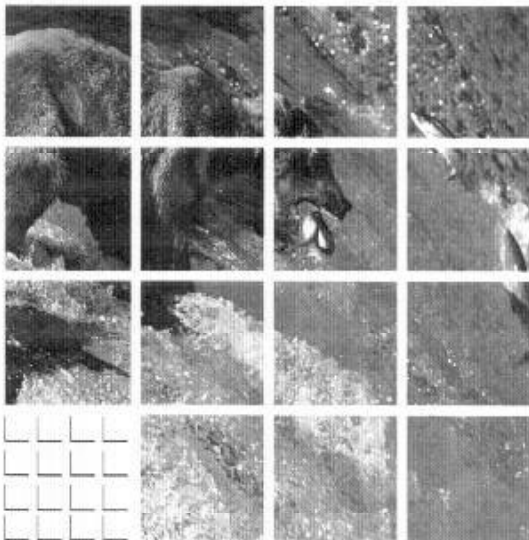


E N T R I X

**EXPOSURE OF OPIHI TO
SPM HOSE SPILL ON KAUAI, HAWAII**

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Project No. 304201

April 22, 1999

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The purpose of this study is to estimate the extent and nature of exposure of limpets (opihi) to petroleum from the SPM Hose Spill in August/September 1998. The overall approach is to compare petroleum-derived hydrocarbon concentrations in opihi from areas oiled with weathered fuel oil from the Tesoro SPM Hose Spill with those measured in opihi from non-oiled or reference areas.

The opihi tissue was analyzed for the amounts and distributions of polycyclic aromatic hydrocarbons (PAHs). The rationale behind using PAHs rather than other measures of hydrocarbon (e.g., total petroleum hydrocarbons) is that PAHs are not produced biogenically and thus are unambiguous indicators of exposure to petroleum-derived material.

Tar balls associated with the SPM Hose Spill began washing ashore at the eastern end of a north-facing beach in the southern Kipu Kai area of Kauai in early September 1998, resulting in a visible coating of oil on the boulders. In this area of the Kipu Kai South Beach, the blackfoot opihi species (*Cellana exarata*) was seen. The yellowfoot species, *C. sandwicensis*, could only be found by venturing into the low intertidal zone.

The Kipu Kai North Beach, just north of Molehu Point, had a sandy beach strand about 5 to 10 meters wide that ended on the seaward side in a limestone bench, apparently at or just above high water.

Two opihi sampling events were conducted. The first event occurred on 23 September 1998 at the oiled boulder area of Kipu Kai South Beach, during which seven blackfoot opihi samples and one yellowfoot opihi sample were collected. The second event occurred on 2 and 3 November 1998 and focused on the blackfoot opihi, *C. exarata*. In November, opihi were collected from Ahukini and two Kipu Kai shores that were possibly or known to be impacted by the SPM Hose Spill. Reference samples were collected from Ninini (near Ahukini), from the Kipu Kai area, and at Haena. Haena was chosen for reference sample collection because it was outside the Kauai area that was impacted by the spill.

ADL laboratory analyzed four of the eight opihi samples collected on 23 September 1998 and all 14 samples collected on 2 and 3 November 1998 for alkylated polycyclic aromatic hydrocarbons (PAHs). Total PAH concentrations were adjusted for interferences in the procedural blank prior to interpretation of the data.

Opihi samples collected on 23 September in the oiled boulder area at Kipu Kai showed adjusted total PAH concentrations ranging from 140 to 410 $\mu\text{g}/\text{kg}$ (parts per billion - ppb) dry weight (dw) for three blackfoot opihi samples, and 14 $\mu\text{g}/\text{kg-dw}$ for the yellowfoot opihi sample. Three blackfoot opihi samples collected on 2 November from the same area contained 13 to 67 $\mu\text{g}/\text{kg}$ adjusted total PAH. Two blackfoot opihi samples collected on 2 November from the limestone outcropping area of Kipu Kai (possibly lightly oiled)

contained 7.6 and 14 $\mu\text{g}/\text{kg}$ adjusted total PAH. The four blackfoot opihi samples collected from non-oiled areas of Kipu Kai on 2 November contained adjusted total PAH concentrations ranging from 15 to 40 $\mu\text{g}/\text{kg}$.

Two blackfoot opihi samples collected in November from a formerly oiled area at Ahukini showed adjusted total PAH concentrations of 13 and 180 $\mu\text{g}/\text{kg}$. The higher value appeared to derive from a combustion source, not from weathered petroleum. Two opihi samples collected from a non-oiled area near Ahukini contained 6.3 and 8 $\mu\text{g}/\text{kg}$ adjusted total PAH. The sample collected from Haena contained 10 $\mu\text{g}/\text{kg}$ adjusted total PAH.

