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A Systems Study of Oil Pollution Abatement and Control for Portland Inner and Outer Harbor, Casco Bay, Maine

Arthur D. Little, Inc.

A SYSTEMS STUDY OF OIL POLLUTION ABATEMENT AND CONTROL FOR PORTLAND INNER AND OUTER HARBOR, CASCO BAY, MAINE

to

STATE OF MAINE
DEPARTMENT OF
ENVIRONMENTAL PROTECTION
STATE HOUSE
AUGUSTA, MAINE 04330

APPROPRIATION NO. 4320-4001

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by

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IMPORTANT NOTICE

This report has been developed for the sole use of the Department of Environmental Protection (DEP), State of Maine. Its purposes are to provide DEP with guidelines for assessing the oil spill potential in Portland Harbor and Casco Bay and identifying vulnerable resources, and analytical means for predicting the trajectory of an oil slick. It also provides a recommended containment, clean-up and disposal plan and an evaluation of oil monitoring and navigational aid systems. The report is not intended for use by third parties and Arthur D. Little, Inc. assumes no responsibility or liability in connection with their use of the contents of this report.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

INTRODUCTION

Associated with the transfer, transport, handling and storage of petroleum crude and products is a certain level of risk that a spill might occur. Should such a spill occur near or on sea water, the spilled material will float, spread and move with the prevailing winds and tidal currents. Depending on the magnitude of the spill, the resultant direction of its movement, and the effectiveness of response efforts, the spill may impact and damage coastal regions which harbor valuable marine life and/or serve as public recreational areas. The economic losses and ecological damage that an oil spill can wield upon the environment can be very large. It is important, therefore, that passive measures be taken to prevent the occurrence of an oil spill in the first place. However, should a spill occur, effective active measures should be deployed quickly and at the optimum location, to contain, collect and dispose of the polluting material to the maximum extent possible before it can reach and damage vulnerable coastal resources.

OBJECTIVES

The Department of Environmental Protection (DEP) of the State of Maine is deeply concerned with the fate of oil spills that may occur in Portland Harbor and Casco Bay. The DEP would like to be able to predict the trajectory of an oil slick and to identify vulnerable resources which may be damaged by the slick. Improved navigational aids and effective oil monitoring systems that may be used in Portland Harbor and Casco Bay are also of interest. The DEP is equally concerned in developing an emergency response and contingency plan that would deal effectively with most oil spills in the area. To achieve these objectives, Arthur D. Little, Inc. contracted with the DEP to conduct a study in which these concerns were addressed.

SCOPE OF WORK

The program consisted of several tasks, the results of which are detailed in this report and summarized below. The output of one task, the development of a contingency response manual, was submitted as a separate report. In addition, working charts which identify vulnerable resources and which may be used for predicting the trajectory of an oil spill have been provided directly to the DEP.

Summaries of the tasks described in this report follow.

Identification of Vulnerable Resources

A comprehensive review was conducted of available literature on marine and recreational resources in the study area. Combined with actual site surveys, the review took into consideration seasonal changes and identified important coastal areas used as breeding and nesting grounds for marine mammals, waterfowl, fish and shellfish. It also identified areas used for recreational and commercial fishing purposes. The severity of impact of an oil spill on the various resources was examined and a chart prepared showing regions which are highly vulnerable and which should receive immediate attention if threatened by an approaching oil spill.

Potential Oil Spill Locations

Shore facilities which handle petroleum crude and products were visited and their storage tanks and handling practices examined. As a result of this task, a chart was prepared in which potential oil spill sources were identified. The sizes of typical spills at these sites were categorized as "minor," "medium" and "Large" in accordance with definitions given in 40 CFR 1510.5.*

Oil Spill Movement

An analytical technique was developed for predicting the trajectory of an oil spill on water so that potential impact areas may be identified. The analytical model took into consideration the increase in the area of the slick with time and the effects of wind and surface currents. The model was used to calculate the probabilities of impact at various coastal regions in the study area for spills occurring at four specific locations, during two seasons (winter, summer), two tidal conditions (peak flood and

*Code of Federal Regulations, Title 40, paragraph 1510.5

peak ebb) and four wind conditions. A summary of the results of this analysis is given in Table 4.3.

Containment, Clean-up and Disposal Systems

In the event of an oil spill, the material must be contained, collected, and eventually disposed of in an acceptable manner. Containment and clean-up equipment, supplies and services, alternative modes of transfer, transport and storage of collected oil-water-solid mixtures, and disposal techniques presently available to the DEP were examined. Several specific recommendations were made to the DEP for the deployment of its containment and clean-up equipment and for improving its response effectiveness to oil spills. A flexible disposal plan was proposed in which locally available barges, trucks and railroad cars can be used for the dual purpose of storage and transport to incinerators or future burial sites.

Oil Monitoring Systems

If an oil spill is detected soon after it occurs and an alarm is transmitted to responsible agencies, the likelihood of effective containment and leak stoppage is increased. An oil spill monitoring and alarm system could thus play an important role in minimizing damage to vulnerable resources.

Oil monitoring systems which are presently available on the market or which are nearing final development were identified and evaluated for their utility in the study area.

Three categories of spill monitoring systems were examined:

1. In-Stream Sensing Units: these units appeared to be best suited for utilization by privately owned industrial shore facilities.

2. In-Water Detection Units: These are ideally suited for use by dock owners and along piers in the Fore River and Front Harbor Area. Effluent discharges may also be monitored with these units.

3. Elevated Water Surface Scanning Units: DEP could install these units on both bridges crossing the Fore River to monitor oil spills upstream.

Navigational Aid Systems

Marine navigational aids and procedures presently employed in Portland Harbor and Casco Bay were evaluated for their adequacy and accuracy. Several recommendations were made which would improve the safety of navigation, reduce the probabilities of collisions and groundings even if tanker traffic should increase at a modest rate.

RECOMMENDATIONS

Several recommendations and suggestions are made throughout this report. In this section, we have selected those recommendations which, in our opinion, should receive immediate attention or a high priority in consideration. The order of presentation of these recommendations follows the order of their appearance in the report and is not an indication of their relative importance or merit.

1. Install a tidal adjusting boom anchor on the pilings of State Pier and on another pier in South Portland such as Pine State Bi-Products Pier. The South Portland anchor point should be located near an access road so that vehicles may approach the collected oil and pump it out.

2. The DEP should attempt to enter into a working agreement with Portland Pipeline Co. to boom in an emergency, from Fish Point area to Portland Pipeline Co. Pier 2 and Pier 2 to Fort Preble Breakwater.

3. Provide tidal adjusting boom anchor fixtures to allow the deployment of a boom across the Presumpscot River, preferably at its intersection with Highway 95 and Blue Star Memorial Highway (U.S. Route 1) Bridges. The fixtures should be designed to permit boom deployment upriver or down river of bridges. A similar system should be provided at Back Cove.

4. Clean and repair the available 1000-ft boom in the State Pier warehouse.

5. Activate the available DEP skimmer as an emergency unit.

6. Uncrate the new section of boom that DEP has acquired and get it in a ready state for deployment to close off the harbor (Fore River).

7. Investigate and develop means for joining various sections of boom presently available from the sources identified in Appendix H.

8. Prepare an inventory of pipeline diameters in shore areas where oil is handled and fabricate or purchase closure clamps for the various pipeline diameters. Also, DEP should stock a supply of wooden wedges that could be driven into holes, cracks or broken pipes to stem the leakage of oil.

9. DEP response personnel should be trained in boom deployment, clean-up operations and methods for stemming liquid flows. The DEP should take advantage of the USCG training program offered in Yorktown. Manufacturers and suppliers of booms and other equipment should also be able to provide training programs to DEP personnel.

10. The DEP should have access to a boat which is compatible with the boom that DEP presently owns and which is capable of transporting it, response personnel and other ancillary equipment to the boom anchoring locations suggested above.

11. It is highly recommended that the DEP have access to a fast service helicopter so that spills in Casco Bay may be investigated and assessed first-hand and the location of spill origin determined accurately for oil trajectory calculations.

12. Establish at DEP headquarters and continually update, a master file of data and information on all equipment and supplies available from local containment and control equipment and supply companies. The file should also include sources of alternative transportation systems that may be used for the dual purpose of storage and transport of recovered spill materials.

13. DEP should begin the long process of selecting and obtaining EPA approval for one or more burial sites, preferably near rail spurs.

14. Until an approved burial site is found, the recommended disposal procedure for oil-soaked solid debris entails collection, transfer and storage in trucks, barges or railroad cars and disposing of the debris by burning in one of the two operating incinerators (IDSOM and McKin).

15. For oil-water mixtures, disposal can be achieved by collecting the mixture in barges and transporting it to shore storage and separation facilities. Unused tanks, barges, tank trucks or railroad tank cars may be used for shoreside storage purposes. Disposal may be achieved by separation, followed by incineration or resale.

16. The DEP should consider renting on a trial basis an elevated water surface scanning monitor such as Wright and Wright manufactures. The unit could be tested by installing it on both bridges across the Fore River with a direct alarm system to either bridge attendants or the DEP.

17. The DEP should approach the appropriate Federal agencies with the following suggested improvements in the navigational aid systems:

- Place a Riding Light on the Portland Sea Buoy.
- Install a high intensity light showing not more than 2° each side of a bearing 319°T on the steeple of the Cathedral.
- Place a station buoy off Witch Rock approximately 30 yd, 100°T from the present Witch Rock Lighted Buoy No. 2.
- Establish and set a new lighted buoy 2090 yd, 275°T from Portland Head.
- Increase the intensity of the Diamond Island Ledge Light.
- Replace No. 1 can buoy upstream from Portland Bridge with a light buoy.
- Place a station buoy on Soliders Ledge approximately 124 yd 020° from the charted position of Lighted Buoy No. 6.
- Erect a 40-ft tower on the existing concrete base on Overset Island with a 360°T light which has a high intensity beam on a bearing of 349°T. Ten feet below the light, a fixed white sectional (passing) light showing white sectors of 330° to 029° and 069° to 180° should be installed as a temporary light for evalua- ation purposes.

18. The following dredging operations should be suggested by the DEP to the cognizant Federal agencies:

- Dredge the area behind red nun buoy No. 6 at the turning basin to a depth of 25 feet.
- The present volume of traffic and present depths do not require that Soldiers Ledge be removed. However, an increase in traffic volume and in vessel drafts to over 50 feet will require that the ledge be removed to a minimum of 65 ft controlling depth. Similarly, in the Portland Outer Harbor, the controlling depth of Anchorage A should be increased to 45 feet if the traffic of vessels, with drafts of 40 feet or more, increases in the future.

19. Tankers anchor in the vicinity of the Portland Light Buoy while awaiting a berth in Portland Harbor. This congested anchorage is outside normal USCG jurisdiction. The location and supervision of this anchorage should be given thorough consideration before a serious accident develops.

Consideration should be given to the establishment of a designated hurricane anchorage in Luckse Sound as an alternate to the non-designated anchorage near the Portland Light Buoy.

20. The restriction on the movement of vessels past Soliders Ledge to ± 1/2 hour each side of high tide does not give sufficient time to make a transit from Hussey Sound to Portland Pipeline berths before the changing of tidal flow. The period for transit should be widened so that the transit could be made in one tide and anchoring offshore in unprotected waters could be avoided.

21. The impact of the marina planned in South Portland between Spring Point and Portland Pipeline Pier No. 2 on navigation safety should be examined carefully before the marina is allowed to operate in that area.

1. INTRODUCTION

1.1 BACKGROUND

Portland Harbor in Maine is the second largest oil terminaling port on the East Coast of the United States. Large quantities of oil and refined petroleum products are brought into Casco Bay in large tankers and barges. Associated with these shipments are the usual complementary activities such as lightering, berthing, unloading/loading, terminaling and transfer to barge, rail, truck and pipeline. The conduct of these activities presents a potential threat of oil spillage and the subsequent pollution of the environment. The possibility of large releases of oil in Portland Harbor and in Casco Bay is of particular concern to the Maine Department of Environmental Protection (DEP).

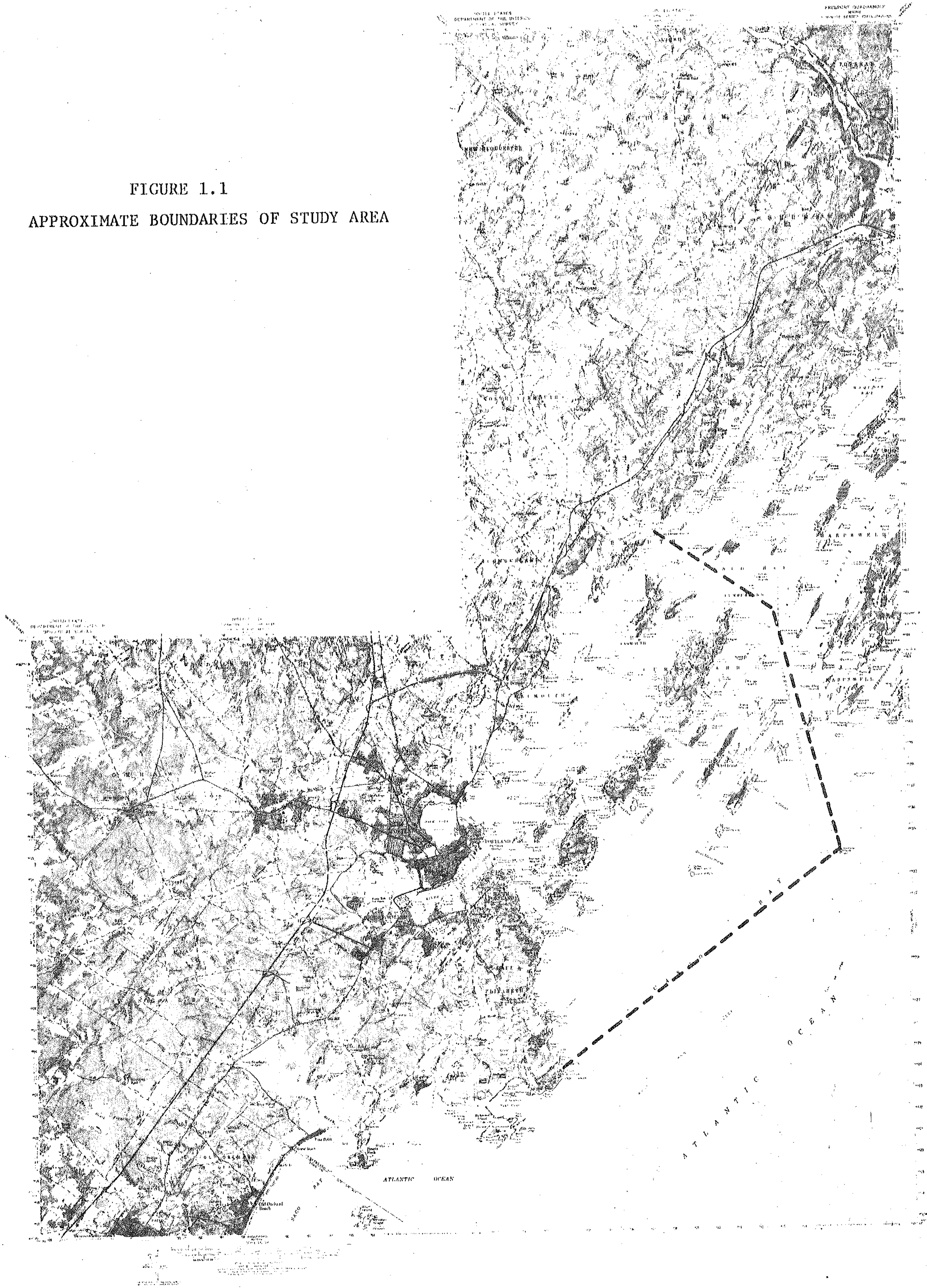
Large oil releases may occur as a result of massive failures of shore storage facilities as well as barge and tanker groundings and collisions. Oil spilled on sea water spreads and travels with the prevailing currents and winds and impacts shores quite removed from the source of the spill. The environmental and ecological damage that could be inflicted is extremely high, particularly to an area where the economy is highly dependent on marine resources.

The Maine Department of Environmental Protection has been deeply interested in reducing the potential for an oil spill in Portland Harbor and Casco Bay. Should a spill accidentally occur, the DEP is equally interested in being able to predict the locations of vulnerable resources and to direct the impetus of the response effort towards minimizing the environmental and ecological damage. To this end, DEP contracted with Arthur D. Little, Inc. to conduct a program addressing these concerns.

1.2 OBJECTIVES

The objectives of the program were to collect pertinent data and information relating to vulnerable resources in the study area (roughly defined in Figure 1.1), develop analytical procedures for predicting

FIGURE 1.1
APPROXIMATE BOUNDARIES OF STUDY AREA



oil movement and trajectories on sea water, evaluate navigational aids and oil monitoring systems for the study area, and prepare a contingency plan for the prevention and control of oil spills in Portland Harbor and Casco Bay.

1.3 SCOPE OF WORK

To achieve these objectives, Arthur D. Little, Inc. conducted a program consisting of the following tasks:

Task A - Development of an Oil Spread Movement Model

The geographical and meteorological environments peculiar to Portland Harbor were examined by utilizing published data on the subject and by undertaking some field trips in the area. Based on the physical environment and recent advances in the theory of oil spread on the sea, the trajectories of oil spills of various sizes at several likely locations within the harbor were quantified. A simplified procedure that may be used by DEP for predicting impact areas of an oil spill was developed.

Task B - Identification of Vulnerable Resources

The Casco Bay area was surveyed to determine the locations of valuable resources which may be vulnerable to oil spills. These areas were found by taking into consideration the extent of the environmental, ecological and social damage that could be inflicted upon them as a result of an oil spill.

Task C - Oil Spill Monitoring Systems

The state of the art of hardware that may be used for oil spill monitoring and sensing was reviewed. Several systems that may be utilized advantageously in Casco Bay were identified.

Task D - Analysis of Critical Shoreside Operations

A survey of critical shoreside operations was conducted. Locations where oil spills may occur were identified and ways in which operations at these locations may be improved so as to reduce the probability of oil spills were suggested.

Task E - Analysis of Navigational Systems

The navigational systems now in use in Casco Bay were surveyed. Based on knowledge of other available systems and the specific traffic conditions in Casco Bay, the adequacy of the existing systems was assessed. Recommendations were made for additional systems, which would reduce the likelihood of collisions and groundings. Justifications were provided for each new system suggested.

Task F - Identification of Containment Equipment

Methods for containing and cleaning up oil spilled on water and land were reviewed. Sources for containment and clean-up equipment available to the DEP were identified, and recommendations made for DEP action.

Task G - Study of Disposal Means

The availability of oil disposal equipment, systems and sites in Portland Harbor was examined. A flexible system of disposal ideally suited to that area was recommended.

Task H - Preparation of a Response Manual

The information developed in earlier tasks was used to develop an operational emergency response manual. The manual allows DEP personnel to predict the trajectory and impact area of an oil spill and to identify sources of containment and disposal equipment in the study area.

1.4 PROGRAM RESULTS

The results of Tasks A through G of the program are presented in this technical report. The order of presentation of results has been slightly changed from the task order to provide a logical presentation. In Chapter 2, we describe the study area and identify the vulnerable resources and their locations (Task B). This is followed by the identification in Chapter 3 of potential sources and locations of oil spills (Task D). Chapter 4 consists of a description of the analytical models used to predict the trajectory of an oil spill in water (Task A). Methods and systems that are presently available to the Maine DEP for containing and disposing of oil spills are discussed in Chapter 5 (Tasks F and G).

A review of oil monitoring systems and their applications to the study area is given in Chapter 6 (Task C), while the final chapter covers navigational aid systems presently utilized in Casco Bay and provides recommendations for improvements (Task E).

Several appendices have been provided to supplement the discussion in the bulk of the report. A large chart which identifies vulnerable resources in the study area has also been included.

Task H, the contingency response manual, is provided as a separate report.

1.5 LIMITATIONS

This study was limited to the area roughly defined in Figure 1.1. The identification of vulnerable resources for this area was based on available published data. No attempt was made to assess the completeness or statistical adequacy of the data or to conduct a new marine resource survey.

In estimating the sizes of potential spills at various shoreside facilities we considered only typical spills encountered at similar facilities. Obviously, larger spills may occur as a result of catastrophic failures, but such events are very rare and highly improbable.

Several assumptions were made in developing the oil movement model. Although it is based on sound hydrodynamic and scientific principles, no experimental data are available whereby this model can be tested. A check on the adequacy of the model will have to await the actual occurrences of oil spills under various weather and tidal conditions.

In developing a recommended containment and disposal system for the DEP, State funding limitations, the present equipment that DEP owns, and the availability to the DEP of local containment supplies, equipment and disposal sites were taken into consideration. The result was a very flexible system that can cope with most reasonably likely oil spill emergencies in Portland Harbor and Casco Bay.

2. IDENTIFICATION OF VULNERABLE RESOURCES

2.1 DESCRIPTION OF STUDY AREA: PORTLAND HARBOR-CASCO BAY

Portland is the largest urban center in the State of Maine and is the second most active petroleum port on the East Coast, with an annual throughput of crude oil and petroleum products totaling over 210 million barrels. The majority of oil-related activity is concentrated along the Fore River with the focus being on the Portland Pipeline Company crude receiving facility in South Portland. Petroleum industry activity is a major end use of the shorefront property in Portland Harbor. Heavy urbanization has eliminated much of the natural wildlife habitat on the mainland but considerable areas of relatively undisturbed natural resources exist in the wetlands, coastal islands, and the marine environment [2.1].

Beyond the immediate area of Portland Harbor, a diversity of activities or end uses are associated with the mainland shorefront property, inter-tidal zone, coastal islands, and offshore environment of Casco Bay. Cultural end uses made of the coastal zone include commerce, recreation, and waterfront residential development. The petroleum industry's co-existence with this multiplicity of acitivities is a concern of the industrial, public, and governmental sectors. One adverse impact of the petroleum industry activity is oil spill contamination. Oil spills have been a recurring problem in Maine and particularly in the Portland Harbor-Casco Bay area. Based on available oil spill records, a total of 451 spills occurred in the State of Maine between 1950-1971. Of these, 336 occurred within the Portland vicinity. This figure is considered to be a conservative estimate in light of the relative lack of records prior to 1968 [2.2].

Efforts have been made at various levels to minimize both the frequency and likelihood of oil spillage and the impacts of oil spillage once it has occurred. The Coast Guard, Multi-Agency Oil and Hazardous Material Pollution Contingency Plan, Region I (coastal); the State of Maine, Department of Environmental Protection, Revised Statutes of 1964, Title 38 (as amended); and the Department of Environmental Protection

(Maine), Oil Discharge Prevention and Control Regulations, are applicable to the Portland study area. Despite these efforts, oil spills will undoubtedly continue to be a source of pollution to the Casco Bay environment, particularly if projected increases in petroleum facilities and tanker activity are realized.

Prevention is obviously the best method of protecting the natural resources, but even with the best handling procedures, improved navigation systems, and better facility operations, oil spills will occur. Where an oil spill has occurred, protection of the natural resources is best accomplished through quick response and rapid recovery of the spilled oil. This minimizes exposure of resources and minimizes impacts. Response and recovery efforts are influenced by the magnitude, location and type of spill, the weather conditions and the availability of containment equipment and personnel. In all likelihood, the longer the response time the greater will be the area and number of resources impacted. Undoubtedly, total protection of the environment under all spill situations will not be possible and recovery personnel will be forced to choose among areas to receive protection based on limited equipment, personnel or accessibility. The purpose of this part of the contingency plan is to provide guidance in maximizing the efficiency of protective efforts when protection cannot be afforded all resources at all locations of potential contamination. Based upon this and more detailed studies of locations and variations in use and vulnerability of ecological and cultural resources, clean-up personnel should be able to minimize the long-term impacts of oil spillage.

The Greater Portland Region is comprised of three cities and ten towns: Portland, South Portland, Westbrook, Scarborough, Falmouth, Cape Elizabeth, Cumberland, Freeport, Gorham, Gray, Yarmouth, North Yarmouth, and Windham. The population for the region is approximately 157,000, with this figure doubling during the months of July and August due to tourism.

Of the thirteen municipalities in the Greater Portland Region, eight are coastal: Freeport, Cumberland, Yarmouth, Falmouth, Portland, South Portland, Scarborough, and Cape Elizabeth. The study area, shown in Figure 1.1, includes six of these municipalities with Scarborough and

Freeport respectively south and north of the study area boundary. Resources are identified in the eight municipalities with emphasis on the six municipalities within the study area.

An oil spill occurring within the study area could readily lead to oil contamination outside the boundaries. Of note is the TAMANO spill, that began in Hussey Sound, and led to oil contamination as far south as Portsmouth, New Hampshire and north at least to Falmouth. Where conditions might lead to oil spreading beyond the defined study area, efforts should be taken to pinpoint potential spill movements and the vulnerability of the resources that may be impacted. The methodology presented in the following discussion is appropriate for assessing the vulnerability of ecological and cultural resources elsewhere within the Maine coastal zone to oil spill contamination.

2.2 METHODOLOGY

Guidance regarding the protection of various areas against oil spill contamination is presented below based on the following criteria:

(a) Nature of end use(s) represented by the resources of an area

(b) Vulnerability of these resources to oil spill contamination

Variations in seasonal use patterns and seasonal resource vulnerability are also discussed.

2.2.1 End Uses and User Groups

A diversity of end uses are made of the Casco Bay area. These end uses may be placed in two general categories: ecological and cultural. There is also a diversity of human user groups which frequent the coastal zone. These fall into four basic categories: residents, commercial users (e.g., fishermen), recreation seekers, and the scientific community. In analyzing the end uses and the user groups with reference to the Casco Bay coastal zone, a general picture of the use patterns by geographic location can be discerned.

Physically, Casco Bay is typical of the Maine coastline. It is characterized by an intertidal zone dominated by rocky headlands interspersed with areas of marsh and coarse-grained beaches. In addition to the shorefront property of the mainland, numerous offshore islands increase the area potentially requiring protection from oil spill contamination.

To assess the locational aspects of end use activity, the study area was divided into two zones: the inshore zone and the offshore zone. The inshore zone is the intertidal environment comprised of rocky shores, tidal flats, salt marshes, beaches and estuaries (specifically the Fore River and the Presumpscot River within the study area). The offshore zone is the subtidal marine environment and overlying waters.

The degree of development associated with shorefront property exerts important influences on the character and intensity of uses of the inshore zone. The following is a list of some of the types of resource-dependent end uses occurring in the inshore zone:

Group 1: Ecological End Uses

- Habitat is maintained for a wide varity of organisms on a seasonal basis.
- Natural processes influence geophysical/geochemical events (e.g., storm buffering, protection against erosion, water quality control by marshes).

Group 2: Cultural End Uses

- Commerical fishing
  - shellfish beds (clams, mussels)
  - marine worms
  - seaweed
- Residential activity
  - view/aesthetics
  - recreation
  - property value
- Recreational/tourism activity
  - beaches (swimming, picnicking)
  - sightseeing (aesthetics)

- fishing
- historical sites
- designated natural areas (Audubon sanctuaries, other Federal, State, or local conservation properties)

- Scientific study and education

In most cases, areas where public access to the intertidal zone is available, the intensity of use will be greater than in those areas where access is limited to private groups or individuals.

A diversity of end uses, though not as extensive a list, covers the same general categories for the offshore zone. The following list indicates the types of resource-dependent end uses occurring in the offshore zone:

Group 1: Ecological End Uses

- Habitat functions
- Influence of natural processes on events

Group 2: Cultural End Uses

- Commercial activity
  - lobstering and other shellfishing
  - finfishing
- Recreational activities
  - boating
  - fishing
  - commercial recreation
  - sightseeing
- Scientific study and educational activities

The offshore zone within Casco Bay is used less intensively than the inshore zone and represents fewer end uses.

2.2.2 Vulnerability of Resources to Oil Spill Contamination

In assessing the vulnerability of the inshore and offshore zones of the study area, published data concerning spill impacts in these and/or analagous environments were used. The biological impact of an oil spill in the marine environment depends on many factors. A summary of these factors is given in the National Academy of Sciences report, "Petroleum in the Marine Environment," [2.3] and includes:

- oil dosage and location
- oil type
- oceanographic conditions
- meteorological conditions
- turbidity
- season
- biota type

The extent to which any oil spill has short- and long-term impacts will depend upon a combination of these factors. Some of these factors, primarily oceanographic and meteorological conditions, may enhance or minimize the observable impact of the spill by influencing its direction and speed, either towards or away from the various resources.

Investigations of the biological impact of oil spills within the Maine Coastal Zone have been of limited scope. The Maine Department of Marine Resources provided some of the earliest investigations of the biological impacts of oil spill contamination in the marine environment in Maine. The most frequently documented impact was to shellfish, specifically in terms of losses or tainting of soft shell clams (Mya arenaria). Of particular interest has been the retention of oil in the sediments and by the clams. In the case of the Northern Gulf spill (1963), samples of sediment and clams had high contaminant hydrocarbon concentrations nine years after the spill. Other observed biological impacts have included losses of lobsters in storage lagoons, losses of finfish, shellfish, marine worms, and marine plants [2.2].

The impact of oil on the marine environment is not completely understood and the level of impact will be specific to each individual spill, with environmental conditions and the type and quantity of oil spilled being of primary importance. Based upon documented incidents, the following criteria are valuable indicators of the sensitivity of a resource or biotic communities to oil and requirements for protection:

- known high sensitivity of a species or community to oil, low recuperative power
- persistence of oil and possibility for recontamination
- feasibility and practicality of employment of clean-up methods

Long-term spill impacts, such as the elimination or modification of a habitat, can result in changes of species composition and subsequent changes in productivity. This could result in eventual losses to commercial fisheries. Short-term impacts may be more visible to the public, as in the case of the aesthetic impact of oiled beaches.

2.2.3 Variation in Seasonal Use and Vulnerability of the Resource

Another consideration in making protection choices is seasonal use patterns of the inshore and offshore zones and seasonal vulnerability as related to individual resources. Variations in use and vulnerability are:

- seasonal variation in use by user groups
- seasonal variation in use and vulnerability by wildlife populations

2.2.3.1 Seasonal Variation in Use by User Groups

The intensity of cultural uses of the inshore and offshore zones varies on a seasonal basis. The most obvious variation in use occurs during the months of July and August when the population of the Greater Portland area doubles due to the large influx of summer residents. Cultural end uses made of the Casco Bay environment are exploited most intensively by all major user groups during the summer months. At this time, the major user groups are expanded from year-round residents and commercial interests (e.g., fishermen) to include summer residents, tourists, and recreation seekers.

2.2.3.2 Seasonal Variation in Use and Vulnerability by Organism Populations

Use patterns by organisms, also vary on a seasonal basis. Seasonal variations occur in the distribution and composition of waterfowl populations, breeding areas for birds and marine mammals, and areas used as nursery grounds, such as salt marshes.

This plan is not directed at the protection of a specific species or a specific end use but the protection of areas which possess value to a number of user groups, and are relatively vulnerable to oil spill contamination. The following discussion of the inshore and offshore zones of the study area describes the end use(s), vulnerability or sensitivity to oil contamination and seasonal variation in use and vulnerability of the zonal components. Its purpose is to assist those involved in oil-spill clean-up in making environmentally sound decisions as to protection priorities when all resources cannot be afforded equal protection.

A resource map (Chart I) is attached to this report. This map indicates the location of major inshore and offshore resources and end use activities. Inshore resources identified include mudflats soft-shell clams, mussel beds, worms, marsh, rocky shores, seaweed and recreational beaches. Offshore resources identified include bird nesting sites, winter waterfowl sites, seal haul-out and pupping sites and major concentrations of boats. Resources, such as lobsters, that occur throughout the study area have not been indicated on this map. Throughout the study area several remnant salt marshes, small private recreational beaches or small clamming areas do occur, but are too numerous to indicate on this map. Also as development patterns change, the locations of bird nesting sites and seal haul-out sites may change. Only documented resources have been identified, but as additional areas are recognized as important resources they may be indicated on the resource map. This map is intended to be used to identify particularly vulnerable resources to oil spill contamination. It is not intended to represent a complete resource inventory of Casco Bay.

2.3 STUDY AREA ENVIRONMENT: RESOURCES AND VULNERABILITY

2.3.1 Inshore Zone

The sensitivity of four distinctive types of intertidal environments to oil contamination is relevant to this study. These environments are: mud flats, marshes, beaches, and rocky shores. Representative examples of each of these environments have been impacted by oil spills and subjected to subsequent scientific study in recent years. These studies appear to provide sufficient information to allow for reasonable estimates of the relative sensitivity of the four zones.

2.3.1.1 Mud Flats

Mud flats are particularly sensitive to oil contamination. The substrate is extremely difficult to clean; and affords opportunities for extensive retention of spilled oil. Mud flats impacted by the TAMANO spill of No. 6 fuel oil in 1972 were judged by the on-site investigators to be the most severely disturbed of the affected marine communities [2.4, 2.5]. The invertebrate infauna, which includes the majority of organisms in the mud flat community, typically experiences heavy initial mortality as the result of smothering by deposited oil. This impact accompanies spills of most crudes and petroleum products in the weight range bounded by "Bunker C" and No. 2 fuel oil.

Depending upon the type of oil and duration of exposure to fractional evaporation prior to impact (i.e., weathering), substantial invertebrate mortality may also be attributable to the toxic effects of the soluble fractions of spilled oil. In general, the most severe of these effects are associated with the lighter refined products and with spills reaching the intertidal zone with less than two days exposure to weathering.

Over the longer term, contamination by oil has resulted in habitat modification of intertidal mud flats. It drastically reduced success in organism recruitment and vigor, and caused subsequent changes in the species composition of the faunal assemblages. Initial recruitment of the commercially valued soft clam (*Mya arenaria*) was reported to be severely impaired on mud flats in Casco Bay contaminated by No. 6 fuel oil [2.4, 2.5]. Commercially valued worms (probably *Nereis* sp.) obtained from oiled areas have been reported by fishermen to be in poor condition [2.5]. Opportunistic oil-tolerant species which rarely dominate unpolluted climax communities tend to be disproportionately abundant in contaminated sites for several years following a spill. In particular, certain polychaete worms in the families Spionidae and Capitellidae can be expected to flourish in place of other indigenous organisms in oiled intertidal (or subtidal) regions [2.6].

Finally, there is the potential problem of the transfer of petroleum-related toxicants and carcinogens from the invertebrate fauna of the tidal flat to vertebrate consumers, including birds, fish, and man. This is one of the least understood aspects of the oil pollution problems. The National Academy of Sciences concluded that the available evidence suggested highly individualistic relationships between petroleum hydrocarbon availability and uptake by various marine consumer species [2.3]. However, there seems to be a paucity of empirical data on the effects from the standpoint of immediate toxicity or long term hydrocarbon accumulation.

There are 2,663 acres of tidal flats within Cumberland County, which includes the six townships of the study area and Scarboro [2.1]. Mud flats within the study area are delineated on the Resource Map. The most vulnerable of these to oil contamination are the extensive flats found along the Fore River, which serves as the focal point for most of the smaller product tankers and barges servicing Casco Bay. While these flats reportedly exhibit somewhat limited faunal diversity and abundance [2.7], they serve as sheltered feeding grounds for large numbers of aquatic birds, including cormorants, ducks, wading birds (e.g., herons), shorebirds, and gulls. These birds are found elsewhere in the study area, but feed in relatively dense concentrations on and around the flats adjacent to the several petroleum terminals in the Fore River. The combination of dense receptor populations and nearby petroleum transfer operations ascribes high vulnerability to the Fore River mud flats. This usage implies that extensive cleanup capabilities could be logically and desirably located at each of the terminal sites, including those dealing primarily with the lightest products (i.e., gasoline, kerosene), where booms are currently not required for each offloading operation.

The convenient geographic spacing of these facilities as well as the potential for collisions anywhere in the heavily traveled Fore River further justify such an allocation of cleanup resources.

2.3.1.2 Marshes

The above discussion of the vulnerability of mud flats to oil contamination can be equally applied to tidal marshes. However, several additional considerations apply to marsh systems. First, tidal marshes, to a greater extent than mud flats, serve as nursery grounds for a wide variety of commercially and/or recreationally valued organisms. These organisms frequent the tidal marsh at stages of their life cycles when they are most vulnerable to oil pollution. Second, tidal marshes contribute substantially to regional biotic productivity through the widespread distribution of decayed marsh vegetation. These and other beneficial functions of tidal marshes (e.g., storm buffering, sediment retention), coupled with their vulnerability to spills, justify the assignment of high priority to the protection of this type of environment.

Characteristic marsh vegetation (e.g., Spartina sp.) seems relatively resistant to long-term adverse impacts from oil contamination. In fact, the marsh is an effective digestor of such contamination. However, the role of oil-contaminated plant detritus in the estuarine food web is poorly understood. Many organisms known to feed upon such detritus (e.g., mullet, fiddler crabs, amphipods) are sensitive to the tainting or toxic effects of various petroleum fractions. The impacts of petroleum contamination (specifically No. 2 fuel oil) on secondary productivity (i.e., the invertebrate community) in a salt marsh has been extensively documented in the Wild Harbor marsh near West Falmouth, Mass., in the aftermath of a small spill in September 1969. One of the most recent of these studies concluded that in 1973, four years after the spill, secondary productivity in the intertidal area was still significantly affected [2.6]. Actual sampling during this investigation produced an average of 310 individuals per sample (marsh samples based on duplicate 1/128 m^2 cores, i.e., 1/64 m^2) in the impacted Wild Harbor Marsh versus an average of 1712 individuals per sample in the Sippewissett (control) marsh. These findings are significant in view of the apparent lack of other spills near either location since the 1969 spill. Although the recovery process appears incomplete in the Wild Harbor marsh as of 1974, the investigators noted in this and previous studies a continued improvement with time [2.6]. Based on available findings, it is reasonable to expect short-term mortality among many components of a spill-impacted tidal marsh with a rapid recovery of vegetative components (i.e., primary productivity) and a much slower recovery of invertebrate faunal componnets (i.e., secondary productivity).

There are 3,678 acres of salt marsh and salt meadow within Cumberland County. The largest areas of salt marsh within the study area are along the upper portions of the Fore River (Portland and South Portland) and along the Presumpscot River (Falmouth). The Maine Department of Inland Fisheries and Game has identified the 86 acres of salt meadow along the Fore River and 127 acres of salt meadow along the Presumpscot River as valuable waterfowl habitat [2.1]. Major areas of salt marsh and salt meadow are delineated on the Resource Map (Chart I). Scattered sites of remnant salt marsh are located on the mainland and coastal island shores throughout the study area.

The salt marsh and coastal salt meadow of the Fore River have been studied recently in conjunction with preparation of the Draft Environmental Impact Statement, Westbrook Arterial, Westbrook-Portland, Maine [2.8]. Along the main channel and tidal creeks are 56 acres of regularly flooded salt marsh dominated by the salt marsh cordgrass (Spartina alterniflora). Other vegetation of the salt marsh are wideongrass (Ruppia maritima) and dwarf spikerush (Eleocharis parvula). Located above the regularly flooded salt marsh are 76 acres of coastal salt meadow dominated by the saltmeadow cordgrass (Spartina patens). The marsh of the Presumpscot River is similar in species composition.

Marsh areas are a valuable source of detritus to the adjacent marine environment. The Maine Department of Inland Fisheries and Game has estimated that about 916 acres of tidal wetlands contribute a portion of their production to the Casco Bay food web. It is estimated that approximately one-half of vegetative production is consumed in the marsh and the remainder is exported to the estuary and marine environment [2.8]. Based on this estimate, the Fore River marsh contributes about 500 tons of vegetative detritus each year to adjacent coastal waters. The Fore River marsh is a productive area. Productivity of the marsh in the Cousins River-Maine was 3.7 tons/acre for S. alterniflora and 7.8 tons/acre for S. patens. However, proportionately greater amounts of low marsh (S. alterniflora) are exported as detritus [2.8].

The marsh in the Fore River is the most vulnerable of the salt marsh communities in the study area to oil spill contamination due to its close proximity to the terminal sites. Protection of the Fore River marsh would best be accomplished by the location of containment and clean-up equipment at each of the terminal sites. The major concentration of Fore River marsh is above the Congress Street bridge, at which point the Fore River narrows to approximately 100 feet. Under normal tidal fluctuations, booming of this area could help to protect the upper marsh from inundation of oil by an unconfined spill.

2.3.1.3 Beaches

The impacts of oil spills on the biota and recreational uses of beach environments have been studied in many locations, including Casco Bay. Much attention has been focused on the efficacy of cleanup efforts, particularly in relation to sandy recreational beaches.

