M/V *Selendang Ayu*
2008 Study Plan for Assessment of Remaining Oil

ABSTRACT

This study plan proposes an assessment of the location, amount, degradation, and bioavailability of the remaining oil from the M/V *Selendang Ayu* incident on "shoreline segments of greatest concern." Focus will be on a series of shoreline segments with a high likelihood of remaining oil and/or those with biological concerns evidenced by previous study results. Target zones within each segment have been identified based on historical oil distribution and loading, and substrate type. The study methods will include a combination of shoreline surveys to describe the amount of oil remaining in zones of historical oiling, collection of oiled sediment samples, collection of invertebrate samples, and deployment of passive samplers, with supporting chemical analyses. It will complement the harlequin duck (HADU) assessment conducted in February 2008 (and previous years). Similar sampling will be conducted in segments where no oil was observed for purposes of comparison.

INTRODUCTION

On 8 December 2004, the M/V *Selendang Ayu (S. Ayu*) ran aground and broke in half in rough seas off Unalaska Island, Alaska (53°38'N, 167°07'W). An estimated 354,218 gallons of oil (339,538 gallons of IFO 380 and 14,680 gallons of marine diesel and miscellaneous oils) were discharged.

Oil from the *S. Ayu* incident impacted the coastline of Unalaska Island from Unalaska Bay to Konets Head, and beyond. Based on Shoreline Cleanup Assessment Team (SCAT) surveys, portions of approximately 70 miles of coast were identified as being in need of cleanup (Unified Command Shoreline Cleanup Summary Status, available at: http://www.dec.state.ak.us/SPAR/PERP/RESPONSE/SUM_FY05/041207201/scat/scat_index.htm). At the conclusion of the cleanup in June 2006, seven shoreline segments failed to reach final cleanup criteria (Unified Command Decision Memorandum, 23 June 2006). Other areas of potential concern are sites where alternative treatment methods were implemented, which may have residual subsurface oil, and heavily oiled areas in more protected locations where natural removal processes may be slow.

Biological sampling has previously demonstrated that trust resources continued to be exposed to hydrocarbons within the spill zone, including samples obtained within areas that met Unified Command cleanup endpoint status. Evidence of this can be found in the sea duck and subsistence sampling results, which revealed that harlequin ducks and blue mussels were still being exposed to oil after the 2005 cleanup activities had concluded (Flint et al., 2008; ATSDR, 2008). The Trustees' concern about the potential threat from remaining oil is also supported by recent literature regarding the persistence of oil in cold environments (Short et al., 2007; DeBruyn et al., 2007; Lee et al., 2003; Owens et al., 2008).

Determining the distribution, weathering, and bioavailability of oil remaining on shorelines affected by the *S. Ayu* in a cost-effective manner presents a considerable challenge. Previous attempts to assess this issue have mainly relied on SCAT methods applied by field teams performing comprehensive foot and skiff surveys of impacted shorelines. The proposed approach builds on these previous SCAT surveys in the development of a targeted sampling design that will be used to focus sampling effort in areas where oil most likely persists, while allocating some effort to discovering oil in areas where biological or geographic factors suggest oil may be present. Targeting the likely worst-case segments will allow the Trustees to assess the presumptive "upper bound" of persistence of *S. Ayu* oil within this environment. Thus, this plan consists of subjective sampling of the most likely locations to have lingering oil. If little or no evidence of oil is found and other indicators of lingering oil show no continuing oil exposure, then further study or remediation will not be required. However, if evidence of oil is found at levels of concern (using any of the available sampling techniques), further work may be required to define the scale of the issue and potential remediation actions.

This project will be divided into two cruises. During Cruise 1 (scheduled for 27 June to 6 July 2008), 43 passive samplers will be deployed among ten selected beach segments of greatest concern and 15 among eleven segments where no oil was observed during the SCAT surveys, although it is noted that these sites were within the oiled area and in close proximity to beach segments that did have oil [1]. During Cruise 2 (approximately one month later; scheduled for 24 July to 8 August 2008), the passive samplers will be retrieved, invertebrate samples will be collected, and an intensive shoreline assessment for both surface and subsurface oil will be conducted to document the extent and degree of remaining oil. Samples of oiled sediments from representative areas will be collected. After both field efforts have been concluded, selected samples will be chemically analyzed and visual oil observations summarized and analyzed. A draft report will be prepared that evaluates the magnitude and frequency of encountered oil and interprets the chemical results in terms of oil weathering and bioavailability. The final report will address review comments.

NEED FOR THE STUDY

Statement of Problem

The Natural Resource Trustees for the *S. Ayu* incident suspect there is remaining oil on the beaches of Unalaska Island. Observations from response and cleanup activities, previous HADU results showing elevated CYP1A (PDR#10 2008), subsistence mussel sampling in 2006 (ATSDR, 2008), and the long term persistence of bunker fuel oil following other spills, particularly where oil stranded high in the intertidal and supratidal zones (e.g., *Arrow* spill; Lee et al., 2003) all indicate the likely continued presence of oil. The extent of oil remaining on these beaches may constrain the recovery of natural resources that inhabit these shoreline and nearshore environments. This exposure includes direct contact with water contaminated by the remaining oil, or exposure through ingestion of prey contaminated by the oil. Continued exposure to toxic polycyclic aromatic hydrocarbons (PAH) is of particular concern, as they elicit manifold adverse effects on biota exposed to them. These species may include intertidal communities, mussels, clams, Pacific herring, pink salmon, sea otters, subtidal communities,

[1] The number of passive sampler arrays in segments with no oil observed was determined based on a power analysis of total PAH for PEMD.

black oystercatchers, seabirds, harlequin ducks, and other sea ducks. In addition, subsistence uses, passive uses, recreation, and tourism may also be impaired because of concerns that the area remains contaminated.

Compliance with Natural Resource Damage Assessment Regulations

Currently, the Trustees lack the data to assess how much oil remains, how it is distributed, the toxicity of the remaining oil (inferred from PAH composition), and the bioavailability of the oil. Resolving these questions will provide the Trustees with information to determine if additional assessment is needed and/or to identify and scale appropriate restoration projects. Consistent with 15 CFR 990.27, the Trustees believe that a field assessment of the shoreline segments of concern is necessary to meet the information requirements of restoration planning. The scope of the study has been narrowed to a subset of priority beach segments ("beach segments of greatest concern") and segments serving as comparison sites.

STUDY DESIGN AND METHODS

Objectives

Determine the presence, distribution, and relative amount of oil remaining on beach segments of greatest concern to determine if S. Ayu oil remains on shorelines within the core spill area. If oil is present, it is important to determine its distribution within a beach segment to identify future assessment needs and/or restoration options. The distribution and amount of oil in specific oiled zones (i.e., the oiled zones identified during previous SCAT surveys) will be compared with the SCAT data from 2005 and/or 2006 to provide information on the relative changes over time and the effectiveness of natural removal processes at each location. Oil source will be evaluated by comparing results from a petrogenic/pyrogenic index based on PAH composition.

Determine the weathering state of remaining oil to evaluate the potential toxicity of remaining oil. Understanding the chemical characteristics of any remaining oil and the rate of degradation are essential for determinations regarding further assessment, restoration, and scaling. A key component of any estimate of chronic injuries to nearshore biota is the anticipated length of time resources may be exposed to toxic oil. Chemical composition analysis of representative samples of the oil will help answer these questions; current composition of PAH and other oil constituents provides both an estimate of the weathering state of the oil (when compared to the original spilled oil) and of the potential chemical toxicity of the remaining oil.

