FINAL
ENVIRONMENTAL IMPACT STATEMENT
FOR
SUNSET BEACH HOTEL DREDGING
EAST AGANA BAY, GUAM

Prepared For
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March, 1989

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

List of Tables continued **PAGE**

I. SUMMARY AND BACKGROUND INFORMATION

A. Introduction/Project Concept

Tourism on Guam has grown consistently over the years with significant increases in recent years. The number of visitors is dramatically increasing each month with nearly a half million tourists in 1988. One million tourists are expected to visit Guam each year by 1993 (GVB, 1987).

The development of Tumon Bay as the tourist center has been consistent over the years, commencing with a boom in the early 1970's and growing with the Japanese trend for tourist travel. Periodic fluctuations in tourism with ups and downs have occurred since then, and overall development on Guam is in a boom period now. Tumon Bay is reacting to this increase with the expansion of existing hotels and development of new ones. In addition to the development of new hotels comes a variety of tourist related commercial developments. These developments are quite evident along Ypao Boulevard.

The Government of Guam has taken major steps to improve the infrastructure of Guam so that tourism has the necessary backbone upon which to grow. The most serious study identifying the needs for increasing tourist development on Guam is the Tumon Bay Master Plan. This plan, completed in 1984, identified the need for infrastructure improvements. According to this plan existing hotels can expand, new hotels can be constructed and associated commercial businesses have the opportunity to develop without taxing existing systems.

The Tumon Bay Master Plan also identified the need for micro-dredging of Tumon Bay. This is needed to improve water depth for basic water recreation over all tidal conditions. At this time, improved infrastructure in Tumon Bay is nearing completion. However, the Tumon Bay Micro-Dredging project is still in the early planning stage. The submittal of appropriate permit applications (ACOE, CZM and GEPA) will be finalized by the third quarter of 1988. Assuming approvals, this project could begin by mid-1989.

Hotel development on Guam is also expanding away from Tumon Bay as tourism grows. Many new tourist facilities can be found throughout the island. Operational facilities now include Cocos Island Resort, Inarajan Shores and Jones Beach Resort in Ipan. Projects still in the planning stage include the Guam Micronesian Cultural Center and Resort at Turtle Cove in Yona, Huchano Golf Course in Mangilao and the Municipal Golf Course in Yigo. Many tourist related businesses such as shops, restaurants and clubs are becoming visible all along the west coast of Guam, particularly in the villages of Tumon, Tamuning and Agana.

Although hotel development continues to occur along Tumon Bay, new resorts are beginning to develop in East Agana Bay. Recently, the Palace Hotel broke ground at Oka Point and the project detailed in this report (Sunset Beach Hotel and Resort) is planned for the Dungcas Beach area. The majority of this resort will be constructed on the site of the old Oka Point Trailer Park, along Dungcas Beach and in the lagoon out to Alupat Island. Aside from tourist resort facilities, condominiums are also under construction in the area. The Bay View Condominium was recently completed on Trinchera Beach just south of the proposed Sunset Beach Hotel. The Oka Point Condominiums are still under construction just north of the proposed Palace Hotel. The Alupang Condominium project has been in existence opposite Alupat Island for 14 years. It is obvious that tourist related development is expanding into those areas north and south of Tumon Bay.

Nearly all beach oriented hotel development on Guam necessitates dredging a deeper swimming area. (Reference the increased number of ACOE applications for swimming holes by major hotels along Tumon Bay and Government of Guam plans to dredge a portion of Tumon Bay). These dredging plans are not restricted only to Tumon Bay. They are also planned at Cocos Island, in the villages of Merizo, Ipan and Yona, at the Commercial Port and within both the eastern and western sections of Agana Bay.

Dredging of reef-flats around Guam is a controversial issue in both governmental and private sectors. This is especially true since, in recent months, the number of dredging applications has risen sharply with the developing tourist industry. There are those who see these projects as a major improvement over the extremely shallow natural water of these bays and others who feel that dredging will only detract further from the natural beauty. Regardless of public or governmental opinion at this stage, some of these bays are far removed from natural conditions which have been modified over the years primarily from extensive human use. Impacts on the lagoon include development of major structures near the bay, which contribute silt-laden runoff through major storm drains, and the multitude of people who, use and impact the beach and lagoon in various ways.

Agana Bay is a naturally beautiful environment even in its somewhat deteriorated state today. Like Tumon Bay, there is one thing certain about East Agana Bay; it will continue to be used by more and more people in years to come. One cannot close his eyes to this and hope all the users will go away. Because of this fact, the entire area, not just the bay, will suffer tremendous environmental pressure and degradation. To alleviate this problem, some form of environmental regulation/protection must be implemented.

This proposed development plan for the northern section of East Agana Bay lagoon and beach area is designed to provide for a greater degree of use. The designs will also improve an environment which has been stressed considerably over the years. The focal point of this Environmental Impact Statement (EIS) is development and improvement within the lagoon and surrounding beaches of this site. This EIS is designed to offer reviewers within the government, and other interested parties, specific information about the project. Physical and biological characteristics of the lagoon and beaches are included so that intelligent and reasonable decisions can be made regarding the development plan. This EIS also offers some suggestions and recommendations to help ensure a high degree of protection during the construction phase of the project.

B. Previous Studies

A number of marine environmental studies involving Agana Bay (at least in part) have been completed over the years. Most of these are the result of biological and physical investigations by the U.S. Navy and by individuals at the University of Guam Marine Laboratory.

1. Studies prior to 1970

Geological studies on East Agana bay date back to Emery (1962) who performed a geological survey of the marine environment of Guam. Tracey, et al. (1959 and 1964) also performed some of the earliest geological survey work on Guam between 1951 and 1954. Two transects of the reef profile in Tracey's work are in East Agana Bay.

2. Studies in the 1970's

Randall (1971) surveyed the entire west coast of Guam, including East Agana Bay, regarding the effects of infestation by the Crown-of-Thorns Starfish (*Acanthaster planci*). Tsuda (1971) investigated the status of *Acanthaster planci* and coral reefs in the Mariana and Caroline Islands which included all of Agana Bay. Randall and Eldredge (1974) investigated the extreme north end of East Agana Bay for the purpose of constructing a marina and resort. This study described the general area and investigated the corals, fish, macroinvertebrates, algae and currents in the vicinity. The project never materialized but was proposed for the same general location as the Sunset Beach Hotel and Resort project. Randall and Holloman (1974) described the entire coastline of Guam detailing East Agana Bay in their Coastal Survey of Guam. East Agana Bay represented Sector VII of this study. The U.S. Navy Oceanographic Office (1974) collected a good deal of data on the micro-invertebrates currents and coral reef ecology of the west coast of Guam.

Randall and Eldredge (1976) investigated the physical characteristics of East Agana Bay as a part of the Atlas of Reef and Beaches of Guam. Rowe and Doty (1977) studied the shallow water Holothurians of Guam which included some work in East Agana Bay. Zolan et al. (1978) investigated the impact of urban runoff water discharged in coastal waters through stormdrains in various areas of Guam. The NAS storm drain in East Agana Bay is identified as one of his study sites. FitzGerald (1978) investigated environmental parameters influencing the growth of the filamentous green alga Enteromorpha clathrata which grows abundantly along the shoreline of Agana Bay. Amesbury (1978) performed studies on the biology of reef fishes of Guam including fish population projections for Agana Bay. Birkeland et al. (1978) investigated the corals, algae and macroinvertebrates of several reef-flat communities on Guam including Agana Bay. This investigation gave some comparisons of diversity between reef-flats. Stojkovich and Smith (1978) performed a comprehensive survey of edible marine shellfish and sea urchins on the reefs of Guam which included data from Agana Bay.

3. Studies in the 1980's

More recent studies of Agana Bay include the 1980 Army Corps of Engineers (ACOE) report regarding planning alternatives for the bay. This paper identified a number of problems within Agana Bay and suggested methods of eliminating them. In 1980 the ACOE also recorded much of Guam's coastline in their Comprehensive Study Shoreline Inventory. Agana Bay represented Section 4 of this report. East and West Agana Bay were surveyed in 1985 by PBEC regarding the Government of Guam Plan to construct a Passenger Line terminal and create new land for development purposes.

C. On-going data collection

The Guam Environmental Protection Agency (GEPA) has been collecting water quality data from East Agana Bay since the early 1970's. Some of their monitoring sampling stations are in proximity to stormdrains and in the vicinity of popular recreation beaches. Analysis of samples from the area is only for bacteriological contamination (Total and Fecal Coliforms). The Aquatic and Wildlife Resources Division of the Department of Agriculture conducts on-going creel surveys along the shoreline of Agana Bay. It's purpose is to assess the use and impact of subsistance and sport fishing on the fish resources in the bay.

The Guam Visitors Bureau (GVB) publishes monthly visitor statistics and compiles these into an annual report to determine visitor trends. The GVB has also funded numerous studies over the years on the preferences of tourists, primarily the Japanese.

D. Permit Requirements for the Project

1. Federal Government Review

There are a number of permits which are required in order for this project to commence. The primary permitting agency is the U.S. Army Corps of Engineers (USACOE) This agency requires at least a Section 10 permit application (River and Harbor Act of 1899) as amended and Section 404 of P.L. 92-532 (Marine Protection, Research and Sanctuaries Act) for dredging within the navigable waters of East Agana Bay. A Section 404 permit will be required if any of the dredge spoil material will be placed in the intertidal zone for beach nourishment. However, if only clean sand is to be placed on the beach (fastland) then the 404 permit will not be required. 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 (CZM) policies regarding use, protection and development of land and water resources. These policies are administered by the CZM office within the Government of Guam Bureau of Planning and an application form must be filed. This application, with additional supporting information, is reviewed by all local and federal agencies. The review must find that the project is consistent with federal government policy prior to approval by the CZM office.

2. Local Government Review

The ACOE permit review process includes reviews by local governmental agencies, interested organizations and concerned individuals and may involve a public hearing. The ACOE 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).

Preliminary project limits for dredging in East Agana Bay were defined by the shoreside property boundary marks and the edge of Alupat Island. Lines were drawn from these boundary marks across the reef-flat out to the north and south tips of Alupat Island, thereby defining the study area and potential dredge zone (approximately 19.3 acres (78,036 m2). The southern half of this area is a large sandy zone which comprises the majority of the area. The remainder of the area is composed of sand covered hard substrate and live coral. A rich coral community exists in the extreme northeast portion of the site. Areas of live coral will not be dredged. An estimated 45,000 cubic yards of mostly unconsolidated material will be removed, a portion of which will be used to nourish the existing shoreline. The remainder will be disposed on shore at approved landfill sites.

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

The GEPA requires a Section 401 Water Quality Certification prior to commencing work in any aquatic area. There is no application form for this certification. Submission of paperwork for the ACOE and CZM permits with a letter requesting such certification is sufficient at this time.

An Environmental Impact Assessment or Statement (EIA/EIS) is a requirement for certain types of projects. Any project which is to be funded by federal dollars, built on federal property or requiring federal permits must prepare at least an EIA. Findings in the EIA will determine the necessity of preparing an EIS, although major projects (as defined by USEPA criteria) require an EIS for its detail. The EIA/EIS is the responsibility of the developer and should be prepared early in the project's planning process.

Governmental review of the project begins once all applicable forms are filed. The ACOE relies heavily on decisions and recommendations in the local government review process. In the event that the project fails in the local government review process, the ACOE will also deny a permit. Approvals at the federal level are usually conditioned with recommendations suggested at the local level. Finally, the ACOE may deny a permit even if local approvals are granted.

II. PROJECT DESCRIPTION

A. Purpose and Need for the Proposed Action

1. Water/Coastal Dependence Objective

The primary goal of this project is to deepen the shallow nearshore reef-flat between the shoreline and Alupat Island. This is needed so that a greater variety of recreational uses can be accommodated, and to prepare the area for future development. At the present time this section of East Agana Bay is extremely shallow and is used for limited water recreation primarily during high tide periods. Immediate water recreation uses proposed for the area as a part of the proposed resort and this application include windsurfing, jet skiing, swimming and snorkeling. Future recreational use (not included in this application) may include a dolphin pool, marina, an underwater tube walkway between the shoreline and Alupat Island and water skiing within the deepened lagoon. This section of coastline is developing rapidly with hotels and condominium projects. Use of the nearshore reef zone will increase dramatically in the next few years. Use zones will be a necessity to prevent conflicts and to protect the users as well. This development plan identifies appropriate use zones for consideration by the review agencies.

A secondary goal, but of great importance to the success of the primary goal, is to significantly improve water quality in the area. An old causeway bisects the reef-flat creating a blockage of water flow between the extreme north end of the bay and the rest of the bay to the south. This causeway and the protected nature of the bay creates a still-water bay lacking adequate water circulation. Water quality has been very poor during recent years because of overflow from sewer manholes which exist within the intertidal zone, and poor flushing and sediment loading from swales and storm drains in the area. All this translates into poor water quality in the area. Sediments from natural and man-made water drainage swales on shore have slowly been filling in the lagoon. The Guam Environmental Protection Agency (GEPA) monitors water quality in the area on a regular basis and regularly reports the area as polluted with high numbers of fecal coliforms. Dredging will improve water quality significantly in the area since the causeway will be removed allowing for better circulation and mixing. Sewer manholes along the beach will be relocated during construction of the proposed resort and this action should eliminate the high concentration of fecal coliform bacteria now entering the bay.

2. Economic Development Objective

The proposed project provides an opportunity to vastly expand Guam's tourist facilities through the development of a unique water park. Part of the park will be constructed on land and the remainder in the nearshore lagoon between Alupat Island and the shoreline. An extensive onshore lagoon system has not been attempted on Guam partly because no suitable site has been identified. This corner of East Agana Bay represents a unique location with steep cliffs, gently sloping beaches, protected lagoon and offshore islet where the development potential is high. For these reasons, the developers have chosen this site to create this new recreational concept for tourists and residents alike.

This proposed 19.3 + acre site will provide a unique water-related facility for tourists and residents and will add to the average length of stay for Japanese tourists on Guam. It will also add to the tourist economic base in terms of daily expenditures, room tax and gross receipts tax revenue.

B. Project Location

This dredging project is proposed over a 19.3 acre area of the shallow water reef-flat between the shoreline at Dungcas Beach and Alupat Island in the extreme northeast corner of East Agana Bay (Figure's 1,2 and 3).

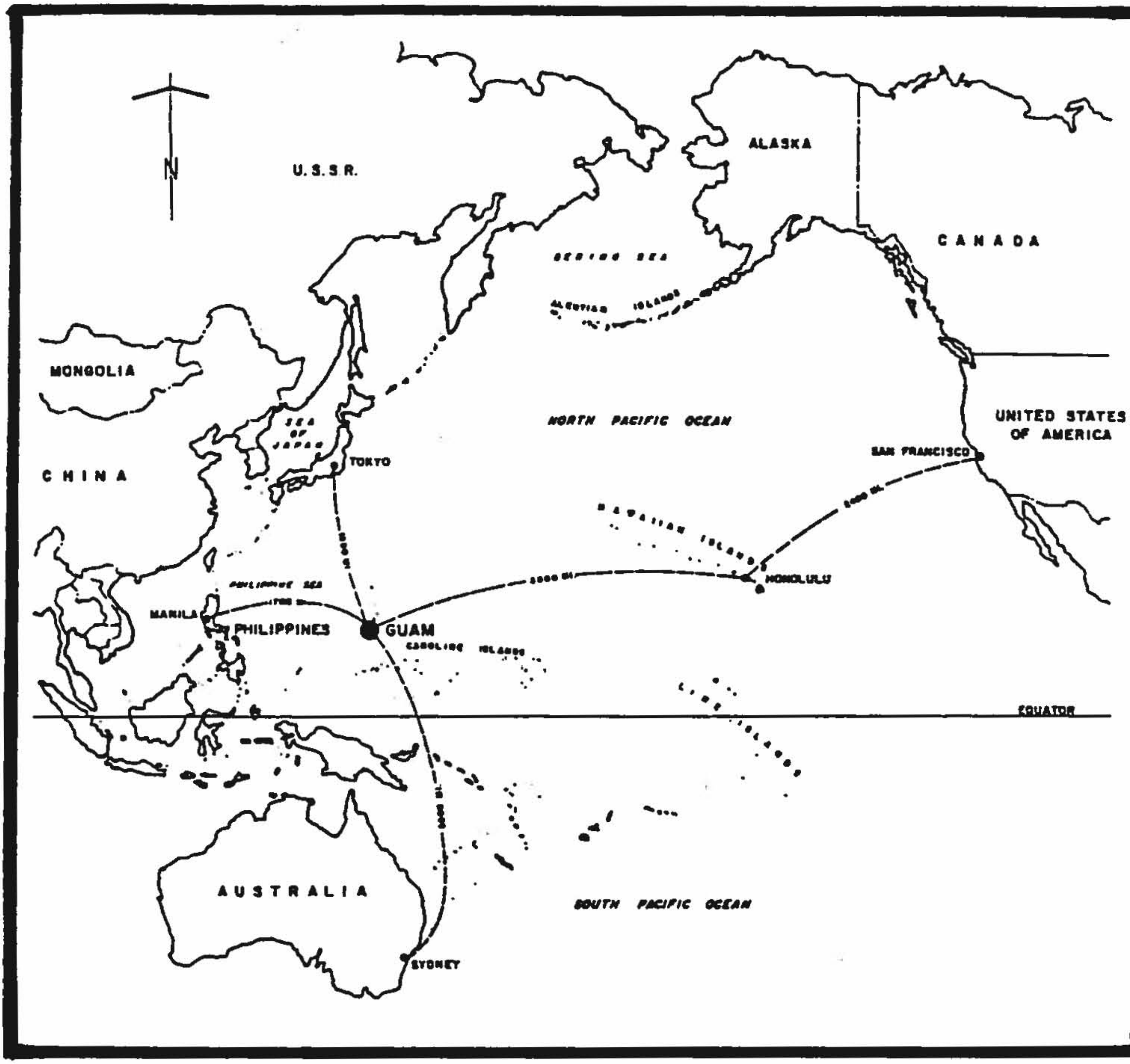

Figure 1. Map depicting Guam as the largest island in the Western Pacific Basin.

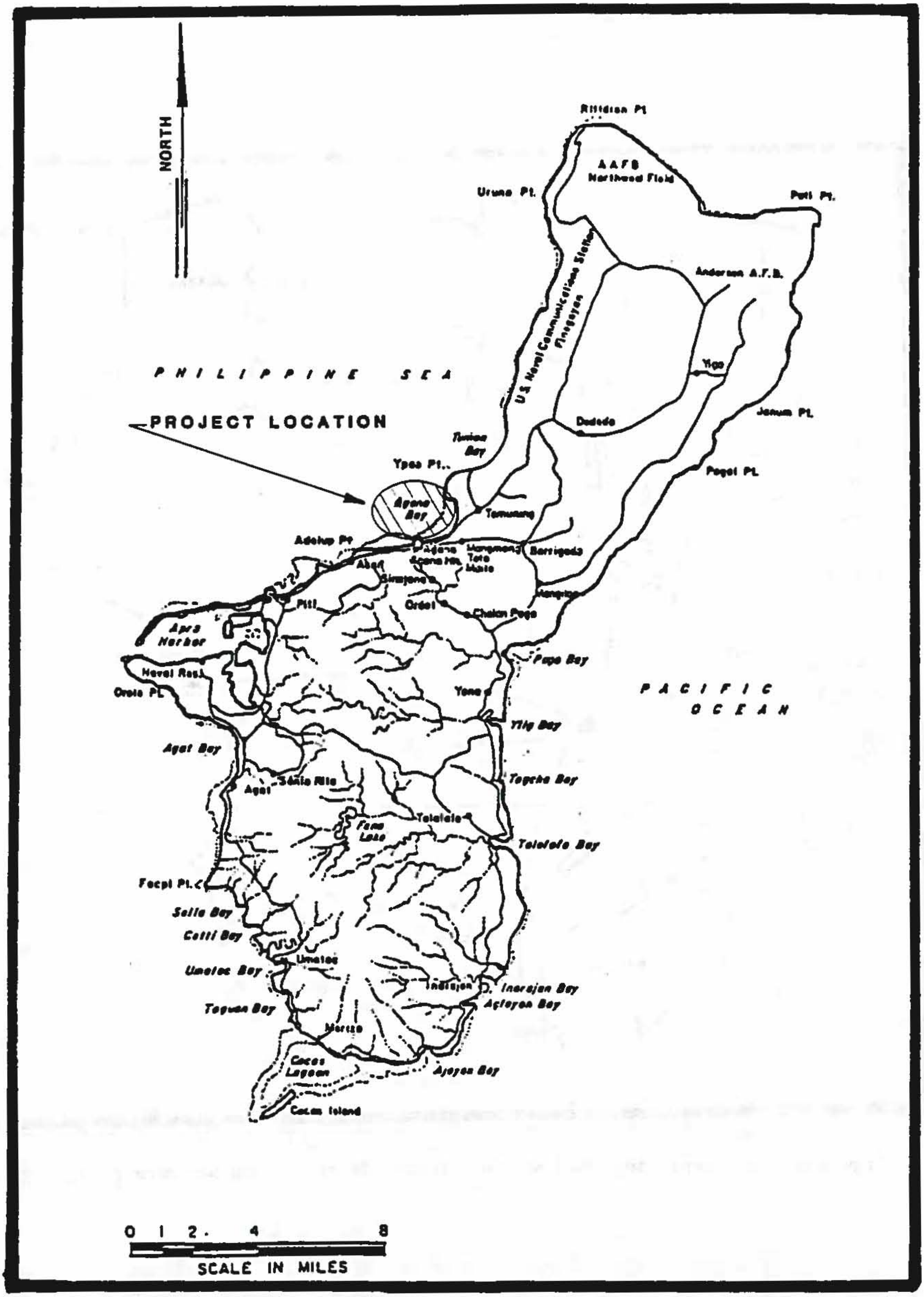

Figure 2. Map of Guam indicating project location in Agana Bay.

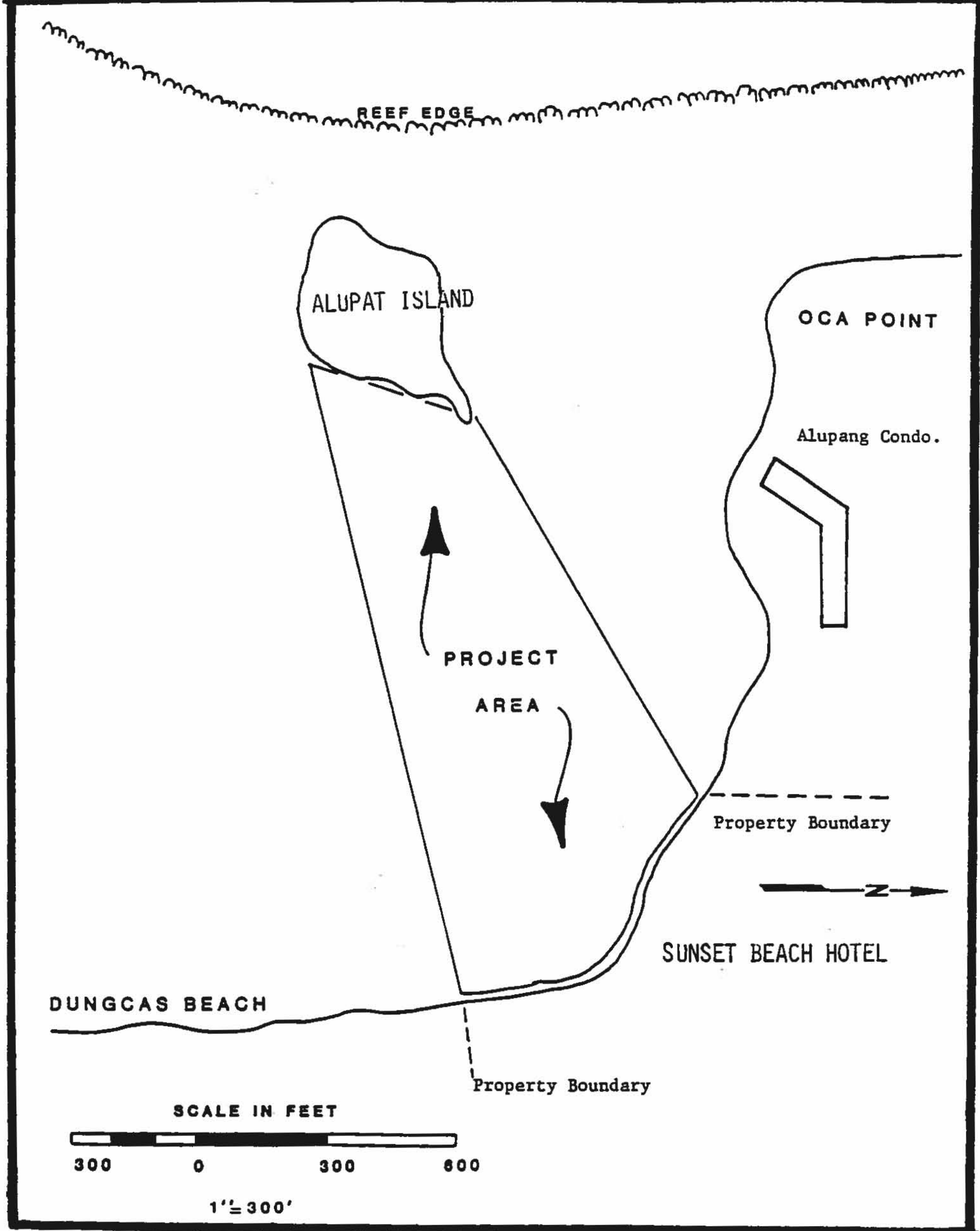

Figure 3. Project area in proximity to surrounding structures.

C. Description of the Project

Preliminary project limits for dredging in East Agana Bay were defined by the shoreside property boundary marks and the edge of Alupat Island. (Figure 3). Lines were drawn from these corner marks across the reef-flat out to the north and south tips of Alupat Island, thereby defining the study area and potential dredge zone (approximately 19.3 acres). The southern half of this area is a large sandy zone which comprises the majority of the area. The remainder of the area is composed of sand covered hard substrate with some live coral. A rich coral community exists in the extreme northeast portion of the site. Areas of live coral will not be dredged. An estimated 45,000 cubic yards of mostly unconsolidated material will be removed over a 6.4 acre area.

Spoil material of suitable size and quality will be placed on Dungcas Beach for beach nourishment. The remaining volume of spoil will be stockpiled and eventually hauled to an approved upland disposal site.

Dredging the sandy and rubble strewn areas to -4.5 ft will also prepare the site for future development objectives while providing adequate water depth for immediate use. Preliminary future plans include placement of an underwater acrylic walkway tube between the shore side resort and Alupat Island. Two unique structures are planned along the walkway: a dolphin show pool at midbay and a small marina near Alupat Island. Development details for these facilities are not addressed in this EIS. When conceptualized, details will follow in an amendment.

D. Proposed Construction Plan Methodology

1. General Comments

Evaluation of substrate probing data suggests that most of the dredged material is unconsolidated sediments (sand and loose coral rubble), which can be removed by simple suction or vacuum methodology. Most of the sandy zone is at least four (4) ft thick and greater than six (6) ft deep in many areas. However, in some areas, loose sediments represent only a thin veneer, on top of hard substrate which may be a few inches thick, or as much as a few feet thick depending on the geology of the area. Some of these areas are entirely devoid of coral or with loose coral pieces and may be dredged without destroying the coral resource. However, as noted previously, depth of hard pavement is unknown. Recent dredging of swimming holes in front of the Pacific Star Hotel and the Pacific Islands Club in Tumon Bay suggest that the pavement may only be a thin veneer underlain by hard packed sand and limestone rubble. In some areas very large boulders exist just under the pavement which would require heavy equipment for removal.

2. Recommended Dredge Area

The recommended dredge area is shown in Figure 4. A thirty foot (minimum) setback from live coral areas is recommended to provide protection to the coral from the construction operations, and to allow for sloughing of the side banks. The dredging should not proceed farther seaward than as shown to preserve the beach at Alupat Island.

The dredge area shown is 280,000 square feet (26,012m^2, 6.4 acres). The average existing depth in this area is -0.2 feet (MLLW), thus to reach a depth of -4.5 feet (MLLW) will require removal of approximately 45,000 cubic yards. Eighty percent of this volume is estimated to be loose unconsolidated sand and the remaining twenty percent is reef pavement or consolidated rubble.

3. Dredging Methodology

Two dredging methods are applicable to the project and have been investigated. They include hydraulic dredging and mechanical dredging.

