

**ENVIRONMENTAL IMPACT ASSESSMENT
FOR
DREDGING AND BEACH NOURISHMENT
ALUPANG BEACH CLUB CONDOMINIUMS
TAMUNING GUAM**

**PREPARE FOR
ALUPANG BEACH CLUB CONDOMINIUMS**

**PREPARED BY
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I. DESCRIPTION OF PROJECT

A. Project Description

1. Purpose and Justification

In recent years, development has expanded north and south of Tumon Bay with many new hotel and residential developments proposed for East Agana Bay. The Palace Hotel is now open at Oka Point and the Onward Agana Hotel project is under construction adjacent to Dungca's Beach. In addition, many condominium projects are also under construction in the area. The Bay View Condominium was completed on Trinchera Beach just south of the Onward Agana project and the Oka Point Condominiums have also been recently completed. The Alupang Cove Condominium has been in existence opposite Alupat Island for 14 years. Construction has begun on the Alupang Beach Club (ABC) Condominiums just north of Alupang Beach Club on the ocean side west of Marine Drive.

Since the reef flats are so shallow, nearly all beach oriented development on Guam necessitates dredging a swimming area. Since the number of people using this area for different activities will only increase in future years, it is important to plan for these activities. The proposed dredge area is located in front of the ABC Condominium and public park, under construction on the southwest side of the condominium project, and will therefore be used by residents of the complex as well as the public.

The proposed project has several purposes. The swimming area will be dredged to enhance its usefulness for swimming during all tide cycles. This area has accumulated layers of brown-black sediment that will be removed to reduce health risks and improve the circulation and aesthetics of the area. The beach fronting the proposed project will be nourished with beach sand above the high water line to enhance it's recreational value.

2. Location

The proposed project is located on the reef flat on the west coast of Guam adjacent to 997 South Marine Drive in Tamuning (Figures 1 and 2). The property is bordered by East Agana Bay on the west and South Marine Drive on the east. The location for the proposed project is shown in Figure 2.

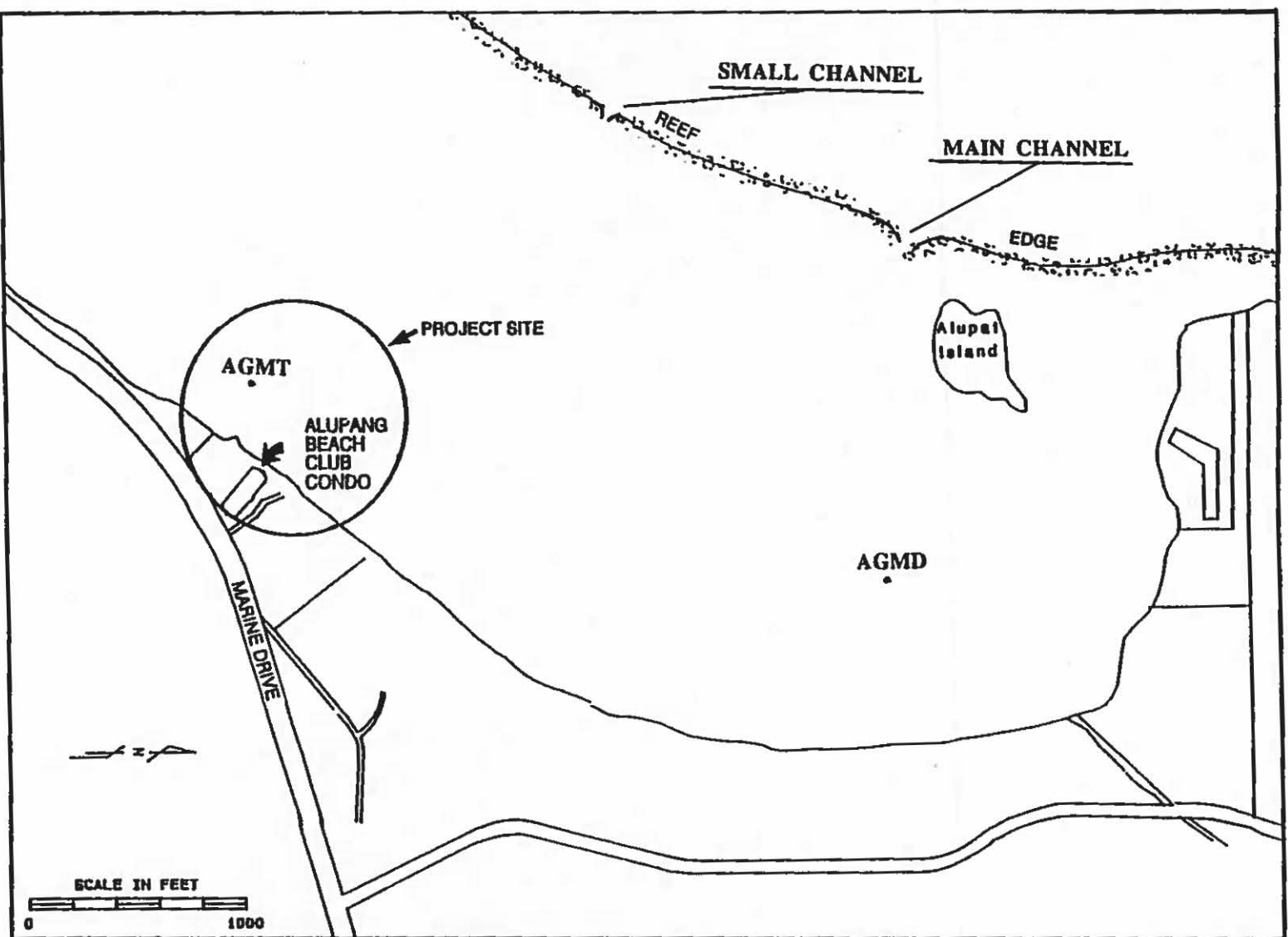


Figure 2. Vicinity map of Agana Bay showing location of ABC Condominium project and GEPA marine monitoring sites (AGMT and AGMD).

3. Project Design

The purpose of the proposed project is to create a swimming area by dredging the nearshore reef flat in East Agana Bay. A portion of the dredge spoil will be used to nourish the beach above the high water line. Sea Engineering, Inc. was contracted to prepare a coastal engineering assessment for the proposed dredging and beach nourishment project (Appendix B). Their design proposes that this swimming area be located 50 to 100 feet seaward of the existing shoreline. This will protect the nearshore fisheries (particularly the seasonal manahac runs) and allow the nearshore reef flat to be exposed during normal low tides and provide food for birds.

The dredge area will be approximately 650 feet long by 150 feet wide (95,500 square feet) with a dredged depth sloping from approximately -1.0 foot to -4.0 feet (at mean low low water, MLLW). The proposed dredge site is located adjacent to both the ABC Condominium project and public park built by ABC Associates (Figure 2) and will be used by the public as well as residents of the project.

The total area to be dredged is approximately 95,500 square feet. The average existing reef flat elevation is +0.3 feet (MLLW). To reach the proposed depth of -4.0 feet will require the removal of approximately 8,000 cubic yards (CY) of reef flat material.

The dredge spoil removed from the site will be sorted. Sixty percent of it's volume (5,000 CY) is estimated to be suitable for beach nourishment above the high water line; the remaining 40 percent is consolidated and unconsolidated coral rubble. The dredge material suitable for beach nourishment will be placed on the beach fronting the ABC Condominiums above the high water line (Figure 3).

EAST AGANA BAY

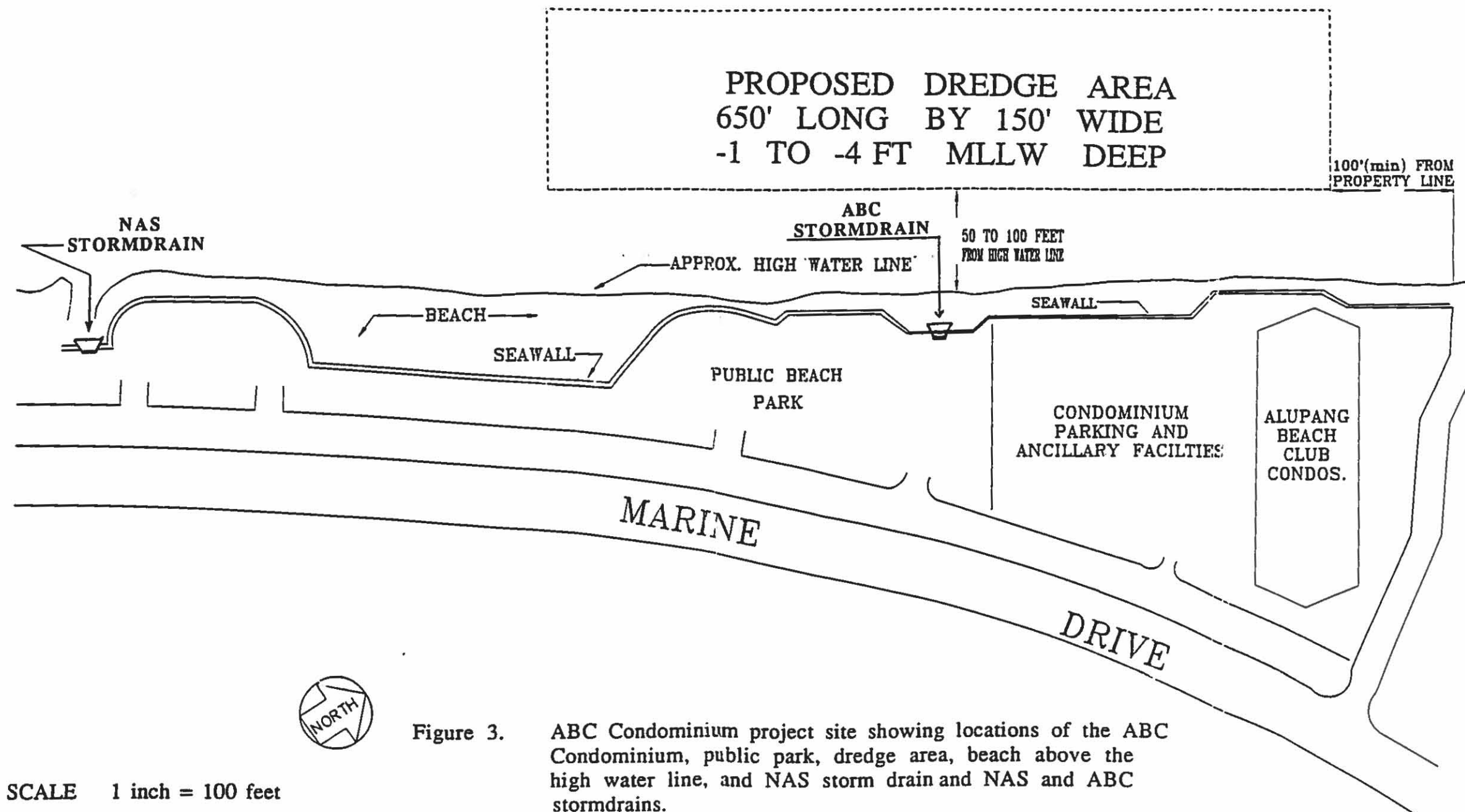


Figure 3. ABC Condominium project site showing locations of the ABC Condominium, public park, dredge area, beach above the high water line, and NAS storm drain and NAS and ABC stormdrains.

4. Construction Activities

a. Site Preparation

i. Grading

Dredging Methodology

The material will be removed via a hydraulic suction dredge. This method is used for dredging shallow sandy reef flat areas and has been successful in the construction of similar dredge zones such as the swimming hole on the reef flat fronting the Onward Agana Beach Hotel in East Agana Bay. The method involves the removal of sand and consolidated and unconsolidated material by a suction dredge operating in the shallow water of the dredge site. The dredge barge is held in place by several anchors and one or two piles driven into the sand. Extending from the barge is a boom on the end of which are two rotating cutter heads. These rotating cutter heads loosen the sand and consolidated reef material which is suctioned into and transported through a large (12" - 18") flexible pipe to a land-based dewatering pit. This dredging methodology decreases the amount of silt-laden water on the reef by removing it from the site along with the dredge spoil

The dredge spoil will be sorted and suitably sized beach sand stockpiled for beach nourishment above the high water line. All dredge spoil is owned by the government and the remaining portion may be requested for particular uses by government representatives. If not used by the government it may be left to the contractor to be used as necessary or trucked off-site to a suitable disposal site.

A detailed dredging plan will be developed by the contractor in an Environmental Protection Plan (EPP).

Beach Nourishment

Suitable beach material is defined as sand sized sediments with grain sizes between 0.2 and 2.0 millimeters (mm). Sand grains smaller than 0.2 mm would not be stable and sand grains larger than 2.0 mm are uncomfortable for bathers. For beach nourishment, only the sand grains coarser than 2 mm will need to be artificially sorted out as the sand grains that are too fine

will be naturally removed by the winnowing action of the waves and currents.

In order to avoid the need to obtain a federal ocean dumping permit under Section 404 of the Clean Water Act, beach nourishment will be restricted above the Mean High Water Line (MHWL). The sand will be placed at the maximum angle of stability up to the desired beach crest elevation. For calcareous sand, the maximum angle of stability is approximately 30 degrees. Within a short time, the sand will slough thus requiring additional maintenance nourishment. As the sand slides farther down the beach face and into the water, it will be sorted by waves and currents in a process called winnowing. Grain sizes that are not stable will wash away. Approximately 75 percent of beach nourishment material is estimated to be stable.

The nourishment, sloughing and winnowing process is repeated until the desired beach slope is reached. Sand on the equilibrium beach face will have a stability approximately equal to that of the adjacent natural beach.

ii. Site Improvements

Currently the nearshore lagoon area of East Agana Bay is very shallow and covered with rubble. Dredging will improve the area for swimming and other passive water sports. The beach is a narrow band, much of which has eroded away over the years. Beach nourishment will add to the aesthetic enjoyment of those using the beach by widening the area of fine sand.

iii. Temporary Facilities

During the dredging process, a sediment basin will be constructed on the beach side of the public park. It will be approximately 50' wide by 100' long and will be removed once all dredging is finished. The staging site for dredging equipment will be located in the same area as that used by the builders of the ABC Condominiums.

iv. Time Factors

Construction time is expected to take approximately two to four months. The project will begin once all permits have been obtained.

b. Construction

i. Structures

No special structures will be built for this project.

ii. Infrastructure Systems

There will be no need of any additional infrastructure systems.

c. Permits Needed

i. Federal Government Review

There are a number of permits which are required in order for this project to commence. The primary Federal permitting agency is the U.S. Army Corps of Engineers (USACOE). This agency requires a Section 10 permit (River and Harbor Act of 1899 as amended), a Section 404 of the Clean Water Act and Section 103 of the Marine Protection, Research and Sanctuaries Act for dredging within the navigable waters of East Agana Bay. Federal government review agencies include the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and the U.S. Environmental Protection Agency (USEPA).

Territorial regulations include the adoption of 16 Federal Coastal Zone Management policies in the Federal Consistency Review regarding use, protection and development of land and water resources. These policies are administered by the Coastal Zone Management Office (CZM) within the Government of Guam Bureau of Planning. This consistency review, with additional supporting information, is reviewed by all local and federal agencies. The consistency review must find that the project is consistent with federal government policy prior to approval by the CZM Office.

ii. Local Government Review

The USACOE permit review process includes review by local governmental agencies, interested organizations and concerned individuals and may involve a public hearing. The USACOE will not issue a permit until all applicable Territorial regulations have been satisfied.

The primary review mechanism for dredging projects within the Government of Guam is the Territorial Seashore Protection Commission (TSPC). However, prior to TSPC approval,

preliminary approval must be obtained by the Development Review Committee (DRC) and a public hearing must be held.

After obtaining TSPC approval and prior to construction, the applicant must obtain a Building Permit from the Department of Public Works (DPW). An Environmental Protection Plan (EPP) must be prepared and approved by the Guam Environmental Protection Agency (GEPA) prior to final approval of a Building Permit application for projects involving substantial alteration to the environment. Preparation of an EPP is the responsibility of the contractor and is intended to specify construction methodology and identify elements of the project which are designed to protect the environment. Mitigation and environmental protection measures are also detailed in the EPP.

GEPA requires a Section 401 Water Quality Certification prior to commencing work in any aquatic area. Submission of paperwork for the USACOE and CZM permits with a letter requesting the 401 Water Quality certification is sufficient as there is no application form for this certification.

An Environmental Impact Assessment (EIA) is required for any project which is federally funded, built on federal property or requiring federal permits. Findings in the EIA will determine the necessity of preparing an Environmental Impact Statement (EIS). The EIA/EIS is the responsibility of the developer and should be prepared early in the project's planning process.

5. Operational Activities

a. Consumption

i. Water

A minimal amount of water will be used in washing equipment during the dredging process.

ii. Electricity

A minimal amount of electricity may be used for lighting the project site during night work.

b. Discharge

i. Solid Waste

There will be a minimal amount of solid waste generated by this project. It will be disposed with solid waste generated by the ongoing ABC Condominium construction project.

ii. Wastewater

There will be no impact to the local sewage system as no wastewater will be produced from this project.

iii. Surface Water Runoff

No change in stormwater runoff is expected.

c. Pollution Generated

i. Emissions

Construction emission impacts will include all the temporary inconveniences that accompany development. Trucks, bulldozers and the suction dredge will all produce emissions and dust may be produced by land based activities. Much of the work will occur in conjunction with the ongoing construction of the ABC Condominium. These emissions are temporary and minimal and can be further minimized by adhering to strict control measures.

ii. Noise

Normal noise emissions from dredging activities will occur on the project site. The contractor will comply with all local and federal regulations pertaining to noise emanating from the site.

6. Biological Description of Site

a. Methodology

i. Terrestrial Flora and Fauna

Surveys were conducted by walking along the beach from beyond the property line to an area south of the NAS stormdrain at the outer boundary of the public park currently under construction. Vegetation was identified as to species. Birds were surveyed as to species and numbers (particularly in the vicinity of the stormdrain) by making observations for 15 minutes on at least two occasions and by conducting several general walks along the shoreline and on the project site.

ii. Marine Flora and Fauna

The reef flat was divided into three zones for survey purposes: Intertidal/Nearshore, Inner Reef Flat and Outer Reef Flat. Seven transects perpendicular to the shoreline were evaluated by PBEC Inc. in the vicinity of the proposed dredge area (Figure 4). Data collected during random 45 minute swims throughout the dredge site were used to compile checklists for fish, corals and marine plants.

To survey substrate types, a half meter quadrat with 16 points was laid on the substrate at ten meter intervals along each transect. Substrate type underlying each of the 16 points was identified as coral, algae, pavement, sand or rubble. These data were then translated into percent coverage of each substrate type.

b. Results

i. Terrestrial Flora and Fauna

Shoreline vegetation at the site consists primarily of coconut palms (Cocos nucifera), beach morning-glory (Ipomoea pes-caprae), common grasses and a few weeds. Alupang Beach Club has planted an ornamental hedge to shield the view of the parking lot from the beach.

Wildlife in the area consists of shore birds and other birds which occasionally frequent the intertidal zone and nearby large trees. Five species of birds were observed during two site visits: the ruddy turnstone (Arenaria i. interpres) common sandpiper (Actitus hypoleucos), reef heron (Egretta s. sacra), golden plover (Pluvialis dominica fulva) and Eurasian tree sparrow (Passer montanus saturatus). The majority of these birds were observed along the beach and delta (formed by the N.A.S. stormdrain) at low tide.

ii. Marine Flora and Fauna

Conspicuous marine wildlife in the study area is very limited. The substrate is composed primarily of sand with a small amount of silt and scattered rubble. Marine algae represented less than five percent substrate cover. Enteromorpha clathrata and Acanthophora spicifera were the most common algal

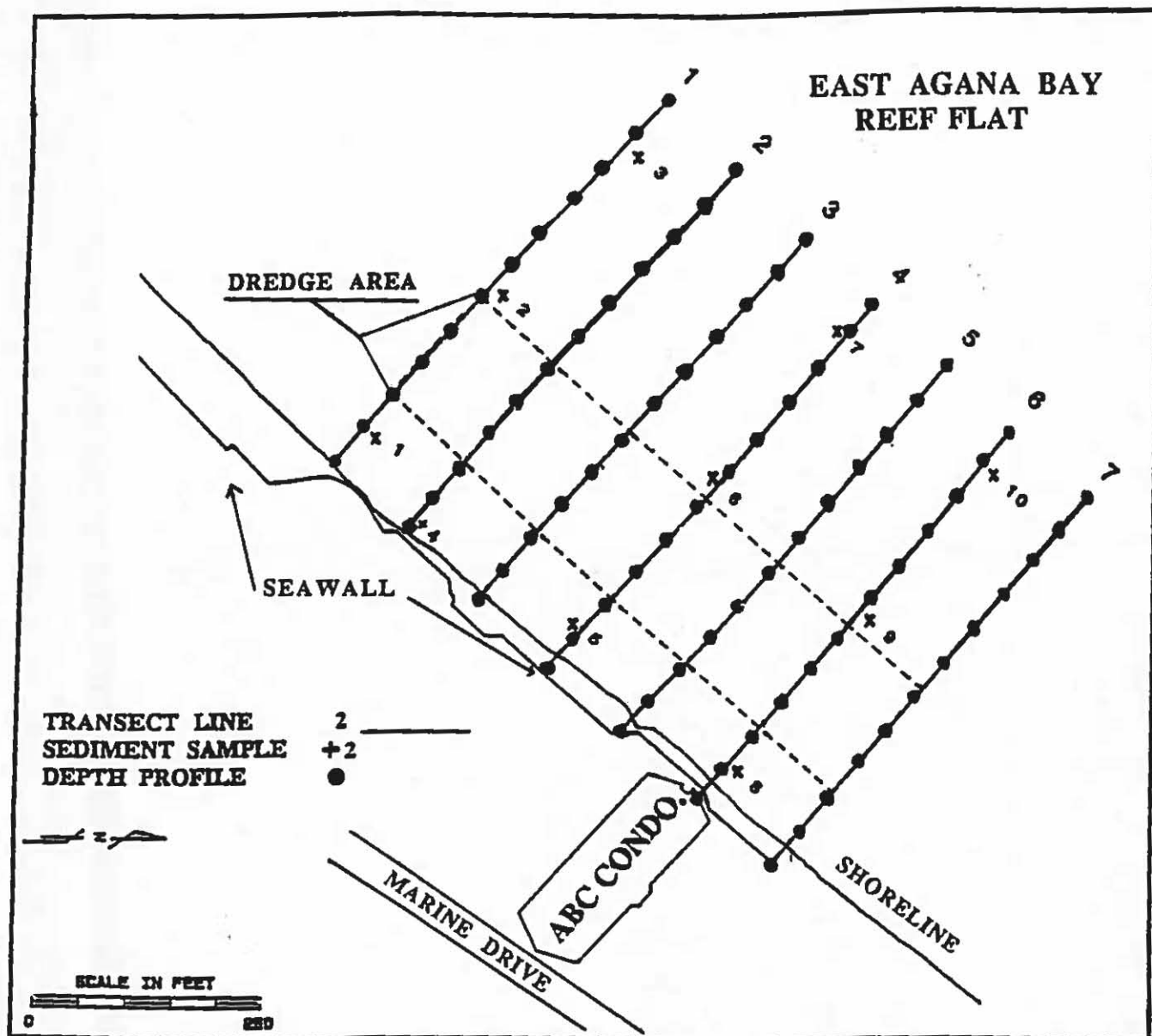


Figure 4. Location of marine transects, sediment depth profile and sediment sampling stations in front of ABC Condominiums, Agana Bay.

species nearshore. Marine algae in the central reef flat was dominated by scattered pieces of Avrainvillea obscura and clumps of Caulerpa sertularoides. A checklist of algal species within the proposed dredge site is compiled in Table 1 (Appendix A).

Two species of seagrass were present seaward of the proposed dredge area; Halophila minor and Halodule uninervis. The seagrasses formed small beds less than five ft in diameter. The small size of the seagrass beds limits their ability to act as a nursery for marine wildlife. Halophila averages 1 inch in height and is probably too small to be an important nursery. Halodule (approximately six inches tall), however, in sufficient quantities, could act as a nursery. Approximately 10 patches of Halodule occur outside but in the vicinity of the proposed dredge area.

Marine fauna in the area is also limited. Only 12 fish representing six species were observed during a 45 minute swim. Table 2 (Appendix A) lists fish species observed within the proposed dredge area and vicinity. A single unidentified Acropora coral (less than 1 ft in diameter) was observed in the dredge area. A checklist of coral species within the proposed dredge site and in the vicinity is compiled in Table 3 (Appendix A). Holothuria atra, the common black sea cucumber was the only conspicuous fauna in the dredge site and was common throughout the area as it is on nearly all sandy reef flats on Guam. A general checklist of macroinvertebrates (conspicuous and inconspicuous) present in the vicinity between the project site and the Paseo de Suzanna is compiled in Table 4 (Appendix A).

c. Endangered Species

No rare, threatened or endangered species of marine or terrestrial flora or fauna were observed in the dredge area or the vicinity of the project site. There is no recent record or evidence of the endangered Green Sea Turtle (Chelonia mydas) nesting along the beach or entering Agana Bay. One bird species, the common sandpiper (Actitis hypoleucos), is considered uncommon by the local Division of Aquatic and Wildlife Resources and is occasionally observed on the sandy beach near the stormdrain delta.

7. Physical Description of Site

a. Lagoon

i. Water Quality

Water quality in the area is variable but generally poor. Stormwater runoff from a stormdrain directly behind the ABC Condominiums (this drain was present during the collection of water quality data, but is being replaced and moved to the northeastern section of Agana Bay), the NAS stormdrain and a small river at Dungca's Beach all contributed to greater than normal levels of pollution in East Agana Bay. The Guam Environmental Protection Agency (GEPA) frequently issues reports that East Agana Bay is polluted and considered unsafe for swimming and fishing.

GEPA regularly collects water samples from two sites in the vicinity of the proposed project. These two marine monitoring stations are designated as AGMT (closest to Alupang Beach Club) and AGMD (Figure 2). Water quality data were analyzed over the period from April 1989 to October 1990 for two parameters: bacteriological contamination and turbidity (Table 5). Bacteriological contamination is evaluated in terms of fecal coliform in the water. Fecal coliform is an indicator of organic materials present in the water, generally the result of animal and human waste or decaying plant matter. Turbidity is the measure of suspended matter in water calculated in Nephelometric Turbidity Units (NTU). Stormwater runoff into Agana Bay carries terrigenous sediments which make the water turbid. Both of these parameters are good indicators of general environmental quality.

The range of fecal coliform at station AGMT (nearest to Island Imports) was 0-102 and 0-72,000 at station AGMD (Table 5). Water quality standards are exceeded if on any sampling date the number of fecal coliform exceed 400 per 100 ml water. Within the review period the standards were exceeded on two occasions at Station AGMD and on no occasions at Station AGMT. Ambient turbidity in Agana Bay as measured at Station AGMT in 1986 and 1987 was 2.20 NTU, and at Station AGMD the ambient turbidity was 5.33. Recorded NTU values at AGMT and AGMD never

exceeded 1.0 NTU over the ambient level, so water quality standards were not exceeded (Table 5).