Determine bioavailability of the remaining oil to assist in evaluating exposure and potential biological effects. Chemical analyses of invertebrates and passive samplers will determine if oil is bioavailable and if continuing exposure can be detected (Carls et al., 2004a;b). This effort is necessary to assess chronic low-level exposure to biota. It complements both the beach pit samples and the HADU study – one of which represents a systematic but macro-level search for oil on a given beach segment; the other reflecting the foraging habits of an obligate intertidal species.

Study Design Overview

The study area is too large and the costs too great to do a complete evaluation of the status of remaining oil in the Unalaska area from the *S. Ayu* oil spill particularly when clean-up operations and nature are presumed to have removed a significant amount of the stranded oil in earlier years. The strategy will be to design a sampling plan that evaluates a subset of the shorelines in the region. The assessment will consist of the following techniques:

1. Visual surveys of surface oil
2. Visual surveys of subsurface oil in excavated pits
3. Sampling of oiled sediments for chemical analysis
4. Deployment of passive samplers for chemical analysis
5. Collection of invertebrate tissues for chemical analysis

Each of these techniques will be deployed using a hierarchical, integrated design to allow the results from one technique to be evaluated in context with the results of another technique. Table 1 describes how these methods will be used to achieve the goals described above.

TABLE 1. Sampling goals and techniques matrix.

Goal	Surface Investigation	Subsurface Investigation	Sediment Sampling	Passive Sampling	Invertebrate Sampling
Presence and distribution	Within segment	Within zone			
Weathering state			Within zone		
Bioavailability				By zone	By zone

The shoreline of the entire core spill area has already been subdivided into segments by SCAT surveys. These segments are 100s to 1000s of meters in length and consist of lengths of shoreline relatively similar in terms of initial gross oiling and shoreline morphology. The segments for investigation were selected based on information from SCAT surveys, preassessment studies, and cleanup activities. These segments included those that: (1) had not reached cleanup endpoint status; (2) were subject to alternative treatment techniques during cleanup, such as berm relocation; (3) were near HADU trap sites[2]; and/or (4) had subsistence samples which showed the presence of oil. Using SCAT and cleanup information, the Trustees categorized these segments into high, moderate, or low likelihood of remaining oil. The segments were mapped. "Shoreline segments of greatest concern" were then selected based on: (1) likelihood of remaining oil and continued persistence; (2) level of exposure in subsistence samples and harlequin ducks where applicable; and (3) geographic distribution and accessibility.

[2] We selected locations for passive sampler deployment near HADU trap sites. However, we note that trap sites were set up for ease of bird capture and do not reflect the exact locations where ducks were foraging. Harlequins are mobile and feed along several m/km of beach, whereas passive samplers collect information in relative proximity to where they are placed. Thus, passive sampler results, while indicating whether bioavailable PAHs are present, do not reflect the exposure of HADU to PAHs in the area.

Appendix 1 lists the segments and a summary of the known information on oiling, along with the justification for selection. A list of backup sites is under preparation in case the selected sites are eliminated (either during review of this plan or in the field) or time allows additional sites to be surveyed during the cruise. Similarly, the Trustees selected eleven comparison segments in Chernofski Harbor and Pumicestone Bay with no oil observed based on information from SCAT surveys, preassessment studies, and the location of HADU trap sites. Figure 1 depicts the locations of the ten selected priority segments in Skan and Makushin Bays for assessment in 2008. Figure 2 depicts the locations of the selected no oil observed segments in Chernofski Harbor and Pumicestone Bay.

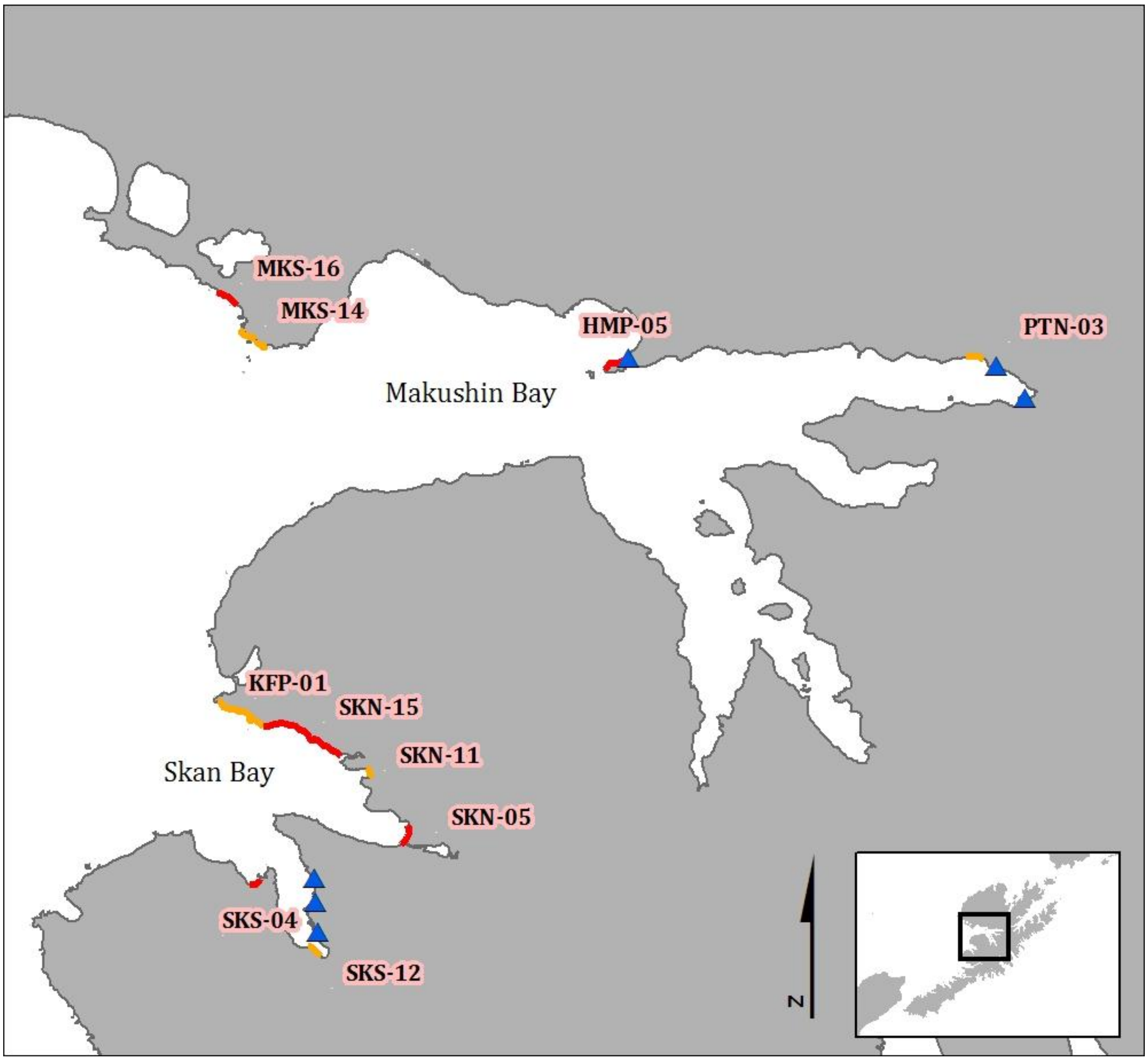

FIGURE 1. Map of priority segments in core spill area. Segments depicted using alternating colors for clarity. Triangles indicate HADU trap sites.

