ENVIRONMENTAL ASSESSMENT
For the implementation of Exxon Valdez Trustee Council project No. 11100836:
- Pilot studies of bioremediation of the Exxon Valdez oil in Prince William Sound beaches

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Abstract: This document is an Environmental Assessment (EA) of the potential impacts of implementing a pilot project to apply bioremediation methods in situ to breakdown and degrade subsurface oil remaining in beaches that were heavily impacted from the 1989 Exxon Valdez oil spill in Prince William Sound Alaska. The 1994 Environmental Impact Statement for the Exxon Valdez Oil Spill Restoration Plan along with the 2010 supplemental EIS to the plan, provide the context for proceeding with remediation efforts. The proposal calls for four test locations representing differences in beach geomorphology. At each location hydrogen peroxide and nutrients will be injected into pipes into the layer where oil remains. Previous studies have shown the oil layer is generally impermeable to flushing by wave and tidal changes, appears to be anoxic and nutrient poor, and liquids injected into the layer, can move horizontally. The injected hydrogen peroxide is expected to break down rapidly into water and oxygen and along with the supplied nutrients, help promote bacterial degradation of the oil. The study will evaluate the efficacy of this approach and if can be applied on a broader scale to other oiled sites.

Because this pilot project is part of a staged approached addressing the question of whether to proceed with more extensive effort to remove remaining oil, cumulative impact analysis and the decision to proceed to full scale remediation is deferred and will be addressed through a subsequent Environmental Analysis, based in part on the outcome of this study. As it stands the environmental impacts from this first stage effort is expected to be minimal and if effective, the treatment will remove potentially toxic lingering oil through a relatively low impact method. Not proceeding with the pilot project would leave natural recovery as the only viable option. Natural recovery is expected to take decades or longer.

The pilot project will require a special use permit from U.S. Forest Service if storage sheds housing the pumping equipment and chemicals are placed above mean high tide. While not directly a part of this assessment, any terms and conditions required of the permit will have to be incorporated into the project plan.

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GLOSSARY OF ABBREVIATIONS

EA – Environmental Assessment

ESI – Environmental Sensitivity Index

EVOSTC – Exxon Valdez Oil Spill Trustee Council

PWS – Prince William Sound

STTP – sodium tripolyphosphate

Type D beach – deep bedrock beach (i.e., bedrock >1.5 m below ground surface)

Type S beach – shallow bedrock beach (i.e., bedrock < 0.8 m below ground surface)

EXECUTIVE SUMMARY

A bioremediation pilot-project will be conducted on four beaches in Prince William Sound, Alaska, to determine whether this approach can be used to remediate beaches that are still contaminated with lingering oil from the 1989 *Exxon Valdez* oil spill. This project is being funded by the *Exxon Valdez* Oil Spill Trustee Council, and is part of a staged effort following a 2006 Reopener Plan as discussed in the 2010 draft Supplemental EIS to the 1994 Exxon Valdez Oil Spill Restoration Plan. The beaches that will be used in this project are on Perry Island (PWS3A44), Eleanor Island (EL056C), Smith Island (SM006B), and Latouche Island (LA015E).

Bioremediation will be attempted by injecting a mixture of hydrogen peroxide (100 mg/liter), lithium nitrate (20 mg N/liter), and sodium tripolyphosphate (2 mg P/liter) into the beach subsurface at four pre-selected locations through three injection wells in deep-bedrock beaches and eight injection wells in shallow-bedrock beaches. The injection rate will be either 1 liter/min/well (deep-bedrock beaches) or 0.2 liter/min/well (shallow-bedrock beaches). The injection wells will be installed by digging pits to a depth of 1.5 m (deep-bedrock beaches) or 0.5 m (shallow-bedrock beaches). An excavator will be used to minimize the disturbance of the beach by minimizing the size of the pits at the surface. Monitoring wells will also be installed to allow collection of groundwater samples and measurement of the groundwater level as a function of time. Samples of oil-contaminated sediment will be collected from the treatment area once per month for the duration of the 90-day study.

Species that could be affected by this study includes Steller sea lions (a federally listed endangered species), harbor seals, sea otters, pigeon guillemots, harlequin ducks, Barrow's goldeneyes, black oystercatchers, Pacific herring, and pink salmon. Pigeon guillemots and Pacific herring are species that were injured by the oil spill and which are not recovering. The major impacts of this project are expected to fall into two areas: (1) impacts due to the physical presence of the research crew and equipment and (2) impacts due to the introduction of chemicals into the beach subsurface. Impacts due to the presence of researchers and equipment will be minimized through appropriate training of the workers and development of work rules that will reduce the opportunity for contact between workers and animals. The bioremediation chemicals that will be introduced into the environment and the concentrations that will be used were selected to minimize the potential for adverse impacts due to chemical addition. The chemicals that will be used either spontaneously decompose to harmless products (i.e., hydrogen peroxide rapidly decomposes to oxygen and water) or will be diluted to background concentrations within a single tidal cycle.

Overall, environmental impacts from this study are expected to be minimal and if proved effective, the treatment will remove potentially toxic lingering oil through a relatively low impact technique. The methods and chemicals that will be used are similar to those that would be used if bioremediation were to treat all of the lingering oil. The results from this pilot project will be used to help address the question of whether to proceed with more extensive effort. As such cumulative impact analysis and the decision to proceed to full scale remediation is deferred and will be examined through a subsequent Environmental Analysis. However because the pilot project plans involve placing a temporary storage shed above mean high tide, a special use permit may be required by the Dept of Agriculture, US Forest Service for this field season. As such USDA will serve as a co-operating agency in any subsequent Environmental Impact Review.

1.0. PURPOSE AND NEED

One of the most surprising revelations from two decades of research and restoration efforts since the 1989 spill is the persistence of subsurface oil in a relatively un-weathered state. This oil, estimated to be around 97.2 metric tons (or 23,000 gallons), is contained in discontinuous patches across beaches that were initially impacted by the spill. The patches cannot be visually identified on the beach surface, but their presence may be a source for continued exposure to oil for sea otters and birds that seek food in sediments where the oil persists. The survey work completed to date indicates that the majority of lingering oil remains in the beaches associated with the (USDA-FS designated) Nellie Juan-College Fiord Wilderness Study Area and is decreasing at a rate of zero to four percent per year with only a five percent chance that the rate is as high as four percent. As a result, it may persist for decades.

To address this concern and promote recovery of the beaches and the effected resources, without disrupting the character of wilderness area by using aggressive clean-up methods that may disrupting recovery, the Trustee Council issued call for proposals seeking low impact methods for remediating the oil.

The proposal under consideration is to determine if bioremediation can be deployed to breakdown the oil in-situ through the injection of nutrients and oxygen into the substrate as a restoration tool to promote recovery If this technology is effective it could lead to development of a comprehensive bioremediation plan that will restore habitats and species that are adversely impacted by the lingering oil.

1.1. BACKGROUND

This environmental assessment (EA) was prepared to support a pilot-scale bioremediation project that has been funded by the Exxon Valdez Oil Spill Trustee Council (EVOSTC) through the FFY 2011 Invitation for Proposals. The 1994 Environmental Impact Statement (EIS) for the Exxon Valdez Oil Spill Restoration Plan along with the 2010 Supplemental EIS (SEIS) to the plan, provide the context for proceeding with remediation efforts. As discussed in the SEIS, to address the issue of lingering oil, the governments developed a restoration plan in 2006 under the terms of the Reopener provision in the Consent Decree with Exxon (http://www.evostc.state.ak.us/facts/reopener.cfm) . To implement the Reopener plan a series of invitations for proposals were issued by the EVOSTC. The 2011 invitation was motivated by recent studies that concluded that between 60 and 100 tons of subsurface oil persists in many Prince William Sound (PWS) beaches that were contaminated following the 1989 *Exxon Valdez* oil spill (Short et al. 2004; Short et al. 2006). The lingering oil was shown to contain relatively high concentrations of polycyclic aromatic hydrocarbons (PAH) that are known to be toxic to fauna and flora (Carls et al. 2001; Short et al., 2004). Sea otters and harlequin ducks foraging the beaches in northern Knight Island maybe exposed to this lingering subsurface oil (Short et al., 2006).

The bioremediation pilot project described in this EA is based on the results of three projects that were previously funded by EVOSTC following the 2006 Reopener plan to understand the distribution of the lingering oil and the reasons for its persistence. The results of these studies are described in the Lingering Oil Report (EVOSTC, 2010). Briefly, the beaches that will be used in this pilot-scale bioremediation project were selected based on the detailed

assessment of oil distribution that was performed during development and validation of a probabilistic model of oil distribution based on correlations between oil persistence and geomorphic and hydrologic parameters of PWS beaches (Michel et al., 2009). The treatment approach that was selected is based on the results of a study that demonstrated that the lingering oil was extensively biodegraded (>80% of PAH degraded within 170 days) when the contaminated sediments were provided with sufficient quantities of oxygen and nutrients (Venosa et al., 2010), and the bioremediation delivery system was designed based on an investigation of the factors affecting the persistence of oil in six PWS beaches (Li and Boufadel, 2010; Bobo et al., 2010; Xia et al., 2010, Guo et al., 2010; Xia and Boufadel, 2010). The latter studies found that, in general, the beaches can be viewed as consisting of two layers: an upper layer that has a high permeability underlain by a much less permeable layer that contained the lingering oil (Fig. 1). The concentrations of nutrients and dissolved oxygen in the lower layer were too low to support oil biodegradation.

