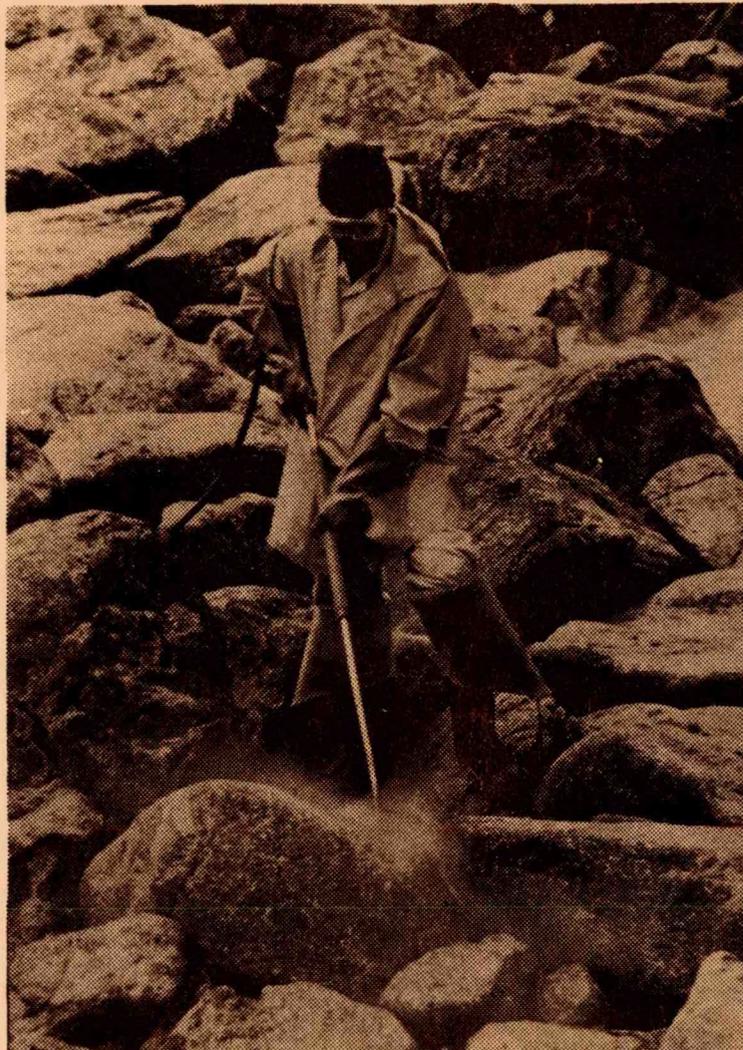


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# The AMOCO CADIZ Oil Spill

THIRD FOLLOW-UP SURVEY OF OIL  
IMPACT ON THE SHORELINE  
JULY 1978



**Research Planning Institute, Inc.**  
806 Pavillion Avenue  
Columbia, South Carolina 29205

For: **National Oceanic and  
Atmospheric Administration**  
Environmental Research Laboratories  
Boulder, Colorado

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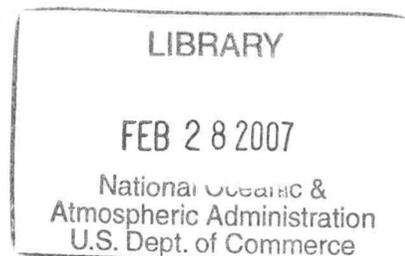
THIRD FOLLOW-UP SURVEY OF OIL IMPACT  
ON THE SHORELINE, JULY 1978

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Cover Photograph: Worker using spraying equipment to clean rocks at station  
F-110 on 3 August 1978.

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## SYNOPSIS

The third in a series of field studies of the Amoco Cadiz spill site of northwest Brittany was conducted on 18-23 July 1978. The field team consisted of three Americans, assisted by personnel of the Centre Oceanologique de Bretagne, a laboratory of the Centre National pour l'Exploitation des Oceans (C.N.E.X.O.). During this study, a total of 66 previously studied stations were analyzed for oil distribution (surficial and subsurface), geomorphic variability, general biologic appearance, and the effectiveness of the clean-up operation.

Most of the coastline previously affected by the spill was relatively free of oil. The surfaces of most beaches were clean, but scattered and discontinuous oil layers were buried beneath the surface at many localities. Those areas which were still seriously oiled are classified as follows (on a geomorphic basis):

- a) Sheltered Marshes - The Ile Grande area remained devastated.
- b) Mixed Sand and Gravel Beaches - The beach at Pte. de Sehar still had much surface and buried oil despite attempts to clean up the area with bulldozers.
- c) Sheltered and Partially Exposed Rocky Areas - Those areas having large boulders or bedrock outcrops where no clean-up measures were applied were still significantly oil-blackened, due primarily to the lack of erosive wave activity during the summer months. Sheltered micro-environments (e.g., sheltered pockets between boulders) also remained heavily oiled.
- d) Sheltered Beaches of Various Grain Sizes - An asphalt crust had formed in many areas where no clean-up measures had been applied.
- e) Sheltered Tidal Flats - Heavy machinery used during clean-up activities had churned the oil below the sediment surface.

The effectiveness of the clean-up operation is related to geomorphic

type of coastline as follows:

- a) Fine-Sand Beaches - very effective.
- b) Coarse-Sand Beaches - generally effective but some sediment remained oil-stained.
- c) Mixed Sand and Gravel Beaches - ineffective when only heavy machinery was used, as at station AMC-16.
- d) Cobble Beaches - very effective when machinery was used in conjunction with high pressure spraying.
- e) Rocky Shorelines (boulder or bedrock) - generally effective at oil removal, but severe losses of attached macro-algae were incurred.
- f) Sheltered Tidal Flats - partially effective, but oil was often churned into sediment below the surface.
- g) Marshes - questionable effectiveness. Very little recovery of the marsh was found, even after an extensive clean-up operation.

With respect to biological recovery, we made the following observations:

- a) Algae - where clean-up was applied (especially high pressure spraying), most of the macro-algae were removed from the rocks. As yet, no recovery is indicated. The large bloom of the green alga, Enteromorpha, may be related to the occurrence of the spill.
- b) Benthos - limpets were unexpectedly common at many areas. Annelid worms still populated areas having fine-grained sediment. No benthic recovery at Ile Grande marsh was found.
- c) Marsh Grasses - at the Ile Grande marsh, only 10-15% recovery of the high marsh grass, Spartina patens, was observed. Recovery of the lower marsh grass, Sesuvium sp., was much less. At another site (station F-136), where no clean-up was applied, the oiled grasses had been killed and remained oil-blackened.

Recommendations for future study include:

- a) Repeat surveys at a limited number of locations, preferably in No-

vember before the winter storm period, and again in April, one year after the spill.

- b) Chemical analysis of the interstitial water at a limited number of previously analyzed areas.
- c) Assessment of the longer-term effects of the oil and clean-up on the macro-algae, particularly in the Portsall area.
- d) Continued monitoring of marsh recovery at Ile Grande. Station F-136 (no clean-up) may provide a control site, although the vegetation is somewhat different.
- e) Monitoring of benthic recovery at Ile Grande marsh.

## INTRODUCTION

This project represents the third field study of the Amoco Cadiz oil spill site conducted by our research group as part of NOAA's Spilled Oil Research (SOR) team's activities. The first study was undertaken during the time of maximum oil spillage from the tanker, 19 March - 2 April, 1978. The second study was undertaken a short time later, 20-28 April, 1978. The results of those activities are contained in Gundlach and Hayes (1978a) and summarized in D'Ozouville, Gundlach and Hayes (1978). Field work for the third study was conducted on 18-23 July 1978.

The purpose of the present investigation is to continue observation of the spill site in order to better understand the on-going processes that influence the distribution and dispersion of Amoco Cadiz oil. The similarity of the Brittany site to areas within the United States, particularly Maine and Alaska, enables us to better predict the reaction of an oil spill should one occur within these areas. Continued monitoring of the spill site also allows for the formulation of better questions and experiments which would increase scientific preparedness for the next oil spill.

## METHODS OF STUDY

The field party consisted of the authors, Jacqui Michel (RPI), and either Serge Berné, Lucien Courtois (both from C.O.B.-C.N.E.X.O.), or Anne Beslier of the Department of Geology at the University of Caen. Dr. Will Davis (EPA, Charleston) accompanied us for two days.

The field survey consisted of detailed observations of oil distribution at 66 sites which were representative of the entire affected shoreline. Trenches were dug in the beaches to determine if oil occurred below the surface. Extensive photographs, and tape-recorded and written notes were used for documentation. At 18 stations, called AMC stations, a topographic beach



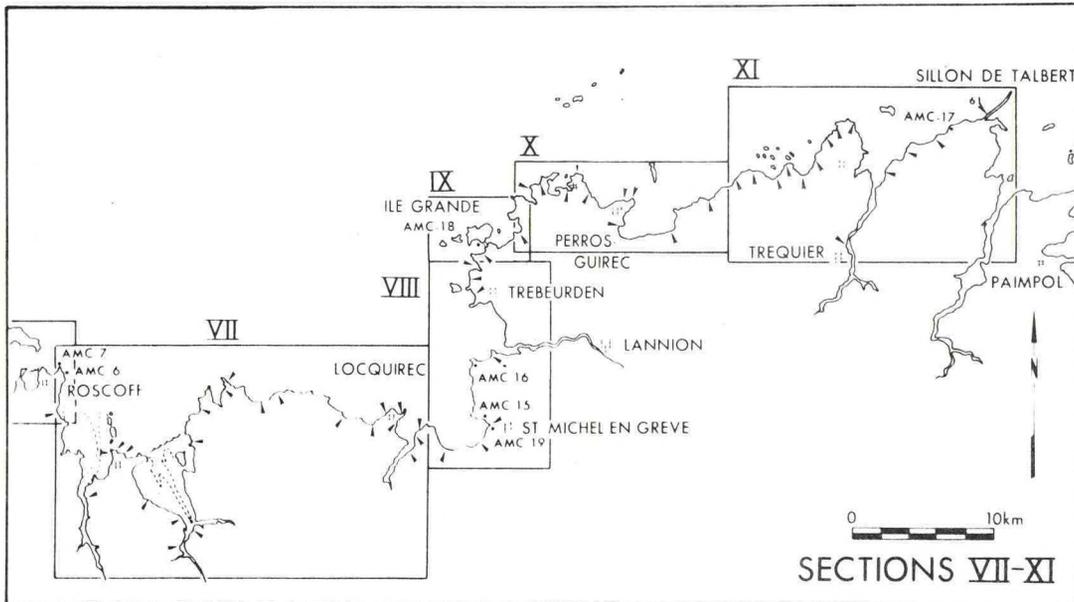
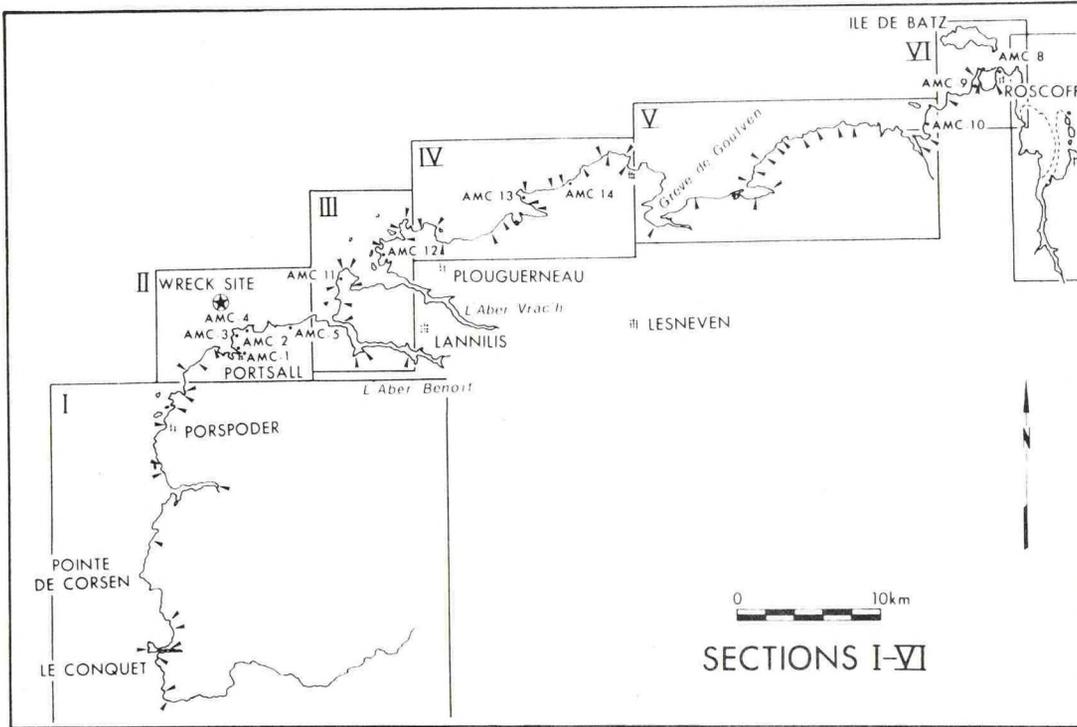


Figure 2. Study sections of the Amoco Cadiz oil spill site.

profile was measured in order to quantitatively analyze changes in beach sedimentation. This is often an excellent indicator of the causes of oil burial and/or removal. The remaining stations, where profiles were not measured, are called F stations. More complete details of this method, called the modified zonal method, are presented in Gundlach and Hayes (1978a; 1978b). Although all stations visited are not discussed in detail in this report, additional information concerning specific sites is available from the authors.

#### FIELD OBSERVATIONS OF OIL IMPACT

The location of all observation stations occupied within the Amoco Cadiz spill site is presented in Figure 1. Those marked by a star were repeated during this survey. Because of the complexity and extent of the spill-affected region, we will continue the method of presentation used in our first report (Gundlach and Hayes, 1978a), in which the spill site was divided into eleven sections (Fig. 2). The eleven sections are discussed below in order from west to east.

##### Section I - Pte. du Raz to Penfoul

This area was free of oil during the first two weeks of the spill, however, a wind shift at the beginning of April brought in large quantities of oil as indicated in Figure 3. A brief description of the initial oil impact in Section I is tabulated in Table 1. Observations made during the most recent survey (July 1978) are summarized in Table 2.

Little oil remained on the shoreline south of station F-104 in July. To the north of this station, many of the rocky areas, which consist of very large boulders, remained heavily oiled (Fig. 4). Beaches having finer grain sizes were generally free of oil due to extensive clean-up activities (although station F-107 is an exception). The oiled rocky areas were particu-

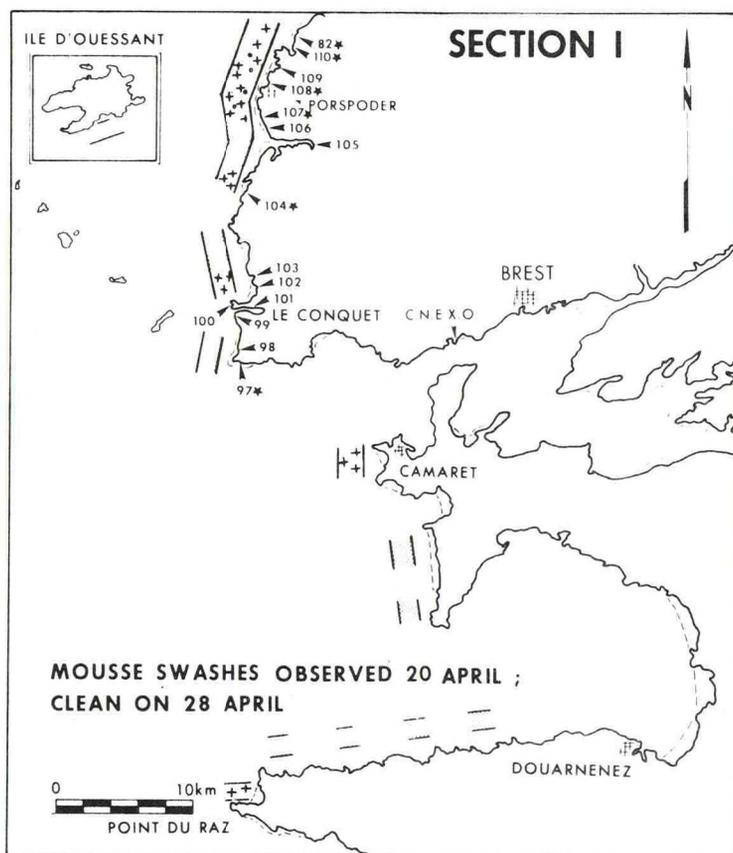


Figure 3. Locations of observation stations within Section I. No oil was in this area during the first two weeks of the spill. The pattern between heavy lines indicates oil distribution as observed during second study period (April 20 to 28). Pluses indicate moderate to heavy oiling of upper intertidal rocks and/or beachface; circles indicate moderate oiling of low-tide terrace; dot pattern indicates light oiling on rocks or beachface. Mousse swashes and heavy oiling were observed south of F-97 during aerial survey of 20 April. By second flight on 28 April, the oil was no longer present. Stars indicate stations revisited during third survey (July 1978).

