

ALASKA LEGISLATURE SPECIAL COMMITTEE/SUBJECT FILE 8672

1992 SCOMM 77: SENATE SPEC. COMM. EXXON VALDEZ OIL SPILL. 1991

209

very low concentrations of oil occur in the surface sediments. The lower intertidal zone would be least impacted by the residual subsurface oil.

With the information available on the likely zone of disturbance by excavation and rock washing, it is assumed that few organisms in the upper and middle intertidal zones would survive. There may also be impacts to these zones resulting from the traffic of equipment and people on the shoreline. It is likely that these surface impacts would extend to some degree into the relatively rich lower intertidal communities.

NOAA estimates that three to five years would be required for biological recolonization after the shoreline stabilizes. Adding one to three years for stabilization, the total recovery period after excavation is estimated to be four to eight years. If excavation does not occur, NOAA estimates recolonization will occur in two to five years at Point Helen and three to six years post-spill at Sleepy Bay.

What would be the secondary impacts from excavation and rock washing?

Increased sediment loading in the water column would be unavoidable during excavation and replacement. Coarse material would settle out readily, although it is likely that oiled silts and clays would settle slowly and might be transported along the beach by tidal currents.

Secondary spills of fuel and process water were estimated using the spill rate of cleanup activities in 1989. Assuming that four or five rock washing units were active for a two-month period, an estimated eight to ten fuel spills would occur.

Excavation and rock washing would disturb wildlife with work activity and noise for six weeks or longer in each work area. Sources of disturbance include personnel, vessels, equipment, and aircraft. Traffic in the intertidal area may further affect the recolonization process.

Exxon estimates that excavation and rock washing at Sleepy Bay would generate 12,000 gallons of skimmed oil/water mixture, 168,000 gallons of wastewater, 500,000 gallons of sludge waste, and 300,000 pounds of air emissions. Fuel consumption is estimated at 400,000 gallons.

What would be the impacts on human use of the shoreline and nearshore waters should subsurface oil not be removed? What would be the related effects of excavation/rock washing?

The State of Alaska indicates that any of the shoreline segments which are candidates for excavation and rock washing are in areas of moderate to high human use. These areas are used throughout the year for recreation, subsistence and commercial fishing, and are of significant cultural importance. Subsurface oil has some capacity to pose an episodic threat to these uses of the shoreline and nearshore waters.

Although sheens are declining in Prince William Sound, and the relationship between sheens and subsurface oil is tenuous in non-storm conditions, commercial fishing in the immediate vicinity could be affected in the event sheening does occur. Episodic releases of subsurface oil may contaminate subsistence fisheries, interfere with shore-based commercial and recreational fishing, and impair use of the shoreline for recreation. Large amounts of subsurface oil can impact recreation and subsistence users who dig fire pits in the upper intertidal zone.

Excavation/rock washing is one of the most predictable means of assuring that oil is removed from the environment rather than remaining as a potential source for episodic exposure during winter storms. The expected impacts of the excavation and cleaning process include potential for temporary sheening or resuspension of oiled particulates, creation of silt plumes, and disturbance by equipment and personnel. These impacts can be mitigated by proper containment of sheens and timing of operations to minimize impacts to resources and users. Recreational and some subsistence uses could resume soon after the treatment process. Other subsistence activities would be delayed four to eight years until natural recolonization of intertidal biota occurred.

FOREWORD

This report was only possible through the dedicated efforts of many individuals who worked extraordinarily long hours for several weeks in meeting the stringent deadlines associated with its production. The authors especially wish to thank Lori Harris of NOAA for her outstanding efforts in compiling both the draft and final manuscripts.

TABLE OF CONTENTS

	<u>Page</u>
I. Definition of Study	1
A. Objective	1
<i>Jacqueline Michel</i>	
1. Statement of the Problem.....	1
2. General Approach.....	2
B. Description of Excavation Rock Washing	3
<i>N.K. Springer, J. J. Kichner, B. A. Twidwell</i>	
1. General Technology.....	3
2. Process Flow Diagram.....	4
3. Overview of Process Capabilities.....	4
4. Operational Concepts and Logistic Considerations.....	6
5. Expected Process and Ancillary Equipment.....	10
6. Operations.....	12
C. Description of Candidate Beaches	16
1. Selection Criteria.....	16
<i>Jacqueline Michel</i>	
2. Geomorphology.....	19
<i>Miles O. Hayes, Ed Owens, and Eugene Pavia</i>	
3. Sediment Oil Content and Composition of Candidate Beaches	39
<i>Jacqueline Michel and Charles Henry</i>	
4. Pore Water Chemistry.....	66
<i>Jerry Neff and Charles Henry</i>	
5. Beach Hydraulics.....	78
<i>Ed Owens</i>	
6. Treatment Histories.....	79
<i>Eugene Pavia</i>	
7. Biological Conditions	80
<i>Ed Long, Charles Cairncross, Jerry Neff, Sam Stoker</i>	
8. Human Uses.....	92
<i>William Copeland</i>	
II. Environmental Considerations.....	94
A. Base Case: Approved 1990 Treatments and Natural Cleansing.....	94
1. Trends in Oil Residue Content of Subsurface Sediment Samples From Prince William Sound.....	94
<i>Hans Jahns</i>	

II. Environmental Considerations, cont.

Page

2. Trends in Natural Removal Rates of Subsurface Oil.....	101
<i>Jacqueline Michel, Miles O. Hayes, Charles Henry</i>	
3. Effects of Subsurface Oil Residues and Projections of Recolonization	108
<i>Ed Long</i>	
4. Sheening—Frequency, Volumes, Persistence.....	123
<i>Gerald Schimke, Jerry Neff, Charles Henry, Marshal Kendziorek, Ed Meggert</i>	
5. Human Use Considerations Under Continued Natural Cleansing and Approved 1990 Treatments.....	145
<i>William Copeland</i>	
6. Ultimate Disposition of Subsurface Oil	146
<i>Jerry Neff, Eugene Pavia, Charles Henry</i>	
B. Excavation/Rock Washing.....	160
1. Effects on Beach Substrate	160
<i>Miles O. Hayes, Ed Owens, Eugene Pavia</i>	
2. Effects on Intertidal Biota and Projections of Recolonization.....	163
<i>Gary Shigenaka, Ed Long, Mark Kuwada, Jerry Neff</i>	
3. Water Quality.....	178
<i>Eugene Pavia and Ed Meggert</i>	
4. Impacts on Human Interests.....	179
<i>Mark Kuwada and William Copeland</i>	
5. Impacts on Cultural Resources	179
<i>William Copeland</i>	
6. Impacts of Waste Handling and Disposal	180
<i>John Wilkinson</i>	
III. Summary.....	183
<i>Jacqueline Michel and John H. Robinson</i>	
References	192
Appendix A: Case Histories.....	A-1
<i>Ed Long, Gary Shigenaka, Charles Cairncross</i>	

LIST OF CONTRIBUTORS

Charles Cairncross	National Oceanic and Atmospheric Administration
William Copeland	Alaska Department of Natural Resources
Miles O. Hayes	Research Planning, Inc./NOAA
Charles Henry	Louisiana State University/NOAA
Hans Jahns	Exxon
Marshal Kendziorek	Alaska Department of Environmental Conservation
Jerzy Kichner	U.S. Coast Guard
Mark N. Kuwada	Alaska Department of Fish and Game
Ed Long	National Oceanic and Atmospheric Administration
Ed Meggert	Alaska Department of Environmental Conservation
Rodger Melton	Exxon
Jacqueline Michel	Research Planning, Inc./NOAA
Ken Middleton	Alaska Department of Fish and Game
Jerry Neff	A. D. Little/Exxon
Ed Owens	Woodward-Clyde Consultants/Exxon
Eugene A. Pavia	Alaska Department of Environmental Conservation
John Phillips	Exxon
John H. Robinson	National Oceanic and Atmospheric Administration
Gerald Schimke	National Oceanic and Atmospheric Administration
Gary Shigenaka	National Oceanic and Atmospheric Administration
Nina Springer	Exxon
Sam Stoker	Woodward-Clyde Consultants/Exxon
Bryson Twidwell	Alaska Department of Environmental Conservation
John Wilkinson	Exxon

LIST OF ABBREVIATIONS

ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
cm	centimeter
GC/MS	gas chromatograph/mass spectrometer
km	kilometers
K _{ow}	octanol/water partition coefficient
mg/kg	milligram per kilogram
µg/l	micrograms per liter
m	meter
mm	millimeter
MLLW	mean lower low water
NEBA	Net Environmental Benefit Analysis
NOAA	National Oceanic and Atmospheric Administration
ng/l	nanograms per liter
ng/mL	nanograms per milliliter
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyls
ppb	parts per billion
ppm	parts per million
SCAT	Shoreline Cleanup Assessment Team
SSAT	Spring Shoreline Assessment Team
TPH	total petroleum hydrocarbons

LIST OF FIGURES

	<u>Page</u>
I-1 Preliminary process diagram (KCM, Inc. and Northwest Enviro Service, 1990)	5
I-2 Beach excavation rock washing project (not to scale).....	13
I-3 Location map showing the two candidate beaches at Sleepy Bay and Point Helen.....	17
I-4 Beach sketch of NOAA's station N-1 at Point Helen at low tide on 24 May 1990. Note presence of storm and spring-tide berms near high-water mark and bedrock outcrop in lower portion of the profile. Buried oil occurs on the upper one-fourth of the beach.....	20
I-5 Beach profile at NOAA's station N-1 at Point Helen that was measured at low tide on 24 May 1990. The beach is classified morphologically into three zones: (1) <u>high-tide berms</u> , an area subject to fluctuations of berm levels during storms and spring tides; (2) <u>stable central ramp</u> , bypass zone with an armor of cobbles and boulders; and (3) <u>low-tide bars</u> , boulder/cobble zone that sometimes contains gravel swash bars.....	21
I-6 Plot of 25 estimates of grain size of surface sediments along NOAA's profile N-1 on 24 May 1990.....	23
I-7 Distribution of grain size of surface sediments adjacent to NOAA's profile N-1 on 24 May 1990. Dots along profile line indicate points where grain size estimates are made	24
I-8 Description of three trenches dug on NOAA's profile N-1 on 24 May 1990 (see Figures I-4, I-5, and I-7 for location). Note tendency for upper units to be somewhat coarser grained than lower units. Also note that the upper sediments in trenches A and B are relatively free of oil as a result of wave action during the non-summer months of 1989 and 1990.....	25
I-9 Plot of grain size estimates for sediments from the trenches described in Figure I-8. These sediments are generally finer than the surface sediments for the entire profile (compare with Figure I-6).....	26
I-10 Beach changes and buried oil at NOAA's profile N-1 at Point Helen. The plot of four profiles measured during	

LIST OF FIGURES, *cont.*

I-11	Point Helen at low tide on 5 January 1990. Note the presence of gravel swash bars in the intertidal zone that were obviously migrating in a southerly direction.....	29
I-12	Detailed map of Sleepy Bay showing the location of the specific section of Sleepy Bay used as a candidate beach for this analysis	31
I-13	Surface sediment distribution map at the head of Sleepy Bay on 24-26 May 1990.....	32
I-14	Field sketch of NOAA's profile N-18 at Sleepy Bay at low tide on 24 May 1990. Note the presence of multiple berms in the high-tide area. Buried oil occurs on the upper one-third of the profile	33
I-15	Plot of NOAA's beach profile N-18 as it appeared on 1 February 1990. During the fall-winter-spring of 1989-1990, the upper part of the profile was host to multiple migrating berms, the central part was relatively stable, and the lower part contained swash bars from time to time, some of which were associated with the river delta	34
I-16	Plot of estimates of the grain size of the surface sediments at 26 intervals along NOAA's profile N-18 on 24 May 1990. Note that mixtures of pebbles and cobbles predominate.....	36
I-17	Description of sediments in two trenches dug on NOAA's profile N-18 on 24 May 1990. See Figure I-14 for location. Surface armoring is not as well developed in these trenches as it is elsewhere in Prince William Sound.....	37
I-18	Plots of the shoreline profile for September and October 1989, at NOAA station N-1, Point Helen. Oil concentrations are shown in mg/kg	40
I-19	Plots of the shoreline profile for November and December 1989, at NOAA station N-1, Point Helen. Oil concentrations are shown in mg/kg	41
I-20	Plots of the shoreline profile for January and February 1990, at NOAA station N-1, Point Helen. Oil concentrations are shown in mg/kg.....	42

LIST OF FIGURES, *cont.*

I-21	Plots of the shoreline profile for September and October 1989, at NOAA station N-18, Sleepy Bay. Oil concentrations are shown in mg/kg.....	45
I-22	Plots of the shoreline profile for November and December 1989, at NOAA station N-18, Sleepy Bay. Oil concentrations are shown in mg/kg	46
I-23	Plots of the shoreline profile for January and February 1990, at NOAA station N-18, Sleepy Bay. Oil concentrations are shown in mg/kg.....	47
I-24	Comparison of Exxon Valdez cargo oil to mousse collected at Sleepy Bay (May 1990). Note the difference in scale of concentration between the two plots	52
I-25	Comparison of Exxon Valdez cargo oil to oil contained within a tar mat in Sleepy Bay. Note the difference in scale of concentration between the two plots	53
I-26	Comparison of Exxon Valdez cargo oil to a surface sample from Sleepy Bay that is heavily weathered. Note the difference in scale of concentration between the two plots	54
I-27	Comparison of Exxon Valdez cargo oil to subsurface oil buried in the spring tide berm at Sleepy Bay (May 1990). Note the difference in scale of concentration between the two plots	57
I-28	Comparison of Exxon Valdez cargo oil to subsurface oil of the upper intertidal zone at NOAA study station N-18 (May 1990). Note the difference in scale of concentration between the two plots	58
I-29	Comparison of Exxon Valdez cargo oil to subsurface oil of the middle intertidal zone at NOAA study station N-18 (May 1990). Note the difference in scale of concentration between the two plots	59
I-30	Comparison of Exxon Valdez cargo oil to subsurface oil of the lower intertidal zone at NOAA study station N-18 (May 1990). Note the difference in scale of concentration between the two plots	60

LIST OF FIGURES, *cont.*

I-31	Comparison of Exxon Valdez cargo oil to subsurface oil at NOAA study station N-1 upper intertidal zone (May 1990). Note the difference in scale of concentration between the two plots.....	61
I-32	Comparison of Exxon Valdez cargo oil to subsurface oil in the spring tidal berm at Point Helen (May 1990). Note the difference in scale of concentration between the two plots.....	62
I-33	Model predictions of concentrations of total PAHs in pore water in contact with intertidal deposits of subsurface oil on shores of Prince William Sound. (a) The initial concentrations case. (b) Comparison of average case and March case.....	70
I-34	Comparison of concentrations of total PAHs in pore water of sediments collected from oiled shores in Prince William Sound in March 1990, predicted by the model and actually measured in pore water samples.....	77
II-1	TPH concentrations in subsurface sediments at 18 Exxon transects in Prince William Sound from September 1989 to March 1990, for all transects and divided into different energy levels.....	100
II-2	Summary of oil spill self-cleaning processes (modified from Vandermeulen, 1977).....	105
II-3	Sheen sightings reported in 1990 by Exxon crews, through 2 June	124
II-4	Plot of average daily wind speed, tidal range, and number of sheens reported by ADEC during the four-month period beginning 14 November 1989	126
II-5	A: Weekly sheen oil volumes based on Exxon data. B: Weekly sheen oil volumes based on ADEC data.....	128
II-6	Weekly sheens in Prince William Sound, as reported by Exxon.....	130
II-7	PAH profiles for North Slope crude oil and sheen oil sampled in the Bay of Isles in April 1989 (upper) and October 1989 (lower).....	133

LIST OF FIGURES, *cont.*

II-8	Comparison of the analysis profiles of Exxon Valdez cargo oil and a sheen collected at Block Island (May 1990)	134
II-9	Comparison of the ion chromatograms (m/e 85) for the sheen sample collected at Block Island and weathered, non-sheening subsurface oil from Sleepy Bay	135
II-10	Comparison of subsurface sediment from Sleepy Bay (non-sheening oil) to a sample collected at the Barren Islands that readily sheens	137
II-11	Zones of convergence in Prince William Sound	141
II-12	Subtidal profiles off NOAA stations N-1 (upper) and N-18 (lower) in June 1990	151

LIST OF TABLES

	<u>Page</u>
I-1 Lists of sites considered for inclusion as a candidate beach representative of the sheltered pocket beach type for rock washing	18
I-2 Concentration of specific compounds in sediments at the candidate beaches.....	63
I-3 Concentrations of total PAHs in pore water and sediments, and of TPH in subsurface sediments collected from several oiled shorelines in Prince William Sound in March 1990	72
I-4 Concentration of specific compounds in pore water collected at candidate beaches during May 1990	74
II-1 Summary of TPH data for all Prince William Sound sediment samples from Exxon's winter monitoring program.....	95
II-2 Summary of TPH data for selected transect Prince William Sound subsurface sediment samples from Exxon's winter monitoring program.....	97
II-3 Regression analysis for TPH data from principal transects	99
II-4 Summary of biological recovery rates for various types of disturbance.....	118
II-5 Subtidal observations at site N-1, Point Helen.....	152
II-6 Subtidal observations at site N-18, Sleepy Bay	154
II-7 Concentration of specific compounds in subtidal sediments at the candidate beaches	155
II-8 Summary of biological recovery rates for previous oil spills	171

I. DEFINITION OF STUDY

I.A. OBJECTIVE

I. A.1 STATEMENT OF THE PROBLEM

Cleanup of the EXXON VALDEZ oil spill has required the use of various shoreline treatment techniques, many of which are new to oil spills. Water flooding, omnibooms, and application of fertilizers were innovative approaches developed and modified for use in addressing the cleanup problems in 1989. One of the shoreline treatment problems in 1990 is the presence of oil which has penetrated into porous sediments and persisted through the first year of fall/winter/spring storms. It is believed that the approved shoreline treatment techniques for 1990, namely, manual removal, spot washing, and bioremediation, will not effectively remove subsurface oil this year. Bioremediation has been shown in laboratory and recent field studies to induce higher respiration rates to depths of 15-30cm, yet the rates are lower than at the surface. The ongoing monitoring program of the use of Inipol and Customblen fertilizers will help answer the questions about the degree and depths of enhanced degradation resulting from nutrient augmentation.

In the event that none of the approved techniques adequately address the subsurface oil treatment problem, the Federal On-Scene Coordinator requested that Exxon determine the feasibility of use of an excavation/rock washing process. Exxon agreed to manage the design and demonstration of a rock washer for removal of subsurface oil as long as an assessment of the net environmental benefit was conducted simultaneously with the engineering development. A committee was formed with representatives from the National Oceanic and Atmospheric Administration (NOAA), State of Alaska, and Exxon, with NOAA designated as the chair, to conduct a Net Environmental Benefit Analysis (NEBA), working in close conjunction with the Engineering Process committee. The NEBA committee was charged with the task to determine if there were net environmental benefits from the excavation and washing of oiled sediments, and return of treated sediments to the excavated site over natural cleansing and the use of approved 1990 treatments.

I. A.2 GENERAL APPROACH

To determine the net environmental benefit of excavation and rock washing of oiled sediments, the NEBA committee developed preliminary selection criteria to identify the types of beaches that would be candidates for rock washing. Based on the assumptions that 1) approved or developing techniques would be adequate for treatment of surface oil, and 2) natural cleansing or bioremediation may be effective for removal of subsurface oil to depths of 10-15cm, this report focuses on deep subsurface oil. The following general criteria were used to identify candidate beaches:

- 1) The degree of subsurface oil contamination was classified as OP*, OL*, or OR* during the Spring Shoreline Assessment Team (SSAT) survey.
- 2) The depth of oil is >15cm.
- 3) The thickness of the oiled sediment zone is >15cm.
- 4) The substrate type is mostly sediment of cobble or finer grain size.
- 5) TAG recommendation was bioremediation or mechanical relocation/till.
- 6) The shoreline was a chronic source of sheens.

*OP = Oil fills pore spaces between sediment particles

OL = Lens or layer of buried oiled sediments

OR = Residual oil on sediments or in pore spaces but not saturated

The committee felt that it was important to identify specific beaches so that the actual operational constraints and environmental conditions of the sites would provide the basis for evaluation. Because so many parts of the evaluation had to be based on the literature and extrapolation of data, it was important that real sites be included. Three specific candidate beaches were to be identified as representative of the range of shoreline types being considered for rock washing treatment. These shoreline types were initially identified as:

- ☐ Exposed, outer beach with long stretches of relatively uniform sediments and little to no operational access problems.
- ☐ Moderate-energy shoreline with highly variable substrate.

- ☐ Sheltered, pocket beach with relatively small areas needing treatment and limited space for onshore operations.

It was agreed that one of the candidate sites should also include an anadromous stream mouth.

Using site-specific examples, the remainder of Section I describes the engineering process envisioned for excavation and rock washing and the existing physical, chemical, and biological conditions of the candidate sites. In the first part of Section II, the persistence and impact of the subsurface oil under a no-treatment condition is assessed. In the second part of Section II, the impacts associated with excavation and rock washing are assessed. Section III consists of a summary statement on the impacts and tradeoff considerations for excavation and rock washing as a shoreline treatment technique.

LB. DESCRIPTION OF EXCAVATION ROCK WASHING

I.B.1 GENERAL TECHNOLOGY

The excavating rock washer is a mechanical process for removing oil from excavated beach rocks and sediments using heated sea water. All equipment components and specifications have not yet been determined, but most characteristics of the process can be identified. Conceptually, this process is intended to be a self-contained, permitted technology that would be capable of excavating and cleaning coarse and most finer beach sediments and replacing the clean material back on the beach. Process objectives include minimization and containment of process wastes and control of suspended sediment plume formation resulting from the excavation.

The equipment used in this process is based on that used extensively in placer mining throughout Alaska, and in gravel classification and washing in Alaska and throughout the United States. The method involves excavating the contaminated material, sorting it according to size, and running it through the washing or tumbling equipment, then replacing the treated and clean sediment near its original location. Generally, the finest sediments become waste and would not be returned to the beach.

To satisfy the need for self-containment and the minimization of wastes, this equipment is augmented with additional equipment capable of excavating oiled beach sediments, separating oil from the process water, cleaning the process water of entrained sediment, recycling the process water, and dewatering and replacing the excavated and cleaned sediment back on the beach. Since the entire process requires an assorted number of individual pieces of varying bulk, and since large volumes of oily wastes are anticipated, ancillary equipment is required. This ancillary equipment would be used to deploy materials onto and off the beach, berth and feed support personnel and store generated waste water, oily slop and contaminated sediment.

I.B.2. PROCESS FLOW DIAGRAM (PRELIMINARY)

See Figure I-1.

I.B.3. OVERVIEW OF PROCESS CAPABILITIES

This equipment does not yet exist. Although smaller-scale equipment developed primarily to clean sand or pebble beaches exists, nothing of the scale and complexity proposed for the present application has ever been built. The selected process is composed of field-tested components. However, operation as a combined unit in an adverse environment (on a barge and between barge and beach) make the following capabilities somewhat uncertain in the field.

- a. The unit can operate at a process rate of 100 cubic yards per hour.
- b. The unit is capable of handling sediment sizes from silt to 24" in diameter although it is not designed for excessive fine sediment or friable sediment loads.
- c. The unit is capable of operating both onshore as well as from a mobile offshore platform, and can be deployed on any size beach where physical access is possible.
- d. The process uses salt water maintained at 160°F or greater to clean the sediment.

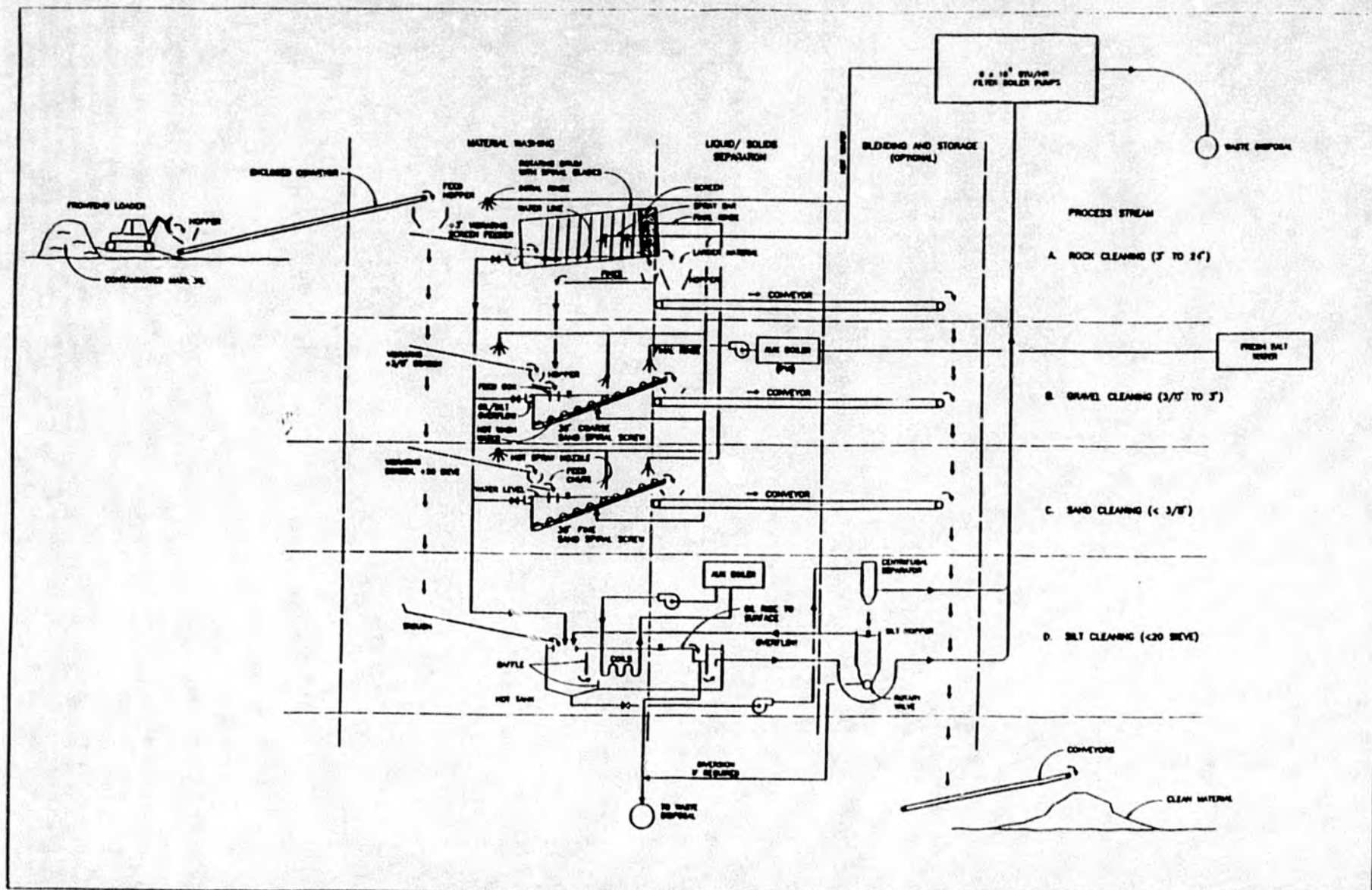


Figure I-1. Preliminary process diagram (KCM, Inc. and Northwest Enviro Service, Inc., 1990).