From these previous studies and the proposed pilot the governments are expected to make a decision on whether broader scale remediation efforts are feasible and warranted under the 2006 Reopener plan as discussed in the lingering oil section of the 2010 SEIS.

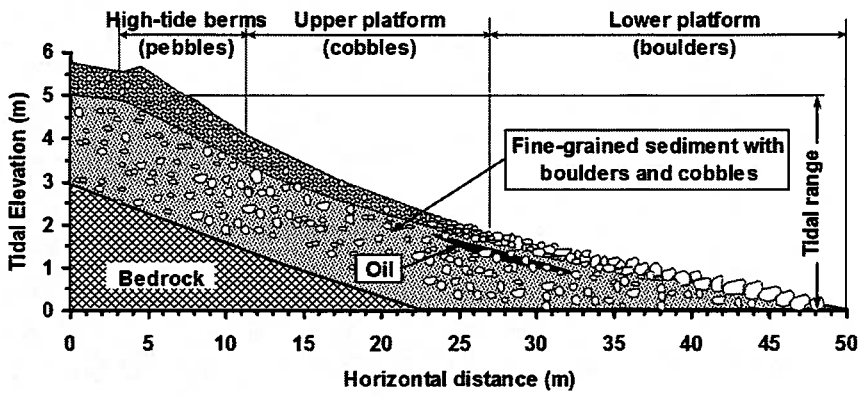

Figure1: Persistence of oil in the lower layer of beaches in Prince William Sound. Copyright Nature Publishing Group, from Li and Boufadel (February, 2010).

1.2. PROJECT AREA

The bioremediation pilot project will be conducted on four beaches in PWS. The beach segments that will be used in this pilot project include EL056C (Eleanor Island), SM006B (Smith Island), PWS3A44 (Perry Island), and LA015E (Latouche Island). The locations of these beaches are shown in Figure 2. The sites on Eleanor Island, Smith Island, and Perry Island are in northern PWS, and the Latouche Island site is in southern PWS. Two of these sites (EL056C and SM006B) were used in the previous hydrological study

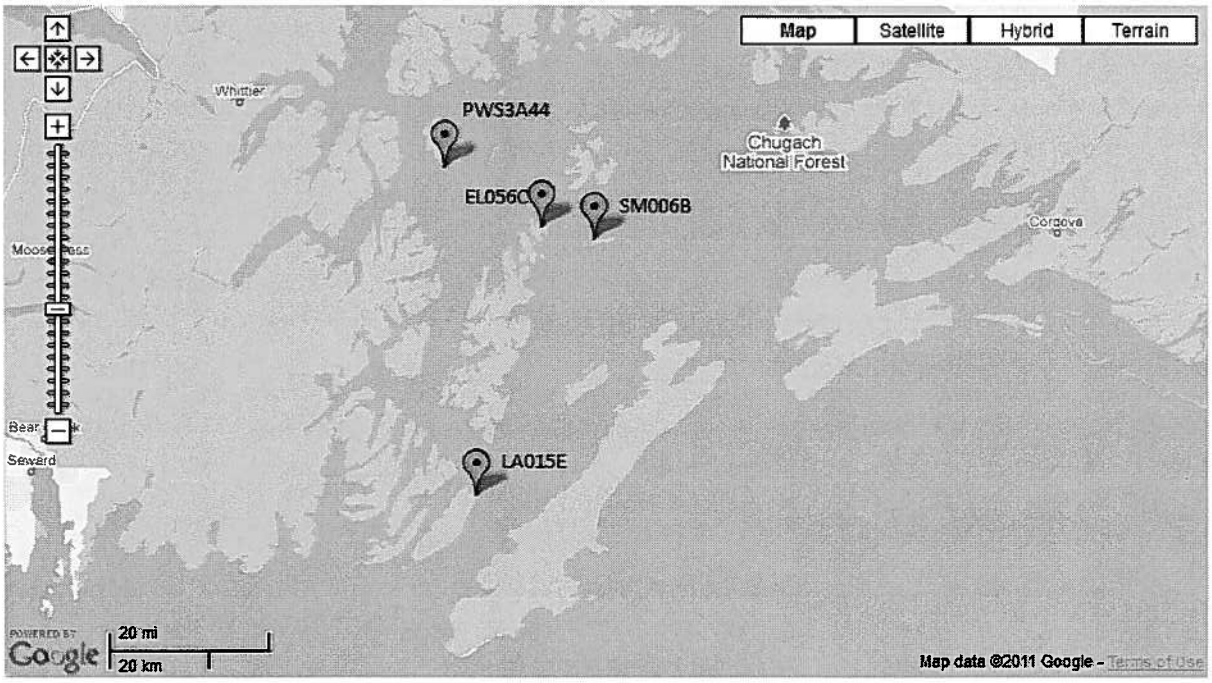

Figure 2: Locations of beaches that will be used in this bioremediation pilot project.

2.0. DESCRIPTION OF ALTERNATIVES

An evaluation of a broad range of options for treating lingering oil was the subject of an earlier EVOSTC funded project (Michel et. al. 2006). The evaluation concluded only two approaches were likely to be feasible: 1) Natural Recovery and 2) Bioremediation. Other methods were considered likely to be ineffective or too environmentally disruptive. This earlier scoping effort when combined with results from subsequent field studies (Li and Boufadel 2010, Boufadel et. al. 2010, and the background provided in the previous section) form the basis for restricting this analysis to two options. The 2010 SEIS discussion on lingering oil included these options by reference.

2.1 NO ACTION / NATURAL RECOVERY

Under the no action alternative, the project will not proceed and information will not be collected as to the feasibility of applying bioremediation methods to degrade lingering oil contained in subsurface layers. No external treatment will be applied and natural recovery will be the only form of remediation. Natural recovery may take decades based on estimates from surveys that the attenuation of oil is extremely slow (Short et al., 2004; Short et al., 2006; Short et al., 2007; Taylor and Reimer, 2008). Natural recovery will still be option for consideration when the decision is faced on whether to apply bioremediation broader scale if the proposed pilot project proceeds under Alternative 1.

2.2. ALTERNATIVE 1. BIOREMEDIATION PILOT PROJECT (CURRENT PROPOSAL)

The bioremediation pilot project was described in the proposal that was submitted to EVOSTC, and the detailed project description can be viewed at the EVOSTC website (http://www.evostc.state.ak.us/Projects/ProjectInfo.cfm?project_id=2189). The proposal "Pilot studies of bioremediation of the Exxon Valdez oil in Prince William Sound Beaches" is hereby incorporated by reference into this EA. The following represents a brief summary of the project..

The two-layer configuration of the beaches and the mid-intertidal-zone location of the lingering oil (Fig. 1) suggest that surface application of bioremediation amendments would be ineffective (Xia et al., 2010). Therefore, the rate-limiting reagents will be delivered directly to the subsurface. Because direct injection of air into the subsurface (i.e., air sparging) would treat a very small area around each well due to the shallow depth of the bedrock (Wong et al., 1997), we will provide nutrients and oxygen by injection of aqueous solutions into wells in the vicinity of the subsurface contaminants.

A critical parameter for the design of the injection system is the depth of the bedrock because beaches with deep bedrock allow high pressure injection of chemicals into the beach, where as nutrients must be released into shallow beaches at a much lower rate (Boufadel and Bobo, 2011; Boufadel et al., 2011). For purpose of this project, beaches are classified as Type D (Deep bedrock) if the bedrock is at least 1.5 m below the surface and Type S (Shallow bedrock) if the bedrock is less than 0.80 m below the surface. On Type D beaches, wells will be installed by excavating pits to a depth of 1.5 m with minimum disturbance of the surrounding beach. A well screened over the bottom 0.30 m will be placed into the pit, and it will be filled to a depth of 0.6 m with excavated sediment. A 0.1-m layer of bentonite (clay) will be emplaced, and the pit will be completely filled with the excavated sediments. The bentonite layer provides a seal that prevents the injected solutions from short circuiting around the pipe to the surface and anchors the well casing into the ground. A tracked excavator equipped with auger and breaker attachments will be used to assist excavation of the well holes. Previous experience with excavation in Type D of beaches suggests that the pit diameter at the surface would be less than 1.0 m if the pits were dug manually, and we expect the mechanical assistance of the excavator will minimize the width even further. Three injection wells will be installed on each Type D beach. The wells will be about 2 m apart in a row that is parallel to the shoreline.