TABLE 1. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section I. Stars indicate stations revisited during field session III, July 1978.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
★F-97	21 Apr	Pointe de St. Mathieu A rocky platform with a small cobble beach.	A few oil blotches along the swash line - mostly small; a few 5 cm tar or mousse balls; rocks spotted with small amount of mousse. Area seemed biologically productive - much algae and limpets.
F-98	21 Apr	Greve de Porsliogan A small cove/pocket, medium grained sandy beach surrounded by a rocky area.	Light oil at all swash lines. Algae productive. Many worm burrows. Some oil burial of 5 cm - very minor.
F-99	21 Apr	Le Conquet - Beach A small sandy pocket beach surrounded by a rocky area.	Very light oil swash lines with more oil along the upper swash line and on some of the rocky areas.
F-100	21 Apr	Pointe de Kermorvan A boulder beach.	Small amounts of mousse in water. Heavy oiling of boulder beach on the north side of the lighthouse.
F-101	21 Apr	Le Conquet-Harbor (East side) Large sand flat exposed at low tide.	Free of oil - boom at harbor entrance.
F-102	21 Apr	Plage de Blancs-Sablons Wide sandy (fine to medium-grained) beach. Rocks at both ends of beach.	Oil streaks over the entire intertidal portion of the beach. Heavy mousse on rocks in NE corner. Oil pools of mousse located on beach - some mousse in water.
F-103	21 Apr	Port Illian Small pocket beach protected by a jutting rocky headland. Fine-sand on beachface; some gravel on the lower portions.	Oil streaked swash lines. Small mousse patches left on the beach surface.
★F-104	21 Apr	Rubian Coarse-sand beach with many cobbles especially on lower beach.	Heavily oiled rocks; moderately oiled coarse-sand beach. Oil pools 5 cm thick in some areas and a coating on the boulders at the base of the sand. Oil buried due to clean-up activity.
F-105	21 Apr	l'Aber Ildut - Estuary Narrow entrance with 2 booms present.	Oiled seaweed along the edge of the channel. Oil sheen on both sides of the booms.
F-106	21 Apr	Melon - South side Small rocky beach with little wave activity.	Entire intertidal zone heavily oiled. Very heavily oiled rocks and mousse in water.
★F-107	21 Apr	Melon - North (harbor) A u-shaped harbor with an island offshore to protect it. Fine-sand beach.	Very heavily oiled beach. Rocks in northern pocket very heavily oiled. Active clean-up effort.
★F-108	21 Apr	Porspoder Fine-grained pocket beach with rocky headlands on both sides.	Rocks heavily oiled; 10-15 cm thick oil on the beach. Mousse in water. Clean-up operation in effect.
F-109	21 Apr	Argenton Small cove, very well protected fine-grained beach.	Thin oil layer covers most of the beach. Heavy oil along edge of the pocket cove. Small amount of mousse in water.
★F-110	21 Apr	Penfoul Small fine-grained estuary.	Heavy oiling on both sides of the estuary; slicks seen over entire area. Clean-up operation in effect.
★F-82	31 Mar- 21 Apr-	Pointe de Landunvez High energy boulder beach on wave-cut granite platform.	-minor tar blotches (3-5 cm) on rocks. -heavily oiled rocks and boulders with some mousse in the water.

TABLE 2. Summary of observations made during the follow-up survey of July 1978 at stations within Section I.

Station Number and Location	Date Visited	Description of Oil Impact
F-97 Pointe de St. Mathieu	24 July 78	No oil apparent along rocks.
F-104 Rubian	24 July 78	Light oil staining on some rocks.
F-107 Melon - North (harbor)	24 July 78	Rocks across channel remain heavily oiled; much oil on and below the surface on south side of beach.
F-108 Porspoder	24 July 78	Rocks across tidal flat remain heavily oiled; walls and beach fairly clean; low-tide terrace rutted from clean-up operation.
F-110 Penfoul	24 July 78	Heavily oiled rocks, especially on south side of channel; active clean-up with high pressure hosing.
F-82 Pointe de Landunvez	3 Aug 78	Oil remains on some rocks, but since this area is more exposed than F-1, less oil is present.

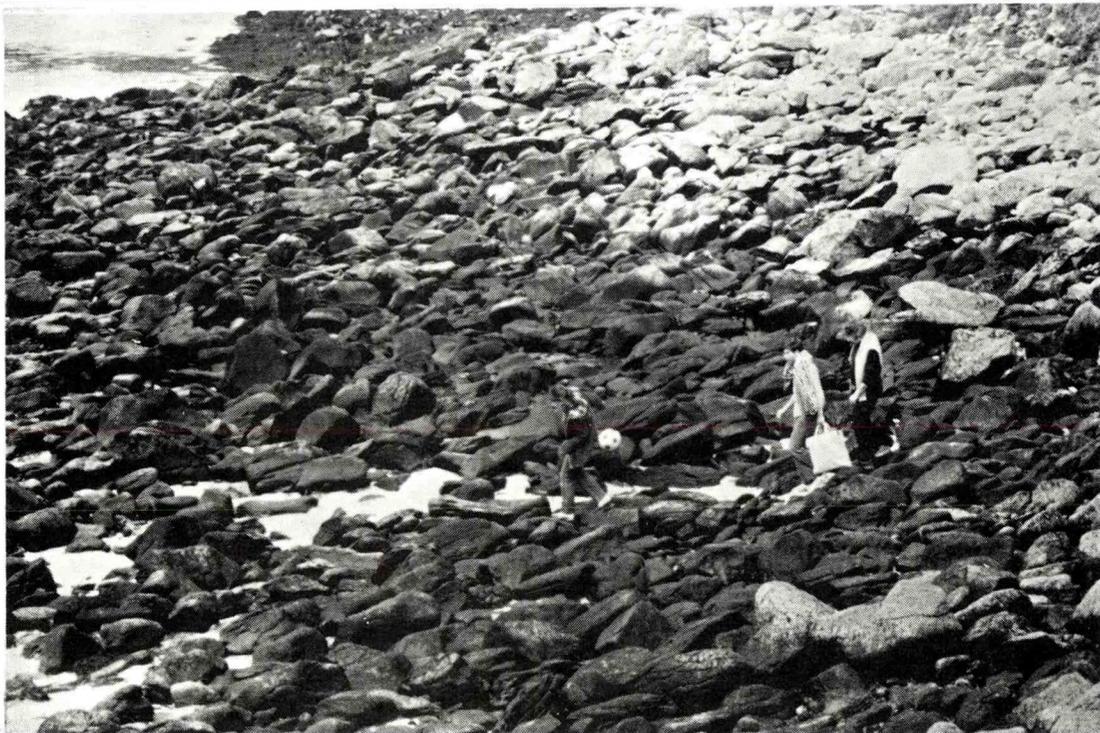


Figure 4. Station F-82 continued to show heavy oiling of the rocky areas on 3 August 1978. A comparison of this photograph with Figure 4-11 (p. 104) in Gundlach and Hayes (1978a) indicates little change since late April.

larly obvious in the more inaccessible areas where clean-up crews were unable to work. It was especially interesting that on the boulder beaches, oil remained in both exposed and sheltered areas, leading one to suspect that wave energy had been very low since April. During our survey in July, waves were always under 20 cm in height. At station F-110, a clean-up of the rocks by French military personnel was in progress (see cover photograph).

#### Section II - St. Sampson to Les Dunes-East

This section is located closest to the wreck site and received the greatest quantities of oil during the initial phases of the spill (Fig. 5). Results of our previous studies are summarized in Table 3, and observations from the present survey are presented in Table 4.

The major aspects of observed oil impact during July 1978 were the following:

1. Many of the originally heavily oiled rocky areas still retained significant quantities of oil. This was particularly true at stations F-1, AMC-4, and the south side of Portsall harbor. At the latter station, much of the attached macro-algae were removed by clean-up with high pressure spraying. Station F-1 was interesting because significant quantities of oil still remained on the boulders. In March, oil that came ashore during the first few days of the spill was removed by wave action within a couple of weeks. The oil on the shoreline in July was a result of the re-oiling that had occurred in April. This much longer persistence of the oil can possibly be attributed to generally low wave energy from April to July, and the evaporation of the oil's lighter components, which would cause a hardened asphalt to form on the rocks.
2. Beaches within the sheltered environment of Portsall harbor (stations AMC-1 and AMC-2) continued to show oil stains, both on the

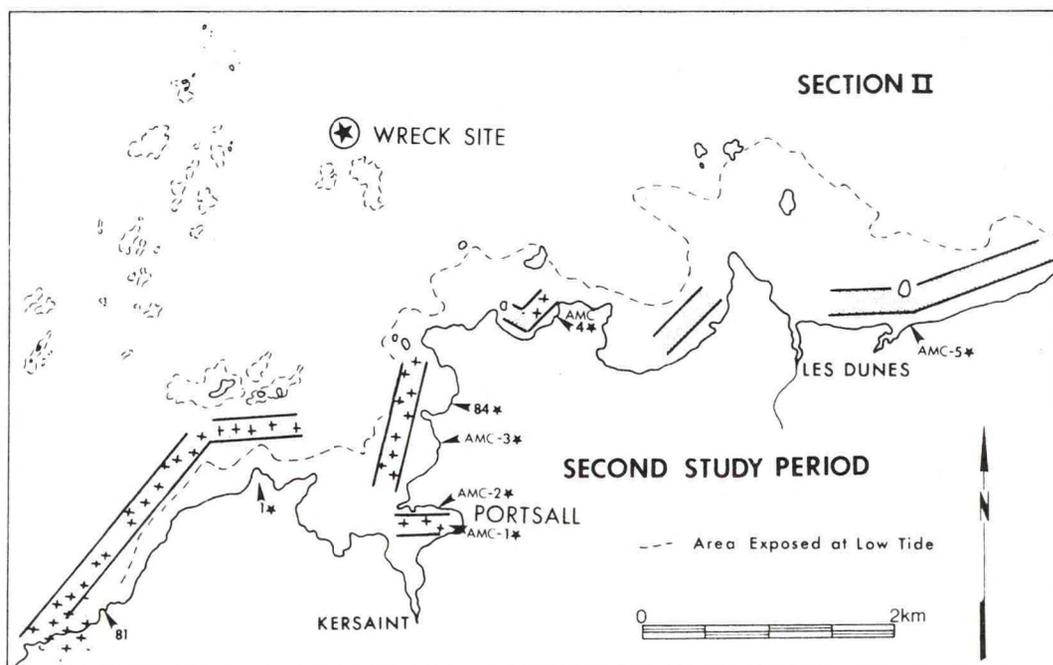
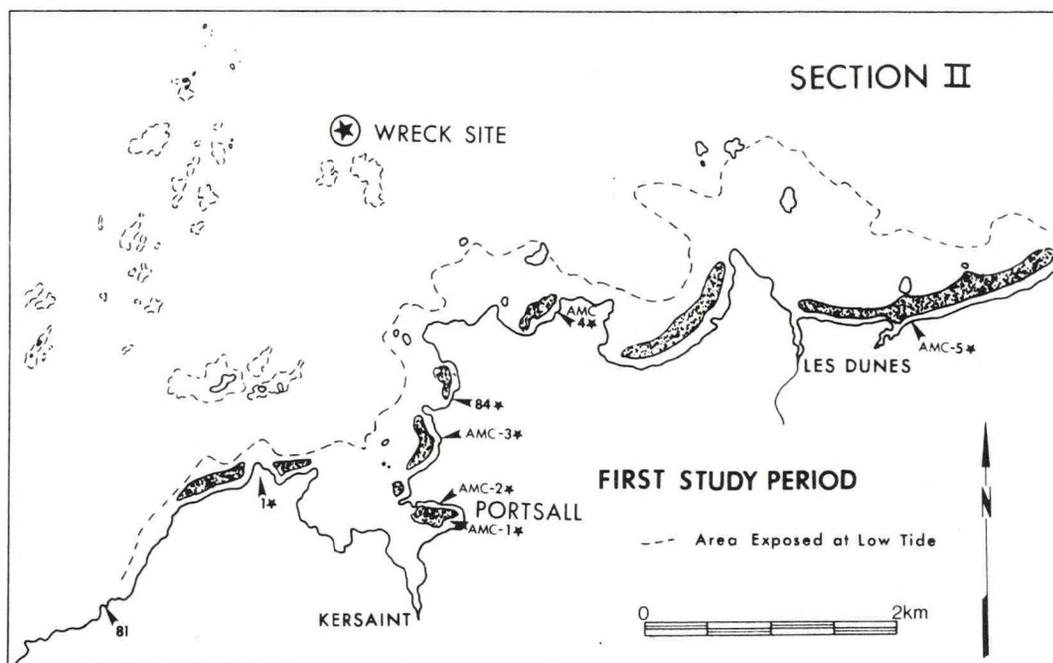


Figure 5. (top) Locations of observation stations in Section II, the Portsall area, during the first study period (March 19 - April 2). Heavy oil accumulations are indicated by the dark-stippled pattern. (bottom) Oil distribution during second study session, 20-28 April. Heavy and light coverage are indicated by plus and light-dot patterns, respectively. Stations reoccupied during third survey (July 1978) are indicated by a star.

TABLE 3. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section II. Stars indicate stations revisited during field session III, July 1978.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-81	31 Mar	St. Sampson Boulder beach on wave-cut rock platform; high energy (1 m waves present).	No oil.
★F-1	19 Mar- 20 Mar- 31 Mar- 21 Apr-	Tremazan Boulder beach on wave-cut rock platform (close to wreck site).	-light mousse in water and along shore. -very heavy oiling, oncoming waves 2 m in height. -only very small scattered blotches of oil remain. -heavily reoiled.
★AMC-1 (F-2)	20 Mar (F)- 22 Mar- 31 Mar- 21 Apr-	Portsall Sheltered embayment, with seawalls, small coarse-grained beaches and fine-sand tidal flat.	-very heavily oiled beach and tidal flat; extensive skimming operation. -still heavily oiled beach; minor oiling on tidal flat. -still heavily oiled beach; some stationary oil on tidal flat; heavy oiling of rocks and seaweed along eastern shore; little oil on surface of water; extensive shoreline clean-up activity.
★AMC-2	22 Mar 31 Mar 21 Apr	Portsall Angular, gravel beach; fine-sand tidal flat.	Heavily oiled beach; clean tidal flat.
★AMC-3 (F-3)	20 Mar (F)- 22 Mar- 31 Mar- 21 Apr-	Portsall-North Cobbles against a seawall along the upper beachface; coarse-sand on rest of beachface; fine-sand low-tide terrace with some algae covered rocks.	-heavily oiled beach, upper low-tide terrace and rocks. -moderate coverage of beachface with thick (10 cm) mousse swashes; still heavily oiled rocks.
★F-84	31 Mar- 21 Apr-	Prat Leac'h-Kerras 0.5 km sand pocket beach with eroding sedimentary backshore.	-very heavily oiled beachface; extensive clean-up operation. -clean beach but new erosion scarp formed along the backshore.
★AMC-4 (F-4)	23 Mar- 31 Mar- 21 Apr-	Les Dunes-West Three pocket, sand beaches within a large sheltered cove. A fine-sand tidal flat is exposed at low tide; each beach has a clay base with eroding clay scarp along the backshore.	-very heavily oiled beachface and upper tidal flat along eastern shore. Very large amphipod kill. Center beach has moderate oiling; western beach clean. -heavily oiled upper beachface. -heavy oil swashes; front-end loaders removing oil and sand from beachface.
★AMC-5 (F-5)	20 Mar (F)- 23 Mar- 26 Mar- 31 Mar- 22 Apr-	Les Dunes-East Large deposition area with a grass stabilized dune field. A flat profile fine-sand beach/low-tide terrace abuts an eroding dune scarp.	-moderate oil streaks on eastern side; fewer on western side. -very heavy oil covering the entire beach on east side and on upper beach of west side. -very heavy oil on east side of stream; large amount of oil buried on west side. -clean east side; very heavy oil on west side. -very light oil swashes; some oil burial on both sides of stream.

TABLE 4. Summary of observations made during the follow-up survey of July 1978 at stations within Section II.

Station Number and Location	Date Visited	Description of Oil Impact
F-1 Tremazan	3 Aug 78	Rocks remain significantly oiled within the intertidal zone.
AMC-1 Portsall	18 July 78	Seawall cleaned but still oil stained; the beachface contains a 1 m swash of oil against seawall, and numerous oil globs; very little oil remaining on the tidal flat, but oil sheens are common as are annelid worms; rocks on other side of tidal flat remain oil stained; macroalgae are mostly gone, filamentous green algae ( <u>Enteromorpha</u> ) are very common.
AMC-2 Portsall	18 July 78	Seawall and upper beachface clean, but lower beachface contains 1 cm thick weathered oil on surface with heavy oil staining below surface to 12 cm. Hundreds of juvenile crabs are present.
AMC-3 Portsall-North	18 July 78	Active clean-up of seawalls and of oil-infilled trenches; algae on rocks; beach remains lightly oil stained.
F-84 Prat Leac'h-Kerras	18 July 78	1-3 cm thick oil/sediment layer buried 20-42 cm deep under clean sand.
AMC-4 Les Dunes-West	18 July 78	Two oil layers buried 74 cm at the mid-beachface; oil contaminated ground water common throughout the area; heavily oiled rocks on both sides of beach.
AMC-5 Les Dunes-East	18 July 78	Some erosion of the dunes behind the beach; the beach is very clean except for some discontinuous oil layers approximately 40 cm deep on the lower beachface.

surface and within the beach sediments.

3. With respect to biological recovery, Arenicola worms were common across the tidal flat. The filamentous green alga, Enteromorpha, was very common on the rocks on the south side of Portsall, and hundreds of juvenile crabs were seen at AMC-2.
4. There was little change in the topographic beach profiles run at the AMC stations, although some erosion had occurred at AMC-4 (Fig. 6a) and a portion of the fore dune had been lost at AMC-5.
5. Although most beaches had some buried oil (see Table 4), it was buried deepest at station AMC-4. A 3-cm oiled-sediment layer was found beneath 74 cm of clean sand along the upper beachface Fig. 6b).

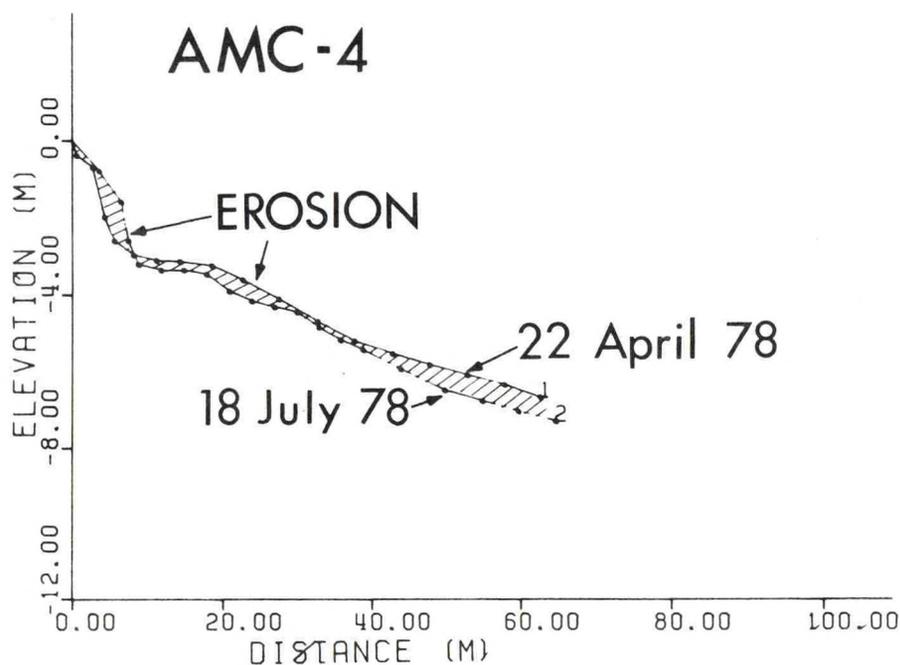


Figure 6a. Comparison of beach profiles taken on 22 April and 18 July at station AMC-4 show that minor erosion has occurred during the intervening time period. Most beaches showed even less change than this one.