- e. The process design minimizes the recycle water rate and make-up water rate. Discharge of any process water as an effluent stream will not be considered as an acceptable option unless it satisfies all laws and regulations concerning discharge standards.
- f. The process dewateres all processed sediment in order to minimize the water content of the processed sediment to an acceptable level for recontouring on the beach.
- g. The unit is designed to minimize rock crushing or breakage. However, when sediments containing both sandstone and shale are processed, shales may be pulverized and could generate heavy sediment loadings when returned to a beach.
- h. The oil content of the final cleaned rocks will be less than 800 parts per million (ppm) total petroleum hydrocarbon (TPH) on composite samples from a representative distribution of sediment sizes.
- i. The process is designed to accomplish the job using only salt water and not any other chemicals to enhance the cleaning of rocks. However, the process has the flexibility to allow addition of chemicals to enhance treatment of recycled process water.
- j. The process will release oil and fine particles during excavation that can be carried by waves and water around and away from the excavation site. These releases must be controlled by other means, such as booms and/or sediment curtains.

I.B.4. OPERATIONAL CONCEPTS AND LOGISTIC CONSIDERATIONS

The excavating rock washing operation entails a sequence of activities and events that must be considered in any evaluation of environmental impact:

Site Selection and Pre-Operational Preparations

The selection of a beach site for excavation rock washing would entail a beach characterization based on existing data, field observation, and measurement. This characterization will yield operational parameters, such as work area, slope and stability of beach, needs for site preparation,

volume and distribution of sediments to be excavated, working conditions, and access to areas to be excavated. The characterization will help determine how the equipment will be mobilized and deployed. In particular, it will help determine which equipment configurations will be employed (and which operations will be conducted) on-beach versus which off-beach. The process is capable of both modes of operation, although off-beach would be generally preferred due to greater mobility and flexibility and lower intrusiveness.

Mobilization

All necessary equipment, barges and boats involved with the excavation project would be marshalled at a nearby port, Valdez, Seward or Whittier, with industrial capabilities. Portable equipment would be loaded onto the appropriate transportation and the process components would be assembled and checked. All elements would be tested to ensure each one is operational and last-minute modifications made. Pollution prevention controls on the barges would be ascertained. A review of all safety, operational, logistical, weather, and pollution plans would be accomplished and last minute changes incorporated.

Site Preparation

Double oil containment booms would be put in place around the area to be excavated and the waste storage and process transporting barges to contain any released oil or sheening from the work site. A crew with boats and cleanup equipment would be on standby for any spill cleanup. Engineering controls would be in place to reduce silt loadings from the excavation. Prior to any process excavation, large debris, such as logs, or any other non-processable material would be gathered and stockpiled on the beach for later replacement or disposal. Clean sediments extending to a depth of approximately 30cm, as much as practical, could be set aside on the beach for later replacement.

Sediment Washing, Dewatering, and Quality Control

Oiled sediments, as well as sediments outside the oiled area (due to a need for a working area and excavation layback), would be excavated.

Rocks larger than the equipment capacity would be separated and stockpiled on the beach for later replacement. Rocks too large to move with the equipment being utilized will remain in place.

The excavated sediments would be size classified then dumped into primary washing units and washed with sea water heated to 160°F or greater. The water would then be recycled to reduce heating requirements and minimize wastewater volumes. The processed sediment would then be dewatered and, if the TPH content is at or less than 800 ppm as determined by an agreed upon test protocol, the processed sediments would be returned to the beach. Dewatering produces the low water content necessary to maximize the stability of returned sediments. Excess water and the oil removed, plus a portion of the fine glacial silts that cannot be processed to the 800 ppm TPH level (probably sediments less than 1mm in size), would be separated for eventual disposal.

The most probable mode of operation would have earth moving equipment and conveyor stations on the beach and all other process equipment on a barge off the beach. Another choice would be operation of the entire process on the beach and do away with the necessity of an offshore processing unit. This scenario is unlikely due to the actual size of the components of the process equipment needed for mobility to "follow" excavation equipment as it progresses along the beach and the real possibility of severe weather damage to the processing equipment.

At a minimum, the equipment on the beach would be a couple of backhoes and/or front end loaders and the termination of the belt conveyor systems. The remainder of the rock wash process equipment would be based on a barge. This would eliminate any construction pads (leveled areas to place the process on) on the beach and would reduce the impact to non-oiled beach segments.

Oil/Water/Solids Separation and Quality Control

The separated oil, sludges, contaminated sediments and oily water would be transferred to a tank on a U.S. Coast Guard-certificated petroleum/waste oil tank barge. When full, the barge would be taken to a

nearby shore facility to further process the waste. No secondary concentrating of oily waste is anticipated to be done on-site.

Handling, Transfer, Storage, and Disposal of Waste

All wastes generated would be transported to a land-based facility for treatment, recovery, or further dewatering and concentration. It is anticipated that the oily solid wastes generated by this process would be transported to an approved landfill.

Control of Oil Leaching, Sheens, and Glacial Fines

A double boom will be in place around the beach and the process and waste storage barges to contain sheens and sediment released as a result of the beach excavation. Pads and pompoms can be used to "wipe up" sheens or concentrations of oil.

Backfill and Beach Recontouring

To the extent that the working area allows, and the rate of return of washed material, portions of the excavation could be backfilled during the processing operation. Prior to demobilization at the particular site, the beach would be re-contoured to original conditions as much as possible.

Frequency of Movements of Equipment

Work on the beach will be governed by the weather conditions encountered and the tide cycle. Assuming that the weather is not a factor, it is anticipated that the work day could be anywhere from eight to fourteen hours. Movements by vessels along the beach would be a function of the excavation progress being made. It is anticipated that the repositioning of equipment would be made at high tide and generally once or twice in a 24-hour period. Depending on the availability of suitable waste storage barges and their capacities, movement to the shore processing facility would be made to coincide with demobilization or when the barge is loaded to its design capacity. A possibility exists, due to barge capacities and the amount of waste that might be generated, that in order to continue uninterrupted excavation operations, more than one waste oil barge would be necessary.

Demobilization

On complete excavation and cleaning of a segment and final beach re-contouring, with agreement by concerned parties, the equipment will be moved to the next beach segment targeted for cleaning and the process will begin again. On termination of all cleaning operations, all vessels will either be released from the site or returned to the port of embarkation for final debrief, unloading and cleaning of the process components.

I.B.5. EXPECTED PROCESS AND ANCILLARY EQUIPMENT

<u>Equipment: Purpose</u>	<u>Type/Example/Size</u>
Debris Removal	Frontend loader tracked w/5 yd ³ /bucket
Conveyor(s)	Covered, w/hand cap. up to 24" rock, 100'-120' length
Water Heater/Boiler(s)	@ 65 mbtu, Area: 15' x 40'
Rock Washer	30' x 7' trommel w/supports and 3- stage vibrating screen on 10'x 20' base
Oil/Water/Solids	2 to 4 sand screws 25' length, settling tanks, separation & dewater pumps, sieves, hydroclones, hoses, pipes; Area 140'x 20'
Beach Regrading	Bulldozer, w/gen. purpose blade
Excavation and Washer Feed Loading	Backhoe(s) and front end loader(s) w/4 or 5 cubic yds bucket
Waste Tank Barge(s)	30k-100k bbl capacity approx 50'x 200' dimension
Crane	10-60 ton capacity
Landing Craft(s)	Handle beach excavation equipment, approx. 3 @ 70'x 30'

Equipment: Purpose. cont.

Type/Example/Size

Deck Barge/Liftboat

50'x 200'; house process equipment

Oil Containment Boom-36"

5,000'-10,000'; around process barge and beach excavation area

Generators

Power auxiliary equipment/lights

Support Vessels and Aircraft

Tugboats (Ocean)

(2) @ 1800-5000 hp;
standby/handle/move barge(s)

OSV/Crewboat

150-180'; equipment and
berthing/messing and A/C landing
pad

Workboats

15-25 ft, transportation to and from
beach, boom deployment

Helicopter

Medical evacuation and rapid
transportation

Personnel

20+ pers to run process/excavation;
50+ pers Support/Vsls/Contract/Sup/
Regulatory

Positions. Locations of Process and Ancillary Equipment

Debris Removal

Beach

Excavation

Beach

Conveyor(s)

Beach excavation area to barge and
back

Water Heater/Boiler(s)

Deck barge/liftboat

Rock Washer

Deck barge/liftboat

Oil/Water/Solids

Deck barge/Liftboat (separation & de-
water)

Beach Regrading

Beach

Waste Tank Barge

Seaward of Deck barge/Liftboat

Positions, Locations of Process and Ancillary Equipment, cont.

Crane	Deck barge/OSV
Landing Craft(s)	Alongside OSV/Deck barge
Oil Containment Boom-36"	OSV/Deck barge/Deployed around the work area
Tugboats (Ocean)	Seaward of deck barge
OSV/Crewboat	Seaward of deck barge
Workboats	OSV/Deck barge/Beach
Helicopter	OSV
Personnel	3-7 pers beach; remainder on vsls/barge
Generators	Process barge/beach

I.B.6. OPERATIONS

Equipment Position

It is anticipated that the deck barge (draft approximately six to eight feet) handling the process equipment will be anchored an expected 50-100 feet from the beach to safely support the anticipated draft in the expected sea, wind and current conditions. Other vessels will be anchored or stationed in the immediate vicinity to best support the process. If a lift boat or jack-up barge is utilized, the distance to the beach will be less than 50 feet, with the distance used depending on bottom conditions such as sediment type and slope. See Figure I-2 for a schematic representation.

Beach Progress

Assuming a 12-hour work day with no breakdown and weather considerations and an excavation cross-section of 25 yards and 0.66 yard depth (60 cm) at a rate of 100 cubic yards per hour, progress up the beach would be at a rate of about 6 yards per hour or about 250 feet per day. Equipment would probably be moved every 12- to 24-hour workday. In actuality, allowing for equipment breakdown, maintenance, and weather-affected delays, progress would likely not exceed 100-150 feet per day.

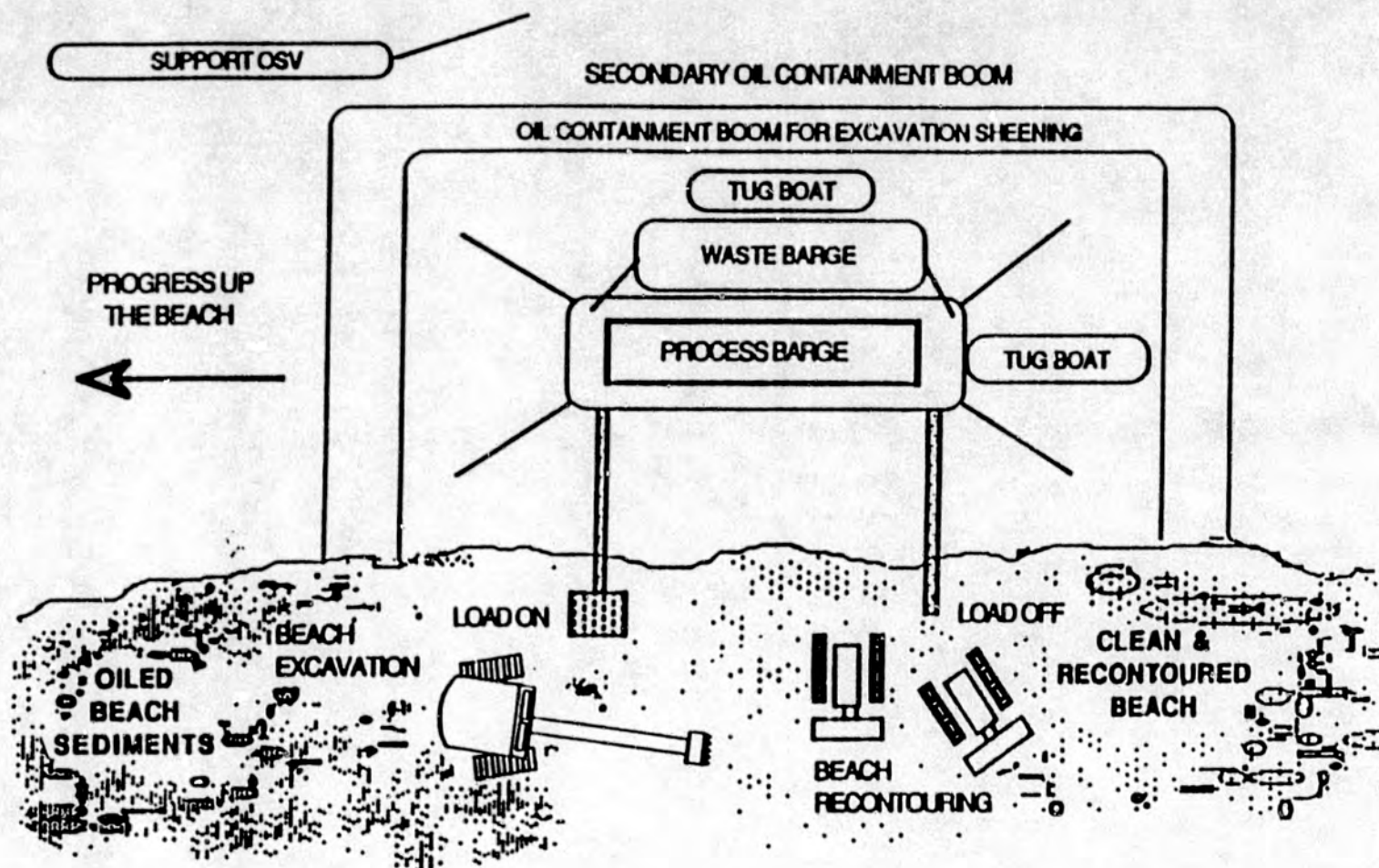


Figure I-2. Beach excavation rock washing project.

Weather Considerations

If the equipment is barge mounted it is anticipated that the weather window would be limited to seas four feet or less and winds less than 20 knots. Barge stability is important for process water clarification purposes and any gravimetric laboratory sampling analysis. A comprehensive heavy weather plan would have to be devised and implemented with contingent "safe anchorages" identified to which the process equipment, waste storage barges, and auxiliary vessels could be moved.

Oil Spill Contingency

Any sheens generated by the excavation process or resulting from handling of oily sediments over water and conveying could be handled with pads and pompoms. However, the concentration of oil in the process water could result in a more significant release through equipment failure.

USCG Marine Safety Office Valdez, Alaska Oil Spill Contingency Plan should be reviewed and implemented as applicable.

State of Alaska Oil Spill Contingency Plan should be reviewed and implemented as applicable.

A comprehensive survey review of the tidal current conditions and bottom composition, contour, and sediment conditions would have to be made to provide for the safe anchoring and navigation of process equipment and all auxiliary vessels.

Secondary Impact: Waste Generation, Air Emissions, Fuel Consumption, and Noise Generation

Machinery involved with the process would produce noise at a level of over 110 decibels (dB). This is a high level of noise that would persist in an operating area during daily work periods of between 8 to 14 hours. At about 1/2 mile away, the perceived noise level would be over 62 dB, well above levels regarded as potentially disturbing to eagles based on 1/4 restrictions for skiffs that produce 90 dB.

It is anticipated that oil/water/sediment wastes will be generated at a rate of up to one barrel per cubic yard of sediment processed. These wastes

will include removed oil, oil sludges, oil/sediment complexes, suspended sediments and water. About one-half gallon per barrel of this waste will constitute removed oil.

These wastes would likely be transported to Valdez, Seward or Whittier ports for treatment (liquids) or for further processing and concentrating for ultimate disposal at a landfill (solids).

Each of these wastes have a potential to impact the environment as a result of spills or accidents causing contamination of beaches, surface waters, soil, and ground water with oil or fine sediment. See Section II.B.6 for a further discussion of potential waste impacts.

Fuel use and air emissions are also significant. For example, if all oiled subsurface sediments at Sleepy Bay were processed, a total of about 400,000 gallons of fuel would be used to run equipment, support vessels, and aircraft, and 300,000 pounds of regulated air pollutants would be emitted over the 4-6 week period required for processing. Waste generation, air emissions, and fuel consumption for Sleepy Bay (LA-16 through LA-20) are illustrated schematically below:

SEDIMENTS EXCAVATED	17,000 cubic yards
Fuel use	400,000 gallons

WASTES GENERATED

Air pollutants	300,000 pounds
Wet skimmed oil	12,000 gallons
Wet, oily solid waste	500,000 gallons
Oily wastewater	168,000 gallons
Processed beach sediment	17,000 cubic yards

LC. DESCRIPTION OF CANDIDATE BEACHES

I.C.1 SELECTION CRITERIA

Using the general criteria outlined above, members of the NEBA Committee developed a list of candidate beaches. The list was compiled using:

- 1) the SSAT database and search criteria on oil type, thickness, and depth;
- 2) the Alaska Department of Environmental Conservation (ADEC) beach profile database; and
- 3) personal observations of the committee members.

It was agreed that Point Helen and Sleepy Bay were the best candidates for the exposed outer beaches and moderate-energy shoreline with variable substrate, respectively (Figure I-3). Specific parts of each area were identified as study areas. However, the initial segment selected for the candidate for the sheltered, pocket beach, KN500, was subsequently rejected because of the presence of an active eagle nest at the site, which restricted all approaches. It was very important that the committee members be able to survey each site with rock washing issues in mind, so another candidate for the sheltered beach type was sought. Several recommended sites were evaluated and none was found to be adequate. After two weeks of effort to identify and field-check sites, it was decided to proceed with only two sites. During the two-week period, 22 sites were suggested, with none of them selected as an appropriate candidate site for the purposes of this study. Table I-1 lists the sites considered for the sheltered pocket beach candidate site (by segment number), the team who inspected or researched the site, and the reason for rejection. It should be noted that rejection of a site as a candidate beach for this study does not necessarily mean that it is not an appropriate site for rock washing.

In the following sections, each of the two candidate beaches is described in detail.

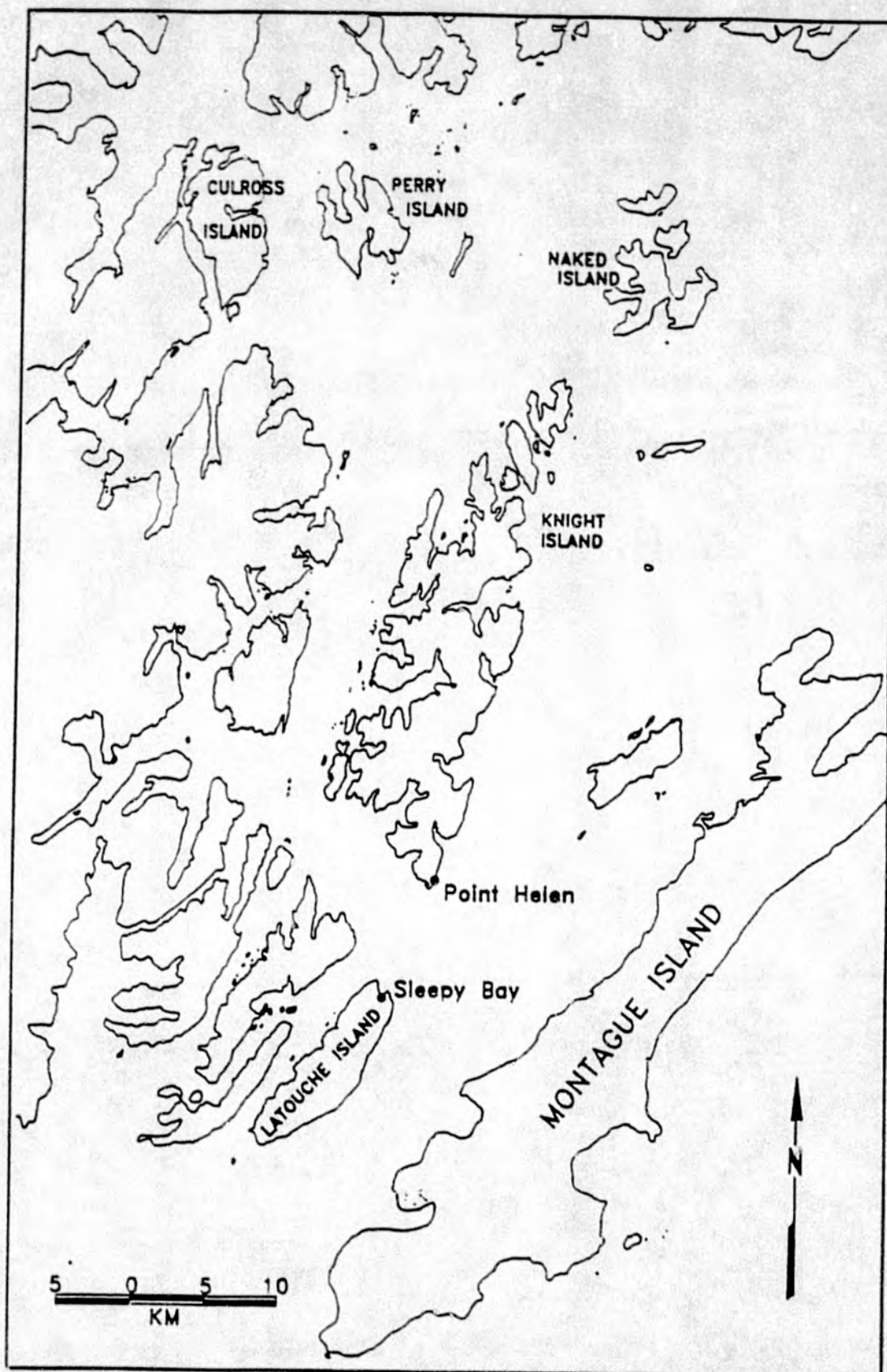


Figure I-3. Location map showing the two candidate beaches at Sleepy Bay and Point Helen.

Table I-1
 Sites Considered for Inclusion as a Candidate Beach
 Representative of the Sheltered Pocket Beach Type for Rock Washing

<u>Site</u>	<u>Rejected By</u>	<u>Reason for Rejection</u>
AE-05	NOAA	Substrate
BP-16 (Marsh Lagoon)	Exxon	Lack of access
CR-05	NOAA	Shallow peat substrate
DI-62	ADNR	Lack of access
DI-67	ADNR	Insufficient oil
EB-11	Consensus	Insufficient oil
EL-10	NOAA	Unapplicable substrate
ER-20	Exxon	Eagle restriction
EL-56	NOAA	Insufficient oil
IN-20	Consensus	Insufficient oil
IN-22	Consensus	Applicable area very small; peat layer limits penetration
KN-113	Consensus	Insufficient oil
KN-121	Consensus	Lack of access
KN-132	NOAA	Unapplicable substrate
KN-134	NOAA	Oil not deep enough
KN-135	Consensus	Lack of oil penetration
KN-211	Consensus	Insufficient oil
KN-213	Exxon	High energy site
KN-500	Consensus	Eagle restriction
LA-17	Consensus	Not low energy
PR-16	Consensus	High/moderate energy Eagle restriction
SP-19	Consensus	Very small beach; limited depth, good bioremediation site

I.C.2. GEOMORPHOLOGY

Point Helen

Introduction. This beach is located on one of the more exposed sites in Prince William Sound. Consequently, it contains abundant coarse material—pebbles, cobbles and boulders—that shows signs of frequent transport by wave-generated currents (i.e., rounding and sorting). Due to uplift in the area on the order of 8 feet during the 1964 earthquake, the beach has not completely readjusted to an equilibrium profile. The specific part of Point Helen used as the candidate beach was 100m to the south and 200m to the north of NOAA Station N-1. Exxon's stations AP-9 and AP-10 are north and south, respectively, of the candidate beach section.

The Beach Profile. The field sketch in Figure I-4 and the profile in Figure I-5 show the morphology of the beach at Point Helen at NOAA's station N-1 on 24 May 1990, which is typical of the entire beach area under consideration in this report. There are three morphologically distinct components of the profile:

1) High-Tide Berms

The upper ± 10 m of the profile was host to a series of migrating spring-tide and storm berms between September 1989 and May 1990, as shown by data collected during NOAA's winter monitoring program (Advanced Technology, Inc. and Continental Shelf Associates, Inc., 1990). The finest surficial materials occurring on the beach (down to pebble size) are found in this area.

2) Stable Central Ramp

A cobble to boulder armor has formed over the surface of this central (10-25m) portion of the profile, which has shown almost no change over the past 9 months. The ratio of boulders to cobbles increases in a seaward direction.