The extreme fecal coliform values recorded indicate a pulse of organics flushed out of the stormdrains by heavy rains. This problem occurs frequently at stormdrains in Agana Bay. During periods of low rainfall pipes are clogged with sand and other terrigenous sediments from minimal pipe discharge. This creates buried layers of decaying organic material in the pipes and along the shoreline. When heavy rainfall flushes out the pipes foul-smelling discharge flows into the nearshore area. This makes the beach and shallow nearshore areas unattractive and smelly, a condition which can last several days.

ii. Currents

Currents along this portion of Agana Bay are normally slow moving and variable, with an overall pattern of water moving to the north. Water eventually exits the bay through the small channel in the reef out from Alupang Beach Club, but most water exits through the bigger channel just south of Alupat Island (Figure 2). Previous current studies were conducted by Randall and Eldredge (1974) and most recently by Sea Engineering, Inc., in 1981. Figures 5 and 6 show results of the two studies. Both surveys utilized dye release to measure currents as the bay is too shallow to use drift drogues.

Current velocities were low for both ebbing and flooding tides on the reef flat. Currents in the channel and cut get considerably stronger, especially during a strong ebbing tide and during storms. The result is a large volume of water entering the bay and seeking a place to exit. Strong rip currents have been observed when wave assault is great enough to break over the reef front transporting a large volume of water onto the reef flat.

Current velocities on the reef flat ranged from 0.04 m/sec (0.08 kts) to 0.15 m/sec (0.29 kts) during Randall and Eldredge's 1974 study. Velocities were greatest at the reef margin exit points, with maximums of 0.9 m/sec (1.8 kts) at the small cut and 1.42 m/sec (2.7 kts) at Alupat channel. Current velocities measured for this study were conducted from August 28 to

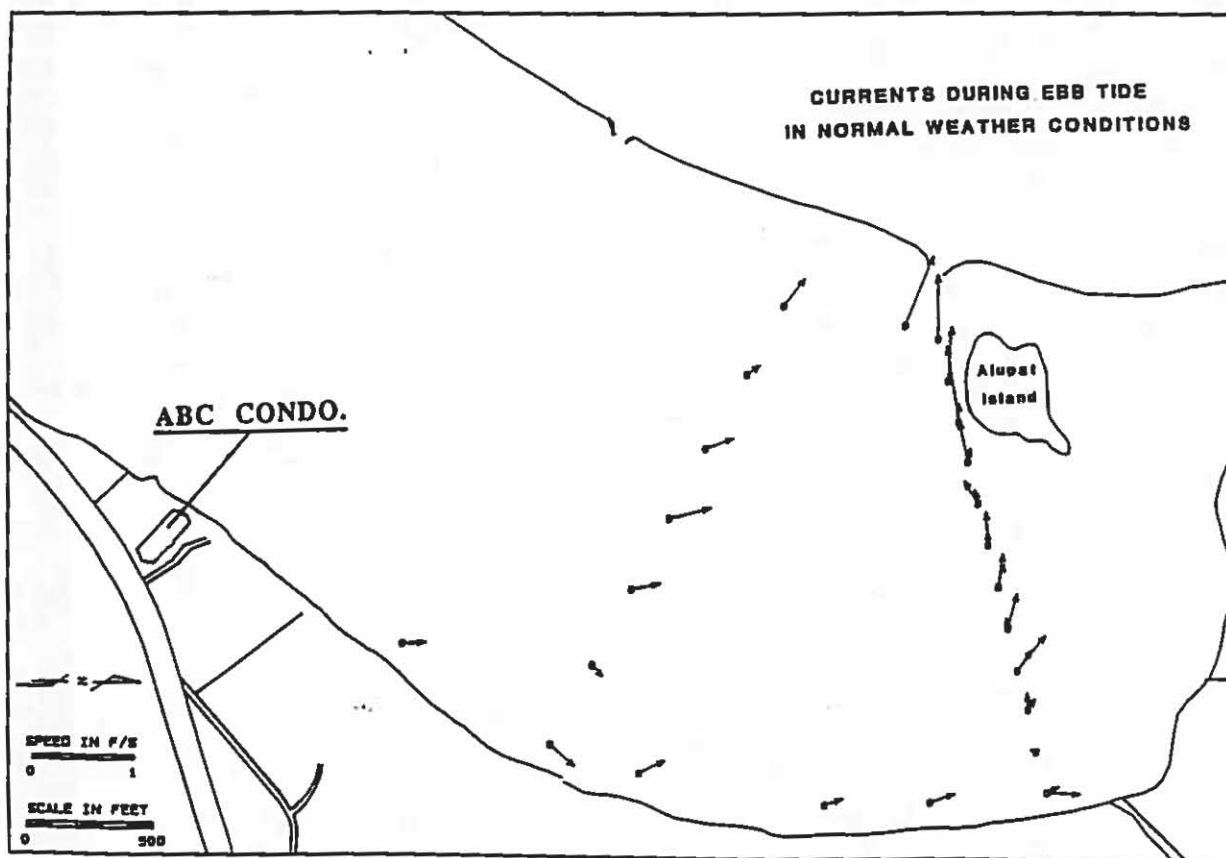
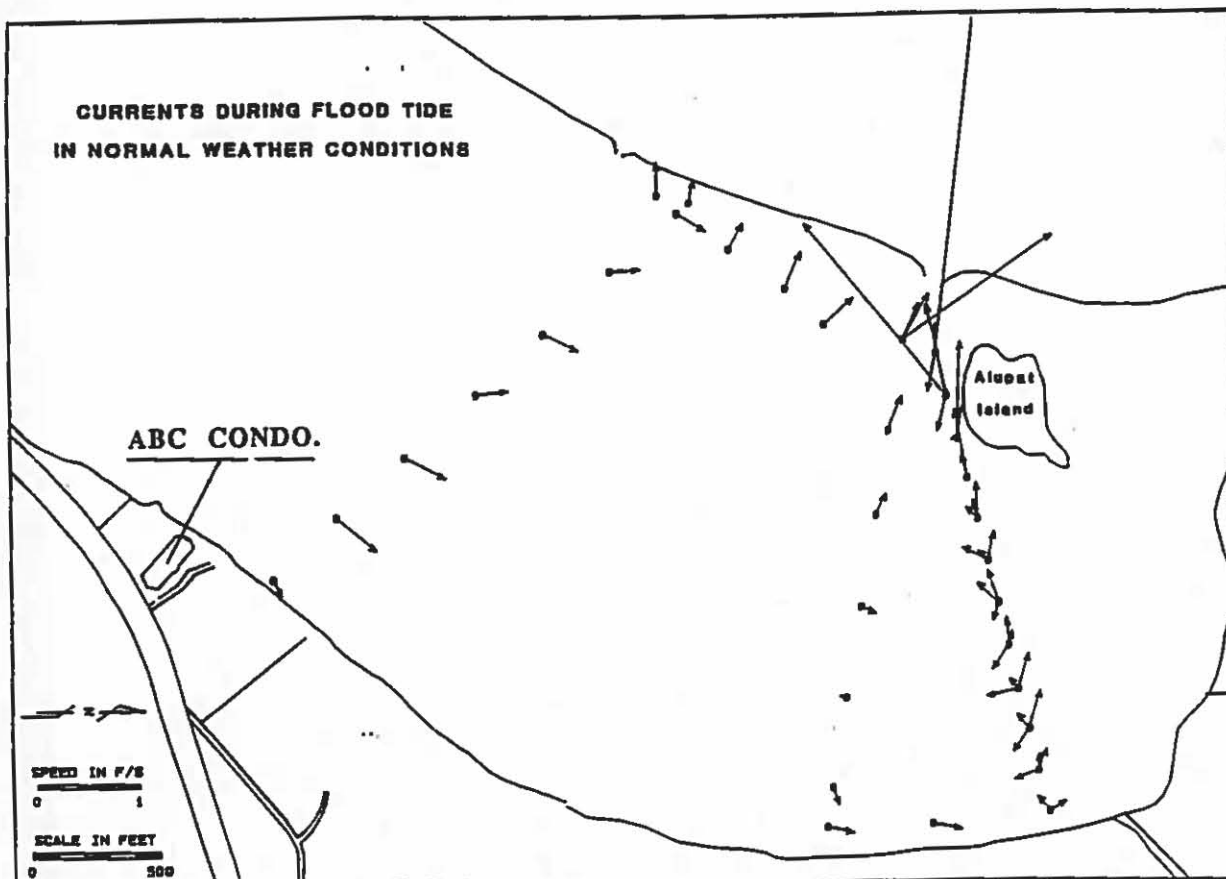


Figure 5. Currents in Agana Bay during ebb and flood tides in normal weather conditions.

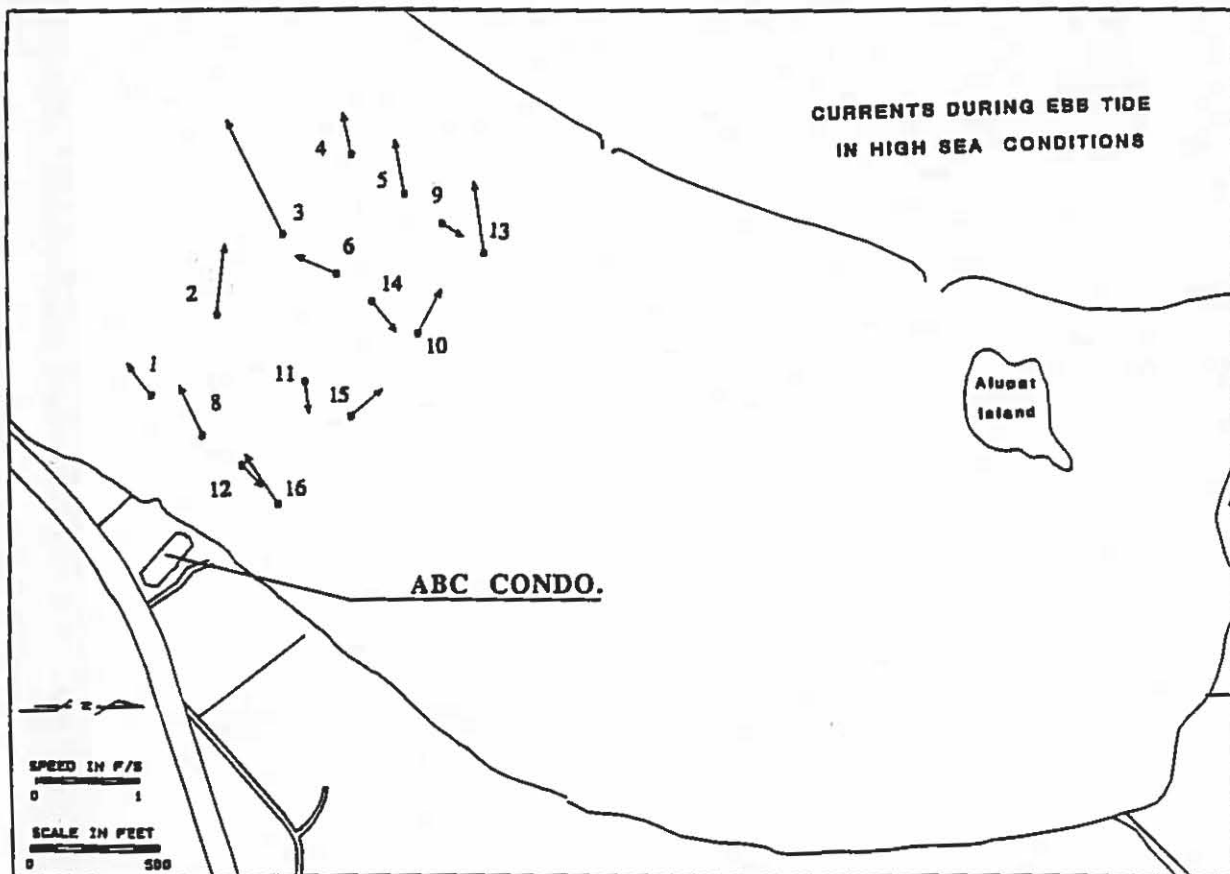
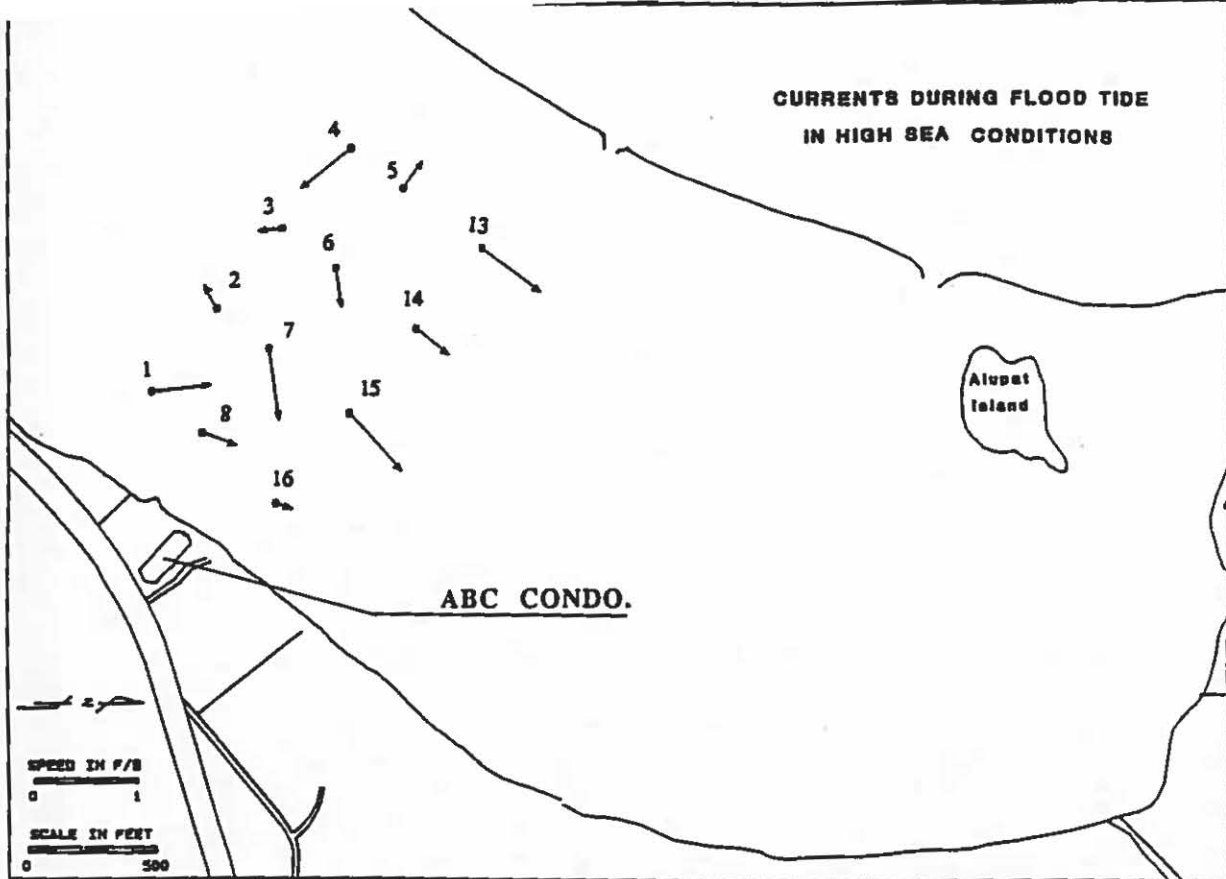


Figure 6. Currents in Agana Bay during ebb and flood tides in high sea conditions.

September 3, 1987. This coincided with a period following the close approach of tropical storm Holly and Typhoon Frieda. As a result, current velocities and directions reflect a storm condition where waves were breaking over the reef and creating a greater than normal volume of water on the reef flat. Several directions and velocities followed data found in Randall and Eldredge (1974). However, because of storm conditions the directions were more variable. It was not possible to measure the currents in the reef cut or Alupat channel as conditions were hazardous in the area. Velocities ranged from 0.04 m/sec (0.08 kts) to 0.38 m/sec (0.72 kts), with an average of 0.14 m/sec (0.27 kts). The greater velocities were measured at station 13 which is closest to the Alupat channel. Tables 6 and 7 (Appendix A) compile current velocities and directions.

iii. Sediment Characteristics

The deposition, accretion and transport of sediments from various sources is a continual process in Agana Bay. Sediments derived from the normal breakdown of marine organisms such as corals, molluscs and calcareous plants are a major source of the substrate sandy portion. The remaining substrate portion is composed of terrigenous sediments deposited into Agana Bay through stormdrains. When the ABC Condominiums are completed, only the NAS stormdrain will remain in the vicinity of the project.

Sediments Deposited by Storm Drains

Stormdrains are a primary source of terrigenous sediments which modify the nearshore profile of many reef flats on Guam. Sediments carried in these stormdrains by storm water runoff create deltas on the reef flat. The configuration of these deltas is influenced by both longshore currents which give them a significant degree of lateral continuity and by the intermittent nature of sediment deposition associated with rainfall. The physical configuration of these deltas is stable. There is, however, continual reworking of surface sediments causing redistribution and removal at the seaward edge. There is a maximum seaward propagation of deltas but no limit to the lateral expansion. Sediment transport data suggest that as long as discharge continues onto the adjacent reef -

=flat, deltas will be subject to minor changes but not complete removal by natural conditions. The seaward and lateral limits of deltas are controlled by the following parameters:

- * Frequency of stormwater drainage
- * Velocity and direction of prevailing currents
- * Increased velocity around the seaward end of the delta increasing erosion at low tides
- * Surrounding topography
- * Degree of man-made disturbances
- * Volume of new sediments carried in and removed by longshore currents
- * Frequency of storm surf

Sediments in the vicinity of stormdrains are very well sorted and contain traces of inorganic materials such as asphalt, glass, rust and insoluble volcanics. Organic detritus is also evident in sediments in the vicinity of stormdrains. Subsurface sediments around stormdrains (deeper than 10 cm) undergo extensive anaerobic activity by the production of hydrogen sulfide. Deeper subsurface sediments (greater than 50 cm) are clean limestone sand of varying small sizes. In addition, a considerable amount of organic detritus and human trash is associated with stormdrain deltas.

One stormdrain will remain in the vicinity of the dredge site. The NAS stormdrain empties at the shoreline in the central part of East Agana Bay on the western edge of the public park next to ABC Condominiums (Figure 2). This stormdrain (and the one that previously existed directly beneath what is now the ABC Condominiums) is responsible for a significant portion of the sediments which have accumulated in East Agana Bay.

The presence of stormdrains has increased sediment transport into the bay making it shallower, especially in areas near stormdrain outlets. This may account for the shallowness of the northern half of Agana Bay when compared with the southern half.

Previous studies indicate that deltas associated with stormdrains do not change size significantly. Tropical Storm Holly and Typhoon Frieda produced heavy surf along Guam's west coast for nearly two weeks in 1987. The surf, strong water movement and increased high tides did not significantly modify these deltas. However, sand throughout the bay was redistributed for a short time. The majority of sand movement was from the south to the north and was only temporary. Within two weeks following these storms, sand moved by water action was redistributed to normal conditions indicating a dynamically stable distribution of sediments and sand throughout East Agana Bay. The same condition has been observed in Tumon Bay.

The most common problem of stormdrains is one associated with the lack of routine maintenance. Frequently, stormdrains are plugged with sand brought in by ocean waves, currents and terrigenous sediments. Over time, buried layers of organic matter collect and create an anaerobic condition through the production of hydrogen sulfide. During heavy rains, the stormdrain pipes are flushed out resulting in the discharge of a dark, foul smelling effluent. This makes the beach and shallow nearshore water very unattractive and smelly, a condition that can last for several days.

Heavy rainfall in early and mid October 1987 caused the above condition. Visual observations were made to document the extent of the problem and to ascertain the general direction of effluent discharge over the reef flat. On October 8, 1987 heavy rain fell practically all day long. The stormdrains (NAS and ABC Condominium) were plugged from non-use. Stormwater backed up in the pipes until the pressure was great enough to flush them clean. Once the water began to flow, sediments in the pipe and nearshore area flushed out into the bay. The plume consisted of a dark mixture of sand, silt, organic detritus, inorganic particles and decomposed vegetable matter, creating a foul smelling effluent. The plume billowed westward into East Agana Bay across the reef flat. A portion of this plume exited through the small cut while the remainder spread out (north) by current and wind action and

eventually exited through the Alupat channel.

Sediment Depth Profiles

The lagoon area is nearly flat and the water depth ranges from 0 to 2 feet at Mean Low Low Water (MLLW). The lagoon substrate is sand, silt and coral rubble. A water jet probe was used to determine the depth of the sand layer and the type of material below the surface. The entire dredge area was probed following a grid pattern that included 77 points (11 per transect), or stations of investigation (Figure 4). The sand layer varied from six inches to over 11 feet thick and the top one foot of the sand layer was mixed with black silt. The dominant material below the sand was consolidated rubble which was difficult to penetrate with the water jet probe, but was distinguishable from the solid coral limestone pavement found at a few stations in the grid. More than half of the proposed dredging will occur in unconsolidated rubble regions (Sea Engineering, Inc., 1991).

Grain Size Analysis

Sediment samples were taken from the reef flat surface at ten locations near the study site (Figure 4). All samples were unconsolidated sand and coral rubble. A sieve analysis was performed to determine the grain size distribution. These results are compiled in Table 8 (Appendix A).

The results show that sediment in the north and south sections of the proposed dredging area is moderately to well sorted while the sediment in the section seaward of the dredge area is poorly sorted. Overall, sediment in the the proposed dredging area is medium to fine sand. A large percentage of the samples had grain sizes that are suitable for beach nourishment.

b. Beach

i. Geology

The beach is mostly sand with some scattered coral rubble. The depth of the sand varies from 1.5 to 7.0 feet along the beach. Below the sand is found consolidated rubble and hard coral limestone pavement. Limestone which underlies the sand is the argillaceous member of Mariana Limestone consisting of 2-6% clay. This causes a yellow to light brown discoloration in the

otherwise white limestone. The upper foot of sand is mixed with black terraginous silt.

ii. Topography

The beach area is on a 1% slope and varies in width from 20 to 40 feet.

iii. Hydrology

The East Agana Bay area is underlain by Mariana Limestone. The water table on the shoreline is approximately at sea level, and moves 1-4 feet above sea level moving away from shore. The northern water lens discharges at the shoreline and in the lagoon.

iv. Climate

The climate of the area is tropical with warm and humid conditions prevailing throughout the year. Temperatures vary from 83 to 92 degrees in the daytime and the middle seventies at night. The coolest months of the year are January and February; the warmest are May and June. Humidity varies from 66 to 84 percent. The surrounding ocean temperature is reasonably constant at 81 degrees.

On the average, slightly less than 90 inches of rain falls on Guam annually. The rainy season extends from July through November, the dry season from January through July. Small scale storms such as thunderstorms and squalls are very common during the rainy season, less so during the dry season. Drought is not unusual, particularly from the months of February through April.

Tradewinds, which approach from the northeast or southeast, are dominant during the dry season, usually producing wind speeds of 7 to 16 knots. Wind direction is variable during the rainy season.

The most common months for typhoons are July through December. Wind velocities of 65 knots or greater, along with intense rainfall, are typical of a typhoon.

v. Agriculture

The predominantly sandy soil in the beach nourishment site is poorly suited to subsistence or commercial farming due to its high salt content, lack of readily available

freshwater, low fertility and damage by wind, salt spray and storm seas.

vi. Soils

The shoreward portion of this area consists of Shioya soil, a light colored limesand in which percolation is downward into the rock. The seaward portion consists of white limesand in which drainage into the watertable is rapid. The beach is subject to erosion and deposition during storms.

8. Land Use

a. Surrounding Uses

Existing lagoon uses in the area include fishing, picnicking, snorkeling, net (talaya) fishing for manahac and other fish, wind surfing, jet skiing and other water-related activities. A number of commercial enterprises that rent water sports equipment (primarily to tourists) are presently operating in the central and northern portions of East Agana Bay.

The area where the Alupang Beach Club rents jet skis and other water recreational vehicles is situated away from the concentrated residential area located in the northern sector of the bay. Other water sport rental companies do operate further north in the bay and some residents have objected to the noise and disruption of privacy these operations create. There are two large houses on the beach and one small apartment complex that are located just north of the Alupang Beach Club.

b. Local Government Plans

There is a seashore use masterplan that has been submitted to the Legislature for final approval. This plan places limits on the use of motorized craft and allots locations for all other marine related activities in Agana, Tumon and Piti Bays. This plan, if signed into law, will allow motorized water craft in the southern portion of East Agana Bay and passive water recreation such as swimming, windsurfing and other non-motorized activities in the northern portion.

c. Service System Capabilities

Minimal utilities will be required during the construction phase of the proposed project.

d. Community Characteristics

The present level of development along Marine Drive in East Agana consists of a wide variety of commercial establishments including a car dealership, plumbing supply store, marine sports clubs, electronics shop and other retailers. Further north along the bay are single family residents, rental apartments, condominium units and high rise hotels. Previous vehicular access to the beach along much of the bay has been eliminated because of recently built curbs and sidewalks. These now run along the stretch of green area and beach (from the ABC Condominiums south to the first commercial building) where vehicles used to park.

A park area being developed along this stretch of Marine Drive is almost completed and provides minimal parking, two beach cabanas and access to the beach. Another park area is being developed adjacent to this project. This is a public park being built along the beach by ABC Condominiums. Under the Adopt-a-park program with the Department of Parks and Recreation, ABC Condominiums will maintain this park once it is completed.

9. Unique Features

a. Archaeological/Cultural/Historical

There are no known historical or archaeological sites or artifacts on the reef flat where the proposed dredging is to occur. The entire shoreline area has been disturbed and altered in recent years. Storms erode the beach and shoreline area and shift sediments around depending on the severity of the storm. There is some historical evidence that an intermittent stream in the area provided freshwater for a small seaside village. Personal communication with the descendant of a family from the area indicated that villagers produced salt there in the late 1800's and early 1900's. This stream emptied into the bay at the location of the present stormdrain behind Alupang Beach Club and may have created the depression in the reef flat and small channel through the outer reef (Figure 2).

Agana Bay has been traditionally used for manahac fishing. These fish enter the bay on certain days of the year, and are caught with nets.

II. ALTERNATIVES TO PROPOSED PROJECT

A. Reasonable Alternative Actions

1. Enhancement of Environmental Quality

The reef flat on the project site is shallow and covered with sand and coral rubble. Dredging will improve usability of the area for water sports. Dredging will also remove some of the foul smelling brown-black sediment that has accumulated on the reef flat. The beach fronting this area of East Agana Bay is severely eroded and needs nourishment. Beach nourishment will add to the enjoyment of those using the area.

2. Avoidance of Adverse Effects

Proper erosion control techniques will be implemented during all phases of construction. A silt curtain will surround both the dredge site and the settling pond.

3. Plan Modification

A number of plans were proposed during the design process, all of which were abandoned. One proposal was to extend the existing depression on the reef flat from the dredged area through the reef front (small channel in Figure 2). This might have allowed discharge from the NAS stormdrain to exit the reef flat rather than accumulate as it currently does. Another plan was proposed to dredge a second deeper area to be used for jet skiing located 50 to 100 feet seaward of the proposed swimming dredge area. A third plan was proposed in which beach nourishment was to be placed below as well as above the high water line.

*No discussion
on benefits or
impacts*

4. Site Selection

No alternative sites were considered for several reasons. The proposed site is in front of the ABC Condominium project as well as the public park, both of which are under construction. Therefore, residents of the condominiums, tourists, and local residents will all be able to utilize the area for water related recreational activities. Since the proposed project is designed to promote residential recreation for this area, it would not be economically feasible to dredge any other area of the bay.