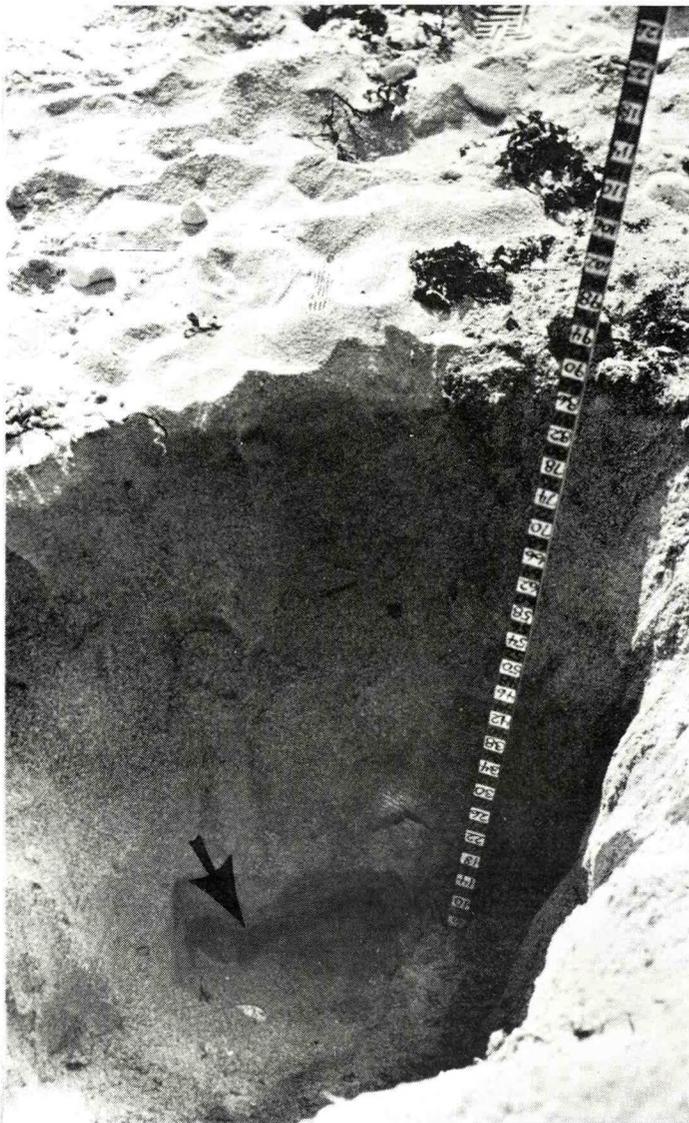


Figure 6b.

Three cm thick layer of oiled sand at depth of 74 cm at station AMC-4 (18 July 1978).

6. Clean-up activities were in progress at station AMC-3. Crews were removing oil from the walls by high pressure spraying. Oiled sediment that had filled the trenches used in the first clean-up effort, was being dug up and hauled away.

### Section III - Les Dunes-East to Plouguerneau

Observations and station locations made during surveys I and II in Section III are presented in Table 5 and Figure 7, respectively. Initially, oil was blown into many of the westward-facing pocket beaches. During July,

TABLE 5. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section III. Stars indicate stations revisited during field session III, July 1978.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-6	20 Mar	Ker-Vigorn Mouth of estuary.	Oil boom deployed - no oil at this time - to become heavily oiled starting 21 March.
F-31	26 Mar	Grand Moulin Western arm of l'Aber Benoit; tidal flat (mud) with rocks along shore.	Very light sheen.
F-32	26 Mar	Le Carpont Arm of l'Aber Benoit; tidal flat.	Heavily oiled.
F-85	31 Mar	Treglonou Large fine-grained tidal flats.	Heavily oiled along shoreline.
★F-40	26 Mar	l'Aber Benoit Entrance to estuary.	Boom in place.
★F-39	26 Mar	Prat Allan Arcuate cobble beach.	Heavily oiled with a large oil pool offshore.
F-38	26 Mar- 22 Apr-	Presqu'ile Ste. Margarite Coarse-sand pocket beach.	-heavily oiled. -oil burial 70 cm and 35 cm with light swashes on surfaces.
★F-37	26 Mar	Presqu'ile Ste. Margarite Coarse-sand pocket beach.	Heavily oiled.
★ANC-11	26 Mar- 1 Apr- 22 Apr-	les Dunes de Ste. Margarite Medium-sand pocket beach backed by eroding dune scarp.	-heavily oiled; extensive clean-up operation with manpower, front-end loaders, and backhoes. -heavily oiled upper berm; front-end loader removing oiled sand. -95% cleaned; some minor burial.
F-33	26 Mar	South of Penn Enez Sand pocket beach.	Heavily oiled.
F-34	26 Mar	Penn Enez Boulders in front of small scarp beach.	60 m - heavily oiled.
F-35	26 Mar	Penn Enez (East side) Small pocket beach.	Moderate oiling.
★F-36	26 Mar	Poullac Harbor Wide exposed sand flat.	No oil.

TABLE 5 (continued)

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
★AMC-12	27 Mar-	St. Cava Coarse-sand beach with a medium-sand, very broad, low-tide terrace lying between two rocky headlands.	-very heavy oiling of beach and upper tidal flat; large kill of cockles.
	1 Apr-		-still heavily oiled beach; manual clean-up operation.
	23 Apr-		-beachface is oil-stained, but without significant accumulations; oil mixed 17 cm into the low-tide terrace by the heavy trucks; interstitial water still contaminated.
★F-41	20 Mar-	Kervenny Brag Sand tidal flat abutting a seawall and rocks located in a large pocket cove.	-very light swashes.
	27 Mar-		-very heavily oiled; extensive clean-up operation underway.
	23 Apr-		-95% clean, but the tidal flat has been churned up by heavy equipment.
★F-7	20 Mar-	Lilia Rocks with algae along a channel at low tide.	-oil streaks on the water; very light oil on shore.
	1 Apr-		-light oil sheen on water; very light oil on shore.
	23 Apr-		-definite mousse zone on algae and rocks.
F-111	23 Apr	Kerjegu Small embayment off of a large sand flat.	Marsh in upper portion of embayment - lightly oiled; otherwise clean.
★F-112	23 Apr	Kelerdut Large tidal flat embayment protected by island and rocks offshore.	Clean tidal flat, but badly oiled shoreline; oiled gravel is piled up to be removed.
★F-113	23 Apr	Porz Guen Rocky headland with small harbor/embayment.	All of the rocks heavily oiled, especially the northern corner of the harbor; beachface is lightly oiled; clean-up operation previously removed much of the oiled algae.
F-42	27 Mar	Porz Guen Angular boulder beach.	Lightly oiled.
★F-114	23 Apr	Porz Guen Sandy pocket beach protected by rocky headlands on the north and west.	No oil.

many of these same areas were still heavily contaminated. A summary of observations made in Section III follows (see also Table 6):

1. There was essentially no change in the topographic profiles of the measured beaches (stations AMC-11 and AMC-12).
2. The oil-removal trench at AMC-11 contained a significant quantity of oil, which was still fresh in appearance. At this same beach, the heavily oiled cobble areas, which were subjected to extensive clean-up activity, appeared to be relatively free of oil. Only small oil blotches were visible on the pebbles.
3. Clean-up of the rocks by high pressure spraying was still in progress at station F-39 (Fig. 8). A clean-up program at AMC-12 was being concluded. It consisted of high pressure spraying of the beach sediments with dispersants. However, the sands of the lower beachface still appeared oil-stained even after several treatments were applied by the clean-up crew.
4. The interstitial ground water at stations AMC-11 and AMC-12 was still contaminated by oil, as indicated by an obvious oil sheen on the surface of the water.
5. On many tidal flat and low-tide terrace surfaces, particularly near the toe of the beach, oil had been churned into the sediment during the clean-up program. This was especially true at stations F-41 and AMC-12.
6. Sediment cemented with asphalt, sometimes called moussecrete, was found along the beaches of the sheltered harbor environment at stations F-111, F-112, and F-113. At F-112, the areal extent of moussecrete was the greatest observed, being over 4 m wide and several tens of meters long (see Fig. 9). Similar deposits of moussecrete have been noted by the authors at the Metula oil spill site of Patagonia, Chile.

TABLE 6. Summary of observations made during the follow-up survey of July 1978 at stations within Section III.

Station Number and Location	Date Visited	Description of Oil Impact
F-40 l'Aber Benoit	18 July 78	Very clean except for minor oil staining on rocks along upper beachface.
F-39 Prat Allan	18 July 78	Extensive on-going clean-up operation with high pressure hoses and trenching to remove oil from gravels along the upper beachface.
F-37 Presqu'ile Ste. Margarite	18 July 78	Discontinuous oil layers 20-25 cm deep, and probably deeper higher on the beachface; very clean surface sand.
AMC-11 Les Dunes de Ste. Margarite	18 July 78	Very clean surface sand but discontinuous oil layers buried 30 cm deep; trenched areas remain as site of heavy oil contamination; ground water consistently contains oil; rocky areas show only scattered (20%) oil coverage due to extensive clean-up.
F-36 Poullac Harbor	18 July 78	No oil; black lichen on the rocks appears similar to oil.
AMC-12 St. Cava	19 July 78	Heavy oil staining along most of lower beachface and upper low-tide terrace; maximum of 6 cm burial; deepest penetration is 13 cm; active clean-up of oiled sand by use of dispersant - apparently not very effective; ground water remains oil contaminated.
F-41 Kervenny Brag	19 July 78	In general, area is clean, but below surface of the tidal flat, oil is mixed in as much as 15 cm; some oiled sediment between rocks but rocks are clean, apparently a result of clean-up activity.
F-7 Lilia	19 July 78	Little to no oil on rocks; isopods very common and algae appear healthy.
F-112 Kelerdut	19 July 78	Two cm thick oil pavement common over much of the beachface, and along surrounding shoreline.
F-113 Porz Guen	19 July 78	Moderate to heavily oiled rocks along high tide swashlines; surface sand clean, but has several buried layers, 35 cm maximum depth.
F-114 Porz Guen	19 July 78	Slight oil staining on rocks.

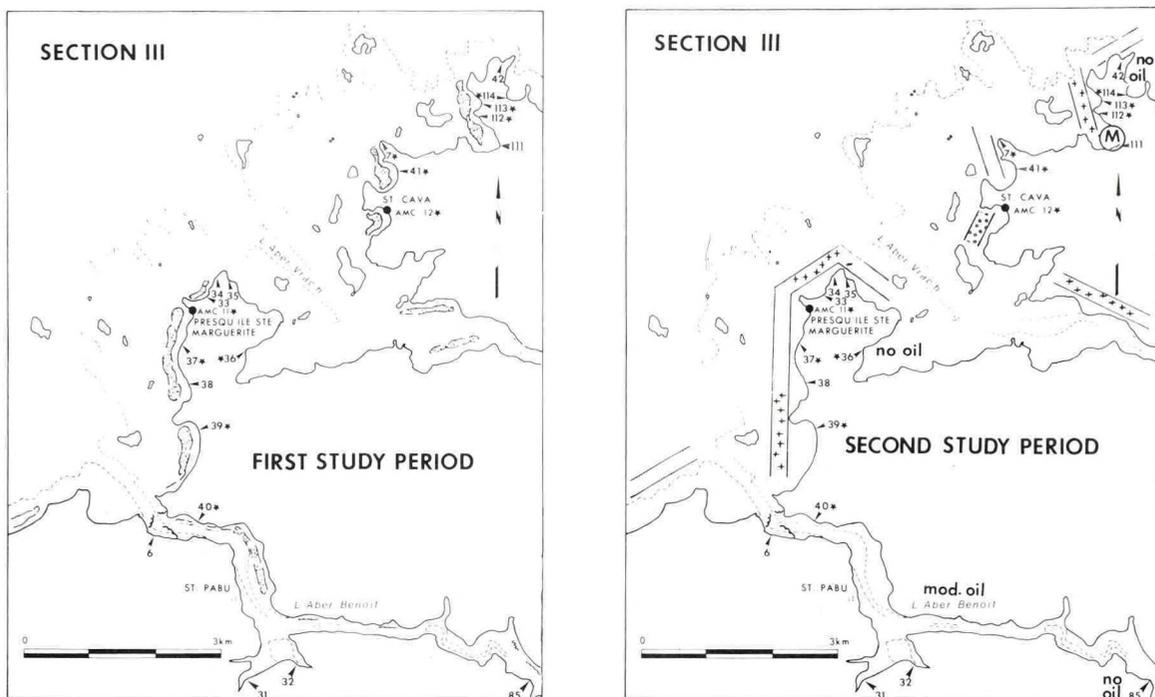


Figure 7. Station locations and oil distribution within Section III during first and second study periods. Initial oil concentrations are indicated by dark stippled pattern. During the second study, heavy and light oil coverage are indicated by the plus and light-dot patterns, respectively. Stations revisited during the present survey are indicated by a star



Figure 8. The clean-up of the oiled cobble area at station F-39 as observed on 18 July. Notice the trench at the right which was dug to capture oily runoff which would later be pumped out.



Figure 9. Overview (top) and close-up (bottom) of "moussecrete" (desiccated mousse mixed with sediment to form asphalt layers) at station F-12 on 19 July 1978.

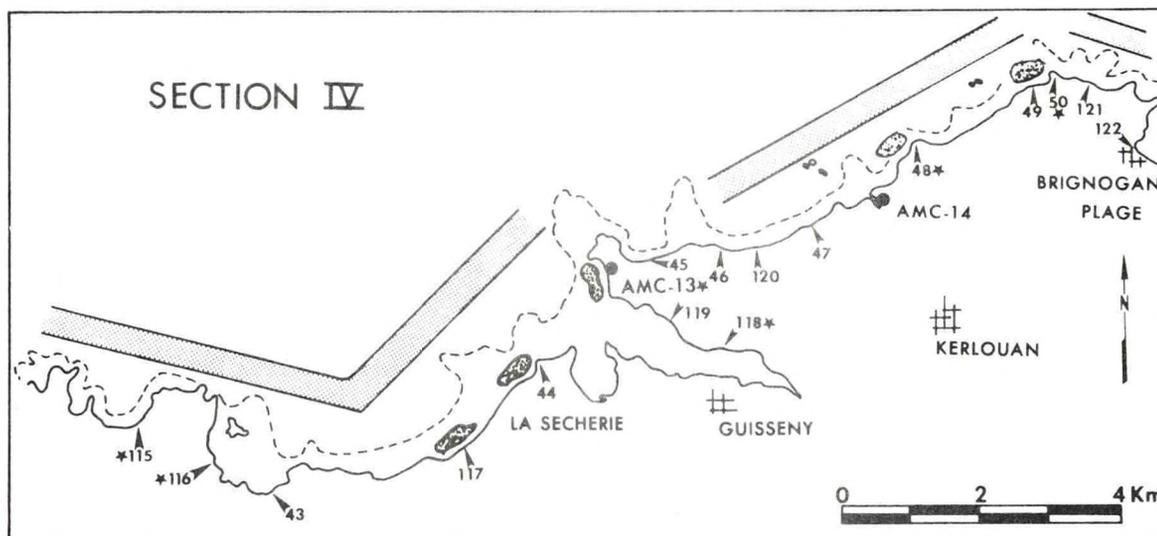


Figure 10. Locations of stations within Section IV. Oil observed during the first study session (March) is marked by the dark-stippled pattern. During the second session (April), only light oil coverage was noted, as indicated by the light-dot pattern. Stations reoccupied during the third study period (July 1978) are indicated by a star.

#### Section IV - Trouloc'h to Brignogan Plage

Oil deposition in this section, at the time of the spill, was generally spotty, due to the overall east-west orientation of the shoreline (Fig. 10). Those areas oriented more north-south were more likely to have been affected (e.g., stations F-44, AMC-13, F-48, and F-50). Details of our initial studies are tabulated in Table 7.

The follow-up survey of July 1978 generally revealed only minor oil remaining on the surface or within the beaches (Table 8). Station F-50 was an exception in that oil was present to a depth of 15 cm along the upper beach-face. Many of the rocky areas, particularly those in sheltered localities, still showed signs of the spill. At stations AMC-13 and F-116, rocks on the north side of the beach were blackened by tar, and had asphalt-cemented sediment between them.

TABLE 7. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section IV. Stars indicate stations revisited during field session III, July 1978.