Within segments, likely oiled zones were identified according to finer-scale measurements of oil distribution, oil loading, and substrate type derived from the SCAT data. This study will evaluate each oiled zone in the selected segments separately. The zones within each segment are described in Appendix 1. Figure 3 depicts a schematic of the zones within a segment. This study is designed to assess the presence, distribution, weathering state, and bioavailability of remaining surface and subsurface oil in the oiled zones within the identified segments. Due to the subjective nature of the segment and zone selection, this study will not provide data for statistical inference about locations not sampled.

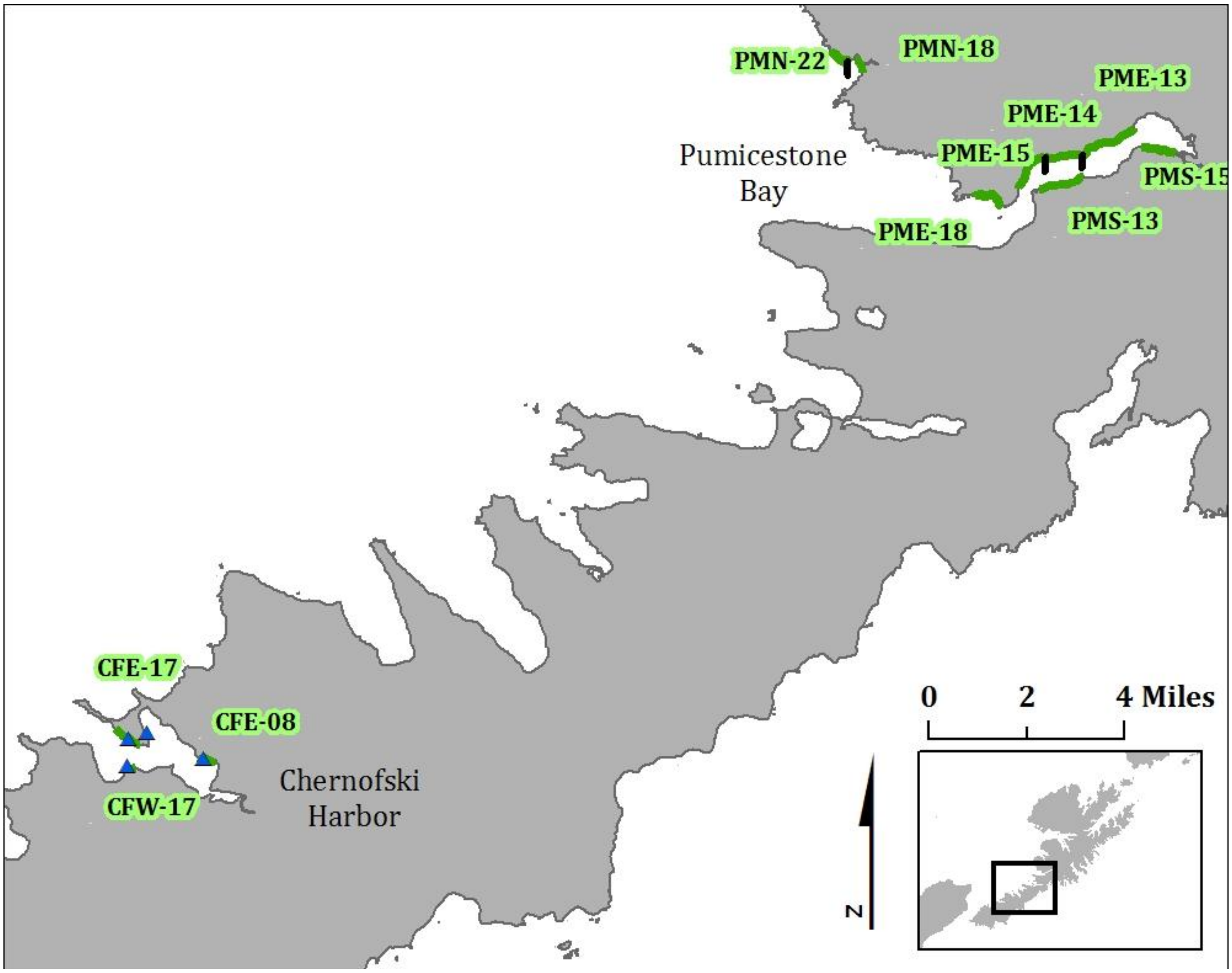

FIGURE 2. Maps of the comparison segments (no oil observed) in Chernofski Harbor and Pumicestone Bay. Segments depicted in green. Triangles indicate HADU trap sites.

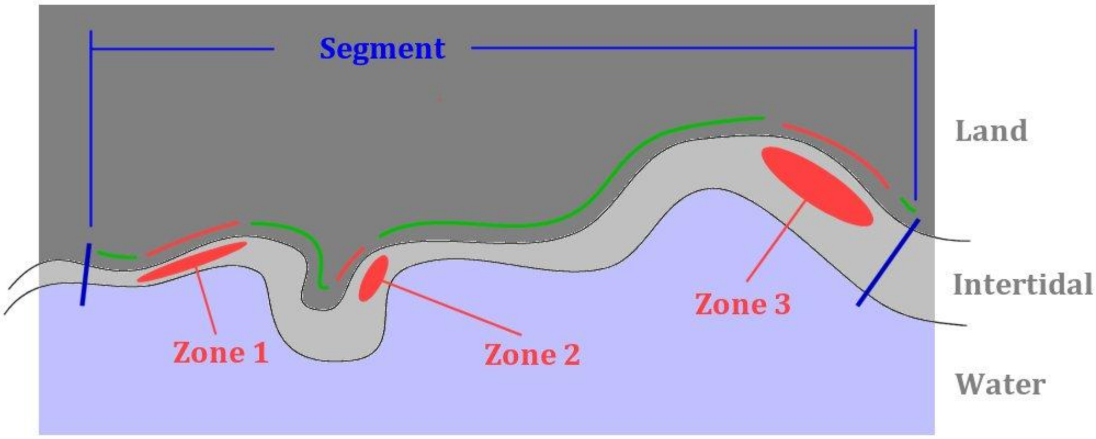

FIGURE 3. Schematic of zones within a segment. Oiled shoreline lengths derived from the oiled zones (red) depicted as the line on the landward side.

Passive Sampling

Passive sampling of ambient water using the methods described in Carls et al. (2004b) will be conducted using a systematic design to cover oiled zones and provide minimal coverage of inter-zone regions. The passive samplers consist of low-density polyethylene membrane devices (PEMDs). They are intended to evaluate the bioavailability of remaining oil at each identified oiled zone. All oiled zones in the high priority segments as described above will be sampled by one or more passive sampling arrays. Passive sampling arrays will be allocated to oiled zones proportional to the alongshore length of that zone as per Table 2, with the caveat that no more than nine arrays will be located in a given segment.[3]

To guide the placement of the passive samplers in the oiled zones, all of the previous information on each oiled zone will be compiled into a booklet for each segment. This information will include SCAT sketches, ground photographs, oblique aerial photography obtained during the response activities, field notes, and GPS coordinates. Furthermore, the Cruise team will include at least one member from ADEC from the previous SCAT teams who is very familiar with the segments and the previous oil distribution. The actual location of the oiled zones will only be known after the subsurface oil surveys are completed during Cruise 2. Therefore, the results for each passive array will be evaluated relative to the proximity of the oiled zones as identified during Cruise 2.