The hydraulic dredging method was proposed by a local contractor, who claims to have a hydraulic dredge capable of removing both unconsolidated sand and reef pavement in shallow water. The dredge operates on tractor-type treads, and does not require the use of temporary causeways or a barge. Should this dredge prove appropriate for the

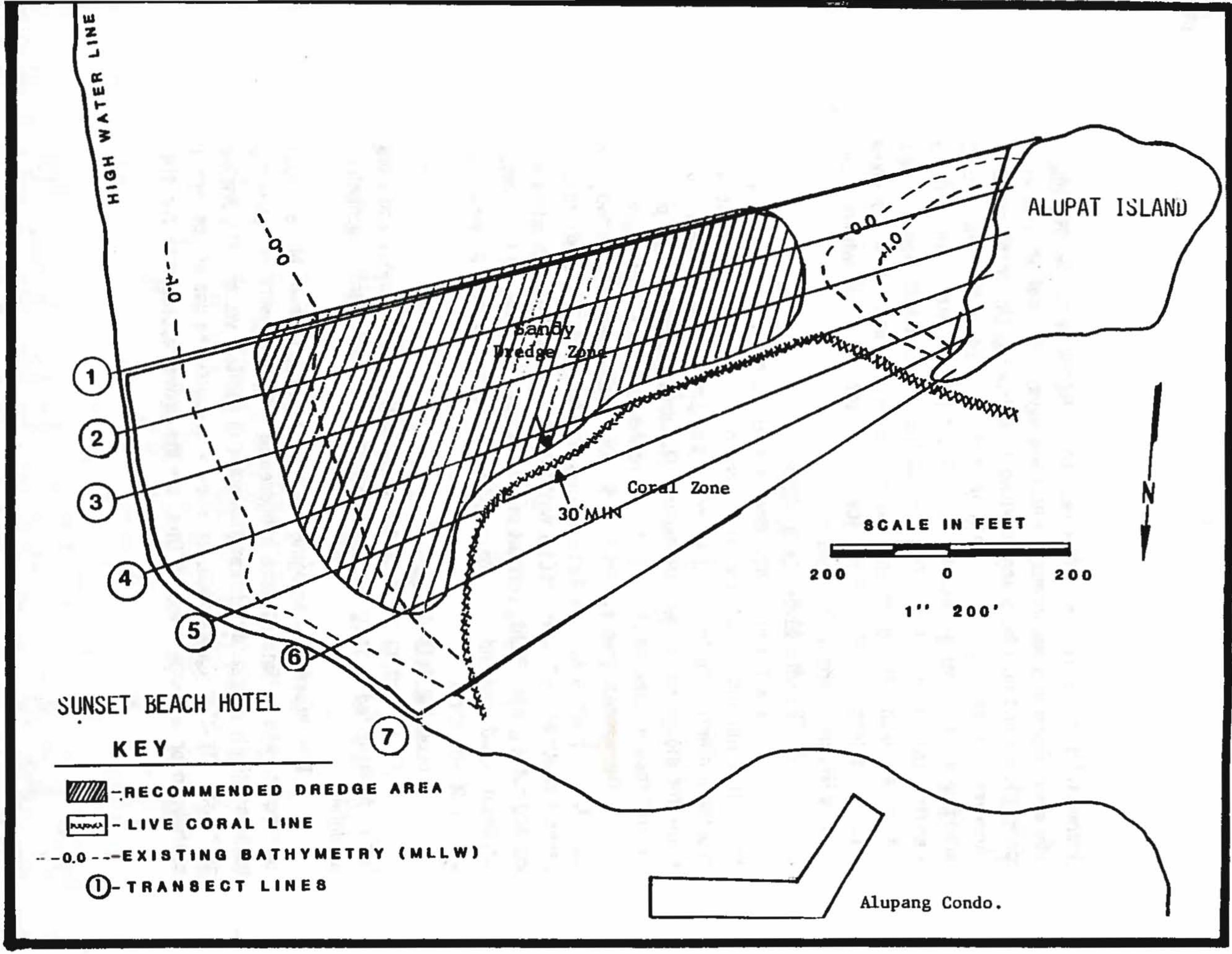

Figure 4. Recommended dredge area.

project, it would likely provide the best efficiency with the lowest environmental impact. Unfortunately, no technical data or work experience was available on the dredge to substantiate the contractor's claim.

The classic method for dredging shallow reef-flat areas is to use mechanical means, such as a backhoe, dragline or clamshell bucket. These methods were successfully utilized in the construction of swimming holes similar to this project at Tumon Bay. The method involves the removal of both unconsolidated material and hard reef pavement from land or from temporary construction causeways. The dredged spoil is then transported to dewatering areas on land. The suitable beach sand is sorted and stockpiled for beach nourishment and the remainder is trucked offsite to a suitable land disposal site. One or more temporary causeways will need to be constructed to allow for access to the outer edge of the dredge area. The causeways will be removed as the dredging operation proceeds shoreward. The number of causeways required will depend on the type and size of equipment the contractor uses.

Under either method, a detailed dredging plan will need to be developed by the successful contractor that will include a sound Environmental Protection Plan (EPP). A requirement of this plan should be the use of sediment screens such as silt curtains to control turbidity in Agana Bay. These screens should completely surround the work area and be constantly maintained throughout the duration of the dredging. Once the screens are set in place, work should proceed diligently and quickly so that the circulation loss caused by the screens will be temporary.

4. <u>Beach Nourishment</u>

Of the 45,000 cubic yards of dredge spoil, it is estimated that approximately 80%, or 36,000 cubic yards is "suitable beach sand." Suitable beach material is defined as sand sized sediments with grains sizes between 0.2 and 2 millimeters. Sand grains smaller than 0.2 would not be stable and sand grains larger than 2 millimeters are uncomfortable for bathers. For beach nourishment, only the sand grains coarser than 2 millimeters 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.

On the average, 17 yards of sand will be needed to nourish a foot of shoreline. Thus, approximately 20,000 cubic yards should be stockpiled to nourish the shoreline in front of the proposed Sunset View Hotel and 300' of adjacent shoreline.

In order to avoid need to obtain a Federal permit under Section 404 of the Clean Water Act, beach nourishment should be restricted to above the Mean High Water Line (MHWL). The sand should be placed at the maximum angle of stability up to the desired beach crest elevation as shown in Figure 5. For calcareous sand, the maximum angle of stability is approximately 30 degrees. Within a short time, the sand will slough thus allowing for further nourishment. As the sand slides farther down the beach face and into the water, it will be sorted by waves and currents. Grain sizes that are not stable will wash away. This process is called winnowing. Approximately 75% of the beach nourishment material is estimated as stable.

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

E. Investigative Methodology

1. Introduction

Only a few studies describing Agana Bay have been conducted over the years. Most of these are the result of environmental baseline studies performed by different individuals at the University of Guam Marine Laboratory and a few by the U.S. Government. Studies on Agana Bay

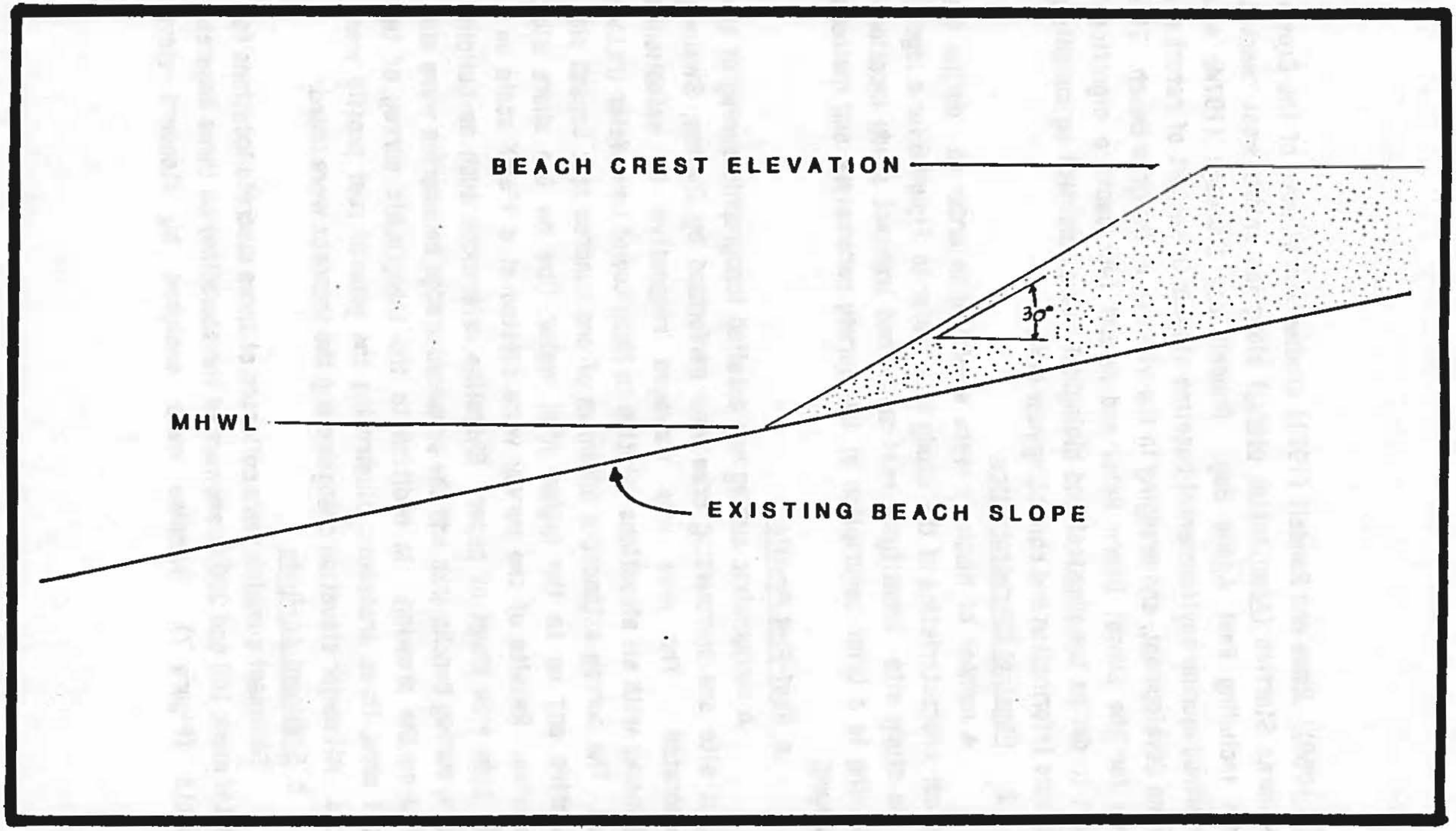

Figure 5. Recommended beach nourishment.

et al.1959). Jones and Randall (1971) studied the effects of the Crown-of-Thorns Starfish (Acanthaster planci) along the entire west coast of Guam including East Agana Bay. Randall and Eldredge (1974) also performed marine environmental baseline studies in support of resort and marine development, and dredging in the vicinity of Dungcas Beach. This study for the Sunset Beach Hotel and Resort represents a significant effort to define the physical and biological characteristics by compiling available information and collecting new data.

2. Physical Characteristics

A number of methods were employed in order to define the physical characteristics of the study site. Refer to Figure 6 for a layout of the study site identifying reef zones and transect study locations. Following is a brief description of the survey parameters and methods employed.

a. Reef-Flat Profile

A bathymetric survey and detailed topographic survey of the project site and surrounding area was performed by Duenas, Swavely Incorporated. The area was surveyed respective to established benchmarks with all elevations relative to Mean Lower Low Water (MLLW) datum. The survey extended a minimum of one hundred feet beyond side boundaries and up to the higher high water line on the shore side boundaries. Results of the survey were plotted at a 1"=50' scale on a single plan size sheet of paper. Shoreline references such as building corners, survey benchmarks and the proposed dredge boundaries were also located on the drawing. In addition to the topographic survey of the project area, three transects illustrating the general reef profile were plotted. All major elevation changes along the transect were noted.

b. Sediment Analysis

Sediment samples were collected at three discrete locations (at the MLLW mark 100 and 200 ft seaward of the shoreline) on three separate transects (Figure 7). Samples were analyzed by standard sieve

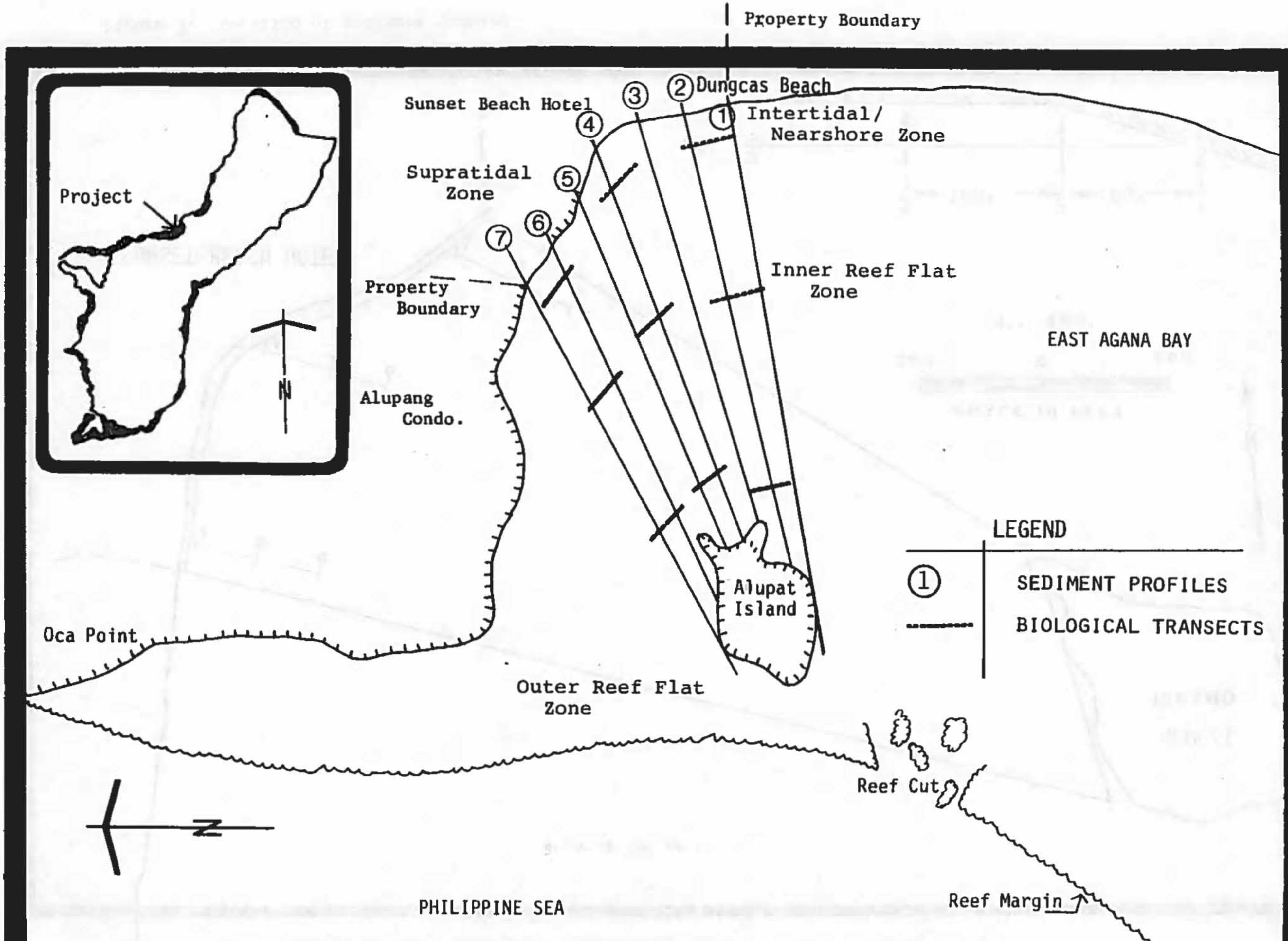

Figure 6. General map (insert) of Guam indicating project location and general vicinity.

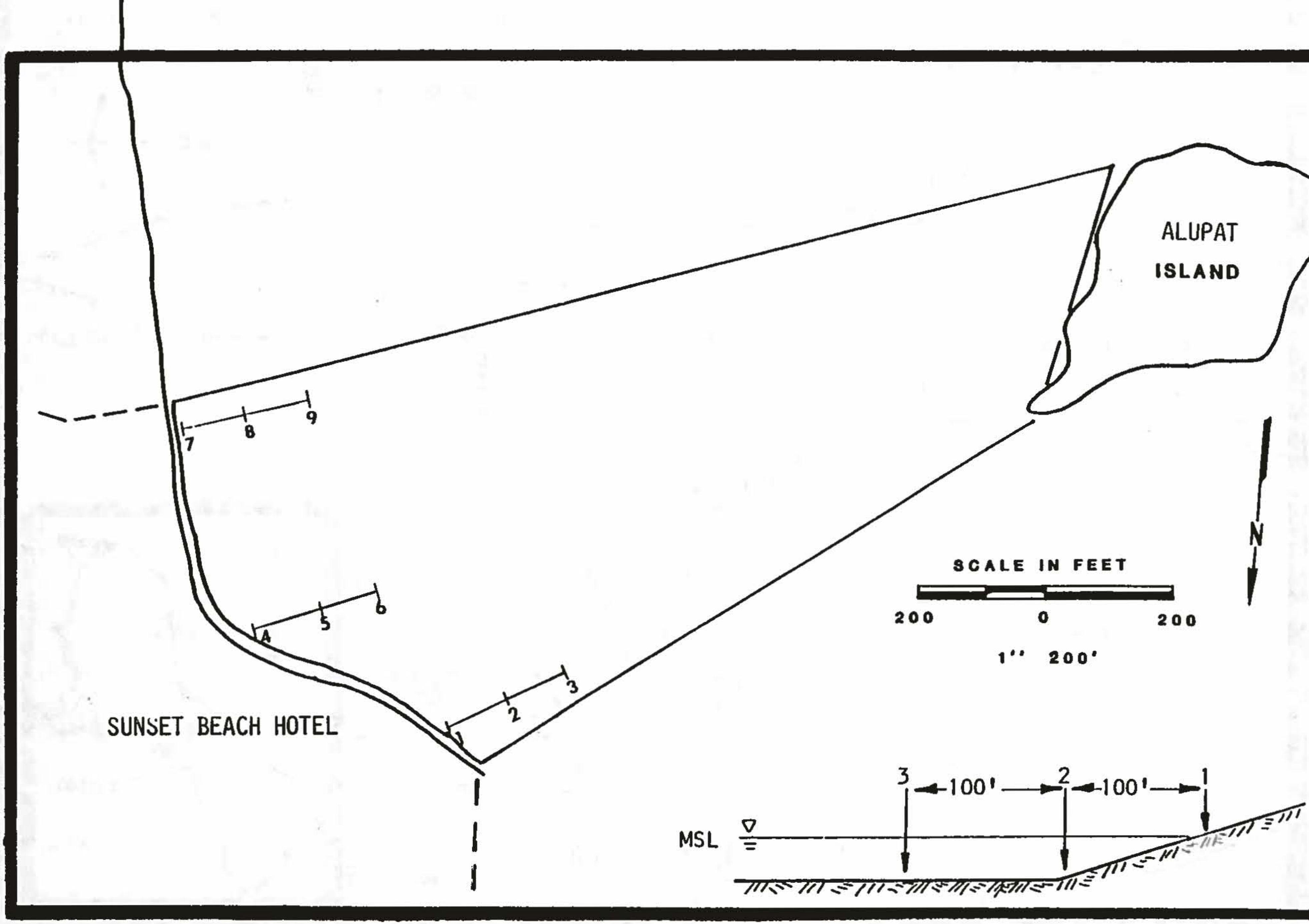

Figure 7. Location of sediment samples.

methodology for grain size and distribution by Geo Engineering and Testing Incorporated. In addition, a visual estimate of the sample's composition and origin was made.

c. Sediment Depth Probing

Depths of sediments within the project site and on the beach were determined by Jet Probing (low pressure water jet) by PBEC Inc. Penetration depth of the probe through unconsolidated sediments was recorded throughout the study area. Seven beach marks were used to locate transects on which probes would be made (Figure 8). Probes were done at the high tide or debris line, MLLW mark and then at approximately 100 ft increments out into the bay to Alupat Island. This combined for a total of approximately 14 probes on each transect. At least two probes were located on the beach and approximately twelve in the water for each transect. Samples were analyzed by Sea Engineering Inc.

d. Beach Profiles

Plotting profile of the beach was an intregal part of the overall mapping survey of the bay and was performed by the surveying crew from Duenas, Swavely Incorporated. Profiles were made using numerous points on the beach. Profiles started on firm, hard ground shoreward of the beach and extended seaward through the intertidal zone to a point where the change in bottom elevation was negligible. Survey readings were taken wherever there was a change in slope, bottom substrate or at approximately 50 ft intervals. Three of these profiles corresponded to sediment sampling transect lines.

e. Current Patterns and Water Circulation

Current velocity and direction were mapped throughout the reef-flat by PBEC Inc. Mapping was done for both ebb and flood tides during normal weather conditions. Fluorsciene dye was used in conjunction with a measured 10m line and handbearing compass. Direction (magnetic north) and time (seconds) of travel over a 10m distance were noted and later computed into velocity (meters per second, m/s).

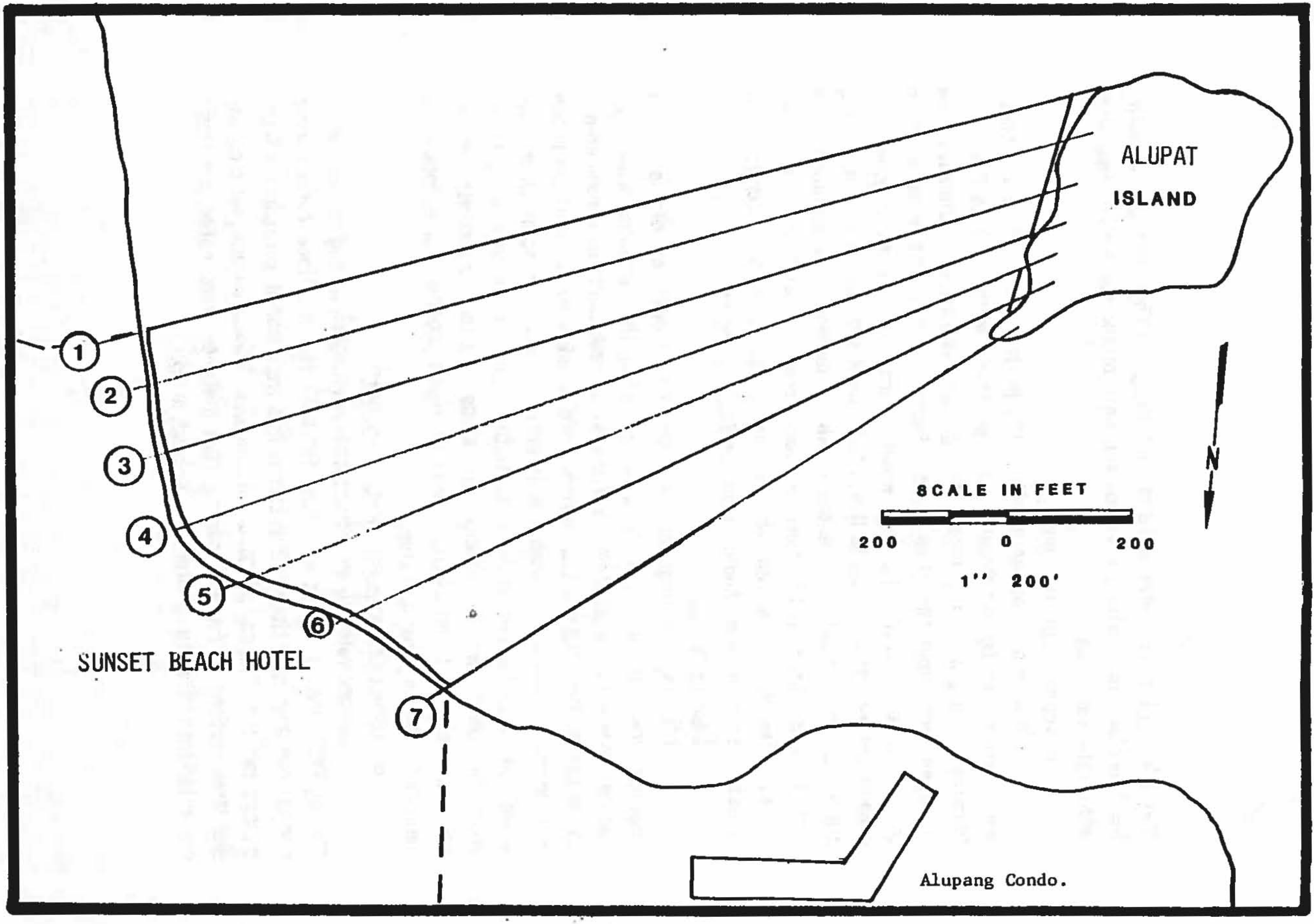

Figure 8. Location of sediment depth profiles.

3. <u>Biological Characteristics</u>

For the purpose of collecting biological data, the reef-flat was divided into three zones (Intertidal/Nearshore, Inner Reef-flat and Outer Reef-flat) (Figure 6). Biological data from the three zones on the reef-flat are discussed in this report in detail. The remaining three reef zones, Reef-Margin, Reef-Front and Submarine Terrace are only discussed in relation to the overall dynamics of the bay, such as water movement and sediment transport since they are outside the limits of the proposed dredging plan.

Seven (7) study transects were evaluated by PBEC Inc. in the vicinity of the project site in East Agana Bay (Figure 6). All study points including three (3) transects were situated north and south along each of these 7 major transect lines within the study area.

Data collected on these transects include percent of substrate type (sand, rubble, pavement, coral, algae and macroinvertebrates). In addition, these transects were used to run fish counts and obtain checklists of the different biological parameters in the general vicinity. Relative abundance was calculated for those biological parameters where numbers were sufficient. These included the corals, fishes and marine plants. Relative abundance categories with brief descriptions are as follows:

(A) Abundant	A species occurring frequently throughout the survey area
(C) Common	A species observed throughout most of the survey area
(O) Occasional	A species observed in more than one particular biosystem/habitat
(R) Rare	A species observed in only one biosystem/habitat

III. ENVIRONMENTAL SETTING WITHOUT THE PROJECT

A. General description of Guam and East Agana Bay

1. Location

Guam is the southernmost and largest of the Mariana Islands, occupying a land area (exclusive of coral reefs) of 212 square miles in the Western Pacific Ocean (Figure 1). It is 3,500 miles west of Hawaii at 13 28' 19" north latitude and 144° 44' 55" east longitude (Agana Monument). Guam is about 30 miles long and tapers in width from about 9 miles in the north to four miles at the central waist, widening again at the south to a maximum width of approximately 12 miles. East Agana Bay is located along the northwest coast of Guam and west of the village of Tamuning. The entire bay and associated reef-flat spans a distance of approximately 1.70 miles (2.74 km) between the Paseo de Susana and Oka Point.

2. Climate

Guam is characterized by a warm, equatorial climate with distinct "wet" and "dry" seasons (Naval Oceanography Command Center 1979). The wet season ranges from July to November with an average monthly rainfall of 11 inches. The dry season extends from December to June with an average of four inches of rain per month. At Apra Harbor, the average annual rainfall is 85 inches with a range between 55 and 120 inches. The average monthly temperature ranges from a low of 79°F to 82°F with the record high and low temperatures being 96°F and 65°F respectively. Humidity ranges between 75 percent, and 80 percent at mid-day, to a high of 85 percent to 90 percent near midnight.

3. Meteorological and Oceanographic Conditions

a. Wind

The prevailing winds on Guam are easterly trade winds, which approach from the northeast through east-southeast sectors. Tradewinds predominate 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 (July through December). Typical tradewind velocity is 7 to 16 knots with velocity in excess of 17 knots occurring less than 5 percent of the time. A wind rose for the island of Guam is shown on Figure 9.

