Cook Inlet Maritime Risk Assessment

Spill Baseline and Accident Causality Study

Prepared for
Nuka Research & Planning Group, LLC
Seldovia, Alaska

File No. 11054.01
29 June 2012
Rev. –

Prepared in collaboration with
Environmental Research Consulting

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Consulting Engineers Serving the Marine Community

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Attachment 1: *Cook Inlet Maritime Risk Assessment: Spill Baseline & Accident Casualty Study: Spill Scenarios and Impacts*, Environmental Research Consulting, April, 2012 1

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Executive Summary

Task 4 of the Cook Inlet Maritime Risk Assessment (CIMRA, Reference 1) studied the historical incidents and vessel traffic in Cook Inlet to define a baseline (2010 – 2014) and projected (2015 – 2020) annual spill rate. An incident is a vessel casualty or accident with or without spillage. Rates were found for four vessel types: tank ships, tank barges, non-tank /non-workboat vessels, and workboats. The workboat vessel type had the highest baseline spill rate, with 0.96 spills per year. The non-tank/non-workboat group had the highest forecasted spill rate, with 1.3 spills per year. The sum of the four vessel type spill rates is 3.9 spills per year.

Spill rate was further refined to define rates with respect to seven spill factor subcategories: vessel type (4), incident type (11), inlet region (3), transiting or moored (2), oil type (4), spill size (2), and season (2). Scenarios were defined for 2,112 unique combinations of vessel types and spill factor subcategories. A relative probability level and consequence level was determined for each scenario. Probability is a quantitative spill rate. Scenario spill rates ranged from 0.000001 to 0.01282 spills per year, with a return period of 78 years for the most frequent spill rate. Consequence is qualitative. Scenario risk is a combination of the probability and consequence.

The majority of scenarios have a relative risk level that is low or very low. The 14 highest risk scenarios are presented. Tank ships have the lowest baseline spill rate, but present the most risk from an oil spill in Cook Inlet. In the following CIMRA task, *Task 5 Consequence Analysis Workshop*, a panel of experts will select a half-dozen scenarios of greatest risk to study further.

Section 1 Introduction

The Cook Inlet Maritime Risk Assessment (CIMRA, Reference 1) evaluates the risk of an oil spill. This report presents a baseline and forecasted spill rate with respect to vessel type, |V. A sixteen year historical baseline of vessel incidents and the CIMRA *Task 3 Vessel Traffic Study* are used. The annual spill rate is the number of spills per year. The spill rate $SR_A|V$ is found by multiplying the averaged annualized number of incidents per traffic day $IR_T|V$, the number of vessel traffic days per year $T|V$, and the percent spill rate in Cook Inlet Ps.

$$SR_A|V = IR_T|V \times T|V \times P$$

Spill scenarios are formulated from the spill factor subcategories: vessel type, incident type, inlet region, transiting or moored, oil type, spill size, and season. The baseline spill rate is parsed to determine the probability of the specific scenario occurring. The consequence, i.e., impact, is defined qualitatively. The spill scenario is placed within a 5x5 matrix of probability and consequence. The two matrix axes both delineate very low, low, medium, high, or very high. Scenario risk is defined as a combination of probability and consequence.

This report is organized into five sections. Section 2 defines the spill baseline 2010-2014 and projected 2015-2020 spill rate (Tasks 4A and 4B laid out in the work plan, Reference 1). Section 3 describes the spill factors by probability, Section 3.1, and by consequence, Section 3.2. Scenario probability is calculated in Section 4. The risk matrices are presented in Section 5 (Tasks 4C and 4D laid out in the work plan, Reference 1). Classifying scenarios' relative risk allows the highest risk scenarios to be found. The CIMRA *Task 5 Consequence Analysis Workshop* will find the absolute risk level that is sufficiently high to merit assessment of risk reduction measures.

Section 2 Spill Baseline

The spill baseline is the number of spills per year with respect to vessel type. The inputs are historical data of spills per year and traffic days per year with respect to vessel type. The spill and traffic data input represent the same period of time, 2010. Historical incident data was gathered for Task 4 by the project team. The incident data base is discussed in Section 2.2. Traffic data was taken from the Task 3 study. The traffic data is discussed in Section 2.3. The baseline scope covered a limited timeline, geography, and types of vessels.

2.1 Baseline Scope

2.1.1 Study Period 2010-2020

The CIMRA project goal is to identify a baseline and a forecasted risk. The risk of oil spills is to be forecasted through 2020. Two time periods have been called out within the ten year study period. The near time period, 2010-2014, represents the baseline risk. The later time period, 2015-2020, takes into account projections for both vessel incidents and vessel traffic, and the probable effects of:

- The Oil Pollution Act of 1990 (OPA 90) mandate for double hulls on cargo tanks for tankers and tank barges, and for bunker tanks in future-built larger non-tank vessels by 2015, which reduces the probability of an impact-related casualty (allision, collision, or grounding) that results in oil spillage;
- An air-emission, regulation-mandated switchover to diesel fuels away from heavy bunker fuels for larger vessels by 2016, which changes the nature of spill impacts due to differences in the toxicity and persistence of the oils.
- Per Reference 1, "The reported recent discovery of additional gas reserves in Cook Inlet, coupled with potential increased demand, could lead to the reopening of the Nikiski LNG facility and add 36 or more gas ship calls at Cook Inlet." An additional 36 gas carrier calls per year are considered in the 2015-2020 analysis.
- Also per Reference 1, "Depending on the route of the Alaska gas pipeline, construction materials for this project could attract 25-50 cargo ship calls to the Port of Anchorage or Port MacKenzie." An additional 50 cargo ship calls per year are considered in the 2015-2020 analysis.

2.1.2 Geography

Spill and casualty data for all locations in Cook Inlet are included. The southern extent of Cook Inlet is defined as in the other CIMRA tasks from 46 CFR 7.165(A): "A line drawn from the southernmost extremity of Kenai Peninsula at longitude 151° 44.0 W to East Amatuli Island Light; thence to the northwestern extremity of Shuyak Island at Party Cape; thence to the eastern most extremity of Cape Douglas."

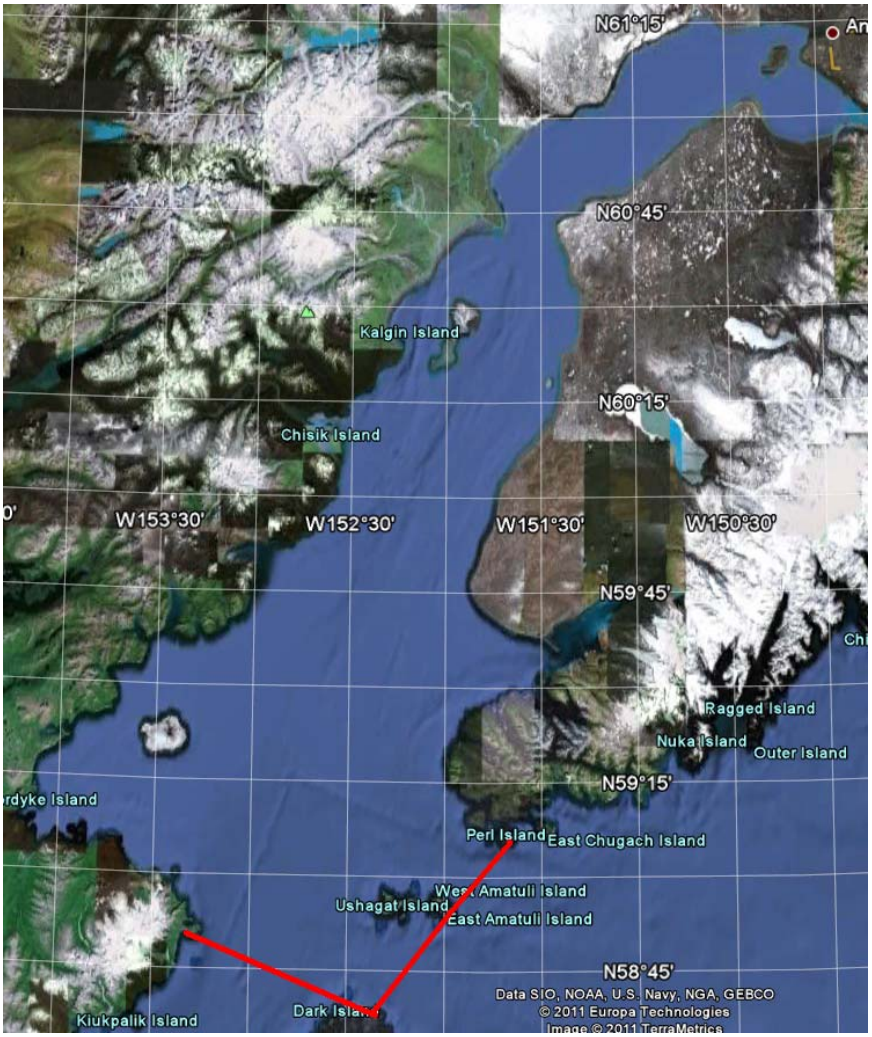

Figure 1 Cook Inlet study area

2.1.3 Vessels

The CIMRA examines vessels greater than 300 GT, and vessels less than 300 GT with a fuel oil carrying capacity of over 10,000 gallons. Small tour boats and fishing vessels are less than 300 GT and do not carry over 10,000 gallons, so they are not included in the study. Although there are past incidents in Cook Inlet from military and research vessels, the traffic numbers for these vessels types are not reported in the Task 3 report. They are also not included in this study, because there is no traffic to define a rate.

2.2 Incident Database

Sixteen years of data are being used in this analysis. The starting date of 1995 is sufficiently recent such that data collection methods are now more consistent than they were in earlier decades. Also, 1995 is the start of the Alaska Department of Environmental Conservation's (ADEC) data collection. Effects of OPA 90 regulations on vessel operations have also been introduced and are captured in the spill statistics.

The end date, 2010, is the same end date year of the *Task 3 Vessel Traffic Study*. It is essential to have incident data over the same time period as traffic data to determine the rate of incidents per traffic volume.

There are 121 incidents in the Cook Inlet incident database. This is a relatively small set of data particularly once subcategories of incidents are defined. Smaller sub-group categories better identify the behavior of the sub-group, but lose statistical significance and confidence because there are too few data points.

This historical incident baseline data is compiled from ADEC, US Coast Guard, and Environmental Research Consulting internal databases, which include a variety of sources including Lloyd's Register Casualty data, various databases developed for the US Coast Guard, National Academy of Sciences, US Environmental Protection Agency (EPA), and American Petroleum Institute. The incident database used to define the spill baseline is entirely derived from historical data. Historical records have variable accuracy and completeness. The records are typically taken manually and transcribed. Human error is a possibility whenever data is handled. The compiled database is checked through for spelling, repeated entries, and consistency. It was verified that well known incidents were included. There may still be omissions in the dataset. Some records give a primary and secondary cause. Only one cause is accounted for in this analysis. The percentage of incidents by cause is defined in Section 3.1.1 as the spill factor: incident type. Uncertainties in the input data carry through the analysis, and may result in uncertainties in the ranking of scenarios. However it is not expected that the selected scenarios for further evaluation would change. Estimates and assumptions are used when the data available is insufficient. Assumptions introduce additional uncertainty.

2.2.1 Spill versus Incident

A vessel "incident" is a casualty or other situation in which it was deemed by the US Coast Guard or Alaskan officials that there was a significant potential for an oil spill. A spill may or may not have occurred. "Spills" are a subset of incidents. The percentage of incidents that result in a spill is called the percent spill rate.

2.2.2 Percent Spill Rate

Vessel spills and potential spill incidents for the years 1995 through 2010 were captured in the database. The database record summary by vessel category recorded in the database is shown in Table 1. The overall weighted average percent spill rate for the whole incident database is 49.6%; i.e., approximately 50 spills occur for every 100 potential spill incidents.

Table 1 Database Spills and Incidents 1995 – 2010

Vessel Type	Number of Spills	Total Incidents	% Spills
Cargo Vessel	4	20	20%
Crude Tanker	5	12	42%
Cruise Ship	0	1	0%
Fishing Vessel	0	1	0%
Gas Carrier	1	3	33%
Industrial Vessel	2	3	67%
Military Vessel	3	4	75%

Vessel Type	Number of Spills	Total Incidents	% Spills
Offshore Supply Vessel	5	11	45%
Oil Spill Response	1	4	25%
Passenger Vessel	0	3	0%
Product Tanker	7	12	58%
Research Vessel	2	2	100%
Tank Barge	24	31	77%
Towboat/Tugboat	6	14	43%
Total	**60**	**121**	**49.6%**

2.3 Traffic Database

Traffic data for 2010 was provided by the Task 3 Vessel Traffic Study, Reference 1, see *Section 3 2010 Vessel Traffic Findings*. The baseline traffic level was defined from both data and approximations. "In 2010, self-propelled vessels (excluding tugs) in excess of 300 gross tons entered Cook Inlet approximately 480 times. This is an approximate number, given that berth records, AIS data and published schedules for individual vessel port calls did not always agree. This level of activity is similar to the results of the Cook Inlet vessel traffic in 2005-2006." The 2010 Vessel Traffic Study found that total vessel traffic volume did not change significantly relative to the 2006 Study. Therefore, the annual volume of traffic is assumed to be unchanged for the baseline time period starting in 1995.

There is the possibility of increased gas carrier and cargo traffic over the study period through 2020. This is accounted for in identifying traffic levels and risk for 2010-2014 and for 2015-2020, discussed in the next sub-section. Any forecasting has uncertainty. The traffic forecast used for this report came from an extensive study,(Reference 1, see *Section 5 Cook Inlet Vessel Traffic Forecast: 2011-2020*). Baseline and forecasted traffic volumes are the best available numbers and used with confidence.

2.4 Vessel Types for Quantitative Analysis

Vessel types in the incident and traffic databases are grouped into four vessel types for the quantitative risk analysis. Vessels are grouped by similar risk profiles. This gives an approximate risk level for the ungrouped vessel types.

Grouping a reduced number of vessel types is necessary for two reasons: limited data, and the different categories of vessels found in the incident database and in the traffic database. To determine an incident baseline rate, the vessel type must have both sufficient incident and traffic data. In Figure 2, the vessel types found in the incident database are given on the left hand side, and the vessel types found in the vessel traffic study are given on the right. Vessel types in white are excluded from the study and discussed in Section 2.5. Arrows and coordinated colors show the mapping from these two sources to the four vessel types.

1. Tank ships.
2. Tank barges.
3. Non-tank/non-workboat vessels.
4. Workboats.

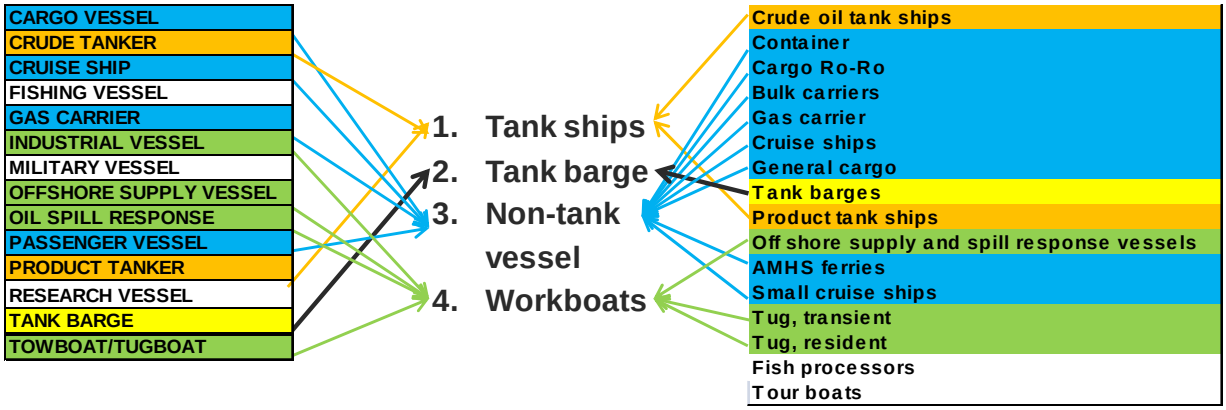

Figure 2 Vessel types defined from the incident database and the Vessel Traffic Study

The grouping above gives sufficient number of incident data points in each vessel type. For example, cruise and passenger vessels were responsible for four incidents in the database, Table 1. Of the four incidents, there were zero spills. This is not enough data to calculate a statistically meaningful incident rate for cruise and passenger vessels. Therefore, the incidents from cruise ships and passenger vessels and the traffic from cruise ships, Alaska Marine Highway System (AMHS) ferries, and small cruise ships are grouped into the non-tank/non-workboat vessel type. The number of spills and number of incidents for each vessel type is given in Table 2. Table 2 presents the same information as Table 1 but grouped into the four vessel-types and excluding the fishing vessel, military vessel, and research vessel-types. The overall weighted average percent spill rate for the four vessel types is 48.2%. The 114 incidents are tabulated in Appendix E by date, vessel name, vessel type, oil persistence, gallons released, and incident type.

Table 2 Spills and incidents by vessel types, 1995 – 2010

Vessel Type	Number of Spills	Number of Incidents	Percentage of Spills
Tank ships	12	24	50.0%
Tank barge	24	31	77.4%
Non-tank vessel	5	27	18.5%
Workboats	14	32	43.8%
Total	**55**	**114**	**48.2%**

2.4.1 Tank Ships

The tank ship group includes tankers carrying oil as their primary cargo. Crude and product tankers are in this vessel type. There are 24 incidents in the baseline incident database, and 242 traffic-days in 2010 from the tank ship group.

2.4.2 Tank Barge

The tank barge group is self explanatory and unique in its level of risk. There are 31 incidents in the baseline incident database, and 408 traffic-days in 2010 from the tank barge group.

2.4.3 Non-Tank Vessel

The non-tank vessel group does not carry oil as its primary cargo. These vessels typically have regular routes and schedules in and out of the inlet. Cargo vessels, gas carriers, and passenger vessels are grouped into non-tank. The non-tank vessel group does not include workboats. There are 27 incidents in the baseline incident database, 497 traffic-days in 2010, and 785 traffic-days per year longer term from the non-tank vessel group.

2.4.4 Workboats

Offshore supply vessels, oil spill response vessels, tugs (without a tank barge), and construction barges are grouped into the workboat category. Workboats are characterized by irregular routing and schedules. This category also includes five (5) resident tugs. As reported in the Vessel Traffic study, "Tugs, for the most part, were found to be less than 300 GT but with fuel capacities greater than 10,000 gallons." There are 32 incidents in the baseline incident database, and 3,653 traffic-days in 2010 for the workboat vessel group.

2.5 Vessel Types Not Included in Quantitative Analysis

Some vessel types have not been considered in the quantitative analysis for any of the following three reasons: insufficient incident data, insufficient traffic data, or outside of the scope defined in Section 2.1.3.

2.5.1 Fishing Vessels and Fish Processors

A significant number of fishing vessel incidents exists in the databases. However, there are insufficient traffic data on fishing vessels to determine a spill rate, so fishing vessels have been removed from the statistical analysis. There were no incidents with oil spill potential for fish processor vessels in the baseline time period. Vessel traffic risk assessments at Prince William Sound, Reference 11, and at Cherry Point, Reference 13, indicate that commercial and tribal fishing vessels can pose a "relatively high risk of collision," but that the expected outflow volume of oil is low.

2.5.2 Research Vessels

There is no reported research vessel traffic in the 2010 database from which to define an incident rate. There were two spills from the *R/V Arctic Wolf* in the incident database.

2.5.3 Military Vessels

There is no military vessel traffic recorded in the 2010 database from which to define an incident rate. Four incidents in the baseline database identified as military vessels were from the USCG cutters *Sedge*, *Mustang*, and *Hickory*. These incidents are not included in the statistical analysis.

2.6 Baseline Spill Rate Formulation and Results

The average number of incidents per year is found by dividing the total number of incidents in the database (given in Table 2) by the duration of the data collection, 16 years. There is variability in the number of spills from year to year. The average is assumed to be a reasonable statistic for quantifying the baseline spill rate. The annual incident rate by vessel

type is listed in the second column of Table 3. The subscript $_A$ stands for the annual rate, as in IR_A. Rates are determined for each vessel type. The | symbol indicates "with respect to" or "given." For example, $IR_A|V$ is the annual incident rate for vessel type V.

The incident rate per vessel traffic day is calculated from the average annual incident rate and the annual traffic rate. The subscript T stands for the rate by vessel traffic day, $IR_T|V$.

$$IR_T|V = I|V \div T|V$$

IR_T = incident rate (number of incidents/vessel traffic days)
I = number of incidents in Cook Inlet
T = number of vessel traffic days in Cook Inlet

The spill rate is found by multiplying the incident rate and the percent spill rate in Cook Inlet. This can be done for either the annual rate or the rate by vessel traffic day. Here, it is done by traffic day for use in the projected spill rate.

$$SR_T|V = IR_T|V \times P_S$$

SR_T = spill rate (number of spills/vessel traffic days)
P_S = percent spill rate in Cook Inlet

The percent spill rate applied is the overall percent spill rate for all vessel types, 48.2%, from Table 2.

Table 3 Baseline incident and spill rates by vessel type, 2010-2014

Vessel Type	Incident Rate$_A$|V No./Year[1]	Traffic |V Days/Year	Incident Rate$_T$|V No./Day	Spill Rate$_T$|V No./Days	Spill Rate$_A$|V No./Year
Tank ships	1.5	242	0.0062	0.0030	0.72
Tank barge	1.9	408	0.0047	0.0023	0.93
Non-tank vessel	1.7	497	0.0034	0.0016	0.81
Workboats	2.0	3653	0.0005	0.0003	0.96

2.7 Forecasted Spill Rate Formulation and Results

Forecasted spill rate is found by multiplying the spill rate by vessel traffic day, $SR_T|V$, and the projected traffic days, $T|V$, with

$$SR_A|V = SR_T|V \times T|V\,.$$

Table 4 Forecasted spill rates by vessel type, 2015-2020

Vessel Type	Baseline Spill Rate$_T$ |V No./Day	Projected Traffic |V Days/Year	Projected Spills$_A$ |V No./Year
Tank ships	0.0030	242	0.72
Tank barge	0.0023	408	0.93
Non-tank vessel	0.0016	785	1.29
Workboats	0.0003	3653	0.96

[1] Number of incidents in Table 2 divided by 16.

Spill volume is highly dependent on vessel type and incident type. Spill factors are described in Section 3. Spill scenarios are defined in Section 4. Spill volume is estimated in Section 5 in the context of a spill scenario. The consequences of these spills, including the spill volumes, are described in Section 5.

Section 3 Spill Factors

In addition to the type of vessel involved, spills are further categorized by six factors (*A, O, G, R, W,* and *M*), which represent:

- Type of incidents: *A* for accident (e.g., drift grounding, collision, transfer error, etc.)
- Type of oil spilled: *O* (crude oil, heavy fuel oil, marine diesel, etc.)
- Representative spill size: *G* for gallons (50th and 95th percentile spill volume)
- Geographic region: *R* (lower inlet, mid-inlet, upper inlet, etc.)
- Seasonality: *W* for winter (non-ice and ice)
- Moored or in-transit: *M*.

Spill factors are identified by how they factor into spill probability, spill consequence, or both. Spill probability factors include:

- Incident type $A\ |V$.
- Geography $R\ |V,T$.
- Moored or in-transit $M\ |V,R,T$.
- Season $W\ |V,T$.
- Percent spill rate $Ps\ |V,A$.
- Probability associated with the representative spill volume size $G\ |\ V,A$.

The $|T$ indicates that the spill probability factor is also a function of the number of traffic days spent in that particular scenario.

Spill consequence factors include spill volume, oil type, region of spill, and season. Oil type only affects consequence and not probability.

3.1 Spill Probability Factors

3.1.1 Incident Probabilities by Incident Type

Incident types are known in the compiled study database for 101 of the 114 incidents. Incident types recorded are: allision, bilge discharge, collision, equipment failure, fire/explosion, grounding, operator error, other, structural failure, transfer error, and unknown. There are 12 incidents with 'unknown' incident type and 1 'other' incident. The "other" and "unknown" incidents are grouped into a single incident type. The number of grounding incidents is assumed to be equally divided into drift groundings and powered groundings. The ratio of 1 to 1 for drift to powered was based on prior risk assessments in Prince William Sound, Aleutian Islands, *2006 Cook Inlet Vessel Traffic Study* (Reference 5), and on select situation reports and expert judgment[2]. Eleven incident types are used in the study. Table 5 lists the incident types, *A*, and the percentages of all the incidents for each vessel type, *V*; $P(A|V)$, where $P(A|V)$ equals the probability of incident type, *A*, given an incident on vessel type, *V*.

[2] Leslie Pearson – by email, 3 November 2011 Re: CI Groundings: Adrift or Powered.

Table 5 Percentage of incidents occurred by incident type with respect to vessel type, *P(A|V)*

Incident Type	Tank Ships	Tank Barge	Non-Tank Vessel	Workboats
Allision	16.3%	12.5%	25.7%	15.5%
Bilge Discharge	4.1%	1.0%	1.0%	3.1%
Collision	1.0%	9.4%	3.7%	15.5%
Equipment Failure	4.1%	1.0%	22.0%	9.3%
Fire	1.0%	1.0%	11.0%	1.0%
Drift Grounding	2.0%	3.1%	3.7%	1.5%
Powered Grounding	2.0%	3.1%	3.7%	1.5%
Operations Error	16.3%	15.7%	7.3%	9.3%
Structural Failure	40.8%	18.8%	11.0%	24.8%
Transfer Error	4.1%	18.8%	7.3%	3.1%
Other and Unknown	8.2%	15.7%	3.7%	15.5%

If a vessel type had no recorded incidents for an incident type, a nominal 1% chance of occurrence was assumed (highlighted in yellow). The non-zero incident type probabilities are each proportioned to maintain a total of 100% in each column. Except for this adjustment, the incident type probabilities are entirely derived from the historical data in Cook Inlet.

The largest *P(A|V)* percentage is a structural failure in a tank ship, which is 41%. The non-tank vessel type has a quarter of its incidents from allisions, and the workboat vessel type has a quarter of its incidents from structural failures.

3.1.2 Incident Probabilities by Location

Three regions are defined within Cook Inlet: Lower, Middle, and Upper. "The boundary between Lower and Middle Cook Inlet was established as an east-west line at the latitude of Anchor Point. The boundary between Middle and Upper Cook Inlet was drawn as an east-west line at the latitude of the East Forelands" (Reference 1). Both incidents and traffic are categorized into region by vessel type.

3.1.2.1 Incident Region

Incident latitude is known in the baseline incident database. If an incident occurred at a latitude greater than 60.71°, then it occurred in the upper region. If an incident occurred at a latitude greater than 59.77° and less than 60.71°, then it occurred in the middle region. Some incident records are precise and others have less accuracy. The incident regions are large enough, however, so that the available data is sufficient to identify the incident region with confidence. For each vessel type, the number of incidents in each region is normalized by the total number of incidents to find $P(R|V)$ in Table 6, with $P(R|V)$ equal to the probability of an incident in region R given an incident on vessel type V.

Table 6 Percentage of incidents occurred in region with respect to vessel type, *P(R|V)*

Vessel Type	Lower	Middle	Upper
Tank ships	17%	58%	25%
Tank barge	13%	42%	45%
Non-tank vessel	26%	26%	48%
Workboats	41%	16%	44%

3.1.2.2 Traffic Region

The time a vessel spends in each region is determined by the destination terminal. The Task 3 Study described activity at the destination terminals and traffic by destination port and by vessel type in Section 3. The days operating in the upper, middle, and lower Cook Inlet were provided for cargo vessels in *Task 3 Study Table 6, List of Cargo (Dry) Ships Entering Cook Inlet in 2010*.

All non-resident traffic enters and leaves the Inlet by lower Cook Inlet. Per Reference 1, "Kachemak Bay in lower Cook Inlet experienced the highest levels of activity in Cook Inlet, primarily due to ferry operations, or vessels awaiting a marine pilot, more favorable weather, or Coast Guard inspection." Tank and non-tank vessels may also wait in the Lower Cook Inlet for a marine pilot, for a USCG inspection, or for a weather window to proceed north. Automatic Identification System (AIS) data does not capture this delay in the lower inlet; this behavior was not captured in the vessel traffic data.

The distribution of workboats to inlet region is an approximation with low confidence. Tug track lines are depicted in Appendix A, "Composite Maps of Cook Inlet Vessel Activity Broken out by Vessel Category, Region, and Quarter (2010)" of the Vessel Traffic Study. Offshore support vessel traffic patterns are described on page 23 of the Vessel Traffic Study. The irregular routes make their traffic region distribution difficult to characterize by region.

Regional distribution of the vessel traffic has larger uncertainty for the Lower Cook Inlet and for workboats. Table 7 gives the percentage of the total vessel traffic days spent in each region by vessel type, *T(R|V)*. *T(R|V)* equals the percentage of traffic time spent in region *R* of all *CI* traffic time with respect to vessel type *V*.

Table 7 Distribution of traffic to region with respect to vessel type, *T(R|V)*

Vessel Type	Lower	Middle	Upper
Tank Ships	16%	76%	8%
Tank Barge	30%	44%	26%
Non-Tank Vessel	26%	18%	55%
Workboats	33%	33%	33%

3.1.3 Incident Probabilities by Vessel Movement

The percentage of time spent in each region is subdivided into time spent in transit or time spent at berth.

3.1.3.1 Incident from Moored or In Transit

For most incidents in the baseline database, it is indicated whether the vessel was moored or in transit at the time of the incident. Some incidents were not specified as occurring either while moored or in transit. These were determined to be one or the other by three reasons. First, some incident types inherently occur from either a moored or at transit operation. For example, groundings only occur while in transit. Second, incidents were attributed to either moored or in transit in the same proportion as the known incidents for the given incident type. For example, of the 14 incidents caused by operations error, six were moored, two were in transit, and six are unknown. The remaining unknown six operations error incidents are split 75% to moored and 25% to transit. Lastly, if there is no known precedent for an incident type to have occurred while either moored or in transit, and all incidents or the incident type were unknown, then a 50% by 50% split is applied. This is the case for incidents involving bilge discharge, fire, structural failure, and other or unknown causes. Limited data reduces the confidence in these percentages. Table 7 gives the likelihood of an incident occurring from either the moored or in transit with respect to incident type. Here, $P(M|A)$ equals the probability of incident occurring while vessel is in-transit or at berth with respect to incident type, A.

Table 8 Percentage of incidents occurred from either moored or in transit with respect to incident type, *P(M|A)*

Incident Type	Moored	Transit
Allision	0%	100%
Bilge Discharge	50%	50%
Collision	0%	100%
Equipment Failure	50%	50%
Fire	50%	50%
Drift Grounding	0%	100%
Powered Grounding	0%	100%
Operation Error	75%	25%
Structural Failure	50%	50%
Transfer Error	100%	0%
Other or Unknown	50%	50%

3.1.3.2 Traffic Days Spent Moored or In Transit with Respect to Vessel Type and Region

The time a vessel spends moored or in transit in each region is determined by the destination terminal. For example, tank ships or tank barges do not make port calls to terminals in the lower inlet, thus all tank ship and tank barge traffic days in the lower inlet are spent in transit; i.e., 0% of the days were spent moored in lower Cook Inlet. Tank ships spend a large majority of their time in the middle inlet (Table 7), but most of this time is spent moored. Tank ship traffic is further described in Table 7 of the *Task 3 Vessel Traffic Study*. As described in Section 3.1.2.2, tank barges may moor temporarily in Lower Cook Inlet; however, this behavior was not captured in the vessel traffic data. The categorization of vessel traffic days

within a region into moored and transit subcategories is an estimate based a limited set of data. Vessels may be loitering, neither moored nor in transit, in Lower Cook Inlet. The distribution of traffic to either moored or in transit has medium confidence. Table 9 gives the estimated percentage of the traffic days spent moored or in transit with respect to vessel type and region, *T(M|V, R)*. Here, *T(M |V, R)* equals the percentage of traffic days spent in transit or at berth of all *CI* traffic time with respect to vessel type *V* and region *R.*

Table 9 Distribution of Traffic to Moored or In Transit with respect to Vessel Type and Region, *T(M|V, R)*

	Lower Inlet		Middle Inlet		Upper Inlet	
Vessel Type	**Moored**	**Transit**	**Moored**	**Transit**	**Moored**	**Transit**
Tank ships	0%	100%	77%	23%	83%	16%
Tank barge	0%	100%	32%	68%	42%	58%
Non-tank vessel	6%	94%	58%	42%	68%	32%
Workboats	57%	43%	57%	43%	57%	43%

3.1.4 Incident Probabilities by Season

There are two prominent seasons in Cook Inlet: ice and non-ice. Ice season is the first quarter of the year. Non-ice is the other three quarters of the year, April through December. In addition to the presence of ice, the winter season is also characterized by poor visibility due to fog and limited daylight and by seasonal wildlife activity. The probability of oil contact with fish, shellfish, birds, and marine mammals are tabulated by season and inlet region on page 108 of Attachment 1.

3.1.4.1 Incident Ice or Non-Ice

The incident date is available in the baseline incident database. For each vessel type, the number of incidents in each season can be counted. The percentage of historical incidents in either season is entirely derived from the historical data in Cook Inlet; results are shown in Table 10, where *P(W|V)* equals the probability of incident occurring in non-ice or in ice season with respect to vessel type.

Table 10 Percentage of incidents occurred in the non-ice and in the ice season with respect to vessel type, *P(W|V)*

Vessel Type	Non-Ice	Ice
Tank ships	42%	58%
Tank barge	84%	16%
Non-tank vessel	74%	26%
Workboats	88%	13%

3.1.4.2 Traffic Ice or Non-Ice

The distribution of traffic by season is from Table 9 of Reference 1. It is generated from “AIS transmitter hits from vessels equipped with AIS.” High confidence is attributed to AIS data. A uniform percentage for all vessel types is calculated from the available data. Aggregating

vessel type behavior for the season spill factor reduces the overall precision of calculation. The distribution of traffic volume by season is given in Table 11, where *T(W)* equals the percentage of traffic days spent in the non-ice season or in the ice season.

Table 11 Distribution of traffic to non-ice or ice season, *T(W)*

Vessel Type	Non-Ice	Ice
All Vessel Types	83%	17%

3.1.5 Percent Spill Rate

Percent spill rate P_s varies by both vessel type and incident type. Percent spill rates are from *Cook Inlet Maritime Risk Assessment: Spill Baseline & Accident Casualty Study: Spill Scenarios and Impacts,* Attachment 1, except for bilge discharge and "other or unknown." Percent spill rates for the near and projected time periods are given in Table 12 and Table 13, respectively. In the projected 2015-2020 time period, the mandated double hulls affects percent spill rate in the impact-related incident types only.

Table 12 Percent spill rate with respect to incident type and vessel type, $P_s|V,A$ (2010-2014)

Incident Type	Tank Ship	Tank Barge	Non-Tank /Non Workboat	Workboat
Allision	68%	76%	5%	5%
Bilge Discharge	50%	50%	50%	50%
Collision	68%	76%	5%	5%
Equipment Failure	40%	40%	20%	20%
Fire	40%	40%	20%	20%
Drift Grounding	91%	77%	5%	5%
Powered Grounding	91%	77%	5%	5%
Operation Error	40%	40%	20%	20%
Structural Failure	40%	40%	20%	20%
Transfer Error	92%	92%	92%	92%
Other or Unknown	71%	71%	71%	71%

Table 13 Percent spill rate with respect to incident type and vessel type, $P_s|V,A$ (2015-2020)

Incident Type	Tank Ship	Tank Barge	Non-Tank /Non Workboat	Workboat
Allision	18%	22%	2%	2%
Collision	15%	13%	2%	2%
Drift Grounding	40%	22%	2%	2%
Powered Grounding	40%	40%	2%	2%

Etkin draws on research by the National Research Council, Herbert Engineering, and her own prior publications. Allision and collision have the same P_s for a given vessel type. The non-impact incident types (equipment failure, fire, operation error, and structural failure) have the same P_s for a given vessel type.

P_s for bilge discharge and "other or unknown" are calculated from the baseline incident database. These P_s values are only with respect to incident type and not vessel type. There are not enough incidents in the Cook Inlet baseline database to refine percent by both factors. Due to their relative low consequence, they were not included in the Attachment 1 study.

3.1.6 Spill Volume Probability

Two representative spill volumes are studied, the 50th and 95th percentiles. The 50th percentile spill is the median (50% larger, 50% smaller). The 50th percentile spill volume has the probability of 1 in 2 if a spill occurs, or 50%. The 95th percentile spill is larger than 95% of the spills and smaller than 5% of the spills. The 95th percentile spill volume has the probability of 1 in 20 if a spill occurs, or 5%. The probability related to spill volume is given in Table 14. The letter *G* is used for the spill volume spill factor, as in gallons.

Table 14 Probability of representative spill volume, given a spill; *P(G)*

Representative Spill Volume	*P(G)*
50th Percentile	50%
95th Percentile	5%

3.2 Spill Consequence Factors

Consequence is a qualitative designation taking into account:

- Volume spilled by scenario.
- Estimated covered area square footage (function of spill size, oil type, and spill location).
- Sensitivity of area covered.
- Estimated ease of cleanup (function of spill size, oil type, and spill location).
- Estimated monetary consequence (cost to vessel owner, port operator, clean up organization, other stakeholders).

These consequence factors are discussed in the following sections.

3.2.1 Oil Type

3.2.1.1 Oil Type Categories

In this study, four oil types have been defined in Table 15. Additional description of each oil type starts on page 79 of Attachment 1.

Table 15 Modified oil type classifications for Cook Inlet Maritime Risk Assessment

General Persistence Category[3]	Suggested Oil Type Categories[4]	Examples in Category
Non-Persistent (NP)	Volatile Fuels	Jet fuel, kerosene, gasoline
Low Persistent (LP)	Light Fuels	Diesel fuel, No. 2 fuel, home heating oil, marine diesel
Medium Persistent (MP)	Lube Oils	Lubricating oils
	Crude Oil	Medium crude oils5
Heavy Persistent (HP)	Heavy Oils	Heavy fuel oil, bunker oils, Bunker A, Bunker B, Bunker C, intermediate fuel oil (IFO), No. 4 fuel, No. 5 fuel, No. 6 fuel, transmix, residual oils/fuel, waste oil

Oil type is an extremely important factor in determining the costs and impacts of spills. The oil type determines the properties of the oil itself and the way in which the oil will behave once it is spilled into the environment.

The characteristics of spilled oil are interrelated and can affect response operations in a number of ways. First, the degree to which the oil evaporates, disperses, and dissolves will affect the amount of oil that is available for removal via mechanical containment and recovery, dispersant application, manual removal, or in situ burning. The degree of weathering, as well as the oil's viscosity, density, adhesiveness, and other characteristics, will affect the effectiveness of these removal techniques. A more detailed examination of oil characteristics is presented in Appendices A, B, and C of Attachment 1. The effect of persistence and toxicity are repeated here:

> *Persistence Effect on Environmental and Socioeconomic Impacts*
>
> *The* persistence *of the oil in the environment can also significantly affect the impacts of a spill, as well as the response strategies and costs. Persistence of petroleum-based oils is a very important consideration in assessing the environmental risk of an oil spill and often affects the resources needed for spill recovery and remediation. The heavier, more persistent fractions of oil are those that adhere to the feathers of birds and fur of mammals, as well as to shoreline and wetland communities. For birds and mammals, this coating can cause hypothermia. For organisms living along shoreline or in wetlands, this can cause smothering. Both smothering and hypothermia can result in mortality, which increases environmental damages.*
>
> *The persistent portions of oil can also coat other surfaces (e.g., tourist beaches, sea walls, marinas, boats) causing socioeconomic impacts. The persistence of oil and the degree to which the oil adheres to shoreline substrates and penetrates those substrates will affect the type of shoreline response that is required.*[6] *The labor and resources, as well as disposal, required for shoreline responses will vary by shoreline type, oil type,*

[3] There is no standard method to determine oil persistence. For example, diesel fuel is sometimes classified as "persistent" and sometimes classified as "non-persistent" (References 3 and 6).

[4] These categories have been used by the EPA in its assessment of impacts of spills from inland facilities regulated by the agency (Reference 3).

[5] Heavy crude oils have many of the same characteristics as heavy oils, and light crudes tend to be more like light fuels. Since most of the crude transported through Cook Inlet will be medium (Alaskan) crude, this is immaterial in this study.

[6] References 9 and 10.

and degree of oiling, which in turn affect the complexity involved in the cleanup.(Reference 8)

Toxicity and Environmental and Socioeconomic Impacts

The toxicity *of the oil determines the adverse effects and mortality of fish, wildlife, and invertebrates after short-term exposure (hours to days). Mortality as well as sub-lethal effects (e.g., reduced fecundity) is relevant to both environmental impacts, as well as socioeconomic impacts in as much as commercial fisheries, subsistence fishing (particularly important in Tribal Nations areas), and recreational fishing are affected. Different organisms have different tolerances of exposure.*

3.2.1.2 Oil Type Correlation with Vessel Type

There is a direct correlation between vessel class and oil type carried. Within the tank ship vessel type, product tankers carry low persistent oil and crude tankers carry medium persistent oil. Tank barges carry non-persistent oil and low persistent oil. Cargo vessels carry low persistent oil. Within the workboat vessel type, offshore supply vessels carry low persistent and tug/ towboats carry heavy persistent. The non-tank/non-workboat vessel type carries heavy persistent oil in 2010-2014, and low persistent oil in 2015-2020. The other vessel types carry the same fuels in the two time periods as shown in Table 16.

Table 16 Oil Types carried by each vessel type by study period

Vessel Type	2010-2014				2015-2020			
	NP	LP	MP	HP	NP	LP	MP	HP
Tank ships		X	X			X	X	
Tank barge	X	X			X	X		
Non-tank vessel				X		X		
Workboats		X		X		X		X

3.2.2 Spill Size

The representative 50th and 95th percentile spill size has been determined for each combination of vessel type and incident type. Whether a vessel is double or single hulled affects its worst case discharge, but not the 50th and 95th percentile volumes. The same spill volumes are used in both the baseline and forecasted time periods. Spill size within the tank ship vessel type is also presented with respect to oil type, and is reflective of the specific type of vessel within this group (i.e., product vs. crude). Table 17 presents outflow by vessel type and by incident type. Incident types are grouped into impact (collision, allision, and grounding), non-impact (equipment failure, fire, operations error, structural failure), and transfer error. Spill volumes are not presented for bilge discharge or for the other incident type. These incident types have a very low spill volume and in turn, a very low consequence.

Table 17 50th and 95th percentile spill volumes by vessel and incident type

Vessel Type	Incident Type	Oil Volume (gallons)	
		Moderate	Large
		50th percentile	95th percentile
Tank Ship with LP (Product Carrier)	Impact	5,000	4,000,000
	Non-Impact	1,000	150,000
	Transfer Error	10	2,000
Tank Ship with MP (Crude Carrier)	Impact	20,000	15,000,000
	Non-Impact	2,000	8,000,000
	Transfer Error	10	2,000
Tank Barge	Impact	500	300,000
	Non-Impact	200	300,000
	Transfer Error	10	2,000
Non-Tank Vessel	Impact	1,000	300,000
	Non-Impact	100	300,000
	Transfer Error	10	2,000
Workboat	Impact	100	20,000
	Non-Impact	10	20,000
	Transfer Error	10	1,000

Spill percentile volumes are based on data from historical spills. There are insufficient data in the small dataset of incidents that occurred between 1995 and 2011 in Cook Inlet to determine the distribution of percentage outflow for each combination of vessel type and incident type. For this reason, the results of outflow analyses conducted on much larger datasets were used to determine the percentile spill volumes for vessel spills in Cook Inlet (References 6, 7). The oil outflow analyses by vessel type and incident type are shown in Tables A4 to A9, and Figures A3 to A8 of Attachment 1.

The relative consequence of the spill is also a function of the spill region and the season. This is presented in a following subsection.

3.2.3 Geographic Region

Inlet regions vary by their sensitivity to an oil spill and the challenges to spill response. Geographical, biological, and environmental factors unique to each inlet region are presented in Attachment 1with reference to the report: NOAA Cook Inlet and Kenai Peninsula, Alaska, Environmental Sensitivity Areas (2002). The geography (shoreline contours), hydrodynamics (currents, tides) of the affected water body, the temperature, and wind affect how oil will flow and behave upon spilling. The shoreline types and other sensitive resources (environmental and socioeconomic) in the proximity of the spill site will affect the types of damages that might occur.

The environmental characteristics of a spill location influence the choice and effectiveness of a spill control and mitigation strategies with regard to logistics, hydrodynamics, weather

conditions, and the types of spill response strategies that can reasonably or legally be employed. In general, spill consequence is higher in the middle and lower than in the upper inlet.

3.2.4 Season

The presence of ice on the water affects spill response in a number of ways. The oil tends to be more viscous, affecting the effectiveness of certain spill response measures. Highly viscous oils are very difficult to disperse chemically. Natural dispersion is significantly reduced in highly viscous oils. More viscous oils are difficult to recover with skimmers and pumps and thus increase response costs.

At the same time, solid, pack, or broke ice, floes, or brash ice, can contain and entrain oil that is spilled on, into, or under the ice. While this sometimes complicates recovery with skimmer and booms, it can also act as a natural containment that isolates spilled oil from the marine environment. Oil spilled under ice will eventually resurface. Recovery can sometimes be safely delayed until winter conditions are more amenable to cleanup operations.

Skimmers used on spills in ice must be able to deal with emulsified, highly weathered oil, and oil that is mixed with a good deal of debris, including ice pieces. Sometimes chemical treatment agents, designed to increase viscoelasticity and cohesiveness of oil, are added to increase the efficiency of skimmers.

In-situ burning is widely touted as an effective means of removing large volumes of spilled oil on ice and in open water situations.

The use of dispersants in icy water conditions has had mixed results.

3.2.5 Combination of Spill Consequence Factors: Oil Type, Volume, Region, and Season

Five very generalized degrees of environmental impact are used in this analysis: very low (VL), low (L), moderate (M), high (H), and very high (VH). A description of the five consequence levels is given in Section 5. This method of describing impacts is used very commonly in environmental risk assessments. Tables 18, 19, and 20 give spill consequence levels by the combination of oil type, volume of oil spilled, and season for Upper, Middle, and Lower Cook Inlet, respectively.

Table 18 Oil spill impacts for Upper Cook Inlet by oil type, volume, and ice season

Oil Type	Volume (gallons)	Non-Ice	Ice
Non-Persistent	10	VL	VL
Non-Persistent	200	VL	VL
Non-Persistent	500	VL	VL
Non-Persistent	2,000	L	VL
Non-Persistent	300,000	M	L
Low Persistent	10	VL	VL
Low Persistent	100	L	VL
Low Persistent	200	L	VL
Low Persistent	500	M	L
Low Persistent	1,000	M	L

Oil Type	Volume (gallons)	Non-Ice	Ice
Low Persistent	2,000	M	L
Low Persistent	5,000	M	L
Low Persistent	20,000	M	L
Low Persistent	150,000	H	M
Low Persistent	300,000	H	M
Low Persistent	4,000,000	H	M
Medium Persistent	10	VL	VL
Medium Persistent	2,000	M	L
Medium Persistent	20,000	M	M
Medium Persistent	8,000,000	H	H
Medium Persistent	15,000,000	VH	VH
Heavy Persistent	10	H	M
Heavy Persistent	100	VL	VL
Heavy Persistent	1,000	L	VL
Heavy Persistent	2,000	L	VL
Heavy Persistent	20,000	M	M
Heavy Persistent	300,000	H	M

Table 19 Oil Spill Impacts for Middle Cook Inlet by Oil Type, Volume, and Ice Season

Oil Type	Volume (gallons)	Non-Ice	Ice
Non-Persistent	10	VL	VL
Non-Persistent	200	VL	VL
Non-Persistent	500	VL	VL
Non-Persistent	2,000	L	VL
Non-Persistent	300,000	M	L
Low Persistent	10	VL	VL
Low Persistent	100	VL	VL
Low Persistent	200	VL	VL
Low Persistent	500	VL	VL
Low Persistent	1,000	L	VL
Low Persistent	2,000	L	VL
Low Persistent	5,000	L	VL
Low Persistent	20,000	M	L
Low Persistent	150,000	M	L
Low Persistent	300,000	M	L
Low Persistent	4,000,000	H	M
Medium Persistent	10	VL	VL
Medium Persistent	2,000	M	M
Medium Persistent	20,000	M	M
Medium Persistent	8,000,000	H	H
Medium Persistent	15,000,000	VH	VH
Heavy Persistent	10	VL	VL

Oil Type	Volume (gallons)	Non-Ice	Ice
Heavy Persistent	100	VL	VL
Heavy Persistent	1,000	L	L
Heavy Persistent	2,000	L	L
Heavy Persistent	20,000	M	M
Heavy Persistent	300,000	H	H

Table 20 Oil spill impacts for Lower Cook Inlet by oil type, volume, and ice season

Oil Type	Volume (gallons)	Non-Ice	Ice
Non-Persistent	10	VL	VL
Non-Persistent	200	VL	VL
Non-Persistent	500	VL	VL
Non-Persistent	2,000	L	VL
Non-Persistent	300,000	M	L
Low Persistent	10	VL	VL
Low Persistent	100	VL	VL
Low Persistent	200	VL	VL
Low Persistent	500	VL	VL
Low Persistent	1,000	L	VL
Low Persistent	2,000	L	VL
Low Persistent	5,000	L	VL
Low Persistent	20,000	M	L
Low Persistent	150,000	M	L
Low Persistent	300,000	M	L
Low Persistent	4,000,000	H	M
Medium Persistent	10	VL	VL
Medium Persistent	2,000	M	M
Medium Persistent	20,000	M	M
Medium Persistent	8,000,000	H	H
Medium Persistent	15,000,000	VH	VH
Heavy Persistent	10	VL	VL
Heavy Persistent	100	VL	VL
Heavy Persistent	1,000	L	L
Heavy Persistent	2,000	L	L
Heavy Persistent	20,000	M	M
Heavy Persistent	300,000	H	H

Section 4 Scenario Spill Rate Calculation and Causality

A spill scenario is defined by its spill factors: vessel type, incident type, inlet region, whether the vessel was moored at in-transit, season, oil type, and a representative spill volume. For example, one scenario is a tank ship carrying low persistent oil that has a drift grounding while transiting in the middle inlet during the non-ice season, which spills a 95th percentile spill volume. The possible values for each spill factor and the number of possible values are repeated here.

