**Preassessment Data Report #2**

**M/V *Selendang Ayu* Oil Spill**

**Surveys of Intertidal, Subtidal, and Anadromous Stream Habitats**

**NOAA**

**Damage Assessment, Remediation, and Restoration Program**

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**Abstract.** On 8 December 2004, the *Selendang Ayu* went aground on Unalaska Island and spilled approximately 321,000 gallons of IFO 380 fuel oil and approximately 15,000 gallons of diesel fuel. About 70 miles of shoreline were within the area of principal oiling, defined as shoreline response segments where some portion required cleanup action. As a preliminary step in the natural resource damage assessment (NRDA) process, NOAA conducted preassessment surveys from December 27, 2004 through February 1, 2005 and from June 2 through 23, 2005. In the winter surveys, NOAA damage assessment teams examined the shoreline for patterns of oil movement and deposition, but daytime high tides were too high to comprehensively examine intertidal habitats for indications of oil impacts on the biota in these habitats. During two extreme low-tide series in June 2005, NOAA and scientists working for the responsible party conducted preassessment surveys of biota in intertidal, subtidal, and stream habitats in the spill area. In visual surveys of the perennial biota (algae and invertebrates) in rocky intertidal habitats, indications of possible adverse impacts of *Selendang Ayu* oil were observed at Spray Cape, but there were no other visible loss of species or reduced abundances of biota observed at other sites that could be attributed to the oil in the time period of 8 December 2004 to 20 June 2005. Shoreline clean-up operations, such as burning of oiled debris, use of heavy equipment, and removal of sand and other material from sections of oiled beaches, very probably killed or removed some beach-wrack biota and infauna to varying degrees. Between 20 and 23 June 2005, the teams observed beach cleaning operations that resulted in the release of oil into surface waters; this release apparently caused bleaching and necrosis of marine algae at HMP-11a. Warm conditions increase both the mobility and toxicity of heavy fuel oil, and these clean up-related oil releases and potential impacts resulting from those releasesmay have continued into the summer months after the field study data collection ended on 23 June 2005. In addition, the U.S. Coast Guard documented more releases of oil from the wrecked *Selendang Ayu* in October and December 2005, some of which stranded on the shoreline. The preassessment-scale surveys were designed to detect gross, acute, readily visible effects, such as acute mass mortality of biota, occurring before 23 June 2005. However, the observations made, as described herein, suggest that injury likely occurred to intertidal and subtidal biota. Additionally, injury to a variety of marine resources can be inferred from experience with similar-sized spills in similar environments and from the scientific literature.

**Introduction**

Preassessment surveys of intertidal, subtidal, and anadromous stream habitats, and associated fauna and flora were conducted in two time periods. In December 2004-January 2005, NOAA staff conducted preliminary field surveys of intertidal shores, subtidal habitats, and freshwater streams on Unalaska Island, in the area affected by the *Selendang Ayu* oil spill. These winter surveys mainly focused on documenting patterns of habitat oiling. Short day lengths, high daytime tides, and adverse weather conditions limited the observations that could be made of biota in these habitats. In June 2005, NOAA teams returned to the spill area during a series of extreme low tides to specifically conduct a second set of preassessment surveys of the biota in intertidal, subtidal, and anadromous stream habitats. Observations made during these surveys are presented below.

**Description of the *Selendang Ayu* Oil Spill**

On 8 December 2004, the *Selendang Ayu* grounded and broke in half on Spray Cape, Unalaska Island, 53o 38’ 04” N, 167o 07’ 30” W (Figure 1). An estimated 335,732 gallons of fuels, mostly Intermediate Fuel Oil (IFO 380), were released following the grounding. Additional information about the incident is available at the Unified Command Website for the *Selendang Ayu* incident:

http://www.dec.state.ak.us/spar/perp/response/sum\_fy05/041207201/041207201\_index.htm.

The Unified Command for the *Selendang Ayu* oil spill divided the 469 miles of shoreline in the potentially spill-affected area into 806 segments (Figure 2). Of these, 123 segments (70 miles) received enough oil somewhere in the segment to require oil clean-up treatment. The sum total of the length of oiled shoreline within all these segments was over 20 miles. One hundred and two of the oiled segments were actually approved for clean-up operations. Primarily because of safety concerns for the cleanup personnel, the remaining 21 segments were not treated.

Beach cleaning operations in the summer of 2005 remobilized unspecified quantities of stranded oil back into surface waters. In October and December 2005, storm waves moved the wrecked sections of the *Selendang Ayu*, causing the release of unknown quantities of additional oil for unknown periods of time. A civilian aircraft reported observing sheen around the vessel on 21 October 2005. The Coast Guard conducted occasional overflights following this report. On 24 October 2005, the Coast Guard conducted two overflights and reported seeing sheen and emulsified oil. This release was thought to have the potential to oil SCAT segments SPR 8, 10, 11, 12 and SKS 1, 2, 3, 4, and 5. The Coast Guard reported seeing a slow rainbow sheen burping up 350 yards from the stern section the following day, and saw a dull sheen the next day. No new oil was observed on the next four overflights conducted from 27 October through 26 November2005, but a thin sheen was observed on 1 December 2005 (information on reports of aerial observations came from a summary compiled by J. Hampton, Coast Guard). Through October 25, 2005, the Unified Command estimated that approximately 1,000 gallons of emulsified oil was released from the *Selendang Ayu* as a result of the storm waves (http://www.dec.state.ak.us/spar/perp/response/sum\_fy05/041207201/sitreps/041207201\_sr\_105.pdf), but this estimate has not been updated and may have missed possible releases occurring before and after October 24, 2005 on days without overflights. There is also no known estimate of the amount of oil that was reportedly released during the December storm.

**Surveys of the Spill Area**

**Winter Surveys: Observations of oil and biota from NOAA field surveys conducted in December 2004 – February 2005.**

*Objectives:* The main objectives of the winter surveys were to document patterns of oiling in habitats and collect ephemeral data (including samples of biota and oil taken from the shore).

*Methods:*NOAA pre-assessment teams conducted field surveys of the spill area on-foot from 27 December 2004 through 1 February 2005, in addition to observations made by Rapid Assessment Technique (RAT) and Shoreline Cleanup Assessment Technique (SCAT) teams. NOAA personnel participating in the pre-assessment field surveys were: Lisa DiPinto, Nick Iadanza, John Cubit, Doug Helton, Ian Zelo, and Daniel Hahn, with assistance from Danielle Savarese (Stratus Consulting). Janis Krukoff

lower tidal elevations. Lindstrom attributed the extent of this bloom to a general lack of grazers at these tidal elevations at this site. The cause for the observed lack of grazers cannot be attributed to oil exposure with the available information.

