanaimo. Inbound and outbound traffic through Prince Rupert, the only other primary port in British Columbia, arrive and depart directly from and to the Pacific, without transiting the Strait of Juan de Fuca. In addition to the primary ports, there are many private deep sea docks, mostly associated with the forest product industry. To assess these movements, terminal managers were contacted at the following ports: Elk Falls, Crofton, Chemainus, Howe Sound (Port Mellon), Squamish, Woodfibre, Cowichan Bay, Cambell River, and Texada Island.

Similar to the Puget Sound ports, container traffic to the British Columbia ports is the fastest growing segment of the marine trade. However, container traffic accounts for only about 10% of the non-petroleum tonnage. Movements to these ports are dominated by grain as well as bulk cargoes, especially coal. There is also a substantial export of forest products from the British Columbia ports.

There is a relatively small amount of crude oil, typically 200,000 to 800,000 metric tons per year, shipped from Vancouver out the Strait of Juan de Fuca. Movements of refined products to and from Canadian ports show large variations from year to year, with up to one-half million tons moving in and out through the Strait.

3.2.2 Historical Traffic Patterns

All vessels 300 GT and above, including tugs and tows, are required to submit advanced reports before entering these waters. This information is transmitted to Tofino VTS, Seattle VTS, and the State of Washington. For this study, the Tofino VTS was the principal source of data for vessel movements. Voyage information provided in the Tofino data summaries include vessel name, vessel type, and origin and destination ports. Tankers and tank barges are also flagged as laden or empty. Using the ship name as the identifier, the Register of Ships, Ref. (6), was cross-referenced for information on vessel size (DWT and GT), speed, and fuel capacity.

This reporting information together with the Tofino VTS and Seattle VTS radar data provide the most accurate records of the numbers, types, and routing of ships transiting the Strait of Juan de Fuca. Table 2 lists the number of transits by ship type through the Strait during 1997. Only vessels that transit along the traffic lanes and are greater than 300 GT are listed. Freight barge tows as well as empty tank barges typically run south of the lanes or along the coast of Vancouver Island and are not included in the summary.

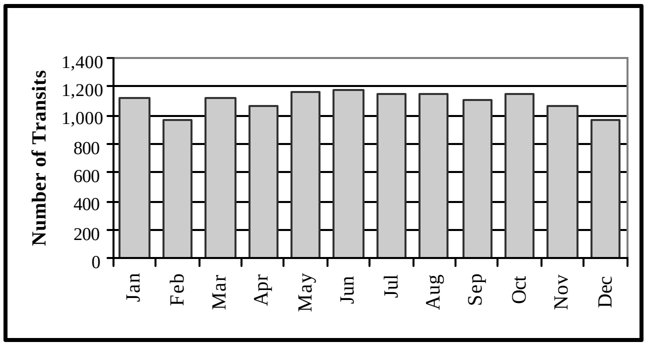
	Inbound Puget Sound	Inbound Canada	Outbound Puget Sound	Outbound Canada	Total Transits
Crude Oil Carriers (Laden)	302	0	15	6	323
Crude Oil Carriers (Ballast	0	6	287	0	293
Product Tankers (Laden)	9	32	174	40	255
Product Tankers (Ballast)	170	24	5	16	215
Tank Barges (Laden)	7	14	140	17	178
Bulk Liquid Carriers	46	135	24	157	362
Bulk Carriers	703	1,701	641	1,763	4,808
Fish Processors (300-3000 GT)	52	5	51	6	114
Fish Processors (>3000 GT)	96	11	96	11	214
Containerships (<4000 TEU)	806	116	566	356	1,844
Containerships (>4000 TEU)	209	30	146	93	478
Ro-ro & Vehicle Carriers	282	138	270	150	840
Passengerships (300-3000 GT)	1	6	3	4	14
Passengerships (>3000 GT)	6	37	15	28	86
Fishing Vessels	108	52	96	64	320
Other Vessles (300-3000 GT)	10	6	10	6	32
Other Vessels (>3000 GT)	7	4	7	4	22
Government Ships	58	143	82	119	402
	3,009	2,470	2,632	2,847	10,958

Table 2 Transits through the Strait of Juan de Fuca during 1997 (Vessels greater than 300 GT)

Bulk carriers and containerships dominate, with more than a 65% share of the number of transits through the Strait. As shown in the table, a significant portion of the bulk carrier trade is inbound and outbound traffic to Canada. The Strait of Juan de Fuca is the preferred route to the ports in the Strait of Georgia and the Puget Sound, both due to the shortness of the route and the comparative ease of passage.

Crude oil carriers primarily move through the Strait of Juan de Fuca, Rosario Strait, Guemes Channel, and the Georgia Strait to the northern refineries. Ships bound for Puget Sound ports pick up their pilot in Port Angeles. Vessels bound for Canada pick up their pilot in Victoria, before proceeding north through Haro Strait.

Figure 1 illustrates the impact of season and day of the week on the frequency of transits. Transits are up about 8% Thursday through Sunday, as compared to Monday through Wednesday. The monthly traffic volume peaks during May through August. These summaries are for vessels of 300 GT or above. There is also considerable traffic of small fishing and recreational boats during the summer months.



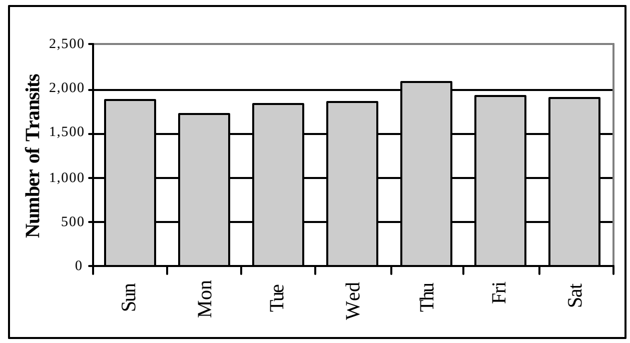


Figure 2 Summary of Transits through the Strait of Juan de Fuca during 1997 (by the month and day of the week – for vessels greater than 300 GT)

3.2.3 Characterization of Current Fleet

The average sizes of the crude oil carriers, containerships, and bulk carriers transiting the Strait of Juan de Fuca in 1997 are summarized in Table 3. Tofino VTS data provided the names of the vessels, and the deadweights and TEU capacities were obtained from the Register of Ships.

Crude oil carriers entering the Puget Sound area are limited by federal and state regulations to a maximum 125,000 tons deadweight. This is below the optimum size with regard to economy, and therefore many of the tankers delivering crude to the Puget Sound refineries fall just below this limiting size. The average deadweight of crude oil carriers calling the Puget Sound region in 1997 was 94,945 tons, whereas the average deadweight of product tankers was slightly over 50,000 tons. Typical tank barge sizes used for coastal trade range from 50,000 to 150,000 barrels.

In 1997, about 20% of the containerships entering the Strait were large post-Panamax containerships (above 32.2 m beam and typically above 4,000 TEU capacity). Most of the bulk carriers were 40,000 DWT and below, with only 5% in excess of 100,000 DWT. The vessels entering the Puget Sound area in 1997 represent over 50 different registries. 95% of the crude oil carriers were U.S. flag, as well as 35% of the product carriers. Petroleum barge operations are primarily run by U.S. concerns under the U.S. flag. About 25% of the containerships comprising about 15% of the TEU capacity are U.S. flag operators involved in domestic trade, whereas the large majority of bulk carriers are foreign flag.

Crude Oil Carriers	less than 75,000 MT	75,000 MT to 110,000 MT	greater than 110,000 MT	Totals
No. of Vessels	85	88	133	306
Av. DWT (M.Tons)	63,397	82,802	123,143	94,945

Containerships Range of Sizes	% by no. of transits	% by TEU's moved	average TEU's per ship	average DWT (M.Tons)
less than 2500 TEU's	44.1%	27.2%	1,746	28,923
2500 to 4000 TEU's	35.3%	36.7%	2,944	43,225
more than 4000 TEU's	20.6%	36.1%	4,965	62,141
			2,832	40,810

Bulk Carriers Range of Sizes	% by no. of transits	average DWT (M.Tons)
up to 50,000 DWT	75.4%	33,615
50,000 to 100,000 DWT	19.8%	65,484
greater than 100,000 DWT	4.8%	171,580
		46,537

Table 3 Average Sizes of Vessels Transiting the Strait of Juan de Fuca in 1997

Typical bunker capacities for the vessels calling the Puget Sound region are listed in Table 4. Bunker capacities were obtained from the Register of Ships and Herbert Engineering Corp. files for as many of the ships transiting the Strait as possible. These values were then weighted against the number of transits to obtain the nominal capacities shown in the table. Bunker capacities for the larger containerships as well as some of the older steamships range up to 7,500 metric tons.

Fuel Bunker Capacity Ship Type	Capacity M.Tons	Typical Fuel Type	Density (t/m3)	Barrels
Crude Oil Carriers				
less than 75,000 MT DWT	3,200	HFO	0.96	20,966
75,000 to 110,000 DWT	3,600	HFO	0.96	23,587
greater than 110,000 DWT	6,000	HFO	0.96	39,311
Product Tankers				
to Canada (av. 22,000 DWT)	1,600	HFO	0.96	10,483
to Puget Sound (av. 55,000 DWT)	3,000	HFO	0.96	19,656
Bulk Liquid Carriers	1,600	HFO	0.96	10,483
Bulk Carriers				
less than 50,000 MT DWT	1,300	HFO	0.96	8,517
50,000 to 100,000 DWT	2,200	HFO	0.96	14,414
greater than 100,000 DWT	4,000	HFO	0.96	26,208
Containerships				
less than 2,500 TEU	2,400	HFO	0.96	15,725
2,500-4,000 TEU	4,400	HFO	0.96	28,828
more than 4,000 TEU	7,500	HFO	0.96	49,139
Vehicle Carriers	2,700	HFO	0.96	17,690
Factory Fishing Vessels				
300 to 3000 GT	460	DO	0.90	3,215
more than 3000 GT	1,500	DO&HFO	0.96	9,828
Passenger				
less than 3000 GT	450	DO	0.90	3,145
more than 3000 GT	2,900	HFO	0.96	19,000
Fishing Boats > 300 GT	225	DO	0.90	1,572
Tug Boats	400	DO	0.90	2,795
Other Vessels				
less than 3000 GT	450	DO	0.90	3,145
more than 3000 GT	1,200	DO	0.90	8,386

Table 4 Typical Bunker Capacities
(for vessels calling the Puget Sound region)

3.3 Forecast Traffic for the Period 2000-2025

Projections for growth in the trade of the various commodities through the year 2025 were developed from the *1999 Marine Cargo Forecast*, Ref. (12), and from discussions with shipping companies.

3.3.1 Forecast Movements of Crude Oil and Petroleum Products

Crude oil receipts are assumed to remain constant over the twenty six year study period. It is anticipated that the Puget Sound refineries will continue to operate at full capacity but without further expansion. As the production of North Slope crude declines, the Alaskan crude will be replaced by foreign imports, which will primarily move on foreign flag vessels.

	U.S. Flag Tankers			Foreign Flag Tankers			% U.S. Flag	% Foreign Flag
	Imports to U.S.	Exports from U.S.	Total U.S. Flag	Imports to U.S.	Exports from Canada	Total Foreign Flag		
1997	24,385	627	25,012	700	376	1,076	95.9%	4.1%
2000	21,678	627	22,305	3,407	376	3,783	85.5%	14.5%
2005	17,818	627	18,445	7,268	376	7,643	70.7%	29.3%
2010	14,645	627	15,272	10,440	376	10,816	58.5%	41.5%
2015	12,037	627	12,664	13,048	376	13,424	48.5%	51.5%
2020	9,894	627	10,521	15,192	376	15,568	40.3%	59.7%
2025	8,132	627	8,759	16,954	376	17,329	33.6%	66.4%

Table 5 Projection of Crude Oil Carried on U.S. and Foreign Flag Vessels

Growth in the waterborne movement of petroleum products in Puget Sound (including import, export, and internal movements) increased at about 8% a year between 1992-1997. A recent study carried out on behalf of the Washington Public Ports Association and the Washington State DOT, Ref. (12), projected continued growth at 5% per year through 2005 and then at 1% per year through 2020. With refineries currently operating at or near their maximum production, the growth through the Strait of Juan de Fuca is projected for imports. For this study, an increase in inbound product movements to the Puget Sound area of about a 5.9% per year is assumed. Exports are forecast to remain flat over the study period.

3.3.2 Forecast Movements of Dry Cargo

Over a five year period through 1997, container trade to British Columbia and Puget Sound ports grew at over 8% a year. The Washington State port study projects continued growth, at 3.5% to 4.5% per year though 2020. For this study, a growth rate of 3.6% per year was assumed through 2025 (see Table 6.) Most of the growth will be realized in the international trade, leading to an increase in larger containerships as discussed in Section 3.3.3.

Grain and forest products have historically accounted for a majority of tonnage, although recently grain movements have shifted to the Lower Columbia River. Pulp and paper have the biggest share of the breakbulk trade although their growth has been flat, as the low container rates have led to a shift towards greater containerization of these commodities. A 1.3% growth in the Puget Sound bulk trade and a 2% increase to Canada are projected over the study period. A 1.2% growth rate for vehicle carriers and a 1% growth rate for bulk liquid movements (chemicals and edible oils) are anticipated. Transits of other vessels such as fishing boats, fish factory vessels, and government vessels are assumed to increase at 1.5% per year to year 2025.

	to/from Puget Sound region			to/from British Columbia			Totals (Inbound & Outbound)		
	TEU's x 1000	M.Tons x 1000	% growth	TEU's x 1000	M.Tons x 1000	% growth	TEU's x 1000	M.Tons x 1000	% growth
1994	2,442	17,576		481	4,566		2,923	22,142	
1995	2,572	18,443	1.0%	489	4,647	1.7%	3,061	23,089	4.3%
1996	2,546	18,106	9.7%	549	5,215	12.3%	3,095	23,321	1.0%
1997	2,635	18,771	5.3%	652	6,194	18.8%	3,287	24,965	7.1%
1998	2,730	19,447	3.6%	675	6,417	3.6%	3,405	25,864	3.6%
1999	2,828	20,147	3.6%	700	6,648	3.6%	3,528	26,795	3.6%
2000	2,930	20,872	3.6%	725	6,887	3.6%	3,655	27,760	3.6%
2005	3,497	24,910	3.6%	865	8,220	3.6%	4,362	33,129	3.6%
2010	4,173	29,728	3.6%	1,033	9,810	3.6%	5,206	39,538	3.6%
2015	4,980	35,478	3.6%	1,232	11,707	3.6%	6,212	47,186	3.6%
2020	5,944	42,341	3.6%	1,471	13,972	3.6%	7,415	56,313	3.6%
2025	7,093	50,531	3.6%	1,755	16,675	3.6%	8,848	67,206	3.6%

Table 6 Projection of Container Movements Through the Strait of Juan de Fuca

3.3.3 Forecast Changes in Vessel Size

A growth in the size of crude oil carriers and containerships is expected. As single hull tankers are phased out, these vessels will be replaced with double hull vessels optimized for the Puget Sound trade, with deadweights of about 125,000 tons and cargo capacity of about 1 million barrels. By 2025, 70% of the waterborne movements of crude oil to the Puget Sound refineries is projected to be carried on tankers of 110,000 tons deadweight and above. In accordance with OPA90 requirements, all these tankers will be double-hulled.

	less than 75,000 MT	75,000 MT to 110,000 MT	greater than 110,000 MT	Average DWT (MT)
1997	27.8%	28.8%	43.5%	94,945
1998	27.3%	28.3%	44.4%	95,416
1999	26.9%	27.8%	45.4%	95,887
2000	26.4%	27.3%	46.3%	96,358
2005	24.1%	24.8%	51.0%	98,712
2010	21.8%	22.4%	55.8%	101,067
2015	19.6%	19.9%	60.5%	103,421
2020	17.3%	17.5%	65.3%	105,775
2025	15.0%	15.0%	70.0%	108,130

Table 7 Projected Size of Crude Oil Carriers

The first of the large 6000 TEU containerships was delivered in 1996, and more than thirty 4500+ TEU containerships were delivered through 1999. The trans-Pacific trade will become increasingly dominated by these post-Panamax containerships, which are projected to carry 70% of the total container traffic and over 85% of the international trade by 2010.

	Portion of TEU's carried			Average Slot Capacity		
	less than 2500 TEU	2500 to 4000 TEU	greater than 4000 TEU	less than 2500 TEU	2500 to 4000 TEU	greater than 4000 TEU
1997	27.2%	36.7%	36.1%	1,746	2,944	4,965
1998	26.3%	35.1%	38.7%	1,746	2,944	5,002
1999	25.3%	33.4%	41.3%	1,746	2,944	5,039
2000	24.4%	31.7%	43.9%	1,746	2,944	5,076
2005	19.7%	23.4%	57.0%	1,746	2,944	5,261
2010	15.0%	15.0%	70.0%	1,746	2,944	5,446
2015	15.0%	15.0%	70.0%	1,746	2,944	5,630
2020	15.0%	15.0%	70.0%	1,746	2,944	5,815
2025	15.0%	15.0%	70.0%	1,746	2,944	6,000

Table 8 Projected Size of Containerships

The sizes of other vessels are assumed to remain constant over the study period.

3.3.4 Forecast Phase-Out of Single Hull Tankers and Tank Barges

The expected depletion of the single hull fleet due to forced retirement under OPA90 was computed for the Jones Act vessels typically calling the Puget Sound area. Partial replacement of these vessels through the construction or conversion of five 125,000 DWT tankers is projected by 2005. A replacement schedule was also developed for the international fleet, and these data were then applied against the anticipated mix of U.S. and foreign flag vessels to determine the ratio of single hull and double hull vessels over the study period (see Table 9). Replacement of some of the larger tank barges will take place by 2005. Economic considerations will likely preclude the replacement of barges under 15000 GT before their mandated retirement in 2015.

Year	Crude Oil Carriers	Product Tankers	Tank Barges
1997	16.7%	17.7%	0.0%
1998	17.0%	18.7%	0.0%
1999	19.4%	21.0%	0.0%
2000	28.8%	29.4%	0.0%
2001	35.9%	36.1%	1.0%
2002	47.1%	45.7%	1.0%
2003	50.7%	49.8%	1.0%
2004	51.7%	51.4%	1.0%
2005	57.4%	57.1%	27.5%
2006	66.5%	66.1%	39.8%
2007	70.4%	70.3%	44.8%
2008	71.1%	71.3%	44.8%
2009	78.3%	79.2%	44.8%
2010	79.7%	80.8%	53.1%
2011	79.9%	81.3%	53.1%
2012	81.6%	83.6%	53.1%
2013	84.2%	87.1%	53.1%
2014	86.5%	90.4%	53.1%
2015	100.0%	100.0%	100.0%

Table 9 Percent of Tanker Fleet with Double Hulls

3.3.5 Projected Fleet Makeup and Total Oil Movements for the Period 2000-2025

The effective utilization of the vessels transiting the Strait was derived from the historical data on cargo movements, size of vessels, and number of transits. For example, the average payload of cargo oil for inbound crude oil carriers was found to be approximately 87% of the deadweight. The number of transits through the Strait of Juan de Fuca was estimated by dividing the projected cargo movements in tons, by the average payload of the vessels trading into the region. Adjustments were made for the anticipated changes in sizes of the tanker and containerships fleets as discussed in Section 3.3.3. All vessels above 300 GT were included in the fleet projection with the exception of empty tank barges, freight barges, and other small vessels that stay clear of the traffic lanes.

In this way, the number, types and sizes of vessels servicing the study region through year 2025 was forecast. As illustrated in Table 10 and Figure 3, the number of vessels over 300 GT in size transiting the Strait is projected to increase by over 50% by the year 2025.

	Projected Transits per Year					
Vessel Type	2000	2005	2010	2015	2020	2025
Bulk Carriers	5,073	5,547	6,065	6,632	7,255	7,939
Containerships	2,440	2,620	2,762	3,246	3,816	4,486
Other Vessels >3000 GT	2,840	2,992	3,153	3,326	3,510	3,712
Other Vessels 300-3000 GT	162	180	193	211	225	245
Barges (Laden)	188	201	215	229	246	264
Tankers (Laden)	570	579	590	604	622	641
	11,273	12,119	12,978	14,248	15,674	17,287

Table 10 Projection of Ships Transiting the Strait of Juan de Fuca (2000-2025)

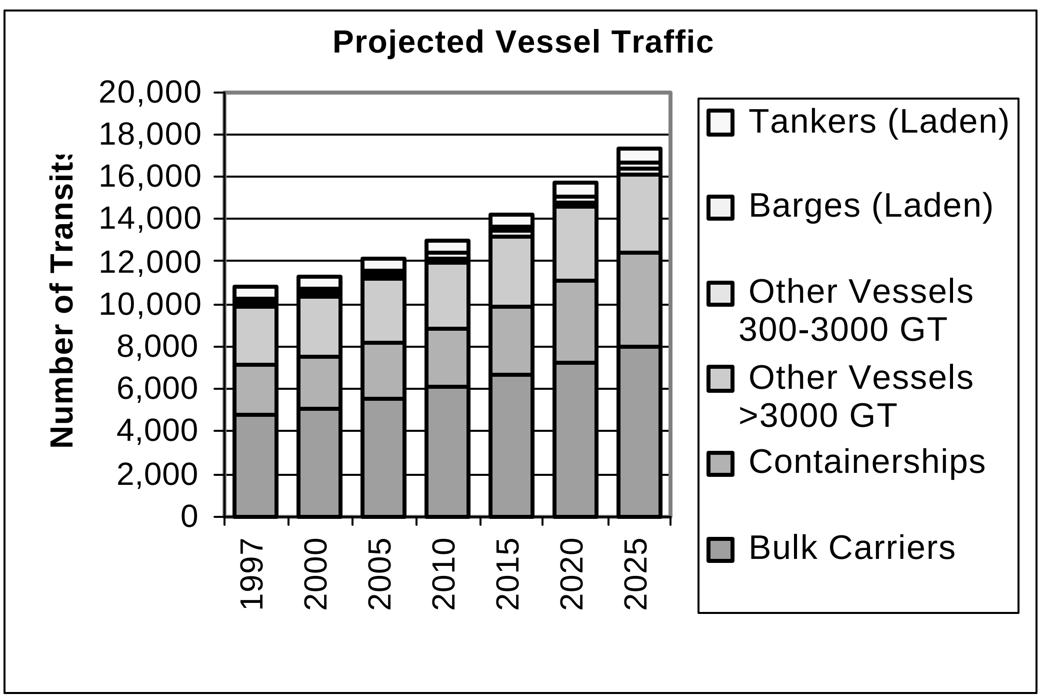


Figure 3 Projected Growth in Traffic Through the Strait of Juan de Fuca

Three potential sources of oil spillage are considered: crude oil, refined petroleum products, and bunkers. When projecting total oil movements, bunkers were taken at 40% of capacity for all inbound vessels, and 70% of capacity for all outbound vessels. A database of bunker movements is not available, and therefore the percentage of bunkers onboard was estimated after discussions with ship operators.

Projections of oil movements through the Strait of Juan de Fuca for the period 2000-2025 are given in Table 11. Oil movements are projected to grow from about 360 million barrels in year 2000, to 457 million barrels in year 2025. Government ships were not included in the oil movement projections, as these vessels were excluded from the benefit-cost analysis.

A detailed summary of transits and oil movements for the year 2000 is shown in Table 12. Such tables were developed for every 5 years through 2025.

		Year 2000		Year 2005		Year 2010		Year 2015		Year 2020		Year 2025	
Inbound and Outbound Voyages		No. of	Oil Carried	No. of	Oil Carried	No. of	Oil Carried	No. of	Oil Carried	No. of	Oil Carried	No. of	Oil Carried
Vessel Type	Vessel Size	Transits	per transit	Transits	per transit	Transits	per transit	Transits	per transit	Transits	per transit	Transits	per transit
Crude Oil Carriers	less than 75,000 DWT	83	400,073	74	398,934	65	400,469	57	399,210	49	401,505	42	400,184
(laden)	75,000 to 110,000 DWT	85	521,242	75	523,041	67	521,824	58	520,053	50	517,944	41	520,803
	greater than 110,000 DWT	145	776,485	156	775,350	166	776,517	176	777,551	186	776,443	195	777,287
	av. 67,000 DWT	6	438,515	6	438,515	6	438,515	6	438,515	6	438,515	6	438,515
(ballast)	less than 75,000 DWT	75	14,676	66	14,676	59	14,676	51	14,676	44	14,676	38	14,676
	75,000 to 110,000 DWT	77	16,511	69	16,511	60	16,511	53	16,511	45	16,511	38	16,511
	greater than 110,000 DWT	131	27,518	140	27,518	151	27,518	159	27,518	168	27,518	176	27,518
	av. 67,000 DWT	6	8,386	6	8,386	6	8,386	6	8,386	6	8,386	6	8,386
Refined Product Carriers	av. 55,000 DWT	213	273,222	226	272,731	240	272,262	256	271,789	273	271,347	290	270,957
(laden)	av. 22,000 DWT	38	111,702	42	111,736	46	111,764	51	111,794	58	111,826	67	111,857
(ballast)	av. 55,000 DWT	191	4,794	190	5,099	190	5,452	190	5,855	191	6,297	190	6,710
	av. 22,000 DWT	26	7,741	26	7,701	26	7,661	27	7,610	26	7,540	27	7,455
Refined Product -Barges	av. 12,000 DWT	172	92,055	183	92,055	195	92,055	207	92,055	221	92,055	235	92,055
(laden)	av. 6,000 DWT	16	46,587	18	46,587	20	46,587	22	46,587	25	46,587	29	46,587
Bulk Liquid Carriers		372	5,766	392	5,766	412	5,766	432	5,766	456	5,766	478	5,766
Bulk Carriers	less than 50,000 DWT	3,826	4,685	4,183	4,685	4,574	4,685	5,003	4,685	5,473	4,685	5,989	4,685
	50,000 to 100,000 DWT	1,003	7,928	1,096	7,928	1,199	7,928	1,311	7,928	1,435	7,928	1,570	7,928
	greater than 100,000 DWT	243	14,414	266	14,414	291	14,414	318	14,414	348	14,414	381	14,414
Containerships	less than 2,500 TEU	1,020	8,648	984	8,648	894	8,648	1,068	8,648	1,274	8,648	1,520	8,648
	2,500-4,000 TEU	788	15,856	692	15,856	530	15,856	634	15,856	756	15,856	902	15,856
	more than 4,000 TEU	632	27,026	944	27,026	1,338	27,026	1,544	27,026	1,786	27,026	2,064	27,026
Vehicle Carriers		870	9,730	924	9,730	980	9,730	1,042	9,730	1,106	9,730	1,174	9,730
Factory Fishing Vessels	300 to 3000 GT	118	1,768	130	1,768	138	1,768	150	1,768	160	1,768	174	1,768
	more than 3000 GT	224	5,405	240	5,405	260	5,405	280	5,405	300	5,405	326	5,405
Passenger	300 to 3000 GT	14	1,153	16	1,153	16	1,153	18	1,153	18	1,153	22	1,153
	more than 3000 GT	90	10,450	98	10,450	104	10,450	112	10,450	120	10,450	130	10,450
Fishing Boats > 300 GT	300 to 3000 GT	334	865	362	865	388	865	418	865	450	865	486	865
Other Vessels	300 to 3000 GT	32	1,730	36	1,730	38	1,730	42	1,730	44	1,730	48	1,730
	more than 3000 GT	22	4,613	26	4,613	26	4,613	28	4,613	32	4,613	34	4,613
		10,852	33,183	11,667	32,139	12,485	31,382	13,719	29,938	15,106	28,640	16,678	27,371
	Total Oil Moved (millions of barrels)	360.1		375.0		391.8		410.7		432.6		456.5	

Table 11 Projected Transits and Oil Movements for the Period 2000-2025

FOR YR 2000		Oil Movement per Transit				Oil Movements for Year			
Inbound Voyages Vessel Type	Vessel Size	Crude Oil barrels	Refined Product barrels	Bunker Fuel Oil barrels	No. of Transits for year	Crude Oil 1000's bbls	Refined Product 1000's bbls	Bunker Fuel Oil 1000's bbls	Oil Movement 1000's bbls
Crude Oil Carriers									
To Puget Sound (laden)	less than 75,000 DWT	401,047		8,386	79	31,683		663	32,345
	75,000 to 110,000 DWT	523,799		9,435	81	42,428		764	43,192
	greater than 110,000 DWT	778,995		15,725	138	107,501		2,170	109,671
To Canada (ballast)	av. 67,000 DWT			8,386	6			50	50
Refined Product Carriers									
To Puget Sound (laden)	av. 55,000 DWT		260,496	4,193	23		5,991	96	6,088
To Canada (laden)	av. 22,000 DWT		104,198	7,862	12		1,250	94	1,345
To Puget Sound (ballast)	av. 55,000 DWT			4,193	179			751	751
To Canada (ballast)	av. 22,000 DWT			7,862	20			157	157
Refined Product on Barges									
To Puget Sound (laden)	av. 12,000 DWT		90,937	1,118	18		1,637	20	1,657
To Canada (laden)	av. 6,000 DWT		45,468	1,118	5		227	6	233
Bulk Liquid Carriers				4,193	186			780	780
Bulk Carriers	less than 50,000 DWT			3,407	1,913			6,517	6,517
	50,000 to 100,000 DWT			5,766	501			2,891	2,891
	greater than 100,000 DWT			10,483	122			1,276	1,276
Containerships	less than 2,500 TEU			6,290	510			3,208	3,208
	2,500-4,000 TEU			11,531	394			4,543	4,543
	more than 4,000 TEU			19,656	316			6,211	6,211
Vehicle Carriers				7,076	435			3,078	3,078
Factory Fishing Vessels	300 to 3000 GT			1,286	59			76	76
	more than 3000 GT			3,931	112			440	440
Passenger	less than 3000 GT			839	7			6	6
	more than 3000 GT			7,600	45			342	342
Fishing Boats > 300 GT				629	167			105	105
Other Vessels	300 to 3000 GT			1,258	16			20	20
	more than 3000 GT			3,355	11			37	37
					5,355	181,612	9,106	34,302	225,019

		Oil Movement per Transit				Oil Movements for Year			
Outbound Voyages Vessel Type	Vessel Size	Crude Oil barrels	Refined Product barrels	Bunker Fuel Oil barrels	No. of Transits for year	Crude Oil 1000's bbls	Refined Product 1000's bbls	Bunker Fuel Oil 1000's bbls	Oil Movement 1000's bbls
Crude Oil Carriers									
From Puget Sound (laden)	less than 75,000 MT DWT	200,523		14,676	4	802		59	861
	75,000 to 110,000 DWT	261,900		16,511	4	1,048		66	1,114
	greater than 110,000 DWT	389,497		27,518	7	2,726		193	2,919
From Puget Sound (ballast)	less than 75,000 MT DWT			14,676	75	0		1,101	1,101
	75,000 to 110,000 DWT			16,511	77	0		1,271	1,271
	greater than 110,000 DWT			27,518	131	0		3,605	3,605
From Canada (laden)	av. 67,000 DWT	423,839		14,676	6	2,543		88	2,631
Refined Product Carriers									
From Puget Sound (laden)	av. 55,000 DWT		260,496	13,759	190		49,494	2,614	52,108
From Canada (laden)	av. 22,000 DWT		104,198	7,338	26		2,709	191	2,900
From Puget Sound (ballast)	av. 55,000 DWT			13,759	12			165	165
From Canada (ballast)	av. 22,000 DWT			7,338	6			44	44
Refined Product on Barges									
To Puget Sound (laden)	av. 12,000 DWT		90,937	1,118	154		14,004	172	14,176
To Canada (laden)	av. 6,000 DWT		45,468	1,118	11		500	12	512
Bulk Liquid Carriers				7,338	186			1,365	1,365
Bulk Carriers	less than 50,000 DWT			5,962	1,913			11,405	11,405
	50,000 to 100,000 DWT			10,090	501			5,059	5,059
	greater than 100,000 DWT			18,345	122			2,233	2,233
Containerships	less than 2,500 TEU			11,007	510			5,614	5,614
	2,500-4,000 TEU			20,180	394			7,951	7,951
	more than 4,000 TEU			34,397	316			10,870	10,870
Vehicle Carriers				12,383	435			5,387	5,387
Factory Fishing Vessels	300 to 3000 GT			2,250	59			133	133
	more than 3000 GT			6,879	112			771	771
Passenger	less than 3000 GT			1,468	7			10	10
	more than 3000 GT			13,300	45			599	599
Fishing Boats > 300 GT				1,101	167			184	184
Other Vessels	300 to 3000 GT			2,201	16			35	35
	more than 3000 GT			5,870	11			65	65
					5,497	7,119	66,708	61,259	135,086

		Oil Movements for Year			
	No. of Transits for year	Crude Oil 1000's bbls	Refined Product 1000's bbls	Bunker Fuel Oil 1000's bbls	Oil Movement 1000's bbls
Inbound	5,355	181,612	9,106	34,302	225,019
Outbound	5,497	7,119	66,708	61,259	135,086
Total	10,852	188,731	75,814	95,561	360,106

Table 12 Vessel and Oil Movement Projections for the Year 2000

4 SPILL RATES FOR THE PUGET SOUND REGION

4.1 Analysis Approach

Historical spill data were used as the basis for establishing the current spill risk level for tankers, tank barges, and freighters. Within the Puget Sound region and offshore approaches, there have been only four spills greater than 10,000 gallons in size initiating from collisions or groundings during the last 20 years. Due to this sparseness of spill data, the frequency and mean size of spills were derived from national statistics, and then these data were projected to the study region. The MINMOD and CASMAIN data sets were obtained from the USCG, and compared to the Minerals Management Service (MMS) database of spills over 1,000 barrels in size, to search out missing records. The Puget Sound spill events were also reconciled against the State of Washington DOE statistics. Canadian spill and accident data were not applied, as spill statistics have not been consistently collected in the Pacific region in recent years.