Located on the western shore of Guam, the project site in East Agana Bay is sheltered from the prevailing winds by surrounding high bluffs and the island itself. Local wind conditions are dominated by nearshore land/sea breezes generated by diurnal heating and cooling of the land.

b. Storms

Guam is subject to strong winds and rain associated with tropical storms and typhoons. Due to its proximity to typhoon breeding grounds to the southeast, the island is threatened year round with the passage of developing typhoons and, on occasion, one or more of full strength. Typhoons are defined as storms with sustained wind velocity equal to or greater than 64 knots, while tropical storms are defined as having sustained wind velocity between 34 and 63 knots. Based on information from the Joint Typhoon Warning Center, U.S. Fleet Weather Central, Guam, an average of 19 typhoons occur annually across the western North Pacific and South China Sea. Several of these, in various stages of development, threaten the Mariana Islands each year. For the 28-year period, 1948-1975, 70 typhoons with at least tropical storm strength..."have developed and were tracked within 180 nautical miles off Guam. Twenty-six (26) of these storms (35 percent) were of typhoon strength at their closest point of approach to Guam" (Joint Typhoon Warning Center, 1987). Tropical storms and typhoons do not have to pass directly over the island to result in severe damage. The eye of the typhoon is usually 25 miles in diameter and wind speeds in the area can be anywhere from 75 to 175 mph or more (e.g., Karen: 207 mph, Pamela: 167 mph)... "50 miles away from the eye, speeds can still reach 70 mph" (Joint

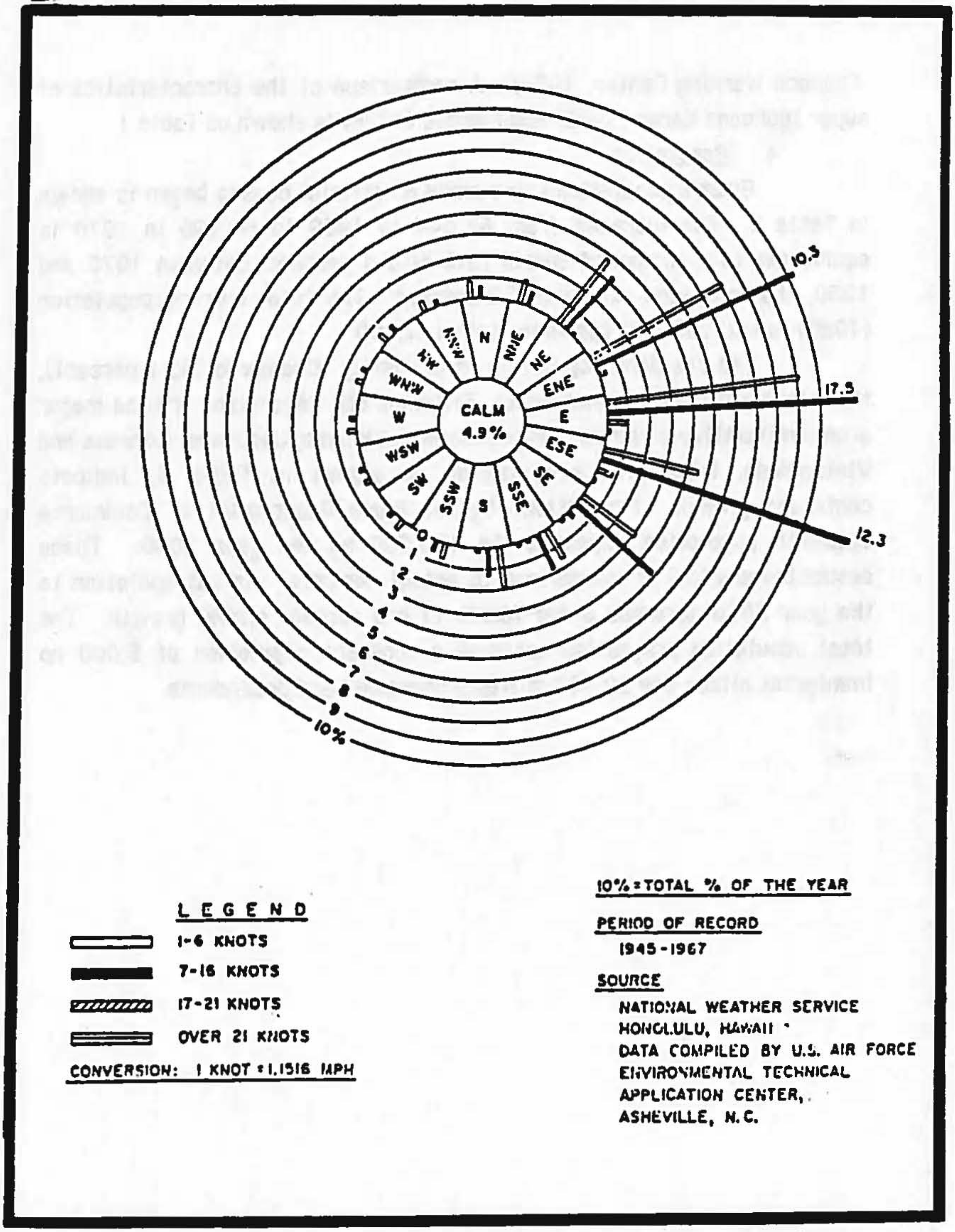

Figure 9. Wind rose depicting prevailing wind conditions in the vicinity of Tumon Bay, Guam

Typhoon Warning Center, 1987). A comparison of the characteristics of super typhoons Karen (1962) and Pamela (1976) is shown on Table 1.

4. Population

Guam's population trend since an official census began is shown in Table 2. The increase from 67,044 in 1960 to 84,996 in 1970 is equivalent to a compound annual rate of 2.4 percent. Between 1970 and 1980, the compound rate was 2.2 percent. The total current population (1988) is estimated at approximately 141,000.

The resident population is primarily Chamorro (62.1 percent), the island's historical inhabitants. Filipinos and Caucasians are the major ethnic minorities along with Micronesians, Chinese, Japanese, Koreans and Vietnamese. Population projections, as shown in Table 3, indicate continued growth. Projections by the Guam Department of Commerce estimate population expansion to 136,200 by the year 2000. These estimates are low in comparison to actual numbers. An extrapolation to the year 2030 assumes a one-fourth of one percent annual growth. The total population projection assumes a constant population of 5,000 no immigrant aliens and 20,000 military personnel and dependents.

Table 1. Characteristics of super-typhoons Karen and Pamela.

Characteristics	Karen Nov. 2, 1962	Pamela May 21, 1976
1. WIND SPEED		
A. Sustained Wind Speeds		
(1) Recorded	125 kts or 144 mph	100 kts or 115 mph
(2) Estimated	150 kts or 173 mph	120 kts or 138 mph
B. Peak Wind Gusts		
(1) Recorded	125 kts or 144 mph	138 kts or 159 mph
(2) Estimated	160-180 kts or 184-207 mph	145 kts or 167 mph
2. FORWARD MOVEMENT OF STORMS OVER GUAM	17 kts or 20 mph	7 kts or 8 mph
3. DURATION OF MAXIMUM WINDS	180 kts or 209 mph for 55 minutes	100 kts or 115 mph for 6 hours. 63 kts or 72 mph for 18 hr.
4. DIRECTION OF MAXIMUM WINDS	East and SE	Northeasterly
5. MINIMUM SEA-LEVEL PRESSURES		
(1) Recorded	931.9 MB	931.79 MB
(2) Estimated	912 MB	930 MB
6. PRESSURE DIFFERENTIALS	60-70 lbs/ft. sq. (in less than a minute)	60-70 lbs/ft. sq. (within minutes)
7. DIAMETER OF THE EYE	8 nm	20 nm
8. TIME TAKEN FOR EYE CENTER PASSAGE OVER THE ISLAND (LONGEST ESTIMATED PATH)	20 minutes (over Umatac)	3 hrs. 31 min. (over Nimitz Hill)
9. MAXIMUM RAINFALL	6.32 (10 in.) (at Taguac)	27 inches (at Taguac)

Table 2. Population of Guam from 1901 to Present.
Population Less Military and Military Dependents.

Year	Totals	
	High	Low
1901	9,676	9,300
1910	11,806	11,000
1920	13,275	12,500
1930	18,509	17,500
1940	22,290	21,250
1950	59,498	31,000
1960	67,044	43,700
1970	84,996	64,680
1980	105,979	86,205
1981	107,122	87,045
1982	108,406	89,546
1983	113,230	
1984	120,470	——
1985	124,837	——
1986	129,546	——
1987	134,624	——
1988 (projected)	140,081	——

Source: U.S. Dept. of Commerce Bureau of Census for 1901-1980. 1981-1988 data are from the 1986 Guam Annual Economic Review.

Table 3. Population projections for Guam.

Year	Total Population
1990	118,700
2000	136,200
2020	143,000
2030	147,000
2035	149,000

Source: Guam Department of Commerce

5. Development and Use of East Agana Bay

a. General Development and Use

East Agana Bay has remained basically unchanged until recently. Development in the general area is undergoing significant changes in terms of major construction. Besides the Sunset Beach Hotel and Resort Complex the new Palace Hotel will be constructed just north of the Alupang Condominium complex. In addition, two large condominium projects are well under way in the area. The Bay View Condominium just opened at Trinchera Beach and the Oka Point Condominium project is still under construction. Smaller apartment buildings and single family dwellings continue to spring up in the area.

Commercial development such as the Island Imports complex continues to grow, with tourism related expansion plans in the central portion of East Agana Bay. Mr. Henry Simpsons commercial development will be concentrating on the tourist industry now that he has sold off the auto sales portion of the business. Effort will now be concentrated in offering tourists water oriented rental equipment. Over the past few years the reef flat area adjacent to Island Imports has been used for jet ski, hovercraft and surf jet rentals. Island Imports also has a year to year lease to use Alupat Island and has spent some time and money developing trails and cleaning up the island.

Besides Island Imports, East Agana Bay has been used over the past two years by several jet ski operations which can be seen daily throughout the Bay. Operations for jet skiis exist from the Paseo to Trinchera Beach. A shallow sand delta near the northern end of East Agana Bay and very shallow conditions in the extreme north end prevent jet skiis from accessing this sector of East Agana Bay. However, jet skiis and hovercraft do land on the sandy beach at Alupat Island on occasion.

b. Historical and Cultural Use

Historically the area was fortified by the Japanese as it was thought to be one of several potential invasion beaches. Two large guns exist on the site for the Sunset Beach Hotel. These guns were built into limestone cave bunkers reinforced with concrete and connected by a maze of narrow tunnels typical of Japanese fortifications throughout the Marianas. These two guns are being removed and will be restored. Upon completion of the Hotel and Resort complex the guns will be placed in a suitable location for viewing.

Culturally, the entire East Agana Bay lagoon is known to have been used for subsistence fishing and is still used in this way today. Seasonal catches of juvenile rabbitfish (manahac) and goat fish (tiao) occur in the nearshore areas throughout the bay. Throw net (talaya) fishermen can be seen walking the beach in search for schools of small fish. However, the high degree of jet ski use in the bay discourages fishing. It is likely that East Agana Bay was used as an early Chamorro settlement or at least a fishing site.

c. Tourism

Tumon Bay has always been the center of tourism development on Guam and all the major hotels are located along, or in close proximity to this bay. The sand beaches, warm water and coral reefs along Tumon

Bay provide visitors with the aquatic and beach experiences they expect on a tropical island.

There are a total of 2,800 hotel rooms directly along or adjacent to Tumon Bay. Just recently, two new hotels were approved for construction by the Territorial Planning Commission (TPC). The Hotel Nikko Guam (500 rooms) and Southern Cliff Hotel (382 rooms) will both be built on Tumon Bay, and will increase Guam's total hotel rooms by 24 percent to 3,472 rooms by 1990. In addition to these, are new hotels for the East Agana Bay area. The Palace Hotel will break ground shortly just north of the Oka Point Condominiums and the Sunset Beach Hotel will soon begin construction at Dungcas Beach.

Visitor arrivals on Guam have steadily increased over the past two decades. Between 1978 and 1986 arrivals increased every year from 238,848 to 407,070 respectively, for an average annual increase of almost 8 percent. Projections for 1987 indicate an increase of 18 percent over 1986 as total visitor arrivals could reach 480,000. Visitor arrivals are expected to increase to approximately one million by the year 1993 (GVB, 1988).

Tourism is Guam's primary industry. Hotel occupancy taxes totalled $4,533,912 for 1986 and are projected at $5.2 million for 1987 (GVB, 1987).

6. Infrastructure

Unlike Tumon Bay, infrastructure in the vicinity of the project site (Dungcas Beach) has not improved dramatically in recent years. Camp Watkins Road is a primary road which brings traffic off Marine Drive into the vicinity of the project site. It is bisected just a short distance northwest of the site by Farenholt Drive which is the access road to the Alupang Condominiums. Camp Watkins Road continues west into Jonestown and eventually to the Guam Memorial Hospital. Farenholt Drive, connects Camp Watkins Road to Hospital Road.

Sewering of the area has been a problem over the years with Dungcas Beach receiving the brunt of pollution from eroding sewer pipes and overflowing manholes nearshore. It is well known that the sewer system in the general area is not sufficient to handle existing needs and cannot be expected to handle loads from major new construction. To meet the sewer and water needs of the construction in the area, a consortium of developers from the Palace Hotel, Sunset Beach Hotel and Oka Point Condominiums have taken the responsibility and upgrade existing facilities so their projects will have adequate sewering and so that residents in the area are not adversely affected by increasing need for these services.

?? Sewer lines along Dungcas Beach will be removed and relocated along Camp Watkins Road and tied into the new sewer line. This line will connect to the Tumon Bay system which is to be reversed and pumped to the Northern District Sewer System easing the load to the Agana Sewer System plant in West Agana Bay.

B. Physical Characteristics of East Agana Bay and Project Site

1. <u>Geology</u>

This coastline is bordered by several members and facies of the Mariana Limestone formation, beach deposits, alluvium and man-made filled land. Marianas limestone borders small sections of the coast with detrital facies (QTmd) found from Oka Point to Dungcas Beach with the coastal cliff being capped with reef faces (QTmr). Alupat Island is composed of detrital faces. The entire shoreline at Dungcas Beach to Trinchera Beach is bordered by low terraces of unconsolidated beach deposits (Qrb). Refer to Figure 10 for identification of geologic conditions.

2. <u>Soils</u>

Guam clay (Unit 1) exists on the low-lying limestone terrace and along the high plateau land bordering East Agana Bay (Tracey <u>et. al.</u>,

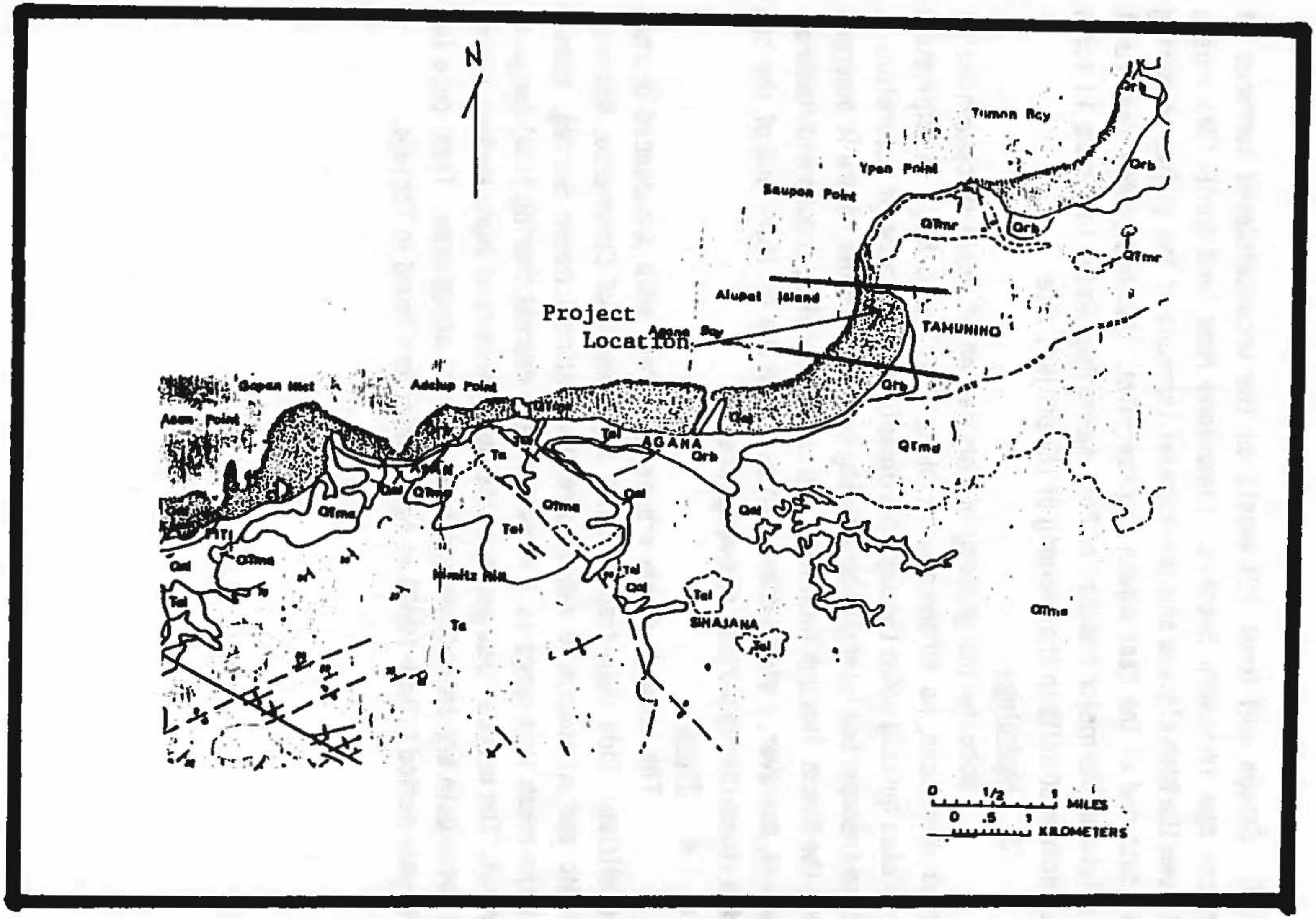

Figure 10. Geologic map of project site. Map modified from Tracey et al. (1964).

1959). Shioya soil (Unit 12) exists on the unconsolidated terraces at Dungcas and Trinchera Beaches. Limestone rock land (Unit 13f) exists between the high plateau and low coastal terraces of the slopes bordering the south end of the East Agana Bay reef-flat. Unconsolidated sand (Unit 1) exists on the major beaches of East Agana Bay. Refer to Figure 11 for a description of soils in the vicinity of the project site.

3. Hydrology

Because the geology of this region of Guam is comprised of porous limestone, no streams exist along East Agana Bay. Precipitation percolates quickly down through the limestone to the zone of saturation. It is then transported laterally by gravity to the shoreline where it emerges along the beach through intertidal and subtidal holes, cracks and fissures. There is, however, a storm drain that exists in the northern end of the bay which flows during periods of heavy rains.

4. Tides

The tides in Guam are semi-diurnal with pronounced diurnal inequalities. Tide data from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, shows that the mean tide range is 1.7 feet and the diurnal (spring tide) range is 2.4 feet. The nearest tide gauge to the study area is at Apra Harbor, Guam, and these data are considered applicable to the study area. Tidal data for a 19-year period (1949-1967) at Apra Harbor are found in Table 4.

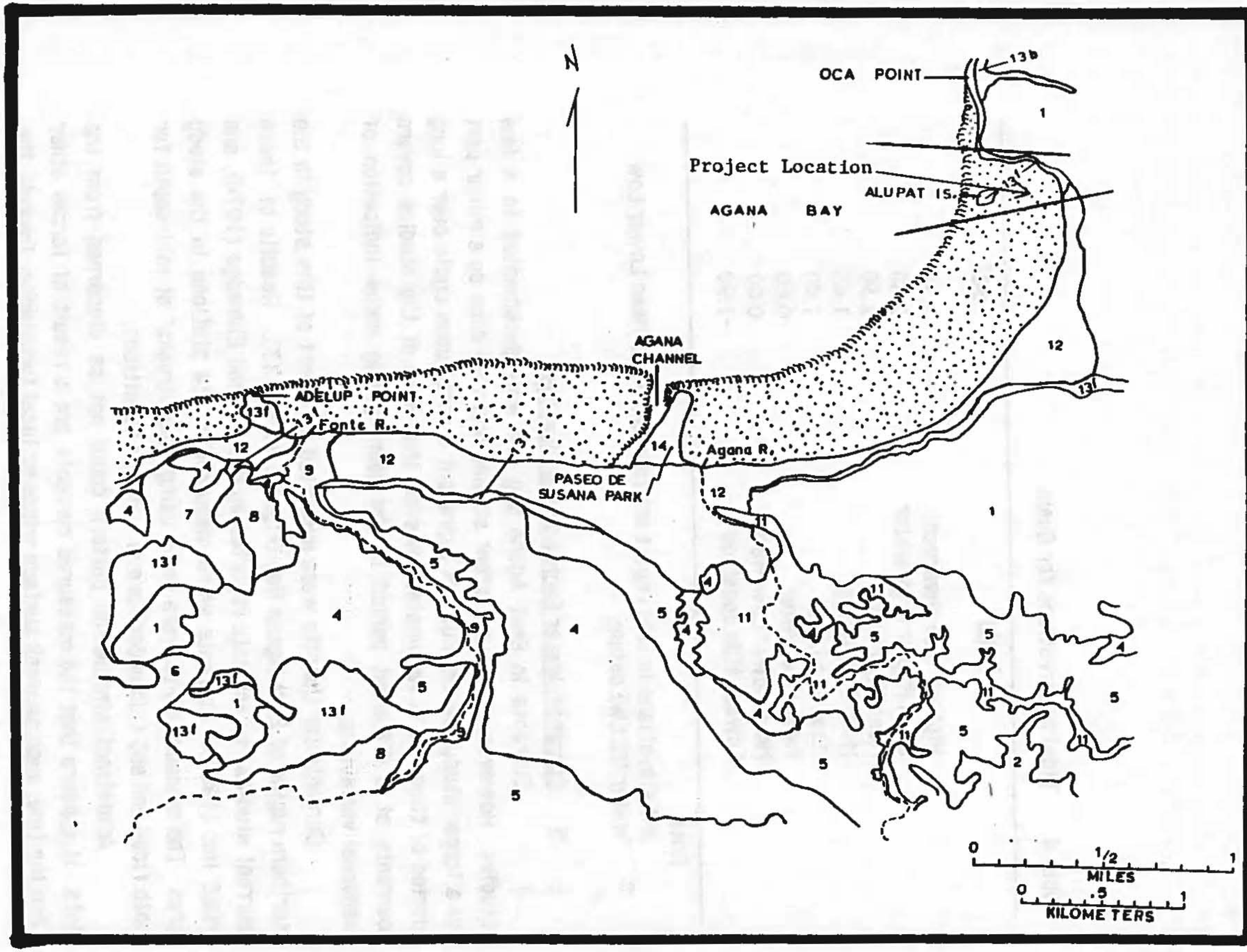

Figure 11. Soils map of the project site. Map modified from Randall and Holloman (1974).

Table 4. Tidal observations for Guam.

Tide	Feet
Highest tide observed	3.30
Mean Higher High Water	2.40
Mean High Water	2.30
Mean Tide Level	1.45
Mean Sea Level	1.40
Mean Low Water	0.60
Mean Lower Low Water	0.00
Lowest tide observed	-1.90

Note:
All elevations in this report are referenced to Mean Lower Low Water (MLLW) datum.

5. Currents, Water Exchange and Flushing

Currents in East Agana Bay are well documented in a few studies. However, previous current studies were all done as a minor part of a larger study and data do not represent a continuous cycle over a long period of time. It is fortunate, however, that each of the studies covers currents at a different period in the year, giving some indication of seasonal variations.

Currents for the site were evaluated as a part of this study in the northern region of East Agana Bay (Figures 12 and 13). Results of these current studies reflect data reported by Randall and Eldredge (1974), and PBEC Inc. (1987). Currents were measured at 24 stations in the study area. The measurements were made using "dye streaks" at mid-depth for both flood and ebb tide under normal weather conditions.

A distinct circulation pattern could not be discerned from the data. It appears that the measured currents are a result of forces other than the tide, such as weak surface winds or local turbulence. Overall, the

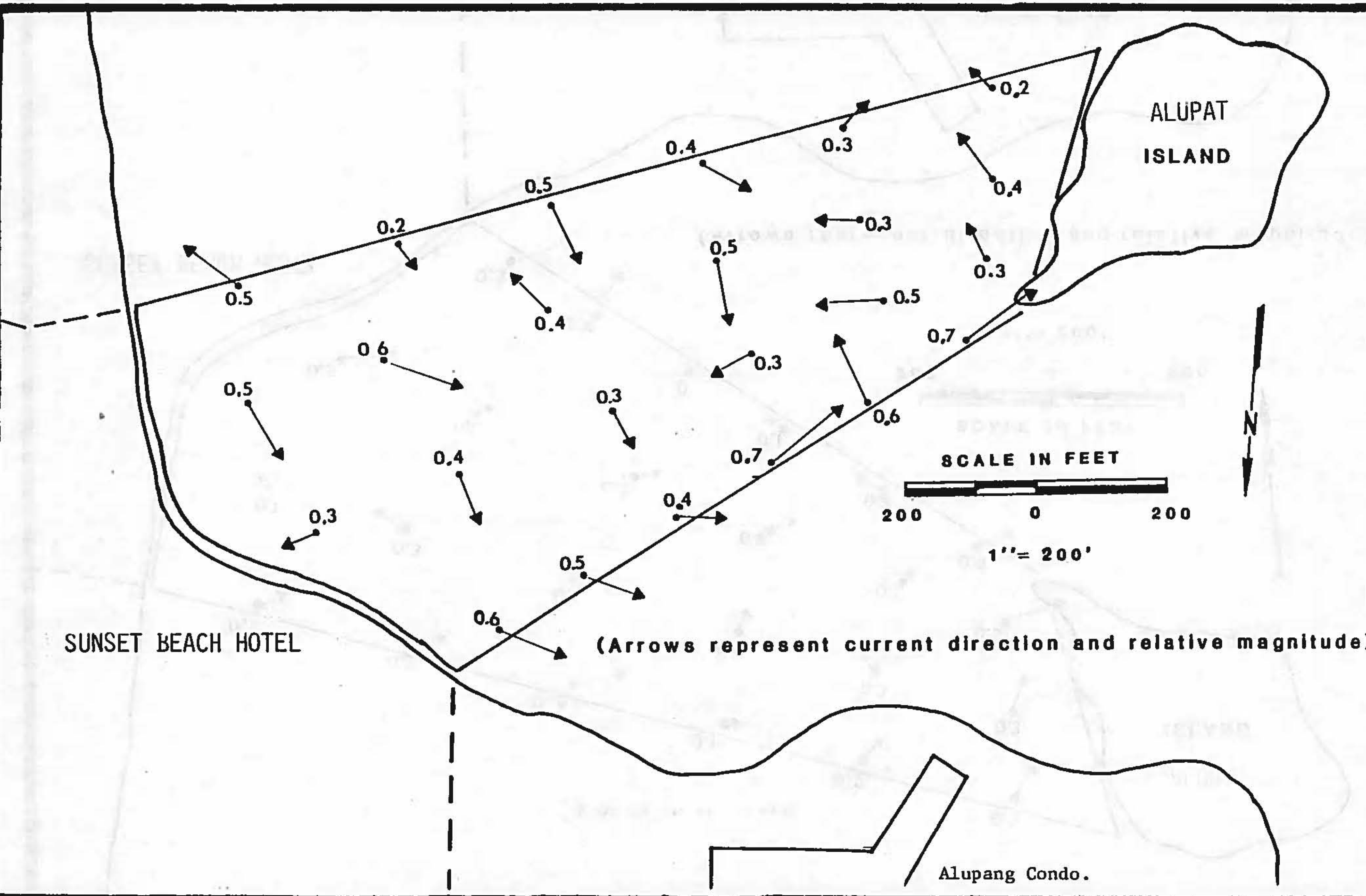

Figure 12. Currents for a flooding tide under normal weather conditions. (Current velocity in ft/sec)

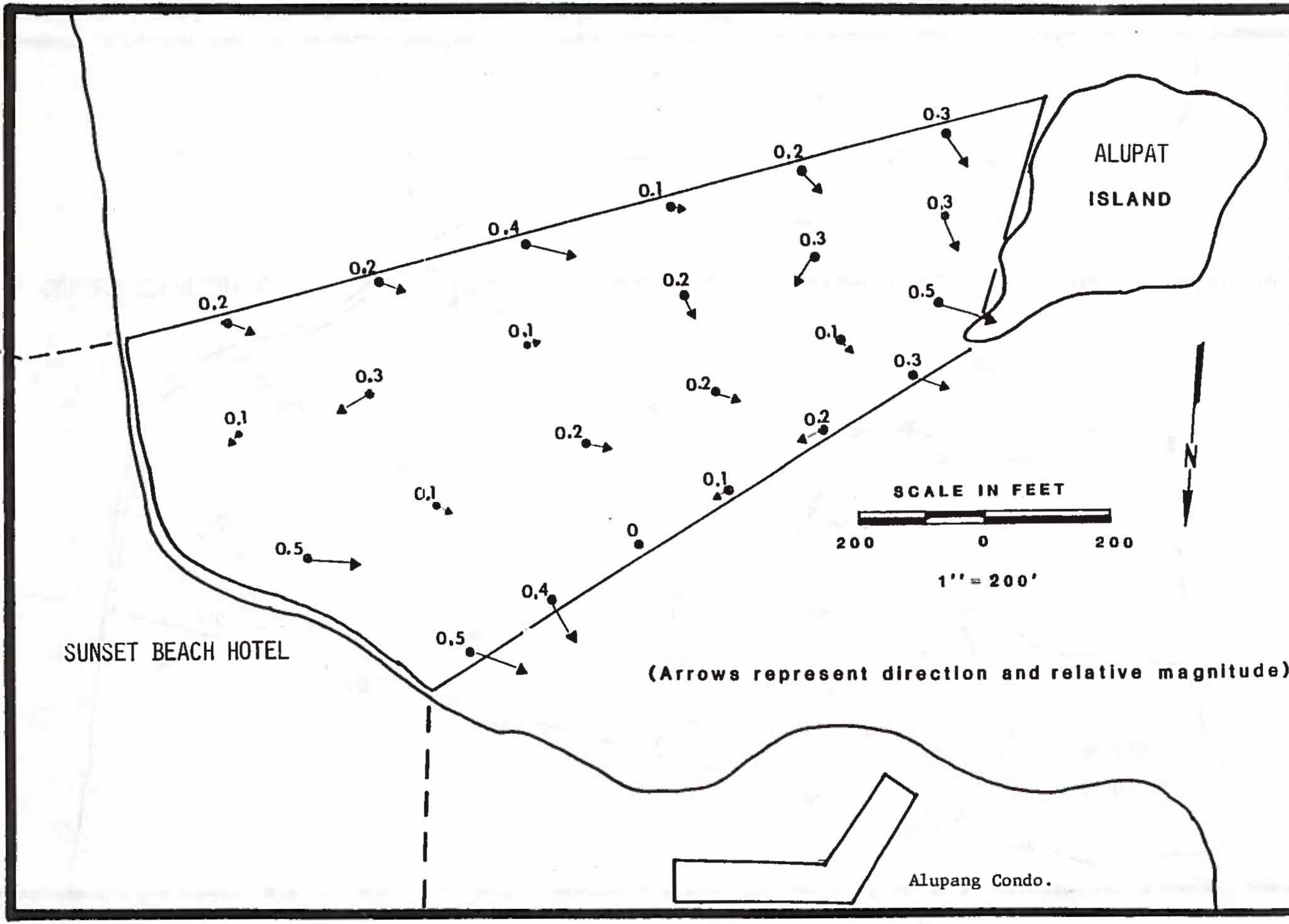

Figure 13. Currents for an ebbing tide under normal weather conditions. (Current velocity in ft/sec).

velocities are weak, and are not expected to cause significant sediment transport. Water circulation and exchange is expected to be poor.