Beaches of cobble, gravel, sand. An abundant and diverse assemblage of cryptic beach invertebrates was observed beneath cobble, drift seaweeds and other beach wrack. These included talitrid amphipods (“beach hoppers”), centipedes, arachnids, and kelp flies. The talitrids were at densities of 1 to 10 per 100 cm2. In some cases, beach biota were within 10 cm of mats of buried oil, but no oil was found on the biota. In addition, on 19 June 2005, oiled wrack (accumulations of dead plant material) harboring amphipods living in direct contact with oil was observed on the beach at SKN-6. Although the amphipods did not appear oiled or to be experiencing acute effects from the oil, amphipods living in such close proximity to oil could serve as potential vectors of oil to higher trophic levels. Foxes were seen overturning rocks and wrack on beaches, apparently feeding on the beach invertebrates found there.

In the course of the surveys, large amounts of beach material were observed being removed from heavily oiled sections of beaches for disposal at waste sites. This material probably contained beach biota. For example, the excavating machinery at SKN-11 was removing the oiled cobble and gravel, placing it in “Super Sacks” for transport out of the area. Any biota in the beach material would have also been removed. Excavating machinery could have also crushed beach biota. In addition, oily debris was moved into piles and burned on some beaches which would have killed beach-wrack fauna and infauna in the vicinity of the fires. Many of the areas where burning of debris was conducted were in high wave energy areas with cobble and pebble sediments that are unstable and dynamic and may have less interstitial biota than areas with lower wave energy and finer sediments.

(http://www.dec.state.ak.us/spar/perp/response/sum\_fy05/041207201/041207201\_OiledDebrisBurns24May05.pdf)

Observations of remobilized oil and apparent impacts on rocky shore substrata and biota:

Beginning on 20 June 2005, new deposits of sticky brown oil were observed in some of the areas surveyed. The oil appeared to have been released from beach cleaning operations in adjacent shoreline segments. In some cases, excavations had been made into layers of oil buried in gravel-cobble beaches, and high tides had lifted oil out of the excavations. Segment HMP-12 was a pilot project for “berm relocation” and “surf-washing,” in which oiled beach material from a section of high beach was bulldozed into a lower intertidal area where wave action could remove the oil. Berm relocation was also used at segments SKN-05, SKN-06, and SKS-04. Table 3 summarizes currently available information from various sources on the response actions taken at each SCAT segment. Because there has not yet been a compiled and verified accounting of the actions taken at all segments, the information in Table 3 should be regarded as giving an approximate sense of what occurred, except descriptions of clean up at segments directly observed by the survey teams for this report.

On 20 June 2005, at the rocky point at HMP-11a, rainbow sheens of oil were observed on tide pools, including oil streaming from floating droplets of black oil. In the mid-tide zone sticky, brown oil was deposited on the rock surface and on attached biota. The fronds of *Palmaria* and holdfasts of *Alaria* in this zone were oiled. In the high intertidal zone and splash-zone, freshly deposited, shiny, sticky oil was also present on rock substrata and on the fronds of the red alga *Porphyra*. Fresh oil was also present on wrack at the higher high water level. The oil appeared to be remobilized from beach cleaning operations to the west of HMP-11a, in segments HMP-11b and HMP-12. Dry tilling to expose buried oil at HMP-12 for removal by natural factors is shown in the photo at the end of this document. (A list of all photos available on the Unified Command website can be found at:

http://www.dec.state.ak.us/spar/perp/response/sum\_fy05/041207201/041207201\_ph\_index.htm).

Freshly remobilized oil was observed in the north part of Skan Bay during the calm weather of 22 June 2005. There were oil sheens on the water surface of the cove at SKN-10 and SKN-11. Oil sheens here ranged from silver through rainbow in color and some brown-black patches of oil were also observed on the water surface of the cove at these SCAT segments. Rainbow sheen covered about 50% of the water surface in the landward part of the cove—an area of several hundred square meters, occupying the landward end of the cove, and extending about 100 m from the beach at the head of the cove. Bands of floating black oil about 1 cm thick were accumulated against the floating fronds of the kelp *Alaria*—the fronds were acting like low-profile oil booms. The oiled *Alaria* bed was about 50 m by 100 m. An on-scene biological advisor for the clean-up said that high tides had washed oil from the excavations made to remove buried oil from the beach. Oil was buried in the berm of the beach at SKN-11 and the beach wrack was more than 80% oiled. A backhoe/front loader and two excavators were digging oiled sediment out of the beach, and the highest concentrations of oil in the water and on the shore were at the beach cleaning operations, diminishing with distance from the excavation sites. There were no booms in place to retain the oil when we made these observations, but (pom-pom) booms were placed along the beach later in the day. The rocky shoreline of SKN-10 projected seawards from the oiled beach at SKN-11, forming the south side of the oiled cove. Freshly deposited, sticky, oil was most evident in the upper intertidal zone of SKN-10, forming a band of oil- a “bath-tub ring” effect- on the rocks. The band was about 20 cm – 45 cm wide (vertical measure) and the coating of oil ranged in thickness from stain to about 5 mm. Shiny black oil was observed on barnacles, mussels, limpets (*Lottia* spp.), *Littorina* *sitkana*, and *Fucus*. At the beach end of the shore (nearest the remobilized oil), 100% of the *Porphyra* were coated with oil.

Upon returning to HMP-11a on 23 June 2005, it appeared that more than 90% of the red alga *Palmaria* had oil on their fronds. The typical color of this alga is dark purple-red to wine red, however, >90% of the oiled fronds (by surface area) were bleached to a light yellow-green color, some almost white, and the tips of the fronds were ragged. Less than 40% of the *Alaria* were oiled at the base. More than 80% of the normally bright green *Acrosiphonia* were also discolored (bleached tips and tan-brown coloration over >80% of the frond surface), although no oil was seen on the fronds of this alga. Submerged *Palmaria* at HMP-11a were also oiled and bleached. As documented in the field photos, all of these algae were common within their zones.

