National Oceanic and Atmospheric Administration and National Marine Fisheries Service Position in Opposition to the Siting of an Oil Refinery by the Pittston Company of New York at Eastport, Maine

by

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1. INTRODUCTION

The Pittston Company of New York (Pittston) proposes to construct and operate an oil refinery at Eastport, Maine (Figure 1). The Environmental Protection Agency (EPA) issued in June 1978 the final environmental impact statement (FEIS) on the issuance of federal permits for Pittston to proceed with the project. The EPA intends to issue in the near future the National Pollution Discharge Elimination System (NPDES) permit to Pittston.

The National Oceanic and Atmospheric Administration (NOAA) and the National Marine Fisheries Service (NMFS) oppose the issuance of the NPDES permit. Legislative authorities for the opposition are the Fish and Wildlife Coordination Act of 1958 and the National Environmental Policy Act of 1969. The EPA criteria for the denial of the NPDES permit are whether "the risk of environmental harm at the site is appreciably greater than the risk presented at other reasonable available alternative sites," and whether "the quality and scarcity of the resources at risk is such that no significant threat to their impairment should be incurred." Both NOAA and NMFS feel that these criteria are met.

To support the NOAA and NMFS opposition to the EPA issuance of the NPDES permit to Pittston, this position paper discusses: (1) the environment, resources, and related economics of the area; (2) the risks of refinery construction and operation; and (3) the environmental, resource, and related economic impacts of refinery construction and operation.

2. ENVIRONMENT, RESOURCES, AND RELATED ECONOMICS OF THE AREA

2.1 HYDROGRAPHY

Circulation near Eastport is dominated by strong tidal currents associated with 18-foot tides and accompanied by weak residual, or net, drifts (Canadian Department of the Environment 1974). Current-meter measurements at about 5 and 15-meter (16 and 49-foot) depths about two kilometers (1.3 miles) off Eastport in Friar Roads (Figure 2) showed stronger currents at flood tide (up to 4.0 knots) than at ebb tide (up to about 3.0 knots). The tidal excursions associated with these currents are about 9 to 10 kilometers (5.6 to 6.3 miles) in channels and greater in shallower water. The amount of water moving north in Grand Manan Channel during the flooding tide is far greater than the intertidal volume of the Passamaquoddy Bay area, which means residence time of water in the region will be short. The rough bottom configuration in the area would interact with the strong tidal currents to produce very turbulent flows.

The residual circulation as portrayed by drift-bottle recoveries is seasonally variable, with wind patterns from the southwest in summer and northwest in winter being the principal cause of variation. However, in all seasons there is a net surface flow southeastward down Western Passage from Passamaquoddy Bay, past Eastport, toward and around Campobello Island, then into a clockwise loop around The Wolves and southward along Grand Manan Island and the Maine Coast. From there the flow can either continue southerly across to the Nova Scotia shore or westerly along the Maine Coast. In the first case it would then move northeastward into the Bay of Fundy on the Nova Scotia side and then move out along the New Brunswick shore, at speeds of 5 to 10 nautical miles per day. If it went to the west it would most likely remain near the coast, to be caught up in the generally counterclockwise pattern of the Gulf of Maine gyre. The gyre is strongest in early summer and weakest in winter.

2.2 HABITATS

The FEIS states that the refinery would transport its refined products to markets throughout New England by sea rather than by land. The selection of this mode of operation stems from certain site-related conditions in the Eastport area--the long distance to its markets (e.g., Boston, New York) and the resultant economic noncompetitveness of the land-based transportation networks (e.g., highways, railroads). Thus, the marine habitats vulnerable to refinery operations at the Eastport site are significantly increased to include those along the East Coast between the on-loading and off-loading points of refined oil. And, because the Eastport site has outflowing waters that can enter either alongshore tidal currents or the Gulf of Maine gyre, site-related activities can impact the marine habitats of the northeastern states boardering the Gulf of Maine and of southeastern Canada.

In the Passamaquoddy Bay area alone (Passamaquoddy Bay exclusive of the St. Croix estuary above St. Andrews, New Brunswick; Western Passage; and Cobscook Bay), there are 90 square miles (58 thousand surface acres) of surface waters during high tide(Anonymous 1959, 1961). Fourteen (nine thousand surface acres) of these 90 square miles are in the intertidal zone. The FEIS partitions the Passamaquoddy Bay area into six habitats -- salt marshes; intertidal mud, sand, and cobble flats; intertidal rocky shorelines, headlands, and rock outcroppings; benthic habitats; high velocity channels; and bays.

The FEIS treats each of these habitats individually to evaluate its uniqueness, and finds that no individual habitat is unique because it is also found elsewhere. However, when these habitats are evaluated collectively, they are unique because of their close association. For example, nowhere else along the Atlantic Coast of the United States can recreational fishermen catch ocean perch (Sebastes marinus) from the shoreline. The ocean perch inhabits these inshore waters because of the close association of cold temperatures and shallow depths. The FEIS does note that "the Cobscook Bay (area) has been described as unique in that though all of the organisms found in the (coastal) waters of states to the south are found there, the existing marine environment is in a condition similar to that which probably was present in Southern New England about a century ago." Additionally, the FEIS states that "the Passamaquoddy Bay (area) does provide extreme bathymetric variability, high species richness, and a relatively clean environment."

2.3 ORGANISMS

The organisms and the communities that they compose at the Eastport site specifically and in the Passamaquoddy Bay area generally are diverse and unique. This diversity of organisms and communities stems from the aforementioned diverse habitats, variable bathymetry, clean environment, and extreme tides. This uniqueness comes from the association of deep cold waters with nearshore environments. This latter association produces an assemblage of organisms that are unusual so close to shore and components of easily disturbed food webs. For example, krill (Meganyctiphanes norvegica), which usually inhabit offshore arctic and subarctic waters and which are reconized by the FEIS as extremely delicate organisms, occur in the Passamaquoddy Bay area and attract such predators as the ocean perch and the endangered right whale (Eubalaena glacialis) into these inshore waters.

To describe those organisms of the Passamaquoddy Bay area with major economic or ecological significance, three groups will be considered--plankton, benthos, and nekton. Plankton is comprised of organisms which are at the mercy of currents and which fall into one of three groups--phytoplankton (plant plankton), zooplankton (animal plankton), and meroplankton (planktonic life stages of benthic invertebrates and fishes). Canadian Department of the Environment (1974), Legare and MacLellan (1960), and Fish and Johnson (1937) have shown that the thorough mixing of the area's waters increases turbidity and reduces light penetrati which reduces phytoplankton abundance. This phytoplankton scarcity keeps the zooplank abundance low, although zooplankton species diversity is high. Zooplankton are least abundant in the spring and most abundant in the summer.
Copepods compose 79 percent of the zooplankton and are a major prey item for juvenile Atlantic herring (*Clupea harengus*). Six species of copepods, three immigrant species and three endemic species, respectively, account for 94 percent of the copepod biomass: *Calanus finmarchicus*; *Pseudocalanus minutus*; *Centropages typicus*; *Totanus discaudatus*; *Acartia clausi*; and *Eurytemora herdmani*.

Meroplankton is a significant portion of the planktonic community. Twenty-two area fish species have planktonic eggs and/or larvae, including several of current importance in the area's fisheries--Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), hake (*Urophycis* sp.), silver hake (*Merluccius bilinearis*), American plaice (*Hippoglossoides platessoides*), winter flounder (*Pseudopleuronectes americanus*), witch flounder (*Glyptocephalus cynoglossus*), and Atlantic herring. Numerous benthic invertebrates have planktonic early life stages including several of economic importance--American lobster (*Homarus americanus*), northern shrimp (Pandalus borealis), sea scallop (Placopecten magellanicus), softshell clam (Mya arenaria), blue mussel (Mytilus edulis), sandworm (Nereis virens), and bloodworm (Glycera dibranchiata).

The benthos (bottom-dwelling organisms) of the area is dominated by boreal species. There are also both arctic and warm temperate species. These species occupy all habitats in the area. The available information attests to a rich abundance as well as to a wide variety of benthic fauna. Perkins and Larsen (1975) assembled a checklist of marine and estuarine invertebrates of the Maine Coast. It contains 767 species and indicates where each species occurs. More recently, McKay (1976) (taken from the FEIS) compiled a list of 836 species of invertebrates that inhabit the Passamaquoddy Bay area. Several thousand species will be added to this faunal list when taxonomic studies of the smaller organisms (Foraminifera, Ciliata, Nematoda, etc.) are conducted.

A study of the subtidal invertebrate fauna at Eastport, Maine, conducted by Plymouth State College, found the following species to be common: jonah crab (Cancer borealis), rock crab (C. irroratus), American lobster (Homarus americanus), hermit crabs (Pagurus acadianus and P. pubescens), barnacle (Balanus balanus), sponges (Porifera), hydroids (Hydrozoa), polychaete worms (Ammotrypane aulogaster, Myxicola infundibulum, and Sabella crassicornis), periwinkles (Littorina littorea, L. obtusata, and L. saxatalis), top shells (Margarites groenlandica, M. costalis, and M. helicna), chiton (Ishnochiton albus), clams (Mya truncata, M. arenaria, Hiatella arctica, and H. striata), mussels (Mytilus edulis, Musculus discors, and Modiolus modiolus), sea scallops (Placopecten magellanicus and Chlamys islandicus), starfish (Asteroiea), sea cucumber (Holothuroides), and green sea urchin (Stongylocentrotus drobachiensis).

In the intertidal zone, many species of periwinkles, limpets, mussels, clams, and worms dominate the habitat. In the silt-clay subtidal areas, polychaete worms, chitons, brittlestars, sea cucumbers, sea urchins, amphipods, and bivalve mollusks are the dominant invertebrates. In the rocky intertidal zones, which are often covered with algae, dense populations of snails, anemones, mussels, and barnacles exist.

Benthic invertebrates constitute some of the most valuable natural resources of the eastern Maine region. Representatives of three major groups (crustaceans, mollusks, and worms) are of significant commercial value at the presei time; echinoids are potentially valuable for commercial purposes. Those species of particular economic value are the American lobster, northern shrimp, sea scallop, softshell clam, blue mussel, sandworm, and bloodworm.

Nekton are free-swimming animals and are divided into fishes and marine mammals. Over 70 species of fish inhabit the Passamaquoddy Bay area, 50 percent of them are year-round residents. Those of economic importance are listed below with comments on the type of fishery and importance of the area's habitats to the species in parentheses: Atlantic herring (most important commercial fishery, major nursery area); Atlantic cod (major commercial and recreational fishery); pollock (major commercial and recreational fishery); haddock (major commercial fishery); winter flounder (major recreational fishery); American plaice; witch flounder; yellowtail flounder (Limanda ferruginea); Atlantic halibut (Hippoglossus hippoglossus); ocean perch (major recreational fishery); Atlantic salmon (Salmo salar) (major recreational fishery, Dennys and St. Croix Rivers have self-sustaining populations, Dennys River is the most important American spawning habitat for the species, the waters around Eastport are very likely important staging grounds for adult fish for up to three months prior to their ascending the Dennys River for spawning, the waters around Eastport are just as likely important transition grounds for up to three months for smolted juveniles prior to their adopting an oceanic existence); alewife (Alosa pseudoharengus); rainbow smelt; Atlantic mackerel (Scomber scombrus); American eel (Anguilla rostrata); and tomcod (Microgadus tomcod).

For marine mammals, seven cetacean species and two pinniped species are common to the Gulf of Maine - Bay of Fundy region and can be encountered at the Eastport site; another 14 cetacean species occur occasionally or only rarely (Katona et al. 1975; Leatherwood et al. 1976) (Table 1).

The harbor porpoise is the most numerous cetacean at the site (Katona et al. 1975). Ecologically it can be defined as a boreal-temperate zone species, common in bays, estuaries, and tidal channels (Gaskin et al. 1974). The diet is mainly smooth, non-spiny rayed fish which are 100-250 millimeters long, especially gadoids and clupeoids. The major dietary items in the western Bay of Fundy are Atlantic herring, pollock, Atlantic mackerel, hakes, and some squids (Sergeant and Fisher 1957). Little is known of the breeding behavior. Copulation and parturition occur in the spring.