3) Low-Tide Bar Zone

This zone, which extends from 25m to the low spring tide line (± 60 m), periodically contains asymmetric bars built by wave action called swash bars. These bars, which characteristically migrate toward the south, may attain heights up to 40 cm, as shown by the survey on

PROFILE N-1 LOCATION Point Helen, Knight Is. PWS, AK DATE 24 May 1990
 RECORDERS MOH, TM, DN PHOTOGRAPHS MOH (SMN-1C 40-2433; SMN-3E1-12); DN (DM-1 (1-113)) TIME 0923
 TIDE STAGE LOW WEATHER clear; 60° WIND SPEED CALM WIND DIRECTION _____
 PROFILE ANGLE 106° (true) WAVE HT. CALM SAMPLES TAKEN: BIO _____ CHEM _____ SED _____
 SEDIMENT TYPE B/C/P

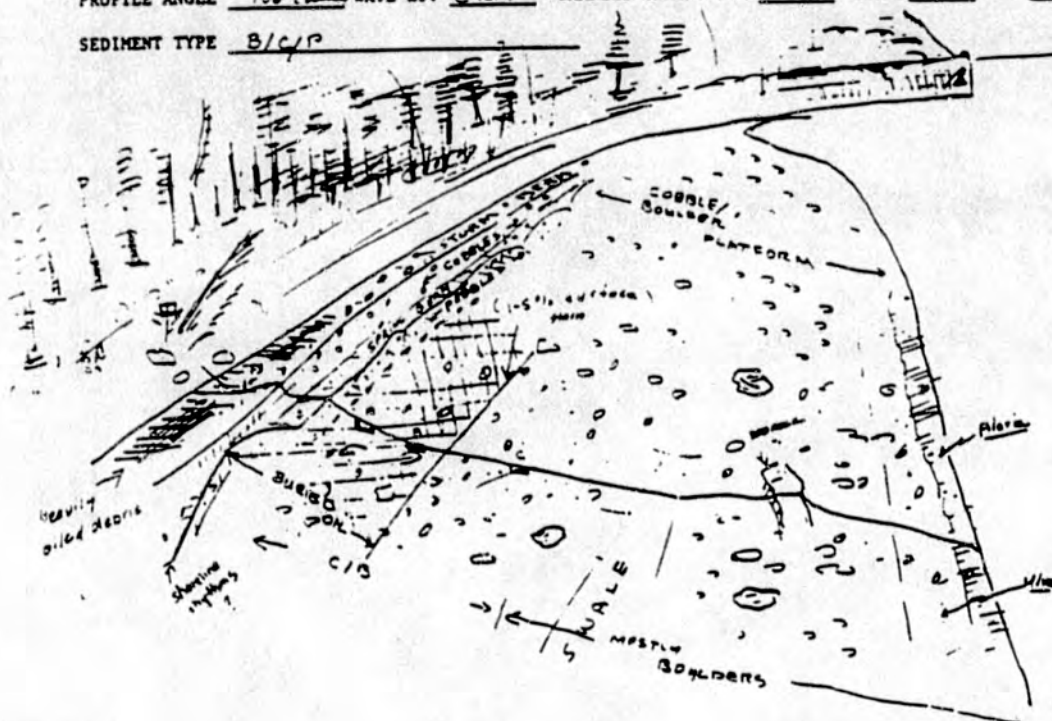


Figure I-4. Beach sketch of NOAA's station N-1 at Point Helen at low tide on 24 May, 1990. Note presence of storm and spring-tide berms near high-water mark and bedrock outcrop in lower portion of the profile. Buried oil occurs on the upper quarter of the beach.

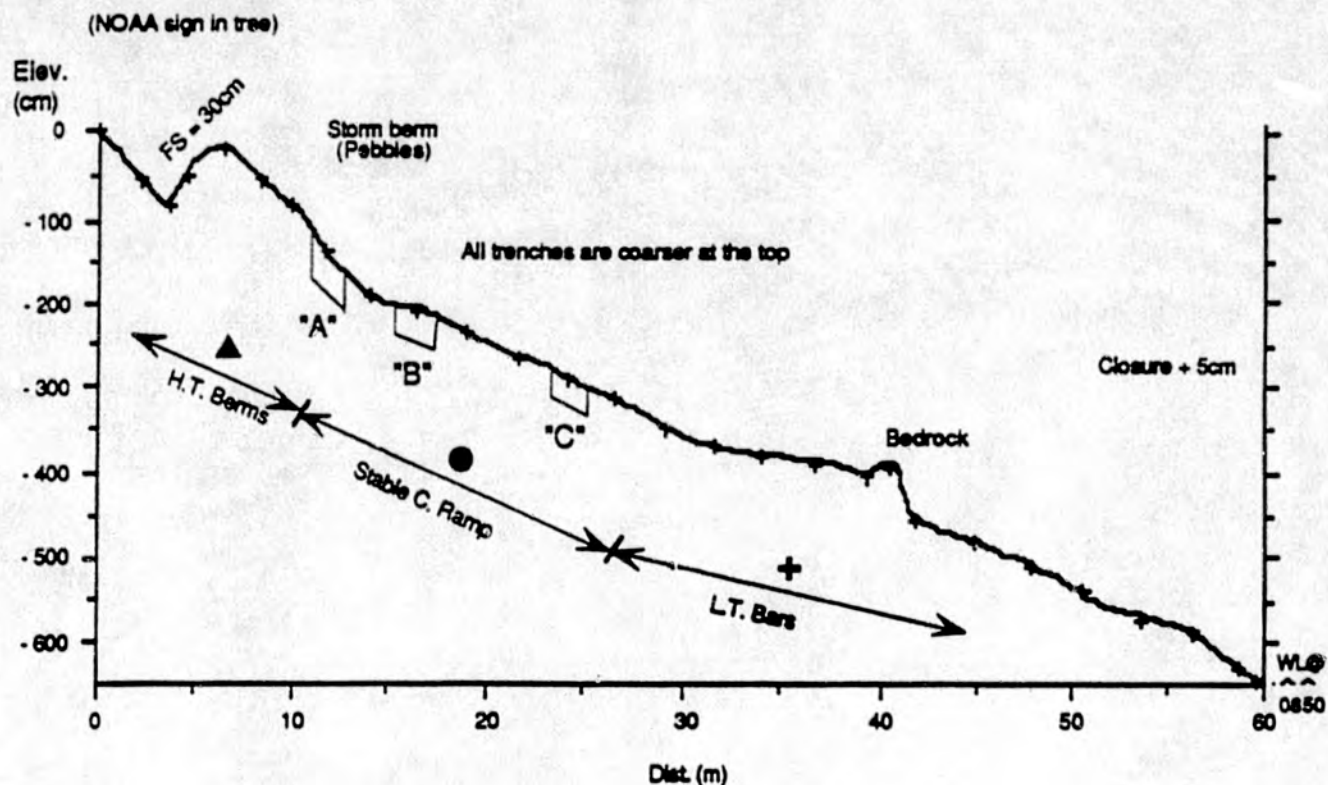


Figure 1-5. Beach profile at NOAA's station N-1 at Point Helen that was measured at low tide on 24 May, 1990. The beach is classified morphologically into three zones: (1) high-tide berms, an area subject to fluctuations of berm levels during storms and spring tides; (2) stable central ramp, bypass zone with an armor of cobbles and boulders; and (3) low-tide bars, boulder/cobble zone that sometimes contains gravel swash bars.

1 February 1990. The surface material is mostly boulders, but patches of bedrock also occur within this zone (Figs. I-4 and I-5).

Composition and Grain Size of Beach Clasts. - The pebbles, cobbles and boulders of Point Helen are no doubt derived locally, probably from outcrops exposed along the shoreline to the north. They are quite hard and do not crumble readily. The composition of the clasts is variable, with the following possibilities (in decreasing order of abundance):

- 1) Slightly metamorphosed deep-water sandstones.
- 2) Dark gray-black or reddish-brown hard siltstone and argillite.
- 3) Miscellaneous basaltic lava, metamorphosed conglomerate, and others.

NOAA's field team measured the detailed distribution of grain size along profile N-1, which is representative of the entire Point Helen area, on 24 May 1990. Careful estimates were made of relative abundance of clast type - pebbles (P), cobbles (C), boulders (B), and granule/sand (G/S) - at 25 evenly-spaced intervals along the profile. These results were plotted on the ternary diagram shown in Figure I-6. The distribution of clast sizes on the surface of the profile is shown on the map in Figure I-7. These diagrams indicate that the surface clasts of the high-tide berms are mixtures of cobbles and pebbles, the stable central ramp has a surface armor of cobbles and boulders, with cobbles predominating, and the low-tide bar zone is dominated by boulders, with cobbles typically making up 25-30% of the total.

Over the winter monitoring period, fourteen trenches were dug and described on this profile. Three were dug on 24 May 1990, and their descriptions are given in Figure I-8. These descriptions show that, in every case, an armor of coarse material overlies fine material at depth. The plot of the estimated grain sizes of the trench sediments on the ternary diagram in Figure I-9 emphasizes further the finer-grained nature of the deeper sediments (compare with Figure I-6).

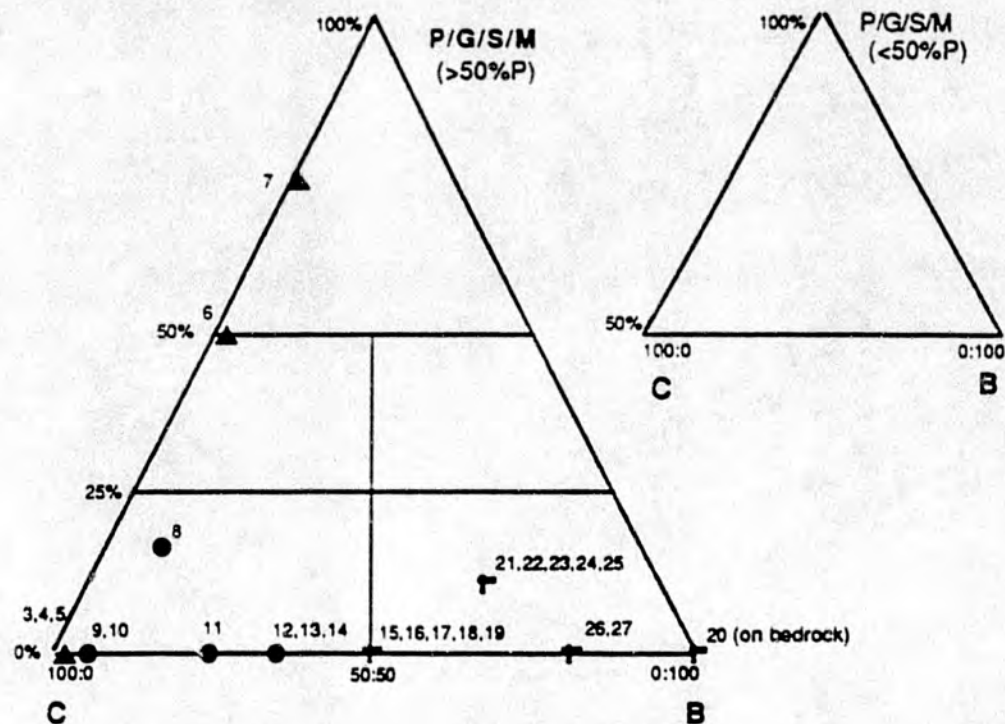
With regard to the rock-washing scenario, only the sediments in the zone between 12 and 21 m would be of interest, because that is where the buried oil occurs (see Figure I-10). The surface layer of sediments in that zone average: 6% B; 74% C; and 20% P. However, the subsurface

ZONAL GRAIN SIZE DESCRIPTION

PROFILE: N-1
DATE: 24 MAY '90

LOCATION: POINT HELEN

X PROFILE STATIONS -OR-
— TRENCH DESCRIPTIONS



	PROCESS ZONES	PROFILE INTERVALS
▲	High-Tide Berms	3 - 8
●	Stable Central Ramp	9 - 15
⬮	Low-Tide Bars	16 - 27

NOTES FOR VERBAL DESCRIPTION:

- ▲: Cobble storm berm with welded pebble spring berm.
- : Cobble ramp, becomes increasingly boulder-bearing seaward.
- ⬮: Boulder platform, cobbly and pebbly, no relief in May but showing swash bar development earlier (e.g., Dec. '89 to Feb. '90).

Figure I-6. Plot of 25 estimates of grain size of surface sediments along NOAA's profile N-1 on 24 May 1990, with respect to relative amounts of boulders (B), cobbles (C), pebbles (P), granule (Gr), sand (S), and mud (M). The beach zones within which the estimates were made are indicated by symbols (▲, ●, ⬮) and the numbers by the symbol represents the profile intervals at which the estimate was made. Profile intervals were usually 1.5-2.0 m apart. Note the clear segregation of size by beach zone, with a distinct increase in grain size in a seaward direction.

N - 1 Point Helen
Surface Grain-size Distribution
24 May 1990

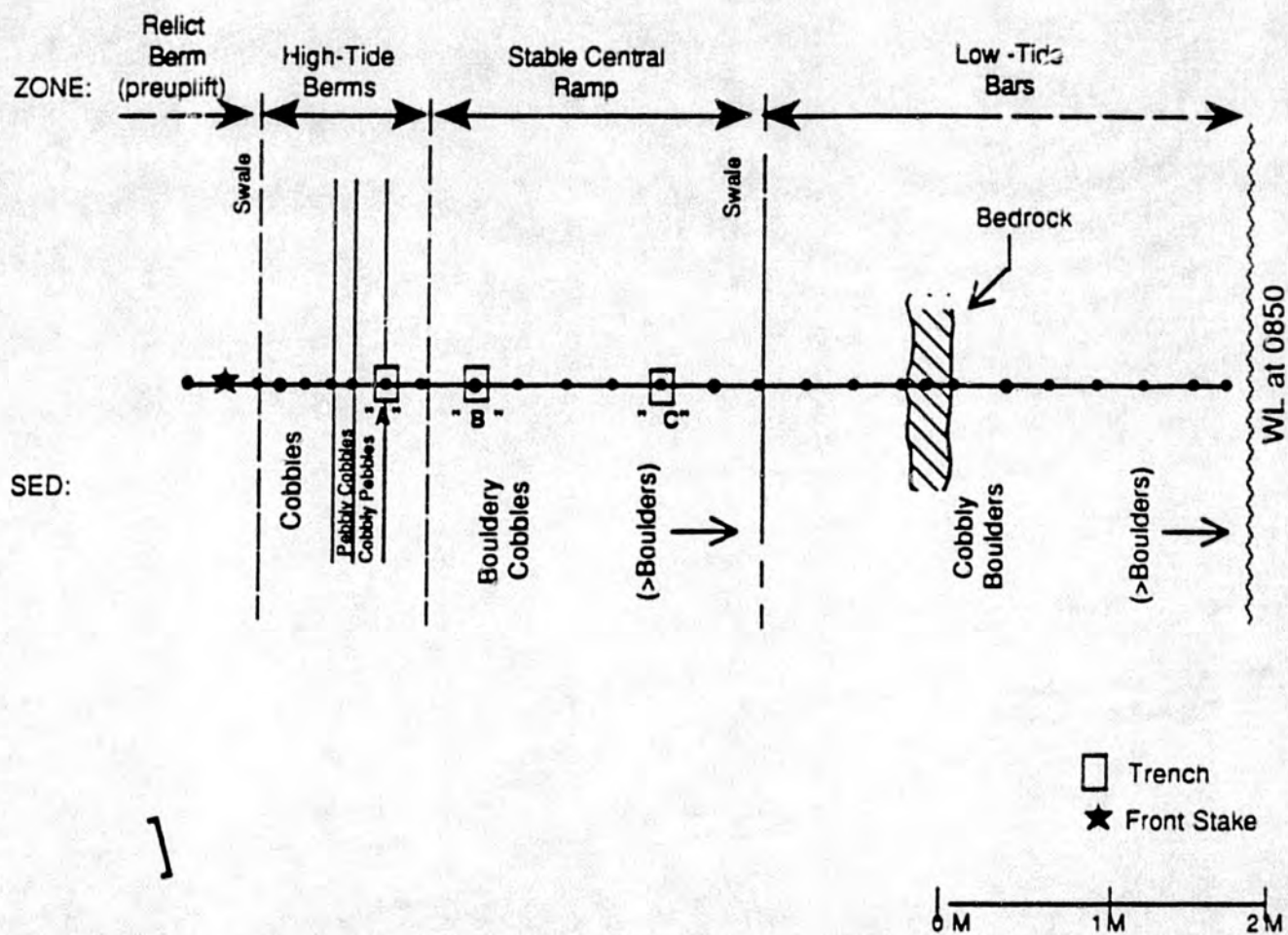
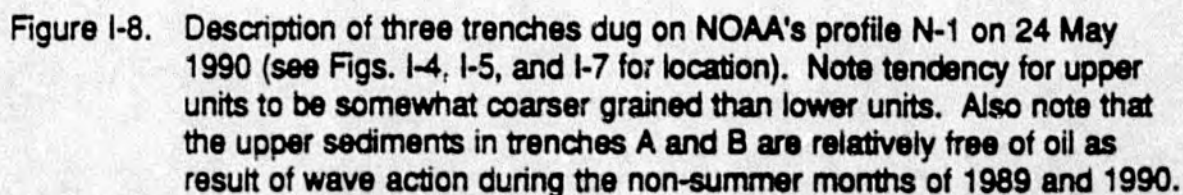


Figure I-7. Distribution of grain size of surface sediments adjacent to NOAA's profile N-1 on 24 May 1990. Dots along profile line indicate points where grain size estimates were made.

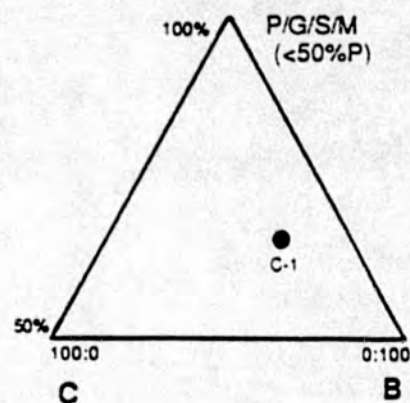
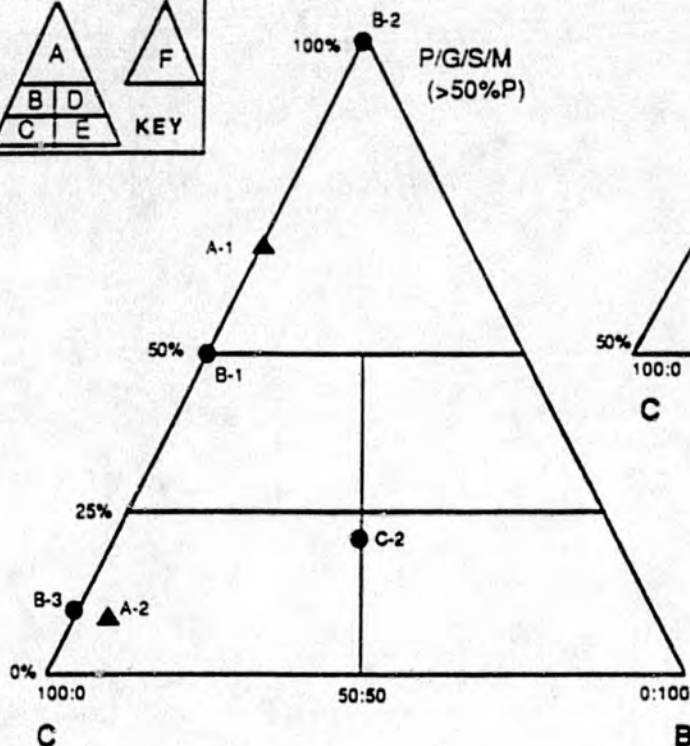
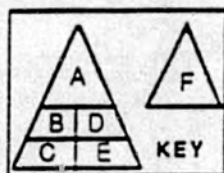


ZONAL GRAIN SIZE DESCRIPTON

PROFILE: N-1
DATE: 24 MAY '90

LOCATION: PT. HELEN

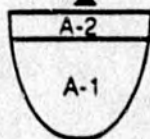
— PROFILE STATIONS -OR-
X TRENCH DESCRIPTIONS



	PROCESS ZONES	TRENCH
▲	High-Tide Berms	"A"
●	Stable Central Ramp	"B" & "C"
⊕	Low-Tide Bars	

NOTES FOR VERBAL DESCRIPTION:

"A"



"B"



"C"

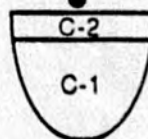


Figure I-9. Plot of grain size estimates for sediments from the trenches described in Figure I-8. These sediments are generally finer than the surface sediments for the entire profile (compare with Fig. I-6).

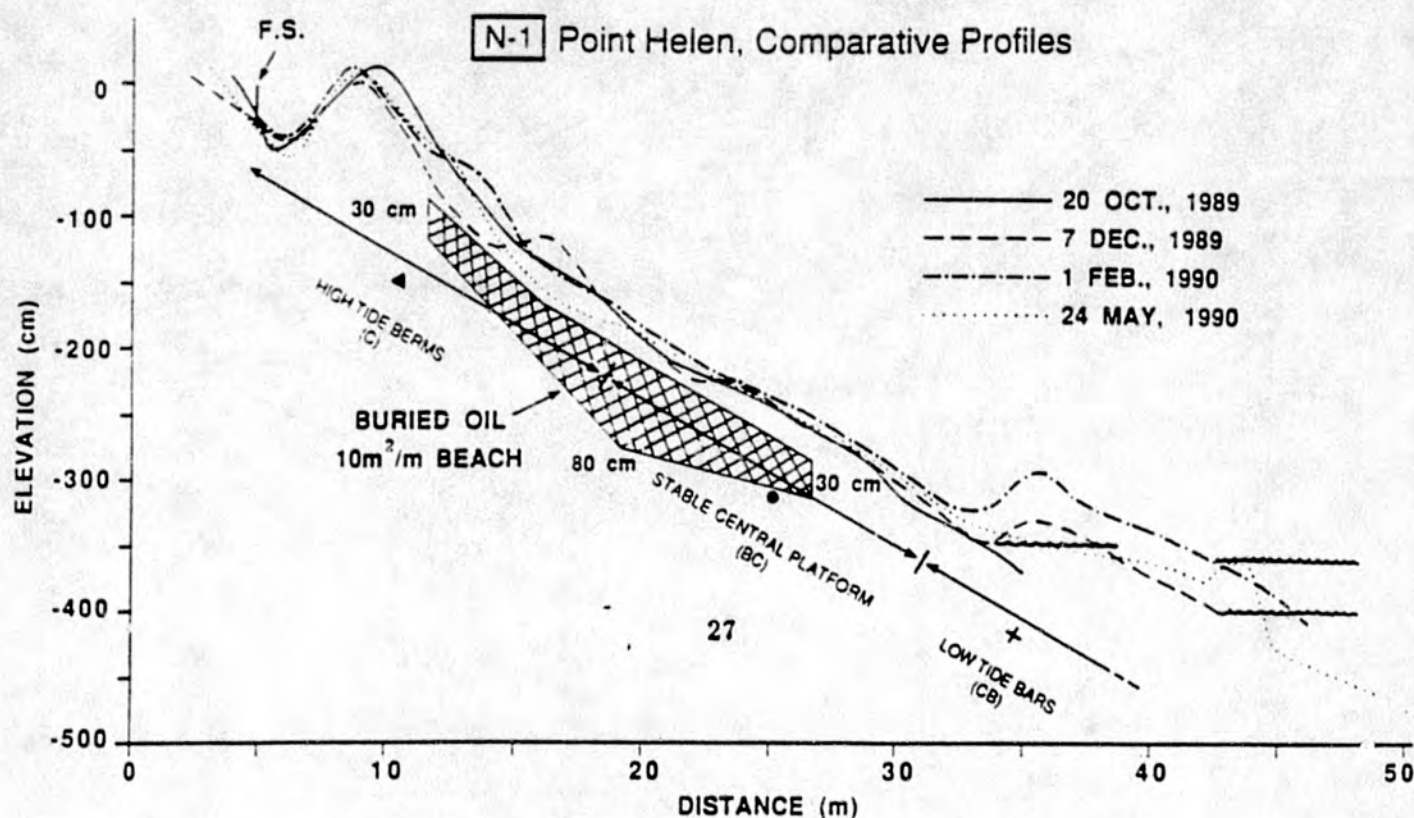


Figure I-10. Beach changes and buried oil at NOAA's profile N-1 at Point Helen. The plot of four profiles measured during the fall-winter-spring interval of 1989-90 reflects the morphological signature of the three designated beach zones: (1) migrating berms in the upper zone; (2) relative stability in the central zone; and (3) migrating bars in the lower zone.

sediments described in the trenches are considerably finer: 1% B; 58% C; and 41% P. If one assumes that in the rock washing process five times more material would be derived from the subsurface than from the surface, the sediments to be washed at Point Helen would have the following grain size:

<u>Sediment Type</u>	<u>Percent</u>	<u>Average Size</u>
Boulders	2	40 cm
Cobbles	61	13 cm
Pebbles	30	2 cm
Granule/Sand*	7	3 mm

Energy Level and Beach Dynamics. - This beach is exposed to the east, the direction from which the dominant winds blew during storms in the fall-winter-spring period of 1989-90, according to data gathered at NOAA's meteorological stations at Lone Tree and Danger islands. The effective fetch distance ranges from 15-20 km in a due easterly direction up to 45-50 km to the NNE. No seasonal measurements of wave or current conditions are available for the site.

As implied above, there is a significant amount of clast transport on this beach on a seasonal basis. The four seasonal profiles plotted on Figure I-10 illustrate the migration of berms in the high-tide portion of the beach and the presence of intermittent swash bars in the low-tide section (see photo in Figure I-11). Apparently, the stable central platform is a zone where finer clasts bypass over the coarse-grained surficial armor without disrupting it.

Sleepy Bay

Introduction. This gravel beach is located at the head of Sleepy Bay, an embayment on the north end of Latouche Island. It is similar to Point Helen in overall morphology, but the grain size of the mobile sediment is

* We assumed that the sediments designated P had a 20% matrix of granule/sand.