Each array will consist of 3 passive samplers deployed in a transect across the shoreline (intertidal and subtidal samplers will not share a common line) (Figure 4). One will be tethered by buoy about 0.5 m below the surface and anchored in about 5 m of water off shore. A second will be dropped to the bottom at that same location. A third will be anchored in the mid-intertidal zone, secured above and below the intertidal zone.

[3] Because segment KPF-01 has nine separate oiled zones, each oiled zone will be sampled with a single array. For the remaining segments, the distribution of PEMDs to zones is as per Table 2.

The passive sampling array transects will be located in the center of the oiled zone if there is only a single transect, or spaced equidistantly across the length of the zone for zones with multiple transects. See schematic layout of the passive samplers in Figure 5. Three passive sampling array transects in Chernofski Harbor (CFE-08, CFE-17, and CFW-17) will be located as close as possible to HADU trap sites in the harbor, with one array per site. Twelve passive sampler arrays will be located in the following segments classified as “no oil observed” by SCAT. One array will be located in PMN-18, PMN-22, PME-13, and PMS-15. Segments with two arrays per segment will be PMS-13, PME-14, PME-15, and PME-18. Samplers will be deployed during Cruise 1 and retrieved during Cruise 2, thus they will be deployed for about 28 days. The samplers will be retrieved from each segment prior to any sediment disturbances, to avoid any potential for artificial remobilization of oil.

TABLE 2. Passive sampling arrays per alongshore length of oiled zone.

Oiled Zone Length (m)	Zone Count	Arrays
<50	15	1
50-<250	12	2
≥250	2	3

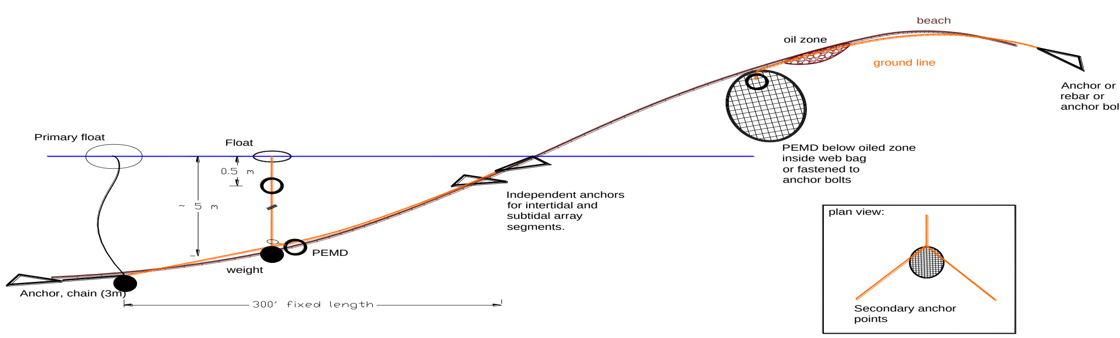

FIGURE 4. Cross-sectional schematic of passive sampling array.

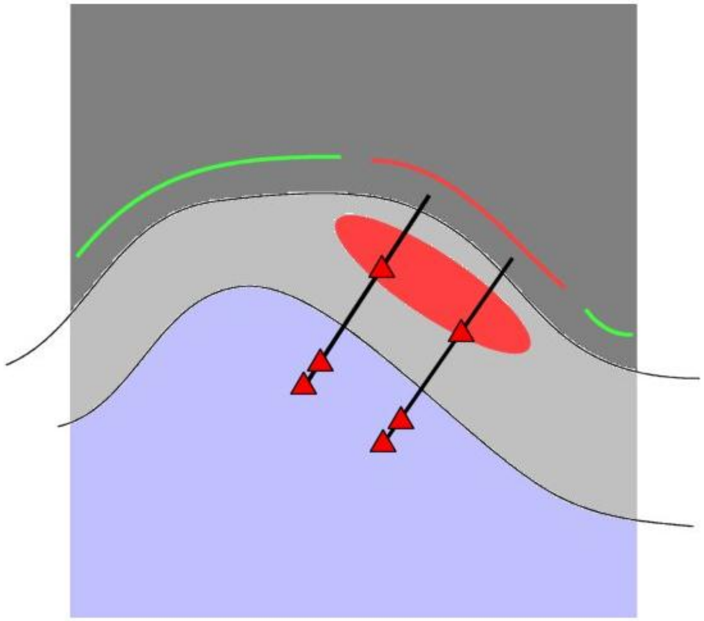

FIGURE 5. Schematic of passive sampling arrays systematically located within oiled zone with the number of arrays proportional to alongshore length of that zone

Visual Surveys of Surface Oiling

During Cruise 2, the presence and distribution of surface oil along the entire length of each of the selected segments will be evaluated by visual survey using the methods described in the NOAA Shoreline Assessment Manual (2000). The segment will be described, sketched, and photographed. The intent is to replicate the nature and coverage of the SCAT surveys carried out after the spill and during the 2005 and 2006 cleanup activities, to allow temporal comparisons.

Invertebrate Tissue Sampling

During Cruise 2, invertebrate tissues will be collected using an opportunistic design. Collection of invertebrates (in combination with the passive samplers) is intended to evaluate the bioavailability of remaining oil at each identified oiled zone. Invertebrates will be collected prior to excavation of pits in each oiled zone. A minimum of three composite invertebrate samples will be collected when available from within, or seaward of, each oiled zone. Invertebrate samples in Chernofski Harbor will be located as close as possible to HADU trap sites in the harbor. For the other reference sites collection will be spaced equidistantly across the length of the single segment located there. Figure 6 presents a schematic layout of invertebrate sampling locations. An opportunistic design is used because the distribution of invertebrates on a shoreline segment is determined by complex habitat requirements and may not coincide exactly with suspected oil locations. At sites where this proposed design cannot be implemented, the general principles will be followed, with collection of samples as close as possible to the oiled areas. At the no oil observed segments, invertebrates will be collected from sites as close to the passive samplers as possible.

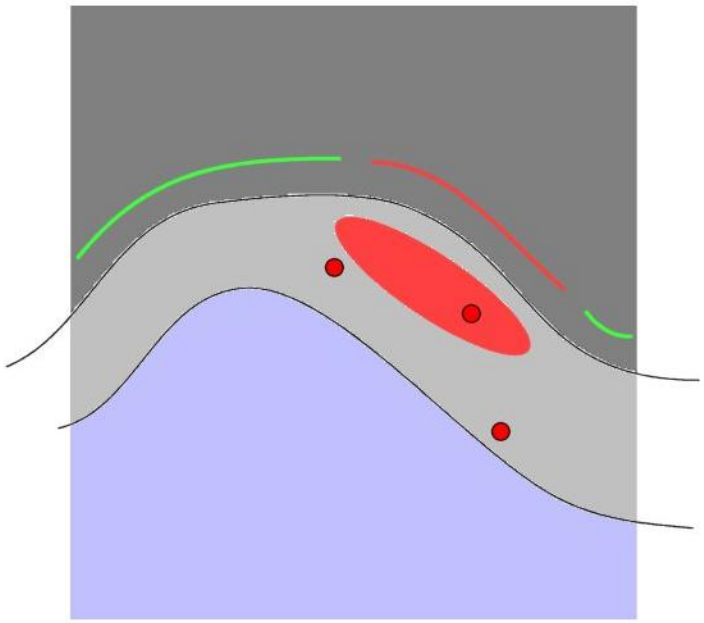

FIGURE 6. Schematic of invertebrate samples randomly located within or seaward of oiled zone.