<u>Station Number</u>	<u>Date(s) Visited</u>	<u>Location and Type of Environment</u>	<u>Description of Oil Impact</u>
★F-115	23 Apr	Penn ar Strejou Small sandy pocket beach facing north; sandy dunes backing the beach; tidal flat in front of beach.	The beach contains some light oil swashes; rocky areas are moderately oiled; some of the algae is coated by a thick covering of mousse.
★F-116	23 Apr	Corejou Neck of a peninsula, connects an island offshore; embayments north and south.	No oil on north side of jetty; lightly oiled cobbles on south side.
F-43	27 Mar- 23 Apr-	Mogueran An embayment with a large tidal flat (1-1½ km) in front; rocky on both sides with much rock debris on beach.	-clean; no oil. -some new oil has come onshore; very light, a mousse froth that is on the upper portions of the beach and is mixed in with the algae.
F-117	23 Apr	Ta Secherie Large sandy beach with sand dunes backing it.	Lightly oiled along the swash lines as well as on some of the rocks.
F-44	27 Mar- 23 Apr-	Le Curnic Contains a jetty separating two sandy beaches; much rock debris on the beaches.	-rocks on the jetty are lightly to moderately oiled. -light oiling of rocks on both sides of jetty; beaches clean except for light oil swash lines.
★F-118	23 Apr	Lerret Near the head of a large estuary/tidal flat.	Marsh in the upper intertidal zone is moderately oiled; light oil swashes on sand leading down from oiled seawall.
F-119	23 Apr	Tresseny Middle of a large estuary/tidal flat.	Lightly oiled rocks and seaweed swash line.
★AMC-13	27 Mar- 23 Apr-	Roc'h Quelenec Medium- to fine-sand beach and tidal flat with rocky headlands on both sides; large boulders on beachface.	-very heavily oiled beachface; oil 30 cm thick, mixed with algae along upper swash zone. -surface 99% clean, but deep 38 cm burial along upper beachface; also has oil contaminated interstitial water.
F-45	27 Mar- 23 Apr-	Neiz Vran Mixed sand and rock debris beach with large tidal flat in front.	-no oil. -upper intertidal algae and seaweed lightly oiled.
F-46	27 Mar	Boutrouille Well-sorted granule beach	Very light oil swashes.
F-120	23 Apr	(near) Louc'h an Dreff Coarse-grained beach with a fine-sand low-tide terrace.	Clean except for a few minor oiled swash lines.
F-47	27 Mar	(near) Kerlouarn Steep, mixed-sand and granule beach.	Lightly oiled rocks.

TABLE 7 (continued)

<u>Station Number</u>	<u>Date(s) Visited</u>	<u>Location and Type of Environment</u>	<u>Description of Oil Impact</u>
AMC-14	27 Mar- 23 Apr-	Kerlouarn Sheltered, grassed, embay- ment used as a small harbor.	-5 m wide heavily oiled grasses. -a dirt road constructed over oiled swash.
★ F-48	27 Mar- 23 Apr-	Carrec zu Sandy beach with large dune system; relict marsh outcrop- ping on beach - therefore, an erosional beach.	-light oil swashes. -clean sand with light oil swashes.
F-49	27 Mar	(near) Chapelle Pol Sandy beach with large dune system; some rocks and rock debris scattered along beach.	Heavily oiled rocks.
★ F-50	28 Mar- 23 Apr-	Lighthouse at Pointe de Beg Pol Rocky point sticking out with sandy beaches on both sides.	-heavy oiling on both rocks and beaches. -sand tinted brown, but now only light- ly oiled; rocks also oiled lightly.
F-121	23 Apr	Kervernen Rocky beach with some sand underneath.	Sand is clean, but rocks are lightly to moderately covered with oil; some algae is clinging to rocks and sur- viving the oil coverage.
F-122a	23 Apr	Brignogan Plage Large harbor tidal flat.	Light oil swashes; light oil on algae; some of the rocks are dark from light oil staining.

TABLE 8. Summary of observations made during the follow-up survey of July 1978 at stations within Section IV.

Station Number and Location	Date Visited	Description of Oil Impact
F-115 Penn ar Strejou	19 July 78	No buried oil; rocks remain oiled to the north.
F-116 Corejou	19 July 78	Moderately oiled rocks along upper beach; clean beach sands.
F-118 Lerret	19 July 78	Clean stone rubble placed in front of seawall is effectively covering oiled portions.
AMC-13 Roch'h Quelenec	19 July 78	Heavily oiled rocks on north side; beach clean except for some minor and discontinuous buried oil layers; some 5 cm tar balls; many <u>Arenicola</u> present.
F-48 Carrec zu	19 July 78	Clean beach; very light oil coating on rocks.
F-50 Lighthouse at Pointe de Beg Pol	19 July 78	Moderate to light oil on the surface and 15 cm into the upper beachface.

Many beaches along this entire section have outcroppings of organic-rich marsh sediments on top of a basal clay (Fig. 11), which were deposited during an earlier time period. Because the surface layer appears black and tar-like, it could easily be mistaken from a distance as oil from the Amoco Cadiz, or perhaps from some earlier spill.

#### Section V - Greve de Goulven to Plouscat

Initially, oil was blown into many of the pocket coves along the westward-facing shoreline of this section (Fig. 12). By late April, most of the major oil masses had been dispersed, and varying quantities of oil were spread along most of the shoreline (Table 9). During the July survey (Table 10), we found that many of the beaches, though clean on the surface, often had some buried oil. Oil was usually present as discontinuous layers of varying



Figure 11. Overview (top) and close-up (bottom) of outcropping peat top of basal clay layer. From a distance, this could easily be mistaken for an oil deposit.

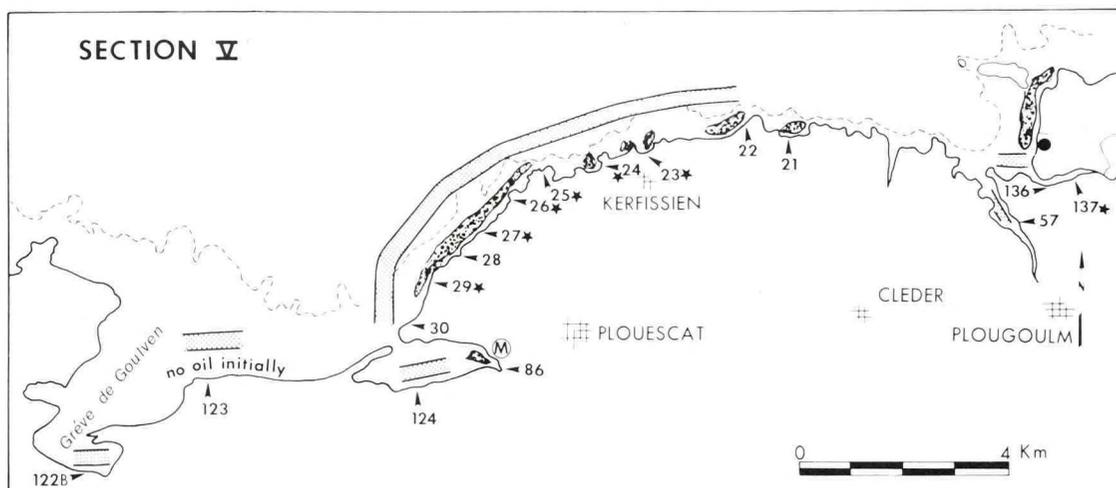


Figure 12. Locations of stations within Section V. Oil as observed during the first study session (March) is marked by the dark stippled pattern. During the second session (April) only light oil coverage was noted, as indicated by the light-dot pattern. Station reoccupied during the present study are indicated by a star.



Figure 13. One portion of the oiled marsh at station F-137. An oil pool is located at the center of the blackened area. Because no clean-up was applied to this site, it may provide a control to the Ile Grande marsh area which was cleaned.

TABLE 9. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section V. Stars indicate stations revisited during field session III, July 1978.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-122b	23 Apr	Gourven Large tidal flat/estuary with a fringing marsh.	Very lightly oiled marsh grass.
F-123	23 Apr	Plage de Ker Emma Wide sandy beach with dune system; large rocks offshore as well as on the lower portions of the beachface.	Some light oil and small tar balls along the last high tide swash line. Fresh mousse (moderate-heavy concentration) coating on algae and rocks.
F-124	23 Apr	Anse de Kernic Large tidal flat with a harbor on one side; fringing marsh on shoreline.	Some darkened marsh grass from light oiling; a few mousse balls along the high tide swash line.
F-86	1 Apr- 23 Apr-	Plouescat Marsh at head of estuary.	-heavily oiled marsh -oiled marsh grass all ripped out; little marsh grass remains; still some patchy oil.
F-30	25 Mar- 23 Apr-	End of Spit at Porz Meur Beach with rocky area to the southwest.	-very light oil. -rocky area moderately oiled; a little mousse foam in the water; light oil swashes on the last high tide line.
★F-29	25 Mar- 23 Apr-	Por au-Streat Breakwater harbor with seawall protecting it from direct wave attack.	-beach heavily oiled; lots of clean-up activity. -just a little oil on beach with some burial along the upper swash line. The rocks are all lightly oiled.
F-28	25 Mar	Frouden Rocky cobble beach with some sandy areas.	Oil pools; clean-up operation in effect.
★F-27	25 Mar	(near) Au Gered Pocket beach.	Heavily oiled gravel beach and rocks.
★F-26	25 Mar	Point at St. Eden Pocket sand beach with rocky headland on both sides.	Heavily oiled rip-rap seawall.
★F-25	25 Mar- 23 Apr-	Pornejen High energy boulder beach.	-heavily oiled rocks; 200 m slick of mousse. -light oil coverage on rocks; much of the oil on rocks removed by high pressure hoses.
★F-24	25 Mar	Poulfuen Pocket beach with rocks on sides.	Heavily oiled.
★F-23	25 Mar- 23 Apr-	Kerfissien Small pocket beach with rocks on sides.	-moderately oiled especially in the eastern zone. -beachface was clean with half-buried, discontinuous mottled oil zone along the swash zone and a few buried tar balls at 50-60 cm.
F-22	25 Mar- 23 Apr-	Anameid High-energy beach with eroding dune scarp and rocky headlands on both sides of a small embayment.	-beach is heavily oiled; heavy mousse swash. -area entirely clean.
F-21	25 Mar	Tavenn Kerbrat Sandy beach with heavy rock debris.	Very light mousse in water.

TABLE 9 (continued)

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-57	28 Mar- 26 Apr-	Plage de Trestrignel Sandy shoreline with some rocks sticking thru a muddy sand flat at the center of the tidal channel.	-light sheen in water. -light oil swash lines along the upper part of the shore; oil burial 6-8 cm on the upper portion of the beachface; live amphipods found along the high tide swash.
F-87	1 Apr	Kerbrat Side of estuary.	Lightly oiled.
F-136	26 Apr	Kerbrat Fine- to medium-sand tidal flat	Very light oil swash along the high tide swash line; no oil burial; live amphipods on the beach.
★ F-137	26 Apr	Cantel Marsh area at the mouth of an estuary.	Marsh heavily oiled with 1 cm thick coverage of oil over marsh; no clean- up operation.
F-138	26 Apr	Traon Feunteun Upper portion of marsh where channel flows into the marsh.	Very lightly oiled; boom ineffectively positioned.

Table 10. Summary of observations made during the follow-up survey of July 1978 at stations within Section V.

Station Number and Location	Date Visited	Description of Oil Impact
F-29 Por au-Streat	20 July 78	Beach surface clean, but oil buried 12-17 cm; much algae ( <u>Enteromorpha</u> ) on surface.
F-27 (near) Au Gered	20 July 78	Exposed rocky area of large boulders; asphalt layers common in sheltered areas between boulders along upper swash zone; organisms very common in lower inter-tidal zone.
F-26 Point at St. Eden	20 July 78	Clean surface sand; discontinuous oil layer buried 50 cm.
F-25 Pornejen	20 July 78	Rocky area 30-40% oil covered; oil globs several mm thick in several localities; green algae ( <u>Enteromorpha</u> ) common.
F-24 Poulfuen	20 July 78	Generally clean, minor oil along rocks at high tide swash.
F-23 Kerfissien	20 July 78	Clean sand except for minor, discontinuous oil layers 35 cm deep.
F-137 Cantel	20 July 78	Several heavily oiled zones of marsh with oil $\frac{1}{2}$ cm thick; marsh grasses in oiled areas are dead.

thickness and depth. Many of the rocky areas remained heavily oiled on the landward (sheltered) side, even though the area is generally well-exposed to wave attack. Moussecrete was common between the boulders.

With respect to biological impact, many of the stations had an enormous quantity of the green alga, Enteromorpha. Station F-137 is an oiled marsh system that was not cleaned. In July, it had several heavily oiled areas in which most of the marsh grass was killed (Fig. 13). This site definitely should be studied further and may provide a possible control site with reference to the Ile Grande marsh area. However, the types of grasses at the two areas are different.

#### Section VI - Foret Dom. de Santec to Roscoff

Section VI was one of the three most heavily impacted areas, generally because it is oriented north-south, and extends further north than all areas to the west (see Fig. 1). Station locations and a brief description of initial oil impact are presented in Figure 14 and Table 11, respectively. Results of the July survey are presented in Table 12.

During the latest survey, we found the following:

1. The beaches were usually clean except for some minor and discontinuous oil layers buried beneath the surface.
2. Only where clean-up activities had churned oil into the sediment (as at station F-18), were there significant quantities of oil buried.
3. Rocks generally appeared to be only lightly oil-stained.
4. The alga, Enteromorpha, was present in extremely large quantities at many stations (see Table 12). At station AMC-7, military personnel were actively removing algae which had been left on the shoreline by the receding tide.
5. Beach profiles were essentially the same as during April.

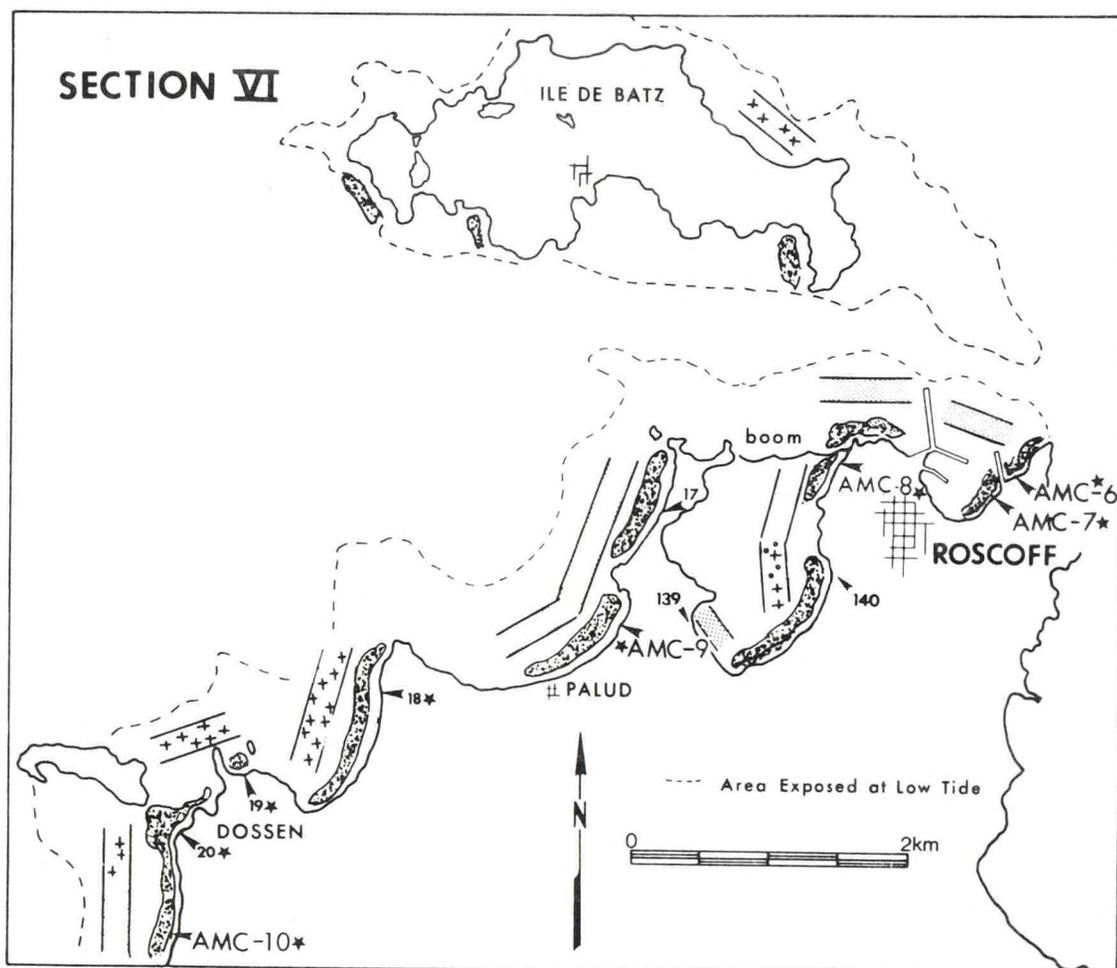


Figure 14. Station locations and oil distribution within Section VI during the first (March) and second (April) study periods. Initial oil concentrations are indicated by dark-stippled pattern. During the second study, heavy and light oil coverage are indicated by the plus and light-dot patterns, respectively. Stations revisited during the third survey (July 1978) are indicated by a star.

TABLE 11. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section VI. Stars indicate stations revisited during field session III, July 1978.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
★AMC-10	24 Mar (F)	Foret Dom. de Santec	-contains a 20 m band of oil along the upper beachface; 12 cm burial.
	25 Mar (AMC)	Eroding dune scarp with wide fine-sand beach grading into a broad low-tide terrace.	-light oil swashes on beach surface; a discontinuous layer buried 8 cm.
	1 Apr-		-very light oil swashes on beach surface; discontinuous layer buried a maximum of 23 cm.
	26 Apr-		
★F-20	24 Mar	Dossen	-tombofo effect; heavy oiling of entire area behind island.
	25 Mar	Wide fine-sand beach/low-tide terrace behind an island.	-surface of low-tide terrace clean; oiled rocks along shoreline; signs of a clean-up operation.
	1 Apr-		-rocks still moderately to heavily oiled; some burial 10-12 cm along upper beachface.
★F-19	24 Mar-	Port au Vil	-very heavily oiled.
	26 Apr-	Small pocket sand beach	-clean beach surface and rip-rap, but 12 cm burial of 4 cm thick oil layer by spring berm deposition; signs of clean-up operation.
★F-18	24 Mar-	Tevenn	-very heavily oiled.
	26 Apr-	Large sand beach oriented into direct wave attack; has a marsh deposit outcropping on the beachface.	-oil well mixed into the beachface by heavy machinery and trenches used in clean-up operation; men working to spray clean rocks to south.
★AMC-9	24 Mar (F)	Cough ar Zac'h	-very heavily oiled beachface and upper low-tide terrace; 8 cm burial along upper beachface.
	25 Mar	Broad medium- to fine-sand beach backed by eroding dune scarp; some rip-rap.	-heavy oiling restricted to 12 m along upper beachface; 8 cm burial.
	1 Apr-		-only light swashes along beachface; burial to 25 cm; clean-up by raking.
F-17	24 Mar-	Centre Helio-Marin	-very heavy oiling of the entire beachface.
	26 Apr-	Wide fine-sand beach backed by eroding dunes.	-no oil on beach surface or buried, but has oiled interstitial water; evidence of mechanical clean-up effort.
F-139	26 Apr	Ruguel Large sand flat with seawall.	Light oil swashes and lightly oiled rocks.
F-140	26 Apr	Lagadenou Small beach with seawall fronting a large sand flat.	Very heavily oiled during March; now has buried oil (3 layers) along beachface; tidal flat still oiled and has oil contaminated ground water.
★AMC-8	24 Mar (F)-	Roscoff - West	-heavy oil coverage of beach, tidal flat and seawall; oil thrown over seawall and into park; oil boom in place across sand flat.
	25 Mar-	Small mixed-sand and gravel beach leading onto a very broad sand flat with some algae coated rocks; seawall and park back the beach.	-decreased amount of oil on the tidal flat; the rest was the same.
	1 Apr-		-very light oiling on the beach; oil buried under 20 cm of cobbles; park heavily oiled, but walkway clean.
	26 Apr-		-oil stained cobbles and wall, but beach appears clean; park is replanted.