B. Analysis of Alternatives

1. Benefits

The reef flat on the project site is shallow and covered primarily with sand, coral rubble and noxious black sediment. Dredging will improve the area for water sports. The beach fronting this area of East Agana Bay is severely eroded and needs nourishment. Beach nourishment will add to the enjoyment of those using the area.

2. Costs and Risks

The dredged area will require periodic dredging, and the beach may require periodic renourishment.

Very little risk is taken to construct the proposed project. Risk lies in not implementing controls that avoid adverse impacts to the surrounding ecosystems.

C. No Action

No action would mean that existing site conditions would prevail in this area of East Agana Bay. However, since construction of condominiums has already begun, an increase in residents would eventually result in an increased usage of the reef flat and adjacent beach. By dredging a portion of the nearshore reef flat, recreational uses of the area will be enhanced. The existing beach has been significantly eroded, and nourishment of the area will increase enjoyment of the beach by the public.

III. NATURE AND MAGNITUDE OF ENVIRONMENTAL CHANGES

A. Description of Impact

1. Construction Activities

a. Costs

The total cost for the proposed project is estimated at \$200,000.00.

b. Target Markets

The dredged area and nourished beach will be used by the public as well as the residents of ABC Condominiums.

c. Pollution

Minimal pollution is expected to be generated by the proposed project if the proper dredging methods are employed, sediments are controlled and care taken during construction. Proper planning and control can offset adverse affects from pollutants.

d. Flora/Fauna

i. Terrestrial

Shorebirds and other terrestrial wildlife will likely be driven away from the work area during the dredging and beach nourishment process. Deltas created by stormdrains in the area are not within the dredging project so will not be impacted by the proposed project. Construction workers, heavy machinery and increased noise levels will create an atmosphere unacceptable to most animals. However, birds and smaller animals will return to the area after the project is completed.

ii. Marine

Some increase in turbidity and sedimentation will occur on the reef flat during dredging activities. High levels of turbidity and sediment loading have a major impact on coral and other sessile forms of marine life. Fish and other mobile forms can swim away or move out of the area until more favorable conditions return. Benthic, burrowing and sessile organisms not removed prior to dredging will be destroyed once dredging commences. Both the degree of suspended sediments as well as the duration of the dredging process are important factors in determining the impact on

the marine environment. The impact of these will be minimized by the proper use of a silt curtain at the start of the dredging period.

Once dredging is completed, the newly dredged areas will recolonize with many of the same species as were previously inhabiting the area, as well as others which are suited to a slightly deeper marine habitat. Similar recolonization occurred following dredging of several swim holes in Tumon Bay including the Ypao Beach swim hole. Deepening this portion of the inner reef flat will improve fish habitat by creating an area that will be submerged at low tide instead of being exposed, and which may be of better overall water quality. Therefore the proposed project will likely result in minimal changes in benthic community characteristics over the long term. The depth of the dredged areas is designed to facilitate normal water circulation to assure that anaerobic muck does not accumulate, a problem in deep dredge areas.

iii. Impacts on Endangered Species

The proposed project will create no adverse impact on rare, threatened or endangered species since no rare or endangered plants or animals were observed or are likely to occur within or in the vicinity of the project site.

e. Sediment Transport

Sediment transport in the coastal environment involves the movement of sediments by waves, currents and tides. The degree to which shorelines erode or accrete depend on the interaction between these factors. A stable shoreline exists when equilibrium is reached between the supply and removal rate of sediments. However, equilibrium rarely exists for long periods of time because the forces which cause sediment transport are always changing.

Sea Engineering, Inc. (1991) examined the impact of transport forces in the vicinity of the proposed project. At the present time, the shoreline is in equilibrium. Although changes occur following storms, the pre-storm shoreline returns soon after the weather returns to normal. They conclude that immediately following dredging, the beach and nearshore area will adjust to reach equilibrium with new wave and current conditions. They predict the

nearshore wave height to increase approximately seven percent in non-storm conditions and four percent during storm conditions. As a result of refraction, wave direction is expected to effect only a limited segment of shoreline near boundaries of the dredge area. These changes are not expected to have a significant effect on sediment transport.

Sea Engineering, Inc. notes that the dredge area may trap sediments in the deepened bottom section. Sediment trapping may disturb the balance between sediment supply and removal and impact sediment transport in the area. The degree of imbalance depends on the rate of sediment trapping. The impact would result in accretion or erosion of sediments on the downstream coastline. Sediment trapping would be lessened by creating equilibrium slopes of 1:15 to 1:20 during the dredging process. However, this may not be practical because of the small size of the dredge zone.

2. Secondary Impacts

a. Income Distribution

A significant portion of the estimated cost of this project is in salaries which will remain in the community. Although insignificant, tax revenues such as Gross Receipts Taxes on construction materials and activities will be temporarily increased.

b. Support Services

Periodic maintenance of the proposed project site is to be contracted so no increase in support services is expected.

c. Population Shifts/Growths

There is no expected increase or shift in population resulting from this project.

3. Multi-Development Impacts

a. Need

Recreational use of the general area will be enhanced by deepening the area for swimming as will nourishment of the beach.

b. Socio-Economic

Creation of a deeper basin will result in increased water recreational uses of the area. Approximately half of the proposed swimming hole is located directly in front of the ABC Condominiums, while the other half is in front of the public beach park presently under construction. The area will therefore be used by residents of the condominium as well as visitors to the public park.

The impact of this project on surrounding property values will be insignificant since property values are already increasing rapidly as a result of hotel and condominium construction in the area.

There will be no infrastructure needs by the proposed project, so local utilities will not be impacted.

B. Magnitude of Impacts

1. Commitment of Resources

A shallow reef flat will be changed to a slightly deeper reef flat, and the shoreline will be nourished with additional beach sand.

The irretrievable commitment of resources as a result of implementing this project are manpower expended on design, dredging and beach nourishment, and fuel expended during the dredging and nourishment process.

2. Environmental

a. Habitat Modification and Loss

Dredging of the nearshore reef flat seaward of the Alupang Beach Club will cause habitat modification with resultant loss of very shallow, temporarily exposed, sand and rubble substrate. The proposed dredging plan will create a deeper marine habitat which will eventually recolonize with similar species already found in the area. No net loss of marine habitat will occur since a slightly deeper area will replace the shallow water habitat now existing in the area.

b. Erosion from Clearing and Grading

An Erosion Control Plan (ECP) will be designed by the contractor and implemented before construction begins. The ECP

will outline methods of erosion control to protect against erosion from dredging and beach nourishment operations.

c. Dredging Impacts

The construction of ABC Condominiums has already impacted beach vegetation so it is unlikely that the proposed dredging project will further impact the area. Stockpiling of dredge spoil will occur along the beach. A suitable location will be chosen and bermed to provide a dewatering basin for the spoil.

Dredging methodology and spoil removal techniques are major considerations in attempting to determine the impact of turbidity. The best way to control turbidity on the marine environment is to minimize the transport of silt and suspended sediments to surrounding areas. This can be done through the effective use of silt curtains which enclose the turbid water until settling can occur. They can also be used to divert a silt plume around an area or to encircle a particularly important resource. The implementation of silt curtains in this region of East Agana Bay would be an excellent method of silt protection.

3. Infrastructure

There should be minimal impact on utilities in the area as very little power or water will be needed and no sewage will be generated. Roads in the area will be used by trucks hauling dredge spoil to designated dump sites.

4. Recreational/Scenic

Although some subsistence fishing occurs along the shores of East Agana Bay, the area is primarily used for recreational purposes, therefore the effects on subsistence fishing will be minimal.

Impacts on recreational resources will be positive. Dredging of the nearshore swimming area will promote year-round increased recreation in the area. Beach nourishment will enhance the use of the area to those who use the beach. As the swimming area is readily accessible to the public via the public beach park, it will be a benefit for those not residing at the ABC Condominiums.

Scenic resources in this area of East Agana Bay will not be impacted by the proposed project.

5. Cultural/Historic

Impacts on cultural and historical resources will be minimal. There are no known historical or archaeological sites or artifacts on the reef flat where the proposed dredging and beach nourishment is to occur.

IV. SIGNIFICANT CRITERIA

A. Statutory Criteria

1. Objectives of Environmental Laws

a. Goals and Objectives

Relevant goals and objectives of existing federal and local environmental laws reinforce the original intent of the National Environmental Policy Act (NEPA) of 1970. This act was promulgated to ensure that all federal agencies consider environmental concerns in all planning and decision-making activities under full public view. Over the past two decades, the intent of NEPA has expanded broadly on Guam to encompass nearly all facets of development. NEPA was designed to foster the wisest use of natural resources available in all environmental settings.

Standards set forth in Guam's existing statutes and regulations, e.g., Guam Air Pollution Control Standards and Regulations of 1987, Revised Guam Water Quality Standards of 1987 and the Soil Erosion and Sedimentation Control Regulations of 1985, provide further criteria which developers must meet to ensure environmentally sound development.

Recently, Executive Order 90-10 requires the preparation of an Environmental Impact Assessment (EIA) for most large developments requesting zone changes and variances.

b. Derived Criteria

Technically derived measurements apply primarily to engineering matters e.g. infrastructure, potable water needs, electrical power demand and wastewater disposal. These must be evaluated to assure that the resources of Guam are not impacted in ways that will deprive residents of basic necessities. These criteria are established by government utility agencies such as the Public Utilities Agency of Guam (PUAG), Guam Power Authority (GPA) and Guam Telephone Authority (GTA).

c. Political, Social and Cultural Criteria

The Department of Land Management (DLM) coordinates the review by the Territorial Land Use Commission (TLUC) and Territorial Seashore Protection Commission (TSPC). Agencies participating in the review include the Bureau of Planning

(BOP), Department of Public Works (DPW) and Guam Environmental Protection Agency (GEPA). The opportunity for testimony at public hearings serve allow significant input from interested groups and individuals. Also, the "significance assessment" of archaeological findings shows the government's sensitivity to local history and customs.

2. Regulatory Standards

a. Air

The U.S. Environmental Protection Agency (USEPA) established national ambient air quality standards in the Clean Air Act of 1977. These standards provide environmental protection by setting pollution level standards or limiting emissions for various classes of pollutants. The Guam Air Pollution Control Standards and Regulations of 1987 authorized the formulation of air quality standards. These standards and regulations are enforced and monitored by the GEPA.

b. Water

It is the public policy of Guam to conserve, protect, maintain and improve the quality of waters on and around the island. The policy maintains that pollutant discharges will not be allowed into any body of water unless the discharge meets the effluent limitations established for that discharge, or receives processing. The policy also provides for prevention, abatement and control of new and existing water pollution. To assist in obtaining this goal, all discharges will be controlled (permitted) either through the National Pollutant Discharge Elimination System (NPDES) or through the GEPA's local permit program. Therefore, pursuant to the authority contained in the Guam Water Pollution Control Act, GEPA has adopted standards for Guam's water quality. The purpose of these Water Quality Standards is to prevent degradation of water resources resulting from pollutant sources. It is not the intent of these standards to restrict activities which may potentially cause pollution, but rather to regulate such activities to control pollution. An Environmental Protection Plan (EPP) must be prepared for all developments prior to construction to ensure that water resources will not be degraded. This EPP is submitted to GEPA for approval.

c. Erosion

Soil erosion and sedimentation from construction activities affect the quality of streams and marine waters on Guam. Therefore, any pollution of stream and marine water must be controlled to ensure a reasonably clean and productive environment. With the promulgation of GEPA's 1985 Soil Erosion and Sedimentation Control Regulations, stricter safeguards are now required in the review of Clearing and Grading and Building Permits. In general, the 1985 Regulations define earthmoving operations that are subject to permits. Regulations require that GEPA must approve an EPP before earthmoving operations are allowed to convene.

V. EVALUATION OF IMPACTS

A. Impacts Compared to Measurements

1. Positive

The East Agana Bay reef flat is a shallow sandy reef flat. During low tides throughout the year numerous sections of the reef are exposed, making swimming impossible, and lowering the suitability of the substrate for marine organisms. In addition, the stormdrains have discharged large amounts of terrigenous silt which has accumulated on the reef flat. The sand overlaying the silt covers noxious smelling anaerobic muds.

Much of Guam's tourism relies on the beauty of its beaches and the recreational potential of its waters. As the local population grows, it too enjoys the waters surrounding Guam, many of which are similar to the reef flat of East Agana Bay. The proposed project will enhance the recreational potential of the reef flat fronting the ABC Condominiums in East Agana and the adjacent public park.

The primary consideration of this proposal is to deepen an area on the reef flat to enhance its usefulness for general swimming. A secondary consideration is that dredging will remove the accumulated layers of noxious sediment which will reduce health risks and improve the aesthetics of the area. Finally, suitable material from the dredging operation will be used to nourish the existing beach and will provide a more usable and enjoyable beach.

The swimming area and beach will be available for use by residents of the ABC Condominiums and the public using the public park located next to the southwest tip of the condominium project. This park (built and maintained by the ABC Condominiums under the Adopt-a-park program) will have parking stalls and picnic cabanas, making it attractive for use on a regular basis by local families.

2. Negative

Although there will be no net loss of habitat, it will be modified from the existing habitat and the dredging process will kill sessile flora and fauna within the dredge area. After the dredging

process is completed, recruitment of species back into the area, as has occurred in the Ypao Beach Swim Hole, is likely.

The silt produced by dredging must be kept to a minimum and contained within the dredge zone so there will be no adverse impacts to the surrounding environment. Properly positioned and maintained silt curtains will minimize movement of silt out of the dredged areas. Reef areas located seaward of the dredge site, particularly on the reef front, are rich in marine organisms and must be protected from siltation.

B. Avoidable and Unavoidable Impacts

1. Avoidable

The temporary disturbances that are associated with construction such as dust, exhaust and noise from the operation of heavy equipment, can be minimized through implementation of precautionary measures and appropriate pollution control techniques. These will be outlined in the Environmental Protection Plan (EPP) to be developed prior to dredging. Soil erosion and stormwater runoff can cause siltation of reefs, kill marine life, stimulate excessive algae growth and deplete the water's dissolved oxygen. Excess erosion and runoff during the proposed activities will be minimized by implementation of an effective erosion control plan.

2. Unavoidable

Impacts which are unavoidable include the modification of natural habitat and killing of sessile flora and fauna within the dredge zone. Although there will be no net loss of habitat, the dredged areas will undergo a change resulting in a deeper habitat. This habitat will be available for recruitment by species present before dredging. It is also likely be colonized by species requiring a slightly deeper habitat than is currently available.

3. Estimated Evaluation of Impacts

a. Rate of Change

The overall rate of change on Guam today is dramatic. The recent demand for housing (single-family, apartments and condominiums), office space, commercial sales, light industrial and tourist/hotel facilities have created a cumulative need for more

"development" in many sectors of Guam. The island's population has increased by 25 percent during the ten year period between 1980 and 1990. The Agana Bay area has experienced a particularly dramatic increase in development over the last two years with numerous hotel and condominium projects, some already built and others either under construction or still to be started. It is likely that this rate of change will continue into the near future (two to three years).

b. Commitment of Resources

Approximately 95,500 square feet of marine wildlife habitat and associated sessile flora and fauna will be irreversibly lost or modified by the proposed dredging and beach nourishment project. Other irretrievable resources committed for this project include the manpower expended on design, dredging and beach nourishment and fuel expended during the dredging and beach nourishment process.

VI. ENVIRONMENTAL PROTECTION MEASURES

A. Sediment Control Plan

All earthmoving activities in the Territory are to be conducted in a manner that prevents accelerated land erosion, transportation of sediment to and along waterways and siltation of rivers, estuaries and marine waters. Stormwater runoff from disturbed areas of a project will be collected and diverted to protect areas from erosion during the stabilization period and will be maintained by the permittee until stabilization is complete.

Erosion and sediment control plans will be prepared as set forth in Section IV B of the Soil Erosion and Sedimentation Control Regulations of 1985 and submitted to GEPA for review. Within 14 days, GEPA will approve or disapprove the Erosion Control Plan. Lack of agency comments within the stipulated time shall constitute approval. Appeals are normally conditional. Any notice of a disapproval must contain any and all reasons for such disapproval.

B. Air Quality

Dust will be kept to minimum at all times, including non-working hours, weekends and holidays. Soil at the project site, haul roads and other areas disturbed by the construction operations will be sprinkled or treated with dust suppressors (water) as necessary to control dust. No power brooming will be permitted. Vacuuming, wet sweeping, wet mopping or wet power brooming will be used instead. Air blowing will be permitted only for cleaning off non-particulate debris.

C. Habitat Restoration

Upon completion of the proposed project, all areas which were disturbed by the project will be stabilized so that erosion and/or sedimentation will be prevented. Any erosion and sedimentation control measures necessary to protect areas from erosion during the stabilization period will be maintained until stabilization is completed. Upon completion of stabilization, all unnecessary or unusable control facilities will be removed, the area graded and the soils stabilized.

VII. MITIGATION MEASURES

A. Short-Term

1. During construction of the proposed onshore activities appropriate dust control techniques will be employed to minimize adverse impacts to air quality.

2. During dredging, a silt curtain will be positioned and properly maintained to ensure that silt will be contained. An Erosion Control Plan will be prepared to outline how erosion impacts will be kept to a minimum.

3. Conspicuous benthic flora and fauna within the dredge zone can be removed from the dredge area once the silt curtains are in place. An Environmental Protection Plan will be prepared and submitted to GEPA for approval prior to dredging. A water and environmental quality monitoring program will be designed to help ensure environmental protection during dredging.

B. Long-Term

1. Once the dredging operation is complete, the dewatering pond will be returned to its original condition. Replanting of the area will assure that erosion does not occur, and will restore habitat for fauna.

REFERENCES

Guam Environmental Protection Agency. 1987. Guam Water Quality Standards.

APPENDIX A

TABLES

Table 1. Checklist of marine algae within the proposed dredge areas in front of ABC Condominiums, Agana Bay.

Relative Abundance

C = Common

U = Uncommon

R = Rare

-- = Not observed

DIVISION Species	Inner Reef Flat	Outer reef Flat
Chlorophyta (Green)		
<u>Avrainvillea obscura</u>	U	C
<u>Boodlea composita</u>	R	R
<u>Caulerpa sertularioides</u>	--	C
<u>Enteromorpha clathrata</u>	C	U
<u>Halimeda macraloba</u>	R	U
<u>Neomeris annulata</u>	--	R
Phaeophyta (Brown)		
<u>Acanthophora spicifera</u>	U	C
<u>Dictyota bartayressi</u>	R	R
<u>Padina tenuis</u>	U	U
<u>Sargassum polycystum</u>	--	R
Rhodophyta (Red)		
<u>Hypnea sp.</u>	--	R
<u>Porolithon onkoides</u>	--	U
<u>P. sp.</u>	R	U
<u>Spyridia filamentosa</u>	U	R
Anthophyta (Seagrass)		
<u>Halodule uninervis</u>	--	U
<u>Halophila minor</u>	--	C
TOTAL DIVISIONS	3	4
TOTAL SPECIES	9	16

Note: The proposed dredge area is on the inner reef flat. The area was at least 95 percent bare sand. No algae was considered "abundant".

Table 2. Checklist of fish within the proposed dredge area and vicinity in front of ABC Condominiums, Agana Bay.

FAMILY Species	LOCATION		
	Inner Reef Flat	Outer Reef Flat	Reef Margin
ACANTHURIDAE (Surgeonfishes)			
<u>Acanthurus lineatus</u>			x
<u>A. mata</u>			x
<u>A. triostegus</u>		x	x
<u>Ctenochaetus striatus</u>			x
ANTENNARIIDAE (Frogfishes)			
<u>Histrio histrio</u> *	x		
APOGONIDAE (Cardinal fishes)			
<u>Apogon novemfasciatus</u> *	x	x	x
<u>A. exostigma</u> *	x		
<u>Cheilodipterus quinquelineatus</u>			x
BALISTIDAE (Triggerfishes)			
<u>Rhinecanthus aculeatus</u>	x	x	
CHAETODONTIDAE (Butterflyfishes)			
<u>Chaetodon bennetti</u>			x
<u>C. citronellus</u>			x
<u>C. ephippium</u>			x
<u>C. ornatissimus</u>			x
<u>C. reticulatus</u>			x
LABRIDAE (Wrasses)			
<u>Halichoeres hortulans</u>			x
<u>H. margarifaceus</u>			x
<u>H. trimaculatus</u>		x	x
<u>Macropharyngodon meleagris</u>		x	
<u>Thalassoma quinquevittata</u>			x
LUTJANIDAE (Snappers)			
<u>Lutjanus sp.</u>			x
MONACANTHIDAE (Filefishes)			
<u>Oxymonacanthus longirostris</u>			x
MULLIDAE (Goatfishes)			
<u>Mulloidichthys flavolineatus</u>			x

Table 2 continued.

FAMILY Species	LOCATION		
	Inner Reef Flat	Outer Reef Flat	Reef Margin
NEMIPTERIDAE (Monocle Breems) <u>Scolopsis cancellatus</u>			x
POMACENTRIDAE (Damsel fishes) <u>Abudefduf sexfasciatus</u>			x
<u>Chromis caerulea</u>		x	
<u>Chrysiptera leucopomus</u>		x	
<u>Plectroglyphidodon dickii</u>		x	x
SCARIDAE (Parrotfishes) <u>Scarus gibbus</u>			x
<u>S. psittacus</u>			x
<u>S. sordidus</u>		x	x
<u>Scarus sp.</u>			x
SYNODONTIDAE (Lizardfishes) <u>Saurida gracilis*</u>	x		
TETRAODONTIDAE (Smooth Puffers) <u>Canthigaster solandri</u>	x	x	x
<u>C. valentini</u>		x	
<u>Anothron hispidus*</u>	x		
ZANCLIDAE (Moorish Idols) <u>Zanclus cornutus</u>			x
Unidentified species white with yellow bar*	x		
TOTAL FAMILIES	6	7	12
TOTAL SPECIES	8	11	27

* These six species were each observed no more than two times during a 45 minute swim within the proposed dredge area on the inner reef flat. All other inner reef flat species were observed outside of the proposed dredge area.

Table 3. Checklist of corals within the proposed dredge area and vicinity of ABC Condominiums, Agana Bay.

FAMILY Species	LOCATION		
	Inner Reef Flat	Outer Reef Flat	Reef Margin
Scleractinia Corals			
<u>Acropora aspera</u>		x	x
<u>A. sp.</u>		x	x
<u>A. palifera</u>			
<u>A. nasuta</u>		x	x
<u>A. humilis</u>		x	x
<u>A. sp. *</u>	x		
<u>A. wardi</u>		x	x
<u>Favia stelligera</u>		x	x
<u>Galaxia fascicularis</u>		x	
<u>Goniastrea retiformis</u>		x	x
<u>Goniopora tenuidens</u>		x	
<u>Leptoria phrygia</u>			x
<u>Lobophyllia corymbosa</u>		x	
<u>Leptastrea purpurea</u>		x	
<u>Montipora lobulata</u>			x
<u>Pavona divaricata</u>			x
<u>Pocillopora danae</u>			x
<u>P. setchelli</u>		x	
<u>P. verrucosa</u>		x	
<u>P. damicornis</u>	x	x	x
<u>P. sp.</u>			x
<u>Porites annae</u>			x
<u>P. cocosensis</u>			x
<u>P. lutea</u>	x	x	x
<u>Psammocora contigua</u>			x
<u>Stylaraea punctata</u>			x
<u>Stylophora mordax</u>			x

- * A single small (one foot diameter) colony was observed within the proposed dredge area. All the other species occur in the vicinity but outside the proposed dredge zone.

Table 3 continued.

FAMILY Species	LOCATION		
	Inner Reef Flat	Outer Reef Flat	Reef Margin
Soft corals			
<u>Sinularia</u> sp.		x	x
<u>Sarcophyton</u> sp.			x
Octocorallia corals			
<u>Heliopora coerulea</u>			x
Milleporina corals			
<u>Millepora dichotoma</u>			x
<u>M. foveolata</u>			x
<u>M. latifolia</u>			x
<u>M. platyphylla</u>			x
TOTALS			
Scleractinian Corals			
Genera	3	9	11
Species	3	15	19
Soft Corals			
Genera	0	1	2
Species	0	1	2
Octocorallia Corals			
Genera	0	0	1
Speices	0	0	1
Milliporina Corals			
Genera	0	0	1
Species	0	0	4

Table 4. General checklist of macroinvertebrates observed on the reef flat in East Agana Bay. 1986 and 1987.

PHYLUM SPECIES	INNER REEF FLAT	OUTER REEF FLAT
Coelenterata		
Burrowing anemone sp.	*	*
<u>Sargartiomorpha paguri</u>		*
Clownfish anemone sp.		*
Anemone sp.	*	
Annelida		
Sabellid polychaete sp. 1 (large)		*
S. sp. 2 (small, white, in sand)	*	
S. sp. 3 (small, brown, in sand)	*	
Terebellid polychaete sp. 1 (red crown)	*	
T. sp. 2	*	
Mollusca (Gastropoda)		
Vermetid sp.		*
<u>Rhinoclavus fasciatus</u>		*
<u>R. sp.</u>		*
<u>Cerithium zonatum</u>	*	
<u>Strombus giberellus gibbosus</u>	*	
<u>Natica sp.</u>	*	
<u>Cyprea moneta</u>		*
<u>Tonna perdx</u>		*
<u>Melea pomum</u>	*	*
<u>Imbricaria punctata</u>		*
<u>Vexillum semifasciatus</u>	*	
<u>V. sp.</u>	*	
<u>Conus pulicarius</u>	*	*
<u>C. eburoeus</u>		*
<u>Terebra affinis</u>	*	*
<u>T. crenulata</u>		*
<u>T. maculata</u>	*	*
<u>T. subulata</u>		*
<u>T. dimidiata</u>		*
<u>T. sp.</u>		*
<u>Pyramidella acus</u>	*	
<u>Otopleura nodicincta</u>	*	*
<u>O. sp.</u>	*	
<u>Pinna muricata</u>	*	*

Table 4 continued.

PHYLUM SPECIES	INNER REEF FLAT	OUTER REEF FLAT
<u>Codakia punctata</u>	*	*
<u>Fragum fragum</u>	*	*
<u>Tridacna squamosa</u>		*
<u>Tellinidae sp.</u>		*
<u>Scutarchopagia scobinatum</u>	*	
<u>Tellina robusta</u>	*	
<u>Tellina sp.</u>	*	
<u>Pitar sp.</u>	*	*
<u>Gapharium pectinatum</u>	*	*
<u>Periglypta reticulata</u>		*
<u>Octopus sp.</u>	*	
Arthropoda (Crustacea)		
<u>Caridean sp.</u>	*	*
<u>Alpheid sp.</u>		*
<u>Peneid sp.</u>		*
<u>Calcinus latens</u>		*
<u>Dardanus megistos</u>		*
<u>D. deformis</u>		*
<u>D. sp.</u>		*
<u>Callapa hepatica</u>	*	
<u>Parthenope sp.</u>	*	
<u>Thalamita spp.</u>	*	
<u>Portunus spp.</u>	*	
<u>Etisus dentata</u>		*
<u>Lydia sp.</u>	*	
<u>Zosymus sp.</u>		*
<u>Xanthid spp.</u>		*
<u>Trapezia sp.</u>		*
<u>Sipuncula spp.</u>	*	*
Echinodermata		
Starfish		
<u>Linckia laevigata</u>		*
Sea Urchins		
<u>Diadema savignyi</u>		*
<u>D. setosum</u>		*
<u>Echinothrix calamaris</u>		*
<u>E. diadema</u>		*

Table 4 continued.