Based on the PAH distribution in samples collected at Kipu Kai in September 1998 and on a comparison of the PAH tissue concentrations measured in opihi from reference sites in November (Table 6-1), a qualitative case can be made for exposure of the blackfoot species (*C. exarata*) to petroleum at this location at this time. This conclusion is based on levels of total adjusted PAH in these samples that were approximately 10 times greater than total adjusted PAH concentrations measured in the Kipu Kai reference areas. In addition, the PAH distribution in the blackfoot samples is dominated by phenanthrene, dibenzothiophene, and their highly alkylated homologues, which though not conclusive in itself, is consistent with exposure to weathered oil. A typical PAH distribution derived from non-petroleum sources (e.g., air-borne particulates, creosote, etc.) is dominated by higher molecular weight PAHs (e.g., chrysene, benzo[a]pyrene).

The differences in PAH concentrations between the September and November samples collected from the oiled boulder area in Kipu Kai (South Beach) suggest that exposure to petroleum from the SPM Hose Spill had diminished to near-background levels by November 1998. Further, based on review of all results presented, there is no indication of exposure to petroleum from the SPM Hose Spill in the November 1998 opihi samples from Ahukini.

1.1 PURPOSE

The purpose of this study is to estimate the extent and nature of exposure of limpets (opihi) to petroleum from the SPM Hose Spill in August/September 1998.

1.2 SPILL EVENT

The Single Point Mooring (SPM) Hose Spill of August 24, 1998, off Barber's Point, Oahu, released IFO-380 (Intermediate Fuel Oil, 380 centistokes) fuel oil. This material is a viscous black oil, with little or no light material in the composition and is considered and used as a bunker fuel. Oil was recovered offshore of Oahu in the two days following the spill. Some of the unrecovered oil was carried by ocean currents to Kauai and washed up on several beaches in the form of tar balls in early September.

Most of the oil stranding occurred in scattered pockets on the east side of Kauai from Kaipu Kai to just north of Kealia. The distance between these points is approximately 31 kilometers. Outside of this area there was a 45 meter beach very lightly oiled with tarballs at Barking Sands on the west side of the island. At Kipu Kai, SCAT reports indicated 250 meters of boulder beach heavily oiled with a SCAT oil character designation of "tar coating" and another 250 meters of very lightly oiled sandy beach. At Ahukini, 160 meters of supratidal basalt bench were recorded to have a 70 percent covering of oil with SCAT character designation "fresh oil". Between Ahukini and Kealia Beach, another 2.8 kilometers of beach were at times designated as very lightly oiled with small tar balls.

1.3 APPROACH

In order to evaluate exposure of the transported oil from the SPM Hose spill to organisms found in the intertidal areas of the impacted Kauai beaches, a study was conducted to measure petroleum-derived hydrocarbons in limpets (opihi). The study included the collection of opihi samples during the beach cleanup (September 23, 1998), as well as six weeks later (November 2 and 3, 1998).

To estimate the extent and nature of exposure of opihi to petroleum derived from the SPM Hose Spill, it was necessary to first compare petroleum-derived hydrocarbon concentrations in opihi from oiled areas with those measured in opihi collected from non-oiled or reference areas. Toward this end, the opihi tissue was analyzed for the amounts and distributions of polycyclic aromatic hydrocarbons (PAHs). The rationale behind using PAHs rather than other measures of hydrocarbon (e.g., total petroleum hydrocarbons, etc.) is that PAHs are not produced biogenically and are unambiguous indicators of exposure to petroleum-derived material. These compounds are also used in

the National Status & Trends Mussel Watch program as an indicator of petroleum-derived pollution in coastal environments (National Oceanic and Atmospheric Administration/National Oceanic Service (NOAA/NOS)). Because of other possible sources of hydrocarbons in Kauai (such as other oil spills and various unknown chronic or episodic releases of petroleum products in both oceanic and nearshore waters), we evaluated and compared the distribution of PAH compounds measured in the opihi tissue with the PAH compounds found in the source oil.

The purpose of and approach to the study were developed in conjunction with representatives of trustee agencies (NOAA/Damage Assessment Center (DAC)), Hawaii Department of Land and Natural Resources (DLNR), United States Fish and Wildlife Service (USFWS), and Hawaii Department of Health (DOH)). This report describes the two sampling events, sampling procedures, chemical analyses, laboratory results, and interpretation of the results.