Bioremediation amendments will be injected at a flow rate of 1.0 liter per minute per well (0.26 gal/min/well) at a pressure of less than 7.0 m of water. A previous study on one of the

Type D beaches that will be used in this pilot project (EL056C) showed that flow rates up to 3.0 liters per minute and pressures to 20 m could be sustained (Boufadel and Bobo, 2011).

Wells on Type S beaches will be installed in pits that will be excavated within the oiled area to a depth of 0.5 m. A well screened over 0.30 m will be placed into the pit, and the well screen will be covered with excavated sediment. A 0.1-m layer of bentonite (clay) will be placed, and the pit will be completely filled with the excavated sediments. Bioremediation amendments will be injected at a flow rate of 0.2 liters per minute per well to maintain a slight positive pressure. Two rows of 4 injection wells will be installed parallel to the shoreline in each Type S beach. The wells in each row will be spaced about 1 m apart, and the two rows will be about 2 m apart.

The concentrations of the nutrient and oxygen solutions were determined based on considerations of environmental and worker safety and engineering practicality. PWS seawater from offshore of each beach will be used to dilute concentrated solutions of hydrogen peroxide (H_2O_2), lithium nitrate ($LiNO_3$), and sodium tripolyphosphate ($Na_5P_3O_{10}$, STTP) to concentrations of 100 mg/l, 20 mg N/L, and 2 mg P/L, respectively. The concentration of hydrogen peroxide was selected because the maximum solubility of oxygen in seawater at 15°C is about 40 mg/l (Metcalf and Eddy, 1991), and higher concentrations may lead to the formation of oxygen gas bubbles that could reduce the permeability of the formation (Spain et al., 1989; Fiorenza and Ward, 1997). The concentrations of nitrate and STTP are sufficient to remove the nutrient limitation to the growth rate of hydrocarbon-degrading bacteria without providing excessive amounts of nutrient to the surrounding offshore environment.

Bioremediation will be conducted over a period of about 90 days. So, the total volume of solution injected into each beach will be about 390 m^3 for Type D beaches and less than 210 m^3 for Type S beaches. Thus, about 39 kg of hydrogen peroxide will be injected into Type D beaches, and 21 kg will be injected into Type S beaches. Also, about 7.8 kg NO_3-N will be injected into Type D beaches, and 4.1 kg NO_3-N will be injected into Type S beaches. The amounts of STTP injected will be 780 g and 410g(both as P) for Type D and Type S beaches, respectively.

In addition to the injection wells, piezometer wells and water sampling wells will be installed in the beach to allow us to monitor changes in groundwater level due to tide and measure the concentrations of bioremediation amendments (nitrate, phosphate, oxygen, and lithium). These wells will be similar to those used in the previous hydrology study (Li and Boufadel, 2010; Xia et al., 2010; Guo et al., 2010, Sharifi et al., 2010). The piezometer wells will be installed at least 4.0 m from the edge of the oiled area, but some sampling wells will be installed within the treatment zone.

Sediment samples will be collected to monitor the concentrations of oil, oil-degrading bacteria, and nutrients (nitrate, phosphate, and lithium). Sediment samples will be collected without replacement at the nodes of a grid that will be established over the oil-contaminated area. The contaminated area will be divided into three zones that represent different distances seaward of the injection wells. Sediment samples will be collected at one-month intervals (starting during plot setup, which will be considered to be time zero). Oil samples will be collected by digging a pit through the oil-contaminated region during low tide and obtaining a sample that encompasses the entire oiled depth. Two samples from different locations—but representing the same distance from the injection wells—will be composited to minimize field variability. The samples will be preserved and analyzed as described in the proposal.

Hydrogen peroxide was selected as the source of oxygen for this study because it is water soluble, decomposes to oxygen and water as the only products (Pardieck et al., 1992), and is an efficient source of oxygen (0.47 grams of O_2 are produced per gram of H_2O_2). Other alternative oxygen sources, such as calcium and magnesium peroxides (e.g., PermeOx® and ORC®), produce less oxygen per gram of compound and produce insoluble residual products (e.g., calcium and magnesium hydroxide), which may reduce the permeability of the formation and make subsequent treatment more difficult. Hydrogen peroxide has been widely used to provide oxygen to support bioremediation of hydrocarbon-contaminated groundwater and subsurface sediments (Fogel et al., 1988; Piotrowski, 1989). Although hydrogen peroxide decomposition can be catalyzed by common minerals and enzymes that are likely to be present in the beach subsurface, it is reasonably stable in the absence of sediments (Lawes, 1990).

Lithium nitrate was selected as the nitrogen source because ammonia utilization by hydrocarbon degraders can result in reduced pH in poorly buffered environments (Wrenn et al., 1994) and can be an electron donor for ammonia-oxidizing bacteria (Madigan et al., 2008). Lithium will be used as a conservative tracer to facilitate estimation of consumption rates for the nutrients and oxygen. Sodium tripolyphosphate was selected as the source of phosphorus because it is more soluble in seawater than either ortho- or pyrophosphate.

3.0. AFFECTED ENVIRONMENT

This bioremediation pilot project will be conducted on four beaches in Western Prince William Sound that contain lingering oil from the *Exxon Valdez* oil spill. These beaches are located on Perry Island (PWS3A44), Eleanor Island (EL056C), Smith Island (SM006B), and Latouche Island (LA015E). The sites are within 50 miles of each and thus are subject to common weather and marine conditions (http://pafc.arh.noaa.gov/). Difference in wave expose (lentic verses lotic conditions) result in some of the differences noted in the sections below, though overall air and soil compositions are similar and the biota found at the locations are typical to what can found along coastal beaches within Prince William Sound. Sensitive resources in the vicinity of each beach were identified based on information contained in "Sensitivity of Coastal Environments and Wildlife to Spilled Oil: Prince William Sound Alaska" (NOAA et al., 2000). Resources specific to each site are described in the subsections that follow. In every case, however, the impacts of project activities on intertidal and subtidal resources must be considered. In particular, clams, mussels, and crabs are important food resources for sea otters (Reidman and Estes, 1990), sea ducks such as harlequin ducks and goldeneyes (Elser, 2000; Elser and Iverson, 2010), and black oystercatchers (Hartwick, 1976).

Because distribution maps for these important intertidal animals are not available, the likelihood of their presence at each site will be discussed based on the site characteristics for the purposes of this EA. In general, littleneck and butter clams, which are the most common and important clam species in PWS, are most abundant in the lower intertidal zone and the shallow subtidal zone. Butter clams, for example are common between about -0.9 m to 1.2 m relative to mean lower low water (MLLW), and littleneck clams are found between about -0.6 m to 1.5 m MLLW (Integral Consulting, 2006). Because they are burrowing organisms, they prefer protected coarse sand and gravel beaches and are not common on shorelines with significant cobble/boulder armoring (Integral Consulting, 2006). Mussels, on the other hand, are common in the lower to middle intertidal zones (0 m to 2 m MLLW) of protected bays (Integral Consulting, 2006). They are most common on bedrock or boulder shorelines but may also form

beds on soft sediments. The crescent gunnel is a common intertidal fish in PWS and is an important prey species for pigeon guillemots, river otters, and mink. Crescent gunnels can sometimes be found in the intertidal zone under rocks or vegetation when the tide is out (McClory and Gotthardt, 2005).

3.1. PWS3A44 (PERRY ISLAND)

Beach segment PWS3A44 is located near the southern tip of Perry Island in northwestern Prince William Sound. The location of this project site is shown in Figure 3 along with sensitive resources. The shoreline faces southeast and consists of a gravel beach bordered by exposed bedrock. Exposed bedrock outcrops are also present near the center of the beach segment in the lower intertidal and subtidal zones. The shoreline is relatively exposed with fetches of about 19 km to the southeast and 23 km to the east.

A Steller sea lion haul-out site is located around the peninsula from PWS3A44 (about 0.8km by shoreline). Steller sea lions are a federally listed endangered species. The concentration given in the legend for the ESI map is "0," and there is no indication that this site is used for mating, calving, or pupping.

An arctic tern nesting site is present on the point about 200 meters south of the beach segment that will be used for this pilot project. The ESI map legend indicates that 16 nesting pairs were present during the surveys used to prepare the map, and the birds would be nesting while this project is underway (i.e., June-September).

A harbor seal haul-out site is located about 3 km across South Bay from the project site. The ESI map legend gives the concentration as "<10." Seals may be present throughout the year. Harbor seals were injured by the *Exxon Valdez* oil spill, but their population has recovered (EVOSTC, 2009).

Sea otters and various bird species are known to frequent the shoreline of South Bay. The sea otter concentration in this area is suggested to be "low." Sea otters were injured by the *Exxon Valdez* oil spill, and their population is recovering (EVOSTC, 2009). Bald eagles, gulls, and oldsquaw are expected to be the only bird species present in the summer, and the concentrations of all of these species are expected to be "low." Bald eagles were injured by the *Exxon Valdez* oil spill, but the population has recovered (EVOSTC, 2009). South Bay is also used by a variety of unspecified water fowl, but these animals are not expected to be present during the summer.

