APPENDIX B

Effects of Low Probability, High-Effects Very Large Oil-Spill Events

Section A — Well Blowout and Pipeline Rupture

Section B — 200,000 bbl Tanker Oil Spill

A. EFFECTS OF A WELL BLOWOUT AND PIPELINE RUPTURE:

An oil spill is the single event with the greatest potential impact to the environment during exploration and development. An Oil Spill Contingency Plan is required prior to approval and conduct of any drilling activity to address the protection of waters and landforms and meet impacts produced as a consequence of accidental spills.

In the Introduction and Basic Assumptions for Effects Assessment section (Sec. IV.A) of this document is a section on oil spills. Based on data obtained on the history of spills on the North Slope, estimates are made as to the number, types, and quantity of spilled crude and refined oil that can be anticipated under the various alternatives. The environmental consequences of these estimates are contained in the discussions by resource throughout the remainder of Section IV.

The purpose of this section is to provide scenarios for low-probability, high-effects, oil-spill events. Two hypothetical cases are considered in this section: a well blowout and an oil-pipeline rupture. A third hypothetical tanker spill case is considered in Section II of this Appendix. These scenarios apply to each of the alternatives described in the EIS

Well Blowout Assumptions: *The Alpine Development Project: Environmental Evaluation Document* (September 1997 Revision), prepared for the U.S. Army Corps of Engineers by Arco Alaska, Inc. et al., identified a well blowout as the "reasonable worst-case" oil spill. In that document, it was estimated that the spill would amount to 1,000 bbl/day. It also was stated that a blowout typically would be controlled within 3 days using heavy muds or other "top kill" intervention.

For purposes of analysis in this IAP/EIS, it was assumed that a relief well would need to be drilled, and that the onsite drill rig would be damaged. For this scenario, an estimated 34 days could elapse prior to controlling the well. An estimated 34,000 bbl of crude oil would spill. If such an event were to occur during exploration, oil from the plume fallout and the wellhead would be deposited over snow and ice surfaces. If such an event occurred during the drilling of a development well, it still is likely that the oil would be deposited over snow and ice surfaces, because those are the prevailing conditions the majority of the year on the North Slope. However, the event could occur during spring breakup or during the summer season and deposit the oil on melting snow and ice or water and vegetation, respectively.

The area affected would be determined by the plume size, which is dictated by flow pressure and the diameter of the orifice. Typically, ≥30 percent of the oil evaporates before settling on land. For this scenario, it is projected that oil droplets settling out from the plume could cover up to several acres in downwind directions. Also, oil flowing from the drill site would spread downslope following the terrain and potentially flow into a lake or waterbody. The estimated area of impact is ≤150 acres.

For a discussion of the Fate and Behavior of Oil Spills, please refer to Section IV.A.3. Given the present technology associated with blowout prevention and effective well control, it is extremely unlikely that an uncontrolled release of crude oil could occur.

Pipeline Rupture Assumptions: A pipeline rupture is identified as the "extreme worst-case" in *The Alpine Development Project: Environmental Evaluation Document* (September 1997 Revision). For purposes of this IAP/EIS, it was assumed that a 14-in diameter pipeline with a flow rate of 48/bbl/minute ruptures with an initial discharge of 50 bbl. The 2,800 bbl of oil contained within the pipeline is assumed to be released due to the distance and gradient to the shutoff valves.

Oil flowing from the pipeline rupture would spread downslope following the terrain and potentially could flow into a lake or waterbody. While the highest probability is that the oil would be deposited on a snow and ice surface, it could be deposited on melting snow, ice, and water, or on vegetation, depending on the time of the year. The estimated area of impact is ≤150 acres.

B. EFFECTS OF A 200,000 BARREL TANKER OIL SPILL:

Assumptions: The environmental impacts of low-probability, high effects, very large tanker spill along the TAPS Tanker Route is analyzed in the Gulf of Alaska/Yakutat Planning Area Oil and Gas Lease Sale 158 (USDOI, MMS, 1995). This appendix uses that information to analyze tanker spills occurring from oil production in the Northeast NPR-A Planning Area. For estimates of the chance of one or more tanker spills occurring from oil production in the planning area, refer to Table IV.A.2-5.

The potential effects of a catastrophic spill of 200,000 bbl are analyzed on representative areas of sensitive resources in the Gulf of Alaska. A very large oil spill is a low-probability event that has the potential for very high effects on the environment. For purposes of analysis, this large oil spill is assumed to occur along the TAPS tanker route in the Gulf of Alaska. The offshore area between Dry Bay and Lituya Bay was chosen as a spill point for this analysis based on the diversity of exposed sensitive environmental resources from an oil spill in this area (Fig. B-1). The spill size was chosen based on the two largest tanker spills in

Table B-1
Hypothetical 200,000-bbl Tanker-Spill-Size Examples[1]

	200,000-bbl spill[2]					
Time After Spill in Days	1	3	10	30	45	60
Oil Remaining (%)	79	70	53	37	33	31
Oil Dispersed (%)	2	7	19	32	35	37
Oil Evaporated (%)	16	21	26	29	30	30
Thickness (mm)	5.1	2.9	1.4	0.7	0.5	0.4
Area of Thick Slick (km^2)[3]	4.7	7.3	12	17	19	21
Discontinuous Area (km^2)[4]	88.0	365.2	1,737.5	7,210.9	12,192.6	17,698.7

Source: USDOI, MMS, Alaska OCS Region, 1993.
[1] Calculated with the SAI oil-weathering model of Kirstein, Payne, and Redding (1983). These examples —for a Cook Inlet Crude type— are discussed in Section IV.A, Fate and Behavior.
[2] Summer 11.7-kn-windspeed, 9.9-°C, 1.0-m-wave height. Average Weather Marine Area C (Brower et al., 1988).
[3] This is the area of oiled surface.
[4] Calculated from Equation 6 of Table 2 in Ford (1985): the discontinuous area of a continuing spill or the area swept by an instantaneous spill of a given volume.

Table B-2
Mass Balance of Oil Through Time of a Hypothetical 200,000-bbl Oil Spill Along Tanker Segment T6

Days	1	3	10	30	45	60
Oil Evaporated[1]	30,000[2]	40,000	48,000	56,000	58,000	58,000
Oil Disbursed[1,3]	4,000	9,000	31,000	55,000	57,000	60,000
Oil Sedimented[1,3]	0	5,000	9,000	11,000	13,000	16,000
Oil Onshore[1,3]	0	17,000	30,000	40,000	45,000	55,000
Oil Remaining[1,3]	162,000	125,000	78,000	36,000	23,000	7,000

Source: MMS, Alaska OCS Region, 1993.
[1] Calculated with the SAI oil-weathering model of Kirstein, Payne, and Redding (1983).
The examples are for a Cook Inlet crude type in Summer 9.9-°C sea-surface temperature and 11.7-kn winds.
[2] Barrels.
[3] Modified to fit fate calculations of Gundlach et al. (1983) and Wolfe et al. (1993).

U.S. waters, the *Burma Agate* near Galveston (247,500 bbl) and the *Exxon Valdez* in Prince William Sound (258,000 bbl) (Anderson, 1994, pers. comm.; Wolfe et al., 1994). The selected area is affected by a 200,000-bbl hypothetical spill with characteristics identified in the following scenario.

Tanker-Spill Scenario: A hypothetical tanker spill occurs along Tanker Segment T6 with onshore winds in summer (Fig. B-1). The 70,000-dead-weight-ton tanker releases 200,000 bbl of Cook Inlet-like crude oil. Weather conditions hamper cleanup activities in the first 10 days and the oil is washed ashore, contacting the coastline within 10 days and affecting the exposed portion of the area within 30 days after its release.

Figures B-1 and B-2 graphically present the estimated conditional probabilities (expressed as percent chance) that an oil spill starting at Tanker Segment T6 in the summer season would contact individual Land Segments (LS's), Sea Segments (SS's), and Environmental Resource Areas (ERA's) within 3, 10, and 30 days, assuming that a ≥1,000-bbl spill occurs along Tanker Segment T6 (USDOI, MMS, 1995).

The hypothetical 200,000-bbl spill occurs approximately 60 km due east of the coast between Dry Bay and Lituya Bay along Tanker Segment T6. The current regime in the vicinity of this hypothetical 200,000-bbl spill is characterized by the flow of the Alaska Current and the

Table B-3
200,000-bbl Spill Dispersed-Oil Characteristics

Time after Spill in Days[1]	Oil Dispersed[1] (%)	Discontinuous Area[1] (km^2)	Assumed Dispersion Depth (m)	Dispersed-oil Concentration (μg/l)
1	2	88.0	1	6,477
3	7	365.2	2	2,731
10	19	1,737.5	7.5	416
30	32	7,210.9	15	84
45	35	12,192.6	17.5	47
60	37	17,698.7	20	30

Source: USDOI, MMS, Alaska OCS Region, 1993. [1]Table B-1.

Alaska Coastal Current. These currents move the oil spill to the north and west along the Gulf of Alaska.

Within 10 days during summer, the Oil-Spill-Risk Analysis (OSRA) estimates oil-spill contact to Kayak Island, Cape Suckling, the area adjacent to Bering Glacier and Kaliakh River (LS's 68, 69, 70 and 71), and the area from the Yahtse River to Yakutat Bay (LS's 74, 75 and 76) from a spill occurring along Tanker Segment T6 (Fig. B-2). By the end of day 30, the OSRA estimates contact to Gore Point and the Pye Islands (LS's 56 and 58) and from Elrington and Latouche Island to Cape Fairweather (LS's 61 through 80) from a spill occurring along Tanker Segment T6 (Fig. B-2).

During summer by the end of day 10, the OSRA estimates oil-spill contact to ERA's 5 through 8 from a spill occurring along Tanker Segment T6 (Fig. B-2). By the end of day 30, the OSRA estimates oil-spill contact to ERA's 5 through 15 and 18 and to SS 1 and 2 from a spill occurring along Tanker Segment T6 (Fig. B-2).

Using the oil-weathering model of Kirstein, Payne, and Redding (1983), the mass balance estimates from the *Amoco Cadiz* oil spill (Gundlach et al., 1983) and the *Exxon Valdez* oil spill (Wolfe et al., 1993), and Table B-1, a qualitative mass balance for a hypothetical oil spill of 200,000 bbl is presented in Table B-2. Approximately 30 percent of the oil is dispersed into the water column. A large component, approximately 28 percent, comes ashore. Approximately 30 percent of the oil is lost to the atmosphere due to evaporation. After 60 days, the oil (7,000 bbl) represented by the slick is no longer visible as a coherent slick and is in the form of tarballs and tar particles suspended in the water column.