Pilot whales and white-sided dolphins are the only other toothed whales commonly occurring at the Eastport site. Although considered common, they are not abundant and rarely occur in large numbers (Geraci and St. Aubin 1977). There was, however, one large stranding of 69 white-sided dolphins at Cobscook, Maine, in 1974 (Prescott et al. 1977). Both species eat fish, occur in shallow and deep water, and are seasonal breeders.

The remaining cetaceans are baleen whales. Of these, the minke whale is probably the most numerous and may approach 80,000 animals in the North Atlantic (National Marine Fisheries Service 1978). It is reported fairly frequently in the Bay of Fundy region and commonly approaches the shore. Of the four baleen whales, the minke is probably the most dependent on fish, although humpback, fin, and right whales commonly consume small fish (juvenile Atlantic herring, anchovies (*Anchoa* spp.), etc.).

Fin and humpback whales are routinely sighted in the Bay of Fundy, with the fin whale seen in the late spring to late summer in nearshore waters (Perkins and Whitehead 1977). Fin whales migrate to southern latitudes in winter. The current North Atlantic population is about 10,000 animals (National Marine Fisheries Service 1978). Fin whales are second in size only to the blue whale and are currently one of the most valuable baleen whales commercially. The International Whaling Commission (IWC) 1978 quota for the North Atlantic population is 470 animals. They feed mostly on krill, but often eat fish, especially anchovies and capelin (*Mallotus villosus*). Mating and calving occur in winter.

Humpback whales make extensive seasonal migrations between high latitude summering grounds and low latitude wintering grounds--the latter around continental coasts or around islands. The western North Atlantic population is estimated at about 1,000 animals(National Marine Fisheries Service 1978).

Right whales inhabit all temperate waters of the world and migrate between summering grounds in cool temperate water, and wintering grounds in warm temperate waters (Reeves et al. 1978). They occur pelagically and along the coast, commonly sighted near shore in the Bay of Fundy region.

They were originally abundant, but were reduced extensively by heavy exploitation. The present worldwide population is probably less than 5,000 animals (National Marine Fisheries Service 1978). There is no estimate for the Northwest Atlantic population, but it probably does not exceed a few hundred. They feed primarily on copepods, near the surface, although some small fish may be taken (Watkins and Schevill 1976).

Harbor seals are a common northern hemisphere, temperate water animal and are quite common in the Bay of Fundy region. There are 6,000 plus animals in Maine and 5,000 - 6,000 in the Canadian Maritime Provinces (Richardson 1976; Katona et al. 1975). They are seashore residents of bays and estuaries, commonly seen resting on low rocks and ledges. They are nonmigratory, but disperse widely after breeding in the spring (Loughlin 1978). Their diet is catholic in that they consume pelagic, demersal, and anadromous fishes, cephalopods, and crustaceans.

Gray seals, a more northern species, are less common than the harbor seal near Eastport. A seasonal population of 100 plus may occur in the United States Gulf of Maine on remote coastal ledges and sand shoals (Gilbert 1977; Katona et al. 1975). They disperse widely after spring and summer parturition along the shores of the Canadian Maritime Provinces, presumably accounting for the animals sighted along the coast of Maine. Their breeding habits are similar to harbor seals.

Significant numbers of marine mammals utilize the food of this area at all trophic levels and as an important reproductive and nursery ground. Harbor and gray seals are dependent on the large fish populations for food and they feed throughout the water column consuming pelagic and demersal species. The toothed whales similarly consume many nearshore and deepwater fish and cephalopods. The baleen whales feed throughout the water column. Right whales feed primarily near the surface on copepods and krill, humpback and minke whales feed occasionally near the surface but more commonly below the surface and at midwater, and the fin whale feeds near the middle of the water column.

Harbor seals and harbor porpoises, which are nonmigratory, utilize the area for reproduction and as a nursery ground. Parturition occurs within the confines of the Bay of Fundy, and after weaning, the young-of-the-year rely on the abundant fish and cephalopod populations for food. Since these seals and porpoises are not migratory, they depend upon the area for food and shelter year-round. Most of the other marine mammal species mentioned above utilize the area in spring and summer as principal feeding grounds prior to migrating to more southern latitudes in the fall and winter.

Since the Eastport - Bay of Fundy complex is important to so many marine mammals, it is important to note the population status of three baleen whales that occur in the area. The fin, humpback, and right whales are listed as endangered pursuant to the Endangered Species Act of 1973. They are protected internationally by being listed in Appendix I of the Convention of International Trade of Endangered Species of Wild Flora and Fauna. The right and humpback are considered by the IWC as protection stocks, and the IWC quota for fin whales is zero for all oceans except the North Atlantic where a take of 470 is allowed.

2.4 USES

The major uses of the environment and resources are commercial fishing and outdoor recreation. Outdoor recreation is closely tied with recreational fisheries. Recreational catches are not included in the statistics presented in the discussion of fisheries to follow because such estimates are available only for New England as a whole.

Recreational opportunities abound in the area. Camping, hiking, hunting, fishin boating, and snowmobiling are available. Special recreation and tourist areas ring the shores. The FEIS lists six institutionalized outdoor recreation areas that now exist (Moosehorn National Wildlife Refuge, Quoddy Head State Park, Cobscook State Park, Gleason Point, Reversing Falls Park, St. Croix National Monument, and Roosevelt Memorial Park). Others have been proposed, however (Deer Island National Marine Park St. Croix International Wild River Park, Machias Seal Island International Wildlife Refuge, and Eastport Harbor National Marine Sanctuary). If the latter proposal were accepted, then the proposed refinery would be located almost dead center in the 16-square-mile sanctuary.

Due to lack of available American tourist information, the discussion offered below deals entirely with southwestern Charlotte County (Canada). Canadian recreatior centers include 57 facilities with 881 units. Campgrounds offer an additional 400 site at 10 locations (Porricelli et al. 1971; McInnis 1976). These are in addition to extensive local, state, and federal recreational holdings and private homes and campsites. About two million people traveled to use these facilities in 1975. Of these, approximately 60 percent were American citizens. They spent over four million dollars in 1975, resulting in an impact of about 11 million dollars and more than 650 jobs. Surveys indicate that more than one-third were there primarily for water-related activities, such as swimming and fishing.

As with tourism in general, little quantified information is available on recreational fishing. In Canada, offshore fishing in rented vessels involves fewer than 10 party or charter boats. However, privately owned craft enter the area in numbers and are used extensively for Atlantic mackerel and ground fishing. The St. Croix and Dennys Rivers are known for Atlantic salmon fishing.

Just as with the habitats, the commercial fisheries vulnerable to the oil refinery operations must include those along the Northeast Coast between the on-loading and off-loading points of refined oil, and within the oceanic currents of the Bay of Fundy and Gulf of Maine. However, if one were to limit the discussion of fisheries, as the FEIS did, to only those in the Bay of Fundy, the FEIS would nonetheless still underestimate the landings and values of those fisheries. Landings from Washington County, Maine, and Charlotte County, New Brunswick (Canadian data are included because neither fish nor spills recognize political boundaries), do not portray the Bay of Fundy fisheries resource, since they do not include catches from the Bay which were landed at ports outside the area. The Washington and Charlotte County invertebrate catch does portray the value of those species at least for the western shore of the Bay since practically all invertebrates are sold locally. The finfish catch, however, cannot be similarly interpreted. For example, Washington County groundfish landings are only 25 percent of the United States groundfish landings from the Bay in 1975. In the case of haddock and pollock, Washington County accounts for only 10 percent of the United States catch from NMFS statistical area 511 alone (Figure 3). The Atlantic herring fishery, however, is conducted locally and, in this case, the Washington County landings do portray the total United States catch from the Bay.

Also, due to the recent price rises and shifts in the relative commercial importance of certain species, the use of landings data only through 1975 contributes to an underestimate of the current value of the Bay of Fundy fishery resources.

The FEIS used incomparable sources of landings statistics. Because of the non-additive nature of the landings statistics, the FEIS could not provide total landings and values for the Bay by country for many species. By using the raw data for NMFS statistical areas 466, 467, and 511, however, the current status of the fisheries of the area can be determined (Figure 3). Between 1975 and 1977, the total United States catch increased by 52 percent (Table 2) and the value increased by 38 percent (Table 3). A doubling of the United States Atlantic herring catch and a 34 percent increase in the value of the United States invertebrate catch accounted for these increases. Canadian landings decreased by 26 percent and the value increased by 228 percent. These changes occurred primarily as a result of a large increase in the Canadian invertebrate catch (primarily sea scallops) and a decrease in the Canadian Atlantic herring catch. A concurrent increase in sea scallop prices increased the value of the Canadian invertebrate catch from 1.6 million dollars in 1975 to 27.7 million dollars in 1977. Thus, the combined United States-Canadian invertebrate catch increased by more than 230 percent while the value exhibited more than a fourfold increase. Although the combined Atlantic herring catch declined, the value rose by 63 percent. The value of Atlantic herring catches is being affected by a change in the Canadian use of this resource. In 1975 Canada invoked quotas and instituted management practices to improve the fishery and reestablish preferred market areas. At the time of implementation, about 98 percent of the catch was directed to reduction processing where the price was about 25 dollars per ton. In 1977, two percent of the catch went to reduction and 98 percent for human consumption. Canadian ex-vessel price is now 225 dollars per ton. World market price is now 400-600 dollars per ton. Groundfish catches from the Bay, however, remained relatively constant during this period.

The overall effect of these changes is a decrease in the total Bay of Fundy landings estimate from 152,563 metric tons in 1975 to 118,264 tons in 1977 principally as a result of declining Atlantic herring landings. However, the total value of the landings increased from 19.6 million dollars to 50.7 million dollars during this period. This increase resulted from the combined effect of rising prices and the substantial increase in sea scallop landings.

The importance of the fishing industry to the local economy is apparent when one considers that the percentage of the population along the Bay of Fundy which is engaged directly in the fishing industry is two percent; whereas for Charlotte County, New Brunswick (the closest, and neighboring, county, for which data are available), the percentage is 11 (or 35 percent of the total work force). Sixty percent of the fishing industry deals with Atlantic herring and 50 percent with American lobster. It is noteworthy that Charlotte County is the primary lobster "holding" or "pounding" area in Canada for shipment of lobsters to the United States.

Finally, it must be noted that the Passamaquoddy Bay - Grand Manan Island Region is the apparent center of the American fishery for juvenile Atlantic herring (sardines). Eastport, Maine, landings are usually three or four times larger than any other region in Maine. Additionally, one should recognize that these juvenile fish are the seed stock for the offshore fishery for adults in the Gulf of Maine.

3. RISKS OF REFINERY CONSTRUCTION AND OPERATION

Since the northern coast of Maine generally and the Passamaquoddy Bay area (including Canadian waters) specifically have diverse and unique marine environments, the proposed siting of a hazardous industry such as an oil refinery has been given detailed consideration by both the American and Canadian governments. The Canadian Department of Fisheries and the Environment (1976) evaluated the environmental vulnerability and navigational risk of 22 potential deepwater tanker ports on the Canadian East Coast. The Passamaquoddy Bay area emerged as the least acceptable site. Because of the environmental vulnerability of the Eastport area the study labeled the area "clearly unacceptable" for a deepwater tanker port. The most pertinent finding of this study was that, "Tanker traffic should not be permitted through Head Harbor Passage (the approach to Eastport), because the value of fisheries and aquatic bird resources in the region is so high that no risk can be afforded. At the same time, the high level of navigational risk associated with the passage adds even further to the unacceptable environmental risk." The high quality of the marine ecosystem at the Eastport site is a partial result of the insignificant shipping of harmful materials through that area. Such shipping is totally controlled by the Canadian government to maintain the valuable resources in that area.

An American study of refinery sites along the American East Coast was conducted by an interagency task force and chaired by the Army Corps of Engineers. From 69 sites nominated for consideration, the list was screened to 19, each of which received detailed evaluation. The study characterized the Eastport site as an alternative exhibiting severe and unacceptable risks to aquatic species and commercial fisheries resources due to the effects of predictable petroleum discharges. Seventeen alternative American sites were rated environmentally superior to the one at Eastport. In particular, it noted that, "its (the Eastport site) approaches are winding; its currents extremely difficult to judge and the area has the highest number of fog days along the coast. Highly sophisticated navigational controls would have to be installed if traffic in this harbor were ever to become heavy. In addition, some dredging is required to provide adequate channel width for large vessels."