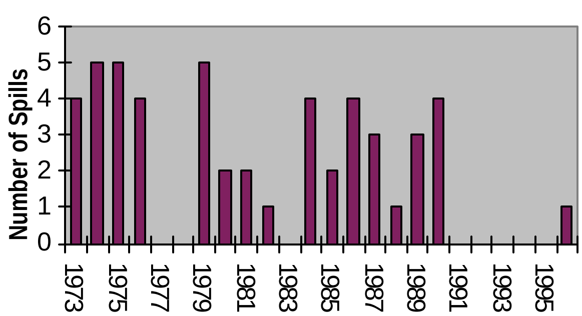
The ratio of tons moved through the Strait of Juan de Fuca as compared to tons moved to U.S. coastal ports is used to project national spill frequency data to the Puget Sound region. Average spill sizes for the region are assumed to be the same as the national averages. As discussed in Section 4.3.2, the overall spill frequency for all vessel types developed with this approach is consistent with the actual spill frequency experienced within the study region over the last twenty years.

CASMAIN and Washington State casualty data were used to estimate the frequency of collisions and grounding accidents. Although all such accidents do not result in spills, this information was needed to estimate avoided costs related to fatalities, injuries, and damage. Spill frequencies and accident rates are based on statistical data through 1997, and are considered applicable to 1997. These data are extended to years beyond 1997 as discussed in Section 5.

4.2 National Spill Rates

4.2.1 Spills in U.S. Waters – National Trends

Historically, large spill accidents generated over 90% of the volume of oil spillage from vessels in U.S. waters. A list of tanker and tank barge casualties of more than 100,000 gallons (2,381 barrels) in size that occurred in U.S. waters during the period 1973-97 are contained in Table 13, and graphically displayed in Figure 4 and Figure 5. These large spills were primarily the result of allision, collision, and grounding accidents. The large majority occurred in harbors and coastal waters, as inland spills are typically smaller in size.



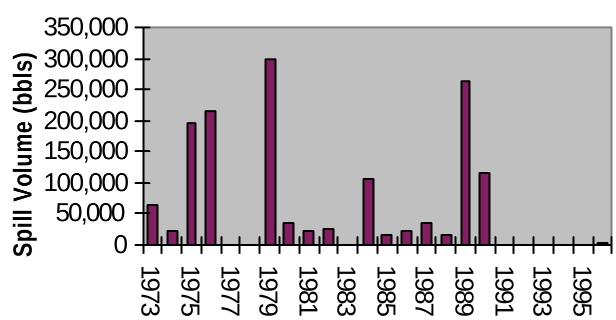
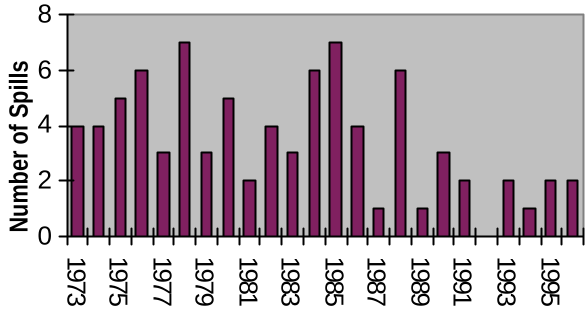


Figure 4 Tanker Spills greater than 100,000 gallons (2,381 barrels) in U.S. Waters



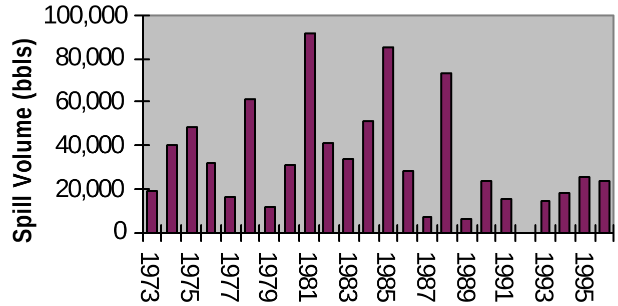


Figure 5 Tank Barge Spills greater than 100,000 gallons (2,381 barrels) in U.S. Waters

	Tankers		Tank Barges	
Year	Number of Spills	Annual Spill Volume (barrels)	Number of Spills	Annual Spill Volume (barrels)
1973	4	63,526	4	18,659
1974	5	22,539	4	39,845
1975	5	195,619	5	47,823
1976	4	216,802	6	32,043
1977	0	0	3	16,381
1978	0	0	7	61,206
1979	5	300,416	3	11,357
1980	2	34,381	5	30,824
1981	2	22,381	2	91,381
1982	1	25,042	4	41,144
1983	0	0	3	33,287
1984	4	105,649	6	50,865
1985	2	16,047	7	84,950
1986	4	23,222	4	28,020
1987	3	34,228	1	7,185
1988	1	15,350	6	73,074
1989	3	264,262	1	6,000
1990	4	115,808	3	23,593
1991	0	0	2	14,855
1992	0	0	0	0
1993	0	0	2	14,200
1994	0	0	1	17,857
1995	0	0	2	24,833
1996	1	3,950	2	23,914
1997	0	0	0	0
	50	1,459,220	83	793,299
Average Spill Size (bbls)		29,184		9,558

Table 13 Tanker and Tank Barge Spills in U.S. Waters (1973-97) for spills greater than 100,000 gallons (2,381 barrels) in size

These data illustrate the marked reduction in the number and volume of large spills since 1990. This is not unexpected – the Exxon Valdez oil spill raised industry awareness of the consequences of oil spills, and the provisions of OPA90 as well as state laws (e.g., tug escort requirements) have contributed to an overall improvement in safety. This improvement in environmental performance has been documented in a number of recent studies, Ref. (13) and Ref. (14).

4.2.2 Spills in U.S. Waters from the Collisions and Grounding of Ships

Collisions, drift and powered groundings are the types of accidents that can be prevented through one or more of the alternatives under evaluation in this study. Therefore, the narrative description associated with each spill event in the USCG database was reviewed to determine if the oil outflow was the direct result of a collision or grounding incident. For example, the initiating cause of the North Cape tank barge spill off Rhode Island was a fire on the tug. The barge was separated from the tug and drifted aground. This accident was counted as a drift grounding. The data set was restricted to spills in coastal waters, harbors, and the adjoining waterways, as such spills are considered most representative of the type of spills likely to occur in the Strait of Juan de Fuca, its offshore approaches, and Puget Sound.

Allision accidents are not included in these collision and grounding summaries. ITOS and rescue tugs are not effective in averting allisions, and it is assumed that docking tugs rather than the escort tugs will be used to bring the freighters into their berths.

A summary of spills from collisions and groundings during the period 1992-1997 is presented in Table 14. Spills over 1,000 gallons (24 barrels) in size are considered. Although the majority of spills were from fishing vessels and other smaller craft, larger vessels were responsible for most of the volume of oil spilled. In particular, tank barges were responsible for most of the spill volume.

The number of spills and spill volume data are provided for three sizes of spills: 1) spills greater than 1,000 gallons, 2) spill greater than 10,000 gallons, herein referred to as *major* spills, and, 3) spills greater than 100,000 gallons, herein referred to as *large* spills. Of interest is that major spills were responsible for 98% of the spill volume from tankers, tank barges, and freighters. Although spills above 100,000 gallons were responsible for over 90% of the spill volume prior to 1990, there have been very few spills of this magnitude in recent years.

Number of Spills (1992-1997)

	>1,000 gal (> 24 bbls)	>10,000 gal (>238 bbls)	% of spills >10,000 gal	>100,000 gal (>2381 bbls)	% of spills >100,000 gal
Tankers	3	2	67%	0	0%
Tank Barges	14	6	43%	3	21%
Freighters	5	4	80%	0	0%
Fishing Boats	27	2	7%	0	0%
Others	11	3	27%	0	0%

Volumes of Spills in Barrels (1992-1997)

	>1,000 gal (> 24 bbls)	>10,000 gal (>238 bbls)	% of outflow from spills >10,000 gal	>100,000 gal (>2381 bbls)	% of outflow from spills >100,000 gal
Tankers	1,306	1,277	98%	0	0%
Tank Barges	48,492	47,721	98%	46,172	95%
Freighters	4,719	4,632	98%	0	0%
Fishing Boats	4,363	2,667	61%	0	0%
Others	2,101	1,595	76%	0	0%

Table 14 Oil Spills in U.S. Harbors and Coastal Waters from Collisions and Groundings Summary by Vessel Type for the period 1992-1997

A comparison of the frequency and volume of spills during 1992-1997 to the prior six years, 1986-1991, is presented in Table 15. Tanker, tank barge, and freighter spills greater than 10,000 gallons in size are considered. During the six year period from 1986-1991, there were 38 collision and grounding spills over 10,000 gallons. In the next six years, from 1992-1997, 12 spills occurred. Although the number of spills from tankers exhibited the largest decline (to 20% of earlier levels), improvements were realized for all three types of vessels.

Number of Spills >10,000 gallons (238 barrels) in size

		Tankers	Tank Barges	Freighters
1986-97	No. of Spills	12	25	13
	Spills/year	1.0	2.1	1.1

		Tankers	Tank Barges	Freighters
1986-91	No. of Spills	10	19	9
	Spills/year	1.7	3.2	1.5
1992-97	No. of Spills	2	6	4
	Spills/year	0.3	1.0	0.7
1992-97 spill frequency as a percent of 1986-91 levels		20%	32%	44%

Volumes of Spills in Barrels

		Tankers	Tank Barges	Freighters
1986-97	Volume (bbls)	300,350	99,456	26,587
	bbls/year	25,029	8,288	2,216
	bbls/spill	25,029	3,978	2,045

		Tankers	Tank Barges	Freighters
1986-91	Volume (bbls)	299,073	51,735	21,955
	bbls/year	49,845	8,622	3,659
	bbls/spill	29,907	2,723	2,439
1992-97	Volume (bbls)	1,277	47,721	4,632
	bbls/year	213	7,953	772
	bbls/spill	639	7,953	1,158
1992-97 spill volumes as a percent of 1986-91 levels		<1%	92%	21%

Table 15 Oil Spills in U.S. Harbors and Coastal Waters from Collisions and Groundings for spills greater than 10,000 gallons (238 barrels) in size

Spill volume from tankers has been especially low in recent years. There were only two collision and grounding accidents during the 1992-1997 period from tankers, and the resulting spills were each under 1,000 barrels. Tank barges, on the other hand, experienced an increase in spill size. This was the result of a number of large spills, particularly the *North Cape* and *Berman* drift grounding casualties.

Number of Spills >10,000 gallons in size (1986-1997)

	Tankers	Tank Barges	Freighters	Totals
Collisions	2	9	5	16
Drift Grounding	0	2	2	4
Powered Grd.	10	14	6	30
	12	25	13	50

	Tankers	Tank Barges	Freighters	mean
Collisions	17%	36%	38%	32%
Drift Grounding	0%	8%	15%	8%
Powered Grd.	83%	56%	46%	60%

Table 16 Spills in U.S. Harbors and Coastal Waters Collision, Drift Grounding and Powered Grounding Breakdown

As shown in Table 16, during the 1986-97 period 32% of the spills were collisions, 8% were drift groundings, and 60% were powered groundings. This is consistent with past statistical analyses. IMO applied a 40% collision:60% grounding ratio in its probabilistic outflow methodology for evaluating tankers.

In the scoping risk assessment of the Puget Sound region performed by VOLPE, Ref. (1), 7% of the collision and grounding accidents were found to be drift groundings. It should be noted that VOLPE also utilized expert opinion to assess risk, and the experts assigned a relatively higher risk to drift groundings. VOLPE's "risk weighted accident significance" for drift groundings is 16%.

4.2.3 Average Spill Volumes

Large spills (spills greater than 100,000 gallons or 2,381 barrels) are low probability events, but have a significant impact on the average spill size. This becomes apparent when reviewing the spill volume summary in Table 15. The average spill size for the 1986-91 and 1992-97 periods is 29,907 barrels and 639 barrels respectively. The 1986-91 spill size is heavily influenced by the 250,000 barrel Exxon Valdez spill. In contrast, during 1992-97 there were only two spills, and by chance they were relatively small in size.

In this study, the 25 year data (Table 13) was used to estimate the average size of spills above 100,000 gallons. The average size of spills between 10,000-100,000 gallons in size was based on 1986-97 data. The proportion of spills (10,000-100,000 gallons spills compared to spills greater than 100,000 gallons in size) was also based on the 1986-97 data. The average sizes of tanker and tank barge spills were divided by the average volume of oil per transit moved on tankers and tank barges in U.S. waters, which was obtained from ACOE data. The average size of freighter and fishing boat spills were divided by estimated bunker quantities. The outflow expressed as a percentage of the oil onboard each vessel type is given in Table 17.

	average spill size (barrels)	oil carried per transit (barrels)	% outflow
tankers	17,570	243,819	7%
tank barges	4,279	56,779	8%

	average spill size (barrels)	average bunkers (barrels)	% outflow
freighters	1,644	8,748	19%
fishing boats & others	852	1,145	74%

Table 17 Oil Spillage vs. Barrels of Oil Carried

4.2.4 Theoretical Oil Outflow Analysis

Although over 25% of the world's tanker fleet is now double-hulled, many of the double hull tankers have been constructed in the last few years. The sparseness of collision and grounding spills from double hull tankers gives reason to believe that this design is effective in mitigating spillage, but there are still insufficient spill statistics to reliably estimate their expected spill volume. Therefore, probabilistic outflow calculations have been carried out to assess the relative effectiveness of double hulls.

The IMO guidelines for evaluating alternative tanker designs, Ref. (15), contain a probabilistic-based procedure for assessing oil outflow performance. Probability density functions describing the location, extent and penetration of side and bottom damage are applied to a vessel's compartmentation, generating the probability of occurrence and collection of damaged compartments associated with each possible damage incident. Calculations were carried out for a series of actual vessels, representative of the types of ships calling the Puget Sound area.

The outflow characteristics for tankers are summarized in Table 18. Three sizes of tankers were evaluated: Panamax (about 40,000 DWT), Aframax (about 90,000 DWT), and 125,000 DWT crude oil carriers. A pre-MARPOL and a MARPOL'78 configuration were evaluated for each size of single hull tanker. The Panamax double hull tankers have 2 meter wide wing tanks and double bottoms, and centerline bulkheads. The Aframax double hull tankers have double hull dimensions between 2.3 and 2.5 meters. Aframax design #1 has a single-tank-across cargo tank arrangement, whereas design #2 has a centerline bulkheads. The 125,000 DWT double hull tankers are representative of the tankers being specially designed and built for the Alaskan North trade. These tankers, arranged with wide double hull dimensions (typically 2.8 to 2.0 meters) and longitudinal sub-division throughout the cargo block, have very good outflow characteristics.

SINGLE HULL TANKERS		Panamax #1	Panamax #2	Aframax #1	Aframax #2	125K dwt #1	125K dwt #2	Average
Side	Prob. Of Zero Outflow (Po)	0.31	0.54	0.22	0.32	0.24	0.34	0.33
	Average Spill Size	8%	4%	12%	11%	8%	8%	8%
	Extreme Spill Size	15%	12%	20%	16%	15%	11%	15%
Bottom	Prob. Of Zero Outflow (Po)	0.13	0.10	0.09	0.09	0.08	0.08	0.09
	Average Spill Size	5%	8%	5%	9%	5%	8%	7%
	Extreme Spill Size	15%	23%	13%	21%	11%	17%	17%
Combined	Prob. Of Zero Outflow (Po)	0.20	0.28	0.14	0.19	0.14	0.18	0.19
	Prob. of Outflow (1-Po)	0.80	0.72	0.86	0.81	0.86	0.82	0.81
	Mean Outflow Parameter	0.047	0.053	0.062	0.081	0.049	0.062	0.059
	Average Spill Size	6%	7%	7%	10%	6%	8%	7%
	Extreme Spill Size	15%	19%	16%	19%	13%	15%	16%

DOUBLE HULL TANKERS		Panamax #1	Panamax #2	Aframax #1	Aframax #2	125K dwt #1	125K dwt #2	Average
Side	Prob. Of Zero Outflow	0.85	0.85	0.85	0.87	0.82	0.90	0.85
	Average Spill Size	11%	11%	20%	16%	11%	11%	13%
	Extreme Spill Size	13%	13%	25%	19%	14%	11%	16%
Bottom	Prob. Of Zero Outflow	0.84	0.84	0.81	0.80	0.82	0.82	0.82
	Average Spill Size	7%	7%	9%	7%	6%	5%	7%
	Extreme Spill Size	10%	10%	13%	11%	8%	8%	10%
Combined	Prob. Of Zero Outflow	0.84	0.84	0.82	0.83	0.82	0.85	0.83
	Prob. of Outflow (1-Po)	0.16	0.16	0.18	0.17	0.18	0.15	0.17
	Mean Outflow Parameter	0.013	0.013	0.022	0.017	0.014	0.010	0.015
	Average Spill Size	8%	8%	13%	10%	8%	7%	9%
	Extreme Spill Size	11%	11%	18%	14%	11%	9%	12%

Table 18 Probabilistic Outflow Analysis of Tankers

The outflow characteristics of tank barges are summarized in Table 19. The tank barges are typical of vessels running in coastwise trade, and have capacities between 50,000 and 150,000 barrels. All of the barges that were evaluated have centerline bulkheads. Cargo tanks are arranged port and starboard, 5 to 7 tanks long. The double hull tank barges have wing tank and double bottom dimensions of approximately 1.2 meters.

SINGLE HULL BARGES		75K bbls #1	150K bbls #1	150K bbls #2	Average
Side	Prob. Of Zero Outflow	0.24	0.19	0.19	0.21
	Average Spill Size	8%	5%	8%	7%
	Extreme Spill Size	13%	10%	13%	12%
Bottom	Prob. Of Zero Outflow	0.23	0.11	0.11	0.15
	Average Spill Size	7%	5%	5%	6%
	Extreme Spill Size	15%	11%	11%	12%
Combined	Prob. Of Zero Outflow	0.24	0.14	0.14	0.18
	Prob. of Outflow (1-Po)	0.76	0.86	0.86	0.82
	Mean Outflow Parameter	0.055	0.044	0.053	0.051
	Average Spill Size	7%	5%	6%	6%
	Extreme Spill Size	14%	11%	12%	12%

DOUBLE HULL BARGES		75K bbls #1	150K bbls #1	150K bbls #2	Average
Side	Prob. Of Zero Outflow	0.87	0.80	0.85	0.84
	Average Spill Size	8%	7%	6%	7%
	Extreme Spill Size	8%	8%	7%	8%
Bottom	Prob. Of Zero Outflow	0.78	0.90	0.87	0.85
	Average Spill Size	6%	6%	4%	5%
	Extreme Spill Size	9%	6%	5%	7%
Combined	Prob. Of Zero Outflow	0.81	0.86	0.86	0.85
	Prob. of Outflow (1-Po)	0.19	0.14	0.14	0.16
	Mean Outflow Parameter	0.012	0.009	0.007	0.009
	Average Spill Size	6%	6%	5%	6%
	Extreme Spill Size	9%	7%	6%	7%

Table 19 Probabilistic Outflow Analysis of Tank Barges

For the bunker tank studies (Table 20) a variety of bunker tank configurations were analyzed, typical of arrangements on tankers, containerships, and bulk carriers. All bunker tanks are arranged adjacent to the side shell. This is a conservative assumption, as there is a growing trend towards providing double hull protection for bunker tanks.

Bunker Spills		Wings in ER	Wings Amidships	Deep Tk Fwd & Wings in ER	DB Side Tanks	Average
Side	Prob. Of Zero Outflow	0.88	0.57	0.85	0.89	0.80
	Mean Spill Size	50%	15%	25%	21%	28%
Bottom	Prob. Of Zero Outflow	0.99	0.96	0.91	0.51	0.84
	Mean Spill Size	4%	8%	11%	10%	8%
Combined	Prob. Of Zero Outflow	0.94	0.80	0.89	0.66	0.83
	Mean Spill Size	45%	14%	19%	12%	22%

Table 20 Probabilistic Outflow Analysis of Freighters

The IMO methodology calls for calculation of three outflow parameters:

- The *probability of zero outflow*, P_0, represents the likelihood that no oil will be released into the environment, given a collision or grounding casualty which breaches the outer hull. P_0 equals the cumulative probability of all damage cases with no outflow.
- The *mean outflow parameter*, O_M, is the non-dimensionalized mean or expected outflow, and provides an indication of a design's overall effectiveness in limiting oil outflow. The mean outflow equals the sum of the products of each damage case probability and the associated outflow. O_M equals the mean outflow divided by the total quantity of oil onboard the vessel.

- The *extreme outflow parameter*, O_E, is the non-dimensionalized extreme outflow, and provides an indication of the expected oil outflow from particularly severe casualties. The extreme outflow is the weighted average of the upper 10% of all casualties (i.e. all damage cases within the cumulative probability range from 0.9 to 1.0).

Single hull tankers have relatively low Po values as a considerable portion of the outer hull is bounded by oil tanks. Double hull tank vessels have high Po values because of the segregation provided by the inner hull. Freighters have relatively high Po values because they have fewer and smaller oil tanks, and therefore a lower likelihood that damage will penetrate the oil tank boundaries.

(1-Po) is the likelihood oil will be spilled given a accident that breaches the outer hull. The ratio of (1-Po) for double hull tankers as compared to single hull tankers is the expected reduction in the number of spills due to double-hulling. Applying the average Po values for tankers, we find that double hull tankers are expected to have 1/5 the number of spills that would otherwise occur with single hull tankers.

Comparing the mean outflow parameters, we find that the expected outflows from double hull tankers and tank barges are 1/4 to 1/5 of the amounts expected from single hull vessels. Dividing the mean outflow parameter by the probability of outflow (1-Po) gives the average spill size as a percent of the payload. Based on the probabilistic analysis, the average spill size for single hull and double hull vessels are roughly equal. It should be noted that the IMO probabilistic approach does not account for differences in crashworthiness between designs. Recent research, Ref. (16), suggests that the double hull structure is effective in mitigating the extent of damage and the expected outflow from collisions and groundings. However, for the purposes of this study, the average spill sizes from single hull and double hull configurations are assumed equal, which is consistent with the results of the probabilistic analysis (refer to Table 18 and Table 19).

The average spill sizes for the extreme (1/10 largest) spills are 16% of payload for single hull tankers and 12% of payload for double hull tankers. In the environmental impact study a spill size equal to 15% of the cargo volume is assumed, which is representative of these large spills. This is considered a conservative estimate of spill size, as anticipated reductions in spill size due to the OPA90 requirements for vessel response plans and spill response training have not been accounted for.

4.3 Accident and Spill Rates for the Puget Sound Region

4.3.1 Projection of Spill Frequency to the Puget Sound Region

The average frequency of spills for 1992-1997 is applied as the reference case in this study. That is, a collision grounding frequency in U.S. harbors and coastal waters of 0.3 spills/year for tankers, 1.0 spills/year for tank barges, and 0.7 spills/year for freighters. The marine industry has undergone fundamental safety improvements since 1990, and continued improvement is an integral part of ISM and other regulatory initiatives such as the Coast Guard “Prevention Through People” program. The reference case is therefore considered a realistic basis for year 1997, with future reductions in spills expected as OPA90, ISM, and STCW become fully implemented.

The reduction in collisions and groundings in U.S. waters since the Exxon Valdez spill does leave us with a relatively small data set of spills to project future trends. Therefore, a sensitivity analysis was carried out, applying the average spill rates for the 1986-1997 period as a "pessimistic" estimate of current spill frequency.

Three options were considered for projecting the national spill rates to Northwest Washington State waters. Spill rates could be adjusted by: 1) the ratio of the tonnage moving through the Strait of Juan de Fuca as compared to the import, export, and domestic tonnage moving through U.S. ports, 2) the number of transits through the Strait of Juan de Fuca as compared to the transits through U.S. ports, or, 3) the number of collision and grounding incidents in the study region as compared to collision and grounding incidents in the U.S.

Accident and incident rates within the study region were reviewed, but option 3) was not applied due to concerns regarding the consistency of the incident rate data collection. VTS, which is an effective platform for collecting incident data, is not implemented in all areas. Also, significant events such as a major accident can focus attention on data collection in a particular region, thereby increasing incident reporting. For example, a dramatic rise in the number of events (accidents, incidents, and unusual events) was recorded in the Puget Sound, coincident with the formalization of the Coast Guard Marine Safety Information System (MSIS) and the Washington State Pilotage Commission near miss reporting system in the early 1990's. This event data is documented in The Washington State Ferries Risk Assessment, Ref. (17).

Projecting spills on the basis of tonnage yields higher spill rates as compared to transits, and this more conservative approach was applied. Nationwide tonnage movements for tankers, tank barges, and freighters were obtained from ACOE data for the period 1986-1997. The projection of spill rates to the Puget Sound region is summarized in Table 21.

		Reference Case based on U.S. coastal and harbor spills during 1992-1997			**"Pessimistic" Projection** based on U.S. coastal and harbor spills during 1986-1997		
		Tanker	Tank Barge	Freighter	Tanker	Tank Barge	Freighter
Historical U.S. spill frequency	spills/year	0.33	1.00	0.67	1.00	2.08	1.08
Return period for U.S. spills		3.0	1.0	1.5	1.0	0.5	0.9
U.S. international and coastal cargo movements	millions M.Tons per year	617.0	55.9	548.9	598.2	54.9	520.8
U.S. spill accident rate	spills/billion MTons moved	0.54	17.89	1.21	1.67	37.95	2.08
Strait of Juan de Fuca cargo movements in 1997	millions M.Tons per year	33.4	2.0	104.8	33.4	2.0	104.8
Projected spill frequency for the Puget Sound region	spills/year	0.02	0.04	0.13	0.06	0.07	0.22
Return period for the Puget Sound region		55	29	8	18	13	5
Return period for the spills >10,000 gallons from collisions & groundings in the Puget Sound region		For tankers, tank barges & freighters 5.5			For tankers, tank barges & freighters 2.9		

Table 21 Projection of Spill Frequency for the Puget Sound Area for Year 1997 (applicable to collision and grounding spills greater than 10,000 gallons in size)

Projecting the spill frequency directly from national statistics is a conservative approach. Although traffic is heavy throughout the study region, many features of this waterway including the extensive coverage of VTS, the wide traffic lanes and deep waters suggest that spill rates in this region should be below national averages. The Coast Guard Ports Needs Study, Ref. (11), found the Puget Sound region to have a lower casualty rate that most other major U.S. ports. The Panel of Experts were asked to project the relative likelihood of collision, powered grounding, and drift grounding spills in the Puget Sound regions as compared to U.S. ports in general. Their median assessment and 90% confidence interval bound are listed in Table 22. The median estimates were applied in the sensitivity analysis.