The species targeted for collection at each segment will depend on prior collections during both response and NRDA activities, so that concentrations and PAH distributions over time can be compared for the same species. For sites with no prior tissue collections, the priority by species will be mussels (*Mytilus*) then gastropods (*Littorina*). Prior to sample collection, the sampling location will be photographed and notes made about the site conditions (e.g., presence of oil, substrate type, condition of animals). Samplers will wear surgical gloves and change gloves after each sample. Attached mussels will be pried away from the substrate with a pre-cleaned knife. Individuals will be of the same shell size, and the size will be recorded. Whole organisms will be wrapped together in clean aluminum foil and placed in a Ziploc bag. The sample and label will be placed inside a second Ziploc bag. The samples will be stored on ice until placed in the freezer onboard the vessel.

Visual Surveys of Subsurface Oiling

Presence and distribution of subsurface oil will be evaluated within each identified oiled zone by locating and excavating pits using methods modified from Short et al. (2004). All oiled zones in the high priority segments as described above will be sampled by excavation of multiple pits. The emphasis of the subsurface oil investigation is on the oiled zones identified during previous SCAT surveys, and is based on the assumption that these areas are most likely to have persistent oil residues and that the boundaries delineated by previous SCAT surveys still represent the area of greatest potential oil. The subsurface oil surveys will not try to re-define the boundaries of these oiled zones; rather, they will determine the frequency and type of subsurface oil encountered within the original boundaries. For segments where berm relocation was conducted, the oiled zone may include the area where the relocated sediments were spread. This approach will allow estimation of oil remaining within specific zones, but cannot be used to evaluate potential for oil persistence outside of those zones, even within a beach segment. The tidal elevation (supra, upper, mid, and lower) of each oiled zone will be recorded.

Pits will be allocated to oiled zones proportionally to the zone surface area as shown in Table 3. The area of each zone will be calculated as the reported alongshore length times the reported cross-shore width (from the most recent SCAT data) plus two meters each on the seaward and landward sides. The buffer will allow for minor inaccuracies in the zone dimensions and reoccupation process, as well as potential mobilization of oiled sediments landward or seaward of the oiled zones defined by the SCAT surveys.

Pits will be located within each zone using a Generalized Random-Tesselation Stratification (GRTS) that has statistical properties similar to random sampling, but balances the samples across geographic space to the extent possible. Stevens and Olsen (2004) and Diaz-Ramos et al. (1996) provide descriptions of the GRTS sample design procedure and its implementation. The new pit data will provide the basis for estimating the percent remaining oil within the original boundary of each zone.

TABLE 3. Pits per area of oiled zone (including seaward and landward buffer).

Buffered Oiled Zone Area (m^2)	Zone Count	Pits
0-<100	1	5
100-<500	11	10
500-<1,000	2	20
1,000-<2,000	10	40
≥2,000	3	80

Pit locations within each oiled zone will be generated prior to fieldwork as random pairs of *x* and *y* coordinates based upon a coordinate system derived from the most recently documented dimensions of the oiled zone (based on review of the 2005 and 2006 SCAT surveys, sketches, GPS data, and photographs). These data will be used to create visualizations of where the remaining oil is expected to occur, for each oiled zone. The center point of each zone will be located and pit locations will be established based upon this center point. Widths and lengths of oiled zones will be assumed to be shore-normal and parallel, respectively.

Additional pits will be located seaward of the oiled zone boundaries within each sampled segment on an as-needed basis to confirm assumptions about the intertidal elevations of the majority of oiling. These pits will be located in areas determined by the field team based on observations of current geomorphology compared to conditions in 2005 and 2006. In areas where there is evidence of significant alongshore sediment transport in the area of the oiled zones, additional pits will be located in areas where deposition of oiled sediments may have occurred. Figure 7 shows a schematic of pit locations.

Pits will be excavated to a minimum depth of 0.5 meters, or the maximum depth possible before encountering bedrock or immovable boulders. SCAT data will be used to identify those oiled areas where the oil was documented to occur deeper or where sediment relocation is likely to result in deeper burial of oiled sediments. On some segments where very deep pits will have to be dug in fine gravel (e.g., SKN-05 where extensive berm relocation was conducted multiple times using equipment that excavated sediments down to 3-4 m), it may not be possible to complete all of the assigned pits. Grain size and visual oiling descriptors will be assigned to vertical layers within the pit using the standard SCAT descriptors (NOAA, 2000). Oiling will primarily be detected from visual and olfactory cues. The total surface area and volume of oiled sediment remaining in each zone, by visual oiling descriptor, will be estimated from the results of the individual pits located within that zone using standard total and ratio estimators. No inference or extrapolation will be made to sediments in intertidal areas outside of the surveyed zone in the segment. Where sufficient data exist, the 2008 observations will be compared with the previous SCAT surveys to provide information on the relative change in the frequency of occurrence and degree of oiled sediments within each oiled zone.

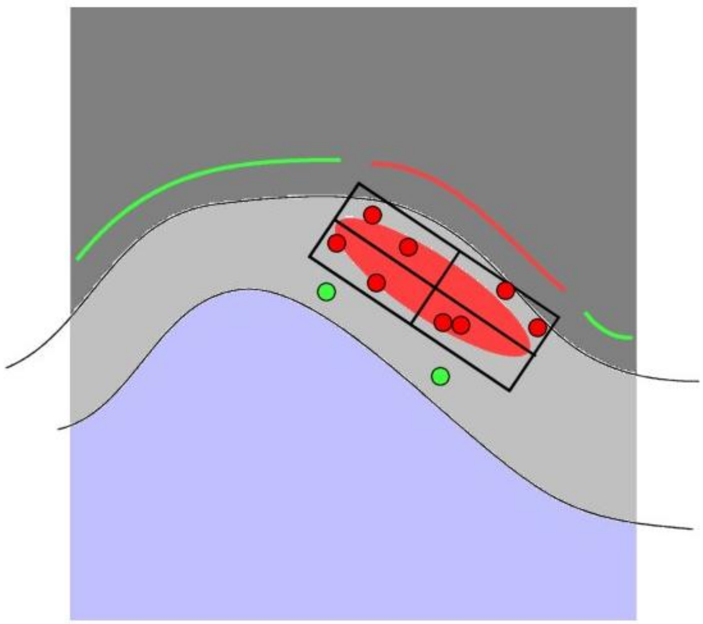

FIGURE 7. Schematic of subsurface pits randomly located within a buffered oiled zone (red) with the number of pits proportional to zone area, and ad-hoc pits located seaward of oiled zones of the zone (green).

Sediment Sampling

Sampling of surface and/or subsurface oiled sediments is intended to evaluate the weathering state of remaining oil within each identified oiled zone. The maximum number of sediment samples collected per zone will be allocated by zone surface area as shown in Table 4. Surface area will be calculated as described above. Samples will be collected from each oiled pit, until the maximum number is reached, by pit number. Pit numbers will be assigned randomly according to the GRTS procedure described above, so the sediment samples from each zone will be selected from a random subsample of all oiled pits in that zone. The sample locations will be mapped and recorded.

Where oiled sediments are detected in a given pit, a composite sediment sample from the oiled layer will be collected using a pre-cleaned stainless steel utensil and placed in a pre-cleaned 8-oz glass jar. Each sampled area will be described and photographed. The samples will be stored on ice until placed in the freezer onboard the vessel.