Tar balls associated with the SPM Hose Spill began washing ashore at the eastern end of a north-facing beach in the Kipu Kai area of Kauai in early September 1998 (Figure 2-1). Cleanup crews were dispatched to the area and collected tar balls by hand and through the use of snares in the surf zone. It appeared that some tar balls had been stranded among the boulders at the eastern end of the beach and had melted from heating by the sun during exposure at low tide, resulting in a coating of oil on approximately 250 meters of the boulders.

On 21 September 1998, representatives of Tesoro and trustee agencies visited the Kipu Kai area to survey the extent of oiling and observe wildlife present. Members of the party included John Cubit and Frank Csulak (NOAA/DAC); Chris Jansen (Tesoro); Gordon Robilliard, Andy Jahn, and Judy Nedoff (ENTRIX); and Lee Ann Woodward (USFWS). Nominal low tide of 0.4 feet MLLW on 21 September was at 0930. The following observations were recorded by Andy Jahn and Gordon Robilliard between 0950 and 1300.

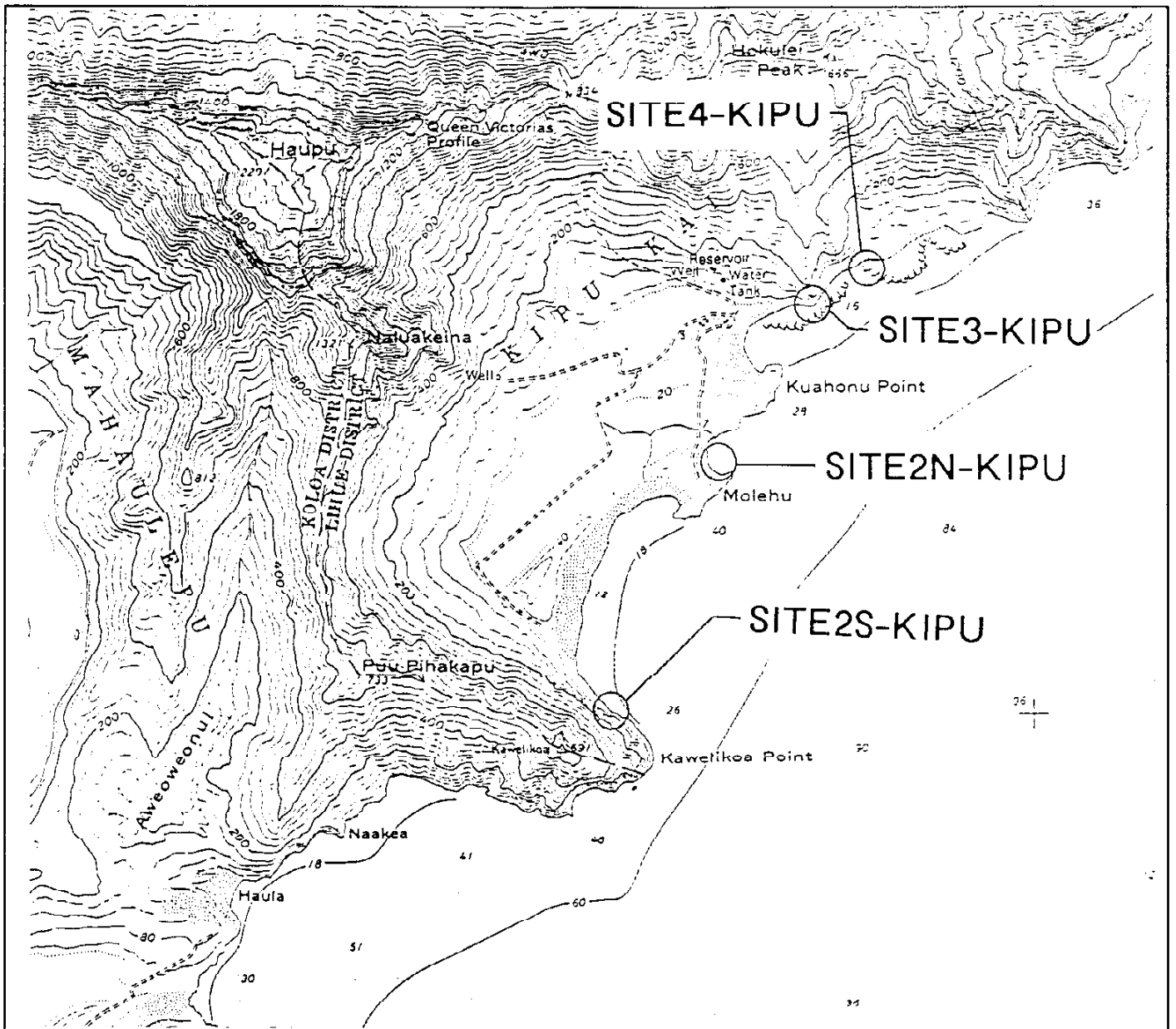
2.1 SOUTH BEACH AREA OF KIPU KAI

This beach is a north-facing boulder slope (Figure 2-1), grading from a sand beach on the west to cliffs at the eastern end (Kaweliko Point), with a total length of approximately 600 meters. Approximately the western 400 meters were explored, and approximately the western 250 meters appeared partially oiled. The boulders were a mixture of very smooth, dense basalt and rougher volcanic material that had cooled while retaining gas bubbles. Some boulders had depressions formed by short-spine urchins at low intertidal or subtidal depths and these boulders had probably been washed ashore by large waves.

Correlated with the eastward change from sand-boulder to steep cliff, the intertidal habitat grades from drier to wetter; white water run-up (west) to breaking wave (east); and high suspended sand load on the west end to very low suspended load near the eastern end. Corresponding increases in algal coating of mid-intertidal rocks, as well as apparent abundance of grapsid crabs, limpets (opihi), helmet urchins, short-spine urchins, and macroalgae were noted (all more abundant toward the eastern portion of the beach). Nerites (small gastropod snails) appeared to be abundant along the entire stretch.

2.1.1 OILING OF BOULDER AREA

Besides some staining of boulders near the western end of the explored area, it was possible to find a thicker coating of oil and occasional tar balls under boulders when they were rolled over. Observations under boulders also revealed the presence of opihi, small (< 1 cm carapace width) grapsid crabs, nerites (some oiled), moderate numbers of a raspberry-colored anemone (6 to 10 under larger boulders), one light-colored nerite,