As stated in the mass balance, approximately 55,000 bbl would be onshore after 60 days. The approximately 55,000 bbl of oil is estimated to landfall portions of the shores of the northern Gulf of Alaska and Prince William Sound, based on the OSRA results discussed above from a spill along Tanker Segment T6.

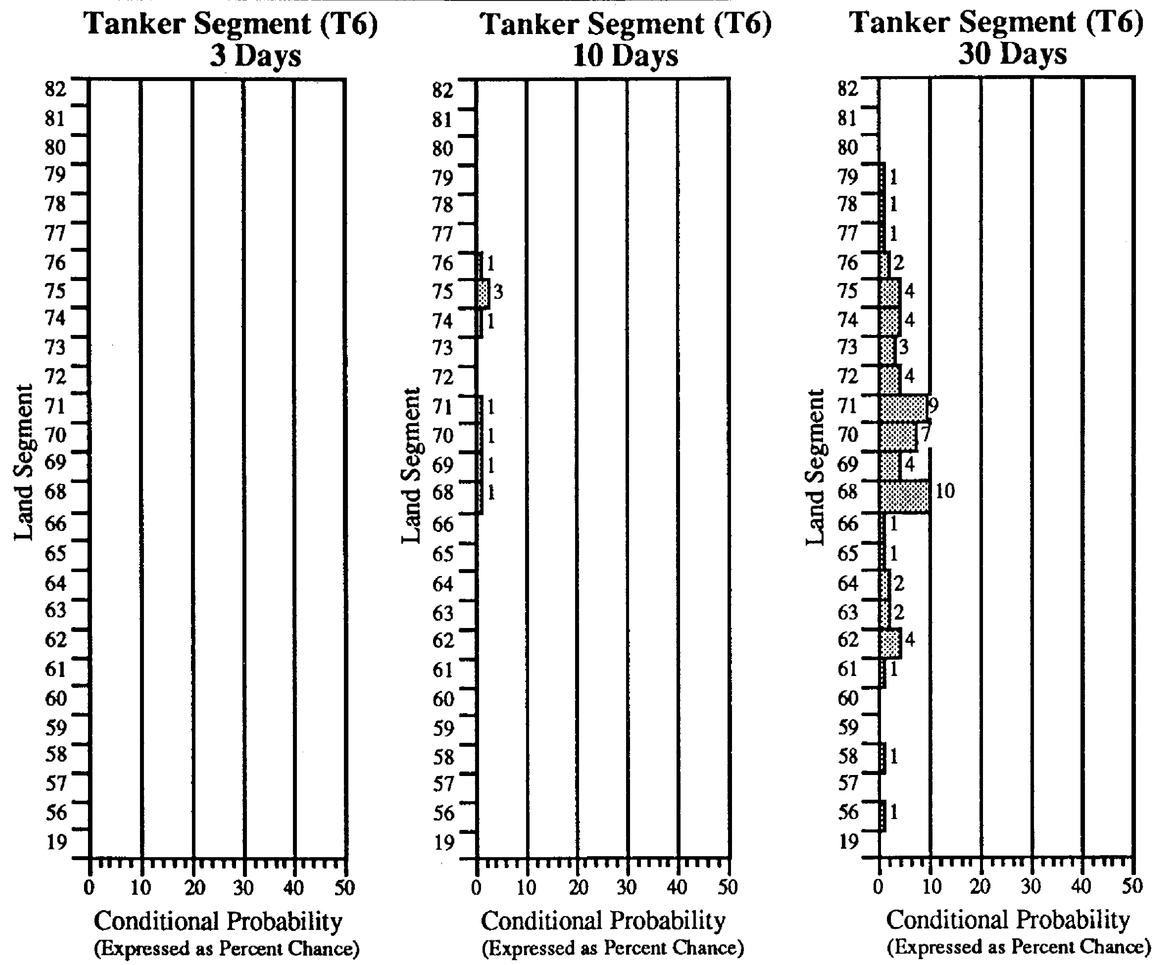
Theoretical calculations of slick size from a hypothetical spill of 200,000 bbl were investigated using the equations of Ford (1985) and Kirstein, Payne, and Redding (1983). Table B-1 shows the estimated areal extent of a continuous thick slick and a discontinuous slick through time.

1. Air Quality: Under this analysis, a 200,000-bbl-oil spill would affect onshore air quality. Emissions would result from evaporation and burning of the spilled oil.

Evaporation of spilled oil is a source of gaseous emissions. Modeling predictions of hydrocarbon evaporation (Payne et al., 1984a,b, 1987) from a 200,000-bbl slick over 30-day periods estimate that 56,000 bbl—or 7,817 tons—of hydrocarbons would evaporate. Because approximately 10 percent of gaseous hydrocarbons are nonmethane volatile organic compounds (VOC), 781.7 tons of VOC would be lost to the atmosphere. The movement of the oil slick during this time would result in lower concentrations and dispersal of emissions over an area several orders of magnitude larger than the slick itself.

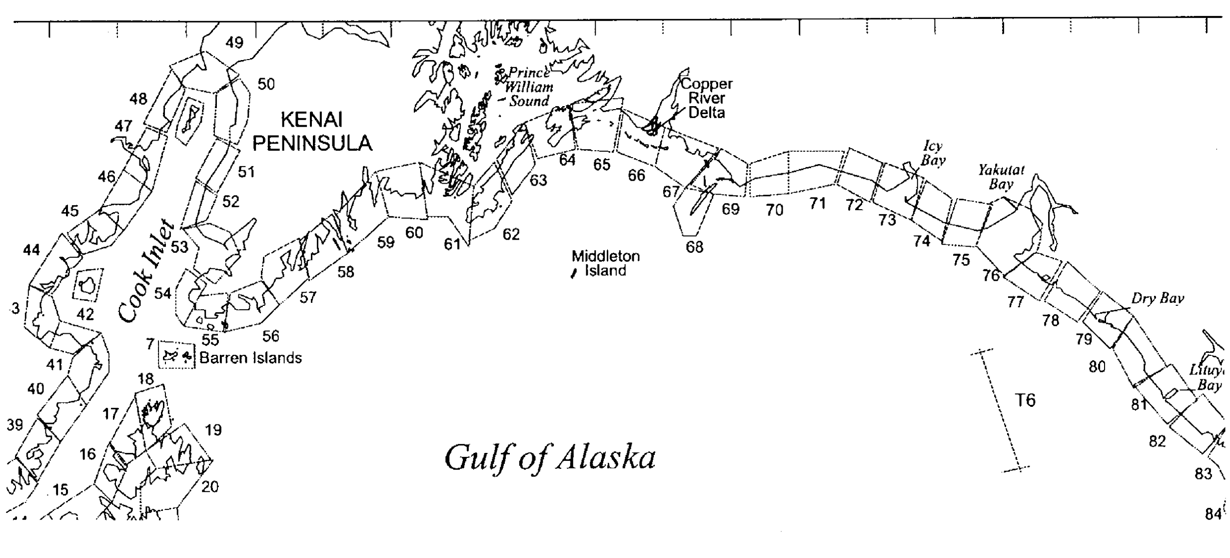
In situ burning is a preferred technique for cleanup and disposal of spilled oil in oil-spill-contingency plans. For catastrophic oil spills, in situ burning may be the only effective technique for spill control.

Burning could affect air quality in two important ways. Burning would reduce emissions of gaseous hydrocarbons



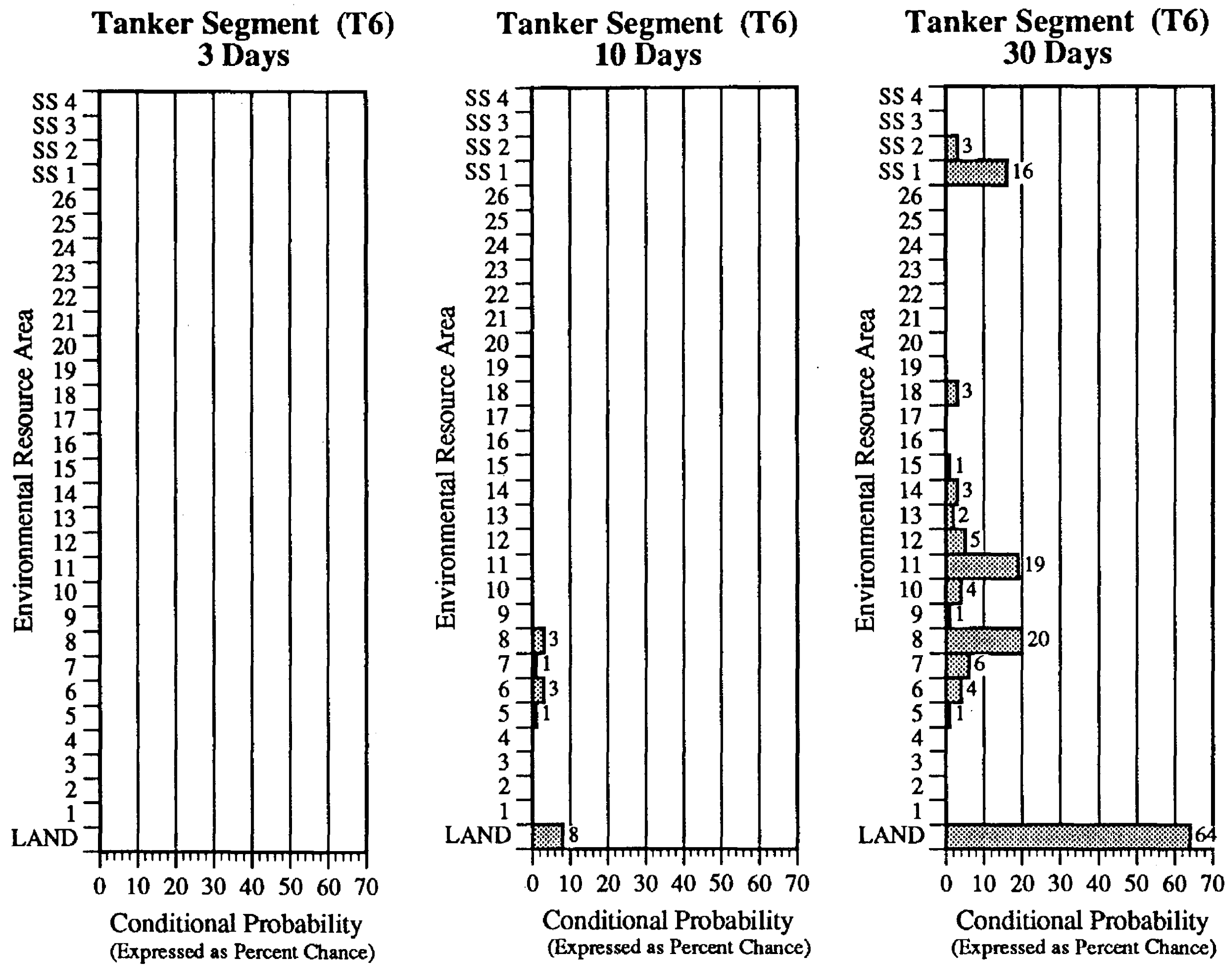
Note: Only land segments with >0.5 conditional probability (expressed as percent chance) are shown on the graph. Land Segments with all values less than 0.5 conditional probability (expresses as percent chance) are not shown.

