United States
Environmental Protection
Agency

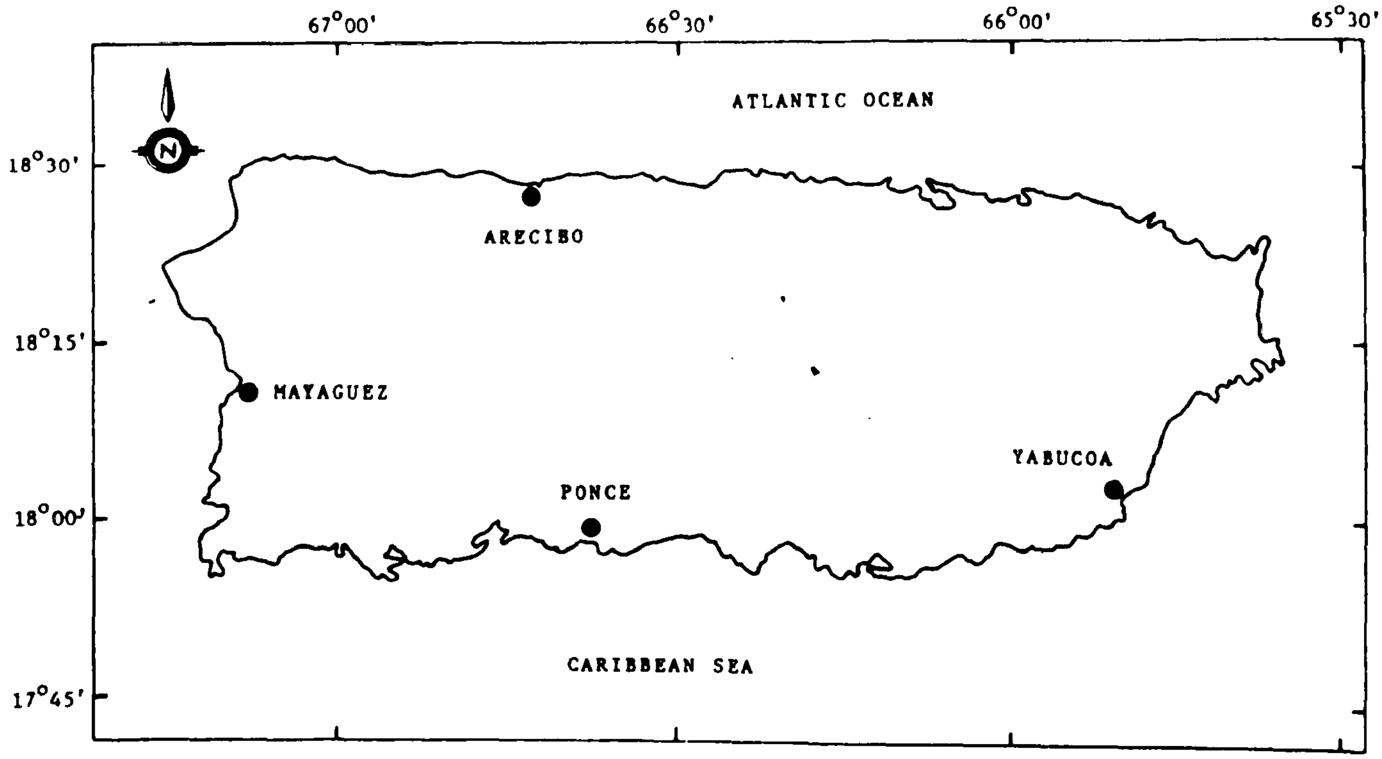
EPA, Region II
Office of Policy and Management
Environmental Impacts Branch
New York, N.Y. 10278

SEPTEMBER 1986

Water

EPA

Draft Environmental Impact Statement for the Designation of Ocean Dredged Material Disposal Sites for Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II
26 FEDERAL PLAZA
NEW YORK. NEW YORK 10278

SEP 3 1986

To All Interested Government Agencies and Public Groups:

This is to inform you that the Draft Environmental Impact Statement (EIS) for the Designation of Ocean Dredged Material Disposal Sites for Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico will be available for public review at the following locations:

U.S. Environmental Protection Agency
Environmental Impacts Branch
26 Federal Plaza, Room 702
New York, New York

U.S. Environmental Protection Agency
Caribbean Field Office
1413 Avenida Fernandez Juncos - Stop 20
Santurce, Puerto Rico

U.S. Environmental Protection Agency
Public Information Reference Unit
Room 2904 (Rear)
401 M Street, S.W.
Washington, D.C.

U.S. Army Corps of Engineers
Jacksonville District Office
400 W. Bay Street
Jacksonville, Florida

U.S. Army Corps of Engineers
San Juan Area Office
400 Avenida Fernandez Juncos
San Juan, Puerto Rico

Puerto Rico Department of
Natural Resources
Oficina 204
Centro Gubernamental
Avenida Rotarios
Arecibo, Puerto Rico

Puerto Rico Department of
Natural Resources
Oficina A
Centro Comercial
2 Alturas de Mayaguez Carr.
Mayaguez, Puerto Rico

Puerto Rico Department of
Natural Resources
5 Calle Celenia
Humacao, Puerto Rico

Puerto Rico Department of
Natural Resources
Hospital Sub-Regional
Ponce, Puerto Rico

This draft environmental impact statement (DEIS) was prepared by the U.S. Environmental Protection Agency (EPA) - Region II, with the assistance of JRB Associates, Inc., an environmental consulting firm. This document has been prepared in accordance with the regulations for implementation of the National Environmental Policy Act (NEPA), and in accordance with EPA's procedures for voluntary preparation of EISs on significant regulatory actions (39 FR 37119).

An EIS is a decision-making document. This DEIS was prepared for the purpose of evaluating the environmental impacts associated with the designation of sites for ocean disposal of dredged material from the harbors of Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico, and utilizes this evaluation in proposing particular sites for designation.

This document is in two volumes. Volume I includes the following: an executive summary plus chapters on the purpose of and need for the action, alternatives, selection of alternate sites and proposed actions, characteristics of the affected environments, and environmental consequences for each disposal site. Volume II includes eight appendices that contain detailed analyses used to evaluate the effects of the proposed action.

Comments concerning the content of this DEIS may be submitted to the EPA for consideration. All comments must be received within 60 days after the date of publication of the Notice of Availability for this DEIS in the Federal Register, which is expected to be October 10, 1986. Please address all comments to Ms. Barbara Pastalove, Chief, Environmental Impacts Branch, Room 702, U.S. Environmental Protection Agency, 26 Federal Plaza, New York, NY 10278.

If you require additional information regarding this DEIS, please contact Mr. Robert Witte, Project Monitor, at (212) 264-5396.

Sincerely,

Christopher J. Daggett
Regional Administrator - Region II

ABSTRACT

ABSTRACT

The proposed action addressed in this Environmental Impact Statement (EIS) is the designation of ocean dredged material disposal sites for Puerto Rico. The purpose of the action is to provide environmentally acceptable alternatives for disposal of dredged material from the four harbors of Arecibo, Mayaguez, Ponce, and Yabucoa.

Locations of presently used interim sites are:

- Arecibo - 1.5 nautical miles (2.7 km) north of the harbor
- Mayaguez - 5 nautical miles (9.3 km) northwest of the harbor
- Ponce - 4 nautical miles (7.4 km) south of the harbor
- Yabucoa - 4.5 nautical miles (8.3 km) east of the harbor.

Two alternate sites for Arecibo and three alternate sites each for Mayaguez, Ponce, and Yabucoa were identified using a site selection methodology developed by the Environmental Protection Agency and the U.S. Army Corps of Engineers.

The analysis conducted for the EIS indicated that at Arecibo the interim site, located approximately 1.5 nautical miles north of the harbor, should be designated as the ocean site for dredged material disposal. At Mayaguez, alternate site 1, approximately 8 nautical miles west of the harbor, should be designated as the ocean site for dredged material disposal. At Ponce, alternate site 1, about 5 nautical miles south of the harbor, should be designated as the disposal site. At Yabucoa, alternate site 2, approximately 6 nautical miles east of the harbor, should be designated as the disposal site.

Alternate land-based disposal methods considered in the analysis included placement of dredged material as hydraulic fill, use of dredged material to create wetlands, and use as cover material in landfills or barren areas. For Arecibo, land-based alternatives are not as environmentally acceptable as the ocean sites for dredged material disposal. For Mayaguez, Ponce, and Yabucoa, suitable areas limited in size may exist, but a lack of site-specific field data prevents an assured determination of the environmental impacts that would result from disposal at those sites.

Draft

Environmental Impact Statement for the Designation of Dredged Material Disposal Sites for the Harbors of Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico

U.S. Environmental Protection Agency
Region II
Environmental Impacts Branch (2PM-EI)
26 Federal Plaza
New York, NY 10278

SEPTEMBER 1986

Draft Environmental Impact Statement
for the Designation of Ocean Dredged Material Disposal
Sites for Arecibo, Mayaguez, Ponce, and
Yabucoa, Puerto Rico
June 1986

Prepared by
Environmental Protection Agency - Region II

Abstract: In accordance with the National Environmental Policy Act (NEPA) and the regulations of the U.S. Environmental Protection Agency (EPA), we have prepared a draft environmental impact statement (DEIS) for the designation of four ocean dredged material disposal sites for Puerto Rico. The purpose of the proposed action is to provide environmentally acceptable alternatives for disposal of dredged material from the harbors of Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico.

The four interim ocean disposal sites (one for each harbor) currently in use were analyzed. In addition, two alternate sites for Arecibo and three alternate sites each for Mayaguez, Ponce, and Yabucoa, as well as other alternatives (including land-based disposal methods), were identified and analyzed. The analyses conducted for the DEIS indicated that for Arecibo, the interim site, located approximately 1.5 nautical miles north of the harbor, should be designated as the ocean site for dredged material disposal. For Mayaguez, an alternate site, approximately 8 nautical miles west of the harbor, should be designated as the ocean site for dredged material disposal. For Ponce, an alternate site, approximately 5 nautical miles south of the harbor, should be designated as the disposal site. For Yabucoa, an alternate site, approximately 6 nautical miles east of the harbor, should be designated as the disposal site.

Written comments must be received no later than 60 days after the publication of the Notice of Availability in the Federal Register, which is expected to be October 10, 1986. These comments should be addressed to Chief, Environmental Impacts Branch, Room 702, U.S. Environmental Protection Agency, 26 Federal Plaza, New York, New York 10278. For additional information, please contact Mr. Robert Witte, Project Monitor, at (212) 264-5396.

Approved by: Christopher J. Daggett
Christopher J. Daggett
Regional Administrator

September 3, 1986
Date

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This draft environmental impact statement (EIS) evaluates the environmental consequences of designating an ocean dredged material disposal site (DMDS) for each of the harbors of Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico. The draft EIS identifies alternate ocean disposal sites for each harbor, characterizes the affected environments and types of materials to be released at the sites, and analyzes potential consequences of the proposed action.

PURPOSE AND NEED FOR THE ACTION

The proposed actions discussed in this draft EIS are the final designations of environmentally acceptable ocean disposal sites for materials dredged from the harbors and surrounding areas of Arecibo Harbor, the Port of Ponce, the Port of Mayaguez, and Yabucoa Harbor (all referred to subsequently as "harbors"). The purpose of the proposed actions is to designate final dredged material disposal sites in accordance with the requirements of the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA) and the U.S. Environmental Protection Agency's (EPA's) implementation of the Ocean Dumping Regulations (40 CFR 220-229).

The harbors of Arecibo, Mayaguez, Ponce, and Yabucoa are essential to the continued commercial and industrial growth of Puerto Rico. Ocean-going ships require channels, berths and turning basins that are, at a minimum, 10 meters deep. Each harbor is subject to gradual shoaling and filling in as a result of sediment inputs from rivers and storm waves. Periodic maintenance dredging is essential for the continued use of these harbors.

Since 1977, the U.S. Army Corps of Engineers (COE) has disposed of materials from dredging operations in Puerto Rico at dredged material disposal sites (DMDSs) designated by EPA on an interim basis. In 1980, the National Wildlife Federation filed suit against the EPA and COE in an attempt to persuade them to designate ocean dredged material disposal sites. Although these four Puerto Rico interim disposal sites are not included in the Consent Order resulting from that suit, EPA is responding to the Corps of Engineers' need to have designated ocean dredged material disposal sites and has initiated the necessary studies to select, evaluate, and designate the most suitable sites for the ocean disposal of dredged materials. This draft EIS was prepared to provide information needed to assess the impacts associated with the final designation of a dredged material disposal site (DMDS) for each harbor.

ALTERNATIVES INCLUDING THE PROPOSED ACTION

The proposed action is for the final designation of ocean dredged material disposal sites for Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico. The alternatives for each area include the following: no-action (continued use of the interim site), non-ocean disposal, designation of the interim site, and designation of one of the alternate sites.

Selection of the no-action alternative would result in EPA refraining from designating ocean disposal sites. This is unacceptable, since continued use of some of the interim sites would result in adverse environmental impacts to reef and beach areas.

The non-ocean disposal alternatives evaluated include land disposal, recycling and re-use options. The dredged material from the four harbors is primarily fine-grained material (silt and clay). This limits the land-based disposal alternatives to the following options:

- Placement as hydraulic fill
- Formation of wetland habitats
- Use as cover material in landfills or barren areas.

Use of these land-based disposal alternatives would be hampered by the limited number and size of potential disposal sites near the harbors and by the possibility that sites with suitable location, topography, and geohydrologic characteristics cannot be acquired.

At Arecibo, there are significant disadvantages associated with all of the land-based alternative disposal options. Hydraulic fill locations are likely to be limited in size and very expensive. Wetland production would be hindered by climatic conditions (high wave energies) and lack of suitable sites. Application of dredged material on land as a cover material could degrade ground water quality in the area, particularly at sites far from the coast. The only option that may be technically, environmentally, and economically feasible is use of one of the barren areas, if site specific studies verify the presence of abandoned sand pits at the site.

The use of land-based disposal alternatives near Mayaguez may be technically feasible. No potential sites for hydraulic filling were identified; however, one potential marsh production site, one or two landfill sites, and one barren area site were identified. Prior to the use of any of these sites for the disposal of dredged materials, an extensive site-specific field study would be required.

The use of land-based disposal alternatives near Ponce may be technically feasible. One potential diked containment area for placement of hydraulic fill and one potential wetland formation area were identified. No landfills were found suitable, but four small sand mining pits could be suitable if found to be permanently unused because of sand depletion. Prior to the use of any of these sites as dredged material disposal sites, an extensive site-specific field study would be required.

The use of land-based dredged material disposal alternatives at Yabucoa may be technically feasible. Sites suitable for hydraulic fill may be available, although no specific sites for diked containment areas were identified. There is sufficient land of suitable topography for diked containment areas near the coast in the Yabucoa Valley, however use of this land might be in competition with its use as farmland. No sites suitable for wetland formation, landfill cover material application, or barren area cover material application were identified near Yabucoa.

From this analysis, it would appear that non-ocean alternatives would be feasible only on a short-term basis, due to limited capacity and potential conflicts with other uses for any possible sites.

Alternate ocean dredged material disposal sites to be evaluated by the EIS were selected using a screening methodology developed by EPA and the COE. A brief description of the phases of EPA/COE's recommended site-designation process follows:

- Phase 1: Establish Zones of Siting Feasibility (ZSF's)
  - A preliminary screening of environmental factors, based on the nine evaluation factors specified in MPRSA Section 102a and the criteria specified in the Ocean Dumping Regulations (ODR, Part 228) to eliminate areas of known conflict with protected resources and existing uses of the ocean
- Phase II: Select Alternate Sites
  - Evaluate interim dredged material disposal sites, and identify other possible ocean disposal sites believed to be in accordance with the ocean dumping criteria
- Phase III: Evaluate Interim and Alternate Sites
  - Evaluate the suitability of each of the sites and select, based on ODR criteria, a site for designation as the DMDS for continuing use.

The locations of the interim sites and the alternate sites selected according to the EPA/COE methodology are indicated below:

• Arecibo (Figure S-1)	Interim Site	LAT 18°30'30"N LONG 66°43'16"W
	Alternate Site #1	LAT 18°31'34"N LONG 66°44'24"W
	Alternate Site #2	LAT 18°31'48"N LONG 66°46'00"W
• Mayaguez (Figure S-2)	Interim Site	LAT 18°15'00"N LONG 67°14'00"W
	Alternate Site #1	LAT 18°15'00"N LONG 67°15'42"W

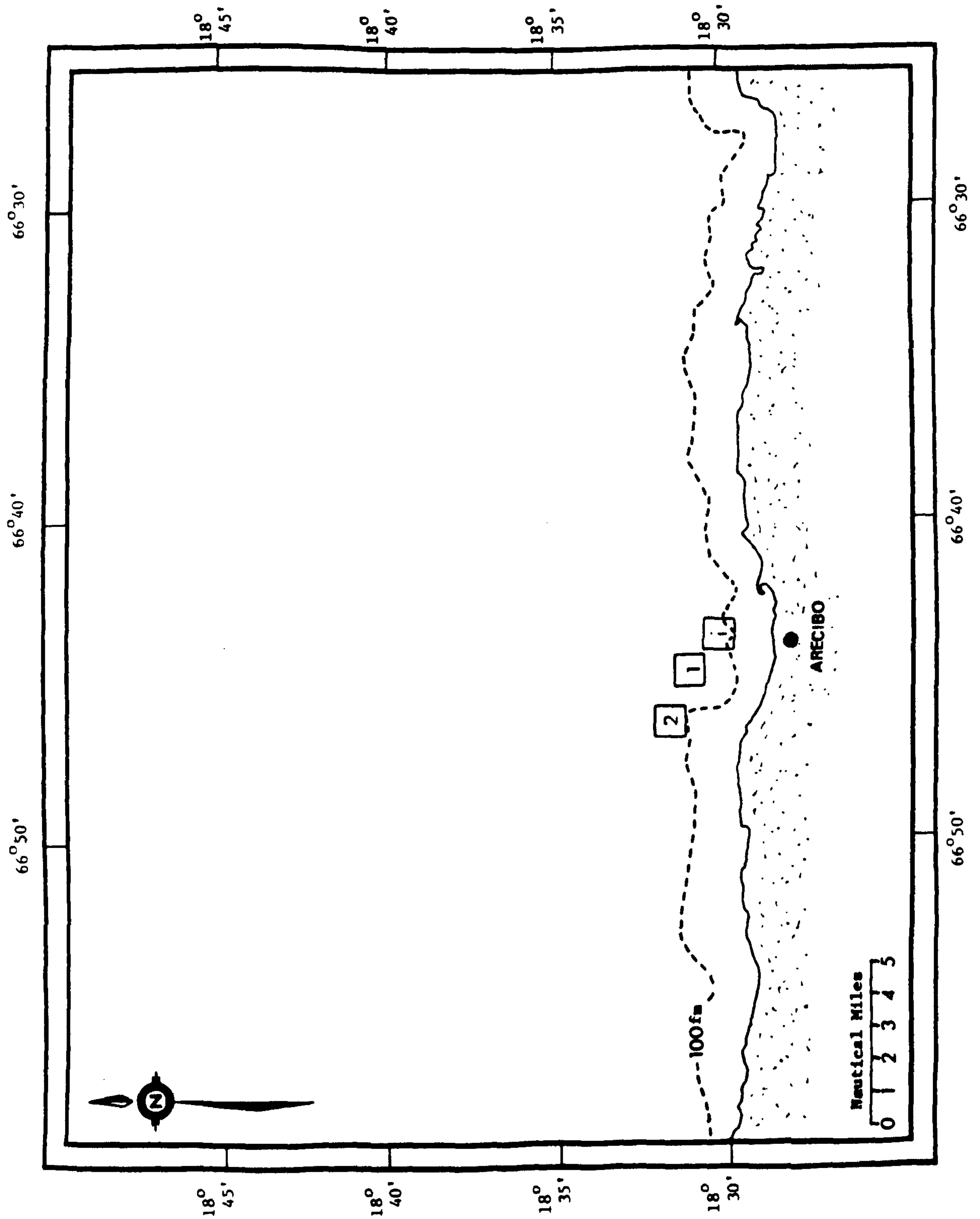


FIGURE S-1. INTERIM AND ALTERNATE SITES FOR ARECIBO

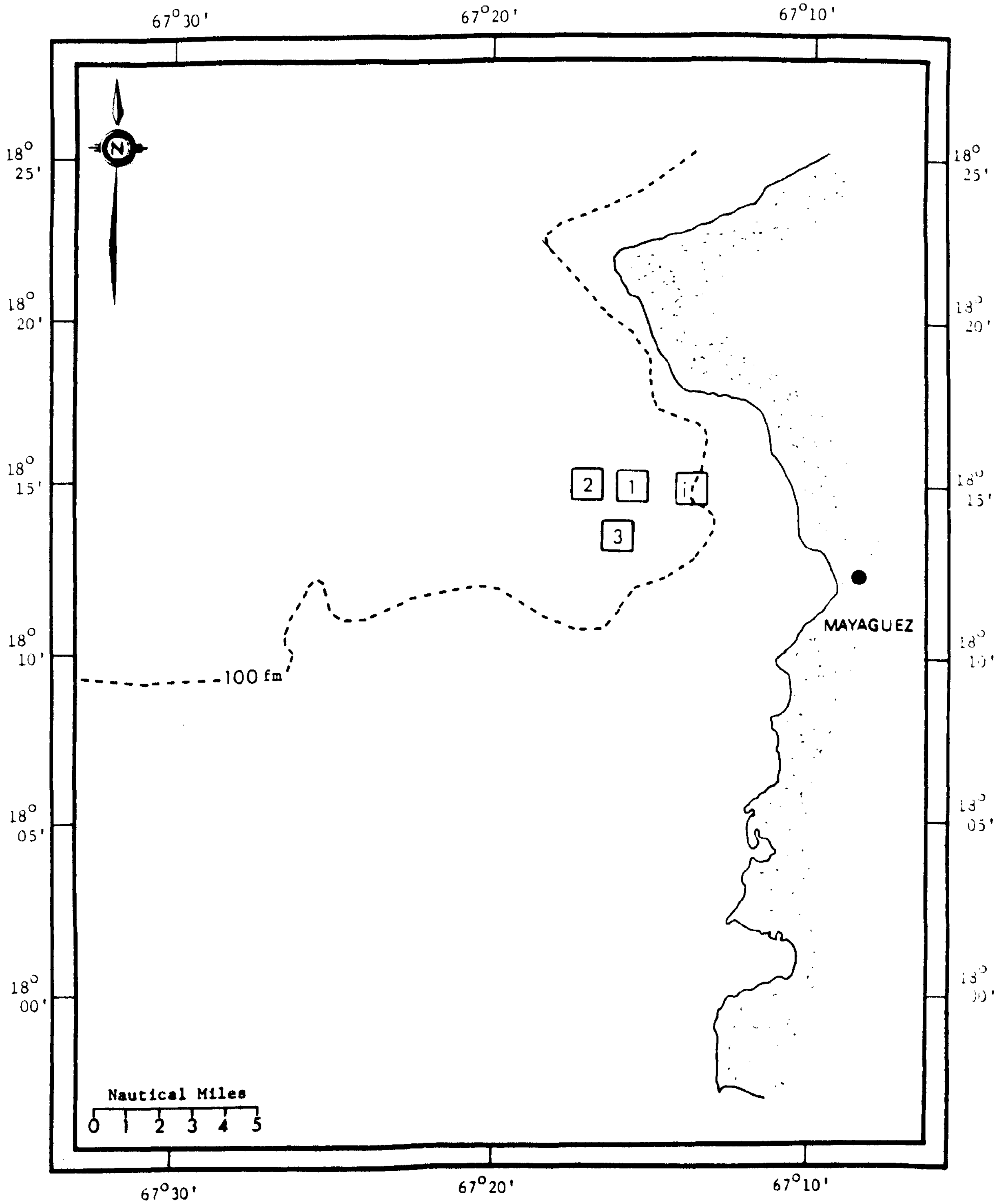


FIGURE S-2. INTERIM AND ALTERNATE SITES FOR MAYAGUEZ

	Alternate Site #2	LAT 18°15'06"N LONG 67°16'48"W
	Alternate Site #3	LAT 18°13'54"N LONG 67°16'24"W
• Ponce (Figure S-3)	Interim Site	LAT 17°55'00"N LONG 66°38'54"W
	Alternate Site #1	LAT 17°53'20"N LONG 66°37'52"W
	Alternate Site #2	LAT 17°52'00"N LONG 66°38'54"W
	Alternate Site #3	LAT 17°52'04"N LONG 66°37'42"W
• Yabucoa (Figure S-4)	Interim Site	LAT 18°02'06"N LONG 65°45'00"W
	Alternate Site #1	LAT 18°01'18"N LONG 65°44'48"W
	Alternate Site #2	LAT 18°03'12"N LONG 65°42'18"W
	Alternate Site #3	LAT 18°03'50"N LONG 65°39'16"W

ENVIRONMENTAL CONSEQUENCES

Continuing use of the interim dredged material disposal site for Mayaguez or Yabucoa Harbors is likely to result in deposition of sediments at levels harmful to corals in reef areas adjacent to the sites. It is not expected that there will be any adverse effects on coral reefs from the use of any of the alternate sites for Mayaguez, alternate sites 2 or 3 for Yabucoa, or the interim or alternate sites for Arecibo or Ponce.

Copepods, fish eggs, and perhaps bivalve eggs can be seriously affected by suspended sediment concentrations such as those immediately resulting from the disposal of dredged materials. However, because of the transient nature of suspended sediment plumes in the deep-water, open-ocean environments of all considered sites, such planktonic organisms would not be exposed to the sediments for time periods long enough to have significant effects.

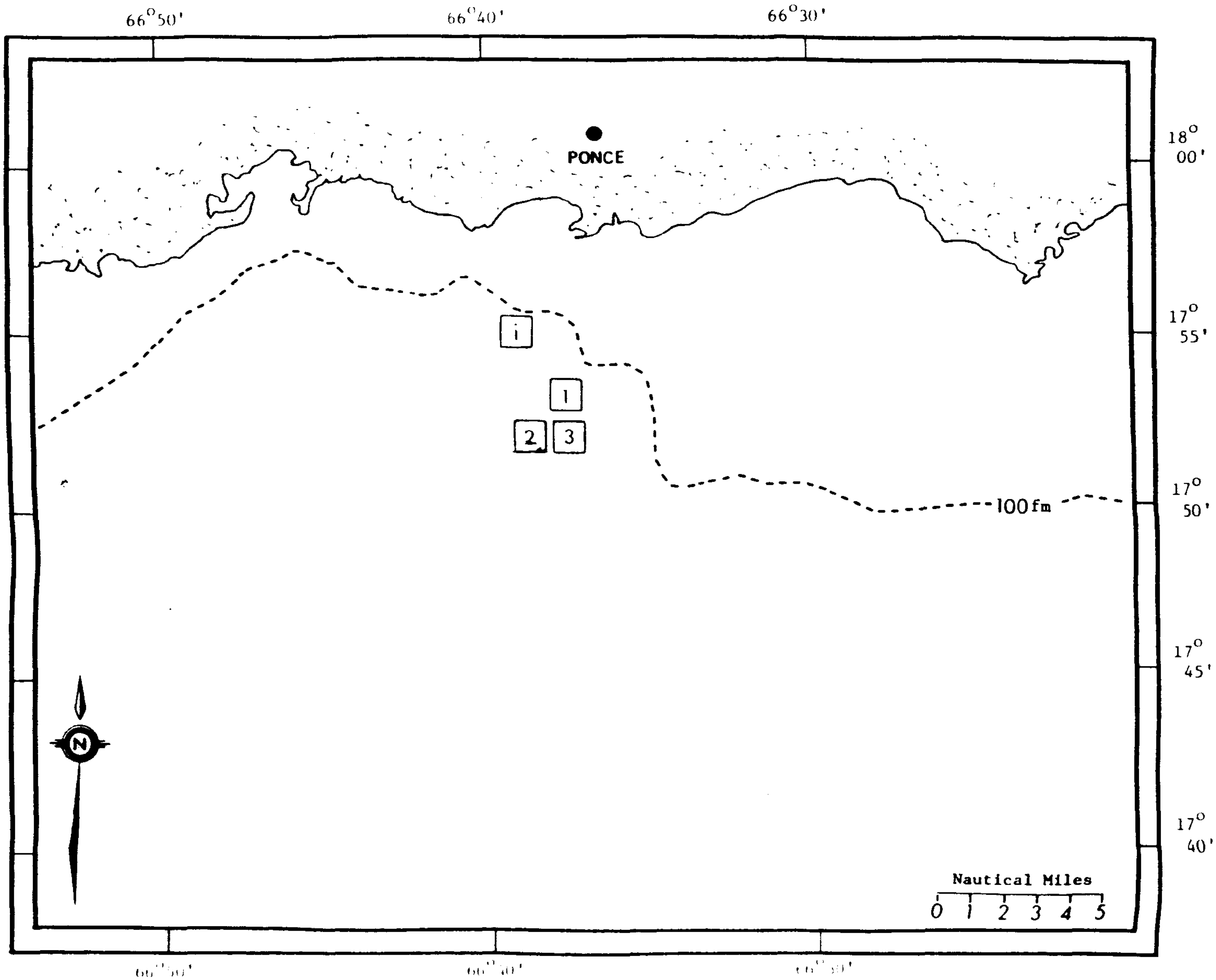


FIGURE S-3. INTERIM AND ALTERNATE SITES FOR PONCE

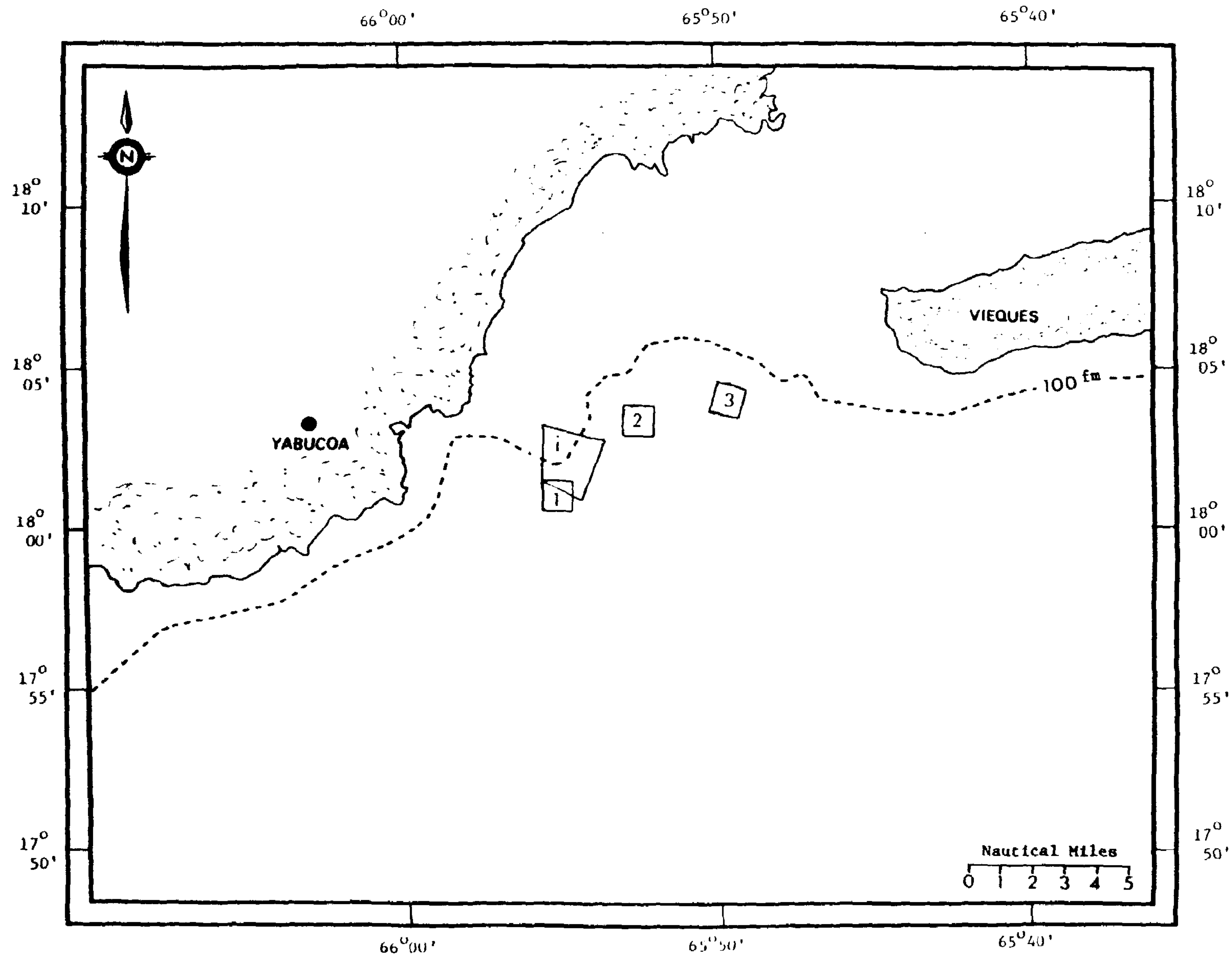


FIGURE S-4. INTERIM AND ALTERNATE SITES FOR YABUCOA

There should be no measurable increases in sediment concentrations at any beaches or shorelines because of dredged material disposal at any of the interim or alternate sites for Arecibo or Mayaguez. Use of alternate site 2 or 3 at Ponce or alternate site 1 at Yabucoa would cause a detectable increase in ambient sedimentation levels at the shoreline.

There should be no effects on mineral resources, natural reserves, commonwealth forests, mangrove nursery areas, critical wildlife areas, or any endangered species' habitats from disposal at the interm or alternate sites for any of the four harbors. Therefore, no unreasonable degradation of the marine environment is expected to occur as a result of the proposed action.

CONCLUSIONS

There is a confirmed need to dispose of large quantities of dredged material from the ports and harbors of Puerto Rico. Land-based disposal methods are not considered viable alternatives to ocean dredged material disposal except on a short-term basis. Thus, the proposed action is designation of dredged material disposal sites (DMDS) for continued use. For one harbor, the proposed DMDS is the interim site. For the other three harbors, an alternate site is proposed.

Of the disposal sites considered for Arecibo, the interim site is the proposed site, 1.5 nautical miles (nmi) north of the harbor.

The proposed site for Mayaguez is alternate site 1. This site is 7 nmi west of the harbor. The interim site was eliminated from consideration because it is in relatively shallow water close to shore, where released dredged materials are likely to be transported into a coral reef area.

The proposed site for Ponce is alternate site 1, which is located 5.5 nmi south of the harbor. The interim site was eliminated from consideration because plumes of suspended sediments from the site are expected to reach the shorelines, beaches, and coral reefs near a commonwealth forest natural reserve area.

The proposed site for Yabucoa is Alternate Site No.2, 6 nmi east of the harbor. The interim site was not selected because it includes a very shallow area inhabited by corals, and because sediment plumes from the interim site could be carried close to shorelines and into an important nearshore commercial fishing area.

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APPENDIX FIGURES (Continued)

APPENDIX FIGURES (Continued)

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1. PURPOSE OF AND NEED FOR ACTION

1. PURPOSE OF AND NEED FOR ACTION

1.1 PURPOSE OF ACTION

The harbors of Arecibo, Mayaguez, Ponce, and Yabucoa are important to the commercial and industrial development of Puerto Rico. Access of ships to the harbors depends on periodic dredging to maintain the authorized depths. In the past, materials from these dredging operations was disposed of at interim designated ocean disposal sites. In 1980, the National Wildlife Federation (NWF) challenged the practice of using interim ocean disposal sites pending completion of long term studies and final designation pursuant to the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA), as amended (86 Stat. 1052, 33 USCA Part 1401 et seq., 45 Fed. Reg 3053 Jan 16, 1980). In resolving the law suit, the EPA and the U.S. Army Corps of Engineers (COE) entered into a consent decree with the NWF to take steps to designate final ocean dredged material disposal sites (DMDSs) for certain sites with interim designation. Although these four Puerto Rican interim disposal sites were not covered by the consent decree, EPA is responding to COE's need to have designated ocean dredged material disposal sites in Puerto Rico. EPA is undertaking studies preparatory to designating a final DMDS at each harbor.

The action proposed in this environmental impact statement (EIS) is the final designation of environmentally acceptable ocean disposal sites for materials dredged from the harbors and areas surrounding Arecibo, Mayaguez, Ponce and Yabucoa. The environmental studies and final designation are being conducted in accordance with the requirements of MPRSA; EPA's implementation of the ocean dumping regulations (ODR) and ODR criteria (40 CFR 220-229); the National Environmental Policy Act (NEPA); and other applicable Federal legislation. Figures 1-1 through 1-4 show the study areas and interim ocean disposal sites for each harbor.

1.2 ARMY CORPS OF ENGINEERS NEED FOR ACTION

Approvals of private permit requests and COE-initiated projects for the ocean dumping of dredged material are made by the U.S. Secretary of the Army in accordance with regulatory criteria established by EPA. Section 103 of

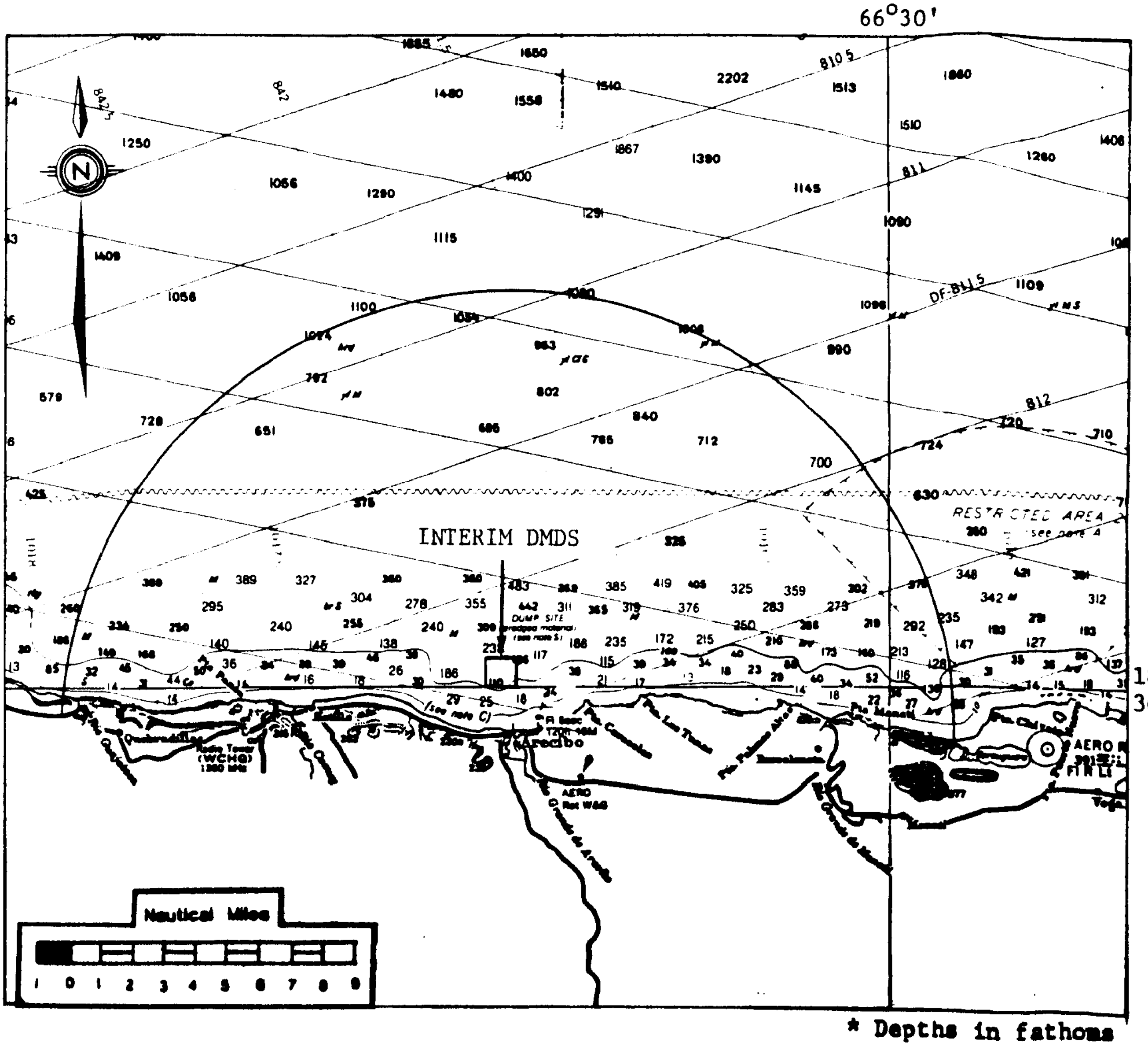


FIGURE 1-1. BASE MAP FOR ARECIBO STUDY AREA

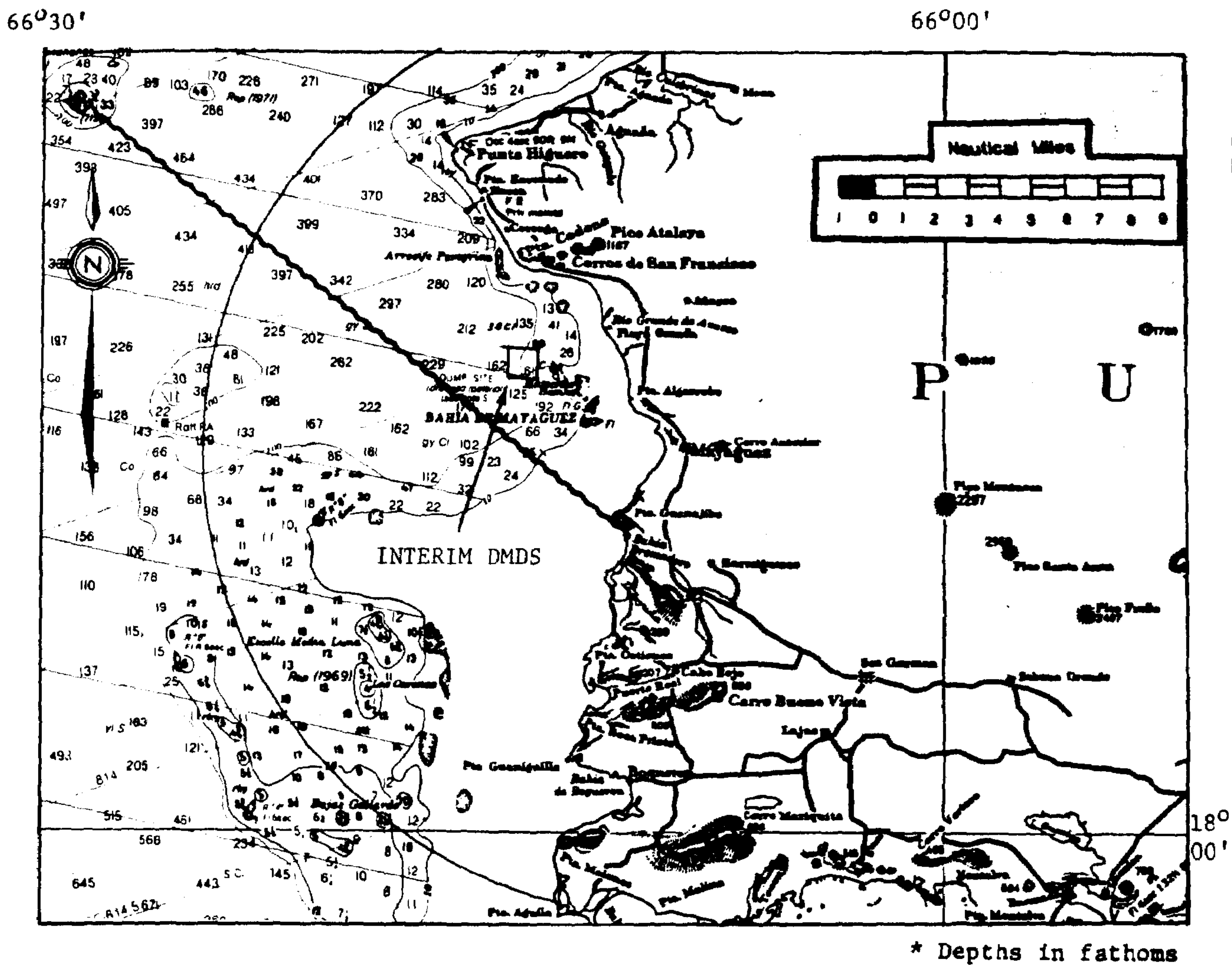


FIGURE 1-2. BASE MAP FOR MAYAGUEZ STUDY AREA

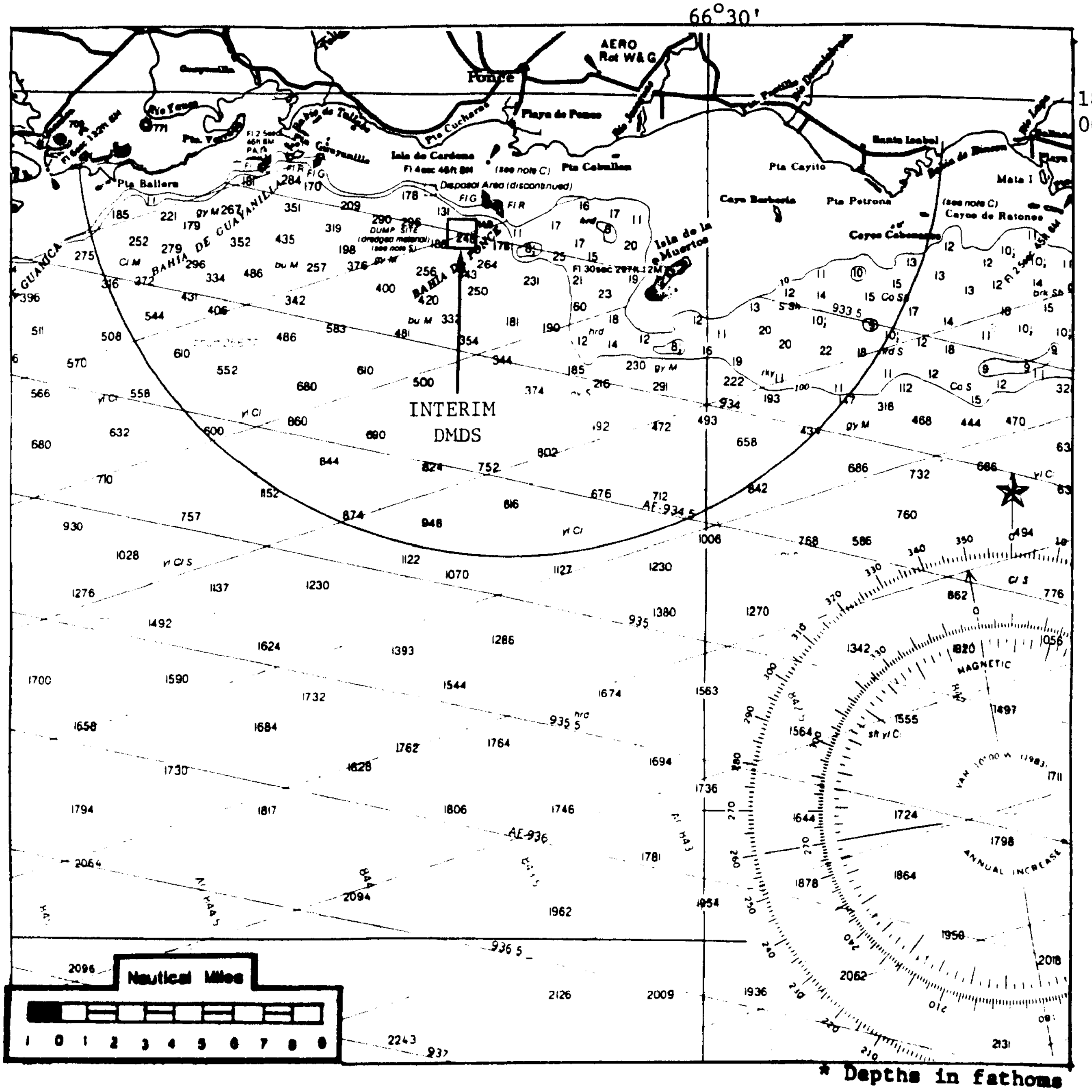


FIGURE 1-3. BASE MAP FOR PONCE STUDY AREA

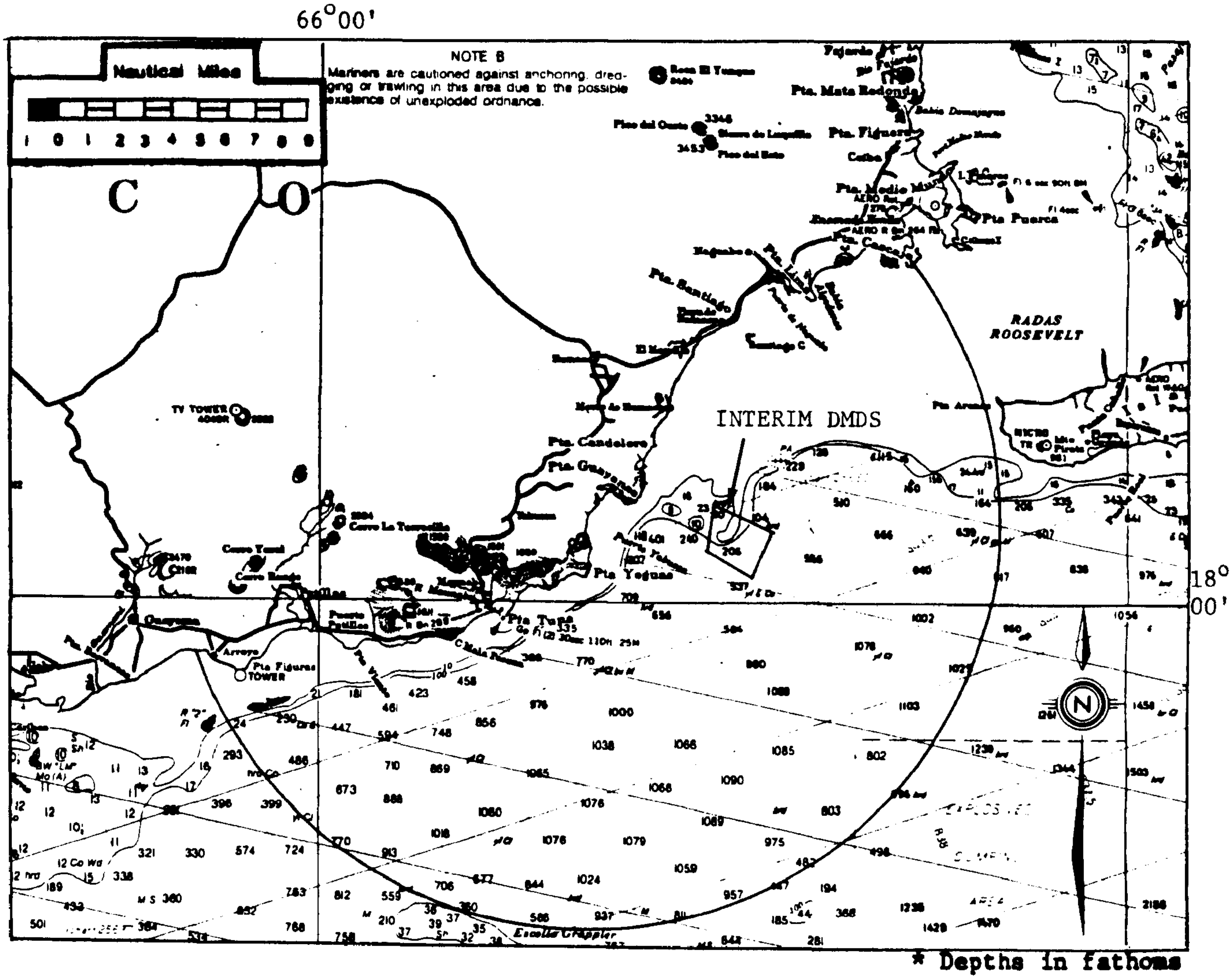


FIGURE 1-4. BASE MAP FOR YABUCOA STUDY AREA

MPRSA requires COE to consider the effects of ocean disposal of dredged material on human health and welfare, or amenities, and on the marine environment, ecological systems, or economic potentialities. The 1977 Ocean Dumping Criteria gave EPA and COE three years to complete studies on 127 dredged material ocean dumpsites. EPA initiated studies on sites, and in 1980 published an amendment to the criteria extending the interim designation of 46 unstudied dumpsites for up to three more years. The amendment also extended the interim designation of 85 additional unstudied dredged-material dumpsites for an indefinite period of at least three years.

In February 1980 the NWF filed suit against the EPA and the COE in an attempt to persuade them to take steps to complete ocean dumpsite designation for the identified sites. These did not include the four sites considered by this EIS. The lawsuit was settled by a stipulation of settlement and dismissal in which COE agreed to issue a guidance memorandum directed to district and division engineers specifying procedures to be followed in determining whether to issue an ocean dumping permit for disposal of dredged material at interim designated dumpsites. The directive from COE Headquarters required the district engineer, before authorizing dumping at interim-approved dumpsites, to assess reasonable availability of alternatives to dumping there. Specifically, the engineer should consider:

- The feasibility and practicability of using a finally designated site or a more fully studied dumpsite in lieu of an unstudied dumpsite.
- The feasibility and practicability of deferring the decision on ocean dumping at the proposed site until site study and/or final designation efforts have been completed, and
- The availability of practicable alternative locations, and methods of disposal or recycling (i.e., land based alternatives) of the material proposed to be ocean-dumped.

Since 1977, the COE in Puerto Rico has used ocean dredged material disposal sites designated by EPA on an interim basis. Use of these sites has been an essential element of COE compliance with the requirements of MPRSA and its ability to carry out its statutory responsibility for maintaining safe navigation in the harbors of Puerto Rico. To continue to maintain these waterways COE considers it essential that EPA identify, evaluate and permanently designate environmentally acceptable ocean dredged material disposal sites. These sites will be used after reviews of each project and permit application have established that the proposed activity is in compliance with the criteria and requirements of EPA and COE regulations.

1.3 CORPS OF ENGINEERS LOCAL NEED FOR ACTION

The harbors of Arecibo, Mayaguez, Ponce, and Yabucoa are essential to the continued commercial and industrial growth of Puerto Rico. Ocean-going ships require channels, berths and turning basins that are, at a minimum, about 6 fathoms (10 meters deep). Periodic maintenance dredging is essential for the continued use of these harbors. Each harbor is subject to gradual shoaling and filling in as a result of sediment deposition from rivers and storm-waves. Without dredging, the harbors would eventually become inaccessible to large commercial vessels. Future dredging actions may include both maintenance dredging and harbor channel deepening.

The following sections discuss the specific dredging needs of each harbor.

1.3.1 Need for Dredging, Arecibo

Arecibo is subject to flash flooding during the rainy season. The Rio Grande de Arecibo and its tributaries, which flow into the harbor, contribute heavily to sediment deposition from May to October. In addition, Arecibo is subject to periodic shoaling because of its exposure to the periodic heavy wave conditions characteristic of the north coast.

Arecibo is an important harbor for ships transporting pharmaceutical supplies and products from a number of pharmaceutical plants located southeast of the port. The amount of dredged material to be removed is likely to be on the order of 75,000 to 150,000 cubic meters (100,000 to 200,000 cubic yards) every three to five years (these estimates are based on data presented in Appendix B).

1.3.2 Need for Dredging, Mayaguez

Flash flooding during the rainy season contributes heavily to sediment deposition in the Mayaguez coastal embayment. The Port of Mayaguez is the principal harbor on Puerto Rico's west coast. A total of 321,764 tons of freight traffic moved through the harbor in 1983 (COE 1981). Dredging volumes in this harbor have varied in past years; the amount of dredged material to be removed is expected to range from 15,000-114,000 cubic meters (20,000 to 150,000 cubic yards) every two to five years (Appendix B).

1.3.3 Need for Dredging, Ponce

Ponce is one of the three principal Puerto Rican harbors able to receive large ocean-going commercial vessels; only the harbor of San Juan handles more tonnage. A total of 854,651 tons of freight traffic (five percent of the waterborne commerce of the island) moved through the Port of Ponce in 1981 (COE, 1983).

There are public and private port facilities at Ponce. The municipal pier and bulkhead area have six ship berths owned and operated by the Municipal Port Authority of Ponce. Five of the berths have depths of about 30 feet and are from 350 to 500 feet long. Adjacent to the municipal bulkhead are a variety of commercial facilities that depend on the port: seven municipal warehouses, a private tuna packing plant, and a 1.6 hectare (4 acre) cargo storage area (COE 1975).

Two rivers, Rio Matilde and Rio Portuques, empty into Ponce Harbor, and the mouth of a third, the Rio Bucana, is about one mile east of the port. These river basins are among the steepest on the island. Therefore, the short, intense showers of the wet season (May through October) result in floods that transport large volumes of sediments to Ponce.

The amount of dredged material that may have to be removed is expected to be on the order of 75,000 to 150,000 cubic meters (100,000-200,000 cubic yards) of sediment every three years (Appendix B). In addition, COE may need to dispose of an unknown quantity of dredged materials from the neighboring

Guayanilla Bay, a harbor whose dredged materials have in the past been dumped at the Ponce DMDS. At Guayanilla, dredging is necessary to keep the harbor open to ocean-going petroleum tankers and local oil barges (COE 1981a).

1.3.4 Need for Dredging, Yabucoa

Yabucoa is the only commercial harbor in southeastern Puerto Rico. Unlike the other three harbors addressed in this EIS, Yabucoa is maintained and operated by the Puerto Rico Port Authority. Cargos at the harbor are mainly crude oils destined for the Sun Oil refinery in Yabucoa.

The amount of dredged material that may have to be removed is expected to be on the order of 380,000 to 450,000 cubic meters (500,000 to 600,000 cubic yards) every five to six years (Appendix B). In addition, the Puerto Rico Port Authority will need to dispose of an unknown quantity of materials from the neighboring harbor and channel at Puerto Las Mareas (Guayama Harbor) (COE 1981b), and the COE will need to dispose of materials from the harbor channels of the Roosevelt Roads naval base (EPA 1981).

1.4 ENVIRONMENTAL PROTECTION AGENCY'S NEED FOR ACTION

The transportation and dumping of materials in ocean waters is regulated under Title I of the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA). Title I requires that the EPA Administrator and the U.S. Secretary of the Army establish permit programs to exclude from the ocean all dredged and nondredged material that might result in unreasonable degradation or endangerment of the marine environment or human health. COE is responsible for dredged-material permits. EPA is responsible for all other wastes. Title I requires EPA to establish criteria, based on the nine evaluation factors specified in MPRSA Section 102(a), to review and evaluate requests for permits. Section 102(c) of Title I authorizes EPA to consider these criteria in designating ocean disposal sites or times for dumping dredged and nondredged material. The statute provides for the case-by-case evaluations of ocean dumping permit applications, and dumping is approved only when there is an affirmative showing of no unreasonable degradation.

To meet its responsibilities under MPRSA, EPA developed Ocean Dumping Regulations (ODR) and criteria (1973) and revised them in January 1977 (40 CFR 220-229). These regulations set forth procedures and criteria for:

- Evaluating dredged material disposal permit applications (Part 225),
- Enforcing permit conditions (Part 226),
- Evaluating proposed actions for environmental impacts (Part 227), and
- Designating and managing disposal sites for ocean dumping (Part 228).

Part 228 establishes the five general and eleven specific criteria that are used to evaluate the environmental acceptability of potential DMDSs.

To carry out its statutory responsibility of maintaining the nation's navigation waterways while complying with the provisions of MPRSA and other applicable federal statutes, COE needs designated DMDSs in Puerto Rico.

In response to this need, EPA has initiated the necessary studies to select, evaluate, and designate the most suitable sites for the ocean disposal of dredged material from the above four harbors. This document has been prepared to provide relevant information needed to assess the impacts associated with the final designation of an DMDS for each harbor.

1.5 INTERNATIONAL CONSIDERATIONS

The principle international agreement governing ocean dumping is the convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, commonly known as the London Dumping Convention (LDC), which became effective in August 1975 upon ratification by 14 contracting countries including the United States (26 UST 2403: TIAS 8165). There are now 44 contracting parties. Designed to control dumping of wastes in the ocean, the Convention specifies that contracting nations will regulate disposal in the marine environment within their jurisdiction and prohibit disposal without permits. Disposal of certain hazardous materials (e.g., radiological, biological, and chemical warfare agents, and high-level radioactive matter) is completely prohibited. Certain other materials (e.g., cadmium, mercury, organohalogens and their compounds, oil, and persistent synthetic or natural materials that float or remain in suspension) are also prohibited as other than trace contaminants unless they are rapidly rendered harmless by physical, chemical, or biological processes in the sea. Other materials (e.g., arsenic, lead, copper, zinc, cyanides, fluorides, organosilicon, and pesticides) not specifically prohibited will require the issuance of a special permit. The nature and quantities of all ocean-dumped material, and the circumstances of disposal, must be periodically reported to the Inter-Governmental Maritime Consultative Organization (IMCO) which is responsible for administration of the Convention.

The criteria of the U.S. Ocean Dumping Regulations are based on the provisions of the LDC and include all the considerations listed in Annexes I, II, and III of LDC. Agreements reached under the LDC allow exclusions from biological testing for dredged material from certain locations. These agreements are also reflected in the U.S. ocean dumping criteria. Thus, when a material is found to be acceptable for ocean dumping under the U.S. ocean dumping criteria, it is also acceptable under the LDC.

2. ALTERNATIVES INCLUDING THE PROPOSED ACTION

2. ALTERNATIVES INCLUDING THE PROPOSED ACTION

2.0 INTRODUCTION

The proposed actions are the permanent designations of ocean dredged material disposal sites at Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico.

Alternatives to the proposed action must be evaluated to meet the requirements of the National Environmental Policy Act (NEPA).

Alternatives considered for each harbor were:

- No-Action: The no-action alternative to final designation is to refrain from designating ocean disposal sites. This would result in continued disposal at the interim ocean disposal sites.
- Non-Ocean Disposal: The non-ocean disposal alternatives to be evaluated include land disposal, recycling, and reuse options.
- Designation of the interim ocean disposal site as the site for continuing use.
- Designation of one of several alternative ocean disposal sites as the site for continuing use.

2.1 NO-ACTION ALTERNATIVE

The no-action alternative to the proposed action would be to refrain from designating ocean sites for the disposal of dredged material from the harbors and areas surrounding Arecibo, Mayaguez, Ponce, and Yabucoa, Puerto Rico. COE uses an interim designated site for each harbor. By selecting the no-action alternative COE would not have EPA-designated ocean disposal sites available, but would continue to use the interim designated sites.

2.2 NON-OCEAN DISPOSAL ALTERNATIVE

Dredged material from the harbors is primarily fine-grained material (silt and clay). The land-based alternatives for the disposal of fine-grained material that were evaluated included:

- Placement as hydraulic fill
- Formation of wetland habitats, and
- Use as cover material in landfills and barren areas.

This section discusses the need for evaluating land-based dredged material disposal, the types of disposal options available, and the potentially suitable sites at each of the four harbors.

2.2.1 Introduction

Disposal of dredged material on land is sometimes technically, economically, and environmentally preferable to disposal at sea. In Puerto Rico, dredged material has been disposed of by both methods. The predominant land-based disposal method has been hydraulic filling, which was used to produce land for industrial development and to fill in wetlands (COE 1975, Colon 1984).

2.2.2 Justification for Evaluation of Land Based Disposal

The action proposed in this EIS is the final designation of environmentally acceptable ocean disposal sites for dredged materials. As required by 40 CFR Part 6 -- Implementation of Procedures on the National Environmental Policy Act of 1969, an EIS must evaluate possible alternatives to the proposed action. The only possible alternative (other than no-action) to the designation of ocean disposal sites would be land-based disposal. Land-based options are examined in the following sections of this chapter.

2.2.3 Available Land-Based Disposal Methods

Disposal of dredged material on land in Puerto Rico is more expensive than ocean disposal. Suitable sites near the harbors are limited and expensive because of their potential commercial value. Each proposed disposal action would need a site-specific impact assessment and engineering study. There is a high potential for environmental damage if the disposal area is improperly designed, constructed, or operated.

2.2.3.1 Factors Affecting Selection of Land-Based Disposal Alternatives

The suitability and availability for land-based disposal options depend on:

- The costs of land, site preparation, and transportation of material to the site.
- The characteristics of the dredged material.
- The environmental and socioeconomic conditions near the harbor.

Table 2-1 compares the dredged material disposal costs of various disposal alternatives. These general data indicate that several land-based alternatives can be cost-competitive with ocean disposal if suitable sites can be located, and if land prices at the sites are lower than the average prices for commercial land near the harbors. However, land is at a premium in Puerto Rico, and land near the harbors considered in this EIS is expensive, ranging from $15 to $30 per square meter, ($60,000 to $120,000 per acre, Franciscas Realty 1984). It is specifically outside of the scope of an EIS to evaluate relative dollar values of environmental resources, or impacts upon those resources, except for the purposes of establishing absolute feasibility of a disposal option.

Land values in this range indicate that land disposal will not be a feasible option in most Puerto Rican locations, and that particularly low-cost land disposal options such as use of barren areas, or abandoned mining pits, or productive disposal options such as valuable wetland creation, are the only feasible land-based alternatives. An evaluation of environmental acceptability and availability of such alternatives in the regions surrounding the four harbors is presented below. A summary of the conclusions of these evaluations is given in Section 2.2.4.

United States Geological Survey (USGS) topographic maps of the four harbors, and studies of waste disposal in Puerto Rico were used to locate sites near each harbor that meet the appropriate disposal site criteria. The results of this analysis are presented in Table 2-2.

TABLE 2-1. COMPARISON OF REPRESENTATIVE COSTS FOR OCEAN AND NON-OCEAN DISPOSAL OPTIONS

DM Disposal Technique	Partial Cost	Modification	Full Disposal Cost $/cy
Ocean Disposal-			
• Clamshell dredge and barge scow (Mayaquez, PR)	0.715[2] to 2.00 cy/nmi	Assuming 1.5 to 8.5 nmi to ocean DMDS	Representative cost $2-5/cy[6] $3.00 cy[2] to 6.08/cy
• COE hopper dredge (national average)	$0.20/cy/nmi[4]	Assuming 1.5 to 8.5 nmi to ocean DMDS	0.45 to $1.70/cy
• Barge scow or hopper dredge, unspecified	$0.1593/cy/nmi[3]	*Assuming 1.5 to 8.5 nmi to ocean DMDS	0.24 to $1.35/cy
Land Disposal-			
• Use of diked containment areas on land	2.5 times cost of open water disposal is dependent on transport distance and site size.[5]		Representative costs
• Marsh production, without revegetation	Dikes cost from $30,000 to $5 million for sites 10 acres to 2500 acres in size in 1972[5]		$0.29-0.78/cy[1]
• Marsh production, with revegetation			$4.50[7]*
• Dewatering at a regional site, then use as landfill cover material			$13 to $21/cy[1]
• Pipeline transport to landfill or or barren area	1 mile, without booster to 2 miles, with booster pump.		$1.65 to $3.08/cy[5]*
• Use for beach nourishment via pipeline to beach, transport 10 nmi or less	2600 feet of pipeline $1.122/cy[5]*		$2.70 to 8.30/cy using transport costs given above
• Use of DM to produce containment islands	2 to 3 1/2 times cost of ocean disposal[1]	OD x 2 = OD x 3.5 =	0.50 to 21.30/cy

Sources:

(1) Coch et al. 1983
(2) Pers. comm. Gerald Atman, COE Jacksonville, FL, June 26, 1984
(3) EPA 1981 (Vieques EIS)
(4) Pers. comm. Dave Mathis, COE Ft. Belvoir, VA, June 20, 1984
(5) Brady, 1976
(6) Pers. comm. Dave Mathis, COE Ft. Belvoir, VA, June 29, 1984
(7) Knutson 1976

* Converted from original (outdated) cost by using factors presented in Englesmann (1984)

TABLE 2-2. COMPARATIVE SUMMARY OF ENVIRONMENTAL CONSEQUENCES OF LAND-BASED ALTERNATIVES

Evaluation Criteria	Placement as Hydraulic Fill	Formation of Wetlands	Use as Cover Material in Landfills	Use as Cover Material in Barren Areas
Air Impacts	Emission of pollutants (CO, particulates, hydrocarbons, NO_x and SO_x) from fuels used by earth-moving equipment during dike construction. Dust from unvegetated dry hydraulic fill.	Possible dust from dry dredged material prior to establishment of complete vegetative cover.	Dust emissions during and after cover material placement likely until vegetative cover established	Dust emissions during and after cover material likely until vegetative cover established.
Water Impacts	Surface water impacts minor if effluent is discharged into salt water and if dikes remain structurally sound; groundwater impacts minor if site overlies saline or brackish groundwater.	Surface water impacts minor if effluent is discharged into salt water and if dikes remain structurally sound; groundwater impacts minor if site overlies saline or brackish groundwater.	Surface water impacts likely because most landfills are not near salt water. Groundwater contamination with salt is likely because most landfills overlie nonsaline water	Surface water impacts likely because most landfills are not near salt water. Groundwater contamination with salt is likely because most landfills overlie nonsaline water
Land Impacts	Would require long term (10 year or more) commitment of 2 to 37 acres per harbor.[1]	Would require decreasing size of nearby lagoons or protected, shallow-water by 4 to 37 acres per harbor.[2]	May cause substantial increase in use rates of existing landfills.	Would fill in and cover abandoned or mined-out portions of quarries or pits, and allow some types of land re-use after fill material has consolidated.

