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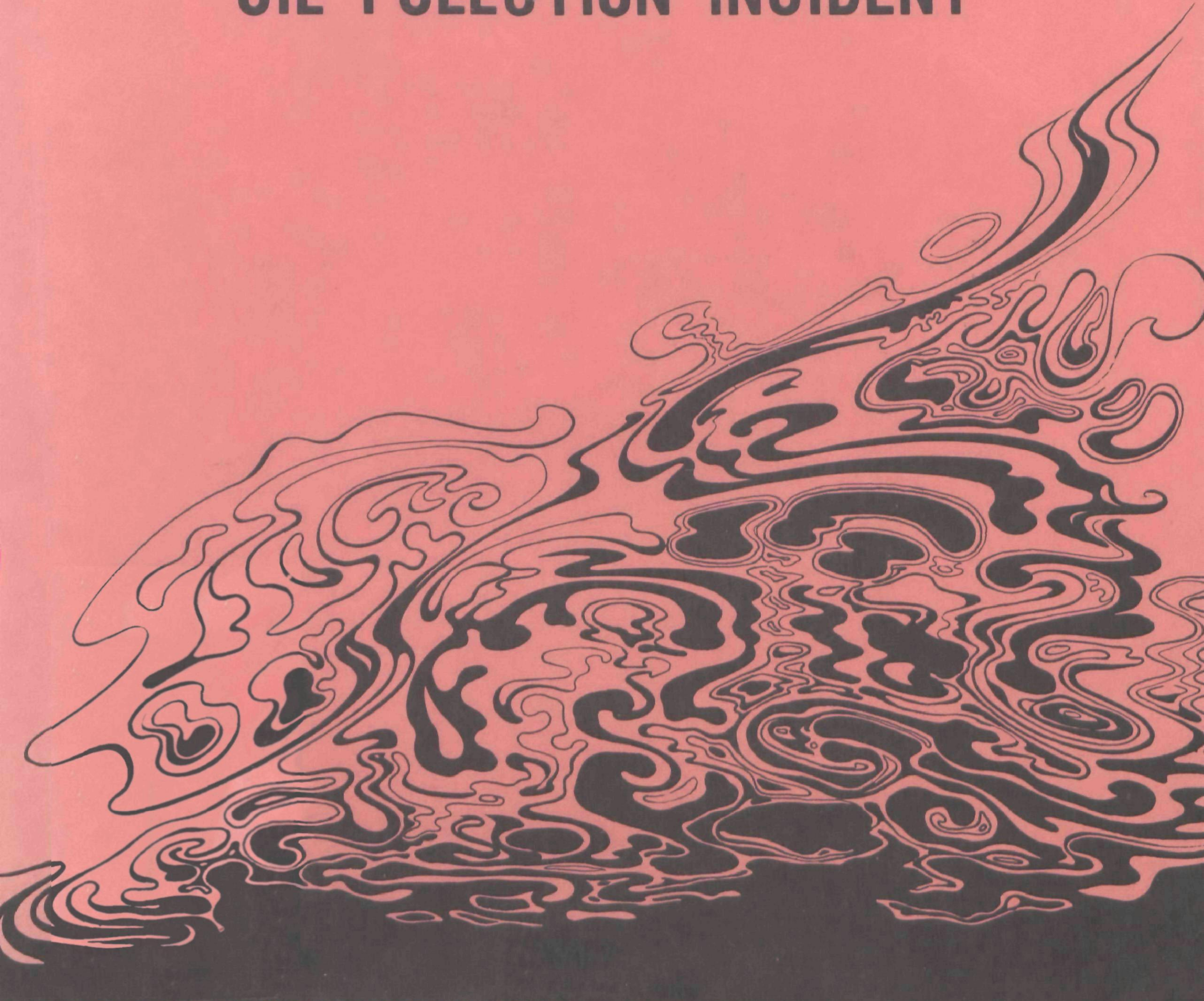
REVIEW OF

SANTA BARBARA CHANNEL OIL POLLUTION INCIDENT



S. DEPARTMENT OF THE INTERIOR ● FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

RESEARCH REPORT

REVIEW OF THE SANTA BARBARA CHANNEL OIL POLLUTION INCIDENT

to

DEPARTMENT OF INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

and

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
WASHINGTON, D. C.

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PACIFIC NORTHWEST LABORATORIES
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FOREWORD

This report summarizes the collection of factual data conducted by Battelle-Northwest for the Department of Interior, Federal Water Pollution Control Administration and the Department of Transportation, United States Coast Guard, under Contract No. 14-12-530 during the period March 17, 1969, through July 11, 1969.

The research team was comprised as follows:

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Acknowledgment must be given to the outstanding cooperation and assistance provided by the many interested parties and agencies involved. Special thanks go to the Federal Water Pollution Control Administration, the United States Coast Guard, the Union Oil Company of California, the Weather Bureau, the U. S. Fish and Wildlife Service, the California Department of Fish and Game, and the University of California at Santa Barbara.

Many others contributed measurably to the conduct of this review and their assistance is acknowledged in later pages.

It must be recognized that technical evaluation of the Santa Barbara Channel incident, from cause through to effect, is still under consideration. Thus this review can only serve to provide a summary "back-drop" in the hope of capturing some of the tenuous and hence perishable lessons from the experience.

The main issue at hand is that when the next incident occurs, regardless of origin, all concerned will be in an improved position to cope with the situation.

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LIST OF FIGURES

(1) Credit Santa Barbara News Press
(2) Credit U. S. Coast Guard
(3) Courtesy Infrared and Optics Laboratory, Institute of Science and Technology, University of Michigan
(4) Courtesy North American Rockwell Corporation

LIST OF TABLES

1.0 INTRODUCTION

1.1 BACKGROUND

On 28 January, 1969, during operations to shut in well A-21 on the offshore drilling Platform A about six miles southeast of Santa Barbara and in 190 feet of water, a leak of mixed crude oil and gas occurred. The well, the fifth drilled from the platform, was at that time nearing the final stages of completion. Estimates of the rate of release of oil at any one time vary by an order of magnitude and are highly qualitative due to the impossibility of making direct measurement of the flow rate or cumulative volume.

For the first few days the released crude oil largely remained at sea in the Santa Barbara Channel. However, starting on 4 February, southeasterly winds began to drive the oil ashore, resulting in contamination of beaches, harbors and rocky coastline, and initiating perhaps the largest oil pollution clean-up operation that has occurred in the United States.

The nature of the Santa Barbara Channel incident is unique in contrast to other major oil spillage incidents such as the TORREY CANYON tanker disaster (March, 1967). The source was characterized as a continuing one rather than an essentially instantaneous release. Thus, the threat to beaches, harbors and ecology continued over an extended period of time and complicated clean-up operations.

The Santa Barbara Channel incident, particularly the restoration and biological assessment aspect, was also complicated by the severe rain storms that occurred both prior to and during the incident.

The intent of this report is to assemble the technical specifics of the incident with emphasis on the pollution control factors. Discussion of the initial cause and nature of the release is beyond the scope of this study, and is only briefly commented on to the extent it had bearing on the pollution control aspects.

As pointed out in "Oil Pollution - A Report to the President," February 1968, technology for control of major oil pollution incidents is far from highly developed. Thus reports of field experiences presented tend to be more qualitative than quantitative. Fortunately, as indicated in the above report, contingency planning received considerable attention. This culminated in a "National Multiagency Oil and Hazardous Materials Contingency Plan," published in September 1968. The latter, and subsequent local agreements, served as the framework for immediate response at the onset of the Santa Barbara incident. Thus existing know-how was expeditiously made available. The management considerations in implementation of the contingency plan are discussed in Section 5.0.

1.2 PURPOSE OF STUDY

The purpose of this review is to assemble a synopsis of defensive, control and clean-up activities in the Santa Barbara Channel in as much technical detail as possible.

1.3 SCOPE OF REVIEW

The specific areas covered in this report parallel those in a previous review conducted for the U. S. Coast Guard.(1) The major areas covered include:

- Environmental conditions.
- Description of the source.
- Management considerations.
- Control of released oil.
- Surveillance experience.
- Behavior of oil at sea.
- Beach and harbor problems.
- Restoration and disposal.
- Biology and ecology.
- Current research and development.

Numerous sources provided the information herein reported either in writing or in personal verbal communications. Although the review cannot be regarded as exhaustive in detail, every attempt was made to fully cover the breadth of the subject. Thus, in several instances the sources ranged from personnel in administrative and technical positions to those supervising work crews in the field.

Principal sources of information:

Federal Agencies

- Federal Water Pollution Control Administration
- U. S. Coast Guard
- Bureau of Commercial Fisheries
- Bureau of Sports Fisheries and Wildlife
- U. S. Geological Survey
- Weather Bureau
- National Park Service

California State Agencies

- Department of Fish and Game
- Water Quality Control Board
- University of California at Santa Barbara

Commercial

- Union Oil Company of California
- Western Oil and Gas Association
- Restoration and Clean-up Contractors

Other

- City of Santa Barbara Administrative Offices
- Santa Barbara County Oil Well Inspection Department
- Santa Barbara News Press
- Various Agency Contractors; Academic Institutions, Museums

Specific and additional sources of information are acknowledged in Section 14.0. Written and photographic information collected during the study is available on file at Battelle-Northwest offices in Richland, Washington.

Extensive use has been made of photographs taken either by the study team or obtained from the sources listed above. It is hoped that this device will emphasize the key points that should be noted.

SECTION 1.0 REFERENCES

1. "Oil Spillage Study - Literature Search and Critical Evaluation for Selection of Promising Techniques to Control and Prevent Damage," November 20, 1967 Report to U. S. Coast Guard from Battelle-Northwest.

2.0 SUMMARY AND CONCLUSIONS

2.1 DESCRIPTION OF THE SOURCE

The geology of the Santa Barbara Channel is relatively complex, with some stratigraphic units cut out of the local section sequences due to depositional interruption or faulting. Producible oil deposits have been encountered in both shallow and deep formations, and slow but continuous ocean floor seepage of oils and tars has occurred at several locations within the 1,750 square mile area for many years.

Ocean floor seepage associated with the well blowout on Platform A showed a high degree of variability with respect to location of the seepage points and magnitude of release with time. Such variability could be due to either changes in seepage pathways resulting from recharge of shallow sands and/or fissures, or to in-well and ocean bottom control operations undertaken from and in the vicinity of Platform A, or to combinations of these factors. In any event, release of oil occurred generally along a line extending 800 and 400 feet east and west respectively from Platform A.

2.2 NATURE OF OIL SPREAD AND SURVEILLANCE

Oil spreading, influenced by weather factors, was highly variable throughout the major period of the incident. Oil slicks moved mostly under the influence of prevailing wind changes as surface water currents in the Santa Barbara Channel generally did not exceed 2.5 nautical miles per day. Under slack or near-slack wind conditions, oil slick plumes generally conformed to expected surface current counterclockwise gyres in the Channel.

Bulk, e.g., "black oil" observed at sea tended to break up with time into "windrows" (parallel to advancing wave fronts) and irregular "ropes." Wind conditions were the predominant factor influencing oil movement and persistance.

Observations of the oil slicks were undertaken by visual, photographic and remote sensing methods with most of the day-to-day mapping of slick movement being carried out by visual observation from aircraft. This mapping, together with surface craft daily observations, provided a basis for predicting slick arrival times and locations at beaches and harbor facilities; and for scheduling both ocean surface and beach counter-measure activities.

Both good and poor results were obtained using airborne photographic techniques (infrared, color, camouflage and panchromatic films) to detect primary and secondary slicks. Because of lack of timeliness, the photographic or remote sensing data collected were not used to any appreciable degree in planning day-to-day control and clean-up activities; but the information gained from these studies indicates that there is considerable potential for developing such useful applications employing these surveillance methods.

Good contrast between oil and water was noted in the ultraviolet (0.32-0.38μ), far infrared (8-14μ) and microwave (1-3 cm) spectral regions using remote sensing instrumentation. Although some ground truth correlations were obtained, additional laboratory and field control data are needed to realize the maximum utility of these 24-hour observation methods.

It must be recognized that the primary motivation for surveillance of oil slicks under "disaster" conditions is the resultant operational utility, i.e., use in "near real time" direction of at sea oil recovery operations or advance warning to shore forces and facilities of an impending threat. In the former case, surface oil recovery operations must generally be conducted during daylight hours and visual observations from spotting aircraft are a reasonable solution. In the latter case, the rate of oil slick movement can generally be forecasted from meteorological conditions and forces appropriately alerted.

Thus the consensus of the contingency team is that the use of surveillance techniques that provide a timely response is adequate. Those involving sophisticated methods or requiring expert and time consuming interpretation have little pollution control utility under "disaster" circumstances.

2.3 CONTROL AT SOURCE

Control of any pollution problem at the source and before it becomes diffused continues to be the obvious and seemingly most practical approach. In the case of the Santa Barbara Channel incident, the source occurred variably along a line approximately 1,200 ft in length and under 190 ft of water. These conditions and exposure to open sea environment resulted in general failure of attempts to capture the oil before it reached the surface. Furthermore, the volatile and flammable nature of the oil-gas mixture in the immediate vicinity of the platform presented an often serious fire hazard.

2.4 CONTROL OF RELEASED OIL AT SEA

Containment of the oil as it emerged directly under the platform on the surface could have been hazardous because of the gas concentrations and resultant potential for fire.

Attempts to control the oil on the surface near the platform were largely unsuccessful, principally due to the lack of satisfactory all weather open sea booms and effective methods of recovering the oil as it accumulated. In order to encompass the entire area of surface oil emission, booms several thousand feet in length would have been required as subsurface currents carried the oil horizontally from the point of emission.

Boom systems are not presently available with a capability to contain oil in an all weather open sea environment. Positioning and mooring present severe problems in deep water and rough seas; it is doubtful that any present system can function properly in conditions exceeding relatively calm or when currents exceed three knots.

Open sea containment of surface oil is probably most effectively accomplished with floating booms. A repositioning capability is desired to compensated for periodic changes in the direction of drift as well as a configuration permiting unrestricted access to both sides of the boom and to the source or other features in the area. The oil must be recovered as it accumulates with mobile skimmers or suction devices.

The effectiveness of chemical dispersant is considered questionable for use on large spills and despite their use at Santa Barbara, oil was deposited on the shore line. However, all persons contacted generally agreed on the following:

1. Chemical treatment of large oil spills is extremely costly.
2. The distribution logistics problem is formidable.
3. Natural agitation is not always adequate for full chemical effectiveness.
4. Effectiveness is greater on thin rather than thick films.
5. Permanence of dispersion under field conditions is doubtful.
6. Information on toxicity to marine organisms is sketchy.

Straw and other commercial sorbents were spread over the oil slick in the vicinity of the platform and near shore. Straw, because of its ready availability, low cost, and relative ease of pickup, was the only sorbent subsequently applied on a large scale. It was found to sorb oil up to four times its weight. At sea recovery of the oil-straw mixture with mechanical devices was considered but not employed and manual pickup in shallow water and after straw washed up on the beach was generally practiced.

Skimming of oil from the surface at sea was constantly hampered by environmental factors, principally wind and waves. One mobile skimmer, an advancing wier or trough, was developed with a capability to traverse slicks, follow and recover the relatively long "ropes" of oil windrowed by the currents and wind, and recover oil retained by the kelp beds. The oil and water were subsequently pumped to decanting and storage tanks aboard ship. Several operational problems were encountered which should be overcome by further development and tests.

Ship-mounted suction devices had utility for recovering the oil accumulated behind containment devices. The suction devices employed were not found effective for the recovery of a thin film of oil and the systems generally lacked mobility.

2.5 DEFENSIVE MEASURES

The defense of harbors was mainly concentrated in efforts to boom off the entrance and thus prevent entry of incoming oil. Secondary booms and other protective devices within the harbor were generally not employed. If an adequate supply of commercial booms had been utilized in the Santa Barbara Harbor, the majority of contamination of boats and harbor facilities may have been averted. The oil which came over or through the porous breakwater could not be prevented.

The extremely heavy in-rush of oil at Santa Barbara presented an unusually severe case. Booming at other harbors was generally successful, particularly if more than one line of defense was used with removal of oil as it arrived.

An air curtain barrier later installed at Santa Barbara proved effective in sheltered waters, allowing ready passage of traffic and capable of being turned on and off to take advantage of natural tidal flushing.

Due to their extent and exposure, total defense of beaches was not practical. In some instances artificial berms were created with construction equipment and high run-up of oil was prevented.

In the majority of cases, mechanical spreading of straw with mulchers at low tide provided a mat for sorption of some of the oil.

2.6 SHORELINE RESTORATION METHODS

Beach cleanup was generally accomplished by spreading absorbent straw before and after arrival of the oil, pushing the mixture into piles either by hand or machines, and loading the accumulation into dump trucks for subsequent inland disposal. The requirement for extensive manual labor made beach cleaning operations extremely slow and costly. Motorized equipment such as graders, bulldozers, loaders, and straw mulchers were employed as much as possible when available. However, many areas were inaccessible to motorized equipment due to lack of access roads or impassability because of heavy seasonal rains.

Two types of motorized equipment proved effective during beach cleaning operations: straw mulchers or spreaders normally used to prevent erosion of highway rights-of-way and graders with tines welded below the blade for raking. The need for equipment modification or more maneuverable and efficient motorized rakes to pile the oily straw mixture is indicated.

Although seeming unsophisticated, the use of straw (not hay) was highly effective due to its ready availability, low cost, and ease of distribution and subsequent pickup. In geographical areas where straw is not readily available, similar materials should be sought and tested in advance.

Chemical dispersants were for all practical purposes not employed in beach restoration as previous experience with chemical treatment of beaches had been unsatisfactory.(1)

In Santa Barbara Harbor, recovery of the majority of the accumulated oil was accomplished by vacuum tank trucks followed by manual spreading and pickup of straw.

The only method found effective for removal of oil stains from rocks and jetties was high pressure water washing followed by sandblasting. Either wet or dry blasting was employed, depending on wind conditions. This method is slow and requires extensive manual labor to remove accumulated debris.

2.7 DISPOSAL OF RECOVERED OIL

The bulk of wastes from clean-up operations consisted of oil-soaked straw, sand and debris (storm debris washed onto the beaches), and oil-seawater mixtures recovered by skimming operations. The solid wastes, over 5,200 large dumptruck loads, were hauled to three major landfill sites east and west of Santa Barbara. Special arrangements were made to dispose of the wastes at these sites with cognizance being given to fire hazard, odor and water contamination considerations. Several problems in logistics were associated with organizing and carrying out this large and somewhat unique operation; and continuous advanced planning, almost on an hourly basis, was required.

Some solid waste material was piled and burned on the beaches; however, smoke and odor problems near the populated areas dictated the abandonment of this disposal method fairly early in the clean-up period.

About 800 barrels of skimmed oil-water mixture were trucked to onshore processing facilities at Carpenteria and Ellwood. There it was blended with the crude petroleum feed collected from nearby producing wells and cleaned to meet pipeline specifications.

2.8 BIOLOGY AND ECOLOGY

The earliest biological effect of the incident showed itself among the sea birds. On 30 January, two days after the initial release, the first oil-soaked dead bird was found. Aerial surveys of the affected area were begun and beach transects were walked daily to find distressed birds. Bird salvage operations were begun at two sites; the birds were washed with detergent and held a short period of time. By 26 March, about 10% of the treated birds survived, closely paralleling bird survival rates of earlier oil spill disasters.

Total known bird losses through 31 March in the area affected were determined to be 3600.

Personnel of the Bureau of Commercial Fisheries (USFWS), the Federal Water Pollution Control Administration, the U. S. Coast Guard, the California Department of Fish and Game, and the University of California at Santa Barbara examined the intertidal and inshore areas. Although these zones were covered with considerable amounts of crude oil, only minimal adverse effects were noted.

Several vessels of the involved agencies were employed to survey the pelagic species. Pelagic fish eggs, larvae, macroplankton and basic hydrographic data such as nutrients, light transmittance and dissolved oxygen were examined. Acoustic surveys detected schools of anchovy, rockfish, squid and jack mackerel.

Bottom characteristics and the condition of the benthic organisms were assessed by California Department of Fish and Game personnel; no evidence of oil contamination on the bottom was noted at depths between 6 and 62 fathoms.

Although the marine mammals in the area became heavily coated with oil, no adverse effects or mortalities could be detected. The mortalities which did occur following the leak could not be attributed to the oil. Scientists involved felt these were simply the "background" or natural deaths which occur within any normal population.

This report covers those programs which examined the short-term effects of the incident. Investigations of the latent or long term effects of the spill are under way. General ecological surveys similar to those previously conducted will be continued at three, six, and twelve month intervals following the spill. It will be possible to then compare them with surveys made prior to and just following the release.

Independent observations made by biologists from other organizations provide further evidence of the lack of any serious acute kills among intertidal species. As of May 23, 1969, no direct evidence has been firmly established that any organisms were killed directly by oil, although there is some evidence of kill by the low salinity resulting from severe storm runoff.

2.0 REFERENCES

1. Oil Spillage Study - Literature Search and Critical Evaluation for Selection of Promising Techniques to Control and Prevent Damage, November 20, 1969. Report to U. S. Coast Guard from Battelle-Northwest.

3.0 ENVIRONMENTAL CONDITIONS

3.1 GEOGRAPHY

The Santa Barbara Channel is an oval basin approximately 75 miles in length and 25 miles in breadth. The long axis of the oval lies essentially on an east-west line extending from Port Hueneme on the east to Point Conception on the west. The area of the Channel is approximately 1,750 square miles.

The Channel is fed by a drainage basin on the north and east, bounded by the Santa Ynez Mountains. This basin encompasses an area of approximately 2,000 square miles. As discussed in Section 3.3, this drainage basin consideration is important due to the severe storm precipitation conditions that occurred in late January and late February.

3.2 PREVAILING METEOROLOGICAL CONDITIONS

Meteorological conditions that prevailed in the Santa Barbara Channel area during January and February, 1969, are of interest from the standpoint of movement and breakup of the oil slick, the large quantities of debris and turbidity carried into the Channel, and the effect on marine organisms of the reduced salinity in the surface waters and intertidal zone.

Two major storms occurred during the period of interest. The first, running from 18 January through 27 January, although occurring prior to the first release of oil, was responsible for severe floods in the South Coast Drainage District. These floods resulted in massive deposits of runoff carried debris along the beaches and coastline and severely hindered cleanup operations, particularly the disposal of oil soaked material.

On the positive side, this severe storm very likely resulted in a lower than normal bird population in the area (Section 11.1).

Overall precipitation for January was four to six times normal. The storm runoff also carried with it large quantities of turbidity and undoubtedly markedly reduced the salinity of the intertidal and surface waters in the Santa Barbara Channel. Rainfall for this storm alone ranged from 10 to over 20 inches throughout the Channel and the adjacent drainage area.[1] The net addition of fresh water to the Channel proper was probably on the order of 15 to 20 inches. As pointed out in Section 3.3, the Santa Barbara Channel is not rapidly flushed and hence this water very likely remained in the Channel through the early days of the incident, clouding analysis of any biological effects, as discussed in Section 11.1. The extensive turbidity introduced very likely also hindered surveillance and identification of the slick spread.

During February, precipitation in the Channel area ranged from two to three times normal.[2] A second major storm occurred during the period 23 February through 1 March, probably contributing 10 to 15 inches net fresh water to the Channel.

Available wind and sea state information is summarized in Table 3-1 from data provided by the U. S. Weather Bureau[3] and the Santa Barbara Group Office of the U. S. Coast Guard.[4]

3.3 OCEANOGRAPHIC CONDITIONS

The current structure in the Santa Barbara Channel is the most important single oceanographic aspect pertinent to the incident. Figure 3.1 indicates the general nature of the average surface currents expected during February as constructed[3] from data provided in reference 5 and reference 6. Current strengths are in nautical miles per day.

Predominant features are the counterclockwise gyres (one or more) occurring within the Channel itself. Along the northern side of the Channel, e.g., the mainland, net surface current averages 2 nautical miles per day. Thus surface material here may require on the order of one month to move the length of the Channel. In the center of the Channel, the residence time of a pollutant must be considerable longer. The across-channel aerial photograph (Figure 3.2) illustrates the gyre effect. Anacapa Island appears in the background.

During March, the surface drift off Southern California shifts to set predominantly southeasterly down coast with typical velocities of 1 to 2 nautical miles/day.[5]

TABLE 3.1. Wind and Sea Conditions Santa Barbara Channel Oil Pollution Incident

		Wind		Wave and Swell	
Date	Time	Velocity Kts.	Direction °True	Height Feet	Direction °True
Jan. 24	0000	6	250	--	--
	0600	5	020	--	--
	1200	7	160	--	--
	1800	8	090	--	--
30	0000	calm		--	--
	0600	calm		--	--
	1200	11	250	--	--
	1415	10-15	230 (M)	--	--
	1800	7	300	--	--
31	0000	12	000	--	--
	0600	6	290	--	--
	0830	6	135	1	190
	1200	5	160	--	--
	1530	0		--	--
	1800	4	330	--	--
Feb. 1	0000	3	350	--	--
	0600	calm		--	--
		(8)	(270)	--	--
	1200	11	220	1	270
	1240	15		5	
	1800	14	320	--	--
	?	6	090	--	--
	?	6	030	1	220
2	0000	calm		--	--
	0600	4	020	--	--
	1130	10	230	1	230
	1200	8	230-260	1	235
	1800	5	250	--	--
3	0000	calm		--	--
	0600	5	010	--	--
	0830	0		calm	--
	1200	6	210	--	--
	1800	3	350	--	--
4	0000	calm		--	--
	0600	calm		--	--
	1045	8	135	1	110
	1200	13	110	--	--
	1800	5	080	--	--
5	0000	5	050	--	--
	0600	3	240	--	--
	1200	13	120	--	--
	1800	12	130	--	--

-- Indicates data not reported
(M) Indicates magnetic bearing

TABLE 3.1 (Contd)

Date	Time	Wind Velocity Kts.	Wind Direction ° True	Wave and Swell Height Feet	Wave and Swell Direction ° True
Feb. 6	0000	15	200	--	--
	0060	12	230	2	225
	1200	12	290	--	--
	1800	10	250	--	--
	?	10	100	2	135
7	0000	5	030	--	--
	0600	0		1	245
	1200	12	130	--	--
	1800	calm		--	--
8	0000	5	020	--	--
	0600	calm		--	--
	0700	3	315	calm	--
	1200	6	220	--	--
	1800	7	250	--	--
9	0000	calm		--	--
	0600	calm		--	--
	1200	7	150	--	--
	1800	6	140	--	--
10	0000	calm		--	--
	0600	calm		--	--
	1200	12	6	--	--
	1800	14	260	--	--
11		No data		No data	
12		No data		No data	
13	0000	8	320	--	--
	0600	7	270	--	--
	1200	7	150	--	--
	1800	8	080	--	--
14	0000	6	030	--	--
	0600	6	020	--	--
	1200	11	120	--	--
	1800	9	110	--	--
15	0000	12	120	--	--
	0600	10	090	--	--
	1200	10	090	--	--
	1800	4	130	--	--
16	0000	4	320	--	--
	0600	5	030	--	--
	1200	5	210	--	--
	1800	calm		--	--
17	0000	calm		--	--
	0600	calm		--	--
	1200	6	160	--	--
	1800	5	260	--	--
18	0000	calm		--	--
	0600	6	350	--	--
	1200	12	260	--	--
	1800	12	280	--	--

TABLE 3.1 (Contd)

Date	Time	Wind Velocity Kts.	Wind Direction ° True	Wave and Swell Height Feet	Wave and Swell Direction ° True
Feb. 19		No data		No data	
20	0000	calm	--	--	--
	0600	calm	--	--	--
	1200	10	220	--	--
	1800	calm		--	--
21	0000	12	300	--	--
	0600	4	250	--	--
	1200	12	250	--	--
	1800	15	130	--	--
22	0000	--	--	--	--
	0600	--	--	--	--
	1200	7	190	--	--
	1800	4	120	--	--
23		No data		No data	
24		No data		No data	
25	0000	--	--	--	--
	0600	--	--	--	--
	1200	9	230	--	--
	1800	7	250	--	--
26	0000	5	050	--	--
	0600	--	--	--	--
	1200	5	220	--	--
	1800	6	240	--	--
27	0000	--	--	--	--
	0600	4	070	--	--
	1200	7	160	--	--
	1800	7	170	--	--
28	0000	6	060	--	--
	0600	7	080	--	--
	1200	6	020	--	--
	1800	6	260	--	--
Mar. 1	0000	--	--	--	--
	0600	9	290	--	--
	1200	7	270	--	--
	1800	12	320	--	--
2	0000	--	--	--	--
	0600	--	--	--	--
	1200	8	190	--	--
	1800	7	250	--	--
3	0000	8	320	--	--
	0600	15	310	--	--
	1200	14	250	--	--
	1800	10	290	--	--

TABLE 3.1 (Contd)

Date	Time	Wind: Velocity Kts.	Wind: Direction ° True	Wave and Swell: Height Feet	Wave and Swell: Direction ° True
Mar. 4	0000	11	280	--	--
	0600	10	250	--	--
	1200	15	210	--	--
	1800	12	330	--	--
5	0000	--	--	--	--
	0600	7	070	--	--
	1200	8	150	--	--
	1800	7	230	--	--
6	0000	16	000	--	--
	0600	7	300	--	--
	1200	15	230	--	--
	1800	12	150	--	--
7	0000	10	310	--	--
	0600	--	--	--	--
	1200	10	270	--	--
	1200	30	320	12	--
	1800	12	300	--	--
8	0000	5	030	--	--
	0600	--	--	--	--
	1200	10	210	--	--
	1800	4	250	--	--
9	0000	--	--	--	--
	0600	--	--	--	--
	1200	10	210	--	--
	1800	--	--	--	--
10	1200	8-10	320	--	--
11	1000	--	--	--	--
12	1100	10	270	--	--
13	1100	15	250	--	--
14	1100	10	140	--	--
15	1200	--	--	--	--
16	1200	--	--	--	--
17	1200	6-10	230	--	--
18	1700	10	130	--	--
19	1500	13	230	--	--
20	1200	8	120	--	--
21	1000	11	090	--	--
22	1200	10	250	--	--

Surface water temperature normally expected in February is 55-56 °F.[5] Tidal range (unadjusted for storm conditions) was 8.4 feet in February.

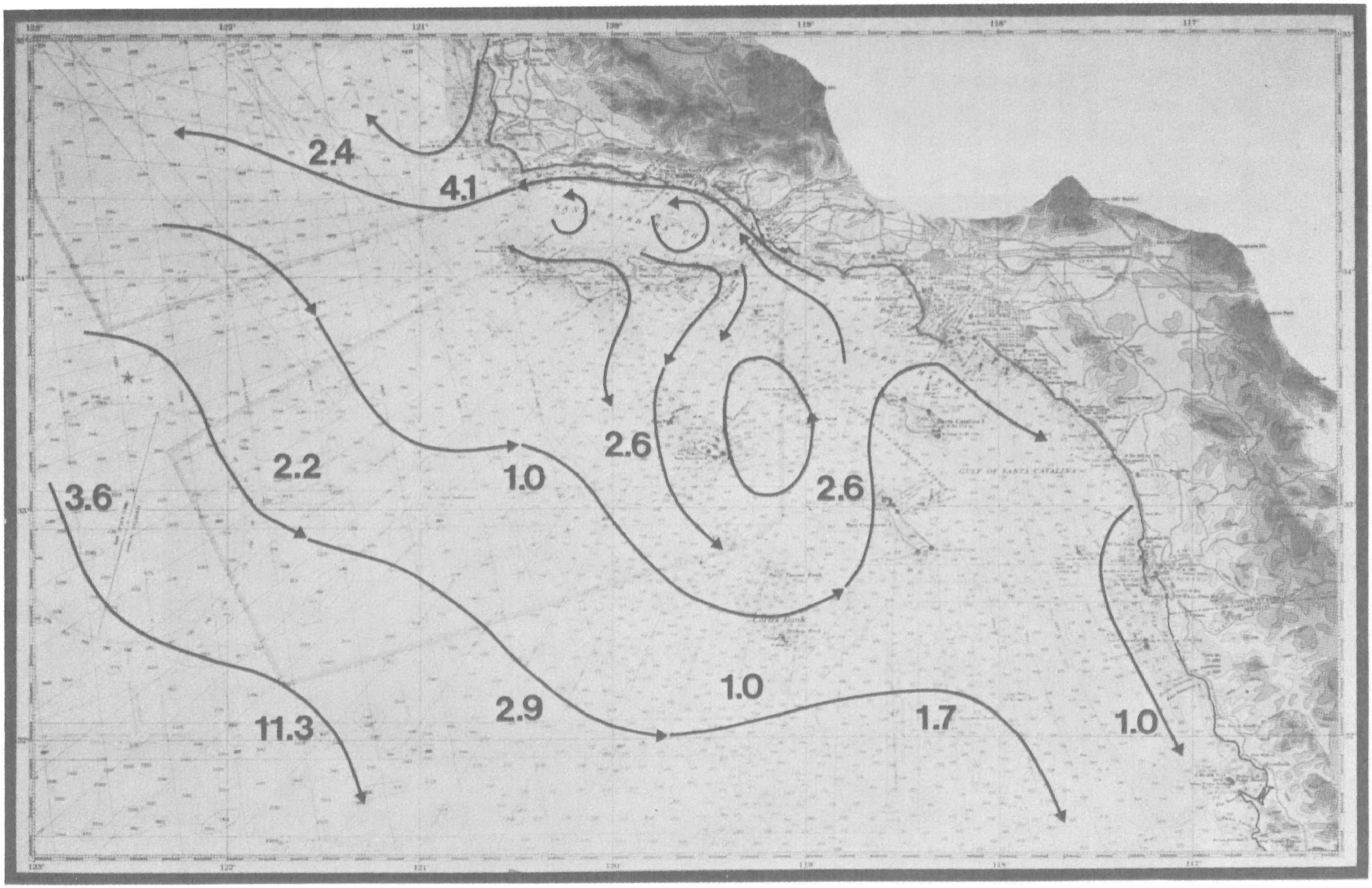


FIGURE 3.1. Southern California Geography and February Predicted Ocean Currents

FIGURE 3.2. Aerial View Across Santa Barbara Channel to the South - Anacapa Island in Background, 14 February, 1969 (courtesy of Santa Barbara News Press)

SECTION 3.0 REFERENCES

1. Climatological Data; U. S. Department of Commerce, Environmental Science Services Administration; California, January 1969, Vol. 73, No. 1.

2. Climatological Data; U. S. Department of Commerce, Environmental Science Services Administration; California, February 1969, Vol. 73, No. 2.

3. Personnel Communication, Mr. Gordon C. Shields, Marine Meteorologist; Weather Bureau Forecast Office, Los Angeles, California.

4. U. S. Coast Guard Situation Reports, Group Office, Santa Barbara, 29 January 1969 to 9 March 1969.

5. Robert de Violani, "Climatic Handbook for Point Mugu and San Nicolas Island," Volume I - Surface Data. Miscellaneous Report, PMR-MR-67-2, 25 October, 1967.

6. A. Fleminger and H. T. Klein, Editors, "California Cooperative Oceanic Fisheries Investigations," Atlas No. 4, December 1966, Scripps Institution of Oceanography.

4.0 DESCRIPTION OF THE SOURCE

4.1 GENERAL GEOLOGY[1]

Santa Barbara Channel, approximately 75 miles long and 25 miles wide, lies within the geomorphic province of southern California known as the Transverse Ranges. These ranges, a series of east-west trending mountains and valleys, lie in a position that is contrary to the northwest-southeast structural and topographic trend of California. The channel is both a topographic and structural basin that occupies about 1750 square miles of ocean, and is located between the coast of Santa Barbara County and an offshore east-west group of four islands. Depths within the channel vary considerably and inconsistently with distance from shore. A maximum water depth of over 2000 feet exists near the center of the submerged basin.

The thickness of individual stratigraphic units varies from place to place, and in some locations units in the sequence are cut out of the local section by faulting or depositional interruption. The section as a whole is made up of a series of interbedded sand and shale bodies with individual members varying in thickness from a few feet to several hundred feet. Oil and gas normally accumulate in the sand bodies; and when favorable entrapment conditions exist, the porosity and permeability are favorable, a reservoir can be produced.