Land Segments



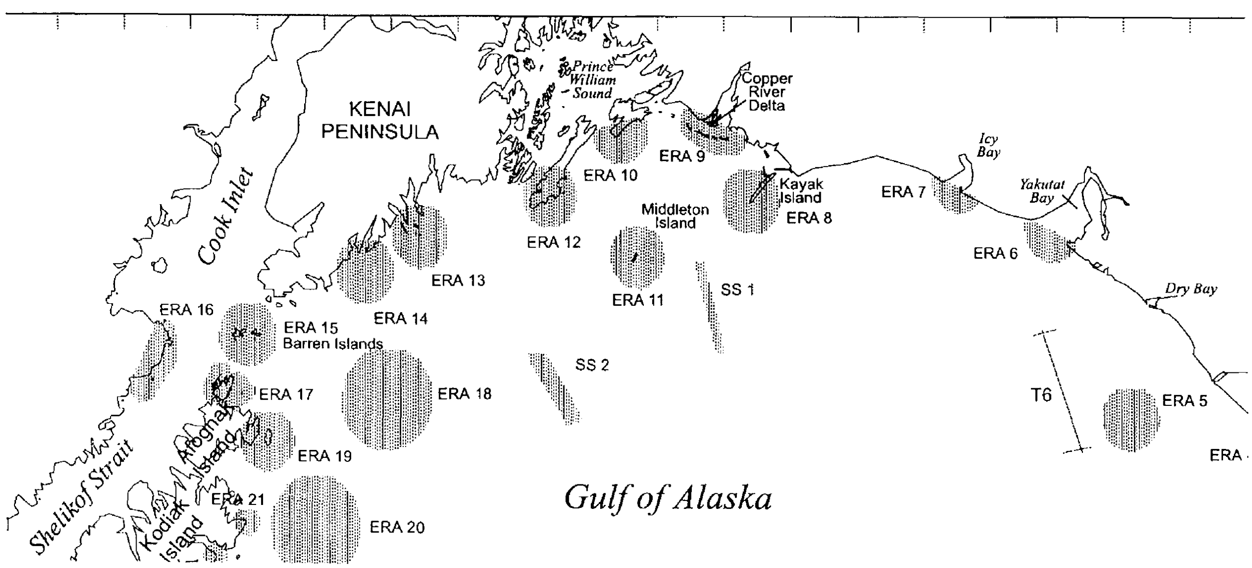
Source: USDOI, MMS, 1995.

Figure B-1. Estimated Conditional Probabilities (expressed as percent chance) That an Oil Spill Greater Than or Equal to 1,000 Barrels Starting at Hypothetical Tanker Segment 6 (T6) in the Summer Season Will Contact a Certain Land Segment within 3, 10, or 30 Days



Note: Only ERA's with >0.5 conditional probability (expressed as percent chance) are shown on the graph. ERA's 1-4, 16, 17, 19-26, and SS's 3 and 4 have <0.5 conditional probability (expressed as percent chance).

Environmental Resource Areas



Source: USDOI, MMS, 1995

Figure B-2. Estimated Conditional Probabilities (expressed as percent chance) That an Oil Spill Greater Than or Equalto 1,000 Barrels Starting at Hypothetical Tanker Segment 6 (T6) in the Summer Season Will Contact Certain Environmental Resource Areas (ERA), Sea Segments (SS), and Land within 3, 10, or 30 Days by 99.98 percent and slightly increase emissions—relative to quantities in other oil and gas industrial operations—of other pollutants. If the oil spill were ignited immediately after spillage, the burn would combust 33 to 67 percent of the crude oil or higher amounts of fuel oil that otherwise would evaporate. On the other hand, incomplete combustion of oil would inject about 10 percent of the burned crude oil as oily soot, plus minor quantities of other pollutants, into the air. For a 200,000-bbl spill, setting fire at the source could burn up to 85 percent of the oil—with 5 percent remaining as residue or droplets in the smoke plume—in addition to the 10-percent soot injection (Evans et al., 1987). Clouds of black smoke from a 360,000-bbl oil-spill tanker fire 75 km off the coast of Africa locally deposited oily residue in a rainfall 50 to 80 km inland. Later the same day, clean rain washed away most of the residue and allayed fears of permanent damage.

Coating portions of the ecosystem in oily residue is the major, but not the only, potential air-quality risk. Recent examination of polycyclic aromatic hydrocarbons (PAH) in crude oil and smoke from burning crude oil indicate that the overall amounts of PAH change little during combustion, but the kinds of PAH compounds present do change. Benzo(a)pyrene, which is often used as an indicator of the presence of carcinogenic varieties of PAH, is present in crude-oil smoke in quantities approximately three times larger than in the unburned oil. However, the amount of PAH is very small (Evans, 1988). Investigators have found that overall, the oily residue in smoke plumes from crude oil is mutagenic but not highly so (Sheppard and Georghiou, 1981; Evans et al., 1987). The Expert Committee of the World Health Organization considers daily average smoke concentrations of more than 250 micrograms per cubic meter to be a health hazard for bronchitis.

Large fires create their own local circulating winds—toward the fire at ground level—that affect plume motion. In any event, soot produced from burning oil spills tends to slump and wash off vegetation in subsequent rains, limiting any health effects in the very short term. Accidental emissions are, therefore, expected to have a low effect on onshore air quality.

Conclusion: Concentrations of criteria pollutants would remain well below Federal air-quality standards.

2. Water Quality: Accidental oil spills would add substances that may be foreign to or increase the concentration of constituents already present in the water column of the northeastern Gulf of Alaska. In general, the added substances may cause sublethal effects in some marine organisms if concentrations are greater than the chronic criteria and lethal effects if concentrations are greater than acute criteria. This analysis considers 15 μg/l to be a chronic criterion and 1,500 μg/l—a hundredfold higher level—to be an acute criterion for total hydrocarbons.

The effects of a very large, 200,000-bbl oil spill on water quality are based on the amount of oil dispersed into the water column; the characteristics of the oil spill are noted in Tables B.1 and B.2. The concentrations are simply estimated from the amount of oil dispersed into the water column for each time interval by assuming that (1) the extent of the discontinuous area estimated for the surface extends into the water column; (2) the depth of mixing is 2 m after 3 days, 7.5 m after 10 days, and 15 m after 30 days; (3) the concentration of the dispersed oil is uniform in the "mixed" watermass; (4) other processes, except sedimentation, affecting degradation of oil or removal of oil from the water column are neglected; and (5) the weight of a barrel of oil is 314.26 pounds.

The waters of the northeastern gulf are stratified in the summer; vertical mixing in the surface layer may be limited to the upper 20 to 25 m. For depth-of-mixing estimates, it is assumed that the oil will be dispersed into the water column to a depth equivalent to the mean monthly significant wave height of 2 m. At the end of 10 days, the oil is assumed to have dispersed to a depth of 7.5 m. At the end of 30 days, the oil is assumed to have dispersed to a depth of 30 m. The depth of mixing during the first day is assumed to be 1 m. Table B.2 shows the estimates of the amount of oil remaining in the water and removed by sedimentation and evaporation for time intervals from 1 to 60 days.

For a 200,000-bbl spill, the estimated concentrations of oil dispersed into the water column are shown in Table B-3. The high concentrations of oil associated with estimating dispersal in the water column may represent an upper range of dispersed-oil concentrations reached during the first several days following a large spill; these concentrations are greater than the total hydrocarbon acute criterion of 1,500 μg/l that was used to evaluate the effects of a 29,000-bbl spill and smaller spills. Between 10 and 30 days after the spill, concentrations of dispersed oil are within the range of concentrations reported for tanker spills of 0.18 and 1.6 MMbbl of oil (NRC, 1985; Gundlach et al., 1983). The amount of dispersed oil in the water after 30 to 60 days emphasizes the time it would take before the oil is reduced to concentrations that are below the total hydrocarbon chronic criteria—15 μg/l—and eventually disappears from the water. Dilution rates associated with permitted discharges suggest that the dispersion rates of oil droplets in the water column may be greater than those estimated for this spill.

Conclusion: The water quality would be reduced from good (unpolluted) to polluted by the presence of hydrocarbons from a large (200,000-bbl) oil spill that has a relatively low probability of occurring. Contamination (the presence of hydrocarbons in amounts >15 μg/l) would be temporary (last for about 2 months or more) and affect an area between 10,000 and 20,000 km^2.

3. Lower-Trophic-Level Organisms: The 200,000-bbl oil spill would expose some lower-trophic-level organisms to petroleum-based hydrocarbons.

The effect of petroleum-based hydrocarbons on phytoplankton, zooplankton, and benthic organisms ranges from sublethal to lethal. Where flushing times are longer and water circulation is reduced (e.g., bays, estuaries, and mudflats), adverse effects are expected to be greater; and the recovery of the affected communities is expected to take longer. Large-scale effects on plankton due to petroleum-based hydrocarbons have not been reported. Assuming that a large number of phytoplankton were contacted by an oil spill, the rapid replacement of cells from adjacent waters and their rapid regeneration time (9-12 hours) would preclude any major effect on phytoplankton communities. Observations in oiled environments show that zooplankton communities experience short-lived effects due to oil. Affected communities appear to recover rapidly from such effects because of their wide distribution, large numbers, rapid rate of regeneration, and high fecundity. Large-scale effects on marine plants and invertebrates due to petroleum-based hydrocarbons have not been reported. The sublethal effects of oil on marine plants include reduced growth and photosynthetic and reproductive activity. The sublethal effects of oil on marine invertebrates include adverse effects on reproduction, recruitment, physiology, growth, development, and behavior (feeding, mating, and habitat selection).

The 200,000-bbl spill is assumed to occur offshore (Tanker Segment T-6). It is also assumed that a portion of it (an estimated 30,000 bbl) will contact the shore within 10 days and cover a discontinuous surface area on the water of about 1,737 km^2. Hence, the 200,000-bbl spill would substantially increase the amount of oil contacting the gulf shoreline and surface waters. For this reason oil from the 200,000-bbl spill is likely to remain in the affected shoreline sediments longer.

