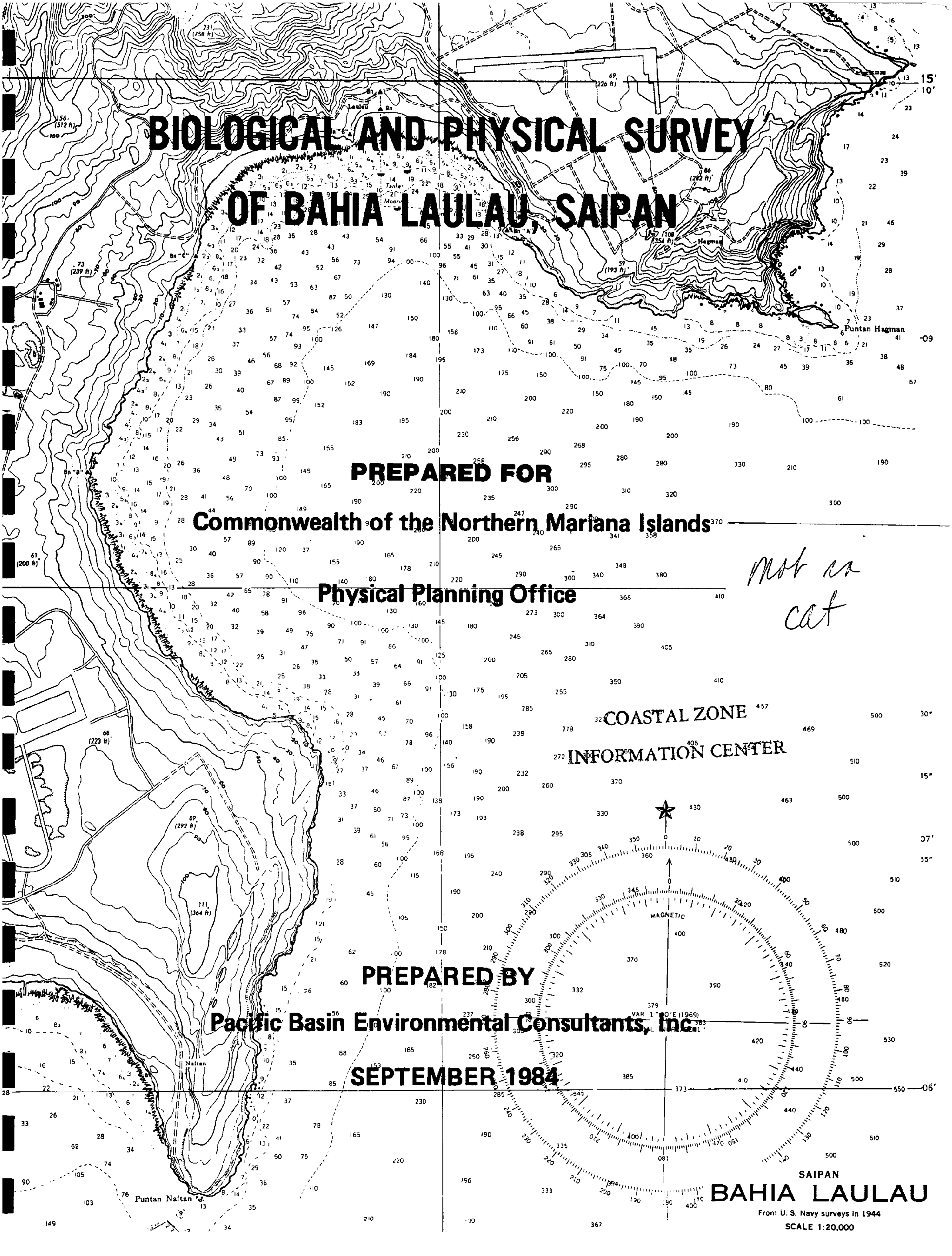
BIOLOGICAL AND PHYSICAL SURVEY OF BAHIA LAULAU, SAIPAN



PREPARED FOR

Commonwealth of the Northern Mariana Islands

Physical Planning Office

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PREPARED BY

Pacific Basin Environmental Consultants, Inc.

SEPTEMBER 1984

FINAL REPORT

BIOLOGICAL AND PHYSICAL SURVEY OF BAHIA LAULAU, SAIPAN

Prepared for

Commonwealth of the Northern Mariana Islands
Planning/Energy Office
Under a Grant from the
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Prepared by

Pacific Basin Environmental Consultants, Inc.

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SUMMARY OF FINDINGS

I. HISTORIC INFORMATION

Historically, Bahia Laulau affords one of the better opportunities to examine ancient Chamorro villages, latte stones, fishing areas and burial grounds. Two major ancient historic sites exist in the vicinity of Bahia Laulau where numerous artifacts have been unearthed. Additionally, the area was used for Japanese and U.S. military purposes during the war as a lee-shore anchorage, military staging site and oil depot. Remnants of military structures can still be seen in the area.

II. PHYSIOGRAPHY AND SHORELINE SITE DESCRIPTIONS

The immediate coastal region within Bahia Laulau is variable and includes low wooded terraces of limesand, recently raised limestone deposits, steep slopes, cliffs and headlands of both older raised limestone and volcanic rocks. Fringing reef platforms of various widths and narrow beaches intermittently border the shoreline.

Site 1 is located along the rugged northeast coastline approximately 800 meters (m) (2,625 ft) west of Hagman Point in a small embayment. A steep volcanic slope forms the northern shoreline and a sheer limestone cliff with a deep concave notch cut at sea level forms the western shoreline.

Site 1a is located in a protected part of the bay approximately 400 m (1,312 ft) northwest of Bapot Point and a narrow subtidal fringing reef platform borders the shore. Intermittently, the cliff face is undercut or notched just above the reef platform.

Sites 2 and 3 are similar in that they are protected from northeast tradewinds and waves and are located in the vicinity of Trinchera Beach where a relatively wide intertidal fringing reef platform borders the shore.

Bioclastic beach deposits, gravel and reef rubble form a narrow sandy beach along the shoreline.

Site 4 is located 1.1 kilometers (0.7 miles) northwest of Dandan Point and is exposed to heavy tradewinds and wave assault. Low cliffs of Marianas limestone form the shoreline. A narrow fringing reef platform borders the shoreline at this site.

III. GEOLOGY

Geologically, Bahia Laulau is indented about half-way into the island perpendicular to the prevailing northeast-southeast trend of the major rock units and topographic features. Thus, it provides a cross-section along which most of the major rock formations and many of the structures, soils and landforms can be viewed and studied.

Site 1 is a very unique and scenic location. There is great geologic diversity, extreme instability of onshore slopes and probably instability offshore due to major faults in the area. There is extreme wave vulnerability to cliffs and headlands, no surface water, fractured and permeable bedrock and a small manganese deposit.

Both Sites 2 and 3 are recreational areas with relatively stable slopes and coastline. Both sites are vulnerable to typhoon swells and flash flooding. Alluvial processes present few sedimentation or drainage problems. However, subsurface porosity may present general construction problems.

Site 4 is an excellent scenic location with a spectacular view of the entire bay and Hagman Point. The area is quite stable and the coastline generally protected from typhoon-driven waves. There are no streams due to a highly porous substrate.

For major on-shore construction of an OTEC facility, Site 4 is the most suitable in that it exhibits the fewest unfavorable geologic constraints. Site 1 is the least favorable construction site since it exhibits the most unfavorable geologic conditions. However, all sites have an abundance of limestone bedrock which is notorious for subsurface permeability and porosity and tends to make it less than favorable for construction from the geologic point of view.

IV. PHYSICAL PARAMETERS

A. Depth and Temperature

Bahia Laulau is a deep bay approximately 731 m (2,400 ft) at the deepest point on a line between Hagman Point and Naftan Point. Slightly deeper depths (823-914 m, 2,700-3,000 ft) exist 1.6 miles offshore on a line 165° (SSE) of the proposed OTEC site on Hagman Point. These depths represent possibly the most significant potential OTEC resource in the world that close to shore.

Temperatures offshore of the proposed OTEC site appear to follow a well defined profile typical in the Western Pacific, i.e., a warm, well mixed surface layer of nearly constant temperature, a thermocline region where temperature declines with increasing depth and a deep cold layer. Temperature decreased from 28.4° C at the surface to 22.5° C at 229 m (751 ft). Between 229 m and 457 m (751-1500 ft) the temperature decreased to 7.4° C. Temperatures at 525 and 550 m (1,723 and 1800 ft) were extrapolated to be 6.4° C and 4.4° C respectively.

B. Currents

There is an overall circular current pattern which exists in Bahia Laulau. A large volume of water enters the southern portion of the bay traveling along the inside contours until it exits at the northeastern opening. It seems that the majority of the water enters the bay from the northeast (prevailing wind direction) and splits apart at Dandan Point in the southern part of the bay. This forms a rather consistent and strong clockwise water pattern within the center of Bahia Laulau. The leading edge of this water mass moves along or near the 100 fathom contour eventually emerging at the northern part of the bay at Hagman Point. Here it enters deeper water and/or merges with the overall water mass moving southeast.

Inside the 100 fathom contour the near-shore water circulation pattern is much more complex and seasonally variable. It is influenced more by the prevailing winds and seas. Data suggest that this current runs counter to the deeper water circulation by following the shoreline. Several small eddies also form in more enclosed areas.

The inshore (reef-flat) current pattern is typical of any reef flat that is influenced by winds and tidal changes. During flood or ebb tides water tends to move towards a channel, cut or low area in the reef. This strong tidal flow usually overpowers the wind-driven water movement unless they happen to be in similar directions.

C. Water Quality

Water quality within the bay is generally excellent. Ten near-shore water samples were evaluated for total and fecal coliform. Samples taken near the northern end of the bay suggest moderately polluted conditions which can be traced to ranches in the vicinity. Most likely, farm animal wastes are being washed down to the bay where total coliform counts show up extremely high. These conditions are not drastic at any time but are more severe than normal conditions following heavy rains.

V. TERRESTRIAL FLORA AND FAUNA

A. Flora

Sixty-four species of terrestrial plants were identified during this survey. All major botanical communities, limestone forests, beach strand, savannah and modified forest are represented in Bahia Laulau. Diversity and species composition of vegetation at Sites 2 and 3 are similar, this being the only major similarity between the four sites examined.

Flora at Sites 1 and 4 is unique compared to Sites 2 and 3. Species composition is low due to intense environmental pressures, i.e., high winds and surf, salt air and rugged terrain. The ground is largely porous limestone which quickly drains all water well below the surface. Compared to Sites 2 and 3 both Sites 1 and 4 are depauperate although a number of different forms do quite well in the adverse conditions.

Sites 2 and 3 are protected from harsh environmental pressures which appears to allow for greater diversity. This is also the site of lush limestone forests located in isolated gullies and/or steep slopes and cliffs. Pemphis acidula (Nigas) is abundant near the ocean.

Sites 2 and 3 also include a ravine community of numerous valleys and gullies. The flora of this community is similar to that found in the limestone forest with a few plants that inhabit wetter areas since water collects in these ravines. One can always find Hibiscus tiliaceus (hibiscus) (Pago), Cycas circinalis (cycad) (Fadang), Areca cathecu (betel-nut palm) (Pugua Machena), Ficus prolixa (banyan) (Nana), several lianas and numerous epiphytes such as ferns.

Flora at Site 4 appears to be the most highly modified within the Bahia Laulau region. The area is dominated by a thick cover of Leucaena leucocephala (tangantangan). Pemphis acidula (Nigas) a scrub-like tree is found in a narrow band along the shoreline with gnarled trunks and twisted roots embedded in the limestone. A few small shrubs stand out here and there but not in great numbers.

Between the rugged coastline vegetation and the thick tangantangan cover is a narrow remnant of a limestone forest. This entire area was most likely a vast limestone forest which stretched from Dandan Point to Unai Laulau.

Beach strand flora is taken to mean those plants most often found growing in the immediate vicinity of the sea. Most of these plants can be found elsewhere on Saipan, however, not as a dominant form like on the strand.

B. Fauna

Birds represented the most abundant type of fauna in the vicinity of Bahia Laulau. A total of 28 species were observed out of 34 species expected to occur in the entire area. All the sites were similar in total number with the exception of Site 4 where only 13 species were observed. The most abundant bird species encountered at the four sites include the Fantail (Chichirika), White-eye (Nossak), Philippine Turtle-dove (Paluman Senesa), Sparrow (Gaga Pale') and Noddy Tern (Fahang). Common species for the bay area include the Bittern (Kakkag), Kingfisher (Sihig), Cardinal Honeyeater (Egigi), Golden Plover (Dulili), Starling (Sali), White Tern (Chunge) and the Reef Heron (Chuchuko).

A number of other vertebrates were observed or are expected to occur in the Bahia Laulau area and these include the following: Three species of rats; Rattus norvegicus (Norway rat), Rattus rattus (roof rat) and Rattus exulans (Polynesian rat); Mus musculns (common mouse); Suncus murinus (common shrew); Canis familiaris (common dog); Felis catus (common cat); Cervus unicolor mariannus (Sambar deer); Pteropus mariannus (Marianas fruit bat); Emoia sp (skink); Emoia cyanura (green-tailed skink);

Anolis carolinensis (anole); Varanus indicus (monitor lizard) and Bufo marinus (marine toad).

VI. MARINE FLORA AND FAUNA

A. Marine Plants

Sixty-nine species of marine algae representing four divisions were recorded from Bahia Laulau. In addition, one species of seagrass, Enhalus acoroides, was recorded. Two narrow fringing reefs (Sites 2 and 3), one reef margin and reef face (Site 2), three shallow submarine terraces (Sites 1a, 2 and 3) and two deeper submarine terraces (Sites 1 and 4) were investigated. A range of habitats including sand floors, reef flat holes, cryptic overhangs, vertical walls and limestone terraces were present at the various sites.

Site 1 is considered extremely depauperate due to the harsh conditions of seas and surf. Site 1a is a calm and quiet bay with luxurient marine life. In general, the variable terrain of Site 2 provided numerous types of habitats for algal species. Site 3 is comparible to Site 2. The algal community at Site 4 is remarkably similar to Site 2 though fewer species were recorded.

Each of the five sites examined in Bahia Laulau presented somewhat different algal communities, largely a function of exposure to the fetch of the open sea and coastal topography. Sites 1 and 4 experience the most regular and severe disturbances due to their direct exposure to windward ground swells. Site 1a is the most protected and Sites 2 and 3 are seasonally variable.

B. Plankton

Analysis of plankton samples for all sites indicate that Sites 1, 3 and 4 had the lowest mean numbers of species with 12, 11 and 12 respectively. Site 2 had the greatest species diversity with an average of 18 species per tow. In terms of total planktonic organisms per tow Site 4 averaged 1,506, followed by Site 3 (1,201), Site 2 (867) and Site 1 (587). These results generally support what would be expected when looking at the current patterns and lack of a reef flat area along the cliffs out to Puntan Hagman. Sites 2, 3 and 4 (particularly Sites 2 and 3) are expected to be rich in plankton considering the current patterns, eddies, shallow areas and extensive reef areas present.

