INTRODUCTION

This Environmental Sensitivity Index (ESI) atlas for Southeast Alaska shows the intertidal habitats, biological resources, and human-use resources that are potentially at risk to impacts from oil spills. This atlas consists of maps at two different scales, to reflect the scale of data collection and optimize presentation of the data. Intertidal habitats and human-use features are shown on U.S. Geological Survey (USGS) 15-minute quadrangles, plotted at a scale of 1:84,000; 72 maps have been compiled and are included in Volume 1. Biological resource information is shown on USGS two-degree sheets, plotted at a scale of 1:280,000; two separate maps are used to show (1) sensitive biological resources, and (2) human use of biological resources. Ten of these sheets have been completed and are included in Volume 2. These pages describe the methods and data sources used to generate the maps, and include legends and tabular data needed to use the maps.

INTERTIDAL HABITATS

The intertidal habitats of Southeast Alaska were mapped during aerial overflights conducted on 22-27 July and 6-12 August 1990. Mapping was restricted to two hours on either side of spring low tides during daylight hours. The surveys were conducted at elevations of 500-1,000 feet and slow air speed. An experienced coastal geologist delineated the coastal types directly onto 1:63,360 scale USGS topographic maps, using a standardized classification scheme. Where appropriate, up to three different coastal habitats were delineated for each shoreline segment. The most frequent habitat combinations were wave-cut platforms with gravel beaches, sheltered rocky platforms with mixed sand and gravel beaches, and exposed tidal flats fronting marshes.

Descriptions of the intertidal communities associated with each shoreline habitat were developed from ground surveys conducted by the Alaska Department of Fish and Game (ADF&G) and the U.S. Fish and Wildlife Service (USFWS). Data were collected on the shoreline habitat, floral and faunal community, substrate, and exposure to wave or tidal energy for 488 plots at 167 sites. Where possible, the presence and morphology of specific species of macroalgae are mentioned as indicators of relative energy of the shoreline segment. Such indicators are valuable in differentiating among rocky shores which have variable wave and tidal energy exposures, a common condition in Southeast Alaska where there are strong, seasonal differences in exposure. The ground surveys of the shoreline habitats were used to spot check the designations made during the aerial surveys.

Prediction of the behavior and persistence of oil on intertidal habitats is based on an understanding of the dynamics of coastal environments, not just the substrate type and grain size. The vulnerability of a particular intertidal habitat is an integration of the following factors:

1. Shoreline type (substrate, grain size, tidal elevation, origin)
2. Exposure to wave and tidal energy
3. Biological productivity and sensitivity
4. Ease of cleanup

All of these factors are used to determine the relative sensitivity of shorelines. Key to the sensitivity ranking is an understanding of the relationships between: physical processes, substrate, shoreline type, product type, fate, and effect, and sediment transport patterns. The intensity of energy expended upon a shoreline by wave action, tidal currents, and river currents directly affects the persistence of stranded oil. The need for shoreline cleanup activities is determined, in part, by the swolson of natural processes in removal of oil stranded on the shoreline.

These concepts have been used in the development of the Environmental Sensitivity Index (ESI), which ranks shoreline environments as to their relative sensitivity to oil spills, potential biological injury, and ease of cleanup. Generally speaking, areas exposed to high levels of physical energy, such as wave action and tidal currents, and low biological activity rank low on the scale, while sheltered areas with associated high biological activity have the highest ranking. The list below includes the shoreline habitats delineated for Southeast Alaska, presented in order of increasing sensitivity to spilled oil:

1. Exposed Rocky Shores
2. Exposed Wave-cut Platforms
3. Not present in study area
4. Sand Beaches
5. Mixed Sand and Gravel Beaches
6A. Gravel Beaches (Granules to Cobblels)
6B. Gravel Beaches (Cobbles to Boulders)
7. Exposed Tidal Flats
8A. Sheltered Impervious Rocky Shores
8B. Sheltered Permeable Rocky Shores
9. Sheltered Tidal Flats
10. Intertidal Marshes

BIOLOGICAL RESOURCES

The biological resource information was derived from various sources, transferred to, and digitized from 1:250,000 scale base maps. The maps have been printed at 1:280,000 scale so they can be readily reproduced. The biological resources are represented by points and polygons on the maps. There is an associated table with the maps that indicates the seasonality of each of the resource groups. This map shows the following resources.