Regarding the shoreline most likely to be contacted, the OSRA estimates that the conditional probability (expressed as percent chance) of an oil spill contacting the shore within 10 days ranges from 1 to 4 percent for 9 eastern land segments (LS's 68-76; Fig. B-1). Conditional probabilities (expressed as percent chance) west of this are <0.5 percent. The OSRA estimates that the conditional probability (expressed as percent chance) of contact within 30 days ranges from 1 to 8 percent for 27 land segments (LS's 7-76 Fig. B-1). However, the 30-day conditional probability (expressed as percent chance) of oil contacting the shore is generally lowest west of Resurrection Bay (1-3%) and highest east of Cape Saint Elias (2-8%). Hence, a majority of the oil from the 200,000-bbl spill that would be washed ashore is expected to contact shoreline areas from Cape Saint Elias east to Icy Bay. A much smaller amount of extremely weathered oil is expected to contact some shoreline areas to the west of Cape Saint Elias.

Based on the above, this analysis has assumed that the 200,000-bbl spill would contact about 40 percent more gulf shoreline, and 300 percent more surface water, with about three times as much oil. Within the sale area, all of the above differences are estimated to increase effects on marine plants and invertebrates in the intertidal area by about 40 percent, and to increase effects on plankton in open-water areas by about 300 percent. However, these increases are expected to have little effect on recovery times in the Gulf of Alaska. This is due primarily to the high rate of hydrologic exchange in open-water areas and the amount of heavy wave action in most intertidal areas.

Based on these estimates and assumptions, the 200,000-bbl oil spill is estimated to have sublethal and lethal effects on 1 to 5 percent of the phytoplankton and zooplankton populations in the sale area. Recovery is expected to take 1 or 2 days for phytoplankton and up to 1 week for zooplankton. The total percentage of plankton affected could increase to about 10 percent if many embayments were contacted by the spill. Recovery within the affected embayments is expected to take 1 to 2 weeks. Most marine plants and invertebrates in subtidal areas are not likely to be contacted by an oil spill (contact estimated at <5%). The 200,000-bbl oil spill is estimated to have lethal and sublethal effects on about 40 to 50 percent of the intertidal and shallow subtidal marine plants and invertebrates in the sale area. Recovery of these communities is expected to take 2 to 3 years in high-energy habitats and up to 7 years in lower-energy habitats.

Conclusion: The 200,000-bbl oil spill is estimated to have lethal and sublethal effects on 1 to 10 percent of the plankton in the proposed sale area. Recovery is expected to take 1 or 2 days for phytoplankton and up to 1 week for zooplankton. The spill also is estimated to have lethal and sublethal effects on about 40 to 50 percent of the intertidal and shallow subtidal marine plants and invertebrates in the sale area. Recovery of these communities is expected to take 2 to 3 years in high-energy habitats and up to 7 years in lower-energy habitats. Less than 5 percent of the subtidal benthic populations in the sale area are expected to be affected.

4. Fishes: The assumed 200,000-bbl-oil spill from a tanker accident that occurs in the southern portion of the sale area during the summer would adversely affect pelagic, semidemersal, and demersal fish that inhabit these waters. The adverse effects, ranging from sublethal to lethal in the event of contact by oil, would not, however, reach any appreciable number of fishes. The 200,000-bbl oil spill would not reach any large ocean area with persistent toxicity (Malins, 1977). These factors, when compared with the large regional fish populations, the seasonal migratory behavior of many species, the low densities within a given habitat, and the wide distribution of the populations over this region and within the sale area, would cause only a very small percentage of a population to be contacted by the assumed 200,000-bbl spill.

Salmon smolt and fry would be at risk during summer. Salmon have economic importance and are abundant over much of Alaska. Salmon smolt and fry would be transiting the coastal area during this time. As revealed by the studies of the *Exxon Valdez* oi spill in Prince William Sound, pink salmon fry would suffer reduced growth due to the metabolic cost of depurating a spill-related hydrocarbon burden (Wertheimer et al., 1993; Carls et al., 1993), and the slower growth of juvenile pinks may have caused an incremental reduction in survival to adulthood. Small numbers of smolt from other salmon species would also be contacted. The coastal areas that are oiled, however, do not represent a large segment of the salmon-spawning habitat or migration routes; e.g., in Prince William Sound, a relatively small segment of pink salmon streams was oiled by the *Exxon Valdez* spill. In three salmon-management districts with 209 identified spawning streams, 29 (14%) actually were on oiled shorelines (Maki et al., 1993). A 200,000-bbl oil spill in offshore waters would have the potential to contact fewer of the larger number of pink salmon-spawning streams and, given the depth at which salmon fry and other salmon usually migrate, perhaps <1 percent of the migrants would be at risk from a 200,000-bbl oil spill.

Pacific herring would also be adversely affected by a 200,000-bbl oil spill because their eggs are laid within the littoral zone, and the resulting larvae and fry spend their first summer in shallow coastal waters before moving offshore in the fall. The number of herring larvae and juveniles that would be affected is indeterminate. However, given the size and distribution of herring populations in the Gulf of Alaska and the limited coastal area contacted, there probably would not be a large-scale loss of herring from a 200,000-bbl oil spill.

Some semidemersal fishes might be injured by contact with a large oil spill; but given their usual habitat in deeper waters, only the limited, low-concentration water-soluble fractions of the oil would reach these depths where it is no longer at concentrations toxic to semidemersal fishes (Kineman, 1980). During summer, some pelagic larvae and juveniles of semidemersal fishes might be at the surface but at comparatively low densities because the pelagic zone where they occur extends to 50 m in deeper waters. Larvae and juveniles are also widely distributed. For these reasons, no appreciable number of larvae or juveniles of semidemersal fishes would be adversely affected by the spill.

Demersal fishes, well offshore and at depth, are not likely to be contacted or affected by the oil spill. Those demersal species with pelagic larvae and juveniles might be affected in the immediate zone of the oil spill, but the numbers so affected would not comprise large numbers of the total populations. This is because densities per square meter of seawater do not range above units of tens, while egg complements of most demersal species range in the thousands (Bakkala, 1975).

Laevastu et al. (1986) assessed the potential effects of a 240,000-oil spill on eastern Bering Sea fishes. They estimated that <0.3 percent of yellowfin sole eggs and larvae would be killed (yellowfin sole were used as an indicator species for all demersal and semidemersal fishes in the study). Laevastu et al. also estimated that a *maximum* 13-percent mortality of outmigrating smolt could occur and that this could translate into a 5-percent loss in returning adults. Because these estimated losses are significantly lower than measurement errors (20-90%) associated with assessing changes in stock size, the authors concluded that a "...tanker accident would have no quantifiable effect on the offshore fishery resources in the eastern Bering Sea." While the eastern Bering Sea and the Gulf of Alaska are physiographically different, they support similar biotic (fish) communities that would be affected by spilled oil in similar fashions. While Laevastu's results are not directly transferable to the Gulf of Alaska, they provide a conservative estimate of the level of effects that can be expected.

Conclusion: The effects on fishes from a 200,000-bbl oil spill are not expected to cause population-level changes. The assumed 200,000-bbl oil spill is estimated to affect <0.3 percent of the offshore marine fisheries resources and <5 percent of the adult salmon resources in the area. However, these conservatively estimated losses would not be detectable using standard fisheries-population-assessment methods.

5. Marine and Coastal Birds: The assumed 200,000-bbl tanker spill would occur offshore Cape Fairweather along Tanker Segment T6 during the summer with onshore winds (Fig. B1). Within 10 days the spill is estimated to have swept over a discontinuous area of 1,737.5 km^2; after 60 days the area of continuous slick is estimated to be 21 km^2 (Table B-1). A portion of the spill is expected to contact marine and coastal bird habitats used especially during winter- and spring-migration periods (murrelets and terns in summer) within Yakutat and Icy Bays and near Kayak Island (ERA's 6, 7 and 8), as well as in the Fairweather Ground and Middleton Island areas (ERA's 5 and 11), as shown in Figure B-2.

Oil-spill mortality in winter and early spring in coastal areas adjacent to the spill area is likely to involve overwintering loons and grebes, cormorants, sea ducks, marbled and Kittlitz's murrelets, pigeon guillemots, gulls, and bald eagles. Based on proportional estimates from EVOS data (Ford et al., 1991; Piatt et al., 1990) and season of occurrence, and assuming equal contact in all habitats, the following approximate carcass recoveries would be expected from a spill in winter/early spring: 337 loons, 382 grebes, 674 cormorants, 1,190 sea ducks, 494 murrelets, 494 guillemots, 539 gulls, and 25 bald eagles. For any of these estimates, actual mortality may be three- to tenfold greater because of failure to recover most carcasses. Effects are expected to be most severe in species such as the yellow-billed loon, pelagic cormorant, harlequin duck, Kittlitz's murrelet, and bald eagle, where even modest losses represent a large proportion of the local—or in some cases Alaskan—populations. Greater mortality in species such as the marbled murrelet and pigeon guillemot, while locally serious in terms of loss to slowly reproducing species, is not expected to represent as severe a loss because of their substantial Alaska populations. Recovery periods for this level of mortality are expected to range from two to five generations.

Mortality in late spring is expected to include larger numbers of migrant waterfowl and shorebirds. Northwest of the spill area the Copper River Delta in particular, while not as likely to be contacted, could suffer catastrophic losses to several populations (potentially 10,000-50,000 individuals of western sandpiper, dunlin, dusky Canada goose) during the spring-migration period, requiring several generations (more for the goose) for recovery. Offshore seabird densities in spring average about 88 birds/km^2, with the potential for tens of thousands of fatalities if the spill swept an area of several hundred square kilometers or more. Recovery from such losses is expected to require at least two to three generations.

After departure of overwintering and southern-latitude migrants, spill mortality in summer is expected to include cormorants, arctic and Aleutian terns, murrelets, guillemot, puffins, and bald eagle in these coastal areas; recovery periods are not likely to change significantly, but substantial mortality at the large Aleutian tern colony near Yakutat would be expected and could represent a serious loss for this species with its relatively small population. Offshore, a spill occurring and contacting primarily the Middleton Island area in summer is expected to cause substantial murre mortality as well as losses of kittiwakes and rhinoceros auklets (potentially 10,000 or more individuals [Gould, Forsell, and Lensink, 1982]). Recovery is expected to require two or more generations. A spill moving into offshore areas could contact many tens of thousands of southern-hemisphere shearwaters present in large flocks during summer, but recovery of this abundant seabird probably would occur rapidly.