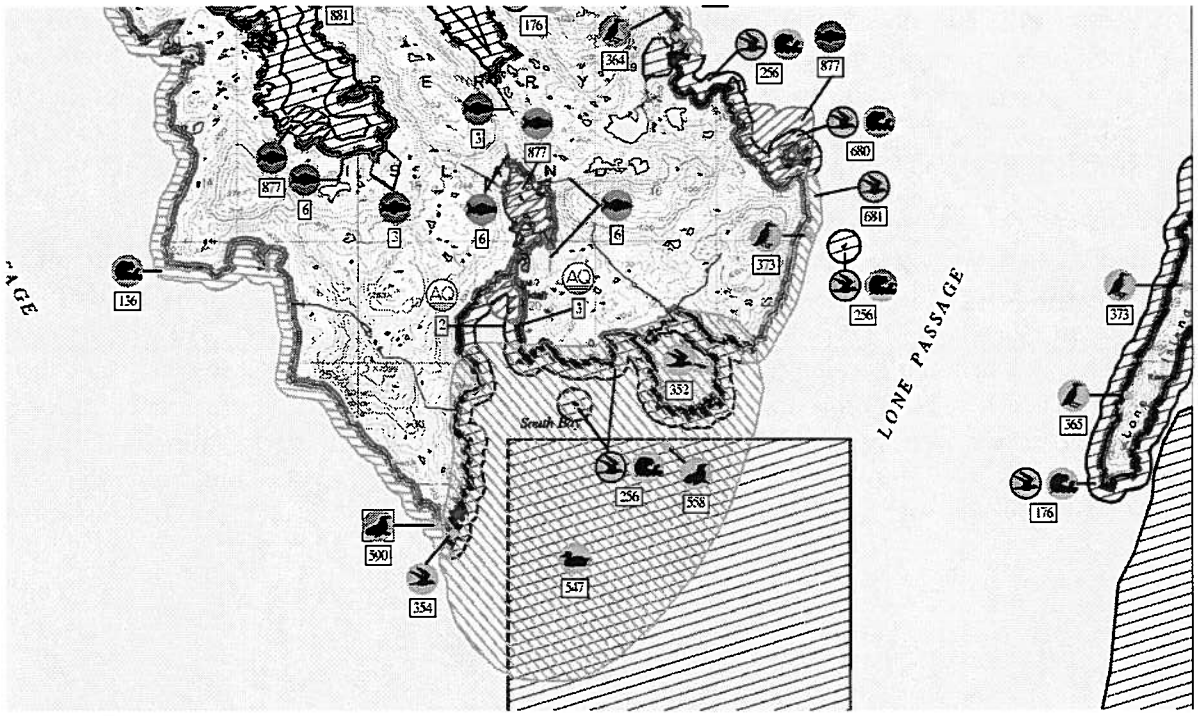

Figure 3: Location of beach segment PWS3A44 (red star) relative to sensitive resources (NOAA et al., 2000).

Several pink salmon streams drain into an enclosed water body (probably an estuary) that is connected to South Bay, but the fish may not be present during this study (presence indicated March-May only). Pink salmon were injured by the *Exxon Valdez* oil spill, but their population has recovered (EVOSTC, 2009). Pacific herring may be transiently present in this body of water (July), but spawning has not been noted in the ESI maps. Pacific herring have been identified as being a species that was harmed by the *Exxon Valdez* oil spill, and their population has not recovered (EVOSTC, 2009). Finally, two aquaculture facilities are located in an inlet from South Bay near its connection to the estuary.

The heaviest lingering oil contamination at PWS3A44 is located between about 2.5 to 3.5 m above MLLW, which is at a higher elevation than the typical distribution range for clams and mussels. The presence of clams is unlikely because this beach is armored by boulders and cobble. The distribution of intertidal species on boulder/cobble beaches is highly skewed toward the lower intertidal and subtidal zone (Gilfillan et al., 1995). Many species would be expected to be associated with the rockweed, which provides food and shelter during low tides. Photographs of this site suggest that rockweed should be easily avoidable.

3.2. EL056C (ELEANOR ISLAND)

Beach segment EL056C is located in a sheltered inlet of Northwest Bay on Eleanor Island (Fig. 4). This site is a gravel beach that is bordered by sheltered rocky shoreline on both sides. The beach faces north and is well sheltered.

A harbor seal haul-out site is located in Northwest Bay almost2 km northwest of the project site. Although seals may be present throughout the year, the concentration is given as "<10" by the ESI map legend. Low concentrations of sea otters may also be present along the shoreline of Northwest Bay throughout the year. A Steller sea lion haul-out site is located over 3.5 km north-northeast of beach segment EL056C, but the distance by water would be closer to 5 km.

Northwest Bay is used by several species of birds during the spring and summer (April-September). So, they may be present during this study. Bird species that are expected include, goldeneyes, black-legged kittiwakes, glaucous-winged gulls, mew gulls, other (unspecified) gulls, marbled murrelets, other (unspecified) murrelets, and pigeon guillemots. All species except the murrelets and black-legged kittiwakes are listed as being present at low concentration. The murrelets and black-legged kittiwakes are listed as being present at medium concentration. Barrow's goldeneyes were injured by the *Exxon Valdez* oil spill, but their population is recovering (EVOSTC, 2009).Marbled murrelets and Killitz's murrelets were injured by the *Exxon Valdez* oil spill, but the extent of their recovery is unknown (EVOSTC, 2009). Pigeon

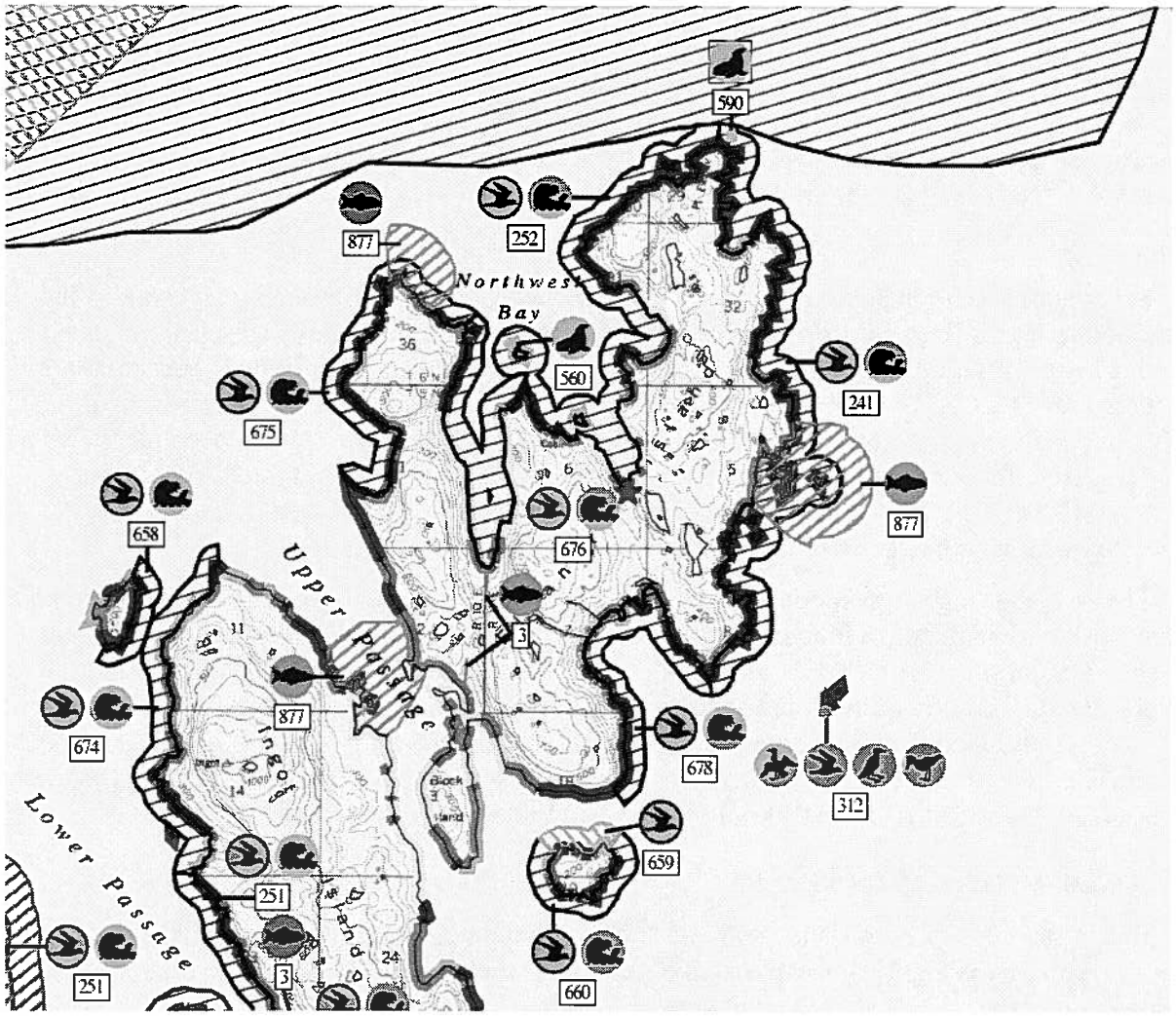

Figure 4: Location of beach segment EL056C (red star) relative to sensitive resources (NOAA et al., 2000).

guillemots were injured by the *Exxon Valdez* oil spill, and their population has not recovered (EVOSTC, 2009).