Basemap taken from U.S.G.S. 1983,
 Lihue quadrangle, Hawaii, 7.5 minute series (topographic).
 Topography from aerial photographs taken in 1960. Field checked in 1963.
 Revised from photographs taken in 1978. Limited field check in 1981.

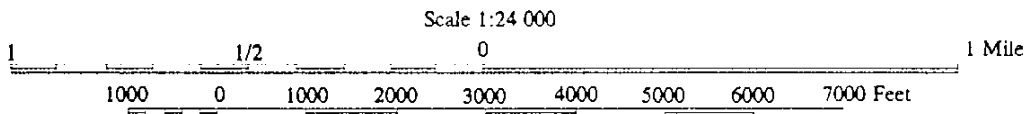


Figure 2-1
 Kipu Kai Sampling
 Locations

Opihi Sampling Sites at Kipu Kai, Kauai, Hawaii

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tubicolus polychaetes, and flatworms. In clean sand beneath the oil, porcellanid crabs, a sipunculid (peanut worm), and amphipods were also observed, all in apparently normal condition. No dead animals were observed.

2.1.2 OPIHI

The majority of opihi seen were the green-mantled/black-foot species, *Cellana exarata*. Only by venturing into the low intertidal could specimens of the yellow-foot species, *C. sandwicensis*, be obtained. The latter were large (>1.5 inches) and covered with turf-like algae. Few of the opihi appeared to be oiled and those that were had a relatively light coating scattered on the shell. Many of the *C. exarata* in the low intertidal were abraded, some so much that the outer protein layer (periostracum) was present only on the last margin of shell growth. This condition was common at the west (sandy) end of the beach, but rare to non-existent toward the east (rocky, high-energy) end.

In parallel with the natural gradient of increasing wave exposure from west to east along this stretch, rocky intertidal organisms become more diverse and abundant with increasing distance from the sandy, non-vegetated beach area. The ease of human access also decreases with increasing distance from the sandy beach, a factor that could also contribute to the perceived gradient of increasing opihi abundance. At some point (estimated by SCAT teams as 250 m from the sand beach), the oiling of the shoreline became little or non-existent toward the east (i.e., Kawelikoa Point).

2.2 NORTH BEACH

The northern beach is just north of Molehu Point (Figure 2-1). This beach had a non-vegetated, sandy stretch about 5 to 10 meters wide that ended on the seaward side in a limestone bench, apparently at or just above high water. This is a high wave energy area, such that a tide pool, or splash pool, occupied much of the lower-elevation areas of the bench. The upper part of the bench was covered by a black-green, felt-like mat, apparently of cyanobacteria ("blue-green algae"). Two oil samples were collected at this beach on 21 September. However, oil was not observed washing up on the beach at the time.