- Vessel type, *V*: 4 types:
  - Tank ships.
  - Tank barge.
  - Non-tank vessel.
  - Workboats.
- Incident type, *A*: 11 types:
  - Allision.
  - Bilge discharge.
  - Collision.
  - Equipment failure.
  - Fire.
  - Drift grounding.
  - Powered grounding.
  - Operations error.
  - Structural failure.
  - Transfer error.
  - Other or unknown.
- Geographic region, *R*: 3 regions:
  - Lower.
  - Middle.
  - Upper.
- Moored or in transit, *M*: 2 operations:
  - Moored.
  - Transit.
- Seasonality, *W*: 2 seasons:
  - Ice.
  - Non-ice.
- Oil type, *O*: 4 types:
  - NP.
  - LP.
  - MP.
  - HP.
- Spill volume, *G*: 2 sizes:
  - 50th.
  - 95th.

1,056 combinations can be made from the number of choices in each of the spill probability factors (*V,A,R,M,W,G*), 4 × 11 × 3 × 2 × 2 × 2. With four possible oil types, there is another factor of 4 in the total combinations of scenarios that are defined: e.g., 1,056 × 4 = 4,224 scenarios. Within the list of 4,224 scenarios, however, there are 2,112 scenarios where the combination of vessel type and oil type is not present in Cook Inlet. Probability and consequence are not defined for these cases. Table 16 shows which combinations are carried in the two time periods. Probability and consequence are defined for the remaining 2,112 scenarios.

4.1 Scenario Probability (Spill Rate)

The scenario probability formulation is an extension of the baseline spill rate formulation from Section 2.6. The scenario probability starts with the baseline incident rate by vessel traffic day, $IR_T\,|V$, and incorporates the spill factor probabilities, $P(A|V)$, $P(R|V)$, $P(M|A)$, and $P(W|V)$ from Tables 4, 5, 7,and 9, respectively. Instead of a uniform percent spill rate, the scenario percent spill rate is determined from its vessel type and incident type, $Ps|V,A$, given in Table 12 and Table 13. The probability with respect to spill size, $P(G)$, is also factored using the values in Table 14, with:

$$SSR_T\,|\,V, A, R, M, W, G = IR_T\,|\,V \times P(A\,|\,V) \times P(R\,|\,V) \times P(M\,|\,A) \times P_S\,|\,V, A \times P(G),$$

SSR_T = scenario spill rate by vessel traffic days (number of spills/vessel traffic days).

The number of traffic days is similarly defined by the known spill factors percentages (Tables 6, 8, and 10), with:

$$SSR_A\,|\,V, A, R, M, W = SSR_T\,|\,V, A, R, M, W \times T\,|\,V \times T(R\,|\,V) \times T(M\,|\,V, R) \times T(W),$$

SSR_A = scenario annual spill rate (number of spills/year),
T = number of vessel traffic days in Cook Inlet (defined in Section 2.6).

The spill scenario probability is the scenario annual spill rate, SSR_A. In the example scenario, with a tank ship carrying low persistent oil that has a drift grounding while transiting in the middle inlet during the non-ice season, which spills a 95th percentile spill volume, the calculation is:

SSR_T = 0.0062 (incidents/traffic-days) × 2% × 58% × 100% × 42% × 91% × 5%
= 1.4×10^{-6} (spills/traffic-days), and

SSR_A = $1.4\text{x}10^{-6}$ (spills/traffic- days) × 242 (traffic-days) × 76% × 23% × 83%
= 4.9×10^{-5} (spills/year).

The annual spill rate can be inverted to find the scenario's return period. The scenario is expected once in the year return period. For example, an annual spill rate of 0.00005 spills per year has a return period of 20,000 years.

4.2 Very Low, Low, Medium, High, and Very High Probability

The probability level thresholds are defined by return periods. A longer return period has a lower probability. These thresholds and the number of scenarios that fall in each threshold range are given in Table 21 for the near and longer term study periods. These threshold divisions were assigned to get a reasonable number of scenarios in the higher probability

categories. Levels are relative and and do not cover equal spans of time. The probability level scale is nonlinear.

Table 21 Probability levels defined and number of scenarios at each level

Probability Level Return Period (years)	> 10,000	< 10,000	< 5000	< 1000	< 500
Number of Scenarios – 2010-2014	1475	111	167	43	52
Number of Scenarios – 2015-2020	1500	107	155	44	42

There are two ways to have a scenario probability of zero. The combination of incident type and moored vs. transit may have a zero percent chance (e.g., allision and moored). These scenarios have an incident rate of zero incidents per vessel traffic days (see Table 8). A combination of region and moored vs. transit may have zero vessel traffic days, (see Table 9). These scenarios have a probability of zero incidents per year or an infinite return period. These scenarios have a *VL* probability.

The 25 highest probability scenarios in each time period are presented in Highest Probability Spill Scenarios 2010-2014, Appendix A, and in Highest Probability Spill Scenarios 2015-2020, Appendix B.

- The shift towards lower probabilities between the two periods is due to decreased percent spill rate Ps in impact-related incident types from double hulls.
- The highest probability scenarios are all 50th percentile spill in the non-ice season
- Moored tank ships in the middle inlet have a relatively high probability of a non-impact spill.
- Non-tank vessels incidents have a higher probability in the later time period when more traffic is projected.
- The three highest probability scenarios are non-tank vessels in the later time period; the shortest return period is 78 years. These scenarios are very low consequence.

Section 5 Risk of Oil Spills to Cook Inlet

Risk is the product of probability and consequence. Scenarios with the greatest probability and consequence pose the greatest risk. Scenario probability is presented in the previous section. Scenario consequence levels are described in Section 5.1. The logic to look up a spill scenario consequence is given in Section 5.2, and the risk matrix for probability and consequence is given in Section 5.3.

5.1 Very Low, Low, Medium, High, and Very High Consequence

Very generalized degrees of environmental impact are defined. Three main considerations are weighed to assign levels: very low, low, moderate, high, and very high:

- Ecosystem and population recovery period[7],
- Extent of geographic area covered, and
- Specific recognition of impacts to threatened species and special management species.

Three recovery periods are used: short-term is less than 2 years, moderate is 2 to 5 years, and long term is greater than 5 years.

The area of impact may be specific, small, large, or larger, and potentially beyond Cook Inlet. A small area is less than half of the inlet. A large area is more than half of the inlet. Specific areas are those in which sensitive species are on the shoreline nesting or fish are spawning, or other mammals gathering. These areas are shown on Environmental Sensitivity Index (ESI) maps developed by NOAA. A key for ESI maps is presented in Figure A22 on page 103 in Attachment 1.

A "significant" impact is an acute or major impact with a lot of mortalities or effects on fecundity. A "very significant" impact at the population level means that a large part of a population is wiped out, and it may take a long time for the population to recover in terms of numbers of individuals. Tradeoffs between recovery time, area covered, and impact severity are described for the five consequence levels as follows:

- **Very High (VH):** Long-term consequences (over five years) anticipated over a large part of Cook Inlet and potentially outside of the Inlet in other areas of Alaskan waters

[7] Determining the rate of ecosystem and population recovery is extremely complex. There are a large number of complex and interrelated factors involved in determining short- and long-term consequences of oil spills. There is considerable and legitimate debate in the scientific community about scientific data on short- and long-term recovery rates and the ways in which the results of many spill impact studies and models should be interpreted and applied. A complete analysis would require highly complex modeling and studies outside of the scope of the Cook Inlet Maritime Risk Assessment project. The rating system presented here and its application to the vessel spill scenarios in the analysis are based on generalized data analyses on spill impacts based on studies of hundreds of spill case studies and over one thousand spill impact studies. In addition to the limitations of assigning impact values to hypothetical spills, there is the not-insignificant issue of cultural values placed on impacts to the environment of Cook Inlet that can only truly be understood and appreciated by the myriad of stakeholders in Cook Inlet and in Alaska as a whole. While from an ecosystem and population-level perspective, recovery rates may be similar to those indicated here, the "acceptability" of any degree of environmental impacts from spills will be a matter for stakeholders to consider. This aspect is outside the scope of this assessment.

and coastal areas and/or significant impacts to threatened species or species indicated for special management. Recovery of populations and ecosystems will take over five years and/or threatened or special-management species will be very significantly impacted at the population level.

- **High (H)**: Moderate-term consequences (two to five years) anticipated over a large part of Cook Inlet or very significant (high) impacts to specific areas of the inlet. Recovery of populations and ecosystems will take two to five years.
- **Moderate (M):** Moderate-term consequences (two to five years) anticipated over a smaller part of Cook Inlet or significant (high) impacts to specific areas of the inlet. Recovery of populations and ecosystems will take two to five years.
- **Low (L):** Significant shorter-term consequences (under two years) to a large part of Cook Inlet or moderate impacts to specific areas of the inlet. Recovery of populations and ecosystems will take less than two years.
- **Very Low (VL):** Significant shorter-term consequences (under two years) to smaller parts of Cook Inlet or low impacts to larger areas of the inlet. Recovery of populations and ecosystems will take less than two years.

Thresholds between the consequence levels are qualitative and not discrete. They do not separate the continuum of consequence levels into equally sized ranges. A moderate consequence is not necessarily twice as bad as a low consequence scenario. Like probability, the scale from very low to very high is nonlinear.

5.2 Scenario Consequence

For each scenario, the vessel type, incident type, and choice of either the 50th or 95th percentile spill volume determine the spill volume in gallons, as shown in Table 17, Section 3.2.2. The volume in gallons, oil type, region, and season, give the relative consequence level, as shown in Tables 18, 19, and 20 for the upper, middle, and lower inlet, respectively, in Section 3.2.5. The number of scenarios that fall in each consequence level are given in Table 22 for the near and longer term study period. The 25 highest consequence scenarios in each time period, excluding scenarios with a zero probability, are presented in Highest Consequence Spill Scenarios 2010-2014, Appendix C, and in Highest Consequence Spill Scenarios 2015-2020, Appendix D.

Table 22 Consequence levels defined and number of scenarios at each level

Consequence Level	Very Low	Low	Medium	High	Very High
Recovery Period of populations and ecosystems	< 2 years	< 2 years	2 to 5 years	2 to 5 years	> 5 years
Number of Scenarios – 2010-2014	1,224	166	314	120	24
Number of Scenarios – 2015-2020	1,242	154	314	114	24

- The overall shift towards lower consequence between the two periods is due to a non-tank/non-workboat vessel type carrying LP rather than an HP oil type.

- The highest consequence scenarios are all 95th percentile spill in the non-ice season
- The very high consequence scenarios are all an impact incident type from a tank ship carrying MP. These crude carriers have the largest oil outflow potential, per Table 17. These scenarios are very low probability.

5.3 Risk, Probability, and Consequences

Each scenario is placed with the risk matrix by its probability level and consequence level. The level of risk is defined as the product of probability and consequence. These levels are defined within Table 23.

Table 23 Risk levels defined

		Probability Level Return Period (years)				
		> 10,000	< 10,000	< 5000	< 1000	< 500
Consequence Level	Very High	VL-VH	L-VH	M-VH	H-VH	VH-VH
	High	VL-H	L-H	M-H	H-H	VH-H
	Medium	VL-M	L-M	M-M	H-M	VH-M
	Low	VL-L	L-L	M-L	H-L	VH-L
	Very Low	VL-VL	L-VL	M-VL	H-VL	VH-VL

Risk matrices are presented for both 2010-2014 (Table 24), and for 2015-2020 (Table 25). Each matrix represents the 1,848 scenarios for which the oil type and vessel type combination is present in the inlet during that time period. These combinations are noted with an X in Table 16. About half of the scenarios are in the VL-VL risk level at the bottom left. Higher risk scenarios are to the right and up in the matrix. There are zero scenarios in the H-VH, VH-VH, or VH-H boxes colored red for the highest risk. The 14 different scenarios in the yellow (M-H and H-M) boxes and in the orange (M-VH, H-H, and VH-M) boxes are listed in Table 26.

The consequence and probability levels are not linear, and as a result, the risk levels in the risk matrix are also not a linear scale from one level to the next. A scenario in the top right box would not necessarily have 25 times the risk of a scenario in the bottom left box.

Table 24 Number of scenarios at each risk level, 2010-2014

		Probability Level Return Period (years)				
		> 10,000	< 10,000	< 5000	< 1000	<500
Consequence Level	Very High	23	0	1	0	0
	High	104	9	7	0	0
	Medium	249	31	28	1	5
	Low	146	7	10	2	1
	Very Low	953	64	121	40	46

Table 25 Number of scenarios at each risk level, 2015-2020

		Probability Level Return Period (years)				
		> 10,000	< 10,000	< 5000	< 1000	<500
Consequence Level	Very High	24	0	0	0	0
	High	100	9	5	0	0
	Medium	267	28	14	1	4
	Low	137	5	12	0	0
	Very Low	972	65	124	43	38

Uncertainties introduced from the compiled incident database and from assumptions remain in the output. The probability and consequence levels are defined rather broadly. By also presenting the top 25 highest probability and consequence scenarios in Appendices A through D, and by presenting the 14 highest risk scenarios in the next subsection, the authors are confident that the greatest risk scenarios are captured. In the following CIMRA task, *Task 5 Consequence Analysis Workshop*, a panel of experts will select a half-dozen scenarios of greatest risk to study further.

5.4 Subset of Highest Risk Scenarios

Table 26, as shown on the following page, presents the highest risk scenarios. Eleven scenarios in this group of higher risk scenarios are from the tank ship vessel category. Of these 11, 10 are carrying medium persistent oil, indicating that they are crude carriers. Crude carriers have the largest volumes associated with the 50th and 95th percentile spills. The largest $P(A|V)$ percentage is a structural failure in a tank ship, e.g., 41% (Table 5). This combination appears five times in this list. Unlike other vessel types, the tank ship group has a majority of its time spent in a single configuration, e.g., moored in the middle inlet (Table 9), and also a majority of the historical incidents in the same region (Table 6). Only two scenarios are in the ice season. The ice season is one quarter of the calendar year, but sees only 17% of the annual traffic (Table 11). The probabilistic approach identified scenarios that are more likely to occur.

Table 26 Highest risk spill scenarios

Vessel	Incident Type	Region	Moored/ Transit	Season	Oil Type	Vol	No. Spills 2010-2014	Risk Level 2010-2014	Risk Level 2015-2020
Tank ships	Allision	Mid	Transit	Non-ice	MP	95th	0.00029	M-VH	VL-VH
Tank ships	Structural failure	Mid	Moored	Non-ice	MP	50th	0.00726	VH-M	VH-M
Tank ships	Operations error	Mid	Moored	Non-ice	MP	50th	0.00436	VH-M	VH-M
Tank ships	Structural failure	Mid	Moored	Ice	MP	50th	0.00208	VH-M	VH-M
Tank ships	Structural failure	Mid	Transit	Non-ice	MP	50th	0.00216	VH-M	VH-M
Tank ships	Allision	Mid	Transit	Non-ice	MP	50th	0.00294	VH-M	M-M
Tank ships	Operations error	Mid	Moored	Ice	MP	50th	0.00125	H-M	H-M
Tank ships	Structural failure	Mid	Moored	Non-ice	MP	95th	0.00073	M-H	M-H
Tank ships	Operations error	Mid	Moored	Non-ice	MP	95th	0.00044	M-H	M-H
Tank barge	Structural failure	Mid	Transit	Non-ice	LP	95th	0.00032	M-H	M-H
Tank ships	Structural failure	Mid	Transit	Non-ice	MP	95th	0.00022	M-H	M-H
Tank barge	Collision	Up	Transit	Non-ice	LP	95th	0.00033	M-H	VL-H
Tank ships	Allision	Mid	Transit	Non-ice	LP	95th	0.00029	M-H	VL-H
Non-tank	Equipment failure	Up	Moored	Non-ice	LP	95th	0.00033*	n/a	M-H
Non-tank	Equipment failure	Up	Moored	Non-ice	HP	95th	0.00021	M-H	n/a

**Number of Spills for Years 2015-2020*

Section 6 Summary

The study baseline spill rates ranged from 0.7 spills per year for tank ships to 1.3 spills per year for non-tank/non-workboat vessels. The baseline and forecasted spill rates for all four vessel types sum to 3.4 and 3.9 spills per year, respectively. The additional 0.5 spills per year are due to the projected increase in traffic volume.

The scenario spill rates by vessel type, incident type, inlet region, transiting or moored, season, oil type carried, and by a representative spill volume ranged from 0.000001 to 0.01282 spills per year, a return period of 78 years. The scenario spill rates were combined with scenario consequence to define a relative scenario risk level. The majority of scenarios have a risk level that is low or very low. Tank ships have the lowest baseline spill rate, but posed the most risk in Cook Inlet. Tank ship risk is primarily attributed to their greater oil capacity and their concentrated operations in the middle region of the inlet. They also showed a high likelihood for a structural failure. There were zero scenarios identified as both very high probability and very high consequence. The risk level sufficiently high to merit assessment of risk reduction measures will be determined in the next task of the CIMRA.

Appendix A Highest Probability Spill Scenarios 2010-2014

SCENARIO								2010-2014			
Scen #	Vessel Type	Accident Type	Region	Moored Or Transit	Season	Oil Type	Volume Percentile	Traffic (days)	# spills / year	Probability	Consequence
140	Tank barge	ALLISION	MIDDLE	TRANSIT	NON-ICE	NP	50th	408	0.008078	Very High	Very Low
668	Tank barge	ALLISION	MIDDLE	TRANSIT	NON-ICE	LP	50th	408	0.007546	Very High	Very Low
1158	Tank ships	STRUCTURAL FAILURE	MIDDLE	MOORED	NON-ICE	MP	50th	242	0.007264	Very High	Medium
630	Tank ships	STRUCTURAL FAILURE	MIDDLE	MOORED	NON-ICE	LP	50th	242	0.007264	Very High	Very Low
246	Tank barge	TRANSFER ERROR	MIDDLE	MOORED	NON-ICE	NP	50th	408	0.006830	Very High	Very Low
774	Tank barge	TRANSFER ERROR	MIDDLE	MOORED	NON-ICE	LP	50th	408	0.006830	Very High	Very Low
1966	Non-tank vessel	TRANSFER ERROR	UPPER	MOORED	NON-ICE	HP	50th	497	0.006331	Very High	Very Low
164	Tank barge	COLLISION	MIDDLE	TRANSIT	NON-ICE	NP	50th	408	0.006058	Very High	Very Low
692	Tank barge	COLLISION	MIDDLE	TRANSIT	NON-ICE	LP	50th	408	0.006058	Very High	Very Low
250	Tank barge	TRANSFER ERROR	UPPER	MOORED	NON-ICE	NP	50th	408	0.005807	Very High	Very Low
778	Tank barge	TRANSFER ERROR	UPPER	MOORED	NON-ICE	LP	50th	408	0.005807	Very High	Very Low
1992	Workboats	ALLISION	UPPER	TRANSIT	NON-ICE	HP	50th	3653	0.004949	Very High	Very Low
260	Tank barge	OTHER OR UNKNOWN	MIDDLE	TRANSIT	NON-ICE	NP	50th	408	0.004716	Very High	Very Low
788	Tank barge	OTHER OR UNKNOWN	MIDDLE	TRANSIT	NON-ICE	LP	50th	408	0.004716	Very High	Very Low
1984	Workboats	ALLISION	LOWER	TRANSIT	NON-ICE	HP	50th	3653	0.004596	Very High	Very Low
1146	Tank ships	OPERATIONS ERROR	MIDDLE	MOORED	NON-ICE	MP	50th	242	0.004358	Very High	Medium
618	Tank ships	OPERATIONS ERROR	MIDDLE	MOORED	NON-ICE	LP	50th	242	0.004358	Very High	Very Low
144	Tank barge	ALLISION	UPPER	TRANSIT	NON-ICE	NP	50th	408	0.004349	Very High	Very Low
672	Tank barge	ALLISION	UPPER	TRANSIT	NON-ICE	LP	50th	408	0.004063	Very High	Very Low
1054	Workboats	OTHER OR UNKNOWN	UPPER	MOORED	NON-ICE	LP	50th	3653	0.003342	Very High	Very Low
2110	Workboats	OTHER OR UNKNOWN	UPPER	MOORED	NON-ICE	HP	50th	3653	0.003342	Very High	Very Low
642	Tank ships	TRANSFER ERROR	MIDDLE	MOORED	NON-ICE	LP	50th	242	0.003341	Very High	Very Low
1170	Tank ships	TRANSFER ERROR	MIDDLE	MOORED	NON-ICE	MP	50th	242	0.003341	Very High	Very Low
696	Tank barge	COLLISION	UPPER	TRANSIT	NON-ICE	LP	50th	408	0.003262	Very High	Low
168	Tank barge	COLLISION	UPPER	TRANSIT	NON-ICE	NP	50th	408	0.003262	Very High	Very Low

Appendix B Highest Probability Spill Scenarios 2015-2020

SCENARIO								2015 - 2020			
Scen #	Vessel Type	Accident Type	Region	Moored Or Transit	Season	Oil Type	Volume Percentile	Traffic (days)	# spills / year	Probability	Consequence
804	Non-tank vessel	ALLISION	UPPER	TRANSIT	NON-ICE	LP	50th	784.9	0.012819	Very High	Very Low
910	Non-tank vessel	TRANSFER ERROR	UPPER	MOORED	NON-ICE	LP	50th	784.9	0.009997	Very High	Very Low
796	Non-tank vessel	ALLISION	LOWER	TRANSIT	NON-ICE	LP	50th	784.9	0.009609	Very High	Very Low
668	Tank barge	ALLISION	MIDDLE	TRANSIT	NON-ICE	LP	50th	408.0	0.007546	Very High	Very Low
1158	Tank ships	STRUCTURAL FAILURE	MIDDLE	MOORED	NON-ICE	MP	50th	242.0	0.007264	Very High	Medium
630	Tank ships	STRUCTURAL FAILURE	MIDDLE	MOORED	NON-ICE	LP	50th	242.0	0.007264	Very High	Very Low
246	Tank barge	TRANSFER ERROR	MIDDLE	MOORED	NON-ICE	NP	50th	408.0	0.006830	Very High	Very Low
774	Tank barge	TRANSFER ERROR	MIDDLE	MOORED	NON-ICE	LP	50th	408.0	0.006830	Very High	Very Low
250	Tank barge	TRANSFER ERROR	UPPER	MOORED	NON-ICE	NP	50th	408.0	0.005807	Very High	Very Low
778	Tank barge	TRANSFER ERROR	UPPER	MOORED	NON-ICE	LP	50th	408.0	0.005807	Very High	Very Low
936	Workboats	ALLISION	UPPER	TRANSIT	NON-ICE	LP	50th	3652.8	0.004949	Very High	Very Low
260	Tank barge	OTHER OR UNKNOWN	MIDDLE	TRANSIT	NON-ICE	NP	50th	408.0	0.004716	Very High	Very Low
788	Tank barge	OTHER OR UNKNOWN	MIDDLE	TRANSIT	NON-ICE	LP	50th	408.0	0.004716	Very High	Very Low
928	Workboats	ALLISION	LOWER	TRANSIT	NON-ICE	LP	50th	3652.8	0.004596	Very High	Very Low
1146	Tank ships	OPERATIONS ERROR	MIDDLE	MOORED	NON-ICE	MP	50th	242.0	0.004358	Very High	Medium
618	Tank ships	OPERATIONS ERROR	MIDDLE	MOORED	NON-ICE	LP	50th	242.0	0.004358	Very High	Very Low
672	Tank barge	ALLISION	UPPER	TRANSIT	NON-ICE	LP	50th	408.0	0.004063	Very High	Very Low
1054	Workboats	OTHER OR UNKNOWN	UPPER	MOORED	NON-ICE	LP	50th	3652.8	0.003342	Very High	Very Low
2110	Workboats	OTHER OR UNKNOWN	UPPER	MOORED	NON-ICE	HP	50th	3652.8	0.003342	Very High	Very Low
642	Tank ships	TRANSFER ERROR	MIDDLE	MOORED	NON-ICE	LP	50th	242.0	0.003341	Very High	Very Low
1170	Tank ships	TRANSFER ERROR	MIDDLE	MOORED	NON-ICE	MP	50th	242.0	0.003341	Very High	Very Low
838	Non-tank vessel	EQUIPMENT FAILURE	UPPER	MOORED	NON-ICE	LP	50th	784.9	0.003260	Very High	Very Low
236	Tank barge	STRUCTURAL FAILURE	MIDDLE	TRANSIT	NON-ICE	NP	50th	408.0	0.003189	Very High	Very Low
764	Tank barge	STRUCTURAL FAILURE	MIDDLE	TRANSIT	NON-ICE	LP	50th	408.0	0.003189	Very High	Very Low
1046	Workboats	OTHER OR UNKNOWN	LOWER	MOORED	NON-ICE	LP	50th	3652.8	0.003103	Very High	Very Low

Appendix C Highest Consequence Spill Scenarios 2010-2014

SCENARIO								2010-2014			
Scen #	Vessel Type	Accident Type	Region	Moored Or Transit	Season	Oil Type	Volume Percentile	Traffic (days)	# spills / year	Probability	Consequence
3176	Tank ships	ALLISION	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000294	Medium	Very High
3172	Tank ships	ALLISION	LOWER	TRANSIT	NON-ICE	MP	95th	242	0.000075	Very Low	Very High
3236	Tank ships	DRIFT GROUNDING	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000049	Very Low	Very High
3248	Tank ships	POWERED GROUNDING	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000049	Very Low	Very High
3200	Tank ships	COLLISION	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000018	Very Low	Very High
3232	Tank ships	DRIFT GROUNDING	LOWER	TRANSIT	NON-ICE	MP	95th	242	0.000012	Very Low	Very High
3244	Tank ships	POWERED GROUNDING	LOWER	TRANSIT	NON-ICE	MP	95th	242	0.000012	Very Low	Very High
3180	Tank ships	ALLISION	UPPER	TRANSIT	NON-ICE	MP	95th	242	0.000009	Very Low	Very High
3196	Tank ships	COLLISION	LOWER	TRANSIT	NON-ICE	MP	95th	242	0.000005	Very Low	Very High
3240	Tank ships	DRIFT GROUNDING	UPPER	TRANSIT	NON-ICE	MP	95th	242	0.000002	Very Low	Very High
3252	Tank ships	POWERED GROUNDING	UPPER	TRANSIT	NON-ICE	MP	95th	242	0.000002	Very Low	Very High
3204	Tank ships	COLLISION	UPPER	TRANSIT	NON-ICE	MP	95th	242	0.000001	Very Low	Very High
3270	Tank ships	STRUCTURAL FAILURE	MIDDLE	MOORED	NON-ICE	MP	95th	242	0.000726	Medium	High
3258	Tank ships	OPERATIONS ERROR	MIDDLE	MOORED	NON-ICE	MP	95th	242	0.000436	Medium	High
2808	Tank barge	COLLISION	UPPER	TRANSIT	NON-ICE	LP	95th	408	0.000326	Medium	High
2876	Tank barge	STRUCTURAL FAILURE	MIDDLE	TRANSIT	NON-ICE	LP	95th	408	0.000319	Medium	High
2648	Tank ships	ALLISION	MIDDLE	TRANSIT	NON-ICE	LP	95th	242	0.000294	Medium	High
3272	Tank ships	STRUCTURAL FAILURE	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000216	Medium	High
4006	Non-tank vessel	EQUIPMENT FAILURE	UPPER	MOORED	NON-ICE	HP	95th	497	0.000206	Medium	High
2880	Tank barge	STRUCTURAL FAILURE	UPPER	TRANSIT	NON-ICE	LP	95th	408	0.000172	Low	High
2866	Tank barge	OPERATIONS ERROR	UPPER	MOORED	NON-ICE	LP	95th	408	0.000158	Low	High
2874	Tank barge	STRUCTURAL FAILURE	MIDDLE	MOORED	NON-ICE	LP	95th	408	0.000148	Low	High
2878	Tank barge	STRUCTURAL FAILURE	UPPER	MOORED	NON-ICE	LP	95th	408	0.000126	Low	High
2844	Tank barge	DRIFT GROUNDING	UPPER	TRANSIT	NON-ICE	LP	95th	408	0.000109	Low	High
2856	Tank barge	POWERED GROUNDING	UPPER	TRANSIT	NON-ICE	LP	95th	408	0.000109	Low	High

Appendix D Highest Consequence Spill Scenarios 2015-2020

SCENARIO								2015 - 2020			
Scen #	Vessel Type	Accident Type	Region	Moored Or Transit	Season	Oil Type	Volume Percentile	Traffic (days)	# spills / year	Probability	Consequence
3176	Tank ships	ALLISION	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000065	Very Low	Very High
3172	Tank ships	ALLISION	LOWER	TRANSIT	NON-ICE	MP	95th	242	0.000016	Very Low	Very High
3236	Tank ships	DRIFT GROUNDING	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000010	Very Low	Very High
3248	Tank ships	POWERED GROUNDING	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000010	Very Low	Very High
3200	Tank ships	COLLISION	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000004	Very Low	Very High
3232	Tank ships	DRIFT GROUNDING	LOWER	TRANSIT	NON-ICE	MP	95th	242	0.000002	Very Low	Very High
3244	Tank ships	POWERED GROUNDING	LOWER	TRANSIT	NON-ICE	MP	95th	242	0.000002	Very Low	Very High
3180	Tank ships	ALLISION	UPPER	TRANSIT	NON-ICE	MP	95th	242	0.000002	Very Low	Very High
3196	Tank ships	COLLISION	LOWER	TRANSIT	NON-ICE	MP	95th	242	0.000001	Very Low	Very High
3240	Tank ships	DRIFT GROUNDING	UPPER	TRANSIT	NON-ICE	MP	95th	242	0.000000	Very Low	Very High
3252	Tank ships	POWERED GROUNDING	UPPER	TRANSIT	NON-ICE	MP	95th	242	0.000000	Very Low	Very High
3204	Tank ships	COLLISION	UPPER	TRANSIT	NON-ICE	MP	95th	242	0.000000	Very Low	Very High
3270	Tank ships	STRUCTURAL FAILURE	MIDDLE	MOORED	NON-ICE	MP	95th	242	0.000726	Medium	High
3258	Tank ships	OPERATIONS ERROR	MIDDLE	MOORED	NON-ICE	MP	95th	242	0.000436	Medium	High
2950	Non-tank vessel	EQUIPMENT FAILURE	UPPER	MOORED	NON-ICE	LP	95th	785	0.000326	Medium	High
2876	Tank barge	STRUCTURAL FAILURE	MIDDLE	TRANSIT	NON-ICE	LP	95th	408	0.000319	Medium	High
3272	Tank ships	STRUCTURAL FAILURE	MIDDLE	TRANSIT	NON-ICE	MP	95th	242	0.000216	Medium	High
2880	Tank barge	STRUCTURAL FAILURE	UPPER	TRANSIT	NON-ICE	LP	95th	408	0.000172	Low	High
2998	Non-tank vessel	OPERATIONS ERROR	UPPER	MOORED	NON-ICE	LP	95th	785	0.000163	Low	High
2962	Non-tank vessel	FIRE	UPPER	MOORED	NON-ICE	LP	95th	785	0.000163	Low	High
3010	Non-tank vessel	STRUCTURAL FAILURE	UPPER	MOORED	NON-ICE	LP	95th	785	0.000163	Low	High
2866	Tank barge	OPERATIONS ERROR	UPPER	MOORED	NON-ICE	LP	95th	408	0.000158	Low	High
2952	Non-tank vessel	EQUIPMENT FAILURE	UPPER	TRANSIT	NON-ICE	LP	95th	785	0.000155	Low	High
2874	Tank barge	STRUCTURAL FAILURE	MIDDLE	MOORED	NON-ICE	LP	95th	408	0.000148	Low	High
2878	Tank barge	STRUCTURAL FAILURE	UPPER	MOORED	NON-ICE	LP	95th	408	0.000126	Low	High

Appendix E Cook Inlet Incident Database 1995-2010

DATE	VESSEL NAME	VESSEL TYPE	OIL PERSISTENCE	GALLONS RELEASED	INCIDENT TYPE
10/26/95	DELTA WESTERN BARGE	TANK BARGE	LOW PERSISTENT	10	STRUCTURAL FAILURE
09/18/95	CROWLEY BARGE	TANK BARGE	LOW PERSISTENT	1	UNKNOWN
09/16/95	CROWLEY BARGE	TANK BARGE	PERSISTENT	1	UNKNOWN
08/08/95	USNS LAWRENCE H. GIANELLA	PRODUCT TANKER	NONPERSISTENT	0	ALLISION
03/11/95	POTOMAC TRADER	CRUDE TANKER	PERSISTENT	0	ALLISION
8/12/96	HOWARD H	TOWBOAT/TUGBOAT	PERSISTENT	1	TRANSFER ERROR
11/17/96	WESTWARD VENTURE	CARGO VESSEL	PERSISTENT	71	OPERATIONS ERROR
07/08/96	IGRIM	PRODUCT TANKER	LOW PERSISTENT	1	STRUCTURAL FAILURE
02/15/96	CHESAPEAKE TRADER	PRODUCT TANKER	PERSISTENT	1	STRUCTURAL FAILURE
09/08/97	MARINE COMMANDER/SHELL C	OFFSHORE SUPPLY VESSEL	LOW PERSISTENT	0	ALLISION
07/13/97	SEALAND ANCHORAGE	CARGO VESSEL	PERSISTENT	1	OPERATIONS ERROR
06/06/97	PETRO MARINE BARGE	TANK BARGE	NONPERSISTENT	3	OPERATIONS ERROR
05/31/97	FNT 255	TANK BARGE	PERSISTENT	4	TRANSFER ERROR
05/08/97	ENERGIZER	TANK BARGE	NONPERSISTENT	10	UNKNOWN
04/05/97	CROWLEY BARGE 450-11	TANK BARGE	NONPERSISTENT	10	TRANSFER ERROR
01/01/97	BARGE 103	TANK BARGE	LOW PERSISTENT	0	ALLISION
12/21/98	FORTY NINER BARGE	TANK BARGE	LOW PERSISTENT	8	STRUCTURAL FAILURE
11/21/98	POLAR EAGLE	GAS CARRIER	PERSISTENT	1	TRANSFER ERROR
11/05/98	IGRIM	PRODUCT TANKER	PERSISTENT	2	STRUCTURAL FAILURE
10/09/98	SS NORTHERN LIGHTS	CARGO VESSEL	PERSISTENT	1	UNKNOWN
08/30/98	CROWLEY BARGE 102	TANK BARGE	LOW PERSISTENT	10	STRUCTURAL FAILURE
06/27/98	TYONEK LADD	TANK BARGE	LOW PERSISTENT	5	UNKNOWN
05/15/98	HANJIN ISTANBUL	CARGO VESSEL	HEAVY PERSISTENT	0	COLLISION
01/03/98	CHAMPION	OFFSHORE SUPPLY VESSEL	LOW PERSISTENT	0	ALLISION
01/01/98	CHESAPEAKE TRADER	CRUDE TANKER	PERSISTENT	0	ALLISION
11/30/99	TUSTUMENA	PASSENGER VESSEL	LOW PERSISTENT	0	ALLISION
10/19/99	ANGELO D'AMATO	CRUDE TANKER	PERSISTENT	0	OTHER
09/28/99	SEALAND TACOMA	CARGO VESSEL	HEAVY PERSISTENT	0	GROUNDING
09/26/99	SEALAND ANCHORAGE	CARGO VESSEL	HEAVY PERSISTENT	0	GROUNDING
07/16/99	CHAMPION	OFFSHORE SUPPLY VESSEL	LOW PERSISTENT	0	ALLISION
04/08/99	CHAMPION	OFFSHORE SUPPLY VESSEL	LOW PERSISTENT	1	OPERATIONS ERROR
03/06/99	POTOMAC TRADER	CRUDE TANKER	PERSISTENT	20	BILGE DISCHARGE
02/06/99	CHESAPEAKE TRADER	CRUDE TANKER	PERSISTENT	420	STRUCTURAL FAILURE
01/31/99	OCEAN LAUREL	CARGO VESSEL	HEAVY PERSISTENT	0	ALLISION
12/21/98	FNT 340	TANK BARGE	LOW PERSISTENT	1	TRANSFER ERROR
01/19/98	RENEW	TANK BARGE	LOW PERSISTENT	0	GROUNDING
12/12/00	SEABULK MONTANA	OFFSHORE SUPPLY VESSEL	LOW PERSISTENT	0	ALLISION
11/15/00	CISPRI RESPONDER	OIL SPILL RESPONSE	LOW PERSISTENT	0	COLLISION
07/30/00	POTOMAC TRADER	CRUDE TANKER	PERSISTENT	0	ALLISION
03/30/00	HANJIN BRISBANE	CARGO VESSEL	HEAVY PERSISTENT	0	ALLISION

DATE	VESSEL NAME	VESSEL TYPE	OIL PERSISTENCE	GALLONS RELEASED	INCIDENT TYPE
01/20/00	TORM PACIFIC	CARGO VESSEL	HEAVY PERSISTENT	0	ALLISION
01/19/00	ENERGIZER	TANK BARGE	NONPERSISTENT	200	ALLISION
11/3/01	CYGNET	TOWBOAT/TUGBOAT	LOW PERSISTENT	2	UNKNOWN
12/30/01	SEABULK PRIDE	CRUDE TANKER	PERSISTENT	0	STRUCTURAL FAILURE
09/04/01	CROWLEY BARGE 102	TANK BARGE	PERSISTENT	7	OPERATIONS ERROR
08/29/01	SCT 280	TANK BARGE	PERSISTENT	50	STRUCTURAL FAILURE
07/26/01	CHILKAT WARRIOR	TANK BARGE	LOW PERSISTENT	0	ALLISION
05/29/01	CHILKAT WARRIOR	TANK BARGE	LOW PERSISTENT	5	TRANSFER ERROR
05/08/01	CHILKAT WARRIOR	TANK BARGE	NONPERSISTENT	2	OPERATIONS ERROR
02/06/01	WESTWARD VENTURE	CARGO VESSEL	HEAVY PERSISTENT	0	FIRE
12/21/02	ANMAJ	PRODUCT TANKER	LOW PERSISTENT	0	STRUCTURAL FAILURE
12/13/02	HANJIN CALCUTTA	CARGO VESSEL	PERSISTENT	0	EQUIPMENT FAILURE
11/27/02	SEABULK MONTANA	OFFSHORE SUPPLY VESSEL	PERSISTENT	50	STRUCTURAL FAILURE
05/19/02	GREAT LAND	CARGO VESSEL	PERSISTENT	0	FIRE
03/22/02	HIGHTIDE	PRODUCT TANKER	LOW PERSISTENT	4	OPERATIONS ERROR
01/29/02	SEABULK PRIDE	PRODUCT TANKER	LOW PERSISTENT	0	STRUCTURAL FAILURE
10/12/03	SENECA	TOWBOAT/TUGBOAT	LOW PERSISTENT	0	UNKNOWN
10/12/03	CROWLEY	TANK BARGE	LOW PERSISTENT	1	UNKNOWN
09/19/03	LUMMI ISLAND	INDUSTRIAL VESSEL	HEAVY PERSISTENT	0	STRUCTURAL FAILURE
09/18/03	BARGE 141	OIL SPILL RESPONSE	LOW PERSISTENT	0	COLLISION
07/23/03	LYKES EAGLE	CARGO VESSEL	PERSISTENT	0	ALLISION
07/09/03	LUMMI ISLAND	INDUSTRIAL VESSEL	PERSISTENT	58	OPERATIONS ERROR
07/01/03	AMERICAN CONSTRUCTION	INDUSTRIAL VESSEL	PERSISTENT	98	STRUCTURAL FAILURE
05/19/03	ARTEMIS	CRUISE SHIP	PERSISTENT	0	FIRE
05/12/03	KRS 250-1	CARGO VESSEL	LOW PERSISTENT	0	ALLISION
05/09/03	MIDNIGHT SUN	CARGO VESSEL	PERSISTENT	0	EQUIPMENT FAILURE
03/02/03	SEABULK ARCTIC	CRUDE TANKER	PERSISTENT	10	UNKNOWN
01/10/03	HAVKONG	GAS CARRIER	HEAVY PERSISTENT	0	STRUCTURAL FAILURE
4/8/04	GLACIER WIND	TOWBOAT/TUGBOAT	PERSISTENT	5	GROUNDING
4/24/04	BLARNEY	TOWBOAT/TUGBOAT	PERSISTENT	0	EQUIPMENT FAILURE
12/17/04	SEABULK PRIDE	CRUDE TANKER	PERSISTENT	20	OPERATIONS ERROR
09/25/04	BARGE 141	OIL SPILL RESPONSE	LOW PERSISTENT	0	STRUCTURAL FAILURE
09/07/04	MIDNIGHT SUN	CARGO VESSEL	PERSISTENT	0	STRUCTURAL FAILURE
08/26/04	SEABULK MONTANA	OFFSHORE SUPPLY VESSEL	PERSISTENT	2	EQUIPMENT FAILURE
07/11/04	OCEAN BEAUTY	CARGO VESSEL	LOW PERSISTENT	1	TRANSFER ERROR
04/17/04	BC 151	TANK BARGE	LOW PERSISTENT	3	OPERATIONS ERROR
04/17/04	CROWLEY BARGE	TANK BARGE	LOW PERSISTENT	3	TRANSFER ERROR
04/12/04	SEABULK MONTANA	OFFSHORE SUPPLY VESSEL	PERSISTENT	40	STRUCTURAL FAILURE
03/14/04	SEABULK ARCTIC	CRUDE TANKER	PERSISTENT	0	OPERATIONS ERROR
03/14/04	SEABULK ARCTIC	CRUDE TANKER	PERSISTENT	1	STRUCTURAL FAILURE

DATE	VESSEL NAME	VESSEL TYPE	OIL PERSISTENCE	GALLONS RELEASED	INCIDENT TYPE
7/7/05	SARA JEAN	TOWBOAT/TUGBOAT	PERSISTENT	2	UNKNOWN
5/10/05	ST MICHAEL	TOWBOAT/TUGBOAT	PERSISTENT	0	UNKNOWN
12/27/05	HORIZON TACOMA	CARGO VESSEL	PERSISTENT	0	STRUCTURAL FAILURE
10/18/05	PEONY	CARGO VESSEL	PERSISTENT	0	ALLISION
09/06/05	TUSTUMENA	PASSENGER VESSEL	LOW PERSISTENT	0	EQUIPMENT FAILURE
04/16/05	SEACOAST (SCT)	TANK BARGE	LOW PERSISTENT	2	STRUCTURAL FAILURE
3/22/06	PACIFIC CHALLENGER	TOWBOAT/TUGBOAT	PERSISTENT	0	COLLISION
1/21/06	PARAGON	TOWBOAT/TUGBOAT	PERSISTENT	0	COLLISION
08/18/06	CROWLEY BARGE 450-10	TANK BARGE	NONPERSISTENT	0	OPERATIONS ERROR
06/19/06	CROWLEY BARGE YUKON	TANK BARGE	NONPERSISTENT	5	STRUCTURAL FAILURE
03/22/06	SCT 282	TANK BARGE	PERSISTENT	0	COLLISION
02/02/06	SEABULK PRIDE	PRODUCT TANKER	PERSISTENT	210	TRANSFER ERROR
02/02/06	SEABULK PRIDE	PRODUCT TANKER	HEAVY PERSISTENT	200	GROUNDING
01/21/06	SCT 344	TANK BARGE	PERSISTENT	0	COLLISION
9/28/07	SAMSON MARINER	TOWBOAT/TUGBOAT	LOW PERSISTENT	14	OPERATIONS ERROR
4/9/07	PROTECTOR	TOWBOAT/TUGBOAT	PERSISTENT	5	UNKNOWN
09/26/07	CISPRI RESPONDER	OIL SPILL RESPONSE	LOW PERSISTENT	1	STRUCTURAL FAILURE
04/17/07	SNUG HARBOR	TANK BARGE	PERSISTENT	20	GROUNDING
02/26/07	MIDNIGHT SUN	CARGO VESSEL	PERSISTENT	0	EQUIPMENT FAILURE
6/13/08	RUSTLER	TOWBOAT/TUGBOAT	PERSISTENT	0	BILGE DISCHARGE
12/15/08	CHAMPION	OFFSHORE SUPPLY VESSEL	LOW PERSISTENT	0	ALLISION
11/17/08	SEABULK ARCTIC	CRUDE TANKER	PERSISTENT	0	STRUCTURAL FAILURE
10/14/08	SEABULK ARCTIC	PRODUCT TANKER	LOW PERSISTENT	0	OPERATIONS ERROR
03/22/08	SEABULK ARCTIC	PRODUCT TANKER	LOW PERSISTENT	1	STRUCTURAL FAILURE
04/08/08	K-SEA POL 1	TANK BARGE	NONPERSISTENT	275	TRANSFER ERROR
5/27/09	PACIFIC CHALLENGER	TOWBOAT/TUGBOAT	PERSISTENT	0	COLLISION
05/27/09	SCT 282	TANK BARGE	PERSISTENT	0	COLLISION
05/27/09	SCT 282	TANK BARGE	NONPERSISTENT	125	ALLISION
01/12/09	POLAR SPIRIT	GAS CARRIER	HEAVY PERSISTENT	0	EQUIPMENT FAILURE
01/05/09	MONARCH	OFFSHORE SUPPLY VESSEL	LOW PERSISTENT	6,000	STRUCTURAL FAILURE
8/6/10	GULF RELIANCE	TOWBOAT/TUGBOAT	PERSISTENT	0	STRUCTURAL FAILURE
10/04/10	HELENKA B	OFFSHORE SUPPLY VESSEL	LOW PERSISTENT	0	EQUIPMENT FAILURE
08/21/10	KENNICOTT	PASSENGER VESSEL	LOW PERSISTENT	0	EQUIPMENT FAILURE
03/30/10	OVERSEAS BOSTON	PRODUCT TANKER	PERSISTENT	0	EQUIPMENT FAILURE

Attachment 1: *Cook Inlet Maritime Risk Assessment: Spill Baseline & Accident Casualty Study: Spill Scenarios and Impacts*, Environmental Research Consulting, April, 2012

Cook Inlet Maritime Risk Assessment: Spill Baseline & Accident Casualty Study

Spill Scenarios and Impacts

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ENVIRONMENTAL RESEARCH CONSULTING

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Description of Report Contents

This report contains a description of the strategic approaches, methodologies, and supporting data employed by Environmental Research Consulting (ERC) for the purposes of:

- Calculating the probabilities of vessel incidents causing oil spillage by incident cause and vessel type;
- Development of the probability distributions of spill volumes given spillage by incident cause and vessel type;
- Analysis of the oil types involved in spills that might hypothetically occur;
- Analyses of the potential impacts of spills given spill volume, oil type, location, and season; and
- Development of a simplified risk matrix rating system for spill impacts.

The methodologies employed were based on the best available data and given the resources and time available for the Cook Inlet Maritime Risk Assessment (CIMRA) project.

The analyses are presented in a more detailed manner than outlined by the Cook Inlet Risk Assessment (CIRA) Advisory Panel in anticipation of potential future requests for further detail or analyses on risk factors, such as a further breakdown of impacts by season.

The results are presented in two parts – the first reflects the aggregated results as requested by the CIRA Advisory Panel. The second contains more detail. The "Detailed ERC Approach" is summarized in the Appendix A of the report with futher details available in the Technical Appendices.

Executive Summary

The Detailed ERC Approach presented in Appendix A was modified in the following ways to incorporate the CIRA Advisory Panel work plan requests:

- Aggregation of seasonal impact data into two ice seasons "ice" (winter) and "no-ice"[1] (spring, summer, and autumn);
- Presentation of two representative spill volumes: 50th percentile (moderate spill) and 95th percentile (large spill);
- Reduction of groupings of vessels into four categories rather than seven categories;
    - Tank ships (product tankers and crude tankers);
    - Tank barges;
    - Non-tank vessels (cargo ships and gas carriers); and
    - Workboat (offshore supply vessels and tug/towboats).

The analyses are presented for two time periods: 2010 – 2014 and 2015 – 2020. This report presents these two sets of analyses. Differences in outcome for these two time periods are based on the following:

- Mandated double hulls on cargo tanks for tankers by 2015, which reduces the probability of an impact-related casualty (allision, collision, or grounding) resulting in oil spillage, as well as reduces the outflow volume of the worst-case discharge (WCD);
- Mandated double hulls on tank barges by 2015, which reduces the probability of an impact-related casualty (allision, collision, or grounding) resulting in oil spillage, but does not affect the outflow volume of the WCD;
- Mandated double-hull construction for bunker tanks for future-built larger non-tank vessels, which reduces the probability of an impact-related casualty (allision, collision, or grounding) resulting in oil spillage, but does not affect the outflow volume of the WCD; and
- Air-emission regulation-mandated switchover to diesel fuels away from heavy bunker fuels for larger vessels by 2016, which changes the nature of spill impacts due to differences in the toxicity and persistence of the oils.

Potential Spillage with Vessel Incident: 2010 – 2014

The probabilities for an incident resulting in any oil spillage by vessel type, hull type, and accident cause are summarized in Table ES-1.

Table ES-1: Spill Probabilities for Cook Inlet Vessel Spill Impact Analysis for 2010 – 2014

Vessel Type[2]	Accident Cause	Spill Probability Given Incident
Tank Ship (Single-Hulled)	**Collision**	0.6800
	Allision	0.6800

[1] Combining the seasons into two seasons – "ice" and "no-ice" relates to the probability side of the risk equation with regard to the likelihood of vessel incidents, but removes some essential detail on the impact side with regard to important seasonal differences in impacts with regard to presence and activities (e.g., spawning) of various groups of species, as well as differences in prevailing winds and currents that would drive the oil in one direction or the other in the event of a spill.

[2] For tank vessels (tankers/tank barges), the hull refers to the cargo hull. For all other vessels the hull refers to the bunker tank hull. For tank vessels (tankers and tank barges), the hull refers to the cargo hull. For all other vessels the hull refers to bunker tanks. Single hulls should be used for pre-2015 scenarios, double-hulls for 2015 and beyond.