	Lower Bound	Median	Upper Bound
Collsions	0.37	0.68	0.86
Powered Groundings	0.44	0.71	1.04
Drift Groundings	0.57	0.83	1.21

Table 22 Panel of Experts Assessment of Relative Likelihood of Accidents in the Puget Sound Region compared to U.S. Ports in General

The return periods between major spills (spills greater than 10,000 gallons in size) are listed in Table 21. For tankers, a spill frequency of once every 55 years is projected for the "probable" reference case, and every 18 years for the "pessimistic" case. When considering all tankers, tank barges, and freighters together, "probable" and "pessimistic" return periods are 5.5 years and 2.9 years respectively. These spill frequencies are assumed applicable to year 1997. As described in Section 5.2, when projecting spills out to year 2025 adjustments were made reflecting the expected impact of the double hull requirements for tank vessels and the STCW and ISM regulations.

Table 23 lists the spill rates and return periods by accident type, obtained by multiplying the accident rates from Table 21 by the conditional probability of the different accident types from Table 16 (0.60 for collisions, 0.32 for powered groundings, and 0.08 for drift groundings).

		Reference Case based on U.S. coastal and harbor spills during 1992-1997			"Pessimistic" Projection based on U.S. coastal and harbor spills during 1986-1997		
		Tanker	Tank Barge	Freighter	Tanker	Tank Barge	Freighter
Projected Spill Rates for the Puget Sound Region (spills/million transits)	Collision	9.8	63.0	5.1	30.4	133.7	8.7
	Powered Grounding	18.4	118.2	9.6	57.0	250.7	16.4
	Drift Grounding	2.5	15.8	1.3	7.6	33.4	2.2
Projected Return Periods for the Puget Sound Region	Collision	173	89	25	56	42	14
	Powered Grounding	92	48	13	30	22	8
	Drift Grounding	694	357	98	224	168	57

Table 23 Projected Spill Frequency for the Puget Sound Region for Year 1997 (by type of accident)

4.3.2 Accidents in the Waters of Northwest Washington State

Over the last twenty years, there were four major spills (spills greater than 10,000 gallons in size) from collision and groundings in the study region. Although this is too small a data set to draw definitive conclusions, the return period of 5 years is consistent with the projections from national data.

Year	Vessel	Vessel Type	Casualty Type	Spill Volume (barrels)
1985	Arco Anchorage	Crude Oil Carrier	Powered Grounding	5,690
1988	Nestucca Barge	Tank Barge	Collision	5,500
1991	Tenyo Maru	Fish Factory Ship	Collision	2,381
1994	Crowley Barge 101	Tank Barge	Powered Grounding	619

Table 24 Collision and Grounding Spills in the Puget Sound Region (Spills greater than 10,000 gallons for period 1980-1999)

Casualty data for collisions and groundings in the study region from the USCG CASMAIN database are summarized in Table 25.

Tankers, tank barges, and freighters were involved in 21 collision and grounding accidents over the 1992-1997 period (an average of 3.5 events per year). Only one of these accidents produced an oil spill greater than 10,000 gallons – the 1994 grounding of Barge 101 off the San Juan Islands. Although 82% of the collision accidents and 72% of the grounding accidents occurred east of Dungeness, these are mostly fishing and passenger ship incidents. 6 of 12 tanker and freighter collisions were in the Strait of Juan de Fuca or the offshore approaches, and 2 of 5 of the tanker and freighter groundings were also located west of Dungeness.

Collisions	Offshore within 60 n.miles of J Buoy	Within 5 miles of J Buoy	Within the Strait of Juan de Fuca	Rotary and Port Angeles Area	Puget Sound including Haro and Rosaio	Totals
Tank Ship	0	1	2	0	0	3
Tank Barge	0	0	0	0	2	2
Freighter	1	1	1	0	6	9
Fishing Boat	2	1	1	0	16	20
Passenger Ship	0	0	0	0	10	10
Freight Barge	0	0	0	0	3	3
Other	0	0	0	0	9	9
Unknown	1	1	4	0	26	32
Totals	4	4	8	0	72	88
	5%	5%	9%	0%	82%	

Note: Total of (88) ships involved in collisions from (44) collision accidents.

Groundings	Offshore within 60 n.miles of J Buoy	Within 5 miles of J Buoy	Within the Strait of Juan de Fuca	Rotary and Port Angeles Area	Puget Sound including Haro and Rosaio	Totals
Tank Ship	0	0	0	1	0	1
Tank Barge	0	0	0	0	2	2
Freighter	1	0	0	0	3	4
Fishing Boat	5	0	1	1	12	19
Passenger Ship	0	0	1	1	6	8
Freight Barge	0	0	0	0	6	6
Other	0	0	0	0	0	0
Unknown	2	0	2	0	9	13
Totals	8	0	4	3	38	53
All ships	15%	0%	8%	6%	72%	

Table 25 Collisions and Grounding Accidents in the Puget Sound Area (from the USCG CASMAIN database for 1992-1997)

A comparison was made between the USCG CASMAIN and State of Washington DOE databases for collision and grounding events for tankers, tank barges and freighters. The state data contained six such collision and grounding accidents. Only one of these accidents was common to both databases. Table 26 summarizes the joint data set. A total of 26 collision and grounding accidents over the 1992-1997 period are recorded, for an average of 4.3 events per year.

Collisions	Offshore within 60 n.miles of J Buoy	Within 5 miles of J Buoy	Within the Strait of Juan de Fuca	Rotary and Port Angeles Area	Puget Sound including Haro and Rosaio	Totals
Tank Ship	0	1	2	0	0	3
Tank Barge	0	0	0	2	2	4
Freighter	1	1	3	0	6	11
Totals	1	2	5	2	8	18
	6%	11%	28%	11%	44%	

Groundings	Offshore within 60 n.miles of J Buoy	Within 5 miles of J Buoy	Within the Strait of Juan de Fuca	Rotary and Port Angeles Area	Puget Sound including Haro and Rosaio	Totals
Tank Ship	0	0	0	1	0	1
Tank Barge	0	0	0	0	3	3
Freighter	1	0	0	0	3	4
Totals	1	0	0	1	6	8
	13%	0%	0%	13%	75%	

Table 26 Collisions and Grounding Accidents in the Puget Sound Area for 1992-1997 (from the USCG CASMAIN and State of Washington DOE databases)

4.3.3 Accident and Spill Rates for the Puget Sound Region

Table 27 contains projected rates for accidents, oil spills, and oil spill volumes within the study region for year 1997. These accident and spill rates are applicable to inbound and outbound, non-government vessels greater than 300 GT in size. Extension of these spill rates to the study period (years 2000-2025) is discussed in Section 5.

		Reference Case			"Pessimistic"		
		Laden Tanker	Laden Tank Barge	Others >300 GT	Laden Tanker	Laden Tank Barge	Others >300 GT
Collision and grounding accidents	accidents per million transits	175	961	365	251	15	83
Severe collision & grounding accidents (breaches hull)	severe accidents per million transits	44	240	91	63	4	21
Oil spills from collision and grounding accidents	spills per million transits	31	197	16	95	418	27
Projected spillage rate from collisions and groundings	barrels spilled per million barrels moved	2	16	3	7	33	5

Table 27 Projected Collisions and Grounding Accident and Spill Rates for Year 1997

Spills per million transits: The spill frequencies from Table 21 divided by the number of transits for the respective vessel types provide the spill rates applicable to year 1997.

Severe accidents per million transits: Collision and grounding accidents in which the outer hull is breached are categorized as “severe” accidents. The rate for severe accidents is computed by dividing the spill rate by the probability that a “severe “accident will result in a spill. This probability, which equals 1-Po, is obtained from the probabilistic oil outflow analysis described in Section 4.2.4.

Accidents per million transits: A collision/grounding accident frequency of 3.5 events per year was assumed based on the CASMAIN Puget Sound accident data (see Section 4.3.2). This applies to year 1997, and includes all tankers, tank barges, and freighters. The equivalent accident rate, rationalized to the number of transits during 1997, is 365 accidents per 1 million transits. The accident frequency was split amongst the ship types in proportion to their likelihood of a “severe” accident. Other ship types such as passenger ships and fish factory ships were assumed to have the same accident rate as freighters. A frequency of 4.3 events per year was assessed to check sensitivity, and found to have only a 1% to 2% impact on overall cost effectiveness.

Barrels spilled per million barrels moved: The annual mean spillage rate for a given ship type equals the product of the number of transits per year, the spill rate (from Table 27), the % outflow in the event of a spill (from Table 17), and the quantity of oil moved per transit for that ship type. The spillage rate is obtained by dividing the mean or expected outflow by the quantity of oil moved.

4.3.4 Projected Spill Rates for Priority 1 Vessels

As part of its Port State Control initiative, the Coast Guard targets those foreign flag vessels considered to present increased risks. Priority I vessels are inspected upon each entry. These are vessels which have accrue 17 or more points, based on the following rating procedure:

- Targeted Owner – Any owner with a U.S. detention in the past year (5 points)
- Targeted Flag State – Exceeds intervention ratio (7 points)
- Targeted Class Society – IMO Resolution A.739 (0-5 points)
- Vessel detained within the past year (5 points)
- Subject to operational control in the past year (1 point each)
- Violation or incident in the past year (1 point each)
- Not previously boarded in the past 6 months (1 point)
- Oil, chemical, or passenger carrier (1 point)
- Bulk carrier in excess of 10 years only (2 points)

During 1998, 11 vessels categorized as *Priority 1* made a total of 60 transits through the Strait of Juan de Fuca. These were primarily fish factory vessels, but also included containerships and bulk carriers.

The Panel of Experts was asked to quantify the increased likelihood of collision and grounding accidents for Priority 1 vessels as compared to other vessels. The median values displayed in Table 28 are applied in this study.

	Median	Standard Deviation
Collisions	2.38	1.26
Powered Groundings	2.87	1.85
Drift Groundings	2.27	1.13

Table 28 Likelihood of Accidents with Priority 1 Vessels Relative to Other Vessels (based on Panel of Expert opinion

5 OIL SPILL BASELINE

5.1 Analysis Approach

The oil spill baseline represents the hypothetical future for the period 2000-2025, without the benefit of any of the alternative measures. The projected spillage includes all spills from collisions and grounding of non-government vessels greater than 300 GT within the study area. The study area incorporates the waters of the Strait de Juan de Fuca, Puget Sound including areas north to the Canadian border, and the offshore approaches within 60 miles of “J” Buoy.

Spill rates are adjusted during the study period for existing regulations whose impacts were not fully realized in 1997 (principally OPA90 single hull phase out requirements, ISM, and STCW), and for the impact of increased traffic density. These projections are combined to produce the oil spill baseline, which serves as the basis for comparing the mitigating effects of the alternative measures.

5.2 Impact of Regulations and Traffic Growth on Accident Rates

5.2.1 Impact of Double Hull Requirements on Spill Frequency and Volumes

The projected transition to double hulls for tankers and tank barges calling the Puget Sound area is presented in Table 9. Based on the probabilistic outflow analysis described in Section 4.2.4, double hull tankers are projected to have 21% of the spills of single hull tankers, and double hull tank barges are projected to have 18% of the spills of single hull tank barges. The expected reduction in the number of spills due to the transition to double hull was calculated by applying these spill reduction factors to the portion of the fleet converted to double hulls each year. The average spill size is assumed to be the same for both single hull and double hull tankers, and therefore the reduction in the number of spills equals the expected reduction in spill volume. As shown in Table 29, by 2015 the phase-in of double hulls is expected to reduce oil spillage to 24.3% of 1997 levels for tankers, and to 18.3% of 1997 levels for tank barges.

Year	Tankers	Tank Barges
1997	1.000	1.000
1998	0.994	1.000
1999	0.972	1.000
2000	0.891	1.000
2001	0.827	0.991
2002	0.733	0.991
2003	0.698	0.991
2004	0.686	0.991
2005	0.634	0.775
2006	0.551	0.675
2007	0.514	0.634
2008	0.506	0.634
2009	0.437	0.634
2010	0.424	0.566
2011	0.420	0.566
2012	0.402	0.566
2013	0.374	0.566
2014	0.348	0.566
2015	0.243	0.183

Table 29 Reduction in the number of spills due to the transition from single hull to double hull tankers and tank barges

5.2.2 Impact of STCW and ISM Code on Accident Rates

The USCG assessment of STCW, Ref. (18), estimated that between 45% and 60% of all accidents with causality primarily related to human factors are addressed by STCW. Recent studies such as the "USCG Quality Action Team Report" have determined that human factors play a principal role in about 80% of marine accidents. Assuming 80% of all collision and grounding events are the result of human error, and that STCW is successful in eliminating one-third to one-half of the accidents it is intended to address, the expected reduction in accidents falls between 12% and 24%. ISM Code implementation will have an additional impact, estimated at up to 10% or 12%. In this report, 12% accident reduction is conservatively applied as the reference case, and 24% and 36% reductions in accidents rates are evaluated in the sensitivity analysis. Spill reduction is assumed directly proportional to accident reduction.

Ref. (18) predicted that 67% of the projected benefits from STCW will be realized after 5 years, and that 100% will be achieved in the tenth year. Assuming a benefit phase in period between 1996 and 2006, the following reductions in the likelihood of an accident are anticipated:

		Conditional Probability of an Accident		
Year	% Benefits	"reference"	"mid range"	"optimistic"
1997	13.4%	1.000	1.000	1.000
1998	26.8%	0.984	0.968	0.952
1999	40.2%	0.968	0.936	0.904
2000	53.6%	0.952	0.904	0.855
2001	67.0%	0.936	0.871	0.807
2002	73.6%	0.928	0.856	0.783
2003	80.2%	0.920	0.840	0.760
2004	86.8%	0.912	0.824	0.736
2005	93.4%	0.904	0.808	0.712
2006	100.0%	0.896	0.792	0.688

Table 30 Reduction in the number of accidents due to STCW and ISM Code Implementation

5.2.3 Impact of Traffic Density on Accident and Spill Rates

For the base condition, the drift and powered grounding rates are assumed constant over the study period. That is, the number of drift and powered groundings are assumed to increase proportionately with the increasing number of vessel transits. Collision rates, on the other hand, can be expected to increase with increased traffic density. To project collision rates, the impact of traffic density on the frequency of encounters was determined through numerical simulation. Three encounter types are considered in the simulation: crossing, head-on, and over-taking encounters. After weighting for the danger level presented by each encounter type, collision rates are assumed proportional to encounter rates. Refer to Section 6.2.2 and Appendices 2 and 3 for further details on the simulation analysis for collisions.

Encounters are tabulated for four vessel groupings: 1) laden tankers, 2) laden tank barges, 3) other vessels >3000 GT, and, 4) vessels between 300 and 3000 GT. Relative risk or "weighting" factors for crossing, head-on, and overtaking encounter were assigned (see Section 6.2.2). The relative likelihood of a collision is standardized to year 1997 by dividing the weighted number of *encounters per transit* in future years by the weighted number of *encounters per transit* for 1997. As shown in Table 31, due to the increase in congestion tankers would be 50% more likely to have a collision in year 2025 as compared to year 1997. The slower vessels such as tank barges experience the greatest increase in encounter frequency, whereas small vessels are least sensitive to increases in traffic.

Year	Tankers	Tank Barges	Vessels >3000 GT	Vessels 300-3000 GT
1997	1.0000	1.0000	1.0000	1.0000
2000	1.0263	1.0571	1.0357	1.0476
2005	1.0789	1.1714	1.1071	1.0952
2010	1.1579	1.3143	1.1786	1.1905
2015	1.2368	1.5429	1.2857	1.2857
2020	1.3684	1.8286	1.4286	1.3810
2025	1.5000	2.2000	1.6071	1.4762

Table 31 Relative Likelihood of a Collision (due to increase in traffic density – baseline without escort tugs)

5.3 Baseline Spill Volumes for the Period 2000-2025

A summary of the baseline spill analysis for the "probable" case is provided in Table 32. The average oil outflow projected during the study period is listed in the right hand column. These outflow projections are graphically displayed in Figure 6. The expected outflow for tankers and tank barges decreases until 2015, at which time the fleet is fully double-hulled. Projected spills from tank barges drop steeply in 2015, when all the barges below 15,000 GT are scheduled for phase-out. After 2015, oil spill volumes in response to increased cargo flows and traffic congestion. In the year 2000 petroleum carriers pose the greatest risk, as tankers and tank barges are responsible for 75% of the total projected outflow. By the year 2025, dry cargo vessels are responsible for 66% of the total projected outflow.

The projected number of collision and grounding accidents increases by 71% over the study period, from 3.77 in year 2000 to 6.44 in year 2025. The number of collisions and groundings increases gradually through year 2006 as the effects of STCW offset the increase in traffic, and then rises steadily through the remainder of the study period. The number of collision and grounding accidents which result in spills greater than 10,000 gallons increases by 37% over the study period. The more gradual growth in spills as compared to accidents is primarily due to the introduction of double hulls for tank vessels, and is also influenced by the expectation that crude oil receipts will remain flat over the study period. The baseline oil spillage is a conservative projection, in that it assumes that no further industry or regulatory initiatives are introduced to offset the risks related to traffic growth.

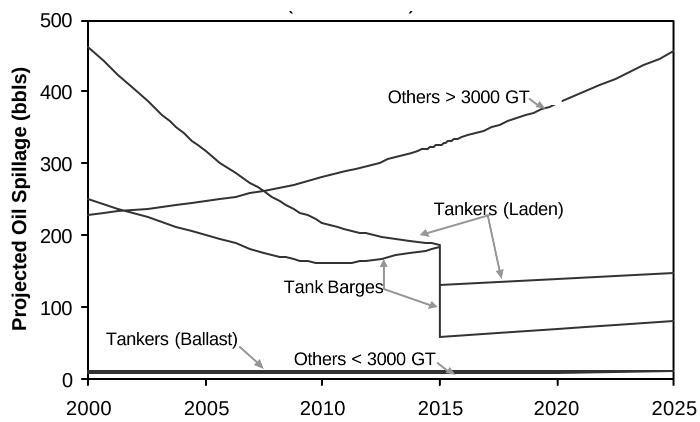


Figure 6 Baseline Oil Spillage by Ship Type (in barrels)

	No. of Collisions	No. of P.Grd.	No. of Dr.Grd.	Total No. of Accidents	No. of Collisions w/outflow	No. of P.Grd. w/outflow	No. of Dr.Grd. w/outflow	Total Accidents w/outflow	Collision Outflow (bbls)	P.Grd. Outflow (bbls)	Dr.Grd. Outflow (bbls)	Total Outflow (bbls)
Tankers (Laden)	0.03245	0.06084	0.00811	0.10139	0.00568	0.01065	0.00142	0.01775	172.3	323.1	43.1	538.5
Tankers (Ballast)	0.02852	0.05347	0.00713	0.08911	0.00121	0.00227	0.00030	0.00379	3.2	6.0	0.8	10.0
Tank Barge	0.05473	0.10261	0.01368	0.17102	0.01122	0.02104	0.00280	0.03506	75.5	141.6	18.9	236.0
Others >3000 GT	1.04018	1.95034	0.26005	3.25057	0.04421	0.08289	0.01105	0.13815	72.0	135.1	18.0	225.1
Others <3000 GT	0.05769	0.10818	0.01442	0.18029	0.00245	0.00460	0.00061	0.00766	2.1	3.9	0.5	6.5
Total Yr 1997	1.21356	2.27543	0.30339	3.79239	0.06477	0.12144	0.01619	0.20240	325.1	609.7	81.3	1,016.1
Tankers (Laden)	0.03125	0.05710	0.00761	0.09597	0.00487	0.00891	0.00119	0.01497	152.8	279.1	37.2	469.0
Tankers (Ballast)	0.02774	0.05069	0.00676	0.08519	0.00118	0.00215	0.00029	0.00362	3.1	5.7	0.8	9.6
Tank Barge	0.05816	0.10315	0.01375	0.17506	0.01192	0.02115	0.00282	0.03589	84.1	149.2	19.9	253.2
Others >3000 GT	1.07702	1.94978	0.25997	3.28676	0.04577	0.08287	0.01105	0.13969	76.3	138.1	18.4	232.9
Others <3000 GT	0.05968	0.10682	0.01424	0.18075	0.00254	0.00454	0.00061	0.00768	2.1	3.8	0.5	6.5
Total Yr 2000	1.25386	2.26753	0.30234	3.82373	0.06629	0.11961	0.01595	0.20184	318.4	575.9	76.8	971.2
Tankers (Laden)	0.03170	0.05509	0.00735	0.09414	0.00352	0.00611	0.00081	0.01044	110.0	191.1	25.5	326.5
Tankers (Ballast)	0.02721	0.04729	0.00631	0.08080	0.00116	0.00201	0.00027	0.00343	3.1	5.5	0.7	9.3
Tank Barge	0.06544	0.10475	0.01397	0.18416	0.01040	0.01664	0.00222	0.02926	73.2	117.1	15.6	205.9
Others >3000 GT	1.18447	2.00596	0.26746	3.45789	0.05034	0.08525	0.01137	0.14696	87.3	147.8	19.7	254.7
Others <3000 GT	0.06474	0.11083	0.01478	0.19035	0.00275	0.00471	0.00063	0.00809	2.3	4.0	0.5	6.9
Total Yr 2005	1.37356	2.32391	0.30986	4.00733	0.06816	0.11473	0.01530	0.19818	275.9	465.4	62.1	803.4
Tankers (Laden)	0.03436	0.05564	0.00742	0.09743	0.00255	0.00413	0.00055	0.00722	79.5	128.7	17.2	225.4
Tankers (Ballast)	0.02866	0.04640	0.00619	0.08124	0.00122	0.00197	0.00026	0.00345	3.4	5.5	0.7	9.6
Tank Barge	0.07785	0.11106	0.01481	0.20372	0.00904	0.01289	0.00172	0.02365	63.5	90.6	12.1	166.2
Others >3000 GT	1.34657	2.14227	0.28564	3.77447	0.05723	0.09105	0.01214	0.16041	103.4	164.4	21.9	289.7
Others <3000 GT	0.07437	0.11713	0.01562	0.20712	0.00316	0.00498	0.00066	0.00880	2.7	4.2	0.6	7.5
Total Yr 2010	1.56180	2.47251	0.32967	4.36398	0.07319	0.11502	0.01534	0.20354	252.4	393.5	52.5	698.3
Tankers (Laden)	0.03758	0.05697	0.00760	0.10214	0.00229	0.00347	0.00046	0.00623	71.1	107.8	14.4	193.2
Tankers (Ballast)	0.03024	0.04584	0.00611	0.08218	0.00129	0.00195	0.00026	0.00349	3.7	5.5	0.7	9.9
Tank Barge	0.09734	0.11829	0.01577	0.23141	0.01130	0.01373	0.00183	0.02686	79.3	96.3	12.8	188.5
Others >3000 GT	1.63017	2.37733	0.31698	4.32448	0.06928	0.10104	0.01347	0.18379	127.1	185.3	24.7	337.0
Others <3000 GT	0.08696	0.12682	0.01691	0.23070	0.00370	0.00539	0.00072	0.00980	3.1	4.6	0.6	8.3
Total Yr 2015 (-)	1.88229	2.72525	0.36337	4.97091	0.08786	0.12558	0.01674	0.23018	284.2	399.5	53.3	737.0
Tankers (Laden)	0.03758	0.05697	0.00760	0.10214	0.00160	0.00242	0.00032	0.00434	49.5	75.1	10.0	134.7
Tankers (Ballast)	0.03024	0.04584	0.00611	0.08218	0.00129	0.00195	0.00026	0.00349	3.7	5.5	0.7	9.9
Tank Barge	0.09734	0.11829	0.01577	0.23141	0.00365	0.00444	0.00059	0.00868	25.6	31.1	4.1	60.9
Others >3000 GT	1.63017	2.37733	0.31698	4.32448	0.06928	0.10104	0.01347	0.18379	127.1	185.3	24.7	337.0
Others <3000 GT	0.08696	0.12682	0.01691	0.23070	0.00370	0.00539	0.00072	0.00980	3.1	4.6	0.6	8.3
Total Yr 2015 (+)	1.88229	2.72525	0.36337	4.97091	0.07951	0.11523	0.01536	0.21011	209.0	301.6	40.2	550.8
Tankers (Laden)	0.04281	0.05866	0.00782	0.10930	0.00182	0.00249	0.00033	0.00465	55.9	76.7	10.2	142.8
Tankers (Ballast)	0.03304	0.04527	0.00604	0.08435	0.00140	0.00192	0.00026	0.00358	4.1	5.6	0.7	10.5
Tank Barge	0.12393	0.12708	0.01694	0.26795	0.00465	0.00477	0.00064	0.01005	32.5	33.3	4.4	70.3
Others >3000 GT	2.01348	2.64269	0.35236	5.00854	0.08557	0.11231	0.01498	0.21286	159.4	209.2	27.9	396.5
Others <3000 GT	0.09995	0.13571	0.01809	0.25375	0.00425	0.00577	0.00077	0.01078	3.6	4.9	0.7	9.1
Total Yr 2020	2.31321	3.00941	0.40126	5.72388	0.09769	0.12726	0.01697	0.24193	255.6	329.7	44.0	629.2
Tankers (Laden)	0.04836	0.06045	0.00806	0.11688	0.00206	0.00257	0.00034	0.00497	62.5	78.1	10.4	151.0
Tankers (Ballast)	0.03584	0.04480	0.00597	0.08661	0.00152	0.00190	0.00025	0.00368	4.6	5.7	0.8	11.0
Tank Barge	0.16001	0.13637	0.01818	0.31457	0.00600	0.00511	0.00068	0.01180	41.8	35.6	4.7	82.2
Others >3000 GT	2.52170	2.94198	0.39226	5.85594	0.10717	0.12503	0.01667	0.24888	202.8	236.6	31.5	470.9
Others <3000 GT	0.11607	0.14742	0.01966	0.28314	0.00493	0.00627	0.00084	0.01203	4.2	5.3	0.7	10.2
Total Yr 2025	2.88198	3.33103	0.44414	6.65715	0.12168	0.14089	0.01878	0.28136	315.8	361.3	48.2	725.3

Table 32 Baseline – Projected Spill Volumes and Number of Accidents per Year (reference case based on "probable" estimate of spill frequency)

6 FORECAST OF BENEFITS

6.1 Analysis Approach

The oil spill baseline provides the expected frequency of the relevant accident types without the alternative measures, and the projected oil outflow for each year during the study period. The relative effectiveness of each alternative in averting collisions, powered groundings, and drift groundings was developed from analysis and, when appropriate, expert opinion. Multiplying the effectiveness ratios by the spill baseline values provides the expected frequency of accidents and quantity of outflow with the alternative measure in place. The difference between the baseline spill volumes and the spill volumes computed with each alternative is the overall benefit, in term of barrels of spilled oil avoided.

For the purposes of this study, weather, operational characteristics of individual ships, aggregate experience levels of each bridge crew, and other factors which influence the likelihood of a spill are accounted for in the baseline accident and spill rates. When applying the relative risk factors associated with each alternative, the same average of environment and related variables are effectively applied by scaling from the baseline accident rate.

Each alternative is only effective in reducing accidents over a part of the study region. For example, escorts are assumed to pick up the vessel a few miles west of "J" Buoy, and cannot be considered effective in averting collisions in the offshore region. In order to apply effectiveness ratios for the alternatives to segments of the waterway, the relative risk of the collision, powered grounding, and drift grounding accidents were sub-divided geographically

6.2 Collision, Powered Grounding, and Drift Grounding Analysis

6.2.1 Traffic Simulation

Traffic flow from the offshore approaches through the Strait to points east of the pilot stations at Port Angeles and Victoria was numerically simulated. The primary inputs into the simulation were the projected transit information over the study period (see Table 11), and the flow patterns and distributions of vessels across the traffic lanes derived from the VTS radar data. The output of the simulation consisted of position distribution information for the various ship types, applied in the drift grounding analysis, and the frequency of encounters between ships, which was used to project changes in collision rates.

By superimposing "snapshots" of traffic at regular intervals, a traffic density profile of the Strait can be constructed for each ship type, as was used in the drift grounding analysis. A typical ship location distribution is illustrated in Figure 7. Noteworthy is the heavy banding in the approaches to "J" Buoy. Once ships enter the Strait, they tend to stay within the designated traffic lanes. Analysis of the VTS radar data found the traffic distribution to conform to a normal distribution with a mean position centered on the lane, and a standard deviation of 0.27 lane widths.

Refer to Appendix 2 for details of the traffic simulation.

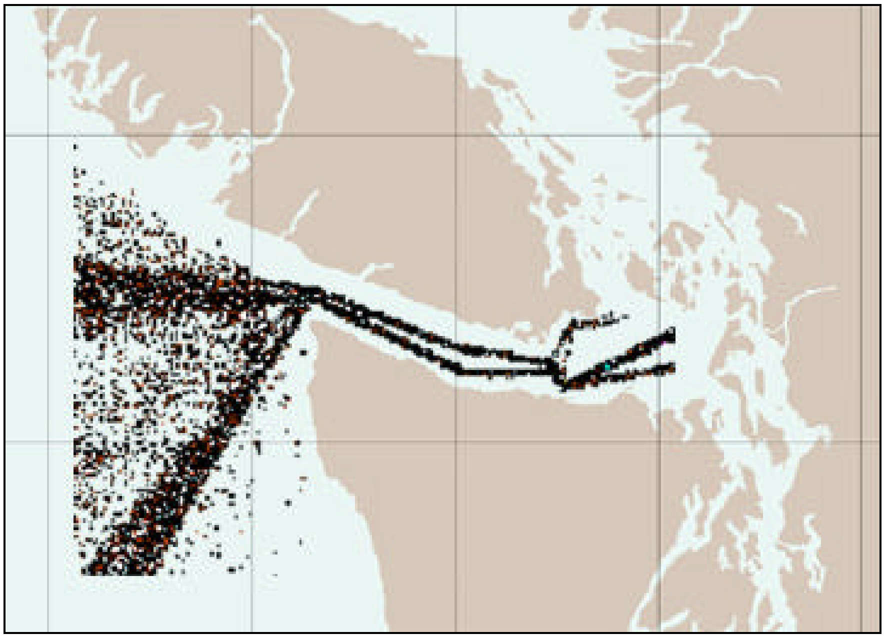


Figure 7 Ship location distribution obtained from simulation

6.2.2 Collision Analysis

Collision analysis was undertaken based upon the concept of encounters. When vessels are in close proximity, there is a potential for collision. Several basic ship profiles were established, and the particular hazards associated with individual portions of the Strait were addressed. The changes in encounter frequencies, after weighting for the danger level presented by each encounter type, were used to predict the changes in collision incidence during the study period.