TABLE 4. Maximum number of sediment samples per area of oiled zone (including seaward and landward buffer).

Buffered Oiled Zone Area (m^2)	Zone Count	Sediment Samples
0-<100	1	3
100-<500	11	5
500-<1,000	2	7
1,000-<2,000	10	10
≥2,000	3	15

Sampling Summary

Table 5 shows a summary of the proposed sampling effort for the selected oiled and no oil observed comparison segments (Appendix 2 shows assignments by zone). This design distributes sampling effort (pits, sediment samples, invertebrate samples, and passive arrays) relatively evenly across the spectrum of oiled zones, as well as areas where no oil was observed. Note that further modifications of this sampling plan may be required to overcome logistical or other issues. Inter-zone passive sampling arrays and additional pits adjacent to oiled zones are not included in the table at this time.

Sample and Data Analysis

The surface and subsurface oil observations will be presented as tabular and graphic summaries of the frequency by type of oil encountered in each zone. If any oil from the *S. Ayu* spill is found, then the answer to the question "Does any *S. Ayu* oil remain on the shoreline?" is yes. The amount of oil remaining within each zone and segment will be further evaluated, in combination with the chemical results, to determine the need for further assessment or remediation.

At the end of Cruise 2, all of the collected sediment samples will be prioritized for chemical analysis. The first analytical tier will include: 1) at least one sediment sample of each type from each oiled zone; 2) sediment samples collected from zones with the most amount of subsurface oil; and 3) half of the sediment samples from each no oil observed site. Based on these results, a second tier of samples will be selected, including the rest of the samples from the no oil observed sites. Up to 60 sediment samples will be analyzed during tiers 1 and 2, to represent different zones and the range of visual oiling conditions. Based on the degree of variation in the sample results, another 30 samples will be selected for analysis in tier 3, for a total of up to 90 sediment samples. All of the passive samplers and invertebrate samples will be analyzed.

TABLE 5. Summary of lengths, oiled zone statistics, and sample counts by technique for selected segments. Type codes are: E – No Endpoint Attainment, A – Alternative Treatment, H – HADU Sampling, S – Subsistence Sampling, NOO – No Oil Observed Segment. See Appendix 1 for descriptions of oiled zones.

Segment	Type	Segment Length (m)	Oiled Zones	Oiled Zone Length (m)	Buffered Oiled Zone Area (m^2)	Oiled				No Oil Observed	
						Pits	Passive Arrays	Invert. Samples	Sed. Samples	Passive Arrays	Invert. Samples
SKN-15	E	2610	4	175	2750	100	6	12	30	-	-
MKS-14	E	687	2	150	2850	60	4	6	17	-	-
MKS-16	E	680	4	246	3363	95	7	12	28	-	-
SKN-05	A	676	1	400	7600	80	3	3	15	-	-
HMP-05	H	877	3	240	1830	60	5	9	20	-	-
SKN-11	S	210	1	30	270	10	1	3	5	-	-
SKS-12	H, A	682	1	250	1050	40	3	3	10	-	-
SKS-04	S, A	234	1	235	1175	40	2	3	10	-	-
PTN-03	H	547	1	400	2400	80	3	3	15	-	-
KFP-01	E	1493	9	621	7404	230	13	27	67	-	-
PMN-18	NOO	499	-	-	-	-	-	-	-	1	3
PMN-22	NOO	986	-	-	-	-	-	-	-	1	3
PMS-13	NOO	1561	-	-	-	-	-	-	-	2	6
PMS-15	NOO	1169	-	-	-	-	-	-	-	1	3
PME-13	NOO	1981								2	3
PME-14	NOO	1275	-	-	-	-	-	-	-	1	6
PME-15	NOO	1507	-	-	-	-	-	-	-	2	6
PME-18	NOO	1737								2	6
CFE-08	NOO	610	-	-	-	-	-	-	-	1	3
CFE-17	NOO	1004	-	-	-	-	-	-	-	1	3
CFW-17	NOO	303	-	-	-	-	-	-	-	1	3
TOTALS						**795**	**47**	**81**	**217**	**15**	**45**

Oil composition analysis in sediment, tissue, and PEMD samples will be by gas chromatography/mass spectrometry (GC/MS) using the methods summarized in Short et al. (1996). These analytes include 24 normal alkanes through n-C40 plus pristine, phytane, biomarkers (e.g., sterane, and hopane), and 44 PAHs, ranging from naphthalene through benzo(ghi)perylene, including the alkylated isomers of naphthalene, fluorene, dibenzothiophene, phenanthrene, fluoranthene/pyrene, and chrysene.

The source of hydrocarbons in sediments, mussels, and PEMDs will be inferred by multiple methods. First, oiling records from the time of the spill through the cleanup process will provide primary evidence that any oil discovered in this study originated from the *S. Ayu*. This evidence includes previous SCAT surveys and associated data. To further inform and authenticate such inferences, oil or oiled sediment samples collected on or nearby specific oiled beaches near the time of the spill will be analyzed for comparison (Table 6). This will account for possible differences among beaches in source oils or source oil ratios from various *S. Ayu* tanks. Collected oil will likely be more weathered than in 2005 and typical weathering patterns will be assumed for data interpretation (e.g., the model of Short and Heintz, 1997). An algorithm that summarizes three independent oil recognition models and two pyrogenic recognition models (Carls, 2006) will be used to ensure that interpretation is not confounded by pyrogenic sources. Highly conserved compounds such as n-C40 and biomarkers can provide additional assessment independent of PAHs and will also be used for source interpretation. However, the originally documented extent and pattern of oil on beaches coated by *S. Ayu* oil will be the most reliable information about the source of oil observed in 2008. In this study we will be less concerned about undocumented confounding sources of oil (at presumptively much smaller concentrations) and more concerned about the toxic potential of remaining oil. Table 6 lists samples collected on or near study segments that may be used to establish oil source and characteristics for weathering analyses.

The toxic potential of PAH in sediment will be estimated by observing the presence or absence of key toxicants, primarily fluorenes, dibenzothiophenes, and phenanthrenes. These compounds are more environmentally persistent and more toxic than the initially abundant naphthalenes; relatively few higher molecular weight PAHs beyond C2 chrysenes dissolve in water, thus may be less biologically available. We will assume that if these compounds are present, they are potentially toxic. This assumption will be further substantiated if the same compounds are detected in PEMDs and if total PAH concentrations in PEMDs vary by degree of site oiling.[4]

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[4] We recognize that actual toxicity estimates require knowledge of both composition and concentration; we will not be able to estimate toxicity because concentration measurement in sediment would require considerably more time and labor than possible for this study. In addition, movement of oil or oil constituents into a biota of interest (e.g., birds) from oil in sediment would be required to understand how oiling relates to toxicity; these mechanisms may include aqueous dissolution, whole oil particles in water, oiled food, encounter of oil in the surface microlayer, and ingestion by preening, and or direct contact with oil during foraging. Because birds are not benthic organisms, sediment quality guidelines are not applicable to this study. Thus the study output will be toxic potential and if that potential exists, further study to estimate toxicity may be required.

TABLE 6. Samples collected on or near study segments that may be used to establish oil source and characteristics for weathering analyses.