A second Canadian study, this time by the Canadian Coast Guard (1976) had 11 criticisms of the accessibility and ship safety associated with the Eastport site. Excerpts from six of those criticisms follow. For tidal currents, the report felt that "the strong tidal currents and current shear effects so prevalent in the area may well impose towing demands beyond the design capabilities of the tugs when a VLCC (very large crude carrier) is being turned off the berth and when manoeuvring product tankers within the terminal operating limits outlined in the proposal." For adverse meteorological condition the report states, "transportation network programme analysis identifies a probable queuing problem because of the unpredictability and frequency of adverse meteorological conditions. If input to the proposed refinery were to be provided by tankers smaller than the "design ship" (a 250,000 dead-weight ton tanker, or VLCC), the queuing problem would be greatly increased. Any queuing problem will inevitably pressure the masters of both the crude oil supply tankers and the product tankers to take additional risks if they are obliged or instructed to meet the proposed oil terminal's schedule. Unacceptable risks to the environment may ensue." For uncertainty of depths the report notes, "The preliminary navigational surveys carried out on behalf of Pittston Company and upon which the proposal is based failed to identify a 9 fathom (54 foot) shallow patch in the Friar Roads Channel charted near the centre line of the approach channel which has been selected by the proponent. The presence of this patch of shallow water, if confirmed, would prevent a loaded VLCC from manoeuvring in the Friar Roads Channel at low water." For adverse weather conditions, the report felt that, "The proposed product tanker berths would be exposed to N.W. gale force winds for 13% of the time during the months of December to March inclusive. During these months, the queuing problem would be compounded, causing bottlenecks in the network system, delays in berthing and occasionally the premature vacation of berths. Premature vacation of berths would result in four transits of the approach channels having to be made by some ships in order to complete discharge or loading. Wind forces causing tankers to range alongside would further complicate the mooring problems caused by the current conditions prevailing at the berths. Extra tropical storms sweeping up the Atlantic seaboard from the Caribbean can cause southerly winds of more than 25 knots to funnel through Cobscook Bay. This would add to the manoeuvring difficulties of ships of all sizes. On average, the area is subject to some 1,990 hours of restricted visibility conditions (visibility less than 2 miles) per annum as observed from 1970 to 1975 at East Quoddy Head lighthouse. This amounts to over 22% of the time. Additionally, snow flurries and blizzards can seriously degrade the performance of radar." For pollution containment and cleanup difficulties, the report notes that, "The proposed containment boom appears cumbersome and difficult to rig.

All known oil boom specifications imply that spills cannot be contained where the current normal to the boom exceeds 1.5 knots. It therefore appears that containment of a spill at almost any point within the proposed Eastport terminal system would be impracticable. Accordingly, the clean up of an oil spill within this area would not be possible without the use of dispersants and detergents with consequential environmental effects. Experience has shown that detection of oil spills in restricted visibility conditions is difficult and sometimes impossible. Clean up activities in such conditions are severely hampered." And finally, for overall navigability, the report states that, "While highly sophisticated aids to navigation can certainly increase the navigator's awareness of track and heading deviations, it should be emphasized that even with massive dredging, the approaches to Eastport would remain 'winding', the currents 'extremely difficult to judge' and weather conditions cannot as yet be controlled. In consequence, the risk of pollution remains high and is environmentally unacceptable."

Another study, this time by the Federal Power Commission was conducted to identify and analyze the feasibility and impact of alternative LNG (liquified natural gas) terminal sites from the American-Canadian border to New York. Thirteen sites were initially identified, including two in the Quoddy Narrows to Petit Manan Island reach. That area received an unacceptable rating on the first screening under the navigation criteria, and on the second level screening the Department of Energy identified environmental and economic constraints as additional problems.

A recent publication of the Maine Governor's Committee on Coastal Development and Conservation entitled "The Maine Coast: Issues to Consider," addresses heavy industry siting. Although it specifically excludes the Pittston refinery from its policies, as having gone beyond the initial site location process, the Committee recommends that, "The State should take steps to limit certain types of heavy industrial development to two general areas along the Maine coast: the Portland area (including the Cities of Portland and South Portland) and the upper Penobscot Bay area (Searsport, Stockton Springs, and Penobscot), with oil-handling facilities limited to the Portland area."

Finally, the FEIS review of alternative sites utilizes 10 criteria (over-the-surface distance to the 60-foot mean low water depth contour, sheltered anchorage, navigational problems for approach, water distance to New York, water distance to Montreal, availability of railroad service, quality of roads for trucking, comparative land cost, comparative development cost, and difficulty obtaining permit) which are weighted equally for rating the various sites (eight in Maine, three in Rhode Island, and one each in Massachusetts, New York, and Delaware). Clearly, some of the criteria are more critical than others. The distance from shore to the 60-foot depth is not comparable to crude or product vessel navigational problems, for example, in determining the risk of environmental harm. In addition, no criterion was established for assessing the value and/or uniqueness of the environment and resources at the various sites--information fundamental to determining risks to the environment and resources at each location, and integral to siting such industries.

3.1 SPILLS

Development of a 250,000-barrel-per-day refinery at Eastport will greatly increase the volume of petroleum moved through Head Harbor Passage as well as down the Atlantic Coast from Eastport to market centers in the Boston and New York City areas. Existing traffic into the Eastport area is approximately 600,000 barrels of fuel oil per year. The proposed refinery would result in an increased movement of petroleum through Head Harbor Passage to approximately 158 million barrels -- a 236 fold increase. Of this volume, approximately 83 million barrels will be incoming crude oil shipped directly into Eastport from the Middle East. On the other hand, 75 million barrels of the total will be refined products including No. 5 fuel oil (41 percent), No. 2 fuel oil (34 percent), gasoline (22 percent), and liquid natural gas (3 percent). These products will be transported along the coast south of Eastport where petroleum traffic is currently limited.

The crude oil will be transported to Eastport via 250,000 dead-weight ton (DWT) tankers (VLCC's). Each VLCC can carry approximately two million barrels (70,900,000 gallons) of high-sulphur crude oil. Forty-nine VLCC transits will be made to Eastport each year. Each VLCC must transit the North Atlantic, the Gulf of Maine, the Bay of Fundy, Head Harbor Passage, and Friar Roads to reach the proposed refinery site. A spill of crude oil involving one VLCC bound for Eastport could release 70 million gallons of crude oil into the environment. By way of comparison, the *Argo Merchant* disaster resulted in a spill of 8 million gallons of heavy fuel oil, the *Amoco Cadiz* released 29 million gallons of crude and refined oil, and the *Torrey Canyon* released 37 million gallons of crude oil.

The potential for spills of refined products is even greater than for crude oil. These products will be transported almost exclusively to markets via coastal tankers or seagoing barges. The route traversed will require navigation through Friar Roads and Head Harbor Passage, down the Bay of Fundy into the Gulf of Maine, and along the coast to ports in New England. The Pittston Company proposes to produce and transport the quantities shown in Table 4. A single spill of No. 2 fuel oil along this coastal area could result in the discharge of over 18 million gallons. This is more than 37 times the amount of No. 2 fuel oil discharged in 1970 by the tanker Arrow in Chedabucto Bay, Nova Scotia. An estimated 56 such annual trips by medium-sized tankers are envisioned to transport No. 2 fuel oil. No. 5 fuel oil in 20-million-gallon shipments will be transported through this area approximately 72 times per year. Gasoline will be towed aboard barges or carried on coastal tankers each holding 13 million gallons of product. A minimum of 52 trips per year would be required to transit the dangerous route from Eastport south along the coast. It is ironic that barges, which have the worst safety record of all modes of bulk waterborne transportation, will be the mode used to transport the product having the greatest toxicity to marine organisms. However, due to the toxicity of each product to be transported and due to the very large volume which may be spilled from any of the 180 product vessel passages per year, any single spill event has the potential for significantly affecting the marine ecosystems anywhere along the vessels' routes.

To estimate the likelihood of a particular amount of a specific type of oil going into solution and remaining there for a certain length of time following a spill, the following general discussion has been prepared, based upon the studies of Malins (1978), National Academy of Sciences (1975), McAuliffe (1966, 1969a, 1969b), Baker (1967), Harned and Owen (1958), and Davis et al. (1942).

The two general considerations for the effects of oil on organisms are that the fewer number of carbon (C) atoms per molecule of a given type of petrochemical, and the more aromatic (or cyclic) that molecule, the more toxic it is. For example, benzene and toluene (both cyclic with only six and seven C atoms per molecule) are the only petrochemicals shown to cause death to marine mammals (via skin contact on unhealthy animals).

Tables 5 , 6, and 7 provide information on: (1) the types of oil components, the percentage of those components, and the range of C atoms per molecule for each component, for a composite of all crude oils and for Arabian light crude oil; (2) the solubility for molecules with various numbers of C atoms for both noncyclic (i.e., paraffin) petrochemicals and cyclic (aromatic) petrochemicals; and (3) the general life expectancy in the water for variously numbered C-atom molecules of petrochemicals.

One can see from Table 5 that about one-half of crude oil is comprised of the low C-atom molecules which are generally more toxic to marine organisms. In addition, those same low C-atom molecules are the ones which are most soluble (Table 6). However, as Table 7 indicates, they are also the ones to remain in the water for the shortest time. On face value it would appear that those forces tending to place and keep in solution a given component of oil were roughly matched by those forces tending to reduce its aquatic existence. However, several environmental factors can significantly influence these opposing forces. Four of these factors--turbulence which increases solubility via increased vertical mixing, turbidity which ties up oil particles and lengthens its aquatic existence, sedimentation which ties up oil particles and later leaches them out over a long period of time (up to a 150 years based on laboratory tests), and low temperatures which reduce surface evaporation--are all found at the Eastport site. Such a combination of factors strongly tends to shift the weight to the increased-life-expectancy side of the argument. Thus, in any analogy drawn between the effects of oil spills at Eastport and at other locations, it is likely that the actual effects at Eastport would be more adverse.

A look at several spill incidents supports the information just presented. The discussion of these incidents stems from the works of Hess (1978), Malins (1978), Hann (1977), and Gunnerson and Peter (1976). In the 1974 spill of the Metula of 196 thousand tons of Arabian light crude oil at the Straits of Magellan, the turbulent cold waters quickly mixed the oil with the water. Only 15 to 35 percent of the overall crude evaporated, and between 75 and 90 percent of the aromatics went into solution. The oil was quickly scoured from the high energy channels but remained in very high proportions in the estuaries, particularly on the mud flats (which is consistent with the research of Blumer and Sass (1972) who showed an affinity by oil for finer sediments and lower-energy environments). The estuaries were labeled "desolate wastelands" two years after the spill. After five months oil mousses were found buried in the beach sands up to 1.6 ft in depth. After two years the high C-atom components of the oil remained.

In the *Arrow* spill of 108 thousand barrels of No. 6 fuel oil in Chedabucto Bay, Nova Scotia, in 1970, the oil, which had a specific gravity close to "1," quickly became tied up with waterborne particulate matter and ultimately settled out into the sediments. Five years later, significant amounts of all components (paraffins were the last to biodegrade vis'-a-vis' aromatics and cycloparaffins) were being slowly released into the intertidal and subtidal areas.

In the *Amoco Cadiz* spill off the French Atlantic Coast in 1978 of 216 thousand tons of light Arabian crude, only 28 to 34 percent evaporated. After one month, 6 to 12 percent of the oil was in the coastal waters and sediments, 19 to 37 percent was on the beaches, 18 to 35 percent was in the offshore waters, and about 12 percent was unaccounted for.

The above incidents have shown that actual spills corroborate the hypothetical fate of oil in environments with cold waters, turbulent flows, and significant amounts of turbidity or suspended particulate matter.

Predictions of dispersion of spilled oil 12 hours after a spill in the Passamaquoddy Bay area are shown in Figures 4 and 5 for spills at the northern end of Campobello Island at low water and near Eastport at high water (Canadian Department of the Environment 1974). As is evident from the figures, the predicted dispersion would very rapidly cover a large amount of the local coastal environment. The turbulent energy of tidal flows would tend to distribute the oil throughout the water column, instead of being confined to a surface slick or "pancake". This fact alone would make containment and cleanup extremely difficult if not impossible. Strong tidal currents also make present-day booms useless.