C. Corals

Ninety-eight species of corals representing 34 genera were recorded from the five study sites along the Bahia Laulau embayment. Considerable variation occured in species richness, size distribution, frequency of occurence, density and percentage of substrate coverage between the five sites and around the various zones discriminated at each site.

One of the most noticeable aspects of the coral communities studied at the five sites in Bahia Laulau is their unequal distribution from the inner reef-flat platform to the 10 m (33 ft) depth contour on the fore-reef slope. Some reef zones have no corals at all while other areas support communities ranging from a few widely scattered colonies and species (reef-flat platform at Sites 2 and 3) to regions where the substrate is dominated by a relatively rich diversity of species (fore-reef slope at Site 2). Much of the regional variation found in the community structure of corals on the reef-flat platform zones is attributable to exposed platforms during low spring tides.

Surface coverage on non-scoured substrates at Site 1 was estimated to range from 10-30 percent. Predominate coral species include seven in the family Pocilloporidae, ten in the family Acroporidae and nine in the family Faviidae. Corals from Site 1 that were not observed at other sites in Bahia

Laulau include Pocillopora ankeli, Scapophyllia cylindrica and Stylaster profundiporus.

The only significant deposits of sediments consisted of poorly sorted mixtures of sand, gravel and rubble in larger holes, troughs and depressions throughout the bay.

D. Macroinvertebrates

Conspicuous macroinvertebrates were collected at four coastal sites in Bahia Laulau. Gastropods were the most commonly collected macroinvertebrates totaling 88 species. Among them, 22 species belong to the family Conidae, ten to the family Muricidae, nine to the family Mitridae and seven to the family Cypraeidae. Nine species of bivalves were collected. Only two species, Astraea rhodostoma and Vasum turbinellas, were collected at all sites. Twelve echinoderm species were observed during the study. The Crown-of-thorns starfish (Acanthaster planci) was conspicuous at all sites and were observed in greater than average numbers.

The reef flats of Sites 2 and 3 were more similar to one another than those of Sites 1, 1a and 4. The intertidal zones were similar to each other. In summary, the conspicuous macroinvertebrates collected and observed represent a typical reef and embayment for a southern Marianas Island. Although not observed during this study, the spiny lobster is known to be a significant resource of Bahia Laulau. They are regularly caught by divers along the reef front and on the reef flat.

E. Fishes

The fish community in Bahia Laulau down to 21 m (70 ft) is fairly diverse and appears to be in a relatively healthy state. This, and the wide range of habitats found there, makes it a potential site for ecological studies on reef fish. Many important species of food fishes are present and the potential for recreational and subsistence fishing is high. The replenishment of harvested food species should not be a problem since the bay is so large and since during most of the year much of it is made inaccessible to fishing by rough seas. The remote regions of the bay should be excellent sources of new recruits for the more heavily fished areas.

Although Bahia Laulau represents a significant recreational and subsistence fishery for the island, preliminary data provides no real basis for the support of an intensive commercial fishery. It is generally considered by local fishermen that fish populations close to the reef flats have declined in recent years due to heavy fishing.

F. Marine Turtles and Mammals

A total of 9 sea turtles were observed during the study. More turtles were observed on the surface at Sites 1 and 4 than at other Sites on the surface or underwater. Two green sea turtles (Chelonia mydas) and one hawksbill (Eretmochelys imbricata) were observed on the surface from our observation post above Site 1. Three green sea turtles (Chelonia mydas) were observed floating off Site 4 from our quarry observation post. One each of the green and hawksbill turtles were observed underwater at Site 2 and one hawksbill at Site 3.

Turtle nesting has been observed in the past at a few isolated beaches which occur within Bahia Laulau. However, no nesting sites were observed during this study. Sites of previous nests were noted at beaches below the airport quarry (Site 4). In the past the majority of sitings occured in the vicinity of Hagman and Naftan Points, these areas being more protected and isolated.

Porpoise, a marine mammal, are known to occur in Bahia Laulau. Small schools of an unidentified variety were observed on two field visits (Feb.

and May 1983). It is likely that porpoise use the bay as a feeding site and for protection during migration. There did not appear to be a resident population of porpoise in the bay. Whale sitings have never been confirmed in the Bahia Laulau area and none were observed during this study.

VII. OTEC DEVELOPMENT

The CNMI government recognizes the importance of OTEC development as a part of its renewable energy program to reduce its dependence on imported fossil fuels.

The Bahia Laulau OTEC site represents one of the best thermal resources for OTEC in the world with an average monthly temperature differential between warm surface and cold deep ocean waters exceeding 21° C at 305 m (1,000 ft). Data indicate that a year-round temperature differential over 21° C exists at a depth of 550 m (1804 ft) and a 23° C differential can be obtained at a depth of 900 m (2,953 ft).

The competing ocean uses on which OTEC facilities may be expected to impact are fisheries, port development, navigation and recreation. However, the location of any OTEC facility can be planned to cause a minimum of interference with shipping and port development. The major ocean uses that would be affected by the Bahia Laulau OTEC facility are fisheries and recreation.

The effect of OTEC development on marine waters relates to the displacement of warm, shallow water with cold, deep water resulting in the modification of temperature, salinity, density, dissolved oxygen, nutrients, carbonates and particulates. Known as "artificial upwelling" it has the potential to increase fish populations with corresponding high yields in productivity. However, it can also modify the near-shore environment negatively depending on the placement of the outfall pipe in proximity to the shore.

VIII. GENERAL DISCUSSIONS

A. Physical and Biological Resources

Bahia Laulau is resource rich in many ways. It is Saipan's largest natural bay offering protection and anchorage for small and large vessels. Although it is located on the windward side of Saipan, much of the bay is protected from direct wave assault and oceanic current patterns. A well developed and highly diverse coral reef fringes most of the inner part of the bay. Those areas of the bay not protected still have a highly diverse reef terrace. This reef provides numerous niches for an incredible array of marine life from the smallest to the largest forms. The reefs provide further protection for animals such as the green sea turtle which is known to nest on the numerous small beaches scattered throughout the bay.

The bay is rich as a fishery resource supported by a diversified plankton population. Local fishermen frequent the bay for sport and subsistence fishing. Throw-net fishermen and spear-fishermen consistently utilize the bay and can be seen out on the bay most days of the year. Plankton samples indicate a healthy population of fish eggs and larvae which support the future subsistence fisheries of the bay.

A manganese deposit located on the Hagman Point cliffline above Forbidden Island is a resource which was developed by the Japanese during the war. It appears that the manganese was stockpiled for eventual removal. The extent of the deposit is unknown. Further studies would be required to determine the exact quantity and quality and potential of this resource.

B. Recreational Resources

Local residents utilize the bay for a number of purposes. Some of these include fishing, boating, swimming and picnicing. In addition to local residents, tourists are now beginning to utilize the bay as well. On any day a number of scuba divers can be seen entering the water in the vicinity of the narrow cut at Bapot Beach. Tourists are also using the bay for sunbathing, picnicing and swimming.

C. Resource Degradation

The reef within Bahia Laulau represents a major resource to the residents of Saipan particularly in terms of a subsistence food source. Some damage to this resource is presently underway as a result of an increase in Acanthaster planci (crown-of-thorns starfish) coral kills and sedimentation from drainage channels along the beach. The impact to recreational uses within Bahia Laulau is a potential problem since both sedimentation and starfish kill reefs. Sedimentation also pollutes the near-shore water by dumping dirt and micro-organisms like coliform into it. Conditions like these are not healthy for swimmers, divers, fishermen or sun bathers.

D. Unique Areas and Features

Aesthetically, Bahia Laulau represents some of the best scenery and beauty which Saipan has to offer. The lagoon is deep blue, reefs colorful and diverse, white sand beaches, rocky outcrops upon which breakers crash, steep cliffs, caverns, underwater caves, dense tropical vegetation and gently sloping fertile soil upland from the shoreline. Overlooking the bay is one of Saipan's best restaurants which commands an exceptional view. It is likely that Bahia Laulau will experience intensive pressure for further development because of its natural beauty.

Hagman Point represents the major unique feature of Bahia Laulau with steep cliffs, isolated coves and beautiful yet rugged terrain. Forbidden Island, aptly named and separated from the main land form by a narrow channel, is the major promontory of the bay. Other unique areas include the protected cove near Bapot Beach where an extremely well developed fringing coral reef exists. Both Bapot Beach and Trinchera Beach are unique areas and represent the best beaches in Bahia Laulau. The reef flats and reef margins are very well developed and are utilized by fishermen and skin and scuba divers alike. Two or three small, isolated beaches exist between Trinchera Beach and Dandan Point and are unique since they are known to be turtle nesting sites.

The bay itself is the largest natural bay on Saipan and one of the largest in the Marianas Archipelago. Deep, cold water near shore represents a unique feature for potential OTEC development.

INTRODUCTION

The Physical Planning Office of the Government of the Northern Mariana Islands issued a request for proposals for a Marine Biological and Physical Survey of Bahia Laulau, Saipan, (Figures 1 and 2) during May 1982. The firm of Pacific Basin Environmental Consultants, Inc. (PBEC) submitted a proposal to the CNMI Planning Office on June 4, 1982, and was awarded the contract on June 28, 1982. Final contract documents were signed by all parties on September 10, 1982. This project is funded under a grant from the U.S. Department of Commerce, Office of Coastal Zone Management (CZM), Coastal Energy Impact Program (CEIP).

The study of Bahia Laulau was initiated because a potential site for an Ocean Thermal Energy Conversion (OTEC) plant had been chosen along the southern edge of Puntan Hagman (Hagman Point) in north Bahia Laulau (Figure 2). Since very limited biological and physical data exists for Bahia Laulau, this study would provide baseline data necessary for planners and others to base major decisions concerning a potential OTEC plant or other future plans for the bay.

SCOPE OF WORK

The scope of work was finalized with input from PBEC, Commonwealth of the Northern Mariana Islands (CNMI) Planning Office, CNMI Fish and Wildlife Division of the Department of Natural Resources and the Coastal Resources Management (CRM) Office. The scope included the following tasks:

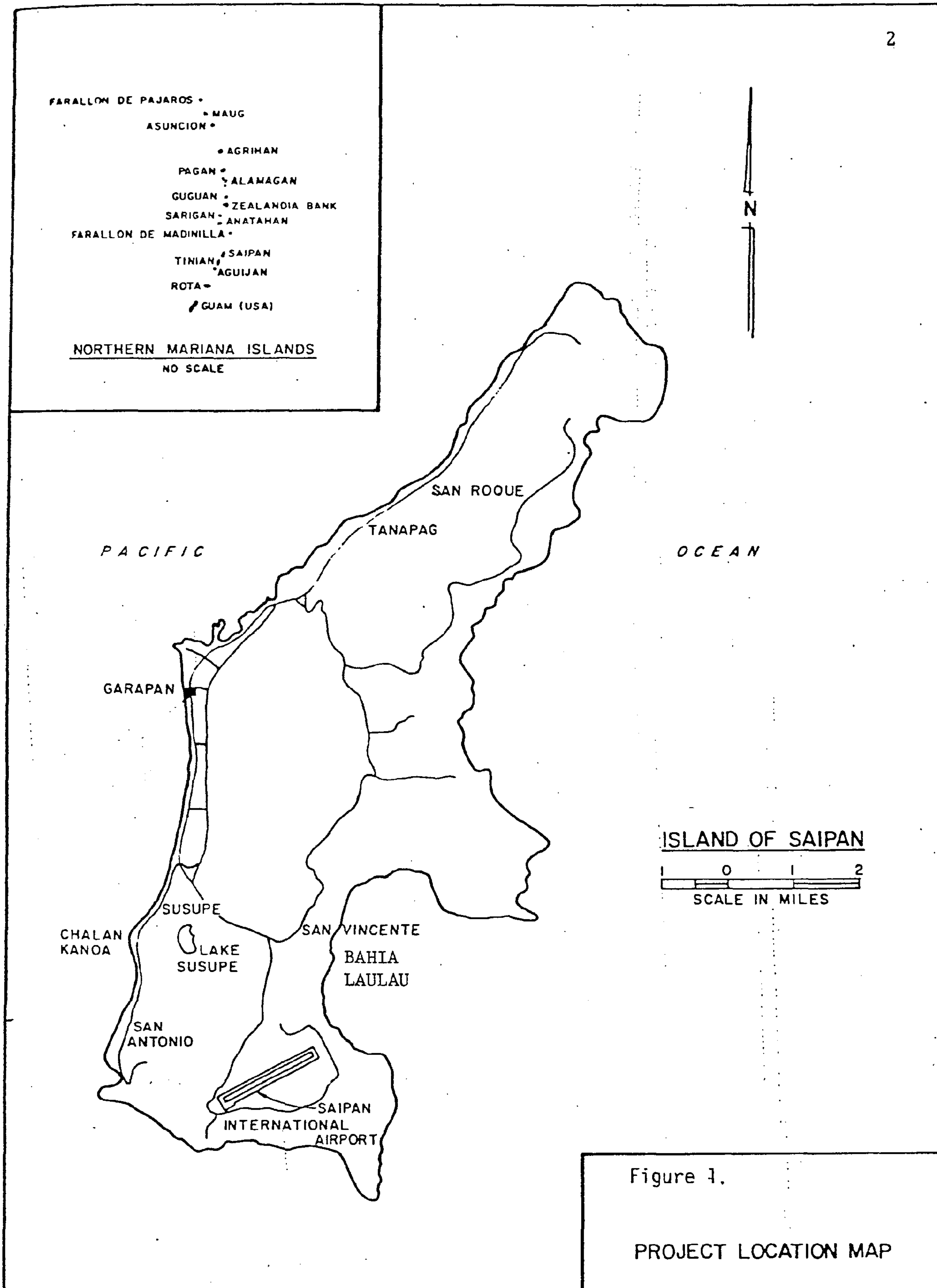

Figure 1.