Along the onshore and offshore areas of the south coast practically all accumulations of oil and gas are complicated to some degree by faulting. Significant changes in the geologic section may occur over relatively short distances. As an example, Figure 4.2 shows two nearly parallel (about 10 miles apart), north-south geologic cross sections. These sections, as shown on Figure 4.1, are about equidistant east and west of Platform A where the well blowout occurred. Recent exploration in the channel has indicated that "...Contrary to some seismic indications, the geology in the channel is proving to be just as complex--if not more so--than the crumpled and faulted rock layers onshore."[2]

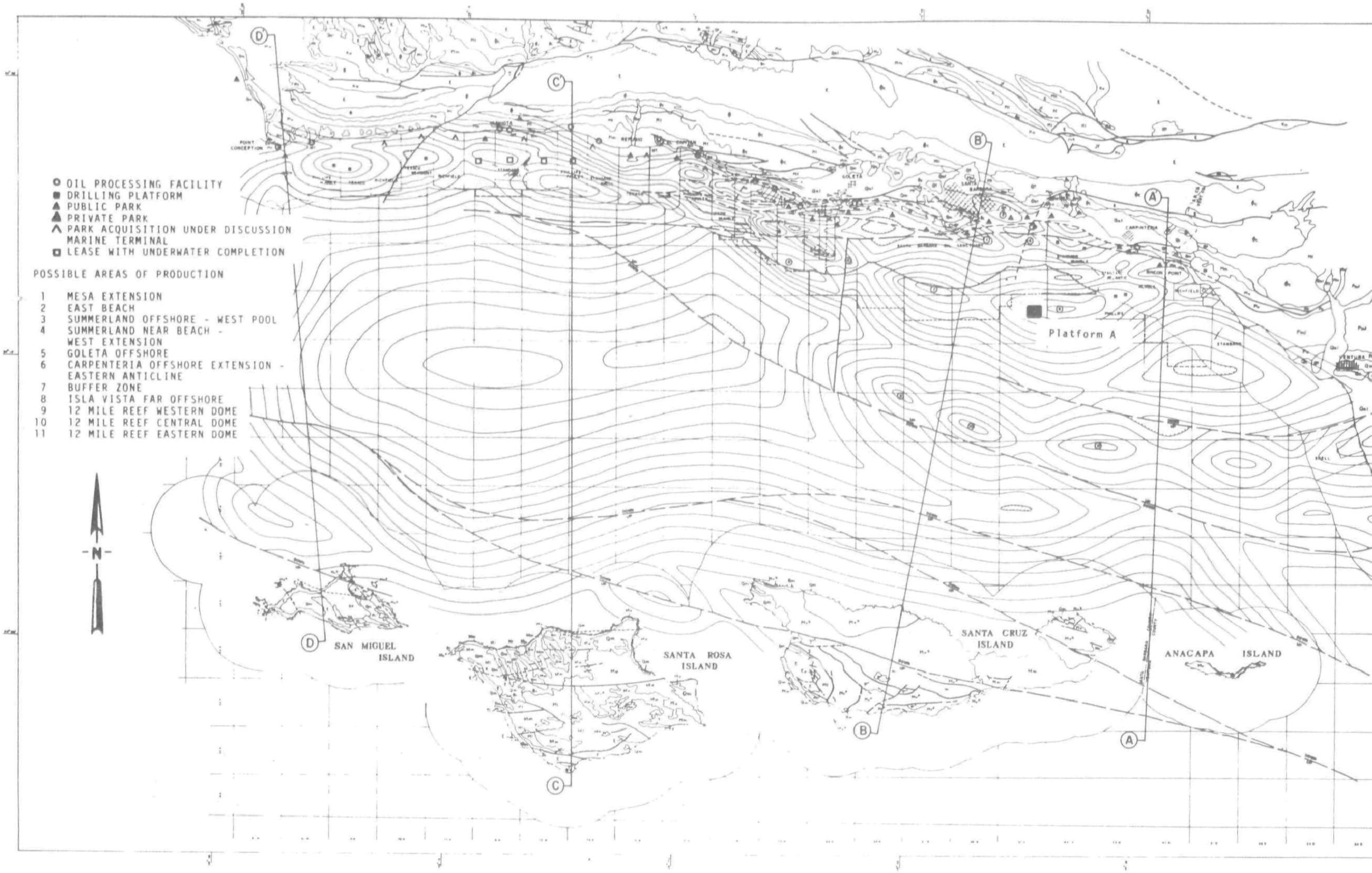


FIGURE 4.1. Santa Barbara Channel Showing Location of Platform A and Position of Geologic Cross Sections(1)

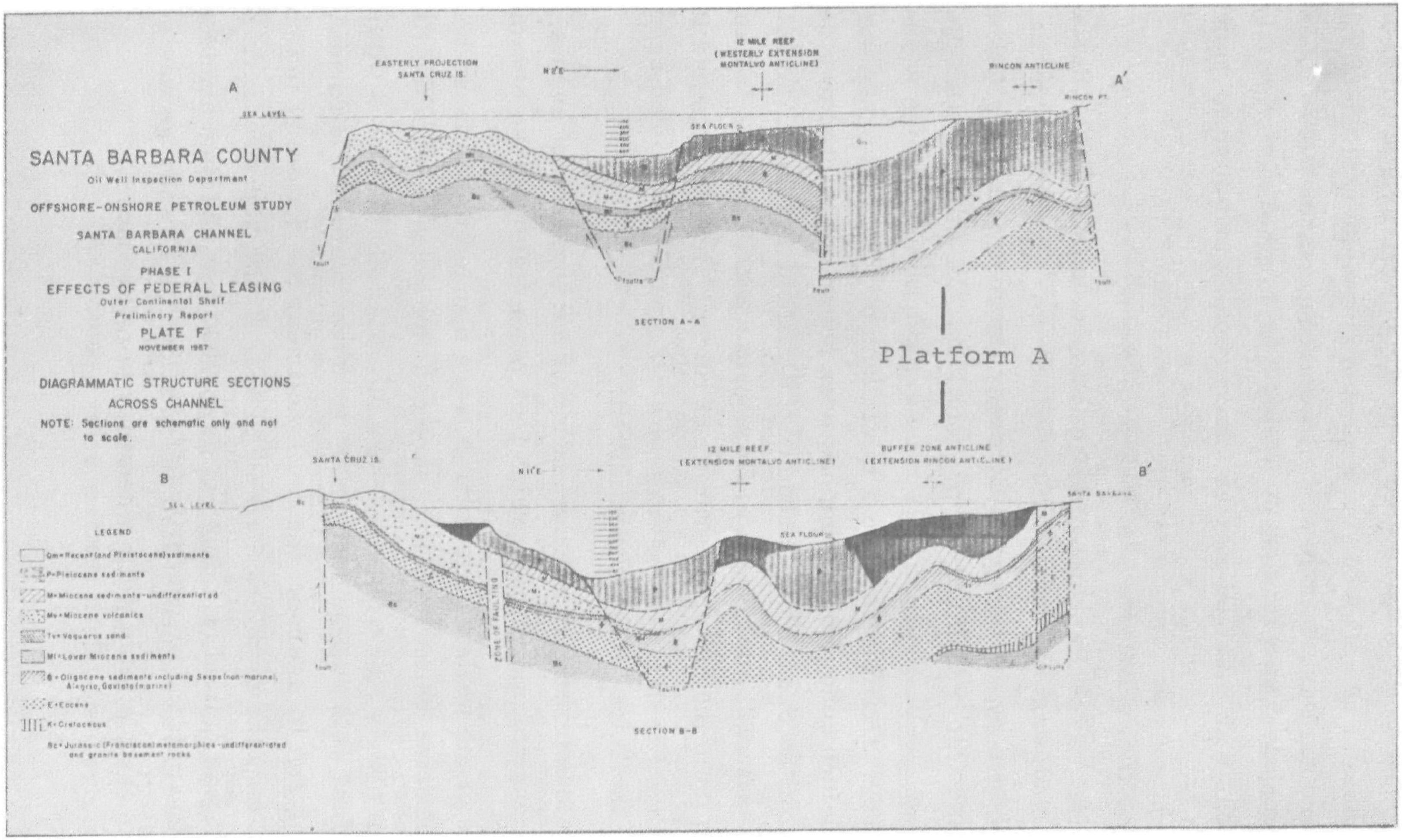


FIGURE 4.2. Structural Sections East (A-A') and West (B-B') of Platform A[1]

4.2 WELL OPERATIONS

The sequence of events related to drilling operations prior to and following the blowout of well A-21 is presented in considerable detail in references 3 and 4. Descriptions of well-control operations subsequent to the issuance of reference 4 (February 9, 1969) were obtained primarily from discussions with involved parties, daily reports and current journal articles.

Fixed drilling Platform A is located in the northeast corner of Tract 402 (Lease OCS-P 0241) about six miles southeast of Santa Barbara and six miles southwest of Carpenteria, California. Operations on the lease are conducted by the Union Oil Company (lessees are Union Oil Company, Texaco Inc., Gulf Oil Corp., and Mobil Oil Corp.). Drilling began on the A-21 well, the fifth well to be drilled from Platform A, on January 14, 1969. Drilling reached a total depth of 3479 feet on January 28, and 13 3/8-inch conductor casing had been set and cemented to a depth of 238 feet below the ocean floor (ocean depth is about 190 feet). At mid-morning on January 28, mud began to flow from the drill pipe as it was being removed from the hole preparatory to running electric logs and later setting production casing. Eight stands of drill pipe (720 feet) had been removed when the "kick" (blowout) occurred.

Table 4.1 following is a condensation of the sequence of events, including well-control operations, which took place following the blowout.

All five of the wells on Platform A were planned to be placed on production in an effort to relieve the pressure causing seepage from the fissures and/or shallow sands. Also, several days following the blowout a directionally-drilled relief well was spudded about 1000 feet south of Platform A (from a floating rig) to intersect the A-21 well near the bottom of the hole. The intent was to pump mud into the well to seal off the high pressure zone. The relief well was drilled to a depth of over 1000 feet and then abandoned after the A-21 well was cement-filled and shallow-zone recharge was noted from several of the platform wells when they were produced.

TABLE 4.1. Well A-21 Control Chronology

Approximate Elapsed Time	Operations and Events
0	Mud flowed out of drill pipe 90 feet above floor of platform.
0-1 minutes	Attempt to screw check valve on top of drill pipe, mud flow 20 feet out of pipe, floor slippery, mud flow ceased and heavy gaseous hydrocarbon mist under pressure issued from pipe, eyes affected, visibility near zero, floor extremely slippery, installation of check valve abandoned.
2-3 minutes	Hooked elevator onto kelly for installation on drill pipe, plug on standpipe broke off rendering mud control through kelly ineffective (attempt abandoned); visibility restricted, communication difficult, decided to drop drill pipe back into hole and shut blowout preventer to contain pressure.
4-13 minutes	Blocks lowered to raise drill pipe, slips removed, hydril blowout preventer actuated to hold pipe column while disconnecting elevator (ineffective). Pipe raised about 30 feet, pipe rams on BOP actuated to hold pipe, elevators disconnected and pipe rams opened to drop pipe in hold, blind rams closed to seal well, flow from well ceased.
14-25 minutes	Bubbles noticed in ocean around platform, large boil appeared about 800 feet from platform (Figure 4.3). Choke and kill operations attempted following well closure were ineffective and thus abandoned.
0.5-18.5 hours	Single stands of drill pipe (check valve on leading stand) were snubbed into the well to reconnect to dropped pipe and circulate mud to seal off leakage into shallow zones, time consuming operation. Drill string was reconnected.
1-7 days	Upon reconnection, bottom of drill pipe was found to be stuck and plugged, attempted to unscrew pipe below check valve to pull pipe and rerun without valve (unsuccessful) so that gun perforator could be lowered to bottom of drill string to punch holes for mud circulation. Decided to mill out valve interior, milling tool obtained, valve milled, drill pipe perforated, and sea

TABLE 4.1. (contd)

Approximate Elapsed Time	Operations and Events
1-7 days (contd)	water followed by 3000 bbls. of heavy mud circulated. Definite reduction noted in amount of oil and gas emerging at ocean surface. Decided to stop pumping mud until additional mud and pumping capacity were available. Sea water continued to be pumped while supplies were amassed.
8-10 days	Worked on assembling supplies needed to mix and pump 14,000 bbls. of heavy-weighted mud into any cavities and to build up the mud column in the hole sufficiently to overcome pressure in the strata from which gas was flowing. High winds and seas caused delay.
11-12 days	Mud pumped into well at high injection rate and pressure. Boils diminished to a few small bubbles, mud return noted. Later there was no visible evidence of leakage at surface, and it was decided to cement and abandon the well. Cement injected in stages and well was filled to ocean bottom. Only a few small gas bubbles were noted under edge of platform.
15-16 days	Increased seepage noted, at reduced rate than originally, extending out to 800 feet from the platform. Adjacent wells put on production in an attempt to reduce pressure in upper sand zone.
Subsequent to 16th day	Several wells on the platform were placed on production in an attempt to relieve pressure. Cement was drilled from the A-21 (blowout) well to a depth of about 175 feet, casing was perforated, and well was placed on production to reduce pressure in shallow zones. Attempts were made to cement fissures on the ocean floor (divers) through which oil was seeping. Rough seas and very restricted visibility made this difficult. Leakage continued at a significantly reduced rate than originally and was believed to originate in shallow zones charged through other wells that were put on production for pressure relief.

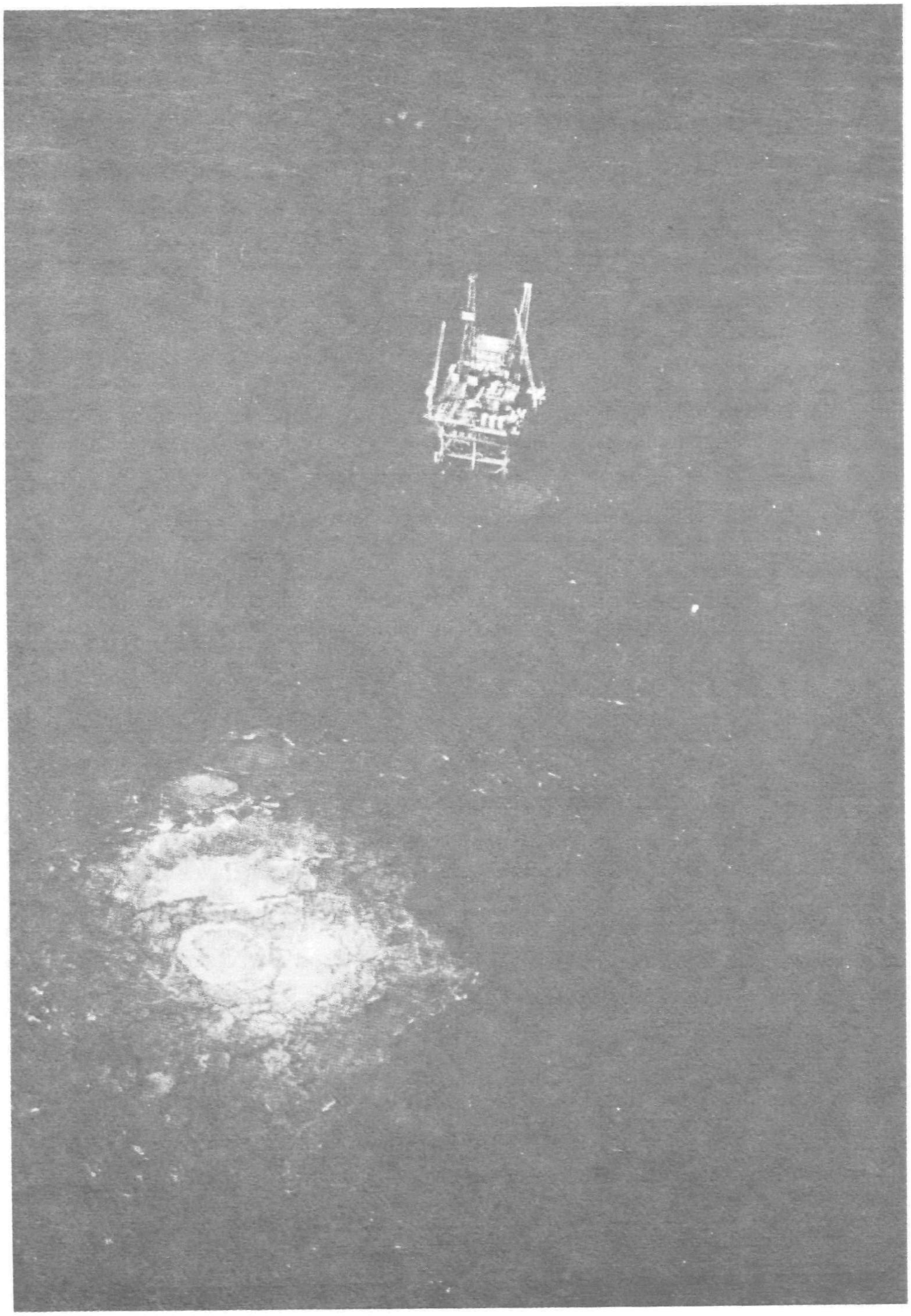


FIGURE 4.3. Oil, Gas and Sediment Boils in Vicinity of Platform A, 29 January, 1969, Shortly Following Blowout (courtesy of Santa Barbara News Press)

4.3 AREAL DISTRIBUTION AND CHRONOLOGY

Information on the ocean floor release of oil and gas resulting from the well blowout consistently indicates appreciable variability in both the location of seepage points and magnitude of release with time. Such variability is not unexpected in consideration that the immediate release source was believed to be primarily shallow sands and/or fissures recharged by the deeper producing zones (via well bores and casing annulus) rather than direct communication between the ocean floor and the deep reservoir. Also, control or defensive operations carried out in the blowout and other wells on the platform caused significant alterations in the pattern and rates of recharge in the shallow sands and fissures. Certainly, the rate of crude oil release was more difficult to estimate than was the location of seepage areas; although very restricted ocean floor visibility due to oil, gas, sediment (and at times storm) turbulence made exact pinpointing of seepage areas difficult.

Estimation of the rate of release and cumulative volume of oil is extremely difficult due to the impossibility of making direct measurement. Estimates by the U. S. Geological Survey[3,4] place the initial seepage rate at about 500 barrels of crude oil per day (maximum of 5000 b/d), and the later sustained release at up to 50 b/d.

More recently, Allen[6] provided a "conservative" release rate estimate of 5000 b/d during the initial eleven days of maximum activity followed by a near steady release rate of 500 b/d out to 100 days from the initial release. He further estimates that the cumulative total was 77,000 barrels after 100 days. This is equivalent to approximately 12,000 tons. For comparison purposes, the TORREY CANYON release has been estimated at 30,000 tons.[7]

Allen's "conservative" release estimates are based upon a 1/1000 inch uniform film thickness over the area observed to be covered. An alternative graded estimate of thickness (1-inch thick over 10,000 sq yards, 1/4-inch thick over 640,000 yards, 1/100 inch over 1 sq mile with 50% water-in-oil emulsion) during the maximum release rate period, resulted in an estimated release rate of 16,000 b/d during the initial period.

In any event, it must be recognized that the variability of oil release in terms of volume and location with time presented a unique and difficult to manage situation. At one period the oil slick covered approximately 500 square miles.[5]

TABLE 4.2. Oil Release Observations

Approximate Elapsed Time	Observations of Oil Released[3,4,5]
0	Well blowout. Mud followed by heavy, gaseous hydrocarbon mist issued from drill pipe.
25 minutes	Drilling platform personnel first noticed bubbles in ocean around platform. A large gas and oil boil (several hundred feet in diameter) appeared about 800 feet east of platform and smaller boils appeared in a line intersecting northeast leg of platform.
1 day	Large boil east of platform persists, smaller boil (30 feet diameter) at northeast leg of platform, lesser bubbling in between and extending in line to 300 feet west of platform.
2 days	Oil and gas bubbles subsided except the single boil at northeast leg which had increased to 300 feet. This condition persisted with only minor changes for about 4 days.
7 days	Some reduction in the amount of oil and gas flow noted following addition of mud to A-21 well. During short time intervals the boil at northeast leg subsided.
12 days	Boil at northeast leg continued as the major seep until mud and cement were placed in well. Following well abandonment, platform and aerial inspection revealed only a few small bubbles issuing at the ocean surface over an area about ten feet in diameter under edge of platform.
16 days	Increased seepage occurred along a line extending to 800 feet east of platform. Believed due to placing another well on production. Later, primary leakage was at northeast leg of platform. The slick from this seepage was from 30-150 feet wide, extending for 1-2 miles.

TABLE 4.2. (contd)

Approximate Elapsed Time	Observations of Oil Released
26 days	Boil at platform leg predominates with lesser bubbling 500 feet east and 300 feet west of platform.
30 days	Minor oil and gas bubbling east and west of platform appearing to stop. Seepage persists at northeast leg.
31 days	Boil at northeast leg diminished and seepage along the east and west lines was renewed.
Subsequent to 31 days	Seepage continued at rate up to an estimated 50 b/d.[5]

SECTION 4.0 REFERENCES

1. D. K. Bickmore, et al. Phase I, Effects of Federal Leasing Outer Continental Shelf, (Preliminary), Oil Well Inspection Dept., County of Santa Barbara, California, November 15, 1967.

2. "Verdict Still to Come in the Santa Barbara Channel," Oil and Gas Journal, vol. 67, no. 9, March 3, 1969, pp. 76-77.

3. E. W. Standley, et al. "First Field Report on Union Oil Co. Lease OCS-P 0241, Platform A, Well A-21," U. S. Geological Survey, February 4, 1969.

4. E. W. Standley, et al. "Second Field Report on Union Oil Co. Lease OCS-P 0241, Platform A. Well No. 21," U. S. Geological Survey, February 9, 1969.

5. U. S. Coast Guard Situation Reports, Group Office, Santa Barbara, 29 January to 28 February 1969.

6. A. A. Allen. Statement to U. S. Senate Interior Committee, Subcommittee on Minerals, Materials, and Fuels; May 20, 1969.

7. J. W. Smith. "The TORREY CANYON Disaster," British Association for the Advancement of Science, Leeds, England, September 6, 1967.

5.0 MANAGEMENT CONSIDERATIONS AND CONTINGENCY PLANNING

Following the TORREY CANYON incident off Lands End, England, in March 1967, the President directed the Secretary of the Interior and Secretary of Transportation to examine how the resources of the nation could best be mobilized against the pollution of water by spills of oil and other hazardous substances. This examination resulted in the report "Oil Pollution - A report to the President," dated February 1968. This report pointed out the need for contingency planning as a necessary first step in combating major water pollution incidents.

The national level effort in contingency planning culminated in September 1968 issuance of the "National Multiagency Oil and Hazardous Materials Pollution Contingency Plan." Agencies signatory to this plan are the Department of the Interior, the Department of Transportation, the Department of Defense, the Department of Health, Education and Welfare, and the Office of Emergency Planning (currently the Office of Emergency Preparedness). The national plan further called for the development of regional contingency plans and for designation of a single on-scene commander (OSC) as the single predesignated executive agent to coordinate and direct such pollution control activities in each area of the region. According to the plan, "the U. S. Coast Guard is assigned the responsibility to furnish or provide for on-scene commanders for the coastal and contiguous zone waters, ports and harbors, Great Lakes and major navigable waterways." The Department of the Interior furnishes or provides on-scene commanders in other areas.

While the authority to furnish or provide OSC's is thus vested in these two agencies, it is recognized that where other Federal agencies are present and have a greater capability, they may be asked to provide the OSC.

Additionally, where Federally owned or operated vessels or facilities are involved, in any geographical area, the intent of the Plan is that the Federal agency most concerned provide the OSC. This means, in effect, that the Army Corps of Engineers (for dams, locks, etc.), the Navy (for its ships), the Air Force, and other such agencies may assume the function of OSC from time to time.

The national contingency plan also provided for the activation of regional operating teams (ROT) in the event of a pollution disaster with representation from the signatory agencies. The ROT as set out in the National Plan has no command responsibility, operational or not. When the Coast Guard provides the on-scene commander, the Coast Guard chain of command is in effect. The ROT advises, except as regards "continuing water pollution control measures," where it has a veto.

One of the purposes of the regional contingency plan was to assess the potential major water pollution threats in the area and to identify resources subject to damage. The regional contingency plan is also intended to establish cooperative agreements with state and local authorities so that in the event of a disaster, defensive resources can be inventoried and made available with a minimum of lost motion and time. At the time of the Santa Barbara Channel oil pollution incident, the appropriate regional contingency plan was in the process of revision and not yet in full effect. However, the federal-state "Cooperative Agreement for Marine Chemical Spill Disasters in and about the State of California" had been promulgated and was amplified by the U. S. Coast Guard 11th District "Marine Chemical Spill Disaster Plan."

This chapter is intended to summarize the management considerations and activities undertaken by the various parties operating under these contingency plans. As of this writing (October 1969) the National Contingency Plan is being revised to reflect lessons learned from the Santa Barbara Channel incident.

5.1 PREPLANNING ACTIVITIES

Although as pointed out above, formal implementation of a Regional Contingency Plan had not been achieved at the time of the incident, substantive agreement had been reached between the State and Federal agencies involved and working arrangements were generally available under the "Cooperative Agreement for Marine Chemical Spill Disasters in and about the State of California."

Planning for coping with an oil pollution incident specifically in the Santa Barbara Channel was initiated in December 1967 under responsibilities outlined in the USCG 11th District "Marine Chemical Spill Disaster Plan." Meetings were held during 1968 in Santa Barbara and Ventura counties with Civil Defense, Law Enforcement, Harbor Administration personnel and various California State agencies. A total of eleven such meetings were held from December 1967 through December 1968. These meetings, although not resulting in a formalized plan, did serve the very useful purpose of establishing lines of communication that later proved extremely useful throughout the incident.

From the industry standpoint, the Western Oil and Gas Association had prepared a Santa Barbara Channel Water Pollution Control emergency statement that reportedly proved valuable in the early stages of the incident in locating equipment and materials. [5]

5.2 INITIAL ACTIONS

Following the initial release from Platform A at about 1100 U 28 January 1969, the Regional Operating Team (ROT) and the Joint Operations Team in Washington, D.C., were alerted on 29 January as called for in the National Multiagency Oil and Hazardous Materials Pollution Contingency Plan. [1] The ROT met 30 January in San Francisco, California, to declare an incident and was then fully activated on 4 February to provide further technical and logistical support to the On-Scene Commander. This initial meeting was held under the auspices of the 12th Coast Guard District in San Francisco although the incident occurred within the jurisdiction of the 11th Coast Guard District. This temporary situation was later rectified with transfer of the ROT activities to Santa Barbara.

The U.S. Coast Guard assumed on-scene command responsibility and established headquarters for the ROT in Santa Barbara on 29 January. [2] At the request of the Union Oil Company, the FWPCA granted permission for use of chemical dispersants as necessary to protect the lives of the crew on the platform from fire and explosion and to control and prevent further pollution. [1]

On 30 January, the FWPCA established a technical staff on scene in Santa Barbara to Provide coordination and technical counsel to the On-Scene Commander and to the Union Oil Company on cleanup and confinement procedures and to monitor the pollution and pollution control measures.[1] On 31 January, the U.S. Weather Bureau established a mobile forecasting unit at Santa Barbara.[3]

5.3 REGIONAL OPERATING TEAM ACTIVITIES

The chairman of the ROT arrived on-scene 30 January and was joined on 31 January by other members or their representatives and the expert team assembled by the Secretary of the Interior. Agencies on the ROT, as well as representatives of the State of California, assembled skilled personnel both in the engineering and biological sciences field. As the need arose, contracts were executed especially in the field of ecological damage assessment and to collect perishable information.

5.4 ON-SCENE ACTIONS

At the onset of the incident, Union Oil Company assumed responsibility for organizing and conducting the control and restoration activities. Federal and state agency partification was directed at providing counsel to the On-Scene Commander and to the Union Oil Company, and monitoring pollution effects in accord with agency capabilities. Some State assistance was also provided for restoration.

Suggestions for control and cleanup were generated by the ROT and On-Scene Commander. While no approved regional plan had been promulgated, recommendations were usually directed to Union Oil Company through the On-Scene Commander to satisfy the command intent of the plan. Among the recommendations were:[3, 4]

1. The need to boom at the source coupled with recovery of oil from the boomed area by use of barges and vacuum pumps.
2. The use of straw as a sorbent for oil.
3. The use of power mulchers for distribution of the straw sorbent.
4. The need to locate and provide on-land disposal sites for oiled debris, straw, and sand.
5. The use of vacuum tank trucks for removal of oil from the Santa Barbara harbor.
6. That chemical dispersants not be employed on the beaches due to potential for driving oil deeper into the sand and producing "quicksand"

condition. Further stipulations were later placed on the use of dispersants at sea (Section 6.2).

7. The procedures for water fowl rehabilitation.

Personnel of the U.S. Coast Guard, FWPCA, and Bureau of Sport Fisheries and Wildlife, and the California Department of Fish and Game conducted aerial and beach surveys and monitored the extent of the oil slick on a near-daily basis until March 1, 1969, and thereafter as required for the OSC. The FWPCA also conducted water quality, biological, and ecological surveys, and arranged for experimental use of aerial remote sensing.

Considerable effort was also devoted to handling and evaluating more than a thousand unsolicited recommendations from vendors and interested citizens.

The U. S. Army Corps of Engineers provided assistance in locating contractors and cleanup equipment. The U. S. Navy provided the services of a yard oiler and five pontoon sections. The Office of Emergency Preparedness provided counsel on the applicability and operation of emergency legislation and regulations.[3]

5.0 REFERENCES

1. DeFalco, P., Jr., Statement to Committee on Public Works, U.S. House of Representatives, February 14, 1969, Santa Barbara.
2. Brown, Lt. G. B. III, USCG, Statement to Subcommittee for Air and Water Pollution, U.S. Senate, 25 February 1969.
3. On-Scene Commander's Report, "The Santa Barbara Channel Oil Pollution Incident, January 1969."
4. Biglane, K. E., Statement to the United States Senate Committee on Public Works, Subcommittee on Air and Water Pollution, Santa Barbara, California, February 25, 1969.
5. Gaines, T. H., Statement to Committee on Public Works, U. S. House of Representatives, February 18, 1969, Santa Barbara.

6.0 CONTROL OF RELEASED OIL

6.1 CONTROL AT SOURCE

6.1.1 Capture Below Sea Level

Several attempts were made to collect the oil mechanically as it issued from the sea floor. Basically the devices used were hoods or inverted funnels placed over a point of emission. The natural buoyancy of the oil caused it to collect at the top of the vessel from whence it could be pumped to storage vessels on the platform.

On about 16 February, a small steel hood was suspended above a fissure near the platform by attaching it to one of the platform legs. Oil was pumped to the platform through a four-inch diameter line at the top; up to 12 bbl of oil per day were recovered during this operation.(1)

A second hood, subsequently known as the "Barbecue Pit", was relatively large and designed to be lowered to the bottom over a fissure. The physical configuration permitted emplacement over the conductor easings of the platform; therefore, it was of a somewhat irregular shape, resembling a three-sided tank. The approximate dimensions were 40 feet long, 30 feet wide, and 55 feet high, with a weight of approximately 25 tons. The size and weight required that a large crane be used for loading and emplacement. Placement was attempted on 10 March, but the hood was severely damaged by waves and currents upon lowering, and it was subsequently removed and dismantled for disposal. The device was never operational.

Structural and particularly emplacement problems associated with mechanical oil capture devices become apparent when wave-induced surge forces in an open ocean environment are examined. The water depth at Platform A is approximately 190 feet, under essentially deep ocean conditions for the passage of waves with periods up to eight or nine seconds.(2) The relationship between wave length (L) and wave period (T) is $L = 5.12T^2$. Effective water motion for progressive deep ocean waves decreases with depth below the still water level (SWL) according to the expression

$Ke^{2\pi y/L}$ where K = a constant, y = vertical distance from the SWL (negative downward), L = wave length and e = base of Natural logarithm. From this expression it is evident that water motion decreases to a lesser degree with depth as the wave length increases for a fixed vertical position.

Emplacement operations were conducted of necessity in the presence of long period waves or swells of relatively low height. For the case of a wave period of 12 seconds, the surge at 190 feet below the SWL is 20 percent of the value at the still water level. Therefore, emplacement operations must include provisions for considerable water movement and wave forces even at 190-foot depth in a deep sea environment. These operations can become particularly difficult (and potentially hazardous) near a rigid structure such as a platform (Figure 6.1).

Subsurface hooding of emission points was hampered since the emissions tended to vary in position from day to day, and severe turbidity limited diving operations. In addition, some of the emission points were as much as 800 feet horizontally from the platform which caused difficulty in piping captured oil to the platform.

6.1.2 Physical Confinement on the Sea Surface

Several types of floating booms, including a rigid "corral", were employed to contain the oil on the surface. Most were deployed in the immediate vicinity of the platform to prevent spread of the oil until it could be recovered. Attempts also were made with booms to prevent the slick from moving toward the beaches. In order to contain the oil as it emerged at the surface, very long booms (up to 1,800 feet) were required since the oil spreads rapidly and surface currents caused the boom to take on a catenary shape. During the early stages of the blowout containment booms would have had to encompass areas of thousands of square feet, based on the estimates of the boil diameter at the sea surface (up to 300 feet).(3)

Booms and containment devices employed or tested at sea in the vicinity of the platform to capture or contain the oil slick included:

- Sheets of rubberized asbestos approximately 36 inches high and one inch thick.

FIGURE 6.1. Platform A (courtesy of Santa Barbara News Press)

- Log booms.
- An inflatable boom 20 inches in diameter with a 30 inch skirt.
- A smaller commercial plastic boom with skirt.
- Rubberized fabric sheet with battens for stiffening.
- A "corral" formed from sheet metal.
- A lattice of steel cables covered with a quilted fabric material.

The log booms were fabricated from telephone poles 30-50 feet long with minimum diameters of 12 inches. Steel cables up to one inch in diameter joined the successive sections and canvas wrapping prevented leakage between sections. The log booms were assembled in lengths up to 1,000 feet or more near shore and towed to the scene. This type of boom generally proved to be ineffective in rough seas because of the inability to conform to the sea surface, thus permitting the oil to be carried over or under. Skirts were not used on the log booms. Several were destroyed by rough seas. Approximately 5,000 feet of log boom was positioned within 1,000 yards of the north side of the platform on 5 February.[4]

The commercial booms employed at sea generally range in price from \$8-\$15/foot (without mooring systems). The cost of emplacement, positioning and/or holding is estimated to range between \$20 and \$50/hr, depending on the number of ships required. Makeshift booms, such as those fabricated from telephone poles, are estimated to cost \$4-\$8/foot.

The steel "corral" was an open cylinder approximately 30-35 feet in diameter and 10-12 feet high. The sheet metal outer covering was braced internally with structural members; 55 gallon drums on the inside provided buoyancy. It was to be towed to the scene and moored on the surface over the boil with the intent that the accumulated oil would be pumped out as it collected. However, the "corral" struck a leg of the platform during placement and was damaged beyond repair before it could be tested.

A large boom (Figure 6.2) was formed from a ten inch square lattice of 1/2 inch diameter steel cables covered by a heavy quilted fabric which was claimed to pass water while retaining the oil. The physical dimensions were 10 feet high by 200 feet long; approximately 3-1/2 feet rode out of the

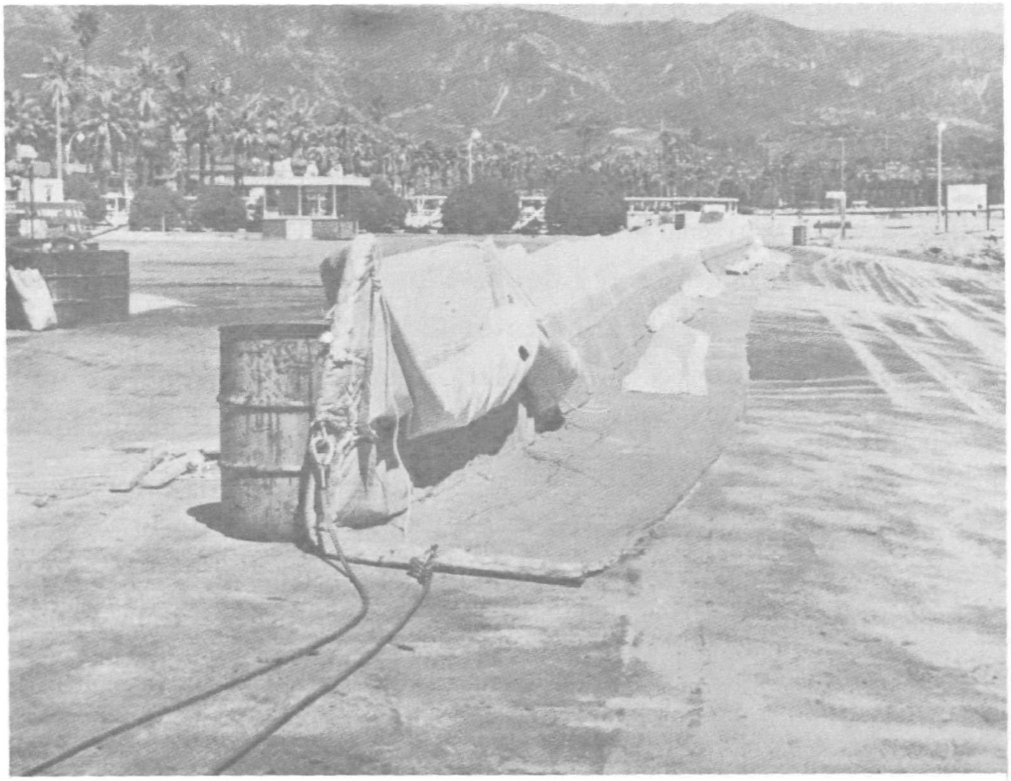


FIGURE 6.2. Large Steel Cable Reinforced Fabric Boom

water. Buoyancy was provided by plastic foam-filled bags on either side. The 200 foot section was towed to sea for tests in late March and tested for several days. The short length employed did not permit evaluation of the effectiveness to contain oil. However, the boom proved strong enough to survive at least 10 days of relatively calm seas. The cost of this boom was reportedly $10,000 for 200 feet.

An inflatable boom was also employed in the vicinity of the platform. The configuration of this boom made it difficult to tow at moderate speeds and it failed structurally. A strengthened version was later used across the mouth of the Santa Barbara harbor but was damaged by a ship. A third, further improved, model used plastic foam instead of air for flotation and reportedly worked satisfactorily across the mouth of the Channel Islands Harbor.