Fish Spawning Areas

These are the known spawning areas for Pacific herring and eulachon (ADFG&G, 1985-1986). These areas are shown on the maps.

Anadromous Fish Streams

Anadromous fish streams designated by ADF&G as “Waters Important to Anadromous Fish” (WITAF, 1992), that are within the area for which shorelines were mapped, are shown on the maps. In fact, the only information used on the maps are anadromous fish streams, which were digitized from the 1:63,360 USGS maps. The remaining streams will be added when the rest of Southeast Alaska is mapped. The seasonal use information for the streams is not included in this data base. The digital data base includes the species found in each stream, but this information is not shown on the maps.

Anadromous fish which spawn in these streams are:

- Sockeye salmon
- Chum salmon
- King salmon
- Steelhead trout
- Coho salmon
- Dolly Varden
- Pink salmon
- Cutthroat trout

Shellfish Beds

The maps indicate where the abalone, geoducks, scallops, and sea urchins are located. These areas are typically very small. These species are present year-round and therefore are always at risk. The shellfish locations were obtained from the ADFG&G Habitat Management Guides (1986).

Waterfowl and Shorebird Concentrations

The spring and fall concentration areas of many species of waterfowl and shorebirds are shown on the maps, as derived from the Habitat Management Guides (1986) by ADF&G as well as 1989 data from the U.S. Fish and Wildlife Service. The basemaps are from the U.S. Forest Service. These different areas are not identified by species but they include some or all of the following species:

Waterfowl

- Mallard
- Northern pintail
- Green-winged teal
- Blue-winged teal
- American wigeon
- Greater scaup
- Lesser scaup
- Common goldeneye
- Barrow’s goldeneye
- Bufflehead
- Oldsquaw
- Harlequin
- Black scoter
- White-winged scoter
- Surf scoter
- Common merganser
- Red-breasted merganser
- Vancouver goose
- Dusky Canada goose
- Greater white-fronted goose
- Snow goose
- Tundra swan
- Trumpeter swan

In the heads of bays and marshes some of the waterfowl, mostly Canada geese, are present all year.

SEA
Seabird Nesting Colonies

The seabird nesting colonies shown on the maps were obtained from ADF&G Habitat Management Guides (1986) and Alaska Seabird Colonies Atlas (1978) by USFWS. The birds are present during the spring and summer. They are not identified by species on the map or in the data base but the colonies include some or all of the following species:

- Black oystercatcher
- Pelagic cormorant
- Leach’s petrel
- Fork-tailed storm petrel
- Pew gull
- Herring gull
- Bonaparte’s gull
- Thayer’s gull
- Glaucous-winged gull
- Common murre

Osprey

The osprey concentration and nesting information was obtained from the Habitat Management Guides (1986) by ADF&G and 1989 data from the USFWS, digitized by U.S. Forest Service. The areas shown on the map are concentration areas and nesting areas combined. However, areas are differentiated as nesting or concentration in the data base. Osprey are present during spring and summer.

Eagle Nests

All known eagle nest sites are shown on the map. The eagles are fairly abundant in Southeast Alaska with over 7400 nests identified in the area. Eagles nest during the spring and summer. They may be present at other times or in areas not associated with nests, although these areas are not indicated on the maps. The nesting sites were digitized by the U.S. Forest Service, Tongass National Forest, from data provided by USFWS (1989).

Sea Otters

The sea otter distribution is based on the Habitat Management Guides (1986) by ADF&G and 1989 data from the USFWS, digitized by U.S. Forest Service. Sea otters are present all year. They remain in the water most of the time; sea otters do not have haulouts areas like seals or sea lions. They do concentrate in kelp beds, where they use the kelp to moor themselves while they sleep, feed, or rest.

Seals and Sea Lions

Both concentration areas and haulout areas for Stellar sea lions and harbor seals are shown on the maps, as provided by the Habitat Management Guides (1986) by ADF&G and 1989 data from the USFWS, digitized by U.S. Forest Service. These are present year round. The sea lions and seals are represented as different patterns on the map. While the map does not identify which areas are the haulouts (versus concentration areas), that information is in the data base.

Bear Concentration Areas

The spring and summer feeding areas of black and brown bears are shown on the maps. The species of bear is not identified on the map, but it is identified in the data base. These areas are shown so that appropriate measures can be taken to protect the spill response personnel in these areas in the event of a spill.