TABLE 11 (continued)

<u>Station Number</u>	<u>Date(s) Visited</u>	<u>Location and Type of Environment</u>	<u>Description of Oil Impact</u>
★AMC-7	24 Mar-	Roscoff - central harbor	-pooled oil 6 cm deep by seawall; rest of beach 70-90% oil covered.
	25 Mar-	Small medium-sand beach between rocks on both sides; backed by a seawall.	-an approximate 70% reduction in oil coverage.
	1 Apr-		-some oil-bound sediment on low-tide terrace; oily sheen present; beachface clean; cleaning wall with detergents.
	26 Apr-		-clean beachface; very minor amount of oil buried at 22 cm.
★AMC-6	24 Mar-	Roscoff - East	-the entire beachface and low-tide terrace had 35-100% oil coverage.
	25 Mar (F)-	Small coarse-sand and gravel beach grading onto a fine-sand tidal flat; rocks are found on both sides; seawall abuts the shore.	-total oil coverage decreased to approximately 20%.
	1 Apr-		-beachface very lightly oiled; seawall and rocks on tidal flat still oil blackened; oil contaminated interstitial water.
	26 Apr-		-still lightly oiled rocks and seawall; cobbles of beachface are oil stained; interstitial water still contaminated.

TABLE 12. Summary of observations made during the follow-up survey of July 1978 at stations within Section VI.

Station Number and Location	Date Visited	Description of Oil Impact
AMC-10 Foret Dom. de Santec	20 July 78	Beach very clean except for minor buried oil layers 8-18 cm deep; <u>Arenicola</u> worms are very common on the low-tide terrace.
F-20 Dossen	20 July 78	Clean - probably due to extensive clean-up operation.
F-19 Port au Vil	21 July 78	Clean surface but thick (4-8 cm) oil (fresh in appearance) layers 12-18 cm deep along upper beachface.
F-18 Tevenn	21 July 78	Clean surface but contains thick (20+ cm) isolated oil layers buried by the heavy machinery used during clean-up; algae being harvested by residents.
AMC-9 Cough ar Zac'h	21 July 78	Very large quantity of algae ( <u>Enteromorpha</u> and <u>Fucus</u> ) which covers most of the intertidal zone; some 2-3 cm tar balls mixed in with the algae; thousands of annelid worms present; scattered oil layers 2-5 cm thick buried 10 cm below the surface.
AMC-8 Roscoff - West	21 July 78	Only very light oil staining of wall rocks to south; beach sediments clean; <u>Enteromorpha</u> and <u>Arenicola</u> common on the tidal flat.
AMC-7 Roscoff central harbor	21 July 78	Some discontinuous oil layers buried 10-20 cm along upper beachface; <u>Enteromorpha</u> algae very common on lower portions of the beach and tidal flat.
AMC-6 Roscoff - East	21 July 78	Lightly oil stained rocks on both sides of clean beach sediments; <u>Enteromorpha</u> algae very heavy over low-tide terrace.

## Section VII - Roscoff to Pte. de Plestin

Section VII contains the Bay of Morlaix as well as a bedrock headland with steep cliffs which stretches from Primel Tregastel to Locquirec (Fig. 15). Oil was initially limited to only a few localities in the area. Of these, Primel Tregastel (F-94) was the most severely affected (Table 13). No oil was found along the beaches within the Bay of Morlaix, yet bottom sampling within the Bay by Dr. Cabioch of the Station Biologique (of Roscoff) and our research group, has revealed significant quantities of oil within the bottom sediments.

Observations made during the July beach survey are presented in Table 14 and summarized below:

1. Most of the sand beaches were free of surface oil, although minor amounts of oil were buried below the surface.
2. The alga, Enteromorpha, was common on rocks and beaches.
3. The cove at Primel Tregastel (F-94) remained heavily contaminated. Rocky areas were superficially coated with oil, and mousse, still brown in color, was present below many of the cobbles. In the center of the beach, oiled cobbles were buried 20 cm by clean cobbles. Most of the interstitial water contained an oil sheen. Directly offshore of this area, some of the heaviest oil contamination of bottom sediments was found.
4. The cobble beach at station F-95, previously subjected to an extensive clean-up operation using bulldozers and water under high pressure (see Fig. 4-50 in Gundlach and Hayes, 1978a, p. 161), had regained a normal beach profile and the cobbles were only lightly oil-stained (Fig. 16).
5. Rocky areas of this section varied greatly in terms of continued oil impact. Most areas were completely free of oil, however, in

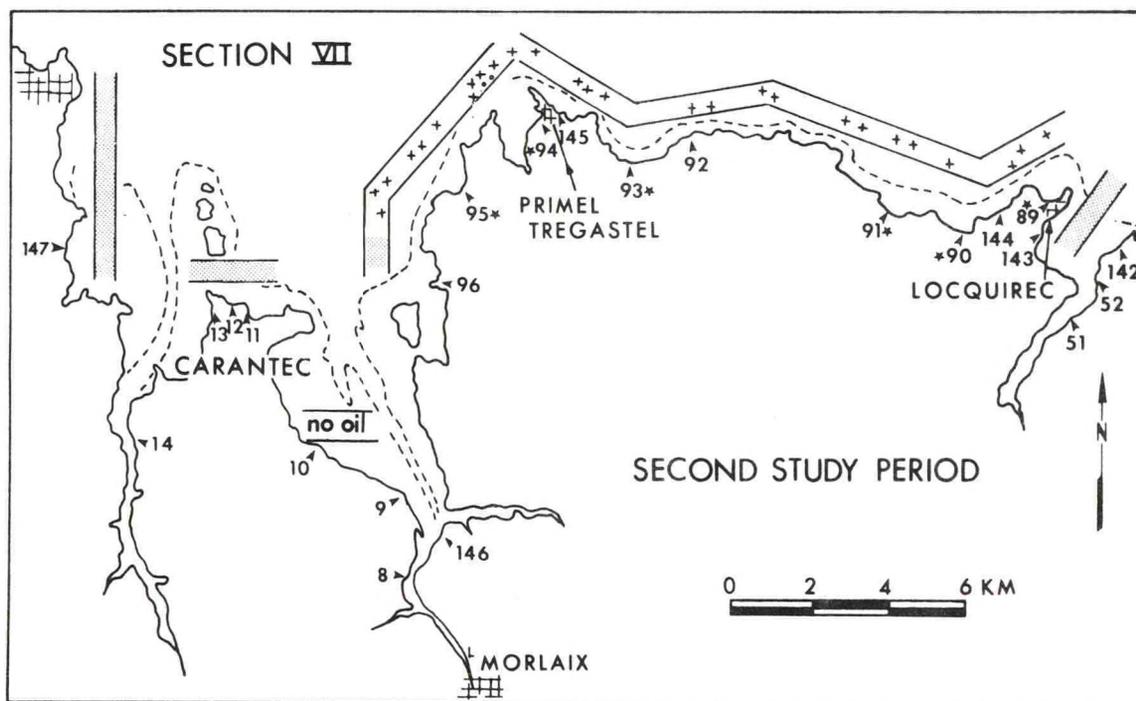
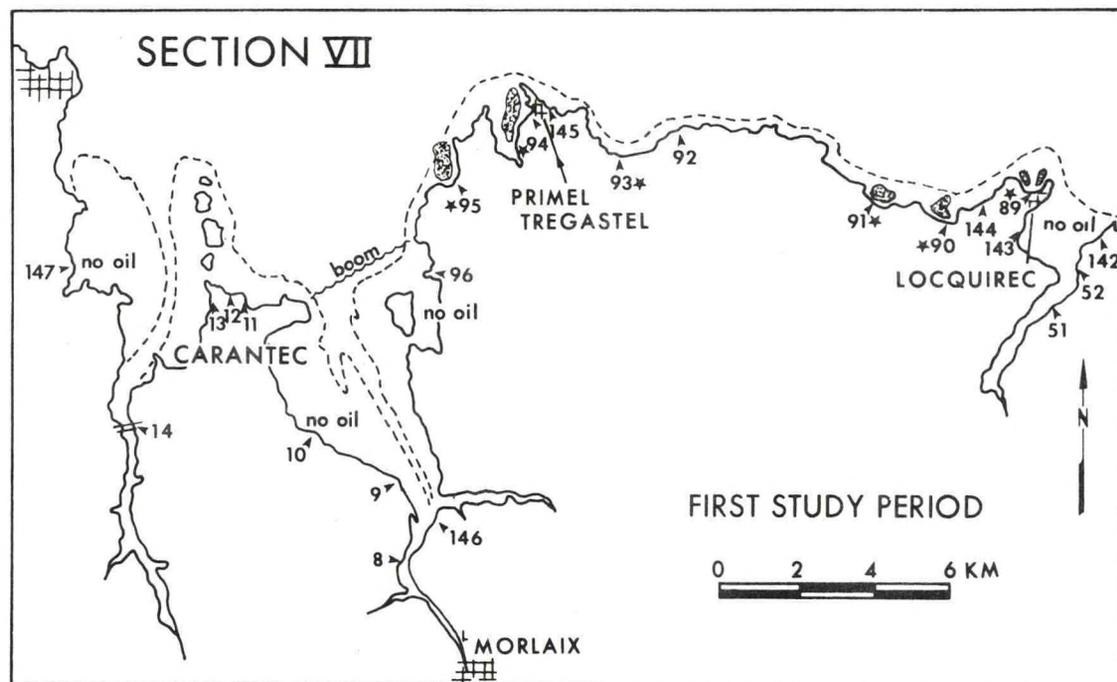


Figure 15. Station locations and oil distribution within Section VII during the first (March) and second (April) study periods. Initial oil concentrations are indicated by the dark-stippled pattern. During the second study, heavy and light oil coverage are indicated by the plus and light-dot patterns, respectively. Stations revisited during the third survey (July 1978) are indicated by a star.

TABLE 13. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section VII. Stars indicate stations revisited during field session III, July 1978.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-147	27 Apr	Port de Pem Poul A seawalled harbor; coarse-sand tidal flat.	Light oil swashes.
F-14	24 Mar- 27 Apr-	Pont de la Corde Tidal flat/estuary with small channel; station at bridge over river.	-no oil. -no oil.
F-13	24 Mar- 27 Apr-	Carantec - West A harbor with a sandy beach and large tidal flat.	-no oil. -light oil swashes.
F-12	24 Mar	Carantec - North Near the mouth of a large estuary and tidal flat.	No oil.
F-11	24 Mar- 27 Apr-	Carantec - East Granule beach.	-no oil. -very light oil on rocks; sand was removed to protect it from being oiled - it will be pushed back later; some light discontinuous burial.
F-10	24 Mar- 27 Apr-	(near) Ty Nod Gravel beach.	-no oil. -no oil.
F-9	24 Mar- 27 Apr-	East toward Dourduff Tidal flat/estuary.	-no oil. -no oil; possible light sheen in the water.
F-8	24 Mar	(near) Morlaix (2 km downriver) Small tidal flat with channel.	No oil
F-146	27 Apr	Dourduff en Mer Wide tidal flat area.	Clean except for an occasional mousse glob on the upper portion of the tidal flat (3 mousse globs/m <sup>2</sup> ); algae very productive.
F-96	2 Apr- 27 Apr-	Terrenez Small harbor with cobble beaches on both sides.	-no oil; boom deployed offshore. -light oiling of cobble beaches.
*F-95	2 Apr- 27 Apr-	le Diben Cobble beach gently sloping onto a very rocky low-tide terrace.	-heavily oiled. -beach and rocks on low-tide terrace heavily oiled; extensive clean-up operation - tractors pushing oiled cobbles into lower swash zone to be cleaned by the waves; high pressure water also being used.
*F-94	2 Apr- 27 Apr-	Primeil Tregastel - West Sheltered harbor; cobble and boulder beach.	-very heavily oiled; extensive clean-up. -moderately to heavily oiled; rocks are extensively coated with oil.
F-145	27 Apr	Primeil Tregastel - East Gravel beach with a large sand tidal flat fronting it; backed by a seawall; upper beach portion consists of cobbles and boulders.	Upper beach is moderately to heavily oiled.

TABLE 13 (continued)

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
★F-93	2 Apr- 27 Apr-	St. Jean de Doigt Cobble and gravel beach.	-light oil on rocks. -rocks and gravel all heavily oiled; oil has sunk into the gravel beach; signs of previous clean-up effort.
F-92	2 Apr- 27 Apr-	West of St. Jean de Doigt Small rocky indentation of the coast.	-no oil on shore; mousse streaks offshore. -some mousse still in the water and now the rocks have a light coating of oil.
★F-91	2 Apr- 27 Apr-	Poul Rodou Pocket beach surrounded by rocky headlands.	-no oil. -moderate to heavy oil on the rocks along the shoreline; light oil swashes on the beachface.
★F-90	2 Apr- 27 Apr-	Le Moulin de la Rive Cobble and gravel beach.	-moderately oiled rocks; clean low-tide terrace. -rocky area heavily oiled; low-tide terrace moderately oiled; active clean-up operation - a tractor is pushing oiled cobbles onto the lower beachface; also use of a high pressure hose.
F-144	27 Apr	Les Sables Blancs Small sandy beach backed by dunes; algal covered rocks on low-tide terrace; rocky headlands on both sides.	Headlands moderately oiled; light oil swashes on beach; location of an oil storage pit.
★F-89	2 Apr- 27 Apr-	Locquirec Rocky and sandy beach with a similar low-tide terrace.	-moderately oiled rocky area. -rocks are moderately to heavily oiled; even the rocks on the low-tide terrace are oiled; a very small clean-up attempt is in effect - mainly steam cleaning.
F-143	27 Apr	Locquirec Port Small jetty protecting a little harbor.	Both sides of jetty clean and no oil in the water; boom in place at front of the port; this area is very biologically productive.
F-51	28 Mar- 27 Apr-	Toul an Hery Upper part of tidal flat in harbor.	-no oil. -light coating of mousse globs along the shoreline; some very light oiling of the seaweed.
F-52	28 Mar- 27 Apr-	(near) Kerdrehoret - West Beach and tidal flat in harbor.	-no oil. -very light oiling here - one small oil glob for each 2 square meters; otherwise, completely clean.
F-142	27 Apr	(near) Kerdrehoret - North Small fine-sand pocket beach.	Some oil droplets on the surface of the rocks; beach is entirely clean; no burial.

TABLE 14. Summary of observations made during the follow-up survey of July 1978 at stations within Section VII.

Station Number and Location	Date Visited	Description of Oil Impact
F-95 le Diben	21 July 78	Coarse-cobble beach; only light (10% coverage) oil splotches remain on cobbles after extensive clean-up.
F-94 Prime! Tregastel West	21 July 78	Rocks and cobble beach remain heavily oiled; in some areas, oil is buried 20 cm by clean material; ground water is heavily contaminated; lower intertidal zone supports extensive biota, including small fish, crabs, and snails and algae ( <u>Enteromorpha</u> ); on the eastern facing side, rocks remain oiled, but the beach is completely free of oil.
F-93 St. Jean de Doigt	21 July 78	Overlooking rocky cliffs; rocks are dark in appearance but unable to determine if oiled. 93-B is very heavily oiled cobble beach; no clean-up applied because of inaccessibility.
F-91 Poul Rodou	21 July 78	Upper swash zone of nearby rocks completely coated with oil still fresh in appearance; biota are most reduced in the upper intertidal zone; oiled ground water from rocks leaches out on the beachface.
F-90 le Moulin de la Rive	21 July 78	Generally clean except for minor oil blotches on cobbles; some leaching of oiled ground water.
F-89 Locquirec	21 July 78	Clean sand burying (21 cm) a discontinuous oil layer; absence of limpets and snails is noticeable; algae ( <u>Enteromorpha</u> ) is common on beach and rocks.