From the standpoint of indigenous biological productivity, beaches may be considered less vulnerable to oil spills than marshes or mudflats. With their constant exposure to harsh physical conditions, beaches, especially the shingle beaches common to the New England coastline, tend to support sparser organism populations than the latter two intertidal environments. Beach environments contribute less to areawide biological productivity than do tidal wetlands. However, the seasonal cycle of littoral sediment transport gives beach sands relatively wide distribution throughout adjacent nearshore waters. The upper layers of these sands are readily permeable to unweathered oil. Thus, oil-contamination of a sandy beach may lead to subsequent and repeated contamination of more productive environments flushed by adjacent waters. When large amounts of sand are removed in beach cleanup efforts, the potential for further erosion may be enhanced [2.9]. In addition, accessible sandy beaches are seasonally valued as recreation areas in New England. Oiling is a presumed deterrent to the recreational use of beaches. These factors combine to make sandy beaches sensitive environments, if left unprotected against oil spills.

The seasonal variations of the littoral sediment transport cycle result in the need for a flexible protective strategy for sandy beaches. If a spill occurs during the warmer months, when sediment accretion is predominant on coastal beaches, cleanup efforts must provide for both initial and subsequent removal of oily sand if chronic contamination is to be avoided. If a spill occurs during the colder months, when sediment is being removed from the beaches, maximum protection could be achieved by preventing initial sedimentation of the spilled oil, especially on the beach itself.

Recreational beach areas are relatively limited within the study area. Most beaches are small and are located in scattered locations along the rocky shores of the mainland and islands. Major recreational beaches within the study area are Willard Beach, South Portland; Sandy Point Beach, Cousins-Island, Western Beach, Long-Island; and Crescent Beach in Cape Elizabeth. A fifth beach area is Promenade Beach in Portland which is not regularly used for recreational purposes due to the poor quality of adjacent waters for swimming [2.10]. Major recreational beaches are identified on the Resource Map (Chart I).

Oiling of beaches can be expected along the Maine Coast. When a spill occurs well off shore, the oil may become mixed with ocean-surface debris that often washes ashore. Removal of this material from a beach is relatively easy. Oil impacting a beach directly presents a more difficult clean-up task. Where initial protection of beach areas is not possible, clean-up activities should proceed as soon after initial contamination as possible. The TAMANO spill resulted in the contamination of Western Beach, Long-Island. The clean-up effort required the removal of 4,510 cubic yards of material of an average sand depth of eight inches. Crescent Beach, Cape Elizabeth was also impacted by the TAMANO spill.

2.3.1.4 Rocky Shores

Most of Casco Bay is bounded by rocky shores. Areas of rocky shores are indicated on the Resource Map. This type of intertidal environment occupies more coastline locally than any of the three zones discussed above. This wide distribution implies that for any given spill incident there would be minimal opportunity for severe reductions in the overall productivity of the rocky shores. In addition, while they are rich in terms of vegetative and invertebrate biomass, these shores do not appear to be among the most vulnerable intertidal habitats to oil contamination in Casco Bay. This judgement is made in light of studies conducted pursuant to the TAMANO spill (1972) and the grounding of the GENERAL M. C. MEIGS in a similar environment in the Pacific Northwest, also in 1972 [2.5, 2.11].

The dominant intertidal algae which function as primary producers on rocky shores (i.e., *Fucus* sp. and *Ascophyllum*) possess mucous coatings which are reported to serve as relatively effective protection against long-term adverse impacts of coating by oil. However, *Fucus* sp. has evidenced retention of spilled oil, with the potential for further contamination of adjacent waters and biota [2.5, 2.11]. Data are lacking on the specific vulnerability of the commercially valued Irish moss (*Chondrus crispus*) which occupies the lower reach of intertidal rocky shores in Casco Bay.

Harvesting of seaweed, principally Irish moss (*Chondrus crispus*), is performed most extensively in the northern part of the Bay. In 1974, Cumberland County had a harvest of Irish moss in excess of one million pounds valued at $54,720. Within the study area, regions particularly valuable as sources of Irish moss have not been identified. At the present time Irish moss is being harvested in the area between Long Island and the Cheabeague Islands. Irish moss is used for packaging of lobsters [2.12]. Impacts of oil contamination to this enterprise are as yet undocumented.

Populations of dominant macrofauna among the invertebrate inhabitants of temperate rocky shores, including periwinkles (*Littorina* sp.) and barnacles (*Balanus* sp. and *Chthamalus* sp.) generally exhibit rapid recovery after suffering heavy initial mortality to the coating effects of oil. Certain other members of these communities, including various amphipod crustaceans and gastropods (*Littorina obtusata*) have become noticeably less abundant at oiled versus control stations. Closely-related opportunistic species (e.g., *Littorina saxatilis*) have coincidentally increased in abundance at such locations [2.5]. Overall, it appears that the absence of conditions favoring sedimentation and retention of relatively fresh oil on rocky shores, combined with their exposure to strong current and wave activity makes these zones more resistant to long-term spill impacts than marshes, mud flats, or beaches.

2.3.2 Offshore Zone

The sensitivity of the offshore zone to oil spill contamination is not as readily documented as that of the inshore zone (intertidal environments). Impacts to four components of the offshore zone within the study area have been documented and have received varying degrees of scientific study. These four components are (1) birds, (2) sea mammals, (3) commercial fisheries (lobsters, finfish, and shellfish, and (4) subtidal benthos.

2.3.2.1 Birds

The plumage of seabirds is water-repellent but oleophilic, (i.e., it readily accumulates oil). Once oiled, the water repellent capacity of plumage is severely impaired. Sea birds are thus readily susceptible to oil contamination particularly those species that spend most of their lives on the water surface. Included in this category of seabirds are the alcids (auks, guillemots, murres, puffins), diving sea ducks (scoters, scaup, eiders, goldeney etc.), loons and grebes. These birds tend to dive when alarmed, and frequently do so in an oil slick. Within the Portland study area a number of these species are permanent or seasonal inhabitants; and they may be adversely affected by an oil slick. A listing of the birds of the coastal zone of Maine, identifying those that inhabit the study area is given in Appendix A.

Seabirds in the study area which are particularly susceptible to oil contamination include the alcid species: the black guillemot (Cepphus grylle), a permanent resident; the diving sea duck species: Greater scaup (Aythya marila), lesser scaup (Aythya affinis), common goldeneye (Bucephala clangula), Barrow's goldeneye (Bucephala islandica), bufflehead (Bucephala albeola), oldsquaw (Clangula hyemalis), harlequin duck (Histrionicus histrionicus), common eider (Somateria spectabilis), white-winged scoter (Melanitta deglandi), surf scoter (Melanitta perspicillata), common scoter (Oedemia migra), hooded merganser (Lophodytes cucullatus), common merganser (Mergus merganser), and the red-breasted merganser (Mergus serrator). With the exception of the common eider, all the diving sea duck species represent wintering populations, with five species, common goldeneye, white-winged scoter, surf scoter, hooded merganser, and red-breasted merganser sometimes seen in the study area year-round [2.13]. Other species particularly susceptible to oil contamination are the loons and grebes. The common loon (Gavia immer) is a permanent resident of the coastal zone and the red throated loon (Gavia stellata), a winter resident. Both species spend much of the winter in marine waters. Several species of grebes do likewise. Loons and grebes feed primarily on fish.

These species spend a great portion of their life on the water surface, dive for food, and are weak fliers, illustrated by their behavior of diving rather than flying in response to danger. This diving behavior and the fact that these birds are highly gregarious enhance the probability of their feathers becoming coated with oil. The cormorants, great cormorant (Phalacrocorax carbo) and double-crested cormorant (Phalacrocorax auritus), also dive for food and may become oiled. The cormorants spend time swimming or resting on the water surface as do the alcids and diving ducks, but also loaf about on pilings and rocky cliffs, thereby somewhat minimizing the possibility of becoming oiled from a spill confined to the water surface. P. auritus is among the most common seabirds of the study area most of the year, being replaced by P. carbo in the winter. One primary effect of oil on seabirds is to pentrate or cling to their plumage. Water then can fill the spaces where air was trapped, resulting in a decrease in heat-insulation and buoyancy. Heavily-oiled birds are further inhibited in their swimming movements and in their attempts to fly. Oiling also encourages excessive preening behavior that further results in damage to the plumage. These birds also may ingest oil which can produce metabolic and behavioral abnormalities. Studies in the British Isles, the Dutch coast and southern Baltic have shown that most oil spill-related casualties occur during the winter when large concentrations of wintering birds are feeding [2.3].

Records of the Maine Audubon Society show that oiled birds found in Casco Bay have included eiders, loons, cormorants, and scoters. The greatest numbers of recorded oiled bird mortalities associated with the TAMANO spill were gulls. During the first week after the TAMANO spill, the oil was heavily concentrated on the water surface resulting in the heaviest loss of eider ducks. The oil was washed ashore on the western side of Ram Island where it collected on rocks and in tidal pools; and oily seaweed was washed ashore on the western side of Outer Green Island. The heaviest recorded mortalities were to gulls, followed by cormorants and eiders [2.5].

Eiders make up a large percentage of the duck population in Casco Bay. Maine is the only eastern state with a breeding population of eiders. Casco Bay represents the southern breeding limit of the eider population. Eiders are not near-shore birds and the largest concentrations occur at Ram Island, with other large concentrations found about Bangs Island, Inner Green Island and Outer Green Island. The known feeding areas are mussel shoals around Ram, Inner Green and Outer Green Islands. There is a seasonal and tidal variation as to preferred feeding sites. No studies are available to pinpoint the eider feeding sites other than about these offshore islands, though it has been speculated that the number of feeding sites has expanded in past years [2.13]. The heaviest concentrations of eider occur between October and April. Eiders nest from mid-April to mid-July, with major nesting sites being on Outer Green, Inner Green, Banks, Munk Rocks, Vail, West Brown Cow, Sand and Crow Islands [2.1].

The islands also serve as nesting sites for a variety of other seabirds. In addition to eiders, the islands are the southern breeding limit for the black guillemot, puffin, razorbill auk and Leach's petrel. The islands represent the northern breeding limit for the glossy ibis and for the snowy egret. Osprey have been observed at the upper end of Casco Bay in the vicinity of Clapboard Island, off Falmouth Foreside [2.13]. Maine's coastal islands also serve as the breeding site of herring, great black back, and laughing gulls; arctic, common, and roseate terns and great blue and black crowned night herons. Nesting activity occurs from the first week in May through the second week in July with nesting activity extending into August for seabirds other than eiders. These islands are of high value as nesting sites due to their seclusion and absence of human activity. Preceding and during the breeding season, areas supporting large concentrations of seabirds should receive priority in protection from oil spill contamination. Oil is also known to affect the viability of eggs. Oiled adults, or the use of oiled seaweed as nesting material have an adverse effect on the hatching rate. Protection of the inshore area, or immediate collection of oiled material would help minimize this possibility. A listing of these islands known to be major nesting sites of seabird populations in Casco Bay is given in Appendix B.

The black duck (Anas rubripes), a surface feeding duck, is a dominant waterfowl in the estuarine portion of the study area. This species occupies the upper Fore River, and the Presumpscot estuary from September through mid-April. Black ducks number from 3,000-5,000 in this area with the heaviest concentration occurring in the Back Cove. During the spring and summer months, other birds occupying these same areas are gulls, cormorants, herons, and shorebirds feeding on the tidal flats. Black ducks and eiders are the major species hunted. Hunting areas for eiders include Richmond, Ram, and Outer Green Islands.

The winter waterfowl inventories conducted by the Maine Fish and Game Department indicate that an estimated 16,000 ducks winter in Casco Bay. In addition to the black ducks and eiders, are the wintering populations of the goldeneye, bufflehead, scaup, scoter and oldsquaw. A tabulation of the abundance of wintering waterfowl species for the past five years, as recorded by the Fish and Game Department, is given in Appendix C.

Both black ducks and eiders are species of limited abundance on the East Coast. In particular, concern has recently been expressed over the decline of black duck populations supplanted by mallards. Based on this consideration, the large numbers of individuals and consistent presence of heavy concentrations in localized areas, the eider and the black duck populations of the study area are worthy of special protection. Eider breeding sites should be protected during mid-April and mid-July. Major bird nesting sites are indicated on the Resource Map (Chart I).

Eiders feed about the mussel shoals associated with Ram, Outer Green, and Inner Green Islands. The heaviest concentrations occur between September and April. These areas of surface water should be protected, and where an oil slick is in close proximity to concentrations of feeding eiders, these birds should be dispersed until the spill is removed or contained. As other major feeding areas are identified, they should be included in the oil spill contingency plan.

2.3.2.2 Sea Mammals

Marine mammals spend a portion of their time at the water surface during feeding and swimming activity. Their fur easily traps oil, and decreases heat-insulation and water repellence. Oil can also result in severe eye-irritation to these mammals [2.14].

The harbor seal (Phoca vitulina) and the gray seal (Halichoerus grypus) utilize at least 200 half-tide ledges and small islands in Maine's estuarine and open ocean waters.

RECOMMENDATION #19

The Arthur D. Little Study states that the anchorage area near the Portland Light Buoy is congested and that thought should be given to an alternate area such as Luckse Sound.

We in the DEP Oil Division feel that this type of decision is outside of our jurisdiction, nor do we have the resources or manpower necessary to make the proper investigation. We suggest that this recommendation be referred to the United States Coast Guard and any other pertinent agency.

Priscilla House
Environmental Technician
Dept. of Environmental Protection
State of Maine

No incidents of contamination of seals by oil have been recorded for the Maine Coast, though incidents of damage to seals have been reported during both the TORREY CANYON incident in Cornwall and the Santa Barbara spill in California [2.14]. Within the study area a number of seal haul-outs and pupping areas occur for the harbor seal. The grey seal has not been sited in the study area for about ten years and has its western limit in the vicinity of Penobscot Bay.

Harbor seals may be observed throughout the study area, including the marine and estuarine oil transfer areas. Appendix D lists seal haul-out and pupping sites within Casco Bay. The harbor seals can be considered most vulnerable in May and June, when the pups are born and are too weak to swim long distances. During other times of the year, the seals may relocate to areas not contaminated by oil [2.15, 2.16].

2.3.2.3 Commercial Fishery

The inshore fishery of Casco Bay is dominated by lobstering, which is practiced extensively throughout the Bay. The total value of lobster landings in Maine exceeded that of all other species combined in 1974, 16.5 million pounds worth approximately $23.2 million. The Portland Harbor study area is located in Cumberland County, for which lobster landings in 1974 totaled 2.3 million pounds worth approximately $3.2 million. Lobster landings for 1974 in the seven coastal counties of Maine are shown in Table 2.1 with Cumberland County providing approximately 14 percent of the total [2.17]. Yet, since 1957, lobster landings have decreased statewide while the number of boats and fishermen have increased. This has also been the case in Cumberland County, where overharvesting of the resource has been cited as the cause of the decreased landings [2.18].

To date, known impacts to lobsters in the immediate study area have been primarily limited to oiling of traps and lines during hauling. One major incident of impacts to lobsters by oil on the Maine coast occurred when the NORTHERN GULF in 1963, lost approximately 1.6 million gallons of Iranian crude oil after running aground on West Cod Ledge in Casco Bay.

TABLE 2.1

LOBSTER LANDINGS, STATE OF MAINE [2.17]
(1974)

County	Pounds	Dollars
Cumberland	2,357,571	3,280,112
Hancock	4,036,936	5,647,808
Knox	4,540,240	6,485,556
Lincoln	1,883,347	2,636,777
Sagadahoc	466,882	630,799
Washington	2,092,157	2,979,699
York	1,080,533	1,552,057
TOTAL	16,457,666	23,212,808

Five tidal storage impoundments, containing 647,000 lobsters were located in the spill area. The impoundments located on Long Island (Friendship, Maine) contained 300,000 lobsters and recorded immediate losses of 28,000 lobsters. Under normal conditions, the dam enclosing the impoundments would have prevented the entrance of oil, but storm conditions led to contamination of the impoundments [2.19].

Impacts of oil to adult lobsters is uncertain. Some of the spilled oil generally floats on the water surface, but various mechanisms, such as sedimentation can result in sinking and a resultant contamination of the substrate and benthic biota. The lobster (Homarus americanus) is susceptible to tainting through direct contact with low concentration oil/water emulsions [2.20]. Tainting could result in adverse affects to the lobster industry. Such impacts to lobsters harvested from Casco Bay have not been recorded.

As reported in reference [2.3], investigations of the changes in the feeding rate and behavior of Homarus americanus to 100 ppm of La Rosa crude or its extracts showed that the exposure to this low concentration of crude produced changes in behavior, while exposure to the soluble fractions did not. The long-term affects of adult lobster exposure to petroleum hydrocarbons is uncertain.

Of greater concern is the effect of oil on the larval stages of the lobster. Larval stages are characteristically more sensitive to oil than adult forms. Wells [2.3] found 100 ppm of Venezuelan crude to be lethal to all four larval stages of Homarus americanus. Long-term exposure of newly hatched larvae to 10 ppm Venezuelan crude resulted in a nine-day mean survival time.

Lobster larvae are present throughout the study area, residing in the plankton of the surface waters. Loss of lobster larvae would probably occur at the immediate site of a spill, irrespective of the type of oil. Whether or not a sufficient concentration of oil would be maintained over a wide enough area for a sufficient period of time to result in measurable losses to the lobster fishery is uncertain. Since the entire study area is known as a lobster ground, rapid response, containment and removal of the oil from the marine environment is recommended to limit the area of exposure and possible losses or tainting of lobsters.

The commercial fishing industry in Portland is based primarily on the offshore fishery within the Gulf of Maine, beyond the three mile limit. The primary exception is menhaden, which are caught within Casco Bay. The Cumberland county menhaden landings for July 1975, were six million pounds [2.12]. Table 2.2 gives an indication of the species composition, size, and value of commercial landings for finfish and shellfish in Cumberland County during 1973 and 1974.

Data are limited on the effects of spilled oil on adult fish in the field. Some investigators, following the spill of the TAMPICO MARU (diesel fuel) and the Santa Barbara Channel crude spill, suggest that adult fish avoid areas of heavy oil contamination [2.14]. However, heavy finfish mortalities were recorded in light product spills off Wake Island and West Falmouth, Mass [2.3]. Low level contamination of surrounding waters can produce an oily taste in fish.

The adult species of the Gulf of Maine fishery are of limited concern, compared to the planktonic and estuarine nursery grounds. Presently, the extent to which the Fore River or the Presumpscot River serve as significant nursery or spawning grounds is undocumented. The Presumpscot River can potentially serve as a coldwater fishery according to the Control Planning Group, but this is dependent on pollution abatement and fish passage. Impacts of oil contamination on estuarine nursery grounds were discussed in Section 2.3.1.2.

Potential impacts to commerical fishermen also include oiling of nets and other equipment, resulting in economic losses due to down-time.

As shown in Table 2.2, the Cumberland County soft clam landings were valued at approximately $450,000 in 1973 and $250,000 in 1974, ranking this local shellfishery second in dollar value to lobstering (shrimping ranked higher but is less confined to the study area covered by this report). The soft-clam fishery is scattered throughout some

TABLE 2.2

CUMBERLAND COUNTY LANDINGS 1973 AND 1974

[2.17]

1973

SPECIES	CUMBERLAND POUNDS	CUMBERLAND DOLLARS
FISH		
ALEWIVES	-	
BLUEFISH	50,557	[illegible],707
BUTTERFISH, LARGE	50	10
COD, WHALE	556	67
COD, LARGE	1,413,410	177,391
COD, MARKET	586,994	75,931
COD, SCROD	60,[illegible]	7,[illegible]
CUSK	368,243	44,[illegible]3
EELS, COMMON	-	
FLOUNDERS, BLACKBACK	8,069	1,[illegible]80
FLOUNDERS, BLACKBACK, SMALL	2,510	[illegible]31
FLOUNDERS, DAB, SEA, UNCL	376,799	56,995
FLOUNDERS, FLUKE, MEDIUM	35	7
FLOUNDERS, GRAY SOLE, UNCL	514,617	120,177
FLOUNDERS, LEMON SOLE	23,680	3,354
FLOUNDERS, YELLOWTAIL, UNCL	10,925	[illegible],038
HADDOCK, LARGE	169,935	44,858
HADDOCK, SCROD	[illegible]3,321	3,585
HAKE, RED	[illegible]	[illegible],722
HAKE, WHITE, LARGE	[illegible]	[illegible]
HAKE, WHITE, MEDIUM	1,[illegible]79	135
HAKE, WHITE, UNCLASSIFIED	676,752	[illegible]
HALIBUT	4,4[illegible]	3,[illegible]61
HERRING, SEA	[illegible],546,09[illegible]	[illegible]
MACKEREL, ATLANTIC	49,308	5,[illegible]
MENHADEN	[illegible],463,620	1[illegible]0,8[illegible]
OCEAN PERCH, ATLANTIC	[illegible],891,642	777,[illegible]
POLLOCK	1,358,960	[illegible]
SHARKS	264	[illegible]
SKATES	3,220	[illegible]
SMELT, ATLANTIC	12,524	4,[illegible]
SWORDFISH	-	-
TUNA, BLUEFIN	42,622	18,557
WHITING	4,436,798	243,58[illegible]
WOLFFISH	2,324	[illegible]
UNCLASSIFIED FOR FOOD	82,763	10,95[illegible]
UNCLASSIFIED FOR INDUSTRIAL	-	-
TOTAL FISH	[illegible],272,470	[illegible],983,[illegible]12
SHELLFISH		
CRABS, ROCK	268,824	27,001
LOBSTERS, AMERICAN, UNCL.	2,359,302	3,071,620
SHRIMP, SALTWATER (HEADS-ON)	4,555,217	1,312,086
CLAMS, HARD (MEATS)	3,117	2,943
CLAMS, SOFT, PUBLIC (MEATS)	[illegible],[illegible]05	435,541
MUSSELS, SEA (MEATS)	71,[illegible]	18,[illegible]
SCALLOPS, SEA (MEATS)	[illegible]	[illegible]
SQUID	[illegible]	[illegible]
SEAWEED, IRISH MOSS	[illegible]	[illegible]
BLOODWORMS	-	-
SANDWORMS	-	-
TOTAL SHELLFISH	8,140,541	4,948,[illegible]
GRAND TOTAL	[illegible],413,011	6,9[illegible],[illegible]85

1974

SPECIES	CUMBERLAND POUNDS	CUMBERLAND DOLLARS
FISH		
ALEWIVES	-	-
ANGLERFISH	11,802	1,009
BLUEFISH	11,981	1,144
COD, LARGE	1,096,499	143,289
COD, MARKET	409,193	63,113
COD, SCROD	201,784	17,785
CUSK	370,286	51,960
EELS, COMMON	3,000	1,350
FLOUNDERS, BLACKBACK	45,939	8,857
FLOUNDERS, BLACKBACK, SMALL	5,620	962
FLOUNDERS, DAB, SEA, LARGE	282,326	45,676
FLOUNDERS, DAB, SEA, SMALL	58,767	8,734
FLOUNDERS, FLUKE, SMALL	80	16
FLOUNDERS, GRAY SOLE, LARGE	201,043	60,245
FLOUNDERS, GRAY SOLE, SMALL	23,096	7,098
FLOUNDERS, LEMON SOLE	-	-
FLOUNDERS, YELLOWTAIL, LARGE	52,363	14,345
FLOUNDERS, YELLOWTAIL, SMALL	2,810	664
HADDOCK, LARGE	65,056	25,839
HADDOCK, SCROD	21,903	4,229
HAKE, RED	33,833	2,936
HAKE, WHITE, UNCLASSIFIED	1,338,100	95,637
HALIBUT	3,105	3,300
HERRING, SEA	3,139,080	119,055
MACKEREL, ATLANTIC	39,555	5,546
MENHADEN	5,863,140	73,667
OCEAN PERCH, ATLANTIC	8,552,770	677,215
POLLOCK	1,512,101	131,524
SHARKS	-	-
SKATES	7,775	530
SMELT, ATLANTIC	1,565	626
STURGEON	168	31
SWORDFISH	112,977	105,781
TILEFISH	510	168
TUNA, BLUEFIN	136,570	76,897
WHITING	2,257,358	134,975
WOLFFISH	4,986	315
UNCLASSIFIED FOR FOOD	51,582	6,617
UNCLASSIFIED FOR INDUSTRIAL	-	-
TOTAL FISH	25,917,823	1,895,139
SHELLFISH		
CRABS, ROCK	229,519	24,573
LOBSTERS, AMERICAN, UNCL.	2,357,571	3,280,112
SHRIMP, SALTWATER (HEADS-ON)	4,044,120	1,384,191
CLAMS, HARD (MEATS)	45	35
CLAMS, SOFT, PUBLIC (MEATS)	276,368	234,164
MUSSELS, SEA (MEATS)	7,845	2,384
SCALLOPS, SEA (MEATS)	12,513	21,780
SQUID	7,035	586
SEAWEED, IRISH MOSS	1,368,000	54,720
BLOODWORMS	-	-
SANDWORMS	-	-
TOTAL SHELLFISH	8,313,016	5,002,545
GRAND TOTAL	34,230,839	6,897,684

8,000 acres of the shallow subtidal benthos of Casco Bay, focusing on locations identified on the Resource Map. An enumeration of the various tracts, as compiled by the Maine Department of Marine Resources is given in Appendix E. This enumeration includes estimates of production capabilities and percent closure (i.e., contamination) of the various tracts.

Numerous reports have documented the extreme vulnerability of soft clams (Mya arenaria) to oil spill impacts. In Maine, spills near Searsport and in Casco Bay have reportedly resulted in heavy soft clam mortality [2.5, 2.19]. The SEARSPORT spill illustrated this species vulnerability to the relatively high percentage of soluble aromatics in some 5-10,000 gallons of light refined products (No. 2 fuel oil and JP-5). Investigators reported the loss of approximately 4.5 million commercial sized clams in less than two weeks following this spill [2.19]. This fuel is currently transported in the vicinity of valued clam beds around Harpswell Neck. The TAMANO spill in Casco Bay apparently demonstrated the adverse impact potential of heavier oils, where investigators reported severely reduced rates of successful larval recruitment of Mya on benthic substrates containing large amounts of spilled #6 fuel oil [2.5, 2.21].

The TAMANO spill also illustrated the degree to which extensive subtidal areas can be quickly contaminated by spilled oil. Cleaning such areas appears impractical. In view of this fact and the wide geographic distribution of clam beds about the Bay, maximum protection of this and the lobster fishery can probably be achieved by locating spill response equipment in the vicinity of potential accidents, rather than the resource. Special attention should be given to routes around Harpswell Neck, where potentially toxic products pass in close proximity to commercial clam beds.

2.3.2.4 Subtidal Benthos

Two principal inadequacies in the existing data preclude an in-depth discussion of vulnerability of benthic communities in the study area. These are: (1) the lack of a comprehensive baseline survey of benthic faunal assemblages in the area; and (2) the lack of sufficient data points to determine the existence of uncontaminated (i.e., "control") conditions. Sampling programs conducted for the Central Maine Power Company [2.22], NEECO [2.23] and following the TAMANO spill [2.5] provide scattered data from various locations. None of these results reveal faunal assemblages representative of "uncontaminated" diversity and abundance (e.g., greater than 300 individuals of 25 or more species). Nor, in general do they show severely "pollution limited" conditions (e.g., fewer than 50 individuals of 10 or fewer species). Diversity and abundance were extraordinarily low in central areas of the Bay in the month following the TAMANO spill. However, the large number and frequency of smaller spills over the years [2.2] casts doubt on elaborate interpretation of all the aforementioned sampling results.

Michael [2.6] noted the persistence of severely limited benthos in the most heavily contaminated subtidal areas 5 years after the West Falmouth spill. As in similarly contaminated intertidal sediments, opportunistic species, such as Spionid and Capitellid polychaete worms, tend to be disproportionately abundant in oil contaminated benthic faunal assemblages. Where such assemblages already exist in the study area (as is probably true, at least seansonally, in the Fore River and Presumpscot Cove) the vulnerability of this benthos to further contamination is relatively slight. These limited communities have fast turnover rates and rapid recovery times. However, the continued uncertainty over benthic faunal composition throughout the study area (excepting the distribution of commercial shell fisheries) precludes further assumptions about community recovery rates.

In any case, it is reasonable to assume that protection or "cleaning" of subtidal benthic environments is impractical <u>in situ</u>. Maximum protection would be afforded by the strategy recommended for protecting offshore commercial fisheries: i.e., maximum availability of containment and removal equipment at likely spill locations.

2.3.3 End Uses of Inshore and Offshore Zones

A variety of end use activities are dependent upon both the inshore and offshore zones. Two end use activities that are important within Casco Bay, and which are also vulnerable to oil spill contamination, are recreational activities and scientific/educational activities.

2.3.3.1 Recreational Activities

Recreation opportunities within the offshore zone are primarily boating and fishing, with these activities being practiced most intensively during the summer months. The presence of an oil spill in the offshore zone could impact recreational sailors and fishermen by prohibiting their use of an area where a slick occurred, causing damage to paintwork or creating an adverse visual impact. Loss of recreational opportunity and damage to paintwork has resulted from oil spills in Casco Bay. Under the class action suit filed by clam diggers, real estate owners and boat owners against the Tanker TAMANO, tentative settlement included payment of damages to 62 boat owners [2.24].

Yacht clubs and marinas where major concentrations of moored boats are located should be protected from oil slicks. The paintwork of boats is easily spoiled by oil. Major concentrations of moored boats include the areas listed in Table 2.3 and indicated on the Resource Map (Chart I). Scattered areas with small numbers of boats occur throughout the study area, usually associated with private residences. All are used most heavily in the summer months.

Sailboat racing is another end use of the offshore zone. Within the study area, racing is sponsored by the Centerboard, Portland, Harraseeket, and Cheabeague Island Yacht Clubs. Racing activity is concentrated in the following offshore areas:

TABLE 2.3

YACHT CLUBS AND MARINAS

South Portland

- Centerboard Yacht Club
- Port Harbor Marina

Falmouth Foreside

- Portland Yacht Club
- Handy Boat Service

Yarmouth

- Yarmouth Boat Yard

Cumberland

- Cheabeague Island Yacht Club

Freeport

- Harraseeket Yacht Club

Yacht Club	Race Course
Centerboard	Off Portland Harbor Entrance
Portland	Falmouth Foreside area and Hussey Sound
Harraseeket	Broad Sound
Cheabeague Island	East Side of Cheabeague Island

The racing schedule is concentrated during the months of July and August. Oil spills have impacted sailboat racing in the Portland vicinity. The TAMANO spill on July 22, 1972 caused the postponements of the Interclub Races at the Harraseeket Yacht Club, which were scheduled for the last weekend in July [2.25]. A second Interclub Race is the Monhegan Island Race during the second weekend in August which covers a triangular course between upper Hussey Sound, Cape Porpoise, and Monhegan Island Areas.

Recreational fishing occurs throughout the study area. No specific location is valued as a recreational fishing spot other than those known to individual fishermen.

The Casco Bay Line could be affected by an oil spill which would create an adverse visual impact in areas visited by tourists during the summer months.

2.3.3.2 Scientific/Educational Activities

The academic community makes use of both the inshore and offshore zones for scientific research and educational purposes throughout the year. A number of universities and institutes are presently conducting research of varying levels of effort within the Casco Bay area. Impact to an area under investigation would effect the direction of the research effort, both for investigations of undisturbed communities and those stressed by other pollutants. Oil impacted inshore and offshore communities may represent research opportunities as to the impacts of oil contamination.

2.4 RECOMMENDATIONS

Three basic strategies can be applied to achieve maximum protection of the resource-dependent end uses described above. These strategies are:

(a) Rapid-response containment and cleanup of spilled oil at the site of spill origin;

(b) Isolation of vulnerable areas from approaching oil through allocation of manpower and equipment to the resource site; and

(c) Cleanup at the impacted resource site.

- Application of the first strategy is recommended in all cases, since it serves to protect all resources. This implies that spill response capabilities should be located at key locations near the most likely points of spill origin.

Resources and end uses which could best be protected by this and neither of the other strategies are:

- Rocky Shores
- Commercial Fisheries
- Subtidal benthos

- Application of the second strategy is recommended with respect to the following areas:

- Mud flats in the Fore River and Presumpscot estuary
- Marshes in the Fore River and Presumpscot estuary
- Recreational beaches
- Bird and sea mammal breeding habitat
- Concentrations of recreational vessels (i.e., marinas, yacht clubs)

- Application of the third strategy is recommended for beach areas and, insofar as practicable, intertidal rocky shores where seaweeds have been heavily oiled.

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3. POTENTIAL OIL SPILL LOCATIONS

There is always a risk of spilling some oil or petroleum product during every transfer, transport and storage operation. Most of these spills however are small and result from minor tank overfilling or drippings from nozzles. These minor spills are similar to those of gasoline leaks that occur during automobile fueling. Large spills are the result of abnormal but infrequent events (accidents) such as what might happen during the failure of a hoseline, gross tank overfills, pipeline ruptures, vessel collisions or groundings, etc.

Several oil and petroleum product handling facilities in the Portland Harbor and Casco Bay areas were visited under this program. A list of the facilities visited is given in Appendix F. The operations, equipment and storage facilities of these companies were examined and estimates made of typical sizes of spills that may result under abnormal circumstances. These estimates were made utilizing previous experiences with similar facilities, and from data derived from the U.S. Coast Guard, EPA and the Office of Pipeline Safety. The potential spill sizes were then categorized as "minor," "medium," or "major" according to the definitions given in 40 CFR 1510.5.* Discharges of 10,000 gallons of oil or less in coastal waters are termed "minor " discharges. Spills of 10,000 - 100,000 gallons are termed "medium" discharges, while spills greater than 100,000 gallons are described as "major."

Obviously, spills greater than those that were estimated for each facility could occur under unforeseen circumstances such as an airplane impacting one or more storage tanks, or a devastating hurricane or earthquake resulting in tank failure. However, such occurrences are very rare events which are likely to result in other more serious impacts, in the disruption of the effectiveness of the response procedures, or in the destruction of the response system itself.

*Code of Federal Regulations, Title 40, Paragraph 1510.5

Figure 3.1 is a map of the study area. Potential sources of minor, medium and major oil spills are identified on the map. Not shown on the map are locations where bunkering operations take place. These operations can be anywhere and are potential sources of minor spills. Similarly, collisions and groundings of tankers at sea or underway in the harbor are potential sources of major spills.

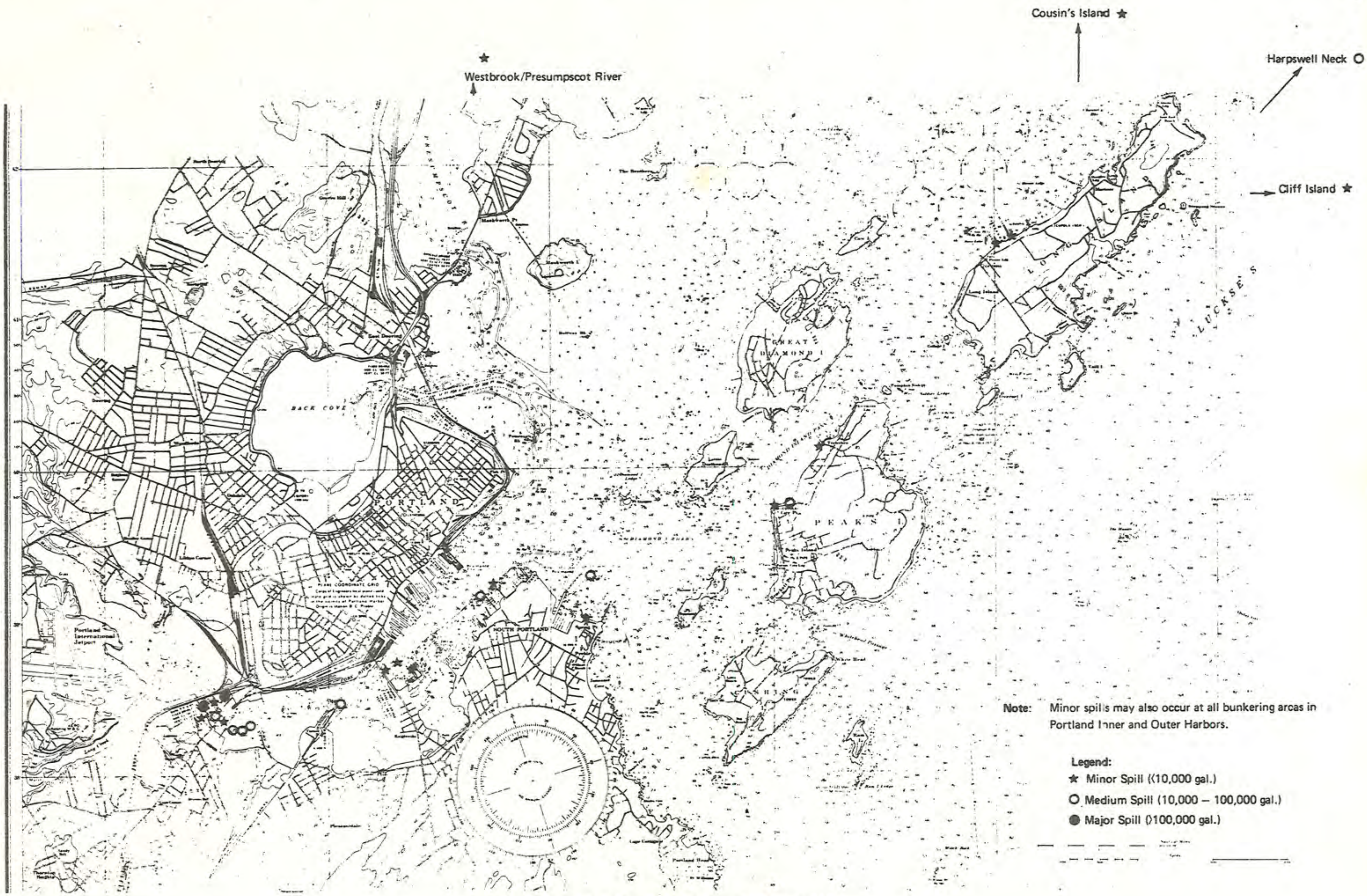


FIGURE 3.1 POTENTIAL LOCATIONS OF OIL SPILLS

4. OIL SPILL MOVEMENT

4.1 INTRODUCTION

An oil spill on the ocean is moved both by wind and surface water currents. The oil slick also spreads due to buoyancy and surface tension forces. Thus a spill offshore may reach the shore and pollute the beaches and the shore area. The purpose of this analysis is to develop a procedure for predicting the movement (tracking) of an oil spill and calculating the probability of oil impacting a given shore area when the spill occurs at a specified location.

The need for knowing the oil slick path and the location of the shore impact arises because of the concern of the public and private agencies for the environmental consequences and danger to the coastal ecology that can be caused by an oil spill occurring near a harbor or a few miles offshore. If the probability of oil impacting a given point of the shore can be predicted, appropriate public agencies can dispatch the necessary personnel and pollution-fighting equipment to the vicinity of the high impact probability area.

To trace the movement of the spill and calculate the shore impact probability one needs to know the following:

- quantity of oil spilled
- the physical properties of the oil
- the wind data for the region
- the tidal and current data for the region.