To evaluate effects of remobilized oil on the intertidal algae, HMP-13 was chosen as a “reference” site for HMP-11a. HMP-13 was the next rocky point to the west of HMP-11a, about 1 mile away. It faced the same direction and had similar wave exposure, but no remobilized oil was found there on 23 June 2005. HMP-13 appeared to be up-current or up-wind from the HMP-11a and the remobilized oil. Clean-up operations in the Hump Back Bay area were underway before HMP-13 was surveyed, so it is possible that the algae at the HMP-13 “reference” site had been oiled prior to the observations. Oil was not observed on the fronds of *Palmaria* at HMP-13, but these algae showed the bleached discoloration similar to, but less than, the oiled fronds at HMP-11a. However, the *Palmaria* fronds at the HMP-13 reference site were not ragged like those at the HMP-11a oiled site. The *Acrosiphonia* was also much less discolored at HMP-13. Bleached fronds of *Alaria* were similar in appearance at sites with recent exposure to oil and at sites without recent exposure to oil.

In the lower intertidal zone, three species of large brown algae appear to have been affected by the oil. *Agarum (or* possibly *Thalassiophyllum)* and *Alaria* were discolored, an effect that diminished with distance from the oiled beach. *Laminaria* formed a nearly continuous bed along the low tide shoreline. The *Laminaria* were bleached and ragged at the end of the shoreline near the beach cleaning operations; this phenomenon decreased to near zero with distance from the beach cleaning operations. *Agarum*, *Alaria,* and *Laminaria* are normally dark brown color. The bleached fronds were pale brown to pale greenish brown. Although *Palmaria* had some bleaching, and *Acrosiphonia* some discoloration, at the HMP-13 reference site, these effects were greater at HMP-11a. Because fronds of *Palmaria* spp. and *Acrosiphonia* spp. can bleach or change color and erode naturally in the summer when they release reproductive cells (S. Lindstrom, pers. comm.), it cannot be concluded that the all of observed color changes, bleaching, and erosion in these two algal species occurred solely as a result of exposure to *Selendang Ayu* oil. However, it can be concluded that most of the adverse effects observed on these and other algal species at HMP-11a was probably due to oil exposure.

Summary of June Intertidal Surveys In the June 2005 survey of intertidal beaches, the subsurface beach fauna were observed living in close association with deposits of oil without any visible oiling on the animals or causing any readily observable effects. However, beach cleaning operations were seen removing large amounts of beach sediment and wrack at some locations, probably removing beach fauna at the same time. A total of 666,592 bags of oily waste material were removed from the shorelines in the spill area as of June 19, 2006. Use of excavators, front-loaders, and other heavy equipment on beaches probably crushed beach-wrack biota and infauna. Burning of oily debris on beaches probably caused additional mortality of the fauna located there.

Observations at Spray Cape (SPR11-SPR13) indicated that some biota had experienced recent adverse impacts by oil or some other factor. Kelps were reduced to stipes. Herbivore abundance appeared to be reduced. Epiphytic overgrowth of various perennial algae by ephemeral green algae at this site, but not others, indicates a reduction in herbivory. The extent of growth of these ephemeral green algae on low intertidal bedrock also indicated reduced herbivory. Although the rotting deposit of beans (“Bean Beach”) was primarily to the southwest of SPR11-SPR13, some rotting beans were also present in segments SPR11-SPR13 and nutrients or other substances released by the beans may have caused, or contributed to, the adverse effects observed for segments SPR11-SPR13.

In the pre-assessment surveys between 27 December 2004 and 20 June 2005, no evidence was found of acute mortality of perennial marine biota (algae and invertebrates) on rocky shore segments other than Spray Cape. On these rocky shores, the major groups of long-lived marine algae and invertebrates of the intertidal and shallow subtidal rocky habitats appeared to be largely intact. No observable changes in abundances or conditions of intertidal biota correlated with degrees of oiling were found prior to 20 June 2005. For example, the large barnacle *Semibalanus cariosus* has a life span of more than a year and has a strong test (shell) that can persist for many months after the animal dies. Therefore, it was a useful indicator of mortality caused by the spilled oil. If the oil had killed this barnacle, a higher relative proportion of empty tests at sites more exposed to oil should have been found. Empty tests of this barnacle were found at all sites, regardless of oiling. However, at all sites more than 50% of the barnacles were alive, and no obvious correlation was found between number of empty tests and degree of oiling as judged by the amount of oil deposited on nearby beaches or reported to have been in the area in SCAT surveys. These observations were consistent over a wide range of sites and for many different types of long-lived biota and suggest that the mortality that was observed is likely due to natural factors. Prior to 20 June 2005, the *Selendang Ayu* oil spill probably did not cause acute mortality for most of the perennial intertidal biota in the spill area except at Spray Cape (but see footnote 2).

However, starting 20 June 2005 indications of adverse impacts were found on various species of marine algae that was likely caused by oil that was recently remobilized from beach cleaning operations during the warming weather of the Aleutian spring and early summer. To separate effects of oil exposure from non-oil factors, such as exposure during the spring low tides, the conditions of the alga fronds were compared as follows: (1) along gradients of exposure to remobilized oil and (2) between sites that differed in the amount of visible remobilized oil. These observations indicated exposure to remobilized oil was a probable cause of adverse impacts on the algae *Palmaria*, *Laminaria*, *Acrosiphonia*, and *Agarum*, all of which showed signs of bleaching and tissue erosion in the areas exposed to oil released from buried deposits of oil by beach cleaning operations. As noted earlier, there was some bleaching of Palmaria and discoloration of Acrosiphonia at the reference site (HMP-13), but these effects were much greater at HMP-11a, suggesting that oil exposure was the predominant cause of these adverse effects.

The surveys ended on 23 June 2005, and no further observations were made on the potential long-term impacts of the *Selendang Ayu* oil released into the spill area by beach cleaning operations in the summer of 2005. However, mechanical excavation and/or tilling occurred at ten or more segments, in addition to that observed at HMP-11b and HMP-12 during the June Survey, and it is likely that some oil was remobilized by the clean up operations at some of these other segments. In addition to *Selendang Ayu* oil released from shoreline deposits, the U.S. Coast Guard also reported releases of oil in October and December 2005 when storms shifted the hull of the *Selendang Ayu* (Table 4). A U.S. Coast Guard overflight on 1 December, 2005 reported sheening originating from the stern section of the vessel. Dan Magone (5 Dec 2005, in litt.) also observed oil slicks on 1 December 2005 in Skan Bay, but the source was unknown. It is also worth noting that many segments where oil had not been observed in winter clean up operations were visibly oiled when the clean up resumed in spring 2005. Many of these segments were observed by helicopter and fixed-wing aircraft in the winter SCAT surveys, however, and oiling at some locations may have been missed with this method. A summary of reports of remobilized oil is given in Table 4.