Booming was often hampered by heavy seas and a number of severe operational problems such as structural integrity of the booms, mooring, alignment and holding with ships, launching from shore, inability to contain the accumulated oil, and dragging of ground tackle. One of the commercial booms was damaged by a ship's propeller and had to be returned to shore for repairs.[5] The booms were often deployed with one end attached to a buoy while a ship maintained the other end on station. The moorings often parted in heavy seas, thus suspending operations. Positioning posed a problem because lateral forces on the relatively long booms and excessive towing forces caused mechanical failure. Floating debris constituted a navigational hazard and its accumulation against booms also produced severe structural forces. Booms that had a relatively high, narrow rectangular cross section were subject to tipping and thus loss of oil retention capability, particularly if mooring lines slackened. Confinement of oil by an encircling boom placed around the platform, even if it had been possible, might have markedly increased the fire hazard and possibly closed down attempts being made to shut in the well. Complete encirclement would have also restricted ship traffic to and from the platform.

6.1.3 Chemical Dispersants

Chemical dispersants were injected underwater near the emission points on the seafloor to reduce the fire hazard of the oil as it emerged on the water surface. The description of chemical dispersants in this section is limited to those applied underwater near the source. A further description of the dispersants applied to the oil slick near the platform and in other areas of the Santa Barbara Channel is included in Section 6. 2. 2.

Polycomplex A-II was applied from the deck of the platform directly into the boil of oil and gas. Application was made by pumping the dispersant through a line extending underwater from the deck of the platform. A total of 25 barrels was applied in this manner up to the latter part of February.[6] Application was subsequently discontinued. Typical application rates of about one barrel per day were reported.

6.2 CONTROL AT SEA

6.2.1 Sorbents

Sorbents applied at sea included straw, perlite,[7] a ceramic catalyst support for sinking oil,[8] foam pads,[9] and micronized talc. Straw was the absorbent judged most successful and was subsequently applied in large quantities. The absorbents were applied primarily to prevent the oil slick from spreading.

The micronized talc tested was similar to that used to absorb oil following the OCEAN EAGLE incident at San Juan, Puerto Rico. Blowers and fertilizer spreaders were used to spread the talc from work boats. Following a test, the talc was judged ineffective because it could not be readily recovered and its use was discontinued.[10, 41] The ceramic catalyst support intended to sink the oil was reportedly applied offshore on one occasion to try to prevent oil from reaching the beaches.

At least two types of straw were used--Bermuda straw and the more common straw from wheat stalks. Bermuda straw, closely resembling hay, is much finer than common straw and, like hay, was found less effective because of the much smaller volume of oil that could be absorbed. Straw reportedly repels water and absorbs 4 to 5 times its weight in oil. Straw was trucked to Santa Barbara from throughout the Southwest. No information could be found regarding mechanical methods tested at sea to recover the agglomerated oil-straw mixture from the surface and no device is known to have been used for the specific purpose of recovering the agglomerated mixture at sea.

Straw spreading was effectively accomplished by mulchers normally used to spread straw along highway borders to prevent soil erosion. Up to 45 tons per day were spread near the platform in late February by two ships.[11] Vessels were also used to spread the straw near shore as shown in Figure 6.3. Up to 140 tons per day were spread by vessels working parallel to the beach a few hundred yards offshore.[12] Individual mulchers were capable of broadcasting 8 to 10 tons of straw per hour.[41]

The effectiveness of sorbents such as straw applied at sea near the platform is doubtful as the straw-oil mixture was not easily recovered at sea and tended to clog skimmers designed for removing oil. However, straw does tend to prevent further oil spreading. Application of straw near shore when the oil was certain to wash ashore did have merit as it facilitated beach cleanup by minimizing penetration into the beach surface.

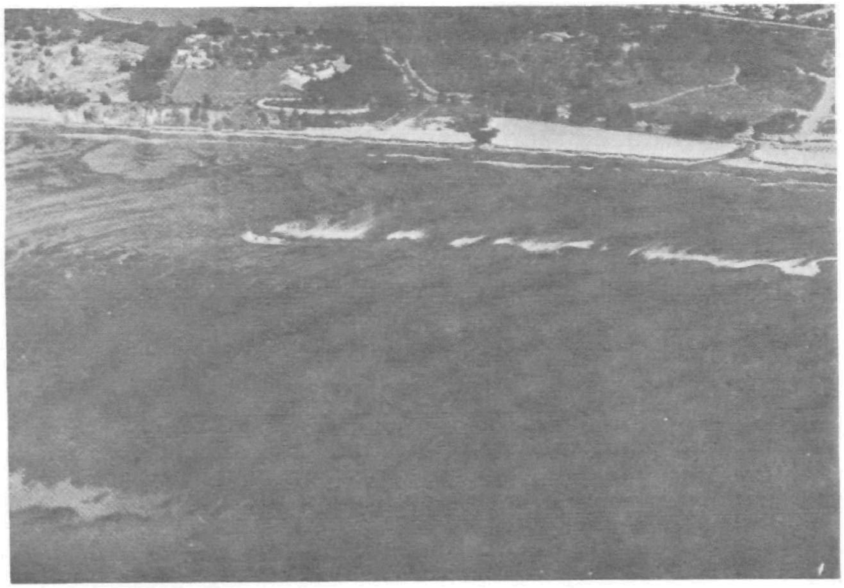


FIGURE 6.3. Workboat Spreading Straw Inside Kelp Beds (courtesy of U.S. Coast Guard)

6.2.2 Chemical Dispersants

Chemical dispersants were applied at sea for two purposes: (1) to prevent the oil slicks from reaching the shore as they approached the beaches, and (2) to reduce the hazardous concentrations of flammable oil in the immediate vicinity of the platform. The application of chemical dispersants was discontinued in all areas other than the immediate vicinity of the platform (within one mile) for safety reasons when the FWPCA advised that the chemical usage had exceeded the manufacturer's recommended application ratio based on the Union Oil Company estimate of 2,500 barrels of oil released.[13] The use of chemical dispersants within state waters (three miles offshore) was opposed by the California Department of Fish and Game because of previously established policy banning the use of any chemical deleterious to marine life.[14]

The majority of the dispersant applied to the slicks to prevent the oil from reaching the beaches was "Correxit 7664" and the application area was normally in excess of one mile offshore. Three hundred thirty seven (337) drums of this dispersant were reportedly applied by two fixed wing aircraft and surface vessels between 30 January and 5 February 1969.[15] The 337 drums (~20,000 gallons) applied should have dispersed a minimum of 200,000 gallons of oil, based on the manufacturer's literature from previous trials.[16] General observations were that the majority of the oil that was located offshore during this period eventually reached the beaches.

The application ratio used was based on the manufacturer's recommended rates and the Union Oil Company estimates of oil released.[17] The dispersants were applied to the slicks either from surface vessels, referred to as "Soap Boats" (Figure 6.4) or fixed wing aircraft, normally used for agricultural crop dusting, flying a few feet above the water surface.[18] Application rates from surface vessels were typically one barrel per hour with a spray pattern about 50 feet wide and the ship advancing at speeds up to three knots. Approximately 40 gallons/acre were applied by the fixed wing aircraft.[19]

FIGURE 6.4. Workboat Distributing Chemical Dispersant (Courtesy of Santa Barbara News Press)

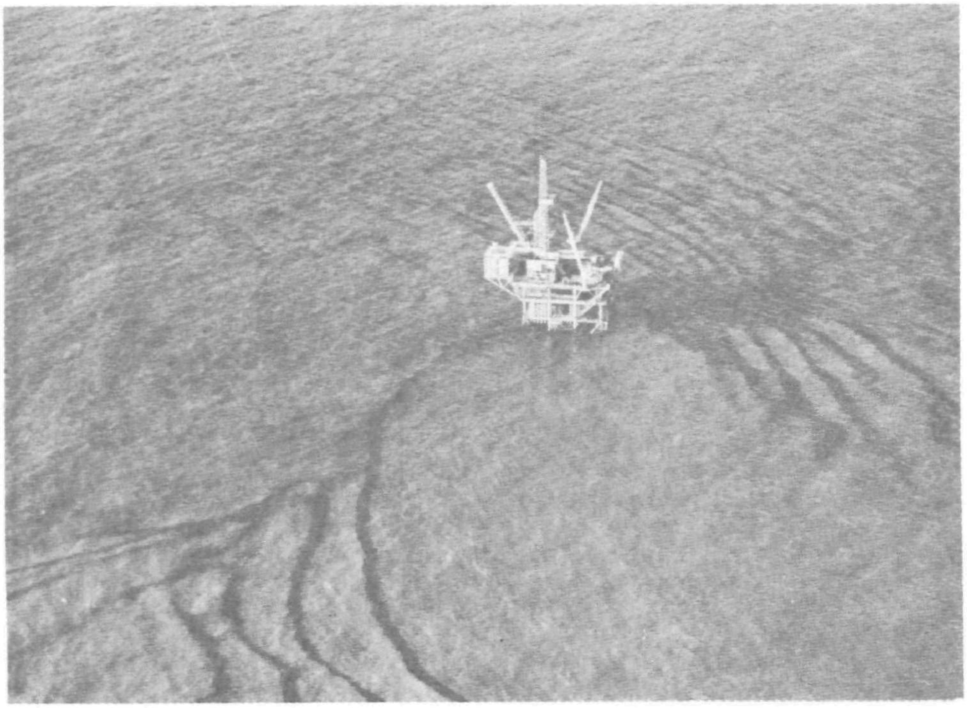


FIGURE 6.5. Oil Distributed in "Ropes and Windrows" (courtesy of Santa Barbara News Press)

The dispersants applied from surface vessels normally required auxiliary "mixer" ships to provide sufficient water surface agitation by their natural screw and hull wake. These auxiliary craft normally followed directly astern on both sides of the spray vessel. Up to four spray vessels and twelve "mixer" ships were employed at various times.[20] The use of chemical dispersants was almost totally discontinued in early March, but resumed again later in the month.

The policy of the FWPCA concerning the use of chemical dispersants in such situations[21] includes the following recommendations:

- Application should be restricted to areas further than 1-1/2 miles offshore to minimize the toxicity to nearshore marine life.
- The rate of application should be limited so as not to exceed a concentration of 5 ppm mixed in the top three feet of the water column.
- Dispersants should not be employed which contain solvents composed of aromatic petroleum fractions or chlorinated hydrocarbons.
- Application should be limited primarily to the leading edge of the slick.

The chemical dispersants used vary in price from about \$2.50-\$5/gallon. The dispersant sprayed from surface vessels was diluted with seawater during application to the water surface in ratios up to 80 parts seawater to one part dispersant.[22] The manufacturers generally supplied representatives and, in at least one case, operating personnel to supervise and conduct spraying operations. Based on manufacturer's literature the chemicals should be able to disperse between 10 and 50 gallons of oil per gallons of dispersant. The amount of dispersants applied during the incident (at least 37,500 gallons), therefore, should have dispersed at least 375,000 gallons of oil. It is impossible to determine if this was indeed the amount dispersed, but it seems highly doubtful as field conditions rarely approach the ideal.

The rental charge for the surface vessels employed to spray the dispersant in the open sea is approximately \$30-\$40/hr and the "mixer" ships probably rented for \$20-\$40/hr. The fixed wing aircraft used for spraying are estimated to have cost between \$30-\$40/hr. Two of these aircraft were employed.

When applied properly, the dispersants were effective in removing the slick from the water surface. Little or no quantitative information is available pertaining to the long term effectiveness, based on continuous visual observations of a particular area, of the dispersants used in the Santa Barbara Channel.

The following chemical dispersants and amounts used were reported by the Union Oil Company from 26 February to 8 March, 1969.

Chemical Dispersant	Amount Reported (55 Gallon bbls)	
Polycomplex A-11	227 1/2	
	20	(30 January to 5 February)
Ara Chem	140 1/2	
Unico	3 1/2	
Crane OD-2	19	
Correxit 7664	337	(30 January to 5 February)

More than 150 products were reportedly offered to the Union Oil Company as possible aids in treating the oil; most were not used because little or no toxicity data were available.[23]

The question of effectiveness of chemical dispersants was put to many, if not all of the contacts made in this review. There was no clear-cut concensus, although the majority felt that while the chemical dispersants decreased, at least temporarily, the visibility of the oil slick, the net effectiveness was marginal and the method was costly at best. Most agreed that mechanical recovery was preferable, if possible on the open sea. Quantitative data for comparative dispersant toxicity and effectiveness are almost wholly nonexistent and should be obtained under practical field conditions.

Subsequent to the initial drafting of this report, additional information was supplied by the Union Oil Company on tests conducted under their auspices.[41] A portion of their report is appended starting on page 6-26. It should be noted that these results apply only to the conditions of the tests and are not necessarily broadly applicable.

6.2.3 Physical Removal

In the first few days following the incident, attempts were made throughout the United States to locate oil skimmer systems. Those located were determined to be either incapable of open sea skimming or unable to be air transported to the scene. As a result, no existing open sea skimmers were brought to the scene, and efforts were directed toward designing systems to be adapted for use with available vessels.

Offshore work boats were equipped with suction pumps to remove the thick oil layers which accumulated on the surface and behind booms. This equipment was effective when the oil layer was up to several inches thick. The MV PIKE I was reported to have skimmed 250 barrels of an oil-water mixture (ratio unspecified) on 3 February.[24] Later in February, MV WINN was fitted with a Union Oil-designed skimming device consisting of a square box or chamber approximately seven feet on each side. Buoyancy was provided by empty 55 gallon drums on the corners. An overflow weir was mounted in the center of the box from which the oil-water mixture was pumped through the bottom of the weir to storage tanks on the ship. A curved boom was used in conjunction with this skimmer to collect the oil.

Operational problems were encountered when it was advanced through the water (too much water recovered), and straw reportedly plugged the intake. However, the device achieved some success when the oil was sufficiently concentrated. On 28 February, off-loading of 218 barrels gross, including 105 barrels of oil, from the WINN was reported.[25]

In early March, MV WINN was equipped with a side-boom skimmer designed by Union Oil Company (Figure 6.6). Two self-priming, high capacity centrifugal pumps were employed to transfer the oil through six-inch diameter lines from the skimmer to on-board storage tanks. These pumps were typical of those commonly used for dewatering behind coffer-dams and are capable of alternately pumping either air or water containing a considerable amount of solids. Each pump had a capacity of about 700 gpm and was equipped with a vacuum assist system for self-priming. The oil recovery apparatus consisted of an adjustable trough mounted transversely between two steel flotation cylinders in an open "V" configuration. The cylinders were approximately 26 inches in diameter and 20 feet long. The opening of the "V" was approximately 20 feet. The trough, ten feet long and 8 inches wide, was in the form of a "J" with the lower lip facing the direction of advance. The oil-water mixture, after entering the trough over the leading edge, was pumped from the bottom of the trough through one of two 6-inch lines. It was estimated that this device, as designed, would recover a 19:1 water to oil mixture.[26] Two 17,500 gallon ship tanks were employed; one for holdup and decanting, and the other for storage of the oil-water emulsion. The mixture was held in the decanting tank approximately 30 minutes before transfer to the storage tank.

This skimming device proved relatively effective while advancing at speeds up to five knots. Initial tests recovered 200 barrels of mixture, including 72 barrels of oil.[27] It was the only skimmer used that was capable of traversing slicks and recovering the "ropes" of oil formed by wind and wave forces and which extended for considerable distances (Figure 6.5). It was also successfully employed to skim the oil held up by kelp beds near shore. Auxiliary vessels were often employed to locate and windrow the oil ahead of the skimmer. The capacity of the skimmer

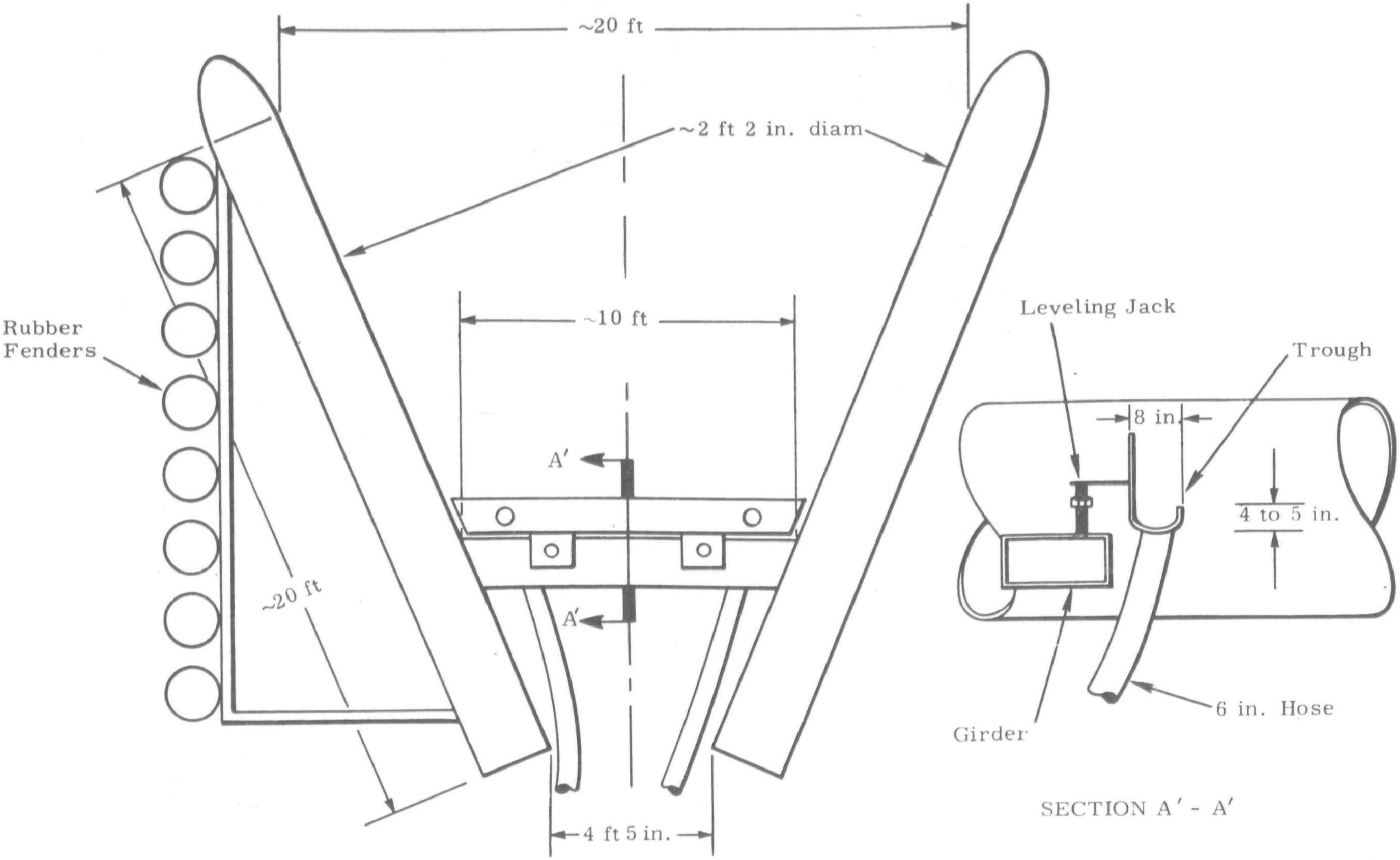


FIGURE 6.6 Open Sea Skimmer

under ideal conditions and working in a relatively thick slick was about 25 barrels per day. As much as 100 barrels of oil were off loaded every three to four days.[40]

Operational problems and limitations encountered during skimming were: (1) the piping between the skimming apparatus and pumps contained restrictions subject to clogging when straw or surface debris was encountered; (2) drag forces caused the skimmer to submerge and thus become ineffective when the speed of advance exceeded five knots; (3) the large physical size prohibited lifting the skimmer aboard ship and, therefore, transport to and from the scene was slow; (4) since a vessel tends to turn "on its bow", the side mounting presented a maneuverability problem in following a narrow "rope" of oil; and (5) splashguards were not included on the outriggers or behind the trough and therefore some of the oil was swept over the device in rough seas.

Skimming operations were not practical in winds exceeding 15 knots. Rough seas prevented operation on many occasions. Skimming was limited to daylight operations; therefore, a considerable amount of time was spent skimming oil that had escaped during the night. It is likely that the overall efficiency of this operation could have been improved if the skimming vessel did not have to spend a significant portion of time hunting for oil "ropes", i.e., some improved system of "spotting" would have increased the effectiveness.

The centrifugal pumps tended to emulsify the oil during each transfer operation and severe problems often were encountered offloading the oil to receiving trucks after the oil had been transferred between tanks at sea. A water-in-oil emulsion was formed with the approximate consistency of light grease after two transfer operations with centrifugal pumps. Chemical demulsifiers were occasionally necessary to achieve transfer.

Another skimming device, "Sea Sweep", was constructed for use at sea (Figure 6.8). This "Sea Sweep" consisted of two 800 foot sections of 20-inch diameter steel pipe joined at one end in the form of a "V" with an

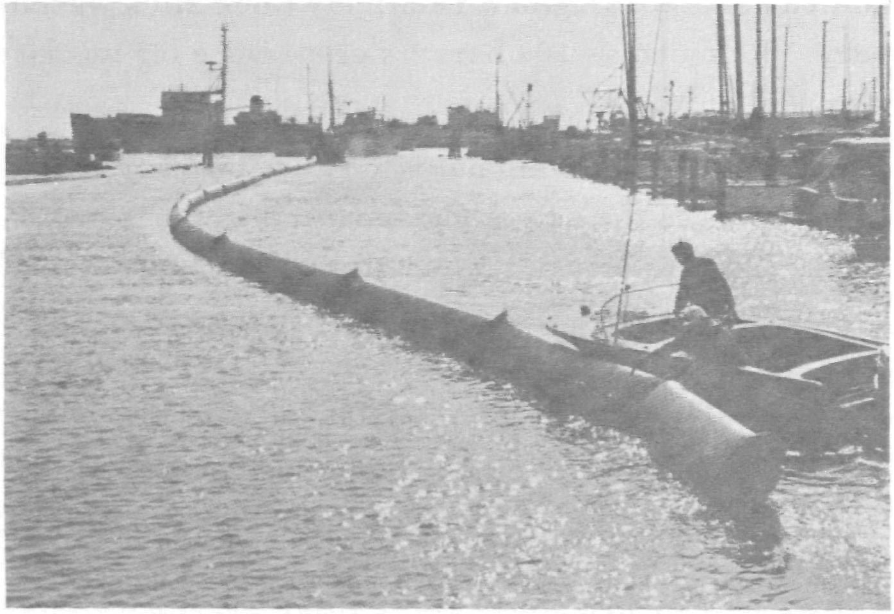


FIGURE 6.7. Inflatable Plastic Boom (courtesy of Santa Barbara News Press)

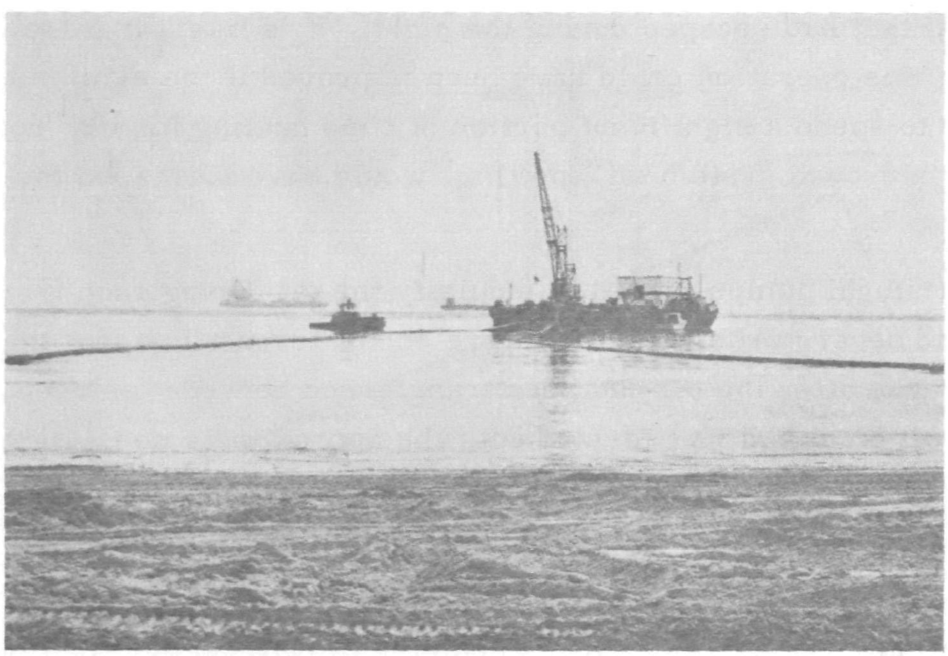


FIGURE 6.8. "Sea Sweep" Being Readied for Deployment (courtesy of Santa Barbara News Press)

opening of between 500-800 feet. Motive power was supplied by tugs. A recovery boat equipped with six pumping stations was to travel at the apex of the "V" and transfer oil to storage barges nearby (capacity, 12,000 barrels). The device encountered severe mechanical problems almost immediately, and the length of the pipe sections was subsequently reduced. Because of its inability to cope with rough seas, operations were terminated in mid-February after one day of operation.[28]

Other schemes considered, but not attempted, included: (1) a large, open bottom barge (140,000 barrel capacity) to be moored over the boil on the surface and the oil was to be pumped aboard and decanted on the scene, (2) 5,000 feet of gill net offered by the Bureau of Commercial Fisheries to drag through the water to collect oil-soaked straw,[29] and (3) commercial kelp harvesters, also to be used for the recovery of oil-soaked straw.

6.3 DEFENSE OF HARBORS

6.3.1 Physical Barriers

Most of the ports and harbors along the Santa Barbara coast were protected with booms strung across the entrances. The booms proved effective in relatively calm seas if the oil was continuously removed as it accumulated. A commercial inflatable boom (Figure 6.7) with a relatively deep skirt was used at Channel Islands Harbor and at Santa Barbara Harbor. Defensive booms prevented oil penetration of the major harbors on several occasions during the month of February. Santa Barbara was the only major harbor penetrated by large amounts of oil, although lesser amounts did enter Ventura Harbor.

Harbors and sloughs protected with floating booms were:

Santa Barbara

a) 2,000 feet of log boom extending south from end of Stearn's Wharf[30]

b) 500 feet of commercial inflatable boom, plus 1800 feet of cork boom[31]

c) Commercial boom with small skirt

d) Air curtain barrier.

Ventura Marina

Log boom (3 rows)

Channel Islands

Commercial inflatable boom

Port Hueneme

Two log booms supplemented with straw between

Point Mugu

a) 2,000 feet of log boom (a second timber boom was subsequently added)

b) 2,000 feet of plastic commercial boom

Avalon

2,000 feet of log boom (not deployed because oil never reached this harbor)

Sandyland

Unconfined straw boom (placed behind artificial berm)

Devereux Slough, Golita Slough, Mandolay Power Plant

Plastic boom

Many operational problems occurred during placement and use of these defensive booms. Floating booms or their moorings failed at Santa Barbara Harbor (inflatable boom), Ventura Harbor (log boom), Point Mugu (log boom), and Sandyland (straw boom). The log booms seemed particularly susceptible to structural failure of attachment cables, generally because of rough seas or heavy storm runoff. Large accumulations of kelp reportedly exerted great pressure against the inflatable boom across the entrance to the Santa Barbara Harbor. Four ships were required to maintain position of a 2,000-foot log boom extending south from the end of Stearn's Wharf.[30] Rerigging or readjustment was necessary at Point Mugu and Ventura. On one occasion the boom got out of adjustment at Ventura and permitted some oil to enter the harbor.[32] Heavy seas broke the Ventura Harbor boom on another occasion and again permitted entry of a small quantity of oil.

Constant removal of oil accumulating behind log booms was necessary to prevent its passage. Generally straw was used to facilitate recovery of the accumulated oil (Figure 6.9). In areas that employed a multiple boom system, such as Port Hueneme and Point Mugu, straw was spread between the strings of logs. Labor forces were on standby to remove oil accumulation behind the booms if there was any possibility of an oil slick entering the area. The necessity of maintaining standby personnel (~$7/hour per man) greatly increased the cost of defensive booming.

The defense of harbor entrances and features within the harbor can require different types of booms. No boom or system employed was completely successful for all of the required protective functions, even in calm water. The protection of rip-rapped or rocky areas such as within the Santa Barbara Harbor was best accomplished by either an unskirted boom or one with a flexible skirt. Rigid skirts extending below the water would be obstructed by underwater objects or often drift too close to the rocks, causing tipping on a falling tide.

Another problem existed on sandy beaches. Most booms observed could not accommodate the effect of tidal flow undercutting the sand at the point where the boom entered the water, thus creating an opening through which the oil could pass under the boom (Figure 6.10). Rigid-skirted booms or those strung tightly could not fill the passage created.

Large quantities of oil entered Santa Barbara Harbor on the night of 4 February. The boom across the entrance originally consisted of a 500-foot section of skirted inflatable boom (Figure 6.7) and an 1800-foot section of an unskirted cork boom stretched between the sandspit and the shore at the foot of Stearn's Wharf. Oil passed under the unskirted portion as it accumulated behind the boom.[33] A mooring line subsequently parted and the shore end of the boom was repositioned nearer the harbor jetty. The inflatable boom was punctured during the operations and permitted oil to come over that portion. The thickness of the accumulated oil behind the boom was estimated to be up to eight inches.[34]

FIGURE 6.9. Straw Being Used Behind Log Boom for Oil Absorption (courtesy of Santa Barbara News Press)

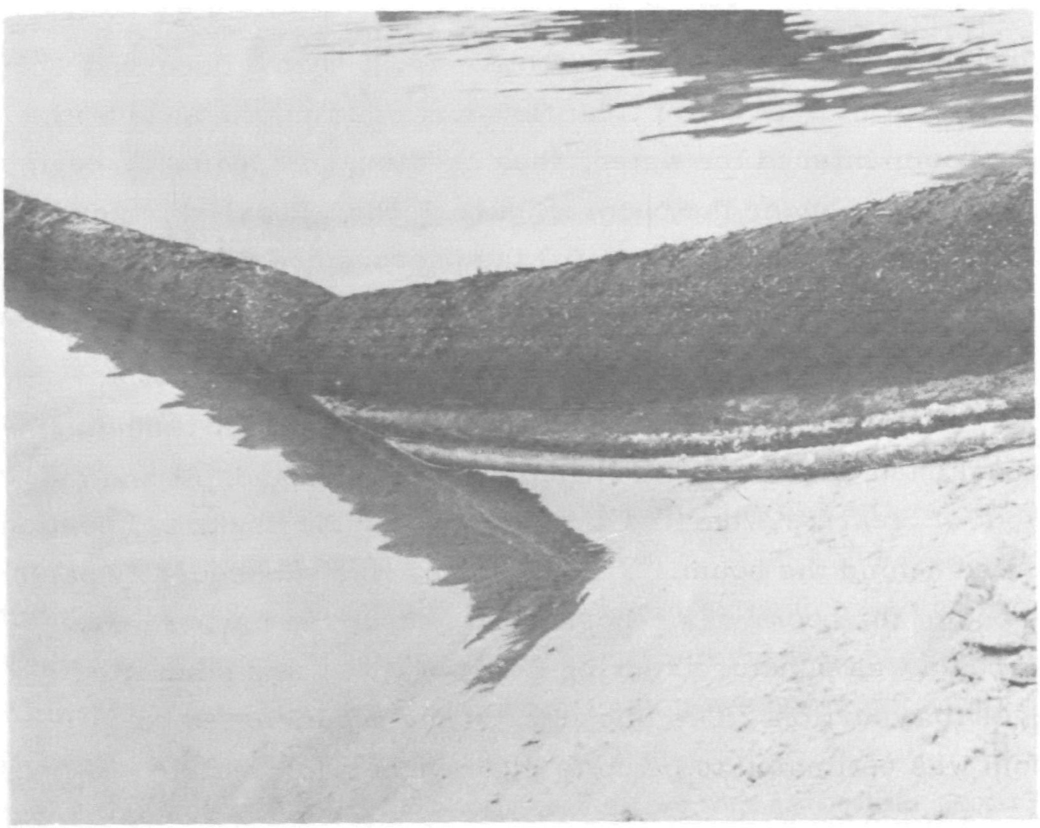


FIGURE 6.10. Semiflexible Boom at Shore Line

6.3.2 Air Curtain Barrier

An underwater bubble or air curtain barrier was installed between the jetty and sandspit at the entrance to the Santa Barbara Harbor (Figure 6.11). The first unit installed was about 500 feet long and was fabricated from one inch diameter aluminum pipe with perforations in the top. Emplacement was near the channel bottom. A portable trailer-mounted air compressor supplied air at nominally 100 psi.

The underwater bubble barrier caused an upwelling flow of water that resulted in a surface current in both directions away from the point of emergence on the surface. The net current effectively prevents passage of oil provided that surface currents are not excessive and that debris does not accumulate to be forced through by the wind. An advantage of this boom is that it permits unimpeded ship traffic. It is also relatively immune to damage by wind and waves.

The air barriers employed were in the development stage at the time of the incident and, therefore, emergency units were not available. The first unit, installed in mid-February, encountered many operational problems including compressor failure, filling of the pipe with sand and water during shutdown, a change of head due to irregular bottom contour resulting in insufficient air along portions of the barrier, inadequate upwelling in shallow water, momentary loss of effectiveness during the passage of ships, and passage of accumulated debris through the barrier.[35]

The barrier was normally shut down during ebb tide to permit the outflow of oil that had accumulated in the harbor.

A second air curtain proved much more effective, although a supplemental floating boom was still required in the shallow water near the sandspit where inadequate upwelling occurred (Figure 6.12). The pipe size was increased to a diameter of two inches and the underwater line was mounted about 15 feet below the water surface to obtain uniform air distribution. Two compressors were used: 600 scfm on the jetty side, and 250 scfm on the sandspit end. Check valves or flaps were reportedly installed over

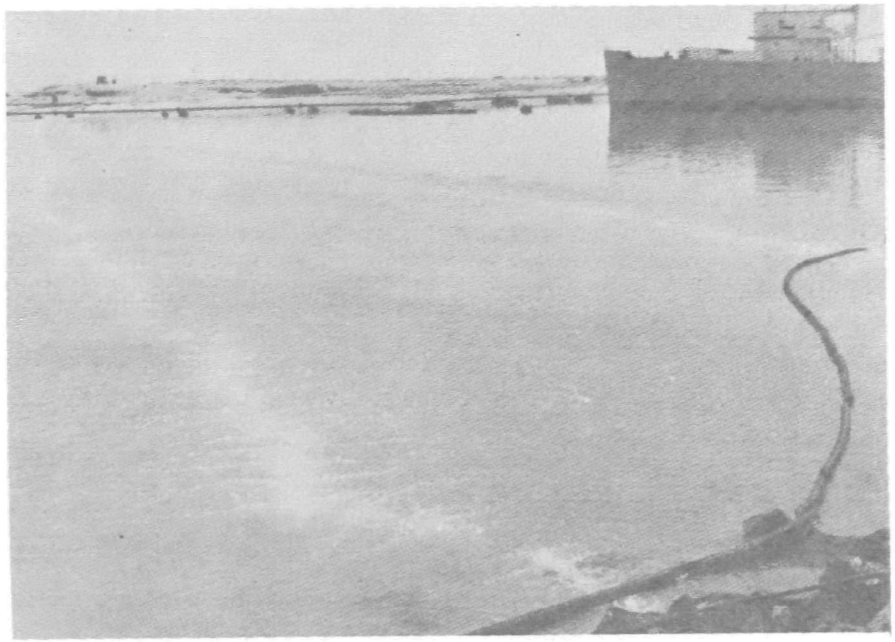


FIGURE 6.11. Air Curtain Barrier in Operation - Santa Barbara Harbor

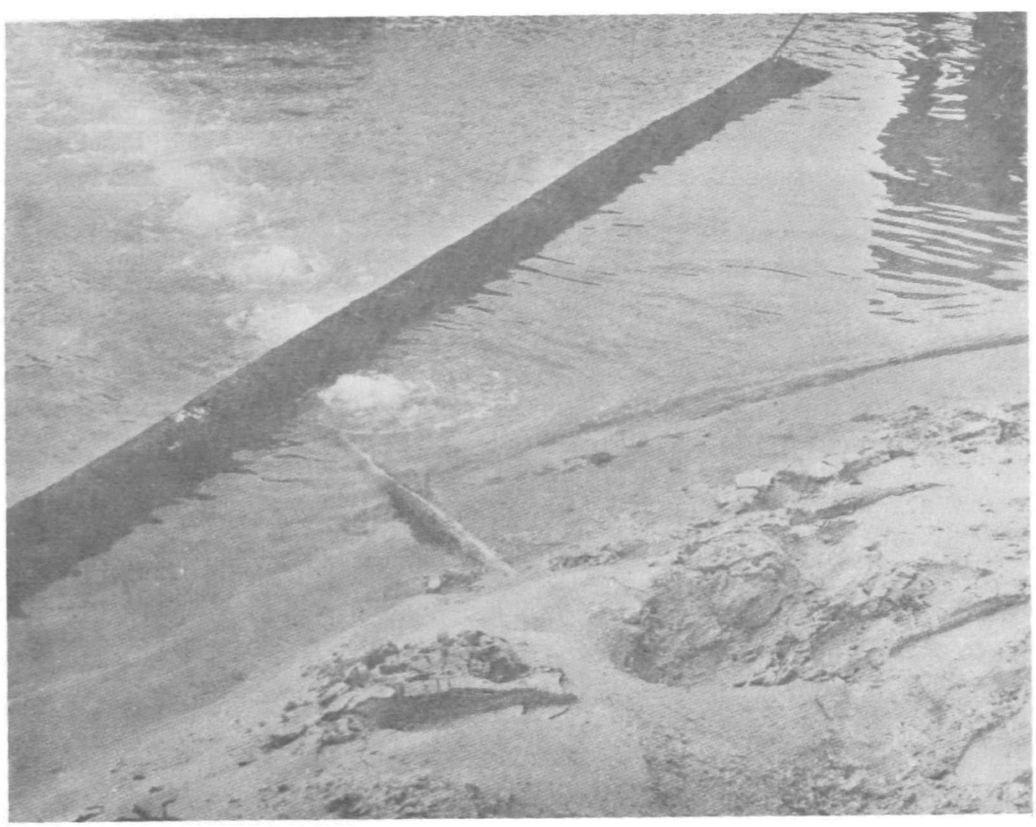


FIGURE 6.12. Area of Low Upwelling with Air Curtain Barrier

the air distribution orifices to prevent the pipe from filling with water and sand when the unit was shut down. The original unit was left in place to trap the oil that was carried past the barrier during passage of ships.[36]

The installation cost of air barriers is estimated to be about $4-$5/foot, exclusive of the compressor, the latter at about $20,000 for a 600 SCFM unit. Typical cost of rental units is about $1.25/SCFM/month.[37] The estimated cost of operating a unit that is periodically turned on and off such as was done at Santa Barbara (including maintenance and surveillance) is $3-$4/SCFM/month.