Summer density of the marbled murrelet in the immediate vicinity of Yakutat Bay ranges from 0.65 to 1.36 birds/km^2, declining to <0.31/km^2 beyond 50 km offshore and most of the area northwest of the bay. The potential spill associated with TAPS traffic is expected to cover a discontinuous area of 7,211 km^2 after 30 days (Table B-1), suggesting that murrelet mortality could total up to many hundreds of individuals. Supporting estimates of potential mortality of this magnitude, murrelets retrieved following the *Exxon Valdez* oil spill totaled about 780 (includes natural mortality), probably representing 10 to 30 percent of the total murrelet deaths during this period (Piatt et al., 1990); potential mortality values must be decreased somewhat because the size of this potential spill is 77 percent of the *Exxon Valdez* spill. Although murrelets have a low productivity, the large size of the eastern gulf population suggests that such mortality would be recovered within a few generations. Offshore average seabird densities in summer are somewhat less than in spring (69 birds/km^2), but mortality would not be expected to be less because of the loss of some eggs and/or young through contact with oiled adults.

Conclusion: The effect of exposure of marine and coastal birds to a 200,000-bbl oil spill in this region is expected to seasonally affect the yellow-billed loon, pelagic cormorant, harlequin duck, Aleutian tern, Kittlitz's murrelet, and bald eagle most severely, causing mortality of many hundreds of these marine birds and tens of eagles, requiring two to five generations for recovery. A spill approaching Middleton Island could contact 10,000 or more murres, kittiwakes, and auklets, requiring two or more generations for recovery.

6. Nonendangered Marine Mammals (Pinnipeds, Cetaceans, and Sea Otters): This analysis assumes that a 200,000-bbl tanker spill occurs offshore Cape Fairweather along Tanker Segment T6 during the summer with onshore winds (Fig. B-1). Within 10 days the spill is estimated to have swept over a discontinuous area of 1,737.5 km (Table B-1); and a portion of the spill is estimated to have contacted sea otter, harbor seal, and nonendangered cetacean habitats within Yakutat and Icy Bays (ERA's 6 and 7, respectively); sea otter and harbor seal habitats near Kayak Island (ERA 8); and northern fur seal habitat in the Fairweather Ground (ERA 5), as shown in Figure B-2. Sea otters within Yakutat Bay and near Kayak Island are expected to be exposed to the spill and to suffer substantial losses (perhaps several hundred animals) to the local populations, with recovery taking more than one generation (perhaps ≥5 years).

Assemblages of harbor seals in Yakutat and Icy Bays and near Kayak Island are expected to be exposed to the spill and a number (perhaps several hundred or more) of them are likely to become oiled and absorb petroleum hydrocarbons through their skin and suffer physiological/toxic stress that might lead to the death of a number of oiled seals (perhaps 100-200 animals), with recovery from this loss taking place within less than one generation (probably 2 years). Groups of northern fur seals (perhaps a few hundred to a few thousand) migrating through the northern gulf in the Fairweather Ground are likely to be exposed to the spill in this offshore habitat. Several hundred to a few thousand fur seals are likely to become oiled and to suffer hypothermia due to oiling of their fur, and many or most of the oiled fur seals are assumed to be killed by this exposure to the spill. Recovery of the Pribilof Islands northern fur seal population (>800,000 seals) is expected to take place within 1 year through population recruitment.

Within 30 days after the spill, more of the spill is expected to contact Kayak Island habitats of sea otters and harbor seals as well as Yakutat and Icy Bays. The spill is estimated to contact sea otter and harbor seal habitats near Montague and Hinchinbrook Islands (ERA's 12 and 10, respectively) and along the lower Kenai Peninsula (ERA's 13 and 14), and to contact northern fur seal and cetacean offshore habitats southwest of Kayak Island (SS 1) westward to Portlock Bank (SS 2 and ERA 18), as shown in Figure B-2. Rafts of sea otters and assemblages of harbor seals along the gulf coast side of Montague and Hinchinbrook Islands and along the lower Kenai Peninsula are likely to be exposed to part of the 200,000-bbl spill and to suffer some losses (such as several hundred sea otters and perhaps ≤100 harbor seals). At 30 days the spilled oil is expected to be very dispersed and at least partly weathered, with much of the toxic components lost; thus, the losses of harbor seals and perhaps sea otters to oil contact at this stage of the spill are expected to be less than losses during the first 10 days of the spill.

Groups of northern furs seals migrating and feeding in offshore habitats southwest of Kayak Island and in Portlock Bank are likely to have some exposure to the spill within days. This exposure is expected to result in the oiling of some fur seals (perhaps a few hundred to a few thousand animals) and the assumed loss of most if not all of these fur seals due to hypothermia from the oiling and reduced thermal insulation.

Cetaceans within Yakutat Bay, such as harbor seal, Dall's porpoise, and killer and gray whales migrating along the coast between Yakutat Bay and Kayak Island at the time the spill contacts these habitats, might encounter oil on the surface of the water when breathing and resting. These encounters are not expected to result in mortalities unless the cetaceans encounter a very large, continuous oil slick of fresh, highly toxic oil from the spill and consequently inhale lethal amounts of toxic fumes, which results in the death of highly exposed whales or porpoises. The number of cetaceans lost to such possible encounters is expected to be few (probably <10 animals). If such losses occurred in a family group of killer whales, recovery could take more than one generation (such as ≥10 years). However, populations of killer whales, porpoises, and other cetaceans in the gulf are likely to replace the loss of 10 to 20 individuals within 1 year.

Cetaceans that might encounter oil from the spill within offshore habitats, such as Fairweather Ground or Portlock Bank, are not expected to suffer any lethal exposure to the spill because the oil is expected to be highly dispersed in these offshore habitats and quite weathered when encountered in the Portlock Bank area.

Conclusion: The potential total loss of sea otters to the 200,000-bbl oil spill (perhaps 1,500-2,000 individuals) is likely to take more than one generation (probably >5 years) for total recovery to take place, while the potential loss of harbor seals (perhaps about 200 individuals) is likely to take less than one generation (perhaps 2 years) for recovery to take place, depending on the population status at the time of the loss and other unrelated factors adversely affecting the regional population. Potential loss of northern fur seals to the spill (perhaps 2,000-3,000 individuals) is expected to take less than one generation (probably 1 year) for recovery to take place. The potential loss of cetaceans (10-20 individuals in a population or group) is likely to affect a family group (such as a killer whale pod) for more than one generation; but such a loss to a population of whales or porpoises is expected to take about 1 year for the population to recover.

7. Endangered and Threatened Species: For the very large oil-spill case it is assumed that one 200,000-bbl-tanker spill occurs offshore approximately 60 km due east of the coast between Dry Bay and Lituya Bay along Tanker Segment T6 in the summer. The OSRA model estimates a 19- and a 20-percent chance of a spill ≥1,000 bbl contacting ERA 11 (Middleton Island) and ERA 8 (Kayak Island), respectively, and a 16-percent chance of that spill contacting SS 1 within 30 days during the summer—assuming that a spill occurs at Tanker Segment T6. The estimated chance of the spill contacting other ERA's ranges from ≤0.5 to 6 percent within 30 days during the summer (Fig. B-2).

a. Whales: Exposure of endangered whales to spilled oil is not expected to occur. Only small numbers of endangered whales are expected to be present in the sale area or in areas contacted by the assumed oil spill. There is a slightly higher potential that humpback whales would be exposed to spilled oil, since humpback whales may be present in the Kayak and Middleton Island area. No effects on the humpback whale population from the EVOS were documented (Dahlheim and Loughlin, 1990). Few fin, sei, blue, right, or sperm whales are expected to be exposed to spilled oil. The estimated conditional probability (expressed as percent chance) of spilled oil contacting SS 1 (16%) is relatively low. For whales that may be in the vicinity of Kayak or Middleton Islands, the chances of contact are slightly higher (19-20%). A few whales may be exposed to spilled oil, resulting in temporary sublethal effects; but no mortalities are expected. The overall effects of exposure of endangered whales to a very large oil spill are expected to be negligible.

b. Steller Sea Lions: The very large oil spill discussed in this analysis could contact Steller sea lion haulouts on Kayak and Middleton Islands, but is not likely to contact any major rookeries. There are no major rookeries in the sale area, and the estimated chance of spilled oil contacting a major rookery adjacent to the sale area is low (≤0.5-5%). The highest estimated probabilities (expressed as percent chance) for ERA's are a 20-percent chance of spilled oil contacting ERA 8 (Kayak Island) and ERA 11 (Middleton Island) within 30 days in the summer. If such a spill occurred, several hundred or more adult and subadult sea lions could be exposed to spilled oil and could experience various degrees of oiling. No changes in distribution, abundance, mortality, pup production, or other potential effects have been attributed to the EVOS (Calkins and Becker, 1990), although the population's continuing decline may have masked some effects. These data suggest relatively low effects of an oil spill on sea lions. Heavily oiled individuals may experience elevated stress that could intensify any other debilitating problems, potentially causing death. Mortalities are expected to be more than 100 individuals, requiring two generations or more for recovery. Even if the spill stays at sea, oil is expected to contact some adults in pelagic waters, resulting in sublethal effects. Overall, Steller sea lions exposed to a very large oil spill would most likely experience temporary, sublethal effects; but exposure could result in lethal effects on some animals. More than 100 mortalities are expected, requiring two generations or more for recovery.

c. Short-Tailed Albatross: Only a small percentage of the short-tailed albatross population would be likely to occur in or near the Sale 158 area. Due to the expected rare occurrence of this species in the area and the relatively low probability of spilled oil contacting their habitat, it is expected that exposure to spilled oil would not occur. The effects of a large oil spill are expected to be negligible.

Conclusion: The overall effects on endangered whales, and the short-tailed albatross from exposure to a very large oil spill are expected to be negligible. Some whales could experience temporary, sublethal effects, but no mortalities are expected. Steller sea lions exposed to a large oil spill would most likely experience temporary, sublethal effects, but exposure could result in lethal effects on some animals. More than 100 mortalities could occur, requiring more than two generations for recovery.

8. Terrestrial Mammals: This analysis assumes that a 200,000-bbl tanker oil spill occurs offshore Cape Fairweather along Tanker Segment T6 during the summer with onshore winds (Fig. B-1). Within 10 days the spill is estimated to have swept over a discontinuous area of 1,738 km^2 (Table B-1), and a portion of the spill is estimated to have contacted coastline habitats of terrestrial mammals from Yakutat Bay westward to Kayak Island (LS's 68-71 and 74-76), as shown in Figure B-1. River otters and brown and black bears frequenting the shoreline of Yakutat Bay westward to Point Manby/Cape Sitkagi to near Icy Bay, and frequenting shoreline habitats from Cape Yakataga/Cape Suckling to Kayak Island, are expected to encounter oil from the spill along the beach and in intertidal habitats. Some river otters (perhaps >50) are likely to be oiled by the spill or to ingest oil through consumption of oiled prey and oiled carrion. A number of river otters (perhaps >50) are likely to be killed by the spill, with total recovery of the local population and intertidal habitats taking >1 year (perhaps ≥3 years).