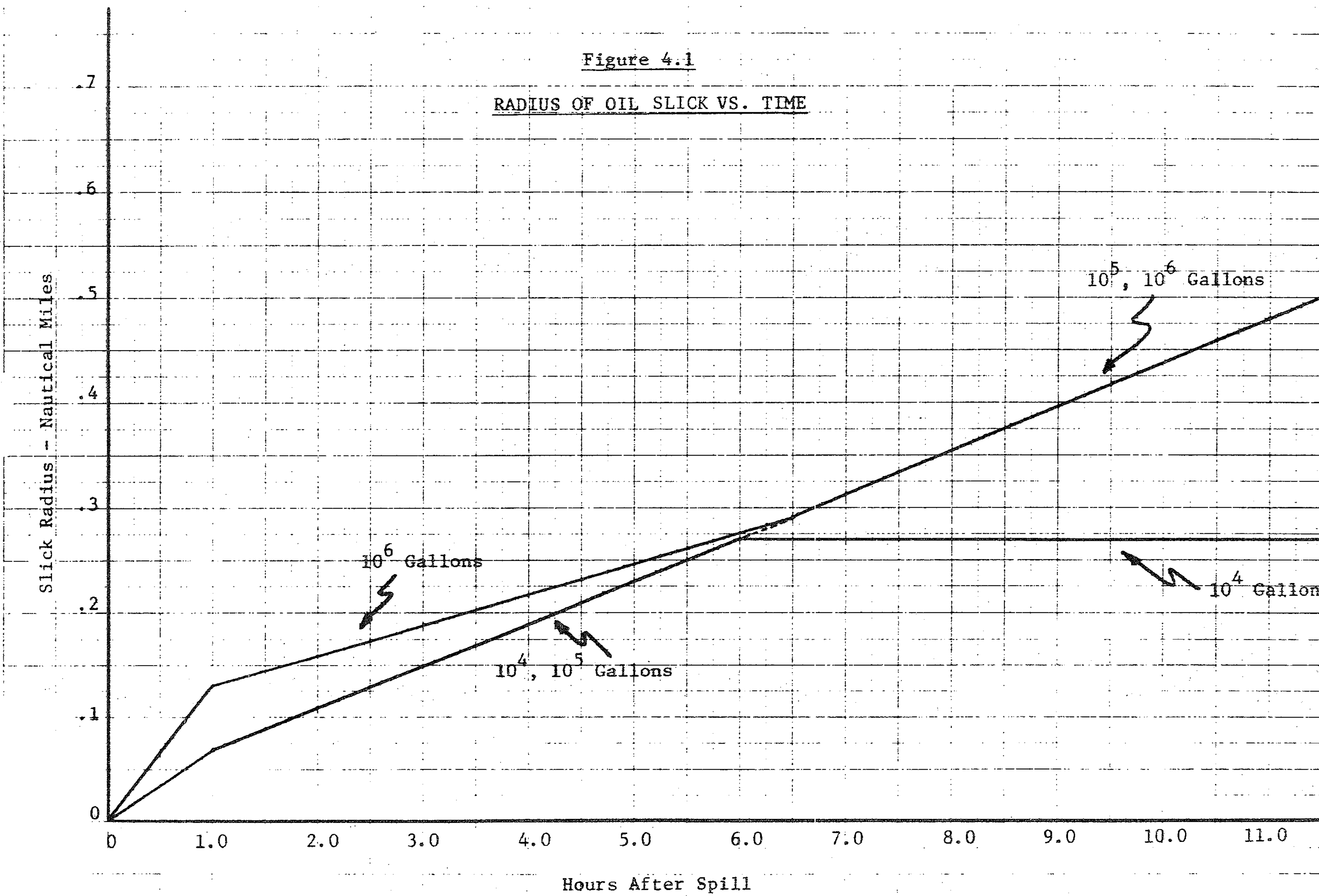
4.2 ANALYSIS OF OIL MOVEMENT

4.2.1 Oil Slick Size Increase with Time

The model available in the literature for predicting the size of the oil slick (spilled instantaneously) with time has been reviewed in Appendix G.1. Based on this analysis, the radius of spill as a function of time for three different spill quantities of crude oil (10^4, 10^5 and 10^6 gallons) has been plotted in Figure 4.1. The manner in which these data are used in the analysis is explained in the next section (4.3).

Figure 4.1

RADIUS OF OIL SLICK VS. TIME



4.2.2 Movement of Oil by Wind

Even though the exact mechanism by which the wind interacts with an oil slick on an ocean and moves the slick is not well understood, approximate measurements indicate that the oil slick moves in the direction of the wind at about 3% of the wind speed. The direction of the wind and its velocity vary with time. In Appendix G.2, a method is given by which the probability of wind blowing in a given direction and its average velocity can be computed from weather data compiled by the National Climatic Service.

4.2.3 Movement of Oil by Surface Water Current and Tides

The slick formed by an oil spill on the water surface is known to move with the prevailing surface current. The tides in the sea also affect the oil slick movement. The tidal velocity and direction in a given location on the sea depend on the time of the day and the geographical configuration (such as the presence of islands) near the location. An oil slick is carried towards the shore by tidal currents during the flood flow and away from the shore during ebb flow. In the absence of wind, an oil slick will move in phase with the tidal ebb and flood and travel approximately along a stream line. However, because of the action of wind, the slick moves on different stream lines at different times of the tidal cycle, reaching a location other than the starting point at the end of one complete tidal cycle.

The reduction of tidal data (available from National Oceanographic and Atmospheric Administration) into suitable form for use in tracking an oil slick in a tidal cycle is explained in Appendix G.3.

In the following section a specific example is considered to illustrate the methodology for predicting the oil impact probability taking into account the effects of oil slick size increase, the wind and tidal effects. The same methodology is utilized in obtaining the oil impact probabilities for Portland shore line. The results are given in Section 4.4.

4.3 METHODOLOGY FOR CALCULATING THE PROBABILITY OF IMPACT OF AN OIL SLICK ONTO THE COASTLINE

The method of calculating of the impact probability is based on the oil slick tracking principle. With the wind assumed to be blowing in a given direction, the path of the oil is tracked on the water surface (method of tracking is explained later) until the oil impacts the shore. Then the probability of impact of that particular area of shore is equal to the probability that the wind is in the assumed direction. If the same area of shore is impacted by the oil movement caused by winds in other directions, then the total probability of that shore being impacted is the sum of the probabilities of wind being in those directions.

The methodology indicated in this section is a general one and can be applied to an oil spill occurring in any season, any time of day, and any location, provided sufficient data exist for tide and wind. The procedure of calculation is illustrated with a specific example.

Consider a (hypothetical) spill occurring near Portland Harbor with the following conditions:

Quantity of oil spilled instantaneously	=	100,000 gallons
Location of spill (see location number III on the map shown in Figure 4.2)	=	near the oil transfer area [43° - 43'N, 70° - 10'W approximately]
Season of the year	=	January
Time of day when spill occurs	=	at peak flood tide

Before the actual plotting can be made on the map to determine the path of the oil slick and hence the shore impact probability, some preliminary calculations have to be made. These are:

- Oil slick size: For the given quantity of spill, the radius of slick is calculated as a function of time. Such a plot is shown for the 100,000 gallon spill on Figure 4.1. For other spill sizes, use the method described in Appendix G.1.

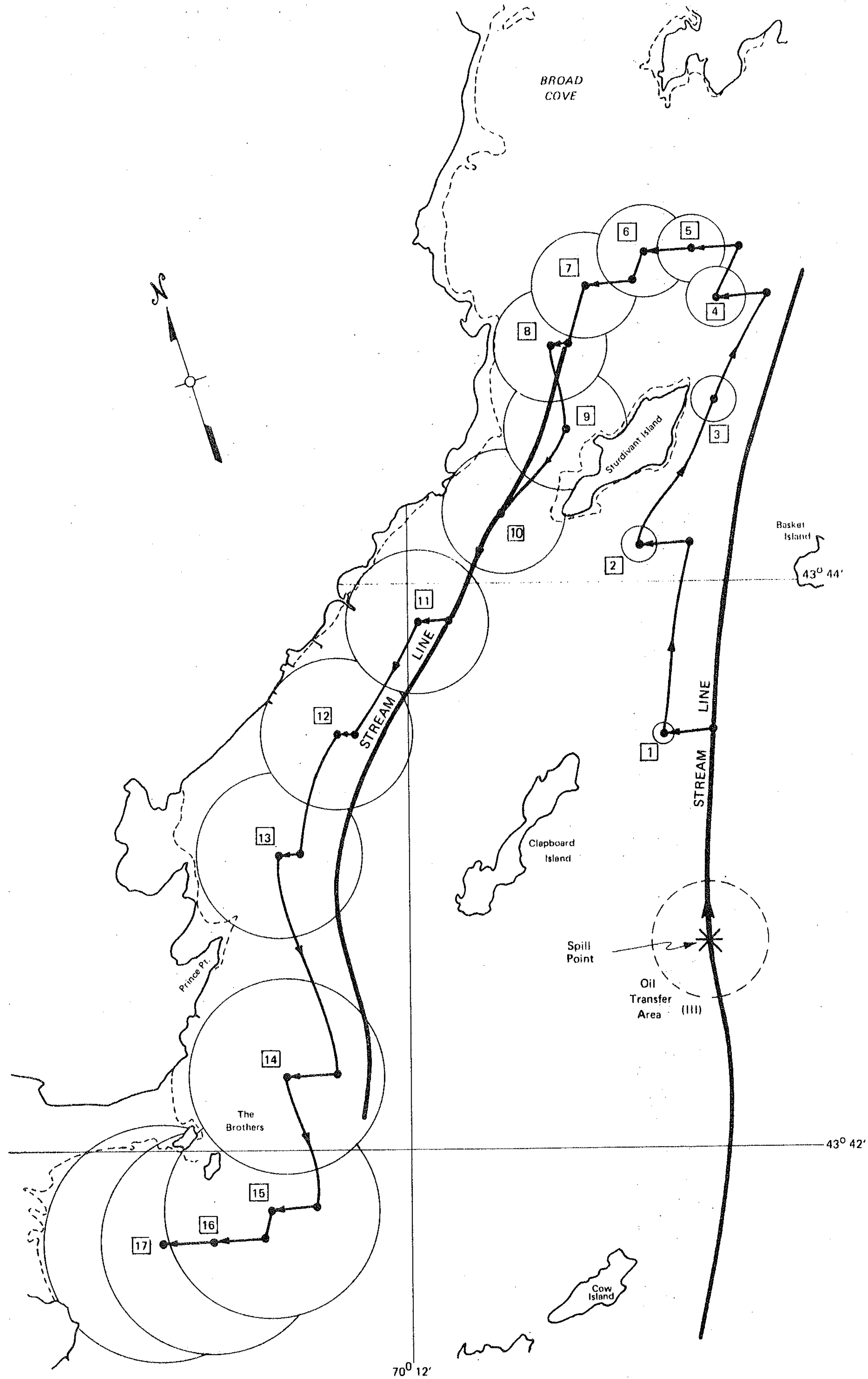


FIGURE 4.2 SPILL TRACKING PROCEDURE WITH CURRENT AND WIND

- Wind data: The most probable weather condition that occurs in Portland area is the D type atmosphere (which occurs 61% of the time). Using the methods discussed in Appendix G.2, the four wind directions having high probability of wind are considered, and the wind probabilities and mean wind speed in each direction are calculated. Tables similar to Tables G.2.2 and G.2.4 are prepared.

  It is seen from Table G.2.4 that in the season DJF near Portland Harbor, the four highest probability winds blow from the overall directions N, NW, SW and E. For our example here, we consider the East wind, which has a probability of 3.24%.

- Tide data: The tidal current data obtained from the tables are reduced to a form shown in Table G.3.1 which indicates the peak tidal velocities in flood and ebb and their respective "periods" for different seasons and locations near Portland Harbor. For the example under consideration for the January season (DJF), at the oil transfer location, the peak flood velocity is 1.5 knots with 5.5 hour half period, and 0.9 knot and 6.5 hour half period respectively for ebb flow. Even though these data are not available for the Oil Transfer Area (III), the tidal data from Hussey-Crow Island measuring station are used judiciously (after suitable modification for the surrounding geography) to obtain the tidal data for the Oil Transfer Area. Also, a single streamline is drawn (shown on the map in Figure 4.2) through the Oil Transfer Area. Judgment is used in drawing this line, taking into account the measured data at Crow Island as to the direction of the current, other nearby geographical features, and knowing the general direction of flow of water during tides.

Based on the values of tidal amplitude and period, the distances traveled by the oil slick center for every half hour are calculated by the method given in Appendix G.3. A table of values of intervals of time, the distance traveled in nautical miles, and the length this represents on the linear scale of the map is prepared. Such a table for a spill in the oil transfer area in January is shown in Table G.3.4.

Having calculated the mean wind velocity, its direction, and the tidal excursion table, we are now ready to plot the oil slick path. This is shown on the map in Figure 4 2. The spill point is represented on the map by No. III. During the first half hour after the spill, the slick center moves 0.74 nautical miles (see Table G.3.4) and at the same time is moved by the East wind in a direction 4.08° south of west (see Table G.2.4) by a distance equal to 3% x 11.13 knots x 1/2 (hr) = 0.17 nautical miles. On the map, the location of the spill center after 1/2 hour is obtained by first tracing 0.74 nautical miles along the floodward streamline, then moving 0.17 nautical miles at 270-4.08° clockwise from North. This position is shown as point No. 1. The size of the spill after one half hour is 0.03 nautical miles in radius (Figure ..1). This is shown as a small circle at location 1.

At location 1, another streamline is now drawn approximately parallel to the previous one but keeping in mind the presence of Sturdivant Island. Then, the procedure indicated above is repeated, noting that the wind blows in the same direction all the time.

It is seen from the map that between one hour and one and one half hour after the spill, the eastern shore of Sturdivant Island is polluted by the oil. Also, because of the East wind, the slick gets pushed toward the main shoreline. During the ebb tide, when the slick is moving in a southerly direction, it is impacting the mainland. Conservatively we assume in our calculations that no oil is lost from the slick to the impacted shore. The center of the slick is assumed to stay on the appropriate streamline one radius from the shore and the slick "rolls" like an expanding hoop along the shoreline.

In the present example, the oil slick impacts the shore line just south of Wildwood Park (see Map in Figure 4.2) to Prince Point in the Portland Harbor area. The probability of impact of this area due to a spill in the oil transfer area (III) is equal to 3.2% (which is equal to the probability of wind being in that direction), when the spill occurs in peak flood tide. However, to obtain the overall impact probability other wind directions and spill times (in the tidal cycle) have to be considered. Results from such calculations made for Portland Harbor area are discussed below.

4.4 RESULTS

For Portland Harbor, we have calculated the probabilities of oil impacting various points on the shore due to an oil spill occurring in one of several spots in the harbor region. Four possible locations for oil spill were considered with spill occurring in either peak flood tide or peak ebb tide. Two seasons were considered. These conditions are summarized in Table 4.1. Sixty-four plots were made and the oil trajectory traced as described in the previous section.

To present the results of the impact data, we have divided the islands and mainland shore into several regions shown in Figure 4.3. The impact of each region by any of the spills considered is recorded in a table. The details of such impacts to various regions of mainland shore and the islands are given in the tables of Appendix G.4.

4.5 DISCUSSION

The results presented in Tables G.4.1 through G.4.4 indicate that the probability of impact of a given shore area depends to a large extent on the location of the spill relative to the shore point. For example the highest probability of impact due to a spill in Portland Breakwater is 63.4% impacting Cushing Island I. However, the probability with which Cushing Island I gets impacted by a spill at Hussey Sound - Cow Island is only 1.29%. The above conclusion could have been qualitatively observed by noting the relative positions of the spill points and Cushing Island (see Figure 4.3), but the quantitative results can be obtained only by a detailed calculation illustrated in earlier sections.

TABLE 4.1

Summary of the Data Considered for Evaluating the Oil Impact Probability in the Neighborhood of Portland Harbor

Locations	(4)	Portland Breakwater(I), Hussey Sound - Crow Island(II), Oil Transfer Area(III) and Portland Harbor Entrance(IV)
Seasons	(2)	January (DJF) and July (JJA)
Tidal Phases	(2)	Peak Flood Velocity, Peak Ebb Velocity
Winds	(4)	Four Directions with High Probabilities of Occurrence

Total Plots = 4 x 2 x 2 x 4 = 64(i.e.,one for each combination of the above)

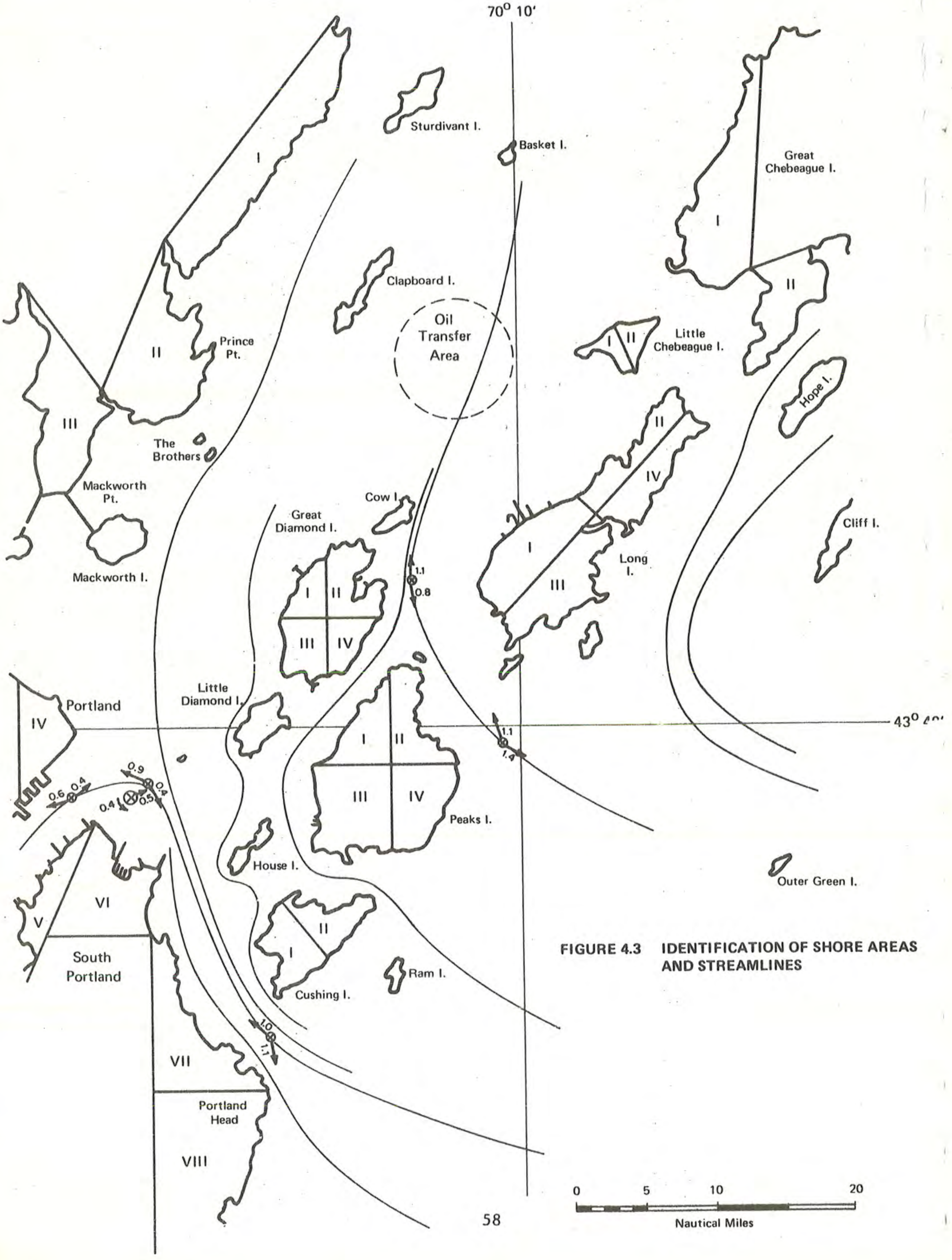


FIGURE 4.3 IDENTIFICATION OF SHORE AREAS AND STREAMLINES

Table 4.3 summarizes the results from Tables G.4.1 - G.4.4. In addition, it indicates the overall impact probability. The results in the last column should be used only as an aid in decision making and not much importance should be given to the quantitative data. This is because, in generating these overall probability values, we have assumed that the spill in each of the four locations considered is equally probable. Before pollution fighting equipment and response personnel may be deployed at locations indicated as being high probability impact areas, a separate analysis has to be made as to the likelihood of oil spills in the locations chosen for this study.

The sum of the probabilities of impact of various shore areas do not add up to 100% for the simple reason that an oil slick impacting a given area can also impact other shore areas. Therefore the probabilities are not mutually exclusive. Also the calculations indicated and the impact probabilities obtained are for an oil trajectory period of 12 hours (one tidal cycle). It is possible that if a larger duration of tracking is considered, somewhat different values for impact probabilities would result.

For an actual spill, for which the location and size and other weather and tidal data are known, it is possible to use the methodology described in this chapter and its related Appendix G to predict the trajectory of the oil and to identify probable shore-impact areas. This procedure is summarized in the "Response Manual" which accompanies this report.

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*"Response Manual for Oil Spills in Portland Harbor and Casco Bay" prepared by Arthur D. Little, Inc. (March 1976).

TABLE 4.3

DEPENDENCE OF OIL IMPACT PROBABILITIES WITH SHORE LOCATION

Shore Location		Percent Impact Probability Due to a Spill in: Portland Breakwater	Hussey Sound Cow Island	Oil Transfer Area	Portland Harbor Entrance	% Overall Impact Probability
Mainland	I*	0	0	26.3	0	6.6
	II	0	1.3	6.4	0	1.9
	III	12.5	0	1.3	0	3.5
	IV	12.9	7.7	1.3	0	5.5
	V	7.7	0	0	0	1.9
	VI	36.5	1.3	0	0	9.5
	VII	47.2	1.3	0	18.9	16.9
	VIII	0	0	0	23.3	5.8
Long Island	I	5.9	33.4	35.8	12.5	21.9
	II	5.9	16.8	11.7	0	8.6
	III	0	7.5	34.1	18.4	15.0
	IV	0	10.2	5.8	0	4.0
Great Diamond Is.	I	0	5.1	0	0	1.3
	II	5.9	12.6	29.1	0	11.9
	III	0	5.1	0	0	1.3
	IV	5.9	0	1.3	0	1.8
Cushing Island	I	63.4	1.3	0	18.9	20.9
	II	10.2	1.3	0	12.5	6.0
Peak Island	I	10.2	0	0	0	2.6
	II	0	27.3	16.5	12.5	14.1
	III	14.5	1.3	0	0	4.0
	IV	0	15.5	28.3	12.5	14.1
Great Chebeague	I	0	12.5	17.6	0	7.5
	II	0	10.2	10.2	0	5.1
Little Chebeague	I	5.9	10.2	19.1	0	8.8
	II	0	7.5	8.6	0	4.0
Cousins Island		0	18.4	5.8	0	6.1

*See Figure 4.3 for location identification

TABLE 4.3 (cont)

Shore Location	Percent Impact Probability Due to a Spill in: Portland Breakwater	Hussey Sound Cow Island	Oil Transfer Area	Portland Harbor Entrance	% Overall Impact Probability
Sturdivant Island	0	18.4	37.3	0	13.9
Basket Island	0	30.9	28.0	0	14.7
Clapboard Island	0	6.4	24.1	0	7.6
Cow Island	5.9	11.6	30.4	0	12.0
Crow Island	5.9	12.6	30.4	0	12.2
The Brothers	12.5	1.3	6.4	0	5.1
Mackworth Island	25.0	6.4	7.7	0	9.8
Ft. Georges	24.8	0	1.3	0	6.5
Little Diamond Island	37.9	6.4	1.3	0	11.4
House Island	47.6	1.3	0	0	12.2
Ram Island	0	10.4	0	30.9	10.3
Overset Island	0	40.8	29.8	18.4	22.3
Vail Island	0	0	5.8	18.4	6.1
Outer Green Island	0	0	5.9	0	1.5
Cliff Island	0	8.6	0	0	2.2
Hope Island	0	10.2	5.8	0	4.0
Pumpkin Nob	0	19.9	6.11	12.5	9.6

5. CONTAINMENT AND DISPOSAL SYSTEMS

5.1 FACTORS INFLUENCING SELECTION OF RESPONSE SYSTEMS

5.1.1 Introduction

The response procedure to an oil spill in coastal waters is highly dependent on several factors, most important among which are the following:

- the location of the spill with respect to vulnerable resources and the availability of containment and disposal equipment
- the size of the spill
- the types of containment and disposal equipment available
- weather conditions
- speed and direction of prevailing currents
- availability of trained response personnel, and
- the time elapsed between the initial discharge and the notification of the responding agency.

Oil spills occur over a wide range of quantities. Smaller spills occur from a variety of incidents, both operational and accidental, and at a large variety of locations ranging from highway drainage systems to small backwaters to oil terminals to main ship channels. The large spills are only associated with catastrophic failures at major oil storage facilities or with collisions and groundings of tankers and large barges in the course of their voyages. Coast Guard statistics show that in 1972, 5412 spills between 0 and 100 gallons accounted for 0.6% of the total released volume; 1608 spills between 100 and 10,000 gallons accounted for 6.5% of the volume; and 82 spills between 10,000 and one million gallons accounted for 92.9% of the released volume. Potential spills in Portland Harbor and Casco Bay are expected to follow a similar pattern. Locations of potential spills in the study area have been identified in Chapter 3.

Obviously, different approaches for containment and disposal should be applied to the more frequent (98.8%) but smaller spills below 10,000 gallons than the rarer (1.2%) but larger spills.

Once a spill occurs, regardless of its size, two steps must be undertaken simultaneously. An attempt must be made at shutting off the source of the discharge if possible. At the same time the spilled material must be effectively contained so that it does not spread over a wide area. Once contained, collection, clean-up and disposal operations can be implemented.

5.1.2 Responsibilities

Nominally and legally, the U.S. Coast Guard becomes the On Scene Coordinator (OSC) of large oil spill operations. Via the Coast Guard's rotating fund, the OSC is empowered to enter into contracts and to make commitments for use of facilities and equipment.

The State of Maine Department of Environmental Protection has legal responsibilities for decisions affecting the State and its waters, and would work closely with the Coast Guard during oil spill operations.

The Environmental Protection Agency (EPA), under Federal law, works with the Coast Guard in water pollution matters. The EPA is responsible for establishing land pollution criteria.

The Maine Port Authority (Department of Transportation) which supervises operation of the port of Portland has a continuing interest in oil spill prevention and oil spill clean-up.

The Portland Pollution Abatement Committee is a voluntary association of terminal and shipping operators. Nevertheless, it is an organization which could be used as a focal point for contact and communication between State agencies and local commercial operations. The Committee produced one of the first oil-spill response plans for the port. However, it has been relatively inactive since DEP established a headquarters in Portland.

The response system to an oil spill will generally stretch well beyond the limits of Portland itself. This entails the transport of liquid and solid debris over the State rail and road networks. While rail and road movement of liquid petroleum and petroleum products in tanks is an accepted event, some municipalities prohibit the passage of open loads of contaminated materials. Likewise, local municipalities may have ordinances concerning disposal sites which prohibit burial of oil-soaked debris even though such a site meets all EPA prerequisites. In some instances, burial may be the subject of individual town action and a permit by the town government may be required.

5.1.3 Review of Containment and Clean-up Procedures

Containment of oil spills on water can be achieved by such methods as floating booms, air bubble barriers, sorbent barriers, chemical barriers, water hose streams, and ship propeller diversion. Land spills on the other hand, can be contained by diking or damming, diversion into trenches and ditches, and the use of coagulating or gelling agents, sorbents and foam-in-place equipment.

Once the oil is contained, clean-up operations on water can be instituted utilizing such techniques as skimming , chemical dispersion, coagulation, sinking, burning or sorbtion. Spills on land may be removed or disposed of by pumping, burning, sorbtion, earth removal, biodegradation, steam cleaning, sand blasting and the use of high-pressure water jets.

5.1.4 Review of Disposal Procedures

The disposal process commences after released oil has been contained and collected. However, in all present methods of recovery and clean-up, relatively large quantities of solids and water become mixed with the oil. The solids may be either organic or mineral, flammable or noncombustible. Large variations in the proportion of oil to water and solids may occur, depending upon the site of the spill and the environmental conditions.

The recovered mixture requires a combination of transportation, storage, separation, and disposition, in sequences determined by the available equipment, the spill location, and the site of ultimate disposition. Simplicity and economy are prime criteria in the selection of a suitable process. The contaminating nature of the mixture makes it desirable to limit handling and rehandling as much as possible, and to utilize bulk methods where feasible.

The choice of a disposal system is governed by the form of the material that is collected. In general, most skimmers and collection devices take in a mixture of oil and water and pump this mixture into temporary storage. Most devices are provided with screens to exclude floating solids above a certain size which would clog the orifices, piping or pumps. These screens are periodically cleaned by hand and the oil-soaked debris is placed on deck, in a bin, or in a barrel. In the case of beach clean-up, large quantities of wet oil-soaked organic materials as well as sand and gravel are removed by mechanical or manual scaping. The principal differences are between the oil-water mixture with its possible contamination by fine solids, all of which can be treated together as a liquid, and the oil-soaked solids which must be handled mechanically. In general the quantities of either mixture which can be stored on board mobile collecting devices are small. Only fixed collection heads using weir or manifold concepts and associated with a non-integral power source have any tankage of consequence for storage purposes.

In summary, then, the procedures and equipment for containing and disposing of oil spills in Portland Harbor and Casco Bay are highly dependent on what equipment is available on short notice. In this chapter, we discuss containment and disposal systems that are readily available to the Department of Environmental Protection of the State of Maine.

5.2 CONTAINMENT AND CLEAN-UP SYSTEMS

Depends on clean-up companies

5.2.1 Available Systems

A survey of containment and clean-up systems available to DEP was conducted. Several companies that specialize in supplying equipment and services relating to oil spill containment and removal were identified. The addresses and telephone numbers of these companies are given in Appendix H. Also provided is a list of oil spill containment and removal equipment and supplies available from these sources.

At the present time, it does not appear that it would be cost-effective for DEP to acquire and maintain containment and clean-up equipment and supplies beyond what it already owns. The alternative is for the DEP to continue to be dependent on competent industrial companies for support in responding to oil spills. However, an effort should be made by DEP to preplan emergencies with the capabilities of each company in mind. Joint training and familiarization programs could also be conducted by DEP for company and DEP response crews.

The choice of one or more companies to respond to a particular spill is highly dependent on the factors discussed earlier (section 5.1). Thus, it is very important that DEP staff be aware of the capabilities and limitations of these companies and update this information regularly. Moreover, DEP must be alert to the possibility that commercially available equipment and devices may decline in capacity relative to needs, in which event the policy of reliance upon them will have to be reconsidered.

5.2.2 Recommended Actions

An examination of potential sources of oil spills on Figure 3.1 suggests the following recommended locations for the deployment of booms and actions for the DEP to pursue:

1. Installation of tidal adjusting anchor points for the deployment of a boom from pilings of State Pier to another pier in South Portland such as a Pine State Bi-Products Pier. Stretching the boom between these two points will close off most of the Fore River/Front Harbor area against oil spills upstream. The South Portland anchor point should be located near an access road so that vehicles may approach the collected oil and pump it out.

2. The DEP should attempt to enter into a working agreement with Portland Pipeline Co. to boom in an emergency, from Fish Point area to Portland Pipeline Co. Pier 2 and Pier 2 to Fort Preble Breakwater. The feasibility of such a boom has already been demonstrated by Portland Pipeline Co.

3. Provide tidal adjusting anchors to deploy a boom across the Presumpscot River, preferably at its intersection with Highway 95 and Blue Star Memorial Highway (U.S. Route 1) Bridges. The fixtures should be designed to permit boom deployment upriver or down river of bridges. The structural bends of the bridges will provide support for the deployed booms.

4. Provide a similar system as 3 above at Back Cove.

5. Clean and repair the available 1000-ft boom in the State Pier warehouse.

6. Activate the available DEP skimmer as an emergency unit.

7. Uncrate the new section of boom that DEP has acquired and get it in a ready state for deployment to close off harbor (Fore River). The boom should be of adequate length to close off the river as indicated under #1 above.

8. Investigate and develop means for joining various sections of boom presently available from the sources identified in Appendix H.

9. Prepare an inventory of pipeline diameters in shore areas where oil is handled and fabricate or purchase closure clamps for the various pipeline diameters. Also, DEP should stock a supply of wooden wedges that could be driven into holes, cracks or broken pipes to stem the leakage of oil.

10. DEP response personnel should be trained in boom deployment, clean-up operations and methods for stemming liquid flows. The DEP should take advantage of the USCG training program offered in Yorktown. Manufacturers and suppliers of booms and other equipment should also be able to provide training programs to DEP personnel.

11. The DEP should have access to a boat which is compatible with the boom that DEP presently owns and which is capable of transporting it, response personnel and other ancillary equipment to the boom anchoring locations suggested above.

12. It is highly recommended that the DEP have access to a fast service helicopter so that spills in Casco Bay may be investigated and assessed first hand, and the origin located accurately for oil trajectory calculations.

5.3 DISPOSAL SYSTEMS

5.3.1 General Background

The principal aim of this task is to identify disposal equipment and facilities now available to the DEP in the Portland Harbor - Casco Bay area. As with containment equipment, it does not appear beneficial to invest at this time in extensive new equipment and facilities for disposal purposes. Furthermore, the disposal process may and probably will have to involve a number of municipalities and agencies other than those directly and immediately concerned with Portland Harbor and Casco Bay. These conditions make it necessary to assemble information on various means of performing the functions required for the disposal process, and then trying to construct a viable system out of the available pieces or elements. This approach differs from that of a fresh design; it is analogous to playing a game of "Scrabble," as opposed to designing a new cross-word puzzle.

The companies listed in Appendix H are available to assist the DEP in containing and cleaning up spills in Portland Harbor and Casco Bay. Disposal may be achieved through other commercial facilities. Liquids may be trucked off by one of the several waste oil companies, and solids may be incinerated in one of the two incinerators in the area capable of burning this type of material. It is significant to note that the capacity of these operations is limited, and that the operations are based on the handling of relatively small batches of material. At the same time it is most significant to note that these contract operations are capable of handling the majority of spill occurrences, even though these constitute only a small fraction of the released volume of oil.

In cases of large or catastrophic spills, such as the TAMANO spill of 1972 which released half a million gallons, there is no system in existence capable of methodical disposal. Damage to the environment from such spills and the cost of disposing of large spills can be minimized by outlining an appropriate system for disposal in advance. However, such a system cannot be very specific since the choice of a disposal system is greatly dependent on the circumstances surrounding a spill and the containment and clean-up systems deployed. The following sections provide guidance to DEP personnel in selecting a disposal system.

5.3.2 Available Disposal Systems

As mentioned earlier, a disposal system consists of several components which include storage, transportation, separation, transfer and handling, and final disposition. In this section, we discuss these various operations and identify options that are available to the DEP in the study area.

5.3.2.1 Storage

Storage is required to accumulate solid and liquid material in sufficient quantities for transport or treatment. Some equipment suitable for this purpose is mobile and can serve the dual function of storage as well as transportation.

5.3.2.1.1 Liquid Storage

- Tanks

Several of the oil terminals have indicated the availability of empty tanks for emergency use. Unfortunately the reason for most permanently empty tanks is their dubious integrity. On the other hand, the terminals are reluctant to commit sound tanks and piping to contamination by an oil-seawater-debris mixture. Since the inventory of the terminals and tank farms fluctuates continuously, it is not feasible to predict the availability of specific tanks. It is suggested that DEP conduct regular checks on the availability and condition of storage tanks in the Portland Harbor area.

- Tank Trucks

For smaller spills, trucks can serve both for storage and transport. Experience has indicated that a fleet can be assembled on short notice from the commercial terminals and operators, the various tank cleaning firms, and the specialized transport companies. A full listing of available equipment, capacities, rates, and 24-hour contact points should be established by DEP and continually updated. The Merrill Transport Company with the largest fleet of tank trailers and the Highway Transport Company are examples of local companies which can provide such vehicles in an emergency.

- Tank Barges

There is a limited number of tank barges in the area. Like most mobile equipment, barges may be assigned to a variety of duties and locations. A listing of equipment available at any one time may become useless and misleading after a short interval. For example, constant liaison with Cianbro, Boston Fuel, and Northeast Oil, would provide information on the ever-changing picture. There are no hopper barges available in Portland. Such barges could be used for collection and storage of recovered oil.

- Railroad Tank Cars

Maine Central Railroad, with its general offices in Portland, would be the principal source of information on the availability of tank cars. Maine Central also owns tracks in Portland and along the waterfront and is in a good position to provide information on spurs and approaches to potential spill locations.

5.3.2.1.2 Solid Storage

- Deck Barges

Cianbro is the principal user of barges in Portland. In lieu of the non-existent hopper barges, Cianbro in the past has put wooden bulwarks on deck barges for oil-soaked solids. This is not an ideal storage method since leakage can occur and the assembly of the bulwarks takes time.

- <u>Gondola Railroad Cars</u>

Maine Central has a number of these cars, mainly for its own use. Most are not watertight and would require lining by plastic to retain oil drippings. While the rates for these cars initially are low, they escalate rapidly with time due to railroad demands. An alternative vehicle is the "air-lift" car with a hinged side and a pneumatically tilting body for unloading.

- <u>Land Storage Areas</u>

Any storage of oil-soaked debris on land requires an oil-tight base to prevent contamination of the underlying ground. One of the oil terminals has a "panic pond" for emergency use, but this probably does not meet the standards required for deliberate use. The McKin Company at Gray owns a concrete lined basin of about 150 ft x 50 ft which has been used for this specific purpose.

The majority of these facilities and equipment from commercial sources cannot be dedicated permanently to standby for emergency oil spill use. Nor does it appear to be feasible for the State to acquire this type of equipment for emergency use only. Initial capital costs and maintenance requirements are high. This type of equipment usually becomes practical if it serves a dual purpose, that is, if it can perform some routine and necessary function between its emergency utilizations. For example, it has been recommended in the past by the Maine Port Authority that a waste barge be procured which could service ships in port (sewage, sludge, and bilge discharges) routinely and which could be immediately used in the event of an oil spill emergency. Alternatively, the State could procure an item of equipment and lease it out for routine operation under the stipulation that it be made available immediately in case of an emergency. Under the present constraints it appears that DEP is better served by maintaining some form of a master contract - on a task basis - with appropriate commercial operators, and a continually updated roster of commercially available equipment and facilities at a central location.

5.3.2.2 Transportation

This component of the disposal system includes various legs from the collection point of the material to intermediate storage or consolidation and possibly to processing or final disposal.

5.3.2.2.1 Transportation of Liquids

Land transportation possibilities consist of tank trailers, trucks, and railroad tank cars. These have already been discussed. Similarly, tank (or hopper) barges can perform both functions on water and have already been discussed.

It is of particular interest that in the case of large spills, initial water transportation of the collected liquids may involve appreciable distances. If the collecting craft or devices have limited storage capacity, they must spend a good part of their time shuttling to shore to deposit their loads. A barge can circumvent this inefficiency by being moored on site and acting as a consolidation point until filled, and only then performing its "transportation" function by moving to shore.

5.3.2.2.2 Transportation of Solids

Similarly, in the case of collected debris, a deck or hopper barge can operate in this manner and avoid time delays and small-scale rehandling of the solids to shore and on shore.

Land transportation can best be accomplished by truck or rail car. Open body trucks of the type used by construction companies are suitable for this purpose if lined with a nonpermeable material. Here also, a roster of available equipment, sources, and rates should be maintained by DEP. Gondola and "air-lift" rail cars have been noted previously.

5.3.2.3 Transfer and Handling

Liquids can either be pumped or conveyed by gravity flow. It is important to note the types and sizes of hose connections and flanges for all potential storage or transport equipment so that random pieces can be inter-connected as needed with minimum delay. The necessary hose sizes, lengths, and fittings should be recorded in an information file. Portable pumps will be required in many instances. Even though these may be common items, their sources, capacities, and connection sizes should be noted.

Solids are generally best handled by front-end loader or by crane and clam-shell bucket. Since these are typical construction equipment, they are available from local construction companies such as Ciambro. In some instances, it will be necessary to package debris in small lots. This will require manual labor utilizing shovels. Similarly, the stripping of trucks, barges, or rail stock will involve manual labor. Aside from shovels and bags or containers, protective clothing will be necessary. Sources for these minor items should be included in the information file.

Transfer sites present special problems:

- Small craft to road vehicles

A number of wharves in Portland Harbor are suitable for this type of operation. Portable pumps and cranes may be required. The wharf surface may require protection, such as by plastic sheeting, to prevent the inevitable leaks and drips from reaching the water again.

- Barge to Rail

Several Portland and South Portland wharves including the Portland Terminal are equipped with spur tracks. A large crawler crane next to the tracks could handle debris from barge to rail car. Here also, local surface protection against leakage and dripping would be required.

- Rail to Land

Maine Central has three abandoned gravel pits, with spur tracks, at Ellsworth and East Machias where debris could be unloaded directly. However, the acceptability of these pits as burial sites, is unresolved. There are no rail spurs servicing either the Windham or the Gray incinerators. The nearest spur is at New Gloucester and intermediate road transport would be required in which case the multiple handling makes this route unattractive.

5.3.2.4 Final Disposition

5.3.2.4.1 Incineration (Liquids and Solids)

Two incinerators exist in the greater Portland area which can handle recovered material. Both lie some 15 or more miles inland from Portland Harbor.

- IDSOM Corporation, Windham

This double unit is manufactured by CONSUMAT and is a high-temperature oil-fired incinerator with afterburner. The units are fed from a hopper by a hydraulic ram. It is not equipped with any handling, storage, or liquid feed facilities. It is only capable of taking bagged contaminated materials. IDSOM is engaged principally in domestic waste disposal by contract with the town of Windham.

