<u>Regulatory Assessment</u>
Use of Tugs to Protect Against Oil Spills in the Puget Sound Area

Technical Appendices

Prepared for:
The United States Coast Guard

Report No. 9522-003
November 15, 1999

Appendices

1 PANEL OF EXPERTS

The scarcity of accident and spill data in the study region necessitated reliance on subjective technical judgements in a number of areas. In addition, the analytic approaches taken in this study required evaluation of several operational aspects of tug operations. 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 experts also provided invaluable insight on the decisions facing a ship's master transiting the Strait of Juan de Fuca.

The workshop was held in Seattle on July 21st and 22nd. The panel consisted of experts in a wide range of marine operations in the study region, and the discussion items similarly ranged widely. Conduct of the workshop initiated with a presentation to the panel members of an overview of the scope of the Regulatory Assessment investigation. Issues related to the scope of the investigations were discussed and the general bounds of the discussion area established. The next phase consisted of a "walk through" of an inbound voyage, presented by a tanker master. The overall decision making process and associated areas of risk were discussed. As the voyage proceeded, interaction with the VTS operators and pilots was described by the appropriate panel members. After completion of the tanker voyage description, a foreign flag bulk carrier master, a containership master, and two tug operators provided additional background on the risks of the waterway and addressed issues specific to their respective trades.

The experts were then asked to evaluate a number of specific issues. For each issue, the facilitators provided background information. Discussion amongst the panel members was followed by formulation of a question or questions to be quantitatively answered. For most of the questions, the experts provided a median assessment and a 90% confidence interval bound. An expert could decline to evaluate any issue on the grounds of lack of expertise in the specific area.

Input from the experts is discussed as applied throughout the report. The general areas addressed by the experts are indicated below:

- The relative likelihood of collisions, powered groundings, and drift groundings in the Puget Sound area (both the whole area, and east of Dungeness only) compared to U.S. waters in general.
- The relative likelihood of collision accidents from overtaking, crossing and head-on encounters. The experts sub-divided the Strait of Juan de Fuca into five segments, and assigned these relative risks to each segment.
- The willingness of an ITOS tug to come to the assistance of a stricken vessel considering tug status (unencumbered, encumbered with non-petroleum tow, or with petroleum tow).
- The time before a tug begins its response to a distressed vessel, considered in terms of time to initiate the call for assistance and time to actually get underway.
- The ability of a stricken vessel to self-repair, after suffering propulsion or steering failure.
- The lowest seastate preventing a connection to a stricken vessel being made. The seastate was expressed in terms of wave height.

- The relative likelihood that a Priority 1 vessels will be involved in collision, powered grounding, and drift grounding accidents as compared to other commercial vessels.
- The effectiveness of one and two escort tug arrangements in reducing the number of collisions, drift groundings, and powered groundings.

Composition of the Panel:

The workshop was facilitated by Herbert Engineering Corp. The composition of the panel was as follows:

Navigation and Operations Expertise

Capt. Jerry Aspland, President of Califonia Mairime Academy

Capt. Rajiv Bandari, Bulk Carrier Master –Borgestad

Capt. Bill Bock, President, Puget Sound Pilots

Capt. B.J. Diggins, Master S.S. Maulani – Matson Navigation

Capt. Bob Wells, Tanker Master (Arco Marine, retired)

Tug Operations and Salvage Expertise

Peter Campbell, FOSS Maritime

Michael Rampolla, Crowley Maritime

David Gray, Naval Architect, Glosten & Assoc.

Other Representatives

Fred Felleman, Ocean Advocates

David Dickens, Naval Architect, D.F. Dickins Associates

Capt. Gary Greene, Commanding Officer, Puget Sound Vessel Traffic Service

Capt. Michael Moore, Commanding Officer, Marine Safety Office Puget Sound

Don Rodden, Regional Supervisor, Environmental Response, Canadian Coast Guard

Facilitators

Keith Michel, Colin Moore, and Nathan Bossett, Herbert Engineering Corp.

James Melendez, Designers & Planners, Inc.

2 STRAIT OF SAN JUAN DE FUCA 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, 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.

2.1 Geographic Description

The region within a 60 nautical mile radius of “J” Buoy, the Strait of Juan de Fuca, and the traffic lanes approaching the Strait from the east were modeled in the numerical simulation. This incorporates the full region assumed within reach of a rescue tug positioned at the western end of the Strait.

With the assistance of the Panel of Experts, the study region was sub-divided into six segments.

1. The Offshore Approaches – This segment consists of the open ocean seaward of the traffic lanes and within a 60 nm radius about “J” Buoy.. Ships are concentrated along a number of dominant shipping lanes, reflecting common routing practices. For example, inbound tankers proceed easterly to avoid proximity to land; and bulk carriers and containerships bound for the Far East take a northwesterly route. At the initiation of the ship lanes, congestion increases and encounters between vessels are more frequent.

2. “J” Buoy Area – This area consists of the transition between the offshore approaches and the Strait proper. Inbound and outbound traffic frequently cross in this region.

3. The Strait of Juan de Fuca – There are two major traffic lanes and a relatively wide separation zone, with one mild course change in each lane. There is deep water to either side of the lanes. The western boundary is 124 deg 40 min west, and the eastern boundary is 123 deg 35 min west.

4. The Rotary – All vessels transiting the Strait pass through this crossing zone. It is bounded on the south and east by the Port Angeles area, to the north by Victoria, and to the west by the Strait proper. VTS serves to mitigate the frequent crossing situations that would otherwise occur. However, collision risk in this area is particularly sensitive to projected increases in traffic levels.

5. Port Angeles – This area serves both as a port call for some traffic and as the Puget Sound pilot station. There are significant grounding and congestion hazards. Vessels bound for U.S. waters will generally stop here to pick up and drop off pilots. The eastern boundary is 123 deg 7 min west.

6. Victoria – Relatively few ships call here, but traffic bound for the northern parts of the sound pass through it. The Canadian pilot station is located immediately to the south of Victoria.

2.2 Traffic Description

VTS Seattle data for a one-year period from July 1999 to June 1999 was analyzed, to determine traffic patterns east of "J" Buoy. Large ship traffic in the interior portion of the study area is concentrated almost exclusively in the designated traffic lanes. The only major deviation from this pattern is the dry cargo barge and empty tank barge traffic, which stays close to shore. This traffic is not considered a significant spill risk because of the lack of outflow potential, and is not a major collision hazard for other vessels because the vessels susceptible to petroleum spillage tend to navigate within the lanes. In the offshore region, there is some coastal traffic that enters the study area but does not transit the Strait.

The traffic was characterized into 17 different ship types. Tofino VTS data provided the type and name of each vessel transiting through the Strait and offshore approaches during 1997. The Register of Ships was cross-referenced to obtain typical speeds and sizes, which are applied in the collision simulation.

	Service Speed (knots)				Vessel Length
Ship Type	Mean	Std. Dev	Minimum	Maximum	(meters)
Crude Oil Carriers	15.0	0.1	14.5	16.5	240
Product Tankers	15.0	0.1	14.5	16.5	175
Tankers Empty	15.0	0.1	14.5	16.5	240
Bulk Liquid Carriers	14.5	0.2	13.0	16.0	175
Bulk Carriers	14.5	0.2	13.0	16.0	200
Fish Factory (300-3000 GT)	14.5	0.2	13.0	16.0	60
Fish Factory (>3000 GT)	14.5	0.2	13.0	16.0	150
Containerships (<4000 TEU)	21.0	0.3	18.0	24.0	200
Containerships (>4000 TEU)	24.5	0.3	22.5	26.5	260
Vehicle Carriers	19.5	0.3	17.5	21.5	175
Passengerships (300<3000 GT)	12.0	N/A	10.0	14.0	60
Passengerships (>3000 GT)	20.5	N/A	19.5	21.5	240
Tank Barge w/ Product	10.0	0.1	9.0	11.0	200
Fishing Vessels	11.0	N/A	10.0	12.0	60
Other Vessels (300-3000 GT)	13.5	N/A	8.5	18.5	60
Other Vessels (>3000 GT)	13.5	N/A	8.5	18.5	140
Government Vessels	20.0	N/A	15.0	25.0	175

Table 1 Nominal Speeds and Ship Lengths by Vessel Type

Speed distributions are taken as truncated normals about the mean, with the exceptions of passenger ships, fishing vessels, and both 'Other' groups, which are assumed to be bounded uniform distributions. A ship will steam at its service speed unless other constraints dictate a speed reduction (presence of escort incapable of that speed, picking up pilot, increased traffic congestion, etc.). For portions of the analysis where escorts are required, most ships are deemed to hire 14.5 knot escorts. Containerships, vehicle carriers, and large passenger ships are assumed to hire escorts capable of 16 knots.

Arrival frequencies were generated for each ship type from the Tofino VTS data. The arrivals were considered on an annual basis, and expected intervals between vessels were calculated from these frequencies. A very satisfactory agreement with the Poisson distribution was observed.

The distribution of likely origination and destination ports was also derived from the Tofino VTS data. For the interior traffic, this routing information was used to distribute vessels amongst the three sets of traffic lanes approaching the rotary. At the 60 nm arc about "J" Buoy denoting the western boundary of the study area, traffic patterns were broken down within 5 degree arcs and a uniform distribution assumed within each arc. It was found unnecessary to obtain separate arcs for each of the 17 ship types, as the observed behavior is adequately characterized by considering 5 vessel groups. These are: tankers, tank barges, bulk carriers, containerships, and other vessels. Vehicle carriers behave similar to containerships.

A sample of the VTS data for the outer waters for a typical month in 1997 is shown in Figure 1. This figure represents Canadian VTS radar data taken at 5 minute intervals.

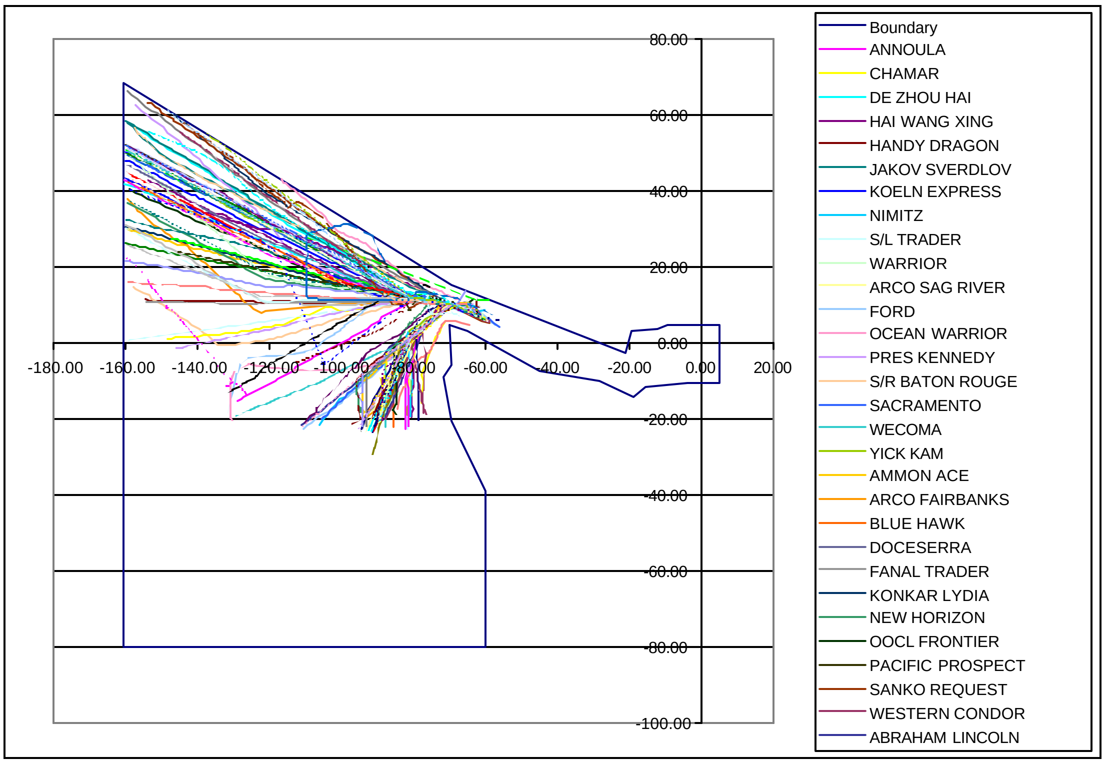


Figure 1 Sample VTS data from one month 1997

Probability density functions characterizing vessel positions within the traffic lanes and their entry and exit points from the study region were derived from the VTS radar data. For example, Figure 2 depicts the distribution of bulk carriers during three winter months as they pass through the 60 nm arc bounding the western end of the analysis region. The assumed 5 degree arc segments are also indicated on the plot. Some paths do not intersect the arc as the vessels exited the Tofino coverage area before radar readings offshore of the arc were recorded. These routes were projected from previous location data. Similarly, functions were developed to characterize the distribution of vessels as they entered the traffic lanes initiated about 8 nm to the west of "J" Buoy.

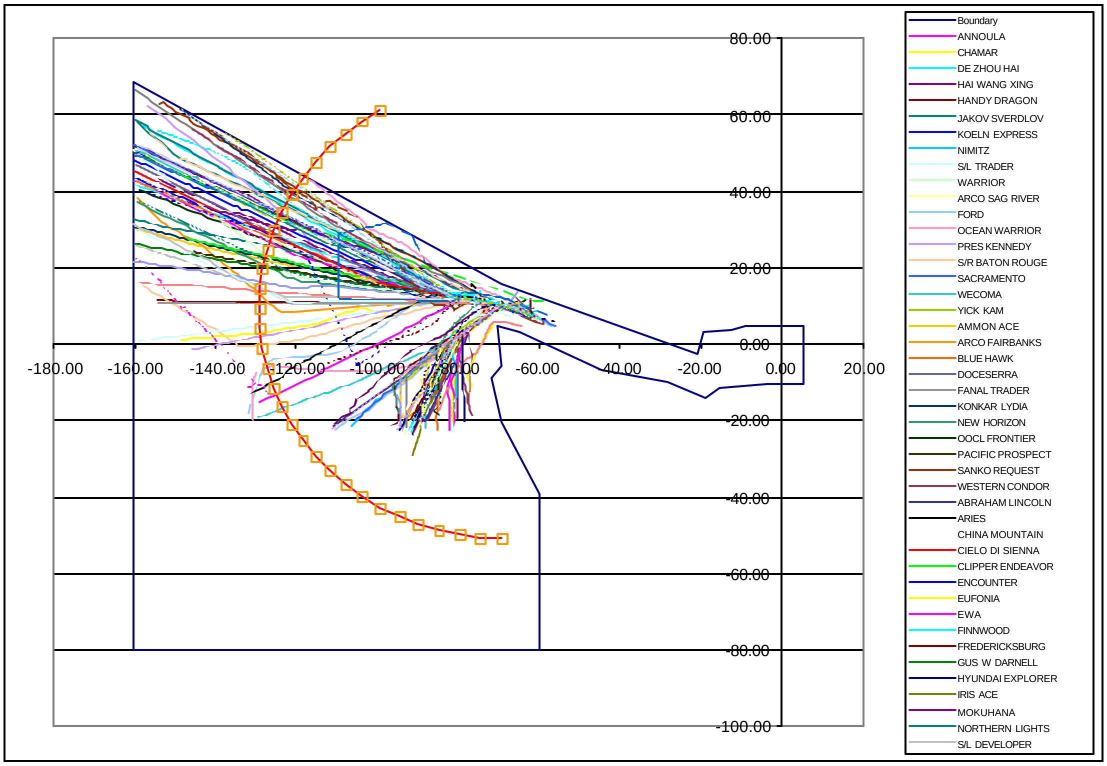


Figure 2 Track Data for bulk carriers intersecting 60 nm arc from J buoy

The data for a period of one year (June 1997 through May 1998) were assembled into joint probability functions for traffic lane entry/exit and external entry/exit through the 60 mile arc. Functions were developed for groups of ships with similar traffic patterns. Sample marginal distributions for these joint probability density functions are shown in Figure 3 and Figure 4 for outbound tankers. In Figure 3 the outbound traffic lanes are segments 4 and 8, and the inbound lanes are 2 and 6. Segments 3, 5 and 7 are the separation zones. The U.S. side bounds segment 1 and the Canadian Vancouver Island side bounds segment 9.

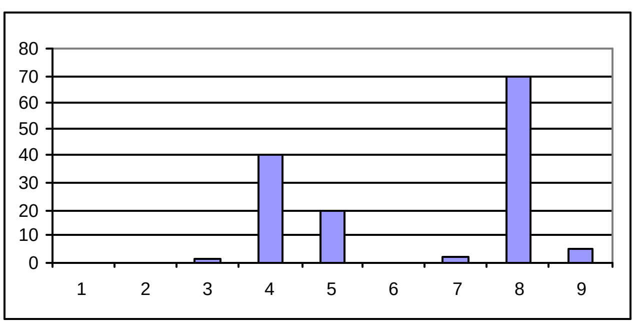


Figure 3 Outbound Tanker Exit Traffic Lane Distribution

In Figure 4 the arc segments are numbered from north to south. See Figure 2 for the arc layout.

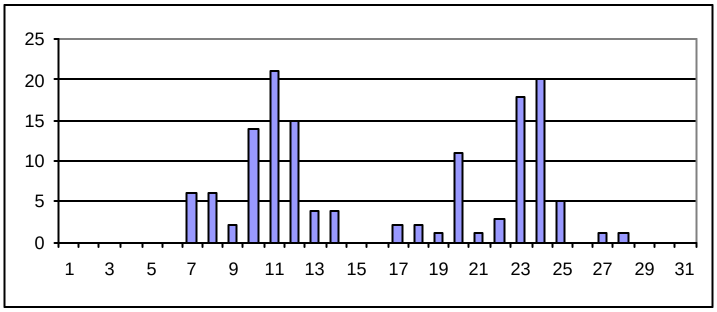


Figure 4 Outbound tanker distribution at 60 nm arc

Similar data obtained from U.S. VTS data such as shown in Figure 5 were used to develop distributions of ships in the Strait east of J buoy.

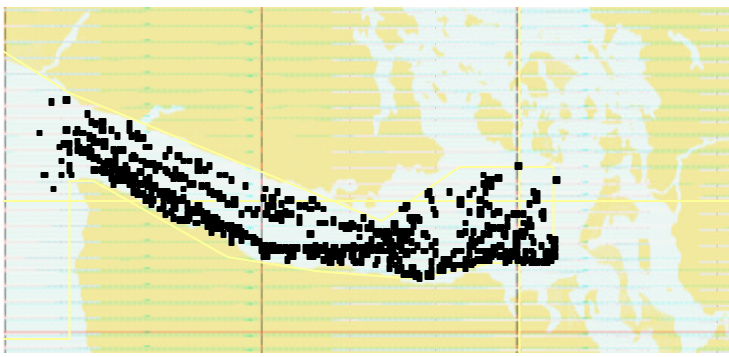


Figure 5 Sample Distribution of Vessels (from VTS Seattle Radar Data)

Once ship traffic has entered the Strait, it conforms well to the designated traffic lanes. Within a traffic lane, vessels were found to closely conform to a normal distribution across the lane. The mean is centered in the lane, with a standard deviation of 0.27 lane widths. The distribution was truncated at 3 standard deviations, corresponding to a vessel 0.31 lane widths outside the lane in either direction. The data for lane distribution interior to the Strait were obtained from the Seattle VTS data. An equivalent analysis was applied to the approach lanes to the west of "J" Buoy.

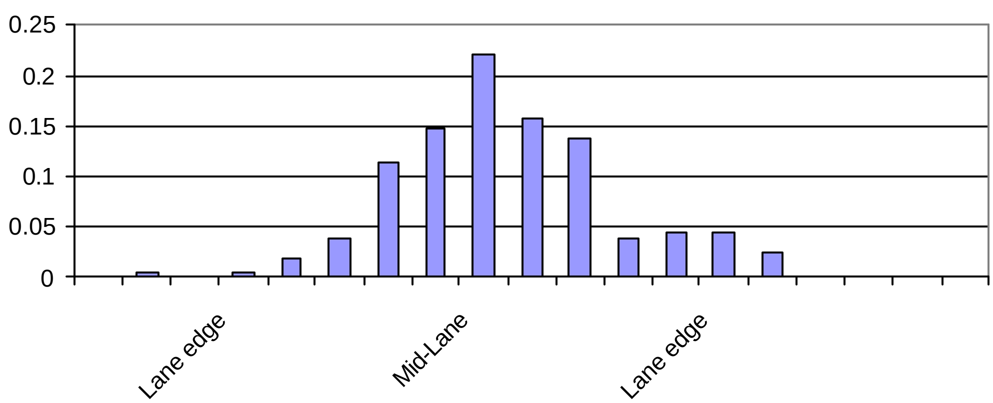


Figure 6 Distribution of Containerships within the Traffic Lane (Inbound vessels within the Strait of Juan de Fuca)

2.3 Routes

A route is defined in the simulation software as a series of waypoints that the ship will travel to in succession. Ship traffic in the Strait generally follows one of 5 different routes, in either direction along the path, with the option of picking up a pilot, so each transit is assumed to follow one of 5*2*2=20 distinct paths. In addition to these possibilities, a particular ship is also assigned a lane position non-dimensionalized with respect to lane width that it retains throughout it's route. Non-dimensionalizing assures that even a ship operating near the edge of a lane will appropriately follow changes in lane width. It is assumed that picking up a pilot takes 15 minutes, and that ships will slow down to 6 knots to commence this process. It is further assumed that in the Rotary (region 4) and in the eastern approaches to the Rotary ships will generally not operate faster than 12 kts. If an escort tug is required, it is picked up or dropped off halfway from the seaward end of the traffic lanes to "J" Buoy.

2.4 Coastal Traffic

In addition to the vessels transiting the Strait, a number of ships crossing through the study area but not entering the Strait were observed. These were included in the analysis as 8 northbound and 8 southbound ships per month evenly distributed across a wide lane offshore. Their profile was selected to match that of large bulk carriers.

2.5 Simulation

The intervals between ships entering the waterway are considered as random variables with a Poisson distribution. Upon arrival, one of the routes appropriate for that type of ship is selected based on the collected annual transit data. Whether an escort is required is also determined. The ship then proceeds along its assigned route, picking up and dropping off escort tugs and/or pilots as necessary. When it has exited the study area, encounters are totaled up and the transit counted as complete. To assure that the Strait is populated with ships throughout the run, an initialization period of two days is allowed to pass before data collection begins. Once the initialization period has ended, position data are collected periodically and the location and types of involved ships are recorded for each encounter that occurs.

2.6 Results of Simulation

The simulation takes small steps through the time domain updating ship positions and tracking encounter and position information as it goes. Based on the Poisson distribution of arrival intervals for each ship, new ships are introduced as appropriate and assigned information on routes, such as whether an escort and/or a pilot is required. Every 8 hours of simulated time, a 'snapshot' of the Strait is taken, which appears much as the VTS radar data for the region. By superimposing many of these snapshots, a traffic density profile of the Strait may be constructed for each ship type. Such distribution profiles were used in the drift grounding analysis. Likewise, a similar density plot of ship encounter events may be constructed. In Figure 7 a basic ship location distribution is illustrated. Noteworthy is the heavy banding in the approaches, as observed in the Tofino VTS data.

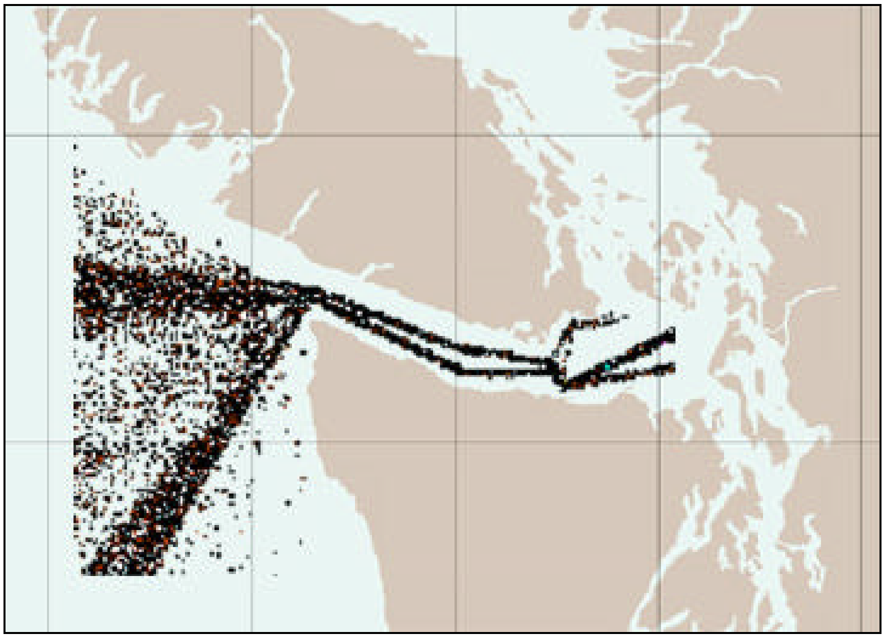


Figure 7 Ship location distribution obtained from simulation

3 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. The effect of vessel slowdown as a result of partial or full escorting requirements, and the likelihood of escort tug-ship collisions was also taken into account.

3.1 Types of Collisions

In assessing the likelihood of accidents due to ship interactions, collisions are divided into three categories: crossing, overtaking, and head on. For each type of collision, the number of accidents is assumed to scale with the number of instances in which a close encounter would have occurred if evasive action had not been taken by either ship. The definition of 'encounter' is different for each type of collision. Previous studies (for example, Ref. (1)) have used definitions based on an encounter radius with possible additional risk factors assigned for the character of the seaway, sea state, visibility, etc. Pedersen, Ref. (2), utilized a similar approach, expanding treatment of vessel dimensions to obtain analytical solutions to collision incidence problems at lane intersections. Others, Ref. (3), have applied fault-tree style analysis, incorporating a large number of variables in their assessment of encounter risk level.

The simulation model facilitates breakdown of risk by ship type and region, which are the two most important factors in assessing effectiveness of the proposed tug options. For the purposes of this study, weather, operational characteristics of individual ships, aggregate experience levels of each bridge crew, and other factors that 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.

Different risk factors are, however, assigned on the basis of the type of encounter and the region in which a particular encounter occurs. Relative risk "weighting" factors of 0.65 for crossing encounters, 0.30 for head on encounters, and 0.05 for overtaking encounters are assumed. Offshore encounters (region 1) are assigned a relative risk factor of 0.5, as compared to 1.0 for regions within the Strait and Rotary. The lower risk factor for the offshore areas is related to the increased space for maneuvering, allowing vessels to re-direct course and provide a wide separation. The number of crossing, head-on and overtaking encounters are multiplied by their respective risk factors, and then multiplied by the appropriate regional risk factor. 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.

3.1.1 Crossing

For a crossing encounter to occur, the following criteria must be satisfied:

- Their projected paths must intersect, and,
- projecting their velocities, when the first ship would arrive at the intersection point, the two vessels are no more than the average of their lengths apart.

Note that it is possible for an encounter to be counted using this definition even of one if the ships is expected to turn before the collision occurs. Thus, collisions resulting from a failure to turn are included.

Because crossing is considered the most dangerous type of encounter, any situation that is at any time a crossing is counted as a crossing, even if it progresses into an overtaking or head-on situation. This could occur, for instance, when one of the ships makes a heading change while the vessels are in close proximity.

3.1.2 Overtaking and Head On

The criteria for overtaking and head on encounters are comparatively simple. If two vessels pass within a distance less than or equal to the average of the ship lengths, an encounter is defined to be in progress. The relative headings of the two ships determine whether an overtaking or a head on encounter has occurred.

3.2 Collision Likelihood by Location

Figure 8, Figure 9, and Figure 10 show the areas of highest encounter likelihood for the year 2000 baseline case. Crossing encounters are concentrated in the vicinity of “J” Buoy and the Rotary. Overtaking encounters primarily occur in the traffic lanes within the Strait of Juan de Fuca, where vessels are operating a close to their service speeds. Head on encounters are most likely in the offshore region, where there are no defined traffic lanes and separation zones.

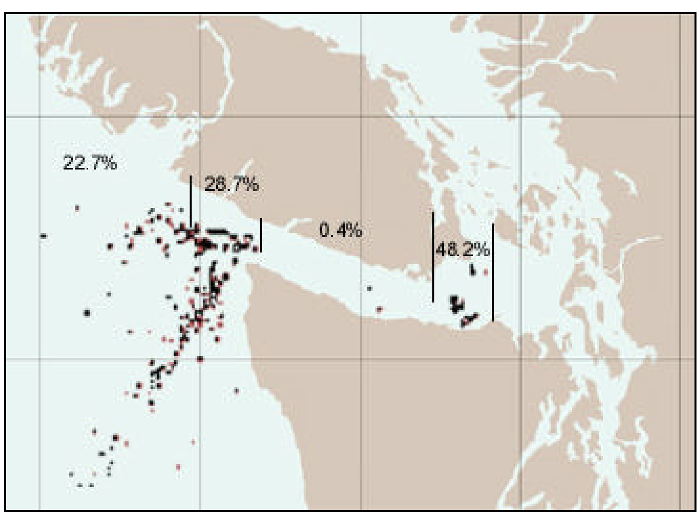


Figure 8 Crossing Encounters

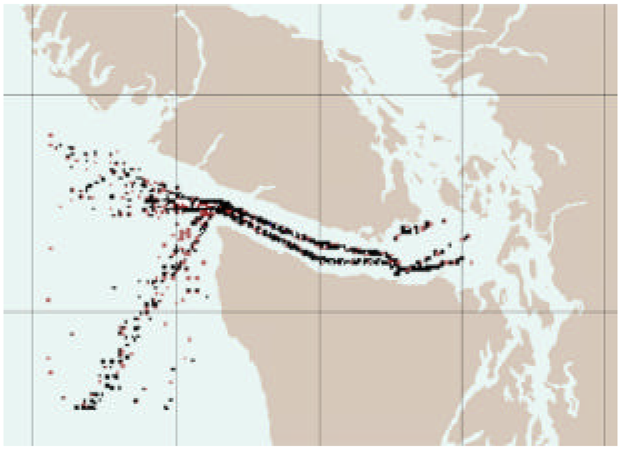


Figure 9 Overtaking Encounters

Figure 10 Head-On Encounters

Applying the regional and encounter type weightings arrives at the distribution shown in . This applies to the Straits and its approaches as modeled in the simulation Figure 11.

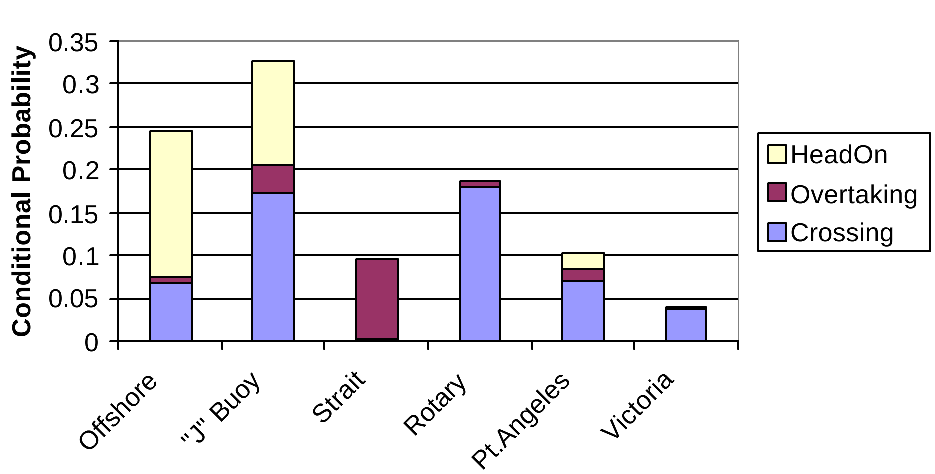


Figure 11 Relative Likelihood of Collision by Location (based on numerical simulation)

Based on a review of casualty statistics, 50% of all collision and grounding accidents were assumed to occur within the Puget Sound, and 50% within the Strait and offshore regions. A comparison between the overall projections from the numerical simulation and expert opinion is presented in Figure 12. The experts attached a higher relative risk to the Rotary area, whereas the simulation has a higher likelihood of collision in the offshore and "J" Buoy regions. The conditional probabilities derived from the Panel of Expert input was applied as the reference condition for the benefit analysis, and the values obtained from the numerical simulation were evaluated in the sensitivity analysis.

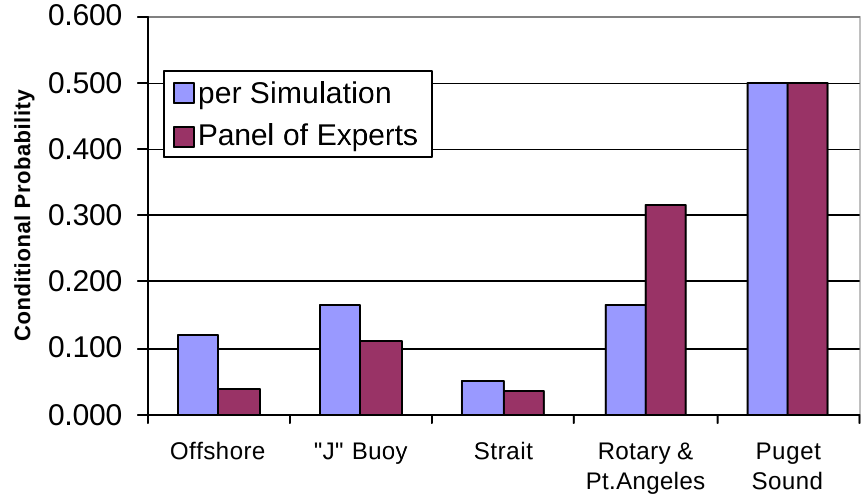


Figure 12 Relative Likelihood of Collision by Location (comparison of numerical simulation to Panel of Expert estimates)

An encounter simulation was initially carried out to determine the impact of increased traffic over the study period. The number of encounters is plotted against the number of transit per year in Figure 13.

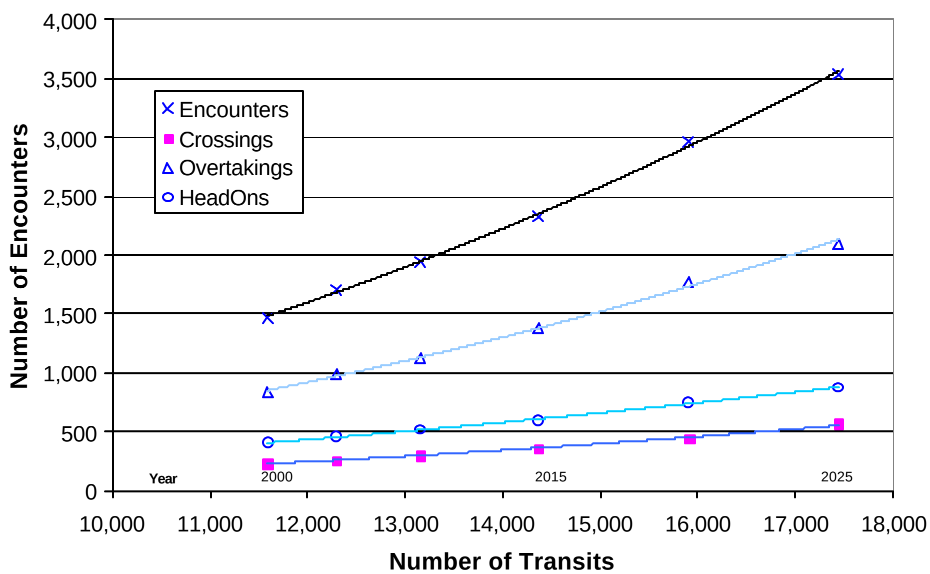


Figure 13 Increase in Encounters for Period 2000-2025 (Base Condition)

Encounters were found to rise at a rate slightly higher than the square of the number of ship transits (see Figure 13). 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).

Encounters were 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. In Figure 14, the relative likelihood of a collision on a per transit basis is plotted vs. time. Collision rates for slower vessels and larger vessels are most sensitive to the increase in traffic.

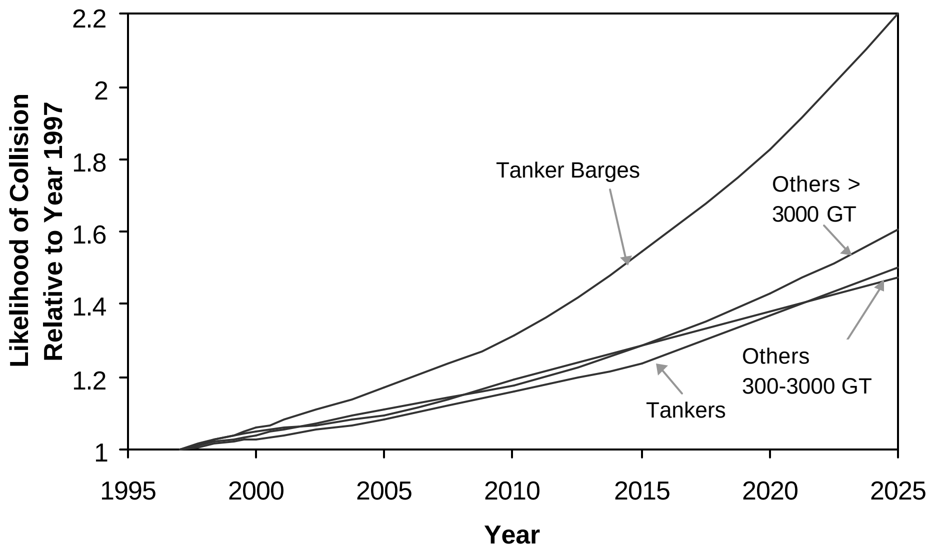


Figure 14 Relative Likelihood of a Collision (due to increase of traffic – baseline without escort tugs)

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. Tug-ship encounters increase the total encounters by additional 15%. In the simulation, an escort tug was not allowed to encounter the vessel it was escorting, and this particular risk was not accounted for in this study.

4 DRIFT GROUNDING ANALYSIS

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.

Under the tasking of this study several rescue and escort tug scenarios have been evaluated. These include:

- Baseline Case – This represents the existing state of tug operations in the study region minus the implementation of the ITOS system. Several tugs operate in the region, and many are capable of rescuing a stricken vessel in the majority of the weather conditions experienced in the Strait of Juan de Fuca and its offshore approaches.

- ITOS Case – Many of the tugs that operate in the region are participants in the ITOS system. While participation in the system does not change normal tug operations, it does provide the Coast Guard VTS operators greater knowledge of the location and capabilities of tugs that may be able to assist a stricken vessel.

- Rescue Tug at "J" Buoy (2 sizes) – Placement of a rescue tug in the vicinity of "J" Buoy has been proposed as a way to improve the rescue capabilities in the western portion of the Strait and its offshore approaches where there are relatively few tugs normally operating. Two size ranges of rescue tug, characterized by horsepower of 5,500 BHP and 10,000 BHP respectively, have been evaluated.

- Escorts – A number of escort options have been identified. The presence of an escort tug (which is matched to its client vessel) should significantly reduce the risk of drift grounding.

The purpose of the drift grounding simulation is to establish a rational basis for evaluating the above alternatives. Its ultimate use has been to determine reductions in the rate of drift grounding for each alternative. The primary result is the relative rate of drift grounding. Absolute rates are highly dependent upon assumptions regarding breakdowns (drifting incidents), and are not used directly in the benefit-cost analysis.

4.1 Assessment of the Rate of Drift Grounding

The approach taken in this analysis is to compare the time required to drift aground to the time required to rescue the vessel under the various tug scenarios described above. 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.

4.2 Land Boundary Model

The shoreline for the simulation is modeled in a simplified manner by connecting straight line segments from key land outcroppings. This “shoreline” represents a small margin over the actual shoreline, and takes into account offshore rocks such as Race Rocks, Smith Island, Duntze Rock and Umatilla Reef. Figure 15 shows an overlay of the model shoreline over a map of the region. Within the water portion of the model a grid at 0.25 nm centers is defined. For each point in the grid the distance to shore in each of eight wind directions is computed and stored for later use.

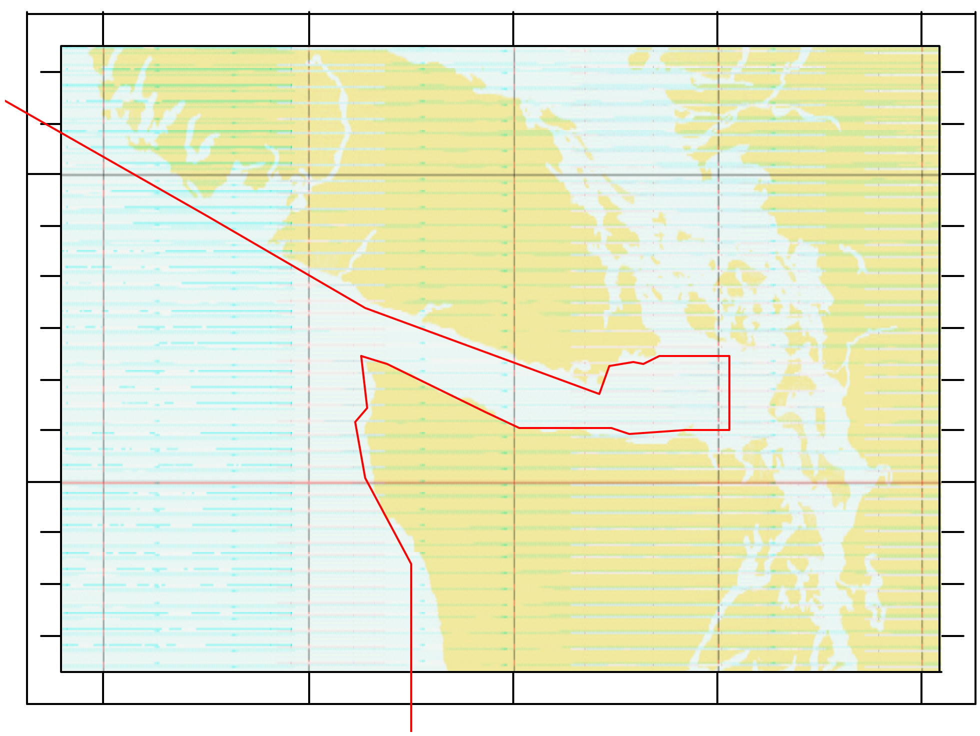


Figure 15 Overlay of model shoreline over map

4.3 Ship Distributions

Ship distribution in the waterway is obtained from the traffic simulations in the collision analysis.

4.4 Environmental Conditions

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 collisions and 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). West of longitude 124°-35'W the weather source is National Climate Data Center Buoy 46041, 7 nm off Cape Elizabeth, Washington. The weather source to the east is Race Rocks on southeastern Vancouver Island. This is consistent with the previous NOAA Ship Drift Analysis, Ref. (5). Utilization of the data from Tatoosh Island located very near "J" Buoy was evaluated. Wind direction data for Tatoosh Island show the effect of shielding of the weather station from southeast winds due to the high mainland in that direction. The southeast winds are essentially replaced by larger south and east wind components having a similar effect on ships adrift in the area. Buoy 46041 was considered to more correctly represent the situation away from the immediate effects of the land shadow. For each weather source the seasonal joint probability distribution of wind speed and direction has been used in the analysis. Four seasons are used, and the simulation is run combining the seasonal results to achieve annual results.

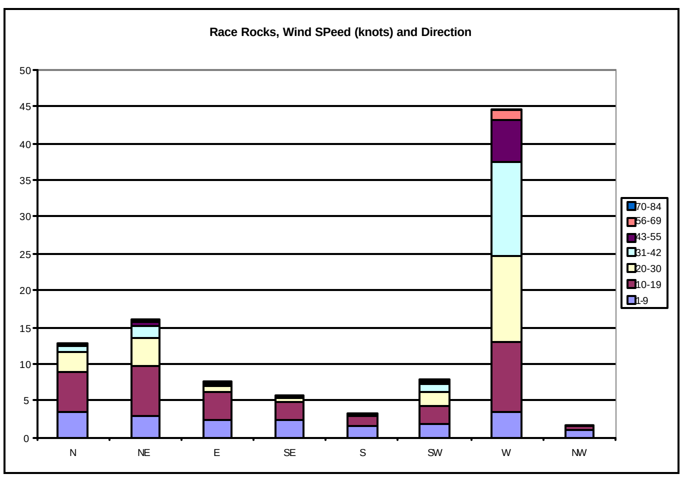


Figure 16 Wind speed and direction probability information for Race Rocks

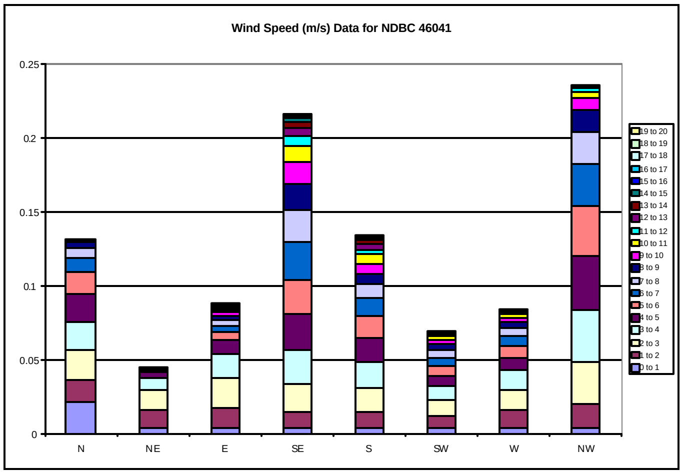


Figure 17 Wind speed and direction probability information for NCDC Buoy 46041

4.5 Drift Grounding Analysis Assumptions

4.5.1 Water grid

The water area is broken into cells of ¼ mile square. This results in approximately 115,000 cells. For each cell the distance to shore in 8 directions is computed and stored. The distance to shore is the distance in the direction opposite the source of the wind.

4.5.2 Ship Transits

For each ship type the collision simulator was run for a period of 10 years to populate the waterway. Each ship is assumed to transit the cell it is in. The total miles “traveled” is then compared to the actual miles traveled obtained from the collision simulation. The rate of drift grounding is scaled by this ratio. For each ship type the number of drift groundings per mile traveled is computed.

4.5.3 Currents

Currents are not included in the simulation on the basis that they average out to zero over the tide cycle and year, and are primarily parallel to the coasts.

4.5.4 Drift Rates

The drift rate is chosen on the basis of OCIMF data, Ref. (5) and adjusted for higher windage vessels. Two base drift rates are assumed, 3% of wind speed for deep draft, low freeboard vessels and 6% of wind speed for high windage ships (e.g. containerships, passenger ships). To investigate the role of drift rate, high end values were also simulated (6% and 10% for the two groups).

4.5.5 Self Repair

Self repair is assumed to have a function similar to the Prince William Sound, Ref. (3), study but offset by an adjustable initiation period (to include the effect of unreported incidents). This initiation period has been assumed to be 0.5 hours. Self repair is assumed to be 100% effective after 24 hours.

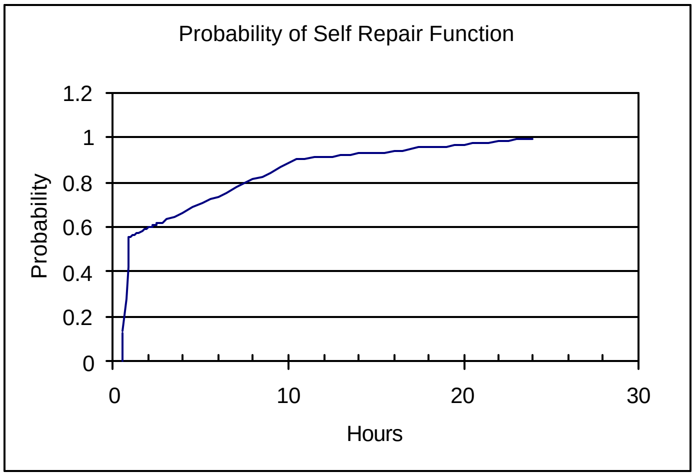


Figure 18 Probability of self repair vs. time

4.5.6 Tugs

Any number of tugs can be included. Each can have an effectiveness number assigned to it that includes geographical distribution of tugs and downtime. Tugs in the waterway are distributed (with appropriate effectiveness numbers) according to the following Figure 19. The arc in the figure is a 60 nm radius about “J” Buoy.