(1) Assuming a dredged material volume of from 69,100 to 600,000 cubic yards and a dredged material depth of from 10 to 20 feet (3 to 6 meters).

(2) Assuming a dredged material volume of from 69,100 to 600,000 cubic yards and a dredged material depth of from 6 to 10 feet (2 to 3 meters).

An analysis was conducted to determine the specific requirements for land-based dredged material disposal sites, using various dredged material disposal techniques. These requirements are described in detail in Appendix E.

The site-suitability analysis was intended only to locate potentially suitable sites for dredged material disposal. The analysis did not account for the possibility that suitable sites may not be available for use because of owner opposition or incompatible current land use, or that local opposition may preclude the use of certain dredged material disposal techniques.

Table 2-3 also lists the number of suitable sites near each harbor for these potential disposal options. At Arecibo and Yabucoa, there are suitable sites for only one of the four disposal options. At Mayaguez and Ponce three of the four options are considered feasible.

2.2.3.2 Land-Based Disposal Options for Fine-Grained Sediments

The dredged material from all of the harbors is primarily fine-grained material (containing high percentages of silt and clay); this factor limits the land-based disposal alternatives to the following options:

- Placement as hydraulic fill
- Formation of wetland habitats
- Use as cover material in landfills or barren areas.

The disposal process for each of these methods are described below. Data on historical use of each method and their respective advantages and disadvantages are presented in Appendix C.

Placement as Hydraulic Fill -- Hydraulic filling is a dredged material disposal method that involves placing the dredged material as a slurry in a contained area on land. Hydraulic filling requires the construction of dikes around a large, flat area that is close to a navigable waterway. The dike must also contain an adjustable dam called a weir. The dredged material is

TABLE 2-3. SUMMARY OF LAND-DISPOSAL SITE SUITABILITY AT ARECIBO, MAYAGUEZ, PONCE AND YABUCOA

Harbor	Number of Potentially Suitable Sites for Each Land-Based Disposal Method			
	Placement as Hydraulic Fill	Formation of Wetlands	Cover Material for Landfills	Cover Material for Barren Areas
Arecibo	0	0	0	1
Mayaguez	0	1	1-2	1
Ponce	1	1	0	4
Yabucoa	1	0	0	0

pumped as a slurry into the diked containment area and the solids are allowed to settle out of the water. The clear water flows out over the weir and into a nearby water body. If the dredged material is sandy, the solids settle out rapidly; the water flows out readily and a stable material results. If the dredged material is clay, the solids settle out very slowly, and sufficient drainage to produce a stable material can take decades (Harrison and Chisolm 1974, McCarthy 1977).

Formation of Wetland Habitats -- This disposal option involves careful site selection, preferably at an elevation within the tidal range, near existing marshes, and in areas protected from high wave energies (Patin 1976; Holloway 1976; Smith 1976). To form a marsh, dikes are built along the perimeter of the site to an elevation that is higher than the highest tide plus a few feet of freeboard to prevent dike erosion by storm waves. The dredged material is hydraulically placed and the site may eventually be revegetated, after sufficient dewatering has occurred. Mangroves are a common type of vegetation used in the formation of wetland habitats in Puerto Rico. Other types of emergent vegetation can be used as well.

Use as Cover Material in Landfills or Barren Areas -- The use of dredged material as a cover material for landfills or barren areas has been suggested as a feasible alternative to ocean disposal. A study of disposal alternatives for dredged material from the New York Harbor area describes two processes by which the dredged material could be handled. In one process, the material could be transported as a slurry through a pipeline from the barge to the landfill or barren area (the disposal site) if the disposal site is within 5 miles of a navigable waterway, and if the topography between the barge off-loading point and the disposal site is not too variable or steep. Once at the disposal site, the dredged material would have to be placed in a diked containment area or in thin layers over large areas to allow drying, prior to vegetating (Coch et at. 1983).

The second possible process requires the use of a large diked containment area. The dredged material would be partially dried at this facility using COE-developed dredged material drying techniques. The material would then be trucked to landfills or barren areas (Coch et al. 1983).

2.2.4 Land-Based Options for Each Harbor

The availability of land-disposal options is evaluated in this section independently for each harbor. A summary of conclusions for all harbors is given in Section 2.2.5.

2.2.4.1 Land-Based Disposal Options for Arecibo

The locations of the mangroves, landfills, and barren areas identified near Arecibo are shown in Figure 2-1. The appropriateness of each site was evaluated, taking into account the site's location relative to Arecibo, its distance from the coast, its elevation, its geohydrology, and other factors. Details of these analyses are presented in Appendix C.

There are significant disadvantages associated with all of the possible alternative disposal options. Hydraulic fill locations, if any suitable sites can be located and acquired, are likely to be limited in size and very expensive. Wetland production would be hindered by ocean conditions (high wave energies) and lack of suitable sites. Application of dredged material on land as a cover material could degrade groundwater quality in the area particularly at sites far from the coast. The only option that might be technically, environmentally, and economically feasible would be use of one of the barren areas, if this site does contain a series of abandoned sand pits, as indicated in one reference map (as discussed in Appendix C, p. C-21). Environmental studies would have be done to determine whether that barren area would have the capacity to receive Arecibo dredged material, and it is likely that environmental and economic factors would mitigate against use of this alternative.

2.2.4.2 Land-Based Disposal Options for Mayaguez

The locations of the mangroves, landfills, and barren areas identified near Mayaguez are shown in Figure 2-2. Appendix C presents details of site evaluations.

The use of land-based disposal alternatives near Mayaguez may be technically feasible. No potential sites for hydraulic filling were identified,

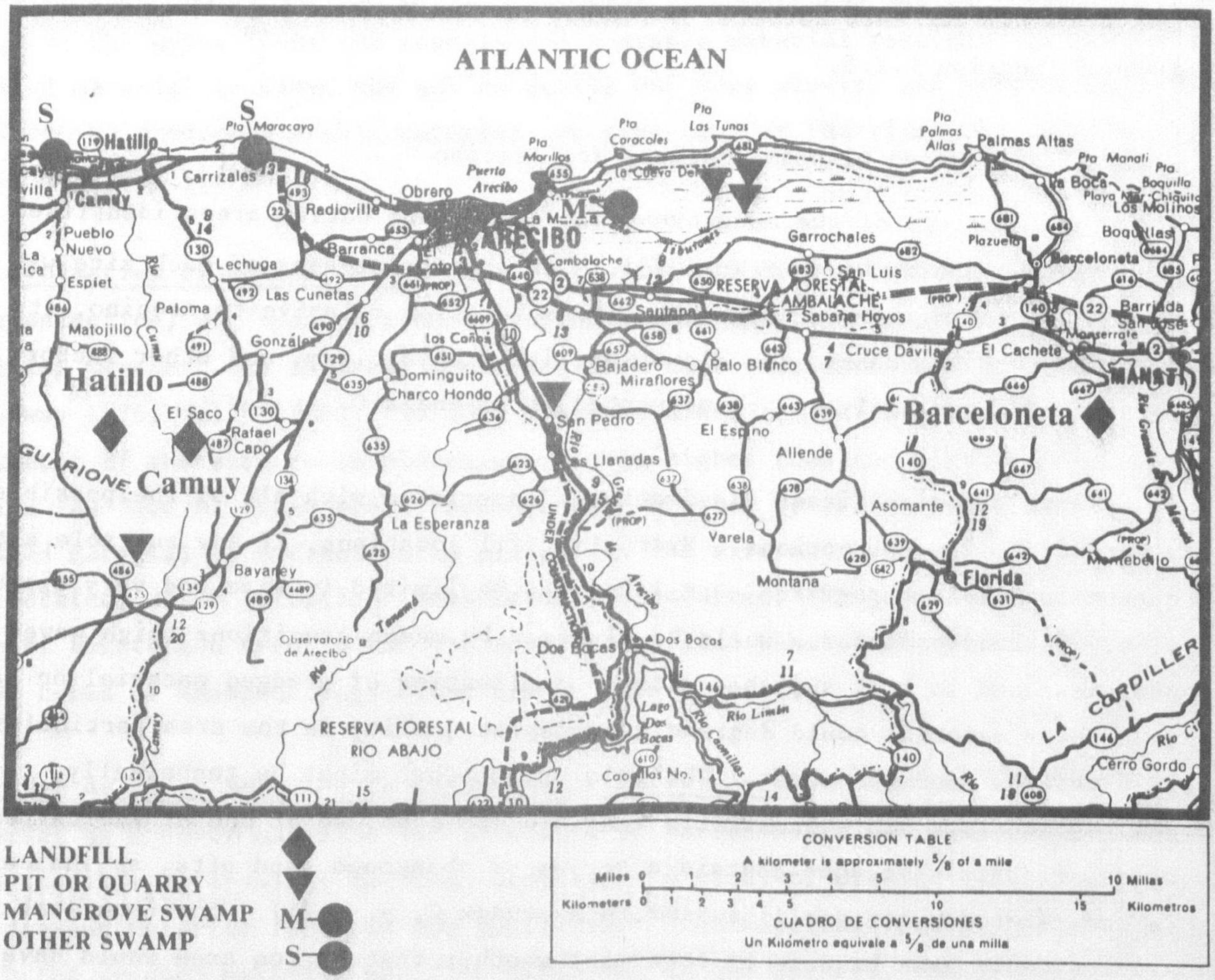


FIGURE 2-1. LOCATIONS OF MANGROVES, LANDFILLS AND BARREN AREAS NEAR ARECIBO

Source: Torrez-Gonzalez and Gomez-Gomez (1982); USGS (1982 d); USGS (1982 e).

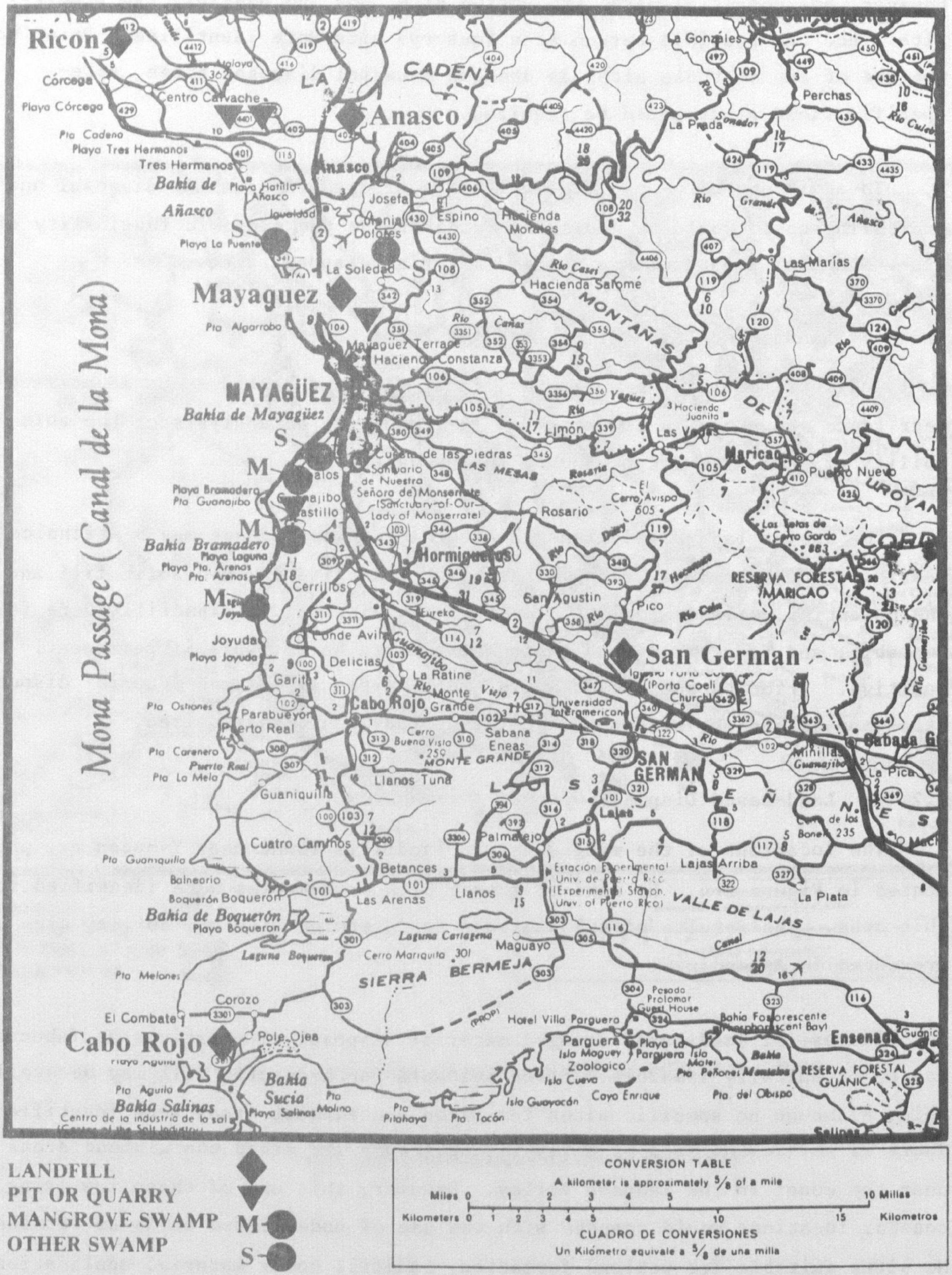


FIGURE 2-2. LOCATIONS OF MANGROVES, LANDFILLS AND BARREN AREAS NEAR MAYAGUEZ

Source: Torrez-Gonzalez and Gomez-Gomez (1982); USGS (1964); USGS (1966).

however, one potential marsh production site, one and possibly two landfill sites, and one possible barren area (quarry) site were identified. Prior to the use of any of these sites as dredged material disposal sites, site-specific field study would be required.

In addition, site-specific evaluation of dredged material disposal and monitoring costs would be necessary to determine the economic feasibility of each potential location as a dredged material disposal site.

2.2.4.3 Land-Based Disposal Options for Ponce

The locations of the mangroves, landfills, and barren areas identified near Ponce are shown in Figure 2-3. The result of an analysis of the suitability of each site are presented in Appendix C.

The use of land-based disposal alternatives near Ponce may be technically feasible. One potential diked containment area site for hydraulic fill and one potential wetlands formation area were identified, no landfills were found suitable, and four small sand mining pits could be suitable if permanently inactive. Prior to the use of any of these sites as dredged material disposal sites, an extensive, site-specific field study would be required.

2.2.4.4 Land-Based Disposal Options for Yabucoa

The locations of the mangroves and landfills found near Yabucoa are presented in Figure 2-4. No sand or gravel pits or quarries were identified in this area. The results of the analyses to determine site suitability are presented in Appendix C.

The use of land-based dredged material disposal alternatives at Yabucoa may be technically feasible. Sites suitable for hydraulic fill may be available, although no specific sites for diked containment areas were identified. There is sufficient land of suitable topography for diked containment areas near the coast in the Yabucoa Valley. However, this use of these low-lying coastal locations would compete with the use of undeveloped areas as farmland. No sites suitable for wetland formation, landfill cover material application, or barren area cover material application near Yabucoa were identified.

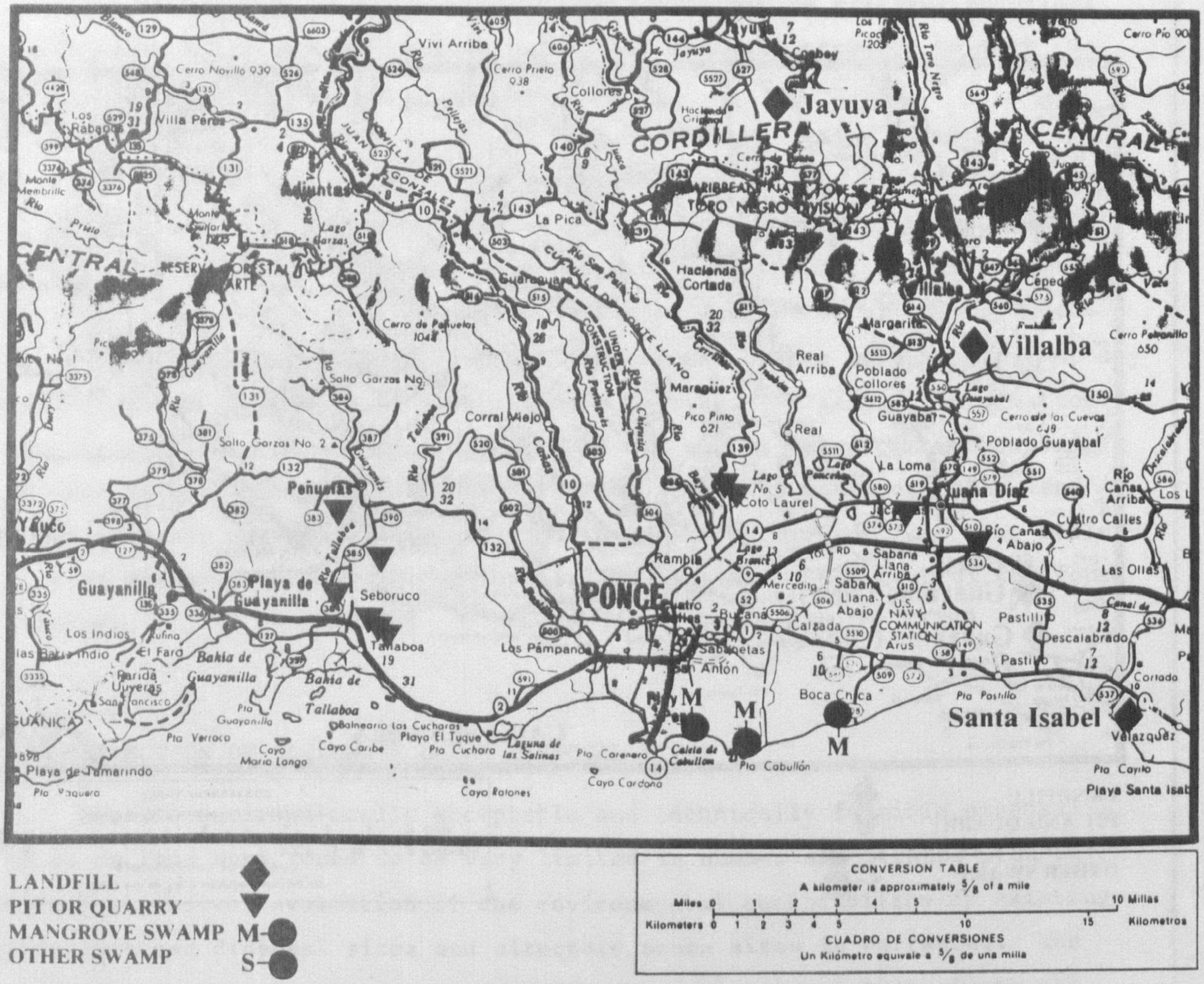


FIGURE 2-3. LOCATIONS OF MANGROVES, LANDFILLS AND BARREN AREAS NEAR PONCE

Source: Torres-Gonzalez and Gomez-Gomez (1982)
USGS (1982 f); USGS (1982 g); USGS (1982 h); USGS (1982 j).

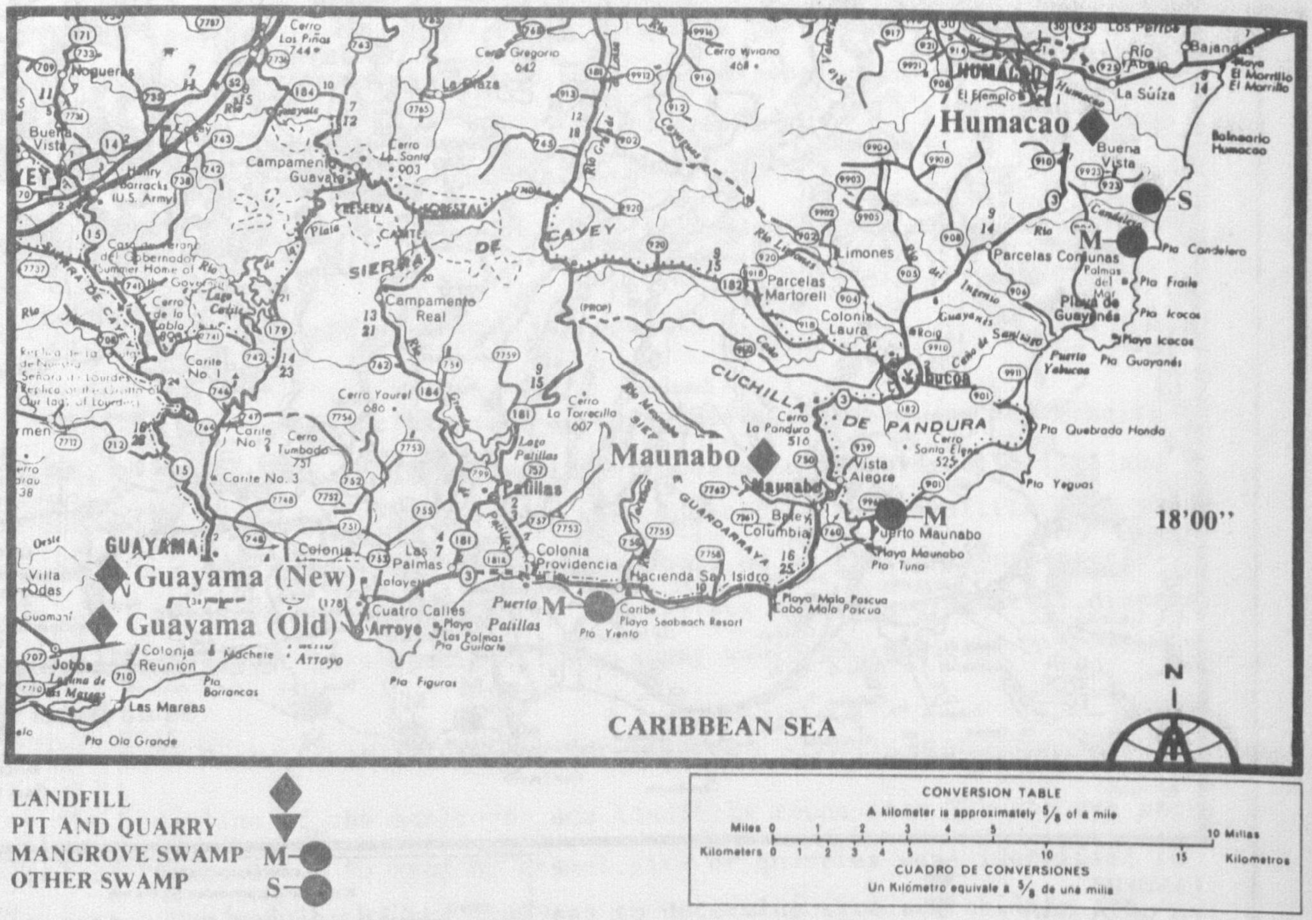


FIGURE 2-4. LOCATIONS OF MANGROVES, LANDFILLS AND BARREN AREAS NEAR YABUCOA

Source: Torrez-Gonzalez and Gomez-Gomez (1982); USGS (1982 j); USGS (1982 k).

2.2.5 Conclusions Concerning Options for Land Disposal

For Arecibo and Ponce, the small number of potentially usable land-disposal areas identified indicates that, even if field studies revealed that sites in those areas were environmentally acceptable as disposal locations, there would still probably not be sufficient regional capacity to meet the maintenance dredging needs of the two harbors.

For Mayaguez and Yabucoa, the possibility of finding usable land-disposal locations cannot be entirely ruled out. Because a number of potentially serious environmental problems can occur from land disposal in inappropriate areas, the absence of site-specific field data for the locations in question means that detailed field studies would be needed before acceptability of any land-disposal site could be established. However, the general information that is available regarding land costs in the region suggests that costs may in fact be prohibitive. For these reasons, it can be concluded that land-based disposal options are not assured in any harbor region, and that evaluation of ocean-based disposal options is thus warranted for each of the four harbors.

2.3 SELECTION OF ALTERNATE OCEAN DISPOSAL SITES

Because environmentally acceptable and technically feasible disposal sites on land were found to be very limited in number and perhaps prohibitively expensive, evaluation of the environmental acceptability of existing interim ocean disposal sites and alternate ocean sites is warranted. The methodology used to select the alternate ocean sites, and to evaluate the interim and alternate ocean sites, is described below.

2.3.1 The EPA/COE Protocol for Ocean Dredged Material Disposal Site (DMDS) Designation

In 1983, EPA and COE developed a handbook (EPA/COE 1983) recommending a protocol to be followed in implementing the ocean dumping regulations (ODR) for designating ocean dredged material disposal sites. This protocol is based on the "tiered" site-selection screening approach of Pequegnat, et al. (1981). For technical guidance, the protocol draws from the approach to biological hazard and effects assessment described in a 1983 EPA workshop report on DMDS evaluation techniques (Reed and Bierman 1983). A brief description of the phases of EPA/COE's recommended site-designation process follows.

- Phase I: Establish Zones of Siting Feasibility (ZSFs)
  - A preliminary screening of environmental factors, based on the nine evaluation factors specified in MPRSA Section 102a and the criteria specified in the Ocean Dumping Regulation (Part 228), to eliminate areas of known conflict with protected resources and existing uses of the ocean.
- Phase II: Select Alternate Sites
  - Evaluate interim dredged material disposal sites, and identify other possible ocean disposal sites believed to be in accordance with the ocean dumping criteria.
- Phase III: Evaluate the Interim and Alternate Sites
  - Evaluate the suitability of each of the sites and select, based on ODR criteria, a site for designation as the DMDS for continuing use.

2.3.1.1 Criteria for Evaluating Interim Sites and Selecting and Evaluating Alternate Sites from the Ocean Dumping Regulations

EPA's 1977 Ocean Dumping Regulations establish five general and eleven specific criteria for evaluating the environmental suitability of ocean disposal sites for dredged materials and other wastes.

Provisions of the general criteria state that:

1) Sites be selected to minimize interference with other activities in the marine environment.
2) Any elevated pollutants concentrations that occur upon dumping must be reduced to either ambient or undetectable levels before reaching any beach, shoreline, marine sanctuary, or geographically limited fishery.
3) The EPA should limit site size so as to localize impacts and facilitate monitoring.
4) The EPA should choose sites beyond the "continental shelf" (depths of 200 meters, or approximately 100 fathoms).

5) The EPA should select previously used disposal sites whenever possible.

The eleven specific criteria (40 CFR 228.6) to be considered in addition to the general criteria described above are as follows:

- Geographical position, depth of water, bottom topography, and distance from the coast;
- Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases;
- Location in relation to beaches and other amenity areas;
- Types and quantities of wastes proposed to be disposed of and methods of release, including methods of packing the waste, if any;
- Feasibility of surveillance and monitoring;
- Dispersal, horizontal transport, and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any;
- Existence and effects of current and previous discharges and dumping in the area (including cumulative effects);
- Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate uses of the ocean;
- The existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys;
- Potential for development or recruitment of nuisance species at the disposal site;
- Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.

This EIS characterizes each of the study sites with respect to these criteria.

2.3.1.2 Phase I: Establish Zones of Siting Feasibility

In October of 1983, EPA conducted a preliminary siting feasibility study (Task 1 report in support of the EIS), in accordance with procedures recommended in the EPA/COE site-designation protocol (EPA/COE 1983). In this approach, the preparers of the assessment develop a series of maps from historical data. The maps deal with important resources (e.g. natural reserves, nursery areas, corals, historic sites) and use categories (e.g. navigation, commercial fishing, recreation) addressed in MPRSA 102(a) and the ODR (Section 228). The maps are used in an overlay technique to successively eliminate sensitive or questionable areas from further analysis. The final composite map serves to define the zone of siting feasibiliity (ZSF) for the study area. The ZSF indicates an area free of sensitive resources or incompatible competing use. The ZSF's for the Puerto Rican study areas are presented in Figures 2-5, 2-6, 2-7 and 2-8. Factors considered in establishing each ZSF included information available at the time on physical oceanographic characteristics, such as surface and deep currents, or degrees of density stratification in the water columns that would affect the transport of disposed materials from the point of release to their settling locations. Practical factors set an upper limit of approximately 15 nmi, or 28 km, on the feasible distance between a potential ocean DMDS location and the principal dredging location. This limit is based on estimates that typical speeds of loaded barges operating in a variety of weather conditions average about 5 knots (nmi/hour), and that the disposal operation may require one to two hours. Fifteen nmi is thus a reasonable estimate of the maximum one-way distance that a barge can travel to complete disposal and return on the same working day. Since numerous environmentally suitable potential DMDS locations were identified within 15 nmi of each harbor, it was not necessary to consider locations beyond that limit.

2.3.1.3 Phase II-Select Alternate Ocean Disposal Sites

Once the ZSF was determined, EPA staff scientists developed a survey cruise plan to gather representative data from the interim designated site and other likely alternate sites. Sites to be considered as alternatives to interim sites were selected from the previously identified ZSF's, with the exception of sites in the Ponce study area. Information obtained in intensive literature searching completed after the Phase I feasibility study provided a more complete characterization of the physical transport conditions in the Ponce region. Because of the scarcity of physical oceanographic data available during the Phase I study, and the consequent lack of assurance that disposal closer to shore would not result in transport into fishing areas east of

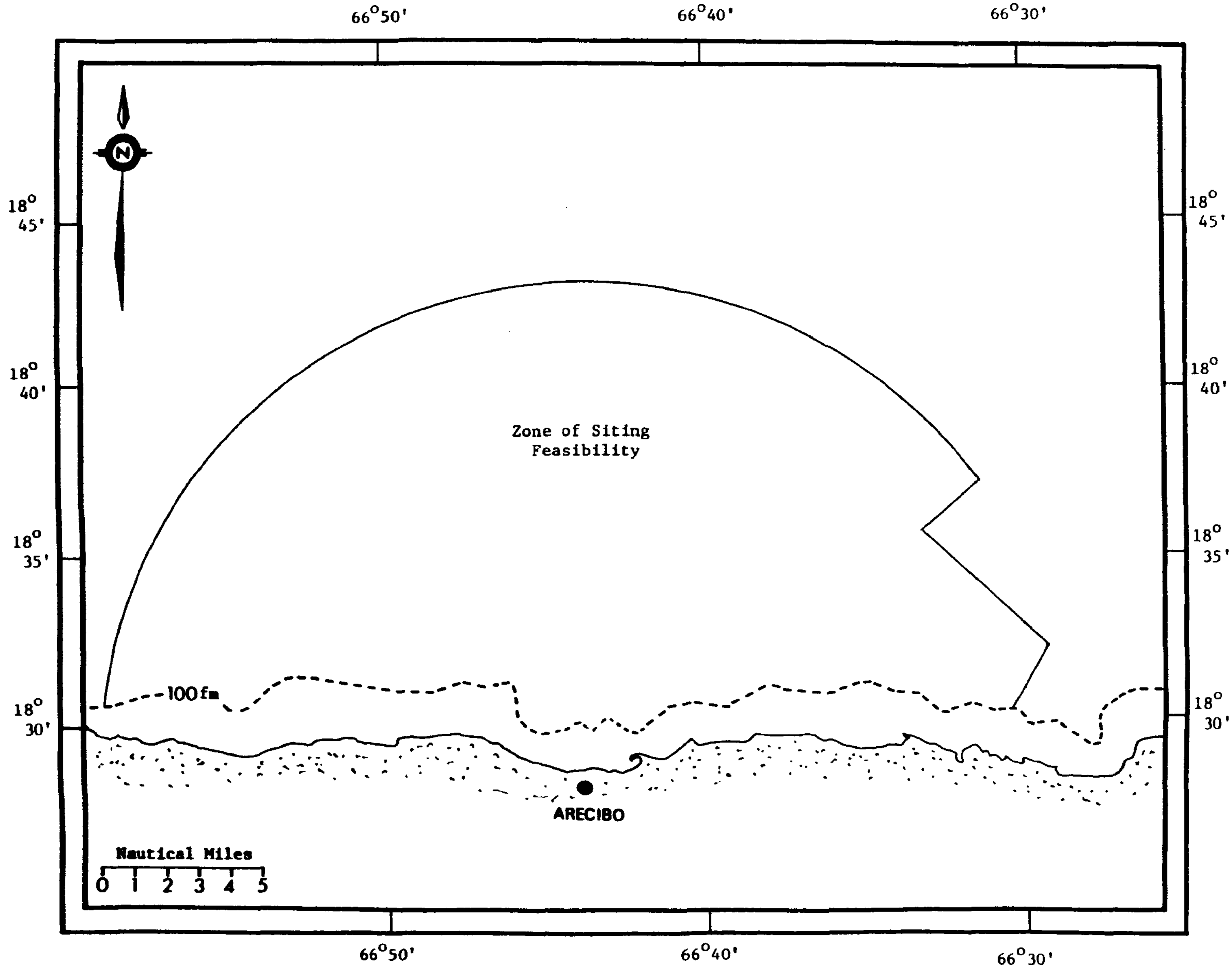


FIGURE 2-5. ZONE OF SITING FEASIBILITY FOR ARECIBO

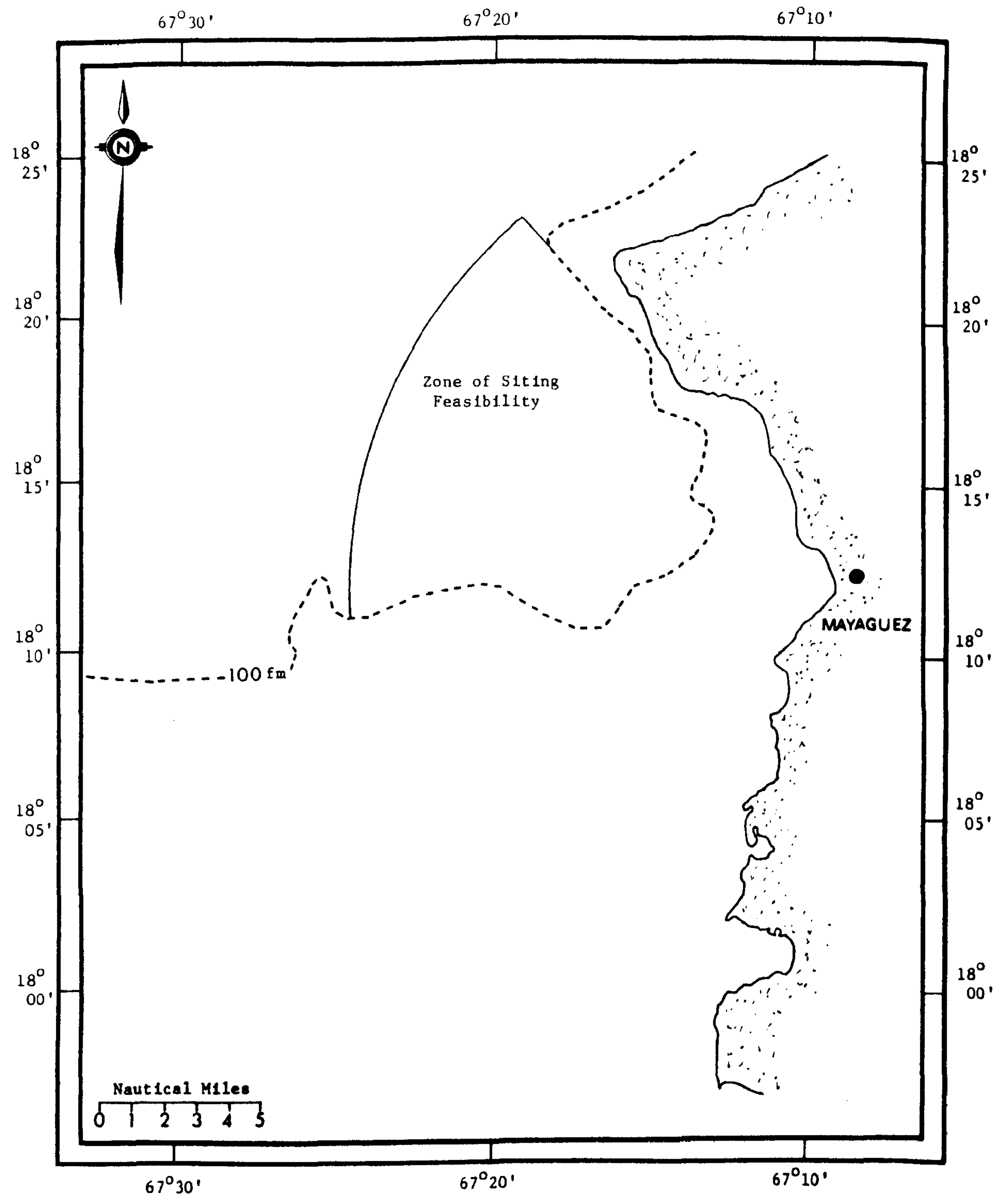


FIGURE 2-6. ZONE OF SITING FEASIBILITY FOR MAYAGUEZ

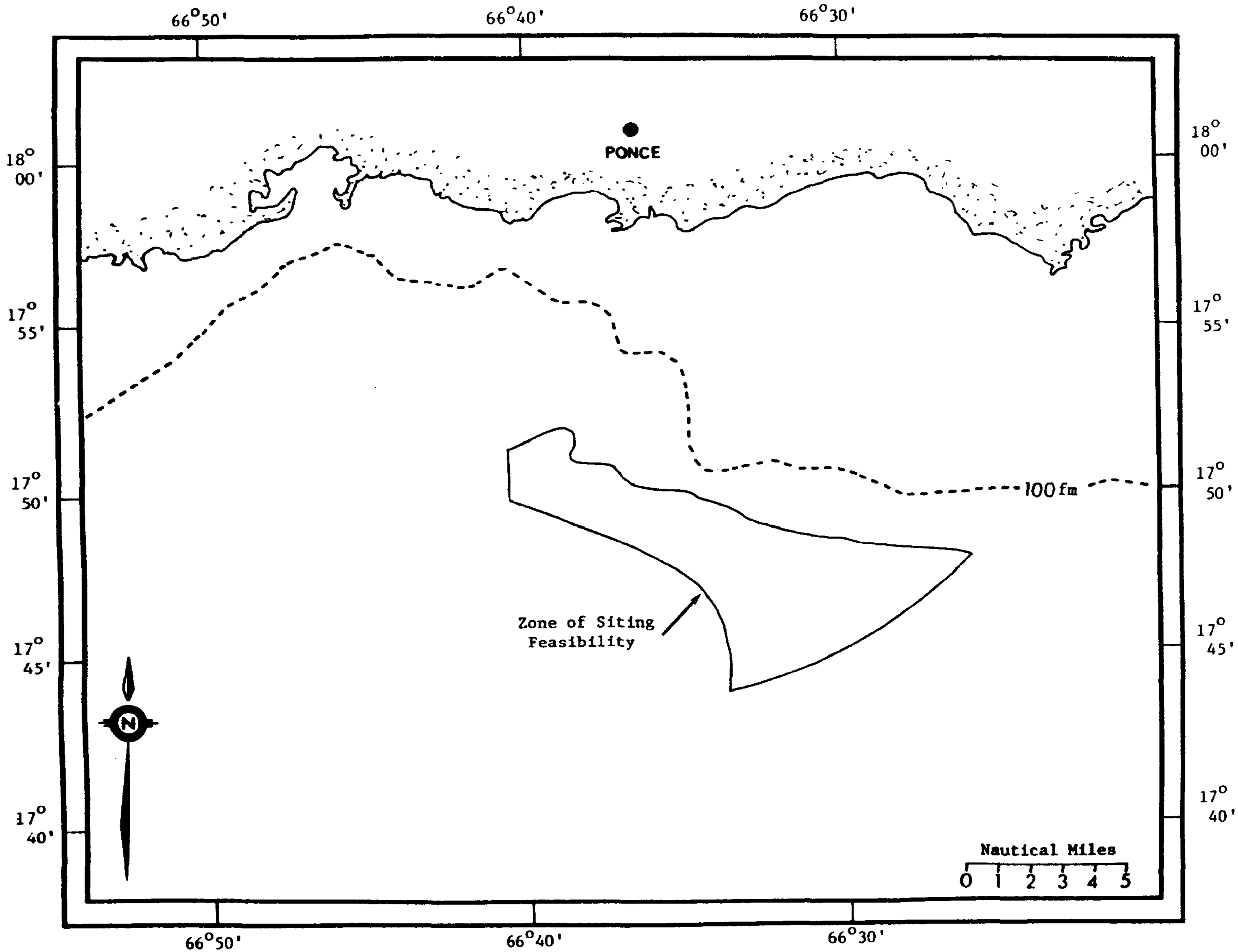


FIGURE 2-7. ZONE OF SITING FEASIBILITY FOR PONCE

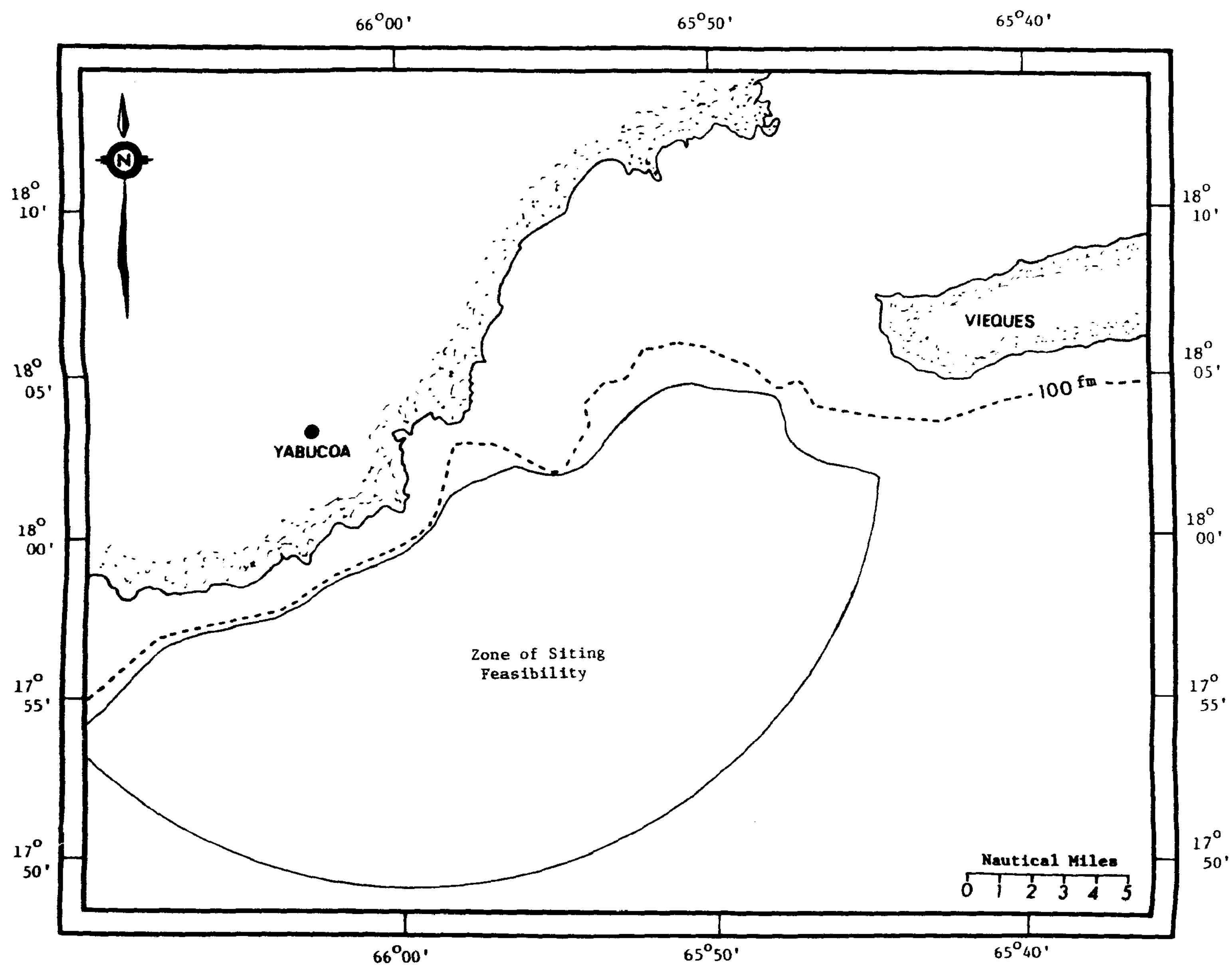


FIGURE 2-8. ZONE OF SITING FEASIBILITY FOR YABUCOA

Ponce, the nearshore border of the Ponce ZSF had originally been placed about 15 km (8 nmi) offshore. The availability of additional data (Wood et al. 1975f, and Puerto Rico Department of Public Works 1974, as cited in Chapter 3 of this report) permitted improved estimation of expected transport conditions in the area. This indicated that disposal in some locations inshore from the original ZSF would not necessarily result in sediment transport into the sensitive fishing regions to the east. Alternate disposal site considered for the Ponce area are thus inshore from the original Ponce ZSF.

In March 1984, the EPA oceanographic survey vessel Antelope collected biological, geological, and chemical data from locations off Arecibo, Mayaguez, Ponce and Yabucoa. A detailed description of data collections and analyses is provided under separate cover in the survey cruise data reports (JRB 1984). Samples were taken at evenly spaced intervals along cruise tracks that were arranged across the ZSF and approximately parallel to the downward slope of the bottom topography. Where isobaths (lines connecting locations of equal depths) were markedly curved (e.g. Mayaguez Bay and off Yabucoa) the cruise tracks ran at acute angles to one another.

Following preliminary analysis of the survey cruise data, alternate sites were selected using the following criteria:

- Depth--The Ocean Dumping Regulations general criteria stipulate that ocean disposal sites must be located beyond the shelf when possible. This condition could be met in Puerto Rico if sites were about 200 meters (or approximately 100 fathoms) deep, or deeper.
- Seafloor Sediment Composition--Preference was given to sites where the bottom sediment composition (grain size) was similar to the typical sediment composition of the material dredged from that harbor.
- Data Availability--If several choices of sites were available that met the first and second criteria, a site was selected that was centered around EPA Survey Cruise Sampling Points.
- Monitoring--Preference was given to sites shallow enough to be monitored using equipment typically available to the EPA. This stipulation sets a 925-1,000 meter limitation unless there are special circumstances requiring deeper disposal sites.

- Representative Depths--Where possible within the 1,000-meter limit, sites should represent the range of depths available in each ZSF.
- Distance from Dredging Site to Disposal Site--If several sites met all the previous criteria, selections were made that minimized the distance from the dredging site to the disposal site.

Three alternate sites were selected for detailed evaluation in the Mayaguez, Ponce and Yabucoa ZSF's. Two sites were selected for Arecibo. A third site was considered unnecessary because of the uniformity of sea floor topography and current patterns along the coastline.

Locations and depths of the alternate sites for each harbor are described in the following sections.

2.4 PROPOSED ACTION FOR ARECIBO

The proposed action for Arecibo is to designate the interim DMDS (Figure 2-9) as the DMDS for continuing use. The characteristics of the dredged material at this harbor, and the environmental characteristics of the proposed site and alternate sites considered, are summarized in this section of the EIS. More detailed descriptions of the environment and expected impacts are given in Chapters 3 and 4.

2.4.1 Characteristics of the Dredged Material - Arecibo

2.4.1.1 Grain Size of Material

Sediment characteristics from four cores collected in Arecibo Harbor were analyzed by the COE (Hilton, 1984). The harbor sediments are predominantly sand. The average specific gravity is 2.53, the average percent moisture is 41.1%, and the average bulk density is 1.91.

2.4.1.2 Existence of Contaminants as Indicated by Elutriate Tests

The elutriate test was developed by EPA and COE to assess the environmental impact of the sediment contaminants. The test was designed to simulate the physical-chemical processes that occur during dredged material disposal to

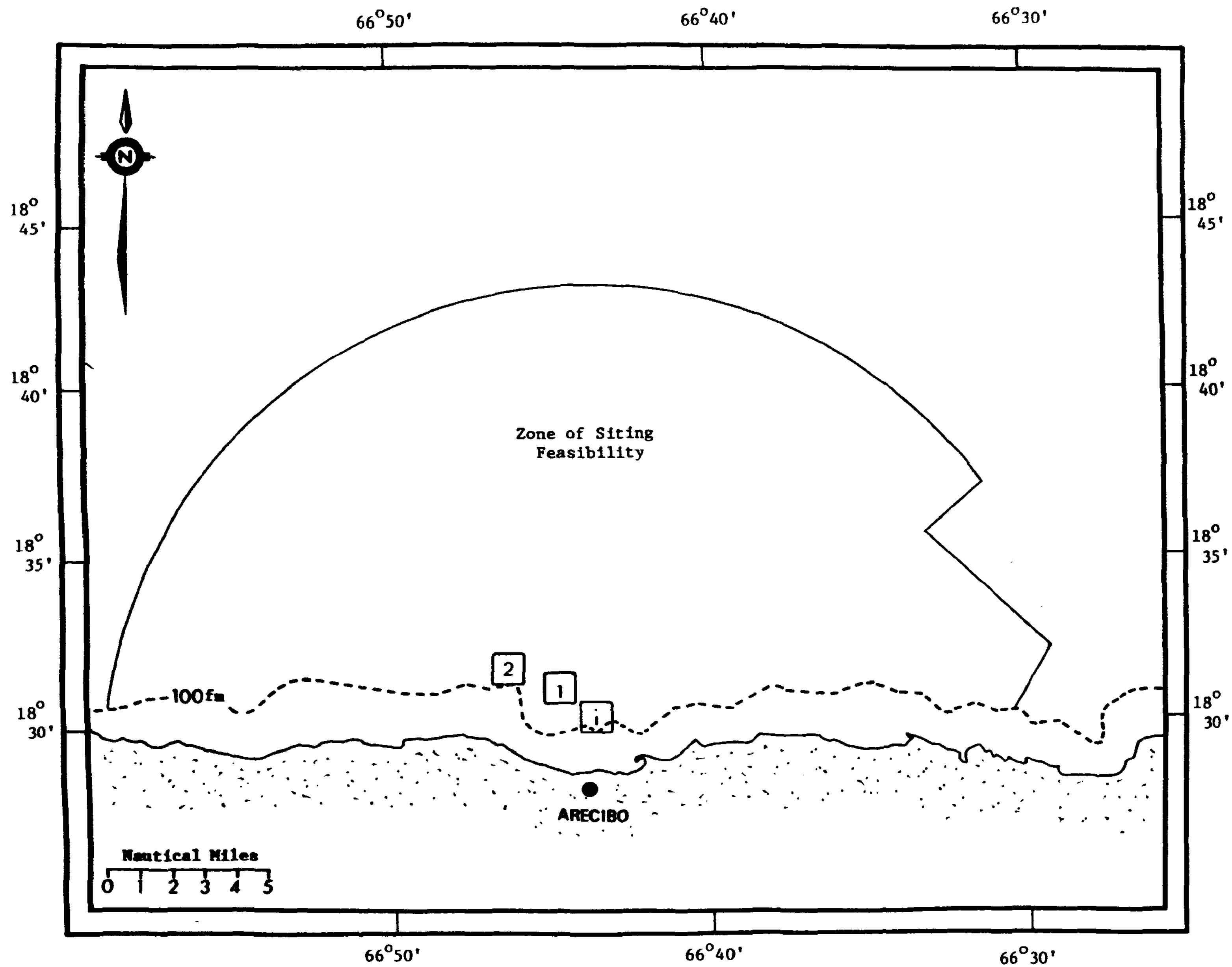


FIGURE 2-9. INTERIM AND ALTERNATE SITES FOR ARECIBO

evaluate the potential release of soluble contaminants. An elutriate test conducted by Caribtec Laboratories, Inc. (1980a) measured levels of ammonia (less than 0.3 ug/l), mercury (less than 0.1 ug/l), PCBs (less than 10 ug/l), cadmium (less than 0.001 ug/l) and oil and grease (less than 0.001 ug/l) in four sediment samples collected from Arecibo Harbor. The test values are not significantly different from ambient concentrations.

2.4.1.3 Existence of Contaminants as Indicated by Bioassay

No bioassay tests have been conducted on sediments taken in or around Arecibo Harbor. EPA evaluations of need for such testing have indicated that the sediments do not contain chemical contaminants, and are of a grain-size compatible with that of the interim DMDS, and thus a need for bioassays is not indicated under Part 227 of the ODR (Appendix D describes these requirements). However, in accordance with Part 227, a determination will be made regarding the need for bioassay testing at the time of each individual permitting action.

2.4.2 <u>Detailed Consideration of the Alternate Sites</u>

The proposed site and two alternate sites were evaluated according to site selection criteria listed in Part 228 of the ODR. The alternate sites were selected to be in accordance with the 5 general ODR criteria (see Section 2.3.1.1 of this EIS). The proposed and the alternate sites were then evaluated under the 11 specific ODR criteria. A summary of the results of these evaluations is presented in Table 2-4, and described below.

(1) <u>GEOGRAPHIC POSITION, DEPTH OF WATER, BOTTOM TOPOGRAPHY AND DISTANCE FROM COAST</u>

The proposed DMDS for Arecibo (the interim DMDS) and the alternate sites considered are shown in Figure 2-9. Table 2-4 describes the position, bottom depth, range and average bottom slope of the proposed DMDS and each of the other sites. Also described are the distance from the nearest coast and the distance from the harbor entrance. The proposed DMDS lies 2.7 km (1.5 nmi) north of Arecibo, about 1.8 km (1 nmi) northwest of Punta Morillos, the closest point on shore. The site has an area of 2.8 km^2 (0.9 nmi^2), and is

TABLE 2-4
COMPARISON OF OCEAN DREDGED MATERIAL
DISPOSAL SITES FOR ARECIBO

COMPARISON FACTOR	EIS SECTION	INTERIM SITE	ALTERNATE SITE 1	ALTERNATE SITE 2
Site Characteristics				
• Latitude	2.3.2	18° 30' 30" N	18° 31' 34" N	18° 31' 48" N
• Longitude	2.3.2	66° 43' 16" W	66° 44' 24" W	66° 46' 00" W
• Water Depth (m)	2.3.2	145 - 416 m	275 - 537 m	210 - 412 m
(ft)		474 - 1368 ft	900 - 1770 ft site is off the shelf	690 - 1360 ft site is off the shelf
• Average bottom slope		15.4%	14.9%	11.5%
• Distance from nearest coast (nmi)	2.3.2	1.0 N (1.8 km)	2.5 N (4.5 km)	2.0 N (4.0 km)
• Distance from harbor (nmi)	2.3.2	1.5 N (2.7 km)	3.5 N (6.5 km)	6.0 N (11.0 km)
Site Location Relative to:				
• Breeding, spawning, nursery, feeding or passage areas	3.1.4.3	1 - 2 nmi N	2 - 3 nmi NW	3-4 nmi NW
• Beaches and other amenity areas	3.1.5	5 -6 nmi NW	6 - 7 nmi NW	8 - 9 nmi NW
Waste Characteristics			Same as for Interim Site ↓	Same as for Interim Site ↓
• Types	2.4.1.1	Sand		
• Typical Barge Load	1.3.1, App. B	2000-4000 cy		
• Quantities/Frequency of Dredging	1.3.1, App. B	150,000 cy/3-5 yrs		
• Discharge methods		Side or bottom dumping from hopper dredges, or clamshell unloading from scow		
Feasibility of Surveillance and Monitoring		Feasible	Feasible	Feasible
Subsurface Transport Characteristics	3.1.1.4			
Velocity (cm/s)		4	4	4
Direction (° True)		270°	270°	270°
Near Bottom Velocity (cm/s)		<5	<5	<5
Direction (True)		270	270	270
Effects of Dredged Material Disposal in Area				
• Previous operations		L	UL	UL
• Present operations		L	UL	UL
Potential Effects on Human Uses of the Area				
• Shipping lanes		UL	UL	UL
• Fishing				
• Recreation				
- Beaching		UL	UL	UL
- Diving areas				
• Areas of Scientific importance		UL	UL	UL
• Mineral Resources		UL	UL	UL
Potential Effects on Site Ecology				
• Marine mammals and threatened or endangered species		UL	UL	UL
• Critical areas				
- Mangroves		UL	UL	UL
- Coral reefs		UL	UL	UL
- Critical wildlife habitats		UL	UL	UL
Potential Effects on Cultural and Historic Resources				
• Shipwrecks		UL	UL	UL

L = Likely
P = Possible
UL = Unlikely

centered at 18°30'30" N, 66°43'16" W. The bottom has an average 15 percent slope to the north, and is otherwise relatively uniform in topography. Bottom depths range from 145 to 416 meters (474 to 1,368 ft).

Alternate site 1 is located 6.5 km (3.5 nmi) northwest of the harbor mouth. The site is centered at 18°31'34" N, 66°44'24" W; it has an area of 2.8 km^2 (0.9 nmi^2). Depth at this site ranges from 275 to 537m (900 to 1770 ft).

Alternate site 2 is located 9 km (6 nmi) northwest of the harbor mouth. The site has an area of 2.8 km^2 (0.9 nmi^2) and its center is at 18°31'48" N, 66°46'00" W. Depth at this site ranges from 210 to 412 m (690 to 1360 ft).

(2) LOCATION IN RELATION TO BREEDING, SPAWNING NURSERY, FEEDING, OR PASSAGE AREAS OF LIVING RESOURCES IN ADULT OR JUVENILE PHASES

Breeding, spawning, and feeding of fish or shellfish may be assumed to occur in any coastal marine waters, including those of the proposed DMDS and the alternate sites. It may also be assumed that many kinds of pelagic (free-swimming) animals such as fish, shrimp, or squid, as well as marine mammals, seabirds or sea turtles may pass through waters of the sites. There is, however, no evidence to suggest that the proposed site or any of the alternate sites have any unique importance to activities of marine animals.

Nursery areas are areas where young organisms are able to find particularly high concentrations of food and/or shelter and protection from predators. Typically, nursery areas are associated with semi-enclosed waters, such as estuaries, bays, or mangrove swamps, from which young organisms are not likely to be transported out to the open sea. Therefore neither the proposed DMDS nor the other sites are likely to serve as nursery areas because they are all in open-ocean locations well flushed by currents.

(3) LOCATION IN RELATION TO BEACHES AND OTHER AMENITY AREAS

The proposed DMDS is about 1.8 km (1 nmi) off Punta Morillos, the nearest shoreline point. It is about 9 to 11 km from the closest recreational beach area. Alternate sites 1 and 2 are 2 km and 5 km farther from that area. No dredged material transport into those areas would be expected to occur as a result of using any of the disposal sites considered.

(4) TYPES AND QUANTITIES OF WASTES PROPOSED TO BE DISPOSED OF, AND PROPOSED METHODS OF RELEASE, INCLUDING METHODS OF PACKING THE WASTE, IF ANY

Identical types and volumes of dredged material would be released at any of the alternate sites. The volume of dredged material that will have to be dredged from Arecibo Harbor annually will vary, depending on rainfall, the prevalence of storms, high surf, and other environmental factors.

The cumulative amount of material deposited over the full time period of a dredging and disposal operation is important in evaluating impacts of the material once it settles to form a deposition mound. Historically, the harbors have been dredged once every three to five years, with an average amount of 114,000 cubic meters (150,000 cubic yards) of material being removed from the harbor during each dredging operation. The short-term effects of disposal, such as turbidity and increased rates of sedimentation, depend on the amount of materials released on each trip. Thus, the quantity of disposed material of concern in evaluating impacts from suspended sediment transport is 2000 to 4000 cubic meters (about 2500 to 5000 cubic yards), the amount contained in a single hopper-dredge or scow load.

(5) FEASIBILITY OF SURVEILLANCE AND MONITORING

Surveillance of dumping operations at the proposed site could be accomplished by placing observers aboard disposal vessels or by helicopter observations. Because the site is close to shore, aerial or ship observations would not be logistically difficult.

Environmental monitoring of the water column and the benthos at the proposed site should present no problems. Monitoring surveys of the site were successfully conducted by the EPA ocean survey vessel Antelope in 1984. The site is 3 to 4 km from Arecibo Harbor and has bottom depths of 145 to 416 meters. Sampling of the water column thus presents no problems since the site is close to Arecibo Harbor in water depths that are easily sampled.

(6) DISPERSAL, HORIZONTAL TRANSPORT AND VERTICAL MIXING CHARACTERISTICS OF THE AREA, INCLUDING PREVAILING CURRENT DIRECTION AND VELOCITY IF ANY

The significant difference between the sites is the water column depth and the bottom profile in the direction of transport relative to the depth to which the dredged material sinks immediately after disposal (about 350-400 m). Currents typically flow in a westerly direction along the coastline, at slow to moderate speeds (3-5 cm/sec). The weak net transport will significantly influence the mixing and dilution of dredged material discharged at the interim and the alternate sites. Bottom profiles at all the sites gradually become shallower (approaching depths of 200-300 m) within 2-4 km of the sites. The interaction of weak, currents with a progressively more shallow sea floor will result in rapid bottom deposition of the dredged material within short distances. Concentrations of deposited sediments will therefore tend to be high within small regions of impact. The disposal of dredged material at either the proposed site or the alternate sites is therefore expected to result in containment of the material in a limited area.

(7) EXISTENCE AND EFFECTS OF CURRENT AND PREVIOUS DISCHARGES AND DUMPING IN THE AREA (INCLUDING CUMULATIVE EFFECTS)

Dredged materials have historically been dumped at the proposed site for Arecibo. No information has been found to indicate that dumping has occurred at any of the alternate sites. Analyses of data from benthic sampling at the proposed site and alternate sites by the 1984 survey cruise indicate that disposal at the proposed site in the part has resulted in an increased percentage of silty sand, as compared to the silt or clayey silt that make up most of the sea floor at equivalent depths off Arecibo. Benthic organisms present at the site reflect this changed sediment type, as will be discussed in point (9) below.

(8) INTERFERENCE WITH SHIPPING, FISHING, RECREATION MINERAL EXTRACTION, DESALINATION, FISH AND SHELLFISH CULTURE, AREAS OF SPECIAL SCIENTIFIC IMPORTANCE AND OTHER LEGITIMATE USES OF THE OCEAN

There are no fish or shellfish culture operations or desalination near the proposed site or any of the other considered sites. There will be no interference with shipping lanes because there are no designated shipping lanes in Puerto Rican waters.

There are some potentially exploitable magnetite sands to the south of the proposed site, close to the Arecibo Harbor entrance. No exploitation of these has occurred in the past and there are no known plans to begin mining these sands. It is not expected that use of the proposed site would result in transport of dredged material onto these sands.

No interference with commercial fishing is expected. There are no extensive fishing operations in the area. The great majority of Puerto Rico's fishermen fish from 20-foot wooden boats, and winds and waves are particularly forceful at many times of year on this side of the island, so that fishing from the small boats is often not possible. A principal form of fishing along the coast to the east of Arecibo is beach seining, which would not be affected by disposal operations at the site. No transport of dredged materials to the beach would be expected from any of the sites considered for this harbor.

Because beaches will not be reached by any sediment released at the disposal sites there will be no effects on recreational swimming, diving, or fishing at the shore. There are several natural preserve areas (two protected mangrove swamps and the Guajataca Cliffs critical habitat area) within the 24 km (15 mile) Arecibo study area, but none would be affected by use of the proposed site.

(9) THE EXISTING WATER QUALITY AND ECOLOGY OF THE SITE AS DETERMINED BY AVAILABLE DATA OR BY TREND ASSESSMENT OR BASELINE SURVEYS

Water quality in the general area of this site and the other considered sites is good, as is typical of well-flushed open water conditions throughout Puerto Rican coastal areas. The waters are usually optically clear, with little suspended material, except for shallow locations closer to shore than the proposed site. There is no evidence of organic enrichment or eutrophication. Oxygen concentrations are high and nutrient concentrations are low.

Benthic organisms present at the proposed site reflect the increased sand content of the site over that of the surrounding area (which presumably reflects past disposal of Arecibo's sandy dredged materials at this site). Among polychaete worms, the most abundant organisms present, as well as among crustaceans, there is a higher percentage of species and individuals present of ecological types suited to sandy environments than is the case at the alternate sites or other locations in the ZSF. The fauna at the proposed site are thus better adapted to survive future disposal operations than are the fauna at the alternate sites.

(10) POTENTIAL FOR THE DEVELOPMENT OR RECRUITMENT OF NUISANCE SPECIES IN THE DISPOSAL SITE

The proposed site and the alternate sites are in deep ocean waters well flushed by currents. Nutrients and decaying organic matter in the dredged materials will therefore not accumulate in sufficient high concentrations to create eutrophication and resulting blooms of potentially noxious phytoplankton. Any human disease organisms that may be present in the dumped materials are very unlikely to survive and reproduce in the cold, highpressure environment of the sea floor at the site.

(11) EXISTENCE AT OR IN CLOSE PROXIMITY TO THE SITE OF ANY SIGNIFICANT NATURAL OR CULTURAL FEATURES OF HISTORICAL IMPORTANCE

No such features have been identified at the site or in areas that will be affected by disposal at the site.

2.4.3 Summary: Proposed Site for Arecibo

It is proposed that the existing interim DMDS for Arecibo be designated as the DMDS for continuing use. The site meets all the criteria of the ODR. Very little transport of materials away from the proposed DMDS is expected. Materials released at this site will tend to be deposited on the sea floor, rather than dispersed, because currents are somewhat weak and the sea floor is not deep enough for prolonged transport of sinking materials to occur. No adverse effects are expected on living or mineral resources, or socio-economic and cultural aspects of the environment from the continuing use of this site. There have been no problems in conducting surveillance and monitoring activities at this site in the past, and none would be expected in the future.

Benthic sampling indicates that previous use of the site for disposal of Arecibo's sandy dredged materrials has resulted in an increased percentage of silt and sand being present at and near the site than is common in the sea floor off Arecibo. This has apparently had some effect on the bethic ecology of the site, with a small increase occurring in the numbers of animals adapted to living in coarser-grained sediments rather than in strictly clay/silt environments. This indicates that the proposed designation and use of the interim DMDS as the DMDS for continuing use should result in less of a change in the ecology of the site than would result from use of any other site in the zone of siting feasibility.

2.5 PROPOSED ACTION FOR MAYAGUEZ

The proposed action for Mayaguez is to designate alternate site 1 (Figure 2-10) as the DMDS for continuing use. The characteristics of the dredged material at this harbor, and the environmental characteristics of the proposed site and the other sites considered, are summarized in this section of the EIS. More detailed descriptions of the environment and expected impacts are given in Chapters 3 and 4.

2.5.1 Characteristics of the Dredged Material - Mayaguez

2.5.1.1 Grain Size of the Material

Sediment characteristics from five cores collected in Mayaguez Harbor were analyzed by COE (Hilton, 1984). The harbor sediments are mixed sand, silt, and clay. The average specific gravity is 2.53, the average percent moisture is 53.0 percent, and the average bulk density is 1.72.