An encounter simulation was initially carried out to determine the impact of increased traffic over the study period. Additional simulations were run to assess the effects of vessel slowdown as a result of partial or full escorting requirements, as well as the likelihood of collisions between the escort tugs and other vessels.

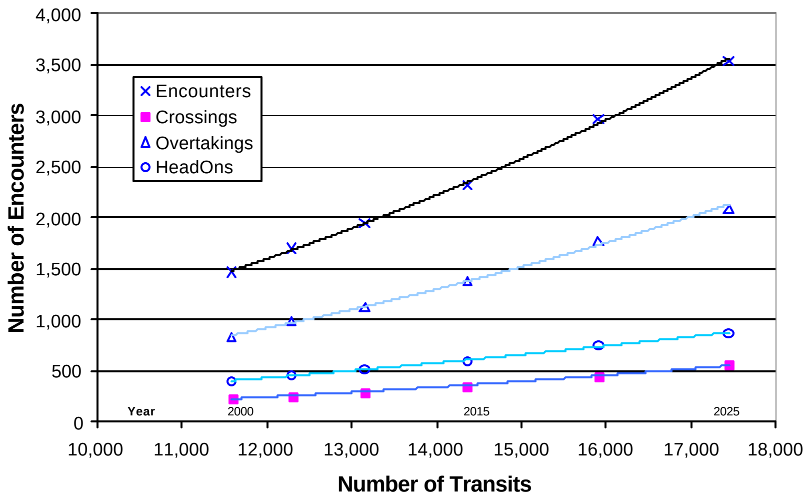


Figure 8 Number of Encounters for Period 2000-2025 (Base Condition)

Encounters were found to rise at a rate slightly higher than the square of the number of ship transits (see Figure 8). Past theoretical treatments have suggested that the growth in encounters should be proportionate to the square of traffic density. The other principal variables influencing this curve include the change in fleet makeup over time (trending towards bigger, faster ships) and the evolving traffic patterns (traffic increases are not distributed evenly amongst routes).

Relative risk “weighting” factors of 0.65 for crossing encounters, 0.30 for head on encounters, and 0.05 for overtaking encounters are assumed. These were estimated based with Panel of Expert input. The number of crossing, head-on and overtaking encounters are multiplied by their respective risk factors – then these products are summed and divided by the number of transits. This “weighted” number of encounters per transit provides a relative indication of the likelihood of a collision. It is assumed that the change in the number of collisions per transit is directly proportional to the change in the “weighted” number of encounters per transit.

The relative likelihood of a collision is standardized to year 1997 by dividing the weighted number of *encounters per transit* in future years by the weighted number of *encounters per transit* for 1997. Results for the initial study without escort tugs are summarized in Table 31. These values were used to project collision rates for the baseline analysis.

Encounter simulations were run for the various escort tug options. Although escort tugs reduce the likelihood of collisions given encounters, the number of encounters increases for two reasons. First, the overall slowing of traffic increases congestion, and secondly, the escort tugs have encounters with other vessels. When all vessels are escorted (ALT. 5), the inter-ship encounter frequency increases by approximately 10% for tankers and freighters, and by 34% for tank barges. Again, the slower tank barges are more sensitive to an increasingly congested waterway. Escort tug-ship encounters increase total encounters by an additional 15%. In the simulation, encounters between an escort tug and other vessels are assessed. Encounters between the tug and the vessel it is escorting as well as encounters between tugs are not considered, and these particular risks are not accounted for in this study.

As escort tugs only accompany vessels over a portion of the study region, it was necessary to determine the relative likelihood of encounters in different segments of the waterway. Figure 9 graphically displays locations of crossing encounters computed in the numerical simulation.

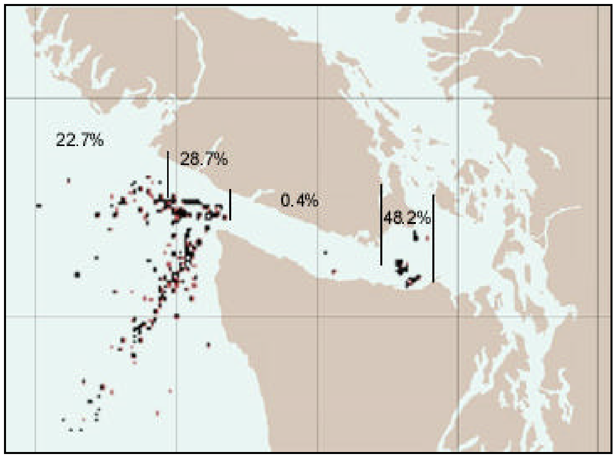


Figure 9 Crossing Encounters

Based on a review of collision incidents of tankers, tank barges, and freighters (see Section 4.3.2), it is assumed that there is an equal probability of a major collision east and west of Dungeness. For the portions to the west of Dungeness, the relative risk is further sub-divided as shown in Table 33. For the region west of Dungeness, the values recommended by the Panel of Experts were applied. The Panel of Experts considered the approaches to the pilot station at Ediz Hook and the crossing areas in the rotary to the north to pose relatively high risks of collision. A regional distribution of collisions developed from the numerical simulation was applied in the sensitivity analysis.

The VOLPE scoping risk assessment, Ref. (1), averaged expert opinion with historical accident data to obtain conditional probabilities of accidents by waterway segment. These data are generally in good agreement, although the Panel of Expert perception of high risk in the Port Angeles and rotary region is not reflected in the VOLPE data.

	VOLPE Study	Based on Simulation	Panel of Experts
offshore approaches	0.260	0.120	0.040
around "J" Buoy		0.165	0.110
within the Strait of Juan de Fuca	0.120	0.050	0.035
at rotary and Port Angeles area	0.140	0.165	0.315
in Puget Sound and Haro & Rosario Straits	0.480	0.500	0.500

Table 33 Conditional Likelihood of a Collision by Waterway Segment

Refer to Appendix 3 for further details on the collision simulation.

6.2.3 Powered Groundings

The number of powered groundings is assumed to increase proportionately with the increasing number of vessel transits, except as mitigated by the presence of an escorting tug. The conditional likelihood of powered groundings applied for the reference case is estimated based on expert opinion and statistical data for groundings. Again, the probabilities are in good agreement with the VOLPE study.

	VOLPE study	Applied Values
offshore approaches	0.150	0.050
around "J" Buoy		0.050
within the Strait of Juan de Fuca incl. rotary	0.230	0.200
in Puget Sound and Haro & Rosario Straits	0.620	0.700

Table 34 Conditional Likelihood of a Powered Grounding by Waterway Segment

6.2.4 Drift Groundings

Drift groundings occur when a vessel or tow loses its ability to proceed due to engine breakdown or steering or towline failure and drifts onto the coast under the influence of wind, waves and current. The rate at which drift groundings occur given a breakdown is dependent upon several factors including:

- Distance from shore,
- Prevailing wind and current directions and strength,
- The ability of the vessel to repair itself, or recover its tow, and,
- The availability of tugs which may be able to prevent the vessel from grounding.

Once grounded, there is the further issue of whether the vessel will actually spill its cargo or fuel before it can be rescued.

In the drift grounding simulation, the time required to rescue the vessel under the various alternatives is assessed against the time to drift aground. The vessel traffic in the region is modeled as a series of ship geographic density distributions. Coupling the ship locations with a probabilistic description of the environmental conditions and a description of the shore boundary permits evaluation of the time to drift ashore from any given point in the region of study. Similarly the tugs operating in the area are modeled in simple geographic density distributions. Based on these data, the time for a tug to arrive at and stabilize the vessel is computed. Critical factors in developing these times include the performance of the tug in transit and rescue modes in the weather conditions in the region, and the drift rates of the stricken vessel.

The drift grounding analysis provides measures of the effectiveness of the various tug alternatives. The role of tugs in preventing drift grounding is significant and complex. As the waterway traffic increases over time, and correspondingly more tugs utilize the waterway, the risk of a drift grounding per transit decreases. The ships are closer on average to the tugs when they go adrift. On the other hand, there are more transits, and thus greater exposure, leading to an increase in drift groundings. Further, as ship sizes increase, the capability of smaller tugs to effect rescue decreases in severe weather.

In Figure 10 each option is scaled relative to the rate of drift grounding under the baseline case for the year 2000. In the drift grounding simulation, the assumed time to alert and mobilize tugs for the base condition (without the benefit of ITOS) is 1.5 hours. This estimate is based on input from the Panel of Experts. ITOS, assumed to improve response time by ½ hour, reduces the likelihood of a drift grounding by about 3%. A rescue tug pre-positioned off “J” Buoy would prevent approximately one-half of the drift groundings in the Strait and offshore approaches, with the large 10,000 HP rescue tug some 10% more effective than a 5,500 HP tug. Escorts provide immediate response, and would avert approximately two-thirds of the drift groundings.

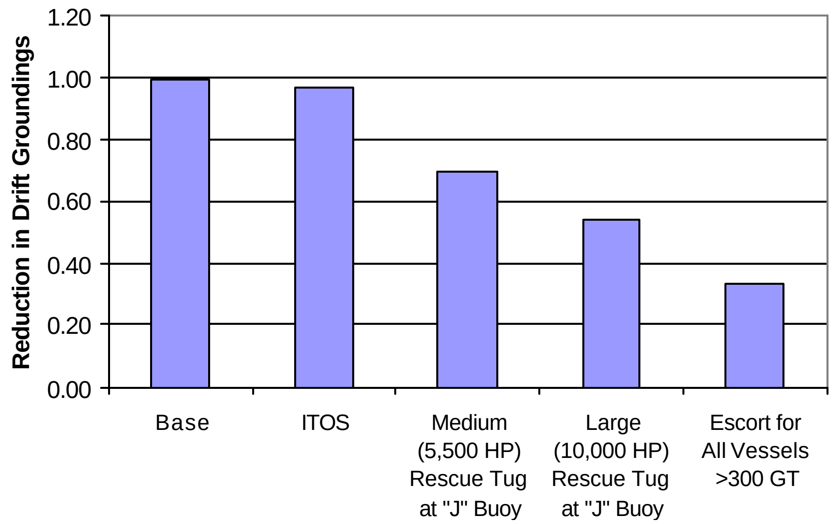


Figure 10 Drift Grounding Reduction Factors (for Year 2000)

Many of the tugs that normally operate in the study region have the capability of assisting a stricken vessel in the majority of the weather conditions experienced in the Strait of Juan de Fuca and its approaches. As a result, the drift grounding simulation demonstrated that for the baseline case, most drift groundings occur in severe weather conditions. Although an escort tug will usually reach a stricken vessel before it drifts aground, their ability to connect and execute a "save" is restricted in these heavy weather conditions. As previously noted, escort tugs are expected to avert two-thirds of the drift groundings. Their effectiveness would approach 100% if the escort tugs could make up and assist the distressed vessel in all weather conditions.

A critical factor in a tug's effectiveness in averting a drift grounding is the proximity to shore of the stricken vessel versus the proximity to the tug. Increasing the speed of a rescue tug improves its effectiveness. The assumed speeds for the 5,500 HP and 10,000 HP rescue tugs are 14.0 knots and 15.0 knots respectively.

The simulation was carried out assuming drifts rates of 3% of wind speed and 6% of wind speed. As explained in Appendix 4, assumptions on the drift rate have a negligible impact on the relative effectiveness of the tug alternatives relative to the baseline condition.

The conditional likelihood of drift groundings was sub-divided between the regions east and west of Dungeness as presented in Table 35. A projection of expected drift grounding locations within the Strait of Juan de Fuca and the approaches to the Strait was obtained from the simulation. Inbound laden tankers approach from the west and have minimal risk of drift grounding west of "J" Buoy. For tank barges and freighters , about 15% of the anticipated drift groundings are west of "J" Buoy and about 45% occur between "J" Buoy and Dungeness.

	VOLPE study	Applied Values
Strait of Juan de Fuca and offshore approaches	0.53	0.60
Puget Sound and Haro & Rosario Straits	0.47	0.40

Table 35 Conditional Likelihood of a Drift Grounding by Waterway Segment

For details of the drift grounding analysis refer to Appendix 4.

6.3 Description of Tug Options

6.3.1 International Tug of Opportunity System – ITOS (ALT. 1)

ITOS enables the VTS operator to more quickly identify the location and capabilities of tugs that may be able to assist a stricken vessel. The quicker response time afforded by ITOS has the potential of averting some drift groundings, but only for a rather narrow window of incident locations and environmental conditions.

The location of tugs within the waterway is based on the USCG ITOS Report, Ref. (19). The willingness of tugs to respond and assist stricken vessels is based on the Panel of Expert's judgment. Unencumbered tugs are assumed willing to respond 88% of the time; tugs encumbered with petroleum tows 11% of the time; and tugs encumbered with non-petroleum tows 37% of the time.

The capability of a tug in stabilizing a vessel is taken as a function of the ship size and the tug power. The mix of tug sizes is based on the existing fleet of tugs servicing the Puget Sound region. The number of tugs transiting the study region is assumed to grow at 1.5% per year through year 2025.

The drift grounding reduction factor for ITOS is about 0.97 for year 2000, and improves to about 0.94 by year 2025. That is, ITOS is expected to reduce the number of drift groundings by approximately 3% in 2000 and 6% in 2025. ITOS is implemented throughout the study area, and these factors are applied to all drift groundings.

ITOS is effective in averting drift groundings only. The number of collision and powered groundings accidents as well as the associated outflow remain unchanged from the baseline values.

6.3.2 Escort tugs (ALT. 2 through ALT. 6)

Escort tugs reduce the risk of collisions, drift groundings, and powered groundings. They can quickly intercede in the event of power or steering failure, and have a limited capability of redirecting a vessel under power. The implementation of tug escorts for dry cargo vessels (ALT. 5 and ALT. 6) means a speed slow down is required for some vessels. Although this will lead to the ships spending more time in the system and experiencing more encounters, the slower speed improves a vessel's own capability to take evasive action. Escort tugs also serve "as an extra set of eyes", although the benefits in this regard are uncertain, as VTS effectively monitors traffic and warns vessels of impending hazards.

A disadvantage of escort tugs is that additional vessels are introduced into the already congested waterway, creating the potential for accidents between the tugs and other vessels.

Escort tugs are assumed appropriately matched to the vessel they are escorting, such that they can substantially influence speed and course of the vessel in the event of power or steering failure. Escort tugs are expected to remain in close proximity to the escorted vessel at all times.

Escort tugs are assumed to pick up inbound vessels and drop off outbound vessels at the western end of the traffic lanes, about 8 miles west or southwest of "J" Buoy. They are therefore considered effective for averting collisions in the convergence and crossing areas immediately to the west of "J" Buoy.

The escort options for laden single hull tankers, ALT. 2 and ALT. 3, are applicable from "J" Buoy to Dungeness, as there are already escorts in place from Dungeness to the refineries. When escorting other vessels, the escorts are taken from "J" Buoy to the origination or destination ports within the Puget Sound area. Escort tugs are not considered effective in averting allisions at the dock, as it is assumed that docking tugs will be employed if escorts are not required.

As discussed in Section 6.2.2, the increased risk of ship-to-ship and ship-to-tug collisions is accounted for by scaling to the increased number of encounters, which were estimated through numerical simulation.

The effectiveness of escort tugs in averting accidents is difficult to analyze on a theoretical basis, and there are insufficient historical data to develop reliable estimates. Best judgement was applied in selecting the expected accident reduction factors for collisions and powered groundings, and then a range of factors was evaluated in the sensitivity analysis. The reduction factors for drift groundings were derived from numerical simulation. Escort tugs will also have some effect on spill size by reducing the collision and grounding energy for some of the accidents they are unable to prevent. This spill reduction is believed to be relatively small, and was not accounted for in the analysis.

Escort tugs are expected to be effective in averting collisions initiated by loss of power or steering, although such events are relatively rare. In fact, none of the major spill events from collisions in U.S. waters during the 1992-1996 period were the result of power or steering loss. Escort tugs will have limited effectiveness in averting other collisions, as there is typically little time to respond and redirect course.

The accident reduction factors applied for escort tugs relative to the baseline condition are given in Table 36. For the reference case, estimates of reduction in drift grounding accidents are developed within the drift grounding analysis, by reducing the time to respond to zero when under escort. As shown in Figure 10, escort tugs have a reduction of risk factor of about 0.34 against drift groundings.

When two vessels each having an escort are involved in an encounter, the overall accident reduction factor for collisions is assumed to be product of the individual factors. For example, if two vessels each having one escort are involved in an encounter, the reduction in collision likelihood between the vessels is assumed to be (0.6)(0.6) = 0.36.

To assess sensitivity to these assumptions on escort tug effectiveness, a number of variations were analyzed. Optimistic and pessimistic projections were evaluated, with collision and powered grounding effectiveness increased by 0.20 and reduced by 0.20 respectively, as well as estimates provided by the Panel of Experts. Care should be taken in comparing the drift grounding effectiveness obtained from the simulation (0.34) directly with the Panel of Experts estimates (0.16 for one tug and 0.09 for two tugs). The simulation provides the reduction factor against the baseline, and recognizes that the tugs transiting the waterway will respond and avert a certain portion of all drift groundings. The expert opinion assumes a vessel has lost power and would otherwise drift aground, but does not account for possible intervention by tugs other than the escort. Thus, applying the expert's values directly against the baseline projections as is done in the sensitivity analysis is a conservative approach, tending to overestimate effectiveness.

	Collisions		Powered Groundings		Drift Groundings	
	Single Tug	Two Tugs	Single Tug	Two Tugs	Single Tug	Two Tugs
Reference	0.6	0.5	0.5	0.4		
Optimistic	0.4	0.3	0.3	0.2		
Pessimistic	0.8	0.7	0.7	0.6		
Panel of Experts	0.58	0.56	0.48	0.40	0.16	0.09

Table 36 Accident Reduction Factors for Escort Tugs

Estimates of reduction in drift grounding accidents are developed within the drift grounding analysis, by reducing the time to respond to zero when under escort. As shown in Figure 10, escort tugs have a reduction of risk factor of about 0.34 against drift groundings.

It is assumed that single hull escorts will not leave their client vessel to assist others, although allowing them to do so is included as a sensitivity study.

6.3.3 Rescue Tugs (ALT. 7 and ALT. 8)

A rescue tug pre-positioned near "J" Buoy improves response to drift groundings in the western portions of the Strait of Juan de Fuca and the offshore approaches where relatively few tugs normally operate. A rescue tug would be built and outfitted specifically for rescue operations. As compared to tugs of opportunity, the rescue tugs provide improved capability for securing and stabilizing stricken vessels in heavy weather conditions. It is assumed that the rescue tug will be used to escort laden tank vessels in the vicinity of "J" Buoy, reducing collision risk.

A 10,000 HP rescue tug is assumed, and a smaller 5,500 HP tug is evaluated in the sensitivity analysis.

6.3.4 Effects of Queuing of Tugs/Vessels

The potential for queuing of escort tugs at the entrance of the Strait of Juan de Fuca was modeled with the Poisson distribution, as the intervals between inbound vessels arriving at "J" Buoy during 1997 was found to closely fit the Poisson distribution. Over the year, the ship arrivals and departures are not completely random. During any given week transit frequencies can vary +- 12% for a particular day (e.g. Thursdays have the highest number of transits and Mondays have the lowest). Also ship transits can vary seasonally +-20% for a particular month (e.g. August has the highest traffic volumes and February has the lowest). These variations in the transit frequencies are accounted for in the analysis.

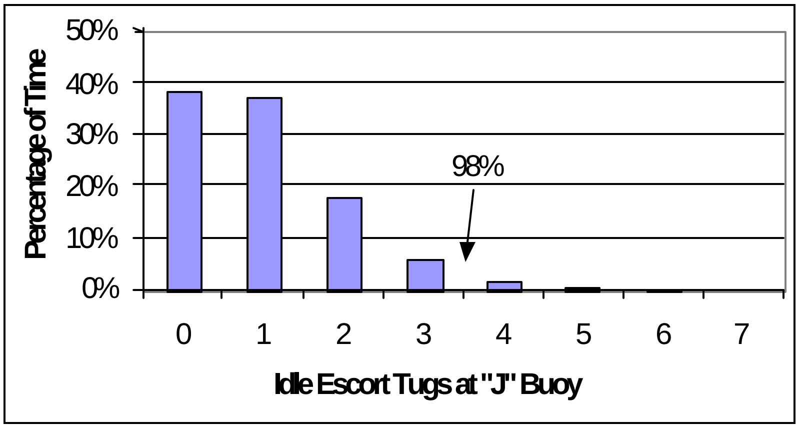


Figure 11 Queuing of Escort Tugs at "J" Buoy for Year 2025 (with escorts provided for all vessels > 300 GT)

ALT. 5, requiring escorts for all vessels greater than 300 GT, was evaluated as it introduces the largest number of tugs into the waterway. Tugs are assumed to wait for arriving vessels at "J" Buoy an average of one hour. For year 2000, 86% of the time there will be zero or one tug waiting, and 97% of the time there will be 2 or fewer tugs waiting. Even at 2025 traffic densities, 98% of the time there will be 3 or fewer tugs waiting (see Figure 11). The escort tugs can stay clear of the traffic lanes until needed, and are not considered a significant risk.

6.4 Benefits - Summary of results

6.4.1 Projections of Oil Spillage

Figure 12 shows the projected oil spillage for the baseline case analysis and the eight alternatives. All projections show a decrease in spillage as STCW and double-hulling of tankers become effective despite increasing traffic. There is a distinct drop as the last single hull tankers are removed from Puget Sound service in 2015. After 2015, the amount of spillage increases as the traffic grows. The figure shows that all alternatives other than escorting virtually all ships have a comparatively small impact on the actual amount of spillage.

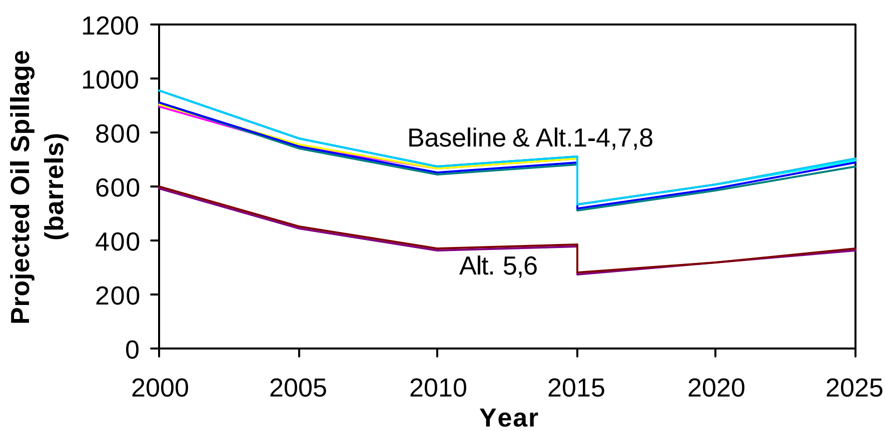


Figure 12 Total projected spillage

Figure 13, Figure 14, and Figure 15 show the contributions from collisions, powered groundings and drift groundings. Powered groundings are the largest contributor to oil spillage (about 50%), followed by collisions (about 40%) and drift groundings (about 10%).

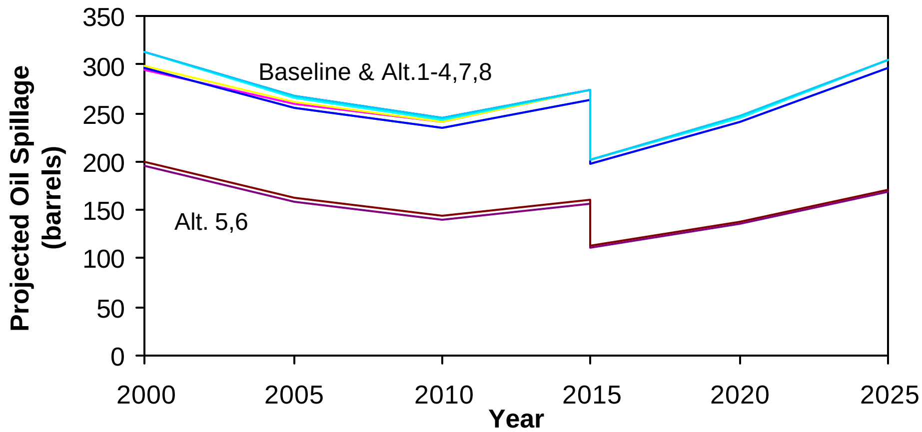


Figure 13 Projected spillage from collisions

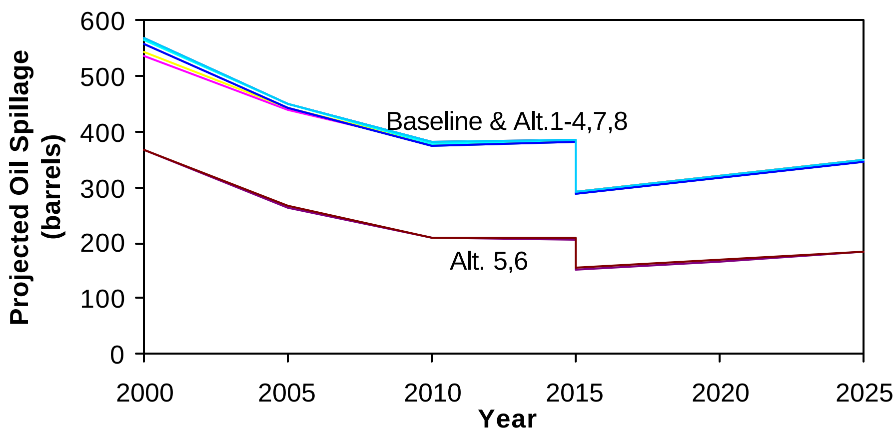


Figure 14 Projected spillage from powered groundings

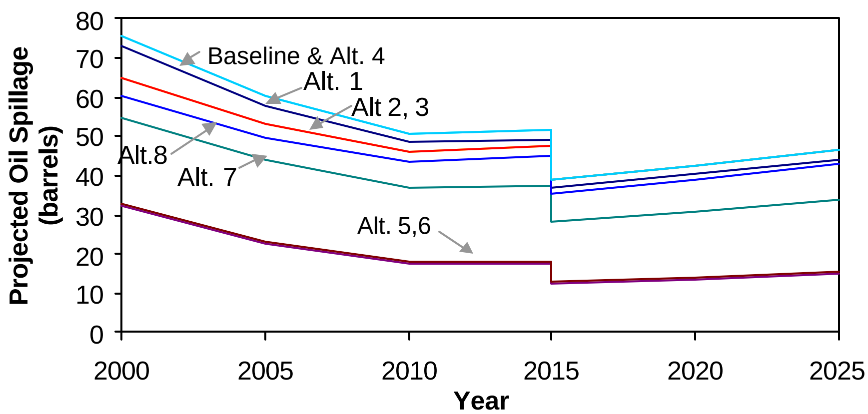


Figure 15 Projected spillage from drift groundings

The present values of barrels of oil spills averted over the study period are given in Table 37. The results are summarized by four major ship types: tankers, tank barges, other vessels greater than 3,000 GT, and other vessels between 300 and 3,000 GT. The ITOS system and the full or nearly full implementation of escort requirements (ALT. 5 and ALT. 6) act on all ship types, whereas the single-hull tanker escort alternatives (ALT. 2 and ALT. 3) are primarily effective at averting spills from tankers. The Priority 1 vessels are all freighters, and thus most of the spillage averted in ALT.4 comes from non-tankers, with small contributions from avoided collisions with tankers and tank barges. Rescue tug alternatives (ALT. 7 and ALT. 8) are most effective in mitigating spills from tankers and tank barges. This is in part due to the assumption that the rescue tug will escort tank vessels in the vicinity of "J" Buoy.

As indicated in Figure 6, the primary source of oil spillage is expected to shift from tanker vessels to other ships. This shift is reflected in the contribution to spills averted by the "other" vessels.

	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	286.1	245.0	4.9	1,274.3	1,262.2	166.0	160.8
Tank Barges	4.7	(0.6)	(0.9)	3.1	898.4	890.2	101.3	99.2
Other Ships (>3000 GT)	10.3	(0.6)	(1.0)	31.0	1,639.6	1,628.5	68.6	3.7
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.8	0.1
Total all ships	25.5	284.9	243.1	39.2	3,855.7	3,789.3	337.7	263.8

Table 37 Present Value of Barrels of Oil Spills Averted (Case A – Reference Case)

The total oil spillage averted is presented in Figure 16. The graph highlights the significant difference between the pollution averted with the general escort options (ALT.5 and ALT.6) as compared to the other alternatives.

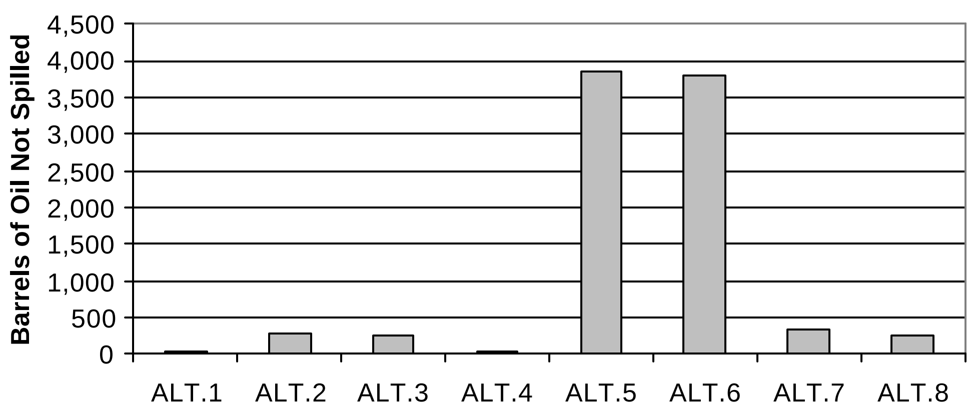


Figure 16 Present Value of Barrels of Oil Spills Averted (Case A – Reference Case)

7 COSTS

This section describes the approach used for estimating net costs for each alternative.