PROJECT LOCATION MAP

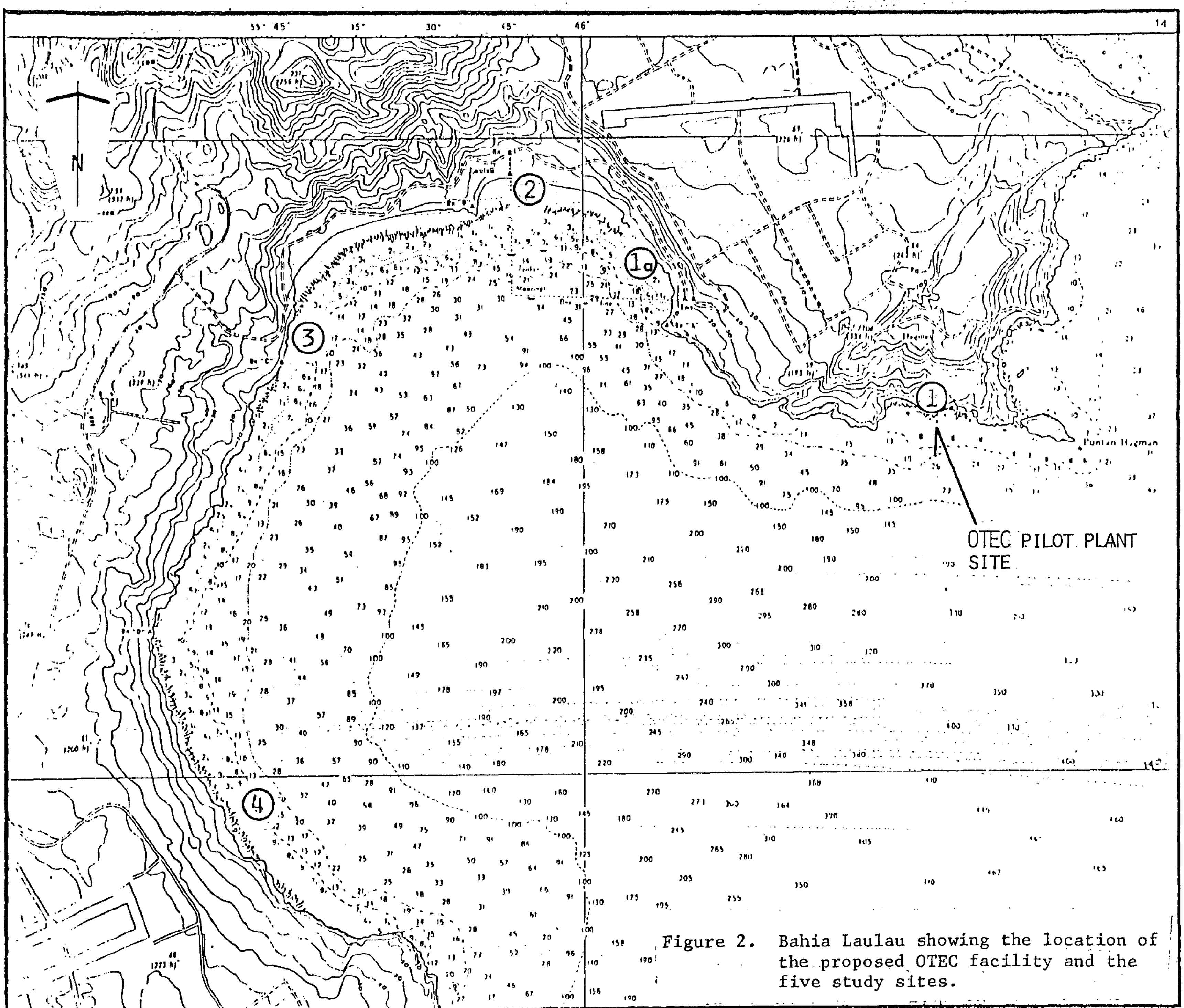

Figure 2. Bahia Laulau showing the location of the proposed OTEC facility and the five study sites.

SCOPE OF WORK

1. Compile complete historical data base of physical, chemical and biological conditions of Bahia Laulau.

2. Conduct field surveys of all major flora and fauna of Bahia Laulau. Count and identify corals, fishes, algae, seagrass, invertebrates, sea turtles and mammals.

3. Conduct quarterly field surveys of abundance and distribution of eggs, larvae and juvenile fishes and other significant marine resources to identify important breeding and nursery areas.

4. Define physical characteristics of submarine lands and reef structures.

5. Through quarterly surveys, define physical characteristics of shallow water including current speed and direction, temperature gradients and salinity.

6. Conduct a deep water temperature profile at depths of 750, 1,000, 1,250 and 1,500 feet off site of proposed OTEC plant.

7. Conduct a field survey of backshore lands to identify terrestrial flora and fauna and physical characteristics.

8. Define resources at Bahia Laulau and identify degradation of same as a result of destructive fishery practices, erosion, sedimentation, crown-of thorns starfish (Acanthaster planci), runoff, fecal coliform, etc.

9. Identify historical resources, pristine areas, unusual oceanographic features and altered shorelines.

10. Prepare three (3) quarterly data reports due 30 days after completion of each of the first three surveys (3 copies) and a final report to include text, data, maps, charts, photos, tables and any other methods necessary to convey the findings. All species will be identified by scientific, Chamorro and English names. Place names will conform with the U.S. Board of Geographical Names. Draft report due 30 days after completion of final survey.

SURVEY TEAM

The survey team assembled for the Bahia Laulau project by PBEC included personnel from the University of Guam (UOG) Marine Laboratory, Guam Division of Aquatic and Wildlife Resources, University of California at Berkeley and the University of Maryland as well as a local field assistant from Saipan. The following is a list of team members with their primary and secondary responsibilities.

Michael J. Wilder, PBEC - Principal Investigator; terrestrial flora; fathometer profiles and deep water temperatures; report preparation.

Ronald D. Strong, PBEC - Project Coordinator; terrestrial fauna; assist in field work; current studies; photography; report preparation.

Lucius Elderedge, UOG Professor - Checklist and evaluation of marine invertebrates.

Ann Kitalong, M.S. Candidate at UOG Marine Lab - Analysis of quarterly plankton samples.

Michael Molina, Guam Division of Aquatic and Wildlife Resources Fisheries Biologist - Checklist and transect analysis of the fishes of Bahia Laulau; data on sea turtles and mammals.

Richard Randall, UOG Associate Professor - Checklist and analysis of the corals; reef physiography; assist with marine geology.

Galt Siegrist, University of Maryland Professor - Evaluation of the marine and terrestrial geology of the Bay; sediment analysis; geological resource evaluation.

Alicia Siegrist - assist with the geological resources and resource economics.

Jeanine Stojkovich, U.C. Berkeley PH.D. Candidate - Checklist and evaluation of marine plants; general field assistance.

Ben Concepcion, Owner of Water Sports, Inc., Saipan - Provide boat and diving equipment for the team; assist in diving operations and logistics; assist with plankton tows and current studies; provide information on recreational and commercial uses of Bahia Laulau.

ACKNOWLEDGEMENTS

Pacific Basin Environmental Consultants, Inc., would like to thank the following individuals and organizations for their assistance and help in planning and carrying out the Bahia Laulau study:

George Chan, David Liem, Elizabeth Udui, George Ehlers and the entire staff from the Physical Planning/Energy Office

Manny Sablan, Paul Benoit, Tami Grove, Debby Knutson, Ben Bland and Ben Aldan of the Coastal Resources Management Office

Representative Ben Sablan, Rufo Lujan, Pat Bryan, Tom Lemke and Thane Pratt of the Fish and Wildlife Division of the Department of Natural Resources

Ivan Groom of Northern Islands Company

GENERAL METHODS AND PROCEDURES

The Bahia Laulau field evaluations were designed to be completed during the initial survey and/or quarterly over a period of one year. The initial survey employed the entire team and covered all aspects of the scope of work. The other three quarterly surveys investigated the currents (reef-flat and offshore) and the planktonic community of the bay, two parameters that vary with time and season. Additional data were collected quarterly to supplement the initial survey and included information on the birds, turtles, marine mammals, Acanthaster planci concentrations, fishes, plankton, currents, wind patterns and nearshore water chemistry.

A total of four survey sites were selected along Bahia Laulau after discussions with the Planning Office, CRM and Fish and Wildlife offices. The four sites represent different habitat and reef types and vary considerably in their exposure to wave assault. The four sites, along with an intermediate site (1a) that was added later, are shown in Figure 2.

Underwater surveys were conducted from the shore using snorkeling and/or scuba equipment at Sites 2 and 3 (reef-flat only). All other sites were investigated by snorkeling and scuba from a zodiac inflatable boat and the M.V. Bahia Laulau. Various methods were used by the individual scientists including timed swims, random counts, depth/timed transects and placed 50 meter (m) (164 feet (ft)) transects. Please refer to the individual sections for detailed methodologies.

HISTORICAL INFORMATION

INTRODUCTION AND GENERAL BACKGROUND

Historical information contained in this section is a compilation of data excerpted from five separate research papers since the middle of this century. For the sake of uniformity the majority of this historical information is taken directly from existing reports. These data present an accurate picture of historical significance in the vicinity of Bahia Laulau to date.

The Mariana Islands are well known to insular geologists for the classic raised coral reef structure of many of the islands. Saipan falls into this category with only minor deposits of volcanic rock exposed in a few of the deeply eroded stream beds in the northwest part of the island.

The larger islands are thought to have emerged from the ocean no earlier than Late Eocene. Soil formation and the introduction of terrestrial flora and fauna presumably proceeded from the time of emergence.

The Bahia Laulau formation is thought to be the result of gradual loss of land through sea and land slides into the precipitous Marianas Trench which runs parallel to the Marianas on their eastern flank.

Accurate historical information regarding Bahia Laulau prior to World War II is sketchy and only a few references exist. However, in 1858 a British Royal Naval Officer by the name of Mr. Harvey, aboard the HMS Magicienne, surveyed and sounded the bay and named it Magicienne Bay, which still stands as its official designation. The Chamorros refer to it as Bahia Laulau which may derive from the Chamorro word laolao, meaning "shaking" or "trembling" a generic word that can apply to the earth's movement during tectonic disruptions. It is known now that a major fault line transverses central Bahia Laulau from Naftan Point to a small ravine near Puntan Hagman.

Historically, work in the vicinity of Bahia Laulau has had two major thrusts; archaeology for the sake of general historical knowledge of the people and customs and military significance for the sake of war strategy.

METHODS

Historical information regarding Bahia Laulau was taken from a number of references but relies mostly on Spoehr (1959), Takayama and Egami (1971), Takayama and Intoh (1976), Reinman (1977) amd Thompson (1977). Field visits to the Bahia Laulau archaeological sites were undertaken to examine them first hand. These field excursions included the upper Laulau Bay Coastal Access Zone, Laulau Site, Bapot Site and the Laulau Rock Shelter. Field observations were noted and compared to findings in the literature.

RESULTS

Laulau Bay Archeological Site

Given a fair amount of superficial and incidental knowledge about the sites of the windward (eastern) coast of Saipan, a zone was defined for intensive archeological survey (Thompson, 1977). This survey was designated The Upper Laulau Bay Coastal Access Zone and it was defined on the basis of reef configuration, shoreline topography, soils, surface slope and continuity of vegetative cover (Fig. 3a).

The reef configuration concerned is the development creating the lagoon in the upper portion of the bay, an area protected from the full force of the northeast swell by the Hagman prominence to the east.

Shoreline topography is that of a gradual slope which rises up from the lagoon in broad beach areas: at Unai Bapot, Unai Laulau and at the small beach in between the two (Fig. 3b). Up the coast from Unai Bapot, the

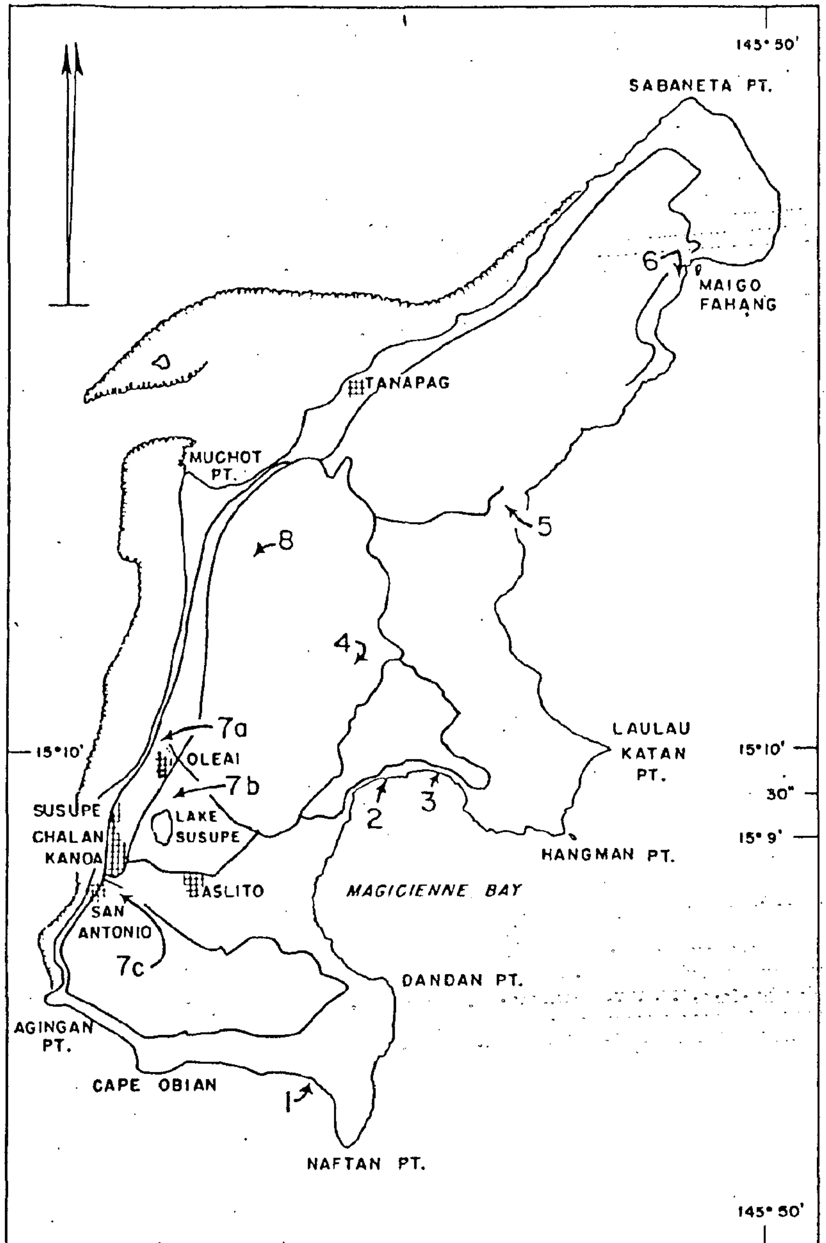

FIG. 3a. Principal archaeological sites of Saipan. Numbers on map refer to following sites: 1, Objan; 2, Laulau; 3, Bapot; 4, As Teo; 5, Talofofo; 6, Fañunchulujan; 7a, Oleai; 7b, Chalan Kija; 7c, Chalan Piao; 8, Chalan Galeite.