PHYLUM SPECIES	INNER REEF FLAT	OUTER REEF FLAT
<u>Tripneustes gratilla</u>	*	
<u>Echinometra matthaei</u>	*	*
Sea Cucumbers		
<u>Actinopyga echinites</u>		*
<u>Bohadschia argus</u>	*	*
<u>B. marmorata</u>	*	*
<u>Holothuria atra</u>	*	*
<u>H. leucospilota</u>	*	*
<u>Chirodota rigida</u>	*	*
Urochoradata (Didemnids)		
Didemnid spp.		*
TOTAL PHYLA	5	5
TOTAL SPECIES	41	53

Note: Most of these species are either infauna or small (smaller than one inch) and inconspicuous, particularly the molluscs and arthropods. Only the common black sea cucumber, Holothuria atra was observed on the surface of the dredge zone. It is likely that many of the smaller, inconspicuous species were present burrowed beneath the substrate.

Table 5. Bacteriological (fecal coliform) and turbidity water quality data from Agana Bay reef flat. April 1989 to October 1990. Stations AGMT and AGMD are located near the NAS storm drain.

DATE	AGMT		AGMD	
	BACT. (#)	TURB. (NTU)	BACT. (#)	TURB. (NTU)
1989				
April	2	0.77	8	1.40
May	102	2.30	72,000*	3.10
July	14	0.45	>2,000*	0.91
Sept.	10	1.70	46	2.00
Oct.	6	1.40	36	2.60
Nov.	10	1.40	4	5.20
Dec.	6	2.80	18	4.30
1990				
Feb.	18	0.72	52	1.80
March	2	0.28	38	0.80
April	0	0.98	0	2.40
Aug.	0	1.10	0	1.80
Sept.	0	2.10	312	8.30
Oct.	6	3.00	124	3.00
Range	0-102	0.28-3.00	0-72,000	0.80-3.00
Mean	13.54	1.46	5,741.38	2.89

Note: Bacteriological water quality standards are exceeded if individual readings are higher than 400 fecal coliforms per 100 ml water. Turbidity standards are exceeded when individual readings are greater than 1 NTU above ambient conditions. Ambient conditions were measured at AGMT and AGMD in 1986 through 1987 and were 2.20 and 5.30 NTU respectively. * Exceeds water quality standards.

Table 6. Current direction and velocity on the reef flat in front of ABC Condominiums during an ebbing tide under stormy conditions. Refer to Figure 4.

STATION	DATE	TIME	VELOCITY (meters/sec)	DIRECTION (Degrees Mag.)
1-1	8/28/87	10:30 am	0.114	232
1-2		10:30 am	0.208	235
1-3		10:30 am	0.385	242
1-4		10:30 am	0.118	256
1-5		10:30 am	0.159	258
1-6		10:30 am	0.126	202
1-8		10:30 am	0.159	204
1-9	9/3/87	6:00 pm	0.086	30
1-10		6:00 pm	0.110	50
1-11		6:00 pm	0.087	62
1-12		6:00 pm	0.082	45
1-13	8/28/87	11:30 am	0.213	260
1-14		11:30 am	0.143	298
1-15		11:30 am	0.117	317
1-16		11:30 am	0.175	235

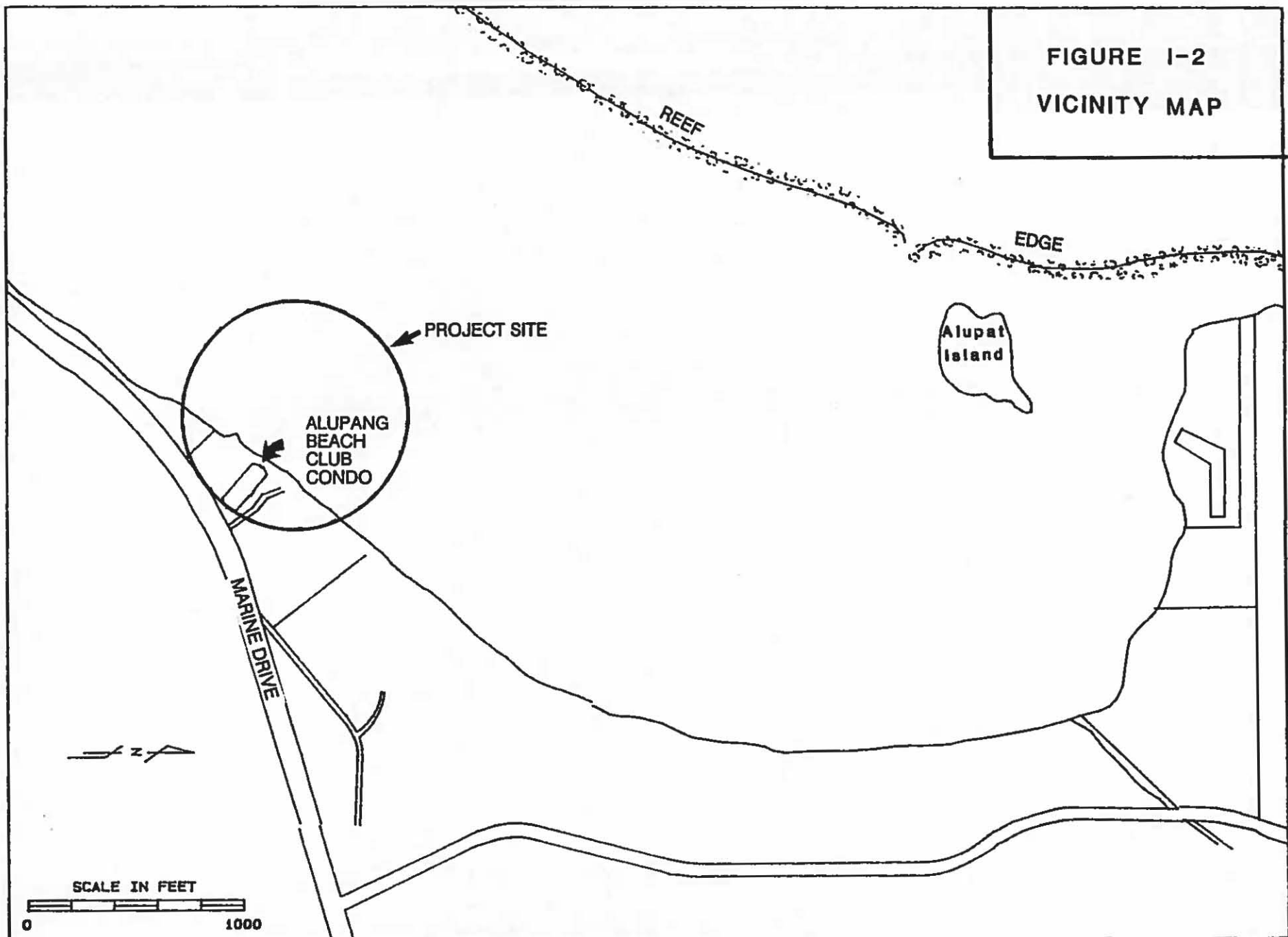
Table 7. Current direction and velocity on the reef flat in front of ABC Condominiums during a flooding tide under stormy conditions. Refer to Figure 5.

STATION	DATE	TIME	VELOCITY (meters/sec)	DIRECTION (Degrees Mag.)
1-1	8/31/87	10:30 am	0.167	352
1-2		10:30 am	0.069	238
1-3		10:30 am	0.062	170
1-4		10:30 am	0.187	138
1-5		10:30 am	0.091	302
1-6	8/31/87	11:00 am	0.109	80
1-7		11:00 am	0.208	80
1-8		11:00 am	0.101	16
1-9		---	---	---
1-10		---	---	---
1-11		---	---	---
1-12		---	---	---
1-13	8/31/87	11:30 am	0.217	35
1-14		11:30 am	0.115	36
1-15		11:30 am	0.222	45
1-16		11:30 am	0.041	18

Table 8. Sieve analysis summary from reef flat sediment samples taken in front of ABC Condominiums, Agana Bay. Samples were taken from ten stations shown on Figure 6.

SAMPLE NUMBER	MEDIUM (mm)	SIZE (ϕ)	STD. DEV. (ϕ)	DESCRIPTION	SORTING
1	0.24	2.06	-0.50	medium to fine sand	well sorted
2	0.41	1.29	-0.92	medium to fine sand	moderately sorted
3	0.44	1.18	-0.87	medium to fine sand	moderately sorted
4	0.42	1.25	-1.38	medium to fine sand	poorly sorted
5	0.59	0.76	-1.41	medium to fine sand	poorly sorted
6	0.38	1.40	-1.61	medium to fine sand	poorly sorted
7	0.59	0.76	-1.07	medium to fine sand	poorly sorted
8	0.22	2.18	-0.54	medium to fine sand	well sorted
9	0.35	1.51	-1.00	medium to fine sand	moderately sorted
10	0.51	0.97	-1.23	medium to fine sand	poorly sorted

FIGURE 1-2
VICINITY MAP



**COASTAL ENGINEERING ASSESSMENT
FOR THE
ALUPANG BEACH CLUB CONDOMINIUMS
AGANA, GUAM**

**Prepared For:
Pacific Basin Environmental Consultants, Inc.
145 Aspinall Ave., Suite 201
Agana, Guam 96910**

**Prepared By:
Sea Engineering, Inc.
Makai Research Pier
Waimanalo, Hawaii 96795**

March 1991

I. INTRODUCTION

Study Area and Project Purpose

The project site is located in East Agana Bay, on the west coast of Guam, at 997 South Marine Drive in Tamuning. The property is bordered by East Agana Bay on the west and South Drive on the east. A location map and vicinity map are shown in Figures I-1 and I-2. In order to enhance the nearshore area fronting the Alupang Beach Club Condominiums for water recreation, dredging of a swimming area and beach nourishment has been proposed.

The purpose of this coastal engineering study is to assist with the preparation of an Environmental Assessment (EA) and permit application for the dredging project. The coastal engineering services do not include detailed engineering design of the project features or preparation of construction plans and specifications.

Scope of Work

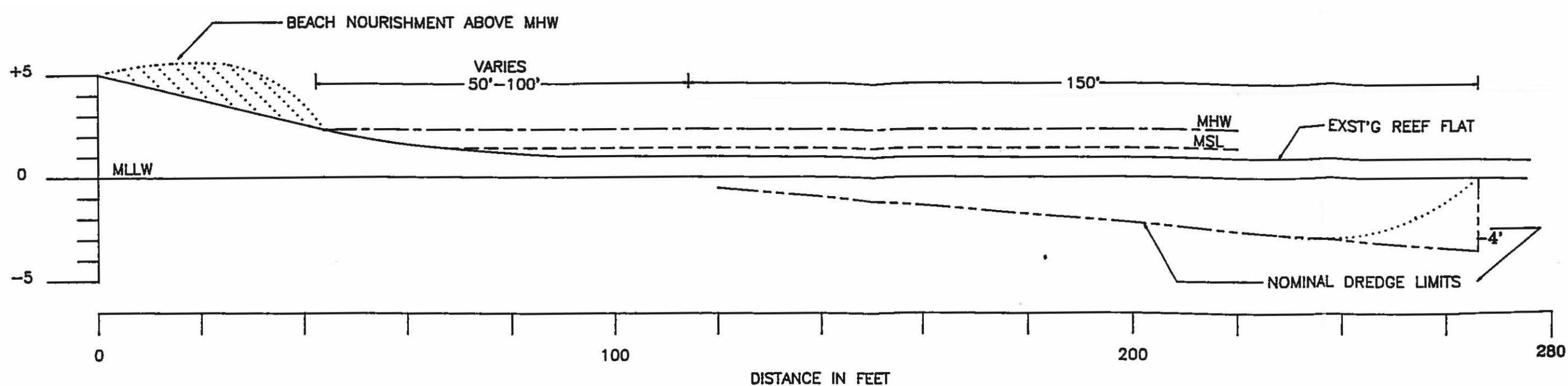
The study consists of preparation of a coastal engineering report, including analysis and presentation of the field data provided by Pacific Basin Environmental Consultants (PBEC), a discussion of coastal processes, development of the dredge plan, and a discussion of coastal engineering impacts of the proposed plan.

General Description of Proposed Project

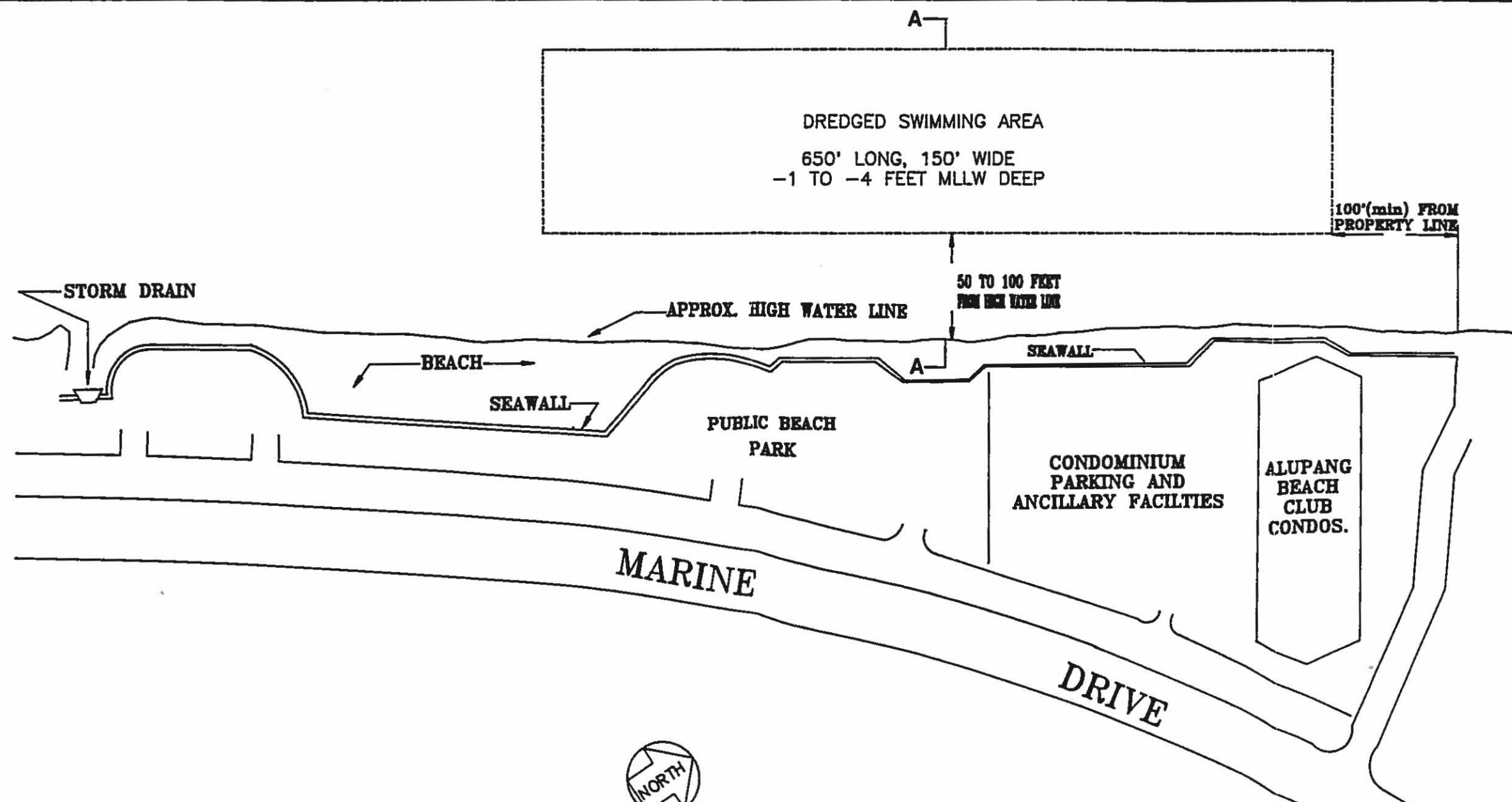
The Alupang Beach Club Condominiums will consist of a 12- story residential apartment building, with a parking structure, swimming pool and other ancillary facilities, located at the north end of the project site. A public beach park will be constructed at the south end of the project site. The existing reef flat fronting the project is very shallow, and practically exposed at low tide, which severely limits its water recreation potential for the condominium residents as well as the beach park users. For this reason, it is desired to dredge a swimming and water recreation area in the nearshore zone. The proposed swimming area would be located 50 to 100 feet seaward of the existing shore, and would be approximately 650 feet long by 150 feet wide, with a dredged depth sloping from about -1 foot on the shore side to about -4 feet on the seaward side. All depths in this report are referenced to a mean lower low water datum (MLLW). The general project features and the proposed dredge areas for water recreation improvement are shown in Figure I-3.

APPENDIX B

COASTAL ENGINEERING ASSESSMENT



TYPICAL CROSS-SECTION (A-A)



ALUPANG BEACH CLUB
CONDOMINIUMS, AGANA, GUAM
"GENERAL PROJECT FEATURES"

SEA ENGINEERING, INC.
Makai Research Pier
Waimanalo, Hawaii 96795
(808) 259-7966-TEL.
(808) 259-8143-FAX.

SEA
COASTAL/OCEAN ENGINEERING
AND MARINE CONSTRUCTION

DATE: MARCH 1991

APPROX.
SCALE: 1" = 100'

FIGURE NO: 1-3

The total area to be dredged is about 95,500 square feet. The average existing reef flat elevation is +0.3 feet MLLW, and to reach the proposed depth of -4 feet will require the removal of approximately 8,000 cubic yards of reef flat material. Sixty percent of this volume, or about 5,000 cubic yards, is estimated to be sand suitable for beach nourishment in the project area. The remaining forty percent is reef pavement (rock) or unconsolidated coral rubble.

Suitable beach nourishment sand would be replaced on the existing shoreline above the mean high water (MHW) line.

II. METEOROLOGY AND OCEANOGRAPHY

Wind

The prevailing winds on Guam are the easterly tradewinds, which approach from the northeast through east-southeast sector. The tradewinds occur over 70 percent of the time and are strongest and most consistent during the dry season from January through May. Wind direction is more variable, with frequent calms, during the typhoon season from July through December. Typical tradewind speeds are 7 to 21 knots, with wind speeds in excess of 21 knots occurring less than 10 percent of the time.

The study area is located on the west, or lee side of the island, and is sheltered from the prevailing tradewinds. Wind statistics from the Marine Climatological Summary (MCS), published by the Japan Meteorological Agency, is shown in Table II-1 and Figure II-1 for wind data during 1972, 1973, 1975 and 1976.

Storms

Guam is subject to strong winds and rain associated with tropical storms and typhoons. Due to its proximity to typhoon breeding grounds, the island is threatened yearly with the passage of developing typhoons, and on occasion one of full strength. During a period from 1948 to 1975 seventy tropical storms and typhoons developed or were tracked within 180 nautical miles of Guam with at least tropical storm strength. Twenty-six of these storms (35%) were of typhoon strength at their closest point of approach to Guam (ref. 1). Tropical storms are defined as having sustained wind speeds between 34 and 63 knots and Typhoons have sustained wind speed greater than 63 knots.

Two of the most devastating typhoons to have hit Guam were typhoon Karen (1962) and Pamela (1976). The characteristics of these super typhoons are presented in Table II-2.

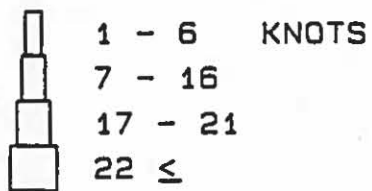
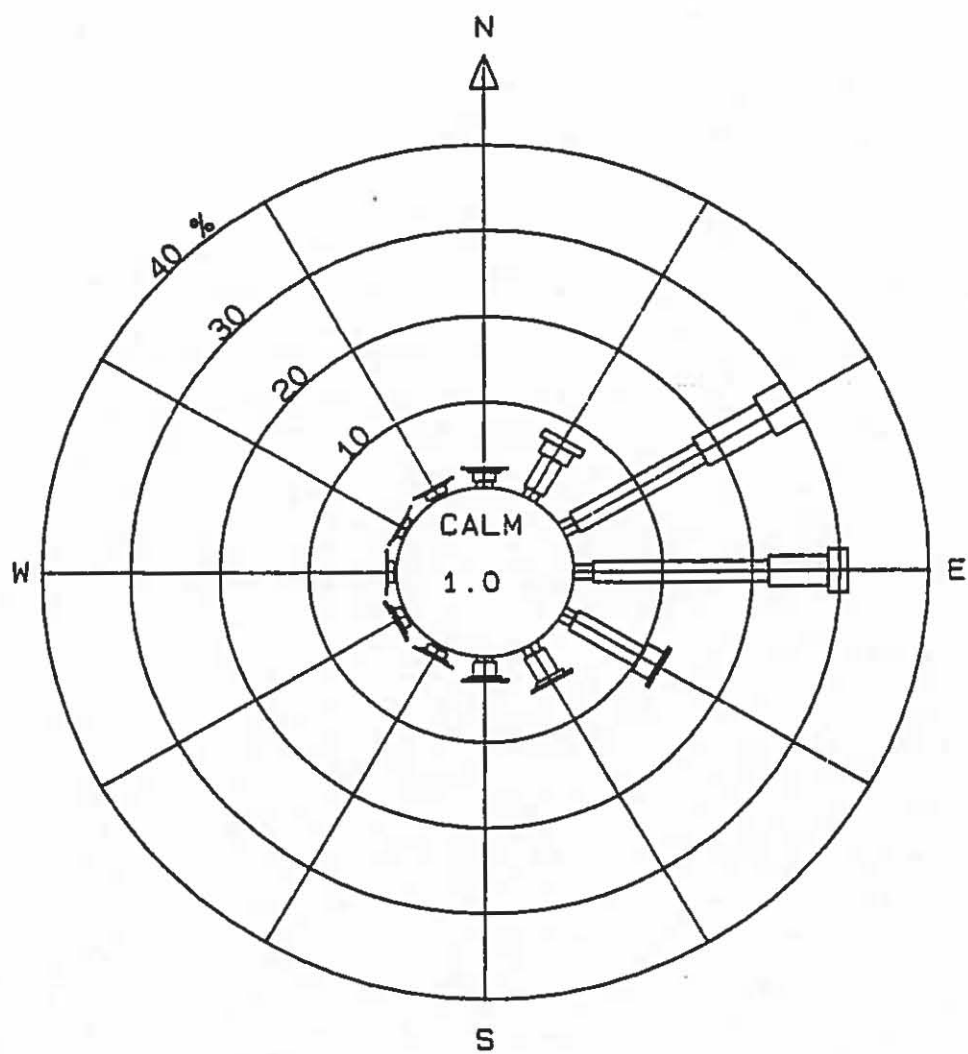


FIGURE II-1

WIND ROSE

TABLE II-1. WIND STATISTICS (%)

Wind Speed (kts)	Direction (degrees)												Total
	<u>35-01</u>	<u>02-04</u>	<u>05-07</u>	<u>08-10</u>	<u>11-13</u>	<u>14-16</u>	<u>17-19</u>	<u>20-22</u>	<u>23-25</u>	<u>26-28</u>	<u>29-31</u>	<u>32-24</u>	
0-1	Calm (1.00)												
1-3	0.38	0.22	0.25	0.46	0.25	0.34	0.09	0.07	0.09	0.07	0.07	0.12	2.42
4-6	0.38	0.83	1.48	1.73	1.23	0.75	0.56	0.35	0.25	0.19	0.10	0.34	8.19
7-10	0.46	1.80	5.24	6.69	3.71	1.62	0.75	0.44	0.35	0.35	0.34	0.44	22.21
11-16	0.55	2.42	11.03	12.93	4.90	1.52	0.94	0.41	0.46	0.35	0.37	0.40	36.29
17-21	0.34	1.65	8.28	6.81	2.16	0.50	0.35	0.31	0.30	0.09	0.16	0.15	21.10
22-27	0.12	0.83	3.16	1.96	0.37	0.22	0.13	0.10	0.19	0.04	0.06	0.06	7.25
28-33	0.04	0.18	0.46	0.30	0.07	0.04	0.10	0.00	0.03	0.07	0.01	0.03	1.34
34-40	0.00	0.00	0.06	0.01	0.01	0.01	0.00	0.00	0.06	0.01	0.00	0.00	0.16
41-47	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
48-55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63<	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	2.27	7.93	29.97	30.89	12.70	5.02	2.94	1.70	1.73	1.20	1.12	1.54	100.00

TABLE II-2
CHARACTERISTICS OF SUPER TYPHOONS

<u>Characteristics</u>	<u>Karen (Nov. 2, 1962)</u>	<u>Pamela (May 21, 1976)</u>
Sustained Wind Speed Recorded (kts)	125	100
Forward Movement of Storm over Guam (kts)	17	7
Minimum Sea-Level Pressure Recorded (mbs)	932	932
Diameter of the Eye (n.m.)	8	20

Waves

The prevailing deepwater wave climate in the study area is presented in the Summary of Synoptic Meteorological Observation (SSMO) prepared by the National Climatic Center. This data is obtained through direct synoptic observation by shipboard personnel in the Guam area and represents data recorded during the 8-year period of 1963-1970 (ref. 4). Because the SSMO data was obtained from vessels in transit that would avoid regions of impending storms or typhoons, the SSMO wave data does not adequately represents the extreme storm wave events.

The SSMO wave data is summarized by height and direction in Table II-3A and Figure II-2A and by height versus period in Table II-3B. This data indicates that the Guam wave climate is dominated by short periods, tradewind-generated waves from the northeast clockwise to southeast. Over 70 percent of wave periods are less than 7 seconds, with wave heights of seven feet or less 84 percent of the time.

The project area, however, is sheltered from the tradewind generated waves and is primarily affected by waves from the west clockwise to the north. Local wind wave heights exceeding 4 feet occur from these directions about 6 percent of the time.

Longer period waves influencing the Guam wave climate are generated by distant storms, as well as by those storms approaching near Guam. Hindcasts by Noda (ref. 5) for tropical storms and typhoons in the Western Pacific for the period from 1975 through 1979 indicate that large, long period waves may approach from the west clockwise to the north much more frequently than indicated by the SSMO data. Wave heights of eight feet or greater approach from this sector approximately 10 percent of the time in an average year. The results of these hindcasts are summarized in Table II-4 and Figure II-2B.