MAP OF HUMAN USE OF BIOLOGICAL RESOURCES

The human-use resource maps show the biological resources that are important based on their utilization by humans, such as areas of concentrated commercial or sport fishing and harvest. These resources are represented by polygons on the map. Some of the species are common throughout their appropriate habitat on the map, such as king crab fisheries areas and groundfish areas. These areas are not depicted on most of the maps, because they are common throughout the marine areas. The polygons representing their distribution would fill the water areas. Instead, those species or groups of species which are “common throughout” are indicated by text in a corner of the map. However, where their distribution represents less than 20 percent of the marine area on a map, they are plotted as polygons on the maps. The following sections describe the human-use resources shown on the maps.

Crab Fishing Areas

There are three crab fisheries in Southeast Alaska: king crab, Tanner crab, and Dungeness crab. These three different crab fisheries are shown on the maps. In some cases, the distribution of the crab fishery may be most of the area on the map. To make the map more readable, these species are referenced in a box indicating that they are common throughout the area; thus they are not shown as polygons on the map. The data base contains the species of crab, but this information is not shown on the maps. The data for these areas were obtained from the Habitat Management Guides (1986) by ADF&G.

Subsistence Areas - Fish and Intertidal Gathering

The digital data base identifies subsistence areas for marine mammal harvesting, deer hunting, trapping and hunting of fur bears, fishing for salmon and other finfish, and collection of invertebrates and intertidal organisms. However, only two different subsistence-use areas are shown on the maps. Salmon and other finfish areas combined are shown as one pattern, and invertebrate and intertidal gathering areas are combined and shown as a separate pattern. The subsistence use information is based on a 1986 study by ADF&G and the Institute of Social and Economic Research (ISER), University of Alaska, Anchorage. The maps indicate areas where 10 percent or more of a community have ever fished for the resource. Based on the nature of the data, no seasonality is associated with the subsistence use areas, however, the seasons for salmon use correspond closely with the seasons for commercial or sport fishing for salmon. The other finfish areas are almost identical to the salmon areas, so it appears that these same areas are fished for other fish when salmon are not present. No time of year for use can be specified for the intertidal gathering areas, since it is not known what species are collected, or if there are any seasonal limitations to collection of the species.

Commercial Fishing

The commercial fishing areas were obtained from personal communications with ADF&G and commercial fisheries biologists familiar with the locations and times of commercial salmon fishing in Southeast Alaska. The regional commercial fisheries biologists delineated the areas on 1:250,000 scale basemaps which were then digitized. The seasonality for the fishing is dependent on the species being fished. The map does not differentiate among the species or seasons for commercial fishing, but the information is in the data base.

Sport Fishing Concentration Areas

The sport fishing areas were obtained from personal communications with ADF&G and sport fisheries biologists familiar with the locations and times of sport salmon fishing in Southeast Alaska. The regional sport fisheries biologists delineated the areas on 1:250,000 scale basemaps which were then digitized. The seasonality for the fishing is dependent on the species being fished. The map does not differentiate among the species or seasons for sport fishing, but the information is in the data base and shown in the seasonality table.

Groundfish Areas

The groundfish distribution was obtained from the Habitat Management Guide (1986) by ADF&G. Groundfish are fairly ubiquitous and are referenced in a box that indicates these species are “common throughout” the map area. They are present year-round. The map does not differentiate among the species of groundfish but the information is in the data base. The species of groundfish included are:

- Groundfish
- Rockfish
- Sablefish
- Starry flounder
- Pacific cod
- Pollock

SEASONALITY

The seasonality of the species represented in this atlas are uniform throughout the area of Southeast Alaska covered by the atlas. Therefore, seasonality is not associated with each polygon or point shown on the maps, but summarized in the table on the next page for all species shown on the maps.
SOUTHEAST ALASKA SEASONALITY TABLE

<table>
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<th>GROUP/SPECIES</th>
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<td>Coho salmon</td>
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</table>

GROUND/FISH

| ROCKFISH |        |        |      |        |
| Sablefish | X | X | X | X |
| Starry flounder | X | X | X | X |
| Pacific cod | X | X | X | X |
| Pollock | X | X | X | X |