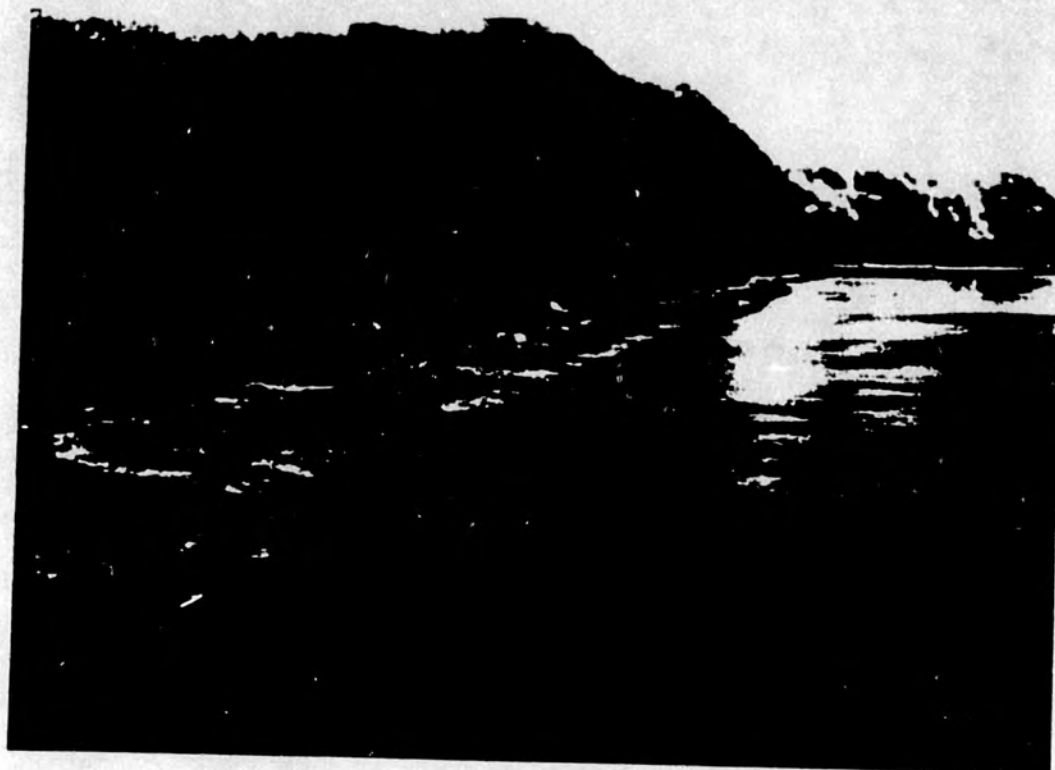


Figure I-11. Point Helen at low tide on 5 January, 1990. Note the presence of gravel swash bars in the intertidal zone that were obviously migrating in a southerly direction.

somewhat smaller because of its more sheltered location. The area of interest is bisected by a small, anadromous stream that is constantly shifting position as it builds a small delta. Due to uplift in the area on the order of 8-10 feet during the 1964 earthquake, the beach has not completely readjusted to an equilibrium profile. The specific area used as the candidate beach is shown in Figure I-12. This area includes NOAA's station N-18 and Exxon's station AP-13.

The Beach Profile. As shown on the map in Figure I-13, the NOAA team surveyed three profiles at the study site in May 1990. In addition, NOAA's permanent station N-18 was surveyed seven times between September 1989 and May 1990.

Exxon and ADEC also had a number of permanent profile sites in this area; thus, the dynamic changes of the profile of the beaches at this site are well documented.

NOAA's profile N-18, illustrated in Figures I-14 and I-15, serves as a basis for the following description:

1) High-Tide Berms

The upper $\pm 10\text{m}$ of the profile typically consists of a number of storm and spring-tide berms, composed mostly of pebbles and cobbles. The berms at the top of the beach were deposited after the beach was flattened during a period of large waves and high tides in October 1989.

2) Stable Central Ramp

Just as at Point Helen, the central portion of the profile has shown little change over the fall-winter-spring interval of 1989-90, except for possibly a small degree of overall lowering. Mixtures of cobbles and pebbles, oriented in bands parallel with the shoreline, cover the entire surface of this zone.

3) Low-Tide Bars

Swash bars showing a range in grain size from sand to cobbles have been observed on the lower portion of the beaches in this area during both the Exxon and NOAA surveys. Many of these bars were associated with the delta at the stream mouth.

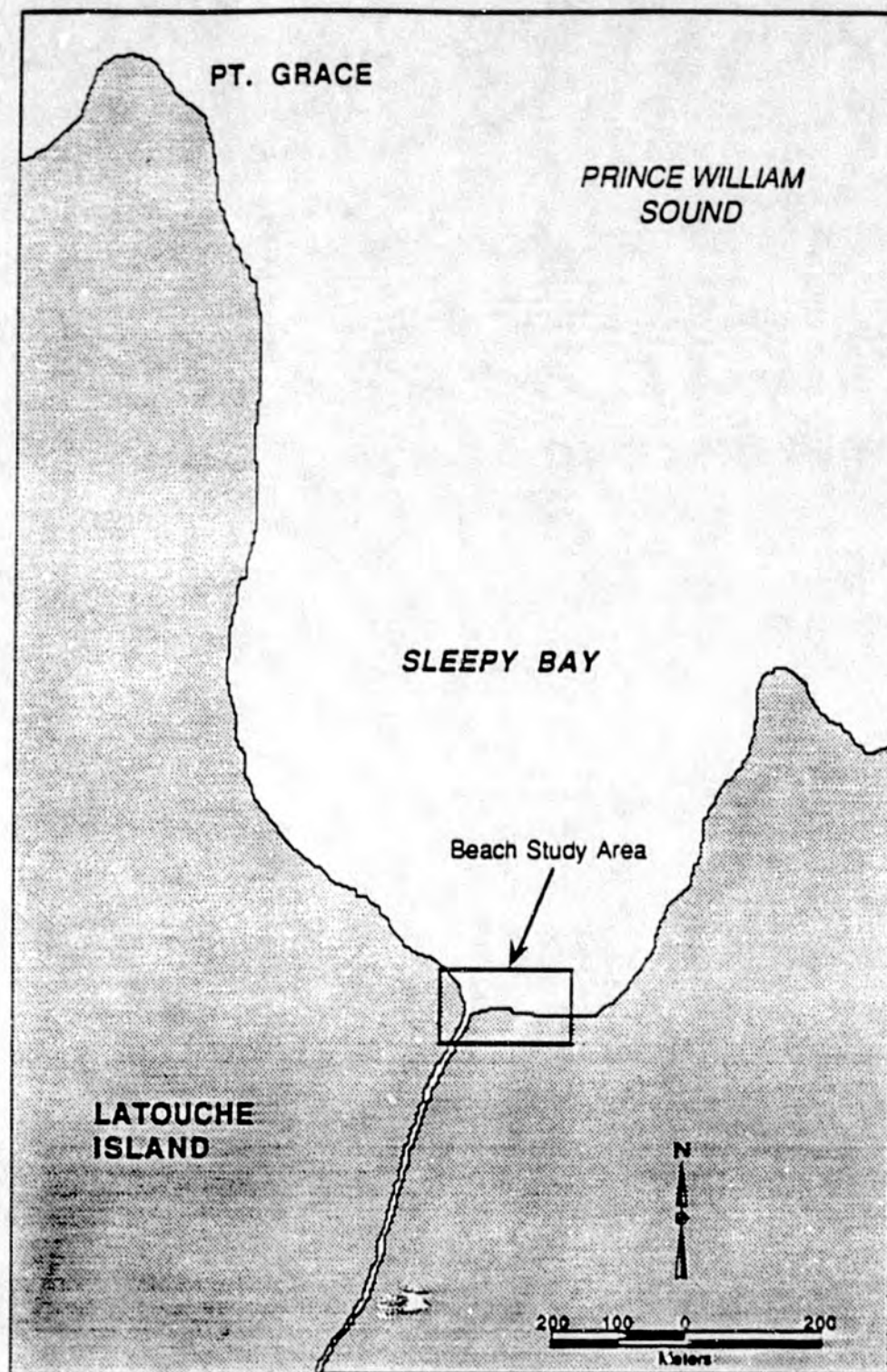


Figure I-12. Map of Sleepy Bay showing the location of the specific section of Sleepy Bay used as a candidate beach for this analysis.

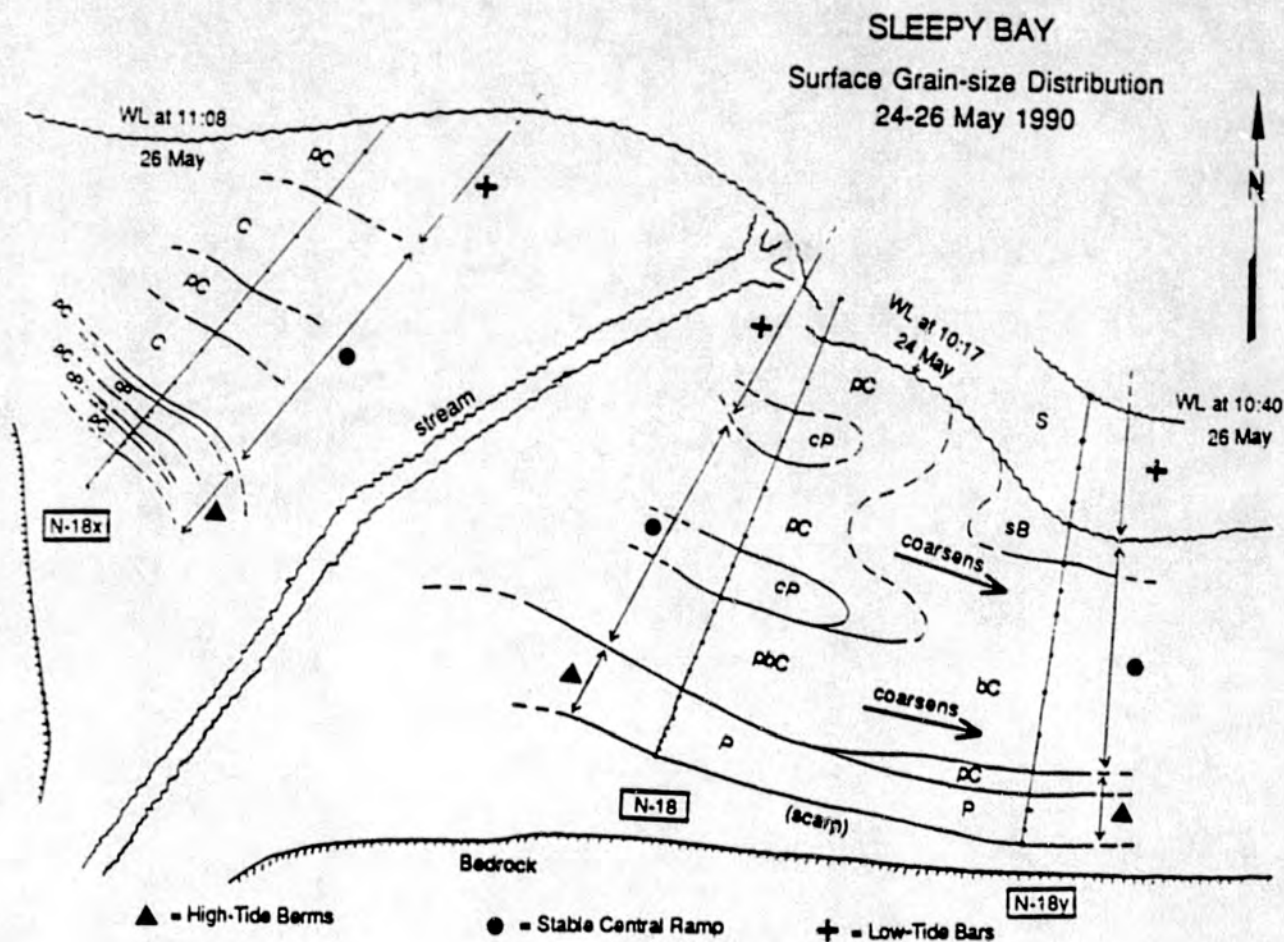


Figure I-13. Surface sediment distribution map at the head of Sleepy Bay on 24-26 May, 1990. Map is based on grain size estimates made along three beach profiles established by NOAA (N-18; N-18x; N-18y). The sediments are mostly parallel bands of different mixtures of pebbles and cobbles. The river mouth migrates constantly, thus these patterns will change in the future.

[illegible]

33

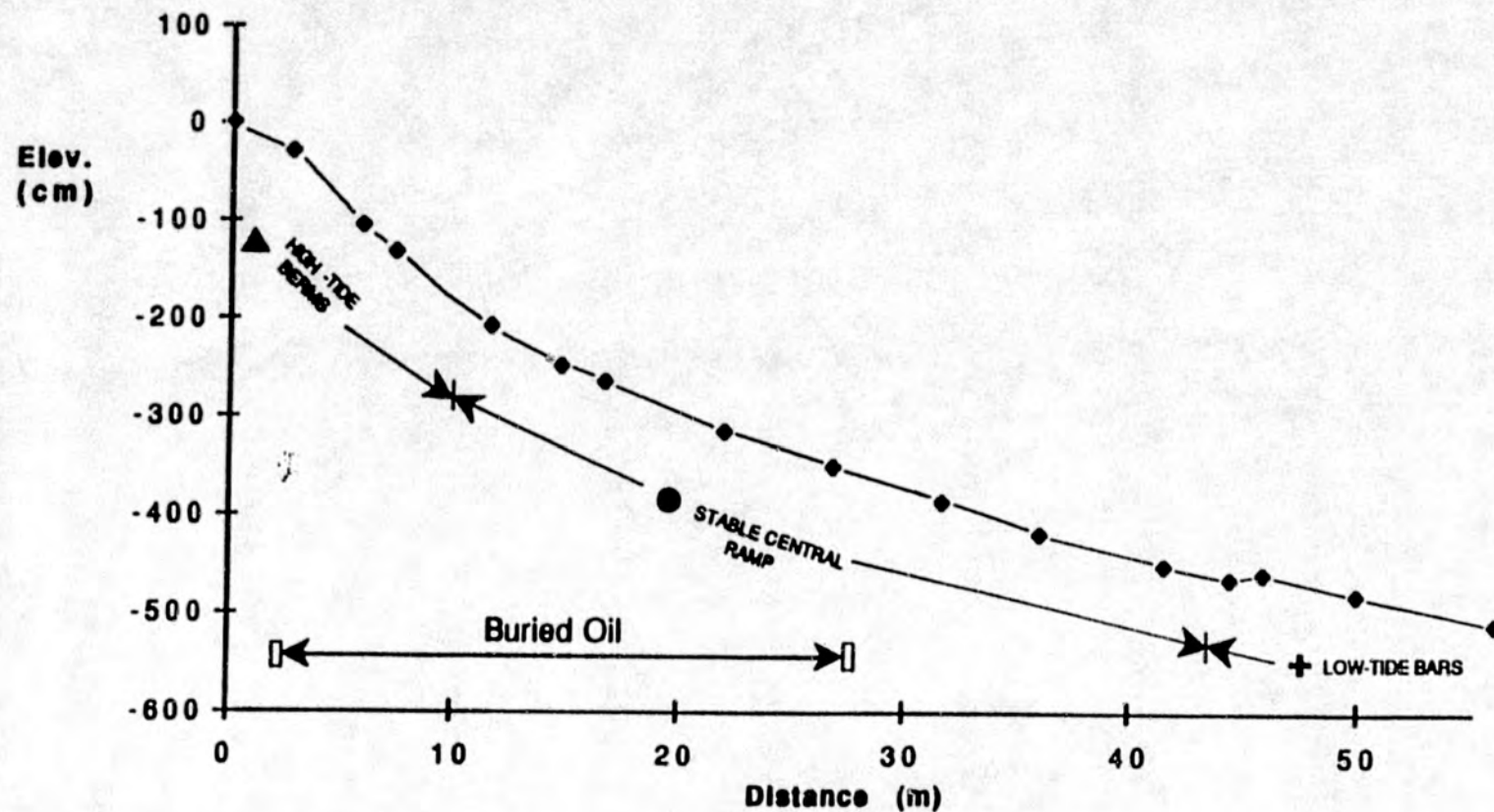


Figure I-15. Plot of NOAA's beach profile N-18 as it appeared on 1 February, 1990. During the fall-winter-spring of 1989-1990, the upper part of the profile was host to multiple migrating berms, the central part was relatively stable, and the lower part contained swash bars from time to time, some of which were associated with the river delta.

Composition and Grain Size of Beach Clasts. The sediments on the beaches at the head of Sleepy Bay are derived from two sources: (1) the rocky headlands located within and to either side of the bay; and (2) the stream and its delta. The coarse clasts, which are quite hard and resistant to breakage, have the same wide variety of composition that is present at the Point Helen site. Dark-colored metamorphosed sandstone, shale, and basaltic lava are common, as well as several other rock types.

A map of the distribution of grain size of the surficial beach materials at the head of Sleepy Bay is presented in Figure I-13. Note that most of the surficial sediments at the site are composed of pebbles and cobbles. Boulders are rare, except to the east of profile N-18y. A plot of 26 grain size estimates for the surficial sediments along NOAA's profile N-18 is given on the ternary diagram in Figure I-16.

Over 30 trenches have been dug by the NOAA team at this site. Two typical trenches from the oiled sector that were dug on 24 May 1990 are shown in Figure I-17. Armoring is relatively poorly developed at this site compared to many others in the Sound, the sediments at depth being only slightly finer than the surface layer (except for the absence of boulders at depth). This probably is a function of the finer-grained, more mobile character of the sediment. However, this beach sediment was mixed significantly during cleanup last summer, and it is possible that there has not been enough time for the armoring process to have matured.

If rock washing were to be carried out at this site, the focus would be on the buried oil, which is located between 3-28m along the profile. The surface layer of sediments in that zone average: 9% B; 40% C; 49% P; and 2% G/S. However, the subsurface sediments described in the trenches are somewhat finer: 1% B; 26% C; and 73% P. If one assumes that in the rock washing process five times more material would be derived from the subsurface than from the surface, the sediments to be washed at Sleepy Bay would have the following grain size:

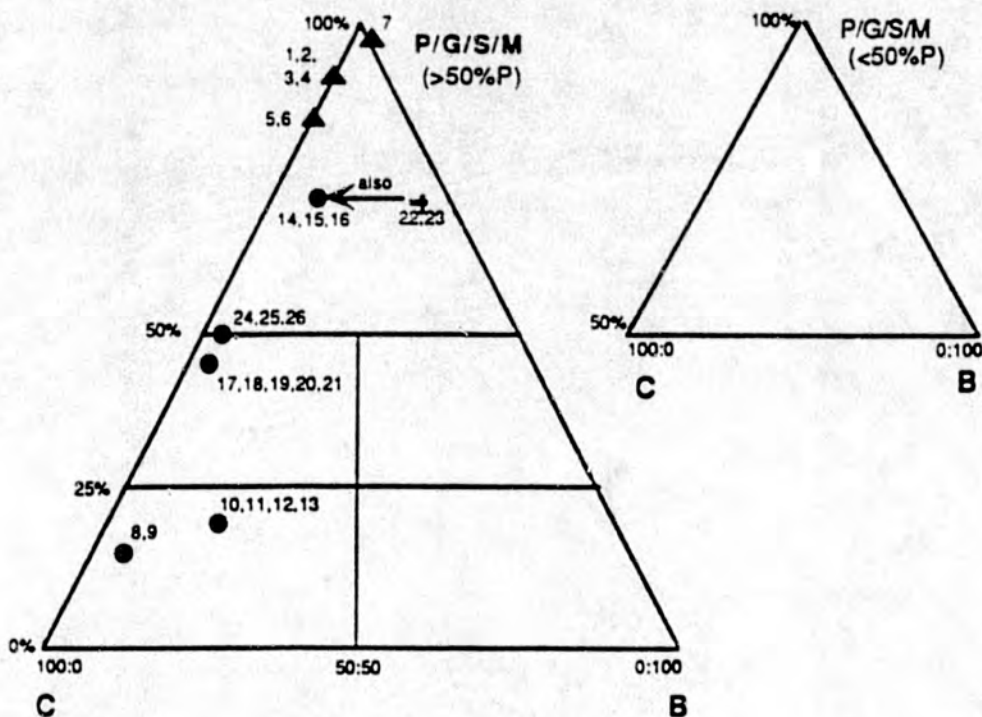
ZONAL GRAIN SIZE DESCRIPTOR

PROFILE: N-18

LOCATION: Sleepy Bay

DATE: 24 MAY '90

X PROFILE STATIONS -OR-
— TRENCH DESCRIPTIONS



NOTES FOR VERBAL DESCRIPTION:

▲: Pebble berm.

●: Pebbly cobbles alternating with muddy pebbles; some boulders, especially higher on ramp.

⇌: Pebbly swash bar over pebbly cobbles.

Figure I-16. Plot of estimates of the grain size of the surface sediments at 26 intervals along NOAA's profile N-18 on 24 May 1990. Note that mixtures of pebbles and cobbles predominate.

SITE N-18

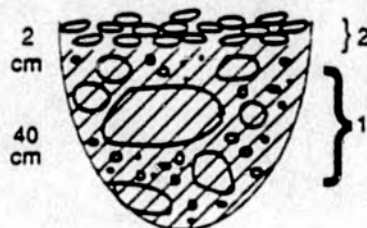
Sleepy Bay, 24 MAY 1990



oil bearing sediments

TRENCH "B"

Photo 31



Ut. 2 70 P, 30 Gr V. discoidal

Ut. 1 5B, 40 C, 40 P, 15 Gr

Ut. 1 Coated with med. brn. mouse, not saturated

Ut. 2 clean

scattered spruce needles in Ut. 1.

TRENCH "C"

Photo 32



Ut. 3 50C, 50P clean

Ut. 2 50P, 40Gr, 10S clean, P's mostly <2cm

Ut. 1 10C, 50P, 40Gr mousse

V. dk. brn. mousse coating in Ut. 1, not saturated

Figure I-17. Description of sediments in two trenches dug on NOAA's profile N-18 on 24 May 1990. See Figure I-14 for location. Surface armoring is not as well developed in these trenches as it is elsewhere in Prince William Sound.

sediments described in the trenches are considerably finer: 1% B; 58% C; and 41% P. If one assumes that in the rock washing process five times more material would be derived from the subsurface than from the surface, the sediments to be washed at Point Helen would have the following grain size:

<u>Sediment Type</u>	<u>Percent</u>	<u>Average Size</u>
Boulders	2	40cm
Cobbles	61	13cm
Pebbles	30	2cm
Granule/Sand*	7	3mm

Energy Level and Beach Dynamics. - This beach is exposed to the east, the direction from which the dominant winds blew during storms in the fall-winter-spring period of 1989-90, according to data gathered at NOAA's meteorological stations at Lone Tree and Danger islands. The effective fetch distance ranges from 15-20 km in a due easterly direction up to 45-50 km to the NNE. No seasonal measurements of wave or current conditions are available for the site.

As implied above, there is a significant amount of clast transport on this beach on a seasonal basis. The four seasonal profiles plotted on Figure I-10 illustrate the migration of berms in the high-tide portion of the beach and the presence of intermittent swash bars in the low-tide section (see photo in Figure I-11). Apparently, the stable central platform is a zone where finer clasts bypass over the coarse-grained surficial armor without disrupting it.

Sleepy Bay

Introduction. This gravel beach is located at the head of Sleepy Bay, an embayment on the north end of Latouche Island. It is similar to Point Helen in overall morphology, but the grain size of the mobile sediment is

* We assumed that the sediments designated P had a 20% matrix of granule/sand.

I.C.3. SEDIMENT OIL CONTENT AND COMPOSITION OF CANDIDATE BEACHES

Point Helen - Oil Content

There are several sources of data on the oil content of sediments along Point Helen. NOAA has a monitoring station about 1,500 meters north of the point. This station was occupied monthly from September 1989 to February 1990, and in May 1990. During these surveys, 37 sediment samples were collected and analyzed for TPH by both weight and volume. The measured concentrations of oil in these samples should be reviewed with caution because the substrate is very heterogeneous in both size and oil content. The samples represent only the finer-grained components since only sediment pebble-sized and smaller can fit into the sampling containers. Because the mass of these large-grained sediments is so large compared to their surface area, the traditional measure of oil contamination in milligrams per kilogram (mg/kg) by weight is not very meaningful. Measuring the oil content of the sediments by volume is a better approach, but it still suffers from disturbance of the sediment packing (thus volume) and poor representation of the entire substrate.

Figures I-18 through I-20 show the sediment analyses for samples collected along the NOAA monitoring beach profile at Point Helen for each month. The values shown are TPH by weight. The values shown on the profile line are surface samples; the samples shown below the line are placed at the depth of sampling. Although there are wide variations, several distinct trends are discernable. The oil was heaviest along the upper one-third of the intertidal zone, covering a width of about 12m. The remainder of the intertidal zone had concentrations in the 100-200 mg/kg range. The oil content of the surface sediments, down to about 30cm, was significantly reduced after September, with all samples except one below 300 mg/kg. Visually, the surface sediments at Point Helen appeared cleaner after the first few fall storms. Surface oil remains as a stain on the cobbles and boulders with heavier coating on the back side of boulders sheltered from waves.