TABLE II-3A. ANNUAL PERCENT FREQUENCY OF DEEPWATER
WAVE HEIGHT BY DIRECTION

HEIGHT (ft)	N	NE	E	SE	S	SW	W	NW	TOTAL PCT
1	0.6	0.9	2.3	0.5	0.4	0.7	0.5	0.4	6.3
1-2	2.3	4.6	11.3	3.1	1.6	1.1	1.4	0.8	26.2
3-4	2.1	7.4	15.5	2.4	1.5	2.1	0.9	0.5	32.4
5-6	1.5	4.4	10.4	0.7	0.8	0.8	0.5	0.3	19.4
7	0.6	2.6	4.1	0.7	0.6	0.7	0.4	0.1	9.8
8-9	0.3	2.1	1.0	0.1	0.1	0.2	0.1	0	3.9
10-11	0.1	0.5	0.7	0.1	0.1	0.1	0.1	0	1.5
12	0.1	0.2	0.1	0	0	0	0.1	0	0.4
13-16	0.1	0.1	0.2	0	0.1	0.1	0.1	0	0.5
17-19	0	0	0	0	0	0	0	0	0.0
20-22	0	0	0	0	0	0	0	0	0.0
23-25	0	0	0	0	0	0	0	0	0.0
26-32	0	0	0	0	0	0	0	0	0.0
33-40	0	0	0	0	0	0	0	0	0.0
41-48	0	0	0	0	0	0	0	0	0.0
49-60	0	0	0	0	0	0	0	0	0.0
61-70	0	0	0	0	0	0	0	0	0.0
71-86	0	0	0	0	0	0	0	0	0.0
87+	0	0	0	0	0	0	0	0	0.0
TOTAL PCT	7.6	22.8	45.6	7.6	5.1	5.8	3.9	2.1	100.4

TABLE II-3B. ANNUAL PERCENT FREQUENCY OF DEEPWATER
WAVE HEIGHT VERSUS WAVE PERIOD

HEIGHT (ft)	Period (seconds)							TOTAL PCT
	6	6-7	8-9	10-11	12-13	13	INDET	
1	1.6	0.1	0	0	0	0	2.4	4.1
1-2	12.0	1.8	0.5	0.1	*	0	0.4	14.9
3-4	17.2	9.6	2.0	0.5	0.1	0	0.6	30.0
5-6	7.0	11.1	4.5	1.1	0.4	0.4	0.4	24.9
7	2.4	5.7	4.9	0.9	0.2	0.1	0.2	14.4
8-9	1.1	2.1	1.7	1.3	0.4	0.1	0.1	6.8
10-11	0.5	0.8	0.9	0.5	0.2	*	0.1	3.1
12	0.2	0.3	0.3	0.3	0.1	0.1	*	1.4
13-16	0.1	0.3	0.2	0.2	0.3	0.1	0.1	1.2
17-19	0	0	0	*	*	0	0	0.1
20-22	0	*	0	0.1	0	0.5	0	0.7
23-25	0	0	0	0	0	*	0	0.1
26-32	0	0	0	0	0	0	0	0.0
33-40	0	0	0	0	0	0	0	0.0
41-48	0	0	0	0	0	0	0	0.0
49-60	0	0	0	0	0	0	0	0.0
61-70	0	0	0	0	0	0	0	0.0
71-86	0	0	0	0	0	0	0	0.0
87+	0	0	0	0	0	0	0	0.0
TOTAL PCT	42.1	31.9	15.0	5.1	1.7	1.4	4.4	101.5

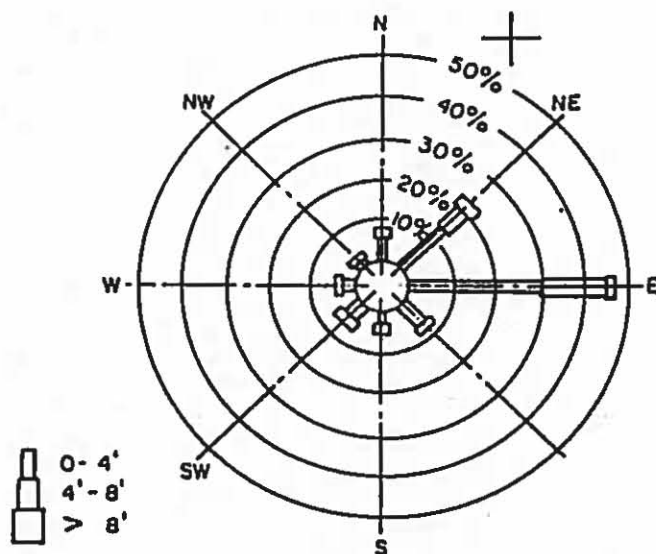


FIGURE II-2A ANNUAL PERCENT FREQUENCY OF DEEPWATER WAVE HEIGHT BY DIRECTION

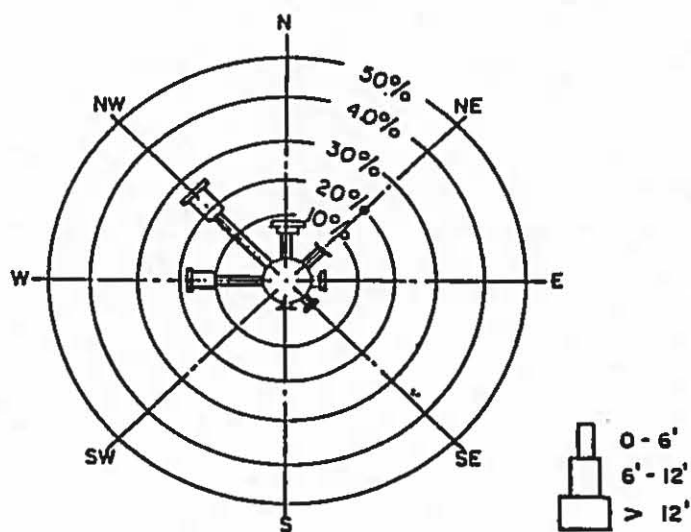


FIGURE II-2B AVERAGE YEARLY PERCENT FREQUENCY OF DEEPWATER WAVE HEIGHT DUE TO TROPICAL CYCLONES BY DIRECTION FOR PERIOD 1975-1979

TABLE II-4 DEEPWATER SIGNIFICANT WAVE HEIGHT STATISTICS
DUE TO WESTERN NORTH PACIFIC TROPICAL CYCLONES,
AVERAGE ANNUAL CONDITIONS FOR THE PERIOD 1975-1979

A. Percent of Time Occurrence of Wave Height Versus Wave Direction

WAVE HEIGHT (ft) (=H)	<u>N</u>	<u>NE</u>	<u>E</u>	<u>SE</u>	<u>S</u>	<u>SW</u>	<u>W</u>	<u>NW</u>	<u>TOTAL</u>
0-2	2.7	1.9	.4	.8	.1	.3	6.5	9.4	22.1
2-4	1.5	1.4	.1	.2	.0	.0	3.1	4.1	10.4
4-6	2.1	1.0	.1	.1	0.0	0.0	2.2	3.3	8.8
6-8	1.1	.4	.1	.1	.0	0.0	1.8	2.3	5.8
8-10	.8	0.0	.1	.1	0.0	0.0	1.5	1.7	4.2
10-12	.4	0.0	.1	.1	0.0	0.0	1.8	1.7	4.1
12-14	.5	0.0	.1	.0	.0	0.0	.4	.7	1.8
14-16	0.0	0.0	.1	.1	0.0	0.0	.9	.0	1.1
= 16	0.0	0.0	1.2	1.1	.5	0.0	.3	.3	3.3
TOTAL	9.0	4.7	2.3	2.6	.7	.3	18.4	23.6	

B. Percent of Time Occurrence of Wave Period Versus Wave Direction

WAVE HEIGHT (sec) (=T)	<u>N</u>	<u>NE</u>	<u>E</u>	<u>SE</u>	<u>S</u>	<u>SW</u>	<u>W</u>	<u>NW</u>	<u>TOTAL</u>
0-6	6.9	4.8	0.0	.4	0.0	.3	11.4	18.0	41.7
6-8	1.6	.9	.1	.1	0.0	.0	3.1	4.5	10.3
8-10	2.1	.7	.0	.0	0.0	.0	1.8	4.0	8.8
10-12	2.1	1.6	.0	.1	0.0	.0	2.4	3.8	10.1
12-14	1.8	.7	0.0	.1	0.0	.0	4.0	5.2	11.7
14-16	1.4	.6	0.0	.2	0.0	.0	2.4	2.9	7.4
16-18	.8	.2	.8	.0	0.0	0.0	1.1	1.8	4.8
= 18	.8	0.0	.2	.3	0.0	.2	2.4	2.3	6.2
TOTAL	17.6	9.5	1.1	1.3	0.0	.5	28.6	42.4	

height and a 12-second period, and Case 3 represents a typhoon wave 25-foot high with a period of 10.7 seconds. Among the components of stillwater level rise, the pressure reduction setup and the storm surge are only applicable to Case 3.

Astronomical Tide - The mean higher high water elevation of 2.4 feet is considered the appropriate astronomical tide component for the calculation of the total design water level rise, because of its relative frequency of occurrence.

Pressure Reduction Setup - In storm conditions the water level rise due to reduced atmospheric pressure is calculated using the following equation:

$$S_p = 1.14 \Delta P$$

where ΔP is the pressure reduction in inches of mercury at the center of the storm. Using ΔP of 2.4 inches of mercury for Case 3, the water level rise is calculated to be 2.7 feet.

Wind Stress Setup - The following equation is used to estimate the wind stress setup near the coastline:

$$S_u = 540 K U^2 X / d$$

where, S_u = wind setup increment
 $K = 3.0 \times 10^{-6}$
 U = wind speed in knots
 X = increment of distance in n.m.
 d = average depth over a increment of distance

The wind setup is calculated as 0.7 feet for Case 3 using a wind speed of 100 knots and an average water depth of 8 feet over the flat reef during high stillwater level rise conditions.

Wave Setup - The water level along a coast is partly a function of the incident wave field. Laboratory studies and field observations show a lowering of the water level, "set down", as the wave approach the break point and a steady rise in water level, "set up", shoreward of the breakers. The wave setup in this study is numerically calculated primarily based on the theoretical " radiation stress" model. For Cases 1, 2, and 3, wave setups at the shore are calculated to be 0.8 feet, 3.2 feet, and 4.0 feet, respectively.

TABLE II-5
ESTIMATED MAXIMUM STILLWATER LEVEL ABOVE MLLW

CASE NUMBER	DEEPWATER HEIGHT (feet)	WAVE PERIOD (sec)	ASTRO. TIDE (feet)	STORM SURGE (feet)	WAVE SETUP (feet)	STILLWATER LEVEL RISE (feet)
1	4	5	2.4	n/a	0.8	3.2
2	15	12	2.4	n/a	3.2	5.6
3	25	10.7	2.4	3.4	4.0	9.8

Nearshore Waves

The shoreline of Agana Bay is well protected from large waves by the wide and shallow reef flat which comprises the bay. The edge of the reef is very shallow, and bares at low tide. Deepwater waves approaching the coast break on the reef edge, dissipating the majority of the energy away from the shore. Remaining energy propagates across the reef as smaller, shorter period waves, breaking and reforming until they ultimately reach the shore.

The height of waves along the shoreline is primarily a function of the deepwater wave climate, nearshore bathymetry, the stillwater level, and bottom friction. A computer model was used to predict wave heights at the shore, given the bottom profile and deepwater wave climate. The model determines two-dimensional wave height only, i.e., it ignores the effects of refraction and diffraction. The model is useful in estimating the change in wave height and wave energy that will result by dredging the nearshore bottom.

The wave heights at the shoreline were estimated for the three possible design wave conditions: Case 1 represents a typical prevailing wave 4 feet high with a 5-second period, Case 2 represents a distant storm swell 15 feet high with a 12-second period, and Case 3 represents a severe storm wave 25 feet high with a 10.7 second period. Each of these wave conditions were investigated for the existing bottom profile and for the bottom profile with the proposed dredging.

The proposed dredging is rectangular in shape, as shown in Figure I-3; 650 feet long and 150 feet wide. The dredging area is 50 to 100 feet seaward of the shoreline.

Table II-6 shows the calculated wave heights and energy at the shoreline with and without dredging. For conditions of typically prevailing waves (Case 1) and a storm swell (Case 2), the calculated wave height and energy are small and the resulting increases of about 10 percent are not significant. For typhoon wave conditions (Case 3) the increases in wave height and energy are 5 percent or less, indicating that the influence of the proposed dredging on wave height and wave energy at the shore would be minor. *

TABLE II-6
ESTIMATED WAVE HEIGHT AND WAVE ENERGY AT THE SHORELINE
FOR EXISTING AND WITH DREDGING CONDITIONS

			<u>EXISTING CONDITION</u>	<u>WITH DREDGING</u>	<u>PERCENT INCREASES</u>
Case 1:	Prevailing Waves	H	0.5 ft	0.6 ft	+7%
	Ho = 4 ft.	E	1.5 lb/ft	1.6 lb/ft	+11%
	T = 5 sec.	S	3.2 ft	3.2	0
Case 2:	Storm Swell	H	1.3 ft	1.4 ft	+7%
	Ho = 15 ft.	E	6.8 lb/ft	7.5 lb/ft	+10%
	T = 12 sec.	S	5.6 ft	5.6 ft	0
Case 3:	Typhoon Waves	H	3.2 ft	3.4 ft	+4%
	Ho = 25 ft	E	52.9 lb/ft	55.7 lb/ft	+5%
	T = 10.7 sec.	S	9.8 ft	9.8 ft	0
Notes:		Ho = Deepwater wave height			
		T = Wave period			
		H = Wave height at the shoreline			
		S = Stillwater level at the shore			

The waves propagating across the reef flat can alter their direction of approach to the shore as a result of changing bottom depths, termed wave refraction. Water waves obey the principals of Snell's Law, as commonly applied to optics and light waves, with the part of the wave in deeper water moving faster than the portion in shallower water and the wave crest attempting to align itself parallel to the bottom contours. Wave refraction analysis on the reef flat indicates wave direction changes would occur only at the north and south edges of the dredged areas. The refracted waves may result in some impact to the shoreline configuration and shape near the edges of the dredged areas as a result of energy redistribution along the shore. However, it is not possible to accurately quantify the magnitude or areal extent of the impact because of the relatively small scale, both in terms of size and depth, of the proposed dredging.

Water Circulation

According to reference 7, currents seaward of the reef edge in Agana Bay exhibit a correlation between current direction and tide phase, with a southerly current during flood tide, shifting through the east to a northerly current during ebb tide. Current speed varies from zero to about three-quarters of a knot.

On the reef flat currents set northerly parallel to the shoreline and then seaward at the north end of the bay. The remnants of the causeway to Alupat Island reportedly restricts circulation at the north end of the bay, particularly during periods of low tide. Previous current studies were conducted by Randall and Eldredge (1974) near the study area in normal weather conditions. Figures II-3 and II-4 show their measurement results. During both ebb and flood tides, current directions set northerly along the shoreline on the reef flat and headed seaward in the channel near Alupat Island. Current speeds on the reef flat were low at a range from 0.13 ft/sec (0.08 kts) to 0.49 ft/sec (0.29 kts). Current speeds were considerably high at the exit channel, with a maximum of 4.7 ft/sec (2.7 kts) during flood tide.

Additional current measurements were conducted by PBEC in 1987 on the reef flat directly seaward of the project site. The current measurements were done during storm sea conditions with the close approach of tropical storm Holly and typhoon Frieda. During the study period, high waves were breaking at the reef margin and creating a greater water volume on the reef than in normal conditions. As a result, the currents for both ebb and flood tides were more variable in direction and greater in speed than those measured during normal sea conditions. The current speeds on the reef ranged from 0.13 ft/sec (0.08 kts) to 1.2 ft/sec (0.72 kts) with an average of 0.46 ft/sec (0.27 kts). The currents in storm conditions are shown in Figures II-5 and II-6. The figures indicate that currents near the shoreline set northerly during a flood tide and set southerly during an ebb tide.

In summary, prevailing currents near the project area set northward during both ebb and flood tide with low speeds less than 0.5 ft/sec. During storm conditions current directions are variable and speeds increase with a maximum speed over 1 ft/sec.

FIGURE II-3

**CURRENTS DURING EBB TIDE
IN NORMAL WEATHER CONDITIONS**

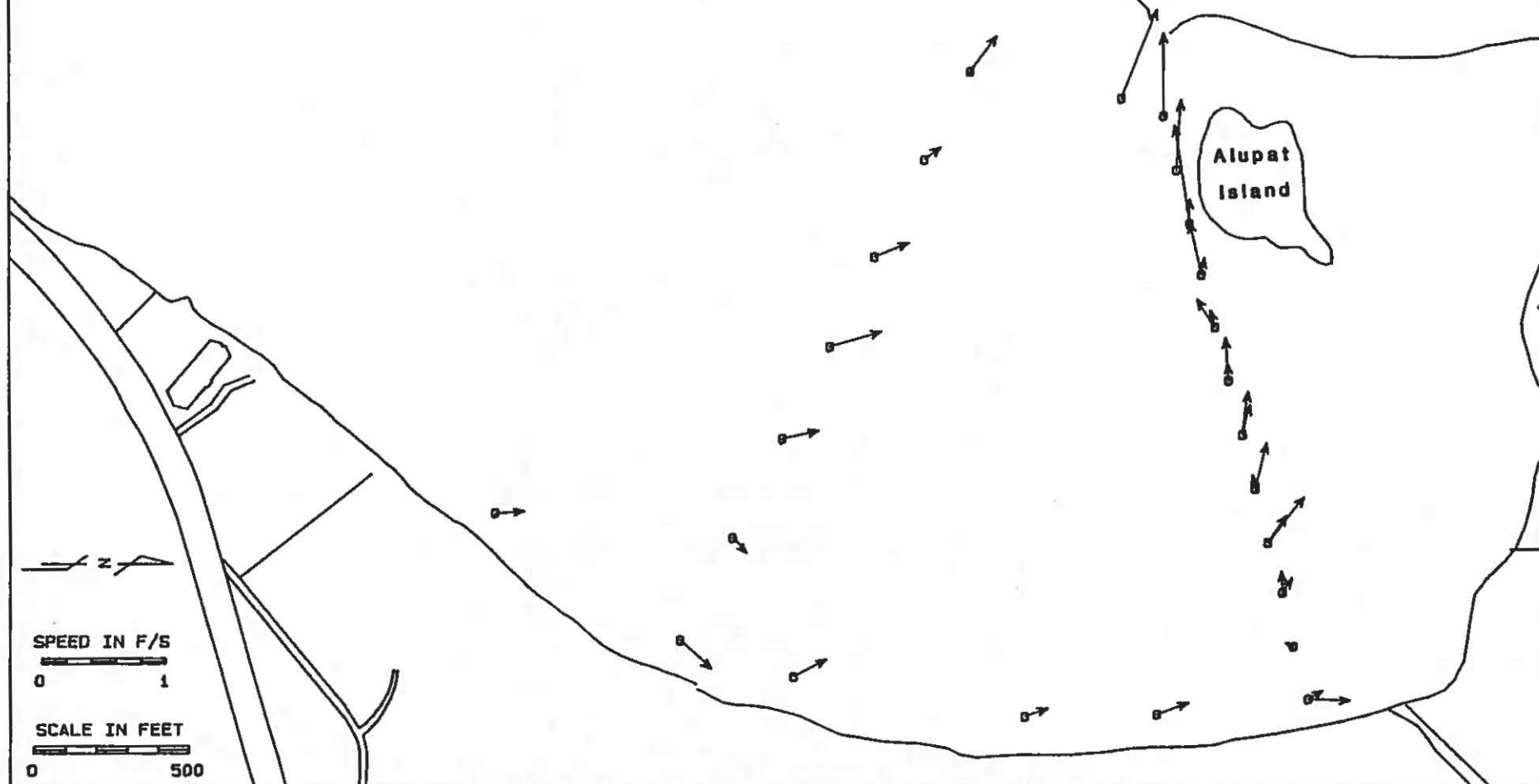


FIGURE II-4
CURRENTS DURING FLOOD TIDE
IN NORMAL WEATHER CONDITIONS

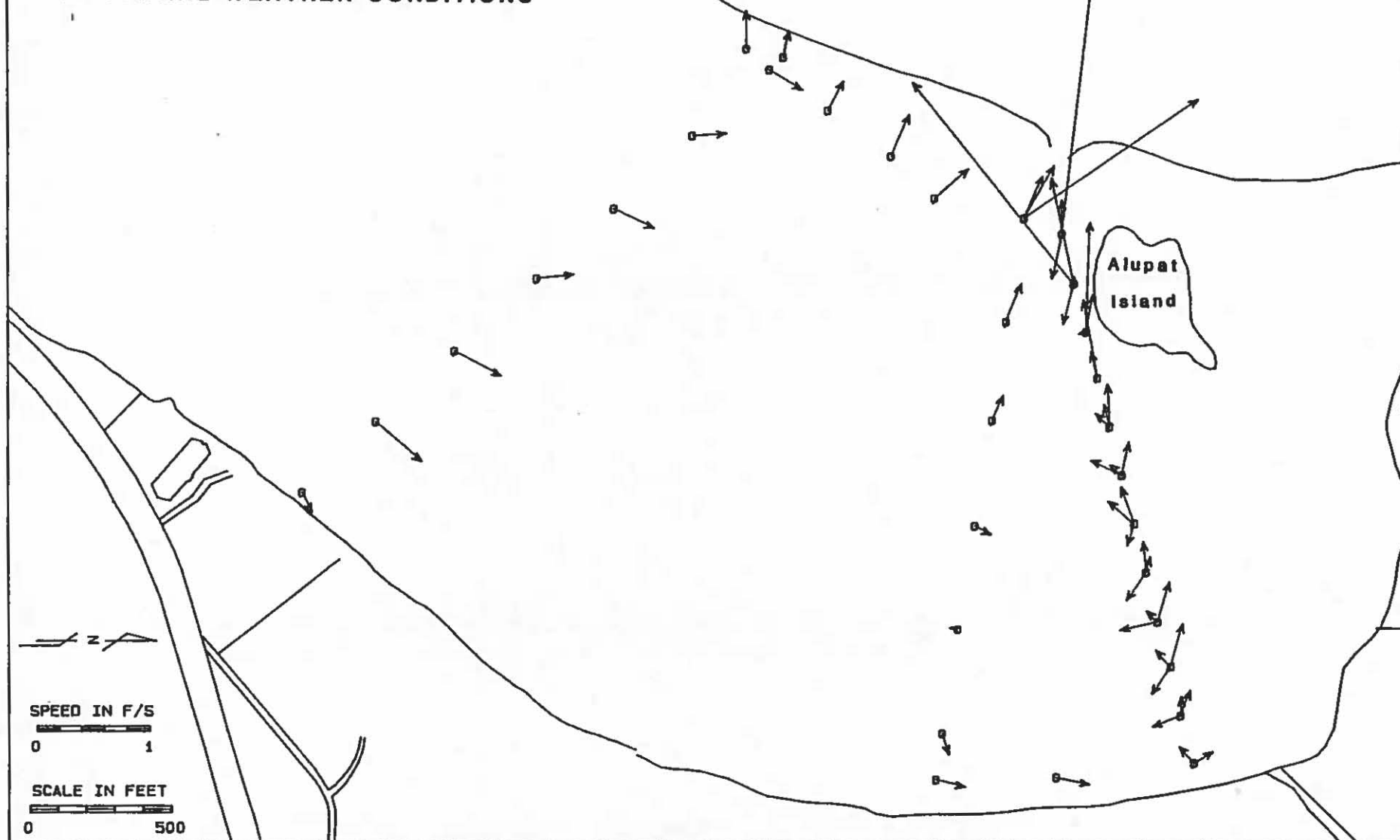


FIGURE II-5
CURRENTS DURING EBB TIDE
IN HIGH SEA CONDITIONS

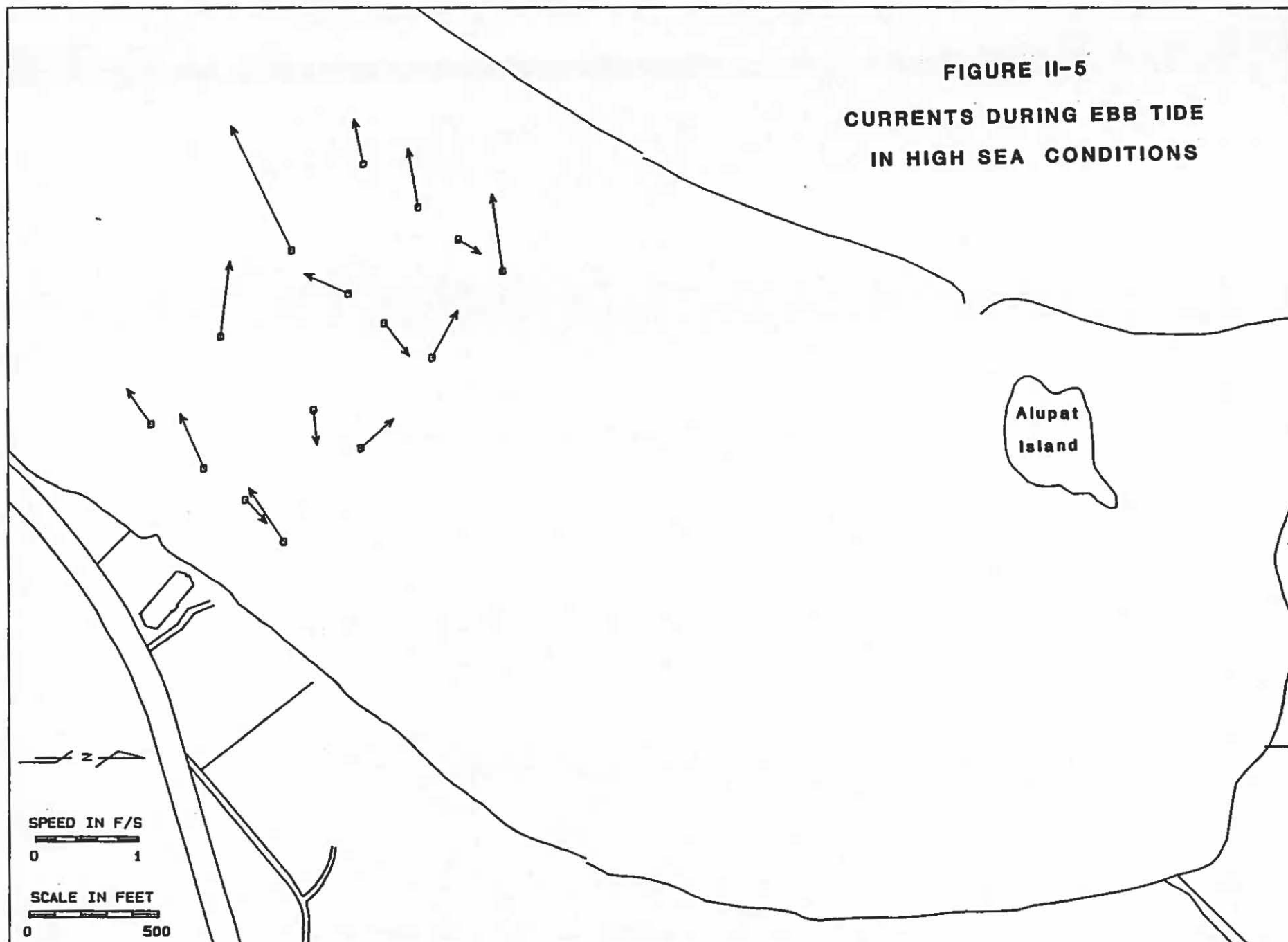
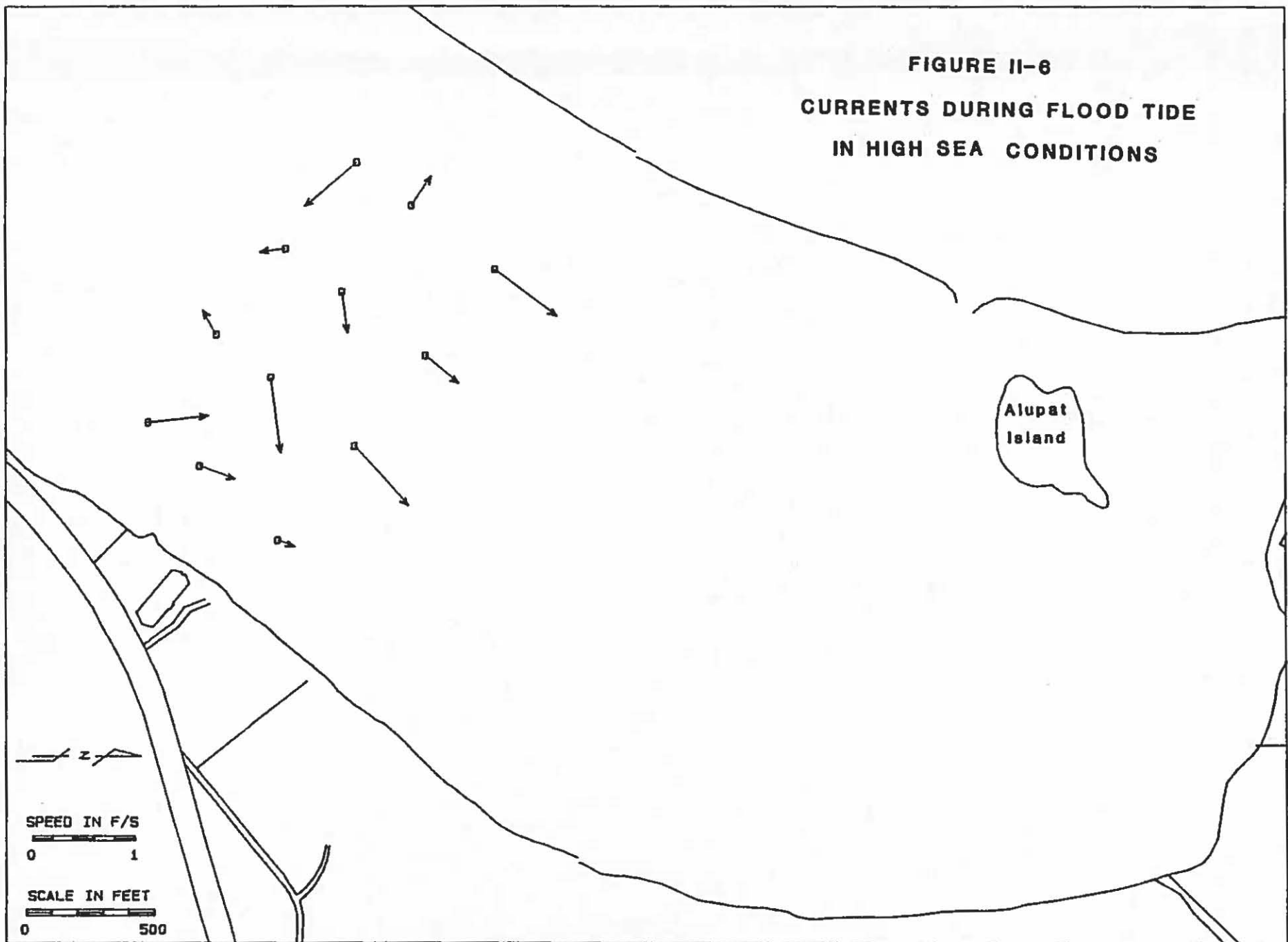


FIGURE II-6
CURRENTS DURING FLOOD TIDE
IN HIGH SEA CONDITIONS



III. SEDIMENT CHARACTERISTICS

Sediment

Sediment samples were taken from the reef flat surface at ten locations in the project area. The locations of the 10 samples are shown in Figure III-1. All samples were unconsolidated sand and small coral rubble. A sieve analysis was performed to determine their grain size distribution. Results of the sieve analysis are summarized on Table III-1.