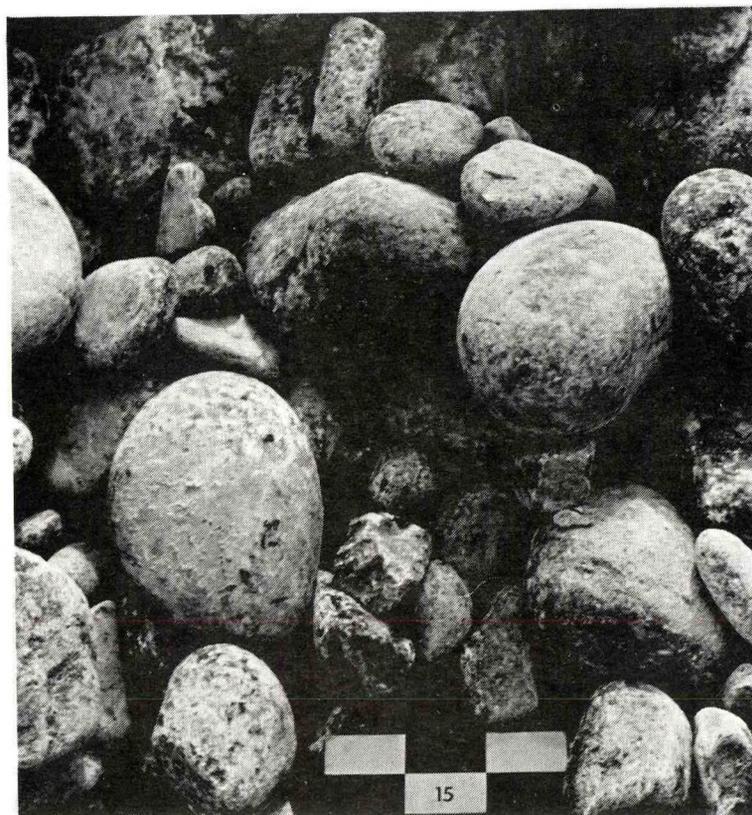
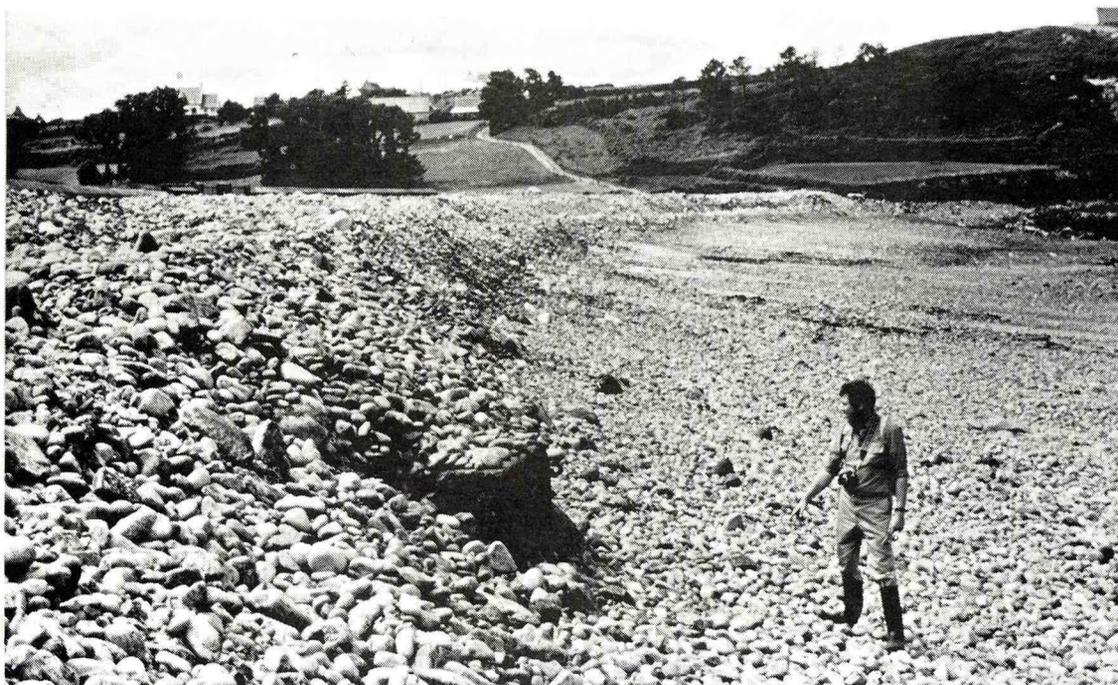


Figure 16. Overview and close-up of the cobble beach at station F-95 on 23 July 1978 (scale is 15 cm). This beach was subjected to an extensive clean-up program utilizing bulldozers and high pressure spraying (see p. 161 in Gundlach and Hayes, 1978a). The results are satisfactory in that the beach has regained its natural profile and the rocks are generally free of oil.

some scattered localities, usually sheltered from westerly winds and waves, the shoreline remained severely contaminated (as at station F-145).

6. The oyster beds on the tidal flats of the Bay of Morlaix (near F-10) were also inspected during this study. No oil or oil sheens were observed. Thousand of oysters were being cultivated and some were harvested while we were there. The level of contamination within the oyster tissue was not determined.

#### Section VIII - St. Efflam to Kerhellen

This section includes two important areas, the huge sandflat called Greve de St. Michel (between stations F-141 and AMC-15), and the Pte. de Sehar (AMC-16). The latter provided an example of a heavily oiled mixed sand and gravel beach. Station locations are presented in Figure 17. Initial oil impact is tabulated in Table 15. Our third follow-up survey revealed the following (see Table 16):

1. Little visible signs of oil were present on the St. Michel sandflat. A few mixed oil and sand layers, left from clean-up, were buried under clean surface sand and created only a very localized source of oil pollution. The shells of the organisms killed in vast quantities during the spill had been removed by the French in preparation for the tourist season.
2. The mixed sand and gravel beach at station AMC-16 remained heavily oiled in spite of the previous use of a bulldozer to push the oiled gravel into the surf zone (see Fig. 4-55A in Gundlach and Hayes, 1978a, p. 169). The appearance of this area in July is sketched in Figure 18, and its topographic profile is presented in Figure 19. Heavily oiled sediment was buried 20-25 cm below the surface of the mid-beachface, and probably extended much deeper below the spring

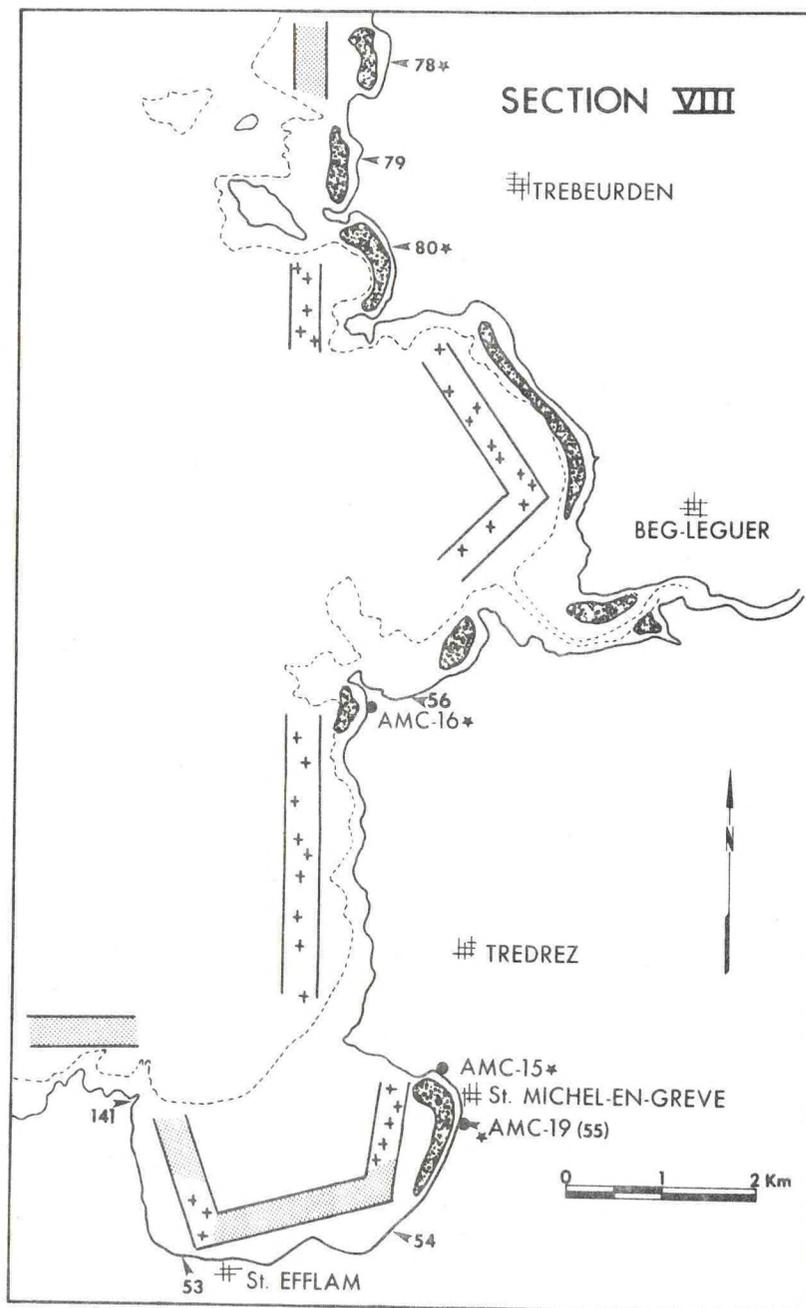


Figure 17. Locations of stations and oil distribution within Section VIII. Oil observed during the first study session (March) is marked by the dark-stippled pattern. During the second study period (April), heavy and light oil coverage are indicated by the plus and light-dot patterns, respectively. Stations which were revisited during the third survey (July 1978) are marked by a star.

TABLE 15. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section VIII. Stars indicate stations revisited during field session III, July 1978.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-141	27 Apr	Pointe de Plestin Exposed pocket beach consisting of medium- to coarse-grained shell material.	No oil except for very light oil splattering along the high tide swash lines.
F-53	28 Mar- 27 Apr-	les Carrieres Large tidal flat embayment.	-no oil -some heavily oiled rocks; no oil at the lower portion of the tidal flat.
F-54	28 Mar- 2 Apr- 27 Apr-	St. Michel-en-Greve (South) Large tidal flat embayment.	-oiled swash lines and some small mousse pools. -millions of dead organisms. -light sheen on upper tidal flat; no oil on the lower portion.
★ AMC-19 (F-55)	28 Mar (F)- 2 Apr (F)- 25 Apr (AMC)-	St. Michel-en-Greve Very large sand flat/embayment.	-heavily oiled along upper portion of beach; large clean-up operation with much manpower and many tractors; oil contaminated interstitial water. -millions of dead organisms. -light swashes on beach; oil buried (30 cm) in infilled collection troughs; interstitial water still oil contaminated.
★ AMC-15	28 Mar- 25 Apr-	St. Michel-en-Greve (NE corner) Mixed sand and gravel beach on edge of very fine-sand tidal flat.	-80 to 100% oil coverage of the beachface and near edge of tidal flat. -still heavily oiled beachface and rocky edge of tidal flat; signs of an extensive clean-up operation; interstitial water oil saturated.
★ AMC-16	28 Mar- 24 Apr-	Pointe de Sehar Large pebble beach between two bedrock areas.	-very heavily oiled; 30 cm penetration of oil into the gravel along the upper beachface. -still oil soaked; at least 15 cm penetration over entire beachface; presence of a bulldozer pushing oiled gravel into furrows to be re-washed by incoming tide and waves.
F-56	28 Mar	Plage de Notigou Sandy pocket beach with outcropping rocks.	Heavily oiled beach and rocks.
★ F-80	31 Mar- 25 Apr-	Plage de Tresmeur Cobble beach leading onto a sandy low-tide terrace.	-heavily oiled. -cobble moderately oiled; low-tide terrace very clean; tractor pushing cobbles seaward so as to allow natural cleansing; high pressure hoses also in use to clean the rocks.
F-79	31 Mar- 25 Apr-	Plage de Porz Termen Medium- to coarse-grained beach within a harbor.	-heavily oiled. -beachface is clean but the rip-rap walls behind the beach are heavily oiled.
★ F-78	31 Mar- 25 Apr-	Kerhellen Coarse sandy beach with rocks on both sides.	-heavily oiled. -rocks on both sides moderately oiled; light oil along the last high tide swash line; also much burial along the upper beachface.

TABLE 16. Summary of observations made during the follow-up survey of July 1978 at stations within Section VIII.

Station Number and Location	Date Visited	Description of Oil Impact
AMC-19 St. Michel-en-Greve	23 July 78	Thick (20-25 cm) oiled sediment in areas of trenching during clean-up; oiled interstitial water very localized and does not extend onto clean sandflat.
AMC-15 St. Michel-en-Greve (NE corner)	23 July 78	Some buried oil but generally clean.
AMC-16 Pointe de Sehar	23 July 78	Gravel beach remains heavily oiled even after mechanical clean-up; mousse/cobble layers are approximately 15 cm thick and extend to about 1 m beneath surface of upper berm; also has thickly oiled lower beachface.
F-80 Plage de Tresmeur	23 July 78	Cobble beach is now clean after extensive clean-up operation; heavily oil blackened rocks are still present to the south.
F-78 Kerhellen	23 July 78	Oil blackened and rutted corner of tidal flat.

berm. Surface sediments also were oiled. The area of the upper low-tide terrace was especially heavily oiled, and would be expected to turn to a durable asphalt pavement if not broken up in the near future.

This station differs from other coarse-grained beaches that are now free of oil (e.g., stations F-80, F-95), in that it initially contained more oil and has finer sediment (mixed sand and gravel vs. well-sorted cobbles). Also, a different clean-up technique was applied (notably, the lack of high pressure spraying). In order for this beach to be cleaned, it is suggested that the thick oil layers be broken up by bulldozers in conjunction with the high pressure spraying technique.

3. Sheltered rocky areas were varied in degree of contamination, but generally continued to be moderately oil-blackened.

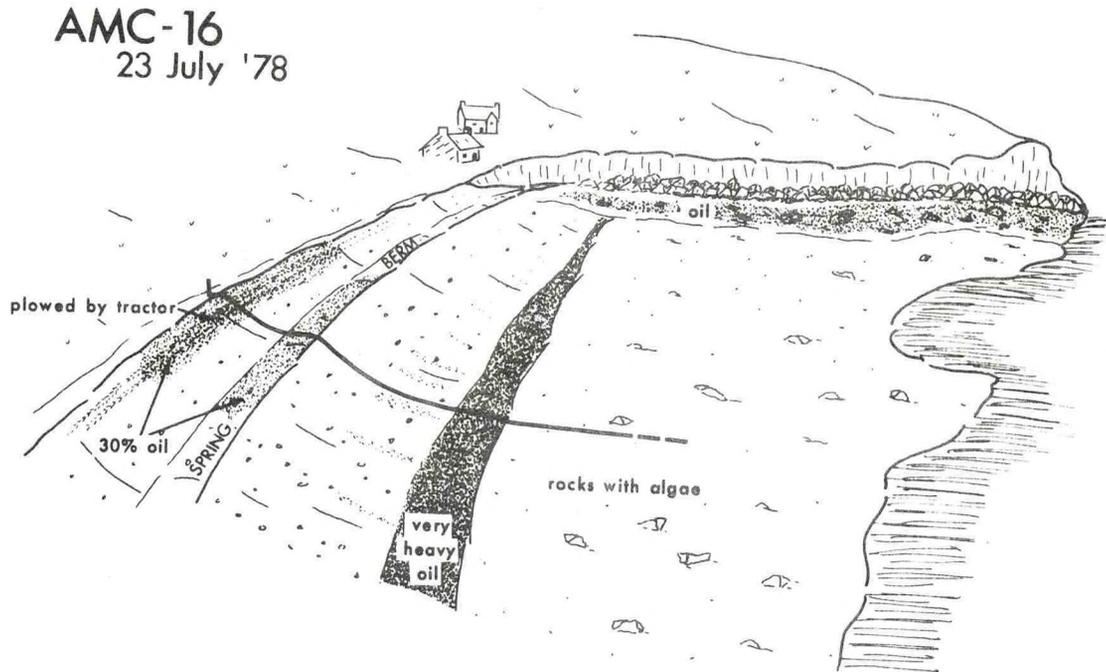


Figure 18. Sketch of station AMC-16 on 23 July 1978. Oil accumulations were heaviest at the toe of the beach as a result of bulldozing during April. If not broken up, this oil will eventually turn into hard asphalt pavement.

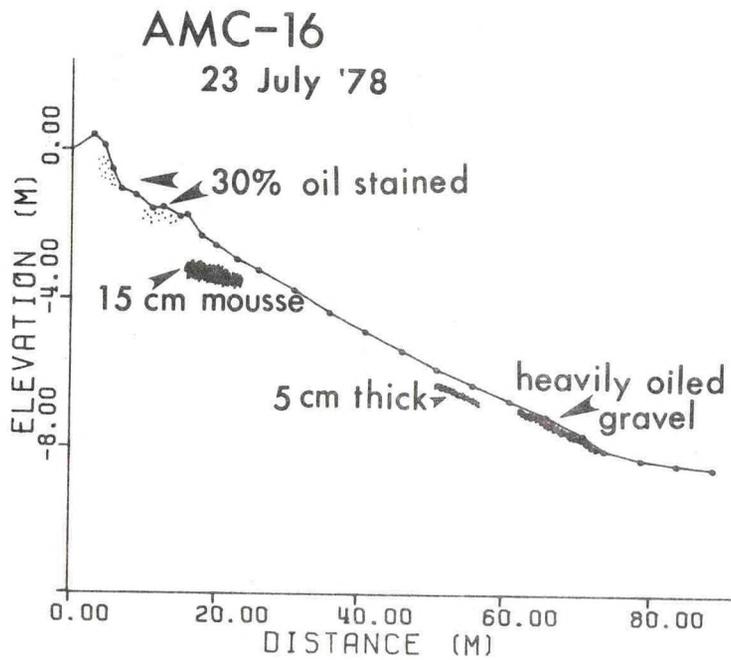


Figure 19. Topographic beach profile of station AMC-16 on 23 July 1978. Buried oil was found generally throughout the beach. It was thickest (15 cm) near the spring tide berm.