Past researchers have attributed the poor circulation and complicated velocity pattern at this end of East Agana Bay to the remains of a causeway which was constructed in 1965. The causeway appears to inhibit flow and circulation by isolating the area from the current pattern that is occurring in the remainder of Agana Bay.

The causeway was constructed using a backhoe which dredged material from each side, creating two channels which are considerably deeper than the surrounding reef platform on both sides of the causeway. The causeway provided access to Alupat Island. The top of the causeway is still slightly exposed during extreme low tides (-0.5 MLLW) which indicates that storm currents and waves have not been severe enough in the past 23 years to completely erode the causeway.

The proposed nearshore dredging will remove the causeway, which should increase water circulation in the area. It is impossible to predict the future current pattern after removal of the causeway, except to state that local velocities should increase but will not exceed velocities in other parts of Agana Bay. Current velocity in the central portion of East Agana Bay is two or three times greater than the northern regions. An increase in water circulation will improve water quality, and is not expected to cause a significant increase in sediment transport during normal weather conditions.

The above discussion assumes that mixing will occur uniformly over depth. In Tumon Bay, a strong density stratification was observed to occur in existing swimming holes. Tumon Bay is the bay immediately north of Agana, in which several nearshore swimming holes similar in design to this project have been constructed. The density stratification was isolated to the swimming holes and has only been apparent during extreme low tides. Density stratification greatly inhibits vertical mixing, and thus could reduce water exchange with the passing flood tide. Stratification is typically caused by an inflow of fresh water, strong solar radiation or an inflow of water of a significantly different temperature. Since all of these conditions were possible at Tumon Bay, the cause of the density stratification located there is unknown.

It is impossible to predict whether stratification will occur with the nearshore dredging of Agana Bay. For density stratification to be created and remain stable, relatively calm conditions are needed. If the local current velocities are increased sufficiently by removal of the causeway, then stratification will not occur even if other conditions are conducive for stratification. However if the local current velocities remain the same, or are only slightly increased, then stratification could occur, especially during low tide. Density stratification in calm water pools tends to create a poor environment for aquatic flora and fauna. Pioneer species do not have a chance to settle in, leaving the area for invasion of underwater species, these which thrive in poor environment conditions.

6. Waves

a. Deepwater Waves

The prevailing wave climate in the study area can be divided into two distinct wave types: (1) waves generated by the prevailing local winds and (2) sea and swell waves from local and distant storms and/or typhoons.

The Summary of Synoptic Meteorological Observations (SSMO) prepared by the National Climatic Center contains deepwater ocean wave statistics. These data were obtained through direct synoptic observations by shipboard personnel in the Guam area over an 8-year period (1963-1970) and represent average conditions during the period of record. These data primarily represent waves generated by local wind conditions when the wind is less than 35 knots. It does not adequately represent the extreme storm wave condition. The SSMO data are summarized by height and direction, and by height versus period. Refer to Tables 5 and 6 and Figures 14 and 15. These data suggest that the Guam wave climate is dominated by short period, tradewind-generated waves from the northeast clockwise to the southeast, with wave heights of seven feet or less 84 percent of the time.

The project area is sheltered from tradewind-generated waves and is primarily effected by waves from the southwest clockwise to the north. Local wind wave heights exceeding four feet occur from these directions about six percent of the time. Longer period waves influencing the Guam wave climate are generated by storm centers 500 to 1,000 miles or more away, as well as by those storms or typhoons approaching Guam. Hindcasts by Noda for typical storms and typhoons in the Western Pacific for the four year period, 1975-1979, indicate that large, long period waves may approach Guam from the west, clockwise to the north, much more frequently than indicated by SSMO data. Wave heights of eight feet or greater approach from this sector approximately 11 percent of the time in an average year. Results of hindcasts are summarized in Table 7 and Figure 15.

The importance of distant storm waves impacting the study area is also shown by a recent analysis of the wave climate at the mouth of Apra Harbor, located on the west coast of Guam, approximately 10 miles south of the project site. Analytical models developed for tropical storms and typhoons in the Western North Pacific since 1961 calculated the characteristics of waves within the generating area, then propagated these waves to Apra Harbor. Analysis indicated that waves reaching Apra Harbor from storms in the Western North Pacific exceed five feet in height (in 100 feet of water), approximately 15 percent of the time. A wave period of about 12 to 16 seconds is considered characteristic of this deepwater swell.

Table 5. 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 6. Annual percent frequency of deepwater wave height versus wave period.

HEIGHT (ft)	Period (seconds) 6	6-7	8-9	10-11	12-13	13	INDET	TOTAL PCT
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

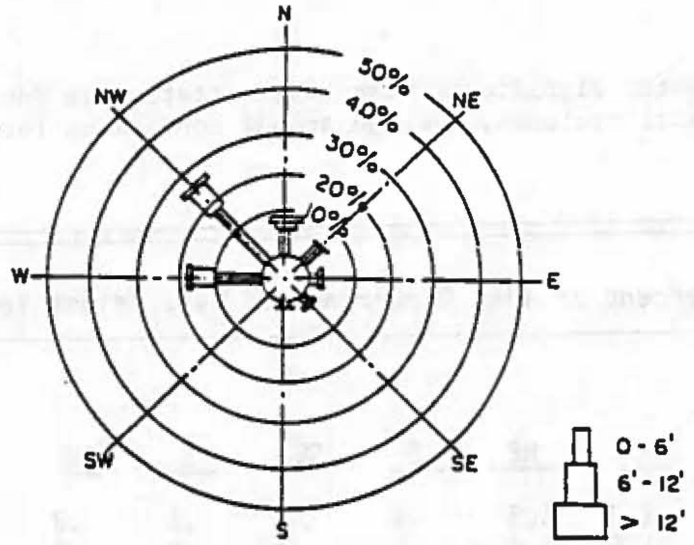

Figure 14. Annual percent frequency of deepwater wave height by direction.

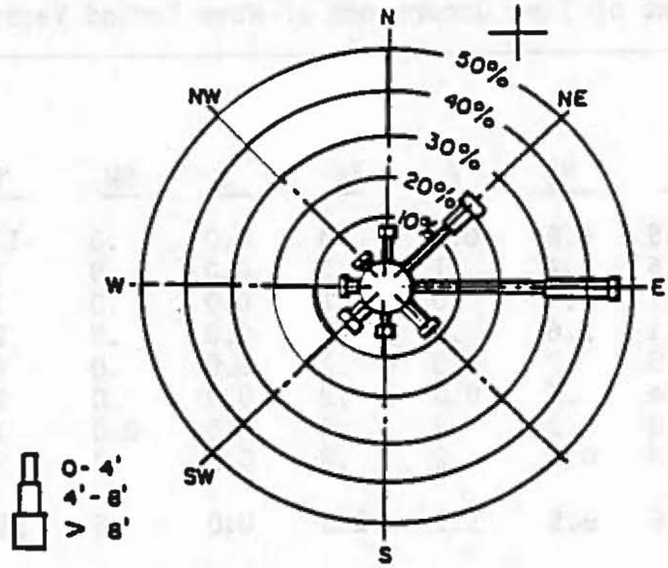

Figure 15. Average yearly percent frequency of deepwater wave heights due to tropical cyclones by direction for period 1975-1979.

Table 7. 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)	N	NE	E	SE	S	SW	W	NW	TOTAL
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)	N	NE	E	SE	S	SW	W	NW	TOTAL
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	

b. Waves Inside East Agana Bay

The shoreline of East Agana Bay is protected from large waves by the wide and shallow reef margin which lines the bay. The project site is further protected by Alupat Island, the small land mass immediately seaward of the proposed dredge area. The edge of the reef margin is extremely shallow, most of which is exposed at MLLW. A survey of the reef margin shows that elevations vary from +0.4 ft MLLW to -2.0ft MLLW, with an average elevation of -0.7 ft MLLW. The reef margin deepens slightly south of Alupat Island, where a small, naturally formed channel exists. The channel has an average depth of -1.0 feet at MLLW and is less than 100 feet wide with scattered coral mounds throughout.

All deeper waves of significant height break on the leading edge of the reef, dissipating the majority of energy away from the shoreline. Smaller waves of shorter periods can be expected to reform, and depending on their height and location of reformation, may travel and break on shore.

The breaking wave heights along the shoreline of East Agana Bay are a function of the deepwater wave climate, nearshore bathymetry, still-water rise, wave set down and bottom friction. Because of the complicated oceanographic processes that occur in this bay, no suitable method is available to accurately predict breaking wave heights at the shoreline. Based on observations of local residents, wave heights at the shoreline are estimated to be zero to six inches for normal conditions, one to two feet under the attack of a large swell from a distant storm and several feet in event of a typhoon. Our experience agrees with these estimates.

A computer model was developed to help determine wave heights at the shore given the bottom profile and deepwater wave climate. The model determines first order wave height estimates only, in that it ignores the important effects of refraction and diffraction, which could be significant on a reef-flat. Excusing these issues, the model was particularly useful in estimating the change in wave height and wave energy that will result by dredging the nearshore bottom.

On Table 8, the expected wave heights at the shoreline were estimated for three extreme wave conditions: Case 1 represents a distant storm which causes large 15 foot, 12 second period swells from the north west, directly impinging the project area; Case 2 represents a typhoon event in which large 25 foot, 10.7 second period waves are accompanied by strong onshore winds, and large water level rise; and Case 3 represents a calm deepwater wave climate with strong, steady, onshore 15 m.p.h. winds that cause waves to be generated on the reef-flat. Each of these wave conditions were investigated for two bottom profiles: Profile 1 is the existing bottom on a transect taken from a position near the center of the site onshore, to a position 2000 feet offshore in deepwater on the north side of Alupat Island; and is Profile 1 after the proposed dredging (the "with project" condition).

The model predicted that under the influence of strong onshore wind or a typhoon, slight increases in wave height, wave energy and wave runup will occur at the shoreline, as a result of dredging the nearshore area. Thus slight increases in beach erosion could occur during these conditions. The increase is small enough that beach nourishment should mitigate the erosion loss. Of concern, however, is that under the influence of a large swell from a distant storm the model predicts large percentage increases in the wave height and wave energy at the shoreline under the "with project" condition. This could significantly increase shoreline erosion during periods of a large deepwater swell wave attack.

The increase in wave height and energy at the shoreline is primarily due to the reduction of bottom friction, which will result from deepening the nearshore zone. The reduction of bottom friction is most pronounced during the distant storm case because of the relative size of the waves and depth of water. Strong onshore wind will generate relatively small waves, and a typhoon will generate large waves but

Table 8. Estimated wave heights and wave energy at the shoreline.

		Profile No: 1 (Existing Condition)	Profile No: 2 (After Dredging)	Percent Increase
Case 1 - Distant Storm	H	0.8 ft.	1.2 ft.	+50%
	E	5.1 lb/ft.	11.5 lb/ft.	+125%
	S	4.2 ft.	4.2 ft.	0%
	R	4.6 ft.	4.6 ft.	0%
Case 2 - Hurricane	H	3.6 ft.	3.8 ft.	+6%
	E	104 lb/ft.	116 lb/ft.	+11%
	S	7.8 ft.	8.1 ft.	+3%
	R	8.9 ft.	9.2 ft.	+3%
Case 3 - Onshore Winds	H	0.161 ft.	0.163 ft.	+1%
	E	0.207 lb/ft.	0.213 lb/ft.	+3%
	S	0	0	-
	R	0	0	-

H = Wave Height at the Shoreline

E = Specific Energy per unit area at the Shoreline

S = Still Water Elevation at the Shoreline

R = Wave Runup Elevation on the Beach

accompanied by a large water level rise. It is the mid-size waves, such as the sizes typically generated by a swell from a distant storm which will be most altered by the project. Distant storm waves from the northwest of deepwater wave heights greater than 5 feet, occur approximately 15 percent of the time.

Under typical prevailing conditions, wave heights in the project area have been observed to be extremely small. Prevailing deepwater waves break on the reef edge and are fully dissipated by bottom friction before they reach the proposed dredge area: Therefore, the project should not alter the existing typical prevailing nearshore wave climate.

7. <u>Water Quality</u>

Water quality in the area is variable and generally poor. Stormwater runoff from the drain directly behind Island Imports, a small stormwater drain at Dungcas Beach and the NAS storm drain, all contribute to greater than normal levels of pollution. The Guam Environmental Protection Agency (GEPA) frequently issues reports that East Agana Bay is polluted and considered unsafe for swimming and fishing.

The GEPA regularly collects water samples from two sites in the vicinity of the proposed project (Figure 16). These two marine monitoring stations are identified as AGMT (closest to Island Imports) and AGMD. Water quality data were analyzed over a 16-month period (January 1986-October 1987) for two parameters, bacteriological contamination (fecal coliforms) and turbidity. Bacteriological contamination is evaluated in terms of fecal coliform (FC) bacteria, which is an indicator of the presence of organic materials. This is usually the result of warm-blooded animal and human waste. Turbidity is the measure of suspended matter in the water calculated in Nephlometric 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.

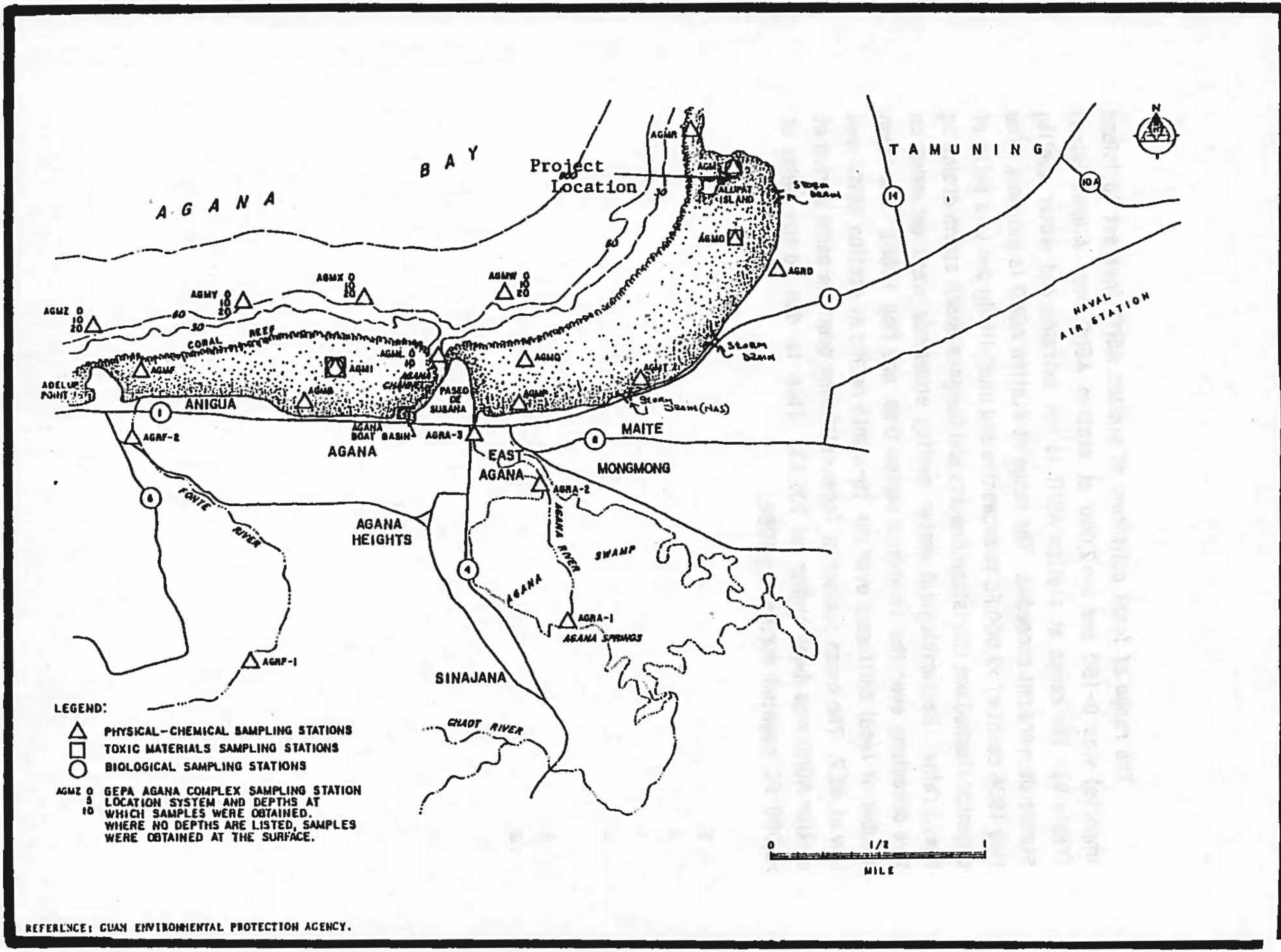

Figure 16. GEPA and PBEC Inc. water quality data monitoring stations in proximity to

The range of fecal coliforms at station AGMT (nearest to Island Imports) was 0-180 and 0->2,000 at station AGMD near Alupat Island (Table 9). The range at station AGMT is not extreme and water quality standards were not exceeded The range at station AGMD is extreme. The May 1986 count of >2,000 FC is excessive and most likely due to a pulse of organics flushed out the Island Imports and Dungcas Beach storm drains by heavy rains. Bacteriological water quality standards were exceeded on two occasions over the 16-month period (Feb. and May 1986). The mean number of fecal coliforms over the 16-month period at station AGMT was low at 43.7. The mean number of fecal coliforms over the same period at station AGMD was much higher at 205.13. This is due to the pulse of >2,000 FC counted during May 1986.

Table 9. GEPA water quality data for East Agana Bay. Bacteriological (Fecal Coliform) and Trubidity Water Quality Data from the Agana Bay reef flat. Sixteen (16) months beginning January 1986 to October 1987.

DATE	STATION AGMT (NAS Storm Drain)		AGMD	
	BACTI. (#)	TURB. (NTU)	BACTI (#)	TURB. (NTU)
1986				
Jan	32	2.30	24	2.40
Feb	134	1.05	840*	26.00*
Mar	0	0.76	96	0.89
Apr	4	0.86	8	3.50
May	28	1.40	>2,000*	1.40
June	2	1.20	42	1.40
July	--	7.90*	--	7.75*
Aug	42	0.52	230	2.30
Sept	2	1.80	2	2.30
Oct	180	3.20	20	1.70
Nov	28	2.60	12	1.70
1987				
Feb	50	1.30	4	2.50
May	0	0.93	4	2.50
Jun	0	0.54	0	1.80
Aug	4	3.70	0	4.70*
Oct	150	5.10*	0	22.00*
Range	0-180	0.54-7.90	0->2,000	0.89-26.0
Mean	43.0	2.20	205.13	5.33

Notes

*Exceeds Water Quality Standards

1988 data were not available because of a GEPA computer access problem.

Turbidity exceeded water quality standards on two occasions at station AGMT (July 1986 and October 1987). Both of these are most likely associated with heavy rains or large waves inside the bay. Water quality standards were exceeded on four occasions at station AGMD (Feb. and July 1986; August and October 1987). Those numbers exceeding the standards at station AGMD were not exceptionally high (7.90 and 5.10 NTU). However, two numbers exceeding water quality standards at station AGMT were exceptionally high (26.0 and 22.0 NTU on February 1986 and October 1987, respectively). The October 1987 value was obviously due to heavy rains and waves associated with tropical storms and typhoons.

An added problem, which occurs frequently at the Island Imports storm drain, is backing up (plugging) of the pipes by sediments and sand. This creates buried layers of decaying organic material in the pipes and along the shoreline. When a heavy rainfall flushes out the pipes, the result is foul-smelling discharge into the near-shore zone. This makes the beach and shallow near-shore areas unattractive and odorous, a condition which can last several days. Mr. Henry Simpson, owner of Island Imports, is attempting to remedy this situation by applying for a dredging permit. This will allow sediments to settle in a holding basin while fine particles will flow out into the ocean through a channel.

B. Sediment Characteristics

a. <u>Sand Size Analysis</u>

Sediment samples were taken from the reef-flat surface at nine locations in Agana Bay. The locations of the nine samples are shown in Figure 7. All samples were unconsolidated sand and gravel with the exception of sample number three, which consisted of solid reef rock. A sieve analysis was performed on each of the eight unconsolidated samples to determine grain size distribution. Results of the seive analyses are summarized in Table 10.

Table 10. Sieve analysis summary of sediment samples.

Sample No.	Median Grain Size (mm)	(ϕ)	Description	Std. Dev. (σ_ϕ)	Sorting
1	3.67	-1.88	gravel/sand	-3.52	extremely poorly sorted
2	0.57	0.81	medium to fine sand	-0.88	moderately sorted
3	-	-	hard reef pavement	-	-
4	3.78	-1.92	gravel/sand	-2.66	extremely poorly sorted
5	0.58	0.78	medium to fine sand	-0.92	moderately sorted
6	0.73	0.45	medium to fine sand	-1.03	moderately sorted
7	0.49	1.02	course to find sand	-1.16	poorly sorted
8	2.90	-1.54	gravel/sand	-3.27	extremely poorly sorted
9	0.70	0.51	coarse to fine sand	-1.18	poorly sorted

The grain size classification is based on the Unified Soil Classification system (corresponds to US Standard Sieve sizes). 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 can be measured in either millimeters or phi units (o), where:

Phi units (o) = $-\log_2$ (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. Grain size distribution is qualitatively described as well sorted if all particles have sizes that are close to the typical size, and poorly sorted if the particle sizes are distributed over a wide range of sizes. Grain size distributions of the eight unconsolidated samples are plotted on Figures 17 through 31

Results indicate that most of the sediment in the project area is sand size and poorly sorted. Sediment on shore is slightly coarser and less sorted that the material offshore. No data was collected regarding the depth distribution of sediment. However, depth layering was observed and large quantities of shell and coral fragments were found at some offshore locations. It appears that an anaerobic decay process is occurring in the sand bottom.

The dashed lines on the grain size distribution graphs (Figures 17 through 31) represent the range of grain sizes typically found on good recreational calcareous sand beaches in Hawaii. A large percentage of the offshore samples had grain sizes which fall within the boundaries indicating that a fair amount of the dredge spoil should be suitable for beach nourishment.

b. 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 referred in Figure 8 and the profiles are

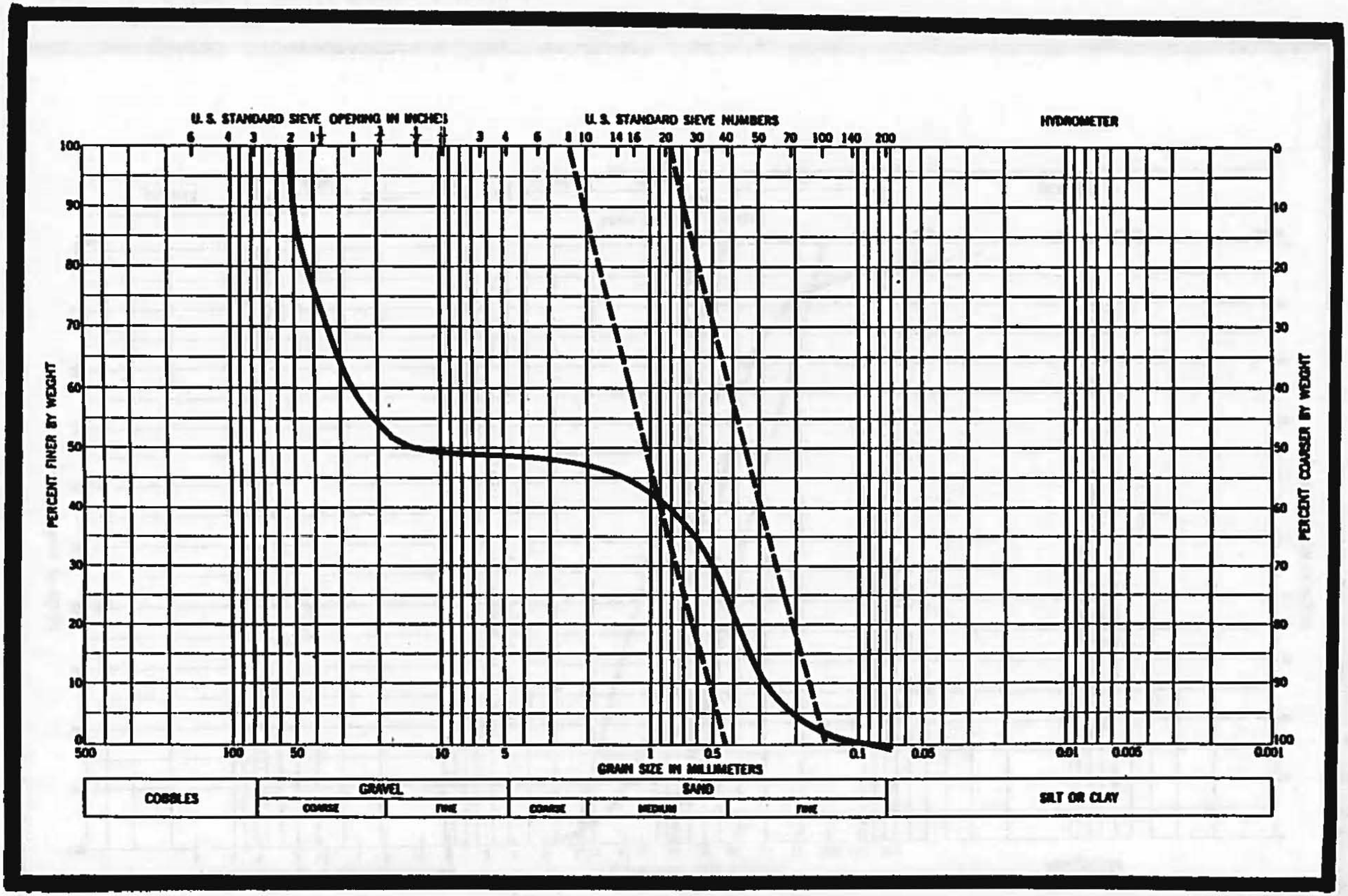

Figure 17. Sediment sample Number 1 analysis.