The grain size classification is based on the United Soil Classification system. The median grain size defines the typical grain size diameter that divides the sample so that half the sample, by weight, has particles coarser than the median size. Grain size diameters are measures in either millimeters or phi units (ϕ), where a phi unit diameter is defined as:

$$\text{Phi unit } (\phi) = -\log_2 (\text{diameter in mm}).$$

The sorting, or standard deviation, is a measure of the degree to which the sample spreads out around the typical particle size. A grain size distribution is described qualitatively as well sorted if all particles have sizes close to a typical size, and poorly sorted if the particle sizes are distributed over a wide range of sizes. The grain size distributions of the 10 samples are plotted on Figures III-2 to III-11.

The grain size analysis shows that sediment in the north and south sections of the proposed dredging areas is moderately or well sorted, but the sediment in the middle section is poorly sorted. The sediment in the proposed dredging varies from medium to fine sand. No data was collected regarding the depth distribution of sediment.

The dashed lines on the grain size distribution graphs (Figures III-2 to III-11) represent the range of grain sizes typically found on good recreational calcareous sand beaches in Hawaii. A large percentage of the samples had grain sizes that fell within the boundaries, indicating that a fair amount of the dredge spoil should be suitable size for beach nourishment.

FIGURE III-1. LOCATION OF PROFILES AND SEDIMENT SAMPLES.

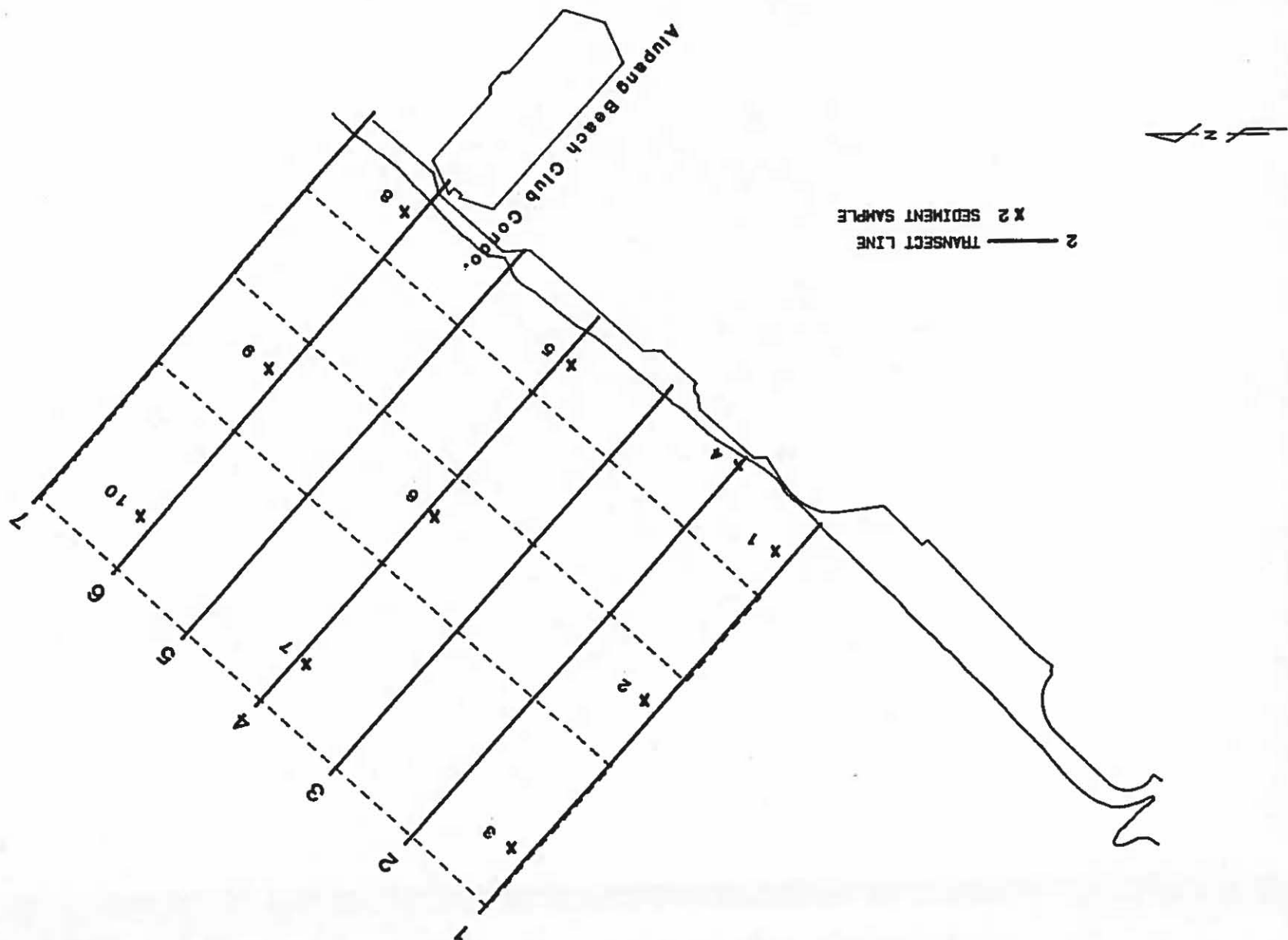


TABLE III-1
SEDIMENT ANALYSIS SUMMARY

SAMPLE NUMBER	MEDIUM GRAIN SIZE		STD. DEV. (σ)	DESCRIPTION	SORTING
	(mm)	(ϕ)			
1	0.24	2.06	-0.50	medium to fine sand	well sorted
2	0.41	1.29	-0.92	medium to fine sand	moderately sorted
3	0.44	1.18	-0.87	medium to fine sand	moderatley sorted
4	0.42	1.25	-1.38	medium to fine sand	poorly sorted
5	0.59	0.76	-1.41	medium to fine sand	poorly sorted
6	0.38	1.40	-1.61	medium to fine sand	poorly sorted
7	0.59	0.76	-1.07	medium to fine sand	poorly sorted
8	0.22	2.18	-0.54	medium to fine sand	well sorted
9	0.35	1.51	-1.00	medium to fine sand	moderatley sorted
10	0.51	0.97	-1.23	medium to fine sand	poorly sorted