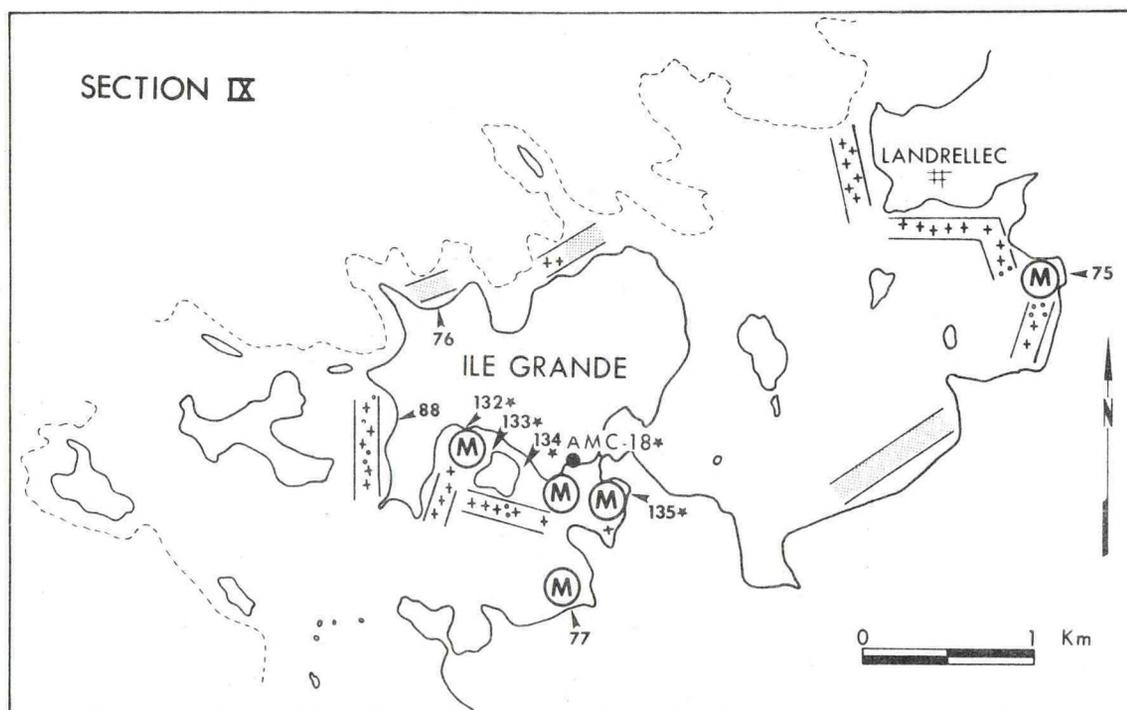


Figure 20. Locations of observation stations within Section IX. Oil coverage for the second study period (April) is indicated as follows: heavy oiling (pluses), light oiling (dot pattern), and oiled marshes (circled M's). Stations reoccupied during the third survey (July 1978) are indicated by a star.

#### Section IX - The Ile Grande Area

Section IX encompasses only the Ile Grande area which was heavily inundated by oil during the initial phases of the oil spill (Fig. 20). Stations F-133 to F-135, including AMC-18, were subjected to a most extensive clean-up operation, which utilized trenches to drain the oil, pumps, and both high and low pressure spraying. Descriptions of each station during the first two surveys are included in Table 17.

The follow-up survey during July 1978 concentrated on the areas that had been previously heavily oiled to determine effectiveness of the clean-up operation and the general recovery rate of the marsh. The observations made at each station are tabulated in Table 18. Results are summarized below:

1. The marsh/tidal flat area on the south side of Ile Grande remained

TABLE 17. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section IX. Stars indicate stations revisited during field session III, July 1978.

<u>Station Number</u>	<u>Date(s) Visited</u>	<u>Location and Type of Environment</u>	<u>Description of Oil Impact</u>
F-77	31 Mar-	Runigou	-heavily oiled.
	25 Apr-	A sand flat with a rip-rap wall along the sides of the flat. A small marsh is also in the area.	-sand flat all clean; rip-rap wall still heavily oiled; marsh remains moderately oiled.
★F-135	25 Apr-	Allee Couverte South side of Ile Grande Marsh; vegetation mainly <u>Juncus</u> marsh grass.	-very heavily oiled, cleanup operation in progress; 5 cm of oil on much of the marsh; soldiers using squeegees to push the oil into the channels where it is being pumped out.
★AMC-18	29 Mar-	Ile Grande Marsh, and west side of D21 bridge to Ile Grande  Large marsh with a wide, muddy sand channel.	-very heavily oiled; oil pools to 27 cm deep; average coverage about 3 cm; thousands of polychaetes worms crawling over the surface of the oil to escape.
	2 Apr-		-oil in same condition; polychaetes all dead and often found in small water pools on the surface of the oil.
	24 Apr-		-visit at hightide; only a light sheen visible on water surface.
	25 Apr-		-area has been manually cleaned; large oil pools drained; marsh still very black but some new green grass shoots appearing.
★F-134	25 Apr-	West Road to RuLosquet Part of Ile Grande Marsh area.	-area oiled; extensive clean-up operation underway: light sprinkler system rinsing the marsh as well as high-pressure hosing.
★F-133	25 Apr-	East Road to RuLosquet Part of Ile Grande Marsh area.	-still completely oiled; many trenches dug to drain oil; blackened; large clean-up underway.
★F-132	25 Apr-	Dourlin Western side of Ile Grande Marsh--a narrow fringing marsh beside a sand flat.	-section 20 m wide remains thinly oiled after clean-up; numerous tire tracks, ditches, trenches on the sand flat as a result of clean-up.
F-88	2 Apr-	Ile Grande Beach (East Facing)	-heavily oiled.
	25 Apr-	Sheltered sandy pocket beach; wave energy usually low due to an island directly offshore.	-heavily oiled shoreline and tidal flat.
F-76	29 Mar-	Northwest Ile Grande Boulder beach.	-lightly oiled boulder beach.
	25 Apr-		-light oil coverage on boulders.
F-75	29 Mar-	(Near) Kerenoc Small marsh in northeast corner of large sand flat, with some rocks.	-small marsh and rocks heavily oiled.
	25 Apr-		-very heavily oiled marsh grasses; some rocks with algae are completely oil covered; a large trench, dug to collect oil, causes serious oiling of the surface of the tidal flat.

TABLE 18. Summary of observations made during the follow-up survey of July 1978 at stations within Section IX.

Station Number and Location	Date Visited	Description of Oil Impact
F-135 Allée Couverte	23 July 78	95% of previously living marsh grass is dead and oil-blackened; only very minor recovery of marsh.
AMC-18 Ile Grande Marsh, and west side of D21 bridge to Ile Grande	23 July 78	Remains 60-70% oil-blackened; some recovery of upper marsh, but little recovery of lower marsh.
F-134 West Road to Rulosquet	23 July 78	Remains heavily oil-blackened and very rutted from clean-up; 10-15% recovery of marsh grasses along upper intertidal zone, less along lower intertidal; some asphalt-like oiled sediment (2 cm thick) at front of island; channel-banks are eroding - probably from lack of holding vegetation; heavy contamination of all standing water.
F-133 East Road to Rulosquet		
F-132 Dourlin	23 July 78	Remains oil-blackened and rutted (from clean-up); some recovery of marsh grasses is indicated.

- oil-blackened, rutted from clean-up, and in certain (limited) localities, heavily oiled.
- The low marsh (populated by Sesuvium) showed little to no recovery while the high marsh, which is populated by Spartina patens, showed partial (10-15%) recovery (see Figs. 21 and 22).
  - The natural channels of the marsh were widened through wall collapse and slumping (Fig. 23, top). The same had occurred within the trenches dug to drain the oil (Fig. 23, bottom). Apparently, the destruction of the marsh vegetation had influenced the binding characteristics of the soil.
  - A visible oil sheen was often present on the standing water of the trenches and channels.



Figure 21. Overview (top) and close-up (bottom) of the upper marsh at Ile Grande on 23 July 1978. The recovery of the marsh grass, Spartina patens, was estimated at 10-15%. Many, but not all, of the grasses pictured are green in appearance. Dried oil is often mixed in with the grasses.

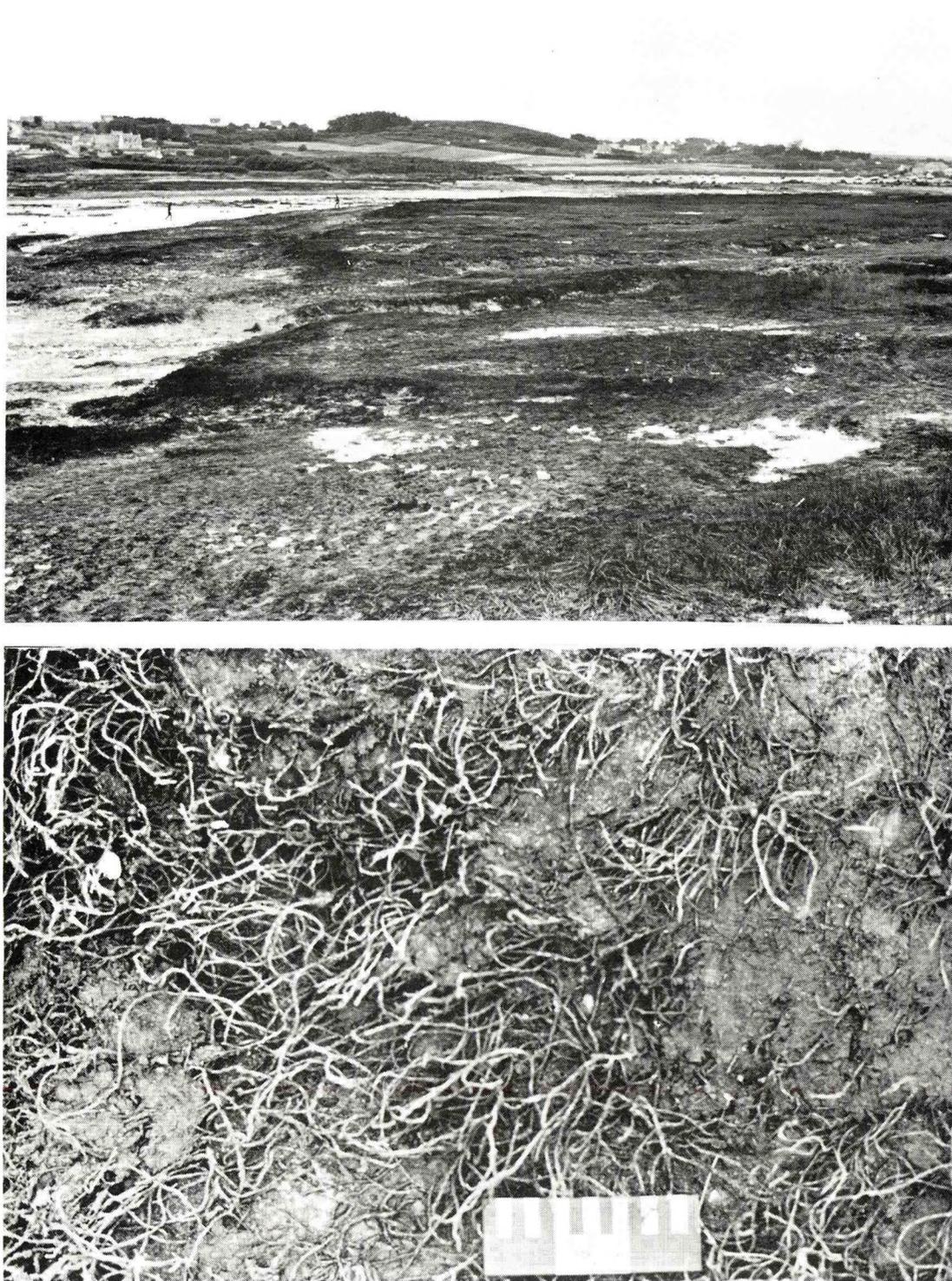


Figure 22. Overview (top) and close-up (bottom) of the lower marsh along profile AMC-18 at Ile Grande. This portion of the marsh, previously covered with *Sesuvium*, showed almost no recovery. The grasses are dead and often are mixed with desiccated oil.



Figure 23. (top) The channels within Ile Grande marsh continue to show clear signs of the oil spill. The channel walls are mostly oil-blackened and an oil sheen is often visible on the standing water. Notice the slumping along the edges of the channel, possibly a response to the destruction of the marsh grasses which previously bound the soil. (bottom) Many parts of the marsh continue to be rutted from the use of heavy machinery and the trenching techniques.

### Section X - Landrellec to Trestel

The western portion of Section X is one of the more popular tourist areas in northern Brittany (Fig. 24). Fortunately, most of the area escaped major oil impact (Table 19). We visited a limited number of localities in July to verify the presence or absence of oil (Table 20). Most of this section had very little to no oil visible along the shoreline. Station F-58, however, was an exception in that the gravel beaches at the base of the granitic cliffs remained heavily oiled. Their general inaccessibility prevented clean-up, and apparently erosive wave action from the northeast had been minor.

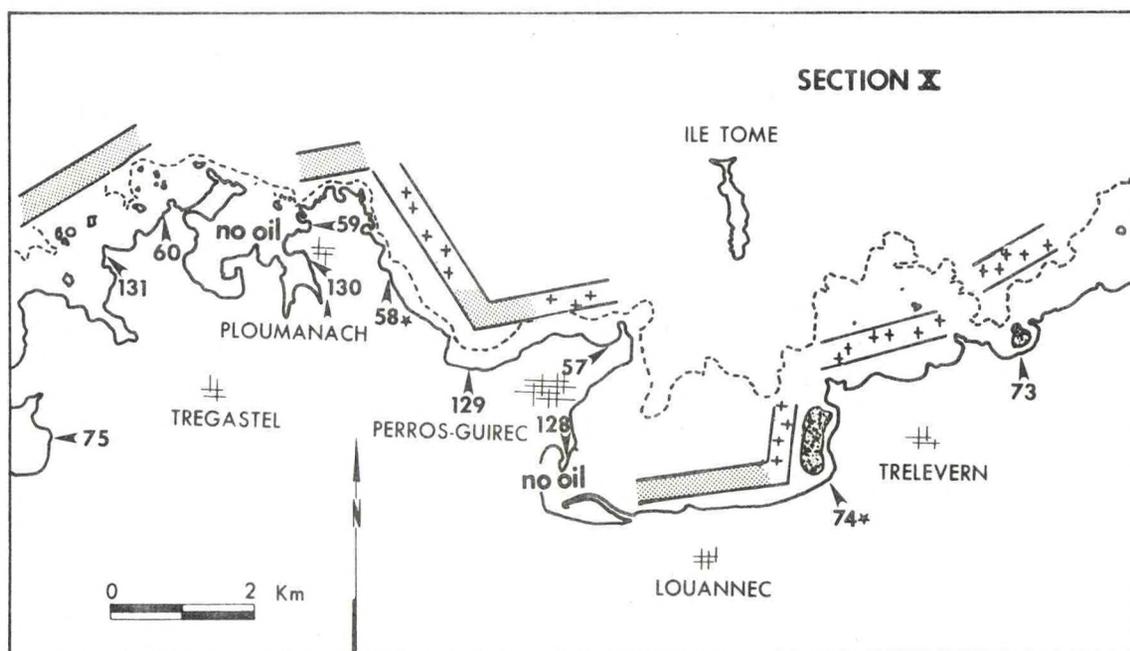


Figure 24. Locations of observation stations within Section X, Landrellec to Trestel. Oil distribution for the first study session (March) is indicated by the dark-stippled pattern. For the second study period (April), heavy and light oil coverage are indicated by the plus and light-dot patterns, respectively. Stations revisited during the third survey (July 1978) are indicated by a star.

TABLE 19. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section X. Stars indicate stations revisited during field session III, July 1978.

<u>Station Number</u>	<u>Date(s) Visited</u>	<u>Location and Type of Environment</u>	<u>Description of Oil Impact</u>
F-131	25 Apr-	Ia Greve Blanche Sandy beach with a large tidal flat and outcropping rocks.	-the beach is very clean with a clean tidal flat; the rocks are somewhat oiled, and are presently being cleaned by a power hose from a water tank-truck.
F-60	28 Mar- 25 Apr-	Coz Porz Coarse-sand beach with large rocks offshore.	-lightly oiled; sand removed from beach as protection measure. -a few isolated mousse balls on the beach; a light oiling on the offshore rocks.
F-130	25 Apr-	Ploumanac'h - South Harbor with a sandy beach.	-clean except for a few oil globs; the rocks have been artificially cleaned.
F-59	28 Mar- 25 Apr-	Ploumanac'h - North Protected small pocket beach; coarse-sand and gravel.	-moderately oiled. -a clean beach; no buried oil layers, but the groundwater is oil saturated.
* F-58	28 Mar- 25 Apr-	East of Ploumanac'h Rocky coast with some small gravel and cobble pocket beaches.	-rocks clean; an oil sheen is on the water. -the pocket beaches are heavily oiled; exposed headlands are very lightly oiled; clean-up in progress.
F-129	25 Apr-	Plage de Trestraou Large fine-sand pocket beach located between two rocky headlands which project almost due north.	-some light oil swashes on the beach; also some oiled cobbles being buried by the fine sand; a tractor is digging up the cobbles and pushing them seaward so that the waves can clean them.
F-57	28 Mar-	Plage de Trestraou Sandy pocket beach.	-very clean except for a light sheen in the water.
F-128	25 Apr-	Perros-Guirec Jetty and harbor.	-jetty lightly oiled on the ocean side; no oil in the interior of the harbor; boom across harbor.
* F-74	29 Mar- 24 Apr-	Nanthouar Large gravel beach.	-rocky area heavily oiled. -lightly oiled swash line on the beach; rocks to the west are moderately to heavily oiled.
F-73	24 Mar- 24 Apr-	Plage de Trestel Medium-sand tidal flat and beach.	-beach is clean; a new seawall is covered with plastic so as to prevent its oiling. -seawall still covered with plastic, so far unoiled; a few light oil swash lines on the beach.

TABLE 20. Summary of observations made during the follow-up survey of July 1978 at stations within Section X.

Station Number and Location	Date Visited	Description of Oil Impact
F-58 East of Ploumanac'h	22 July 78	A large quantity of oil remains on the upper portion of the gravel beaches in the area.
F-74 Nanthouar	22 July 78	A very light oily swashline remains in rocky area; cobbles are completely clean.

#### Section XI - Port Blanc to Sillon de Talbert

Section XI is located furthest from the wreck site (see Fig. 2). It is 130 km from the wreck to the base of Sillon de Talbert (Fig. 25). Initially, oil coverage was heavy in places, especially in many of the westward-facing crenulate-shaped bays (Table 21). During the July follow-up survey, a limited number of stations were revisited (Table 22). Station F-66 at Castel Meur remained heavily contaminated, although the majority of the spilled oil had been removed. Oil was particularly obvious along the rocky areas (Fig. 26). It was also buried in beachface gravels and occurred on the upper portion of the tidal flat. Asphalt had begun to form within the central rocky area indicated in Figure 26 (top). The interstitial ground water in most areas still contained an oil sheen.