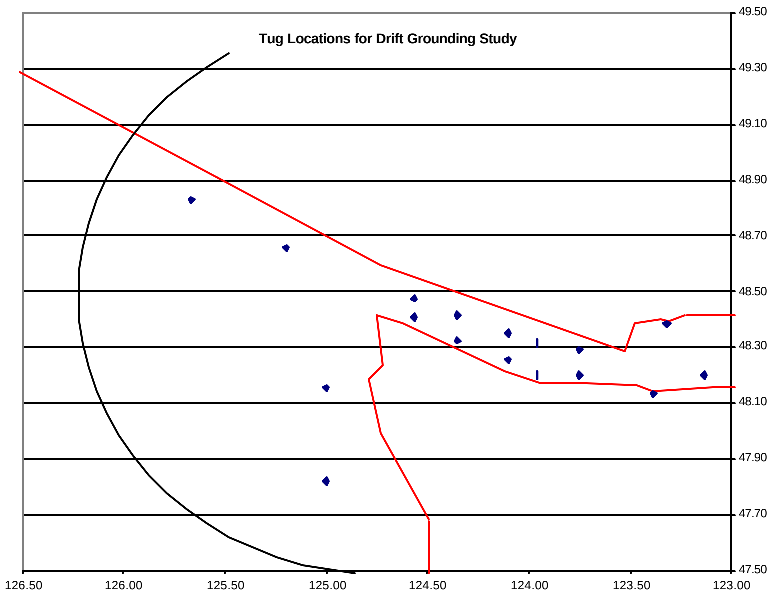


Figure 19 Distribution of tugs in the waterway for simulation

Each marker represents the position of a tug in the model. The effectiveness of each tug is scaled according to the expected number of tugs in the waterway from the USCG analysis. For example, in section 3W of the waterway the USCG report, Ref. (6), indicates that there are 1.49 tugs on average, of which 45% are unencumbered, 22.7% are encumbered with a petrochemical tow, and 32.3% are encumbered with a non-petrochemical tow {Table 8 of the USCG report). For the drift grounding analysis these 1.5 tugs are distributed equally over four points represented by the four markers just east of Cape Flattery (see Figure 19).

The willingness to assist is dependent upon the status of the tug (i.e whether it is unencumbered, encumbered with a non-petroleum tow, or encumbered with a petroleum tow). The willingness to assist is taken from the Panel of Experts judgements. These are:

Tug State	Tug Willingness to Assist
Unencumbered	88%
Encumbered with petrochemical tow	11%
Encumbered with non-petrochemical tow	37%

Table 2 Tug Willingness to Assist

The ratios of the various states for a tug vary over the region. The ratios developed in draft USCG ITOS Report, Ref(6), encompassing segments 1, 2, 3W. 3E and 4 have been used. These are:

	Expected Number of Tugs in Area at a Given Time										
	1	2	3	3W	3E	4	5	6	7	8	9
AVERAGE	1.02	0.62	3.57	1.49	2.09	2.72	3.54	4.11	4.01	11.71	3.14
November	1.06	0.27	3.42	1.21	2.21	2.91	2.27	5.67	5.03	12.39	2.82
December	0.97	0.56	2.86	1.33	1.52	2.00	3.51	3.51	3.63	11.34	2.87
January	0.77	0.62	3.33	1.41	1.92	2.02	4.68	3.08	3.10	12.00	2.16
February	0.75	0.58	3.54	1.19	2.35	2.91	3.65	3.58	3.60	11.18	2.88
March	0.64	0.82	4.18	2.02	2.16	3.36	3.43	4.44	4.93	10.90	3.73
April	No Data										
May	1.90	0.90	4.12	1.76	2.35	3.14	3.67	4.37	3.75	12.45	4.37

Table 3 Expected Number of Tugs in Area at a Given Time

The probability of tug rescue is the maximum of the probabilities of any available tug rescue effecting a save.

Tug rescue probability is a function of time available. The time available is the time to drift ashore minus a number of components. These include:

a) *Time to alert and mobilize the tug*. This represents the time from initial drifting to contacting the tug of preference for the rescue attempt, plus the time from initial contact to getting underway. This is estimated from Panel of Experts data and discussion, industry contacts and previous studies. The ITOS system is assumed to reduce this time by 0.5 hours, as VTS has the locations of potential rescue tugs readily available. Similarly, for a dedicated rescue tug the initial response time is significantly reduced.

b) *Time for the tug to arrive.* This is computed from distance and weather dependent speed. Data for tug performance degradation as a function of weather is taken from the Prince William Sound Risk Assessment, Ref.(3). Tugs under 3000 BHP are assumed to have a speed of 12 knots. The medium 5,500 HP rescue tug and the large 10,000 HP rescue tug are assumed to have service speeds of 14 knots and 15 knots respectively.

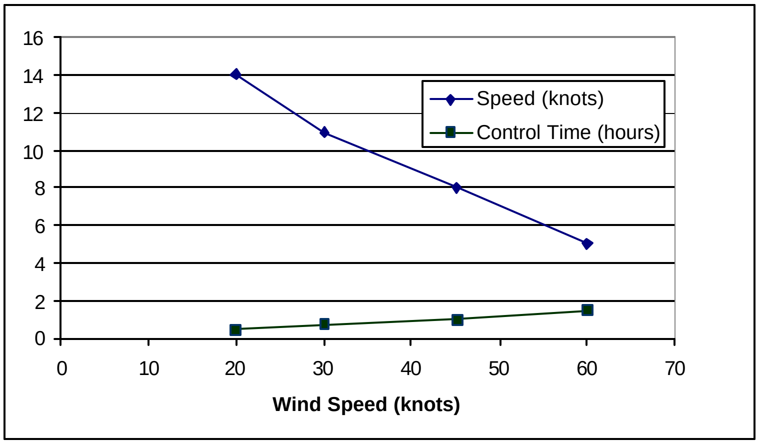


Figure 20 Tug performance degradation in weather

c) *Time for the tug to connect*. This is obtained from the "Disabled Tanker Towing Study", Ref.(7), data provided by Glosten Associates for Hinchinbrook Entrance. This was selected as most closely representing the study region.

d) *Time for the tug to stabilize the vessel*. Based upon the disabled tanker study data, this is typically about 0.25 hours for tankers in 30 knots wind. This was extended to smaller ships and high windage ships. The vessel is assumed to linearly decrease its drift rate to zero during this period. This is equivalent to assuming the full drift speed for one-half the stabilization time. A sample of the stabilization data is shown below.

Tanker Name	Deadweight	Length	Beam	Draft	Displace ment	Wind Speed	Sig. Wave Height	Modal Wave Period	Tug Force at 10 deg. to Bow	Time to Stop Downwind Drift	Maximum Downwind Drift Distance (c.g.)	Crosswind Drift when Downwind Drift is Arrested (c.g.)	Average Downwind Drift Speed with Tug
	Ltons	ft.	ft.	ft.	Ltons	knots	ft.	sec.	kips	hrs.	n.m.	n.m.	knots
OVERSEAS OHIO	90,000	855	105.9	49.1	104,482	33	15	11.8	50	0.45	0.48	0.96	1.1
OVERSEAS OHIO	90,000	855	105.9	49.1	104,482	33	15	11.8	100	0.13	0.17	0.33	1.3
OVERSEAS OHIO	90,000	855	105.9	49.1	104,482	33	15	11.8	150	0.08	0.12	0.22	1.5
OVERSEAS OHIO	90,000	855	105.9	49.1	104,482	33	15	11.8	200	0.07	0.10	0.19	1.5
OVERSEAS OHIO	90,000	855	105.9	49.1	104,482	41	20	13.6	50	failed to check drift			2.2
OVERSEAS OHIO	90,000	855	105.9	49.1	104,482	41	20	13.6	100	0.23	0.34	0.68	1.5
OVERSEAS OHIO	90,000	855	105.9	49.1	104,482	41	20	13.6	150	0.12	0.20	0.37	1.7
OVERSEAS OHIO	90,000	855	105.9	49.1	104,482	41	20	13.6	200	0.08	0.15	0.28	1.8

Table 4 Sample Stabilization Time Data

This has been implemented in the following table for analysis purposes:

Tug Requirement Matrices (time to stop drifting in hours)

Category A

	Wind Speed (knots) <20	20 - 30	>30
3,000 BHP	1.00	24.00	24.00
6,000 BHP	0.15	0.35	1.00
10,000 BHP	0.10	0.35	0.45

Ship Types	Drift Ratio
Tanker (crude) > 110 MDWT	.03 - .06
Container > 4000 TEU	.06 - .10

Category B

	Wind Speed (knots) <20	20 - 30	>30
3,000 BHP	0.25	1.00	24.00
6,000 BHP	0.15	0.45	1.00
10,000 BHP	0.10	0.25	1.00

Ship Types	Drift Ratio
Tanker (crude) < 110 MDWT	.03 - .06
Tanker Product	.03 - .06
Tanker Empty	.06 - .10
Container < 4000 TEU	.06 - .10
Passenger > 3000 GT	.06 - .10
Vehicle Carrier	.06 - .10
Bulk Carrier > 50 MDWT	.03 - .06
Bulk Liquid Carrier	.03 - .06

Category C

	Wind Speed (knots) <20	20 - 30	>30
3,000 BHP	0.25	0.45	24.00
6,000 BHP	0.15	0.35	1.00
10,000 BHP	0.10	0.25	0.45

Ship Types	Drift Ratio
Bulk Carrier < 50 MDWT	.03 - .06
Fish Factory > 3000 GT	.06 - .10
Other > 3000 GT	.06 - .10
Government	.06 - .10

Category D

	Wind Speed (knots) <20	20 - 30	>30
3,000 BHP	0.08	0.18	0.15
6,000 BHP	0.08	0.18	0.15
10,000 BHP	0.08	0.18	0.15

Ship Types	Drift Ratio
Tub Barge	.03 - .06
Fish Factory > 3000 GT	.06 - .10
Other < 3000 GT	.06 - .10
Passenger < 3000 GT	.06 - .10

Table 5 Tug Stabilization Time Matrices

e) The tug is limited in the sea state in which it can rescue the vessel. This is assumed to be a function of wave height and is most dependent upon tug size (assumed related to horsepower). Currently, there is a break at over/under 7000 BHP representing a split between coastwise and offshore tugs. Wave height has been converted to wind speed using the Beaufort wind scale. The limiting wave height is based on Panel of Experts responses. The current equivalent wind speeds limiting rescue are 30 knots for tugs less than 7000 BHP and 40 knots for more powerful tugs.

4.5.7 Escort tugs

Escort tugs are maintained in close proximity to the ship they are escorting, and thus available to provide immediate response to the vessel when adrift. This has been modeled by reducing the response time to zero for escorted vessels.

The reference case assumes escort tugs will remain with the escorted vessel, and not assist other vessels in distress. In the sensitivity analysis, a study was undertaken assuming the escorts would respond to other ships in the waterway.

4.5.8 Future projections

The major factors are the number and makeup of the fleet transiting the Strait of Juan de Fuca, and number and makeup of the tug fleet. The number of tugs in the waterway is scaled based upon the overall traffic growth for the region. This growth rate is taken to be 1.5% per year. The fleet makeup is the same as for the collision simulation model.

4.6 Drift Grounding Analysis – Summary of Results

The drift grounding analysis provides measures of the effectiveness of the various tug operations scenarios. Once the rate of drift grounding is established, the amount of oil expected to spill or avoided being spilled can be estimated.

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.

The majority of the weather conditions in the study region permit rescue by medium (3,000-7,000 BHP) and large (>7,000 BHP) tugs. For example, 99% of the time the winds offshore (Buoy 46041 data) are less than 30 knots, which is the assumed limit for connection for the 3000 BHP tug. A critical factor in averting drift groundings is the response time, which is a function of the proximity to shore versus proximity to the tug. A rescue tug's effectiveness is enhanced by increasing its speed, and improving its ability to makeup to a distressed vessel in heavy weather.

In the following sections measures of the effectiveness of the options are presented in relative terms, and in terms of actual drift rates. Sensitivity investigations into some key parameters are also presented.

4.6.1 Relative Effectiveness of Various Tug Operations Scenarios

In order to assess the cost benefit of the various options available for rescue or escort tug services the reduction in drift groundings for each option is required. In Figure 21 below each option is scaled relative to the rate of drift grounding under the Baseline Case for the year 2000.

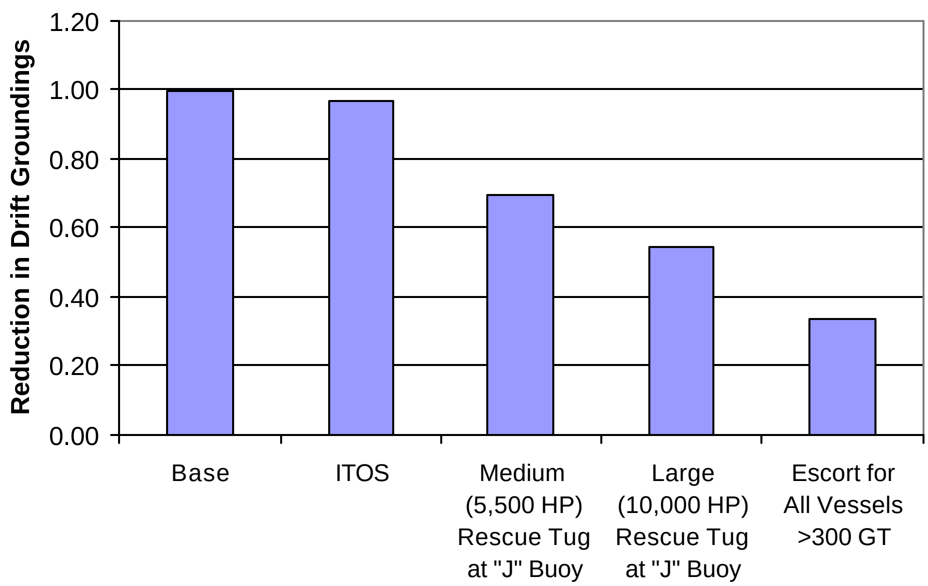


Figure 21 Drift Grounding Reduction Factors (for Year 2000)

The base rate of drift grounding is computed by summing over each grid cell the probability of drift grounding given a breakdown. The vessel traffic simulation study provides the propability a ship of a particular type will occupy each grid cell. The time to drift to shore in a given direction in a given sea/wind condition is computed for each ship type. The most effective tug, derived from the combination of tug speed, distance away and capability (connection time and limiting sea) that produces the highest probability of a save in the sea/wind condition is determined. If the time required for that tug to arrive, connect and stabilize the vessel is less than the time to drift ashore then the tug is assumed to have saved the vessel. In addition, there is a probability (very high after the initial hour or so) of the vessel effecting repairs and thus not drifting ashore. Combining these rescue modes means that for each direction/sea/wind combination there is a probability of drift grounding for a specific vessel type from each grid cell that is:

Pdg = (1 - probability of self repair/rescue) x (1 – probability of tug rescue).

This is summed up for all direction/sea/wind combinations weighted by their probability of occurring. Summing over all cell locations for all ship types gives the overall rate of drift grounding given a breakdown. The rate of drift grounding for specific ship types can be obtained separately.

Once the base rate of drift grounding rate is established then the impact of the various tug operations scenarios can be evaluated from the information above. In Figure 22, the reduction in drift grounding rate for the ITOS system, medium and large rescue tugs at "J" Buoy, and escorting vessels is presented for all ships. In the benefit-cost analyses these have been broken into four ship types.

The reduction in drift grounding rate is obtained by comparing the rate of drift grounding for the various alternatives to the base rate. Each of the alternatives reduces the response time for tug rescue. The rescue tug and escort tug options expand the range of weather conditions that vessels can be rescued in.

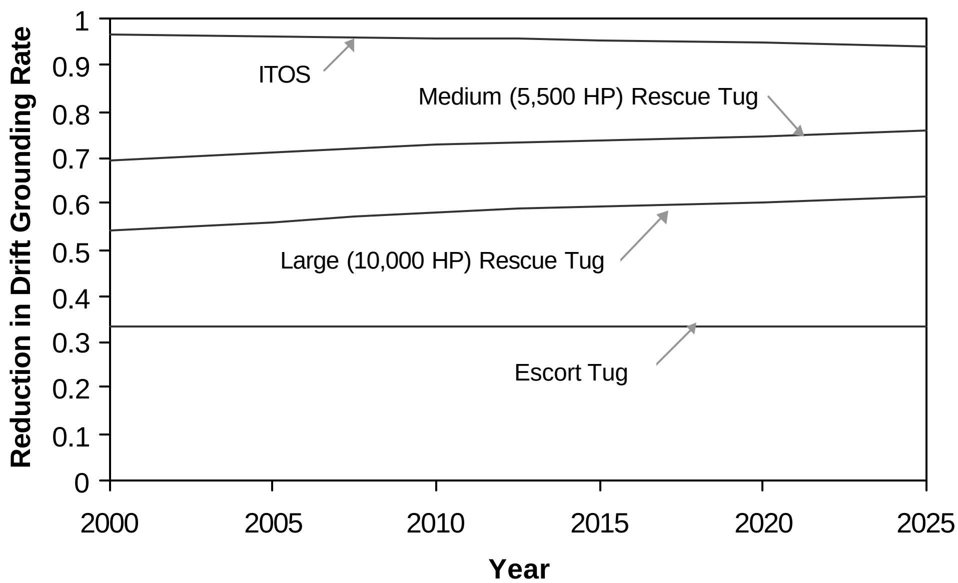


Figure 22 Reduction in Drift Grounding Rate for Various Alternatives

4.6.2 Tug Operation Scenario Effectiveness Over Time

The study period extends from 2000 to 2025. Drift grounding analyses were carried out for the years 2000, 2010 and 2025 to investigate whether the effectiveness of the various tug operation scenarios varies over time. As shown in Figure 22, there gradual changes in effectiveness for ITOS and the rescue tug options. The ITOS tug system becomes slightly more effective over time due to the increase in the number of available tugs in the waterway. There is about a 6% degradation in rescue tug effectiveness as the fleet ship sizes gets larger over time and becomes more difficult to save in severe weather.

4.6.3 Influence of drift rate assumptions

The speed at which a vessel drifts under the influence of wind and waves has a significant influence upon the rate of drift grounding. Drift speeds have been investigated by OCIMF, Ref. (5), and others, primarily for tankers. In this investigation drift speeds have been characterized as a ratio of wind speed based upon the OCIMF work for loaded tankers and other deep draft, low freeboard vessels, and at a higher rate based upon increased windage area and reduced draft for other ship types. The reference case drift ratios were 0.03 and 0.06 respectively. To investigate the sensitivity of tug effectiveness to drift rates, the base year 2000 analyses were also performed at higher drift ratios of 0.06 and 0.10 respectively.

These investigations demonstrate that the grounding rate increases very close to linearly with drift ratio. Doubling the drift rate ratio effectively doubles the drift grounding rate. This has been found true on an individual incident basis, and with regard to the overall system.

On the other hand, the influence of drift ratio assumptions upon the relative effectiveness of the alternatives as compared to the base case is almost negligible. In Figure 23 the drift grounding rate for the base condition is set to 1. The reduction in drift groundings for the alternatives relative to the non-dimensionalized base case is essentially the same for each alternative. The base case assumes tugs of opportunity will respond, but without the benefit of ITOS or other alternatives. Increasing the drift rate has proportionate effects on the base case and each alternative condition, leaving the relative difference between the base case and alternative largely unchanged.

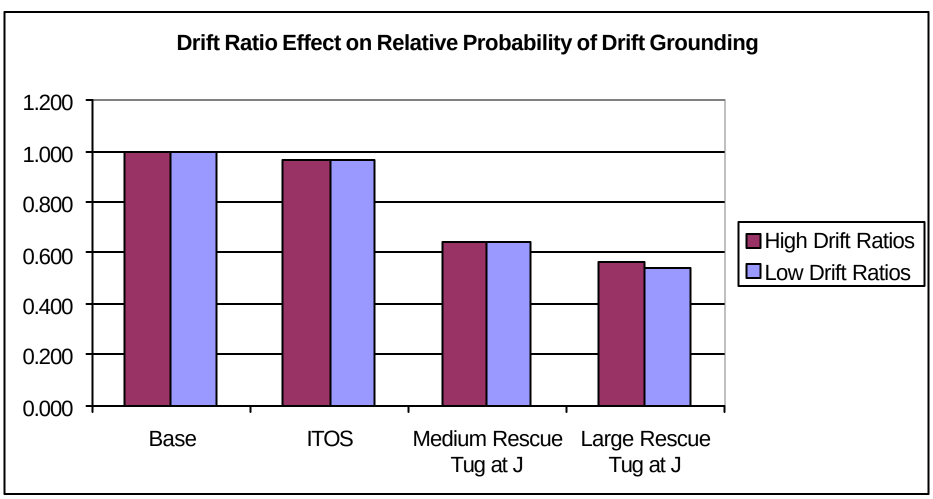


Figure 23 Influence of Drift Ratio On Tug Scenario Effectiveness

4.6.4 Time to grounding

In the analysis it is assumed that the wind and waves driving the vessel ashore last long enough for the vessel to ground. This is a conservative assumption leading to higher grounding rates. In actuality, extreme storm conditions rarely persist more than a few hours. Further, stricken vessels will be assisted or self-repaired after some period of time. In this investigation a cut-off for drift grounding at 24 hours has been assumed (except where noted).

The base case represents the combination of tugs in the waterway and self repair. If the vessels were never assisted nor capable of self repair, the rate of drift groundings would be more than 30 times the base case. For some locations and wind directions the ships would drift out to sea. Of the groundings, two-thirds would have taken more than 24 hours to occur. If there were no tugs providing assistance, the drift grounding rate would be about 1.4 times the base case.

4.6.5 Distribution of grounding

One of the features of the drift grounding model is that it provides the ability to identify where a ship is likely to ground given the traffic patterns, tug operation scenarios and weather conditions. Figure 24 shows a sample distribution of grounding density along the Olympic Peninsula and Vancouver Island shorelines. The figure also includes a density plot of the rate of grounding for ship locations in the waterway. This is discussed in Section 4.6.6, Risk Areas of Waterway

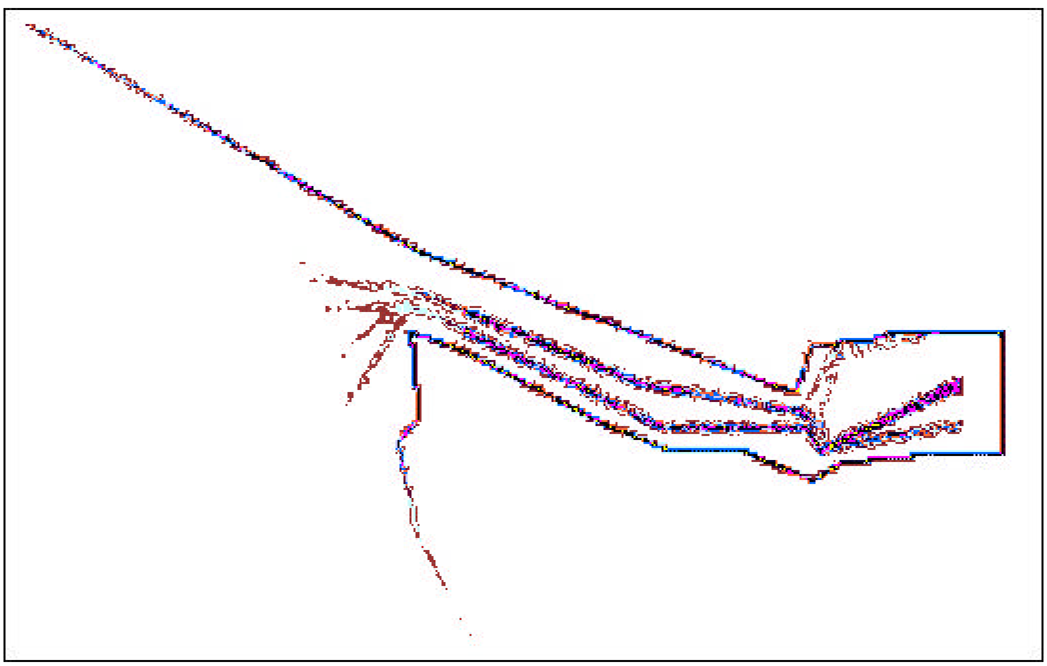


Figure 24 Sample grounding source and location density plot

From plots like Figure 24 one can identify the high risk areas of the region. High risk areas include the north shore of the Olympic Peninsula, especially near Port Angeles, where traffic is close to shore and the prevailing winds blow onto shore. Similarly, the northwestern portion of the study region reflects the risk due to the high concentration of ships traveling on northern Great Circle routes to the Orient. Note that the highest grounding rates are within the Strait.

To quantify these risks study areas were developed as outlined in Figure 25. Three regions of grounding interest were identified. These are the west and north coasts of the Olympic Peninsula and the southwest coast of Vancouver Island. The eastern portion of the Strait was excluded because most of the tug operation scenarios have little impact on the area.

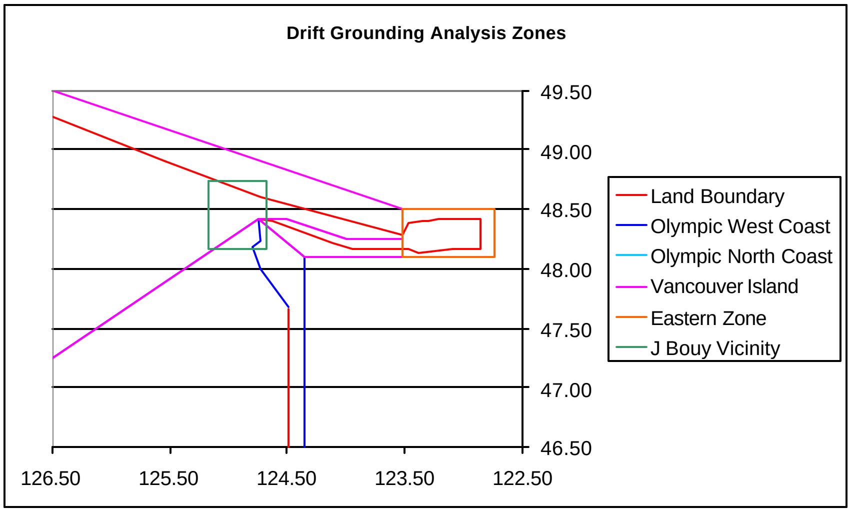


Figure 25 Drift grounding analysis zones

In Table 6 the percentage of groundings in each of the regions for the Year 2000 are shown. This represents where the vessels ground. The distribution indicates that most groundings occur within the Strait on the Olympic North coast or on Vancouver Island and that the risk is about evenly distributed. The presence of tugs, especially a rescue tug at “J” Buoy, reduces the relative risk of grounding on the Olympic West Coast as well as reducing the overall rates. The larger, faster rescue tug is relatively more effective in preventing grounding on the Vancouver Island shore since the time for the tug to arrive on scene plays a larger role in the rate of drift grounding. The impact on the North Olympic peninsula is smaller since the time to drift ashore is shorter on average. Thus, the north peninsula groundings represent a larger proportion of the remaining drift groundings.

Distribution of Groundings	West Olympic	North Olympic	Vancouver Island
Self Rescue only	8%	46%	46%
Base	6%	48%	45%
ITOS	6%	48%	45%
Medium Rescue Tug at J	4%	49%	47%
Large Rescue Tug at J	4%	52%	44%

Table 6 Distribution of Grounding Locations

However, the distribution is quite different for laden tankers. In Table 7 the percentage of groundings for laden tankers in each of the regions for the Year 2000 are shown. For all tug operation scenarios the highest risk (75%) is along the north coast of the Olympic Peninsula. This is due to the proximity of the of the inbound traffic lane to that shore.

Distribution of Groundings	West Olympic	North Olympic	Vancouver Island
Self Rescue only	4%	75%	20%
Base	3%	77%	20%
ITOS	3%	77%	20%
Medium Rescue Tug at J	2%	73%	25%
Large Rescue Tug at J	2%	76%	22%

Table 7 Distribution of Grounding Locations for Laden Tankers

4.6.6 Risk Areas of Waterway

To illustrate the impact of the tug operation scenarios on the risk of drift grounding for a ship in the waterway by region the rate of drift grounding for laden tankers was evaluated under the Base condition and with a large rescue tug at “J” Buoy. The region represents where the vessel was when power or steering was lost. The regions evaluated were the “J” Buoy vicinity defined in Figure 25, the area west of the U.S. VTS boundary, the region east of the VTS boundary and west of latitude 123°-35’, and the area east of 123°-35’. The area west of the U.S. VTS boundary includes the “J” Buoy vicinity. Drift grounding reduction factors for laden tanker are shown in Table 8. As expected, the rescue tug is most effective in the region near “J” Buoy and to the west.

Region	Reduction in Drift Groundings
“J” buoy vicinity	0.36
West of 124-40	0.36
123-35 to 124-40	0.53
East of 123-35	0.82

Table 8 Reduction in the Likelihood of Drift Grounding by Region (for Laden Tankers assuming Rescue Tug at “J” Buoy)

5 COST ANALYSIS

5.1 Introduction

The following sections provide background on costs and assumptions used to generate the compliance costs and avoided costs.

Final Cost / Benefit Summary (**Table 9**)

This sheet summarizes the net costs and benefits for the reference case (Case A).

The individual cost build-up for each alternative is presented in . For each alternative, summary results are presented for the industry compliance costs, enforcement costs, and avoided casualty costs. All costs are computed each year over the 26 year period from 2000 to 2025. However, these tables only indicate cost for every 5th year for readability purposes. As indicated in the main report, all costs are over this period are discounted 7% per year to a net present value in 1999 dollars.

For all alternatives, the avoided costs are based on the conditional probability of the cost occurring, given a casualty, multiplied by the average costs. For each alternative the average avoided costs per casualty are simply the number of casualties avoided.

Cost Build-up ALT. 1 – ITOS (**Table 10**)
Cost Build-up ALT. 2 - Two Tug Escort for Laden Single Hull Tankers (**Table 11**)
Cost Build-up ALT. 3 - One Tug Escort for Laden Single Hull Tankers (**Table 12**)
Cost Build-up ALT. 4 – Tug Escort for Priority I Vessels (**Table 13**)

The summary sheets for these options include the tugs as the primary cost of compliance, and do not include any cost associated with slow down of the tankers or Priority I ships. It is assumed that the escort tug speed is generally consistent with the speed of the escorted vessel.

Cost Build-up ALT. 5 – Tug Escort for All Vessels > 300 GRT (**Table 14**)
Cost Build-up ALT. 6 – Tug Escort for All Vessels > 3000 GRT (**Table 15**)

These summary sheets are used to develop the annual and net present value costs for both the large tug escort fleets, as well as the ship costs for the reduced transit speeds.

Cost Build-up ALT. 7 – Rescue Tug for All Vessels > 300 GRT (**Table 16**)
Cost Build-up ALT. 8 – Rescue Tug for All Vessels > 3000 GR (**Table 17**)

These two alternatives include dedicated tug escort costs and avoided casualty costs. As these options do not involve escorts, there are no costs associated with the slow down of vessels.

Escort Tug Costs – Dedicated and Charter Basis (**Table 18**)

This summary sheet presents the build-up of costs for escort tugs. There are three tug sizes representing 12, 14.5, and 16 knot escort speeds. As indicated in the main report, two different approaches were evaluated for estimating costs: 1) costs developed based on dedicated escort tug costs, allocating the full purchase and operating costs of the tugs to the escort operation, and, 2) chartering multi-use tugs for the escort. Alternatives 2, 3, and 4 use the chartering option. Alternatives 5 and 6 are based on the dedicated tug fleet costing option.

***Dedicated Rescue Tug Costs** (Table 19)*

The costs for dedicated rescue tugs are based on the purchase of new tugs. The operational profile assumes the tug is on-station at sea about 80% of the time. As with the escort tugs, three sizes have been developed, 3000HP, 5500HP, and 10,000HP. The reference case in the main report applies the rescue capabilities and costs associated with the large 10,000 HP tug.

***Ship Charter Rates – for reduced transit speeds** (Table 20 **and** Table 21)*

As described in the main report, transit reduction costs are typically developed by estimating daily and hourly capital, operating, and cargo costs for those ships subject to speed reductions. Fast passenger carriers were assessed using a different method, allocating costs to additional fuel consumption only.

5.2 Final Cost / Benefit Summary

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 9 Net Cost Effectiveness for Reference Case

5.3 Cost Build-up for Alternatives

5.3.1 Cost Build-up ALT. 1 - ITOS

Type of Benefits & Costs		PV 1999	2000	2005	2010	2015	2020	2025
Cost of Alternative								
Industry Compliance								
Number of Tugs in sustem	No.		107	110	112	115	118	121
Tug Equipment Annualized	$		78,457	80,657	82,123	84,323	86,523	88,723
Computer annual cost	$		5,585	5,585	5,585	5,585	5,585	5,585
Administration & Maintenance	$		25,000	25,000	25,000	25,000	25,000	25,000
Total Cost	millions $	1.245	0.109	0.111	0.113	0.115	0.117	0.119
Ship Costs (reduced transit speed)	millions $	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Enforcement Costs	millions $	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs								
Avoided Casualties								
- Tank vessels			0.00085	0.00097	0.00114	0.00137	0.00162	0.00190
- Cargo & Passenger >=3000 GT			0.00868	0.00990	0.01161	0.01492	0.01884	0.02348
- Cargo & Passenger (300 to 3000 GT)			0.00048	0.00055	0.00063	0.00080	0.00097	0.00118
- Total All Ship Types			0.01000	0.01142	0.01339	0.01708	0.02143	0.02656
Avoided Costs - Fatalities	$ / Casualty							
- Tank vessels	$6,600		6	6	8	9	11	13
- Cargo & Passenger >=3000 GT	$412,500		3579	4084	4790	6153	7770	9686
- Cargo & Passenger (300 to 3000 GT)	$211,200		100	116	134	168	204	249
- Total All Ship Types	millions $	0.058	0.004	0.004	0.005	0.006	0.008	0.010
Avoided Costs - Injuries								
- Tank vessels	$9,866		8	10	11	14	16	19
- Cargo & Passenger >=3000 GT	$5,161		45	51	60	77	97	121
- Cargo & Passenger (300 to 3000 GT)	$297,511		141	163	189	237	288	350
- Total All Ship Types	millions $	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Ship Damage								
- Tank vessels	$98,720		84	96	113	135	160	187
- Cargo & Passenger >=3000 GT	$392,246		3404	3883	4555	5851	7389	9211
- Cargo & Passenger (300 to 3000 GT)	$84,841		40	46	54	68	82	100
- Total All Ship Types	millions $	0.055	0.004	0.004	0.005	0.006	0.008	0.009
Avoided Costs - Time out of Service								
- Tank vessels	$51,900		44	50	59	71	84	98
- Cargo & Passenger >=3000 GT	$140,248		1217	1388	1629	2092	2642	3293
- Cargo & Passenger (300 to 3000 GT)	$167,990		80	92	107	134	163	198
- Total All Ship Types	millions $	0.021	0.001	0.002	0.002	0.002	0.003	0.004
Avoided Costs - Lost Cargo								
- Tank vessels	$49,360		42	48	56	68	80	94
- Cargo & Passenger >=3000 GT	$196,123		1702	1942	2277	2925	3694	4605
- Cargo & Passenger (300 to 3000 GT)	$42,420		20	23	27	34	41	50
- Total All Ship Types	millions $	0.028	0.002	0.002	0.002	0.003	0.004	0.005
Total Avoided Costs	millions $	0.164	0.011	0.012	0.014	0.018	0.023	0.028
Net Costs	millions $	1.081	0.099	0.099	0.099	0.097	0.094	0.091
Pollution Averted	barrels	25.5	2.4	2.3	2.1	1.9	2.4	2.9
Net Cost-Effectiveness	$/barrel	$42,382						

Table 10 ALT. 1 Costs -- ITOS

5.3.2 Cost Build-up ALT. 2 - Two Tug Escort for Laden Single Hull Tankers

Type of Benefits & Costs		PV 1999	2000	2005	2010	2015	2020	2025
Cost of Alternative								
Industry Compliance								
Dedicated Tug Costs								
No. 14.5 knot Tugs required	No.		4	4	2	0	0	0
Cost of 14.5 knot Tugs	millions $	$157.387	21.558	21.558	10.779	0.000	0.000	0.000
Charter Tug Costs								
No. 14.5 knot Transits	No.		404	248	117	0	0	0
Cost of 14.5 knot Tugs	millions $	$52.408	10.282	6.312	2.978	0.000	0.000	0.000
Ship Costs (reduced transit speed)		$ -	0.000	0.000	0.000	0.000	0.000	0.000
Enforcement Costs		$0.000	0	0	0	0	0	0
Avoided Costs								
Avoided Casualties								
- Tank vessels			0.01323	0.00869	0.00533	0.00000	0.00000	0.00000
- Cargo & Passenger >=3000 GT			-0.00161	-0.00108	-0.00054	0.00000	0.00000	0.00000
- Cargo & Passenger (300 to 3000 GT)			-0.00009	-0.00006	-0.00003	0.00000	0.00000	0.00000
- Total All Ship Types			0.01153	0.00755	0.00475	0.00000	0.00000	0.00000
Avoided Costs - Fatalities	$ / Casualty							
- Tank vessels	$6,600		87	57	35	0	0	0
- Cargo & Passenger >=3000 GT	$412,500		-665	-445	-224	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$211,200		-19	-12	-6	0	0	0
- Total All Ship Types	millions $	($0.003)	-0.001	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Injuries								
- Tank vessels	$9,866		131	86	53	0	0	0
- Cargo & Passenger >=3000 GT	$5,161		-8	-6	-3	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$297,511		-27	-18	-9	0	0	0
- Total All Ship Types	millions $	$0.001	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Ship Damage								
- Tank vessels	$98,720		1306	858	526	0	0	0
- Cargo & Passenger >=3000 GT	$392,246		-632	-423	-213	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$84,841		-8	-5	-3	0	0	0
- Total All Ship Types	millions $	$0.004	0.001	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Time out of Service								
- Tank vessels	$51,900		687	451	277	0	0	0
- Cargo & Passenger >=3000 GT	$140,248		-226	-151	-76	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$167,990		-15	-10	-5	0	0	0
- Total All Ship Types	millions $	$0.003	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Lost Cargo								
- Tank vessels	$49,360		653	429	263	0	0	0
- Cargo & Passenger >=3000 GT	$196,123		-316	-212	-107	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$42,420		-4	-3	-1	0	0	0
- Total All Ship Types	millions $	$0.002	0.000	0.000	0.000	0.000	0.000	0.000
Total Avoided Costs	millions $	$0.006	0.001	0.001	0.001	0.000	0.000	0.000
Net Costs	millions $	$52.403	10.281	6.311	2.977	0.000	0.000	0.000
Pollution Averted	barrels	284.9	65.0	30.3	12.4	0.0	0.0	0.0
Net Cost-Effectiveness	$/barrel	183,964						

Table 11 ALT. 2 Costs -- Two Tug Escort for Laden Single Hull Tankers

5.3.3 Cost Build-up ALT. 3 - One Tug Escort for Laden Single Hull Tankers

Type of Benefits & Costs		PV 1999	2000	2005	2010	2015	2020	2025
Cost of Alternative								
Industry Compliance								
Dedicated Tug Costs								
No. 14.5 knot Tugs required	No.		2	2	1	0	0	0
Cost of 14.5 knot Tugs	millions $	$75.954	10.779	10.779	5.390	0.000	0.000	0.000
Charter Tug Costs								
No. 14.5 knot Transits	No.		404	248	117	0	0	0
Cost of 14.5 knot Tugs	millions $	$26.204	5.141	3.156	1.489	0.000	0.000	0.000
Ship Costs (reduced transit speed)		$0.000	0.000	0.000	0.000	0.000	0.000	0.000
Enforcement Costs		$0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs								
Avoided Casualties								
- Tank vessels			0.01111	0.00742	0.00471	0.00000	0.00000	0.00000
- Cargo & Passenger >=3000 GT			-0.00249	-0.00162	-0.00081	0.00000	0.00000	0.00000
- Cargo & Passenger (300 to 3000 GT)			-0.00014	-0.00009	-0.00004	0.00000	0.00000	0.00000
- Total All Ship Types			0.00848	0.00571	0.00385	0.00000	0.00000	0.00000
Avoided Costs - Fatalities	$ / Casualty							
- Tank vessels	$6,600		73	49	31	0	0	0
- Cargo & Passenger >=3000 GT	$412,500		-1028	-668	-336	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$211,200		-29	-19	-9	0	0	0
- Total All Ship Types	millions $	($0.005)	-0.001	-0.001	0.000	0.000	0.000	0.000
Avoided Costs - Injuries								
- Tank vessels	$9,866		110	73	46	0	0	0
- Cargo & Passenger >=3000 GT	$5,161		-13	-8	-4	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$297,511		-41	-26	-13	0	0	0
- Total All Ship Types	millions $	$0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Ship Damage								
- Tank vessels	$98,720		1096	733	465	0	0	0
- Cargo & Passenger >=3000 GT	$392,246		-977	-635	-319	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$84,841		-12	-8	-4	0	0	0
- Total All Ship Types	millions $	$0.001	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Time out of Service								
- Tank vessels	$51,900		576	385	245	0	0	0
- Cargo & Passenger >=3000 GT	$140,248		-349	-227	-114	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$167,990		-23	-15	-8	0	0	0
- Total All Ship Types	millions $	$0.001	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Lost Cargo								
- Tank vessels	$49,360		548	366	233	0	0	0
- Cargo & Passenger >=3000 GT	$196,123		-489	-318	-160	0	0	0
- Cargo & Passenger (300 to 3000 GT)	$42,420		-6	-4	-2	0	0	0
- Total All Ship Types	millions $	$0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total Avoided Costs	millions $	($0.002)	-0.001	0.000	0.000	0.000	0.000	0.000
Net Costs	millions $	$26.206	5.141	3.156	1.489	0.000	0.000	0.000
Pollution Averted	barrels	243.1	54.9	26.0	10.9	0.0	0.0	0.0
Net Cost-Effectiveness	$/barrel	107,798						

Table 12 ALT. 3 Costs -- One Tug Escort for Laden Single Hull Tankers

5.3.4 Cost Build-up ALT. 4 – Tug Escort for Priority I Vessels

Type of Benefits & Costs		PV 1999	2000	2005	2010	2015	2020	2025
Cost of Alternative								
Industry Compliance								
Tug Costs								
No. 14.5 knot Tugs required	No.		1	1	1	1	1	1
Cost of 14.5 knot Tugs	millions $	59.566	5.390	5.390	5.390	5.390	5.390	5.390
Charter Tug Costs								
No. 14.5 knot Transits	No.		62	67	72	77	83	90
Cost of 14.5 knot Tugs	millions $	9.976	0.787	0.847	0.913	0.983	1.059	1.141
Ship Costs (reduced transit speed)		0.000	0.000	0.000	0.000	0.000	0.000	0.000
Enforcement Costs		0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs								
Avoided Casualties								
- Tank vessels			0.00052	0.00055	0.00062	0.00071	0.00084	0.00100
- Cargo & Passenger >=3000 GT			0.03197	0.03354	0.03666	0.04155	0.04613	0.05246
- Cargo & Passenger (300 to 3000 GT)			0.00026	0.00029	0.00033	0.00037	0.00042	0.00047
- Total All Ship Types			0.03276	0.03437	0.03761	0.04264	0.04739	0.05393
Avoided Costs - Fatalities	$ / Casualty							
- Tank vessels	$6,600		3	4	4	5	6	7
- Cargo & Passenger >=3000 GT	$412,500		13189	13834	15123	17139	19029	21639
- Cargo & Passenger (300 to 3000 GT)	$211,200		56	61	69	79	89	100
- Total All Ship Types	millions $	0.170	0.013	0.014	0.015	0.017	0.019	0.022
Avoided Costs - Injuries								
- Tank vessels	$9,866		5	5	6	7	8	10
- Cargo & Passenger >=3000 GT	$5,161		165	173	189	214	238	271
- Cargo & Passenger (300 to 3000 GT)	$297,511		79	85	98	111	125	141
- Total All Ship Types	millions $	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Ship Damage								
- Tank vessels	$98,720		51	54	61	70	83	98
- Cargo & Passenger >=3000 GT	$392,246		12541	13155	14381	16297	18095	20576
- Cargo & Passenger (300 to 3000 GT)	$84,841		22	24	28	32	36	40
- Total All Ship Types	millions $	0.162	0.013	0.013	0.014	0.016	0.018	0.021
Avoided Costs - Time out of Service								
- Tank vessels	$51,900		27	29	32	37	43	52
- Cargo & Passenger >=3000 GT	$140,248		4484	4704	5142	5827	6470	7357
- Cargo & Passenger (300 to 3000 GT)	$167,990		45	48	55	63	70	80
- Total All Ship Types	millions $	0.058	0.005	0.005	0.005	0.006	0.007	0.007
Avoided Costs - Lost Cargo								
- Tank vessels	$49,360		26	27	31	35	41	49
- Cargo & Passenger >=3000 GT	$196,123		6271	6577	7190	8149	9048	10288
- Cargo & Passenger (300 to 3000 GT)	$42,420		11	12	14	16	18	20
- Total All Ship Types	millions $	0.081	0.006	0.007	0.007	0.008	0.009	0.010
Total Avoided Costs	millions $	0.475	0.037	0.039	0.042	0.048	0.053	0.061
Net Costs	millions $	9.502	0.750	0.809	0.870	0.935	1.006	1.081
Pollution Averted	barrels	39.2	3.3	3.3	3.5	3.6	4.1	4.7
Net Cost-Effectiveness	$/barrel	242,466						