The degree of oil contamination of the subsurface sediments has also visually improved. In the fall, sediments in trenches were described as

Station N-1

Δ Oil Conc. (mg/kg)

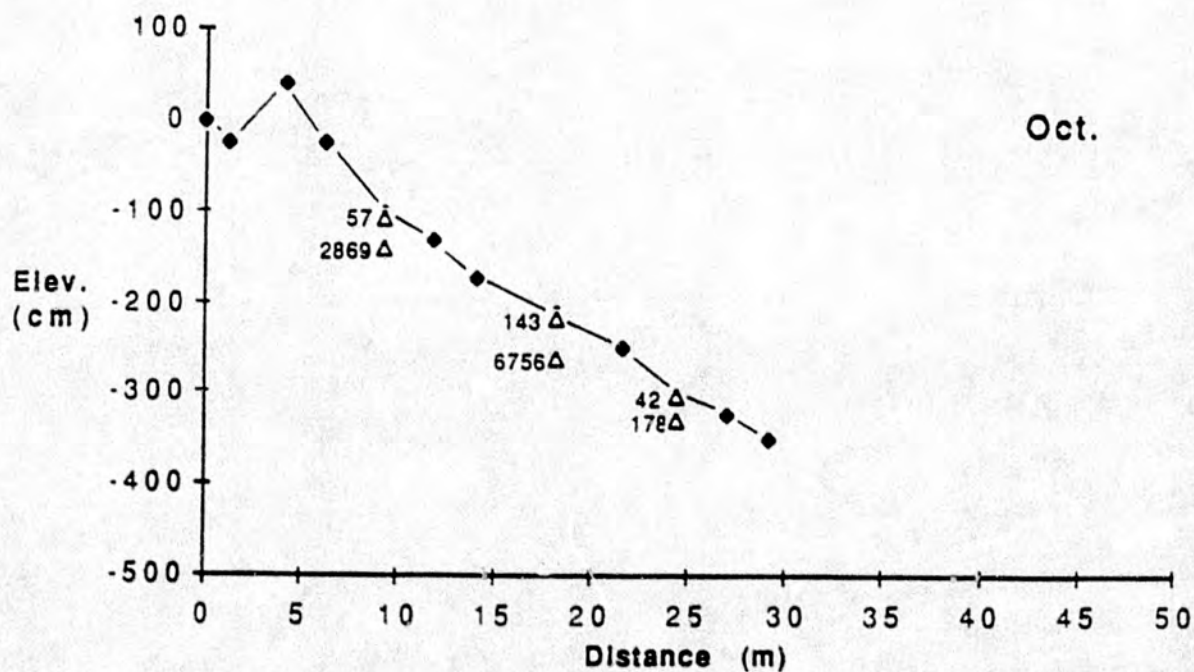
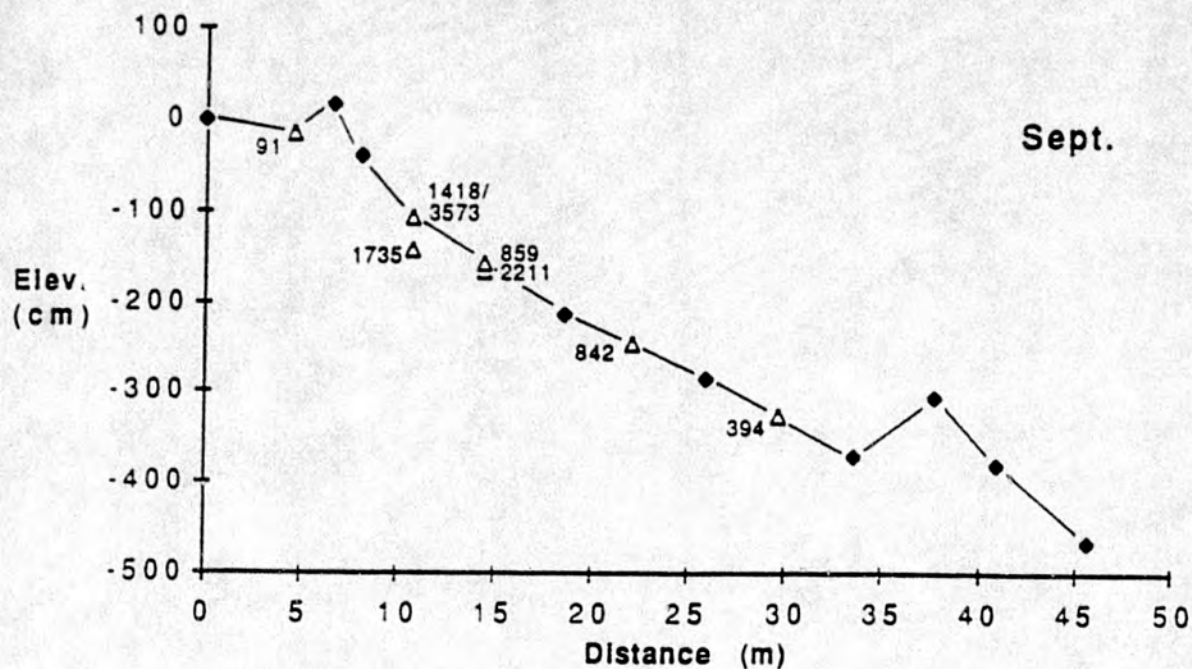


Figure I-18. Plots of the shoreline profile for Sept. and Oct., 1989, at NOAA Station N-1, Point Helen. Oil concentrations at the depths are shown in mg/kg.

Station N-1

Δ Oil Conc. (mg/kg)

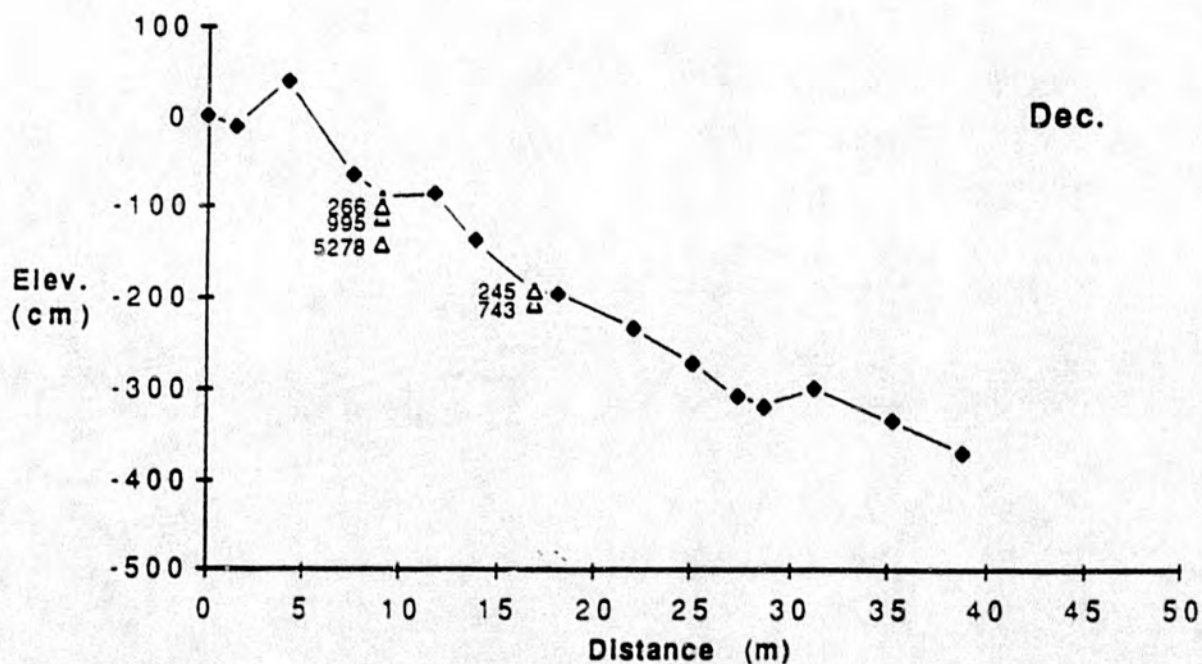
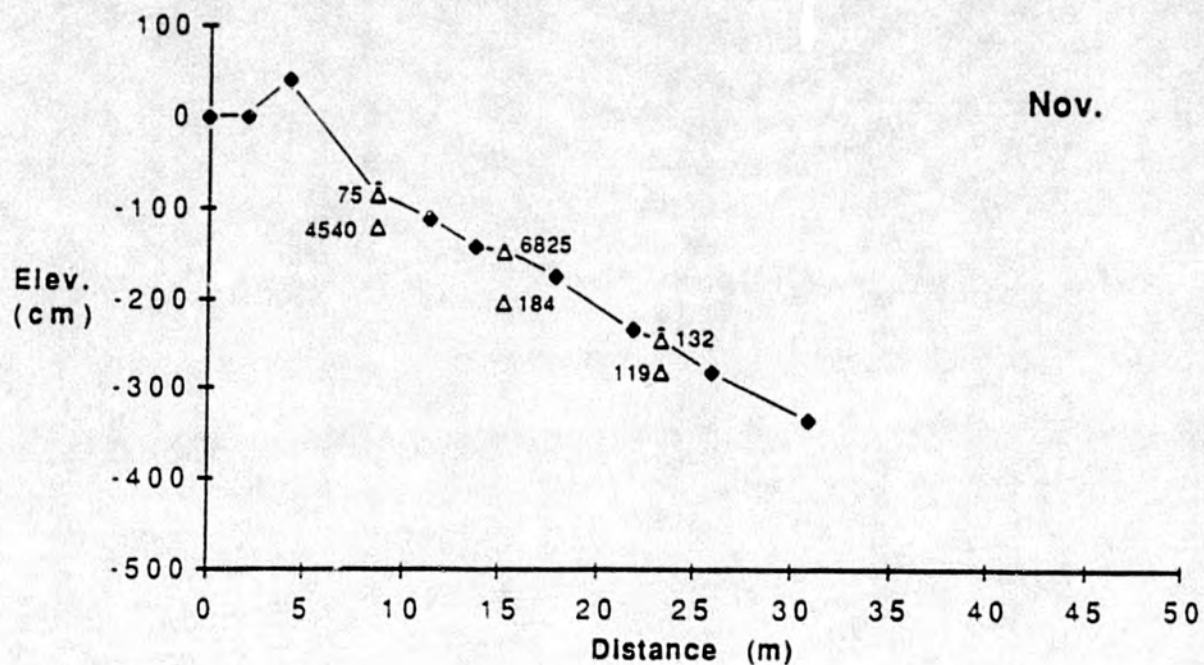


Figure I-19. Plots of the shoreline profile for Nov. and Dec., 1989, at NOAA Station N-1, Point Helen. Oil concentrations at the depths are shown in mg/kg.

Station N-1

Δ Oil Conc. (mg/kg)

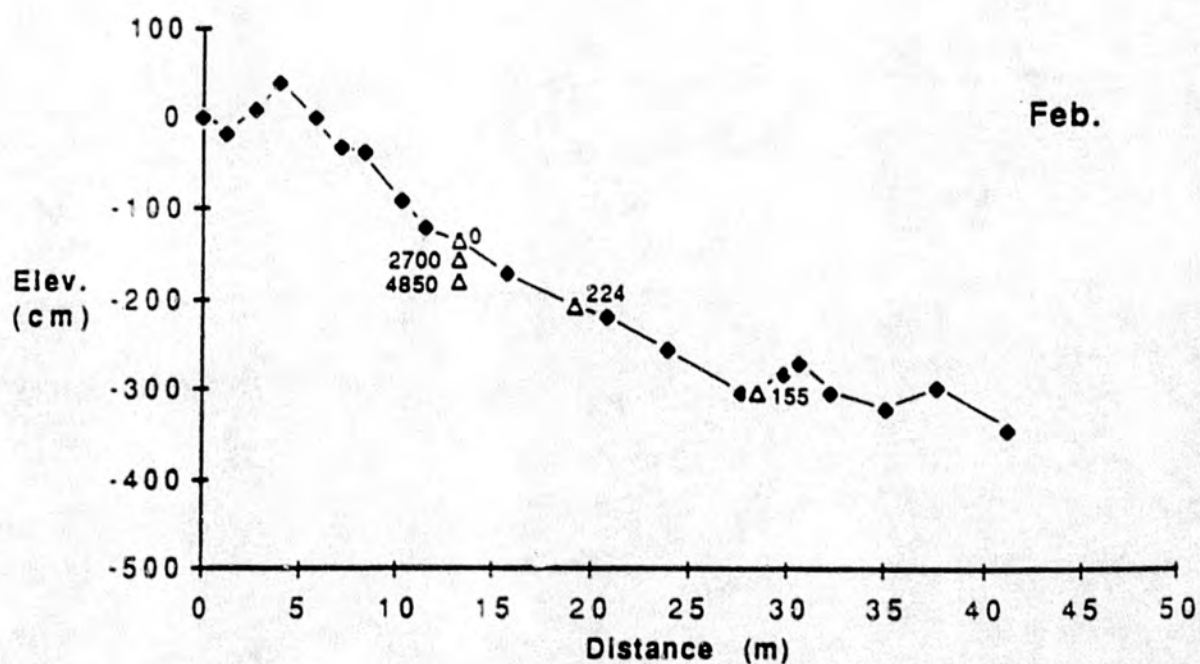
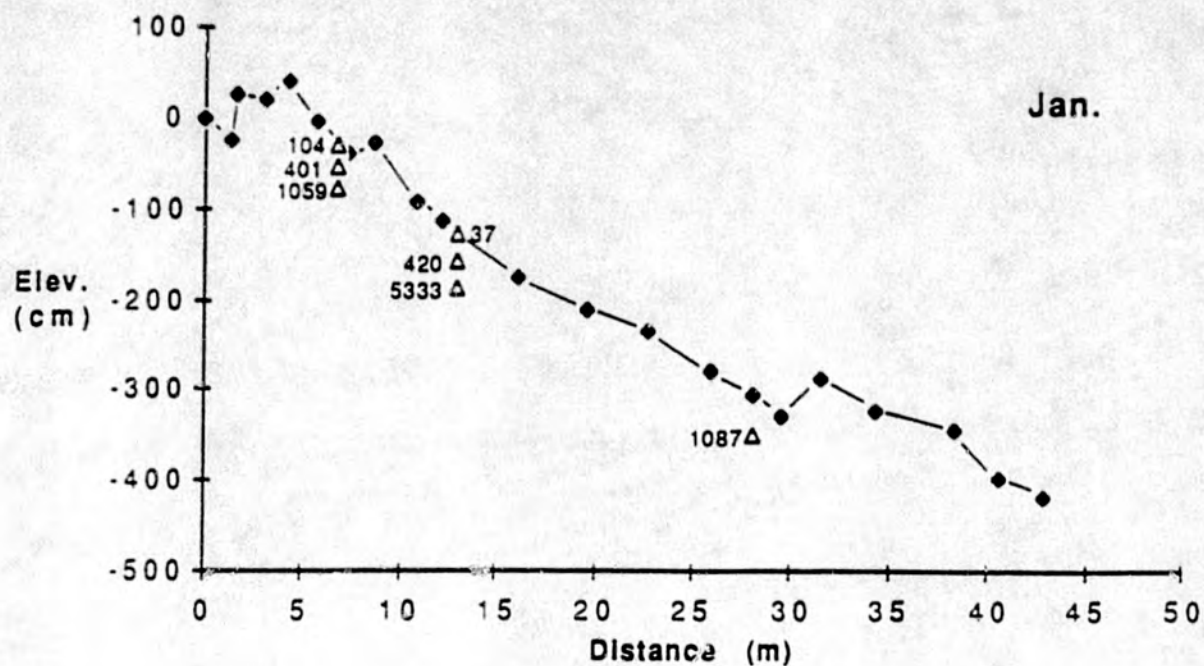


Figure I-20. Plots of the shoreline profile for Jan. and Feb., 1990, at NOAA Station N-1, Point Helen. Oil concentrations at the depths are shown in mg/kg.

heavily coated with liquid, black oil which floated on the water table. By spring, the oil was described as light to moderate. The average oil content of samples collected at depths greater than 30cm from the upper third of the beach ranged between 2,000 and 3,500 mg/kg, with no distinct trend over time. Large variations in the oil content of subsurface sediments are expected, so it will be difficult to rely upon analytical measures. Visual observations are very important, and visually there has been a significant reduction in the amount of oil in subsurface sediments, even below 30cm.

An estimate of the volume of oil in the candidate beach at Point Helen is based on the following assumptions:

- 1) Width of subsurface oil = 12m, based on a maximum extent of >1,000 ppm by weight in any samples collected from NOAA's station between September 1989 and February 1990.
- 2) Depth of subsurface oil = 100cm (average maximum)
50cm (average at the edges)

Top 20cm are "clean."

- 3) Oil content of subsurface sediments is determined from the following percent oil by volume measurements of NOAA samples over the winter:

<u>Month</u>	<u>Maximum %</u>	<u>Mean %</u>
Feb	1.1	0.85
Jan	1.1	0.4
Dec	1.0	0.5
Nov	0.78	0.78
Oct	<u>1.1</u>	<u>0.82</u>
Mean	1.0	0.67 = 0.5%

These values are for the smaller components of the beach sediment (granule to pebble). According to grain-size descriptions of trenches at N-1 at Point Helen in May 1990, the subsurface sediments are about 50 percent cobble or greater and 50 percent pebble/granule/sand. It is assumed that the volumetric amount of oil on a cobble/boulder is negligible.

The cross-sectional area of oiled sediments is calculated as:

$$\begin{aligned} 12 \text{ m} \times 1 \text{ m} &= 12 \text{ m}^2 \\ &- 2.4 \text{ m}^2 && \text{(reduction due to the clean top 20 cm)} \\ &- \underline{3.0 \text{ m}^2} && \text{(due to thinner depth of oil at edges)} \\ &6.6 \text{ m}^2 && \text{oiled sediment per linear m of beach} \end{aligned}$$

The oil volume per linear meter of beach is calculated as:

$$\begin{aligned} &6.6 \text{ m}^2 \times 0.5\% \text{ oil by volume} \times 1 \text{ m beach length} \times 0.5 (\% < \text{cobble}) \\ &= 0.016 \text{ m}^3 \quad \text{or} \quad 4.3 \text{ gallons per linear meter of beach} \end{aligned}$$

ADEC performed similar calculations based on an oiled zone at 30-120cm depth and estimated 6.2 gallons per meter of beach.

The area of Point Helen selected for review is 300m long, thus that shoreline is estimated to contain 1,290 gallons of oil. Assuming that the returned sediments still contain 800 ppm oil by weight (or an estimated 0.1 percent by volume), washing will remove approximately 1,030 gallons from this 300m stretch of shoreline. For all the area of Point Helen which has subsurface oil (an estimated 2,500m length), washing would remove an estimated 8,700 gallons from the subsurface sediments.

Sleepy Bay - Oil Content

There are three sources of data on subsurface oil volume at Sleepy Bay: NOAA's winter monitoring program; Exxon's March 1990 survey; and a June 1990 survey by Exxon. The oil distribution on the surface and in the subsurface is highly variable in Sleepy Bay, thus there were different results for each of the programs monitoring the degree and changes in oiled sediments. NOAA's monitoring station is located 50m to the east of the major stream. It has been occupied monthly between September 1989 and February 1990 and again in May 1990. A total of 43 sediment samples have been analyzed for TPH from this station, and the results are shown in Figures I-21 through I-23. The zone of subsurface oil is about 25m, wider than Point Helen. The oil concentrations in the surface sediments have been reduced from about 1,000 ppm in the fall to 100 ppm in the late winter.

Station N-18

Δ Oil Conc. (mg/kg)

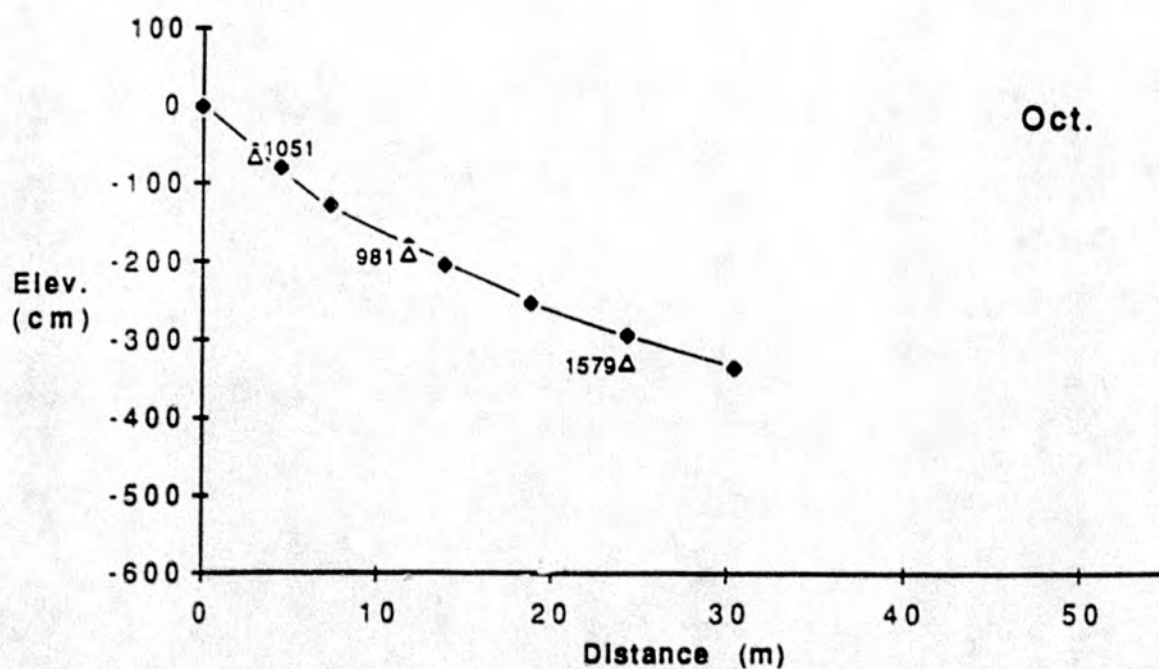
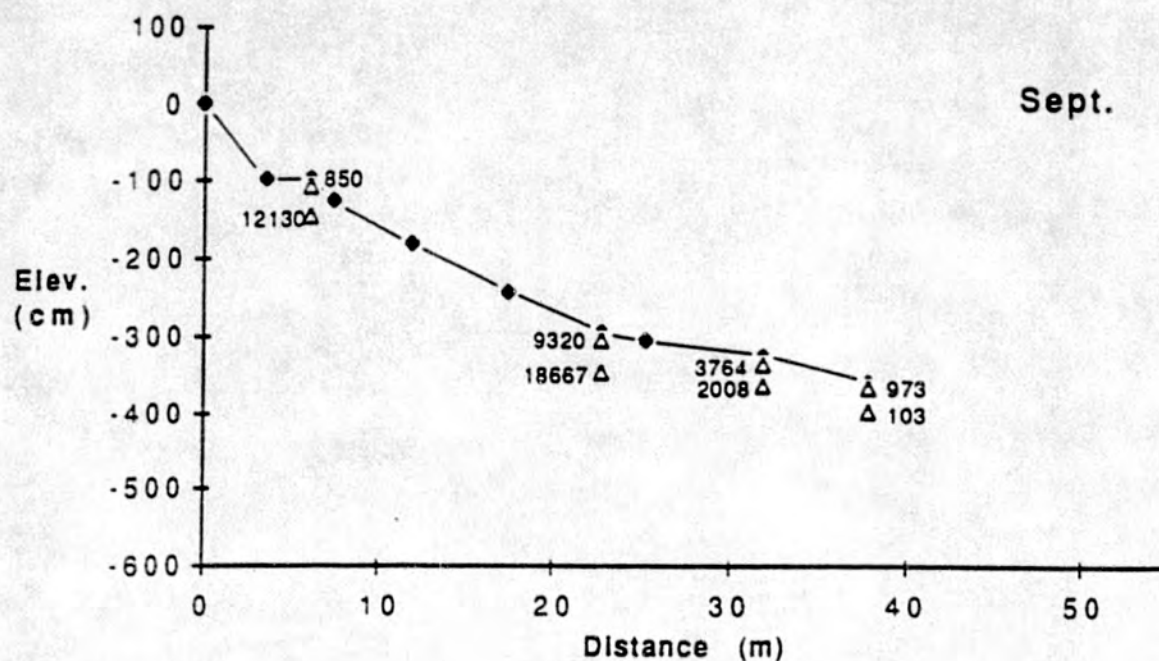


Figure I-21. Plots of the shoreline profile for Sept. and Oct., 1989, at NOAA Station N-18, Sleepy Bay. Oil concentrations at the depths are shown in mg/kg.