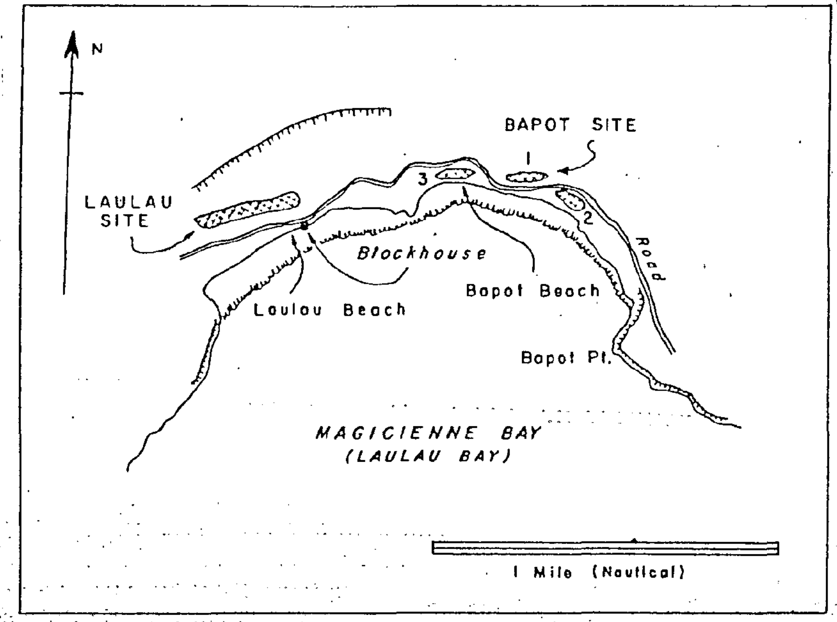

FIG. 3b. Magicienne Bay, Saipan, showing location of Laulau and Bapot Sites.

beach gives way to limestone cliffs. About 500 m (1,640 ft) further towards Hagman the lagoon edge meets the shoreline and ocean waves pound directly onto the cliffs of the shore. There is a ravine at this reef terminus which is mainly washed clear of soil and artifacts. This ravine is a convenient upper limit for the zone.

At the opposite end of the main lagoon formation is the lower limit of Unai Laulau. Here a ravine opens out of the island and creates a well defined terminus to the beach. The lagoon continues some 400 m (1,312 ft) down the coast from this point but becomes quite thin well before its terminus.

The lower limit ravine just mentioned defines the terminus of the beach while the next ravine down the coast (in which the main road is situated) empties into the sea at the point where the lagoon terminates. Inland, this ravine presents a heavily washed area that serves well as the lower limit of the zone. As with the upper area, the beach terminus is followed by a limestone bluff and cliff formation.

While direct access to the water is not impossible up or down the coast from the area just defined, it is, in a word, inconvenient. The general impression was that sites were less common outside the zone and absent on certain heavily sloping surfaces.

The inland limit of the zone is generally defined as the 61 m (200 ft) elevation above mean sea level. There are broad plateaus inland of this elevation in the southern portion of the island, the area leading to the Hagman prominence above Bahia Laulau, the area inland of the coast between Puntan Nanasu and Puntan Tanke and across the northeast face of the upper tip of the island. The descent from the plateaus to the coast in the access zone usually consists of small escarpments or heavy slopes dropping quickly to about 31 m (100 ft) where more gradual slopes are encountered leading to the beach.

Excavations at Bahia Laulau

The following is a general location and description of excavations at Bahia Laulau. The Laulau site is located on the northwestern shore of the Bay on the east coast of Saipan (Fig. 3b). The site lies about 150 feet inland from the beach and to the west is a narrow road that runs around Magicienne Bay. The Laulau site is approximately 183 m (600 ft) long and 61 m (200 ft) wide with its long dimension paralleling the shoreline. It is northwest of a massive, concrete Japanese blockhouse built on the beach and commanding the bay. The Laulau site is a coastal one permitting the combination of good farmland with access to the resources of the sea. This site was mostly undisturbed by military operations but was partially excavated by the Japanese for military purposes.

North and east along the shores of Bahia Laulau is a coastal terrace about 93 m (300 ft) wide upon which is found the Bapot site. The soil is good and there is reasonable access to reef and offshore fishing. This area is the site of three clusters of Latte houses: Bapot I consists of two, Bapot II of four and Bapot III of five. All have been disturbed by defensive trenching by the Japanese military forces and a road also cuts across the former occupation area. Shards are distributed throughout the area. It is probable that the area once contained numerous house sites.

Northwest of the site there are a series of limestone cliffs. A large limestone segment has fallen away from the cliff edge and forms a rock shelter. This is Laulau Rock Shelter, a significant archeological find. The ground at the rock shelter is approximately 35 m (115 ft) above sea level.

From the rock shelter the terrain slopes gradually down to the beach and the site is located on this sloping ground.

Surface features of the site consist of scattered shards plus the remains of four latte houses; all badly disintegrated. Two latte houses are located at each end of the site. The four houses are in rough alignment. It is quite possible that other latte houses once existed, but have since disintegrated. At the time of excavation, some of the site was planted in maize, coconut palms and bananas. The rest was lying fallow in grass. According to Chamorro informants, the land has always been hand-tilled. In Japanese times it was used for tobacco. Recently it was used primarily for growing maize.

The beach at the point of the site is bordered by a wide, fringing reef. As the location is on the tradewind side of the island, the waters of Bahia Laulau are usually rough. In early times it would have been difficult to bring canoes of any size over the fringing reef; however, the reef fishing is excellent.

At the Laulau site, two structures were excavated: House A, the southwestern most latte house; and the rock shelter.

Military Significance

In the 1950's both the U.S. Navy and Army Corps of Engineers undertook studies in Bahia Laulau for military purposes. Primarily, the military was interested in utilizing the bay as a landing site, limited lee anchorage and oil depot. The majority of this information was collected by the Army Corps of Engineers in their Military Geology of Saipan, Mariana Islands in three volumes: I, Introduction and Engineering Aspects; II, Water Resources; and III, Beach and Terrain Analysis. The purpose of this survey was two-fold. The first was to collect scientific information through a field study of major islands in the Pacific and the second was to publish this information in a form usable by the U.S. Armed Forces and Civil Administrators working on assignments in the islands.

Since the war, a number of studies on a wide variety of subjects have taken place in the Mariana Islands. Most of these studies were undertaken by the CNMI government to learn more about the islands for the purposes of development. Most of these studies are geological, archaeological or biological.

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PHYSIOGRAPHY AND SHORELINE SITE DESCRIPTIONS

INTRODUCTION

The immediate coastal region within the Laulau embayment is quite variable and includes low wooded terraces of limesand, recently raised limestone deposits and steep slopes, cliffs and headlands of both older raised limestone and volcanic rocks. Fringing reef platforms of various widths and narrow beaches intermittently border the shoreline.

METHODS

Describing the shoreline features of each Site in Bahia Laulau required literature search and field mapping. Prior to actual field evaluations, a composite map was drawn from existing data and maps (Cloud 1959, Doan and Siegrest, 1979, Eldredge and Randall, 1980). These maps were then taken into the field and checked for accuracy. Four (4) sites were chosen for detailed study. However, a fifth site (1a) was added for its uniqueness and because it was a frequent rest spot between investigations at other sites. All study sites were evaluated on foot and offshore by boat. Brief descriptions of shoreline features at the five study sites follow. Refer to Figures 4a and 4b for details.

RESULTS

Site 1 is located along the wave-assaulted northeast section of Bahia Laulau about 800 m (2,625 ft) west of Puntan Hagman in a small angular enbayment where Mariana Limestone is in fault contact with volcanics of the Hagman formation. A steep volcanic slope forms the northern shoreline of the site and a sheer limestone cliff with a deep concave notch cut at sea level forms the western shoreline. Large blocks and boulders, presumably wedged out from the adjacent steep slopes and cliff face, buttress the

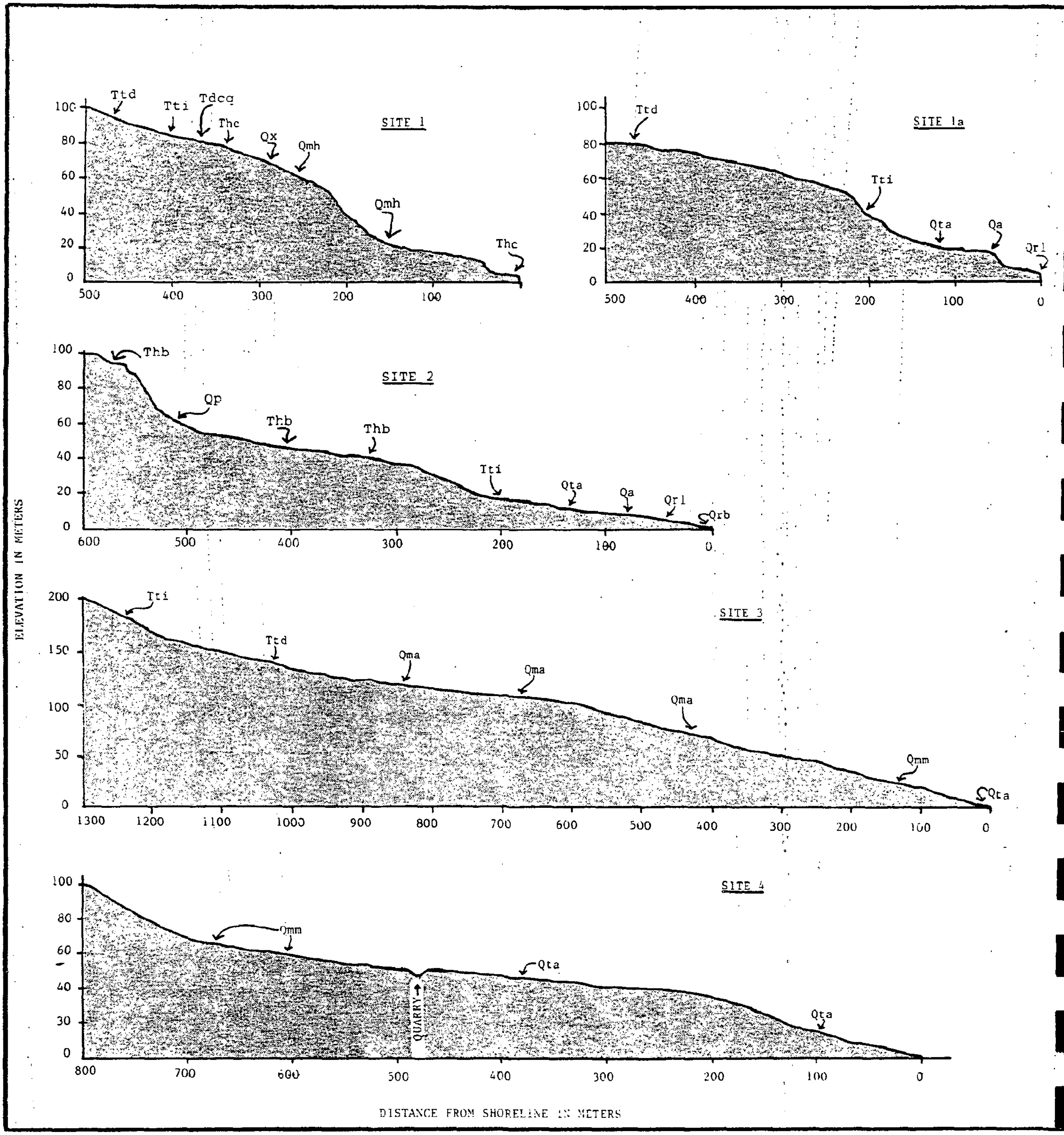

Figure 4a. Profile of terrestrial sections for sites 1, 1a, 2, 3 and 4 at Bahia Laulau. Refer to Table 1 for Rock Unit symbols.

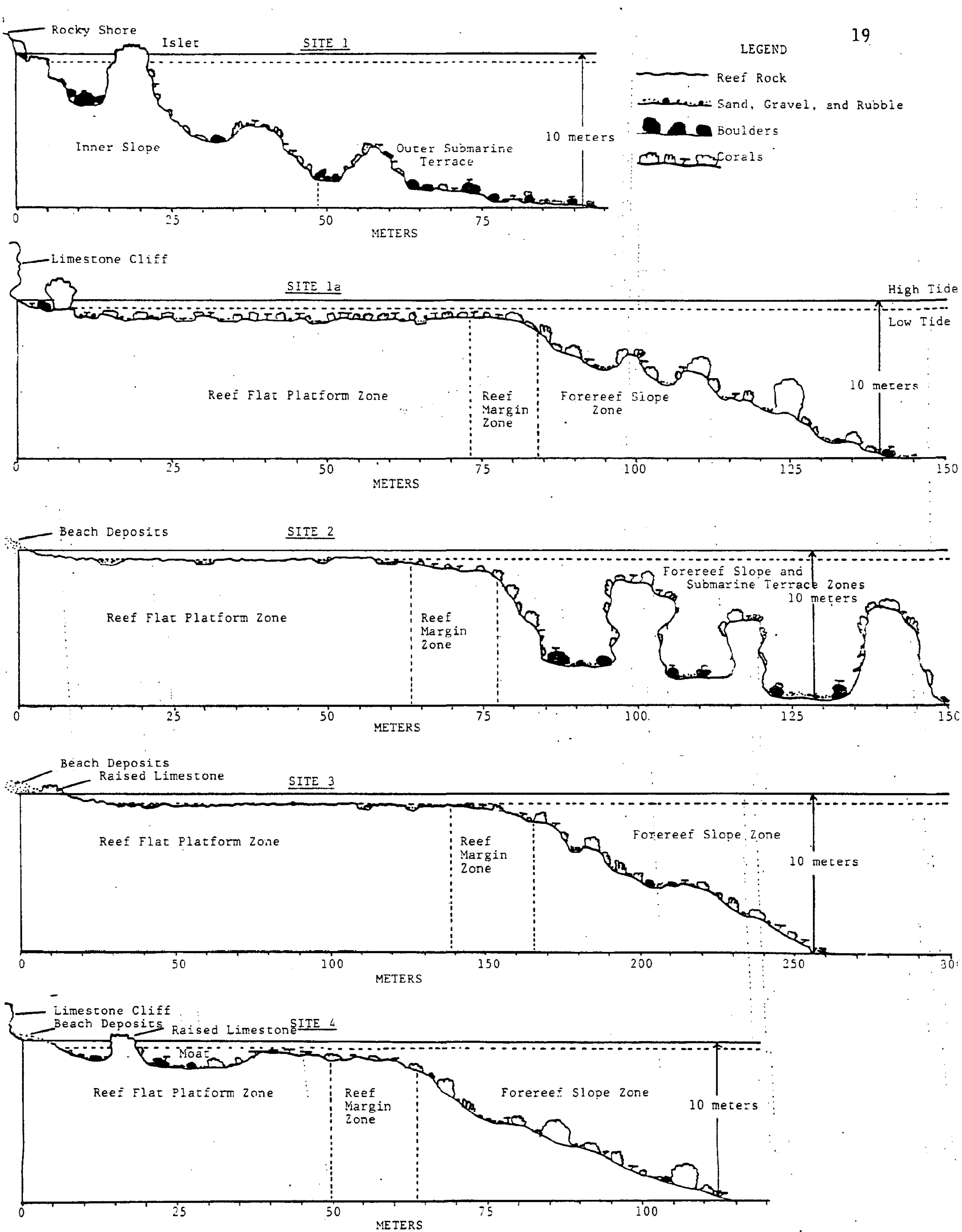

Figure 4b. Vertical profiles of Sites 1, 1a, 2, 3 and 4 at Bahia Laulau showing submarine topography, reef zones, water depth and relative distribution of corals and sediments.

shoreline and at a few places form small wave-washed islets a few meters from shore.