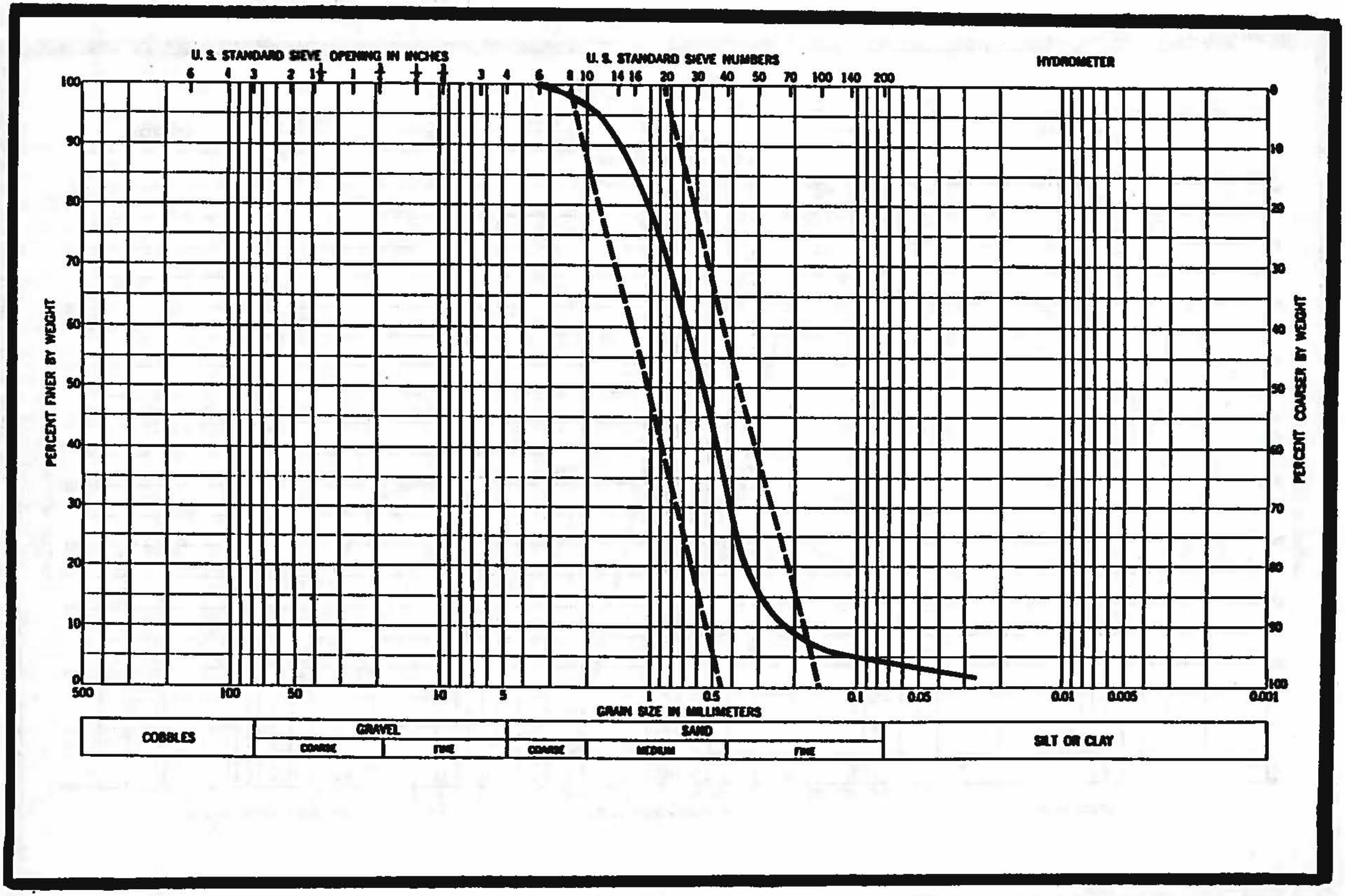

Figure 18. Sediment sample Number 2 analysis.

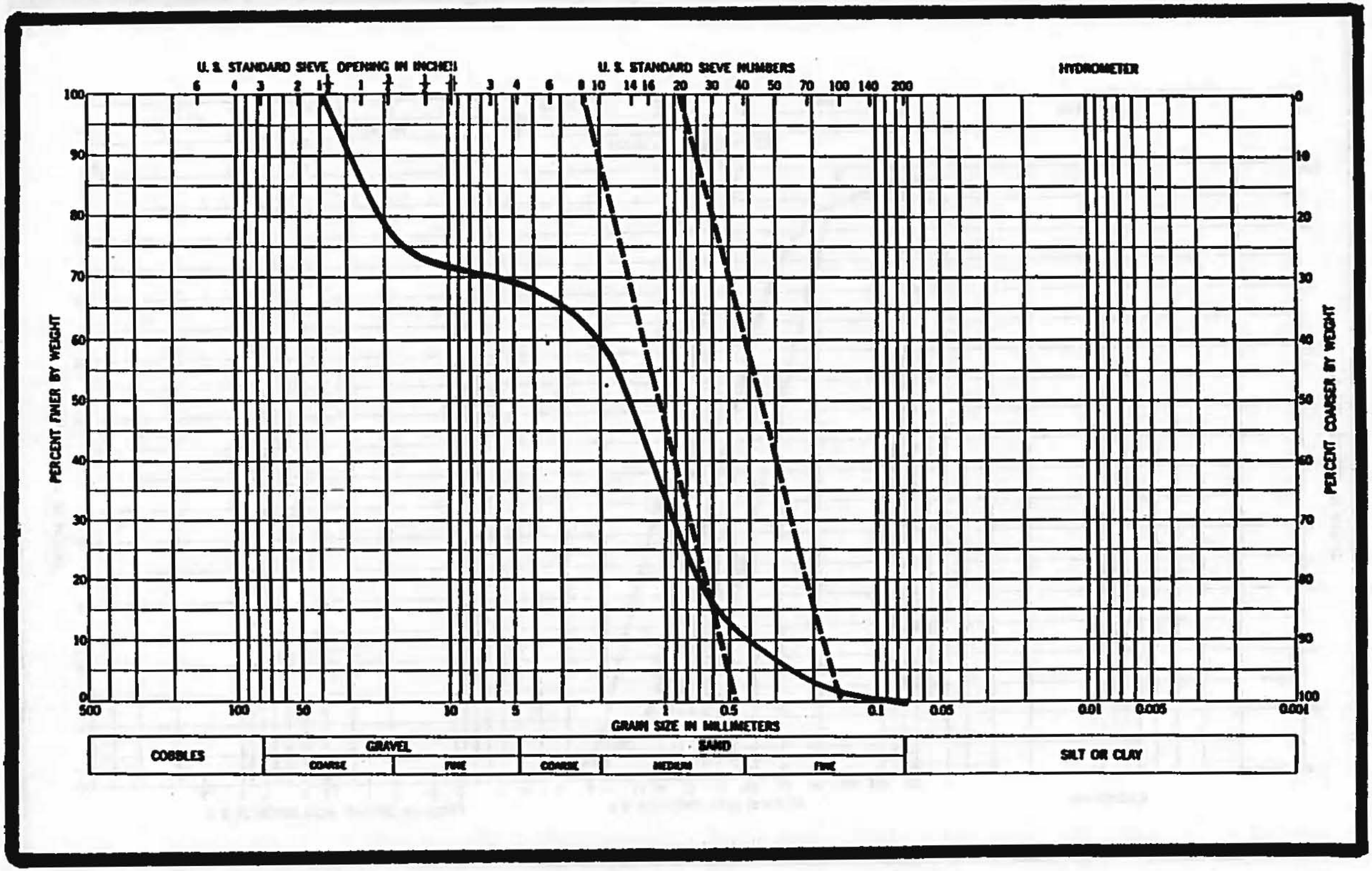

Figure 19. Sediment sample Number 4 analysis.

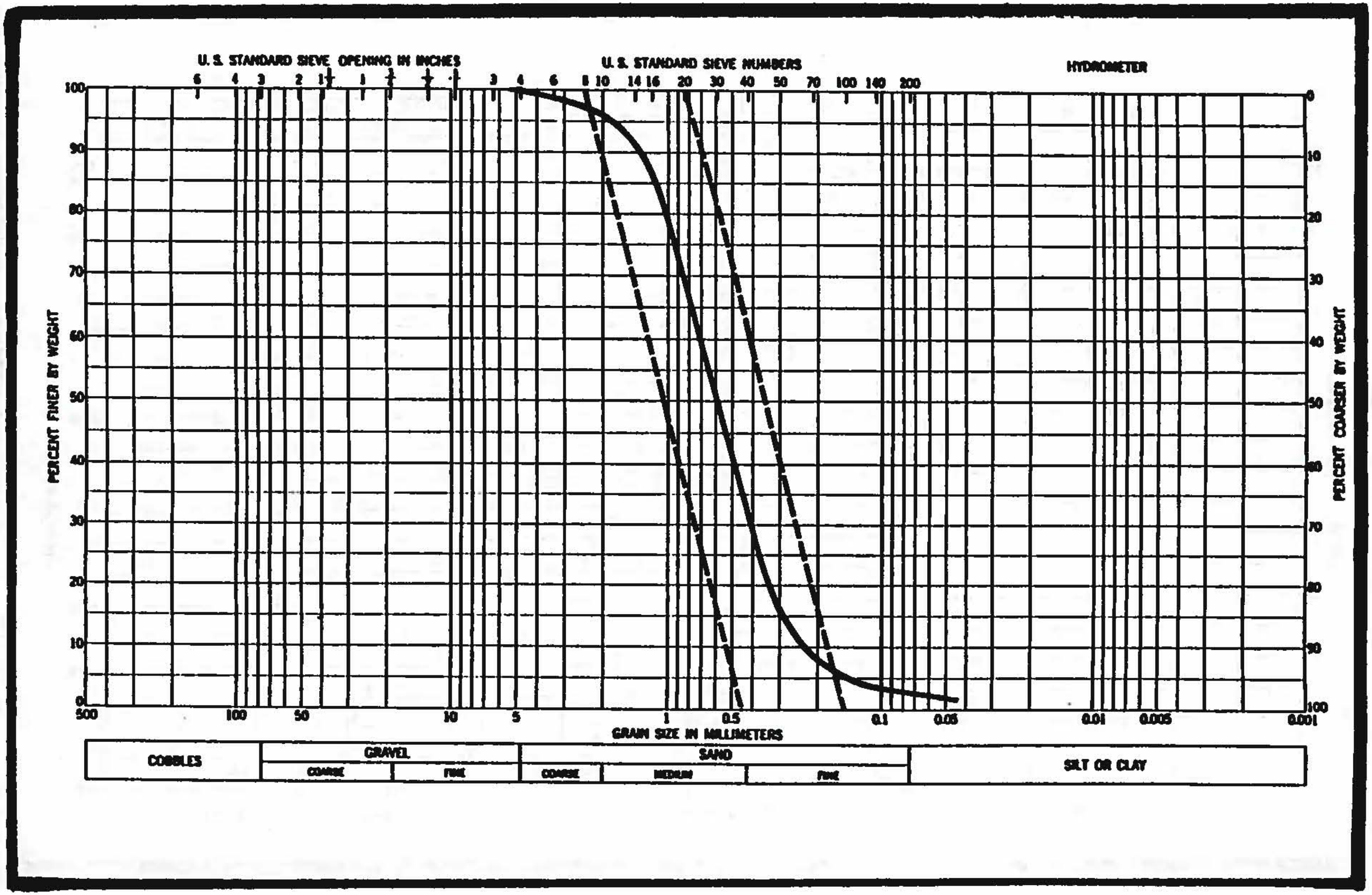

Figure 20. Sediment sample Number 5 analysis.

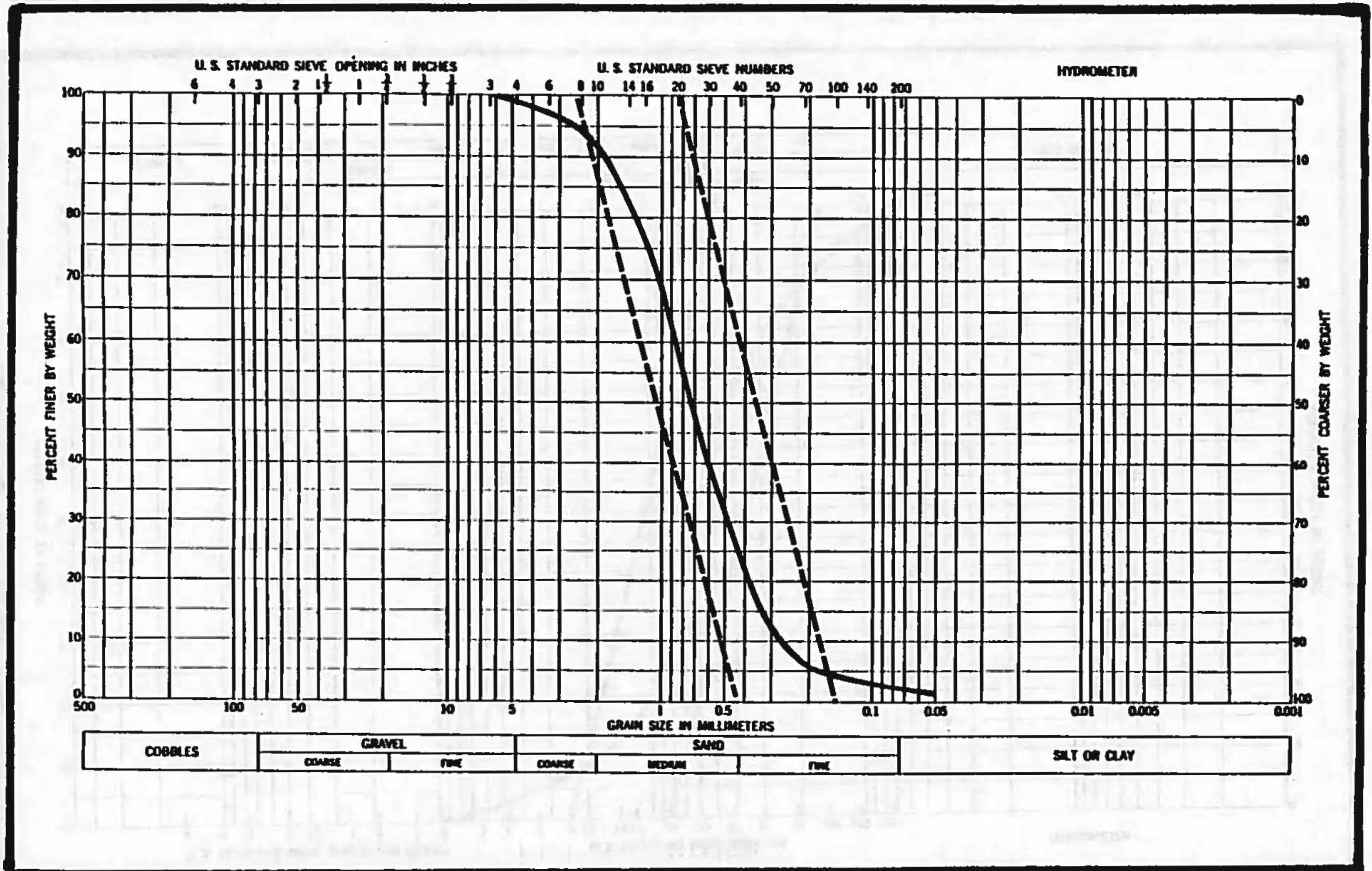

Figure 21. Sediment sample Number 6 analysis.

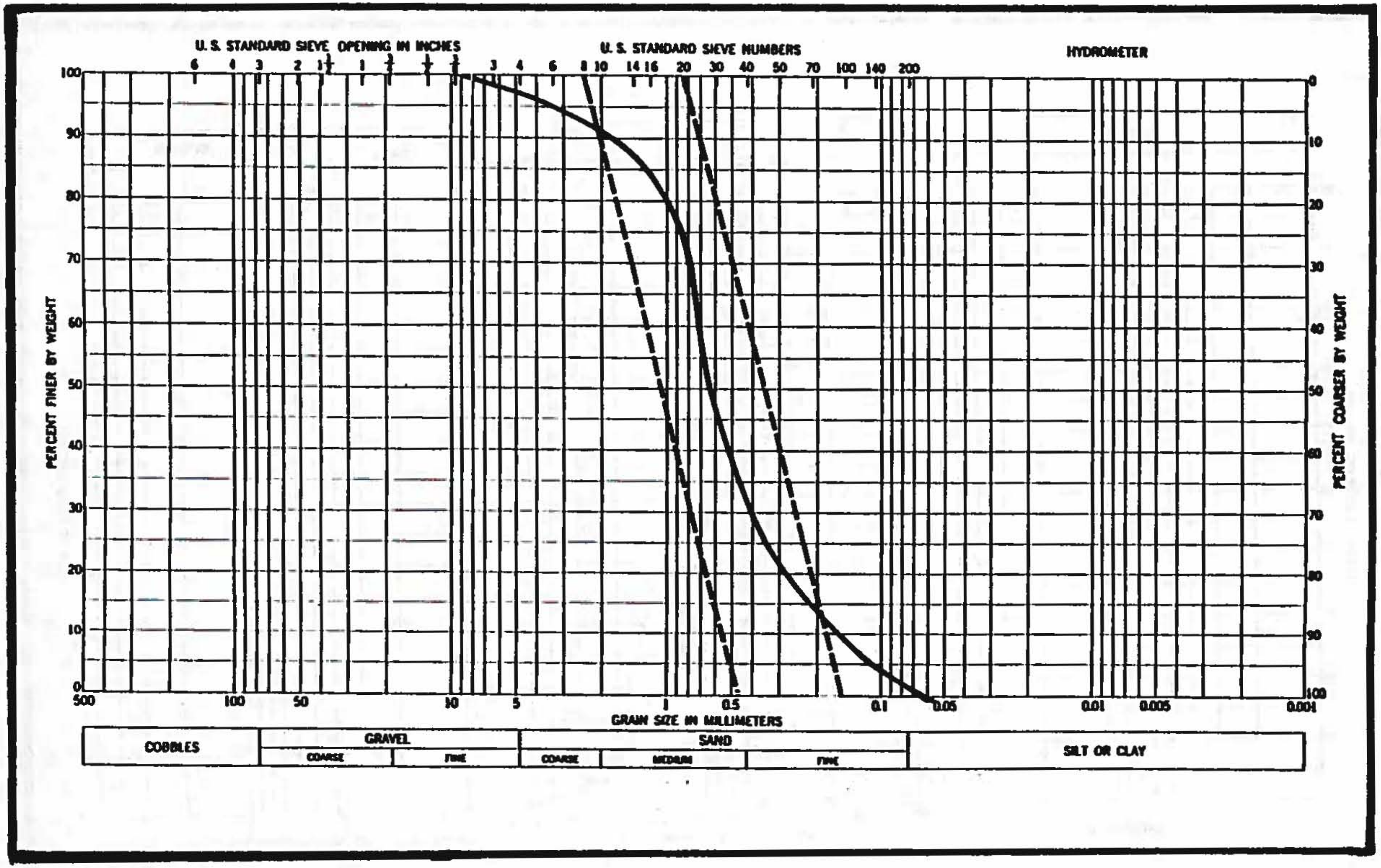

Figure 22. Sediment sample Number 7 analysis.

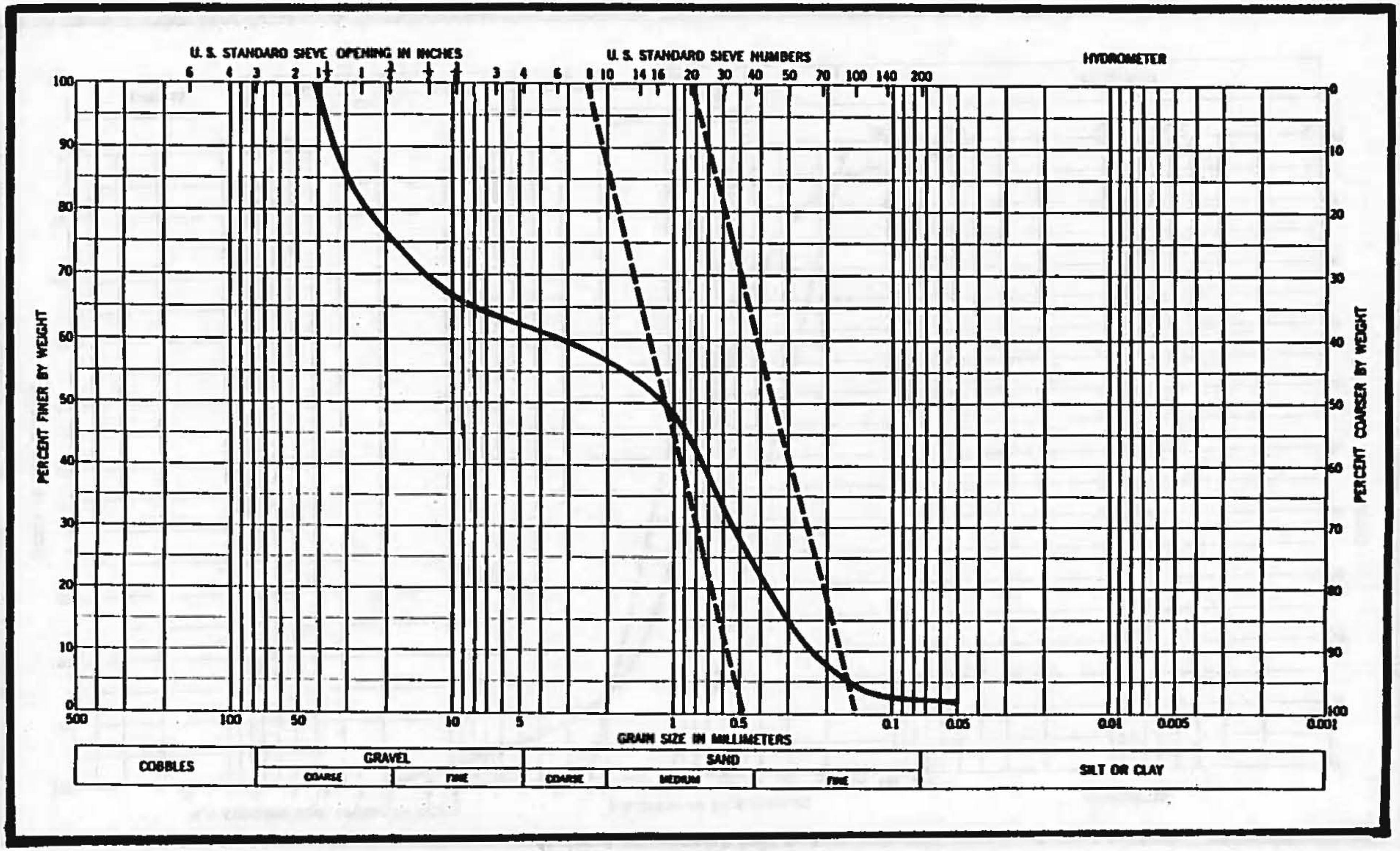

Figure 23. Sediment sample Number 8 analysis.

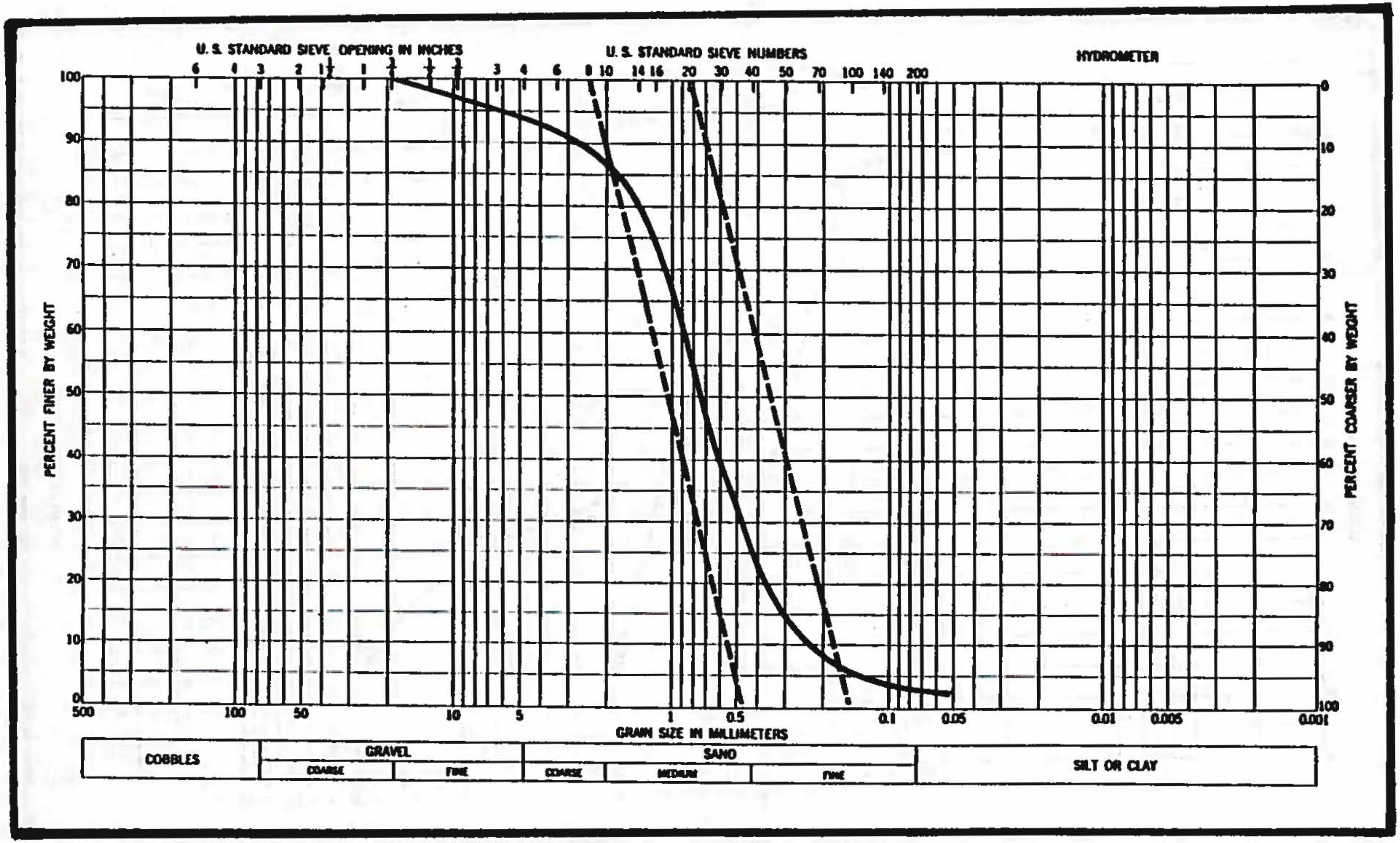

Figure 24. Sediment sample Number 9 analysis.

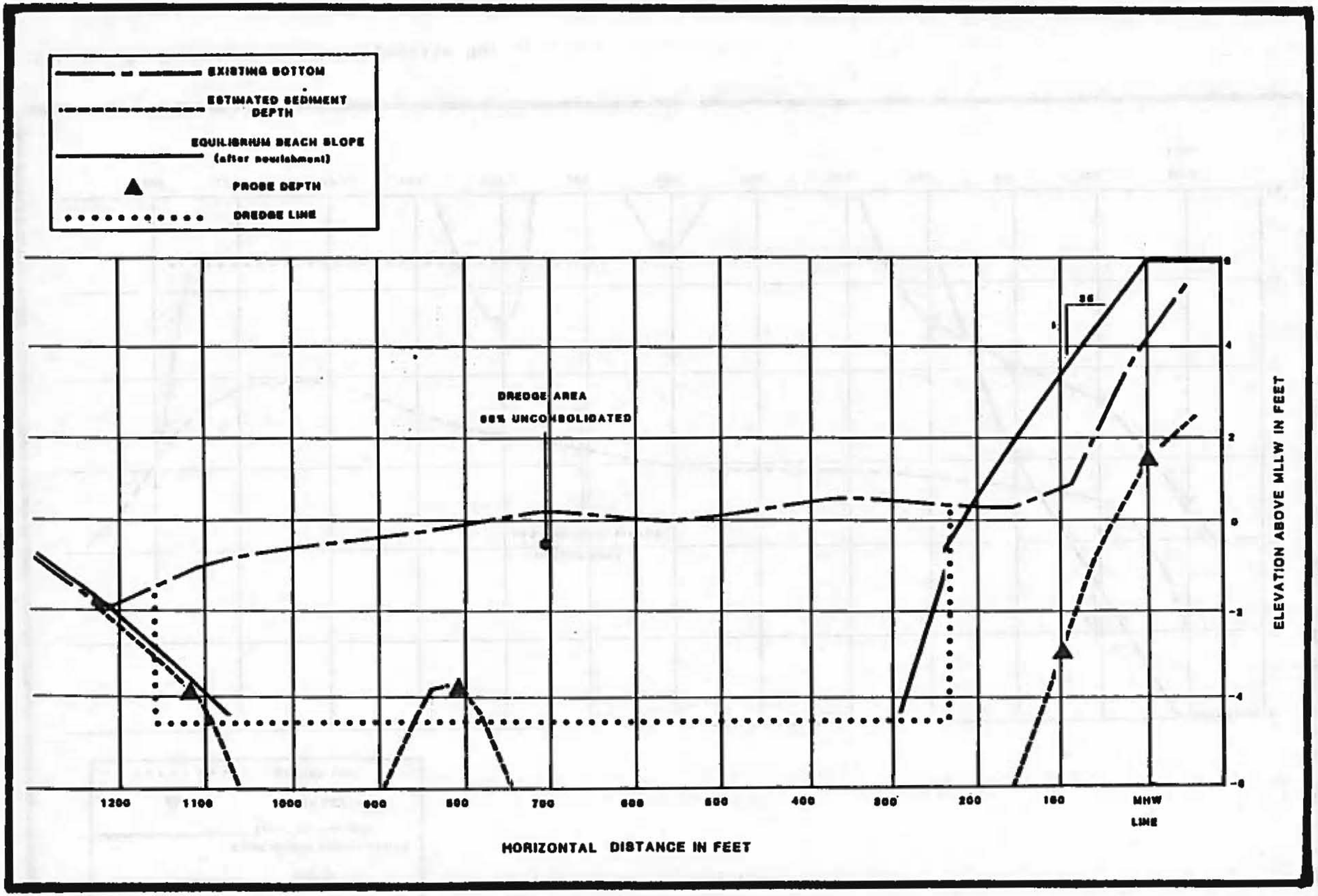

Figure 25. Nearshore sediment profile No. 1.