7.1 Assumptions for Developing Costs

In general the basic assumptions for developing the costs for specific options are taken from the methodologies developed in VOLPE's OPA90 programmatic assessment, Ref. (14). The cost of each alternative in the regulatory assessment reflects the individual option's costs for industry compliance combined with the cost of government enforcement. The period of the analysis is for 26 years, from 2000 through 2025. The stream of yearly costs over this 26 year period are discounted at 7% per year, to a present value in 1999 dollars for each of the options.

These discounted compliance and enforcement costs have been subsequently reduced by the amount of the avoided costs to calculate the net costs associated with each alternative. The savings associated with these avoided costs are based on the avoided costs realized by avoiding accidents that presumably would occur in the absence of each alternative rule. As with the compliance and enforcement costs, the avoided costs are presented as annual costs over the 26 year analysis period and discounted at 7% to 1999 dollars. Subtracting these avoided costs from the discounted compliance and enforcement costs provides the net costs. The avoided costs developed in this study are limited to monetary values of vessel damage and repairs, human injuries and deaths, and lost cargo shipments associated with vessel casualties.

7.2 International Tugs of Opportunity System (ITOS)

The ITOS Coalition began its implementation plan for ITOS in 1997, and on May 1, 1997 an assessment of a $50 arrival fee was initiated for all vessels greater than 300 GT transiting the Strait of Juan de Fuca. Implementation of the ITOS program included procurement of computer systems located at the Marine Exchange (MAREX), and installation of VHF radio transponders for over 100 tugboats.

The forecast cost for ITOS according to Ref. (20) was based on start-up costs of $490,000 and annual recurring costs ranging from $84,000 to $156,000. Assuming a five-year payoff of capitalized equipment the MAREX and the ITOS Coalition determined that they would require approximately $267,000 per year, and that a vessel assessment of $50 per arrival would cover all associated costs.

7.2.1 Historical ITOS Costs

Recent conversations with Robert Bohlman of MAREX have generally confirmed the initial cost estimates for start-up fees, used primarily for tugboat transponders and the computer and backup systems at MAREX. Operating expenses including maintenance and repair expenses have been less than $10,000 per year since the system became operational, with little management and oversight required by MAREX.

7.2.2 Forecast of ITOS Costs for Period 2000-2025

One method of forecasting ITOS costs for the entire 26-year analysis period is to simply multiply the current $50 assessment per ship arrival by the projected number of arrivals each year. This cost basis assumes that the actual cost borne by the shipping companies reflect the regulatory cost associated with the rule. Alternatively, the annualized cost for the initial and ongoing capital and operating expenditures can be estimated. The latter approach is applied in this study, as it provides a more accurate accounting of overall costs.

The preferred method of cost allocation for regulatory assessment of electronic systems, which have an accelerated rate of obsolescence, is to convert each capital expenditure to an annualized equivalent cost over the projected life of the equipment. This annualized capital is added to the other annual recurring costs to develop the cost stream over the assessment period.

The following assumptions were made when projecting the costs for ITOS over the 2000-2025 study period:

- Transponder installations are assumed to be $5150 per tugboat based on 1997 costs of about $4500 per tug, with a projected life of 10 years. It is projected that the transponders could have a service life of more than 10 years. However, the 10 year life is selected as a reasonable maximum for a relatively high technology component operating in the marine environment. Extending the service life beyond 10 years would likely require significant additional maintenance and repair allocations in the later years.

- Computer costs are assumed to be $22,900 based on 1997 estimates of approximately $20,000, with a projected life of 5 years.

- Annual administration, maintenance and repair costs of $25,000 per year are assumed.

- The number of tugboats in the ITOS system with transponders is assumed to begin at the current level of 106. A growth rate in the number of tugs participating in the system of 1.5% per year is assumed over the study period.

These assumed ITOS costs result in an annual compliance cost of about $110,000 for the base year. This equates to about $20 per vessel arrival, as compared to the fee of $50 per arrival currently assessed by the ITOS Coalition. MAREX confirmed that the system is being amortized at an accelerated rate, and that if the level of service provided by ITOS remains unchanged, a reduction in the fee can be expected in future years.

7.3 Escort Tugs

ALT. 2 through ALT. 6 are various implementations of tug escort programs. For all options it is assumed that the tug size is appropriately matched to the vessel, consistent with current regulations for escort tugs.

7.3.1 Forecast of Escort Tug Costs

Escort tug costs for all of the escort alternatives have been developed for two methods; purchasing dedicated escort tugs, and for chartering multi-use tugs. A discussion of the assumptions for the two methods follows.

Dedicated Escort Tugs

A major consideration in developing the costs for a dedicated escort tug fleet is the determination of the required number of tugs. The average number of tugs required can be estimated from the number of ship transits per year and the average escort time. However, ship arrivals and departures are somewhat random in nature and there are weekly and seasonal variations in traffic volume. The required number of tugs to establish a dedicated escort tug fleet is closer to the peak tug usage rather than the average tug usage.

For each alternative, the number of tugs that might be simultaneously employed must be assessed. The Poisson distribution closely fits the historical data on intervals between vessels transiting the Strait of Juan de Fuca, and is applied in this study to determine tug requirements. Seasonal and daily variations in ship arrivals and departures are also accounted for in the analysis.

Service speeds for the escort tugs of 12 knots, 14.5 knots, and 16 knots were assumed and matched to the escorted vessel. Most modern tugs do not exceed about 15 knots, and about 16 knots is considered a practical upper limit for tug escort speed assuming a new specially built tug. For this assessment, the average escort transit time from "J" Buoy to the port was determined for each ship type, by assigning the appropriate speed escort tug. The 14.5 knot tugs are employed for tankers, and the 16.0 knots are employed for all vessels with service speeds of 16 knots or more. The tug transit time, based on the slower of the ship's service speed or the tug's service speed, was increased by 60% to account for tug repositioning following the escort. The Poisson distribution was applied to the transit projections, to ascertain the percentage of time various numbers of tugs are required. The 95% probability or 5% probability of exceedence is used to establish the reasonable number of tugs assumed in the escort fleet for the cost evaluation.

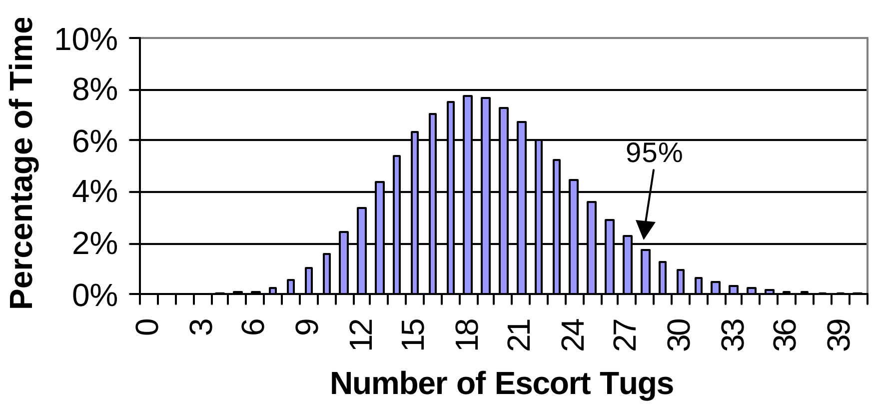


Figure 17 Required number of dedicated escort tugs (ALT. 5)

The cost for the dedicated fleet assumes a life of 15 years for escort tugs. This is a value typically applied in industry for the projected useful life of ships. Extending the life of the tugs will have a relatively small impact on the present value costs, particularly after increased maintenance costs are accounted for. The crew and consumable costs are based on a mean utilization of approximately 16 hours per day.

Chartering Multi-Use Tugs

An alternative method for assessing the cost implications of escort tugs is to apply "per transit" charter costs. This approach assumes the tugs can be employed for other service when not engaged in escorting.

Since these tugs will be primarily, but not exclusively, used for escort service, the following assumptions were applied when developing the escort costs:

- Average times under escort are approximately 12, 9 and 10 hours respectively for the 12, 14.5 and 16-knot tugs. The total time for each escort voyage including tug waiting and relocation are assumed to be 25, 19 and 21 hours respectively. The 16 knot tugs typically have longer routes, as they predominately escort containerships to southern Puget Sound. This accounts for their longer service time as compared to the 14.5 knot escort tugs.
- Capital, insurance, and maintenance and repair costs are based on a full 24-hour day rate charged for each escort.
- Manning, supplies, fuel and lube are based on the actual service hours, and the consumption rates applicable to each escort.

For ALT. 5 and ALT. 6, which employ a large number of escort tugs ensuring high tug utilization, both methodologies (i.e. procuring dedicated escort tugs or chartering multi-use tugs) generate roughly equivalent costs. For these large-scale escort alternatives, the slightly higher cost for a dedicated escort tug fleet is considered more appropriate for compliance costs estimates. For ALT. 2, 3, and 4 which have escort fleets that are small and relatively under-utilized, the chartering of multi-use tugs will be significantly less expensive. For these alternatives, the chartering option has been used to develop the final compliance costs applied in the benefit-cost analysis.

Cost Basis for the Escort Tugs

The tug costs for both dedicated and chartered tugs were developed from the purchase price, crew cost, fuel and consumables costs, insurance, maintenance, repair, and back-up cost during annual maintenance. See the Appendix for details of the cost development. A summary of the costs for the three tug sizes is indicated in Table 38.

	12 Knot	14.5 Knot	16 Knot
Tug Purchase Price	$6,000,000	$13,000,000	$16,800,000
Installed BHP	4000	9000	11600
Approx. Daily Rate	$7,993	$14,766	$18,042
Average $ / Escort	$7,487	$12,725	$16,960

Table 38

7.3.2 Forecast of Ship Costs due to Reduced Transit Speeds

The assessment of the cost of the alternatives also includes the effect of escort tugs on the transit speed for each type of vessel. Most ship types are assigned tug escorts that have a service speed equal to or faster than the typical transit speed of the vessel without escort. In these cases there is assumed to be no impact on transit speed for implementing the escort alternative. However, the typical transit speeds for containerships, vehicle carriers, and the larger passenger ships are generally exceed the maximum 16 knot escort speed. For these vessels, the costs due to reduced transit times have been developed. These costs are a function of the number of transits, the average lost time per transit, and the average hourly costs for ship and cargo.

The lost time per transit is not a direct function of the ratio of escort speed to ship service speed. Discussions with containership operators indicate that these fast ships are not able to maintain their full service speed through the waterway. Maneuvering, embarking and disembarking pilots, and port approaches all effect the overall transit speed and tend to reduce the potential impact of the escort speed reduction. For this assessment the average speed loss was based on the difference between typical unescorted transit times and the simulated escort times for each ship type. The lost time is related to the ship's service speed and on average ships of 20 knot service will loose approximately one hour per transit, and ships of 25 knot service speed will lose approximately two hours per transit. The lost time for other service speeds is interpolated between these values.

For each of the applicable ship types (except the passenger ship type), a design was selected representative of the mean size and speed for that ship type. Typical daily and hourly rates were developed which include capital recovery of ship construction costs, crew costs, stores and subsistence, maintenance and repair, insurance, fuel oil, lube oil, and other standard operating costs. Costs were developed assuming an international fleet, and then the daily rate for each ship type was adjusted to reflect the percentage of Jones Act U.S. Flag vessels, which have substantially higher costs.

Cargo value was established as follows:

- Containers at $60,000 per TEU, average of eastbound and westbound per Ref. (11).
- New autos at $12,000 each.

Daily and hourly rates for cargo delay are based on capital recovery of 10% of the cargo value divided by 365 days per year. The net cost effectiveness is relatively insensitive to these estimated cargo values, as the cost of ship delay represents only about 10% of the overall compliance costs.

Passenger ships generally have sufficient speed and power reserves to maintain the present voyage itinerary regardless of the one hour per transit delay from the escort. It is assumed that the passenger ships make up the one hour delay over a 24 hour period. An increase in fuel consumption of about 14% is projected over the 24 hours. For a typical 25,000 to 30,000 horsepower passenger liner this amounts to $1500 in additional fuel for every escorted transit.

Summary costs for one hour of lost transit time are as follows:

- Containerships < 2000 TEU $ 2,596
- Containership 2000-4000 TEU $ 3,617
- Containerships > 4000TEU $ 5,642
- Vehicle Carriers $ 1,910
- Passenger Liners $ 1,476

7.3.3 Forecast of Industry Compliance for Period 2000-2025

The escort tug costs and ship speed reduction costs are projected over the assessment period by using the forecast transit information for each ship type.

Costs for escorting laden single hull tankers east of Dungeness are not included in the analysis, as a two tug escort requirement already applies. Correspondingly, the benefits associated with the existing escort are not included in the benefit analysis.

7.4 Pre-Positioned Rescue Tugs

ALT. 7 and ALT. 8 involve stationing a rescue tug at the mouth of the Strait of Juan de Fuca, for the purposes of aiding vessels in distress and escorting tank vessels about "J" buoy. No impact on vessel transit times is expected.

7.4.1 Rescue Tug Operational Requirements

The rescue tug is a dedicated tugboat equipped to respond and provide assistance to distressed vessels primarily by towing. Rescue tugs are frequently arranged with capabilities for pumping, fire fighting, and pollution response.

For the purpose of this regulatory assessment, the rescue tugboat has been sized to provide effective rescue capabilities for most vessels transiting the Strait of Juan de Fuca, during all but the worst storm condition. The general operational requirements of the selected tug are:

- About 10,000 horsepower
- VSP or Z-Drive tractor configuration
- 100 to 110 metric ton bollard pull
- free running speed of 14 to 15 knots
- winch, towing gear, etc. to conduct ocean salvage and rescue

It is assumed that the rescue tug is continuously manned and "on station", which means the tug spends a majority of its time on patrol and underway.

7.4.2 Cost of Alternatives

The acquisition and operational costs for the rescue tug dominate costs for the rescue tug option. The following cost components were consider when developing the overall costs of the alternative:

- *Capital Costs* – The purchase price for a new US built tug is converted to annualized equivalent costs over the life of the tug (assumed to be 7% over a 15 year period).
- *Manning, stores, supplies, and provision costs* – All assume continuous on-station manning.
- *Fuel and Lube Oil* – Consumable costs are based on the following operational profile: 50% of time at half power on patrol, 15% of time at full power conducting drills or responding, 15 % idling, and 20% in standby mode.
- *Insurance, maintenance and repair* – Assumed at typical values for tugs of this size.

The rescue tug system also assumes the charter of a stand in replacement tug for approximately 20 to 25 days per year for general maintenance, repair, and annual dry-docking of the rescue tug. All tugboat costs are based on the actual costs incurred and do not include operating profit for the organization operating the rescue tug.

The complete development of the rescue tug cost (capital, crewing, supplies, consumables, insurance, M&R, and back-up during annual maintenance) is included in the Appendix. A cost summary for the 10,000 horsepower rescue tug is as follows:

- Purchase Price $ 14,700,000
- Total Annual Cost $ 5,484,000 (capital and operational)
- Total Cost per Month $ 488,300

For the new tug, the annualized capital cost and maintenance cost are $1,614,000 and $367,500 respectively. An alternative to a new rescue tug is to purchase an existing tug that meets these operational capabilities. In the sensitivity analysis, use of a US Navy T-ATF class tug was evaluated. Annual capital costs of $250,000 together with annual maintenance costs of $500,000 were assumed. Total annual costs for the T-ATF tug is $4,081,000.

7.4.3 Forecast of Escort Tug Costs for Period 2000-2025

Annual capital and operating costs are assumed constant over the 26 year assessment period. Although the service life of the rescue tug is assumed to be 15 years, the annualized costs have been continued for the full 26 year assessment period. This effectively means that a similar cost replacement tug will be purchased in 2015.

7.5 Enforcement Costs

Enforcement of shipping tug requirements through the Straits of Juan de Fuca will be the responsibility of the U.S. Coast Guard. The Coast Guard will need a method to ensure that these tug requirements are met.

Presently, the U.S. Coast guard utilizes the Vessel Traffic System (VTS) to ensure tug requirements are met in Puget Sound. Normally, the harbor pilot embarked on the escorted vessel will contact VTS via radio and report the presence of escort tugs. Moreover, the radar returns of the escort tugs are seen in the vicinity of the escorted vessel by VTS. Thus, the Coast Guard utilizes both radio reports and radar to confirm required tugs are escorting a vessel in Puget Sound.

Since VTS operates throughout the region, the Coast Guard will also be able to use VTS for tug enforcement in the Straits of Juan de Fuca. VTS operators will be able to obtain radio reports and see radar returns of the presence of any required tugs in the Straits. Although there is no requirement for harbor pilots on vessels in the Straits, radio reports can be obtained from the vessel master and/or the escort/rescue tug(s) with radar verification.

The use of the VTS for enforcement will not require any additional equipment of personnel by the Coast Guard. Enforcement will only require that present VTS operators verify the required tug(s) presence via radio and radar when required. Therefore, the enforcement cost for any tug requirements through the Straits of Juan de Fuca is considered negligible.

7.6 Developing Avoided Costs for all Alternatives

Avoided costs for fatalities, injuries, ship damage, lost ship time, and cargo damage are based on the conditional probability of the cost occurring, given a casualty, multiplied by the average cost. For each alternative these average costs per avoided casualty are simply multiplied by the number of casualties avoided.

7.6.1 Avoided Fatalities and Injuries

The valuation assigned to avoided fatalities and injuries is taken from The 1991 USCG Port Needs Study (PNS) Ref. (11). As noted in Appendix G "Method of Estimating Avoided Costs" from Ref. (14), these 1990 recommended values for fatalities and injuries are adjusted to 1996 dollars. The recommended values in 1996 dollars are:

Fatalities $2,754,863
Injuries $413,023

These values are converted to 1999 dollars for the evaluation in this regulatory assessment.

The conditional probability of a fatality (or an injury) given a vessel casualty was also taken from the PNS study. These conditional probabilities are listed separately for three vessel types (tank vessels, medium and large dry cargo and passenger vessels, and small dry cargo and passenger vessels), and summed for all casualty types (collisions, groundings, and allisions). The conditional probabilities and average fatality and injury costs per casualty are summarized in Table 39.

	Fatalities		Injuries	
Ship Type	Deaths per casualty	Cost ($) per casualty	Injuries per casualty	Cost ($) per casualty
Tanker and Tank Barge	0.20%	$6,600	1.95%	$9,866
Large Dry Cargo & Passenger Ships	12.50%	$412,500	1.02%	$5,161
Small Dry Cargo & Passenger Ships	6.40%	$211,200	58.80%	$297,511

Table 39 Cost of Fatalities and Injuries per Casualty

7.6.2 Avoided Ship Damage

Using the methodology suggested in the Appendix G of Ref. (14) and the casualty data summarized in the PNS Study, Ref. (11), the average cost for vessel damage given a casualty was developed. The probabilities and ship damage costs are summed separately for three vessel types (tank vessels, medium and large dry cargo and passenger vessels, and small dry cargo and passenger vessels), using a weighted average of the severity of light, moderate, and severe damages. As with fatalities and injuries, the average costs per damage are multiplied by the conditional probability of a casualty resulting in damage to the ship.

7.6.3 Avoided Ship Out of Service Time

Using the methodology suggested in the Appendix G of Ref. (14) and the casualty data summarized in the PNS Study, Ref. (11), the average idle vessel cost given a casualty was developed. The probabilities and ship damage and idle costs are summed separately for three vessel types (tank vessels, medium and large dry cargo and passenger vessels, and small dry cargo and passenger vessels), using a weighted average of the severity of light, moderate, and severe damages. As with fatalities and injuries, the average idle vessel costs from a damage are multiplied by the conditional probability of a casualty resulting in damage to the ship.

7.6.4 Avoided Cargo Damage

The methodology suggested in Appendix G of Ref. (14) and the casualty data summarized in the PNS Study, Ref. (11) give no specific details which can be used to directly estimate the cargo damage costs. This study assumes that cargo damage costs are approximately 50% of the average ship damage costs.

8 BENEFIT-COST EVALUATION

8.1 General

All costs are taken to present value in 1999. The *Avoided Costs* are subtracted from the *Cost of Compliance and Enforcement* to obtain the *Net Costs.* The *Net Cost-Effectiveness* equals the *Benefits* (present number of barrels of oil not spilled) divided by the *Net Cost*.

(1) Cost of Alternative
  Industry compliance costs (includes tug costs and costs of reduced transit speeds)
  Enforcement costs
(2) Avoided Costs
  Fatalities and injuries
  Damage related costs (includes damage to vessel and cargo losses)
(3) Net Costs (1) - (2)
(4) Pollution averted (in terms of barrels of oil not spilled)
(5) Net Cost-Effectiveness (3)/(4)

8.2 Analysis of Net Cost Effectiveness

The benefit-cost analysis for the reference case (Case A) is summarized in Table 40, and the net cost effectiveness for each alternative is graphically displayed in Figure 19. Key assumptions applicable to Case A include:

- Projected growth in traffic and oil movements is according to Table 11.
- The basis for the frequency of oil spills from collisions and groundings is historical data for the period 1992-1997. These are the “probable” spill rates presented in Table 21 and Table 23.
- The anticipated reduction in spills from collisions and groundings due to implementation of the double hull provisions of OPA90 is in accordance with Table 29, and the reduction in the number of collision and grounding accidents due to implementation of STCW is in accordance with Table 30.
- For the escort tug options, ALT. 2 through ALT. 6, the escort is assumed to assist only the vessel it is escorting. It is not deployed to assist nearby unescorted vessels that may have lost power or steering.
- Escort tugs are assumed appropriately matched to the vessel they are escorting.
- For the rescue tug alternatives, ALT. 7 and ALT. 8, the tug is assumed pre-positioned in the vicinity of “J” Buoy. The tug is used to escort inbound and outbound laden tank vessels through the crossing zone immediately to the west of “J” Buoy.
- A 10,000 HP rescue tug is assumed for the reference condition.

The sensitivity of the averted oil outflow and net cost effectiveness to many of the key assumptions is discussed in Section 8.3.

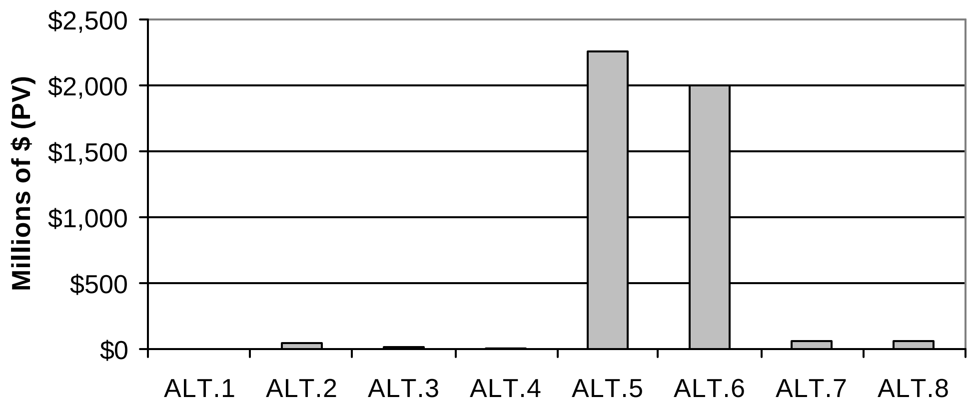


Figure 18 Net Costs (Reference Case A)

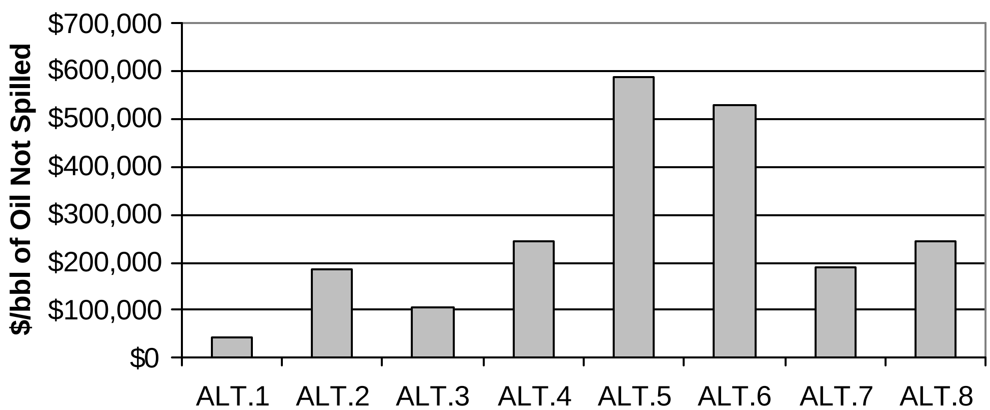


Figure 19 Net Cost Effectiveness (Reference Case A)

Benefits & Costs	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6	ALT 7	ALT 8	Units
Industry Compliance									
Tug Costs	1.2	52.4	26.2	10.0	2,054.6	1,847.3	64.8	64.8	million $ (PV)
Ship Operating Costs	0.0	0.0	0.0	0.0	224.1	224.1	0.0	0.0	million $ (PV)
Enforcement Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	million $ (PV)
Total Cost of Alternative	1.2	52.4	26.2	10.0	2,278.7	2,071.4	64.8	64.8	million $ (PV)
Fatalities	0.1	0.0	0.0	0.2	9.2	8.9	0.4	0.0	million $ (PV)
Injuries	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.0	million $ (PV)
Private Damage	0.1	0.0	0.0	0.3	16.5	16.1	0.7	0.1	million $ (PV)
Total Avoided Costs	0.2	0.0	0.0	0.5	26.2	25.3	1.1	0.1	million $ (PV)
Net Costs	1.1	52.4	26.2	9.5	2,252.5	1,996.4	63.6	64.7	million $ (PV)
Pollution Averted	26	285	243	39	3,856	3,789	338	264	barrels of oil (PV)
Net Cost-Effectiveness	$42,382	$183,964	$107,798	$242,466	$584,190	$526,846	$188,461	$245,131	$ per bbl not spilled

Table 40 Benefit & Cost Summary for Reference Case A

ITOS (ALT. 1) is the most cost-effective due to its low cost, although the barrels of oil spill averted is modest compared to the other alternatives. ALT. 2 and ALT. 3 are the most cost effective of the escort options, as they apply specifically to laden single hull tankers which have comparatively higher spill risks than the double hull tankers and freighters.

The other escort options, ALT. 4 through ALT. 6, have relatively higher costs per barrel not spilled. This is related to the high cost of escort service together with significant industry costs associated with slowing down containerships and other high speed vessels.

The low probability of drift groundings compared to other types of accident limits the effectiveness of rescue tugs (ALT. 7 and ALT. 8). As discussed in the next section, a substantial portion of the pollution averted by the rescue tug is attributable to its assumed use as an escort for laden tank vessels.

8.3 Sensitivity Analysis

A number of sensitivity analyses were performed to evaluate their impact on the benefit-cost analyses. These are:

- Case B Pessimistic spill rates (spill frequency based on 1986-97 spill statistics),
- Case C Reducing the assumed effectiveness of double-hulls by 50%,
- Case D Sensitivity to effectiveness of STCW and ISM code,
- Case E Excluding the use of rescue tugs as escorts around "J" Buoy,
- Case F Using collision factors based on numerical simulation,
- Case G Assuming escort tugs assist other stricken vessels,
- Case H Sensitivity of effectiveness factors for escort tugs,
- Case I Using a smaller (5500 BHP vs. 10,000 BHP) rescue tug,
- Case J Using the US Navy 7,200 BHP T-ATF class tug as the rescue tug,
- Case K Tug barge accident rate reduced for Puget Sound operations,
- Case L Apply extreme spill sizes for drift groundings east of Dungeness,
- Case M Apply reduced spill size for tank vessels to account for OPA90 effects, and,
- Case N Adjust for relative risk of Puget Sound region vs. U.S. ports in general.

As a basis for comparison, the results for the Reference Case A are reproduced in Table 41.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	286.1	245.0	4.9	1,274.3	1,262.2	166.0	160.8
Tank Barges	4.7	(0.6)	(0.9)	3.1	898.4	890.2	101.3	99.2
Other Ships (>3000 GT)	10.3	(0.6)	(1.0)	31.0	1,639.6	1,628.5	68.6	3.7
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.8	0.1
Total all ships	25.5	284.9	243.1	39.2	3,855.7	3,789.3	337.7	263.8
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	42,382	183,964	107,798	242,466	584,190	526,846	188,461	245,131

Table 41 Base Case A: Reference

8.3.1 Case B: Pessimistic Spill Projections

Oil spill statistics for 1992 to 1997 show a significant drop in the number of spills, especially for tankers where spills have dropped to 20% of the previous six year period. Significant reductions have been noted for other ships as well. An analysis assuming that there has been no fundamental change was performed, where the oil spillage was projected utilizing statistics from 1986-97. This analysis shows a significant impact on spills averted as there is potentially more oil being spilled, and thus each alternative averts more spillage. Further, the impact is most significant on those alternatives that address tankers directly. Use of this assumption is considered very conservative, as it does not fully account for improvements in operations and standards in recent years.