Station AMC-17 still contained some oil-stained sediments along the beachface, as well as some thicker oil accumulations on the low-tide terrace. In addition, some of the large boulders were covered with tar. As at other beaches, the alga, Enteromorpha, was present in very large quantities. No change in the beach profile was found.

TABLE 21. Summary of observations made during field sessions I and II (March and April, 1978) at stations within Section XI. Stars indicate stations revisited during field session III, July 1978.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-72	29 Mar-	Les Dunes near Port Blanc	-heavily oiled gravel and rip-rap near dune area.
	24 Apr-	Sand and gravel beach with a large tidal flat and dunes.	-minor oiling along the high tide swash line; the tidal flat is very clean.
F-71	29 Mar-	Crech Arel Sandy beach with low-tide terrace.	-clean beach but some oiled rocks.
★F-70	29 Mar-	(Near) Pellinic Marsh.	-oiled marsh covered by an average 3 cm of oil.
	24 Apr-		-still very heavily oiled; no clean-up.
F-69	29 Mar-	Bugelos - Coz Castel Tidal flat surrounded by large rocks.	-oiled rocks surrounding large tidal flat.
	24 Apr-		-rocks still appear heavily oiled; no oil on tidal flat itself; marsh grasses appear oiled; clean-up operation has left area completely dug-up.
F-127	24 Apr	Anse de Gourmel Large sandy tidal flat.	Sand flat is very bioproductive; thousands of worm burrows and many cockles; beach and tidal flat are clean except for a minor oiled seaweed swash line along the last high tide swash; rocky areas on both sides of this sand area are heavily oiled.
F-68	29 Mar-	(near) Kergonet	-tidal flat and rocks both oiled.
	24 Apr-	Sandy beach with large tidal flat.	-very heavily oiled along the upper portions of the tidal flat as well as the beachface; tidal flat itself is all soaked with oil; trenches dug to trap and pump out the oil remain heavily oiled.
★F-67	29 Mar-	Porz Scaff	-oiled gravel and rocks.
	24 Apr-	Small pocket beach with a seawall behind it.	-all the cobble on the beach are heavily oiled as is most of the lower beachface.
★F-66	29 Mar-	Castel Meur	-heavily oiled gravel beach; large clean-up operation underway.
	24 Apr-	Gravel and cobble beach with a large tidal flat; many cobbles outcrop on the tidal flat.	-very heavily oiled here; mousse is 1-2 cm thick on much of the beach; some of the limpets have survived but many dead cockles and crabs are seen floating in oil pools; straw used to absorb some of the oil is still on the beach and tidal flat.

TABLE 21 (continued)

<u>Station Number</u>	<u>Date(s) Visited</u>	<u>Location and Type of Environment</u>	<u>Description of Oil Impact</u>
F-65	29 Mar- 24 Apr-	Porz Bugale Small, mixed sand and cobble beach.	-no oil. -light oiled swash line along the last high tide line.
F-64	29 Mar	Treguier Estuarine tidal flat with a major channel flowing north.	No oil.
F-126	24 Apr	Luzuret Broad rocky tidal flat.	Beach area clean; rocks very lightly oiled.
F-63	29 Mar- 24 Apr-	Plage de Beni Sand and cobble beach.	-no oil. -lightly oiled swash lines.
F-62	29 Mar	Kermagen Boulder and cobble beach.	A little oil on the boulders.
★AMC-17	29 Mar- 24 Apr-	Port la Chaîne Coarse-sand crenulate-shaped beach between rocky headlands.	-very thick oil accumulations on beach; oil contaminated interstitial water. -light oil staining of beach sediments; some oil buried on beachface (15 cm) and on low-tide terrace; interstitial water still contaminated.
F-125	24 Apr	le Quebo Mixed sand and gravel beach.	Some minor oil blotches on the rocks; otherwise completely clean.
F-61	29 Mar- 24 Apr-	Sillon de Talbert A flying gravel spit.	-lightly oiled rocks; clean beach. -rocks lightly oiled; this is the furthest eastern extent of the oiling.

TABLE 22. Summary of observations made during the follow-up survey of July 1978 at stations within Section XI.

Station Number and Location	Date Visited	Description of Oil Impact
F-70 (Near) Pellinic	22 July 78	Oiled marsh area; some grasses killed, others remain blackened; some recovery is indicated.
F-67 Porz Scaff	22 July 78	Oiled rocks; 10 cm layer of asphalted cobbles along upper beachface; a new oily swashline is present.
F-66 Castel Meur	22 July 78	Area remains heavily contaminated as indicated by oil-blackened rocks, buried oil, asphalt in sheltered areas, and oil sheens on the ground water.
AMC-17 Port la Chaine	22 July 78	No oil remains on the surface of the beachface; some oil-stained sand 15 cm below surface; oiled sediment (15 cm thick) along upper low-tide terrace caused by heavy machinery during clean-up; oil-stained cobbles on beach to south; heavy coverage of ( <u>Enteromorpha</u> ) algae.

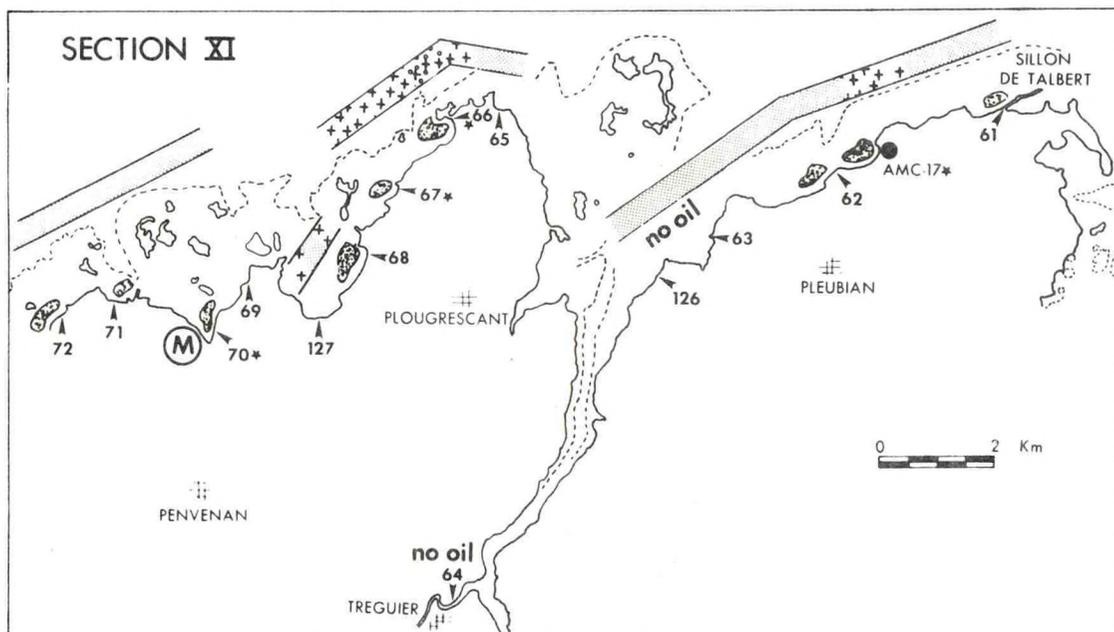


Figure 25. Locations of observation stations within Section XI, Port Blanc to Sillon de Talbert. Oil distribution for the first study session (March) is indicated by the dark-stippled pattern. For the second study period (April), heavy and light oil coverage are indicated by plus and light-dot patterns, respectively. Stations revisited during the third survey (July 1978) are indicated by a star.



Figure 26. Photographs of Castel Meur (F-66) facing south (top) and north (bottom). Arrows indicate areas where heavy oil accumulations remain. Even after a large clean-up operation, this station is still severely contaminated.

## CONCLUSIONS

Continued Oil Impact

Much of the previously oiled Brittany coast was free of oil in July 1978. However, remnants of the spill were observed as scattered oil layers buried beneath the surface of most beaches, and as tar-blotches on cobbles, gravel, and seawalls.

The areas that were still heavily contaminated can be divided into the following, geomorphologically-based categories:

1. Sheltered Marshes - The prime example of this category is the Ile Grande marsh, where even after a diligent clean-up effort, the area remained severely oil-stained. Another marsh area, station F-137, is worthy of continued study since no clean-up was applied. Although initial oil coverage was not nearly as heavy as at Ile Grande, most grasses that came in contact with the oil were killed.
2. Mixed Sand and Gravel Beaches - The beach at Pte. de Sehar (AMC-15) continued to have thick accumulations of both buried and surface oil. Bulldozing alone was not effective in removing the oil. Clean-up by heavy machinery in conjunction with high pressure spraying is recommended for such beaches in the future. If nothing more is done at this beach, the oil will harden to asphalt and essentially cement part of the beach.
3. Sheltered and Partially Exposed Rocky Areas - Many of the boulder beaches as well as bedrock areas remained noticeably contaminated. Although most of these sites are located in sheltered environments, some are exposed to the open ocean. The persistence of oil in generally exposed localities is somewhat puzzling, but may be explained as follows:
  - a. Wave activity since April has probably been relatively low.

(Waves were less than 20 cm during this study).

- b. Sheltered micro-environments exist in most of the boulder-strewn areas. Oil remained only on the landward, sheltered side of the boulders, or in the pockets formed between the rocks. Typical examples of this effect occur at stations F-1, F-25, F-27, F-66, and F-81.
4. Sheltered Beaches of Different Grain Sizes - In many of the sheltered areas that were not cleaned, the oil had turned to an asphalt crust on the sediment surface (e.g., station F-112).
5. Sheltered Tidal Flats - Oil was churned into the fine-grained tidal flats by the heavy machinery used during the clean-up operation at many localities. This resulted in scattered, but thick, accumulations of oiled sediment buried below a relatively clean surface. The rutted appearance of the flats, noticeable in April, had been somewhat smoothed by tidal action. The interstitial water continued to show oil sheens. Typical examples are stations F-34, F-66, and F-94.

#### Effectiveness of Clean-Up

Clean-up by high pressure spraying continued at stations AMC-3, F-39, and F-110. In addition, the heavily oiled sediment within the clean-up trenches at AMC-3 was being removed manually. This source of continued oil contamination was a major concern of our previous assessment of the clean-up program (Gundlach and Hayes, 1978a). No other clean-up operation was noted by our group.

The effectiveness of the clean-up program may also be categorized according to geomorphic beach type. The classification is listed below in order of decreasing effectiveness:

1. Fine-Sand Beaches - Clean-up was very effective. Only minor buried

oil layers remain (e.g., AMC-5, AMC-9, and AMC-10).

2. Cobble Beaches - Cobble beaches were very effectively cleaned when heavy machinery was used in conjunction with high pressure spraying, as at stations F-80 and F-95.
3. Rocky Shores - High pressure spraying was generally effective (e.g., station F-110), but not without the biological penalty of the removal of most of the attached algae (e.g., stations AMC-1 and AMC-3).
4. Coarse-Sand Beaches - Clean-up was generally effective, but some oil-stained sediment remains on and below the surface (e.g., stations AMC-12 and AMC-17).
5. Mixed Sand and Gravel Beaches - Clean-up was ineffective when only a bulldozer was used to push sediments into the surf zone, as at station AMC-16.
6. Sheltered Tidal Flats - Clean-up was only partially effective. The major accumulations of oil were removed, but often some oil was churned into the flat and buried beneath the surface (e.g., stations F-34, F-66, and F-94).
7. Marshes - The clean-up of marshes is a most difficult problem during any oil spill. In France, clean-up of the Ile Grande marsh has shown limited to rather questionable effectiveness. Major oil accumulations have been removed, but the area remains oil-blackened, generally lifeless, and deeply rutted from the use of heavy machinery.

#### Biological Observations

1. Algae - In many places, the macro-algae have been completely removed by the clean-up process, particularly as a result of high pressure spraying. No recovery of attached macro-algae was noted. However, the green alga, Enteromorpha, was present in very large

quantities on most beaches and rocky areas. This "bloom" of Enteromorpha may be a result of the spill.

2. Benthos - Benthic organisms, particularly limpets, were unexpectedly common in many localities (e.g., stations AMC-17 and F-29). Annelid worms were almost always present, even if the interstitial water was still contaminated. Juvenile crabs were present in large numbers at station AMC-2. In contrast, no benthic organisms were, as yet, observed at Ile Grande marsh. At other localities, the effect of the spill on the organisms was difficult to visually determine without pre-spill data.
3. Marsh Grasses - At station F-136, where no clean-up had occurred, grasses in contact with the oil were killed. At the Ile Grande marsh, grasses of the high marsh, particularly Spartina patens, showed an estimated 10-15% recovery. Those grasses lower on the marsh, particularly Sesuvium sp., had little to no new growth.

#### RECOMMENDATIONS FOR FUTURE STUDY

Further study of the Amoco Cadiz spill site is warranted from the standpoint of understanding the longer-term persistence of oil in certain environments, the biological effects of the remaining oil, and the time necessary for complete recovery. A program encompassing the following studies is recommended:

- a. Repeat survey of those areas still containing significant quantities of oil. Surveys before the winter storm period, and then again in April, one year after the spill, are recommended. Synchronizing the ground surveys with the French vertical aerial photography would improve methods of estimating the quantity of oil along the shoreline.
- b. Resampling interstitial waters for chemical analysis in areas still

- contaminated would yield information concerning the persistence of low-level contamination within beach sediments.
- c. Continued assessment of the effects of the spill on macro-algae and the monitoring of algal recovery at particular, previously surveyed locations.
  - d. Continued monitoring of recovery of the marsh grasses at Ile Grande through the establishment of a large number of observation stations within the marsh. Station F-136, which had no clean-up, may provide a control site, although the vegetation type is somewhat different.
  - e. Analysis of the benthic repopulation of the Ile Grande marsh, with respect to species type and time necessary to regain community stability.

We once again stress the necessity of fielding a multi-disciplinary survey team in order to gain maximum understanding of the study area from a variety of viewpoints in the most efficient manner.

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## REFERENCES

- D'Ozouville, L., E. R. Gundlach, and M. O. Hayes, 1978, Effect of coastal processes on the distribution and persistence of oil spilled by the Amoco Cadiz - preliminary conclusions: In Proceedings, Consequences of the Amoco Cadiz Oil Spill on Fisheries and Ecology, Center Oceanologique de Bretagne - Special Report, Brest, France.
- Gundlach, E. R. and M. O. Hayes, 1978a, Chapter 4, Investigations of Beach Processes (166 p.): In The Amoco Cadiz Oil Spill, A Preliminary Scientific Report (W. N. Hess, editor), NOAA-EPA Special Report, 283 p.
- Gundlach, E. R. and M. O. Hayes, 1978b, Classification of coastal environments in terms of potential vulnerability to oil spill damage: Marine Technology Society Journal, Vol. 12 (4), p. 18-27.

## APPENDIX I

Reports, Publications, and Presented Papers  
 resulting from  
 The Study of The Amoco Cadiz Oil Spill  
 by Our Research Group

Reports

- Gundlach, E. R. and M. O. Hayes, 1978a, Chapter 4, Investigations of Beach Processes (166 p.): In The Amoco Cadiz Oil Spill, A Preliminary Scientific Report (W. N. Hess, editor), NOAA-EPA Special Report, 238 p.
- Gundlach, E. R. and M. O. Hayes, 1978, The Amoco Cadiz Oil Spill, Third Follow-up Survey of Oil Impact on the Shoreline, July 1978: Research Planning Institute, Inc., Columbia, South Carolina, 67 p.

Publications

- D'Ozouville, L., E. R. Gundlach, and M. O. Hayes, 1978, Effect of coastal processes on the distribution and persistence of oil spilled by the Amoco Cadiz - preliminary conclusions: In Proceedings, Consequences of the Amoco Cadiz Oil Spill on Fisheries and Ecology, Centre Oceanologique de Bretagne - Special Report, Brest, France.
- Hayes, M. O., E. R. Gundlach, and L. D'Ozouville, Role of dynamic coastal processes on the impact and dispersal of the Amoco Cadiz oil spill (March 1978), Brittany, France: submitted to the 1979 Oil Spill Conference, sponsored by American Petroleum Institute, U.S. Environmental Protection Agency and U.S. Coast Guard, Los Angeles, March 1979.

Presentations

- D'Ozouville<sup>\*</sup>, L., E. R. Gundlach, and M. O. Hayes, Effect of coastal processes on the distribution and persistence of oil spilled by the Amoco Cadiz - preliminary conclusions: presented at 1978 I.C.E.S. meeting, Brest, France, May 1978.
- Gundlach<sup>\*</sup>, E. R., J. H. Rule, and M. O. Hayes, Physical and chemical influences on the distribution and persistence of oil in sediments (onshore and offshore) - a synthesis of previous studies and discussion of future research: to be presented at the 1979 Oil Spill Conference, sponsored by American Petroleum Institute, U.S. Environmental Protection Agency and U.S. Coast Guard, Los Angeles, March 1979.

## APPENDIX I (continued)

- Hayes<sup>\*</sup>, M. O., Impact of Amoco Cadiz oil on the Brittany shoreline: presented at the Keystone Conference on Assessment of Ecological Impacts of Oil Spills, American Institute of Biological Sciences, Keystone, Colorado, June 1978.
- Hayes<sup>\*</sup>, M. O. and E. R. Gundlach, Beach processes and oil sediment interactions at the Amoco Cadiz oil spill site: to be presented at the Annual Meeting of the American Association for the Advancement of Science, Houston, Texas, January 1979.
- Hayes<sup>\*</sup>, M. O., E. R. Gundlach, and L. D'Ozouville, Role of dynamic coastal processes in the impact and dispersal of the Amoco Cadiz oil spill (March 1978), Brittany, France: to be presented at the 1979 Oil Spill Conference, sponsored by the American Petroleum Institute, U.S. Environmental Protection Agency and U.S. Coast Guard, Los Angeles, March 1979.

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