Table ES-1: Spill Probabilities for Cook Inlet Vessel Spill Impact Analysis for 2010 – 2014		
Vessel Type[2]	**Accident Cause**	**Spill Probability Given Incident**
with LP	**Grounding**	0.9100
	Structural Failure	0.4000
	Fire	0.4000
	Equipment Failure	0.4000
Tank Ship (Single-Hulled) LP	**Operations Error**	0.4000
	Transfer Error	0.9231
Tank Ship (Single-Hulled) with MP	**Collision**	0.6800
	Allision	0.6800
	Grounding	0.9100
	Structural Failure	0.4000
	Fire	0.4000
	Equipment Failure	0.4000
	Operations Error	0.4000
	Transfer Error	0.9231
Tank Barge (Single-Hulled) with LP	**Collision**	0.7600
	Allision	0.7600
	Grounding	0.7600
	Structural Failure	0.4000
	Fire	0.4000
	Equipment Failure	0.4000
	Operations Error	0.4000
	Transfer Error	0.9231
Tank Barge (Single-Hulled) with NP	**Collision**	0.7600
	Allision	0.7600
	Grounding	0.7600
	Structural Failure	0.4000
	Fire	0.4000
	Equipment Failure	0.4000
	Operations Error	0.4000
	Transfer Error	0.9231
Non-Tank Vessel (Single-Hulled) with HP	**Collision**	0.0450
	Allision	0.0450
	Grounding	0.0450
	Structural Failure	0.2000
	Fire	0.2000
	Equipment Failure	0.2000
	Operations Error	0.2000
	Transfer Error	0.9231
Workboat (Single-Hulled) with LP	**Collision**	0.0450
	Allision	0.0450
	Grounding	0.0450
	Structural Failure	0.2000
	Fire	0.2000
	Equipment Failure	0.2000
	Operations Error	0.2000
	Transfer Error	0.9231
Workboat (Single-Hulled) with HP	**Collision**	0.0450
	Allision	0.0450
	Grounding	0.0450
	Structural Failure	0.2000
	Fire	0.2000

Table ES-1: Spill Probabilities for Cook Inlet Vessel Spill Impact Analysis for 2010 – 2014		
Vessel Type[2]	**Accident Cause**	**Spill Probability Given Incident**
	Equipment Failure	0.2000
	Operations Error	0.2000
	Transfer Error	0.9231

Potential Spillage with Vessel Incident: 2015 – 2020

The probabilities for an incident resulting in any oil spillage by vessel type, hull type, and accident cause are summarized in Table ES-2.

Table ES-2 Spill Probabilities for Cook Inlet Vessel Spill Impact Analysis for 2015 – 2020		
Vessel Type	**Accident Cause**	**Spill Probability Given Incident**
Tank Ship (Double-Hulled) with LP	**Collision**	0.1500
	Allision	0.1500
	Grounding	0.1800
	Structural Failure	0.4000
	Fire	0.4000
	Equipment Failure	0.4000
	Operations Error	0.4000
	Transfer Error	0.9231
Tank Ship (Double-Hulled) with MP	**Collision**	0.1500
	Allision	0.1500
	Grounding	0.1800
	Structural Failure	0.4000
	Fire	0.4000
	Equipment Failure	0.4000
	Operations Error	0.4000
	Transfer Error	0.9231
Tank Barge (Double-Hulled) with LP	**Collision**	0.1300
	Allision	0.1300
	Grounding	0.2200
	Structural Failure	0.4000
	Fire	0.4000
	Equipment Failure	0.4000
	Operations Error	0.4000
	Transfer Error	0.9231
Tank Barge (Double-Hulled) with NP	**Collision**	0.1300
	Allision	0.1300
	Grounding	0.2200
	Structural Failure	0.4000
	Fire	0.4000
	Equipment Failure	0.4000
	Operations Error	0.4000
	Transfer Error	0.9231
Non-Tank Vessel (Double-Hulled)	**Collision**	0.0190
	Allision	0.0190
	Grounding	0.0190
	Structural Failure	0.2000
	Fire	0.2000
	Equipment Failure	0.2000
	Operations Error	0.2000
	Transfer Error	0.9231

Table ES-2 Spill Probabilities for Cook Inlet Vessel Spill Impact Analysis for 2015 – 2020		
Vessel Type	**Accident Cause**	**Spill Probability Given Incident**
Workboat (Double-Hulled) with LP	**Collision**	0.0190
	Allision	0.0190
	Grounding	0.0190
	Structural Failure	0.2000
	Fire	0.2000
Workboat (Double-Hulled) with LP	**Equipment Failure**	0.2000
	Operations Error	0.2000
	Transfer Error	0.9231
Workboat (Double-Hulled) with HP	**Collision**	0.0190
	Allision	0.0190
	Grounding	0.0190
	Structural Failure	0.2000
	Fire	0.2000
	Equipment Failure	0.2000
	Operations Error	0.2000
	Transfer Error	0.9231

Probability Distribution of Spill Volumes: 2010 – 2014

The results of analyses of probability distributions of the volume of oil spillage by vessels in Cook Inlet *given that a spill does occur* are presented in Table ES-3 by vessel type and accident cause. The volumes are shown as the 50th percentile[3] (moderate) spill volume and the 95th percentile (large) spill volume. For informational purposes, the worst-case discharge (WCD) spill volume is also presented.

Table ES-3: Spill Volumes for Cook Inlet Incidents by Vessel Type and Cause: 2010 – 2014			
Vessel Type Hull Oil Type	**Accident Cause**	**Oil Volume (gallons)**	
		Moderate	**Large**
		50th%tile	**95th%tile**
Tank Ship (Single-Hulled) with LP	**Collision**	5,000	4,000,000
	Allision	5,000	4,000,000
	Grounding	5,000	4,000,000
	Structural Failure	1,000	150,000
	Fire	1,000	150,000
	Equipment Failure	1,000	150,000
	Operations Error	1,000	150,000
	Transfer Error	10	2,000
Tank Ship (Single-Hulled) with MP	**Collision**	20,000	15,000,000
	Allision	20,000	15,000,000
	Grounding	20,000	15,000,000
	Structural Failure	2,000	8,000,000
	Fire	2,000	8,000,000
	Equipment Failure	2,000	8,000,000
	Operations Error	2,000	8,000,000
	Transfer Error	10	2,000

[3] A percentile spill is the spill volume associated with the nth probability. In other words, the volume for the nth percentile spill is that spill volume larger than n% of spills for that vessel type and cause. The nth percentile is smaller than 100 – n% of spills. The "25th percentile spill" is defined as the spill volume larger than 25% of the spills but smaller than 75% of the spills. The 50th percentile spill is the median (50% larger, 50% smaller).The 95th percentile spill is larger than 95% of the spills and only smaller than 5% of the spills. Only 5% of the spills is larger.

Table ES-3: Spill Volumes for Cook Inlet Incidents by Vessel Type and Cause: 2010 – 2014			
Vessel Type Hull Oil Type	**Accident Cause**	**Oil Volume (gallons)**	
		Moderate	**Large**
		50th%tile	**95th%tile**
Tank Barge (Single-Hulled) with LP	**Collision**	500	300,000
	Allision	500	300,000
	Grounding	500	300,000
	Structural Failure	200	300,000
	Fire	200	300,000
Tank Barge (Single-Hulled) with LP	**Equipment Failure**	200	300,000
	Operations Error	200	300,000
	Transfer Error	10	2,000
Tank Barge (Single-Hulled) with NP	**Collision**	500	300,000
	Allision	500	300,000
	Grounding	500	300,000
	Structural Failure	200	300,000
	Fire	200	300,000
	Equipment Failure	200	300,000
	Operations Error	200	300,000
	Transfer Error	10	2,000
Non-Tank Vessel (Single-Hulled) with HP	**Collision**	1,000	300,000
	Allision	1,000	300,000
	Grounding	1,000	300,000
	Structural Failure	100	300,000
	Fire	100	300,000
	Equipment Failure	100	300,000
	Operations Error	100	300,000
	Transfer Error	10	2,000
Workboat (Single-Hulled) with LP	**Collision**	100	20,000
	Allision	100	20,000
	Grounding	100	20,000
	Structural Failure	10	20,000
	Fire	10	20,000
	Equipment Failure	10	20,000
	Operations Error	10	20,000
	Transfer Error	10	1,000
Workboat (Single-Hulled) with HP	**Collision**	100	20,000
	Allision	100	20,000
	Grounding	100	20,000
	Structural Failure	10	20,000
	Fire	10	20,000
	Equipment Failure	10	20,000
	Operations Error	10	20,000
	Transfer Error	10	1,000

Probability Distribution of Spill Volumes: 2015 – 2020

The results of analyses of probability distributions of the volume of oil spillage by vessels in Cook Inlet *given that a spill does occur* are presented in Table ES-4 by vessel type and accident cause. The volumes

are shown as the 50th percentile[4] (moderate) spill volume and the 95th percentile (large) spill volume. For informational purposes, the worst-case discharge (WCD) spill volume is also presented.

Table ES-4 Spill Volumes for Cook Inlet Incidents by Vessel Type and Cause: 2015 – 2020

Vessel Type	Accident Cause	Oil Volume (gallons)	
		Moderate	Large
		50th%tile	95th%tile
Tank Ship (Double-Hulled) with LP	Collision	5,000	4,000,000
	Allision	5,000	4,000,000
	Grounding	5,000	4,000,000
	Structural Failure	1,000	150,000
	Fire	1,000	150,000
	Equipment Failure	1,000	150,000
	Operations Error	1,000	150,000
	Transfer Error	10	2,000
Tank Ship (Double-Hulled) with MP	Collision	20,000	15,000,000
	Allision	20,000	15,000,000
	Grounding	20,000	15,000,000
	Structural Failure	2,000	8,000,000
	Fire	2,000	8,000,000
	Equipment Failure	2,000	8,000,000
	Operations Error	2,000	8,000,000
	Transfer Error	10	2,000
Tank Barge (Double-Hulled) with LP	Collision	500	300,000
	Allision	500	300,000
	Grounding	500	300,000
	Structural Failure	200	300,000
	Fire	200	300,000
	Equipment Failure	200	300,000
	Operations Error	200	300,000
	Transfer Error	10	2,000
Tank Barge (Double-Hulled) with NP	Collision	500	300,000
	Allision	500	300,000
	Grounding	500	300,000
	Structural Failure	200	300,000
	Fire	200	300,000
	Equipment Failure	200	300,000
	Operations Error	200	300,000
	Transfer Error	10	2,000
Non-Tank Vessel (Double-Hulled) with LP	Collision	1,000	300,000
	Allision	1,000	300,000
	Grounding	1,000	300,000
	Structural Failure	100	300,000
	Fire	100	300,000
	Equipment Failure	100	300,000
	Operations Error	100	300,000

[4] A percentile spill is the spill volume associated with the nth probability. In other words, the volume for the nth percentile spill is that spill volume larger than n% of spills for that vessel type and cause. The nth percentile is smaller than 100 – n% of spills. The "25th percentile spill" is defined as the spill volume larger than 25% of the spills but smaller than 75% of the spills. The 50th percentile spill is the median (50% larger, 50% smaller).The 95th percentile spill is larger than 95% of the spills and only smaller than 1% of the spills. Only 1% of the spills is larger.

Table ES-4 Spill Volumes for Cook Inlet Incidents by Vessel Type and Cause: 2015 – 2020			
Vessel Type	**Accident Cause**	**Oil Volume (gallons)**	
		Moderate	**Large**
		50th%tile	**95th%tile**
	Transfer Error	10	2,000
Workboat (Double-Hulled) with LP	**Collision**	100	20,000
	Allision	100	20,000
	Grounding	100	20,000
	Structural Failure	10	20,000
	Fire	10	20,000
	Equipment Failure	10	20,000
	Operations Error	10	20,000
	Transfer Error	10	1,000
Workboat (Double-Hulled) with HP	**Collision**	100	20,000
	Allision	100	20,000
	Grounding	100	20,000
	Structural Failure	10	20,000
	Fire	10	20,000
	Equipment Failure	10	20,000
	Operations Error	10	20,000
	Transfer Error	10	1,000

Oil Types in Potential Spills

Based on an analysis of oil types involved in past spill and potential spill incidents in Cook Inlet, and projections for future changes in oil consumption, the oil types in Table ES-5 were used in the spill impact analysis.

Table ES-5: Oil Categories for Cook Inlet Spill Impact Analysis		
Vessel Type	**Years 2010 – 2014**	**Years 2015 – 2020**
Tank Ship	Low Persistent Medium Persistent	Low Persistent Medium Persistent
Tank Barge	Low Persistent Non-Persistent	Low Persistent Non-Persistent
Non-Tank Vessel	Heavy Persistent	Low Persistent
Work Boat	Low Persistent Heavy Persistent	Low Persistent Heavy Persistent

Potential Spill Impacts

Table ES-6 summarizes the relative probabilities of impact by oil spilled in the three Cook Inlet sub-areas by ice season. *Note that this only reflects the probability that there would be oil contact, not the degree of impact or injury, which varies by type of species and the oil type.*

Table ES-6: Summary of Biological Contact Probability of Cook Inlet Sub-Areas by Season											
Cook Inlet Sub-Area	**Season[5]**	**Moderate or High Probability of Contact**									
		Fish		**Shellfish**	**Birds**				**Marine Mammals**		
		Salmon	**Herring**	**Razor Clams**	**Water-fowl**	**Sea Birds**	**Shore Birds**	**Steller's Eider**	**Otters**	**Sea Lions**	**Whales**
Upper	**No-Ice**	**H**		**H**	**H**					**M**	**M**

[5] Impacts differ by season (spring, summer, winter, and autumn). The seasons of spring, summer, and autumn are combined here to create a "non-ice" season. The impacts are averaged over the three seasons to present a single "no-ice" impact.

Table ES-6: Summary of Biological Contact Probability of Cook Inlet Sub-Areas by Season											
Cook Inlet Sub-Area	Season[5]	Moderate or High Probability of Contact									
		Fish		Shellfish	Birds				Marine Mammals		
		Salmon	Herring	Razor Clams	Water-fowl	Sea Birds	Shore Birds	Steller's Eider	Otters	Sea Lions	Whales
	Ice			H						M	
Middle	No-Ice			H	H		H	H		M	M
	Ice			H			H			M	
Lower	No-Ice		H			H			H	M	
	Ice							H	H	M	

The relative degree of sensitivity to oiling of the different species types by the four different oil categories is shown in Table ES-7. The different oil categories differ with regard to their impacts to different organisms and habitats based on their overall toxicity, persistence, and adherence (coating) propensity, as summarized in Table ES-8. (Note that only Low Persistent and Heavy Persistent oil was evaluated in the analysis since the analyses were limited to one oil type per aggregated vessel group.) The groups of species also differ in their behavior and probability of contact with the oil.

Table ES-7: Summary of Overall Degree of Sensitivity to Oiling										
Oil Category	Degree of Sensitivity to Oiling									
	Fish		Shellfish	Birds				Marine Mammals		
	Salmon	Herring	Razor Clams	Water -fowl	Sea Birds	Shore Birds	Steller's Eider	Otters	Sea Lions	Whales[6]
Non-Persistent	H	H	L	L	L	L	L	L	L	L
Low Persistent	H	H	M	M	M	L	M	M	M	L
Med. Persistent	M	M	H	H	H	M	H	H	H	L
Heavy Persistent	L	L	H	H	H	H	H	H	H	L

Table ES-8: Basic Oil Properties as Affect Wildlife and Habitat Impacts			
Oil Category	Oil Property		
	Toxicity	Persistence	Adherence
Non-Persistent	VH	VL	VL
Low Persistent	H	L	L
Med. Persistent	M	M	H
Heavy Persistent	L	VH	VH

The degrees of environmental impact of potential spills into the waters of Cook Inlet from vessels were analyzed with regard to the main factors that would affect those impacts – oil type, spill volume, location, and season. The results are summarized in Table ES-9 through Table ES-11 by Cook Inlet sub-area (the location of the spill). Note that spills of larger volumes of oil in one sub-area will almost certainly affect other parts of Cook Inlet, as well as areas outside of Cook Inlet. Since there were to be only two "seasons" – "ice" and "no-ice", the results for the seasons of spring, summer, and autumn were averaged.

Very generalized degrees of environmental impact presented in these tables are defined on a five-point scale as follows, with the approximate point system developed to allow for a quasi-quantitative ranking for the purpose of risk assessment:[7]

[6] Whales are not generally considered to be highly sensitive to oil spills because of avoidance behavior, but there special management mandates mitigation of all possible impacts from oil spills and cleanup activities.
[7] Determining the rate of ecosystem and population recovery is extremely complex. There are a large number of complex and inter-related factors involved in determining short- and long-term consequences of oil spills. There is

- **Very High Impact (VH) (5 points):** Long-term impacts (over five years) anticipated over a large part of Cook Inlet and potentially outside of the Inlet in other areas of Alaskan waters and coastal areas and/or significant impacts to threatened species or species indicated for special management. Recovery of populations and ecosystems will take over five years and/or threatened or special-management species will be very significantly impacted at the population level.
- **High Impact (H) (4 points)**: Moderate-term impacts (two to five years) anticipated over a large part of Cook Inlet or very significant (high) impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take two to five years.
- **Moderate Impact (M) (3 points):** Moderate-term impacts (two to five years) anticipated over a smaller part of Cook Inlet or significant (high) impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take two to five years.
- **Low Impact (L) (2 points):** Significant shorter-term impacts (under two years) to a large part of Cook Inlet or moderate impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take less than two years.
- **Very Low Impact (VL) (1 point):** Significant shorter-term impacts (under two years) to smaller parts of Cook Inlet or low impacts to larger areas of the Inlet. Recovery of populations and ecosystems will take less than two years.

The oil volumes presented in the tables are based on magnitudes of spill volume by oil type for the different vessel type incidents analyzed.

Table ES-9: Oil Spill Impacts for Upper Cook Inlet by Oil Type, Volume, and Ice Season

Oil Type	Volume (gallons)	No-Ice	Ice
Non-Persistent	**10**	VL	VL
Non-Persistent	**200**	VL	VL
Non-Persistent	**500**	VL	VL
Non-Persistent	**2,000**	L	VL
Non-Persistent	**300,000**	M	L
Low Persistent	**10**	VL	VL
Low Persistent	**100**	L	VL
Low Persistent	**200**	L	VL
Low Persistent	**500**	M	L
Low Persistent	**1,000**	M	L
Low Persistent	**2,000**	M	L
Low Persistent	**5,000**	M	L
Low Persistent	**20,000**	M	L
Low Persistent	**150,000**	H	M
Low Persistent	**300,000**	H	M

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considerable and legitimate debate in the scientific community about scientific data on short- and long-term recovery rates and the ways in which the results of many spill impact studies and models should be interpreted and applied. A complete analysis would require highly complex modeling and studies outside of the scope of the Cook Inlet Maritime Risk Assessment project. The rating system presented here and its application to the vessel spill scenarios in the analysis are based on generalized data analyses on spill impacts based on studies of hundreds of spill case studies and over one thousand spill impact studies. In addition to the limitations of assigning impact values to hypothetical spills, there is the not insignificant issue of cultural values placed on impacts to the environment of Cook Inlet that can only truly be understood and appreciated by the myriad of stakeholders in Cook Inlet and in Alaska as a whole. While from an ecosystem and population-level perspective, recovery rates may be similar to those indicated here, the "acceptability" of any degree of environmental impacts from spills will be a matter for stakeholders to consider. This aspect is outside the scope of this assessment.

Table ES-9: Oil Spill Impacts for Upper Cook Inlet by Oil Type, Volume, and Ice Season			
Oil Type	**Volume (gallons)**	**No-Ice**	**Ice**
Low Persistent	**4,000,000**	H	M
Medium Persistent	**10**	VL	VL
Medium Persistent	**2,000**	M	L
Medium Persistent	**20,000**	M	M
Medium Persistent	**8,000,000**	H	H
Medium Persistent	**15,000,000**	VH	VH
Heavy Persistent	**10**	H	M
Heavy Persistent	**100**	VL	VL
Heavy Persistent	**1,000**	L	VL
Heavy Persistent	**2,000**	L	VL
Heavy Persistent	**20,000**	M	M
Heavy Persistent	**300,000**	H	M

Table ES-10: Oil Spill Impacts for Middle Cook Inlet by Oil Type, Volume, and Ice Season			
Oil Type	**Volume (gallons)**	**No-Ice**	**Ice**
Non-Persistent	**10**	VL	VL
Non-Persistent	**200**	VL	VL
Non-Persistent	**500**	VL	VL
Non-Persistent	**2,000**	L	VL
Non-Persistent	**300,000**	M	L
Low Persistent	**10**	VL	VL
Low Persistent	**100**	VL	VL
Low Persistent	**200**	VL	VL
Low Persistent	**500**	VL	VL
Low Persistent	**1,000**	L	VL
Low Persistent	**2,000**	L	VL
Low Persistent	**5,000**	L	VL
Low Persistent	**20,000**	M	L
Low Persistent	**150,000**	M	L
Low Persistent	**300,000**	M	L
Low Persistent	**4,000,000**	H	M
Medium Persistent	**10**	VL	VL
Medium Persistent	**2,000**	M	M
Medium Persistent	**20,000**	M	M
Medium Persistent	**8,000,000**	H	H
Medium Persistent	**15,000,000**	VH	VH
Heavy Persistent	**10**	VL	VL
Heavy Persistent	**100**	VL	VL
Heavy Persistent	**1,000**	L	L
Heavy Persistent	**2,000**	L	L
Heavy Persistent	**20,000**	M	M
Heavy Persistent	**300,000**	H	H

Table ES-11: Oil Spill Impacts for Lower Cook Inlet by Oil Type, Volume, and Ice Season			
Oil Type	**Volume (gallons)**	**No-Ice**	**Ice**
Non-Persistent	**10**	VL	VL
Non-Persistent	**200**	VL	VL
Non-Persistent	**500**	VL	VL
Non-Persistent	**2,000**	L	VL
Non-Persistent	**300,000**	M	L
Low Persistent	**10**	VL	VL
Low Persistent	**100**	VL	VL
Low Persistent	**200**	VL	VL
Low Persistent	**500**	VL	VL
Low Persistent	**1,000**	L	VL
Low Persistent	**2,000**	L	VL
Low Persistent	**5,000**	L	VL
Low Persistent	**20,000**	M	L
Low Persistent	**150,000**	M	L
Low Persistent	**300,000**	M	L
Low Persistent	**4,000,000**	H	M
Medium Persistent	**10**	VL	VL
Medium Persistent	**2,000**	M	M
Medium Persistent	**20,000**	M	M
Medium Persistent	**8,000,000**	H	H

Table ES-11: Oil Spill Impacts for Lower Cook Inlet by Oil Type, Volume, and Ice Season			
Oil Type	**Volume (gallons)**	**No-Ice**	**Ice**
Medium Persistent	**15,000,000**	VH	VH
Heavy Persistent	**10**	VL	VL
Heavy Persistent	**100**	VL	VL
Heavy Persistent	**1,000**	L	L
Heavy Persistent	**2,000**	L	L
Heavy Persistent	**20,000**	M	M
Heavy Persistent	**300,000**	H	H

Summary of Spill Impacts and Probabilities for 2010 – 2014

Spill impacts and probabilities by vessel type, hull, incident cause, spill volume, and season are presented in Tables ES-12 – ES-13 for each of the three sub-areas of Cook Inlet for the 2010 – 2014 time period.

Table ES-12: Spill Impacts and Probabilities Summary – Upper Cook Inlet 2010 – 2014						
Vessel Type/ Oil Type	**Cause**	**Prob. of Spill**	**Degree of Impact by Ice Season and Volume**			
			Moderate Spill		**Large Spill**	
			No-Ice	**Ice**	**No-Ice**	**Ice**
Tank Ship LP	**Collision**	0.68	M (3)	L (2)	H (4)	M (3)
	Allision	0.68	M (3)	L (2)	H (4)	M (3)
	Grounding	0.91	M (3)	L (2)	H (4)	M (3)
	Structural	0.40	M (3)	L (2)	H (4)	M (3)
	Fire	0.40	M (3)	L (2)	H (4)	M (3)
	Equipment	0.40	M (3)	L (2)	H (4)	M (3)
	Operations	0.40	M (3)	L (2)	H (4)	M (3)
	Transfer	0.92	VL (1)	VL (1)	M (3)	L (2)
Tank Ship MP	**Collision**	0.68	M (3)	M (3)	VH (5)	VH (5)
	Allision	0.68	M (3)	M (3)	VH (5)	VH (5)
	Grounding	0.91	M (3)	M (3)	VH (5)	VH (5)
	Structural	0.40	M (3)	L (2)	H (4)	H (4)
	Fire	0.40	M (3)	L (2)	H (4)	H (4)
	Equipment	0.40	M (3)	L (2)	H (4)	H (4)
	Operations	0.40	M (3)	L (2)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	M (3)	L (2)
Tank Barge LP	**Collision**	0.76	M (3)	L (2)	H (4)	M (3)
	Allision	0.76	M (3)	L (2)	H (4)	M (3)
	Grounding	0.76	M (3)	L (2)	H (4)	M (3)
	Structural	0.40	L (2)	VL (1)	H (4)	M (3)
	Fire	0.40	L (2)	VL (1)	H (4)	M (3)
	Equipment	0.40	L (2)	VL (1)	H (4)	M (3)
	Operations	0.40	L (2)	VL (1)	H (4)	M (3)
	Transfer	0.92	VL (1)	VL (1)	M (3)	L (2)
Tank Barge NP	**Collision**	0.76	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.76	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.76	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Non-Tank HP	**Collision**	0.05	L (2)	VL (1)	H (4)	M (3)
	Allision	0.05	L (2)	VL (1)	H (4)	M (3)
	Grounding	0.05	L (2)	VL (1)	H (4)	M (3)

Table ES-12: Spill Impacts and Probabilities Summary – Upper Cook Inlet 2010 – 2014						
Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Non-Tank/Non-Workboat Vessel HP	Structural	0.20	VL (1)	VL (1)	H (4)	M (3)
	Fire	0.20	VL (1)	VL (1)	H (4)	M (3)
	Equipment	0.20	VL (1)	VL (1)	H (4)	M (3)
	Operations	0.20	VL (1)	VL (1)	H (4)	M (3)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Workboat LP	Collision	0.05	L (2)	VL (1)	M (3)	L (2)
	Allision	0.05	L (2)	VL (1)	M (3)	L (2)
	Grounding	0.05	L (2)	VL (1)	M (3)	L (2)
	Structural	0.20	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.20	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.20	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.20	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	M (3)	L (2)
Workboat HP	Collision	0.05	VL (1)	VL (1)	M (3)	M (3)
	Allision	0.05	VL (1)	VL (1)	M (3)	M (3)
	Grounding	0.05	VL (1)	VL (1)	M (3)	M (3)
	Structural	0.20	VL (1)	VL (1)	M (3)	M (3)
	Fire	0.20	VL (1)	VL (1)	M (3)	M (3)
	Equipment	0.20	VL (1)	VL (1)	M (3)	M (3)
	Operations	0.20	VL (1)	VL (1)	M (3)	M (3)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)

Table ES-13: Spill Impacts and Probabilities Summary – Middle Cook Inlet 2010 – 2014						
Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Tank Ship LP	Collision	0.68	L (2)	VL (1)	H (4)	M (3)
	Allision	0.68	L (2)	VL (1)	H (4)	M (3)
	Grounding	0.91	L (2)	VL (1)	H (4)	M (3)
	Structural	0.40	L (2)	VL (1)	M (3)	L (2)
	Fire	0.40	L (2)	VL (1)	M (3)	L (2)
	Equipment	0.40	L (2)	VL (1)	M (3)	L (2)
	Operations	0.40	L (2)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Tank Ship MP	Collision	0.68	M (3)	M (3)	VH (5)	VH (5)
	Allision	0.68	M (3)	M (3)	VH (5)	VH (5)
	Grounding	0.91	M (3)	M (3)	VH (5)	VH (5)
	Structural	0.40	L (2)	VL (1)	H (4)	H (4)
	Fire	0.40	L (2)	VL (1)	H (4)	H (4)
	Equipment	0.40	L (2)	VL (1)	H (4)	H (4)
	Operations	0.40	L (2)	VL (1)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	M (3)	M (3)
Tank Barge LP	Collision	0.76	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.76	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.76	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)

Table ES-13: Spill Impacts and Probabilities Summary – Middle Cook Inlet 2010 – 2014						
Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Tank Barge LP	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Tank Barge NP	Collision	0.76	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.76	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.76	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Non-Tank/Non-Workboat Vessel HP	Collision	0.05	L (2)	L (2)	H (4)	H (4)
	Allision	0.05	L (2)	L (2)	H (4)	H (4)
	Grounding	0.05	L (2)	L (2)	H (4)	H (4)
	Structural	0.20	VL (1)	VL (1)	H (4)	H (4)
	Fire	0.20	VL (1)	VL (1)	H (4)	H (4)
	Equipment	0.20	VL (1)	VL (1)	H (4)	H (4)
	Operations	0.20	VL (1)	VL (1)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	L (2)	L (2)
Workboat LP	Collision	0.05	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.05	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.05	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.20	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.20	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.20	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.20	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Workboat HP	Collision	0.05	VL (1)	VL (1)	M (3)	M (3)
	Allision	0.05	VL (1)	VL (1)	M (3)	M (3)
	Grounding	0.05	VL (1)	VL (1)	M (3)	M (3)
	Structural	0.20	VL (1)	VL (1)	M (3)	M (3)
	Fire	0.20	VL (1)	VL (1)	M (3)	M (3)
	Equipment	0.20	VL (1)	VL (1)	M (3)	M (3)
	Operations	0.20	VL (1)	VL (1)	M (3)	M (3)
	Transfer	0.92	VL (1)	VL (1)	L (2)	L (2)

Table ES-14: Spill Impacts and Probabilities Summary – Lower Cook Inlet 2010 – 2014						
Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Tank Ship LP	Collision	0.68	L (2)	VL (1)	H (4)	M (3)
	Allision	0.68	L (2)	VL (1)	H (4)	M (3)
	Grounding	0.91	L (2)	VL (1)	H (4)	M (3)
	Structural	0.40	L (2)	VL (1)	M (3)	L (2)
	Fire	0.40	L (2)	VL (1)	M (3)	L (2)
	Equipment	0.40	L (2)	VL (1)	M (3)	L (2)
	Operations	0.40	L (2)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Tank Ship MP	Collision	0.68	M (3)	M (3)	VH (5)	VH (5)
	Allision	0.68	M (3)	M (3)	VH (5)	VH (5)

Table ES-14: Spill Impacts and Probabilities Summary – Lower Cook Inlet 2010 – 2014						
Vessel Type/ Oil Type	**Cause**	**Prob. of Spill**	**Degree of Impact by Ice Season and Volume**			
			Moderate Spill		**Large Spill**	
			No-Ice	**Ice**	**No-Ice**	**Ice**
Tank Ship MP	**Grounding**	0.91	M (3)	M (3)	VH (5)	VH (5)
	Structural	0.40	M (3)	M (3)	H (4)	H (4)
	Fire	0.40	M (3)	M (3)	H (4)	H (4)
	Equipment	0.40	M (3)	M (3)	H (4)	H (4)
	Operations	0.40	M (3)	M (3)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	M (3)	M (3)
Tank Barge LP	**Collision**	0.76	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.76	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.76	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Tank Barge NP	**Collision**	0.76	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.76	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.76	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Non-Tank/Non-Workboat Vessel HP	**Collision**	0.05	L (2)	L (2)	H (4)	H (4)
	Allision	0.05	L (2)	L (2)	H (4)	H (4)
	Grounding	0.05	L (2)	L (2)	H (4)	H (4)
	Structural	0.20	VL (1)	VL (1)	H (4)	H (4)
	Fire	0.20	VL (1)	VL (1)	H (4)	H (4)
	Equipment	0.20	VL (1)	VL (1)	H (4)	H (4)
	Operations	0.20	VL (1)	VL (1)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	L (2)	L (2)
Workboat LP	**Collision**	0.05	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.05	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.05	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.20	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.20	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.20	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.20	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Workboat HP	**Collision**	0.05	VL (1)	VL (1)	M (3)	M (3)
	Allision	0.05	VL (1)	VL (1)	M (3)	M (3)
	Grounding	0.05	VL (1)	VL (1)	M (3)	M (3)
	Structural	0.20	VL (1)	VL (1)	M (3)	M (3)
	Fire	0.20	VL (1)	VL (1)	M (3)	M (3)
	Equipment	0.20	VL (1)	VL (1)	M (3)	M (3)
	Operations	0.20	VL (1)	VL (1)	M (3)	M (3)
	Transfer	0.92	VL (1)	VL (1)	L (2)	L (2)

Summary of Spill Impacts and Probabilities for 2015 – 2020

Spill impacts and probabilities by vessel type, hull, incident cause, spill Volume, and season are presented in Tables ES-15 – ES-17. - for each of the three sub-areas of Cook Inlet for the 2015 – 2020 time period.

Table ES-15: Spill Impacts and Probabilities Summary – Upper Cook Inlet 2015 – 2020

Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Tank Ship LP	Collision	0.15	M (3)	L (2)	H (4)	M (3)
	Allision	0.15	M (3)	L (2)	H (4)	M (3)
	Grounding	0.18	M (3)	L (2)	H (4)	M (3)
	Structural	0.40	M (3)	L (2)	H (4)	M (3)
	Fire	0.40	M (3)	L (2)	H (4)	M (3)
	Equipment	0.40	M (3)	L (2)	H (4)	M (3)
	Operations	0.40	M (3)	L (2)	H (4)	M (3)
	Transfer	0.92	VL (1)	VL (1)	M (3)	L (2)
Tank Ship MP	Collision	0.15	M (3)	M (3)	VH (5)	VH (5)
	Allision	0.15	M (3)	M (3)	VH (5)	VH (5)
	Grounding	0.18	M (3)	M (3)	VH (5)	VH (5)
	Structural	0.40	M (3)	L (2)	H (4)	H (4)
	Fire	0.40	M (3)	L (2)	H (4)	H (4)
	Equipment	0.40	M (3)	L (2)	H (4)	H (4)
	Operations	0.40	M (3)	L (2)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	M (3)	L (2)
Tank Barge LP	Collision	0.13	M (3)	L (2)	H (4)	M (3)
	Allision	0.13	M (3)	L (2)	H (4)	M (3)
	Grounding	0.22	M (3)	L (2)	H (4)	M (3)
	Structural	0.40	L (2)	VL (1)	H (4)	M (3)
	Fire	0.40	L (2)	VL (1)	H (4)	M (3)
	Equipment	0.40	L (2)	VL (1)	H (4)	M (3)
	Operations	0.40	L (2)	VL (1)	H (4)	M (3)
	Transfer	0.92	VL (1)	VL (1)	M (3)	L (2)
Tank Barge NP	Collision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.22	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Non-Tank/Non-Workboat Vessel LP	Collision	0.02	L (2)	VL (1)	H (4)	M (3)
	Allision	0.02	L (2)	VL (1)	H (4)	M (3)
	Grounding	0.02	L (2)	VL (1)	H (4)	M (3)
	Structural	0.20	VL (1)	VL (1)	H (4)	M (3)
	Fire	0.20	VL (1)	VL (1)	H (4)	M (3)
	Equipment	0.20	VL (1)	VL (1)	H (4)	M (3)
	Operations	0.20	VL (1)	VL (1)	H (4)	M (3)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Workboat LP	Collision	0.02	L (2)	VL (1)	M (3)	L (2)
	Allision	0.02	L (2)	VL (1)	M (3)	L (2)
	Grounding	0.02	L (2)	VL (1)	M (3)	L (2)
	Structural	0.20	VL (1)	VL (1)	M (3)	L (2)

Table ES-15: Spill Impacts and Probabilities Summary – Upper Cook Inlet 2015 – 2020						
Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Workboat LP	Fire	0.20	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.20	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.20	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	M (3)	L (2)
Workboat HP	Collision	0.02	VL (1)	VL (1)	M (3)	M (3)
	Allision	0.02	VL (1)	VL (1)	M (3)	M (3)
	Grounding	0.02	VL (1)	VL (1)	M (3)	M (3)
	Structural	0.20	VL (1)	VL (1)	M (3)	M (3)
	Fire	0.20	VL (1)	VL (1)	M (3)	M (3)
	Equipment	0.20	VL (1)	VL (1)	M (3)	M (3)
	Operations	0.20	VL (1)	VL (1)	M (3)	M (3)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)

Table ES-16: Spill Impacts and Probabilities Summary – Middle Cook Inlet 2015 – 2020						
Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Tank Ship LP	Collision	0.15	L (2)	VL (1)	H (4)	M (3)
	Allision	0.15	L (2)	VL (1)	H (4)	M (3)
	Grounding	0.18	L (2)	VL (1)	H (4)	M (3)
	Structural	0.40	L (2)	VL (1)	M (3)	L (2)
	Fire	0.40	L (2)	VL (1)	M (3)	L (2)
	Equipment	0.40	L (2)	VL (1)	M (3)	L (2)
	Operations	0.40	L (2)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Tank Ship MP	Collision	0.15	M (3)	M (3)	VH (5)	VH (5)
	Allision	0.15	M (3)	M (3)	VH (5)	VH (5)
	Grounding	0.18	M (3)	M (3)	VH (5)	VH (5)
	Structural	0.40	L (2)	VL (1)	H (4)	H (4)
	Fire	0.40	L (2)	VL (1)	H (4)	H (4)
	Equipment	0.40	L (2)	VL (1)	H (4)	H (4)
	Operations	0.40	L (2)	VL (1)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	M (3)	M (3)
Tank Barge LP	Collision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.22	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Tank Barge NP	Collision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.22	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)

Table ES-16: Spill Impacts and Probabilities Summary – Middle Cook Inlet 2015 – 2020						
Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Non-Tank/Non-Workboat Vessel LP	Collision	0.02	L (2)	VL (1)	M (3)	L (2)
	Allision	0.02	L (2)	VL (1)	M (3)	L (2)
	Grounding	0.02	L (2)	VL (1)	M (3)	L (2)
	Structural	0.20	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.20	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.20	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.20	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Workboat LP	Collision	0.02	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.02	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.02	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.20	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.20	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.20	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.20	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Workboat HP	Collision	0.02	VL (1)	VL (1)	M (3)	M (3)
	Allision	0.02	VL (1)	VL (1)	M (3)	M (3)
	Grounding	0.02	VL (1)	VL (1)	M (3)	M (3)
	Structural	0.20	VL (1)	VL (1)	M (3)	M (3)
	Fire	0.20	VL (1)	VL (1)	M (3)	M (3)
	Equipment	0.20	VL (1)	VL (1)	M (3)	M (3)
	Operations	0.20	VL (1)	VL (1)	M (3)	M (3)
	Transfer	0.92	VL (1)	VL (1)	L (2)	L (2)

Table ES-17: Spill Impacts and Probabilities Summary – Lower Cook Inlet 2015 – 2020						
Vessel Type/ Oil Type	Cause	Prob. of Spill	Degree of Impact by Ice Season and Volume			
			Moderate Spill		Large Spill	
			No-Ice	Ice	No-Ice	Ice
Tank Ship LP	Collision	0.15	L (2)	VL (1)	H (4)	M (3)
	Allision	0.15	L (2)	VL (1)	H (4)	M (3)
	Grounding	0.18	L (2)	VL (1)	H (4)	M (3)
	Structural	0.40	L (2)	VL (1)	M (3)	L (2)
	Fire	0.40	L (2)	VL (1)	M (3)	L (2)
	Equipment	0.40	L (2)	VL (1)	M (3)	L (2)
	Operations	0.40	L (2)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Tank Ship MP	Collision	0.15	M (3)	M (3)	VH (5)	VH (5)
	Allision	0.15	M (3)	M (3)	VH (5)	VH (5)
	Grounding	0.18	M (3)	M (3)	VH (5)	VH (5)
	Structural	0.40	M (3)	M (3)	H (4)	H (4)
	Fire	0.40	M (3)	M (3)	H (4)	H (4)
	Equipment	0.40	M (3)	M (3)	H (4)	H (4)
	Operations	0.40	M (3)	M (3)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	M (3)	M (3)
Tank Barge LP	Collision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.22	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)

Table ES-17: Spill Impacts and Probabilities Summary – Lower Cook Inlet 2015 – 2020						
Vessel Type/ Oil Type	**Cause**	**Prob. of Spill**	**Degree of Impact by Ice Season and Volume**			
			Moderate Spill		**Large Spill**	
			No-Ice	**Ice**	**No-Ice**	**Ice**
Tank Barge LP	**Fire**	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Tank Barge NP	**Collision**	0.13	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.13	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.22	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.40	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.40	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.40	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.40	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Non-Tank/Non-Workboat Vessel LP	**Collision**	0.02	L (2)	L (2)	H (4)	H (4)
	Allision	0.02	L (2)	L (2)	H (4)	H (4)
	Grounding	0.02	L (2)	L (2)	H (4)	H (4)
	Structural	0.20	VL (1)	VL (1)	H (4)	H (4)
	Fire	0.20	VL (1)	VL (1)	H (4)	H (4)
	Equipment	0.20	VL (1)	VL (1)	H (4)	H (4)
	Operations	0.20	VL (1)	VL (1)	H (4)	H (4)
	Transfer	0.92	VL (1)	VL (1)	L (2)	L (2)
Workboat LP	**Collision**	0.02	VL (1)	VL (1)	M (3)	L (2)
	Allision	0.02	VL (1)	VL (1)	M (3)	L (2)
	Grounding	0.02	VL (1)	VL (1)	M (3)	L (2)
	Structural	0.20	VL (1)	VL (1)	M (3)	L (2)
	Fire	0.20	VL (1)	VL (1)	M (3)	L (2)
	Equipment	0.20	VL (1)	VL (1)	M (3)	L (2)
	Operations	0.20	VL (1)	VL (1)	M (3)	L (2)
	Transfer	0.92	VL (1)	VL (1)	L (2)	VL (1)
Workboat HP	**Collision**	0.02	VL (1)	VL (1)	M (3)	M (3)
	Allision	0.02	VL (1)	VL (1)	M (3)	M (3)
	Grounding	0.02	VL (1)	VL (1)	M (3)	M (3)
	Structural	0.20	VL (1)	VL (1)	M (3)	M (3)
	Fire	0.20	VL (1)	VL (1)	M (3)	M (3)
	Equipment	0.20	VL (1)	VL (1)	M (3)	M (3)
	Operations	0.20	VL (1)	VL (1)	M (3)	M (3)
	Transfer	0.92	VL (1)	VL (1)	L (2)	L (2)

Appendix A: Additional Details

Cook Inlet vessel traffic creates concern over incidents (casualties, errors, and accidents) that could cause oil spillage that would impact the sensitive environment of the area. Once the probabilities of the various kinds of vessel incidents have been determined based on past accident rates and analyses of current and projected future vessel traffic, the next steps in the Cook Inlet Maritime Risk Assessment are to:

- Estimate the probabilities that vessel incidents (by vessel type, hull type, and incident type) will result in oil spillage now and in the future;
- Develop the probability distributions of spill volumes (by vessel type, hull type, and incident type); and
- Analyze the environmental impacts that would occur in the event of oil spillage (by spill volume, oil type, location, and season.

The "event tree" for probabilities of outcomes for vessel incidents is summarized in Figure ESD-1.

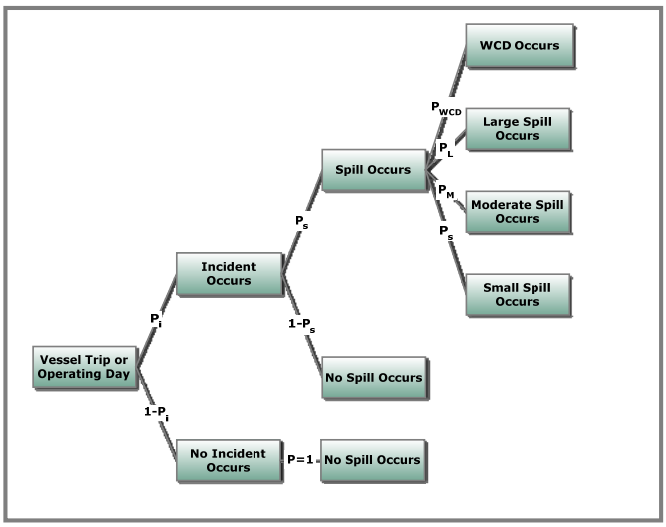

Figure ESD-1: Event Tree for Spills from Vessel Incidents in Cook Inlet

This report presents these three sets of analyses. The analyses have been conducted for the near-future and for 2015 and beyond. Differences in outcome for these two time period are based on the following:

- Mandated double hulls on cargo tanks for tankers by 2015, which reduces the probability of an impact-related casualty (allision, collision, or grounding) resulting in oil spillage, as well as reduces the outflow volume of the worst-case discharge (WCD);
- Mandated double hulls on tank barges by 2015, which reduces the probability of an impact-related casualty (allision, collision, or grounding) resulting in oil spillage, but does not affect the outflow volume of the WCD;
- Mandated double-hull construction for bunker tanks for future-built larger non-tank vessels, which reduces the probability of an impact-related casualty (allision, collision, or grounding) resulting in oil spillage, but does not affect the outflow volume of the WCD; and

- Air-emission regulation-mandated switchover to diesel fuels away from heavy bunker fuels for larger vessels by 2016, which changes the nature of spill impacts due to differences in the toxicity and persistence of the oils.

Potential for Spillage with Vessel Incident

The probabilities for an incident resulting in any oil spillage by vessel type, hull type, and accident cause are summarized in Table APPA-1.

Table APPA-1: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis

Vessel Type	Accident Cause	Hull[8]	Spill Probability Given Incident
Product Tanker	Collision	Single	0.6800
		Double	0.1500
	Allision	Single	0.6800
		Double	0.1500
	Grounding	Single	0.9100
		Double	0.1800
	Structural Failure	Single	0.4000
		Double	0.4000
	Fire	Single	0.4000
		Double	0.4000
	Equipment Failure	Single	0.4000
		Double	0.4000
	Operations Error	Single	0.4000
		Double	0.4000
	Transfer Error	Single	0.9231
		Double	0.9231
Crude Tanker	Collision	Single	0.8100
		Double	0.1900
	Allision	Single	0.8100
		Double	0.1900
	Grounding	Single	0.9300
		Double	0.2000
	Structural Failure	Single	0.4000
		Double	0.4000
	Fire	Single	0.4000
		Double	0.4000
	Equipment Failure	Single	0.4000
		Double	0.4000
	Operations Error	Single	0.4000
		Double	0.4000
	Transfer Error	Single	0.9231
		Double	0.9231
Tank Barge	Collision	Single	0.7600
		Double	0.1300
	Allision	Single	0.7600
		Double	0.1300
	Grounding	Single	0.7600
		Double	0.2200

[8] For tank vessels (tankers/tank barges), the hull refers to the cargo hull. For all other vessels the hull refers to the bunker tank hull. For tank vessels (tankers and tank barges), the hull refers to the cargo hull. For all other vessels the hull refers to bunker tanks. Single hulls should be used for pre-2015 scenarios, double-hulls for 2015 and beyond.

Table APPA-1: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis			
Vessel Type	**Accident Cause**	**Hull[8]**	**Spill Probability Given Incident**
Tank Barge	**Structural Failure**	**Single**	0.4000
		Double	0.4000
	Fire	**Single**	0.4000
		Double	0.4000
	Equipment Failure	**Single**	0.4000
		Double	0.4000
	Operations Error	**Single**	0.4000
		Double	0.4000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Non-Tank/Non-Workboat Vessel	**Collision**	**Single**	0.0450
		Double	0.0190
	Allision	**Single**	0.0450
		Double	0.0190
	Grounding	**Single**	0.0450
		Double	0.0190
	Structural Failure	**Single**	0.2000
		Double	0.2000
	Fire	**Single**	0.2000
		Double	0.2000
	Equipment Failure	**Single**	0.2000
		Double	0.2000
	Operations Error	**Single**	0.2000
		Double	0.2000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Gas Carrier	**Collision**	**Single**	0.0450
		Double	0.0190
	Allision	**Single**	0.0450
		Double	0.0190
	Grounding	**Single**	0.0450
		Double	0.0190
	Structural Failure	**Single**	0.2000
		Double	0.2000
	Fire	**Single**	0.2000
		Double	0.2000
	Equipment Failure	**Single**	0.2000
		Double	0.2000
	Operations Error	**Single**	0.2000
		Double	0.2000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Offshore Supply Vessel (OSV)	**Collision**	**Single**	0.0450
		Double	0.0190
	Allision	**Single**	0.0450
		Double	0.0190
	Grounding	**Single**	0.0450
		Double	0.0190
	Structural Failure	**Single**	0.2000
		Double	0.2000
	Fire	**Single**	0.2000

Table APPA-1: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis			
Vessel Type	**Accident Cause**	**Hull[8]**	**Spill Probability Given Incident**
Offshore Supply Vessel (OSV)	**Fire**	**Double**	0.2000
	Equipment Failure	**Single**	0.2000
		Double	0.2000
	Operations Error	**Single**	0.2000
		Double	0.2000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Tug/Tow Boat	**Collision**	**Single**	0.0450
		Double	0.0190
	Allision	**Single**	0.0450
		Double	0.0190
	Grounding	**Single**	0.0450
		Double	0.0190
	Structural Failure	**Single**	0.2000
		Double	0.2000
	Fire	**Single**	0.2000
		Double	0.2000
	Equipment Failure	**Single**	0.2000
		Double	0.2000
	Operations Error	**Single**	0.2000
		Double	0.2000
	Transfer Error	**Single**	0.9231
		Double	0.9231

Probability Distribution of Spill Volumes

The results of analyses of probability distributions of the volume of oil spillage by vessels in Cook Inlet *given that a spill does occur* are presented in Table APPA-2 by vessel type, hull type, and accident cause. The volumes are shown as the 25th percentile[9] (small) spill volume, 50th percentile (median or moderate) spill volume, the 95th percentile (large) spill volume, and the worst-case discharge (WCD) spill volume.

Table APPA-2: Spill Volumes for Cook Inlet Vessel Incidents by Vessel Type, Hull, and Cause						
Vessel Type	**Accident Cause**	**Hull[10]**	**Oil Volume (gallons)**			
			Small	**Moderate**	**Large**	**WCD**
			25th %tile	**50th %tile**	**95th%tile**	
Product Tanker	**Collision**	**Single**	200	5,000	4,000,000	21,000,000
		Double	200	5,000	4,000,000	7,980,000
	Allision	**Single**	200	5,000	4,000,000	21,000,000
		Double	200	5,000	4,000,000	7,980,000
	Grounding	**Single**	200	5,000	4,000,000	21,000,000
		Double	200	5,000	4,000,000	7,980,000
	Structural Failure	**Single**	50	1,000	150,000	21,000,000
		Double	50	1,000	150,000	7,980,000

[9] A percentile spill is the spill volume associated with the nth probability. In other words, the volume for the nth percentile spill is that spill volume larger than n% of spills for that vessel type and cause. The nth percentile is smaller than 100 – n% of spills. The "25th percentile spill" is defined as the spill volume larger than 25% of the spills but smaller than 75% of the spills. The 50th percentile spill is the median (50% larger, 50% smaller).The 95th percentile spill is larger than 99% of the spills and only smaller than 1% of the spills. Only 1% of the spills is larger.

[10] For tank vessels (tankers and tank barges), the hull refers to the cargo hull. For all other vessels the hull refers to the bunker tank hull. Single hulls should be used for pre-2015 scenarios, double-hulls for 2015 and beyond.