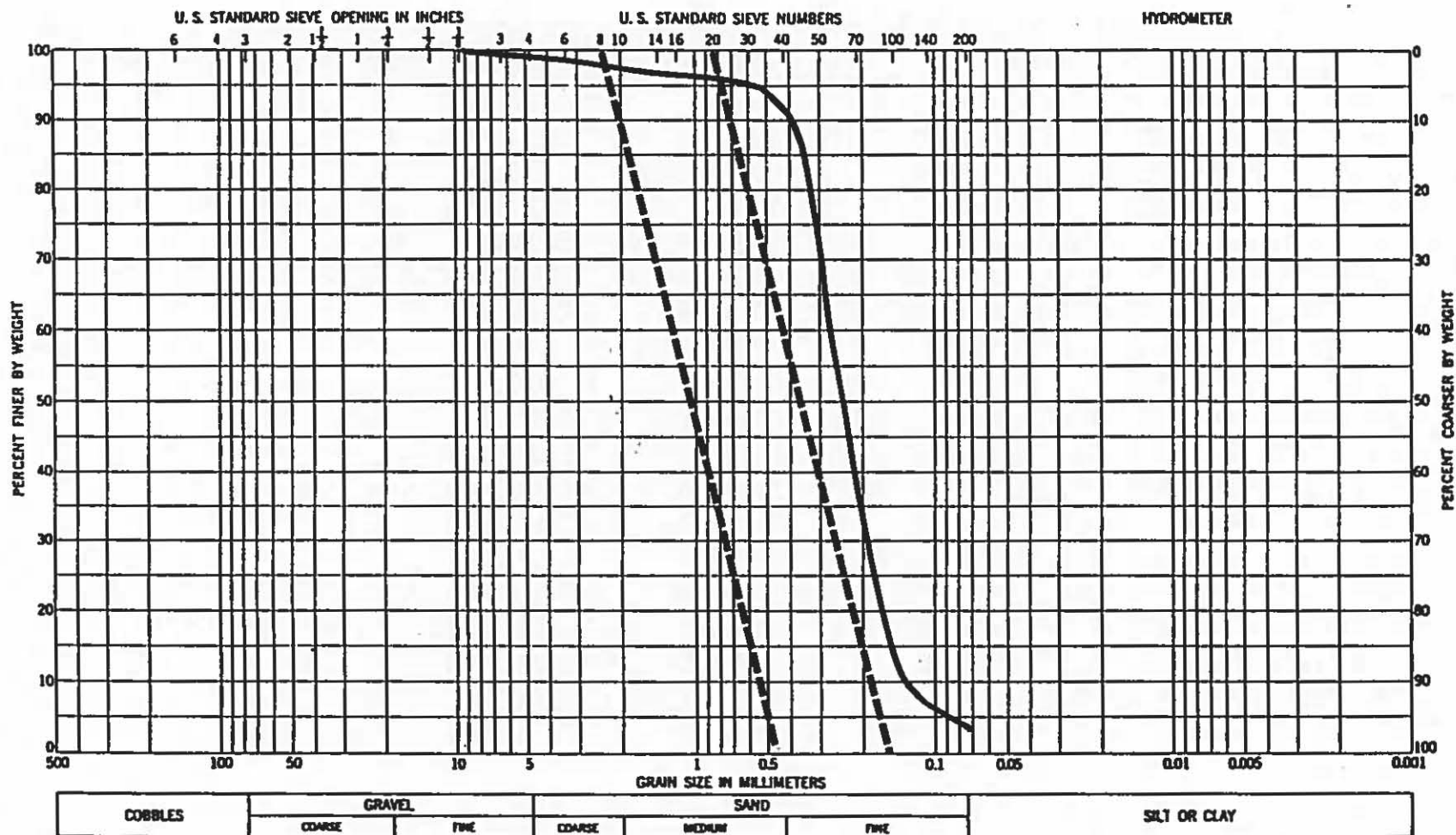


FIGURE III-2

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 1

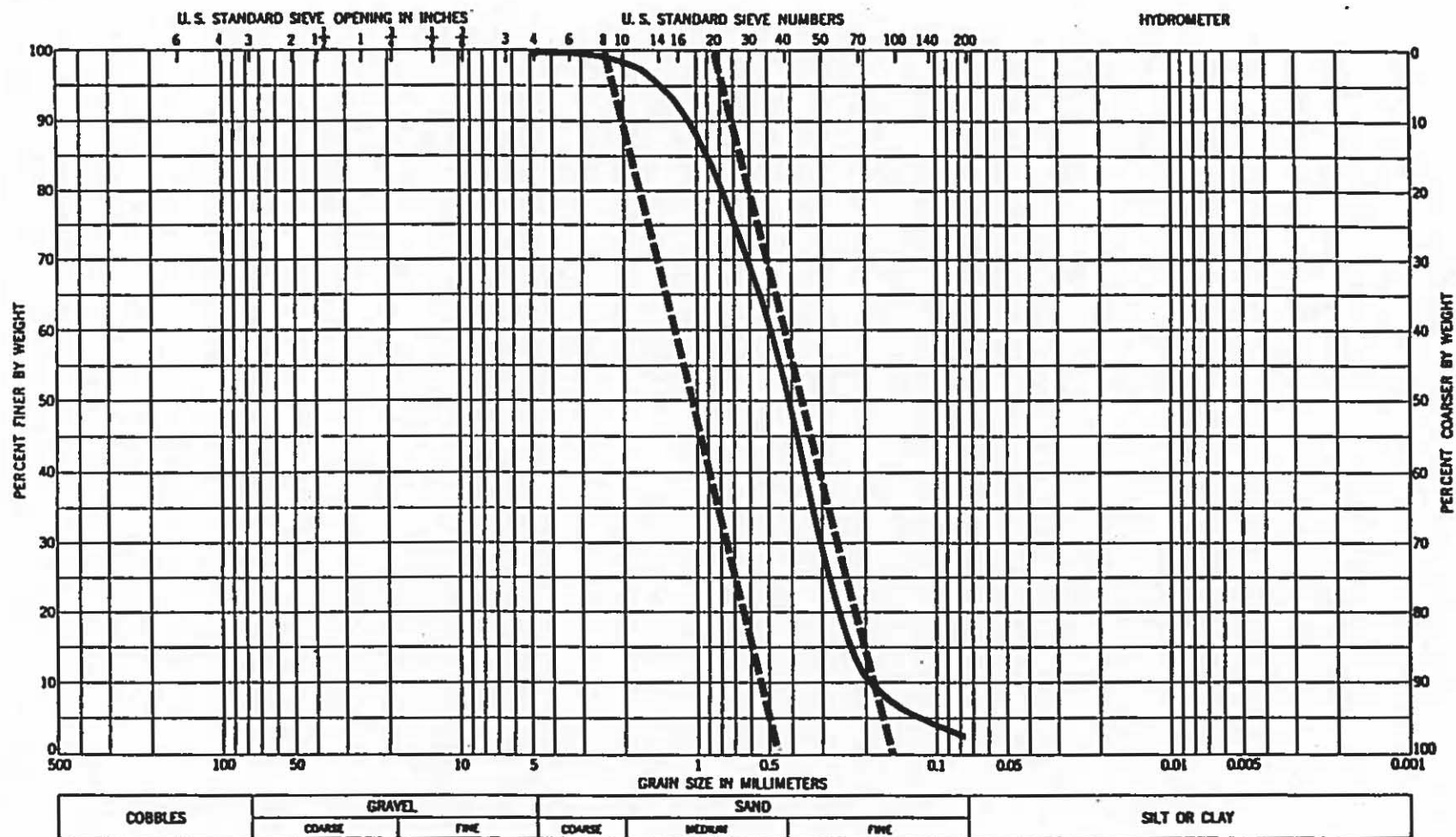


FIGURE III-3

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 2

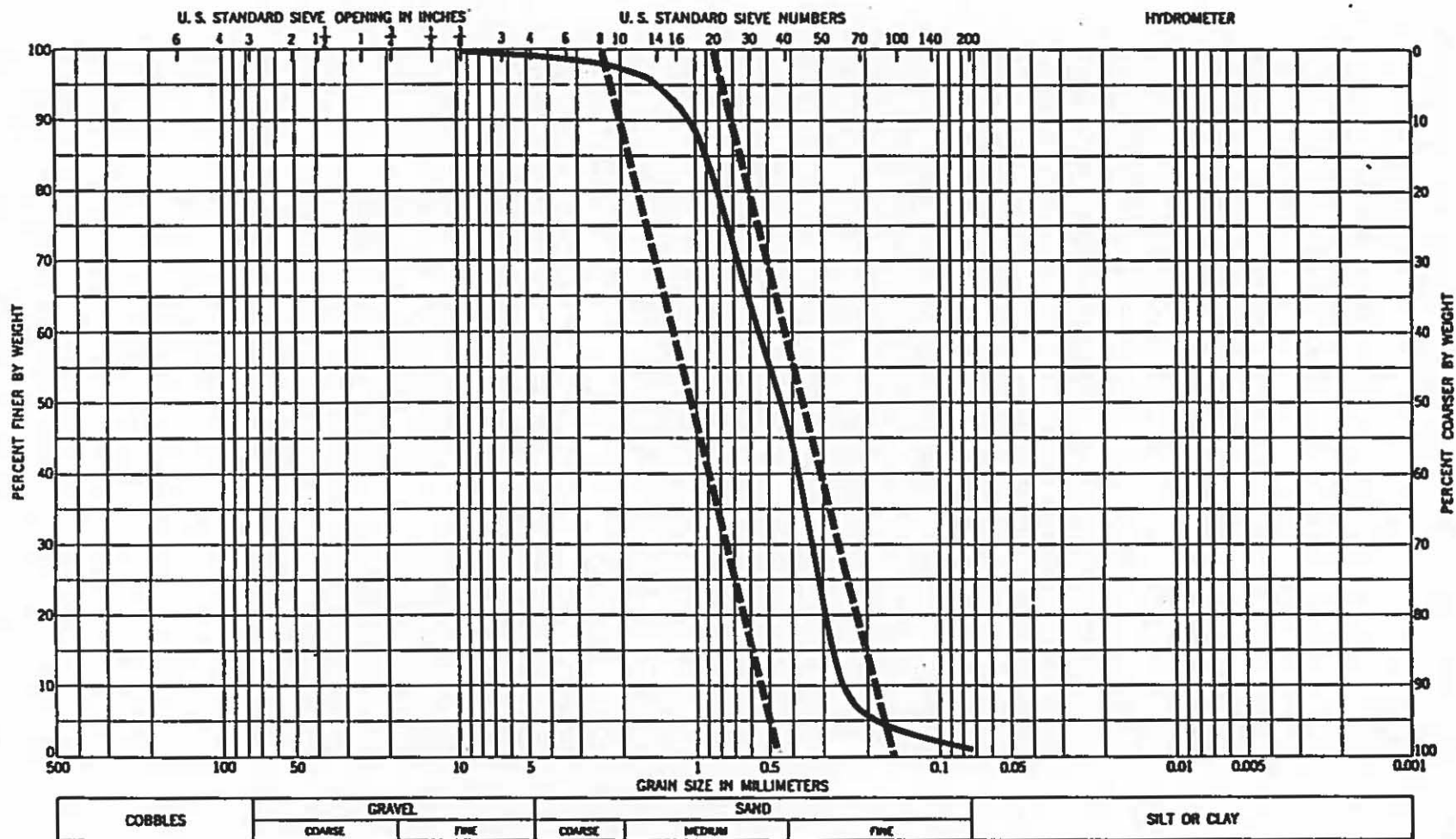


FIGURE III-4

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 3

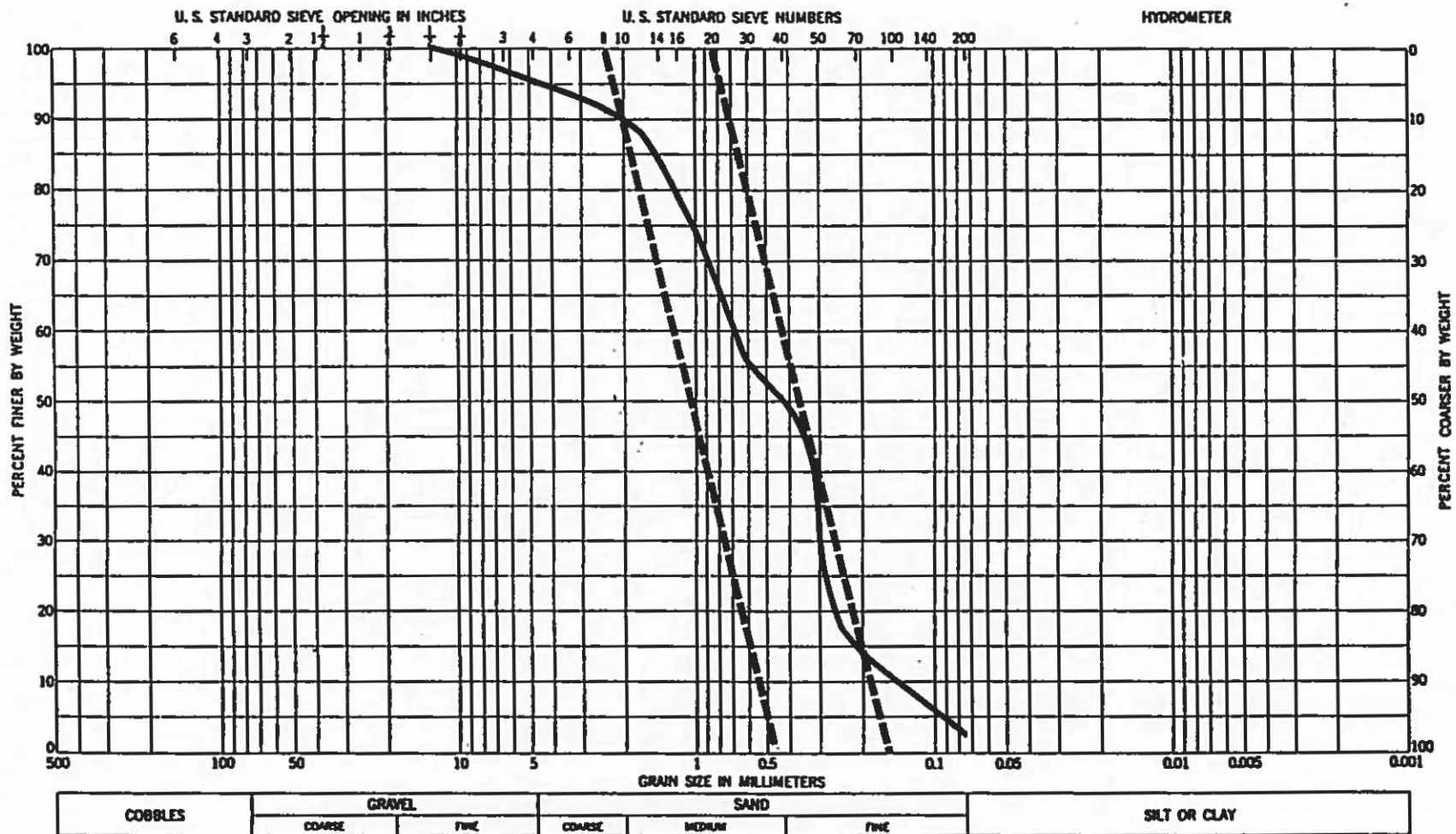


FIGURE III-5

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 4

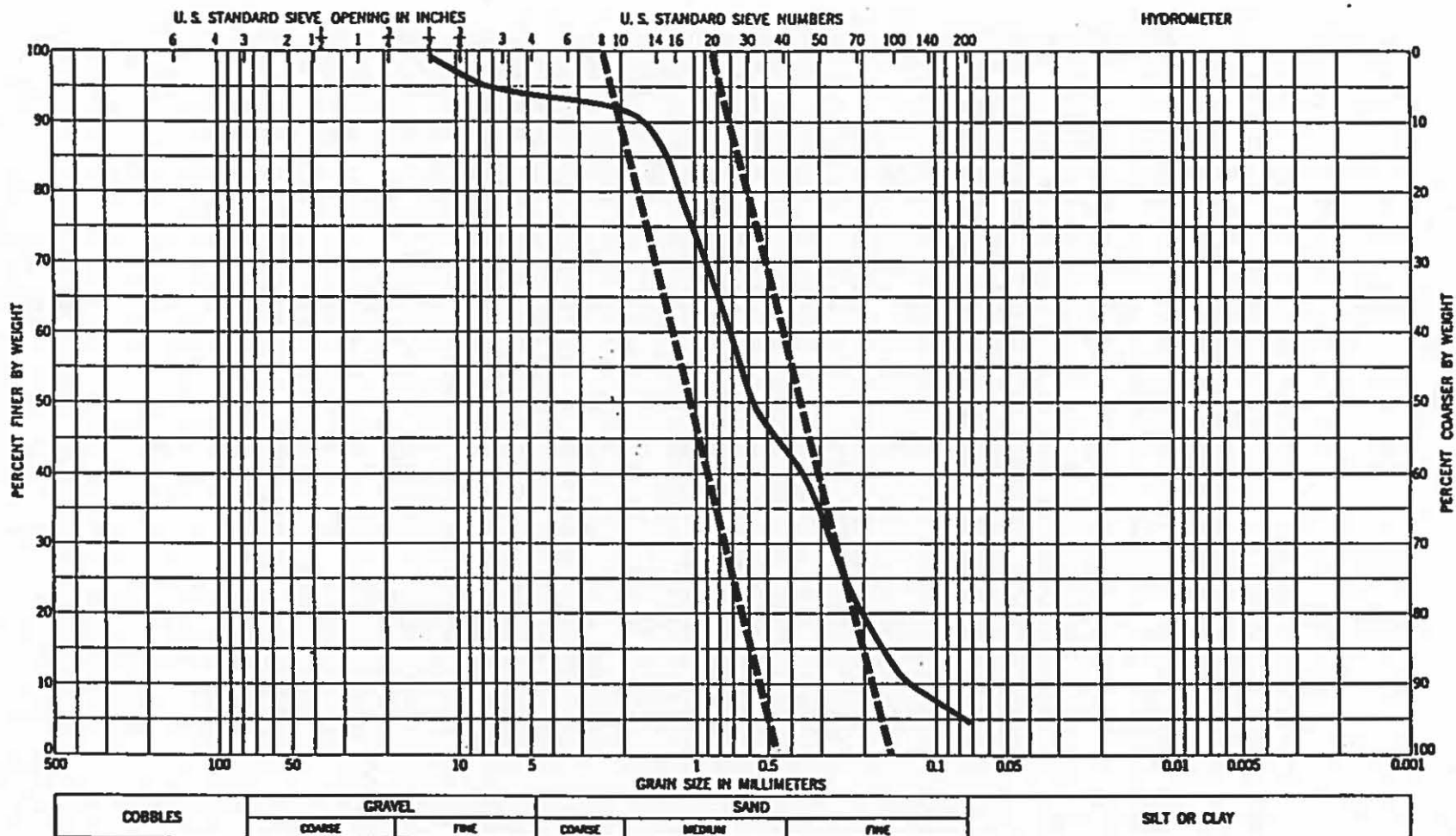


FIGURE III-6

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 5



FIGURE III-7

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 6

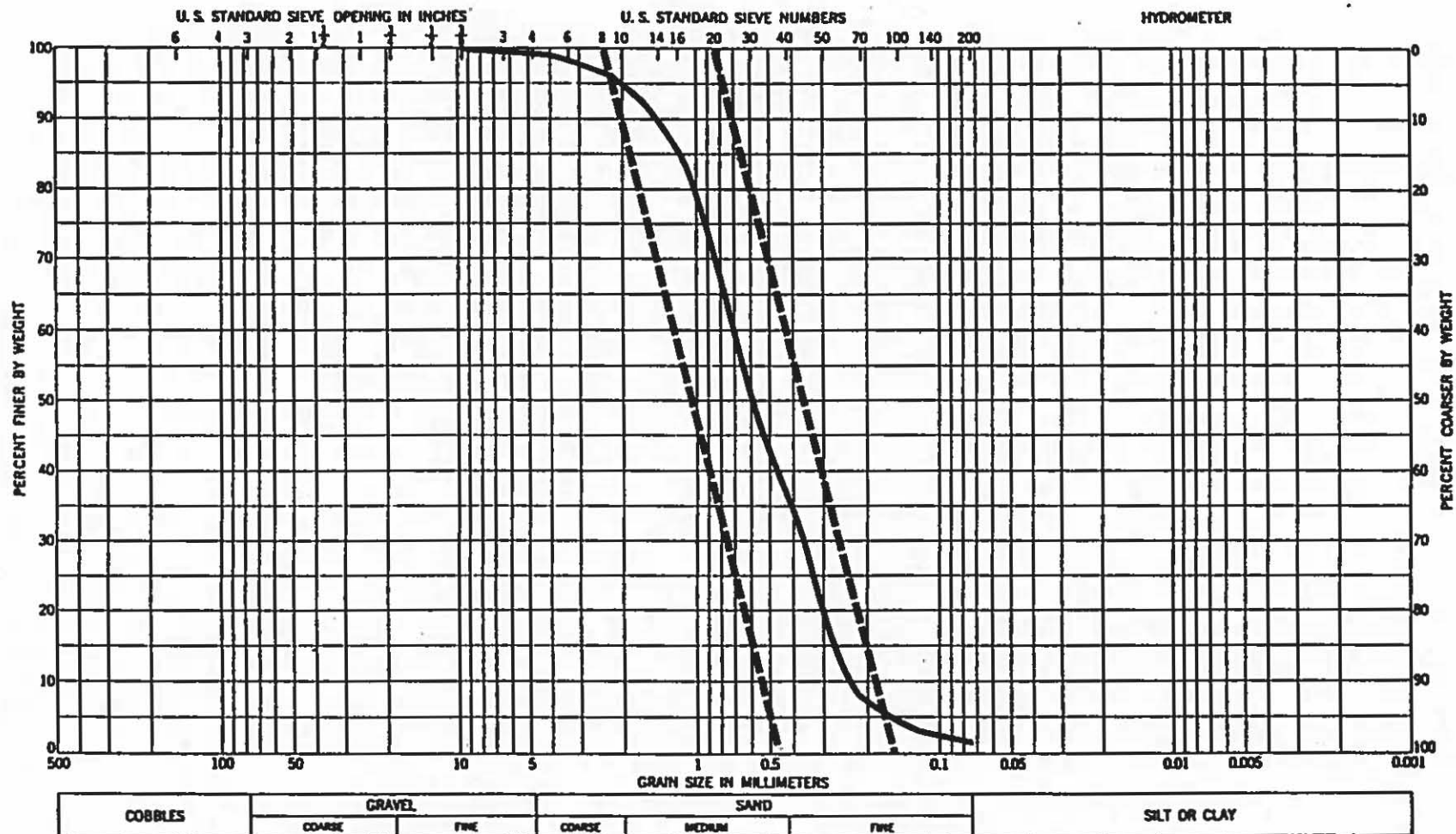


FIGURE III-8

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 7

Extreme Waves

Two super typhoons, Karen and Pamela, have been examined to determine estimated extreme wave conditions. Based on the characteristics of these typhoons presented in Table II-2, the following values were used for calculation of extreme wave conditions:

	<u>KAREN</u>	<u>PAMELA</u>
Maximum Sustained Wind Speed in Knots (U)	125	100
Hurricane Forward Speed in Knots (V)	17	7
Radius of Maximum Wind in n.m. (R)	6	12
Pressure Drop at the Center of Hurricane in Inches of Mercury (ΔP)	2.4	2.4

These characteristics are considered reasonably typical for a severe typhoon in the vicinity of Guam, although no frequency analysis has been done to estimate the probable recurrence interval.

Deepwater typhoon wave conditions can be determined using the following equations; with α assumed to be unity:

$$H = 16.5 \exp(R \Delta P / 100) \{1 + 0.208 \alpha V / \sqrt{U}\}$$
$$T = 8.6 \exp(R \Delta P / 200) \{1 + 0.104 \alpha V / \sqrt{U}\}$$

The calculated deepwater wave conditions are the following:

	<u>KAREN</u>	<u>PAMELA</u>
Deepwater Wave Height in Feet (H)	25.1	25.2
Wave Period in Seconds	10.7	10.7

Thus a deepwater wave height and period of 25 feet and 10.7 seconds is considered reasonably representative of extreme storm conditions.

Tide

The tides in Guam are semi-diurnal with pronounced diurnal inequalities. Tide data from the US Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, shows that the mean tide range is 1.7 feet and the diurnal range is 2.4 feet.

Tide data for the 19-year period between 1949 and 1967 at Apra Harbor, immediately south of the project site, is as follows:

	<u>Feet</u>
Highest Tide Observed	3.3
Mean Higher High Water	2.4
Mean High Water	2.3
Mean Sea Level	1.4
Mean Low Water	0.6
Mean Lower Low Water	0.0
Lowest Tide Observed	-1.9

Stillwater Level Rise

The rise in stillwater level in the nearshore area is a function of the astronomical tide, storm surge due to reduced atmospheric pressure and wind stress, and wave setup. The total water level rise is assumed to be the linear summation of these components. The total water level is given by:

$$St = Sa + Sp + Su + Sw$$

where,

- St = total stillwater level rise above datum
- Sa = astronomical tide
- Sp = rise due to reduced atmospheric pressure
- Su = rise due to wind stress
- Sw = wave setup.

The still water level rise is examined for three deepwater wave conditions: Case 1 represents a typically prevailing wave in the Guam area with 4-foot wave height and 5-second wave period, Case 2 represents a distant storm swell with a 15-foot wave

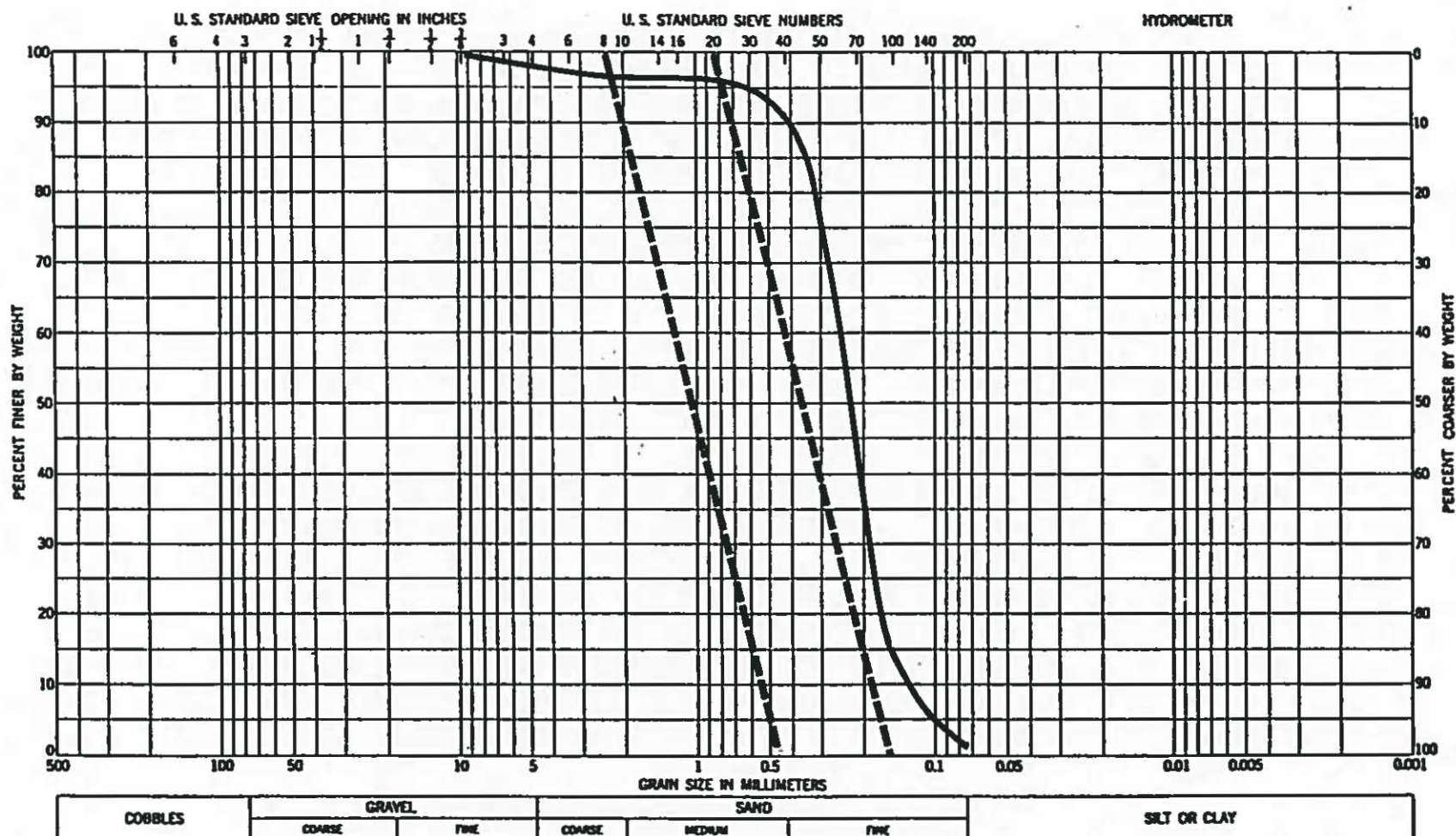


FIGURE III-9

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 8

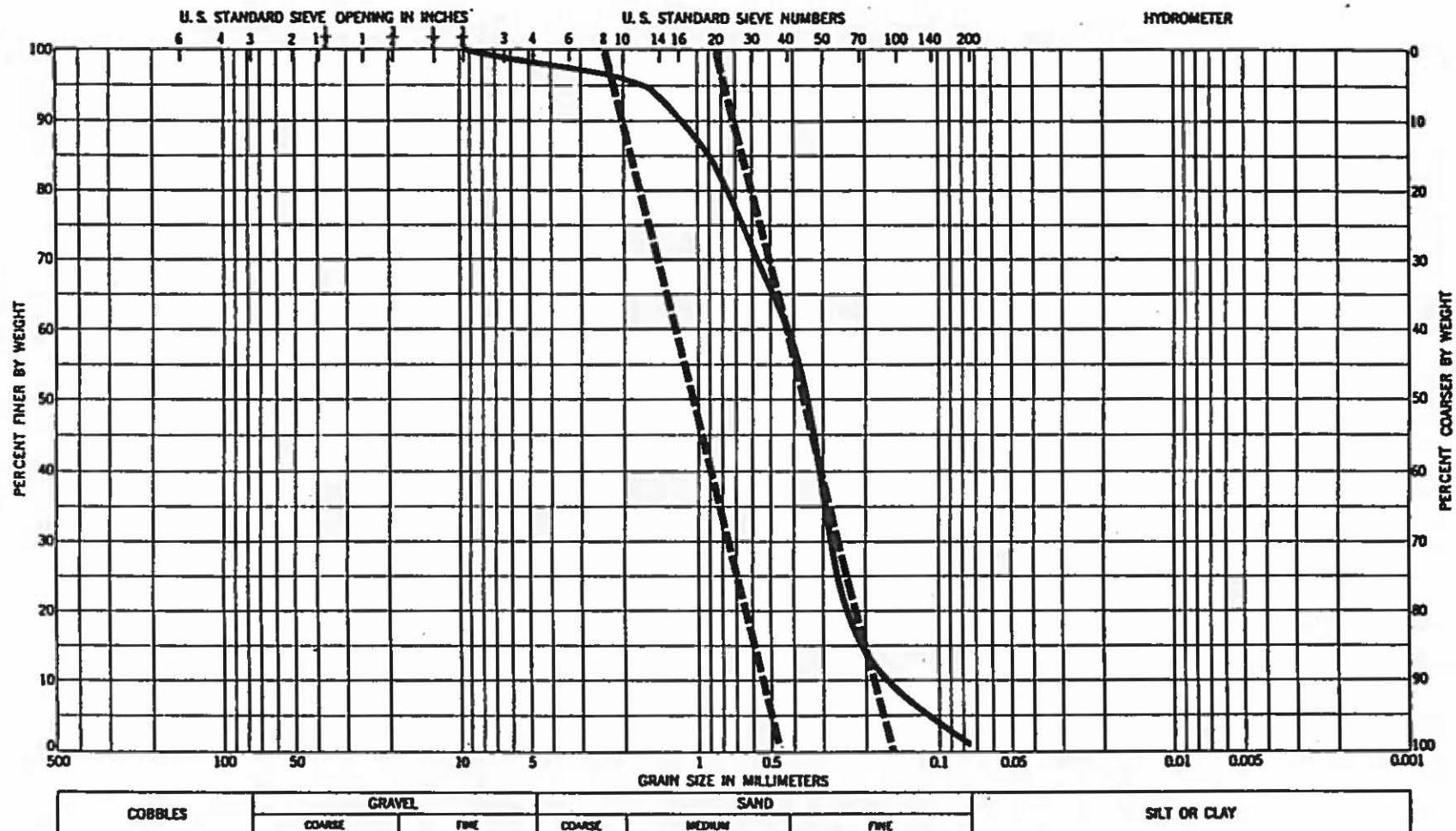


FIGURE III-10

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 9

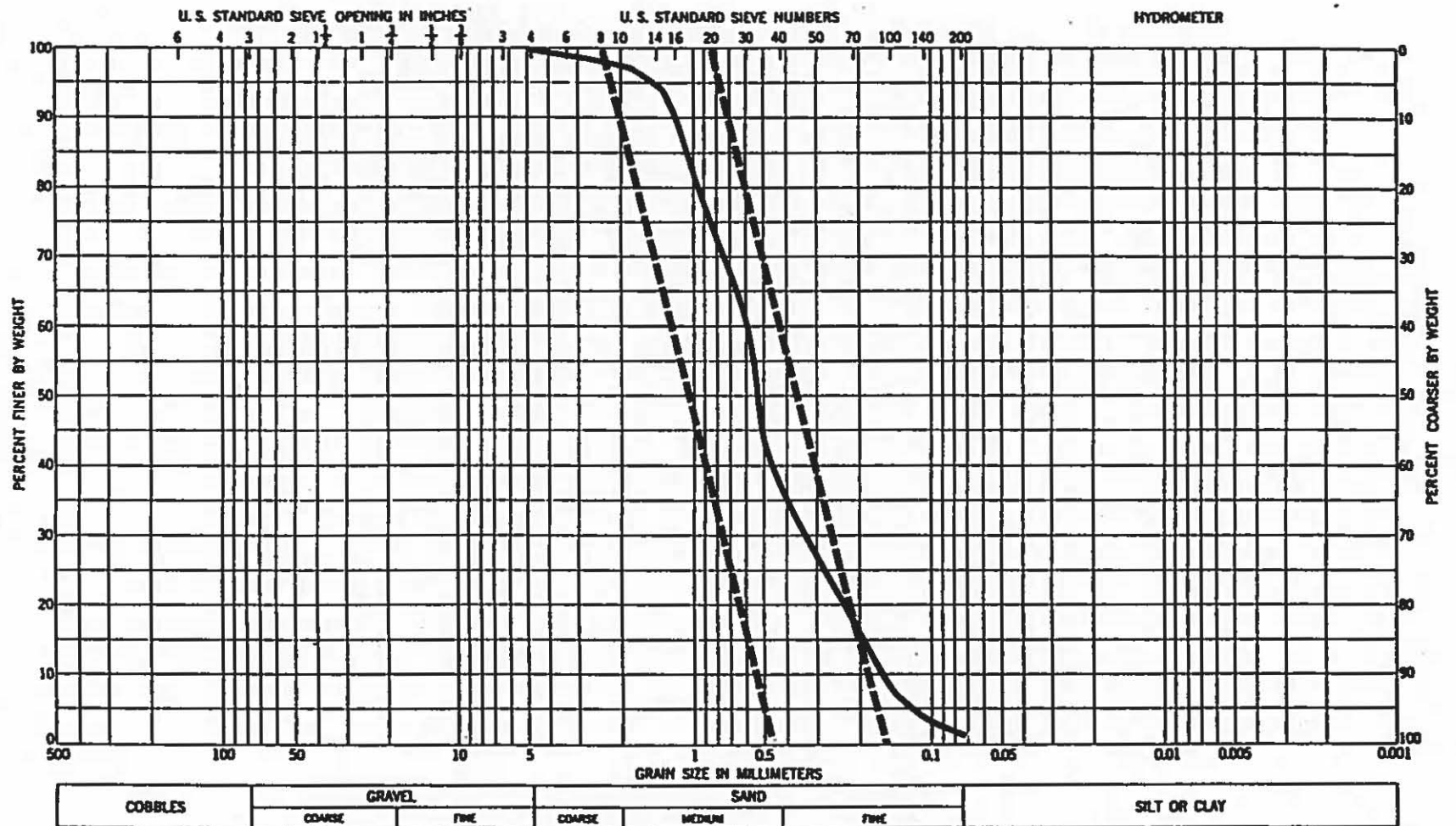
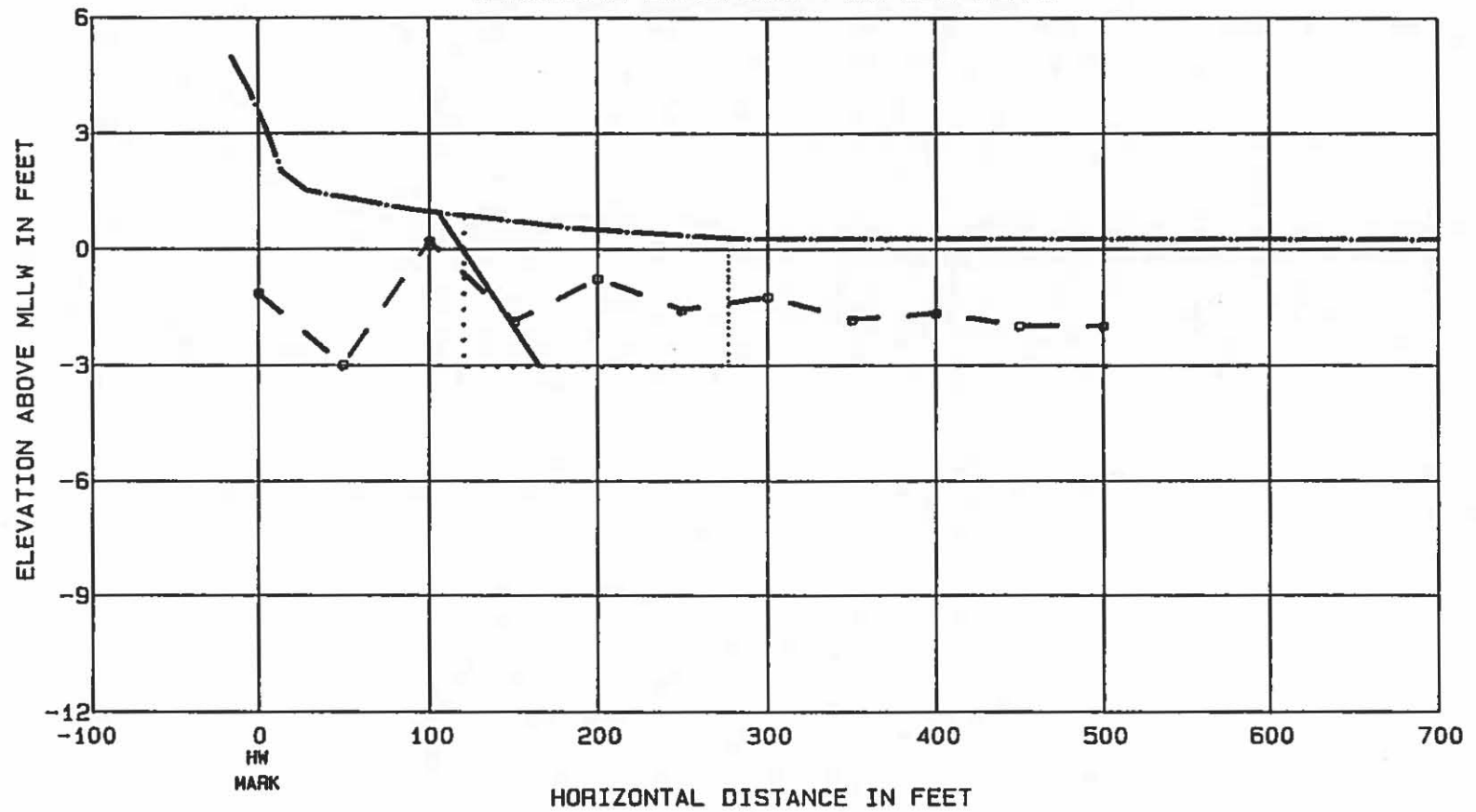