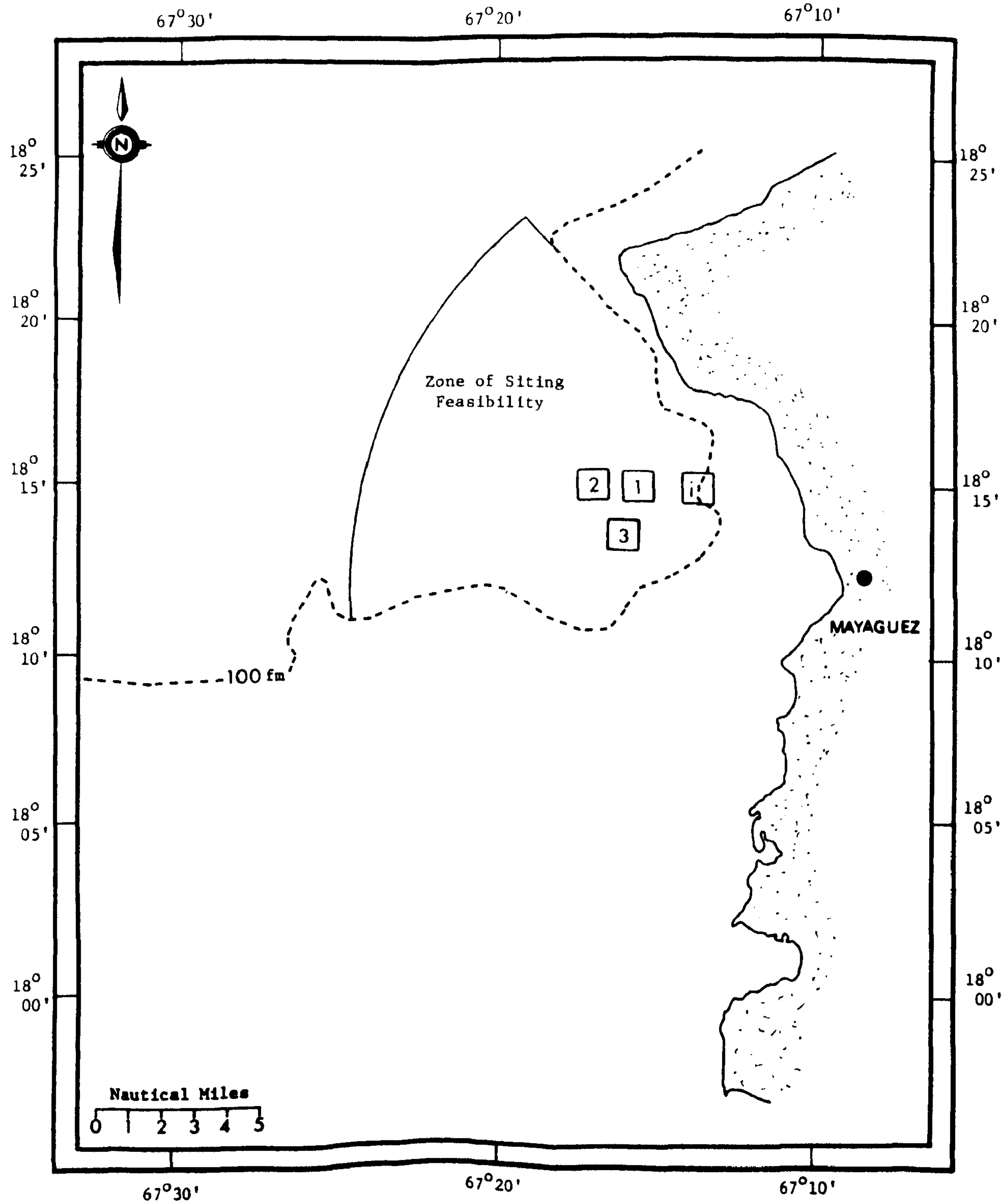


FIGURE 2-10. INTERIM AND ALTERNATE SITES FOR MAYAGUEZ

2.5.1.2 Existence of Contaminants as Indicated by Elutriate Tests

An elutriate test conducted by Caribtec Laboratories, Inc. (1980b) measured ammonia (less than 0.3 ug/l), mercury (less than 0.1 ug/l), PCBs (less than 10 ug/l), cadmium (less than 0.001 ug/l) and oil and grease (less than 0.001 ug/l) in four sediment samples collected from Mayaguez Harbor. The test values are not significantly different from ambient concentrations.

2.5.1.3 Existence of Contaminants as Indicated by Bioassays

No bioassay tests have been conducted on sediments taken in or around Mayaguez Harbor. EPA evaluations of the need for such testing in the past have indicated that the sediments did not contain chemical contaminants and were of a grain-size composition compatible with that of the interim site, so that a need for bioassays was not indicated under Part 227 of the ODR (Appendix D describes these requirements). However, in accordance with Part 227, a determination will be made regarding the need for bioassay testing at the time of each individual permitting action.

2.5.2 Detailed Consideration of the Alternate Sites

The proposed site, two other alternate sites, and the interim site were evaluated according to site selection criteria listed in Part 228 of the ODR. The three alternate sites were selected in accordance with the 5 general ODR criteria (see Section 2.3.1.1 of this EIS). Results of the evaluations according to the specific criteria of the ODR are summarized in Table 2-5 and described below.

(1) GEOGRAPHIC POSITION, DEPTH OF WATER BOTTOM TOPOGRAPHY AND DISTANCE FROM COAST

The proposed DMDS for Mayaguez (alternate site 1), the interim site and the other sites considered are shown in Figure 2-10. Table 2-5 shows the position, bottom depth range, and average bottom slope of each of the sites. Also described are the distance from the nearest coast and the distance from the harbor entrance. The proposed DMDS lies 13 km (7 nmi) northwest of Mayaguez Harbor, about 8 km (4.5 nmi) from the nearest coast. The site is centered at 18°15'00" N, 67°15'42" W, and has an area of 2.8 km^2 (0.9 nmi^2).

TABLE 2-5
COMPARISON OF OCEAN DREDGED MATERIAL
DISPOSAL SITES FOR MAYAGUEZ

COMPARISON FACTOR	EIS SECTION	INTERIM SITE	ALTERNATE SITE 1	ALTERNATE SITE 2	ALTERNATE SITE 3
Site Characteristics					
• Latitude	2.3.3	18° 15' 00" N	18° 15' 00" N	18° 15' 00" N	18° 13' 54" N
• Longitude	2.3.3	67° 14' 00" W	67° 15' 42" W	67° 16' 48" W	67° 16' 24" W
• Water Depth (m)	2.3.3	90 - 300 m	350 - 380 m	420 - 440 m	325 - 380 m
(ft)		290 - 990 ft	1150 - 1260 ft	1380 - 2640 ft	1070 - 1254 ft
• Average Bottom slope		12%	1.7%	1.4%	3.1%
• Distance from nearest coast (nmi)	2.3.3	2.5 W (4.5 km)	3.5 W (6.5 km)	4.0 W (7.5 km)	5.0 W (9 km)
• Distance from harbor (nmi)	2.3.3	5.0 W (9 km)	7.0 W (13 km)	8.0 W (15 km)	6.5 W (12 km)
Site Location Relative to:					
• Breeding, spawning, nursery, feeding or passage areas	3.2.4.3	2-3 nmi W	4-5 nmi W	5-6 nmi W	5-6 nmi SW
• Beaches and other amenity areas	3.2.5	2-3 nmi SW	4-5 nmi SW	5-6 nmi SW	5-6 nmi SW
Waste Characteristics			Same as for Interim Site	Same as for Interim Site	Same as for Interim Site
• Types	2.5.1.1	Sand, silt, clay	↓	↓	↓
• Typical Barge Load	1.3.2, App. B	2000-4000 cy			
• Quantities/Frequency of Dredging	1.3.2, App. B	69,100-cy/2 yrs			
• Discharge methods		Side or bottom dumping from hopper dredges, or clamshell unloading from scow			
Feasibility of Surveillance and monitoring	Feasible	Feasible	Feasible	Feasible	
Subsurface Transport Characteristics	3.2.1.4				
Velocity (cm/s)		15	15	15	15
Direction (° True)		180°	225°	225°	225°
Near-bottom velocity (cm/s)		15	15	15	15
Direction (True)		180°	225°	225°	225°
Potential Effects on Human Uses of the Area					
• Shipping		UL	UL	UL	UL
• Fishing		UL	UL	UL	UL
• Recreation - Beaching - Diving aread		UL	UL	UL	UL
• Areas of Scientific importance		L	UL	UL	UL
• Mineral resources		UL	UL	UL	UL
Potential Effects on Site Ecology					
• Marine mammals and threatened or endangered species		UL	UL	UL	UL
• Critical areas					
- Mangroves		UL	UL	UL	UL
- Coral reefs		L	UL	UL	UL
- Critical wildlife habitats		UL	UL	UL	UL
Potential Effects on Cultural and Historic Resources					
• Shipwrecks		UL	UL	UL	UL

L = Likely
P = Possible
UL = Unlikely

The sea floor has an average slope of 1.7 percent to the west, and is otherwise relatively uniform in topography. Bottom depths range from 350 to 380 m (1150 to 1260 ft).

The Mayaguez interim site is located 9 km (5 nmi) northwest of the harbor mouth. The site has an area of 0.9 nmi^2 (2.8 km^2); it is centered at 18°15;00" N, 67°14'00" W. Depth at this site ranges from 90 to 300 m (290 to 990 ft).

Alternate site 2 is located 15 km (8 nmi) northwest of the harbor mouth. The site has an area of 2.8 km^2 (0.9 nmi^2) and is centered at 18°15'06" N, 67°16'48" W. Depth at this site ranges from 420 to 440 m (1380 to 2640 ft).

Alternate site 3 is located 12 km (6.5 nmi) west-northwest of the harbor mouth. The site has an area 2.8 km^2 (0.9 nmi^2) and is centered 18°13'54" N, 67°16'24" W. Depth at this site ranges from 325 to 380 m (1070 to 1254 ft).

(2) <u>LOCATION IN RELATION TO BREEDING, SPAWNING NURSERY, FEEDING, OR PASSAGE AREAS OF LIVING RESOURCES IN ADULT OR JUVENILE PHASES</u>

Breeding, spawning, and feeding of fish or shellfish may be assumed to occur in any coastal marine waters, including those of the proposed site and the alternate sites. It may also be assumed that many kinds of pelagic animals such as fish, shrimp, or squid, as well as marine mammals, seabirds or sea turtles may pass through waters of the sites. There is however no evidence to suggest that the proposed site or any of the other considered sites have any unique importance to marine animals. As was the case in the Arecibo study area (see Section 2.4.2), neither the proposed DMDS for Mayaguez, nor the other sites considered, are likely to serve as nursery areas, because they are all in open-ocean locations well-flushed by currents.

There should be no adverse effects on corals or their associated fish communities from the disposal of dredged materials at the proposed site or the other alternate sites. Use of the interim site, however, is likely to result in deposition of sediments at levels harmful to corals in the reef areas just south of the site. Use of any of the alternate sites is expected to result in sediment plumes that disperse and then settle out before reaching any of the area's reefs. Use of the interim site, however, will not typically result in dispersion of the dredged materials in an extended plume. The bottom at this site is sufficiently shallow that the mass of released materials will land on the sea floor before reaching the state of dynamic collapse and dissipation. Consequently, sediment deposition concentrations at or near the site will be high, well above the value found to cause mortality in some common Puerto Rican corals.

The location of the sediment mound predicted from the model is actually between 1 and 2 km (0.5 and 1 nmi) away from the nearest charted coral reef area (see Section 4.5.2). However, uncertainties about current speed, direction, and exact point of release mean that the actual mound location could be displaced by such a distance from the predicted location. Therefore, it is possible, and in fact likely over a period of years involving numerous disposal operations, that conditions could create unacceptably high levels of sediment deposition on the reefs adjacent to the interim site.

(3) LOCATION IN RELATION TO BEACHES AND OTHER AMENITY AREAS

There will be no measurable increases in sediment concentrations at any beaches or shorelines because of dredged material disposal at the interim site or alternate sites 2 and 3. Sedimentation plumes from disposal at any of the sites would not be expected to reach the waters of the shoreline anywhere in this area.

(4) TYPES AND QUANTITIES OF WASTES PROPOSED TO BE DISPOSED OF, AND PROPOSED METHODS OF RELEASE, INCLUDING METHODS OF PACKING THE WASTE, IF ANY

Identical types and volumes of dredged material would be released at any of the considered sites. The volume of dredged material that will have to be dredged from Mayaguez Harbor annually will be variable, depending on rainfall, the prevalence of storms, high surf, and other factors.

The cumulative amount of material that is deposited over the full time period of a dredging and disposal operation is important in evaluating impacts of material once it settles to form a deposition mound. Historically, the harbors have been dredged once every 2 years, with an average amount of 53,500 cubic meters (70,000 cubic yards) of material being removed from the harbor during each dredging operation. The short-term effects of disposal depend on the amount of materials released on each trip. Thus, the quantity of disposed material of concern in evaluating impacts from transport of suspended sediments is 2000 to 4000 cubic meters (about 2500 to 5000 cubic yards), the amount contained in a single hopper-dredge or scow load.

(5) FEASIBILITY OF SURVEILLANCE AND MONITORING

Surveillance of dumping operations at the proposed site could be accomplished by placing observers aboard disposal vessels or by helicopter observations. Because the site is close to shore, aerial or ship observations would not be logistically difficult.

Environmental monitoring of the proposed site should present no problems. Monitoring surveys of the site were successfully conducted by the EPA ocean survey vessel Antelope in 1984. Benthic monitoring with a box core sampler is feasible since the depth range of the site is from 350 to 380 meters, less than the practical limit for box core sampling.

(6) DISPERSAL, HORIZONTAL TRANSPORT AND VERTICAL MIXING CHARACTERISTICS OF THE AREA, INCLUDING PREVAILING CURRENT DIRECTION AND VELOCITY IF ANY

Depth is the primary difference between the proposed Mayaguez DMDS and the three alternate sites. With a depth range of 90 to 300 m, the interim site is considerably shallower than alternate sites, which range from 350 to 400 meters deep as a group. At the shallower interim site, the dredged material would be deposited on the bottom in higher concentrations over a smaller area than at the alternate sites. Because of tidal influences, nearshore currents tend to flow northward on the flood tide and southward at ebb tide. However, there are eddies and flow reversals in the nearshore area because of complex bottom topography, tidal forcing, winds and surface runoff. Offshore currents flow predominantly to the north.

(7) EXISTENCE AND EFFECTS OF CURRENT AND PREVIOUS DISCHARGES AND DUMPING IN THE AREA (INCLUDING CUMULATIVE EFFECTS)

It is not known whether disposal of dredged materials has occurred in the past at the proposed Mayaguez DMDS or any of the other alternate sites. Dumping has occurred at approximately 2-year intervals at the interim site. Analyses of data from benthic sampling at the proposed site and alternate sites by the 1984 survey cruise did not reveal any effects of previous disposal on the sediment grain sizes and biota of the proposed site.

(8) INTERFERENCE WITH SHIPPING, FISHING, RECREATION MINERAL EXTRACTION, DESALINATION, FISH AND SHELLFISH CULTURE, AREAS OF SPECIAL SCIENTIFIC IMPORTANCE AND OTHER LEGITIMATE USES OF THE OCEAN

There are no fish or shellfish culture operations or desalination near the proposed site of any of the alternate sites. There will be no interference wth shipping lanes because there are no designated shipping lanes in Puerto Rican waters.

Fish catches in the Mayaguez area are primarily made up of reef fishes and other species of fish and shellfish that depend on coral reef systems for food. Reef fishes such as grunts, snappers, and groupers make up a large percentage of the catch. It is not expected that disposal of dredged materials at the proposed DMDS would damage coral reefs or their associated fish or shellfish assemblages. It is possible that disposal at the existing interim site will damage or even kill corals in the nearshore area south of the site, as discussed in Section 4.5.2. Such damage to corals in this nearshore area could perhaps decrease the productivity of local fishery resources.

(9) THE EXISTING WATER QUALITY AND ECOLOGY OF THE SITE AS DETERMINED BY AVAILABLE DATA OR BY TREND ASSESSMENT OR BASELINE SURVEYS

Water quality in the general area of the proposed DMDS and the alternate sites is good, as is typical of well-flushed open water conditions throughout Puerto Rican coastal areas. The waters are usually optically clear, with little suspended material, except for shallow locations closed to shore than the proposed site. There is no evidence of organic enrichment of eutrophication, oxygen concentrations are high and nutrient concentrations are low, as would be expected in tropical waters such as these.

Sediments at all of the sites are primarily silts and clays. Taxonomic analyses of the fauna collected at the proposed site reveal that the great majority of the taxa (taxonomic groups) present at all sites are deposit-feeders, an ecological type well-adapted to living in high-turbidity such as might be created by dredged material disposal. Other common ecological types present were carnivores and herbivores, ecological types also able to live in turbid environments. Analyses of the biological data for other groups indicate that they share the basic ecological characteristics of the majority of polychaetes in being well adapted to turbidity. It is not likely, therefore, that continued use of the site will have a detrimental effect on benthic communities outside of the immediate burial mound.

(10) POTENTIAL FOR THE DEVELOPMENT OR RECRUITMENT OF NUISANCE SPECIES IN THE DISPOSAL SITE

Because the proposed site, and all considered sites, are in deep ocean waters well flushed by currents, any nutrients or decaying organic matter in the deposited dredged materials will not accumulate in sufficient high concentrations to create eutrophication and resulting blooms of potentially noxious phytoplankton. Any human disease organisms that may be present in the dumped materials are very unlikely to survive and reproduce in the cold, high-pressure environment of the sea floor at the site.

(11) EXISTENCE AT OR IN CLOSE PROXIMITY TO THE SITE OF ANY SIGNIFICANT NATURAL OR CULTURAL FEATURES OF HISTORICAL IMPORTANCE

There is one shipwreck in the nearshore area close to the interim site. Disposal at the proposed site will not affect this feature.

2.5.3 Summary: Proposed Site for Mayaguez

The proposed action for Mayaguez Harbor is the final designation of alternate site 1 as the dredged material disposal site for continuing use. The proposed Mayaguez DMDS meets all ODR criteria. It is not proposed that the formerly used interim DMDS be re-designated for continuing use, because of the proximity of that site to coral reefs. It is expected that disposal operations at the interim DMDS will result in exposure of the coral reefs that begin 1 to 2 km southeast of the site to increases in sedimentation rates sufficient to damage living corals and decrease reef productivity. In addition, the interim site does not meet the general ODR criterion of being off the shelf: The depth range at the site is 90 to 300 meters (49 to 164 fathoms), while the limit on the depth of the shelf is conventionally defined as 200 meters (approximately 100 fathoms).

No adverse effects are expected on living resources such as corals, fisheries, or nursery grounds from use of the proposed DMDS. It has no unique ecological or environmental characteristics, being similar in sediment type and in its benthic biological community to most other sites in the Mayaguez study area.

No effects are expected on any mineral resources, or socio-economic and cultural aspects of the environment from use of the proposed site. There should be no problems conducting surveillance activities, and the ability to conduct environmental modeling was demonstrated by the successful sampling operations of the 1984 OSV Antelope survey cruise.

2.6 PROPOSED ACTION FOR PONCE

The proposed action for Ponce is to designate alternate site 1 (Figure 2-11) as the DMDS for continuing use. The characteristics of the dredged material at this harbor, and the environmental characteristics of the proposed site and the other sites considered, are summarized in this section of the EIS. More detailed descriptions of the environment and expected impacts are given in Chapters 3 and 4.

2.6.1 Characteristics of the Dredged Material - Ponce

2.6.1.1 Grain Size of the Material

The material to be dredged from Ponce Harbor is predominantly silt (COE 1980c). Results of 17 borings taken from the harbor (COE 1983) indicated that materials in the northeast corner of the Municipal Bulkhead Turning Basin are composed of 4 m (14 ft) of fill material underlain by silt through a depth of

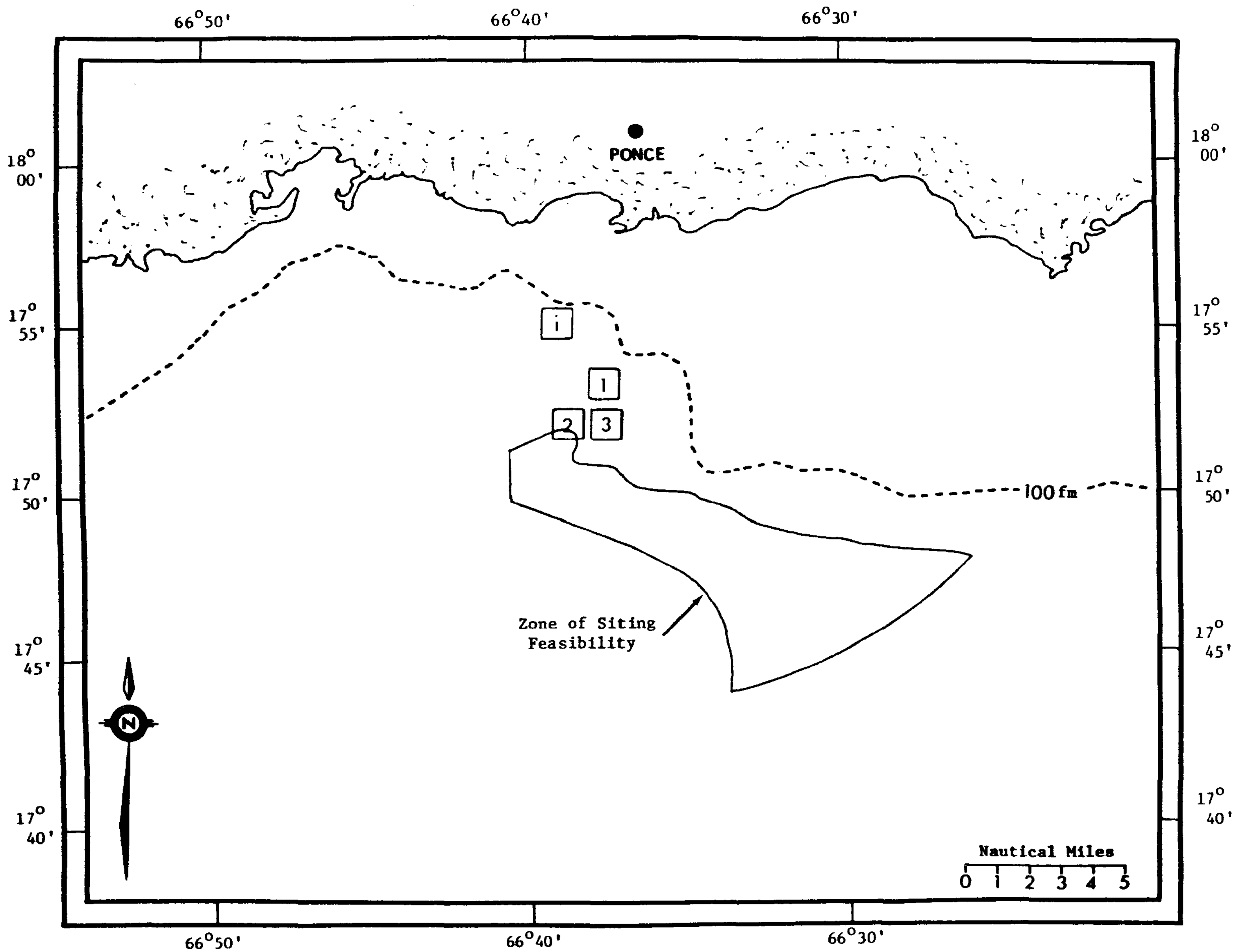


FIGURE 2-11. INTERIM AND ALTERNATE SITES FOR PONCE

11 m (36 ft) below mean low water. The fill material is soft cement waste and is considered an inorganic silt. The underlying material is a dark gray, very soft, somewhat plastic, inorganic silt with small amounts of sand and shell. In the remainder of the core borings, the material is silt from the surface through 11 m. The silt is dark gray, very soft, slightly sandy in some areas, slightly plastic, with a small amount of clay.

2.6.1.2 Existence of Contaminants as Indicated by Elutriate Tests

Chemical analyses were conducted on receiving water from the Ponce interim disposal site and interstitial water from Ponce Harbor sediment (COE 1983). Test results were compared with Goldberg values (typical sea-water values). Receiving-water concentrations at the interim disposal site were found to be similar to Goldberg values except for elevated concentrations of chromium and lead. Interstitial water had a higher concentration of cadmium, copper, and zinc than water at the interim DMDS.

2.6.1.3 Existence of Contaminants as Indicated by Bioassay

Bioassays are used during the permit process to determine whether or not a dredged material is environmentally acceptable for ocean dumping. Bioassay tests provide a measure of the potential impacts of the dredged material on the marine ecosystem. ODR requirements are that the liquid phase, suspended particulate phase and solid phase of the dredged material must be analyzed separately. The toxicological methods used to evaluate dredged materials are described in Appendix D.

Bioassay data from a study conducted by Jones, Edmunds, and Associates, Inc. (1979) on sediments collected from three locations in Ponce Harbor are presented in Table 2-6. The study concluded that the limiting permissible concentrations (LPC) based on the liquid phase or suspended particulate phase bioassays would not be approached during ocean disposal of the three sediments. The conditions under which this evaluation was made was not specified in the report. In the solid phase bioassays, none of the three sediments was toxic to the test organisms. Survival of the polychaetes (*Neanthes arenaceodentata*) in sediment 2 was significantly different from the control ($p=0.05$),

TABLE 2-6. RESULTS OF BIOASSAYS CONDUCTED ON THREE SEDIMENTS FROM PONCE HARBOR

	Sediment 1	Sediment 2	Sediment 3
• Liquid phase (# control survival/# test survival)			
Menidia menidia Fish	30/30	28/24	28/28
Mysidopsis bahia Mysid shrimp	30/26	30/28	30/30
Palaeomonetes pugio Grass shrimp	28/29	30/29	28/20 (1)
• Suspended particulate phase (# control survival/# test survival)			
Menidia menidia Fish	30/29	30/30	30/30
Mysidopsis bahia Mysid shrimp	30/27	30/27	30/29
Palaeomonetes pugio Grass shrimp	28/27	28/24	28/28
• Solid phase (% control survival/% test survival)			
Neanthes arenaceodentata Polychaete worm	100/99	100/94 (1)	100/98
Mercenaria mercenaria Clam	100/100	100/100	100/100
Palaeomonetes pugio Grass shrimp	100/98	100/100	100/98

• Bioaccumulation Potential-Mercenaria mercenaria (ug/g)

	Control	Sediment 1	Sediment 2	Sediment 3
Petroleum hydrocarbons	ND	ND	ND	ND
Mercury	0.027	0.0257	0.0219	0.0332
Cadmium	0.034	0.038	0.052	0.38

Notes: (1) Significantly different from control (p=0.05)
ND - Not detectable: limit of detection = 2 ug/g

Source: Jones, Edmunds and Associates, Inc. 1979 but did not differ from control survival by greater than 10 percent and therefore, does not exceed the LPC. Bioaccumulation tests conducted with clams (Mercenaria mercenaria) showed no tendency to accumulate mercury, cadmium, or petroleum hydrocarbons.

2.6.2 Detailed Consideration of the Alternate Sites

The proposed site, the interim site and two other alternate sites were evaluated according to site selection criteria listed in Part 228 of the ODR. The alternate sites were selected to be in accordance with the 5 general ODR criteria (see Section 2.3.1.1 of this EIS). Results of the evaluations according to the 11 specific ODR criteria are summarized in Table 2-7, and described below.

(1) GEOGRAPHIC POSITION, DEPTH OF WATER BOTTOM TOPOGRAPHY AND DISTANCE FROM COAST

The proposed DMDS for Ponce (alternate site 1), the interim site, and the other sites considered are shown in Figure 2-11. Table 2-7 shows the position, bottom depth range and average bottom slope of each of the sites. Also shown are the distance from the nearest coast and the distance from the harbor entrance. The proposed DMDS lies 10 km (5.5 nmi) south of Ponce, about 8 km (4 nmi) from the nearest coast. The site has an area of 2.8 km^2 (0.9 nmi^2) and is centered at 17°53'20" N, 66°37'52" W. The bottom has an average 12 percent slope to the south-southwest. Bottom depths range from 330 to 540 meters (181 to 295 fathoms).

The Ponce interim site is located 7.5 km (4 nmi) southwest of the harbor mouth. The site has an area of 2.8 km^2 (0.9 nmi^2) and is centered at 17°55'00" N, 66°38'54" W. Depth at this site ranges from 237 to 490 (780 to 1620 feet).

Ponce alternate site 2 is located 12 km (6.5 nmi) south of the harbor mouth. The site has an area of 2.8 km^2 (0.9 nmi^2); it is centered at 17°52'00" N, 66°38'54" W. Depth at this site ranges from 51 to 700 (1680 to 2310 feet).

TABLE 2-7
COMPARISON OF OCEAN DREDGED MATERIAL DISPOSAL SITES FOR PONCE

COMPARISON FACTOR	EIS SECTION	INTERIM SITE	ALTERNATE SITE 1	ALTERNATE SITE 2	ALTERNATE SITE 3
Site Characteristics					
• Latitude	2.3.4	17° 55' 00" N	17° 53' 20" N	17° 52' 00" N	17° 52' 04" N
• Longitude	2.3.4	66° 38' 54" W	66° 37' 52" W	66° 38' 54" W	66° 37' 42" W
• Water Depth (m)	2.3.4	237 - 490 m	330 - 540 m	510 - 700 m	330 - 625 m
(ft)		780 - 1620 ft	1086 - 1770 ft	1680 - 2310 ft	1090 - 2060 ft
• Average Bottom slope		14.4%	124	10.8%	16.8%
• Distance from nearest coast (nmi)	2.3.4	3.0 S (5.5km)	4.0 S (7.5 km)	6.0 S (11 km)	6.0 S (11 km)
• Distance from harbor (nmi)	2.3.4	4.0 S (7.5 km)	5.5 S (10 km)	6.5 S (12 km)	6.5 S (12 km)
Site Location Relative to:					
o Breeding, spawning, nursery, feeding or passage areas	3.3.4.3	3 - 4 nmi SE	6 - 6 nmi SE	6 - 7 nmi S	6 - 7 nmi SE
Waste Characteristics					
• Types	2.6.1.1	Silt	Same as for Interim Site	Same as for Interim Site	Same as for Interim Site
• Typical Barge Load	1.3.3, App. B	2000-4000 cy	↓	↓	↓
• Quantities/Frequency of Dredging	1.3.3, App. B	250,000-290,000 cy/3 yrs	↓	↓	↓
• Discharge methods		Side or bottom dumping from hopper dredges,or clamshell unloading from scow	↓	↓	↓
Feasibility of Surveillance and Monitoring		Feasible	Feasible	Feasible	Feasible
Subsurface Transport Characteristics	3.3.1.4				
Velocity (cm/s)		5 - 10	5 - 10	5 - 10	5 - 10
Direction (° True)		280°	280°	300°	300°
Near-bottom (cm/s)		5	5	5	5
Direction (True)		315°	315°	315°	315°
Potential Effects on Human Uses of the Area					
• Shipping		UL	UL	UL	UL
• Fishing		UL	UL	UL	UL
• Recreation					
- Beaching		L	UL	L	L
- Diving aread					
• Areas of Scientific importance		UL	UL	UL	UL
• Mineral Resources		UL	UL	UL	UL
Potential Effects on Site Ecology					
• Marine mammals and threatened or endangered species		UL	UL	UL	UL
• Critical areas					
- Mangroves		UL	UL	UL	UL
- Coral reefs		UL	UL	UL	UL
- Critical wildlife habitats		UL	UL	UL	UL
Potential Effects on Cultural and Historic Resources					
• Shipwrecks		UL	UL	UL	UL

L = Likely
P = Possible
UL = Unlikely

Ponce alternate site 3 is located 11 km (6.5 nmi) south of the harbor mouth. The site is centered at 17°52'04" N, 66°37'42" W and has an area of 2.8 km^2 (0.9 nmi^2). Depth at this site ranges from 330 to 625 m (1090 to 2060 feet).

(2) LOCATION IN RELATION TO BREEDING, SPAWNING NURSERY, FEEDING, OR PASSAGE AREAS OF LIVING RESOURCES IN ADULT OR JUVENILE PHASES

Breeding, spawning, and feeding of fish or shellfish may be assumed to occur in any coastal marine waters, including those of the proposed site and the other considered sites. It may also be assumed that many kinds of pelagic animals such as fish, shrimp, or squid, as well as marine mammals, seabirds or sea turtles may pass through waters of the sites. There is however no evidence to suggest that the proposed site or any of the other sites have any special characteristics in regards to such activities of marine animals.

Neither the proposed site nor the other considered sites are likely to serve as nursery areas, because they are all in open-ocean locations well flushed by currents.

(3) LOCATION IN RELATION TO BEACHES AND OTHER AMENITY AREAS

Several beaches and other stretches of shoreline would be affected by the sediment plumes from disposal under typical oceanographic conditions at Ponce. There are several beach areas west of Ponce Harbor. The closest of these is beyond Punta Cucharas, approximately 7 km (4 nmi) from the interim site. Other beaches are located 1 to 3 km (0.5-1.5 nmi) to the west of Punta Verraco, and along the coastline of the Guanica Commonwealth Forest. Concentrations of sediments in these areas would not be measurably increased as a result of dredged material disposal at the proposed site. However, it is expected that concentrations in the beach areas off Punta Verraco and Guanica Forest would be measurably increased by disposal operations at any of the other sites considered.

(4) <u>TYPES AND QUANTITIES OF WASTES PROPOSED TO BE DISPOSED OF, AND PROPOSED METHODS OF RELEASE, INCLUDING METHODS OF PACKING THE WASTE, IF ANY</u>

Identical types and volumes of dredged material would be released at any of the alternate sites. The volume of dredged material that will have to be dredged from Ponce Harbor annually will vary, depending on rainfall, the prevalence of storms, high surf, and other environmental factors.

The cumulative amount of material deposited over the full time period of a dredging and disposal operation is important in evaluating impacts of material if it settles to form a deposition mound. Historically, the harbors have been dredged once every three years, with an average amount of 190,000 to 220,000 cubic meters (250,000 to 290,000 cubic yards) of material being removed during each dredging operation. The short-term effects of disposal, such as turbidity and increased sedimentation rates, depend on the amount of materials released on each trip. Thus, the quantity of disposed material of concern in evaluating impacts from suspended sediment transport is 2000 to 4000 cubic meters (about 2500 to 5000 cubic yards), the amount contained in a single hopperdredge or scow load.

(5) <u>FEASIBILITY OF SURVEILLANCE AND MONITORING</u>

Surveillance of dumping operations at the proposed site could be accomplished by placing observers aboard disposal vessels or by helicopter observations. Because the site is close to shore, aerial or ship observations would not be logistically difficult.

Environmental monitoring of the water column and the benthos at the proposed site should present no problems. Monitoring surveys of the site were successfully conducted by the EPA ocean survey vessel Antelope in 1984. Benthic monitoring with a box core sampler is feasible since the depth of range at the site is 330 to 540 meters, less than the practical limit for box core sampling.

(6) DISPERSAL, HORIZONTAL TRANSPORT AND VERTICAL MIXING CHARACTERISTICS OF THE AREA, INCLUDING PREVAILING CURRENT DIRECTION AND VELOCITY IF ANY

At the Ponce sites, depth is not the major determinant of bottom deposition. The major difference affecting sediment deposition at the sites considered is related to their distances away from shallow, nearshore shelf areas. Dredged material released at the interim site has the greatest potential for bottom deposition on the insular shelf of any of the considered sites because this flow is expected to carry sediments in significant concentrations into nearshore areas. Disposal at the proposed site is least likely to result in transport into nearshore areas.

(7) EXISTENCE AND EFFECTS OF CURRENT AND PREVIOUS DISCHARGES AND DUMPING IN THE AREA (INCLUDING CUMULATIVE EFFECTS)

No information has been found to indicate that dredged material disposal has occurred at the proposed Ponce DMDS or any of the other alternate sites. Dumping has occurred at approximately 3-year intervals at the interim site. Analyses of data from benthic sampling at the proposed site, interim site and other alternate sites by the 1984 survey cruise did not reveal any effects of previous disposal on the sediment grain sizes or the biota of the proposed site.

(8) INTERFERENCE WITH SHIPPING, FISHING, RECREATION MINERAL EXTRACTION, DESALINATION, FISH AND SHELLFISH CULTURE, AREAS OF SPECIAL SCIENTIFIC IMPORTANCE AND OTHER LEGITIMATE USES OF THE OCEAN

There are no fish or shellfish culture operations or desalination near the proposed site of any of the alternate sites. There will be no interference wth shipping lanes because there are no designated shipping lanes in Puerto Rican waters.

Principal commercial fishing grounds in the Ponce area are on the broad shelf area to the east. Fishing occurs throughout the shelf area, particularly at coral reefs and near the offshore islands. Specific information was not found concerning the amount of fishing at the large reefs west of the Port. If fishing does occur in that area, then the impact of sediments carried into the area from disposal at Alternate Sites 2 or 3 or the interim Site would perhaps affect numbers of fish available to fishermen.

(9) THE EXISTING WATER QUALITY AND ECOLOGY OF THE SITE AS DETERMINED BY AVAILABLE DATA OR BY TREND ASSESSMENT OR BASELINE SURVEYS

Water quality in the general area of the proposed Ponce DMDS and at the alternate sites is good, as is typical of well-flushed open water conditions throughout Puerto Rican coastal areas. The waters are usually optically clear, with little suspended material, except for shallow locations closer to shore than the proposed site. There is no evidence of organic enrichment or eutrophication; oxygen concentrations are high and nutrient concentrations are low.

Sediments at all of the sites are primarily silts and clays. Taxonomic analyses of benthic organisms collected at the proposed site reveal that the majority of the taxa (taxonomic groups) present are deposit-feeders, an ecological type well-adapted to living in high turbidity such as might be created near the sea floor by dredged material disposal. Other common ecological types were carnivores and herbivores, also able to live in turbid environments. It is not likely, therefore, that use of the site will have a detrimental effect on the benthic community outside of any immediate burial mound that might be formed if immediate deposition, rather than transport and dispersal, were to occur.

(10) POTENTIAL FOR THE DEVELOPMENT OR RECRUITMENT OF NUISANCE SPECIES IN THE DISPOSAL SITE

Because the proposed site, and all considered sites, are in deep ocean waters well flushed by currents, any nutrients or decaying organic matter in the dredged materials will not accumulate in sufficiently high concentrations to create eutrophication and resulting blooms of potentially noxious phytoplankton. Any human disease organisms that may be present in the dumped materials are very unlikely to be able to survive and reproduce in the cold, high pressure environment of the sea floor at the site.

(11) EXISTENCE AT OR IN CLOSE PROXIMITY TO THE SITE OF ANY SIGNIFICANT NATURAL OR CULTURAL FEATURES OF HISTORICAL IMPORTANCE

No such features have been identified at the site or in areas that will be affected by disposal at the site.

2.6.3 Summary: Proposed Site for Ponce

The proposed action for Ponce is the final designation of alternate site 1 as the DMDS for continuing use. The proposed Ponce DMDS meets all ODR criteria. It is not proposed that the formerly used interim DMDS be re-designated for continuous use, because it is expected that transport of suspended materials from disposal at that site may result in increased sedimentation rates in beach, coral reef, and preserve areas along the coast west of Ponce, in violation of general criterion Number 2 of the ODR.

No adverse effects are expected on living resources, including corals, fisheries, and nursery grounds, from use of the proposed DMDS. It has no unique ecological or environmental characteristics, being similar in sediment type and in its benthic biological community to most other sites in the Ponce study area.

No effects are expected on any mineral resources, or socio-economic and cultural aspects of the environment from use of the proposed site. There should be no problems conducting surveillance activities, and the ability to conduct environmental monitoring was demonstrated by successful sampling operations during the 1984 OSV Antelope survey cruise.

2.7 PROPOSED ACTION FOR YABUCOA

The proposed action for Yabucoa is to designate Alternate Site 2 (Figure 2-12) as the DMDS for continuing use. The characteristics of the dredged material at this harbor, and the environmental characteristics of the proposed site and the other sites considered, are summarized in this section fo the EIS. More detailed descriptions of the environment and expected impacts are given in Chapters 3 and 4.

2.7.1 Characteristics of the Dredged Material - Yabucoa

2.7.1.1 Grain Size of Material

Samples taken from Yabucoa Harbor indicate that the sediment is composed of silt and sand (COE, 1980d). The uppermost deposit is reported to consist of fine silt. Below a depth of 14 m (47 ft) the sediment is 30% sand.

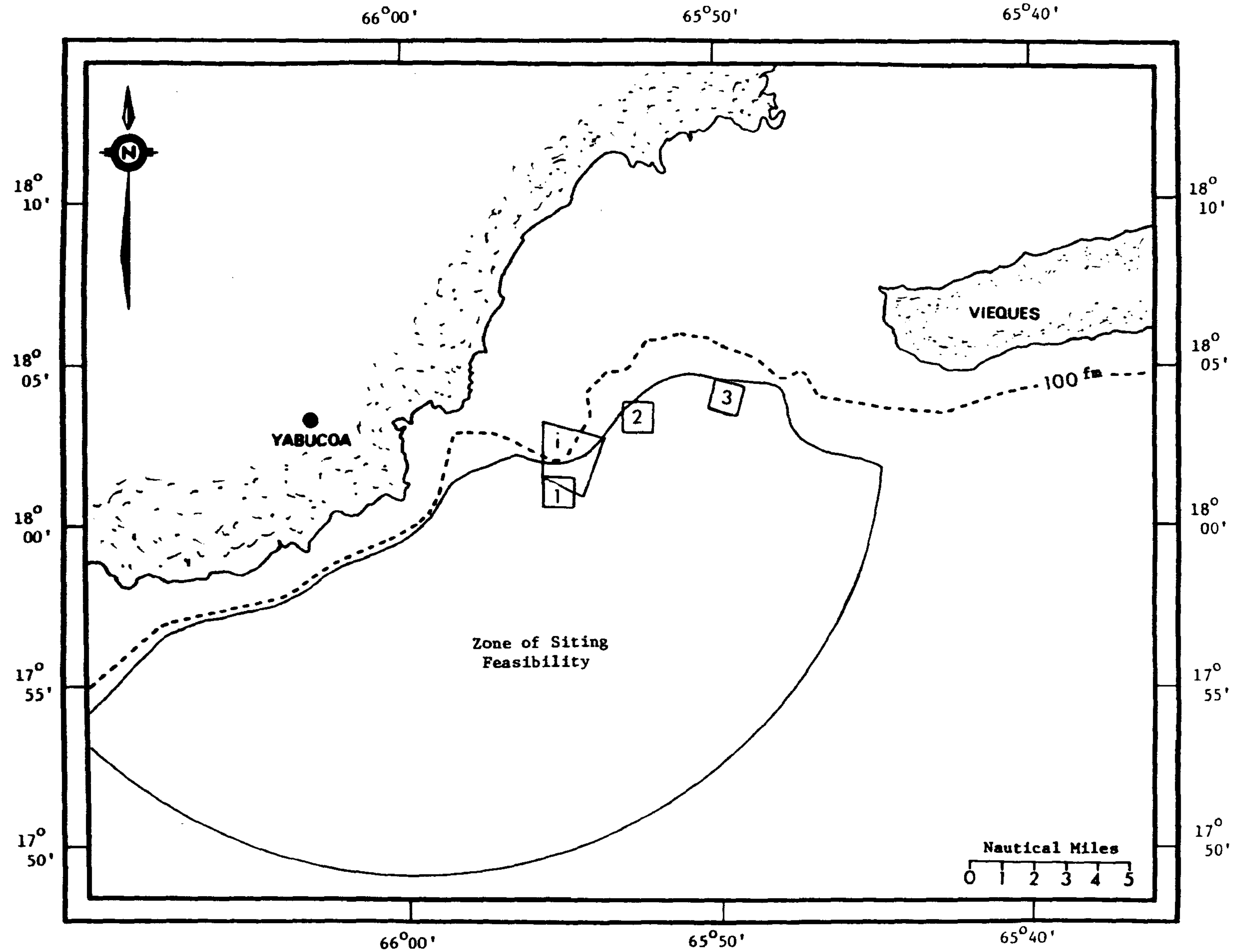


FIGURE 2-12. INTERIM AND ALTERNATE SITES FOR YABUCOA

2.7.1.2 Existence of Contaminants as Indicated by Elutriate Tests

An elutriate test conducted by Laboratorio de Analisis Ambiental, Inc. (1980) measured mercury (less than 0.1 ug/l), cadmium (less than 10 ug/l), DDT (less than 1.0 ug/l), and PCBs (less than 1.0 ug/l) in three sediment samples collected from Yabucoa Harbor. The test values are not significantly different from ambient concentrations. Petroleum hydrocarbon concentrations in elutriate from Yabucoa Harbor sediments ranged from 10 ug/l-15 ug/l.

2.7.1.3 Existence of Contaminants as Indicated by Bioassays

Bioassay data from a study conducted by Caribtec Laboratories, Inc. (1980c) on sediments collected from the Yabucoa Harbor Entrance Channel are presented in Table 2-8. Results of the liquid phase tests indicate that test organism survival was significantly different ($p=0.05$) from control survival in two of the three organisms tested. Results of the suspended particulate phase tests indicated that test organism survival was significantly different ($p=0.05$) from control survival in all three of the organisms tested with LC50 values as low as 12.5 percent. Results from those five bioassays must be evaluated in terms of initial mixing before a determination of potential impact from disposal of the dredged materials can be made. Results of the solid phase bioassays indicated that no environmental impact would be expected from disposal of that phase. Results of the bioaccumulation studies for mercury, cadmium, and petroleum hydrocarbons indicated some potential for uptake. Any such indication is a potential cause for concern. According to the federal criteria and procedures for bioassay testing, if a greater than 10 percent average mortality occurs in the control organisms, the test data must be discarded and the experiment repeated (EPA/COE 1977). Therefore, these bioassay test results have been included in the DEIS for information purposes only. They would not be acceptable for a permitting action.

The Laboratorio de Analisis Ambiental, Inc. (1980) conducted two bioassays on the liquid phase of sediments from the Sunoil Entrance Channel. They conducted a gamete fertilization rate bioassay which looks at effects on the fertilization rate of echinoid gametes (Tripneustes esculentus - white sea urchin) and a diatom bioassay that measures effects on diatom population

TABLE 2-8. RESULTS OF BIOASSAYS CONDUCTED ON THREE SEDIMENTS FROM YABUCOA HARBOR

	Liquid Phase	Suspended Particulate Phase
Mysidopsis bahia (96-hr TL50) Mysid shrimp	100%	13% (1)
Skeletonema costatum (96-hr EC50) Alga	70% (1)	12.5% (1)
Haemulon flavineatum (96-hr TL50) Fish	70% (1)	68% (1)

Solid Phase (% Survival)

	Control	Exposed
Mercenaria mercenaria Clam	98%	99%
Nereis virens Polychaete worm	68%	75%
Nerita tesselata Snail	79%	77%

Bioaccumulation (mg/kg)

	Mercury		Cadmium		Petroleum Hydrocarbons	
	Control	Exposed	Control	Exposed	Control	Exposed
Mercenaria mercenaria Clam	1.22	5.26	0.74	0.68	270	422 (1)
Nereis virens Polychaete worm	2.56	4.20	1.9	3.4 (1)	ND	ND
Nerita tesselata Snail	6.0	4.33 (1)	2.3	2.1	ND	ND

Notes: (1) Significantly different from control (p=0.05)
ND - Not detectable: insufficient tissue weight precluded analysis

Source: Caribtec Laboratories, Inc. 1980 growth rates (Skeletonema costatum). Results of the gamete fertilization and diatom bioassays indicate that there was no toxicity even at an elutriate concentration of 100 percent. The authors therefore concluded that the liquid phase of the proposed dredged material would not have any significant adverse ecological impact on water quality or marine biota.

2.7.2 Detailed Consideration of the Alternate Sites

The proposed site, the existing interim site, and two other Alternate Sites were evaluated according to site selection criteria listed in Part 228 of the ODR. The Alternate Sites were selected to be in accordance with the 5 general ODR criteria (see Section 2.3.1.1 of this EIS).

The proposed DMDS and the Alternate Site were then evaluated under the 11 specific ODR criteria. Results of these evaluations according to the specific ODR criteria are summarized in Table 2-9, and described below.

(1) GEOGRAPHIC POSITION, DEPTH OF WATER BOTTOM TOPOGRAPHY AND DISTANCE FROM COAST

The proposed DMDS for Yabucoa (alternative site 2), the interim site, and the other sites considered are shown in Figure 2-12. Table 2-9 shows the position, bottom depth range and average bottom slope of each of the sites. Also shown are the distance from the nearest coast and the distance from the harbor entrance. The proposed DMDS lies 11 km (6 nmi) east of Yabucoa Harbor, about 8 km (4.5 nmi) from the nearest shoreline. The site has an area of 2.8 km^2 (0.9 nmi^2), and is centered at 18°03'12" N, 65°42'18" W. The sea floor has an average slope of 15 percent to the east. Bottom depths in this site range from 788 to 1052 meters (431 to 575 fathoms).

The Yabucoa interim site is located 8 km (4.5 nmi) east of the Yabucoa harbor mouth. The site is an irregularly shaped 4-sided polygon with sides measuring 3.2 km (1.7 nmi), 2.4 km (1.3 nmi), 3.7 km (2 nmi), and 3.7 km (2 nmi); and totalling an area of approximately 3.3 nmi^2 (10 km^2). The site is centered at 18°02'06" N, 65°45'00" W. Depth at this site ranges from 27 to 909 m (90 to 3000 ft).

TABLE 2-9
COMPARISON OF OCEAN DREDGED MATERIAL
DISPOSAL SITES FOR YABUCOA

COMPARISON FACTOR	EIS SECTION	INTERIM SITE	ALTERNATE SITE 1	ALTERNATE SITE 2	ALTERNATE SITE 3
Site Characteristics					
• Latitude	2.3.5	18° 02' 06" N	18° 01' 18" N	18° 03' 12" N	18° 03' 50" N
• Longitude	2.3.5	65° 45' 00" W	65° 44' 48" W	65° 42' 18" W	65° 39' 16" W
• Water Depth (m)	2.3.5	27 - 909 m	406 - 910 m	788 - 1052 m	732 - 938 m
(ft)		90 - 3000 ft	1340 - 3000 ft	2586 - 3450 ft	2420 - 4000 ft
• Average Bottom slope		17.3%	28.7%	15%	11.7%
• Distance from nearest coast (nmi)	2.3.5	3.5 E (6.5 km)	4.0 E (7.5 km)	4.5 E (8 km)	5.5 E (10 km)
• Distance from harbor (nmi)	2.3.5	4.5 E (8 km)	5.0 E (9 km)	6.0 E (11 km)	8.5 E (15 km)
Site Location Relative to:					
• Breeding, spawning, nursery, feeding or passage areas	3.4.4.3	none identified within 15 mile radius	none identified within 15 mile radius	none identified within 15 mile radius	none identified within 15 mile radius
• Beaches and other amenity areas	3.4.5	4 - 5 nmi E	4 - 5 nmi E	7 - 8 nmi NE	10 - 11 NE
Waste Characteristics					
• Types	2.7.1.1	Silty sand	Same as for Interim Site	Same as for Interim Site	Same as for Interim Site
• Typical Barge Load	1.3.4, App. B	2000-4000 cy	↓	↓	↓
• Quantities/Frequency of Dredging	1.3.4, App. B	500,000-600,000/ 5-6 yrs	↓	↓	↓
• Discharge methods		Side or bottom dumping from hopper dredges, or clamshell unloading from scow	↓	↓	↓
Feasibility of Surveillance and Monitoring		Feasible	Feasible	Feasible	Feasible
Subsurface Transport Characteristics	3.4.1.4				
Velocity (cm/s)		15	15	25	25
Direction ($^{\circ}$ True)		250°	250°	200°	210°
Near-bottom velocity (cm/s)		5 - 10	5 - 10	5 - 10	15
Direction ($^{\circ}$ True)		225 - 250°	225 - 250°	225 - 250°	315 - 45°
Potential Effects on Human Uses of the Area					
• Shipping		UL	UL	UL	UL
• Fishing		L	L	UL	UL
• Recreation					
- Beaching		L	L	UL	UL
- Diving areas					
• Areas of Scientific Importance		L	UL	UL	UL
• Mineral Resources		UL	UL	UL	UL
Potential Effects on Site Ecology					
• Marine mammals and threatened or endangered species		UL	UL	UL	UL
• Critical areas		UL	UL	UL	UL
- Mangroves		L	L	UL	UL
- Coral reefs		UL	UL	UL	UL
- Critical wildlife habitats					
Potential Effects on Cultural and Historic Resources					
• Shipwrecks		P	UL	UL	UL

L = Likely
P = Possible
UL = Unlikely

Yabucoa Alternate Site 1 is located 9 km (5 nmi) southeast of the Yabucoa habor mouth. The site has an area of 2.8 km^2 (0.9 nmi^2) and is centered at 18°01'18" N, 65°44'48" W. Depth at this site ranges from 406 to 910 m (1340 to 3000 feet).

Yabucoa Alternate Site 3 is located 15 km (8.5 nmi) east of the Yabucoa harbor mouth. The site covers an area of 2.8 km^2 (0.9 nmi^2) and is centered at 18°03'50" N, 65°39'16" W. Depth at this site ranges from 732 to 938 m (2420 to 4000 feet).

(2) LOCATION IN RELATION TO BREEDING, SPAWNING NURSERY, FEEDING, OR PASSAGE AREAS OF LIVING RESOURCES IN ADULT OR JUVENILE PHASES

Breeding, spawning, and feeding of fish or shellfish may be assumed to occur in any coastal marine waters, including those of the proposed site and the other considered sites. It may also be assumed that pelagic animals such as fish, shrimp, or squid, as well as marine mammals, seabirds or sea turtles may pass through waters of the sites. There is however no evidence to suggest that the proposed site or any of the Alternate Sites have any unique importance to the activities of marine animals. Neither the proposed site nor the other sites considered are likely to serve as nursery areas, because they are all in open-ocean locations well flushed by currents.

The northwest corner of the interim site is over very shallow water; this is an area characterized by hard bottom, and some corals were found to be present by the 1984 survey cruise. Disposal at this site would therefore be likely to result in damage to corals. Disposal at Alternate Site 1 would perhaps also result in such damage to corals in nearby shelf areas.

(3) LOCATION IN RELATION TO BEACHES AND OTHER AMENITY AREAS

Several beaches and stretches of shoreline would be reached by the sediment plumes created by disposal under typical oceanographic conditions at Yabucoa. Beach areas southwest of Yabucoa Harbor could be affected. The closest of these is Playa Maunabo, approximately 18 km (10 nmi) from the interim site. Another is located to the southwest off Cabo Mala Pascua. Concentrations from disposal at the interim site or alternate site 1 are expected to cause unacceptable effects on nearshore water quality. Use of either of these disposal sites for a typical disposal operation might cause an increase in ambient sediment levels at the shoreline, which is unacceptable under ODR criteria.

(4) TYPES AND QUANTITIES OF WASTES PROPOSED TO BE DISPOSED OF, AND PROPOSED METHODS OF RELEASE, INCLUDING METHODS OF PACKING THE WASTE, IF ANY

Identical types and volumes of dredged material would be released at any of the alternate sites. The volume of dredged material that will have to be dredged from Yabucoa Harbor annually will be variable, depending on rainfall, the prevalence of storms, high surf, and other factors.

The cumulative amount of material deposited over the full time period of a dredging and disposal operation is important in evaluating impacts of material if it settles to form a deposition mound. Historically, the harbors have been dredged once every three to five years, with an average amount of 114,000 cubic meters (150,000 cubic yards) of material being removed from the harbor during each dredging operation. The short-term effects of disposal depend on the amount of materials released on each trip. Thus, the quantity of disposed material of concern in evaluating impacts from transport of suspended sediments is 2000 to 4000 cubic meters (about 2500 to 5000 cubic yards), the amount contained in a single hopper-dredge or scow load.

(5) FEASIBILITY OF SURVEILLANCE AND MONITORING

The proposed site is characterized by deep water with depths ranging from 788 to 1052 meters (2600 to 3450 feet). Transit distances to the site are not so large as to prevent surveillance. The sea floor is deep, which may present some problems for monitoring activities. However, monitoring of the previously used interim DMDS also has presented problems in the past. In areas closer to shore than the proposed site, including at the interim site, hard bottom was struck by the box-core sampler, which was damaged, and there were difficulties in achieving successful coring operations in other shallow portions of the ZSF. Because of the very steep escarpment that forms the shelf edge throughout the Yabucoa area, all off-shelf sites in the area will contain deep-water locations. Sampling was successfully accomplished at the center of the proposed site on the 1984 cruise, because sufficient cable has been installed on the OSV Antelope to permit deep-water box core deployment.

(6) DISPERSAL, HORIZONTAL TRANSPORT AND VERTICAL MIXING CHARACTERISTICS OF THE AREA, INCLUDING PREVAILING CURRENT DIRECTION AND VELOCITY IF ANY

The principal difference between the interim site and the three alternate sites is their depth ranges. The interim site is located over the shelf-break with the northwest corner of the site in shallow water (20-40 m) and the southeast corner of the site over the continental slope in water as deep as 900 m. In contrast to the alternate sites where depths are no less than 400 m, at the interim site significantly higher concentrations of dredged material would be deposited on the bottom, because of the shallowness of portions of the site. Disposal operations at the three alternate sites would tend to result in southwesterly offshore transport over deep water with dispersion of the dredged material to negligible concentrations in the water column and on the bottom.

Current measurement data are available from numerous previous studies to characterize surface and subsurface transport patterns over the deep ocean off Yabucoa. Subsurface currents are strongly influenced by the complex bottom topography of the region with rapid flow along the steep escarpment over the slope. Subsurface flow is characterized by eddies on the order of 20 km wide, extending to depths of 400 m. Disposal of dredged material at alternate site 2 and to a lesser extent at alternate site 3 would tend to result in rapid dispersion of the waste plume over a long distance over deep water. Expected environmental concentrations of suspended sediments from dredged material disposal at those sites would be negligible.

(7) EXISTENCE AND EFFECTS OF CURRENT AND PREVIOUS DISCHARGES AND DUMPING IN THE AREA (INCLUDING CUMULATIVE EFFECTS)

No information has been found to indicate that disposal has occurred at the proposed site or either of the other alternate sites. Data on sediment types from benthic sampling at the proposed site, the interim site, and alternate sites by the 1984 survey cruise did not reveal any effects of previous discharges at the interim site; where soft-bottom was found, sediments were similar in composition to those throughout the Yabucoa study area.

(8) INTERFERENCE WITH SHIPPING, FISHING, RECREATION MINERAL EXTRACTION, DESALINATION, FISH AND SHELLFISH CULTURE, AREAS OF SPECIAL SCIENTIFIC IMPORTANCE AND OTHER LEGITIMATE USES OF THE OCEAN

There are no fish or shellfish culture operations or desalination near the proposed site of any of the alternate sites. There will be no interference with shipping lanes because there are no designated shipping lanes in Puerto Rican waters.

A principal fishing area of the Yabucoa region is the very narrow shelf south of Cabo Malo Pascua. Because of the very deep waters in this region, suitable shallow fishing areas are very limited and fishermen concentrate their efforts along this coastline. Use of alternate site 1 or the interim site would be expected to result in transport of some dredged materials into this area. It is possible that such increased turbidity would decrease availability of fish to fishermen by causing periodic movement out of the area.

(9) THE EXISTING WATER QUALITY AND ECOLOGY OF THE SITE AS DETERMINED BY AVAILABLE DATA OR BY TREND ASSESSMENT OR BASELINE SURVEYS

Water quality in the general area of this site and the alternate sites is good, as is typical of well-flushed open water conditions throughout Puerto Rican coastal areas. The waters are usually optically clear, with little suspended material, except for shallow locations closed to shore than the proposed site. There is no evidence of organic enrichment of eutrophication, oxygen concentrations are high and nutrient concentrations are low.

Sediments in soft-bottom sites of the Yabucoa ZSF are primarily silts and clays. Taxonomic analyses of the fauna collected at the proposed disposal site and other locations throughout the ZSF reveal that the majority of the taxa (taxonomic groups) present at all sites are deposit feeders, an ecological type well-adapted to living in high-turbidity environments. Other common ecological types were carnivores and herbivores, also able to live in turbid areas. It is not likely, therefore, that use of the proposed DMDS will have a detrimental effect on soft-bottom benthic communities of the area.

(10) POTENTIAL FOR THE DEVELOPMENT OR RECRUITMENT OF NUISANCE SPECIES IN THE DISPOSAL SITE

Because the proposed site, and all considered sites, are in deep ocean waters well flushed by currents, any nutrients or decaying organic matter in the dumped dredged materials will not accumulate in sufficient high concentrations to create eutrophication and resulting blooms of potentially noxious phytoplankton. Any human disease organisms that may be present in the dumped materials are unlikely to be able to survive and reproduce in the cold, high pressure environment of the sea floor at the site.

(11) EXISTENCE AT OR IN CLOSE PROXIMITY TO THE SITE OF ANY SIGNIFICANT NATURAL OR CULTURAL FEATURES OF HISTORICAL IMPORTANCE

One shipwreck has been identified, near alternate site 1 and the interim site. Use of the proposed site will have no effect on this feature.

2.7.3 Summary: Proposed Site for Yabucoa

The proposed action for Yabucoa Harbor is the final designation of alternate site 2 as the DMDS for continuing use. This site meets all ODR criteria. It cannot be recommended that the interim DMDS or alternate site 1 be designated as the DMDS for continuing use. The interim DMDS includes a very shallow, shelf area, and thus does not meet the second general criterion of the ODR (see page 2-17). Live corals have been identified within the interim site and adjacent to alternate site 1. Finally, transport modeling indicates that disposal at either of these two sites is likely to result in transport of suspended sediments into the shoreline areas to the southwest, where the very narrow shelf is an important fishing area.

No adverse effects are expected on living resources, including corals, fisheries, and nursery grounds, from use of the proposed DMDS. It has no unique ecological or environmental characteristics, being similar in sediment type and in its benthic biological community to most other locations of the similar depth in the Ponce study area.

No effects are expected on any mineral resources, or socio-economic and cultural aspects of the environment from use of the proposed site. There should be no problems conducting surveillance activities, and the ability to conduct environmental monitoring was demonstrated by successful sampling operations at this site during the 1984 OSV Antelope survey cruise.

3. CHARACTERISTICS OF AFFECTED ENVIRONMENTS

3. CHARACTERISTICS OF AFFECTED ENVIRONMENTS

3.0 INTRODUCTION

This chapter describes the natural and man-made (socioeconomic) environments of the four study areas (Arecibo, Mayaguez, Ponce and Yabucoa). These descriptions include only those elements of the environments that may be affected by use of the interim dredged material disposal site, or any of the alternate sites being evaluated in the EIS.

The different elements of the environments are described with differing levels of detail, depending on their relative importance to the selection of a recommended site for each harbor. Thus, benthic biology, coral reef ecology, and the effects of ocean currents on sediment transport and dispersal are discussed in more detail than other components of the ecosystem.

Section 3.0 discusses aspects of protected resources that are applicable to all four harbor areas. Sections 3.1, 3.2, 3.3 and 3.4 present information specific to Arecibo, Mayaguez, Ponce and Yabucoa respectively.

3.0.1 Soft-Bottom Benthic Communities

This section discusses certain general characteristics of benthic organisms that affect their sensitivity to turbidity or burial by dredged material disposal. These characteristics apply equally to benthic communities in the zones of siting feasibility (ZSF's) at each harbor. Specific characteristics of the benthic biota of the ZSF's will be described in Sections 3.1.4, 3.2.4, 3.3.4, and 3.4.4, for Arecibo, Mayaguez, Ponce and Yabucoa, respectively.

Animals that inhabit similar sediment types (i.e., sediments with similar mixes of particle sizes, ranging from muds to coarse sands) will be similar in their susceptibility to harm from increased turbidity or burial under deposited sediments. There is a close relationship between habitat grain size and the sensitivity of organisms to dredged material impacts. Based on this relationship, sediment and biological data collected from the four ZSF's by the EPA 1984 Survey Cruise, and biological data from historical sources can be used to determine the principal feeding strategies and other ecological characteristics in the soft-bottom benthic communities within sediment-transport distance of interim and alternate disposal sites. The information can be used to predict dredged material impacts on benthic organisms following release at potential disposal sites.

Areas with fine-grained sediments (muds and fine silts) will typically have relatively high turbidity levels, especially near the sea floor, and therefore tend to be colonized by turbidity-resistant benthic organisms, whereas other types will be eliminated. Suspension-feeders, animals that trap food particles from water passed through filtering mechanisms of various kinds, are often not able to survive in turbid water because their feeding organs become blocked or clogged by accumulations of fine sediment particles. Examples of suspension feeders common in most nearshore waters are some bivalve molluscs (such as many clams, oysters and scallops) and members of groups of polychaete worms, such as the families Sabellidae, Serpulidae, or Chaetopteridae, that use particularly delicate filtering structures to trap food. The deposition of fine-grained dredged materials (muds or even fine silts) in the habitats of such organisms will either impair or destroy their feeding capabilities, and may in some cases destroy respiratory organs as well.

In contrast, deposit feeders, typically burrowing animals that either ingest materials buried in sediments, or ingest the sediments themselves and absorb attached organic matter, will be affected very little by increases in turbidity. Deposit feeders include a large variety of animals, such as worms of many kinds representing over a dozen major taxonomic groups, tiny burrowing crustaceans, some bivalves, and certain snails. Such animals will typically not be harmed by inputs of suspended mud or fine silts to their areas. However, the deposition of sand or coarse silts can have a devastating effect on deposit feeders. Many of these burrowing animals may be unable to move properly through, or will be abraded by, coarse or mixed sediments, or will be abraded by or unable to survive ingestion of coarse sand particles.

Because deposition of sediments unlike those already present in an area may damage or kill many of the resident benthic invertebrates, and then prevent recolonization by animals of the same or similar kinds, EPA and COE have recommended that dredged materials be disposed of in areas with similar sediment characteristics to the materials being dumped. Thus, an important factor considered in the selection and evaluation of potential dredged material disposal sites (DMDSs) is how well the sediment type and associated biological community at and surrounding each potential site match the characteristics of sediments most likely to be dredged from the principal harbor(s) of the region served by that site.

Characterizations of sediments from each harbor are given in Section 2.4. Descriptions of the biota and sediment types present in the areas of proposed disposal sites for each of the four harbors are given in Sections 3.1.4, 3.2.4, 3.3.4, and 3.4.4.

3.0.2. Ecological Characteristics of Puerto Rican Corals and Associated Fish Communities

Features common to coral reefs throughout the harbor areas considered in this EIS are summarized in this section. Locations of corals at or near proposed disposal sites for each harbor are discussed in Chapter 4 and shown in Figures 4-1 through 4-8. Coral reefs are exceptionally productive marine habitats second only to certain seagrass flats in the production of organic materials by living organisms (Levinton 1982). Because of the relatively low productivity of surrounding tropical seas, coral reefs in all areas of the world are important in their ability to trap and rapidly recycle available nutrients to their associated plant and animal communities. The highly productive nature of Puerto Rican coral reefs has been confirmed by Odum, Burkholder and Rivero (1959) and Glynn (1964). Puerto Rican coral reefs also play an important role in supporting the island's small-scale (artisanal) fisheries.

Coral reefs are common along all coasts of Puerto Rico with the exception of the north coast, where they are generally absent. They are present along the coastlines at or adjacent to the dredged material disposal sites for Mayaguez, Ponce and Yabucoa. The absence of coral reefs on the north coast, where Arecibo is located, has been attributed to the influx of waters from the four largest Puerto Rican rivers (the Arecibo, Manati, Plata and Loiza), which empty into the sea off the north coast. The influence of these rivers results in reduced salinities and high turbidities, both of which are unfavorable to the growth of corals. Normally heavy seas that constantly resuspend sediments along this coast may also be a factor in creating turbidity that prevents successful coral colonization (Glynn 1973).

Reefs characteristic of the Puerto Rican coast include fringing-reef communities of shallow areas, dominated by the coral _Porites furcata_. Dominant species inhabiting _Porites_ communities include the mantis shrimp, _Gonodactylus oerstedii_; the green crab, _Mithrax sculptus_; the crab, _Petrolisthes galathinus_; the echinoid, _Echinometra lucunter_; the sea cucumber, _Holothuria parvula_; and the brittle star, _Ophiothrix angulata_. Young spiny lobsters (_Panulirus argus_) are often found in _Porites furcata_ reefs (Glynn 1964). In addition to fringing reefs, all three coasts also have deeper offshore bank reefs. A prominent coral of Puerto Rican offshore reefs is the golden brown elkhorn coral _Acropora palmata_. Elkhorn coral contains numerous indentations and holes, which provide refuges for large numbers of spiny lobsters of all sizes.

The great majority of fishermen in Puerto Rico are individual small-boat operators, who collectively land approximately 6 million pounds per year of finfish and shellfish, much of which is harvested from coral reef environments (Puerto Rico Department of Agriculture 1975, 1980, 1981). The catches are in large part composed of reef fishes and other species that live near reefs and depend on coral reef systems for food (Parrish and Zimmerman 1977) and protection (Bakus 1966). Reef-associated fishes such as grunts, snappers and groupers make up about 51 percent of the catch of Puerto Rico's fishermen (Weiler and Suarez-Caabro 1980). Not only reef-related species derive nourishment from the coral reef community; benthic invertebrates and fishes of adjacent soft-bottom areas do so as well. Benthic invertebrates of these sand or mud environments receive substantial energy from reef-derived detritus (particulate organic materials). They pass this energy through the food chain to the various kinds of demersal fishes (bottom-feeding) that typically feed on sand and mud communities, as well as to the reef-associated fishes that occasionally forage on neighboring flats (Parrish and Zimmerman 1977).

Adult reef fishes often migrate to the shelf edge or non-reef areas to spawn; possibly because this increases the chance of keeping the eggs and young larvae out of the reach of reef predators (Colin 1982). Recruitment (the metamorphosis and settling of juvenile aquatic animals into their adult habitats) may follow a strictly planktonic larval existence, or may be preceded by intermediate periods spent in shallow, nearshore habitats.

The following section discusses the importance of one kind of nearshore environment that shelters the young of some species of reef fishes as well as other open-water fishes.

3.0.3 Mangroves: Special Breeding and Nursery Areas

Recruitment and settling of juvenile fish and shellfish into their adult habitats often follows a larval and early juvenile period spent in protected nearshore environments. In Puerto Rico, as in many other tropical coastal areas, mangroves are particularly important in serving this purpose. Mangrove swamps and estuaries are the feeding areas for the juveniles of such commercially valuable Puerto Rican fish as the yellow fin mojarra and many snapper (lutjanid) and grunt (pomadasyid) species (Austin and Austin 1971; Ogden 1982). Interdependencies between the fishery-supporting coral reefs and nearby coastal mangroves make it important to evaluate the potential for impacts from dredged material disposal on both habitats.