Brown and black bears that frequent the above oiled shoreline habitats are likely to ingest oiled prey and oiled carrion, with perhaps 20 to 30 bears affected. Assuming that all the bears that ingest oiled food items are killed, total recovery of brown and black bear populations and local habitats is expected to take >1 year (perhaps >3 years). Although moose that occur along the shoreline of oiled shoreline habitats (Yakutat Bay/Kayak Island) may encounter oil on the beaches and mudflats while foraging on willow and other browse, they are not likely to ingest oiled intertidal vegetation during this time of the year and thus are not expected to ingest oil-contaminated vegetation and suffer mortalities or other adverse effects.

Within 30 days the 200,000-bbl oil spill is estimated to contact terrestrial mammal coastal habitats from Cape Fairweather westward to Montague Island and coastline areas on the lower Kenai Peninsula (LS's 56, 58, and 80-61, respectively), as shown in Figure B-1. More oil from the spill is expected to contact river otter and brown and black bear coastal habitats from Yakutat Bay to Kayak Island, and the spill is estimated to oil other habitats along the coast of the Copper River Delta, on Hinchinbrook and Montague Islands, and along the southern coast of the Kenai Peninsula. Some additional river otters (perhaps 100-200 individuals) and black and brown bears (perhaps 50-100 individuals) are likely to come in contact with oil on the beaches and intertidal mudflats and to ingest oiled prey or carrion. However, by 30 days the beached oil is expected to be quite weathered and far less toxic than the oil that reaches the coast within 10 days; thus, fewer bears and river otters (perhaps 30-40 bears and <50 otters) are expected to suffer lethal doses of oil from ingestion of contaminated food sources. These additional losses of river otters and bears and contamination of habitats are likely to recover within less than one generation (or within about 1-2 years).

Although the coastal habitats of Sitka black-tailed deer on Montague and Hinchinbrook Islands are expected to be oiled by the 200,000-bbl oil spill, black-tailed deer are not likely to be directly exposed to the oil because they generally do not forage on kelp and other intertidal vegetation during the summer season, when the spill is assumed to occur. Thus, Sitka black-tailed deer are not expected to suffer mortalities from the spill.

Conclusion: The potential loss of river otters (perhaps 50-100 individuals) and contamination of intertidal habitats from the 200,000-bbl oil spill is estimated to take more than 1 year to recover (probably ≥3 years), while the potential loss of brown and black bears (perhaps 50-70 individuals) is estimated to take more than 1 year (perhaps >3 years). Neither moose nor Sitka black-tailed deer are likely to suffer mortalities or other effects from the 200,000-bbl oil spill, assuming that it occurs during the summer.

9. Economy of the Yakutat Borough: The most relevant historical experience of a tanker spill in Alaskan waters is the EVOS of 1989, which spilled 258,000 bbl. This spill generated enormous employment that rose to the level of 10,000 workers directly doing cleanup work in relatively remote locations. Smaller numbers of cleanup workers returned in the warmer months each year following 1989 until 1992. Numerous local residents quit their jobs to work on the cleanup at often significantly higher wages, which generated a sudden and significant inflation in the local economy (Cohen, 1993). Anecdotal information indicates that housing rents in Valdez in 1989 increased from 25 percent in some cases to sixfold in others, and inflated rents continued into 1990. Prices of food and other goods increased only slightly, because people could drive to Anchorage to purchase them (Henning, 1993, pers. comm.). Research shows that no data on inflation were gathered in a systematic way during the *Exxon Valdez* oil spill, although most observers agree that there was temporary inflation.

The number of cleanup workers actually used for a very large oil spill of 200,000 bbl would depend to a great extent on what procedures are called for in the oil-spill-contingency plan, how well prepared with equipment and training the entities responsible for cleanup were, how efficiently the cleanup was executed, and how well the coordination of cleanup was executed among numerous responsible entities. A very large oil spill of 200,000 bbl resulting from activity associated with Sale 158 could generate about the same number of workers associated with the *Exxon Valdez* spill—or 10,000 cleanup workers at the peak of the cleanup effort. Housing for cleanup workers would likely be located outside of Yakutat in some type of temporary enclave, such as those developed during the *Exxon Valdez* spill. Based on experience from the *Exxon Valdez* oil spill, all communities proximate to the oil-spill-cleanup effort could experience temporary increases in wage rates and a shortage of housing, which could cause significant housing-rent increases.

Conclusion: A very large spill of 200,000 bbl would create effects similar to those experienced with the *Exxon Valdez* spill. Short-term employment could reach or exceed 10,000 people, along with price inflation above 25 percent during the first 6 months of the cleanup operation. Long-term economic effects would be minimal.

10. Commercial Fisheries: The 200,000-bbl oil spill would affect the Gulf of Alaska commercial-fishing industry by exposing it to petroleum-based hydrocarbons. The 200,000-bbl spill would substantially increase the amount of oil contacting shoreline and open-water commercial fishing grounds. Because more shoreline would be contacted with more oil, oil from the 200,000-bbl spill likely would remain for a longer period in shoreline sediments. Within the Gulf of Alaska area this is not expected to result in additional closures because any large spill is large enough by itself to close northeastern gulf commercial fisheries. However, once the spill was northwest of the TAPS tanker route (the predominate direction of ocean currents), there would be substantially more oil moving out of the area from the 200,000- bbl spill. Hence, the oil from the 200,000-bbl spill is likely to enter and more strongly affect the commercial fishing grounds within portions of Prince William Sound and farther west toward Resurrection Bay. Due to the greater presence of oil in these areas, more fishery closures are expected with a 200,000-bbl spill that moves outside of the TAPS tanker route.

The estimated economic effect of a 200,000-bbl oil spill on the gulf commercial-fishing industry is based on what occurred during the larger (258,000 bbl) *Exxon Valdez* oil spill and a smaller (4,000-bbl) spill, and depends primarily on the highly variable *Exxon Valdez* spill cost estimates (ranging from $9-43 million/year for 2 years). The value of the gulf commercial fishery (Prince William Sound to Cape Fairweather) is estimated at $75 to $200 million per year, depending on the price per year and numbers caught. Hence, in any 2-year period when the value of the northeastern gulf commercial fishery is estimated to be about $75 million per year, a 2-year loss of about $9 million per year represents a 12-percent-per-year loss for 2 years. A 2-year loss of about $43 million per year represents a 57-percent-per-year loss for 2 years. In a 2-year period when the annual value of the northeastern gulf commercial fishery is estimated to be closer to $200 million, a 2-year loss of about $9 million per year represents a 5-percent-per-year loss for 2 years, whereas a 2-year loss of $43 million per year represents a 22-percent-per-year loss for 2 years.

Because the occurrence of a large oil spill (e.g., 200,000 bbl) would preclude any knowledge of what the commercial fishery would have been worth (due to closures), the value of the commercial fishery at the time of the 200,000-bbl oil spill is assumed to be the estimated average annual value of the gulf commercial fishery. In terms of the estimated average annual value (about $125 million), a 2-year loss of about $9 million per year represents a 7-percent-per-year loss for 2 years, whereas a 2-year loss of about $43 million per year represents a 34-percent-per-year loss for 2 years. These estimates are the same as for large spill because, as indicated above, any large oil spill is large enough to close the same amount of commercial fishery within the sale area. However, if it is assumed that the oil from the 200,000-bbl oil spill also moves outside and northwest of the sale area, additional closures are expected from Prince William Sound to Resurrection Bay. It is estimated that these additional closures would further reduce the value of gulf commercial fisheries (excluding Kodiak and Cook Inlet) by about 30 percent for 2 years. Hence, estimated gulf commercial fishing losses due to the 200,000-bbl oil spill are estimated to range between $45 million (7+30 = 37%) and $80 million (34+30 = 64%) per year for 2 years following the spill.

Thus, based on loss estimates from the *Exxon Valdez* spill and the estimated annual value of the northeastern gulf commercial fishery, the 200,000-bbl oil spill could result in an economic loss to the northeastern gulf commercial fishing industry of 12 to 57 percent per year for 2 years (within the sale area). However, in terms of the estimated average annual value of the northeastern gulf commercial fishery, the 200,000-bbl oil spill is more likely to result in a loss of about 7 to 34 percent per year for 2 years within the sale area. Additional closures northwest of the sale area are estimated to increase this loss to between 37 and 64 percent per year for 2 years following the spill. Compensation to the commercial-fishing industry for participating in the cleanup of an oil spill is likely to exceed these economic losses by several orders of magnitude.

Conclusion: Based on the assumptions discussed in the text, adjusted *Exxon Valdez* spill loss estimates, and the average annual value of the Gulf of Alaska commercial fishery, the 200,000-bbl oil spill is estimated to result in economic losses to the gulf commercial-fishing industry ranging from 37 to 64 percent per year for 2 years following the spill.

11. Subsistence-Harvest Patterns: This analysis assumes that a 200,000-bbl tanker oil spill occurs offshore Cape Fairweather along Tanker Segment T6 during the summer with onshore winds (Fig. B-1). Within 10 days the spill is estimated to have swept over a discontinuous area of 1,738 km (Table B-1), and a portion of the spill is estimated to have contacted coastline habitats from Yakutat Bay westward to Kayak Island, as shown in Figure B-1. Within 30 days the 200,000-bbl oil spill is estimated to contact the entire coastline associated with the Yakutat and Cordova subsistence-harvest areas.

The effects on subsistence-harvest patterns would be comparable to the effects from the *Exxon Valdez* oil spill of 1989, because both tanker spills would have occurred at similar times and would be of approximately the same size. The primary difference between the two incidents is in the geography of the spills, which makes Yakutat more instantaneously subject to contact. The annual round of harvest activities for Yakutat indicates that some harvests, such as for harbor seal, salmon, and marine invertebrates, could have begun. The instantaneous nature of the event would not permit opportunistic "stocking up" of available resources. Using experience from the *Exxon Valdez* spill as a gauge, effects on subsistence-harvest patterns for the residents of Yakutat and Cordova—especially for intertidal resources and some fish species—would be expected to last for at least 4 years.