Sample	Collection Date	Notes
MKS-16		Use same samples as MKS-14 (MKS-10 & MKS-5)
MKS-14	03/20/05	1600250
	01/31/05	MKS-10 sample
	01/31/05	MKS-5 sediment samples, associated with a stream.
	01/27/05	MKS-5 sediment samples, associated with streams
HMP-05	02/01/05	HMP-12 sample
PTN-03	01/31/05	(2) samples, oil & sediment.
	12/31/04	Polaris sample
	2/1/05	Polaris (2) PTN-4
KPF-01		Use same samples as SKN-15
SKN-15	01/06/05	high intertidal oil sample
	12/25/04	(2) SKN-14
	12/28/04	(2) SKN-14
	12/31/04	Polaris (3) SKN-14
	01/11/05	SKN-14 samples from stream area
	02/01/05	Polaris (2)
	03/19/05	1600236
		Use same samples as SKN-11 if needed
SKN-11	12/27/04	Use same samples as SKN-14 & SKN-15 if necessary
SKN-05	01/18/05	oiled gravel
SKS-12	1/8/05	(1) sample + (10) samples from adjacent SKS beaches
SKS-04	01/09/05	Use same samples as SKS-12
Pumicestone	01/14/05	oil. PMN-15
	01/21/05	PMN-18. Trench
	01/21/05	sediment. PMN-20/21
	01/21/05	sediment. PMN-20/21
	1/13/2005	stream sediment. PMS-16/17/18
	1/13/2005	stream sediment. PMS-16/17/18
	4/11/2008	1600511-1600514, 1600516-1600519
Chernofski	12/27/04	(1) oil, (3) sediment
	12/27/04	(6) oiled bird carcasses
	1/20/05	(1) oil

All of the PEMD samples from the no oil observed segments will be used to determine the average total PAH loading. The total PAH loading on the PEMD samples from the oiled zones will be compared with the results from the no oil observed sites. If a sample from the oiled zones is higher than the mean plus one standard deviation of the no oil observed sites, then the answer to the question "Is the oil bioavailable?" will be yes for that sample. The same approach will be used to interpret the invertebrate tissue samples. In addition, where available, PAH concentration and distributions in tissues will be compared with prior tissue sample results to identify temporal patterns.

All of the data will be used together in a weight-of-evidence approach to guide the Trustees in determining whether further study or restoration will be required. The study results will inform the Trustees as to the following:

(1) If oil from the *S. Ayu* is found on the shoreline, the amount and degree of degradation of the oil will be considered in estimating how long until natural attenuation is complete.
(2) If the total PAH in any passive sampler or tissue sample is above the x + 1 s.d. of samples from the no oil observed areas, the amount of PAH will be considered in estimating chronic impacts and how long until chronic impacts to nearshore resources and related services cease.
(3) If oil is present in identifiable patches and remains toxic, the parties will investigate targeted removal of the oil as a restoration alternative.

REPORTS

Summary of the visual observations should be completed 30 days post cruise; chemical analyses 120 days post cruise, and draft report 180 days post cruise. The final report will be completed within 30 days after receipt of review comments. The final report will provide a basis for considering further assessment and/or restoration planning.

SCHEDULE

March 1-30, 2008:	Develop study plan. Select project leaders and identify team members. Identify vessel charter.
April 1-30:	Finalize study plan, initiate logistics (finalize vessel charter and purchase materials).
April-May:	Assemble supplies and ship to Dutch Harbor. Select final beach segments based on all available data, including 2008 HADU CYP1A results and invertebrate results.
June 27- July 6:	Cruise 1. Deploy passive samplers.
July 24-August 8:	Cruise 2. Retrieve passive samplers, collect tissue samples, and conduct surface and subsurface oil surveys.
February 2009:	Draft report due. Final report to be submitted within 30 days after receipt of comments.

BUDGET (Draft)

Charter: Cruise 1- 8 days (minimum of 5 field crew) .... Provided by RP
Charter: Cruise 2 - 16 days (minimum of 8 field crew) .... Provided by RP

NOAA Auke Bay Laboratory
Chemical analyses:
126 invertebrate samples $75,600
186 passive samplers…………..………………………..........…..…$111,600
60 sediment samples……………… ....…………$33,000
30 sediment samples (if necessary)……………….........…………$16,500
36 source samples……………… ....…………$19,800

Passive sampler gear, anchor hardware $52,000
Shipping, containers, misc. supplies…………………..… $10,000
Travel ....………………………………………………………$18,000
Labor - Technician and professional support during cruise.........................<u>$28,000</u>
Total NOAA Auke Bay Laboratory..$364,500

Alaska Department of Environmental Conservation
Cruise 1: Two DEC staff - Travel/Per diem= $1684; Salary= $4800. ....$12,968
Cruise 2: Four DEC staff - Travel/Per diem/Salary ....<u>$78,314</u>
Total DEC $91,282

Contractor Support
Industrial Economics, Inc. (IEc) $25,000

Research Planning, Inc. (RPI)
Salaries
Task 1: Plan Development, Planning, Logistics, Permitting ......………$35,178
Task 2: Cruise 2: Cruise Leader and Field Scientist..............................$57,592
Task 3: Report Production $54,395
Task 4: Technical Support to Trustees..$17,922
Travel, Other Direct Costs $12,590
Total RPI..$177,677

Total Costs – Trustees..$658,459

LITERATURE CITED

ATSDR (Agency for Toxic Substances and Disease Registry). 2008. Health Consultation: Evaluation of Blue Mussel Samples Collected in May 2006. M/V Selendang Ayu Oil Spill, Unalaska, Alaska. U.S. Department of Health and Human Services, Atlanta, GA., 9 pp.

Carls, M.G., P.M. Harris, and S.D. Rice. 2004a. Restoration of oiled mussel beds in Prince William Sound, Alaska. Marine Environmental Research 57(5):359-376.

Carls, M.G., L.G. Holland, J.W. Short, A. Heintz, and S.D. Rice. 2004b. Monitoring polynuclear aromatic hydrocarbons in aqueous environments with passive low-density polyethylene membrane devices. Environmental Toxicology and Chemistry 23(6):1416-1424.

Carls, M.G. 2006. Nonparametric identification of petrogenic and pyrogenic hydrocarbons in aquatic ecosystems. Environmental Science & Technology 40(13): 4233-4239.

DeBruyn, A.M.H., B.G. Wernick, C. Stefura, B.G. McDonald, B. Rudolph, L. Patterson, and P.M. Chapman. 2007. In situ experimental assessment of lake whitefish development following a freshwater oil spill. Environmental Science & Technology 41:6983-6989.

Diaz-Ramos, S., Stevens, D.L. Jr., and A.R. Olsen. 1996. EMAP Statistical Methods Manual. U.S. Environmental Protection Agency, Office of Research and Development, National Health Effects and Environmental Research Laboratory, Western Ecology Division. Corvallis, OR. EPA/620/R-96/XXX.

Flint, P.L., J.L. Schamber, K.A. Trust, A.K. Miles, B.W. Wilson. 2008. Preassessment Data Report #10: Chronic exposure of seaducks to oil released by the *Selendang Ayu* at Unalaska Island. http://alaska.fws.gov/fisheries/contaminants/spill/sa_record.htm

Lee, K., R.C. Prince, C.W. Greer, K.G. Doe, J.E.H. Wilson, S.E. Cobanli, G.D. Wohlgeschaffen, D. Alroumi, T. King, and G.H. Trenblay. 2003. Composition and toxicity of residual Bunker C fuel oil in intertidal sediments after 30 years. Spill Science & Technology 8(2):187-199.