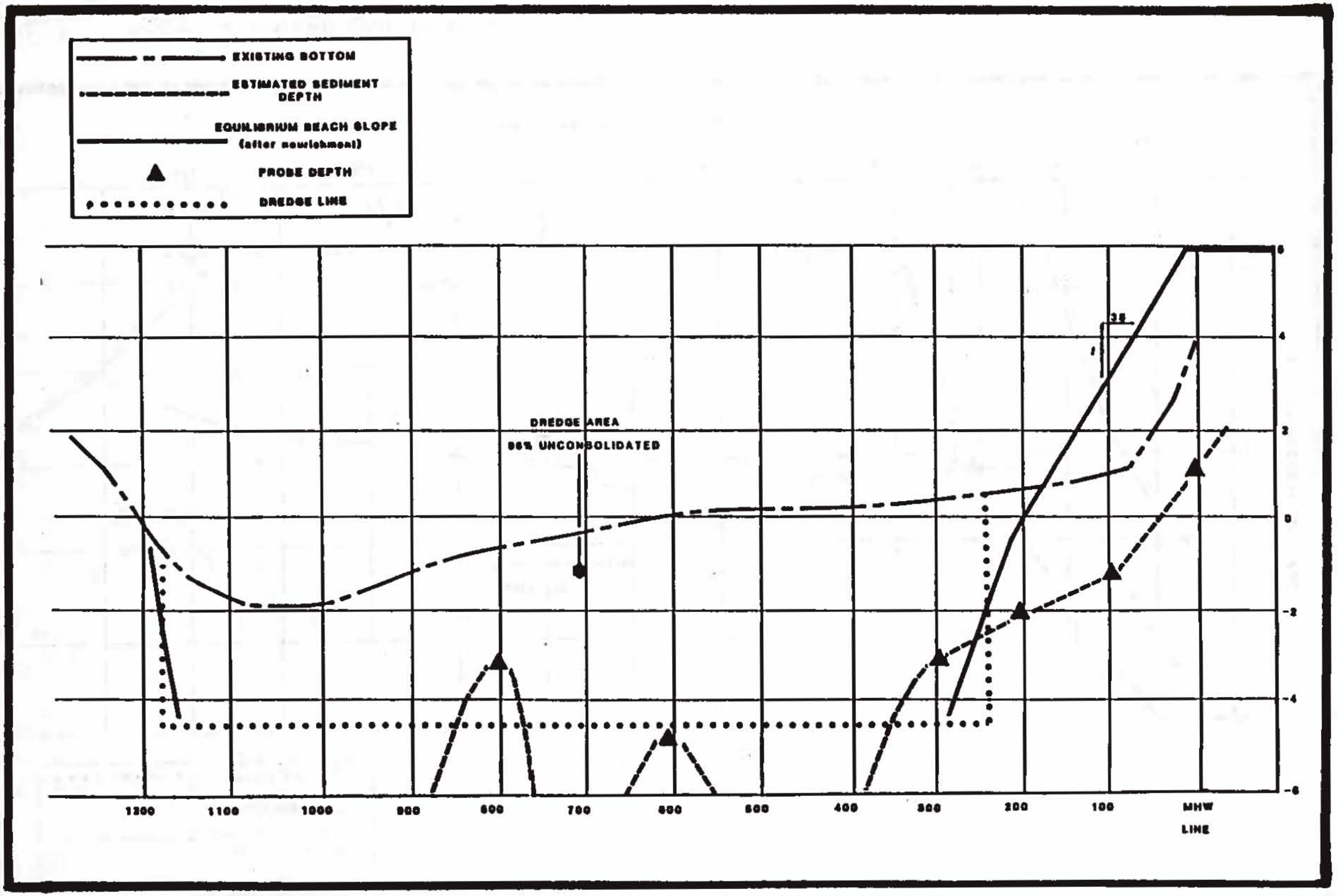

Figure 26. Nearshore sediment profile No. 2.

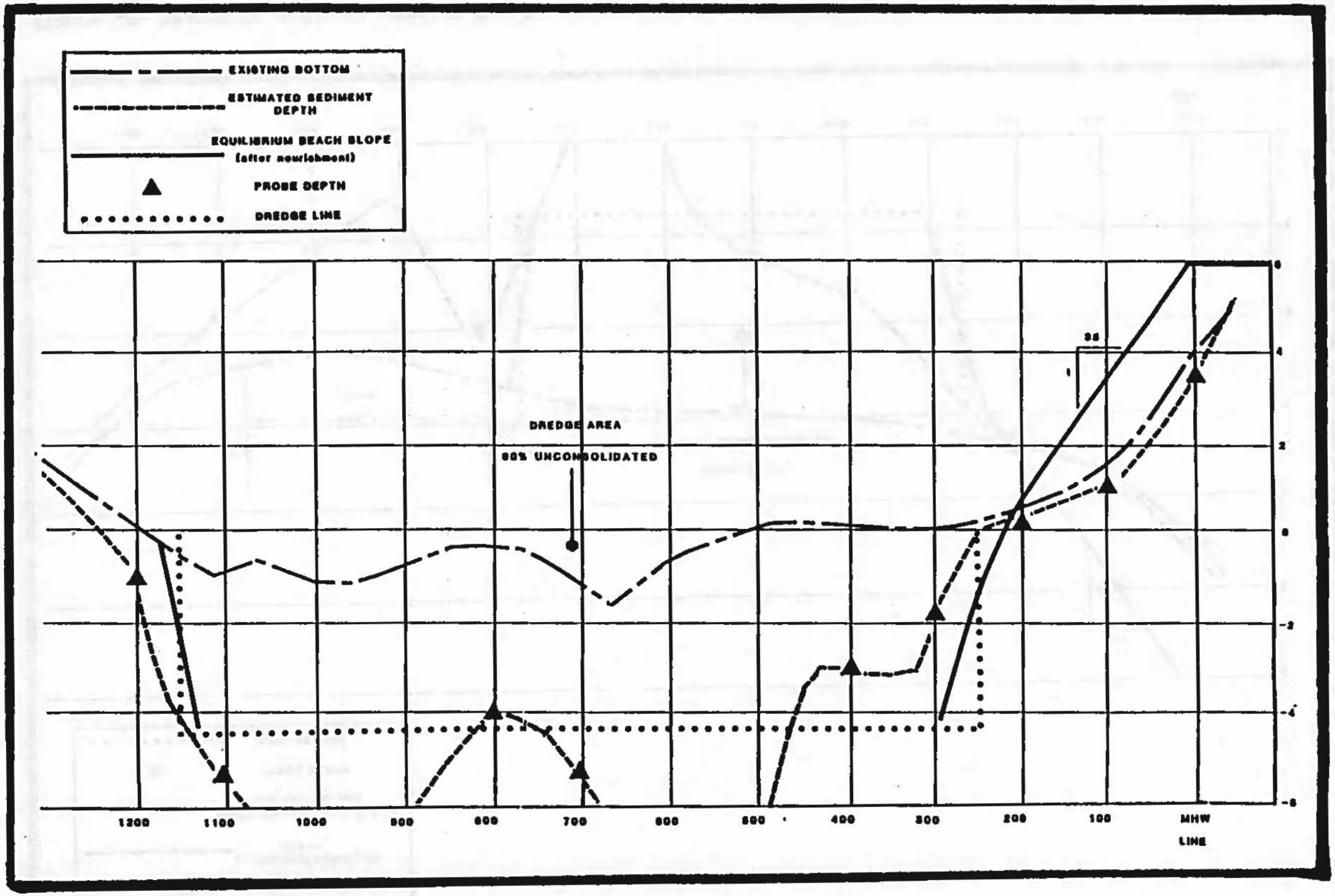

Figure 27. Nearshore sediment profile No. 3.

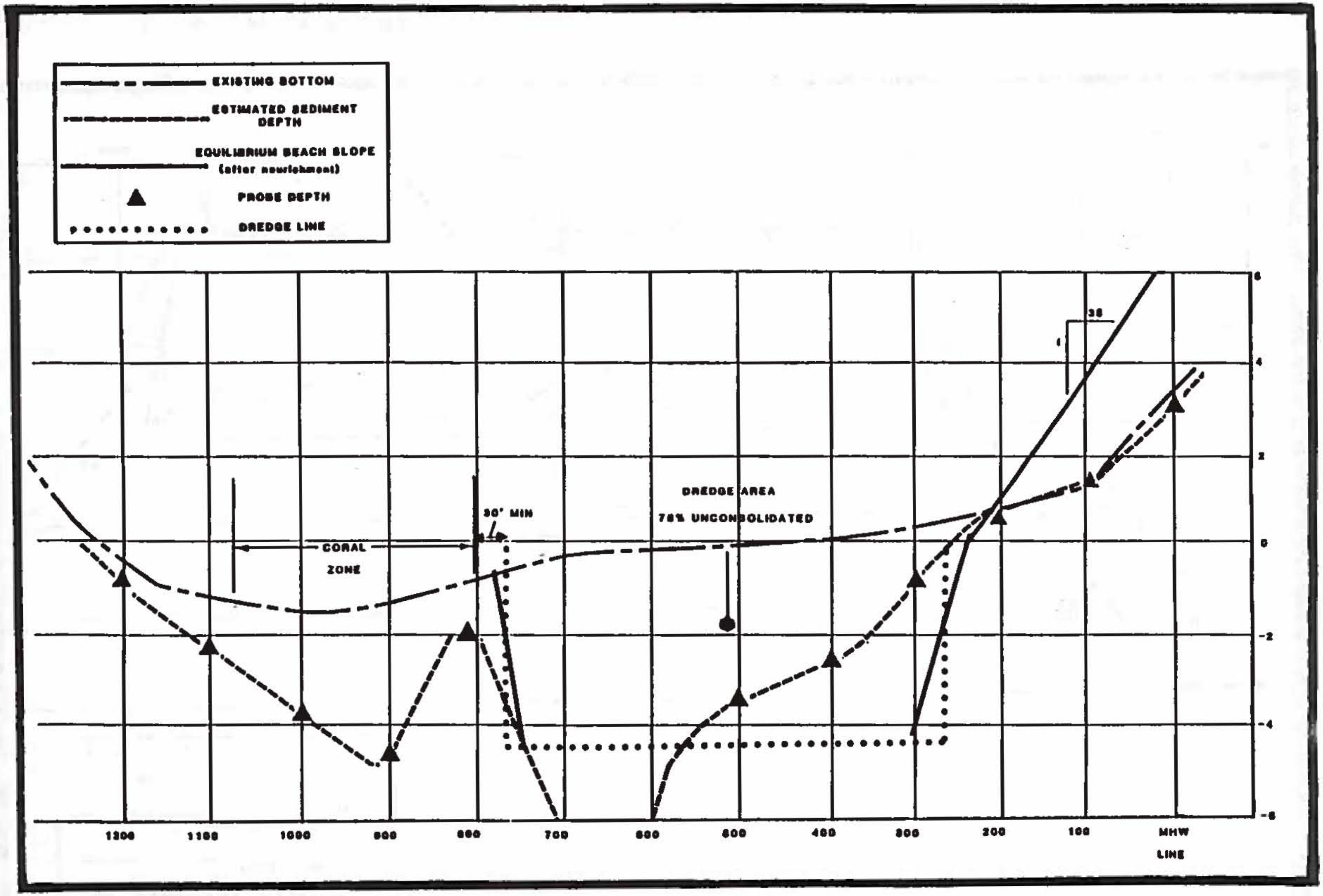

Figure 28. Nearshore sediment profile No. 4.

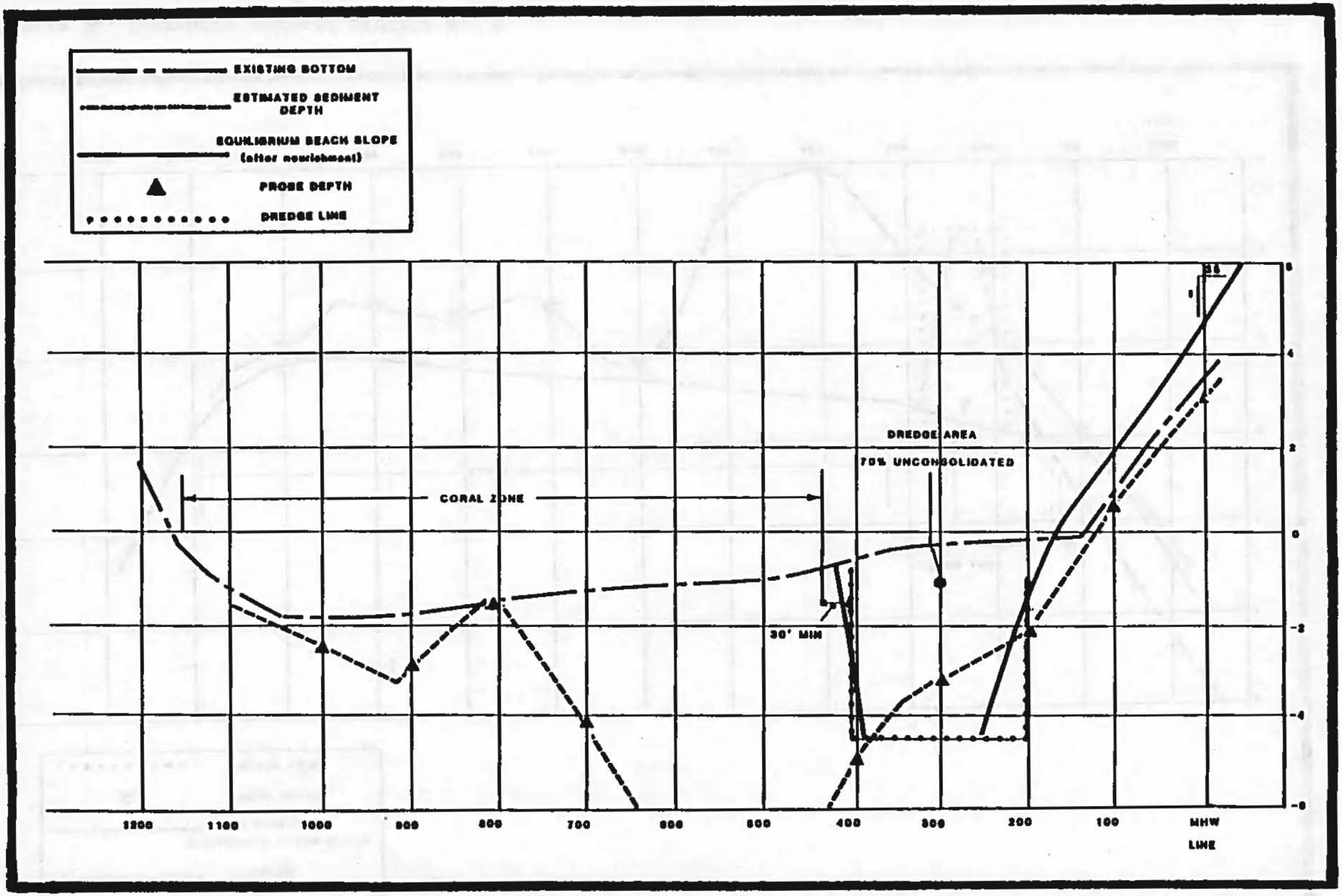

Figure 29. Nearshore sediment profile No. 5.

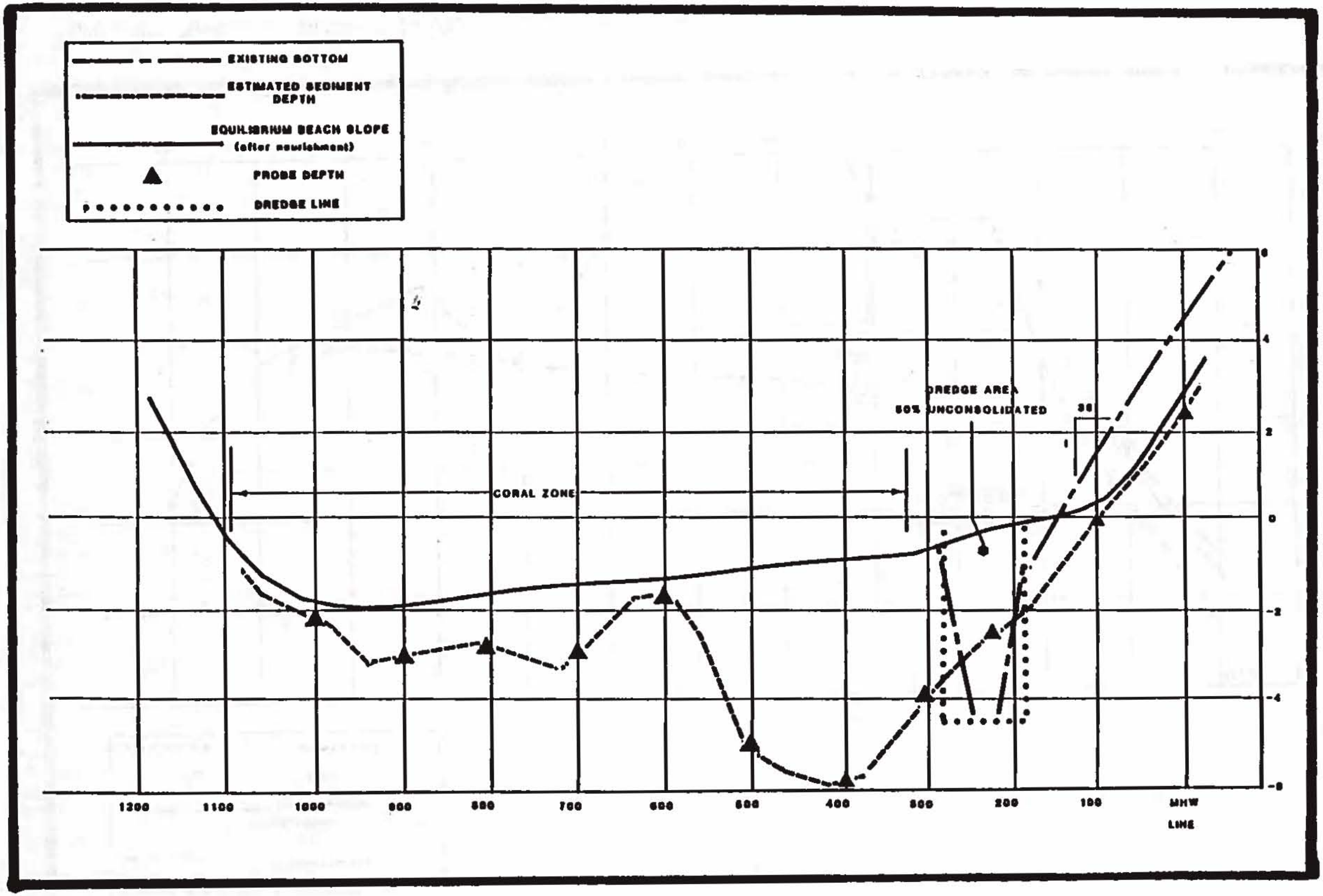

Figure 30. Nearshore sediment profile No. 6.

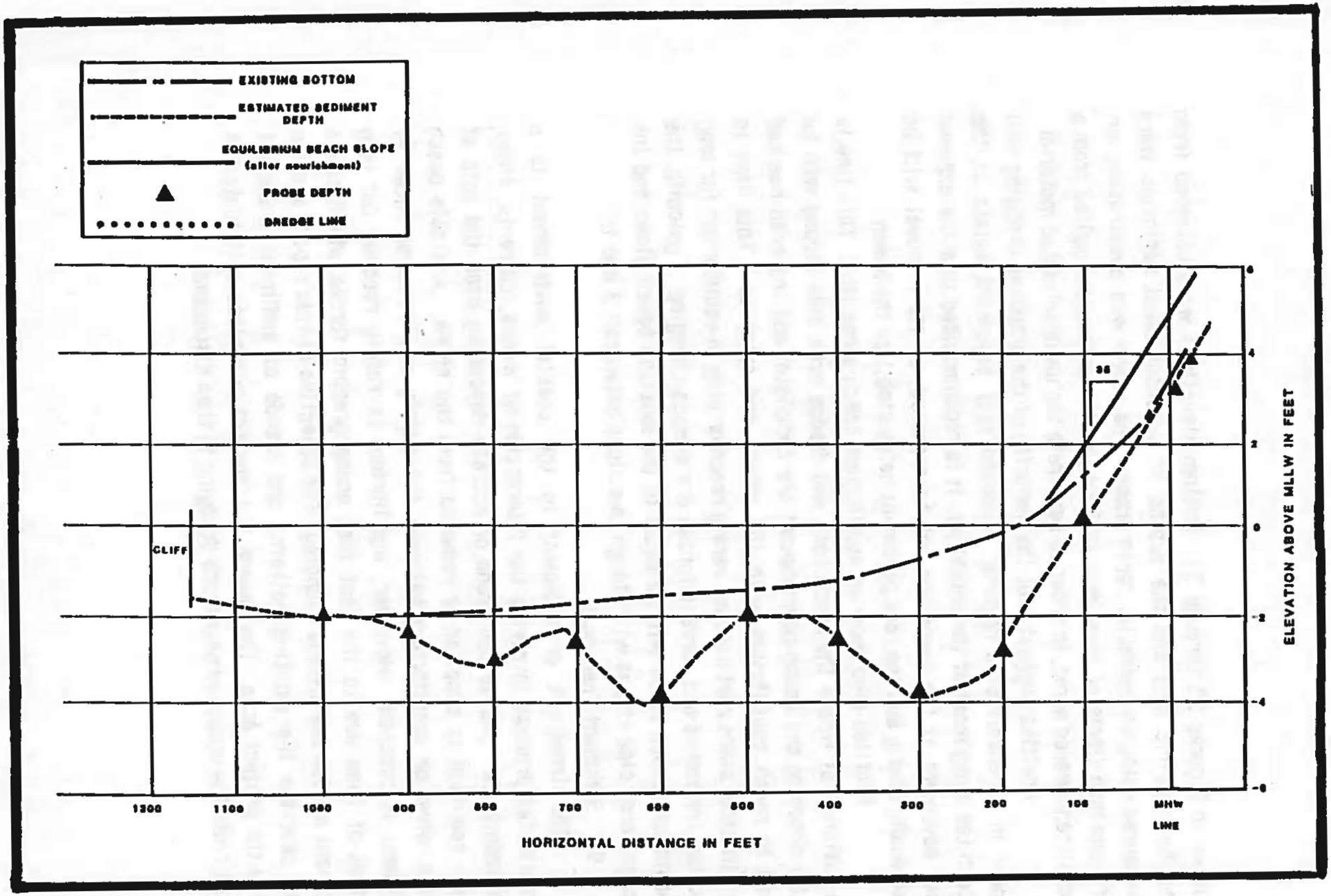

Figure 31. Nearshore sediment profile No. 7.

shown in Figures 25 through 31. Bottom elevations were obtained from the bathymetric map and the depths of unconsolidated sediment were measured using an hydraulic depth probe. The probe was constructed out of a one inch diameter steel pipe utilizing water pressure supplied from a gasoline powered pump, in order to penetrate the unconsolidated material.

Profiles suggest that the majority of the proposed dredging will occur in unconsolidated regions. Exposed reef pavement exists at the beach toe along most of the shoreline. It is recommended that the exposed reef pavement at the beach toe not be removed, as its removal will be extremely costly and the reef pavement helps stabilize the beach.

Profiles also show an equilibrium beach slope line. This line is an estimate of where the beach face and dredge area side slopes will be after dredging and beach nourishment are complete, and the area has had time to reach equilibrium with the waves and currents. This line is hypothetical since real beaches rarely reach or stay in equilibrium for long because the waves and current forces are always changing. Typically, the equilibrium beach slope will be equal to the existing beach slope and the dredged area side slopes will slough to a slope between 1:3 and 1:6.

9. Sediment Transport

The transport of sediment in the coastal environment is a complicated process involving the interaction of waves, currents, tides, and sediments. Shores can erode or accrete depending upon 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. However, equilibrium is rarely reached for long periods of time due to the fact that 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 inside the project area. The change in transport processes anticipated to result from the proposed nearshore dredging is then discussed.

a. Existing Shoreline Conditions

The shoreline in the northern portion of East Agana Bay can be described by three beach sectors, as shown in Figure 32. Beach sector "A" consists of steep limestone slopes and cliffs with large boulders and limestone terraces at the base. The beach was void of sand size material. Beach sector "B" is transitioned between shoreline cliffs and a low lying backshore. The beach varied in width from 10-20 feet and was composed of coarse to medium sized calcareous sand, and gravel sized coral rubble. No evidence of erosion was seen. Beach sector "C" had a low lying backshore on which residential houses and apartments were constructed. The beach was composed of medium to fine calcareous sand and varied in width from 25 to 35 feet. Signs of erosion were present above the high water line such as exposed tree roots, and small erosion scarps that undermine the vegetation line in some locations. It appears erosion had occurred along the beach sector during storm or high wave conditions. The reef-flat from the shore out to Alupat Island consists of fine to medium grain sized calcareous sand. Seaward of the island is reef pavement and scattered live coral.

Remnants of a causeway exist between the shore and Alupat Island. The causeway was constructed in 1965 out of dredged reef-flat sand.

b. Present Sediment Transport

Little movement of sediment appears to have occurred in the project area during normal oceanographic conditions. During storms or high wave conditions, movement of bottom sediment in the study area and some beach erosion is expected.

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

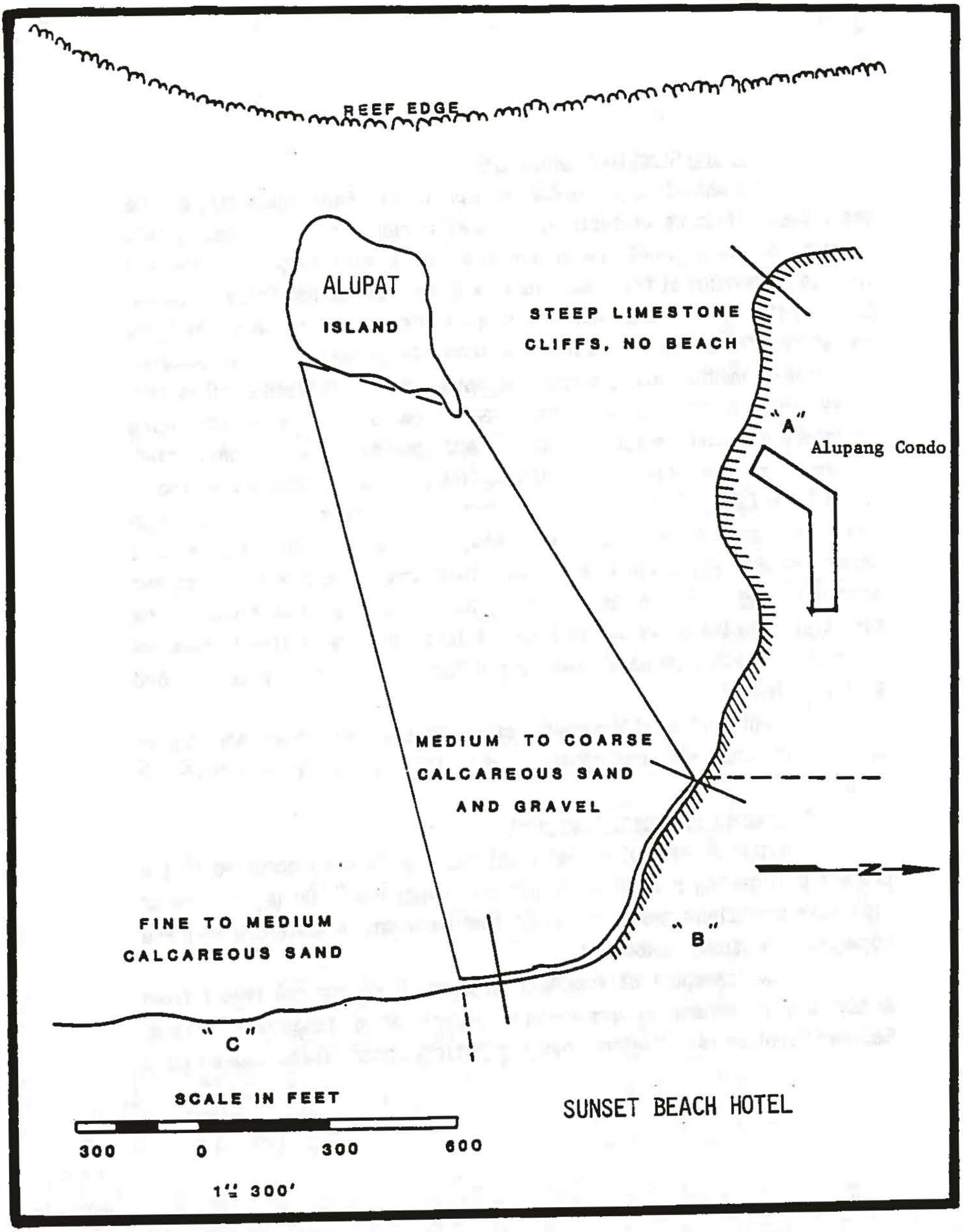

Figure 32. Existing shoreline condition.