6.3.3 Other

The chemical dispersant "Polycomplex A-11" was applied inside the entrance to Santa Barbara Harbor to reduce fire hazard by dispersing oil. This particular dispersant was reportedly chosen because it was known to have a flashpoint in excess of 300 °F. Application was limited to one or two days following penetration of oil into the harbor.

6.4 DEFENSE OF BEACHES

6.4.1 Artificial Berms

Artificial berms erected in several locations were constructed of either beach sand or soil. Areas protected by berms included a residential development on the Ventura waterfront,[38] the upper end of the beach lagoon adjacent to the bird sanctuary of East Beach,[39] and the upper end of Mandolay beach. A weir was constructed at Sandyland cove and a dike was erected along a portion of Edgecliff Lane. The artificial berms were effective, but some subsequently had to be broken and rebuilt to permit draining of water accumulated by storm runoff.

Selected waterfront features such as bulkheads at the "Castle" at Sandyland were protected with plywood and sheets of plastic. Bulkheads can be protected with plywood and/or plastic for approximately $3-$5/foot in areas that do not have excessive wave action.

6.4.2 Sorbents

Straw was the principal sorbent material applied on the beaches. It was applied both from vehicles on the beach and ships operating parallel to the beaches a few hundred yards from shore. Several hundred tons were applied by these ships in the near-shore waters using mulchers (blowers) developed for highway applications. Vehicles equipped with similar mulchers spread the straw in the intertidal zone both before and after deposition of oil. A considerable amount of straw was also applied by hand.

Limited amounts of "Ekoperl," a proprietary product, and talc were tried but their use was discontinued due to cost and the difficulty in subsequent pickup. Additional discussions on the use of straw are given in Section 10.0.

APPENDED INFORMATION FROM UNION OIL COMPANY OF CALIFORNIA[41]

Qualitative Evaluation of Corexit 7664 and Polycomplex A-11 Dispersion of Crude Oil on Sea Water

A qualitative test of Corexit 7664 and Polycomplex A-11 to disperse crude oil floating on sea water was conducted on February 9, 1969 near Platform A in the channel at Santa Barbara. The tests were observed by Dr. P. J. Kinney and Dr. Don Button of the University of Alaska and Ken Becker of Enjay Chemical Company.

The dispersants were sprayed on a floating crude oil slick with dilution water from a moving boat. Following were observed:

1. There appears to be no significant difference in the dispersion ability of Corexit and Polycomplex when Polycomplex is applied to approximately one-half the dosage rate of Corexit.
2. When either Corexit or Polycomplex was sprayed on a black crude slick and not mixed by the wake of a moving boat, very little dispersion of the floating crude occurred at the point of spray entry into the floating crude. There appeared to be a sharp reduction in surface tension. The floating crude oil pulled away from the point leaving a brownish wrinkled floating layer of thicker crude surrounding green water. Microscopic inspection of the brownish layer revealed water in oil emulsion.
3. When either Corexit or Polycomplex was sprayed on a black crude slick and mixed by the wake of the boat moving at 10 knots/hour, there appeared to be good dispersion along the boat's path for a width of 150 ft.

Green water was evident in the wake with small patches of black crude spreading out into iridescent and gray films. The boat path remained open in the slick. After one hour, a bucket sample of sea water from the opened path contained many 0.010 inch diameter and smaller spherical particles of black oil. Some of the larger particles of black oil floated to the surface in the bucket and broke into an iridescent film. Many of the smaller particles failed to rise to the surface of the sample after one hour of settling.

4. When the boat was run through the slick at 10 knots/hour with no application of dispersants, the slick was dispersed along the boat's path very similar to the runs with dispersants. The boat path remained open in the slick. The bucket sample of sea water from the open path appeared similar to those obtained in the dispersant runs. There were possibly a few more larger spheres of oil that settled to the surface and decayed into an iridescent film.
5. It was concluded that the dispersants tested were not significantly better than the mechanical mixing energy supplied by a boat's propellers when attempting to break up an oil slick in open sea.

Discussion

The tests were conducted utilizing the supply ship Pike I which is a flat bottom vessel of 130 ft length, 30 ft beam and twin screw with 1300 h.p. All running tests were conducted at 10 knots/hour at an estimated 70% power setting.

The dispersants were applied by pumping 200 barrels/hour of sea water through a 1-1/2 in. pipe by 20 ft long nozzle spray boom mounted forward and two 1-1/2 in. fire nozzles mounted aft. The spray system gave a net 30 ft wide spray application on either side of the vessel. The dispersants were added into the suction of the sea water pump at the following rates:

	Barrels/hour (55 gal/bbl)
Corexit 7664	2-1/2
Polycomplex A-11	1

A black crude oil slick of approximately 200 feet width and 2 mile plus length was utilized for the tests. Thickness of the oil in the slick was estimated to be approximately 1/16 inch thick at the center. The boat cut across the width of the slick during the test runs. Winds were slight at less than three knots/hour from 310 degree compass bearing. Ocean swells were slight (one foot) with no wind ripples.

Polycomplex A-11 Versus Corexit

These tests were conducted in standard glass sampling jugs with screw metal tops and graduation tapes from top to bottom.

Test I

Water - 7500 cm^3

Oil - 1800 cm^3 (twenty gravity)

Polycomplex A-11 - 125 cm^3, added to surface of oil. Jug was inverted with vigorous action six times.

Perfect complexing occurred. Breaking time - 1 hour. The separation was not complete. The salt water was still heavily clouded and instead of the original 1800 cm^3 of oil, we now had a measurement of 2400 cm^3 of same color density. Test discontinued at one hour.

Note

The manufacturer states that "for complete dispersion you must have at least 50 times as much water as oil". In this test we had only four times plus as much water.

Test II

Corexit 7664 - 125 cm^3 added in a duplicate situation to Test I. Also, six vigorous inversions of the jug were made.

Breaking time - 1-1/2 minutes. The separation was complete.

Another 25 cm^3 of Corexit 7664 was added, and again six inversions of the jug. Breaking time - 6 minutes. Break was complete, with a total of 200 cm^3 of Corexit 7664 used. Test discontinued.

Conclusions

Polycomplex A-11 complexed this crude sample completely, and proved vastly superior to Enjay Corexit 7664.

Dispersant Evaluation

Material: ARA Gold Crew Bilge Cleaner
ARA Chem. Inc.
808 Gable Way, El Cajon, California

Summary

ARA Gold Crew Bilge Cleaner has the ability to disperse the type of oil being lost at Platform A in concentrations as low as four gallons of chemical per barrel of oil, provided the oil is relatively nonweathered and the chemical is applied with a great deal of agitation. Chemical concentrations approaching seven to ten gallons per barrel of oil added with violent agitation, followed by further agitation such as boat wakes gave rapid visible results. It is infeasible and economically unsound to attempt to disperse the oil once it has lost its light fractions through weathering and is approaching the consistency of a heavy gas oil or light residuum. It is felt that ARA Gold Crew would work excellent in quite low concentrations on light oil spills or iridescent slicks within harbor confines. Its toxicity to marine life is currently being checked by means of bioassays.

Discussion

Sunday, March 2, 1969, I accompanied Mr. W. L. Tinker, representative of ARA Gold Crew aboard the M. V. "Coast Tide" for an evaluation of the effectiveness of this chemical to permanently disperse the oil slick from Platform A. The system employed for applying the dispersant consisted of a sump pump taking sea water suction, and a second pump taking suction on barrels of the chemical, admixing it with the sea water and discharging the mix through two fire hoses equipped with 90 gpm nozzles at a pressure of 85 psi. The hoses were affixed on each side of the vessel just forward of mid-ship. Application was made by directing the nozzles straight down from the hull then whipping the nozzles, adjusted for a nearly straight stream of water, through an arc of 10 to 15 degrees perpendicular to the side of the hull. This resulted in a violent agitation of the water surface from a distance of about six to ten feet. The strength of the stream alone was sufficient to break up the continuity of the oil slick.

Additional agitation of the oil-chemical mix was provided by work boats plying at fairly high speeds across and through the sudsy wake left by the chemical. The suds resulting from application of the chemical are in themselves of little value. Little, if any, chemical action was noted in the foam line. For inner harbor work esthetics would be better served if no suds were produced. ARA Gold Crew in comparison to other dispersants noted, primarily the Crain OD-2, could be rated as a low sudser.

The chemical as it works, first turns the oil to a dark brownish color. This effect was particularly notable as the work boats plowed through our wake. The black oil from their bow could be seen turning brown as the chemical-oil mix became agitated together. It is apparent that dispersion, regardless of chemical concentration, is slow and inadequate unless proper agitation is provided. The volume of oil on the surface at the time the test was made and the combined boat and wave action made it essentially impossible to retrace our path and determine if a clear swath had been established. Even so, I was convinced the product was doing a good job of dispersing the oil.

Some rather crude hand tests were made using one quart Mason jars to further determine the chemical's effectiveness. By sampling the oil and the chemical mixture being applied, hand mixes were prepared and agitated by shaking. At concentrations of approximately four gallons of chemical per barrel of oil, it was noted that shaking did disperse the oil and that no oil clung to the sides of the jar. Upon standing, the oil re-agglomerated at the surface, but had lost its stickiness. Slight agitation, similar to wave action, would again disperse the oil throughout the jar. Results at such low concentrations would be slow, but with continued wave action would probably be effective.

Where lesser amounts of chemical were tried, some dispersion took place, but the oil came back together on standing and would not again disperse on shaking. My rather rapid conclusion would be that a concentration in the area of ten gallons of chemical per barrel of oil would be the most economical and yet effective application of the ARA Gold Crew.

Later tests on heavily weathered oil proved completely ineffective. Chemical was applied essentially full strength with the result that some iridescent film was released, which could only result in the oil becoming even more sticky and tarry. It is my opinion that the use of dispersants on weathered oil is a waste of money.

It would be most interesting to apply ARA Gold Crew to an inner harbor light slick and note the results. I can visualize for such work application by a Hudson type sprayer from a skiff, since the degree of agitation could probably be much less and the production of suds is undesirable.

Bioassays are being run on the material by the Nuss Corporation to determine its toxicity to marine life.

Chemical Testing

Vessel: M. V. Pike I

Equipment: Side beam sprayers, one out each side. Booms about 15 ft long with three spray heads on each boom; using vessel's pumps on sea suction to supply water at about 30-32 lb pressure. Engineer unable to estimate pumping rate. The chemical was being added, using a small portable barrel pump.

Dosage: Chemical was being added at the rate 1 bbl/40 min. Would estimate this to be a ratio of water to chemical of about 40/1 to 50/1.

Comments: This type of spraying provides none of the agitation of the water surface required to mix the chemical with the oil. Chemical solution appeared to ride on top of surface. This method appears to be very unsatisfactory except in possibly very choppy water or unless a very high concentration of chemical is used. About 3-4 parts of oil to one-part chemical. No information was available as to the manufacturer's recommended concentration or method of application.

Chemicals Tested

1. Polycomplex A-11. They were just finishing the last couple of barrels when I arrived. Took two samples: (1) Sample immediately after spraying. (2) Sample after second application.

On both of these samples, the oil would break down into small particles on agitation. However, as soon as agitation was stopped, the oil would quickly rise to the surface in a thick, sticky film.

2. Crane Industrial Product OD-2 Biodegradable Oil Slick Disperser. Sample of the sprayed oil differed little from the samples sprayed with the Polycomplex A-11. However, when adding the undiluted chemical to a sample of oil using one part chemical to about 3-4 part oil, the oil immediately broke down into a very light emulsion. This emulsion was not sticky and showed no visible change after setting for two days.

On March 5, 1968 received information on manufacturer's recommended concentration and application. On light and moderate spills on water, the manufacturer recommends using one part chemical to 3 parts water sprayed over the oil slick. Then after about 30 minutes, slick should be agitated to disperse the oil. On heavy oil slicks, undiluted chemical should be sprayed directly onto the spill at a ratio of one part chemical to six parts oil. Used under these conditions, I believe that this material would do a good job of dispersing an oil slick.

Feasibility Tests on Removing Or Controlling Free Oil from the Surface of Water by the use of Scott Industrial Foams

On Saturday, February 22, 1969, a series of tests were conducted by Mr. Ron St. Pierre, Mr. Skip St. Pierre, and Mr. Pat Zaremba of Wilshire Foam Products, to determine the feasibility of using Scott Industrial Foam to remove or control free oil contamination from the surface of the ocean. The tests were witnessed by Mr. Ross Wright and Mr. Sam Taber and several other members of the Union Oil Company. The testing was performed from the deck of a boat provided by Union Oil Company about eight miles offshore of Santa Barbara, California.

The first tests were run to determine how much oil would be absorbed by foam as it floated freely on the surface of the ocean. The foam used for these tests was 24 x 36 x 4 inch samples of Scott Industrial Foam 10 PPI, 20 PPI, 30 PPI and 60 PPI.

The various foams were put over the side of the boat and directly into an oil slick. They were allowed to remain in the oil for periods ranging from 5 to 30 minutes. The foam was then removed from the oil and examined to check oil absorption and penetration. The penetration was determined by cutting into the center of the 4 inch slabs of foam and observing same. Penetration was approximately 1/2 to 3/4 inch in all cases. The surface absorption was visually examined. After each test, an attempt was made to squeeze out the oil that had been absorbed by the foam.

Upon our examination of this first test, it was decided that the 20 PPI foam worked best, however, it did not absorb enough oil to make its use for large oil spillage applications practical. Both Mr. Wright and Mr. Taber of Union Oil Company agreed with our conclusion with this phase of the testing.

The second test was run on a 24 x 36 x 4 inch piece of 10 PPI foam. Weights were attached along one of the 36 inch dimensions and a buoyant material was attached along the other 36 inch dimension of the material. The foam was then suspended over the side of the boat from a long pole and emersed in the water so that approximately 12 inches protruded above the water. Lines were attached to the foam so that it could be held in an upright position while suspended at a right angle to the side of the boat.

The boat then proceeded at a slow speed, (approximately 2 or 3 knots) through the oil slick. As the foam was moved through the water, it was observed that the water was passing freely through the foam while the oil remained on the upstream surface of the foam. The foam was then removed and examined. A large quantity of oil was found on the upstream side of the foam, while no oil was found on the downstream side of the foam. This test indicated to us that the 10 PPI foam could be efficiently used in the control, or pick-up of oil from the surface of water.

The foam could be used to prevent oil from moving from one place to another, or to move the oil from one place to another, or to actually pick up small quantities of oil from the surface of the water. Mr. Ross Wright of Union Oil observed this portion of the testing and agreed with our conclusions. However, he stated that Union Oil was interested only in a finished product that was ready for use. They were not in a position to do research work with the media only.

In summary, we believe the absorption tests were not, in our opinion, practical. However, the boom type tests employing the 10 PPI were quite successful. We believe it is for Wilshire to interest an outside company in pursuing the above use of the 10 PPI on a commercial basis. There are several such companies on the West Coast that we will be contacting regarding this matter.

Throughout the entire testing program, we had the complete cooperation and assistance of the people from Union Oil Company.

United Sierra Talc Test

Tuesday, March 11 0530-1830 5 hours

Left L. B. at 0530 for S. B. to set up Talc test. At 1030 accompanied by Dan Dunlap on "Winn" proceeded to Platform A. Found some streaks of fairly heavy new oil. Sprayed United Sierra Talc on these streaks using regulation foamite generator and ship's salt water fire system. System pressure was 50 psi and we used a 1-1/2 inch orifice nozzle. Talc could be sprayed in a fairly even spread about 10-12 feet wide. Put out 10 sacks in approximately 25 min covering an estimated 1/4 mile circle. Then observed carefully by travelling periphery. Talc definitely does not sink the oil. It will combine to a small degree forming small curds which still float. It would take forever to clearup any degree at all of slick using this material. At 1 p.m. abandoned the test and skimmed until 3:45 p.m. when rough water caused us to quit. Arrived Stearns wharf at 5:30 p.m.

SECTION 6.0 REFERENCES

1. Oil and Gas Journal, March 17, 1969, p. 49.
2. Wiegel, "Oceanographical Engineering," Prentice Hall, Inc., Englewood Cliffs, N.Y., 1964.
3. Coast Guard On-Scene Commander's Report.
4. Ibid
5. Union Oil Company Daily Report, 3 March, 1969.
6. Union Oil Company Daily Report, 9 March 1969.
7. Santa Barbara News Press, 7 February, 1969.
8. Coast Guard Situation Report No. 4, 30 January, 1969.
9. Union Oil Company Daily Report, 22 February, 1969.
10. Ibid, 11 March, 1969.
11. Union Oil Company Daily Report, 26 February, 1969.
12. Ibid, 12 February, 1969.
13. Coast Guard Situation Report, No. 15, 1 February, 1969.
14. Letter from R. J. Kaneen, California Department of Fish and Game, to Coast Guard On-Scene-Commander, 15 May, 1969.
15. Personal Communication with Thomas H. Gaines of Union Oil Company.
16. Enjay Magazine, Fall 1968 Issue.
17. Personal Communication with Thomas H. Gaines, Union Oil Company.
18. Coast Guard Situation Report No. 10, 31 January, 1969.
19. Personal Communication with Thomas H. Gaines, Union Oil Company.
20. Ibid
21. A Statement to the United States Senate Committee on Public Works, by Kenneth E. Biglane of the FWPCA, 25 February, 1969.
22. Letter from W. H. McNeeley of Ara Chem, Inc. to FWPCA, 25 March, 1969.
23. Chemical and Engineering News, 17 March, 1969, p. 40.
24. "Offshore Oil Well Blowout, Union Oil Company Well," Harbormaster of Santa Barbara Report, 22 April, 1969.
25. Union Oil Company Daily Report, 1 March, 1969.
26. Personal Communication, Capt. Tatro, MV WINN.
27. Union Oil Company Daily Report, 7 March, 1969.
28. Santa Barbara News Press, 17 February, 1969.

29. Summary of Coast Guard Situation Reports, 4 February, 1969.

30. Coast Guard On-Scene - Commander's Report.

31. "Offshore Oil Well Blowout, Union Oil Company Well," Harbormaster of Santa Barbara Report, 22 April, 1969.

32. Union Oil Company Daily Report, 12 February, 1969.

33. Personal Communication, Santa Barbara Harbormaster.

34. Ibid

35. Union Oil Company Daily Report, 23 February, 1969.

36. Personal Communication, R. S. Crog, Union Oil Company.

37. Personal Communication, E. K. Thompson, Crosby and Overton.

38. Santa Barbara News Press, 8 February, 1969.

39. Union Oil Company Daily Report, 17 February, 1969.

40. Personal Communication, George P. Metson, General Marine Transport of Santa Barbara Inc. June 26, 1969.

41. T. H. Gaines. "Notes on Pollution Control Santa Barbara." Appendix III, undated.

7.0 SURVEILLANCE

7.1 VISUAL OBSERVATION

Surveillance of the progressive development and movement of the oil slicks on the ocean was undertaken by both surface and airborne methods. Surface observation utilized Coast Guard patrol craft and work boats to report general slick behavior and relative thickness. There was no significant amount of mapping carried out from the surface craft, but a considerable effort in mapping the movement and extent of the oil was made by both visual and photographic techniques from aircraft.

Frequent flights were made in USCG and USFWS aircraft by contingency team observers who plotted the position of the slicks on blank charts of the Santa Barbara Channel. Such mapping was semiquantitative in that distances, slick width and relative thickness were estimated by eye. Also, the area covered by the many slicks and the large number of "stringers" emanating from primary and secondary slicks resulted in a very complex pattern that would be difficult to map in its entirety solely from visual observation. Attention, therefore, was focused on mapping the primary oil patches as these were determinable from the continuity of connection with surface leakage at Platform A and from color contrast, i.e., the darkest color was indicative of a relatively thick oil film. The proximity of oil to beaches and kelp beds also was observed and plotted so that control or clean-up operations could be scheduled and instigated as appropriate. Visual and photographic mapping could not be effectively pursued during hours of darkness, since no significant amount of the slick was discernible even with moonlight illumination.

In one instance, a USGS mobile radar-tracking station (M-33 unit) located on a hill overlooking the area used an X-Y plotter to track a low flying USGS plane as it visually traced along the path of the major slick.(1) Although the accuracy of the observation was good, the method was fairly well restricted to determining the boundaries of the major slicks.

Oil location diagrams (constructed primarily from visual observations) were prepared daily by the U. S. Coast Guard showing the chronological development and movement of the slicks. An example of such diagrams is shown in Figure 8.7.

7.2 PHOTOGRAPHIC

Varying results were obtained using aerial photography to detect and map the oil slicks. Generally, as with most photographic techniques, factors such as film sensitivity, lighting, altitude and haze were responsible for the varied results. The later vast area of oil spread made it difficult to obtain good real-time photographic coverage due to both the long flight periods involved and to changes in lighting and visibility over the large area encompassed. Thus, the assemblage and interpretation of photomosaics would be an arduous task.

The Apollo-9 astronauts, in-flight at the time of the oil spill incident, were requested to attempt to photograph the area. It is understood that at least one photograph showing essentially the entire oil slick coverage was successfully obtained.

7.2.1 Infrared Sensitive Film

Several organizations (U. S. Geological Survey, Air Force) made infrared photographic flights over the oil slicks. Colored infrared (false color) film was fairly efficient in detecting the slicks and the oil-water interface at low (5000-10,000 feet) altitudes. Vegetation (e.g., kelp) also showed good contrast, as expected, on infrared color plates. Oblique photographs were taken on some of the high altitude flights to obtain maximum reflection from the oil slicks; in some instances this enhanced the contrast of the oil-covered surface; in other instances sunlight reflected from the water surface made it difficult to define the oil slicks.

Photographs taken from a plane showed good definition of oil intermingled with kelp (Figure 7.1). Good contrast in this case was obtained using Infrared Ektachrome Film with either the K-2 (yellow) or 25A (red) filter.[2]

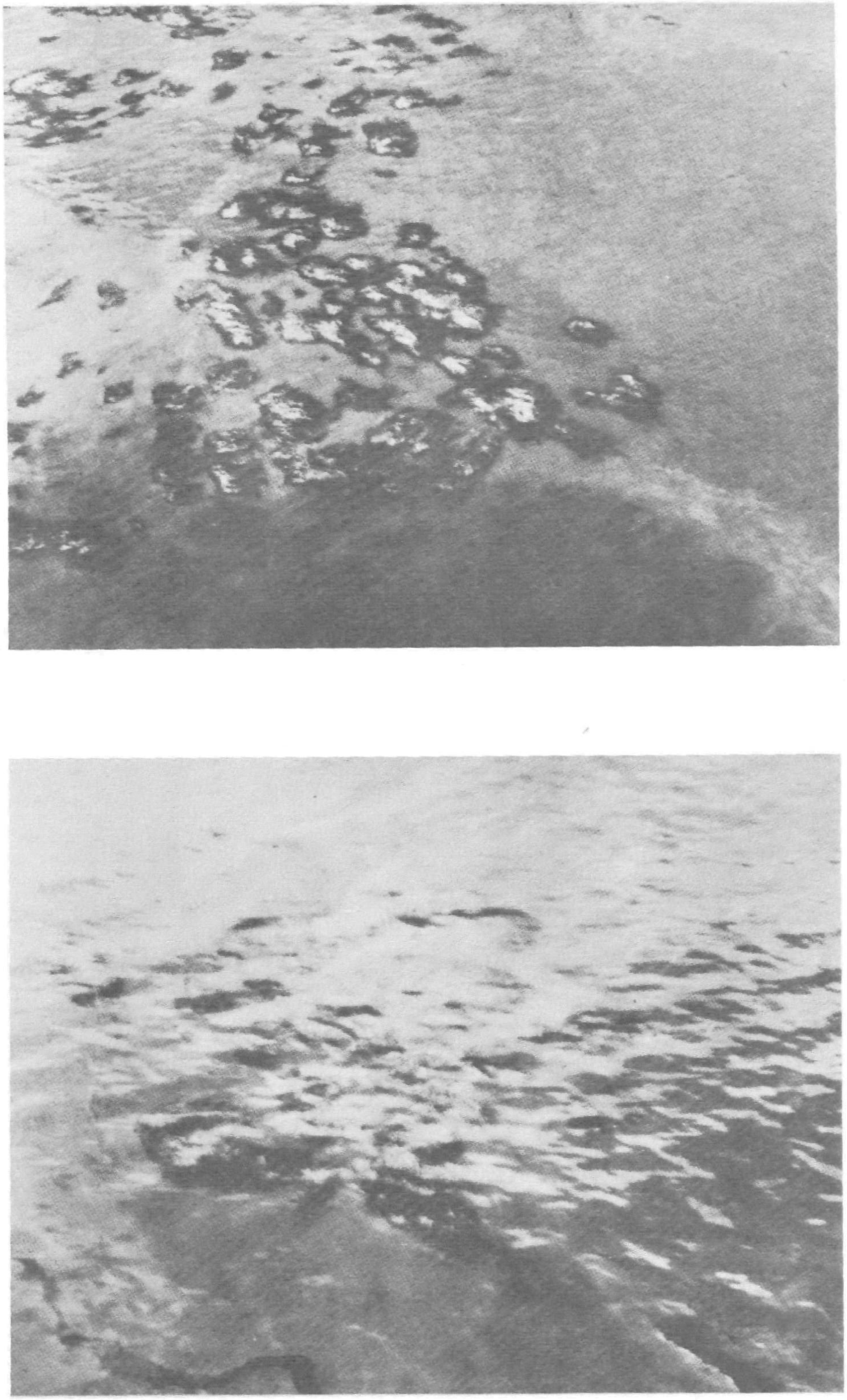


FIGURE 7.1. Infrared Ektachrome - Contrast of Oil and Kelp

Flights also were made using "Camouflage Detection" film which gives a black and white image with high sensitivity in the near infrared region. With some exceptions, the series of sequential photos which made up the film strips did not reveal the definitive oil-water interface that could be discerned by other than a highly-competent film interpreter.

7.2.2 Panchromatic and Color Film

Panchromatic (black and white) photographic results, in general, were much like those obtained using the Camouflage Detection film. That is, in some cases quite good definition of the oil slicks was evident; however, usually the results were similar to those in Figure 7.2 in which there is poor contrast even in the vicinity of the platform.

Conventional color film exposures, obtained by the U. S. Geological Survey and the Naval Air Station at Point Mugu, generally showed good contrast when taken at low altitudes. The latter organization reported good oil-water contrast on the Ektachrome (color) movie film made from a low-flying helicopter. Still color photos taken from the shoreline showed the oil slick partially, and improved definition was obtained on near-flat views. High-altitude color photographs were in most all instances ineffective in defining the oil slicks due primarily to haze interference.

7.3 REMOTE SENSORS

Several types of passive, remote sensing systems were evaluated to determine their effectiveness in detecting the oil slicks and in defining both the chemical and physical characteristics of the slicks. Systems used by the governmental agencies and private organizations known to have participated employed infrared, ultraviolet, multiband video and microwave detectors. All of the instruments were mounted in aircraft with one exception: a trailer with boom-mounted microwave radiometers (Aerojet General Corp.) was used along the Rincon Causeway to obtain spectral response data on nearshore oil slicks and deposits.

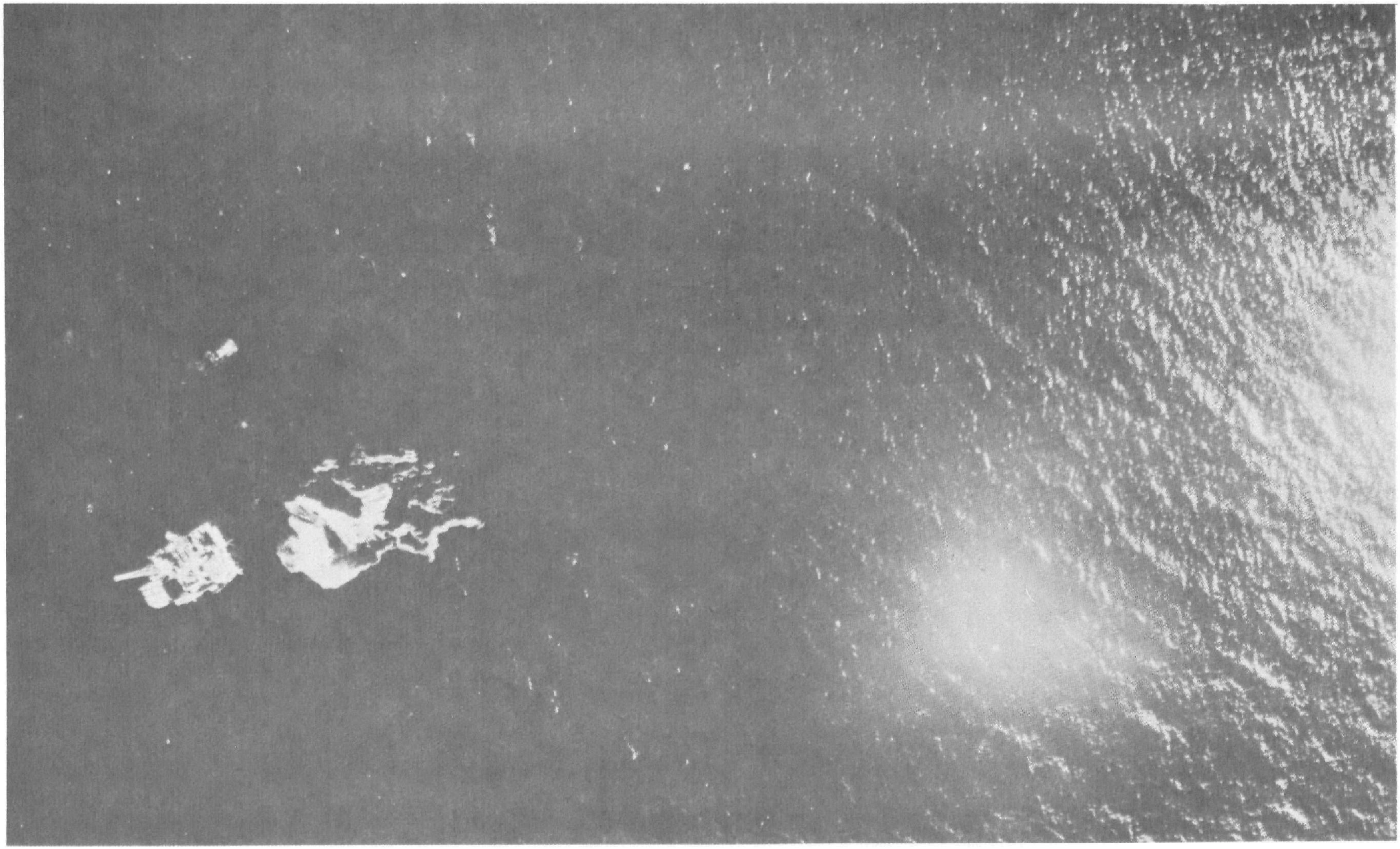


FIGURE 7.2. Aerial Photography Panchromatic Film - K-2 Filter

The considerable amount of remote sensing studies undertaken was concurred in by recommendations of the OST Special (Dubridge) Panel, to-wit, "...Advanced techniques such as infrared, which will eventually be capable of estimating thickness, state of oxidation and physical factors of the oil slick should be employed..."[3]

7.3.1 Infrared and Ultraviolet Scanning

Airborne infrared scanning and recording equipment was used by the USGS, University of Michigan and North American Rockwell to determine response characteristics in the near (0.8-1.0μ) and thermal (8-14μ) infrared regions. Generally, similar responses and results were noted by these observers. The infrared (IR) flights were made at fairly low altitudes (2000-10,000 feet) and under varying weather and lighting conditions. Good contrast between oil slick and water was obtained during clear weather (night or day) in the thermal (8-14μ) region. Very little contrast was noted in the near IR region. As expected, IR results showed decreasing contrast and definition as the weather varied from haze to total overcast.[4] That thermal IR sensing methods are capable of detecting oil slicks under clear, nighttime conditions is clearly evident from Figure 7.3.

Thin oil films near the edge of the primary (thick) slick emanating from the platform area showed the highest oil-water contrast in the thermal region. In this case the oil slick appeared colder than the adjacent water surface (cold shows as dark exposure on the scanner film). The relatively thick oil layer near the platform showed much less contrast in the thermal region, and its response was about the same or perhaps slightly warmer than the water surface temperature. Reasons for the different responses have yet to be resolved; however, several possible causative factors concern: surface characteristics (roughness) of the oil film, changes in chemical composition of the oil with aging which might result in spectral characteristic changes, and heat transfer phenomena associated with film thickness, evaporation rates and/or composition. Laboratory measurements and analyses are presently being undertaken to better define the quantitative information obtainable from remote sensed data collected on the flyovers.

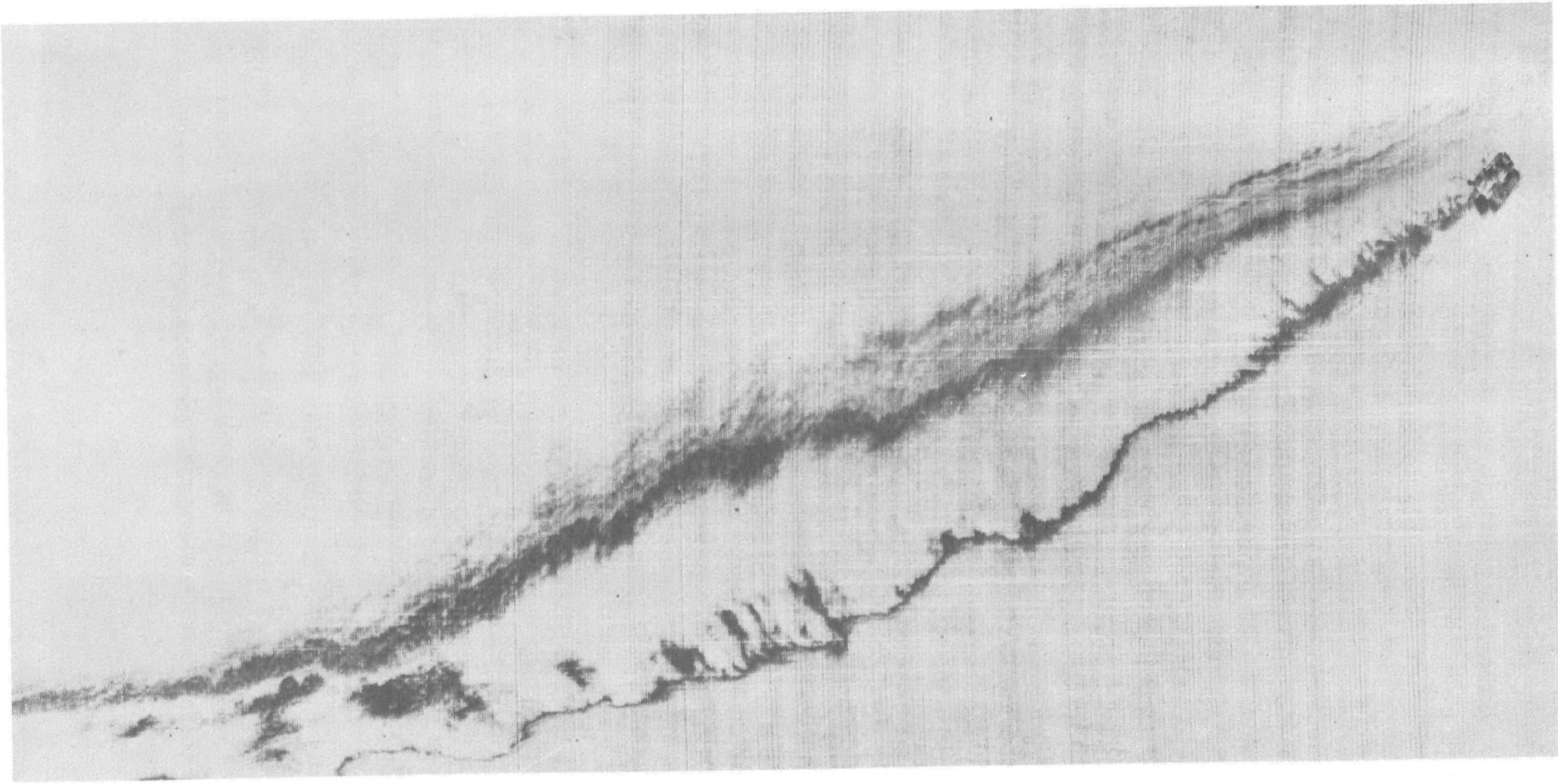
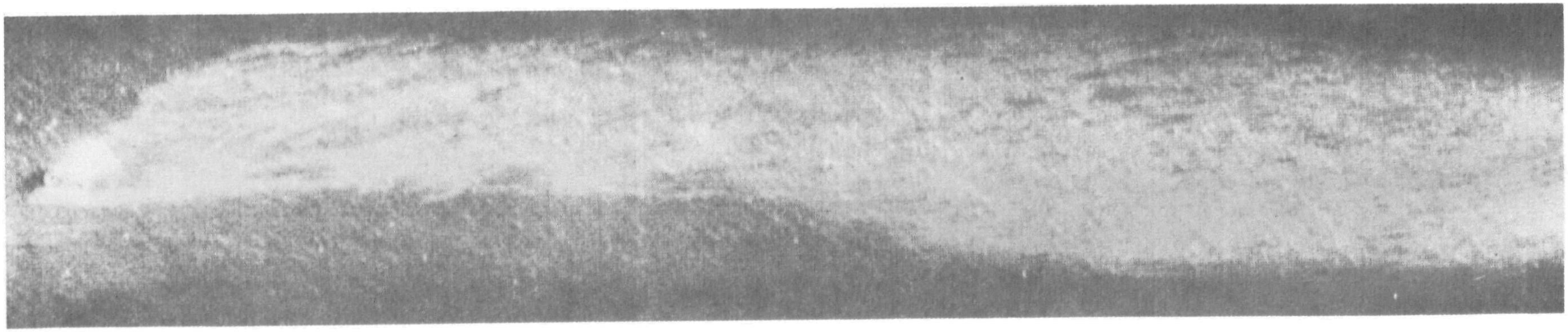


FIGURE 7.3. Nighttime Image (8-13μ band) of Platform A and Oil Seepage. Flown 27 March, 1969 (Courtesy of North American Rockwell)

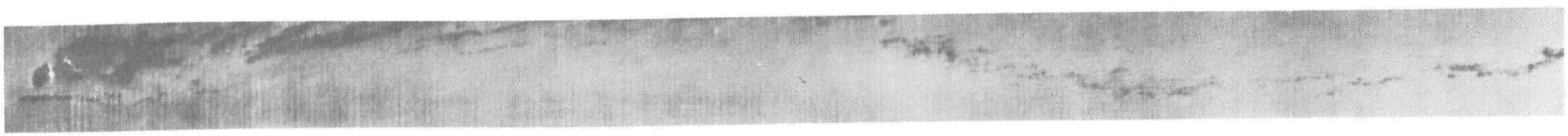
Some ground truth measurements were taken in conjunction with a North American Rockwell flight on 24 March.[5] A small patch of Platform A crude oil on the water surface was sequentially scanned and surface observations were made of slick size, thickness, oil and water temperatures as the aircraft collected data on the expanding slick. Hopefully, these results will be quantitatively correlatable with much of the imagery collected over the channel oil spill.