- McKin Company, Gray

The incineration unit of this company is locally designed and is capable of burning both debris and sludge. It is oil-fired and is equipped with storage facilities. The furnace is conveyor fed. McKin operates a tank cleaning and sludge disposal business throughout the area and has the necessary cleaning equipment and transport.

5.3.2.4.2 Oil Waste Operations (Liquids only)

Several companies in the area collect waste oil which ultimately can be utilized in several ways. Waste oil is sometimes used for surfacing unpaved secondary roads. It can also be fed into the final coking stages of an oil refinery process. Waste oil can be purified and used as a low grade fuel and at times it has been applied to sand and gravel used in civil works foundations and substrata. Companies such as the Maine Waste Oil Company of South Paris, or the Portland-Bangor Waste Oil Division of Dickie-Dare, Inc., collect these liquid wastes and truck them off as the raw material of their business.

5.3.2.4.3 Burial (Solids only)

A feasible, but highly constrained, method of solid disposal is burial at an approved site and by a method where no danger of soil or groundwater contamination can occur. At the present no such sites exist in the State of Maine. Approval, in accordance with the EPA Region I Guidelines requires extensive preliminary investigation into the topography, geology, and hydrology of the propsed site. Provided these initial requirements are met, considerable site preparation work is required before any material may be deposited. Appreciable costs are associated with both phases of this work.

5.3.3 A Disposal System Plan for Portland Harbor and Casco Bay

5.3.3.1 General Considerations

The transport and extended storage of oil and water and debris increases the dangers of contamination of additional areas as well as the costs of disposal. The handling of the materials in small batches present personnel protection problems as well as increased risks of secondary contaminations. Therefore, a planned system should strive to perform the process as close to the spill site as possible and to handle the material in bulk wherever possible.

There are no suitable burial sites in the vicinity of Portland due to the high value of land, even though some locales might be physically suitable. Incineration of solids, and possibly of waste oil and sludge is preferrable. An incinerator on the shores of the Harbor would be most advantageous.

The City of Portland is firmly committed to waste compaction and there exists no possibility of municipal erection of a suitable incinerator. The capacity of the existing compaction system is sufficient to handle the waste from the islands, and this eliminates the proposed concept of an incinerator on Peaks Island.

The barge-mounted incinerator is technically feasible. Such an installation could be moored at the waterfront and used for domestic and industrial waste disposal. At times of emergency, it could be moved to a suitable Harbor or Bay location in the vicinity of the clean-up operations. However, no agency could be found that is capable of sponsoring such a project at this time.

Barge and rail transportation of debris shows many advantages due to the quantities that can be handled, and due to the removal of transportation from the road system and population concentrations. Rail lines do not service the two existing incinerators at Gray and Windham. However, railroads may be used in conjunction with burial disposal sites on trackage in other parts of the State.

Barges used near a spill site for consolidating recovered material, storing it, and in due course bringing it to shore, can result in considerable savings in time, effort, and risk of secondary spills. No barges suitable for solid debris are now available in Portland but makeshifts are feasible. Tank barges for liquids may be available at the time of a spill. The barge could transfer oil-water mixtures to storage tanks at one of the terminals. If it is of sufficient capacity, it could serve as a storage facility by itself. Storage of large quantities of oil-water mixtures allows the natural separation of oil and water, and reduces later problems of treatment.

5.3.3.2 Limitations

As indicated earlier, numerous uncertainties exist in major oil spill situations. First, the location of the casualty cannot be predicted. Second, the circumstances of tide, weather and sea cannot be predetermined so that the behavior of the spill can take many different courses. Third, the availability of facilities and equipment at the time of spill is not fixed since these have to be drawn from commercial, dual-purpose sources.

These factors combine into a requirement for flexibility which can only be achieved by planning alternatives and redundancies for the disposal system. The alternatives take care of possible variation in location, behavior, and composition of the spill and its debris. The redundancies take care of potential system component failures.

Under the existing constraints, it is not feasible to design a complete new disposal process or to assemble one single process out of existing elements. It might appear that such an approach does not differ widely from past practice. Yet, there are substantial improvements which can be achieved simply by appropriate preliminary actions and preplanning. In the absence of any other permanently-functioning organization for spill clean-up and disposal in Portland Harbor, it appreas that the void must be filled by the DEP by maintaining an emergency response plan and a comprehensive information file. The following is a recommended plan for a flexible disposal system for large oil spills in Portland Harbor and Casco Bay. This plan is also summarized in Figure 5.1.

5.3.3.3 Recommended Plan

All available transportation and disposal methods will be utilized in the disposition of materials recovered from an oil spill. Liquids (oil and water mixtures) will be incinerated or accepted by commercial waste oil dealers or delivered to terminals equipped for handling such materials. Solids will be incinerated or buried.

Small spills will be disposed of by contract with commerical companies or by the terminals themselves, in cases where the terminals are responsible for the spill. At the present, there is no <u>single</u> organization with the equipment and capabilities for disposing of the materials recovered from large oil spills:

- The Coast Guard acts as On Scene Coordinator in the event of large spill emergencies but possesses no disposal capability in the Portland Harbor area. However, USCG can call upon its North Atlantic Strike Team and the ADAPTS oil spill containment and clean-up system. The Coast Guard is also empowered to contract with commerical operators in such emergencies.

- The Department of Environmental Protection, State of Maine, has no disposal facilities.

- No other governmental agencies, either Federal or State or municipal, can provide equipment or facilities for ultimate disposal of retrieved materials.

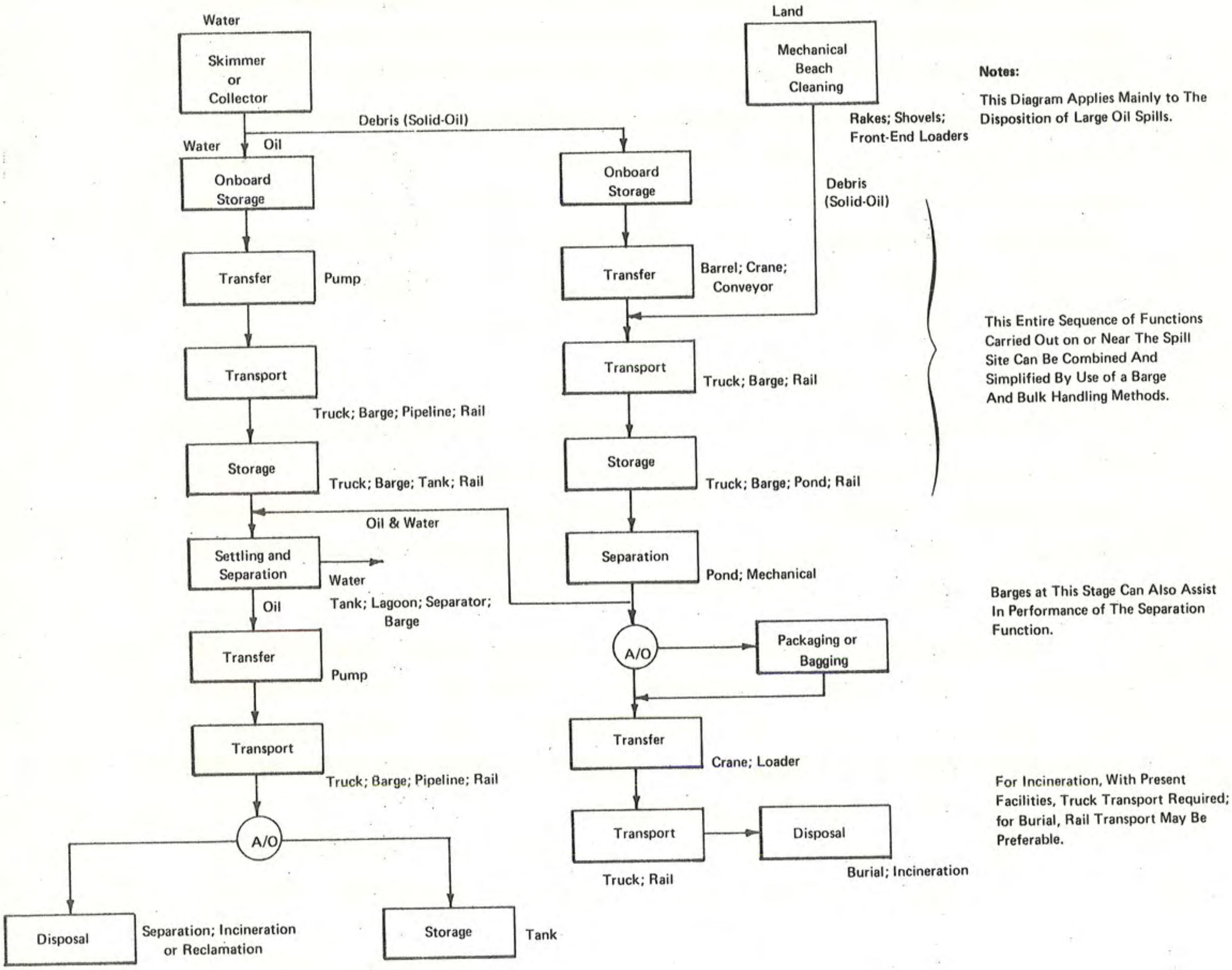

FIGURE 5.1 SCHEMATIC SEQUENCE OF DISPOSAL FUNCTIONS, INDICATING ALTERNATIVE METHODS

- A large variety of commercial operations, including railroads, transport companies, oil handling and distribution operators, construction companies, and waste handling companies, can provide elements of a disposal system by contract.

Since there is no single organization with capabilities to establish an emergency standby system of response personnel , equipment, and facilities to be used in case of large oil spill emergencies, we can only define tasks which should be undertaken by DEP in the immediate future, and outline feasible methods of disposal utilizing various combinations of commercial equipment and facilities which may be available at the time of a spill.

Equipment Information File

Establish a file of all types of equipment available in case of emergency. This task can utilize present DEP office space on the State Pier in Portland, but will require allocation of a portion of the time of a DEP employee throughout the year. The file should be updated frequently and consistently, say on a monthly basis. It should contain data on the equipment, its characteristics, rental rates, sources and locations. The file should be a simple catalogue and card type of listing without expensive or sophisticated data systems. It should include:

- Road Tractors
- Road Trailers - tank and construction
- Trucks, misc.
- Fixed Tanks for storage and separation
- Barges - Deck, Tanks
- Cranes - Crawler, railroad
- Rolling Stock - Tank cars, gondola cars, air-lift cars
- Wharves - With roadways, with spur tracks
- Portable Equipment - pumps, hoses, hand tools, plastic sheeting, personnel protection, packaging, etc.

- Construction Type Equipment - Bulldozers, front-end loaders, back hoes
- Oil/water Separators
- Incinerators
- Settling Ponds and Basins

Burial Site Determination

Initiate action to establish one or more approved disposal-by-burial sites for contaminated solid debris. Preferably such a site or sites will be in proximity to a rail spur. Direct unloading is a desirable feature. Otherwise, good road access must be available. This task requires contracting for the topographical survey work, run-off studies, groundwater studies, percolation tests, and geological studies necessary to establish suitability and obtain EPA approval. This task must be performed by qualified field personnel under the direction of the DEP.

The DEP must then complete the administrative requirements to establish the site, and must obtain ownership or lease of the area as necessary. Site preparation can then commence.

Transportation Information File

The ultimate destination of debris will be either a burial site or an incinerator outside of Portland. Road and rail routes from the Harbor area to each of these points must be laid out. A canvas of all municipalities and townships along these routes must be performed to establish any restrictions on passage of liquid or solid debris, or of the conditions which must be met to permit passage of such materials. The end point of this task is a network of approved routes to all final disposition points from the Portland Harbor area. This may include the problems of trucking through Portland itself, e.g., from the wharves to Windham or Gray.

Alternative Transportation Systems

The following different systems should exist in the planning stage so that methods suitable to any particular spill may be selected without delay. The principal factors will be the size of spill, the location of the spill, the point where material is recovered, place of final disposition and the local or seasonal conditions which affect the situation. The equipment file provides information on available equipment. The selected equipment is then matched at the time of emergency with the following transportation and disposal alternatives:

Road Haul of Liquids and Solids:

- wharfage in the harbor area
- protection for the wharf roadway
- transfer equipment - crawler crane, portable pumps and hoses
- bagging facilities and materials for solids
- plastic liners for open trucks, if necessary
- trucks - tank, open body
- offloading equipment, such as a crane, at the destination area for solids whether it be a burial site or an incinerator
- in case of burial of solids, a bulldozer or similar earth moving equipment is required at the site.

Rail Haul of Solids for Burial:

- wharfage in the harbor area with spur track
- protection for the wharf surface in the loading area
- crawler crane, or railway crane, for transfer
- gondola or airlift cars
- plastic liners for railroad stock
- offloading equipment, i.e., crawler or railway crane
- trucks for final transfer, if necessary

- earthmoving equipment for covering site
- miscellaneous hand tools and personnel protection

Rail Haul of Liquids:

- wharfage in the harbor area with spur track
- portable pumps and hoses
- railroad tank cars

Rail haul would only be used if large quantities were delivered to terminal storage or shipped to refineries. These facilities would be equipped with railcar off-loading capabilities.

Barge Consolidation of Liquids:

- tank or hopper barges, with mooring gear
- portable pumps and hoses
- tugs, when required
- drip pans or coamings for barges

Further transport and disposition covered by road haul of liquids and solids, and rail haul of liquids above.

Barge Consolidation of Solids:

- hopper barge or deck barge with tight bulwarks and mooring gear
- plastic liners and pans for collecting oil drips and leaks
- hand tools and personnel protection equipment for control and cleanup
- tugs, when required

Further transport and disposition is covered by road haul of liquids and solids, or rail haul of solids for burial above. In case barge-to-rail transfer is possible at a shoreline point other than a wharf, the area under the crane-held load between barge and railcar must be protected by sheeting or similar portable devices.

It should be noted that, at present, the choices and capabilities are extremely limited concerning incineration and burial of debris. The two commercial incinerators are of limited capacity and provide the only disposal method for solids. In the event a burial site is found, and in the event of a large spill, it is expected that both types of disposal will have to be used to their capacity. At this time the plan need not consider the matter of selection between the two disposal methods. The transportation alternatives present the main choice.

Planning considerations for each item of equipment and each transportation disposal method listed must be established. For example, a tank truck of a given size can be counted upon to produce a certain number of gallon-miles (or ton-miles) of haulage per day. A crawler crane of given capacity and with a given size bucket can transfer a certain weight (or volume) of material per hour. When distances and quantities for a spill become known, these factors can be applied to find the required numbers of each type of equipment. Such planning factors should be included in the equipment information file for each item.

6. OIL MONITORING SYSTEMS

6.1 LOCATIONS WARRANTING OIL SPILL DETECTION SYSTEMS

National oil spill statistics indicate that accidental discharges of oil frequently occur during hours of darkness when it is difficult to discern oil on water. A high percentage of spills are also experienced during weekends when plant facilities are either unattended or have a limited number of on-duty plant personnel. A predominant number of spills are experienced at marine terminals during oil loading and unloading operations when terminal personnel and tanker crews are concentrating on making and breaking flange connections, raising and lowering flexible hose lines, opening and closing valves, metering flow rates, checking tank or cargo compartment oil levels, or handling mooring lines. During such intensive and concentrated activities leakage and spillage of oil and oil products can frequently go undetected for considerable periods of time. Oil leaking from oil-saturated earth in a number of marine and marketing terminals in the Fore River area of Portland and South Portland has been a continuing water pollution problem. Most terminals have instigated action to reduce and eventually to eliminate this type of oily discharge during heavy rain-icy/snow conditions.

To reduce labor-intensive and costly harbor patrol actions, automated visual and/or audible detection and alarm systems would be advantageous. Additional benefits can be gained from the fast detection of a spill by the use of monitoring systems that communicate directly with the various DEP field stations and by strategically placing these units near potential spill sources. Such systems can reduce the time for locating a water or land spill and for responding with a rapid and effective containment action. The Environmental Protection Agency has determined that the cost of recovering spilled oil ranges from $10 to $20 per gallon and that a 50 percent recovery of spilled oil can be termed as a successful response action. Obviously the speed with which an oil spill is detected has considerable bearing on preventing an oil slick from spreading, reducing the fire hazard, and effectively controlling the impact on the marine environment.

Our examination of the shoreside activities in Casco Bay (see Chapter 3) showed a number of oil storage and handling operations any of which could be a potential source of an accidental oil release. Two of these locations, Portland Pipeline Piers 1 and 2 and Central Maine Power facilities on Cousins Islnad are already protected by oil slick detection systems. On the other hand, the state-of-the-art and cost considerations exclude the use of oil monitoring systems at the present time during offshore bunkering of sea-going vessels and at facilities of fuel oil suppliers on Casco Bay islands (i.e., Long Island, Chebeague Island, Cliff Island and Peaks Island). Oil monitoring systems should be considered for the following locations:

Fore River - Front Harbor area
Harpswell Neck, vicinity of U.S. Naval Reserve Tank Farm
Long Island, vicinity of King Resources
The Sun (Webber) Oil terminal area
S. D. Warren Co., Division of Scott Paper Co.
U.S. Coast Guard Captain of the Port and Aids to Navigation Base

The types of systems that may be used at these facilities are discussed in Section 6.3 below.

6.2 BASIC DATA ON SPILL MONITORING SYSTEMS

A review of currently available equipment that may be used for protecting the waters of Casco Bay from major oil spill damage by detecting an oil spill at an early stage revealed a number of systems. These are described in detail in Appendix I.

The systems fall into three basic categories:

In-Stream Sensing Units

Such systems, through various physical principles, detect the presence of oil in a flowing stream such as an effluent discharge. Examples of these units are those manufactured by:

- Bull and Roberts, Inc.,
- Teledyne Analytical Instruments,

- Galbraith Pilot Marine Corp., and
- C.E. Invalco.

In-Water Detection Units

These systems generally float in an open waterbody and detect an oil slick when it passes in close proximity to the floating sensor. Manufacturers of such units are:

- Durham Associates, Inc.,
- Totco Division of Baker Oil Took Corp.,
- Bennett Pollution Controls, Ltd., and
- Spectrogram Corporation.

Elevated Water Surface Scanning Units

These are located in an elevated position over a waterbody. Any oil slick that passes on the water surface within the scan area is detected by the device. Manufacturers of these units are:

- Wright & Wright,
- Rambie, Inc., and
- Baird-Atomic, Inc. (under development)

6.3 UTILIZATION OF OIL SPILL MONITORING SYSTEMS IN CASCO BAY

The three classes of units described above can be utilized in the Casco Bay area as follows:

In-Stream Sensing Units

The four units listed are designed to operate in a water stream such as an effluent discharge to detect an accidental spill, or any oily discharge before or after an oil and water separator. It does not appear practical for the State of Maine DEP to acquire such units, that vary from a low acquisition cost of $1,800 to a high of $12,030, for use at privately owned industrial locations. It is recommended, however, that the various oil product handlers be urged by DEP to acquire and utilize such monitoring and warning systems, individually or as a consortium when communal discharges into public waters may be involved.

In-Water Detection Units

These types of floating units would be most effective if installed under loading/offloading dock areas or ship/boat bunkering areas. However, they should be protected from physical impact and from the wash of ship propellers.

The acquisition costs for single units vary from a low of $975 to a high of $4,600. However, detection of spills would be improved if the units were positioned at each end of a marine loading dock to compensate for tidal influences.

The acquisition and use of these units would normally be the responsibility of the dock owners or, as is evident in the Fore River area, multiple users of a single dock. Provision for the units from State funding would be cost prohibitive considering that most waterfront facilities have loading and unloading piers. Each pier in the Fore River and Front Harbor Area and in the vicinity of Sun Oil facility and the U.S. Naval Reserve Tank Farm would benefit from the use of this type of spill monitoring system. In addition to their potential use in pier areas, the warning systems may have application in effluent discharge areas if they are not left high and dry at low tide.

Elevated Water Surface Scanning Units

Both the Wright & Wright and Rambie, Inc. units would have similar applications although there is a considerable difference in the basic price range, (viz. Wright & Wright $9,900 and Rambie, Inc. $16,700). Since both units have just undergone research and development, and some Federal testing, they do not fall into the category of time-tested and proven devices. In this respect, the rental program provided by the Wright & Wright may be worthy of Maine DEP investigation. It appears advantageous to rent and evaluate the system on the basis of 50 percent of the rental cost applied to the purchase price. Another advantage is the prompt delivery by Wright & Wright (two weeks lead time following an order) as compared to Rambie (120 days after receipt of order).

These units could be positioned on both bridges crossing the Fore River to monitor all plants upriver of the bridges. The monitoring could then be assigned to the individual bridge attendants or to the closest industrial facility. Although no cost figures are available and competitive bids would be warranted, an alarm could be transmitted to the DEP Portland headquarters on the State Pier by self-dialling phone. When such an alarm is received, DEP personnel could deploy a containment boom from the State pier to the opposite shore to contain a spill within the confines of the river.

In summary, only water scanning units appear to be in any way a State responsibility. The Fore River presents a suitable monitoring area. Once proven, a similar system may be utilized at the Presumpscot River.

6.4 OTHER MONITORING SYSTEMS

An additional monitoring system is in an advanced state of development and should become available on the market soon. It would behoove the State DEP to maintain a close watch on the Baird-Atomic system (see Appendix I). This system could monitor spills at the mouth of the Fore River, prior to its entry into Casco Bay. In the Fore River/Front Harbor area, elevated scanners positioned in close proximity to the State Pier or at the mouth of the River can provide coverage of the Chevron Terminal.

This system could also be utilized at offloading piers similar to the Portland Pipeline location where tankers would dock simultaneously on each side of the pier structure. Units would be mounted on an elevated tower positioned at appropriate inshore and offshore locations on the piers. The scanners would then operate in a fan fashion covering the width (1200 ft at 60 ft elevation) of the ocean beyond the width of the pier plus the beam of both docked tankers. Additional scan coverage can be gained by positioning portable units on the outboard bulwarks of each tanker.

The present initial cost of the system ($35,000) should drop to about $25,000 once it is in production.

An emergency pump shutdown system, manufactured and sold by Sentry Systems, Inc. (see Appendix I), is also worthy of further investigation. It costs about $1000 per valve for a typical loading dock with 8 to 16 valves.

This loading operation shutdown control system can prevent spills at all oil company marketing terminals where petroleum products are loaded onto tankers and barges. There are operating installations at a number of locations on the Gulf Coast but none on the East or West Coast.

Since this system is a plant operational type system, it would not be cost effective for the State DEP to purchase and install it. However, a test or prototype installation could be a means of encouraging individual companies to consider the acquisition and use of "Spill Sentry" systems.

7. MARINE NAVIGATION IN PORTLAND INNER AND OUTER HARBORS

7.1 INTRODUCTION

Marine traffic in the Portland Harbor-Casco Bay areas is expected to grow over the next decade as the importation, storage, and redistribution of petroleum and other products becomes more important. The main deep water approaches from the south between Portland Head and Ram and Cushing Islands, are wide and depths of 40 feet or more can be taken well into the Portland outer harbor. In addition, there are several other narrow and relatively shallow passages between islands from the eastward and northward, which are not as well marked and used only by local vessels and small craft. Although the harbor is ice free year-round, inclement weather and heavy fog during the summer months in particular can slow, delay and provide an additional hazard to maritime traffic in the area.

This survey of marine navigation in the Portland Harbor area is a step toward determining whether or not the existing system is adequate for present and future demands of the Port. Marine navigation systems are briefly described and the safety measures and hazards to navigation in the Portland Outer and Inner Harbors are reviewed. Some improvements are suggested which could enhance the safety of ship movement operations, increase the availability of the harbor to larger ships, and reduce the possibility of inadvertant oil spills due to groundings or collisions.

7.2 MARINE NAVIGATION

The Federal Government, under Statute 14 USC 81, has assigned responsibility for visual, audible, and electronic aids to the U.S. Coast Guard for U.S. territorial waters and adjacent areas [7.1]. The aids are established primarily to provide the user with a position determination capability to avoid hazards, maintain a fixed position, or to reach a given destination. The civil maritime navigation requirements are divided into three categories:

- High Seas
- Coastal Confluence Zone
- Harbor, Estuary and Marine Terminals

Navigation

RECOMMENDATION #19

The Arthur D. Little Study states that the anchorage area near the Portland Light Buoy is congested and that thought should be given to an alternate area such as Luckse Sound.

We in the DEP Oil Division feel that this type of decision is outside of our jurisdiction, nor do we have the resources or manpower necessary to make the proper investigation. We suggest that this recommendation be referred to the United States Coast Guard and any other pertinent agency.

Priscilla House
Environmental Technician
Dept. of Environmental Protection
State of Maine

7.2.1 Navigation on the High Seas

The high seas are those areas remote from land masses where visual references to land or other fixed or floating aids are not practical and where hazards of shallow waters and of collision are minimal. Celestial navigation and dead reckoning procedures are the time honored means for open ocean navigation and can provide two positions each day, at sunrise and sunset, to accuracies of about ± 3 nm when visual conditions are favorable. Over the past 25 years, LORAN-A, OMEGA, NAVSAT and recently LORAN-C have become available for use by commercial shipping. Where coverage is available, LORAN-C now provides position accuracies to ± 0.25 nm, 98% of the time without serious degradation at sunrise and sunset. System improvements now underway may provide a 15 to 20 fold improvement in these LORAN-C position accuracies.

Table 7.1 lists the operating characteristics for several long-range electronic navigation systems, the first three of which are in use on commercial vessels. The last two systems are used mainly by the military and to some extent by others for exploration, survey, and research purposes.

7.2.2 Navigation in the Coastal Confluence Zone

The Coastal Confluence Zone (CCZ) includes all waters contiguous to major land masses or island groups where ships tend to converge toward harbors and where significant traffic exists in patterns parallel to the coastlines. The CCZ extends to distances of at least 50 nm from shore or to the 600 fathom curve, whichever is farther from the shoreline. Table 7.2 lists the systems that are used in the Coastal Confluence Zone (CCZ).

The National Plan for Navigation (NPN) developed by the Department of Transportation and USCG was first issued in April 1972 and an Annex to the Plan was issued in July 1974. The Annex specifies that the navigation accuracy requirement in the Coastal Confluence Zone must provide 95 percent assurance that a vessel can be navigated with tolerance of no more that 1/4 nm along a track to its designated destination or

TABLE 7.1
LONG-RANGE ELECTRONIC NAVAIDS

Type	Estimated Useful Range	Estimated RMS Accuracy	Comments
Loran A	600-900 nm	± 1.0-5 nm	• Insufficient coverage • Less accuracy with sky wave
Loran C	1200-1500 nm	± 0.1-1.4 nm	• Insufficient coverage • Expensive installation • Used mainly by military • Less accuracy with sky wave
OMEGA	5000 nm	± 1-2 nm	• Projected worldwide coverage by 1974 • Less accuracy at night • Moderate price receiving equipment available 1972
Satellite	Worldwide	± 0.1-2 nm	• High accuracy but requires very expensive receivers • Provides fix information approximately once every 120 min.
Inertial	3-12 hours	> 2 nm hour	• Highest cost installation • Needs complementary navigation system for high accurancy • Not generally suitable for use by commercial shipping

TABLE 7.2
COASTAL/CONFLUENCE ELECTRONIC NAVAIDS

Type	Estimated Useful Range	Estimated RMS Accuracy	Comments
Radar	200 ft-60 nm	± 1 :2500	• Has limited range • Used mainly for general search and hazard warning
Decca	150-300 nm	± 0.1-1.0 nm	• Has good accuracy • Is widely used • Sky wave interference limits night coverage and reduces accuracy
Loran C	1200-1500 nm	± 0.2-1.4 nm	• Insufficient coverage • Expensive installation • Used mainly by military • Less accurate with sky wave
Satellite	Worldwide	± 0.1-2 nm	• High accuracy requires very expensive receivers • Provides fix information approximately once every 120 minutes
Radio Beacons	50-200 nm	± 3°LOP only	• Low accuracy (1 mile error/1° 60 nm) • Low cost receivers • Low cost transmitters • Required on all ships over 1600 tons traveling international trade routes

within its designated shipping lane. To provide the navigation accuracy and coverage required, the LORAN-C System is being upgraded and expanded to cover the entire U.S. Coastal Confluence Zone and will completely replace the LORAN-A System by 1985.

At present,the LORAN-A System provides electronic navigation coverage along all coastlines of the United States, the Great Lakes, Gulf of Alaska, Hawaiian Islands, and Puerto Rico. However, the system is old, expensive to maintain and only provides a position accuracy of ± 0.5 to ± 3.0 nm, which is degraded under many night time conditions of operation. The LORAN-A navigation system is to be phased out of operation over the next seven to ten year period.

As of 16 May 1974, LORAN-C became the approved navigational system for the CCZ. At present four LORAN-C stations provide East Coast coverage. A new master station is now in operation at Caribou, Maine which upgrades the accuracy of the East Coast LORAN-C chain. Additional chains will be established in the Gulf of Mexico, on the U.S. and Canadian West Coast and in the Gulf of Alaska to provide better than, ± 0.1 nm position accurancy (95%) of the time. Table 7.3 indicates the present implementation schedule of the new LORAN-C navigation chains [7.2]. Figure 7.1 shows the coverage that is expected of the new Loran-C installations in the Coastal Confluence Zone of the United States [7.3].

The LORAN-C coast charts for the U.S. East Coast are now available and most of the rest of this group is currently scheduled to be issued by mid 1976. The remaining charts for the Gulf and West Coast and Alaskan waters are scheduled to be available by the end of 1976. As the advantages of LORAN-C become apparent to tanker operation, it can be expected that most tankers will install LORAN-C navigation equipment over the next few years.

The coastal tankers which carry refined products are already being equipped with LORAN-C to take advantage of the improved positional accuracy and navigation safety that it can provide in coastal waters.

TABLE 7.3
IMPLEMENTATION SCHEDULE FOR COASTAL CONFLUENCE REGION

U.S. West Coast Chain (5 new stations)	Summer 1976
Gulf of Alaska Chain (3 new stations)	January 1977
Gulf of Mexico Chain (3 new stations)	Summer 1978
U.S. East Coast Chain (new master station); Caribou test facility operational as LORSTA Caribou*	Summer 1978
U.S. East Coast Chain (Great Lakes Station)	Spring 1980

*LORAN-C test facility, Caribou, Maine, was activated for experimental purposes during summer 1974.

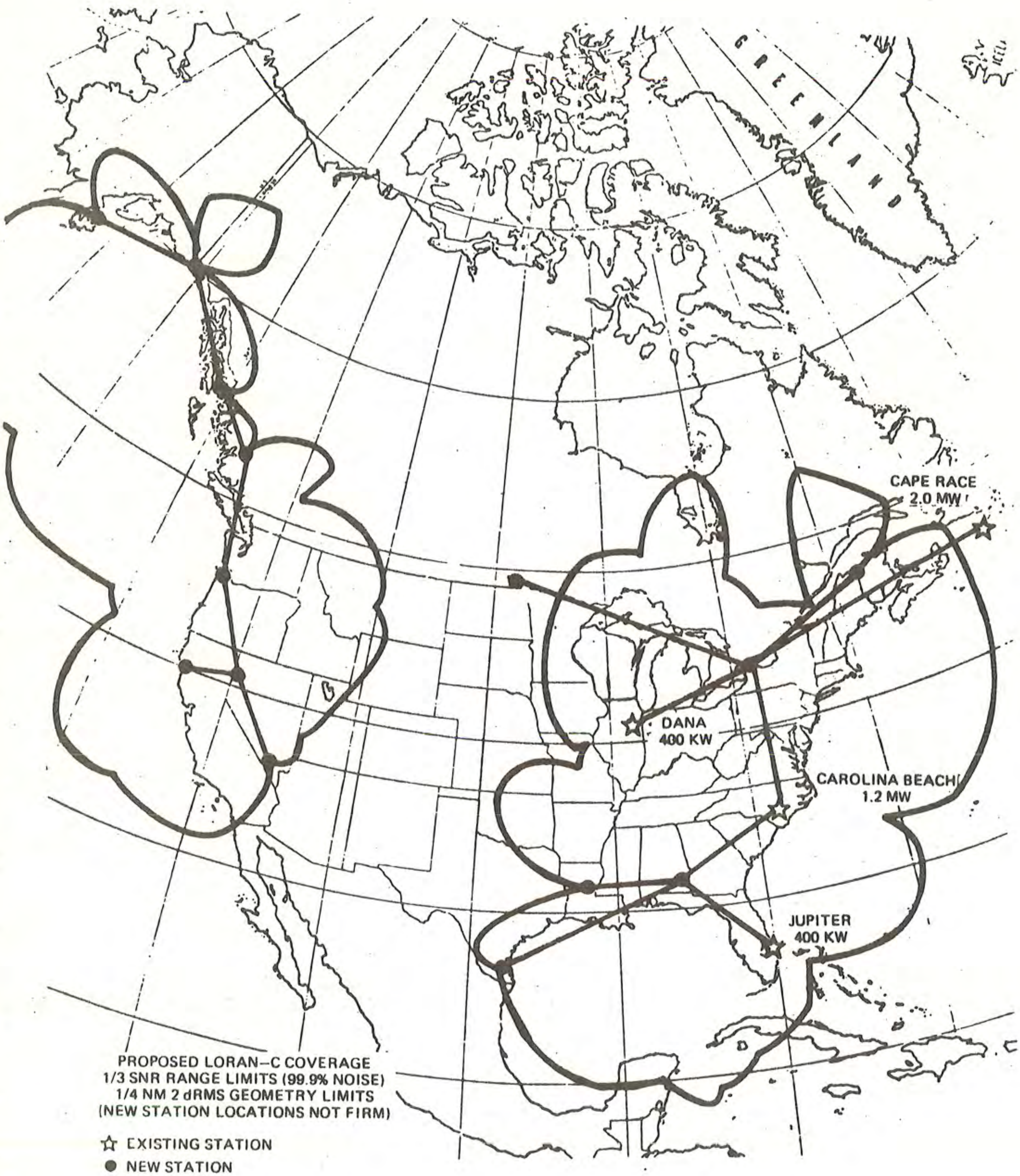

FIGURE 7.1 LORAN-C COVERAGE

7.2.3 Harbor, Estuary and Marine Terminals

Harbor, estuary and marine terminal areas consist of waters inside the mouths of bays and rivers where terminals are located. The specialized navigation techniques being developed for congested waterways and harbors by the U.S. Coast Guard are important to Portland. These systems are designed specifically for the heavily congested channel and marine terminal environment and are essential to the orderly management of tightly scheduled traffic in restricted waters. It is the most demanding of the three categories, since operations are generally in crowded, shallow waterways and are often near other passing or anchored vessels. Operations require the highest degree of vessel control to avoid collision or stranding. Audio/visual navaids are commonly used in these areas and can provide ideal positioning information under good conditions. However, they are inadequate in times of poor visibility and are relatively ineffective for all-weather channel and harbor safety control. The harbor surveillance radar displays and communications systems that are included in Vessel Traffic Systems (VTS) improve the safety of operations and provide a degree of service not approached by audible and visual aids alone.

The U.S. Coast Guard has been studying the requirements of VTS for the past several years and implemented the first two such systems in 1972 at San Francisco, California and Puget Sound, Washington. Other systems are being installed at Houston/Galveston, New Orleans, and New York. Each system involves mandatory bridge to bridge (B to B) communications, a Traffic Separation Scheme (TSS) and a Vessel Movement Reporting System (VMRS), plus some form of advisory, or radar, ship and harbor surveillance. The primary objective of these systems is to improve marine safety while facilitating the orderly movement of vessels. This will be accomplished with these systems by providing mariners with more accurate and timely information, to aid them in navigating their vessels, and by coordinating traffic movements to minimize potential accident situations.

Although Portland is the second largest oil terminaling port on the Atlantic Coast (after Philadelphia, Pa.), the overall marine traffic requirements are apparently not high enough to warrant an advanced form of vessel traffic system installed and operated by the U.S. Coast Guard. However, the Portland Pilots have provided an unofficial marine advisory service to incoming and outgoing traffic for many years. This service provides weather, sea state, traffic movement, pilot scheduling and other information to aid the safe movement of commerical marine traffic in the Casco Bay/Portland Harbor areas, on a 24 hour year-round basis. Unless new oil refinery and terminal requirements or other unforeseen developments materialize to increase dramatically the number of commercial vessels moving into and out of Portland each day, a strong demand for a formal Vessel Traffic Control System (VTS) in the Casco Bay/Portland area may never develop.

However, implementation of the proposed NEECO terminal just south of Fish Point with its estimated requirements for 130 to 150 tankers per year in the 80,000 to 100,000-ton range and other supportive marine operations, could modify this conclusion.

7.3 NAVIGATION PROCEDURES AND REQUIREMENTS

7.3.1 Description of the Area

Portland Harbor is located at the western end of Casco Bay and is the largest and most important port in Maine. The approaches to Portland Harbor are lined with ledge, reef, shore and island areas (See Figure 7.2). The main approach for oil tankers is from the south beginning near the Portland Sea Buoy. Coastal shipping generally approaches from the south from between Cape Elizabeth and West Cod Ledge. An eastern approach is sometimes used beginning just south of Halfway Rock Light. In each case traffic is guided by buoys, lights and outstanding features of the shoreline to the Harbor entrance between Portland Head and Ram and Cushing Islands.

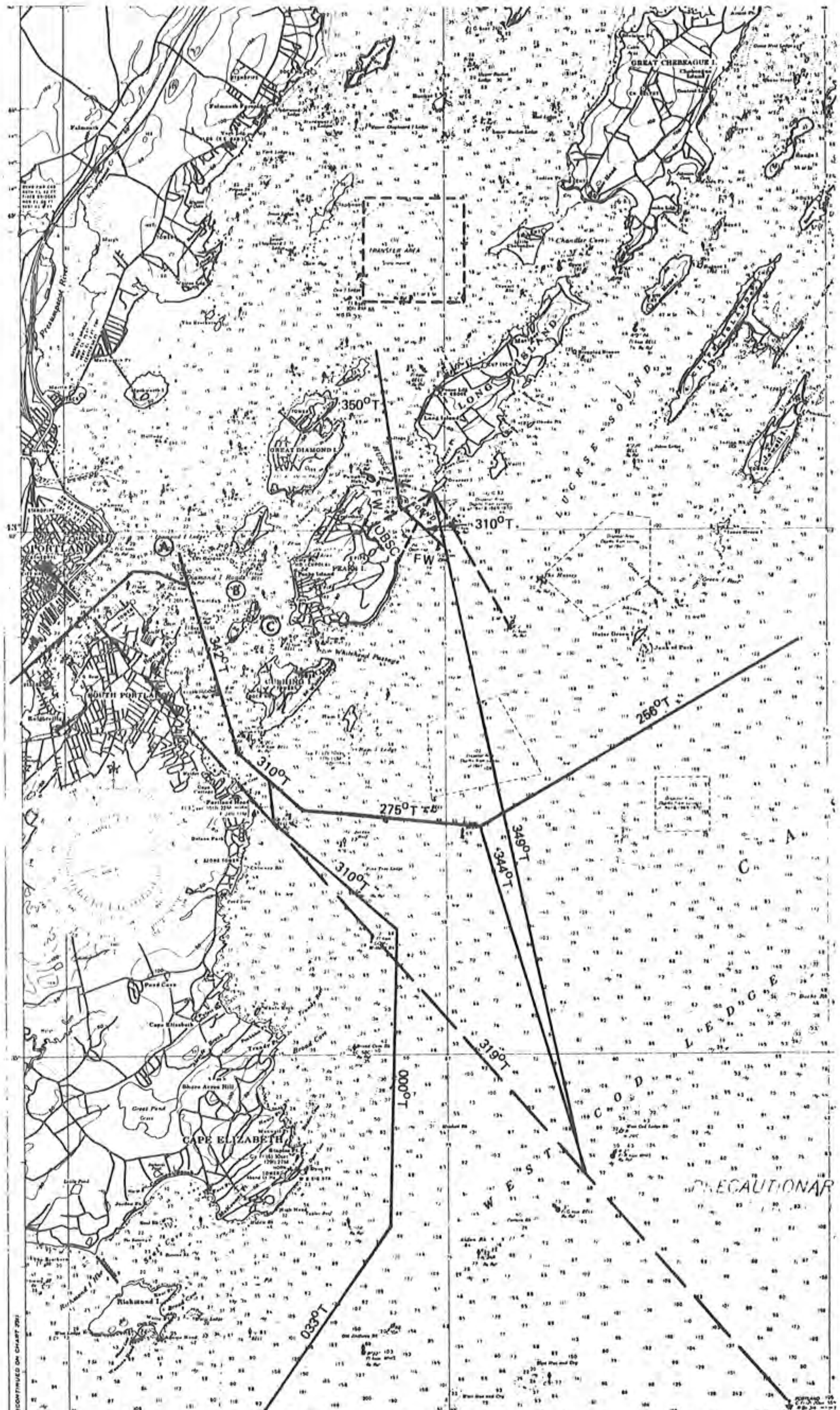

FIGURE 7.2 APPROACHES TO PORTLAND AND HUSSEY SOUND

Portland Harbor is comprised of two distinct connected areas (see Figure 7.3). The outer harbor comprises the area westward of Cushing, Peaks, House and Great and Little Diamond Islands from the entrance at Portland Head Light to the entrance of Fore River at Fish Point. The outer harbor includes the three deepwater general anchorages A, B and C and the Portland Pipeline Co. Pier No. 2 just westward of Spring Point.