Table 13 ALT. 4 Costs -- Tug Escort for Priority I Vessels

5.3.5 Cost Build-up ALT. 5 – Tug Escort for All Vessels > 300 GT

Type of Benefits & Costs		PV 1999	2000	2005	2010	2015	2020	2025
Cost of Alternative								
Industry Compliance								
Dedicated Tug Costs								
No. 16 knot Tugs required	No.		10	10	11	12	13	15
Cost of 16 knot Tugs	millions $		65.855	65.855	72.440	79.026	85.611	98.782
No. 14.5 knot Tugs required	No.		18	20	21	23	25	26
Cost of 14.5 knot Tugs	millions $		97.012	107.791	113.181	123.960	134.739	140.129
No. 12 knot Tugs required	No.		0	0	0	0	0	0
Cost of 12 knot Tugs	millions $		0.000	0.000	0.000	0.000	0.000	0.000
Total Tug Costs	millions $	$ 2,054.598	162.867	173.646	185.621	202.986	220.350	238.911
Charter Tug Costs								
No. 16 knot Transits	No.		3323	3559	3759	4307	4941	5683
Cost of 16 knot Tugs	millions $		56.357	60.360	63.752	73.046	83.798	96.382
No. 14.5 knot Transits	No.		6917	7447	8022	8655	9351	10114
Cost of 14.5 knot Tugs	millions $		88.019	94.763	102.080	110.135	118.991	128.701
No. 12 knot Transits	No.		611	661	709	760	816	879
Cost of 12 knot Tugs	millions $		4.575	4.949	5.308	5.690	6.110	6.581
Total Tug Costs	millions $	$ 1,906.791	148.951	160.072	171.140	188.871	208.899	231.664
Ship Costs (reduced transit speed)								
Containerships <2000 TEU								
Nunber of Transits			1020	984	894	1068	1274	1520
Lost time per Transit	hours		1.24	1.24	1.24	1.24	1.24	1.24
Lost Hours	hours		1264.8	1220.16	1108.56	1324.32	1579.76	1884.8
Hourly Cost - Ship and Cargo	$/hour		2596	2596	2596	2596	2596	2596
Ship Costs	millions $	$ 37.048	3.283	3.168	2.878	3.438	4.101	4.893
Containerships 2000-4000 TEU								
Nunber of Transits			788	692	530	634	756	902
Lost time per Transit	hours		1.24	1.24	1.24	1.24	1.24	1.24
Lost Hours	hours		977.12	858.08	657.2	786.16	937.44	1118.48
Hourly Cost - Ship and Cargo	$/hour		3617	3617	3617	3617	3617	3617
Ship Costs	millions $	$ 34.120	3.534	3.104	2.377	2.844	3.391	4.046
Containerships >4000 TEU								
Nunber of Transits			632	944	1338	1544	1786	2064
Lost time per Transit	hours		1.8	1.8	1.8	1.8	1.8	1.8
Lost Hours	hours		1137.6	1699.2	2408.4	2779.2	3214.8	3715.2
Hourly Cost - Ship and Cargo	$/hour		5642	5642	5642	5642	5642	5642
Ship Costs	millions $	$ 132.817	6.419	9.587	13.589	15.681	18.139	20.962
Vehicle Carriers								
Nunber of Transits			870	924	980	1042	1106	1174
Lost time per Transit	hours		0.9	0.9	0.9	0.9	0.9	0.9
Lost Hours	hours		783	831.6	882	937.8	995.4	1056.6
Hourly Cost - Ship and Cargo	$/hour		1910	1910	1910	1910	1910	1910
Ship Costs	millions $	$ 18.455	1.495	1.588	1.685	1.791	1.901	2.018
Passenger Carrier								
Nunber of Transits			89	97	105	112	120	129
Lost time per Transit			1.0	1.0	1.0	1.0	1.0	1.0
Lost Hours	hours		89	97	105	112	120	129
Hourly Cost - Ship and Cargo	$/hour		1476	1476	1476	1476	1476	1476
Ship Costs	millions $	$ 1.679	0.131	0.143	0.155	0.165	0.177	0.190
Total Ship Costs	millions $	$ 224.120	14.863	17.590	20.683	23.919	27.709	32.109
Enforcement Costs		$ -	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs								
Avoided Casualties								
- Tank vessels			0.15384	0.16270	0.17934	0.19982	0.22059	0.24586
- Cargo & Passenger >=3000 GT			1.65544	1.74361	1.90503	2.18484	2.53211	2.96276
- Cargo & Passenger (300 to 3000 GT)			0.09416	0.09935	0.10841	0.12108	0.13346	0.14921
- Total All Ship Types			1.90344	2.00566	2.19279	2.50573	2.88616	3.35784
Avoided Costs - Fatalities	$ / Casualty							
- Tank vessels	$6,600		1015	1074	1184	1319	1456	1623
- Cargo & Passenger >=3000 GT	$412,500		682868	719239	785825	901246	1044496	1222139
- Cargo & Passenger (300 to 3000 GT)	$211,200		19887	20983	22897	25571	28186	31513
- Total All Ship Types	millions $	$ 9.206	0.704	0.741	0.810	0.928	1.074	1.255
Avoided Costs - Injuries								
- Tank vessels	$9,866		1518	1605	1769	1971	2176	2426
- Cargo & Passenger >=3000 GT	$5,161		8544	8999	9832	11276	13068	15291
- Cargo & Passenger (300 to 3000 GT)	$297,511		28014	29558	32254	36022	39705	44392
- Total All Ship Types	millions $	$ 0.490	0.038	0.040	0.044	0.049	0.055	0.062
Avoided Costs - Ship Damage								
- Tank vessels	$98,720		15187	16062	17705	19726	21776	24272
- Cargo & Passenger >=3000 GT	$392,246		649340	683924	747242	856995	993211	1162132
- Cargo & Passenger (300 to 3000 GT)	$84,841		7989	8429	9198	10272	11323	12659
- Total All Ship Types	millions $	$ 8.798	0.673	0.708	0.774	0.887	1.026	1.199
Avoided Costs - Time out of Service								
- Tank vessels	$51,900		7984	8444	9308	10370	11448	12760
- Cargo & Passenger >=3000 GT	$140,248		232173	244538	267178	306420	355125	415522
- Cargo & Passenger (300 to 3000 GT)	$167,990		15818	16690	18212	20340	22419	25066
- Total All Ship Types	millions $	$ 3.344	0.256	0.270	0.295	0.337	0.389	0.453
Avoided Costs - Lost Cargo								
- Tank vessels	$49,360		7594	8031	8852	9863	10888	12136
- Cargo & Passenger >=3000 GT	$196,123		324670	341962	373621	428498	496606	581066
- Cargo & Passenger (300 to 3000 GT)	$42,420		3994	4215	4599	5136	5661	6330
- Total All Ship Types	millions $	$ 4.399	0.336	0.354	0.387	0.443	0.513	0.600
Total Avoided Costs	millions $	$ 26.237	2.007	2.114	2.310	2.645	3.058	3.569
Net Costs	millions $	$ 2,252.481	175.724	189.122	203.995	224.260	245.002	267.451
Pollution Averted	barrels	3,855.7	386.8	358.5	333.7	276.0	315.2	363.2
Net Cost-Effectiveness	$/barrel	$584,190						

Table 14 ALT. 5 Costs -- Tug Escort for All Vessels > 300 GT

5.3.6 Cost Build-up ALT. 6 – Tug Escort for All Vessels > 3000 GT

Type of Benefits & Costs		PV 1999	2000	2005	2010	2015	2020	2025
Cost of Alternative								
Industry Compliance								
Tug Costs								
No. 16 knot Tugs required	No.		10	10	11	12	13	15
Cost of 16 knot Tugs	millions $		65.855	65.855	72.440	79.026	85.611	98.782
No. 14.5 knot Tugs required	No.		14	16	17	18	20	21
Cost of 14.5 knot Tugs	millions $		75.454	86.233	91.623	97.012	107.791	113.181
Total Tug Costs	millions $	$ 1,797.517	141.309	152.088	164.063	176.038	193.403	211.963
Charter Tug Costs								
No. 16 knot Transits	No.		3310	3544	3742	4288	4922	5660
Cost of 16 knot Tugs	millions $		56.137	60.105	63.463	72.723	83.476	95.992
No. 14.5 knot Transits	No.		6768	7282	7846	8463	9145	9892
Cost of 14.5 knot Tugs	millions $		86.123	92.663	99.840	107.692	116.370	125.876
No. 12 knot Transits	No.		277	298	320	341	366	393
Cost of 12 knot Tugs	millions $		2.074	2.231	2.396	2.553	2.740	2.942
Total Tug Costs	millions $	$ 1,847.318	144.333	155.000	165.700	182.968	202.586	224.810
Ship Costs (reduced transit speed)								
Containerships <2000 TEU								
Nunber of Transits			1020	984	894	1068	1274	1520
Lost time per Transit	hours		1.24	1.24	1.24	1.24	1.24	1.24
Lost Hours	hours		1264.8	1220.16	1108.56	1324.32	1579.76	1884.8
Hourly Cost - Ship and Cargo	$/hour		2596	2596	2596	2596	2596	2596
Ship Costs	millions $	$ 37.048	3.283	3.168	2.878	3.438	4.101	4.893
Containerships 2000-4000 TEU								
Nunber of Transits			788	692	530	634	756	902
Lost time per Transit	hours		1.24	1.24	1.24	1.24	1.24	1.24
Lost Hours	hours		977.12	858.08	657.2	786.16	937.44	1118.48
Hourly Cost - Ship and Cargo	$/hour		3617	3617	3617	3617	3617	3617
Ship Costs	millions $	$ 34.120	3.534	3.104	2.377	2.844	3.391	4.046
Containerships >4000 TEU								
Nunber of Transits			632	944	1338	1544	1786	2064
Lost time per Transit	hours		1.8	1.8	1.8	1.8	1.8	1.8
Lost Hours	hours		1137.6	1699.2	2408.4	2779.2	3214.8	3715.2
Hourly Cost - Ship and Cargo	$/hour		5642	5642	5642	5642	5642	5642
Ship Costs	millions $	$ 132.817	6.419	9.587	13.589	15.681	18.139	20.962
Vehicle Carriers								
Nunber of Transits			870	924	980	1042	1106	1174
Lost time per Transit	hours		0.9	0.9	0.9	0.9	0.9	0.9
Lost Hours	hours		783	831.6	882	937.8	995.4	1056.6
Hourly Cost - Ship and Cargo	$/hour		1910	1910	1910	1910	1910	1910
Ship Costs	millions $	$ 18.455	1.495	1.588	1.685	1.791	1.901	2.018
Passenger Carrier								
Nunber of Transits			89	97	105	112	120	129
Lost time per Transit			1.0	1.0	1.0	1.0	1.0	1.0
Lost Hours	hours		89	97	105	112	120	129
Hourly Cost - Ship and Cargo	$/hour		1476	1476	1476	1476	1476	1476
Ship Costs	millions $	$ 1.679	0.131	0.143	0.155	0.165	0.177	0.190
Total Ship Costs	millions $	$ 224.120	14.863	17.590	20.683	23.919	27.709	32.109
Enforcement Costs		$ -	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs								
Avoided Casualties								
- Tank vessels			0.15251	0.16134	0.17779	0.19808	0.21863	0.24366
- Cargo & Passenger >=3000 GT			1.64484	1.73216	1.89182	2.16940	2.51450	2.94259
- Cargo & Passenger (300 to 3000 GT)			0.01650	0.01803	0.02078	0.02443	0.02819	0.03286
- Total All Ship Types			1.81385	1.91152	2.09040	2.39191	2.76132	3.21911
Avoided Costs - Fatalities	$ / Casualty							
- Tank vessels	$6,600		1007	1065	1173	1307	1443	1608
- Cargo & Passenger >=3000 GT	$412,500		678497	714514	780376	894876	1037232	1213818
- Cargo & Passenger (300 to 3000 GT)	$211,200		3485	3807	4390	5160	5953	6939
- Total All Ship Types	millions $	$ 8.940	0.683	0.719	0.786	0.901	1.045	1.222
Avoided Costs - Injuries								
- Tank vessels	$9,866		1505	1592	1754	1954	2157	2404
- Cargo & Passenger >=3000 GT	$5,161		8489	8939	9764	11196	12977	15186
- Cargo & Passenger (300 to 3000 GT)	$297,511		4909	5363	6184	7269	8386	9775
- Total All Ship Types	millions $	$ 0.199	0.015	0.016	0.018	0.020	0.024	0.027
Avoided Costs - Ship Damage								
- Tank vessels	$98,720		15056	15927	17552	19554	21583	24054
- Cargo & Passenger >=3000 GT	$392,246		645183	679432	742060	850938	986304	1154220
- Cargo & Passenger (300 to 3000 GT)	$84,841		1400	1529	1763	2073	2391	2788
- Total All Ship Types	millions $	$ 8.656	0.662	0.697	0.761	0.873	1.010	1.181
Avoided Costs - Time out of Service								
- Tank vessels	$51,900		7915	8373	9227	10280	11347	12646
- Cargo & Passenger >=3000 GT	$140,248		230686	242932	265325	304255	352655	412694
- Cargo & Passenger (300 to 3000 GT)	$167,990		2772	3028	3492	4104	4735	5520
- Total All Ship Types	millions $	$ 3.159	0.241	0.254	0.278	0.319	0.369	0.431
Avoided Costs - Lost Cargo								
- Tank vessels	$49,360		7528	7964	8776	9777	10792	12027
- Cargo & Passenger >=3000 GT	$196,123		322591	339716	371030	425469	493152	577110
- Cargo & Passenger (300 to 3000 GT)	$42,420		700	765	882	1036	1196	1394
- Total All Ship Types	millions $	$ 4.328	0.331	0.348	0.381	0.436	0.505	0.591
Total Avoided Costs	millions $	$ 25.282	1.932	2.035	2.224	2.549	2.952	3.452
Net Costs	millions $	$ 1,996.354	154.240	167.643	182.522	197.408	218.159	240.620
Pollution Averted	barrels	3,789	380.5	352.7	327.9	270.5	309.1	356.4
Net Cost-Effectiveness	$/barrel	$526,846						

Table 15 ALT. 6 Costs -- Tug Escort for All Vessels > 3000 GT

5.3.7 Cost Build-up ALT. 7 – Rescue Tug for All Vessels > 300 GT

Type of Benefits & Costs		PV 1999	2000	2005	2010	2015	2020	2025
Cost of Alternative								
Industry Compliance								
Tug Costs								
Cost of 10,000HP Rescue Tug	millions $	$64.758	5.9	5.9	5.9	5.9	5.9	5.9
Ship Costs (reduced transit speed)								
Enforcement Costs		$0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs								
Avoided Casualties								
- Tank vessels			0.01611	0.01632	0.01743	0.01902	0.02116	0.02380
- Cargo & Passenger >=3000 GT			0.07275	0.07505	0.08047	0.08972	0.10041	0.11269
- Cargo & Passenger (300 to 3000 GT)			0.00399	0.00414	0.00440	0.00479	0.00515	0.00561
- Total All Ship Types			0.09284	0.09551	0.10231	0.11352	0.12671	0.14211
Avoided Costs - Fatalities	$ / Casualty							
- Tank vessels	$6,600		106	108	115	126	140	157
- Cargo & Passenger >=3000 GT	$412,500		30008	30959	33195	37010	41418	46485
- Cargo & Passenger (300 to 3000 GT)	$211,200		842	875	930	1011	1087	1186
- Total All Ship Types	millions $	$0.386	0.031	0.032	0.034	0.038	0.043	0.048
Avoided Costs - Injuries								
- Tank vessels	$9,866		159	161	172	188	209	235
- Cargo & Passenger >=3000 GT	$5,161		375	387	415	463	518	582
- Cargo & Passenger (300 to 3000 GT)	$297,511		1186	1233	1310	1424	1531	1670
- Total All Ship Types	millions $	$0.021	0.002	0.002	0.002	0.002	0.002	0.002
Avoided Costs - Ship Damage								
- Tank vessels	$98,720		1590	1611	1721	1877	2089	2350
- Cargo & Passenger >=3000 GT	$392,246		28535	29439	31565	35193	39384	44202
- Cargo & Passenger (300 to 3000 GT)	$84,841		338	352	373	406	437	476
- Total All Ship Types	millions $	$0.380	0.030	0.031	0.034	0.037	0.042	0.047
Avoided Costs - Time out of Service								
- Tank vessels	$51,900		836	847	905	987	1098	1235
- Cargo & Passenger >=3000 GT	$140,248		10203	10526	11286	12583	14082	15805
- Cargo & Passenger (300 to 3000 GT)	$167,990		670	696	740	804	864	943
- Total All Ship Types	millions $	$0.146	0.012	0.012	0.013	0.014	0.016	0.018
Avoided Costs - Lost Cargo								
- Tank vessels	$49,360		795	805	860	939	1044	1175
- Cargo & Passenger >=3000 GT	$196,123		14267	14720	15783	17596	19692	22101
- Cargo & Passenger (300 to 3000 GT)	$42,420		169	176	187	203	218	238
- Total All Ship Types	millions $	$0.190	0.015	0.016	0.017	0.019	0.021	0.024
Total Avoided Costs	millions $	$1.123	0.090	0.093	0.100	0.111	0.124	0.139
Net Costs	millions $	$63.635	5.769	5.766	5.760	5.749	5.736	5.720
Pollution Averted	barrels	338	43.2	33.6	26.9	17.5	19.3	21.4
Net Cost-Effectiveness	$/barrel	$188,461						

Table 16 ALT. 7 Costs -- Rescue Tug for All Vessels > 300 GT

5.3.8 Cost Build-up ALT. 8 – Rescue Tug for All Tank Vessels

Type of Benefits & Costs		PV 1999	2000	2005	2010	2015	2020	2025
Cost of Alternative								
Industry Compliance								
Tug Costs								
Cost of 10,000HP Rescue Tug	millions $	64.757881	5.9	5.9	5.9	5.9	5.9	5.9
Ship Costs (reduced transit speed)								
Enforcement Costs		$0.000	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs								
Avoided Casualties								
- Tank vessels			0.01425	0.01433	0.01519	0.01658	0.01849	0.02087
- Cargo & Passenger >=3000 GT			0.00338	0.00369	0.00426	0.00514	0.00639	0.00802
- Cargo & Passenger (300 to 3000 GT)			0.00019	0.00020	0.00024	0.00027	0.00032	0.00037
- Total All Ship Types			0.01782	0.01822	0.01969	0.02200	0.02519	0.02926
Avoided Costs - Fatalities	$ / Casualty							
- Tank vessels	$6,600		94	95	100	109	122	138
- Cargo & Passenger >=3000 GT	$412,500		1394	1520	1756	2121	2634	3309
- Cargo & Passenger (300 to 3000 GT)	$211,200		40	43	50	58	67	78
- Total All Ship Types	millions $	$0	0.002	0.002	0.002	0.002	0.003	0.004
Avoided Costs - Injuries								
- Tank vessels	$9,866		141	141	150	164	182	206
- Cargo & Passenger >=3000 GT	$5,161		17	19	22	27	33	41
- Cargo & Passenger (300 to 3000 GT)	$297,511		56	60	70	82	94	110
- Total All Ship Types	millions $	$0	0.000	0.000	0.000	0.000	0.000	0.000
Avoided Costs - Ship Damage								
- Tank vessels	$98,720		1407	1415	1500	1637	1825	2061
- Cargo & Passenger >=3000 GT	$392,246		1325	1446	1670	2017	2505	3147
- Cargo & Passenger (300 to 3000 GT)	$84,841		16	17	20	23	27	31
- Total All Ship Types	millions $	$0	0.003	0.003	0.003	0.004	0.004	0.005
Avoided Costs - Time out of Service								
- Tank vessels	$51,900		740	744	789	861	960	1083
- Cargo & Passenger >=3000 GT	$140,248		474	517	597	721	896	1125
- Cargo & Passenger (300 to 3000 GT)	$167,990		31	34	39	46	53	62
- Total All Ship Types	millions $	$0	0.001	0.001	0.001	0.002	0.002	0.002
Avoided Costs - Lost Cargo								
- Tank vessels	$49,360		704	707	750	818	913	1030
- Cargo & Passenger >=3000 GT	$196,123		663	723	835	1008	1252	1573
- Cargo & Passenger (300 to 3000 GT)	$42,420		8	9	10	12	13	16
- Total All Ship Types	millions $	$0	0.001	0.001	0.002	0.002	0.002	0.003
Total Avoided Costs	millions $	$0	0.007	0.007	0.008	0.010	0.012	0.014
Net Costs	millions $	$65	5.852	5.852	5.851	5.850	5.848	5.845
Pollution Averted	barrels	264	37.9	27.5	20.0	10.1	11.0	12.0
Net Cost-Effectiveness	$/barrel	$245,131						

Table 17 ALT. 8 Costs -- Rescue Tug for All Tank Vessels

5.4 Escort Tug Costs – Dedicated and Charter Basis

	12 Knot Escort Tug				14.5 Knot Escort Tug				16 Knot Escort Tug			
			Capital	Recurring			Capital	Recurring			Capital	Recurring
Operating Days	340	days/year			340	days/year			340	days/year		
Acquisition		$	6,000,000			$	13,000,000			$	16,800,000	
Annual Capital	10.98%	Annual Equivalent (7% of 15 years)		$658,768	10.98%	Annual Equivalent (7% of 15 years)		$1,427,330	10.98%	Annual Equivalent (7% of 15 years)		$1,844,560
Crew Costs												
Manning Level	5	per tug			6	per tug			6	per tug		
Crews/Tug	2				2				2			
Average Crew Cost	200	$/day			200	$/day			200	$/day		
Benefits	1.3				1.3				1.3			
Total Crew Cost		$/year		884,000		$/year		1,060,800		$/year		1,060,800
Stores, supplies, provisions												
Supplies/provisions	25	$/person/day			25	$/person/day			25	$/person/day		
Fresh Water	5	$/person/day			5	$/person/day			5	$/person/day		
Sewage	5	$/person/day			5	$/person/day			5	$/person/day		
Total		$/year		119,000		$/year		142,800		$/year		142,800
Fuel Oil (average per year)												
Installed BHP	4000	horsepower			9000	horsepower			11600	horsepower		
Operating Days	340	per year			340	per year			340	per year		
Operating Hours	8160	per year			8160	per year			8160	per year		
Specific Fuel Consumption	0.05	Gal/hp/hour			0.05	Gal/hp/hour			0.05	Gal/hp/hour		
Fuel Cost	0.8	$/Gallon			0.8	$/Gallon			0.8	$/Gallon		
Alongside Dock												
% of time at Dock	20%				20%				20%			
hours	1632	per year			1632	per year			1632	per year		
% power	0%				0%				0%			
Consumption	0	Gal. Per year			0	Gal. Per year			0	Gal. Per year		
Idle												
% of time Idle	15%				15%				15%			
hours	1224	per year			1224	per year			1224	per year		
% power	10%				10%				10%			
Consumption	24480	Gal. Per year			55080	Gal. Per year			70992	Gal. Per year		
Half Power												
% of time at half power	15%				15%				15%			
hours	1224	per year			1224	per year			1224	per year		
% power	50%				50%				50%			
Consumption	122400	Gal. Per year			275400	Gal. Per year			354960	Gal. Per year		
Full Power												
% of time at full power	50%				50%				50%			
hours	4080	per year			4080	per year			4080	per year		
% power	100%				100%				100%			
Consumption	816000	Gallon / year			1836000	Gallon / year			2366400	Gallon / year		
Total Consumption	962880	Gallon / year			2166480	Gallon / year			2792352	Gallon / year		
Annual Fuel Cost		$/year		770,304		$/year		1,733,184		$/year		2,233,882
Lube Oil												
Lube Oil Cost	2.50	$/Gallon			2.50	$/Gallon			2.50	$/Gallon		
Consumption Rate	5%	ratio to Fuel Oil			5%	ratio to Fuel Oil			5%	ratio to Fuel Oil		
Consumption	48144	Gallon / year			108324	Gallon / year			139617.6	Gallon / year		
Annual Lube Cost		$/year		120360		$/year		270810		$/year		349044
Insurance												
Gross Tonnage	200	GRT			475	GRT			600	GRT		
Hull Insurance	0.60%	% of Acquisition			0.60%	% of Acquisition			0.60%	% of Acquisition		
P & I	200	$ / GRT			200	$ / GRT			200	$ / GRT		
Annual Insurance				76,000				173,000				220,800
M&R												
Drydock and Surveys	1.5%	% of Acquisition			1.5%	% of Acquisition			1.5%	% of Acquisition		
Maintenance	1.0%	% of Acquisition			1.0%	% of Acquisition			1.0%	% of Acquisition		
Annual M&R				150,000				325,000				420,000
Back-up Tug during DD		Add 5% for charter		138,922		Add 5% for charter		256,646.21				313,593.76
Dedicated Total Tug Costs		per year		2,917,353		per year		5,389,570			16,800,000	6,585,389
		per day		**7,993**		**per day**		**14,766**				**18,042**
Tug Charter Rate												
Standard Escort Time	25	hours			19	hours			21	hours		
Hours at full power	12	hours			9	hours			10	hours		
Full Daily Capital				1,938				4,198				5,425
Crew (based on escort hours)				1,354				1,235				1,365
Stores, supplies, provisions				182				166				184
Fuel Oil (based on hours)												
Idle												
hours	1.0	per escort			1.0	per escort			1.0	per escort		
% power	10%				10%				10%			
Consumption	20	Gal. Per escort			45	Gal. Per escort			58	Gal. Per escort		
Half Power												
hours	12.0	per escort			9.0	per escort			10.0	per escort		
% power	50%				50%				50%			
Consumption	1200	Gal. Per escort			2025	Gal. Per escort			2900	Gal. Per escort		
Full Power												
hours	12.0	per escort			9.0	per escort			10.0	per escort		
% power	100%				100%				100%			
Consumption	2400	Gallon / escort			4050	Gallon / escort			5800	Gallon / escort		
Total Consumption	3620	Gallon / escort			6120	Gallon / escort			8758	Gallon / escort		
Escort Fuel Cost		$/escort		2,896		$/escort		4,896		$/escort		7,006
Lube Oil												
Lube Oil Cost	2.50	$/Gallon			2.50	$/Gallon			2.50	$/Gallon		
Consumption Rate	5%	ratio to Fuel Oil			5%	ratio to Fuel Oil			5%	ratio to Fuel Oil		
Consumption	181	Gallon / escort			306	Gallon / escort			437.9	Gallon / escort		
Annual Lube Cost		$/escort		453		$/escort		765		$/escort		1094.75
Insurance (full daily rate)				224				509				649
M&R (full daily rate)				441				956				1,236
Total cost per Escort				**7,487**				**12,725**				**16,960**

Table 18 Escort Tug Costs

5.5 Dedicated Rescue Tug Costs

	Rescue Tug 1- 3000 HP				Rescue Tug 2 - 5500 HP				Rescue Tug 2 - 10000 HP			
			Capital	Recurring			Capital	Recurring			Capital	Recurring
Operating Days	340	days/year			340	days/year			340	days/year		
Acquisition		$	4,500,000			$	7,700,000			$	14,700,000	
Daily Capital	10.98%	Annual Equiv. (7% of 15 years)		$494,076	10.98%	Annual Equival (7% of 15 years)		$845,419	10.98%	Annual Equiva (7% of 15 years)		$1,613,981
Crew Costs												
Manning Level	7	per tug			8	per tug			8	per tug		
Average Crew Cost	330	$/day			330	$/day			330	$/day		
Benefits	1.5				1.5				1.5			
Total Crew Cost		$/year		1,264,725		$/year		1,445,400		$/year		1,445,400
Stores, supplies, provisions												
Supplies/provisions	35	$/person/day			35	$/person/day			35	$/person/day		
Fresh Water	8	$/person/day			8	$/person/day			8	$/person/day		
Sewage	8	$/person/day			8	$/person/day			8	$/person/day		
Total		$/year		121,380		$/year		138,720		$/year		138,720
Fuel Oil - On patrol												
Installed BHP	3000	horsepower			5500	horsepower			10000	horsepower		
Operating Days	340	per year			340	per year			340	per year		
Operating Hours	8160	per year			8160	per year			8160	per year		
Specific Fuel Consumption	0.05	Gal/hp/hour			0.05	Gal/hp/hour			0.05	Gal/hp/hour		
Fuel Cost	0.8	$/Gallon			0.8	$/Gallon			0.8	$/Gallon		
Alongside Dock												
% of time at Dock	20%				20%				20%			
hours	1632	per year			1632	per year			1632	per year		
% power	0%				0%				0%			
Consumption	0	Gal. Per year			0	Gal. Per year			0	Gal. Per year		
Idle												
% of time Idle	15%				15%				15%			
hours	1224	per year			1224	per year			1224	per year		
% power	10%				10%				10%			
Consumption	18360	Gal. Per year			33660	Gal. Per year			61200	Gal. Per year		
Half Power												
% of time at half power	50%				50%				50%			
hours	4080	per year			4080	per year			4080	per year		
% power	50%				50%				50%			
Consumption	306000	Gal. Per year			561000	Gal. Per year			1020000	Gal. Per year		
Full Power												
% of time at full power	15%				15%				15%			
hours	1224	per year			1224	per year			1224	per year		
% power	100%				100%				100%			
Consumption	183600	Gallon / year			336600	Gallon / year			612000	Gallon / year		
Total Consumption	507960	Gallon / year			931260	Gallon / year			1693200	Gallon / year		
Annual Fuel Cost		$/year		406,368		$/year		745,008		$/year		1,354,560
Lube Oil												
Lube Oil Cost	2.50	$/Gallon			2.50	$/Gallon			2.50	$/Gallon		
Consumption Rate	5%	ratio to Fuel Oil			5%	ratio to Fuel Oi			5%	ratio to Fuel Oil		
Consumption	25398	Gallon / year			46563	Gallon / year			84660	Gallon / year		
Annual Lube Cost		$/year		63495		$/year		116408		$/year		211650
Insurance												
Gross Tonnage	200	GRT			200	GRT			200	GRT		
Hull Insurance	0.60%	% of Acquisition			0.60%	% of Acquisition			0.60%	% of Acquisition		
P & I	400	$ / GRT			400	$ / GRT			400	$ / GRT		
Annual Insurance				107,000				126,200				168,200
M&R												
Drydock and Surveys	1.5%	% of Acquisition			1.5%	% of Acquisition			1.5%	% of Acquisition		
Maintenance	1.0%	% of Acquisition			1.0%	% of Acquisition			1.0%	% of Acquisition		
Annual M&R				112,500				192,500				367,500
Management Cost	5.0%	% of Operating Cost		103,773				138,212				184,302
Total Tug Costs				2,673,317				3,747,866			14,700,000	5,484,312
Back-up Tug during DD												
Days Required	25	days/year			25	days/year			25	days/year		
Charter Rate	7500	$ / day			10000	$ / day			15000	$ / day		
Annual Back-up Tug				187,500				250,000				375,000
Annual Tutal Tug & Backup				2,860,817				3,997,866				5,859,312

Table 19 Costs for Dedicated Rescue Tug

5.6 Ship Charter Rates – for reduced transit speeds

	1800 TEU			3000 TEU			5000 TEU		
	Input	Notes	Daily Cost	Input	Notes	Daily Cost	Input	Notes	Daily Cost
Ship Price	26,000,000			42,000,000			70,000,000		
Capital Recovery Factor	12%			12%			12%		
Daily Capital	3120000	at 350 days per year	8914	5040000	at 350 days per year	14197	8400000	at 355 days per year	23662
No. Crewmembers	20			23			26		
Crew Cost	30000	average $/crew/year	1714	30000	average $/crew/year	1971	30000	average $/crew/year	2229
Crew Subistance	4.00	$/crew/day	80	4.00	$/crew/day	92	4.00	$/crew/day	104
Stores and Supplies	5.00	$/crew/day	100	5.00	$/crew/day	115	5.00	$/crew/day	130
Maitenance & Repair									
Lightship	12,000	m. ton		18,000	m. ton		23,000	m. ton	
Horsepower	22,000	m. HP		35,000	m. HP		50,000	m. HP	
Hull Steel	4	$ / LSton		4	$ / LSton		4	$ / LSton	
Hull Outfit	12	$ / LSton		12	$ / LSton		12	$ / LSton	
Hatchcovers	1.5	$ / LSton		1.5	$ / LSton		1.5	$ / LSton	
Accommodations Outfit	600	$ / crewmember		600	$ / crewmember		600	$ / crewmember	
Machinery	10	$ / HP		10	$ / HP		10	$ / HP	
Total M&R	442000		1245	678800		1912	918100		2586
Insurance									
Hull	3.0%	% of ship price		2.2%	% of ship price		1.4%	% of ship price	
War Risk	0.4%	% of ship price		0.4%	% of ship price		0.4%	% of ship price	
P&I	3.5%	% of ship price		2.6%	% of ship price		1.7%	% of ship price	
Total Insurance	1794000		5054	2184000		6152	2450000		6901
Management Fee	7%	% excluding capital	574	7%	% excluding capital	717	7%	% excluding capital	837
Total Daily Charter Rate			17681			25157			36449
1999 Market Charter Rate (Used)			11200			17300			27400
Fuel Cost									
CSR for at sea rate	85%	% MCR		85%	% MCR		85%	% MCR	
HFO Cost	100	$/ m. ton		100	$/ m. ton		100	$/ m. ton	
Specific Fuel Consumption	150	g / HP / hour		150	g / HP / hour		150	g / HP / hour	
HFO Consumption	67.32	m. ton / day		107.1	m. ton / day		153	m. ton / day	
% at sea	0.88	at CSR power		0.88	at CSR power		0.88	at CSR power	
% maneuvering	0.04	at 50% CSR power		0.04	at 50% CSR power		0.04	at 50% CSR power	
% in port	0.08	at 500 HP		0.08	at 500 HP		0.08	at 500 HP	
Lube Cost	1	$ / liter		1	$ / liter		1	$ / liter	
Lube SFC	0.7	g / HP / hour		0.7	g / HP / hour		0.7	g / HP / hour	
Lube Consumption	340	liter / day		541	liter / day		773	liter / day	
Total Annual Fuel	2203783			3502998			5002092		
Total Annual Lube	111044			176661			252373		
Total Fuel and Lube	2314827		6521	3679659		10365	5254465		14801
Port Charges	100000	$ / Voyage		100000	$ / Voyage		100000	$ / Voyage	
Voyages / year	7			7			7		
Total Port Charges	700000		1972	700000		1972	700000		1972
Total Average Daily Cost			26173			37494			53222
Cargo Value (60k.TEU, @10%			29589			49315			82192
			113%			132%			154%
Adjustment for US Built Ships									
% of transits	25%		32,716	0%		37,494	0%		53,222
Multiplier	2			2			2		
Total daily Cost (Ship & Cargo)			62305			86809			135414

Table 20 Ship Charter Rates -- Containerships

	Car Carrier			Large Passenger		
	Input	Notes	Daily Cost	Input	Notes	Daily Cost
Ship Price	30,000,000			200,000,000		
Capital Recovery Factor	12%			12%		
Daily Capital	3600000	at 355 days per year	10141	24000000	at 355 days per year	67606
No. Crewmembers	20			657		
Crew Cost	30000	average $/crew/year	1714	30000	average $/crew/year	56314
Crew Subistance	4.00	$/crew/day	80	4.00	$/crew/day	2628
Stores and Supplies	5.00	$/crew/day	100	5.00	$/crew/day	3285
Maitenance & Repair						
Lightship	16,400	m. ton		16,400	m. ton	
Horsepower	19,500	m. HP		30,000	m. HP	
Hull Steel	4	$ / LSton		4	$ / LSton	
Hull Outfit	12	$ / LSton		12	$ / LSton	
Hatchcovers	1.5	$ / LSton		1.5	$ / LSton	
Accommodations Outfit	600	$ / crewmember		600	$ / crewmember	
Machinery	10	$ / HP		10	$ / HP	
Total M&R	494000		1392	981200		2764
Insurance						
Hull	2.2%	% of ship price		2.2%	% of ship price	
War Risk	0.4%	% of ship price		0.4%	% of ship price	
P&I	2.6%	% of ship price		2.6%	% of ship price	
Total Insurance	1560000		4394	10400000		29296
Management Fee	7%	% excluding capital	538	7%	% excluding capital	6600
Total Daily Charter Rate			18359			168493
1999 Market Charter Rate (Used)						
Fuel Cost						
CSR for at sea rate	85%	% MCR		85%	% MCR	
HFO Cost	100	$/ m. ton		100	$/ m. ton	
Specific Fuel Consumption	150	g / HP / hour		150	g / HP / hour	
HFO Consumption	59.67	m. ton / day		91.8	m. ton / day	
% at sea	0.88	at CSR power		0.88	at CSR power	
% maneuvering	0.04	at 50% CSR power		0.04	at 50% CSR power	
% in port	0.08	at 500 HP		0.08	at 500 HP	
Lube Cost	1	$ / liter		1	$ / liter	
Lube SFC	0.7	g / HP / hour		0.7	g / HP / hour	
Lube Consumption	301	liter / day		464	liter / day	
Total Annual Fuel	1953934			3003300		
Total Annual Lube	98425			151424		
Total Fuel and Lube	2052360		5781	3154724		8887
Port Charges	100000	$ / Voyage		100000	$ / Voyage	
Voyages / year	7			7		
Total Port Charges	700000		1972	700000		1972
Total Average Daily Cost			26112			179351
Cargo Value (60k.TEU, @10%		6000*12000	19726		Say $100 / passenger / day	200000
			76%			112%
Adjustment for US Built Ships						
% of transits						
Multiplier						
Total daily Cost (Ship & Cargo)			45838			379351

Table 21 Ship Charter Rates – Car Carriers and Passenger Ships

6 NRDAM/CME RESULTS

This section contains the NOAA NRDAM/CME summary reports of total injury and damage results for the six spill scenarios. Also presented are the spill plume trajectory maps and fate analysis graphs.

6.1 Large Spill, East Location

6.1.1 Summary Tables

Table 22, 23 and 24 summarize wildlife and fishery losses, as well as natural resource damages associated with the large spill scenario in the east location. The information was obtained from the NOAA NRDAM/CME.

WILDLIFE CATEGORY	TOTAL NUMBER OF LOSSES
Waterfowl	82,110
Seabirds	31,276
Wading birds	--
Shorebirds	18
Raptors, kingfishers	--
Cetaceans	--

Table 22 Summary of Wildlife Losses for the Eastern Large Spill

FISHERY CATEGORY	KG ADULTS	NUMBER OF YOY
Small pelagic fish	--	429
Large pelagic fish	--	--
Semi-demersal groundfish	104	8,760
Demersal groundfish	2	36
Crustaceans	--	146
Cephalopods (squid)	--	--
Mollusks	495,502	345
Other benthic invertabrates	177	--

Table 23 Summary of Fishery Losses for the Eastern Large Spill

CATEGORY OF LOSS	DAMAGE IN 1998 US $
Catch	293,663
Hunting	447,852
Wildlife non-consumptive	588,997
Beach	8,271,941
Restoration cost-assimilative capacity[1]	1,643
Total	9,604,096

Table 24 Damage Assessment Summary for the Eastern Large Spill

[1] Restoration of cost-assimilative capacity is the costs for removing residual chemical from water, sediment, and shoreline.

6.1.2 NOAA NRDAM/CME Model Output

This section contains the NRDAM/CME report detailing the summary of total injury and damages resulting from the large spill located near the eastern boundary of the study area.

NRDA REPORT: SUMMARY OF TOTAL INJURY AND DAMAGES (1998 US $)

```
                              Scenario: EAST LARGE SPILL

  Spill date: Apr.  1, 1998
  Location:   48.165N,  123.449W
  Alaskan North Slope Crude Oil
       12412.530 MT,  OIL #:      0   8  1


  ---------------------------------------------------------------------------
  Category                                    Without        Including
  Of Loss                                   Restoration     Restoration


  Wildlife killed (# animals)                 113413.1       113412.1
  Fishery stock killed (kg)                   495785.3       495785.3
  Fishery young-of-yr killed (# at 1yr)         9715.4         9715.4
  Lost catch (kg)                             150525.9       150525.9
  Lost #-years fish, shellfish               4092422.0      4092422.0
  Lost hunting (# animals)                     46417.1        46417.1
  Lost #-years wildlife                       615203.6       615192.8

  Damages: catch (US $ )                      293663.        293663.
  Damages: hunting (US $ )                    447852.        447852.
  Damages: wildlife non-consumptive           588997.        588947.

  Damages: Total compensable value           1330512.       1330462.
    for fish and wildlife losses


  Beach damages:  all shorelines             8271941.       8271941.


  Damages: Total compensable value           9602453.       9602403.
    for all natural resource losses (US $ )



  Restoration costs for all habitats                              0.
  Restocking costs for all species                             5735.
  Restoration cost-assimilative capacity        1643.          1643.
    for a remaining mass (MT) of:           129.97070      129.97070


  Total compensable value and all            9604096.       9609781.
    estimated restoration costs (US $ )


  Habitat restoration plus restocking costs ($       5735.32)
    are more than    10. times the resulting reduction in
    compensable value ($     50.00)
    Habitat restoration and restocking are assumed not performed.
```

TOTAL DAMAGES ASSESSED (1998 US $) 9604096.

#	Habitat Type	Sediment or Habitat Area (m2) Toxic Long Term	Sedmnt.Replaced or Capped	Replanted Only
	Total	.00000E+00	.00000E+00	.00000E+00

TOTAL KILLS BY SPECIES AND BY CATEGORY, ASSUMING RESTORATION PERFORMED:

Wildlife species	Number killed
Dabbling ducks,coots	.0357
Geese	.0446
Swans	.0001
Diving ducks	65459.1000
Loons	8089.4380
Grebes	8561.4590
Small alcids	13143.4600
Cormorants, anhinga	6195.8270
Guillemots	4334.9300
Gulls	6134.7660
Murres	1464.8880
Terns	1.9294
Herons and egrets	.0128
Sandpipers, plovers	18.2150
Oystercatcher, stilt	.0027
Bald eagles	.0000
Kingfishers	.0000
Toothed whales	.0245
Sea lions	1.6357
Phocid seals	6.3546

Wildlife category	Number killed
Waterfowl	82110.0800
Seabirds	31275.8000
Wading birds	.0128
Shorebirds	18.2177
Raptors, kingfishers	.0000
Cetaceans	.0245
Pinnipeds (seals)	7.9904

Fishery species	kg adults killed	# YOY killed
Herring, sea	.0000	425.9684
Smelt	.0000	2.9684
Chinook or Barracuda	.0013	.0000
Chum salmon/Billfish	.0028	.0000

Coho salmon	.0023	.0000
Pink salmon or Bonit	.0041	.0000
Sockeye salmon	.0077	.0000
Cod	5.8638	154.3610
Dogfish	75.8518	8421.4220
Greenlings	6.2622	.8628
Halibut	.5498	.9227
Pollock	7.5086	182.5502
Rockfish	8.2339	.0000
Flounders	1.0588	.2410
Other groundfish	.9807	35.5039
Shrimp, Northern	.0020	145.5058
Clams, geoduck	495502.2000	345.1384
Sea urchins	176.7493	.0000

Fishery category	kg adults killed	# YOY killed
Small pelagic fish	.0000	428.9368
Large pelagic fish	.0182	.0000
Semi-demersal ground	104.2701	8760.1180
Demersal groundfish	2.0395	35.7450
Crustaceans	.0020	145.5058
Mollusks	495502.2000	345.1384
Other benthic invert	176.7493	.0000

Area swept by surface slicks: .186408E+11 m2 .407121E+10 m2-days

Shorelines oiled above lethal threshold,
by shoreline type (assuming no restoration performed):

Shore type	Length (m)	m-days	Area (m2)	m2-days
Sand Beach	.216658E+06	.578231E+08	.476647E+07	.127211E+10
Intertidal Wetland	.593072E+04	.138409E+07	.125138E+07	.292043E+09

1

6.1.3 Fate Analysis Summary

Figure 26 outlines the fate of the oil spilled in the east large spill scenario. Figure 27 show the trajectory of the oil during the spill. All results are from the NOAA NRDAM/CME.

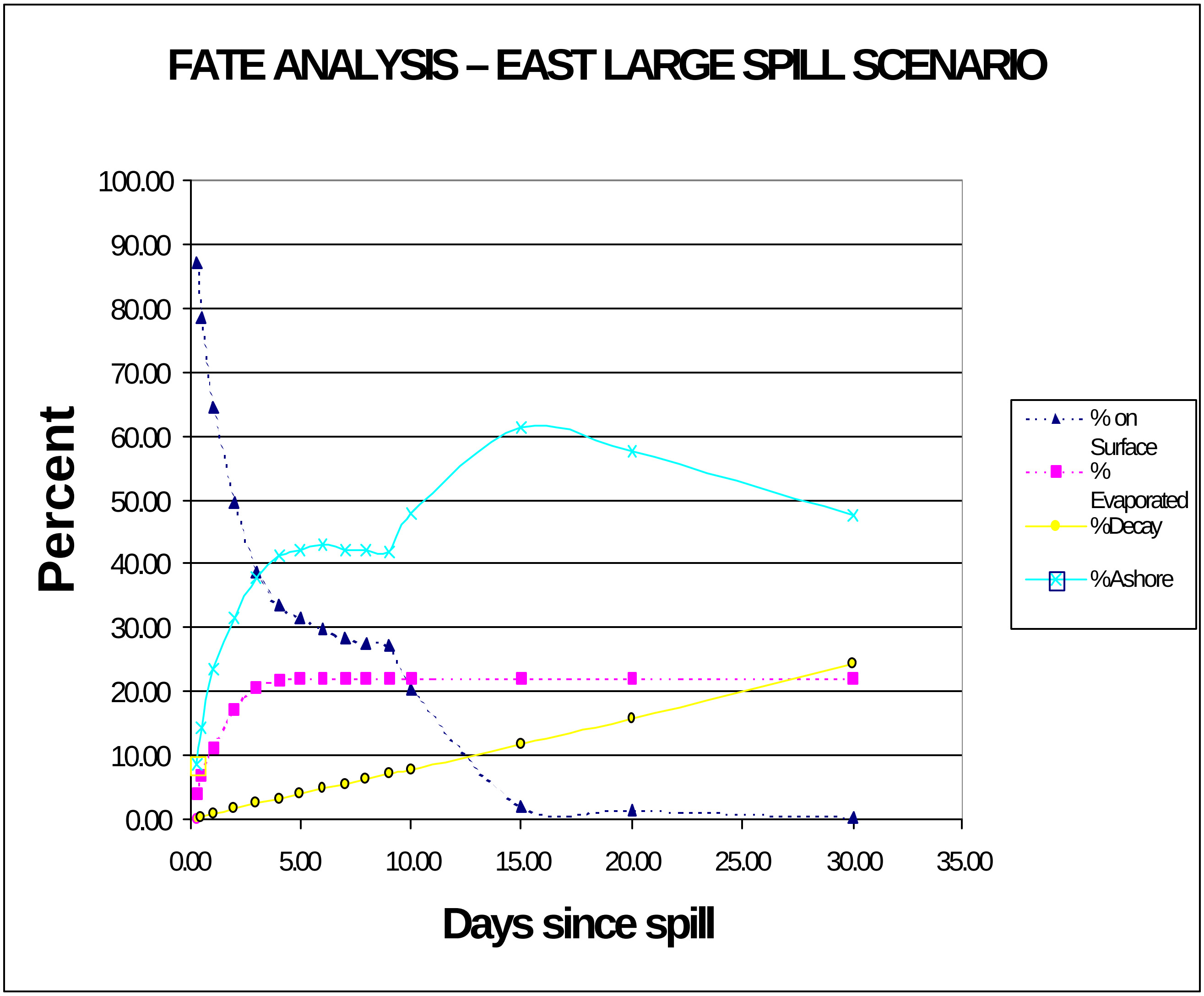


Figure 26 Fate Analysis Large Spill, East Location

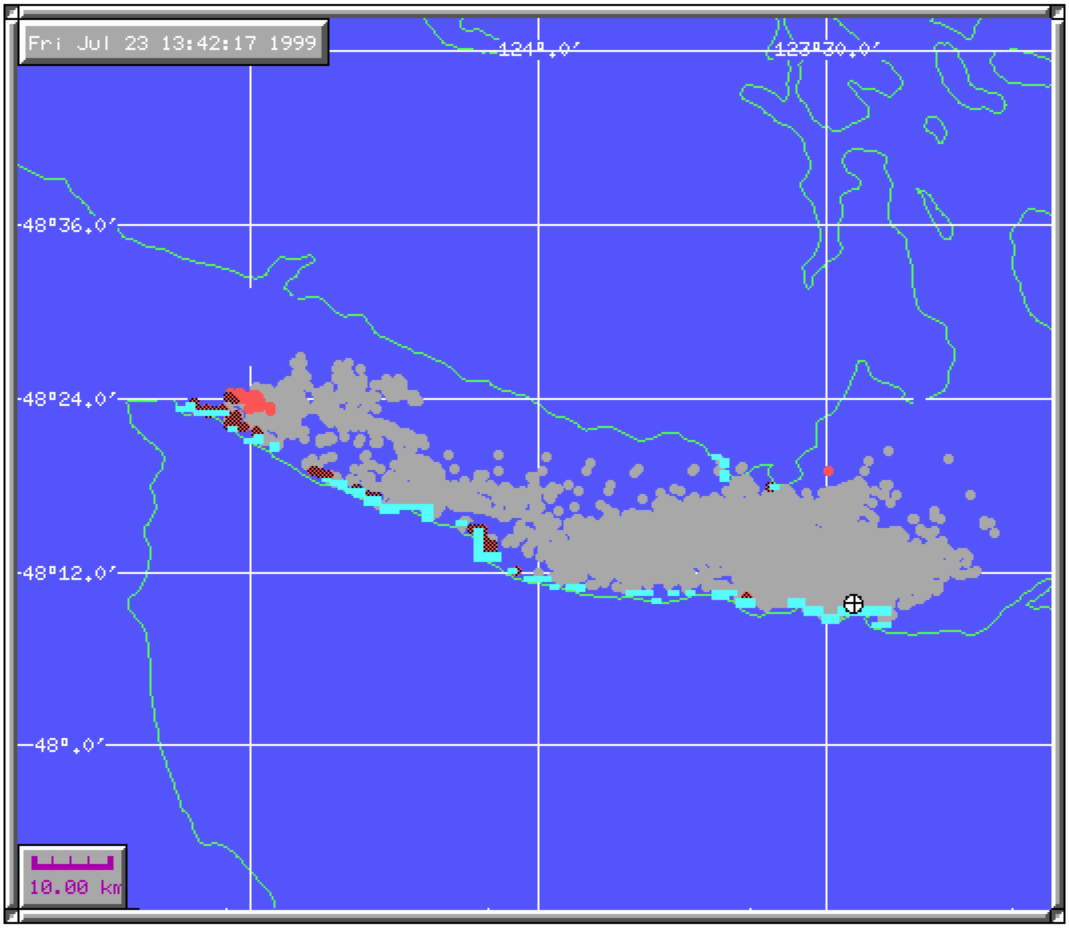


Figure 27 Plume Trajectory: Large Spill, East Location

6.2 Medium Spill, East Location

6.2.1 Summary Tables

Table 25, 26 and 27 summarize wildlife and fishery losses, as well as natural resource damages associated with the medium spill scenario in the east location. The information was obtained from the NOAA NRDAM/CME.