Pacific herring may be present in the waters surrounding the northwestern side of Northwest Bay in July. This area is >3 km from the project location. Also, a stream used by pink salmon to spawn drains into an inlet in Northwest Bay. The salmon stream is well separated from our study site by a peninsula (>3.5 km by water and >1.5 km by land).

This beach is predominantly gravel with scattered boulders and cobble. It was used in a previous research study led by the principal investigator (PI) for this study, and many pictures of the area are available but none show evidence of mussel beds. The distribution of intertidal species on gravel beaches is skewed toward the lower intertidal and subtidal zone (Gilfillan et al., 1995). Many species would be expected to be associated with the rockweed, which provides food and shelter during low tides. The rockweed appears to be easily avoidable.

3.3. SM006B (SMITH ISLAND)

Beach segment SM006B is an exposed gravel beach on Smith Island. This beach has fetches of about 10 km to the north and over 40 km to the northeast. Its location is shown in Figure 5.

A variety of (unspecified) waterfowl and shorebirds are present along the shoreline of Smith Island from March-May, and so, they may still be present during site setup. Also, black scoters are present from March-September at a medium concentration. Bald eagles nest along shorelines in this part of Prince William Sound between April and August, possibly including the shoreline of Smith Island. Tanner crabs are also present throughout the area, possibly including the area around Smith Island. Tanner crabs spawn until June and eggs may be present throughout the summer.

A variety of birds and mammals may be present in the vicinity of a small island off the western tip of Smith Island (about 2 km from the project site). Mammals present around this small island include sea otters and harbor seals, including a harbor seal haul-out site. Several nesting colonies of birds are present on this island, including two colonies of pigeon guillemots and colonies of arctic terns, black oystercatchers, horned puffins, tufted puffins, and parakeet auklets. The puffins and auklets appear to be most abundant, with between 30 and 50 nesting pairs. Black oystercatchers were injured by the *Exxon Valdez* oil spill, but their population is recovering (EVOSTC, 2009).

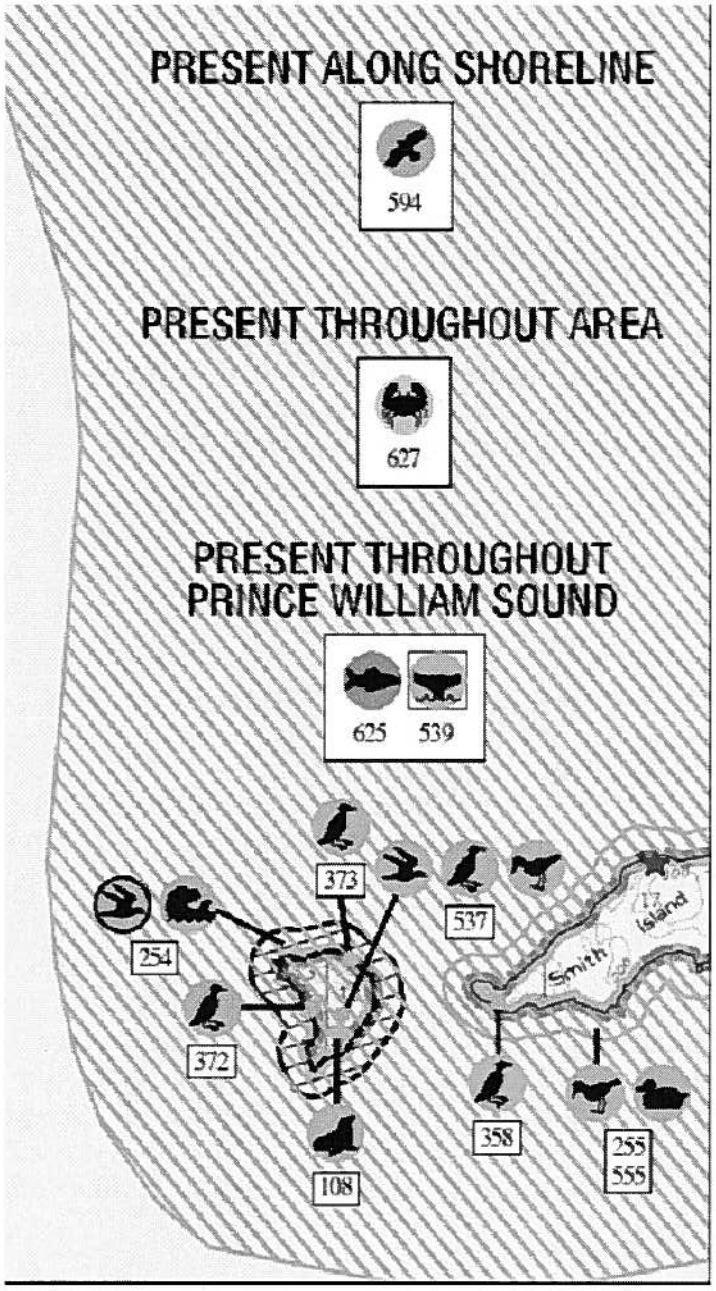

Figure 5: Location of beach segment SM006B (red star) relative to sensitive resources (NOAA et al., 2000).

The waters around Smith Island support many fish species, including yellowfin sole, which spawn between May and August, which is when this project will be conducted. Other fish species likely to be present offshore of Smith Island during this study include arrowtooth flounder, flathead sole, rock sole, Pacific cod, black cod (sablefish), sculpin, and walleye pollock. In addition, humpback and killer whales, which occur throughout Prince William Sound, may also be present during the time we will be conducting this study. Killer whales were injured by the *Exxon Valdez* oil spill, but their population is recovering (EVOSTC, 2009).

SM006B is an exposed sand and gravel beach with heavy cobble and boulder armoring. The heaviest lingering oil contamination is located between about 1.8 to 2.8 m above MLLW, which is at a higher elevation than the typical distribution range for clams and mussels. This beach was used in a previous research study led by the principal investigator (PI) for this study, and many pictures of the site are available but none show evidence of mussel beds. The distribution of intertidal species on this type of beach is highly skewed toward the lower intertidal and subtidal zone (Gilfillan et al., 1995). Many species would be expected to be associated with the rockweed, which provides food and shelter during low tides. The rockweed at this site appears to be easily avoidable.

3.4. LA015E (LATOUCHE ISLAND)

Beach segment LA015E is a gravel beach on the northeast end of Latouche Island that is bounded on both sides by exposed wave-cut platforms in bedrock (Fig. 6). The beach faces northeast where the fetch is about 24 km. Significant fetches also exist to the north (12 km) and east (16 km).

Harlequin ducks and gulls are present along the northern shore of Latouche Island throughout the spring and summer (April-September) when this project will be conducted. Harlequin ducks were injured by the *Exxon Valdez* oil spill, but their population is recovering (EVOSTC, 2009). Harlequin ducks are also present in high concentrations along the western shore of Latouche Island along with lower concentrations of common mergansers and other (unspecified) mergansers. A variety of bird species are present on the eastern and western shores of Latouche Island during the spring and summer. These include black-legged kittiwakes, glaucous-winged gulls, mew gulls, Kittlitz's murrelets, marbled murrelets, and other (unspecified) murrelets. Bald eagles and pigeon guillemots are present in low concentrations on the eastern shore of Latouche Island. No nesting areas are indicated on the ESI map for Latouche Island.

Several bird species are present throughout Southern Montague Strait, including black-legged kittiwakes, fork-tailed storm petrels, shearwaters, white-winged scoters, surf scoters, other (unspecified) scoters, marbled murrelets, ancient murrelets, Kittlitz's murrelets, other (unspecified) murrelets, common murres, other (unspecified) murres, glaucous-winged gulls, and mew gulls.

Sea otters may be present along the eastern shore of Latouche Island at low concentrations.

Several pink salmon streams are present in the vicinity of LA015E. Two of the streams discharge on the northern end of the island, and several others discharge on its western or eastern sides. The legend for the ESI map indicates that the salmon spawn in the closest stream (about 200 m northwest of the project site) from August to October, as do most of the streams that discharge to the west or east. The fish spawn from March to May in the other stream that discharges on the north side of the island (about 1.5 km from LA015E by land and >2 km by sea). A sockeye salmon stream discharges on the western side of the island (about 5.5 km from the study site by sea). The sockeye salmon spawn during the time that this study will be conducted (May-August).