For periods of time longer than 12 hours, the oil would follow the residual circulation around Campobello Island and southward along the Maine Coast or the coast of Grand Manan Island, within a week, and then into the Gulf of Maine eddy. Drifters released in the Passamaquoddy Bay area have been recovered all along the south side of the Bay of Fundy, on the Maine Coast west of the region; and as far away as Cape Cod and Nantucket. To quote the Canadian Department of the Environment (1974), "Oil can be expected to drift through the whole Gulf of Maine/Bay of Fundy system."

3.2 DISCHARGES

Discharges will include scheduled ones that occur during oil refinery operations and accidental ones that occur during vessel/shore transfer operations. The scheduled daily discharges will be 864,000 gallons of refining wastewater, 39,456,000 gallons of refining cooling water, 14,500 gallons of sanitary waste, 2,000,000 gallons of rainwater runoff, and 1,500,000 gallons of tanker ballast and bilge water. All of these discharges except the refining cooling water will contain oil. The National Pollution Discharge Elmination System Permit requirement limits the amount of oil in the discharge waters to 15 milligrams of oil per 1 liter of water discharged. At this rate, 90 gallons of oil would be deposited into Deep Cove daily. The oil will be almost entirely refined products which are generally more toxic than crude oil to marine organisms.

The FEIS leaves a number of questions unanswered about the thermal discharge which are necessary to analyze its effects upon the habitats, organisms, and uses of the receiving body of water. What is the location of the diffuser with respect to the shore? This location will have a bearing on the ability of organisms to escape the area when discharge temperatures exceed lethal levels. At what range of depths beneath the surface will the diffuser operate? This range will have a bearing on the organisms and life stages vulnerable to the thermal discharge. What is the configuration of the thermal plume under various hydrographic regimes in the receiving body of water? For a constant outflow rate, this/these configuration(s) will have a bearing on the ability of an organism to maintain itself in the thermal plume and become vulnerable to cold shock when the once-through portion of the cooling system shuts down for necessary cleaning and maintenance, and on the amount and distribution of the receiving body of water which will be excluded to various biological activities for various organisms and life stages. How often, how long, and at what times will the once-through portion of the cooling system be shut down for routine maintenance and/or cleaning? These shutdown parameters will have a bearing on what organisms and life stages will be exposed and how often they will be exposed to cold shock. What types and amounts of chemicals will be used to remove corrosion and biofouling from the condensor tubes and discharge pipe. Since significant amounts of chromate and chlorine are normally used in such operations, these chemical discharges will have a bearing on the lethal and sublethal effects on organisms exposed to the thermal discharge activities. The FEIS did note that the ambient current in Deep Cove is about 1 knot which is not adequate for rapid dilution of any such discharge.

Discharges as a result of routine vessel/shore transfer operations are estimated in the FEIS on the basis of historical data for the oil port at Milford Haven, Wales, United Kingdom. The FEIS states that their data, when corrected to include only spills occurring at berth, result in a loss factor of 0.000041 percent of all oil transferred. This contrasts with historical data for Portland, Maine, New England's largest oil port, which shows a loss rate of 0.0002 percent of all oil handled. Using corrected Milford Haven data, it is estimated that 86 barrels per year would be spilled during routine transfer operations. If the Portland data turns out to be more representative, the annual amount would be approximately 420 barrels. However, the aforementioned Canadian Coast Guard report noted that, "The Pittston report has enumerated the oil spills at Milford Haven over several years of tanker operation (from 1963 - 1971). However, it would appear that the heavy oil spills amounting to several hundred tons have not been included in the annual average percent of cargo handled, but have been given separately at the bottom of the diagram (Fig. XIV). Ninety percent of oil pollution incidents are caused by human error. The Pittston report oil pollution figure of twenty barrels spilt per annum, based on a tanker tonnage comparison with Milford Haven is far too optimistic. Many minor spills can be expected in the first year of operation when newly trained personnel make errors causing oil spillages. A failure in the chicksan metal arms, blockage in the drainage system of the concrete oil dock, excessive rain water, a defect in the oily water or slop pump on the dock could easily lead to 20 barrels of fuel oil going into Deep Cove in one incident."

Assuming that the amount per spill is relatively constant and that the spill frequency bears a constant relationship to the number of transfer operations, it is estimated that 90 percent of the oil spilled will be refined petroleum hydrocarbons. The product tanker berths are in Deep Cove, and the crude tanker berth is in Broad Cove.

3.3 IMPINGEMENT/ENTRAINMENT

The FEIS has not considered the effects of impinging organisms on the screens and of entraining organisms through the condensor cooling pipes of the once-through cooling portion of the refining cooling water system. The only information the FEIS provides is that the cooling water will be taken from Broad Cove, the intake will be a screened flume, and the flow rate will be 39,456,000 gallons per day.

For impingement analysis the following information must be provided. What will be the range of depths beneath the surface of the intake? This range will have a bearing on what organisms and life stages will be vulnerable. What will be the area of the mouth of the intake? For a constant intake rate this area will have a bearing on the intake velocity and the ability of organisms to escape the inflow or to avoid suffocation on the intake screens. What will be the size of the mesh on the intake screens? The size will have a bearing on the ability of an organism to avoid entrainment. How often will the intake screens be cleaned? This frequency will have a bearing on the ability of an organism to avoid suffocation. How will the screens be cleaned? This cleaning will have a bearing on whether the organism will suffer mechanical damage or physiological impairment. Where will the debris to be washed off the screens be placed? Since such debris is often placed in the discharge waters, it will have a bearing on whether or not there will be secondary entrainment.

For entrainment analysis the following information must be provided. What will be the maximum elevation in temperature of the once-through cooling water above the ambient temperature (ΔT max)? This is not necessarily the same as the ΔT at the point of discharge into the receiving body of water (ΔT dis) and will have a bearing on the ability of organisms to avoid lethal and sublethal effects of the entrainment process. What will be the duration of ΔT max on the one hand, and of the entire entrainment process on the other hand? These durations will have a bearing on the ability of organisms to avoid lethal and sublethal effects of the entrainment process. What will be the values for pressure elevations, shearing forces, gas saturation, and mechanical buffeting in the condensor cooling tubes? These values will have a bearing on the ability of organisms to avoid lethal and sublethal effects of the entrainment process.

3.4 DREDGING

About 1,450,000 cubic yards of material which are mostly rock would be removed from the two proposed pier sites in Broad and Deep Coves. Because of the mostly rock composition of the sites, some blasting will be needed. Although blasting introduces a risk not found at soft-bottom sites, the FEIS notes that blasting would be lethal only within 200 yards of the detonation point unless unusually large amounts of explosives are used. Also, the dredging permit stipulates that blasting must cease if it is determined that fish migration and/or spawning are threatened.

A potentially significant problem associated with dredging is turbidity induced by the removal of bottom sediments. The FEIS feels that because at least 90 percent of the particles in the spoils are greater than or equal to 0.25 millimeters, that those particles will settle out within 30 minutes and 1.8 kilometers of the disturbance. The remaining 10 percent of the spoils which contains particles less than 0.25 millimeters in diameter will have the potential for inducing significant amounts of turbidity, though. If maintenance dredging is necessary as indicated in the Canadian Coast Guard (1976) study, then the dredge spoils would very likely contain oil deposited through scheduled discharges, possible accidental discharges, and possible spills. Thus, secondary oil pollution is a real possibility.

4. ENVIRONMENTAL, RESOURCE, AND RELATED ECONOMIC IMPACTS OF REFINERY CONSTRUCTION AND OPERATION

Two comprehensive studies that relate to the proposed siting of an oil refinery at Eastport, Maine, should be examined by the reader (Canadian Department of the Environment 1974; Canadian Department of Fisheries and the Environment 1976). The discussion that follows can cover only a fraction of that contained in the two aforementioned studies. The following discussion will deal with the impacts of spills, discharges, dredging, and conflicting uses on the organisms, habitats, and associated uses at the Eastport site specifically and in the Passamaquoddy Bay area and Bay of Fundy region generally.

4.1 SPILLS

The effects of a spill can be divided into short-term and long-term effects. In general, long-term effects of spills are often interchangeable with the effects of discharges which will be discussed later. At the Eastport site, with its diversity of habitats and extremes of tides, a large spill of any oil type would have significant short-term effects (Canadian Department of the Environment 1974). A large spill would spread over a broad area of the American and Canadian shoreline. An obvious short-term effect of such a spill would be the coating of mud flats, marsh areas, rocky coastlines, and the resident benthic organisms. Another short-term effect would be that fish caught in weirs would likely be killed or made unfit for sale. Fishing gear would also be destroyed functionally in a number of cases.

Tidal and wind conditions are of extreme magnitudes, causing ineffective containment of spills, so that widespread mechanical control of spills would likely be ineffective, and mortality due to physical damage and coating would be significantly increased. The detergents which have been used to clean up oil spills have a more severe and immediate effect, however, and limpets that have been observed grazing on rocks covered with weathered oil were killed by the detergents used to remove the oil (Smith 1968).

Because of the tidal and bathymetric characteristics, turbulence throughout the water column is predictable. In the case of a major spill this would increase mixing, especially of the lighter, more toxic fractions. Because of turbidity and vertical diffusion gradients, oil adhering to particles could be moved down to the sediments. The result would be extensive impact on plankton and benthos.

With respect to plankton, for two area phytoplanktonic species, Asterionella japonica and Halosphaera sp., respectively, crude oil of an unspecified concentration has been shown to cause death (Smith 1968) and kerosene at three ppm has been shown to slow growth (Aubert et al. 1969). Studies of phytoplankton populations have shown a lack of population growth, as evidenced by a cessation of cellular division, at a concentration as small as 0.0001 ppm for an unspecified type of oil (Mironov 1970), and a 60 percent decrease in photosynthesis when exposed to 100 ppm of No. 2 fuel oil (Gordon and Prouse 1973).

For zooplankton, Smith (1968) has shown that for one of the three endemic species in the area, Acartia clausi, that death can result within 10 minutes to exposure to as little as one ppm of an unspecified oil. Mironov (1972) has shown that A. clausi and Calanus spp. adults suffered 100 percent mortality within one day when exposed to 100 ppm of No. 2 fuel oil, and larvae suffered 100 percent mortality within one day at 1,000 ppm and within three-to-four days at 100 ppm of No. 2 fuel oil. Zooplankton, by ingesting oil particles and incorporating them into feces, transport still more oil to the sediments. Conover (1971) has shown for the Arrow spill that 20 percent of the particulate oil was deposited as zooplankton feces.

The impact on meroplankton would be exacerbated in boreal waters because of the relatively longer amount of time spent by pelagic larvae during their development there. Meroplanktonic larvae of the barnacle Balanus sp. show abnormal development when subjected to 10 ppm of an unspecified oil (Mironov 1970). Mironov (1968) has also demonstrated that Balanus sp. larvae are about 100 times more sensitive to oil pollution than are the adults. For the American lobster, Wells (1972) noted that Venezuelan crude at 100 ppm was lethal to the meroplanktonic larvae after one day, at 10 ppm permitted larvae to develop only to the ninth day, at six ppm delayed the molting of stage III larvae into stage IV larvae, and at one ppm caused controls to develop more slowly and rarely to molt to the fourth stage; those that did molt retained some juvenile characteristics. In this light, Allen (1971) has shown that such abnormally developing lobster larvae ultimately fail to reach a marketable size. Wells and Sprague (1976) have shown more severe effects, however, for Venezuelan crude, in that they found that 0.86 ppm could destroy stage I larvae. Forns' (1977) work showed the same level of toxicity as in Wells and Sprague's (1976) work, but this time with South Louisiana crude.

For benthic invertebrate early life stages that are meroplanktonic, Renzoni (1973) showed that spermotozoa of some marine bivalve mollusks are particularly sensitive to crude oils and their lighter derivatives. Studies conducted by other workers indicate sensitivity of many invertebrate larvae and adults to the light oil fractions. Consequently, if a spill occurred during spawning periods for commercial or recreational species it is possible that local populations of some shellfish could be significantly diminished.