WILDLIFE CATEGORY	TOTAL NUMBER OF LOSSES
Waterfowl	27,994
Seabirds	10,115
Wading birds	--
Shorebirds	2
Raptors, kingfishers	--
Cetaceans	--
Pinnipeds (Seals)	2
Other mammals	--
Reptiles	--

Table 25 Summary of Wildlife Losses for the Eastern Medium Spill

FISHERY CATEGORY	KG ADULTS	NUMBER OF YOY
Small pelagic fish	--	53
Large pelagic fish	--	--
Semi-demersal ground	11	966
Demersal groundfish	--	4
Crustaceans	--	16
Cephalopods (squid)	--	--
Mollusks	54,666	37
Other benthic invert	20	--

Table 26 Summary of Fishery Losses for the Eastern Medium Spill

CATEGORY OF LOSS	DAMAGE IN 1998 US $
Catch	32,628
Hunting	132,576
Wildlife non-consumptive	199,955
Beach	658,197
Restoration cost-assimilative capacity	263
Total	1,023,619

Table 27 Damage Assessment Summary for the Eastern Medium Spill

6.2.2 NOAA NRDAM/CME Model Output

This section contains the NRDAM/CME report detailing the summary of total injury and damages resulting from the medium spill located near the eastern boundary of the study area.

```
        NRDA REPORT: SUMMARY OF TOTAL INJURY AND DAMAGES (1998 US $ )
                    Scenario: EAST MEDIUM SPILL SCEANRIO

  Spill date: Apr.  1, 1998
  Location:   48.165N,  123.449W
  Fuel Oil No. 6 (Bunker C) - Low Volatiles
         928.271 MT,  OIL #:      0  28  2


  ---------------------------------------------------------------------------
  Category                                    Without        Including
  Of Loss                                   Restoration     Restoration


  Wildlife killed (# animals)                   38112.8         38112.5
  Fishery stock killed (kg)                     54697.9         54697.9
  Fishery young-of-yr killed (# at 1yr)          1076.0          1076.0
  Lost catch (kg)                               16711.5         16711.5
  Lost #-years fish, shellfish                 451488.3        451488.3
  Lost hunting (# animals)                      15120.3         15120.3
  Lost #-years wildlife                        204003.0        204000.2

  Damages: catch (US $ )                        32628.          32628.
  Damages: hunting (US $ )                     132576.         132576.
  Damages: wildlife non-consumptive            199955.         199942.

  Damages: Total compensable value             365159.         365146.
    for fish and wildlife losses


  Beach damages:  all shorelines               658197.         658197.


  Damages: Total compensable value            1023357.        1023344.
    for all natural resource losses (US $ )



  Restoration costs for all habitats                                0.
  Restocking costs for all species                               1437.
  Restoration cost-assimilative capacity          263.            263.
    for a remaining mass (MT) of:             20.78014        20.78014


  Total compensable value and all             1023619.        1025043.
    estimated restoration costs (US $ )


  Habitat restoration plus restocking costs ($       1436.51)
    are more than    10. times the resulting reduction in
    compensable value ($     12.69)
    Habitat restoration and restocking are assumed not performed.
```

TOTAL DAMAGES ASSESSED (1998 US $) 1023619.

#	Habitat Type	Sediment or Habitat Area (m2) Toxic Long Term	Sedmnt.Replaced or Capped	Replanted Only
	Total	.00000E+00	.00000E+00	.00000E+00

TOTAL KILLS BY SPECIES AND BY CATEGORY, ASSUMING RESTORATION PERFORMED:

Wildlife species	Number killed
Dabbling ducks,coots	.0039
Geese	.0048
Swans	.0000
Diving ducks	22316.7800
Loons	2757.9110
Grebes	2918.8360
Small alcids	4480.9670
Cormorants, anhinga	2112.3270
Guillemots	1477.8970
Gulls	1543.7780
Murres	499.4206
Terns	.4855
Herons and egrets	.0014
Sandpipers, plovers	2.1006
Oystercatcher, stilt	.0003
Bald eagles	.0000
Kingfishers	.0000
Toothed whales	.0069
Sea lions	.4103
Phocid seals	1.5941

Wildlife category	Number killed
Waterfowl	27993.5400
Seabirds	10114.8800
Wading birds	.0014
Shorebirds	2.1009
Raptors, kingfishers	.0000
Cetaceans	.0069
Pinnipeds (seals)	2.0045

Fishery species	kg adults killed	# YOY killed
Herring, sea	.0000	52.3127
Smelt	.0000	.3637
Chinook or Barracuda	.0001	.0000
Chum salmon/Billfish	.0003	.0000

Coho salmon	.0002	.0000
Pink salmon or Bonit	.0004	.0000
Sockeye salmon	.0008	.0000
Cod	.6419	17.0300
Dogfish	8.3035	929.1016
Greenlings	.6855	.0949
Halibut	.0579	.1018
Pollock	.8220	20.1400
Rockfish	.9014	.0000
Flounders	.1159	.0266
Other groundfish	.1074	3.9170
Shrimp, Northern	.0002	16.1759
Clams, geoduck	54666.7600	36.7515
Sea urchins	19.5000	.0000

Fishery category	kg adults killed	# YOY killed
Small pelagic fish	.0000	52.6764
Large pelagic fish	.0019	.0000
Semi-demersal ground	11.4122	966.4683
Demersal groundfish	.2233	3.9436
Crustaceans	.0002	16.1759
Mollusks	54666.7600	36.7515
Other benthic invert	19.5000	.0000

Area swept by surface slicks: .200885E+10 m2 .461467E+09 m2-days

Shorelines oiled above lethal threshold,
by shoreline type (assuming no restoration performed):

Shore type	Length (m)	m-days	Area (m2)	m2-days
Sand Beach	.110460E+06	.191751E+08	.243011E+07	.421855E+09

1

6.2.3 Fate Analysis Summary

Figure 28 outlines the fate of the oil spilled in the east medium spill scenario. Figure 29 show the trajectory of the oil during the spill. All results are from the NOAA NRDAM/CME.

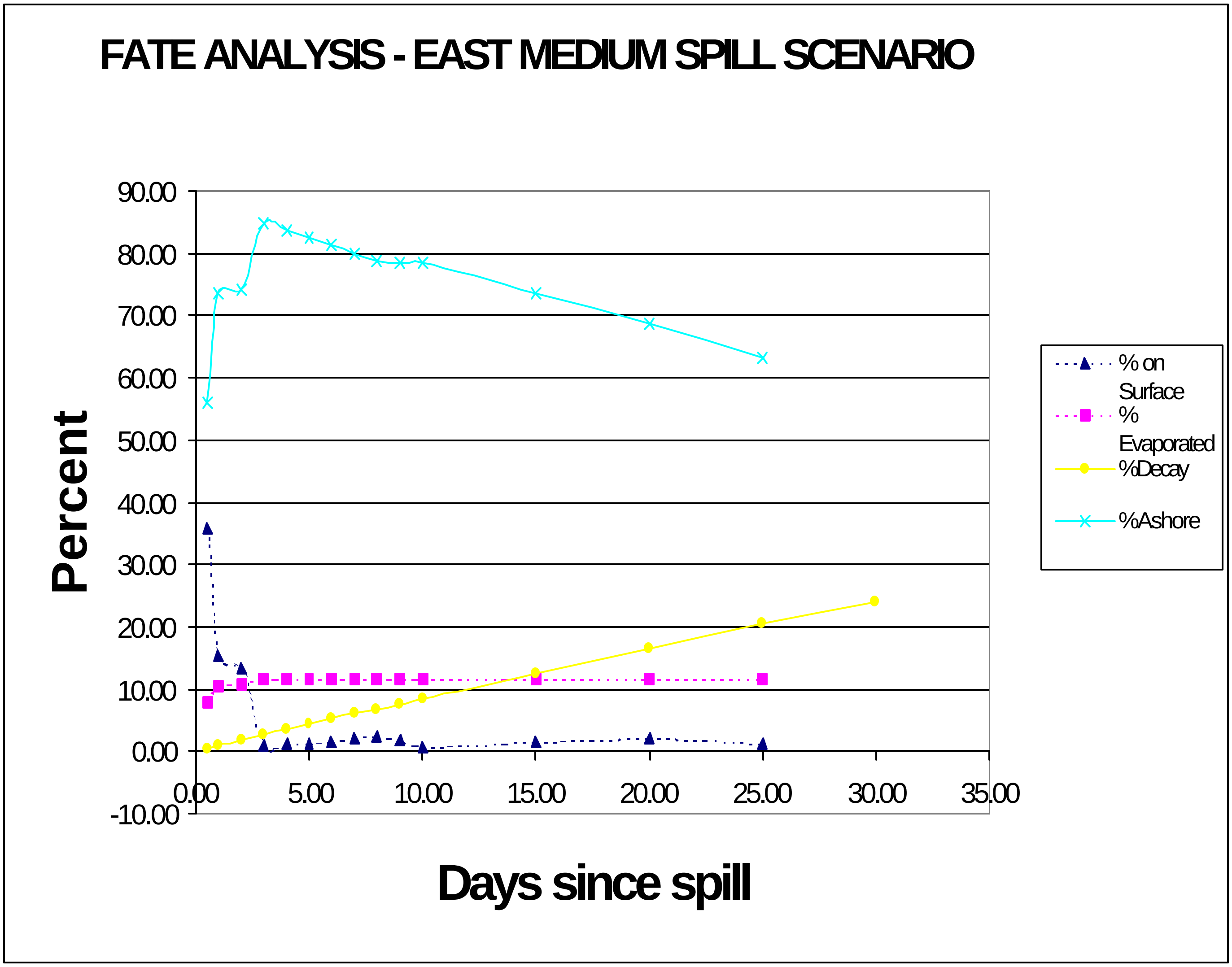


Figure 28 Fate Analysis Medium Spill, East Location

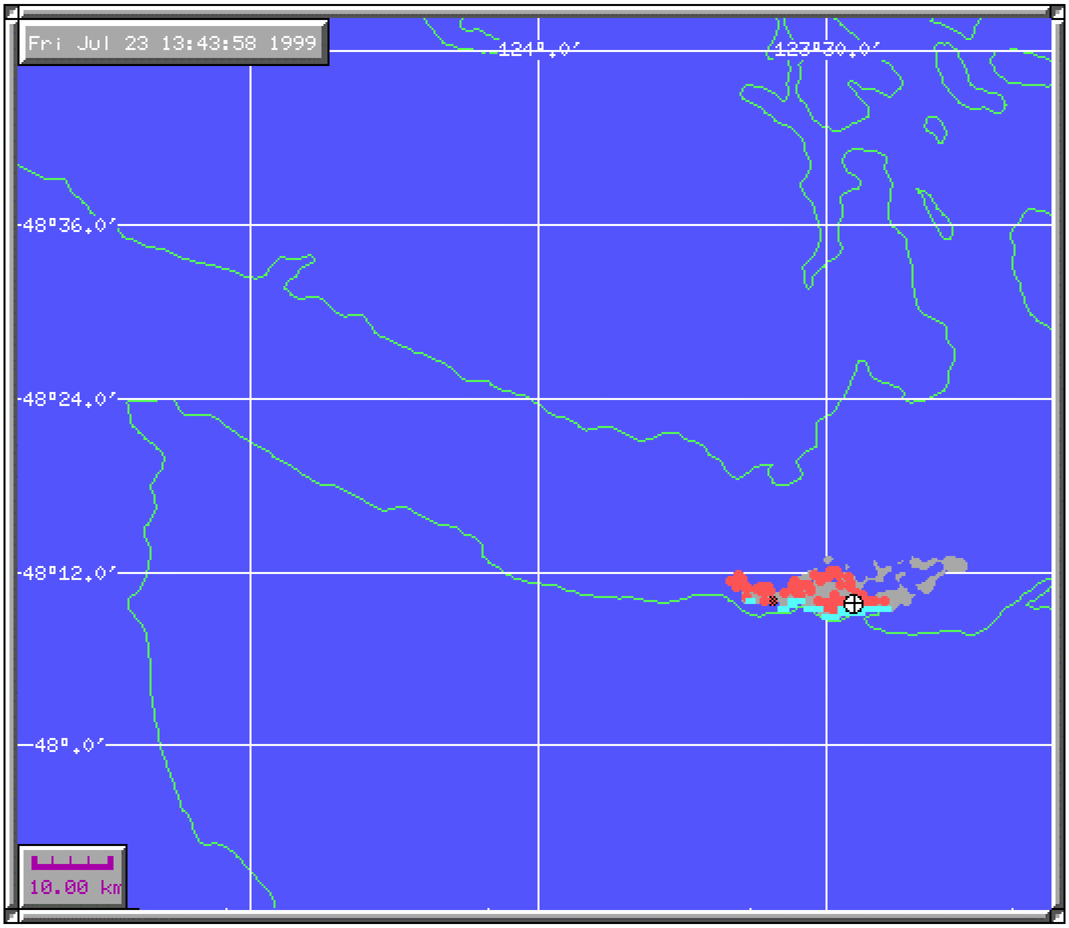


Figure 29 Plume Trajectory: Medium Spill, East Location

6.3 Small Spill, East Location

6.3.1 Summary Tables

Table 28 and 29 summarize wildlife and natural resource damages associated with the small spill scenario in the east location. The information was obtained from the NOAA NRDAM/CME.

WILDLIFE CATEGORY	TOTAL NUMBER OF LOSSES
Waterfowl	25,129
Seabirds	9,045
Wading birds	--
Shorebirds	--
Raptors, kingfishers	--
Cetaceans	--
Pinnipeds (Seals)	2
Other mammals	--
Reptiles	--

Table 28 Summary of Wildlife Losses for the Eastern Small Spill

CATEGORY OF LOSS	DAMAGE IN 1998 US $
Catch	3,545
Hunting	113,695
Wildlife non-consumptive	179,438
Beach	243,965
Restoration cost-assimilative capacity	87
Total	540,730

Table 29 Damage Assessment Summary for the Eastern Small Spill

6.3.2 NOAA NRDAM/CME Model Output

This section contains the NRDAM/CME report detailing the summary of total injury and damages resulting from the small spill located near the eastern boundary of the study area.

```
         NRDA REPORT: SUMMARY OF TOTAL INJURY AND DAMAGES (1998 US $ )
                      Scenario: EAST SMALL SPILL SCENARIO

  Spill date: Apr.  1, 1998
  Location:   48.165N,  123.449W
  Fuel Oil No. 6 (Bunker C) - Low Volatiles
         301.874 MT,  OIL #:      0  28  2


  ---------------------------------------------------------------------------
  Category                                    Without         Including
  Of Loss                                   Restoration     Restoration


  Wildlife killed (# animals)                    34175.8         34175.5
  Fishery stock killed (kg)                           .0              .0
```

Fishery young-of-yr killed (# at 1yr)	.0	.0
Lost catch (kg)	1675.9	1675.9
Lost #-years fish, shellfish	.0	.0
Lost hunting (# animals)	13386.9	13386.9
Lost #-years wildlife	182747.4	182745.1
Damages: catch (US $)	3545.	3545.
Damages: hunting (US $)	113695.	113695.
Damages: wildlife non-consumptive	179438.	179427.
Damages: Total compensable value for fish and wildlife losses	296678.	296666.
Beach damages: all shorelines	243965.	243965.
Damages: Total compensable value for all natural resource losses (US $)	540643.	540631.
Restoration costs for all habitats		0.
Restocking costs for all species		1259.
Restoration cost-assimilative capacity	87.	87.
for a remaining mass (MT) of:	6.87412	6.87412
Total compensable value and all estimated restoration costs (US $)	540730.	541978.

Habitat restoration plus restocking costs ($ 1259.46)
are more than 10. times the resulting reduction in
compensable value ($ 11.31)
Habitat restoration and restocking are assumed not performed.

TOTAL DAMAGES ASSESSED (1998 US $) 540730.

#	Habitat Type	Sediment or Habitat Area (m2) Toxic Long Term	Sedmnt.Replaced or Capped	Replanted Only
	Total	.00000E+00	.00000E+00	.00000E+00

TOTAL KILLS BY SPECIES AND BY CATEGORY, ASSUMING RESTORATION PERFORMED:

Wildlife species	Number killed
Diving ducks	20033.4200
Loons	2475.6600

Grebes	2620.1070
Small alcids	4023.0320
Cormorants, anhinga	1896.1550
Guillemots	1326.6390
Gulls	1350.0400
Murres	448.3068
Terns	.4246
Toothed whales	.0061
Fur seals	.0013
Sea lions	.3592
Phocid seals	1.3954
Sea otters	.0009

Wildlife category	Number killed
Waterfowl	25129.1800
Seabirds	9044.5980
Cetaceans	.0061
Pinnipeds (seals)	1.7558
Other mammals	.0009

Area swept by surface slicks: .508988E+09 m2 .169397E+09 m2-days

Shorelines oiled above lethal threshold,
by shoreline type (assuming no restoration performed):

Shore type	Length (m)	m-days	Area (m2)	m2-days
Sand Beach	.963743E+05	.118761E+08	.212023E+07	.261274E+09

1

6.3.3 Fate Analysis Summary

Figure 30 outlines the fate of the oil spilled in the east small spill scenario. Figure 31 show the trajectory of the oil during the spill. All results are from the NOAA NRDAM/CME.

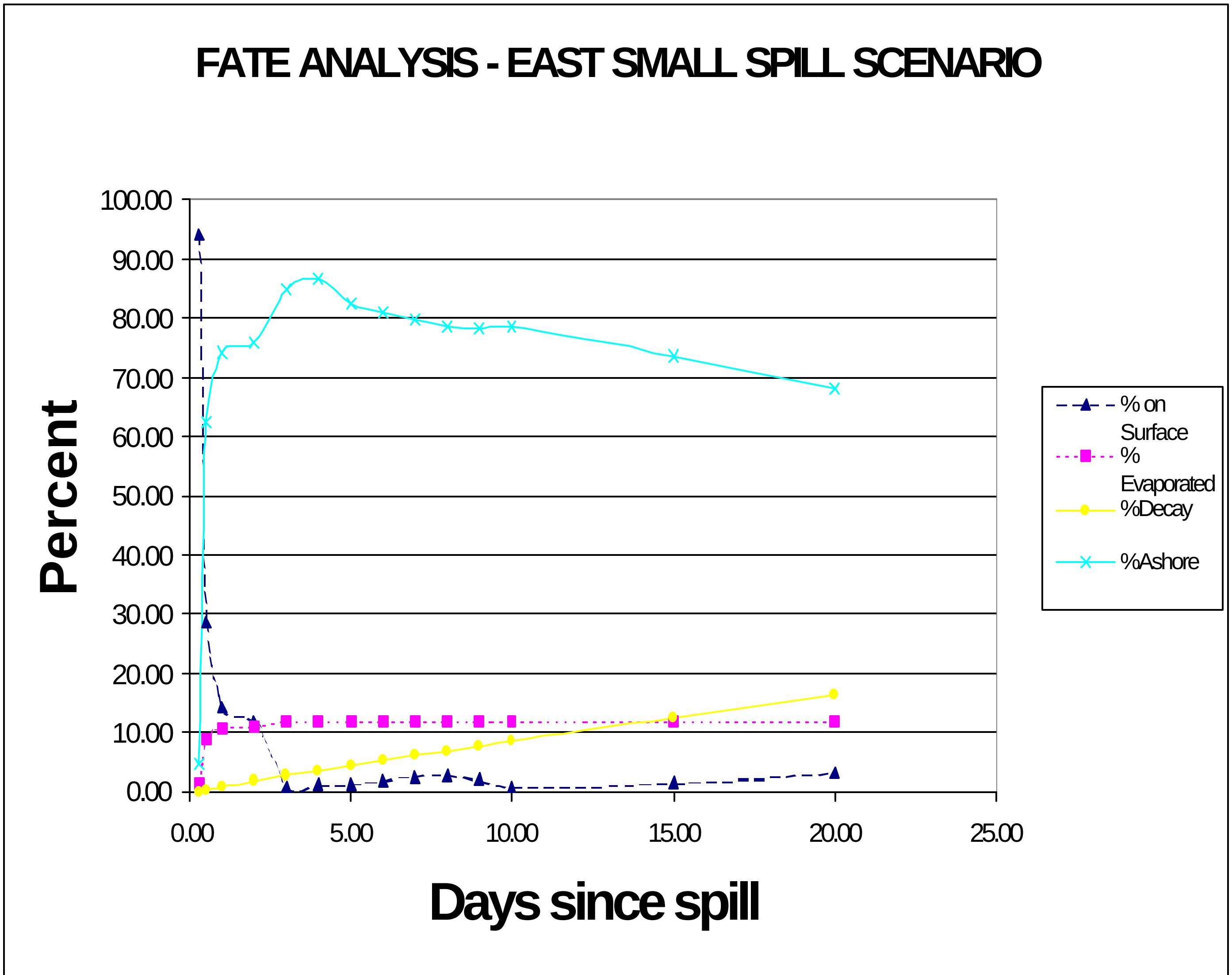


Figure 30 Fate Analysis Small Spill, East Location

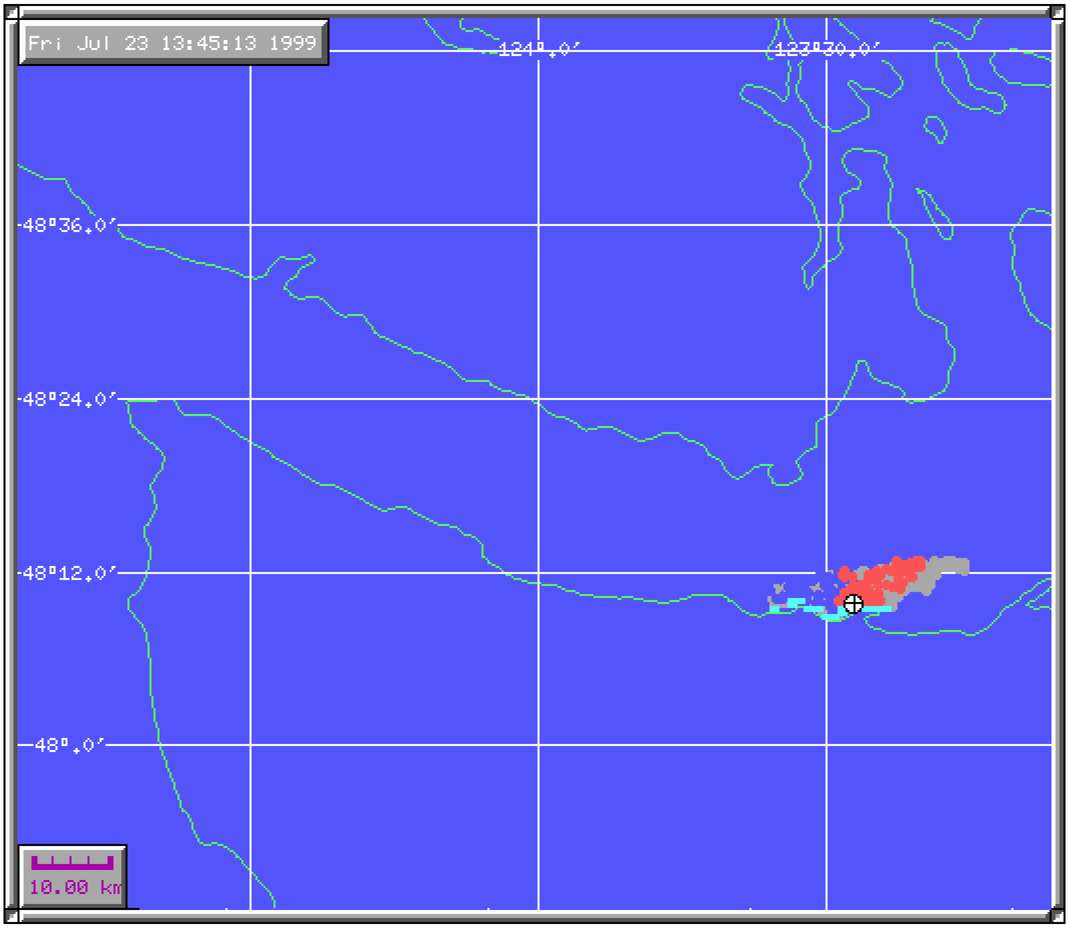


Figure 31 Plume Trajectory: Small Spill, East Location

6.4 Large Spill, West Location

6.4.1 Summary Tables

Table 30, 31 and 32 summarize wildlife and fishery losses, as well as natural resource damages associated with the large spill scenario in the west location. The information was obtained from the NOAA NRDAM/CME.

WILDLIFE CATEGORY	TOTAL NUMBER OF LOSSES
Waterfowl	3,655
Seabirds	3,874
Wading birds	13
Shorebirds	802
Raptors, kingfishers	6
Cetaceans	1
Pinnipeds (Seals)	10
Other mammals	6
Reptiles	--

Table 30 Summary of Wildlife Losses for the Western Large Spill

FISHERY CATEGORY	KG ADULTS	NUMBER OF YOY
Small pelagic fish	--	--
Large pelagic fish	--	--
Semi-demersal ground	2,305	499
Demersal groundfish	83	9
Crustaceans	32	41,792
Cephalopods (squid)	1,273	--
Mollusks	49	--
Other benthic invert	462	--

Table 31 Summary of Fishery Kills for the Western Large Spill

CATEGORY OF LOSS	DAMAGE IN 1998 US $
Catch	26,759
Hunting	138,376
Wildlife non-consumptive	40,750
Beach	4,841,182
Restoration cost-assimilative capacity	8,449
Total	5,055,516

Table 32 Damage Assessment Summary for the Western Large Spill

6.4.2 NOAA NRDAM/CME Model Output

This section contains the NRDAM/CME report detailing the summary of total injury and damages resulting from the large spill located near the western boundary of the study area.

```
        NRDA REPORT: SUMMARY OF TOTAL INJURY AND DAMAGES (1998 US $ )
                     Scenario: WEST LARGE SPILL SCENARIO

  Spill date: Apr.  1, 1998
  Location:   48.490N,  124.790W
  Alaskan North Slope Crude Oil
       12412.530 MT,  OIL #:      0   8  1


  ---------------------------------------------------------------------------
  Category                                  Without        Including
  Of Loss                                  Restoration     Restoration


  Wildlife killed (# animals)                   8383.5          8367.1
  Fishery stock killed (kg)                     4205.1          4205.1
  Fishery young-of-yr killed (# at 1yr)        42299.5         42299.5
  Lost catch (kg)                              25630.4         25630.4
  Lost #-years fish, shellfish                622551.6        622551.6
  Lost hunting (# animals)                      9717.7          9717.6
  Lost #-years wildlife                        42770.5         42698.1

  Damages: catch (US $ )                       26759.          26759.
  Damages: hunting (US $ )                    138376.         138375.
  Damages: wildlife non-consumptive            40750.          37922.

  Damages: Total compensable value            205884.         203056.
    for fish and wildlife losses


  Beach damages:  all shorelines             4841182.        4841182.


  Damages: Total compensable value           5047067.        5044238.
    for all natural resource losses (US $ )



  Restoration costs for all habitats                               0.
  Restocking costs for all species                             30459.
  Restoration cost-assimilative capacity        8449.           8449.
    for a remaining mass (MT) of:           339.10900       339.10900


  Total compensable value and all            5055516.        5083146.
    estimated restoration costs (US $ )


  Habitat restoration plus restocking costs ($       30458.79)
    are more than    10. times the resulting reduction in
    compensable value ($   2829.00)
```

Habitat restoration and restocking are assumed not performed.

TOTAL DAMAGES ASSESSED (1998 US $) 5055516.

	Sediment or Habitat Area (m2)		
# Habitat Type	Toxic Long Term	Sedmnt.Replaced or Capped	Replanted Only
Total	.00000E+00	.00000E+00	.00000E+00

TOTAL KILLS BY SPECIES AND BY CATEGORY, ASSUMING RESTORATION PERFORMED:

Wildlife species	Number killed
Dabbling ducks,coots	.1677
Geese	.0251
Swans	.0008
Diving ducks	3585.7130
Loons	55.9441
Grebes	13.6080
Albatroses	3.9792
Small alcids	3541.1080
Cormorants, anhinga	89.2081
Gulls	33.3041
Kittiwakes	.4325
Shearwaters, fulmers	158.8210
Storm petrels	3.8062
Terns	43.1784
Herons and egrets	12.9551
Sandpipers, plovers	800.5850
Oystercatcher, stilt	1.5601
Kingfishers	5.5269
Baleen whales	.0247
Toothed whales	.0007
Dolphins, porpoises	1.0196
Fur seals	8.3245
Sea lions	.1695
Phocid seals	1.9782
Sea otters	5.6108

Wildlife category	Number killed
Waterfowl	3655.4580
Seabirds	3873.8380
Wading birds	12.9551
Shorebirds	802.1451
Raptors, kingfishers	5.5269
Cetaceans	1.0449
Pinnipeds (seals)	10.4722
Other mammals	5.6108

Fishery species	kg adults killed	# YOY killed
Jacks	.5696	.0000
Chinook or Barracuda	.0084	.0000
Chum salmon/Billfish	.0266	.0000
Coho salmon	.0150	.0000
Pink salmon or Bonit	.0392	.0000
Sockeye salmon	.0740	.0000
Cod	15.3065	97.7177
Dogfish	10.6059	326.6833
Greenlings	52.4908	1.5940
Halibut	1.0289	.4006
Pollock	13.2206	72.7668
Ocean perch	8.5326	.0000
Rockfish	651.6006	.0000
Sablefish	212.4114	.0000
Temperate bass/trout	7.8295	.0000
Whiting	1331.9110	.0000
Flounders	83.1222	.9638
Other groundfish	.0000	7.6506
Crab, dungeness	14.9619	.0000
Shrimp, Northern	17.2899	41791.7100
Squid	1273.0970	.0000
Scallops	49.1934	.0000
Sea urchins	461.7618	.0000

Fishery category	kg adults killed	# YOY killed
Large pelagic fish	.7329	.0000
Semi-demersal ground	2304.9380	499.1625
Demersal groundfish	83.1222	8.6144
Crustaceans	32.2518	41791.7100
Cephalopods (squid)	1273.0970	.0000
Mollusks	49.1934	.0000
Other benthic invert	461.7618	.0000

Area swept by surface slicks: .107656E+11 m2 .151247E+10 m2-days

Shorelines oiled above lethal threshold,
by shoreline type (assuming no restoration performed):

Shore type	Length (m)	m-days	Area (m2)	m2-days
Sand Beach	.127418E+06	.328955E+08	.280319E+07	.723701E+09

1

6.4.3 Fate Analysis Summary

Figure 32 outlines the fate of the oil spilled in the west large spill scenario. Figure 33 show the trajectory of the oil during the spill. All results are from the NOAA NRDAM/CME.

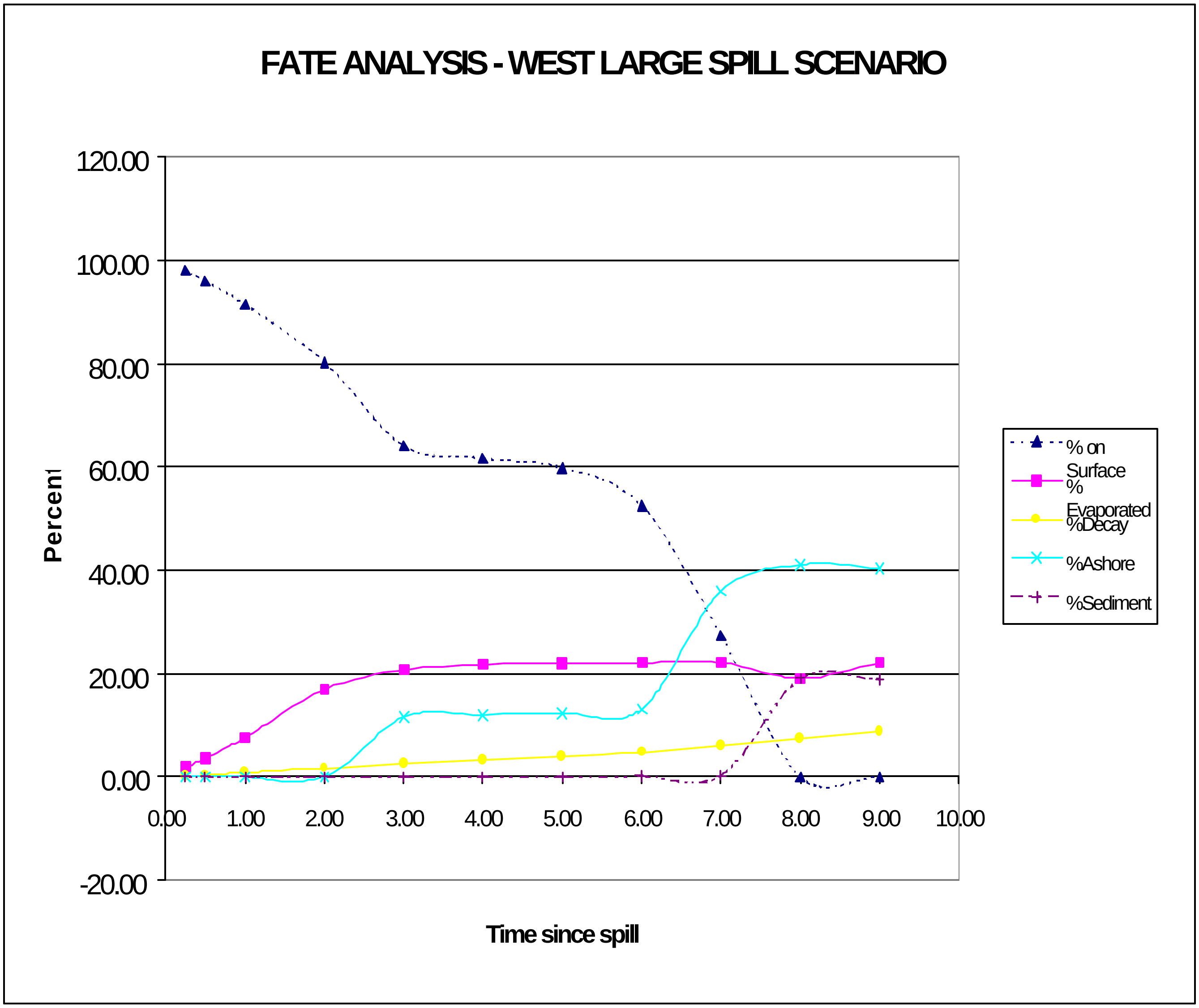


Figure 32 Fate Analysis Large Spill, West Location

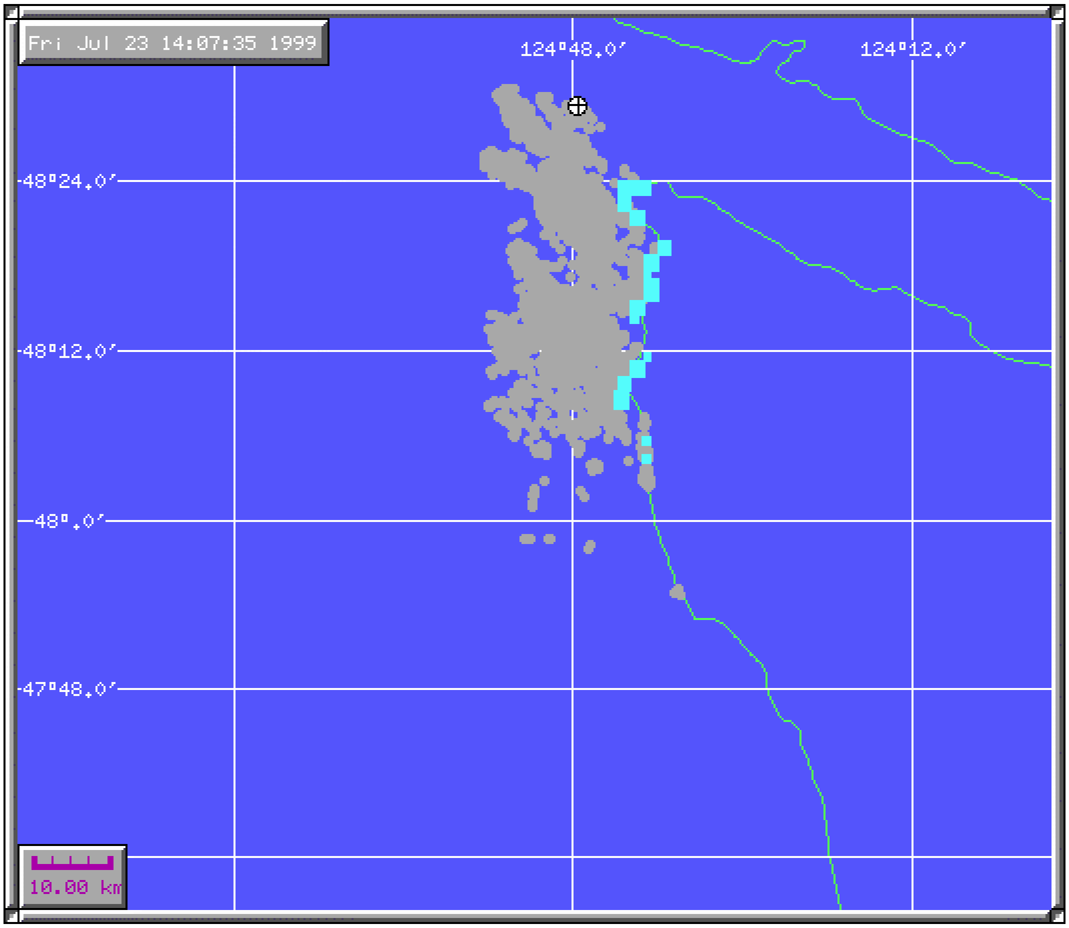


Figure 33 Plume Trajectory: Large Spill, West Location

6.5 Medium Spill, West Location

6.5.1 Summary Tables

Table 33 and 34 summarize wildlife and natural resource damages associated with the medium spill scenario in the west location. The information was obtained from the NOAA NRDAM/CME.

WILDLIFE CATEGORY	TOTAL NUMBER OF KILLS
Waterfowl	3,752
Seabirds	4,023
Wading birds	4
Shorebirds	258
Raptors, kingfishers	1
Cetaceans	--
Pinnipeds (Seals)	13
Other mammals	6
Reptiles	--

Table 33 Summary of Wildlife Losses for the Western Medium Spill

CATEGORY OF LOSS	DAMAGE IN 1998 US $
Catch	10,750
Hunting	20,210
Wildlife non-consumptive	36,431
Beach	432,869
Restoration cost-assimilative capacity	--
Total	500,259

Table 34 Damage Assessment Summary for the Western Medium Spill

6.5.2 NOAA NRDAM/CME Model Output

This section contains the NRDAM/CME report detailing the summary of total injury and damages resulting from the medium spill located near the western boundary of the study area.

```
         NRDA REPORT: SUMMARY OF TOTAL INJURY AND DAMAGES (1998 US $ )
                     Scenario: WEST MEDIUM SPILL SCENARIO

  Spill date: Apr.  1, 1998
  Location:   48.490N,  124.790W
  Fuel Oil No. 6 (Bunker C) - Low Volatiles
         928.271 MT,  OIL #:      0  28  2

---------------------------------------------------------------------------
  Category                                    Without        Including
  Of Loss                                   Restoration     Restoration


  Wildlife killed (# animals)                     8064.7         8057.2
```

Fishery stock killed (kg)	.0	.0
Fishery young-of-yr killed (# at 1yr)	.0	.0
Lost catch (kg)	9761.8	9761.8
Lost #-years fish, shellfish	.0	.0
Lost hunting (# animals)	2435.5	2435.5
Lost #-years wildlife	40956.1	40909.7
Damages: catch (US $)	10750.	10750.
Damages: hunting (US $)	20210.	20210.
Damages: wildlife non-consumptive	36431.	33944.
Damages: Total compensable value for fish and wildlife losses	67391.	64903.
Beach damages: all shorelines	432869.	432869.
Damages: Total compensable value for all natural resource losses (US $)	500259.	497772.
Restoration costs for all habitats		0.
Restocking costs for all species		28800.
Restoration cost-assimilative capacity	0.	0.
for a remaining mass (MT) of:	.00076	.00076
Total compensable value and all estimated restoration costs (US $)	500259.	526571.

Habitat restoration plus restocking costs ($ 28799.72)
are more than 10. times the resulting reduction in
compensable value ($ 2487.56)
Habitat restoration and restocking are assumed not performed.

TOTAL DAMAGES ASSESSED (1998 US $) 500259.

#	Habitat Type	Sediment or Habitat Area (m2) Toxic Long Term	Sedmnt.Replaced or Capped	Replanted Only
	Total	.00000E+00	.00000E+00	.00000E+00

TOTAL KILLS BY SPECIES AND BY CATEGORY, ASSUMING RESTORATION PERFORMED:

Wildlife species	Number killed
Diving ducks	3680.0570
Loons	57.6752
Grebes	13.9661
Albatroses	3.8838

Small alcids	3670.7340
Cormorants, anhinga	92.1600
Gulls	32.5057
Kittiwakes	.4222
Murres	6.9108
Phalaropes	15.1174
Shearwaters, fulmers	155.0143
Storm petrels	3.7149
Terns	42.1435
Herons and egrets	4.1933
Sandpipers, plovers	257.1236
Oystercatcher, stilt	.5036
Kingfishers	1.7890
Baleen whales	.0189
Toothed whales	.0005
Dolphins, porpoises	.7819
Fur seals	10.6670
Sea lions	.1650
Phocid seals	1.9259
Sea otters	5.6944

Wildlife category	Number killed
Waterfowl	3751.6980
Seabirds	4022.6070
Wading birds	4.1933
Shorebirds	257.6272
Raptors, kingfishers	1.7890
Cetaceans	.8014
Pinnipeds (seals)	12.7579
Other mammals	5.6944

Area swept by surface slicks: .276184E+10 m2 .658158E+09 m2-days

Shorelines oiled above lethal threshold,
by shoreline type (assuming no restoration performed):

Shore type	Length (m)	m-days	Area (m2)	m2-days
Sand Beach	.733917E+05	.138198E+08	.161462E+07	.304030E+09

1

6.5.3 Fate Analysis Summary

Figure 34 outlines the fate of the oil spilled in the west medium spill scenario. Figure 35 show the trajectory of the oil during the spill. All results are from the NOAA NRDAM/CME.

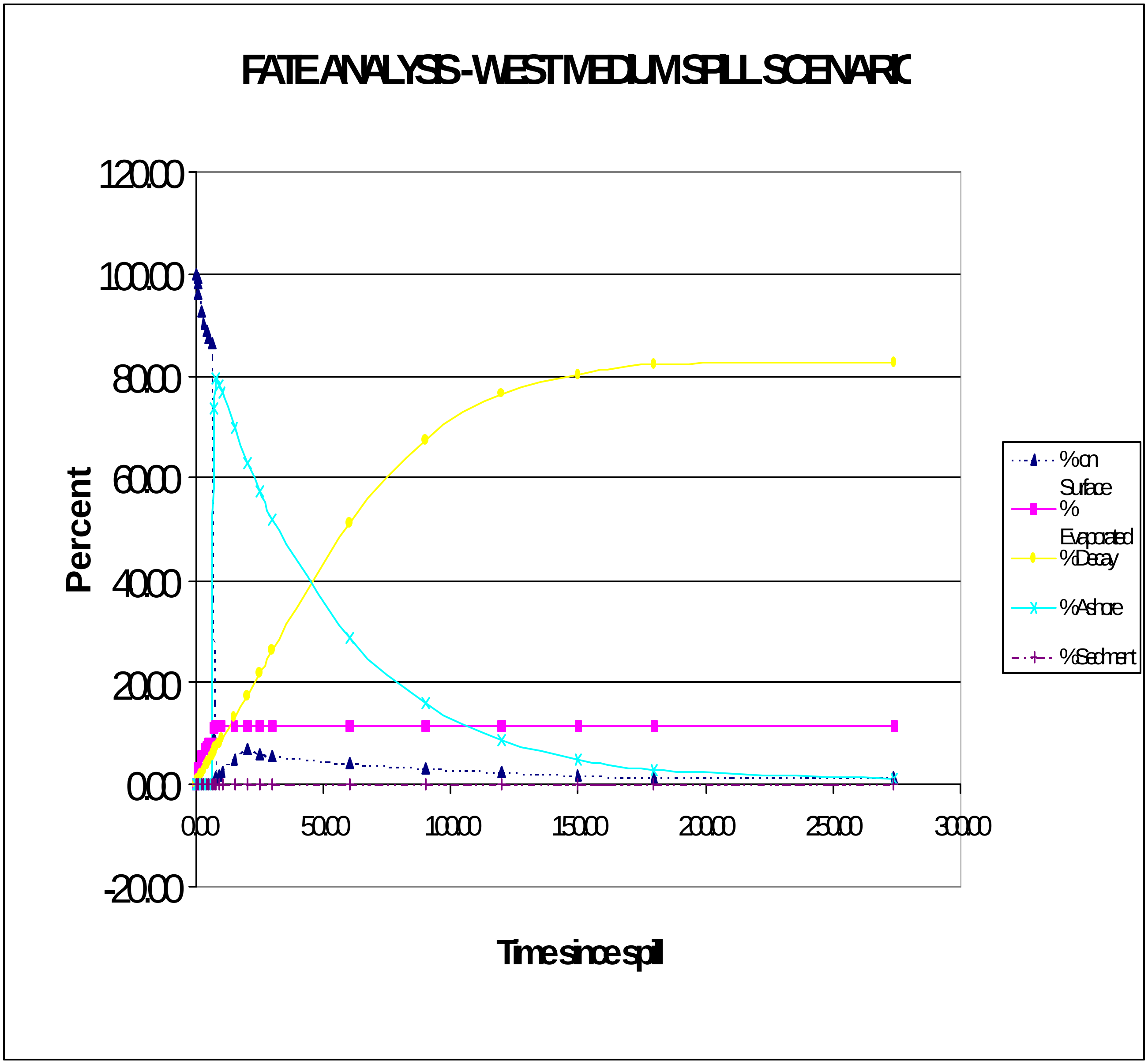


Figure 34 Fate Analysis Medium Spill, West Location

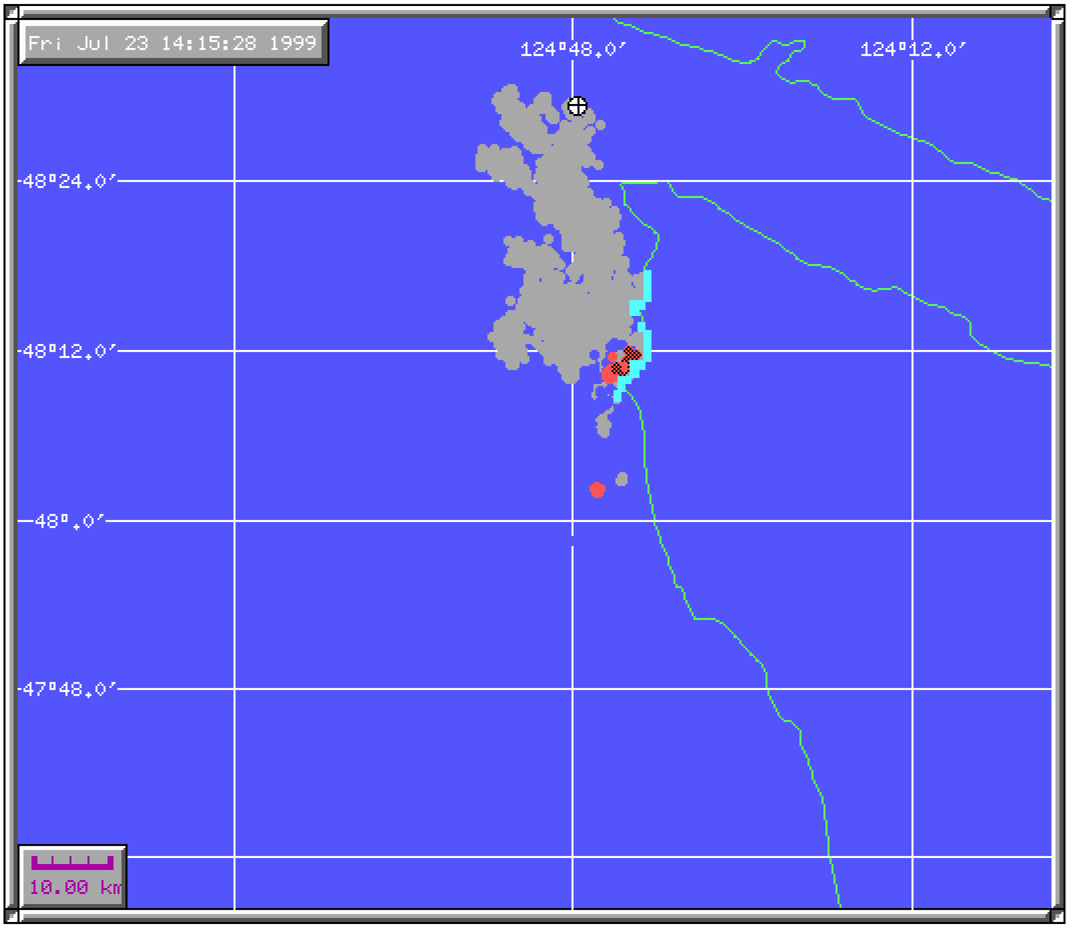


Figure 35 Plume Trajectory: Medium Spill, West Location

6.6 Small Spill, West Location

6.6.1 Summary Tables

Table 35 and 36 summarize wildlife and natural resource damages associated with the small spill scenario in the west location. The information was obtained from the NOAA NRDAM/CME.