In Puerto Rico, and the tropics in general, mangrove forests consist of a series of zones, each characterized by a predominant species of tree. Forests bordering quiet, open water at elevations that may be flooded by spring tides are composed primarily of the red mangrove, *Rhizophora mangle*, while the next zone towards higher ground is dominated by the black mangrove, *Avicennia tomentosa*. Mangroves send breathing roots upwards for a meter or more from the mud surface. A diverse and particularly productive community of marine organisms inhabits the submerged root and sediment ecosystem of the primarily black-mangrove swamps of protected shorelines. Characteristic shellfish and other benthic animals of Puerto Rican mangrove communities include the edible oyster, *Crassostrea rizophorae*; the crab, *Aratus pisonii*; the shrimp, *Stenopus hispidus*; the spotted sea cucumber, *Stichopus badionotus*; the tunicate, Ascidia nigra; the marine snail, Littorina angulifera; the sea anemone, Bartholomea annulata; and the large polychaete worm, Sabellastarte magnifica. There are also highly productive phytoplankton and zooplankton assemblages, supported by the rapid input of nutrients from land run-off and the recycling of decaying plant litter and other mangrove and algal debris.

The variable salinity and temperatures of the shallow waters of mangrove swamps and mangrove-lined estuaries, together with their limited depth and spatial extent, make them unsuitable as permanent habitats for adult fish of most species. But the abundance of small-scale refuge areas, and the rich concentrations of food organisms and high organic-content detritus, make them particularly good habitats for larval and juvenile stages of many species of fish and shrimp. Mangrove systems thus ultimately provide energy to open-water marine food chains through the emigration of young fish and shrimp that achieved their early growth by feeding on the high densities of prey organisms in the mangrove communities. Information on the species of fish in Puerto Rico that use mangrove nursery grounds and would potentially be affected by use of the various dredged material disposal sites under consideration is presented in the following section, and later for each harbor area.

3.0.4 Fisheries

The entire Puerto Rican shelf out to bottom depths of 0 to 40 fathoms (0-72 meters), also referred to as the "platform", is heavily used by commercial and recreational fishermen, especially on the east, south and west areas of the island (Caribbean Fishery Management Council 1984). As of 1982, CODREMAR (an abbreviated acronym for the Corporation for Development of Fluvial, Lacustrine and Marine Resources of the Puerto Rico Department of Natural Resources) reported a total of 1,872 fishing boats under operation in Puerto Rico (Caribbean Fishery Management Council 1984). The majority of the boats are small, one-man wooden boats with limited ranges (O'Connor 1983). Exploited fishes are thus mainly reef fishes, which are the most concentrated and abundant fishes in the nearshore areas accessible to these artisanal (small-boat) fishermen. Commercially important reef fishes throughout the island include groupers, mojarras, porgies, snappers and grunts. Fishes from these three groups constituted 51 percent of the 1978 Puerto Rico landings (Weiler and Suarez-Caabro 1980, as cited in O'Connor 1983).

Total landings in Puerto Rico were 4.7×10^6 lbs. for the period from October 1982 to July 1983 (Caribbean Fishery Management Council 1984). Highest landings were off the west coast (2.3×10^6 lbs.), followed by those for the south coast (1.2×10^6) and the east coast (8×10^5). Fishing is least productive on the north coast (5×10^5), in part because of the high seas that generally limit small boat operations, but also because of the limited number of coral reefs (see Section 3.0.2).

3.1 CHARACTERIZATION OF THE AFFECTED ENVIRONMENT FOR ARECIBO

3.1.1 Oceanographic and Climatological Characteristics, Arecibo

3.1.1.1 Bathymetry

The shelf (the sea floor out to depths of 200 meters) is a fairly constant 2 to 3 kilometers wide along the north coast of Puerto Rico near Arecibo (Figure 3-1 and 1-1). The width of the slope from 180-meter (100-fathom) depths to 900-meter (500-fathom) depths is more variable. The slope is narrowest (7 kilometers) directly north of Arecibo Harbor. West of the harbor, the 900-meter (500-fathom) depth is reached about 12 kilometers offshore. East of the harbor, it is reached at about 9 kilometers. The bottom has a 6° gradient to the north at the interim and alternate sites.

3.1.1.2 Climatology

The climate of Arecibo is dominated by the easterly trade winds. Data gathered in Barceloneta, about 16 km (10 miles) west of Arecibo, from July-December 1974, show an average wind velocity of 4.2 m/s, with an average maximum velocity of 6.7 m/s between 1230 and 1530 hours and an average minimum velocity of 3.1 m/s between 0630 and 0930 hours (Black & Veatch 1975). The surface of the nearshore ocean near Arecibo is choppy from mid-day to 1600 hours; otherwise, the surface is generally calm. Sea waves commonly run three meters in height and may reach seven meters or greater several times a year (Black and Veatch 1975).

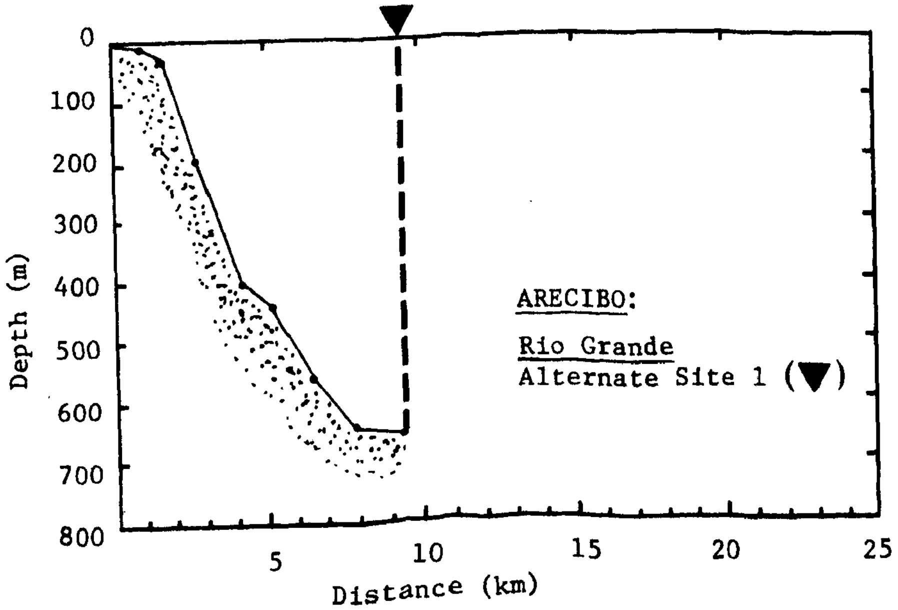


FIGURE 3-1. BATHYMETRIC PROFILE OFFSHORE FROM ARECIBO, RIO GRANDE TO ALTERNATE SITE 1

3.1.1.3 Hydrography

Figure 3-2 shows temperature data gathered from six deep-water sampling stations at Punta Manati, approximately 21 km east of Arecibo (Wood et al. 1975b). The maximum seasonal difference in surface water temperatures was 2.6°C, and little seasonal temperature change occurred below 250 meter depths. A deeper thermocline (the depth of the sharpest temperature change between surface and deeper waters) occurred in winter and spring than in summer and fall.

The salinity data from the same study (Figure 3-3) reveal an increase in salinity from the surface to about 150 m, with a slight decrease at greater depths. The highest surface salinity occurs in the spring, due to dry-season evaporation; wet-season dilution causes minimum surface salinity in the fall. Salinity at 50-100 m reaches a minimum in the winter, when low salinity surface water is mixed down by storms. It increases steadily throughout the rest of the year.

The density profiles resulting from these temperature and salinity values for the Punta Manati area are shown in Figure 3-4. The winter and spring profiles show a shallower pycnocline (the depth of the greatest density gradient) than in summer and fall. In winter and spring, pycnocline depths are about 125 m with an average density gradient of 9×10^{-6}/m. In comparison, summer and fall are characterized by a pycnocline depth of 60-80 meters and an average density gradient of 2×10^{-5}/m. These depths will affect the depth to which released dredged materials will sink in the initial, rapid descent phase, and therefore affect the amount of time sediments will spend in the water before settling out. This information is used in the sediment transport model used to predict ultimate transport distances and deposition concentrations (Section 4-1).

3.1.1.4 Circulation

Surface currents on the north shore of Puerto Rico generally travel parallel to the shore from east to west, with a small net drift to the west. Deeper currents tend to travel opposite to the surface currents. As shown in Figure 3-5, measurements at the Isolte site (Puerto Rico Nuclear Center 1975),

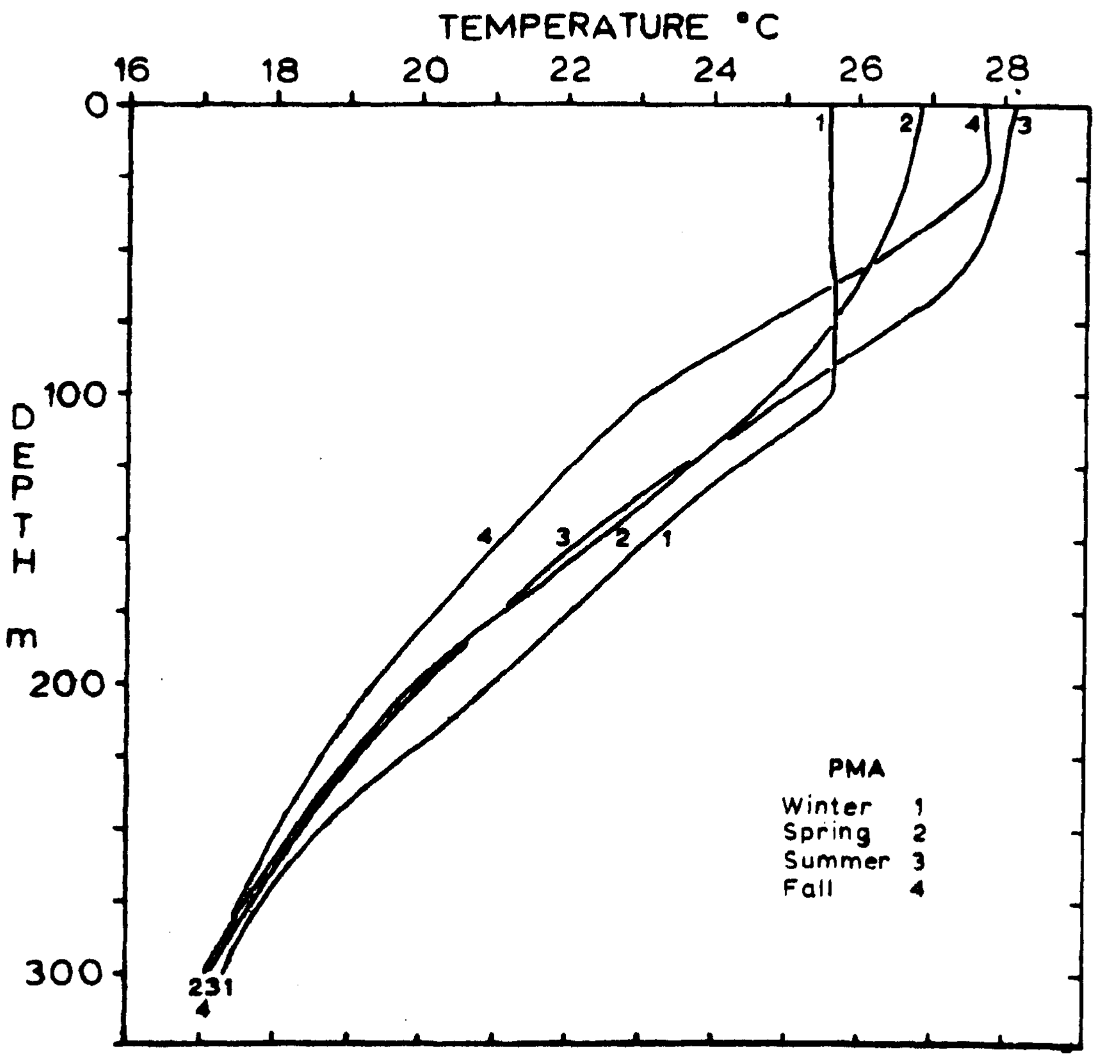


FIGURE 3-2. AVERAGED SEASONAL TEMPERATURE PROFILE OFF PUNTA MANATI, 1973 AND 1974

Source: Wood et al. 1975b.

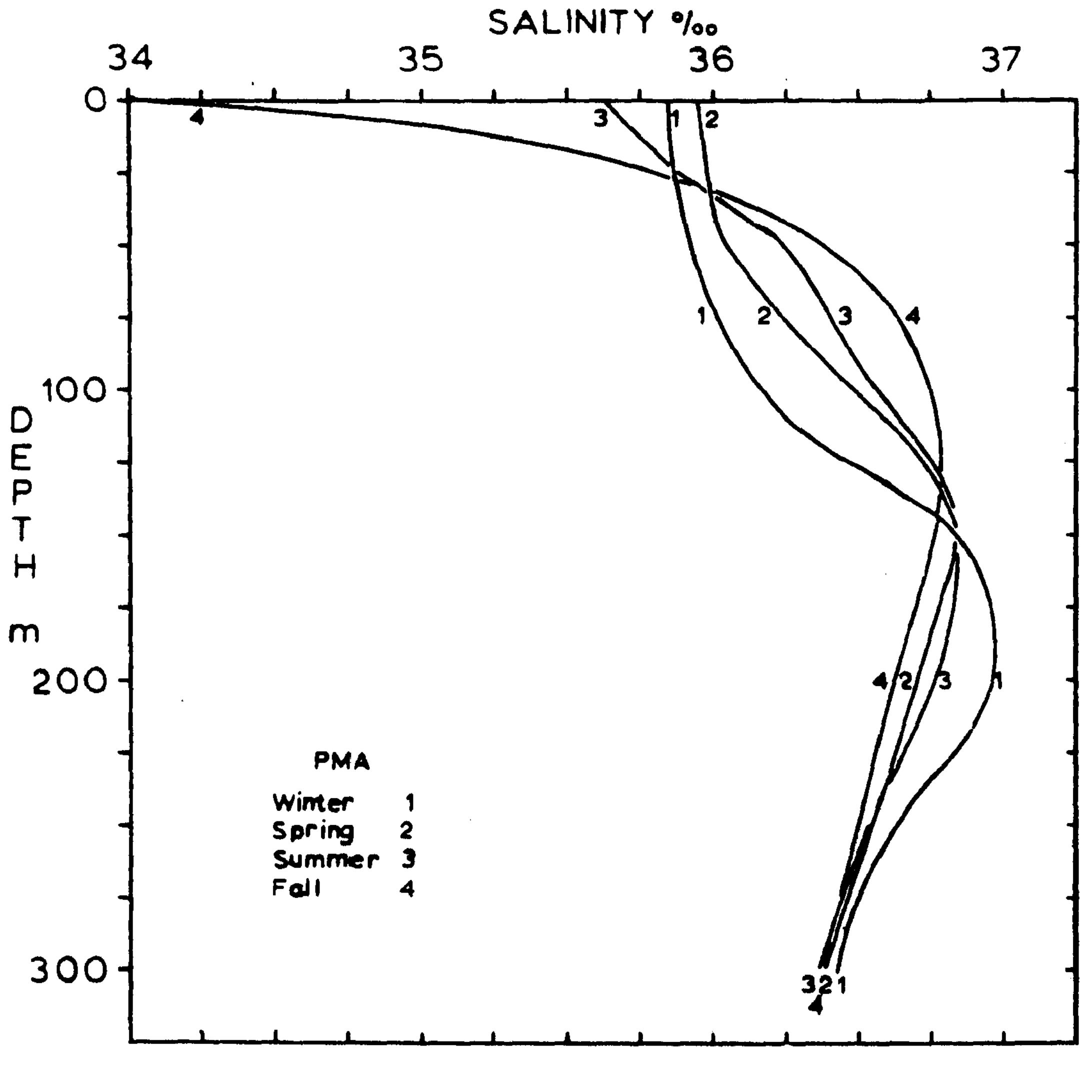


FIGURE 3-3. AVERAGED SEASONAL SALINITY PROFILES OFF PUNTA MANATI, 1973 AND 1974

Source: Wood et al. 1975b.

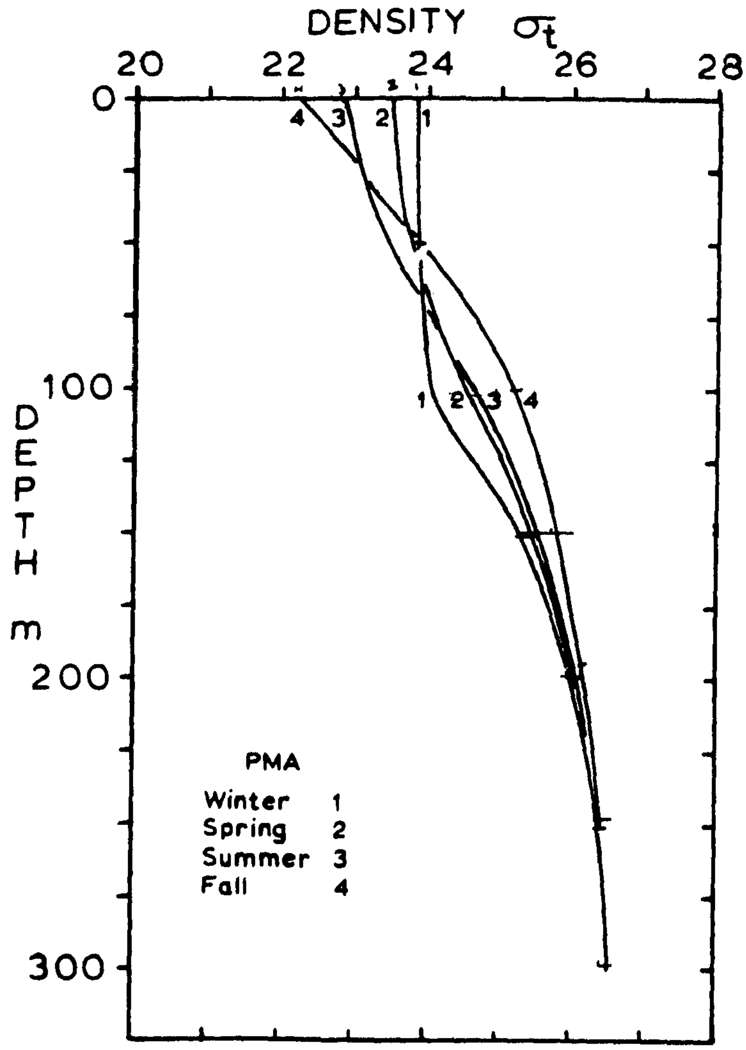


FIGURE 3-4. AVERAGED WATER DENSITY PROFILES, BY SEASON, OFF PUNTA MANATI, 1973 AND 1974

Source: Wood et al. 1975b.

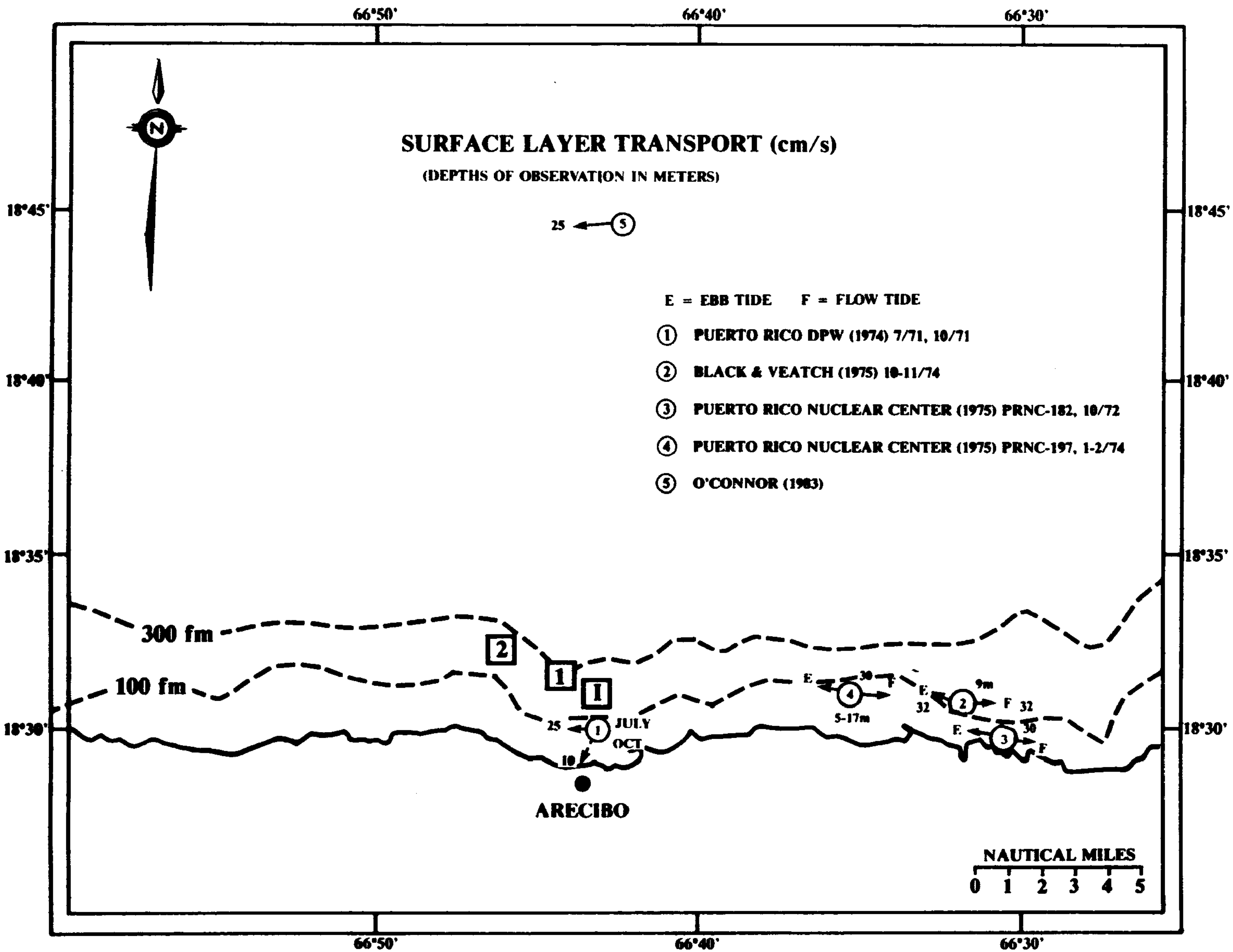


FIGURE 3-5. SURFACE LAYER TRANSPORT, ARECIBO STUDY AREA

the Punta Manati site (Wood et al. 1975b), and at Barceloneta (Black and Veatch 1975) all show maximum velocities of about 30 cm/sec. The maximum velocities are westward during ebb flow and eastward during flood flow. The literature indicates that net drift velocities average 3-5 cm/sec. The study at the Isolte site found that the net drift direction seemed to have a seasonal pattern, with eastward net drift during the summer and westward net drift during the winter. Onshore net drift was observed in October 1971 at Arecibo (Puerto Rico DPW 1974), while Black and Veatch found a net offshore drift at Barceloneta in October-November 1974. The Isolte study also showed deep-water currents (Figure 3-6) that resulted in a subsurface net drift to the east, while the surface net drift was to the west.

3.1.2 Geologic and Geochemical Characteristics, Arecibo

The interim and alternate sites at Arecibo have similar bottom types and sediment characteristics. The following sections describe the surficial geology, the bottom types, grain size distributions, and geochemical characteristics at each of the sites.

3.1.2.1 Surficial Geology

Along the north coast of Puerto Rico, the basement rock is predominantly limestone. Outcrops commonly occur near shore with the number diminishing in deeper waters (EPA 1982). Beach rock deposits (sand that has been cemented with iron oxides and/or precipitated calcium carbonate) are also common within the Arecibo study area (Guillou and Glass 1957).

Overlying the limestone and beach rock are several meters of sediments derived from land and marine sources. In areas of rapid currents or extensive wave action, such as in the beach zones adjacent to Arecibo (Figure 3-7), the sediments are predominantly coarse-grained materials, composed of quartz particles or shell fragments. Quartz grains originating from rock weathering and alluvial transport are found near river mouths along this coast (EPA 1982). Sediments composed mostly of shell fragments and other calcium carbonate materials formed by marine organisms are more typically present in offshore areas.

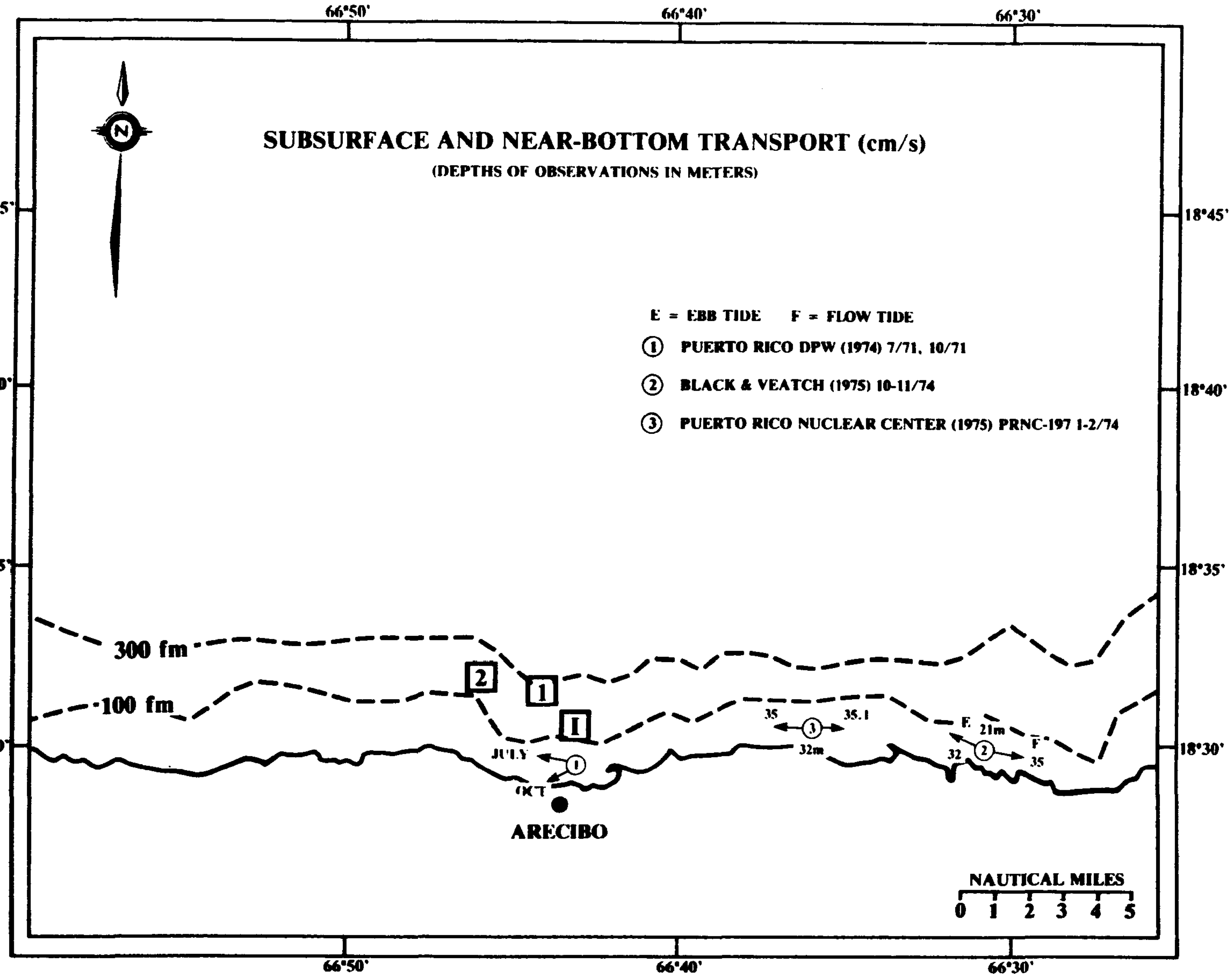


FIGURE 3-6. SUBSURFACE AND NEAR-BOTTOM TRANSPORT, ARECIBO STUDY AREA

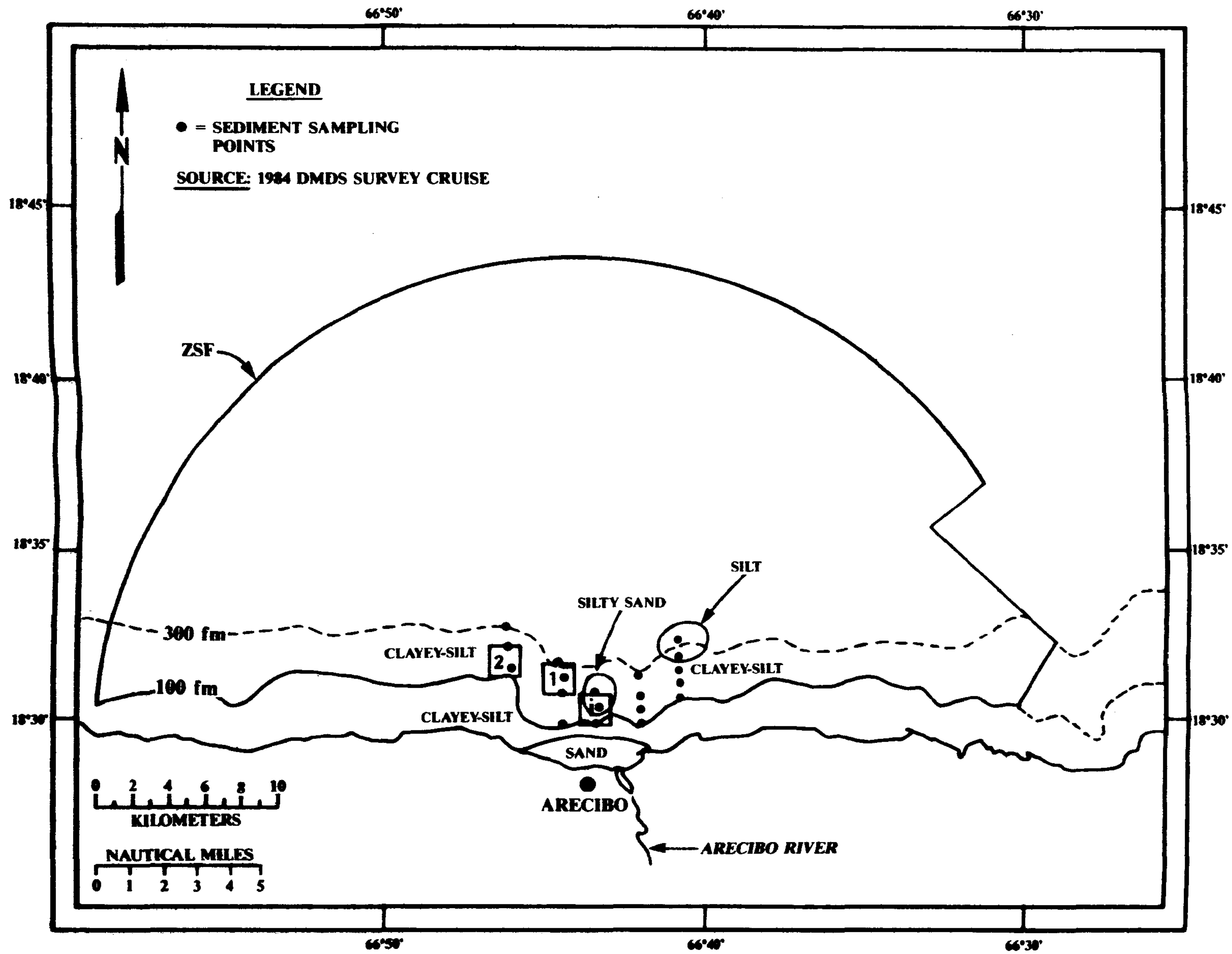


FIGURE 3-7. SEDIMENT SAMPLING POINTS AND IDENTIFIED SEA-FLOOR SEDIMENTS OFF ARECIBO

Fine grained sediments are found where currents are relatively slow and where sediment-laden rivers discharge into the sea. At Arecibo, the Rio Grande de Arecibo frequently floods and causes extensive sedimentation and shoaling in Arecibo Harbor (COE 1980e). Fine-grained sediments replace the nearshore sand along the coast within 1 to 2 nmi of the harbor, reflecting the river's influence.

3.1.2.2 Sea-Floor Characteristics and Sediment Textures

Sediment sampling off Arecibo during the 1984 Survey Cruise indicates that the bottom is soft past the 100-fathom depth (Figure 3-7). This verifies earlier studies (Schneidermann et al. 1976) of bottom types on the Puerto Rico shelf.

The 22 samples collected in the Arecibo area contained approximately 60 percent silt, 30 percent clay, and less than 10 percent sand. The measurement scale used is the Wentworth scale (Levinton 1982), in which silt is composed of particles from 0.0039 to 0.0313 mm in longest dimension. Sand particles are larger, ranging from 0.0625 to 1.0 mm. Clay particles are much smaller, ranging from 0.00024 to 0.00195 mm in longest dimension.

Interim Site - The sediments at the Interim Site are more coarse grained (e.g., sandier) than in other areas adjacent to the site. Samples collected within the Interim Site contained from 53 to 68 percent sand. This probably reflects the predominantly sandy nature of the material dredged in the past from Arecibo Harbor and dumped at the Interim Site (COE 1980e).

Alternate Site 1 - The sediments are predominantly silty, ranging from 59 to 85 percent silt, less than 10 percent sand, and the remainder clay. The sediments appear to be uniformly silty within this site.

Alternate Site 2 - The bottom sediments are predominantly silty with 55 to 70 percent silt, 25 to 33 percent clay, and 8 to 19 percent sand.

3.1.2.3 Sediment Mineralogy

Mineral compositions of the sediments at the interim and alternate sites are correlated with the sediment sources and particle size distributions at the sites.

The sand-sized material is likely to be composed of over 60 percent quartz, magnetite particles, and possibly hornblende particles that have been weathered from rocks on the island (Schneidermann et al. 1976; Guillou and Glass 1957; Kaye 1959). The other 40 percent of this sand fraction is calcium carbonate particles from shell fragments and other marine skeletal materials (Schneidermann et al. 1976). Sand particles can be considered relatively inert; they do not react chemically with each other or with the sea water to any great extent.

The silt fraction contains organic matter derived from marine and terrestrial sources. Silt particles are not cohesive or sticky, and their tendency to absorb metals or contaminants is very limited when compared to clay particles. The clay fraction of mixed sediments such as those at Arecibo has several properties that determine the general texture, transport behavior, and density of the sediments. First, a very small percentage by weight of clay in the sediment can have a marked effect on the physical properties of the sediment. Clays and partially clayey sediments are more cohesive than non-clayey sediments. Second, clays exhibit high degrees of cation exchange capacity, the capacity to temporarily adsorb ions onto the electrochemically-charged surfaces of the clay particles. For this reason, clays are more likely than other sediments to adsorb innocuous ions, such as potassium, or toxic ions, such as cadmium or other heavy metals from the water column (McCarthy 1977). Sediments of 25 to 33 percent clay, such as those found at alternate site 2 for Arecibo, will exhibit substantial increases in density and cohesiveness compared to sediments of adjacent locations which contain a smaller percentage of clay. Sediment characteristics will affect the type of benthic organisms inhabiting the site, and thus may influence the magnitude of ecological disturbance that may occur if dredged material is released at a given site (see discussion of soft-bottom benthos, earlier in this chapter).

3.1.3 Water Quality

Surface waters throughout the Arecibo study area are clear, warm, oxygen-saturated and nutrient depleted. Below the surface mixed layer, oxygen remains undepleted, and nutrient levels become very high. In summary, water quality in the area of the interim and alternate sites is excellent, and is typical of tropical open-ocean conditions.

3.1.3.1 Turbidity

Secchi disc depth readings taken from shallow (<15 m) nearshore waters (<2 nmi from shore) near Barceloneta (8 to 11 nautical miles east of Arecibo) are presented in Figure 3-8 (Puerto Rico Department of Public Works 1974). Secchi depths range from 5-24 m. Nearshore readings taken in studies of a proposed North Coast Nuclear Plant Unit No. 1 Site adjacent to Punta Las Tunas (5-7 miles east of Arecibo) ranged from 7-20 m (Puerto Rico Nuclear Center 1975). The lower values, indicating turbid water, were found at sites closest to shore; the higher values, indicating greater clarity, were found further from shore. The turbidity levels for Barceloneta are associated with runoff from the Rio Grande de Arecibo and the Rio Grande de Monati (Puerto Rico Department of Public Works, 1974). Transparency measurements indicated a transmission of 97-100% per 10 cm at all times.

3.1.3.2 Dissolved Oxygen

Dissolved oxygen concentrations are consistently at or near saturation levels in the surface water (Wood et al. 1975b). Figure 3-9 presents the average dissolved oxygen depth profiles by season at Punta Manati, 11 miles east of Arecibo, for 1973 and 1974. Some super-saturation was measured at depths of 25-75 m because of photosynthesis. Oxygen levels decrease slightly with depth. The greatest average dissolved oxygen values, except for the winter season, were found around 100 m (5.0 ml/l). The oxygen minimum occurred at about 225 m (4.0 ml/l) for all seasons except fall, when a distinct minimum was measured at 150 m (4.0 ml/l). Generally, there is very little seasonal change in dissolved oxygen.

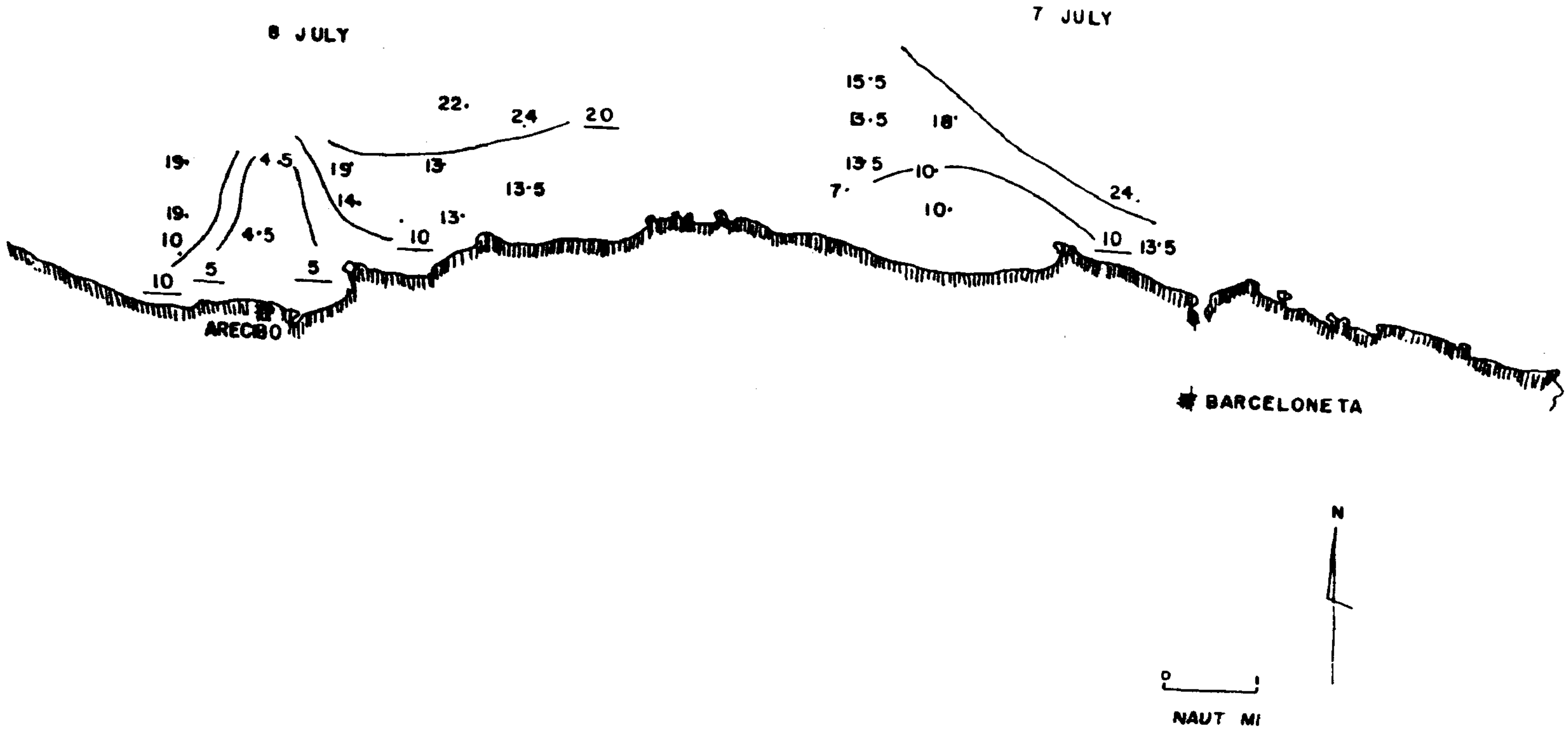


FIGURE 3-8. SECCHI DISK READINGS IN METERS FOR NEAR SHORE WATERS NEAR BARCELONETA, JULY 1971

Source: Puerto Rico Department of Public Works 1974.

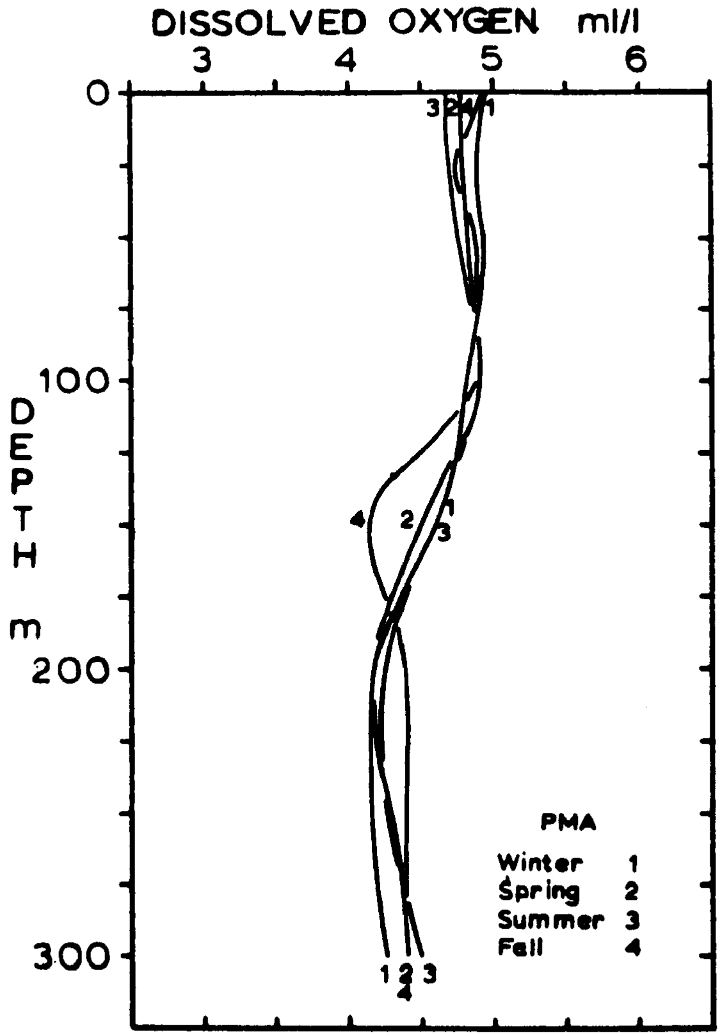


FIGURE 3-9. AVERAGED DISSOLVED OXYGEN DEPTH PROFILES, BY SEASON, AT PUNTA MANATI, 1973 AND 1974

Source: Wood et al. 1975b.

3.1.3.3 Nutrients

Nutrient levels in surface waters exhibit little seasonality, reflecting the relatively stable marine conditions associated with Puerto Rico's tropical climate. Surface waters are typically low in nutrients (phosphate, nitrate, and silicate), but concentrations increase with depth below the pycnocline.

Seasonal concentrations of reactive phosphate measured near Punta Manati are presented in Figure 3-10 (Wood et al. 1975b). Surface water concentrations, although typically very low (0.05 ug-at P/l) throughout the year, vary from a summer low of 0.02 ug-at P/l to a winter high of 0.09 ug-at P/l). There is little seasonal variation in phosphate levels. Phosphate values are constant throughout the upper mixed layer and through the pycnocline to about 200 m. Peak values at the deepest point sampled were about 0.5 ug-at P/l. A similar pattern was observed at the North Coast Nuclear Plant #1 site location. Surface layer concentrations of phosphate at this site were below ug-at P/l and remained constant to approximately 150 m. Below 150 m, phosphate concentration gradually increased with depth (Puerto Rico Nuclear Center 1975).

Fall concentrations of nitrate measured near Punta Manati are presented in Figure 3-11 (Wood et al. 1975b). At the deepest station sampled (Station C), the surface nitrate concentration was 0.3 ug-at N/l. The concentration remained constant to approximately 100 m and then gradually increased to 14 ug-at N/l at 300 m. At the North Coast Nuclear Plant #1 site (Puerto Rico Nuclear Center 1975) nitrate concentrations at the deepwater site increased almost linearly with depth from nearly 0 at 100 m to 27.9 ug-at N/l at 1,000 m. This profile is typical for the North Atlantic Ocean (Puerto Rico Nuclear Center 1975).

Studies conducted off Barceloneta, about 8 to 11 nmi east of Arecibo (Puerto Rico Department of Public Works 1974), measured silica concentrations ranging from 0-0.23 mg/l S/l in surface waters. No data on subsurface silica concentrations were found for this area.

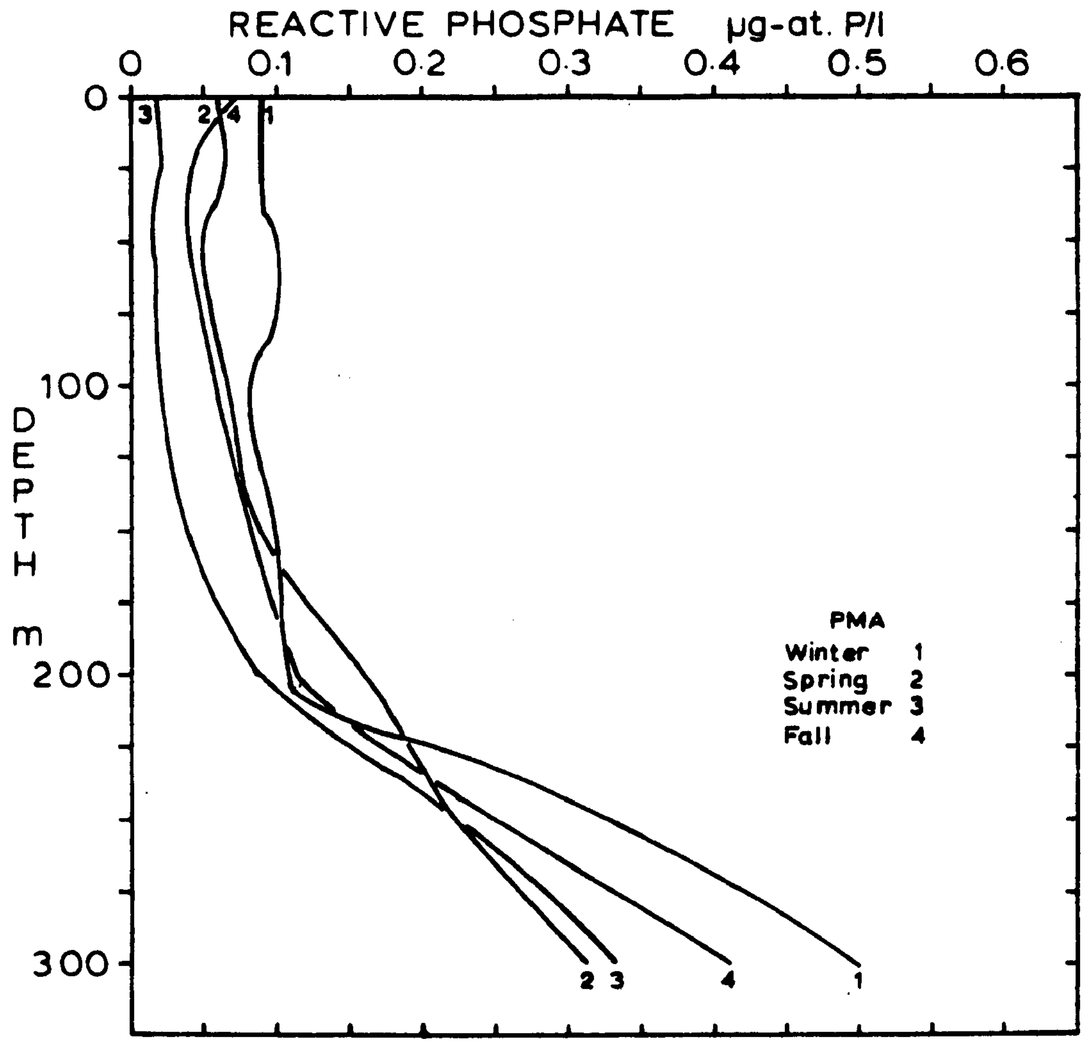
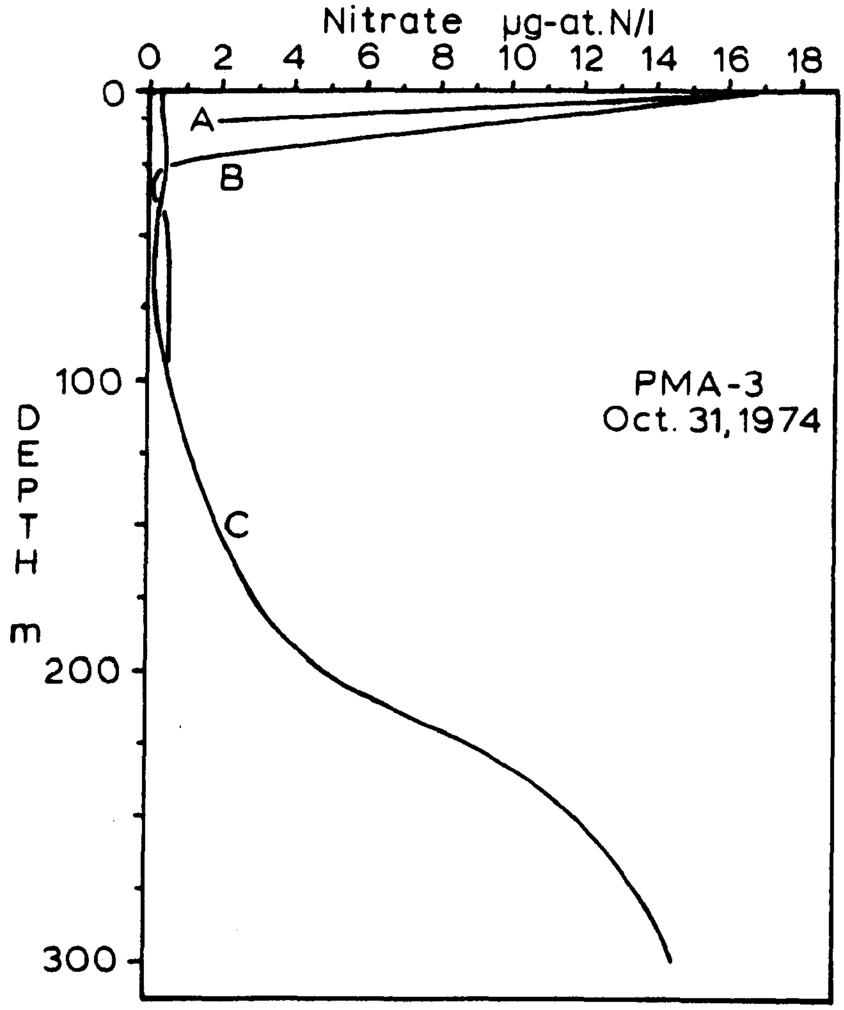


FIGURE 3-10. AVERAGED REACTIVE PHOSPHATE DEPTH PROFILES, BY SEASON, AT PUNTA MANATI, 1973 AND 1974

Source: Wood et al. 1975b.



A - Nearshore Station
B - Depth about 125 m
C - Depth about 325 m

FIGURE 3-11. PLOT OF NITRATE VS. STANDARD DEPTH FOR THE FALL SEASON, AT PUNTA MANATI, 1974

Source: Wood et al. 1975b.

	TTAXA	SCNT	SHNWVR	PIELOU
GRAVEL	0.36007	0.20736	0.24168	0.15529
	0.0651	0.2993	0.2246	0.4392
	27	27	27	27
SAND	0.49266	0.42428	0.50053	0.46601
	0.0090	0.0274	0.0078	0.0143
	27	27	27	27
SILT	-0.44761	-0.35797	-0.42463	-0.37337
	0.0192	0.0668	0.0273	0.0551
	27	27	27	27
CLAY	-0.35742	-0.35017	-0.40919	-0.41512
	0.0672	0.0734	0.0341	0.0313
	27	27	27	27
FINES	-0.49332	-0.42362	-0.49971	-0.46442
	0.0089	0.0277	0.0080	0.0147
	27	27	27	27
DPFT	-0.38064	-0.40209	-0.40204	-0.37936
	0.0501	0.0376	0.0376	0.0510
	27	27	27	27

Table 3-1 Correlation Matrix for Sediment Grain Size, Biological Parameters and Station Depth from the March, 1984 EPA/JRB Survey Offshore of Arecibo , Puerto Rico. (Correlation coefficients are listed first with significance levels listed second and the number of comparisons third). TTAXA = total number of taxa, SCNT = total number of individuals of all taxa, SHNWVR = Shannon - Weaver Diversity Index, PIELOU = Pielou's Eveness Index.

3.1.4.3 Mangrove Breeding and Nursery Areas

Commercially important marine fish of Puerto Rico's north coast, such as pompano, mullet, and mojarra, use mangrove estuaries as breeding areas and nursery grounds (Austin 1971). Mangrove environments, with their variable salinities and temperatures and limited spatial extents, are not primary year-round habitats for adult fish of most species. However, they are very suitable for the development of juveniles (Austin 1971). The north coast has several particularly extensive mangrove areas. One of these, the red mangrove area along Cano Tiburones, is immediately adjacent to Arecibo (see Figure 3-12).

According to Austin and Austin's 1971 study of fish feeding habits in the Cano Tiburones area, "a very large invertebrate population is present; in particular, the crustacean Macrobrachium carcinus" (the commercially valuable fresh or brackish-water prawn). The authors noted that, "All of the carnivorous fish examined, which feed on crustaceans, had consumed primarily juvenile M. carcinus," indicating that as a juvenile this mangrove crustacean is an important component of the food chain supporting commercially important fish. Thus, there is evidence to suggest that Cano Tiburones provides important productivity inputs to open-water marine food chains, including those of commercially important species, around Arecibo Harbor.

3.1.4.4 Preserves and Reserves

As discussed previously, some mangroves that provide nursery areas for commercially valuable fish are located along the Arecibo coast (see Figure 3-13). There are three coastal areas near Arecibo designated by the Commonwealth of Puerto Rico as critical wildlife areas. These are the Guajataca Cliffs critical habitat area, 9-11 miles along the coast to the west of the harbor, the Carrizales Mangrove Swamp, 4 miles west of the harbor and the Cano Tiburones Swamp, 1-8 miles to the east.

3.1.4.5 Threatened and Endangered Species

Two general types of animals with marine or semi-marine habitats in Puerto Rico include these federally designated endangered species: Sea turtles and the brown pelican.

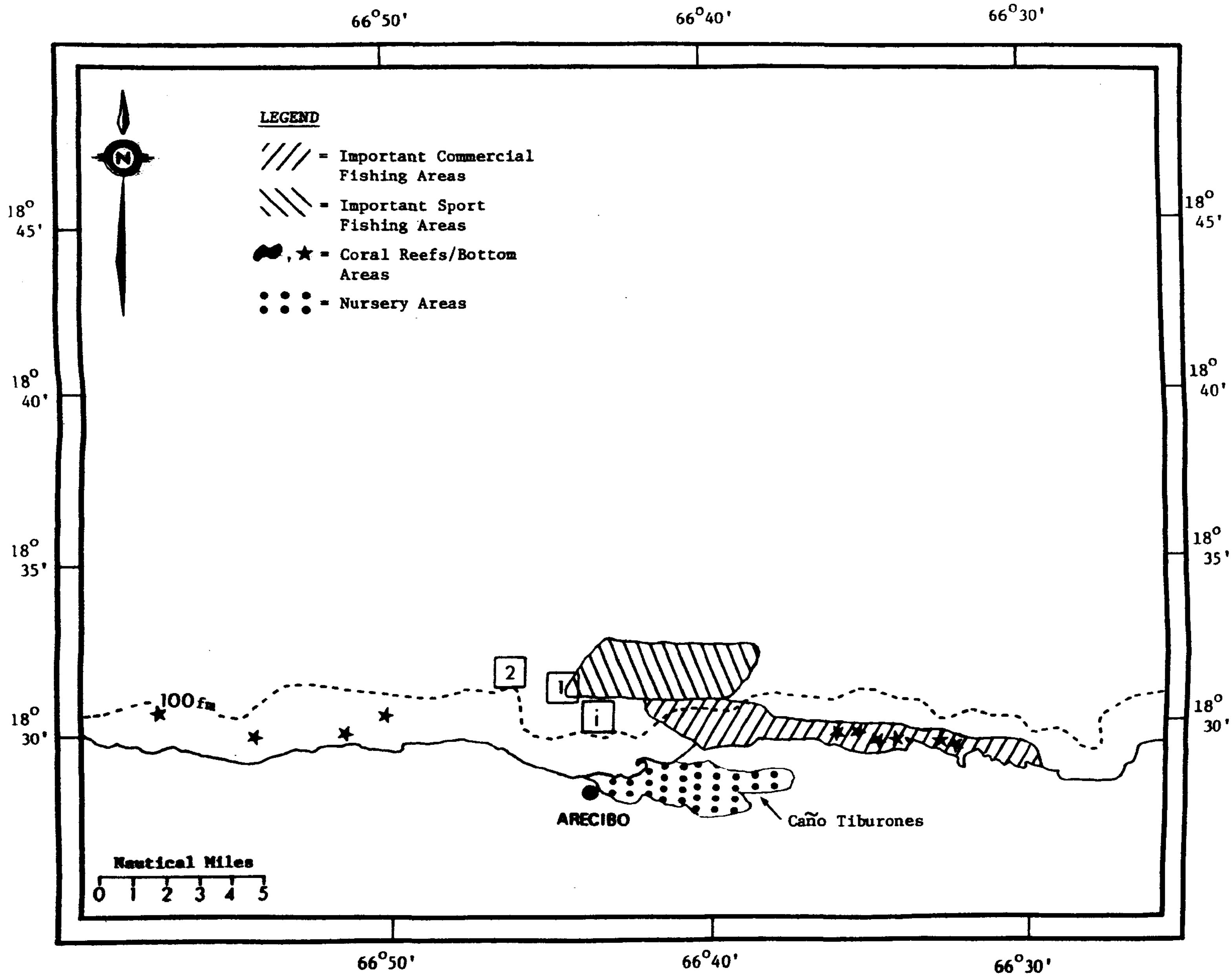


FIGURE 3-12. LIVING MARINE RESOURCES NEAR ARECIBO

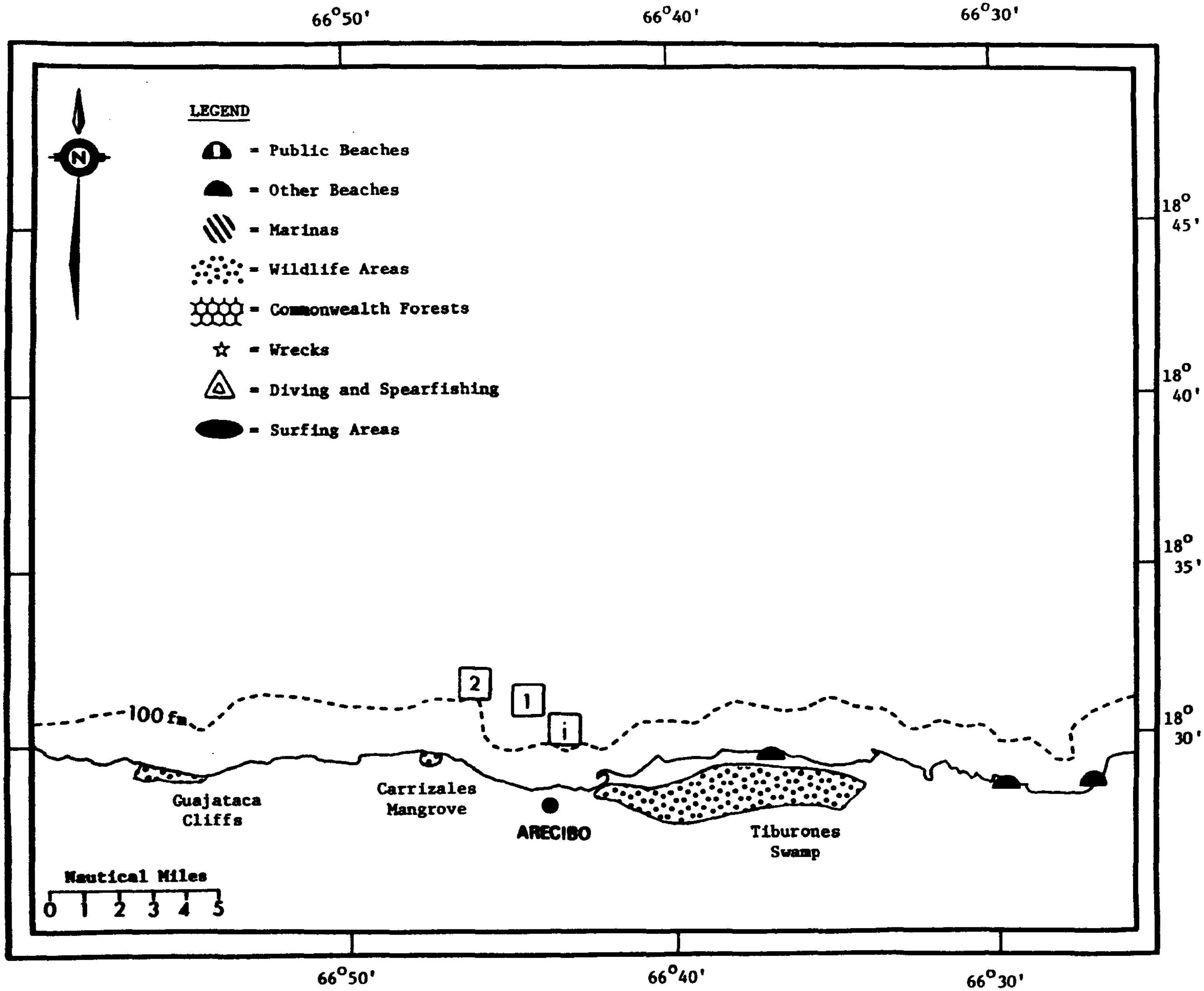


FIGURE 3-13. RECREATIONAL AREAS, PRESERVES AND SHIPWRECKS NEAR ARECIBO

Hawkbill sea turtles (Eretmochelys imbricata), green turtles (Chelonia mydas), leather back turtles (Dermochelys coriacea), and loggerheads (Caretta caretta) forage in the mangroves and seagrass beds of the Puerto Rican coast and nest along the beaches. It has not been reported whether sea turtles forage in the mangrove areas or nest on the beaches near Arecibo.

The brown pelican historically nested on Enrique Key and Turrumote Key. They often live in mangrove habitats and only rarely move offshore. It has not been reported to what extent brown pelicans inhabit shoreline areas adjacent to the Arecibo study area.

A list of threatened or endangered species identified in the Arecibo study are is presented in Table 3-6.

3.1.5 Recreational Areas

With the exception of some important game-fish fishing areas, which will be discussed in Section 3.1.9, few recreational areas exist within a 15-mile radius of Arecibo. There are three swimming beaches to the east of Arecibo, with the closest approximately 8 miles from the harbor (see Figure 3-13). Although there is large surf along much of the north coast, recreational surfing on this coast is limited primarily to areas beginning 40 miles to the east of Arecibo, near San Juan. In general, most recreational establishments for scuba diving, snorkeling, and sailing on the north coast are located near the prime tourist area of San Juan. According to the Puerto Rico Coastal Management Plan (DOC 1978), no marinas are located along the Arecibo coastline.

3.1.6 Shipping Lanes

Between 1979 and 1981, the Seventh Coast Guard District evaluated the need to establish formal shipping lanes for Puerto Rico. Their report (46 FR 48376, October 1, 1981) concluded that in some areas vessel traffic had been divided naturally into directional lanes according to prevailing currents. In other areas, traffic density and use conflicts did not warrant the designation of specific lanes. Therefore, there are no formal shipping lanes off Arecibo or other areas of Puerto Rico.

3.1.7 Mineral Resources

Although some seismic exploration for oil and gas has been conducted along the north coast of Puerto Rico, including the Arecibo ZSF, no oil or gas deposits have been identified within the ZSF or at the sites under consideration (PR Geological Survey 1983).

Quartz (siliceous) sands are in demand in Puerto Rico as constituents of concrete. Calcareous sands (from coral, limestone, and shell fragments) are used in plasters. The supplies of quartz sands in the islands are limited. Most mineable sand dunes have been mined out, and mining of the beaches is prohibited. As a result of these shortages, the USGS performed a survey to locate offshore sand resources. The survey located sources sufficient to meet the needs of the island (USGS 1983).

There are known deposits of magnetite sands south of the ZSF. No data were currently found describing the northward extent of these sands. Thus, it is possible that the deposits may extend into the sourthern part of the ZSF near the mouth of the Rio Grande de Arecibo closest to the interim site. There has been interest in using offshore quartz sand deposits to alleviate shortages, but mining of these sands is not presently considered to be economically feasible, even though the sands may contain up to 25 percent magnetite (PR Geological Survey 1983; Guillou and Glass 1957). No quartz deposits have been identified at any site in the Arecibo ZSF.

3.1.8 Shipwrecks or Other Features of Historical or Cultural Importance

No shipwrecks have been identified in the Arecibo study area (University of Puerto Rico 1974). No other features of historical or cultural importance have been identified in the study area.

3.1.9 Fisheries of the Arecibo Area

The bulk of the Puerto Rican commercial fishing fleet consists of small boats fishing for reef-associated species on the islandic shelf (see Section 3.0.4). The north coast is generally the least active fishing area in Puerto Rico, because heavy seas and relatively high winds make small-boat fishing on this coastline impractical on many occasions. Also, corals are poorly developed on this coastline (see Section 3.0.2). Beach seining is a common fishing method used along the northern shore (particularly in the area shown as a "commercial fishing area" in Figure 3-12). On occasions when "blue-water" (clear water, typical of offshore conditions) occurs within about 3 miles of the coastline, sport fishing boats search for marlin and other large game fish (CODREMAR* 1983; Bird 1960). Therefore, there is some sport fishing within the ZSF and near the interim and alternate sites at various times throughout the year.

3.2 CHARACTERIZATION OF THE AFFECTED ENVIRONMENT FOR MAYAGUEZ

3.2.1 Oceanographic and Climatological Characteristics

3.2.1.1 Bathymetry

The width of the shelf along the west coast of Puerto Rico is quite variable (as seen in Figures 3-14 and 1-2). The shelf extends approximately 16 km from the shoreline south of Mayaguez, but narrows to approximately 5 km directly north of the harbor. It narrows gradually to about 2 km width at Punta Cadena, about 10 nmi to the north, and then remains about 1 to 2 km wide as far as Punta Higuero, 16 km north of Mayaguez. The zone of siting feasibility (Figure 2-6) is thus bordered by shallow waters to the south and by land on the north, where the coastline turns in an east-west direction out to Punta Higuero. To the northwest, the bottom slopes at a 2° gradient to a maximum depth to the west of 850 m; and then becomes more shallow as it approaches Isla Desecheo, about 25 km from site 2.

3.2.1.2 Climatology

As in most of Puerto Rico, there are only small seasonal and diurnal variations in the climate near Mayaguez. Because hurricanes typically travel

*Corporation for the Development of Fluvial, Lacustrine, and Marine Resources, Commonwealth of Puerto Rico, Department of Natural Resources.