Station N-18

Δ Oil Conc. (mg/kg)

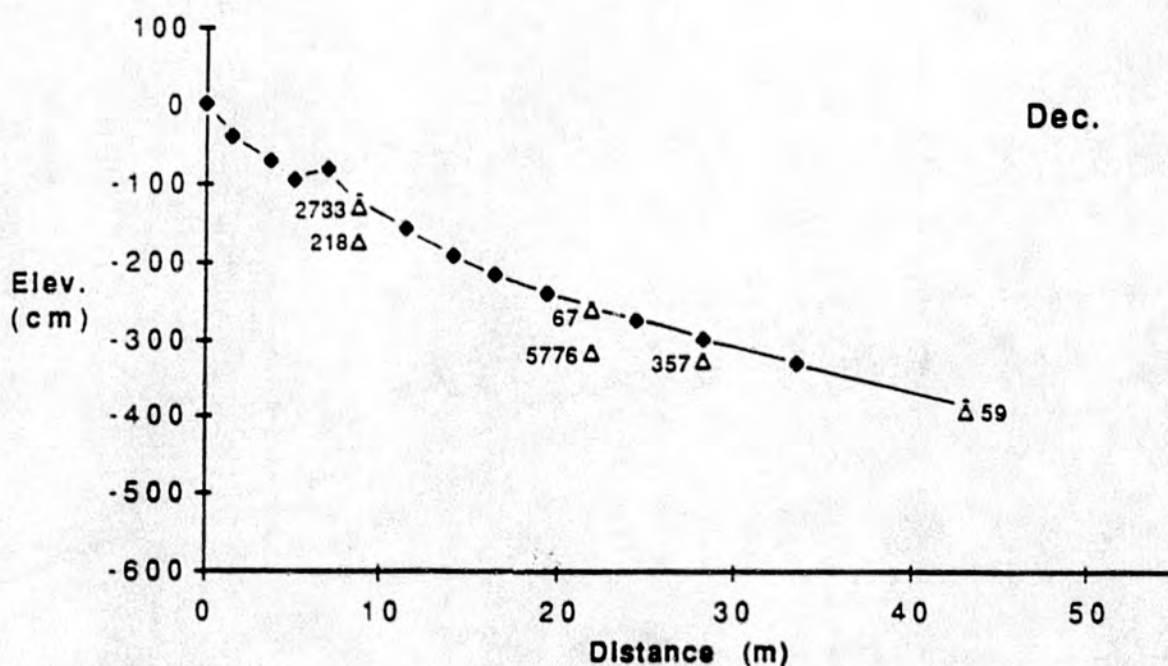
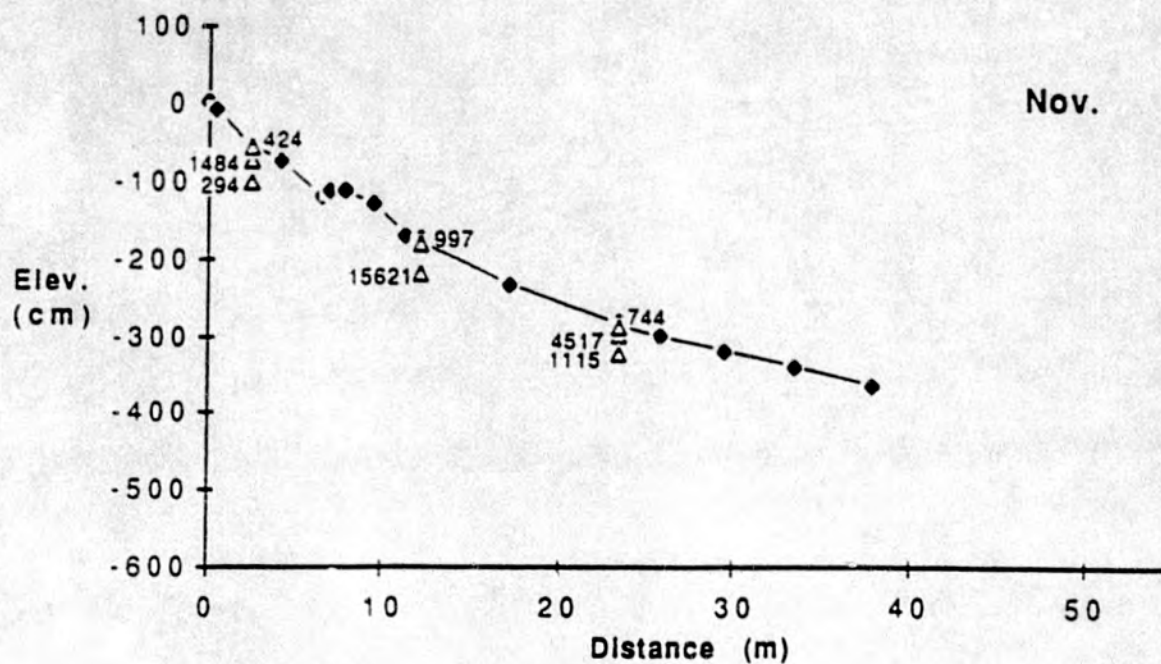


Figure I-22. Plots of the shoreline profile for Nov. and Dec., 1989, at NOAA Station N-18, Sleepy Bay. Oil concentrations at the depths are shown in mg/kg.

Station N-18

Δ Oil Conc. (mg/kg)

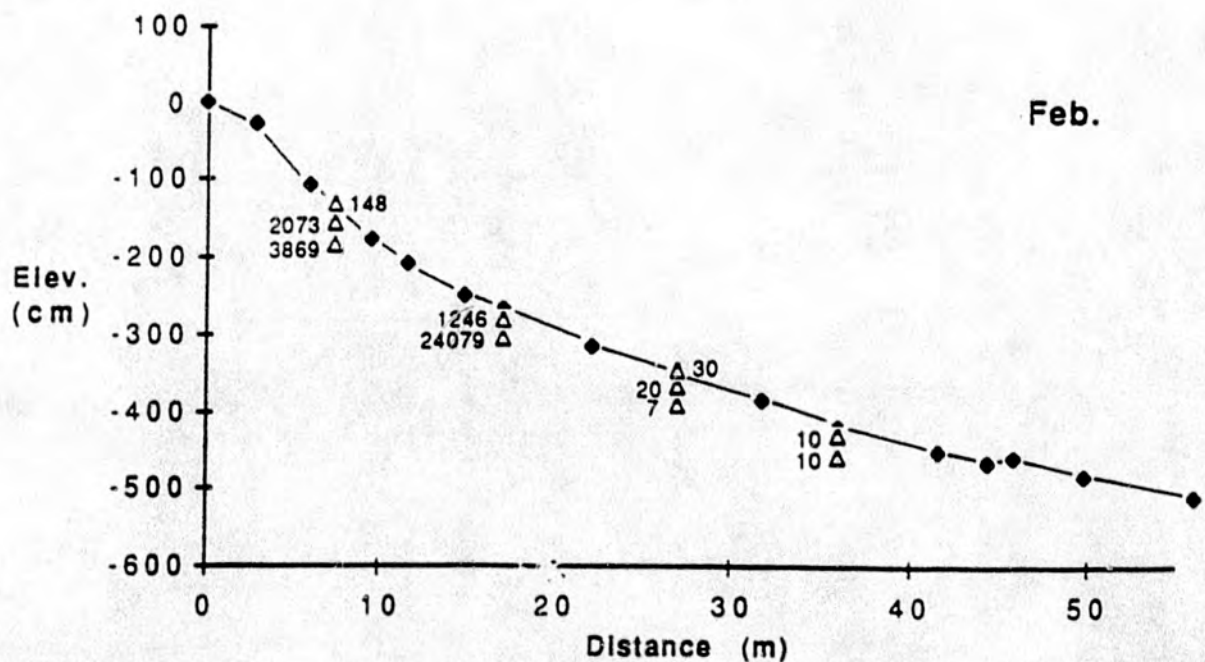
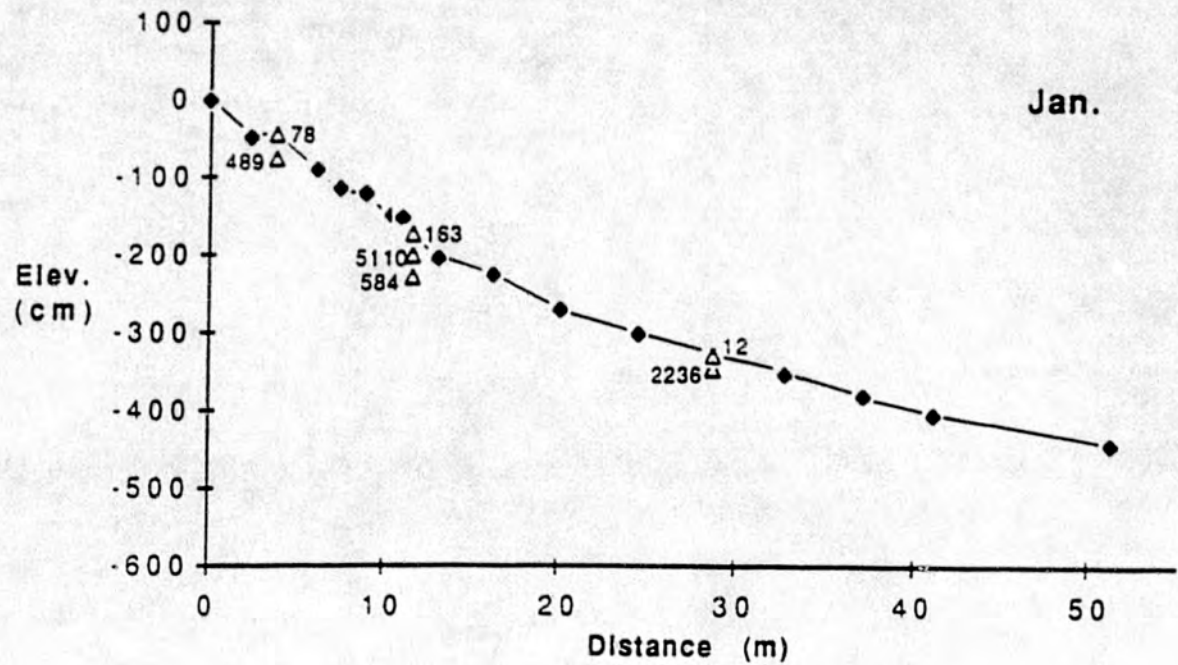


Figure I-23. Plots of the shoreline profile for Jan. and Feb., 1990, at NOAA Station N-18, Sleepy Bay. Oil concentrations at the depths are shown in mg/kg.

However, there are wide variations in oil distribution with depth and over time, as a function of sediment reworking. The initial heavy oiling of sediments at the high-tide berm (over 12,000 mg/kg in September) was greatly reduced as the berm (composed of pebble-sized sediments) was eroded, reformed, and migrated with changing neap to spring tides. The central part of the beach had high subsurface oil concentrations throughout the monitoring period, ranging from 5,800 to 24,000 mg/kg, with the natural variation masking any temporal trends. In fact, the highest value measured was for a February 1990 sample from the upper part of the central platform. The rest of the intertidal zone has relatively low levels of oil contamination, with concentrations in February of 50 mg/kg or less.

An estimate of the volume of oil in the candidate beach at Sleepy Bay using NOAA data is based on the following assumptions:

- 1) Width of subsurface oil = 25m
- 2) Depth of subsurface oil = 60cm (average maximum)
30cm (average at the edges)

Top 20cm are "clean."

- 3) Oil content of subsurface sediments is determined from the following percent oil by volume measurements of NOAA samples over the winter:

<u>Month</u>	<u>Maximum %</u>	<u>Mean %</u>
Feb	4.5	1.4
Jan	0.7	0.4
Dec	1.0	0.4
Nov	2.6	1.0
Oct	0.9	0.3
Sept	3.3	1.4
Mean	2.2	0.8

These values are for the smaller components of the beach sediment (granule to pebble). According to grain-size descriptions of trenches in the candidate beach area of Sleepy Bay in May 1990, the subsurface sediments

are about 25 percent cobble or greater and 75 percent pebble/granule/sand. It is assumed that the volumetric amount of oil on a cobble/boulder is negligible.

The cross-sectional area of oiled sediments at Sleepy Bay is calculated as:

$$25 \text{ m} \times 0.6 \text{ m} = 15 \text{ m}^2$$

$$-5 \text{ m}^2 \text{ (reduction due to the clean top 20 cm)}$$

$$-3.75 \text{ m}^2 \text{ (due to thinner depth of oil at edges)}$$

$$6.25 \text{ m}^2 \text{ oiled sediment per linear m of beach}$$

The oil volume per linear meter of beach is calculated as:

$$6.25 \text{ m}^2 \times 0.8\% \text{ oil by volume} \times 1 \text{ m beach length} \times 0.75$$

$$(\% < \text{cobble}) =$$

$$0.0375 \text{ m}^3 \quad \text{or} \quad 9.9 \text{ gallons per linear meter of beach}$$

The area of Sleepy Bay selected for review is 300 m long, thus that shoreline is estimated to contain 2,960 gallons of oil, about 2 1/4 times more than the amount estimated for Point Helen. Again, assuming that the returned sediments still contain 800 ppm oil by weight (or an estimated 0.1 percent by volume), washing will remove approximately 2,600 gallons from this 300m stretch of shoreline.

Exxon survey teams collected thirteen samples from the eastern section of Sleepy Bay in March 1990 and eleven samples in June 1990. Exxon sampled relatively large intervals, such as from 20 to 40cm in their samples. In March, TPH concentrations in the upper 22m of the beach ranged from 234 to 7,254 mg/kg and averaged 2,363 mg/kg. In June, TPH concentrations in the upper zone ranged from 117 to 11,009 mg/kg and averaged 3,415 mg/kg. Using these numbers and the oil thicknesses measured in each pit, Exxon calculated oil loading as follows:

March 1990	5.0 gallons of oil/meter of beach
June 1990	6.1 gallons of oil/meter of beach

Chemical Composition of Stranded Oil at the Candidate Beaches

Field investigations and detailed gas chromatograph/mass spectrometer (GC/MS) analyses of representative samples collected during May 1990 field investigations of the candidate beaches (LA-18/19, Sleepy Bay, and KN-405, Point Helen) suggest a diversity in weathering processes (fates) and chemical composition of the stranded oil. Oil spilled into the environment is subject to physical and chemical changes. These changes are generally known as weathering and include physical transport mechanisms and chemical/biological alterations of the spilled oil. When spilled oil is stranded on a beach, these weathering processes continue but are modified by the environment (beach material, tides, wave action, etc.) on which it is stranded. The primary weathering processes include spreading, evaporation, dissolution, dispersion, photochemical oxidation, water-in-oil emulsification, adsorption onto suspended material (particulate and colloidal), biodegradation, and various shoreline interactions. Penetration of the oil into the subsurface of the beach and the fate of that oil is the focus of this investigation.

The detailed chemistry data obtained from the May 1990 investigations have been synthesized and presented to provide an understanding of the composition of the remaining oil. Discrete samples were chosen to reflect the different types of oil identified by visual inspection of the beach. The data are presented as histogram plots comparing the "fresh" EXXON VALDEZ cargo oil to May 1990, samples (e.g., mousse, tar mat, weathered oil residues). It should be noted that each of the compositional histograms (Figures I-24 through I-32) are limited in that they present only the relative abundances of the target compounds, namely the polynuclear aromatic hydrocarbon (PAH) compounds. PAHs represent only a small fraction of the "whole" oil remaining; PAHs comprise less than 1% of the fresh oil. The compounds targeted were chosen because of their relative abundance in the spilled oil, persistence in the environment, and toxicological concerns. The y-axis of the plot represents the concentration of individual target compounds in the sample (including the sediment) and are reported as ng of analyte per mg of sample weight (ppm).

Sleepy Bay. Sleepy Bay contains stranded oil characterized as moderate to heavily weathered on the surface with patches of less

weathered mousse and fresher oil contained within exposed tar mats. The mousse found in Sleepy Bay is characteristically an oil-in-water emulsification which is very stable. Figure I-24 shows a comparison of EXXON VALDEZ cargo oil to mousse collected from the surface at Sleepy Bay 14 months after the spill. The slight differences noted between the spilled oil and the 14-month old mousse represent only part of the chemical changes that have occurred during its formation. The GC/MS analysis indicates evaporative and dissolution loss of the lighter constituents. Only slight preferential degradation was noted, indicating very little microbial degradation has occurred. Mousse in the environment is characteristically a very stable material that is slow to degrade without physical breakup since most of the weathering fates are surface dependant. Microbial and photooxidation of the mousse occurs only on the very surface. The resulting effect is the formation of a hard crust which encapsulates the remaining oil within, thus retarding further degradation. The mousse sample collected at Sleepy Bay did not readily sheen. If the emulsion is broken by physical action or even by elevating the temperature (mousse exposed to the solar radiation will act as a black body), the mousse will sheen.

Tar mats represent another pathway of oil degradation. As the tar mat continues to weather, it will ultimately form an asphalt pavement which is very resistant to continued dispersion and degradation. Both the mousse and tar mat are primarily surface impacts only. The recommended treatment is physical removal; therefore, they are not characteristic of the type of oil which the rock washer is expected to remove. Their inclusion in this study is to provide a comprehensive comparison of the types of oil present at the candidate sites, and for contrast with the subsurface oil. Figure I-25 shows a comparison of fresh EXXON VALDEZ oil to a sample of tar mat. Like the mousse sample shown in Figure I-24, the tar mat has undergone only slight weathering. The fresher oil contained within the tar mat will readily sheen.

An example of surface oil from Sleepy Bay that has been significantly degraded compared to EXXON VALDEZ cargo oil is shown in Figure I-26. The heavily weathered oil has lost all of the lighter constituents, the non-alkylated (parent) and C-1 and C-2 PAH homologs are significantly reduced relative to the more degradation-resistive C-3 and C-4 PAH homologs, and

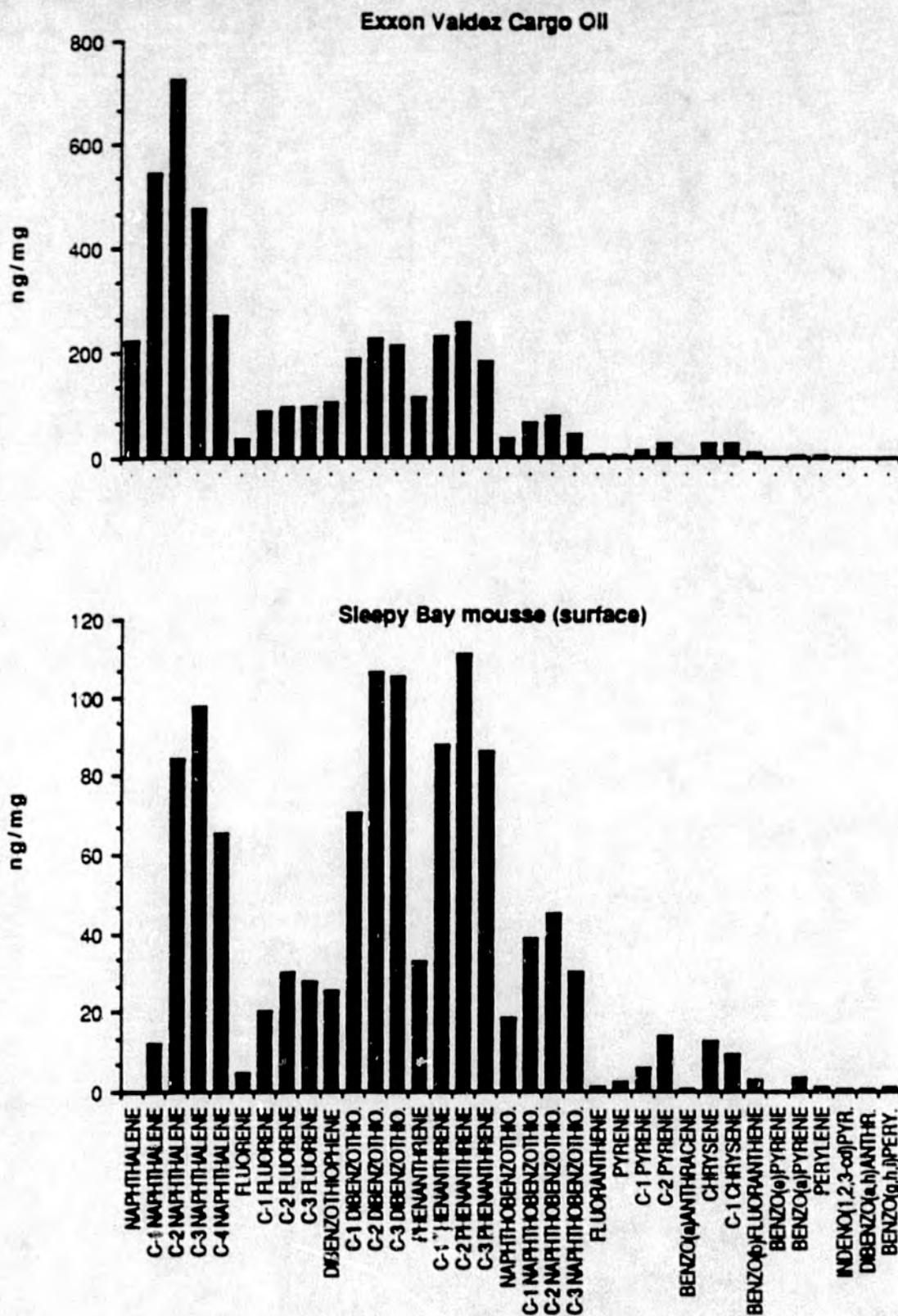


Figure I-24. Comparison of Exxon Valdez cargo oil to mousse collected at Sleepy Bay (May 1990). Note the difference in scale of concentration between the two plots.

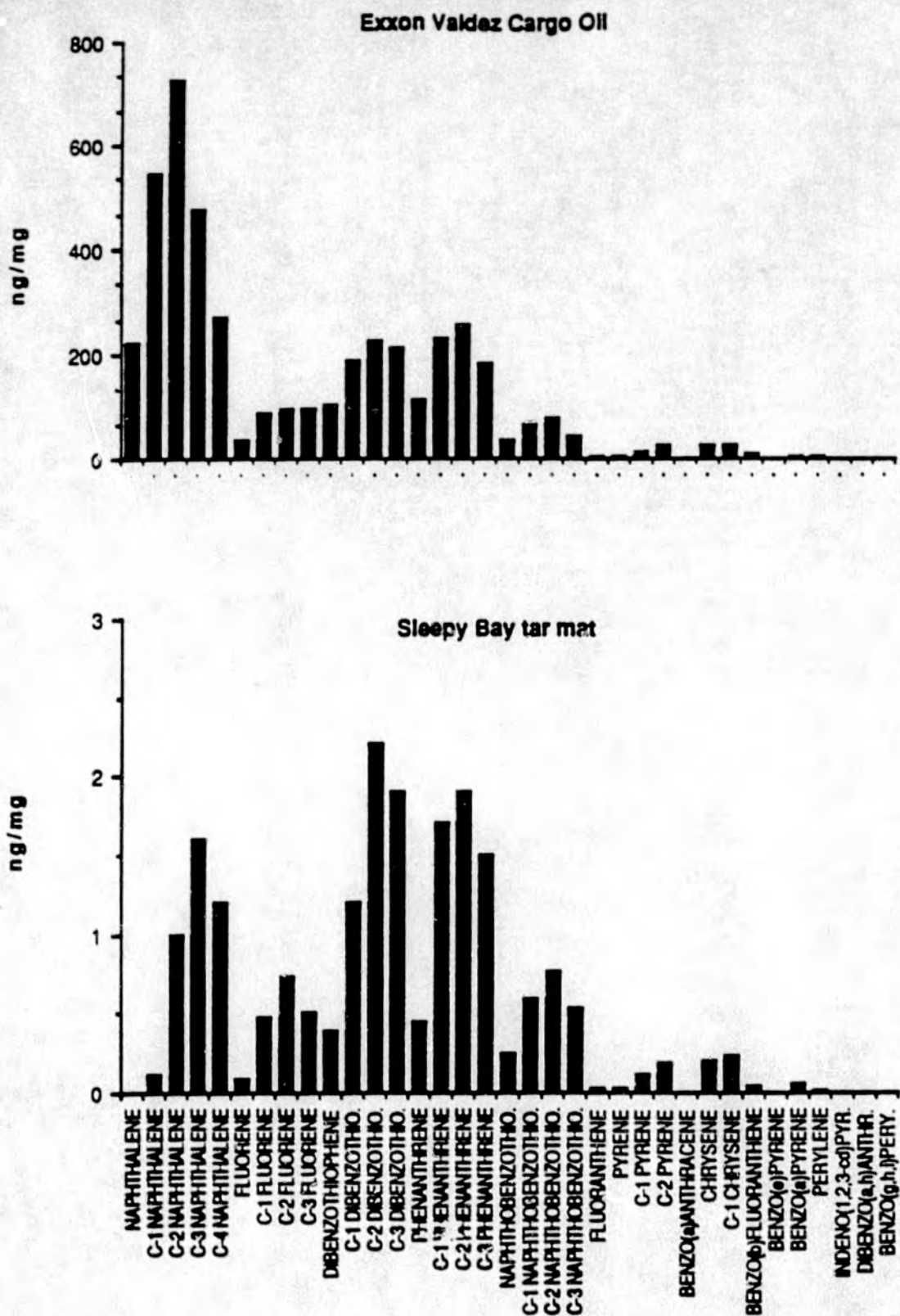


Figure I-25. Comparison of Exxon Valdez cargo oil to oil contained within a tar mat at Sleepy Bay. Note the difference in scale of concentration between the two plots.