WILDLIFE CATEGORY	TOTAL NUMBER OF LOSSES
Waterfowl	3,286
Seabirds	3,577
Wading birds	7
Shorebirds	349
Raptors, kingfishers	3
Cetaceans	--
Pinnipeds (Seals)	13
Other mammals	5
Reptiles	--

Table 35 Summary of Wildlife Losses for the Western Small Spill

CATEGORY OF LOSS	DAMAGE IN 1998 US $
Catch	13,195
Hunting	17,702
Wildlife non-consumptive	33,774
Beach	94,028
Restoration cost-assimilative capacity	--
Total	158,699

Table 36 Damage Assessment Summary for the Western Small Spill

6.6.2 NOAA NRDAM/CME Model Output

This section contains the NRDAM/CME report detailing the summary of total injury and damages resulting from the small spill located near the western boundary of the study area.

```
         NRDA REPORT: SUMMARY OF TOTAL INJURY AND DAMAGES (1998 US $ )
                    Scenario: WEST MEDIUM SPILL SCENARIO

 Spill date: Apr.  1, 1998
 Location:   48.490N,  124.790W
 Fuel Oil No. 6 (Bunker C) - Low Volatiles
        301.874 MT,  OIL #:      0  28  2


 ---------------------------------------------------------------------------
 Category                                    Without        Including
 Of Loss                                   Restoration     Restoration


 Wildlife killed (# animals)                     7250.6         7240.4
```

Fishery stock killed (kg)	.0	.0
Fishery young-of-yr killed (# at 1yr)	.0	.0
Lost catch (kg)	8947.6	8947.6
Lost #-years fish, shellfish	.0	.0
Lost hunting (# animals)	2133.6	2133.6
Lost #-years wildlife	36971.6	36917.0
Damages: catch (US $)	13195.	13195.
Damages: hunting (US $)	17702.	17702.
Damages: wildlife non-consumptive	33774.	31464.
Damages: Total compensable value for fish and wildlife losses	64671.	62361.
Beach damages: all shorelines	94028.	94028.
Damages: Total compensable value for all natural resource losses (US $)	158699.	156389.
Restoration costs for all habitats		0.
Restocking costs for all species		28474.
Restoration cost-assimilative capacity	0.	0.
for a remaining mass (MT) of:	.00056	.00056
Total compensable value and all estimated restoration costs (US $)	158699.	184863.

Habitat restoration plus restocking costs ($ 28474.37)
are more than 10. times the resulting reduction in
compensable value ($ 2310.00)
Habitat restoration and restocking are assumed not performed.

TOTAL DAMAGES ASSESSED (1998 US $) 158699.

Habitat # Type	Sediment or Habitat Area (m2) Toxic Long Term	Sedmnt.Replaced or Capped	Replanted Only
Total	.00000E+00	.00000E+00	.00000E+00

TOTAL KILLS BY SPECIES AND BY CATEGORY, ASSUMING RESTORATION PERFORMED:

Wildlife species	Number killed
Diving ducks	3223.3790
Loons	50.7701
Grebes	12.2526
Albatroses	3.4585

Small alcids	3250.1810
Cormorants, anhinga	81.2895
Gulls	28.0213
Kittiwakes	.3634
Murres	12.3693
Phalaropes	27.0578
Shearwaters, fulmers	134.3738
Storm petrels	3.8941
Terns	36.2811
Herons and egrets	6.5889
Sandpipers, plovers	347.7596
Oystercatcher, stilt	.7913
Kingfishers	2.8110
Baleen whales	.0160
Toothed whales	.0005
Dolphins, porpoises	.6621
Fur seals	11.3921
Sea lions	.1392
Phocid seals	1.6239
Sea otters	4.9729

Wildlife category	Number killed
Waterfowl	3286.4020
Seabirds	3577.2900
Wading birds	6.5889
Shorebirds	348.5508
Raptors, kingfishers	2.8110
Cetaceans	.6786
Pinnipeds (seals)	13.1552
Other mammals	4.9729

Area swept by surface slicks: .162950E+10 m2 .386065E+09 m2-days

Shorelines oiled above lethal threshold,
by shoreline type (assuming no restoration performed):

Shore type	Length (m)	m-days	Area (m2)	m2-days
Sand Beach	.374974E+05	.689499E+07	.824944E+06	.151688E+09

1

6.6.3 Fate Analysis Summary

Figure 36 outlines the fate of the oil spilled in the west small spill scenario. Figure 37 show the trajectory of the oil during the spill. All results are from the NOAA NRDAM/CME.

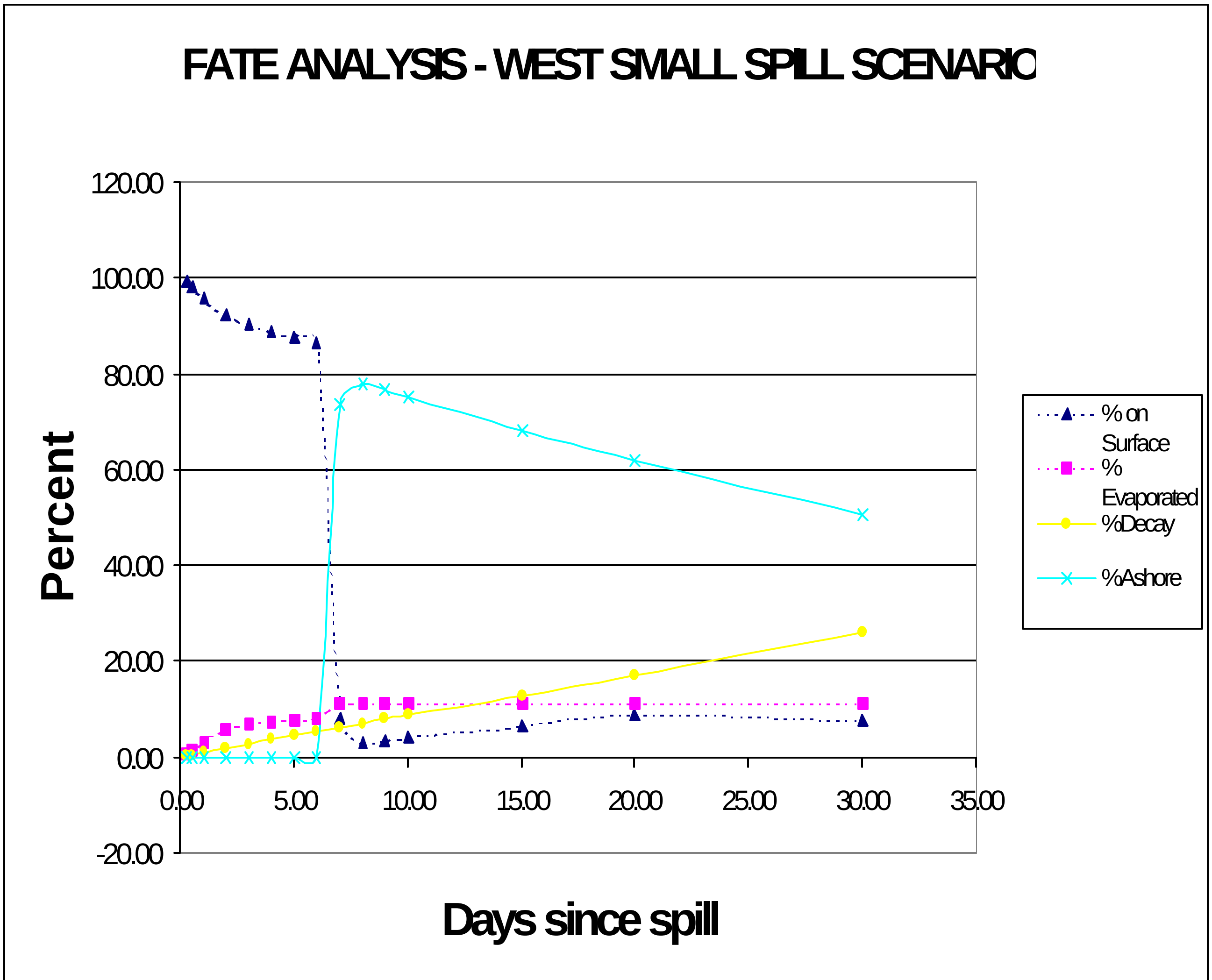


Figure 36 Fate Analysis Small Spill, West Location

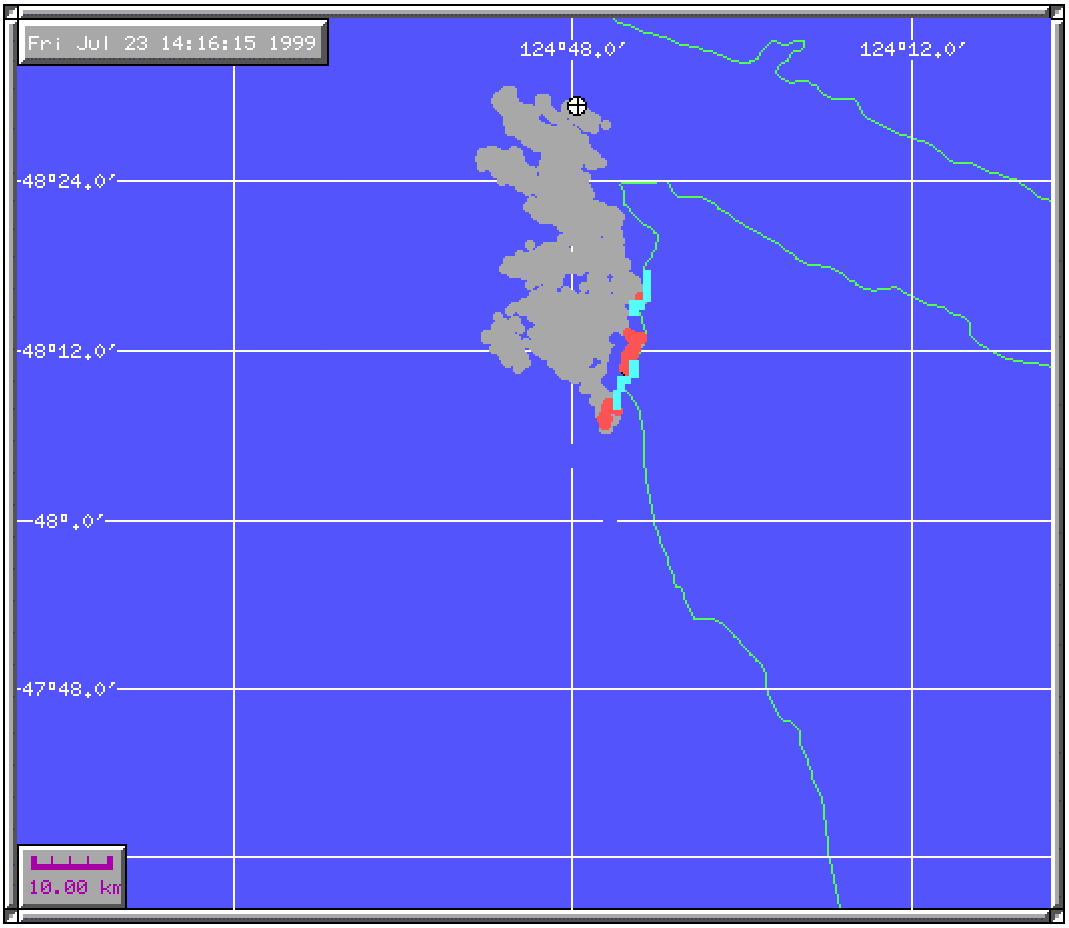


Figure 37 Plume Trajectory: Small Spill, West Location

6.7 NRDAM/CME WASHINGTON BIOLOGICAL GRID

Figure 38 outlines the biological grid breakout used by the NOAA NRDAM/CME in the study area.

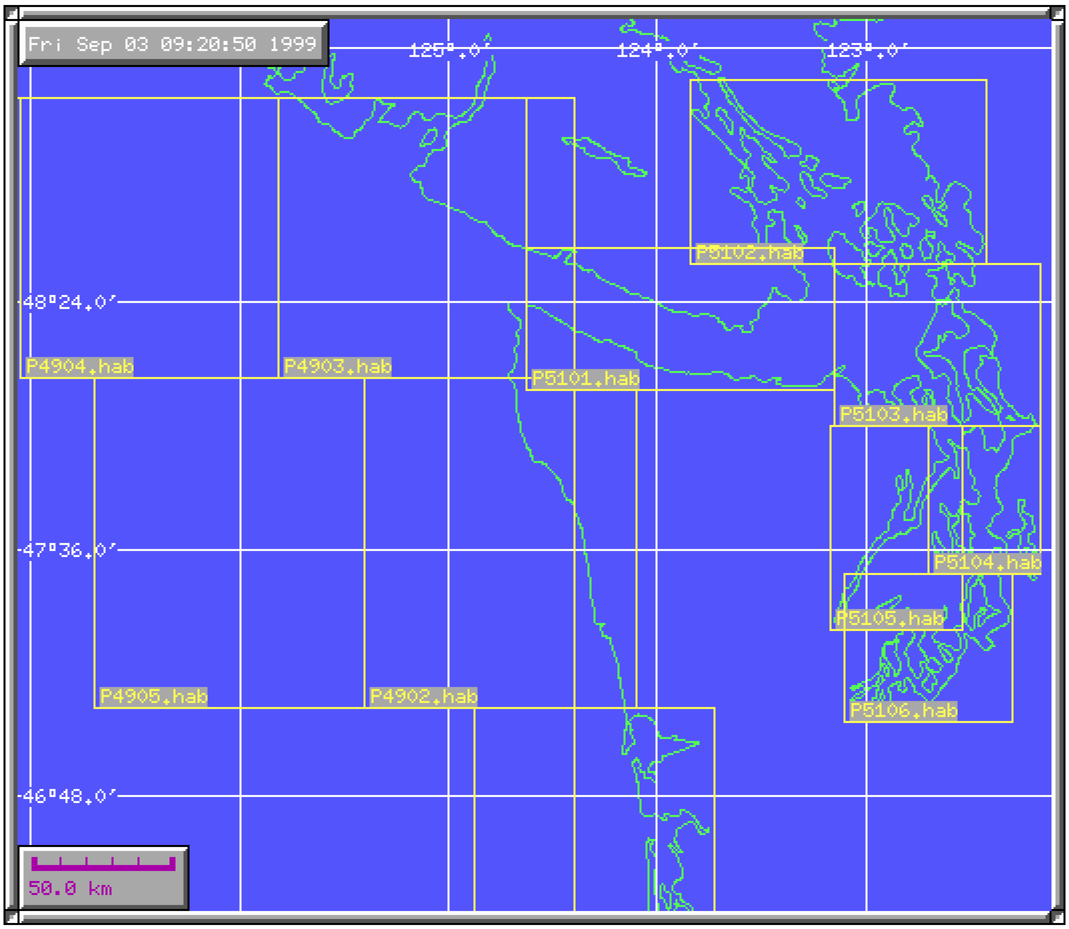


Figure 38 NOAA NRDAM/CME Biological Grid System

7 OIL SPILL COMPENSATION SCHEDULE RESULTS

Table 37 summarize the results for all six spill scenarios, the total damage, as well as damage per gallon are listed. The following sections show the Washington State DOE OSCS analysis for the scenarios.

SPILL SCENARIO	TOTAL DAMAGE ($)	DAMGE PER GALLON ($/GAL)
Large Spill, East Boundary	119,747,561	31.51
Medium Spill, East Boundary	10,240,568	40.96
Small Spill, East Boundary	3,327,949	40.93
Large Spill, West Boundary	136,014,711	35.79
Medium Spill, West Boundary	11,676,630	46.71
Small Spill, West Boundary	3,796,920	46.70

Table 37 OSCS Results Summary

7.1 Large Spill, East Location

Marine/Estuarine Compensation Schedule - excluding Columbia River Estuary
Rescue Tug Risk Assessment

Spill date	*Table Zone*	*Waterbody affected*	*Location*	*Amount Spilled (g)*	*Product Type*	*24 Hour Recovery(g)*
4/1/98	303	Strait of Juan de Fuca	Port Angeles	3,800,000	Crude	0

HABITAT VULNERABILITY (HVS)

	Marine Intertidal (MI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
MI-1	Exposed & semi-exposed rocky shores	0.5	3.7	4.3	3.1
MI-1	Exposed & semi-exposed rocky shores (kelp/eelgrass)	1.4	5.55	6.45	4.65
MI-2	Semi-exp. cobble & mixed coarse beaches	0.4	3.2	3.2	3.2
MI-2	Semi-exp. cobble & mixed coarse beaches (kelp/eelgrass)	0.2	4.8	4.8	4.8
MI-3	Semi-exposed gravel beaches	1.2	3.2	1.4	2.0
MI-3	Semi-exposed gravel beaches (kelp/eelgrass)	2.6	4.8	2.1	3.0
MI-4	Exposed sandy beaches	0.2	2.9	1.3	1.8
MI-4	Exposed sandy beaches (kelp/eelgrass)	1.4	4.35	1.95	2.7
MI-5	Protected rocky shores	0.9	3.0	3.5	3.0
MI-6	Protected mud flats	0.1	3.8	2.7	4.3

Marine Subtidal (MS) Habitats

		Percent	Oil(ac)	Oil(mech)	Oil(pers)
MS-1	Shallow subtidal rock & boulder (kelp/eelgrass)	0	5.55	5.55	4.65
MS-1	Shallow subtidal rock and boulder	0	3.7	3.7	3.1
MS-3	Deep subtidal cobble & mixed coarse	0	1.5	2.2	2.2
MS-4	Shallow subtidal mixed-coarse to mixed fine	0	3.6	3.6	3.6
MS-5	Shallow subtidal gravel or mixed fine	0	2.8	1.6	2.3
MS-6	Deep subtidal sand	0	1.6	2	1.6
MS-7	Deep subtidal mixed-fine	0	1.5	2.6	3.1
MS-8	Deep subtidal mud	0	2	2	3.2
MS-9	Open water	91.1	5	3.2	2.2
	Estuarine Intertidal (EI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
EI-1	Open rocky shores		3	3.5	3
EI-1	Open rocky shores (k/eg)		4.5	5.25	4.5
EI-2	Open mixed-coarse beaches & low marsh		3.7	3.2	3.2
EI-2	Open mixed-coarse beaches & low marsh (k/eg)		5.55	4.8	4.8
EI-3	Open gravel beaches		3.4	1.5	2.2
EI-4	Open sandy beaches		3.3	2.8	2.3
EI-4	Open sandy beaches (k/eg)		4.95	4.2	3.45
EI-5	Sandy low marshes		3.5	3	3
EI-6	Mixed-fine beaches and low marshes		4.3	4.3	4.3
EI-7	Saline lagoons		3.7	3.7	4.1
EI-8	Low-salinity lagoons		3	3.5	3.9
EI-9	Mud flats		3.7	2.6	4.1
EI-9	Mud flats (kelp/eelgrass)		5.55	3.9	6.15
EI-10	High salt marshes		3	3.5	3.9
EI-11	Transition zone wetlands		3	3.5	3.9
	Estuarine Subtidal (ES) Habitats				
ES-1	Shallow subtidal rock and boulders		3.2	3.2	2.6
ES-2	Deep subtidal rock and boulders		2.3	2.3	2.8
ES-3	Shallow subtidal cobble and mixed-coarse		2.6	3.2	3.2
ES-4	Deep subtidal cobble and mixed-coarse		1.5	2.2	2.2
ES-5	Shallow subtidal sandy or mixed-fine		3.2	3.2	3.2
ES-6	Deep subtidal sandy or mixed-fine		2	2.4	2.8
ES-7	Shallow subtidal muddy bays		3	2.4	3.9
ES-7	Shallow subtidal muddy bays (kelp/eelgrass)		4.5	3.6	5.85
ES-8	Deep subtidal muddy bays		1.8	1.8	2.9
ES-9	Open water		5	3.2	2.2

* The individual habitat vulnerability score is multiplied by 1.5 due to the presence of seagrass or kelp

HVS(ac) = 4.93
HVS (mech) = 3.18

HVS (pers) = 2.28

BVS = 3.5 * The bird vulnerability score is multiplied by 1.5 when state or federal T& E species present (bald eagle)

MVS = 6 * The marine mammal vulnerability score is multiplied by 1.5 when state or federal T& E species present (stellar sealion)

MFVS = 5
SFVS = 5
RVS = 5

SAVS:

Habitat type	*%*	Chinook - Subyr	Ch-sub (adjust)	Chinook - Year	Ch-yr (adjust)
Intertidal - Rocky	2.8	1	0.028	1	0.028
Intertidal - Cobble	0.6	2	0.012	3	0.018
Intertidal - Gravel	3.8	3	0.114	3	0.114
Intertidal - Sand (vegetated)	1.4	4	0.056	3	0.042
Intertidal - Sand (unvegetated)	0.2	3	0.006	3	0.006
Intertidal - Mud (vegetated)	0	4	0	3	0
Intertidal - Mud (unvegetated)	0.1	3	0.003	3	0.003
Subtidal	0	2	0	2	0
Pelagic	91.1	4	3.644	4	3.644
Total Score			3.863		3.855

Habitat type	*%*	Pink	Pink (adjust)	Coho	Coho (adjust)
Intertidal - Rocky	2.8	1	0.028	1	0.028
Intertidal - Cobble	0.6	2	0.012	3	0.018
Intertidal - Gravel	3.8	3	0.114	3	0.114
Intertidal - Sand (vegetated)	1.4	5	0.07	5	0.07
Intertidal - Sand (unvegetated)	0.2	3	0.006	3	0.006
Intertidal - Mud (vegetated)	0	5	0	5	0
Intertidal - Mud (unvegetated)	0.1	3	0.003	3	0.003
Subtidal	0	2	0	2	0
Pelagic	91.1	4	3.644	4	3.644
Total Score			3.877		3.883

Habitat type	*%*	Chum	Chum (adjust)	Sockeye	Sockeye (adj)
Intertidal - Rocky	2.8	1	0.028	2	0.056
Intertidal - Cobble	0.6	2	0.012	2	0.012
Intertidal - Gravel	3.8	3	0.114	2	0.076
Intertidal - Sand (vegetated)	1.4	5	0.07	2	0.028
Intertidal - Sand (unvegetated)	0.2	3	0.006	2	0.004
Intertidal - Mud (vegetated)	0	5	0	2	0
Intertidal - Mud (unvegetated)	0.1	3	0.003	3	0.003
Subtidal	0	2	0	1	0
Pelagic	91.1	4	3.644	4	3.644
Total Score			3.877		3.823

Pink salmon are present: SAVS = 3.8638

*SVS is multiplied by 1.5 due to likely exposure of state/federal T & E species (Elwha Summer steelhead)

Final SAVS = 5.7957

SVS(at) =	35.23	OIL (at) =	0.9
SVS (mi) =	33.48	OIL (mi) =	3.6
SVS (per) =	32.58	OIL (per) =	5

$Damages = 0.1 *{[SVS_at*Spill vol*Oil_at]+[SVS_mi *(Spill vol-24 hr. recov. vol)*Oil_mi]+[SVS_per*(Spill vol-24 hr. recov. vol)*Oil_per]}

= 0.1 *{(35.23*3,800,000*0.9)+(33.48*3,800,000*3.6)+(32.58*3,800,000*5)}

=

TOTAL $ = $119,747,560.80 (which equates to $31.51 per gallon)

7.2 Medium Spill, East Location

Marine/Estuarine Compensation Schedule - excluding Columbia River Estuary
Rescue Tug Risk Assessment

Spill date	*Table Zone*	*Waterbody affected*	*Location*	*Amount Spilled (g)*	*Product Type*	*24 Hour Recovery(g)*
4/1/98	303	Strait of Juan de Fuca	Port Angeles	250,000	Bunker C	0

HABITAT VULNERABILITY (HVS)

	Marine Intertidal (MI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
MI-1	Semi-exposed gravel beaches	3.4	3.2	1.4	2.0
MI-1	Semi-exposed gravel beaches (kelp/eelgrass)	10.7	4.8	2.1	3.0
MI-2	Exposed sandy beaches	0.4	2.9	1.3	1.8
MI-2	Exposed sandy beaches (kelp/eelgrass)	1.8	4.35	1.95	2.7
	Marine Subtidal (MS) Habitats				
MS-1	Shallow subtidal rock & boulder (kelp/eelgrass)	0	5.55	5.55	4.65
MS-1	Shallow subtidal rock and boulder	0	3.7	3.7	3.1
MS-3	Deep subtidal cobble & mixed coarse	0	1.5	2.2	2.2
MS-4	Shallow subtidal mixed-coarse to mixed fine	0	3.6	3.6	3.6
MS-5	Shallow subtidal gravel or mixed fine	0	2.8	1.6	2.3
MS-6	Deep subtidal sand	0	1.6	2	1.6
MS-7	Deep subtidal mixed-fine	0	1.5	2.6	3.1
MS-8	Deep subtidal mud	0	2	2	3.2
MS-9	Open water	83.7	5	3.2	2.2

	Estuarine Intertidal (EI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
EI-1	Open rocky shores		3	3.5	3
EI-1	Open rocky shores (k/eg)		4.5	5.25	4.5
EI-2	Open mixed-coarse beaches & low marsh		3.7	3.2	3.2
EI-2	Open mixed-coarse beaches & low marsh (k/eg)		5.55	4.8	4.8
EI-3	Open gravel beaches		3.4	1.5	2.2
EI-4	Open sandy beaches		3.3	2.8	2.3
EI-4	Open sandy beaches (k/eg)		4.95	4.2	3.45
EI-5	Sandy low marshes		3.5	3	3

EI-6	Mixed-fine beaches and low marshes	4.3	4.3	4.3
EI-7	Saline lagoons	3.7	3.7	4.1
EI-8	Low-salinity lagoons	3	3.5	3.9
EI-9	Mud flats	3.7	2.6	4.1
EI-9	Mud flats (kelp/eelgrass)	5.55	3.9	6.15
EI-10	High salt marshes	3	3.5	3.9
EI-11	Transition zone wetlands	3	3.5	3.9
	Estuarine Subtidal (ES) Habitats			
ES-1	Shallow subtidal rock and boulders	3.2	3.2	2.6
ES-2	Deep subtidal rock and boulders	2.3	2.3	2.8
ES-3	Shallow subtidal cobble and mixed-coarse	2.6	3.2	3.2
ES-4	Deep subtidal cobble and mixed-coarse	1.5	2.2	2.2
ES-5	Shallow subtidal sandy or mixed-fine	3.2	3.2	3.2
ES-6	Deep subtidal sandy or mixed-fine	2	2.4	2.8
ES-7	Shallow subtidal muddy bays	3	2.4	3.9
ES-7	Shallow subtidal muddy bays (kelp/eelgrass)	4.5	3.6	5.85
ES-8	Deep subtidal muddy bays	1.8	1.8	2.9
ES-9	Open water	5	3.2	2.2

* The individual habitat vulnerability score is multiplied by 1.5 due to the presence of seagrass or kelp

HVS(ac) = 4.90
HVS (mech) = 2.99
HVS (pers) = 2.29

BVS = 3.5 * The bird vulnerability score is multiplied by 1.5 when state or federal T& E species present (bald eagle)

MVS = 6 * The marine mammal vulnerability score is multiplied by 1.5 when state or federal T& E species present (stellar sealion)

MFVS = 5
SFVS = 5
RVS = 5

SAVS:

Habitat type	%	Chinook - Subyr	Ch-sub (adjust)	Chinook - Year	Ch-yr (adjust)
Intertidal - Rocky	0	1	0	1	0
Intertidal - Cobble	0	2	0	3	0
Intertidal - Gravel	14.1	3	0.423	3	0.423
Intertidal - Sand (vegetated)	1.8	4	0.072	3	0.054
Intertidal - Sand (unvegetated)	0.4	3	0.012	3	0.012
Intertidal - Mud (vegetated)	0	4	0	3	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0

Pelagic	83.7	4	3.348	4	3.348
Total Score			3.855		3.837

Habitat type	%	Pink	Pink (adjust)	Coho	Coho (adjust)
Intertidal - Rocky	0	1	0	1	0
Intertidal - Cobble	0	2	0	3	0
Intertidal - Gravel	14.1	3	0.423	3	0.423
Intertidal - Sand (vegetated)	1.8	5	0.09	5	0.09
Intertidal - Sand (unvegetated)	0.4	3	0.012	3	0.012
Intertidal - Mud (vegetated)	0	5	0	5	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0
Pelagic	83.7	4	3.348	4	3.348
Total Score			3.873		3.873

Habitat type	%	Chum	Chum (adjust)	Sockeye	Sockeye (adj)
Intertidal - Rocky	0	1	0	2	0
Intertidal - Cobble	0	2	0	2	0
Intertidal - Gravel	14.1	3	0.423	2	0.282
Intertidal - Sand (vegetated)	1.8	5	0.09	2	0.036
Intertidal - Sand (unvegetated)	0.4	3	0.012	2	0.008
Intertidal - Mud (vegetated)	0	5	0	2	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	1	0
Pelagic	83.7	4	3.348	4	3.348
Total Score			3.873		3.674

Pink salmon are present: SAVS = 3.8278

*SVS is multiplied by 1.5 due to likely exposure of state/federal T & E species (Elwha Summer steelhead)

Final SAVS = 5.7417

SVS(at) =	35.14	OIL (at) =	2.3
SVS (mi) =	33.23	OIL (mi) =	5
SVS (per) =	32.53	OIL (per) =	5

$Damages =

0.1 *{[SVS_at*Spill vol*Oil_at]+[SVS_mi *(Spill vol-24 hr. recov. vol)*Oil_mi]+[SVS_per*(Spill vol-24 hr. recov. vol)*Oil_per]}

=

0.1 *{(35.14*250,000*2.3)+(33.23*250,000*5)+(32.53*250,000*5)}

=

TOTAL $ = $10,240,567.50 (which equates to $40.96 per gallon)

7.3 Small Spill, East Location

Marine/Estuarine Compensation Schedule - excluding Columbia River Estuary

Rescue Tug Risk Assessment

Spill date	*Table Zone*	*Waterbody affected*	*Location*	*Amount Spilled (g)*	*Product Type*	*24 Hour Recovery(g)*
4/1/98	303	Strait of Juan de Fuca	Port Angeles	81,300	Bunker C	0

HABITAT VULNERABILITY (HVS)

	Marine Intertidal (MI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
MI-1	Semi-exposed gravel beaches	3.7	3.2	1.4	2.0
MI-1	Semi-exposed gravel beaches (kelp/eelgrass)	11.4	4.8	2.1	3.0
MI-2	Exposed sandy beaches	0.4	2.9	1.3	1.8
MI-2	Exposed sandy beaches (kelp/eelgrass)	1.9	4.35	1.95	2.7
	Marine Subtidal (MS) Habitats				
MS-1	Shallow subtidal rock & boulder (kelp/eelgrass)	0	5.55	5.55	4.65
MS-1	Shallow subtidal rock and boulder	0	3.7	3.7	3.1
MS-3	Deep subtidal cobble & mixed coarse	0	1.5	2.2	2.2
MS-4	Shallow subtidal mixed-coarse to mixed fine	0	3.6	3.6	3.6
MS-5	Shallow subtidal gravel or mixed fine	0	2.8	1.6	2.3
MS-6	Deep subtidal sand	0	1.6	2	1.6
MS-7	Deep subtidal mixed-fine	0	1.5	2.6	3.1
MS-8	Deep subtidal mud	0	2	2	3.2
MS-9	Open water	82.6	5	3.2	2.2

	Estuarine Intertidal (EI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
EI-1	Open rocky shores		3	3.5	3
EI-1	Open rocky shores (k/eg)		4.5	5.25	4.5
EI-2	Open mixed-coarse beaches & low marsh		3.7	3.2	3.2
EI-2	Open mixed-coarse beaches & low marsh (k/eg)		5.55	4.8	4.8
EI-3	Open gravel beaches		3.4	1.5	2.2
EI-4	Open sandy beaches		3.3	2.8	2.3
EI-4	Open sandy beaches (k/eg)		4.95	4.2	3.45

EI-5	Sandy low marshes	3.5	3	3
EI-6	Mixed-fine beaches and low marshes	4.3	4.3	4.3
EI-7	Saline lagoons	3.7	3.7	4.1
EI-8	Low-salinity lagoons	3	3.5	3.9
EI-9	Mud flats	3.7	2.6	4.1
EI-9	Mud flats (kelp/eelgrass)	5.55	3.9	6.15
EI-10	High salt marshes	3	3.5	3.9
EI-11	Transition zone wetlands	3	3.5	3.9
	Estuarine Subtidal (ES) Habitats			
ES-1	Shallow subtidal rock and boulders	3.2	3.2	2.6
ES-2	Deep subtidal rock and boulders	2.3	2.3	2.8
ES-3	Shallow subtidal cobble and mixed-coarse	2.6	3.2	3.2
ES-4	Deep subtidal cobble and mixed-coarse	1.5	2.2	2.2
ES-5	Shallow subtidal sandy or mixed-fine	3.2	3.2	3.2
ES-6	Deep subtidal sandy or mixed-fine	2	2.4	2.8
ES-7	Shallow subtidal muddy bays	3	2.4	3.9
ES-7	Shallow subtidal muddy bays (kelp/eelgrass)	4.5	3.6	5.85
ES-8	Deep subtidal muddy bays	1.8	1.8	2.9
ES-9	Open water	5	3.2	2.2

* The individual habitat vulnerability score is multiplied by 1.5 due to the presence of seagrass or kelp

HVS(ac) = 4.89
HVS (mech) = 2.98
HVS (pers) = 2.29

BVS = 3.5 * The bird vulnerability score is multiplied by 1.5 when state or federal T& E species present (bald eagle)

MVS = 6 * The marine mammal vulnerability score is multiplied by 1.5 when state or federal T& E species present (stellar sealion)

MFVS = 5
SFVS = 5
RVS = 5

SAVS:

Habitat type	*%*	Chinook - Subyr	Ch-sub (adjust)	Chinook - Year	Ch-yr (adjust)
Intertidal - Rocky	0	1	0	1	0
Intertidal - Cobble	0	2	0	3	0
Intertidal - Gravel	15.1	3	0.453	3	0.453
Intertidal - Sand (vegetated)	1.9	4	0.076	3	0.057
Intertidal - Sand (unvegetated)	0.4	3	0.012	3	0.012
Intertidal - Mud (vegetated)	0	4	0	3	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0

Pelagic	82.6	4	3.304	4	3.304
Total Score			3.845		3.826

Habitat type	%	Pink	Pink (adjust)	Coho	Coho (adjust)
Intertidal - Rocky	0	1	0	1	0
Intertidal - Cobble	0	2	0	3	0
Intertidal - Gravel	15.1	3	0.453	3	0.453
Intertidal - Sand (vegetated)	1.9	5	0.095	5	0.095
Intertidal - Sand (unvegetated)	0.4	3	0.012	3	0.012
Intertidal - Mud (vegetated)	0	5	0	5	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0
Pelagic	82.6	4	3.304	4	3.304
Total Score			3.864		3.864

Habitat type	%	Chum	Chum (adjust)	Sockeye	Sockeye (adj)
Intertidal - Rocky	0	1	0	2	0
Intertidal - Cobble	0	2	0	2	0
Intertidal - Gravel	15.1	3	0.453	2	0.302
Intertidal - Sand (vegetated)	1.9	5	0.095	2	0.038
Intertidal - Sand (unvegetated)	0.4	3	0.012	2	0.008
Intertidal - Mud (vegetated)	0	5	0	2	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	1	0
Pelagic	82.6	4	3.304	4	3.304
Total Score			3.864		3.652

Pink salmon are present: SAVS = 3.8159

*SVS is multiplied by 1.5 due to likely exposure of state/federal T & E species (Elwha Summer steelhead)

Final SAVS = 5.72385

SVS(at) =	35.11	OIL (at) =	2.3
SVS (mi) =	33.20	OIL (mi) =	5
SVS (per) =	32.52	OIL (per) =	5

$Damages =
0.1 *{[SVS_at*Spill vol*Oil_at]+[SVS_mi *(Spill vol-24 hr. recov. vol)*Oil_mi]+[SVS_per*(Spill vol-24 hr. recov. vol)*Oil_per]}
=
0.1 *{(35.11*81,300*2.3)+(33.20*81,300*5)+(32.52*81,300*5)}
=

TOTAL $ = $3,327,948.51 (which equates to $40.93 per gallon)

7.4 Large Spill, West location

Marine/Estuarine Compensation Schedule - excluding Columbia River Estuary

Rescue Tug Risk Assessment

Spill date	*Table Zone*	*Waterbody affected*	*Location*	*Amount Spilled (g)*	*Product Type*	*24 Hour Recovery(g)*
4/1/98	101	Pacific Ocean	Buoy "J"	3,800,000	Crude	0

HABITAT VULNERABILITY (HVS)

	Marine Intertidal (MI) Habitats		Percent	Oil(ac)	Oil(mech)	Oil(pers)
MI-1	Exposed & semi-exposed rocky shores		1.5	3.7	4.3	3.1
MI-1	Exposed & semi-exposed rocky shores (kelp/eelgrass)		2.7	5.55	6.45	4.65
MI-2	Semi-exp. cobble & mixed coarse beaches		1.2	3.2	3.2	3.2
MI-2	Semi-exp. cobble & mixed coarse beaches (kelp/eelgrass)		1.8	4.8	4.8	4.8
MI-3	Semi-exposed gravel beaches		1.2	3.2	1.4	2
MI-3	Semi-exposed gravel beaches (kelp/eelgrass)		0.2	4.8	2.1	3
MI-4	Semi-protected mixed-fine beaches	(kelp/eelgrass)	0.1	4.8	3.9	5.55

	Marine Subtidal (MS) Habitats			
MS-1	Shallow subtidal rock & boulder (kelp/eelgrass)	0	5.55	5.55	4.65
MS-1	Shallow subtidal rock and boulder	0	3.7	3.7	3.1
MS-3	Deep subtidal cobble & mixed coarse	0	1.5	2.2	2.2
MS-4	Shallow subtidal mixed-coarse to mixed fine	0	3.6	3.6	3.6
MS-5	Shallow subtidal gravel or mixed fine	0	2.8	1.6	2.3
MS-6	Deep subtidal sand	0	1.6	2	1.6
MS-7	Deep subtidal mixed-fine	0	1.5	2.6	3.1
MS-8	Deep subtidal mud	0	2	2	3.2
MS-9	Open water	91.3	5	3.2	2.2

	Estuarine Intertidal (EI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
EI-1	Open rocky shores		3	3.5	3
EI-1	Open rocky shores (k/eg)		4.5	5.25	4.5
EI-2	Open mixed-coarse beaches & low marsh		3.7	3.2	3.2
EI-2	Open mixed-coarse beaches & low marsh (k/eg)		5.55	4.8	4.8
EI-3	Open gravel beaches		3.4	1.5	2.2

EI-4	Open sandy beaches	3.3	2.8	2.3
EI-4	Open sandy beaches (k/eg)	4.95	4.2	3.45
EI-5	Sandy low marshes	3.5	3	3
EI-6	Mixed-fine beaches and low marshes	4.3	4.3	4.3
EI-7	Saline lagoons	3.7	3.7	4.1
EI-8	Low-salinity lagoons	3	3.5	3.9
EI-9	Mud flats	3.7	2.6	4.1
EI-9	Mud flats (kelp/eelgrass)	5.55	3.9	6.15
EI-10	High salt marshes	3	3.5	3.9
EI-11	Transition zone wetlands	3	3.5	3.9
	Estuarine Subtidal (ES) Habitats			
ES-1	Shallow subtidal rock and boulders	3.2	3.2	2.6
ES-2	Deep subtidal rock and boulders	2.3	2.3	2.8
ES-3	Shallow subtidal cobble and mixed-coarse	2.6	3.2	3.2
ES-4	Deep subtidal cobble and mixed-coarse	1.5	2.2	2.2
ES-5	Shallow subtidal sandy or mixed-fine	3.2	3.2	3.2
ES-6	Deep subtidal sandy or mixed-fine	2	2.4	2.8
ES-7	Shallow subtidal muddy bays	3	2.4	3.9
ES-7	Shallow subtidal muddy bays (kelp/eelgrass)	4.5	3.6	5.85
ES-8	Deep subtidal muddy bays	1.8	1.8	2.9
ES-9	Open water	5	3.2	2.2

* The individual habitat vulnerability score is multiplied by 1.5 due to the presence of seagrass or kelp

HVS(ac) = 4.95
HVS (mech) = 3.31
HVS (pers) = 2.34

BVS = 7.5 * The bird vulnerability score is multiplied by 1.5 when state or federal T& E species present (bald eagle)

MVS = 7.5 * The marine mammal vulnerability score is multiplied by 1.5 when state or federal T& E species present (stellar sealion)

MFVS = 5
SFVS = 4
RVS = 5

SAVS:

Habitat type	%	Chinook - Subyr	Ch-sub (adjust)	Chinook - Year	Ch-yr (adjust)
Intertidal - Rocky	4.2	1	0.042	1	0.042
Intertidal - Cobble	3	2	0.06	3	0.09
Intertidal - Gravel	1.4	3	0.042	3	0.042
Intertidal - Sand (vegetated)	0.1	4	0.004	3	0.003
Intertidal - Sand (unvegetated)	0	3	0	3	0
Intertidal - Mud (vegetated)	0	4	0	3	0

Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0
Pelagic	91.3	4	3.652	4	3.652
Total Score			3.8		3.829

Habitat type	%	Pink	Pink (adjust)	Coho	Coho (adjust)
Intertidal - Rocky	4.2	1	0.042	1	0.042
Intertidal - Cobble	3	2	0.06	3	0.09
Intertidal - Gravel	1.4	3	0.042	3	0.042
Intertidal - Sand (vegetated)	0.1	5	0.005	5	0.005
Intertidal - Sand (unvegetated)	0	3	0	3	0
Intertidal - Mud (vegetated)	0	5	0	5	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0
Pelagic	91.3	4	3.652	4	3.652
Total Score			3.801		3.831

Habitat type	%	Chum	Chum (adjust)	Sockeye	Sockeye (adj)
Intertidal - Rocky	4.2	1	0.042	2	0.084
Intertidal - Cobble	3	2	0.06	2	0.06
Intertidal - Gravel	1.4	3	0.042	2	0.028
Intertidal - Sand (vegetated)	0.1	5	0.005	2	0.002
Intertidal - Sand (unvegetated)	0	3	0	2	0
Intertidal - Mud (vegetated)	0	5	0	2	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	1	0
Pelagic	91.3	4	3.652	4	3.652
Total Score			3.801		3.826

Pink salmon are present: SAVS = 3.8147

*SVS is multiplied by 1.5 due to likely exposure of state/federal T & E species (Ozette sockeye)

Final SAVS = 5.7221

SVS(at) =	39.67	OIL (at) =	0.9
SVS (mi) =	38.03	OIL (mi) =	3.6
SVS (per) =	37.06	OIL (per) =	5

$Damages = 0.1 *{[SVS_at*Spill vol*Oil_at]+[SVS_mi *(Spill vol-24 hr. recov. vol)*Oil_mi]+[SVS_per*(Spill vol-24 hr. recov. vol)*Oil_per]}

= 0.1 *{(39.67*3,800,000*0.9)+(38.03*3,800,000*3.6)+(37.06*3,800,000*5)}

=

TOTAL $ = $136,014,711.00 (which equates to $35.79 per gallon)

7.5 Medium Spill, West Location

Marine/Estuarine Compensation Schedule - excluding Columbia River Estuary

Rescue Tug Risk Assessment

Spill date	*Table Zone*	*Waterbody affected*	*Location*	*Amount Spilled (g)*	*Product Type*	*24 Hour Recovery(g)*
4/1/98	101	Pacific Ocean	Buoy "J"	250,000	Bunker C	0

HABITAT VULNERABILITY (HVS)

	Marine Intertidal (MI) Habitats		Percent	Oil(ac)	Oil(mech)	Oil(pers)
MI-1	Exposed & semi-exposed rocky shores		1.1	3.7	4.3	3.1
MI-1	Exposed & semi-exposed rocky shores (kelp/eelgrass)		0.2	5.55	6.45	4.65
MI-2	Semi-exp. cobble & mixed coarse beaches		2.5	3.2	3.2	3.2
MI-2	Semi-exp. cobble & mixed coarse beaches (kelp/eelgrass)		2.2	4.8	4.8	4.8
MI-3	Semi-exposed gravel beaches		1.1	3.2	1.4	2
MI-3	Semi-exposed gravel beaches (kelp/eelgrass)		0	4.8	2.1	3
MI-4	Semi-protected mixed-fine beaches	(kelp/eelgrass)	0	4.8	3.9	5.55

	Marine Subtidal (MS) Habitats			
MS-1	Shallow subtidal rock & boulder (kelp/eelgrass)	0	5.55	5.55	4.65
MS-1	Shallow subtidal rock and boulder	0	3.7	3.7	3.1
MS-3	Deep subtidal cobble & mixed coarse	0	1.5	2.2	2.2
MS-4	Shallow subtidal mixed-coarse to mixed fine	0	3.6	3.6	3.6
MS-5	Shallow subtidal gravel or mixed fine	0	2.8	1.6	2.3
MS-6	Deep subtidal sand	0	1.6	2	1.6
MS-7	Deep subtidal mixed-fine	0	1.5	2.6	3.1
MS-8	Deep subtidal mud	0	2	2	3.2
MS-9	Open water	92.9	5	3.2	2.2