BEARS

| Black bear | X | X | X | X |
| Brown bear | X | X | X | X |

MARINE MAMMALS

| Harbor seal | X | X | X | X |
| Stellar sea lion | X | X | X | X |
| Sea otter | X | X | X | X |

BIRDS

| Shorebirds | X | X |        |        |
| Waterfowl | X | X | X |        |
| Trumpeter swan | X | X |        |        |
| Sea birds | X | X |        |        |
| Eagles | X | X |        |        |

CRABS

| Brown king crab | X | X |        |        |
| Red king crab | X | X |        |        |
| Dungeness crab | X | X |        |        |
| Tanner crab | X | X |        |        |

SHRIMP

| Pot shrimp | X |        |      |        |
| Trawl shrimp | X |        |      |        |

MOLLUSCS

| Abalone | X | X | X | X |
| Geoduck | X | X | X | X |
| Sea urchin | X | X | X | X |
| Scallop | X | X | X | X |

HUMAN-USE FEATURES

Human-use features that may be affected by an oil spill, or aid in the response to an oil spill, are depicted on the 1:84,000 scale intertidal habitat maps. These features are:

- Marinas, moorages, and harbor facilities
- Boat ramps
- Aquaculture facilities
- Log storage areas
- Airports

Marinas and boat ramps were identified based on information from the topographic maps, visual observations during the shoreline overflights (1990), and 1990 Southeast Alaska Harbor and Boating Facility Directory (Alaska Department of Transportation and Public Facilities). Aquaculture facilities shown on the maps include fish hatcheries, salmon holding pens, and shellfish growing areas, as regulated by Alaska Department of Natural Resources. Log storage areas are based on visual observations from the 1990 overflights as well as data from Log Transfer and Storage Facilities in Southeast Alaska: A Review (USFS, 1985). Airport locations were identified based on visual observations during the overflights.

DIGITAL DATA DESCRIPTION

The maps in this atlas were generated from a completely digital data base using Geographic Information Systems (GIS) software (pcARC/INFO v. 3.4D Plus). The biological information in the digital version is more detailed than shown on the maps. The associated data base includes seasonality, and in some cases abundance. The information is included at the species level, where available. The commercial fish and sport fish areas are delineated at the species level. The waterfowl and shorebirds assemblages do not have species-specific information since it was not available at the time of data entry. Data table sources and scale of data entry are itemized below.

SOUTHEAST ALASKA DATA TABLES

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<thead>
<tr>
<th>Description</th>
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<td>Osprey distribution</td>
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<td>Anadromous fish stream</td>
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Shoreline Habitat Descriptions

**EXPOSED ROCKY SHORES**

**DESCRIPTION**

- Steep (greater than 30 degrees), bedrock cliff with an intertidal zone too narrow to have any accumulated sediments.
- There is no evidence of a platform cut into the bedrock.
- This shoreline type is never used in combination with another shoreline type. However, they are frequently found interspersed with wave-cut platforms.
- The rock surface can be highly irregular, with numerous cracks and crevices.
- Wave energy is high enough to limit attached algae within the entire intertidal zone to less than 40 percent cover.
- Barnacles are uncommon in the higher intertidal zone, but barnacles, mussels, snails, and algae are common in the mid and lower zones.
- Sugar wrack is restricted to the subtidal zone. Sea girdle and split whip wrack in the lower intertidal zone indicates moderate wave and tidal energies. Winged kelp indicates moderate to very rough wave activity. *Hedophyllum sessile* has narrow, smooth, strap-shaped blades in exposed settings. Three-ribbed kelp indicates a wave-beaten coast.

**PREDICTED OIL BEHAVIOR**

- Oil is held offshore by wave reflection off the steep cliffs.
- Any oil that is deposited is removed rapidly from exposed faces.
- Oil persistence is related to the incoming wave energy or tidal currents; both can be highly variable along Southeast Alaska.
- The most resistant oil would remain as a band at or above the high-tide line.
- Impacts to intertidal communities are expected to be of short duration.
- An exception would be where heavy concentrations of a light refined product (e.g., No. 2 fuel oil) came ashore very quickly.
- Greatest impacts are likely to be to birds when present at nesting colonies or feeding in nearshore waters.