Present Value of Barrels of Oil Spill Averted	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	31.5	890.1	762.1	14.4	3,937.9	3,902.9	517.3	501.2
Tank Barges	10.1	1.1	(0.0)	6.3	1,904.3	1,887.9	216.5	212.0
Other Ships (>3000 GT)	17.7	1.0	(0.0)	52.7	2,806.7	2,788.8	119.8	8.6
Other Ships (300-3000 GT)	0.4	0.0	(0.0)	0.2	74.3	14.3	3.1	0.2
Total all ships	59.7	892.2	762.1	73.6	8,723.3	8,593.8	856.6	722.1
% change from "Expected"	134%	213%	213%	88%	126%	127%	154%	174%
Net Cost Effectiveness								
U.S.$ per Barrel not spilled	16,109	58,665	34,330	124,575	256,031	230,163	73,270	89,368

Table 42 Case B: Pessimistic Spill Rates
(based on 1986-97 spill statistics)

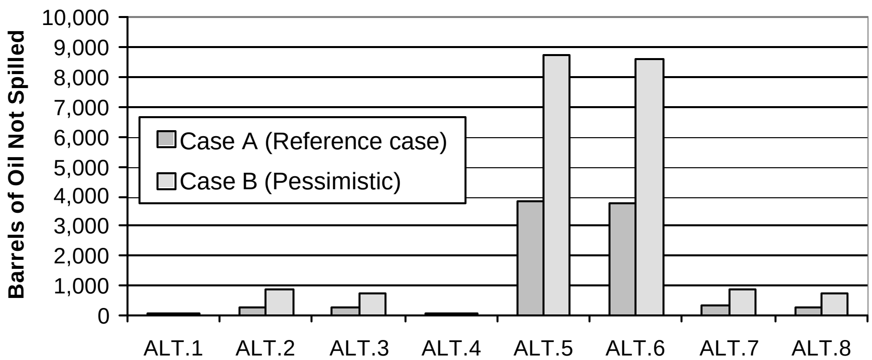


Figure 20 Present Value of Barrels of Oil Spills Averted
(Comparison between Case A and Case B)

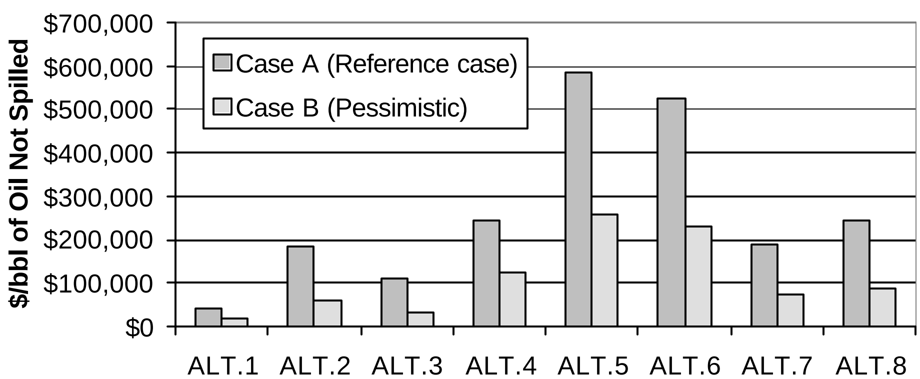


Figure 21 Net Cost Effectiveness
(Comparison between Case A and Case B)

8.3.2 Case C: Reducing the Assumed Effectiveness of Double-Hulls by 50%

In the reference case, the effectiveness of double-hull tankers and tank barges in reducing the number of oil spills is based on results from the probabilistic outflow analysis. For example, double-hull tankers are expected to spill oil in 20% of the casualties that penetrate the hull. This is consistent with the limited data available on double-hull incidents. To evaluate sensitivity to these projections, the assumed effectiveness was halved, leading to more oil spillage potential, and thus more oil spillage averted.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	15.5	352.0	302.4	7.3	1,955.5	1,938.1	243.4	235.7
Tank Barges	6.7	(0.8)	(1.1)	4.4	1,212.1	1,200.6	136.5	132.9
Other Ships (>3000 GT)	10.3	(0.8)	(1.1)	31.0	1,639.7	1,628.6	68.6	3.6
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.8	0.1
Total all ships	32.8	350.4	300.2	42.8	4,850.7	4,775.6	450.3	372.4
% change from "Expected"	29%	23%	24%	9%	26%	26%	33%	41%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	32,955	149,549	87,291	221,792	464,366	418,038	141,336	173,661

Table 43 Case C: Assumes 50% Reduction in the Effectiveness of Double Hulls

8.3.3 Case D: Sensitivity to Effectiveness of STCW and ISM Code

In the reference case, STCW has been assumed effective in reducing the number of accidents by 12% upon full implementation. The impact of ISM and STCW are difficult to predict and, as discussed in Section 5.2.2, may be higher than 12%. To assess sensitivity, accident reduction factors of 24% and 36% have been assumed for Case D1 and Case D2 respectively.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	9.2	264.1	226.1	4.5	1,153.8	1,142.8	151.1	146.5
Tank Barges	4.3	(0.5)	(0.8)	2.8	815.6	808.2	91.9	90.1
Other Ships (>3000 GT)	9.2	(0.6)	(0.9)	27.8	1,471.8	1,461.9	61.6	3.3
Other Ships (300-3000 GT)	0.2	(0.0)	(0.0)	0.1	39.0	7.5	1.6	0.1
Total all ships	23.0	263.0	224.3	35.3	3,480.3	3,420.3	306.3	240.0
% change from "Expected"	-10%	-8%	-8%	-10%	-10%	-10%	-9%	-9%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	47,736	199,288	116,827	270,772	647,979	584,425	208,125	269,486

Table 44 Case D1: STCW and ISM Code Accident Reduction Projection of 24%

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	8.3	242.1	207.1	4.0	1,033.3	1,023.4	136.3	132.2
Tank Barges	3.8	(0.5)	(0.7)	2.5	732.8	726.1	82.6	81.0
Other Ships (>3000 GT)	8.2	(0.5)	(0.8)	24.7	1,304.0	1,295.2	54.7	2.9
Other Ships (300-3000 GT)	0.2	(0.0)	(0.0)	0.1	34.6	6.6	1.4	0.1
Total all ships	20.5	241.1	205.5	31.3	3,104.8	3,051.4	274.9	216.2
% change from "Expected"	-20%	-15%	-15%	-20%	-19%	-19%	-19%	-18%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	54,399	217,397	127,507	306,156	727,195	655,926	232,274	299,203

Table 45 Case D2: STCW and ISM Code Accident Reduction Projection of 36%

8.3.4 Case E: Rescue Tugs Not Used to Escort Tankers at "J" Buoy

The reference case assumes the rescue tug, when not actively engaged in rescue operations, will provide escort services to laden tankers in the vicinity of "J" Buoy. Provision of an escort significantly mitigates the likelihood of a collision involving the escorted vessel. Utilization of the tug in this manner does not measurably influence its effectiveness in rescuing a stricken vessel as the tug remains in close proximity to "J" Buoy.

If the rescue tug is not utilized as an escort for tank vessels, spillage for ALT. 7 and ALT. 8 increases, principally from collisions in the vicinity of "J" Buoy.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	286.1	245.0	4.9	1,274.3	1,262.2	69.2	64.0
Tank Barges	4.7	(0.6)	(0.9)	3.1	898.4	890.2	40.7	38.6
Other Ships (>3000 GT)	10.3	(0.6)	(1.0)	31.0	1,639.6	1,628.5	64.9	0.0
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.7	0.0
Total all ships	25.5	284.9	243.1	39.2	3,855.7	3,789.3	176.4	102.6
% change from "Expected"	0%	0%	0%	0%	0%	0%	-48%	-61%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	42,382	183,964	107,798	242,466	584,190	526,846	361,112	631,173

Table 46 Case E: Rescue Tugs not Used to Escort Tankers at "J" Buoy

8.3.5 Case F: Variation in the Likelihood of Collisions by Waterway Segment

The Panel of Experts was asked to evaluate the areas of the region in terms of relative likelihood of collisions. They assigned the majority of risk to the region near the Rotary and the immediate vicinity of Port Angeles, while downplaying the risks in the offshore regions. Issues they raised when assessing the increased risk near Port Angeles include the number of operational tasks occurring, congestion particularly in way of the pilot station, and required changes in speed. The reference case utilizes the experts' assignment of conditional likelihood of collisions by waterway segment.

The numerical simulations showed a significant number of crossing encounters in the area just west of "J" Buoy. This increases the projected likelihood of collision and powered grounding in the western regions, reducing the effectiveness of escort services that don't extend that far, and increasing that of a rescue tug.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	267.7	230.3	4.4	1,213.2	1,202.1	191.4	186.2
Tank Barges	4.7	(0.8)	(1.1)	2.8	854.0	846.4	118.0	115.9
Other Ships (>3000 GT)	10.3	(0.9)	(1.2)	29.9	1,578.3	1,568.1	70.5	5.6
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	42.0	7.3	1.8	0.1
Total all ships	25.5	265.9	227.9	37.3	3,687.5	3,623.9	381.6	307.8
% change from "Expected"	0%	-7%	-6%	-5%	-4%	-4%	13%	17%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	42,382	197,093	114,994	255,329	611,107	551,147	166,650	209,987

Table 47 Case F: Collision Location Probabilities based on Numerical Simulation rather than Panel of Expert Judgement

8.3.6 Case G: Assuming Escort Tugs Assist Other Stricken Vessels

In the reference case escort tugs are restricted from assisting other vessels. It was assumed that for liability reasons they would be unwilling to leave their assignment. However, if mandated to do so, they would be effective in reducing oil spills for those alternatives utilizing escorts.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	299.2	258.1	13.0	1,274.3	1,262.2	166.0	160.8
Tank Barges	4.7	24.0	23.7	6.7	898.4	890.2	101.3	99.2
Other Ships (>3000 GT)	10.3	25.9	25.6	39.7	1,639.6	1,628.5	68.6	3.7
Other Ships (300-3000 GT)	0.3	0.7	0.7	0.4	43.4	12.4	1.8	0.1
Total all ships	25.5	349.9	308.1	59.8	3,855.7	3,793.3	337.7	263.8
% change from "Expected"	0%	23%	27%	53%	0%	0%	0%	0%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	42,382	148,520	83,623	156,649	584,190	526,258	188,461	245,131

Table 48 Case G: Escort Tugs used to Assist Other Stricken Vessels

8.3.7 Case H: Variations in the Assumed Effectiveness of Escort Tugs

As described in Section 6.3.2, there is considerable uncertainty as to the relative effectiveness of escort tugs in averting collisions and powered groundings. To assess sensitivity to the assumptions on escort tug effectiveness, the accident reduction factors were increased by 0.20 (20%) for the "pessimistic" evaluation (Case H-1), and reduced by 0.20 (20%) for the "optimistic" evaluation (Case H-2). In Case H-3, estimates provided by the Panel of Experts were applied.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	203.9	162.7	2.0	663.5	659.8	122.2	117.0
Tank Barges	4.7	(1.2)	(1.5)	1.3	392.9	390.2	73.7	71.6
Other Ships (>3000 GT)	10.3	(1.3)	(1.6)	17.9	879.4	875.8	66.8	1.9
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	25.2	2.1	1.7	0.0
Total all ships	25.5	201.3	159.5	21.2	1,961.0	1,927.8	264.4	190.5
% change from "Expected"	0%	-29%	-34%	-46%	-49%	-49%	-22%	-28%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	42,382	260,356	164,366	457,778	1,154,838	1,041,648	240,827	339,587

Table 49 Case H-1: Pessimistic Effectiveness Assumptions for Escort Tugs

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	368.2	327.2	7.9	1,802.7	1,786.2	209.7	204.5
Tank Barges	4.7	0.0	(0.3)	5.0	1,323.4	1,313.5	128.8	126.7
Other Ships (>3000 GT)	10.3	0.0	(0.3)	44.1	2,288.6	2,275.2	70.5	5.6
Other Ships (300-3000 GT)	0.3	0.0	(0.0)	0.2	59.2	14.6	1.8	0.1
Total all ships	25.5	368.3	326.6	57.2	5,473.8	5,389.4	410.8	336.9
% change from "Expected"	0%	29%	34%	46%	42%	42%	22%	28%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	42,382	142,253	80,199	162,710	409,608	368,541	154,813	191,806

Table 50 Case H-2: Optimistic Effectiveness Assumptions for Escort Tugs

Present Value of Barrels of Oil Spill Averted	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	294.1	267.4	5.2	1,362.8	1,350.1	170.4	165.2
Tank Barges	4.7	(0.8)	(0.8)	3.3	977.8	969.2	104.0	101.9
Other Ships (>3000 GT)	10.3	(0.8)	(0.9)	32.9	1,746.2	1,734.7	68.8	3.9
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	46.1	9.0	1.8	0.1
Total all ships	25.5	292.4	265.6	41.5	4,132.8	4,062.9	345.0	271.1
% change from "Expected"	0%	3%	9%	6%	7%	7%	2%	3%
Net Cost Effectiveness								
U.S.$ per Barrel not spilled	42,382	179,202	98,655	228,085	544,610	490,953	184,452	238,499

Table 51 Case H-3: Panel of Experts' Assessment of Escort Tug Effectiveness

8.3.8 Case I: Using a Smaller (5,500 BHP vs. 10,000 BHP) Rescue Tug

In the reference case a large 10,000 HP rescue tug was included. Utilizing a smaller, slower tug would reduce costs, but also reduces the oil spills averted for ALT.7 and ALT.8. Rescue operations will be inhibited by reduced severe weather performance and reduced range. The significant reduction in cost, however, is outweighed by the increase in spillage, making this alternate approach less cost effective than the larger tug.

Present Value of Barrels of Oil Spill Averted	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	286.1	245.0	4.9	1,274.3	1,262.2	145.0	140.5
Tank Barges	4.7	(0.6)	(0.9)	3.1	898.4	890.2	82.1	81.3
Other Ships (>3000 GT)	10.3	(0.6)	(1.0)	31.0	1,639.6	1,628.5	54.2	3.7
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.4	0.1
Total all ships	25.5	284.9	243.1	39.2	3,855.7	3,789.3	282.7	225.6
% change from "Expected"	0%	0%	0%	0%	0%	0%	-16%	-14%
Net Cost Effectiveness								
U.S.$ per Barrel not spilled	42,382	183,964	107,798	242,466	584,190	526,846	153,148	195,457

Table 52 Case I: Use 5,500 HP Rescue Tug in lieu of 10,000 HP Tug

8.3.9 Case J: Using a US Navy T-ATF 7,200 HP Salvage Tug as the Rescue Tug

The US Navy has surplus 13.8 knot, 7,200 HP tugs. One tug has been leased to DONJON MARINE, and the Navy has solicited bids for the lease of a second tug. When analyzing this option, a bareboat charter rate of $250,000 per annum is assumed. This is about 15% of the annualized capital costs for a new 10,000 HP tug. Maintenance costs are increased from $367,500 to $500,000 per year. The performance of the T-ATF tug was treated as equivalent to the 10,000 HP tug, so that benefits in terms of barrels oil not spilled are identical to the reference case.

Present Value of Barrels of Oil Spill Averted	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	286.1	245.0	4.9	1,274.3	1,262.2	166.0	160.8
Tank Barges	4.7	(0.6)	(0.9)	3.1	898.4	890.2	101.3	99.2
Other Ships (>3000 GT)	10.3	(0.6)	(1.0)	31.0	1,639.6	1,628.5	68.6	3.7
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.8	0.1
Total all ships	25.5	284.9	243.1	39.2	3,855.7	3,789.3	337.7	263.8
% change from "Expected"	0%	0%	0%	0%	0%	0%	0%	0%
Net Cost Effectiveness								
U.S.$ per Barrel not spilled	42,382	183,964	107,798	242,466	584,190	526,846	130,266	170,640

Table 53 Case J: Use US Navy T-ATF 7,200 HP Tug in lieu of 10,000 HP Tug

8.3.10 Case K: Reduced Tank Barge Accident Rate for Puget Sound Operations

In the reference case, tank barges are assumed to have the same accident rate as the national average. The Puget Sound area has a history of tug operators who utilize an experienced, stable work force. The Panel of Experts indicated that the accident rate in the Puget Sound region for tug barge operations might be significantly lower, perhaps only 43% of the national rate. This results in less spillage in the oil spill baseline. The effectiveness of all alternatives except those escorting laden single-hull tankers is reduced, as there is less oil spillage to be mitigated.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	10.2	286.2	245.0	5.1	1,274.2	1,261.6	164.7	159.6
Tank Barges	2.0	(0.2)	(0.4)	1.4	386.3	382.6	43.2	42.3
Other Ships (>3000 GT)	10.3	(0.6)	(0.9)	31.2	1,639.6	1,628.0	67.2	2.3
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.7	0.1
Total all ships	22.8	285.3	243.7	37.8	3,343.5	3,280.5	276.9	204.2
% change from "Expected"	-11%	0%	0%	-4%	-13%	-13%	-18%	-23%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	47,434	183,664	107,525	251,305	673,725	608,592	229,961	316,822

Table 54 Case K: Reduced Tank-Barge Accident Rate for Puget Sound Operations

8.3.11 Case L: Assume Extreme Outflows for All Drift Groundings East of Dungeness

In the reference case, the mean spill sizes as percentages of cargo payload presented in Section 4.2.3 are applied for all spill accidents. To investigate the impact of spill size, extreme rather than mean spill sizes were applied for all drift groundings located in the Strait of Juan de Fuca or the offshore approaches. Tanker and tank barge spills were taken at 15% of their payload, and freighter spills at 30% of the bunker fuel onboard. ITOS and the rescue tug alternatives (ALT. 1, ALT. 7, and ALT. 8) are most heavily impacted by this change, as their primary function is to respond to vessels in distress.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	17.0	329.9	288.8	4.9	1,371.4	1,359.3	212.7	204.7
Tank Barges	7.2	(0.6)	(0.9)	3.1	944.7	936.4	122.6	119.4
Other Ships (>3000 GT)	14.0	(0.6)	(1.0)	31.9	1,699.6	1,688.5	91.9	3.7
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.8	0.1
Total all ships	38.6	328.7	286.9	40.1	4,059.1	3,992.6	429.0	327.9
% change from "Expected"	51%	15%	18%	2%	5%	5%	27%	24%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	28,039	159,442	91,338	237,045	554,922	500,011	148,350	197,184

Table 55 Case L: Extreme Spill Sizes Applied for Drift Groundings East of Dungeness

8.3.12 Case M: Reduced Average Spill Size for Tank Vessels for OPA90 Effects

The average spill sizes for vessels are based on historical data, and do not fully account for third order (spill size reduction) effects of regulations adopted since 1990. A reduction in spill size for tank vessels is anticipated due to improved response capability, brought about by OPA90 requirements for training and drilling, enhanced shore resources, and Vessel Response Plans. The "Interim Regulatory Impact Analysis for Vessel Response Plans" projected spill size reductions of 10% for collisions and 15% for groundings. Applying these reductions in spill size to tank vessels results in up to a 13% reduction in overall benefits, as shown in Table 56.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	8.9	248.9	213.1	4.3	1,115.7	1,105.2	144.7	139.9
Tank Barges	4.1	(0.5)	(0.8)	2.7	781.6	774.4	88.1	86.3
Other Ships (>3000 GT)	10.3	(0.6)	(1.0)	31.0	1,639.6	1,628.5	68.6	3.7
Other Ships (300-3000 GT)	0.3	(0.0)	(0.0)	0.1	43.4	8.3	1.8	0.1
Total all ships	23.6	247.7	211.4	38.2	3,580.4	3,516.5	303.2	230.0
% change from "Expected"	-7%	-13%	-13%	-3%	-7%	-7%	-10%	-13%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	45,780	211,528	123,984	248,978	629,119	567,713	209,865	281,134

Table 56 Case M: With Average Spill Size for Tank Vessels Adjusted for Anticipated Impact of OPA90 VRP Regulations

8.3.13 Case N: Apply Panel of Expert Assessment of Relative Risk of Puget Sound Region

The Panel of Experts were asked to project the relative likelihood of collision, powered grounding, and drift grounding spills in the Puget Sound region as compared to U.S. ports in general (refer to Section 4.3.1 and Table 22 for details). In this sensitivity analysis, the Panel of Experts' median estimate of relative risk for the Puget Sound area is applied against the projected rates. This reduces the baseline spill projections and therefore overall benefits.

	Present Value of Barrels of Oil Spill Averted							
	ALT. 1	ALT. 2	ALT. 3	ALT. 4	ALT. 5	ALT. 6	ALT. 7	ALT. 8
Tankers	8.5	207.7	179.2	3.3	906.7	898.5	124.6	120.3
Tank Barges	3.9	(0.4)	(0.6)	2.1	639.6	634.0	75.8	74.0
Other Ships (>3000 GT)	8.6	(0.4)	(0.7)	22.0	1,166.1	1,158.6	56.4	2.5
Other Ships (300-3000 GT)	0.2	(0.0)	(0.0)	0.1	30.8	5.7	1.4	0.1
Total all ships	21.2	206.9	177.9	27.5	2,743.3	2,696.7	258.3	196.9
% change from "Expected"	-17%	-27%	-27%	-30%	-29%	-29%	-24%	-25%
	Net Cost Effectiveness							
U.S.$ per Barrel not spilled	52,380	253,310	147,310	350,386	823,859	742,992	247,185	328,465

Table 57 Case N: Reduced Risk in Puget Sound versus U.S. Ports in General (per Panel of Expert Input)

9 QUALITATIVE ENVIRONMENTAL IMPACT ASSESSMENT

The qualitative environmental impact assessment outlines the potential impact of oil spills on the environment. Under this regulatory assessment the Coast Guard is considering various options for improving maritime safety in the Puget Sound area. The qualitative assessment provides the decision-makers with a characterization of the likely environmental effects that can be prevented through the implementation of the proposed safety measures. The safety measures as outlined in section 2.1 are intended to reduce the possibility of an oil spill due to a collision or drift grounding. This qualitative study considered three spill volumes at two different locations. The analysis describes the natural resources at risk, the extent of the simulated water and shoreline contamination, the impact to natural resources, the impact to trade, tourism and recreation, and the conditions and capabilities for spill response.

9.1 Site Description/Environmental Values

9.1.1 Washington Coast

The Washington outer coast extends approximately 75 miles between Cape Flattery and Grays Harbor. The northern coast has immense biological, cultural and aesthetic importance. Its highly productive coastal environment provides a wide diversity of shorelines and marine habitats. Tatoosh Island on the west boundary of the Strait of Juan de Fuca is home to one of Washington State's largest seabird colonies. The region extending from Cape Flattery to Destruction Island hosts Washington's entire sea otter population and a large population of river otters.

The outer coast consists of parks, wildlife refuges, and preserves, such as the Olympic National Park and Olympic Coast Marine Sanctuary (OCMS). The OCMS spans 3,310-square miles of marine waters from Cape Flattery to the mouth of the Copalis River. It supports one of the most diverse marine mammal faunas in North America and provides a critical link in the Pacific migratory flyway. The Olympic National Park is known for its coastal strip that spans 57 miles across the most primitive natural coastline in the lower 48 States. The park is designated by the United Nations Educational Scientific and Cultural Organization (UNESCO) as a Biosphere Reserve and a World Heritage Site. About 70 percent of the park area is a congressionally designated wilderness.

Just offshore, from Cape Flattery to Point Grenville, a string of rocky and windswept islands supports large seabird colonies. Three species of cormorants, glaucous-winged gulls and common murres use these islands as breeding grounds. Marbled murrelets, federally listed as threatened species, are of special concern due to their high vulnerability to oil spills and abundance in the region. Bald eagles are protected by the Federal Endangered Species Act and are important to the marine ecosystem in the region.

Six species of whales and dolphins regularly inhabit in the region's nearshore zone. The entire U.S. population of gray whales migrates through the Washington waters in the Spring and Fall. Humpback whales are found in the waters primarily during summer and concentrate west of the entrance to the Strait of Juan de Fuca. The Washington coast region is also the pupping and resting site for harbor seals, which are permanent residents in the region.

The Washington outer coast is home to the members of Quinault, Hoh, Quileute, and Makah Indian tribes. For centuries, Native Americans have engaged in fishing activities that have become inseparable from their culture. Fishing is the mainstay for several Native American villages as well as large segments of the population residing in shoreline cities. Fisheries operated by Native Americans are called "treaty fisheries", while non-Native fisheries are designated as "non-treaty fisheries". According to Department of Fisheries and Wildlife estimates, treaty saltwater fisheries in 1993 harvested 17.7 million pounds (25 percent of the total saltwater catch in Puget Sound), while treaty freshwater fisheries in 1994 accounted for 2.2 million pounds (99.9 percent of the total freshwater catch in Puget Sound). The shellfish industry makes Washington State the largest producer of cultured clams and one of the top two producers of cultured mussels in the western United States. Willapa Bay, Grays Harbor and Puget Sound are major oyster cultivation regions.

9.1.2 Strait of Juan de Fuca

The Strait of Juan de Fuca, located in the Northwest corner of Washington State, is an 80-mile long waterway that stretches from Cape Flattery to the San Juan Islands. The Strait borders the United States and Canada, and provides a passage to both Washington State and Canadian ports. The Strait provides habitat for many species of birds, fisheries, and mammals that are important to the overall ecology of the Puget Sound area. Abundant food resources and exceptional water quality make these waters a favored mammal feeding, breeding and resting site. Kelp and eelgrass beds found nearshore not only serve as nursery areas for a variety of fish, but also create protected waters for resting marine birds and waterfowl. Dynamic intertidal zones along the Strait support diverse communities of marine invertebrates, and host numerous recreation and cultural resources. Offshore waters seasonally accommodate large numbers of seabirds and are important migration corridors for marine mammals.

Numerous species of birds reside or visit the Strait of Juan de Fuca; the most abundant are colonial nesting species such as the rhinoceros auklet, tuff puffin, double-crested and pelagic cormorant, and glaucous-winged gull. Protection Island is home to approximately 16 percent of Washington's entire seabird breeding population, including as many as 17,000 breeding pairs of rhinoceros auklets. Marbled murrelet, bald eagle and peregrine falcon also exist in the region. Five common resident species of whales and dolphins are found in the Strait, consisting of gray whale, minke whale, orca, Dall's porpoise, and harbor porpoise. There are eleven more species of whales and dolphins that are considered rare visitors to the region, including the humpback whale, a federally listed endangered species. The islands, nearshore rocks and beaches of the Strait provide breeding and resting sites for harbor seals. The largest concentrations of harbor seals are found on Protection Island, Smith Island, and Dungeness Spit. Steller sea lions (federally listed as threatened), California sea lions, and northern elephant seals also exist in the region as regular seasonal residents or migrants.

The Strait is rich in fishery resources, a variety of baitfish, shellfish, and salmon are present throughout the region. Salmon holds special commercial and environmental values in Washington, and endangered populations of salmon are protected by the 1998 Endangered Species Act. Three important fisheries areas in the Strait are Discovery Bay, Sequim Bay, and Dungeness Bay.

9.2 Methodology

9.2.1 General Approach

The qualitative environmental impact assessment (EIA) identified sensitive environmental resources, describes environmental effects and vulnerability of oil spills in the Puget Sound area. Given the complexities and limits of the study, the approach adopted had the following elements:

- Problem formulation. Problem formulation is a planning and scoping process that establishes the goals, breadth, and focus of the risk analysis. A conceptual model was developed to identify environmental resources to be protected, the data needed, and the analysis to be used.

- Analysis. This analysis phase developed profiles of environmental exposure and effects of oil spills. The exposure profile characterized the ecosystem that may be exposed and described the magnitude and patterns of exposure. Impacts to tourism, recreation and impairments of waterway movements were also examined.

The methodology used in the EIA contains the following steps:

1. Determination of spill scenarios. Six representative spill scenarios were chosen to define the hazards and impacts of spills on the environment. Spill trajectories were determined for each scenario.

2. Determination of spill consequences. Once the spill scenarios and trajectory were defined, various computer models were used to simulate and assess the impacts of oil spills.

3. Determination of tug benefits. As a spill response asset, tugs provide benefits in controlling and minimizing the effects of spills. The analysis identified the various capabilities tugs and salvage vessels have in mitigating the damages associated with an oil spill.

4. Determination of oil spill response capability. The evaluation of spill countermeasure preparedness determined the spill response capability of the region.

9.2.2 Determination of spill scenarios

This section describes the consultation process, rationale and assumptions used in establishing the spill scenarios. Spill scenarios were chosen to best reflect the types and locations of spills considered most likely to happen as discussed below. Variables for the spill scenarios include spill location, spill quantity, oil type, time of spill, wind, current, and resource closures.

9.2.2.1 Spill Location

The first spill location chosen (48°-10’N, 123°-27’W) was on the east boundary of the Strait of Juan de Fuca, where “spurs” for specific destination begins, i.e., Rosario Strait and Puget Sound. This location represents the eastern boundary of the regulatory alternatives under consideration. The area is highly sensitive in terms of spill accident and environmental resources. The east boundary of the Strait serves a crossroad for the waterway, handling large traffic bound for U.S. ports, and all traffic between Washington and the British Columbia ports. Oil products are frequently shipped between British Columbia and Washington State ports, as major refineries are located at Anacotes, Bellingham, and Vancouver.

The eastern region of the Strait of Juan de Fuca is significant not only as a transport medium, but also as an area with outstanding environmental values. It is home to many National Wildlife Refuges, including Dungeness, San Juan Islands, and Protection Island. Rich fisheries resources are found in Discovery Bay, Sequim Bay, and Dungeness Bay. Considering the traffic pattern and distribution of natural resources in the region, the first spill location was selected on the eastern boundary of the Strait.

The second spill location (48°-29’N, 124°-47’W) was chosen at the west boundary of the Strait of Juan de Fuca in the vicinity of the “J” buoy. This corresponds to the western edge of the area covered under the proposed regulatory measures. Both traffic characteristics and environmental sensitivity influenced the selection of location. The Strait of Juan de Fuca has the highest density of shipping traffic in the region. Due to the relative shortness of the route and the deep and wide nature of the passage, the waterway is the preferred route for ocean-going vessels calling at Puget Sound and the Strait of Georgia ports. Traffic generally approaches the Strait from the northwest and the south and southwest at the J buoy. As a result, the spill location was selected at the location where inbound traffic converges.

The west boundary of the Strait of Juan de Fuca is also an important location in terms of natural resources. The area is significant for its productive natural habitats and rich cultural resources. It includes beaches of the Olympic National Park, at least four Indian reservations (Makah, Quillayute, Hoh, and Quinault), three National Wildlife Refuges, and the Olympic Coast Marine Sanctuary. Placing an oil spill on the west boundary of the strait recognizes both high accident potential and environmental sensitivity.

9.2.2.2 Spill Quantity and Oil Type

The worst-case spill scenario applies to oil tankers, which can produce catastrophic environmental impacts due to large volumes of oil carried. The spill quantity was determined as the greater of one full tank or 15 percent[1] of the total combined bunker and cargo capacity for the tanker. As mentioned in section 3.2.3, the average size of crude oil carriers transiting the Strait of Juan de Fuca in 1997 is 94,945 metric tons. Fifteen percent of the tanker capacity is approximately 3.8 million gallons.

Crude oil is being transported extensively between the Puget Sound area and the Alaska North Slope, and a crude oil spill can cause significant environmental damages. Crude oil stranded on the shoreline tends to smother organisms. It can cause mortality in birds from ingestion during preening as well as from hypothermia caused by matted feathers. Therefore, the worst-case scenario considered a 3.8 million gallons tanker spill of Prudhoe Bay crude oil.

The medium spill scenario evaluated a spill from a smaller capacity tanker or barge. The volume of the spill was determined as 15 percent of the average tanker or barge capacity. In the case where total barge volume exceeded the tanker volume, 15 percent of the average tanker load was used. Based on 1996 and

[1] Based on historical tanker spills, 15 percent of the tanker capacity is used as a conservative estimate for the worst case scenario. For the Exxon Valdez accident, about one-fifth of the total cargo, 11.2 million gallons of oil, spilled into the sea.