	Estuarine Intertidal (EI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
EI-1	Open rocky shores		3	3.5	3
EI-1	Open rocky shores (k/eg)		4.5	5.25	4.5
EI-2	Open mixed-coarse beaches & low marsh		3.7	3.2	3.2
EI-2	Open mixed-coarse beaches & low marsh (k/eg)		5.55	4.8	4.8

EI-3	Open gravel beaches	3.4	1.5	2.2
EI-4	Open sandy beaches	3.3	2.8	2.3
EI-4	Open sandy beaches (k/eg)	4.95	4.2	3.45
EI-5	Sandy low marshes	3.5	3	3
EI-6	Mixed-fine beaches and low marshes	4.3	4.3	4.3
EI-7	Saline lagoons	3.7	3.7	4.1
EI-8	Low-salinity lagoons	3	3.5	3.9
EI-9	Mud flats	3.7	2.6	4.1
EI-9	Mud flats (kelp/eelgrass)	5.55	3.9	6.15
EI-10	High salt marshes	3	3.5	3.9
EI-11	Transition zone wetlands	3	3.5	3.9
	Estuarine Subtidal (ES) Habitats			
ES-1	Shallow subtidal rock and boulders	3.2	3.2	2.6
ES-2	Deep subtidal rock and boulders	2.3	2.3	2.8
ES-3	Shallow subtidal cobble and mixed-coarse	2.6	3.2	3.2
ES-4	Deep subtidal cobble and mixed-coarse	1.5	2.2	2.2
ES-5	Shallow subtidal sandy or mixed-fine	3.2	3.2	3.2
ES-6	Deep subtidal sandy or mixed-fine	2	2.4	2.8
ES-7	Shallow subtidal muddy bays	3	2.4	3.9
ES-7	Shallow subtidal muddy bays (kelp/eelgrass)	4.5	3.6	5.85
ES-8	Deep subtidal muddy bays	1.8	1.8	2.9
ES-9	Open water	5	3.2	2.2

* The individual habitat vulnerability score is multiplied by 1.5 due to the presence of seagrass or kelp

HVS(ac) = 4.92
HVS (mech) = 3.23
HVS (pers) = 2.29

BVS = 7.5 * The bird vulnerability score is multiplied by 1.5 when state or federal T& E species present (bald eagle)

MVS = 7.5 * The marine mammal vulnerability score is multiplied by 1.5 when state or federal T& E species present (stellar sealion)

MFVS = 5
SFVS = 4
RVS = 5

SAVS:

Habitat type	*%*	Chinook - Subyr	Ch-sub (adjust)	Chinook - Year	Ch-yr (adjust)
Intertidal - Rocky	1.3	1	0.013	1	0.013
Intertidal - Cobble	4.7	2	0.094	3	0.141
Intertidal - Gravel	1.1	3	0.033	3	0.033
Intertidal - Sand (vegetated)	0	4	0	3	0
Intertidal - Sand (unvegetated)	0	3	0	3	0
Intertidal - Mud (vegetated)	0	4	0	3	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0

Pelagic	92.9	4	3.716	4	3.716
Total Score			3.856		3.903

Habitat type	%	Pink	Pink (adjust)	Coho	Coho (adjust)
Intertidal - Rocky	1.3	1	0.013	1	0.013
Intertidal - Cobble	4.7	2	0.094	3	0.141
Intertidal - Gravel	1.1	3	0.033	3	0.033
Intertidal - Sand (vegetated)	0	5	0	5	0
Intertidal - Sand (unvegetated)	0	3	0	3	0
Intertidal - Mud (vegetated)	0	5	0	5	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0
Pelagic	92.9	4	3.716	4	3.716
Total Score			3.856		3.903

Habitat type	%	Chum	Chum (adjust)	Sockeye	Sockeye (adj)
Intertidal - Rocky	1.3	1	0.013	2	0.026
Intertidal - Cobble	4.7	2	0.094	2	0.094
Intertidal - Gravel	1.1	3	0.033	2	0.022
Intertidal - Sand (vegetated)	0	5	0	2	0
Intertidal - Sand (unvegetated)	0	3	0	2	0
Intertidal - Mud (vegetated)	0	5	0	2	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	1	0
Pelagic	92.9	4	3.716	4	3.716
Total Score			3.856		3.858

Pink salmon are present: SAVS = 3.8705

*SVS is multiplied by 1.5 due to likely exposure of state/federal T & E species (Ozette sockeye)

Final SAVS = 5.8058

SVS(at) =	39.72	OIL (at) =	2.3
SVS (mi) =	38.04	OIL (mi) =	5
SVS (per) =	37.10	OIL (per) =	5

$Damages =
0.1 *{[SVS_at*Spill vol*Oil_at]+[SVS_mi *(Spill vol-24 hr. recov. vol)*Oil_mi]+[SVS_per*(Spill vol-24 hr. recov. vol)*Oil_per]}
=
0.1 *{(39.72*250,000*2.3)+(38.04*250,000*5)+(37.10*250,000*5)}
=

TOTAL $ = $11,676,630.13 (which equates to $46.71 per gallon)

7.6 Small Spill, West location

Marine/Estuarine Compensation Schedule - excluding Columbia River Estuary

Rescue Tug Risk Assessment

Spill date	*Table Zone*	*Waterbody affected*	*Location*	*Amount Spilled (g)*	*Product Type*	*24 Hour Recovery(g)*
4/1/98	101	Pacific Ocean	Buoy "J"	81,300	Bunker C	0

HABITAT VULNERABILITY (HVS)

	Marine Intertidal (MI) Habitats		Percent	Oil(ac)	Oil(mech)	Oil(pers)
MI-1	Exposed & semi-exposed rocky shores		1	3.7	4.3	3.1
MI-1	Exposed & semi-exposed rocky shores (kelp/eelgrass)		0.2	5.55	6.45	4.65
MI-2	Semi-exp. cobble & mixed coarse beaches		2.6	3.2	3.2	3.2
MI-2	Semi-exp. cobble & mixed coarse beaches (kelp/eelgrass)		2.3	4.8	4.8	4.8
MI-3	Semi-exposed gravel beaches		1.2	3.2	1.4	2
MI-3	Semi-exposed gravel beaches (kelp/eelgrass)		0	4.8	2.1	3
MI-4	Semi-protected mixed-fine beaches	(kelp/eelgrass)	0	4.8	3.9	5.55

	Marine Subtidal (MS) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
MS-1	Shallow subtidal rock & boulder (kelp/eelgrass)	0	5.55	5.55	4.65
MS-1	Shallow subtidal rock and boulder	0	3.7	3.7	3.1
MS-3	Deep subtidal cobble & mixed coarse	0	1.5	2.2	2.2
MS-4	Shallow subtidal mixed-coarse to mixed fine	0	3.6	3.6	3.6
MS-5	Shallow subtidal gravel or mixed fine	0	2.8	1.6	2.3
MS-6	Deep subtidal sand	0	1.6	2	1.6
MS-7	Deep subtidal mixed-fine	0	1.5	2.6	3.1
MS-8	Deep subtidal mud	0	2	2	3.2
MS-9	Open water	92.7	5	3.2	2.2

	Estuarine Intertidal (EI) Habitats	Percent	Oil(ac)	Oil(mech)	Oil(pers)
EI-1	Open rocky shores		3	3.5	3
EI-1	Open rocky shores (k/eg)		4.5	5.25	4.5
EI-2	Open mixed-coarse beaches & low marsh		3.7	3.2	3.2
EI-2	Open mixed-coarse beaches & low marsh (k/eg)		5.55	4.8	4.8
EI-3	Open gravel beaches		3.4	1.5	2.2
EI-4	Open sandy beaches		3.3	2.8	2.3

EI-4	Open sandy beaches (k/eg)	4.95	4.2	3.45
EI-5	Sandy low marshes	3.5	3	3
EI-6	Mixed-fine beaches and low marshes	4.3	4.3	4.3
EI-7	Saline lagoons	3.7	3.7	4.1
EI-8	Low-salinity lagoons	3	3.5	3.9
EI-9	Mud flats	3.7	2.6	4.1
EI-9	Mud flats (kelp/eelgrass)	5.55	3.9	6.15
EI-10	High salt marshes	3	3.5	3.9
EI-11	Transition zone wetlands	3	3.5	3.9
	Estuarine Subtidal (ES) Habitats			
ES-1	Shallow subtidal rock and boulders	3.2	3.2	2.6
ES-2	Deep subtidal rock and boulders	2.3	2.3	2.8
ES-3	Shallow subtidal cobble and mixed-coarse	2.6	3.2	3.2
ES-4	Deep subtidal cobble and mixed-coarse	1.5	2.2	2.2
ES-5	Shallow subtidal sandy or mixed-fine	3.2	3.2	3.2
ES-6	Deep subtidal sandy or mixed-fine	2	2.4	2.8
ES-7	Shallow subtidal muddy bays	3	2.4	3.9
ES-7	Shallow subtidal muddy bays (kelp/eelgrass)	4.5	3.6	5.85
ES-8	Deep subtidal muddy bays	1.8	1.8	2.9
ES-9	Open water	5	3.2	2.2

* The individual habitat vulnerability score is multiplied by 1.5 due to the presence of seagrass or kelp

HVS(ac) = 4.92
HVS (mech) = 3.23
HVS (pers) = 2.30

BVS = 7.5 * The bird vulnerability score is multiplied by 1.5 when state or federal T& E species present (bald eagle)
MVS = 7.5 * The marine mammal vulnerability score is multiplied by 1.5 when state or federal T& E species present (stellar sealion)

MFVS = 5
SFVS = 4
RVS = 5

SAVS:

Habitat type	*%*	Chinook - Subyr	Ch-sub (adjust)	Chinook - Year	Ch-yr (adjust)
Intertidal - Rocky	1.2	1	0.012	1	0.012
Intertidal - Cobble	4.9	2	0.098	3	0.147
Intertidal - Gravel	1.2	3	0.036	3	0.036
Intertidal - Sand (vegetated)	0	4	0	3	0
Intertidal - Sand (unvegetated)	0	3	0	3	0
Intertidal - Mud (vegetated)	0	4	0	3	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0

Pelagic	92.7	4	3.708	4	3.708
Total Score			3.854		3.903

Habitat type	*%*	Pink	Pink (adjust)	Coho	Coho (adjust)
Intertidal - Rocky	1.2	1	0.012	1	0.012
Intertidal - Cobble	4.9	2	0.098	3	0.147
Intertidal - Gravel	1.2	3	0.036	3	0.036
Intertidal - Sand (vegetated)	0	5	0	5	0
Intertidal - Sand (unvegetated)	0	3	0	3	0
Intertidal - Mud (vegetated)	0	5	0	5	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	2	0
Pelagic	92.7	4	3.708	4	3.708
Total Score			3.854		3.903

Habitat type	*%*	Chum	Chum (adjust)	Sockeye	Sockeye (adj)
Intertidal - Rocky	1.2	1	0.012	2	0.024
Intertidal - Cobble	4.9	2	0.098	2	0.098
Intertidal - Gravel	1.2	3	0.036	2	0.024
Intertidal - Sand (vegetated)	0	5	0	2	0
Intertidal - Sand (unvegetated)	0	3	0	2	0
Intertidal - Mud (vegetated)	0	5	0	2	0
Intertidal - Mud (unvegetated)	0	3	0	3	0
Subtidal	0	2	0	1	0
Pelagic	92.7	4	3.708	4	3.708
Total Score			3.854		3.854

Pink salmon are present: SAVS = 3.8687

*SVS is multiplied by 1.5 due to likely exposure of state/federal T & E species (Ozette sockeye)

Final SAVS = 5.8031

SVS(at) =	39.72	OIL (at) =	2.3
SVS (mi) =	38.04	OIL (mi) =	5
SVS (per) =	37.10	OIL (per) =	5

$Damages =
0.1 *{[SVS_at*Spill vol*Oil_at]+[SVS_mi *(Spill vol-24 hr. recov. vol)*Oil_mi]+[SVS_per*(Spill vol-24 hr. recov. vol)*Oil_per]}
=
0.1 *{(39.72*81,300*2.3)+(38.04*81,300*5)+(37.10*81,300*5)}
=

TOTAL $ = $3,796,972.15 (which equates to $46.70 per gallon)

8 COMPARISON OF MODEL RESULTS

Table 38 contains damage assessment results from NRDAM/CME and OSCS. 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 OSCS has a more geographically specific database for natural resources but does not take into account the fate (evaporation, decay, emulsification, etc.) of the spilled oil. The results from OSCS tend to bias toward high value because the worst damage conditions are always considered. The NRDAM/CME distributes biological and natural resources evenly throughout the biological provinces and therefor will not account for impact on local high population areas.

SPILL SCENARIO	NRDAM/CME ($ DAMAGE)	OSCS($ DAMAGE)
Large Spill, East Boundary	9,604,096	119,747,561
Medium Spill, East Boundary	1,023,619	10,240,568
Small Spill, East Boundary	540,730	3,327,949
Large Spill, West Boundary	5,055,516	136,014,711
Medium Spill, West Boundary	500,259	11,676,630
Small Spill, West Boundary	158,699	3,796,920

Table 38 A Comparison of Damage Assessment from NRDAM/CME and OSCS

9.1 Eastern Location, Large Spill

Text Summary

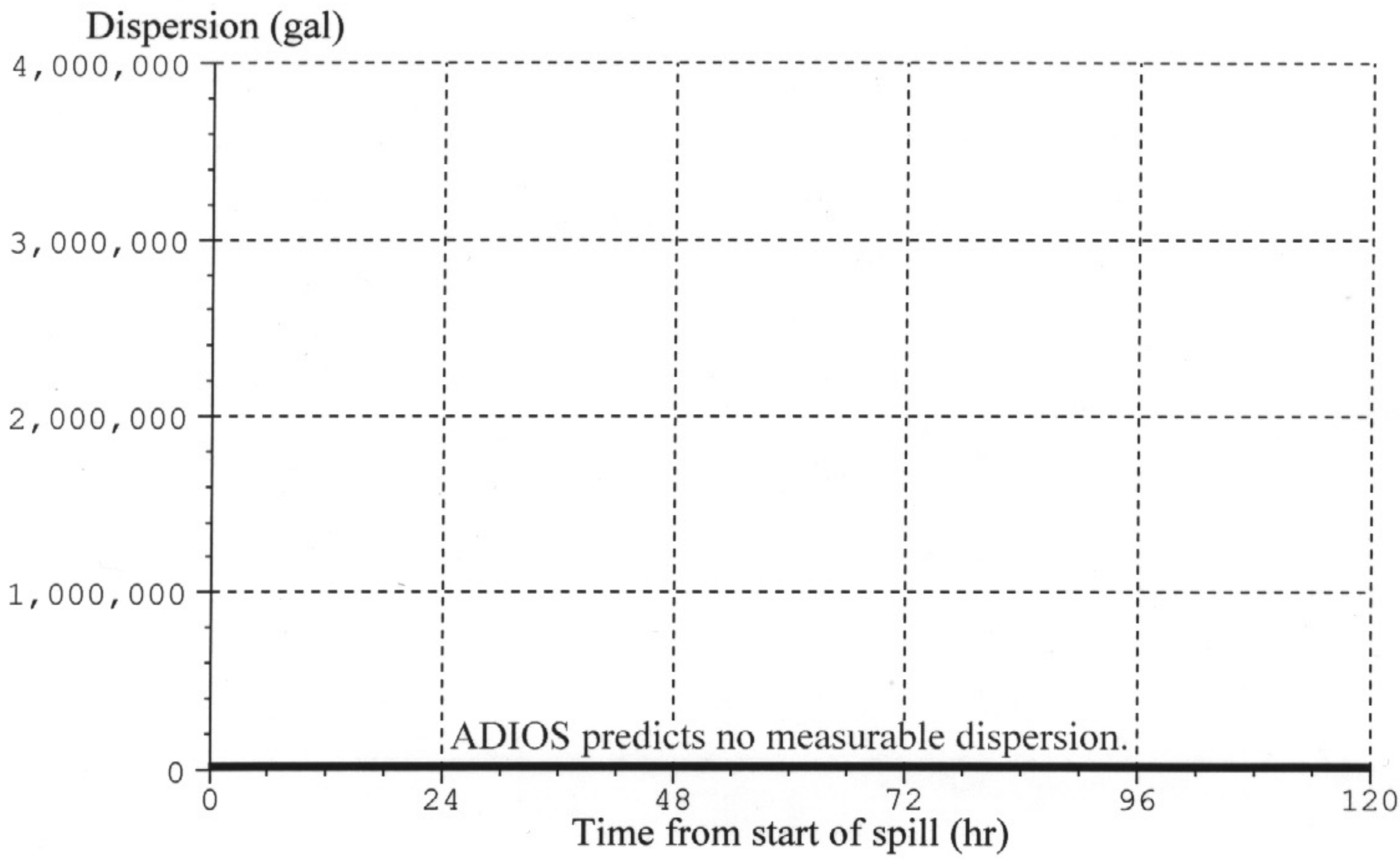
ADIOS(TM) 1.1

```
OIL OR PRODUCT:
    Oil Name:               PRUDHOE BAY
    Location:               NORTH SLOPE, ALASKA
    Synonyms:               Not Available
    Product Type:           Crude
    Comments:               Not Available

INITIAL PHYSICAL PROPERTIES:
    Density:                0.91 g/cc at 11.0 C    (24.8 API)
    Kinematic Visc:         96.4 cSt at 11.0 C
    Pour Point:             between -42.0 C and 0.0 C
    Flash Point:            30.0 C
    Aromatics:              10.00 weight %
    Emulsification:         Begins after 5% evaporated (estimated
value)
                            No library data is available on mousse
formation.

WIND _WAVE DATA:
    Wind Speed:             Variable
    Wave Height:            Default values

SURFACE WATER PROPERTIES:
    Temperature:            11 C
    Salinity:               32.0 ppt
    Density:                1.02444 g/cc

SPILL DATA:
    Continuous release of 3800000 gal over 4 hr

WARNING:
    Estimated emulsification constant could affect accuracy of
viscosity and
    water content predictions.
```

Dispersion

ADIOS(TM) 1.1

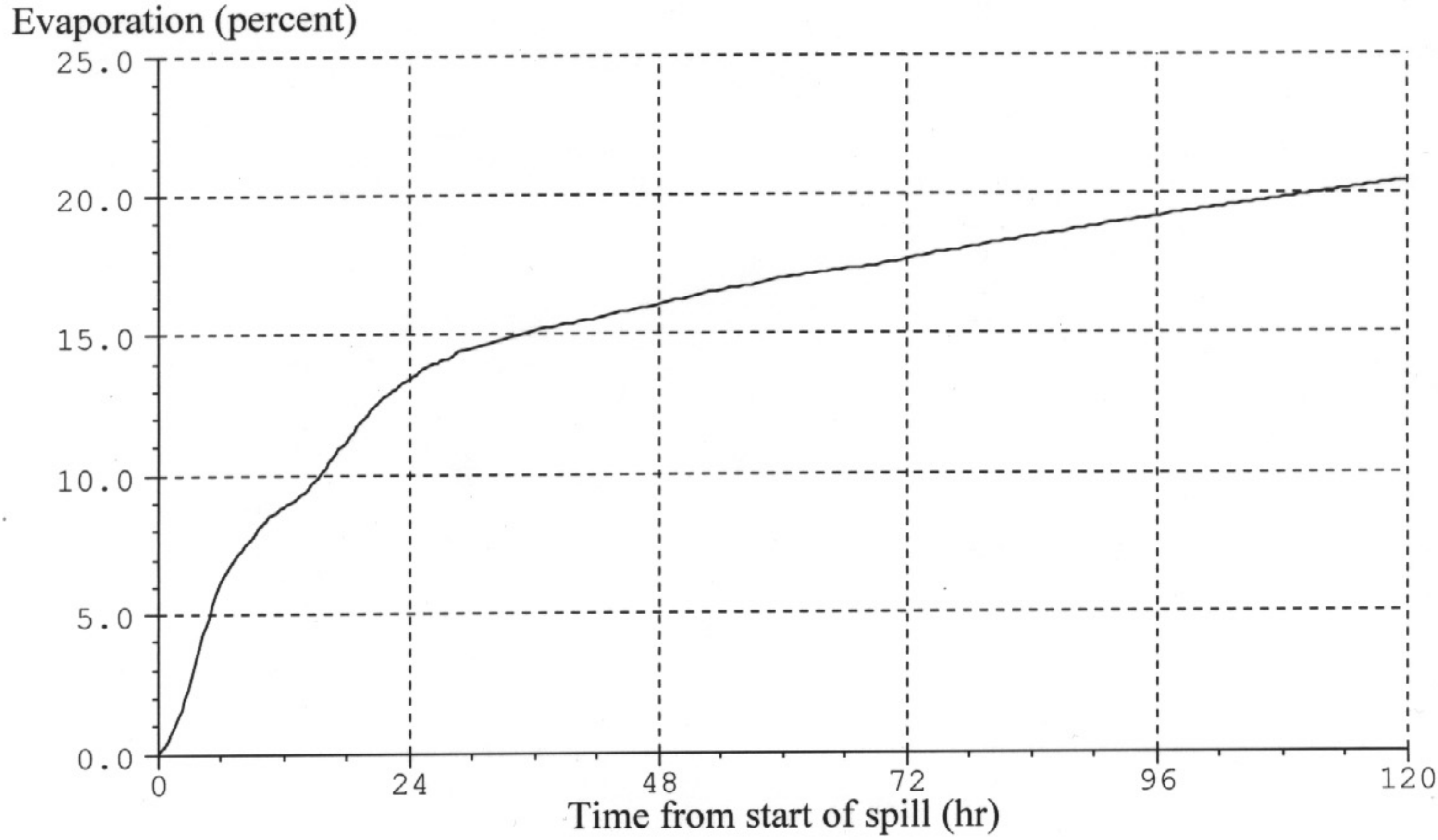
```
Oil Name: PRUDHOE BAY
API: 24.8                                   Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                            Wave Height: Default values

Water Temperature: 11 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Evaporation

ADIOS(TM) 1.1

```
Oil Name: PRUDHOE BAY
API: 24.8                                  Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                           Wave Height: Default values

Water Temperature: 11 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```

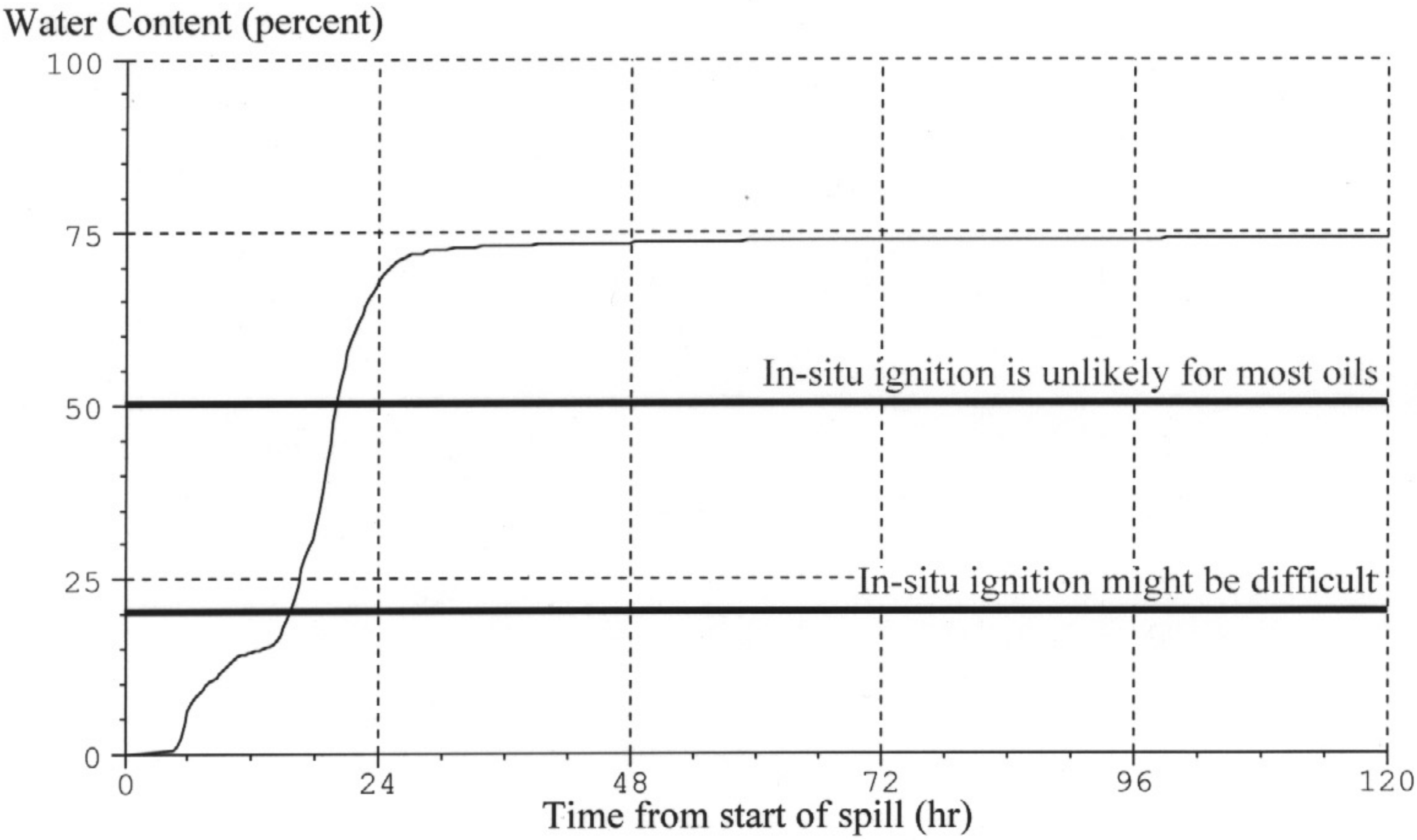


Eastern Location, Large Spill

Water Content

ADIOS(TM) 1.1

```
Oil Name: PRUDHOE BAY
API: 24.8                                Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                         Wave Height: Default values

Water Temperature: 11 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```

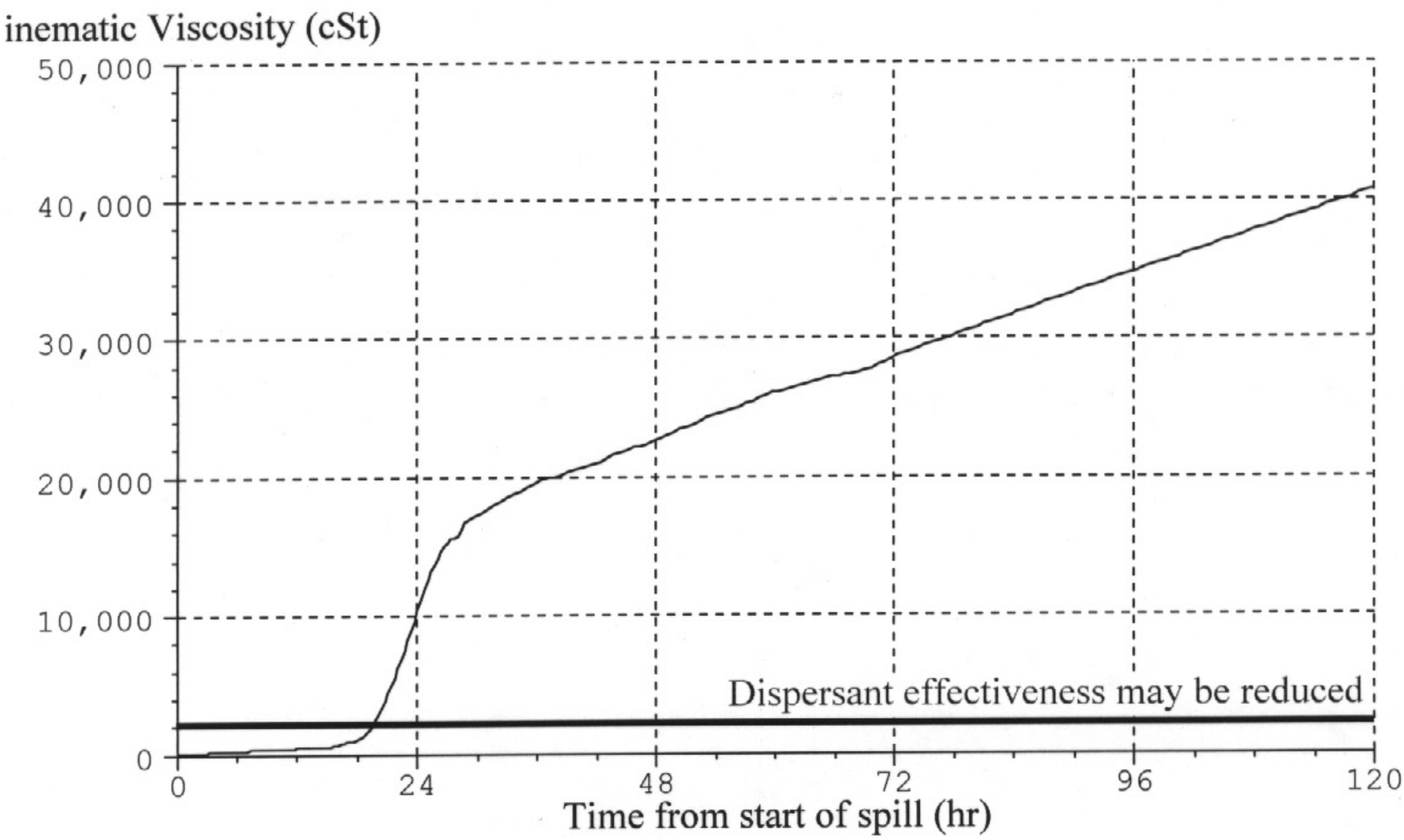


Eastern Location, Large Spill

Viscosity

ADIOS(TM) 1.1

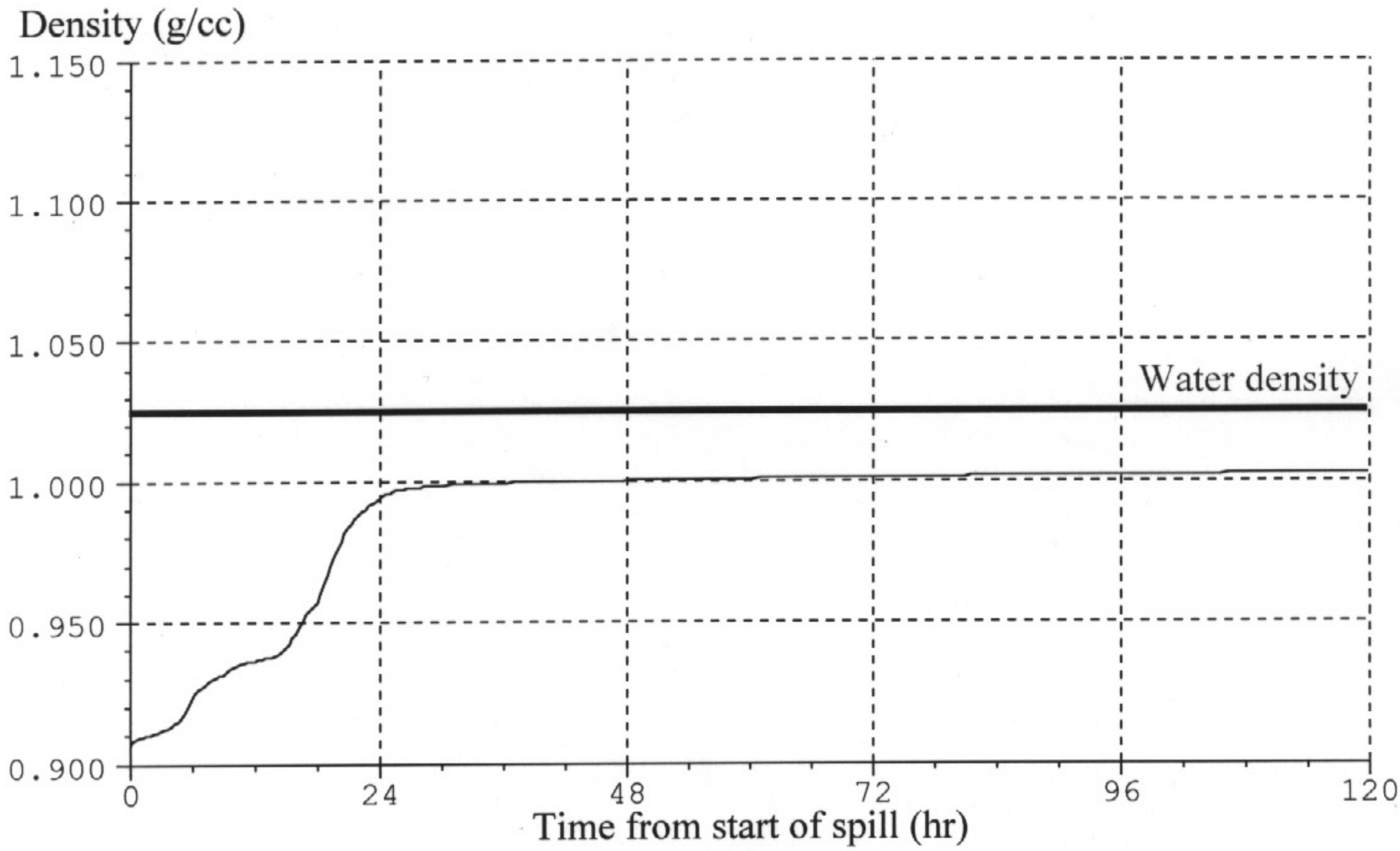
```
Oil Name: PRUDHOE BAY
API: 24.8                                  Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                          Wave Height: Default values

Water Temperature: 11 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Density

ADIOS(TM) 1.1

```
Oil Name: PRUDHOE BAY
API: 24.8                          Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                  Wave Height: Default values

Water Temperature: 11 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Eastern Location, Large Spill

Time hours	Total Released gallons	Evaporated percent	Dispersed percent	Floating percent
0	0	0	0	100
3	2,850,000	4	0	96
6	3,800,000	6	0	94
9	3,800,000	8	0	92
12	3,800,000	9	0	91
15	3,800,000	11	0	89
18	3,800,000	12	0	88
21	3,800,000	13	0	87
24	3,800,000	13	0	87
27	3,800,000	14	0	86
30	3,800,000	14	0	86
33	3,800,000	15	0	85
36	3,800,000	15	0	85
39	3,800,000	16	0	84
42	3,800,000	16	0	84
45	3,800,000	16	0	84
48	3,800,000	17	0	83
54	3,800,000	17	0	83
60	3,800,000	18	0	82
66	3,800,000	18	0	82
72	3,800,000	18	0	82
78	3,800,000	18	0	82
84	3,800,000	18	0	82
90	3,800,000	19	0	81
96	3,800,000	19	0	81
102	3,800,000	19	0	81
108	3,800,000	19	0	81
114	3,800,000	20	0	80
120	3,800,000	20	0	80

Text Summary

ADIOS(TM) 1.1

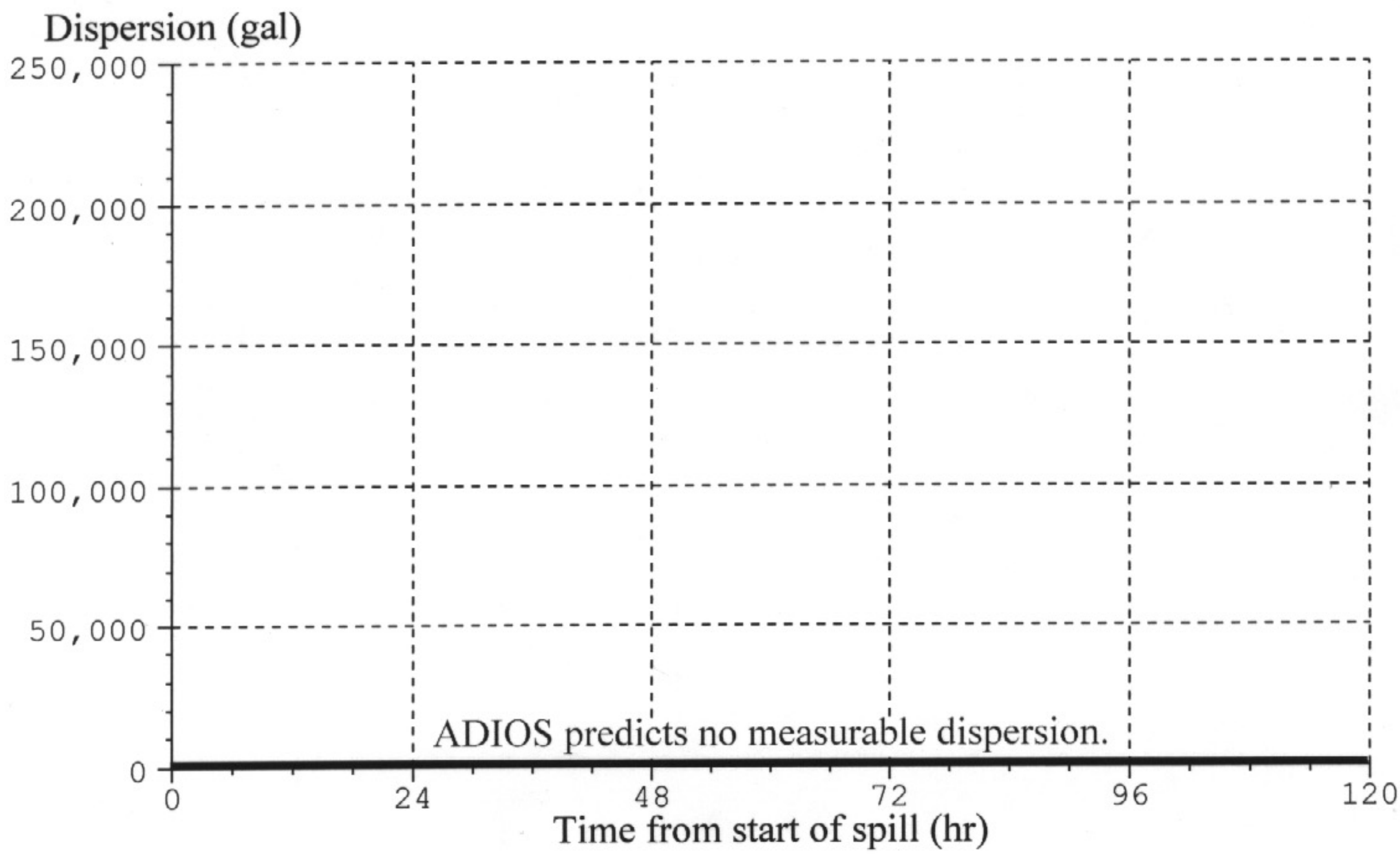
```
OIL OR PRODUCT:
    Oil Name:                BUNKER C FUEL OIL
    Location:                Not Available
    Synonyms:                FUEL OIL NO.6,HEAVY FUEL OIL,HEAVY RESIDUAL
FUEL OIL
    Product Type:            Refined
    Comments:                The emulsification constant and final water
content
                             are based on observations made by NOAA.

INITIAL PHYSICAL PROPERTIES:
    Density:                 0.97 g/cc at 11.0 C   (14.1 API)
    Kinematic Visc:          62,901 cSt at 11.0 C
    Pour Point:              between -4.0 C and 15.0 C
    Flash Point:             between 60.0 C and 174.0 C
    Aromatics:               55.0 weight %
    Emulsification:          Begins after 18% evaporated (estimated
value)
                             Data indicates mousse forms after 18%
evaporated.


WIND _WAVE DATA:
    Wind Speed:              Variable
    Wave Height:             Default values


SURFACE WATER PROPERTIES:
    Temperature:             11 C
    Salinity:                32.0 ppt
    Density:                 1.02444 g/cc