The Portland inner harbor is considered to be in two sections; the outer port or Main Harbor, extending from Fish Point to Portland Bridge; and the inner area, or Fore River, from the Portland Bridge southwestward to the Veterans Memorial Bridge.

7.3.2 Approach to Portland Harbor

Periodic surveys are required to provide for the safe and rapid passage of marine traffic in channels, harbors, and terminal areas. The Navaids* must be continuously appraised and upgraded as required, the hazardous areas identified, dredged and marked and navigable channel markers upgraded and new more modern equipment positioned and installed. These are U.S. Coast Guard responsibilities. However, it must be clearly kept in mind that simply increasing the number of Navaids may not yield the benefits desired. A proliferation of navigational aids can result in the dissipation of funds and increased operation and maintenance costs.

All foreign and United States vessels under register in the foreign trade and drawing over nine feet of water must take on pilots to enter Portland Harbor. Pilotage is optional for vessels in coastal trade or fishing vessels under enrollment or license who have a person on board licensed as a pilot by the Federal government.

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*Aids-to-Navigation and Navaids are used interchangeably in this report and relate to marks placed by people. They include lighthouses, sea buoys, buoys, day beacons and fog signals.

Major shipping generally begins its approach to Portland Harbor from the Portland Sea Buoy which is located 5.3 miles east-southeastward of Cape Elizabeth Light and approximately 9 miles from Spring Point. The Portland Sea Buoy only recently replaced the Portland Lightship. It is a discus shaped buoy 40 ft in diameter with a high intensity flashing strobe light, fog horn and RACON (radar repeater) beacon on a mast 10 meters above the water surface. According to navigators in the Portland area, although the Sea Buoy is a reliable device it is sometimes difficult to determine an accurate range and bearing from an approaching ship to the buoy at night. It is suggested that a constant intensity Riding Light be placed on the mast to help correct this problem.

There is a non-designated anchorage area in the vicinity of the Sea Buoy beyond the 3-mile limit of the Territorial Sea. At times, six or more tankers have been at anchor waiting for berthing space within the greater Portland Harbor area. This is a non-supervised anchorage. The water depth in the area is 90 to 120 ft and the bottom is mainly a loose granular material. Anchors do not hold well in this area particularly under moderate sea and swell conditions and considerable lengths of chain are required for successful anchoring in waters this deep. Vessels dragging anchor can present an oil spill hazard and a safety problem to other vessels unable to maneuver rapidly enough to avoid an impending collision.

The Portland pilots generally board vessels near the Portland Sea Buoy and set a course of approximately 310° T to pass between buoys No. 2 and No. 3 at West Cod Ledge and Corwin Rock. This course is on a bearing line which includes the Sea Buoy, the Willard Rock Light Buoy, Portland Head Light and the Cathedral Spire. At night, it would be helpful if a flashing strobe light or a sector light (2° width) were placed on the highly visible Cathedral Spire. The proposed light would clearly mark this course through the dangerous West Cod Ledge which has shoal areas as shallow as 21 and 32 ft adjacent to the marked channel. In addition, this heading is used by the pilots to check for gyro and other navigational equipment errors on the vessel just after getting underway from the Sea Buoy. A course of approximately 342°T is then taken to bell buoy No. 1 which is about 3-3/4 miles due east of Portland Head Light.

Vessels coming from the north approach buoy No. 1 from an easterly direction beginning from just south of Halfway Rock Light. All traffic then follows a course of 275° toward Portland Head. Buoy No. 2 marks the shallow 33 ft depth at Witch Rock and is passed on the right and Jordan Reef with its 23 ft depth is passed on the left just before beginning the turn north into the Portland Harbor entrance fairway. The three sector (green, white, red) chromic light at Portland Head marks 2° sectors on the 275° bearing and provides excellent bearing information when visibility is unlimited.

Navigators report that the Witch Rock buoy moves from its set position in high sea conditions. A smaller Station Buoy set close by the Witch Rock buoy, would indicate such movement and warn the navigator of a potentially dangerous situation. Also, the northern edge of Jordan Reef is hazardous and it is recommended that the 40 ft depth adjacent to the navigation track toward Portland Head be marked with a light buoy. This buoy would also aid the pilot in starting his turn to the right to position his vessel properly in the Portland Harbor entrance fairway just north of Portland Head.

Vessels up to about 20,000 tons in the coastal trade generally approach Portland from the south and pass well inside the Sea Buoy. This traffic generally follows a course to pass between the Sea Buoy and Cape Elizabeth with a heading toward Willard Rock before setting a course for the Portland Harbor entrance fairway north of Portland Head Light.

7.3.3 The Outer Harbor Area

Portland Harbor includes the waters of the entrace channel north of Portland Head, the protected waters south of Great Diamond Island, and those west of Cushing, Peaks and House Islands to Fish Point at the northern end of the City of Portland waterfront area.

The dangerous areas off the tip of Cushing and House Islands are well marked with a light buoy and with a fixed light structure. The shoal area 700 yds south of old Fort Preble is also well marked with a bell buoy. Each of these aids has a radar reflector and provides an excellent radar target. Spring Point is marked by a structure at the end of the breakwater with a flashing light, radar reflector, and horn. The navigable channel is approximately 1000 ft wide at the Spring Point Light. Although the Portland Harbor entrance fairway is a hazardous area, it is considered well-marked and not a difficult passage.

The outer harbor entrance is dredged and swept clean to a minimum depth of 45 ft. A course of approximately 342°T is followed from the entrance of this fairway off Portland Head at the Cushing Island Buoy No. 2, and carries through the Diamond Ledge flashing light which is located on a 23-ft tower with radar reflector. However, the intensity of this important mark should be increased to facilitate identification against the strong background lighting that sometimes makes this light difficult to identify.

Three anchorage areas in the outer harbor are available. Anchorage A northwest of Diamond Island Ledge, is about 128 acres in size but is limited to ships with less than 30-ft drafts. If there is an increase in vessel traffic with drafts of 40 ft or more, the controlling depth of Anchorage A may need to be increased to 45 ft. The House Island Anchorage B is bordered by House Island, Little Diamond Island, and Diamond Island Ledge. This anchorage is about 230 acres in size and has a control depth of 45 ft. Anchorage C is bordered by House, Peaks, and Cushing Islands and is about 55 acres in size and also has a control depth of 45 ft. A fourth anchorage designated as an oil transfer area is located 3.5 miles north of Pipeline Pier No. 2 in Hussey Sound and is larger in size than the first three anchorages with an area of approximately 640 acres and depths between 45 and 60 ft. While this anchorage is designated as an oil transfer area on USGS Charts 315 and 325 with an area of 410 acres, it has recently been unofficially defined by the Portland Pilots as an anchorage approximately 1 square mile in size (see Figure 7.2). It provides an anchorage for all ships that would normally anchor near the Sea Buoy but instead, choose to anchor in the safe and protected waters inside Hussey Sound.

The entrance channel turns westward at Spring Point Light and widens to approximatley 1,450 ft on a westerly course past Portland Pipeline Pier No. 2 and Diamond Ledge Light. (see Figure 7.3)

The City of South Portland is planning to establish a marina at the site of the former shipyard between Spring Point and Portland Pipeline Pier No. 2. A small boat marina and the increased use of small craft at this location poses a significant long-term hazard to the incoming and outgoing oil tankers and tugs at Portland Pipeline Pier No. 2. The inexperienced seamanship of the small boaters can and will interfere with the safe operation and docking of tankers at Portland Pipeline Pier No. 2 while the quickwater (wakes) of the major vessles, and particularly the tugs, can set up swells and rough water in the semi-closed marina area. These unavoidable conditions can pose a hazard to the small craft and their operators in the unprotected marina. A marina should not be permitted to operate at this location without first carefully assessing the important operational factors and the available means to insure the safety of these operations.

The entrance to the Back Cove area is approximately 1500 yards to the north of Fish Point and Anchorage A. The entrance channel to Back Cove is marked with buoys 3 and 6 and is approximatley 1200 yards in length with a control depth of 17 feet. The Sun Oil Company (now Webber Oil Company) terminal is relatively small and the only oil terminal facility in this area. It is located on the north side of the channel outside of the swing type railroad bridge. There is about 10 feet of water alongside the Webber Pier.

The channel and pier areas are mostly sand bottom and except for occasional rock or debris offer no serious hazard to shallow draft coastal tankers and barges if taken with caution near high tide.

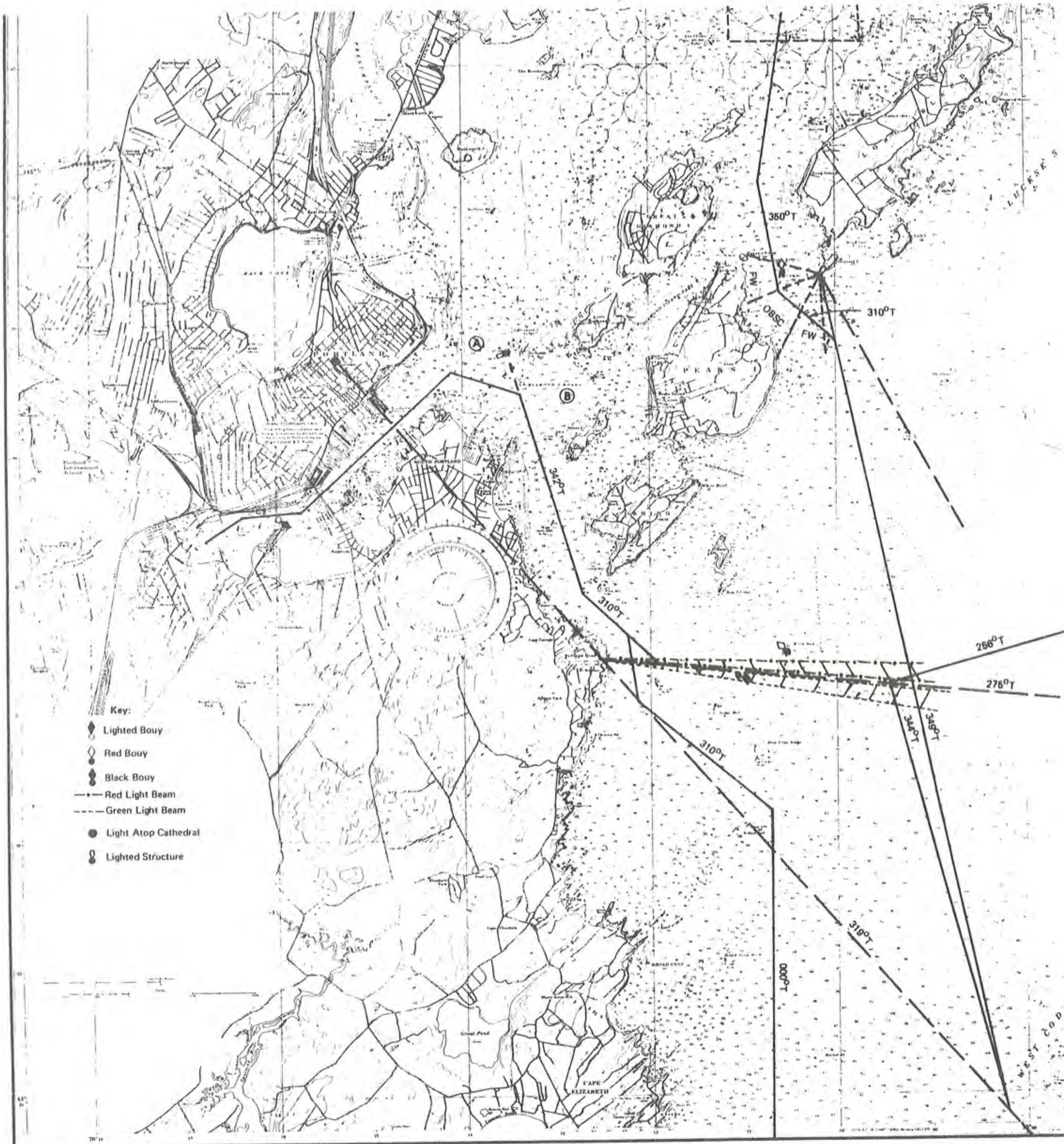


FIGURE 7.3 APPROACHES TO PORTLAND INNER AND OUTER HARBORS SHOWING IMPROVED AIDS-TO-NAVIGATION

Maneuvering to the pier requires caution but is not considered particularly difficult by the experienced seaman. A nun buoy should be placed to mark the very shallow sand bar area on the north side of the channel 1000 yards west of the channel entrance. Such a buoy would provide guidance to mariners so that they may keep to the north side of the channel and avoid the rocky shoal areas to the left.

7.3.4 The Inner Harbor

Where the navigation channel turns southward opposite Fish Point it is reduced to a nominal 1100-ft width and 35-ft control depth. At a point opposite Brown Wharf, the 35-foot dredged channel narrows to approximately 700 feet with a gradual transition down to a 500-ft width approximately 800 feet downstream of Portland Bridge. The channel width is then reduced to the 98-ft horizontal clearance between fenders at the Portland Bascule Bridge. This narrow width limits the size of tankers that can navigate upstream of the bridge. The mooring sections of the bridge are not raised to a fully vertical position and this further restricts clearance of vessels with high bridge structures.

There is always danger of a ship-bridge collision since vessels with up to 90-ft beams are brought through the narrow 98-ft passage. A ship-bridge collision could be very dangerous. To reduce the potential for injury and loss of life in the near term, the vehicle barriers on the bridge should be moved back a safe distance to minimize this danger.

Above the bridge, the 35-ft deep navigation channel widens to approximately 400 feet just before passing buoy No. 1. This buoy is a particularly important marker in an upstream passage since it indicates where the channel turns to the right, and also the shoal areas to the left (see Figure 7.3).

Can Buoy No. 1 is very difficult to see from amidships or the stern bridge of a tanker. At night, the docking pilots generally require one of the accompanying tugs to illuminate the buoy with a powerful spot light so that the precise change in course can be made without danger of grounding. Can Buoy No. 1 should be replaced with a light buoy to improve navigational safety at this point in the channel

The channel turns to the right approximately 800 feet above Portland Bridge. The navigation channel then continues almost due west about 3500 feet and holds its 400-ft width. The channel then turns left on a southwesterly heading and widens into a dredged 35-ft deep turning basin just east of the old Vaughn Bridge. The maximum width of the turning basin is approximately 700 feet. The basin is dredged to 35 feet.

The red nun buoy No. 6 at the western end of the turning basin marks the shallow sand bar, and occasional rock area behind it. With the 8 to 10-foot tides normal to Portland, the sand bar is exposed at low tide. Although tugboat support is almost always used to help turn around outgoing tankers in the turning basin, the sand bar behind buoy No. 6 is an unnecessary hazard. Consideration should be given by the Army Corps of Engineers to dredge the area behind buoy No. 6 a distance of 150 to 200 feet to a controlling depth of 25 feet. The increased size of the turning basin would provide for a quicker and less hazardous turn-around of oil tankers heading downstream (see Figure 7.3).

The 35-foot dredged channel runs from the turning basin an additional 1200 feet upstream in a northeasterly direction to terminate at the Veterans' Memorial Bridge, which is approxiamtely 1.5 miles upstream of the Portland Bridge. It is a fixed span bi-level structure with a highway on the upper level and railroad tracks on the lower level. Since the bridge clearance above mean high water is only about 10 feet, no commercial traffic goes beyond the bridge.

7.3.5 The Hussey Sound Passage

Oil tankers are frequently seen anchored in the designated Oil Transfer Area north of Hussey Sound in the inner bay. To enter this anchorage, these vessels must pass through Hussey Sound (see Figure 7.2).

The pilot usually boards the inbound vessel at the Portland Sea Buoy and a course is set through West Cod Ledge. From West Cod Ledge, a northerly course is taken to pass east of the Portland Harbor approach buoy No. 1 to pass between bell buoy No. 3 and light buoy No. 4 at the entrance to Hussey Sound. This course is set to pass well clear of flashing light buoy No. 2 that marks a 45-ft shoal area.

Hussey Sound has depths in the range of 60 to 100 feet and a channel width of 1000 feet or more throughout the passage. The primary Aids-to-Navigation are light buoys 3, 6 and 7 and a shallow "S" course must be steered through this passage using these aids. The passage is approximately 2000 yards in length. The inbound passage is usually set to pass close to Buoy No. 6 which marks the southeasterly edge of Soldiers Ledge.

Soldiers Ledge is the principal navigation hazard. It has a depth of only forty feet at mean-low-water. It is marked by red buoy No. 6 which has a flashing light and radar reflector and is located on the southwest corner of the ledge. There is approximately 1400 feet of water between buoy 6 and buoy 7 at Pumpkin Knob, and they are at a critical part of the passage. Careful navigation and experienced judgement is required to navigate this passage safely on a routine basis.

The navigation of large tankers up to 100,000 DWT with lengths of 1000 feet and drafts to 48 feet through Hussey Sound is made more difficult by the tidal currents of 1 to 2 knots during flood and ebb tides and the strong winds that sometimes blow in this area. However, the State of Maine, Department of Environmental Portection allows passage through Hussey Sound only within one-half hour either side of high tide. The purpose of this regulation is to restrict passage of the largest vessels to times of maximum high water and minimum currents.

The Hussey Sound passage is well buoyed and marked in accordance with present practice. However, aids that are carefully selected for the purpose could increase the safety of navigation in this area and reduce the risk of grounding and the potential for oil spills:

a. Since the Soldiers Ledge buoy can be moved off station by combinations of wind, seas, and tide conditions it is recommended that a small station buoy be set on Soldiers Ledge approximately 124 yards and 020° from the charted position of buoy No. 6. The fixed separation distance between the two buoys will provide an excellent indication to the pilot that the buoys have not moved from their set positions.

b. To provide additional guidance throughout the inbound/outbound passage, it is recommended that a sectored light be installed on a trial basis. It is suggested that a temporary 40-ft tower be erected on the existing concrete base on Overset Island for this purpose. A 360° primary light should be installed at the maximum tower height. This light should have a high intensity beam on a bearing of 349°T. Ten feet below the primary light, a fixed white sectional (passing) light showing flashing white sectors of 330° to 029° and 069° to 180° should be installed.

c. The volume of traffic and draft of ships presently using the Hussey Sound passage do not require that Soldiers Ledge be removed. However, should the volume of traffic increase, and the drafts of vessels using the passage increase to over 50 feet, the ledge should be removed to a controlling depth of 65 feet. This would allow passage of oil carriers up to about 275,000 DWT.

Tanker movement through the Hussey Sound passage is currently limited by the State of Maine to thirty minutes before and after high tide. This may be too restrictive. The short time span does not allow enough time to bring an oil carrier from the protected Oil Transfer Area, through Hussey Sound to Portland Harbor Approach Buoy No. 1, and on into the Portland Pipeline berths on the same tide. As a result, an additional period of anchoring is required in fishing waters eastward of Ram Island. This area provides no protection from the open sea and wind conditions and is a potentially dangerous situation that needs to be improved. Increasing the time span on either side of high tide for vessel transit through Hussey Sound, and allowing for the expert judgement in these matters could improve this situation.

An alternate deep water anchorage to the undesignated anchorage areas near the Portland Sea Buoy and the one inside Hussey Sound should be considered. Lukse Sound could provide such protected anchorage for large tankers without the dangers of the open sea conditions at the Sea Buoy or the requirement for two passages through Hussey Sound. However, Lukse Sound should be carefully surveyed for suitable anchoring conditions and for the degree of protection it can provide to vessels during periods of heavy winds and seas before it is established as an anchorage.

7.4 SUMMARY

The following findings and recommendations are made to improve marine navigation in the Portland Harbor and Hussey Sound areas:

7.4.1 Portland Harbor and the Fore River

Aids-to-Navigation

- Place a Riding Light on the Portland Sea Buoy. A high intensity strobe light is in use now as a primary light but makes it difficult for an observer to determine the distance off the buoy at night.
- Install a high intensity light showing not more than 2° each side of a bearing 319°T on the steeple of the Cathedral.
- Place a station buoy off Witch Rock approximately 30 yd, 100°T from the present Witch Rock Lighted Buoy No. 2.

- Establish and set a new lighted buoy 2090 yd, 275°T from Portland Head to mark the 43-ft depth on the northern edge of Jordan Reef.
- Increase the intensity of the Diamond Island Ledge Light to facilitate identification against the strong background lighting.
- Replace No. 1 can buoy upstream from Portland Bridge with a light buoy for greater visibility at night.

Dredging

- In the Portland Outer Harbor, consider increasing controlling depth of Anchorage A to 45 feet. This dredging would be required if vessel traffic, with drafts of 40 feet or more, increases in the future.
- Dredge the area behind red nun buoy No. 6 at the turning basin to a depth of 25 feet. This will greatly improve the ability to turn tankers without risk of grounding.

Hazards

- The close proximity of the proposed marina and the proposed special anchorage in the old shipyard at Spring Point, poses a significant long term hazard to the large oil tankers moving to and from berths at Portland Pipeline Pier No. 2, the tugs (1 to 3) that are assisting the tanker, and the small craft in the vicinity of the marina. The inexperienced seamanship of the pleasure boaters can interfere with the safe operations of the oil tankers while the wakes of the tugs and major vessels pose a hazard to the small craft. For this reason it is recommended that the impact of the marina on navigation safety be examined carefully before the marina is allowed to operate in that area.

- The horizontal clearance of the Portland Bascule Bridge is 98 feet. The bascule spans do not open to a vertical position to give maximum horizontal clearance through the opening. As a result, the available width is restrictive for vessels with high bridge structures. Therefore, any increase in future traffic with vessels of greater size to piers and terminals beyond the Portland Bridge is not likely.

7.4.2 Hussey Sound

Aids-to-Navigation

- Place a station buoy on Soldiers Ledge approximately 124 yd 020° from the charted position of Lighted Buoy No. 6.

- Erect a 40-ft tower on the existing concrete base on Overset Island with a 360°T light which has a high intensity beam on a bearing of 349°T. Ten feet below the light, a fixed white sectional (passing) light showing white sectors of 330° to 029° and 069° to 180° should be installed as a temporary light for evaluation purposes.

Dredging

- The present volume of traffic and present depths do not require that Soldiers Ledge be removed. However, an increase in traffic volume and in vessel drafts to over 50 feet will require that the ledge be removed to a minimum of 65 ft controlling depth.

Hazards

- The restriction on the movement of vessels past Soldiers Ledge to ± 1/2 hour each side of high tide does not give sufficient time to make a transit from Hussey Sound to Portland Pipeline berths before the changing of tidal flow. The period for transit should be widened so that the transit could be made in one tide and anchoring offshore in unprotected waters could be avoided.

7.4.3 Anchorages, Vessel Traffic Control, and Background Lighting

Portland Sea Buoy Anchorage

Tankers anchor in the vicinity of the Portland Light Buoy while awaiting a berth in Portland Harbor. At times, six or more vessels have been counted anchored in the area. Most are fully laden tankers heading for Portland Pipeline Pier No.2. In some cases a liquefied petroleum gas (LPG) tanker making for the Portsmouth area will also anchor in this area. The Captain of the Port agreed that this unsupervised anchorage is a hazardous situation and there is danger of oil spills and serious accidents. However, this anchorage is beyond the 3-mile limit, and outside normal USCG jurisdiction. The location and supervision of this anchorage should be given thorough consideration before a serious accident develops.

Luckse Sound Anchorage

Consideration should be given to the establishment of a designated hurricane anchorage in Luckse Sound. This location has considerable merit as an alternate to the non-designated anchorage near the Portland Light Buoy. In addition, the hazards in the approach are few and can be avoided because of ample sea room.

Vessel Traffic Control

No supervised Vessel Traffic System is justified in the Portland Harbor area at present. A 24-hour vessel harbor advisory service operated by the USCG or under USCG jurisdiction would be a valuable service. Although the pilots operate such a service now and it does provide valuable traffic movement, weather, and other information, it is operated mainly to fulfill the pilots' requirements for information.

Background Lighting

A common problem in coastal harbor approaches and in built-up harbor areas is the confusion of navigational aids with bright background lights. Although this situation in the Portland Harbor area is not unusually bad at present, it is noticeable particularly in the vicinity of the Portland Pipeline Pier No. 2. This factor should be taken into consideration when plans for future construction are proposed so that appropriate controls may be applied if needed.

7.5 REFERENCES

7.1 Harslip D.T. and Goldsmith A.; Meeting of Maritime Requirements in United States Waters - Journal of Institute of Navigation; Vol. 21, No. 2 (Summer 1974).

7.2 Wild Goose Association; LORAN and OMEGA Chart Availabilities; Radio Navigation Journal (1975).

7.3 Wild Goose Association; Chronology of Coast Guard Plan for LORAN-C System Phase-In; Proceedings of the LORAN-C Workshop; June 5, 6, & 7 1974. Sponsored by USCG under Contract DOT-CG 429-38-A.

APPENDICES

APPENDIX A

BIRDS OF CASCO BAY*

Gaviiformes

Common Loon	PR	
Red-throated Loon	S4-My4*	

Podicipediformes

Red-necked Grebe	S4-My1	
Horned Grebe	O1-My1	

Pelecaniformes

Great Cormorant	S2-Ap4	
Double-crested Cormorant	Ap2-N4	

Ciconiiformes

Great Blue Heron	Ap1-D2*	
Green Heron	Ap4-S4	
Snowy Egret	Ap2-S2	
Black-crowned Night Heron	Ap1-O3	

Anseriformes

Canada Goose	F4-My4	O1-D2
Brant	Mr2-My4	O4-D2
Mallard	S1-My1*	
Black Duck	PR	
Greater Scaup	O1-Ap4	
Lesser Scaup	Mr2-My1	O1-N2

* The notations after each name indicate when the species is most likely to be seen in this region. The weeks are indicated by numbers. For example, Je2 is the second week in June. PR indicates species that are permanent residents. An asterisk (*) indicates that the species is seen occasionally throughout the year.

Birds of Casco Bay* (Continued)

Anseriformes (Continued)

Common Goldeneye	O2-My1*	
Barrow's Goldeneye	N2-Ap2	
Bufflehead	O2-Ap4	
Oldsquaw	O3-My3	
Harlequin Duck	O3-Mr4	
Common Eider	PR	
King Eider	N1-Ap3	
White-winged Scoter	S1-Je1*	
Surf Scoter	O1-Je1	
Common Scoter	S1-My2	
Hooded Merganser	Mr4-My1	O2-D4*
Common Merganser	O2-Ap3	
Red-breasted Merganser	S4-My4*	

Charadriiformes

Semipalmated Plover	My3-Je2	Jy4-O2
American Golden Plover	Au3-O4	
Black-bellied Plover	My2-Je2	Jy4-O4*
Whimbrel	My3-Je2	Jy1-S3
Spotted Sandpiper	Ap4-O1	
Soliday Sandpiper	My1-Je2	Jy3-S4
Greater Yellowlegs	Ap3-Je1	Jy4-N1
Lesser Yellowlegs	Ap3-My4	Jy3-S3
Knot	My4-Je2	Au1-S4
White-rumped Sandpiper	Jy4-N1	
Least Sandpiper	My2-Je2	Jy1-O1
Dunlin	My3-Je1	S3-N4
Short-billed Dowitcher	My3-Je1	Jy1-O1
Semipalmated Sandpiper	My2-Je3	Jy1-O3
Western Sandpiper	Jy3-S4	
Sanderling	My3-Je2	Au1-N2
Red Phalarope	My1-My3	Jy3-O1
Great Black-backed Gull	PR	
Herring Gull	PR	
Ring-billed Gull	S1-My1*	
Laughling Gull	My1-S4	
Bonaparte's Gull	My3-Je2	Au1-N1*
Common Tern	My2-S4	
Roseate Tern	My4-Au4	
Arctic Term	My3-Au4	
Black Guillemot	PR	

Coraciiformes

Belted Kingfisher	Ap1-O3*

APPENDIX B

IMPORTANT BIRD NESTING ISLANDS*

Locations

Location	Latitude	Longitude
Cape Elizabeth		
Ram Island	44°33′00″	70°15′36″
Portland		
Inner Green Island	43°40′00″	70°06′18″
Outer Green Island	43°39′00″	70°07′24″
Vail Island	43°40′06″	70°09′30″
Ram Island	43°38′12″	70°10′12″
Junk of Pork	43°38′54″	70°07′18″
Cumberland		
W. Brown Cow Island	43°41′42″	70°04′18″
Sand Island	43°42′48″	70°06′24″
Bangs Island	43°43′30″	70°05′30″
Stockman Island	43°44′06″	70°04′54″
Crow Island	43°43′42″	70°06′12″
Upper Green Island	43°46′12″	70°05′00″
Mink Rocks	43°42′00″	70°04′30″

* Personal communications: Howard Mendall, Maine Cooperative Wildlife Research Unit; William Snow and Frank Gramlich, USF&WS, Augusta; Richard Anderson, Maine Audubon Society; and Dr. William Drury, Mass. Audubon Society.

CUMBERLAND COUNTY

(Data compiled 1965-1973)

Portland

Ram Island

(migrant Brant)	
Great Black-Backed Gull	500 pairs
Herring Gull	4000 pairs
Black Guillemot	6 (?)

Inner Green Island

Double-crested Cormorant	200 nests
(migrant Brant)	
Eider	150 (° present)
Great Black-backed Gull	100 pairs
Herring Gull	280 pairs
Common Seal	62
Grey Seal	1

Outer Green Island

Double-crested Cormorant	660 nests
Eider	50 nests (10 ° present)
Great Black-backed Gull	75 pairs
Herring Gull	200 pairs
Black Guillemot	2 pairs

Junk o' Pork

Double-crested Cormorant	350 nests (135)
Herring Gull	25 pairs

Cumberland

West Brown Cow

Double-crested Cormorant	350 pairs
Eiders	
Great Black-backed Gull	25 pairs
Herring Gull	50 pairs

Munk Gull

Eiders	250 (° present)
Herring Gull	100 pairs

Cumberland Continued

Haddock Rock

Double-crested Cormorant	25 pairs
Herring Gull	100 pairs

Sockman Island

Eiders	
Great Black-backed Gull	75 pairs
Herring Gull	550 pairs

Bangs Island

Eiders	(few)
Great Black-backed Gull	15 pairs
Herring Gull	75 pairs

Goose Nest Island

Great Black-backed Gull	6 pairs
Herring Gull	50 pairs

Upper Green Island

Double-crested Cormorant	1 pair
Eiders	(few)
Merring Gull	400 pairs

Lower Clapboard

Common Tern	300 pairs
Common Seal	15

Harpswell

Eagle Island

Eiders	
Great Black-backed Gull	25 pairs
Herring Gull	100 pairs

APPENDIX C

MAIN SPECIES OF WINTER WATERFOWL

Winter Waterfowl Inventory, Casco Bay, 1970-1974[2.1]

	Specie						
Year	Black Duck	Goldeneye	Dufflehead	Scaup	Scoter	Eider	Old Squaw
1970	6,500	2,000	350	0	100	2,800	0
1971	5,500	1,000	1,100	500	300	2,700	0
1972	7,800	1,100	560	300	50	6,800	0
1973	8,926	1,899	885	90	125	8,555	41
1974	10,183	1,325	707	325	36	8,984	48
Average	7,782	1,465	720	243	122	5,968	18

APPENDIX D

CASCO BAY SEAL HAULOUTS [2.16]

ADULTS

(No. of Pups in Parantheses)

	1973 (Total Coverage)	1974 (Sampled)	1975 (Sampled)
Clapboard Is.	20 (7)	25	--
Mill Creek	34 (7)	0	--
Halfway Rock	10	--	--
Fort Georges	2	--	--
Stave Is.	3	0	12
Brown Cow	1	--	--
Inner Green Is.	64 (2)	28	35
Lower Basket Is. L.	10 (5)	--	--
Upper Basket Is. L.	17	--	--
Sturdevantt Is. L.	6 (1)	--	--
Sandy Pt. Lgs.	1	--	18
Wolf's Neck	3 (1)	--	--
Flying Pt. L.	19 (9)	--	--
Moshier Is.	9 (4)	--	--
Upper Green Is.	11 (3)	--	--
French Is.	24 (11)	--	--
Bustin's L.	4	--	--
Little Whaleboat Is.	12 (4)	--	--
Sister L.	13 (5)	4	25
Lookout Point Harpswell Neck	5 (3)	--	--
Birch Is.	2	--	--
Goose Is.	19 (5)	--	30
Brant Ledges	13 (5)	--	--
Goslings Is.	1 (1)	--	12

APPENDIX E

SOFT SHELL CLAM (MYA ARENARIA) PRODUCTION*

CUMBERLAND COUNTY

Town	Growing Area Acres	Growing Area Closed Acres	% Cl.	Estimated Production Capability Bushels	Estimated Production Capability Closed Area	% Closed
Brunswick	1638	176	11	130325	10680	8
Harpswell	2621	175	7	256525	11725	5
Freeport	1491	678	45	203270	87300	43
Yarmouth	782	59	7.5	123055	6300	5
Cumberland	448	63	14	41845	6250	15
Falmouth	392	367	94	58390	57275	98
Portland	385	283	74	23535	17585	65
Cape Elizabeth	52	27	52	1975	1350	66
Scarboro	299	189	100	32275	29475	100
	8008	2017		871195	227940	26.2

*Source: State of Maine, Department of Maine Reserves (1962-1967, Updated 1973)

APPENDIX E cont'd

CUMBERLAND COUNTY

Scarboro Chart 231

Location	Map Area No.	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acre	%	Closed Bu.	%
Spurwink River	2	C-18	15	75	4875	15	100	4875	100
Nonesuch River	3	C-12	58	100	5800	58	100	5800	100
Nonesuch River	4	"	38	150	5700	38	100	5700	100
Nonesuch River	5	"	18	150	2700	18	100	2700	100
Nonesuch River	6	"	10	150	1500	10	100	1500	100
Nonesuch River	7	"	15	200	3000	5	33.3	200	10
Scarboro River	8	"	42	200	8400	42	100	8400	100
Scarboro River	14	"	3	100	300	3	100	300	100
			199	95	32275	189	95	29475	91.3
						Conditional 14,000			

Cape Elizabeth Chart 231

Location	Map Area No.	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acre	%	Closed Bu.	%
Spurwink River	1	C-13	27	50	1350	25	100	1350	100
Chart 315									
Cresent Beach	115		25	25	625				
			52		1975	25	48	1350	68.4

Portland

Location	Map Area No.	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acre	%	Closed Bu.	%
Mackworth Pt.	111	C-14	38	150	5700	38	100	5700	
Martin Pt.	111A	"	194	25	4850	25	12.9	625	12.9
Great Diamond	114	"	66	100	6600	66	100	6600	
Peaks Is.	1016	"	26	35	910	26	100	910	
Long Is.	101A	C-14A	15	150	2250	15	100	2250	
Long Is.	101B	"	10	150	1500	10	100	1500	
Little Chebeaque	107	C-15	5	35	175				

APPENDIX E cont'd

Portland Continued

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Jewell Is.	122	0-15	18	50	900				
Cliff Is.	123	0-15	3	50	150				
Cliff Is.	124	0-15	5	50	250				
Cliff Is.	125	0-15	5	50	250				
			385		23535	349	91%	17585	74.7

Falmouth

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Falmouth Foreside	109	C-15	20	150	3000	20	100	3000	
Mussell Cove	110	C-15	89	175	15575	89	100	15575	
Mackworth Point	111	C-14	258	150	38700	258	100	38700	
Clapboard Island	130	0-15	4	35	140				
Stave Is.	127	0-15	3	25	75				
Bates Is.	126	0-15	18	50	900				
			392		58390	367	94%	57275	96%

Cumberland

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Great Chebeaque Island	106	0-15	209	100	20900				
" "	113	0-15	31	75	2325				
Chandler Cove	128	C-14B	23	50	1150	23		1150	
Johnson Cove	129	0-15	38	150	5700				
Little Chebeaque Island	107	0-15	26	35	910				

Cumberland Continued

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Broad Cove	102	0+5 C-15	81	60	4860	10	12.3	600	12.3
Duck Harbor	108	C-15	25	150	3750	25		3750	
Falmouth Foreside	109	C-15	5	150	750	5		750	
Sturdevant Island	131	0-15	10	150	1500				
			448		41845	63	14%	6250	15%

Yarmouth

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Lambert Point	95	C-16	49	250	12250	49	100	12250	
Royal River	96	C-16	21	150	3150	21	100	3150	
" "	97	C-16	10	50	500	10	100	500	
Barker Pt.	98	C-16	25	100	2500	25	100	2500	
White Cove	99	0-15	94	200	18800				
Drinkwater Point	100	0-15	15	150	2250				
Prince Pt.	101	C-16B	3	50	150	3	100	150	
Broad Cove	102	0-15	148	60	8880				
Cousins Is.	103	0-15	183	200	36600				
" "	104	0-15	23	50	1150				
" "	105	0-15	5	25	125				
" "	112	0-15	176	200	35200				
Mosier Is.	132	0-15	30	50	1500				
			782		123055	108	14%	13550	15%

APPENDIX E cont'd

Freeport

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Maquoit Bay	85	0-17	62	35	2170				
"	86	0-17	66	150	9900				
Williams Is.	87	0-17	3	100	300				
lying Pt.	88	0-17	501	150	75150				
olf Neck	89	C-17	92	100	9200	92	100	9200	100
Harraceket River	90	C-17	130	100	13000	130	100	13000	100
" "	91	C-17	224	100	22400	224	100	22400	100
taples Pt.	92	C-17	112	150	16800	112	100	16800	100
" "	93	C-17	41	150	6150	41	100	6150	100
Stockbridge Point	94	B-16	84	50	4200				
ambert Pt.	95	C-16	176	250	44000	176		44000	
			1491		203270	687	43%	87300	45%

Harpswell

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Indian Pt.	19	0-22	92	75	6900				
E.Harpswell	20	0-22	112	75	8400				
Long Island	20A	0-22	8	75	600				
Dingley Is.	21	0-22	43	150	6450				
Hopkins Is.	22	0-22	15	25	375				
Cundys Is.	23	C-18E	15	50	750	15	100	750	100
Leavitts Is.	24	0-21	23	25	575				
Cundys Is.	25	0-18E	6	25	150	6	100	150	100
Sandy Cove	26	0-21	10	25	250				
Yarmouth Is.	27	0-21	8	150	1200				
" "	27A	0-21	13	5	750				

Harpswell Continued

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Hen Cove	28	0-21	10	25	250				
Hen Cove	28A	0-21	3	50	150				
Quahog Bay	29	0-21	3	25	75				
Quahog Bay	30	0-21	8	25	200				
Quahog Bay	31	0-21	20	150	3000				
Quahog Bay	32	0-21	8	150	1200				
Rich Cove	33	C-21	10	150	1500				
Ben Island	33B	0-21	5	100	500				
Rich Pt.Cove	33A	0-21	8	25	200				
Brishvard Cove	34	0-21	10	150	1500				
Orrs Cove	35	0-21	8	50	400				
Doughty Cove	36	C-18A	69	75	5175	69	100	5175	10[illegible]
Sebascodegan Island	37	0-19	53	35	1855				
Doughty Point	39	0-19	145	150	21750				
Fales Hill	40	0-19 C18J	20	50	1000	10	50	500	50
	41	0-19	18	75	1350				
Strawberry Creek	41A	0-19	38	50	1900				
Card Cove	42	C-18F	23	100	2300	23	100	2300	100
Gunpoint Cove	42A	0-20	13	25	325				
Card Cove	42B	C-184	13	100	1300	13	100	1300	10[illegible]
Long Point Is.	43	0-20	18	75	1350				
Long Point Cove	43A	0-20	13	50	650				

APPENDIX E cont'd

Harpswell Continued

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Quohog Bay	43B	O-20	10	50	500				
Gun Point	44	O-20	10	50	500				
Makerel Cove	45	C-18D	11	50	550	11	100	550	100
Bailey Is.	45A	C-18D	8	50	400	8	100	400	100
Wills Gut	46	C-18D	10	75	750	10	100	750	100
Bailey Is.	46A	C-18B	20	50	1000	20	100	1000	100
Lowell Cove	47	C-18D	13	50	650	13	100	650	100
Beals Cove	48	O-19	18	50	900				
Reed Cove	49	O-19	13	75	975				
Dipper Cove	51	O-19	40	75	3000				
Orrs Island	52	O-19	5	75	375				
Ewinnarrows	53	O-19	15	35	525				
Harpswell Cove	54	O-19	204	50	10200				
Harpswell	55	O-19	10	150	1500				
Harpswell	55A	O-19	15	150	2250				
Mill Cove	56	O-19	132	35	4620				
Widgeon Cove	57	O-19	143	150	21450				
Merriman Cove	57A	O-19	10	150	1500				
Clark Cove	58	O-19	13	150	1950				
Harpswell Harbor	59	O-19	48	150	7200				
S. Harpswell	60	C-18	99	100	9900	99	100	9900	100
Ash Pt. Cove	60A	C-18	36	100	3600	36	100	3600	100

APPENDIX E cont'd

Harpswell Continued

Location	Map Area Number	Shellfish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Potts Harbor	61	C-18	13	25	325	13	100	325	100
Basin Point	62	C-18	18	25	450	18	100	450	100
Basin Point	63	O-18	5	25	125				
Basin Cove	64	C-18	5	150	750	5	100	750	100
Peter Cove	65	O-18	8	25	200				
Blain Cove	66	C-18	64	150	9600	64	100	9600	100
Curtis Cove	67	O-18	18	150	2700				
Middle Bay	68	O-18	61	150	9150				
Harpswell Neck	69	O-18	8	150	1200				
Wilson Cove	70	O-18	28	50	1400				
Wilson Cove	71	O-18	5	25	125				
Jordan Pt.	72	O-18	28	150	4200				
Middle Bay Cove	73A	O-18	128	100	12800				
Middle Bay	73	O-18	362	100	36200				
Mere Pt. Bay	74	C-18C	23	150	3450	23	100	3450	100
Birch Island	75	B-17	5	150	750				
Upper Goose Island	76	O-17	3	150	450				
Upper Goose Island	77	O-17	25	150	3750				
Lower Goose Island	78	O-17	5	150	750				
Little Whale-beat Island	79	O-18	10	150	1500				
			2634		257400	456	17%	40600	16%

APPENDIX E cont'd

Brunswick

Location	Map Area Number	Shell Fish Area No.	Acres	Bu/A	Bu.	Closed Acres	%	Closed Bushels	%
Middle Ground	17C	C-18B	15	100	1500	15	100	1500	100
Middle Ground	17D	C-18B	10	100	1000	10	100	1000	100
Woodward Cove	18	C-18A, 0-23	173	150	25950	8	100	1000	
Buttermilk Cove	18A	C-18A	15	25	375	15	100	375	100
Thomas Bay	18B	0-23	115	100	11500				
New Meadow River	18C	C-18B	5	100	500	5	100	500	100
New Meadow River	18D	C-18B	20	35	700	20	100	700	100
Prince Pt.	38	0-19	59	50	2950				
Harpswell Cove	54	0-19	204	50	10200				
Middle Bay	73	0-18	581	100	58100				
Mere Point	80	C-18C	1	150	150	1	100	150	100
Mere Point	81	C-18C	3	65	195	3	100	195	100
Mere Point	82	C-18C	2	25	50	2	100	50	100
Mere Point Neck	83	0-17	3	150	450				
Mere Point Neck	84	0-17	13	150	1950				
Maquoit Bay	85	0-17 C-17A	419	35	14665	31	7.4	3100	
			1638		130325	176	11%	10680	8%

APPENDIX F

LIST OF SHORESIDE FACILITIES VISITED

American Oil Co. - S. Portland

B. P. Oil Corp. (Gibbs Oil Corp) - S. Portland

Central Maine Power Co. - Peaks Island

Central Maine Power Co. - S. Portland

Chevron, Co. - South Portland

Clark's Store - Long Island

Clyde Bowen Garage - Chebeague Island

Exxon Co. USA - S. Portland

Fisherman's Island Marina - Peaks Island

Getty Oil Co. - S. Portland

Gulf Oil Corporation - Portland (Fore River)

Harbor Supply Oil Company - Portland Inner and Outer Harbor

King Resources Co. - Long Island

Mobil Oil Corp. - S. Portland

Northeast Petroleum Corp. - S. Portland

Peaks Island Marina - Peaks Island

Port Harbor Marina - S. Portland

Portland Pipeline - S. Portland

S. D. Warren Co. - Westbrook (Presumpscott River)

Shell Oil Co. - S. Portland

Southern Marine Vocational Technical Institute - S. Portland

Sun Oil Co. (Webber Oil Company)

Texaco, Inc. - S. Portland

United States Coast Guard - Portland

United States Naval Reserve Tank Farm - Harpswell Neck

Whittens Service Center - Peaks Island

APPENDIX G.1

G.1.1 OIL SIZE INCREASE WITH TIME

The spread of instantaneously released oil on water is a well-studied phenomenon. Fay [G.1], Fannelop and Waldman [G.2] have developed theories to predict the growth of an oil slick on calm water. It has been found that the theories agree reasonably well with observational data from large-scale spills from tankers [G.1] such as TORREY CANYON. The spreading of oil has also been theorized by Murray [G.3] to be a turbulent diffusion phenomenon (on the ocean surface). This theory is probably more applicable to continuous spills from stationary sources. Another theory has been developed by Raj [G.4] based on laboratory experimental data and theoretical analysis to explain the spreading of continuously released oil on calm water. However, for large-scale short-duration spills, such as may occur in an accident involving the collision of an oil tanker (and its subsequent leak), we recommend the use of the Fay [G.1] model.