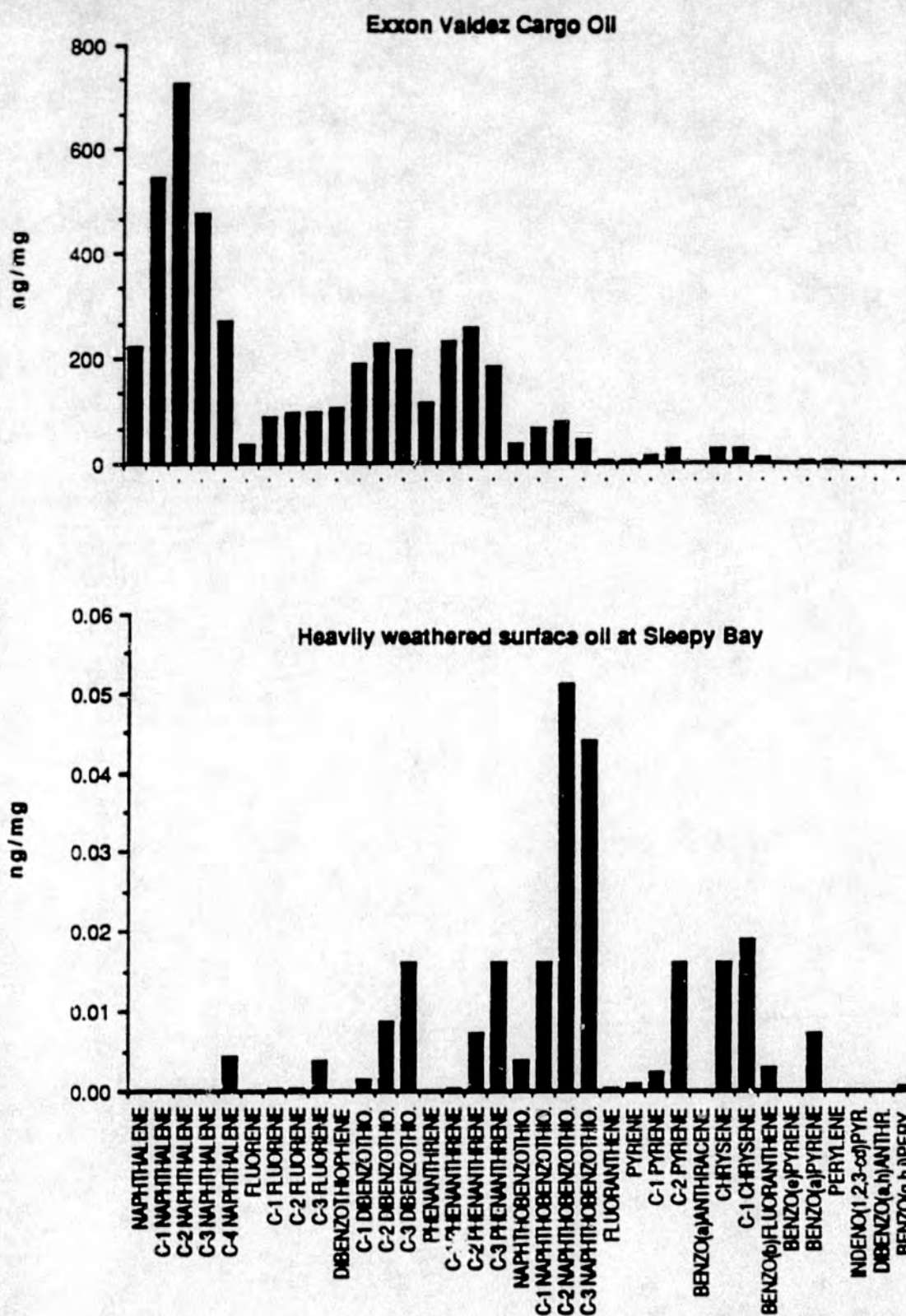


Figure I-26. Comparison of Exxon Valdez cargo oil to a surface sample from Sleepy Bay that is heavily weathered. Note the difference in scale of concentration between the two plots.

the sulfur heterocycle compounds generally show less reduction compared to PAHs with similar molecular weights (e.g., the C-3 dibenzothiophenes, MW=226, are slower to degrade than the C-3 phenanthrenes, MW=220). These changes are consistent with normal degradation in the environment and reflect loss of individual constituents by dissolution and evaporation of the lower molecular weight and more water-soluble compounds in addition to preferential degradation by microbial processes. The sulfur heterocycles (dibenzothiophenes and naphthobenzothiophenes) are becoming more predominant in the target compound profile; this pattern is suggestive of a resistance to microbial degradation relative to the other target compounds. Oil of this composition will not sheen.

Subsurface oil demonstrates a range of weathering similar to the surface. Based on data collected from the NOAA winter study in Prince William Sound and on field observations in May 1990, the absolute quantity of subsurface oil is generally higher in concentration. The subsurface weathering processes differ relative to the surface. The physical composition of the oil varies from a heavily weathered oil residue with a "peat-like" feel to a fresher oil partially emulsified with water and fine colloidal and particulate material. The subsurface oil penetrated the beach substrate while still a relatively fresh oil, filling in available pore spaces. Through continual interactions with the water column (tidal action, etc.) and exposure to fine sediments, organic colloids, natural surfactants, as well as microbial-mediated oxidation and surfactant action, the oil has become viscous, characteristically more "mousse-like," and less mobile.

Interestingly, the composition of the oil buried under the the spring tide berms at Sleepy Bay at depths to 30cm demonstrates significant weathering and is characteristically dissimilar in appearance to "fresh" crude oil or the surface mousse typically encountered in Prince William Sound and the Gulf of Alaska. This oil does not sheen. The degree of weathering is significant, being characterized as moderately weathered. It would appear that the beach is acting in a fashion analogous to a trickle filter system used for waste water treatment. Snow melt, rain, and tidal activities carry nutrients, bacteria, and detrital material from the upland area and the open bay to the berm where it trickles through the berm sediments which are partially coated with oil. This process is probably

most effective during the late spring and summer months when the temperature is warmer and runoff is greater. The upper intertidal and middle intertidal subsurface oil is characteristically not as weathered as that in the spring berm. Factors which may contribute to the reduced degradation rates in the lower areas noted are the physical distribution of the oil (clumpy and "mousse-like") and higher overall oil concentration in the subsurface sediments, which reduces the effectiveness of natural dispersion and degradation activities since they are primarily active at the surface only. Figures I-27 through I-30 show compositional histograms of the target constituents in the oil monitored for the spring tide berm, and the upper, middle, and lower intertidal zones, respectively. Note the changes relative to reference EXXON VALDEZ cargo oil. Oil of this composition doesn't normally sheen.

Point Helen. Only a limited number of May 1990, samples were analyzed from Point Helen. An upper intertidal zone subsurface sample collected at the NOAA study station, N-1, suggest that significant weathering has occurred (see Figure I-31). Neither of the samples collected at Point Helen generated a sheen. The relative composition was similar to that found in the spring tide berms at Sleepy Bay and Point Helen shown in Figures I-27 and I-32, respectively. PAH concentration data of subsurface oil from the Exxon Winter study show similar degradative changes in composition. These values are included in Table I-2.

Very little attention has been given to the saturate fraction of the stranded oil. All of the subsurface samples analyzed showed marked decreases in the lower molecular weight (less than n-C20) aliphatic compounds with a marked preference for the non-branched relative to the branched hydrocarbons. The isoprenoid hydrocarbons norpristane, pristane, and phytane showed a marked resistance to change as well as did the heavier paraffins (greater than n-C20); this selective preference indicates microbial degradation has occurred.

In summary, oil stranded on the candidate beaches can be described as four discrete types: mousse, tar mat, moderate to heavily weathered surface oil residues, and subsurface oil. The composition of the subsurface oil suggests that significant weathering has modified the stranded oil. The current composition of the subsurface oil is moderately weathered and

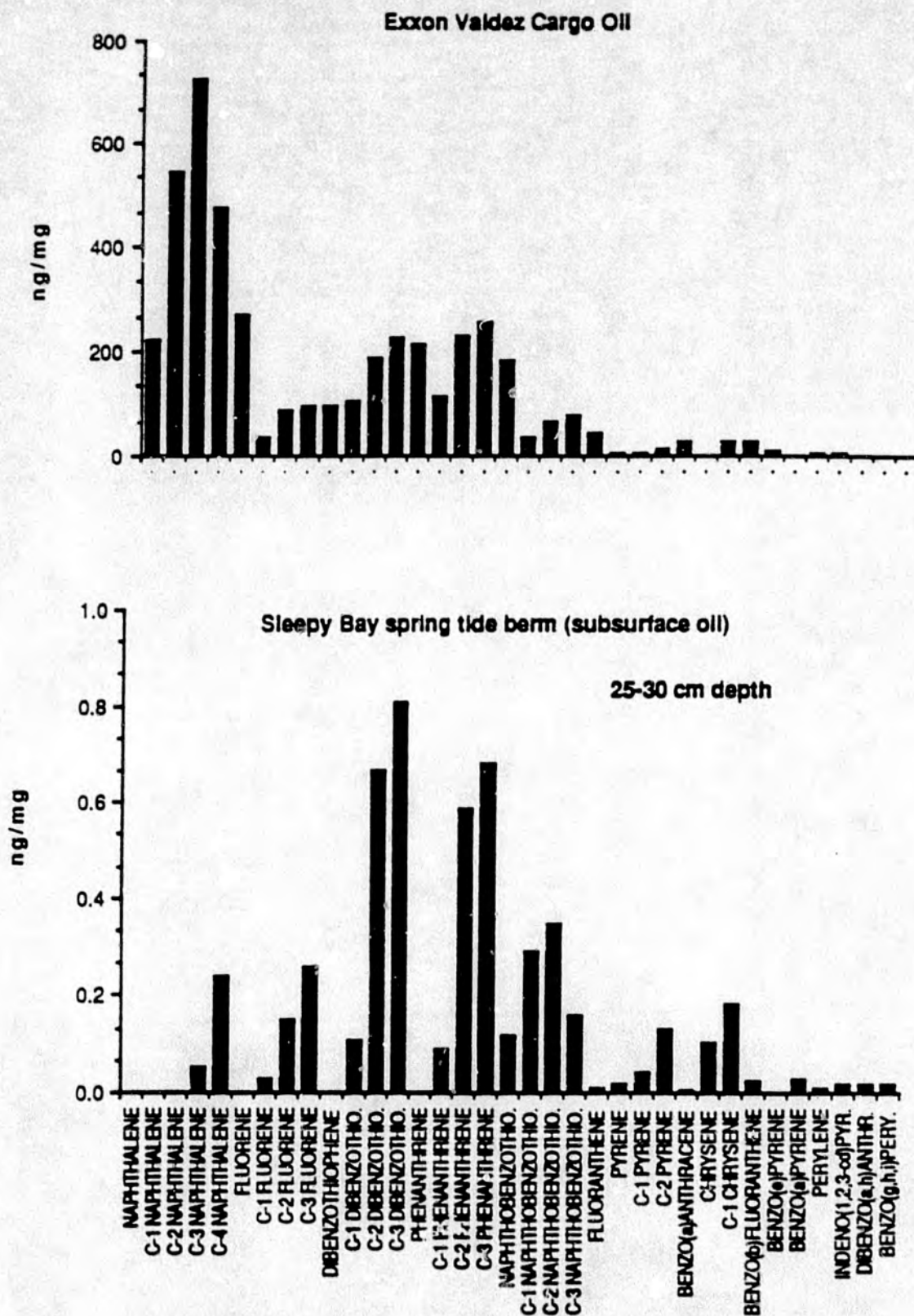


Figure I-27. Comparison of Exxon Valdez cargo oil to subsurface oil buried in the spring tide berm at Sleepy Bay (May 1990). Note the difference in scale of concentration between the two plots.

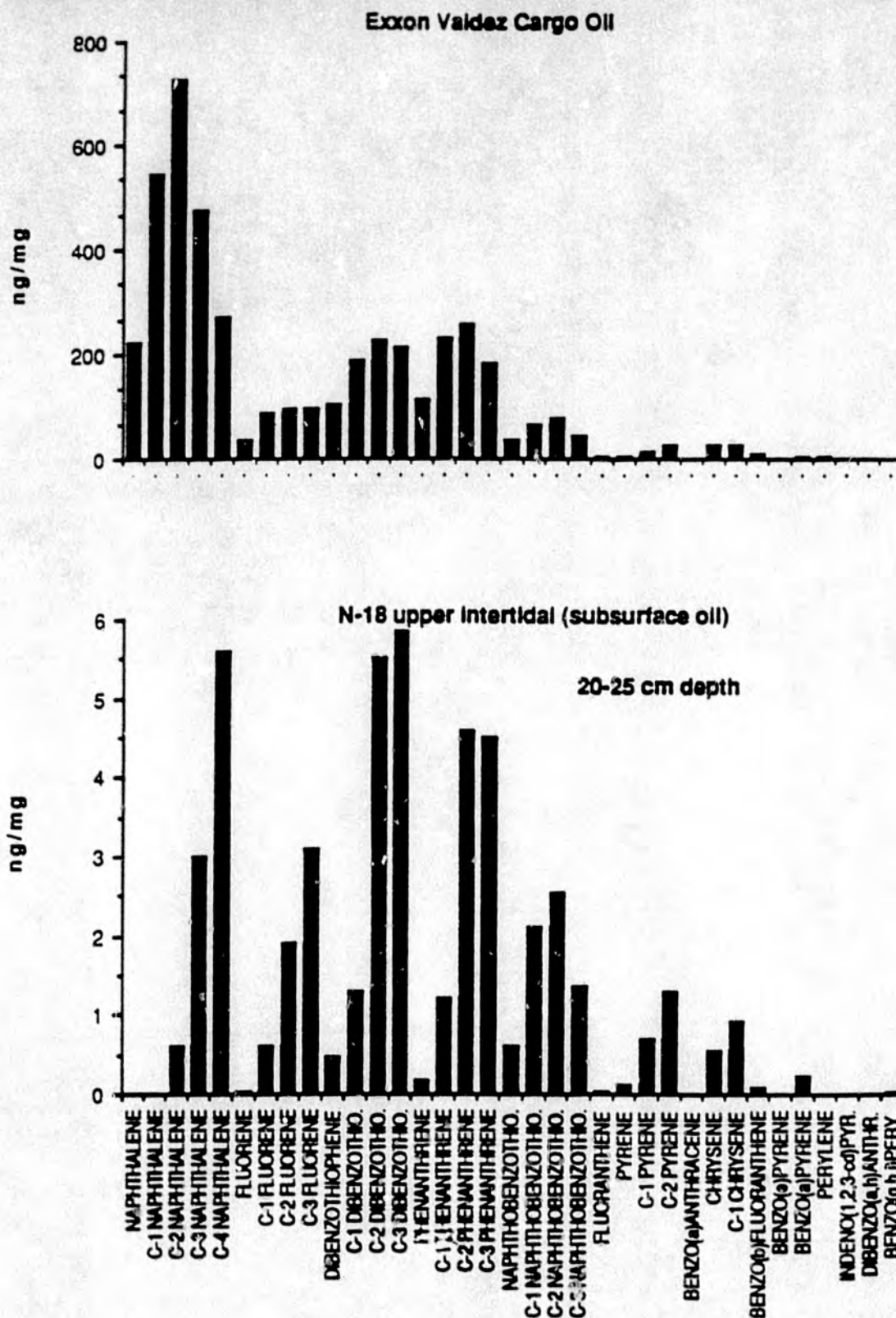


Figure I-28. Comparison of Exxon Valdez cargo oil to subsurface oil of the upper intertidal zone at NOAA study station N-18 (May 1990). Note the difference in scale of concentration between the two plots.

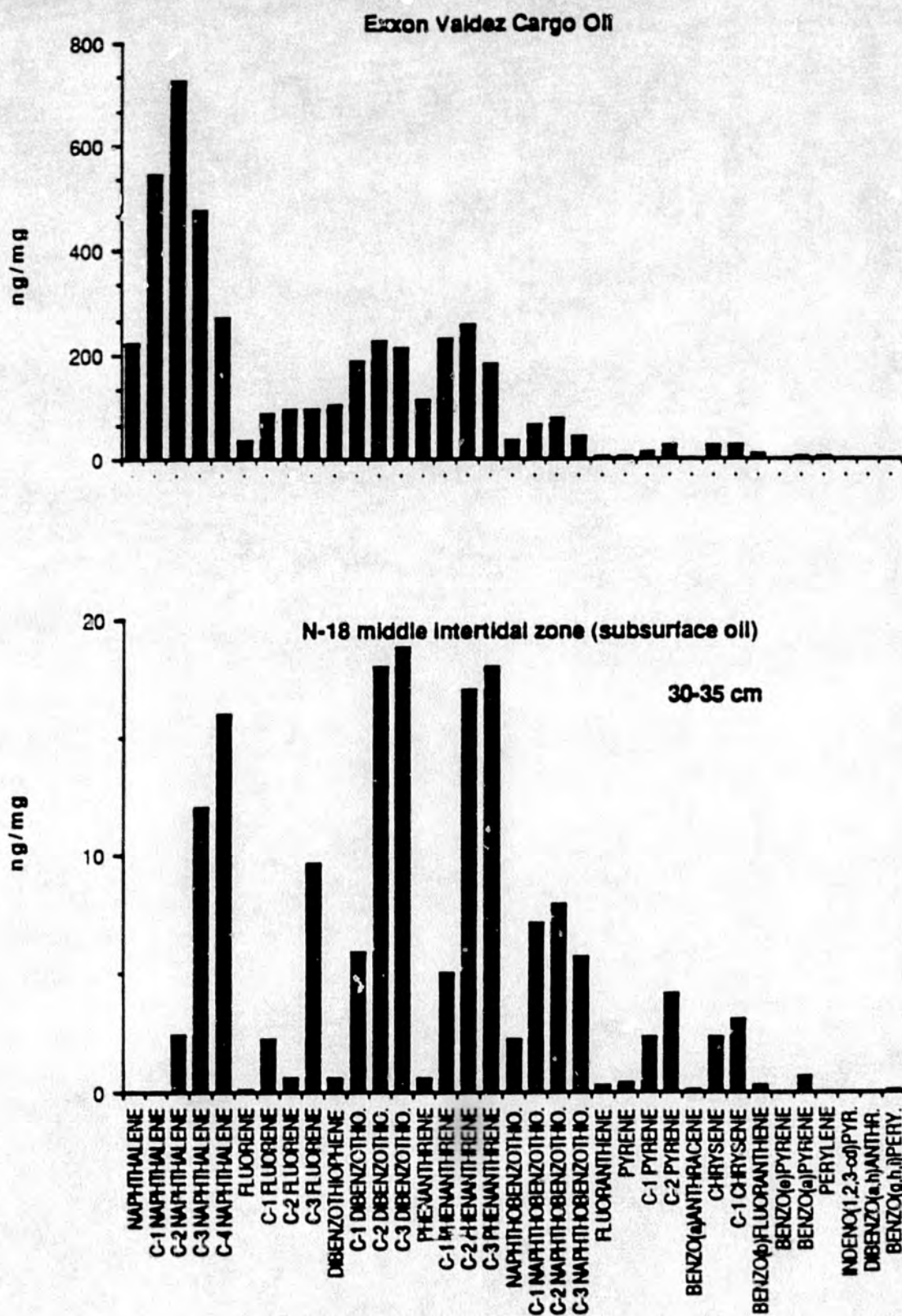


Figure I-29. Comparison of Exxon Valdez cargo oil to subsurface oil of the middle intertidal zone at NOAA study station N-18 (May 1990). Note the differences in scale of concentration between the two plots.

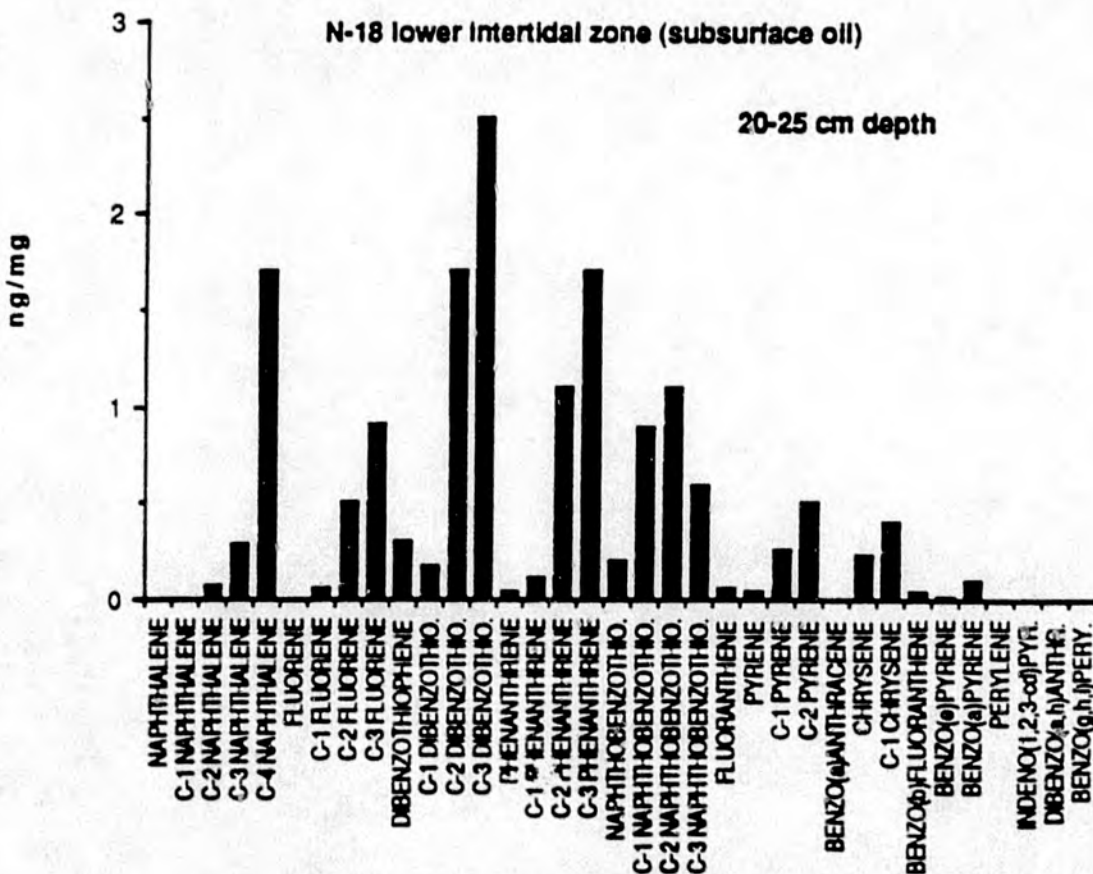


Figure I-30. Comparison of Exxon Valdez cargo oil to subsurface oil of the lower intertidal zone at NOAA study station N-18 (May 1990). Note the difference in scale of concentration between the two plots.

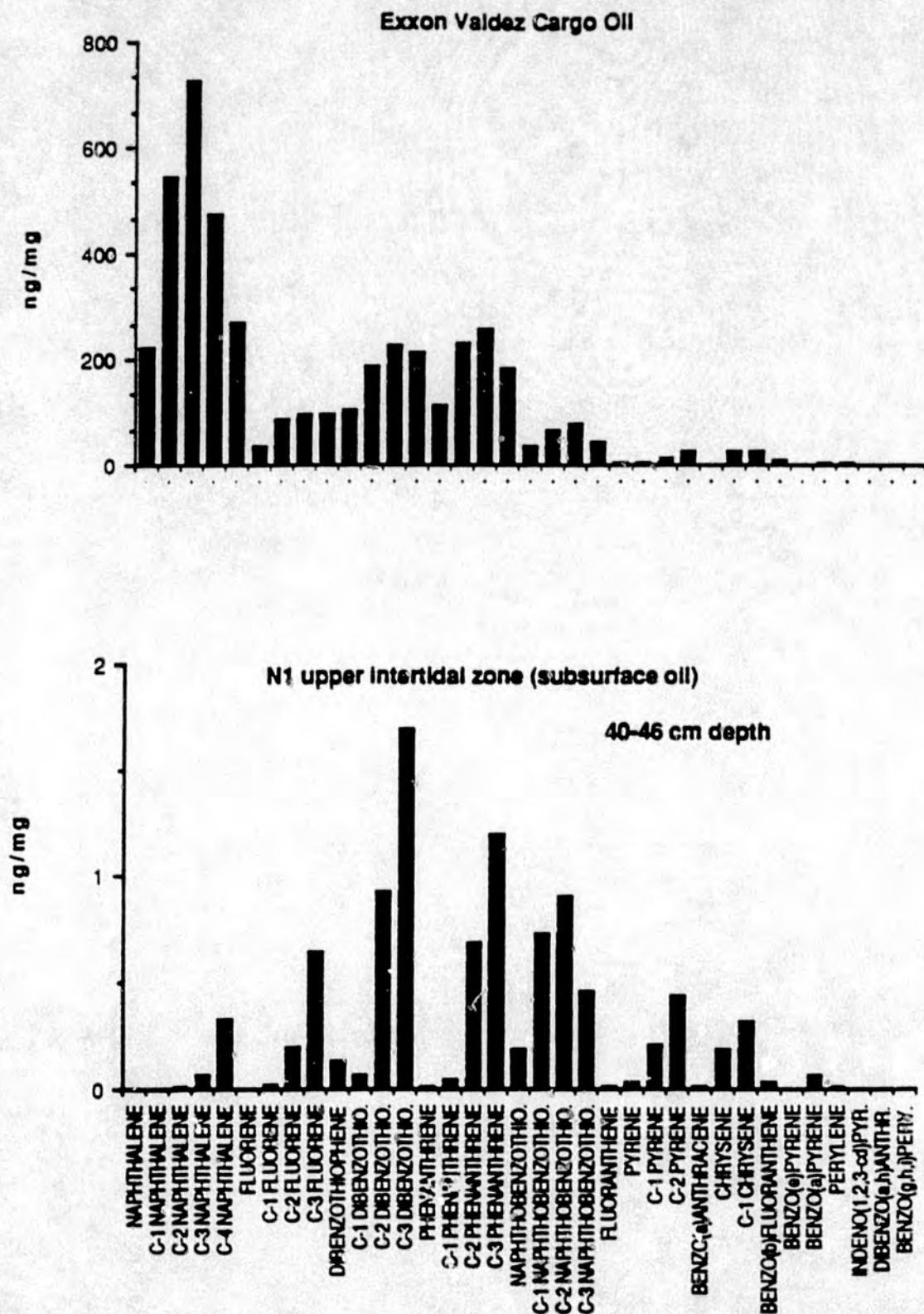


Figure I-31. Comparison of Exxon Valdez cargo oil to subsurface oil at NOAA study station N-1 upper intertidal zone (May 1990). Note the difference in scale of concentration between the plots.