SPILL DATA:
    Continuous release of 250000 gal over 4 hr


WARNING:
    The water temperature is below the maximum reported pour point
for this
    oil or refined product.  It may not pour, which would cause
ADIOS to give
    inaccurate predictions.
```

Dispersion

ADIOS(TM) 1.1

Oil Name: BUNKER C FUEL OIL
API: 14.1 Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
Wave Height: Default values

Water Temperature: 11 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.

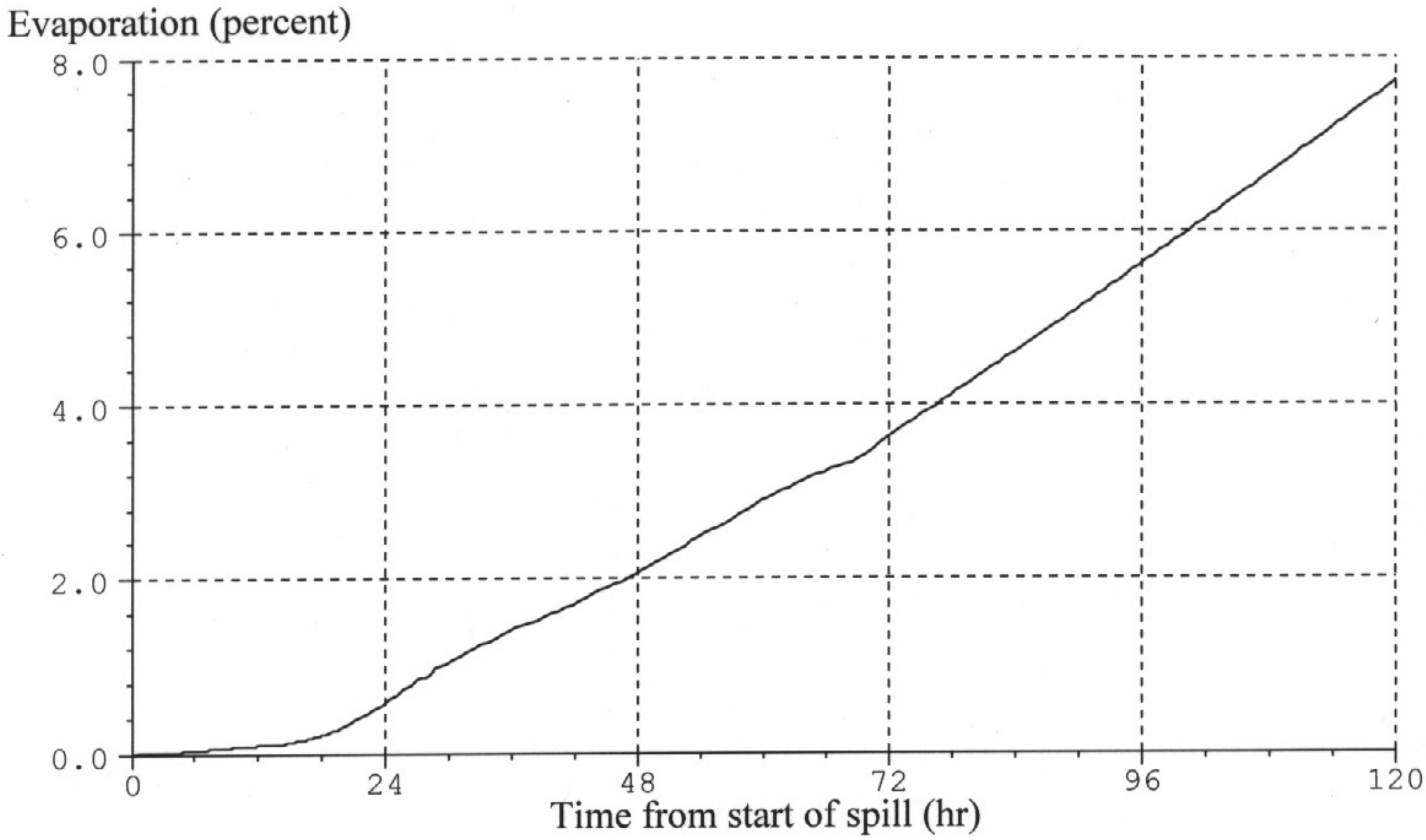


Evaporation

ADIOS(TM) 1.1

Oil Name: BUNKER C FUEL OIL
API: 14.1   Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                             Wave Height: Default values

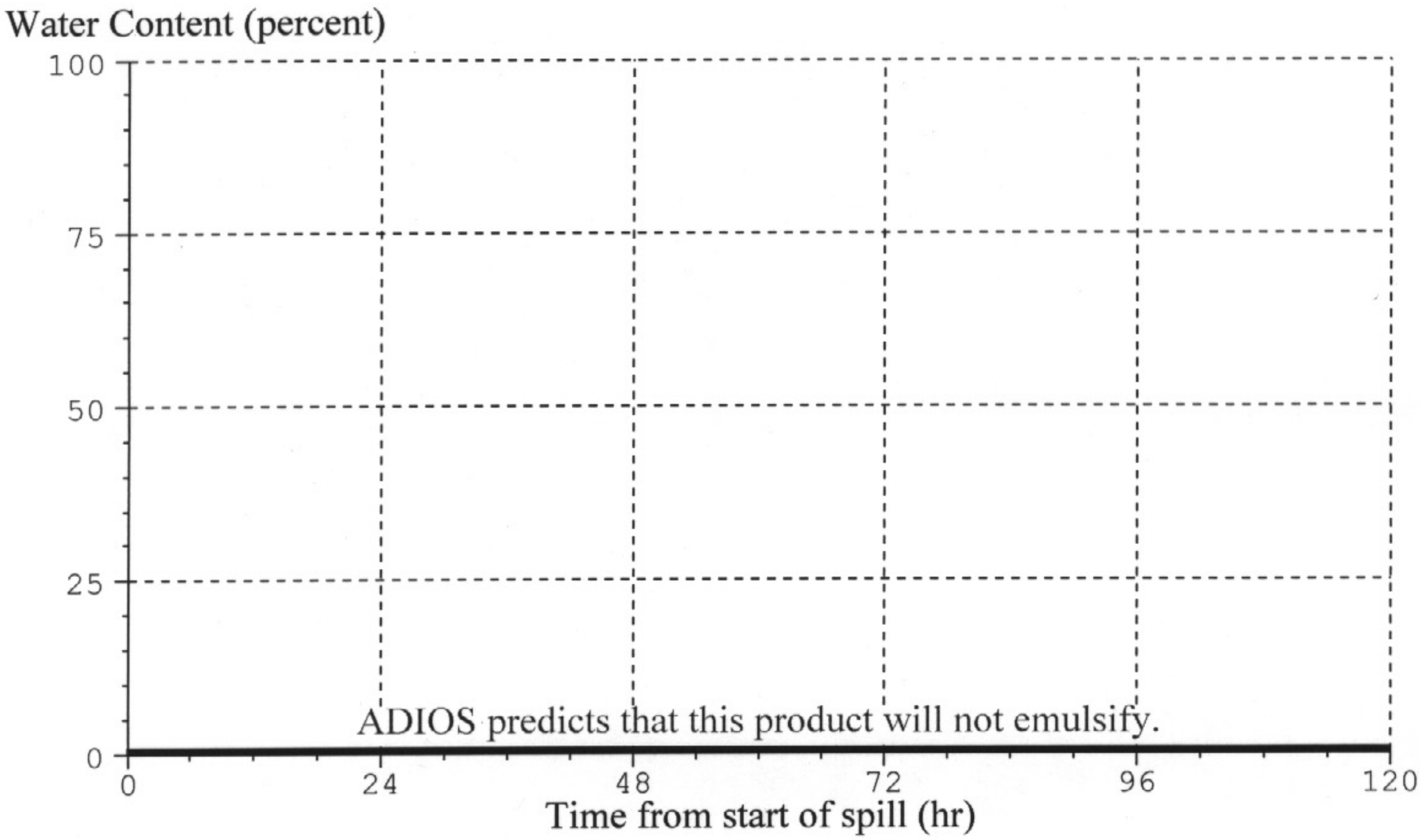
Water Temperature: 11 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.



Water Content

ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                                 Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                          Wave Height: Default values

Water Temperature: 11 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```

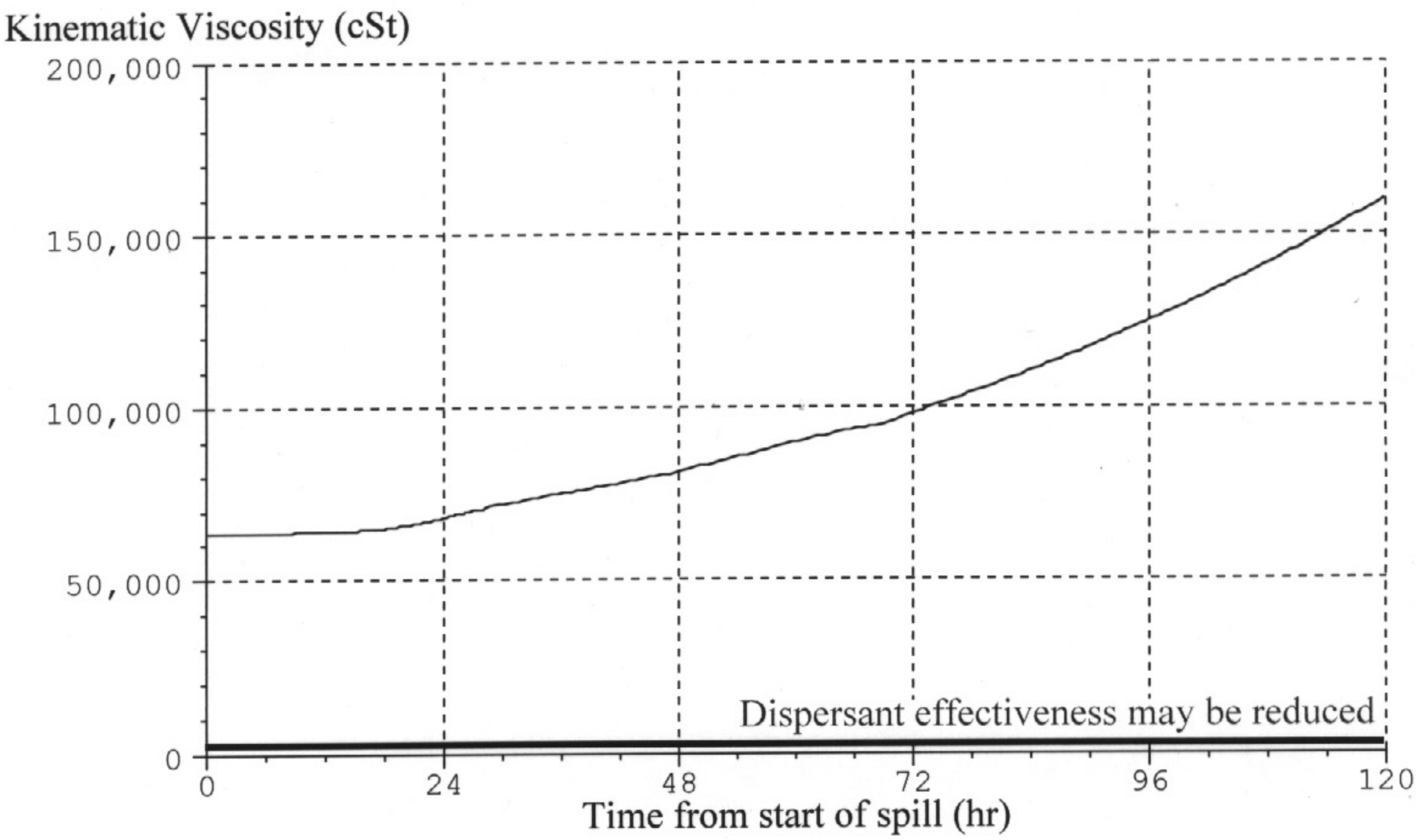


Eastern Location, Medium Spill

Viscosity

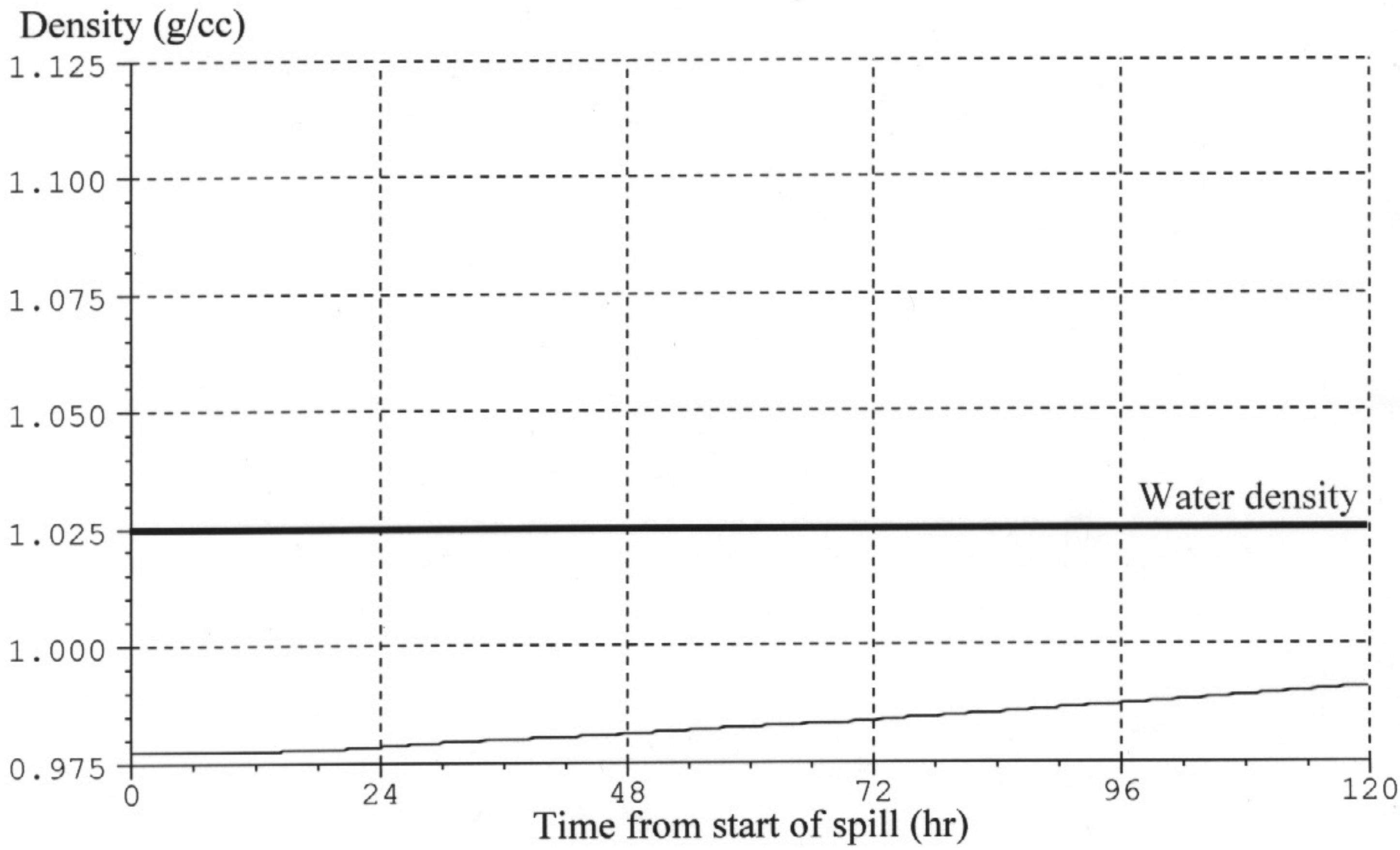
ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                              Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                      Wave Height: Default values

Water Temperature: 11 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Density ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                                    Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                             Wave Height: Default values

Water Temperature: 11 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Eastern Location, Medium Spill

Time hours	Total Released gallons	Evaporated percent	Dispersed percent	Floating percent
0	0	0	0	100
3	187,500	0	0	100
6	250,000	0	0	100
9	250,000	0	0	100
12	250,000	0	0	100
15	250,000	0	0	100
18	250,000	0	0	100
21	250,000	0	0	100
24	250,000	0	0	100
27	250,000	1	0	99
30	250,000	1	0	99
33	250,000	1	0	99
36	250,000	1	0	99
39	250,000	2	0	98
42	250,000	2	0	98
45	250,000	3	0	97
48	250,000	3	0	97
54	250,000	3	0	97
60	250,000	4	0	96
66	250,000	4	0	96
72	250,000	4	0	96
78	250,000	5	0	95
84	250,000	5	0	95
90	250,000	5	0	95
96	250,000	6	0	94
102	250,000	6	0	94
108	250,000	6	0	94
114	250,000	7	0	93
120	250,000	7	0	93

Text Summary

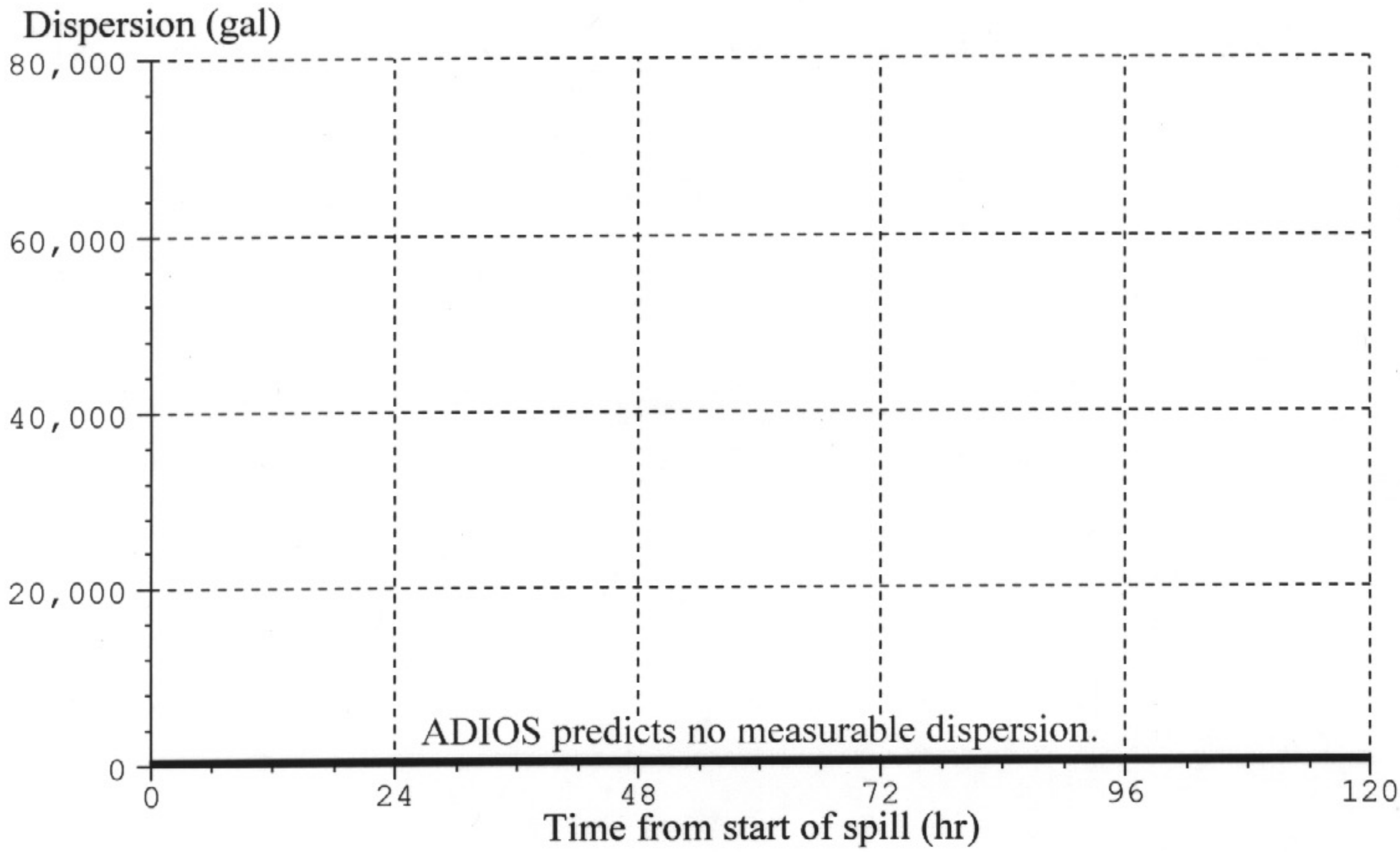
ADIOS(TM) 1.1

```
OIL OR PRODUCT:
    Oil Name:               BUNKER C FUEL OIL
    Location:               Not Available
    Synonyms:               FUEL OIL NO.6,HEAVY FUEL OIL,HEAVY RESIDUAL
FUEL OIL
    Product Type:           Refined
    Comments:               The emulsification constant and final water
content
                            are based on observations made by NOAA.

INITIAL PHYSICAL PROPERTIES:
    Density:                0.97 g/cc at 11.0 C    (14.1 API)
    Kinematic Visc:         62,901 cSt at 11.0 C
    Pour Point:             between -4.0 C and 15.0 C
    Flash Point:            between 60.0 C and 174.0 C
    Aromatics:              55.0 weight %
    Emulsification:         Begins after 18% evaporated (estimated
value)
                            Data indicates mousse forms after 18%
evaporated.

WIND _WAVE DATA:
    Wind Speed:             Variable
    Wave Height:            Default values

SURFACE WATER PROPERTIES:
    Temperature:            11 C
    Salinity:               32.0 ppt
    Density:                1.02444 g/cc

SPILL DATA:
    Continuous release of 81300 gal over 4 hr

WARNING:
    The water temperature is below the maximum reported pour point
for this
    oil or refined product.  It may not pour, which would cause
ADIOS to give
    inaccurate predictions.
```

Dispersion

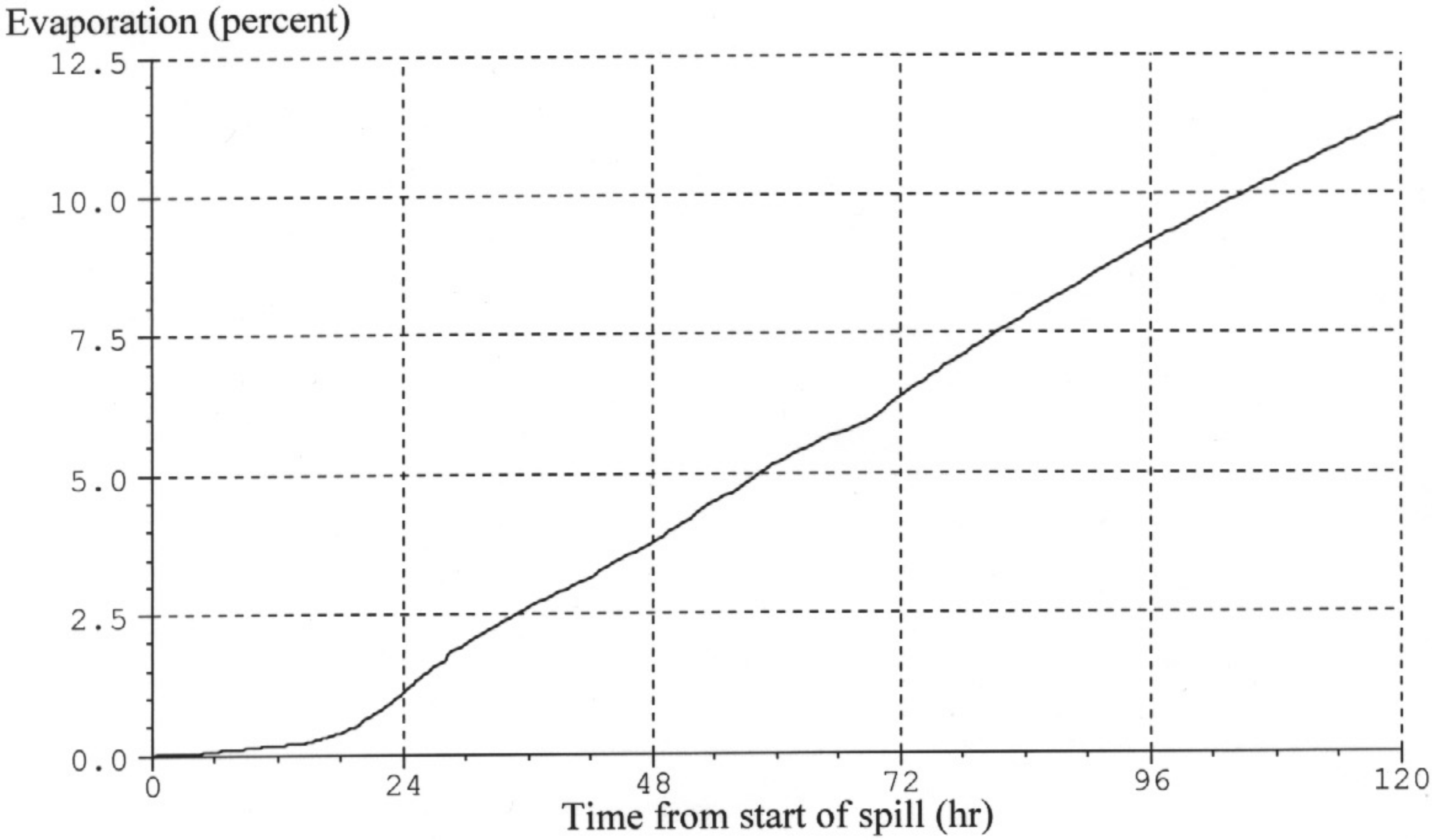
ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                                    Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                             Wave Height: Default values

Water Temperature: 11 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Evaporation ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                              Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                       Wave Height: Default values

Water Temperature: 11 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```

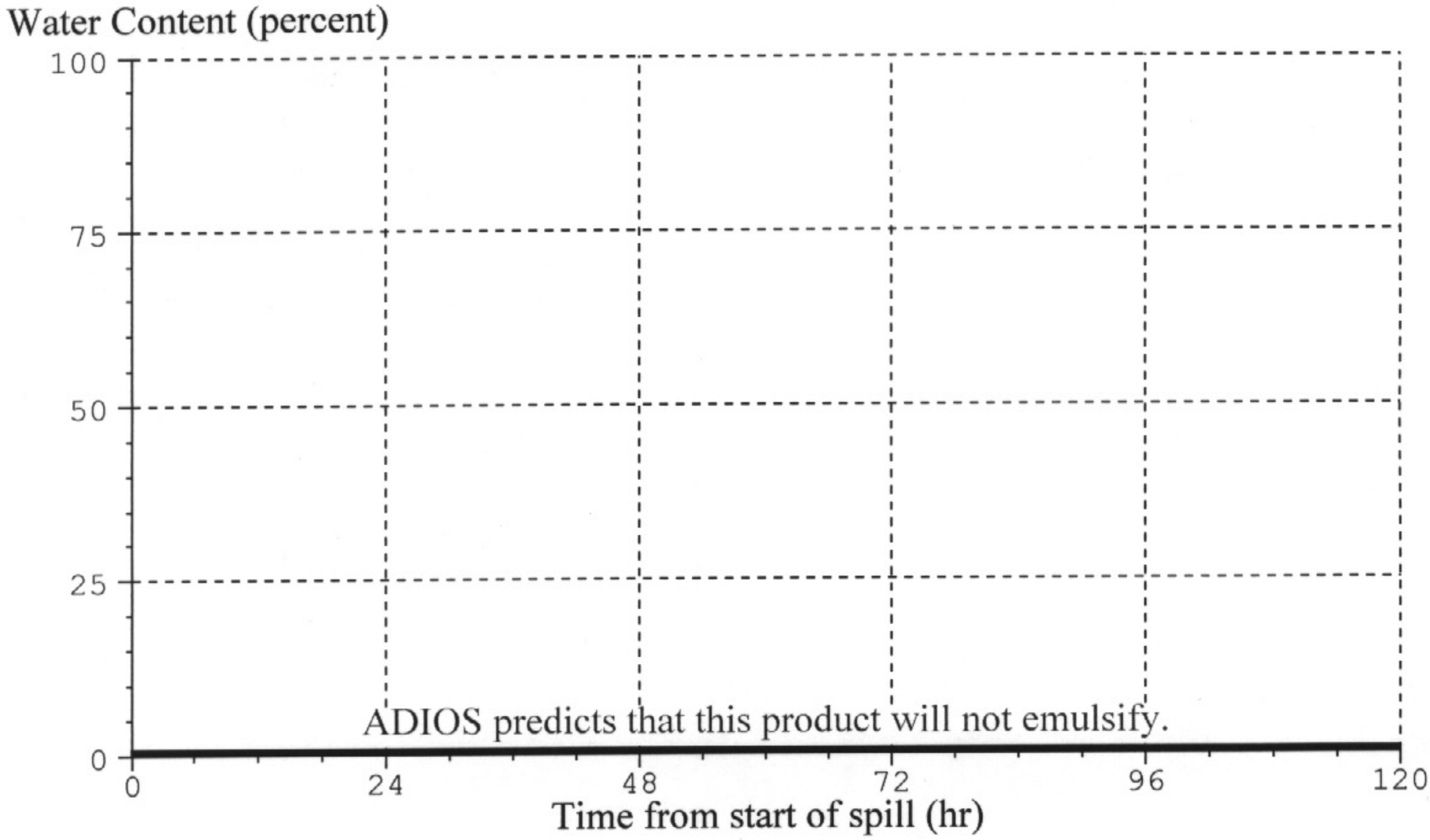


Water Content

ADIOS(TM) 1.1

Oil Name: BUNKER C FUEL OIL
API: 14.1
Pour Point: between -4.0 C and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
Wave Height: Default values

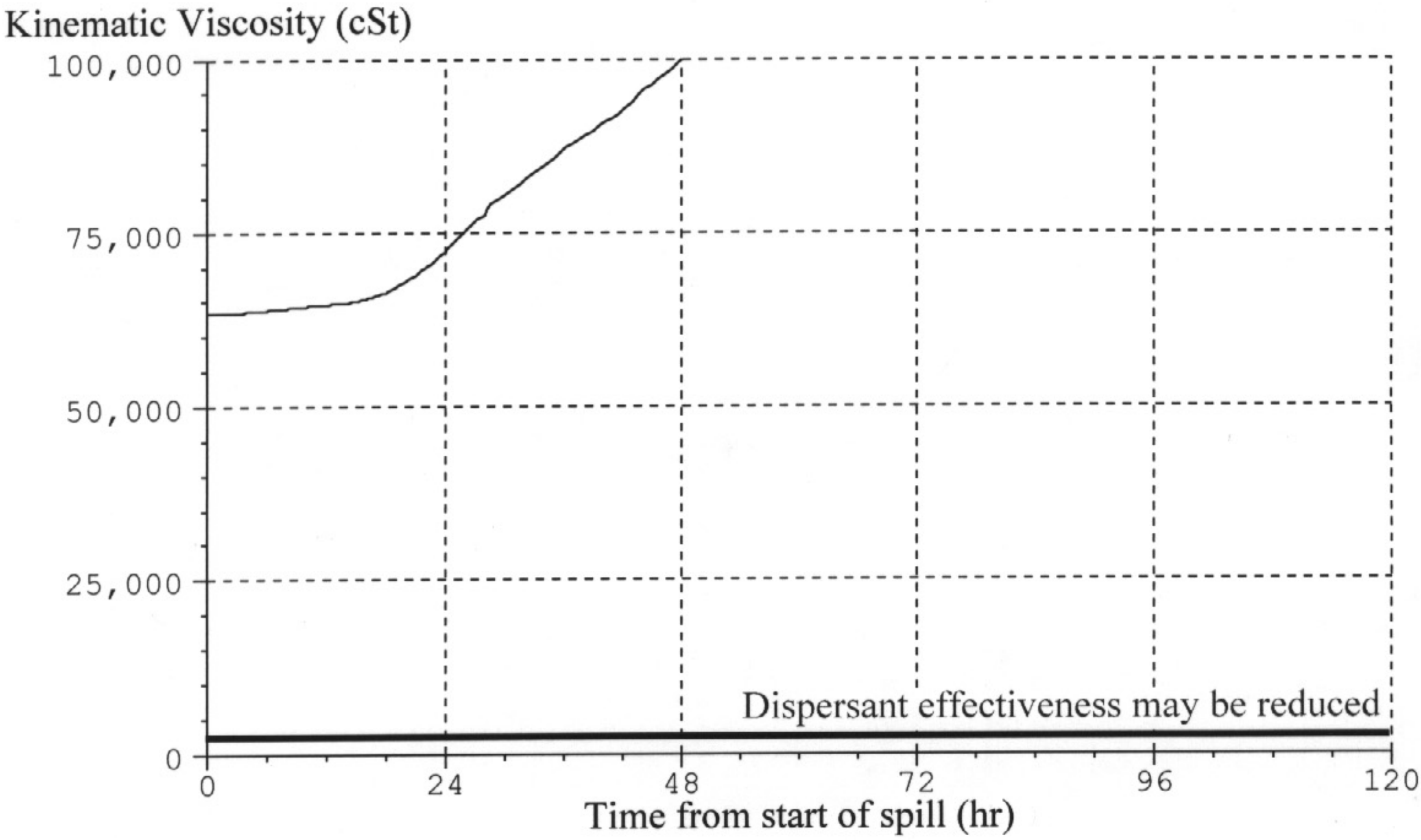
Water Temperature: 11 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.



Viscosity

ADIOS(TM) 1.1

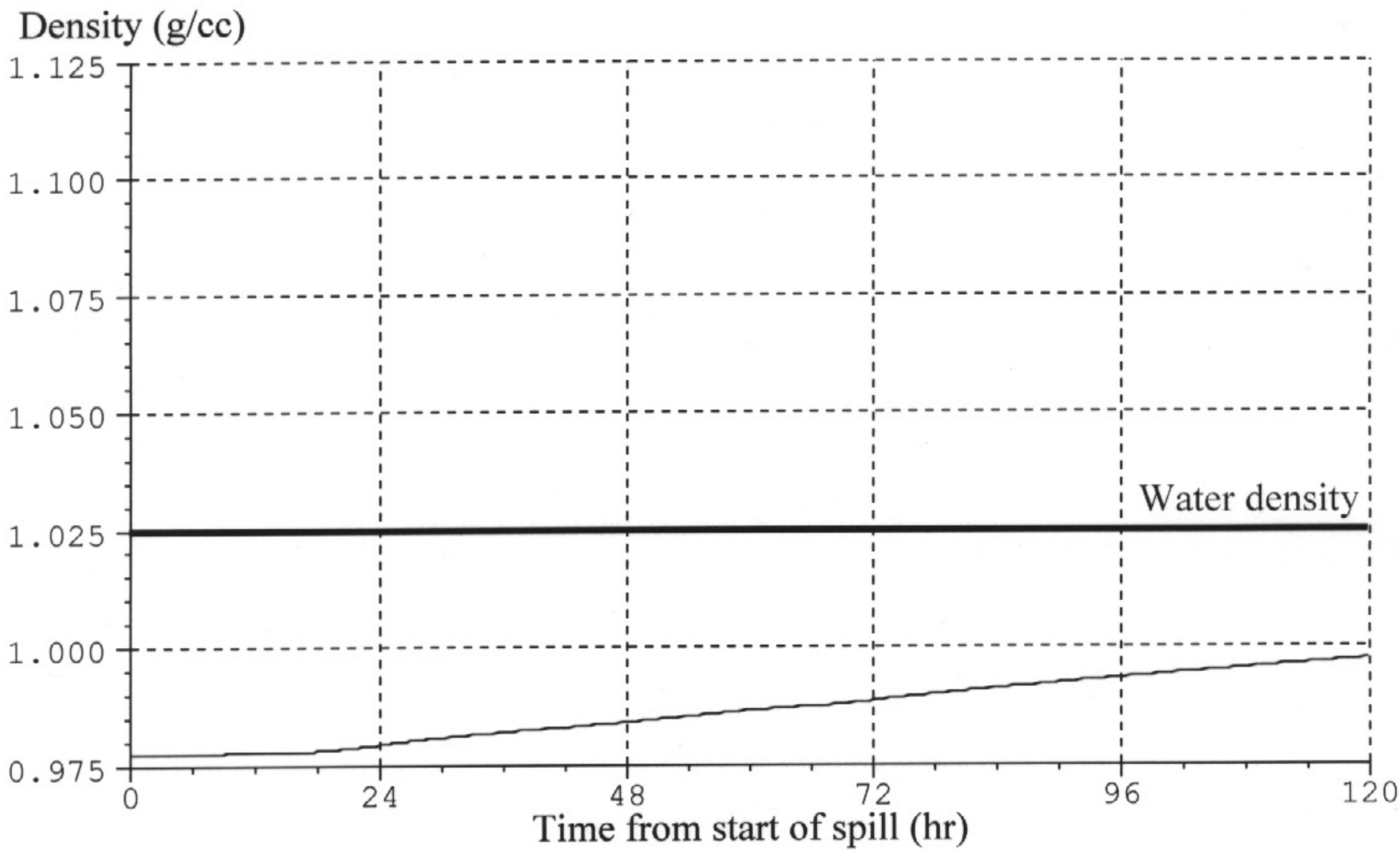
```
Oil Name: BUNKER C FUEL OIL
API: 14.1                                    Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                             Wave Height: Default values

Water Temperature: 11 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Density

ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                                    Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                             Wave Height: Default values

Water Temperature: 11 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Eastern Location, Small Spill

Time hours	Total Released gallons	Evaporated percent	Dispersed percent	Floating percent
0	0	0	0	100
3	187,500	0	0	100
6	250,000	0	0	100
9	250,000	0	0	100
12	250,000	0	0	100
15	250,000	0	0	100
18	250,000	0	0	100
21	250,000	0	0	100
24	250,000	0	0	100
27	250,000	1	0	99
30	250,000	1	0	99
33	250,000	1	0	99
36	250,000	1	0	99
39	250,000	2	0	98
42	250,000	2	0	98
45	250,000	3	0	97
48	250,000	3	0	97
54	250,000	3	0	97
60	250,000	4	0	96
66	250,000	4	0	96
72	250,000	4	0	96
78	250,000	5	0	95
84	250,000	5	0	95
90	250,000	5	0	95
96	250,000	6	0	94
102	250,000	6	0	94
108	250,000	6	0	94
114	250,000	7	0	93
120	250,000	7	0	93

Text Summary

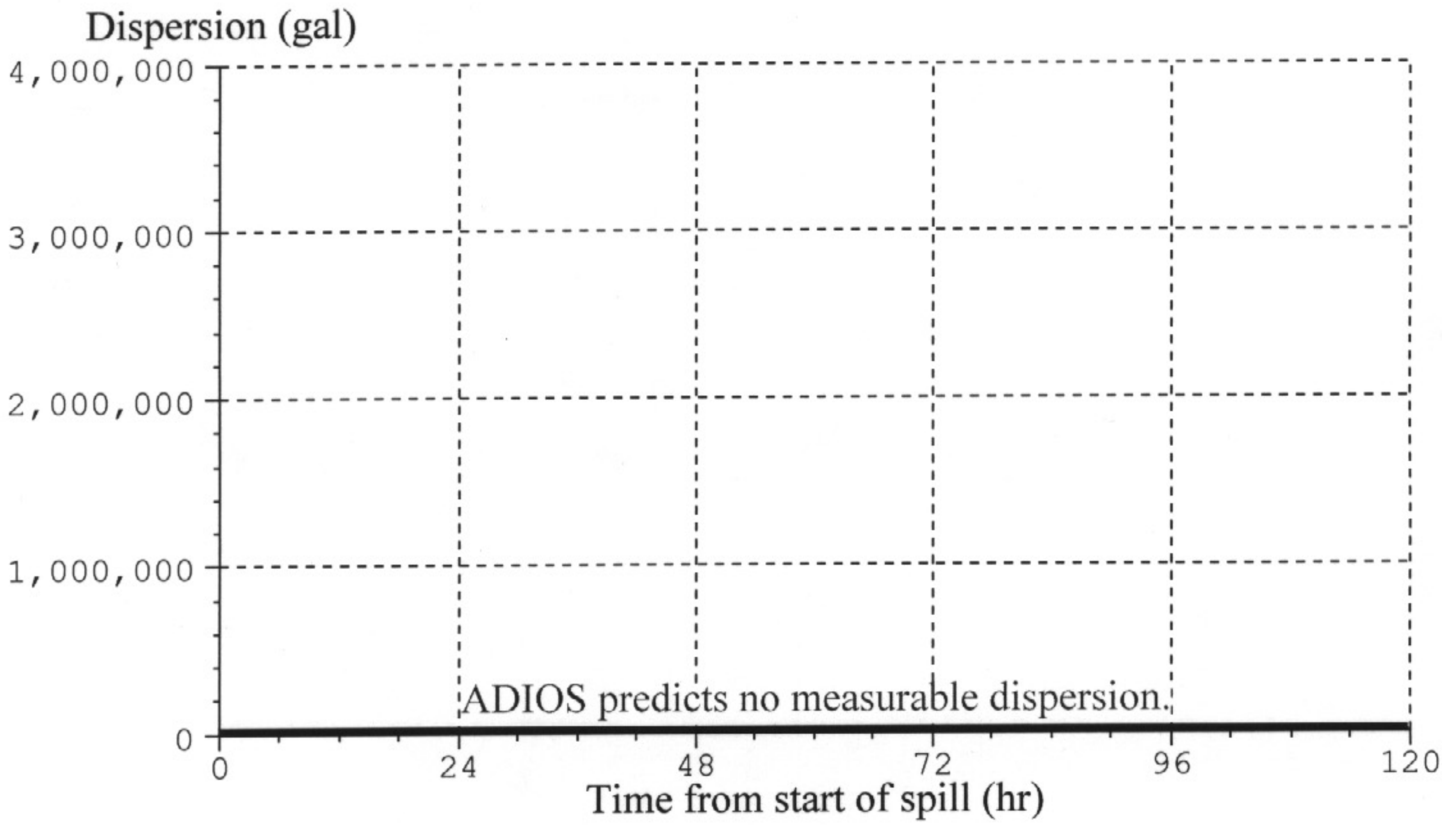
ADIOS(TM) 1.1

```
OIL OR PRODUCT:
    Oil Name:               PRUDHOE BAY
    Location:               NORTH SLOPE, ALASKA
    Synonyms:               Not Available
    Product Type:           Crude
    Comments:               Not Available

INITIAL PHYSICAL PROPERTIES:
    Density:                0.91 g/cc at 9.0 C    (24.8 API)
    Kinematic Visc:         109 cSt at 9.0 C
    Pour Point:             between -42.0 C and 0.0 C
    Flash Point:            30.0 C
    Aromatics:              10.00 weight %
    Emulsification:         Begins after 5% evaporated (estimated
value)
                            No library data is available on mousse
formation.


WIND _WAVE DATA:
    Wind Speed:             Variable
    Wave Height:            Default values


SURFACE WATER PROPERTIES:
    Temperature:            9 C
    Salinity:               32.0 ppt
    Density:                1.02477 g/cc


SPILL DATA:
    Continuous release of 3800000 gal over 4 hr


WARNING:
    Estimated emulsification constant could affect accuracy of
viscosity and
    water content predictions.
```

Dispersion

ADIOS(TM) 1.1

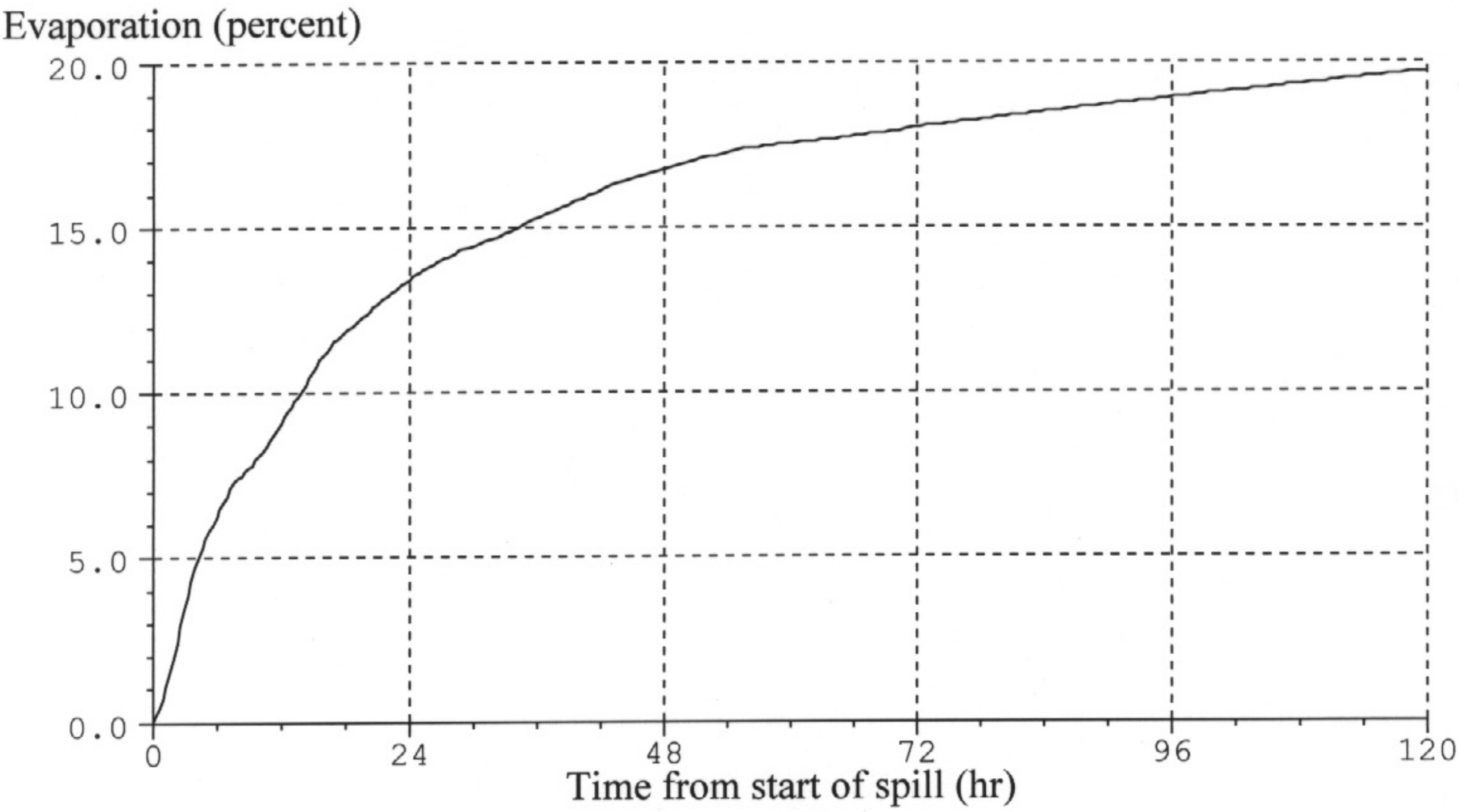
```
Oil Name: PRUDHOE BAY
API: 24.8                                    Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                             Wave Height: Default values

Water Temperature: 9 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Evaporation

ADIOS(TM) 1.1

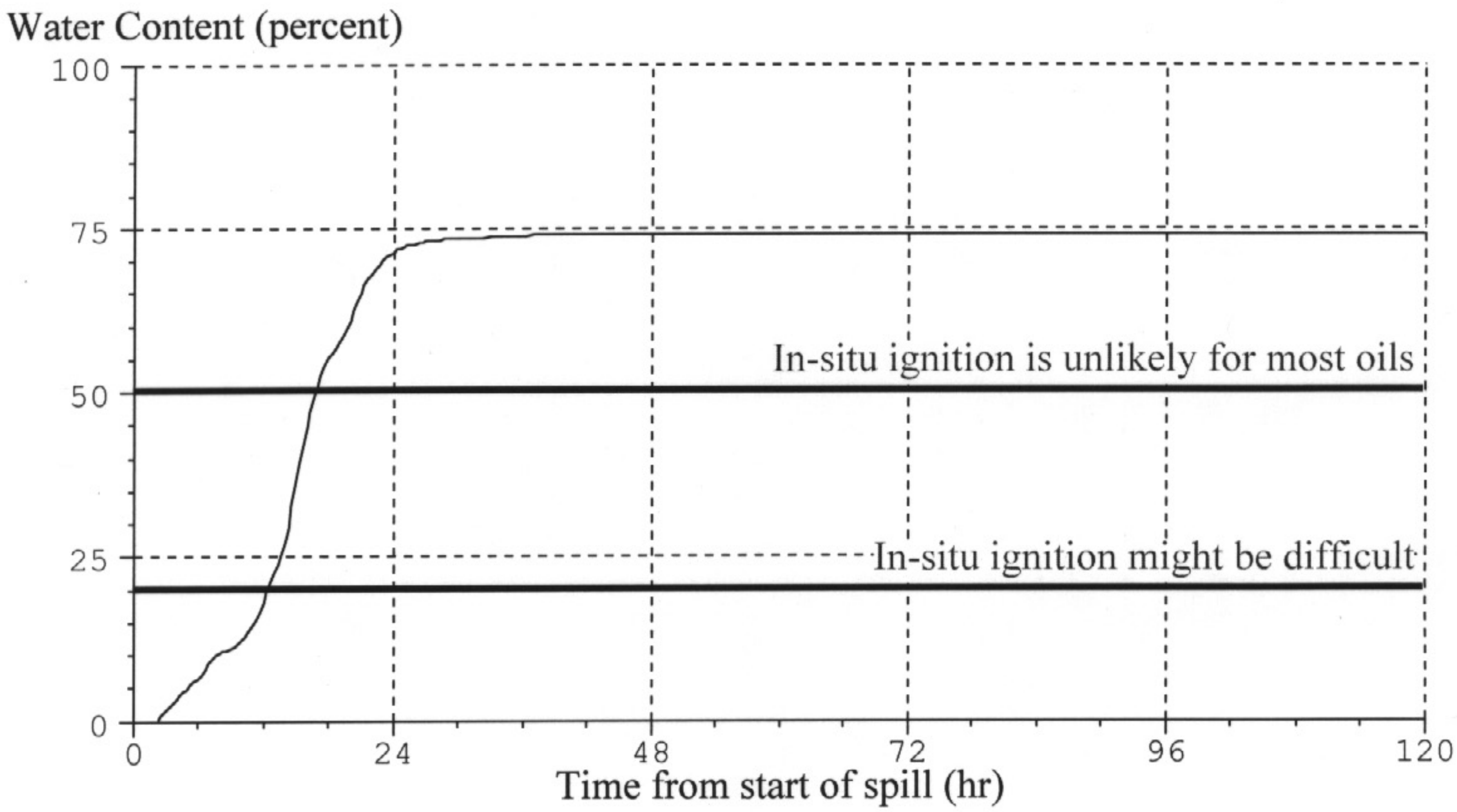
```
Oil Name: PRUDHOE BAY
API: 24.8                                  Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                          Wave Height: Default values

Water Temperature: 9 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Water Content

ADIOS(TM) 1.1

```
Oil Name: PRUDHOE BAY
API: 24.8                                  Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                          Wave Height: Default values

Water Temperature: 9 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```

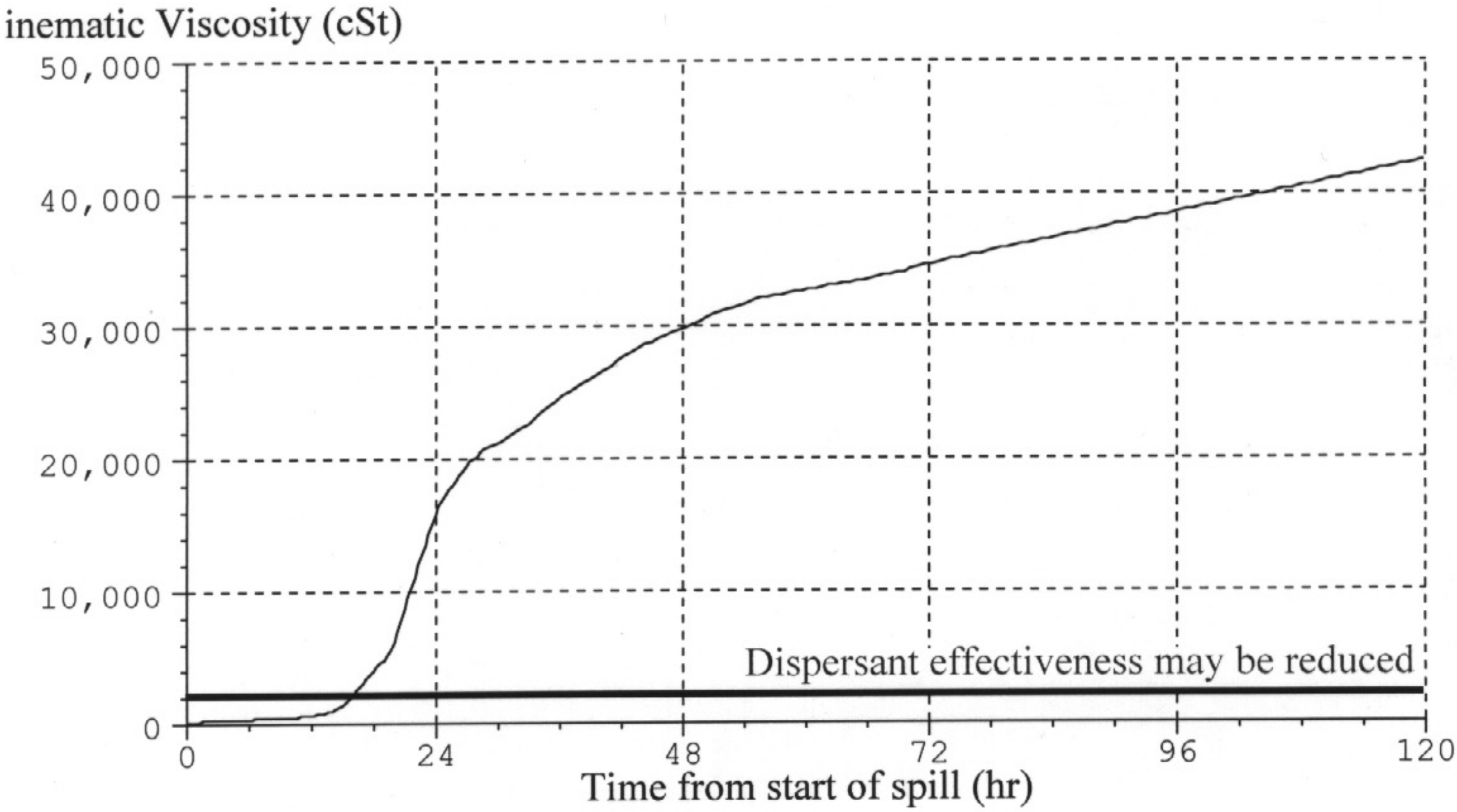


Viscosity

ADIOS(TM) 1.1

Oil Name: PRUDHOE BAY
API: 24.8
Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
Wave Height: Default values

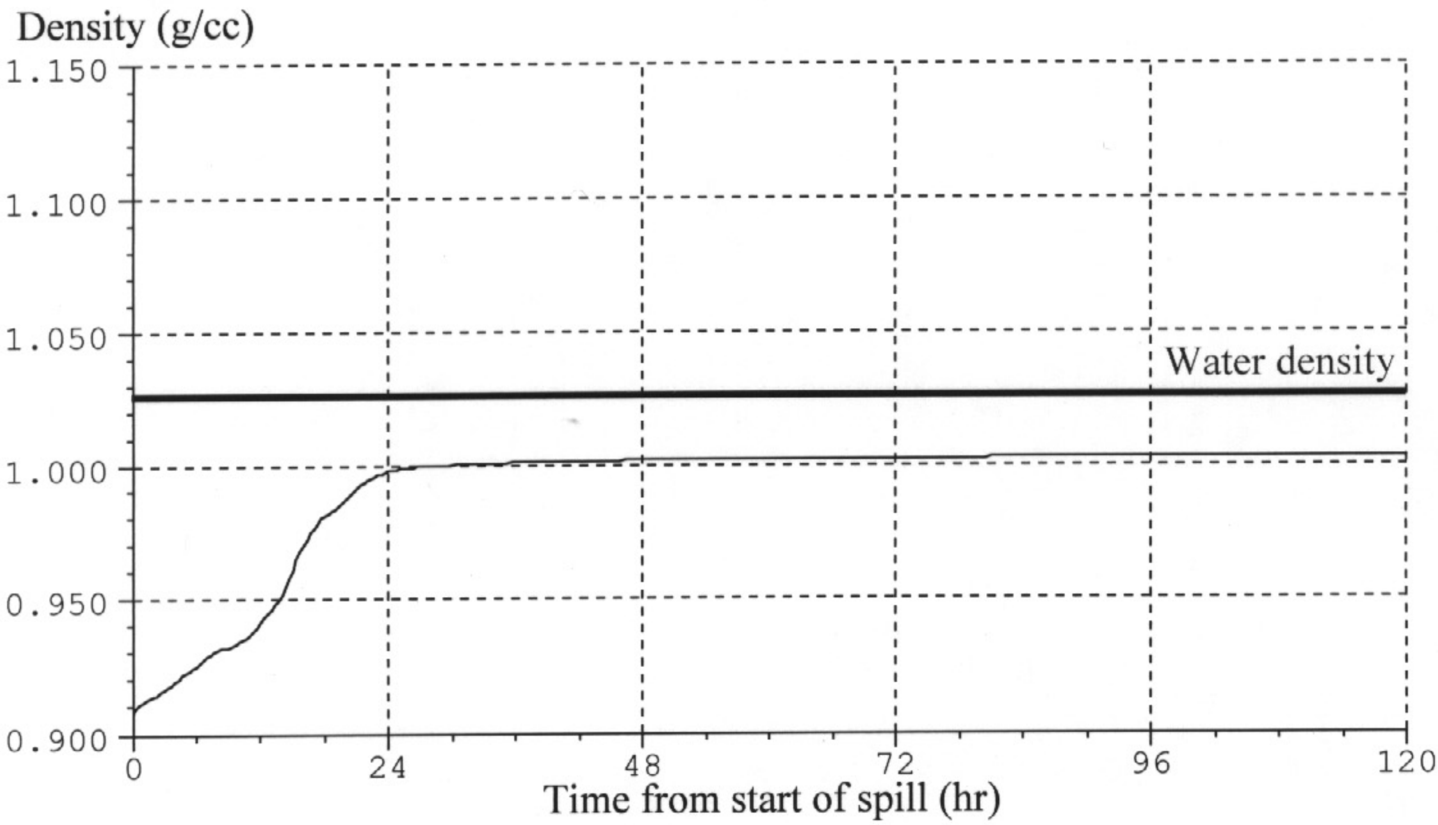
Water Temperature: 9 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.



Density

ADIOS(TM) 1.1