Two sampling events were conducted. The first event occurred on 23 September 1998 at the oiled boulder area of Kipu Kai South Beach. The second event occurred on 2 and 3 November 1998, and encompassed sampling at Kipu Kai South Beach, North Beach, and reference locations; Ahukini (previously oiled) and Ninini Point (reference); and Kee Beach at Haena (reference). Both events included representatives of Tesoro and trustee agencies (Table 3-1).

3.1 OPIHI SAMPLING IN SEPTEMBER 1998

On 23 September 1998, personnel from ENTRIX, NOAA, USFWS, and DLNR obtained tissue samples from two species of limpet (opihi, *Cellana exarata* [blackfoot] and *C. sandwicensis* [yellowfoot]) as well as the helmet urchin (Ha uke uke, *Colobocentrotus atrata*) from an oiled section of South Beach at Kipu Kai. A summary of these samples is shown in Table 3-2. Observations of the sampling team indicated that the blackfoot opihi species (*C. exarata*) was by far the more common at the mid-intertidal level accessible to the collection team. This species scrapes algal film off the mid-intertidal rocks. The yellowfoot species, *C. sandwicensis*, is said to graze macroalgae in the lower intertidal zone.

These species are all consumed by humans in the recreational fishery. Both opihi species are important in the Hawaiian culture. Opihi are potentially exposed to hydrocarbons through absorption from the water, dermal contact, and through feeding by rasping oil and oil-coated algae off the rocks. These samples were collected for analysis of the amount of petroleum hydrocarbons in the tissue. The sampling on 23 September 1998 was done to get an indication of the potential exposure of these intertidal animals to petroleum hydrocarbons while oil was still present on the upper beach at Kipu Kai.

A wooden post on the slope above the North Beach area was chosen by the field team as a landmark above the reach of common winter storm waves. Collection of opihi samples from the largest boulders began at this point and proceeded approximately west toward the sandy beach area. A total of seven blackfoot opihi samples and one yellowfoot opihi sample were collected. Opihi sampling methods are described in Section 4.0.

Table 3-1. Participants at 23 September 1998 Sampling Event

Name of Personnel	Organization
Dr. John Cubit	NOAA/DAC
Mr. Don Heacock	DLNR
Dr. Lee Ann Woodward	USFWS
Ms. Liz Galvez	Hawaii Department of Health
Ms. Kathy Ho	Hawaii Attorney General's Office
Dr. Andy Jahn	ENTRIX
Ms. Judy Nedoff	ENTRIX
Mr. Chris Jansen	Tesoro Hawaii Corporation

Table 3-2. Sample Collected at Kipu Kai South Beach 23 September 1998

Sample ID	Date Collected	Area - Location	Sample Type	Sample Analyzed?	Jars Filled
BLACKFOOT1	9/23/98	Kipu Kai - South Beach	Oiled	YES	1
BLACKFOOT2	9/23/98	Kipu Kai - South Beach	Oiled	NO	1
BLACKFOOT3	9/23/98	Kipu Kai - South Beach	Oiled	NO	1
BLACKFOOT4A/B	9/23/98	Kipu Kai - South Beach	Oiled	YES	2
BLACKFOOT5	9/23/98	Kipu Kai - South Beach	Oiled	NO	1
BLACKFOOT6	9/23/98	Kipu Kai - South Beach	Oiled	YES	1
YELLOWFOOT1	9/23/98	Kipu Kai - South Beach	Oiled	YES	1
KKCRAB-092398	9/23/98	Kipu Kai - South Beach	Oiled	NO	1
KKURCHIN1	9/23/98	Kipu Kai - South Beach	Oiled	NO	1
KKURCHIN2	9/23/98	Kipu Kai - South Beach	Oiled	NO	1
KKURCHIN3	9/23/98	Kipu Kai - South Beach	Oiled	NO	1

3.2 OPIHI SAMPLING IN NOVEMBER 1998

The objective of the November 1998 sampling was to collect opihi both at Kipu Kai and at other beaches that had been oiled by the SPM Hose Spill as well as at non-oiled sites. Results would allow the following:

1. Comparison of PAH levels present in opihi over time, i.e., levels in opihi collected in September when oil was present at Kipu Kai vs. levels in opihi collected six weeks later from the same location; and
2. Comparison of PAH levels in previously exposed opihi with the natural or chronic background hydrocarbon levels seen in opihi collected from locations out of the area impacted by the SPM Hose Spill (i.e., reference sites).