Site 1a is located in a relatively protected section of Bahia Laulau approximately 400 m (1,312 ft) northwest of Puntan Bapot where a narrow subtidal fringing reef platform borders the shore. A low cliff of Mariana Limestone buttressed with numerous blocks and boulders forms an irregular shoreline along the site. Intermittently, the cliff face is prominently undercut or notched just above reef platform level.

Site 2, also somewhat protected from Northeast Tradewind wave assault, is located 450 m (1,476 ft) east of Trinchera where a relatively wide intertidal fringing reef platform borders the shore. Beach deposits, composed mostly of bioclastic sand, gravel and rubble of reef origin, form a narrow band along the shoreline.

The shoreline features at Site 3 are quite similar to those of Site 2 except for greater exposure to tradewind waves and a narrow band of recently emerged limestone (less than 1 m high) that separates bioclastic beach deposits from the intertidal fringing reef platform.

Site 4, located 1.1 kilometers (0.7 miles) northwest of Puntan Dandan, is exposed to heavy tradewind wave assault. Low limestone cliffs of Mariana Limestone form the shoreline. Although extensive beach deposits are absent along the shoreline, a few small patches of bioclastic rubble have accumulated at erosional reentry areas along the cliff face. A narrow fringing reef platform borders the shoreline at this site.

CONCLUSIONS

Sites 1 and 4 are the most unique and different of all five sites. Both are unprotected against heavy ocean swells and are, therefore, usually rough and dangerous in terms of currents and seas.

Sites 2 and 3 are quite similar although Site 2 is slightly more protected from northeast tradewinds. Both have intertidal fringing reef platforms and bioclastic beach deposits. A narrow cut through the reef at Site 2 provides reasonable access to the bay.

Site 1a is the most protected site since it is tucked in and away from prevailing winds and waves. It is more similar to Sites 2 and 3 than Sites 1 and 4.

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GEOLOGY

INTRODUCTION

Saipan exhibits the same high degree of geologic diversity and complexity that characterizes the other major islands in the southern Marianas. A core of Eocene-Oligocene submarine volcanic and volcanoclastic rocks, formed as the result of tectonic plate convergence, has been veneered with progressively younger sequences of shallow-water limestones. Vertical tectonic adjustments of the island-arc system, including net uplift, faulting and tilting, coupled with sea level fluctuations arising from Pleistocene glaciation cycles, have raised and terraced Saipan and the other "high" islands in the southern Marianas.

Bahia Laulau is indented about half-way into the island perpendicular to the prevailing northeast-southwest trend of the major rock units and topographic features (Figure 5). Thus, it provides a cross-section along which most of the major rock formations and many of the structures, soils and landforms can be viewed and studied.

METHODS

The goal of this study is to prepare geologic environmental evaluations of four pre-selected onshore sites in Bahia Laulau where land-use modifications have been suggested (Figure 6).

In order to carry out this objective in 3½ field days, heavy reliance is placed on supplementary sources, including earlier published maps, data, reports, and on aerial photo interpretation. Seven field transects were required to sample, describe and evaluate the geologic materials in the vicinity of the four sites and to verify the air photo analysis.

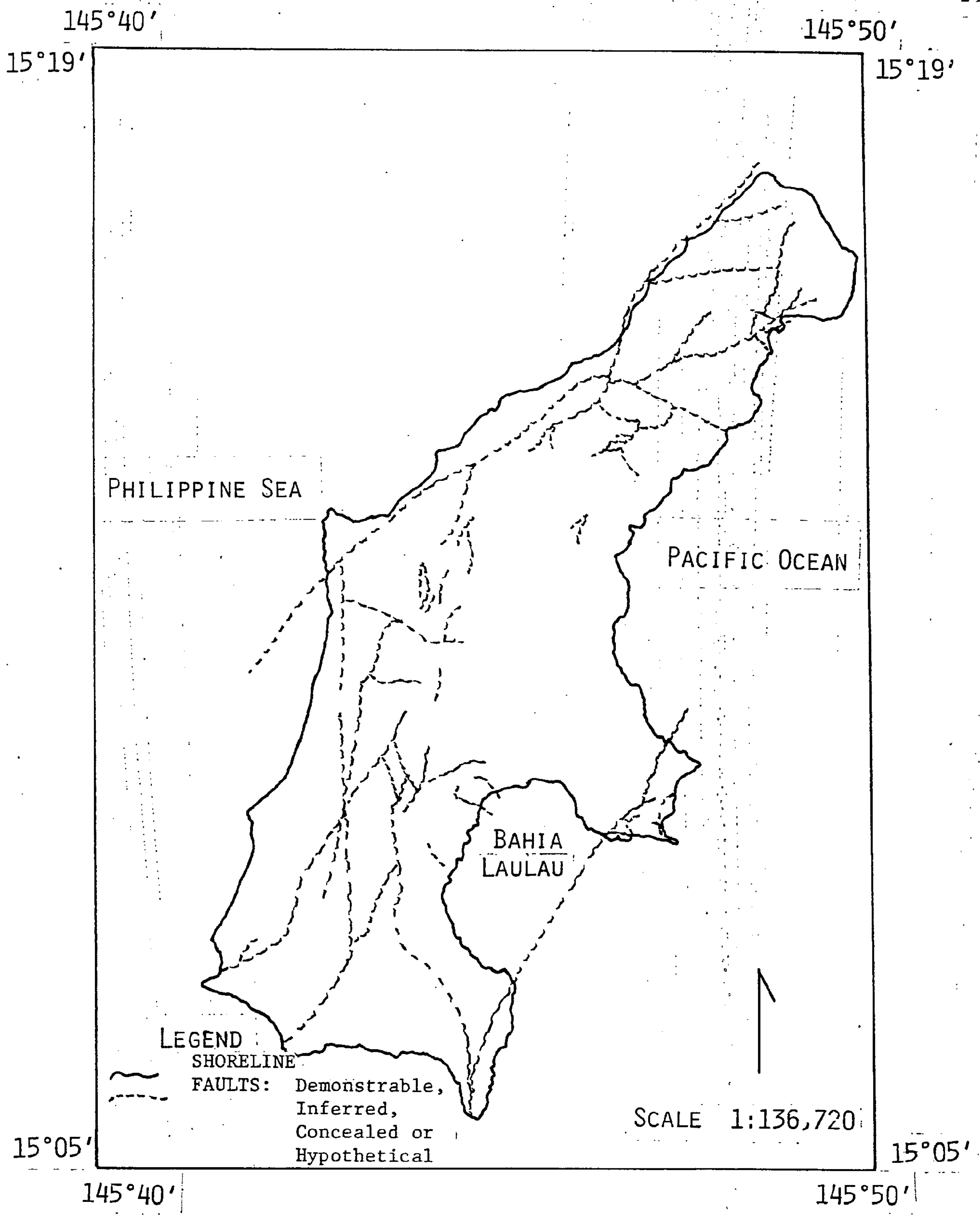


Figure 5. Reference map of Saipan (after Cloud, et. al., 1956).

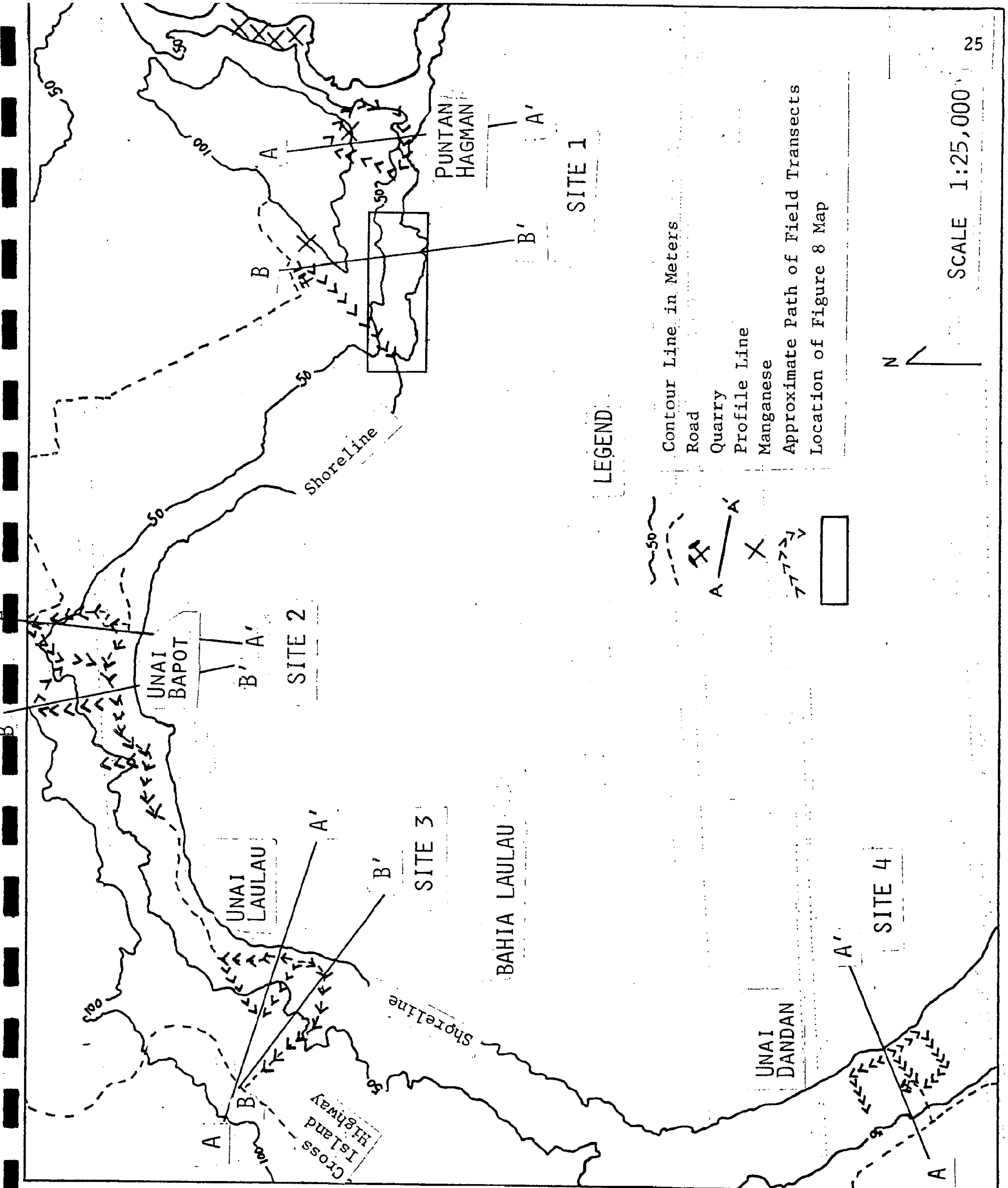


Figure 6. Reference and topographic base map of Bahia Laulau. Study sites and vertical section lines indicated.

Any new land-use activity requires some thought on possible environmental effects. Along Bahia Laulau eight geologic-related factors or conditions were considered necessary to arrive at reasonable site evaluations and site-to-site comparisons.

Rock Units: Distribution, thicknesses, stratigraphic position, structural and physical properties.

Rationale: The mineral composition, grain size geometry (texture) and fracture characteristics of a rock body place limits on engineering and building applications. They control the type and thickness of soil cover, slope and terrain morphology, surface and groundwater hydrology and economic resource potential. In Table 1 (Appendix A) we present a list of the mapped units and a general summary of their important characteristics used for site evaluations (Modified from Cloud, et. al., 1956).

Soil Units: Distribution, thicknesses, composition and physical properties of mapped soil units.

Rationale: Engineering properties of soils are derived from their basic mineral composition and thickness. Strength, sensitivity to vibration or excavation, compressability, erodability, permeability, shrink-swell potential and ease of excavation must be considered in site studies.

Table 2 (Appendix A) lists the major mapped soil units around the sites of Bahia Laulau and their important characteristics (Modified from McCracken, 1957).

Slope and Stability: Slope stability is evaluated by estimating the "safety factor", defined as the ratio of resisting forces (usually shear strength of slope materials acting along potential slip planes) to driving forces (usually the weight of the slope material including vegetation and buildings).

Rationale: Forces are static; they change with time, earthquakes and planned and unplanned slope modification. There are many signs of historic, ongoing and potential slope instability around Bahia Laulau; several of the latter could be catastrophic. Moreover, submarine slope instability should not be overlooked at any site where underwater structures are planned.

Table 3 presents a classification of the principal types of downhill movement or mass wasting (Keller, 1982). Where observed, they are noted on the profiles included with the site evaluations.

Table 3. Classification of Mass Wasting.

Type of Movement		Materials: Rock	Materials: Soil
Slides (variable water content and rate of movement)		Slump Blocks Translation slide	Slump blocks (Rotational slide Soil slip (planar)
Falls		Rock fall	Soil fall
Flows	Slow	Rock creep	Soil creep
		Unconsolidated materials (saturated)	
	Rapid	Earthflow Mudflow (incl. submarine) Debris avalanche	
Complex		Combinations of slides and flows	

Geologic Hazards: Geologically-related conditions that can lead to loss of life and property.

Rationale: Excluding slope instability already mentioned and the overall problem of earthquakes, danger from flooding must be considered the most serious geologic hazard within Bahia Laulau. Flooding could be from either storm or typhoon-generated waves or flash floods where the rock and soils favor surface runoff.

In considering beach flooding by typhoon-generated swells, we can compare sites by computing an Index of Specific Vulnerability, V_S (Doan and Siegrist, 1979). V_S is based upon empirically derived attenuation functions (Komar, 1976) and studies done on Guam in connection with Typhoon Pamela (Ogg, 1977).

A typhoon-generated wave with a height in meters before breaking, Ho, is attenuated when traveling across a reef flat of width w, by the empirical function:

$$Ha = Ho\ (0.9)^{w/115}$$

where Ha is the attenuated height upon arriving at the beach. The Index of Specific Vulnerability is calculated as:

$$V_S = Ha - (1/D_{max} - Ha)$$

where D_{max} is the maximum effective depth of water shoreward of the reef front. On Saipan V_S ranges from 3.1 (Tanapag) to 7.6 (Fahang) with 9.0 being the maximum vulnerability.

Alluvial Processes: Drainage; overland soil and stream erosion and deposition; potential sedimentation problems.

Rationale: Qualitative assessments of the position and condition of nearby streams and gulleys should accompany environmental evaluations. Soil is essentially a non-renewable resource in the tropics. Land stripped of vegetation will be quickly eroded down to bedrock on all but gentle slopes. Alluvium-choked ephemeral streams indicate soil and slope erosion upstream, episodic or possibly catastrophic stream discharge, flood potential and eventual sediment buildup downstream or on the reef flat.

Subsurface: Porosity and permeability; infiltration rates.