Information collected by the USGS and with the multi-spectral instrumentation of the University of Michigan indicated that the greatest oil-water contrast was in the thermal infrared and ultraviolet ($0.32 - 0.38\mu$) regions. Wavelengths between these regions showed much less differentiation of the oil and water. Figures 7.4 through 7.6 show typical responses of the oil, kelp and water in the various spectral regions (photos courtesy of Infrared and Optics Laboratory, Institute of Science and Technology, the University of Michigan).[6] Figure 7.2 is a panchromatic photograph, taken in the early morning, which shows Platform A and a boat spreading chemicals to disperse the oil. Very little indication of the slick is evident. Figure 7.4 shows the two regions of the spectrum where good contrast exists between the oil and water. The ultraviolet image shows the entire slick to best advantage, while the thermal infrared image shows selected portions of the slick (edges?) which are at a lower apparent temperature. Differences in the width of the imagery are due to the use of part of the scanning angle capacity for viewing an IR reference source.

Figures 7.5 and 7.6 show how oil and kelp areas can be differentiated spectrally. The response for oil shows high reflectance in the ultraviolet and no reflectance in the near infrared, while kelp shows absorption in the ultraviolet region but high reflectance in the near infrared.[6] One would expect kelp partly contaminated with oil to show a significant reflectance-absorption contrast in the UV region; unfortunately, ground truth information was not available for correlation with data collected on this sensing flight. As a matter of interest, the apparent "path" of uniform width just inside and parallel to the seaward edge of the kelp bed in Figure 7.6 is the

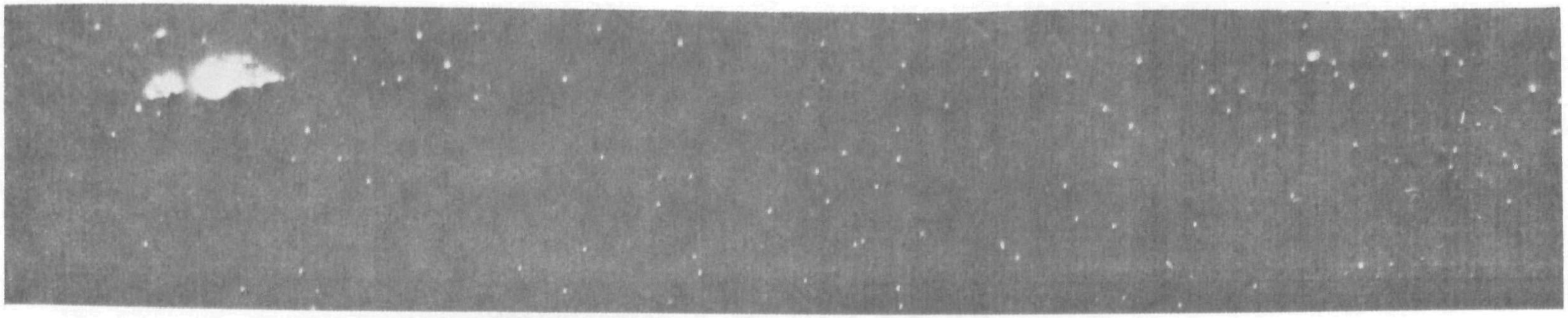


Ultraviolet - .32 to .38μ

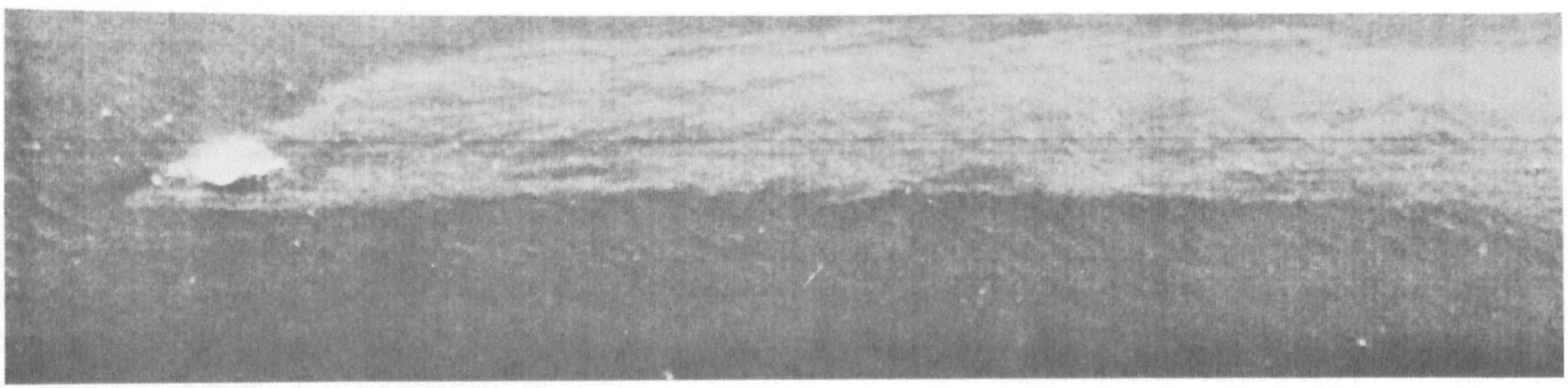


Infrared - 8.0 to 13.5μ

FIGURE 7.4. Remote Sensing Imagery
Ultraviolet 0.32 to 0.38 μ
Infrared 8.0 to 13.5 μ

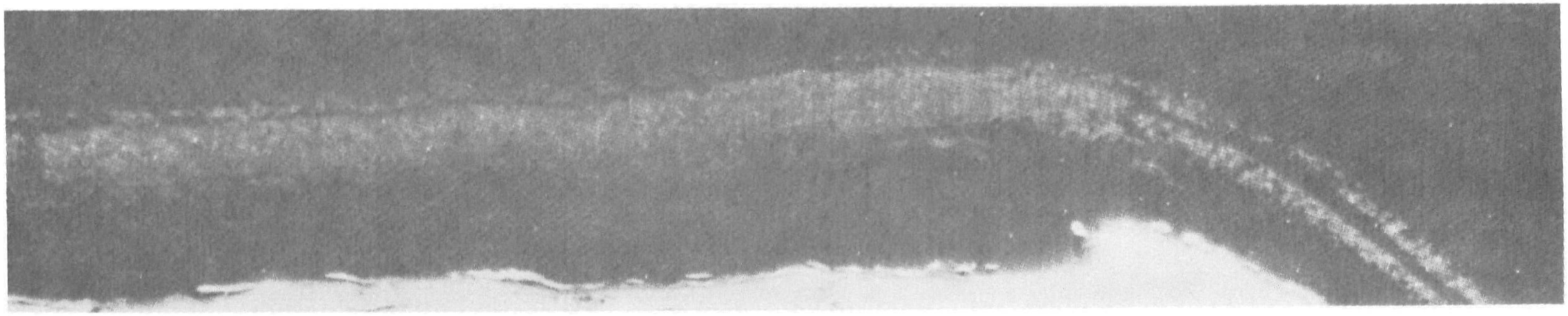


Infrared - 0.8 to 1.0μ

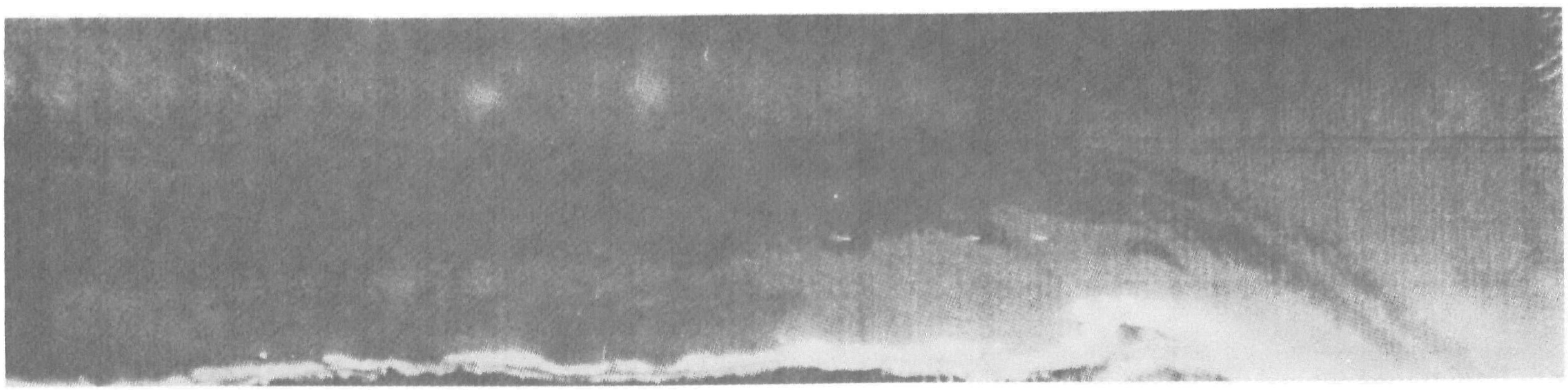


Ultraviolet - .32 to .38μ

FIGURE 7.5. Remote Sensing Imagery
Ultraviolet 0.32 to 0.38 μ
Infrared 0.8 to 1.0 μ



Infrared - 0.8 to 1.0μ



Ultraviolet - .32 to .38μ

FIGURE 7.6. Remote Sensing Imagery - Kelp Beds

Infrared	0.8 to 1.0 μ
Ultraviolet	0.32 to 0.38 μ

swath removed by a kelp cutter. Also, dark streaks within the slick on the UV display and light sections in the slick on the thermal IR display may be indicative, in part, of an oil-dispersant mixture. Additional ground control data and/or laboratory measurements will be required to determine response characteristics of such mixtures before quantitative conclusions can be drawn.

Thermal infrared imagery was successful in discriminating between oil-coated and clean surficial kelp fronds. Figure 7.7 shows oil-free kelp as a light (warm) area; kelp containing oil is darker (cooler) than the surface water. Oil slicks moving from the kelp toward the beach also show good contrast (Figures 7.3 and 7.7 courtesy of Space Division of North American Rockwell Corp.).

7.3.2 Other

Microwave radiometer flights were made by North American Rockwell; the previously mentioned, near-shore microwave measurements were made by Aerojet General Corporation; and microwave oil characteristic measurements were conducted in the laboratory by Ryan Aeronautical Company.

Airborne microwave radiometer (non-imaging) results showed contrasts exist between oil and water. The instrument in this case is sensitive to long wavelength radiation (up to several centimeters), and thus responds strongly to media characteristics which affect emissivity. The apparemt temperature of the oil slick, as determined with a 19.35 GHz microwave radiometer, was higher than that of the adjacent water surface.(4) Nearshore (Rincon Causeway) observations showed a similar response from microwave radiometers operating at frequencies of 13.4 and 37 GHz.(7) Additional results from these nearshore studies are still being evaluated as are those laboratory measurements and correlations on oil thickness, dielectric constants and age characteristics made by the Ryan Aeronautical Company.(8)

FIGURE 7.7. Thermal Infrared (8-13μ) Image Illustrating the Contrasting Hot Returns of Surficial Fronding Kelp and the Colder Streaks of Oil

Personnel of the TRW Company, using an airborne spectrometer (0.4-0.7μ range), were able to discern changes in the percentage of light reflectance and spectral curves as the oil film thinned and thickened.[9]

North American Rockwell Corporation attempted remote detection of the oil slick using a multiband video system consisting of four Panasonic TV cameras to provide multiplexed information to a video tape recorder. One camera was unfiltered; the remaining three were equipped as follows: 4000 Å ±100 Å (violet interference filter), 7000 Å ±100 Å (near IR interference filter), and Wratten 18A filter (UV band pass). The violet and UV filtered cameras reportedly gave little useful information due to high attenuation in the optics and vidicon in these spectral regions. The unfiltered camera provided coverage but showed no unique or applicable discriminating ability. The near IR filtered unit showed surface fronding kelp distinctly with response contrasts similar to those noted in color IR film exposures and 0.8-1.0μ scanning results.[4]

Much potentially beneficial information was collected relative to the oil slick by using both photographic and remote sensing techniques. Most of this probably will be soon available in the form of reports and journal articles. Belatedly, the studies revealed several specific areas whereby the usefulness of existing and future collected data would be enhanced insofar as deriving optimum plans for combating an oil spill:

- Additional ground truth information is desirable for correlation with photographic and remote sensor response. Included in this category are oil film thickness, temperature and composition as functions of time (aging) and location. Also, for future applications, the above information should be determined for various typical crude oil sources.

- Control data are needed on the spectral response of various oil-dispersant mixtures as functions of chemicals and concentrations used.

TABLE 7.1. Organizations Participating in Photographic and Remote Sensing Surveillance Operations

Aerial Photography

Organization	Technique	Remarks*
U. S. Air Force	Ektachrome IR Aerial Film Ektachrome Aerial Film	variable results variable results
U. S. Navy	Ektachrome Movie Film	good contrast
U. S. Geological Survey	Ektachrome IR Aerial Film Ektachrome Aerial Film	poor contrast good contrast (low alt.)
	Panchromatic Film	good contrast (low alt.)

Remote Sensing

Organization	Technique	Remarks*
U. S. Geological Survey	Ultraviolet Scanning	good contrast (low alt.)
	Thermal IR Scanning	fair contrast (low alt.)
University of Michigan	Multispectral Scanner	
	Ultraviolet	good contrast
	Near IR	poor contrast
	Thermal IR	good contrast
North American Rockwell Corp.	Thermal IR Mapper Microwave Radiometer Multiband Video	good contrast good response good contrast (near IR)
Aerojet General Corp.	Microwave Radiometers (trailer and boom mounted)	good contrast
Ryan Aeronautical Co.	Microwave Radiometer (laboratory measurements)	results not known
TRW Co.	Spectrometer, near IR	good response

* Remarks refer to oil-water contrast unless otherwise noted.

SECTION 7.0 REFERENCES

1. Personal Communication, Mr. H. B. Skibitzke, USGS, March 26, 1969.

2. Personal Communication, Mr. A. Caldwell, FWPCA Santa Barbara Sub-office, May 7, 1969.

3. J. C. Calhoun (chmn.), "Immediate Recommendations of the Oil Spill Panel" (letter) to Dr. L. A. Dubridge, February 21, 1969, p. 3.

4. Personal Communication, Mr. R. A. Fowler, North American Rockwell Corp., April 2, 1969.

5. Memorandum of March 25, 1969, from Santa Barbara Sub-office FWPCA (R. G. Wills to V. W. Tenney) "Ground Control for North American Rockwell Flyover on 24 March, 1969.

6. Personal Communication, Mr. F. C. Polcyn, Infrared and Optics Lab., IST, the University of Michigan, April 22, 1969.

7. Personal Communication, Mr. D. T. Trexler, Aerojet General Corporation, April 3, 1969.

8. Personal Communication, Mr. J. M. Kennedy, Ryan Aeronautical Company, April 2, 1969.

9. Personal Communication, Mr. Peter White, TRW Company, April 2, 1969.

8.0 DISTRIBUTION AND BEHAVIOR OF OIL AT SEA

The nature of oil behavior at sea is important in predicting its movement toward threatening resources, determining its character when it reaches a beach, and in the design of equipment for its recovery at sea.

8.1 SPREAD AND PATH OF OIL MOVEMENT - CHRONOLOGY

Chronological information on the gross spread and movement of the oil slick was obtained largely from visual reconnaissance flights by a number of observers. These flights were generally made daily (sometimes more frequently) and were principally directed at obtaining operational information of use in warning coastal communities of impending threats. As such, the data tend to be qualitative.

Daily oil location diagrams have been prepared by the U. S. Coast Guard On-Scene Commander based on the above observations.(1) An example diagram is shown in Figure 8.7 near the time of maximum oil spread.

Except under conditions of low wind velocity, the oil moved largely under the influence of the prevailing winds. In the Santa Barbara Channel area, the normally prevailing winds were west to northwest at Point Conception, west to southwest at mid-Channel and east to northeast at Point Mugu--i.e., no obvious wind vector during the period ventilated and hence tended to remove oil from the Channel. Thus the storm commencing on 4 February and continuing through 7 February with winds shifting from the southeast clockwise to the west, acted on the inventory of oil slick accumulated since the initial release on 28 January.

A Weather Bureau meteorologist estimated that downwind oil slick drift ranged from 10 to 20 percent at the surface wind velocity and stated "... instances of skin layer shear were noted with surface oil moving rapidly past nearly stationary free floating debris suspended less than half an inch below the water surface."(2)

The above is in contrast with the experience in the TORREY CANYON incident during which the oil movement rate averaged 3.3 to 3.4 percent of the wind velocity.(3)

Much of the oil contaminated area observed in reconnaissance flights was noted as "iridescent." The quantity of oil required to create this condition is on the order of 100-200 gallons per square mile.[4] The observation "black oil" probably represents concentrations greater than 2,000 gallons per square mile.

Additional discussion on this matter is given in Section 4.3.

8.2 BREAKUP BEHAVIOR OF SLICK

Oil on the surface tended to form streaks often described as "windrows" or "ropes" with irregular and unpredictable patterns. The formation and variability of these are shown in Figures 8.1, 8.2, 8.3, and 8.4. This pattern of oil behavior increased the difficulty of at-sea skimming or treating with dispersants or straw.

8.3 CHANGES IN PHYSICAL AND CHEMICAL PROPERTIES

Oil released to the sea surface undergoes marked changes with time. These changes include evaporation of the more volatile constituents, dissolution of water solubles, oxidation, and emulsification.

The following limited results were obtained on a simple atmospheric pressure, distillation of a sample of "Platform A" crude[5]:

Boiling Point °C	Volume % Distilled
206	2.5
232	5.0
282	10.0
322	15.0
345	18.0

Based on the above and work by the British Petroleum Co., Ltd.[6], it appears that evaporative losses at sea were less than 20 volume percent.

Observers noted the existence of water-in-oil emulsions ranging up to 50 percent water.[7]

No other information was obtained on changes in physical properties.

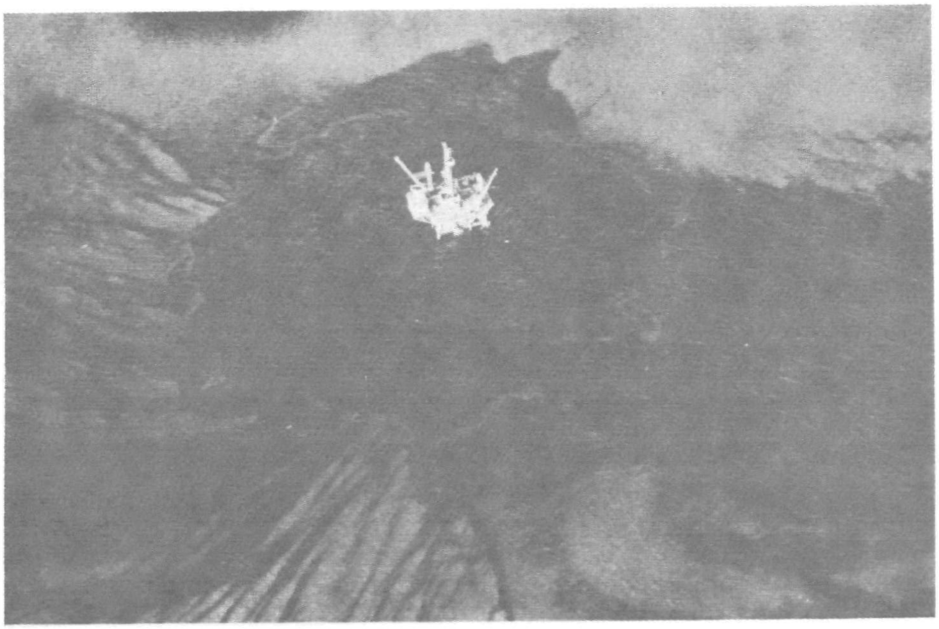


FIGURE 8.1. Oil Behavior Near Platform (courtesy of Santa Barbara News Press)

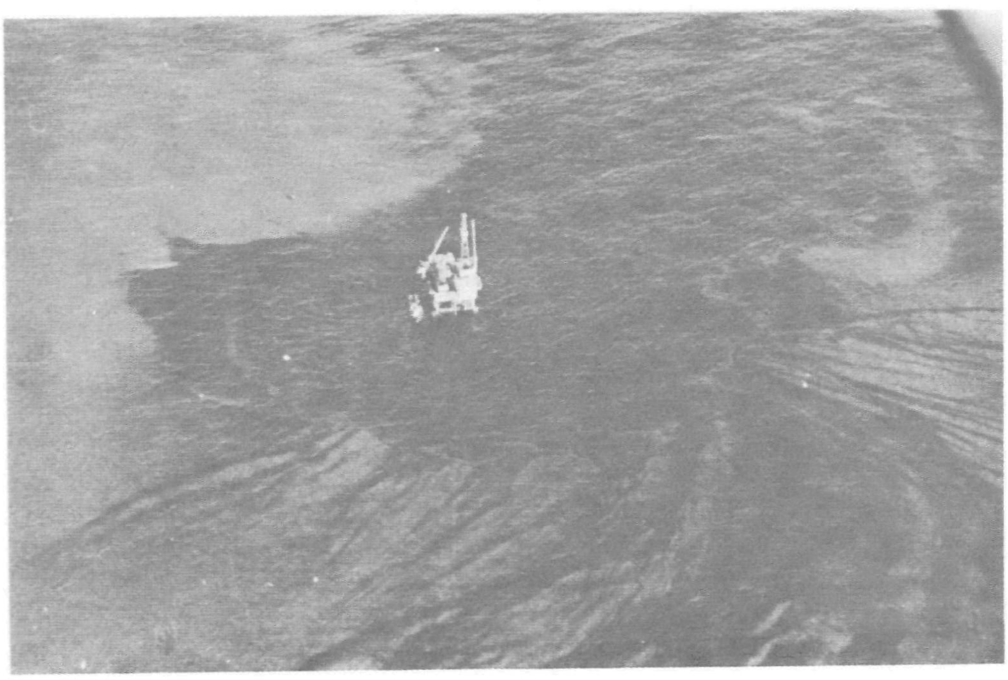


FIGURE 8.2. Oil Behavior Near Platform (courtesy of Santa Barbara News Press)

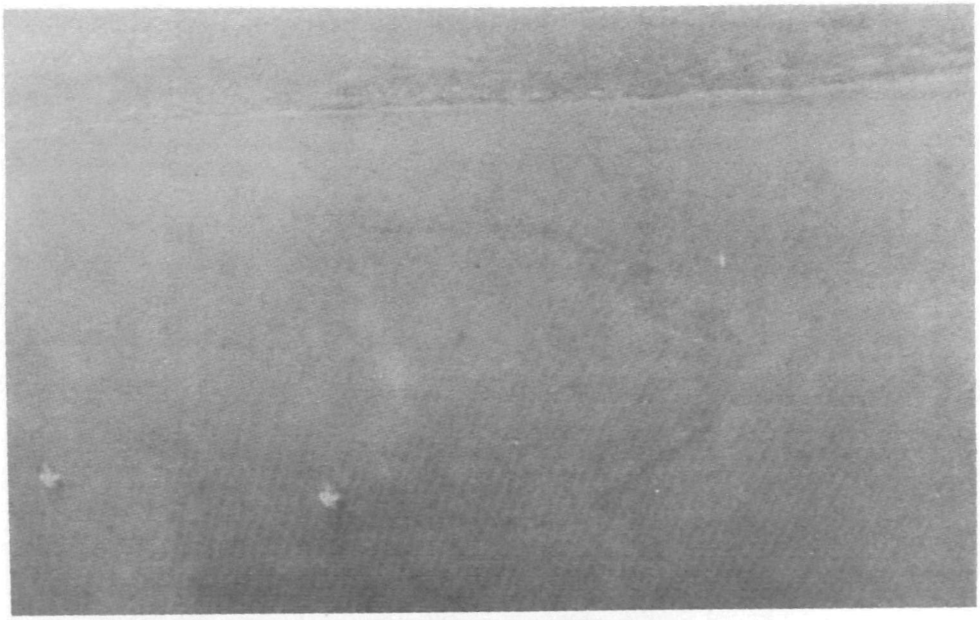


FIGURE 8.3. Oil Plume Leaving Platform, 26 February, 1969

FIGURE 8.4. Oil "Windrows and Ropes" Santa Barbara Harbor in Upper Left, Boat Spreading Straw or Dispersant, 26 February, 1969.

8.4. INTERACTION WITH OFFSHORE KELP BEDS

The kelp beds offshore in the Santa Barbara Channel, with their tendency to hold up debris, formed a natural barrier partially protecting the coast line. The diurnal land-sea breeze gradually would bring the oil ashore but the kelp undoubtedly had the beneficial effect of affording additional time for oil weathering and evaporation of non-volatile fractions. Much of the iridescence repeatedly seen in reconnaissance flights near the coast line undoubtedly resulted from the gradual bleeding of thin films from the oil retained in these beds.

Figures 8.5 and 8.6 illustrate the oil streamers being driven out of the kelp by an onshore breeze.

SECTION 8.0 REFERENCES

1. On Scene-Commander's Report: Santa Barbara Oil Pollution Incident, January 1969, Lt. George H. Brown III.
2. Memorandum Gordon C. Shields, Marine Meteorologist to Director, Western Region Salt Lake City, Utah, February 25, 1969.
3. Smith, J. E., Ed., "Torrey Canyon Pollution and Marine Life," Cambridge at the University Press, 1968, pp. 150-162.
4. "Oil Spillage Study - Literature Search and Critical Evaluation for Selection of Promising Techniques to Control and Prevent Damage," Battelle-Northwest, November 20, 1967.
5. Personal Communication, E. C. Martin, Battelle-Northwest, May 19, 1969.
6. Brunnock, J. V., D. F. Duckworth, and G. G. Stephens, Analysis of Beach Pollutants, J. Inst. of Petroleum 54, 310-325, November 1968.
7. Alan, A. A., Statement Presented to U. S. Senate Interior Committee, Subcommittee on Minerals, Materials, and Fuels. May 20, 1969.

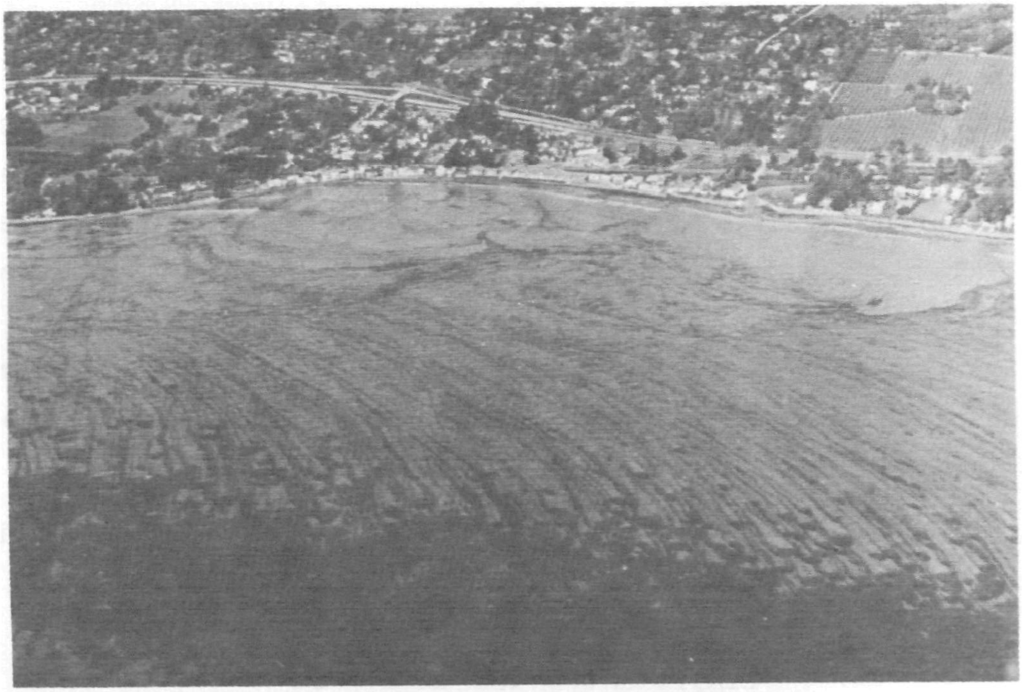


FIGURE 8.5. Oil Streamers Emerging from Kelp Beds (courtesy of U. S. Coast Guard)

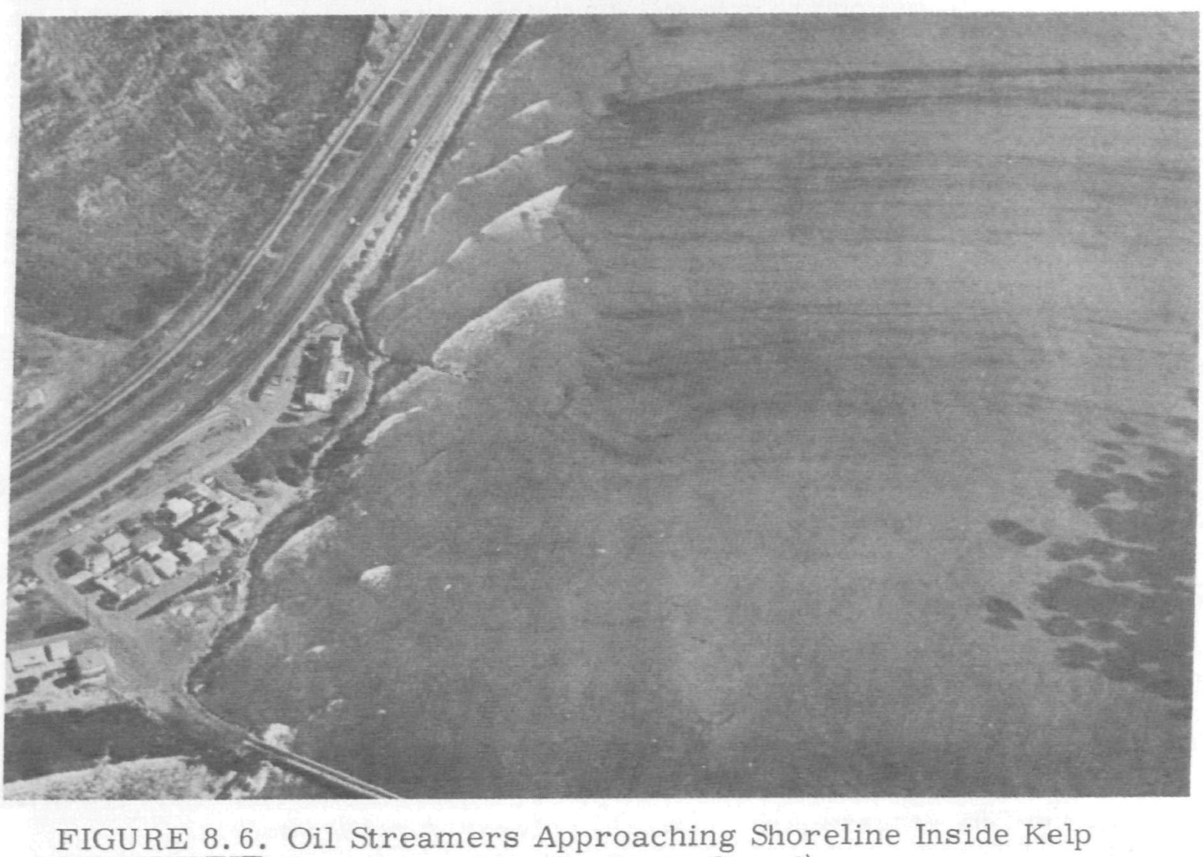


FIGURE 8.6. Oil Streamers Approaching Shoreline Inside Kelp (courtesy of U. S. Coast Guard)

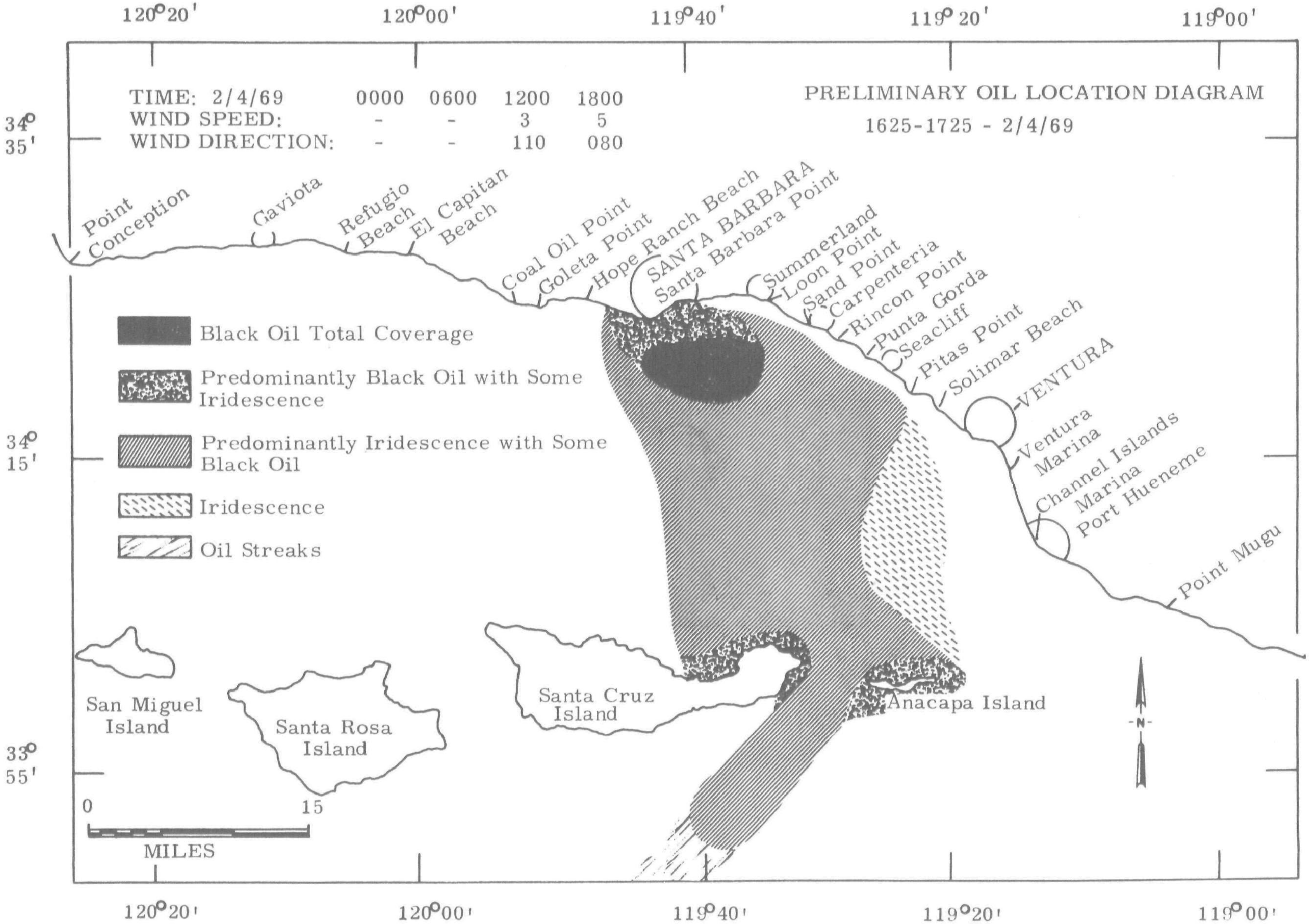


FIGURE 8.7. Example Oil Location Diagram

9.0 BEACH AND HARBOR PROBLEMS

9.1 WINTER STORM EFFECTS

The winter storm and unusually high tides, which occurred before and during the incident, imposed a significantly larger burden on beach clean-up operations (cf Section 3.0). The unseasonably large quantity of debris washed into the Channel during the heavy storm period prior to the incident was subsequently deposited on the beaches. The accumulation was several feet thick at and above the high tide line in the Santa Barbara area (Figure 9.1). Later storms and strong onshore winds deposited more driftwood and kelp. Debris on the water surface impeded skimming operations and increased the pressure against containment booms when it accumulated behind them. Large quantities of oil-contaminated kelp and debris were deposited on the beaches during storms several days after the blowout. This debris can serve as a sorptive agent if pushed into the surf prior to the arrival of oil.