NOAA. 2000. Shoreline Assessment Manual. Third Edition. HAZMAT Report No. 2000-1. Office of Response and Restoration, NOAA, Seattle, WA, 99 pp.

Owens, E.H., E. Taylor, and B. Humphrey. 2008. The persistence and character of stranded oil on coarse-sediment beaches. Marine Pollution Bulletin 56:14-26.

Short, J.W., G.V. Irvine, D.H. Mann, J.M. Maselko, J.J. Pella, M.R. Lindeberg, J.R. Payne, W.B. Driskell, and S.D. Rice. 2007. Slightly weathered *Exxon Valdez* oil persists in Gulf of Alaska beach sediments after 16 years. Environmental Science and Technology 41:1245-1250.

Short, J.W., S.D. Rice, M.R. Lindeberg, and M.G. Carls. 2005. Use of polyethylene membrane devices for monitoring diesel oil contamination on and within beaches. 31st Annual Aquatic

Toxicity Workshop. Charlestown, Prince Edward Island, Canada, Canadian Department of Fisheries and Oceans.

Short, J.W., M.R. Lindeberg, P.M. Harris, J.M. Maselko, J.J. Pella, and S.D. Rice. 2004. Estimate of oil persisting on beaches of Prince William Sound, 12 years after the *Exxon Valdez* oil spill. Environmental Science and Technology 38(1):19-25.

Short, J.W. and R.A. Heintz.1997. Identification of *Exxon Valdez* oil in sediments and tissues from Prince William Sound and the northwestern Gulf of Alaska based on a PAH weathering model. Environmental Science and Technology 31(8): 2375-2384.

Short, J.W., T.J. Jackson, M.L. Larsen, and T.L. Wade. 1996. Analytical methods used for the analysis of hydrocarbons in crude oil, tissues, sediments, and seawater collected for the natural resources damage assessment of the *Exxon Valdez* oil spill. S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A. Wright (eds.). American Fisheries Society Symposium 18, Bethesda, Maryland, pp. 140-148.

Stevens, D.L., Jr., and A.R. Olsen. 2004. Spatially-balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

Appendix 1: Beach Segments of Greatest Concern with Zone Priorities.

Segment	Justification	Length (m)	Zone Description
SKN-15	High likelihood of oil & No endpoint.	2610	Zone B: 5 x 30 meter area, 10-40% ST/CT/CV. Buried oil present and undefined.
			Zone C: 4 x 25 meter area, 10-60% coverage of CT/CV to 20 cm deep. High concentration (PO) of buried oil present and undefined.
			Zone D: 15 x 60 meter area, 30-60% ST/CT/CV.
			Zone E: 15 x 60 meter area, 30-45% coverage of ST/CT/CV to 20 cm deep.
MKS-14	High likelihood of oil & No endpoint	687	Zone A: 15 x 100 meter area, 1% coverage of CT.
			Zone B: 15 x 50 meter area, 60% coverage of PO.
MKS-16	High likelihood of oil & No endpoint	680	Zone B: 10 x 100 meter area, buried oil lens in p/c.
			Zone C: 0.5 x 18 meter area, buried AP. Likely larger area.
			Zone D: 15 x 78 meter area, 60-100% coverage of CT/CV on p/c.
			Zone F: 4 x 50 meter area, <20% CV/AP in Boulders.
SKN-05	Moderate likelihood of oil & alternative treatment	676	Zone A: 15 x 400 meter oiled berm CT.
HMP-05	Moderate likelihood of oil & HADU site	877	Zone B: Final record incomplete. 2.5 x 60 meter area, 25% coverage of PO in cobbles received treatment but no final record after treatment was completed. PEST requested more work to remove PO from between boulders and rock.
			Zone C: Final record incomplete. 3.5 x 160 meter area, 5-15% coverage of CT/ST. Good effort noted by PEST but no final record after treatment was completed.
			Zone D: 8 x 20 meter area, 5-15% coverage of CT/ST.
SKN-11	Subsistence samples	210	Zone A: 5 x 30 meter area, 15% coverage of ST. Minor oiling on boulders.
SKS-12	HADU site & alternative treatment	682	Zone A: 0.2 x 250 meter area, <1% coverage of TB.
SKS-04	Subsistence samples & alternative treatment	234	Zone A: 1 x 235 meter area, 1% CT.
PTN-03	HADU site	547	Zone A: 2 x 400 meter area, 75% coverage of PO.
KPF-01	Moderate likelihood of oil & No endpoint	1493	Zones A: 2 x 100 meter area, 1% coverage of CT.
			Zones B1: 1 x 24 meter area, 9% coverage of CV/CT.
			Zones B2: 10 x 25 meter area, 9% coverage of CV/CT.
			Zones C: 2 x 30 meter area, 7% coverage of CV/CT.
			Zones D: 13 x 22 meter area, 8% coverage of CT.
			Zones E: 25 x 50 meter area, 5% coverage of CT/ST.
			Zones F: 3 x 150 meter area, 17% coverage of CV/CT.
			Zones G: 10 x 200 meter area, 5% coverage of CT/CV.
			Zones H: 20 x 20 meter area, 20% coverage of CT.

(Abbreviations: Surface Oiling Descriptors for Thickness -- PO Pooled Oil (fresh oil or mousse > 1 cm thick); CV Cover (oil or mousse from >0.1 cm to < 1 cm on any surface); CT Coat (visible oil <0.1 cm, can be scraped off with fingernail); ST Stain (visible oil, cannot be scraped off with fingernail).

Appendix 2: Assignment of Pits, Sediment Samples, Invertebrate Samples, and Passive Sampler Arrays by Zone.

Segment	Zone	Width (m)	Buffered Width (m)	Length (m)	Area (m^2)	Pits	Sediment Samples	Invert collections	Passive Arrays
SKN-15	B	5	9	30	270	10	5	3	1
SKN-15	C	4	8	25	200	10	5	3	1
SKN-15	D	15	19	60	1140	40	10	3	2
SKN-15	E	15	19	60	1140	40	10	3	2
MKS-14	A	15	19	100	1900	40	10	3	2
MKS-14	B	15	19	50	950	20	7	3	2
MKS-16	B	10	14	100	1400	40	10	3	2
MKS-16	C	0.5	4.5	18	81	5	3	3	1
MKS-16	D	15	19	78	1482	40	10	3	2
MKS-16	F	4	8	50	400	10	5	3	2
SKN-05	A	15	19	400	7600	80	15	3	3
HMP-05	B	2.5	6.5	60	390	10	5	3	2
HMP-05	C	3.5	7.5	160	1200	40	10	3	2
HMP-05	D	8	12	20	240	10	5	3	1
SKN-11	A	5	9	30	270	10	5	3	1
SKS-12	A	0.2	4.2	250	1050	40	10	3	3
SKS-04	A	1	5	235	1175	40	10	3	2
PTN-03	A	2	6	400	2400	80	15	3	3
KPF-01	A	2	6	100	600	20	7	3	2
KPF-01	B1	1	5	24	120	10	5	3	1
KPF-01	B2	10	14	25	350	10	5	3	1
KPF-01	C	2	6	30	180	10	5	3	1
KPF-01	D	13	17	22	374	10	5	3	1
KPF-01	E	25	29	50	1450	40	10	3	2
KPF-01	F	3	7	150	1050	40	10	3	2
KPF-01	G	10	14	200	2800	80	15	3	2
KPF-01	H	20	24	20	480	10	5	3	1