The objectives of the November opihi sampling were to obtain (up to three) replicate samples of *Cellana exarata* (blackfoot opihi) from three oiled beaches (Kipu Kai South, Kipu Kai North, and Ahukini), from three non-oiled beaches nearby the oiled beaches, and from a beach that was out of the area impacted by oil. Based on observations concerning animal locations, greater availability, and potential exposure to spilled oil, this sampling focused on the blackfoot opihi, *C. exarata*.

The sampling team for the 2 and 3 November 1998 effort is provided in Table 3-3.

3.2.1 NOVEMBER SAMPLING LOCATIONS

Samples were collected from Ahukini (Figure 3-1) and two Kipu Kai shores (Figure 2-1) that were known to be impacted by the SPM Hose Spill. In addition, samples were collected from reference or "non-oiled" shores. One reference site was near Ahukini (Figure 3-1), two reference sites were in the Kipu Kai area (Figure 2-1), and one reference site, at Haena (Figure 3-2), was chosen because it was outside the Kauai area that was impacted by the spill. Table 3-4 describes the sampling locations and associated photographs. Photographs can be found in Appendix A. A summary of samples collected on 2 and 3 November 1998 is shown in Table 3-5.

At the time of sample collection, it was observed that there was a scarcity of relatively large opihi. None of the opihi appeared to be oiled and no oil was observed in the sample collection areas. It should be noted that at the Kipu Kai - North Beach, the yellowfoot and blackfoot opihi were found in the same intertidal area. Therefore, the samples collected from this site contained a few yellowfoot opihi (*C. sandwicensis*). It is not expected that this had any effect on the analytical results.

Table 3-3. Personnel Present at 2 and 3 November 1998 Sampling Event

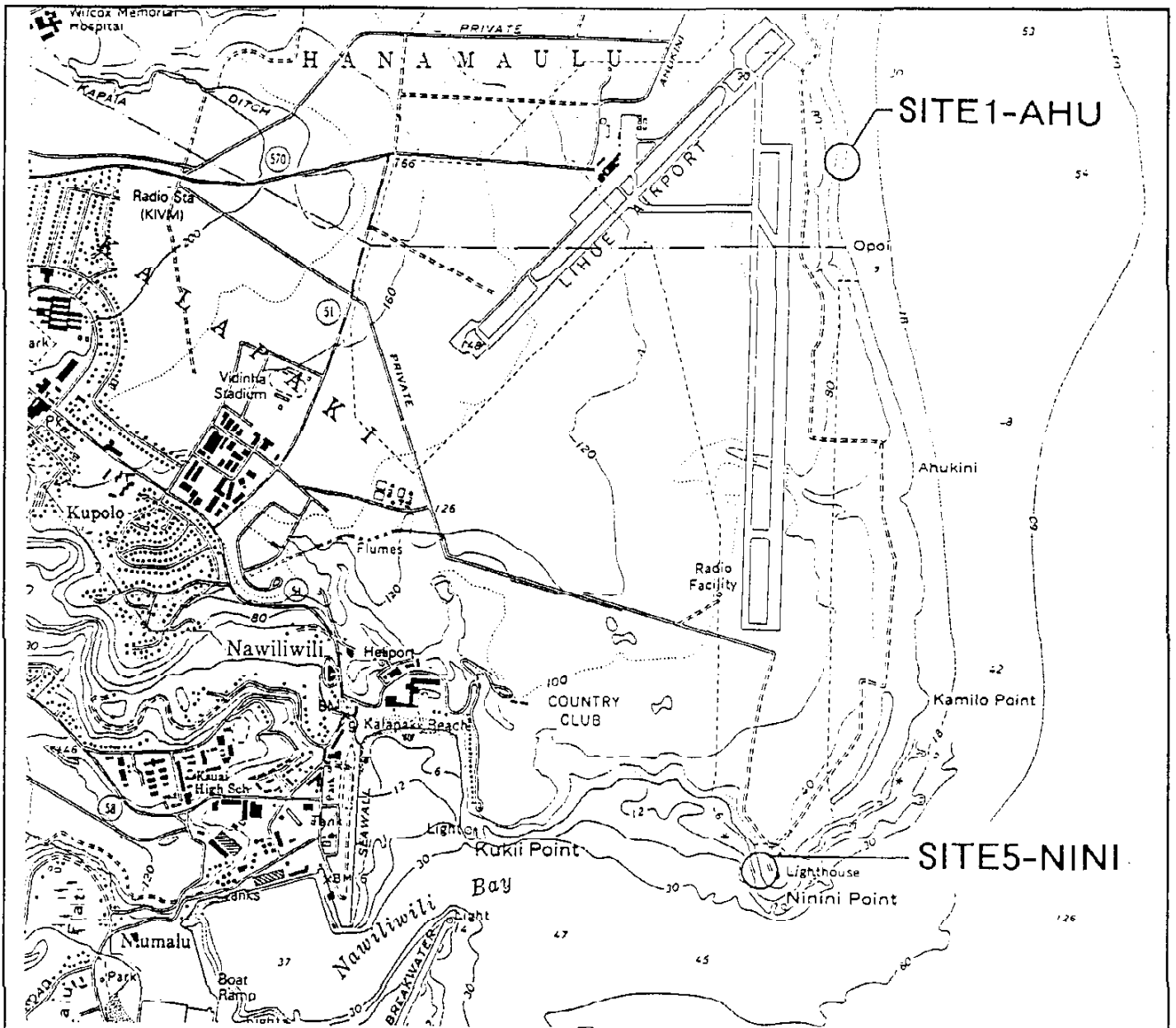
Name of Personnel	Organization
Ms. Stephanie Sakurai	Clayton Environmental Consultants
Mr. Stan Souza	Clean Islands Council (CIC)
Mr. Don Heacock	DLNR
Ms. Rose Chu	Tesoro Hawaii Corporation
Mr. Richard Rosen	Tesoro Hawaii Corporation
Ms. Regie Kawamoto	University of Hawaii, Zoology Department
Dr. Alison Kay	University of Hawaii
Mr. Dwayne Minton	University of Hawaii