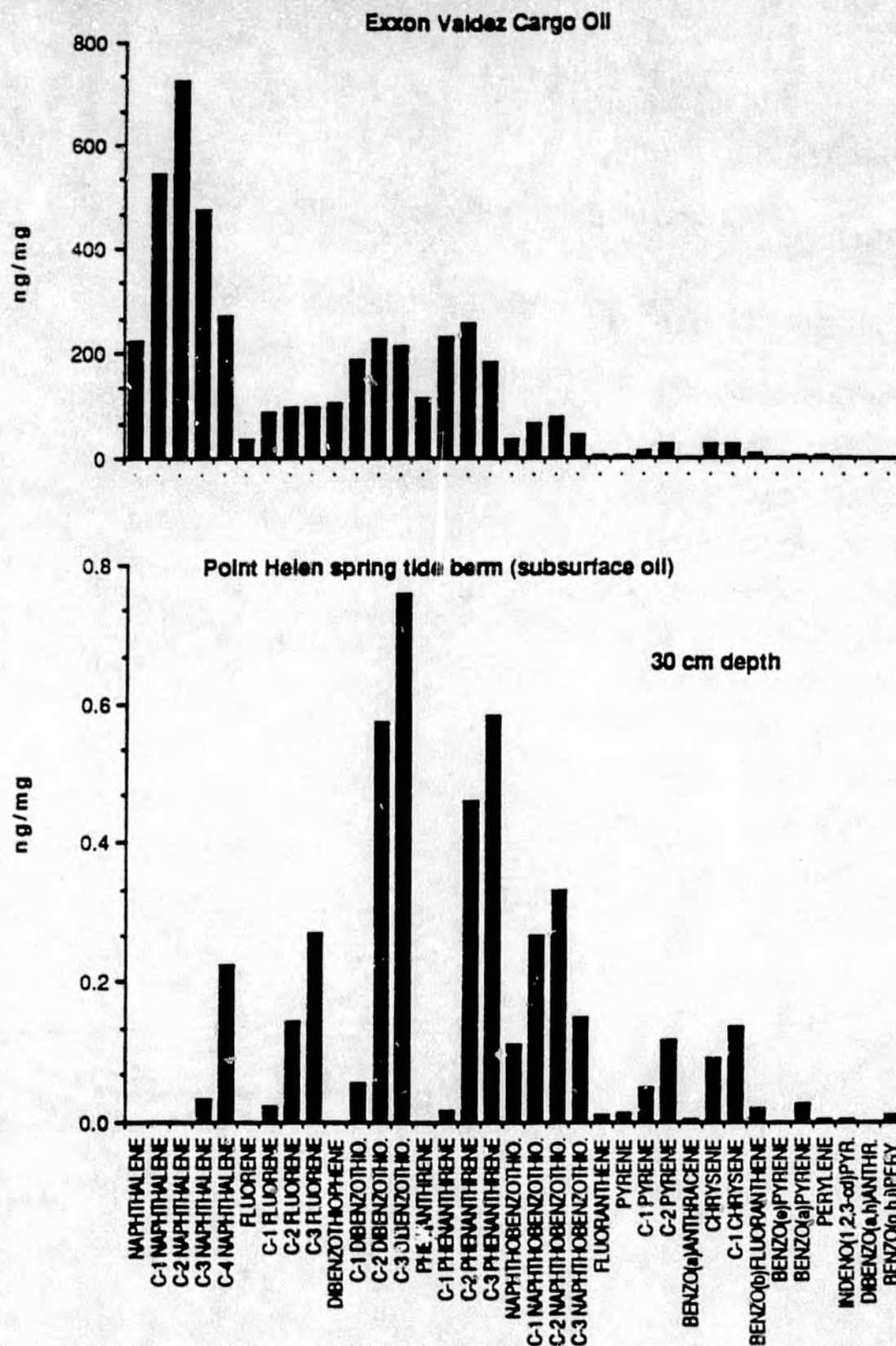


Figure I-32. Comparison of Exxon Valdez cargo oil to subsurface oil in the spring tidal berm at Point Helen (May 1990). Note the differences in scale of concentration between the two plots.

Table I-2. Concentration of Specific Compounds in Sediments at the Candidate Beaches.

GC/MS QUANT RESULTS					
STATION:	LA-19	LA-19	LA-19	LA-19	N18
SAMPLE TYPE:	mousse	tar/grav	grav./peb.	grav./peb.	grav./peb.
DEPTH:	0-5 cm	0-5 cm	0-5 cm	25-30 cm	20-25 cm
LAB ID:	N0143-2	N0143-5	N0143-6	N0143-1	N0145-10
MONTH SAMPLED:	MAY, '90	MAY, '90	MAY, '90	MAY, '90	MAY, '90
RELATED FIGURE:	F 1-24	F 1-25	F 1-26	F 1-27	F 1-28
COMPOUND	(ng/mg)	(ng/mg)	(ng/mg)	(ng/mg)	(ng/mg)
NAPHTHALENE	0.1400	0.0021	ND	ND	ND
C-1 NAPHTHALENE	12.0000	0.1200	ND	ND	ND
C-2 NAPHTHALENE	84.0000	1.0000	ND	0.0014	0.0700
C-3 NAPHTHALENE	98.0000	1.6000	ND	0.0540	0.2900
C-4 NAPHTHALENE	65.0000	1.2000	0.0042	0.2400	1.7000
FLUORENE	4.5000	0.0820	ND	0.0000	0.0000
C-1 FLUORENE	20.0000	0.4800	0.0003	0.0290	0.0600
C-2 FLUORENE	30.0000	0.7400	0.0004	0.1500	0.5100
C-3 FLUORENE	28.0000	0.5000	0.0037	0.2600	0.9100
DIBENZOTHIOPHENE	26.0000	0.3900	ND	0.0007	0.3100
C-1 DIBENZOTHIOPHENE	71.0000	1.2000	0.0013	0.1100	0.1800
C-2 DIBENZOTHIOPHENE	110.0000	2.2000	0.0087	0.6700	1.7000
C-3 DIBENZOTHIOPHENE	100.0000	1.9000	0.0160	0.8100	2.5000
PHENANTHRENE	33.0000	0.4500	ND	ND	0.0400
C-1 PHENANTHRENE	88.0000	1.7000	0.0002	0.0870	0.1100
C-2 PHENANTHRENE	110.0000	1.9000	0.0073	0.5900	1.1000
C-3 PHENANTHRENE	86.0000	1.5000	0.0160	0.6800	1.7000
NAPHTHOBENZOTHIOPHENE	18.0000	0.2500	0.0036	0.1200	0.2000
C-1 NAPHTHOBENZOTHIOPHENE	39.0000	0.5900	0.0160	0.2900	0.9000
C-2 NAPHTHOBENZOTHIOPHENE	45.0000	0.7600	0.0510	0.3500	1.1000
C-3 NAPHTHOBENZOTHIOPHENE	30.0000	0.5400	0.0440	0.1600	0.5900
FLUORANTHRENE	1.4000	0.0230	0.0002	0.0078	0.0600
PYRENE	2.0000	0.0350	0.0008	0.0210	0.0400
C-1 PYRENE	6.0000	0.1000	0.0023	0.0450	0.2600
C-2 PYRENE	14.0000	0.1900	0.0160	0.1300	0.5100
BENZO(a)ANTHRACENE	0.5200	0.0057	0.0000	0.6800	0.0000
CHRYSENE	13.0000	0.2000	0.0160	0.1000	0.2300
C-1 CHRYSENE	9.3000	0.2300	0.0190	0.1800	0.4100
BENZO(b)FLUORANTHRENE	3.1000	0.0400	0.0028	0.0240	0.0400
BENZO(e)PYRENE	ND	0.0040	0.0000	0.0006	0.0100
BENZO(a)PYRENE	3.7000	0.0530	0.0073	0.0280	0.1000
PERYLENE	0.8800	0.0088	ND	0.0110	ND
INDENO(1,2,3-cd)PYR.	0.7700	0.0013	ND	0.0200	ND
DIBENZO(a,h)ANTHR.	0.5200	ND	ND	0.0160	ND
BENZO(g,h,i)PERY.	1.2000	0.0097	0.0007	0.0200	ND

All values are valid to two significant figures only.

Table I-2. Cont.

GC/MS QUANT RESULTS				
STATION:	N18	N18	N1	KN-405
SAMPLE TYPE:	grav./peb.	grav./peb.	grav.	grav./peb.
DEPTH:	30-35 cm	20-25 cm	40-46 cm	30 cm
LAB ID:	N0145-9	N0145-11	N0145-5	N0143-3
MONTH SAMPLED:	MAY, '90	MAY, '90	MAY, '90	MAY, '90
RELATED FIGURE:	F 1-29	F 1-30	F 1-31	F 1-32
COMPOUND	(ng/mg)	(ng/mg)	(ng/mg)	(ng/mg)
NAPHTHALENE	ND	ND	ND	ND
C-1 NAPHTHALENE	0.0400	0.0100	ND	ND
C-2 NAPHTHALENE	2.4000	0.6200	0.0100	0.0014
C-3 NAPHTHALENE	12.0000	3.0000	0.0600	0.0325
C-4 NAPHTHALENE	16.0000	5.6000	0.3300	0.2354
FLUORENE	0.1000	0.0300	ND	ND
C-1 FLUORENE	2.2000	0.6100	0.0200	0.0223
C-2 FLUORENE	0.6100	1.9000	0.2000	0.1444
C-3 FLUORENE	9.6000	3.1000	0.6400	0.2690
DIBENZOTHIOPHENE	0.6000	0.4600	0.1300	ND
C-1 DIBENZOTHIOPH.	5.9000	1.3000	0.0600	0.0554
C-2 DIBENZOTHIOPH.	18.0000	5.5000	0.9200	0.5739
C-3 DIBENZOTHIOPH.	19.0000	5.9000	1.7000	0.7578
PHENANTHRENE	0.6100	0.1600	0.0100	ND
C-1 PHENANTHRENE	5.0000	1.2000	0.0400	0.0172
C-2 PHENANTHRENE	17.0000	4.6000	0.6900	0.4598
C-3 PHENANTHRENE	18.0000	4.5000	1.2000	0.5818
NAPHTHOBENZOTHIOPH.	2.2000	0.6100	0.1900	0.1095
C-1 NAPHTHOBENZOTHIOPH.	7.1000	2.1200	0.7300	0.2680
C-2 NAPHTHOBENZOTHIOPH.	7.9000	2.5400	0.9000	0.3321
C-3 NAPHTHOBENZOTHIOPH.	5.7000	1.3700	0.4600	0.1488
FLUORANTHENE	0.2500	0.0200	0.0100	0.0090
PYRENE	0.4100	0.1100	0.0300	0.0134
C-1 PYRENE	2.3000	0.6900	0.2100	0.0489
C-2 PYRENE	4.1000	1.3000	0.4400	0.1161
BENZO(a)ANTHRACENE	0.0600	0.0000	0.0100	0.0033
CHRYSENE	2.3000	0.5600	0.1900	0.0904
C-1 CHRYSENE	3.1000	0.9200	0.3200	0.1368
BENZO(b)FLUORANTHENE	0.2900	0.0800	0.0300	0.0195
BENZO(e)PYRENE	ND	ND	ND	ND
BENZO(a)PYRENE	0.6700	0.2300	0.0600	0.0265
PERYLENE	0.0000	ND	0.0100	0.0034
INDENO(1,2,3-cd)PYR.	0.0000	ND	ND	0.0031
DIBENZO(a,h)ANTHR.	0.0000	ND	ND	ND
BENZO(g,h,i)PERY.	0.1000	0.0300	ND	0.0094

All values are valid to two significant figures only.

Table I-2. Cont.

GC/MS QUANT RESULTS		
STATION:	AP-10	AP-10
SAMPLE TYPE:	-	-
DEPTH:	50-60 cm	5-15 cm
LAB ID:	B8	B24
MONTH SAMPLED:	Jan. '90	Sept. '89
RELATED FIGURE:	-	-
COMPOUND		
NAPHTHALENE	0.0008	0.0000
C-1 NAPHTHALENE	0.0000	0.0000
C-2 NAPHTHALENE	0.1500	0.0071
C-3 NAPHTHALENE	0.6900	0.0520
C-4 NAPHTHALENE	1.1000	0.3500
FLUORENE	0.0036	0.0000
C-1 FLUORENE	0.1500	0.0260
C-2 FLUORENE	0.4900	0.1600
C-3 FLUORENE	0.5000	0.2800
DIBENZOTHIOPHENE	0.0100	0.0053
C-1 DIBENZOTHIOPHENE	0.2300	0.0640
C-2 DIBENZOTHIOPHENE	0.7600	0.4400
C-3 DIBENZOTHIOPHENE	0.7200	0.5310
PHENANTHRENE	0.1800	0.0070
C-1 PHENANTHRENE	0.3400	0.0980
C-2 PHENANTHRENE	0.9000	0.5200
C-3 PHENANTHRENE	0.7800	0.5800
NAPHTHOBENZOTHIOPHENE		
C-1 NAPHTHOBENZOTHIOPHENE		
C-2 NAPHTHOBENZOTHIOPHENE		
C-3 NAPHTHOBENZOTHIOPHENE		
FLUORANTHENE	0.0027	0.0000
PYRENE	0.0100	0.0110
C-1 PYRENE	0.1100	0.0810
C-2 PYRENE		
BENZO(a)ANTHRACENE	0.0000	0.0000
CHRYSENE	0.0660	0.0620
C-1 CHRYSENE	0.1400	0.1400
BENZO(b)FLUORANTHENE	0.0000	0.0075
BENZO(e)PYRENE		
BENZO(a)PYRENE		
PERYLENE		
INDENO(1,2,3-cd)PYR.		
DIBENZO(a,h)ANTHR.		
BENZO(g,h,i)PERY.	0.0049	0.0000

All values are valid to two significant figures only.

* Values given as parts per thousand in the oil.

immobile. Microbial degradation will continue, and be a function of exposed surface area of the oil, nutrient availability, and temperature. As the degradation continues, the composition of the subsurface oil will become similar to that described for the heavily weathered surface sample (Figure I-26).

I.C.4. PORE WATER CHEMISTRY

In the intertidal zone, the space between the grains of sediment (the pore or interstitial space) may be filled with water or air. The water table in the sediments on the shore rises and falls with the tide and usually is somewhat higher than the tidal level due to capillary lift of water in small pore spaces and to inflow of surface runoff water from the adjacent land and upper shore. On the falling tide, the pore water drains from the sediments lying above the tide level. Most of this drainage is subsurface and the water emerges below the tide level. However, in some cases, particularly in sandy or silty sediments (or in areas with large tidal ranges), subsurface drainage can not keep pace with the rate of decrease in tidal height and some of the water drains out onto the surface of the beach above the tide level and flows down the beach face. During periods of snow melt or rain, runoff of freshwater from land mixes with the saline interstitial water and moves with it down through the beach substrate on the falling tide.

If the intertidal sediments contain subsurface deposits of oil, the interstitial water moving with the tides through the sediments may come in contact with the oil and carry away some of it in solution or in particulate form. The amount of oil removed with the flushing of intertidal water will depend on the relative amount of surface area available for contact between the oil and water and on the degree of weathering of the oil. If the subsurface sediments are saturated with petroleum, there will be little contact between the oil and interstitial water. The oil will be relatively immobile unless removed physically by storm action or man's activities. If the concentration of oil is lower and only a fraction of the available pore space is occupied by the oil (e.g., the sediment particles have a surface coating of oil), there will be substantial surface area for contact between oil

and interstitial water during each tidal cycle. Hydrocarbons may be leached continuously into the interstitial water as the interstitial water is replaced by tidal pumping and surface runoff until no leachable hydrocarbons remain. The weathered oil is somewhat less sticky than fresh crude oil, due to formation of stable oil/clay flocs (see Section II.A.5). Therefore, droplets may be dislodged by the flowing water and carried away with it.

The rate of transport of oil from the subsurface deposits depends on the amount of water that comes in contact with the oil each day and the tendency of the individual hydrocarbons remaining in the oil to move from the solid oil phase into the water phase. As the more soluble components of the oil are leached out by the flowing water, the remaining oil becomes more viscous and the rate of leaching of soluble components and dispersion of droplets into the water decreases. Thus, it can be expected that the rate of removal of oil from a subsurface oil deposit will decrease with time. Therefore, information about the composition and concentrations of petroleum hydrocarbons in the pore water is important in predicting the potential environmental fate and effects of weathered oil buried in the upper intertidal zone of some beaches in Prince William Sound.

A mathematical model was developed to predict the concentrations of PAHs (the most toxic fractions of the spilled oil) in pore water in contact with subsurface oil deposits. The model also predicts the rate at which PAHs will be leached from the deposits during tidal flushing of the intertidal zone. Validation of model predictions was provided by analysis of pore water samples from several shores where subsurface oil was present. A detailed description of the model and predicted leaching rates of PAHs from subsurface oil deposits is available from Exxon as a separate report.

In a two-phase, oil/water system, organic solutes such as PAHs will tend to become distributed between the water and oil phases according to their relative solubilities in the two phases. The distribution of the PAHs between the two phases can be expressed as a distribution or a partition coefficient. Octanol/water partition coefficients (K_{ow}) derived empirically or theoretically are frequently used to estimate the concentration of a sparingly soluble organic compound such as a PAH in water in equilibrium with a solid phase (sediment organic carbon, bulk petroleum, or the tissues of a marine organism). In the model, concentrations of

different PAHs in sediment pore water in equilibrium with subsurface oil deposits were calculated based on the K_{ow} of each PAH and its concentration in a typical sample of subsurface oil. The oil samples used to calculate concentrations of PAHs in pore water included relatively lightly weathered oil similar to that which originally came ashore, moderately weathered subsurface oil collected at several locations in Prince William Sound in January 1990, and more highly weathered subsurface oil from March 1990.

It was necessary to make several assumptions in the model. All of these assumptions were conservative (e.g., they predict higher concentrations of PAHs in pore water than are likely to occur). The major assumption is that equilibrium is reached between the deposit of subsurface oil and pore water flowing over and coming into momentary contact with the oil. This could be the case if the contact time between pore water and the oil deposit is long enough, on the order of several minutes (Karickhoff, 1980). However, it is unlikely that contact between pore water and oil will reach equilibrium.

Three sets of calculations were made with the model:

- ☐ Initial-concentration-case equilibrium calculations representative of oil at high concentrations at a weathering state of the oil when it first came ashore;
- ☐ Average-case calculations representative of the average oil loading and composition found during January sampling; and
- ☐ March-case calculations using actual oil loading and composition from March samples to predict water quality.

The concentrations of PAHs in the oily sediments were measured by gas chromatography/mass spectrometry. Data were acquired for 46 samples of subsurface oily sediments chosen to be representative of the samples taken in the winter beach monitoring program. Twelve additional subsurface sediment samples, as well as pore water samples taken from the same trenches as the sediment samples, from the March 1990 survey, were also analyzed. The inputs to the model for the three test cases were as follows:

- Initial-concentration case equilibrium calculations were made using PAH concentrations determined by taking the average plus the standard deviation from the three samples with the highest measured PAH concentrations. These samples are the least weathered samples of all those that were analyzed for PAHs. Therefore, they are reasonable representations of the concentrations of PAHs in the oil that came ashore.
- Average-case equilibrium calculations were made using the average PAH concentrations from seven subsurface sediment samples taken in January 1990.
- March-cases represent equilibrium calculations using PAH concentrations and TPH concentrations in individual samples collected during March, 1990. Pore water samples were also collected at the same locations and depths as the sediment samples.

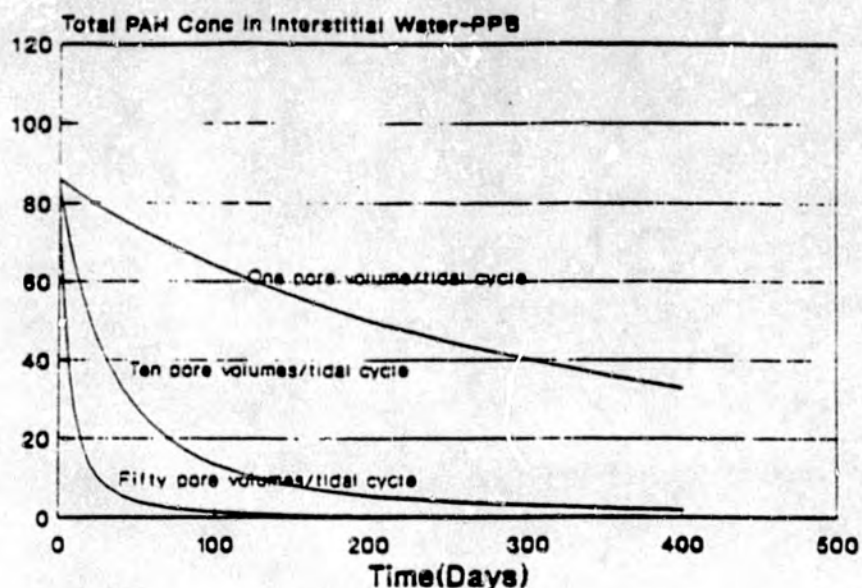
Concentrations of PAHs leaching into pore water over time were calculated based on the number of volumes of pore water that flow through the sediment during each tidal cycle. Estimates of beach flushing were made using fluid flow models that indicate that about 10 pore volumes flow through intertidal sediments of a cobble beach or a cobble beach underlain with sand during each tidal cycle. The actual flushing rate of a beach depends on several physical properties of the beach and is quite variable. Therefore, sensitivity cases were run to show the effect of flushing rates from 1 to 50 pore volumes/tidal cycle, a realistic range for different substrate types.

Initial-Concentration-Case Calculations. The leaching rates of individual PAHs were calculated over time based on the concentrations of the PAHs remaining in the subsurface oil. Values for individual PAHs were summed to produce an estimate of the leaching rate for total PAHs at three flushing rates (Figure I-33). Two tidal cycles per day were assumed for these calculations. The maximum concentration of TPH (5,000 mg/kg) was used.

In all three cases, the initial total PAH concentrations in the interstitial water were about 86 ppb. For the base case of 10 pore

Reduction in Total PAH vs Time

A) Initial Concentration Case



B) Comparison Average Case vs March Model Predictions

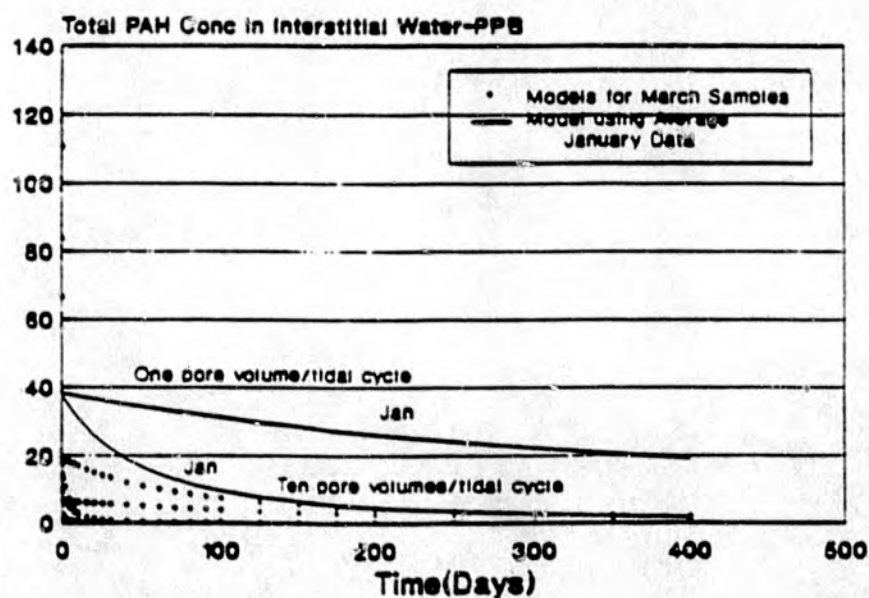


Figure I-33. Model predictions of concentrations of total PAHs in pore water in contact with intertidal deposits of subsurface oil on shores of Prince William Sound: (A) the initial concentrations case; and (B) comparison of average case and March case.

volumes/tidal cycle, the concentration drops to about 50 ppb after 20 days or 400 pore volumes of water. After 50 days, the concentration of total PAHs has dropped to about 30 ppb.

For the case of 50 pore volumes/tidal cycle, the concentration of total PAHs in pore water drops to 20 ppb within two weeks and continues to fall rapidly. On the other hand, for the case of 1 pore volume/tidal cycle, the concentration drops slowly, reaching about 65 ppb in 100 days.

Average-Case Calculation. Predicted concentrations of total PAHs for average case conditions are lower than those for the initial-case conditions (Figure I-33). The predicted initial concentration of total PAHs in pore water is about 37 ppb. The lower concentrations are due to the fact that the oil is more weathered and has lower concentrations of leachable PAHs. The rate of decrease in the concentration of total PAHs in the leach water is greater for the average case than for the initial case conditions. This is due to the lower oil loading on the subsurface sediments in January than earlier as a result of natural beach cleaning by fall and winter storms.

March-Case. The model was run using the data for the concentrations of PAHs in sediments collected in March 1990. The predicted concentrations of total PAHs in pore water are shown in Figure I-33 as dots. As expected, because of continued weathering and decreases in concentrations of oil remaining in subsurface sediments, the predicted concentrations of total PAHs in pore waters in equilibrium with the subsurface oily sediments are lower than in the January case. Predicted concentrations of total PAHs in pore water generally are below 20 ppb.

Field Observations. During the field survey in early March, pore water samples were collected at the same locations and depths as subsurface sediment samples. The results of analysis of the pore water samples for PAHs were used to validate model predictions of PAH concentrations in pore water.

The results, in general, support the premise that model predictions are conservative and that concentrations of PAHs in interstitial water in equilibrium with subsurface oil deposits are low (Table I-3). A total of eleven pairs of subsurface sediment and pore water samples were analyzed. Suspended particles or flocs were removed from the pore water samples by

Table I-3
Concentrations of Total PAHs in Pore Water and Sediments,
and of TPH in Subsurface Sediments Collected From
Several Oiled Shorelines in Prince William Sound in March 1990

Location	Site/Pit	PAH			TPH
		Sediment mg/kg	Water ng/L	Oil mg/kg	Sediment mg/kg
Foul Pass	AP-4/1	0.02	63.5	1621	12.4
Passage Pt.	AP-5/3	0.01	63.1	5347	2.25
	79.1*				
Latouche Bay	AP-12/1	0.07	709.9	836	82.7
Sleepy Bay	AP-13/1	32383	14293	5684	5697
Sleepy Bay	AP-13/4	0.14	124	3261	43.6
Sleepy Bay	AP-13/6	0.14	3821	2937	48.3
Latouche	AP-14/1	17899	10715	3271	5472
Latouche	AP-14/2	0.05	119.9	1693	32
NW Evans I.	AP-15/2	1.06	198.4	2684	394.2
NW Evans I.	AP-15/EB**		148.1		
S Elrington I.	AP-18/2	0.14	546	10543	13.2
Reference Site	AP-21C/1	0.0005	118.9	662	0.47
Blank		0.002	20.4		0.004
Prudhoe Bay Crude Oil				16556	

*Unfiltered sample

**Equipment blank