**RESPONSE CONSIDERATIONS**

- On most shorelines, cleanup is not necessary and may be dangerous.
- Access is usually very difficult.
- High-pressure spraying with ambient water is effective while oil is still fresh. Any spraying should be restricted to use during mid and higher tides, to prevent impacts to the rich biota in the lower intertidal zone.
EXPOSED WAVE-CUT PLATFORMS  

DESCRIPTION
• Bedrock platform (less than 30 degrees slope) of highly variable width, backed by a steep rocky scarp.
• Sometimes the platforms can be very wide, up to 500 meters, though normally they are less than 100 meters.
• The platform surface is irregular and there may be accumulations of sand- to boulder-sized material throughout the platform. However, the bedrock surface is the dominant substrate.
• Commonly, the platform has a narrow, gravel or mixed sand and gravel beach perched at the base of the scarp. When the beach has multiple berms built by waves, it is designated as a separate shoreline type on the maps.
• Attached algal cover in the intertidal zone averages 45 percent.
• There is a very high density and diversity of animals; most common are amphipods, barnacles, polychaetes, and oligochaetes.
• Tidal pools are common in the mid and lower intertidal zone, with an associated biotic richness.
• The degree of exposure to high waves and tidal energies can be highly variable, both spatially and seasonally. Sea girdle and split whip wrack in the lower intertidal zone indicate areas of moderate energy. Where winged kelp is present, it indicates moderate to very rough waves. *Hedophyllum sessile* has narrow, smooth, strap-shaped blades in exposed settings.
• They can be used as haulouts by marine mammals.

PREDICTED OIL BEHAVIOR
• Oil will not adhere to the rock platform, but rather be transported across the platform and accumulate along the high-tide line. The wetted rock surface and attached algae prevent oil from sticking to the rock surface.
• Oil can penetrate and persist in surficial sediments, if present.
• Persistence of oiled sediment is usually short-term (days to weeks), except in wave shadows or large sediment accumulations.
• Heavy accumulations of oil can temporarily cover the entire intertidal zone during falling tides, resulting in mortality of tidal pool biota by smothering or exposure to the toxic fractions of fresh oil or refined products.

RESPONSE CONSIDERATIONS
• In areas of high exposure to waves and tidal flushing, no cleanup is necessary.
• Where oil has persisted in coarse sediment at or above the high-tide line, the sediments may be relocated to the upper intertidal zone for reworking by waves.
• Manual removal of residual surface oil may be needed in wave shadows, both on the platform and along the high-tide line.

SAVANNA BEACHES  

DESCRIPTION
• Moderately sloping beach with at least 75 percent of the surface substrate composed of sand particles (less than 2 millimeters in size).
• Fine-grained sand beaches are uncommon; most sand beaches are coarse-grained.
• Fine gravel may be a minor component (less than 25 percent of the surface).
• The sediments are readily mobilized by normal wave activity.
• Only species present are sand fleas.

PREDICTED OIL BEHAVIOR
• During small spills, oil will concentrate in a band along the high-tide line.
• Under heavy accumulations, oil can cover the entire intertidal area, although the oil will be lifted off the lower part of the beach with each rising tide.
• Maximum penetration of oil into fine-grained sand will be less than 20 cm; oil penetration into coarse-grained sand can reach 25 cm.
• Burial of oiled layers by clean sand within the first few weeks after the spill will be limited usually to less than 30 cm, whereas burial by up to 60 cm on coarse-grained beaches is possible, given enough time (measured in months).
• Deepest burial will occur if the oil is stranded onshore at the beginning of an accretionary period, such as after a storm.
• Much of the oil will be removed during the next storm.
• Biological impacts are likely to be low, except for when the beaches are being used by shorebirds for resting and foraging.

RESPONSE CONSIDERATIONS
• Sand beaches are relatively easy to clean because the usually hard substrate will support pedestrian and vehicular traffic.
• Oiled wrack and other debris should be removed.
• Natural cleansing of these beaches is most advisable, especially during the storm season, unless there is the potential for contamination of other resources using the beach.
MIXED SAND AND GRAVEL BEACHES  

**DESCRIPTION**
- Moderately sloping beach composed of a mixture of sand and gravel (each greater than 25 percent).
- The high-tide berm area is usually composed of sand or fine gravel (pebbles to cobbles), whereas the lower part of the beach is coarser, with cobbles to boulders.
- Because of the mixed sediment sizes, there may be zones of sand, pebbles, or cobbles.
- Sediment mobility and desiccation on exposed beaches results in less than 20 percent attached algae, mussels, and barnacles. Biomass is usually less than 1 percent periwinkles, limpets, and barnacles, with abundant sand fleas.
- Greater than 20 percent attached algae, mussels, and barnacles indicates beaches that are relatively sheltered, with the more stable substrate supporting a richer biota.