Ichthyoplankton has been found to be sensitive to oil on a short-term basis. Laboratory studies on Atlantic cod and Atlantic herring embryos (Kuhnhold 1969, 1978; Linden 1978; Struhsaker 1977) indicate lower embryo vitality, reduced heartrate, reduced hatching, and increased abnormalities due to oil pollution. Atlantic cod and pollock embryos collected in the area of the Argo Merchant oil spill of No. 6 fuel oil showed increased morbidity, mortality, and abnormal embryo development, based upon cytogenetic examination (Longwell 1978). Fish embryos collected in the area of a gasoline spill showed greater than 75 percent mortality (Longwell, personal communication). In studies on the effects of Iranian crude on cod eggs and larvae, Kuhnhold (1970) found that when the water-soluble fraction was between 0.1 and 1 ppm, that the impact on eggs was sublethal and on embryos and larvae was lethal. In Kuhnhold's (1972) further work on Iranian crude on cod larvae, he found with one day of exposure at 10 ppm that 99 percent died, at one ppm that 63 percent died, and at 0.1 ppm that 33 percent died. At the above concentrations, that is, 10, 1, and 0.1 ppm, 100 percent of the larvae died after 4.2, 8.4, and 14 days, respectively. In similar studies on the effect of Venezuelan crude on cod larvae, Kuhnhold (1972) found with four days of exposure to 0.1 ppm that 20 percent died, and with four days of exposure to 10 ppm that 40 percent died. With Libyan crude, 10 ppm killed cod eggs (Kuhnhold 1970). Additional work by Kuhnhold (1974) on cod eggs, this time with No. 2 fuel oil, showed that when the water-soluble fraction was between 0.015 and 3.5 ppm, that there were abnormalities in embryonic development, and that when the total hydrocarbons were between 1 and 12 ppm there was 100 percent mortality. Sherman (1978) has indicated that 0.25 ppm of No. 6 fuel oil is lethal to developing cod embryos (larvae). In work with Atlantic herring ichthyoplankters, Kuhnhold (1969) found 100 percent of all eggs and fry died after three-to-four days when exposed to No. 2 fuel oil at a concentration of five ppm. Kuhnhold (1978) found far more severe effects on winter flounder eggs by No. 2 fuel oil--0.01 ppm cause the female fish to reabsorb their eggs, with those eggs which were spent showing reduced survival beyond the yolk-sac-larval stage, and 0.001 ppm caused a 19 percent reduction in the viable hatch.

Although nekton are not noted for being significantly affected, in short-term tests with the winter flounder, Sprague and Carson (1970) noted that one-half of all adult fish died after one week when subjected to No. 2 fuel oil at 1,000 ppm. Atlantic silversides (Menidia menidia) exhibited histological damage to their chemoreceptory organs when placed in test tanks with an unspecified crude oil at a water-soluble level of 12 ppm (Gardner 1972).

With respect to short-term effects on benthos, an unspecified crude oil at an overall concentration of 1,000 ppm, which probably represents an effective water-soluble concentration of about 10 ppm, causes death to the coelenterate Tubularia crocea (Hepple 1971).

For Passamaquoddy Bay area mollusks, Blumer et al. (1971) found that when blue mussels were exposed to a large spill of No. 2 fuel oil that gonads failed to develop, leading to collapse of the population. Also for blue mussels, Gonzalez et al. (1976) found that when the water-soluble fraction of No. 2 fuel oil was in concentrations as low as 0.01 ppm, that there was a cessation of normal filter-feeding activities, and in concentrations as low as 1 ppm, there was cessation of byssal thread attachment. Dunning and

Major (1974) found that when blue mussels were exposed to No. 2 fuel oil at a concentration of 12 percent of the water-soluble extract, that there was a partial depression of the respiration rate (an indicator of physiological stress) and at a concentration of 24 percent of the water-soluble extract, that there was a complete inhibition of respiration, prevention of byssal thread secretion, and decreased rate of shell closure. In the Dunning and Major (1974) study, blue mussels begin to show signs of physiological stress to concentrations of No. 2 fuel oil as low as 0.25 ppm. In another study of blue mussels, Gilfillan (1973) showed that an emulsion of one percent of the water-soluble extract of mid-continent crudes caused erratic stimulation of respiration and depression of filtering (above one percent concentration of the water soluble extract in this case) at normal salinity; increased respiration and filtering rate at a salinity of 21 parts per thousand ($^{o}/oo$) (at a concentration of the water-soluble extract above 10 percent, both the respiration and filtering rate decreased rapidly); and a cessation of respiration and filtering rate at 11 $^{o}/oo$. For the softshell clam, Thomas (1973) discovered that oil would tend to flow into the burrows of the organism and force it to move onto the exposed substrate and thus suffer far greater predation than usual. Stainken (1977) showed also for the softshell clam that under winter conditions that No. 2 fuel oil at 50 ppm for 28 days, followed by unpolluted water for 14 days, caused an 18.3 percent mortality. The remainder of research on Passamaquoddy Bay mollusks deals with snails, where Jacobsen and Boylan (1973) found that as little as 0.001 ppm of kerosene decreased the ability of *Nassarius* sp. to recognize its food upon coming into contact with it. In addition, Thomas (1978) reported that in Chedabucto Bay, Nova Scotia, site of the aforementioned *Arrow* spill, *Thais lapillus*, *Littorina saxatilis*, and *L. obtusata* were significantly reduced in number following that spill.

In Wells' (1972) study of Venezuelan crude, he found that for adult lobsters, one-half of all test organisms died after four days when subjected to as small a concentration as two ppm. Also for lobsters, all fractions of La Rosa crude at 10 ppm double the amount of time it takes an individual to feed (Atema and Stein 1972). Not only do crude oils affect feeding times, but Blumer et al. (1973) have shown that both crude oil at an unspecified concentration and kerosene at 10 ppm lessen chemoreception, heighten stress behavior, reduce aggression, and reduce grooming.

There are several types of long-term effects, depending on the amount of oil spilled, the type of oil, and the habitat affected. The effects of oil on water column organisms will decrease as the oil weathers and the toxic components are reduced. However, planktonic embryos and larvae could still be impacted by the presence of the slick. Adult fish and benthic organisms in coastal and offshore waters would probably not suffer further impact based on results in the areas of other oil spills such as the Argo Merchant. However, over 90 percent of all adult lobsters which were held in tidal pounds at the time of an oil spill in the Bay of Fundy, and transferred to clean water within two-to-three days, died within three months, which indicates delayed impact. Lobsters held continuously in clean water for the same period of time showed no increase in mortality.

On rocky shores where there is wave action, recovery, first of algae, then of faunal components, will be relatively rapid once the oil slick has dissipated and no further oil is deposited. Oil will persist for years in sediments on tidal flats, in marsh areas, or coves, however. For example, following the oil spill of the Arrow in Chedabucto Bay, in cove areas three species of macrophytes, Ascophyllum nodosum, Chondrus crispus, and Fucus vesiculosus, showed a significant reduction in population size and have not yet recovered fully (Thomas 1978). Such persistent oil will continue to affect benthic animals; recolonization will be slow, species diversity will be low, and species of commercial importance such as the softshell clam will not be safe for human consumption for possibly 10 years (Sanders 1978; Gilfillan and Vandermeulen 1978).

For the horse mussel (Modiolus modiolus), it was found that after the Arrow spill of No. 2 fuel oil, the species concentrated the pollutant in its body at a level of 125 ppm, well above the level necessary to taint the flesh and make it unfit for human consumption (Scarratt et al. 1970). For the softshell clam, Thomas (1973, 1978) noted that after the aforementioned Arrow spill that population levels plunged and are still minimal today, years later. Gilfillan and Vandermeullen (1978) reported that when softshell clams were exposed to No. 2 fuel oil, that even six and seven years later their flesh was permeated with 200 ppm of the pollutant, that the number of adults in the population had significantly decreased, that the species showed a one-to-two year lag in growth rate compared to normal populations, and that the population exhibited a low recovery rate and highly stressed condition. Gardner et al. (1973) found that four months after a spill of No. 2 fuel oil that gonadal tumors were developing in softshell clams. In this light, Barry and Yevich (1975) found that No. 2 fuel oil at a field concentration as low as seven ppm induced gonadal tumors.

In another example, Dow and Hurst (1975) reported a loss, over three years of 50 million softshell clams, representing 85 percent of a stock in the immediate vicinity of a No. 2 fuel oil spill in Searsport, Maine. Another instance of severe, but localized damage has been reported for a spill of No. 2 fuel oil from a grounded barge in Buzzards Bay, Massachusetts, in 1969. Following the spill, large-scale mortalities of fish, mollusks, and other invertebrates in the tidal and intertidal waters of the Wild Harbor area of Buzzards Bay were reported. Later sampling of the area in the spring of 1970 revealed massive mortalities of benthic invertebrates. The species composition of the surviving benthos shifted from a typical mixed community to a single species dominance of a pollution indicator--the polychaete worm, Capitella capitata. Within two years of the spill, the area showed some signs of recovery. However, eight years later, at least one sampling location did not reach its normal species assemblage. And in the other sampling locations sublethal chronic effects have been detected in fish and crab populations. The clam flats have not yet been reopened (Sanders 1978).

A spill of 500,000 gallons of No. 6 fuel oil in 1970 caused severe damage in Chedabucto Bay, Nova Scotia. Approximately 60 miles of shoreline were adversely affected. Losses of shellfish, intertidal crustaceans, and attached algae were reported just after the spill. Subsequent monitoring of the area has been continued. It is estimated that four-to-eight years will be required for recovery of the algal populations. The softshell clam populations will require an estimated 10 years to reach one-half of their former population densities (Vandermeulen 1978).

There are few data for either significant long or short-term impacts on marine mammals. This does not suppose there is none, but rather that they have not been common in areas where large spills have occurred. Impact is probable along coastal areas where these mammals regularly reside and breed if for no other reason than that of irritation of sensitive skin, or of sight or respiratory difficulties. Certainly, indirect impacts could result from such changes as a reduction in the food supply (fishes).

To estimate the specific impacts of a spill on the fauna of an area it is necessary to consider the species and life stages present in a given habitat at a given time, the type and amount of oil as well as its water-solubility, and the distribution and concentration of the water-soluble fraction of a given oil necessary to cause a specific lethal or sublethal response in a given species and life stage. A simple model has been constructed to approximate effects of an oil spill on selected fishes and benthic invertebrates representative of the Passamaquoddy Bay area. Basically, the model estimates the area, in terms of surface waters, intertidal waters, and all waters, which would contain lethal concentrations of oil resulting from the spillage of either a VLCC's total load of crude oil or a medium-sized tanker's total load of No. 2 fuel oil. Tables 8 and 9 summarize these calculations for representative groupings of coldwater fauna, and for Passamaquoddy Bay or physiologically similar species, respectively.

Assumptions that must be met for this approach are: (1) that the water-soluble fraction of the spilled oil disperses evenly horizontally and vertically throughout the water column (in the case of "intertidal" and "all waters" scenarios) or within the upper six feet of the water column (in the case of the "surface" scenario); and (2) that the lethal concentrations shown in Tables 8 and 9 remain in the water body at least as long as the duration of the applicable bioassays (e.g., for a 96-hr bioassay, the components must remain in the water for just as long).

Both assumptions would probably not be met entirely. However, with respect to assumption (1), the strong tidal currents and vertical mixing in the Passamaquoddy Bay area would probably distribute the water-soluble fractions rather uniformly. Even if dispersion were uneven and left some areas with a sublethal level of toxicant, it would be compensated by the higher level effects in other areas. It is also apparent the area in which sublethal effects would occur would be significantly larger than the area of lethal effects. Also, what has not even been considered is the ability of currents to move toxicants as a whole from one area into a totally new one, potentially multiplying by several times the affected region.

With respect to the second assumption, Chapter 3 presents a positive argument, based upon empirical evidence, that the lethal concentrations indicated in Tables 8 and 9 could likely remain in the marine environment in a soluble state as long as the applicable bioassays. As Chapter 3 indicated, the site-specific characteristics of the Eastport area contribute significantly to the validity of assumption (2).

The selection of the 6-ft, 30-ft mean, and 100-ft mean depths for the various scenarios is based upon: (1) the 6-ft depth from the surface effectively covers most of the neustonic organisms/life stages (e.g., Atlantic cod eggs, American lobster larvae, blue mussel larvae); (2) the 30-ft mean depth covers intertidal waters in the Passamaquoddy Bay area under all conditions; and (3) the 100-ft depth conservatively approximates the average depth of the entire Passamaquoddy Bay area.

The selection of the two extreme conditions, that is, all oil staying at the surface or all oil dispersing down through the water column, also displays the variability in the effects resulting from such a spill. Thus, the biological effects resulting from any intermediate scenario for the fate of the oil lie between the effects displayed in Tables 8 and 9.