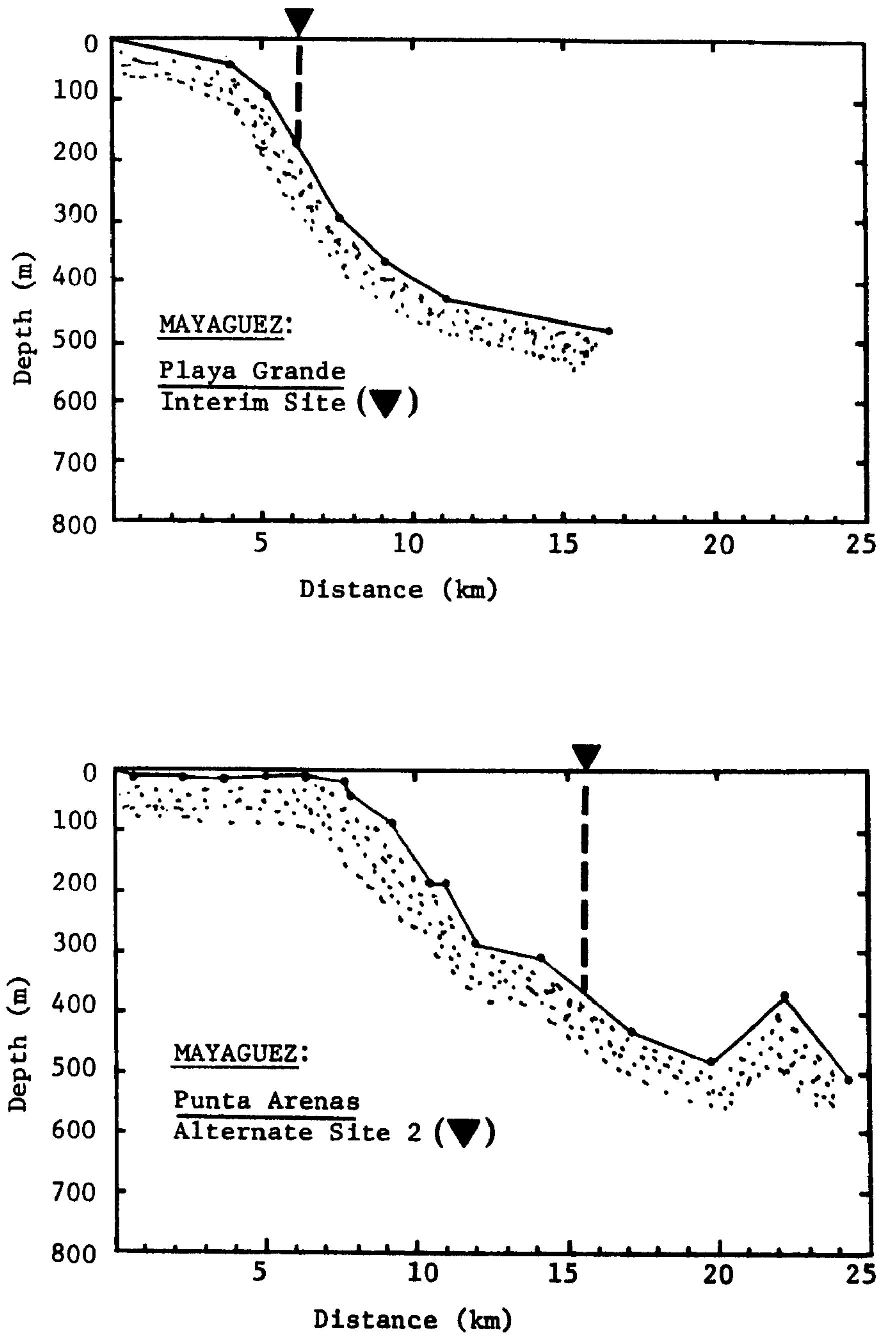


FIGURE 3-14. BATHYMETRIC PROFILES OFFSHORE FROM PLAYA GRANDE AND PUNTA ARENAS

from east to west over Puerto Rico, the number of severe storms is less on the west coast than at eastern locations such as Yabucoa. Wind data from Ramey Field (32 km north of Mayaguez) for the period 1940-1953 show surface winds predominantly from the east or northeast, with an annual hourly maximum velocity of 7.0 m/s and an annual hourly minimum of 3.3 m/s (Puerto Rico Water Resources Authority, 1959). Near Mayaguez, however, the sea breeze can be opposite to the easterly trade winds, frequently becoming dominant and resulting in on-shore westerly winds (Puerto Rico DPW 1974).

3.2.1.3 Hydrography

Temperature data were gathered from six deep-water sites at Punta Higuero (Wood et al. 1975a), 22 km (12 nmi) north of Mayaguez (Figure 3-15). The maximum seasonal surface temperature variation is 2°C, and little seasonal change occurs below depths of 150 m. The thermocline in winter and spring is deeper than the summer and fall thermocline.

Salinity profiles from Punta Higuero show an increase in salinity from the surface to 150 m, and a slight decrease below 150 m (Figure 3-16). This pattern does not change seasonally. The highest surface salinity occurs in the spring due to dry season evaporation; wet season dilution causes minimum surface salinity in the fall. In the 50-100 m depth range, the salinity is a minimum in the winter, when storms cause this subsurface water to mix with the low salinity surface water, and increases steadily throughout the rest of the year. As mentioned earlier, no significant seasonal effects are observed below depths of 150 m.

The density profiles resulting from these temperature and salinity values for the Punta Higuero area are shown in Figure 3-17. The winter and spring profiles show a deeper pycnocline and a smaller density gradient than in summer and fall. The figure shows a mixed surface layer of approximately 100 meters and an average density gradient of 9×10^{-6}/m. In comparison, summer and fall are characterized by a mixed surface layer of 50 m and an average density gradient of 2×10^{-5}/m.

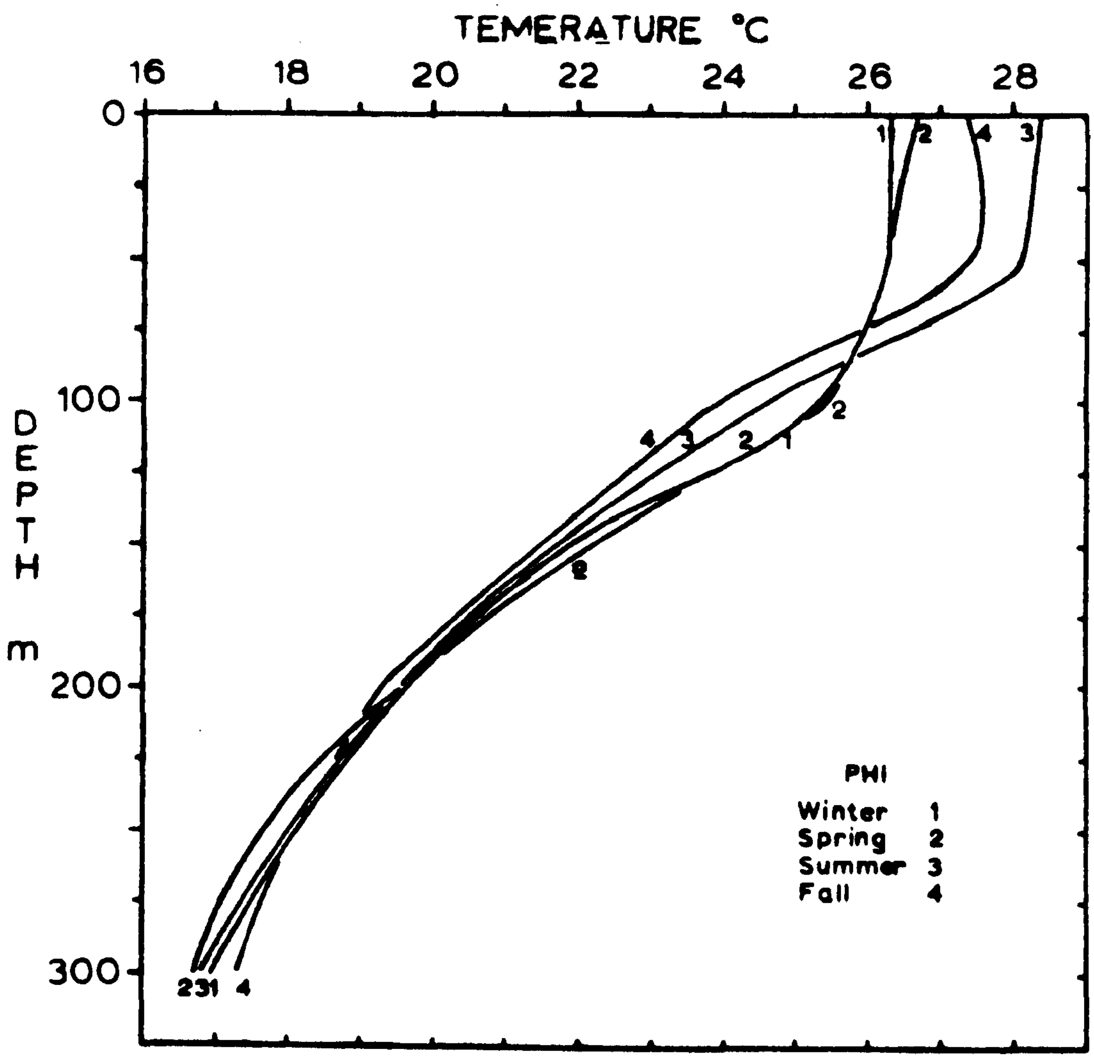


FIGURE 3-15. AVERAGED TEMPERATURE PROFILES, BY SEASON, OFF PUNTA HIGUERO, 1973 AND 1974

Source: Wood et al. 1975a.

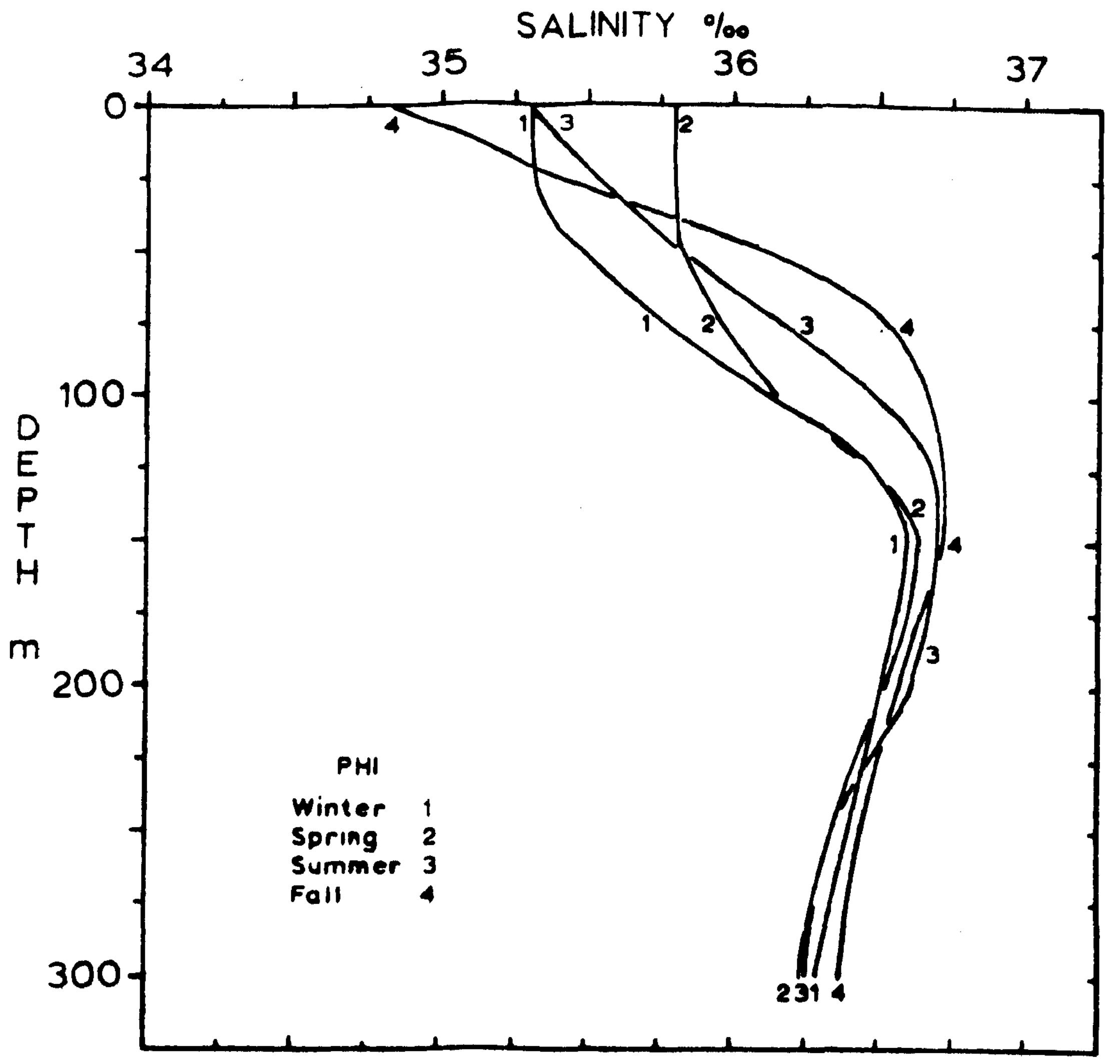


FIGURE 3-16. AVERAGED SALINITY PROFILES, BY SEASON, OFF PUNTA HIGUERO, 1973 AND 1974

Source: Wood et al. 1975a.

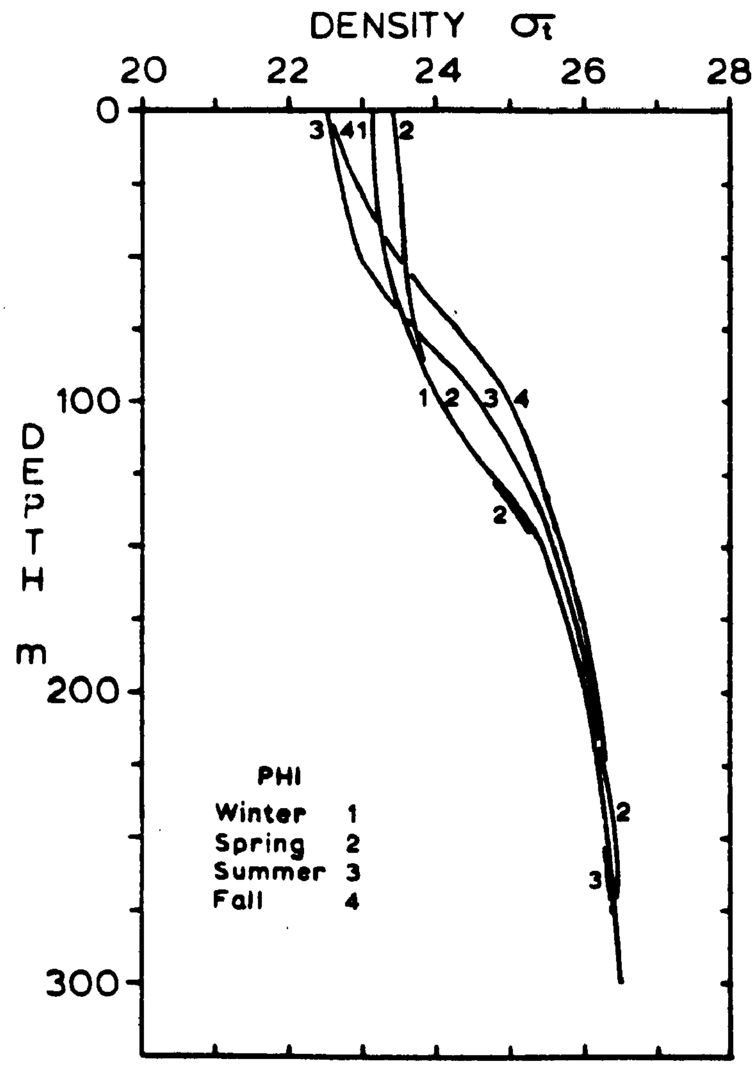


FIGURE 3-17. AVERAGED DENSITY PROFILES, BY SEASON, OFF PUNTA HIGUERO, 1973 AND 1974

Source: Wood et al. 1975a.

3.2.1.4 Circulation

Surface currents north and south of Puerto Rico generally travel toward the west due to the easterly trade winds. The current along the south coast turns northward through Mona Passage and is typically to the north off the west coast of the island. However, numerous eddies and reversals occur in the nearshore waters due to complex bottom topography, tides, wind fluctuations, and surface runoff (Wood et al. 1975a).

Surface currents in the Mayaguez study area tend to flow northward at flood tide and southward at ebb tide. Figure 3-18 shows nearshore surface current data near Mayaguez and Punta Ostiones (Puerto Rico DPW 1974) and near Punta Higuero (Wood et al. 1975a). The surface-current data at both sites show seasonal differences in current direction, with flow always roughly parallel to the shore. Net surface current speeds at Punta Higuero are approximately 30 cm/sec; data near Mayaguez showed net velocities of about 15 cm/sec. Subsurface and near-bottom current measurements at nearshore locations monitored for the Punta Ostiones study were generally parallel to the shore at about 15 cm/s. Other subsurface current measurements are shown in Figure 3-19. Directions were south or southeastward, at speeds of about 15 cm/sec.

3.2.2 <u>Geologic and Geochemical Characteristics</u>

The interim and alternate sites at Mayaguez all contain areas of soft bottom composed of fine-grained sediments. The following sections describe the surficial geology, the bottom types, grain size distributions, and geochemical characteristics of sites in the Mayaguez.

3.2.2.1 Surficial Geology

The basement rock underlying most of the Mayaguez ZSF is limestone, with numerous geologic faults (Morelock et al. 1983; Briggs and Akers 1965). Overlying the limestone in most areas of the ZSF is a thick blanket of sediments. Seismic profiles indicate sediment thicknesses of 100 to 200 meters (Morelock et al. 1983).

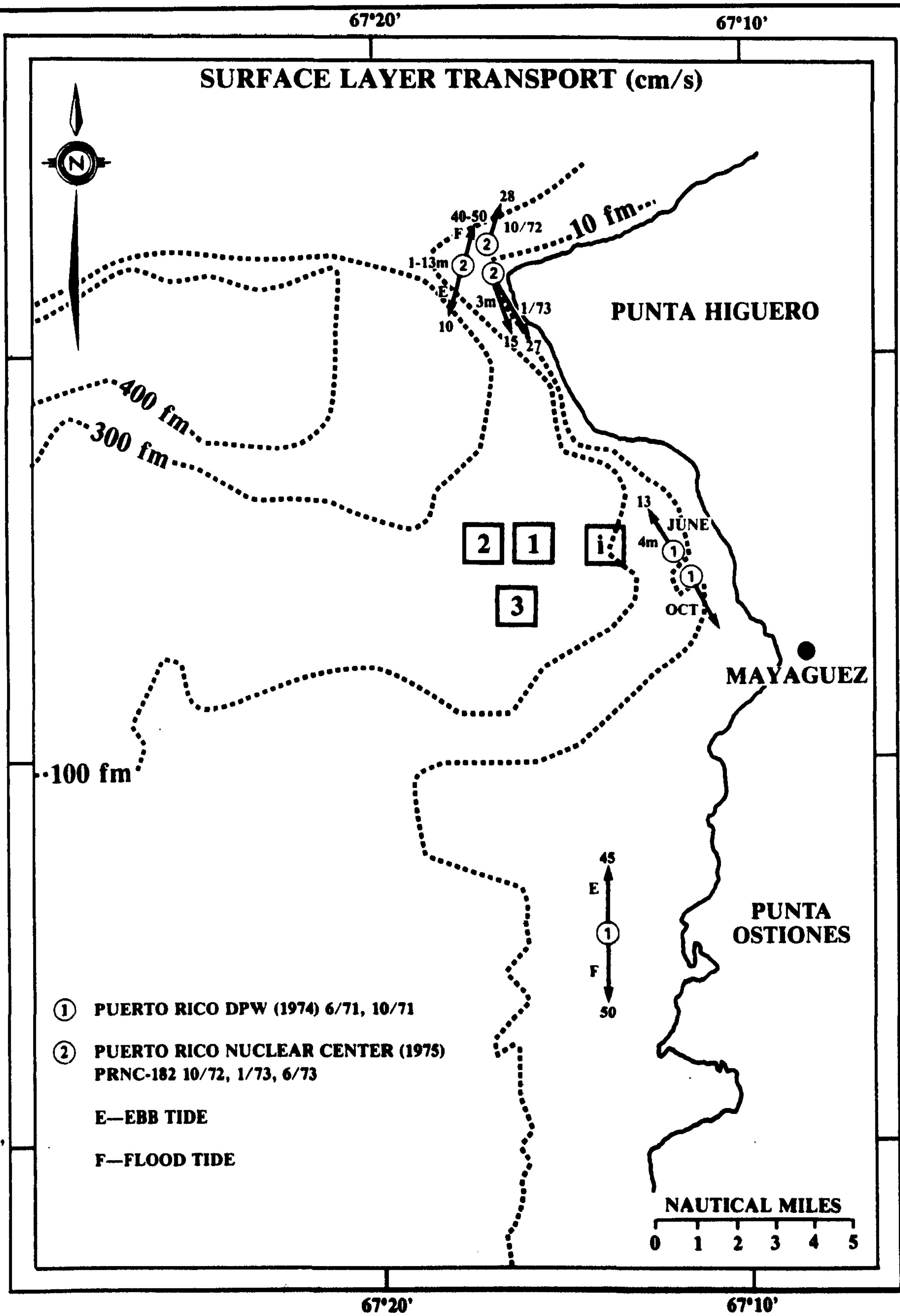


FIGURE 3-18. SURFACE LAYER TRANSPORT, MAYAGUEZ STUDY AREA

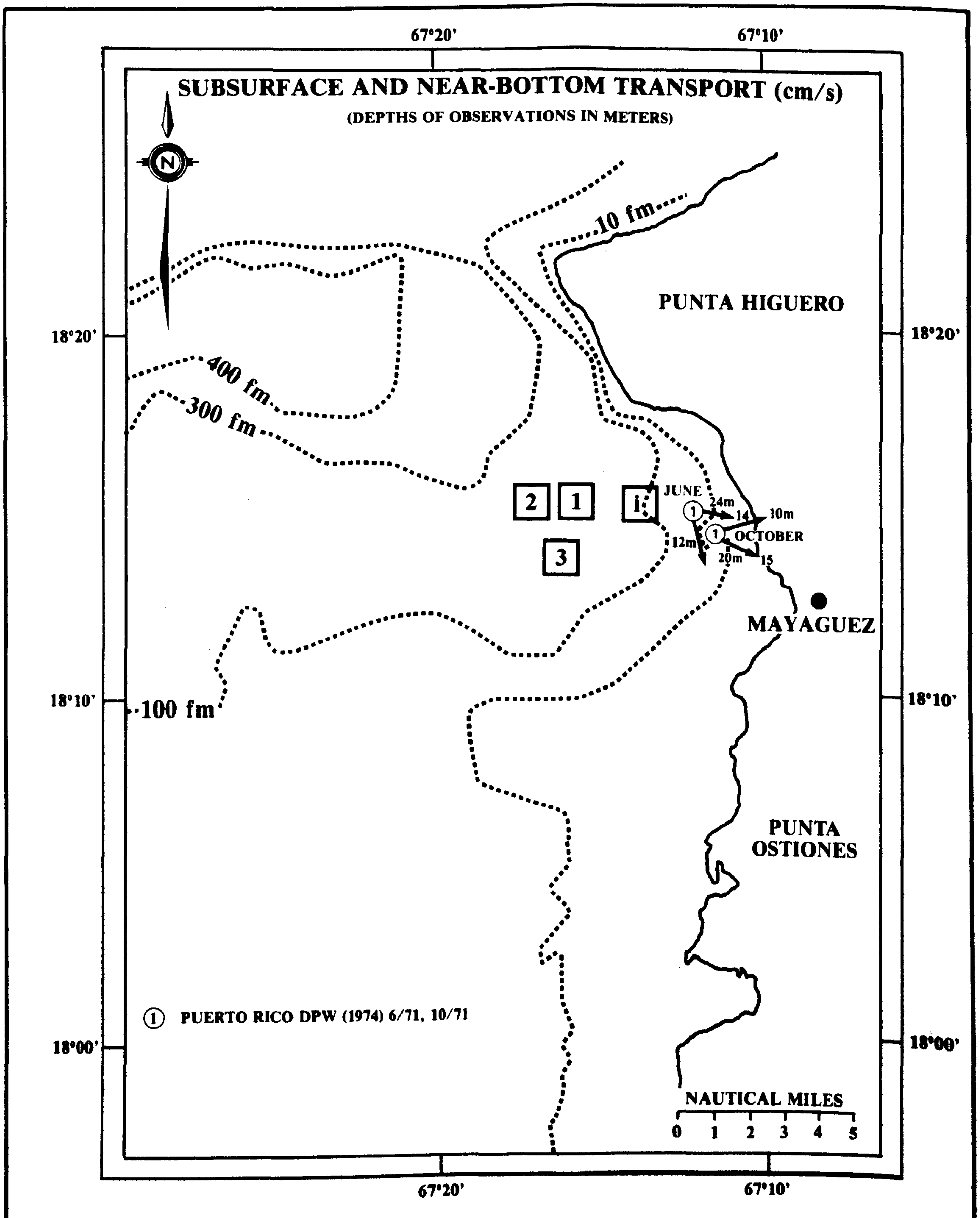


FIGURE 3-19. SUBSURFACE AND NEAR-BOTTOM TRANSPORT, MAYAGUEZ STUDY AREA

Much of the area is covered by sediments of terrestrial rather than marine origin. Three major rivers discharge sediments into the ZSF. The largest river, the Añasco River, drains an area covering about 340 square kilometers. Five major floods from this river have occurred since 1889. During these major floods and the smaller annual floods, large quantities of sediments are moved from the estuaries into Añasco Bay, in the eastern part of the ZSF. Two smaller rivers (Yaguez River, which flows through Mayaguez, and the Guanajibo River to the south) also contribute sediments to the western coast, but in far smaller volume than the Añasco (Morelock et al. 1983).

3.2.2.2 Sea Floor Characteristics and Sediment Textures

Acoustic surveys during the 1984 survey cruise indicated several areas of hard bottom within the ZSF (Figure 3-20). Preliminary acoustic data indicated that 10 of the 22 stations occupied by the ship in the ZSF were hard bottom locations. These data do not preclude the possibility of thin (less than 10 cm) layers of soft sediments overlaying the hard substrate. In areas along the western coast where sediment inputs are relatively high, most of the bottom is likely to be covered with redistributed sediments. Even so, hard bottoms can occur on topographic highs and in areas having high current energies. The presence of hard substrate is not surprising because sediment-covered or partially sediment-covered patch reefs are common in this part of the western coast, and wave refractions and current patterns along this coast are complex (Morelock et al. 1983), which could result in scouring bottom currents. These factors could account for the absence of a thick sediment cover over old reefs or bedrock outcrops in parts of the ZSF.

Samples taken from the alternate sites indicated soft bottom conditions; however, one sample on the eastern part of the interim site indicated a hard bottom.

The 22 sediment samples collected in the Mayaguez ZSF were predominantly silt. The samples contained an average of 76 percent silt, 40 percent clay, and 13 percent sand. Sediments collected at the various sites were as follows:

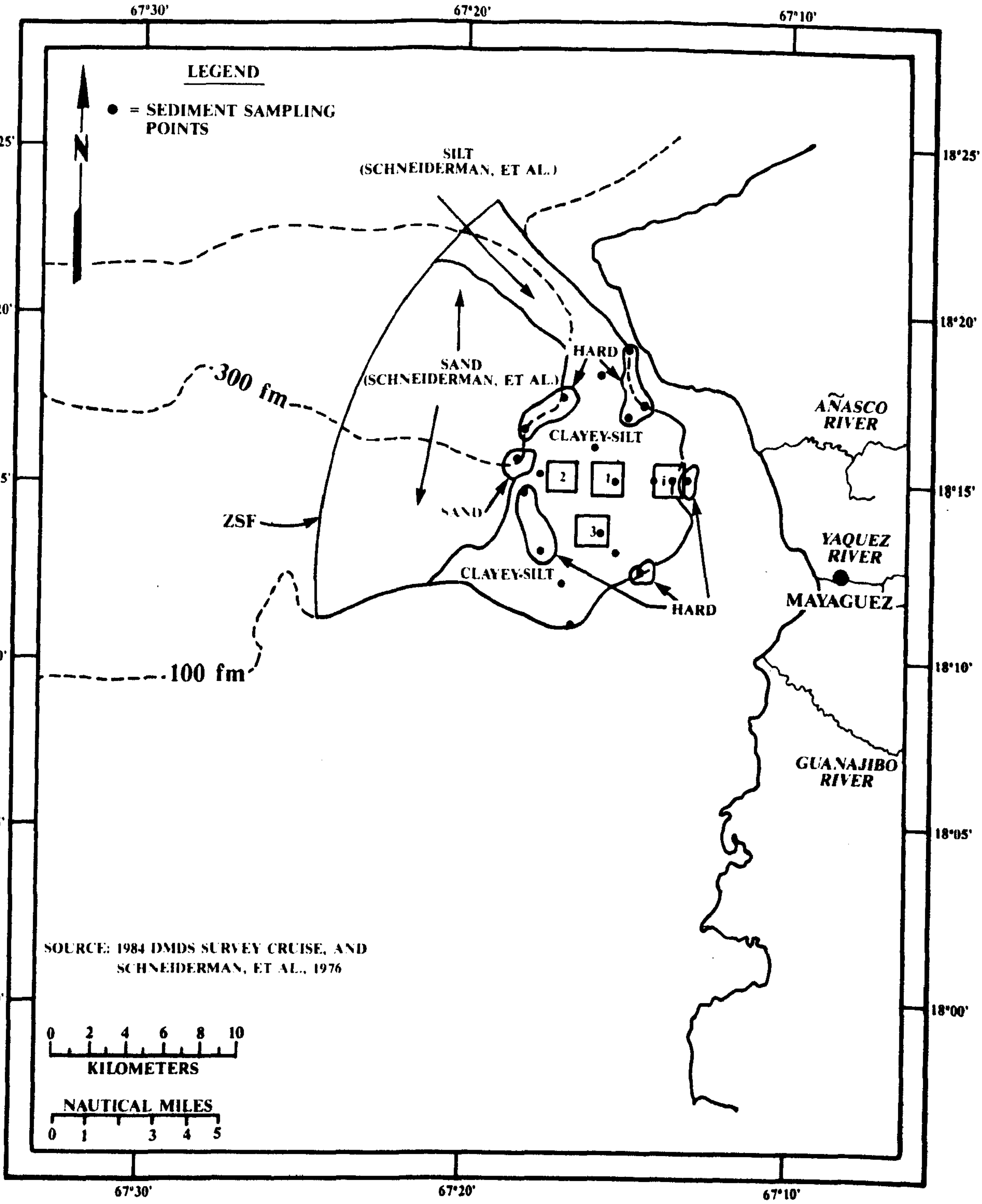


FIGURE 3-20. SEDIMENT SAMPLING POINTS AND IDENTIFIED SEA-FLOOR SEDIMENTS IN MAYAGUEZ ZSF

Interim Site - The sediments at the interim site are fine-grained mixtures of silts and clays. They range in composition from 5 to 26 percent sand, 58 to 61 percent silt, and 17 to 36 percent clay. On the eastern part of the interim site, one sample test indicated a hard bottom. Depths range from 43 to 143 fathoms.

Alternate Site 1 - The sediments are silty clays with more than 60 percent silt, more than 25 percent clay, and 5 percent or less sand. The depth in the center of the site is 180 fathoms and the bottom slopes westward.

Alternate Site 2 - The sediments are silty clays very similar in composition to those from alternate site 1. The depth is about 23 fathoms in the center of the site, and the bottom slopes to the northwest.

Alternate Site 3 - The fine-grained sediments at this site consist of 10 percent or less sand, about 70 percent silt, and 20 percent clay. The depth ranges from over 150 fathoms to over 180 fathoms, and the bottom slopes to the northwest.

3.2.2.3 Sediment Mineralogy

Sediments of terrestrial origin in the ZSF come from weathered volcanic and metamorphic rocks that have been transported via rivers into coastal waters (Meyerhoff 1932; Morelock et al. 1983).

The sand fraction from Añasco River consists of quartz from andesitic and granitic intrusive rocks, along with associated resistant minerals such as feldspar. Other minerals from volcanic ash, tuff, pyroclastics, and conglomerates may also be present. Sands from the Yaguez River are dark, due to their volcanic derivation. They contain minor amounts of chromite derived from serpentine (Morelock et al. 1983; Schneidermann et al. 1976; Guillou and Glass 1957). About 97 percent of the sand fraction on the shelf off the Añasco Bay is of terrestrial origin; the remainder is carbonaceous skeletal material (Morelock et al. 1983).

The silt-sized particles are composed of very fine river sands and organic materials, derived primarily from terrestrial plants (Morelock et al. 1983).

The clays found in the Añasco River and Añasco Bay are kaolinite, montmorillonite, chlorite, and illite (Morelock et al. 1983). It is likely that smaller volumes of the similar clays are discharged from Yaguez River as well. Montmorillonite has a very high cation exchange capacity, a measure of a clay's ability to adsorb positively charged ions onto the electrochemically charged surfaces of the crystal structure (McCarthy 1977). The clay particles in the sediments can adsorb toxins from the water column. Because of this property, clays could contribute to the contaminant binding properties of sediments at various sites.

3.2.3 Water Quality

Surface waters throughout the Mayaguez study area are clear, warm, oxygen saturated and nutrient depleted. Below the surface mixed layer, oxygen remains undepleted, and nutrient levels become very high. In summary, water quality in the area of the interim and alternate sites is excellent, and is typical of tropical open-ocean conditions.

3.2.3.1 Turbidity

Secchi disc depth readings taken from shallow (<15 m) nearshore waters, less than 2 nm offshore near Mayaguez, ranged from 6-29 m (Puerto Rico Department of Public Works 1974). The lower values, indicating turbid water, were taken at sites closest to shore; the higher values, indicating greater clarity, were found further from shore. Based on these measurements, it appears that the waters in the ZSF are optically clear and contain little suspended material (EPA 1981).

3.2.3.2 Dissolved Oxygen

Dissolved oxygen concentrations are consistently at or near saturation levels in the surface waters (Wood et al. 1975a; Puerto Rico Nuclear Center 1974). Figure 3-21 presents the average dissolved oxygen depth profiles by

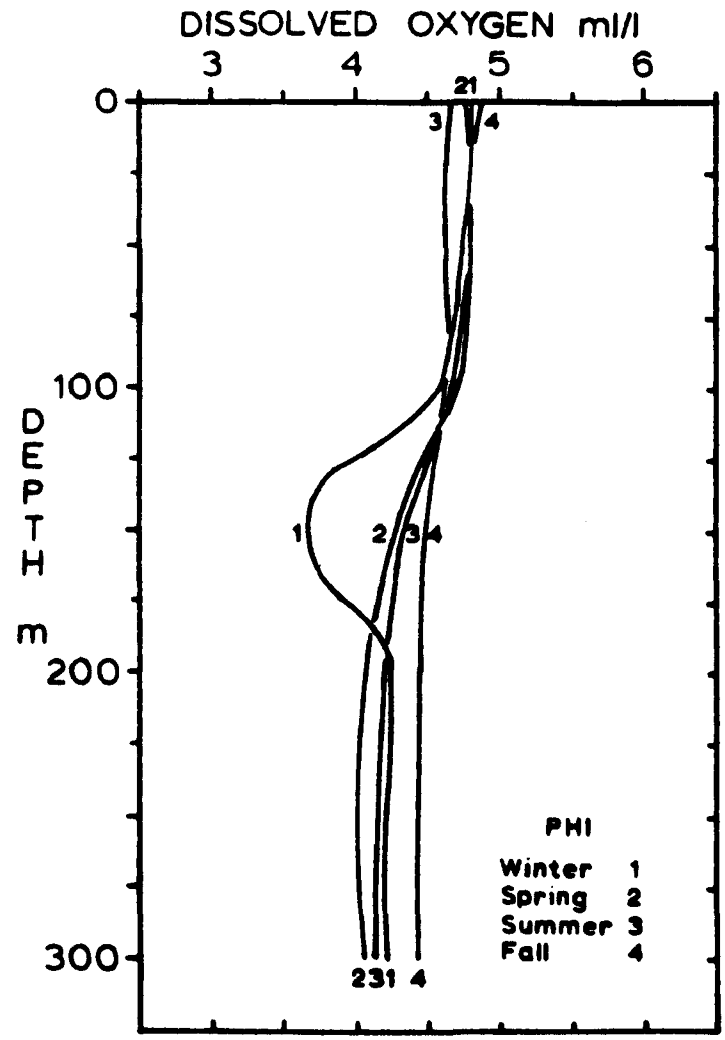


FIGURE 3-21. AVERAGED DISSOLVED OXYGEN DEPTH PROFILES, BY SEASON, AT PUNTA HIGUERO, 1973 AND 1974

Source: Wood et al. 1975a.

season at Punta Higuero, approximately 9 miles north of Mayaguez, for 1973 and 1974. Little change in surface dissolved oxygen concentration by season can be observed. Oxygen levels decrease slightly with depth, but remain high (on the order of 4.0-4.5 ml/l). Some supersaturation was measured at depths of 25-75 m, apparently as a result of increased photosynthesis. The greatest dissolved oxygen values (4.7-5.0 ml/l) were measured at approximately 100 m. Minimum dissolved oxygen concentrations were measured at around 250 m for all seasons except winter, when minima were recorded at around 150 m. With the exception of the winter minimum, there was very little seasonal change in surface or deeper water dissolved oxygen concentrations.

3.2.3.3 Nutrients

Nutrient levels in surface waters exhibit little seasonality, reflecting the relatively stable marine conditions associated with Puerto Rico's tropical climate. Surface waters are typically low in nutrients (phosphate, nitrate, and silicate), but concentrations increase with depth below the pycnocline.

Seasonal concentrations of reactive phosphate measured near Punta Higuero are presented in Figure 3-22 (Wood et al. 1975a). Surface water concentrations are typically low (0.05 ug-at P/l) throughout the year. Slightly higher values were measured during the spring season (surface water 0.11 ug-at P/l), with concentrations up to 0.13 ug-at P/l at 50 m. Phosphate values are generally constant throughout the upper mixed layer and through the pycnocline to about 100 m. The phosphate concentration steadily increased with depth below 100 m. Peak values at the deepest point sampled occurred in the spring (0.57 ug-at P/l) and were lowest in the fall (0.37 ug-at P/l).

Summer and fall concentrations of nitrate measured near Punta Higuero are presented in Figure 3-23. The nitrate concentration was less than 1 ug-at N/l from the surface down to 75 m in the summer and 35 m in the fall. Nitrate values were greater in the fall (between 50 and 150 m) than in the summer. Little seasonal difference was found below 150 m. The concentrations of nitrate increased with depth, ranging from 2 ug-at N/l at 100 m to greater than 13 ug-at N/l at 300 m.

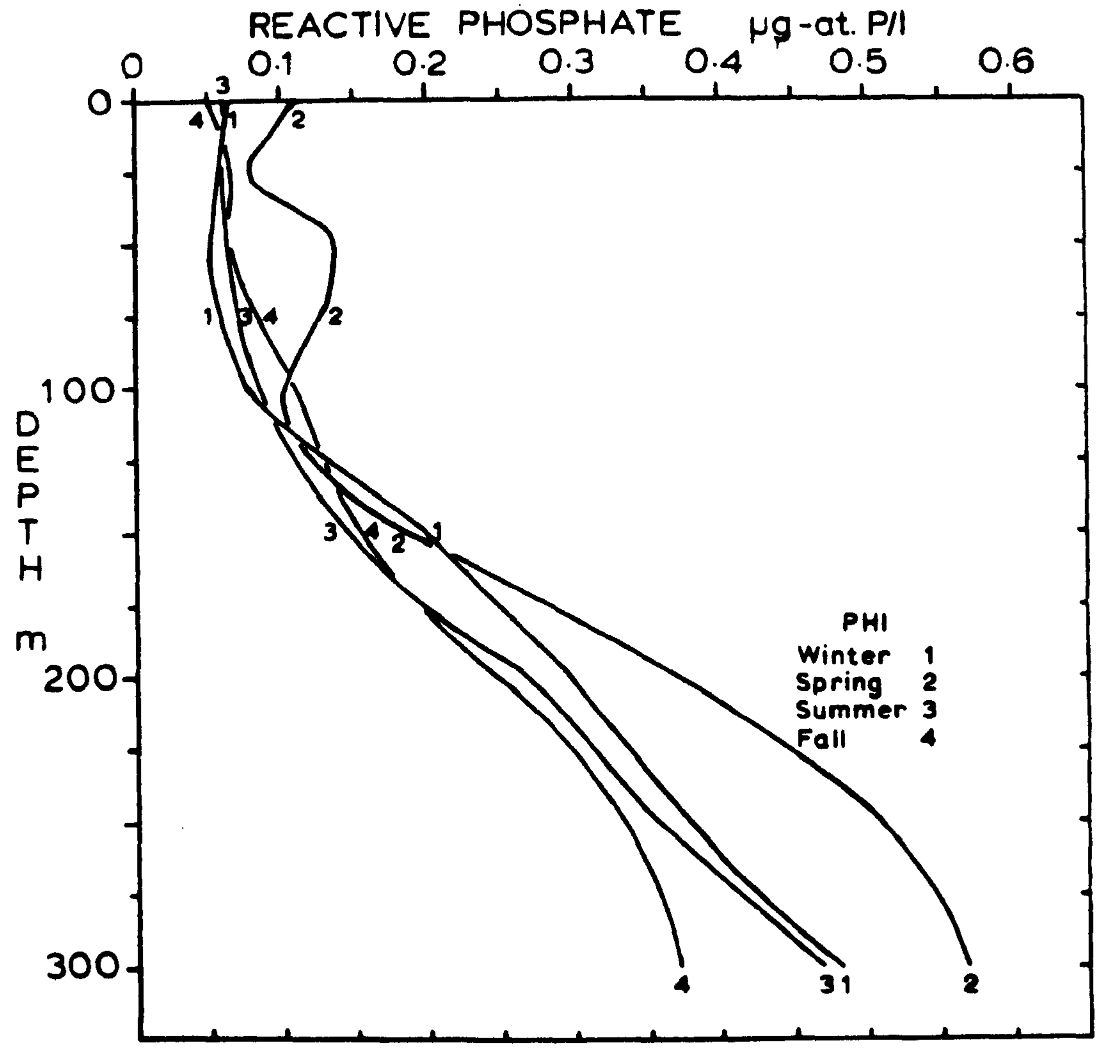


FIGURE 3-22. AVERAGED REACTIVE PHOSPHATE DEPTH PROFILES, BY SEASON, AT PUNTA HIGUERO, 1973 AND 1974

Source: Wood et al. 1975a.

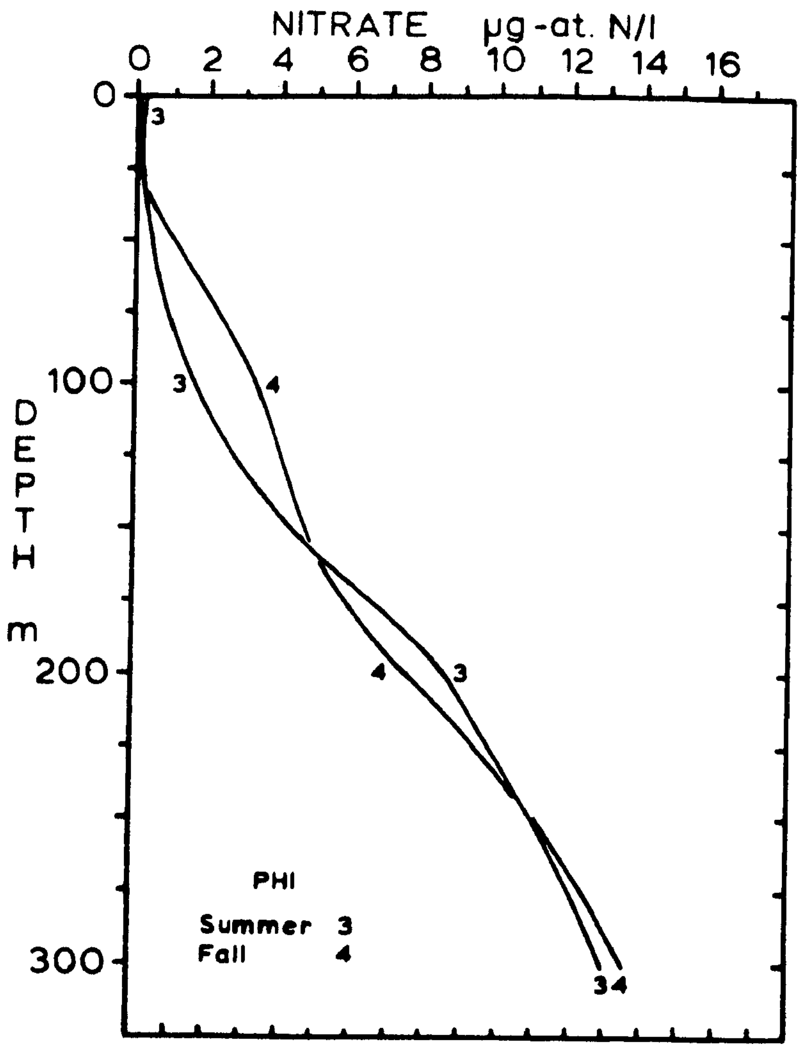


FIGURE 3-23. NITRATE DEPTH PROFILE FOR THE SUMMER AND FALL SEASONS AT PUNTA HIGUERO, 1974

Source: Wood et al. 1975a.

Studies conducted in nearshore waters off Mayaguez measured silica concentrations ranging from 0 to 0.33 mg/1 in surface waters (Puerto Rico Department of Public Works 1974). No data on subsurface silica concentrations were available for this area.

3.2.4 Biota

Species identified in the Mayaguez study area are included in the species list presented in Table 3-5.

3.2.4.1 Benthic Invertebrates

Information presented here is based on analyses of the biological sampling conducted on EPA's 1984 survey cruise in Puerto Rico (JRB Associates).

The hard-bottom communities, as observed in bottom photographs, were sparse, consisting of sponges, gorgonians and unidentified encrusting organisms. These communities appeared to be limited in distribution by generally high levels of fine-sediment cover.

The soft-bottom community in the Mayagüez region was dominated by polychates (174 taxa), followed by crustaceans (71 taxa), molluscs (51 taxa, primarily gastropods and pelecypods), 14 minor taxa (primarily sipunculids) and echinoderms (10 taxa). The majority of the 320 total taxa were deposit feeders, typical of fine-grained sedimentary environments generally occurring at the Mayaguez site. The mean number of taxa per sample (station and replicate) was relatively high (50). The number of individuals per sample for each taxon was relatively low, the majority occurring in densities of only one to five individuals per 0.065 m^2. The species having the highest densities were the polychaetes Levinsenia uncinata, Melinna sp. Euchone sp. D and prionospio sp. F; the pelecypod Nuculana sp. F; and the sipunculid Golfingia tricocephalad.

The soft-bottom community was dominated by deposit feeding organisms (primarily polychaetes) typical of the fine-grained sediments occurring at the site. The number of taxa and number of individuals per sample were quite variable, as indicated by the variability of diversity values among the different samples. The types of taxa were relatively different among samples, suggesting a patchy distibution of many organisms. Two station groups were observed based on the results of cluster analysis (Table 3-2); however, the groups did not correspond to any obvious trends in sediment grain size distribution and were not indicative of any influence from past dredged material disposal at the Ponce DMDS.

3.2.4.2 Coral Reefs

Coral reefs are well-developed along the middle and southern portions of Puerto Rico's west coast (Almy and Carrion Torres 1963). None of the alternate sites are directly over any of the major reefs known to exist in the Mayaguez study area (see Figure 3-24). The alternate sites were selected to exclude all hard-bottom areas that were tentatively identified in other parts of the ZSF by acoustic measurements during the 1984 survey cruise. However, the eastern half of the interim site is adjacent to the most seaward of the three major coral reefs off Mayaguez (Figure 3-24).

3.2.4.3 Mangrove Breeding and Nursery Areas

Commercially or recreationally important species of marine fish, such as ladyfish, pompano, mullet, and mojarra, use the mangrove estuaries in the Mayaguez study area as nursery grounds (Austin 1971). The mangrove environment, while inhospitable to many adult fish, is suitable for the development of juveniles (Austin 1971). The west coast, and the Mayaguez area in particular, have many rivers and streams and a large volume of freshwater drainage to the sea because of heavy rainfall in the adjacent mountains. Many of these drainages form deep brackish-water estuaries bordered by mangroves. An important mangrove habitat is located 4.5 half miles south of Mayaguez (Figure 3-24) where the Guanajibo River flows into Mayaguez Bay. A second mangrove habitat, Joyuda Lagoon, is located about 5 miles south of the harbor. The mouth of the Añasco River, 4 miles north of Mayaguez, also has limited mangrove growth.

	TTAXA	SCNT	SHNWVR	PIELOU
GRAVEL	-0.10641	-0.09862	-0.05493	-0.02387
	0.6646	0.6879	0.8233	0.9227
	19	19	19	19
SAND	0.07749	-0.07734	-0.07158	-0.14833
	0.7525	0.7530	0.7709	0.5445
	19	19	19	19
SILT	0.13186	0.23651	0.24607	0.29366
	0.5905	0.3296	0.3099	0.2224
	19	19	19	19
CLAY	-0.25035	-0.13417	-0.15382	-0.08749
	0.2836	0.5839	0.5295	0.7217
	19	19	19	19
FINES	-0.07654	0.07804	0.07193	0.14835
	0.7555	0.7508	0.7698	0.5444
	19	19	19	19
DPFT	-0.35236	-0.45368	-0.50116	-0.55726
	0.1390	0.0511	0.0288	0.0132
	19	19	19	19

Table 3-2 Correlation Matrix for Sediment Grain Size, Biological Parameters and Station Depth from the March, 1984 EPA/JRB Survey Offshore of Mayaguez, Puerto Rico. (Correlation coefficients are listed first with significance levels listed second and the number of comparisons third). TTAXA = total number of taxa, SCNT = total number of individuals of all taxa, SHNWVR = Shannon - Weaver Diversity Index, PIELOU = Pielou's Eveness Index.

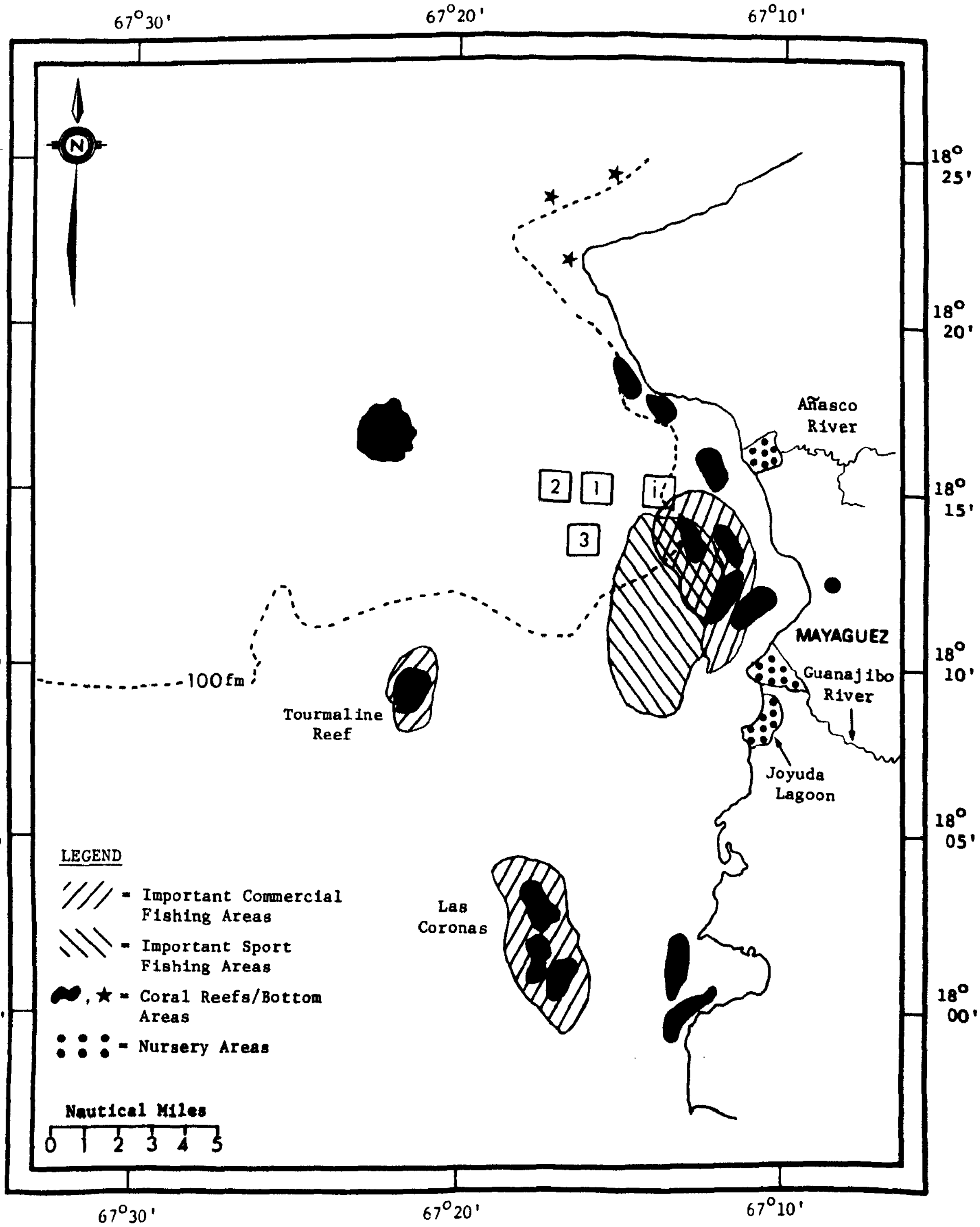


FIGURE 3-24. LIVING MARINE RESOURCES NEAR MAYAGUEZ

3.2.4.4 Preserves and Reserves

Critical Wildlife Habitats along the Mayaguez coast include the Sabanetas Swamp, about 5 nmi north, and Pta. Guanajibo, about 4 nmi southwest of the Port (Figure 3-25).

Other areas designated as special planning areas by the Puerto Rico Office of Coastal Zone Management (U.S. DOC 1978) include the Tourmaline Reefs Reserve, about 11 nmi southwest of the port areas, and the Joyuda Mangrove Reserve, about 5 miles southward along the coast (see Figure 3-24).

3.2.4.5 Threatened and Endangered Species

Threatened and endangered marine species in Puerto Rico include several species of sea turtle and the brown pelican (see species list in Section 3.1.4.4). The Cabo Rojo region, about 7 to 15 miles south of Mayaguez, is an important sea turtle habitat and nesting area.

No data were obtained on the frequency of occurrence or population density of brown pelicans near Mayaguez. Boqueron State Forest, 13 to 14 miles south of Mayaguez, supports large numbers of pelicans (U.S. DOC 1978).

A list of threatened and endangered species identified in the Mayaguez study area is presented in Table 3-6.

3.2.5 <u>Recreational Areas</u>

The recreational areas within a 15-mile radius of Mayaguez include several heavily used bathing beaches (Puerto Rico Tourism Company 1983) and one publicly maintained beach at Añasco, due east of the interim site (Figure 3-25).

Other popular swimming areas are located at Playa Grande, approximately 2 nmi east of the interim site and a little further north, near Rincon. Popular Rincon area beaches such as Punta Higuero are 5 to 6 nmi north of the interim and alternate sites. Punta Higuero, 2 miles north of Rincon, is especially popular for surfing.

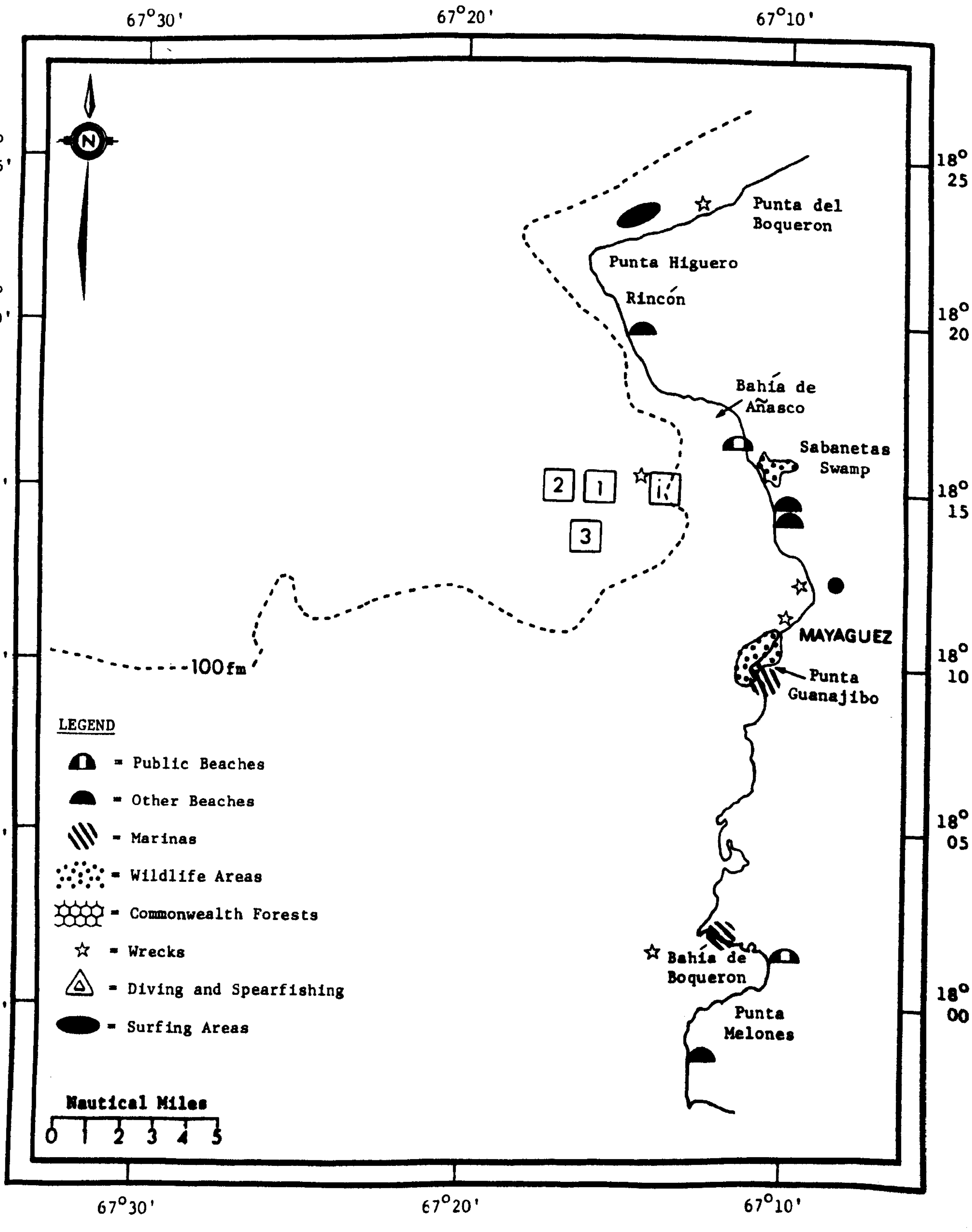


FIGURE 3-25. RECREATIONAL AREAS, PRESERVES AND SHIPWRECKS NEAR MAYAGUEZ

The large number of coral reefs inshore and south of the interim site are likely recreational sites for scuba, snorkeling, and recreational fishing. No information was found to indicate how frequently these sites are used.

3.2.6 Shipping Lanes

There are no formally established shipping lanes for Puerto Rican ports and harbors. A two-year study conducted by the Seventh Coast Guard District (46 FR 48376, October 1, 1981) determined that such lanes were not warranted by the movements of vessel traffic near the island.

3.2.7 Mineral Resources

Quartz sand and metallic mineral deposits occur in the offshore portions of the Mayaguez ZSF. A large quartz sand deposit occurs in the western half of the Mayaguez ZSF (Cox and Briggs 1973). There are no known oil and gas deposits or important concentrations of magnetite sands or mineral resources in the study area (Guillou and Glass 1957; Alonso 1983; Cox and Briggs 1973; Schneidermann et al. 1976). A salt-producing solar evaporator is located in southwestern Puerto Rico about 15 nmi south of Mayaguez (White and Tuchman 1982).

3.2.8 Shipwrecks or Other Features of Historical or Cultural Importance

One shipwreck is immediately adjacent to the Mayaguez interim site (Figure 3-25, University of Puerto Rico 1974). No wrecks have been identified at or near any of the Alternate Sites. No other features of historical or cultural importance have been identified in the Mayaguez ZSF.

3.2.9 Fisheries

A large part of the Puerto Rican commercial fishing fleet consists of small boats fishing for coral-reef associated species on the islandic shelf. The west coast is the most productive fishing region of the island, with 48 percent of the total landings between October 1982 and July 1983 (Caribbean Fishery Management Council 1984). Most of the west coast harvest is taken on the broad shelf area to the south of Mayaguez. The principal fishermen's cooperative organization for this area, in the municipality of Cabo Roja, is typically responsible for over 40 percent of Puerto Rico's total annual catch.

Four large reefs lying just offshore of Mayaguez are commonly used by local fishermen (Figure 3-24). The interim site is less than 1 nmi to the northwest of the most seaward of these reefs. Heavy fishing also occurs about 9 nmi southwest of Mayaguez, around the Tourmaline reef, and further south around the Las Coronas reefs.

3.3 CHARACTERIZATION OF THE AFFECTED ENVIRONMENT FOR PONCE

3.3.1 Oceanographic and Climatologic Characteristics

3.3.1.1 Bathymetry

Bottom topography in the central south coast of Puerto Rico off Ponce is characterized by a narrow shelf about 1 to 3 nmi wide (Figures 1-3 and 3-26a). Distinct submarine canyons extend to the south and southwest of Punta Verraco and Punta Guayanilla. East of the interim and alternate disposal sites, the shelf becomes very broad (4 to 10 nmi out to the 200-m isobath). Off the area of Punta Cabullon and Punta Pastillo (Figure 3-26b) the shelf is particularly shallow (<20 m) and relatively broad (6-7 nmi).

3.3.1.2 Climatology

The southern coast of Puerto Rico has a tropical-marine climate dominated by persistent easterly trade winds. Air temperature and wind patterns vary only slightly on a seasonal basis. Mean monthly air temperatures for Ponce range from 25°C (February) to 28°C (August). Infrequently, tropical storms or the remnants of a winter cold front interrupt the easterly trade winds. Wind records indicate average speeds of 4-6 m/sec from the east-southeast about 40 percent of the time (COE 1975).

3.3.1.3 Hydrography

The waters of the Caribbean Sea south of Puerto Rico are characterized by four distinct water masses: (1) Tropical Surface Water, (2) Subtropical Underwater, (3) Antarctic Intermediate Water, and (4) Venezuelan Bottom Water. Vertical temperature, salinity, and density profiles for the region are shown in Figures 3-27, 3-28, and 3-29, respectively. The upper water mass, Tropical

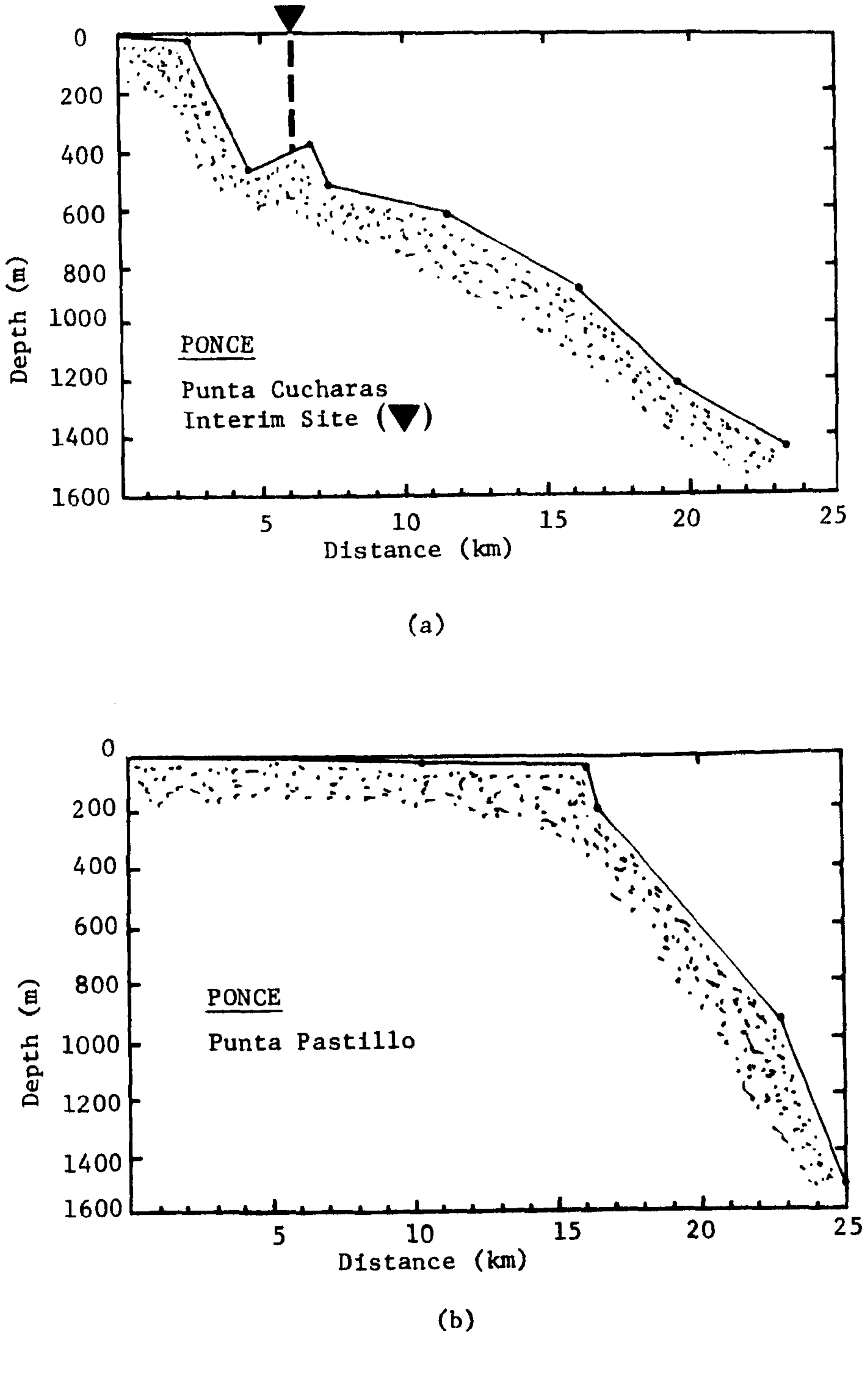


FIGURE 3-26. BATHEMETRIC PROFILES OFFSHORE FROM PUNTA CUCHARAS AND PUNTA PASTILLO

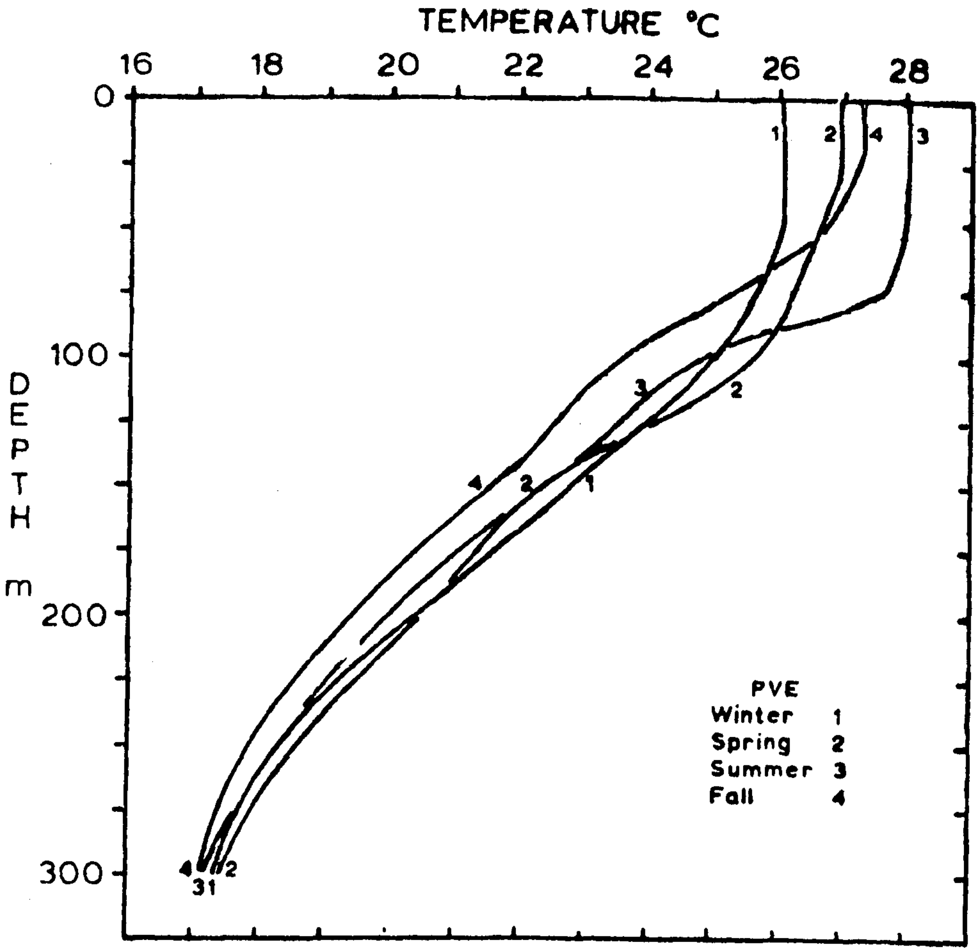


FIGURE 3-27. AVERAGED TEMPERATURE PROFILE, BY SEASON, OFF PUNTA VERRACO, 1973 AND 1974

Source: Wood et al. 1975f.