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, depth, bed form and flow characteristics. For a flat, shallow, slightly rippled sea bed composed of medium sized sand grains, (such as the case for the northern portion of East Agana Bay), the threshold value can be assumed to be a function of the current velocity and the horizontal pressure gradient at the sea bed.

Coastal currents under normal conditions reach velocities of up to 0.7 ft./sec with an average of 0.2 ft./sec. Steady currents of these velocities will instigate little sediment transport. However, these currents are capable of transporting a significant sediment load that is lifted into suspension by some other means, such as waves.

In Figure 33 water depth versus wave height were plotted for three different sand grain diameters. This illustrates 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 oscillatory 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 are based on theoretical information using Shield's criteria for initial motion, Kamphuis' curves for the friction factor and linear wave theory for oscillatory flow velocities as suggested by Sleath. Although this information is extremely theoretical and may not represent conditions exactly inside East Agana Bay, the curves do show the relative significance of the different parameters that control the initiation of sediment motion. For example, the plot illustrates that initial motion is extremely sensitive to change in wave height, and only slightly sensitive to change in depth. Furthermore, it illustrates that wave heights need not be very large in order to initiate motion. The plot also shows that larger size grains are more stable than smaller ones, as expected.

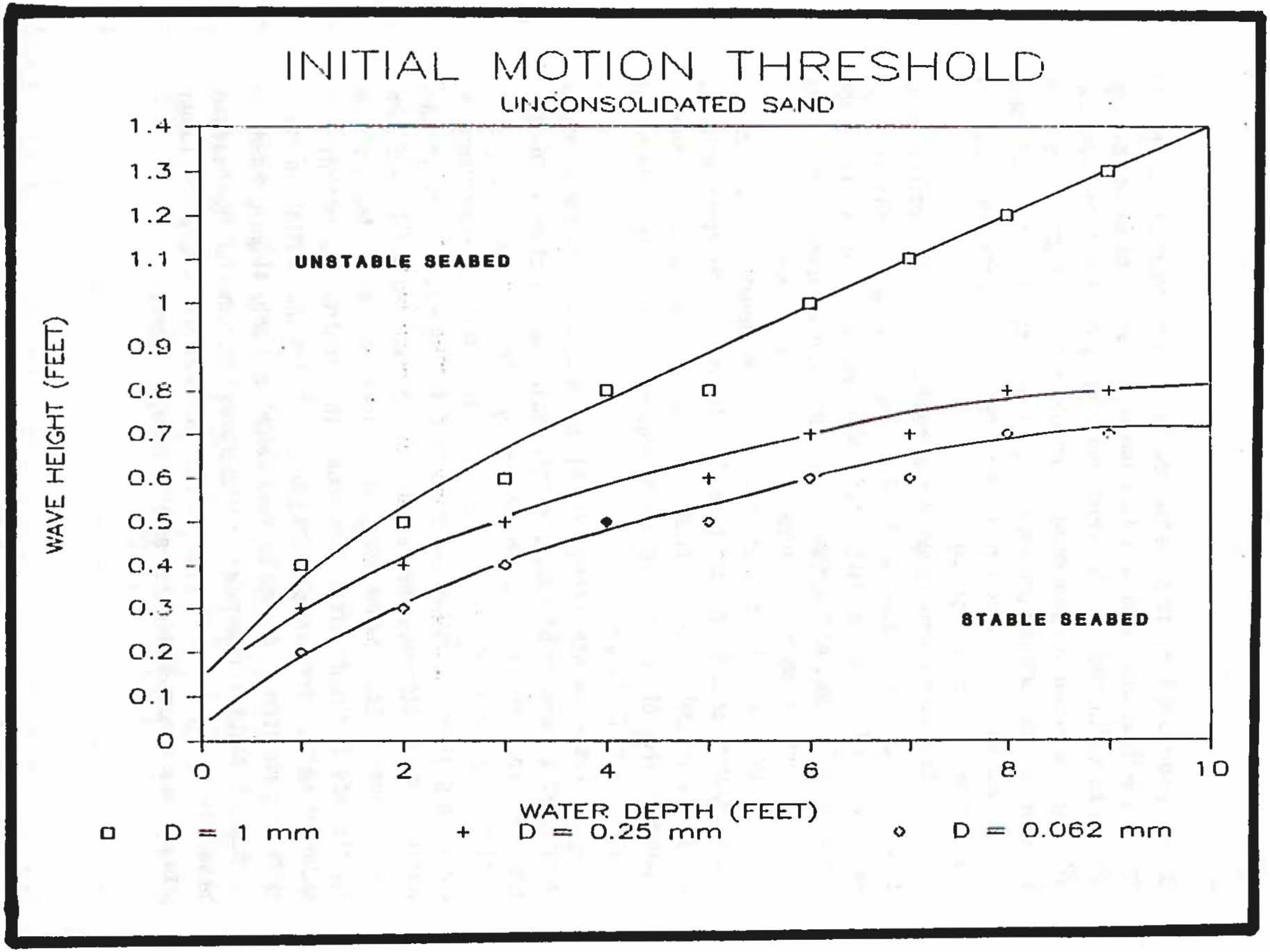

Figure 33. Initial motion threshold of wave height and water depth.

Another parameter governing initial motion which wasn't compared in this plot is wave period (time for the passage of successive wave crests). Shorter periods will cause more instability and longer periods will cause less. Since the period of waves on the reef-flat is unknown, a value of ten seconds was used to represent normal conditions.

This analysis illustrates that wave heights of one foot are needed to cause sediment of all sizes to go into motion, and of only one half foot to cause small sized sediment in shallow areas to go into motion. Wave heights on the reef-flat have been estimated to range between zero and six inches under typical 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, although unknown, could be large during a large typhoon. However, this is the normal condition for most shallow bays along the west coast of Guam.

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 take over and carry the sediments along the shore.

As discussed in the previous report section, coastal currents in the study area during typical prevailing oceanographic conditions are weak and erratic. There does not appear to be any steady or tidally fluctuating pattern. Coupled with the small size of reef-flat waves, significant sediment transport is not expected during typical prevailing oceanographic conditions.

Because of the difficulty in obtaining current data during storms, the strength and pattern of coastal currents during storms or high wave conditions is unknown, and it is impossible to predict sediment transport during these events. The potential for large transport is present, as predicted by the previous initial motion analysis. However, evidence of large historical beach changes have not been found. Discussions with long-term local residents indicate that changes in beach width have occurred, especially after storm events. But overall, the shoreline has been reported as being relatively stable. The stability of the causeway is evidence that sediment transport during the past 23 years has not been severe in the project area. The causeway will still be exposed during extreme low tides. However, evidence of erosion above the water line was seen at Dungcas Beach, indicating storm wave damage is possible to the shoreline south of the project site.

10. <u>Air Quality</u>

Air quality in the project site is excellent. There are no major commercial developments or industry in the vicinity which would bring heavy particulates down on the site. The only air pollution problem which exists near the site would be vehicular traffic on Marine Drive.

11. <u>Reef-Flat Zones and Substrate Types</u>

The project site represents the extreme northern end of East Agana Bay including Lot #5172-3-R9 New, part of Dungcas Beach, Alupat Island and the adjacent reef-flat (Figure 3).

a. <u>Supratidal Zone</u>

This zone includes approximately 800 linear ft of the supratidal shoreline, along Dungcas Beach fronting lot #5172-3-29 New. The shoreline at the northern end of this East Agana Bay reef-flat platform consists of a limestone cliff approximately 70 ft high at the seaward edge. This headland dips down to the north were it forms an irregular limestone slope about 20 ft high. The slope is set back from the shoreline at the north end of the project site by a strip of unconsolidated beach deposits, and it dips below the general level of these deposits at the south end of the project lot. Unconsolidated beach deposits border the remaining third of the shoreline within the project and continue south of the project site.

At this time, the supratidal zone of the project site is primarily cleared land with some larger trees still remaining. The mat forming grass (Paspalum vaginatum) forms a band along the beach over most of the site. Remnants of natural limestone vegetation exist along the seaward edge of the cliffline at the extreme northern edge of the Bay. Large coconut palms can be found on the site as well.

Alupat Island is a rocky limestone islet resting on the outer part of the reef-flat. The highest point on Alupat Island is approximately 63 ft and the island is covered with thick natural limestone vegetation. The island is uninhabited but is presently under lease by Mr. Henry Simpson of Island Imports Inc. Recent improvements include clearing of the beach and development of trails throughout the island.

Cliffs and steep slopes border the shoreline except along the south side where a sandy beach and sand bar have developed. Regions of bare rock are very rough and irregular because of solution pitting. A prominent +6 ft fossil nip is cut into the rocky cliffs of Alupat Island in the shoreline. A few limestone blocks several meters in diameter have eroded from the rocky cliffs, and now rest on the reef-flat at several locations around Alupat Island.

The shoreline along Agana Bay is flat and well developed with residential housing and apartments. Alupang Cove Condominiums exist on the low limestone cliff along the north end of the reef-flat. The Oka Point Condominiums are under construction further to the north, and the Bay View Apartments were recently completed to the south of the project site on Trinchera Beach. Individual houses and smaller apartment complexes are scattered. The Oka Point Trailer Park was recently relocated to make way for this development. The village of Tamuning borders the shoreline south of the project site and is extensively developed with commercial and residential buildings.

b. Intertidal/Nearshore Zone

The intertidal/nearshore zone is quite varied throughout the project site. At the north end of the project site this zone contains scattered boulders and course gravel mixed with beach sand. The intertidal zone at the north end of the project site is bordered by steep but low limestone slopes and cliffs. The limestone cliffs are cavernous with sea level nips cut at the base. The intertidal/nearshore zone in the southern portion of this project site, and consists of unconsolidated beach deposits.

The intertidal/nearshore zone is dominated by sand (66.67 percent). Approximately one third of the zone (31.63 percent), is covered by patches of algae. Rubble is scarce (1.70%) and live coral is absent because of the lack of hard pavement and/or poor water quality. Substrate types are represented by only three of six categories (Table 11).

The beach and intertidal/nearshore zone within the project site is under-lain by a sewer trunk line. Manhole covers rise above the general level of the beach approximately 100m apart. Overflowing of these manholes has been a continuing problem causing polluted conditions within the bay on a regular basis.

At Alupat Island the intertidal/nearshore zone consists of a prominent nip cut along the rocky shoreline. Unconsolidated sand and gravel exist on the east (shoreward) side of the island with the development of a well defined sand bar and small beach. A boulder zone is located along the north side of the sand bar where it joins the island. The seaward side of the island receives more wave assault, and at places the floor of the nip cut is scoured by the action of wave-transported sand and gravel.

c. Reef-Flat Platform Zones

The reef-flat platform can be divided into two distinct zones: inner reef-flat and outer reef-flat. The outer reef-flat is slightly higher in elevation with respect to the inner reef-flat and, consequently, is exposed during low and minus tides. The inner reef-flat is usually covered with water even at low tides particularly in the moat. It is exposed during minus tides. The northern extreme of the project site reef-flat can be further subdivided into a wide inner sandy subzone and a narrower mixed coral subzone. The outer reef-flat platform is considerably narrower than the inner reef-flat platform and is interrupted by a shallow channel to the south side of Alupat Island. At low tide the channel is 0.3-0.5m deep. Observations indicate that this channel was most likely dredged. Randall and Eldredge (1974) suggest this is the case since natural channels usually have well rounded boulders on their floors, whereas many boulders in this channel are angular and irregular. Another shallow channel cuts across the reef margin and outer reef-flat zone approximately 1000 ft further south of the first channel. This is the primary area for water to exit the reef-flat along this region of East Agana Bay. At low tide this channel is slightly more shallow than the channel at Alupat Island.

A causeway was partly constructed between Guam and Alupat Island in 1965. The remnants of this causeway are obvious today and the top is exposed during very low tides. Material to construct this causeway was dredged from either side creating two channels which are considerably deeper than the surrounding terrain.

Depth of the various reef-flat zones were indicated in the bathymetric survey performed by Duenas and Swavely Incorporated. At extreme low tides (-0.9 ft) much of the inner reef-flat sand subzone would be exposed, except for depression holes and the man-made channels. It is apparent that the inner reef-flat sand subzone increases in depth seaward toward the coral subzone, which is the deepest part of the reef-flat.

The coral subzone, grades into the outer reef-flat zone which is partly to mostly exposed during extreme low tide. The seaward portion of the outer reef-flat is flat and pavement-like with little relief except for occasional shallow depressions and holes. Within the inner portion of the outer reef-flat, boulder zones have developed from material which has been eroded from the reef margin and reef front, and tossed up by storm and typhoon waves. These boulder zones are very well developed on both sides of the shallow channel north of Alupat Island.

Between Alupat Island and the north shore of Agana Bay, the inner reef-flat coral subzone is wider than that to the south of the island. A slight depression on the outer reef-flat zone is found at the extreme northwest corner of the reef-flat platform, near a narrow fringing reef commonly known as "Rick's Reef."

The inner reef-flat sand subzone substrate consists mostly of sand, gravel and mollusk shells. Relief is relatively flat except for a few deeper holes up to a meter or more in diameter located nearshore. These holes are the result of submarine springs of fresh water which loosen the sand at the point of emergence. A plastic lime-mud forms a band approximately 20-40m wide along the shoreline in the inner reef-flat sand subzone.

Substrate in the inner reef-flat zone is dominated by sand, and rubble (79.16 percent and 16.86 percent respectively). Rubble is comprised of small scattered boulders and coral-algal-mollusk parts. Sand decreases seaward while the coral algal-mollusk rubble increases. The extreme seaward edge of the inner reef-flat coral subzone consists of dead Acropora thickets, boulders, coral algal-mollusk-rubble and a thin veneer of sand over consolidated reef rock. Algae represents a mere 2.65 percent and live coral is sparse (no live coral was counted on transects but does exist in the zone) (Table 8). Four of six substrate types are represented in this zone.

The outer reef-flat zone consists of a consolidated reef rock platform except for the inner portion which contains accumulations of boulder rubble. The outer part of this zone is flat and pavement-like with unconsolidated sand material appearing as a thin veneer in shallow holes and depressions. The outer reef-flat platform is dominated by rubble (54.72 percent) and sand (28.22 percent). Algae comprises nearly 9.28

percent and live coral 4.36 percent. Coral in this zone is patchy and primarily isolated in an area to the north- east of Alupat Island. All six substrate categories were represented in this reef-flat zone (Table 11).

Table 11. Percent cover of substrate type for each reef-flat zone in the vicinity of the project site.

Transect	Live Coral	Algae	Sand	Rubble	Pavement	Other
		Intertidal/Nearshore zone				
1-1	0	10	159	7	0	0
4-1	0	57	119	0	0	0
7-1	0	100	74	2	0	0
Percent Cover		**031.63**	**66.67**	**1.70**	**0**	**0** = 100
		Inner Reef-flat Platform Zone				
1-2	0	2	121	53	0	0
4-2	0	0	163	13	0	0
7-2	0	12	134	23	7	0
Percent Cover		**0 2.65**	**79.16**	**16.86**	**1.33**	**0** = 100
		Outer Reef-flat Platform Zone				
1-3	0	15	47	111	0	3
4-3	0	6	83	82	0	5
7-3	23	28	19	93	11	2
Percent Cover	**4.36**	**9.28**	**28.22**	**54.17**	**2.08**	**1.89** = 100

C. Biological Characteristics of the Project Site

1. Terrestrial Flora and Fauna

a. Shoreline Vegetation

Vegetation along the shoreline in this region of East Agana Bay is typical of coastlines on the west side of Guam and is quite varied because of geological variation within the region (Table 12). The rocky cliffline zone along the northeast sector of the project site is dominated by small Pago trees (Hibiscus tiliaceus) and the hardy salt-tolerant shrub Pemphis acidula. Scattered along this sector of coastline are occasional coconut trees (Cocos nucifera) and ironwood trees (Casuarina equisetifolia). Common grasses and weeds can be found on the upper flat plateau where trailer houses once existed.

Shoreline vegetation changes dramatically in the central to southern sectors of the project site because of the change in geological formation. Steep rocky cliffs of the northeast sector give way to gently sloping limestone and sand which supports a greater diversity of vegetation. In this central sector can be found more coconut and ironwood trees and a greater number of smaller shrubs and herbs like the small shrub Pluchea indica, beach sunflower (Wedelia biflora), Scaevola taccada and the beach morning glory (Ipomoea pes-caprae). Medium sized trees (Thespesia populnea and Hernandia nymphaeifolia) also exist along the strand in this sector. However, Pemphis acidula is no longer evident.

A shallow ravine cuts through the project where beach deposits begin creating a natural barrier between the north and south sectors of the site. This ravine is the natural drainage swale which carries stormwater off the higher, flat plateau region on the north side of the site where houses once stood. Within this ravine are found numerous shrubs, herbs and vines, a few ornamentals and banana trees. The common taro plant (Colocasia esculenta) is found at the beach end of the ravine where water tends to pool. Common forms of vegetation in the general area are the yellow oleander (Thevetia peruviana), croton (Codiaeum

Table 12. Checklist of terrestrial beach strand flora observed or known to occur in the vicinity of the project site including Alupat Island. *Denotes those plants on Alupat Island.

Species	Common Name	Chamorro Name
*Bidens pilosa	Beggars Tick	---
*Carica papaya	Papaya	---
Casuarina equisetifolia	Ironwood	Gago
Cocos nucifera	Coconut Palm	Niyog
Codiaeum variegatum	Croton	Leston Puyitos
Colocasia esculenta	Taro	Suni
Hernandia nymphaeifolia	---	Nonak
*Hibiscus tiliaceus	Hibiscus	Pago
*Ipomoea pes-caprae	Beach Morning Glory	Alalag-Tasi
Jatropha curcas	Physic-Nut	Tuba-Tuba
*Leucaena leucocephala	---	Tangan Tangan
*Messerschmidia argentea	Messerschinidia	Hunig
*Pemphis acidula	---	Nigas
Pluchea indica	---	---
Saccharum spontaneum	Wildcane	---
*Scaevola taccada	Scaevola	Nanaso
*Stachytarphota indica	False Verbana	---
Thespesia populnea	---	Banalo
Thevetia peruviana	Be Still Tree	---
Wedelia biflora	---	Masigsig

variegatum), Jatropha curcas, and tangantangan (Leucaena leucocephala). On the beach, is the medium sized strand tree Messerschmidia argentea, one of the most common beach trees on the island.

Vegetation along the southern sector of the project site is limited to scattered coconut trees which form a natural boundary line. There is very little remaining of what was once a rather well developed limestone remnant. All remaining vegetation was bulldozed when the site was cleared in early 1988.

b. Terrestrial Fauna

Terrestrial fauna at the site is limited to birds and other small forms (Table 13). The only birds observed on the site were Black Drongos (Dicrurus macrocercus harterti), Eurasian Tree Sparrows (Passer montanus saturatus) and a few White Terns (Gygis alba candida). No Philippine Turtle Doves or Yellow Bitterns were observed on the site, although it is likely that they utilize the area on a limited basis. Information from the Division of Aquatic and Wildlife Resources (AWR), as well as from other ornithologists, indicates that no native forest birds are found along the East Agana Bay area. The FY 1986 report of the AWR states that native forest birds are now primarily restricted to northern Guam, centered around Northwest Field and portions of Andersen Air Force Base. One native species that could be found in the project area is the Yellow Bittern (Ixobrychus sinensis) which is found in savannah and secondary forests over the entire island. However, no bitterns were observed during surveys conducted for this study.

Shorebirds are seasonally found along Agana Bay. Most shorebirds are migratory and leave Guam by early May and don't return until early September. Small resident populations of Golden Plover (Pluvialis dominica fulva), Gray-tailed Tattler (Heteroscelus brevipes) and Whimbrel (Numenius phaeopus variegatus) stay through the summer. The indigenous Reef Heron (Egretta s. sacra) is found year-round on Guam.

Table 13. Checklist of terrestrial fauna observed or known to occur in the vicinity of the project site including Alupat Island. *Denotes fauna observations on Alupat Island. (E) observed but expected to occur.

Species	Common Name	Chamorro Name
AVIFAUNA		
Arenaria i. interpres*	Ruddy Turnstone	Dulili
Dicrurus macrocercus harterti	Black Drongo	Sali Taiwan
Egretta s. sacra*	Reef Heron	Chuchuko
Gygis alba candida	White Tern	Chunge
Heteroscelus brevipes	Gray-tailed Tattler	Dulili
Ixobrychus sinensis (E)	Yellow Bittern	Kakkak
Numenius phaeopus variegatus*	Whimbrel	Kalalang
REPTILES		
Carlia fuscum	Skink	Guali'ek Halom Tano
Emoia caeruleocauda*	Blue-tailed Skink	"
Gehyra sp.*	Gecko	Achiak
Hemidactylus frenatus	Gecko	Guali'ek
Lepidodactylus lugubris*	Mourning Gecko	Guali'ek
Boiga irregularis (E)	Brown Tree Snake	Kolepbla
MAMMALS		
Canis familiaris	Feral Dog	Gal'lagu
Felis catus	Ferl Cat	Katu
Mus musculus (E)	Mouse	Cha'kan Manila
Rattus sp. (E)	Rat	Chaka

Surveys during both early morning hours and periods of low tide during April and May revealed few species of shorebirds. The Golden Plover (Pluvialis dominica fulva) was the only species commonly observed, occurring in areas of short grass, along the beach and in intertidal areas. A single Whimbrel (Numenius phaeopus variegatus), and a few Tattlers (Heteroscelus sp.) and Ruddy Turnstones (Arenaria i. interpres) were also observed along the shoreline and on Alupat Island. No other shorebirds were observed except for a couple of Reef Herons (Egretta sacra) seen on Alupat Island. No rare, threatened or endangered species of birds were observed in the survey area.

Common reptiles such as geckos (Hemidactylus frenatus, Gehyra sp. and Lepidodactylus lugubris), the Blue-tailed Skink (Emoia caeruleocauda) and common skink (Carlia fuscum) were observed. Although not actually observed, it is very likely that shrews, mice and rats inhabit the vegetated, wooded and beach areas as trash and litter are found throughout the survey area. These rodents are likely also found on Alupat Island. The only other mammals that were observed in the area were stray dogs and cats which roam the beach and general area in search of food.

c. Endangered Species

Most of Guam's native forest birds are considered threatened or endangered species and several are listed in the federal register as endangered on the island of Guam. No endangered species of birds are found within the proposed project area nor has any portion of the site been designated as critical habitat for any threatened or endangered species. No terrestrial species of flora or fauna found within the project site are listed as threatened or endangered.

2. Marine Flora and Fauna

a. Intertidal/Nearshore Zone

- Marine Plants- Four of the five divisions of marine plants were observed or are known to occur in the intertidal/nearshore zone of the project site. The only division absent is the Phaeophyta (brown algae). Enteromorpha intestinales is the most conspicuous marine plant within this zone growing in thick mats along the shoreline, particularly where freshwater enters the bay (northern sector). This alga occurs as thick mats along Tumon Bay and is considered an annoyance by hotel owners who remove it regularly. The seagrass (Enhalus acoroides) is found clumped within the intertidal/nearshore zone and in isolated areas within the central sector. Refer to Table 14 for a complete checklist of marine plants observed or known to occur within this reef zone.

- Corals- No live corals were observed in the intertidal/nearshore zone within the project site. A review of the literature (Randall and Eldredge, 1974) confirms our observations (Table 15). Corals are absent from this zone because of long periods of desiccation during low tides, higher temperature of water related to shallow water levels over all tidal conditions. Other reasons include lack of hard pavement upon which corals can attach and grow, and lowered salinity related to freshwater runoff from stormwater and lens seepage into the intertidal/nearshore zone.

- Fishes-

Fish fauna was rather depauperate and quite limited along the nearshore and intertidal zone. The most numerous fishes were small forms such as gobies and blennies which often live in burrows and among rubble in very shallow water. Some fishes are also associated with clumps and small stands of various species of marine plants.

A total of 14 species of fish was recorded over three transects within the intertidal/nearshore zone (Table 16). Most species were rare or occasional with only the damselfish, Dascyllus aruanus, commonly observed. Gobies were considered abundant.

-Macroinvertebrates- Ghost crabs (Ocypode sp.) were occasionally observed along the sandy beaches along with many burrowing crabs. Randall and Eldredge (1974) determined the density of the burrowing crabs to be approximately 52/m^2. Amphipods were also quite common on the

Table 14. Checklist of marine plants observed or known to occur in the vicinity of the project site. Relative abundance: (A) Abundant, (C) Common, (O) Occasional, (R) Rare, (X) denotes observations from the literature.

SPECIES	Intertidal/Nearshore	Inner Reef-flat	Coral Zone	Outer Reef-flat	Reef Margin	Reef Front
ALGAE						
Acanthophora spicifera			X			
Actinotrichia fragilis			X	X		
Amphiroa fragilissima			X	O	X	X
Avrainvillea obscura		O				
Boodlea composita		C	X			
Bryopsis pennata				O	X	X
Caulerpa racemosa			X	O	X	X
C. sertularioides			X	R		
C. taxifolia				X		
Champsia sp.			X			
Chlorodesmus fasigata					X	X
Desmia horemanni						X
Dictyota bartayresii		C	X			
Enteromorpha intestinales	A	C	X			
Entophyuslis sp.	C					
Galaxaura sp. 1			X	X	X	X
Galaxaura sp. 2			X	X		
Gedlidiella acerosa				O		
Gracilaria salicornia	R	A	X			
Halimeda macroloba		C	X			

Table 14. continued.

		I/N	IRF	C	ORF	RM	RF
H. opuntia		C	C	X	O		
Hypnea sp.					X		
Jania capillacea				X	C	X	X
J. decussato-dichotoma				X	X	X	
Lobophora variegata				X			
Microcoleus lyngbyaceus			C	X	O		
Neogoniolithon frutescens				X	X		
Padina minor				X			
P. tenuis				X			
Polysiphonia sp.				X			
Porolithon onkodes					C	X	
P. gardineri				X	X	X	
Ralfsia pangoensis		O			X		
Sargassum cristaefolium			O	X			
S. polycystum				X			
Schizothrix calicola					O		
S. mexicana			C				
Sphacelaria tribuloides					X		
Spyridia velasquezii			O				
Turbinaria ornata				X	O	X	X
Valonia fastigiata				X			
ANGIOSPERMS (Marine)							
Enhalus acoroides		R	R	X	X		
Halophila minor							
TOTALS							
Divisions	**5**	**4**	**4**	**4**	**4**	**3**	**3**
Genera	**32**	**7**	**11**	**24**	**17**	**8**	**8**
Species	**41**	**7**	**12**	**30**	**21**	**10**	**8**

Table 15. Checklist of corals observed or known to occur in the vicinity of the project site. Relative abundance: (A) Abundant, (C) Common, (O) Occasional, (R) Rare, (X) denotes observations from the literature.

Species	Intertidal/Nearshore	Inner Reef-flat	Coral Zone	Outer Reef-flat	Reef Margin	Reef Front
Acanthastrea echinata						X
Acropora aspera		X	X	O		
A. convexa				C	X	
A. nana				O	X	
A. nasuta				O	X	X
A. palmerae					X	
A. surculosa				X	X	
Astreopora myriophthalma						X
Favia pallida					X	X
Favites complanata					X	X
Goniastrea retiformis			X	O	X	X
Heliopora coerulea			X		X	X
Leptastrea purpurea			X		X	X
L. transversa					X	X
Leptoria gracilis					X	X
Montipora elschneri					X	X
M. lobulata						X
M. tuberculata						X
M. verrilli					X	X
Pavona clavus						X
P. decussata		R	X			

Table 15. continued.

		I/N	IRF	C	ORF	RM	RF
P. frondifera				X			
P. (P.) obtusata				X			
P. varians						X	X
Platygyra rustica							X
P. sinensis							X
Pocillopora brevicornis						X	
P. damicornis			R				
P. setchelli						X	X
Porites australiensis							X
P. cocosensis				X			
P. compressa			X	X	O		
P. lobata						X	X
P. lutea			R	X	C	X	X
P. (S.) iwayamaensis							X
Porites sp.						X	X
Psammocora contigua				X	O	X	
P. nierstraszi				X			
Stylarea punctata			X	X			
Stylocoeniellia armata				X	X	X	X
Stylophora mordax						X	X
TOTALS							
Genera	**18**	**0**	**5**	**9**	**5**	**15**	**16**
Species	**41**	**0**	**6**	**14**	**10**	**24**	**25**

Table 16. Relative abundance of fishes observed or previously reported in the vicinity of the project site. A=Abundant, C=Common, O=Occasional, R=Rare. (X)=previously reported (Randall and Jones, 1974).