The values in Tables 8 and 9 were determined by the formula at the bottom of each table. In essence, what the formula does is: (1) take the volume of oil in either a VLCC or a medium-sized refined-product tanker ("A"); (2) convert the volume from gallons to cubic feet; (3) determine the fraction of that volume that is soluble in water ("B"); (4) expand the value for the volume of the water-soluble fraction by the appropriate ratio of concentration ("1,000,000/C"); and (5) divide by the appropriate volume-at-depth for one surface acre. This process yields the number of surface acres at-depth potentially saturated by the appropriate lethal concentration of oil. Also, by relating the affected volume to the volume of the Passamaquoddy Bay area, one can envision the magnitude of any single major spill.

Tables 8 and 9 do show that significant damage would occur to many commercially, recreationally, and ecologically valuable species in the area. A single catastrophic spill of either crude or refined oil in the Passamaquoddy Bay area could eliminate the multimillion dollar (Table 3) commercial fishery for invertebrates through outright toxicity. In some cases, the overkill factor exceeds 73 (larval lobsters). Because the effects of such oil pollution would likely last more than a decade (Vandermeulen 1978), the damage to the areal benthic invertebrate fishery alone would be measured in tens if not hundreds of millions of dollars (Table 3). It is interesting to note that in the case of American lobsters, the surface-water habitat could potentially be saturated at the lethal level for the entire Bay of Fundy (3.6 million surface acres). The implications for the fisheries in the whole Bay of Fundy - Gulf of Maine complex are clear, particularly in light of the hydrographic conditions in the region (See Section 2.1). The effects on the finfishery are equally significant as can be seen in Tables 8 and 9. The valuable juvenile Atlantic herring fishery, which could come into even more economic prominence with the enactment of the Fishery Conservation and Management Act of 1976, will face a particularly severe risk due to spill effects.

4.2 DISCHARGES

Studies in large containers and also in coastal waters where there are chronic inputs of petroleum hydrocarbons have shown phytoplankton community composition shifts from large to smaller species. Additionally, the use of water for cooling with the resultant temperature changes could destroy large numbers of phytoplankton and zooplankton. In an area of high turbidity and large tidal fluxes, this could have significant effects upon resident communities.

Zooplankton, including Acartia clausi and A. tonsa, to which No. 2 fuel oil was added over a period of time in large microcosms at the University of Rhode Island (simulation chronic exposure), were affected at all levels of organization. Biomass and abundance were significantly decreased; respiration and feeding were depressed, and metabolic stress was evident throughout the period of oil addition (MERL 1978). In addition, laboratory experiments in which A. clausi and Oithona nana were exposed to fuel oil and crude oil indicated significant mortality even at levels as low as 0.001 ppm (Mironov 1969).

Fish and shellfish are susceptible to hydrocarbon uptake, resulting in tainting of the flesh. Experiments were conducted in which Atlantic salmon were exposed to four-to-five ppm for 68 days. After four-to-six days, tainting of the flesh was obvious (Brandal et al. 1976). This is significant because of the significant fishery in the area. Fortunately, it appears that once the volatile compounds disappear, the fish can depurate. However, for fish exposed constantly or migrating through an area of chronic pollution, tainting of the flesh is a distinct possibility, especially in fish with a high fat content (Atlantic herring, Atlantic salmon). This would make the fish unfit for human consumption and therefore unmarketable.

Recent studies following a fuel oil spill (Argo Merchant) and gasoline spill (Ocean Barge 250) indicate that fish such as yellowtail flounder and winter flounder have high incidence of hydrocarbons in body tissues, including the flesh (MacLeod et al. 1978; Griswold, personal communication). Some of this was attributable to the spill with which the fish were associated, but the results also indicated that fish associated with coastal regions have higher than normal incidence of petroleum hydrocarbons in their bodies. Tainting has not been studied in these fish, but the possibilities for tainting are present, as well as indications of reduced fecundity and larval survival in winter flounder and Pacific herring (Kuhnhold, personal communication; Struhsaker 1977). The ramifications on the juvenile Atlantic herring fishery in the area are clear.

Bivalve mollusks, softshell clams in particular, show slower growth rates, reduced recruitment, and are unfit for human consumption due to uptake of petroleum components (Gilfillan and Vandermeulen 1978; Sanders 1978). In an area of extensive mud flats where commercial and recreational shellfishing is important, chronic exposure to oil would be detrimental to the local economy.

The impact of chronic oil pollution on American lobsters would be much like that of other shellfish. Lobsters are known to be attracted to such refined petroleum products as gasoline, and tainting of the flesh is common (Blumer et al. 1973). As lobsters are important to the economy of the area, chronic oil pollution could have a serious impact on the fishery.

Chronic oiling generally causes some population changes, especially in the benthos. Little is known about the total impact of these changes in ecosystems. However, in this region of diverse habitats and specialized food webs and ecological interactions, the impact could be substantial.

4.3 DREDGING

Dredging impacts associated with the siting of the refinery at Eastport will fall into one of four categories--direct mortality, turbidity, smothering, and toxicity (Ecological Analysts, Inc. 1976). With respect to turbidity, the FEIS acknowledges that blasting and dredging will significantly disrupt the bottom sediments, a portion of which will be placed into suspension and transported by currents where it can potentially result in substantial impacts to productive biological habitats in adjacent areas. Kaplan et al. (1974) found that such turbidity was both lethal and caused severe impacts in estuaries and bays. Sherk (1971) specifically noted that the effects of dredging-generated turbidity included decreased light penetration, loss of habitat, direct mortality of all life stages of microzooplankton and larvae of larger organisms, clogging of gills, flocculation of algae, increased microbial activity, and depleted dissolved oxygen supplies.

Finally, the Canadian Coast Guard (1976) study noted that some maintenance dredging may be necessary. However, all sediments dredged up after the oil refinery would begin operation would likely have been exposed to the chronic allowable discharges and acute accidental spills of oil during routine refinery operations. Thus, maintenance dredging would likely expose the area to the toxic effects of secondary oil pollution (Ecological Analysts, Inc. 1976).

4.4 CONFLICTING USES

At risk are several activities that could compete with the oil refinery for the available environment and its resources; those already discussed (commercial fishing, recreational fishing, tourism, boating, and other water-related activities) and a number of others (shellfish aquaculture, lobster pounding, outdoor recreational areas, and tidal power projects).

The Passamaquoddy Tribal Council has proposed a tidal power project and shellfish aquacultural development in Half Moon Cove, 2.3 miles northwest of the refinery site. See Section 4.2 for a discussion of the effects of oil on shellfish.

The pounding/holding of American lobsters in this area amounts to 5.2 million pounds per year. Studies have found: (1) interference with olfaction, disruption of behavior, and death by toxication in pounds where the amount of oil was insufficient to coat either the lobsters or their habitat; and (2) oil coating and penetration of habitats in pounds (Porricelli et al. 1971; Barry and Yevich 1975). Although oil-booming equipment will be offered to pound keepers by Pittston, the effectiveness of such equipment is questionable. United States Coast Guard studies of openwater booming systems and of the ineffective booming around the sunken dredge barge Pennsylvania indicate that the equipment is ineffective under certain conditions. The Amoco Cadiz oil spill report notes the failure of a boom system and resulting impacts to a pound in France (Hess 1978).

In addition to the established parks listed in Chapter 2, Deer Island is being considered as a national marine park, the St. Croix River as an international wild river park, Machias Seal Island as an international bird sanctuary, and Eastport Harbor as a national marine sanctuary.

The Army Corps of Engineers is studying the feasibility of constructing a federal tidal power project in the Cobscook Bay area. Although the FEIS finds the two projects compatible with the addition of navigational locks, concerns have surfaced. At public hearings and in a letter from the Army Corps of Engineers to the Regional Administrator of the EPA, reservations were expressed about possible air quality constraints should both the tidal power project and the refinery be developed.

4.5 SUMMARY

The FEIS acknowledges, and we concur, that "The operation of the refinery represents the commitment of the community, region, and state to accept the risk, however small (large), that an accident could affect all or portions of the diverse and abundant marine life in the area. Thus, the refinery may represent a commitment to an industrial activity which could result in the suppression or even elimination of a renewable resource - fish and other marine life. In addition, this could result in the suppression or elimination of the fishing industry in the Passamaquoddy area."

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Table 1. Occurrence of marine mammals near the Eastport site.

Common name	Scientific name
Common occurrence	
Harbor porpoise	*Phocoena phocoena*
Pilot whale	*Globicephala melaena*
White-side dolphin	*Lagenorhyncus acutus*
Fin whale	*Balaenoptera physalus*
Minke whale	*Balaenoptera acutorostrata*
Humpback whale	*Megaptera novaeangliae*
Right whale	*Eubalaena glacialis*
Harbor seal	*Phoea vitulina*
Gray seal	*Halichoerus grypus*
Rare occurrence	
White-beaked dolphin	*Lagenorhynchus albirostris*
Common dolphin	*Delphinus delphis*
Killer whale	*Orcinus orca*
Bottlenosed dolphin	*Tursiops truncatus*
Gray grampus	*Grampus griseus*
Striped dolphin	*Stenella cooruleoalba*
Beluga	*Delphinapterus leucas*
Sei whale	*Balaenoptera borealis*
Blue whale	*Balaenoptera musculus*
Sperm whale	*Physeter catodon*
Pygmy sperm whale	*Kogla breviceps*
Northern bottlenosed whale	*Hyperodon ampullatus*

Table 2. American and Canadian catches (metric tons, live weight except mollusks) from the Bay of Fundy in 1975 and 1977.

	United States		Canada		Total	
	1975	1977	1975	1977	1975	1977
Invertebrates	2,424	2,843	684	7,564	3,108	10,407
Atlantic herring	2,992	6,530	125,350	85,203	128,342	91,733
Atlantic mackerel	0	0	718	N/A[a]	718	N/A[a]
Diadromous species	322	114	3,381	N/A[a]	3,703	N/A[a]
Other finfish	948	660	15,744	15,464	16,692	16,124
Total	6,686	10,147	145,877	108,231	152,563	118,264

[a] Data not yet available and excluded from totals.

Table 3. Estimated value (dollars) of American and Canadian catches from the Bay of Fundy in 1975 and 1977.

	United States		Canada		Total	
	1975	1977	1975	1977	1975	1977
Invertebrates	6,679,416	8,979,501	1,603,000	27,676,000	8,282,416	36,655,501
Atlantic herring	293,717	701,625	5,623,283	8,939,366	5,917,000	9,640,991
Other finfish	115,812	124,866	5,244,188	4,294,000[a]	5,360,000	4,418,866
Total	7,088,945	9,805,992	12,470,471	40,909,366	19,559,416	50,715,358

[a] Excludes value of diadromous species and Atlantic mackerel.

Table 4. Production and transport of oil by Pittston.

Product	Maximum vessel size (DWT)	Approximate vessel capacity		Minimum number of vessel trips per year (loaded)
		Barrels	Gallons	
No. 5 fuel oil	70,000[a]	479,657	20,145,585	72
No. 2 fuel oil	70,000[a]	440,532	18,502,233	56
Gasoline	40,000[b]	311,364	13,077,729	52

[a] Medium-size tanker.

[b] Coastal tanker or barge.

Table 5. Crude oil components by percent and C atoms per molecule.

Component	Percent	No. of C atoms
	Composite of crudes	
Gasoline	30	10-12
No. 2 fuel oil	15	12-20
No. 5 & 6 fuel oil	25	20-40
Residual oil	20	40+
	Arabian light crude	
Gasoline	(b)	5-10
No. 2 fuel oil	(b)	12-25
No. 5 fuel oil[a]	(b)	12-30+

[a] 75% No. 6 fuel oil + 25% No. 2 fuel oil.
[b] Not given.

Table 6. Solubility of noncyclic (paraffins) and cyclic (aromatics) oil components of various C-atom numbers per molecule[(a)].

No. of C atoms	Solubility (ppm)
Paraffins	
5	40
6	10
7	3
8	1
12	0.01
30	0.002
Aromatics	
6	1,800
7	500
8	175
9	50
14	0.075
18	0.002

[(a)]Data derived from freshwater analysis. Seawater reduces solubility by 12-30%.

Table 7. Life expectancy in marine environment for variously numbered C-atom molecules of petrochemicals.