The driftwood on the beaches often had to be cut up before it could be removed and all driftwood and other debris were necessarily removed whether it was oil contaminated or not. The debris deposited by the storms on rocky areas or riprap had to be removed by hand before the oil could be cleaned from the rocks. Union Oil Company estimated[14] that over 30,000 tons of storm debris was disposed of.

On one occasion in mid-February, 20 to 30 knot winds from the southeast blew oily caps of breakers and kelp over the Santa Barbara Harbor breakwater.[1] Storm runoff in the Ventura River caused overflowing into the harbor and deposition of large amounts of floating debris; this same runoff reportedly broke the boom across the entrance of the harbor.[2] Several artificial berms had to be broken to release storm runoff. These were subsequently repaired.

A typical sand beach is composed of a terrace, or berm, of sand above the water surface and bars in the surf zone parallel to the beach.[3] The berm is approximately flat and constantly changes size and shape, depending upon wave action. A continuous seasonal interchange of sand occurs between the berm and sub-surf bars. Winter storm waves tend to

FIGURE 9.1. Storm Debris on Beach Near Santa Barbara

transfer sand from the berm (in some cases total sand removal) to the bars. Subsequent calmer conditions will reestablish the beach and berm. Severe storms which had immediately preceded the initial oil release removed large quantities of sand from the berm to the bars; therefore, the oil coming ashore on some of the more remote beaches may have been covered with fresh clean sand brought in during calmer weather before commencement of cleaning operations. These oil-contaminated layers of sand will likely remain in place until future storms again remove the layer of sand which covered them.

9.2 FIRE HAZARDS

The most significant fire hazard existed in the vicinity of Platform A where concentrations of fresh oil and gas occurred. The weathered oil reaching the beaches posed no real fire hazard and was, in fact, difficult to ignite. The wind generally kept the gas from accumulating to a hazardous level around the platform, although evacuation was necessary on 30 January because of hazardous gas concentrations accumulating in slack wind conditions. During the 26 February storm, lightning struck the gas vent stack of a nearby platform, starting a fire which caused no damage.

When the oil initially entered Santa Barbara Harbor on 4 February, several precautionary measures were taken to reduce the potential fire hazard, including disconnecting electrical leads to boats in the harbor and spraying chemical dispersant on the oil.(4) Later, the use of solvents, gasoline and detergents for cleaning boats was prohibited in the harbor because of potential fire hazard. The Santa Barbara Fire Department checked the harbor atmosphere with a commercial explosimeter; no explosive mixture was indicated.(5) Similar tests two weeks later on incoming oily kelp also indicated no combustible vapors. The Fire Department also performed crude bench tests to determine the temperature at which combustion of the surface oil could be sustained. A small can was filled with oil and a thermometer immersed near the surface. A torch was then applied; combustion was not sustained until the temperature exceeded 190 °F.

The chemical dispersant (Polycomplex A-11) was spread on the entering oil slick near the harbor entrance to disperse the oil and thus reduce the fire hazard.[6] The use of dispersants within one mile of Platform A was subsequently permitted to reduce fire hazard.[7]

9.3 SPECIAL CONSTRAINTS

The relatively fresh crude oil which came ashore in the vicinity of Pitas Point on 31 January was observed to sink immediately into the sand without leaving a residue.[8] Similar behavior has been observed during past crude oil spills in the Long Beach area when the unweathered crude oil came directly ashore.[9] The depth of penetration of the relatively fresh crude into the beach on this particular occasion is not known.

The oil-soaked straw recovered from beaches often had to be mixed with additional straw and sand before dumping inland. Thus, an extra handling operation was required. Some loads of oil-soaked beach debris that were trucked inland for dumping were rejected at the dump site and had to be returned for supplementation with dry straw and sand.[10]

Porosity of the breakwater forming the outside of the Santa Barbara Harbor undoubtedly permitted some passage of oil into the harbor. The breakwater is constructed of large boulders with no filler material between. The porosity was evidenced by sand deposits fanning out from openings between the rocks in the inner harbor (Figure 9.2).

Inconvenience and hazards to navigation occurred in several locations during protective and recovery operations. Notices to Mariners were issued on several of these occasions concerning the presence of unlighted booms in certain areas, mainly around the entrance to ports and harbors. Mariners were advised to stay outside a five mile radius of Platform A. Booms across the entrance to harbors were closed when the arrival of oil was imminent, thus preventing passage of vessels. A request to open the booms to permit entry of a ship into the Santa Barbara Harbor was denied on at least one occasion because of the danger of the accumulated oil entering the harbor.[11]

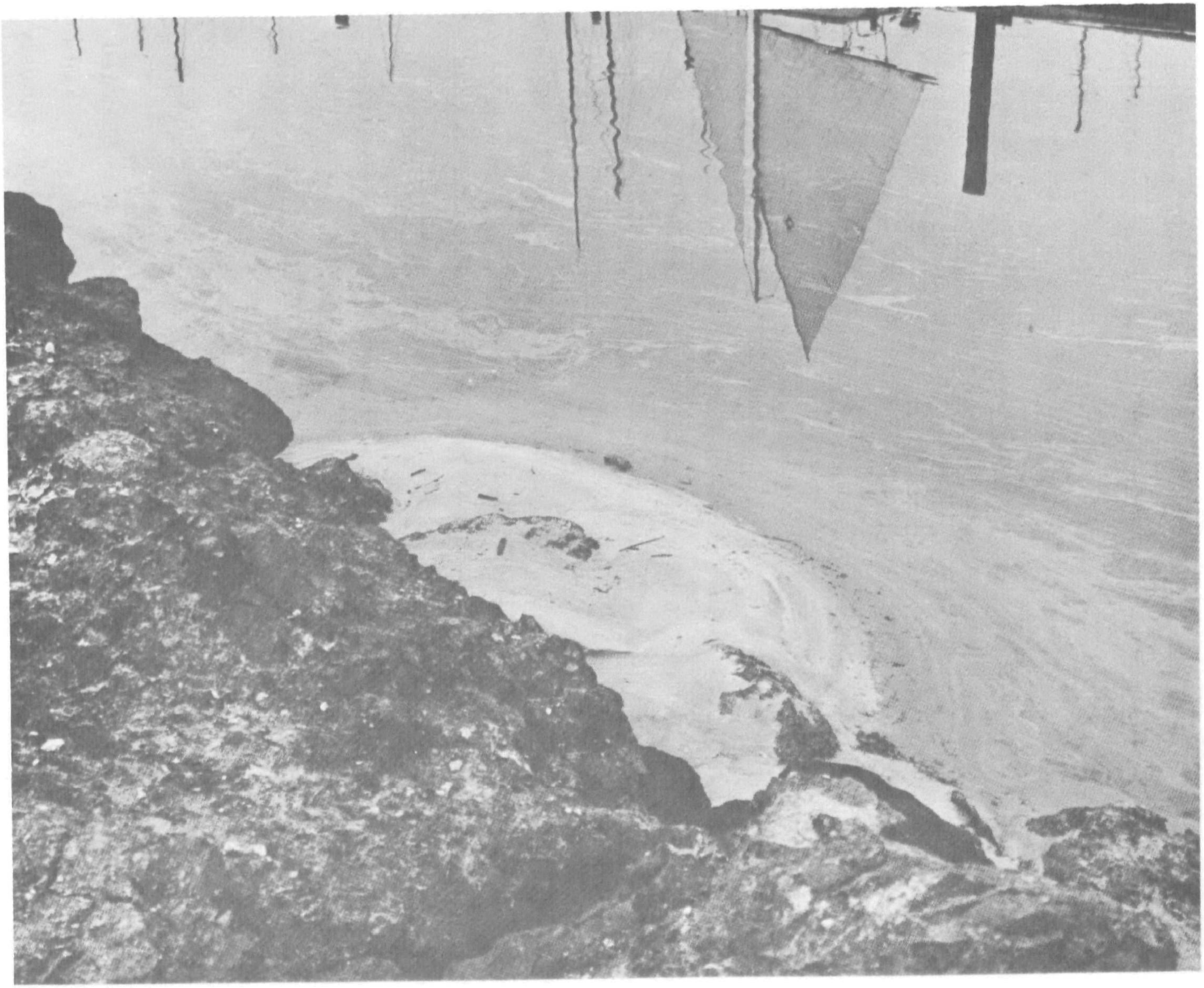


FIGURE 9.2. Sand Deposits Inside Santa Barbara Harbor Breakwater Indicating Breakwater Porosity

9.4 LITTORAL SAND TRANSPORT

Littoral sand transport is the net along-shore movement of beach material under the influence of wave-induced currents. The along-shore currents are created when incoming waves strike the shoreline at an angle; therefore, the drift generally depends upon the direction of the prevailing waves. The coastline of California between Point Conception and the Los Angeles area has an approximate east-west orientation. The prevailing waves in this region are westerly and therefore the net transport of sand is eastward along the coast. The net drift along the Santa Barbara coast is approximately 300,000 cubic yards per year.[12]

The breakwater which forms the Santa Barbara Harbor is the first major obstruction, south of Point Conception, to this flow of sand along the coast. Correspondingly, a large sandspit results inside the outer end of the breakwater. Past observations[13] have established the average rate of sand deposition on this sandspit to be 400 to 900 cubic yards per day. During storm conditions, the rate of growth has exceeded 2500 cubic yards per day as a consequence of depletion of beach material from the west.

Year-round maintenance dredging operations are required to prevent harbor mouth obstruction by bypassing sand past the harbor. A dredge (Figure 9.3) transfers the sand by pipe line to a point eastward down coast where it is again picked up by the prevailing littoral drift.

Oil that came ashore on the sandspit at the Santa Barbara entrance was subsequently covered with fresh uncontaminated sand. Inspection of a vertical cross-section of this sandspit (Figure 9.4) revealed layers of oil-soaked sand up to several feet below the surface.

The dredge discharge (Figure 9.5) contained an undeterminable amount of oil, even if it was removing accumulated sand from an area where the beach surface appeared clean. Thus, the presence of the buried oil will be witnessed for some time into the future as the dredge redeposits it further down the coast. This source of further oil pollution on previously cleaned beaches did not appear severe during observations in late March.

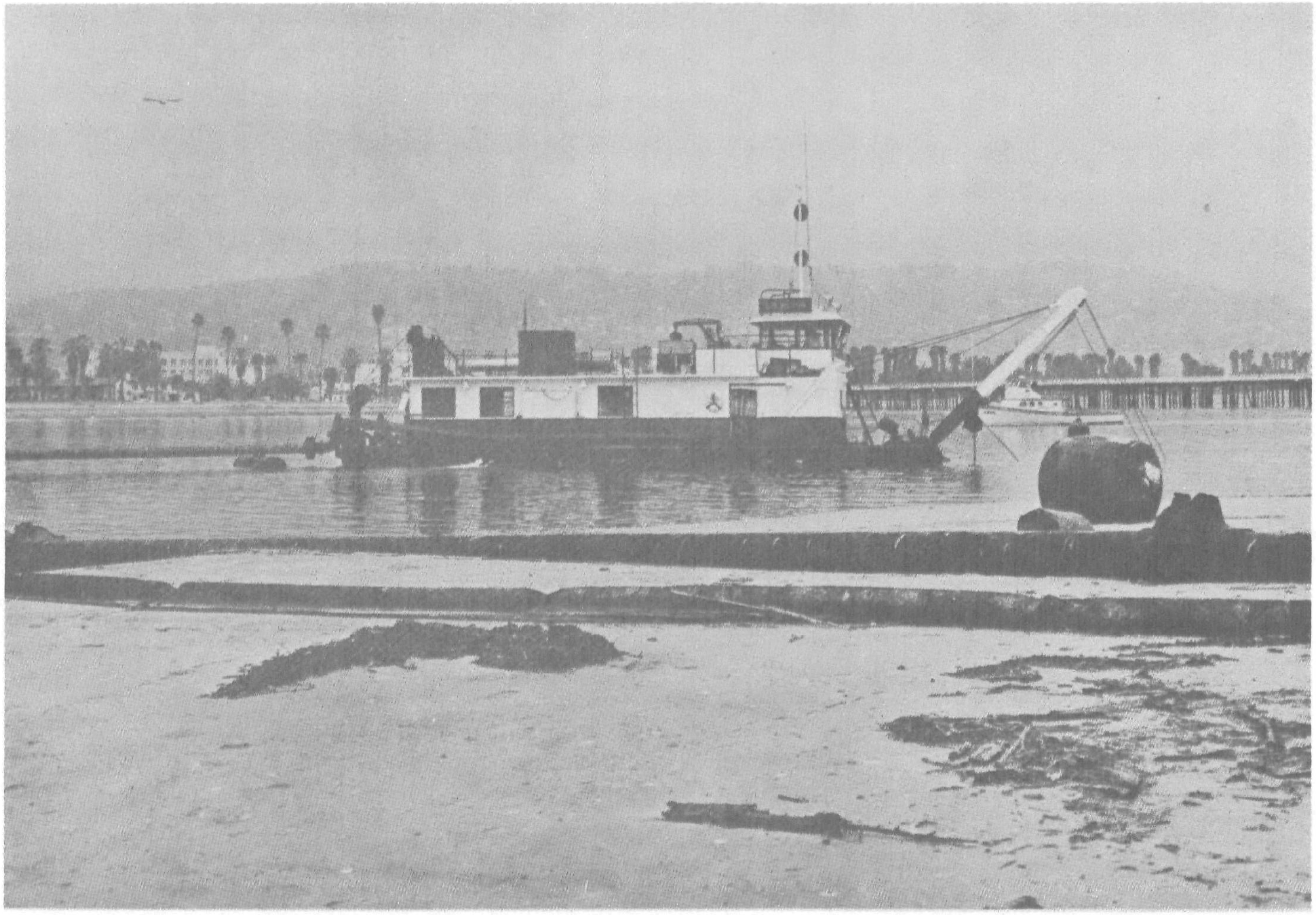


FIGURE 9.3. Santa Barbara Harbor Dredge Maintenance

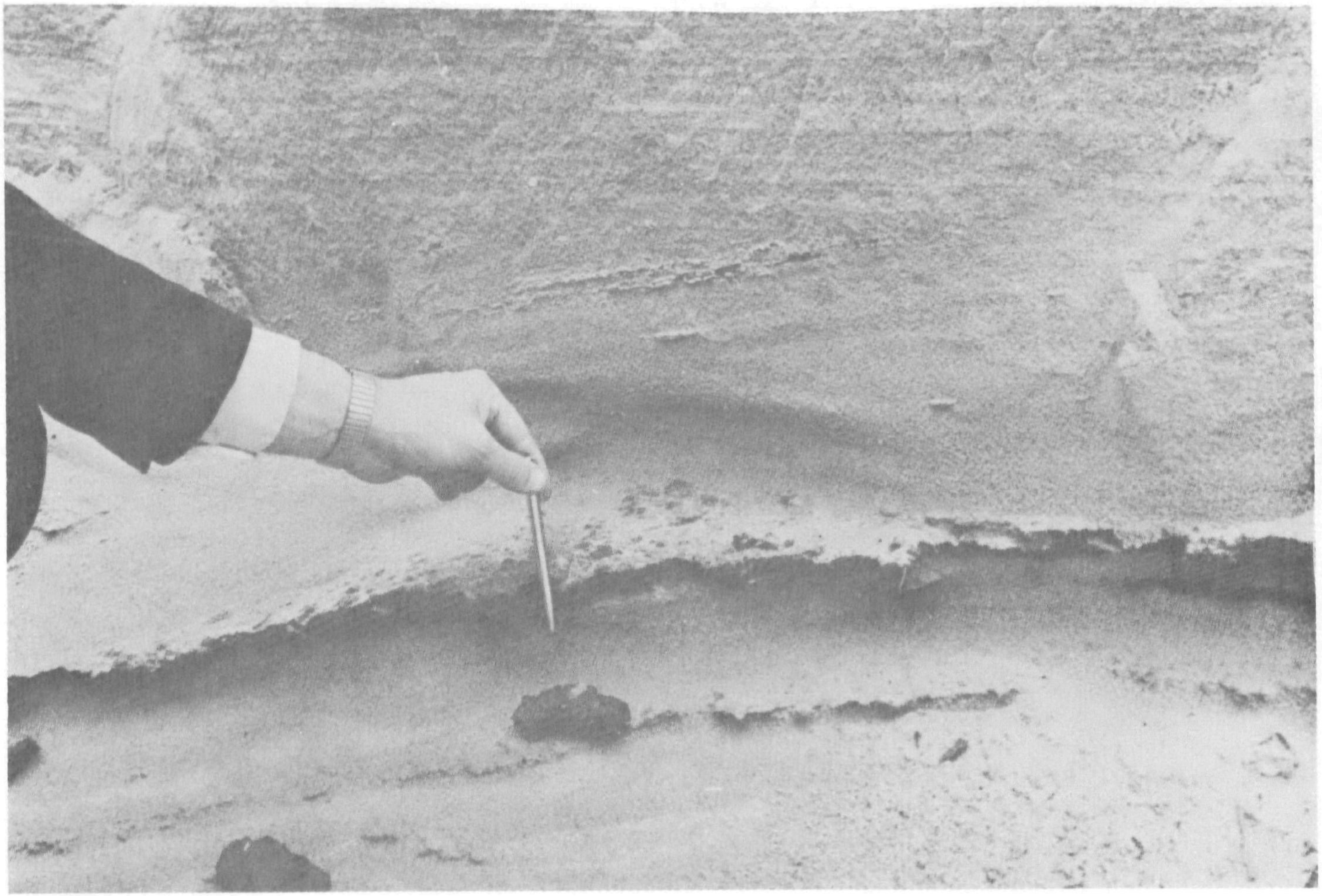


FIGURE 9.4. Oil Deposits in Santa Barbara Harbor Sandspit Covered by Littorally Drifted Sand

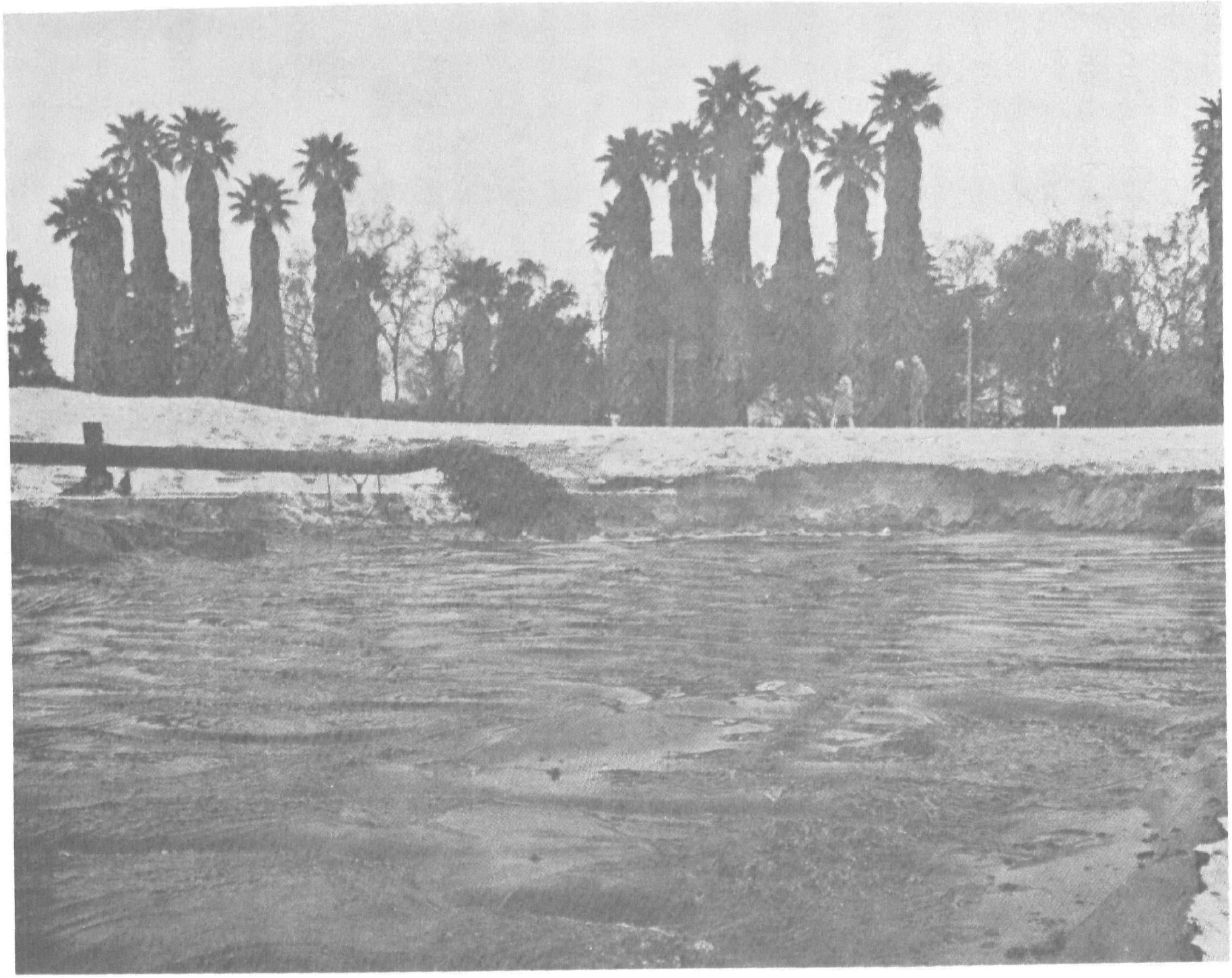


FIGURE 9.5. Santa Barbara Harbor Maintenance Dredge Discharge

Other beach areas where the deposited oil was similarly covered by sand due to littoral transport will also undoubtedly yield some amount of further contamination in the future, especially during winter storms that erode the beaches. This contamination will probably not represent a serious problem or require clean-up operations as the oil is associated with sand grains and will generally sink below the surf zone.

SECTION 9.0 REFERENCES

1. Offshore Oil Well Blowout Union Oil Company Well. A report of the Harbormaster of Santa Barbara. April 22, 1969.

2. Union Oil Company Daily Report of 2/24/69.

3. Willard Bascom. "Waves and Beaches," Doubleday and Company, Garden City, New York, 1964. p. 188.

4. Offshore Oil Well Blowout Union Oil Company Well. A report of the Harbormaster of Santa Barbara. April 22, 1969.

5. Chemical and Engineering News, March 17, 1969. p. 42.

6. Personal communication: Fire Marshal, Santa Barbara Fire Department.

7. U. S. Coast Guard Situation Report No. 73, 26 February, 1969.

8. U. S. Coast Guard Situation Report No. 10, 31 January, 1969.

9. Personal communication: Captain W. H. Putman, State of California Department of Fish and Game.

10. Union Oil Company Daily Report of 2/14/69.

11. Offshore Oil Well Blowout Union Oil Company Well. A report of the Harbormaster of Santa Barbara. April 22, 1969.

12. Willard Bascom. "Waves and Beaches," Doubleday and Company, Garden City, New York, 1964. p. 228.

13. Ibid. p. 222.

14. Gains, T. H. "Notes on Pollution Control Santa Barbara," Union Oil Company of California, undated.

10.0 SHORELINE RESTORATION METHODS

10.1 BEACHES

The priority established for the cleanup of the coastline was as follows:[1] (1) marinas, (2) public beaches, (3) less accessible public beaches, (4) private beaches, and (5) rock riprap. The oil was most heavily deposited on approximately 30 miles of the coastline between Point Conception and Point Dume.[2] The oil reaching the shore was generally weathered sufficiently to prevent significant penetration of the beach surface which greatly facilitated clean up operations. Most observers felt that the depth of penetration was less than 1/2 inch. An exception was noted near Pitas Point on 31 January when fresh crude oil came ashore and reportedly immediately sank below the surface (Section 9.0).

Cleaning and restoration of beaches were generally accomplished by spreading straw on the deposited oil, collecting the oily mixture, and subsequently hauling it to an inland dump for disposal. Straw reportedly absorbs four to five times its weight in oil under optimum conditions. Collection of the oily straw and other debris on the beaches was accomplished principally by mechanized devices such as bulldozers, graders and loaders, although a significant amount was removed by manual labor (Figure 10.1). During one period of beach restoration, 550 personnel, 54 watercraft, 29 pieces of heavy equipment, 96 trucks and 7000 tons of straw and hay were employed for cleanup of the beaches and harbors.[3] The total amount of straw employed was alternatively estimated as 3000 tons by another source.[4]

Later estimates[21] indicate that the clean-up effort peaked at almost 1,000 men and 125 pieces of mechanical equipment. Up to June 1, 1969, 9,826 truck loads of oil-soaked straw and debris had been disposed of.

The rental rate for heavy equipment similar to that employed for beach cleaning operations normally ranges from \$20-\$30/hour. Lighter equipment such as smaller trucks and portable cranes rent for approximately \$8-\$20/hour. The straw used was obtained through brokers and cost approximately \$24/ton initially; the price reportedly rose to approximately \$35/ton when the immediate supply became exhausted.[5] Wages paid to laborers for beach cleanup were \$3.97/hour and the billing charge was

FIGURE 10.1. Application and Removal of Straw on Beaches (courtesy of Santa Barbara News Press)

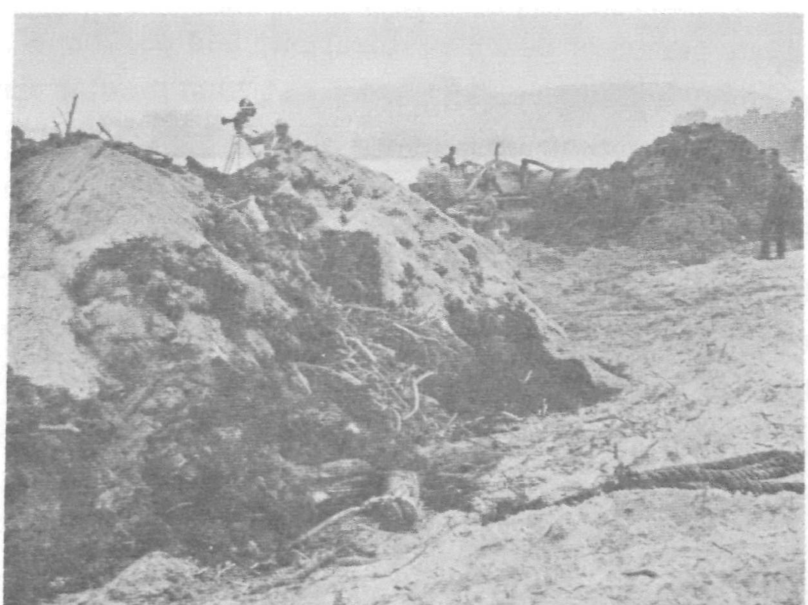


FIGURE 10.2. Oiled Straw and Debris (courtesy of Santa Barbara News Press) Press)

approximately $7.00/hour.[6] In addition, an unknown amount of overtime wages was paid at a correspondingly higher rate. The rental rate for watercraft is approximately $20/hour for vessels 50 feet long and approximately $40/hour for vessels 120 feet long.[7]

Union Oil Company estimated[21] that 400 man hours of labor supplemented with four skip loaders, two bulldozers and ten trucks were required to clean one mile of beach, under typical conditions encountered. Based on these values, we estimate the cost of beach cleanup in the neighborhood of $5,000 per mile (about $1 per linial foot) including transportation and possible added costs of land fill disposal sites. Costs for cleaning rip-rap and rocky coast line undoubtedly run higher.

Straw was the primary absorbent material used for beach cleanup although limited amounts of "Ekoperl" and talc were tried.[8] Chemical detergents were not employed for beach cleaning operations as it was felt that dispersed oil might sink in and lubricate the sand, causing excessive erosion or limiting the use of wheeled vehicles on the beaches. The latter situation was encountered on English beaches following the TORREY CANYON stranding. In the Santa Barbara incident, access to some beaches was restricted when heavy seasonal rains made the access roads impassable.

Straw was spread on the beaches between high and low tides, both before and after the oil reached shore. The oily mixture was worked into piles either manually or by machines and subsequently loaded for transport to inland dumps. The mixtures often contained excessive oil and further operations were required to mix dry straw and sand with the oily contaminant.[9]

Debris deposited in and around rocky areas, such as rip-rap, was removed by hand before cleaning the oil from the rocks. Considerable manual effort was also required on beach areas, such as the Harbor sandbar, inaccessible to motorized equipment. Following removal of the majority of the oil and debris, the sandy beaches were worked with commercial motorized sand sifters normally employed to recover litter on the beaches.

The general procedure that evolved during operations was to permit the oil to come ashore and be deposited at the high tide line, spread straw on the oil, and push it into piles (Figures 10.2, 10.3, and 10.4). Recovery operations were concentrated at the high tide line rather than the intertidal zone.

Two types of large motorized equipment which proved especially effective for spreading and recovery of straw were mulchers or straw-spreaders (Figure 10.5) normally used for spreading straw on highway right-of-ways to prevent soil erosion, and graders with tines below the blade for raking (Figure 10.6). Two types of motorized hay rakes were tested but found ineffective for recovery of oil-soaked straw.[10]

The only type of straw effective for absorbing the oil on beaches was that derived from wheat stalks. "Bermuda straw," which is much finer and more closely resembles hay, would not absorb the oil well.[11]

Burning of the oil-soaked straw on the beaches generally was ineffective and the burning operations often had to be suspended because of smoke.[12] Driftwood and other debris which had been deposited on the beaches (Figure 11.1) was often successfully burned, including that contaminated with oil. Burning operations were conducted on several beaches. At one time 24 fires were counted at Carpenteria Beach State Park.[13] These operations were subsequently suspended due to smoke complaints. Diesel fuel was successfully employed to start fires.[14] A diesel oil fueled, blower type burner was tried with good results and employed in subsequent burning operations. Heavy rains tended to hamper burning.

A tabulation of some of the more significant equipment and materials used for beach restoration (excerpted from Union Oil Company reports) is given below:

Materials

Straw
Ekoperl
Talc

Chemicals Employed for Secondary Cleanup of Equipment etc.

DIX-11
Uniflame
T-5-X
Solvents
Diesel Fuel

Motorized Equipment

Bulldozers
Skiploaders (D-4, D-6, D-8)
Backhoes
Tractors
Cranes
Hayblowers
Dump Trucks

Hand Equipment

Pitch Forks
Steel Brooms
Square Point Shovels
Rakes
Axes
Hand Saws
Rope

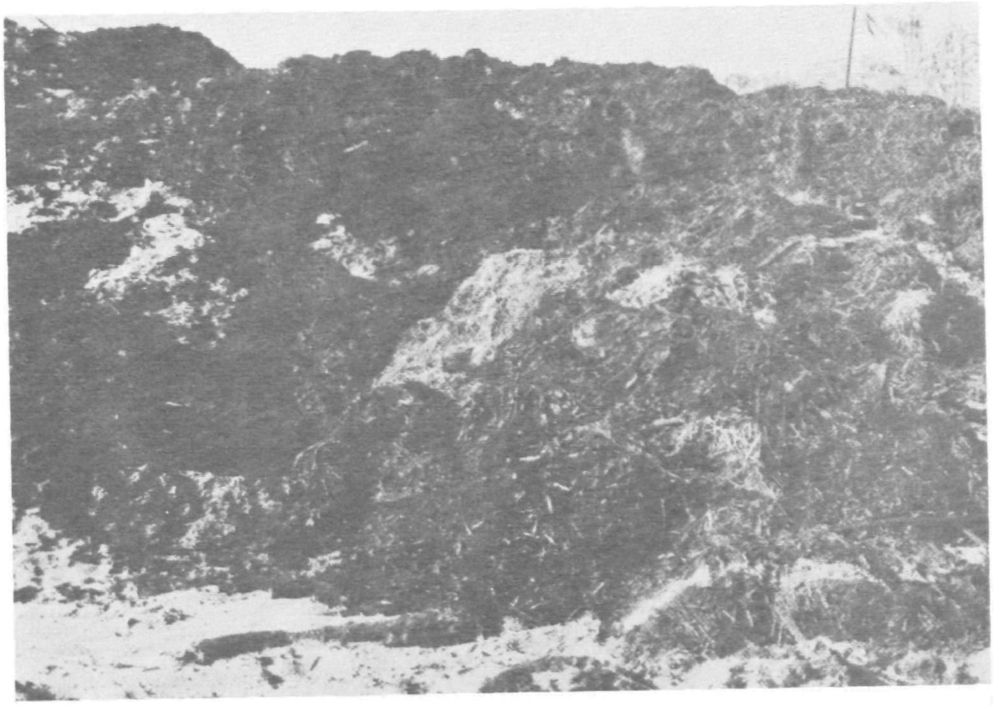


FIGURE 10.3. Oiled Straw

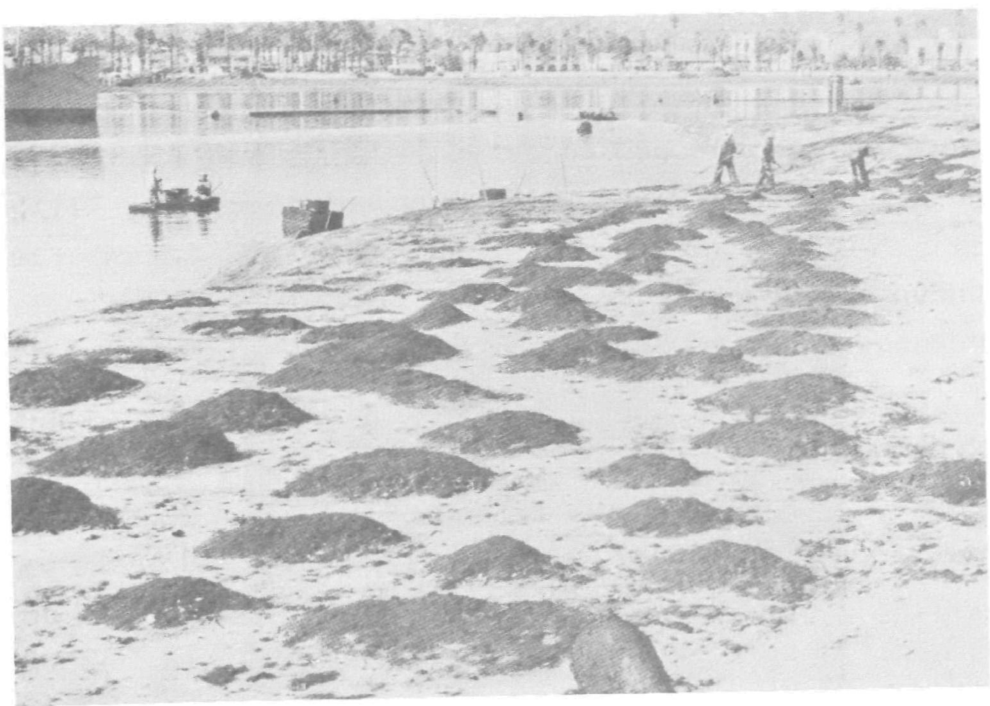


FIGURE 10.4. Oiled Sand on Santa Barbara Harbor Sand Bar

FIGURE 10.5. Power Mulcher Spreading Straw

FIGURE 10.6. Grader Modified with Tines Welded to Blade

Motorized Equipment (contd)

Motorized Rakes
Graders
Sand-sifting Machine
Fork Lifts
Brush Burner
Sandblasters
Chain Saws
Fertilizer Spreaders
High Pressure Water Cleaning Units
Numerous Utility Vehicles and Trucks

Hand Equipment (contd)

Pick Axe
Flood Lamps
Hudson Sprayers
Rotary Barrel Pumps

10.2 CLEANING OF HARBORS

Harbor oil contamination was most severe at Santa Barbara, although some oil did penetrate into the Ventura Harbor. The majority of the oil came through the Santa Barbara Harbor entrance when defensive measures failed; however, a smaller amount came over and through the porous breakwater (Section 9.0). Most of the oil was recovered by drag booms which concentrated in the vicinity of the small boat launching ramp, whence it was transferred to tank trucks equipped with suction pumps (Figure 10.7). Propeller wash from taut-moored vessels in the harbor was effective for moving the oil into the center of the channel.[15] Skirted booms proved effective for dragging operations to contain oil-soaked straw and kelp. Subsequent cleanup of residual oil and floating debris such as kelp was accomplished principally by application of straw, followed by manual labor pickup. A limited amount of "Ekoperl" was also applied in the harbor. Portable water pumps were employed to wash the oil off the decks of ships and from around otherwise inaccessible places such as ships' berths. Light equipment such as these pumps are estimated to cost approximately $10/hour with operator.