Table 3-4. November Opihi Sample Locations

Area - Sample Type	Location	Landmark	Photo No.
Ahukini - Oiled	Ahukini	East of drainage ditch at end of airport	1 through 6
Ahukini - Reference	Ninini Point near Lighthouse	Western side of the lighthouse	7 through 9
Kipu Kai - Oiled	South Beach	Approx. 25 m north of wooden post	10 through 14
Kipu Kai - Oiled	North Beach	Southwest side of beach near limestone overhang and from northeastern side of beach near limestone shelf	15 and 16
Kipu Kai - Reference	North of Kuahonu Point	Basalt boulder beach	17 and 18
Kipu Kai - Reference	Further North of Kuahonu Point	Basalt boulder beach	19 and 20
Iaena - Reference	Kee Beach	Basalt boulders west of Haena State Park	21 and 22

Table 3-5. Sample Locations and Replicates Collected November 1998

Sample ID	Date Collected	Area - Location	Sample Type	Jars Filled	Approximate No. Per Jar
SITE1-AHU	11/2/98	Ahukini	Oiled	2	Jar 1: 51 Jar: 2: 38
SITE5-NINI	11/3/98	Ahukini - Ninini Point near Lighthouse	Reference	2	Jar 1: 58 Jar 2: 83
SITE2S-KIPU	11/2/98	Kipu Kai - South Beach	Oiled	3	Jar 1: 45 Jar: 2: 48 Jar 3: 58
SITE2N-KIPU	11/2/98	Kipu Kai - North Beach	Oiled	2	Jar 1: 28 Jar: 2: 13
SITE3-KIPU	11/2/98	Kipu Kai - North of Kuahonu Point	Reference	2	Jar 1: 41 Jar: 2: 52
SITE4-KIPU	11/2/98	Kipu Kai - Further North of Kuahonu Point	Reference	2	Jar 1: 32 Jar: 2: 41
SITE6-KEE	11/3/98	Haena - Kee Beach	Reference	1	Jar 1: 53



Basemap taken from U.S.G.S. 1983,
 Lihue quadrangle, Hawaii, 7.5 minute series (topographic).
 Topography from aerial photographs taken in 1960. Field checked in 1963.
 Revised from photographs taken in 1978. Limited field check in 1981.