1997 United States Waterway Data the spill volume was calculated to be 0.25 million gallons[2]. Bunker No. 6 oil was selected as the oil for the medium spill because of its propensity to cause adverse environmental effects. When Bunker No. 6 oil is spilled on water, it tends to spread into thick slicks which can cause extensive pollution. Since the oil is less volatile than crude oil, it can spread and be carried longer distances by winds and currents. Spilled oil can cause lethal injury to seabirds and marine mammals by coating and smothering them as well as by long-term exposure to contaminated sediment.

The small spill scenario considered a bunker spill. The amount of spill was 10 percent of 3,000 metric tons, which was based on the bunker capacity for typical merchant vessels. The quantity for the small spill scenario was determined to be 81,300 gallons[3]. Bunker No. 6 oil was also used for the small spill scenario.

9.2.2.3 Time of Spill

Due to the importance of bird and fishery resources, the study selected the season for the spill that had the highest impact on these resources. In general, natural resources of the Puget Sound area have the highest risk of oil exposure in Spring. Salmon are of special importance to Washington State's commercial and environmental value. Although salmon are present year-round throughout the region, the juvenile stage of most salmon occurs in April and makes them more vulnerable to oil spills. There are also numerous species of marine birds, waterfowl, and seabirds that are either residents or seasonal visitors in the Strait of Juan de Fuca. Placing an oil spill in April inflicted greater impact on birds because it extended the pollution to wintering birds. Therefore, the selection of the spill time is a conservative assumption that allows the greatest impacts on natural resources.

9.2.2.4 Wind and Current

Wind data was obtained from the National Data Buoy Center (NDBC). The Coastal-Marine Automated Network (C-MAN) of the NDBC provides barometric pressure, wind direction, speed and air temperature data; some C-MAN stations also measure sea water temperature, water level, waves, relative humidity, precipitation, and visibility. Hourly wind speed and direction were obtained through the C-MAN station. Tatoosh Island data was used for the west boundary of the Strait of Juan de Fuca, while Smith Island data was applied for the east boundary.

Current and tide information was obtained from the 1998 Current and Tide Tables provided by the National Oceanic and Atmospheric Administration (NOAA). Various NOAA weather stations such as those located at the Strait of Juan de Fuca entrance, Admiralty Inlet, San Juan Channel, and Race Rock were used for tidal current readings. Current vectors were spread to cover the entire spill area based on interpolation and extrapolation.

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[2] 0.25 million gallons is a representative and conservative estimate for a medium oil spill. For the Nestucca oil spill, 231,000 gallons of bunker oil was released to the ocean.

[3] Considering the New Carissa spill which spilled approximately 70,000 gallons of oil, the size of the small spill scenario is a representative and conservative estimate.

9.2.2.5 Resource Closures

As a result of oil spills, harvest and recreation areas are subject to closure. Closures were indicated for each spill scenario, and occurred in some of the following types of areas:

Harvest areas:

- seaward fish habitat
- landward fish habitat
- structured fish habitat
- seaward shellfish habitat
- sandward shellfish habitat
- structured shellfish habitat
- waterfowl hunting area
- mammal hunting and trapping area

Recreation areas:

- national beaches
- State beaches

For fish and shellfish habitats, closures applied to the areas that were swept by surface slicks. For waterfowl habitats, closure occurred to the inland area where oil contamination was found. Beach closures were measured in days and linear kilometers of beach. The magnitude of beach closure was based on the length of shorelines that was oiled above the lethal threshold, and the duration was determined based on the historical beach restoration and cleanup rate.

9.2.2.6 Scenario Summary

Summarizing the above findings, Table 58 below lists the variables for each spill scenario. Some variables are not included because the information is time series data, such as wind and current data.

The spills in the eastern location represent grounding scenarios, while the spills in the western location represent collisions. These spill scenarios represent the types of spills that can be reduced or prevented through the implementation of regulatory alternatives.

SCENARIO	LOCATION	SPILL QUANTITY	TYPE OF OIL	MONTH/DAY OF SPILL
1	East boundary of the Strait of Juan de Fuca	3.8 MGal	Prudhoe Crude Oil	4/1
2	East boundary of the Strait of Juan de Fuca	0.25 MGal	Bunker No. 6 Oil	4/1
3	East boundary of the Strait of Juan de Fuca	81,300 Gal	Bunker No. 6 Oil	4/1
4	West boundary of the Strait of Juan de Fuca	3.8 MGal	Prudhoe Crude Oil	4/1
5	West boundary of the Strait of Juan de Fuca	0.25 MGal	Bunker No. 6 Oil	4/1
6	West boundary of the Strait of Juan de Fuca	81,300 Gal	Bunker No. 6 Oil	4/1

Table 58 Oil Spill Scenario Summary

9.2.3 Determination of Spill Consequences

The tools used for the qualitative EIA included:

1. NOAA Natural Resource Damage Assessment Model for Coastal and Marine Environment (NRDAM/CME) – oil spill trajectory analysis and impact assessment.

2. Washington State Department of Ecology, Oil Spill Compensation Schedule (OSCS) – impact assessment.

3. NOAA Automated Data Inquiry for Oil Spills (ADIOS) – oil fate model.

Spill consequences were obtained by running oil spill scenarios using the NRDAM/CME. Once the spill trajectories and impact areas were determined, environmental and economic damages were quantified using the both NRDAM/CME compensable value submodel and OSCS. The study used the ADIOS model to verify oil fate, such as dispersion, evaporation, and water content. This section explains the selection of the models used and identifies model shortcomings and constraints.

9.2.3.1 NRDAM/CME

The U.S. Department of the Interior issued the NRDAM/CME to provide a simplified procedure for natural resource damage assessment. As mandated by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Oil Pollution Act of 1990 (OPA 90), NRDAM/CME is a modeling system to assess damages from oil spills.

The NRDAM/CME is a sophisticated mathematical model that simulates oil spills in all U.S. coastal and marine environments. Through a synthesis of complex spatial and time series geographical, topographical, oceanographic and meteorological datasets, NRDAM/CME models the transport and fate of oil, and ultimately determines the effects on natural resources and the costs of these damages.

The NRDAM/CME consists of a series of linked submodels and databases, in which a geographical information system (GIS) supplies spatial environmental and biotic information to the physical fates, biological effects, and restoration submodels. The physical fate submodel computes the trajectory and spread of marine spills until all environmental exposure levels are below the minimum thresholds. The biological effect submodel computes the direct and indirect effects to natural resources in terms of loss and disrupted services. Direct biological injury includes the direct lethal effects on eggs, larvae, juvenile and adult fish and shellfish, birds, mammals, reptiles and lower trophic level biota. Indirect and long term effects consider the eventual loss of biological species, and the disruption in the food chain. The restoration submodel evaluates a range of restoration actions and determines the costs of the most feasible restoration action. The compensable value submodel computes damages as a result of injury and lost use values.

Two sets of input data are required to create a model: spill data and weather data. The basic spill parameters consist of the time and location of the spill, the volume and type of the oil spilled and the duration of the spill. The weather parameters consist of air and sea temperature, wind and current speed and direction. These weather parameters may be built in the form of a time series to reflect the dynamic nature of the ocean environment.

An essential aspect of any oil spill model is the ability to represent the environment of an oil spill. Since the NRDAM/CME includes a wide variety of assumptions to simplify the reality of oil spills, the model has some deficiencies or limitations. In general, the NRDAM/CME applies to smaller, and less complex spills where the use of average values and the generalization of effects will not result in glaring distortions of spill impacts. For example, the model's biological database does not provide precise locations of biological resources throughout the area, but instead distributes the resources uniformly over the biological provinces. As a result of these assumptions, the model has a $100,000 limitation on damages generated.

9.2.3.2 OSCS

The OSCS was incorporated by the 1992 Washington State Preassessment Screening and Oil Spill Compensation Schedule Rule. The purpose of the OSCS is to simplify natural resource damage assessment for oil spills. By establishing a ranking system that rates environmental sensitivity and the persistence of spilled oil, the model assess monetary compensation for natural resource damages resulting from an oil spill.

The compensation schedule consists of two main components: the oil effects rankings and the resource vulnerability rankings. Oil effects rankings are relative rankings of different classes of oil based on their chemical, physical, and mechanical properties, as well as other factors that affect severity and persistence of oil spilled in the environment. Resource vulnerability rankings consider the relative vulnerability rankings for seven resources in the receiving environment. They are:

1. habitat vulnerability
2. marine bird vulnerability
3. marine mammal vulnerability
4. marine fisheries vulnerability
5. shellfish vulnerability
6. salmon vulnerability
7. recreation vulnerability.

The vulnerability rankings take into account: (1) the location of spill, (2) habitat and public resource sensitivity to oil, (3) seasonal distribution of resources, (4) areas of recreation use and aesthetic importance, (5) the proximity of the spill to important habitats of birds, aquatic mammals, fish, or endangered or threatened species, and (6) other areas of special ecological or recreational importance. The model also allows damages to be adjusted according to actions taken by the responsible party to reduce environmental injury.

As a simplified methodology for assessing oil spill damages, the OSCS requires the following data input:

- oil type
- spill volume
- spill area
- season of greatest spill impact
- percent-coverage of habitat affected by the spill
- response action taken by responsible party

The compensation schedule is constructed from field and laboratory data; it is an appropriate tool for natural resource damage assessment for small spills. Through legislative negotiation, the model is applied to calculate damages between $1 and $50 per gallon of spilled oil. OSCS has certain limitations that it tends to over-estimate oil spill damages, as the model uses the most sensitive subregion to quantify the total damage throughout the region. Furthermore, OSCS is an simplified assessment method that applies to small oil spills.

9.2.3.3 ADIOS

ADIOS was developed by NOAA as a tool to improve oil spill planning and response. ADIOS supports a database of approximately one thousand types of oil, and a short-term oil fate model that estimates the state of spilled oil, such as dispersion, evaporation, and water content. It is not a trajectory model.

ADIOS requires the input of real time environmental data including the following:

- oil type
- wind and wave data
- water properties (temperature, salinity or density)
- spill volume and duration.

By combining the input data and the oil property information in the oil library, the model estimates the weathering process of spilled oil.

Like any oil spill models, there are various assumptions and limitations associated with ADIOS. It assumes that oil spreads unhindered in open ocean conditions under wind and gravity effects. Therefore, once the oil is confined by land boundaries, or the spreading process is dominated by currents, ADIOS's spreading algorithm is no longer valid. For small to medium sized spills, the process occurs in a few hours, while for larger spills, it takes a few days. ADIOS also makes the assumption that the temperature of the oil remains unchanged at the sea water temperature. If solar radiation, sea-air interactions, or other factors are significant to cause oil temperature change, results from ADIOS calculations may not be accurate. For most of the oils, ADIOS estimates when mousse formation occurs and determines the value of emulsification constant. When the model contains insufficient emulsification data, ADIOS result may not be accurate because the model predictions are very sensitive to emulsification.

In summary, the algorithms in ADIOS are derived mainly from documented lab experiments on a relative small selection of oils. When the equations are applied to a wide range of oil types under a wide range of conditions, the model may produce unreliable results. ADIOS results should be used with caution.

9.2.4 Determination of Tug as Spill Response Assets

Oil spills cause considerable disruption on resources, human use of the resources, trade, commerce, and private individuals. Tugs can not guarantee that spill accidents will not occur, but they provide an addition means of safety. In case of a spill, tugs can also provide secondary services, such as fire fighting and spill response operations. Because of the significant benefits that tugs can provide, a qualitative analysis of tug benefits as a spill response asset was conducted.

9.2.5 Determination of Spill Response Capabilities

The regional oil spill response capability was based on the U.S. Coast Guard (USCG) Oil Spill Removal Organization (OSRO) classification system. The OSRO classification system is a voluntary system that evaluates and ranks an OSRO's capability to respond within a Captain-of-the-Port (COTP) zone. An OSRO must have the capability to effectively deploy and operate equipment and sustain response operations when an oil spill occurs. Three components used to classify an OSRO include containment, recovery, and storage devices. Furthermore, classifications are provided for four different operating environments: rivers and canals, inland, Great Lakes, and oceans.

All response resources, including non-dedicated and contracted equipment are considered for the classification process. The identified resources must be capable of deployment within stipulated response time in specific operating environment. In general, "A" classification indicates the fastest response time, but the least amount of total equipment and recovery capability. An "E" classification indicates the slowest response time, but the greatest amount of equipment and recovery capability. Classifications B-D fall in the middle of the ranking requirements.

9.3 Environmental Assessment

This section provides information on the environmental resources and resource use that are affected by oil spills. Impacts were quantified including the consideration of spatial, temporal and cumulative aspects. Results from different assessment methods were analyzed, and the limitations that the assessments may impose on the conclusion of this study were identified and discussed.

9.3.1 Affected Environmental and Natural Resources

9.3.1.1 Aquatics

This section describes fish and shellfish resources likely to be impacted by oil spills. In general, the most serious effects are expected to be associated with species in early life stages, such as eggs, spawn, larvae, and juveniles.

1. Herring. Herring prespawning holding areas are located in the Protection Island area between Sequim and Discovery Bays, and within Discovery Bay. Spawning areas include Discovery, Sequim, and Dungeness Bays. Eggs are deposited on marine vegetation, such as eelgrass or algae, within the shallow subtidal and intertidal zones. Exposure of prespawning herring to oil can result in the accumulation of hydrocarbon compounds in eggs. Herring eggs and larvae are highly susceptible to oil exposure, which can cause lethal injuries.
2. Surf Smelt. Spawning areas are found along the outer Olympic Peninsula and the Strait of Juan de Fuca, in Sequim Bay and Dungeness Bay. Surf smelt eggs and larvae are highly susceptible to injury from oil exposure.
3. Pacific Sand Lance. Spawning areas are documented in Sequim, Dungeness, and Port Townsend Bays. Larvae are widespread in the region including Discovery Bay, Sequim Bay, Dungeness Bay, and in the Strait. Eggs and larvae are highly sensitive to oil, which can cause lethal injury.
4. Pacific Salmon. Salmon spawn and rear in all major Washington watersheds and in many smaller tributaries. Juvenile and adult salmon are present year round in the region. The oil sensitivity of salmon varies with species, stocks and river systems.
5. Rockfish. High densities of juvenile rockfish are found in kelp beds throughout the region. Kelp beds are critical to the survival of the juveniles. Kelp beds found from Cape Flattery to Neah Bay and Pillar point east to Jim Creek are high priority areas for protection.
6. Lingcod. The area at the mouth of the Pysht River near Pillar Point holds important lingcod nursery grounds.
7. Cancer Crab. Cancer crabs are present near shore and in the intertidal area. Important locations include Discovery Bay, Dungeness Bay, western Freshwater Bay, Crescent Bay, Agate Bay, and the mouth of Lyre River.
8. Clam. Clams are found throughout the region with higher concentration in Dungeness Bay, Sequim Bay, and Discovery Bay. Clams have a high risk of oil exposure throughout the year because of their sessile lifestyle.

9. Geoduck clam. Geoducks are found throughout the region. The species has high sensitivity to oil during the spawning and larval period from April to August.
10. Pacific oyster. Pacific oysters are present in the lower intertidal and shallow subtidal zones in Dungeness Bay and Sequim Bay. Due to their sessile nature, they are subject to high risk of oil exposure.
11. Sea urchin. Sea urchins are found in the kelp beds throughout the region. Adults are susceptible to oil exposure via the consumption of contaminated algae and kelp. Highest risk for this type of exposure is from April to November.
12. Northern abalone. Abalone are found along exposed or semi-exposed bedrock or boulder shorelines from the intertidal zone to depths of 20 meters. Adults are susceptible to oil exposure via the consumption of contaminated algae and kelp. Highest risk of this type of exposure is from April to November.
13. Octopus. Octopuses are present in caves or dens from the lower intertidal to the subtidal zones. Octopuses are exposed to oil via consumption of contaminated prey, especially clams and crabs. The population which lives in the lower intertidal and shallow subtidal areas is subject to exposure during extreme low tides.
14. Pandalid shrimp. Harvest area occurs in water 100 to 200 meter deep. Coonstripe and spot prawns are found in shallow and lower intertidal zones.

9.3.1.2 Sensitive Wildlife

Sensitive wildlife, including marine mammals and seabirds, are at risk from oil spills because of their abundance in the region. For example, otters are at high risk because they are a slow moving, non-migratory species that have dense fur coats. Predator and scavenging birds, such as bald eagles, crows, and gulls that feed on other birds or oiled substances are also put at risk by oil spills. This section identifies the locations of sensitive wildlife including seabird or heron colonies, marine mammal haulout sites, and nesting sites of sensitive species such as the bald eagle. Table 59 provides the location of seabird colonies, Table 60 describes the location of marine mammal haulout areas[4], and Table 61 lists the location of sensitive nesting species.

[4] Marine mammal haulout site refers to a location where marine mammals come ashore.

REGION	SENSITIVE WILDLIFE AREA WITH SEABIRD COLONIES
Cape Flattery	Seal & Sail Rocks, Tatoosh Island
Shipwreck Pt. to Kydaka Pt.	
Clallam Bay to Pillar Point	
Twin Rivers	
Salt Creek	
Port Angeles	
Dungeness Rec. Area	Dungeness spit and bay
Sequim Bay	Protection Island
Port Townsend	
Fort Ebey/Smith Island	Smith Island
Cape Alava	Ozette/Bodelteh Islands, Cape Alava, White Rock
South Lake Ozette	Jagged Island, Carroll Islands, Sea Lion Rock
La Push	James Island Complex, Quillayute Needles
Hoh River	Destruction Island
Queets	Tunnel Island, Split/Willoughby Rocks/Rock 535
Quinault	Point Grenville
Copalis Beach	

Table 59 Location of Seabird Colonies Sort by Region

REGION	SENSITIVE WILDLIFE AREA WITH MARINE MAMMAL HAULOUT SITES
Cape Flattery	Tatoosh Island
Shipwreck Pt. to Kydaka Pt.	
Clallam Bay to Pillar Point	Slip Point, Pillar Point
Twin Rivers	West Twin River
Salt Creek	Tongue Point
Port Angeles	
Dungeness Rec. Area	Dungeness spit and bay
Sequim Bay	Sequim Bay/Kiapot Spit, Protection Island
Port Townsend	Kilsut Harbor Spit, Kilsut Harbor
Fort Ebey/Smith Island	Smith Island
Cape Alava	Ozette/Bodelteh Islands, Cape Alava, Sand Point
South Lake Ozette	Carroll Islands, Sea Lion Rock
La Push	Quillayute Needles, Giants Graveyard
Hoh River	Destruction Island
Queets	Split/Willoughby Rocks/Rock 535
Quinault	Cape Elizabeth
Copalis Beach	

Table 60 Location of Marine Mammal Haulout Sites Sort by Region

REGION	SENSITIVE WILDLIFE AREA WITH NESTING SPECIES
Cape Flattery	Mushroom Rock, Tatoosh Island, Fuca Pillar, Portage Head
Shipwreck Pt. to Kydaka Pt.	
Clallam Bay to Pillar Point	Slip Point, Pillar Point
Twin Rivers	West Twin River
Salt Creek	
Port Angeles	
Dungeness Rec. Area	
Sequim Bay	Sequim Bay/Kiapot Spit, Protection Island
Port Townsend	Marrowstone Point, Glen Cove, Kilsut Harbor
Fort Ebey/Smith Island	Long Point
Cape Alava	Point of Arches, Ozette/Bodelteh Islands, Cape Alava
South Lake Ozette	Jagged Island, NW of Cape Johnson Rocks, SW of Cape Johnson Rocks
La Push	James Island Complex, Quillayute Needles, Giants Graveyard, Headland east of Hoh Head
Hoh River	
Queets	Tunnel Island
Quinault	Pratt Cliff, Cape Elizabeth
Copalis Beach	

Table 61 Location of Sensitive Nesting Species Sort by Region

9.3.1.3 Beach Recreation

Oil spills cause adverse impacts on recreation uses of adjacent beaches and coastal areas. Penetration and persistence of oil depend on shoreline properties, such as the shoreline type and degree of exposure to waves and currents. In general, areas of relatively uniform sediment type and grain size allow deeper penetration of oil. Areas that experience strong wave action and tidal current have lower sensitivity than sheltered areas.

The loss in beach recreation values is caused by lost visitation due to official closures and loss of beach related activities such as swimming, sunbathing, and beach walks. The Washington coastline, consisting of the 109,435-meter-long Olympic National Park beach, is considered a national treasure.

9.3.2 Impact Assessment

9.3.2.1 Large Spill, East Boundary

Major spills, particularly those that occur close to shore, may have severe impacts on fish, birds, and aquatic mammals. The worst-case scenario near the eastern boundary of the study area simulates an oil spill resulting from the grounding of a crude oil tanker. In this study, the simulated spill of 3.8 million gallons of crude oil impacted an area of about 18,640 km^2 (7,197 sq. mile), including beaches and shorelines along the Strait of Juan de Fuca, as well as a portion of shorelines in Canada. Prudhoe crude oil tends to emulsify quickly and form stable emulsion. After about five days, about one-fifth of the oil evaporated and another one-tenth decayed. Very little oil dispersed into the water column. An oil-water emulsion formed, the emulsion can be very sticky and difficult to clean up. As oil spread out over the sea surface, cleanup and recovery operations impaired waterway movement and led to closure of the waterway to vessel traffic. The oil plume spread from the spill location near Port Angeles to the mouth of the Strait. Two to three weeks after the spill, the majority of the remaining oil had washed ashore. Oil extended along approximately 217 kilometers (135 miles) of sandy beach and 6 kilometers (3.7 miles) of intertidal wetlands. Due to the extensive shoreline contamination, average beach closures of up to 45 days were expected.

This simulated discharge indicated impacts to a wide range of species including fish, waterfowl, seabirds, cetaceans, and other wildlife that thrive in the marine habitat. Adult fish living in nearshore waters and juveniles in shallow water nursery grounds were at high risk to exposure from dispersed or dissolved oil. Birds that congregate in large numbers on the sea or shoreline to breed and feed were also found at risk from oil exposure. Significant environmental and biological injuries were seen in the area between Neah Bay and Port Angeles. Significant losses of waterfowl on the order of 80-82,000 fatalities and losses of seabirds on the order of 30-32,000 were seen. A small number of shorebirds and seals were also impacted. Among fishery resources, mollusk experienced the most significant injuries with losses of approaching half a million kilograms of adults, accounting for over 90 percent of the total fishery losses. In addition to the direct ecological damages, additional losses were felt in reduction of fishing catches, as well as beach damage and other non-consumptive[4] damages.

9.3.2.2 Medium Spill, East Boundary

The risk of oil exposure for marine life is closely related to the degree of contact with a contaminated sea surface. The simulated medium spill in the east location produced a smaller area of oil contamination and less severe natural resource damage. The bunker oil spill of 0.25 million-gallon impacted an area of approximately 2,009 km^2 (776 sq. miles) and contaminated 110 kilometers (68 miles) of sandy beaches of the Strait, resulting in average beach closures of about one week.

Bunker No. 6 oil is a heavy and viscous oil that is unlikely to mix into the water column. Since it was persistent, the spilled oil spread and was carried a long distance by winds and currents. The oil plume spread throughout the Strait from Dungeness National Wildlife Refuge west to Neah Bay. During the first three days of the spill, the spreading oil plume and recovery operations forced restrictions on normal waterway movement. After three days, 10 percent of the spill volume evaporated and the majority of the remaining oil washed ashore. Since the oil was highly viscous, the effectiveness of a dispersant was reduced. Stranded oil remained on the surface, resulting in coating of wildlife and smothering of intertidal organisms.

The amount of natural resources impacted is proportionate to the amount and types of marine life present in the area. This simulated spill resulted in great losses to waterfowl, seabirds, and mollusks in the Puget Sound and Strait biological province. Waterfowl fatalities on the order of 20-30,000 birds occurred, accounting for approximately 75 percent of the non-fishery wildlife loss. Seabird fatalities accounted for approximately 25 percent or the remaining non-fishery losses. A limited number of seal were also impacted. Among fishery resources, shellfish suffered great losses that would lead to a decline in populations. Mollusks, specifically Geoduck clams, were severely affected and accounted for over 90 percent of the total fishery losses. Diving ducks received the most severe injury among the waterfowl category.

[4] Non-consumptive losses include fishing and wildlife viewing, open water recreation and wetlands recreation.

9.3.2.3 Small Spill, East Boundary

The extent of oil contamination for the small simulated spill was naturally less than for the medium and large spills. An 81,300-gallon spill near the coast of Port Angeles spread over an area of 509 km^2 (197 sq. miles). As the oil slick moved west, over 90 kilometers of sandy beach were oiled. After four days, about 85 to 90 percent of the oil washed ashore. Ten percent of the bunker fuel evaporated after 5 days. Beach closures of about three days were experienced during the cleanup phase of the spill recovery process.

Marine mammals, birds that feed by diving or that form flocks on the sea, as well as marine life on shorelines were vulnerable to adverse effects from this oil spill. Most environmental and biological injuries occurred in the Strait biological province, with total wildlife losses on the order of 30-35,000 fatalities. Waterfowl losses accounted for approximately seventy-five of the projected non-fishery impact and seabirds for the remaining 25 percent. No significant impacts on fishery resources were felt as the dissolved oil concentration in the water and sediment remained below the toxic threshold.

9.3.2.4 Large Spill, West Boundary

A spill in the open ocean may have less environmental effects as the oil naturally dissipates and disperses. However, when a spill washes ashore, environmental impacts can be significant. The spill modeled in the west boundary represented a major collision in open ocean near the “J” buoy. This simulated spill of 3.8 million-gallons of Prudhoe crude oiled an estimated surface area of 10,766 km^2 (4,157 sq. miles). Due to the prevailing wind and currents in the area, the oil slick spread south along Washington outer coast. Ship traffic diverted around the slick. A week after the spill, the majority of the plume came ashore. About half of the original spill volume lay upon the beach surface or mixed into the sediment. The remaining oil had evaporated or decayed. The oil slick impacted approximately 127 kilometers (79 miles) of beaches, resulting in beach closures averaging up to approximately a month and a half.

The area most impacted was from Cape Flattery to Grays Harbor in the Washington outer coast and segments of the western Canadian coastline. The spill affected a number of wildlife species, among those, waterfowl, seabirds, and shorebirds receive the most injuries. Direct mortality rates for waterfowl and seabirds were lower than for the large spill in the eastern boundary. Loss for waterfowl and seabirds approached 3-4,000 individuals for both categories. A higher impact occurred among shorebirds, wading birds, raptors, and seals. Among fishery resources, semi-demeral groundfish, cephalopods (squid) and other benthic invert received the most severe injuries. More than half of the mortality was from the semi-demersal groundfish category, approximately 4-4,500 kilograms of adults. In addition to the impact felt among adult fishes, over 40,000 young crustaceans were affected. The spill had significant economic impact on recreation areas, harbors, and fishing grounds during closures.

9.3.2.5 Medium Spill, West Boundary

The spill trajectory for the medium size spill contaminated an area of 2,762 km^2 (1,066 sq. miles) along the Washington State outer coast biological province. A simulated bunker oil spill near the “J” buoy resulted in spreading of an oil plume down the outer coast of Washington, disrupting fishing and vessel movement in the plume area. After about a week, over 80 percent of the oil plume washed ashore, contaminating approximately 73 kilometers (45 miles) of sandy beach.

This spill caused injury to many difference species of marine life. Some species experienced only a low level of impact, e.g., cetaceans and raptors, whereas others, e.g., waterfowl and waterbirds, suffered a high level of injuries. Losses of waterfowl and seabirds were on the order of 3-4,000 individuals. Shorebirds that feed in intertidal habitats, where oil stranded, were also at risk of oil contamination. However, mortality rates for shorebirds were considerably less because they rarely enter the water. The impact of the oil spill on fishery resources was minimal as oil contamination in the water column remained below the toxic threshold level. However, sublethal effects such as injuries that affect the health and physical condition of organisms (including eggs and larvae) occurred.

9.3.2.6 Small Spill, West Boundary

A simulated bunker oil spill of 81,300 gallons produced an oil slick that covered an area of 1,630 km^2 (629 sq. miles) including 37 kilometers (23 miles) of sandy beach. Beaches and fishery grounds were closed following the spill for three days.

Seabirds and marine mammals, which are especially vulnerable to floating oil, suffered damage. Between 5,000 to 6,000 of waterfowl and seabirds were injured or killed. Fishery impacts were minimal because the oil concentration remained below the lethal threshold. Areas designated by the State or federal governments as wilderness areas, such as the OCMS and Olympic National Park, also suffered impacts, because the public's perception of them as pristine was damaged by the spill.

9.3.3 Discussion

9.3.3.1 Discussion of Model Results

The use of several oil spill models offsets the weaknesses and assumptions associated with each model if used alone. NRDAM/CME is a sophisticated dynamic model for oil spill fate and compensation analysis valid throughout the entire United States. While the NRDAM/CME has a broad coverage, OSCS provides a more geographically specific database for natural resources in Washington State. ADIOS provides a validation of oil fate analysis.

The Washington State Department of Ecology conducted the OSCS analysis using information from the NRDAM/CME. Information including trajectory maps and the extent of surface and coastal oiling from the NRDAM simulation were provided to the Washington State DOE to complete the analysis. Since the trajectory results from the NRDAM/CME provided poor resolution for shoreline impact projections, the breakdown of the habitat regions was estimated. However, the poor map resolution had minimum effects on the results because the assessment was conducted on the most sensitive subregion that was clearly identified. For all scenarios, the impact covered the entire most sensitive subregion. For all of the spill scenarios, the habitat vulnerability scores were very similar, and the habitat types impacted were dominated by open water habitats. Endangered or threatened species of the region such as the bald eagle, stellar sea lion, Elwha Summer steelhead, and Ozette sockeye were considered.

Although the actual values of the damage from the OSCS and the NRDAM/CME are sometimes orders of magnitude apart, they provide comparable environmental damage ratings. The results from OSCS tend toward high value because this model always considers the worst damage conditions. The OSCS also does not take into account the fates (evaporation, decay, emulsification, etc.) of the spilled oil. In a major spill situation, a complete natural resource damage assessment would be required since the model's dollar value outputs are not completely representative of the impact (the non-monetary aspects) of damage done to the environment.