Oil persisted in 26 segments at levels above that determined as “end point” by the Unified Command after clean up operations ended in 2005 (Table 4). When the response officially ended on 23 June 2006, six segments had still not achieved end point status, with residual oil left to be removed by natural processes. This lingering oil has the potential to cause some continuing level of injury until natural recovery occurs.

**Surveys of Subtidal Habitats in June 2005**

*Methods:* Subtidal habitats were briefly surveyed by divers using the same basic methods of close-up observations employed in the intertidal surveys and by tethered video. These subtidal surveys were conducted on the same cruise as the intertidal surveys. The divers examined the subtidal habitats for presence of oil and indications of injury that may have resulted from exposure to oil. In addition a tethered video camera was deployed from the *Ocean Olympic* to look for presence of oil and potential injury. The diver representing NOAA was Alan Fukuyama, who also participated in the intertidal surveys. Gary Mauseth or Greg Challenger represented the responsible party on the dives, with Bruce Kvan as back-up.

*Observations and Discussion:* The diving team did four dives: one at Alimuda Bay, two at Humpback Bay, and one at Spray Cape near the *Selendang Ayu* wreck. The latter three were in the main spill area; Alimuda Bay received less oil. Cold water conditions limited the duration of the dives to about 30-35 minutes. Divers did not go below 61 feet. Most of the habitats surveyed were in depths less than 50 feet.

The divers found scattered “tar spots” in 15-20 feet of water in one of the Humpback Bay locations, which was adjacent to HMP-12. This was just offshore of the location of a test berm relocation exercise. Videos from the tethered camera and the divers found no definite indications of adverse impacts of oil in this area. No oil was observed at the other three dive locations.

**Surveys of Anadromous Fish and Streams in June 2005**

*Methods:* In June 2005, Nick Iadanza and John Hudson surveyed ten anadromous fish stream systems for presence of oil and fish and other indications of potential exposure of the fish to oil (Table 5). These ten streams were chosen because:

The streams were in the set of streams monitored for dissolved PAHs (polycyclic aromatic hydrocarbons) by the NOAA Auke Bay Laboratory team. This set included both oiled and unoiled streams. The Auke Bay study results are reported separately in the report in the Administrative Record, entitled “***Selendang Ayu* oil risk to early life stage salmon” (**Mark G. Carls, John Hudson and Stanley D. Rice, NOAA/NMFS/Auke Bay Laboratory, 11305 Glacier Hwy. Juneau, AK 99801)

SCAT surveys had reported oil up into the stream system, not just at the mouth of the stream.

The surveyors walked the streams, making close visual observations for the presence of oil and fish. In some cases, they examined submerged rock surfaces for biota and collected fish in sieves for closer examination.

*Observations and Discussion:* In the June 2005 surveys, oil sheen was found on upstream (freshwater) portions of the stream system at SKN 14, including in rearing habitat for coho salmon and Dolly Varden char. Of the anadromous streams visited, SKN-14 contained the highest quantity and quality of coho salmon rearing habitat. Because oil was deposited along the banks of this system for up to 1.7 km upstream of the mouth, large numbers of juvenile coho, and their invertebrate prey, were potentially exposed to oil. Sculpin eggs were also present.

Tar spots and tar balls were also found in the stream bed at MKS-5. This stream contained juvenile coho salmon (young of the year through 2-year old stages) and Dolly Varden Char.

The stream at HMP-12 was examined on 20 June 2005, when clean-up crews were working on a deposit of oil from the adjacent beach at HMP-11b. The high intertidal area at HMP-12 had been tilled to expose the buried oil to removal by natural factors after bulk removal of oil deposits by hand, which includes remobilization by wave action, according to information posted on the Unified Command website (http://www.dec.state.ak.us/spar/perp/response/sum\_fy05/041207201/041207201\_index.htm). Oil-stained rocks and tar balls mixed with sediment were found along portions of the stream bank, where Iadanza reported 100% cover of oil on stream banks on the lower 100m of stream during a 19 January 2005 site visit. In the second trip to HMP-12 (23 June 2005), a 60% cover of oil was observed deposited on a gravel berm adjacent to the salmonid stream at a distance of 80 - 100m from the stream mouth. On both visits to HMP-12 (20 and 23 June 2005), oil sheen was seen in the intertidal areas of the beach on both sides of the stream mouth, below the location where beach materials had been redistributed. There was oiled wrack near the stream mouth and oil-stained rocks in the stream mouth.

Most of the visible deposits of oil in the winter surveys had been removed from the upstream (freshwater) portions of the remaining previously oiled streams that they examined by the time of the June, 2005 surveys. However, some oil still remained on the marine beaches at the mouths of some of these streams. At HMP 11, oil sheen was observed draining from marine beach cleaning operations on both sides of the stream. Oil and oil sheen was also observed on the marine beach at PTN 3. Oil was also found on the marine beaches and rocks of shoreline segments SKN 14, SPR 3, PTN 3, HMP 11, and HMP 12, at, or adjacent to the mouths of anadromous fish streams.

**Observations of possible effects of oil on fish in anadromous streams** Coho salmon, Dolly Varden char, and sculpin were observed in streams that had been oiled to some degree by *Selendang Ayu* oil. These observations are not sufficient in themselves to detect adverse impacts, if any, of the oil but they strongly suggest exposure of these fish to oil.

However, mortality of the smelt eulachon (*Thaleicthys pacificus*) was observed in Humpback Bay (HMP 9 and HMP 12) on 20 June 2005 in areas where oil was being remobilized by beach-cleaning operations. On this date, fresh, sticky oil recently deposited on the shore at these sites or immediately adjacent to these sites was observed. At the high tide line of the beach at the mouth of the stream at HMP-12, 332 dead adult eulachon were found. Examination of a sub-sample of these fish indicated that the females were full of eggs and the males had testes that were intact; the fish had not yet spawned. The condition of the fish indicated they had died within the previous 24 hours. Schools of live eulachon were observed in the stream HMP-12. Approximately 200 dead eulachon were observed under similar circumstances at the mouth of the stream at HMP-9. These eulachon were also in pre-spawning condition (full of eggs and testes intact).