Rationale: Very little surface water is retained on the Tagpochau Limestone and virtually none on the Mariana and Tanapag formations in the Bahia Laulau area. Infiltration rates are extreme. These formations are honeycombed with planar fractures, irregular fissures, caverns and caves. Surface instability arising from these subsurface features is demonstrated by swales and sink holes. Heavy construction planned for sites on these formations should be preceded by thorough subsurface investigation including geophysical surveying and borings.

Coastline Configuration: Position and configuration of the coastline as it relates to historic typhoon and normal seasonal wave energy directions.

Rationale: All the coastal areas around Bahia Laulau are to some degree vulnerable to rapid erosional-depositional changes brought on by storm waves.

Expectable sea and swell directions from local and regional weather patterns range from east to northeast except from June to August when low to moderate east-southeast seas can be expected (Doan and Siegrist, 1979). Historically, the typhoon-generated wave directions around Saipan range from the southeast to southwest.

At each of the study sites, rates of sea cliff and headland retreat and/or backshore and beach redistribution and removal are dependent on wave direction and magnitude as well as coastline configuration.

Economic Resources: Estimate of the type of mineral resources in the vicinity of each site.

Rationale: Bahia Laulau rocks have yielded limited quantities of highgrade manganese ores associated with the Tagpochau Limestone formation. It was pointed out by Cloud et. al. (1956), that although total manganese at depth may be considerable, renewed mining would be dependent on external economic factors, especially world markets.

Bahia Laulau rock formations were also examined for possible use as construction aggregate. Obviously, a well designed sampling and testing program is mandated before claiming the certainty of any material being an economic resource.

RESULTS

Site 1, Sabanen Hagman

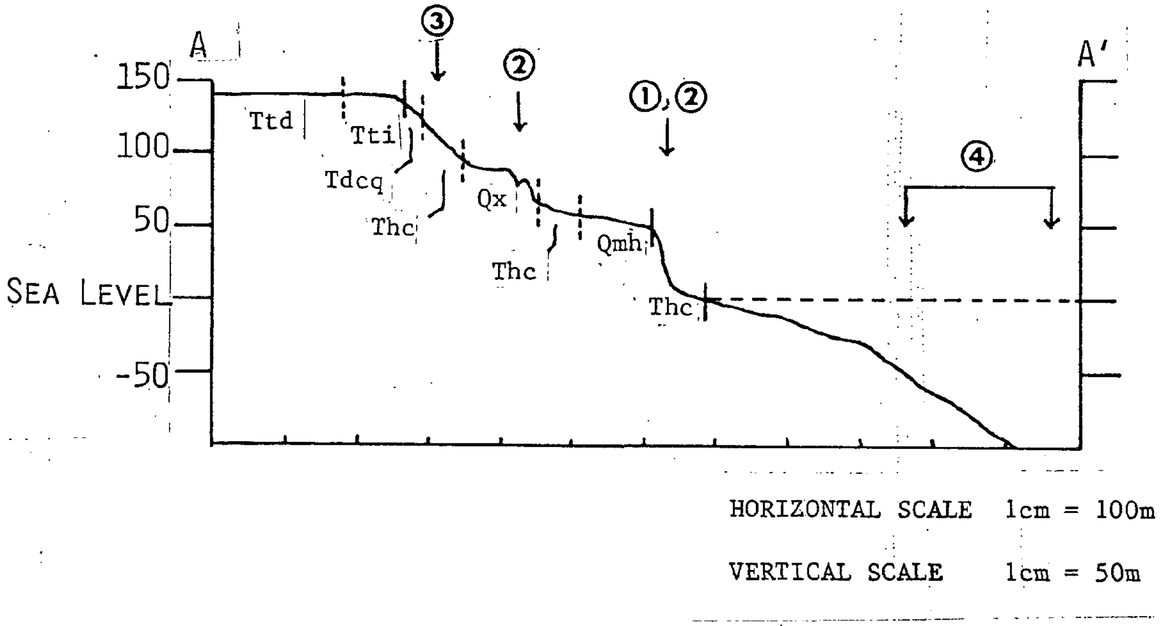
Location: On terraced coastline east of Isleta Maigo (Unai Hagman)

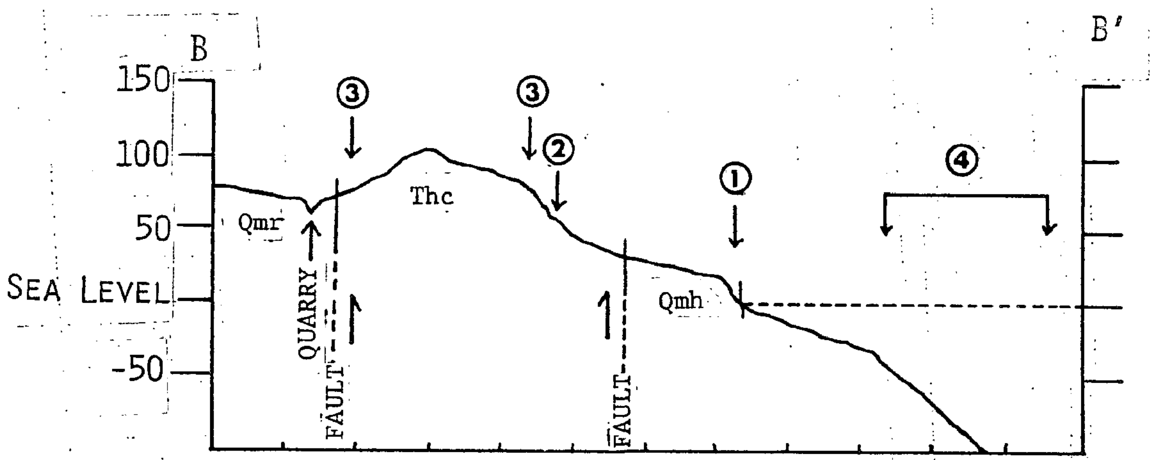
Profile: Figures 7a,b

Local Rock Units: (13 units - High Diversity) (Rock unit symbols from Table 1)

Bedrock Units:	Mariana (dominant)	Qmm, Qmr
	Tagpochau	Tti, Ttd, Ttr, Ttt, Tm
	Densinyama	Tdcq
	Hagman (dominant)	Thc
Mass Wasting Units:	Slump blocks	Qx
	Debris blocks	Ql
Unconsolidated Units:	Beach	Qrl
	Older Terrace Deposits	Qp

The structural geology and stratigraphy are very complex; all the formations on the peninsula are cut by normal faults, some with large displacements. The Hagman formation also displays growth faults. Joints and joint sets are very pronounced in the Mariana but less so in the Tagpochau formations. Relatively steep dipping stratification planes contribute to reducing slope safety factors.





Figures 7a and 7b. Vertical cross-sections at Sabanen Kagman. Vicinity of Site 1. Section lines from Figure 6. Rock unit symbols from Table 1. Circled numbers refer to text on Slope Stability.

A fracture compilation done by aerial photo interpretation (Figure 8) reveals that the peninsula including Site 1 is bounded on at least three sides by faults and is cut by several prominent lineaments that could well be other faults or major joint traces.

Local Soil Units: (7 units)

Saipan - Chacha

Dandan

Akina - Dago

Chinen

Rough stony land on limestone (dominant)

Rough broken land (dominant)

Quarries

Most slopes are too steep to allow soil formation: Very shallow stony to no soils on rough pinnacled Mariana formation.

Slope Stability: (See Figures 7a,b)

The following types of mass wasting were observed in and around Site 1.

Rock falls: (ongoing): Labeled 1 on Figure 6, 7a,b: Hagman and Mariana formations.

Rock slides: (historic and ongoing): Labeled 2 on Figure 6, 7a,b: Hagman and Mariana formations: Both rotational and translational types.

Soil creep: (ongoing): Labeled 3 on Figure 6, 7a,b: Hagman, Tagpochau (Ttd) and Densinyama formations.

Mass wasting on the south Hagman coastline is both active and unpredictable. Highly fractured bedrock, steeply-dipping soft and weathered volcanic strata, extremely steep slopes, high relief, sparse vegetation and low-level shock waves from earthquakes and storm swells contribute to lessen safety factors to Site 1. Many of the slopes on Puntan Hagman are barely stable.

Figure 8, shows the peninsula including Site 1 and depicts the distribution of historic and ongoing downhill movement of materials. From air photos: rock falls, rock and debris slides and soil creep can be plainly discerned.

Directly offshore from Site 1, in Bahia Laulau, the submarine slope exceeds 18° within .5 km of the shore (location 4 on Figures 7a,b). This slope is considerably higher than the 2° to 4° slopes at which underwater muds start to slump, flow or form turbidity currents. The thinly-bedded, tuffaceous Hagman formation probably crops out on these slopes in a line between Dandan and Hagman. Periodically, and especially in a seismic region such as the Marianas, we should anticipate significant submarine movement of Hagman-derived muds along the slopes. It also appears from the directions of dip of the Hagman as seen near Site 1 that they coincide roughly with the direction of submarine slope, thus further reducing any safety factor.

Several writers (Tayama, 1938; Cloud, et. al., 1956) have suggested major submarine slumping as a possible mechanism for the formation and present configuration of Bahia Laulau.

Danger from Flooding

The probability of Site 1 being flooded by either storm waves or surface water is nil.

Alluvial Processes

There are no permanent streams in the Hagman area and only one or two important gully systems for storm drainage. Surface drainage across the

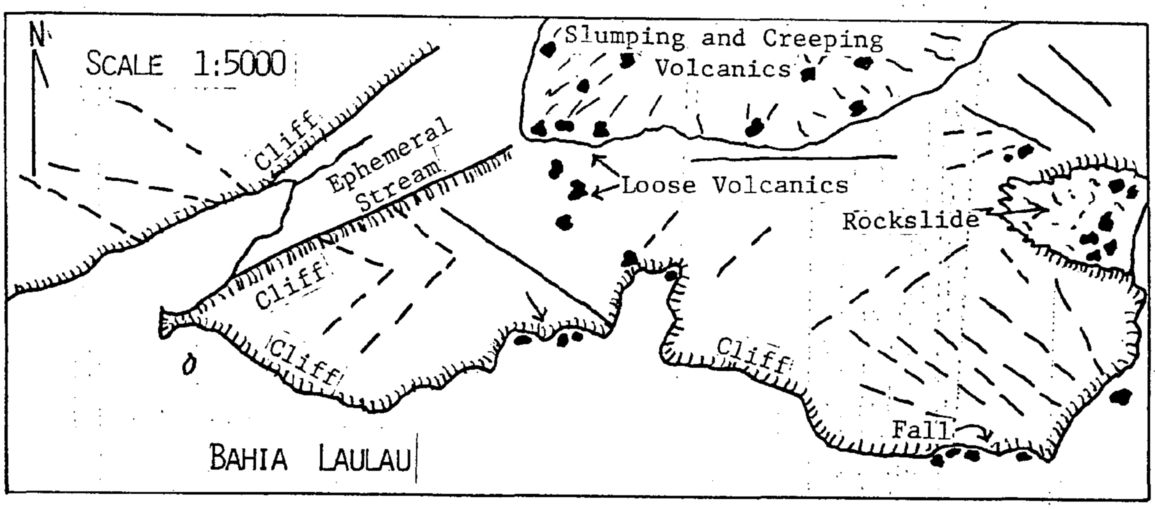


Figure 8. Map of fracture traces and mass wasting at Site 1. See Figure 6. Solid lines indicate probable fault; dashed lines probable joints. Analysis from airphoto and ground verification.

Mariana Limestone is short-lived because of its high permeability. Slopes on the Hagman formation are highly vulnerable to sheetwash and soil removal.

Subsurface

From the nature of the outcrops it is obvious that the Mariana and Tagpochau formations possess high porosity-permeability zones. Wells sunk in them, depending upon location, would only hit water at the contact between them and the underlying Hagman or at the freshwater-saltwater interface near sea level. Certainly, any construction planned for such heavily fractured and relatively soluble rock as the Mariana or Tagpochau Limestone demands a complete subsurface evaluation.

Coastline Configuration

The Hagman site generally faces south with several prominent headlands developing southeast and southwest faces. However, normal NE tradewinds seriously affect erosion rates by refraction around Isleta Maigoi. Tropical storms and typhoons would probably attack the base of Site 1 directly promoting active coastline retreat and generating sufficient submarine instability to initiate submarine slides directly off the site.

Economic Resources

The Japanese successfully developed a small manganese prospect on the east side of Hagman peninsula. The black oxide ore can still be seen stockpiled on a bluff overlooking Unai Hagman. No estimate of reserves is available. Such an estimate would require extensive geophysical surveying and exploratory drilling.

The stockpiled material was mined from the Tagpochau formation, occurring as both a vein filling and as the matrix in a breccia zone. Grinding, washing and jigging would probably concentrate the ore efficiently and inexpensively (using seawater).

The Mariana Limestone formation has been actively quarried on Hagman for fill material. The rock is crumbly and powdery and lacks any good aggregate quality. Andesite gravels in the Hagman formation, however, certainly are well-suited for construction aggregate and appear at the top of the cliffs east of Site 1.

Site 2, Unai Bapot

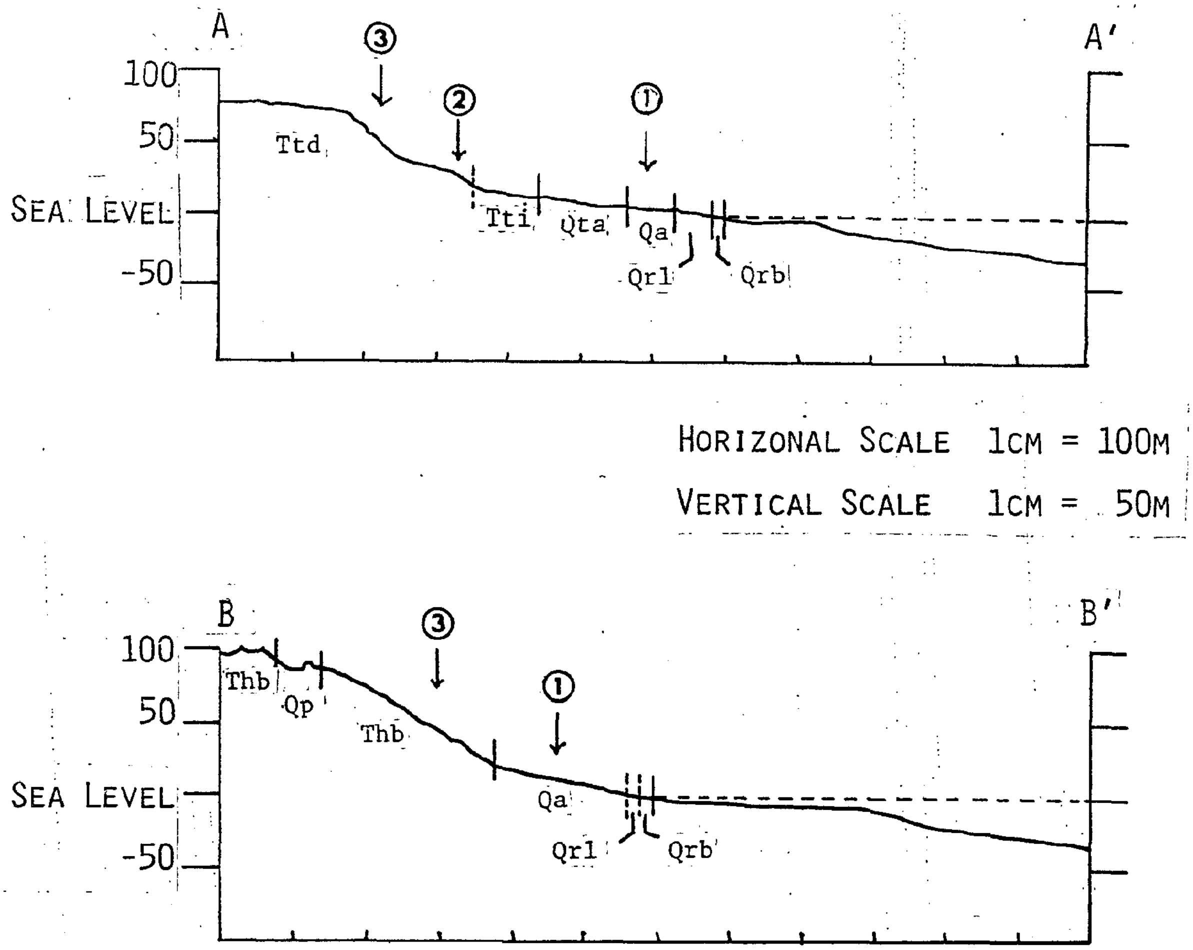
Location: Beach and backshore 400 m (1,312 ft) northeast of Trinchera Limestone and upslope terrain northwest of beach.