9.3.3.2 Comparison of Scenarios and Historical Spills

The reliability of modeling environmental impact hinges on the quality and suitability of available data. This study also reviewed various historic oil spills that are most representative in size, location, and condition to the model spills. Because damage assessments are unique for each spill due to different response actions and spill conditions, costs for historical spills should not be compared to model spills. However, actual spill incidents provide a range and magnitude of possible environmental damages. The following spill incidents are used to verify model results, as well as to provide an understanding of the impacts of oil spill pollution in the region.

1. Arco Anchorage

On December 21, 1985, the tank vessel ARCO Anchorage ran aground in Port Angeles Harbor spilling 239,000 gallons of Alaska North Slope Crude Oil. The oil was carried west almost to Neah Bay and east to Dungeness Spit. Impacts within Port Angeles included shoreline oiling of approximately 7,000 feet (1.33 miles) of beach along Ediz Hook. To the east of Port Angeles at Dungeness Spit, about 15 miles of shorelines were lightly impacted with oil. To the west of Port Angeles, shorelines at Crescent Bay, Little Agate Bay, Freshwater Bay, and Pillar Point were also lightly contaminated. No impacts were observed in Canada from this incident.

The Arco Anchorage incident is similar to the medium spill scenario in the east location. The impacted areas obtained from spill trajectory analysis covers an area from Dungeness to Neah Bay, which corresponds closely to the actual spill incident.

2. Tenyo Maru

On July 22, 1991, the fish processor vessel Tenyo Maru and the China freighter Tuo Hai collided in the Pacific Ocean, approximately 20 miles west of Cape Flattery, Washington, and 20 miles south of Vancouver Island, Canada. The accident caused a spill of 100,000 gallons involving intermediate fuel oil, diesel fuel, and fish oil. Beaches were fouled with oil from Vancouver Island, British Columbia to northern Oregon. The oil slick had spread over a large area, impacts were scattered along the entire Washington State shoreline and the northern beaches of Oregon with the heaviest contamination along the Makah Indian Reservation and the Olympic National Park shoreline. According the consent decree, natural resource damages associated with the spill account for $5.2 million including costs to restore, rehabilitate, replace or acquire natural resources.

The trajectory results from the medium and small spill scenarios in the west are comparable to the Tenyo Maru incident. For the scenarios, oil slicks were found along the Washington outer coast from Cape Flattery to the Columbia River.

3. Nestucca

On December 23, 1988, the tug Ocean Service collided with its tow, the barge Nestucca, releasing 231,000 gallons of Bunker C oil into the ocean. The collision occurred approximately 3 kilometers off the Washington coast, near Grays Harbor. The oil impacted several coastal beaches in the area of Ocean Shores, and spread to the north contaminating the northern part of Washington coastline. Approximately 110 miles of Washington Coastline were oiled. Oil came ashore in Canada on Vancouver Island from near Victoria in the southeast to Cape Scott in the north. The Canadian Coast Guard estimated that a total of 95 miles of shorelines were oiled, with 1.5 miles heavily oiled. The response costs and compensation damages accounted for approximately $10.5 million, in which approximately half for response costs and half for compensation.

The Nestucca incident corresponds to the medium spill scenario. The extent of shoreline contamination obtained from the spill trajectory agree with the actual spill incident, where over 100 miles of shorelines were contaminated.

9.4 Economic Assessment

This qualitative economic assessment provides information about the socio-economic impacts of oil spills on the communities of Washington State, including trade, tourism, and recreation. This section provides a brief description of the conditions and potential oil spill impacts of these economic resources.

Washington State boasts 76 public ports and is a major center for international commerce and continental trans-shipment. Oil spills jeopardize marine safety and disrupt the shipping network in Washington. The availability of waterborne transportation in the Puget Sound region is crucial for many different industries that rely on water transportation. The marine ports at Seattle and Tacoma provide ship to land transportation connection for over 2 million container units each year. Summing the results from three of the largest ports, Bellingham, Seattle, and Tacoma, port activities support over 45,600 jobs. Many industries such as the manufacturing, transportation, and trade industries, will suffer great economic losses if vessel access to the Sound is denied due to a spill.

Fish and aquaculture brings approximately $81.5 million to Washington’s economy, while the total value of goods and services produced in Puget Sound economy is roughly 1000 times larger. Although fishing and aquaculture are not large industries in the Puget Sound region, they are the mainstays of several small coastal communities. They are considered key industries because they have significant local economic impacts. Willapa Bay, Grays Harbor, and Puget Sound are the major regions for oyster aquaculture. Fishing fleets are based in all major towns around Puget Sound, including Anacortes, Bellingham, Tacoma, and Port Townsend. Fishing is a critical component of the way of living for Indian tribes; for centuries, Native Americans have engaged in fishing activities, which have become inseparable from their culture. Clean water is an essential element for fishing industries as edible oysters can only be grown in pristine waters, and wild salmon can only regenerate in high-quality streams. Pollution associated with oil spills presents a significant threat to water quality and fisheries resources. Contamination of fishing ground can severely impact the fishing industries.

Many recreational activities in the Sound are water dependent. These sectors include sport fishing, sail, power boating, and use of waterfront parks. Access to shoreline locations and water is essential for these industries, and water quality is essential for recreation fishing, boating, and swimming. Tourism is an important part of the economy of Washington State, and it provides over $921 million in income and employment for over 17,500 persons[5]. Based on 1987 estimates, residents and visitors make an estimated 4.5 million annual trips to engage in water related activities in western Washington[6]. A large oil spill can cause severe pollution to beaches, waters and wildlife in the Sound. Such an environmental disaster can cause shut down of marine related recreation industries, and damage the recreational amenity value of Puget Sound which can result in long term economic impacts.

A number of other industries also take advantage of the amenity value of waterfront. Many service establishments are found in waterfront locations because the view and access to beaches attract customers. A few of the water related industries include restaurants, retail shops, and museums. Although these industries are not water dependent, the access and quality of water have serious impacts to their revenues.

In summary, Table 62 describes the nature of water dependence for various industries in the Puget Sound region. The entities described are industries that can be affected by oil spills.

[5] Based on 1992 Northwest Marine Trade Association estimates reported in the Washington CEO.

[6] Interagency Committee for Outdoor Recreation, Washington Outdoors: Assessment and Policy Plan 1990-1995, 1990.

	TYPE OF DEPENDENCE			
INDUSTRY	**DIRECT USE OF WATER**	**TRANSPOR-TATION**	**SHORELINE AMBIANCE**	**QULITY OF LIFE AS WORKFORCE ATTRACTOR**
Fishing	*	*		
Forestry		*		
Heavy Construction	*	*		
Manufacturing:	--	--	--	--
Wood Products	*	*		
Food Processing		*		
Ship/Boat Building & Repair		*		
Aircraft		*		
Other		*		
Advanced Technology:	--	--	--	--
Software		*		*
Biotechnology				*
Electronics				*
Environmental Technology	*			*
Wholesale Trade		*		
Retail Trade			*	
Services	--	--	--	--
Marine Related		*	*	
Other			*	*

Table 62 Nature of Water Dependence by Industry

Source: The Sound Economy: Puget Sound Region's Industries and their Relationship to the Sound by People for Puget Sound.

9.5 Tugs as Spill Response Assets

The employment of tugs lowers the risk of environmental contamination and the probability of pollution occurring as a result of marine accident. The cost-benefit of preventing an oil spill casualty for the various measures under consideration has been outlined in section 8 of this report. Tugs and Oil Spill Response Vessels (OSRVs) can also be utilized after an incident has occurred in reducing the amount of oil that flows out of a damaged vessel and aid in containing or removing oil from the environment.

Tugs currently operating in Puget Sound and Strait of Juan de Fuca have limited oil spill response equipment onboard. Generally tugs only carry enough equipment to be able to respond to a self-caused spill. The tugs can be called upon to assist in the deployment of booms, skimmers, and towing of oil recovery barges. Tugs can also serve in the role of fire fighting. Current capabilities range from smaller boats carrying simple fire hoses to larger tugs with the ability to deploy 6,000 gallons of foam and deliver 6,600 gpm of fire fighting water.

Oil response vessels in Puget Sound area are equipped with booms and skimmers and have temporary oil storage capabilities. OSRVs are designed and built specifically to recover spilled oil. Some OSRVs have temporary storage for 4,000 barrels of recovered oil, and the ability to separate oil and water aboard ship. To enable the OSRV to sustain cleanup operations, recovered oil can be transferred into other vessels or barges. Organizations such as the Marine Spill Response Corporation (MSRC) and Clean Sound Cooperative maintain specialized response vessels and support equipment. MSRC, for example, maintains oil spill barges with storage capabilities of 38,000 barrels, approximately 20,000 feet of oil containment booms and oil skimmers with a combined effective capacity of about 23,000 barrels per day. Other oil spill recovery vessels such as JBF response vessels are capable of recovering up to 5,000 barrels per hour.

In addition to their primary role of towing and providing maneuver assistance, tugs offer other prevention services as outlined above. The sooner the response vessels arrive on site of the incident the greater the amount of oil that can be recovered and therefore the less the impact on the natural resources. In the event of an oil spill or other non-towing casualty, tugs are important assets in recovery activities.

9.6 General Protection/Oil Spill Response Capability

The regional oil spill response capability is identified by the USCG OSRO classification system. Since the OSRO classification system is a voluntary process, the information may not represent the actual spill response capability in the region. Nonetheless, it serves as a general reference for spill countermeasure preparedness and capability for the region.

The OSRO classification is based on the OSRO's operational capability in containment, recovery, and storage devices. The minimum equipment standards and the maximum response times for different classification levels are described. Table 63 lists the operational requirements for the river and canal environment, Table 64 is for the inland environment, and Table 65 is for the ocean environment.

OPERATION REQUIREMENTS	CLASSIFICATION				
	A	B	C	D	E
Containment/protective boom	2,000 ft total	4,000 ft containment boom; 4,000 ft protective boom	4,000 ft containment boom; 10,000 ft protective boom	4,000 ft containment boom; 16,000 ft protective boom	4,000 ft containment boom; 22,000 ft protective boom
Oil recovery equipment (skimmers, vacuums, etc.)	50 Bbl/day of EDRC	1,250 Bbl/day of EDRC	1,500 Bbl/day of EDRC	3,000 Bbl/day of EDRC	6,000 Bbl/day of EDRC
Recovered oil storage	100 Bbl of TSC	2,500 Bbl of TSC	3,000 Bbl of TSC	6,000 Bbl of TSC	12,000 Bbl of TSC
Boom deployment response time	1 hr	--	--	--	--
Oil equipment and temporary storage response time	2 hrs	--	--	--	--
Facility response time	--	6 hrs for high volume ports; All other locations 12 hrs.	6 hrs for high volume ports; All other locations 12 hrs.	30 hrs for high volume ports; All other locations 36 hrs.	54 hrs for high volume ports; All other locations 60 hrs.
Vessel response time	--	12 hrs for high volume ports; All other locations 24 hrs.	12 hrs for high volume ports; All other locations 24 hrs.	36 hrs for high volume ports; All other locations 48 hrs.	60 hrs for high volume ports; All other locations 72 hrs.

Table 63 Summary of Operational Requirements for River and Canal Environment

All equipment to be used in the river and canal environment must be capable of operating in 1-foot wave heights. Additional boom requirements are:

- Boom height (inches, draft plus freeboard): 6-18
- Reserve buoyancy to weight ratio: 2:1
- Total tensile strength (lbs): 4,500
- Skirt fabric tensile strength (lbs): 200
- Skirt fabric tear strength (lbs): 100

OPERATION REQUIREMENTS	CLASSIFICATION				
	A	B	C	D	E
Containment/protective boom	2,000 ft total	6,000 ft containment boom; 6,000 ft protective boom	12,000 ft containment boom; 12,000 ft protective boom	18,000 ft containment boom; 18,000 ft protective boom	24,000 ft containment boom; 24,000 ft protective boom
Oil recovery equipment (skimmers, vacuums, etc.)	50 Bbl/day of EDRC	1,250 Bbl/day of EDRC	10,000 Bbl/day of EDRC	20,000 Bbl/day of EDRC	40,000 Bbl/day of EDRC
Recovered oil storage	100 Bbl of TSC	2,500 Bbl of TSC	20,000 Bbl of TSC	40,000 Bbl of TSC	80,000 Bbl of TSC
Boom deployment response time	1 hr	--	--	--	--
Oil equipment and temporary storage response time	2 hrs	--	--	--	--
Facility response time	--	6 hrs for high volume ports; All other locations 12 hrs.	6 hrs for high volume ports; All other locations 12 hrs.	30 hrs for high volume ports; All other locations 36 hrs.	54 hrs for high volume ports; All other locations 60 hrs.
Vessel response time	--	12 hrs for high volume ports; All other locations 24 hrs.	12 hrs for high volume ports; All other locations 24 hrs.	36 hrs for high volume ports; All other locations 48 hrs.	60 hrs for high volume ports; All other locations 72 hrs.

Table 64 Summary of Operational Requirements for Inland Environment

All equipment to be used in inland environment must be capable of operating in 3-foot wave heights. Additional boom requirements are:

- Boom height (inches, draft plus freeboard): 18-42
- Reserve buoyancy to weight ratio: 2:1
- Total tensile strength (lbs): 15-20,000
- Skirt fabric tensile strength (lbs): 300
- Skirt fabric tear strength (lbs): 100

OPERATION REQUIREMENTS	CLASSIFICATION				
	A	B	C	D	E
Containment/protective boom	2,000 ft total	8,000 ft containment boom; 8,000 ft protective boom	12,000 ft containment boom; 12,000 ft protective boom	18,000 ft containment boom; 18,000 ft protective boom	24,000 ft containment boom; 24,000 ft protective boom
Oil recovery equipment (skimmers, vacuums, etc.)	50 Bbl/day of EDRC	1,250 Bbl/day of EDRC	10,000 Bbl/day of EDRC	20,000 Bbl/day of EDRC	40,000 Bbl/day of EDRC
Recovered oil storage	100 Bbl of TSC	2,500 Bbl of TSC	20,000 Bbl of TSC	40,000 Bbl of TSC	80,000 Bbl of TSC
Boom deployment response time	1 hr	--	--	--	--
Oil equipment and temporary storage response time	2 hrs	--	--	--	--
Facility response time	--	6 hrs for high volume ports; All other locations 12 hrs.	6 hrs for high volume ports; All other locations 12 hrs.	30 hrs for high volume ports; All other locations 36 hrs.	54 hrs for high volume ports; All other locations 60 hrs.
Vessel response time	--	12 hrs for high volume ports; All other locations 24 hrs.	12 hrs for high volume ports; All other locations 24 hrs.	36 hrs for high volume ports; All other locations 48 hrs.	60 hrs for high volume ports; All other locations 72 hrs.

Table 65 Summary of Operational Requirements for Ocean Environment

All equipment to be used in ocean environment except shoreline protection boom must be capable of operating in 6-foot wave heights. Additional containment boom requirements are:

- Boom height (inches, draft plus freeboard): > 42
- Reserve buoyancy to weight ratio: 3:1 to 4:1
- Total tensile strength (lbs): > 20,000
- Skirt fabric tensile strength (lbs): 500
- Skirt fabric tear strength (lbs): 125

Shoreline protection boom requirements are:

- Boom height (inches, draft plus freeboard): > 18
- Reserve buoyancy to weight ratio: > 2:1
- Total tensile strength (lbs): > 15,000
- Skirt fabric tensile strength (lbs): >300
- Skirt fabric tear strength (lbs): >100

For the Puget Sound Captain-of- the-Port (COTP) zone, the following OSROs are identified to provide spill response equipment and service in region.

Company: CLEAN SOUND					**Shoreline Cleanup: No**					
Operating Environment	**Facilities**					**Vessels**				
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
Rivers/Canals										
Inland		*	*	*	*		*	*	*	*
Oceans										
Company: FOSS ENVIRONMENTAL					**Shoreline Cleanup: Yes**					
Operating Environment	**Facilities**					**Vessels**				
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
Rivers/Canals	*	*	*	*	*	*	*	*	*	*
Inland	*	*	*	*	*	*	*	*	*	*
Oceans										
Company: MSRC					**Shoreline Cleanup: Yes**					
Operating Environment	**Facilities**					**Vessels**				
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
Rivers/Canals	*	*	*	*	*	*	*	*	*	*
Inland	*	*	*	*	*	*	*	*	*	*
Oceans				*	*		*	*	*	*
Company: CLEAN PACIFIC					**Shoreline Cleanup: Yes**					
Operating Environment	**Facilities**					**Vessels**				
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
Rivers/Canals	*	*	*	*	*	*	*	*	*	*
Inland	*	*	*	*	*	*	*	*	*	*
Oceans				*	*		*	*	*	*
Company: GLOBAL DIVING & SALVAGE					**Shoreline Cleanup: Yes**					
Operating Environment	**Facilities**					**Vessels**				
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
Rivers/Canals										
Inland	*					*				
Oceans										

Table 66 Summary of Puget Sound Oil Spill Response Capability

Source: USCG Guidelines for Classifying Oil Spill Removal Organizations.

10 SMALL BUSINESS ASSESSMENT

The Regulatory Flexibility Act (5 U.S.C. 601 *et seq*.) requires the U.S. Coast Guard (USCG) to consider whether any potential rulemaking will have a significant economic impact on a substantial number of small entities. The Act recognizes three categories of small entities and defines them as:

1. Small business - any business which is independently owned and operated and not dominant in its field as defined by the Small Business Administration (SBA) regulations under Section 3 of the Small Business Act.

2. Small organization - any non-for-profit enterprise that is independently owned and not dominant in its field.

3. Small government jurisdiction - any cities, towns, townships, villages, school districts, or special district governments with a population of less than 50,000.

This section is included to meet the Regulatory Flexibility Act requirement.

10.1 Purpose

A Presidential determination on April 28, 1996 expanded upon the requirement of P.L. 104-58 requiring the Secretary of Transportation to determine the adequacy of all vessel safety and environmental protection measures in effect in Puget Sound area waters. The USCG is partnering with the Washington State Department of Ecology (DOE) to develop a long-term management plan. The objective of the plan is to reduce the risk of oil spills by enhancing marine safety and environmental protection efforts in the region. One aspect of the plan is to consider the cost-benefits of either employ escort tugs for vessels or impose escort tug requirements on vessels transiting the Strait of Juan de Fuca.

10.2 Methodology

10.2.1 Small Businesses

To determine the qualification of an entity as a small business, the SBA's definitions of 13 CFR 121 were used. 13 CFR 121 defines small businesses by the number of employees or revenue in dollars. Table 67 lists the 13 CFR 121 Standard Industrial Classification (SIC) definitions for the applicable Water Transportation industry in the Straits.

This study investigated small businesses that own and operate vessels and are subject to the proposed alternative regulations. The alternatives included: two tug escort for laden single hull tankers, single tug escort for laden single hull tankers, single tug escort for Priority one vessels, dedicated single tug escort for all vessels greater than 300 GT, dedicated single tug escort for all vessels greater than 3000 GT, a dedicated rescue tug for all vessel greater than 300 GT, or a dedicated rescue tug for all laden tank vessels.

SIC Code	Description	Standard
4412	Deep Sea Foreign Transportation of Freight	500 Employees
4424	Deep Sea Domestic Transportation of Freight	500 Employees
4449	Water Transportation of Freight, Not Elsewhere Classified (N.E.C.)	500 Employees
4481	Deep Sea Transportation of Passengers, Except by Ferries	500 Employees
4482	Ferries	500 Employees
4489	Water Transportation of Passengers, N.E.C.	500 Employees
4499	Water Transportation Services, N.E.C.	$3.5M Revenue

Table 67 Small Business Administration Applicable Standard Industrial Classifications

Various methods were used to identify specific businesses that meet these criteria. The Small Business Administration web site and the *Dun & Bradstreet Regional Business Directory* were searched to identify specific small businesses in Washington State within the above SIC Codes. In addition, a copy of *The Marine Directory: Greater Puget Sound and Washington Coast* was obtained from the Marine Exchange of Puget Sound in Seattle, Washington. This directory lists maritime industry companies and organizations and the maritime services provided in the Greater Puget Sound Area and on the Washington Coast. The applicable water transportation industry companies identified were researched via the Internet or contacted by telephone to obtain specific information to identify them as small businesses that would be directly affected by any new tug requirements in the Straits.

10.2.2 Compliance Cost

The first task was to determine the cost of compliance (if any) of new tug requirements in the Straits by estimating the extra acquisition, crew, supplies, stores, provisions, fuel oil, lube oil, insurance, and M&R costs. Section 7 (COST) and Appendix 5 provides a detailed breakdown of these costs. The ITOS, escort and rescue tug (ALT.1 through ALT.8) costs and shipping delay costs (ALT.5 and ALT.6) for each transit were obtained by dividing the total cost by the number of estimated transits for each alternative. The final total costs for the various alternatives are summarized in Table 68. ALT.1, ITOS, is based on an arrival fee and ALT.2 through ALT.8 are based on a per transit cost. Due to regulations phasing out the use of single hull tankers, ALT.2 and ALT.3 will only apply through 2014.

Since laden single hull tankers and Priority 1 vessels normally transit the Straits at 14 kts, ALT.2 through ALT.4 assume a tug capable of 14.5 kts is used. A 10,000 HP rescue tug is used to meet the requirements for ALT.7 and ALT.8 to ensure the tug is capable to meet the needs of all types of vessels.

ALT.	Description	Tug Cost (per Transit)
1	ITOS for all vessels > 300 GT	$20 (per arrival)
2	2 Tug Escort for laden single hull tankers	$25,450
3	1 Tug Escort for laden single hull tankers	$12,725
4	1 Tug Escort for Priority 1 vessels	$12,725
5	1 Tug Escort for all vessels >300 GT	$12,877 (14.5 Kts) $19,818 (16 Kts)
6	1 Tug Escort for all vessels >3000 GT	$10,710 (14.5 Kts) $19,895 (16 Kts)
7	Rescue Tug for all vessels >300 GT	$520
8	Rescue Tug for all laden tank vessels	$10,280

Table 68 Tug Costs

Some vessels normally transit the Straits at speeds greater than 16 kts. If an escort tug is required for any of these vessels, additional costs will be incurred due to the delayed destination arrivals. These costs are not paid to a tug service but are extra costs in crew, supplies, stores, provisions, fuel oil, lube oil, insurance, and M&R costs due to the longer transit time. Table 69 shows the additional costs for these vessels assuming a tug capable of 16 kts is used.

ALT.	Container Ships <2,000 TEU	Container Ships 2,000-4,000 TEU	Container Ships >4,000 TEU	Vehicle Carriers	Passenger (Cruise) Carriers
5	$2,596	$3,617	$5,642	$1,910	$1,476
6	$2,596	$3,617	$5,642	$1,910	$1,476

Table 69 Additional Shipping Delay Costs per Transit for Vessels with Normal Transit Speeds > 16 kts

10.3 Findings

A search of the Small Business Administration web site revealed only six small businesses which have applicable SIC Codes. After contacting these businesses, it was revealed that they do not have any vessels over 300 gross tons. Therefore, they would not be obligated to meet any new tug requirements in the Straits, and would have no additional costs in any of the alternatives.

A search of the *Dun & Bradstreet Regional Business Directory* web site revealed 22 potential small businesses. Upon further research via web sites or telephone, these companies were determined to be either a large business due to number of employees, revenue, and/or owned by another company or did not have vessels greater than 300 GT.

The *Marine Directory: Greater Puget Sound and Washington Coast* provided by the Marine Exchange of Puget Sound listed 47 potential small businesses. After further research via web sites and/or telephone, these companies were found not to have vessels over 300 gross tons and/or were large businesses due to number of employees, revenue, and/or owned by another company.

10.4 Conclusion

Since no small businesses affected by any possible new tug requirements in the Straits were identified, it is determined that none of the alternatives in this study will have a significant direct economic impact on a substantial number of small businesses.

Note: This analysis does not research the possible indirect economic impact on other small businesses related to the maritime industry. Any new requirement for the use of a tug(s) may cause large water transportation companies to use other less expensive and faster waterways, ports, and harbors. Any loss of water transportation business in the Greater Puget Sound Area may have a significant effect on other small businesses and companies that indirectly support the maritime industry.

11 REFERENCES

1 Volpe National Transportation Center, "Scoping Risk Assessment, Protection Against Oil Spill in the Marine Waters of Northwest Washington State", July 1997.

2 Thompson, Richard, "Oceanography of the British Columbia Coast".

3 Department of Commerce, NOAA, "United States Coast Pilot, Pacific Coast: California, Oregon, Washington, and Hawaii," Volume 7, 31st Edition, 1997.

4 Lewis, E.V., Editor, "Principles of Naval Architecture", Society of Naval Architects and Marine Engineers, 1988.

5 Statistics Canada, "Shipping in Canada, 1997", 1997.

6 Lloyd's Register, "Register of Ships, 1996-97", May 1997.

7 Allan and Dickens, "Oil Spill Prevention in Southwest Canada Waters", prepared for the Canadian Council of Ministers of the Environment, 1995.

8 Murray Fenton & Associates Limited, "Emergency Towing, A Study on Behalf of the Department of Transport", July 1993.

9 Emergency Towing System Task Force for the Washington State Office of Marine Safety, "An Oil Spill Prevention Proposal for A Dedicated Rescue Tug to Protect the Strait of Juan de Fuca and Adjacent Pacific Coast", August 1994.

10 Drewry, "Ship Costs – Issues, Developments and Prospects to 2003", May 1999.

11 Volpe National Transportation Center, "Port Needs Study (Vessel Traffic Services Benefits), Volume I: Study Report", DOT-CG-N-01-91-1.2, August 1991.

12 The Columbus Group and BST Associates, "1999 Marine Cargo Forecast, Technical Report", March 1999.

13 National Research Council, "Double-Hull Tanker Legislation, An Assessment of the Oil Pollution Act of 1990", 1998.

14 Volpe National Transportation Center, "OPA 90 Programatic Regulatory Assessment (PRA) – Part 2, Cost Effectiveness of Selected Regulations", October 1998.

15 IMO, " Interim Guidelines for Approval of Alternative Methods of Design and Construction of Oil Tankers under Regulation 13F(5) of Annex I of MARPOL 73/78," Resolution MEPC.66(37), Adopted September 14, 1995.

16 Rawson, Charles et al, "Assessing the Environmental Performance of Tankers in Accidental Grounding and Collision", SNAME Transactions, 1998.

17 George Washington University, Rensselaer Polytechnic Institute, and Virginia Commonwealth University, "The Washington State Ferries Risk Assessment, Final Report" , July 1, 1999.

18 U.S. Coast Guard, Regulatory Assessment of STCW.

19 Commandant (G-MSE-1), U.S. Coast Guard, "Analysis of the Geographic Coverage Provided by the International Tug of Opportunity System from November 1998 – May 1999", 30 July 1999 (draft).

20 Department of Transportation, U.S. Coast Guard, "Addendum – Report to Congress on International, Private-Sector Tug-of-Opportunity System (ITOS) for the Waters of the Olympic National Marine Sanctuary and the Strait of Juan de Fuca", 1997.

21 Applied Science Associates, Inc. "The CERCLA Type A Natural Resources Damage Assessment Model for Coastal and Marine Environment (NRDAM/CME) Documentation, Volume 1", June 1994.

22 Bennett, J., Logan, R. and Heimowitz, P., State-of-the-Art or Junk Science? The Natural Resource Damage Assessment Models, *1997 International Oil Spill Conference Proceedings,* 1997.

23 Geselbracht, L. and Logan, R., "Washington's Marine Oil Spill Compensation Schedule – Simplified Resource Damage Assessment".

24 Geselbracht, L. and Logan, R., "Development of the Washington State Oil Spill Compensation Schedule", September 1992.

25 Washington Department of Ecology Oil Spill Damages Model, Chapter 173-183 WAC, "Preassessment Screening and Oil Spill Compensation Schedule Regulations".

26 NOAA, "Automated Data Inquiry for Oil Spills (ADIOS) User's Manual", April 1994.

27 Washington Department of Ecology, "Strait of Juan de Fuca, Washington Geographic Response Plan", Publication No. 94-202, 1996.

28 Washington Department of Ecology, "Outer Coast, Washington Geographic Response Plan", Publication No. 95-266, 1996.

29 Washington Department of Ecology, "Grays Harbor, Washington Geographic Response Plan".

30 Washington Department of Ecology, "Millapa Bay, Washington Geographic Response Plan".

31 Northwest Area Committees, "Northwest Area Contingency Plan", 1998.

32 Washington Department of Ecology, "Oil Spills in Washington State: A Historical Analysis", April 1997.

33 Etkin, D., Historical Overview of Oil Spills from All Sources (1960-1998), *1999 International Oil Spill Conference Proceedings*, 1999.

34 Sommers, P. and Canzoneri, D., "The Sound Economy: Puget Sound Region's Industries and Their Relationship to the Sound", Report for People for Puget Sound, August 1996.

35 Strong Trade Growth Predicted through Washington's Ports, *Marine Digest and Transportation News*, May 1999.

36 National Data Buoy Center, Coastal-Marine Automated Network (C-MAN) Historical Data.

37 Island Canoe, Inc., 1998 Current and Tide Tables Columbia River to Desolation Sound, 1997.

38 U.S. Army Corps of Engineers Navigation Data Center, 1996 and 1997 United States Waterway Data.

39 U.S. Army Corps of Engineers, "Waterborne Commerce of the United States, Part 4 Waterways and Harbors Pacific Coast, Alaska and Hawaii", 1997.

40 U.S. Coast Guard, "Evaluation of Oil Tanker Routing".

41 Sawano, N., What Has Been Happening After Oil Spills on Sand Beach, *1999 International Oil Spill Conference Proceedings*, 1999.

42 NOAA, "1967-1991 Summaries of Significant U.S. and International Spills", September 1992.

43 The Tenjo Maru Oil Spill Natural Resource Trustees, "Draft Restoration Plan and Environmental Assessment for the Tenyo Maru Oil Spill", 1999.

44 Marine and Fishing Industry Profile, *Washington CEO*, 1994.

45 U.S. Coast Guard, "Guidelines for Classifying Oil Spill Removal Organizations", April 1997.

46 U.S. Coast Guard, Puget Sound Data Analysis 2-99, Washington Department of Ecology Spill Data from Compendium Report.

47 U.S. Coast Guard, VTS Summary Statistics 1995-1998.