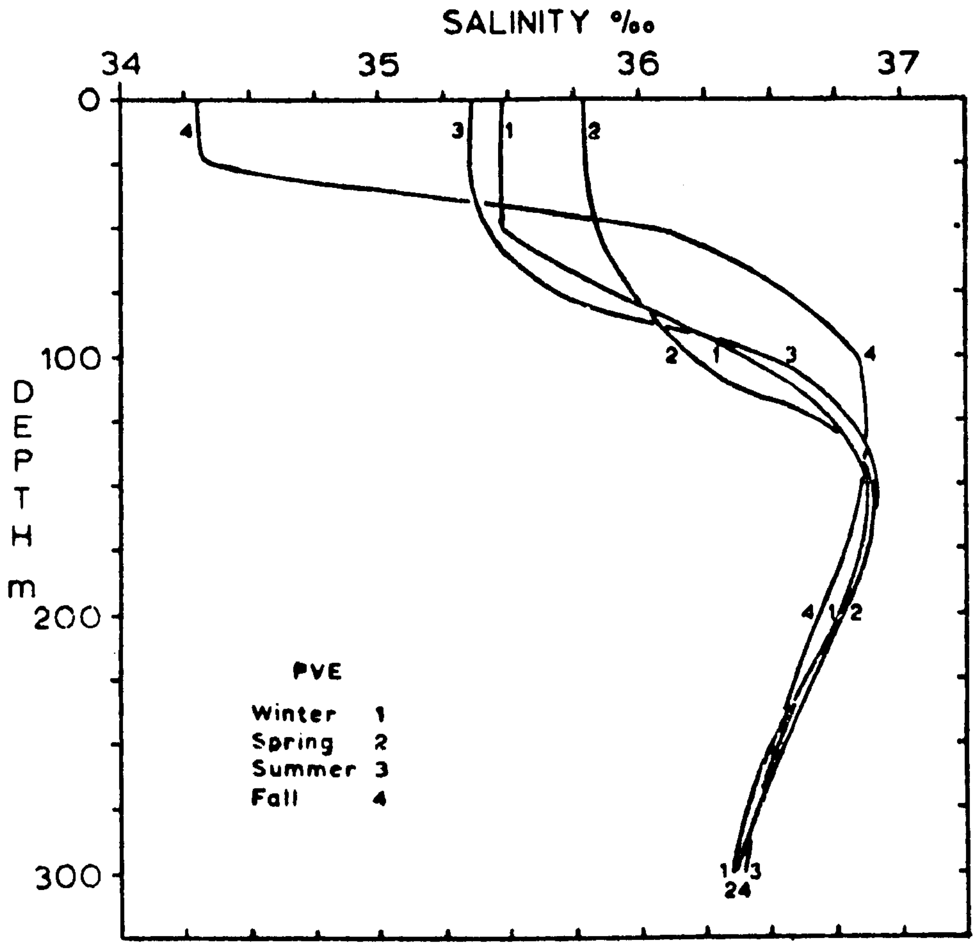


FIGURE 3-28. AVERAGED SALINITY PROFILE, BY SEASON, OFF PUNTA VERRACO, 1973 AND 1974

Source: Wood et al. 1975f.

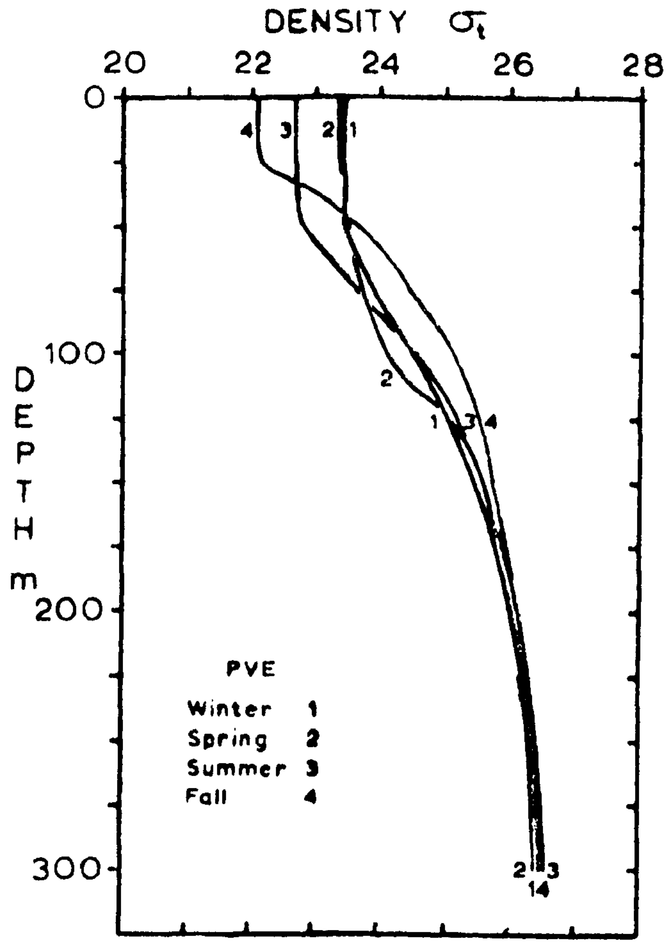


FIGURE 3-29. AVERAGED WATER DENSITY PROFILES, BY SEASON, OFF PUNTA VERRACO, 1973 AND 1974

Source: Wood et al. 1975f.

Surface Water (TSW), extends to a pycnocline at approximately 75 m. In this upper layer, temperatures range from 25 to 29°C and salinity from 33 to 36 $^{o}/oo$. The Subtropical Underwater (SUW) extends below the pycnocline from approximately 100 to 200 m, and is characterized by a relatively more saline, cooler layer (20-25°C, 36.8-37.2 $^{o}/oo$). Vertical mixing between the upper layer and the SUW layer below the pycnocline is sharply restricted as a result of the strong density gradients across that boundary resulting from the differences in temperature and salinity. Information on the depths of water mass boundaries in the Ponce area is given in more detail in Appendix F, Section 1. The information is not very complete for this area, as little direct current measurement has been done here. The data that are available have been incorporated into the model used to predict sediment transport patterns from the potential disposal sites, the results of which are presented in Chapter 4. The SUW layer is deeper (from 200 to 600 m) and gradually changes to cooler water (20-70°C), with salinity ranging from 35-36.8 $^{o}/oo$. Antarctic Intermediate Water (AIW) at 600-800 m is cold water (6-7°C) with a constant salinity (34.8 $^{o}/oo$). Venezuelan Bottom Water, with temperatures of 4-5°C and salinities of about 35 $^{o}/oo$, is found below about 100 meters. Such depths are reached along this steeply sloping coastline within 7 nmi of shore, 2 to 3 nmi south of alternate sites 2 and 3 (Atwood et al. 1976).

3.3.1.4 Circulation

The dominant large-scale transport regime off the southern coast of Puerto Rico is the warm Caribbean Current (26-29°C). This current flows in a general westerly direction parallel to the coastline. At some times, a counter current is observed close to shore along this coast, suggesting a relatively small, transient bight (loop current) off the main westward flow (Atwood et al. 1976). Comprehensive large-scale summaries of the region's surface drift indicate that the surface velocity ranges from about 15 to 40 cm/sec in a westerly direction (Wust 1964; U.S. Naval Hydrographic Office 1972). Specific features of surface and subsurface flow in the Ponce region are presented in Figures 3-30 and 3-31.

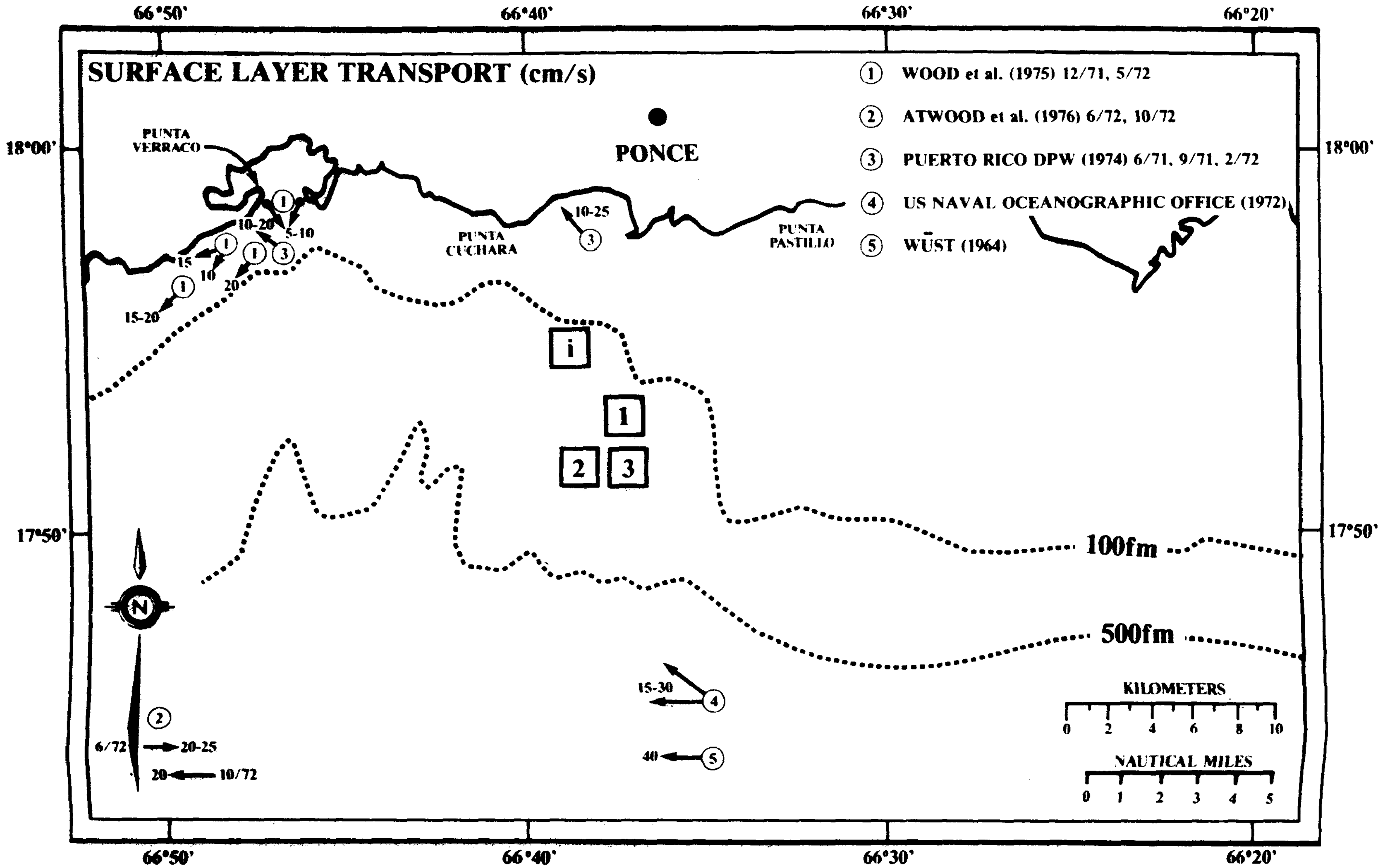


FIGURE 3-30. SURFACE LAYER TRANSPORT, PONCE STUDY AREA

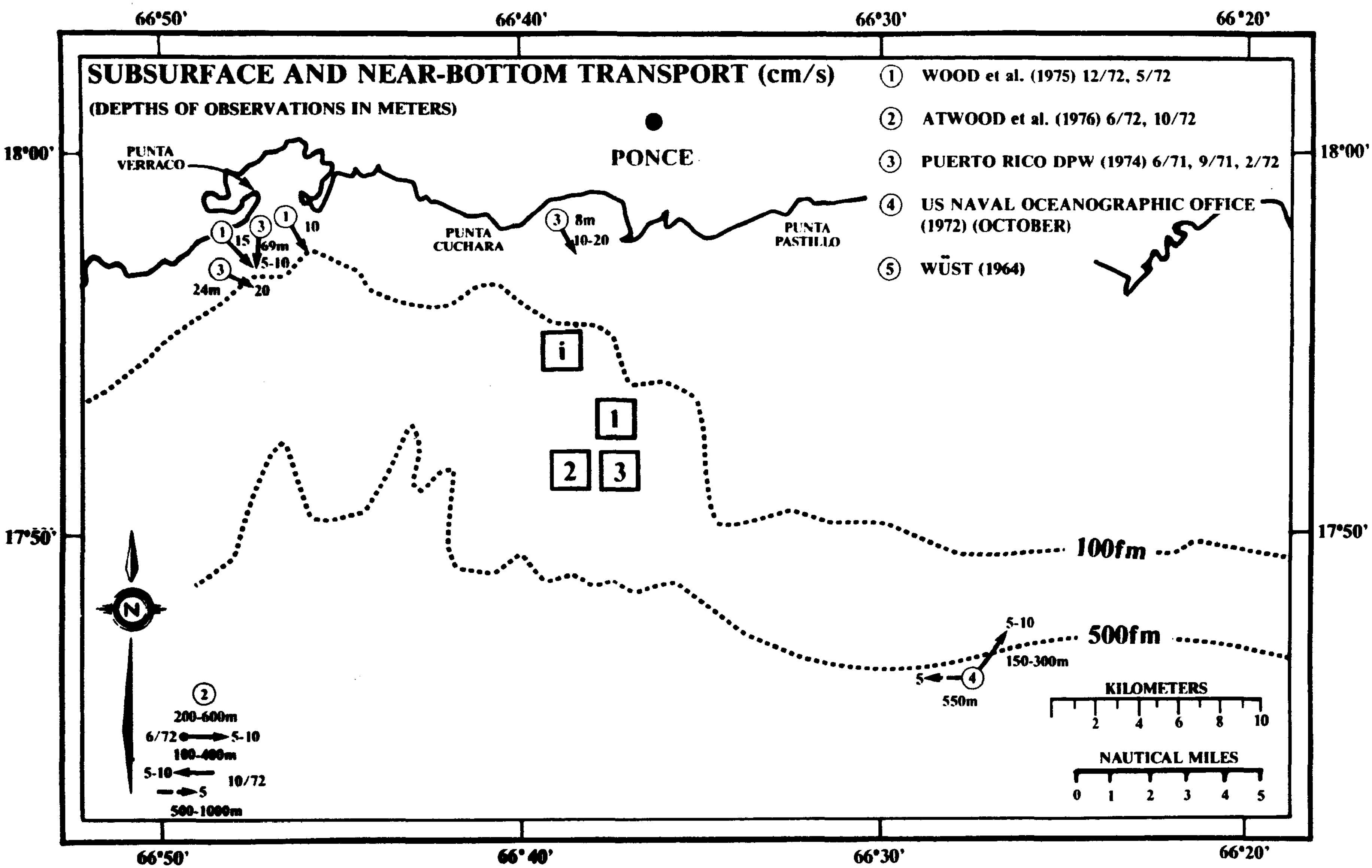


FIGURE 3-31. SUBSURFACE AND NEAR-BOTTOM TRANSPORT, PONCE STUDY AREA

Tidal and Diurnal Wind Influences

The tidal cycle near Ponce is mixed-diurnal. The diurnal tide moves from east to west past Ponce and Punta Verraco with a tidal height range of about 20 $\pm$ 15 cm (Wood et al. 1975f). Nearshore studies near Guayanilla and Punta Verraco indicate that since the total tidal height range is small, wind-driven circulation processes would be dominant over tidal effects in the region near Ponce (Hernandez-Avila et al. 1979). When wind stress influences are removed, mean tidal velocities on the south coast of Puerto Rico are: Ebb tide (6 cm/sec, SSE), and flood tide (10 cm/sec, WNW) (Hernandez-Avila et al. 1979).

Continuous surface layer current measurements suggest that there is net transport at speeds of 5-20 cm/sec toward the southwest (Punta Verraco, Punta Guayanilla), with significant diurnal variation resulting from the land-sea breeze effect (night speeds decreasing in relation to daytime speeds, Hernandez-Avila et al. 1979).

Subsurface Transport

Deep water current reversals have been reported east of Ponce in the vicinity of Punta Tuna (Oser and Freeman 1969; Burns and Car 1975). In the northern Caribbean Sea, Atwood et al. (1976) used dynamic height calculations to infer deep-water flow reversals. Subsurface current profiles (made in October over the 1000 m isobath at Station 41) offshore from the alternate disposal sites clearly indicate flow reversals of from 250 to 500 m (U.S. Naval Oceanographic Office 1972). Within depth layers of 140-250 m, flow is cross-slope to the northeast at 8-9 cm/sec. In contrast, at about 500 m, transport is to the west at about 5 cm/sec. The deep current measurement (5 cm/sec, 500 m) at Station 41 is consistent with the speed and direction (5 cm/sec, W) of geostrophic calculations along 67°00' W at 500 m using data from October 1972 (Atwood et al. 1976).

3.3.2 Geologic and Geochemical Characteristics

The sediments at the Ponce interim and alternate sites are soft silts and clays that are primarily derived from land-based sources. This section describes the basement rock, seafloor characteristics, sediment textures, and sediment mineralogy for sites in the Ponce ZSF.

3.3.2.1 Surficial Geology

The southern coast of Puerto Rico is characterized by very permeable limestones covered by a sediment layer of variable thickness (Morelock et al. 1977). Although few limestone outcrops occur, areas of consolidated sand and consolidated gravel are relatively common. Many of these occur as hardened offshore sand bars or low tide deposits (Guillou and Glass 1957). The most common sediment type that overlies the limestone on the shelf is described as a brown mud that is low in calcium carbonate. This mud deposit is bordered on the east and west by calcareous sands and gravels (Schneidermann et al. 1976). Near shore, the sands are lower in calcium carbonate. They consist of dark-colored siliceous, volcanic sands and andesitic gravels (Guillou and Glass 1957; Kaye 1959).

Sediment from land sources comes principally from the Portugues and Bucana Rivers that flow through Ponce. These rivers flood frequently and deposit sediment and debris into the Port of Ponce (COE 1975). The sediment from the rivers moves westward (Kaye 1959).

Flood control projects have been initiated by the COE and include re-inforcement of river banks, installation of debris basins, and channelization of some sections of the rivers (Dichiara, 1984). These efforts should reduce the long-term sediment input to the waters south of Ponce.

3.3.2.2 Sea Floor Characteristics and Sediment Textures

Within the Ponce ZSF, soft bottom was encountered in 23 of 24 sediment samples (Figure 3-32). At the interim and alternate sites, the bottom is soft and consists of fine-grained sediments.

The 21 sediment samples collected in the Ponce ZSF were predominantly silt, with an average of 60 to 65 percent silt, 20 to 25 percent clay, and less than 15 percent sand.

Interim Site - Samples are more clayey and less silty than sediments from the alternate sites. Clay contents ranged from 21 to 43 percent, silt was 56 to 68 percent, and sand was 1 to 10 percent. This site has a minimum depth of

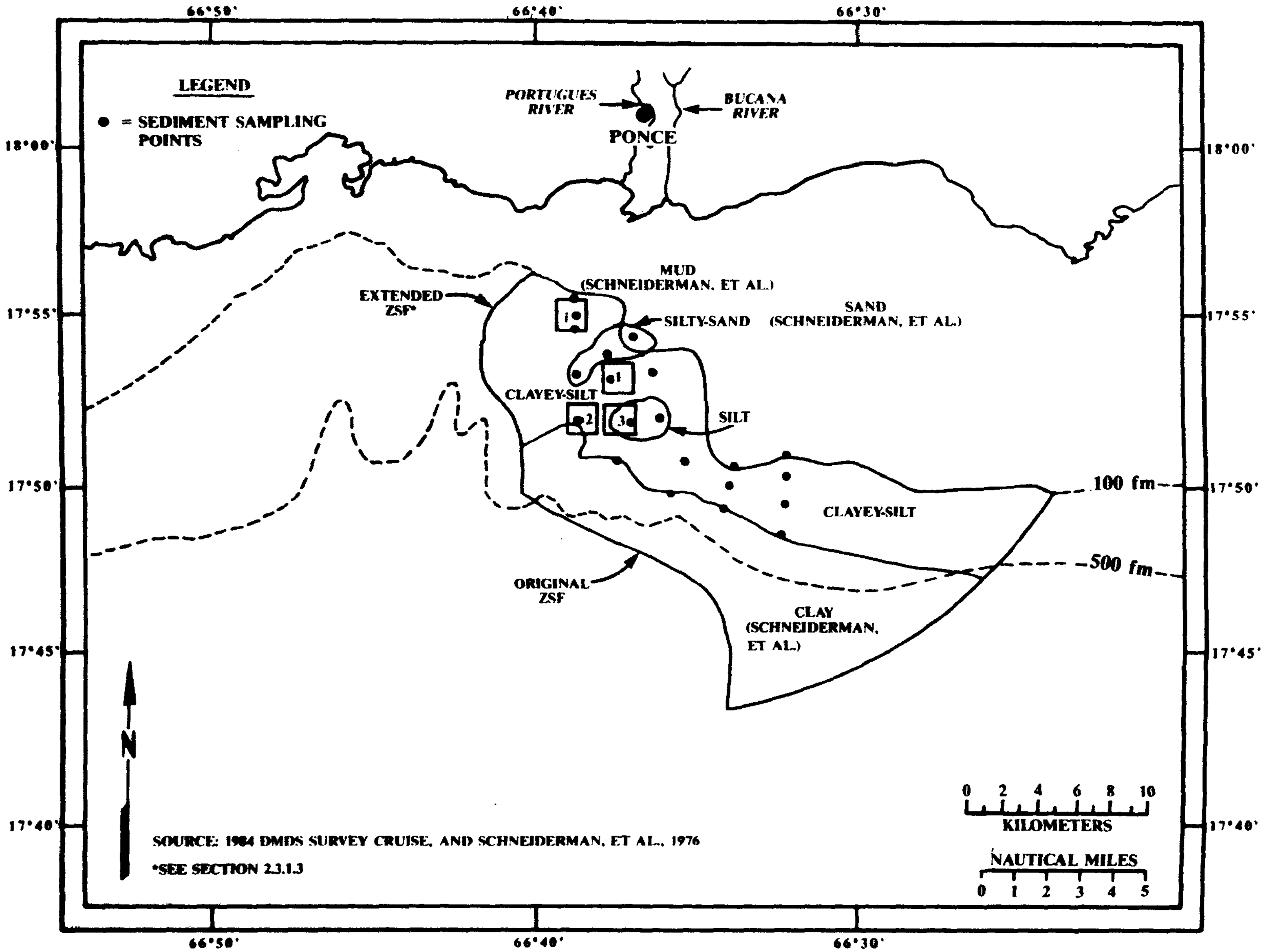


FIGURE 3-22. SEDIMENT SAMPLING POINTS AND IDENTIFIED SEA-FLOOR SEDIMENTS IN PONCE ZSF

about 150 m and slopes to the south to a depth of about 500 m. The average degree of slope across the site is 14.5 percent.

Alternate Site 1 - sediments are clayey-silts, averaging about 60 percent silt and 35 percent clay, with less than 10 percent sand. The minimum depth is about 366 m, and the site slopes westward to a depth of over 500 m. The degree of slope is about 8 percent.

Alternate Site 2 - Samples taken in and near this site are over 60 percent silt, less than 10 percent sand, and about 20 percent clay. The depth ranges from about 450 to about 650 m, and the slope averages 6 to 7 percent.

Alternate Site 3 - The sediments are also predominantly silt, with over 60 percent silt, 15 to 30 percent clay, and less than 10 percent sand. Depths range from 475 to 600 m and the slope averages 5.5 to 6 percent.

3.3.2.3 Sediment Mineralogy

Most of the sediment within the Ponce ZSF is apparently land-derived material that was discharged from rivers near Ponce (Schneidermann et al. 1976). The fluvial sediment moves westward along the coast and becomes mixed with marine calcareous material (Kaye 1959; Guillou and Glass 1957).

The sand fraction near shore occurs in narrow beaches, and consists of quartz sand and dark-colored andesitic gravel that is more cobbly east of Ponce and more sandy west of Ponce (Kaye 1959; Guillou and Glass 1957). There are occasional outcrops of consolidated sand (beach rock) or consolidated gravel (Guillou and Glass 1957). Farther offshore, the sand fraction is dominated by calcium carbonate. On the southern Puerto Rico shelf, the sand fraction averages 70 to 85 percent calcium carbonate, which is derived from mollusc shells, coral fragments and other biogenic sources (Schneidermann et al. 1976).

The silt fraction contains very fine sands and organic materials. At Ponce, large quantities of organic matter are discharged by two sewage treatment plants, a tuna processing plant, and several sources of untreated sewage (COE 1975).

The clay fraction consists of clay minerals, amorphous silica, hydrous oxides of iron and aluminum, and colloidal organic matter. All of these materials exhibit some degree of cation exchange capacity, through which nutrients or contaminants can be temporarily adsorbed by the sediments (McCarthy 1977). No data were found describing the types and relative amounts of clay minerals in sediments near Ponce.

3.3.3 Water Quality

Surface waters throughout the Ponce study area are clean, warm, oxygen saturated and nutrient depleted. Below the surface mixed layer, oxygen remains undepleted, and nutrient levels become very high. In summary, water quality in the area of the interim and alternate sites is excellent, and is typical of tropical open-ocean conditions.

3.3.3.1 Turbidity

Secchi disc depth readings taken from shallow (<15 m) nearshore waters, less than 2 nmi offshore near Ponce and Guayanilla are presented in Figures 3-33 and 3-34. Secchi depths ranged from 1 to 24 m. The lower values, indicative of turbid water, were from sites closest to shore, and higher values, indicating greater clarity, were taken further from shore. Based on these measurements it appears that the waters in the ZSF are optically clear and contain little suspended material (EPA 1981).

3.3.3.2 Dissolved Oxygen

Dissolved oxygen concentrations are consistently at or near saturation levels in surface waters (Wood et al. 1975e). Figure 3-35 presents the average dissolved oxygen depth profiles by season at Punta Verraco, 11 miles west of Ponce, for 1973 and 1974. There is little seasonal change in surface dissolved oxygen concentration. Oxygen levels decrease slightly with depth, but still remain high at lower depths (on the order of 4.5 ml/l). The highest dissolved oxygen values were measured in winter. The lowest dissolved oxygen

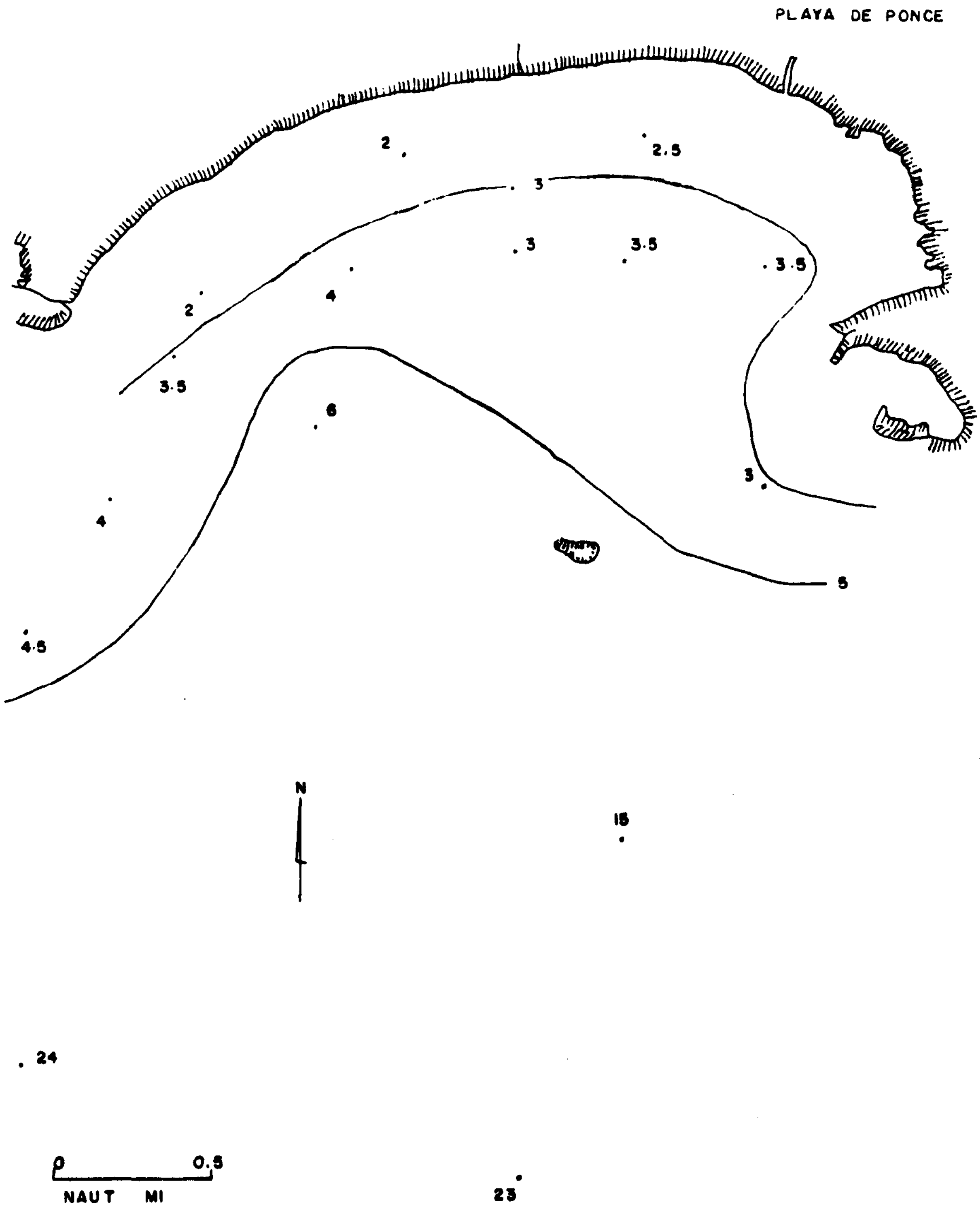


FIGURE 3-33. SECCHI DISK READINGS IN METERS FOR NEARSHORE WATERS NEAR PONCE, SEPTEMBER 1971

Source: Puerto Rico Department of Public Works 1974

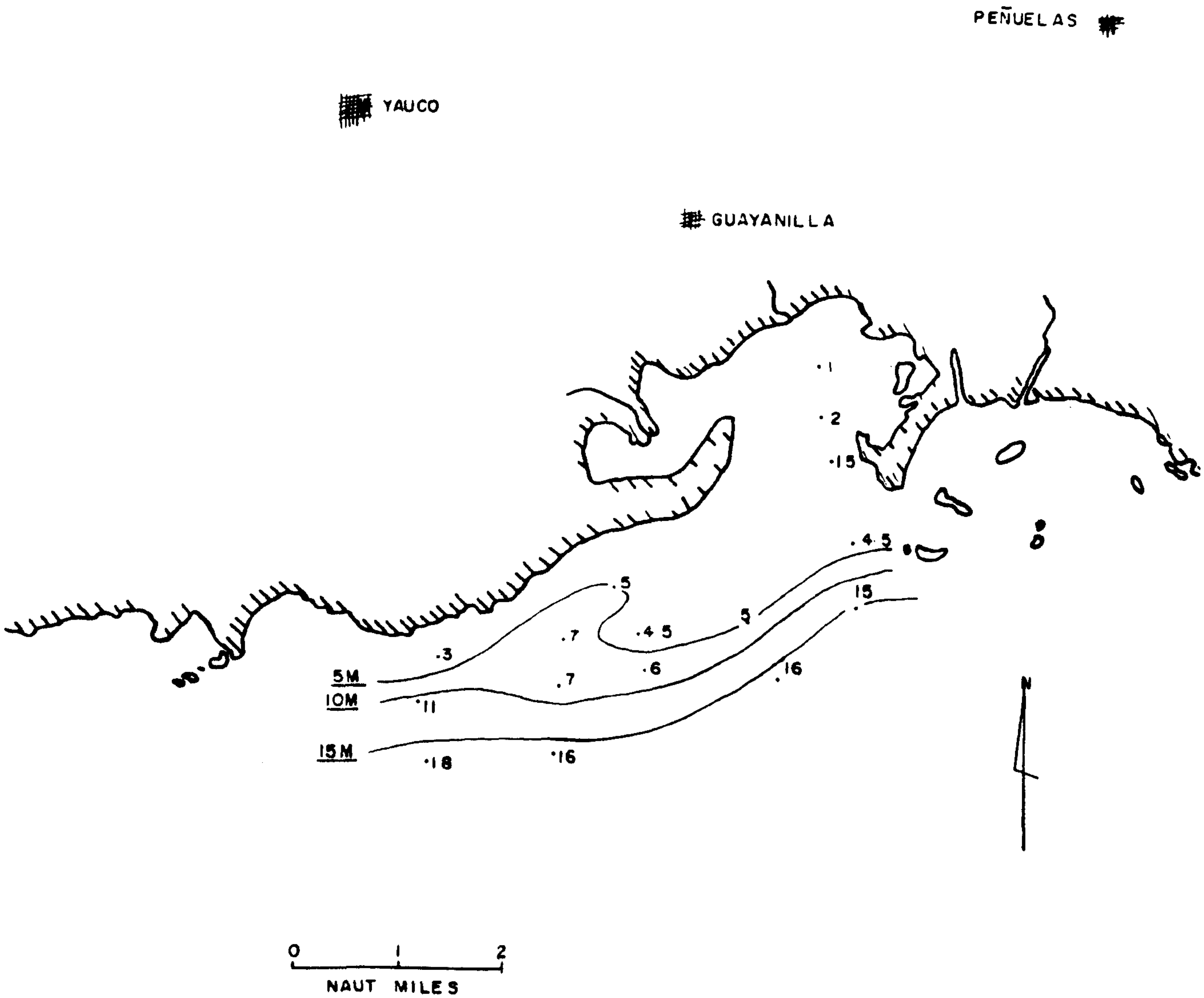


FIGURE 3-34. SECCHI DISC READINGS, IN METERS, FOR NEARSHORE WATERS NEAR GUAYANILLA, OCTOBER 1971

Source: Puerto Rico Department of Public Works 1974.

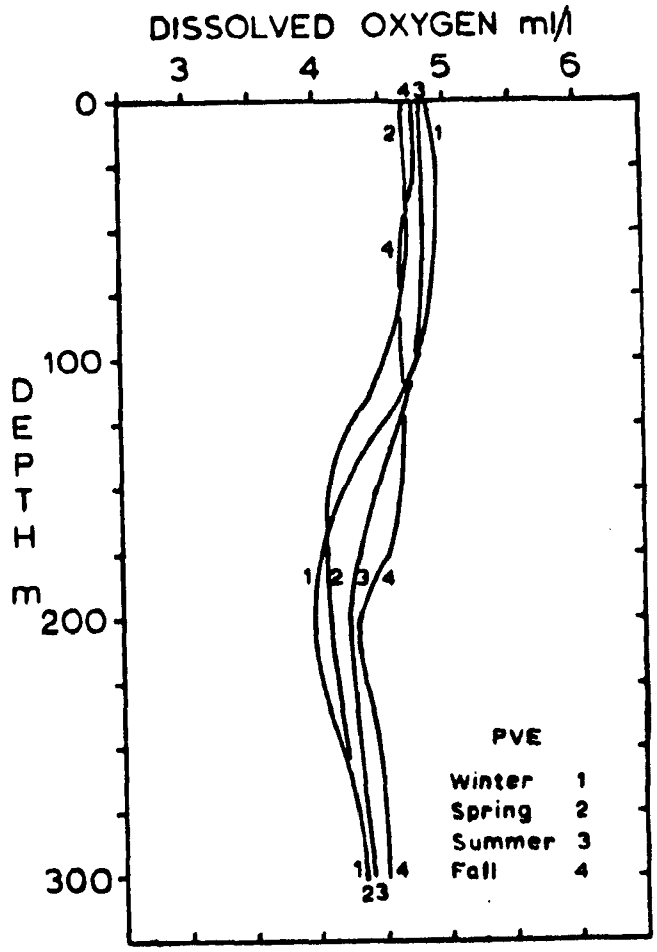


FIGURE 3-35. AVERAGED DISSOLVED OXYGEN DEPTH PROFILES BY SEASON, AT PUNTA VERRACO, 1973 AND 1974

Source: Wood et al. 1975f.

values occurred at about 200 m in all seasons except spring, when they occurred at about 160 m. The lowest single dissolved oxygen value was about 3.9 ml/l at 200 m during the winter season.

3.3.3.3 Nutrients

Nutrient levels in the surface waters show little seasonality, reflecting the relatively stable marine conditions associated with Puerto Rico's tropical climate. Surface waters are low in phosphate, nitrate, and silicate. Concentrations of these nutrients increase with depth below the pycnocline.

Seasonal concentrations of reactive phosphate measured in the vicinity of Punta Verraco are presented in Figure 3-36. Surface water concentrations are very low (0.05 ug-at P/l) throughout the year. There is little seasonal variation in phosphate levels. Phosphate values are generally low throughout the upper mixed layer and through the pycnocline to about 200 m. Peak values at the deepest point sampled were about 0.33 ug-at P/l. In winter the concentration begins to increase at 100 m and reaches about 0.38 ug-at P/l at 300 m.

Seasonal concentrations of nitrate are presented in Figure 3-37. The concentration of nitrate was less than 1 ug-at N/l from the surface to about 75 m in the summer and to 35 m in the fall. Nitrate values between 30 and 125 m were higher in the fall than in the summer. Little seasonal difference was found below 125 m. The concentration of nitrate increased with depth from about 2 ug-at N/l at 100 m to greater than 13 ug-at N/l at 300 m.

Surface silica values are low. Studies off Ponce and off Guayanilla, 10 miles to the west (Puerto Rico Department of Public Works 1974), found silica concentrations ranging from 0.03 to 0.10 mg/l in surface waters. No data on subsurface silica concentrations were found for this area.

3.3.4 Biota

Species identified in the Ponce study area are included in the species list presented in Table 3-5.

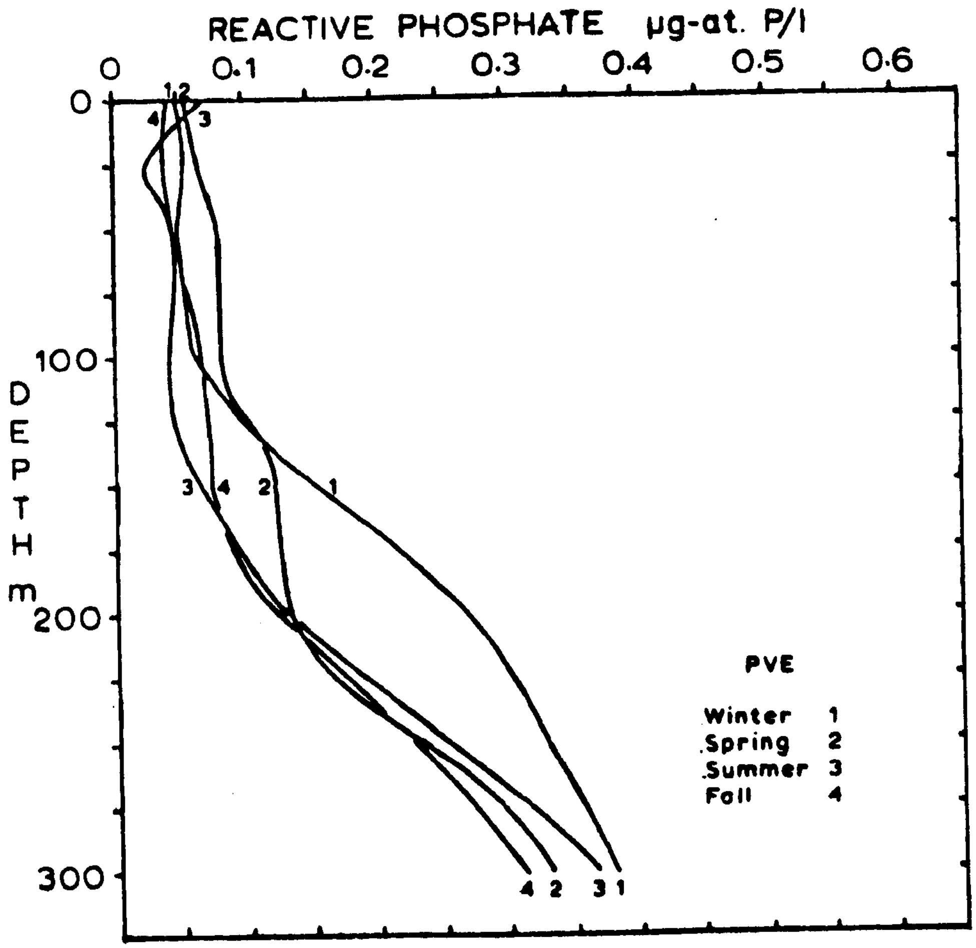


FIGURE 3-36. AVERAGED REACTIVE PHOSPHATE DEPTH PROFILES, BY SEASON, AT PUNTA VERRACO, 1973 AND 1974

Source: Wood et al. 1975f.

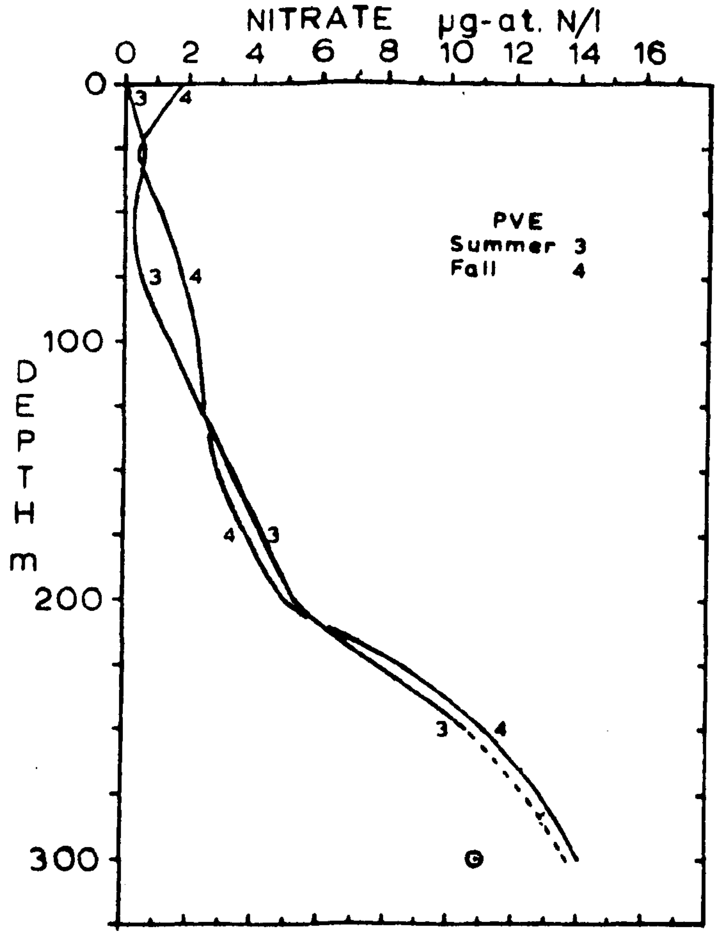


FIGURE 3-37. AVERAGED NITRATE DEPTH PROFILES FOR THE SUMMER AND FALL SEASONS, AT PUNTA VERRACO, 1974

Source: Wood et al. 1975f.

3.3.4.1 Benthic Invertebrates

Information presented in this section is based on analyses of the biological samples conducted on EPA's 1984 DMDS survey cruise in Puerto Rico (JRB 1984).

The benthic community at the proposed site was dominated by deposit feeding organisms (primarily polychaetes) typical of the fine-grained sediments occurring at the site. The number of taxa and number of individuals per taxon were low for most samples, although the types of taxa were relatively different among samples suggesting a patchy distibution of many organisms. Six potential station groups were observed based on the results of cluster analysis, however, the groups did not correspond to any obvious trends in sediment grain size distribution and were not indicative of any influence from past dredged material disposal at the Ponce DMDS (Table 3-3).

The total number of individuals per sample (all taxa combined) at all sampling locations off Ponce were also corespondingly low, with a mean of 87 and a range of 26 to 176 individuals. Only nine of the 357 total taxa occurred in more than half of the samples, with only two taxa (the pelecypod Vesicomya pilula and the rhynchocoels) occurring in more than 20 samples (24 and 23, respectively). Of these nine taxa, only four (V. pilula, the sipunculid Golfingia tricocephala, pelecypods, and members of the polychaete family Ampharetidae) were found in abundances greater than 10 individuals per sample. These data indicate similar low numbers of individuals for most taxa, but also suggest dissimilarity in the types of taxa occurring among different samples.

Polychaetes were the most abundant benthic organisms in all locations off Ponce (143 taxa), followed by crustaceans (98 taxa), molluscs (92 taxa, primarily gastropods and pelecypods), 17 minor taxa (primarily sipunculids and rhynchocoels), and echinoderms (17 taxa). The majority of the 357 total taxa found in the region were deposit feeders typical of fine-grained sedimentary environments such as that generally occurring at the proposed site. The average number of taxa per sample (station and replicate) was relatively low (38) ranging from 16 to 55 taxa. The number of individuals per sample for

	TTAXA	SCNT	SHNWVR	PIELOU
GRAVEL	0.03509	0.05798	0.04627	0.03420
	0.8566	0.7651	0.8116	0.8602
	29	29	29	29
SAND	0.04823	-0.06403	-0.10559	-0.18144
	0.8038	0.7414	0.5857	0.3462
	29	29	29	29
SILT	0.00715	0.13340	0.13970	0.20457
	0.9707	0.4903	0.4698	0.2871
	29	29	29	29
CLAY	-0.12220	-0.09191	-0.00958	0.04833
	0.5277	0.6354	0.9607	0.8034
	29	29	29	29
FINES	-0.04891	0.06087	0.10229	0.17754
	0.8011	0.7538	0.5975	0.3569
	29	29	29	29
DPFT	-0.11098	-0.27236	-0.25750	-0.30853
	0.5816	0.1693	0.1947	0.1174
	27	27	27	27

Table 3-3 Correlation Matrix for Sediment Grain Size, Biological Parameters and Station Depth from the March, 1984 EPA/JRB Survey Offshore of Ponce, Puerto Rico. (Correlation coefficients are listed first with significance levels listed second and the number of comparisons third). TTAXA = total number of taxa, SCNT = total number of individuals of all taxa, SHNWVR = Shannon - Weaver Diversity Index, PIELOU = Pielou's Eveness Index.

each taxon was also low, with the majority occurring in densities of only one to three individuals per 0.065 m^2. The species having the highest density (30 individuals per 0.065 m^2) was the pelecypod (a bivalve mollusc) Nuculana sp., occurring in one replicate sample collected at the interim site. A high density of pelecypods also occurred at a location about 7 km (4 nmi) southeast of the proposed site, where one taxon had a density of 35 individuals per 0.065 m^2 (however this taxon may comprise several species). The two stations with high pelecypod densities were at approximately the same depth (370 m, or 1200 ft). The similarity in the bivalves present at the interim site and this other similar-depth site where no disposal has occurred is in accordance with the general lack of significant faunal differences between the Ponce interim site and other similar sites in the region. This suggests that disposal at the Ponce site in the past has resulted in deposition that did not make major changes in the benthic ecology of the site, or did not result in substantial deposition at the site. The latter is a reasonable possibility, given the potential for dispersion by horizontal transport and mixing before deposition can occur at deepwater sites such as this.

3.3.4.2 Coral Reefs

Small reefs occur in great abundance all along the south coast of Puerto Rico, including the Ponce Study area (Almy and Carrion-Torres 1963). Coral reefs important to fishing occur around Caja de Muertos Island and Berberia Key (see Figure 3-38). Other commercially important reefs occur about 10 nmi directly west along the coast, in the coastal waters just outside Guayanilla Bay.

3.3.4.3 Mangrove Breeding and Nursery Areas

Mangrove swamps and estuaries are important nursery areas for commercially valuable marine fish such as lady fish, pompano, and several varieties of snapper (Austin 1971). Organically rich mangrove root systems not only offer protection to juvenile fish, but also support the productivity of the invertebrates and algae upon which many of them feed. There is extensive mangrove growth near the Ponce study area, including large stretches of coastline near Guayanilla Bay and Guanica Harbor. Guayanilla, one of the largest

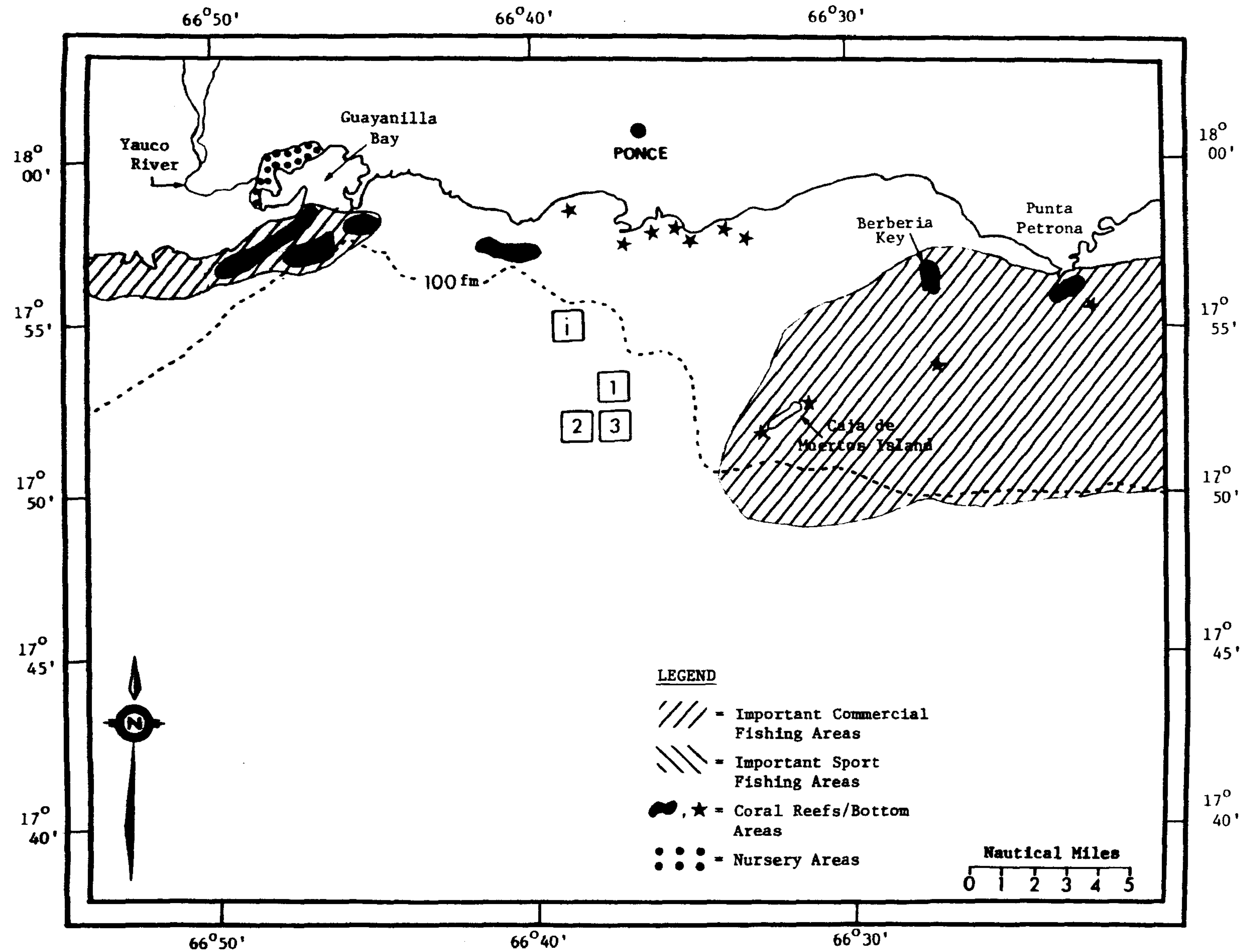


FIGURE 3-38. LIVING MARINE RESOURCES NEAR PONCE

bays in southern Puerto Rico, is the closest to Ponce, lying approximately 8 miles westward along the coast (see Figure 3-38). The Yauco River drains into this bay. A very high year-round population of portunid crabs (principally Callinectes danae), provides an excellent food source for juvenile fish in Guayanilla Bay.

3.3.4.4 Preserves and Reserves

Critical wildlife habitats in the Ponce study area include the Guanica Forest Reserve about 12 nmi west of Ponce, and Punta Cabullones, 2 to 3 nmi to the east. In addition, the Caja de Muertos Reserve, composed of Caja de Muertos Islands and nearby Berberia Key, lies from 4 to 9 nmi east of alternate site 1 and 3 (see Figure 3-39).

3.3.4.5 Threatened and Endangered Species

Threatened and endangered marine species in Puerto Rico include several sea turtles and the brown pelican. Caja de Muertos Island, a natural reserve 4 nmi east of Alternate Site 3, is a nesting ground for sea turtles (DOC 1978, and Figure 3-39). Very high densities of turtles occur on beaches of this island.

It is not known to what extent pelicans inhabit the Ponce coastal area. If they are present, they will be primarily in the nearshore areas of the mainland and perhaps at Caja de Muertos. Pelicans typically remain close to land, making only short trips over offshore waters, except when migrating. They feed principally along the coast where the small fish they eat are relatively abundant.

A list of threatened and endangered species identified in the Ponce study area is presented in Table 3-6.

3.3.5 Recreational Areas

There are several beach areas to the west of Ponce (Figure 3-39). The closest of these is just past Punta Cucharas, approximately 4 nmi from the interim site. Another is located further to the west, off Punta Verraco and two others are located within the Guanica Forest area.

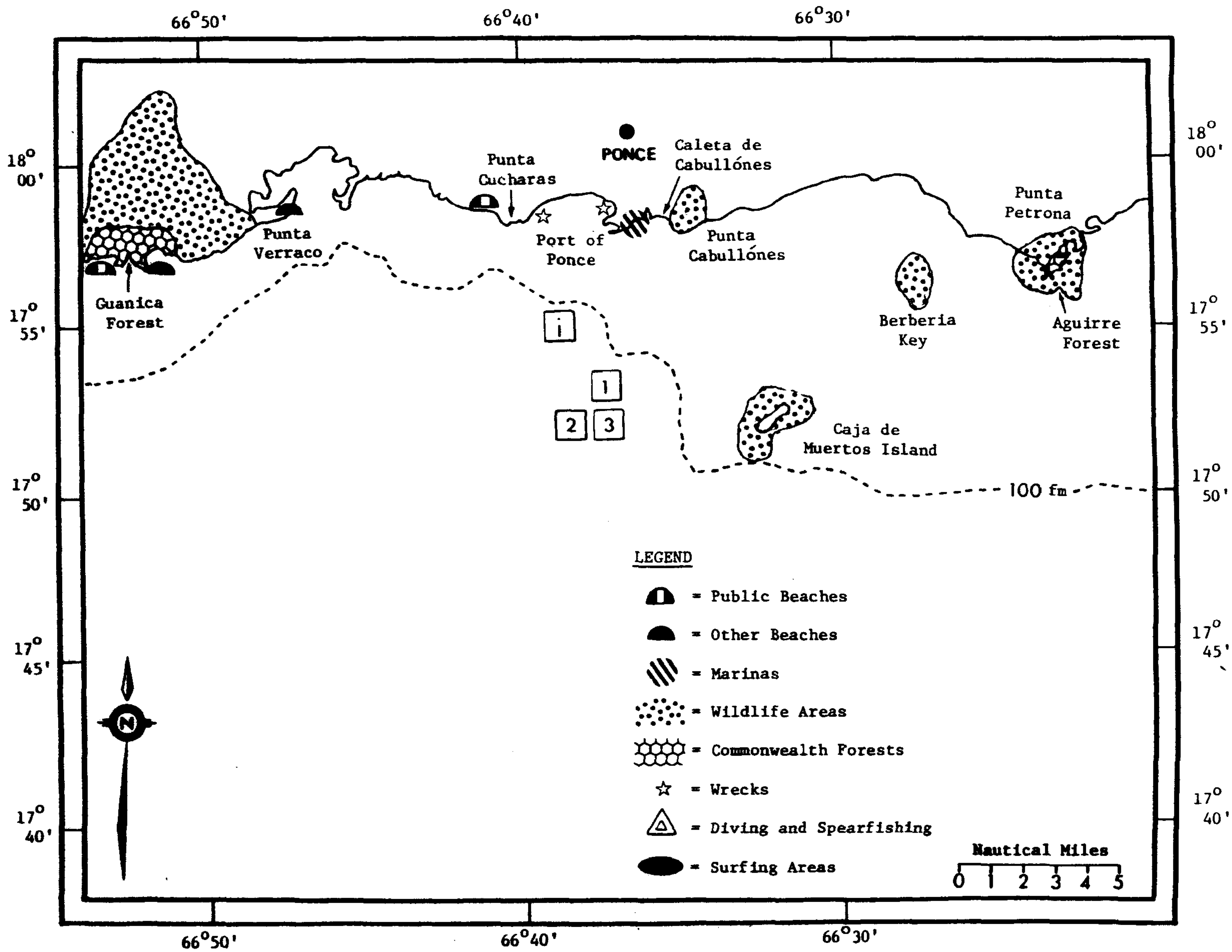


FIGURE 3-39. RECREATIONAL AREAS, PRESERVES AND SHIPWRECKS NEAR PONCE

There is a marina east of Ponce near Punta Cabullones. This facility supports some of the extensive commercial fishing that occurs to the east and west. It is also used as a base for recreational boating and fishing.

3.3.6 Shipping Lanes

There are no formally established shipping lanes for Puerto Rican ports and harbors. A 2-year study conducted by the Seventh Coast Guard District (46 FR 48376, October 1, 1981) determined that such lanes were not warranted by the amount and direction of vessel traffic near the island.

3.3.7 Mineral Resources

There are no known deposits of oil, gas, high-magnetite sands, or quartz sands at any of the potential disposal sites or near the Ponce ZSF (Alonso 1983; Guillou and Glass 1956; Schneidermann et al. 1976). There is no solar salt production in this area (White and Tuchman 1982).

3.3.8 Shipwrecks or Other Features of Historical or Cultural Importance

There are no shipwrecks at or immediately adjacent to any of the potential disposal sites for Ponce. The only known wrecks are in the shore zone, over 3 nmi away from the interim site (Figure 3-39, University of Puerto Rico 1974). No other features of historical or cultural importance have been identified in the Ponce ZSF.

3.3.9 Fisheries

The bulk of the Puerto Rican fishing industry consists of small boats fishing for reef-associated species over the shelf. Records of fish landings for October 1982 through July 1983 show the south coast harvest as the second largest portion of the island's fish and shellfish landings (1.2×10^6 lbs., 25 percent of the total, Caribbean Fishery Management Council 1984).

Commercial fishing activities of municipalities throughout the central south coast are concentrated on the shelf, particularly the broad area just east of the Ponce ZSF extending eastward along the shelf boundary for 10 to 15 miles (Figure 3-38). Commercial species commonly landed from this area include grunts, porgies, goatfish, mackerel, groupers, snappers, squirrel fish, ballyhoo, barracuda, triggerfish, parrot fish, spiny lobster, sea turtles, conch, and octopus. Major sport fishes include tarpon, king mackerel, and various sharks (COE 1975).

3.4 CHARACTERIZATION OF THE AFFECTED ENVIRONMENT FOR YABUCOA

3.4.1 Oceanographic Characteristics

3.4.1.1 Bathymetry

Bottom topography of the southeastern coast of Puerto Rico is characterized by a pronounced change from north to south. To the north of Yabucoa there is a broad shallow shelf (Figure 1-4). The sea floor then drops off rapidly (from less than 30 m down to 800 m or more) just south of Punta Guyanes and Vieques Island. The insular shelf to the south, at Punta Yeguas, and continuing to the west, past Punta Tuna, is very narrow (2 to 3 nmi) with the slope dropping off sharply to depths of 800-1000 m over distances of less than 2 km from the coast (Figure 3-40 and 1-4). Bottom depths then slope gently (15° slope) from south of Yabucoa to the 2000 m depth of the Virgin Islands Trough about 40 km to the south-southeast. A prominent topographic feature is Grappler Bank (80 m depth), about 18 nmi southwest of the interim disposal site.

3.4.1.2 Climatology

This area is characterized by a tropical-marine climate with persistent easterly trade winds. The monthly mean air temperature varies only slightly (1.5°C) from the annual mean of 27°C (Atwood et al. 1976). Seasonal changes result in a transition in the predominant wind direction from north-northeast in winter to east in the summer. Wind observations indicate average speeds of 4.5-5 m/sec in autumn, 6-8 m/sec in summer and stronger northerly winds of greater than 14 m/sec occurring occasionally (about a 2% frequency) during the winter and spring (Atwood et al. 1976).

Wave regimes in the coastal region of southeastern Puerto Rico are strongly influenced by the prevailing wind patterns. Frequency statistics,

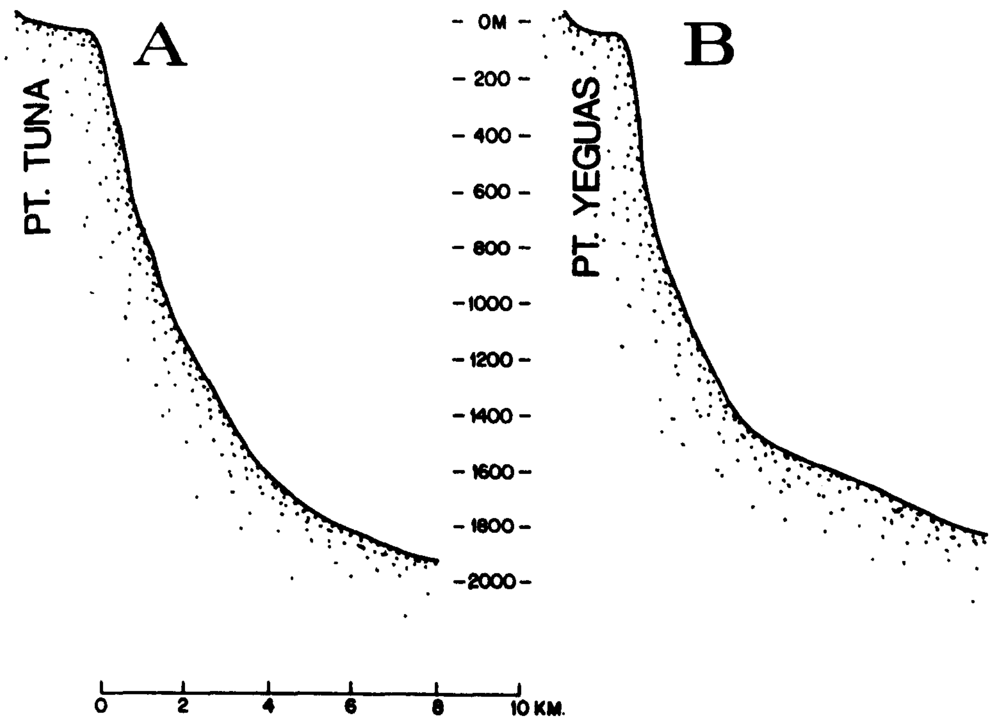


FIGURE 3-40. BATHYMETRIC PROFILES OFFSHORE FROM PUNTA TUNA (A) AND PUNTA YEGUAS (B)

Source: Atwood et al. 1976.

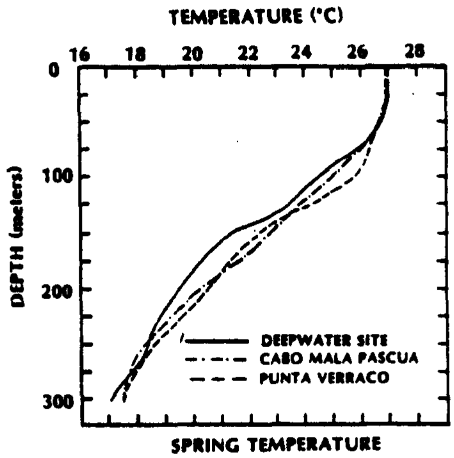
compiled by the U.S. Naval Weather Service Command (1974), have been summarized by Hernandez-Avila et al. (1979) and Atwood et al. (1976). Average wave height is 1 m with an average wave period of 5.9 sec. Wave heights range from 0.3-1.4 m with wave periods less than 6 sec during 79% of the year. The relationship of wave height to wind speed for the Vieques/Yabucoa area indicates that for a typical summer/autumn windspeed of 4-8 m/sec, the corresponding wave height is about 0.3-1.2 m.

Hurricanes occur in the Caribbean, principally between June and November. Bretschneider (1977) has estimated that the "most probable" hurricanes will have windspeeds of greater than 41 m/sec, with waves averaging over 7 m in height.

3.4.1.3 Hydrography

The waters of the Caribbean Sea off southeastern Puerto Rico are characterized by four distinct water masses: (1) Tropical Surface Water; (2) Subtropical Underwater; (3) Antarctic Intermediate Water and (4) Venezuelan Bottom Water. Temperature, salinity and density profiles from the region are shown in Figures 3-41, 3-42 and 3-43 respectively. The upper-layer water mass, Tropical Surface Water (TSW), extends to a depth of 75 m with temperature ranging from 25°-29° C and salinity varying from 33-36 ^{o}/oo. The Subtropical Underwater (SUW) below the pycnocline at about 100 to 200 m is characterized by a more constant density (temperature of 20-25°C, salinity of 26.8-37.2 ^{o}/oo) than the TSW layer. The strong density differences between the two layers results in minimum vertical mixing between them. Between 200 and 600 m, temperatures drop from 20 to 7°C and salinity ranges from 36.8 to 35 ^{o}/oo. Antarctic Intermediate Water (AIW) at 600 to 800 m is characterized by cold temperatures (6-7°C) and salinity of 34.8%. Below this layer, North Atlantic Deep Water and Venezuelan Bottom Water (4-5°C, 35 ^{o}/oo salinity) extend from 800 m to the bottom. (Atwood et al. 1976; Hernandez-Avila et al. 1979; Lopez and Tilly 1983).

Inspection of seasonal density profiles off Cabo Mala Pascua about 9 miles southwest of Yabucoa suggests a pycnocline depth of about 50-75 m in the summer/autumn and about 100 m in the winter/spring. The most probable seasonal depths are 100 m (February-March) and 40-50 m (September-November).



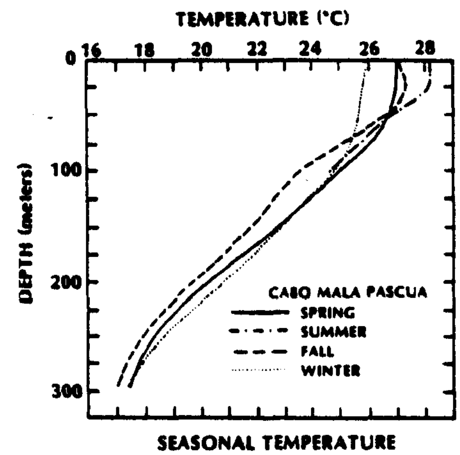
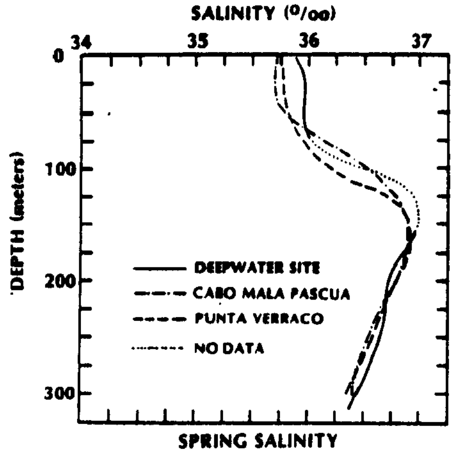


FIGURE 3-41. SPRING AND SEASONAL TEMPERATURE PROFILE FOR DEEPWATER SITE, CABO MALA PASCUA AND PUNTA VERRACO

Source: EG&G 1978.



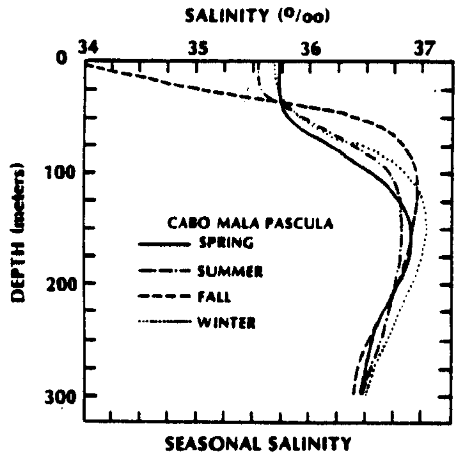


Figure 3-42. SPRING AND SEASONAL SALINITY PROFILE FOR DEEPWATER SITE, CABO MALA PASCUA AND PUNTA VERRACO

Source: EG&G 1978.