According to the Fay model, there are three regimes of spread: gravity-inertia, gravity-viscous, and surface tension-viscous. Each regime of oil spread is characterized by a spreading force (gravity or surface tension) and by a resisting force (inertia, viscous drag). The law of spread in each regime and the duration that each regime lasts are indicated in Table G.1.1. It is seen from this table that in the first two regimes, the radius of the oil slick is dependent on the volume of oil spilled.

In obtaining the results indicated in Table G.1.1 it was assumed that the oil slick expands uniformly (radially) and that it remains in one piece. Also, it has been assumed that there is no mass loss from the oil slick due to evaporation or dissolution. It should be kept in mind that although the uniform spreading scenario suggested by this model is idealistic, the total area of spread given by the model is expected to correspond with reasonable accuracy to the actual spreading area of a real slick.

TABLE G.1.1

Equations of Radial Spread of Oil on Water

Spread Regimes → Geometry of Spread ↓	Gravity – Inertia	Gravity – Viscous	Viscous – Surface Tension
Radial	$0 < t < 0.546 \left[\frac{V}{G\nu_w}\right]^{1/3}$ $r = 1.14\,(GV)^{1/4}\; t^{1/2}$	$0.546 \left[\frac{V}{G\nu_w}\right]^{1/3} \leqslant t \leqslant 0.375 \frac{\rho_w}{\sigma}\left[G\, V^2 \nu_w\right]^{1/3}$ $r = 0.98 \left[\frac{G^2V^4}{\nu_w}\right]^{1/12} t^{1/4}$	$t > 0.375 \frac{\rho_w}{\sigma} [G\; V^2\; \nu_w]^{1/3}$ $r = 1.6 \left[\frac{\sigma}{\sqrt{\mu_w \rho_w}}\right]^{1/2} t^{3/4}$

$G = g(1 - \rho_{liq}/\rho_{water})$ = effective gravity (m/s^2)

g = acceleration due to gravity = 9.8 m/s^2

r = radius of spread (m)

t = time (s)

V = volume of liquid spilled (m^3)

ν_w = kinematic viscosity of water (m^2/s)

σ = surface tension of oil (N/m)

In Figure 4.1, the radius of spread of oil is plotted as a function of time for three different quantities of spill for a specific type (density) of oil, using the Fay Model. The termination of spread is generally assumed to occur when the film thickness of oil is about a millimeter. This is in keeping with observations from large-scale spills. Also, Fay [G.1] has theorized that this cessation of spread is caused by the evaporation of some oil fractions which reduces the spreading force to zero (effectively altering the surface tension). Sometimes, however, oil spills are visible even when the film thicknesses are of the order of a few microns. In order to be conservative, therefore, in the estimate of the impact probability, we assume that the spill expands until the oil thickness becomes of the order of 50 microns.

An example is shown below to indicate the methodology of calculation of the oil slick radius at any given time. This calculation will be useful in obtaining the radius value for a spill volume not given in Figure 4.1.

Example

Oil Properties

Density $= \rho_{liq} = 950 \text{ kg/m}^3$

Interfacial tension between oil and water $= \sigma = 0.03 \text{ N/m}$

Sea Water Properties

Density of water $= \rho_w = 1000 \text{ kg/m}^3$

Kinematic viscosity of water $= \nu_w = 10^{-6} \text{ m/s}^2$

Volume of oil spill = V = 10,000 gallons (U.S.) = 37.85 m^3

From Table G.1.1, the time for changeover from gravity viscous to gravity inertia regime of spread is

$$t_1 = 0.546 \times \left[\frac{37.85}{9.8(1 - 0.95) \times 10^{-6}} \right]^{1/3} = 233 \text{ second}$$

Similarly, the surface tension - viscous regime of spread starts after a time t_2, given by:

$$t_2 = 0.375 \times \frac{1000}{0.03} \left[9.8 \times (1 - .95) \times 37.85^2 \times 10^{-6} \right]^{1/3} = 1111 \text{ second}$$

Assuming final thickness of slick is 50×10^{-6} m, the final radius

$$\text{of spread} = \left[\frac{37.85}{\pi \times 50 \times 10^{-6}} \right]^{1/2} = 491.0 \text{ m} = 0.263 \text{ nautical miles}$$

The law of spread in the various regimes expressed in nautical miles and hours for 10,000 gallon spill (for the above oil) can be shown to be

Gravity inertia regime: $r = 0.0766\ t^{1/2}$

Gravity viscous regime: $r = 0.03863\ t^{1/4}$

Surface tension-viscous regime: $r = 0.0695\ t^{3/4}$

Where r is in nautical miles and t is in hours.

Table G.1.2 summarizes the results of calculations for three spill sizes.

TABLE G.1.2

Calculations for Three Spill Sizes

Spill Size	10,000 gallons 35.96 metric tons	100,000 gallons 359.6 metric tons	1,000, 000 gallons 3596 metric tons
First critical time t_1	233 sec (0.065 hr)	501 sec (0.139 hr)	1079 sec (0.3 hr)
Second critical time t_2	1111 sec (0.309 hr)	5157 sec (1.43 hr)	23,940 sec (6.65 hr)
Maximum radius of spread (final thickness 50 microns)	0.3 Nautical Miles	0.8 Nautical miles	2.7 Nautical miles
Equation of spread in various regimes (r in nautical miles, t in hours)			
Gravity-Inertia	$r = 0.0766\ t^{1/2}$	$r = 0.136\ t^{1/2}$	$r = 0.242\ t^{1/2}$
Gravity-Viscous	$r = 0.03863\ t^{1/4}$	$r = 0.083\ t^{1/4}$	$r = 0.179\ t^{1/4}$
Surface Tension-Viscous	$r = 0.0695\ t^{3/4}$	$r = .0695\ t^{3/4}$	$r = 0.0695\ t^{3/4}$
Time to reach maximum radius	6.1 hr	27.7 hr	128.2 hr

APPENDIX G.2

WIND DATA AND THEIR USE

The direction and magnitude of the wind on the surface of the Earth change continuously with time. They also vary from point to point and are different at different heights above the ground. However, in any given location, certain directions and certain velocities occur more often than others. These preferred directions and velocities do change with seasons but may also exhibit diurnal changes.

The accuracy with which one can predict the wind direction and velocity depends on the extent of the available data. The finer the time intervals over which the data are recorded, the better the estimate of the probability prediction. Even though the direction and magnitude probability can be established reasonably accurately (even from coarse time interval data), it is very difficult to estimate the duration over which a wind of a given velocity and a given direction would persist. In effect, certain apriori assumptions have to be made in applying available wind data to the prediction of oil slick movement. One of these would be to assume that the direction and velocity of wind do not change over the period for which slick movement calculations are performed.

The National Climatic Center (NCC) of the National Oceanic and Atmospheric Administration [G.5] compiles wind data for particular locations within the United States. The wind velocity, direction, cloud cover, temperature, humidity, etc. are recorded hourly, over years, to arrive finally at a wind distribution data sheet. Such data sheets for Portland, Maine are reproduced in Tables G.2.1. and G.2.3.

The data sheet indicates 16 directions of the wind and seven wind speed categories. The numbers in the table indicate the number of times the wind with a velocity within a given range and with direction within $\pm$ 11.25° of the given compass direction occurred. Tables such as G.2.1 are prepared for each stability class of the atmosphere and for each season. Table G.2.1. specifically refers to D class stability for the season June, July and August. The data in this Table are the cumulative data for nine years of observation in Portland, Maine.

TABLE G.2.1

WIND DATA FOR PORTLAND, MAINE (JJA)

- Season = June, July, August (JJA) FREQUENCY DISTRIBUTION STATION =14764 PORTLAND,MAINE/WSO 55-64 -24OBS

SPEED(KTS)

DIRECTION	1 - 3	4 - 6	7 - 10	11-16	17-21	GREATER THAN 21	AVG SPD	TOTAL
N	39	166	230	163	24	0	8.7	622
NNE	22	98	164	144	9	0	9.0	437
NE	26	121	201	61	4	1	7.8	414
ENE	28	121	263	134	12	4	8.7	562
E	38	182	335	178	11	4	8.6	748
ESE	23	104	165	97	3	0	8.2	392
SE	29	100	95	57	2	0	7.4	283
SSE	25	141	275	230	23	7	9.5	701
S	40	233	712	1017	120	10	10.8	2132
SSW	34	172	477	287	28	7	9.2	1005
SW	31	127	247	182	11	0	8.7	598
WSW	32	110	250	267	42	8	10.2	709
W	35	144	138	146	18	1	8.8	482
WNW	21	106	116	128	9	2	8.9	382
NW	30	77	95	108	19	4	9.3	333
NNW	25	90	135	141	14	3	9.3	408
AVG	2.8	5.1	8.4	12.8	18.1	24.3	9.0	
TOTAL	478	2092	3898	3340	349	51		

NUMBER OF OCCURRENCES OF D STABILITY = 10581

NUMBER OF CALMS WITH D STABILITY = 373

The wind on the ocean surface has been observed to move an oil slick in the direction of the wind at about 3% of its velocity. It is therefore logical to assume that the probability of an oil slick moving in a particular direction by wind is identical to the probability distribution of the wind. For analyzing the problem of oil slick movement in the neighborhood of Portland Harbor we consider those directions of the wind that have the four largest probabilities of occurrence. In addition, instead of each direction wind vector representing a direction spread of ± 11.25°, we recalculate the probabilities and mean wind velocities so that the resultant directions of the four largest probabilities represent an angular spread of ± 22.5°. This calculation is shown below.

Example for Calculating Wind Probabilities

Consider, for example, that we are interested in determining the directions and the wind velocities in those directions having high probabilities of occurrence. It is seen that for the season JJA, directions S, W, NW, and E have respectively the highest probabilities of occurrence (see Table G.2.1). Table G.2.2 shows the reduced data from Table G.2.1 (for the season JJA) for the above principal directions and their neighboring directions. The mean velocities in each direction and their probability of occurrence are shown. Since we are interested in the probability that the wind is within ± 22.5° we compute its "mean" direction and mean velocity by a vector addition of the mean wind velocities weighted by the individual probabilities. This is shown in Figure G.2.1 for wind from S direction in the season June, July, August (JJA).

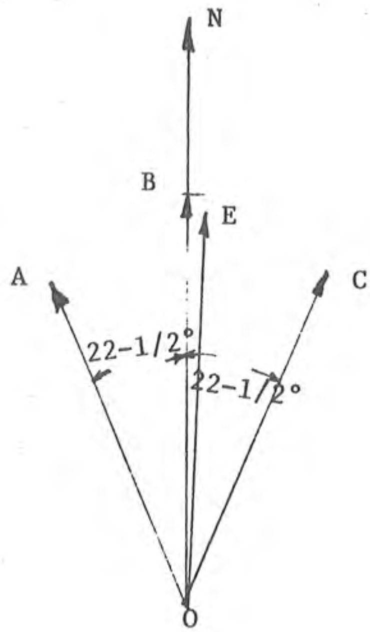
The probability and mean velocity of the resultant vector are given by:

$$P = 1/2\ P_1 + P_2 + 1/2\ P_3$$

and $$\vec{U}_{mean} = \frac{\left[1/2\ P_1\vec{U}_1 + P_2\vec{U}_2 + 1/2\ P_3\vec{U}_3\right]}{P}$$

FIGURE G.2.1

DETERMINATION OF EFFECTIVE WIND DIRECTION AND PROBABILITY



Season: JJA   Atmosphere: D

OA = SSE wind - probability of occurrence = 6.63%, mean velocity = 9.5 knots

OB = S wind - probability of occurrence = 20.15%, mean velocity = 10.8 knots

OC = SSW wind - probability of occurrence = 9.5%, mean velocity = 9.2 knots

OE = weight vector - sum of OS, OB, and OC = .0663 OA + 0.2015 OB + 0.095 OC

TABLE G.2.2

REDUCED WIND DATA FOR JJA

Season: JJA Atmospheric Class: D

Wind Blowing from Direction	No. of Observations in the Direction*	Probability of Occurrence of Direction %	Mean Wind Velocity Knots	Weighted Vectorial Mean Velocity Knots	Angle from Due North of the Mean Vector Direction Degrees	Overall Probability of Occurrence in the Resultant Direction %
SSE	701	6.63	9.5			
S	2132	20.15	10.8	10.17	± 0.93°	28.22
SSW	1005	9.5	9.2			
WSW	709	6.7	10.2			
W	482	4.56	8.8	8.93	90° - 4.58°	9.72
WNW	382	3.61	8.9			
ENE	562	5.31	8.7			
E	748	7.07	8.6	8.31	270° - 1.81	11.58
ESE	392	3.7	8.2			
WNW	382	3.61	8.9			
NW	333	3.15	9.3	8.81	135° + 0.68°	6.89
NNW	333	3.86	9.3			

*Total number of observations in Class D = 10581

TABLE G.2.3

WIND DATA FOR PORTLAND, MAINE (DJF)

FREQUENCY DISTRIBUTION   STATION =14764 PORTLAND,MAINE/WSD 55-5

Season: Dec-Jan-Feb: Nine year cumulative data (DJF)

DIRECTION	SPEED(KTS) 1 - 3	4 - 6	7 - 10	11-16	17-21	GREATER THAN 21	AVG SPD	TOTAL
N	52	331	877	713	138	51	10.3	2162
NNE	18	121	350	416	138	41	11.7	1084
NE	9	74	160	109	58	22	11.1	432
ENE	11	35	71	66	42	33	12.9	258
E	10	46	79	49	23	18	11.0	225
ESE	8	31	44	33	20	8	10.9	144
SE	8	26	35	27	8	11	10.9	115
SSE	10	41	67	64	16	25	11.8	223
S	20	73	166	167	39	19	10.7	484
SSW	12	97	294	292	28	5	10.2	728
SW	17	97	376	394	41	10	10.4	935
WSW	25	124	350	585	120	56	11.8	1260
W	32	166	274	468	116	46	11.5	1102
WNW	42	161	266	501	84	8	10.8	1062
NW	39	204	316	515	104	25	10.9	1203
NNW	37	222	408	636	126	28	11.0	1457
AVG	2.9	5.1	8.5	13.1	18.3	24.9	10.8	
TOTAL	350	1849	4133	5035	1101	406		

NUMBER OF OCCURRENCES OF D STABILITY = 13151

NUMBER OF CALMS WITH D STABILITY = 277

The resultant vector $\vec{OE}$ is given by (refer to Table G.2.2)

$$\vec{OE} = 0.2015 \times \vec{OB} + \left(\frac{0.0663}{2}\right) \times \vec{OA} + \left(\frac{0.095}{2}\right) \vec{OC}$$

where $\vec{OA}$, $\vec{OB}$, and $\vec{OC}$ represent the mean wind velocity vectors from directions SSE, S, and SSW respectively. The probability of occurrence of OE is given by

$$P(\vec{OE}) = 0.2015 + \frac{(0.0633 + 0.095)}{2} = 0.2822$$

For calculating the probabilities of oil impact on the shorelines of Portland Harbor, we have considered four highest probability wind directions (in a manner indicated by the above discussion) and two seasons; names, DJF and JJA. Only D atmosphere is considered, since it occurs 61.1% of the time in a year. The results are given in Tables G.2.2 and G.2.4.

TABLE G.2.4

REDUCED WIND DATA FOR DJF

Season: DJF   Atmospheric Class: D

Wind Blowing from Direction	No. of Obser-vations in the Direction*	Probability of Occurrence of Direction %	Mean Wind Velocity Knots	Weighted Vectorial Mean Velocity Knots	Angle from Due North of the Mean Vector Direction Degrees	Overall Probability of Occur-rence in the Resultant Direction %	Remarks
NNW	1457	11.08	11.0				
N	2162	16.44	10.3	10.35	180° - 1.03°	26.1	The angle is counted in clockwise direction from due North (geographic)
NNE	1084	8.24	11.7				
WNW	1062	8.08	10.8				
NW	1203	9.15	10.9	10.49	135° - 1.93°	18.73	
NNW	1457	11.08	11.0				
SSW	728	5.54	10.2				
SW	935	7.11	10.4	10.41	45° - 4.06°	14.67	
WSW	1260	9.58	11.8				
ENE	258	1.96	12.9				
E	225	1.71	11.0	11.13	270° - 4.08°	3.24	
ESE	144	1.09	11.13				

*Total number of observations in Class D = 13151

APPENDIX G.3

TIDAL DATA ANALYSIS FOR USE IN OIL SLICK MOVEMENT ANALYSIS

G.3.1 INTRODUCTION

The tidal current magnitude near a shore varies from point to point. The variation is caused by the variations in the depth of flow, by channeling effects that are created by narrow passages between islands or between an island and the mainland, flow of rivers into the sea, and several other causes (salinity gradients, recirculation, etc.). The tidal currents also have a time-varying character. The magnitude of tidal velocity at the surface, at any location, varies with a definite period. For about six hours, the flow direction is toward the shore (flood), and for the next six hours, it is away from shore (ebb). It is not generally true that the flood time half period and the amplitude (of velocity) are equal to the corresponding ebb values. Typical tidal data measured near Portland Harbor are schematically shown in Table G.3.1. The table shows that the half period for flood is five and one half hours, and the ebb half period is seven hours.

Tidal data are available for specific locations in Tables of Tidal Currents, published by NOAA [G.6]. A typical data page from tide tables is shown in Table G.3.2. The tables consist essentially of four tide velocity data for each day, giving the peak values and the times when they occur and the slack (zero velocity) times.

For predicting the motion of oil spills, in principle, it is necessary to have the tide data for the entire region over which the spill is likely to occur and spread. However, such a detailed description is hardly available. Consider, for example, the Portland Harbor area. Data on the direction and magnitude of tidal velocity are available only from six stations; i.e., from Hussey-Overset, Hussey-Crow Island, Grand Truck, Diamond Ledge, Portland Breakwater, and Portland Harbor Entrance. There are no tidal data for places close to the oil transfer area (see Figure G.3.1) or on the eastern side of Long Island. Similarly,

TABLE G.3.1

REDUCED TIDE DATA FOR VARIOUS LOCATIONS NEAR PORTLAND HARBOR

Location	Season	FLOOD FLOW: Maximum Tidal Velocity u_1 in Knots	FLOOD FLOW: Half Period T_1 in Hours	EBB FLOW: Maximum Tidal Velocity u_2 in Knots	EBB FLOW: Half Period T_2 in Hours
I Portland Breakwater	JAN	0.51	5.5	0.71	6.5
	JULY	0.29	5.5	0.47	6.5
II Hussey Sound Crow Island	JAN	1.51	5.5	0.83	6.5
	JULY	0.84	5.5	0.75	6.5
III Oil Transfer Area	JAN	1.5	5.5	0.9	6.5
	JULY	1.0	5.5	0.8	6.5
IV Portland Harbor Entrance	JAN	.75	5.5	.80	6.5
	JULY	0.75	5.5	0.8	6.5

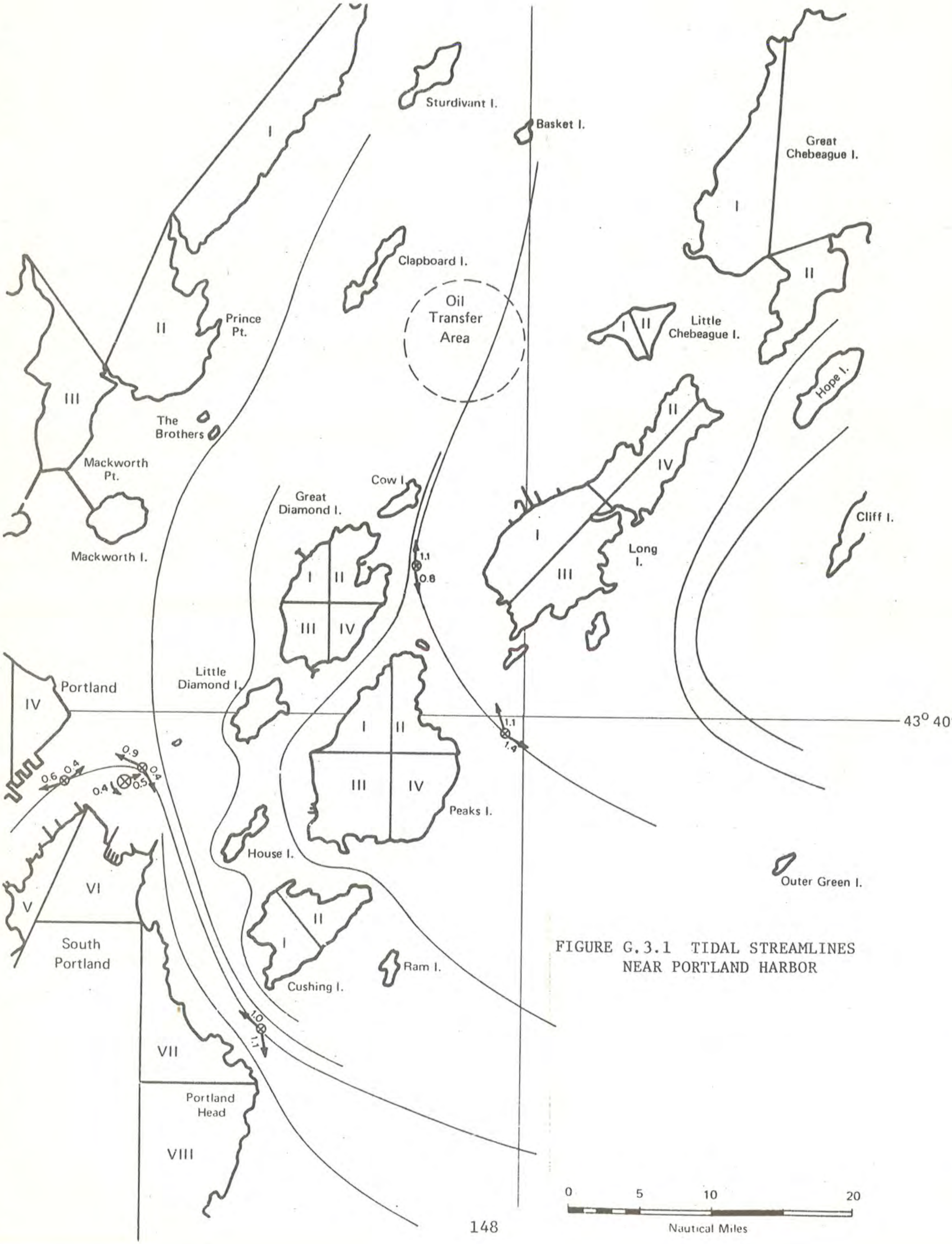


FIGURE G.3.1 TIDAL STREAMLINES NEAR PORTLAND HARBOR

TABLE G.3.2

TYPICAL NOAA TIDAL DATA

PORTSMOUTH HARBOR ENTRANCE (OFF WOOD I.), N.H., 1972

F-FLOOD, DIR. 355° TRUE   E-EBB, DIR. 195° TRUE

JANUARY

DAY	SLACK WATER TIME H.M.	MAXIMUM CURRENT TIME H.M.	VEL. KNOTS
1	0030	0313	1.8E
SA	0645	0858	1.4F
	1243	1546	2.3E
	1934	2142	1.2F
2	0121	0403	1.8E
SU	0718	0947	1.4F
	1331	1629	2.3E
	2022	2228	1.2F
3	0210	0449	1.8E
M	0924	1034	1.3F
	1416	1715	2.2E
	2109	2311	1.2F
4	0257	0535	1.7E
TU	0917	1117	1.2F
	1509	1756	2.1E
	2153	2352	1.2F
5	0343	0619	1.7E
W	1007	1202	1.1F
	1554	1939	1.9E
	2234		
6		0034	1.1F
TH	0429	0707	1.6E
	1058	1247	1.0F
	1628	1923	1.4E
	2325		
7		0119	1.1F
F	0516	0752	1.5E
	1152	1334	0.8F
	1714	2009	1.7E
8	0011	0204	1.0F
SA	0604	0843	1.5E
	1247	1424	0.7F
	1904	2057	1.5E
9	0100	0253	1.0F
SU	0655	0934	1.4E
	1345	1515	0.6F
	[illegible]	2148	1.4E
10	0150	0342	0.7F
M	0746	1028	1.4E
	1442	1610	0.6F
	1959	2241	1.3E
11	0241	0434	0.9F
TU	0838	1123	1.5E
	1538	1705	0.6F
	2057	2336	1.3E
12	0332	0525	0.9F
W	0928	1217	1.6E
	1627	1801	0.6F
	2153		
13		0027	1.3E
TH	0421	0618	1.0F
	1015	1309	1.7E
	1716	1852	0.7F
	2244		
14		0119	1.4E
F	0508	0709	1.1F
	1100	1354	1.8E
	1809	1943	0.9F
	2332		
15		0207	1.5E
SA	0553	0758	1.2F
	1143	1439	2.0E
	1841	2032	1.0F

DAY	SLACK WATER TIME H.M.	MAXIMUM CURRENT TIME H.M.	VEL. KNOTS
16	0016	0255	1.5E
SU	0637	0844	1.3F
	1223	1524	2.1E
	1922	2117	1.2F
17	0058	0342	1.4E
M	0721	0933	1.4F
	1302	1606	2.2E
	2002	2204	1.3F
18	0140	0427	1.9E
TU	0806	1018	1.5F
	1341	1651	2.3E
	2042	2248	1.5F
19	0222	0513	2.0E
W	0852	1105	1.5F
	1422	1736	2.3E
	2125	2335	1.5F
20	0306	0602	2.1E
TH	0941	1154	1.5F
	1505	1923	2.3E
	2210		
21		0022	1.5F
F	0353	0651	2.1E
	1034	1244	1.4F
	1553	1914	2.2E
	2258		
22		0113	1.6F
SA	0445	0742	2.1E
	1132	1337	1.3F
	1648	2004	2.0E
	2351		
23		0204	1.5F
SU	0543	0839	1.9E
	1234	1430	1.2F
	1753	2101	1.9E
24	0049	0300	1.4F
M	0645	0939	1.9E
	1339	1529	1.0F
	1905	2158	1.8E
25	0150	0357	1.3F
TU	0749	1041	1.9E
	1444	1630	0.9F
	2017	2303	1.7E
26	0251	0456	1.2F
W	0852	1147	1.7E
	1547	1736	0.9F
	2125		
27		0008	1.5E
TH	0352	0555	1.2F
	0952	1259	2.0E
	1646	1845	0.7F
	2227		
28		0115	1.5E
F	0450	0700	1.2F
	1048	1403	2.0E
	1740	2000	1.0F
	2323		
29		0216	1.7E
SA	0544	0756	1.2F
	1140	1456	2.1E
	1830	2100	1.1F
30	0015	0310	1.7E
SU	0635	0845	1.2F
	1227	1537	2.1E
	1916	2138	1.1F
31	0103	0353	1.8E
M	0723	0928	1.2F
	1312	1614	2.1E
	1959	2209	1.2F

FEBRUARY

DAY	SLACK WATER TIME H.M.	MAXIMUM CURRENT TIME H.M.	VEL. KNOTS
1	0147	0431	1.8E
TU	0808	1012	1.2F
	1354	1649	2.1E
	2040	2243	1.2F
2	0229	0510	1.8E
W	0853	1052	1.2F
	1434	1727	2.0E
	2121	2329	1.2F
3	0310	0549	1.7E
TH	0939	1134	1.1F
	1513	1805	1.9E
	2202	2359	1.2F
4	0349	0532	1.7E
F	1025	1217	1.0F
	1550	1847	1.8E
	2243		
5		0042	1.1F
SA	0439	0715	1.6E
	1115	1300	0.9F
	1627	1931	1.6E
	2328		
6		0127	1.1F
SU	0512	0802	1.6E
	1238	1349	0.8F
	1709	2018	1.5E
7	0015	0213	1.0F
M	0559	0852	1.5E
	1304	1449	0.7F
	1802	2109	1.4E
8	0107	0304	0.9F
TU	0652	0945	1.5E
	1403	1533	0.6F
	1909	2202	1.3E
9	0202	0355	0.9F
W	0749	1040	1.5E
	1500	1629	0.6F
	2017	2258	1.3E
10	0257	0450	0.9F
TH	0846	1139	1.5E
	1553	1726	0.6F
	2118	2355	1.3E
11	0350	0545	1.0F
F	0939	1233	1.7E
	1642	1821	0.8F
	2213		
12		0050	1.4E
SA	0441	0639	1.1F
	1029	1322	1.8E
	1727	1914	0.9F
	2303		
13		0141	1.6E
SU	0528	0730	1.2F
	1115	1411	2.0E
	1809	2005	1.1F
	2348		
14		0232	1.8E
M	0614	0821	1.4F
	1159	1458	2.2E
	1850	2051	1.4F
15	0032	0318	2.0E
TU	0659	0910	1.5F
	1241	1541	2.3E
	1931	2138	1.5F

DAY	SLACK WATER TIME H.M.	MAXIMUM CURRENT TIME H.M.	VEL. KNOTS
16	0114	0405	2.1E
W	0745	0957	1.6F
	1324	1627	2.4E
	2012	2225	1.7F
17	0158	0452	2.2E
TH	0832	1045	1.7F
	1407	1714	2.4E
	2056	2312	1.7F
18	0242	0539	2.3E
F	0921	1134	1.6F
	1453	1801	2.3E
	2142	2359	1.7F
19	0330	0628	2.2E
SA	1014	1223	1.5F
	1543	1850	2.2E
	2233		
20		0049	1.7F
SU	0422	0722	2.2E
	1112	1316	1.4F
	1640	1943	2.0E
	2328		
21		0142	1.5F
M	0520	0817	2.0E
	1214	1411	1.2F
	1745	2039	1.9E
22	0028	0237	1.3F
TU	0623	0916	1.9E
	1320	1509	1.0F
	1855	2139	1.6E
23	0132	0334	1.2F
W	0729	1021	1.9E
	1426	1612	0.8F
	2006	2247	1.5E
24	0237	0436	1.0F
TH	0834	1136	1.8E
	1530	1757	0.8F
	2113		
25		0003	1.5E
F	0340	0541	1.0F
	0935	1303	1.8E
	1629	2016	0.9F
	2213		
26		0131	1.6E
SA	0439	0659	1.0F
	1031	1405	1.9E
	1722	2108	1.1F
	2307		
27		0228	1.6E
SU	0532	0824	1.1F
	1121	1450	2.0E
	1808	2118	1.1F
	2355		
28		0309	1.7E
M	0620	0848	1.1F
	1208	1521	2.0E
	1851	2124	1.1F
29	0039	0336	1.8E
TU	0705	0912	1.1F
	1250	1553	2.0E
	1931	2138	1.1F

TIME MERIDIAN 75° W. 0000 IS MIDNIGHT. 1200 IS NOON.

the flow direction and magnitude of flows between islands such as Peaks and Cushing or between Great Diamond and Peaks Island are not known.

In situations such as these where the tidal data are sparse, considerable judgment has to be used in drawing on the map both the streamlines (and therefore directions of tidal motion), as well as the magnitude of the peak velocities. For example, it is seen from the directions of the peak ebb and flood flows at the two stations, Portland Harbor Entrance and Portland Breakwater, that the tidal flow between Cushing Island and the mainland is almost parallel to the shore. A part of this flow bends and floods the channel, and the other part moves up in a NE direction. In the region south of Portland Head, the tidal velocity directions are essentially East-West because there are no islands to provide a channeling effect for water flow. In the open sea, the tidal velocities are normal to the shoreline. It is based on these arguments that the streamline A is drawn. Similar typical streamlines are drawn at other places on the map in Figure G.3.1 which roughly indicate the direction of motion of water due to tidal action near Portland Harbor.

A small particle floating on the sea water surface should theoretically execute the approximate sinusoidal motion in keeping with the velocity of the tidal currents. The particle should move back and forth on a streamline if there are no other forces on the particle. In real situations, however, not only is the particle size finite, but it is also subjected to a variety of other forces, such as the wind, the eddies, swirls, and thermal convection that may be present in the water. Therefore, the particle will move around on the water surface, not necessarily constrained to a streamline. Similarly, an oil slick which has spread out on the water surface experiences different tidal vecloities at different locations of the slick, especially if the slick is located in a channel area (such as between two islands). Also, when the tidal streamlines bifurcate (see, for example, the entrance to the Harbor Channel, Figure G.3.1, the oil slick also may be split. Because of this differential tidal action on different parts of the oil slick, the slick motion due to tidal action cannot be represented by the motion of the center of the slick alone. However, including these effects in an impact probability calculation (and procedure) is extremely complicated. Even though the motion (by tides) of the oil slick cannot be completely described by the motion of the slick center from the point of view of conservative (impact probability) calculation it may not be too inaccurate to assume that the motion of the center describes the movement of the slick. This way, all of the oil will be in one slick (because no provision is made for slick splitting), and therefore its radius will be larger than what it would be if slick splitting or elongation by differential tidal action is considered. Hence, there will be a larger probability of shore impact, thus leading to a conservative estimate.

G.3.2 TIDE DATA REDUCTION

Table G.3.1 indicates the flood and ebb tide peak velocities and their half periods for four locations near Portland Harbor. These data were compiled from the tidal current data tables [G.6]. To calculate the distance moved on a stream time by the center of the oil slick as a function of time, we model the tidal cycle as consisting of two different sinusoidal waves having different velocity amplitudes and periods. Figure G.3.2 shows schematically the flood and ebb flow sinusoidal velocities and also defines the terminology used.

The flood tide has a velocity amplitude u_F and half period $T_F/2$. Respective values for ebb tide are u_E and $T_E/2$.