Table APPA-2: Spill Volumes for Cook Inlet Vessel Incidents by Vessel Type, Hull, and Cause						
Vessel Type	Accident Cause	Hull[10]	Oil Volume (gallons)			
			Small	Moderate	Large	WCD
			25th %tile	50th %tile	95th%tile	
Product Tanker	Fire	Single	50	1,000	150,000	21,000,000
		Double	50	1,000	150,000	7,980,000
	Equipment Failure	Single	50	1,000	150,000	21,000,000
		Double	50	1,000	150,000	7,980,000
	Operations Error	Single	50	1,000	150,000	21,000,000
		Double	50	1,000	150,000	7,980,000
	Transfer Error	Single	1	10	2,000	21,000,000
		Double	1	10	2,000	21,000,000
Crude Tanker	Collision	Single	500	20,000	15,000,000	75,000,000
		Double	500	20,000	15,000,000	28,500,000
	Allision	Single	500	20,000	15,000,000	75,000,000
		Double	500	20,000	15,000,000	28,500,000
	Grounding	Single	500	20,000	15,000,000	75,000,000
		Double	500	20,000	15,000,000	28,500,000
	Structural Failure	Single	100	2,000	8,000,000	75,000,000
		Double	100	2,000	8,000,000	28,500,000
	Fire	Single	100	2,000	8,000,000	75,000,000
		Double	100	2,000	8,000,000	28,500,000
	Equipment Failure	Single	100	2,000	8,000,000	75,000,000
		Double	100	2,000	8,000,000	28,500,000
	Operations Error	Single	100	2,000	8,000,000	75,000,000
		Double	100	2,000	8,000,000	28,500,000
	Transfer Error	Single	1	10	2,000	75,000,000
		Double	1	10	2,000	75,000,000
Tank Barge	Collision	Single	100	500	300,000	1,900,000
		Double	100	500	300,000	1,520,000
	Allision	Single	100	500	300,000	1,900,000
		Double	100	500	300,000	1,520,000
	Grounding	Single	100	500	300,000	1,900,000
		Double	100	500	300,000	1,520,000
	Structural Failure	Single	50	200	300,000	1,900,000
		Double	50	200	300,000	1,520,000
	Fire	Single	50	200	300,000	1,900,000
		Double	50	200	300,000	1,520,000
	Equipment Failure	Single	50	200	300,000	1,900,000
		Double	50	200	300,000	1,520,000
	Operations Error	Single	50	200	300,000	1,900,000
		Double	50	200	300,000	1,520,000
	Transfer Error	Single	1	10	2,000	1,900,000
		Double	1	10	2,000	1,900,000
Non-Tank/Non-Workboat Vessel	Collision	Single	100	1,000	300,000	605,000
		Double	100	1,000	300,000	605,000
	Allision	Single	100	1,000	300,000	605,000
		Double	100	1,000	300,000	605,000
	Grounding	Single	100	1,000	300,000	605,000
		Double	100	1,000	300,000	605,000
	Structural Failure	Single	10	100	300,000	605,000
		Double	10	100	300,000	605,000
	Fire	Single	10	100	300,000	605,000

Table APPA-2: Spill Volumes for Cook Inlet Vessel Incidents by Vessel Type, Hull, and Cause						
Vessel Type	Accident Cause	Hull[10]	Oil Volume (gallons)			
			Small	Moderate	Large	WCD
			25th %tile	50th %tile	95th%tile	
Non-Tank/Non-Workboat Vessel	Fire	Double	10	100	300,000	605,000
	Equipment Failure	Single	10	100	300,000	605,000
		Double	10	100	300,000	605,000
	Operations Error	Single	10	100	300,000	605,000
		Double	10	100	300,000	605,000
	Transfer Error	Single	1	10	2,000	605,000
		Double	1	10	2,000	605,000
Gas Carrier	Collision	Single	500	5,000	2,000,000	3,500,000
		Double	500	5,000	2,000,000	3,500,000
	Allision	Single	500	5,000	2,000,000	3,500,000
		Double	500	5,000	2,000,000	3,500,000
	Grounding	Single	500	5,000	2,000,000	3,500,000
		Double	500	5,000	2,000,000	3,500,000
	Structural Failure	Single	50	500	1,000,000	3,500,000
		Double	50	500	1,000,000	3,500,000
	Fire	Single	50	500	1,000,000	3,500,000
		Double	50	500	1,000,000	3,500,000
	Equipment Failure	Single	50	500	1,000,000	3,500,000
		Double	50	500	1,000,000	3,500,000
	Operations Error	Single	50	500	1,000,000	3,500,000
		Double	50	500	1,000,000	3,500,000
	Transfer Error	Single	1	10	1,000	3,500,000
		Double	1	10	1,000	3,500,000
Offshore Supply Vessel (OSV)	Collision	Single	10	100	20,000	36,000
		Double	10	100	20,000	36,000
	Allision	Single	10	100	20,000	36,000
		Double	10	100	20,000	36,000
	Grounding	Single	10	100	20,000	36,000
		Double	10	100	20,000	36,000
	Structural Failure	Single	1	10	20,000	36,000
		Double	1	10	20,000	36,000
	Fire	Single	1	10	20,000	36,000
		Double	1	10	20,000	36,000
	Equipment Failure	Single	1	10	20,000	36,000
		Double	1	10	20,000	36,000
	Operations Error	Single	1	10	20,000	36,000
		Double	1	10	20,000	36,000
	Transfer Error	Single	1	10	1,000	36,000
		Double	1	10	1,000	36,000
Tug/Tow Boat	Collision	Single	5	100	20,000	42,000
		Double	5	100	20,000	42,000
	Allision	Single	5	100	20,000	42,000
		Double	5	100	20,000	42,000
	Grounding	Single	5	100	20,000	42,000
		Double	5	100	20,000	42,000
	Structural Failure	Single	10	100	20,000	42,000
		Double	10	100	20,000	42,000
	Fire	Single	10	100	20,000	42,000
		Double	10	100	20,000	42,000

Table APPA-2: Spill Volumes for Cook Inlet Vessel Incidents by Vessel Type, Hull, and Cause						
Vessel Type	Accident Cause	Hull[10]	Oil Volume (gallons)			
			Small	Moderate	Large	WCD
			25th %tile	50th %tile	95th%tile	
Tug/Tow Boat	Equipment Failure	Single	10	100	20,000	42,000
		Double	10	100	20,000	42,000
	Operations Error	Single	10	100	20,000	42,000
		Double	10	100	20,000	42,000
	Transfer Error	Single	1	10	1,000	42,000
		Double	1	10	1,000	42,000

Oil Types in Potential Spills

Based on an analysis of oil types involved in past spill and potential spill incidents in Cook Inlet, and projections for future changes in oil consumption, the oil types in Table APPA-3 were used in the spill impact analysis.

Table APPA-3: Oil Categories for Cook Inlet Spill Impact Analysis		
Vessel Type	Years 2012 – 2014	Years 2015 – 2020
Product Tanker	Low Persistent	Low Persistent
Crude Tanker	Medium Persistent	Medium Persistent
Tank Barge	Low Persistent Non-Persistent	Low Persistent Non-Persistent
Non-Tank/Non-Workboat Vessel	Heavy Persistent	Low Persistent
Gas Carrier	Heavy Persistent	Low Persistent
Offshore Supply Vessel	Low Persistent	Low Persistent
Tug/Tow Boat	Heavy Persistent	Heavy Persistent

Potential Spill Impacts

Table APPA-4 summarizes the relative probabilities of impact by oil spilled in the three Cook Inlet sub-areas by season. *Note that this only reflects the probability that there would be oil contact, not the degree of impact or injury, which varies by type of species and the oil type.* (The sensitivity of the species is addressed in Table APPA-5.)

Table APPA-4: Summary of Biological Contact Probability of Cook Inlet Sub-Areas by Season											
Sub-Area	Season	Moderate or High Probability of Contact									
		Fish		Shellfish	Birds				Marine Mammals		
		Salmon	Herring	Razor Clams	Water-fowl	Sea Birds	Shore Birds	Steller's Eider	Otters	Sea Lions	Whales
Upper Cook Inlet	Spring	H		H	H					M	M
	Summer			H	M					H	
	Autumn	H		H	H					M	H
	Winter			H						M	
Middle Cook Inlet	Spring			H	H		H	H		M	M
	Summer			H	M		M			H	M
	Autumn			H	H		M			M	M
	Winter			H			H			M	
Lower Cook Inlet	Spring		H			H			H	M	
	Summer		H			M			H	H	
	Autumn					H			H	M	
	Winter							H	H	M	

The relative degree of sensitivity to oiling of the different species types by the four different oil categories is shown in Table APPA-5. The different oil categories differ with regard to their impacts to different

organisms and habitats based on their overall toxicity, persistence, and adherence (coating) propensity, as summarized in Table APPA-6. The groups of species also differ in their behavior and probability of contact with the oil.

Table APPA-5: Summary of Overall Degree of Sensitivity to Oiling

Oil Category	Degree of Sensitivity to Oiling									
	Fish		Shellfish	Birds				Marine Mammals		
	Salmon	Herring	Razor Clams	Water -fowl	Sea Birds	Shore Birds	Steller's Eider	Otters	Sea Lions	Whales [11]
Non-Persistent	H	H	L	L	L	L	L	L	L	L
Low Persistent	H	H	M	M	M	L	M	M	M	L
Med. Persistent	M	M	H	H	H	M	H	H	H	L
Heavy Persistent	L	L	H	H	H	H	H	H	H	L

Table APPA-6: Basic Oil Properties as Affect Wildlife and Habitat Impacts

Oil Category	Oil Property		
	Toxicity	Persistence	Adherence
Non-Persistent	VH	VL	VL
Low Persistent	H	L	L
Med. Persistent	M	M	H
Heavy Persistent	L	VH	VH

The degrees of environmental impact of potential spills into the waters of Cook Inlet from vessels were analyzed with regard to the main factors that would affect those impacts – oil type, spill volume, location, and season. The results are summarized in Table APPA-7 through Table APPA-9 by Cook Inlet sub-area (the location of the spill). Note that spills of larger volumes of oil in one sub-area will almost certainly affect other parts of Cook Inlet, as well as areas outside of Cook Inlet.

Very generalized degrees of environmental impact presented in these tables are defined on a five-point scale as follows, with the approximate point system developed to allow for a quasi-quantitative ranking for the purpose of risk assessment:[12]

- **Very High Impact (VH) (5 points):** Long-term impacts (over five years) anticipated over a large part of Cook Inlet and potentially outside of the Inlet in other areas of Alaskan waters and coastal areas and/or significant impacts to threatened species or species indicated for special

[11] Whales are not generally considered to be highly sensitive to oil spills because of avoidance behavior, but there special management mandates mitigation of all possible impacts from oil spills and cleanup activities.

[12] Determining the rate of ecosystem and population recovery is extremely complex. There are a large number of complex and inter-related factors involved in determining short- and long-term consequences of oil spills. There is considerable and legitimate debate in the scientific community about scientific data on short- and long-term recovery rates and the ways in which the results of many spill impact studies and models should be interpreted and applied. A complete analysis would require highly complex modeling and studies outside of the scope of the Cook Inlet Maritime Risk Assessment project. The rating system presented here and its application to the vessel spill scenarios in the analysis are based on generalized data analyses on spill impacts based on studies of hundreds of spill case studies and over one thousand spill impact studies. In addition to the limitations of assigning impact values to hypothetical spills, there is the not insignificant issue of cultural values placed on impacts to the environment of Cook Inlet that can only truly be understood and appreciated by the myriad of stakeholders in Cook Inlet and in Alaska as a whole. While from an ecosystem and population-level perspective, recovery rates may be similar to those indicated here, the "acceptability" of any degree of environmental impacts from spills will be a matter for stakeholders to consider. This aspect is outside the scope of this assessment.

management. Recovery of populations and ecosystems will take over five years and/or threatened or special-management species will be very significantly impacted at the population level.

- **High Impact (H) (4 points)**: Moderate-term impacts (two to five years) anticipated over a large part of Cook Inlet or very significant (high) impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take two to five years.
- **Moderate Impact (M) (3 points):** Moderate-term impacts (two to five years) anticipated over a smaller part of Cook Inlet or significant (high) impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take two to five years.
- **Low Impact (L) (2 points):** Significant shorter-term impacts (under two years) to a large part of Cook Inlet or moderate impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take less than two years.
- **Very Low Impact (VL) (1 point):** Significant shorter-term impacts (under two years) to smaller parts of Cook Inlet or low impacts to larger areas of the Inlet. Recovery of populations and ecosystems will take less than two years.

The oil volumes presented in the tables are based on magnitudes of spill volume by oil type for the different vessel type incidents analyzed.

Table APPA-7: Oil Spill Impacts for Upper Cook Inlet by Oil Type, Volume, and Season

Oil Type	Volume (gallons)	Spring	Summer	Autumn	Winter
Non-Persistent	**1**	VL	VL	VL	VL
Non-Persistent	**10**	VL	VL	VL	VL
Non-Persistent	**50**	VL	VL	VL	VL
Non-Persistent	**100**	VL	VL	VL	VL
Non-Persistent	**200**	VL	VL	VL	VL
Non-Persistent	**500**	VL	VL	VL	VL
Non-Persistent	**2,000**	L	L	L	VL
Non-Persistent	**300,000**	M	M	M	L
Non-Persistent	**1,520,000**	H	H	H	L
Non-Persistent	**1,900,000**	H	H	H	L
Low Persistent	**1**	VL	VL	VL	VL
Low Persistent	**10**	VL	VL	VL	VL
Low Persistent	**50**	VL	VL	VL	VL
Low Persistent	**100**	VL	VL	VL	VL
Low Persistent	**200**	VL	VL	VL	VL
Low Persistent	**500**	VL	VL	VL	VL
Low Persistent	**1,000**	L	L	L	VL
Low Persistent	**2,000**	L	L	L	VL
Low Persistent	**5,000**	L	L	L	VL
Low Persistent	**20,000**	M	M	M	L
Low Persistent	**36,000**	M	M	M	L
Low Persistent	**150,000**	M	M	M	L
Low Persistent	**300,000**	M	M	M	L
Low Persistent	**605,000**	M	M	M	L
Low Persistent	**1,000,000**	H	H	H	M
Low Persistent	**1,520,000**	H	H	H	M
Low Persistent	**1,900,000**	H	H	H	M
Low Persistent	**2,000,000**	H	H	H	M
Low Persistent	**3,500,000**	H	H	H	M
Low Persistent	**4,000,000**	H	H	H	M

Table APPA-7: Oil Spill Impacts for Upper Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Low Persistent	**7,980,000**	H	H	H	M
Low Persistent	**21,000,000**	VH	H	VH	M
Medium Persistent	**1**	VL	VL	VL	VL
Medium Persistent	**10**	VL	VL	VL	VL
Medium Persistent	**100**	VL	VL	VL	VL
Medium Persistent	**500**	L	L	L	VL
Medium Persistent	**2,000**	M	M	M	L
Medium Persistent	**20,000**	M	M	M	M
Medium Persistent	**8,000,000**	H	H	H	H
Medium Persistent	**15,000,000**	VH	VH	VH	VH
Medium Persistent	**28,500,000**	VH	VH	VH	VH
Medium Persistent	**75,000,000**	VH	VH	VH	VH
Heavy Persistent	**1**	VL	VL	VL	VL
Heavy Persistent	**5**	VL	VL	VL	VL
Heavy Persistent	**10**	VL	VL	VL	VL
Heavy Persistent	**50**	VL	VL	VL	VL
Heavy Persistent	**100**	VL	VL	VL	VL
Heavy Persistent	**500**	L	L	L	VL
Heavy Persistent	**1,000**	L	L	L	VL
Heavy Persistent	**2,000**	L	L	L	VL
Heavy Persistent	**5,000**	M	M	M	L
Heavy Persistent	**20,000**	M	M	M	M
Heavy Persistent	**42,000**	M	M	M	M
Heavy Persistent	**300,000**	H	H	H	M
Heavy Persistent	**605,000**	H	H	H	M
Heavy Persistent	**1,000,000**	VH	H	VH	H
Heavy Persistent	**2,000,000**	VH	H	VH	H
Heavy Persistent	**3,500,000**	VH	H	VH	H

Table APPA-8: Oil Spill Impacts for Middle Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Non-Persistent	**1**	VL	VL	VL	VL
Non-Persistent	**10**	VL	VL	VL	VL
Non-Persistent	**50**	VL	VL	VL	VL
Non-Persistent	**100**	VL	VL	VL	VL
Non-Persistent	**200**	VL	VL	VL	VL
Non-Persistent	**500**	VL	VL	VL	VL
Non-Persistent	**2,000**	L	VL	L	VL
Non-Persistent	**300,000**	M	L	M	L
Non-Persistent	**1,520,000**	H	M	H	L
Non-Persistent	**1,900,000**	H	M	H	L
Low Persistent	**1**	VL	VL	VL	VL
Low Persistent	**10**	VL	VL	VL	VL
Low Persistent	**50**	VL	VL	VL	VL
Low Persistent	**100**	VL	VL	VL	VL
Low Persistent	**200**	VL	VL	VL	VL
Low Persistent	**500**	VL	VL	VL	VL
Low Persistent	**1,000**	L	VL	L	VL
Low Persistent	**2,000**	L	VL	L	VL
Low Persistent	**5,000**	L	VL	L	VL
Low Persistent	**20,000**	M	L	M	L

Table APPA-8: Oil Spill Impacts for Middle Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Low Persistent	**36,000**	M	L	M	L
Low Persistent	**150,000**	M	L	M	L
Low Persistent	**300,000**	M	L	M	L
Low Persistent	**605,000**	M	L	M	L
Low Persistent	**1,000,000**	H	M	H	L
Low Persistent	**1,520,000**	H	M	H	L
Low Persistent	**1,900,000**	H	M	H	L
Low Persistent	**2,000,000**	H	M	H	L
Low Persistent	**3,500,000**	H	M	H	L
Low Persistent	**4,000,000**	H	M	H	M
Low Persistent	**7,980,000**	H	M	H	M
Low Persistent	**21,000,000**	VH	H	VH	M
Medium Persistent	**1**	VL	VL	VL	VL
Medium Persistent	**10**	VL	VL	VL	VL
Medium Persistent	**100**	VL	VL	VL	VL
Medium Persistent	**500**	L	VL	L	VL
Medium Persistent	**2,000**	M	L	M	M
Medium Persistent	**20,000**	M	M	M	H
Medium Persistent	**8,000,000**	H	H	H	H
Medium Persistent	**15,000,000**	VH	VH	VH	VH
Medium Persistent	**28,500,000**	VH	VH	VH	VH
Medium Persistent	**75,000,000**	VH	VH	VH	VH
Heavy Persistent	**1**	VL	VL	VL	VL
Heavy Persistent	**5**	VL	VL	VL	VL
Heavy Persistent	**10**	VL	VL	VL	VL
Heavy Persistent	**50**	VL	VL	VL	VL
Heavy Persistent	**100**	VL	VL	VL	VL
Heavy Persistent	**500**	L	VL	L	VL
Heavy Persistent	**1,000**	L	VL	L	L
Heavy Persistent	**2,000**	L	VL	L	L
Heavy Persistent	**5,000**	M	L	M	M
Heavy Persistent	**20,000**	M	M	M	M
Heavy Persistent	**42,000**	M	M	M	M
Heavy Persistent	**300,000**	H	M	H	H
Heavy Persistent	**605,000**	H	M	H	H
Heavy Persistent	**1,000,000**	VH	H	VH	VH
Heavy Persistent	**2,000,000**	VH	H	VH	VH
Heavy Persistent	**3,500,000**	VH	H	VH	VH

Table APPA-9: Oil Spill Impacts for Lower Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Non-Persistent	**1**	VL	VL	VL	VL
Non-Persistent	**10**	VL	VL	VL	VL
Non-Persistent	**50**	VL	VL	VL	VL
Non-Persistent	**100**	VL	VL	VL	VL
Non-Persistent	**200**	VL	VL	VL	VL
Non-Persistent	**500**	VL	VL	VL	VL
Non-Persistent	**2,000**	L	VL	L	VL
Non-Persistent	**300,000**	M	L	M	L
Non-Persistent	**1,520,000**	H	M	H	L
Non-Persistent	**1,900,000**	H	M	H	L

Table APPA-9: Oil Spill Impacts for Lower Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Low Persistent	**1**	VL	VL	VL	VL
Low Persistent	**10**	VL	VL	VL	VL
Low Persistent	**50**	VL	VL	VL	VL
Low Persistent	**100**	VL	VL	VL	VL
Low Persistent	**200**	VL	VL	VL	VL
Low Persistent	**500**	VL	VL	VL	VL
Low Persistent	**1,000**	L	VL	L	VL
Low Persistent	**2,000**	L	VL	L	VL
Low Persistent	**5,000**	L	VL	L	VL
Low Persistent	**20,000**	M	L	M	L
Low Persistent	**36,000**	M	L	M	L
Low Persistent	**150,000**	M	L	M	L
Low Persistent	**300,000**	M	L	M	L
Low Persistent	**605,000**	M	L	M	L
Low Persistent	**1,000,000**	H	M	H	L
Low Persistent	**1,520,000**	H	M	H	L
Low Persistent	**1,900,000**	H	M	H	L
Low Persistent	**2,000,000**	H	M	H	L
Low Persistent	**3,500,000**	H	M	H	L
Low Persistent	**4,000,000**	H	M	H	M
Low Persistent	**7,980,000**	H	M	H	M
Low Persistent	**21,000,000**	VH	H	VH	M
Medium Persistent	**1**	VL	VL	VL	VL
Medium Persistent	**10**	VL	VL	VL	VL
Medium Persistent	**100**	VL	VL	VL	VL
Medium Persistent	**500**	L	VL	L	VL
Medium Persistent	**2,000**	M	L	M	M
Medium Persistent	**20,000**	M	M	M	H
Medium Persistent	**8,000,000**	H	H	H	H
Medium Persistent	**15,000,000**	VH	VH	VH	VH
Medium Persistent	**28,500,000**	VH	VH	VH	VH
Medium Persistent	**75,000,000**	VH	VH	VH	VH
Heavy Persistent	**1**	VL	VL	VL	VL
Heavy Persistent	**5**	VL	VL	VL	VL
Heavy Persistent	**10**	VL	VL	VL	VL
Heavy Persistent	**50**	VL	VL	VL	VL
Heavy Persistent	**100**	VL	VL	VL	VL
Heavy Persistent	**500**	L	VL	L	VL
Heavy Persistent	**1,000**	L	VL	L	L
Heavy Persistent	**2,000**	L	VL	L	L
Heavy Persistent	**5,000**	M	L	M	M
Heavy Persistent	**20,000**	M	M	M	M
Heavy Persistent	**42,000**	M	M	M	M
Heavy Persistent	**300,000**	H	M	H	H
Heavy Persistent	**605,000**	H	M	H	H
Heavy Persistent	**1,000,000**	VH	H	VH	VH
Heavy Persistent	**2,000,000**	VH	H	VH	VH
Heavy Persistent	**3,500,000**	VH	H	VH	VH

Summary of Spill Impacts and Probabilities

Spill impacts and probabilities by vessel type, hull, incident cause, spill volume probability, and season are presented in Tables APPA-10 through APPA-12 for each of the three sub-areas of Cook Inlet.

Table APPA-10: Spill Impacts and Probabilities Summary – Upper Cook Inlet

Vessel Type/ Oil Type	Cause	Hull	P_S[13]	Degree of Impact by Season and Volume Probability[14]															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Product Tanker LP	Coll	SH	0.68	1	1	1	1	2	2	2	1	4	4	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Alli	SH	0.68	1	1	1	1	2	2	2	1	4	4	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Grou	SH	0.91	1	1	1	1	2	2	2	1	4	4	4	3	5	4	5	3
		DH	0.18	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Stru	SH	0.40	1	1	1	1	2	2	2	1	3	3	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	2	2	1	3	3	3	2	4	4	4	3
	Fire	SH	0.40	1	1	1	1	2	2	2	1	3	3	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	2	2	1	3	3	3	2	4	4	4	3
	Equi	SH	0.40	1	1	1	1	2	2	2	1	3	3	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	2	2	1	3	3	3	2	4	4	4	3
	Oper	SH	0.40	1	1	1	1	2	2	2	1	3	3	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	2	2	1	3	3	3	2	4	4	4	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	5	4	5	3
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	5	4	5	3
Crude Tanker MP	Coll	SH	0.81	2	2	2	1	3	3	3	3	5	5	5	5	5	5	5	5
		DH	0.19	2	2	2	1	3	3	3	3	5	5	5	5	5	5	5	5
	Alli	SH	0.81	2	2	2	1	3	3	3	3	5	5	5	5	5	5	5	5
		DH	0.19	2	2	2	1	3	3	3	3	5	5	5	5	5	5	5	5
	Grou	SH	0.93	2	2	2	1	3	3	3	3	5	5	5	5	5	5	5	5
		DH	0.20	2	2	2	1	3	3	3	3	5	5	5	5	5	5	5	5
	Stru	SH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
	Fire	SH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
	Equi	SH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
	Oper	SH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
	Tran	SH	0.92	1	1	1	1	1	1	1	1	3	3	3	2	5	5	5	5
		DH	0.92	1	1	1	1	1	1	1	1	3	3	3	2	5	5	5	5
Tank Barge NP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Alli	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Grou	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Fire	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Equi	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2

[13] Probability that incident will result in spill.

[14] Scores on 5-point environmental impact scores for impact based on spill volume for 25th percentile, 50th (median) percentile, 95th percentile, and WCD scenarios by vessel type, hull, and incident cause. Different scores are presented for each season as appropriate.

Table APPA-10: Spill Impacts and Probabilities Summary – Upper Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S[13]	Degree of Impact by Season and Volume Probability[14]															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Tank Barge NP	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Tran	SH	0.76	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	2
		DH	0.13	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	2
Tank Barge LP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.22	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Alli	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Grou	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Fire	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Equi	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.22	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Tran	SH	0.40	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	3
		DH	0.40	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	3
Non-Tank/Non-Workboat Vessel HP (SH) LP (DH)	Coll	SH	0.05	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
		DH	0.02	1	1	1	1	2	2	2	1	3	3	3	2	3	3	3	2
	Alli	SH	0.05	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
		DH	0.02	1	1	1	1	2	2	2	1	3	3	3	2	3	3	3	2
	Grou	SH	0.05	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	4	4	4	3	4	4	4	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	4	4	4	3	4	4	4	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	4	4	4	3	4	4	4	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	4	4	4	3	4	4	4	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	3
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	2
Gas Carrier HP (SH) LP (DH)	Coll	SH	0.05	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.02	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Alli	SH	0.05	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.02	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Grou	SH	0.05	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.02	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Stru	SH	0.20	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.20	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Fire	SH	0.20	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.20	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Equi	SH	0.20	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.20	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Oper	SH	0.20	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.20	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	5	4	5	4
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	3
OSV LP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2

Table APPA-10: Spill Impacts and Probabilities Summary – Upper Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S[13]	Degree of Impact by Season and Volume Probability[14]															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
OSV LP	Alli	DH	0.02	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	2
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	2
Tug/Tow HP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	3
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	3

Table APPA-11: Spill Impacts and Probabilities Summary – Middle Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Product Tanker LP Product Tanker LP	Coll	SH	0.68	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Alli	SH	0.68	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Grou	SH	0.91	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.18	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Stru	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Fire	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Equi	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Oper	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	5	4	5	3
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	5	4	5	3
Crude Tanker MP	Coll	SH	0.81	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.19	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Alli	SH	0.81	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.19	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Grou	SH	0.93	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5

Table APPA-11: Spill Impacts and Probabilities Summary – Middle Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Crude Tanker MP	Grou	DH	0.20	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Stru	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Fire	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Equi	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Oper	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Tran	SH	0.92	1	1	1	1	1	1	1	1	3	2	3	3	5	5	5	5
		DH	0.92	1	1	1	1	1	1	1	1	3	2	3	3	5	5	5	5
Tank Barge NP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Alli	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Grou	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Fire	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Equi	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Tran	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
Tank Barge LP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Alli	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Grou	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Fire	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Equi	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Tran	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
Non-Tank/Non-Workboat Vessel HP (SH) LP (DH)	Coll	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Alli	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Grou	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2

Table APPA-11: Spill Impacts and Probabilities Summary – Middle Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Non-Tank/Non-Workboat Vessel HP (SH) LP (DH)	Oper	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	4	3	4	4
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
Gas Carrier HP (SH) LP (DH)	Coll	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Alli	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Grou	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Stru	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Fire	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Equi	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Oper	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	5	4	5	5
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	4	3	4	2
OSV LP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
Tug/Tow HP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	3	3	3	3
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	3	3	3	3

Table APPA-12: Spill Impacts and Probabilities Summary – Lower Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Product Tanker LP	Coll	SH	0.68	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Alli	SH	0.68	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Grou	SH	0.91	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.18	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Stru	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Fire	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Equi	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Oper	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	5	4	5	3
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	5	4	5	3
Crude Tanker MP	Coll	SH	0.81	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.19	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Alli	SH	0.81	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.19	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Grou	SH	0.93	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.20	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Stru	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Fire	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Equi	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Oper	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Tran	SH	0.92	1	1	1	1	1	1	1	1	3	2	3	3	5	5	5	5
		DH	0.92	1	1	1	1	1	1	1	1	3	2	3	3	5	5	5	5
Tank Barge LP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Alli	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Grou	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Fire	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Equi	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Tran	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
Tank Barge NP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Alli	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Grou	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2

Table APPA-12: Spill Impacts and Probabilities Summary – Lower Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Tank Barge NP	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Fire	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Equi	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Tran	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
Non-Tank/Non-Workboat Vessel HP (SH) LP (DH)	Coll	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Alli	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Grou	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	4	3	4	4
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
Gas Carrier HP (SH) LP (DH)	Coll	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Alli	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Grou	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Stru	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Fire	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Equi	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Oper	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	5	4	5	5
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	4	3	4	2
OSV LP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Alli	DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2

Table APPA-12: Spill Impacts and Probabilities Summary – Lower Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
OSV LP	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
Tug/Tow HP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	3	3	3	3
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	3	3	3	3

Technical Appendix A: Development of Potential Oil Spill Scenarios

From the perspective of oil spill impacts, the following factors are important in developing the various oil spill scenarios:

- Spill volume;
- Characteristics of the oil based on type;
- Spill location with respect to sensitive resources and current/wind effects; and
- Season with respect to water temperature, presence/absence of ice, logistical response issues, wildlife life cycles and migratory patterns.

Potential Oil Spill Volumes

The potential oil spill volumes for vessel casualties depend on three factors:

- Vessel Type (oil as cargo or bunkers)
- Vessel Size (oil capacity)
- Accident Cause

Vessel Type and Oil Capacity

Based on the incident records of 1995 – 2011 and the vessel traffic study, the vessel capacities for vessels transiting Cook Inlet are as shown in Table A1.

Table A1: Oil Capacities (Gallons) for Vessels Transiting Cook Inlet

Vessel Type	Capacity Based on Analysis of Vessels Involved in Incidents During 1995 – 2011		Capacity Based on Data in 2007 Cook Inlet Vessel Traffic Study		Maximum Volume[15] Applied in Impact Analysis
	Mean	SD	Mean	SD	
Non-Tank/Non-Workboat Vessel	612,729	435,832	864,232	1,459,706	605,000
Crude Tanker	16,582,294	5,106,257	94,529,660	17,752,359	75,000,000
Gas Carrier	4,662,443	5,775,163	5,781,941	1,285,022	3,500,000
Offshore Supply Vessel	17,600	37,119	84,000	0	36,000
Passenger Vessel	139,188	101,925	108,558	1,164,830	84,000
Product Tanker	13,109,919	4,201,578	25,696,117[16]	9,307,883	21,000,000
Tank Barge	2,339,720	1,639,224	N/A	N/A	1,900,000
Tow/Tug	65,654	58,564	56,000	0	42,000

Note that the maximum volumes by vessel type used in the spill impact analysis are based on 80% full capacity for cargo tanks and 70% full for bunker tanks as per standard methodologies employed by naval architects and engineers in oil outflow studies[17] (Michel and Thomas 2000; Rawson et al. 1998).

Probability Distributions of Spill Volumes – Methodology

Given the maximum quantity of oil that would spill from a vessel in the event of a total release, the spill volumes that might be expected in different types of spills can be estimated for each vessel.

[15] Based on 80% full capacity for cargo tanks and 70% full for bunker tanks as per standard methodologies employed by naval architects and engineers in oil outflow studies (Michel and Thomas 2000; Rawson et al. 1998).
[16] Correction made for tanker Angelica Schulte from capacity of 146.7 million noted in 2007 Traffic Study to 30,868,000 gallons as per deadweight tonnage data.
[17] Michel and Thomas 2000; Rawson et al. 1998.

With each vessel transit or vessel operating day, there is a small probability that there will be an accident of some kind. In the event of a vessel accident or casualty, there is, in turn, a certain probability that the event will result in the spillage of oil either from the vessel's cargo tanks, if it is a tanker or tank barge, or from the vessel's bunker tanks if it is a non-tank vessel. Note that tank vessels also have bunkers and that all vessels carry a certain amount of other types of oils for lubrication and general operations. This study focuses on the larger amounts of oil present in cargo tanks and bunker fuel tanks as these represent the greatest potential spill volumes.

If there is a spill, the volume could be very small (i.e., only a gallon or less) or constitute the release of the entire oil contents of the vessel (i.e., a "worst-case discharge" or WCD). There is a probability associated with each potential spill volume. The series of probabilistic events leading from a vessel transit or day of operation to a spill is shown in Figure A1.

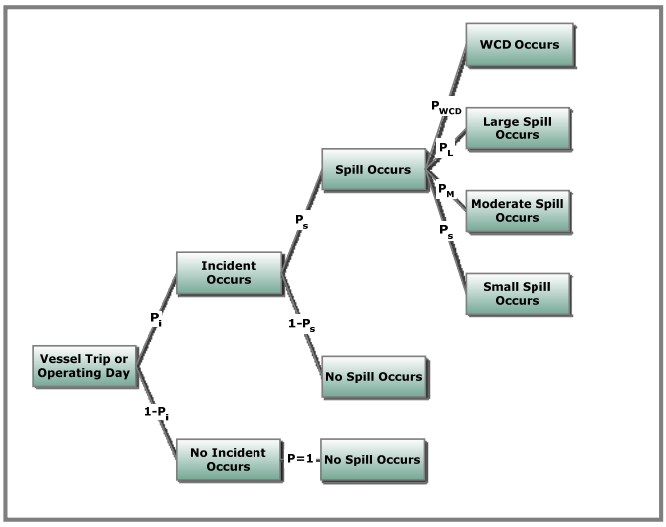

Figure A1: Event Tree for Spills from Vessels

Given that a spill *does* occur after an accident or casualty incident occurs, the spillage volume is dependent on the amount of oil on board and the percentage outflow from the tank(s) containing the oil. The former is determined by the vessel type and the latter is determined by both the vessel type and the accident cause. With 8 vessel types and 9 accident causes[18] for each vessel type, there are theoretically 72 vessel-type/cause combinations as in Table A2.

Table A2: Vessel-Accident Cause Combinations

Vessel Type	Cause								
	Allision	Bilge Discharge	Collision	Equipment Failure	Fire	Grounding	Operations Error	Structural Failure	Transfer Error
Non-Tank/Non-Workboat Vessel	CV_a	CV_b	CV_c	CV_e	CV_f	CV_g	CV_o	CV_s	CV_t
Crude Tanker	CT_a	CT_b	CT_c	CT_e	CT_f	CT_g	CT_o	CT_s	CT_t
Gas Carrier	GC_a	GC_b	GC_c	GC_e	GC_f	GC_g	GC_o	GC_s	GC_t

[18] "Other" and "unknown" were eliminated.

Table A2: Vessel-Accident Cause Combinations									
Vessel Type	**Cause**								
	Allision	**Bilge Discharge**	**Collision**	**Equipment Failure**	**Fire**	**Grounding**	**Operations Error**	**Structural Failure**	**Transfer Error**
Offshore Supply	OS_a	OS_b	OS_c	OS_e	OS_f	OS_g	OS_o	OS_s	OS_t
Passenger Vessel	PV_a	PV_b	PV_c	PV_e	PV_f	PV_g	PV_o	PV_s	PV_t
Product Tanker	PT_a	PT_b	PT_c	PT_e	PT_f	PT_g	PT_o	PT_s	PT_t
Tank Barge	TB_a	TB_b	TB_c	TB_e	TB_f	TB_g	TB_o	TB_s	TB_t
Tow/Tug Boat	TG_a	TG_b	TG_c	TG_e	TG_f	TG_g	TG_o	TG_s	TG_t

Within each of these Vessel Type-Cause combinations there is a probability distribution function (PDF) of spill volumes. A PDF is a graphed curve showing the cumulative probabilities of spill volumes from which percentile spills can be determined. In turn, a percentile spill is the spill volume associated with the nth probability. In other words, the volume for the nth percentile spill is that spill volume larger than n% of spills for that vessel type and cause. The nth percentile is smaller than 100 – n% of spills. For example, the "10th percentile spill" is defined as the spill volume larger than 10% of the spills but smaller than 90% of the spills. The 95th percentile spill is larger than 99% of the spills and only smaller than 1% of the spills. Only 1% of the spills is larger. A representative PDF is shown in Figure A2. The data are summarized in Table A3.

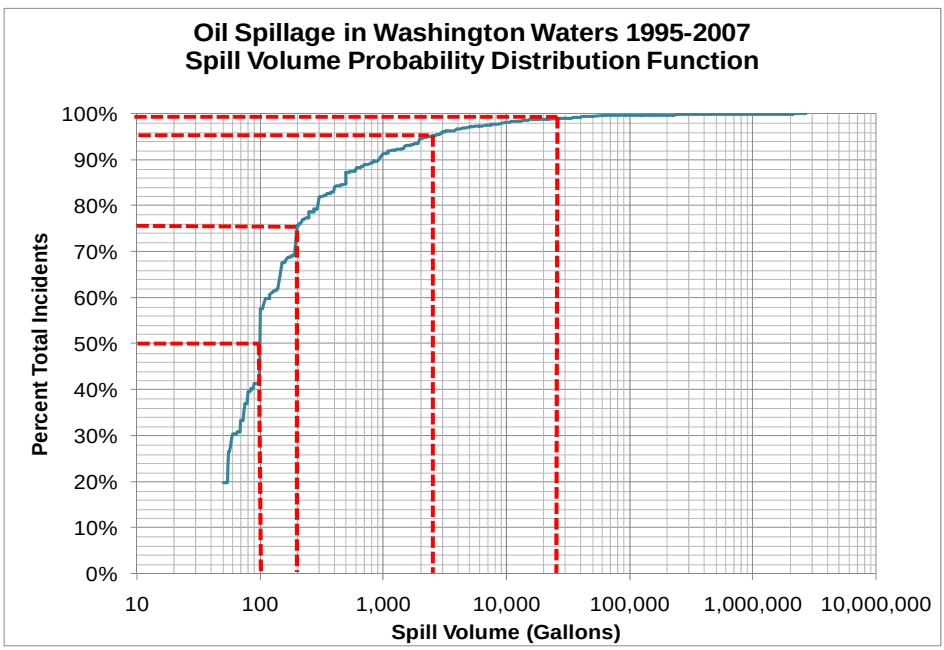

Figure A2: Representative Probability Distribution Function of Spill Volume Categories[19]

Table A3: Probability Distribution of Spill Volumes for Oil Spills in Washington Waters 1995 – 2007			
Percentile	**Volume**	**% Spills This Volume or Smaller**	**% Spills Larger**
25th percentile	55 gallons	25%	75%
50th percentile	100 gallons	50%	50%

[19] With 50 gallon minimum; Etkin et al. 2009.

Table A3: Probability Distribution of Spill Volumes for Oil Spills in Washington Waters 1995 – 2007			
Percentile	**Volume**	**% Spills This Volume or Smaller**	**% Spills Larger**
75th percentile	200 gallons	75%	23%
90th percentile	900 gallons	90%	10%
95th percentile	2,300 gallons	95%	5%
95th percentile	27,500 gallons	99%	1%
100th percentile (Largest Spill)	2,688,000 gallons	100%	0%

There are insufficient data in the small dataset of incidents that occurred between 1995 and 2011 in Cook Inlet to determine the distribution of percentage outflow for each vessel type and accident cause. For this reason, the results of outflow analyses conducted on much larger datasets were used to determine the PDFs for vessel spills in Cook Inlet.[20] The oil outflow analyses by vessel type and cause are shown in Tables A4 to A9, and Figures A3 to A8.

Table A4: Oil Cargo Outflow from Tanker Collisions, Allisions, and Groundings in US Waters[21]	
Percent Oil Outflow	**% Incidents (Probability of Outflow Loss This Magnitude)**
0.002% Oil Contents	36.1%
0.02% Oil Contents	11.1%
0.05% Oil Contents	13.9%
0.2% Oil Contents	11.1%
0.7% Oil Contents	5.6%
1.3% Oil Contents	11.1%
3.1% Oil Contents	8.3%
20% Oil Contents	2.8%

Table A5: Oil Cargo Outflow from Tanker Non-Impact Accidents[22]	
Percent Oil Outflow	**% Incidents (Probability of Outflow Loss This Magnitude)**
<0.01% Oil Contents	57.7%
0.02% Oil Contents	15.4%
0.06% Oil Contents	3.8%
0.16% Oil Contents	7.7%
0.54% Oil Contents	7.7%
11.5% Oil Contents	7.7%

Table A6: Oil Cargo Outflow from Tank Barge Collisions, Allisions, and Groundings in US Waters	
Percent Oil Outflow	**% Incidents (Probability of Outflow Loss This Magnitude)**
<0.001% Oil Contents	17.6%
0.01% Oil Contents	22.4%
0.03% Oil Contents	22.9%
0.20% Oil Contents	11.2%
0.5% Oil Contents	7.1%
1.0% Oil Contents	5.9%
3.0% Oil Contents	6.5%
7.5% Oil Contents	2.3%
15.0% Oil Contents	1.8%
23.0% Oil Contents	1.8%

[20] Etkin 2002; Etkin 2003.
[21] Assuming that a spill has occurred.
[22] Structural failure, fire, sinking. Assuming that a spill has occurred.

Table A7: Oil Cargo Outflow from Tank Barge Non-Impact Accidents	
Percent Oil Outflow	**% Incidents (Probability of Outflow Loss This Magnitude)**
<0.001% Oil Contents	45.1%
0.001% Oil Contents	9.0%
0.002% Oil Contents	6.8%
0.004% Oil Contents	9.8%
0.01% Oil Contents	7.5%
0.02% Oil Contents	9.4%
0.07% Oil Contents	2.6%
0.1% Oil Contents	3.4%
0.6% Oil Contents	3.0%
1.8% Oil Contents	1.9%
6.3% Oil Contents	0.4%
14.3% Oil Contents	0.4%
18.6% Oil Contents	0.4%
27.0% Oil Contents	0.4%

Table A8: Bunker Outflow from Non-Tank/Non-Workboat Vessel Collisions, Allisions, and Groundings in US Waters	
Percent Oil Outflow	**% Incidents (Probability of Outflow Loss This Magnitude)**
<0.001% Oil Contents	4.1%
0.01% Oil Contents	18.4%
0.03% Oil Contents	8.2%
0.15% Oil Contents	18.4%
1.6% Oil Contents	10.2%
4.3% Oil Contents	8.2%
10.0% Oil Contents	4.1%
16.0% Oil Contents	6.1%
33.3% Oil Contents	8.2%
59.0% Oil Contents	10.2%
100.0% Oil Contents	4.1%

Table A9: Bunker Outflow from Non-Tank/Non-Workboat Vessel Non-Impact Accidents[22]	
Percent Oil Outflow	**% Incidents (Probability of Outflow Loss This Magnitude)**
<0.001% Oil Contents	6.1%
0.001% Oil Contents	14.3%
0.003% Oil Contents	12.2%
0.008% Oil Contents	6.1%
0.015% Oil Contents	10.2%
0.06% Oil Contents	12.2%
0.1% Oil Contents	14.3%
0.8% Oil Contents	4.1%
3.0% Oil Contents	4.1%
12.0% Oil Contents	4.1%
36.0% Oil Contents	4.1%
40.0% Oil Contents	2.0%
71.0% Oil Contents	2.0%
91.0% Oil Contents	2.0%
100.0% Oil Contents	2.0%

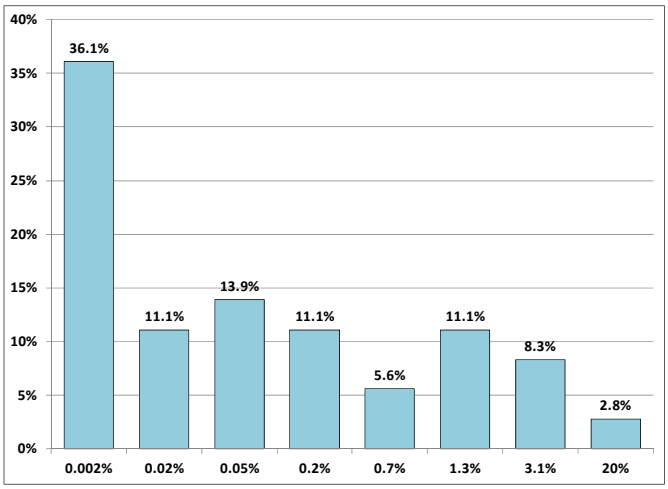

Figure A3: Percentage Oil Outflow from Tanker Groundings, Allisions, Groundings

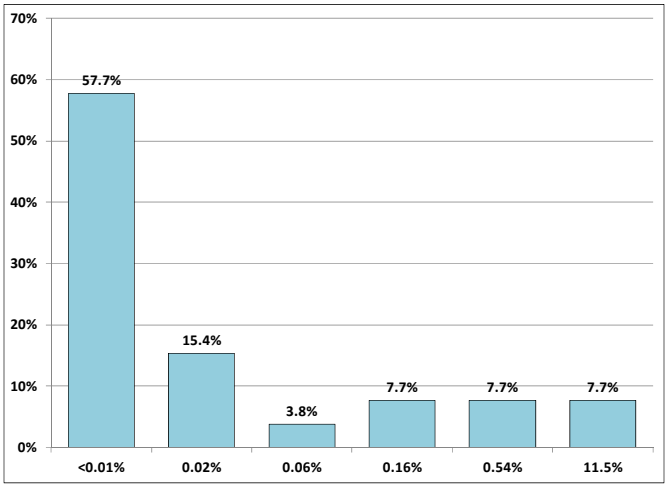

Figure A4: Percentage Oil Outflow from Tanker Non-Impact Accidents

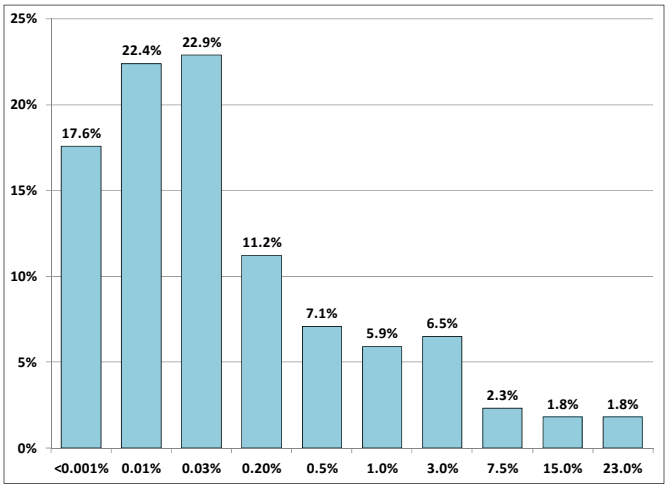

Figure A5: Percentage Oil Outflow from Tank Barge Groundings, Allisions, Groundings

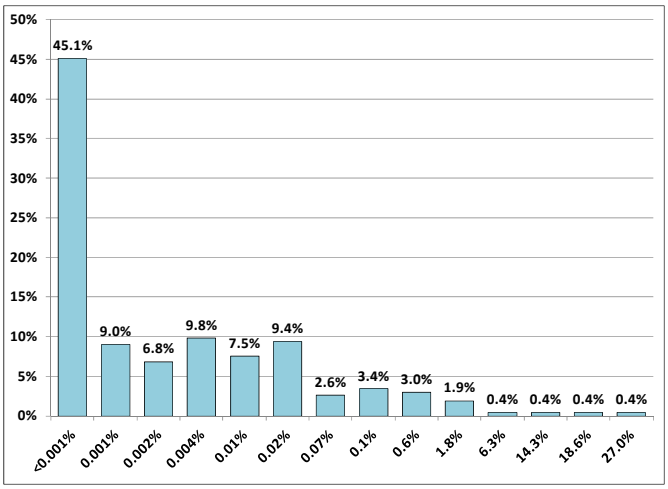

Figure A6: Percentage Oil Outflow from Tank Barge Non-Impact Accidents

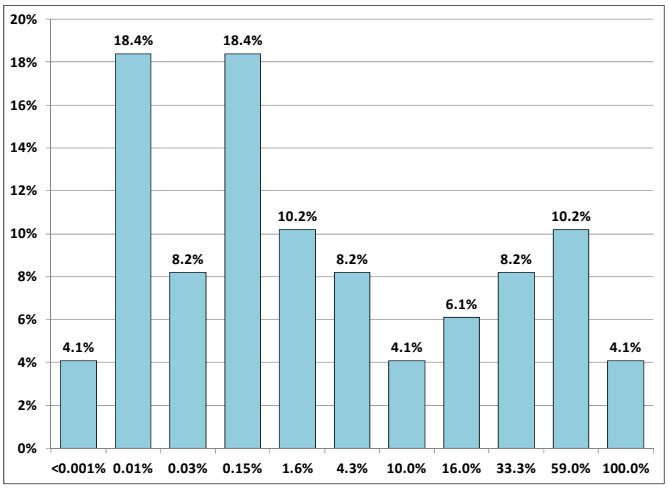

Figure A7: Percentage Oil Outflow from Non-Tank Vessel Allisions/Collisions/Groundings

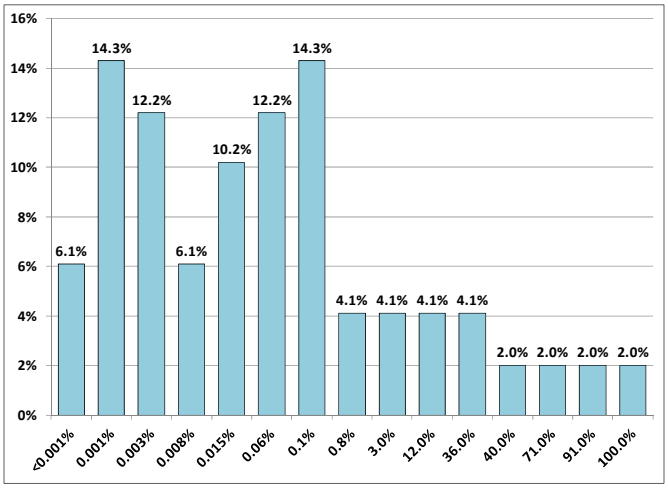

Figure A8: Percentage Oil Outflow from Non-Tank/Non-Workboat Vessel Non-Impact Accidents

A theoretical worst-case discharge (total loss of oil cargo) from a fully-loaded large tanker did not occur in US waters during 1985-2000, though a few such incidents (involving the sinking or hard drift groundings of fully-loaded tankers) have occurred in foreign waters and two incidents involving smaller tankers occurred in US waters prior to 1985 (Tables A10 and A11). It is theoretically possible for such a spill to occur in Cook Inlet, and other parts of the US, and should thus be considered for risk analysis and contingency planning purposes.