Dead eulachon were observed being eaten by kittiwakes, a juvenile bald eagle, and a fox during the survey at this site. The eulachon could therefore have served as a mechanism to get oil into the food web. It is not certain that the eulachon were killed by oil from the *Selendang Ayu*, in part because no “control” sites or other reference information were available to determine if such mortality occurs naturally. However oil was present in the environment when and where the fish died, and the gravid condition of the dead fish indicated mortality was not a result of spawning, so mortality from exposure to oil is one possible cause of death (among other possibilities).

The presence of oil in June 2005 on the marine beaches at the mouths of five streams indicates the potential for storms waves and tides to subsequently move the oil and recontaminate the lower reaches of these streams after the June surveys were finished. Oil released from beach cleaning operations in summer/fall 2005 and discharged from the *Selendang Ayu* starting in the fall of 2005 could have also recontaminated the streams after our June 2005 surveys.

The stream surveys conducted in late June 2005 are not sufficient in themselves to determine if salmonids in the *Selendang Ayu* spill area were injured, or not, by the oil that washed into the freshwater streams in early December 2004. The necessary comparative data from previous years combined with other sites to determine if the coho salmon and Dolly Varden char observed in these streams were at reduced or unimpacted densities are not available. Pink salmon juveniles probably would have migrated to sea before June 2005, especially because the winter of 2004-2005 was reported as unusually warm, which would have accelerated time to hatching and alevin development, so there may have been some mortality to juvenile pink salmon that would not be observed during the June 2005 survey. It is possible that fish in the oiled streams could have suffered sub-lethal adverse effects, such as impaired development, growth, reproduction, long-term survival, or site-return from exposure to non-lethal concentrations of oil.

**Determination**

The observations made during the winter and June surveys, together with information coming from the Unified Command, are sufficient to make the determination that some level of injury did occur to at least some of the resources and habitats examined in the intertidal, subtidal and anadromous stream surveys as a result of the *Selendang Ayu* oil spill, including from the clean-up operations that took place following the spill. The most evident injuries are those caused by the response - removal of oiled sediments or burning of wrack from the shoreline with its associated fauna - and those to habitats, such as the oiled vegetation and heavily oiled shoreline of some salmonid streams. Some of the impacts to algal species in and around those being actively cleaned during the June 2005 survey may have resulted from remobilized oil. These impacts could have continued throughout the clean-up operations in the rest of the summer. At Spray Cape, there appears to have been a lack of herbivores, possibly a result of the spill, and resulting bloom of ephemeral green algae. There were also observations of dead eulachon, which could potentially be a result of exposure to oil from the *Selendang Ayu*.

Much of the most apparent and likely injury appears to be the result of response actions taken during warmer weather at some of the most heavily oiled areas. Biota in these areas and those nearby were exposed to remobilized oil, and some injury is likely to have resulted from that exposure- such as the apparent oil-related injuries to some algal species. While not observable in our surveys, there is also likely to have been sub-lethal effects to some biota within the areas most affected by the spill. However, the magnitude of likely injury resulting from the *Selendang Ayu* incident is relatively moderate, except perhaps at the most heavily oiled areas and those in the vicinity of oil remobilized during the cleanup operations in the spring and summer of 2005. The total length of shoreline where oil was observed to be present is approximately twenty miles, so some degree of injury to these habitats and biota likely occurred over a large area. The observations made during the winter and June surveys, together with information obtained from the response efforts, and what can be reasonably inferred from experience with the effects of similarly-sized spills in similar environments and the scientific literature indicate that an as yet undetermined amount of restoration will be needed to address the injury to natural resources and services in the intertidal, subtidal, and anadromous stream habitats.

Contact John Kern at john.kern@noaa.gov for more information

**Figure 1. SCAT survey map showing most of the area surveyed in the studies described in this report.** Chernofski Harbor is about 20 km southwest of “ALM” (Alimuda Bay) at lower left.



**Figure 2. Detailed map of SCAT segments (1 of 6)**



**Figure 2. Detailed map of SCAT segments (2 of 6)**



**Figure 2. Detailed map of SCAT segments (3 of 6)**



**Figure 2. Detailed map of SCAT segments (4 of 6)**



**Figure 2. Detailed map of SCAT segments (5 of 6)**



**Figure 2. Detailed map of SCAT segments (6 of 6)**



**Table 1**. *Selendang Ayu* oil spill segments surveyed in June 2005.

|  |  |  |  |
| --- | --- | --- | --- |
| **Date** | **Segment** | **Date** | **Segment** |
| 6/2/2005 | ALM 8 | 6/9/052 | UDE3 |
|  | ALM 7 |  | UDE1 |
|  | ALM 6 |  | VLC9 |
|  | ALM10 |  | VLC10 |
|  | CFS 19 |  |  |
|  | CFS 20 | 6/19/2005 | SKN 3 |
| 6/3/2005 | KMK 30 |  | SKN 4 |
|  | PMS 7 |  | SKN 7 |
|  | PMS 10 |  | SKN 6 |
| 6/4/2005 | SPR 11 |  | PMS 16 |
|  | SPR12 | 6/20/2005 | HMP 12 |
|  | SKS 4 |  | HMP 9 |
|  | SKS 6 |  | PTN 3 |
| 6/5/2005 | CNB9 |  | PTS 11 |
|  | CNB10 | 6/21/2005 | MKS 4 |
|  | PTN2 |  | MKS 5 |
|  | PTN3 |  | MKS 6 |
| 6/6/2005 | HMP7 |  | SPR 2 |
|  | HMP6 |  | SPR 3 |
|  | HMP10 |  | UDW 1 |
|  | HMP11 | 6/22/2005 | SKN 14 |
|  | HMP5 |  | SKN 10 |
| 6/7/2005 | SKN8 |  | SKN 11 |
|  | SKN9 |  | SKN 7 |
|  | SKN11 |  | PMS 20 |
|  | SKN12 | 6/23/2005 | HMP 11 |
|  | SKN14 |  | HMP 13 |
|  | SKN15 |  |  |
| 6/8/2005 | SKS 18 |  |  |
|  | SKS 14 |  |  |
|  | SKS 15 |  |  |
|  | SKS 16 |  |  |
|  | SKS 17 |  |  |