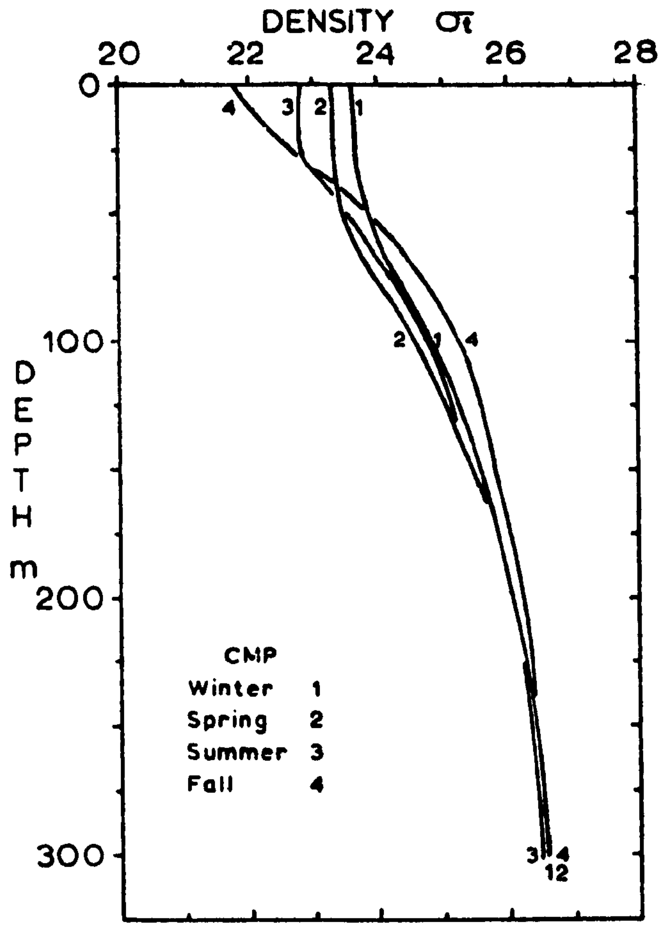


FIGURE 3-43. AVERAGED WATER DENSITY PROFILE, BY SEASON, OFFSHORE OF CABO MALA PASCUA, 1973 AND 1974

Source: Wood et al. 1975e.

3.4.1.4 Circulation

The dominant large scale transport regime off the south coast of Puerto Rico is the warm (26-29°C) Caribbean Current. This current, driven by the predominant northeasterly trade winds of low latitudes, flows in a westerly direction. Comprehensive summaries of the surface-layer net transport of the Caribbean are presented in Wüst (1964) and Lee et al. (1978). In general, surface drift near Yabucoa is on the order of 18-40 cm/sec towards the west and southwest. Surface and subsurface current patterns in Yabucoa are particularly complex, possibly due to "island effects", which are typically observed when a major current is deflected by the corner of a large island (Lopez and Tilly 1983).

Tidal and Diurnal Wind Influences

The tidal cycle near Yabucoa is a mixed-diurnal cycle. The diurnal tide moves from east to west past Yabucoa and Cabo Mala Pascua, with a tidal height range of about 25 ± 15 cm (Wood et al. 1975).

Over the shelf region of the Vieques Passage, between the east coast and the island of Vieques, tidal forcing is a dominant component of the circulation. Tidal transport tends to flow parallel to the coastline. Ebb tide flow is towards the northeast and east at speeds of 20-36 cm/s while flood tide flow is towards the southwest at 20-30 cm/s (Figure 3-44). Maximum tidal excursions in the passage are about 9 km (EPA 1981).

Northeast of the interim site, surface tidal currents are about 20 cm/s with net transport to the northwest, while subsurface tidal currents are about 7 cm/s or less with net flow to the south-southeast (EPA, 1981). Surface circulation in deep water is dominated by wind driven currents. Offshore surface transport is generally towards the west-southwest at speeds of 5-40 cm/s (Wust 1964; Burns and Çar 1975; Lee et al. 1978). Within the nearshore region of the narrow continental shelf, surface flow ranges from 5-25 cm/s towards the southwest and the northeast, parallel to the coastline. The open ocean westerly flow appears to separate into two flows near the southeast corner of Puerto Rico with transport towards the southwest (as at Cabo Mala Pascua) and towards the northeast (as at Punta Tuna and Punta Yeguas) (Wood et al. 1975d).

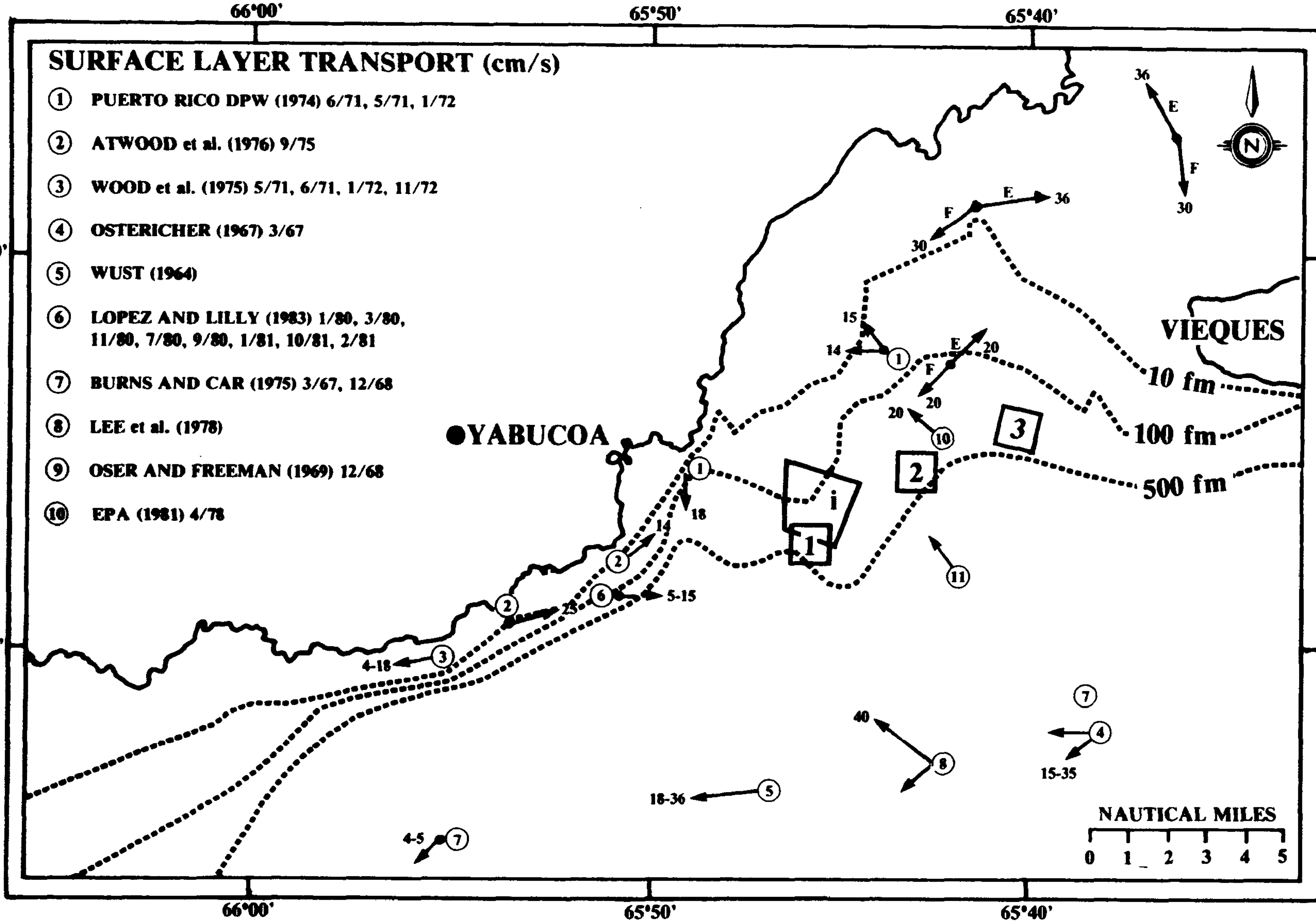


FIGURE 3-44. SURFACE LAYER TRANSPORT, YABUCOA STUDY AREA

Subsurface Transport

Few current meter measurements have been made in the region at intermediate depths where potential disposal sites for Yabucoa are located. The few deepwater measurements (1000-2000 m) offshore of Yabucoa and Punta Tuna do provide some information on subsurface circulation features in the vicinity, which allows some extrapolation of what the general subsurface circulation patterns at the sites may be (Figure 3-45).

Available data from deepwater current-meter arrays suggest the presence of sub-surface currents that follow bottom isobaths within the depth layer of 100-300 m (Burns and Car 1975; Oser and Freeman 1968). At 600 m the cross-slope transport in the vicinity of Alternate Sites 2 and 3 is to the northeast, towards Vieques Island (Oser and Freeman 1968).

Based on a series of hydrographic sections off Punta Tuna and Punta Yeguas in 1980, Lopez and Tilly (1983) demonstrated the presence of eddies on the order of 5 to 15 nmi (10-25 km) in radius, located about 9 to 15 nmi south and southwest of the interim and alternate disposal sites (Figure 3-45). In addition to the anti-cyclonic (counter-clockwise) eddy shown, cyclonic (clockwise) eddies were also observed south of Jobos Bay to the west of the Yabucoa region. The eddies, coherent to depths of 100-400 m below the upper mixed layer, are indicative of the high potential in this area southeast of Puerto Rico for flow in directions opposite to the large-scale general circulation patterns. In general, subsurface transport processes are considerably more complex and less well understood than surface flow, and are strongly influenced by the steep bottom topography of the region. Subsurface currents offshore vary with depth, and with flow reversals and large-scale eddies. Typical flow within nearshore waters 100-300 m deep was usually to the southwest or west, parallel to isobaths, at speeds ranging from 5-25 cm/sec.

3.4.2 Geologic and Geochemical Characteristics

The sediments at the Yabucoa interim and alternate sites are silty but somewhat coarser than the sediments near the other three harbors. The geology and sea floor characteristics near this harbor also differ from that of the other harbors. This section describes the geology, sea floor characteristics, sediment textures and sediment mineralogy in the Yabucoa ZSF.

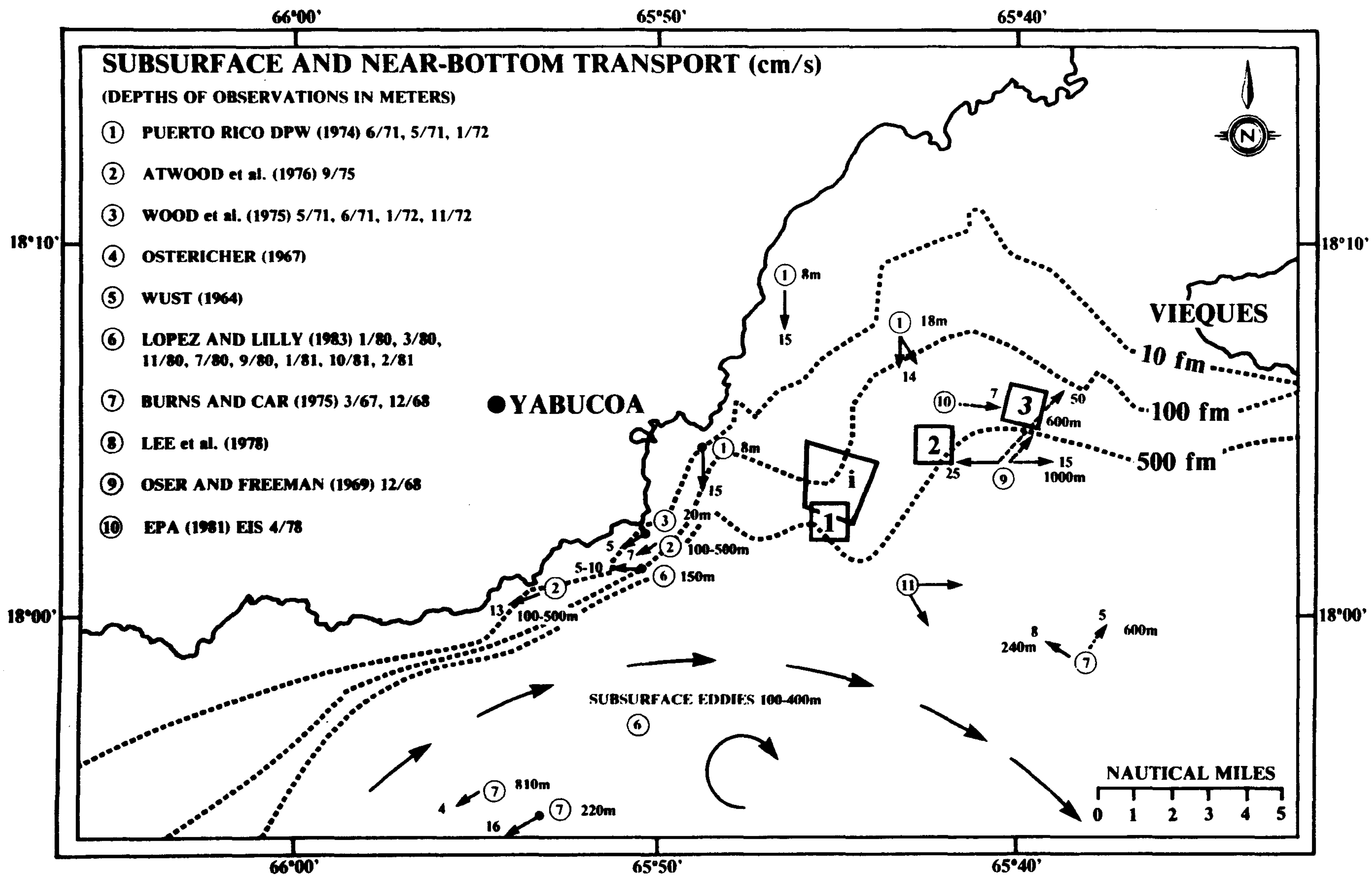


FIGURE 3-45. SUBSURFACE AND NEAR-BOTTOM TRANSPORT, YABUCOA STUDY AREA

3.4.2.1 Surficial Geology

The city of Yabucoa is in a broad alluvial valley bounded by high granitic mountains. The bedrock types in this area are granites and diorites (Meyerhoff 1932). These types of rocks weather slowly to produce soils that are very sandy, with low clay contents. Eroded soils are carried by the Guayanes and Santiago Rivers and discharged into the Vieques Passage at the Port of Yabucoa.

The rock types at the interim and alternate sites can be extrapolated from the rock types of Eastern Puerto Rico and Vieques Island. The rock types beneath the sediments in the Yabucoa ZSF may include granite and diorite, or sandstones and siltstones that are comprised of volcanic sediments (e.g. lava, tuff, and breccia). Small limestone lenses or areas of hydrothermally altered rock may also occur. These rock types are extrapolated from a hydrogeological map of Puerto Rico by Briggs and Akers (1965).

3.4.2.2 Sea Floor Characteristics and Sediment Textures

At the 24 stations surveyed in the Yabucoa ZSF, five had hard bottoms. These hard-bottom areas corresponded to steep portions of the shelf edge, as shown in Figure 3-46.

The sediment samples in the Yabucoa ZSF were predominantly silt; the average sand content was 25 to 30 percent. Silt and clay averaged 50 to 60 percent and 15 to 20 percent, respectively.

Interim Site - This site slopes steeply to the south. The southern portion is extremely steep and is devoid of sediments (EPA 1981). The sediments in the central and northern portions are sandy (50-80 percent sand), with 20 to 40 percent silt and less than 15 percent clay. The slope in the northern section is about 6 percent. The depth ranges from less than 180 m in the northern half to over 650 meters in the southern half.

Alternate Site 1 - The sediments are finer grained than at the interim site. The average sediment composition is 50 to 60 percent silt, 20 percent clay and 15 to 30 percent sand. Depths range from about 700 to over 1000 m. The slope at this site averages 15 percent.

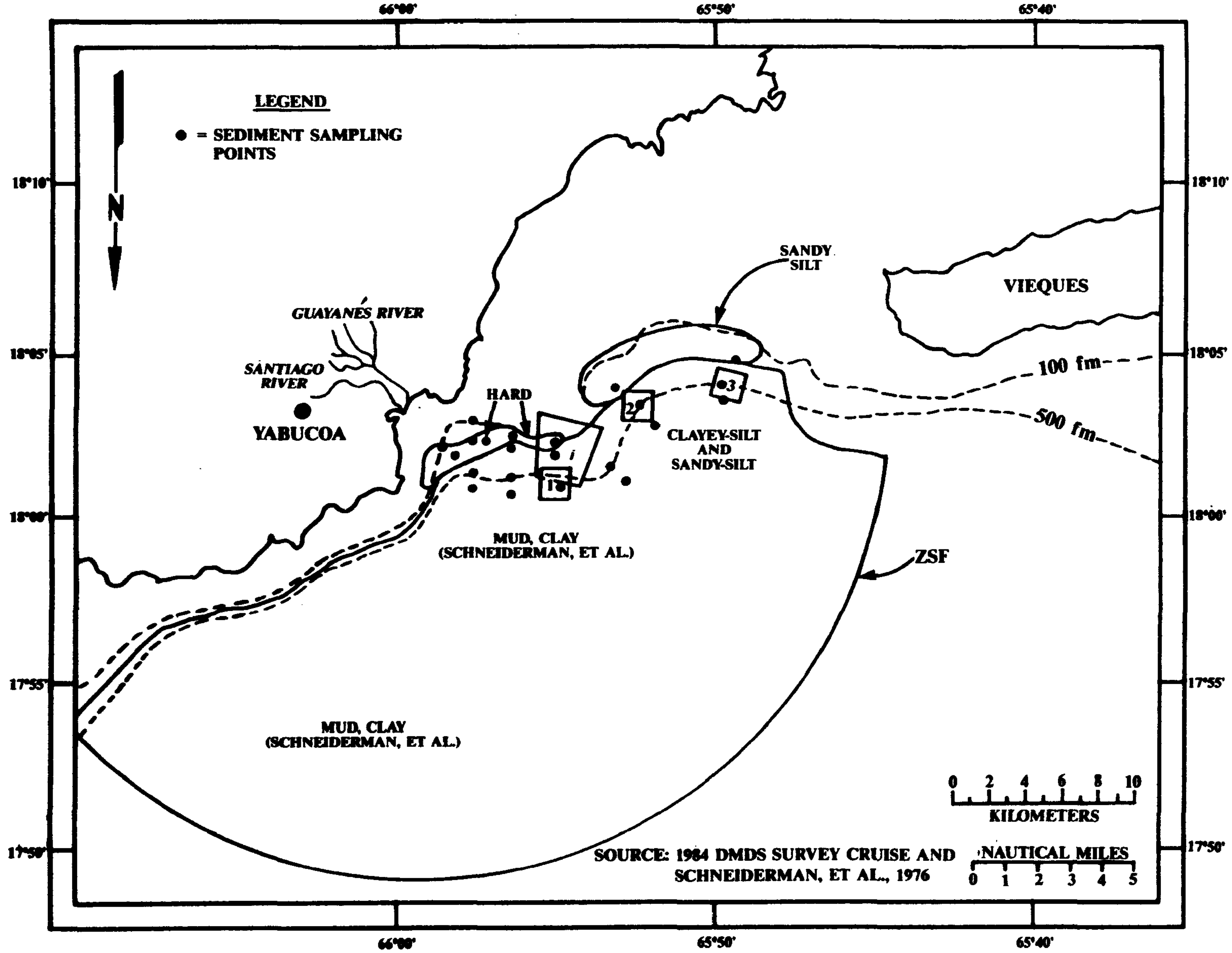


FIGURE 3-46. SEDIMENT SAMPLING POINTS AND IDENTIFIED SEA-FLOOR SEDIMENTS IN YABUCOA ZSF

Alternate Site 2 - Sediments contain less than 10 to 40 percent sand. The higher sand contents are found in the shallower areas and the lower sand contents are found in the deeper areas. This is likely due to the higher current velocities in the shallower zones. Depths at the site range from about 780 to over 1100 m. The slope averages 9 percent.

Alternate Site 3 - Samples taken in and near this site are silty, containing from 50 to 75 percent silt, 10 to 45 percent sand and 10 to 20 percent clay. As with sediments at alternate site 2, the sandier sediments at this site are found in the shallower waters. Depths range from about 230 to about 800 m. Slopes range from 22 to 28 percent.

3.4.2.3 Sediment Mineralogy

The sediments in the shallower portions of the Yabucoa ZSF are very coarse grained and are predominantly marine in origin. The shallow, high energy areas contain shell fragments with less than 2 percent noncalcareous material (Schneidermann et al. 1976; Bowman et al. 1975). The deeper portions of the Yabucoa ZSF accumulate fine-grained, land-derived and marine materials. The deepest areas contain the more clayey sediments and the areas having intermediate depths have siltier sediments (1984 survey cruise). Because the sediments are derived from both marine and land sources, the sand fraction is likely to contain predominantly calcareous materials, with only minor amounts of quartz and other minerals that are resistant to weathering. The sand fraction is predominantly calcareous materials on most of the outer shelf of Puerto Rico (Schneidermann et al. 1976).

The silt fraction is very-fine material, and contains very small amounts of organic materials. Samples collected in the shallow, high energy areas north of the Yabucoa ZSF contained less than 1 percent organic material. Most of this material was plant debris (Bowman et al. 1975). The mineralogy of the clay fraction is likely to be highly variable. Data on the types of clay minerals present were not available.

3.4.3 Water Quality

Surface waters throughout the Yabucoa ZSF are clean, warm, oxygen saturated and nutrient depleted. Below the surface mixed layer, oxygen remains undepleted, and nutrient levels become very high. In summary, water quality in the area of the interim and alternate sites is excellent, and is typical of tropical open-ocean conditions.

3.4.3.1 Turbidity

Secchi disc depth readings taken from shallow (<15 m) nearshore waters (less than 2 nmi offshore) near Yabucoa and Humacao, 8-9 nmi north of Yabucoa Harbor, ranged from 3-42 m (Puerto Rico Department of Public Works 1974). The lower values, indicating turbid water, were from sites closest to shore and higher values, indicating greater clarity, were further from shore. Concentrations of suspended material in the area of the Vieques deep water disposal site (in the ZSF) are presented in Figure 3-47 (EG&G 1978). Values range from 0.2-5.7 mg/l above the pycnocline to 0.1-2.5 mg/l just below the pycnocline, and 0-0.48 mg/l in the near bottom waters. All of the turbidity readings were well below 1.0 Nephelometric Turbidity Units (NTU), which indicates that water in this area is optically clear and contains little suspended material.

3.4.3.2 Dissolved Oxygen

Dissolved oxygen concentrations are consistently at or near saturation levels in the surface waters near Yabucoa (EG&G 1978; Atwood 1976). Figure 3-48 presents the average dissolved oxygen depth profile by season for Cabo Mala Pascua, about 10 nmi southwest of Yabucoa Harbor. Little change in dissolved oxygen concentration by season can be observed. The area is characterized by an oxygen-rich, warm surface layer about 75 m deep. The greatest average dissolved oxygen values were measured in the winter. The dissolved oxygen minimum occurred at about 200 m, with slightly shallower depths in the spring and slightly deeper in the summer. The dissolved oxygen content in the mid to bottom waters dropped to a minimum of 4.1 ml/l in the spring. The majority of the dissolved oxygen values were greater than 4.5 ml/l. A similar profile showing little seasonal variation was measured off Punta Tuna, about 5 nmi southwest of Yabucoa (Atwood et al. 1976).

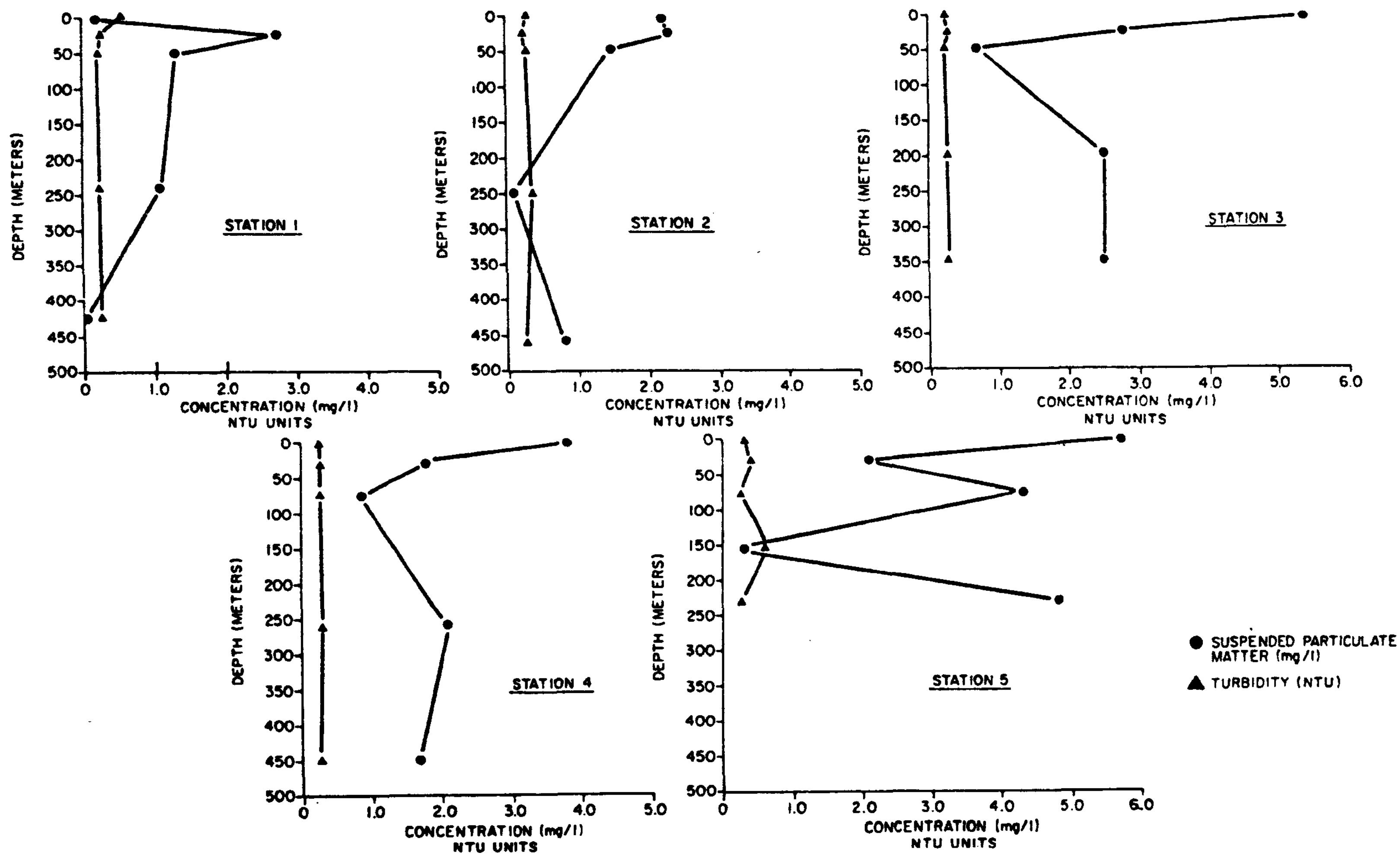


FIGURE 3-47. SUSPENDED PARTICULATE MATTER CONCENTRATIONS AND TURBIDITY PROFILES AT THE ROOSEVELT ROADS NAVAL STATION DISPOSAL SITE

Source: EG&G 1978.

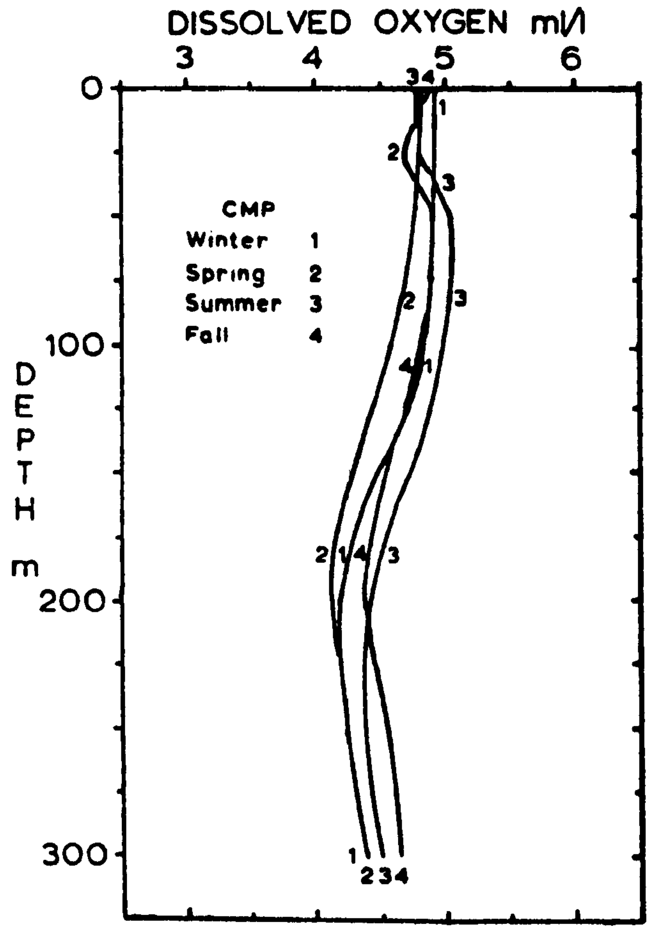


FIGURE 3-48. AVERAGED DISSOLVED OXYGEN DEPTH PROFILES, BY SEASON, AT CABO MALA PASCUA, 1973 AND 1974

Source: Wood et al. 1975e.

3.4.3.3 Nutrients

Nutrient levels in surface waters exhibit little seasonality, reflecting the relatively stable marine conditions associated with Puerto Rico's tropical climate. Surface waters are low in nutrients (phosphate, nitrate and silicate). Concentrations of these major nutrients increase with depth below the pycnocline.

Seasonal concentrations of reactive phosphate measured near Cabo Mala Pascua are presented in Figure 3-49 (Wood et al. 1975d). Surface concentrations are generally low (0.05 ug-at P/l) throughout the year. Phosphate values remain low down to nearly 200 m and then increase to 0.30 ug-at P/l at the deepest point sampled (Atwood et al. 1976). Phosphate profiles in the vicinity of Punta Tuna exhibited a similar pattern. Values ranged from 0.0-0.25 ug-at P/l at the surface and increased to 1.7-1.9 ug-at P/l at 1000 m (Atwood et al. 1976; DOE/EA-0062). There are slight seasonal variations in phosphate concentration.

Summer and fall concentrations of nitrate measured near Cabo Mala Pascua are presented in Figure 3-50 (Wood et al. 1975d). Surface nitrate concentrations were low in the upper mixed layer. At 150 m nitrate concentrations began to increase to 10.5 ug-at N/l in the summer and 20 ug-at N/l in the fall.

Similar nitrate profiles have been observed elsewhere in the Yabucoa study area. Nitrate concentrations around Punta Tuna increased from 1 micromolar at the surface to 26 micromolar at 1000 m (DOE).

Surface silica values are low. Studies in the vicinity of Yabucoa and Humacao (Puerto Rico Department of Public Works 1974) measured silica concentrations ranging from 0.09-0.6 mg/l in surface waters. Atwood et al. (1976) measured silicate concentrations in subsurface waters in the vicinity of Punta Tuna (Figure 3-51). Silicate concentrations in the upper mixed layer ranged from 1-3 ug-at S/l. Silica concentrations began to increase at 200 m and reached 27 ug-at S/l at the deepest point sampled (1000 m). The vertical distribution pattern of silicate did not vary substantially throughout the study.

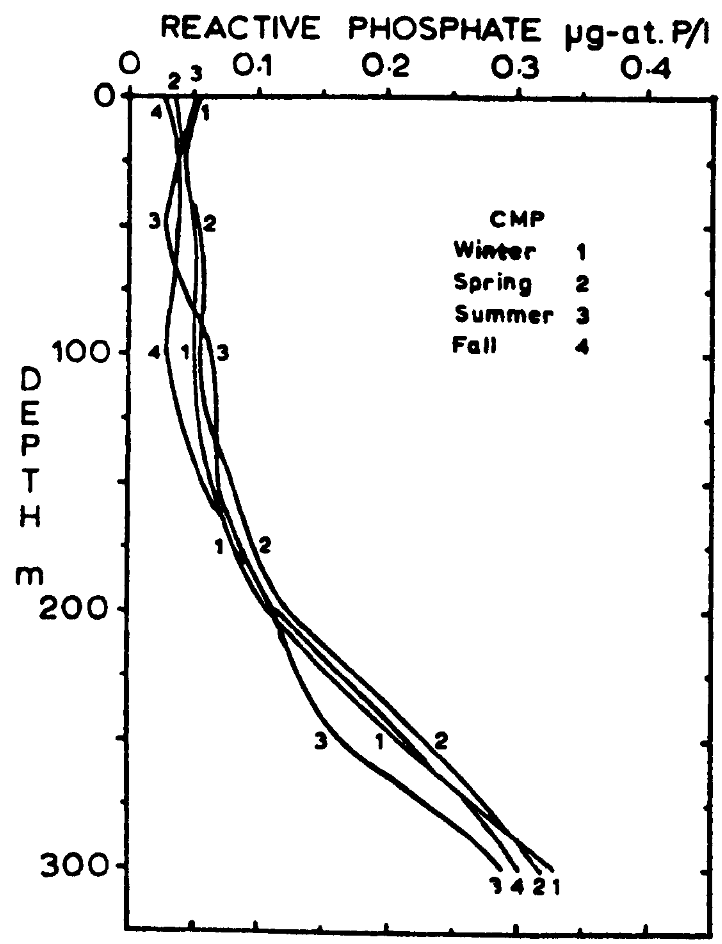


FIGURE 3-49. AVERAGED REACTIVE PHOSPHATE DEPTH PROFILES, BY SEASON. AT CABO MALA PASCUA, 1973 AND 1974

Source: Wood et al. 1975e.

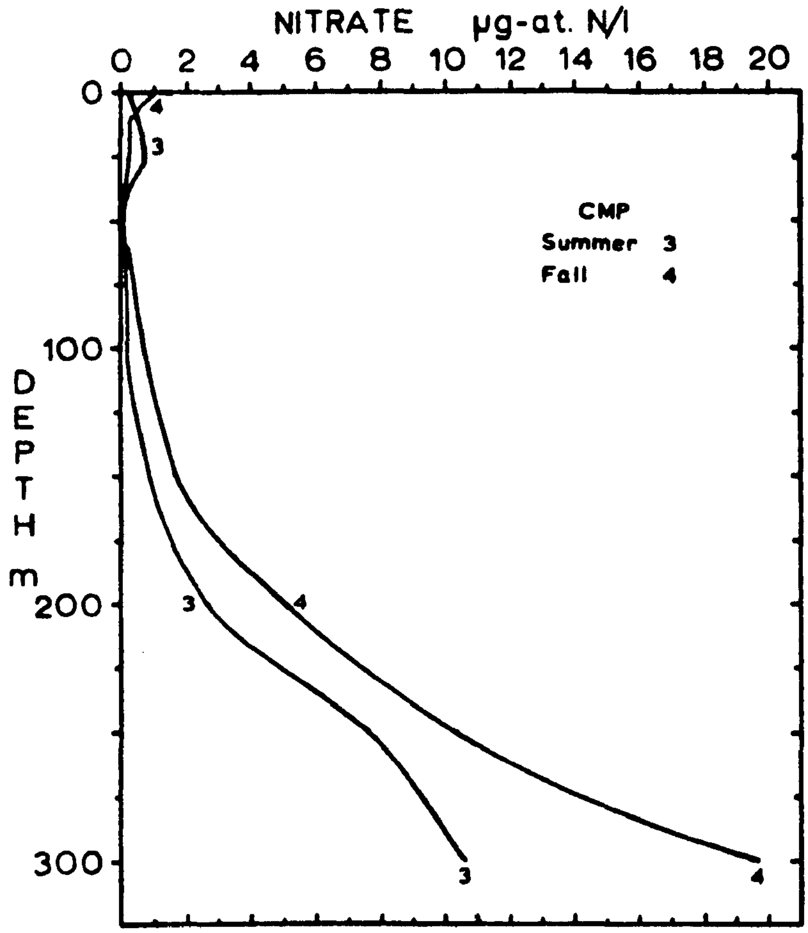


FIGURE 3-50. AVERAGED NITRATE DEPTH PROFILES FOR THE SUMMER AND FALL SEASONS, AT CABO MALA PASCUA, 1974

Source: Wood et al. 1975e.

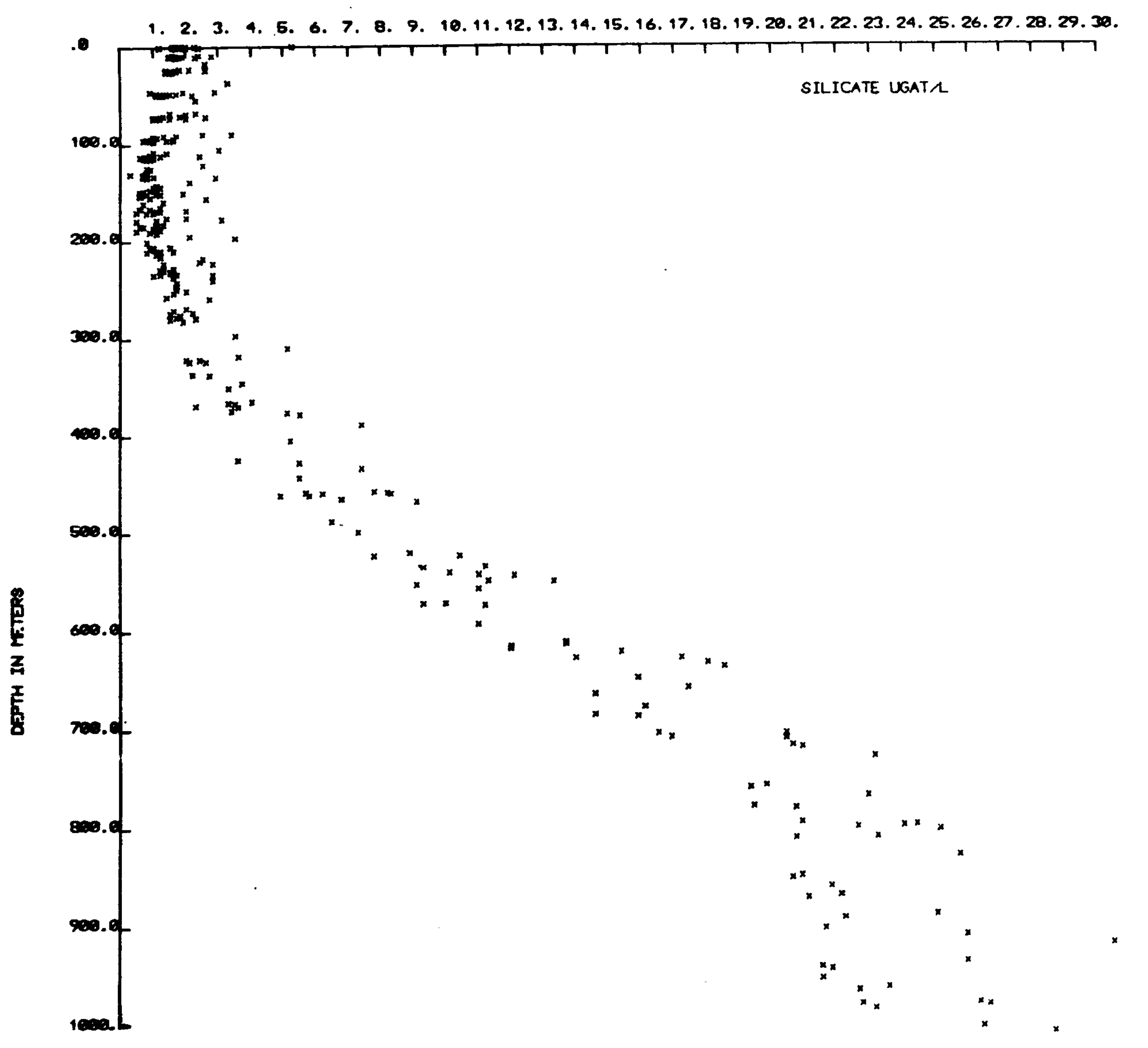


FIGURE 3-51. COMPOSITE SILICATE DEPTH PROFILES OF ALL UNIVERSITY OF PUERTO RICO OTEC CRUISES, SEPTEMBER 1975 TO MAY 1976

Source: Wood et al. 1976.

3.4.4 Biota

Species identified in the Yabucoa study area are included in the species list presented in Table 3-5.

3.4.4.1 Benthic Invertebrates

Information presented in this section is based on analyses of the biological samples conducted on EPA's 1984 DMDS survey cruise in Puerto Rico (JRB 1984).

The benthic community in the Yabucoa study area is dominated by deposit feeding organisms (primarily polychaetes) typical of fine-grained sediments occurring at the disposal site. However, increased numbers of filter feeders were present, reflecting the relatively heterogenous sedimentary environment at the Yabucoa site. Two station groups were distinguished based on cluster analysis. Both groups contain stations representing a broad range of survey depths (600 to 3300 feet), and are characterized by extremely variable values for diversity and evenness (Table 3-4).

Polychaetes (185 taxa) were dominant in the Yabucoa study area, followed by crustaceans (90 taxa), molluscs (57 taxa, primarily gastropods and pelecypods), 16 minor taxa (primarily sipunculids), and echinoderms (9 taxa). The majority of the 357 total taxa were deposit feeders, however, filter feeders, carnivores and herbivores were also common as would be expected from the relatively heterogenous sedimentary environment. The mean number of taxa per sample (station and replicate) was relatively low (40) and extremely variable, ranging from 12 to 77. The total number of individuals per sample (all taxa combined) was moderate (mean of 87), but was highly variable, with a range of 18 to 615. The number of individuals per sample for each taxon was low, with the majority of taxa occurring at densities of only one to four individuals per $0.065m^2$.

3.4.4.2 Coral Reefs

Reefs are well developed along the east coast of Puerto Rico, with exceptional development found in the fringing reefs around La Cordillera, about 40

	TTAXA	SCNT	SHNWVR	PIELOU
GRAVEL	0.33560	0.56375	-0.40884	-0.51382
	0.1601	0.0119	0.0822	0.0244
	19	19	19	19
SAND	0.40724	0.62189	-0.29218	-0.47037
	0.0835	0.0045	0.2248	0.0421
	19	19	19	19
SILT	-0.45420	-0.66231	0.30607	0.49415
	0.0508	0.0020	0.2025	0.0315
	19	19	19	19
CLAY	-0.30164	-0.52923	0.30079	0.43724
	0.2095	0.0198	0.2108	0.0612
	19	19	19	19
FINES	-0.42693	-0.65298	0.32089	0.50161
	0.0683	0.0024	0.1804	0.0287
	19	19	19	19
DPFT	-0.51951	-0.10736	-0.32599	-0.17133
	0.0111	0.6258	0.1290	0.4344
	23	23	23	23

Table 3-4 Correlation Matrix for Sediment Grain Size, Biological Parameters and Station Depth from the March, 1984 EPA/JRB Survey Offshore of Yabucoa , Puerto Rico. (Correlation coefficients are listed first with significance levels listed second and the number of comparisons third). TTAXA = total number of taxa, SCNT = total number of individuals of all taxa, SHNWVR = Shannon - Weaver Diversity Index, PIELOU = Pielou's Eveness Index.

miles northeast along the coastline from Yabucoa (Almy and Carrion-Torres 1963). As shown in Figure 3-52, one reef is located about 4 nmi northeast of Punta Guayanes, considerably inshore of the sites under consideration in this EIS. No corals have been positively identified at any of the alternate sites or the interim site. However, an unspecified sinuous ridge that has morphology similar to a coral reef is identified by the NOAA topographic chart for the region (NOAA 1980) as passing through the central northern, shallow section of the Yabucoa interim site. At that point the depth of the sea floor is typically about 36 m (20 fathoms), with the narrow ridge extending upwards to a depth below the surface of only 16 m (9 fathoms).

3.4.4.3 Mangrove Breeding and Nursery Areas

No areas of special importance as breeding or nursery areas for juvenile fish have been described for areas near Yabucoa. Numerous fish species are especially abundant in the shallow shelf area immediately to the north of the Yabucoa study area. A literature search did not produce evidence of specific coastal breeding areas being used preferentially by local fish species. However, all shelf areas are spawning locations, with perhaps some preference shown by certain species for spawning near the shelf edge (Colin 1983).

3.4.4.4 Preserves and Reserves

Critical wildlife habitats in the Yabucoa study area include the Ceiba Forest Reserve, about 11-12 nmi northeast of the Port of Yabucoa and the Humacao Swamp and Pterocarpus Forest Reserve, about 15 km (8 nmi) to the northeast (Figure 3-53).

The Ceiba Forest Reserve is inhabited by manatees, an endangered species that feeds in seagrass beds at the shoreline. There is also a large population of the white-cheeked pintail, an endangered duck species. The Ceiba Forest Reserve also contains the West Indian tree duck, which is on the Commonwealth of Puerto Rico endangered species list. The heavily forested Humacao Preserve contains the most extensive remaining tract of the rare *Pterocarpus officinalis*.

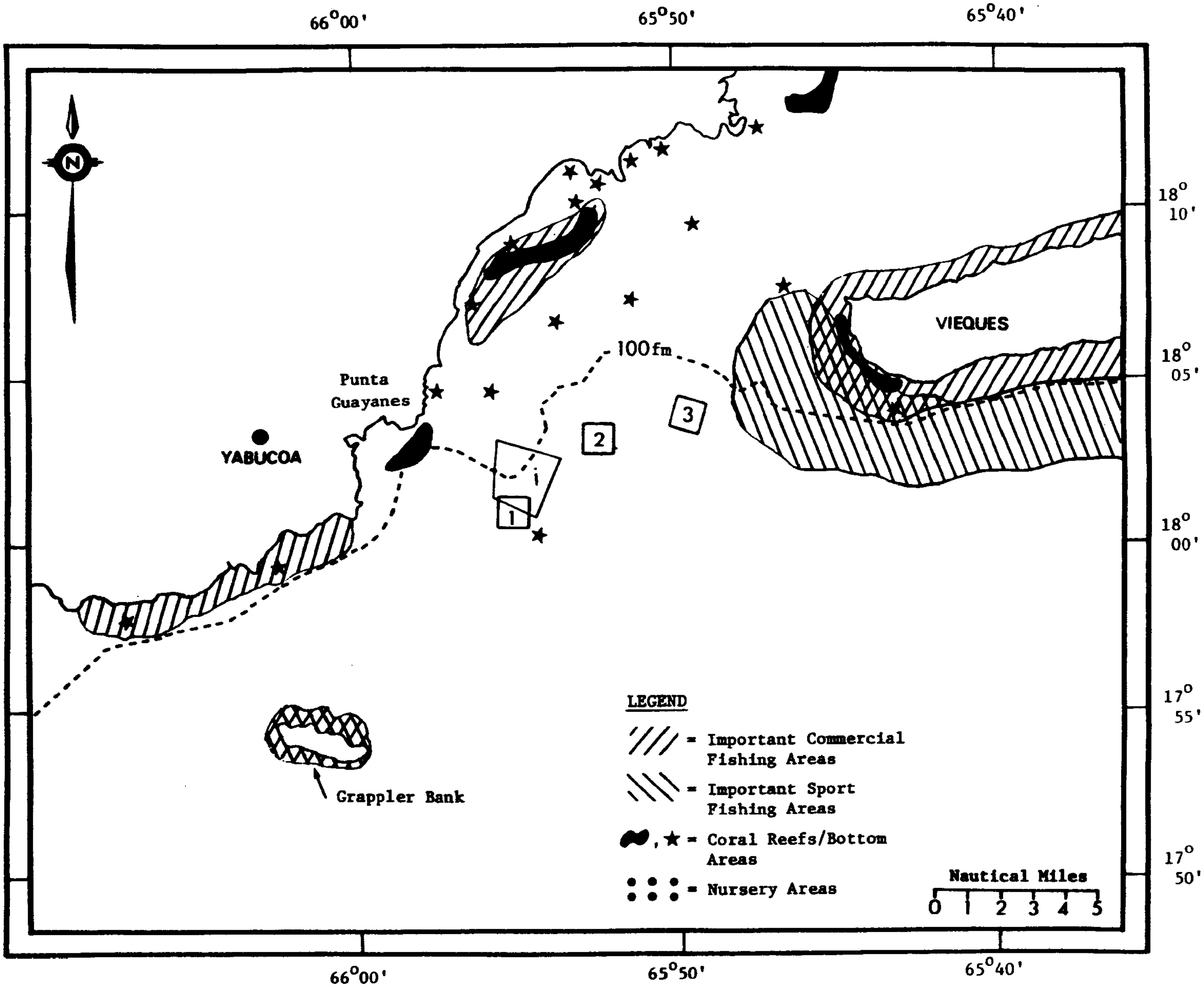


FIGURE 3-52. LIVING MARINE RESOURCES NEAR YABUCOA

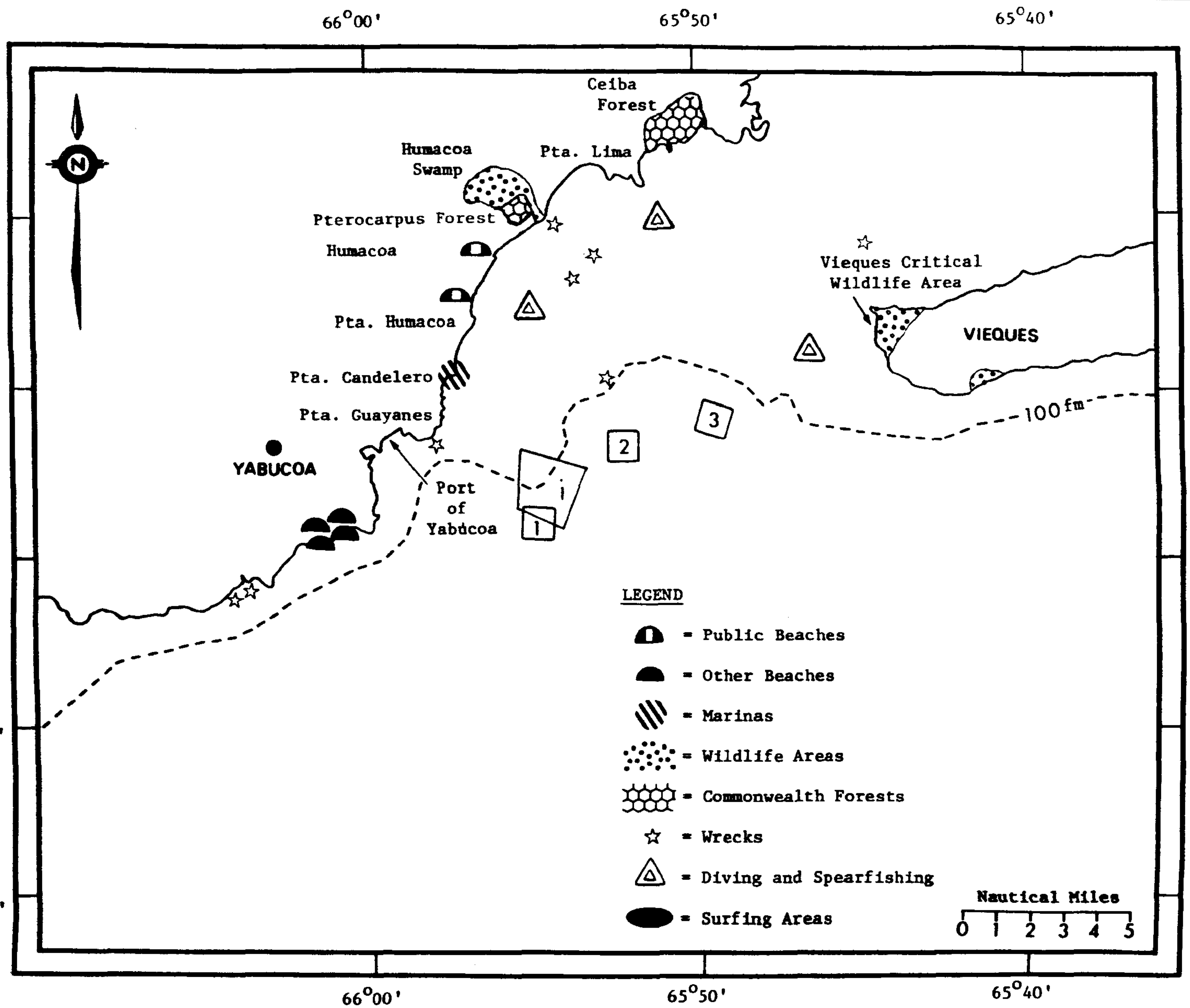


FIGURE 3-53. RECREATIONAL AREAS, PRESERVES AND SHIPWRECKS NEAR YABUCOA

3.4.4.5 Threatened and Endangered Species

Threatened and endangered marine species in Puerto Rico that may be affected by dredged material disposal include several sea turtles and the brown pelican. Vieques Island, 13 to 14 nmi east of Yabucoa and 5 nmi east of alternate site 3, is a nesting ground for sea turtles. No regular sea turtle habitats have been reported within 5 nmi of the proposed sites.

Any brown pelicans that live on the mainland shore or Vieques Island would not be expected to frequent areas affected by disposal at any of the sites; pelicans typically remain close to shore except for brief trips or while migrating.

A list of threatened and endangered species identified in the Yabucoa study area is presented in Table 3-6.

3.4.5 Recreational Areas

A number of recreational sites exist within a 15 mile radius of Yabucoa including the Grappler Bank area, approximately 18 km (10 nmi) southeast of the Port of Yabucoa, the site of a growing fishery. Another intensively used sport fishing area is located in the southern and western nearshore waters of Vieques Island (Figure 3-52).

In general, the east coast of Puerto Rico is most heavily used by tourists around the resort towns of Humacao and Fajardo (Figure 3-53). Sport fishermen and divers from Humacao travel from the resort area out to Vieques Island. A major attraction is snorkeling and diving around the reefs found along the shelf in this area (Figure 3-52).

Other recreational features of the area include a number of beaches and a marina (see Figure 3-53). Sailing and windsurfing equipment is available out of Humacao (Puerto Rico Tourism, CO. 1983).

3.4.6 Shipping Lanes

There are no formally established shipping lanes for Puerto Rican ports and harbors. A two-year study conducted by the Seventh Coast Guard District (46 FR 48376, October 1, 1981) determined that such lanes were not warranted by the amount and direction of vessel traffic near the island.

3.4.7 Mineral Resources

There are no oil or gas, magnetite, or other known mineral deposits in the vicinity of the Yabucoa ZSF or any of the sites (Alanso 1983; Guillou and Glass 1957; Cox and Briggs 1973). There are no solar salt producers along this section of the Puerto Rico Coast (White and Tuchman 1982). A major quartz sand source is located about 5 nmi to the north of the ZSF, beyond the island of Vieques (Grove and Trumball 1978).

3.4.8 Shipwrecks or Other Features of Historical or Cultural Importance

There is one shipwreck 1 nmi south of the southern corner of the Yabucoa interim site, and less than a mile southeast of alternate site 1 (Figure 3-53). All other shipwrecks reported in this area are on the shelf area two or more nautical miles to the south of the ZSF (University of Puerto Rico 1974).

No other features of historical or cultural importance have been identified in the Yabucoa ZSF.

3.4.9 Fisheries

The bulk of the Puerto Rican fishing industry consists of small boats fishing over the shelf. The east coast is third among the four coasts in landings, with 8 x 10^5 pounds (about 17% of total Puerto Rican landings) for the period October 1982-July 1983 (Caribbean Fishery Management Council, 1984). Of the east coast total, 6.6 x 10^4 pounds were reported from the Yabucoa fishing district. This composed about 1.4 percent of the island's total landings. Figure 3-52 shows coral reefs and fishing grounds in the vicinity of Yabucoa. The wide shelf area northward from Yabucoa is fished extensively. The narrow "sill-reef" zone southwards along the coast from

Yabucoa is also important for fisheries in this area (Cole 1976). The Grappler Bank (about 14 nmi southwest of the Port of Yabucoa) is an important fishing area that lies within the Yabucoa study area but was excluded from the ZSF (Puerto Rico Department of Agriculture 1980). It is 8 nmi from alternate site 1.

3.5 IDENTIFICATION OF ORGANISMS

A taxonomic list of scientific names and common names of species identified in the Puerto Rico dredged material disposal site areas is presented in Table 3-5. A similar list for Puerto Rican threatened and endangered species is presented in Table 3-6.

Table 3-5. Taxonomic List of Species Identified in the Study Area of the Puerto Rico Dredged Material Disposal Sites

---

Animals

- Phylum Coelenterata (Cnidaria)
  - Class Anthozoa
    - Subclass Zoantharia
      - *Acropora cervicornis* -- staghorn coal
      - *Acropora palmata* -- elkhorn coral
      - *Bartholomea annulata* -- sea anemone
      - *Montastrea cavernosa* -- cavernous star coral
      - *Pocillopora* sp. -- coral
      - *Porites furcata* -- finger coral
      - *Siderastrea siderea* -- star coral
      - *Stephanaria* sp. -- coral

- Phylum Rhynchocoela (nemertine worms or ribbon worms)
  - Unidentified spp.

- Phylum Mollusca
  - Class Gastropoda (snails, conchs, etc.)
    - *Littorina angulifera* -- periwinkle
  - Class Pelecypoda (bivalves)
    - *Crassostrea rizophorae* -- oyster
    - *Nuculana* sp. -- clam
    - *Vesicomya pilula* -- clam
  - Class Cephalopoda
    - Order Dibranchia
    - Suborder Octopoda (octopi)
      - Unidentified spp.

- Phylum Annelida (segmented worms)
  - Class Polychaeta
    - *Euchone* sp. -- a filter feeding Sabellid tubeworm
    - *Levinsenia uncinata* -- an herbivorous Paraonid
    - *Melinna* sp. -- a deposit feeding Ampharetid
    - *Prionospio* sp. -- a filter/deposit feeding Spionid
    - *Sabellastarte magnifica* -- a filter feeding Sabellid tubeworm

- Phylum Sipunculida
  - *Golfingia tricocephala* -- peanut worm

Table 3-5. Taxonomic List of Species Identified in the Study Area of the Puerto Rico Dredged Material Disposal Sites (continued)

Animals (continued)

Phylum Arthropoda
Subphylum Mandibulata

Class Crustacea
Subclass Copepoda -- copepods
Subclass Malacostraca
Order Decapoda
Aratus pisonii -- crab
Callinectes danae -- a portunid crab
Gonodactylus oerstedii -- mantis shrimp
Macrobrachium carcinus -- freshwater prawn
Mithrax sculptus -- green crab
Panulirus argus -- spiny lobster
Petrolisthes galathinus -- an anomuran crab
Stenopus hispidus -- shrimp

Phylum Echinodermata

Class Ophiuroidea
Ophiothrix angulata -- spiny brittle star

Class Echinoidea
Echinometra lucunter -- sea urchin

Class Holothuroidea
Holothuria parvula -- sea cucumber
Stichopus badionotus -- spotted sea cucumber

Phylum Chordata
Subphylum Urochordata (Tunicata)

Class Ascidia
Ascidia nigra -- sea squirt

Subphylum Vertebrata

Class Osteicthyes (bony fish)
Subclass Actinopterygii (ray-finned fish)
Order Beloniformes
Family Hemiramphidae -- halfbeaks
Hemiramphus sp. -- ballyhoo
Order Beryciformes
Family Holocentridae -- squirrelfishes

Table 3-5. Taxonomic List of Species Identified in the Study Area of the Puerto Rico Dredged Material Disposal Sites (continued)

Animals (continued)

Order Clupeiformes
- Family Elopidae -- tarpons
  - *Elops saurus* -- ladyfish
  - *Megalops atlanticus* -- tarpon

Order Perciformes
- Family Balistidae -- triggerfishes
  - *Balistes* sp. -- triggerfish
- Family Coryphaenidae -- dolphins
  - *Coryphaena equiselis* -- pompano
- Family Gerreidae -- mojarras
  - *Gerres cinereus* -- yellowfin mojarra
- Family Istiophoridae -- billfishes
  - *Makaira* sp. -- marlin
- Family Lutjanidae -- snappers
  - *Lutjanus* sp. -- snappers
- Family Mugilidae -- mullets
  - *Mugil* sp. -- mullet
- Family Mullidae -- goatfishes
- Family Pomadasyidae -- grunts
  - *Haemulon* sp. -- grunts
- Family Scaridae -- parrotfishes
  - *Scarus* sp. -- parrotfish
  - *Sparisoma* sp. -- parrotfish
- Family Scombridae -- tunas
  - *Scomber* sp. -- mackerel
  - *Scomberomorus cavalla* -- king mackerel
- Family Serranidae -- sea basses and groupers
- Family Sparidae -- porgies
  - *Archosargus rhomboidalis* -- sea bream
- Family Sphyraenidae -- barracudas
  - *Sphyraena barracuda* -- great barracuda

Plants

Subdivision Angiospermae (flowering plants)
- Class Magnoliopsida
  - Order Cornales
    - Family Rhizophoracea (mangroves)
      - *Avicennia tomentosa* -- black mangrove
      - *Rhizophora mangle* -- red mangrove

Table 3-6. Taxonomic List of Threatened and Endangered Species Identified in the Study Area of the Puerto Rico Dredged Material Disposal Sites

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Animals

Phylum Chordata
Subphylum Vertebrata

- Class Reptilia
  - Order Testudines (Chelonia)
    - Family Cheloniidae (sea turtles)
      - *Caretta caretta* -- loggerhead turtle
      - *Chelonia mydas* -- green turtle
      - *Dermochelys coriacea* -- leatherback turtle
      - *Eretmochelys imbricata* -- hawksbill turtle
      - *Lepidochelys* sp. -- Olive Ridley turtle
- Class Aves (birds)
  - Order Anseriformes
    - Family Anatidae
      - *Anas bahamensis* -- white-cheeked pintail duck
      - *Dendrocygna arborea* -- West Indian tree duck
  - Order Pelecaniformes
    - Family Pelecanidae
      - *Pelecanus occidentalis* -- brown pelican
- Class Mammilia
  - Order Cetacea
    - Suborder Mysticeti
      - *Megaptera novaeangliae* -- humpback whale
  - Order Sirenia
      - *Trichechus manatus* -- West Indian manatee

Plants

Pterocarpus officinalis -- pterocarp tree

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4. ENVIRONMENTAL CONSEQUENCES

4. ENVIRONMENTAL CONSEQUENCES

4.0 INTRODUCTION

The following sections of this chapter describe general and site-specific impacts expected from ocean disposal of dredged material. Section 4.1 discusses the analytical transport model used to estimate distribution patterns and concentrations of dumped dredged material. Section 4.2 discusses the sensitivities of various marine animals to elevated sediment levels. Section 4.3 discusses the lethal and sublethal thresholds for reef-building corals. Site-specific effects are presented in Sections 4.4 through 4.7. Sections 4.8 through 4.10 discuss the consequences of the proposed site designations for all harbors.

4.1 METHODS FOR EVALUATING EXPECTED TRANSPORT OF SEDIMENT PLUMES FROM DISPOSAL SITES

An analytical computer model was developed for this EIS to predict the transport of dredged materials released at the proposed disposal sites off the coasts of Puerto Rico. The model calculates the water column concentrations of solids, based on the specific characteristics of the dredged materials and the oceanographic characteristics existing at each disposal site. The model is based on the following parameters:

- Volume of disposed dredged material (m^3)
- Density of dredged material (kg/m^3)
- Water content of dredged material (%)
- Subsurface current speed at disposal site (cm/sec)
- Water density profile
- Dredged material grain size distribution
- Bottom depth profile.

Using these data, the following outputs are generated:

- Dilution 4 hours after dumping (the suspended sediment dilution factor)
- Bottom sediment concentration distribution (relating to sedimentation rate)
- Bottom sediment thickness distribution (relating to burial mound thickness)

The analytical model is based on the three-phase sediment descent scheme introduced by Koh and Chang (1973). The phases of descent are:

- Convective descent
- Dynamic collapse
- Passive dispersion

In convective descent, the disposed material sinks rapidly, entraining ambient water as it sinks. If the mass of dredged material and entrained water reaches the neutral buoyancy depth (where the density of the diluted dredged material equals the density of the surrounding water), dynamic collapse begins. In dynamic collapse, the dredged material cloud becomes compressed around the neutral buoyancy depth. After a few minutes of dynamic collapse, passive dispersion begins. At this point, the dredged material reacts as individual particles subject to advective, dispersive, and settling forces until the particles land on the sea floor.

The transport model addresses all three descent phases. Appendix G provides a detailed discussion of the model's development and application to determine bottom sediment concentration, thickness distributions and suspended solids concentration of each plume four hours after dumping.

4.2 SENSITIVITIES OF MARINE ORGANISMS OTHER THAN CORALS TO SUSPENDED SEDIMENTS

Stern and Stickle (1978) reviewed the effects of turbidity and suspended sediments on aquatic organisms. In these studies, lethal or sub-lethal effects occurred at concentrations of suspended solids as low as 40 mg/l for the copepod Acartia tonsa and as high as 77,000 mg/l for the euryhaline shrimp Palaemon macrodactylus (Table 4.2.1).

Among the organisms tested, those with the greatest sensitivity to suspended sediment concentrations included two copepods (which were unable to feed above thresholds of 40 mg/l and 250 mg/l), fish eggs (which were delayed in hatching at 100 mg/l), and bivalve molluscs (which had unusually high rates of abnormal development at 188 mg/l). Adult benthic crustaceans tested showed tolerances for much higher concentrations of sediments. Results of 200-hour LC_{50} tests for these organisms ranged from 32,000 mg/l for the Dungeness crab (Cancer magister) to 77,000 mg/l for the euryhaline shrimp Palaemon macrodactylus. A 25-day test with a juvenile Dungeness crab resulted in an LC_{50} value of 9,000 mg/l, the lowest value for any of the tested benthic crustaceans.

Comparison of these sensitivity levels to results of the sediment transport modeling described above indicates that only the most sensitive organisms tested--the copepods, fish eggs, and perhaps some bivalve eggs--would be seriously affected by environmental suspended sediment concentrations expected from open-ocean disposal of dredged materials off Puerto Rico. All effects observed at relevant concentrations in the laboratory tests were chronic effects, resulting from an exposure of several hours or days to the test concentrations of sediments. Because of the transient nature of suspended sediment plumes in well-flushed, open-ocean waters, neither pelagic (free-swimming) marine animals such as fish, shrimp, and squid, nor plankton will be exposed for significant time periods to dredged material disposal plumes.

Principal mechanisms that might result in chronic exposures to turbidity as a result of disposal at deep, open-ocean sites off Puerto Rico are as follows:

- Settling and resuspension of materials resulting in elevated turbidities in a layer just above the sea floor,
- Trapping of a portion of the sediment plume in a shallow, poorly-mixed, or semi-enclosed area where it enters shallow waters near a coastline, or

TABLE 4.2.1. SUMMARY OF THE ADVERSE EFFECTS OF SUSPENDED SEDIMENTS ON MARINE ORGANISMS

Species	Effect	Result
Crustacean-Zooplankton		
Eurytemora affinis		
Copepod	Decrease in rate of ingestion	250 mg/l solids[b]
Acartia tonsa		
Copepod	Decrease in rate of ingestion	40 mg/l solids[b]
Crustacean-Benthic		
Anisogammarus confervicolus		
Amphipod	200 hour-LC_{50}	35,000 mg/l Kaolin[b]
Crangon nigromaculata		
Spot tailed sand shrimp	200 hour-LC_{50}	50,000 mg/l Kaolin[b]
Palaemon macrodactylus		
Euryhaline shrimp	200 hour-LC_{50}	77,000 mg/l Kaolin[b]
Cancer magister		
Dungeness crab	200 hour-LC_{50}	32,000 mg/l Kaolin[b]
Cancer magister (juvenile)		
Dungeness crab	25 day-LC_{50}	9,000 mg/l Kaolin[a]
Mollusc-Bivalve		
Crassostrea virginiea		
American oyster	Reduction in number of eggs developing normally	188 mg/l silt[b]
Fish		
Perca flavescens (eggs)		
Yellow perch	Delayed hatching	100 mg/l suspended sediment[b]
Aplodinotus grunniens (eggs)		
White perch	Delayed hatching	100 mg/l suspended sediment[b]
Morone chrysops (eggs)		
Striped bass	Delayed hatching	100 mg/l suspended sediment[b]
Alosa pseudoharengus (eggs)		
Alewife	Delayed hatching	100 mg/l suspended sediment[b]

Sources:

(a) Peddicord et al. (1978)
(b) Stern and Stickle (1978)

- Continuous, intensive disposal operations over a period of several days or weeks, as might occur from large-scale harbor construction activities, as opposed to typically short duration maintenance dredging operations.