No. of C atoms	Comments
10-12	Only traces left
<12	50% remains after 8 hr at 5°C and 9-12 knot winds
12-20	75% lost quickly
<15	Remains <10 days
15-25	Limited volatility, remains in slick
17-18	10% on beach after 1 yr
19-20	50% on beach after 1 yr
20-40	<10% lost
23-24	Almost all on beach after 1 yr
>25	Retained

Table 8. Reported lethal toxicity and estimated lethal area of the water-soluble fraction of crude[a] and refined[b] oil to coldwater marine species from four phyla.

Phyla (species)	Lethal concentration (ppm) of water-soluble fraction[c]		Lethal area (and proportion of Passamaquoddy Bay area waters) due to tanker spill (acres)[d]			
	Crude oil	Refined	Intertidal[e]	All waters[f]	Intertidal[e]	All waters[f]
Echinodermata (sea cucumbers - 2 spp.)	10.8	2.3	67,160(1.17)	20,147(0.35)	493,784(8.57)	148,135(2.57)
Mollusca (10 spp.)	9.8	2.3	74,013(1.28)	22,203(0.39)	493,784(8.57)	148,135(2.57)
Arthropoda (crabs-4 spp., shrimps-5 spp.)	2.3	2.3	315,361(5.48)	94,608(1.64)	493,784(8.57)	148,135(2.57)
(amphipod-1 sp., isopod-1 sp., mysid-1 sp., and barnacle-1 sp.)	8.5	4.1	85,333(1.48)	25,598(0.44)	277,001(4.81)	83,101(1.44)
Chordata (fishes-5 spp.)	1.8	1.8	402,961(7.00)	120,888(2.10)	630,946(10.95)	189,292(3.29)

Data from Rice et al. (1975) and Rice et al. (1976).
(a) Cook Inlet and Prudhoe Bay.
(b) No. 2 fuel.
(c) One-half of test specimens died within 4 days.
(d) Determined by formula: $\frac{1,000,000 \cdot A \cdot B}{7.48\ gal/ft^3 \cdot C \cdot D}$

where: A=capacity of tanker (gal) - crude, 70,900,000; refined, 18,502,223;
B=water-soluble fraction of cargo - crude, 10%; refined, 60% (Moore 1973);
C=lethal concentration of water-soluble fraction (given); and
D=volume of water body (ft^3) under 1 surface acre - intertidal, 1,306,800; all waters, 4,356,000.

(e) 30-ft mean depth.
(f) 100-ft mean depth.

Table 9. Reported lethal toxicity and estimated lethal area of the water-soluble fraction of different oils to commercially important Passamaquoddy Bay or physiologically similar species.

Species	Type of oil	Concentration of water-soluble fraction (ppm)	Exposure time necessary to kill one-half of test specimens (days)	Lethal area (and proportion of Passamaquoddy Bay area waters) due to tanker spill (acres)[a] Surface[b]	Intertidal[c]	All waters[d]	Reference
Sandworm (*Nereis diversicolor*)	Artem crude	15.00	6	-[h]	48,354(0.84)	14,504(0.25)	(i)
Blue mussel (*Mytilus edulis*)	Cook Inlet crude	5.15	1	-[h]	140,836(2.45)	42,251(0.73)	(j)
	No. 2 fuel	3.11	1	-[h]	365,178(6.40)	109,553(1.90)	(j)
American lobster[e] (*Homarus americanus*)	Venezuelan crude	0.86	4	4,216,900(73.21)	843,380(14.64)	253,013(4.39)	(k)
Atlantic cod[f] (*Gadus morhua*)	Libyan crude	10.00	4[g]	362,655(6.30)	72,531(1.26)	21,758(0.38)	(l)
Saffron cod (*Eleginus gracilis*)	Cook Inlet crude	2.48	1	-[h]	292,463(5.08)	87,737(1.52)	(j)
	No. 2 fuel	2.93	4	-[h]	387,613(6.73)	116,284(2.02)	(j)
Pacific herring[e] (*Clupea harengus pallasi*)	Cook Inlet crude	3.00	4	1,208,845(20.99)	241,769(4.20)	72,531(1.26)	(m)
	No. 2 fuel	20.00	4	283,925(4.93)	56,785(0.99)	17,037(0.30)	(n)

(a) Determined by formula: $\frac{1,000,000 \cdot A \cdot B}{7.48\ gal/ft^3 \cdot C \cdot D}$;

where: A=capacity of tanker (gal) - crude, 70,900,000; refined, 18,502,223;
B=water-soluble fraction of cargo - crude, 10%; refined, 60% (Moore 1973);
C=lethal concentration of water-soluble fraction (given); and
D=volume of water body (ft^3) under 1 surface acre - intertidal, 1,306,800; all waters, 7,840,800

(b) 6-ft depth from surface.
(c) 30-ft mean depth.
(d) 100-ft mean depth.
(e) Larva.
(f) Egg.
(g) 95% kill.
(h) Rarely or never found as adults in surface waters unless in inshore waters.
(i) Kasymov and Aliev (1973)
(j) Rice et al. (1976)
(k) Wells and Sprague (1976)
(l) Kuhnhold (1970)
(m) Vaughan (1973)
(n) Rice et al. (1975)

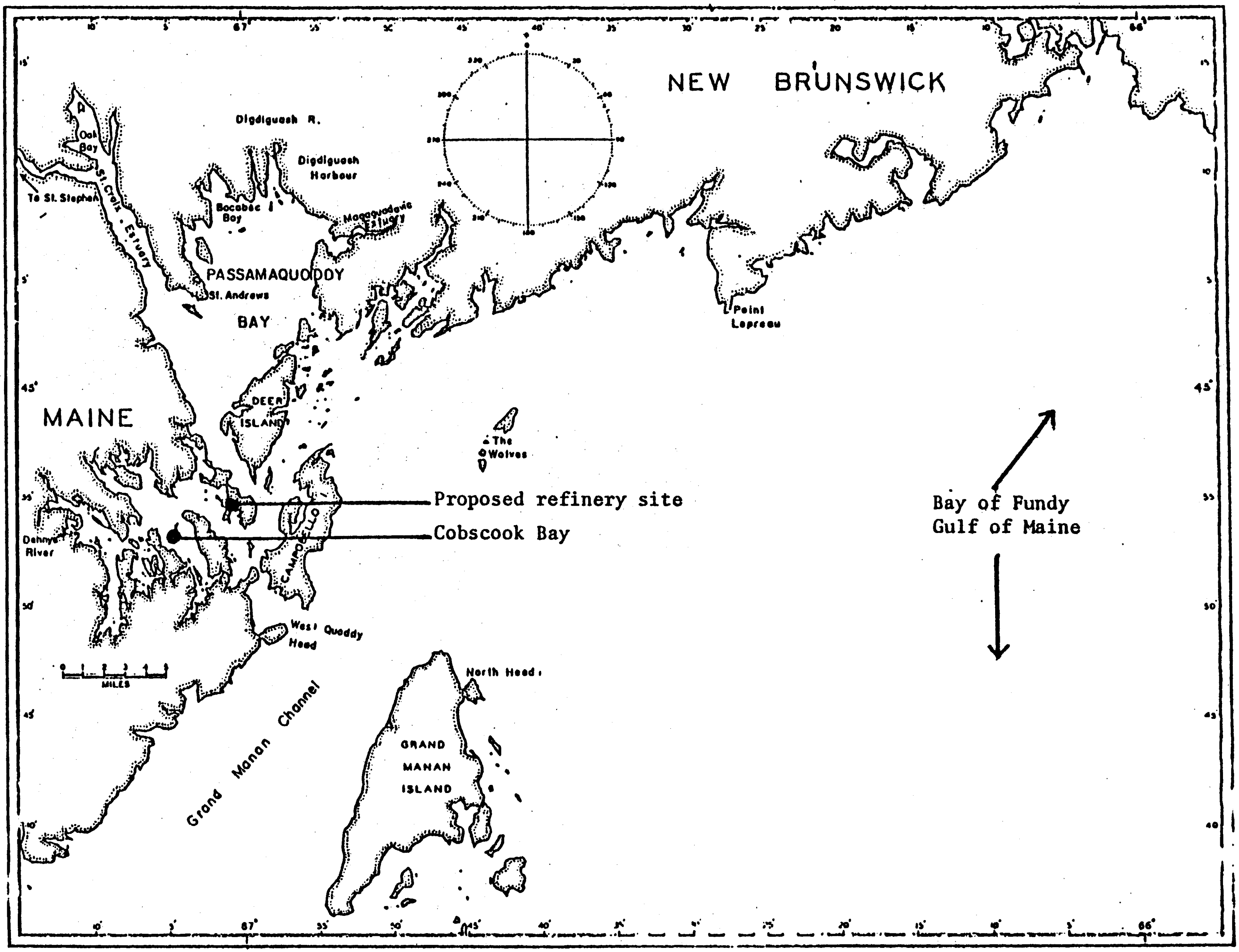

Figure 1. Proposed refinery site within Passamaquoddy Bay - Bay of Fundy - Gulf of Maine complex.

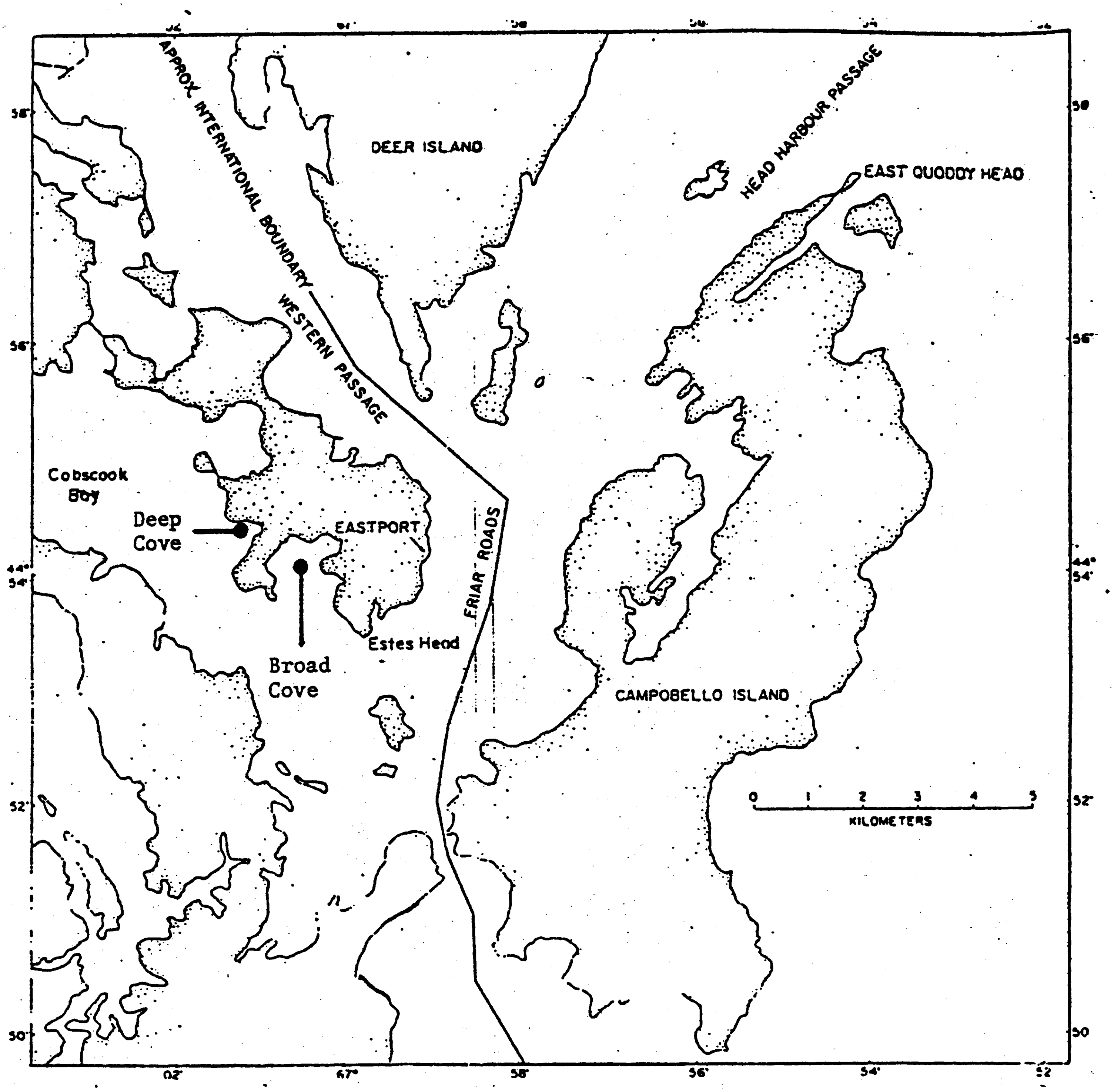

Figure 2. Location of water bodies relative to Eastport site.