Profile: Figure 9a,b

Local Rock Units (Nine mapped units) (Rock unit symbols from Table 1)

Bedrock Units:	Tanapag	Qta
	Tagpochau	Tti, Ttd
	Hagman	Thc, Thb
Unconsolidated Units:	Beach Deposits	Qrb
	Emerged Limesands	Qrl
	Alluvium	Qa
	Older Terrace Deposits	Qp

The supratidal zone or backshore is dominated by Tanapag limestone and emerged sand and sandy gravel beach deposits. Northwest of the beach road the Tagpochau crops out along buttresses and benches between ephemeral stream valleys. Upslope the Tagpochau Limestone is underlain by highly weathered, tuffaceous Hagman volcanics and volcanoclastic sediments. Outcrops of the calcareous sandstone and shaly Donni member (Ttd) of the Tagpochau Limestone can be viewed on the hilly road leading almost due north from the beach road (following the former Japanese railroad line).



Figures 9a and 9b. Vertical cross-sections at Unai Bapot. Vicinity of Site 2. Section lines from Figure 6. Rock unit symbols from Table 1. Circled numbers refer to text on Slope Stability.

Normal stratigraphic relationships are evidence for little or no faulting. Jointing in the limestone member of the Tagpochau (Tti) is prominent but with no apparent pattern.

Beach deposits and emerged limesands are both calcareous and non-calcareous (silicate, oxide). Iron oxide (magnetite) and iron- titanium oxide (ilmenite) is found along intertidal foreshore, beach, emerged beach and in ephemeral stream deposits (Qa).

Soil Units: (5 units)

Saipan - Chacha

Lito - Akino - Dago

Chinen

Shioya

Rough stony land on limestone

Rough broken land

Good correlation exists between soil and rock units. Saipan - Chacha on Tagpochau; rough stonyland on Tanapag; rough broken land on Hagman; Shioya soils on calcareous sands and gravels.

Slope Stability: (Figures 9a,b)

Lower slopes are generally stable with minor soil creep on Tagpochau Limestone buttresses along the road. Slopes on Hagman and Donni member of Tagpochau Limestone display slumping and major soil creep (location 3, Figures 9a,b). Several mudflows are interlayered with alluvial valley fills (location 1, Figures 9a,b). A rock slide talus deposit (location 2, Figures 9a,b), occurs at the base of a steep Tagpochau Limestone cliff.

The index of Specific Vulnerability, V_S, ranges from 7.3 to 7.7, second highest on Saipan and third highest among all beaches on Rota, Tinian and Saipan. Moreover Unai Bapot's location on the north side of Bahia Laulau means that H_o, the initial height of typhoon-generated waves, might grow to be well in excess of the standard nine-meter typhoon wave (Bascom, 1964).

Alluvial Processes

Ephemeral streams draining the slopes north and northwest of Site 2 have deposited substantial alluvial fans composed of gravels, cobbles and sand intercalated with clay-rich layers and occasional debris flows. These deposits are designated Qa on Figures 9a,b. The large quantity of these materials attests to the velocity and discharge of flash floods as well as to upper slope instability, soil erosion and gullying. Eventually, this predominantly silicate-oxide detritus reaches the beach and reef flat area where it first forms small deltas; later the sandy portion is redistributed parallel to the beach by longshore currents while the clays are carried downward.

Subsurface

The Tanapag and Tagpochau Limestone formations are doubtless cavernous. Although no sinkholes were observed, a large cave in the Tagpochau limestone formation has its entrance on the beach road 400 m (1,312 ft) west of Site 2. Fresh water probably runs off the upslope Hagman limestone formation, down to the cavernous Tagpochau limestone formation and back to either the impermeable Hagman or to the water table which is in hydrostatic balance with sea level.

Coastline Configuration

Unai Bapot is positioned in Laulau such that is receives minimum expectable Northeast tradewind swell and maximum expectable typhoon swell.

Economic Resources

The Tagpochau formation cropping out immediately north of the beach road appears to possess the requisite density required for construction aggregate. It certainly appears no different in hand specimens from Tagpochau Limestone material presently being mined for aggregate near Marpi.

Site 3, Unai Laulau

Location: Northwest extreme on Bahia Laulau, 1.7 km (1.1 mile (m)) west-southwest of Unai Bapot, 150 m (492 ft) along coast northeast of point where beach road turns west toward Cross-Island highway.

Profile: Figured 10a,b

Rock Units: (7 mapped units) (Rock unit symbols from Table 1)

Bedrock Units:	Tanapag	Qta
	Mariana (dominant)	Qma, Qmm
	Tagpochau	Qti, Qtd
Unconsolidated Units:	Beach deposits	Qrb
	Alluvium	Qa

There are no volcanic rocks at Site 3. The stratigraphic sequence features Tanapag reefal limestone veneering seaward benches of Mariana and Tagpochau formation. Tagpochau Donni sandstone member (Ttd) is in fault contact with Tagpochau limestone on slope of major north-south ravine (north of Chamorro Village).

Soil Units: (4 units)

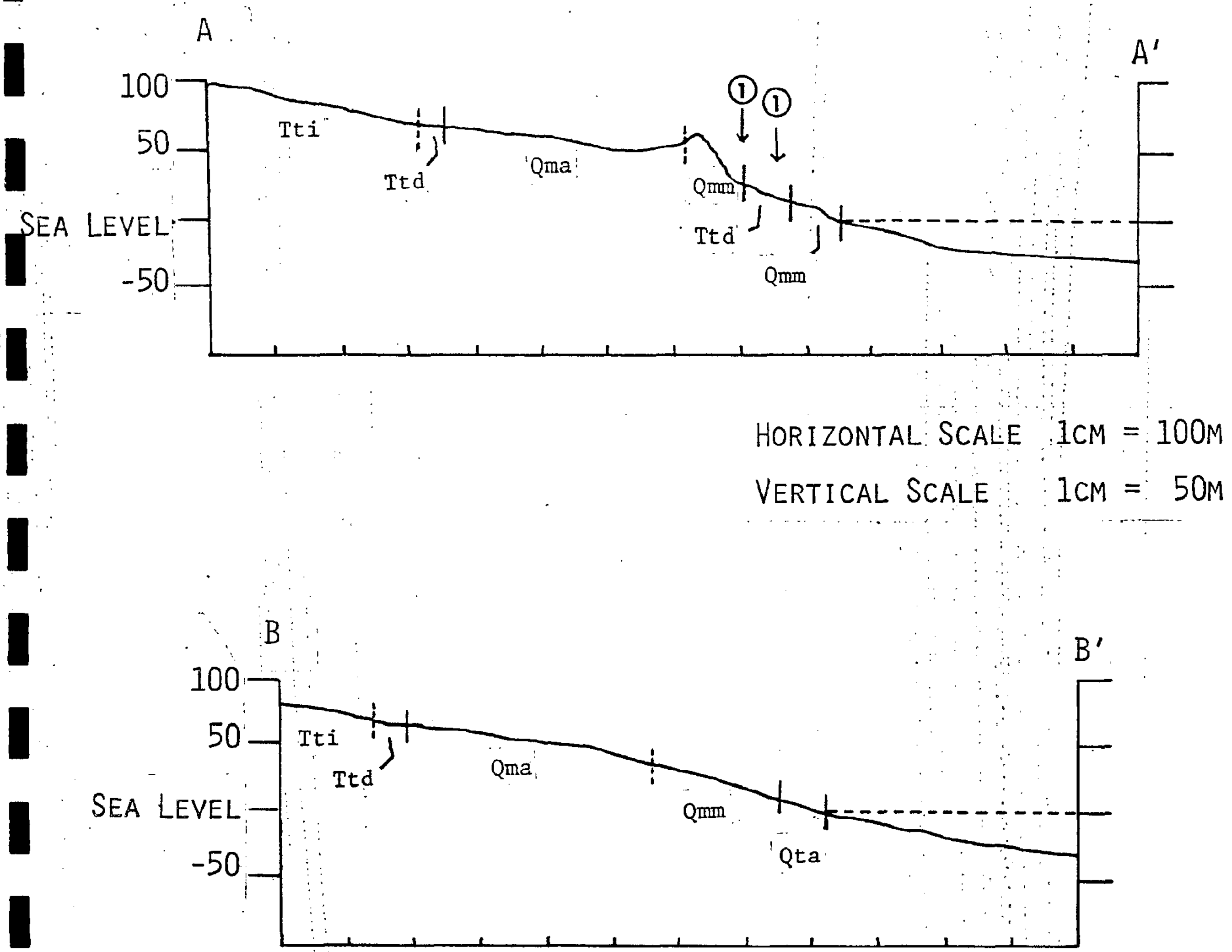
Saipan - Chacha

Chinen

Shioya

Rough Stony Land on Limestones

Shallow yellow-red to reddish yellow brown clay loams on Mariana and Tagpochau Limestone formation.



Figures 10a & 10b. Vertical cross-sections at Unai Laulau. Vicinity of Site 3. Section lines from Figure 6. Rock unit symbols from Table 1.

Slope Stability: (Figures 10a,b)

Relative stability of slopes characterizes this site. Minor slumping occurs in the Tagpochau (Ttd) Donni sandstone member (location 1, Figures 10a,b). Possible rotational sliding of Tagpochau limestone is indicated at fault in ravine. Soil creep is evidenced on road and hillsides below Chamorro Village.

Danger from Flooding

Danger of flooding is less severe than at Site 2. V_S ranges from 5.1 to 5.5. Downslope runoff and stream discharges are not likely to cause dangerous flooding. The small watershed (collecting area) and lack of impermeable volcanics needed to prevent infiltation and loss of discharge lower the possibility of serious flooding.

Site 3 is somewhat more protected than Site 2 from flooding due to expectable typhoon-generated swells; it is generally more susceptible to tradewind-driven wave flooding.

Alluvial Processes

Some active soil erosion and alluvial transport were noted in gullys along the road. Alluvial fill occupies a major ravine north of Chamorro Village. The road itself may become a sediment channel during typhoon conditions.

Subsurface

Highly fractured bedrock. Construction on Mariana and Tagpochau limestone units inadvisable without thorough subsurface investigation.

Coastline Configuration

Vulnerable to both typhoon and tradewind propagated waves. Active headland erosion on cliffs below Chamorro Village; very susceptible to major storms. Longshore drift is generally northeast to southwest.

Economic Resources

Rubbly, sugary coralline Mariana limestone was formerly quarried from the hillside immediately north of road, 400 m (1,312 ft) west of Bay. No potential for aggregate-quality materials.

Site 4, Unai Dandan

Location: Immediately southeast of Unai Dandan along 10 m (33 ft) high wave-cut bench, approximately 500 m (1,640 ft) from northeast end of airport runway.

Profile: Figure 11

Rock Units: (4 units:low diversity) (Rock unit symbols from Table 1)

Bedrock Units:	Tanapag	Qta
	Mariana (dominant)	Qmm, Qmh
Unconsolidated Units:	Beach Deposits	Qrb

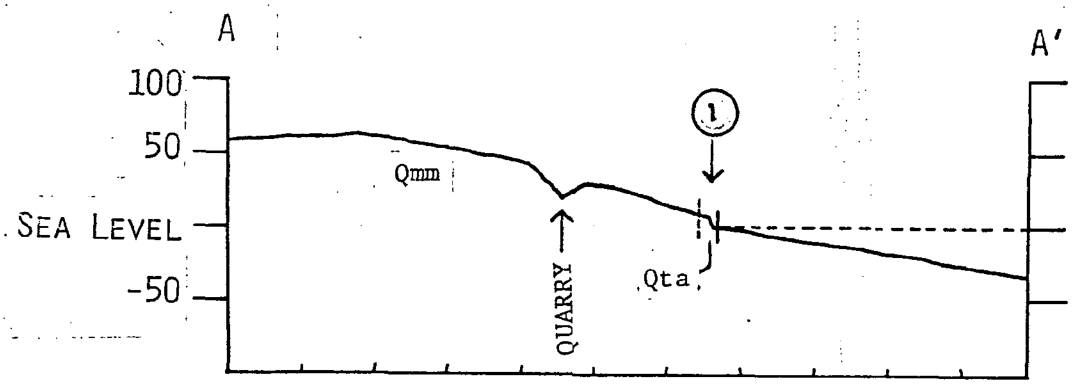
Ten and thirty-meter wave-abrasion terraces cut into massive and cavernous Mariana forereef detrital limestone. Numerous solution pipes and joints are found in Mariana and in subordinate Tanapag limestone. No faulting evident. Secondary solution features are pervasive in quarry outcrops of Mariana limestone.

Soil Units: (1 unit)

Rough stony land on limestone. Soil found only in irregular pockets in solution pipes and joints in limestone.

Slope Stability: (Figure 11)

Slopes at Site 4 are stable. Only occasional rock falls from open-tension fractures above wave-cut notches present any slope problems (Location 1, on Figure 11).



HORIZONTAL SCALE 1CM = 100M

VERTICAL SCALE 1CM = 50M

Figure 11. Vertical cross-section at Unai Dandan. Vicinity of Site 4. Section line from Figure 6. Rock unit symbols from Table 1. Circled numbers refer to text on Slope Stability.