**PREDICTED OIL BEHAVIOR**
- During small spills, oil will be deposited along and above the high-tide swash.
- During large spills, oil will spread across the entire intertidal area.
- Oil penetration into the beach sediments may be up to 50 cm; however, the sand fraction can be quite mobile, and oil behavior is much like on a sand beach if the sand fraction exceeds about 40 percent.
- Burial of oil may be deep at and above the high-tide line, where oil tends to persist, particularly where beaches are only intermittently exposed to waves.
- On the more sheltered beaches, extensive asphalt pavements can form if there is no removal of heavy oil accumulations, because most of the oil remains on the surface.
- Once formed, these pavements can persist for many years.
- Oil can be stranded in the coarse material on the lower part of the beach, particularly if the oil is weathered or emulsified.

**RESPONSE CONSIDERATIONS**
- Remove heavy accumulations of pooled oil from the upper beachface.
- All oiled debris should be removed.
- Sediment removal should be limited as much as possible.
- Low-pressure flushing can be used to float oil away from the sediments for recovery by skimmers or sorbents. High-pressure spraying should be avoided because of the potential for transporting large amounts of oiled sediments to the lower intertidal or subtidal zones.
- Mechanical reworking of oiled sediments from the high-tide zone to the upper intertidal zone can be effective in areas regularly exposed to wave activity (as evidenced by storm berms). However, oiled sediments should not be relocated below the mid-tide zone.
- In-place tilling may be used to reach deeply buried oil layers in the middle zone of exposed beaches.

GRAVEL BEACHES (GRANULES TO COBBLES)  

**DESCRIPTION**
- Moderately sloping beach composed primarily of pebbles and cobbles (from 4 to 256 cm). No sand is evident on the surface, and there is less than 20 percent sand in the subsurface.
- There are zones of pure pebbles or cobbles, with the pebbles forming berms at the high-tide line and the cobbles dominating the lower beachface.
- Sediment mobility prevents more than 20 percent attached algae, barnacles, and mussels.
- Moderate amounts of drift wood are generally present.

**PREDICTED OIL BEHAVIOR**
- Deep penetration and rapid burial of stranded oil is likely on exposed beaches.
- On exposed beaches, oil can be pushed over the high-tide and storm berms, pooling and persisting above the normal zone of wave wash.
- Long-term persistence will be controlled by the depth of penetration versus the depth of routine reworking by waves.
- On relatively sheltered beaches, formation of asphalt pavements is likely where accumulations are heavy.

**RESPONSE CONSIDERATIONS**
- Remove heavy accumulations of pooled oil from the upper beachface.
- All oiled debris should be removed.
- Sediment removal should be limited as much as possible.
- Low- to moderate-pressure flushing can be used to float oil away from the sediments for recovery by skimmers or sorbents. High-pressure spraying should be avoided because of the potential for transporting large amounts of oiled sediments to the lower intertidal or subtidal zones.
- Mechanical reworking of oiled sediments from the high-tide zone to the upper intertidal zone can be effective in areas regularly exposed to wave activity (as evidenced by storm berms). However, oiled sediments should not be relocated below the mid-tide zone.
- In-place tilling may be used to reach deeply buried oil layers in the middle zone of exposed beaches.
GRAVEL BEACHES (COBBLES TO BOULDERS)  ESI = 6B

DESCRIPTION
- Moderately to steeply sloping beaches composed primarily of rounded, large cobbles to boulders. There is no sand on the surface, and less than 20 percent in the subsurface.
- The upper beach has well-sorted cobble berms, whereas the lower part of the beach can be dominated by a stable boulder platform.
- On more exposed gravel beaches, the attached algae, barnacles, and mussels cover less than 20 percent.
- Relatively sheltered gravel beaches are indicated where the attached algae, barnacle, and mussel cover is greater than 20 percent.
- Moderate amounts of driftwood are present.