**Table 2.** Examples of mature perennial biota found on rocky shores in the spill area, June 2005.

|  |  |
| --- | --- |
| **Invertebrates** | **Common name category** |
| *Henricia* | starfish |
| *Katharina* | chiton |
| *Littorina* *sitkana* | snail |
| *Lottia digitalis* | limpet |
| *Lottia pelta* | limpet |
| *Nucella emarginata* | snail |
| *Calliostoma ligatum.* | snail |
| *Balanus glandula* | barnacle |
| *Semibalanus cariosus* | barnacle |
| *Mytilus trossulus* | mussel |
|  |  |
| **Marine algae** |  |
| *Laminaria* | kelp |
| *Alaria* | kelp |
| *Cymathere* | kelp |
| *Fucus* | rockweed |
| *Hedophyllum* | kelp |
| *Neorhodomela larix* | red alga |
| *Petrocelis* | tar-spot alga |
| *Agarum (or* possibly *Thalassiophyllum)* | kelp |
| The individuals of these species were large enough that they were probably present in the spill area before 8 December 2004, when the *Selendang Ayu* wrecked at Spray Cape. | |

**Table 3.** Summary of clean up methods by segment. Segments in bold type were locations not treated due to safety concerns. Does not include segments which had no observable oil (NOO) in winter (2004-2005) and which had a No Further Treatment (NFT) recommendation in spring (2005). When more than one oiling category is used for a segment, the highest was put in this table.