4.3 METHODS FOR DETERMINING SENSITIVITY OF CORAL COMMUNITIES TO DREDGED MATERIAL DISPOSAL

Puerto Rico has well-developed coral reefs along its southern, eastern and western coastlines. Groupers, snappers, mojarras and many of the other finfishes caught by the small-scale fisheries depend on coral reef systems for food and protection. This section describes the types of sub-lethal and lethal damage to coral reefs that can be caused by turbidity and sedimentation from dredged material disposal at any location. It explains the methods used in this EIS to evaluate the potential for coral damage from the use of ocean Dredged Material Disposal Sites (DMDS's). Later sections of the chapter evaluate the effects of disposal at the particular interim and alternate sites considered for each harbor.

4.3.1 Types of Sediment Impact on Reef Communities

Coral reefs grow best in clear, well-flushed waters with low concentrations of suspended sediments and low rates of sedimentation. As turbidity and sedimentation increase, coral reefs undergo reduction in percent cover, reduction in species diversity, slowed growth rates, and the elimination of sediment-intolerant species (Bak 1978; Loy, 1976; Roy and Smith 1971).

There is little quantitative information on the effects of dredging or dredged material disposal on reef-associated fauna other than corals. The turbidity effect most frequently reported is the migration of fish from the affected area (Amesburg 1981; Brock et al. 1966; Galvin 1981). A reduction in the number of mollusc and echinoderm species has also been reported (Brock et al. 1966; Galvin 1981). Given the lack of quantitative information, it is difficult to predict specific effects of disposal on components of the community other than corals. As noted by Johannes (1978), "So central are corals to the integrity of the reef community, when they are killed migration or death of much of the other reef fauna ensues. Therefore the environmental tolerances of the reef community as a whole cannot exceed those of its corals, and this fact provides us with convenient preliminary criteria for setting up standards for protecting reef communities from pollution."

The principal mechanisms by which dredged material disposal can damage reef-building corals are: 1) turbidity; 2) sedimentation; 3) burial; 4) abrasion; and 5) toxicity. These mechanisms are discussed in detail in Appendix E. Three in particular, turbidity, sedimentation and burial, probably present the greatest threat.

4.3.2 Effects of Turbidity and Impact Threshold Levels

An increase in turbidity decreases the coral growth rates and ultimately causes mortality by reducing the amount of available light. All reef-building corals require light because the symbiotic algae contained in their tissues require light as an energy source for photosynthesis. Coral are dependent on these algae to produce substances needed in the deposition of the coral's carbonate skeleton. Continued exposure to high levels of turbidity results in loss of the algae and eventual death of the coral.

Concentrations of suspended sediment chronically in excess of 10 mg/l result in significant degradation of coral reefs, with reductions in growth rates typically occurring at lower concentrations (see Appendix E). Nichols et al. (1972) reported reefs at St. Croix to be severely stressed by dredging activities that raised suspended sediment concentration to 10 mg/l and above. Reefs of *Acropora palmata* at St. Thomas were near death in an area where suspended matter concentrations were about 20 mg/l (Grigg et al. undated, as reviewed by Rogers 1977). For comparison, ambient concentrations of suspended sediment in nearshore Caribbean waters are typically below 2 mg/l with high winds occasionally raising concentrations to 5 mg/l (Glynn 1976; Griffin 1974; 1976; Rogers 1977).

4.3.3 Effects of Sedimentation and Impact Threshold Levels

Sedimentation (the relatively gradual settling of sediment particles) can also result in mortality of corals or sublethal responses such as reduced growth rates. Deposition of sediment on reefs or rocky outcrops can also inhibit the settling of coral larvae, so that new reef areas cannot be established.

Inhibition of growth for some species has been reported at sedimentation rates of about 1 $mg/cm^2/day$ (Allen and Dodge 1974). On the other hand Kohlemainen (1973) found some species to be unaffected after 9 days exposure to 150 $mg/cm^2/day$ though growth rates were not measured. A review of available literature suggests that two sedimentation rates, 10 and 50 $mg/cm^2/day$ are appropriate estimates of thresholds for morbidity and mortality of Puerto Rican corals (Appendix E). At sedimentation rates in excess of 50 $mg/cm^2/day$, only a small fraction of available substrate is typically occupied by living corals and only the most sediment-tolerant forms are capable of surviving (Randall and Birkaland 1978). Sedimentation rates as low as 10 $mg/cm^2/day$ kill or exclude some sediment- intolerant species and produce sublethal responses in those species that are able to survive. Loya (1976) found that reefs in Puerto Rico exposed to sedimentation at a rate of 15 $mg/cm^2/day$ were characterized by lower coral species diversity and lower coral coverage of the available substrate than reefs typically exposed to 3 $mg/cm^2/day$. Lasker (1980) found that <u>Montastrea cavernosa</u> could remove up to 14 $mg/cm^2/day$. <u>M. Cavernosa</u> was reported to be a comparatively efficient sediment remover, so that many other species will tolerate significantly less sedimentation.

4.3.4 Effects of Burial

Burial is rapid, essentially instantaneous, smothering beneath a large amount of sediment, as opposed to the more gradual process of sedimentation. Most corals can survive burial for only a limited period of time. The duration of survival depends on the particular species. <u>Porites</u> spp. and <u>Pocillopora</u> spp. tested by Edmondson (1928) survived burial from 12 hours to 24 hours whereas <u>Stephanaria</u> spp. remained alive after five days. Kolehmainen (1973) studied the effects of burial on Puerto Rican corals and found that corals buried for less than 24 hours recovered completely, but tissue disintegration resulted if burial continued more than 30 hours.

A detailed review of available literature (Appendix E) suggests that burial beneath 1.5 mm of sediment (approx. 200 mg/cm^2) is lethal to many of the more sensitive species. Independent studies on Puerto Rico corals have found this depth of burial to cause mortality in *Siderastrea siderea* (Kolehmainen 1973) andd *Acropora palmata* (Rogers 1977). *Acropora palmata* and *Porites furcata*, are particularly sensitive corals that are abundant in Puerto Rican reef communities. Another slightly less sensitive species, *Acropora cervicornis*, (with a threshold sensitivity of 200 mg/cm^2 per day), is also common in Puerto Rico.

4.3.5 Conclusion: Coral Sensitivity Thresholds to Sedimentation

Based on the discussions of the preceding section and Appendix E, coral sensitivity thresholds considered in this EIS are 10 mg/cm^2 per day (0.1 kg/m^2 per day) of sedimentation for sub-lethal effects, and 50 mg/cm^2 per day (0.5 kg/m^2 per day) for lethal effects. In Sections 4.4, 4.5, 4.6, and 4.7, sediment dispersal patterns predicted from a transport model are compared to these threshold levels at each of the alternate sites. The results of those comparisons indicate whether the use of particular disposal sites would be expected to kill corals or to inflict sub-lethal damage by increasing sedimentation rates in areas containing living reefs.

4.4 ENVIRONMENTAL CONSEQUENCES OF DREDGED MATERIAL DISPOSAL FOR ARECIBO

This section summarizes the environmental impacts expected from disposal at each of the sites considered for Arecibo. A summary of the environmental characteristics and potential impacts at each site, as they pertain to protection under the ocean dumping regulations, is presented in Chapter 2 (Table 2-4).

4.4.1 Impacts on Beaches and Shorelines

There will be no measurable increases in sediment concentrations at any beaches or shorelines because of dredged material disposal at the interim site or any of the alternate sites. Sedimentation plumes from disposal at any of the sites would not be expected to reach the waters in the shore zone anywhere in the Arecibo area (Figure 4-1).

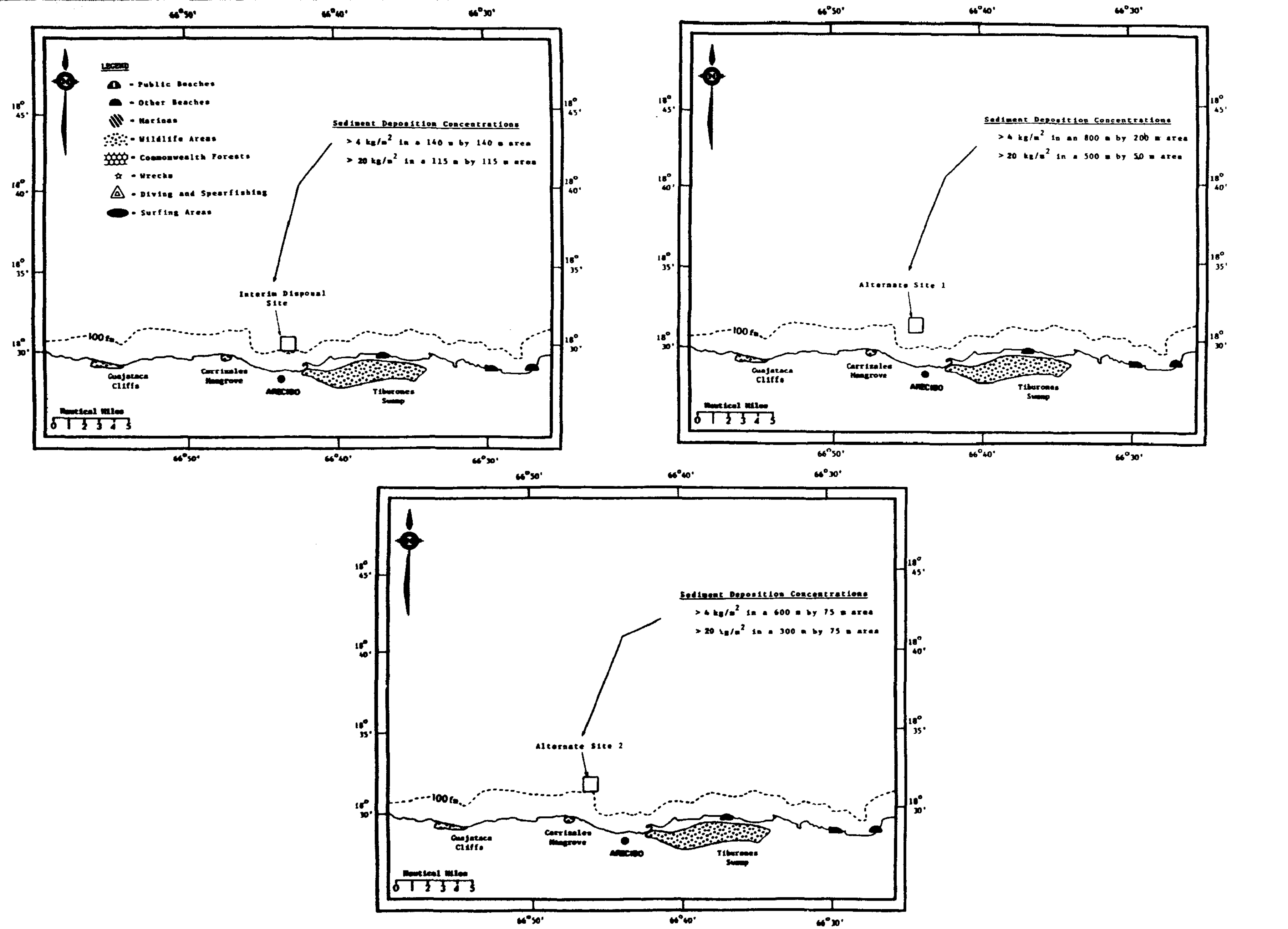

FIGURE 4-1. MAPS OF RECREATIONAL AREAS AND PUBLIC RESOURCES FOR THE INTERIM AND ALTERNATE SITES NEAR ARECIBO SHOWING SEDIMENT DEPOSITION CONCENTRATION

4.4.2 Impacts on Coral Reefs

There are no major coral reefs in the study area.

4.4.3 Impacts in Preserve or Reserve Areas or Mangrove Nursery Areas

There will be no effects on any natural reserve, Commonwealth forest, mangrove nursery area or critical wildlife area from disposal at the interim site or any of the alternate sites. The study area contains the Guajataca Cliffs critical habitat area, 9-11 mi along the coast to the west of the harbor, the Carrizales Mangrove Swamp, 4 mi west of the harbor and the Tiburones Swamp, 1-8 mi to the east. Sediment plumes from disposal at any of the sites would not be expected to reach the water in or immediately adjacent to any of these areas (Figure 4-1).

4.4.4 Effects on Threatened and Endangered Species

Disposal at any of the sites considered would not affect sea turtle habitats. It is not known to what extent marine turtles feed in the mangrove areas near Arecibo, or nest on its beaches. However, all potential disposal sites are well offshore from any possible sea turtle feeding or breeding habitats, and the minimal ocean transport predicted by the model for this area would not be sufficient to carry released materials at significant concentrations into the nearshore waters (Figure 4-1).

For the same reason, there will be no effect on brown pelicans from disposal at any of the sites. Breeding areas and principal feeding areas for pelicans are close to shore and released materials would not be transported into those waters in appreciable quantities. Because there would be no significant horizontal transport of the sediment mass before it reaches the sea floor at any of the potential Arecibo sites, it is unlikely that pelicans would fly over and feed from waters containing suspended sediments in the short time period before the disposed materials reached the sea floor.

4.4.5 Shipping Lanes

There are no designated shipping lanes in the harbor. No significant impact to shipping is expected from the disposal of dredged material at any of the sites.

4.4.6 Mineral Resources

No effects are expected on any mineral resources from disposal at the interim site or any of the alternate sites. No such features have been identified in the Arecibo ZSF. There are known deposits of magnetite sands south of the ZSF and it is possible that these deposits may extend into the southern part of the ZSF near the interim site. However, sediment plumes from disposal at any of the sites would not be expected to reach the deposits.

4.5 ENVIRONMENTAL CONSEQUENCES OF DREDGED MATERIAL DISPOSAL FOR MAYAGUEZ

This section summarizes the environmental impacts expected from disposal at each of the sites considered for Mayaguez. A summary of the environmental characteristics and potential impacts at each site, as they pertain to protection under the ocean dumping regulations, is presented in Chapter 2, (Table 2-5).

4.5.1 Impacts on Beaches and Shorelines

There will be no measurable increases in sediment concentrations at any beaches or shorelines because of dredged material disposal at the interim or alternate sites. Sedimentation plumes from disposal at any of the sites would not be expected to reach the waters of the shoreline anywhere in this area (Figure 4-2).

4.5.2 Impacts on Coral Reefs

There should be no adverse effects on corals from the disposal of dredged materials at any of the alternate sites. Use of the interim site, however, is likely to result in deposition of sediments at levels harmful to corals in the reef areas just south of the Site (Figure 4-3). Use of any of the alternate sites is expected to result in sediment plumes that disperse and then settle

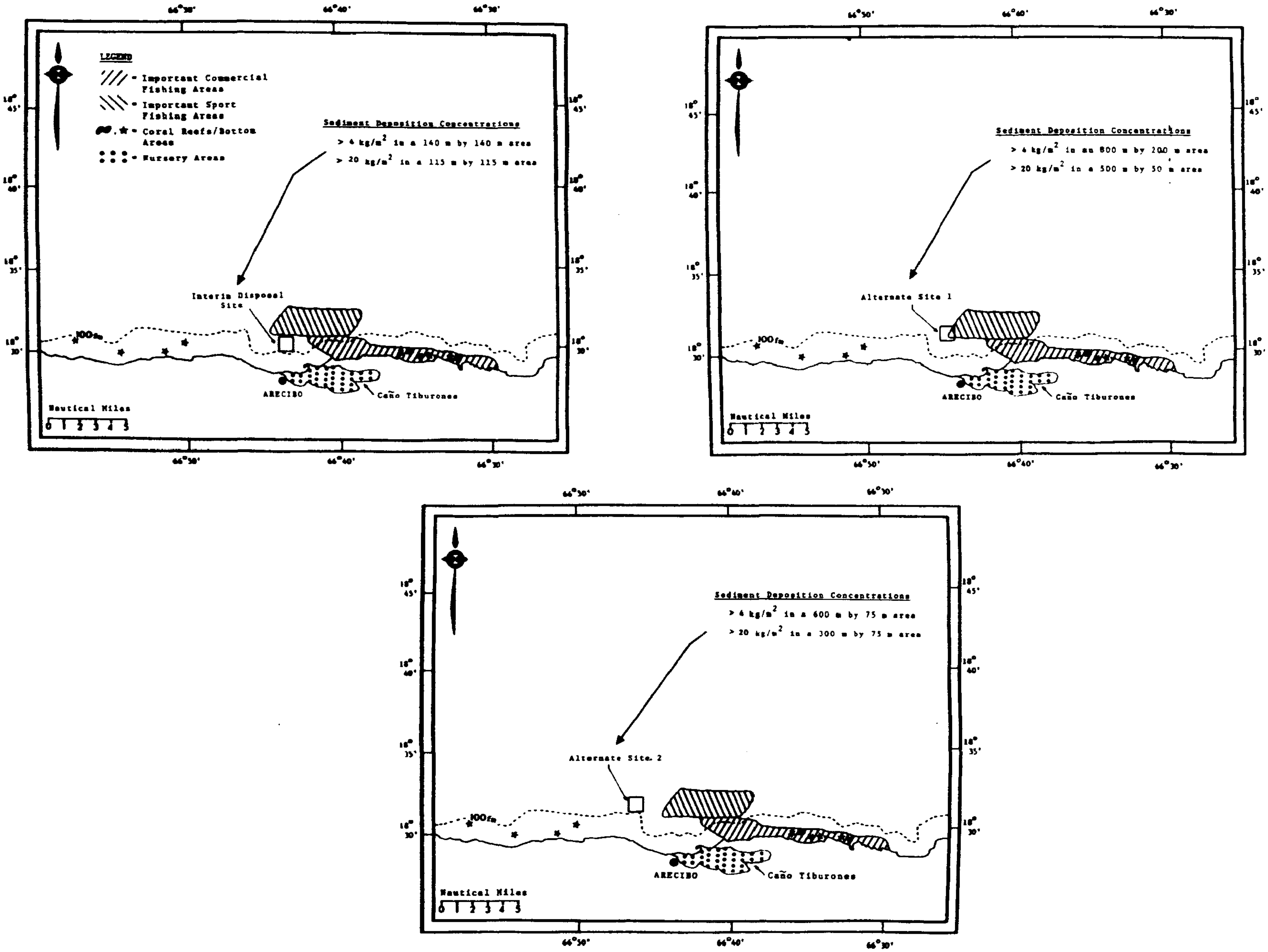

FIGURE 4-2. SEDIMENT DEPOSITION RELATIVE TO ARECIBO LIVING RESOURCES

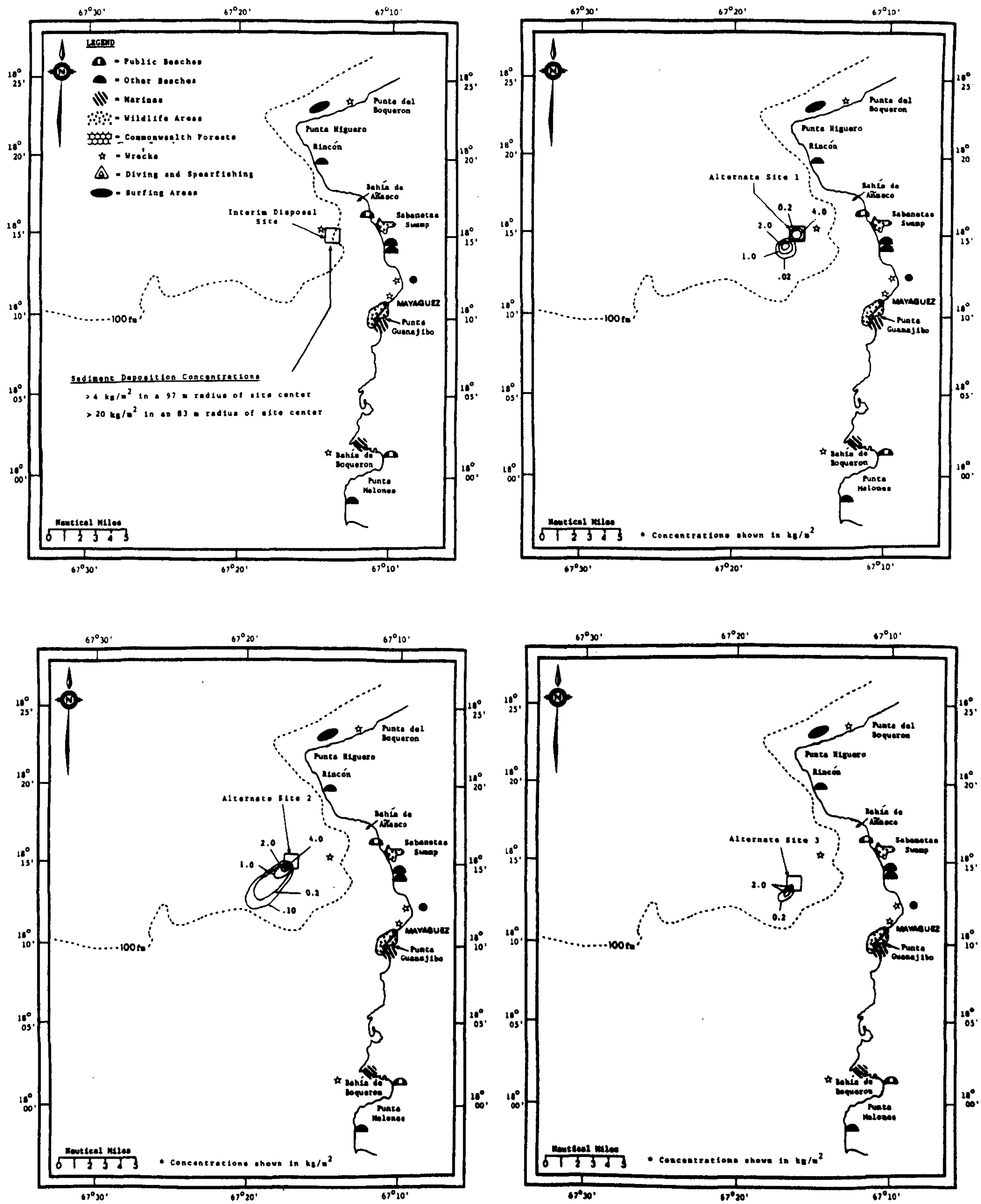

FIGURE 4-3. MAPS OF RECREATIONAL AREAS AND PUBLIC RESOURCES FOR THE INTERIM AND ALTERNATE SITES NEAR MAYAGUEZ SHOWING SEDIMENT DEPOSITION CONCENTRATION

out before reaching any of the area's reefs. Use of the interim site, however, will not typically result in dispersion of the dredged materials in an extended plume. This is because the bottom at this site is sufficiently shallow that the mass of released materials will land on the sea floor before reaching the state of dynamic collapse and dissipation. Consequently, sediment deposition concentrations at or near much of the Site will be very high, well above the value of 2 kg/m^2 found to cause mortality in sedimentsensitive corals such as Porites furcata and several of the Acropora species, all of which are quite common in this region. Concentrations lethal to these corals could be reached at the principal deposition area as a result of release of one typical barge load of dredged material. Continuous use of the site over a period of several days would result in sediment accumulation to levels that would be lethal to even more resistant coral species.

Figure 4-4 incates that the location of the sediment mound predicted from this model is actually between a half and one nmi away from the nearest charted coral reef area. However, uncertainties about current speed, direction, and point of release (e.g. release may not begin in the center of the Site as was assumed in the model), means that the actual mound location could be displaced by at least one nmi from the predicted location. Thus, it is possible, and in fact likely over a period of years involving numerous disposal operations, that navigational and current conditions would combine to create unacceptably high levels of sediment deposition on the reefs adjacent to the interim site.

Disposal at any of the alternate sites would not create high levels of sediment deposition in any coral area. This is because the sea floor at these sites is deeper than the level at which the inital mass of released sediments will reach its depth of neutral density and begin the process of horizontal mixing in a dispersion plume. Plumes from disposal at each of the alternate sites will dissipate to levels approximately equal to minimum average nearshore sedimentation rates in Puerto Rico (0.05 kg/m^2) before reaching any known coral reefs.

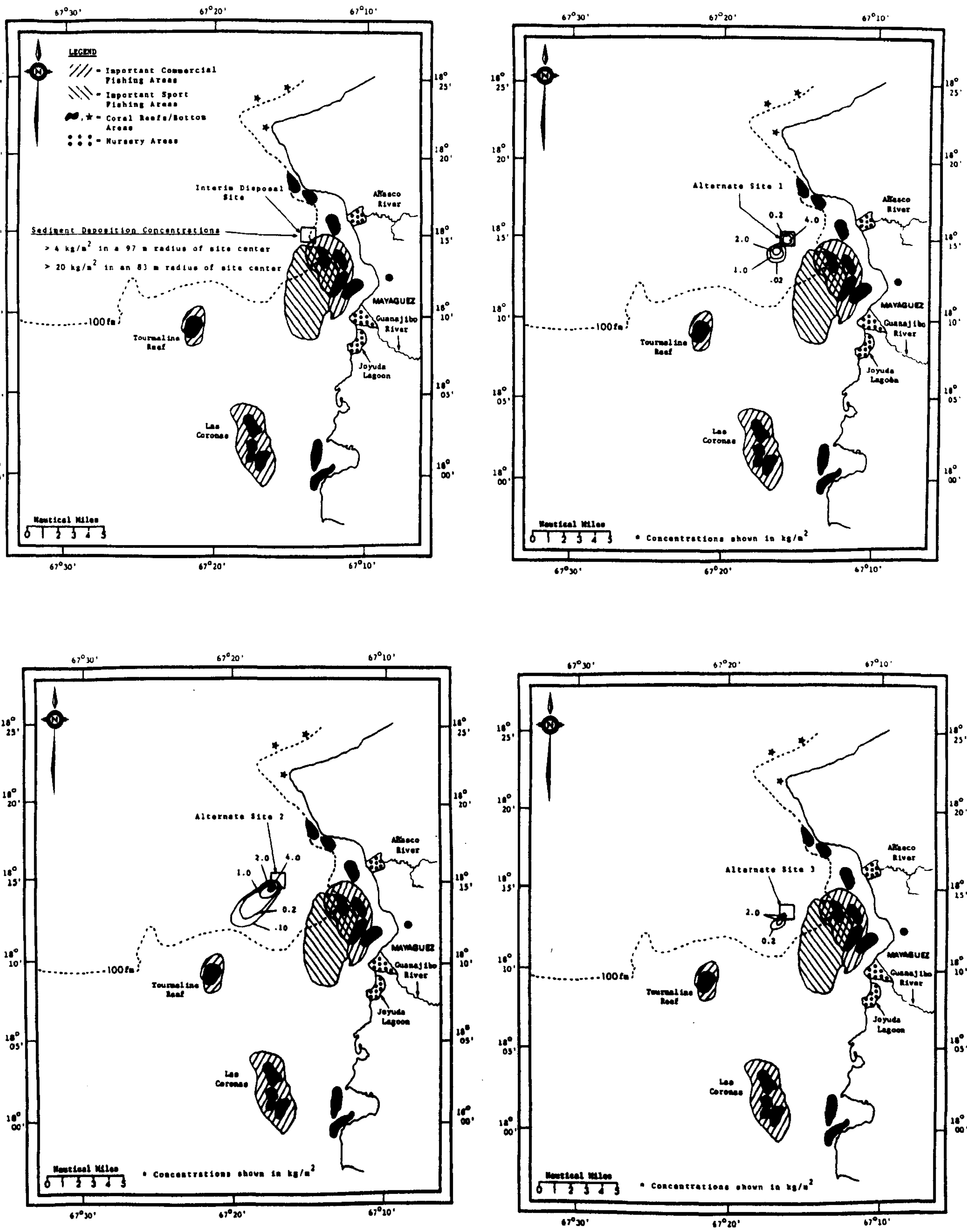

FIGURE 4-4. SEDIMENT DEPOSITION RELATIVE TO MAYAGUEZ LIVING RESOURCES

4.5.3 Impacts in Preserve or Reserve Areas or Mangrove Nursery Areas

There will be no effects on any natural reserve, Commonwealth forest, mangrove nursery area, or critical wildlife area from disposal at the interim site or any of the alternate sites. The only such features within the study area are the Joyuda Lagoon mangrove reserve, 5 mi along the coast to the harbor, the Guanajibo River mangrove area, 3 mi to the south, and the Anasco River mangrove area, 5 mi to the north of the harbor. Sediment plumes from disposal at any of the sites would not be expected to reach the water in or immediately adjacent to any of these features (Figure 4-3).

4.5.4 Effects on Threatened and Endangered Species

Disposal at any of the sites would not affect sea turtle habitats. Marine turtles are reported to nest in the Cabo Rojo region, south of the Joyuda Lagoon. All potential disposal sites are at least 7 nmi away from this area, and ocean transport, as predicted by the model, is not sufficient to carry released materials to this area (Figure 4-3).

For the same reason, there will be no effect on the brown pelican from disposal at any of the sites. Pelicans are primarily a nearshore species and would thus only rarely, if ever, fly over and feed from waters in the dredged material plumes.

4.5.5 Shipping Lanes

There are no designated shipping lanes in the harbor. No significant impact on shipping is expected from the disposal of dredged material at any of the sites.

4.5.6 Mineral Resources

There will be no effects on any mineral resources from disposal at the interim or alternate sites. A large quartz sand deposit is located about 1/2 nmi west of Alternate Site 2 and extends seaward (Cox and Briggs 1973). Sediment plumes from disposal at site 2 could reach these quartz sand deposits, but the area likely to be affected is small compared to the total size of the resource.

4.6 ENVIRONMENTAL CONSEQUENCES OF DREDGED MATERIAL DISPOSAL FOR PONCE

This section summarizes the environmental impacts expected from disposal at each of the sites considered for Ponce. A summary of the environmental characteristics and potential impacts at each site, as they pertain to protection under the ocean dumping regulations, is presented in Chapter 2 (Table 2-7).

4.6.1 Impacts on Beaches and Shorelines

Several beaches and stretches of shoreline would be affected by the sediment plumes created by disposal under typical oceanographic conditions at Ponce (Figure 4-5). There are several beach areas west of Ponce Harbor that could be affected. The closest of these is beyond Punta Cucharas, approximately 4 nmi from the interim site. Other beaches are located to the west, one off Punta Verraco and two others along the coastline of the Guanica Commonwealth Forest, which is designated as a reserve area by the Forestry Service of the Puerto Rico Department of Natural Resources. Disposal at the interim site or Alternate Sites Nos. 2 or 3 would result in concentrations in these areas exceeding the threshold sedimentation value of 0.01 kg/m^2 that is expected to cause unacceptable effects on nearshore water quality under the second general criterion of the ODR. Use of either of these disposal sites for a typical disposal operation would be expected to cause a detectable increase in ambient sedimentation levels in nearshore waters. Disposal at Alternate Site No. 1 (the proposed site) is not expected to cause adverse impacts to beaches and shorelines.

4.6.2 Impacts on Coral Reefs

There should be no adverse effects on corals from the disposal of dredged materials at any of the evaluated sites. The only large coral reefs are outside the area of influence of the 0.1 kg/m^2 sediment deposition plume. Although reefs to the northwest may be exposed to lower levels of sedimentation (Figure 4.6), no adverse effects on corals there are expected.

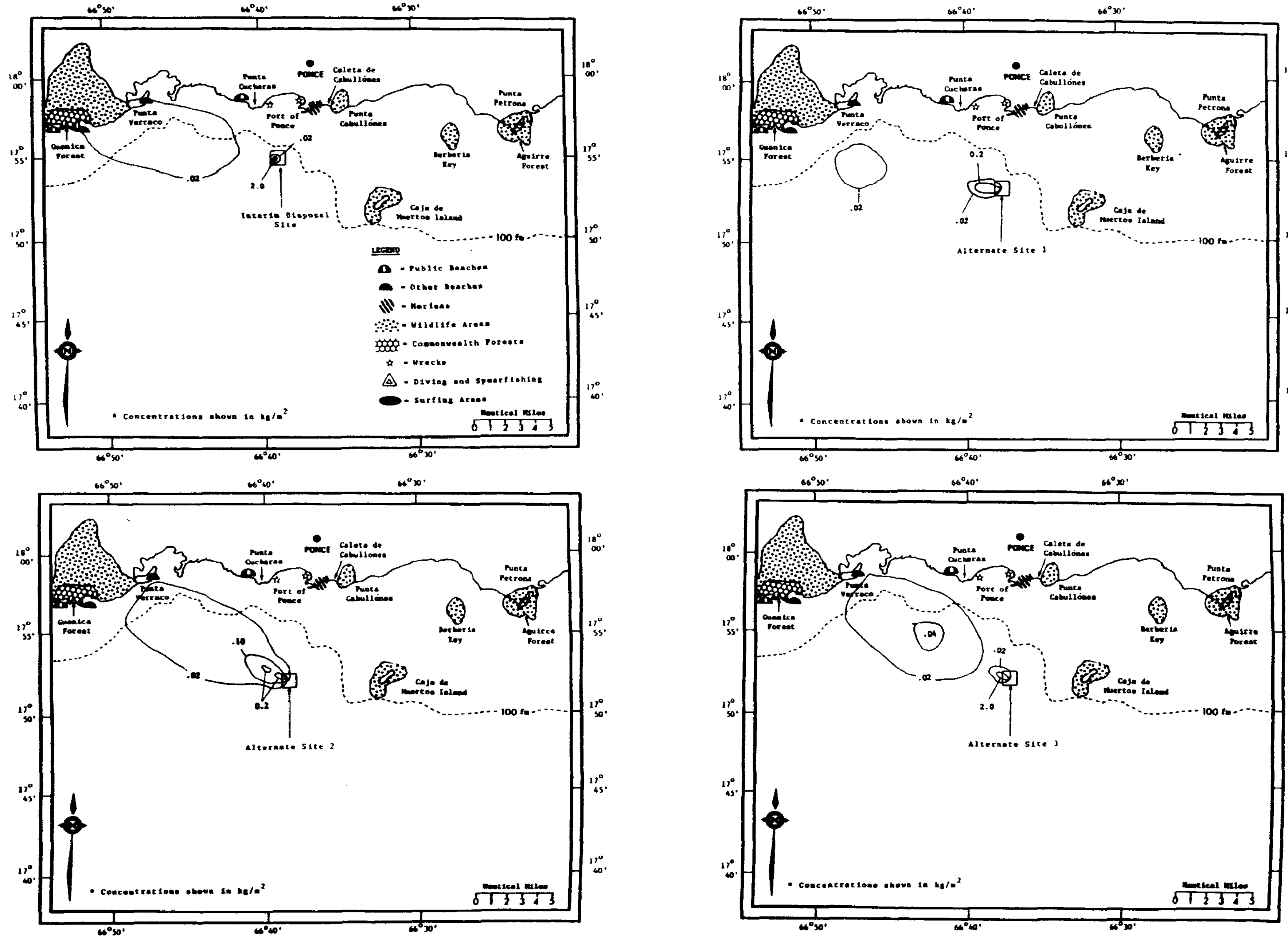

FIGURE 4-5. MAPS OF RECREATIONAL AREAS AND PUBLIC RFSOURCES FOR THE INTERIM AND ALTERNATE SITES NEAR PONCE SHOWING SEDIMENT DEPOSITION

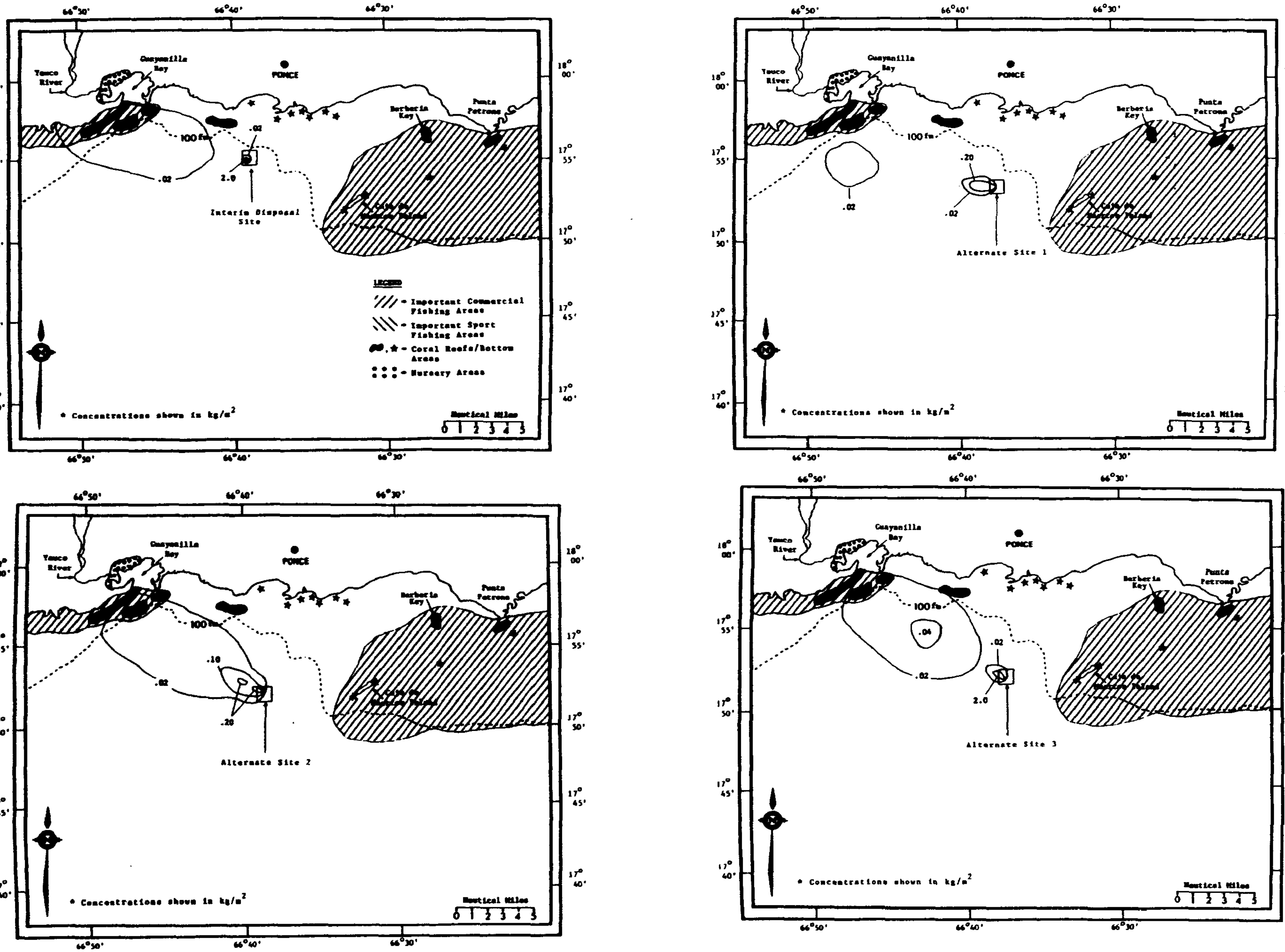

FIGURE 4-6. SEDIMENT DEPOSITION RELATIVE TO PONCE LIVING RESOURCES

4.6.3 Impacts in Preserve or Reserve Areas, or Mangrove Nursery Areas

There will be no effects on any natural reserve, Commonwealth forest, mangrove nursery area or critical wildlife area from disposal at the interim or alternate sites. Such features within the Ponce study area include the Guanica Commonwealth Forest and adjacent critical habitat area, 7-12 mi along the coast to the west of the harbor, the Guayanilla Bay mangroves, 6-7 miles west of the harbor, Cabullan mangroves, 3 miles to the east, Punta Petrona mangroves and Aguirre Commonwealth Forest, 12 miles to the east. Also in the study area is the Caja de Muertos Island Reserve, 5 nmi east of alternate site 3, which includes the Berberia Key, 3 nmi to the northeast. It is possible that disposal at the interim site under certain typical oceanographic conditions would produce a plume of sediment at above ambient levels that would be transported into the nearshore waters of the coastal Guanica Commonwealth Forest and its protected adjacent lands. However, sedimentation levels in that preserve's coastal waters would not be expected to exceed the minimum 0.5 kg/m^2 threshold expected to damage sensitive marine organisms (Figure 4-5).

4.6.4 Effects on Threatened and Endangered Species

Disposal at any of the sites under consideration would not affect sea turtle habitats. Sea turtles are reported to nest on Caja de Muertos Island. All disposal sites are to the west of the island, so that the westward flowing currents typical in the area will tansport dredged materials away from the island. For the same reasons, there will be no effect on the brown pelican from disposal at any of the sites. Pelican habitats are close to shore and released materials will not be transported there in any appreciable quantities.

4.6.5 Shipping Lanes

There are no designated shipping lanes in the harbor. No significant impact to shipping is expected from disposal of dredged material at any of the sites.

4.6.6 Mineral Resources

There will be no effects on any mineral resources from disposal at the interim or alternative sites. No mineral resources have been identified in or near the ZSF.

4.7 ENVIRONMENTAL CONSEQUENCES OF DREDGED MATERIAL DISPOSAL FOR YABUCOA

This section summarizes the environmental impacts expected from disposal at each of the sites considered for Yabucoa. A summary of the environmental characteristics and potential impacts at each site, as they pertain to protection under the ocean dumping regulations, is presented in Chapter 2 (Table 2-9).

4.7.1 Impacts on Beaches and Shorelines

Several beaches and stretches of shoreline would be reached by the sediment plumes created by disposal under typical oceanographic conditions at Yabucoa (Figure 4-7). There are several beach areas southwest of Yabucoa Harbor that could be affected. The closest of these is Playa Maunabo, approximately 10 nmi from the interim site. Another is located to the southwest off Cabo Mala Pascua. Disposal at Alternate Site 1 would result in concentrations at this site that could exceed the threshold sedimentation value of 0.01 kg/m^2 that is expected to cause unacceptable effects on nearshore water quality. Use of this disposal site for a typical disposal operation would under some typical oceanographic conditions be expected to cause a detectable increase in sedimentation levels in nearshore waters. Disposal at the interim site and Alternate Sites 2 and 3 would not result in concentrations that exceed the threshold sedimentation value and is therefore not expected to cause any unacceptable effects on nearshore water quality.

4.7.2 Impacts on Coral Reefs

Modeling indicates that there would not be adverse effects on corals from the disposal of dredged materials at Alternate Sites 2 or 3. The principal coral reefs in the area are not within the area of influence of the 0.1 kg/m^2 sediment deposition plume, although reefs to the southwest may be exposed to

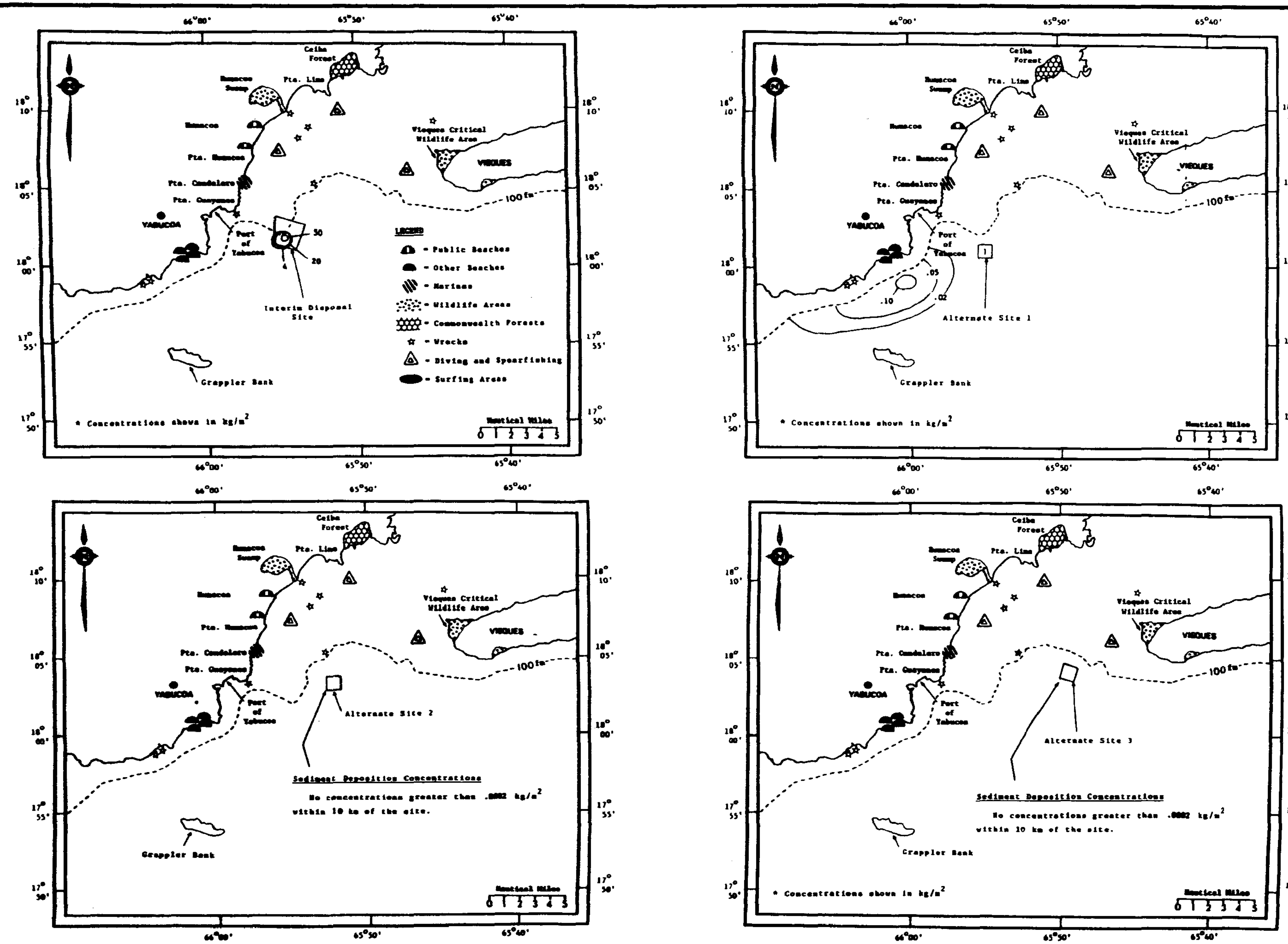

FIGURE 4-7. MAPS OF RECREATIONAL AREAS AND PUBLIC RESOURCES FOR THE INTERIM AND ALTERNATE SITES NEAR YABUCOA SHOWING SEDIMENT DEPOSITION

lower levels of sedimentation not expected to harm corals (0.05 kg/m^2) (Figure 4.8). No adverse effects on coral are expected below sedimentation concentrations of 0.1 kg/m^2. However, serious adverse coral impacts may occur from continued use of the interim site. Live corals inhabiting the shallow northwestern portion of the site were identified by acoustic identification of hard bottom areas, together with inadvertant collection of portions of live reef corals during bottom sampling on the 1984 survey cruise. In addition to the probability that materials released in the site will be deposited on corals inhabiting the site itself, there is also a high probability that severe storm conditions at some future time would cause resuspension and transport of materials away from the original deposition mound and into the shallow areas inhabitied by corals. Modeling of storm resuspension is described in Appendix H.

Because disposal at alternate site 1 would also be expected to result in transport into nearshore waters, it is possible that use of that site would also result in sediment deposition on corals present in shelf areas.

4.7.3 Impacts in Preserve or Reserve Areas, or Mangrove Nursery Areas

There will be no effects on any natural reserve, Commonwealth forest, mangrove nursery area or critical wildlife area from disposal at the interim or Alternate Sites. The Ceiba Commonwealth Forest, 10-12 mi along the coast to the north of the harbor, the Humacao Mangrove Swamp, 7 mi to the northeast, and the Vieques Critical Wildlife Area on the westernmost end of Vieques Island, 5 nmi northeast of Alternate Site 3, are located within the study area, but sediment plumes from disposal at any of the sites would not be expected to reach the water in or immediately adjacent to any of these features (Figure 4-7).

4.7.4 Effects on Threatened and Endangered Species

There is no site under consideration where disposal would affect sea turtle habitats. Rare marine turtles are reported to nest on Vieques Island 13 to 14 nmi east of Yabucoa. All study sites are well offshore of this area, and ocean transport is not sufficient to convey released material at concen-

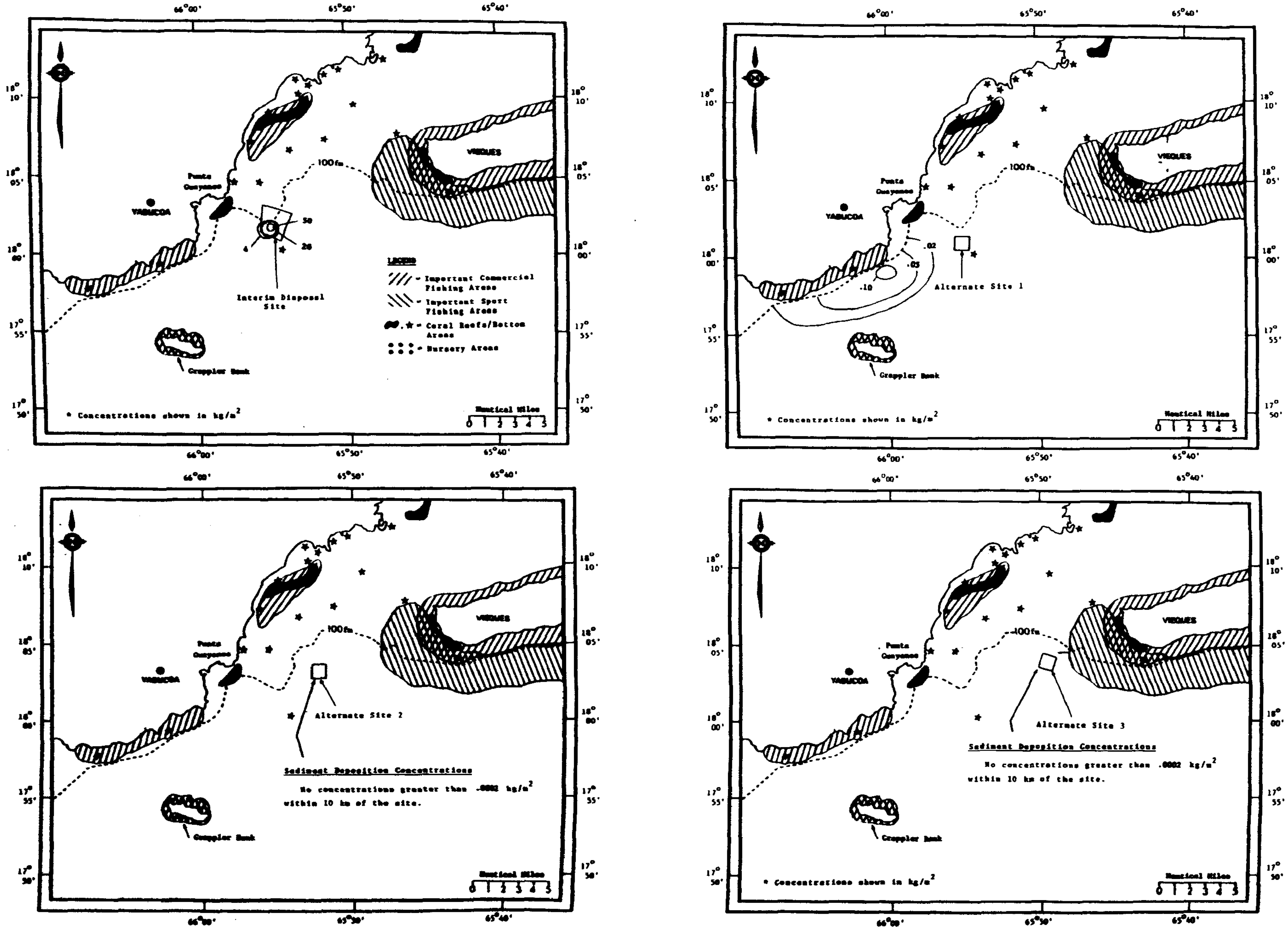

FIGURE 4-8. SEDIMENT DEPOSITION RELATIVE TO YABUCOA LIVING RESOURCES

trations of concern to the critical area (Figure 4-7). For the same reason, there will be no effect on the brown pelican from disposal at any of the sites. Breeding and feeding areas for pelicans occur much closer to shore than the sites considered.

4.7.5 Shipping Lanes

There are no designated shipping lanes in the harbor. No significant adverse impact will result from the disposal of dredged material at any of the proposed sites.

4.7.6 Mineral Resources

There will be no effects on any mineral resources from disposal at the interim or alternate sites. No mineral resources have been identified within the ZSF. A major quartz sand source is located about 5 nmi to the north of the ZSF, beyond the island of Vieques (Grove and Trumball 1978). Sediment plumes from disposal at any of the sites would not be expected to reach this deposit.

4.8 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES FOR ALL HARBORS

Use of the proposed sites will require expenditure of funds to pay costs of transporting dredged materials to the site, which will include costs of fuel, an irretrievable resourcce. Disposal of dredged materials at the sites will not result in irretrieval commitment of other resources. There will be changes in the benthic marine ecosystem where dredged materials are deposited, but these are not expected to have irreversible effects on any marine resources.

4.9 STEPS TO MINIMIZE ADVERSE EFFECTS TO THE ENVIRONMENT FOR ALL HARBORS

Principal potential environmental effects of dredged material disposal at the four proposed DMDSs are as follows:

- Reduction of localized water quality during short initial mining period.

- Burial of benthic invertebrates in localized sediment deposition areas. (This is most likely at Arecibo, and less likely in other areas due to dispersion of released materials over deep water).

The effects of dumping will be mitigated as long as the barge is in motion during the disposal operation, to increase dispersion of released sediments.

4.10 RELATIONSHIP BETWEEN SHORT-TERM USE OF THE ENVIRONMENTAL AND ENHANCEMENT OF LONG-TERM USE OF THE ENVIRONMENT FOR ALL HARBORS

The designation and use of the proposed Arecibo, Mayaguez, Ponce and Yabucoa disposal sites will result in short-term changes in benthic ecosystems where sediments are deposited. Short-term and long-term enhancement of human uses of the environment in these regions will result because the availability of sites for dredged material disposal will allow for maintenance dredging of harbors required to support regional commerce and industries. Ocean disposal provides an alternative to environmentally less desirable land-disposal options for each harbor.

5. CONTRIBUTORS TO THE EIS

5.0 CONTRIBUTORS TO THE EIS

This EIS was prepared with the assistance of the technical and scientific staff of the Environmental Toxicology and Ecological Assessment Division and the Water Programs Division of JRB Associates (JRB), McLean, Virginia and JRB offices in Seattle, Washington and La Jolla, California. Applied Sciences Associates (ASA) provided a resuspension model for the project. This section summarizes the backgrounds and qualifications of the primary contributors to the EIS and indicates the sections to which they contributed.

The EIS was prepared under the direction of Mr. Robert Hargrove of the Environmental Impacts Branch of the Environmental Protection Agency, Region II. Mr. Hargrove served as the Government's Work Assignment Manager. Ms. Linda Comerci of the Region II Water Permits and Compliance Branch assisted Mr. Hargrove in reviewing the preliminary draft.

<u>Paul Campanella, Ph.D.</u>

Dr. Campanella was the JRB Project Manager for the EIS. He has a Ph.D. in Ecology/Resource Management from Syracuse University. Dr. Campanella is the JRB Environmental Toxicology and Ecological Assessment Division manager.

<u>F. Kim Devonald, Ph.D.</u>

Dr. Devonald was the Work Assignment Manager and Technical Coordinator for the EIS. She has a Ph.D. in Oceanography from the Scripps Institution of Oceanography. As Work Assignment Manager and Technical Coordinator, Dr. Devonald has managed the technical staff in the organization and writing of the EIS.

The technical contributors to individual sections of the EIS are identified in Table 5-1.

TABLE 5-1. CONTRIBUTORS TO THE ENVIRONMENTAL IMPACT STATEMENT

RESPONSIBLE PERSON	CHAPTER				APPENDIX						
	1	2	3	4	B	C	D	E	F	G	H
MANAGEMENT STAFF											
Paul Campanella Ph.D. Ecology/ Resource Management	X	X	X	X	X	X	X	X			
Kim Devonald Ph.D. Oceanography	X	X	X	X	X	X	X	X	X	X	
TECHNICAL STAFF											
Vivien Bacaner M.S. Environmental Science	X	X	X	X							
Terry Grist B.A. Geography/ Human Ecology	X	X	X	X							
Constance Spooner B.S. Agronomy/ Soil Science	X	X	X	X	X						
Andrew Stoddard Ph.D. Environmental Engineering			X	X					X	X	
Cindy Van Duyne B.A. Biology/ Environmental Studies			X	X							
Richard Wagner M.S. Environmental Engineering			X	X						X	

TABLE 5-1. CONTRIBUTORS TO THE ENVIRONMENTAL IMPACT STATEMENT (Continued)

RESPONSIBLE PERSON	CHAPTER				APPENDIX						
	1	2	3	4	B	C	D	E	F	G	H
Jeff Weiler M.S. Resource Economics/ Environmental Mgmt.	X	X	X	X							
Roger Wells M.S. Ocean Engineering						X				X	
Don Weston Ph.D. Marine Science			X	X				X			
Janet Zuckerman MPH Water Quality/ Environmental and Industrial Health		X	X	X			X				
ASA (Applied Science Associates) Malcolm Spaulding Ph.D. Ocean Engineering											X

6.0 GLOSSARY, LIST OF ABBREVIATIONS, AND UNIT CONVERSION TABLE

6.1 GLOSSARY

ABUNDANCE - Relative number of individuals of a species inhabiting an area.

AMBIENT - The existing conditions of an environment.

AMPHIPODS - An order of crustaceans; the two marine groups of amphipods, hyperiideans and gammarideans, inhabit open ocean waters or are bottom dwellers.

ASSEMBLAGES - A group of organisms sharing a common habitat.

BATHYMETRY - The bottom topography (distribution of bottom depths) of an aquatic region.

BASELINE CONDITIONS - The physical, chemical and biological conditions existing in an environment prior to an activity that might change the conditions of that environment.

BENTHIC - Pertaining to the bottom in an aquatic system, including soft-bottom and hard-bottom conditions; [organisms]: living in or on the sea floor or in or on the soft or hard bottom of a fresh or brackish water environment.

BENTHOS (BENTHIC ORGANISMS) - Marine animals or plants living on or in bottom sediments.

BIOASSAY - Exposure of a test organism to a sample to determine the lethal concentration of a pollutant to the organism.

BIOGEOGRAPHIC - Geographic distribution of animal and plant life.

BIOMASS - The mass of living matter, including stored food, present in any given volume of habitat.

BIOTA - The animal and plant life living within a given area.

BLOOM - High concentration of aquatic plants that results from rapid reproduction due to an increase of nutrients.

CALCAREOUS OOZE - A fine-grained pelagic deposit containing more than 30 percent calcium carbonate.

CIRCULATION PATTERN - The general geometric configuration of oceanic currents.

CLAMSHELL DREDGE - A crane-operated device used for dredging in confined areas. The device consists of two shell-like halves that are lowered in an open position and then mechanically closed to contain and remove dredged material.

CLAY - Sediment with particle diameters less than 1/256 mm.

CONTINENTAL MARGIN - Zone separating continental land masses from the deep sea floor.

CONTINENTAL SHELF - The zone bordering a continent extending from the line of permanent immersion to the depth (usually about 180 m) where there is a rather steep descent toward the great depths.

CONTINENTAL SLOPE - The slope from the outer edge of a continental shelf to the deep sea floor.

CRUSTACEANS - Animals with jointed appendages and a segmented external skeleton. The group is primarily aquatic. It includes crabs, shrimps, lobsters, mysids, amphipods, and microscopic benthic and planktonic forms.

CURRENT METER - A device used to measure the speed and direction of flowing water.

CURRENT SHEAR - The measure of the spatial rate of change of current velocity with units of $cm\text{-}sec^{-1}\ m^{-1}$

DEMERSAL - Living in the water near the bottom, and typically finding food on the bottom.

DIATOMS - Free-floating algae with siliceous external skeletons.

DILUTION - A reduction in concentration.

DISPERSION - The dissemination of discharged material over large areas by turbulence and currents.

DISSOLVED OXYGEN - Amount of oxygen dissolved in a unit volume of water.

DIVERSITY - A measure of the variety of species in a community.

DOMINANCE - Control by a species or group of species of the energy flow and environment within a community.

DREDGING - Removal of sediment from the floor of a body of water in order to maintain an adequate clearance for shipping.

DRY WEIGHT - The weight of remaining biomass after the water has been removed from a sample.

ECHINODERMS - Principally benthic marine animals having calcareous plates with projecting spines forming a rigid or articulated skeleton or plates and spines embedded in the skin. These organisms have a radially symmetrical, usually five-rayed, body and include the sea starfish, sea urchins, crinoids, and sea-cucumbers.

ECONOMIC RESOURCE ZONE - The ocean zone within 200 nautical miles from shore in which the adjacent coastal state possesses exclusive rights to the living and non-living ocean resources.

ECOSYSTEM - An ecological community together with its physical environment, considered as a unit, each influencing the properties of the other and both necessary for the maintenance of life.

EDDY - A current of water moving contrary to the direction of the main current; typically a circular motion.

EPIPELAGIC - Ocean zone ranging from the surface to a depth of 200 meters.

FORAMINIFERA - Single-celled, planktonic protozoans possessing shells, usually of calcium carbonate.

GASTROPODS - Molluscs with a distinct head, generally with eyes, tentacles, a broad, flat foot, and a spiral shell.

HOPPER DREDGE - A self-propelled hydraulic dredge that utilizes a trailing dredge head. Dredged material is deposited in a storage area -- "hopper" -- and later dumped or pumped onto a disposal site.

HYDRAULIC FILL - The deposition at a disposal site of dredged slurry by means of centrifugal pumping action.

ICHTHYOPLANKTON - Fish eggs and weakly motile fish larvae.

INDICATOR SPECIES - A species of organism characteristic of a certain water mass.

IN SITU - In the natural or original position.

ISLAND MASS EFFECT - A phenomenon in which the abundance or biomass of organisms in the immediate vicinity of an island is markedly higher than the surrounding oceanic area.

ISOPODS - The second largest order of crustaceans. These flattened bottom-dwelling arthropods are generally scavengers.

LC_{50} - A bioassay or toxicity measure to determine the concentration of pollutant that causes 50 percent mortality in the population of test organisms during a unit time ("lethal concentration for 50 percent").

MACROZOOPLANKTON - Planktonic organisms with lengths between 200 and 2000 micra, composed mainly of copepods, chaetognaths, and larval forms.

MEROPLANKTON - Organisms that spend only a portion of their life cycle as plankton; usually composed of floating developmental stages (i.e., eggs and larvae) of the benthos and nekton organisms. Also known as temporary plankton.

MICRO-NUTRIENT - Substance that an organism must obtain from its environment to maintain health, though necessary only in minute amounts.

MICRO-ORGANISMS - Microscopic organisms, including bacteria, protozoans, yeast, viruses, and algae.

MIXED LAYER - The upper layer of the ocean that is well mixed by wind and wave activity. Within this layer temperature, salinity, and nutreint concentration values are essentially homogeneous with depth.

NERITIC - Relating to the waters over the continental shelf.

NMI - Nautical mile; the length of one minute of longitude at the equator. One nmi is equal to 1.151 statute miles.

ORTHO-PHOSPHATE - One of the salts of orthophosphoric acid; one of the components in seawater that is of fundamental importance to the growth of marine phytoplankton.

OXIDATION - The process in which a substance gives up oxygen, removes hydrogen from another substance, or attracts negative electrons.

PARTICULATE CARBON - Finely divided solid particles of carbon suspended in the water column.

PELAGIC - Free-swimming: living in water and having sufficient strength of movement that the major force of movements is due to own actions rather than to passive transport along with water currents.

PHYTOPLANKTON - Minute passively floating plant life of a body of water; the base of the food chain in the sea.

PLANKTON - Aquatic animals and plants, usually small and often microscopic in size, that drift passively with ambient water movements; the plants (phytoplankton) are unicellular algae, the animals (zooplankton) include protozoans (unicellular) and a wide variety of tiny multicellular animals. Multicellular zooplankton are mostly crustaceans, but also include the larvae of benethic animals, small specialized worms, and gelatinous animals related to sea squid or jellyfish.

POLYCHAETE WORMS - Segmented worms (of the phylum Annelida), forming a major group that is primarily aquatic. Among the most diverse and abundant groups of non-microscopic benthic animals.

PRIMARY PRODUCTION - The amount of organic matter synthesized by organisms from inorganic substances in a given time in a given volume of water, or in a given amount of space in a terrestrial system.

PTEROPODA - The sea butterflies, an order of pelagic gastropod molluscs in which the foot is modified into a pair of large fins and the shell, when present, is thin and glasslike.

PYCNOCLINE - The depth at which the density of seawater changes maximally.

REACTIVITY - The tendency of a substance to combine with another substance.

RECRUITMENT - Addition to a population by reproduction of new individuals or species.

SAND - Sediment with particle diameters ranging from 1/16 to 2 mm.

SEA STATE - Numerical or written description of ocean surface roughness: the average height of the highest one-third of the waves observed in a wave train.

SECCHI DISC - A device used to measure the clarity of seawater.

SHOAL - A shallow area within a harbor, river, etc. Shoaling is the result of deposition of sediment by prevailing currents.

SILT - Sediment with particle diameters ranging from 1/256 to 1/16 mm.

SLURRY - The mixture of sediment and water that is collected by dredging activities.

TEMPORAL DISTRIBUTION - The geographical range of an organism over time.

TERRIGENOUS - Relating to sediment derived directly from the erosion of rocks on the earth's surface.

THERMOCLINE - The region of the water column where temperature changes most rapidly with depth.

TROPHIC LEVELS - Any of the feeding levels through which the passage of energy of an ecosystem proceeds. Typical marine trophic levels include: phytoplankton, zooplankton, fish.

TURBIDITY - The degree of decreased optical clarity of water (due to suspended or dissolved materials).

UPWELLING - The rising of water toward the surface from subsurface layers of a body of water. Upwelling is most prominent where persistent wind blows parallel to a coastline so that the resultant wind current sets away from the coast. The upwelled water, besides being cooler, is rich in nutrients, and regions of upwelling are generally also areas of rich fisheries.

VERTICAL DISTRIBUTION - The frequency of occurrence over an area in the vertical plane.

WET WEIGHT - The weight of a sample of organisms before interstitial water is removed.

ZOOPLANKTON - The passively floating or weakly swimming animals of an aquatic ecosystem.

6.2 LIST OF ABBREVIATIONS AND ACRONYMS

AS: ·Alternate Site

CEC: Cation Exchange Capacity

COE: U.S. Army Corps of Engineers

CODREMAR: Corporation for the Development of Lacustrine, Estuarine, and Marine Resources (Puerto Rico)

cm: centimeter

cm/sec: centimeters per second

DM: Dredged Material

DMDS: Dredged Material Disposal Site

EIS: Environmental Impact Statement

EPA: Environmental Protection Agency

IS: Interim Site

kg: kilogram

km: kilometers

km^2: square kilometer

l: liters

LC50: lethal concentration for 50% of individuals

LPC: limiting permissable concentration

m: meters

m^3: cubic meters

MEC: maximum environmental concentration

mg: milligrams

mg/l: milligrams/liter

mi: miles

ml: milliliters

mm: millimeter

MPRSA: Marine Protection, Research and Sanctuaries Act

NEPA: National Environmental Policy Act

nmi: nautical miles

NWF: National Wildlife Federation

NOAA: National Oceanographic and Atmospheric Administration

ODR: Ocean Dumping Regulations

o/oo: parts per thousand

%: percent

PRDPW: Puerto Rico Department of Public Works

PRNC: Puerto Rico Nuclear Center

USGS: United States Geological Survey

ZSF: Zone of Siting Feasibility

ug-at: microgram-atoms

6.3 UNIT CONVERSION TABLE

To Convert	To	Muliply By
Length:		
inches	centimeters	2.54
centimeters	inches	0.39
yards	meters	0.90
meters	yards	1.11
miles	kilometers	1.61
kilometers	miles	0.62
miles	nautical miles	0.87
nautical miles	miles	1.15
nautical miles	kilometers	1.85
kilometers	nautical miles	0.54
Area:		
square inches	square centimeters	6.49
square centimeters	square inches	1.54
square yards	square meters	0.8
square inches	square yards	1.25
acres	hectares	0.40
hectares	acres	2.47
Weight:		
ounces	grams	28.0
grams	ounces	0.04
pounds	kilograms	0.45
kilograms	pounds	2.22
tons	metric ("long") tons	0.9
metric ("long") tons	tons	1.11
Velocity:		
miles per hour	knots	0.87
knots	miles per hour	1.15
knots	centimeters per second	51.0
centimeters per second	knots	0.02
Depth:		
fathoms	feet	6
meters	fathoms	0.55
fathoms	meters	1.83
Volume:		
cubic yards	cubic meters	0.76
cubic meters	cubic yards	1.32

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7.0 REFERENCES

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