Conclusion: Subsistence harvests in the 200,000-bbl-spill case would be reduced or substantially altered by as much as 80 percent in Yakutat and Cordova for at least 1 year and, to a lesser extent, for selected subsistence resources 3 to 4 years beyond.

12. Sociocultural Systems: This analysis assumes that a 200,000-bbl tanker oil spill occurs offshore Cape Fairweather along Tanker Segment T6 during the summer with onshore winds (Fig. B-1). Within 10 days the spill is estimated to have swept over a discontinuous area of 1,738 km (Table B-1), and a portion of the spill is estimated to have contacted coastline habitats from Yakutat Bay westward to Kayak Island, as shown in Figure B-1. Within 30 days the 200,000-bbl oil spill is estimated to contact the entire coastline associated with the Yakutat and Cordova subsistence-harvest areas.

The location of the 200,000-bbl spill off Cape Fairweather suggests that spill effects on Yakutat would be instantaneous, with little time to prepare, and could be expected to last at least 4 years. Individuals and communities that depend on income from commercial fisheries would experience stress and anxiety from debt burden, income shortfalls, litigation, and fear for the future should the fisheries they participate in or depend on in other capacities be shortened or terminated due to the accidental spill.

Considerable stress and anxiety also would be expected over the loss of subsistence resources, contamination of habitat, fear of the health effects of eating contaminated wild foods, and the need to depend on the knowledge of others about environmental contamination (Maganak, 1990; Fall, 1992; McMullen, 1993). Individuals and the communities of Yakutat and Cordova would be increasingly stressed during the time needed to modify subsistence-harvest patterns by selectively changing harvest areas, if available. Associated culturally significant activities, such as the organization of subsistence activities among kinship and friendship groups and the relationships among those that customarily process and share subsistence harvests, would be modified or would decline as well.

The 200,000-bbl-spill case also would be expected to affect individuals and institutions in ways similar to the experience from the *Exxon Valdez* spill. As shown by that spill, some individuals found a new arena for pre-existing personal and political conflict, especially over the dispensation of money and contracts. In the smaller communities, cleanup work produced a redistribution of resources, creating new schisms in the community (Richards, undated). Many members of small communities were on the road to sobriety prior to the spill; but after the spill some people began drinking again, producing the re-emergence of numerous alcohol-related problems, such as child abuse, domestic violence, and accidents, that were there before (Richards, undated).

Institutional effects included additional burdens being placed on local government, disruption of existing community plans and programs, strain on local officials, difficulties dealing with the spiller, community conflict, disruptions of customary habits and patterns of behavior, emotional effects and stress-related disorders, confronting environmental degradation and death, and violation of community values (Endter-Wada, 1992). Postspill stress resulted from this seeming loss of control over individual and institutional environments as well as from secondary episodes such as litigation, which produced secrecy over information, uncertainty over outcomes, and community segmentation (Smythe, 1990; Picou and Gill, 1993). Attempts to mitigate effects met with a higher priority placed on concerns over litigation and a reluctance to intervene with people for fear it might benefit adversaries in legal battles (Richards, undated).

Conclusion: Sociocultural systems in the communities of Yakutat and Cordova are expected to undergo severe individual, social, and institutional stress and disruption in the year of the 200,000-bbl spill that would last at least 4 years thereafter.

13. Archaeological Resources: The 200,000-bbl oil spill would affect archaeological resources by creating surface-disturbing activities resulting from emergency shoreline treatment. Following the *Exxon Valdez* oil spill, Exxon developed and funded a Cultural Resource Program to ensure that potential effects on archaeological sites were minimized during shoreline treatment (Betts, 1991). This program involved a team of archaeologists who performed reconnaissance surveys of the affected beach segments, reviewed proposed oil-spill treatment, and monitored treatment. As a result of the coastline surveys, hundreds of archaeological sites were discovered, recorded, and verified. This resulted in the most comprehensive archaeological record of Alaskan coastline ever documented.

Although a number of sites in the *Exxon Valdez* spill area were vandalized during the 1989 cleanup season, the large number of Exxon and government-agency archaeologists visible in the field may have lessened the amount of site vandalism that may have occurred (Mobley, 1990).

The Dekin study (1993) found that small amounts of petroleum hydrocarbons may occur in most archaeological sites within the study area. This suggests a low-level petroleum contamination that had not previously been suspected. Since the researchers found no evidence of extensive soil contamination from a single definable source (i.e., the oil spilled from the *Exxon Valdez*), they "...now add the continuing contamination of soils from small and large petroleum spills in areas where present and past land use coincide" (Dekin, 1993). Vandalism was found to have a significant effect on archaeological site integrity but could not be tied directly to the oil spill (Dekin, 1993).

Conclusion: The expected effect on onshore archaeological resources from a large oil spill is uncertain, but data from the *Exxon Valdez* oil spill indicate that <3 percent of the resources within a spill area would be significantly affected.

14. Recreation and Tourism: This analysis assumes that a 200,000-bbl tanker spill occurs approximately 60 km due east of Glacier Bay National Park and Preserve between Dry Bay and Lituya Bay during the summer. Within 10 days the spill is estimated to contact the coastal areas of Wrangell-Saint Elias National Park and Preserve and the Tongass National Forest adjacent to Yakutat Bay. Within 30 days the oil spill would move north and west along the Gulf of Alaska in the Alaska Current and Alaska Coastal Current and contact coastal areas in Prince William Sound and the Kenai Fjords National Park. The spill also would contact Glacier Bay National Park and Preserve within 30 days.

Recreation and tourism activities in coastal areas contacted by the spill would in all likelihood be precluded until spill-cleanup operations and natural processes restored the sites to a relatively natural condition. Oil-spill-cleanup activity would disturb resources in the area 200 m inward from the waterline, as happened with the *Exxon Valdez* oil spill oil-spill cleanup.

The effect of a large spill on Prince William Sound's tourist industry would be very similar to that of the *Exxon Valdez* spill. The immediate effect of a large oil spill contacting the northern coast of the Gulf of Alaska would be the cancellation of tourist plans to visit the area contacted by the spill. The biggest effect would be felt by small charter-boat, lodge, and sport-fishing operations that normally would get many of their bookings just before the summer season. Lodges and fishing operations in the Yakutat area would probably suffer the largest economic losses as a result of the spill. Other tourist attractions along the Gulf of Alaska and areas adjacent to the area of spill contact could expect a decline in the number of bookings for the summer. Major cruise lines, which require deposits from customers, would probably be least affected by the oil spill. Major economic losses could be expected for the tourist season following the spill; however, tourist levels would be expected to rebound to prespill levels 1 year after the spill, as was the experience with the *Exxon Valdez* spill.

Conclusion: The 200,000-bbl oil spill would preclude recreation and tourism activities in the coastal areas of the Wrangell-Saint Elias National Park and Preserve, Tongass National Forest, Prince William Sound, and Glacier Bay National Park and Preserve until spill-cleanup operations and natural processes restored the sites. Major economic losses could be expected for the tourist industry following the spill, with small charter-boat, lodge, and sportfishing operations in the Yakutat area being the hardest hit. However, tourist levels would be expected to rebound to prespill levels 1 year after the spill.

15. Land Use Plans and Coastal Management Programs: In the event of a 200,000-bbl oil spill, greater effects would be experienced by most biological resources in coastal environments and intertidal areas; by subsistence users; and by cultural and archaeological resources. Water quality would exceed the acute chronic criterion for >l month. Because these greater levels of effects are perpetrated by an accidental oil spill along a transportation route that is not inherently more dangerous than other potential routes, most Statewide and district policies would apply here.

Statewide standards and district policies related to coastal development; geophysical hazards; energy facilities; transportation and utilities; and historic, prehistoric, and archaeological resources can be applied better when an actual development is proposed. Nothing in the scenario is inherently in conflict with these policies. The broader Statewide standards and district policies related to subsistence; habitat; and air, land, and water quality can be applied more easily with the information available at the lease-sale stage.

The greater level of effects identified in above Sections II.a through II.n do not translate into greater potential for conflict with these Statewide standards and district policies for the reason stated above—the spill that is the source of the effects is accidental and does not reflect a particular siting decision for transporting oil to market.

Regardless of the method used for transshipment, all oil leaving the State of Alaska travels by tanker. Mitigating measures that reinforce MMS regulations related to oil-spill-contingency (OSCP's) plans and regulations that ensure safe drilling operations ameliorate potential conflict on the drilling site; but in this instance the spill occurs while the product is being transported to market. Tanker traffic is not controlled by MMS; however, OSCP's are required for tankers and would need to be in place before the oil was transported.

Conclusion: Conflicts with the Statewide standards and Yakutat District policies related to site-specific decisions are not inherently in conflict with the scenario. Effects of a 200,000-bbl spill could affect the habitat; subsistence; and air-, land-, and water-quality standards of the ACMP and the Yakutat District plan.

REFERENCES

Anderson, C.M. 1994. Telephone Conversation of Nov. 21, 1994, From Caryn Smith, Oceanographer, USDOI, MMS, Alaska OCS Region, to Cheryl M. Anderson, USDOI, MMS, TAG, Herndon, VA.; Subject: Crude Oil-Spills Sizes on the OCS.

Betts, R.C., C.B. Wooley, C.M. Mobley, J.D. Haggarty, and A. Crowell. 1991. Site Protection and Oil Spill Treatment at SEL-188, an Archaeological Site in Kenai Fjords National Park, Alaska. Anchorage, AK: Exxon Company, U.S.A., 79 pp. plus bibliography.

Calkins, D.G. and E. Becker. 1990. Assessment of Injury to Sea Lions in Prince William Sound and the Gulf of Alaska, Preliminary Status

Report for April Through December 1990. *In: Exxon Valdez* Oil Spill Natural Resource Damage Assessment. NRDA Marine mammal Study No. 4, Unpublished Report. Juneau, AK: State of Alaska, Dept. of Fish and Game.

Carls, M.G., L. Holland, M. Larsen, J.L. Lum, D. Mortensen, S.Y. Wang, and A.C. Wertheimer. 1993. Effects of Oil Contaminated Food on the Growth of Juvenile Pink Salmon *Oncorhynchus Gorbuscha. In: Exxon Valdez* Oil Spill Symposium. Feb. 2-5, 1993, Anchorage, AK. Anchorage, AK.

Cohen, M.J. 1993. The Economic Impacts of the *Exxon Valdez* Oil Spill on Southcentral Alaska's Commercial Fishing Industry. *In: Exxon Valdez* Oil Spill Symposium Abstract Book , B. Speis, L.J. Evans, B. Wright, M. Leonard, and C. Holba, eds. and comps. Feb. 2-5, 1993, Anchorage, AK: *Exxon Valdez* Oil Spill Trustee Council; University of Alaska Sea Grant College Program; and American Fisheries Society, Alaska Chapter, pp. 227-30.