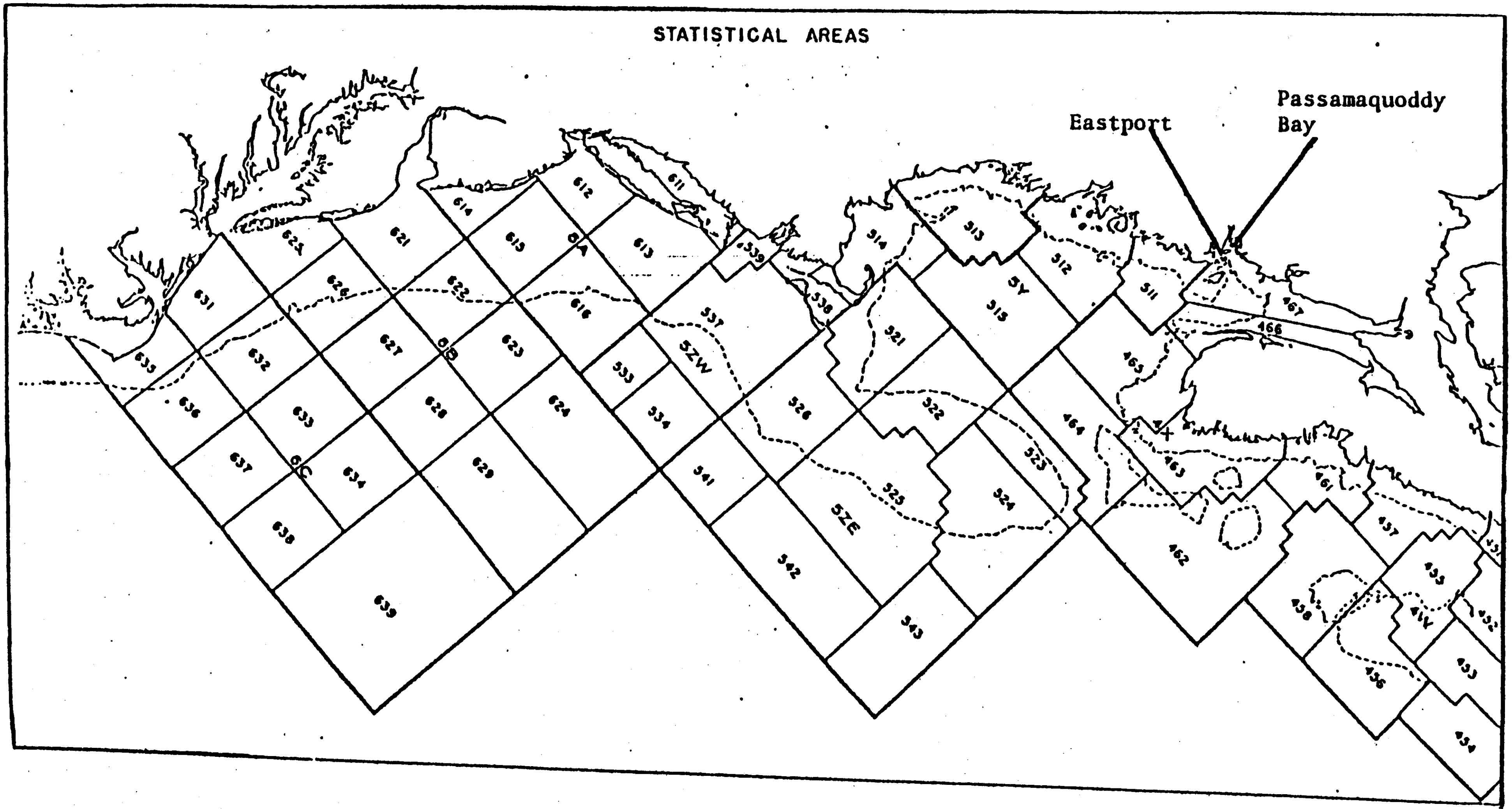

Figure 3. NMFS statistical areas.

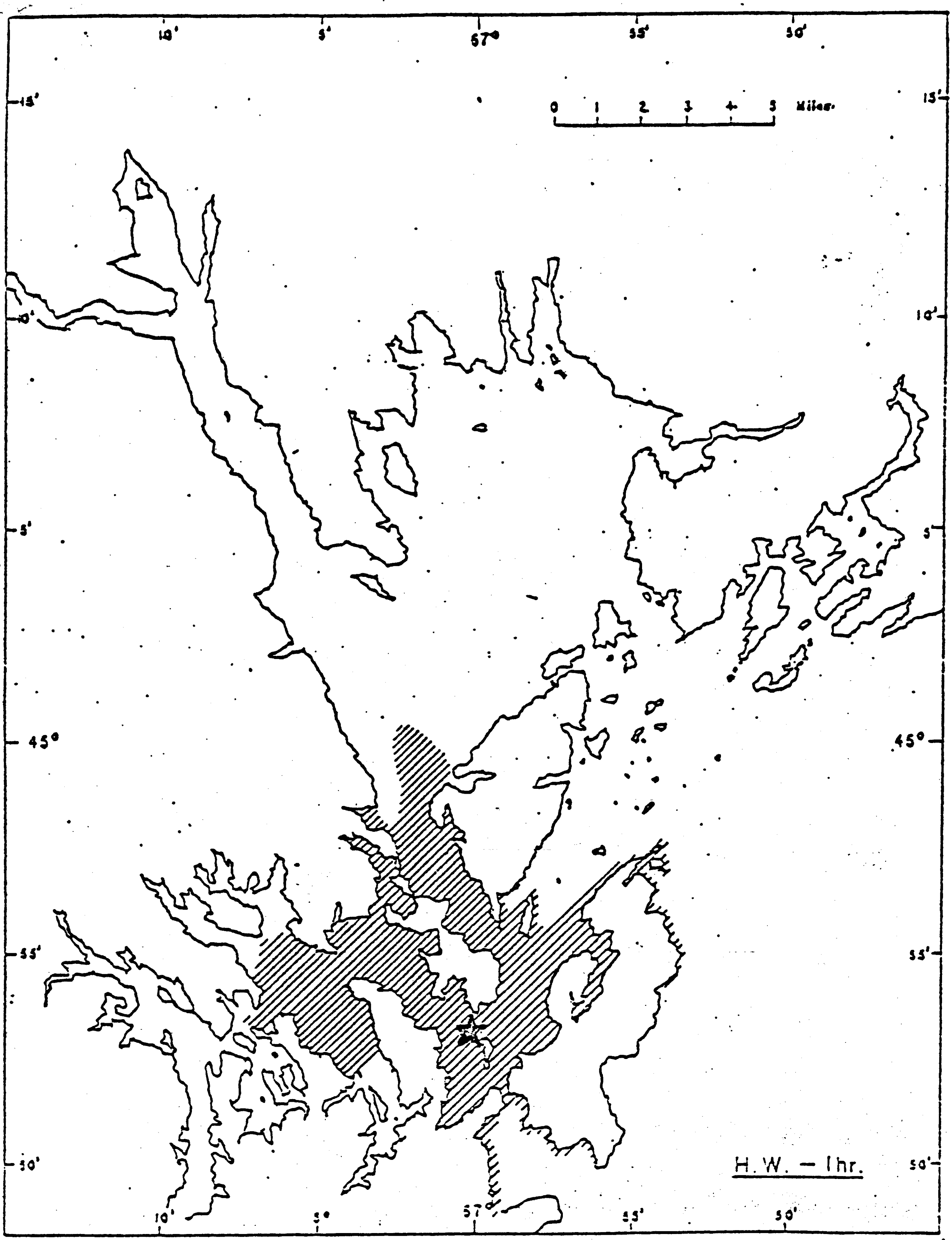

Figure 4. Predicted dispersion of oil 12 hours after a spill off Eastport (star) at high water minus 1 hour. From Canadian Department of the Environment (1974).

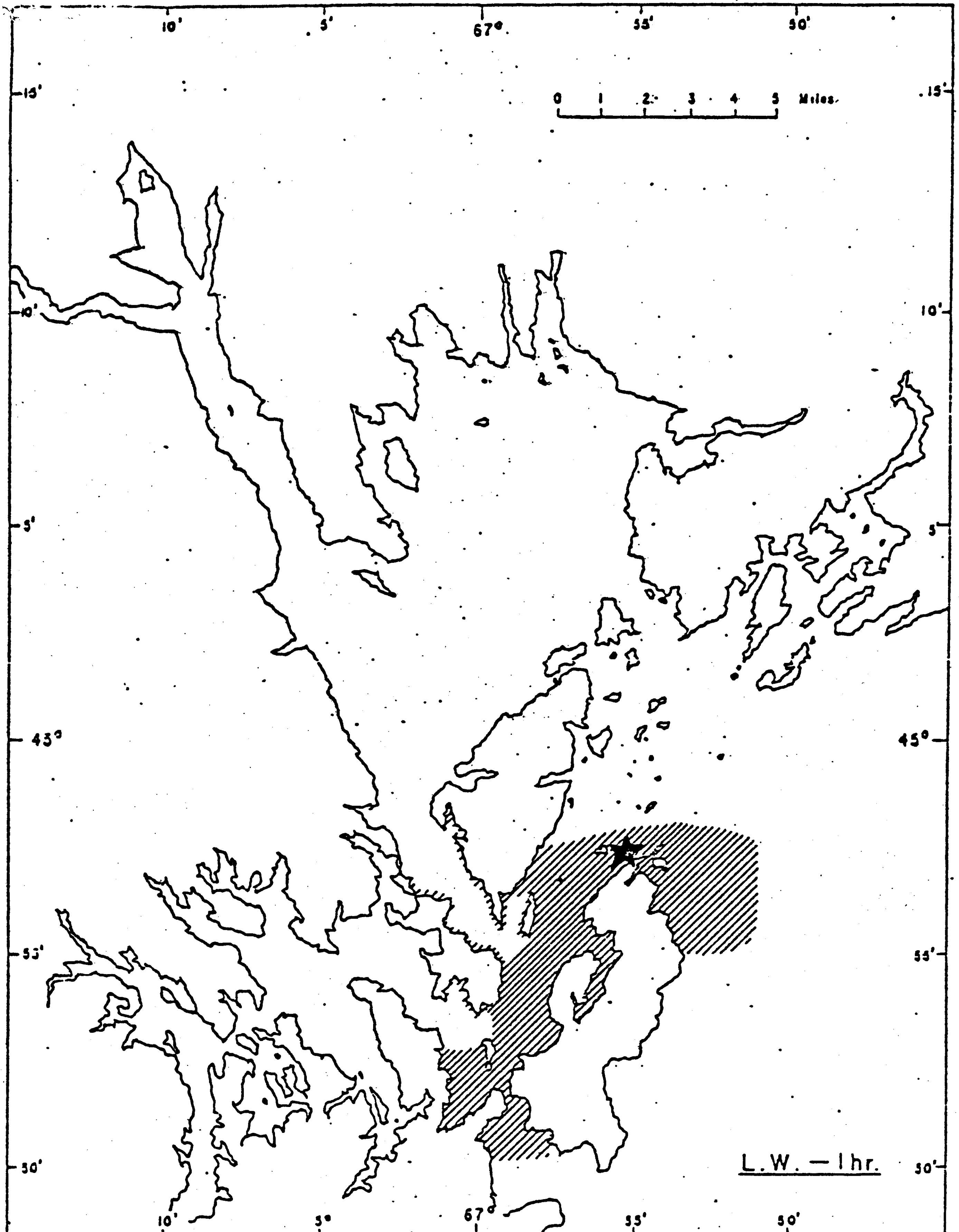

Figure 5. Predicted dispersion of oil 12 hours after a spill off Campobello Island (star) at low water minus 1 hour. From Canadian Department of the Environment (1974).