```
Oil Name: PRUDHOE BAY
API: 24.8                                 Pour Point: between -42.0 C
and 0.0 C
Mousse Const: 5% evaporated
Wind Speed: Variable
                                          Wave Height: Default values

Water Temperature: 9 C
Continuous release of 3800000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Western Location, Large Spill

Time hours	Total Released gallons	Evaporated percent	Dispersed percent	Floating percent
0	0	0	0	100
3	2,850,000	4	0	96
6	3,800,000	6	0	94
9	3,800,000	7	0	93
12	3,800,000	9	0	91
15	3,800,000	10	0	90
18	3,800,000	11	0	89
21	3,800,000	12	0	88
24	3,800,000	13	0	87
27	3,800,000	13	0	87
30	3,800,000	14	0	86
33	3,800,000	14	0	86
36	3,800,000	15	0	85
39	3,800,000	15	0	85
42	3,800,000	16	0	84
45	3,800,000	16	0	84
48	3,800,000	16	0	84
54	3,800,000	17	0	83
60	3,800,000	17	0	83
66	3,800,000	17	0	83
72	3,800,000	17	0	83
78	3,800,000	18	0	82
84	3,800,000	18	0	82
90	3,800,000	18	0	82
96	3,800,000	18	0	82
102	3,800,000	19	0	81
108	3,800,000	19	0	81
114	3,800,000	19	0	81
120	3,800,000	19	0	81

Text Summary

ADIOS(TM) 1.1

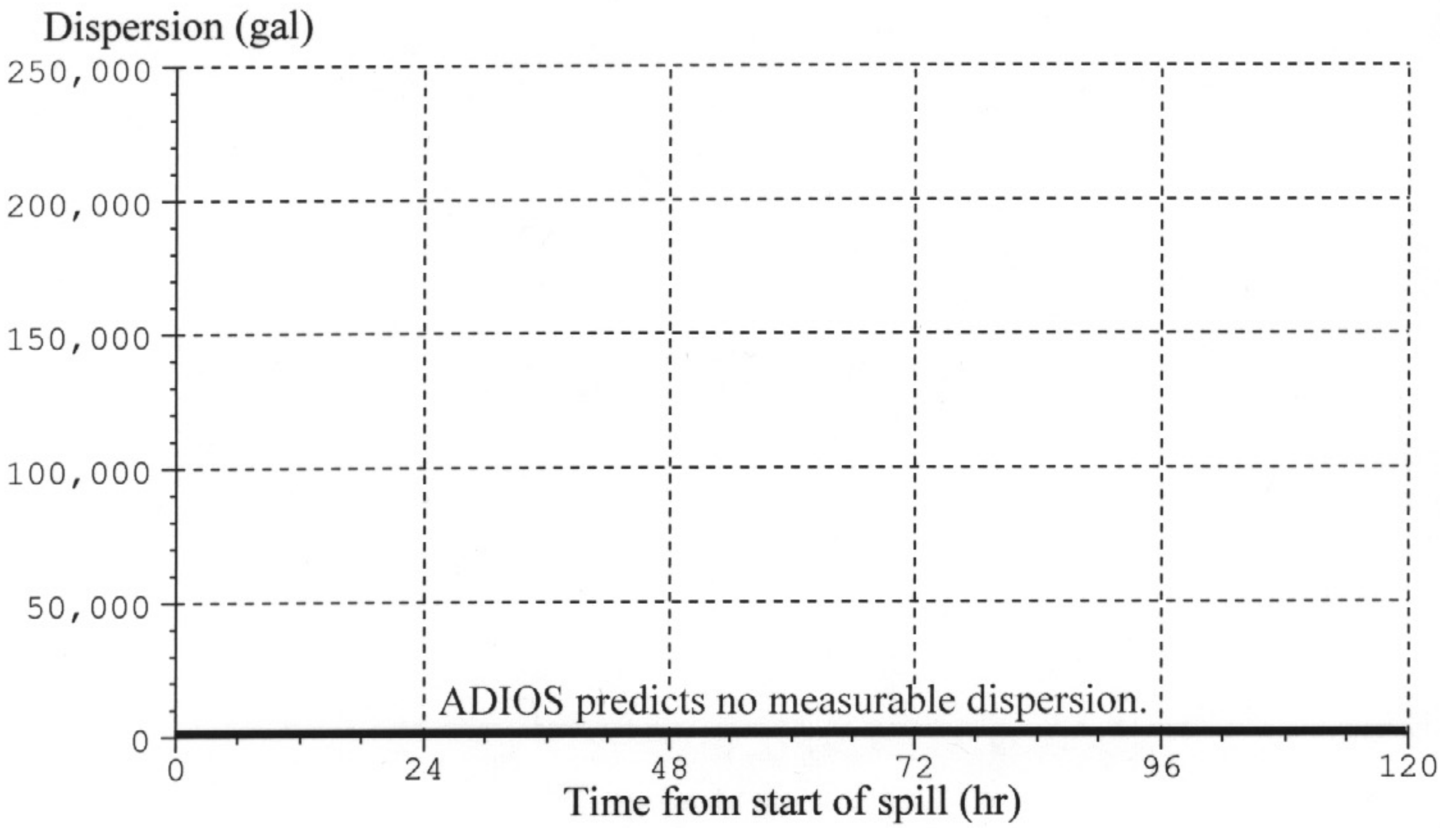
```
OIL OR PRODUCT:
    Oil Name:               BUNKER C FUEL OIL
    Location:               Not Available
    Synonyms:               FUEL OIL NO.6,HEAVY FUEL OIL,HEAVY RESIDUAL
FUEL OIL
    Product Type:           Refined
    Comments:               The emulsification constant and final water
content
                            are based on observations made by NOAA.

INITIAL PHYSICAL PROPERTIES:
    Density:                0.98 g/cc at 9.0 C    (14.1 API)
    Kinematic Visc:         71,257 cSt at 9.0 C
    Pour Point:             between -4.0 C and 15.0 C
    Flash Point:            between 60.0 C and 174.0 C
    Aromatics:              55.0 weight %
    Emulsification:         Begins after 18% evaporated (estimated
value)
                            Data indicates mousse forms after 18%
evaporated.

WIND _WAVE DATA:
    Wind Speed:             Variable
    Wave Height:            Default values

SURFACE WATER PROPERTIES:
    Temperature:            9 C
    Salinity:               32.0 ppt
    Density:                1.02477 g/cc

SPILL DATA:
    Continuous release of 250000 gal over 4 hr

WARNING:
    The water temperature is below the maximum reported pour point
for this
    oil or refined product.  It may not pour, which would cause
ADIOS to give
    inaccurate predictions.
```

Dispersion

ADIOS(TM) 1.1

Oil Name: BUNKER C FUEL OIL
API: 14.1 Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
Wave Height: Default values

Water Temperature: 9 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.

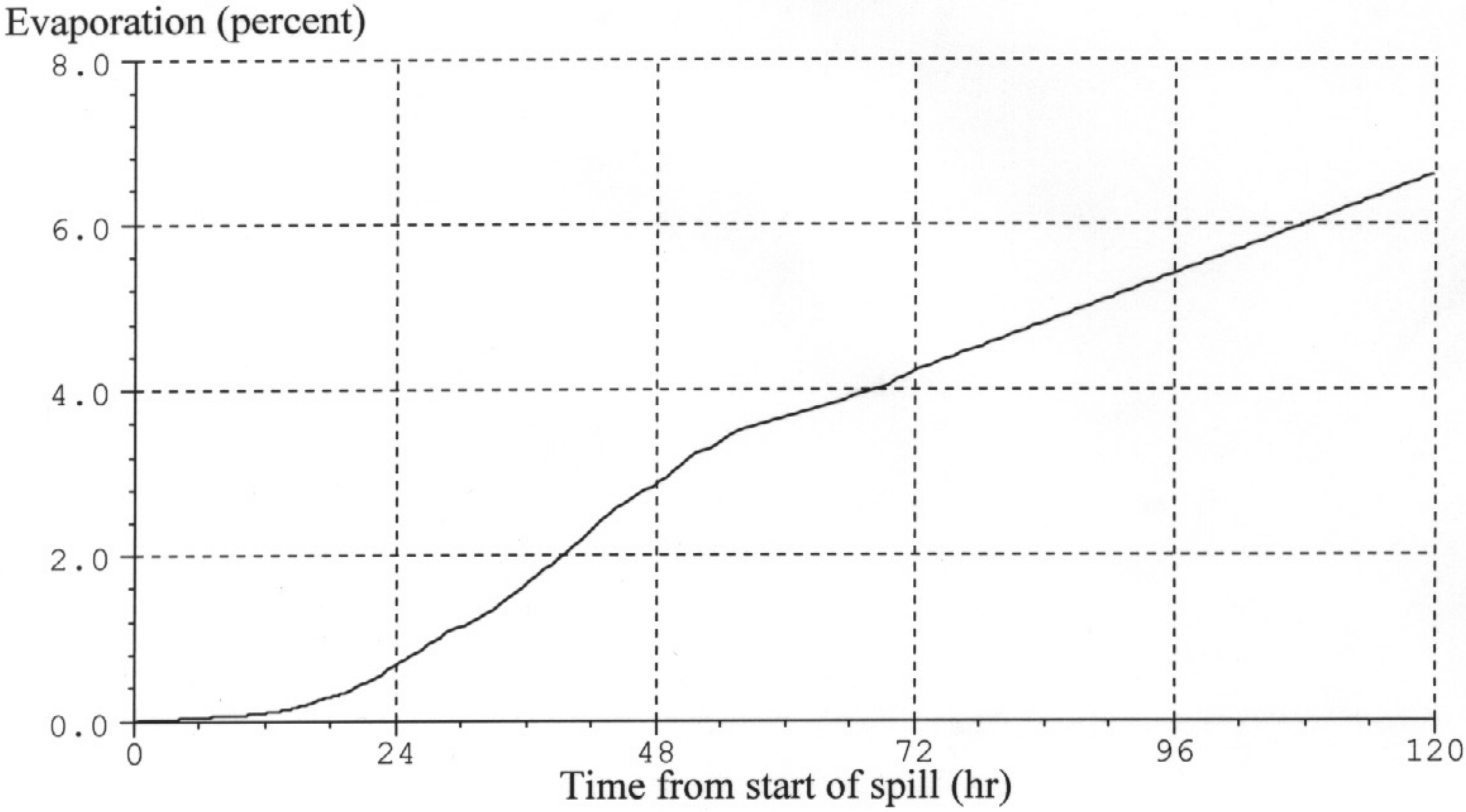


Evaporation

ADIOS(TM) 1.1

Oil Name: BUNKER C FUEL OIL
API: 14.1
Pour Point: between -4.0 C and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
Wave Height: Default values

Water Temperature: 9 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.

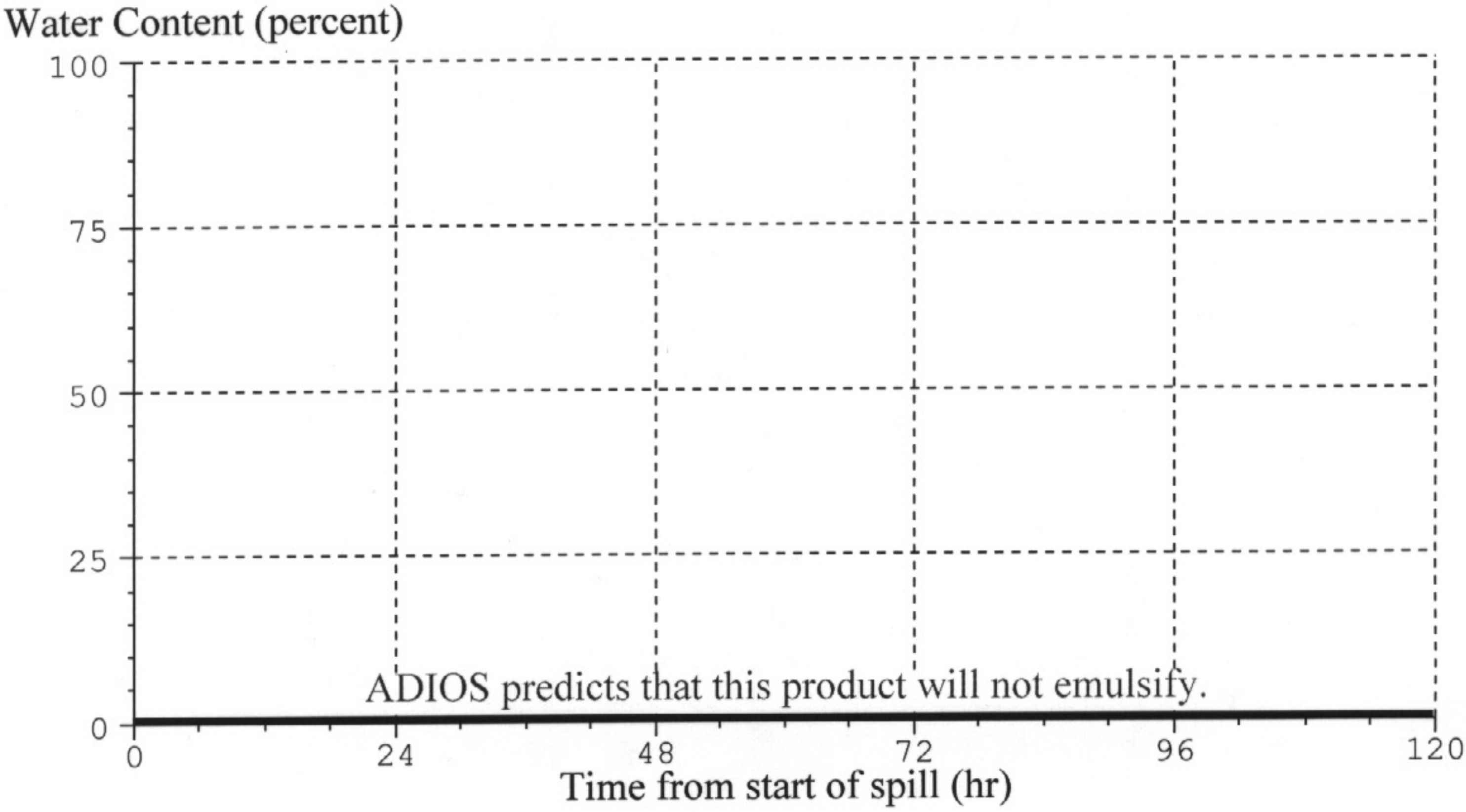


Water Content

ADIOS(TM) 1.1

Oil Name: BUNKER C FUEL OIL
API: 14.1
Pour Point: between -4.0 C and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
Wave Height: Default values

Water Temperature: 9 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.

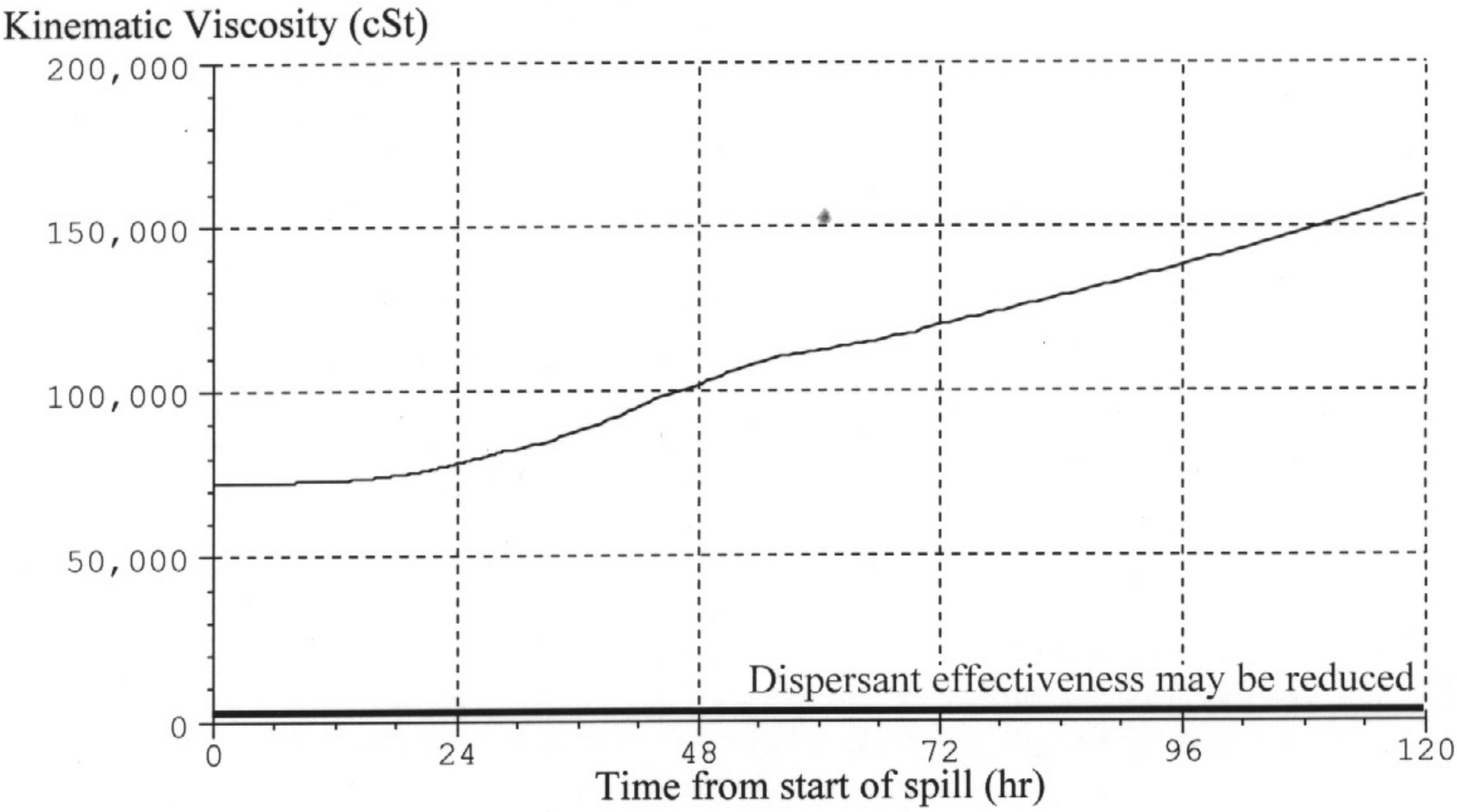


Viscosity

ADIOS(TM) 1.1

Oil Name: BUNKER C FUEL OIL
API: 14.1 Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
Wave Height: Default values

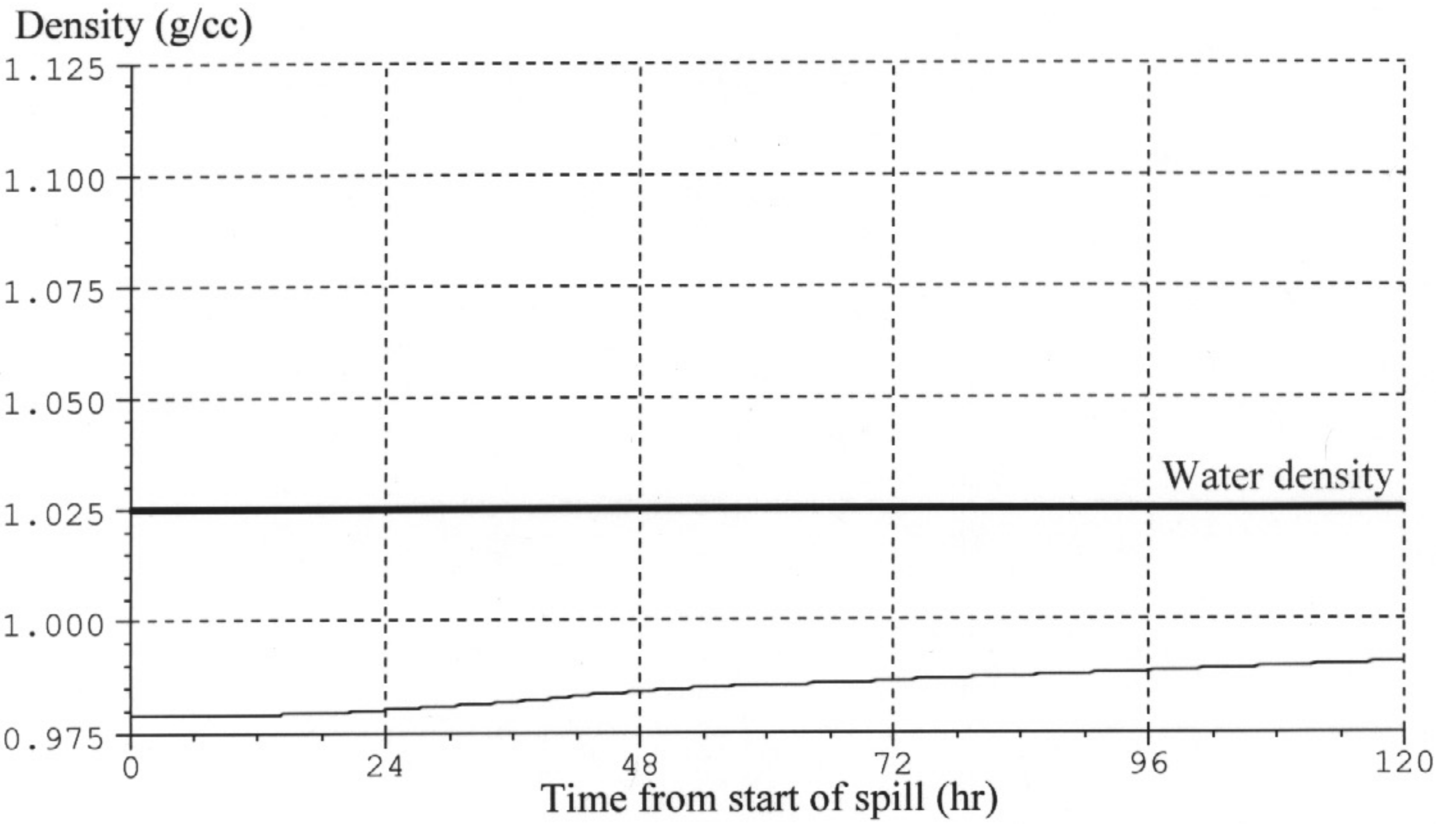
Water Temperature: 9 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.



Density

ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                                  Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                          Wave Height: Default values

Water Temperature: 9 C
Continuous release of 250000 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Western Location, Medium Spill

Time hours	Total Released gallons	Evaporated percent	Dispersed percent	Floating percent
0	0	0	0	100
3	187,500	0	0	100
6	250,000	0	0	100
9	250,000	0	0	100
12	250,000	0	0	100
15	250,000	0	0	100
18	250,000	0	0	100
21	250,000	0	0	100
24	250,000	0	0	100
27	250,000	0	0	100
30	250,000	1	0	99
33	250,000	1	0	99
36	250,000	1	0	99
39	250,000	1	0	99
42	250,000	2	0	98
45	250,000	2	0	98
48	250,000	2	0	98
54	250,000	3	0	97
60	250,000	3	0	97
66	250,000	3	0	97
72	250,000	4	0	96
78	250,000	4	0	96
84	250,000	4	0	96
90	250,000	5	0	95
96	250,000	5	0	95
102	250,000	5	0	95
108	250,000	5	0	95
114	250,000	6	0	94
120	250,000	6	0	94

Text Summary

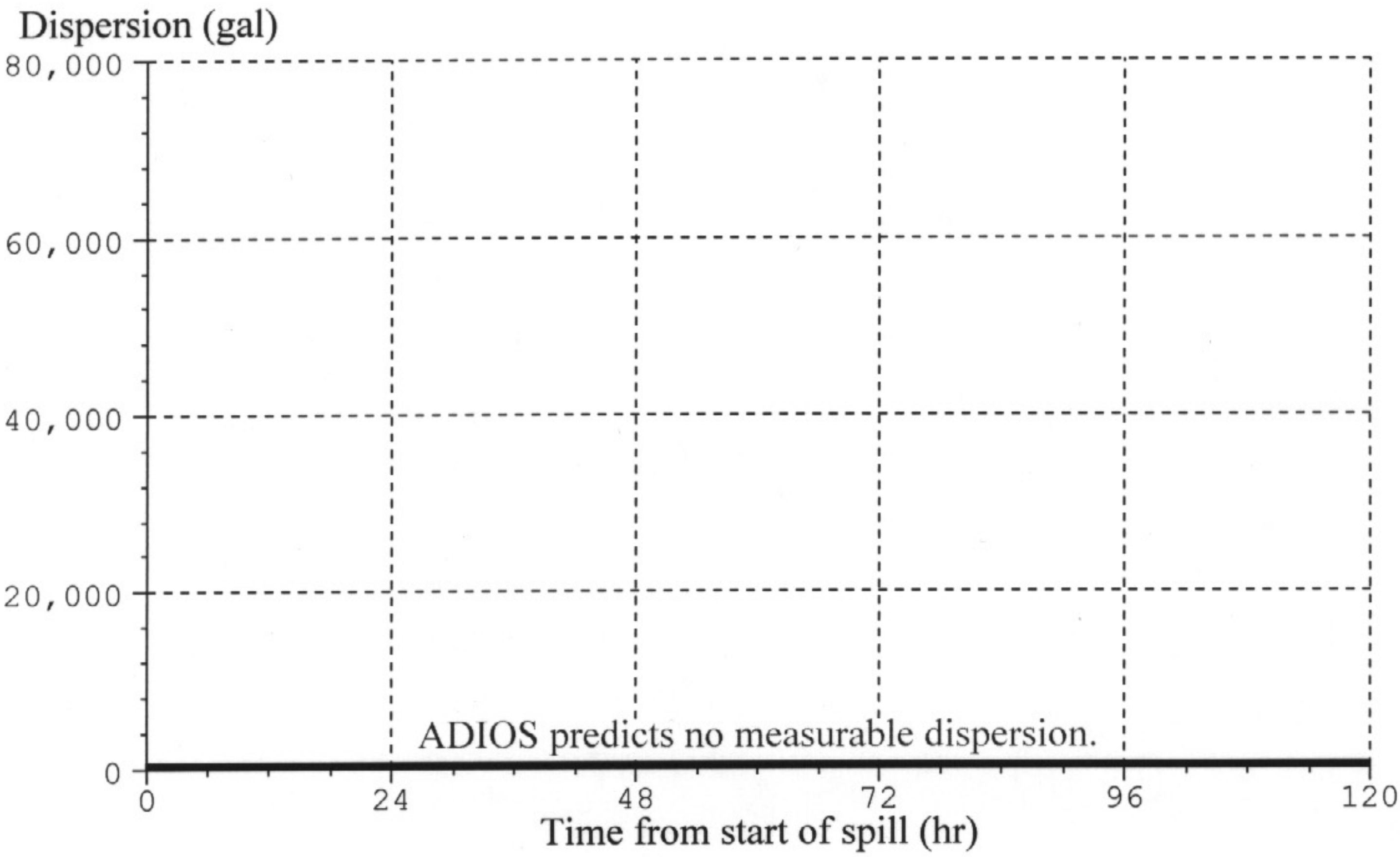
ADIOS(TM) 1.1

```
OIL OR PRODUCT:
    Oil Name:               BUNKER C FUEL OIL
    Location:               Not Available
    Synonyms:               FUEL OIL NO.6,HEAVY FUEL OIL,HEAVY RESIDUAL
FUEL OIL
    Product Type:           Refined
    Comments:               The emulsification constant and final water
content
                            are based on observations made by NOAA.

INITIAL PHYSICAL PROPERTIES:
    Density:                0.98 g/cc at 9.0 C   (14.1 API)
    Kinematic Visc:         71,257 cSt at 9.0 C
    Pour Point:             between -4.0 C and 15.0 C
    Flash Point:            between 60.0 C and 174.0 C
    Aromatics:              55.0 weight %
    Emulsification:         Begins after 18% evaporated (estimated
value)
                            Data indicates mousse forms after 18%
evaporated.


WIND _WAVE DATA:
    Wind Speed:             Variable
    Wave Height:            Default values


SURFACE WATER PROPERTIES:
    Temperature:            9 C
    Salinity:               32.0 ppt
    Density:                1.02477 g/cc


SPILL DATA:
    Continuous release of 81300 gal over 4 hr


WARNING:
    The water temperature is below the maximum reported pour point
for this
    oil or refined product.  It may not pour, which would cause
ADIOS to give
    inaccurate predictions.
```

Dispersion

ADIOS(TM) 1.1

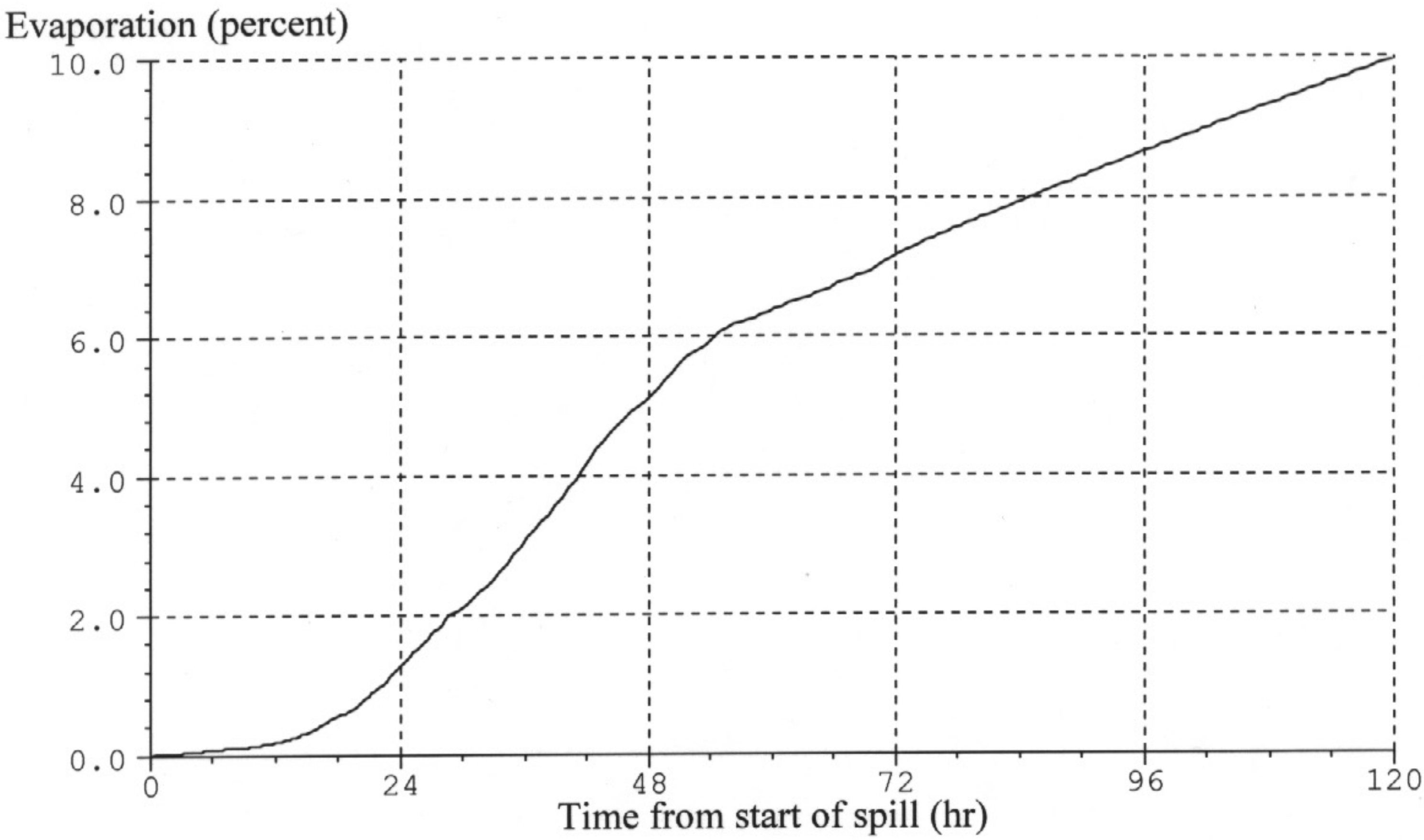
```
Oil Name: BUNKER C FUEL OIL
API: 14.1                                   Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                           Wave Height: Default values

Water Temperature: 9 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Evaporation

ADIOS(TM) 1.1

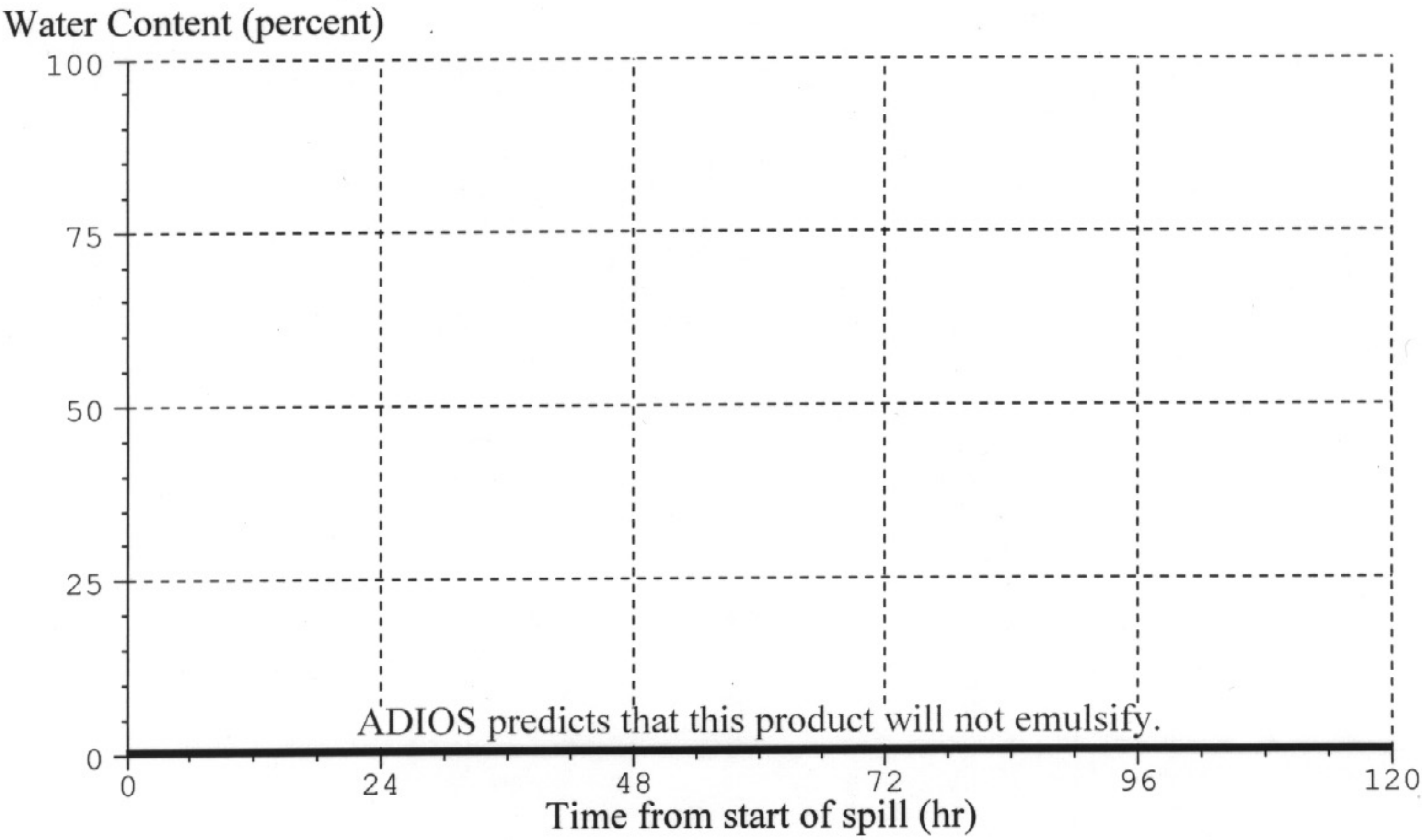
```
Oil Name: BUNKER C FUEL OIL
API: 14.1                                  Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                          Wave Height: Default values

Water Temperature: 9 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Water Content

ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                              Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                       Wave Height: Default values

Water Temperature: 9 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```

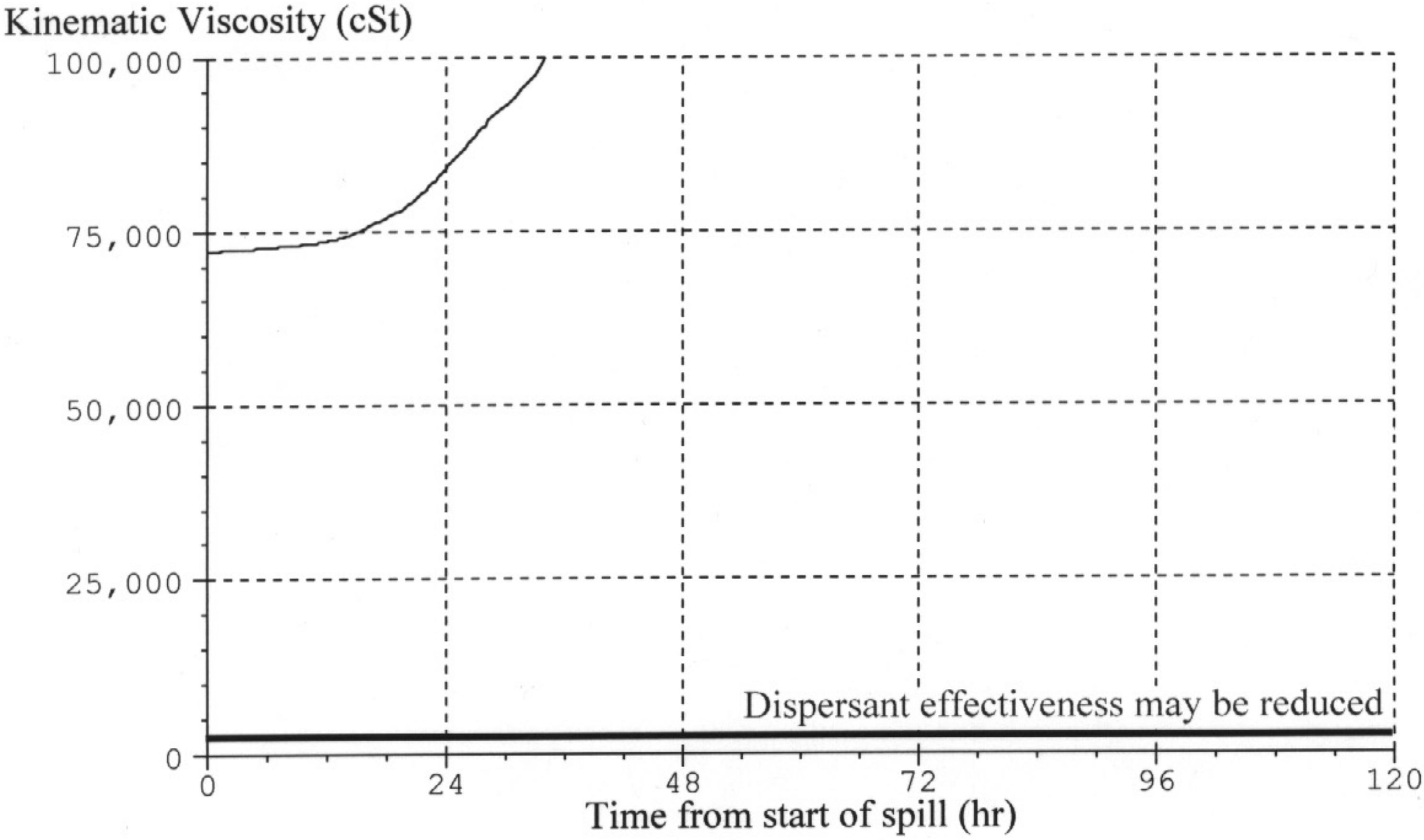


Viscosity

ADIOS(TM) 1.1

Oil Name: BUNKER C FUEL OIL
API: 14.1
Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
Wave Height: Default values

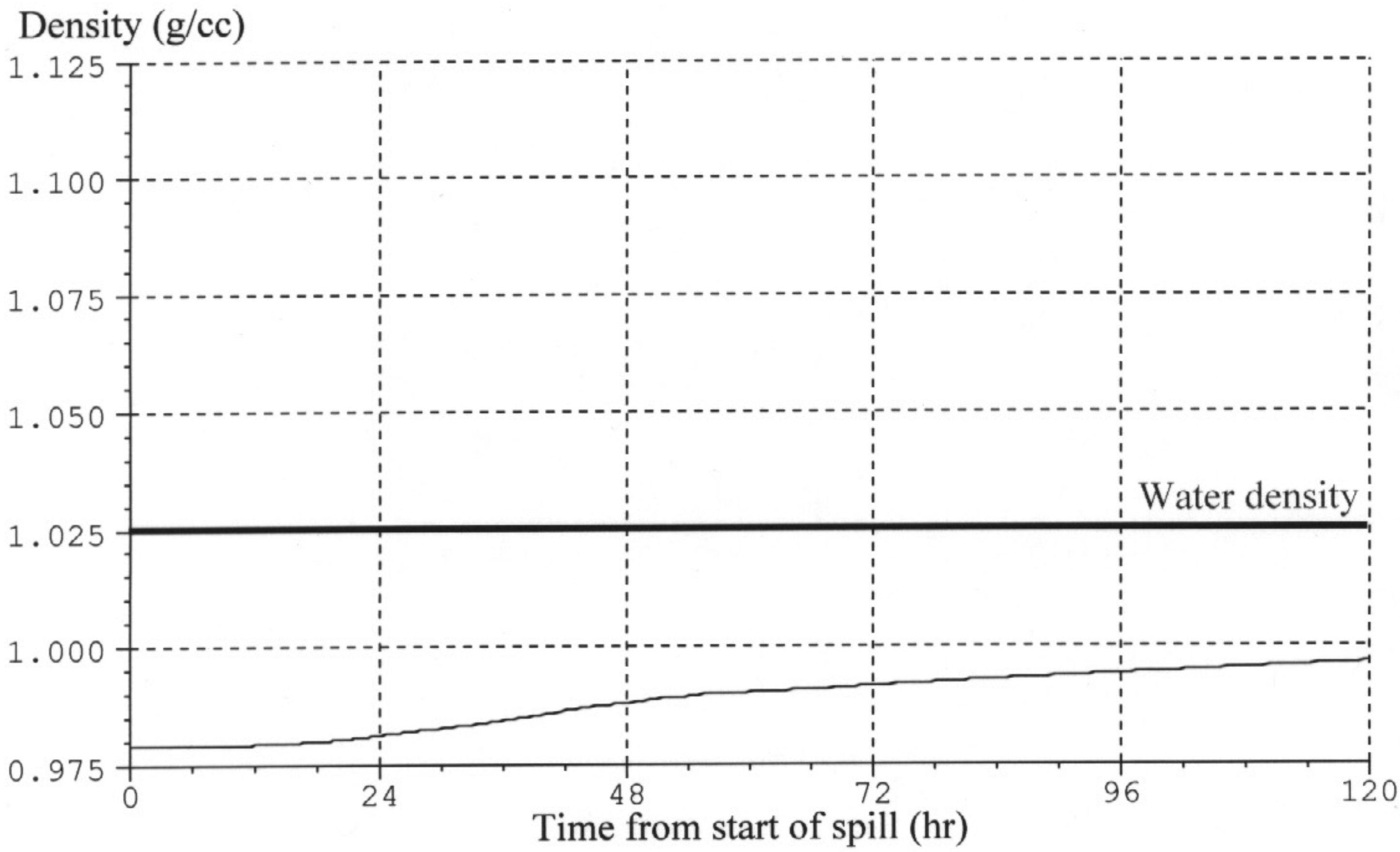
Water Temperature: 9 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.



Density

ADIOS(TM) 1.1

```
Oil Name: BUNKER C FUEL OIL
API: 14.1                              Pour Point: between -4.0 C
and 15.0 C
Mousse Const: 18% evaporated
Wind Speed: Variable
                                       Wave Height: Default values

Water Temperature: 9 C
Continuous release of 81300 gal over 4 hr
*Insufficient emulsification data, answers may be inaccurate.
```



Western Location, Small Spill

Time hours	Total Released gallons	Evaporated percent	Dispersed percent	Floating percent
0	0	0	0	100
3	60,975	0	0	100
6	81,300	0	0	100
9	81,300	0	0	100
12	81,300	0	0	100
15	81,300	0	0	100
18	81,300	0	0	100
21	81,300	0	0	100
24	81,300	1	0	99
27	81,300	1	0	99
30	81,300	2	0	98
33	81,300	2	0	98
36	81,300	3	0	97
39	81,300	3	0	97
42	81,300	4	0	96
45	81,300	4	0	96
48	81,300	5	0	95
54	81,300	5	0	95
60	81,300	6	0	94
66	81,300	6	0	94
72	81,300	7	0	93
78	81,300	7	0	93
84	81,300	7	0	93
90	81,300	8	0	92
96	81,300	8	0	92
102	81,300	8	0	92
108	81,300	9	0	91
114	81,300	9	0	91
120	81,300	9	0	91

10 REFERENCES FOR APPENDICES

1 Fowler, Jones, and Shaw, “Risk Analysis of Oil Spills From Tankers in UK Waters,” Det Norske Veritas Industry Limited, 1995

2 Pederson, Preben Terndrup, “Probablilty of Grounding and Collision Events,” Technical University of Denmark

3 Det Norske Veritas, George Washington University, and Rensselaer Polytechnic Institute and Le Moyne College, “Prince William Sound, Alaska Risk Assessment Study,” 1996

4 Lewis, E.L. , Editor, “Principles of Naval Architecture,” Society of Naval Architects and Marine Engineers, 1988

5 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.

6 Oil Companies International Marine Forum, “Disabled tankers **:** report of studies on ship drift and towage,” 1981

7 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)

8 Glosten Associates, “Disabled Tanker Towing Study,” July 1984