The heaviest lingering oil contamination at LA015E is located between about 2.8 to 3.2 m above MLLW, which is at a higher elevation than the typical distribution range for clams and mussels. This beach is heavily armored by boulders and cobble, and the distribution of intertidal

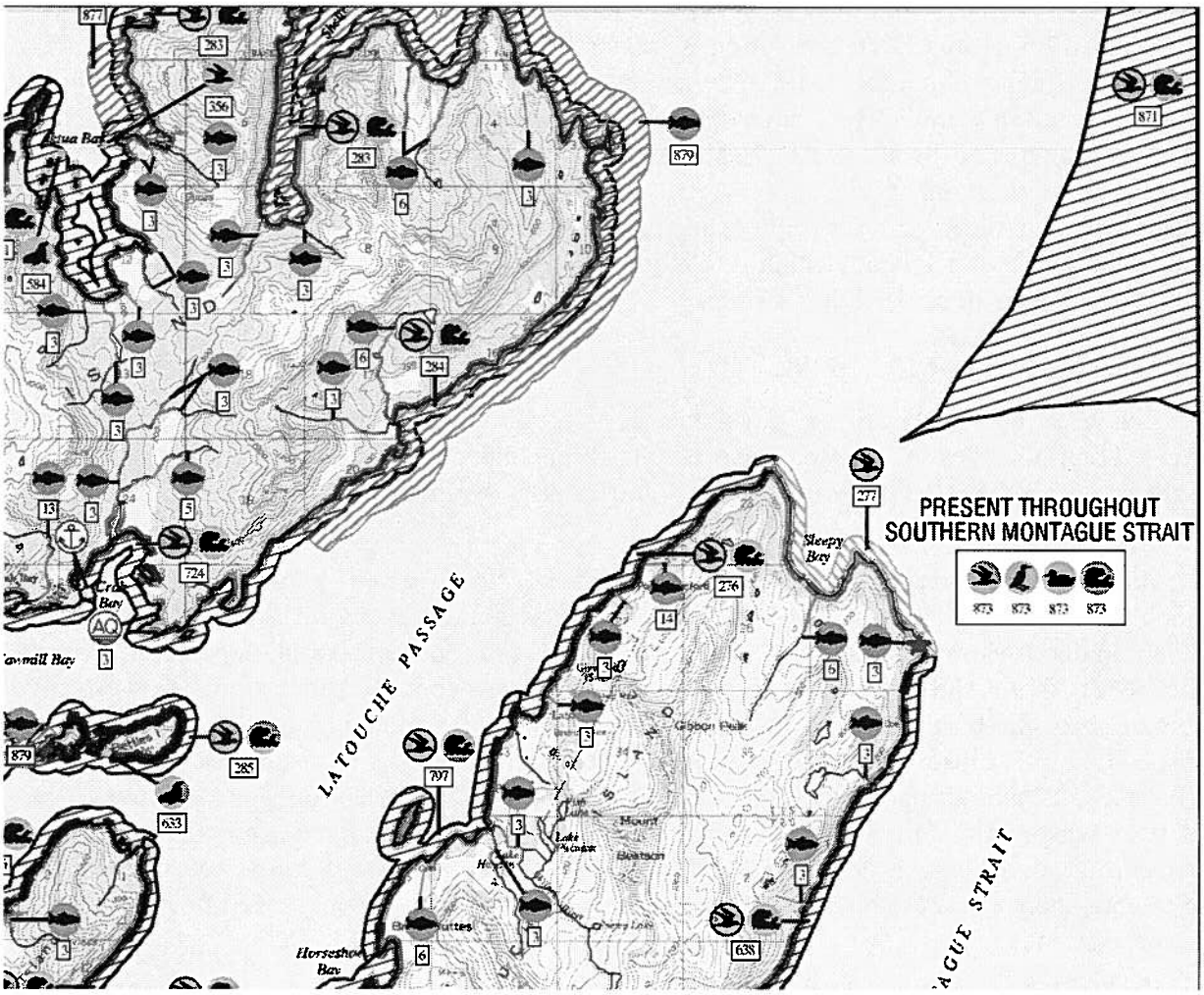

Figure 6: Location of beach segment LA015E (red star) relative to sensitive resources (NOAA et al., 2000).

species on this type of beach is highly skewed toward the lower intertidal and subtidal zone (Gilfillan et al., 1995). Many species would be expected to be associated with the rockweed, which provides food and shelter during low tides. Photographs of this site suggest that rockweed should be easily avoidable.

4.0. ENVIRONMENTAL AND ECONOMIC CONSEQUENCES

4.1 NO ACTION

Under the no action alternate, active remediation will not be considered as potential treatment option. Information will not be collected as to the efficacy of bioremediation proposed in Alternate 1. Since natural degradation, rates are low, the oil and its toxic components is likely to persist for decades. While the oil will remain sequestered in subsurface anoxic layers, and thus not available to most organisms, digging animals such sea otters and humans seeking clams, can potentially be exposed. Current studies as well as future studies will be addressing the issue of

harm and risk of leaving the oil in place. The no action alternative here leaves natural recovery as the only means through the oil will eventually be removed. While that may be the best recourse after weighing all factors, a more informed decision can be made after the completion of current studies and determining if bioremediation is a viable approach.

4.2. ALTERNATIVE 1: BIOREMEDIATION PILOT PROJECT

In discussion of the consequences it can be stated up front that the project as proposed would have no measurable adverse impacts on air quality, water quality, essential fish habitat, nor present any significant damage to the coastal habitats. The analysis that follows looks at potential for wildlife and human use impacts and the consideration of impacts to the soil based on the injection of chemicals into the substrate.

4.2.1 IMPACT ON KEY RESOURCES.

The most sensitive resources that could be affected by this study includes Steller sea lions (a federally listed endangered species), harbor seals, sea otters, pigeon guillemots, harlequin ducks, Barrow's goldeneyes, black oystercatchers, Pacific herring, and pink salmon. Pigeon guillemots and Pacific herring are species that were injured by the oil spill and which are not recovering.

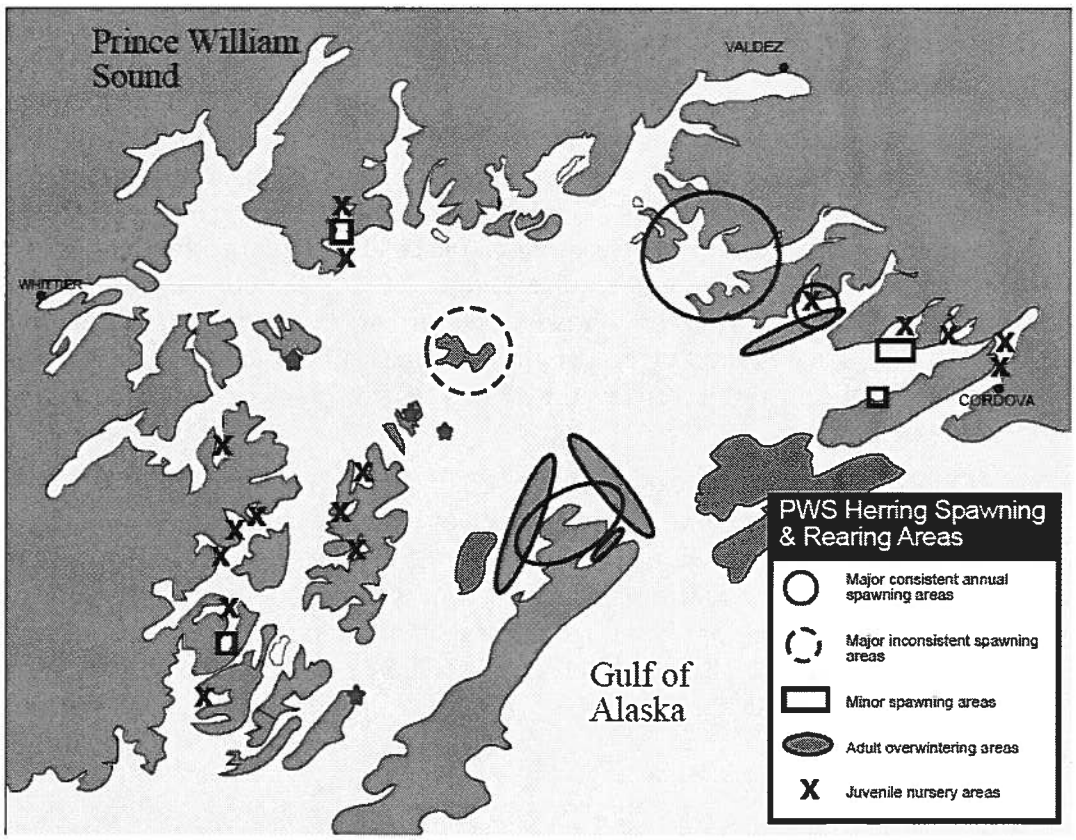

Figure 7: Location of major and minor herring spawning and nursery areas relative to project beaches (red stars) (Brown and Carls, 1998).