Let us assume that the spill occurs at the time when there is peak flood tide. That is, t, the time, is zero at peak flood tide (see Figure G.3.2). Then the distance moved by the slick center in a time t is given by

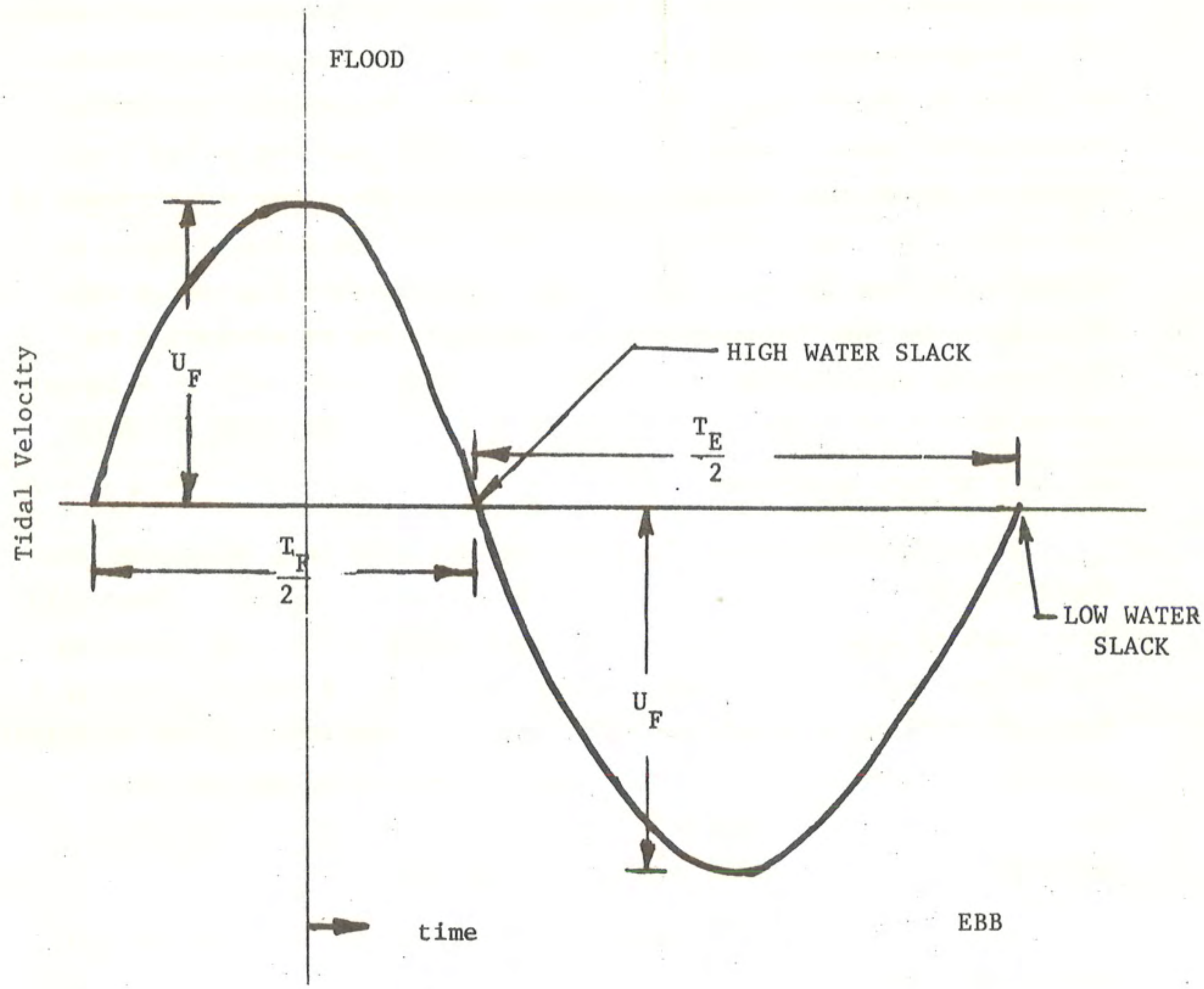


FIGURE G.3.2

Two Half Sinusoidal Model for Tidal Velocity

$$x = \int_{o}^{t} u_F \cos(2\pi \frac{t}{T_F})\ dt$$

$$\text{i.e., } x = \frac{u_F\ T_F}{2\pi}\ \sin(2\pi \frac{t}{T_F})$$

Hence, distance moved between time t_1 and time t_2 is given by

$$x(t_2) - x(t_1) = \Delta x = \frac{u_F\ T_F}{2\pi} \qquad \sin(2\pi \frac{t_2}{T_F}) - \sin \frac{2\pi\ t_1}{T_F}$$

for $t_2 < T_F/4$

This equation is useful in calculating the distance traveled in given intervals of time.

Table G.3.3 gives the formulae for calculating the distance moved by the slick center as a function of time when the spill occurs at peak flood velocity. Based on the above formulae the distance moved by the slick center on a streamline in half hour time intervals is calculated. A typical result obtained by such a calculation is shown in Table G.3.4. This table indicates the distance moved in nautical miles along the streamline when the spill occurs at peak ebb flow. The positive signs indicate the movement in the flood direction, and negative signs indicate the motion in the ebb tide direction.

In applying the results of Table G.3.4 to obtain the impact probability, it is assumed that the tidal velocity amplitude and period does not change from streamline to streamline in a reasonably small area. This is true in most places except when the tidal flow is between two islands fairly close to each other. The oil slick center, it may be recalled, moves from streamline to streamline (during its motion with the tides) due to the action of the wind.

TABLE G.3.3

Distance Traveled for Various Times When the Spill Occurs at Peak Flood Time

Time (t)	x(t)
$0 \leq t \leq \frac{T_F}{4}$	$\frac{u_F T_F}{2\pi} \sin(2\pi \frac{t}{T_F})$
$\frac{T_F}{4} \leq t \leq \left(\frac{T_F}{4} + \frac{T_E}{2}\right)$	$\frac{u_F T_F}{2\pi} + \frac{u_E T_E}{2\pi} \left[\cos\left(2\pi \frac{\left(t - \frac{T_F}{4}\right)}{T_E}\right) - 1\right]$
$\left(\frac{T_F}{4} + \frac{T_E}{2}\right) \leq t \leq \frac{T_E + T_F}{2}$	$\frac{1}{\pi} \left(\frac{u_F T_F}{2} - u_E T_E\right) + \frac{u_F T_F}{2\pi} \left[1 - \cos 2 \frac{\left(t - \frac{T_F}{4} - \frac{T_E}{2}\right)}{T_F}\right]$

From the above formulae, the $x(t_1)$ and $x(t_2)$ are calculated from which Δt can easily be obtained.

TABLE G.3.4

TYPICAL CALCULATED DISTANCES TRAVELED ALONG STREAMLINE

SEASON JANUARY
LOCATION OIL TRANSFER AREA
SPILL OCCURS AT PEAK FLOOD FLOW
MAXIMUM FLOOD VELOCITY= 1.50 KNOTS
MAXIMUM EBB VELOCITY= 0.90 KNOTS
HALF PERIOD OF FLOOD TIDE= 5.50 HOURS
HALF PERIOD OF EBB TIDE= 6.50 HOURS

1 NAUTICAL MILE= 9.25 CMS

INITIAL TIME	FINAL TIME	DISTANCE TRAVELLED	TOTAL DISTANCE
Hours	Hours	Nautical Miles	Nautical Miles
0.00	0.00	0.00	0.00
0.00	0.50	0.74	0.74
0.50	1.00	0.68	1.42
1.00	1.50	0.56	1.98
1.50	2.00	0.40	2.39
2.00	2.50	0.21	2.60
2.50	3.00	-0.00	2.60
3.00	3.50	-0.11	2.71
3.50	4.00	-0.21	2.92
4.00	4.50	-0.30	3.21
4.50	5.00	-0.37	3.58
5.00	5.50	-0.42	4.00
5.50	6.00	-0.45	4.45
6.00	6.50	-0.45	4.89
6.50	7.00	-0.42	5.31
7.00	7.50	-0.37	5.68
7.50	8.00	-0.30	5.98
8.00	8.50	-0.21	6.19
8.50	9.00	-0.11	6.30
9.00	9.50	0.00	6.30
9.50	10.00	0.21	6.51
10.00	10.50	0.40	6.91
10.50	11.00	0.56	7.48
11.00	11.50	0.68	8.16
11.50	12.00	0.74	8.90

APPENDIX G.4
OIL IMPACT PROBABILITY ESTIMATES

The following tables indicate the probabilities of oil impact of shore areas when the oil is spilled in four selected locations near the Portland Harbor. Four principal wind directions are considered, in two seasons and spill occurring in either peak flood tide or peak ebb tide. The shore regions are identified in Figure G.3.1.

Each of the Tables G.4.1 through G.4.4 contains

- the location of the spill
- the season (DJF or JJA) for which calculations are made
- the direction of the wind which is considered in the calculations
- the shore area impacted by the spill.

Corresponding to each wind direction and shore location impacted (each square in the table) two numbers are written. The upper number indicates the overall percentage probability of impact with spill occurring at peak flood tide and the lower number indicates the percentage probability for peak ebb tide spill. (When the square is blank,no impact occurs. When only one number is written it means that impact occurs either in flood or in ebb tide spill only.)

Consider the case of a spill occurring at the Oil Transfer Area (III) in season DJF at peak flood tide. The trace shown in Figure 4.2 indicates that the Mainland shore is impacted when the wind is from the easterly direction. Reference to Table G.2.4 indicates that the probability of wind being in this direction is only 3.25%. This number therefore should have been indicated in the third column in Table G.4.3. Indeed that would be so if eight principal wind directions were considered in the oil path tracking (instead of four directions as has been done in the present calculations). However, since only four wind directions are considered, the wind direction probabilities have to be suitably changed. This change is indicated in Tables G.4.5a and G.4.5b. From Table G.4.5a it is seen that the effective probability of wind blowing from the East becomes 5.16% (instead of 3.25%), when only four wind directions are considered as possible. This number (5.16%) is entered in Table G.4.3 column 3 for Mainland impact areas.

Similarly for season JJA with a spill in Oil Transfer Area (III), Mainland region I is impacted by a southerly wind with 50.03% probability in both flood and ebb tides.

Therefore, the overall probability of impact of Mainland I, due to a spill in the Oil Transfer Area (III) is

$$= \frac{0 + 0 + (0 + 5.16) + 0 + 0 + (50.03 + 50.03) + 0 + 0}{4} = 26.31\%$$

where four in the denominator represents two possible seasons and two possible tidal times when the spill can occur. This total probability (26.31%) is entered in the last column in Table G.4.3. Similar calculations have been indicated for impact to other parts of the shore.

For a spill occurring at the other three locations, the impact probability to Mainland I happens to be zero. Therefore, the total probability of impact to Mainland I due to a spill at any of the four sites (equally probable spill)

$$P_{total} = \frac{1}{4} \times 0 + \frac{1}{4} \times 0 + \frac{1}{4} \times 26.31 + \frac{1}{4} \times 0) = 6.58\%$$

This number can be interpreted as the probability with which the shore region of Mainland I will be impacted due to an oil spill occurring anywhere (within the area bounded by the four spill locations considered) in the Portland Harbor area, irrespective of the time of day and season of the year. However, in using this number in any decision-making process some personal judgment is necessary since the number does not indicate whether the area of Mainland I will be impacted or not by a spill occurring at a specific point. This latter question can only be answered by a detailed oil path tracking - a procedure described in detail in the "Response Manual" accompanying this report.

TABLE G.4.1

Spill at Portland Breakwater

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location: **Mainland**									
I									0.0
II									0.0
III						50.03			12.51
IV			5.16 5.16				20.53 20.53		12.85
V			5.16 5.16				20.53		7.71
VI	41.61		5.16 5.16		12.21		20.53 20.53	17.23	36.45
VII	41.61 41.61	23.38	5.16 5.16	29.85 29.85				17.23	47.17
VIII									0.0
Long Island									
I		23.38							5.85
II		23.38							5.85
III									0.0
IV									0.0

TABLE [illegible].4.[illegible]

Spill at Portland Breakwater

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Great Diamond Island									
I									0.0
II									5.85
III									0.0
IV									5.85
Cushing Island									
I	41.61 41.61	23.38 23.38	5.16	29.85 29.85	12.21 12.21			17.23 17.23	63.43
II		23.38						17.23	10.15
Peaks Island									
I		23.38						17.23	10.15
II									0.0
III		23.38						17.23 17.23	14.46
IV									0.0
Great Chebeague Island									
I									0.0
II									0.0

TABLE G.4.1
Spill at Portland Breakwater

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Little Chebeague Island									
I		23.38							5.85
II									0.0
Cousin Island									0.0
Sturdivant Island									0.0
Basket Island									0.0
Clapboard Island									0.0
Cow Island		23.38							5.85
Crow Island		23.38							5.85
The Brothers						50.03			
Mackwopth Island						50.03 50.03			
Ft. Georges		23.38	5.16			50.03	20.53		24.78
Little Diamond Island		23.38 23.38				50.03	20.53	17.23 17.23	37.94
House Island	41.61	23.38 23.38	5.16	29.85	12.21		20.53	17.23 17.23	47.64
Ram Island									0.0
Overset Island									0.0
Vail Island									0.0

TABLE G.4.1

Spill at Portland Breakwater

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:		-							
Outer Green Island									0.0
Cliff Island									0.0
Hope Island									0.0
Pumpkin Nob									0.0

TABLE G.4.2

Spill at Hussey Sound-Cow Island

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Mainland									
I									0.0
II			5.16						1.29
III			5.16						0.0
IV			5.16 5.16						7.71
V			5.16						0.0
VI			5.16						1.29
VII			5.16						1.29
VIII									0.0
Long Island									
I	41.61			29.85	12.21	50.03			33.43
II						50.03		17.23	16.82
III				29.85					7.47
IV		23.38						17.23	10.15

TABLE G.4.2

Spill at Hussey Sound-Cow Island

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Great Diamond Island									
I							20.53		5.13
II				29.85					12.60
III							20.53		5.13
IV									0.0
Cushing Island									
I			5.16						1.29
II			5.16						1.29
Peaks Island									
I									0.0
II	41.61		5.16	29.85	12.21		20.53		27.34
III			5.16						1.29
IV	41.61						20.53		15.54
Great Chebeague Island									
I						50.03			12.51
II		23.38						17.23	10.15

TABLE G.4.2

Spill at Hussey Sound-Cow Island

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Little Chebeague Island									
I		23.38						17.23	10.15
II				29.85					7.47
Cousin Island		23.38				50.03			18.35
Sturdivant Island		23.38				50.03			18.35
Basket Island		23.38				50.03			30.86
Clapboard Island			5.16				20.53		6.42
Cow Island			5.16				20.53 20.53		11.56
Crow Island				29.85			20.53		12.60
The Brothers			5.16						1.29
Mackwopth Island			5.16				20.53		6.42
Ft. Georges									0.0
Little Diamond Island			5.16				20.53		6.42
House Island			5.16						1.29
Ram Island	41.61								10.40
Overset Island	41.61			29.85	12.21 12.21	50.03		17.23	40.79
Vail Island									0.0

TABLE G.4.2

Spill at Hussey Sound-Cow Island

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Outer Green Island									
Cliff Island		23.38						17.23 17.23	8.62
Hope Island		23.38						17.23	10.15
Pumpkin Nob	41.61		51.6		3.64		20.66		19.88

TABLF G.4.3

Spill at Oil Transfer Area

SEASON	J A N U A R Y				J U L Y				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Mainland									
I			5.16			50.03 50.03			26.31
II			5.16				20.53		6.42
III			5.16						1.29
IV			5.16						1.29
V									0.0
VI									0.0
VII									0.0
VIII									0.0
Long Island									
I	41.61			29.85 29.85	12.21 12.21			17.23	35.75
II					12.21			17.23 17.23	11.67
III	41.61	23.38		29.85	12.21 12.21			17.23	34.12
IV		23.38							5.84

Arthur D Little, Inc.

TABLE G.4.3
Spill at Oil Transfer Area

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Great Diamond Island									
I									0.0
II	41.61			29.85	12.21 12.21		20.53		29.11
III									0.0
IV			5.16						1.29
Cushing Island									
I									0.0
II									0.0
Peaks Island									
I									0.0
II	41.61				12.21 12.21				16.51
III									0.0
IV	41.61 41.61			29.85					28.27
Great Chebeague Island									
I		23.38		29.85				17.23	17.62
II		23.38						17.23	10.15

TABLE G.4.3

Spill at Oil Transfer Area

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Little Chebeague Island									
I				29.85	12.21			17.23 17.23	19.13
II								17.23 17.23	8.62
Cousin Island		23.38							5.84
Sturdivant Island		23.38	5.16			50.03 50.03	20.53		37.28
Basket Island	41.61	23.38		29.85				17.23	28.02
Clapboard Island			5.16			50.03	20.53 20.53		24.06
Cow Island	41.61		5.16	29.85	12.21 12.21		20.53		30.40
Crow Island	41.61		5.16	29.85	12.21 12.21		20.53		30.40
The Brothers			5.16				20.53		6.42
Mackwopth Island			5.16 5.16				20.53		7.71
Ft. Georges			5.16						1.29
Little Diamond Island			5.16						1.29
House Island									0.0
Ram Island									0.0
Overset Island	41.61	23.38		29.85	12.21 12.21				29.82
Vail Island		23.38							

Arthur D Little, Inc.

TABLE G.4.3

Spill at Oil Transfer Area

SEASON	J A N U A R Y				J U L Y				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Outer Green Island				29.85					5.85
Cliff Island									0.0
Hope Island		23.38							5.84
Pumpkin Nob					12.21 12.21				6.11
Sunset Pt./Prince Pt.						50.03 50.03			25.02

TABLE G.4.4

Spill at Portland Harbor Entrance

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Mainland									
I									0.0
II									0.0
III									0.0
IV									0.0
V									0.0
VI									0.0
VII			5.16			50.03	20.53		18.93
VIII	41.61		5.16 5.16				20.53 20.53		23.25
Long Island									
I						50.03			12.51
II									0.0
III		23.38				50.03			18.35
IV									0.0

TABLE G.4.4

Spill at Portland Harbor Entrance

SEASON	JANUARY				JULY				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Great Diamond Island									
I									0.0
II									0.0
III									0.0
IV									0.0
Cushing Island									
I			5.16			50.03	20.53		18.93
II						50.03			12.51
Peaks Island									
I									0.0
II						50.03			12.51
III									0.0
IV						50.03			12.51
Great Chebeague Island									
I									0.0
II									0.0

TABLE G.4.4

Spill at Portland Harbor Entrance

SEASON	J A N U A R Y				J U L Y				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Little Chebeague Island I									0.0
II									0.0
Cousin Island									0.0
Sturdivant Island									0.0
Basket Island									0.0
Clapboard Island									0.0
Cow Island									0.0
Crow Island									0.0
The Brothers									0.0
Mackworth Island									0.0
Ft. Georges									0.0
Little Diamond Island									0.0
House Island									0.0
Ram Island		23.38				50.03 50.03			30.86
Overset Island		23.38				50.03			18.35
Vail Island		23.38				50.03			18.35

TABLE G.4.4

Spill at Portland Harbor Entrance

SEASON	J A N U A R Y				J U L Y				
WIND DIRECTION	North	South-West	East	North-West	North-West	South	East	West	TOTAL PROBABILITY %
Location:									
Outer Green Island									0.0
Cliff Island									0.0
Hope Island									0.0
Pumpkin Nob						50.03			12.51

TABLE G.4.5a

Effective Wind Probabilities Assuming Only Four Principal Directions are Possible

Season DJF — D Weather — Portland Harbor

Approximate Direction	Mean Wind Velocity Knots	Direction of Vector from N Clockwise Degrees	Probability of Occurrence from Wind data, percent p	Effective Probability Percent $p_e = \frac{p}{\Sigma p}$
N	10.35	180 - 1.03	26.10	41.61
NW	10.49	135 + 1.93	18.73	29.85
SW	10.41	45 + 4.06	14.67	23.38
E	11.13	270 - 4.08	3.24	5.16
			Total 62.74	100.00

TABLE G.4.5b

Effective Wind Probabilities Assuming Only Four Principal Directions are Possible

Season JJA — D Weather — Portland Harbor

Approximate Direction	Mean Wind Velocity Knots	Direction of Vector from N Clockwise Degrees	Probability of Occurrence from Wind data, percent p	Effective Probability Percent $p_e = \frac{p}{\Sigma p}$
S	10.17	+ 0.93	28.22	50.03
W	8.93	90 - 4.58	9.72	17.23
E	8.31	270 - 1.81	11.58	20.53
NW	8.81	135 + 0.68	6.89	12.21
			Total 56.41	100.00

APPENDIX G.5

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G.3. Murray, S. P., "Turbulent Diffusion of Oil in the Ocean," Limnology and Oceanography, Volume 17, No. 5, September 1972, pages 651-660.

G.4. Raj, P. K. "Spreading of Continuously Released Oil on Water," Draft Report to the United States Coast Guard under Contract No. DOT-CG-24-655A, (1975).

G.5. "Seasonal and Annual Wind Distribution by Pasquill Stability Classes (Star Program)," National Climatic Center, NOAA, Environmental Data Service, Federal Building, Ashville, NC, (1972).

G.6. "Tidal Current Tables," U.S. Department of Commerce, National Oceanic and Atmospheric Administration, (1972).

APPENDIX H

RESPONSE CAPABILITIES
AND
INVENTORY OF CONTAINMENT AND
CLEAN-UP EQUIPMENT
IN PORTLAND, MAINE

AMOCO
Clarks Road
South Portland, Maine
(207-799-8566)

Ray MacLean
Home: 799-1336

1700 Feet BP 18" boom
240 Feet mini seal boom 8"
Boom barge 26 feet
1 Floating saucer skimmer powered gas engine
(5) 15 pound boxes oil snare

BOSTON FUEL TRANSPORTATION, INC.
36 New Street
East Boston, Massachusetts
(617) 567-9100

Vincent Tibbetts

1 Towboat
1 Bunkering barge

WILBUR BROWN
202 Cottage Road
South Portland, Maine
(207) 799-5505

1 50' Work boat (Venturer)

CASCO POLLUTION CONTROL CO., INC.
14 Bagley Avenue
South Portland, Maine
(207) 799-0850

Floating Equipment:

1 32' Work board
1 34'x15' Barge equipped with 2000 gallon tank and 800' 18" boom
1 16' Fiberglass boat (modified as work boat)
1 16' Aluminum work boat
2 40 HP outboard motors
1 30 HP outboard motor
1 25 HP outboard motor
1 85 HP outboard motor

Casco Pollution Control Co., Inc. (cont.)

Trucks and Trailers

1 International Tank Truck 2,600 gallon
1 GMC 2-ton van
1 Ford Econoline 200
1 Boat trailer
1 Boom trailer equipped with 500' 18" boom
1 Tank trailer 5,000 gallon

Pumping Equipment

1 Trash pump 4 cycle rated 36,600 GPH
1 Trash pump 4 cycle rated 21,600 GPH
2 High pressure pumps rated 105 lbs. PSI
500' 3" Discharge hose
200' 3" Suction hose
200' 2-1/2" Discharge hose
60' 2-1/2" Tapered Nozzles
1 Acqua pump rated 600 gallons per hour
1 24" Skimmer head

Lighting Equipment

1 Homelite generator
4 500 watt Flood lights (500'string-1 light per hundred feet)

Miscellaneous

25 Bags Ecopearl
550 Conweb
Anchors: 4 22s Danforth, 2 40s Danforth
500' 5/8" Poly line
1,000' 3/8" Poly line
24 Pair work gloves
100 lbs. Rags
12 Pair rain gear
6 Brooms
6 Shovels
6 Rakes
100 4-mill Plastic bags
12-55 gallon drums

Access To:

50 Bags Slick Wick
100 Sorbent sheets
50 Sorbent pillows
100" Absorbent boom

Casco Pollution Control Co., Inc. (cont.)

Equipment on Order

1,000" 18" Boom
1 20" Aluminum work boat
1 40 HP Outboard motor
1 20' Boat trailer
VHF Communications under negotiation

CENTRAL MAINE POWER
Cousins Island
Yarmouth, Maine
(207) 846-5730

Herb Griffin
Home: 623-3492

1700 feet of 36" Sea boom
100 55 Gallon drums (200 within 24 hours)

CENTRAL WHARF TOWBOAT COMPANY, INC.
72 Commercial Street
Portland, Maine
(207) 772-8319

Frederick S. Boyce
Home: 799-2137

1 1600 HP Towboat
1 1900 HP Towboat
1 3500 HP Towboat

CHEVRON OIL COMPANY
175 Front Street
South Portland, Maine
(207) 799-5561

H. Bruns
Home: 799-3933

5 Cases of absorbent blanket
2000' 36" boom
30 55 gallon drums (30 within 24 hours)

CIANBRO CORPORATION
1004 Congress Street
Portland, Maine
(207) 772-1968

Robert Thomas

Floating Equipment:

1 Pontoon barge 40'x45' 90 tons, 20,000 gals
4 Pontoon barges 40'x50' 100 tons, 23,000 gals
2 Steel barges 50'x70' 200 tons
1 Monarch barge 34'x110' 200 tons, 46,000 gals
1 Newport dump barge 28'x115' 250 c.y.
1 Dinny self-prop barge 20'x40' 10 tons
1 Tug cadet 40' 165 HP
1 Tug Fannie J 67' 400 HP

Cianbro Corporation (cont.)

Pumps:

3	1 1/2"	5,800	gallons	per	hour
23	2"	8,000	"	"	"
24	3"	16,000	"	"	"
68	4"	30,000	"	"	"
46	6"	90,000	"	"	"
14	8"	125,000	"	"	"
1	10"	200,000	"	"	"

THE CRAGO COMPANY, INC.
Route 26
Gray, Maine
(207) 657-4785

Brian Preble
Home: 657-3349

2 5200 gallon Thompson Tank vacuum trailers
1 350 gallon Thompson Tank vacuum trailer
3 6000 gallon Tank trailers with pumps
2 Van trucks equipped for tank cleaning or oil spills
1 Trailer mounted trailer
3 Utility pick-ups
1 Air compressor-gas & electric portable pumps
1 Floating Weir skimmer
1 30' Work boat equipped for boat booming

DEPARTMENT OF ENVIRONMENTAL PROTECTION
40 Commercial Street
2nd Level
Portland, Maine

David Sait
Home: 892-6632

2000 feet 36" T/T Boom
1 Chevrolet C/10 truck
1 19 foot Grady white boat

EXXON COMPANY, U.S.A.
1 Lincoln Street
South Portland, Maine
(207) 767-2141

T. F. Dunn
Home: 799-7588

6 cases Absorbent blanket
* 1500 ' 36" boom SHARED WITH GULF AND GETTY
50 55 ballon drums within 24 hours

GOLTEN SHIP REPAIR, INC.
400 Commercial Street
Portland, Maine
(207) 774-7846

James McCabe
Home: 799-4685

1 50'x14' Steel work boat 225 HP diesel (Boyce)
1 45'x14' Wood work boat 200 HP diesel (Pilot)
1 25'x12' Steel barge - 200 HP gas
1 14'x8' Steel barge 25 HP diesel
1 4'x40" Steel barge 200 HP diesel
1 93'x16' Steel tanker - Buda Diesel capacity (1,000 bbls. Audrey Hudgins)
2 1/2" Centrifugal pumps powered by 100 HP engine
Pump units are built up to pump plain water or plain chemical, or the chemical can be mixed in the pump with the water at any given percentage
3 Single cylinder gas driven 1 1/4 pumps
2 Experimental oil scoop units with 25' suction hoses
1 2 1/2" Centrifugal trash pump 100 HP powered for use with oil removal equipment
2 3/4 Ton vans
1 3/4 Ton pickup trucks for transportation of equipment
1 1 1/2 Ton stake body truck

All floating equipment is equipped with VHF radios plus two portable radios for supervisor control of operations.

GULF OIL COMPANY
601 Danforth Street
Portland, Maine
(207) 774-8204

1500 feet 36" Boom shared by Exxon and Getty
100 55 gallon drums (500 within 24 hours)

KING RESOURCES COMPANY
Long Island
Maine
(207) 766-2914

Richard Shields
Home: (207) 345-2161

3 100,000 gallon Underground slop tank
1 60,000 barrel Underground concrete glop tank
1 Viking transfer pump, 100 barrels per hour capacity
1 5,000 Gallon tank truck
2 Twin weirs, 5'x25' with baffles
750 feet of oil boom

MAINE COASTAL SERVICES
Wharf 3, 50 West Commerical, R.
Portland, Maine
(207) 774-6044

Joseph Pastore
Home: 829-3767

Floating Equipment:

1 70' work boat
1 32' work boat (inboard)
1 22' steel work and tug boat (inboard)
1 35' x 15' steel work barge
1 18' fiberglass boat/55 horse (outboard)
2 16' fiberglass boats/40 horse (outboard)
1 15' aluminum boat/35 horse (outboard)
1 Swiss & Thompson skimmer
1 Portable vacuum tank unit (1,000 gal) on order

Trucks and Trailers:

1 30' oil spill trailer
1 Tandem diesel with 3,300 gal. vac tank
1 Vacuum unit 4,200 gal
1 Vacuum unit 6,300 gal
1 GMC 2 ton rack truck/2 ton winch (20¢ per mile)
2 Dodge 1 ton vans (15¢ per mile)
1 White tank truck 2,800 gal. (20¢ per mile)
4 Boat trailers
1 6 ton steel trailer

Pumping Equipment:

1 10,000 PSI water blaster on trailer
1 Trash pump 4"/100' suction hose & 100' discharge hose
1 2-1/2" goulds molasses pump/100' suction hose & 100' discharge hose
1 2" goulds molasses pump/100' suction hose & 100' discharge hose
2 2" petroluem pumps/100' suction hose & 100' discharge hose
1 Aqua pump: rated at 600 gal per hour
(more hoses available on all pumps at green book rates.)
Plus 10%

Booms

1500'/36" colloid oil containment boom
500'/15" colloid oil containment boom

Miscellaneous equipment such as brooms, shovels, rakes, pitch forks, wheel barrels, squeegees, maps, Sorbent Sciences' sorbent sheets, pillows, sponges, polyurethane and polyester pads, rolls and bales of 3M sheets, sweeps and pollow.
30 55-gallon drums.

MAINE HELICOPTERS, INC.
465 Congress Street
Portland, Maine
(207) 774-8214

Andrew Berry
Home: 865-3861

2 Helicopters for patrol, surveillance, etc.

MOBIL OIL COMPANY
48 Main Street
South Portland, Maine
(207) 799-8541

Andrew Kowalsky
Home: 883-4913

2000 Feet sea boom

NORTHEAST PETROLEUM CORPORATION
17 Main Street
South Portland, Maine
(207) 799-4755

Richard Chase
Home: 781-2704

	Location:
1 2" Portable electric pump (110V-AC) self priming centrifugal, 75 GPM with 100' extension cord Exp. Proof)	Main Warehouse
1 2' Portable gasoline driven pump	Main Warehouse
60' 2" Oil discharge hose quick coupled	Main Warehouse
10 50 Gallon oil drums	Tank Farm Rd.
1 300 Gallon skid tank	Tank Farm Rd.
1 Roll 36' conweb absorbent	Storage Shed at Pond
6 Colloid absorbent 4' pillow booms	Main Warehouse
1 Box Conweb pads	Storage Shed at Pond
1700' 36" Seaboom (stored in water) (360' permanently installed, 1340' rafted in water)	Mobil Dock

PORTLAND FIRE DEPARTMENT
380 Congress Street
Portland, Maine
(207) 772-6531

Chief Joseph Cremo
Phone: 772-6531

1 Fire Boat

PORTLAND HARBOR POLLUTION ABATEMENT COMMITTEE
40 Commercial Street
Portland, Maine
(207) 773-5608

Edward Langlois
Home: 623-3492

500 Nierad Slickbar boom (used) stored at Maine State Pier
Supply of Oil Spill Booklets (Information booklet on Oil Spills)
Supply of State of Maine Contingency Plan
Copy of Marine Disaster Plan
Oil Spill Red Alert Book (Pertinent information for Portland Harbor and State of Maine)
Helicopter Pad on Roof

Portland Harbor Pollution Abatement Committee (cont.)

1 15' Boat
1 15 HP Motor and tank
1 20' Barge
2 1,000 gallon Tanks
1 5,000 gallon Rubber tank (with fittings)

* The PHPAC has an inventory of known boom manufacturers throughout the country where contact could be made to move boom into Maine in case of serious emergency.

PORTLAND PILOTS INC.
42 Commercial St.
Portland, Maine
(207) 774 5623

Captain Howard Wentworth
Home: 772-5258

2 Steel boats (Portland Pilor) Director 6 channel VHF 60 KW 110 volt generating capacity

PORTLAND PIPE LINE CORPORATION
335 Forest Avenue
Portland, Maine
(207) 772-4603

Wallace McGrew
Home: 799-0187

Location:

403' 3' Sea boom 3PF — Stationary under Pier #2
550' 6" Neirad Mark IV Boom
50' 6" Bennett Float Boom
1875' 18" Uniroyal Model "C" mini Sealdboom-Marine Terminal-Pier #2
188' 3' Sea boom 3 PF } Used for Routine
165' 3' Goodyear Sea Sentry Inflated Boom } Booming of Tankers
1400' 18" Uniroyal Model "C" mini Sealdboom-(Spare-stored at Pier #2)
1200' 36" Coastal Boom
2,000' 36" Colloid Chemical CoBoom
312' 36" T-T Boom
200' 36" Uniroyal Model "C" Mini Sealdboom
100' 18" Bennett Wireless Boom
100' 4" Neirad Fload Boom
45' 6" Neirad Mark VI Boom

Other Equipment and Materials:

1 60 Bbl. Unitized Vacuum Truck
10 55 Gallon Drums (20 within 24 hours)
2 Apparatus OELA III Portable, Self-adjusting, floating oil skimmers, with one Flexible 50' metal suction hose
200 bbs. Miscellaneous absorbent materials manufactured by Conwed and others.

SEACOAST OCEAN SERVICES
P. O. Box 2316
South Portland, Maine 04106
(207) 774-2111

Robert Madsen
Home: 799-5047

3 35' Diesel powered work boats
1 25 Ton Loraine track mounted crane
2 19' Fiberglass I/O workboats/speedboats 165 HP
1 19' Aluminum I/O workboat/speedboat 140 HP
1 20' Aluminum custom boom boat
2 16' Aluminum custom boom boats
2 17' Fiberglass runabouts
2 15' Fiberglass runabouts
1 16' Aluminum runabout
1 12' Aluminum runabout
1 65 HP Mercury motor
6 50 HP Evinrude motors
2 20 HP Mercury motors
2 18 HP Evinrude motors
1 10 HP Mercury motor
1 Rheinwerft Skimmer - Model 1500
2 1000 gallon skid mounted vacuum units
1 T-T Skimmer self propelled
1 33'x14' Pontoon barge (for storage of 1800' boom & 6000 gal. slops
1 4800 Gallon vacuum truck
2000' Used 36" Containment boom
2000' New 36" Containment boom
320' Used 18" Uniroyal boom
400 Bags urethane absorbent
100 Rolls absorbent blankets
50 Boxes absorbent pads
30 Colloid absorbent booms
100 Grefco absorbent booms
1 Trailer mounted heated high pressure water washer 150 175
1000-1200 PSI
1 1971 Ford Econovan truck
1 1972 Ford 12 passenger van truck
1 1972 Dodge 500 stake truck 14' with 1600 lb. power lift gate
1 Holsclaw boat trailer model C-450
1 Holsclaw boat trailer model 575
1 25 Watt base VHF radio
4 Portable VHF Radios - explosion proof
150 55-gallon drums
Miscellaneous pumps, blower, hoses, chemicals, etc.

Equipment located at 37 Custom House Wharf, Portland, Maine

SHELL OIL COMPANY
5 Central Avenue
South Portland, Maine
(207) 767-2161

Richard Anderson
Home: 781-2704

5 18 lb. Sorbent C
16 Bags petropak
16 Absorbent booms 5' each
0-10 55 Gallon drums
1500' 36" boom shared by Exxon, Gulf and Getty

SUN OIL COMPANY
93 Kensington Street
Portland, Maine
(207) 773-6467

Kevin Brennan
Home: 767-2258

1000' MP Bar boom
50-200 55 Gallon drums (200 within 24 hours)

TEXACO
102 Mechanic Street
South Portland, Maine
(207) 799-3394

Charles Farnham
Home: Buxton, Maine
929-4410

1950 feet Mark VI suck bar boom
500 feet Jaton boom
14'x26' Barge 240 HP
Slurp skimmer with gasoline pumps and related hose

U. S. COAST GUARD
259 High Street
South Portland, Maine
(207) 799-5531

1 40' Utility boat
1 44' Motor lifeboat
1 110' Tug yankton
1 65' Harbor tug
1 40' Buoy boat

All boats equipped with communications

APPENDIX I

MANUFACTURERS AND GENERAL SUPPLIERS OF OIL MONITORING SYSTEMS

I.1 AQUALERT MODEL - 240

Manufacturer

Bull and Rorberts, Inc.
785 Central Avenue
Murray Hill New Jersey 07974
(201) 464-6500

Operational Characteristics

Range - Heavy Oil 0-50 ppm
Light Oil 0-100 ppm

Accuracy - 5% full scale (standard application)

Repeatability - 2%

Operates with less than 1% light transmission

Ambient Temperature - 32°F to 140°F

Lamp Life - 5,000 hours

The Aqualert Model-240 is an in-line, continuous, oil detector, pollution monitor. Instrument operation is based on the measurement of light transmission through the fluid being monitored and its potential contaminant. The measured value of the transmitted light is used as an index of sample stream contamination. Two segments of light spectrum are monitored. The first is an ultraviolet wavelength which is selectively absorbed by organic materials. The second is the visible light portion of the lamp output, used as a reference which compensates for the presence of light absorbent materials that are not specific absorbers in the UV wavelength. Absorption depends on the absorption coefficient of the material. The reading is compared with a curve for a specific contaminant and indicates the contaminant concentration. A sketch of this device is shown in Figure I.1.

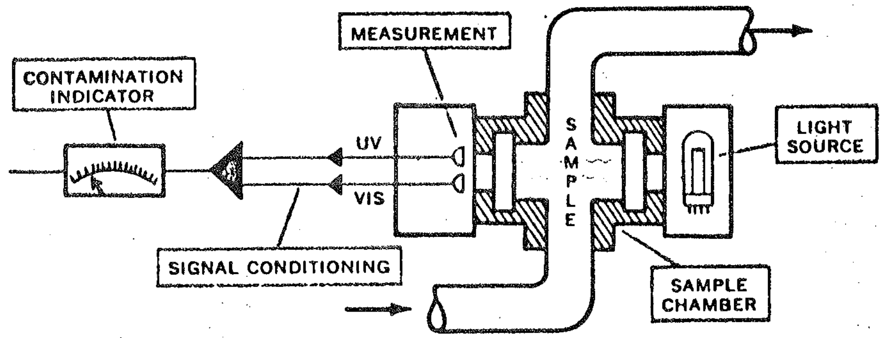

FIGURE I.1 - AQUALERT MODEL - 240

Cost

The base price of the device is $3,250 without the alarm. The manufacturer does not install the system.

I.2 OIL-IN-WATER ANALYSIS SYSTEM

Manufacturer

Teledyne Analytical Instruments
333 West Mission Drive
San Gabriel, California 91776
(213) 283-7181

Operational Characteristics

The TAI oil-in-water analysis system is a dual wavelength ultra-violet analyzer combined with an essential sample conditioning system. The dual beam analyzer employs a reference signal at a wavelength of 4,000 Angstroms where oil does not absorb. Although the reference signal is affected by turbidity, as is the measuring signal (2,540 Angstroms), electronic circuitry within the unit compensates by comparing the two signals and ratioing turbidity to zero. The unit functions as the sample is fed into both sides of a conditioning system for sample preparation. A high-speed, high-sheer homogenizer disperses any oil in the sample, including small and large oil droplets, and oil adsorbed onto foreign matter. A portion of the stream is conditioned to remove all oil (dissolved and undissolved) without altering the background (organic or inorganic non-oil compounds). The analyzer then substracts the background from the total and reads the contribution of oil only. The analyzer is calibrated with a known standard on a one-time basis. Figure I.2 is a sketch of the system.

The unit can be used continuously or intermittently to gain an accurate analysis (±1%) of oil in an effluent stream discharges. The samples are drawn from both sides. A continuous record of oil content is obtained and relays are provided that would permit the use of an alarm system such as a light, bell or siren. The cubicle provides sheidling against cold weather and human interference factors.

Cost

The base price of a standard unit Model 661C is $10,530 whereas an explosion proof unit adaptable for industry which handled flammable liquids is $12,030.