Dahlheim, M.E. and T.R. Loughlin. 1990. Effects of the *Exxon Valdez*Oil Spill on the Distribution and Abundance of Humpback Whales in Prince William Sound, Southeast Alaska, and the Kodiak Archipelago. *In: Exxon Valdez* Oil Spill Natural Resource Damage Assessment. NRDA Marine Mammal Study No. 1, Unpublished Report. Seattle, WA: USDOC, NOAA.

Dekin, A.A., Jr. 1993. Exxon Valdez Oil Spill Archaeological Damage Assessment, Management Summary, Final Report. Contract No. 53-0109-1-00325. Juneau, AK: USDA, Forest Service.

Emdter-Wada, J. 1992. Social Economic and Subsistence Effects of the *Exxon Valdez* Oil Spill on the Kodiak Region. *In:* Conference Proceedings, Alaska OCS Region, Fourth Information Transfer Meeting. Jan. 28-30, 1992, Anchorage, AK. OCS Study, MMS 92-0046. Anchorage, AK: USDOI, MMS, AK OCS Region, pp. 283-88.

Evans, D.D. 1988. Combustion of Oil Spills on Water. *In:* Technology Assessment and Research Program for Offshore Minerals Operations. OCS Study, MMS 86-0057. Washington, DC: USDOI, MMS pp. 169-177.

Fall, J.A. 1992. Changes in Subsistence Uses of Fish and Wildlife Resources in 15 Alaska Native Villages Following the *Exxon Valdez* Oil Spill. *In*: Conference Proceedings, Alaska OCS Region, Fourth Information Transfer Meeting, Jan. 28-30, 1992, Anchorage, Ak. Anchorage, AK: USDOI, MMS, AK OCS Region, pp. 261-70.

Ford, R.G. 1985. Oil Slick Sizes and Length of Coastline Affected: A Literature Survey and Statistical Analysis. Contract No 14-12-0001-30224. Los Angeles, CA: USDOI, MMS, Pacific OCS Region, 34 pp.

Ford, R.G., M.L. Bonnell, D.H. Varoujean, G.W. Page, B.E. Sharp, D. Heinemann, and J.L. Casey. 1991. Assessment of Direct Seabird Mortality in Prince William Sound and the Western Gulf of Alaska Resulting From the *Exxon Valdez* Oil Spill. Portland, OR: Ecological Consulting, Inc., 153 pp.

Gould, P.J., D.J. Forsell, and C.J. Lensink. 1982. Pelagic Districution and Abundance of Seabirds in the Gulf of Alaska and Eastern Bering Sea. FWS/OBS-82/48. Anchorage, AK: USDOI, FWS, Biological Services Program, and USDOI, BLM, 294 pp.

Gundlach, E.R., P.D. Boehm, M. Marchand, R.M. Atlas, D.M. Ward, and D.A. Wolfe. 1983. The Fate of *AMOCO Cadiz* Oil. *Science* 221:122-129.

Kineman, J.J., R. Elmgren, and S. Hansson eds. 1980. The *Tsesis* Oil Spill: Report of the First Year Scientific Study (October 26, 1977 to December 1978). Boulder, CO: USDOC, NOAA, OMPA, 296 pp.

Kirstein, B.E., J.R. Payne, and R.T. Redding. 1983. Oil-Weatering Computer Program Users' Manual: Multivariate Analysis of Petroleum Weathering in the Marine Environment-Sub Arctic. Partial Final Report. Anchorage, AK: USDOC, NOAA, and USDOI, MMS, 88 pp.

Laevastu, T., R. Marasco, N. Bax, T. Honkalehto, R. Fredin, F. Fukuhara, A. Gallager, J. Ingraham, P. Livinston, R. Miyarhara, and N. Pola. 1985. Evaluation of the Effects of Oil Development on the Commercial Fisheries in the Eastern Bering Sea. OCS Study, MMS 85-107, OCSEAP Final Reports of Principal Investigators, Vol. 36, Part 1(Dec. 1985). Anchorage, AK: USDOC, NOAA, and USDOI, MMS, pp. 1-48.

Malins, D.C. 1977. Biotransformation of Petroleum Hydrocarbons in Marine Organism Indigenous to the Arctic and Subarctic. *In:* Fate and Effects of Petroleum Hydrocargons, in Marine Ecosystems and Organisms, Proceedings of a Symposium, D.A. Wolfe, ed. Nov. 10-12, 1976, Seattle, WA, New York; Pergamon Press. Sponsored by USDOC, NOAA, and SEPA.

McMullen, E. 1993. Testimony Dated Mar. 24, 1993, of Elenore McMullen, Chief, Native Village of Port Graham, Alaska, Before the U.S. House of Representatives' Committee on Merchant Marine and Fisheries. Washington, DC: U.S. Government Printing Office.

Mobley, C.M., J.C. Haggarty, C.J. Utermoble, M. Eldridge, R.E. Reanier, A. Crowell, B.A. Ream, D.R. Yeaner, J.M. Erlandson, P.E. Buck, W.B. Workman, and K. W. Workman. 1990. The 1989 *Exxon Valdez* Cultural Resource Program. Anchorage, AK: Exxon Shipping Company and Exxon Company, USA, 300 pp.

National Research Council. 1985. *Oil in the Sea: Inputs, Fates, and Effects.* Washington, DC: National Academy Press. 601 pp.

Payne, J.R., B.E. Kirstein, G.D. Jr. McNabb, J.L. Lambech, R. Redding, R.E. Jordan, W. Hom, C.de Oiliveria, G.S. Smith, D.M. Baxter, and R. Gaegel. 1984. Multivariate Analysis of Petroleum Weathering in the Marine Environment - Sub Arctic. Vol I - Technical Results. Environmental Assessment of the Alaskan Continental Shelf. Final Reports of Principal Investigators, Vol 21 (Feb. 1984). Juneau, AK: USDOC, NOAA, and USDOI, MMS, 686 pp.

Payne, J.R., B.E. Kirstein, G.D. Jr. McNabb, J.L. Lambech, R. Redding, R.E. Jordan, W. Hom, C.de Oiliveria, G.S. Smith, D.M. Baxter, and R. Gaegel. 1984. Multivariate Analysis of Petroleum Weathering in the Marine Environment - Sub Arctic. Vol II - Appendices. Environmental Assessment of the Alaskan Continental Shelf. Final Reports of Principal Investigators, Vol 21 (Feb. 1984). Juneau, AK: USDOC, NOAA, and USDOI, MMS, pp. 1-56.

Payne, J.R., G.D. McNabb, L.E. Hachmeister, B.E. Kirstein, J.R. Clayton, C.R. Phillips, R.T. Redding, C.L. Clary, G.S. Smith, and G.H. Farmer. 1987. Development of a Predictive Model for Weathering of Oil in the Presence of Sea Ice. OCS Study, MMS 89-0003. OCSEAP Final Reports of Principal Investigators, Vol. 59 (Nov. 1988). Anchorage, AK: USDOC, NOAA, and USDOI, MMS, pp. 147-465.

Piatt, J.F., C.J. Lemsink, W. Butler, M. Kendziored, and D.R. Nysewander. 1990. Immediate Impact of the *Exxon Valdez* Oil Spill on Marine Birds. *The Auk* 107:387-397.

Picou, J.S. and D.A. Gill. 1993. Long-Term Social Psychological Impacts of the *Exxon Valdez* Oil Spill. *In*: *Exxon Valdez* Oil Spill Symposium Abstract Book, B. Spies, L.J. Evans, B. Wright, M.

Leonard, and C. Holba, eds. and comps., Feb. 2-5, 1993, Anchorage, Ak. Anchorage, AK: *Exxon Valdez* Oil Spill Trustee Council; University of Alaska, Sea Grant College Program; and American Fisheries Society, Alaska Chapter, pp. 223-26.

Richards, B. No Date. Mitigating Psychological and Social Impacts of the *Exxon Valdez* Spill on Small Villages. Paper presented at: SFAA Meetings; Diaster Research Conference.

Sheppard, E.P. and P.E. Georghiou. 1981. The Mutagenicity of Prudhoe Bay Crude Oil and Its Burn Residues. *In*: Proceedings of the Fourth Arctic Marine Oilspill Program Technical Seminar, Jun. 16-19, 1981, Edmonton, Alberta, Canada. Ottawa, Ontario: Environmental Protection Service, Environmental Emergency Branch, pp. 195-213.

Smythe, C.W. 1990. In the Second Year: Continuing Village Impacts of the *Exxon Valdez* Oil Spill. *In:* 1990 Alaska Science Conference Proceedings of the 41st Arctic Science Conference: Circumpolar Perspectives. Oct. 8-10, 1990, Anchorage, AK. Anchorage, AK: American Association for the Advancement of Science, Alaska Division.

Wertheimer, A.C., A.G. Celewycz, M.G. Carls, and M.V. Sturdevant. 1993. The Impacts of the *Exxon Valdez* Oil Spill on Juvenile Pink and Chum Salmon and Their Prey in Nearshore Marine Habitats. *In*: *Exxon Valdez* Oil Spill Symposium, B. Spies, L.J. Evans, B. Wright, M. Lenard, and C. Holba, eds. and comps. Feb 2-5, 1993, Anchorage, AK. Anchorage, AK: Exxon Valdez Trustee Council; University of Alaska, Sea Grant College Program and American Fisheries Society, Alaska Chapter.

Wolfe, D.A., M.J. Hameedi, J.A. Galt, G. Watabayashi, J.W. Short, C.E. O'Clair, S. Rice, J. Michel, J.R. Payne, J.F. Braddock, S. Hanna, and D.M. Sale. 1993. Fate of the Oil Spilled From the T/V *Exxon Valdez* in Prince William Sound, Alaska. *In*: *Exxon Valdez* Oil Spill Symposium Abstract Book, B. Spies, L.J. Evans, B. . Wright, M. Leonard, and C. Holba, eds and comps., Feb. 2-5, 1993, Anchorage, Ak. Anchorage, AK: *Exxon Valdez* Oil Spill Trustees; University of Alaska, Sea Grant College Program; and American Fisheries Society, Alaska Chapter, pp. 6-9.

Wolfe, D.A., M.J. Hameedi, J.A. Galt, G. Watabayashi, J. Short, O'Claire, S. Rice, J. Michel, J.R. Payne, J. Braddock, S. Hanna, and D. Sale. 1994. The Fate of the Oil Spilled From the *Exxon Valdez*. *Environmental Science and Technology* 28(13):561A-568A.