| **SEGMENT NAME** | **WINTER OILING CAT.** | **SPRING OILING CAT.** | **SPRING**  **CLEAN-UP?** | **MANUAL CLEAN-UP** | **MECH. REMOVAL** | **MECH. TILL** | **BERM RELOC-ATION** | **OPEN BURN** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ALM03 | NOO | MODERATE | YES | X |  |  |  |  |
| ALM09 | NOO | MODERATE |  |  |  |  |  |  |
| AND01 | LIGHT | LIGHT | NFT |  |  |  |  |  |
| AND06 | LIGHT | LIGHT | YES | X |  |  |  |  |
| AND07 | NOO | HEAVY | NFT |  |  |  |  |  |
| AND08 | NOO | HEAVY | YES | X |  |  |  |  |
| ASP07 | NOO | LIGHT | YES | X |  |  |  |  |
| ASP14 | NOO | MODERATE | YES | X |  |  |  |  |
| ASP15 | NOO | LIGHT | YES | X |  |  |  |  |
| ASP16 | NOO | LIGHT | YES | X |  |  |  |  |
| BCK07 | NOO | HEAVY | YES | X |  |  |  |  |
| BCK09 | HEAVY | MODERATE | YES | X |  |  |  |  |
| BCK11 |  | HEAVY | YES | X |  |  |  |  |
| CBE21 | HEAVY | NOO | NFT |  |  |  |  |  |
| CNB01 | NOO | MODERATE | YES | X |  |  |  |  |
| CNB10 | NOO | LIGHT | YES | X |  |  |  |  |
| CNB11 | NOO | LIGHT | YES | X |  |  |  |  |
| CNB14 | NOO | LIGHT | YES | X |  |  |  |  |
| CNB15 | NOO | LIGHT | YES | X |  |  |  |  |
| CNB17 | NOO | MODERATE | YES | X |  |  |  |  |
| CNB19 | MODERATE | LIGHT | NFT |  |  |  |  |  |
| CNB20 | MODERATE | HEAVY | YES | X |  |  |  |  |
| CNB21 | HEAVY | HEAVY | YES | X |  |  |  |  |
| HMP02 | NOO | HEAVY | YES |  |  |  |  |  |
| HMP03 | NOO | HEAVY | YES |  |  |  |  |  |
| HMP05 | HEAVY | HEAVY | YES | X |  |  |  |  |
| HMP06 | HEAVY | HEAVY | YES | X |  |  |  |  |
| HMP07 | HEAVY | HEAVY | YES | X | X | X |  |  |
| HMP08 | HEAVY | LIGHT | YES | X |  |  |  |  |
| HMP10 | HEAVY | HEAVY | YES | X |  |  |  |  |
| HMP11 | HEAVY | HEAVY | YES | X | X | X |  | X |
| HMP12 | HEAVY | HEAVY | YES | X | X | X | X |  |
| HMP13 | HEAVY | HEAVY | YES | X |  |  |  |  |
| KFP01 | NOO | HEAVY | YES | X |  |  |  |  |
| KFP02 | NOO | HEAVY | YES | X |  |  |  |  |
| KFP03 | NOO | HEAVY | YES | X |  |  |  |  |
| KFP04 | NOO | VERY LIGHT | X | X |  |  |  |  |
| KFP05 | LIGHT | VERY LIGHT | NFT |  |  |  |  |  |
| KFP07 | LIGHT | VERY LIGHT | NFT |  |  |  |  |  |
| KFP08 | NOO | HEAVY | YES | X |  |  |  | X |
| KFP09 | MODERATE | HEAVY | YES | X |  |  |  |  |
| KFP10 | NOO | HEAVY | YES | X |  |  |  |  |
| KMK02 | NOO | HEAVY | YES | X |  |  |  |  |
| KMK06 | MODERATE | MODERATE |  |  |  |  |  |  |
| KMK07 | MODERATE | HEAVY | YES | X |  | X |  |  |
| KMK08 | HEAVY | NOO | NO |  |  |  |  |  |
| KMK09 | HEAVY | HEAVY | YES | X |  |  |  |  |
| KMK11 | HEAVY | LIGHT | YES | X |  |  |  |  |
| KMK15 | NOO | LIGHT | YES | X |  |  |  |  |
| KMK26 | NOO | HEAVY | YES | X |  |  |  |  |
| KMK27 | MODERATE | HEAVY | YES | X |  |  |  |  |
| KMK28 | HEAVY | HEAVY | YES | X |  |  |  |  |
| KMK29 | HEAVY | LIGHT | NFT |  |  |  |  |  |
| KMK30 | HEAVY | HEAVY | YES | X |  |  |  |  |
| KMK32 | NOO | MODERATE | YES | X |  |  |  |  |
| KSB01 | NOO | MODERATE | YES | X |  |  |  |  |
| KSB02 | MODERATE | HEAVY | YES | X |  |  |  |  |
| KSB03 | NOO | HEAVY | YES | X |  |  |  |  |
| KSB08 | MODERATE | MODERATE | YES | X |  |  |  |  |
| KSB10 | HEAVY | MODERATE | YES | X |  |  |  |  |
| KSB15 | NOO | LIGHT | YES | X |  |  |  |  |
| KTS19 |  | LIGHT | YES | X |  |  |  |  |
| MKS01 | HEAVY | HEAVY | YES | X | X | X |  | X |
| MKS02 | HEAVY | HEAVY | YES | X | X | X |  |  |
| MKS03 | HEAVY | LIGHT | YES | X |  |  |  |  |
| MKS04 | HEAVY | NOO | NFT |  |  |  |  |  |
| MKS05 | HEAVY | HEAVY | YES | X |  |  |  |  |
| MKS06 | HEAVY | HEAVY | YES | X |  |  |  |  |
| MKS07 | LIGHT | HEAVY | YES | X |  |  |  |  |
| MKS08 | LIGHT | NOO | NFT |  |  |  |  |  |
| MKS09 | HEAVY | HEAVY | YES | X |  |  |  |  |
| MKS10 | HEAVY | NOO | NFT |  |  |  |  |  |
| MKS11 | HEAVY | HEAVY | YES | X |  |  |  |  |
| MKS12 | NOO | HEAVY | YES | X |  |  |  |  |
| **MKS13** | NOO | HEAVY | NFT |  |  |  |  |  |
| **MKS14** | NOO | HEAVY | NFT |  |  |  |  |  |
| **MKS15** | NOO | HEAVY | NFT |  |  |  |  |  |
| **MKS16** | NOO | HEAVY | NFT |  |  |  |  |  |
| **MKS17** | NOO | HEAVY | NFT |  |  |  |  |  |
| **MKS18** | NOO | HEAVY | NFT |  |  |  |  |  |
| NGE07 | LIGHT | LIGHT | YES | X |  |  |  |  |
| NGW01 | LIGHT | LIGHT | NFT |  |  |  |  |  |
| NGW02 | MODERATE | LIGHT | YES | X |  |  |  |  |
| NGW03 | MODERATE | LIGHT | YES | X |  |  |  |  |
| NGW04 | LIGHT | LIGHT | NFT |  |  |  |  |  |
| NGW05 | LIGHT | LIGHT | NFT |  |  |  |  |  |
| NGW06 | LIGHT | LIGHT | NFT |  |  |  |  |  |
| NGW07 | LIGHT | LIGHT |  |  |  |  |  |  |
| PMN02 | HEAVY | NOO | NFT |  |  |  |  |  |
| PMN10 | LIGHT | NOO | NFT |  |  |  |  |  |
| PMN12 | LIGHT | LIGHT | NFT |  |  |  |  |  |
| PMN13 | NOO | VERY LIGHT | NFT |  |  |  |  |  |
| PMN15 | NOO | MODERATE | YES | X |  |  |  |  |
| PMN16 | NOO | MODERATE | YES | X |  |  |  |  |
| PMN24 | LIGHT | NOO | NFT |  |  |  |  |  |
| PMN25 | LIGHT | NOO | NFT |  |  |  |  |  |
| PMN28 | NOO | HEAVY | YES | X |  |  |  |  |
| PMS05 | LIGHT | LIGHT |  |  |  |  |  |  |
| PMS06 | LIGHT | MODERATE | YES | X |  |  |  |  |
| PMS10 | MODERATE | MODERATE | YES | X |  |  |  |  |
| PMS11 | LIGHT | LIGHT |  |  |  |  |  |  |
| PTN01 | MODERATE | LIGHT | NFT |  |  |  |  |  |
| PTN02 | NOO | HEAVY | YES | X |  |  |  |  |
| PTN03 | HEAVY | HEAVY | YES | X |  |  |  |  |
| PTN04 | HEAVY | HEAVY | YES | X |  |  |  |  |
| PTN10 | LIGHT | HEAVY | YES | X |  |  |  |  |
| PTS01 | LIGHT | HEAVY | YES | X |  |  |  |  |
| PTS03 | LIGHT | NOO | NFT |  |  |  |  |  |
| PTS04 | LIGHT | NOO | NFT |  |  |  |  |  |
| PTS05 | MODERATE | MODERATE | NFT |  |  |  |  |  |
| PTS06 | NOO | NOO | NO |  |  |  |  |  |
| PTS07 | MODERATE | LIGHT | NFT |  |  |  |  |  |
| PTS08 | MODERATE | NOO | NFT |  |  |  |  |  |
| PTS10 |  | MODERATE | NFT |  |  |  |  |  |
| SKN04 | NOO | LIGHT | YES | X |  |  |  |  |
| SKN05 | HEAVY | HEAVY | YES | X |  | X | X | X |
| SKN06 | NOO | MODERATE | YES | X |  |  | X |  |
| SKN08 | HEAVY | MODERATE | YES | X |  |  |  | X |
| SKN11 | HEAVY | HEAVY | YES | X | X | X |  | X |
| SKN12 | LIGHT | HEAVY | YES | X |  |  |  |  |
| SKN13 | HEAVY | MODERATE | YES | X |  |  |  |  |
| SKN14 | HEAVY | HEAVY | YES | X |  |  |  |  |
| SKN15 | HEAVY | HEAVY | YES | X |  |  |  | X |
| SKS01 | NOO | HEAVY | YES | X |  |  |  |  |
| SKS02 | NOO | HEAVY | YES | X |  |  |  |  |
| SKS03 | NOO | HEAVY | YES | X |  |  |  |  |
| SKS04 | MODERATE | HEAVY | YES | X | X | X | X |  |
| SKS06 | HEAVY | HEAVY | YES | X |  |  |  |  |
| SKS10 | NOO | HEAVY | YES | X |  |  |  |  |
| SKS11 | NOO | HEAVY | YES | X |  |  |  |  |
| SKS12 | NOO | LIGHT | YES | X |  |  |  |  |
| SKS13 | NOO | MODERATE | YES | X |  |  |  |  |
| SKS14 | NOO | MODERATE | YES | X |  |  |  |  |
| SKS15 | NOO | HEAVY | YES | X |  |  |  |  |
| SKS16 | NOO | HEAVY | YES | X |  |  |  |  |
| SKS17 | NOO | MODERATE | YES | X |  |  |  |  |
| SKS18 | HEAVY | HEAVY | YES | X | X | X |  |  |
| SMB06 |  | HEAVY | YES | X |  |  |  |  |
| SPR01 | NOO | MODERATE | YES | X |  |  |  |  |
| SPR02 | HEAVY | MODERATE | YES | X |  |  |  |  |
| SPR03 | NOO | LIGHT | YES | X |  |  |  |  |
| SPR04 | HEAVY | MODERATE | YES | X |  |  |  |  |
| SPR05 | HEAVY | NOO | NFT |  |  |  |  |  |
| SPR07 |  | MODERATE | YES | X |  |  |  |  |
| SPR09 |  | MODERATE | YES | X |  |  |  |  |
| SPR10 |  | LIGHT | YES | X |  |  |  |  |
| SPR11 | LIGHT | HEAVY | YES | X |  |  |  |  |
| SPR12 |  | HEAVY | YES | X |  |  |  |  |
| UDE16 | LIGHT | LIGHT | YES | X |  |  |  |  |
| WDE03 | MODERATE |  |  |  |  |  |  |  |
| UDW01 | NOO | HEAVY | YES | X |  |  |  |  |
| UDW04 | NOO | LIGHT | YES | X |  |  |  |  |
| UNK03 |  | LIGHT | YES | X |  |  |  |  |
| VLC01 |  | HEAVY | YES | X |  |  |  |  |
| VLC10a |  | LIGHT | YES | X |  |  |  |  |