Table A10: Worst-Case Discharge Tanker Spills[23] In Non-US Waters (1985-2000)[24]

Tanker	Year	DWT	Est. Cargo[25] (gallons)	Amt. Spilled (gallons)	% Loss	Location
Athenian Venture	1988	31,016	10,602,000	10,602,000	100%	Canada
Odyssey	1988	140,616	43,100,000	43,100,000	100%	Canada
Thanassis A.	1994	38,263	10,900,000	10,900,000	100%	Hong Kong
Kinsei Maru	1985	2,990	840,000	840,000	100%	Japan
Katina P.	1992	69,992	19,609,800	19,609,800	100%	South Africa
Braer	1993	89,730	25,000,000	25,000,000	100%	UK
Cosmas A.	1994	27,643	7,081,000	7,081,000	100%	Hong Kong
Ife	2001	10,671	3,386,292	3,386,292	100%	Nigeria
Da Qing 243	1997	24,704	7,473,600	5,000,000	82%	China
Aegean Sea	1992	114,036	34,500,000	21,900,000	78%	Spain
Haven	1991	232,163	70,235,300	42,336,000	74%	Italy

Table A11: Worst-Case Discharge Tanker Spills[23] In/Near US Waters (1985-2000)[24]

Tanker	Year	DWT	Est. Cargo[25] (gallons)	Amt. Spilled (gallons)	% Loss	Location
Hawaiian Patriot	1977	101,038	31,185,000	31,185,000	100%	370 mi. off Hawaii
Pegasus	1968	30,000	9,597,000	9,597,000	100%	Off Maine
Mandoil II	1968	42,000	12,930,120	12,930,120	97%	Off Oregon
Gezina Brovig	1970	16,000	4,925,760	4,704,000	95%	Off Puerto Rico
Keo	1969	30,000	9,235,800	8,800,000	95%	120 mi. off Massachusetts
Spartan Lady	1975	20,724	6,380,091	6,000,000	94%	20 mi. off New York
Epic Colocotronis	1975	64,000	19,703,040	17,955,000	91%	62 mi. off Puerto Rico
Gulfstag	1966	20,000	6,157,200	5,586,000	91%	Off Texas
Texaco Oklahoma	1971	35,072	10,797,266	9,450,000	88%	Off Maine
Argo Merchant	1976	28,691	8,832,811	7,700,000	87%	25 mi. off Massachusetts

Worst-case discharges (WCDs) were added to oil spillage potentials for all vessel accidents in the Cook Inlet analyses, which estimates the amount of spillage based on percent outflow and the estimated oil content from Table A1 based on vessel type.

For tankers (tank ships), the worst-case discharge (WCD) for double-hulled tankers were corrected to take into account the reduced oil outflow that is predicted on the basis of analyses conducted for the International Maritime Organization (IMO), as shown in Table A12.[26] These analyses essentially showed that the presence of double hulls on the cargo tanks of tankers would reduce the probability that a collision, allision, or grounding involving a double-hulled tanker would result in a spill. At the same time,

[23] Not including military-related incidents, such as the intentional spillage from tankers in the Arabian Gulf during the 1991 Gulf War.
[24] DWT > 10,000 tons
[25] Cargo capacity estimated from deadweight tonnage (assumed 80% full).
[26] Herbert Engineering et al. 1999; Michel & Thomas 2000; Rawson et. al. 1999.

it was predicted the presence of double-hulled cargo tanks would reduce the total volume of spillage in the case of a worst-case discharge scenario by 50%. For example, if the very largest spill scenario for a single-hulled tanker would result in the spillage of 50 million gallons, the same incident involving a double-hulled tanker would, most likely, result in the spillage of only 25 million gallons. Other studies have estimated the reduction in volume spillage from double-hulled tankers as 70% for 240,000 DWT tankers and 40% for smaller (40,000 DWT) tankers.[27] The most recent, and most robust, analysis of spillage from double-hulled tankers (and tank barges) indicates that the volume of spillage from double-hulled tankers is reduced by 62%, and by 20% for double-hulled tank barges.[28]

The same studies examined the effects of double hulls on bunker tanks. While the presence of double-hulled bunker tanks would reduce the probability of an accident resulting in spillage, in the case of very large or worst-case discharge scenarios, the volume of oil spilled would not be reduced.

Table A12: Influence of Double Hulls on Future Spill Risks[29]

Vessel Tank Type	Influence of Double Hulls		
	Spill Probability Grounding/Collision/Allision	Small to Median Spill Volume Scenario	Largest Spill Volume Scenario
Tanker Cargo	Reduced[30]	No effect	Reduce volume by 50 – 70%
Vessel Bunker	Reduced by 52%[31]	No effect	No effect

A detailed study on the effects of double hulls on the reduction in the probability of spillage for groundings, allisions, and groundings in tankers and tank barges is summarized in Table A13.

Table A13: Double-Hull vs. Single-Hull Tank Vessel Spillage Probabilities[32]

Vessel Type	Side Impact		Bottom Impact		Side and Bottom Impact	
	SH	DH	SH	DH	SH	DH
Tanker 80,000-100,000 DWT	0.68	0.15	0.91	0.18	0.81	0.17
Tanker 135,000-160,000 DWT	0.65	0.19	0.92	0.18	0.79	0.18
Tanker 265,000-300,000 DWT	0.81	0.19	0.93	0.20	0.88	0.20
Tank Barge 5,500 DWT	0.76	0.13	0.76	0.22	0.76	0.19

The probabilities of spillage with an incident by vessel type, hull, and cause are shown in Table A14.

Table A14: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis

Vessel Type	Accident Cause	Hull[33]	Spill Probability Given Incident
Product Tanker	**Collision**	**Single**	0.6800
		Double	0.1500
	Allision	**Single**	0.6800
		Double	0.1500
	Grounding	**Single**	0.9100
		Double	0.1800

[27] National Research Council 1991.
[28] Yip et al. 2011.
[29] Based on Etkin 2002 with modifications for findings in Yip et al. 2011 and National Research Council 1991.
[30] See Table CC.
[31] Based on Michel and Winslow 1999.
[32] The probability that an accident will result in oil spillage of any volume. Based on National Research Council 1998.
[33] For tank vessels (tankers and tank barges), the hull refers to the cargo hull. For all other vessels the hull refers to the bunker tank hull.

Table A14: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis			
Vessel Type	**Accident Cause**	**Hull[33]**	**Spill Probability Given Incident**
Product Tanker	**Structural Failure**	**Single**	0.4000
		Double	0.4000
	Fire	**Single**	0.4000
		Double	0.4000
	Equipment Failure	**Single**	0.4000
		Double	0.4000
	Operations Error	**Single**	0.4000
		Double	0.4000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Crude Tanker	**Collision**	**Single**	0.8100
		Double	0.1900
	Allision	**Single**	0.8100
		Double	0.1900
	Grounding	**Single**	0.9300
		Double	0.2000
	Structural Failure	**Single**	0.4000
		Double	0.4000
	Fire	**Single**	0.4000
		Double	0.4000
	Equipment Failure	**Single**	0.4000
		Double	0.4000
	Operations Error	**Single**	0.4000
		Double	0.4000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Tank Barge	**Collision**	**Single**	0.7600
		Double	0.1300
	Allision	**Single**	0.7600
		Double	0.1300
	Grounding	**Single**	0.7600
		Double	0.2200
	Structural Failure	**Single**	0.4000
		Double	0.4000
	Fire	**Single**	0.4000
		Double	0.4000
	Equipment Failure	**Single**	0.4000
		Double	0.4000
	Operations Error	**Single**	0.4000
		Double	0.4000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Non-Tank/Non-Workboat Vessel	**Collision**	**Single**	0.0450
		Double	0.0190
	Allision	**Single**	0.0450
		Double	0.0190
	Grounding	**Single**	0.0450
		Double	0.0190
	Structural Failure	**Single**	0.2000
		Double	0.2000
	Fire	**Single**	0.2000

Table A14: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis			
Vessel Type	**Accident Cause**	**Hull[33]**	**Spill Probability Given Incident**
Non-Tank/Non-Workboat Vessel	**Fire**	**Double**	0.2000
	Equipment Failure	**Single**	0.2000
		Double	0.2000
	Operations Error	**Single**	0.2000
		Double	0.2000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Gas Carrier	**Collision**	**Single**	0.0450
		Double	0.0190
	Allision	**Single**	0.0450
		Double	0.0190
	Grounding	**Single**	0.0450
		Double	0.0190
	Structural Failure	**Single**	0.2000
		Double	0.2000
	Fire	**Single**	0.2000
		Double	0.2000
	Equipment Failure	**Single**	0.2000
		Double	0.2000
	Operations Error	**Single**	0.2000
		Double	0.2000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Offshore Supply Vessel (OSV)	**Collision**	**Single**	0.0450
		Double	0.0190
	Allision	**Single**	0.0450
		Double	0.0190
	Grounding	**Single**	0.0450
	Grounding	**Double**	0.0190
	Structural Failure	**Single**	0.2000
		Double	0.2000
	Fire	**Single**	0.2000
		Double	0.2000
	Equipment Failure	**Single**	0.2000
		Double	0.2000
	Operations Error	**Single**	0.2000
		Double	0.2000
	Transfer Error	**Single**	0.9231
		Double	0.9231
Tug/Tow Boat	**Collision**	**Single**	0.0450
		Double	0.0190
	Allision	**Single**	0.0450
		Double	0.0190
	Grounding	**Single**	0.0450
		Double	0.0190
	Structural Failure	**Single**	0.2000
		Double	0.2000
	Fire	**Single**	0.2000
		Double	0.2000
	Equipment Failure	**Single**	0.2000
		Double	0.2000

Table A14: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis			
Vessel Type	**Accident Cause**	**Hull[33]**	**Spill Probability Given Incident**
Tug/Tow Boat	**Operations Error**	**Single**	0.2000
		Double	0.2000
	Transfer Error	**Single**	0.9231
		Double	0.9231

For the Cook Inlet analysis, the following was applied to the potential spill volume for accidents:

- For double-hulled tankers, a spill reduction of 62% from worst-case discharges for allisions, collisions, and groundings;
- For double-hulled tank barges, a spill reduction of 20% from worst-case discharges for allisions, collisions, and groundings;
- The probability of a zero-outflow (no spill) outcome for tank vessels was determined by the data in Table A13, assuming that an allision or collision would have side impact, and a grounding would have bottom impact;
- The probability of a zero-outflow (no spill) outcome for vessels carrying oil only as bunkers is based on studies of bunker tank outflow used for IMO standards;[34] The probability of a worst-case discharge (WCD) is conservatively (i.e., over-estimated) estimated to be 0.0004 based on the number of worst-case discharges per spill incidents in international analyses;[35]
- For non-impact accidents (structural failures, fires, sinkings) and incidents with other causes (equipment failure, Operations Error, transfer error, other, bilge discharge), the probability of no spill (zero outflow) is assumed to be 0.6 based on a rough estimation from the Cook Inlet incident data;[36]
- For non-impact accidents for single- and double-hulled tank vessels, the reduction in spillage with double hulls would provide similar protection to prevent a full-release of oil cargo though there are no data to support this since no studies have been conducted;
- The likelihood of a WCD (full cargo) release for non-impact incidents, with the exception of transfer errors, is assumed to be 0.0001, i.e., less than for an impact-related incident based on anecdotal evidence from international analyses;[35]
- The probability of a spill occurring during an oil transfer operation (between vessels or between a vessel and a dockside facility is 0.0004 based on a study conducted in Washington state;[37]
- The probability of a spill given a transfer error is 0.923 based on the data for Cook Inlet incidents;[38] and
- The probability distribution of spill volumes for transfer-related spills is based on the data in Table A15.

[34] Michel and Winslow 1999.
[35] Etkin 2001 and other ERC international spill data.
[36] Overall average percentage of incidents that result in spills for Cook Inlet incidents is 40%.
[37] Etkin 2006.
[38] The probability of a transfer error resulting in a spill is this high based on the fact that in most cases the error is only recognized with the event of spillage, often in the amount of 1 – 10 gallons or so.

Table A15: Spill Volumes for Transfer-Related Incidents[39]	
Spill Volume	**Percent Incidents with Spillage This Magnitude**
1 gallon	25.0%
5 gallons	15.0%
10 gallons	10.0%
20 gallons	10.0%
50 gallons	20.0%
200 gallons	10.0%
500 gallons	5.0%
2,000 gallons	4.0%
10,000 gallons	0.9%
100,000 gallons	0.09%
WCD	0.01%

Probability Distributions of Spill Volumes – Results

Projected spillage for Cook Inlet by vessel type (and hull type) and accident type are shown in Tables A16 to A52. These values are to be applied to the spill scenario impact analyses. ***Since double-hulls on tank vessels are mandated by the Oil Pollution Act of 1990 (OPA 90) by 2015, for scenarios in 2015 or later, the data for double-hulled tank vessels should be applied in the risk analysis.***

The probabilities in Tables A16 through A52 are for outflows given a vessel accident. In many cases, there will be no oil outflow (i.e., a 0% or 0-gallon spill). The probability of this occurrence is in the first row of each table for the vessel type (and hull) and accident type. The remaining probability (i.e., 1 – probability of zero outflow) is distributed across the various spill volumes. The probabilities shown for the 50th and 95th percentile spills are the probability that *given a spill* the spill will be in that size range.

Table A16: Projected Spills from Cook Inlet SH Product Tanker Collisions and Allisions			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence[40]**
0% (No Spill)	0	0.3200	-
0.002% Contents Spilled	420	0.2445	0.3596
0.02% Contents Spilled	4,200	0.0752	0.1106
0.05% Contents Spilled	10,500	0.0941	0.1384
0.2% Contents Spilled	42,000	0.0752	0.1106
0.7% Contents Spilled	147,000	0.0379	0.0557
1.3% Contents Spilled	273,000	0.0752	0.1106
3.1% Contents Spilled	651,000	0.0562	0.0826
20% Contents Spilled	4,200,000	0.0190	0.0279
WCD Single-Hull	21,000,000	0.0027	0.0040
50th Percentile Spill[41]	**5,000**	**-**	**0.1100**
95th Percentile Spill	**4,000,000**	**-**	**0.0300**

[39] Based on analyses of US spills for 1995 – 2004. Spill volumes reported as actual volumes rather than as percentage outflows.

[40] The probabilities shown are the probability that given a spill occurrence, the spill will be in that size range.

[41] A percentile spill is the spill volume associated with the nth probability. In other words, the volume for the nth percentile spill is that spill volume larger than n% of spills for that vessel type and cause. The nth percentile is smaller than 100 – n% of spills. For example, the "10th percentile spill" is defined as the spill volume larger than 10% of the spills but smaller than 90% of the spills. The 95th percentile spill is larger than 95% of the spills and only smaller than 5% of the spills. Only 1% of the spills is larger. Note that the zero-outflow scenario (0% spillage) is not included as part of the probability distribution function analysis.

Table A17: Projected Spills from Cook Inlet SH Product Tanker Groundings			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0900	-
0.002% Contents Spilled	420	0.3272	0.3596
0.02% Contents Spilled	4,200	0.1006	0.1105
0.05% Contents Spilled	10,500	0.1260	0.1385
0.2% Contents Spilled	42,000	0.1006	0.1105
0.7% Contents Spilled	147,000	0.0508	0.0558
1.3% Contents Spilled	273,000	0.1006	0.1105
3.1% Contents Spilled	651,000	0.0752	0.0826
20% Contents Spilled	4,200,000	0.0254	0.0279
WCD Single-Hull	21,000,000	0.0036	0.0040
50th Percentile Spill[42]	**5,000**	**-**	**0.1100**
95th Percentile Spill	**4,000,000**	**-**	**0.0300**

Table A18: Projected Spills from Cook Inlet SH Product Tanker Non-Impact Accidents[43]			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.6000	-
0.01% Contents Spilled	2,100	0.2263	-
0.02% Contents Spilled	4,200	0.0604	0.5769
0.06% Contents Spilled	12,600	0.0149	0.1540
0.16% Contents Spilled	33,600	0.0302	0.0380
0.54% Contents Spilled	113,400	0.0302	0.0770
11.5% Contents Spilled	2,415,000	0.0302	0.0770
WCD Single-Hull	21,000,000	0.0001	0.0770
50th Percentile Spill	**1,000**	**-**	**0.5000**
95th Percentile Spill	**150,000**	**-**	**0.0800**

Table A19: Projected Spills from Cook Inlet DH Product Tanker Collisions and Allisions			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.8500	-
0.002% Contents Spilled	420	0.0539	0.3593
0.02% Contents Spilled	4,200	0.0166	0.1107
0.05% Contents Spilled	10,500	0.0208	0.1387
0.2% Contents Spilled	42,000	0.0166	0.1107
0.7% Contents Spilled	147,000	0.0084	0.0560
1.3% Contents Spilled	273,000	0.0166	0.1107
3.1% Contents Spilled	651,000	0.0124	0.0827
20% Contents Spilled	4,200,000	0.0042	0.0280
WCD Double-Hull	7,980,000	0.0006	0.0040
50th Percentile Spill	**5,000**	**-**	**0.1100**
95th Percentile Spill	**4,000,000**	**-**	**0.0300**

[42] A percentile spill is the spill volume associated with the nth probability. In other words, the volume for the nth percentile spill is that spill volume larger than n% of spills for that vessel type and cause. The nth percentile is smaller than 100 – n% of spills. For example, the "10th percentile spill" is defined as the spill volume larger than 10% of the spills but smaller than 90% of the spills. The 95th percentile spill is larger than 95% of the spills and only smaller than 5% of the spills. Only 1% of the spills is larger. Note that the zero-outflow scenario (0% spillage) is not included as part of the probability distribution function analysis.

[43] Includes structural failure, fire, sinking, equipment failure, and Operations Error, but not transfer errors.

Table A20: Projected Spills from Cook Inlet DH Product Tanker Groundings			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.7200	-
0.002% Contents Spilled	420	0.1006	0.3593
0.02% Contents Spilled	4,200	0.0310	0.1107
0.05% Contents Spilled	10,500	0.0387	0.1382
0.2% Contents Spilled	42,000	0.0310	0.1107
0.7% Contents Spilled	147,000	0.0156	0.0557
1.3% Contents Spilled	273,000	0.0310	0.1107
3.1% Contents Spilled	651,000	0.0232	0.0829
20% Contents Spilled	4,200,000	0.0078	0.0279
WCD Double-Hull	7,980,000	0.0011	0.0039
50th Percentile Spill	**5,000**	**-**	**0.1100**
95th Percentile Spill	**4,000,000**	**-**	**0.0300**

Table A21: Projected Spills from Cook Inlet DH Product Tanker Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.6000	-
0.01% Contents Spilled	2,100	0.2263	0.5769
0.02% Contents Spilled	4,200	0.0604	0.1540
0.06% Contents Spilled	12,600	0.0149	0.0380
0.16% Contents Spilled	33,600	0.0302	0.0770
0.54% Contents Spilled	113,400	0.0302	0.0770
11.5% Contents Spilled	2,415,000	0.0302	0.0770
WCD Double Hull	7,980,000	0.0001	0.0003
50th Percentile Spill	**1,000**	**-**	**0.6000**
95th Percentile Spill	**150,000**	**-**	**0.0300**

Table A22: Projected Spills from Cook Inlet SH/DH[44] Product Tanker Transfer Errors			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0769	-
0.000005% Contents Spilled	1	0.2308	0.2500
0.00002% Contents Spilled	5	0.1385	0.1500
0.00005% Contents Spilled	10	0.0923	0.1000
0.0001% Contents Spilled	20	0.0923	0.1000
0.0002% Contents Spilled	50	0.1846	0.2000
0.001% Contents Spilled	200	0.0923	0.1000
0.002% Contents Spilled	500	0.0462	0.0500
0.01% Contents Spilled	2,000	0.0369	0.0400
0.05% Contents Spilled	10,000	0.0083	0.0090
0.5% Contents Spilled	100,000	0.0008	0.0009
WCD Double/Single Hull	21,000,000	0.0001	0.0001
50th Percentile Spill	**10**	**-**	**0.1000**
95th Percentile Spill	**2,000**	**-**	**0.0400**

[44] It is assumed that the probability of a worst-case discharge and the volume of a WCD during transfer operations from a single and double-hulled tanker would be the same since the leakage would likely come from the hoses or other transfer operations equipment.

Table A23: Projected Spills from Cook Inlet SH Crude Tanker Collisions and Allisions			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.1900	-
0.002% Contents Spilled	1,500	0.2912	0.3595
0.02% Contents Spilled	15,000	0.0896	0.1106
0.05% Contents Spilled	37,500	0.1121	0.1384
0.2% Contents Spilled	150,000	0.0896	0.1106
0.7% Contents Spilled	525,000	0.0452	0.0558
1.3% Contents Spilled	975,000	0.0896	0.1106
3.1% Contents Spilled	2,325,000	0.0670	0.0827
20% Contents Spilled	15,000,000	0.0226	0.0279
WCD Single-Hull	75,000,000	0.0032	0.0040
50th Percentile Spill	**20,000**	**-**	**0.1100**
95th Percentile Spill	**15,000,000**	**-**	**0.0300**

Table A24: Projected Spills from Cook Inlet SH Crude Tanker Groundings			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0700	-
0.002% Contents Spilled	1,500	0.3344	0.3596
0.02% Contents Spilled	15,000	0.1028	0.1105
0.05% Contents Spilled	37,500	0.1288	0.1385
0.2% Contents Spilled	150,000	0.1028	0.1105
0.7% Contents Spilled	525,000	0.0519	0.0558
1.3% Contents Spilled	975,000	0.1028	0.1105
3.1% Contents Spilled	2,325,000	0.0769	0.0827
20% Contents Spilled	15,000,000	0.0259	0.0278
WCD Single-Hull	75,000,000	0.0037	0.0040
50th Percentile Spill	**20,000**	**-**	**0.1100**
95th Percentile Spill	**15,000,000**	**-**	**0.0300**

Table A25: Projected Spills from Cook Inlet SH Crude Tanker Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.6000	-
0.01% Contents Spilled	7,500	0.2263	0.5769
0.02% Contents Spilled	15,000	0.0604	0.1540
0.06% Contents Spilled	45,000	0.0149	0.0380
0.16% Contents Spilled	120,000	0.0302	0.0770
0.54% Contents Spilled	405,000	0.0302	0.0770
11.5% Contents Spilled	8,625,000	0.0302	0.0770
WCD Single Hull	75,000,000	0.0001	0.0003
50th Percentile Spill	**2,000**	**-**	**0.5800**
95th Percentile Spill	**8,000,000**	**-**	**0.0800**

Table A26: Projected Spills from Cook Inlet DH Crude Tanker Collisions and Allisions			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.8100	-
0.002% Contents Spilled	1,500	0.0683	0.3595
0.02% Contents Spilled	15,000	0.0210	0.1105
0.05% Contents Spilled	37,500	0.0263	0.1384

Table A26: Projected Spills from Cook Inlet DH Crude Tanker Collisions and Allisions			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0.2% Contents Spilled	150,000	0.0210	0.1105
0.7% Contents Spilled	525,000	0.0106	0.0558
1.3% Contents Spilled	975,000	0.0210	0.1105
3.1% Contents Spilled	2,325,000	0.0157	0.0826
20% Contents Spilled	15,000,000	0.0053	0.0279
WCD Double-Hull	28,500,000	0.0008	0.0042
50th Percentile Spill	**20,000**	**-**	**0.1100**
95th Percentile Spill	**15,000,000**	**-**	**0.0300**

Table A27: Projected Spills from Cook Inlet DH Crude Tanker Groundings			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.8000	-
0.002% Contents Spilled	1,500	0.0719	0.3595
0.02% Contents Spilled	15,000	0.0221	0.1105
0.05% Contents Spilled	37,500	0.0277	0.1385
0.2% Contents Spilled	150,000	0.0221	0.1105
0.7% Contents Spilled	525,000	0.0112	0.0560
1.3% Contents Spilled	975,000	0.0221	0.1105
3.1% Contents Spilled	2,325,000	0.0165	0.0825
20% Contents Spilled	15,000,000	0.0056	0.0280
WCD Double-Hull	28,500,000	0.0008	0.0040
50th Percentile Spill	**20,000**	**-**	**0.1100**
95th Percentile Spill	**15,000,000**	**-**	**0.0300**

Table A28: Projected Spills from Cook Inlet DH Crude Tanker Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.6000	-
0.01% Contents Spilled	7,500	0.2263	0.5769
0.02% Contents Spilled	15,000	0.0604	0.1540
0.06% Contents Spilled	45,000	0.0149	0.0380
0.16% Contents Spilled	120,000	0.0302	0.0770
0.54% Contents Spilled	405,000	0.0302	0.0770
11.5% Contents Spilled	8,625,000	0.0302	0.0770
WCD Double Hull	28,500,000	0.0001	0.0003
50th Percentile Spill	**2,000**	**-**	**0.5800**
95th Percentile Spill	**8,000,000**	**-**	**0.0800**

Table A29: Projected Spills from Cook Inlet SH/DH Crude Tanker Transfer Errors			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0769	-
0.000001% Contents Spilled	1	0.2308	0.2500
0.000007% Contents Spilled	5	0.1385	0.1500
0.000013% Contents Spilled	10	0.0923	0.1000
0.000027% Contents Spilled	20	0.0923	0.1000
0.000067% Contents Spilled	50	0.1846	0.2000
0.00027% Contents Spilled	200	0.0923	0.1000
0.00067% Contents Spilled	500	0.0462	0.0500

Table A29: Projected Spills from Cook Inlet SH/DH Crude Tanker Transfer Errors			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0.0027% Contents Spilled	2,000	0.0369	0.0400
0.013% Contents Spilled	10,000	0.0083	0.0090
0.13% Contents Spilled	100,000	0.0008	0.0009
WCD Double/Single Hull	75,000,000	0.0001	0.0001
50th Percentile Spill	**10**	**-**	**0.1000**
95th Percentile Spill	**2,000**	**-**	**0.0400**

Table A30: Projected Spills from Cook Inlet SH Tank Barge Collisions and Allisions			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.2400	-
0.001% Contents Spilled	19	0.1338	0.1761
0.01% Contents Spilled	190	0.1702	0.2239
0.03% Contents Spilled	570	0.1740	0.2289
0.20% Contents Spilled	3,800	0.0851	0.1120
0.5% Contents Spilled	9,500	0.0540	0.0711
1.0% Contents Spilled	19,000	0.0448	0.0589
3.0% Contents Spilled	57,000	0.0494	0.0650
7.5% Contents Spilled	142,500	0.0175	0.0230
15.0% Contents Spilled	285,000	0.0137	0.0180
23.0% Contents Spilled	437,000	0.0137	0.0180
WCD Single Hull	1,900,000	0.0030	0.0039
50th Percentile Spill	**500**	**-**	**0.2200**
95th Percentile Spill	**300,000**	**-**	**0.0180**

Table A31: Projected Spills from Cook Inlet SH Tank Barge Groundings			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.2300	-
0.001% Contents Spilled	19	0.1355	0.1760
0.01% Contents Spilled	190	0.1725	0.2240
0.03% Contents Spilled	570	0.1763	0.2290
0.20% Contents Spilled	3,800	0.0862	0.1119
0.5% Contents Spilled	9,500	0.0547	0.0710
1.0% Contents Spilled	19,000	0.0454	0.0590
3.0% Contents Spilled	57,000	0.0501	0.0651
7.5% Contents Spilled	142,500	0.0177	0.0230
15.0% Contents Spilled	285,000	0.0139	0.0181
23.0% Contents Spilled	437,000	0.0139	0.0181
WCD Single Hull	1,900,000	0.0031	0.0040
50th Percentile Spill	**500**	**-**	**0.2300**
95th Percentile Spill	**300,000**	**-**	**0.0180**

Table A32: Projected Spills from Cook Inlet SH Tank Barge Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.4000	-
0.001% Contents Spilled	19	0.1057	0.1762
0.01% Contents Spilled	190	0.1345	0.2242
0.03% Contents Spilled	570	0.1375	0.2292

Table A32: Projected Spills from Cook Inlet SH Tank Barge Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0.20% Contents Spilled	3,800	0.0673	0.1122
0.5% Contents Spilled	9,500	0.0427	0.0712
1.0% Contents Spilled	19,000	0.0354	0.0590
3.0% Contents Spilled	57,000	0.0390	0.0650
7.5% Contents Spilled	142,500	0.0138	0.0230
15.0% Contents Spilled	285,000	0.0108	0.0180
23.0% Contents Spilled	437,000	0.0108	0.0180
WCD Single Hull	1,900,000	0.0024	0.0040
50th Percentile Spill	**200**	**-**	**0.2200**
95th Percentile Spill	**300,000**	**-**	**0.0280**

Table A33: Projected Spills from Cook Inlet DH Tank Barge Collisions and Allisions			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.8700	-
0.001% Contents Spilled	19	0.0229	0.1762
0.01% Contents Spilled	190	0.0291	0.2238
0.03% Contents Spilled	570	0.0298	0.2292
0.20% Contents Spilled	3,800	0.0146	0.1123
0.5% Contents Spilled	9,500	0.0092	0.0708
1.0% Contents Spilled	19,000	0.0077	0.0592
3.0% Contents Spilled	57,000	0.0085	0.0654
7.5% Contents Spilled	142,500	0.0030	0.0231
15.0% Contents Spilled	285,000	0.0023	0.0177
23.0% Contents Spilled	437,000	0.0023	0.0177
WCD Double Hull	1,520,000	0.0005	0.0038
50th Percentile Spill	**500**	**-**	**0.2300**
95th Percentile Spill	**300,000**	**-**	**0.0180**

Table A34: Projected Spills from Cook Inlet DH Tank Barge Groundings			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.7800	-
0.001% Contents Spilled	19	0.0387	0.1759
0.01% Contents Spilled	190	0.0493	0.2241
0.03% Contents Spilled	570	0.0504	0.2291
0.20% Contents Spilled	3,800	0.0246	0.1118
0.5% Contents Spilled	9,500	0.0156	0.0709
1.0% Contents Spilled	19,000	0.0130	0.0591
3.0% Contents Spilled	57,000	0.0143	0.0650
7.5% Contents Spilled	142,500	0.0051	0.0232
15.0% Contents Spilled	285,000	0.0040	0.0182
23.0% Contents Spilled	437,000	0.0040	0.0182
WCD Double Hull	1,520,000	0.0009	0.0041
50th Percentile Spill	**500**	**-**	**0.2300**
95th Percentile Spill	**300,000**	**-**	**0.0180**

Table A35: Projected Spills from Cook Inlet DH Tank Barge Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.4000	-
0.001% Contents Spilled	19	0.1057	0.1762
0.01% Contents Spilled	190	0.1345	0.2242
0.03% Contents Spilled	570	0.1375	0.2292
0.20% Contents Spilled	3,800	0.0673	0.1122
0.5% Contents Spilled	9,500	0.0427	0.0712
1.0% Contents Spilled	19,000	0.0354	0.0590
3.0% Contents Spilled	57,000	0.0390	0.0650
7.5% Contents Spilled	142,500	0.0138	0.0230
15.0% Contents Spilled	285,000	0.0108	0.0180
23.0% Contents Spilled	437,000	0.0108	0.0180
WCD Double Hull	1,520,000	0.0024	0.0040
50th Percentile Spill	**200**	**-**	**0.2200**
95th Percentile Spill	**300,000**	**-**	**0.0180**

Table A36: Projected Spills from Cook Inlet SH/DH Tank Barge Transfer Errors			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0769	-
0.0001% Contents Spilled	1	0.2308	0.2500
0.0003% Contents Spilled	5	0.1385	0.1500
0.0005% Contents Spilled	10	0.0923	0.1000
0.0011% Contents Spilled	20	0.0923	0.1000
0.0026% Contents Spilled	50	0.1846	0.2000
0.0105% Contents Spilled	200	0.0923	0.1000
0.0263% Contents Spilled	500	0.0462	0.0500
0.1053% Contents Spilled	2,000	0.0369	0.0400
0.5263% Contents Spilled	10,000	0.0083	0.0090
5.2632% Contents Spilled	100,000	0.0008	0.0009
WCD Double/Single Hull	1,900,000	0.0001	0.0001
50th Percentile Spill	**10**	**-**	**0.1000**
95th Percentile Spill	**2,000**	**-**	**0.0400**

Table A37: Projected Spills from Cook Inlet Non-Tank/Non-Workboat Vessel (SH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.9550	-
0.001% Contents Spilled	6	0.0018	0.0406
0.01% Contents Spilled	61	0.0082	0.1851
0.03% Contents Spilled	182	0.0036	0.0813
0.15% Contents Spilled	908	0.0082	0.1851
1.6% Contents Spilled	9,680	0.0045	0.1016
4.3% Contents Spilled	26,015	0.0036	0.0813
10.0% Contents Spilled	60,500	0.0018	0.0406
16.0% Contents Spilled	96,800	0.0027	0.0609
33.3% Contents Spilled	201,465	0.0036	0.0813
59.0% Contents Spilled	356,950	0.0045	0.1016
WCD Single Hull	605,000	0.0018	0.0406

Table A37: Projected Spills from Cook Inlet Non-Tank/Non-Workboat Vessel (SH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
50th Percentile Spill	**1,000**	**-**	**0.1900**
95th Percentile Spill	**300,000**	**-**	**0.1000**

Table A38: Projected Spills from Cook Inlet Non-Tank/Non-Workboat Vessel (DH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.9810	-
0.001% Contents Spilled	6	0.0008	0.0417
0.01% Contents Spilled	61	0.0035	0.1823
0.03% Contents Spilled	182	0.0016	0.0833
0.15% Contents Spilled	908	0.0035	0.1823
1.6% Contents Spilled	9,680	0.0019	0.0990
4.3% Contents Spilled	26,015	0.0016	0.0833
10.0% Contents Spilled	60,500	0.0008	0.0417
16.0% Contents Spilled	96,800	0.0012	0.0625
33.3% Contents Spilled	201,465	0.0016	0.0833
59.0% Contents Spilled	356,950	0.0019	0.0990
WCD Double Hull	605,000	0.0008	0.0417
50th Percentile Spill	**1,000**	**-**	**0.1800**
95th Percentile Spill	**300,000**	**-**	**0.1000**

Table A39: Projected Spills from Cook Inlet Non-Tank/Non-Workboat Vessel (SH/DH Bunker) Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.8000	-
<0.001% Contents Spilled	1	0.0120	0.0606
0.001% Contents Spilled	6	0.0290	0.1465
0.003% Contents Spilled	18	0.0240	0.1212
0.008% Contents Spilled	48	0.0120	0.0606
0.015% Contents Spilled	91	0.0200	0.1010
0.06% Contents Spilled	363	0.0240	0.1212
0.10% Contents Spilled	605	0.0290	0.1465
0.80% Contents Spilled	4,840	0.0080	0.0404
3.0% Contents Spilled	18,150	0.0080	0.0404
12.0% Contents Spilled	72,600	0.0080	0.0404
36.0% Contents Spilled	217,800	0.0080	0.0404
40.0% Contents Spilled	242,000	0.0040	0.0202
71.0% Contents Spilled	429,550	0.0040	0.0202
91.0% Contents Spilled	550,550	0.0040	0.0202
WCD Single/Double Hull	605,000	0.0040	0.0202
50th Percentile Spill	**100**	**-**	**0.1000**
95th Percentile Spill	**300,000**	**-**	**0.0200**

Table A40: Projected Spills from Cook Inlet Non-Tank/Non-Workboat Vessel (SH/DH Bunker) Transfer Errors			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0769	-
0.0002% Contents Spilled	1	0.2308	0.2500
0.0008% Contents Spilled	5	0.1385	0.1500
0.002% Contents Spilled	10	0.0923	0.1000
0.003% Contents Spilled	20	0.0923	0.1000
0.008% Contents Spilled	50	0.1846	0.2000
0.033% Contents Spilled	200	0.0923	0.1000
0.083% Contents Spilled	500	0.0462	0.0500
0.33% Contents Spilled	2,000	0.0369	0.0400
1.65% Contents Spilled	10,000	0.0083	0.0090
16.5% Contents Spilled	100,000	0.0008	0.0009
WCD Double/Single Hull	605,000	0.0001	0.0001
50th Percentile Spill	**10**	**-**	**0.1000**
95th Percentile Spill	**2,000**	**-**	**0.0400**

Table A41: Projected Spills from Cook Inlet Gas Carrier (SH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.9550	-
0.001% Contents Spilled	35	0.0018	0.0406
0.01% Contents Spilled	350	0.0082	0.1851
0.03% Contents Spilled	1,050	0.0036	0.0813
0.15% Contents Spilled	5,250	0.0082	0.1851
1.6% Contents Spilled	56,000	0.0045	0.1016
4.3% Contents Spilled	150,500	0.0036	0.0813
10.0% Contents Spilled	350,000	0.0018	0.0406
16.0% Contents Spilled	560,000	0.0027	0.0609
33.3% Contents Spilled	1,165,500	0.0036	0.0813
59.0% Contents Spilled	2,065,000	0.0045	0.1016
WCD Single Hull	3,500,000	0.0018	0.0406
50th Percentile Spill	**5,000**	**-**	**0.1900**
95th Percentile Spill	**2,000,000**	**-**	**0.1000**

Table A42: Projected Spills from Cook Inlet Gas Carrier (DH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.9810	-
0.001% Contents Spilled	35	0.0008	0.0417
0.01% Contents Spilled	350	0.0035	0.1823
0.03% Contents Spilled	1,050	0.0016	0.0833
0.15% Contents Spilled	5,250	0.0035	0.1823
1.6% Contents Spilled	56,000	0.0019	0.0990
4.3% Contents Spilled	150,500	0.0016	0.0833
10.0% Contents Spilled	350,000	0.0008	0.0417
16.0% Contents Spilled	560,000	0.0012	0.0625
33.3% Contents Spilled	1,165,500	0.0016	0.0833
59.0% Contents Spilled	2,065,000	0.0019	0.0990
WCD Double Hull	3,500,000	0.0008	0.0417

Table A42: Projected Spills from Cook Inlet Gas Carrier (DH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
50th Percentile Spill	**5,000**	**-**	**0.1800**
95th Percentile Spill	**2,000,000**	**-**	**0.1000**

Table A43: Projected Spills from Cook Inlet Gas Carrier (SH/DH Bunker) Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.8000	-
<0.001% Contents Spilled	1	0.0120	0.0606
0.001% Contents Spilled	35	0.0290	0.1465
0.003% Contents Spilled	105	0.0240	0.1212
0.008% Contents Spilled	280	0.0120	0.0606
0.015% Contents Spilled	525	0.0200	0.1010
0.06% Contents Spilled	2,100	0.0240	0.1212
0.10% Contents Spilled	3,500	0.0290	0.1465
0.80% Contents Spilled	28,000	0.0080	0.0404
3.0% Contents Spilled	105,000	0.0080	0.0404
12.0% Contents Spilled	420,000	0.0080	0.0404
36.0% Contents Spilled	1,260,000	0.0080	0.0404
40.0% Contents Spilled	1,400,000	0.0040	0.0202
71.0% Contents Spilled	2,485,000	0.0040	0.0202
91.0% Contents Spilled	3,185,000	0.0040	0.0202
WCD Single/Double Hull	3,500,000	0.0040	0.0202
50th Percentile Spill	**500**	**-**	**0.1000**
95th Percentile Spill	**1,000,000**	**-**	**0.0400**

Table A44: Projected Spills from Cook Inlet Gas Carrier (SH/DH Bunker) Transfer Errors			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0769	-
0.00003% Contents Spilled	1	0.2308	0.2500
0.00014% Contents Spilled	5	0.1385	0.1500
0.0003% Contents Spilled	10	0.0923	0.1000
0.0006% Contents Spilled	20	0.0923	0.1000
0.0014% Contents Spilled	50	0.1846	0.2000
0.0057% Contents Spilled	200	0.0923	0.1000
0.0143% Contents Spilled	500	0.0462	0.0500
0.0571% Contents Spilled	2,000	0.0369	0.0400
0.286% Contents Spilled	10,000	0.0083	0.0090
2.86% Contents Spilled	100,000	0.0008	0.0009
WCD Double/Single Hull	3,500,000	0.0001	0.0001
50th Percentile Spill	**10**	**-**	**0.1000**
95th Percentile Spill	**1,000**	**-**	**0.0400**

Table A45: Projected Spills from Cook Inlet OSV[45] (SH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.9550	-
0.001% Contents Spilled	0.4	0.0018	0.0406

[45] Offshore supply vessel.

Table A45: Projected Spills from Cook Inlet OSV[45] (SH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0.01% Contents Spilled	4	0.0082	0.1851
0.03% Contents Spilled	11	0.0036	0.0813
0.15% Contents Spilled	54	0.0082	0.1851
1.6% Contents Spilled	576	0.0045	0.1016
4.3% Contents Spilled	1,548	0.0036	0.0813
10.0% Contents Spilled	3,600	0.0018	0.0406
16.0% Contents Spilled	5,760	0.0027	0.0609
33.3% Contents Spilled	11,988	0.0036	0.0813
59.0% Contents Spilled	21,240	0.0045	0.1016
WCD Single Hull	36,000	0.0018	0.0406
50th Percentile Spill	**100**	**-**	**0.1500**
95th Percentile Spill	**20,000**	**-**	**0.1000**

Table A46: Projected Spills from Cook Inlet OSV (DH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.9810	-
0.001% Contents Spilled	0.4	0.0008	0.0042
0.01% Contents Spilled	4	0.0035	0.0182
0.03% Contents Spilled	11	0.0016	0.0083
0.15% Contents Spilled	54	0.0035	0.0182
1.6% Contents Spilled	576	0.0019	0.0099
4.3% Contents Spilled	1,548	0.0016	0.0083
10.0% Contents Spilled	3,600	0.0008	0.0042
16.0% Contents Spilled	5,760	0.0012	0.0063
33.3% Contents Spilled	11,988	0.0016	0.0083
59.0% Contents Spilled	21,240	0.0019	0.0099
WCD Double Hull	36,000	0.0008	0.0042
50th Percentile Spill	**100**	**-**	**0.0150**
95th Percentile Spill	**20,000**	**-**	**0.0100**

Table A47: Projected Spills from Cook Inlet OSV (SH/DH Bunker) Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.8000	-
<0.001% Contents Spilled	0.2	0.0120	0.0606
0.001% Contents Spilled	0.4	0.0290	0.1465
0.003% Contents Spilled	1	0.0240	0.1212
0.008% Contents Spilled	3	0.0120	0.0606
0.015% Contents Spilled	5	0.0200	0.1010
0.06% Contents Spilled	22	0.0240	0.1212
0.10% Contents Spilled	36	0.0290	0.1465
0.80% Contents Spilled	288	0.0080	0.0404
3.0% Contents Spilled	1,080	0.0080	0.0404
12.0% Contents Spilled	4,320	0.0080	0.0404
36.0% Contents Spilled	12,960	0.0080	0.0404
40.0% Contents Spilled	14,400	0.0040	0.0202
71.0% Contents Spilled	25,560	0.0040	0.0202
91.0% Contents Spilled	32,760	0.0040	0.0202
WCD Single/Double Hull	36,000	0.0040	0.0202

Table A47: Projected Spills from Cook Inlet OSV (SH/DH Bunker) Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
50th Percentile Spill	**10**	**-**	**0.1200**
95th Percentile Spill	**20,000**	**-**	**0.0200**

Table A48: Projected Spills from Cook Inlet OSV (SH/DH Bunker) Transfer Errors			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0769	-
0.003% Contents Spilled	1	0.2308	0.2500
0.014% Contents Spilled	5	0.1385	0.1500
0.028% Contents Spilled	10	0.0923	0.1000
0.056% Contents Spilled	20	0.0923	0.1000
0.14% Contents Spilled	50	0.1846	0.2000
0.56% Contents Spilled	200	0.0923	0.1000
1.4% Contents Spilled	500	0.0462	0.0500
5.6% Contents Spilled	2,000	0.0369	0.0400
27.8% Contents Spilled	10,000	0.0083	0.0090
WCD Double/Single Hull	36,000	0.0009	0.0010
50th Percentile Spill	**10**	**-**	**0.1000**
95th Percentile Spill	**1,000**	**-**	**0.0450**

Table A49: Projected Spills from Cook Inlet Tug/Tow Boat (SH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.9550	-
0.001% Contents Spilled	0.4	0.0018	0.0406
0.01% Contents Spilled	4	0.0082	0.1851
0.03% Contents Spilled	13	0.0036	0.0813
0.15% Contents Spilled	63	0.0082	0.1851
1.6% Contents Spilled	672	0.0045	0.1016
4.3% Contents Spilled	1,806	0.0036	0.0813
10.0% Contents Spilled	4,200	0.0018	0.0406
16.0% Contents Spilled	6,720	0.0027	0.0609
33.3% Contents Spilled	13,986	0.0036	0.0813
59.0% Contents Spilled	24,780	0.0045	0.1016
WCD Single Hull	42,000	0.0018	0.0406
50th Percentile Spill	**100**	**-**	**0.1500**
95th Percentile Spill	**20,000**	**-**	**0.1000**

Table A50: Projected Spills from Cook Inlet Tug/Tow Boat (DH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.9810	-
0.001% Contents Spilled	0.4	0.0008	0.0417
0.01% Contents Spilled	4	0.0035	0.1823
0.03% Contents Spilled	13	0.0016	0.0833
0.15% Contents Spilled	63	0.0035	0.1823
1.6% Contents Spilled	672	0.0019	0.0990
4.3% Contents Spilled	1,806	0.0016	0.0833
10.0% Contents Spilled	4,200	0.0008	0.0417
16.0% Contents Spilled	6,720	0.0012	0.0625

Table A50: Projected Spills from Cook Inlet Tug/Tow Boat (DH Bunker) Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
33.3% Contents Spilled	13,986	0.0016	0.0833
59.0% Contents Spilled	24,780	0.0019	0.0990
WCD Double Hull	42,000	0.0008	0.0417
50th Percentile Spill	**100**	**-**	**0.1500**
95th Percentile Spill	**20,000**	**-**	**0.1000**

Table A51: Projected Spills from Cook Inlet Tug/Tow Boat (SH/DH Bunker) Non-Impact Accidents			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.8000	-
<0.001% Contents Spilled	0.1	0.0120	0.0606
0.001% Contents Spilled	0.4	0.0290	0.1465
0.003% Contents Spilled	1	0.0240	0.1212
0.008% Contents Spilled	3	0.0120	0.0606
0.015% Contents Spilled	6	0.0200	0.1010
0.06% Contents Spilled	25	0.0240	0.1212
0.10% Contents Spilled	42	0.0290	0.1465
0.80% Contents Spilled	336	0.0080	0.0404
3.0% Contents Spilled	1,260	0.0080	0.0404
12.0% Contents Spilled	5,040	0.0080	0.0404
36.0% Contents Spilled	15,120	0.0080	0.0404
40.0% Contents Spilled	16,800	0.0040	0.0202
71.0% Contents Spilled	29,820	0.0040	0.0202
91.0% Contents Spilled	38,220	0.0040	0.0202
WCD Single/Double Hull	42,000	0.0040	0.0202
50th Percentile Spill	**100**	**-**	**0.1000**
95th Percentile Spill	**20,000**	**-**	**0.0200**

Table A52: Projected Spills from Cook Inlet Tug/Tow Boat (SH/DH Bunker) Transfer Errors			
Percent Oil Outflow	**Spill Volume (gallons)**	**Probability of Outflow Loss This Magnitude**	**Probability of Volume Given Spill Occurrence**
0% (No Spill)	0	0.0769	-
0.002% Contents Spilled	1	0.2308	0.2500
0.012% Contents Spilled	5	0.1385	0.1500
0.024% Contents Spilled	10	0.0923	0.1000
0.048% Contents Spilled	20	0.0923	0.1000
0.12% Contents Spilled	50	0.1846	0.2000
0.48% Contents Spilled	200	0.0923	0.1000
1.2% Contents Spilled	500	0.0462	0.0500
4.8% Contents Spilled	2,000	0.0369	0.0400
23.8% Contents Spilled	10,000	0.0083	0.0090
WCD Double/Single Hull	42,000	0.0009	0.0010
50th Percentile Spill	**10**	**-**	**0.1000**
95th Percentile Spill	**10,000**	**-**	**0.0100**

Spill Volumes Defined for Spill Scenario Impact Analysis

The spill volumes selected for the spill scenario impact analysis for Cook Inlet are as shown in Table A53 by vessel type and cause. The "small" scenarios were defined as the spill volume that represented approximately the 25th percentile[46] of spill volumes from the outflow analyses. "Moderate" scenarios represent approximately the 50th percentile spill volume. "Large" scenarios represent approximately the 95th percentile volume.

Table A53: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis

Vessel Type	Accident Cause	Hull[47]	Oil Volume (gallons)			
			Small	Moderate	Large	WCD
			25th %tile	50th %tile	95th%tile	
Product Tanker	Collision	Single	200	5,000	4,000,000	21,000,000
		Double	200	5,000	4,000,000	7,980,000
	Allision	Single	200	5,000	4,000,000	21,000,000
		Double	200	5,000	4,000,000	7,980,000
	Grounding	Single	200	5,000	4,000,000	21,000,000
		Double	200	5,000	4,000,000	7,980,000
	Structural Failure	Single	50	1,000	150,000	21,000,000
		Double	50	1,000	150,000	7,980,000
	Fire	Single	50	1,000	150,000	21,000,000
		Double	50	1,000	150,000	7,980,000
	Equipment Failure	Single	50	1,000	150,000	21,000,000
		Double	50	1,000	150,000	7,980,000
	Operations Error	Single	50	1,000	150,000	21,000,000
		Double	50	1,000	150,000	7,980,000
	Transfer Error	Single	1	10	2,000	21,000,000
		Double	1	10	2,000	21,000,000
Crude Tanker	Collision	Single	500	20,000	15,000,000	75,000,000
		Double	500	20,000	15,000,000	28,500,000
	Allision	Single	500	20,000	15,000,000	75,000,000
		Double	500	20,000	15,000,000	28,500,000
	Grounding	Single	500	20,000	15,000,000	75,000,000
		Double	500	20,000	15,000,000	28,500,000
	Structural Failure	Single	100	2,000	8,000,000	75,000,000
		Double	100	2,000	8,000,000	28,500,000
	Fire	Single	100	2,000	8,000,000	75,000,000
		Double	100	2,000	8,000,000	28,500,000
	Equipment Failure	Single	100	2,000	8,000,000	75,000,000
		Double	100	2,000	8,000,000	28,500,000
	Operations Error	Single	100	2,000	8,000,000	75,000,000
		Double	100	2,000	8,000,000	28,500,000
	Transfer Error	Single	1	10	2,000	75,000,000
		Double	1	10	2,000	75,000,000

[46] A percentile spill is the spill volume associated with the nth probability. In other words, the volume for the nth percentile spill is that spill volume larger than n% of spills for that vessel type and cause. The nth percentile is smaller than 100 – n% of spills. The "25th percentile spill" is defined as the spill volume larger than 25% of the spills but smaller than 75% of the spills. The 50th percentile spill is the median (50% larger, 50% smaller).The 95th percentile spill is larger than 99% of the spills and only smaller than 1% of the spills. Only 1% of the spills is larger.