PREDICTED OIL BEHAVIOR
- Oil will penetrate up to depths of 1 meter in the well-sorted, permeable berms.
- On exposed beaches, oil can be pushed over the high-tide and storm berms, pooling and persisting above the normal zone of wave wash.
- Long-term persistence will be controlled by the depth of penetration versus the depth of routine reworking by storm waves, which will be highly variable throughout the area. Amount of attached algae will indicate sediment mobility.
- On relatively sheltered beaches, formation of asphalt pavements is likely where accumulations are heavy.

RESPONSE CONSIDERATIONS
- Remove heavy accumulations of pooled oil from the upper beachface.
- All oiled debris should be removed.
- Sediment removal should be limited as much as possible.
- Low- to high-pressure flushing can be used to float oil away from the sediments for recovery by skimmers or sorbents.
- Mechanical reworking of oiled sediments from the high-tide zone to the upper intertidal zone can be effective in areas regularly exposed to wave activity (as evidenced by storm berms). However, oiled sediments should not be relocated below the mid-tide zone.
- In-place tilling may be used to reach deeply buried oil layers in the middle zone of exposed beaches.

EXPOSED TIDAL FLATS  ESI = 7

DESCRIPTION
- Flat (less than 5 degrees) accumulations of sediment, dominated by sand, although may include silt and gravel components.
- Commonly are associated with mouths of streams or rivers, fronting marsh vegetation.
- The width can vary from a few meters to nearly one kilometer, though most flats are less than 100 meters wide.
- Presence of energy from waves or tidal and riverine currents is indicated by ripples in sand, scour marks around gravel, striation marks in silt and clay, and low sand ridges or bars migrating over the surface of the flat.
- Clams and worms are abundant. In areas of glacial outwash influence (e.g., Gustavus), the abundant boulders and cobbles have attached algae.

PREDICTED OIL BEHAVIOR
- Oil does not usually adhere to the surface of exposed tidal flats, but rather moves across the flat and accumulates at the high-tide lines.
- Heavy accumulations will cover the flat at low tide, but be lifted off with the rising tide.
- Oil generally does not penetrate the water-saturated sediments. However, refined products will penetrate any part of the flat which drains at low tide.
- Oil will persist the longest at the upper part of the flat.
- Biological impacts can be severe, primarily to infauna, thereby reducing food sources for birds.

RESPONSE CONSIDERATIONS
- Currents and waves are usually very effective in natural removal of the oil.
- Any cleanup activity must be sure not to mix the oil deeper into the sediments.
- Cleanup should focus on removal of oil accumulated at the high-tide line, particularly where the flat adjoins a beach.
SHELTERED, IMPERMEABLE ROCKY SHORES  

DESCRIPTION
• Bedrock shore of variable slope (from vertical cliffs to wide, rocky ledges) which is sheltered from exposure to most wave and tidal energy.
• The wider shores may have some surface sediments, but the bedrock is the dominant substrate type; thus it is termed “impermeable.”
• Species density and diversity vary greatly, but barnacles, snails, mussels, clams, periwinkles, amphipods, polychaetes, rockweed, and crabs are often very abundant.
• Attached algae averages 50 percent cover overall. Sugar wrack is restricted to the subtidal; \textit{Hedophyllum sessile} has broad, highly corrugated blades with few longitudinal splits.

PREDICTED OIL BEHAVIOR
• On all rocky shores, oil will adhere readily to the rough rocky surface, particularly along the high-tide line, forming a distinct oil band.
• Fractures in the bedrock will be sites of pooling and oil persistence.
• Even on wide ledges, the lower intertidal zone usually stays wet (particularly when covered by algae), preventing oil from adhering to the rock surface.
• Heavy and weathered oils can cover the upper zone with little impacts to the rich biological communities of the lower zone.
• Fresh oil and light refined products have high acute toxicities which can affect attached organisms after even short exposures.

RESPONSE CONSIDERATIONS
• Low- to high-pressure spraying at ambient water temperatures is most effective when the oil is fresh.
• Extreme care must be taken not to spray in the biologically rich lower intertidal zone or when the tidal level reaches that zone.
• Cutting of oiled, attached algae is not recommended; tidal action will eventually float this oil off, so sorbent booms should be deployed.

SHELTERED, PERMEABLE ROCKY SHORES  

DESCRIPTION
• Relatively steep and short rocky shore which is covered with a thick veneer of angular rubble without any evidence of rounding by sediment transport.
• The surface rubble is highly variable in packing, but there is always some permeability in the surface material.
• Species density and diversity vary greatly, but barnacles, snails, mussels, clams, periwinkles, amphipods, polychaetes, rockweed, and crabs are often very abundant.
• Attached algae averages 50 percent cover overall. Sugar wrack is restricted to the subtidal; \textit{Hedophyllum sessile} has broad, highly corrugated blades with few longitudinal splits.