Debris, kelp, and oil-soaked straw were recovered from the water surface by men working from punts (Figure 10.8), designed for oil spill cleanup in the Los Angeles-Long Beach Harbor area. These were about ten feet long by four feet beam, with a freeboard of about 18 inches. The recovered material was generally placed in 55-gallon open drums to facilitate subsequent handling. The debris was recovered with either pitchforks or hand rakes.

FIGURE 10.7. Removal of Oil from Santa Barbara Harbor Using Vacuum Trucks

FIGURE 10.8. Removal of Oil from Santa Barbara Harbor Using Straw

The suction pump trucks employed to pump the concentrated oil accumulation from the water surface were similar to those used to empty septic tanks. The capacity was typically 4200 gallons and several were used at the Harbor each day. Twelve hundred barrels of oil were reportedly recovered by these trucks on 6 February.[16]

A commercial skimmer, tested in Santa Barbara Harbor, employed a rotating cylinder covered with oil absorbent plastic foam. Debris picked up by the foam, i.e., straw and driftwood damaged the foam, and, hence, the device was not used.[5]

Several techniques were employed to clean various harbor facilities, depending on the nature and accessibility. The launching ramp area, dredge, and protecting plastic panel shield around the "Undersea Gardens," a marine aquarium, were steam cleaned.[17] The sea-wall was also steam cleaned with steam and 120 °F water which necessitated covering nearby boats with plastic sheeting.[18] Riprap and the walkway along the breakwater were washed with pressurized water streams and steam cleaned. The riprap inside the Santa Barbara Harbor was subsequently sandblasted to improve its appearance. Floats in the harbor were hand scrubbed with commercial "waterless" hand cleaning compound and wiped off.

Of the approximately 750 boats which were berthed in the harbor, it was estimated that over 700 were stained by oil.[19] Cleaning the hulls with chemical solvents was prohibited by the Santa Barbara Fire Department due to fire hazard and waste pollution considerations. Therefore, the cleaning of hulls that could not be removed from the water was limited to waterless hand cleaner which could be wiped off following application. Very few boat hulls had been successfully cleaned as of late March, in part due to residual oil being released to the harbor waters from the shoreline. Boat baths and small booms commonly placed around and under small craft in harbors afforded protection to a few boats.

10.3 CLEANING OF ROCKS AND JETTIES

Several methods were used to remove deposited oil from rocks and riprapped areas. The riprapped areas presented a severe problem because of the numerous inaccessible cracks and crevices into which the oil had penetrated. Methods tested included washing with cold and hot (120 °F) pressurized water streams, steam cleaning, application of chemical detergents (on a limited basis), and sandblasting. Of these methods, only sandblasting was found to satisfactorily remove stains despite the slowness of the process. The air was supplied to the nozzles by standard compressors (100 psig). Up to four spray nozzles could be operated from a single 1200 scfm compressor.[20] Application was either wet or dry, depending on the prevailing wind direction, with the dry blasting being slightly more effective.

Effective cleaning of riprap such as that on the jetty of Santa Barbara Harbor entailed three separate operations: (1) hand removal of debris, (2) washing down with a stream of pressurized cold water, and (3) sandblasting. Typical rates for wet sandblasting were 60 to 80 feet per day per spray nozzle, working on a six to eight foot wide strip of nominally two foot diameter boulders. Protective booms were placed while sandblasting the inside of the harbor jetty to prevent further contamination of the harbor waters.

SECTION 10.0 REFERENCES

1. "Offshore Oil Well Blowout, Union Oil Company Well," Santa Barbara Harbormaster Report, 22 April, 1969.
2. Map Supplement from Coast Guard On-Scene Commander's Report.
3. Summary of Union Oil Company Cleanup Activities (based on progress reports furnished to the On-Scene Commander).
4. Thomas H. Gaines, Union Oil Co. Statement 18 February, 1969.
5. "The Santa Barbara Channel Oil Pollution Incident January 1969 - On-Scene - Commander's Report.
6. Personal Communication, E. K. Thompson, Crosby and Overton Inc.

7. Quotation from General Marine Transport Inc. Santa Barbara, California.

8. Union Oil Company Daily Report, 11 February, 1969.

9. Ibid., 14 February, 1969.

10. Ibid., 17 February, 1969.

11. Personal Communication with D. D. Shaw of Crosby and Overton Inc.

12. Union Oil Company Daily Report, 16 February, 1969.

13. Santa Barbara News Press, 14, February, 1969.

14. Union Oil Company Daily Report, 26 February, 1969.

15. "Offshore Oil Well Blowout, Union Oil Company Well," Santa Barbara Harbormaster Report, 22 April, 1969.

16. Santa Barbara News Press, 6 February, 1969.

17. Union Oil Company Daily Report, 17 February, 1969.

18. Ibid.. 18 February, 1969.

19. Santa Barbara News Press, 16 February, 1969.

20. Personal Communication with D. D. Shaw of Crosby and Overton Inc.

21. Gains, T. H. "Notes on Pollution Control Santa Barbara," Union Oil Company of California, undated.

11.0 DISPOSAL OF WASTES AND RECOVERED OIL

Wastes from clean-up operations consisted primarily of oil-soaked straw (with admixed sand in most cases) from beach, harbor and sea cleaning; a considerable amount of oil-soaked debris (tree limbs, etc.), due to high water in coastal streams, that was washed to sea and later deposited on beaches concurrent with oil deposition; small amounts of other absorbents (e.g., perlite) used on beach and harbor cleanup; and oil-water mixtures removed from the water surface by skimming operations.

11.1 IN-PLACE BURNING

Most of the straw and debris was trucked to landfill areas; however, in some instances these combustibles were piled and incinerated on the beaches (Figure 11.1). For the most part, burning was abandoned as a disposal method in later phases (16 February, Ref. 1) of the cleanup due to voiced objections to the smoke and odor. In all cases where wastes were burned in-place, it was necessary to obtain burning permits from appropriate city or county authorities. Originally, some difficulties were encountered in kindling the waste material; later a blower-type, diesel-fed burner was found to give good ignition.[(1)] In general, however, and with the exception of storm debris burning, combustion of oil recovered on the beaches (largely mixed with straw) was impaired by the fire retardant properties of included wet sand. In addition, due to the sulfur content (1.2 to 1.5 percent in fresh oil as released) burning possibly would have caused an air pollution problem.

On-site burning, though objectionable from several viewpoints, had a number of advantages. Some of these are apparent in the following discussion wherein problems attendant to hauling and landfill operations are pointed out.

It is evident that in-place burning attempts in the event of future incidents must consider the unexpected complexities introduced by nature (such as storm debris) and the possible need for mobile high temperature

FIGURE 11.1. Burning Operations on Beach (courtesy of Santa Barbara News Press)

(artificially fueled) incineration equipment which substantially reduces the potential air pollution problem. Such considerations must be integrated with beach cleaning methods which will undoubtedly involve sorbents such as straw.

11.2 LANDFILL DISPOSAL

The disposal of solid waste by landfill (shallow burial) was considered as the simplest of disposal methods; however, there were a number of problems which had to be surmounted in this particular case due to the scale of the operation, the time element, and the somewhat unique characteristics of the disposed material. Some of the items requiring consideration were:

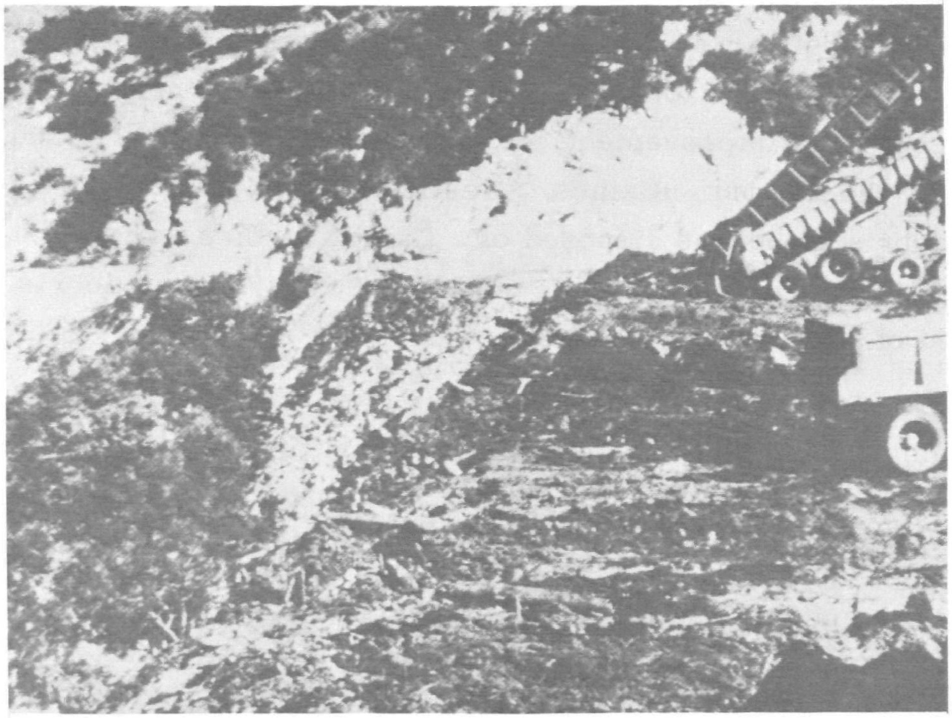
- The disposal site(s) should be situated so that burial would not constitute either a short term (e.g., fire, odor) or long term (groundwater contamination) problem.
- It was desirable that the disposal site be close to the clean-up areas to minimize hauling distance, traffic problems, etc.
- There was need to arrange for beach access (sometimes through private property) for heavy collection, loading and hauling equipment. In practice, this required considerable advanced planning.
- The relative remoteness of the major disposal sites selected made some road improvement work necessary to accommodate the dump trucks. Also, the extremely heavy rains resulted in the sites being inaccessible for several days during which waste material was stockpiled on the beaches.
- Legal responsibilities with regard to long-term liabilities had to be resolved between the property owner(s) and the clean-up contractor.

A number of dumpsites were used for solid waste disposal. Early in the beach clean-up operation, relatively minor amounts of wastes were trucked to established Santa Barbara, Ventura and Oxnard disposal grounds. However, the bulk of the wastes was hauled to two sites where specific arrangements had been made for landfill burial and to a third site where the oil-sand mixture was used for road building. In some instances the oil content of the waste was high enough to allow free drainage. In these cases, the waste was returned to the beach area for introduction of additional straw and sand.

Over 2,200 large dumptruck loads of wastes (estimated 30,000 yd^3) were trucked to the head of a small side canyon near the crest of the watershed in Toro Canyon (Figure 11.2). An estimated 3-4 acres (horizontal surface) of fill were placed in the canyon. One criterion for selecting this site, about 10 miles east of Santa Barbara, was the recognition that it would not be subjected to significant leaching by regional groundwaters. In late March, after the site had been abandoned insofar as waste oil residue dumping was concerned, the site had been completely backfilled and there was no visible evidence of the waste nor significant petroleum odor. Periodic checking of the small stream in this canyon has failed to reveal the presence of any oily effluent.(2)

Later in the clean-up operation, arrangements were made to dispose of solid wastes in an area about 25 miles west of Santa Barbara (Abercrombie Ranch). Here, about 1,000 loads of waste material (estimated 10,000 yd^3) were dumped down a hillside. There was some concern over this site with respect to material being washed by heavy rains into an ephermeral streambed at the base of the hill, and disposal was relocated to more level ground (Hollister Ranch) a short distance away. About 6 acres of ground were filled at these adjacent sites. Information on the stream indicated that there had been flow during the past winter for the first time in 8 years.(2) Although no surface or groundwater contamination problems are anticipated at either of these two disposal sites, periodic confirmatory observations are planned by the California State Water Quality Control Board.

About 2,000 loads (estimated 20,000 yd^3) of beach clean-up wastes were hauled to a river bottom fill area on the south bank of the Santa Clara River near Oxnard. The material was used as road foundation on this reclaimed river bottom land.(3)



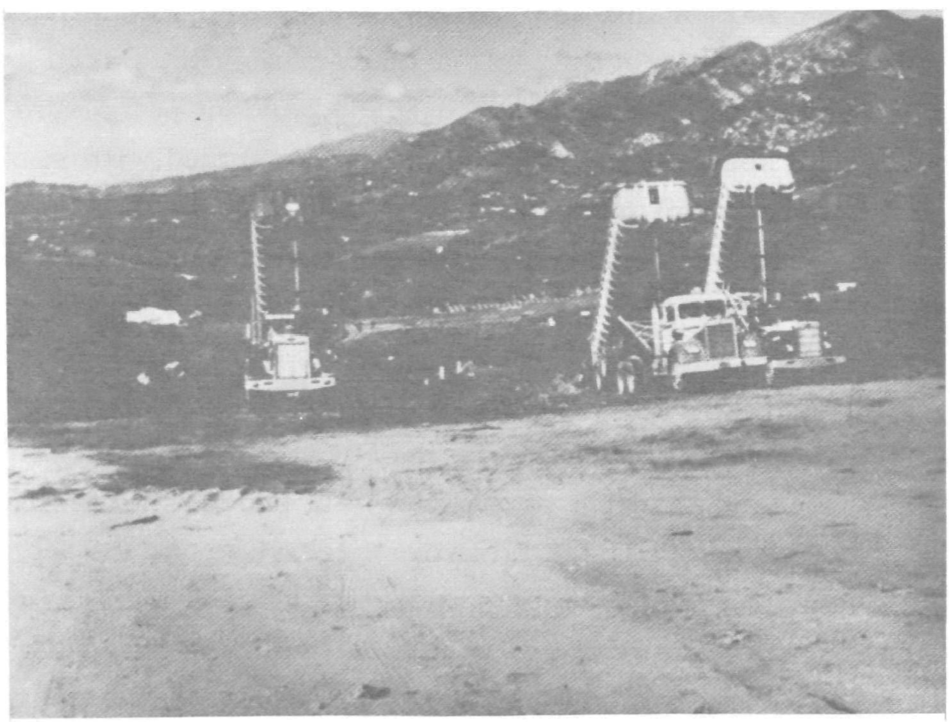


FIGURE 11.2. Disposal of Waste by Landfill Burial

Waste disposal was a major and relatively expensive operation that required and received considerable planning and cooperation. Over 30 large trucks were in continuous waste-hauling operation at one period of the undertaking. The total cost of landfill disposal (including hauling, dump fees, road improvement, etc.) is estimated at about $200,000 or $\$4/yd^3$ by the authors. Gaines,[6] estimated that over 30,000 tons of storm debris alone was disposed of. Gaines further states that, "up to June 1, 1969, 9,826 truck loads of oil-soaked straw and debris had been disposed of."

The lesson to be learned here is that, in the event of another major oil spillage incident, the problem of disposal of waste oil and associated material can be a significant problem. This can be of even increased concern in areas where water supplies are dependent upon groundwater sources.

The major problem of locating acceptable waste disposal sites that arose in this particular incident dictates the advisability of incorporating a survey of potential disposal areas as part of the contingency plan.

11.3 DISPOSAL OF SKIMMED OIL

Oil from harbor and sea-skimming operations constituted a potential, though negligible, recoverable product rather than a waste. Generally, the skimmed material contained from 30-50 percent petroleum[1] (emulsified with sea water). Vacuum trucks equipped with suction hoses were used to remove oil from the harbor at the shoreline (Figure 10.7), and oil-water mixtures collected by sea skimmers were transferred to tank trailers at Stearns Wharf. These mixtures were trucked to either local processing or disposal facilities depending upon the quality of the recovered material. About 400 barrels of the mixture were trucked to the Standard Oil Company processing facility at Carpenteria, California,[4] and an equal amount was sent to the Richfield processing facility at Ellwood, California.[5] These facilities receive crude oil from wells in the area, separate water, free gas and extraneous material from the crude (physical separation) to meet pipeline specifications, and ship the clean product to refineries. The skimmed mixture was blended into the normal plant feed stream for processing. Some problems in equipment fouling were presented by the heavy, thick crude. Also, straw tended to clog pumps and valves to such an extent that only an estimated 25 barrels of oil were recovered at the Richfield facility.[5]

It was reported[5] that skimmed oil was disposed to an approved liquid waste disposal site at Fillmore, California; however, attempts to confirm this were not successful.

SECTION 11.0 REFERENCES

1. Anonymous Union Oil Company Daily Reports on Clean-Up Operations, February 10 - March 21, 1969.
2. Personal Communication, Mr. Kenneth Jones, California State Water Quality Control Board, San Luis Obispo, California, April 21, 1969.
3. Personal Communication, Mr. Frank Robinson, Ventura Coastal Refuse Disposal Company, June 19, 1969.
4. Personal Communication, Mr. John Herring, Producing Department, Standard Oil Company, Carpenteria, California, April 7, 1969.
5. Personal Communication, Mr. Elmer Robertson, Richfield Production Division, Ventura, California, June 18, 1969.
6. Gaines, T. H. "Notes on Pollution Control, Santa Barbara", undated.

12.0 BIOLOGICAL AND ECOLOGICAL SURVEYS AND FINDINGS

To determine the biological impact of the Santa Barbara pollution incident and its impact on the plant and animal communities, a base line of previous studies on the macroflora, fauna and plankton of the area is essential. It is fortunate that extensive studies of marine flora and fauna have been made in the area from the depths of the Channel up through the intertidal zone. The University of California at Santa Barbara (UCSB) and Santa Barbara City College (SBCC) use the intertidal zone as an outdoor laboratory. Similarly, the University of California-Scripps Institution of Oceanography and the Allan Hancock Foundation of the University of Southern California have made extensive studies of the offshore waters of the Channel.

The USFWS, Bureau of Commercial Fisheries and Bureau of Sport Fisheries and Wildlife have studied commercial fisheries, marine mammals and waterfowl in the area. The California Department of Fish and Game has made studies of the intertidal zone of the mainland and Channel Island's fish and wildlife resources.[1] The Water Quality Control Board investigated the oceanographic regime of the area.[2] With these data from the various institutions, a baseline understanding of organisms in the area is available.

An estimation of the biological cost of the oil release was of primary concern to the agencies involved. Studies were initiated as soon as personnel became available; some, of necessity, are on-going. Background information regarding general biological and ecological effects were well documented.[24] There were four basic areas of investigation throughout the period following the oil release. These were:

- Sea birds
- Intertidal and nearshore communities
- Offshore and benthic communities
- Marine mammals.

In addition, some comments are presented on related projects, such as bioassays and hydrographic measurements, and natural phenomena which occurred during the period (e.g., the heavy precipitation and flooding).

This portion of the report attempts to document the surveys conducted during and after the incident. Relevant laboratory studies are also reported. It is not our purpose, however, to go beyond the scope of general documentation. Conclusions and evaluations are not included as these must necessarily derive from studies currently in progress,

12.1 SEA BIRDS

Crude oil presents special problems in pollution control. Since it is relatively insoluble in water, it tends to spread on the surface in films of variable thickness. The effect on the biological communities involved is most notable when the oil comes ashore--the most likely contact point for water birds. On 30 January, 1969, the first dead bird was found. The following day personnel from the Bureau of Sport Fisheries and Wildlife, USFWS, arrived and began aerial surveillance of the Channel and shore bird populations to establish the number and species of affected waterfowl. Approximately 50 miles of coastal transects and 80 miles of Channel transects were flown daily from 4 February through 8 February, and on alternate days 9 February through 14 February (Figure 12.1). Subsequently, weekly flights were made.[(1)] Two California State Department of Fish and Game vessels were also on the lookout for distressed birds and mammals following the transects shown on Figure 12.1.

Early estimates indicated a population of about 12, 000 birds in the Santa Barbara Channel area. Average counts ran about 3, 490 on the transects during the eighteen days of flights.[(25)] No significant change from day to day was observed. However, there appeared to be a definite movement away from the area.[(1)] The kinds of birds counted, in their order of frequency were gulls (three species); grebes (95% Western); cormorants; scoters; shore birds; loons; and a very small percentage of pelagic species. The Western grebes and cormorants were most affected by the oil; sea gulls were the least affected.[(1)]

In addition, four beach transects were walked to observe shore birds. Initially, one control and three contaminated transects were established; however, the control transect also became oil soaked. The Santa Barbara

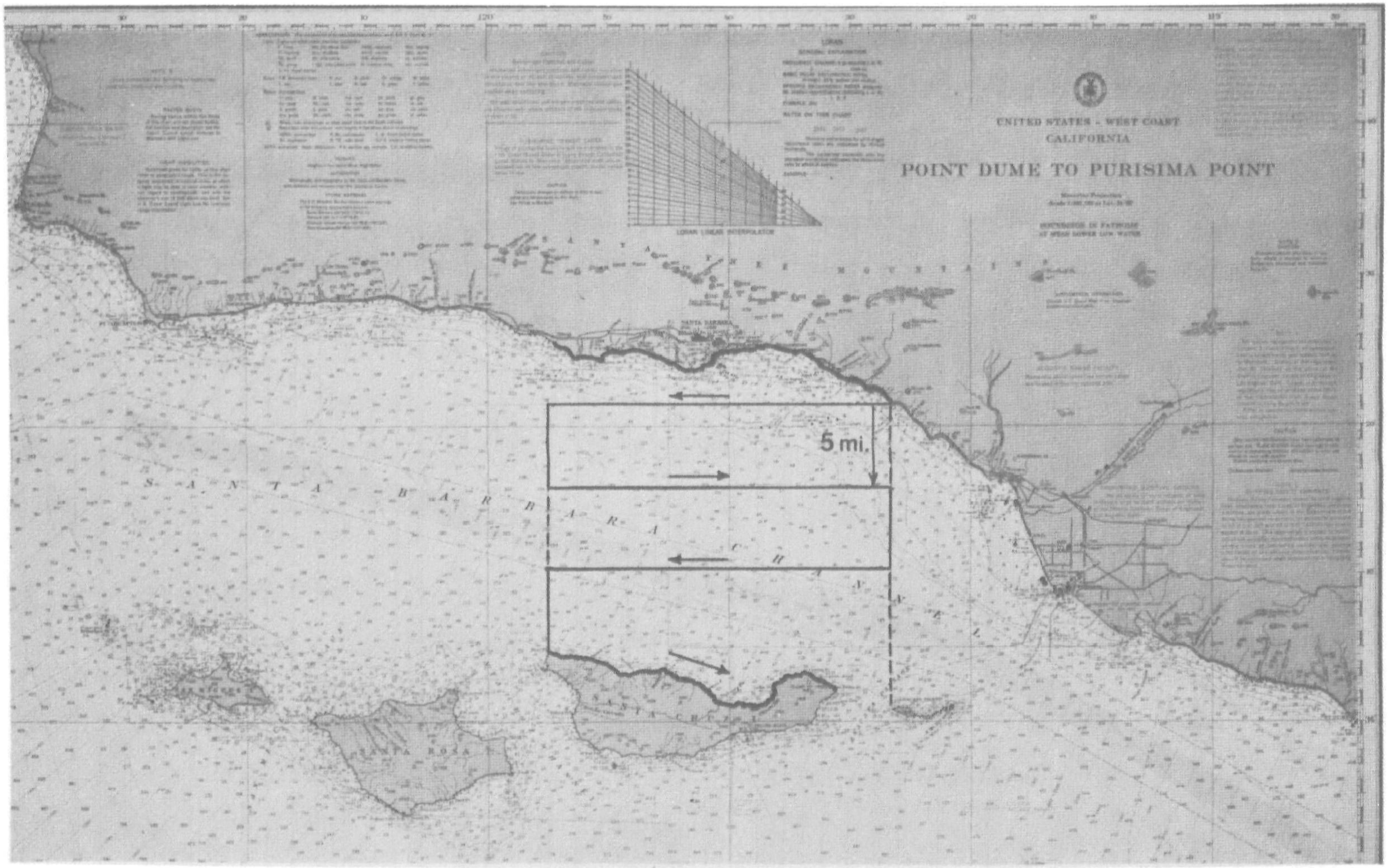


FIGURE 12.1. Location and Direction of Aerial Transects, U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife

FIGURE 12.2

SANTA BARBARA WILDLIFE STUDY - AERIAL TRANSECTS
DATA COLLECTION FORM

Date:________

Transect:________ Time: Start:________

Observer(s):________ Stop:________

Weather:________ Total Time:________

Low Tide Time:________

Bird Observations

Species	Dead	Affected by Oil	Normal	Total
Loon (sp.)				
Grebe (sp.)				
Shearwater				
Brown pelican				
Cormorant (sp.)				
Black brant				
C. goldeneye				
Bufflehead				
Scoter (sp.)				
Red-br. merganser				
Unknown waterfowl				
Great blue heron				
A. egret				
Black oystercatcher				
Black-bellied plover				
Whimbrel or M. godwit				
Willet				
Turnstone (sp.)				
Sanderling				
Sandpiper (sp.)				
Phalarope (sp.)				
Gull (sp.)				
Tern (sp.)				
C. murre				
Pigeon guillemot				
Murrelet (sp.)				
Others				
Unidentified				
Total Birds				
			Mammal Observations	
Sea lion				
Harbor seal				
Porpoise				
Whale				
Others				
Total Mammals				

Notes:

Chapter of the Audubon Society also assisted with the transects and made weekly counts in the Carpinteria and Goleta Marshes. The counts can be compared with several made during 1966.[1]

One of the first reactions to the oil spill was the establishment of bird salvage operations for oiled birds. Personnel of the Childs' Estate (a municipal zoo), local and humane society officials, California State Department of Fish and Game, and the Union Oil Company established two centers, and provided Polycomplex A-11 to wash the birds. Treatment generally consisted of chemical washing followed by placing the birds in a warm recovery room.

Approximately 900 birds were treated at the Carpinteria State Beach and 670 at the Childs' Estate.[3] Although early estimates (13 February) of survival ranged as high as 50%, this decreased to 27.5% by 19 February and to a low of 10% by 1 April;[1] this closely parallels the results of the TORREY CANYON and OCEAN EAGLE incidents. Total known bird losses through 31 March in the area affected by the oil spill were determined to be 3,600.[25] Survivors of the treatment were distributed to three locations. Some were released; others were sent to the San Diego Zoo; and some were banded and released in the vicinity of Vandenberg Air Force Base.[3]

The University of California at Santa Barbara (Dr. Barbara Drinkwater) statistically examined the methods which were most successful with each species.[4] Her reasons for such an approach were threefold. First, there was (and still is) an almost complete lack of published material regarding bird salvage. Second, the bird cleaning group did not include a pathologist with the resultant lack of immediate feedback to pinpoint the cause of death. Finally, physiological data were lacking.

At the time of this writing, Dr. Drinkwater and her group are compiling a computer program. When their results are available, they will have compiled the mean survival rate for each species for each type of treatment, as well as the interaction of the two factors. Statistical variables will be available relating survival to:

1. Species
2. Amount of oil

FIGURE 12.3

SANTA BARBARA BEACH BIRD STUDY

Date:______________
Transect:______________ Time: Start:______________
Observer(s):______________ Stop:______________
Weather:______________ Total Time:______________

Bird Observations

Species	Dead	Oil Stained*	Soaked*	Clean*	Total	Remarks (Feeding, Flying or Resting)
Red-throated loon						
Common loon						
Western Grebe						
Double crested cormorant						
Surf scoter						
Killdeer						
Black-bellied plover						
Snowy plover						
Whimbrel						
Marbled godwit						
Willet						
Sanderling						
Knot						
Western sandpiper						
Least sandpiper						
Gulls (all species)						
Royal tern						
Others:						
Unidentified						
Total						

* Oil stained - those birds with body feathers with oil but not ragged in appearance.
Oil soaked - those birds with body feathers heavy with oil and ragged in appearance.
Clean - those birds with little or no oil on their plumage.

Additional Notes

BEACH CONDITION (Oil contamination, clean-up activity, number of people, etc.)

ANIMALS OBSERVED OFFSHORE (Bird and mammals seen, flight pattern and activity)

UNUSUAL ANIMAL BEHAVIOR

(Use other side as needed)

3. Species and amount of oil
4. Treatment
5. Treatment and species
6. Condition prior to treatment

Dr. Drinkwater to date has compiled and coded data as follows:

1. SPECIES - 26 species treated, each species assigned number.
2. NUMBER - UCSB identification number.
3. CLEANING - type of cleaning compound used.
4. AMOUNT OF OIL - whether light, medium or heavy oil covering.
5. CONDITION BEFORE CLEANING - quiet or active.
6. CONDITION AFTER CLEANING - quiet or active.
7. SIDE EFFECTS - such as convulsions, respiratory trouble.
8. TREATMENT - 15 treatments tried, some in combination, such as butter, vitamins, fish.
9. SURVIVAL PERIOD - number of days lived after cleaning.
10. FATE - whether dead, alive, released.[4]

Mr. Jack Hemphill (USFWS-BSF&W) during the United States Senate hearings in Santa Barbara (24-25 February) stated: "The current practice of cleaning birds with a detergent removes the protective oils as well as the petroleum. As a result, a prolonged rehabilitation period, extending through a complete moult, is currently advocated to prevent death by exposure. An efficient method of oil removal in combination with the application of a substitute oil or wax which would provide immediate protection from the elements may prove a logical solution."

Mr. Hemphill continued, "Bird losses, to this point, have been relatively moderate. That bird losses have been low is purely fortuitious; the ingredients for a major avian disaster were present. Various factors appear to have mitigated bird losses. It was the consensus that bird populations in the area were generally low, due in part to the storm immediately preceding the spill. Many birds were driven out of danger, including an estimated 25,000 pintails reported in the area prior to the storm. Flooded inland areas may have provided a haven for some of the shore birds in search of food. Seasonal migrations of various species such as the brant and sooty shearwater had not begun, thus reducing the total number of birds in the area and potential exposure to contamination. It is frightening to think what might have happened had the usual flight of brant landed here during the critical period. Almost the entire population of this specie could have been exposed to extermination.

" ... Over 5,800 birds were treated following the TORREY CANYON spill; it is conceivable that facilities for treating up to 100,000 birds might be required should an oil spill occur in certain critical areas; for example, Cook Inlet, Alaska, during the months of May and September. The manpower and facilities for such an operation would be staggering. On the other hand, the annihilation of one or more species of waterfowl could be the alternative."[5]

Despite the very considerable effort and expense devoted to bird cleaning and care, the results appear to be no better than in the case of the TORREY CANYON incident.[24] Undoubtedly the effort put forth in Santa Barbara saved many birds and it was apparent that many birds died as much due to the stresses of captivity and handling as to oil contamination *per se*.

The facilities and procedures set up by Union Oil Company were in the nature of an assembly line. This undoubtedly reduced mortality resulting from unnecessary handling.

12.2 INTERTIDAL AND NEARSHORE COMMUNITIES

The most practical and useful method for assessing oil damage to marine macrofauna and flora in the intertidal zones is to compare periodic observations, i.e., beach surveys, made before and after oil deposition. This method obviously requires base-line information or background data collected before the incident. In most oil pollution incidents, such background data have been lacking. Fortunately, in terms of assessment of damage in the Santa Barbara Channel, the late E. Yale Dawson established and surveyed intertidal pollution monitoring stations along the sourthern California coast in 1957.[6] Dawson's stations were again surveyed by marine biologists from UCSB in 1967. During this intervening ten year period, little change had occurred in the marine fauna and flora. These data collected by Dawson and UCSB marine biologists provide a valuable base line for assessment of damage to the intertidal organisms as a result of the oil release and shoreline deposition.

Under the direction of Professor Michael Neushul, of UCSB, student biologists assisted the FWPCA in making transects and samplings of the beaches to estimate the amount of oil on the stations.[7] Details of the procedures are not presented here, but, in brief, two students assigned to a station recorded a number of items observed along a transect line running from Dawson's benchmark to a stake at the water's edge at low tide. Some of the items observed and recorded for each station were:

1. Beginning of high tide mark and oil mark on the beach.
2. Kinds and number of organisms alive or dead touching the transect line.
3. Surface samples of beach sand to estimate oil on the station.
4. Sand core samples for estimation of amount of oil penetrating beach.
5. Photographs of each line transect.
6. Photographs of oil-covered live, moribund, or dead organisms.

The survey included ten of Dawson's stations (Figure 12.4) on 8 and 9, February, 1969, about ten days after the initial oil release. Some stations were resurveyed in March. Observations for each beach transect are detailed in reports prepared by students and submitted to Professor Neushul. Studies were conducted at El Capitan Beach, Coal Oil Point, Goleta Point, Santa Barbara Point, Eucalyptus Lane, Loon Point, Carpenteria Reef, Rincon Beach, Palm Street Beach, Arroyo Sequit (Table 12.1), and in two locations in Santa Barbara Harbor. Surveys were comprised of observations of the various zones (intertidal, midwater, open water) as well as the benthos.[1]

In summary, UCSB beach transect studies showed that no significant acute oil kills of intertidal organisms were observed at any of the ten stations surveyed.

Independent observations made by biologists from other organizations provide further evidence of the lack of any serious acute kills among intertidal species. Mr. C. M. Seeley, aquatic biologist, Federal Water

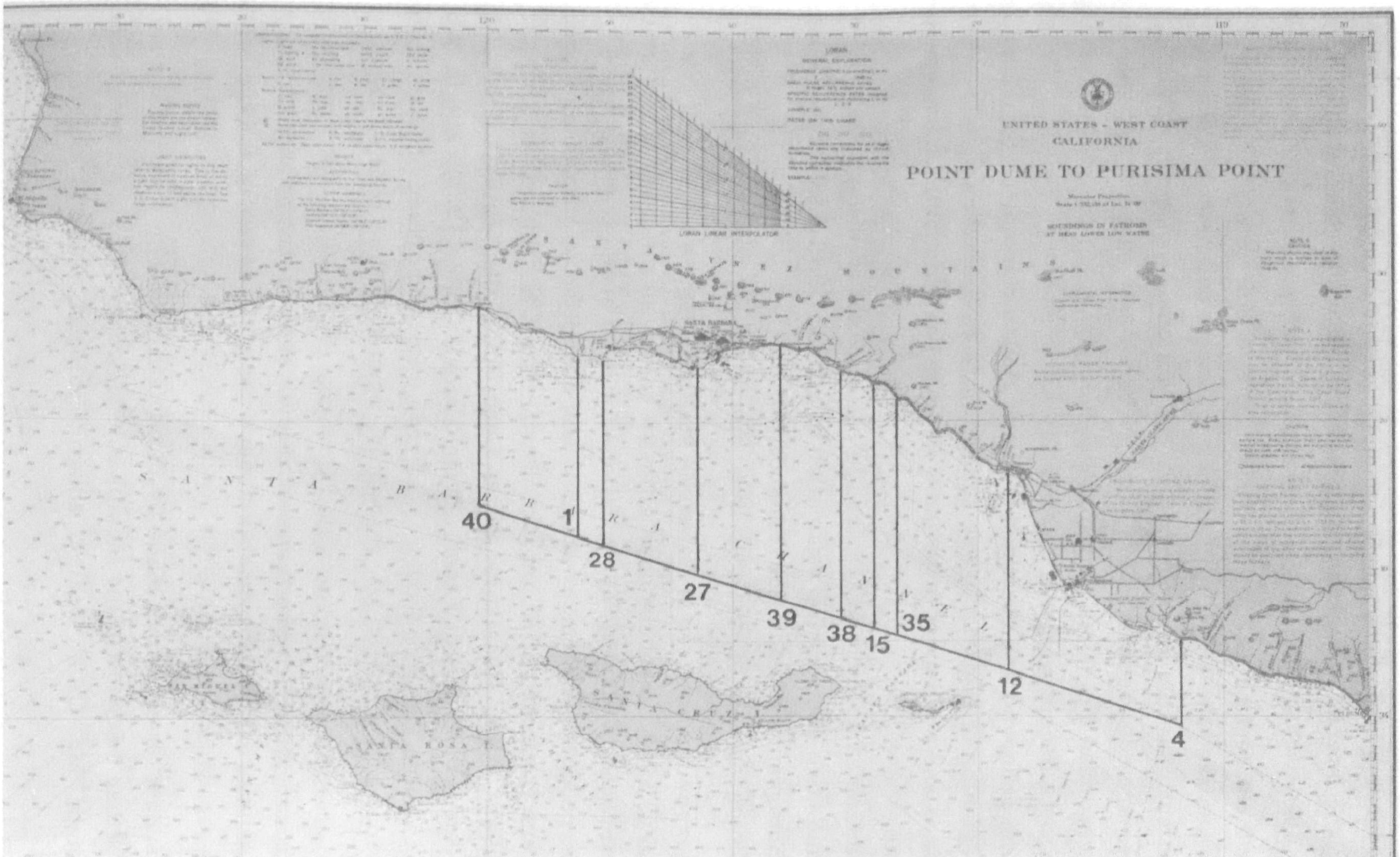


FIGURE 12.4. Beach Transect Sites for Intertidal Study

TABLE 12.1. Biological Stations (Beach Transects) Surveyed by University of California, Santa Barbara Students, February-March, 1969

(West to East) Station No.	Name
40	El Capitan Beach
1	Coal Oil Point
28	Goleta Point
27	Santa Barbara Point
39	Eucalyptus Lane, Montecito
38	Loon Point, Summerland
15	Carpenteria Reef
35	Rincon Beach
12	Palm Street Beach, near Ventura River
4	Arroya Sequit, Los Angeles County

Pollution Control Administration, observed no obvious oil-killed organisms with the exception of at least several hundred dead wavy-top snails or wavy top turbans (Astrea undosa) found dead or dying on oil covered beaches at Carpinteria on 9 February.[8] At present no direct evidence has been firmly established that these wavy-top snails were killed directly by oil; rather, it appears that the kill most likely resulted from sudden exposure to fresh water runoff resulting from rain storms. W. C. Johnson, FWPCA, reported that about a week before the incident the Santa Barbara coast was subjected to heavy rains and flooding; therefore, damage to the biota in some areas on the coast could be the results of fresh water rather than oil.[1]

The FWPCA examined the biological damage created in the Santa Barbara Harbor. In addition, they compiled data accumulated by Santa Barbara City College. Inspections of the intertidal zone revealed very little initial adverse effect obviously due to oil. Some mortalities were observed, however, this may have been due to the hot water used to clean the jetty.[1] Near the end of March, however, some possible effects may have begun to manifest themselves. R. H. Clawson (FWPCA) noticed an apparent degradation of fauna while the flora increased in abundance. This was interpreted as a possible long-term manifestation of the oil's toxicity.[26]

The Bureau of Commercial Fisheries provided an experienced observer, John B. Glude, Deputy Regional Director, Pacific Northwest Region, who observed the effects of crude oil spills in England and France following the TORREY CANYON incident and in Puerto Rico following the wreck of the tanker OCEAN EAGLE. Glude observed the intertidal zone at Channel Islands Harbor, Ventura, El Capitan Beach, Goleta County Beach, and Santa Barbara beaches during the period 13-15 February, 1969. He reported in summary that the only mortality observed among intertidal species was of mussels (*Mytilus californianus*) ranging from an estimate of about one percent on the rocky beach area southeast of Santa Barbara to about 10 to 20 percent at the entrance to Channel Islands Harbor.[9] He also believed that the lack of damage presently observed among intertidal organisms is largely because only limited amounts of dispersant chemicals were used in Santa Barbara and further because crude oil by itself is not highly toxic to the macrofauna and flora which he observed.