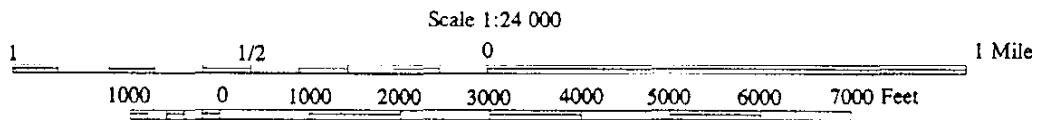
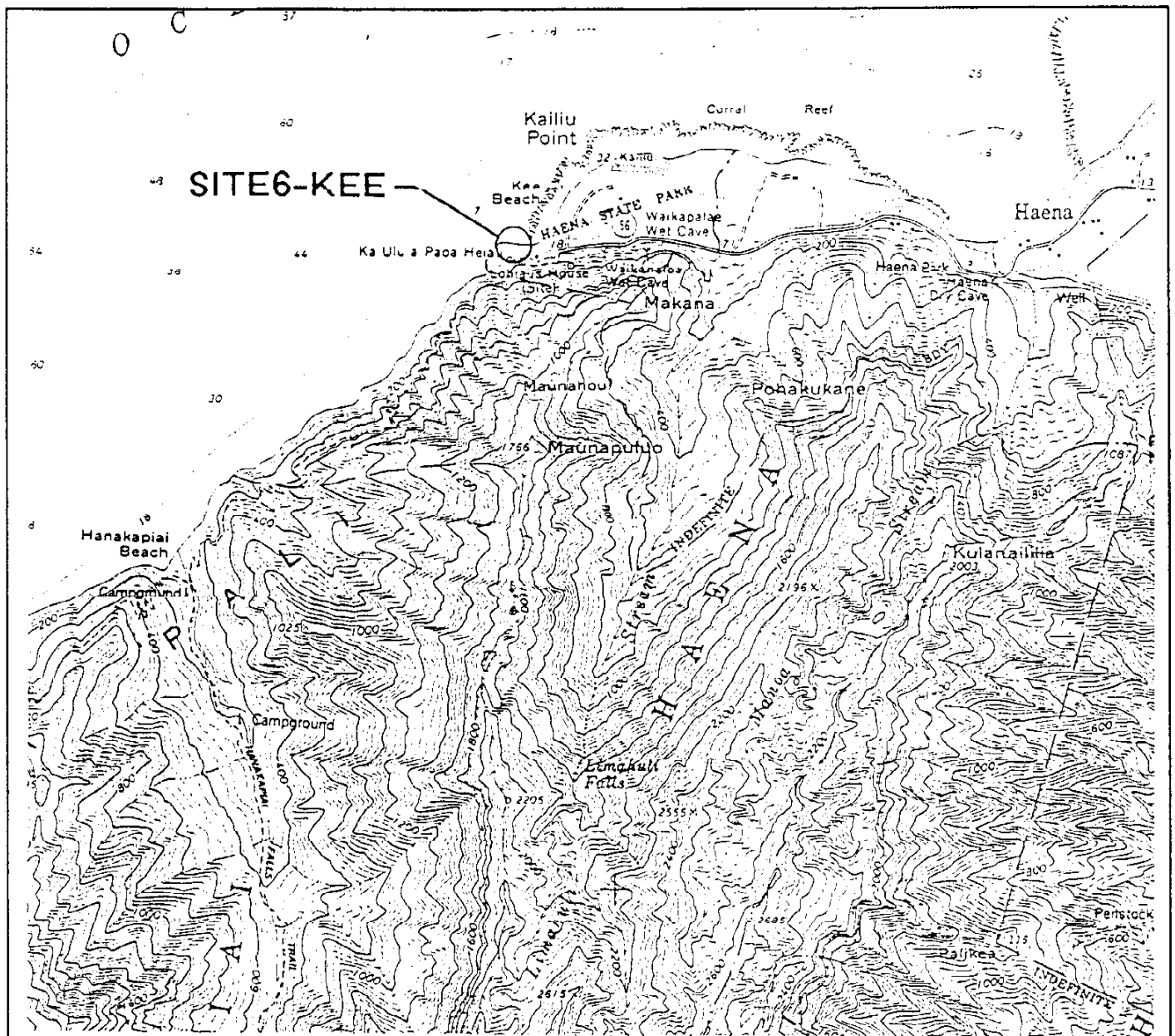


Figure 3-1
 Ahukini Sampling
 Locations

Opihi Sampling Sites at Ahukini, Lihue, Kauai, Hawaii

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Basemap taken from U.S.G.S. 1983,
 Haena quadrangle, Hawaii, 7.5 minute series (topographic).
 Topography from aerial photographs taken in 1960. Field checked in 1965.
 Revised from photographs taken in 1977. Limited field check in 1981.

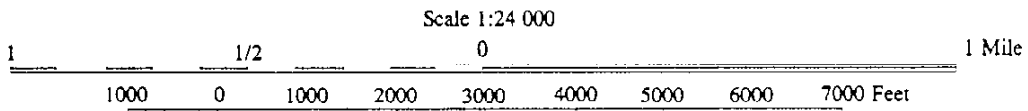


Figure 3-2
 Haena Sampling
 Location

Opihi Sampling Site at Kee Beach, Haena, Kauai, Hawaii

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