The major impacts of this pilot project can be divided into two areas: (1) impacts due to the physical presence of the research crew and equipment and (2) impacts due to the introduction of chemicals into the beach subsurface. Although Pacific herring may be transiently present near one of the study sites (PWS4344), it is not considered to be a major or minor spawning or nursery area (Fig. 7). Therefore, even though Pacific herring is a species of concern, it is unlikely to be affected by this project. Although Steller sea lions, harbor seals, and pigeon guillemots feed in near-shore water, they are most active in the subtidal zone (Merrick and Loughlin, 1997; Frost et al., 2001; Piatt and Nettleship, 1985), which would not be directly impacted by chemical additions. Therefore, the major impact to these species would be due to the presence of workers during installation or removal of equipment, system maintenance, and sample collection. The potential impacts on pink salmon are similar: no reasonable transport mechanism could expose returning fish or their eggs to chemicals introduced to the beach subsurface in this study. Therefore, the main potential impact to pink salmon would be due to encounters with researchers when they are present in the area. Sea otters, harlequin ducks, Barrow's goldeneyes, and black oystercatchers forage in intertidal zones, which is the area that will be impacted by this pilot project. Any impacts of this work on intertidal invertebrates, which constitute the main prey for these species, could exert indirect impacts on their populations. Therefore, both potential impact mechanisms may be important for these species.

4.2.2. IMPACTS DUE TO RESEARCHERS AND EQUIPMENT

As described in Section 1.3, this project will involve installation of injection and monitoring wells and construction of an equipment shed on each beach. In addition, samples will be collected several times during the study by excavating small pits in within the treatment area. At the end of the study (early September), all of the equipment will be removed. All of these activities will require several workers to be present on the beach for significant lengths of time. Well installation and equipment setup will require a crew of 6 to 8 persons, an excavator, and a variety of hand tools. This crew will work on the beach for 2 to 3 days during daylight hours. A similar level of effort will be required to remove the equipment from the beaches at the end of the study. Sample collection will be performed by 3 to 4 persons working on the beach during low tide for about one day.

The impact of the presence of researchers on marine mammals and birds will be minimized by training all crew members regarding the importance of avoiding contact with animals. As indicated in the beach descriptions (Sections 3.1 to 3.4), the known seal/sea lion haul-out sites are at least 0.8 km from the study beaches and are not accessible by foot. The closest bird nesting site is about 200 m (PWS4344), but like the seal and sea lion haul-out sites, none of the bird nesting sites are accessible by beach. Therefore, it will be relatively easy to prevent crew members from approaching these sites.

One of the study sites (LA015E) is relatively close (about 200 m) to a stream in which pink salmon are known to spawn (Fig. 6). Spawning occurs from August to October in this stream, which is near the end of this study. So, the most potential for impacts due to this project would be when equipment is removed from the beach in September. Figure 8 shows the distribution of oil as determined by a recent survey. In general, the oil is concentrated near the southern end of this beach segment, whereas the stream is north of it. To prevent impacts on this stream, an exclusion zone will be established on the north end of this beach segment beginning at about 80 m on the x axis (Fig. 8).No equipment will be allowed in the exclusion zone, and workers will be allowed in the area only with permission from the team leader. The beginning of the exclusion zone will be marked with flagging tape or flagged posts before work begins, and the markers will be removed when the work is completed.

Impacts due to excavation of pits for installing wells will be minimized by using an excavator equipped with an auger, bucket, and hydraulic pick to minimize the size of the hole needed for each well. Hand digging these pits would normally result in a pit diameter at the surface equal to about equal to the pit depth, but the excavator should reduce the required diameter by a factor of two to three. The load exerted by the excavator would be about 520 lbs/ft^2, which is less than the load exerted by a walking 200-lb man (about 600 lbs/ft^2). To minimize the impact of the excavator in the intertidal zone, it will be offloaded from the barge at high tide. When it must be operated in the intertidal zone, the excavator will be driven onto a platform consisting of two 8' x 4' plywood boards to reduce the load to 180 lbs/ft^2. So, the impact of the excavator should be minimal.

Impacts due to the excavator and worker foot traffic on intertidal organisms that may be

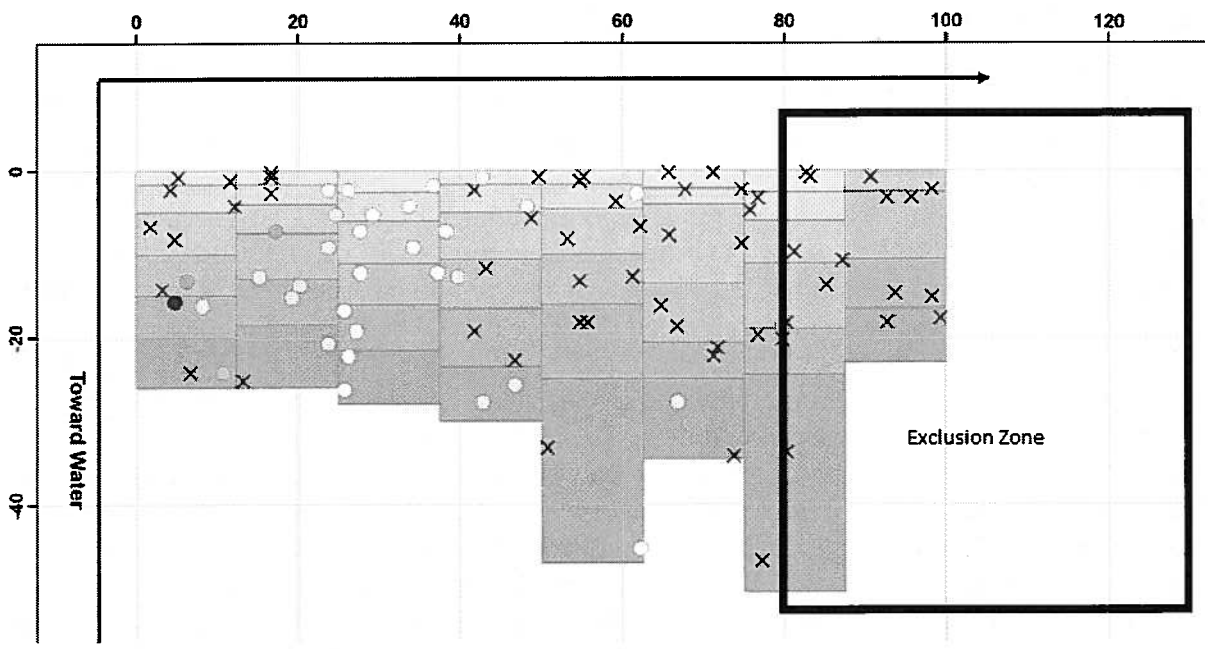

Figure 8: Location of lingering oil on LA015E. The presence of oil in permeable sediments is indicated by red (high oil residue), orange (medium oil residue), yellow (low oil residue), and green (film/sheen) circles. Impermeable, oil-free surfaces are indicated by "x." Distances are given in meters.

present in the work area will be minimized by surveying the area to identify high concentrations of animals, such as snails and crescent gunnels, which could be injured or killed if stepped upon or driven over. To the extent possible, these areas will be avoided. In particular, equipment and worker traffic will be diverted around areas that are covered by rockweed whenever possible as many intertidal organisms may shelter underneath it while the tide is out. As mentioned in the site descriptions (Section 3), most of the intertidal organisms on these beaches are expected to be present predominantly in the middle to lower intertidal zone, and most of the work will be conducted in the middle to upper intertidal zone. So, it should be possible to avoid extensive contact with these species.

4.2.3. IMPACTS DUE TO CHEMICAL ADDITION

The chemicals that will be added to the beach subsurface during this study are all relatively benign, and the concentrations that will be used are as low as feasible without compromising performance. Hydrogen peroxide (H_2O_2), which will be used as the oxygen source, decomposes to oxygen (O_2) and water (H_2O) in a reaction that can be catalyzed by a common enzyme (i.e., catalase, which is possessed by all aerobic organisms) and by commonly occurring iron and manganese minerals (e.g., hematite) (Pardieck et al., 1992). Typical half-lives for decomposition of hydrogen peroxide to oxygen of between about 0.25 to 6 hours have been reported (Lawes, 1990).Since the injection rate used in this study is expected to induce a groundwater flow velocity of about 10 m/day on Type D (deep bedrock) beaches, the concentration of hydrogen peroxide would be reduced by about 95% within 10 m of the injection well in the worst case. Faster reaction rates are more typical than slow rates, however; so, there is little chance that hydrogen peroxide would be detectable within a meter or two of the injection well. Therefore, the probability of hydrogen peroxide being discharged to the ground surface before being completely converted to oxygen is extremely small.