The California State Department of Fish and Game and the U. S. Park Service coordinated their efforts in surveying the shore and nearshore marine communities around Anacapa Island (a national refuge) on 5 and 14 February and Santa Cruz Island on 11-14 February, 1969.[10] Figure 12.5 illustrates the area studied for oil damage. Marine biologists of the California Department of Fish and Game led by C. H. Turner worked the area from the vessel COUGAR (U. S. Park Service) and ALASKA (Department of Fish and Game) and smaller skiffs. Four transects extending from above high tide line into depths not exceeding 50 feet were established and studied at Anacapa Island, and at eleven locations at Santa Cruz Island.

Turner reported: "In general, the various animal and plant assemblages observed appeared normal and healthy, although some of those in the intertidal (splash zone to just below low tide) were coated with varying amounts of oil. Oil was observed on the surface canopy of many of the kelp

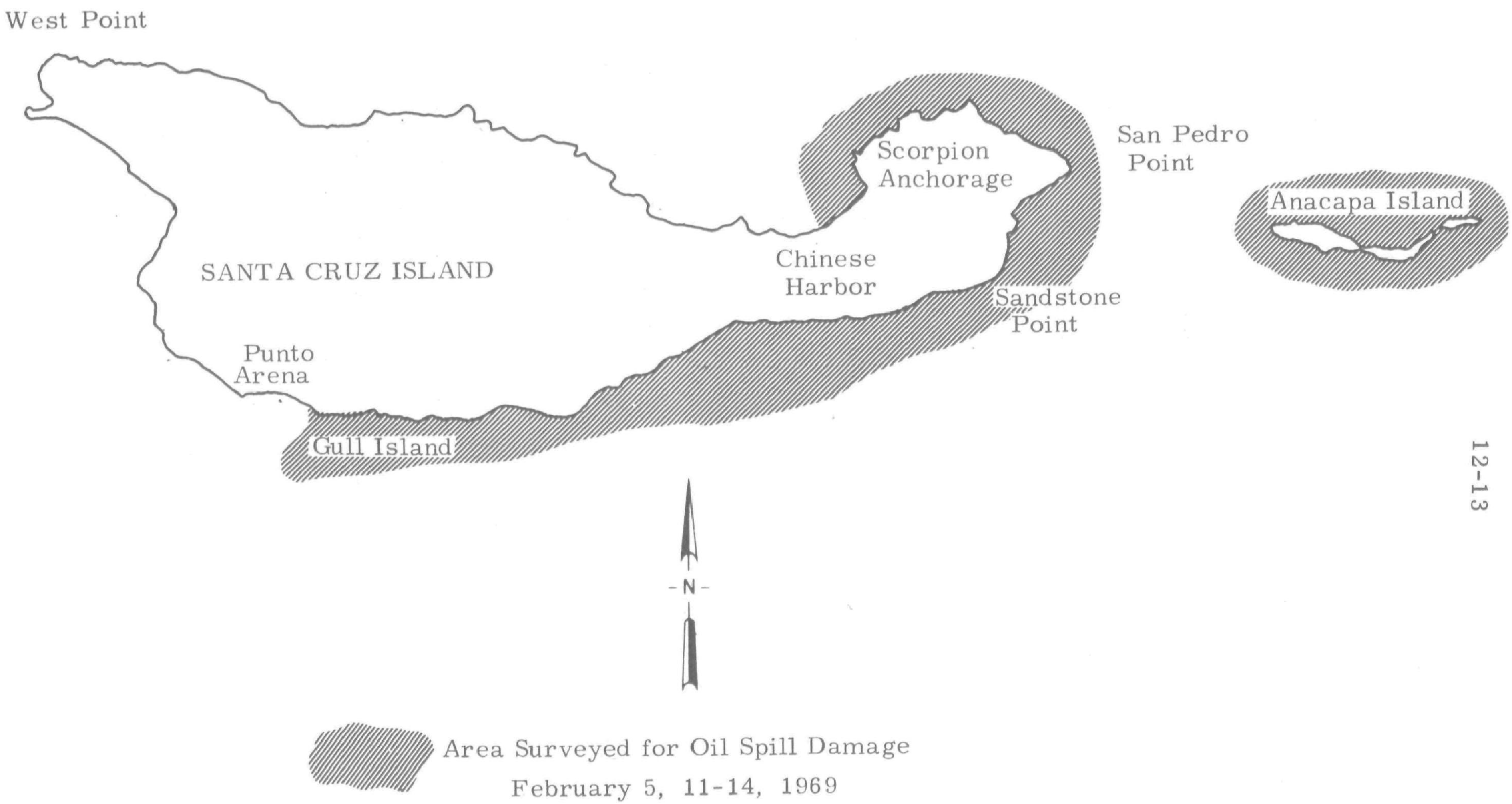


FIGURE 12.5. Area Surveyed for Oil Spill Damage, 5, 11-14, February, 1969, California State Department of Fish and Game

(Macrocystis) beds, but most of this oil was easily shaken off the stipes, indicating that self cleaning would follow storms and heavy seas. Surf grass (Phyllospadix) at Anacapa Island, which was heavily coated with oil on February 5, was appreciably cleaner on February 14. Subtidal plants and animals appeared untouched by the oil.

"Black abalones (Haliotis cracherodii) and numerous other intertidal animals, algae (Hysperophychus and Pelvetia) and surf grass (Phyllospadix) were heavily coated with oil at Punta Arena. None appeared in distress, however, and we presume most will survive. Losses to this island's intertidal life should not exceed 5 to 10 percent (subjective estimate) and the subtidal life should be unharmed."[(10)]

Dr. W. J. North, California Institute of Technology conducted a one-week study to determine possible oil damage to marine life three weeks after the initial oil release.[(11)] This study, sponsored by the Western Oil and Gas Association, included surveys of about 10 miles of beach exposed to oil deposition. No evidence of damage to marine life was found near shore with the possible exception of one dead Pismo Clam.

Concern was expressed about the important kelp-bed resources being contaminated with oil, but North, who has made major contributions on the biology of the giant kelp (Macrocystis) and the utilization of kelp-bed resources,[(12)] reported kelp beds were unharmed. He explained that kelp secretes a mucus substance (polysaccharide) which prevents oil from adhering to the living tissue of the plant.

Possible latent effects were examined by D. Straughan of the University of Southern California, Allen Hancock Foundation. Samples of 5 intertidal species were examined to determine if the surviving animals were reproducing and if repopulation was occurring in devastated areas. She concluded that, except in areas still badly polluted, the examined species are reproducing normally.[(27)]

12.3 OFFSHORE AND BENTHIC SURVEYS

The USFWS Bureau of Commercial Fisheries conducted offshore surveys aimed at determining the oil's effect on pelagic fish eggs and larvae, phytoplankton and zooplankton and spawning as well as related hydrographic conditions such as nutrient concentrations, dissolved oxygen, and light transmittance. The eggs, larvae, and zooplankton were taken in 0.5 meter nets with 1/3 mm mesh. Oblique tows were made through the water column; in addition, samples were taken at 1 and 5 meters in horizontal tows. Near surface phytoplankton and microzooplankton were sampled through 0.04 mm mesh sieves. All specimens were examined immediately on retrieval and preserved later for more detailed analysis.[13]

The cruise of the R/V DAVID STARR JORDAN was designed to study the area of the spillage and determine the effects on pelagic eggs and larvae. The presence and absence of larvae and eggs on anchovy was no different than long-term average variations. In addition to anchovy larvae, the samples included larvae of hake, rockfish (Sebastodes spp.), sciaenids (Cynoscion spp.), sand dab (Citharichthys spp.), English sole (Parophrys spp.), deep sea smelt (Leuroglossus spp.) and flounder (Pleuronichthys spp.) in approximate amounts expected for the areas sampled. Some specimens were taken from beneath oil slicks; no dead eggs or larvae were found. Phytoplankton and zooplankton from near-surface samples appeared normal and were not adversely affected.[14]

The hydrographic studies indicated varying light transmittance according to the thickness of the oil layer. There was complete light transmission in areas of thin slicks decreasing to nearly zero light transmission under thicker layers.

UCSB biologists Drs. Alfred Ebling and Adrian Wenner, aboard the FWPCA chartered SWAN, continued a study begun long before the spill. Dr. Wenner examined plankton samples for larval stages of the sand crab, Emerita, and found them to be present in abundance. Dr. Ebling was examining the kelp fish population in order to compare post-spill data with data he had collected in the four previous years. As yet, no statement can be made on the actual effect of the oil deposition. In every case the data were not completely analyzed or were simply incomplete.[15]

The State of California Department of Fish and Game aboard the

ALASKA surveyed the Santa Barbara Channel to determine the effects of oil pollution on the pelagic fishes of the area. Acoustic surveys, similar to those routinely conducted since 1965, were made along 96 miles of acoustic transects. The echo sounder detected schools of anchovy, rockfish, squid, and, perhaps, jack mackerel.

Since 1965, this area had been surveyed 12 times in a similar manner. Compared with previous surveys, those following the oil release ranked second in number of anchovy schools. There was apparently an unusual seasonal abundance since anchovies are generally scarce during this time period.

In addition, three transects were established from 10 meter depth to 50 fathoms. A drag net (otter trawl) with 1-1/2 inch stretch mesh was used on the transects to capture fish. All fish captured were weighed and measured to establish baselines for future investigation. The dominant fish caught were sea perch, followed by flat fish (Pleuronectidae), sharks, and angel sharks. Midwater trawls, limited to two due to inclement weather, also indicated better than average catches of jack mackerel and bonito, two species last taken in 1963.[(16)]

California State Department of Fish and Game personnel also assessed bottom characteristics and the condition of benthic organisms along three transects ranging in depths from 2 to 62 fathoms. Samples were taken with a Ponar 0.1 meter square dredge and a 41-foot headrope gulf shrimp trawl. Twenty-six dredge samples were taken in depths between 2 and 50 fathoms. Seventeen 10-minute bottom trawls were completed between 16 and 62 fathoms.

No evidence of oil contamination on the bottom was noted at depths between 6 and 62 fathoms. Oil or oil emulsion occurred in the dredge sample taken inside Santa Barbara Harbor.[(17)]

None of the reporting groups defined any significant detrimental effects upon the fauna. The R/V DAVID STARR JORDAN studies indicated "minimal adverse effects: on the plankton in the area. California Fish and Game Cruise Reports also indicate the damage was minimal or nonexistent among benthic organisms and pelagic fishes.

12.4 MARINE MAMMALS

In the early stages of the Santa Barbara Channel oil pollution investigations, concern was expressed for the marine mammal populations in the area. California Fish and Game personnel examined Santa Cruz and Anacapa Island on 5 February and 11-14 February, 1969, to assess the effects of the oil spill on the marine communities. Approximately 35 California Sea Lions (Zalophus californianus) were observed coated with oil but in no apparent distress. Another group of about 300 were observed in the area with no signs of oil coating.[10]

On 10 February, field personnel reported the oil slick had not extended westward as far as Santa Rosa and San Miguel Islands, and the small colony of fur seals (Callorhinus ursinus) on San Miguel had not been affected. Press reports stated "... nine dead (Elephant Seals) and 35 so heavily coated with oil that none were likely to survive." However, upon personal contact with California Fish and Game personnel at Terminal Island, California, it was disclosed that all but one of the nine "dead" elephant seals (Mirounga angustirostris) on San Miguel Island had left the island as had the remaining 35 "doomed" seals, apparently under their own power since they were above the high water line.

Other seals and sea lions observed in the vicinity of Anacapa and Santa Cruz islands did not appear to be affected although they had been observed swimming in areas where oil was present. When the Department skiff approached, the already oil-covered seals were aroused, dove into the water and received an additional coat of oil. As the skiff departed, the seals crawled back onto the rocks and fell asleep, apparently unaffected by the oil.[18]

Marine mammals reported during this period (28 January to 31 March) to have washed ashore dead in the study period numbered three sea lions and four porpoises. Autopsies performed on two porpoises failed to incriminate oil contamination as the cause of death.[25]

The California Grey Whales (Eschrichtius gibbosus) received a great degree of notoriety. They were in the peak of their northern migration period during the period of major oil release. By 10 February, only five grey whales had been observed in the area since the initiation of oil release. All of these appeared to be in good condition. Observers reported the whales appeared to be just "passing through."

Six whales (five California Grey Whales and one Pilot whale) were stranded along beaches north of the Santa Barbara area. This is about normal according to the Bureau of Commercial Fisheries personnel;[19] and not unusually high according to Mr. R. L. Brownell, Jr. of the Los Angeles County Museum of Natural History. Brownell, in reviewing records from between 1960 and 1968, noted that 15 to 20 California Grey Whales were stranded along the California coast. "Of these, five were found between mid January and mid May 1961, and three between February 25 and March 15, 1964."[20]

Examination on 14 March by FWPCA personnel at the site of a stranding produced the following information: "The dead whale, a male California Grey Whale, was located on the beach near the foot of a 75 foot bluff.... It was washed ashore on 12 March. The body and head show considerable evidence of bites, presumably from sharks of good size. No oil was seen on the body surface, but had any been originally present it would probably have been lost when the body was covered and uncovered with sand."[20]

The whale was transferred to the Pt. Molate Whaling Station for further examination. The whale was in an advanced state of decomposition; the viscera were severely autolysed. Visual inspection of the baleen, mouth and blow-hole showed no traces of oil. Tissue samples were taken by BCF personnel for analysis.[21] The FWPCA analysed these tissues on 17 March, 1969. They were unable to detect the presence of oil in the tissues provided.[28]

Transects have since been flown by the Bureau of Commercial Fisheries from Santa Barbara north to Coos Bay, Oregon and from Coos Bay to Cape Flattery, Washington. Five to six hundred whales were seen in each transect; no additional mortalities or strandings were observed.[19]

Thus, in general, although most mammal species in the area received some oil coating, minimal effects can be attributed to the oil. The seals and sea lions which became covered appeared normal. The whales migrating through the channel either were able to avoid the oil or were unaffected when in contact with it.

12.5 RELATED STUDIES AND EVENTS

12.5.1 Bioassays

When the leak occurred, only very limited background material was available concerning the toxicity of various chemicals used in spill treatment. However, from previous experience (e.g., TORREY CANYON), it was known that at least certain dispersants were considerably more toxic than the oil itself. Thus, the FWPCA, with limited facilities at the site, set up small bioassays to evaluate both the immediate effects of crude oil and oil-with-dispersant mixtures used at Santa Barbara.

A preliminary test used the salt water minnow, Fundulus parvipinnis, to test "Corexit 7664," "Corexit"-Oil mixtures and oil alone.[1] Limited investigations, using goldfish, were made on the relative toxicities of "UNICO"; "E-147"; "Besline"-Oil Mixture; "Polycomplex A-11", with and without oil; and the household detergent "Joy."[22]

"Corexit 7664" was also tested at the BCF Fishery-Oceanography Center at La Jolla, California. This bioassay employed the eggs and early larvae of the northern anchovy, Engraulus mordax. Two experimental containers of sea water each containing 25 eggs were used for concentrations of "Corexit" ranging from 2-100 ppm.[14]

The California Department of Fish and Game has established criteria for assessing the suitability of oil spill treatment chemicals. Their primary goal is the protection of fish and wildlife, but aesthetic and recreational use is also considered. Any application of a potential contaminant must be evaluated with respect to the area or volume it will occupy as a function of time; once this has been determined, it must be decided what changes the dispersant may bring about in the physical, chemical and biological characteristics of the environment.

A summary of their criteria of toxicity is as follows:

1. No toxicity to selected plants and animals at 100 times the concentration

of the treatment chemical expected at the edge of the zone of application as calculated from static bioassay TL_m values.

2. Selected plants and animals should not be adversely affected at concentrations occurring in the zone of dilution as determined by long-term flowing water bioassay of emulsions, nor should the detergents or their metabolites accumulate in the food chain.
3. Establish time-to-death versus concentration relationship of the treatment chemical and emulsion.
4. No toxicity or fouling of birds or mammals.
5. Toxicity tests must be performed on the detergent, solvent, and stabilizer portions of the treatment chemical in addition to emulsions resulting from oil treatment.
6. Toxicity tests must be performed according to standard methods on susceptible and sensitive species from lists supplied by the Department.

With regard to biodegradability, the factors are as follows:

1. The treatment chemical or emulsions should show no toxicity to the appropriate decomposer bacteria.
2. An analytical measure should be made of the rate of decay of the treatment chemical and resulting emulsions in a simulated marine environment.
3. The effect of essential nutrients on the rate of decay of the surfactant-oil complex needs to be determined.
4. The biochemical oxygen demand with rate-factor of the treatment chemical and resulting emulsions.

Following the initial drafting of this report, information was provided by the Union Oil Company[29] on bioassay studies of several proprietary chemical treating agents. This information is appended (page 12-23) without comment. Suffice it to say, conclusions drawn from bioassay evaluation must recognize the specific conditions under which these tests were conducted. Further investigations are necessary before any responsible conclusions regarding relative toxicities can be made.

12.5.2 Flood Damage

Almost concurrently with the oil spill, one of the heaviest rainfalls in the past 100 years occurred throughout Southern California. The flooding which occurred in conjunction with the rainfall carried large quantities of debris, earth and silt into the Channel. Much of the debris was washed onto the beaches and was covered with oil. The silt remained in suspension for several days and, in some cases, could be seen clearly from the air for several weeks. In addition, just prior to the rains, agricultural areas of Santa Barbara, Ventura and neighboring counties had been heavily treated with pesticides. During the floods a large portion of these chemicals was undoubtedly washed to sea.

On 9 February, Mr. Charles Seeley of the FWPCA reported at Carpenteria State Beach that he "walked up the beach for about 150 yards and found numerous wavy-top snails (Astrea undosa) dead or dying on the sand and in, or covered by, the heavy oil and debris deposits. A conservative estimate of numbers would be several hundred dead." On February 13, 1969, he reported "It was of interest to note that the storm debris which inundates the beach northwest of Carpenteria Creek is relatively scarce below the creek. Also, no specimens of Astrea were observed in this section."[8]

Thus it would appear that the marked salinity decrease and, perhaps, the introduction of abnormal quantities of silt, debris, and pesticides contributed to the overall mortality in the area. The mortalities caused by the flood effects may indeed be masked by the presence of oil on specimens, perhaps already dead or dying, which were washed up onto the beaches.

12.5.3 Dissolved Oxygen Studies

The dissolved oxygen (DO) regime in Santa Barbara Harbor was monitored from 7 to 11 February, 1969. Samples were collected by FWPCA field personnel at various tides to assess the exchange of harbor water. In addition, the water within the "Undersea Gardens," an aquarium in the harbor, was monitored from 6 to 11 February, 1969. These data are given in Table 12.2.

The DO determinations were made with an azide modification of the Winkler method. Surface samples were taken one foot below the surface and bottom samples one foot above the bottom. Table 12.2 indicates slightly lower values than those reported in earlier work in 1959.[2] These latter studies found the amount of dissolved oxygen in all areas of Southern California to a depth of 200 feet was usually between 5 and 10 ppm.

TABLE 12.2. Dissolved Oxygen at Santa Barbara Harbor

Date	Station	Time	Depth	Temp.	DO mg/l
2/7/69	2	1445	Surf.	14.0 °C	4.95
2/8/69	1	1330	Surf.	15.5 °C	4.95
			1.5 m	14.0 °C	5.0
			3.0 m	14.0 °C	5.40
	1	1900	Surf.	14.0 °C	5.25
			1.7 m	13.5 °C	5.60
			3.4 m	13.5 °C	5.50
2/9/69	1	0940	Surf.	13.5 °C	4.85
			1.5 m	13.5 °C	4.82
			3.0 m	13.5 °C	4.70
2/9/69	1	1650	Surf.	14.5 °C	4.80
			1.7 m	14.0 °C	4.75
			3.0 m	14.0 °C	4.65
2/10/69	3	0950	Surf.	14.5 °C	4.80
			2.0 m	14.3 °C	4.50
	4	1000	Surf.	14.3 °C	5.10
			2.5 m	14.3 °C	5.00
			5.0 m	14.3 °C	4.84
	5	1030	Surf.	14.3 °C	5.30
			3.0 m	14.0 °C	5.20
			6.0 m	14.0 °C	5.20
2/11/69	1	1020	Surf.	14.5 °C	5.04

Only five samples (of 450) had concentrations below 5.5 ppm. Unfortunately, they present no data within the Santa Barbara Harbor, thus making direct comparisons impossible.

The FWPCA also determined respiration rates within the "Undersea Garden." These were determined by the incubation of light and dark bottles *in situ*. These data, however, are incomplete.

APPENDED INFORMATION FROM UNION OIL CO. OF CALIFORNIA[29]

Results of a Bioassay for Union Oil Company

The results of our investigation of the fish tolerance of several surfactants of different manufacture are presented in this report.

On March 13, 1969, seven samples of surfactants of different manufacture were received from Mr. Harry M. Brandt of the Technical Service Division of Union Oil Company. We have performed 96-hour TL_m or Median Tolerance Limit assays on all seven samples.

The seven samples are the following:

1. ARA Gold Crew Bilge Cleaner; Ara Chem. Inc.
   A somewhat viscous, clear, liquid miscible with water.
2. Corexit 7664; Enjay Chem. Co.
   A somewhat viscous, clear liquid miscible with water.
3. Crain OD-2; Crain Ind. Prod. Co.
   Resembles green soap. Miscible with water.
4. H 4000; Verne Hollander
   Clear, kerosene odor, forms white emulsion with water.
5. Polycomplex A-11; Guardian Chem. Corp.
   A somewhat viscous, clear, liquid miscible with water.
6. Surfemul #5; 3C Chemical Corp.
   A milky-white aqueous dispersion.
7. Unico; Universal Supply Co.
   Resembles green soap. Miscible with water.

The bioassay conducted for the Union Oil Company was a static type carried out according to the procedures of the Standard Methods for the Examination of Water and Wastewater, Twelfth Edition. (1965)

Two containers of five fish each in six liters of artificial sea water were used for each dilution level of each sample. At least four dilution levels were used for each surfactant sample. At least ten control fish were similarly treated for each sample series. Each container was aerated slowly with filtered air throughout each test. This was necessary to maintain the dissolved oxygen level above 4 mg/L.

The dissolved oxygen (DO) was measured using a Precision Scientific Co. galvanic cell oxygen analyzer. The analyzer was calibrated in air saturated artificial seawater. The known value of 7. 3 mg oxygen per liter of seawater at 21 °C was used. Tables supplied by Precision Scientific Co. were used to convert meter readings to mg/L.

The pH value of each test container was recorded using a Coleman pH meter.

The water temperature throughout the test remained at 21-22 °C.

The fish used (Fundulus parvipinnis) in the Union Oil Company bioassay were obtained from the brackish water areas just to the south of Seal Beach. The fish were collected at high tide at different intervals using a small seine. The fish were acclimatized for at least 14 days to laboratory conditions before use. They were fed frozen brine shrimp once a day except for two days preceeding a test.

Artificial seawater mixed 2:1 with ocean water was used to acclimatize the fish. Artificial seawater alone was used as dilution water for the surfactants in each test to avoid other contaminants. This was permissible since no exact source was specified and the concentrations of salts were within the accepted range.

The weight of all fish in each test container averaged 2 to 2-1/2 g/ℓ.

Preli minary exploratory tests had to be conducted for each sample because at the time of the test little information had been found in the literature and no other indication of the tolerance of fish to the material was known. In some cases a second preliminary test was necessary as the concentrations in the first test were in steps of one-hundred.

Results

Surfactant	24 hr TL_m in ppm	96 hr TL_m in ppm
ARA Bilge Cleaner	128	128
Corexit 7664	15, 900 (?)	7, 200
Crain OD-2	125 (?)	118
H-4000	118	81
Polycomplex A-11	225	134
Surfemul #5	350	350
Unico	220	220

All 70 control fish survived the test.

Discussion

A reduction in toxicity of the surfactants was apparent in the static tests. In four of the samples the 24 hr TL_m and the 96 hr TL_m were the same. A semi-dynamics test in which the liquids test is periodically renewed in order to nullify the loss from volatilization of the test materials would enable more precise measurement of tolerance.

The pH appeared virtually independent of the material tested and the tolerance of the fish to the material. The dilution water used for the May 6th tests was somewhat lower in pH than that run previously. A check shows no effect of this decrease on the significance of the test.

The 24 hr TL_m of Corexit 7664 was determined by drawing a line from the single point of 70% survival parallel to the line for the 96 hr TL_m. This is because no point higher in concentration than 10,000 ppm was established.

Generally when two test concentrations one above and one below the TL_m have proved unquestionably lethal to some (about 20% or more) but not to all of the test animals, the determination of survival percentages at intermediate concentrations is not essential. This was only achieved in two of the samples tested here. However, as stated in Standard Methods, testing of more concentrations may not be justifiable when the increase reliability of the estimate thus achieved has no immediate practical import. Lacking any knowledge to the contrary, the intervals used in this test are presumed satisfactory.

Reference:

Standard Methods for the Examination of Water and Wastewater, 12th ed., 1966.

American Public Health Association, Inc.,
1790 Broadway, New York, New York 10019

May 12, 1969

SECTION 12.0 REFERENCES

1. Johnson, W. C. Biological Input of Oil Spill from Offshore Oil Well Break. Memo to R. C. Bain, Chief, Operations Section, California-Nevada Basins, FWPCA, February 19, 1969, 4 pp.
2. State of California Water Pollution Control Board. Oceanographic Survey of the Continental Shelf Area of Southern California. Water Pollution Control Board, Sacramento, California, Publication No. 20, 560 pp. 1959.
3. Shanks, Warren, Biologist, Bureau of Sport Fisheries & Wildlife, Portland, Oregon. Personal Interview, April 3, 1969.
4. Drinkwater, Dr. Barbara, University of California at Santa Barbara, Personal Communication, April 7, 1969.
5. Hemphill, Jack E. Report - Santa Barbara Channel Oil Spill. Manuscript for presentation to the Hearings of the U. S. Senate, Santa Barbara, California, February 24-25, 1969, Bureau of Sport Fisheries and Wildlife, 5 pp.
6. Dawson E. Yale. (Allan Hancock Found. - Oceanographic Survey) Section IV. A primary report on the benthic marine flora of Southern California. In Oceanographic Survey of the Continental Shelf of Southern California, pp. 169-264, State Water Pollution Control Board, Sacramento, California Publication No. 20, 1959.
7. Neushul, Michael. Personal Interview, March 20, 1969, UCSB.
8. Seeley, Charles. Trip Report: Santa Barbara Oil Spill, February 5-14, 1969. Memo to Chief, Operations Branch, Calif. Nevada Basins, FWPCA, February 25, 1969, 4 pp.
9. Glude, John B. Observations on the Effects of the Santa Barbara Oil Spill on Intertidal Species. Draft of John B. Glude, Deputy Regional Director, Pacific Northwest Region, BCF, Seattle, Wash., April 10, 1969, 9 pp.
10. Turner, Charles H. Inshore Survey of Santa Barbara Oil Spill. California State Department of Fish and Game, Cruise Report 69A2, Feb. 5-6; Feb. 11-14; 1969, 3 pp.
11. Anonymous. Oil-spill damage to marine life scant. The Oil and Gas Journal, March 17, 1969, pp. 65-68.
12. North, Wheeler J. and Carl L. Hubbs. (ed) 1968. Utilization of Kelp-Bed Resources in Southern California. California State Department of Fish and Game, Fish Bulletin 139, 264 pp.
13. Smith, Paul. Cruise Report - R/V David Starr Jordan, Cruise 33. USFWS, BCF, 5 pp. 1969.
14. Smith, Paul and Reuben Lasker. Appendum to Cruise Report #33, Crude Oil Reconnaissance. U. S. Government Memorandum 3201.6, February 18, 1969, 2 pp. Also Commercial Fisheries Review, Vol. 31, No. 3, March 1969, pp. 6, 7.

15. Hof, Charles. "What Role Have the Biologists at UCSB Played in Solving the Problems Demonstrated by the Blowout on Platform A?" Typewritten Report for Political Science 166 (UCSB), 11 pp. 1969.

16. Mais, K. F. Pelagic Fish Survey of Santa Barbara Oil Spill. California State Department of Fish and Game, Cruise Report 69A4, February 18, 1969, 4 pp.

17. Jow, Tom. Preliminary Cruise Report. California State Department of Fish and Game, February 3-7, 11, 1969, 3 pp.

18. Turner, Charles H. and Jack Prescott, California State Department of Fish and Game, Personal Interview, April 10, 1969.

19. Roppel, Al. Bureau of Commercial Fisheries (USFWS). Personal Interview, April 4, 1969.

20. Brownell, R. J., Jr. Letter to Sen. Alan Cranston, March 24, 1969.

21. Seeley, Charles M. Trip Report to Pt. Molate Whaling Station and Autopsy of the Pacifica California Grey Whale Specimen. U. S. Government Memo, March 17, 1969, 2 pp.

22. Merrill, John. FWPCA, Personal Interview, March 20-21, 1969.

23. Zobell, C. E. The Occurrence, Effects and Fate of Oil Polluting the Sea. Proc. Int. Conf. Wat. Poll. Res., Pergamon Press, pp. 85-118. 1964.

24. Battelle Memorial Institute. Oil Spillage Study Literature Search and Critical Evaluation for Selection of Promising Techniques to Control and Prevent Damage. BMI-AD-666-289, Ch. 6. 1967.

25. State of California Department of Fish and Game. Progress Report on Wildlife Affected by the Santa Barbara Channel Oil Spill. January 28-March 31, 1969. 8 pp.

26. Clawson, R. H. U. S. Government Memo Re: Biota on Pilings Supporting Stearn's Wharf. Mimeo. 1 p. 1969.

27. Straughan, D. Breeding Activity of Intertidal Species. USC, Allen Hancock Foundation, Mimeo, 2 pp. 1969.

28. Federal Water Pollution Control Administration. Report on Whale Tissue. 17 March 1969. Mimeo, 2 pp.

29. Gaines, T. H. 'Notes on Pollution Control, Santa Barbara", undated, Appendix III.

13.0 ON-GOING RESEARCH AND DEVELOPMENT PROGRAMS

Numerous research and development programs in the overall field of oil pollution have been proposed, are currently underway, or are anticipated in the future. Since it is important that workers in the field know of, and are in contact with, complementary efforts, Table 13.1 is attached summarizing twenty-three publicly sponsored research programs underway as of mid-May, 1969. This table does not include the various Federal and State agency in-house efforts or individual petroleum company activities. Nevertheless, it is hoped that the summation will be of assistance in coordinating various efforts and in avoiding unnecessary duplication.

TABLE 13.1. ONGOING RESEARCH & DEVELOPMENT PROGRAMS
MAY, 1969

PROJECT TITLE/DESCRIPTION	SPONSOR	CONTRACTOR/GRANTEE	ESTIMATED PROJECT COST	REMARKS
13.1 Prevention of Oil Release				
1. In-Tank Gellation to Reduce Oil Loss from Tankers	Federal Water Pollution Control Administration	Western Company 2201 Waterview Pkwy. Richardson, Texas	$ 42,290 (1st Phase)	Onboard and portable facilities.
2. Development of Equipment for Control of Oil Spillage and Systems for Aerial Delivery	U. S. Coast Guard	Ocean Science and Engineering	290,710	Air transportable tanker emergency unloading equipment.
13.2 Control and Restoration				
1. Oil-Water Separation System for Treatment of Oil Wastes	Federal Water Pollution Control Administration	Garrett Corporation Airesearch Manufacturing Company	78,178	High Capacity (500 gpm) centrifuge.
2. Prevention and Elimination of Oil Pollution in the Buffalo River	Federal Water Pollution Control Administration	City of Buffalo 65 N. Vagora Street Buffalo, N.Y. 14202	737,194	Cornell Aeronautical Laboratory subcontractor. Evaluation of oil control methods, particularly the air curtain barrier.
3. Investigation of Recovery of Large Marine Oil Spills by Use of a Vortex Assisted Air Lift System	Federal Water Pollution Control Administration	Battelle-Northwest Richland, Washington 99352	29,880 (1st Phase)	
4. Test and Evaluate Mechanical and Pneumatic Barriers to Contain Spilled Oil and Means for Removing the Contained Oil in Harbors and Adjacent Waters	Federal Water Pollution Control Administration	Maine Port Authority Portland, Maine 04111	100,850	Eighteen months' study.
5. Analysis of Methods for Removal of Oil from Harbor Waters	U. S. Naval Civil Engineering Laboratory, Naval Facilities Engineering Command	Battelle-Northwest Richland, Washington 99352	16,750	
6. Evaluate Stresses on High Seas Oil Booms	U. S. Coast Guard	Hydronautics Inc., Laurel, Md.	62,790	Development of boom design criteria.
7. Evaluate Use of Sand for Sinking of Oil Slicks	U. S. Coast Guard	U. S. Army Corps of Engineers	10,000	/aluation of treated sand using .ooper dredges.

TABLE 13.1 (CONTD). ONGOING RESEARCH & DEVELOPMENT PROGRAMS

MAY, 1969

PROJECT TITLE/DESCRIPTION	SPONSOR	CONTRACTOR/GRANTEE	ESTIMATED PROJECT COST	REMARKS
13.3 Biological & Ecological Effects				
1. Pathological Effects of Oil on Birds Caught in the Santa Barbara Oil Slick	Federal Water Pollution Control Administration	University of California at San Diego	31,000	
2. Ecological Effect of the Santa Barbara Channel Oil Pollution Incident	Western Oil & Gas Assoc. Los Angeles, California	University of Southern Calif., Allen Hancock Foundation, Los Angeles, California	150,000	
3. Resurvey of Santa Barbara Inter-tidal Zone Transects	Federal Water Pollution Control Administration	University of California at Santa Barbara	7,000	
4. Fishes of the Santa Barbara Kelp Forest	National Science Foundation Office of Sea Grant Programs	University of California at Santa Barbara	18,000	Ecological Study. Principal Investigator: Dr. A. Ebling.
5. Population Dynamics of Inter-tidal Organisms	National Science Foundation Office of Sea Grant Programs	University of California at Santa Barbara	29,000	
6. Effects of oil on plankton	National Science Foundation Office of Sea Grant Programs	University of California at Santa Barbara	17,293	
13.4 Other				
1. The Spreading of Oil Films	Federal Water Pollution Control Administration	New York University School of Engineering & Sciences. Univ. Heights, Bronx, N.Y. 10453	27,000	
2. Oil Tagging Systems Study	Federal Water Pollution Control Administration	Melpar Inc., 7700 Arlington Blvd. Falls Church, Va. 22046	50,000	Determine operational systems for tagging, petroleum & petroleum products with chemicals & other identifying tags.
3. Review of the Santa Barbara Channel Oil Pollution Incident	Federal Water Pollution Control Administration, U.S. Coast Guard	Battelle-Northwest Richland, Washington 99352	22,900	
4. Investigation of Microwave Measurements of Oil Slicks	U.S. Coast Guard	Aerojet General Corp.	48,285	
5. Investigation of Ultraviolet and Infrared Spectra of Oil Slicks	U.S. Coast Guard	University of Michigan	52,644	
6. Identification of R & D Requirements	U.S. Coast Guard	A. D. Little, Cambridge, Mass.	47,235	
7. Microwave Radiometric Measurement of Oil and Sea Temperature	National Science Foundation Office of Sea Grant Programs	University of California at Santa Barbara	38,000	Principal Investigator: Dr. N. K. Saunders.
8. Chemical Determination of Source Pollutant Tars	National Science Foundation Office of Sea Grant Programs	University of California at Santa Barbara	16,500	Heavy metal concentrations in natural seeps and production crude oil. Principal Investigator: Dr. P. G. Mikolaj.
9. The Effects and Implications of Petroleum Pollutants on Resources of the Santa Barbara Channel	National Science Foundation Office of Sea Grant Programs	University of California at Santa Barbara	.0,000	Principal Investigator: Dr. P. G. Mikolaj.
10. Evaluation of Remote Sensing Data	Federal Water Pollution Control Administration	University of Michigan	16,600	

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