**Table 4.** Summary of observations pertinent to oil remobilization made in the Selendang Ayu spill area from June 2005 onwards.

|  |  |
| --- | --- |
| **DATES** | **OBSERVATIONS** |
| 20-23 June 2005: | NOAA survey teams documented remobilized oil from beach cleaning operations in Skan Bay (SKN10-11) and probably from beach cleaning operations in Hump Back Bay (~HMP10-12). |
| August-September 2005 | Scott Arnold, Alaska Department of Health and Social Services, reported elevated levels of total PAHs in blue mussels from various locations in Skan Bay, but not in other nearby bays |
| ~September 2005: | Mark Carls reported increase of oil in PEMD samplers at Skan Bay (SKN-14). |
| 21 October 2005 | Unnamed observer in civilian aircraft reported what appeared to be a sheen around thevessel. Coast Guard reported oil from Selendang in water and onshore around wreck (Spray Cape) and Skan Bay. |
| 24 October 2005 | Coast Guard reported seeing sheen and emulsified oil coming from the stern of the *Selendang Ayu*. |
| 25 October 2005 | Coast Guard observed a rainbow sheen burping up from around 350 yards from the vessel. |
| 1 December 2005: | Coast Guard/ADEC reported sheening from the vessel (POLREP 104). |
| 1 December 2005 | Dan Magone reported oil on about 200 feet of shoreline near the Selendang; “grass has distinctive droopy look….” |
| 3 December 2005 | Dan Magone reported “ribbon of oil sheen” in inner bay of “Lower Skan Bay”. |
| Feb or March 2006(?) | Seaduck crews reported sticky oil blobs on beach and oiled scaup. |

**Table 5.** Final Status of 2005 Non-End Point Segments

| **SEGMENT** | **SEGMENT LENGTH (km)** | **OILED LENGTH (km)** | **FINAL STATUS** | **DATE of STATUS DETERMINATION** |
| --- | --- | --- | --- | --- |
| BCK11 | 0.951 | 0.08 | End Point Reached | 6/8/06 |
| HMP06 | 0.463 | 0.08 | Natural Recovery | 6/6/06 |
| HMP11b | 0.300 | 0.12 | End Point Reached | 6/6/06 |
| KFP01 | 1.494 | 0.635 | Natural Recovery | 6/13/06 |
| KFP02 | 0.536 | 0.38 | End Point Reached | 6/12/06 |
| KFP03 | 0.239 | 0.03 | End Point Reached | 6/12/06 |
| KFP10a | 1.102 | 0.36 | End Point Reached | 6/12/06 |
| KMK26 | 0.265 | 0.02 | End Point Reached | 6/4/06 |
| KMK30 | 1.839 | 0.04 | End Point Reached | 6/4/06 |
| MKS13 | 1.507 | 0.02 | End Point Reached | 6/4/06 |
| MKS14 | 0.688 | 0.14 | Natural Recovery | 6/4/06 |
| MKS16 | 0.681 | 0.265 | Natural Recovery | 6/4/06 |
| MKS17 | 1.294 | 0.08 | End Point Reached | 6/4/06 |
| SKN05 | 0.676 | 0.6 | End Point Reached | 6/5/06 |
| SKN06 | 1.854 | 0.02 | End Point Reached | 6/5/06 |
| SKN08 | 0.128 | 0.082 | End Point Reached | 6/5/06 |
| SKN11 | 0.210 | 0.24 | End Point Reached | 6/5/06q |
| SKN12 | 1.172 | 0.025 | End Point Reached | 6/5/06 |
| SKN15 | 2.610 | 2.073 | Natural Recovery | 6/12/06 |
| SKS03 | 0.865 | 0.122 | Natural Recovery | 6/8/06 |
| SKS04 | 0.235 | 0.235 | End Point Reached | 6/8/06 |
| SKS06 | 0.439 | 0.04 | End Point Reached | 6/8/06 |
| SKS11c | 0.045 | 0.08 | End Point Reached | 6/12/06 |
| SKS18d,e,g | 3.610 | 0.354 | End Point Reached | 6/12/06 |
| SPR11a | 1.210 | 0.1 | Natural Recovery | 6/8/06 |
| SPR12 | 0.593 | 0.2 | End Point Reached | 6/8/06 |

**Table 6.** Locations of anadromous fish streams surveyed in June 2005.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Incident Command Segment Code** | **General Location Name** | **Site of Auke Bay Hydrocarbon Monitoring Stations** |
| 1. | MKS 5 | Makushin Bay South (Glacier Valley Creek) | X |
| 2. | HMP 9 | Humpback Bay |  |
| 3. | HMP12 | Humpback Bay |  |
| 4. | PTN 3 | Portage Bay North |  |
| 5. | PTS 10 | Portage Bay South |  |
| 6. | SKN 4 | Skan North | X |
| 7. | SKN 14 | Skan North | X |
| 8. | SPR 3 | Spray Cape |  |
| 9. | PMN 20/21 | Pumicestone North | X |
| 10. | PMS 16 | Pumicestone South | X |

**Photo of Dry Tilling to Expose Buried Oil at HMP-12 (2 December 2005)**



(photo taken by ADEC)