Family/Species	Zone Intertidal Nearshore	Inner Reef-flat	Outer Reef-flat
ACANTURIDAE (Surgeonfish)			
Acanthurus mata	O	O	R
A. nigrofuscus	-	-	X
A. triostegus	-	-	O
APOGONIDAE (Cardinalfish)			
Apogon novemfasciatus	O	O	O
Cheilodipterus quinquelineatus	-	R	O
ATHERINIDAE (Silversides)			
Unidentified silversides	-	O	-
BALISTIDAE (Triggerfish)			
Rhinecanthus aculeatus	R	-	O
BLENNIIDAE (Blennies)			
Petroscirtes mitratus	-	-	X
Salarias fasciatus	O	R	X
Unidentified Blennies	O	O	O
BOTHIDAE (Flounders)			
Bothus mancus	-	-	X
CHAETODONTIDAE (Butterflyfish)			
Chaetodon auriga		R	R
C. citrinellus			O
C. ephippium		R	X

Table 16. Continued

Family/Species	Intertidal Nearshore	Zone Inner Reef-flat	Outer Reef-flat
C. lunula	-	-	R
C. lineolatus	-	-	R
Heniochus acuminatus	-	-	R
GOBIIDAE (Gobies)			
Amblygobius albimaculatus	R	O	O
Oplopomus oplopomus	-	-	X
Unidentified Gobies	A	C	C
HOLOCENTRIDAE (Squirrelfish)			
Flammeo sammara	-	-	R
Myripristis sp.	-	-	R
LABRIDAE (Wrasses)			
Anampses caeruleopunctatus	-	-	X
Bodianus axillaris	-	-	X
Halichoeres margaritaceus	-	-	X
H. trimaculatus	-	O	O
Hemigymnus melapterus	-	-	X
Labroides dimidiatus	-	-	X
Stethojulis bandanensis	-	O	O
Thalassoma hardwickei	-	-	R
LETHRINIDAE (Emperors)			
Lethrinus harak	-	O	O
Lethrinus sp.	-	-	X
LUTJANIDAE (Snappers)			
Lutjanus fulvus	-	-	O

Table 16. Continued

Zone Family/Species	Intertidal Nearshore	Inner Reef-flat	Outer Reef-flat
MUGILIDAE (Mullet)			
<u>Mugil cephalus</u>	-	-	X
MULLIDAE (Goatfish)			
<u>Mulloidichthys flavolineatus</u>	R	-	R
<u>Parupeneus barberinus</u>	-	O	O
<u>P. poryphyreus</u>	-	-	O
<u>P. trifasciatus</u>	-	-	X
NEMIPTERIDAE (Breams)			
<u>Scolopsis cancellatus</u>	-	-	O
OSTRACIONTIDAE (Boxfish)			
<u>Ostracion meleagris</u>	-	-	X
POMACENTRIDAE (Damselfish)			
<u>Abudefduf leucozonus</u>	R	-	R
<u>A. septemfasciatus</u>	-	-	O
<u>A. sexfasciatus</u>	O	C	C
<u>Chromis caerulea</u>	-	-	C
<u>Chrysiptera glaucus</u>	-	R	X
<u>C. leucopomus</u>	-	O	R
<u>Dascyllus aruanus</u>	C	O	A
<u>Pomacentrus pavo</u>	-	R	O
<u>Stegastes nigricans</u>	O	-	-
SCARIDAE (Parrotfish)			
<u>Scarus lepidus</u>	-	-	X
<u>S. sordidus</u>	-	-	X

Table 16. Continued.

Family/Species	Zone Intertidal Nearshore	Inner Reef-flat	Outer Reef-flat
SCORPAENIDAE (Scorpionfish)			
Synonceia verrucosa	-	R	-
SIGANIDAE (Rabbitfish)			
Siganus spinus	-	-	O
SYNGNATHIDAE (Pipefish)			
Corythoichthys intestinalis	-	O	O
TETRAODONTIDAE (Puffers)			
Canthigaster solandri	R	O	C
Arothron meleagris	R	-	-
ZANCLIDAE (Moorish Idol)			
Zanclus cornutus	-	-	X
Total Species Per Zone	14	22	53

beaches and within the intertidal/nearshore zone. Large concentrations of amphipods were particularly evident in the vicinity of beach junk and _Enteromorpha_ mats. With the exception of the thick _Enteromorpha_ mats, flora and fauna within the intertidal/nearshore zone around Alupat Island is similar. Randall and Eldredge (1974) determined that "limpets, chitons, nerites and littorine snails and graspid crabs are found in the sea-level nips and on other rocky surfaces at the north end of East Agana Bay and Alupat Island. Refer to Table 17 for a complete checklist of macro-invertebrates observed or known to occur within the intertidal/nearshore of the project site.

b. Inner Reef-Flat Platform Zone

- Marine Plants- The _Enteromorpha_ community which dominates the intertidal/nearshore zone diminishes in a seaward direction and is nearly absent on the inner reef-flat zone. All five divisions of marine plants were observed or are known to occur in this reef-flat zone, including 12 species of 11 genera (Table 14). The most abundant alga is _Gracillaria salicornis_ which forms numerous, hollow, dome-shaped growths that are overgrowing and killing living corals further out toward Alupat Island. Two species of algae, _Caulerpa racemosa_ and _C. taxifolia_, form extensive mats several meters in diameter within this reef zone. Other clump-forming algae include _Dictyota_ sp., _Acanthophora spicifera_ and _Halimeda opuntia_. Common species occurring in this zone include _Boodlea composita_, _Dictyota bartayresii_, _Halimeda macroloba_, _Microcoleus lyngbyaceus_ and _Schizothrix mexicana_, the last two being indicator organisms of the division Cyanophyta (blue-green algae). Conspicuous patches of _Halimeda macroloba_ and _Avrainvillea obscura_ are found wherever accumulations of sand are present. Refer to Table 11 for a complete checklist of marine plants observed or known to occur in this reef zone of the project site.

-Corals- Although no live corals were observed on transects run for in this zone, live coral does exist within the area. Six species of coral representing five genera occur in this region of the reef-flat (Table 15).

Table 17. Checklist of Macro-invertebrates observed or known to occur in the vicinity of the project site. Relative Abundance: (A) Abundant, (C) Common, (O) Occasional, (R) Rare. (X) denotes observations from the literature.

	Intertidal/Nearshore	Inner Reef-flat	Coral Zone	Outer Reef-flat	Reef Margin
MOLLUSCA					
Ctene bella	-	C	X	-	-
Cymatium nicobaricum	-	-	X	-	-
Cymatium sp.	-	-	X	-	-
Cypraea moneta	-	X	X	X	X
Dolibrifera dolibrifera	-	-	X	-	-
Drupa sp.	-	-	X	-	-
Gafrarium pectanatum	-	A	-	-	-
Gibberillus gibberillus	-	X	X	-	-
Littorina sp.	X	-	-	-	-
Mitra sp. 1	-	X	X	-	-
Mitra sp. 2	-	X	X	-	-
Mytilus septifer	-	-	-	X	-
Natica sp.	-	X	X	X	-
Nerita bensoni	-	-	X	-	-
N. plicata	X	-	-	-	-
Otopleura sp.	-	-	X	-	-
Pinctada margaritifera	-	X	X	-	-
Pinna muricata	-	X	X	-	-
Pollia undosa	-	X	X	-	-
Pupa pupa	-	X	-	-	-

Tabel 17. Continued

	I/N	IRF	C	ORF	RM
"Pyramedellid" sp.	-	-	X	-	-
Quidnophagus palatum	-	C	X	-	-
Terebra maculata	-	X	X	-	-
Tellina sp.	-	X	X	-	-
Tridacna maxima	X	X	X	-	-
Trochus niloticus	-	-	-	X	-
Vasum turbinellum	-	-	X	-	-
"Vermetid" sp.	-	-	X	X	X
Volvetella sp.	-	-	X	-	-
ANNELIDA					
Eurythoe sp.	-	-	X	X	-
Sabellastarte sp.	-	-	X	X	-
Spirorbis sp.	-	-	X	X	X
Unidentifiable spp.	-	X	X	X	-
INSECTA					
Halobates sp.	X	-	-	-	-
CRUSTACEA					
"Amphipod" sp.	C	-	-	-	-
"Balanid" sp.	-	-	-	X	-
Calappa calappa	-	X	X	-	-
Dardanus sp.	-	-	-	X	-
Enoplometopus sp.	-	-	X	-	-
Grapsus grapsus	C	-	-	-	-
"Grapsid" spp.	-	-	-	X	-
"Ocypodid" sp.	X	-	-	-	-
Percnon sp.	-	-	X	-	-
"Porcellanid" sp.	-	-	-	X	-
"Portunid" sp.	-	C	C	C	-
"Stomatopod" sp. 1	-	O	-	X	-
"Stomatopod" sp. 2	-	O	-	-	-
"Stomatopod" sp. 3	-	-	O	-	-

Table 17. Continued.

	I/N	IRF	C	ORF	RM
ECHINODERMATA					
Acanthaster planci	-	-	-	-	X
Actinopyga mauritiana	-	-	X	A	X
A. miliaris	-	-	X	X	X
Bohadschia argus	-	-	X	X	X
Diadema savignyi	-	-	X	X	-
D. setosum	-	-	X	X	-
Echinometra mathaei	-	-	X	X	-
Holothuria atra	-	X	X	A	-
H. edulus	X	-	-	A	-
H. leucospilota	-	X	X	A	-
H. miliaris		-	X	X	A
Linckia laevigata	-	-	X	C	-
Polyplectana kefersteini	-	-	X	-	-
Stichopus chloronotus	-	-	X	-	-
Tripneustes gratilla	-	-	X	X	-

Pocillopora damicornis, Acropora aspera and Porites lutea are the most conspicuous corals within the inner reef-flat zone. However, these species rarely occur because the area continues to be dominated by a loose sandy substrate. Randall and Eldredge (1974) determined that live coral represents less than two percent throughout this reef-flat zone with the exception of a coral rich area near Alupat Island (Figure 4).

Corals are particularly absent from the inner reef-flat except in the man-made channel along the causeway. Here, deeper water collects larger boulders giving corals the water depth and hard substrate adequate for coral growth.

-Fishes-

Fish fauna in the inner reef-flat was more diverse than the inshore zone with a total of 22 species recorded over three transects (Table 16). The substrate in this zone has little coral or other relief and most fish were associated with isolated rubble, debris, metal objects and seagrass (Enhalus) clumps scattered throughout the area. A few ornamentals such as butterflyfish, damselfish and wrasses appeared in this zone although none were common. No species were abundant in the area although gobies and the damselfish, Abudefduf sexfasciatus ,were commonly observed.

A few food fish were encountered in the inner reef-flat zone although they were few in number and small in size. Some species observed include the surgeonfish, Acanthurus mata, the emperor, Lethrinus harak and the goatfish, Parupeneus barberinus.

-Macro-invertebrates- Conspicuous macro-invertebrates within the inner reef-flat include polychaetes annelids and holothurians. Fairly large concentrations of Cerithium sp. form bands in the mid to outer part of the inner reef-flat sand zone. Randall and Eldredge (1974) made the same observation but did not have a reason for these concentrations. Most likely the concentration of Cerithium sp. is related to water chemistry which attracts the animal to a particular food source. This animal is also scattered more randomly throughout the zone. Burrowing organisms abound throughout the inner reef-flat zone. These consist of numerous tube worms, anemones, sipunculans and a variety of bivalve mollusks.

The most abundant bivalve in this reef-flat zone is Gafrarium pectanatum. Common bivalves in this zone include Quidnipagus palatum and Ctena bella. Many sand-associated mollusks and crustaceans are found in this reef flat zone which include numerous portunid and stomatopod burrows. Refer to Table 17 for a checklist of macroinvertebrates observed or known to occur in the area.

c. Outer Reef-Flat Platform Zone

-Marine Plants- All five divisions of marine plants were observed or are known to occur on the outer reef-flat platform of the project site. Although algae represented slightly less than 10 percent of the substrate cover (Table 11), diversity was quite good. Twenty one species of algae representing 17 genera were observed in this zone on the reef-flat (Table 14). The most common species of algae are the reef building coralline algae Porolithon onkodes, Jania capillacea, Microcoleus lyngbyaceus, Halimeda opuntia and H. macroloba and Schizothrix calcicola. The seagrass Enhalus acroides was observed in very small and isolated patches on the outer reef-flat zone.

-Corals- The outer reef-flat zone is one of the most diverse regions of the reef in terms of corals. Ten species of coral representing five genera were observed or are known to occur on this reef-flat zone (Table 15). The most common species of corals occurring on this reef-flat zone are Acropora aspera, Porites lutea and P. compressa. Psammocora contigua, Acropora nasuta and A. nana were observed occasionally on this reef-flat zone.

The richest coral development within the project site is found on the outer reef-flat zone to the northeast of Alupat Island. This coral zone (Figure 4) is approximately 18.4 acres (74,320m^2) in size and is dominated by one species, Pavona frondifera. This coral-rich zone should be protected from any dredging activity.

-Fishes-

The outer reef-flat contains the greatest diversity and numbers of fishes found within the project site. A total of 53 species have been reported from this zone including 34 species recorded during this survey (Table 16). Fish were not only more numerous but also larger in size with more food species occurring here.

The damselfish, Dascyllus aruanas, was abundant in this zone while Abudefduf sexfasciatus, Chromis aerulea the puffer, Canthigaster solandi and gobies were commonly observed. Some of the food fish found in this area include surgeonfish, squirrelfish, emperors, snappers, mullet, goatfish, parrotfish and rabbitfish.

The north and northwestern portions of the study site contain areas of live coral. A few locations have extensive live coral, primarily Porites and Pavona, approaching 80-90% cover in some areas (Table 11). Much of the fish fauna can be found in these live coral areas, especially butterflyfish (5 species observed), wrasses (8 species observed or reported) and damselfish (7 species observed).

-Macro-invertebrates- The most conspicuous macro-invertebrates observed or known to occur on the outer reef-flat zone are the sea cucumbers such as Holothuria atra, H. leucospilata, H. edulis, Actinopyga mauritiana and A. miliaris which are all abundant. Adults of the blue starfish, Linckia laevigata, were commonly observed throughout the outer reef-flat zone and were particularly abundant in the channel near Alupat Island. Sea urchins of the genera Diadema and Echinometra were found on the rocky boulder substrate and within the coral community of the outer reef-flat zone. Refer to Table 17 for a checklist of conspicuous macro-invertebrates observed or known to occur on this sector of reef-flat.

d. Endangered Species

Both the Green Sea Turtle (Chelonia mydas) and Hawksbill Turtle (Eretomochelys imbricata) are listed on the federal Endangered Species List. During this survey, no sea turtles were observed in East Agana Bay nor were there any signs of nesting on the beaches. There are no recent records of sea turtles being harvested or observed on the reef-flat within Agana Bay. Usage of Agana Bay by turtles is most likely infrequent or accidental and it is not considered to be critical habitat for survival of the species. No other species of marine flora or fauna occurring in Agana Bay are considered to be locally threatened or endangered.

3. Fisheries

a. Subsistence and Sport Fishing

Agana Bay is an important area for both subsistence and sport fishing activities. Individuals and groups are regularly observed using thrownets, gill nets, surround nets, hook and line and spears within the bay. Catches of seasonal juvenile rabbitfish (manahac) also occur along the inshore areas throughout Agana Bay.

The Guam Division of Aquatic and Wildlife Resources (AWR) has been conducting monthly inshore fisheries surveys along Guam's shoreline for many years. Survey area of Region is East Agana Bay. Data are collected by fishing method, species taken and total weight of each species harvested. An attempt to obtain data from AWR on use and total harvest in Agana Bay was unsuccessful. It was not possible, according to AWR, to break down their computer-stored data by area and maintain a reasonable level of confidence in the results.

Islandwide inshore fishing methods resulted in a total annual harvest of 171 metric tons for FY 1986 (AWR, 1986). Goatfish (Mullidae) accounted for almost a third of the total finfish harvest at 30.2 percent, followed by surgeonfish (Acanthuridae) at 16.5 percent and triggerfish (Balistidae) at 12.8 percent. Hook and line was by far the most popular fishing method accounting for approximately 60 percent of total participation, followed by cast net at 13.7 percent and gill net at 12.5 percent. Local and subsistence fishermen can frequently be seen walking the shoreline of Agana Bay with throw nets (talaya). Spearfishing and surround netting are more common further out in the bay in deeper water and near areas of coral growth. Limited harvesting of bivalves (clams) also occurs within the intertidal and nearshore zone of Agana Bay.

b. Seasonal Fisheries

The seasonal harvest of certain juvenile fishes is widely anticipated by local fishermen. These include juvenile goatfish (tiao) harvested primarily in March and April, juvenile rabbitfish (manahac) harvested primarily from April thru June and juvenile jacks (e'e') which are usually harvested during July and August.

Data collected by AWR indicate that 6.6 metric tons of manahac were harvested in inshore waters during FY 1985. This harvest of juvenile rabbitfish was unusually low during FY 1986 with a total of only 3.8 metric tons taken. Recent data provided by AWR give harvest data for May and June 1988. During a six-day period from May 10-15, a total of 931 participants harvested 14,618 kg of manahac island-wide. Fishing in East Agana Bay accounted for 370 participants (39.7%) and a harvest of 2,966 kg (20.3%). During a six-day harvest period from June 7-12, a total of 510 participants landed a total of 14,382 kg of manahac. In this case, East Agana Bay accounted for 295 of the participants (57.8%) and 8,499 kg of fish (59.1%). For the two-month period, East Agana Bay accounted for 46.1% of the participants and 39.5% of the manahac catch.

Harvesting of manahac, tiao and e'e' is known to take place at general locations around the island although Agana Bay and Merizo are two of the more important harvesting locations. The prolific filamentous alga Enteromorpha clathrata, found in the intertidal zone along Agana Bay, especially near stormwater outfalls, is known to be a preferred food for the juvenile rabbitfish.

These seasonal juvenile fish runs are highly predictable. The manahac, primarily Siganus spinus and S. argenteus, first appear on the reef-flats a few days before or after the last quarter moon in April and May. Occasionally, a third run occurs in June and a fourth in late October or early November, again during the last phase of the moon (Kami and Ikehara, 1976).

IV. ENVIRONMENTAL IMPACT OF THE PROPOSED PROJECT

A. Habitat Modification and Loss

Dredging a 6.4 acre area in East Agana Bay will cause habitat modification with resultant loss of shallow, sometimes exposed, sand/rubble/algal substrate. A zone will be created by this project which will average 4.5 ft deeper than what now exists. The proposed dredging plan will create a deeper marine habitat which will eventually recolonize with similar species found in the area now. No net loss of marine habitat will occur, with a slightly deeper area replacing the shallow water habitat now found in the area.

Preliminary investigations indicate that it would be more environmentally sound to leave, untouched, a narrow band along the shore in the intertidal zone. This narrow band, approximately 20-30 ft wide, would not be dredged and would serve as a buffer between the bay and the beach. This would also keep a large portion of the intertidal zone intact and would therefore have less impact on shorebirds and seasonal manahac runs.

B. Turbidity and Sediment Transport

1. Turbidity During Construction

Regardless of the methodology chosen to dredge East Agana Bay, some increase in turbidity and sedimentation will occur on the reef-flat during construction. High levels of turbidity and sediment loading has a primary impact on corals and other sessile forms of marine life. Fishes and other mobile forms can swim or move out of the area until more favorable conditions return. Both the degree of suspended sediments as well as the cumulative length of time of the dredging process are important factors in determining the impact on the marine environment. Dredging methodology and spoil removal techniques are major considerations in attempting to determine the extent of turbidity. Other factors include bottom topography, current direction and velocity and use of silt control devices such as berms or silt curtains.

mollusks will be affected

Coral appears to be the primary resource to be protected during the dredging period. The majority of the live coral is located in the northwest corner of the project site in the outer limits of the dredging zone. Nearshore currents in the area generally flow parallel to shore. Under normal conditions, silt-laden water would not move towards the outer reef. However, there are areas of rich coral growth in close proximity to the proposed dredging. These areas of live coral, identified in this report, must be protected from potential adverse impacts of siltation.

The best way to control the potential impact of turbidity on the marine environment is to minimize the production of silt and suspended sediments. One of the most desirable methods is to use a suction dredge which lifts loose sand, sediment and rubble by air/water suction and transports it through a pipe to a bermed settling basin onshore for dewatering. This method produces less siltation around the work area since all materials are sucked into the pipe with surrounding water and carried away. This would be the preferable dredging method for those areas with loose sediments. Hard pavement or larger boulders would have to be removed by clamshell bucket or a backhoe at low tide and would likely require the construction of temporary causeways.

Silt curtains, which enclose the turbid water until settling can occur, are effective barriers to siltation. They can also be used to divert a silt plume around an area or to encircle a particularly important resource. Silt curtain use in this region of East Agana Bay would be an excellent choice of silt protection because of the low velocity of currents.

2. <u>Predicted Sediment Transport After Dredging</u>

Immediately following the completion of dredging, the beach and offshore areas will first adjust to reach an equilibrium state with the new current and wave conditions. As discussed in Chapter III-B-6, the nearshore wave height is estimated to increase slightly during distant typhoon events associated with strong onshore winds. Little to no change in wave size is expected during typical prevailing conditions. It is impossible to accurately predict how the changed wave climate will affect the conditions on the beach slope in terms of sorting and winnowing of exposed sediments by waves, currents and tide. All sediment particles that are finer than that which would be stable in the new wave climate, will be transported to areas of greater depth and lower wave energy. Silt and clay will stay in suspension and will be dispersed outside the reef-flat. This process is typical of beach nourishment projects.

Because typical prevailing wave heights are not expected to change, it is reasonable to assume that the beach characteristics after beach nourishment, will be similar to the existing equilibrium beach characteristics during typical prevailing conditions.

During storm or large wave conditions the nearshore wave climate is estimated to increase as a result of the changed bottom. It is not possible to quantitatively predict how the changed wave climate will effect sediment transport and beach stability. However, when wave heights and energy are increased, sediment movement at the shoreline will also increase. The changed conditions are anticipated to be localized to the shoreline in the immediate vicinity of the proposed dredging. Since beach nourishment is planned in this area, some or most of the potential increase in erosion will be mitigated.

C. Circulation, Flushing and Water Quality

Preliminary investigations indicate that water quality and circulation should improve as a result of the proposed dredging. By dredging the proposed area, flushing will be increased. The problem of stormwater runoff from drains at Dungcas Beach, NAS and Island Imports will be somewhat alleviated, thus improving the existing poor water quality.

Bacterialogical contamination within the proposed dredging area periodically exceeds water quality standards. This is, in part, due to an existing causeway which inhibits flow and circulation of water between the outer reef and inner lagoon. Dredging will remove the causeway and promote increased flushing, circulation and mixing in the area. Overall water quality will improve as a result of this action. Sediment transport will not be significantly increased during normal weather conditions.

D. Other Construction Impacts

Shorebirds and other terrestrial wildlife will likely be driven out of the work area during the dredging phase. Construction workers, heavy machinery and increased noise levels will create an atmosphere unacceptable to most animals. Many of the birds and smaller animals will return to the area after the project is completed.

Some beach strand and nearshore vegetation will likely be removed or destroyed as dredging equipment and vehicles move along the bay. Stockpiling of sand (dredged material) will occur along the beach. A suitable location will be chosen and bermed to provide a dewatering basin for the spoil.

Nearby residential and condominium dwellers will also be affected by the increase in noise and activity. The Alupang Condominium Complex lies in close proximity to the proposed project. Proper erosion control measures must be installed to insure the water quality in the area does not deteriorate further. One can expect the present level of water quality to remain unchanged during the dredging process but will improve once the project is completed.

E. Effects on Subsistence, Harvesting and Sport Fishing

Nearshore subsistence fishing and gathering will be impacted by the proposed project. Bivalve mollusks are popular local delicacies which are dug from the shallow waters of Tumon Bay. Many mollusks as well as other burrowing and sessile organisms will be removed during dredging operations.

Subsistence fishing occurs all along East Agana Bay from the shoreline to the outer reef. Rod and reel, throw net (talaya), surround net, gill net and spearfishing have all been observed in the bay. Seasonal runs of the juvenile rabbitfish (manahac) and juvenile goatfish (tiao) have also been recorded in East Agana Bay. Preliminary information suggests that the shallow water fisheries should not be severely impacted if a narrow band of intertidal habitat along the shoreline is left undredged and areas of rich coral are protected. Since there will be no net loss of marine habitat, with some shallow portions of the bay being slightly deepened, some nearshore fisheries may eventually be enhanced.

Subsistence fishing will be directly impacted by the increase in tourists and recreational enthusiasts using the deepened area. Dredging will create an atmosphere which will promote the use of motorized jet skiis, paddleboats and windsurfers. This will undoubtedly interfere with the local residents ability to fish. Spearfishing may need to be regulated to a specific area so as not to interfere with recreational water sports. Areas for use of motorized thrill-craft will also have to be clearly marked so that safe multiple uses of the area are possible.

F. Effects on Recreational and Scenic Resources

Overall impacts on recreational and scenic resources should be positive. The proposed project will provide an area close to the beach where local residents and tourists can swim and recreate over all tide cycles all year long. Water activities in this area are presently restricted since the water is much too shallow during low tides to swim or snorkel. This deepened zone will also allow for increased usage for windsurfers, paddleboats and other recreational equipment. Improvements in water quality due to upgrading the sewer and stormwater systems will benefit recreational users and fishermen, as the project should greatly reduce the frequency of polluted conditions now common in the north part of East Agana Bay.

Upon completion of the proposed project, several problems will need to be addressed. User conflicts will arise between swimmers, snorkelers, fishermen, windsurfers and thrillcraft operators. Several user groups will need to be separated and regulations will need to be administered.

Tourists visiting the island will expect to be able to swim or use jet skiis at will, and locals will expect to be able to fish at leisure. Careful consideration must be taken to respect the interests of all user groups involved.

Dredging will create an atmosphere for a variety of activities in the area. This will promote tourism and attract many to the recreational facilities provided by the hotel.

The scenic beauty of the area will be dramatically increased. Dredging will ultimately provide an asthetically pleasing view for hotel guests and Alupang Condominium residents. Water quality will greatly improve, thus attracting many tourists to the hotel. Condominium residents value their "ocean view" and units will be in great demand.

G. Other Positive Impacts

Tourism is Guam's primary industry. As more facilities are built, the number of off-island tourists will increase dramatically. Tourism generates millions of dollars for the island economy annually. Dredging in the proposed area will help the tourist industry by offering a hotel with a breathtaking view of the ocean. This is what is expected when vacationing on a tropical island. By offering excellent facilities to tourists, Guam's economy will surely increase significantly. This will create employment for the local population and tremendous income for the island.

V. ALTERNATIVES TO THE PROPOSED PROJECT

A. No Action

The alternative of no action would result in maintaining present conditions along the nearshore area of East Agana Bay. Most of the northern bay would remain so shallow that swimming and other recreational activities would be severely limited or impossible during low tides. This condition will only get worse over the years since storm drains continue to silt in the bay. Water quality would continue to be degraded, with frequent increased levels of fecal coliform bacteria. Flushing and circulation would be hampered by the shallowness of the reef-flat and existence of an old sand/sediment causeway.

B. Alternate Site Selection

An alternate site for the proposed project is not a viable alternative. It would not make sense to dredge a swimming zone in any other location since the hotel is planned on the shore opposite this region.

C. Plan Modification

Modification to the proposed plan is possible depending upon the nature and extent of the modifications. The dredge zone could be reduced in length or width or undredged zones could remain untouched where there are resources to be protected.

VI. Mitigation and Environmental Protection Measures

Several environmental protection and mitigation measures should be implemented during the design and dredging phases of the project. Some potential measures might include the following.

1. Encircle the dredge area with a silt curtain to contain sediments and reduce turbidity outside the work zone.

2. Limit dredging to areas of sand and rubble only. Avoid rich coral areas such as those found at the extreme north end of the bay. Protect coral areas by proper use of silt curtains.

3. Transplant some of the larger coral heads that would be in the way of the dredging zone.

4. Consider building concrete fishing platforms along the outer reef-flat to mitigate potential loss of nearshore and subsistence fishing. This action if deemed appropriate, would be coordinated with the appropriate local regulatory agencies.

5. Leave a 20-30 ft wide band of intertidal habitat seaward of the beach that will not be dredged. This will reduce potential impacts to shorebirds and shallow water marine life and provide a buffer between the deeper dredged zone and the beach.

6. Transplant any seagrass (Enhalus) beds that would be dredged into adjacent shallow water habitat.

7. Coordinate dredging operations with the Dept. of Agriculture, Aquatic and Wildlife Resources Division, to protect juvenile rabbitfish (manahac) runs known to occur in the bay. These runs are seasonal and highly predictable and no dredging or other in-water work should occur for a few days before and a few days after these events.

8. Require the preparation of an Environmental Protection Plan (EPP) prior to initiating work on the proposed dredging project.

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