[47] For tank vessels (tankers and tank barges), the hull refers to the cargo hull. For all other vessels the hull refers to the bunker tank hull. Single hulls should be used for pre-2015 scenarios, double-hulls for 2015 and beyond.

Table A53: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis						
Vessel Type	Accident Cause	Hull[47]	Oil Volume (gallons)			
			Small	Moderate	Large	WCD
			25th %tile	50th %tile	95th%tile	
Tank Barge	Collision	Single	100	500	300,000	1,900,000
		Double	100	500	300,000	1,520,000
	Allision	Single	100	500	300,000	1,900,000
		Double	100	500	300,000	1,520,000
	Grounding	Single	100	500	300,000	1,900,000
		Double	100	500	300,000	1,520,000
	Structural Failure	Single	50	200	300,000	1,900,000
		Double	50	200	300,000	1,520,000
	Fire	Single	50	200	300,000	1,900,000
		Double	50	200	300,000	1,520,000
	Equipment Failure	Single	50	200	300,000	1,900,000
		Double	50	200	300,000	1,520,000
	Operations Error	Single	50	200	300,000	1,900,000
		Double	50	200	300,000	1,520,000
	Transfer Error	Single	1	10	2,000	1,900,000
		Double	1	10	2,000	1,900,000
Non-Tank/Non-Workboat Vessel	Collision	Single	100	1,000	300,000	605,000
		Double	100	1,000	300,000	605,000
	Allision	Single	100	1,000	300,000	605,000
		Double	100	1,000	300,000	605,000
	Grounding	Single	100	1,000	300,000	605,000
		Double	100	1,000	300,000	605,000
	Structural Failure	Single	10	100	300,000	605,000
		Double	10	100	300,000	605,000
	Fire	Single	10	100	300,000	605,000
		Double	10	100	300,000	605,000
	Equipment Failure	Single	10	100	300,000	605,000
		Double	10	100	300,000	605,000
	Operations Error	Single	10	100	300,000	605,000
		Double	10	100	300,000	605,000
	Transfer Error	Single	1	10	2,000	605,000
		Double	1	10	2,000	605,000
Gas Carrier	Collision	Single	500	5,000	2,000,000	3,500,000
		Double	500	5,000	2,000,000	3,500,000
	Allision	Single	500	5,000	2,000,000	3,500,000
		Double	500	5,000	2,000,000	3,500,000
	Grounding	Single	500	5,000	2,000,000	3,500,000
		Double	500	5,000	2,000,000	3,500,000
	Structural Failure	Single	50	500	1,000,000	3,500,000
		Double	50	500	1,000,000	3,500,000
	Fire	Single	50	500	1,000,000	3,500,000
		Double	50	500	1,000,000	3,500,000
	Equipment Failure	Single	50	500	1,000,000	3,500,000
		Double	50	500	1,000,000	3,500,000
	Operations Error	Single	50	500	1,000,000	3,500,000
		Double	50	500	1,000,000	3,500,000
	Transfer Error	Single	1	10	1,000	3,500,000
		Double	1	10	1,000	3,500,000
OSV	Collision	Single	10	100	20,000	36,000

Table A53: Spill Volumes for Cook Inlet Vessel Spill Impact Analysis						
Vessel Type	Accident Cause	Hull[47]	Oil Volume (gallons)			
			Small	Moderate	Large	WCD
			25th %tile	50th %tile	95th%tile	
Offshore Supply Vessel (OSV)	Collision	Double	10	100	20,000	36,000
	Allision	Single	10	100	20,000	36,000
		Double	10	100	20,000	36,000
	Grounding	Single	10	100	20,000	36,000
		Double	10	100	20,000	36,000
	Structural Failure	Single	1	10	20,000	36,000
		Double	1	10	20,000	36,000
	Fire	Single	1	10	20,000	36,000
		Double	1	10	20,000	36,000
	Equipment Failure	Single	1	10	20,000	36,000
		Double	1	10	20,000	36,000
	Operations Error	Single	1	10	20,000	36,000
		Double	1	10	20,000	36,000
	Transfer Error	Single	1	10	1,000	36,000
		Double	1	10	1,000	36,000
Tug/Tow Boat	Collision	Single	5	100	20,000	42,000
		Double	5	100	20,000	42,000
	Allision	Single	5	100	20,000	42,000
		Double	5	100	20,000	42,000
	Grounding	Single	5	100	20,000	42,000
		Double	5	100	20,000	42,000
	Structural Failure	Single	10	100	20,000	42,000
		Double	10	100	20,000	42,000
	Fire	Single	10	100	20,000	42,000
		Double	10	100	20,000	42,000
	Equipment Failure	Single	10	100	20,000	42,000
		Double	10	100	20,000	42,000
	Operations Error	Single	10	100	20,000	42,000
		Double	10	100	20,000	42,000
	Transfer Error	Single	1	10	1,000	42,000
		Double	1	10	1,000	42,000

Oil Types

The benefit of breaking the spills into the different oil categories for this study is that one can make qualitative projections of potential environmental impacts due to the persistence, toxicity, and coating/mechanical injury effects that differ considerably between oil types.

Though each petroleum-based oil has its unique characteristics, for the purpose of modeling and damage or impact estimation, it is useful to put the various oils into one of four basic categories. These categories are generally based on the density (specific gravity) of the oils but also incorporate the concentrations of aromatics, which tend to be more toxic and evaporate more easily, versus concentrations of heavier components, which are less toxic but are highly persistent in the environment. Ultimately, these are the factors that will determine short- and long-term impacts on natural and socioeconomic resources.

In this study the oil types have been defined as in Table A54.

Table A54: Modified Oil Type Classifications for Cook Inlet Maritime Risk Assessment		
Persistence Category[48]	**Oil Types**[49]	**Examples in Category**
Non-Persistent	Volatile Distillates	Jet fuel, kerosene, gasoline[50]
Low Persistent	Light Fuels	Diesel fuel, No. 2 fuel, home heating oil, marine diesel
Medium Persistent	Lube Oils	Lubricating oils
	Crude Oil	Medium crude oils[51]
Heavy Persistent	Heavy Oils	Heavy fuel oil, bunker oils, Bunker A, Bunker B, Bunker C, intermediate fuel oil (IFO), No. 4 fuel, No. 5 fuel, No. 6 fuel, transmix, residual oils/fuel, waste oil

Volatile Distillates

This category includes refined petroleum products that are highly toxic but evaporate relatively rapidly, such as gasoline, jet fuel, kerosene, crude condensate, and No. 1 fuel oil. In the US, this category is called "Group I Oil" that consists of hydrocarbon fractions at least 50% of which, by volume, distill at a temperature of 340ºC (645ºF); and at least 95% of which, by volume, distill at a temperature of 370ºC (700ºF).

In general, these oils exhibit the following behavior:

- Highly volatile (evaporate completely within one to two days);
- Contain high concentrations of toxic soluble compounds;
- Capable of causing localized, severe impacts to surface and subsurface resources, and contaminating drinking water; and
- Generally nearly impossible to clean up with conventional response tools.

Light Fuels

This category incorporates crude oils and refined petroleum products that are quite toxic but also contain some persistent components. These oils do not evaporate as readily as volatile distillates. The category includes: No. 2 fuel, diesel fuel, light crude oil, gas oil, hydraulic oil, and catalytic feedstock. In the US, this category is called "Group II Oil", including crude oil and products that have a specific gravity less than 0.85 [API° >35.0].

These oils are:

- Moderately toxic and will leave a residue of up to one-third of the spill amount after a few days;
- Contain moderate concentrations of toxic soluble compounds;
- Capable of oiling surface and subsurface resources with long-term contamination potential;
- Generally possible to clean up with effective response tools.

[48] There is no standard method to determine oil persistence. For example, diesel fuel is sometimes classified as "persistent" and sometimes classified as "non-persistent" (See Davis et al. 2003; Etkin 2002.)
[49] These categories have been used by the EPA in its assessment of impacts of spills from inland facilities regulated by the agency (Etkin 2004).
[50] Gasoline can be separated out as a separate category if desired.
[51] Heavy crude oils have many of the same characteristics as heavy oils, and light crudes tend to be more like light fuels. Since most of the crude transported through Cook Inlet will be medium (Alaskan) crude this is immaterial in this study.

Medium Oils

This category includes crude oils and refined petroleum products that are moderately toxic and moderately persistent, such as most crude oils, lube oil, and intermediate fuel oil (IFO). This category would also include synthetic crudes. In the US, these oils are considered "Group III Oils", having a specific gravity between 0.85 and less than 0.95 [API° ≤35.0 and >17.5].

In general, these oils exhibit the following behavior:

- About one-third will evaporate within 24 hours;
- Oil contamination of can be severe and long-term;
- Oil impacts to waterfowl and fur-bearing mammals can be severe; and
- Cleanup is most effective if conducted quickly.

Heavy Oils

This category includes crude oil and petroleum products that are very persistent, though less toxic. This group includes heavy fuel oil, Bunker C, No. 5 or No. 6 fuel, and heavy crude oils. This category would also include bitumen blends. In the US, these oils are classified as Group IV, having a specific gravity between 0.95 to and including 1.0 [API° ≤17.5 and >10.0].

In general, these oils exhibit the following behavior:

- Heavy oils with little or no evaporation or dissolution;
- Heavy contamination likely;
- Severe impacts to waterfowl and fur-bearing mammals (coating and ingestion);
- Long-term contamination of sediments possible;
- Weathers very slowly; and
- Shoreline and substrate cleanup is difficult under all conditions.

Spill Impacts: The Effects of Oil Type

Oil type is an extremely important factor in determining the costs and impacts of spills. The oil type determines the properties of the oil itself and the way in which the oil will behave once it is spilled into the environment. (A more detailed examination of oil characteristics is presented in Appendices A and B.)

The characteristics of spilled oil are inter-related and can affect response operations in a number of ways. First, the degree to which the oil evaporates, disperses, and dissolves will affect the amount of oil that is available for removal via mechanical containment and recovery, dispersant application, manual removal, or in situ burning. The degree of weathering, as well as the oil's viscosity, density, adhesiveness, and other characteristics will affect the effectiveness of these removal techniques.

Oil Evaporation Effect on Environmental and Socioeconomic Impacts

The most toxic substances in oil (e.g., benzene, toluene, ethylbenzene, and xylene) are also more likely to evaporate and disperse, which reduces the time that they remain concentrated in the aquatic environment.

The toxic effects of oil are usually realized in the first hours to days of a spill. Evaporation of the volatile hydrocarbons leaves behind the heavier, more persistent fractions of oil. Evaporation rates are dependent on temperature with higher evaporation in warmer temperatures.

The more oil that evaporates, the less oil there is to clean up, and the less oil that persists in the environment to impact natural and socioeconomic resources. At the same time, the presence of volatile components generally means that there will be at least some toxic impacts from the oil, which translates to environmental and socioeconomic damages as well.

Oil Density Effect on Environmental and Socioeconomic Impacts

Density, the mass per unit volume of the oil, determines its buoyancy in water. Density is commonly expressed in grams per cubic centimeter (g/cm^3).[52] The density of oil increases with weathering (evaporation of volatile hydrocarbon components) and decreasing temperature.

The density of oil affects its buoyancy and the possibility of sinking. Oil will sink if its density is higher than that of the water. It will also sink when it comes in contact with sediment or other particles or debris that makes the mixture heavier than water. Sunken oil presents significant challenges for spill response.

Oil density also affects the rate of natural dispersion with denser oils dispersing more readily. Denser oils also spread faster on the water surface in the early stages of a spill. Denser oils are also more likely to form stable emulsions.[53] Dispersion, spreading, and emulsion formation all affect spill response costs. While natural dispersion will tend to reduce response costs, as there is less to effectively remove, spreading and emulsion formation both tend to increase costs. With oil spreading, it is more difficult to locate and contain oil for mechanical recovery or to effectively burn or chemically disperse the oil.

Oil Viscosity Effect on Environmental and Socioeconomic Impacts

Viscosity is a measure of the resistance of oil to flowing once in motion. Oil viscosity increases as weathering progresses and increases with decreasing temperature. Viscosity is one of the most important properties for spill behavior as it affects: spreading - the more viscous the oil the more slowly it spreads, and emulsification – the more viscous the oil the more stable the emulsion.

Viscosity also affects the effectiveness of certain spill response measures. Highly viscous oils are very difficult to disperse chemically. Natural dispersion is also significantly reduced in highly viscous oils. More viscous oils are difficult to recover with skimmers and pumps and thus tend to increase response costs.

Interfacial Tension and Environmental and Socioeconomic Impacts

Interfacial tension is a measure of the surface forces that exist between the interfaces of the oil and water and the oil and air. Interfacial tensions (oil and air and oil and water) are insensitive to temperature, but

[52] Pure water has a density of 1 g/cm^3; seawater generally has a density of 1.03 g/cm^3.
[53] A water-in-oil emulsion is a stable emulsion of small droplets of water incorporated in oil. Oil spills on water may form stable water-in-oil emulsions that can have very different characteristics than the parent crude oil.

are affected by evaporation. Interfacial tension affects the rate and type of spreading on the water surface as well as sheen[54] formation. Interfacial tension also affects emulsion rates and emulsion stability.

Since chemical dispersants work by reducing the oil and water interfacial tension to allow a given mixing energy[55] to produce smaller oil droplets, the degree of interfacial tension in an oil will affect the ability of an oil to be chemically dispersed. Oils with high interfacial tensions are more difficult to disperse with chemical dispersing agents, and also disperse less naturally. This will tend to limit the effectiveness of dispersants and require more expensive mechanical methods for cleanup.

At the same time, mechanical recovery with oleophilic skimmers (e.g., rope-mop and belt skimmers) work better on oils with moderate to high interfacial tensions. Increased effectiveness of mechanical recovery will generally reduce response costs. The amount of oil recovered offshore (on the water surface) will be greater reducing the amount of oil on the shoreline where cleanup tends to be more labor-intensive and expensive. If more oil can be recovered on the water surface, the less impact on shorelines.

Oil Pour Point Effect on Environmental and Socioeconomic Impacts

The "pour point" of a particular oil is the lowest temperature at which the oil will still flow. Below this temperature the oil begins to develop an internal yield stress and, in essence, solidifies. The pour point temperature increases with weathering (evaporation of volatile components). Pour point affects spreading on the water surface. Oils that are at temperatures below their pour points will not spread and are more difficult to disperse. Viscosity increases dramatically at temperatures below the pour point.

Because oils will resist flowing toward skimmers or down inclined surfaces in skimmers, there are significant challenges in mechanical oil recovery at these temperatures. The solidification of the oil below its pour point also causes problems in storage and transfer. These factors can increase spill response costs because more work needs to be done manually.

Adhesiveness Effect on Environmental and Socioeconomic Impacts

The adhesiveness of an oil is the degree to which oil remains on a surface after contact and draining. This character has an effect on spill impacts by way of the amount of oil that will stick to surfaces, including shoreline substrates and structures (e.g., piers, boats, seawalls). Higher adhesion increases damage costs and increases shoreline cleanup costs. At the same time, adhesion can increase the effectiveness of some on-water recovery methods, including use of oleophilic skimming devices.

Emulsification Effect on Environmental and Socioeconomic Impacts

A water-in-oil emulsion[56] is a stable emulsion of small droplets of water incorporated in oil. Oil spills on water may form stable water-in-oil emulsions that can have very different characteristics than the parent

[54] A "sheen" is a very thin layer of oil on the water surface. Rainbow-colored sheens are generally 0.0003 mm thick. Silver sheens are usually about 0.0001 mm thick.
[55] Waves and sea state.
[56] Water-in-oil emulsion is colloquially called "chocolate mousse".

crude oil. The tendency to form emulsions, the stability[57] of those emulsions, and the water content of stable emulsion are all important characteristics of an oil that can affect impacts as well as response.

Emulsification can have significant impacts on spill response and impacts. Emulsified oils can be very persistent in the environment. Strongly emulsified oils are also highly viscous, often with 10 to 100 times the viscosity of the parent oil. Oils with relatively high concentrations of asphaltenes are most likely to form stable water-in-oil emulsions. Some heavy oils do not easily form emulsions because the high viscosity of the oil prevents the uptake of water. Some light or medium oils do not form an emulsion immediately, but once evaporation occurs and the asphaltene concentration increases, the emulsification process begins and usually proceeds quickly thereafter.

Emulsions can present challenges for all types of response strategies, increasing costs and logistical concerns, such as increases in storage of collected oil (i.e., larger volume with oil/water mixture).

Persistence Effect on Environmental and Socioeconomic Impacts

The *persistence* of the oil in the environment can also significantly affect the impacts of a spill, as well as the response strategies and costs. Persistence of petroleum-based oils is a very important consideration in assessing the environmental risk of an oil spill and often affects the resources needed for spill recovery and remediation. The heavier, more persistent fractions of oil are those that adhere to the feathers of birds and fur of mammals, as well as to shoreline and wetland communities. For birds and mammals, this coating can cause hypothermia. For organisms living along shoreline or in wetlands, this can cause smothering. Both smothering and hypothermia can result in mortality, which increases environmental damages.

The persistent portions of oil can also coat other surfaces (e.g., tourist beaches, sea walls, marinas, boats) causing socioeconomic impacts. The persistence of oil and the degree to which the oil adheres to shoreline substrates and penetrates those substrates will affect the type of shoreline response that is required.[58] The labor and resources, as well as disposal, required for shoreline responses will vary by shoreline type, oil type, and degree of oiling, which in turn affect the complexity involved in the cleanup.[59]

Toxicity and Environmental and Socioeconomic Impacts

The *toxicity* of the oil determines the adverse effects and mortality of fish, wildlife, and invertebrates after short-term exposure (hours to days). Mortality as well as sub-lethal effects (e.g., reduced fecundity) is relevant to both environmental impacts, as well as socioeconomic impacts in as much as commercial fisheries, subsistence fishing (particularly important in Tribal Nationsareas), and recreational fishing are affected. Different organisms have different tolerances of exposure.

[57] Emulsion stability can be: low, which indicates the emulsion is unstable and will break quickly once removed from the mixing environment; moderate, which means the emulsion will break within a few hours; or high, which means the oil forms a very sTable Bmulsion that is unlikely to break even after standing for 24 hours.
[58] Etkin et al. 2008a, 2008b.
[59] Etkin 2001b, 2003.

Mechanical Injury and Environmental and Socioeconomic Impacts

Oil can also cause "mechanical injury" based on its adhesive properties. This injury is caused by coating, fowling or clogging of organisms and their appendages and apertures, such that movements and behaviors are mechanically inhibited.[60]

Oil Types for Cook Inlet Scenarios

The types of oil carried by vessels in Cook Inlet vary by vessel type. An analysis of oil types in vessel incidents in Cook Inlet from 1995 through 2010 is shown in Table A55.

Table A55: Oil Types in Cook Inlet Vessel Incidents 1995 – 2010

Oil Category	Vessel Type						
	Tank Vessels			Non-Tank Vessels			
	Product Tanker	Crude Tanker	Tank Barge	Non-Tank/Non-Workboat Vessel	Gas Carrier	Offshore Supply Vessel	Tug/Tow Boat
Non-Persistent	8.5%	0%	29%	0%	0%	0%	0%
Low Persistent	**58%**	0%	**45%**	10%	0%	**73%**	21%
Medium Persistent	25%	**100%**	13%	10%	0%	27%	21%
Heavy Persistent	8.5%	0%	13%	**80%**	**100%**	0%	**57%**

The percentage distribution of oil types for future spills in Cook Inlet will vary with the types of oil transported as bunker fuel and as cargo. There are no available data for future projections of types of oil transported. It is known, however, that there will be a gradual changeover from heavy bunker fuel (heavy persistent) consumption by all vessels to diesel fuels (low persistent) because of regulations regarding air emissions for larger ships.[61] This affects both tankers and non-tank vessels (e.g., Non-Tank/Non-Workboat Vessels), but since the greater risk for spillage from tankers is from cargo rather than bunkers, bunker fuel spillage for tankers is not considered in this analysis.

The oil categories by vessel type and time period that have been considered in the impact analysis for oil spillage in Cook Inlet are shown in Table A56.

Table A56: Oil Categories for Cook Inlet Spill Impact Analysis

Vessel Type	Years 2012 – 2014	Years 2015 – 2020
Product Tanker	Low Persistent	Low Persistent
Crude Tanker	Medium Persistent	Medium Persistent
Tank Barge	Low Persistent Non-Persistent[62]	Low Persistent Non-Persistent
Non-Tank/Non-Workboat Vessel	Heavy Persistent	Low Persistent

[60] French-McCay et al. 2009.

[61] Until 2010, Annex VI to MARPOL 73/78 limited the sulphur content of marine fuel oil to 1.5% per mass and applied in designated SOx Emission Control Areas (SECA). A new provision for the further reduction of sulphur content of marine fuels specifies a maximum sulphur content of 1.0% by 2010 and 0.1% by 2015. In practice, this means that ships operating in the ECAs would have to switch from low sulphur fuel oil (LSFO) with a sulphur content of 1.5% before 2010 to marine gas oil (MGO) with a sulphur content of 0.1% by 2015.

[62] Non-persistent oil is included as a second category for tank barges because of the relatively high occurrence of jet fuel spills from tank barges in the 1995 – 2010 incident data. Since the impacts of this oil category are distinctly different from the other categories, a separate analysis of spill impact of non-persistent oil was included.

Table A56: Oil Categories for Cook Inlet Spill Impact Analysis		
Vessel Type	**Years 2012 – 2014**	**Years 2015 – 2020**
Gas Carrier	Heavy Persistent	Low Persistent
Offshore Supply Vessel	Low Persistent	Low Persistent
Tug/Tow Boat	Heavy Persistent	Heavy Persistent

Spill Oil Type-Volume Combinations for Impact Analysis

Combining oil categories by vessel type and time period shown in Table A56 and the spill volumes by oil type and cause shown in Table A53 gives the spill scenarios in Table A57 for the time period 2012 – 2014 and Table A58 for the time period 2015 – 2020. In viewing the differences between the two scenario tables, it is important to keep in mind that the changes from the time period 2012 – 2014 to the time period 2015 – 2020 are based on three factors:

- The change from single-hulled to double-hulled cargo tanks on tank vessels (tankers and tank barge), which reduces the WCD spillage volume and reduces the probability that a spill will occur, though it does not affect the probability distribution of spill volumes if a spill *does occur*.
- The change from single-hulled to double-hulled bunker tanks on non-tank vessels, which reduces probability of a spill occurring with an impact incident, but does not affect the WCD spillage volume or the probability distribution of spill volumes if a spill does occur.
- The change from heavy bunker fuel oils, which are in the "heavy persistent" oil category, to diesel fuels, which are in the "low persistent" oil category, for Non-Tank/Non-Workboat Vessels and gas carriers.

Table A57: Cook Inlet Oil Spill Scenarios for Years 2012 – 2014						
Vessel Type[63]	**Accident Cause**	**Oil Type[64]**	**Spill Volume (gallons)**			
			25th %tile	**50th %tile**	**95th %tile**	**WCD**
SH Product Tanker	**Collision**	**LP**	200	5,000	4,000,000	21,000,000
	Allision	**LP**	200	5,000	4,000,000	21,000,000
	Grounding	**LP**	200	5,000	4,000,000	21,000,000
	Structural Failure	**LP**	50	1,000	150,000	21,000,000
	Fire	**LP**	50	1,000	150,000	21,000,000
	Equipment Failure	**LP**	50	1,000	150,000	21,000,000
	Operations Error	**LP**	50	1,000	150,000	21,000,000
	Transfer Error	**LP**	1	10	2,000	21,000,000
SH Crude Tanker	**Collision**	**MP**	500	20,000	15,000,000	75,000,000
	Allision	**MP**	500	20,000	15,000,000	75,000,000
	Grounding	**MP**	500	20,000	15,000,000	75,000,000
	Structural Failure	**MP**	100	2,000	8,000,000	75,000,000
	Fire	**MP**	100	2,000	8,000,000	75,000,000
	Equipment Failure	**MP**	100	2,000	8,000,000	75,000,000
	Operations Error	**MP**	100	2,000	8,000,000	75,000,000
	Transfer Error	**MP**	1	10	2,000	75,000,000
SH Tank Barge - NP	**Collision**	**NP**	100	500	300,000	1,900,000
	Allision	**NP**	100	500	300,000	1,900,000
	Grounding	**NP**	100	500	300,000	1,900,000
	Structural Failure	**NP**	50	200	300,000	1,900,000

[63] SH = single hull (i.e., single-hulled cargo tanks for tank vessels; single-hulled bunker tanks for non-tank vessels)
[64] NP = non-persistent; LP = low persistent; MP = medium persistent; HP = heavy persistent.

Table A57: Cook Inlet Oil Spill Scenarios for Years 2012 – 2014						
Vessel Type[63]	Accident Cause	Oil Type[64]	Spill Volume (gallons)			
			25th %tile	50th %tile	95th %tile	WCD
SH Tank Barge - NP	Fire	NP	50	200	300,000	1,900,000
	Equipment Failure	NP	50	200	300,000	1,900,000
	Operations Error	NP	50	200	300,000	1,900,000
	Transfer Error	NP	1	10	2,000	1,900,000
SH Tank Barge - LP	Collision	LP	100	500	300,000	1,900,000
	Allision	LP	100	500	300,000	1,900,000
	Grounding	LP	100	500	300,000	1,900,000
	Structural Failure	LP	50	200	300,000	1,900,000
	Fire	LP	50	200	300,000	1,900,000
	Equipment Failure	LP	50	200	300,000	1,900,000
	Operations Error	LP	50	200	300,000	1,900,000
	Transfer Error	LP	1	10	2,000	1,900,000
SH Non-Tank/Non-Workboat Vessel	Collision	HP	100	1,000	300,000	605,000
	Allision	HP	100	1,000	300,000	605,000
	Grounding	HP	100	1,000	300,000	605,000
	Structural Failure	HP	10	100	300,000	605,000
	Fire	HP	10	100	300,000	605,000
	Equipment Failure	HP	10	100	300,000	605,000
	Operations Error	HP	10	100	300,000	605,000
	Transfer Error	HP	1	10	2,000	605,000
SH Gas Carrier	Collision	HP	500	5,000	2,000,000	3,500,000
	Allision	HP	500	5,000	2,000,000	3,500,000
	Grounding	HP	500	5,000	2,000,000	3,500,000
	Structural Failure	HP	50	500	1,000,000	3,500,000
	Fire	HP	50	500	1,000,000	3,500,000
	Equipment Failure	HP	50	500	1,000,000	3,500,000
	Operations Error	HP	50	500	1,000,000	3,500,000
	Transfer Error	HP	1	10	1,000	3,500,000
SH Offshore Supply Vessel	Collision	LP	10	100	20,000	36,000
	Allision	LP	10	100	20,000	36,000
	Grounding	LP	10	100	20,000	36,000
	Structural Failure	LP	1	10	20,000	36,000
	Fire	LP	1	10	20,000	36,000
	Equipment Failure	LP	1	10	20,000	36,000
	Operations Error	LP	1	10	20,000	36,000
	Transfer Error	LP	1	10	1,000	36,000
SH Tug/Tow Boat	Collision	HP	5	100	20,000	42,000
	Allision	HP	5	100	20,000	42,000
	Grounding	HP	5	100	20,000	42,000
	Structural Failure	HP	10	100	20,000	42,000
	Fire	HP	10	100	20,000	42,000
	Equipment Failure	HP	10	100	20,000	42,000
	Operations Error	HP	10	100	20,000	42,000
	Transfer Error	HP	1	10	1,000	42,000

Table A58: Cook Inlet Oil Spill Scenarios for Years 2015 – 2020						
Vessel Type	Accident Cause	Oil Type	Spill Volume (gallons)			
			25th %tile	50th %tile	95th %tile	WCD
DH Product Tanker	Collision	LP	200	5,000	4,000,000	7,980,000
	Allision	LP	200	5,000	4,000,000	7,980,000
	Grounding	LP	200	5,000	4,000,000	7,980,000
	Structural Failure	LP	50	1,000	150,000	7,980,000
	Fire	LP	50	1,000	150,000	7,980,000
	Equipment Failure	LP	50	1,000	150,000	7,980,000
	Operations Error	LP	50	1,000	150,000	7,980,000
	Transfer Error	LP	1	10	2,000	21,000,000
DH Crude Tanker	Collision	MP	500	20,000	15,000,000	28,500,000
	Allision	MP	500	20,000	15,000,000	28,500,000
	Grounding	MP	500	20,000	15,000,000	28,500,000
	Structural Failure	MP	100	2,000	8,000,000	28,500,000
	Fire	MP	100	2,000	8,000,000	28,500,000
	Equipment Failure	MP	100	2,000	8,000,000	28,500,000
	Operations Error	MP	100	2,000	8,000,000	28,500,000
	Transfer Error	MP	1	10	2,000	75,000,000
DH Tank Barge - NP	Collision	NP	100	500	300,000	1,520,000
	Allision	NP	100	500	300,000	1,520,000
	Grounding	NP	100	500	300,000	1,520,000
	Structural Failure	NP	50	200	300,000	1,520,000
	Fire	NP	50	200	300,000	1,520,000
	Equipment Failure	NP	50	200	300,000	1,520,000
	Operations Error	NP	50	200	300,000	1,520,000
	Transfer Error	NP	1	10	2,000	1,900,000
DH Tank Barge - LP	Collision	LP	100	500	300,000	1,520,000
	Allision	LP	100	500	300,000	1,520,000
	Grounding	LP	100	500	300,000	1,520,000
	Structural Failure	LP	50	200	300,000	1,520,000
	Fire	LP	50	200	300,000	1,520,000
	Equipment Failure	LP	50	200	300,000	1,520,000
	Operations Error	LP	50	200	300,000	1,520,000
	Transfer Error	LP	1	10	2,000	1,900,000
DH Non-Tank/Non-Workboat Vessel	Collision	LP	100	1,000	300,000	605,000
	Allision	LP	100	1,000	300,000	605,000
	Grounding	LP	100	1,000	300,000	605,000
	Structural Failure	LP	10	100	300,000	605,000
	Fire	LP	10	100	300,000	605,000
	Equipment Failure	LP	10	100	300,000	605,000
	Operations Error	LP	10	100	300,000	605,000
	Transfer Error	LP	1	10	2,000	605,000
DH Gas Carrier	Collision	LP	500	5,000	2,000,000	3,500,000
	Allision	LP	500	5,000	2,000,000	3,500,000
	Grounding	LP	500	5,000	2,000,000	3,500,000
	Structural Failure	LP	50	500	1,000,000	3,500,000
	Fire	LP	50	500	1,000,000	3,500,000
	Equipment Failure	LP	50	500	1,000,000	3,500,000
	Operations Error	LP	50	500	1,000,000	3,500,000
	Transfer Error	LP	1	10	1,000	3,500,000

Table A58: Cook Inlet Oil Spill Scenarios for Years 2015 – 2020						
Vessel Type	Accident Cause	Oil Type	Spill Volume (gallons)			
			25th %tile	50th %tile	95th %tile	WCD
DH Offshore Supply Vessel	Collision	LP	10	100	20,000	36,000
	Allision	LP	10	100	20,000	36,000
	Grounding	LP	10	100	20,000	36,000
	Structural Failure	LP	1	10	20,000	36,000
	Fire	LP	1	10	20,000	36,000
	Equipment Failure	LP	1	10	20,000	36,000
	Operations Error	LP	1	10	20,000	36,000
	Transfer Error	LP	1	10	1,000	36,000
DH Tug/Tow Boat	Collision	HP	5	100	20,000	42,000
	Allision	HP	5	100	20,000	42,000
	Grounding	HP	5	100	20,000	42,000
	Structural Failure	HP	10	100	20,000	42,000
	Fire	HP	10	100	20,000	42,000
	Equipment Failure	HP	10	100	20,000	42,000
	Operations Error	HP	10	100	20,000	42,000
	Transfer Error	HP	1	10	1,000	42,000

Spill Impacts: The Effects of Spill Location Type

The impacts of spills of each oil type will be affected by their individual properties, as well as by the environment into which the oil spills. The characteristics of a spill location also determine the potential effectiveness of a spill response with regard to logistics, hydrodynamics, weather conditions, and the types of spill response strategies that can reasonably or legally be employed. The effectiveness of the response, in turn, determines the degree to which the environmental and socioeconomic impacts of the spill can be mitigated or reduced. It is important to remember that a spill response can only mitigate a percentage of the damages from a spill depending on the type of response employed and the efficacy of the oil removal. In most cases, this will represent a small percentage of the oil spillage. Except under highly unusual circumstances (i.e., sheltered waters with little to no current around a pre-boomed dock-side vessel), mechanical containment and recovery will remove 3 – 10%, and occasionally as much as 25%. Chemical dispersant application and in-situ burning will have much higher efficacy, though there are limitations to the use of these strategies that need to be considered in response decisions.

Response Considerations for Spills into Water

For spills into bodies of water, the important factors with regard to impacts are:

- The geography (shoreline contours) and hydrodynamics (currents, tides) of the affected water body, as well as the temperature and winds will affect the ways in which the oil will flow and behave upon spilling, as well as the potential effectiveness of spill control and mitigation strategies.
- The *shoreline types* and other sensitive resources (environmental and socioeconomic) in the proximity of the spill site will affect the types of damages that might occur.

In an open water body or flowing river or stream, the other factors that would increase damages to environmental resources would be factors that would hinder spill response measures, particularly currents that exceed the critical velocity of 0.35 to 0.5 meters per second (0.7 to 1 knot) When currents exceed this

velocity, oil will begin to entrain (go under) the boom regardless of its construction (Figure A9). The oil loss increases with the current velocity or speed. If the current is 1.0 knots, the oil begins to go under the boom in relatively small amounts. By the time the currents reach 3 knots, half of the oil is going under the boom. These losses will occur at different rates as the current velocity changes (Table A59).

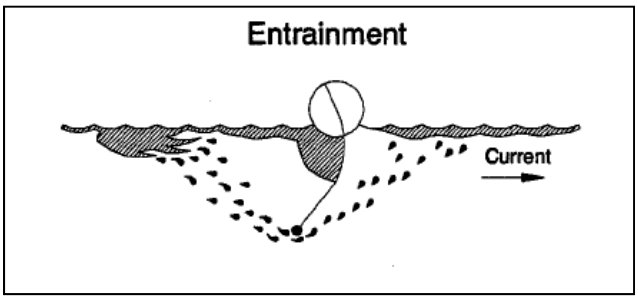

Figure A9: Oil loss Under Boom through Entrainment

Table A59: Oil Loss through Entrainment under Booms			
Current Speed		**Oil Loss**	**Oil Retention**
knots	**m/s**		
0.7	**0.4**	**0%**	**100%**
1.2	**0.6**	**2%**	**98%**
2.2	**1.1**	**17%**	**83%**
2.8	**1.4**	**39%**	**61%**
3.6	**1.9**	**57%**	**43%**
4.2	**2.2**	**63%**	**37%**
5.1	**2.6**	**85%**	**15%**

In most marine locations, tidal currents are complex, varying from day to day and throughout the day. In freshwater inland rivers and streams, variations in currents will be dependent on location and the amount of water in the stream or river, which will vary seasonally and by inputs from tributaries. In both types of water bodies, there may be many locations in which currents regularly exceed critical velocity. There are ways to somewhat overcome this by adjusting the angle of the boom relative to the current (i.e., the vector or direction of the current is at an angle to the boom). In that case higher currents can be accommodated. The problem with this approach is that the current direction varies spatially and with time (i.e., it is *dynamic*). The boom would have to be facing the current at different angles at different locations and at different times. This is sometimes done in spill responses with cascading booms all placed at different angles and moved every few hours with the tides.

The critical velocity for containment booms *facing perpendicular* to the current is about 0.7 knots (or 0.4 meters per second). In other words, oil will be lost under the boom (entrained) when the current exceeds about 0.75 knots. This value is independent of boom skirt depth. In rivers and estuaries where the currents exceed 1 knot, booms are usually put into booms are often used in a *deflection* mode at various angles to the current so that the critical velocity is not exceeded and oil is not lost. The appropriate deflection angles are shown in Table A60. Since booming is an essential part of spill response plans, both for the purpose of containment for mechanical recovery and protection of sensitive areas, any compromise in the effectiveness of booming will tend to drive up damages to sensitive shoreline and nearshore resources.

Table A60: Deflection Angles and Critical Current Velocities		
Deflection Angle	**Velocity of Perpendicular Current Before Critical Velocity Reached**[65]	
	Meters per second (m/s)	**Knots**
90º	0.5	1.0
75º	0.5	1.0
60º	0.6	1.2
45º	0.7	1.4
35º	0.9	1.7
15º	1.9	3.7

Response Issues for Spills Affecting Shoreline Substrates

Shoreline areas and land-based substrates most sensitive to oiling include those with long oil residency – fine-grained (silt-mud) flats, marshes, and lagoons – as well as shorelines with the greatest potential for penetration and remobilization – coarse-grained (cobble, cobble-boulder mix) substrates. The degree to which oil adheres to and penetrates into various types of shorelines is determined by complex factors.[66] The oil holding capacity of a particular substrate is related to:

- Sediment type (porosity and permeability);
- Oil type (viscosity and adhesiveness); and
- Water and air in the pore spaces of the sediment.

Impacts to different shoreline types are summarized in Table A61.

Table A61: Shoreline Substrate Types and Spill Damage Implications	
Type Name	**Damage Issues**
Rock platform	Low penetration and residency; oil will wash off with wave action
Rock cliff	Low penetration and residency; oil will wash off with wave action
Rock with gravel beach	Some penetration and potential remobilization
Rock sand gravel beach	Some penetration and potential remobilization
Rock with sand beach	Some penetration and potential remobilization
Gravel beach	Higher penetration and potential remobilization
Gravel flat	Higher penetration and potential remobilization
Sand gravel beach	Some penetration and potential remobilization
Sand beach	Lower penetration and potential remobilization
Sand gravel flat	Some penetration and potential remobilization
Sand flat	Lower penetration and potential remobilization
Mud flat	Long residency and difficulties with cleanup
Estuary, marsh, lagoon	Long residency and difficulties with cleanup
Man-made (solid)	Lower penetration
Riprap	Higher penetration and remobilization

The behavior of spilled oil as it first strands on a shoreline or first spills onto or into a substrate depends on a number of interrelated factors: oil type and characteristics (e.g., viscosity); oil thickness on the substrate; time until impact (i.e., degree of weathering); timing with regard to tides; weather during and after the spill; and nearshore wave energy, in the case of spills into water. The adhesiveness of oil to

[65] The velocity of the current that would be encountered if the boom were perpendicular to the current.
[66] Etkin et al. 2008a, 2008b.

shoreline substrates, in turn, depends on the properties of the oil, especially viscosity[67]. The degree of weathering can have a significant impact on the ability of oil to adhere to a substrate. Weathering can also cause emulsification, which can also change the oil viscosity. The degree of emulsification depends on the chemical composition of the oil. The degree of weathering that occurs is related to oil type and environmental conditions. Lighter oils evaporate more quickly than heavier oils. Temperature, wind, light conditions, and other environmental factors can influence the rate of weathering.

Fresh oils tend to be less adhesive than more weathered oils. Light fuels or volatile organic distillates tend to be relatively non-adhesive. Heavier fuels tend to be more adhesive than lighter oils. Penetration into the substrate will also depend on oil type. All other things being equal (e.g., shoreline porosity) heavier oils will penetrate less than lighter oils. Oil viscosity is positively correlated to oil adhesion on the shoreline. Adhesion is inversely related to penetration – the more adhesive an oil, the lower its penetration potential. Oil thickness on the shoreline is a factor of the amount spilled, spill trajectory, oil properties, steepness of the shoreline slope, tidal conditions at the time of shoreline impact, and the porosity of the surface.

Oil behavior at the shoreline or in a substrate is also highly dependent on the substrate characteristics, particularly porosity and permeability. The substrate structure largely determines the degree of oil penetration.[68] Penetration will be less in substrates with very fine granules that are packed closely together, and greater in more coarsely-grained substrates. If the pores are large and inter-connected, the substrates will be more "permeable" and allow deeper penetration and lateral movement of the oil through capillary action.

Bedrock is largely impermeable to oil except when it is able to enter crevices or fractures in rock surfaces. Gravel tends to have large inter-connected pore spaces that will allow oil to readily penetrate. Sand and mud beaches tend to have tightly-packed sediments with small pore spaces that are less permeable to oil, though some lighter oils can penetrate. Some substrates have features that can influence oil retention and penetration that are not related to granule size. Tidal flats often have holes from burrowing animals that will allow oil penetration.[69] Oil adhesion can also be influenced by the presence of vegetation, such as in wetlands or mangroves.[70] Ice is another substrate that can cause variations in oil adhesion and penetration based on its nature (tightly packed, granular, smooth, or rough.[71]

Nearshore wave energy can affect the degree of initial deposition and penetration for spills into water.[72] The effectiveness of wave energy in removing or re-floating oil is dependent on the permeability of the shoreline substrate, as well as the oil type and weathering condition with respect to adhesiveness. Wave energy can effectively remove oil from a bedrock shoreline where there is little, if any, penetration. Wave action can also cause the shoreline substrate to redistribute itself, as in the case of gravel or sand. This action can affect the degree of oil retention and re-floating. The extent of oiling on the shoreline is also dependent on the tidal stage at the time of oil deposition.

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[67] Fingas 2001.
[68] Harper et al. 1995; Harper and Sergy 2007.
[69] Howard and Little 1987.
[70] Michel et al. 1998; Lytle and Lytle 1987; Baca et al. 1983.
[71] Owens and Sergy 2004.
[72] Humphrey 1993.

Response Issues Related to the Presence of Ice[73]

The presence of ice on the water affects spill response in a number of ways. The oil tends to be more viscous, affecting the effectiveness of certain spill response measures. Highly viscous oils are very difficult to disperse chemically. Natural dispersion is also significantly reduced in highly viscous oils. More viscous oils are difficult to recover with skimmers and pumps and thus increase response costs.

At the same time, solid, pack, or broke ice, floes, or brash ice, can contain and entrain oil that is spilled on, into, or under the ice. While this sometimes complicates recovery with skimmer and booms, it can also act as a natural containment that isolates spilled oil from the marine environment. Oil spilled under ice will eventually resurface. Recovery can sometimes be safely delayed until winter conditions are more amenable to cleanup operations.

Skimmers used on spills in ice must be able to deal with emulsified, highly weathered oil and oil that is mixed with a good deal of debris, including ice pieces. Sometimes chemical treatment agents designed to increase viscoelasticity and cohesiveness of oil are added to increase the efficiency of skimmers.

In-situ burning is widely touted as the most effective means of removing large volumes of spilled oil on ice and in open water situations. Air pollution and safety issues need to be considered.

The use of dispersants in icy water conditions has had mixed results. Issues related to efficacy and potential impacts need to be considered.

Spill Impacts: Cook Inlet Location Geographical Factors

The unique geographical features of Cook Inlet will affect the impacts of any spills that would occur in a number of ways:

- Hydrodynamics (currents, tides, wave heights) will affect the way in which spilled oil will travel and spread on the water surface;
- Current velocity and wave height will also affect the degree to which booming, both for shoreline protection and for mechanical containment for on-water oil recovery operations, will be effective;
- Prevailing wind patterns will also affect the way in which the oil spreads and its trajectory on the water surface;
- The water and air temperatures in different seasons will affect the behavior of oil with respect to rates of evaporation and dispersion and viscosity;
- Presence or absence of ice will affect the behavior of the oil and strategies for spill response; and
- Types of shoreline substrates and configurations of the coastline will affect the degree of impacts on shoreline resources, as well as determine the nature of shoreline cleanup response strategies.

Sub-Areas of Cook Inlet

In this risk assessment study, Cook Inlet has been sub-divided into three sub-areas, as shown in the map in Figure A10:

- Upper Cook Inlet: north of 60.71ºN (West and East Forelands);

[73] Reviewed in Etkin 1990.

- Middle Cook Inlet: north of 59.80ºN northward to 60.71ºN (northern Iniskin Peninsula to Anchor Point on Kenai Peninsula); and
- Lower Cook Inlet: southward of 59.80ºN to northernmost part of Shelikof Strait (Cape Douglas to Dark Island) and eastward across Kennedy and Stevenson Entrances.

Figure A10: Cook Inlet Study Area Sub-Area Divisions

Shoreline Features of Cook Inlet[74]

The four types of shorelines found in Cook Inlet, shown in decreasing order of sensitivity to oil impacts, and with their Environmental Sensitivity Indices (ESI) are:

- Salt/Brackish Marsh – ESI 10A;
- Sheltered Tidal Flat – ESI 9;
- Sheltered Rocky Shore – ESI 8A; and
- Exposed Tidal Flat – ESI 7.

Salt/brackish marshes (Figure A11) are intertidal habitats colonized by perennial vascular plants able to tolerate water-logged soil conditions. Marshes provide nursery and feeding habitat for many species of fish and wildlife. Marshes are highly susceptible to oil spill impact because they occur at the high-tide line where oil tends to concentrate. They are the most sensitive intertidal habitat because of their high biological utilization and value, difficulty of cleanup, and potential for long-term impacts to both the habitat and the organisms that rely upon it.

[74] NOAA Cook Inlet and Kenai Peninsula, Alaska, Environmental Sensitivity Areas (2002)

Figure A11: Example of Salt/Brackish Marsh Shoreline (ESI 10A)

Sheltered tidal flats (Figure A12) are intertidal habitats that are flat, unvegetated, sheltered from strong tidal currents or wave action, and dominated by soft, muddy substrate. Sheltered tidal flats support large populations of benthic organisms and are important feeding and resting areas for birds and fish. Oil penetration into the muddy, saturated sediment will be limited except where these sediments are highly burrowed by animals. The high biological utilization, soft substrate, and low-energy setting make these habitats highly sensitive to oil spill impacts and almost impossible to clean.

Figure A12: Example of Sheltered Tidal Flat Shoreline (ESI 9)

Sheltered rocky shores (Figure A13) are bedrock shores sheltered from direct wave attack and highly variable in width, from vertical walls to platforms hundreds of meters wide. They have rich intertidal communities. Oil tends to adhere readily to the rough rocky surface, particularly along the high-tide line. Fractures will be sites of pooling and long-term persistence of oil. Cleanup can be intrusive, usually requiring flushing techniques.

Exposed tidal flats (Figure A14) are intertidal habitats that are also flat and unvegetated; however, the substrate is dominated by sand, and exposure to tidal currents or wave activity is evidenced by the presence of wave-built sand ridges or bars. In middle and lower Cook Inlet, they support large populations of shellfish which are sought by both humans and wildlife. They are important feeding and resting areas for birds, fish, seals, and sea lions. Oil does not readily adhere to or penetrate the compact, water-saturated sediments; instead, oil is pushed across the surface and accumulates at the high-water line. Exposure to the water-accommodated fraction or smothering can affect infauna. Cleanup is always difficult because of the potential for mixing oil deeper into the sediments.

Figure A13: Example of Sheltered Rocky Shore (ESI 8A)

Figure A14: Example of Exposed Tidal Flat (ESI 7)

Geographical and Climate Overview

Cook Inlet measures 160 miles in length by 70 miles at its widest point. Depths range from 480 feet to extensive tidal flats.[75] Air temperatures range from above 70ºF in summer to less than -30ºF in winter.

Due to the large tidal range and shallow bathymetry, the waters of Upper Cook Inlet warm rapidly in late spring-early summer and cool rapidly during the autumn months. Lower inlet waters are directly influenced by communications with northern Gulf of Alaska waters, so that these waters are warmer in the mean and exhibit less seasonal variability than the upper inlet waters. Mean water temperatures range from about 36ºF in winter to 50ºF in late summer[76].

Prevailing wind speed and direction vary seasonally and by location in Cook Inlet. Monthly average data for central and lower Cook Inlet are shown in Figure A15. Winds in the winter months average 9 – 10 meters/second (20 – 23 mph) and decrease to 5 – 6 meters/second (11 – 13 mph) in summer in Middle Cook Inlet. Prevailing winds are from the southeast in winter and from the northeast in the winter. In Lower Cook Inlet, average wind speeds are generally lower, ranging from 3 to 5 meters/second (7 – 11 mph), with similar directional patterns as Middle Cook Inlet. Wind speed is important in determining the

[75] See Figures 12 and 13.
[76] Okkonen et al. 2009.

behavior of spilled oil because wind pushes the oil across the water surface at a velocity of 3% of wind speed.

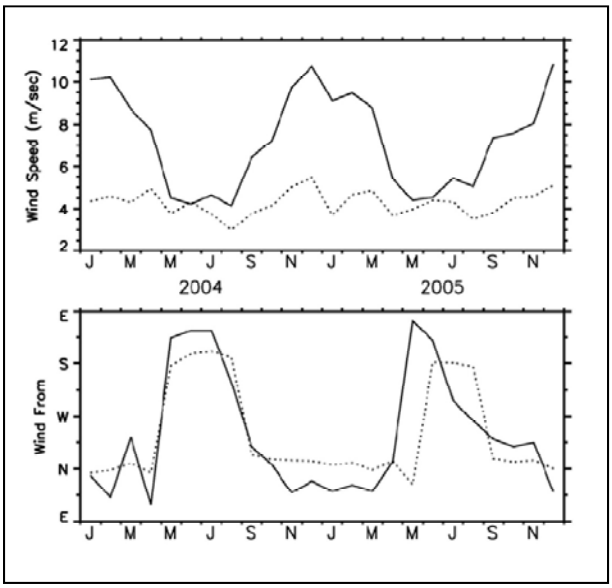

Figure A15: Monthly Average Wind Speed and Direction in Lower and Middle Cook Inlet[77]

Oceanography of Cook Inlet

The physical oceanography of Cook Inlet is characterized by complex circulation with variability at tidal, seasonal, annual, and inter-annual time scales. Circulation is dominated by tidal flow which generates three major rip currents with roughly north-south axes aligned with local bathymetry. Tidal rips have speeds up to six knots, and they account for the majority of volume transport in and out of the inlet (Figures A16 – A18). Tidal currents average 1 – 2 knots maximum in Lower Cook Inlet and 5 – 6 knots maximum in Upper Cook Inlet. During times of extreme tides, maximum currents of 8 knots occur near the Forelands, which is at the southern end of Northern Cook Inlet and the northern end of Middle Cook Inlet.[78] Maximum ebb current is approximately one knot greater than the maximum flood current due to the large inflow of river water into Upper Cook Inlet, which results in the net outflow of water from Cook Inlet into Shelikof Strait south of Lower Cook Inlet. The size of the inlet and the tidal velocities combine to produce out-of-phase tidal heights for Seldovia and Anchorage. The tidal range in the northern section of Cook Inlet is from 33 feet above mean low water to minus 6 feet from mean lower low water.[79]

[77] Okonenen et al. 2009. Monthly average wind speed (top) and vector-averaged direction (bottom) at Kamishak Bay in lower Cook Inlet (solid line) and Drift River in Middle Cook Inlet (dotted line).
[78] Currents exceeding one knot create significant challenges for containment/protection booming in spill response.
[79] Russell 1999.