FIGURE III-11

SEDIMENT SIZE DISTRIBUTION - SAMPLE NO. 10

FIGURE III-12

NEASHORE SEDIMENT PROFILE NO.1



- — — — — EXISTING BOTTOM
- - - - - EST'D SEDIMENT DEPTH
- DREDGE LINE
- ○ — SEDIMENT FILL
- PROBE DEPTH

FIGURE III-13
NEARSHORE SEDIMENT PROFILE NO.2

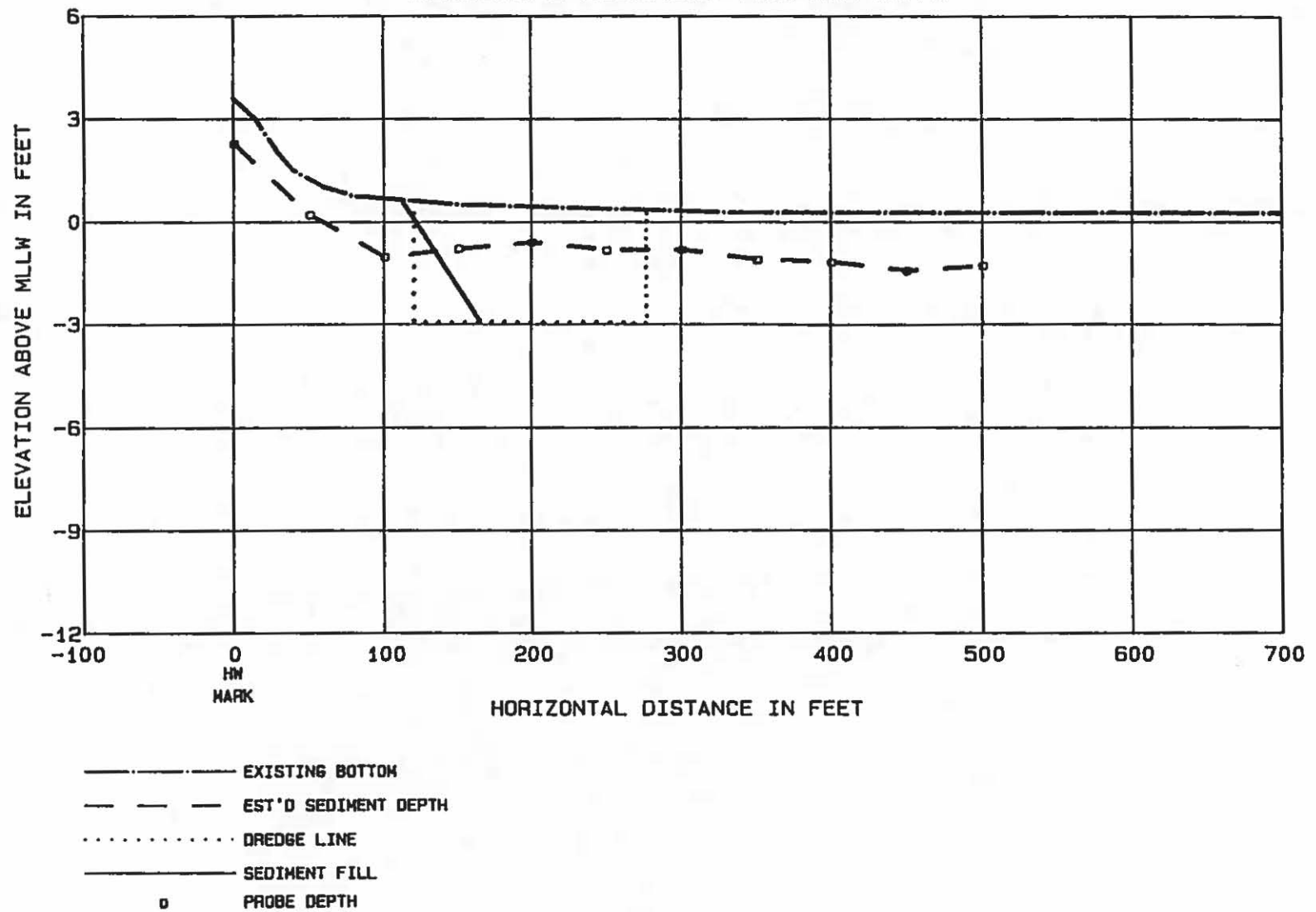


FIGURE III-14
NEARSHORE SEDIMENT PROFILE NO. 3

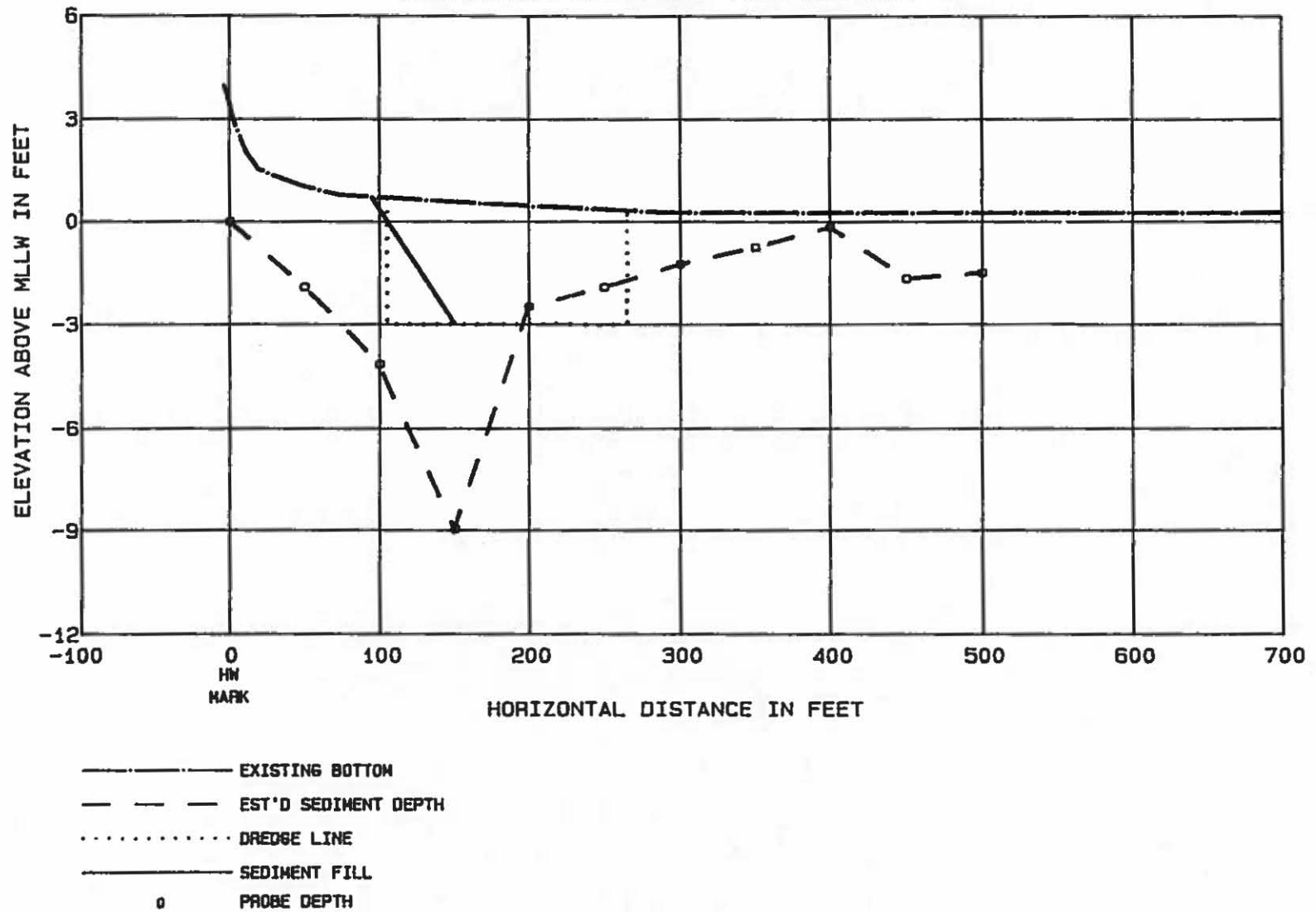
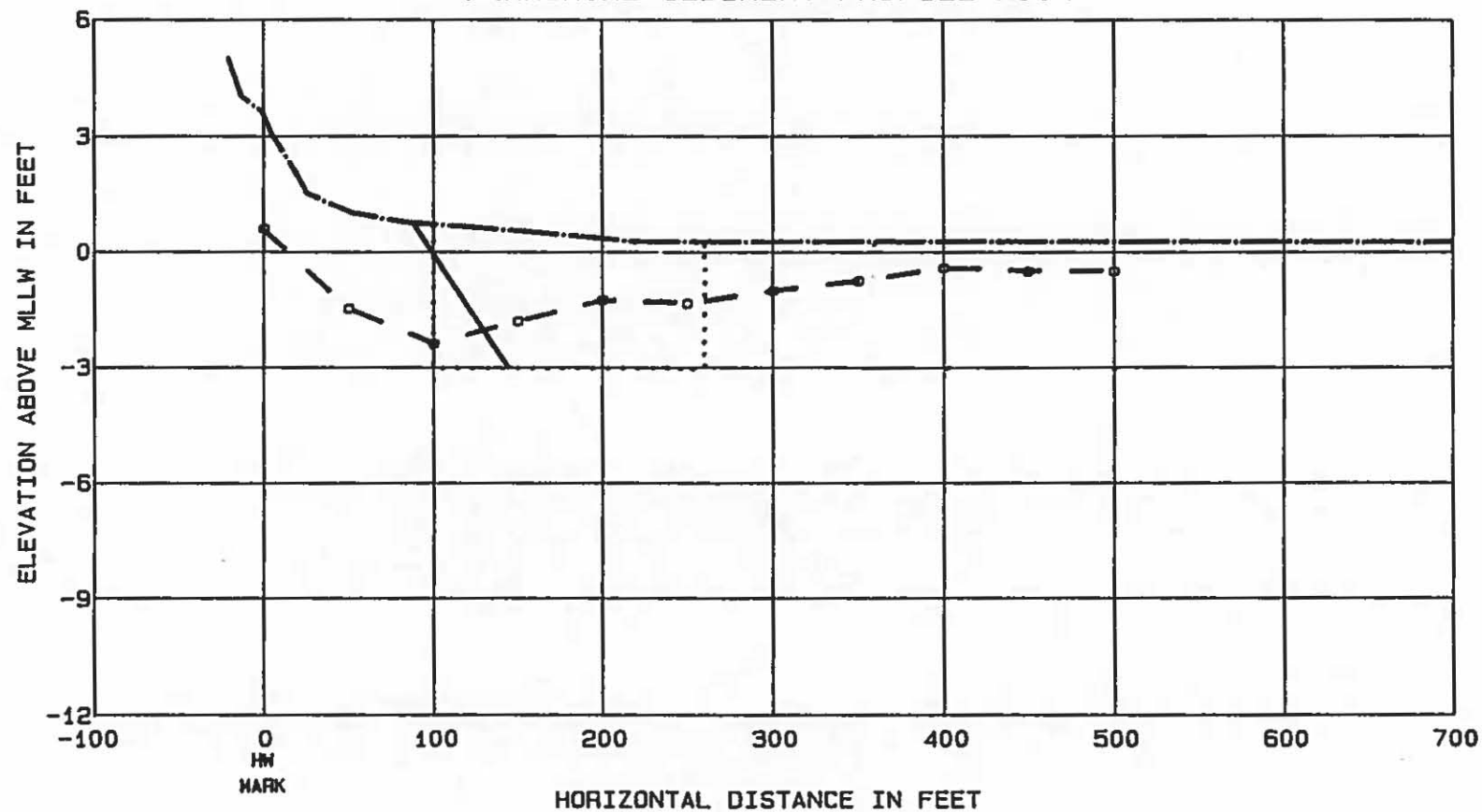


FIGURE III-15
NEARSHORE SEDIMENT PROFILE NO.4



- EXISTING BOTTOM
- - - EST'D SEDIMENT DEPTH
- DREDGE LINE
- SEDIMENT FILL
- o PROBE DEPTH

FIGURE III-16
NEARSHORE SEDIMENT PROFILE NO.5

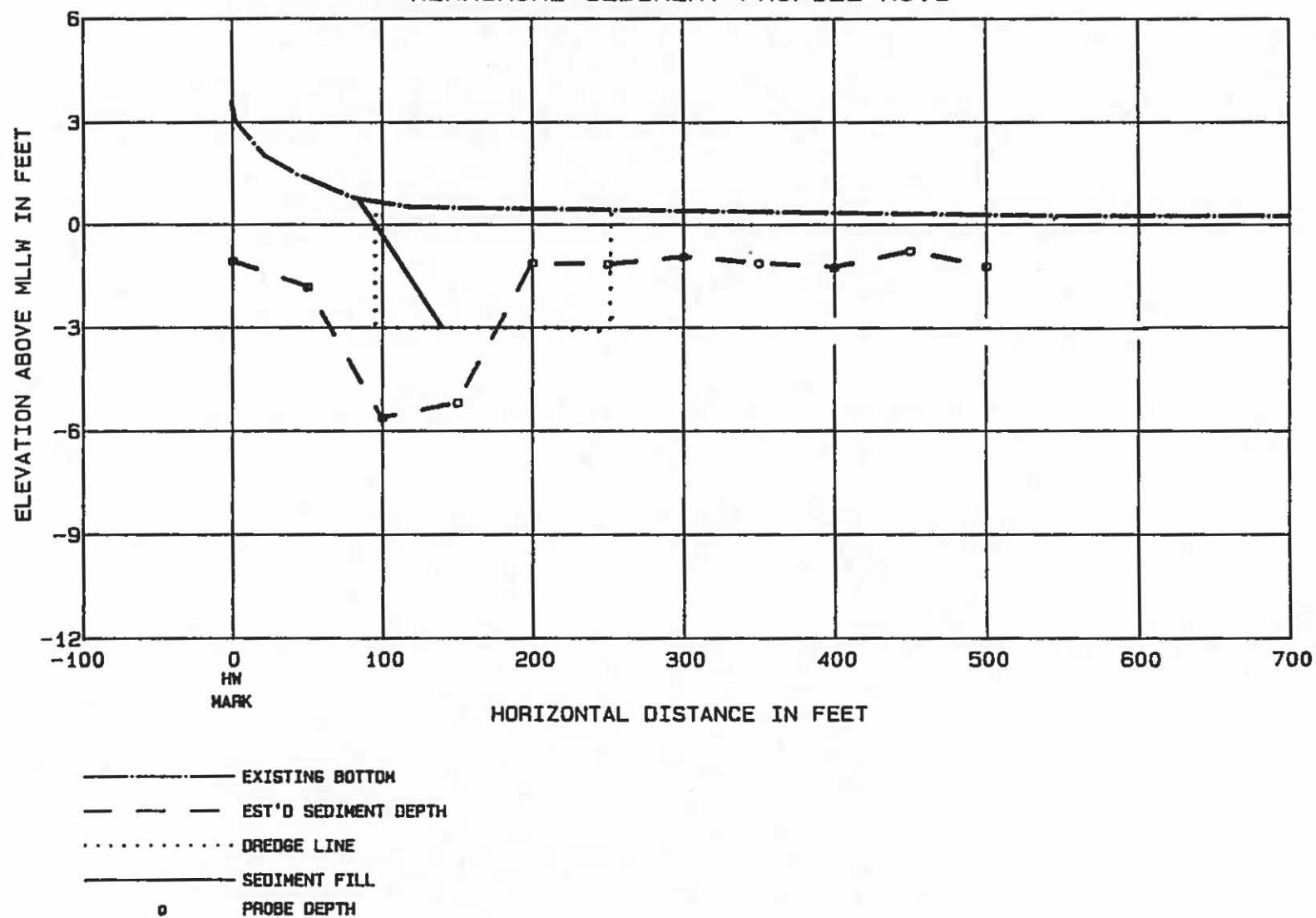


FIGURE III-17
NEARSHORE SEDIMENT PROFILE NO.6

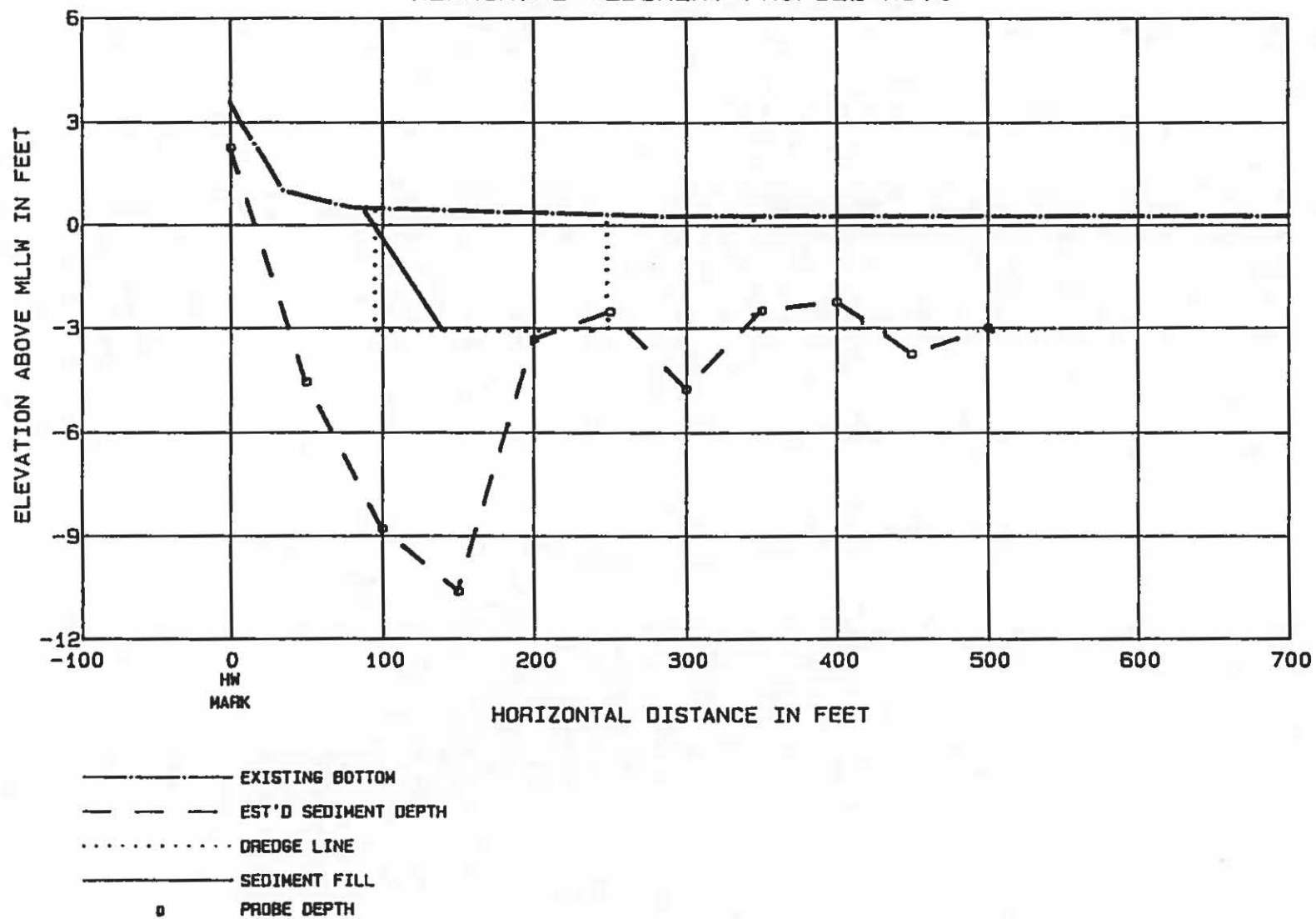
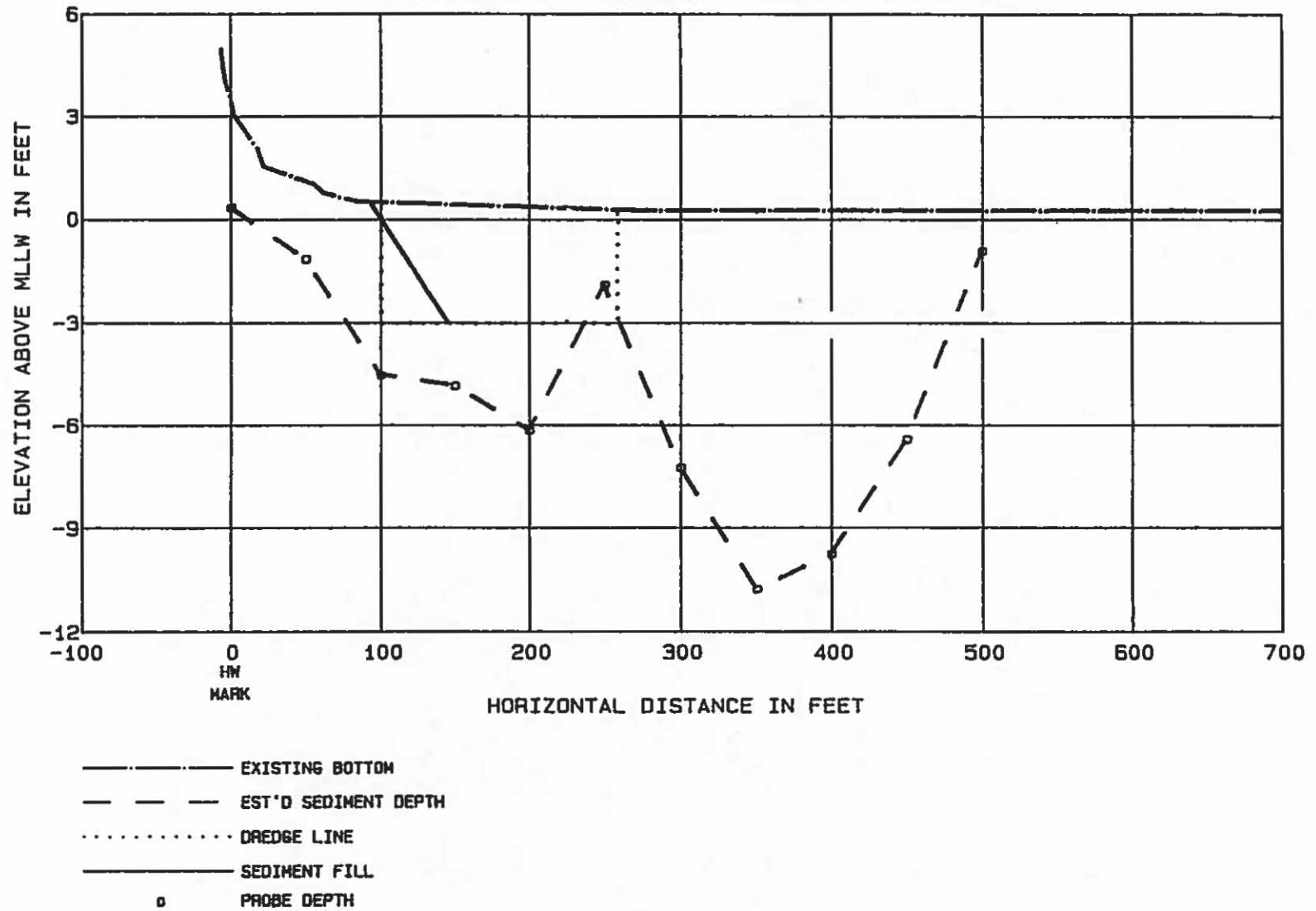


FIGURE III-18

NEARSHORE SEDIMENT PROFILE NO. 7



Sediment Depth Profiles

The bottom elevation and depth of unconsolidated sediments were plotted for seven profiles which transect the proposed dredge area. The locations of the profiles are shown in Figure III-1 and the profiles are shown on Figures III-12 to III-18. Bottom elevations were obtained from the bathymetric map and the depths of unconsolidated sediment were measured using a hydraulic depth probe.

The profiles show an equilibrium beach slope ranging from IV:15H TO IV:20H. This slope is an estimate of the dredge area side slopes after the dredging. The sand layer varies from a half foot to over 11 feet thick and more than a half of the proposed dredging will occur in unconsolidated regions. The dominant material below the sand is consolidated rubble. Solid reef rock limestone pavement was found at a few locations in the probed area.

IV. SEDIMENT TRANSPORT

Sediment transport in the coastal environment is a complicated process involving the interaction of waves, currents, tides, and sediments. Shores will erode or accrete, depending on the rate at which sediment is supplied or removed from the shore. A stable beach exists when an equilibrium between the supply and removal rates of sediment is reached. An equilibrium is, however, rarely reached for long periods of time because the oceanographic forces which cause sediment motion are always changing.

The objective of this report section is to describe the existing patterns and trends of sediment transport in the project area and to examine the proposed dredging location and its impact on the beach.

Existing Shoreline Conditions

At the project site the beach is composed of medium to fine sized calcareous sand with some scattered coral rubble. The high water line is approximately three and a half feet above mean lower low water. The bathymetric survey map shows that the elevation of the flat reef is only inches above mean lower low water within about 700 feet seaward of the high water line, indicating that the nearshore reef flat is exposed at mean lower low tide. Evidence of both sand accretion and erosion was seen along various parts of the shore both east and west of the project site on a site visit of December 14, 1990.

Present Sediment Transport

The transport of sediment in coastal waters can result from either the movement of progressive waves or a longshore current. Sediment motion is initiated when the bottom shear stress caused by a progressive wave train or a steady coastal current exceeds a threshold value. The threshold value is a function of the sediment shape, density, grain size, water depth, bed form, and flow characteristics. For a flat, shallow, slightly rippled sea bed composed of medium sized sand, such as the case for Agana Bay, the threshold value is assumed to be a function of the current velocity and the horizontal pressure gradient at the sea bed. Coastal currents in the project vicinity under normal conditions reach speeds of up to 0.5 ft/sec and under storm condition about 1.2 ft/sec. Steady currents of these speeds will initiate a small amount of sediment transport. These currents are also, however, capable of transporting a significant sediment load that is lifted into suspension by some other means such as waves.

In Figure IV-1 water depth versus wave height are plotted for three different sand grain sizes to illustrate the combination of conditions needed to cause unconsolidated sand grains on a slightly rippled horizontal sea bed to start movement under the motion of progressive waves. The water depth range, sand grain size, bed form, and sediment density were chosen to best model conditions in the project area. The data is based on theoretical information using Shield's criteria for initial motion, Kamphuis's curves for the friction factor, and linear wave theory for oscillatory flow velocities as suggested by Sleath (ref. 8). Although this information is theoretical and may not represent exactly the conditions inside Agana Bay, the curves do show the relative significance of the different parameters that control the initiation of sediment motion.

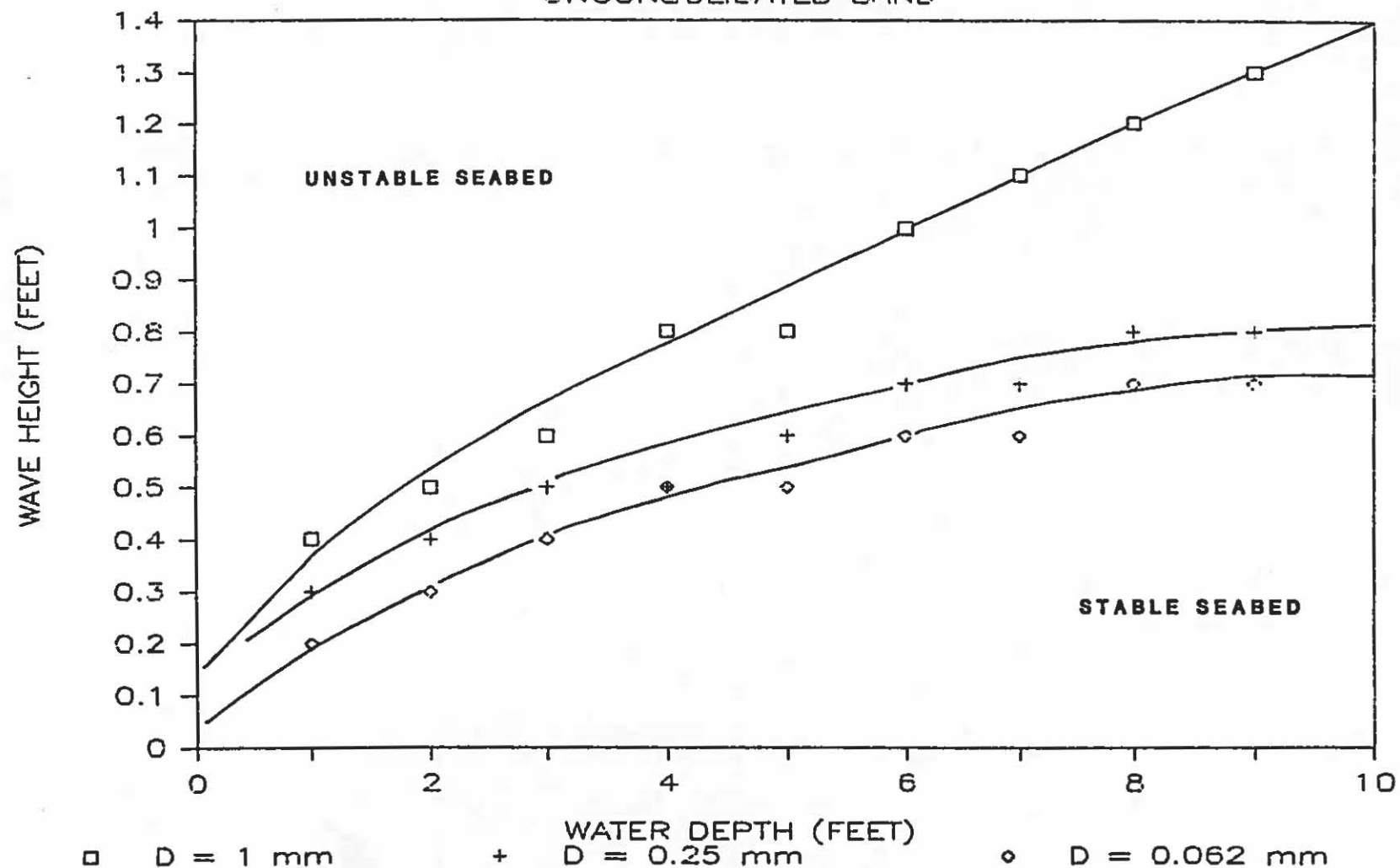
This analysis illustrates that wave heights of one foot^{*} are needed to cause sediment of all three sizes to go into motion and of only one half foot to cause small sized sediment in shallow area to go into motion. Wave heights on the reef flat have been estimated to be only about six inches or less under typically prevailing conditions, one to two feet for large swell conditions, and several feet for typhoon conditions. Thus, even under typically prevailing conditions, some sediment motion can be expected to occur on the reef flat. The total transport will be large during a large swell or typhoon conditions.

Although waves can easily cause suspension of sediments, their ability to transport sediments is extremely limited because of the low mass transport velocities associated with non-breaking oscillatory waves. However, once sediments are put into suspension, coastal current can easily carry the sediments along the shore.

During typically prevailing oceanographic conditions, coastal currents in the study area are weak with a prevailing direction to the north. Steady long term sediment transport is expected to the north. Coastal current speeds increase during storm events, and although the current directions are increasingly variable, a significant amount of net sediment transport is expected to the north because of the channel at the north end of the bay where a large amount of water exits the reef flat.

FIGURE IV-1

INITIAL MOTION THRESHOLD UNCONSOLIDATED SAND



Predicted Sediment Transport After Dredging

Immediately following the completion of dredging, the beach and nearshore water area will first adjust to reach an equilibrium state with the new wave and current conditions. The nearshore wave height has been predicted to increase only about 7 percent in non-storm conditions and 4 percent in storm conditions. Wave direction has also been shown to change along only a limited segment of the shoreline near the boundaries of the dredging area as a result of refraction. The small increases in wave height and slight changes in wave energy distribution should not have a significant effect on sediment transport.

On the other hand, the dredged area may trap sediment in the deepened bottom section. This sediment trapping may disturb the balance between sediment supply and removal, and, as a result, have an impact on sediment transport. The degree of impact depends on the rate of sediment trapping. If the sediment trapping in the dredged section is a significant amount, and the sediment supply to the down stream shoreline is limited, erosion may occur along the down stream shoreline. Sediment trapping would be lessened by creating equilibrium side slopes of 1:15 to 1:20 during the dredging process.

With normal wave conditions and with prevailing northerly currents, some sediment transport is always expected on the shallow reef flat. However, sediment movements is greatest on the beach slope where waves break and cause sand to be placed in suspension, resulting in sand movement both along the shore and the onshore-offshore.

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