

## Executive Summary

### Background

Oil and gas exploration, production, and transportation activities in Cook Inlet, Alaska have the potential for impacting marine resources. Though these operations are well-managed and are regulated so as to minimize the input of pollutants to the marine environment, the longer-term accumulation of pollutants in depositional areas on the sea floor is an area of concern when contemplating future Outer Continental Shelf (OCS) leases.

After discharge, contaminants that are in a particulate form or which are sorbed to particles after discharge are rapidly diluted due to a large combined water flow from tidal, current, and riverine inputs of fresh and seawater. Though at low levels in the water column, a combination of oceanographic and sediment transport processes pointed to the lower Cook Inlet (Kamishak and Kachemak Bays) and Shelikof Strait as potential areas for this longer-term deposition of these sorbed pollutants.

Estimation of current impact and prediction of future environmental risk and impacts were complicated by the existence of multiple sources of similar pollutant assemblages to the region beyond exploration and production (E&P) operations. Natural oil seepages were common in the area and were known to represent an important part of the hydrocarbon assemblage in the sedimentary environments of areas of the Gulf of Alaska. Oil spillages, especially that from the *Exxon Valdez* spill, were potential contributors, though no evidence of the impact of this spill, in particular, was observed in the subtidal sediments of Cook Inlet or Shelikof Strait. Tremendous quantities of suspended material were swept into the region from glacial runoff with associated metals and hydrocarbons. Municipal discharges and other permitted industrial (e.g., seafood processing) discharges contributed important quantities of wastes over time to the immediate coastal areas and presumably to the area's deeper depositional locations.

### Study Rationale

Because of the need to definitively examine the distribution and environmental risk of anthropogenic chemicals (i.e., metals, petroleum hydrocarbons including polynuclear aromatic hydrocarbons [PAHs]) in advance of any future oil and gas E&P activities that could potentially affect the lower Cook Inlet and Shelikof Strait, MMS contracted with Arthur D. Little, Inc. (ADL) to undertake a two-year study in the region.

The objectives of the study were to:

- Evaluate the Shelikof Strait and outermost Cook Inlet as potential depositional areas or "traps" for oil industry contaminants
- Determine whether contaminant concentrations in sediments of these areas pose an environmental risk
- Determine whether contaminants in these areas have accumulated relative to pre-industry concentrations

- Determine whether any increases can be correlated with specific discharge events or activities (e.g., the *Exxon Valdez* oil spill)
- Determine the importance of other hydrocarbon and metal sources to the sediments

The study objectives were recast in a risk assessment-type framework (U.S. EPA; EPA/630/R-95/002, *Draft Proposed Guidelines for Ecological Risk Assessment*). In this framework a formulation of the problem leads to a characterization of exposure and effects, which in turn leads to a characterization of the risk. This program was structured to follow that approach to meeting the goals.

In designing an investigation to meet these goals, ADL and its team members put forth several hypotheses for scientific testing. These hypotheses were:

- Hypothesis 1: The offshore area of outermost Cook Inlet and Shelikof Strait is not a trap for organic and metal pollutants (i.e., there is no indication of deposition)
- Hypothesis 2: Concentrations of organic and metal contaminants in sediment cores do not show increases since before offshore oil exploration and production began in Cook Inlet (circa 1963)
- Hypothesis 3: Compositions of organics and metals in sediment cores do not show changes in composition since before offshore oil exploration and production began in Cook Inlet (circa 1963)
- Hypothesis 4: Concentrations of organic and metal contaminants in outermost Cook Inlet and Shelikof Strait do not pose any environmental risk

The field program was designed to collect data to test these null hypotheses. Hypotheses are stated as the null hypotheses since the null hypotheses were tested during the statistical analyses.

## Field Program Design

The design of the data acquisition/field program for the two-year study focused on two facets. The first was the deep subtidal bottom sediments of the region as the focal point of any long-range contaminant deposition. The design was intended to obtain both chemical (i.e., exposure) and biological (i.e., effects) data on surface sediments. It also was directed at looking at historical deposition in the study area through the use of dated sediment cores. The second facet addressed the status of chemical body burdens in bottom-feeding fish and indicators of sublethal effects. These "biomarker" measurements were made to address their exposure to contaminants.

The field sampling design included:

- Separation of the study area into four zones, each assumed to be relatively homogeneous
- The selection of a group of random sediment stations in each zone from a large number of candidate stations, each station representing a replicate of that zone
- The selection of fixed or biased stations at key locations from which we wanted to obtain data
- The selection of a limited number of stations from each zone (including the fixed stations) from which to take replicates to examine within-station variability

- The selection of additional sampling stations in the Gulf of Alaska off the Kenai Peninsula to represent "upstream" source material
- The selection of additional stations south of Shelikof Strait to examine longer-range transport
- The field-truthing of the suitability of each station prior to sampling
- The sampling of stations for surface sediments; selected locations for sediment coring; and selected locations for obtaining fish samples
- The selection and sampling of potential contaminant sources -- oil seeps; river runoff; coal seams; and oil and gas operational discharges

## Analytical Design

The analytical design centered on organic (i.e., petroleum-related) and metal parameters as measured in sediment, sediment core, fish tissue, and source samples. The design consisted of the following measurements:

- Petroleum hydrocarbons (PHC), including PAHs of petroleum and other origins, and steranes/triterpanes (S/T) in sediments and PAHs in fish tissue
- The use of detailed alkylated PAHs and S/T to elucidate source characteristics of source samples and source identification in the field samples
- Major and trace metals including silver, aluminum, arsenic, barium, beryllium, calcium, cadmium, chromium, copper, iron, mercury, potassium, manganese, magnesium, nickel, lead, antimony, selenium, tin, thallium, vanadium, and zinc in sediments
- Acid volatile sulfide/simultaneously extracted metals (AVS/SEM) in sediments (Year 1 only)
- All metals except calcium, potassium, magnesium, and nickel in fish tissues
- Amphipod toxicity tests in sediments
- Reporter gene system (RGS) P450 measurements for sediment and fish tissue extracts
- Cytochrome P450 (CYP1A) induction determinations on selected tissues
- Dating of sediment cores by <sup>210</sup>Pb and <sup>137</sup>Cs methods and analysis of core sections for hydrocarbons and metals as in the surface sediments
- Sediment profile imagery (SPI) of surface sediments (Year 1 only)

## Findings

The analysis of the findings was used to perform tests of the study's four hypotheses, using field data from 1997 and 1998. The outcomes of this hypothesis testing are as follows:

- *Potential for contaminant deposition in the study area.* In summary, in the context of the null hypothesis, **the surface sediments of outermost Cook Inlet and the Shelikof Strait are traps for fine-grained sediment and are potential traps for contaminants from oil and gas production activities in upper Cook Inlet.** However, based on evaluations of the organic and inorganic data, no contamination in the surface sediments from oil and gas production activities in upper Cook Inlet was identified. Elevated Hg concentrations were identified in Kachemak Bay. However, the present-day Hg levels are comparable to values observed throughout the twentieth century, suggesting that the Hg results are typical for the region.

- *Contaminant depositional changes over time.* In summary, in the context of the null hypothesis, **the concentrations of metals and organics (i.e., PAHs) in sediments in outermost Cook Inlet and Shelikof Strait have not increased significantly since offshore oil exploration and production began in Cook Inlet (circa 1963).**
- *Compositional changes over time.* In the context of the null hypothesis, **the composition (source[s]) of metals in the sediments of outermost Cook Inlet and Shelikof Strait do not appear to have changed since offshore oil exploration and production began in Cook Inlet (circa 1963).** The composition of hydrocarbons in sediment cores shows subtle changes in outermost Cook Inlet over the past 25 to 50 years, but these changes do not appear to be correlated with petroleum production activities or spills.

The study of the magnitude of sediment deposition from the major rivers in the region (i.e., Susitna-Knik-Matanuska; Copper River) indicates that the Copper River accounts for 10 to 20 percent of the total sediment deposited in the study area.

- *Assessment of risk.* The two sampling seasons have provided a picture of contaminants and potentially toxic trace substances in the environment at very low concentrations with an attendant low biological risk. Using multiple measures of risk that were built into the study design, we conclude that **the concentrations of organics (i.e., PAHs) and metals do not appear to pose any immediate ecological risk to the marine environment in the study area.**

The concentrations of trace metals are consistently below the risk levels identified by Long and Morgan (1995), except for Ni, which has a crustal abundance higher than the designated effects range-low (ERL) and effects range-medium (ERM) concentrations, and Cu. Concentrations of Cu exceeded the ERL in a number of cases, but source sediment from the Susitna River along with Alaskan rocks, show that natural levels of Cu are all close to or above the ERL value.

The concentrations of PAH detected in sediments are also below the ERL identified by Long and Morgan (1990).

The P450 RGS results also indicated low to negligible biological risk associated with extractable organic compounds, namely PAH, in the sediments. Sediment bioassays with two species of amphipods indicate that sediment chemicals do not exhibit any significant toxicity. Some low survival rates appear to be related to testing sediments with high silt content rather than any trace chemicals in the sediments.

The levels and patterns of induction of CYP1A in cells of bottom-dwelling fish (i.e., Halibut and Pacific Cod) are consistent with some mild induction by contaminants, but with weak induction in the gills they appear not to be waterborne, but rather from the diet. None of the measured contaminants in the fish tissues correlated with CYP1A induction, but chlorinated hydrocarbons were not measured. Specifically, the results on the hepatocytes and the kidney cells are consistent with some low level of enzyme-

inducing compounds in the diet of these fish. There were no significant correlations between the CYP1A scores and the locations (i.e., zones) of the fish.

In summary, using multiparameter measures to assess potential exposure and potential risk, the comprehensive findings of this two-year investigation indicate that **the current concentrations of metals and PAHs in the Shelikof Strait and Outermost Cook Inlet are neither linked to oil and gas development in the upper Cook Inlet, nor to the *Exxon Valdez* oil spill. The residues that are present, from a combination of natural sources -- river inputs, oil seepages, etc. -- pose no significant risk to the biota and the benthic environment of outermost Cook Inlet and Shelikof Strait.** The degree of current risk is indeed very low and is similar to non-impacted coastal regions in Alaska and elsewhere.