Nitrate and phosphate (as lithium nitrate and sodium tripolyphosphate) will also be injected into the beach subsurface. The concentrations that will be used for these nutrients will be 20 mg N/liter and 2 mg P/liter, respectively. These compounds are being used to provide nutrients to support the growth of hydrocarbon-degrading bacteria. Three wells will be installed on the Type D beaches, and nutrients will be injected at 1 liter/min/well (3 liters/min/beach). Eight wells will be installed on Type S (shallow bedrock) beaches, and nutrients will be injected at a flow rate of 0.2 liters/min/well (1.6 liters/min/beach). Therefore, nitrate will be introduced at a rate of about 86 g N/day on Type D beaches and about 46 g N/day on Type S beaches. The rates of phosphorus addition will be about 9 mg P/day and 5 mg P/day on Type D and Type S beaches, respectively. Even if the concentrations of these nutrients are not reduced during transport through the beach subsurface, they would be subjected to substantial dilution by each tidal cycle. The beaches that will be used in this study vary between about 50 to 150 m in width (along-shore dimension), and the average difference between low and high tide is about 4 m. Therefore, if one assumes the width of the intertidal zone is about 30 m in the across-shore dimension (13% beach slope), each tidal cycle would provide 3 to 9 million liters of dilution water. Since there are approximately two tidal cycles per day, the maximum concentrations of nitrate and phosphate offshore of each study site would be between 5 to 14 μg N/liter and 0.5 to 1.4 μg P/liter, respectively. Background concentrations of nitrate in Prince William Sound have been reported to range between about 3 to 300 μg N/liter in the summer, and background concentrations of phosphorus range from about 3 to 60 μg P/liter (McRoy and Eslinger, 1995; Eslinger et al.,

2001). So, the worst-case scenario for the effect of nutrient injection would result in near-shore nutrient concentrations near the low end of typical background levels.

4.2.4. IMPACTS TO HUMAN USE

To the extent possible, effects on human use will be minimized. The sites are remote but may have occasional visits by recreational boaters. Storage sheds on the upper beaches may serve as attractant to the curious. Therefore, signs will be posted informing users about the study being conducted and requesting that they respect the integrity of the work in progress. There will be no significant physical barriers to human use, however (except that the equipment sheds will be locked to prevent unauthorized entry). The equipment and chemicals present at the sites will not pose any hazard to human users of the shoreline unless they break into the shed and drink or bathe in the concentrated remediation solutions. The drums used to contain the concentrated solutions will be labeled to indicate the presence of hazardous chemicals.

For upland use and the placement of storage shed above mean high tide a special use permit is required by the U.S. Department of Agriculture, U.S. Forest Service as the land owner at three of the four sites. The sheds are to house pumping equipment and generators that will inject the treatment chemical into the oil layer at low pressure over a continuous 90 day period. Conditions and stipulations required by that permit may need to be incorporated into the project planning.

5.0. CUMULATIVE EFFECTS

One of the objectives of this pilot-scale project is to determine the feasibility and potential benefits of conducting bioremediation on a wider scale to address the problem of lingering oil from the *Exxon Valdez* oil spill. As such, this project was designed to use equipment, installation methods, and chemical concentrations that are similar to those that would be used in a full-scale implementation. If this project is successful, the observations, experiences, and measurements will provide the basis for conducting further Environmental Analysis to accesses the cumulative impact of applying this method to broader area. Accordingly at this point a full cumulative impact analysis is premature. In addition, these areas are in the (USDA-FS designated) Nellie Juan-College Fiord Wilderness Study Area and are managed for preserving its remote wilderness character and no recent activity nor any foreseeable future activities, aside from the potential for other bioremediation projects, would cumulatively result in any significant effects to the human environment.

6.0. ENVIRONMENTAL ANALYSIS CONCLUSIONS

1) *Can the proposed action reasonably be expected to cause substantial damage to the ocean and coastal habitats and/or essential fish habitat as defined under the Magnuson-Stevens Act and identified in FMPs?*

   No. The pilot project test sites are quite limited in size and already contain toxic oil in the subsurface. The activities are not expected to expose any of the oil. As shown in Figure 7, none of the areas are associated with historical herring spawning sites. Also, only one pink salmon stream is sufficiently close to a study site (LA015E; Fig. 6) to be potentially impacted by any of the activities associated with this project. As described in Section 4.2, the likely location of the treatment area is sufficiently distant from this stream that it can be protected by establishment of appropriate work rules.

2) *Can the proposed action be expected to have a substantial impact on biodiversity and/or ecosystem function within the affected area (e.g., benthic productivity, predator-prey relationships, etc.)?*

No. The proposal is to remove a potential threat to the ecosystem by promoting bacterial growth to breakdown the subsurface oil. As described in Section 4, the only likely disturbance would be for predators that forage in the intertidal zone during low tide, and that disturbance would only occur while workers are present on the beach. Workers will be present on each beach for about 3 days during site setup, 2 days when the equipment is being removed, about one day per month for sample collection, and several hours per week to perform routine maintenance. Overall, workers are likely to be present on each beach for a complete tidal cycle on only about 7 or 8 days during the entire study.

3) *Can the proposed action reasonably be expected to have a substantial adverse impact on public health or safety?*

No. As discussed in section 4.2.3 the treatment chemicals that will be deployed are relatively benign and will break down quickly. Warning labels will be placed on the chemical storage containers. None of the activities associated with this project would affect public health or safety.

4) *Can the proposed action reasonably be expected to adversely affect endangered or threatened species, their critical habitat, marine mammals, or other non-target species?*

No. Although Steller sea lion haul-out sites are present within the general area of two of the project sites (PWS4A44 and EL056C), they are sufficiently distant (>0.8 km with no easy access) that no significant impacts can be expected. Similarly, harbor seal haul-out sites are in the vicinity of three project sites (PWS4A44, EL056C, and SM006B), but the distance is sufficient ($\geq$2 km) and access is sufficiently limited that no impacts are anticipated. Sea otters may be present in the general vicinity of all of the sites, but their concentrations are listed as "low," and interference with their foraging activity would only occur when workers are present on the beach. In addition because the sites contain lingering oil, if successful in removing the oil the project should lessen the harm to foraging otters than if the project did not take place.

5) *Are significant social or economic impacts interrelated with natural or physical environmental effects?*

No. The sites themselves are remote and not easily accessible. While there is some potential for recreational boaters or wildness guides and their clients to observe field activates and the storage sheds, the proponents will use that as opportunity to educate the public about the project through informational posters placed on site (section 4.2.4). Any impacts this will have the wilderness experience should be slight.

6) *Are the effects on the quality of the human environment likely to be highly controversial?*

No. This pilot project this is not expected to have controversial effects on the human environment. As a part of a staged approach to address the issue of lingering oil, there has been opportunity for public input at Exxon Valdez Trustee Council meetings as well as during the process of drafting the 2010 SEIS. No controversial issues regarding this approach were brought up in those forums. If the project proves successful consideration

may be made to apply it to a broader area. That decision will provide opportunity for additional public input.

7) *Can the proposed action reasonably be expected to result in substantial impacts to unique areas, such as historic or cultural resources, park land, prime farmlands, wetlands, wild and scenic rivers, essential fish habitat, or ecologically critical areas?*

   No unique areas or resources are on the beach segments being treated and no significant impacts are expected. The USDA permit issued for housing of equipment above mean high tide will provide stipulations that minimize use of the associated upland area and avoidance of locations that may contain cultural resources. No substantial impacts are expected.

8) *Are the effects on the human environment likely to be highly uncertain or involve unique or unknown risks?*

   The risks to the human environment are well understood and expected to be insignificant.

9) *Is the proposed action related to other actions with individually insignificant, but cumulatively significant impacts?*

   No cumulative impacts are expected. If the pilot-scale project is successful at removing oil, an expanded project may be considered as discussed in section 5.0 but at this point it would be premature to conduct an analysis of those impacts.

10) *Is the proposed action likely to adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural or historical resources?*

    No. The locations of study are not associated with any known historical sites or other sensitive locations. A special use Forest Service permit is required for upland uses (placement of a storage shed housing equipment) and the issuing of the permit involves tribal consultation and consultation with the State Historic Preservation Office. No concerns about cultural resources were identified.

11) *Can the proposed action reasonably be expected to result in the introduction or spread of a nonindigenous species?*

    No organisms, indigenous or nonindigenous, will be introduced into the environment as a result of this project.

12) *Is the proposed action likely to establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration?*

    No. As discussed in section 1.1 this project will inform a future decision about whether to apply bioremediation technique on a larger scale but does not presuppose that decision

13) *Can the proposed action reasonably be expected to threaten a violation of Federal, State, or local law or requirements imposed for the protection of the environment?*

    No.

14) Can the proposed action reasonably be expected to result in cumulative adverse effects that could have a substantial effect on the target species or non-target species?

No. This project will test the feasibility of applying a technique to render harmless, oil that is toxic to sea otters, harlequin ducks and the intertidal communities that are considered resources that have not fully recovered from the 1989 oil spill.

7.0. LIST OF CONTRIBUTORS AND CONTACTS

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USDA Forest Service, Chugach National Forest, Glacier Ranger District
State of Alaska, Dept of Natural Resources, Alaska State Historic Preservation Office

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