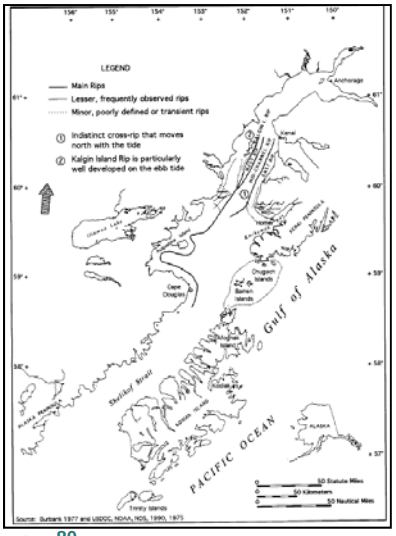

Figure A16: Rip Tides in Cook Inlet[80]

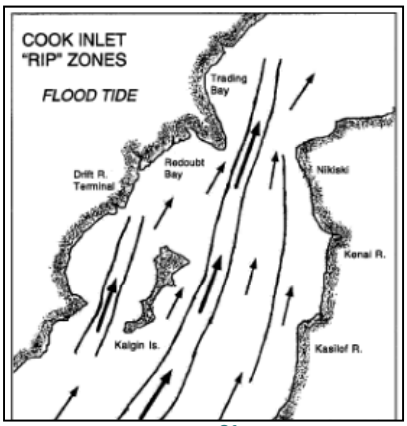

Figure A17: Cook Inlet Rip Zones – Flood Tide[81]

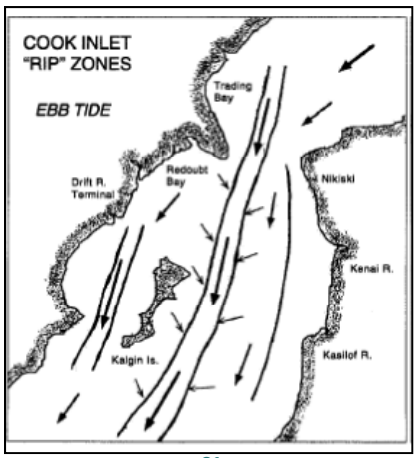

Figure A18: Cook Inlet Rip Zones – Ebb Tide[81]

[80] Wilson and Tomlins 1999; Burbank 1977.
[81] Whitney 1999.

Significant non-tidal circulation features exist as well, including a buoyancy-driven current flowing to the south along the western shore of Cook Inlet, a concentrated, intense, bathymetrically-steered westward flow across lower Cook Inlet, and a slow flow to the north in central and eastern Cook Inlet (Figure A19). These are driven, respectively, by the freshwater flux from Cook Inlet's western shore, and the flow through the open boundary between Cook Inlet and the Gulf of Alaska.[82]

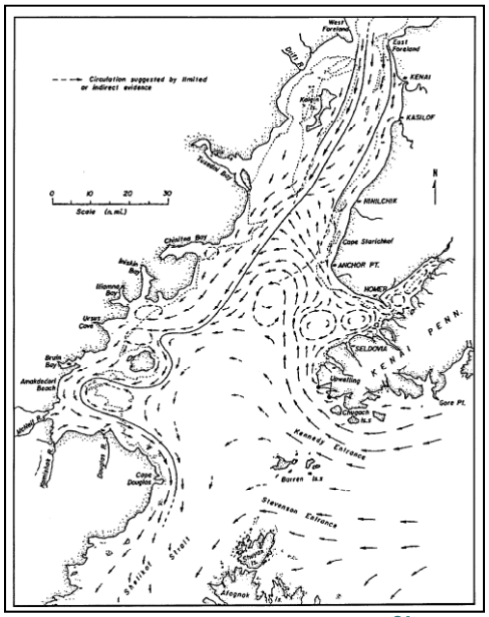

Figure A19: Net Surface Circulation in Lower Cook Inlet[81]

Sea Ice Conditions

Sea ice conditions vary by location in Cook Inlet. Figures A20 and A21 show typical and extreme sea ice conditions in the area, respectively. Typically, in winter through March, Lower Cook Inlet is ice-free except for nearshore areas. The northern part of Middle Cook Inlet and all of Upper Cook Inlet have ice floes and strips. Under extreme conditions, ice is present in parts of Lower Cook Inlet.

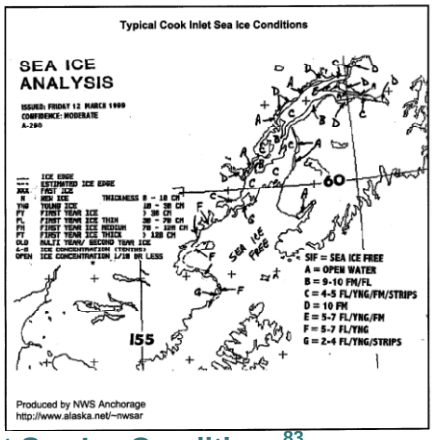

Figure A20: Typical Cook Inlet Sea Ice Conditions[83]

[82] Johnson and Okkonen 1999.
[83] Russell 1999.

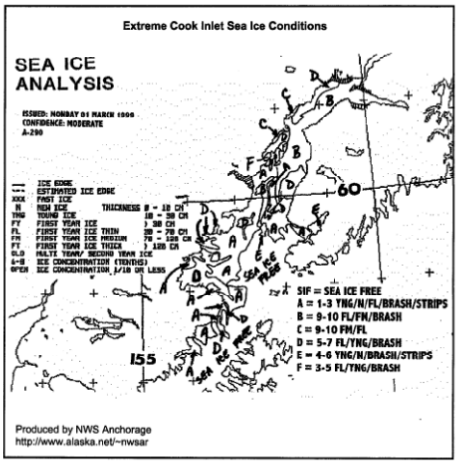

Figure A21: Extreme Cook Inlet Sea Ice Conditions

Spill Impacts: Cook Inlet Location Biological Factors[84]

The potential for biological impacts in the event of an oil spill is of greatest concern both for the environmental impacts as well as for the socioeconomic and cultural impacts associated with impacts to fish and wildlife that are important commercially and culturally for the people of Cook Inlet and the region.

Fish

Cook Inlet has numerous Pacific herring (*Clupea harengus pallasi*) spawning areas. These intertidal and subtidal areas are used for spawning from May through mid-June. Adult herring form large spawning groups and deposit their eggs onto eelgrass, kelp, and other suitable substrate in nearshore areas. Because spawning occurs in shallow water, both adults and eggs are susceptible to exposure to both floating oil slicks and oil stranded on adjacent intertidal areas. Herring eggs are susceptible to mortality, reducing hatching success, and an overall decrease in the percentage of viable hatch. Herring provide an important item in the diet of marine fishes, mammals, and birds, and are also an important commercial fishery.

The region also includes anadromous fish streams. Wild stocks of anadromous salmon are major components to the marine ecosystems of Cook Inlet and the Kenai Peninsula. All five salmon species are present – chinook, coho, chum, pink, and sockeye. When adult fish return to their natal streams to spawn as early as May (sockeye) and as late as November (coho), they tend to concentrate at the stream mouths prior to moving upstream. Most spawning beds are well upstream, beyond the limit of tidal excursions that could carry oil slicks inland. Juvenile salmon can be present throughout the area and tend to concentrate in shallow, nearshore habitats. They are especially susceptible because of the potential for higher exposures and increased sensitivity to oil when first in seawater.

Shellfish

Cook Inlet holds major razor clam (*Siliqua patula*) beds in intertidal and shallow subtidal areas. The razor clams are an important food item for birds and sea otters, and support subsistence and sport fisheries in

[84] NOAA Cook Inlet and Kenai Peninsula, Alaska, Environmental Sensitivity Areas (2002)

the region. Because they are sedentary filter-feeders and occur in nearshore areas, they are at risk of contamination by spilled oil.

Birds

There are numerous areas in Cook Inlet that are documented as marine bird nesting sites from May through September. Birds are in the vicinity of the colony from April through October. Nesting sites are of particular concern because of the high concentration of birds in adjacent waters, the potential for contamination of eggs and young by oiled feathers on the adult, and disturbances to the colony by oil spill cleanup activity. The marine bird species present in Cook Inlet include:

- Northern fulmar
- Black-legged kittiwake
- Fork-tailed storm-petrel
- Cormorant
- Black oystercatcher
- Common eider
- Glaucous-winged gull
- Pelagic cormorant
- Red-faced cormorant
- Double-crested cormorant
- Mew gull
- Arctic tern
- Rhinoceros auklet
- Parakeet auklet
- Common murre
- Tufted puffin
- Horned puffin
- Pigeon guillemot
- Ancient murrelet
- Thick-billed murre
- Leach's storm-petrel
- Aleutian tern
- Herring gull
- Glaucous-winged/herring gull hybrid

There are at least 309 documented bald eagle nests along the shoreline of Cook Inlet. Although bald eagles are present year-round, the greatest danger to the eagles is during the spring and summer nesting season. Eagles can become oiled when they feed on oiled prey, and eggs can become contaminated with oil carried on the plumage of nesting adults.

Seabirds are also present in large concentrations in some parts of Cook Inlet during the summer and winter feeding and during fall staging. Migratory waterfowl congregate in large concentrations in coastal areas of Cook Inlet in the spring (mid-April to mid-May) and fall (mid-August through November). Waterfowl present include:

- Dabbling ducks (pintail, widgeon, green-winged teal, northern shoveler, and mallard);
- Diving ducks (scaups, scoters, canvasbacks, goldeneyes, bufflehead, oldsquaw, harlequin, and mergansers); and
- Geese and swans (Canada goose, snow goose, white-fronted goose, tundra swan, and trumpeter swan).

Waterfowl are particularly vulnerable to oiling during the molting period (late June to mid-August) and the winter season. Areas along the western coast of Cook Inlet (Susitna Flats, Trading Bay, and Redoubt Bay), as well as Kenai River, Kasilof River, and Chickaloon Bay, are especially important as spring migration areas. Steller's eider is listed as Threatened under the Endangered Species Act. Steller's eider are concentrated in some areas of Cook Inlet during winter and spring.

There are also several shorebird concentration areas in the form of intertidal staging areas where large numbers of shorebirds rest and feed during spring and fall migrations. Areas identified as shorebird concentration areas contain dense populations of *Macoma* clams, which are a critical food item for shorebirds. If clam beds are impacted by oil, shorebird populations will also be severely impacted.A large number of species can be present, with the dominant species including:

- Least sandpiper;
- Western sandpiper; and
- Semipalmated plover.

Marine Mammals

There are several harbor seal haulout concentrations areas in Cook Inlet. These are locations where harbor seals (*Phoca vitulina richardsi*) have been documented to concentrate for resting, molting, and pupping. Harbor seals are present in the area year-round; however they are most sensitive when hauled out of water and during pupping which occurs during June and July. Pups are born at the same locations as those used as haulouts at other times of year. Harbor seals rely on blubber to conserve body heat; thus, oil impacts are related to ingestion and inhalation. Harbor seal populations have declined precipitously since 1984, making them highly sensitive to additional stress from exposure to oil and disturbances during cleanup activities.

There are also two Steller sea lion haulouts where Stellar sea lions (*Eumetopias jubatus*) rest, molt, and pup. Sea lions are present year-round; they are, however, most sensitive during haulout. Sugarloaf Island and Pye Island are the only known rookeries in the region and thus are of major concern. Sea lions rely on blubber to conserve body heat; thus, oil impacts are related to ingestion and inhalation. Their populations have declined precipitously since 1970, with declines as great at 93%, making them highly sensitive to additional stress from exposure to oil and disturbances during cleanup activities.

Sea otters (*Enhydra lutris*) are concentrated in the areas of Kamishak and Kachemak Bays and along the southern shoreline of Kenai Peninsulat. On the peninsula, the otters have the highest concentrations at the heads of the bays. Sea otters are highly sensitive to oil spills, suffering death from hypothermia and severe internal injuries from ingestion and inhalation of oil.

There are Beluga whale (*Delphinapterus leucas*) concentrations in Cook Inlet. Belugas are year-round residents but tend to concentrate near river mouths in the upper inlet in the spring and early summer. In fall and winter, belugas spread out to cover Upper Cook Inlet from Kalgin Island north. Gray whales' spring migration (April to May) route follows the Kenai Peninsula south past the Barren Islands en route to their summer feeding grounds in the Chukchi and Bering Seas. Humpback whales concentrate around the Barren Islands in the summer and fall. Killer whales are most common in the summer around the islands of the Kenai Peninsula and in Kachemak Bay. Other than the beluga, whale species are not common in Cook Inlet, although the pass by the Kenai Peninsula during migration. Fine whales have been spotted occasionally in the mouth of the inlet. Humpback whales are very common off the Barren Islands in summer. Dolphins are widely distributed throughout the region. Whales and dolphins are not considered to be highly sensitive to oil spills, but their special management status mandates mitigation of all possible impacts from oil spills and their cleanup.

Spill Impacts: Cook Inlet Seasonal/Locational Environmental Factors[85]

The presence of sensitive wildlife and wildlife habitats vary by location and season in each of the sub-areas of Cook Inlet. An overview of these areas is presented here. The key to the Environmental Sensitivity Index (ESI) maps presented is shown in Figure A22.

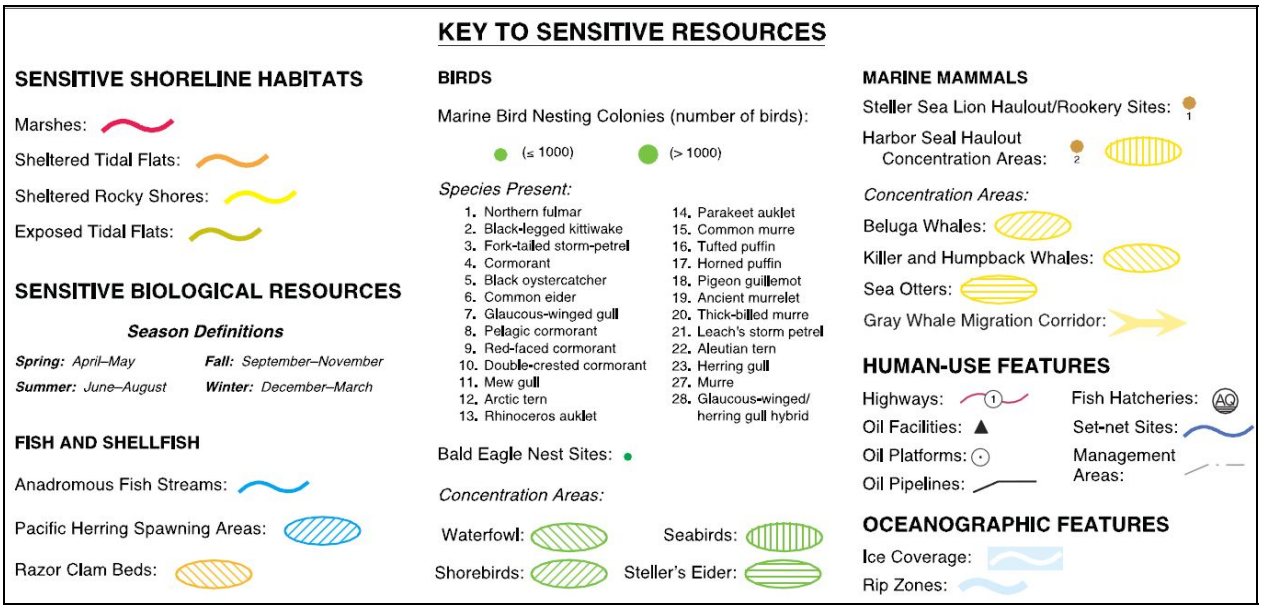

Figure A22: Key for ESI Maps

Upper Cook Inlet

Upper Cook Inlet has extensive areas of salt/brackish marshes, some sheltered and exposed tidal flats. There are tidally- affected anadromous fish streams that empty into the inlet waters, particularly on the northern and western parts of the inlet. The Anchorage Coastal Wildlife Refuge is location in Turnagain Arm in northeastern Upper Cook Inlet.

In the spring into early summer (Figure23), there are extensive areas in Upper Cook Inlet where beluga whales concentrate near river mouths. There are also harbor seal haulout areas. Migratory waterfowl gather in many sections. There are numerous marine bird nesting colonies some of which contain more than 1,000 birds at a time, particularly in May into early summer. Anadromous fish (sockeye salmon, in particular) return to their natal streams in May. Summer distributions (Figure A24) are similar, though numbers of migratory birds are lower. Bald eagles nest in the spring and summer.

[85] NOAA Cook Inlet and Kenai Peninsula, Alaska, Environmental Sensitivity Areas (2002)

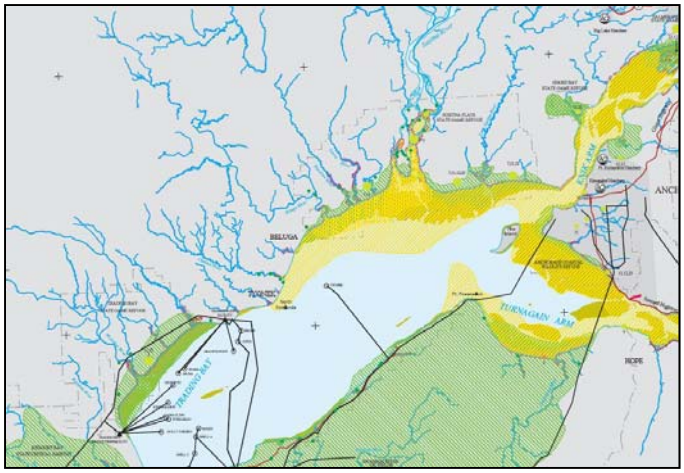

Figure A23: ESI Map of Upper Cook Inlet in Spring

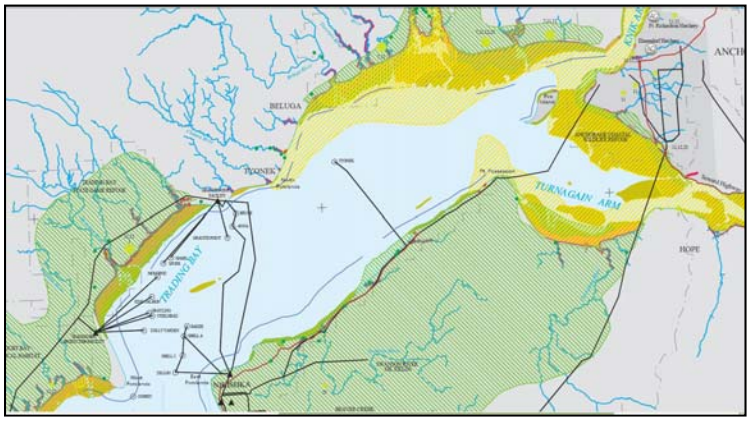

Figure A24: ESI Map of Upper Cook Inlet in Summer

In the autumn, there are again migratory birds. Coho salmon return to natal streams for spawning. The area in which beluga whales concentrate extends through much of the Upper inlet area (Figure A25). In the winter months,[86] there are no longer threats to marine mammals and migratory birds (Figure A26).

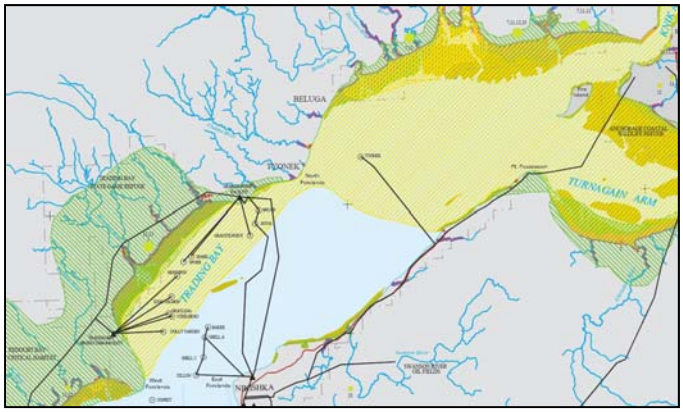

Figure A25: ESI Map of Upper Cook Inlet in Autumn

[86] December through March.

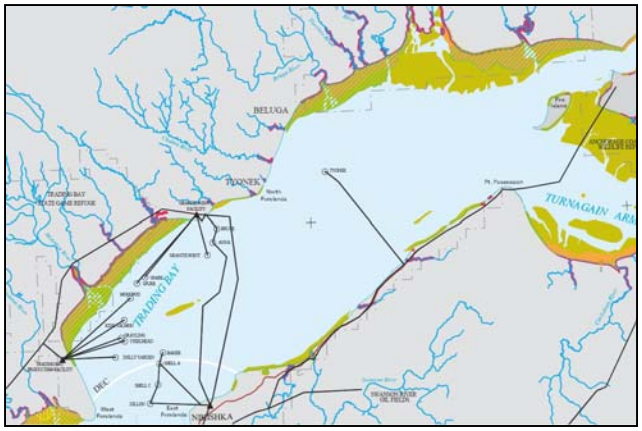

Figure A26: ESI Map of Upper Cook Inlet in Winter

Middle Cook Inlet

Middle Cook Inlet has several areas of salt/brackish marsh as well as sheltered tidal flats. Anadromous streams empty into the Redoubt Bay on the western shore. There are also extensive razor clam beds on the western shore of Redoubt Bay. Kalgin Island, an Alaskan State Critical Habitat, is situated in the middle of the inlet. The island has extensive wetland areas and is a critical habitat in spring and fall for waterfowl and shorebirds. There are harbor seal haulouts on the island as well.

There are some areas in which beluga and killer whales concentrate in the spring. Migratory waterfowl concentration nesting areas, as well as concentration areas for Steller's eider, a Threatened species, in middle Cook Inlet in the spring (Figure A27).

Beluga whales concentrate in some areas. Spring and summer distributions are similar (Figure A28).

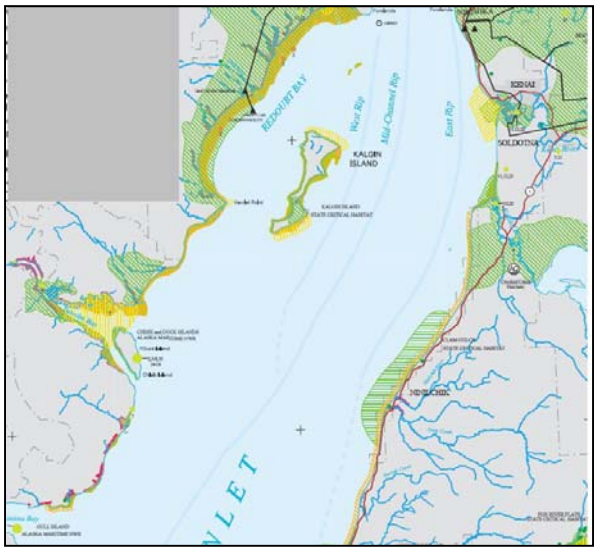

Figure A27: ESI Map of Middle Cook Inlet in Spring

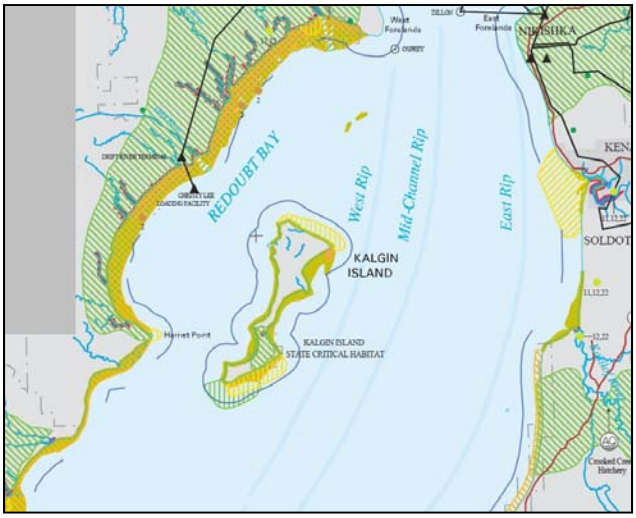

Figure A28: ESI Map of Middle Cook Inlet in Summer

In the autumn there are migratory waterfowl and marine birds in the region (Figure A29). By winter, these have left, but there is a Steller's eider concentration area of concern in Middle Cook Inlet (Figure A30).

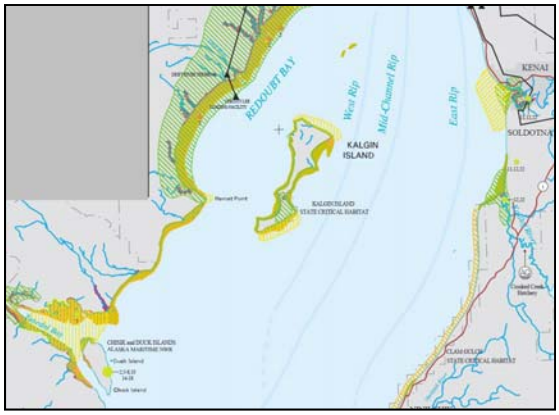

Figure A29: ESI Map of Middle Cook Inlet in Autumn

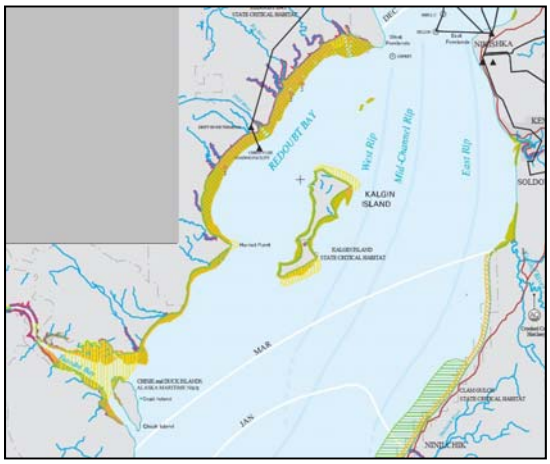

Figure A30: ESI Map of Middle Cook Inlet in Winter

Lower Cook Inlet

Lower Cook Inlet includes several salt/brackish marsh, sheltered tidal flat, and exposed tidal flat areas. On the eastern side of the inlet is the Kachemak Bay State Critical Habitat, which has an important Pacific herring spawning area. There is a second major Pacific herring spawning area in Kamishak Bay. On the western shore, there is the Gull Island Alaska Maritime National Wildlife Reserve, as well as the Alaska Maritime National Wildlife Reserve. Lower Cook Inlet also includes the Barren Islands Alaska Maritime National Wildlife Refuge, which includes a Steller sea lion haulout. Sugarloaf Island (along with Pye Island, which is outside the study zone) is one of the only two known Steller sea lion rookeries in the area.

During the all months, sea otters are common through Kachemak and Kamishak Bays. There are large numbers of harbor seal haulouts and marine bird colonies (Figure A31). In summer (Figure A32), there are large areas of sea birds, as well as killer and humpback whales near Kenai Peninsula, Kachemak Bay, and Kennedy Entrance.

Figure A31: ESI Map of Lower Cook Inlet in Spring

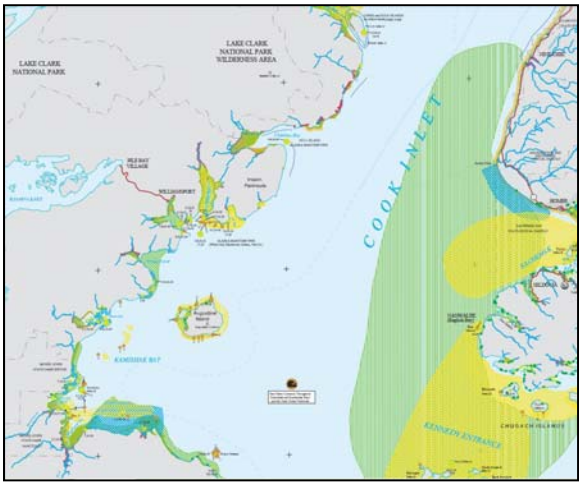

Figure A32: ESI Map of Lower Cook Inlet in Summer

In the autumn, there large areas of marine bird concentration, as well as concentrations of killer and humpback whales around the Barren Islands Alaska Maritime National Wildlife Refuge (Figure A33).

In the winter, waterfowl and Steller's eider concentrate in Kachemak Bay. Sea otters and harbor seals remain in many areas around Augustine Island and along the western shores of Kamishak Bay (Figure A34).

Figure A33: ESI Map of Lower Cook Inlet in Autumn

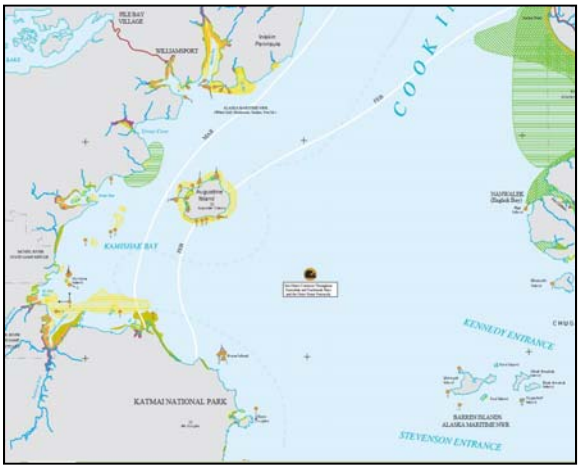

Figure A34: ESI Map of Lower Cook Inlet in Winter

Table A62 summarizes the relative probabilities of impact by oil spilled in the three Cook Inlet sub-areas by season. Note that this only reflects the probability that there would be oil contact, not the degree of impact or injury, which varies by type of species and the oil type.

The sensitivity of the species is addressed in Table A63.

Table A62: Summary of Biological Contact Probability of Cook Inlet Sub-Areas by Season

Sub-Area	Season	Moderate or High Probability of Contact									
		Fish		Shellfish	Birds				Marine Mammals		
		Salmon	Herring	Razor Clams	Water-fowl	Sea Birds	Shore Birds	Steller's Eider	Otters	Sea Lions	Whales
Upper Cook Inlet	Spring	H		H	H					M	M
	Summer			H	M					H	
	Autumn	H		H	H					M	H
	Winter			H						M	

Table A62: Summary of Biological Contact Probability of Cook Inlet Sub-Areas by Season											
Sub-Area	Season	Moderate or High Probability of Contact									
		Fish		Shellfish	Birds				Marine Mammals		
		Salmon	Herring	Razor Clams	Water-fowl	Sea Birds	Shore Birds	Steller's Eider	Otters	Sea Lions	Whales
Middle Cook Inlet	Spring			H	H		H	H		M	M
	Summer			H	M		M			H	M
	Autumn			H	H		M			M	M
	Winter			H			H			M	
Lower Cook Inlet	Spring		H			H			H	M	
	Summer		H			M			H	H	
	Autumn					H			H	M	
	Winter							H	H	M	

The relative degree of sensitivity to oiling of the different species types by the four different oil categories is shown in Table A63. As previously discussed, the different oil categories differ with regard to their impacts to different organisms and habitats based on their overall toxicity, persistence, and adherence (coating) propensity, as summarized in Table A64. The groups of species also differ in their behavior and probability of contact with the oil.

Table A63: Summary of Overall Degree of Sensitivity to Oiling										
Oil Category	Degree of Sensitivity to Oiling									
	Fish		Shellfish	Birds				Marine Mammals		
	Salmon	Herring	Razor Clams	Water -fowl	Sea Birds	Shore Birds	Steller's Eider	Otters	Sea Lions	Whales [87]
Non-Persistent	H	H	L	L	L	L	L	L	L	L
Low Persistent	H	H	M	M	M	L	M	M	M	L
Med. Persistent	M	M	H	H	H	M	H	H	H	L
Heavy Persistent	L	L	H	H	H	H	H	H	H	L

Table A64: Basic Oil Properties as Affect Wildlife and Habitat Impacts			
Oil Category	Oil Property		
	Toxicity	Persistence	Adherence
Non-Persistent	VH	VL	VL
Low Persistent	H	L	L
Med. Persistent	M	M	H
Heavy Persistent	L	VH	VH

The degree of impact by different oils will also depend in large part of the degree of contact and the duration of the exposure, particularly with regard to toxicity. The "dose" of oil is a combination of the toxicity of the oil based on its chemical components, the duration of the exposure in time, and the sensitivity of the particular organisms. The volume of spillage, as well as the oil type, are important factors in determining dose.

Behavior of Oil in Cook Inlet

While each oil spill is a unique event whose outcome in terms of impacts depends on a wide variety of situation- and location-specific factors, there are certain general observations that have been made on past spills and certain general characteristics of spills that can be derived from knowledge of the physics and

[87] Whales are not generally considered to be highly sensitive to oil spills because of avoidance behavior, but there special management mandates mitigation of all possible impacts from oil spills and cleanup activities.

chemistry involved. The general behavior of oil spills and general projections of the variety of vessel-sourced spills[88] that might occur in Cook Inlet are reviewed here.

Spread of Oil (Slick Size)

The size of an oil slick on the water surface is dependent on the volume of oil. Oil spreads out very quickly from its source of spillage to a thin layer that is about 0.1 mm thick. As it spreads even more into a "sheen" it decreases in thickness to about 0.0003 mm for a "rainbow" sheen and 0.0001 mm for a "silver" sheen. Table A65 shows the areal coverage of some representative volumes of spillage as fresh slicks and as sheens.

Note that spilled oil rarely stays in a continuous slick, especially with larger spill volumes and in areas of active currents and winds. The oil will spread not only out to become thinner, but also form patches and windrows. Emulsified oil ("mousse") will tend to be considerably thicker on the water surface than fresh oil, but this contains a large percentage of water in addition to oil.

Table A65: Approximate Areal Coverage of Oil Slicks

Spill Volume (gallons)	Area of Coverage (Square Miles)		
	Fresh Slick	Rainbow Sheen	Silver Sheen
1	0.00001	0.005	0.01
10	0.0001	0.05	0.1
100	0.001	0.5	1.0
1,000	0.014	5.0	10
10,000	0.14	50	100
100,000	1.4	500	1,000
1,000,000	14.0	5,000	10,000
10,000,000	140	50,000	100,000
75,000,000	1,100	360,000	1,100,000

Oil Persistence on Water Surface

The oil "persists" on the water surface, i.e., stays as a "slick" or fragments of "slicks" or sheen for a certain amount of time before it evaporates, disperses, and/or dissolves. The rate of evaporation will vary with oil type, with lighter oils (non-persistent and low persistent) evaporating more quickly and to a greater extent than heavier oils. Water temperature also affects the rate of evaporation with evaporation increasing with temperature. The estimated time on the water surface for crude oil spills (medium persistent) is shown in Table A66.[89]

Table A66: Estimated Time on Water Surface for Crude Oil Spills in Cook Inlet

Spill Volume (gallons)	Estimated Time on Water Surface	
	Summer (50ºF)	Winter (36ºF)
1	2.0	2.0
10	2.0	2.0
100	2.1	2.1
1,000	2.8	2.8
10,000	10.1	10.1
100,000	20.1	30.4
1,000,000	22.3	32.6

[88] Refer to Table 59.
[89] Based on methodology presented in Appendix B. (SL Ross et al. 2003).

Table A66: Estimated Time on Water Surface for Crude Oil Spills in Cook Inlet		
Spill Volume (gallons)	**Estimated Time on Water Surface**	
	Summer (50ºF)	**Winter (36ºF)**
10,000,000	43.7	54.0
75,000,000	198.5	208.8

Spill Trajectories

The trajectory (movement on the water surface) of spilled oil will depend on conditions in the area of spillage, including wind speed and direction, current velocity and direction, tidal influences, and the geographical contours of the coastline. The fate of the oil will depend on the oil type, water and air temperatures, and water salinity. The effects will depend on these factors combined with the presence of organisms in the path of the spill trajectory, the volume of oil, the duration of exposure, and the sensitivity of the organisms.

A relatively small spill (100 gallons or less, perhaps up to 1,000 gallons) will tend to impact a relatively small area, though the actual impacts will depend both on oil type and the location of the spill. If the spill occurs in a highly sensitive location or in close proximity to such a site, there could be considerable localized damages. While the ecosystem and local populations of wildlife will recover in a relatively short period of time in most cases, if the spill occurs in the nesting area of an endangered species, e.g., it could cause a relatively significant amount of long-term damage.

Based on the information available on currents, tides, and winds in Cook Inlet, the *very rough* projections in Table A67 could be made with regard to the trajectories of moderate-sized to larger spills by sub-area and season.[90] Very large spills (1 million gallons or more) would tend to spread throughout large areas of Cook Inlet with the slicks moving with the ebb and flood tides.

Table A67: Estimated Path of Spilled Oil in Cook Inlet				
Sub Area	**Spring**	**Summer**	**Autumn**	**Winter**
Upper Cook Inlet	Prevailing SW winds push oil towards NE; Oil moves at 0.5 mph ; Flood tides bring oil high into marsh areas, shorelines, streams	Prevailing NE winds push oil towards SW; Oil moves at 0.3 mph ; Flood tides bring oil high into marsh areas, shorelines, streams	Prevailing NW winds push oil towards SE; Oil moves at 0.5 mph ; Flood tides bring oil high into marsh areas, shorelines, streams	Prevailing SE winds push oil towards NW; Oil moves at 0.6 mph ; Flood tides bring oil high into marsh areas, shorelines, streams; Sea ice deters movement of oil slick
Middle Cook Inlet	Prevailing SW winds push oil towards NE; Oil moves at 0.3 mph ; Flood tides bring oil into marsh areas streams	Prevailing NE winds push oil towards SW; Oil moves at 0.3 mph ; Flood tides bring oil into marsh areas streams	Prevailing NW winds push oil towards SE; Oil moves at 0.3 mph ; Flood tides bring oil into marsh areas streams	Prevailing SE winds push oil towards NW; Oil moves at 0.3 mph ; Flood tides bring oil into marsh areas streams

[90] Without the benefit of running spill trajectory models, such as SIMAP or GNOME, it is difficult to predict with any degree of accuracy where spilled oil might go and the way in which it might behave in the environment. While prevailing wind patterns and currents can be used to predict the general path of a spill, variations in the wind at the time of the spill and the exact timing of the spill with regard to tidal cycles can have a significant impact on the trajectory, fate, and effects of oil. For this reason, it is highly recommended to employ a stochastically-based oil spill trajectory, fate, and effects model to determine the range of possible outcomes given random variations in the timing and wind/current/tide conditions for a spill.

Table A67: Estimated Path of Spilled Oil in Cook Inlet				
Sub Area	**Spring**	**Summer**	**Autumn**	**Winter**
Lower Cook Inlet	Prevailing SW winds push oil towards NE; Oil moves at 0.3 mph ; Flood tides bring oil into marsh areas streams	Prevailing NE winds push oil towards SW; Oil moves at 0.3 mph ; Flood tides bring oil into marsh areas streams	Prevailing NW winds push oil towards SE; Oil moves at 0.3 mph ; Flood tides bring oil into marsh areas streams	Prevailing SE winds push oil towards NW; Oil moves at 0.3 mph ; Flood tides bring oil into marsh areas streams

Fate of Oil

The behavior or fate of the oil four oil groups in different temperatures, representative of winter and summer seasons, by spill volume were modeled using NOAA's ADIOS2 software. Jet fuel was used as the representative Non-Persistent Oil, diesel fuel as the representative Low Persistent Oil, Alaskan North Slope Crude as the representative Medium Persistent Oil, and Bunker C (No. 6 Fuel) as the representative Heavy Persistent Oil.

The results with regard to the "oil budget" or percentage of oil that ultimately evaporates, remains in the environment, and disperses without consideration of any spill response is shown in Tables A68 through A71 for the four oil categories. Different general spill volumes were run based on spill volumes determined for the different vessel types and spill causes. Because the water temperature is most important in determining the differences between seasons in the fate of the oil, summer and autumn were grouped together along with winter and spring. Spills of less than 100 gallons were not modeled due to limitations of the ADIOS2 software. Spills of this volume would have a relatively limited duration on the water surface.

Table A68: Fate of Spilled Non-Persistent Oil (Jet Fuel) Based on ADIOS2 Modeling[91]						
Spill Volume (gallons)	**Summer/Autumn**			**Winter/Spring**		
	Percent Evaporated	**Percent Dispersed**	**Percent Remaining**	**Percent Evaporated**	**Percent Dispersed**	**Percent Remaining**
100	69%	20%	10%	42%	45%	13%
1,000	50%	35%	15%	42%	47%	11%
10,000	50%	36%	13%	39%	44%	17%
100,000	48%	37%	15%	37%	46%	17%
1,000,000	46%	40%	14%	34%	47%	19%
10,000,000	46%	44%	10%	35%	55%	10%
75,000,000	44%	43%	13%	34%	53%	13%

Table A69: Fate of Spilled Low-Persistent Oil (Diesel) Based on ADIOS2 Modeling[92]						
Spill Volume (gallons)	**Summer/Autumn**			**Winter/Spring**		
	Percent Evaporated	**Percent Dispersed**	**Percent Remaining**	**Percent Evaporated**	**Percent Dispersed**	**Percent Remaining**
100	39%	35%	27%	36%	52%	13%
1,000	41%	45%	14%	35%	53%	12%
10,000	40%	48%	12%	34%	55%	10%
100,000	38%	45%	17%	31%	55%	13%
1,000,000	36%	45%	18%	32%	56%	12%

[91] For a jet fuel spill, evaporation and dispersion are very rapid so that the results shown occur within on e day of the spill for smaller spills and two to three days for the largest spills.
[92] Evaporation and dispersion occur rapidly with a diesel spill. The results shown are within one day for smaller spills and within two to three days for larger spills.

Table A69: Fate of Spilled Low-Persistent Oil (Diesel) Based on ADIOS2 Modeling[92]						
Spill Volume (gallons)	Summer/Autumn			Winter/Spring		
	Percent Evaporated	Percent Dispersed	Percent Remaining	Percent Evaporated	Percent Dispersed	Percent Remaining
10,000,000	35%	50%	15%	31%	56%	14%
75,000,000	36%	53%	10%	31%	59%	10%

Table A70: Fate of Spilled Medium-Persistent Oil (ANS Crude) Based on ADIOS2 Modeling[93]						
Spill Volume (gallons)	Summer/Autumn			Winter/Spring		
	Percent Evaporated	Percent Dispersed	Percent Remaining	Percent Evaporated	Percent Dispersed	Percent Remaining
100	53%	3%	44%	45%	3%	52%
1,000	50%	3%	47%	43%	3%	54%
10,000	48%	2%	50%	41%	2%	57%
100,000	43%	2%	56%	37%	2%	61%
1,000,000	38%	1%	61%	33%	1%	65%
10,000,000	33%	1%	65%	30%	1%	69%
75,000,000	32%	1%	67%	29%	1%	70%

Table A71: Fate of Spilled Heavy-Persistent Oil (Bunker C-No. 6 Fuel) Based on ADIOS2 Modeling[93]						
Spill Volume (gallons)	Summer/Autumn			Winter/Spring		
	Percent Evaporated	Percent Dispersed	Percent Remaining	Percent Evaporated	Percent Dispersed	Percent Remaining
100	18%	0%	82%	16%	0%	84%
1,000	18%	0%	82%	16%	0%	84%
10,000	17%	0%	83%	15%	0%	85%
100,000	16%	0%	84%	14%	0%	86%
1,000,000	15%	0%	85%	13%	0%	87%
10,000,000	13%	0%	87%	11%	0%	89%
75,000,000	12%	0%	88%	10%	0%	90%

In general, it has been observed that the larger the spill and the colder the water, the slower the evaporation and dispersion rate. The heavier the oil, the less evaporates and disperses, and the more remains. For heavy persistent spills, a large percentage – 84% to 90% is still present after 5 days. For medium persistent spills, 70% is remaining after that time. For low persistent and non-persistent oil spills, 10% to 17% remains. With larger spills, the evaporation and dispersion rate occurs more slowly and to a lesser extent.

For non-persistent spills (e.g., jet fuel or gasoline), additional time will result in nearly all of the oil evaporating and/or dispersing. (The results shown are limitations of the ADIOS2 model algorithms.)

General Conclusions on Potential Spill Impacts

The degrees of environmental impact of potential spills into the waters of Cook Inlet from vessels were analyzed with regard to the main factors that would affect those impacts – oil type, spill volume, location, and season. The results are summarized in Table A72 through Table A74 by Cook Inlet sub-area (the location of the spill). Note that spills of larger volumes of oil in one sub-area will almost certainly affect other parts of Cook Inlet, as well as areas outside of Cook Inlet.

[93] Results after 5 days.

Very generalized degrees of environmental impact presented in these tables are defined on a five-point scale as follows, with the approximate point system developed to allow for a quasi-quantitative ranking for the purpose of risk assessment:[94]

- **Very High Impact (VH) (5 points):** Long-term impacts (over five years) anticipated over a large part of Cook Inlet and potentially outside of the Inlet in other areas of Alaskan waters and coastal areas and/or significant impacts to threatened species or species indicated for special management. Recovery of populations and ecosystems will take over five years and/or threatened or special-management species will be very significantly impacted at the population level.
- **High Impact (H) (4 points)**: Moderate-term impacts (two to five years) anticipated over a large part of Cook Inlet or very significant (high) impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take two to five years.
- **Moderate Impact (M) (3 points):** Moderate-term impacts (two to five years) anticipated over a smaller part of Cook Inlet or significant (high) impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take two to five years.
- **Low Impact (L) (2 points):** Significant shorter-term impacts (under two years) to a large part of Cook Inlet or moderate impacts to specific areas of the Inlet. Recovery of populations and ecosystems will take less than two years.
- **Very Low Impact (VL) (1 point):** Significant shorter-term impacts (under two years) to smaller parts of Cook Inlet or low impacts to larger areas of the Inlet. Recovery of populations and ecosystems will take less than two years.

The oil volumes presented in the tables are based on magnitudes of spill volume by oil type for the different vessel type incidents analyzed.

Table A72: Oil Spill Impacts for Upper Cook Inlet by Oil Type, Volume, and Season

Oil Type	Volume (gallons)	Spring	Summer	Autumn	Winter
Non-Persistent	**1**	VL	VL	VL	VL
Non-Persistent	**10**	VL	VL	VL	VL
Non-Persistent	**50**	VL	VL	VL	VL
Non-Persistent	**100**	VL	VL	VL	VL
Non-Persistent	**200**	VL	VL	VL	VL
Non-Persistent	**500**	VL	VL	VL	VL
Non-Persistent	**2,000**	L	L	L	VL
Non-Persistent	**300,000**	M	M	M	L

[94] Determining the rate of ecosystem and population recovery is extremely complex. There are a large number of complex and inter-related factors involved in determining short- and long-term consequences of oil spills. There is considerable and legitimate debate in the scientific community about scientific data on short- and long-term recovery rates and the ways in which the results of many spill impact studies and models should be interpreted and applied. A complete analysis would require highly complex modeling and studies outside of the scope of the Cook Inlet Maritime Risk Assessment project. The rating system presented here and its application to the vessel spill scenarios in the analysis are based on generalized data analyses on spill impacts based on studies of hundreds of spill case studies and over one thousand spill impact studies. In addition to the limitations of assigning impact values to hypothetical spills, there is the not insignificant issue of cultural values placed on impacts to the environment of Cook Inlet that can only truly be understood and appreciated by the myriad of stakeholders in Cook Inlet and in Alaska as a whole. While from an ecosystem and population-level perspective, recovery rates may be similar to those indicated here, the "acceptability" of any degree of environmental impacts from spills will be a matter for stakeholders to consider. This aspect is outside the scope of this assessment.