PREDICTED OIL BEHAVIOR
• On all rocky shores, oil will adhere readily to the rough rocky surface, particularly along the high-tide line, forming a distinct oil band.
• Oil will penetrate into the crevices formed by the surface rubble and pool at the contact of the surface and the rubble.
• Under heavy accumulations, oil will form pools and, eventually, pavements.
• Where the rubble is loosely packed, oil will penetrate deeply, causing long-term contamination of the subsurface sediments.

RESPONSE CONSIDERATIONS
• Low- to high-pressure spraying at ambient water temperatures is most effective when the oil is fresh.
• Extreme care must be taken not to spray in the biologically rich lower intertidal zone or when the tidal level reaches that zone.
• Cutting of oiled, attached algae is not recommended; tidal action will eventually float this oil off, so sorbent booms should be deployed.
• These sites will have to be revisited often for manual removal of residual surface pavements. Little can be done where subsurface contamination occurs.
**SHELTERED TIDAL FLATS**

**DESCRIPTION**
- Very flat surface composed of silt and clay, but with a minor sand component.
- There is no evidence of tidal and riverine current energy which could move sediments around on the flat.
- They are located at the heads of bays or along small streams, and always occur in conjunction with marshes.
- They have large populations of clams and worms.

**PREDICTED OIL BEHAVIOR**
- Oil does not usually adhere to the surface of sheltered tidal flats, but rather moves across the flat and accumulates at the high-tide line.
- Very heavy accumulations will cover the flat at low tide, but will lift off with the rising tide.
- Oil will not penetrate the water-saturated sediments at all, but rather remain on the surface.
- In areas of high suspended sediments, sorption of oil can result in contaminated sediments that can be deposited on the flats.
- When sediments are contaminated, oil will persist for many years.
- Biological impacts can be severe.

**RESPONSE CONSIDERATIONS**
- Any cleanup activity must be sure not to mix the oil deeper into the sediments.
- The soft substrate will not support any foot or vehicular traffic, so all operations should be conducted from shallow-draft boats.
- Cleanup should focus on removal of oil accumulated at the high-tide line; sorbents can be used to recover oil as it is naturally removed over time.

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**INTERTIDAL MARSHES**

**DESCRIPTION**
- Vegetated middle intertidal zone dominated by Lyngbye’s sedge (Carex lyngbyei), alkali grass (Puccinellia nutkaensis), arrowgrass (Triglochin maritimum), and plantain (Plantago maritima).
- Higher intertidal zone inundated on an almost daily basis and dominated by Lyngbye’s sedge, silverweed (Potentilla egedii), hairgrass (Deschampsia sp.), plantain, lyme grass (Elymus arenarius), and Trichophorum caespitosum.
- The substrate is usually fine sand and mud, but there may also be a narrow band of sand and gravel at the high-tide line in more exposed settings.

**PREDICTED OIL BEHAVIOR**
- Oil adheres readily to marsh vegetation.
- The band of coating will vary widely, depending upon the tidal stage at the time oil slicks are in the vegetation. There may be multiple bands.
- Large slicks will persist through multiple tidal cycles and coat the entire stem from the high-tide line to the base.
- If the vegetation is thick, heavy oil coating will be restricted to the outer fringe, with penetration and lighter oiling to the limit of tidal influence.
- Medium to heavy oils do not readily adhere to or penetrate the fine sediments, but they can pool on the surface and in burrows.
- Light oils can penetrate the top few centimeters of sediment and deeply into burrows and cracks (up to 1 meter).

**RESPONSE CONSIDERATIONS**
- Under light to moderate oiling, natural recovery is the best option.
- Any cleanup activity must be sure not to mix the oil deeper into the sediments. Trampling of the roots must be minimized.
- Cutting of oiled vegetation should only be considered when other resources present are at great risk from leaving the oiled vegetation in place.
- Heavy accumulations of pooled oil can be removed by vacuum, sorbents, or low-pressure flushing. During flushing, care must be taken to prevent transport of oil to sensitive areas downslope or along shore.