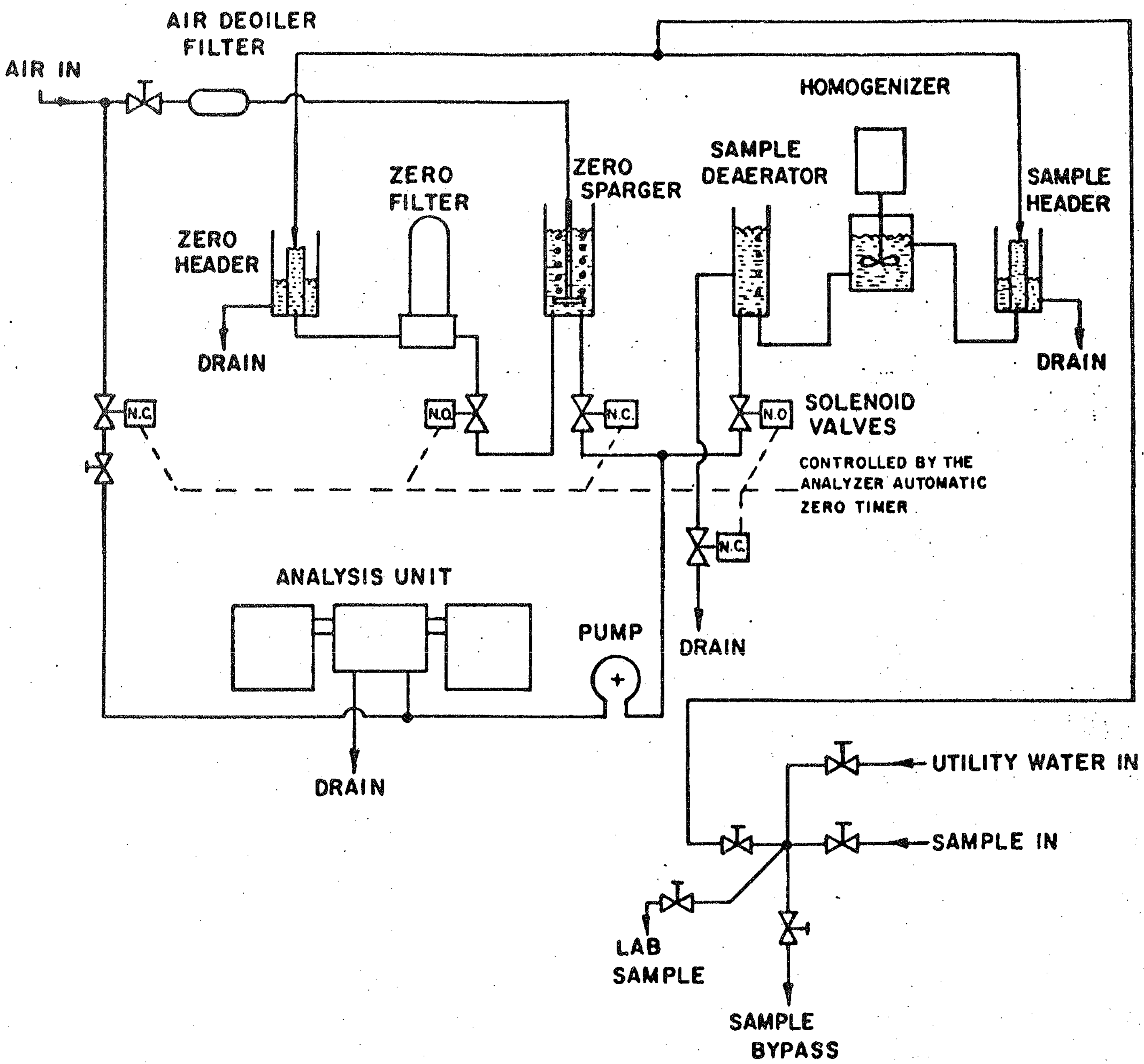

FIGURE I.2 TELEDYNE'S OIL-IN-WATER ANALYSIS SYSTEM

I.3 OIL-IN-WATER DETECTOR AND CONTROL SYSTEM

Manufacturer

Galbraith Pilot Marine Corporation
166 National Road
Edison, New Jersey 08817
(201) 287-2810

The system is also handled and distributed by Pollution Measurements, Inc., 600 Fourth Avenue, Brooklyn, New York 11205, (202) 768-8300.

Operational Characteristics

This is an in-line, direct liquid-sensing type, oil-in-water detector. The unit is self-cleaning, and installed directly in the main pipe stream with no bypass required. The standard system consists of a 1-1/4 inch cell and valve assembly, and control panel. The components are constructed of marine grade materials suitable for use with sea water. The signal alarm point is preset to the desired detection level (normally five parts per thousand); when reached, the relay in the control box is energized, the control system actuated. The unit can be wired to stop pump motors or to operate a solenoid check valve. It could also be designed to divert a contaminated water flow into a temporary retention tank or waste treatment pond or holding basin. It is capable of detecting oil at a level of 5000 ppm. Figure I.3 shows the various components of the Galbraith detection sensor.

Cost

The base price of the panel cell and valve is $1,000 with an additional $800 if a solenoid valve is desired.

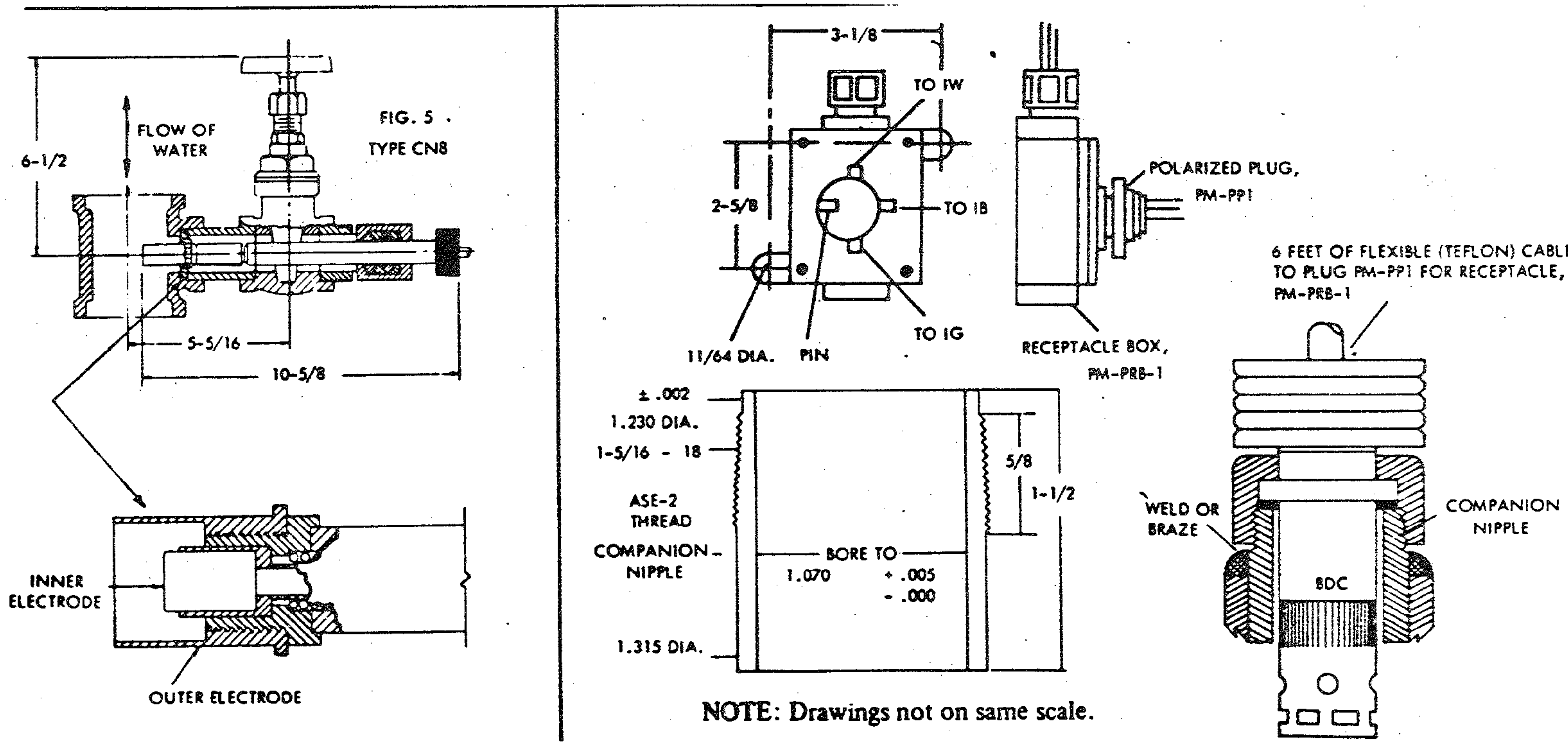

FIGURE I.3 COMPONENTS OF GALBRAITH'S DETECTION SENSOR

I.4 DURHAM OIL DETECTOR SYSTEM

Manufacturer

Durham Associates, Inc.
100 Elm Street
Milford, New Hampshire 03055
(603) 673-6021

Operational Characteristics

The Durham System is a portable, floating, in-the-water type oil and/or petroleum products detection device. The main housing supports a selective permeable membrane at the water line, allowing petroleum products to pass into a receptacle while preventing the penetration of water. The ingested oil coalesces, and actuates an audible, visual alarm in the control receiver. The control receiver can be activated in two ways: (1) Via a cable, up to 1,000 ft in length, or (2) by transmitted radio signal. Detection time is dependent upon slick thickness. For a large spill of crude oil, detection time required to trigger the device may be 30 seconds or less.

The cable unit has the following specifications:

Detector Buoy	Power Supply	None Required
Detector Buoy	Dimensions	16" high (12" draft), 12" diameter
Detector Buoy	Weight	15 lb
Receiver/Monitor	Power Supply	115 VAC, 50/60 Hz
Receiver/Monitor	Emergency Power	External 12 VDC
Alarm Threshold		8 ml collected sample
Alarm Range		1,000 ft

The radio unit has the following specifications:

Detector Buoy	Power Supply	13.5 volt Mercury Cells
Detector Buoy	Dimensions	Same as cable unit, except for 54" antenna mast
Detector Buoy	Weight	17 lb
Receiver/Monitor	Power Supply	110/220 VAC, 50-60 Hz
Receiver/Monitor	Emergency Power	External, 13.6 VOC
Receiver/Monitor	Dimensions	3" X 12" X 18"

Alarm Threshold	8 ml collected sample
Alarm Range	5-25 miles depending upon monitor antenna height
Transmission Mode	16F3, Two-tone sequential
Transmission Mode	148-174 MHz

Cost

The base price of a single channel unit which includes one buoy is $975; a 10-channel unit capable of monitoring ten locations simultaneously again with one buoy, is $1,275. It is possible to connect two buoys if they are not too far apart in parallel to a single alarm. This would be a typical installation for one dock location using detectors at each end of the dock. In the event that the dock and loading or offloading vessel is fully boomed one detector may make an appropriate installation.

I.5 INFRARED OIL FILM MONITOR

Manufacturer

Wright and Wright, Inc.
80 Winchester Street
Newton, Massachusetts 02161
(617) 969-2915

Operational Characteristics

This monitor was developed under USCG sponsorship. It utilizes infrared reflectance at the 3 micron water molecule resonance band to detect floating oil slicks. The instrument consists of a transmitter and a receiver in rugged, cast aluminum housings which are mounted above the water to be monitored. The transmitter projects a light beam to the water surface and the reflected infrared light is analyzed by the receiver. An alarm is activated when oil is detected. If desired, instrument response time can be adjusted to ignore small slicks. The Infrared Oil Film Monitor, Model C, includes an automatic failure alarm and self-test features, and is designed for six months of continuous unattended operation in a harsh environment.

Once installed the system can provide continuous spill detection under any weather conditions. Since the unit, or any of its components does not make physical contact with the water, it is not susceptible to marine fouling or impact damage. It can be mounted on a piling, pier, bridge, or small craft bow with the sheen detection instruments mounted from six to 30 ft above the water. One model is available for use at heights in excess of 30 ft and explosion proof housings can be provided.

An auxiliary piece of equipment, the "Remote Readout Unit," is available. This unit is cabinet mounted and is connected by cable to the Infrared Oil Film Monitor. It is designed to permit the Infrared Oil Film Monitor to activate automatically remote control equipment (e.g. motors, solenoids, skimmers, etc.). With the Remote Readout Unit, a technician at a remote location can observe the status of the Infrared Oil Film Monitor and the water surface below it.

The Remote Readout Unit incorporates the following features:

1. A red lamp (OIL ALARM) to indicate that the instrument has detected an oil film. This lamp is normally off and lights when an oil slick is within the instrument field-of-view. The lamp goes off when the slick has passed.
2. A loud audible alarm sounds when the red lamp (OIL ALARM) is on. The audible alarm can be switched off, if desired.
3. A DPDT relay (with each contact rated at 10 Amps, 115 VAC) is activated when the red lamp (OIL ALARM) is on. This relay can be used to activate remote control equipment when oil is detected.
4. An analog meter readout of the signal processing circuitry of the Infrared Oil Film Monitor.
   Low meter reading - clean water (no oil)
   High meter reading - oil on water
5. A green lamp (INSTRUMENT STATUS) to indicate that the Infrared Oil Film Monitor is operating properly. This lamp is normally on and goes off only when a component failure has occurred within the instrument. The Infrared Oil Film Monitor has been designed for at least six months continuous unattended operation with no maintenance required during this period.
6. Built-in logic to prevent OIL ALARM from activating when INSTRUMENT STATUS lamp is not on.

Figure I.4 depicts a typical installation:

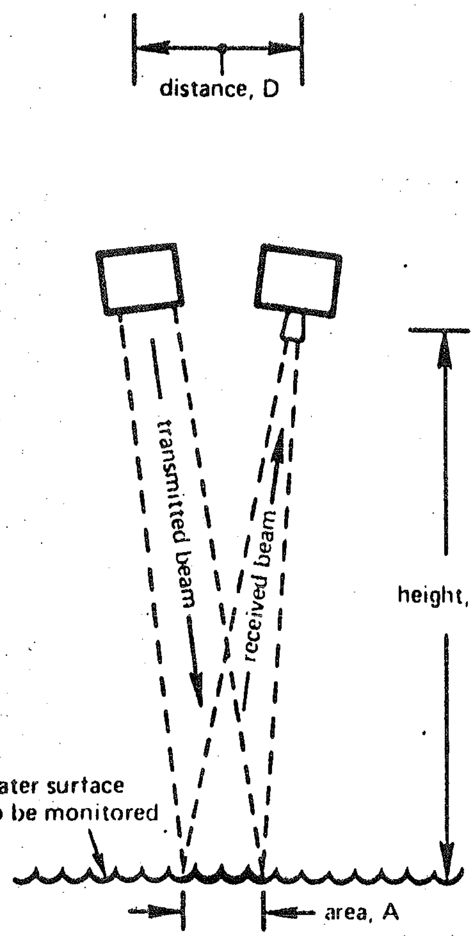

FIGURE I.4 INFRARED OIL FILM MONITOR INSTALLATION

The Infrared Oil Film Monitor is mounted 6 to 30 feet (H) above the water directly above the water surface to be monitored (A) normally one square foot of water surface. The transmitter and receiver are less than 1 foot apart (D) and the tilt angles are within ± 1% off vertical. The tidal range of 8 to 10 ft as experienced in Casco Bay will have no effect on this instrument since it is equipped with an automatic gain control that is activated by any weakening of the signal.

Cost

The following price and delivery information applies to this system and its components as of 9/8/75:

	1-5 units*
Infrared Oil Film Monitor Model C	$ 7,100.00
Infrared Oil Film Monitor Model CX (for operation over 30 feet)	8,400.00
Infrared Oil Film Monitor Model D (Model C in explosion proof housing - not certified)	9,100.00
Infrared Oil Film Monitor Model D (certified explosion-proof by UL or Factory M ual)	Contact factory
Remote Readout Unit Model R	800.00
Additional Transmitters Model FL (in floodlight housings)	720.00
Custom Housings (boat-mounted, etc.)	Contact factory
Rental Units (Model C only) for evaluation or short-term use	Contact factory
For Delivery Information	Contact factory

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* Prices are FOB factory and do not include applicable taxes, duties, insurance and other shipping charges. Prices are subject to change without notice.

The DEP may be interested in an evaluation rental. On this basis, the following rental charges were applicable as of 9/5/75:

<u>Option #1</u>

$710/month* for Model C $80/month* for Remote Readout Unit	Straight rental @ 10% of purchase price per month. 50% of rental fee will be applied toward purchase price if instrument is bought at end of rental period. One-way shipping cost paid by Wright. Return shipping cost paid by customer.

<u>Option #2</u>

same as Option #1 plus $200 and round trip air fare from Boston, Mass.	Instrument delivered to installation site by Wright & Wright. One Wright & Wright engineer will assist customer for three consecutive days in set-up, alignment, calibration, and testing of instrument. Return shipping costs paid by customer. 50% of rental fee plus 50% of air fare will be applied toward purchase price if instrument is bought at end of rental period.

* Rental fees do not include insurance on rental equipment, mounting costs (e.g. hardward, brackets, cabling, conduits...) or applicable taxes.

NOTE: The explosion-proof Infrared Oil Film Monitor, Model D, is not available for Evaluation Rental.

I.6 D-O-W (DISPERSED OIL-IN-WATER) MONITOR

Manufacturer

C-E Invalco
Division of Combustion-Engineering, Inc.
P.O. Box 556
Tulsa, Oklahoma
(918) 932-5671

Operational Characteristics

The D-O-W (Dispersed Oil-In-Water) Monitor provides continuous on-line monitoring of effluent streams, detecting oil in water normally in a range of 0 to 150 ppm, with accuracy of ± 5.0%. The monitor operates effectively to temperatures up to 175°F, and working pressures of 60 psig.

The monitor a dual beam light measuring system which continuously monitors the rate of ultraviolet absorption in the process stream. Clear water transmits UV light with very little absorption whereas most petroleum oils and their derivatives absorb UV either partially or completely. Thus, variations in absorption provide a sensitive and accurate means for the determination of oil contained in water.

Output from the system is displayed on an indicating meter or operational chart recorder. With some modifications, audible and visible alarms could be incorporated in the system.

Power requirements - 95-130 VAC, single phase 60 Hz, 60 watts
Input range (crude, fuel and lube oils) - 0-20 or 0-150 ppm
Maximum Fluid Temperature - 175°F
Ambient Temperature - 40°F to 150°F
Maximum Pressure of Detector Cell - 60 psig working, 100 psig test
Nominal Sample Flow Rate - 1 gpm
Pressure Drop at 1 gpm - 10 psig
Pressure Drop at 1 gpm with static mixer - 20 psig
Detector Cell Connections - 1/4" NPT inlet and outlet
Connections Required in Main Stream Piping - 1" NPT

For use at a loading/unloading pier, the incorporation of a small pump would be required to draw a continuous water sample from the dock area and feed the sample into the monitoring system.

Cost

The base price of a unit with a weatherproof and explosion proof housing is $5,732.83. About 2 weeks lead time can be anticipated following an order.

I.7 OIL SENSOR MODEL I

Manufacturer

Rambie, Inc.
Irving Business Park
1100 E. Airport Parkway
Irving, Texas 75061
(214) 438-6909

Operational Characteristics

The Oil Sensor consists of two major assemblies, the Transmitter-Receiver and Power Supply with interconnecting cables.

The Transmitter-Receiver is mounted at any height between 10 and 100 feet above water, with its optical axis perpendicular to the water surface. An infrared beam is transmitted to the water, then reflected back to the receiver where it is spectrally analyzed at two wavelengths to test for the presence of oil. The Transmitter-Receiver is located where oil spilled on the water surface is likely to be carried past its field of view by natural spreading, wind, water current or waves.

The Power Supply conditions the power line voltage for the Receiver and is mounted at any convenient location. It is connected to the Transmitter-Receiver with an electrical cable. An alarm cable connects the user supplied alarm equipment to the sensor through the Power Supply. The transmitter receives its power directly from the power line.

Two sets of relay contacts, one normally open and one normally closed, are provided through the alarm cable from the Power Supply. The relay changes state when an alarm occurs.

At the user's discretion, the alarm can be actuated when oil is first detected or delayed any period between 1 second and 36 minutes. Two delay alarm modes can be used, when oil is present continuously for a selected period or when oil is present at the beginning and end of a selected period.

The processed +1.0 to -2.5 volt dc signal is available to a load greater than 5,000 ohms.

The sensor continuously checks its power supply voltages, input signal lever and processed output signal. A relay is actuated when any of these voltages are out of tolerance. The relay contacts are provided to the user in the alarm cable.

A circle of diameter .02 times the height is viewed.

Eighty volt-ampere is required from a 115+ 12 volt 60± 5 Hz single phase source.

The operating range is -28°C to +65°C.

Environmental tests have been performed in accordance with Military Specifications MIL-E-164000 and MIL-STD-810B for supply line voltage and frequency variation, +75°C storage temperature, operating temperature, radio frequency, susceptibility and emission, accelerated life, rain, salt fog, sunshine and shock.

The sensor is designed to comply with the National Electrical Code for operation in Class I Division I Group D areas, and to meet the explosive atmosphere tests of MIL-STD-810B, Method 511, Procedures I and II.

Size and Weight:

Transmitter-Receiver:

Weight - 50 lb (22.7 kg)
Size - 26 in. x 16 in. x 12 in. high
(660 x 406 x 305 mm)
Mounting - Three 5/16"-18 (7.9 mm - 18) tapped holes at 120 degree intervals on a 5 in. (127 mm) diameter bolt circle

Power Supply:

Weight - 75 lb (34.5 kg)
Size - 19 in. x 17 in. x 10 in. high
(483 x 432 x 254 mm)
Mounting - Four 1/2 in. (13.7 mm) diameter bolt holes in a 15 3/4 in. x 5 1/2 in. (400/140 mm) pattern

Figure I.5 shows the operation of Rambie's Oil Sensor Model I

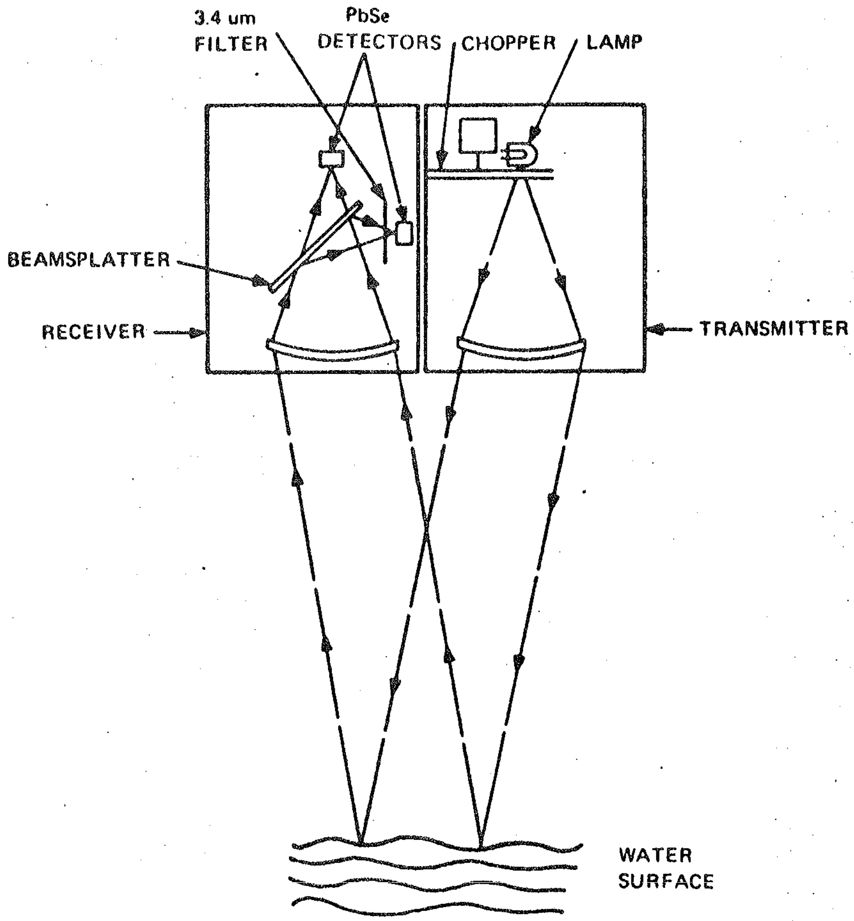

FIGURE I.5 RAMBIE'S OIL SENSOR MODEL I

Cost

The base price is $16,700 FOB Irving, TX and units are available within 120 days after receipt of an order.

I.8 OIL-ON-WATER DETECTOR (MODEL 1479)

Manufacturer

Totco Division of Make Oil Tool Corp.
506 Paula Avenue
Glendale, California 91201
(213) 240-3314

Operational Characteristics

This system was originally manufactured by Hallikainen Instruments of Richmond, California.

This oil-on-water detector consists of two parts, a monitor and a control section. The monitor, which is tethered, floats in the water. Two floating pontoons support an explosion-proof housing. An S shaped baffle provides a path for the flowing surface water through the monitor at the base of the housing. A beam of light is focused through a lens onto the water surface. The resultant reflected light is refocused by another lens onto a photocell. As a hydrocarbon slick appears, the reflected light intensity at this cell increased by 50 to 100%. The measurement is then based on the differential between the reflected light photo-cell and a photo-cell measuring the source lamp intensity. The two cells are used in a bridge circuit, the output of which is converted to a current signal which is transmitted to the control section via a shielded cable. Power is also carried by this cable.

The control section provides an alarm function as well as a 0-10 volt DC output signal proportional to the reflected light intensity. The maximum signal level achieved by a hydrocarbon slick is 7-8 volts. Clean water had approximately a 2 volt output.

The detector response is adjustable at the control section by the setting of a time constant and the desired alarm level. Minimum sensitivity of the unit is 5 or 6 drops of oil flowing on a water surface.

Periodic maintenance is required at the monitor. The lens window should be cleaned every few months. An air column is maintained between the water surface and the window to minimize the effects of splashing. However, to maintain maximum sensitivity, this window must be kept clear. A dirty window is indicated by a reduction in the average signal level from the control section.

Monitor dimensions - 3 ft x 5 ft with pontoons

Cable Length - Maximum 5,000 ft from monitor to control

Power at Control Section - 115 volts, 60 , single phase, 200 watts

External Alarm Contacts - Up to 1 amp at 125 volts

Output to a Recorder - 0-10 volts DC

Response - Adjustable from 5-600 seconds

Approximate Shipping Weight - 300 lb

Ambient Temperature Limits - 32-120°F

Zero Drift - $\pm$2.5%

Housings - Designed for Class I, Group D, Division 1 areas as defined by NFPA

The alarm circuit can be present to any desired signal level and once activated can energize remote visual or audible alarms at one or more surveillance stations.

Cost

The base price for the entire unit less remote alarm installations is in the vicinity of $1,500. The local distributor for the New England area states that the unit has temporarily gone off the market and is undergoing 12 months of evaluation prior to incorporating a number of improvements into the system.

I.9 BENNETT OIL SPILL DETECTION SYSTEM

Manufacturer

Bennett Pollution Controls, Ltd.
119 Charles Street
N. Vancouver, B. C.
Canada

Operational Characteristics:

Detector/Transmitter

The oil detection element is constructed in the form of a loop from a porous oleophilic material. Two pieces of the material are butt joined using an oil soluble, water insoluble adhesive. In the presence of hydrocarbons, the joint parts separate thus permitting the sensing tube to drop and initiate the transmission of the detector signal. The detector element will part within a few seconds of oil contact in the case of #2 or light oil and within one minute in the case of #5 oil or equivalent. Higher viscosity oils have difficulty in penetrating the element and as a result, the unit is not recommended for such oils. The element is replaced by the use of two ball lock pins. Adjustment of the joint line to just above the water level is easily performed.

Each positioned buoy is identified with a three digit number with the first digit identifying its group. Prior to shipping, this number is set into the telemetry system of the transmitter permitting its identification by the receiver. Once the sensing tube has tripped the magnetic switch, the telemetry system and transmitter are automatically turned on. At that time, a double series of coded, two tone frequency shift keyed signals are transmitted. To ensure reception of the signal, it is repeated after twenty seconds and every minute thereafter. The system provides a high degree of security and permits reception even in the presence of other transmissions.

Because the security of the system is considered to be extremely important, a battery level check is provided. Should the battery voltage drop below the required operating level, the transmitter will initiate a separate signal. This results in a flashing visual display and the lighting of the 'Low Battery' indicator on the receiver.

To ensure water tightness, an air valve is installed which permits pressurizing of the transmitter capsule and checking for leakage. To minimize damage to seals, the unit has been designed to be charged through the antenna. Similarly, an 'On-Off' switch is provided which is activated by a magnet mounted in a plastic holder, screwed into a blind hole on the top of the transmitter capsule.

Detector/Receiver

Each receiver is coded to accept signals from a group of monitoring buoys. Upon receiving a signal from a buoy, the receiver automatically scans the message for accuracy and coding. Should the incoming signal match the group coding of the receiver and not contain and coding data errors, the number of the signaling buoy is displayed on the console of the receiver, the oil spill indicator light is illuminated, and the external alarm contacts close. Subsequent signals are displayed as they arrive with the preceding signals being moved into the storage register. Messages stored are shown by indicator lights which are numbered from one to four. Pushing the 'Cancel' button permits the recall of the preceding messages. This memory feature allows more than one buoy to signal into the receiver without loss of a message and permits determination of the size or direction of travel of a spill when a number of buoys are being used.

When incoming signals are not coded to match the receiver coding the signal is ignored. When the signal approximates the receiver coding but contains a data error, which is determined by the receiver logic, the buoy number is displayed in a flashing mode and the 'Data Error' indicator is illuminated but the external alarm contact will not close.

The receiver is not fitted with an 'On-Off' switch in order to prevent the inadvertent shutting down of the receiving system. A small light appearing in the upper display window indicates 'Power On'. To ensure that all lights are operational, a 'Lamp Test' button is provided. Should it be desired to listen to the channel of the system in operation, the 'Audio Test' button may be pressed and locked into position. When the 'Audio Test' button is released, all background noise is filtered out and the distinctive noise of the frequency shift keyed (FSK) signal is heard. This may be turned off by pressing the 'Audio-Off' button.

An antenna is provided for use with the receiver. In some instances, it may be preferred to use a remote antenna, which has proven to be satisfactory.

The power input is normally set for 110 volts AC with a normal draw of 1/10 ampere. When desired, the receiver can be provided with a 220 volt AC connection.

Cost

The base price of the unit is as follows:

Oil spill detection transmitter - $1,600.00

Oil spill detection receiver - $1,600.00

F.O.B. Vancouver, B.C.

NOTE: 10% import duty applicable for deliveries within USA

I.10 OIL DETECTION SYSTEM

Manufacturer

Spectrogram Corporation
385 State Street
North Haven, Connecticut 06473
(203) 281-0122

Operational Characteristics

The system operates on the principle of petroleum products exhibiting a fluorescent characteristic when subjected to high energy activation. When an oil sample is irradiated with high energy emission such as short wavelength ultraviolet or x-ray energy, the sample will absorb a portion of the excitation energy and reradiate lower energy of a longer wavelength such as visible light. Since both the wavelength of maximum energy absorption and the wavelength of reradiated energy are a function of the molecular composition of the oil, the oil detection buoy provides an alarm signal upon the detection and identification of a specific oil type.

The basic system consists of a land station, 3 buoys (2 simultaneously operational, one stand-by) and the interconnecting cables. The land station or main console contains the power supplies, strip chart recorders and the alert/alarm logic circuitry. Each buoy contains an excitation energy source, a multi-channel optical detection system, solid state detectors, integrated circuit photometric amplifiers and logic circuitry, and various local power supplies. The buoys derive operating power from the main console via the interconnecting cable. This waterproof cable also carries the necessary data signals from the buoys to the console recorders and the alert/alarm network, thus providing final contact closures for external and remote indications such as lights, audible alarms, or the "shut-down" of the transfer pumping system.

The units have had a 12 month test period under varying weather conditions. One system was installed at a tidal river location, and the second at a barge loading/unloading dock.

The basis system typically included three oil detection buoys, one land based recorder/power console, and the required interconnecting waterproof cable.

Cost

An oil detection buoy consists of a flotation housing and an electro-optical sensor head. The sensor head is a completely sealed unit and contains the detection optics and all electronics including threshold and alarm circuitry. The oil detection buoys are priced at $3,650.00 each.

The land based recorder/power console is capable of providing power and recording the signal levels from two operating buoys. The recording signal levels provide a permanent record of the area under surveillance. Included in the land system is an audible alarm that indicates a buoy has detected oil. The console operates from 115 volts, 60 Hertz, AC and provides the 12 volt DC power required by the buoy. The land console is priced at $950.00

Additionally a five wire waterproof cable is required to interconnect the oil detection buoy to the land based console. This cable is priced at $5.00 per foot, and depends upon the specific installation.

The manufacturer/supplier normally provides a two day installation, supervision and training period that also covers the routine maintenance requirements. This training and installation program is priced at $525.00 plus travel expenses. Instruction and operating manuals are provided.

Therefore, a system consisting of 3 oil detection buoys, one land station, 500 feet of interconnecting cable and installation and training has a selling price of $14,925.00. Delivery is nominally 90 days ARO and is FOB North Haven, Connecticut.

I.11 MULTISPECTRAL ACTIVE/PASSIVE SCANNER

(Fluorescence Oil Spill Detector)

Manufacturer

Baird-Atomic, Inc.
125 Middlesex Turnpike
Bedford, Massachusetts 01730
(617) 276-6140

Operating Characteristics

The oil sensor projects a beam of ultra-violet radiation and simultaneously observes the fluorescence emitted by oil on water. To overcome the effects of varying range, natural sea fluorescence, atmospheric conditions, and lamp aging, the ratio (rather than the amplitude) of the observed fluorescence in two spectral regions is used to determine the presence and type of oil.

Recent tests indicate a maximum useful range of 600 feet at night and 30 feet in daylight with 6 month lamp life. A range of 900 feet has been achieved, but with a lamp life of 4 hours continuous use.

Head - 24" W x 30" D x 12" H, 95 pounds

Base - 24"W x 30" D x 24" H, 110 pounds

Power - 110 VAC, 60 Hz, 1400 watts

Operating Temperature - -30 to 120° F

Environment - Waterproof, oilproof, dustproof, explosion proof, (internally pressurized with dry inert nitrogen, pressure switch power interlock)

Lamp Life - 6 months (12 hours per night)

Because light is mostly reflected at shallow illumination angles, fluorescence cannot be effectively stimulated within 6 degrees of the horizon. Thus, to achieve a range of 600 feet, the detector must be at least 60 feet above sea level to provide an illumination angle of more than 6 degrees. This maximum ration (10:1) of range to height represents one of the major installation considerations in some applications. The following specifications would fall into a preliminary category.

Range - 600 ft maximum, less in fog

Hours of Operation - 45 minutes after sunset to 45 minutes before sunrise

Elevation Scan - 6 to 30 degrees below horizon (adjustable) at 0.5 degrees per second

Azimuth Scan - ± 150 degrees (adjustable) at 2.5 degrees per second

Scan Patterm - Programmable

Alarm Criteria - Detection on two consecutive scans

Beam Size - 0.5 degrees elevation x 1.5 degrees azimuth (projects to maximum of 50 x 25 ft. on sea surface at 600 ft. and 6 degrees below the horizon)

Minimum Spill Size - 75% of beam area

Minimum Spill Thickness - 1 micron (at maximum range)

Display - Remote via RF or wire

Indicators - Power On
Equipment Active
Equipment Failure
Oil Alarm
Oil Type
Position

Cost

The base price of a unit has been established at $35,000 for the initial unit although this price would probably drop to $25,000 once production was underway.

Motorola AR.81 FM transmitter alarms are available at $2,000 which greatly reduce the expense of a travel line.

I.12 SPILL SENTRY

Manutacturer

Sentry Systems, Inc.
5202 Ashbrook Street
Houston, Texas 77036
(713) 661-0216

Operational Characteristics

Rather than being classified as an oil sensing system, this product would fall under the category of a spill prevention unit. It comprises a system of power actuators that operate loading valves and controls associated with tanker or barge loading operations. A master panel incorporates controls for opening, closing or throttling loading valves. It is also equipped with an "Emergency Shut Down Knob" (ESD Knob); the actuation of which shuts down the entire loading operation immediately. A lightweight hand carried "emergency station" equipped with one ESD knob on either the dock or the on-loading vessel can shut down the entire loading process once a potential spill has been sensed or is imminent.

Normally the manufacturer would send a company representative to survey and measure the dock, pipelines and valving to determine where the various mountings would be located and to determine the engineering requirements for either cylinder or rotary actuators for adaption of existing valves. This action can be eliminated if the plant can provide a detailed engineering description of the dock and its loading equipment.

Figure I.6 indicates a typical installation of the system.

The Control Valves F. in the power circuit, are located on the Master Panel, and are positioned manually to open, close, or throttle the Loading Valves J. Speed Controls H govern the opening and closing rates. For gate valves, the closing thrust, supplied by Actuator I, is limited by Regulators C2, to assure that force for opening Valves J will be greater.

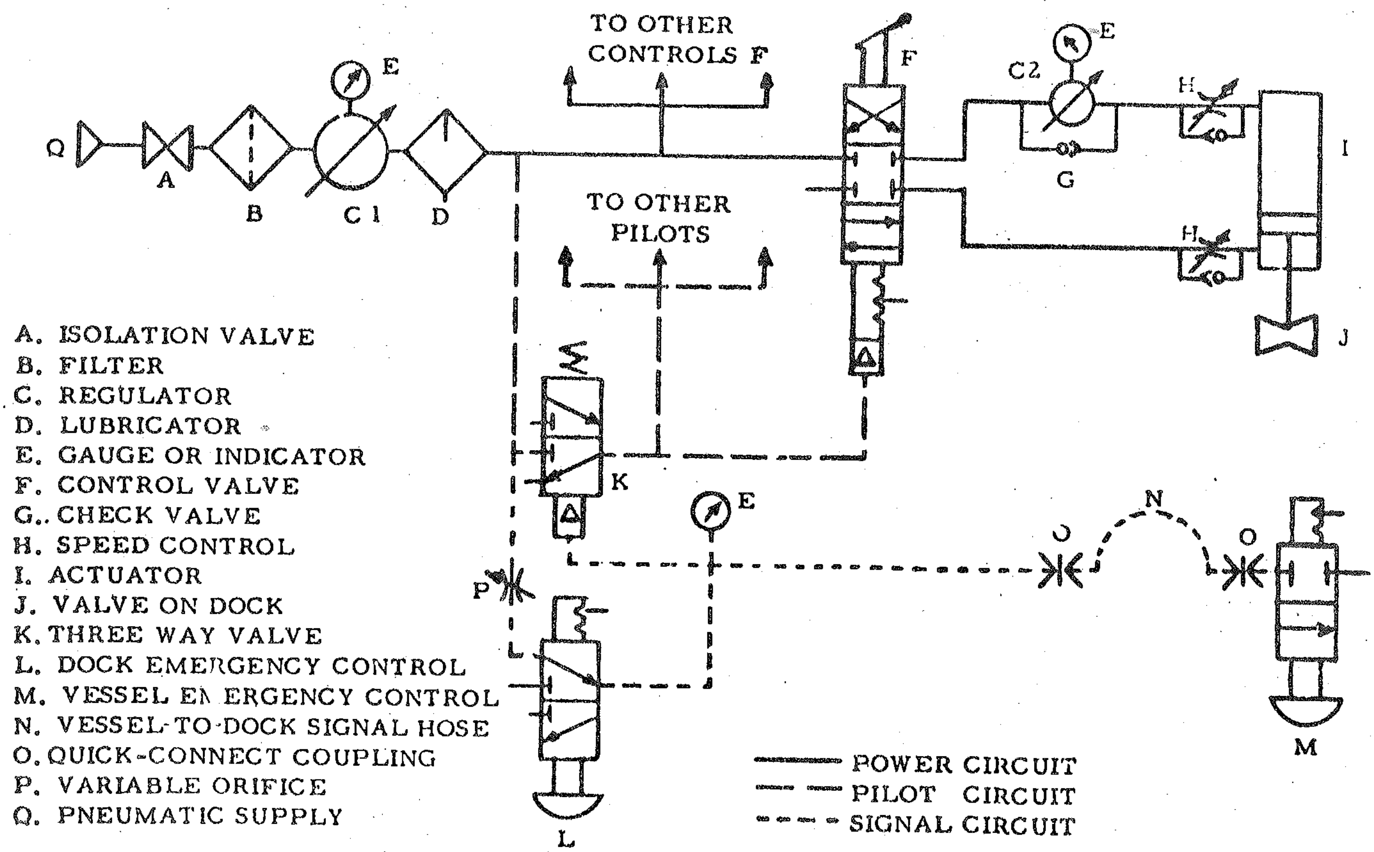

FIGURE I.6 SPILL SENTRY

During normal operation, pressure is maintained in the signal circuit, holding Valve K in the position shown. Actuation of Valves L or M, or breakage of the Hose N, as by excessive motion of the vessel, results in the loss of signal pressure. This causes Valves K to shift, thereby initiating Emergency Shut Down.

When Valve K shifts, pilot pressure is applied at Valves F, shifting them to the extreme out position. This closes (or opens, if so intended) Valves J, shutting down the loading operation. Valves J can be reset only from the Master Panel.

Not shown are other devices which can be incorporated in the system. Among these are sensors to detect level of liquid in the tanks, to automatically initiate EDS, sound an alarm, or perform other functions, such as shutting off pumps. Similarly, protective devices can be included to respond to excessive flow, pressure, explosive vapors, fire, or other undesirable or unsafe conditions.

Cost

It is difficult to present a base price since the installation would differ by terminal; however, an average loading dock having 8 to 16 flow control valves would cost in the vicinity of $1,000 a valve to modify into an automated system.

DATE DUE
GORHAM CAMPUS

[redacted]