Table A72: Oil Spill Impacts for Upper Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Non-Persistent	**1,520,000**	H	H	H	L
Non-Persistent	**1,900,000**	H	H	H	L
Low Persistent	**1**	VL	VL	VL	VL
Low Persistent	**10**	VL	VL	VL	VL
Low Persistent	**50**	VL	VL	VL	VL
Low Persistent	**100**	VL	VL	VL	VL
Low Persistent	**200**	VL	VL	VL	VL
Low Persistent	**500**	VL	VL	VL	VL
Low Persistent	**1,000**	L	L	L	VL
Low Persistent	**2,000**	L	L	L	VL
Low Persistent	**5,000**	L	L	L	VL
Low Persistent	**20,000**	M	M	M	L
Low Persistent	**36,000**	M	M	M	L
Low Persistent	**150,000**	M	M	M	L
Low Persistent	**300,000**	M	M	M	L
Low Persistent	**605,000**	M	M	M	L
Low Persistent	**1,000,000**	H	H	H	M
Low Persistent	**1,520,000**	H	H	H	M
Low Persistent	**1,900,000**	H	H	H	M
Low Persistent	**2,000,000**	H	H	H	M
Low Persistent	**3,500,000**	H	H	H	M
Low Persistent	**4,000,000**	H	H	H	M
Low Persistent	**7,980,000**	H	H	H	M
Low Persistent	**21,000,000**	VH	H	VH	M
Medium Persistent	**1**	VL	VL	VL	VL
Medium Persistent	**10**	VL	VL	VL	VL
Medium Persistent	**100**	VL	VL	VL	VL
Medium Persistent	**500**	L	L	L	VL
Medium Persistent	**2,000**	M	M	M	L
Medium Persistent	**20,000**	M	M	M	M
Medium Persistent	**8,000,000**	H	H	H	H
Medium Persistent	**15,000,000**	VH	VH	VH	VH
Medium Persistent	**28,500,000**	VH	VH	VH	VH
Medium Persistent	**75,000,000**	VH	VH	VH	VH
Heavy Persistent	**1**	VL	VL	VL	VL
Heavy Persistent	**5**	VL	VL	VL	VL
Heavy Persistent	**10**	VL	VL	VL	VL
Heavy Persistent	**50**	VL	VL	VL	VL
Heavy Persistent	**100**	VL	VL	VL	VL
Heavy Persistent	**500**	L	L	L	VL
Heavy Persistent	**1,000**	L	L	L	VL
Heavy Persistent	**2,000**	L	L	L	VL
Heavy Persistent	**5,000**	M	M	M	L
Heavy Persistent	**20,000**	M	M	M	M
Heavy Persistent	**42,000**	M	M	M	M
Heavy Persistent	**300,000**	H	H	H	M
Heavy Persistent	**605,000**	H	H	H	M
Heavy Persistent	**1,000,000**	VH	H	VH	H
Heavy Persistent	**2,000,000**	VH	H	VH	H
Heavy Persistent	**3,500,000**	VH	H	VH	H

Table A73: Oil Spill Impacts for Middle Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Non-Persistent	**1**	VL	VL	VL	VL
Non-Persistent	**10**	VL	VL	VL	VL
Non-Persistent	**50**	VL	VL	VL	VL
Non-Persistent	**100**	VL	VL	VL	VL
Non-Persistent	**200**	VL	VL	VL	VL
Non-Persistent	**500**	VL	VL	VL	VL
Non-Persistent	**2,000**	L	VL	L	VL
Non-Persistent	**300,000**	M	L	M	L
Non-Persistent	**1,520,000**	H	M	H	L
Non-Persistent	**1,900,000**	H	M	H	L
Low Persistent	**1**	VL	VL	VL	VL
Low Persistent	**10**	VL	VL	VL	VL
Low Persistent	**50**	VL	VL	VL	VL
Low Persistent	**100**	VL	VL	VL	VL
Low Persistent	**200**	VL	VL	VL	VL
Low Persistent	**500**	VL	VL	VL	VL
Low Persistent	**1,000**	L	VL	L	VL
Low Persistent	**2,000**	L	VL	L	VL
Low Persistent	**5,000**	L	VL	L	VL
Low Persistent	**20,000**	M	L	M	L
Low Persistent	**36,000**	M	L	M	L
Low Persistent	**150,000**	M	L	M	L
Low Persistent	**300,000**	M	L	M	L
Low Persistent	**605,000**	M	L	M	L
Low Persistent	**1,000,000**	H	M	H	L
Low Persistent	**1,520,000**	H	M	H	L
Low Persistent	**1,900,000**	H	M	H	L
Low Persistent	**2,000,000**	H	M	H	L
Low Persistent	**3,500,000**	H	M	H	L
Low Persistent	**4,000,000**	H	M	H	M
Low Persistent	**7,980,000**	H	M	H	M
Low Persistent	**21,000,000**	VH	H	VH	M
Medium Persistent	**1**	VL	VL	VL	VL
Medium Persistent	**10**	VL	VL	VL	VL
Medium Persistent	**100**	VL	VL	VL	VL
Medium Persistent	**500**	L	VL	L	VL
Medium Persistent	**2,000**	M	L	M	M
Medium Persistent	**20,000**	M	M	M	H
Medium Persistent	**8,000,000**	H	H	H	H
Medium Persistent	**15,000,000**	VH	VH	VH	VH
Medium Persistent	**28,500,000**	VH	VH	VH	VH
Medium Persistent	**75,000,000**	VH	VH	VH	VH
Heavy Persistent	**1**	VL	VL	VL	VL
Heavy Persistent	**5**	VL	VL	VL	VL
Heavy Persistent	**10**	VL	VL	VL	VL
Heavy Persistent	**50**	VL	VL	VL	VL
Heavy Persistent	**100**	VL	VL	VL	VL
Heavy Persistent	**500**	L	VL	L	VL
Heavy Persistent	**1,000**	L	VL	L	L
Heavy Persistent	**2,000**	L	VL	L	L
Heavy Persistent	**5,000**	M	L	M	M

Table A73: Oil Spill Impacts for Middle Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Heavy Persistent	**20,000**	M	M	M	M
Heavy Persistent	**42,000**	M	M	M	M
Heavy Persistent	**300,000**	H	M	H	H
Heavy Persistent	**605,000**	H	M	H	H
Heavy Persistent	**1,000,000**	VH	H	VH	VH
Heavy Persistent	**2,000,000**	VH	H	VH	VH
Heavy Persistent	**3,500,000**	VH	H	VH	VH

Table A74: Oil Spill Impacts for Lower Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Non-Persistent	**1**	VL	VL	VL	VL
Non-Persistent	**10**	VL	VL	VL	VL
Non-Persistent	**50**	VL	VL	VL	VL
Non-Persistent	**100**	VL	VL	VL	VL
Non-Persistent	**200**	VL	VL	VL	VL
Non-Persistent	**500**	VL	VL	VL	VL
Non-Persistent	**2,000**	L	VL	L	VL
Non-Persistent	**300,000**	M	L	M	L
Non-Persistent	**1,520,000**	H	M	H	L
Non-Persistent	**1,900,000**	H	M	H	L
Low Persistent	**1**	VL	VL	VL	VL
Low Persistent	**10**	VL	VL	VL	VL
Low Persistent	**50**	VL	VL	VL	VL
Low Persistent	**100**	VL	VL	VL	VL
Low Persistent	**200**	VL	VL	VL	VL
Low Persistent	**500**	VL	VL	VL	VL
Low Persistent	**1,000**	L	VL	L	VL
Low Persistent	**2,000**	L	VL	L	VL
Low Persistent	**5,000**	L	VL	L	VL
Low Persistent	**20,000**	M	L	M	L
Low Persistent	**36,000**	M	L	M	L
Low Persistent	**150,000**	M	L	M	L
Low Persistent	**300,000**	M	L	M	L
Low Persistent	**605,000**	M	L	M	L
Low Persistent	**1,000,000**	H	M	H	L
Low Persistent	**1,520,000**	H	M	H	L
Low Persistent	**1,900,000**	H	M	H	L
Low Persistent	**2,000,000**	H	M	H	L
Low Persistent	**3,500,000**	H	M	H	L
Low Persistent	**4,000,000**	H	M	H	M
Low Persistent	**7,980,000**	H	M	H	M
Low Persistent	**21,000,000**	VH	H	VH	M
Medium Persistent	**1**	VL	VL	VL	VL
Medium Persistent	**10**	VL	VL	VL	VL
Medium Persistent	**100**	VL	VL	VL	VL
Medium Persistent	**500**	L	VL	L	VL
Medium Persistent	**2,000**	M	L	M	M
Medium Persistent	**20,000**	M	M	M	H
Medium Persistent	**8,000,000**	H	H	H	H
Medium Persistent	**15,000,000**	VH	VH	VH	VH
Medium Persistent	**28,500,000**	VH	VH	VH	VH

Table A74: Oil Spill Impacts for Lower Cook Inlet by Oil Type, Volume, and Season					
Oil Type	**Volume (gallons)**	**Spring**	**Summer**	**Autumn**	**Winter**
Medium Persistent	**75,000,000**	VH	VH	VH	VH
Heavy Persistent	**1**	VL	VL	VL	VL
Heavy Persistent	**5**	VL	VL	VL	VL
Heavy Persistent	**10**	VL	VL	VL	VL
Heavy Persistent	**50**	VL	VL	VL	VL
Heavy Persistent	**100**	VL	VL	VL	VL
Heavy Persistent	**500**	L	VL	L	VL
Heavy Persistent	**1,000**	L	VL	L	L
Heavy Persistent	**2,000**	L	VL	L	L
Heavy Persistent	**5,000**	M	L	M	M
Heavy Persistent	**20,000**	M	M	M	M
Heavy Persistent	**42,000**	M	M	M	M
Heavy Persistent	**300,000**	H	M	H	H
Heavy Persistent	**605,000**	H	M	H	H
Heavy Persistent	**1,000,000**	VH	H	VH	VH
Heavy Persistent	**2,000,000**	VH	H	VH	VH
Heavy Persistent	**3,500,000**	VH	H	VH	VH

Summary of Spill Impacts and Probabilities

Spill impacts and probabilities by vessel type, hull, incident cause, spill volume probability, and season are presented in Table A75 to Table A77 for each of the three sub-areas of Cook Inlet. The 5-point scoring methodology was applied.

Table A75: Spill Impacts and Probabilities Summary – Upper Cook Inlet																			
Vessel Type/ Oil Type	**Cause**	**Hull**	**P_S[95]**	**Degree of Impact by Season and Volume Probability[96]**															
				p = 0.25				**p = 0.50**				**p = 0.01**				**p = 0.0004**			
				Sp	**Su**	**Au**	**Wi**	**Sp**	**Su**	**Au**	**Wi**	**Sp**	**Su**	**Au**	**Wi**	**Sp**	**Su**	**Au**	**Wi**
Product Tanker LP	**Coll**	**SH**	0.68	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**4**	**4**	**4**	**3**	**5**	**4**	**5**	**3**
		DH	0.15	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**4**	**4**	**4**	**3**	**4**	**4**	**4**	**3**
	Alli	**SH**	0.68	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**4**	**4**	**4**	**3**	**5**	**4**	**5**	**3**
		DH	0.15	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**4**	**4**	**4**	**3**	**4**	**4**	**4**	**3**
	Grou	**SH**	0.91	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**4**	**4**	**4**	**3**	**5**	**4**	**5**	**3**
		DH	0.18	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**4**	**4**	**4**	**3**	**4**	**4**	**4**	**3**
	Stru	**SH**	0.40	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**2**	**5**	**4**	**5**	**3**
		DH	0.40	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**2**	**4**	**4**	**4**	**3**
	Fire	**SH**	0.40	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**2**	**5**	**4**	**5**	**3**
		DH	0.40	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**2**	**4**	**4**	**4**	**3**
	Equi	**SH**	0.40	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**2**	**5**	**4**	**5**	**3**
		DH	0.40	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**2**	**4**	**4**	**4**	**3**
	Oper	**SH**	0.40	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**2**	**5**	**4**	**5**	**3**
		DH	0.40	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**2**	**4**	**4**	**4**	**3**
	Tran	**SH**	0.92	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**5**	**4**	**5**	**3**
		DH	0.92	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**5**	**4**	**5**	**3**
Crude Tanker MP	**Coll**	**SH**	0.81	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**3**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
		DH	0.19	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**3**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
	Alli	**SH**	0.81	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**3**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
		DH	0.19	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**3**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**

[95] Probability that incident will result in spill.

[96] Scores on 5-point environmental impact scores for impact based on spill volume for 25th percentile, 50th (median) percentile, 95th percentile, and WCD scenarios by vessel type, hull, and incident cause. Different scores are presented for each season as appropriate.

Table A75: Spill Impacts and Probabilities Summary – Upper Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S[95]	Degree of Impact by Season and Volume Probability[96]															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Crude Tanker MP	Grou	SH	0.93	2	2	2	1	3	3	3	3	5	5	5	5	5	5	5	5
		DH	0.20	2	2	2	1	3	3	3	3	5	5	5	5	5	5	5	5
	Stru	SH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
	Fire	SH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
	Equi	SH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
	Oper	SH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	3	3	2	4	4	4	4	5	5	5	5
	Tran	SH	0.92	1	1	1	1	1	1	1	1	3	3	3	2	5	5	5	5
		DH	0.92	1	1	1	1	1	1	1	1	3	3	3	2	5	5	5	5
Tank Barge NP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Alli	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Grou	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Fire	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Equi	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	2
	Tran	SH	0.76	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	2
		DH	0.13	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	2
Tank Barge LP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.22	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Alli	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Grou	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.40	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Fire	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Equi	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.13	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
		DH	0.22	1	1	1	1	1	1	1	1	3	3	3	2	4	4	4	3
	Tran	SH	0.40	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	3
		DH	0.40	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	3
Non-Tank/Non-Workboat Vessel HP (SH) LP (DH)	Coll	SH	0.05	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
		DH	0.02	1	1	1	1	2	2	2	1	3	3	3	2	3	3	3	2
	Alli	SH	0.05	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
		DH	0.02	1	1	1	1	2	2	2	1	3	3	3	2	3	3	3	2
	Grou	SH	0.05	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	4	4	4	3	4	4	4	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	4	4	4	3	4	4	4	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	4	4	4	3	4	4	4	3

Table A75: Spill Impacts and Probabilities Summary – Upper Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S[95]	Degree of Impact by Season and Volume Probability[96]															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Non-Tank/Non-Workboat Vessel HP (SH) LP (DH)	Equi	DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	4	4	4	3	4	4	4	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	3
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	2
Gas Carrier HP (SH) LP (DH)	Coll	SH	0.05	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.02	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Alli	SH	0.05	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.02	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Grou	SH	0.05	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.02	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Stru	SH	0.20	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.20	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Fire	SH	0.20	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.20	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Equi	SH	0.20	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.20	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Oper	SH	0.20	2	2	2	1	3	3	3	2	5	4	5	4	5	4	5	4
		DH	0.20	1	1	1	1	2	2	2	1	4	4	4	3	4	4	4	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	5	4	5	4
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	4	4	4	3
OSV LP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Alli	DH	0.02	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	2	3	3	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	2
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	2
Tug/Tow HP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	3
		DH	0.92	1	1	1	1	1	1	1	1	2	2	2	1	3	3	3	3

Table A76: Spill Impacts and Probabilities Summary – Middle Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Product Tanker LP	Coll	SH	0.68	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Alli	SH	0.68	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Grou	SH	0.91	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.18	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Stru	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
Product Tanker LP	Fire	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Equi	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Oper	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	5	4	5	3
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	5	4	5	3
Crude Tanker MP	Coll	SH	0.81	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.19	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Alli	SH	0.81	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.19	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Grou	SH	0.93	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
Crude Tanker MP	Grou	DH	0.20	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Stru	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Fire	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Equi	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Oper	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Tran	SH	0.92	1	1	1	1	1	1	1	1	3	2	3	3	5	5	5	5
		DH	0.92	1	1	1	1	1	1	1	1	3	2	3	3	5	5	5	5
Tank Barge NP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Alli	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Grou	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Fire	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Equi	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Tran	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
Tank Barge LP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Alli	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Grou	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2

Table A76: Spill Impacts and Probabilities Summary – Middle Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Tank Barge LP	Stru	DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Fire	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Equi	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Tran	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
Non-Tank/Non-Workboat Vessel HP (SH) LP (DH)	Coll	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Alli	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Grou	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	4	3	4	4
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
Gas Carrier HP (SH) LP (DH)	Coll	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Alli	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Grou	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Stru	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Fire	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Equi	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Oper	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	5	4	5	5
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	4	3	4	2
OSV LP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2

Table A76: Spill Impacts and Probabilities Summary – Middle Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
OSV LP	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
Tug/Tow HP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	3	3	3	3
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	3	3	3	3

Table A77: Spill Impacts and Probabilities Summary – Lower Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Product Tanker LP	Coll	SH	0.68	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Alli	SH	0.68	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.15	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Grou	SH	0.91	1	1	1	1	2	1	2	1	4	3	4	3	5	4	5	3
		DH	0.18	1	1	1	1	2	1	2	1	4	3	4	3	4	3	4	3
	Stru	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Fire	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Equi	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Oper	SH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	5	4	5	3
		DH	0.40	1	1	1	1	2	1	2	1	3	2	3	2	4	3	4	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	5	4	5	3
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	5	4	5	3
Crude Tanker MP	Coll	SH	0.81	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.19	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Alli	SH	0.81	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.19	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Grou	SH	0.93	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
		DH	0.20	2	1	2	1	3	3	3	4	5	5	5	5	5	5	5	5
	Stru	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Fire	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Equi	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Oper	SH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
		DH	0.40	1	1	1	1	3	2	3	3	4	4	4	4	5	5	5	5
	Tran	SH	0.92	1	1	1	1	1	1	1	1	3	2	3	3	5	5	5	5
		DH	0.92	1	1	1	1	1	1	1	1	3	2	3	3	5	5	5	5

Table A77: Spill Impacts and Probabilities Summary – Lower Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Tank Barge LP	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Alli	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Grou	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Fire	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Equi	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Tran	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Coll	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Alli	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Grou	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
Tank Barge NP	Stru	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Fire	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Equi	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.13	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Oper	SH	0.76	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.22	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
	Tran	SH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
		DH	0.40	1	1	1	1	1	1	1	1	3	2	3	2	4	3	4	2
Non-Tank/Non-Workboat Vessel HP (SH) LP (DH)	Coll	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Alli	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Grou	SH	0.05	1	1	1	1	2	1	2	2	4	3	4	4	4	3	4	4
		DH	0.02	1	1	1	1	2	1	2	1	3	2	3	2	3	2	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	4	3	4	4	4	3	4	4
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	4	3	4	4
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
Gas Carrier HP (SH) LP (DH)	Coll	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Alli	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Grou	SH	0.05	2	1	2	1	3	2	3	3	5	4	5	5	5	4	5	5
		DH	0.02	1	1	1	1	2	1	2	1	4	3	4	2	4	3	4	2
	Stru	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5

Table A77: Spill Impacts and Probabilities Summary – Lower Cook Inlet																			
Vessel Type/ Oil Type	Cause	Hull	P_S	Degree of Impact by Season and Volume Probability															
				p = 0.25				p = 0.50				p = 0.01				p = 0.0004			
				Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi	Sp	Su	Au	Wi
Gas Carrier HP (SH) LP (DH)	Stru	DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Fire	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Equi	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Oper	SH	0.20	1	1	1	1	2	1	2	1	5	4	5	5	5	4	5	5
		DH	0.20	1	1	1	1	1	1	1	1	4	3	4	2	4	3	4	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	5	4	5	5
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	4	3	4	2
OSV LP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Alli	DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.02	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
		DH	0.20	1	1	1	1	1	1	1	1	3	2	3	2	3	2	3	2
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	1	3	2	3	2
Tug/Tow HP	Coll	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Alli	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Grou	SH	0.05	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.02	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Stru	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Fire	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Equi	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Oper	SH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
		DH	0.20	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
	Tran	SH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	3	3	3	3
		DH	0.92	1	1	1	1	1	1	1	1	2	1	2	2	3	3	3	3

Technical Appendix B: Toxicity Classifications for Petroleum

Toxicity and Environmental and Socioeconomic Impacts

The *toxicity* of the oil determines the adverse effects and mortality of fish, wildlife, and invertebrates after short-term exposure (hours to days). Mortality as well as sub-lethal effects (e.g., reduced fecundity) is relevant to both environmental impacts, as well as socioeconomic impacts in as much as commercial fisheries, subsistence fishing (particularly important in Tribal Nationsareas), and recreational fishing are affected.

In the field, lethal and sub-lethal toxic effects are determined not only by the composition of the oil itself but also by the length of time that the susceptible organisms are exposed to the oil, i.e., the actual *dose exposure* (time x toxicity) that the organisms experience.

Oil toxicity is determined by the presence of aliphatics[97], monoaromatic hydrocarbons[98], and polycyclic aromatic hydrocarbons (PAH)[99].Toxicity is generally expressed in terms of "LC_{50}", which is the concentration at which 50% of the population of a particular species dies. Another commonly used measure of toxicity is EC_{50}, which is the median concentration at which an effect other than death is the observed endpoint (e.g., reduced fecundity or narcotic effects).

Different organisms have different tolerances of exposure. Some species are particularly sensitive to exposure to hydrocarbons (Figure A1).

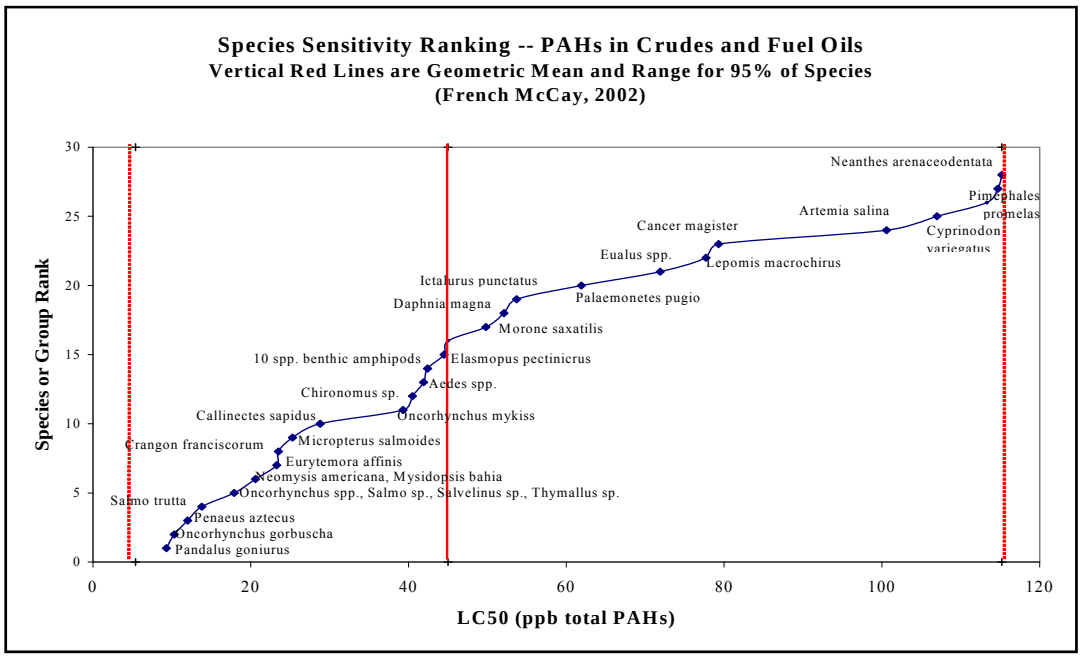

Figure B1: Species Sensitivity Rankings – PAHs in Crudes and Fuel Oils[100]

[97] Straight-chain hydrocarbons (e.g., alkanes)
[98] Benzene, toluene, ethylbenzene, xylenes, and alkyl-substituted benzenes.
[99] Also known as "polynuclear aromatic hydrocarbons", including naphthalenes, phenanthrenes, fluorenes, and dibenzothiophenes.
[100] French-McCay 2002.

Another method for determining relative toxicity is the acute toxicity relative ranking score.[101] The acute toxicity (OIL_{AT}) is determined by the relative composition of 1-, 2-, and 3-ringed aromatic compounds weighted by the aqueous solubility of the aromatic compounds.

The Acute Toxicity Score is therefore based on the percentage of bioavailable components in the oil that could cause toxicity to fish, invertebrates, and wildlife. Bioavailable components are those that are soluble or semi-soluble in water (i.e., 1- to 3-ring aromatic compounds), such that they can dissolve from the oil into water and then be taken up by the organisms directly from the water or through the gut (if oil is ingested).

A raw acute toxicity relative ranking score (1 to 5) is calculated as follows:

$$OIL_{AT} = \frac{[(SOL_1 \cdot PCT_{WT1}) + (SOL_2 \cdot PCT_{WT2}) + (SOL_3 \cdot PCT_{WT3})]}{170}$$

where:
SOL_i = solubility in seawater of i-ring aromatic hydrocarbons, where i = 1, 2 or 3
PCT_{WTi} = percent weight of i-ring aromatic hydrocarbons in the spilled oil, i = 1, 2 or 3
The weighted percentages and solubility quotients are divided by the value 107, to bring Prudhoe Bay crude oil, with a raw acute toxicity score of 96.3, to a ranked value of 0.9. The values are ranked relative to the most and least toxic substances on roughly a five-point scale with gasoline at the highest toxicity of 5.0.

Examples of acute toxicity scores for the most common oils are shown in Table B1. Calculations for acute toxicity relative ranking scores for four other oil types not covered in Table B2 that are transported by pipeline are shown in Table B3. ERC's toxicity rankings for these oils are in Table B4.

Table B1: Acute Toxicity Relative Ranking Scores for Common Oils [102]

Oil Category	Wash. Dept. Ecology 2003 Ranking
Crude oils	0.9 (Prudhoe Bay)
Heavy oils (Bunker C)	2.3
Light oils (diesel or No. 2 fuel)	2.3
Gasoline	5.0
Jet fuel	1.4
Non-petroleum oils	1.4

[101] Described in Washington Department of Ecology (2003) and Geselbracht and Logan (2003)
[102] Based on Washington Department of Ecology 2003.

Table B2: Acute Toxicity Relative Rankings for Other Oils					
Chemical Parameter[103]	Solubility (mg/L)	Percent by Volume of Oil			
		Synthetic Crude	Condensate	Cold Lake Bitumen[104]	MacKay River Heavy Bitumen[105]
1-Ring Aromatics					
Benzene	825	0.1000%	1.3100%	0.0280%	0.0280%
Toluene		0.3300%	2.5300%	0.0990%	0.0990%
Ethylbenzene		0.1200%	0.2900%	0.0360%	0.0360%
Xylenes (total)		0.4200%	2.1000%	0.1500%	0.1500%
1,3,5-trimethylbenzene		0.0430%	0.1800%	0.0200%	0.0200%
1,2,4-trichlorobenzene		0.1600%	0.3400%	0.0610%	0.0610%
Total 1-Ring Aromatics		**1.1730%**	**6.7500%**	**0.3940%**	**0.3940%**
2-Ring Aromatics					
1-methylnaphthalene	22.5	0.0099%	0.0190%	0.0007%	0.0007%
2-methylnaphthalene		0.0079%	0.0110%	0.0004%	0.0004%
Naphthalene		0.0085%	0.0086%	0.0005%	0.0005%
Total 2-Ring Aromatics		**0.0263%**	**0.0386%**	**0.0016%**	**0.0016%**
3-Ring Aromatics					
Fluorene	0.9	0.0014%	0.0015%	0.0005%	0.0005%
Phenanthrene		0.0012%	0.0025%	0.0005%	0.0005%
Total 3-Ring Aromatics		**0.0026%**	**0.0040%**	**0.0010%**	**0.0010%**
Total Percentage of All Aromatics		**1.20%**	**6.79%**	**0.40%**	**0.40%**
Total Preliminary Raw Score		9.6832	55.6962	3.2509	3.2509
Raw Score (Divided by 107)		**0.0905**	**0.5205**	**0.0304**	**0.0304**
Approximate Ranking (5-pt scale)		1	2.5	1	1

Table B3: Comparison of Aromatic (PAH) Content and Relative Toxicity Rankings			
Oil Type	Total Aromatics[106]	WA Ecology Ranking	ERC Ranking
Crude	1.7%[107]	0.9	n/a
Gasoline	24.7%	5.0	n/a
No. 2 Fuel	6.6%	2.3	n/a
No. 6 Fuel	8.3%	2.3	n/a
Synthetic Crude	1.2%	n/a	0.8
Condensate	6.8%	n/a	2.5
Cold Lake Bitumen	0.4%	n/a	0.3
Mackay River Heavy Bitumen	0.4%	n/a	0.3

Toxicity varies by temperature and exposure time as shown in the Figure B2. In general, the greater the duration of the exposure to the toxic compounds, the higher the mortality. Toxicity *decreases* with temperature.

[103] 1-, 2-, and 3-ring aromatics are included as they are known to be soluble and bio-available in solution after a spill.
[104] Diluted with condensate.
[105] Diluted with synthetic light oil.
[106] Including 1-, 2-, and 3-ring aromatics.
[107] Based on French-McCay 2002.

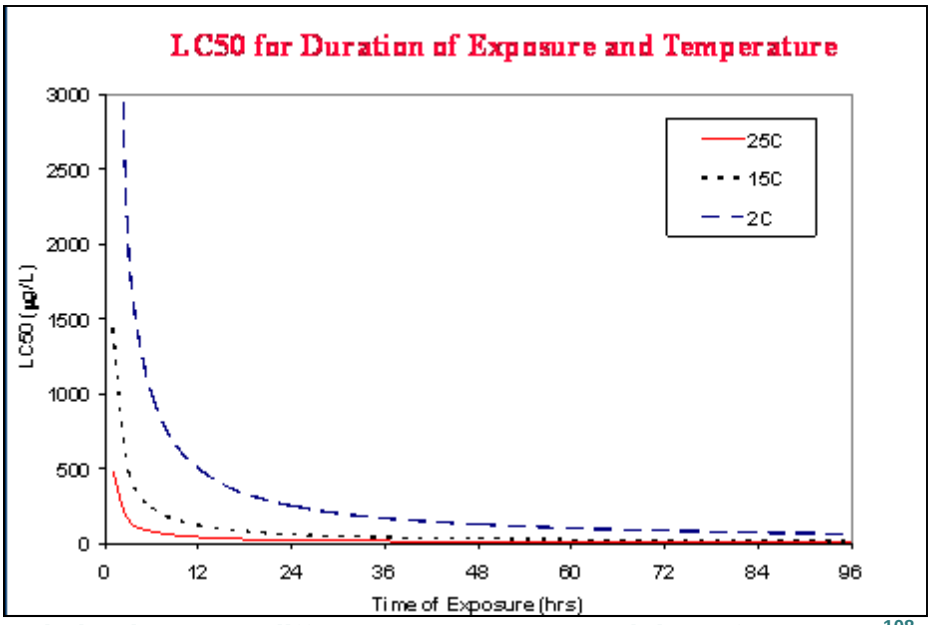

Figure B2: Variation in LC_{50} at different temperatures and time of exposure[108]

CCME 2008[109] Chemical Hazard Rankings

Another method of ranking the toxicity of oil is to apply the CCME standards. The CCME 2008 chemical hazard rankings for petroleum hydrocarbons are based upon the fraction of toxic and mobile components in each product. Lighter compounds, such as benzene, are more toxic and mobile than heavier components of petroleum. The CCME rankings of petroleum hydrocarbons are shown in Table B4.

Table B4: CCME 2008 Petroleum Hydrocarbon Chemical Hazard Classification

Petroleum Hydrocarbon Group	Carbon Group	Included Oils or Petroleum Fractions	CCME Hazard Classification[110]
Gasoline	**n/a**	Gasoline	H
Kerosene	**n/a**	Jet fuels	H
Diesel	**n/a**	Heating oils, No. 2 fuels	M
Heavy Oils	**n/a**	Bunker fuels, intermediate fuel oils, residual oils	L
CCME F1	**C6 – C10**	Benzene, toluene, ethylbenzene, xylene[111], 1-ring polycyclic aromatic hydrocarbons	H
CCME F2	**C11 – C16**	2- and 3-ring polycyclic aromatic hydrocarbons, naphtha, kerosene, jet fuels, diesel fuels, No. 2 fuels, heating oils	M
CCME F3	**C17 – C34**	Heavy fuels, bitumen, lubricating oils, intermediate fuel oils	L
CCME F4	**C35 – C50**	Waxes, heavy fuels, lubricating oils	L

Crude oil is not included as such in the CCME Chemical Hazard Classifications. Crude oils vary considerably in their composition and properties. Some analyses have identified as many as 17,500

[108] Applied Science Associates, Inc.
[109] Canadian Council of Ministers of the Environment (CCME). 2008.
[110] H = high hazard, M = medium hazard , L = low hazard.
[111] Often referred to collectively as "BTEX" compounds.

compounds in a crude oil.[112] Presumably, a classification of a particular crude oil would depend on the relative composition of F1, F2, F3, and F4 fractions. A lighter crude oil with a higher proportion of BTEX (F1) and F2 components and fewer heavier components would likely receive a "high" hazard classification. A heavier crude oil would receive a lower hazard classification due to the greater proportion of F3 and F4 fractions and a lower proportion of F1 and F2 fractions.

Since in the NCSCS scoring system a "high" classification receives a score of 8, "medium" a score of 4, and "low" a score of 2, the classification of a crude oil (or other petroleum mixture) could be calculated as:

$$\text{Petroleum Mixture Hazard Ranking} = 8(p_{F1}) + 4(p_{F2}) + 2(p_{F3}) + 2(p_{F4})$$

Where p_{Fi} = the relative proportion of Fi petroleum hydrocarbons in mixture.

Obtaining published data on the hydrocarbon fraction breakdown (specifically as C6 – C10, C11 – C16, C17 – C34, and C35 – C50) for specific crude oils is often difficult. Generally, published data on crude oils, as well as refined products, include a more conventional breakdown by hydrocarbon groups, as shown in Table B5.

Table B5: Hydrocarbons Groups of Crude Oil and Refined Petroleum Products

Hydrocarbon Group		Carbon Number	CCME[113]	Soluble	Volatile	Potential Impacts		
						Toxic	Coat	Mechanical
Aliphatics/Saturates		**C1–C38**	**F1–F4**	Low	High	High	Low	Low
Aromatics	**BTEX[114]**	**C6–C8**	**F1**	High	High	Moderate	Low	Low
	C2 benzene	**C12**	**F2**	Moderate	Low	High	Low	Low
	C3 benzene	**C13**	**F2**		Low	High	Low	Low
	2-ring PAH	**C10–C11**	**F2**	Moderate	Low	High	Low	Low
	3-ring PAH	**C13–C14**	**F2**	Moderate	Low	High	Low	Low
	4-ring PAH	**C16–C20**	**F3**	Moderate	Low	Moderate	Moderate	Moderate
Polars[115]		**C12+**	**F2**	Low	Low	Varies	Varies	Varies
Asphaltenes		**C5–C7**	**F1**	Low	Low	Low	High	High
Naphthenes[116]		**C8–C20+**	**F1–F3**	Low	Low	Low	High	High
Waxes		**C20–C40**	**F3–F4**	Low	Low	Low	High	High

The typical compositions of common oils and petroleum products are in Table B6.

[112] Fingas 2011.
[113] Based on carbon number.
[114] Monoaromatic hydrocarbons, including benzene, toluene, ethylbenzene, and xylene. Many analytical reports do not separate monoaromatic hydrocarbons from polycyclic aromatic hydrocarbons. The latter are more toxic.
[115] Also "resins", anomalous polar compounds containing oxygen, nitrogen, metals or sulfur (e.g., carbazole).
[116] Also called "cycloalkanes".

Table B6: Typical Composition of Some Oils and Petroleum Products[117]							
Hydrocarbons		**% (except for metals)**					
Group	**Class**	**Gasoline**	**Diesel**	**Light Crude**	**Heavy Crude**	**IFO[118]**	**Bunker C[119]**
Approximate Carbon Range		C5–C12	C13–C17	C5–C45	C5–C45	C13–C45	C20–C45
CCME Class (Carbon Range[120])		F1/F2	F2	F2[121]	F2/F3[122]	F2/F3/F4	F3/F4
CCME Assigned Hazard Class		H (F1)	M (F2)	None	None	L (F3/F4)	L (F3/F4)
Saturates	**Total**	50 – 60	65 – 95	55 – 90	25 – 80	25 – 35	20 – 30
	Alkanes	45 – 55	35 – 45	-	-	-	-
	Cycloalkanes[123]	5	30 - 50	-	-	-	-
	Waxes	-	0 – 1	0 – 20	0 – 10	2 – 10	5 – 15
Olefins[124]		5 – 10	0 – 10	-	-	-	-
Aromatics	**Total**	25 – 40	5 – 25	10 – 35	15 – 40	40 – 60	30 – 50
	BTEX	15 – 25	0.5 – 2.0	0.1 – 2.5	0.01 – 2.0	0.05 – 1.0	0 – 1.0
	PAHs	-	0 – 5	10 – 35	15 – 40	30 – 50	30 – 50
Polar s	**Total**	-	0 – 2	1 – 15	5 – 40	15 – 25	10 – 30
	Resins	-	0 – 2	0 – 10	2 – 25	10 – 15	10 – 20
	Asphaltenes	-	-	0 – 10	0 – 20	5 – 10	5 – 20
Metals[125]		-	-	30 – 250	100 – 500	100 – 1,000	100 – 2,000
Sulfur		0.02	0.1 – 0.5	0 – 2	0 – 5	0.5 – 2.0	2 – 4

The CCME 2008 Chemical Hazard Classifications[126] are based primarily on the potential for human and ecological health effects. For petroleum, those impacts are presumed to come primarily from the presence of BTEX compounds, which are more toxic and mobile than other components of the oil.

CCME 2008 separately assigns chemical hazard rankings to specific polycyclic aromatic hydrocarbons (PAHs), as it does to other specific petroleum hydrocarbon components, (e.g., benzene), as shown in Table B7.

Table B7: CCME Classification for Isolated Petroleum Hydrocarbons			
Hydrocarbon Group	**Chemical**	**Hazard Classification**	**CCME Chemical Hazard Score**
BTEX	**Benzene**	H	8
	Ethylbenzene	M	4
	Xylenes	M	4
	Toluene	M	4
Polycyclic Aromatic Hydrocarbons (PAHs)	**Coal tar**	H	8
	Creosote	M	4
	Acenaphthene	M	4
	Acenaphthylene	M	4
	Acridine	H	8
	Anthracene	M	4

[117] From Fingas 2011.
[118] Intermediate fuel oil (a mixture of diesel and heavy residual fuel).
[119] No. 6 fuel oil.
[120] Based on carbon count ranges presented in this table.
[121] Based on relative proportion of BTEX, which is similar to diesel, classified as F2.
[122] Based on relative proportion of BTEX, which is more similar to IFO and Bunker C (F3or F4) than diesel (F2).
[123] Naphthenes
[124] Also called “alkenes”.
[125] In parts per million (ppm).
[126] From the National Classification System for Contaminated Sites (NCSCS) Guidance Document.

Table B7: CCME Classification for Isolated Petroleum Hydrocarbons			
Hydrocarbon Group	**Chemical**	**Hazard Classification**	**CCME Chemical Hazard Score**
	Benzo(a)anthracene	H	8
	Benzo(a)pyrene	H	8
	Benzo(b)fluoranthene	H	8
	Benzo(g,h,i)perylene	H	8
	Benzo(k)fluoranthene	H	8
	Chrysene	M	4
	Dibenzo(a,h)anthracene	H	8
	Fluoranthene	M	4
	Fluorene	M	4
	Indeno(1,2,3-c,d)pyrene	H	8
	Methylnaphthalenes	M	4
	Naphthalene	M	4
	Phenanthrene	M	4
	Pyrene	M	4
	Quinoline	H	8
	Unspecified PAH or mixture	H	8

There is no "persistence" component built into the CCME classification itself. Persistence is, however, included in the NCSCS scoring system under a separate category of modifying factors for chemical hazard rankings in the scoring system. Persistent substances included as examples under this modification factor include:

- Aldrin
- Dieldrin
- PCBs
- Benzo(a)pyrene
- Hexachlorobenzene
- PCDDs/PCDFs (dioxins and furans)
- Chlordane
- Methylmercury
- Toxaphene
- DDT
- Mirex
- Alkylated lead
- DDE
- Octachlorostyrene

The only substance in this list commonly found in petroleum is benzo(a)pyrene, a polycyclic aromatic hydrocarbon (PAH). Presumably other PAHs might be considered to be included under persistent substances. In addition, the evaluation method for defining a substance as persistent for the purpose of modifying the Contaminant Characteristics score, a half-life of 182 days or more in water or soil, and 365 days or more in sediment would likely include many PAHs. At the same time, CCME 2008 excludes metals and metalloids from this persistent classification based on the fact that, while not degrading in the environment, these substances are also not readily bio-available. Some of the heavier PAHs, particularly 4-ring PAHs, and persistent asphaltenes are not completely bio-available, though some of their parent compounds may be.

The "persistence" factor needs to be incorporated into damage modeling based on three impact categories. The first is the persistence in the environment for longer-term environmental impacts, assuming a reasonable degree of bio-availability and the fact that not all environmental impacts are directly related to toxicity from ingestion or contact. Mechanical injury and coating impacts are related to persistence without having a toxicity component. The second category is related to socioeconomic impacts,

particularly with regard to any longer-term impacts on fisheries, and the coating of economically-significant shoreline features (e.g., tourist beaches, marinas, shore-front property). The third category, response is affected by oil persistence in that shoreline (and soil sediment) cleanup operations, as well as most aspects of on-water recovery, are basically focused on the more persistent fractions of the spilled oil rather than on the volatile components that evaporate relatively quickly.

Impacts from petroleum are generally due to three different components – toxicity, persistence, and mechanical injury. Lighter oils, i.e., those with higher proportions of F1 and F2 fractions, tend to be more toxic but have less persistence in the environment. Heavier oils, i.e., those with higher proportions of F3 and F4 components, tend to cause more mechanical injury and are more persistent.

Technical Appendix C: Other Key Oil Characteristics

Oil Evaporation

The most toxic substances in oil (e.g., benzene, toluene, ethylbenzene, and xylene) are also the most volatile, i.e., most likely to evaporate. The higher the percentage of volatile components in the oil, the greater percentage evaporates. Evaporation rates are higher in warmer temperatures. Evaporation percentages of some common oils transported by pipeline are shown in Table C1.

Table C1: Evaporation Percentages for Selected Reference Oils

Oil Type	Evaporation % (after 24 hours)	
	1ºC	15ºC
Crude	22	25
Gasoline	88	88
Fuel #2 (Diesel)	16	34
Fuel #6	6	4
Synthetic Crude	24	30
Condensate Blend	57	75
Cold Lake Bitumen	14	17
Heavy Bitumen	9	13

Oil Persistence on Water Surface

The oil "persists" on the water surface, i.e., stays as a "slick" or fragments of "slicks" or sheen for a certain amount of time before it evaporates, disperses, and/or dissolves. One method for approximating the time which oil stays on the water surface is to apply the following formulae based on spill volume.[127]

For crude oil spills greater than or equal to 1,000 barrels (bbl):

$$PD_{>1000bbl} = 0.0001S - 1.32T + 33.1$$

PD = persistence in days
S = spill size in bbl
T = water temperature in degrees Celsius

For spills less than 1,000 bbl:

$$PD_{<1000bbl} = 0.0034S + 2.02$$

Oil Density

Density, the mass per unit volume of the oil, determines its buoyancy in water. Density is commonly expressed in grams per cubic centimeter (g/cm^3)[128] or in ºAPI. The units are related as follows:

$$^{o}API = (141.5 / sp.gr.) - 131.5$$

[127] SL Ross et al. 2003.
[128] Pure water has a density of 1 g/cm^3; seawater generally has a density of 1.03 g/cm^3.

$$sp.gr. = \frac{141.5}{(^{o}API + 131.5)}$$

Note that a low ºAPI oil has a high density and specific gravity, and a high ºAPI oil has a low density and specific gravity. The density of oil increases with weathering (evaporation of volatile hydrocarbon components) and decreasing temperature. The densities of some common oils are shown in Table C2.

Table C2: Density for Selected Reference Oils

Oil Type	Specific Gravity (g/cm^3)	ºAPI
Heavier Crude	0.905	24.9
Alberta Crude	0.840	37.0
Alaskan North Slope	0.896	26.4
Sweet Louisiana Crude	0.845	35.9
Gasoline	0.750	57.2
Fuel #2 (Diesel)	0.838	37.4
Fuel #6	0.983	12.4
Gasoline	0.750	57.2
Synthetic Crude	0.886	28.2
Condensate Blend	0.744	58.7
Cold Lake Bitumen	0.948	17.8
Heavy Bitumen	0.952	17.1

Adhesiveness Effect on Environmental and Socioeconomic Impacts

The adhesiveness of a specified oil is the degree to which oil remains on a surface after contact and draining. This character has an effect on spill impacts by way of the amount of oil that will stick to surfaces, including shoreline substrates and structures (e.g., piers, boats, seawalls). There is no standard methodology for determining adhesiveness. One methodology that was applied by Belore (2010) measured the grams of oil that stuck to a square meter of surface. This testing allowed for a relative comparison of adhesiveness between various oils, as shown in Table C3.

Table C3: Adhesiveness for Selected Reference Oils

Oil Type	Adhesion (g/m^2)
Crude	28
Alaska North Slope Crude	28
Alberta Sweet Mixed Blend Crude	13
Sweet Louisiana Crude	18
Intermediate Fuel Oil (IFO 180)	49
Jet Fuel (Jet A/Jet A-1)	1
Gasoline	1
Fuel #2 (Diesel)	6
Fuel #6	85
Synthetic Crude	18
Condensate Blend	2
Cold Lake Bitumen	98
Heavy Bitumen	52

Oil can also cause "mechanical injury" based on its adhesive properties. This injury is caused by coating, fowling or clogging of organisms and their appendages and apertures, such that movements and behaviors are mechanically inhibited.[129]

Washington Department of Ecology (2003) developed a formula to calculate a relative mechanical injury index (on a scale of 0 to 5) based on specific gravity[130], as follows:

$$MechanicalInjury = \frac{(sp.gr. - 0.688)}{0.062}$$

The result is then rounded to the nearest 0.1 to derive the relative score with higher scores denoting more mechanical injury. Since specific gravity can change with temperature (and weathering), mechanical injury is related to these factors as well. In higher temperatures mechanical injury reduces slightly.

Examples of mechanical injury rankings and other oil properties for eight reference oils are shown in Table C4.

Table C4: Mechanical Injury Rating for Selected Reference Oils

Oil Type	Mechanical Injury Rank
Crude	3.6
Alaska North Slope Crude	3.4
Alberta Sweet Mixed Blend Crude	2.5
Sweet Louisiana Crude	2.5
Intermediate Fuel Oil (IFO 180)	4.9
Jet Fuel (Jet A/Jet A-1)	2.0
Gasoline	1.0
Fuel #2 (Diesel)	3.2
Fuel #6	5.0
Synthetic Crude	3.1
Condensate Blend	0.9
Cold Lake Bitumen	4.2
Heavy Bitumen	4.3

Persistence Effect on Environmental and Socioeconomic Impacts

Persistence of petroleum-based oils is a very important consideration in assessing the environmental risk of an oil spill. The heavier, more persistent fractions of oil are those that adhere to the feathers of birds and fur of mammals, as well as to shoreline and wetland communities. For birds and mammals, this coating can cause hypothermia. For organisms living along shoreline or in wetlands, this can cause smothering. Both smothering and hypothermia can result in mortality, which increases environmental damages. The persistent portions of oil can also coat other surfaces (e.g., tourist beaches, sea walls, marinas, boats) causing socioeconomic impacts.

Persistence is not easily determined for specific types of oil. Persistence is a complex characteristic of oil related to viscosity, adhesiveness, and evaporative character that accounts for a given oil's duration in the

[129] French-McCay et al. 2009.
[130] The density of the oil relative to water, which is the same as its density in g/cm^3.

environment before degrading. [131] The degree of persistence is determined primarily by the presence of heavier components, such as waxes, asphaltenes, and polar compounds. Persistence varies with wave energy, substrate permeability and exposure, and weathering. [132]

There is no direct measure of persistence since it depends on a number of other oil characteristics. It is usually measured in relative terms, comparing one oil type to others, and with regard to the amount of time that oil remains in the environment based on empirical data collected in the aftermath of historical spills. One example of a relative ranking for persistence of oil is that developed by Washington State Department of Ecology, as shown in Table C5.

Table C5: Relative Ranking Scores for Classified Oils [133]

Representative Oil	Persistence [134]	Anticipated Time in Environment
Prudhoe Bay Crude Oil	5	5 – 10 years or more
Bunker C	5	5 – 10 years or more
No. 2 Fuel Oil	2	1 month to one year
Gasoline	1	1 day to weeks
Kerosene	1	1 day to weeks
Kerosene-type Jet Fuel	1	1 day to weeks

It the 1995 report *A Critical Review of Toxicity Values and an Evaluation of the Persistence of Petroleum Products for Use in Natural Resource Damage Assessments*, the American Petroleum Institute (API) reviewed persistence of crude oil and various petroleum products with the objective to assess the relative persistence of oil products in the aquatic environment, and to rank oil products based upon their persistence in the aquatic environment. The results of API's analysis with regard to persistence of various broad categories of petroleum products are shown in Table C6 and Figure C1. Figure C1 shows the persistent fraction of petroleum products in aquatic environments, expressed as percent of original material remaining in water, sediment, and soil. For each pair, the top bar represents the most persistent components and the bottom bar the least persistent components.

Table C6: Numerical Scale for Relative Oil Persistence in the Aquatic Environment [135]

Oil/Oil Product	Relative Persistence Ranking [136]	Persistence Classification
Gasoline	1	"Relatively non-persistent"
Jet Fuel	2	
No. 2 Fuel Oil	8	
Lube Oils	55	"Slightly persistent"
Light Crude Oil	320	"Highly persistent"
No. 6 Fuel Oil	400	
Medium Crude Oil	450	
Heavy Crude Oil	590	
Residual Asphaltenes	1,600	

[131] Davis et al. 2004.
[132] "Weathering" is the physical and chemical breakdown of oil upon exposure to sunlight and air. Weathering processes are predominated by evaporation.
[133] Based on Washington Department of Ecology 2003 (Washington DOE Damage Compensation Schedule)
[134] Ranks are based on scale of 1 to 5 for least to most.
[135] Based on API 1995.
[136] Relative ranking with "1" being least persistent to "1,600" being extremely persistent.

In addition, API (1995) discusses two aspects of persistence that need to be considered in terms of environmental impacts – toxicity- and habitat-based concerns. With regard to toxicity-based concerns for oil persistence, the report explains that there is low bio-availability of oil in the water column or dissolved fractions after the oil weathers. Weathering changes the characteristics of the oil in that various compounds evaporate or become less available due to aggregation through sedimentation, precipitation, or emulsification. Based on this fate of spilled oil, the report states:

> *A common industry perspective is that the persistent oil compounds from a spill (residues, tar balls, mousse, etc.) are of low concern since they are not bio-available. Thus multiplying a toxicity factor by a persistence factor in a compensation table seems illogical and is questioned. The argument is made that if the more persistent compounds are not bio-available due to their form and low solubility, they cannot exert a toxic impact or cause biological injury.*

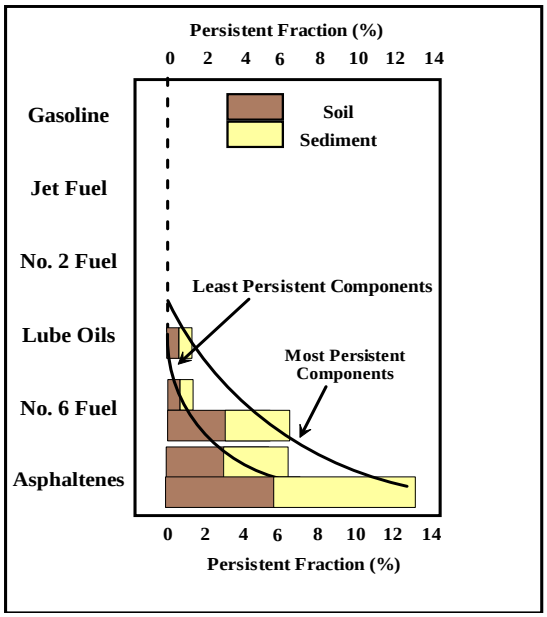

Figure C1: Persistent Fraction of Petroleum Products on Aquatic Environments[137]

API (1995) also criticizes attempts to relate persistence and *acute* toxicity as the latter involves brief exposure. *Chronic* effects could, however, be more appropriately related to the toxicity-based context of persistence.

The second area of concern with respect to oil persistence, according to the API report, is the physical or mechanical disruption due to the presence of oil residues in habitats. Residual oil can interfere with the normal physical characteristics of substrates and sediments and make them inhabitable. Oil residues can also agglomerate with inorganic and organic particles or debris and become ingestible. "This physical interference may persist for significant periods of time since the same characteristics of the weathered hydrocarbons reduce their biological availability also allow them to persist as a potential habitat impediment," the report concludes.

[137] American Petroleum Institute (API) 1995.

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