Danger from Flooding

None. Rapid infiltration of surface water prevents sheetwash or channel flow. Typhoon waves from unexpectable NE direction could easily spray upper 30 m bench.

Alluvial Processes

No surface water. Any mobilized soil moves into fractures and solution pipes, not along surface.

Subsurface

Very porous with high implied permeability. Random surface depressions and perhaps sink holes to be expected. Thorough subsurface analysis must precede heavy construction.

Coastline Configurations

Northeast facing coastline along Bahia Laulau should anticipate almost constant wave attack. Headlands will be especially vulnerable at Site 4.

Economic Resources

The Mariana limestone has been quarried at this site practically since the reconquest of Saipan. It appears on 1946 airphotos. The material in outcrop is deceptively hard and appears to be appropriate for aggregate. But, like most near-surface Mariana limestone, the rocks have been altered by solution and reprecipitation giving it a marbleized patina. Subsurface samples tend to be more crumbly and chalky except along solution pipes and fractures where the limestone resembles outcrop samples.

DISCUSSION

Comparison of Sites

Table 4 (Appendix A) presents a synopsis of the major features presented in the site evaluations, enabling qualitative comparisons to be drawn. For major on-shore construction, Site 4 is generally the most suitable in that it exhibits the fewest unfavorable geologic constraints. However, all the sites have an abundance of limestone bedrock that is notorious for subsurface permeability and porosity. Very careful field mapping, geophysical profiling, airphoto interpreting and drilling should precede heavy construction. The presence of fractures and caverns may be such as to preclude any of the sites being acceptable.

Geologically, Site 1 offers to tourists and naturalists alike one of the most uniquely interesting and important landscapes in the entire Northern Marianas. Hagman constitutes an outdoor laboratory illustrating the major steps in the 30-million year physical evolution of Saipan from a submarine volcano to a terraced "high" island.

CONCLUSIONS

Site 1 is a very diverse area and scenic location. It has great diversity of geology, extreme instability of onshore slopes, probable instability offshore, wave-vulnerability to cliffs and headlands, no surface water, fractured and permeable bedrock and a small manganese prospect.

Site 2 is generally a peaceful recreational site. However, it is highly vulnerable to typhoon swells as well as to flash flooding down ravines to the north. Although there is a strong possibility of flooding, the lower elevation slopes are stable.

Site 3 is generally a recreational location like Site 2 with relatively stable slopes and coastline. There is the potential danger of flooding during typhoons like Site 2. Alluvial processes in the area present few sedimentation or drainage problems. However, subsurface porosity may present construction problems.

Site 4 is a scenic location with excellent view of Bahia Laulau and Hagman. Here there are stable slopes and the coastline is generally protected from typhoon-driven waves. However, prevailing winds and waves create rough offshore conditions as a normal occurence. The substrate is very porous and there are no streams.

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PHYSICAL PARAMETERS

INTRODUCTION

This section includes data on physical parameters found specifically within Bahia Laulau or in the general Saipan area. General climatological data include: air temperature, relative humidity, rainfall, wind direction and speed, sea temperature, occurence of tropical disturbances and typhoons. Specific data collected within Bahia Laulau include deep oceanic water temperature and salinity, wind direction and speed, bathymetric profile, inshore and offshore current patterns and nearshore water quality.

METHODS

General climatological data mentioned above were compiled from existing data (U.S. Naval Weather Service Command, 1971; Naval Oceanography Command Center, Guam, 1983; U.S. Department of Commerce, National Climate Center, 1981). Wind direction and speed were measured during each of the four field investigations.

Oceanic temperature and salinity were measured on November 4, 1982 at the surface and four depths (229 m (750 ft), 305 m (1,000 ft), 381 m (1,250 ft), 457 m, (1,500 ft)) directly offshore of the proposed OTEC site (Figure 12) (Table 5, Appendix A). All sampling was carried out from the M/V Bahia Laulau and the CRMO Zodiac utilizing a 1.2 liter Nanson-type water sampler (G.M. Manufacturing Co.) equipped with Kahlisco deep sea reversing thermometers (-2° to 35°C). By using the combination of protected and unprotected reversing thermometer readings, accurate temperature measurements were determined and the depths calculated.

A single bathymetric profile was taken off the proposed Bahia Laulau OTEC site. This profile was made to a depth of 732 m (2,400 ft) with a

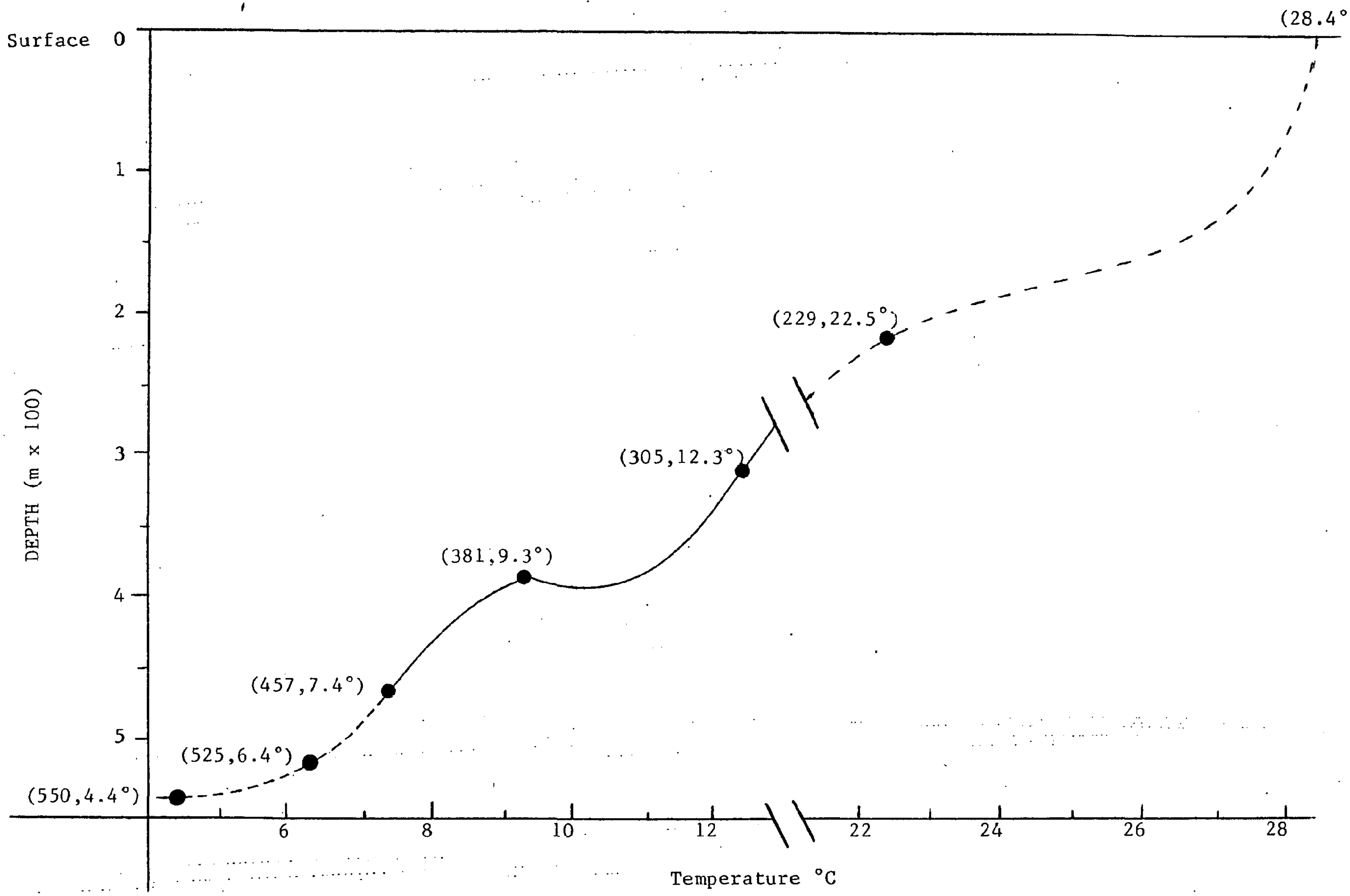


Figure 12. Temperature profile from surface to depth of 457 m (1500 ft) off proposed OTEC site.

Fine Line Fathometer (Ross Model 400-A). The transect followed a compass course of 165°(SSE) until the limit of the recording fathometer was reached (Figure 13).

To determine general water movement patterns of the Bay, a necessity for a potential OTEC operation or other future activity that may be planned for the area, it was determined that a year-long study was necessary using drift drogues placed at various points within Bahia Laulau.

Water movement and current patterns were investigated quarterly over a year period employing 1 m and 5 m drift drogues offshore and fluorescene dye releases on the reef-flats. Drogues were checked every 30 to 60 minutes after release and their position determined by triangulation (fix) on preestablished marks with a hand-bearing compass. Depending upon the distance traveled, the drogue was then either picked up and restarted or allowed to drift another 30 to 60 minutes. Tracks were then plotted on a chart to determine general water movement patterns. Additionally, at the time of every set or fix the direction and velocity of the wind was noted.

On the reef flats, dye was released and allowed to travel a distance of 10 m (33 ft). The time and direction of travel were recorded, and from this direction and velocity (meters/second) of the current were determined. Each dye release was repeated three times and averaged for each location. Dye release studies were done only for sites 2 and 3 where reef flats occur.

Nearshore water quality has only been superficially evaluated in the Bahia Laulau area. The CNMI Department of Environmental Quality collected water samples from 10 stations in Bahia Laulau during February 1983 (Figure 13). These 10 samples were evaluated for total and fecal coliform only indicating the degree of pollution in localized areas. Future

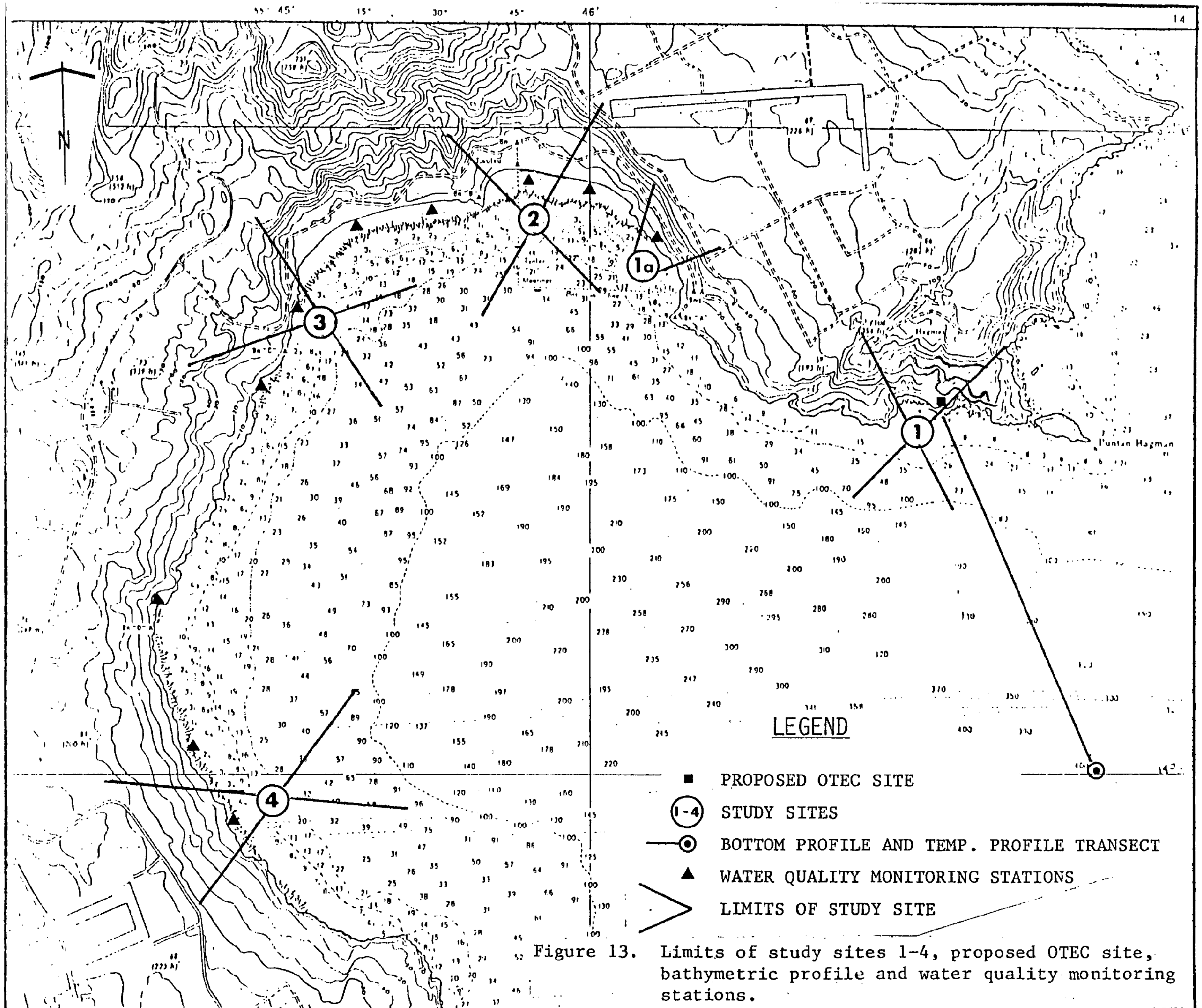


Figure 13. Limits of study sites 1-4, proposed OTEC site, bathymetric profile and water quality monitoring stations.

monitoring will include five additional parameters; turbidity, suspended solids, chlorides (salinity), dissolved oxygen and pH.

RESULTS

Air Temperature

The island of Saipan is located between 15°05' and 15°20' North latitude and 145°40' and 145°50' East longitude. The climate of Saipan is considered tropical, being almost uniformly warm and humid throughout the year. Afternoon temperatures are typically in the middle or high eighties and nighttime temperatures typicallty fall to the middle or low seventies. The average annual temperature on Saipan is 27.5° C (81.5°F), with a mean maximum temperature of 32.2° C (90°F) and a mean minimum temperature of 22.2° C (72°F) (U.S. Naval Weather Service, 1971). The daily temperature fluctuation is about 10°F. The hottest months are usually June through October, while the cooler season falls between the months of January and April.

Relative Humidity

Relative humidity generally varies from 75 to 100 percent with an annual mean value of 81 percent (U.S. Naval Weather Service, 1971). Humidity commonly ranges from around 65-75 percent in the early afternoon or during the winter months to 85-95 percent at night or during the hotter, rainy months (Naval Oceanography Command Center, Guam, 1983). Both temperature and humidity vary only slightly throughout the year, but rainfall and wind conditions vary markedly and it is these variations that define the seasons on Saipan.

Rainfall

Annual rainfall on Saipan averages approximately 86 inches with a monthly average of 7.2 inches. The wettest months are August and

September with averages of about 13-14 inches while the dryest months are February and March which average 2.5 - 3.5 inches of precipitation (Hinz, 1980 and U.S. Dept. of Commerce, National Climate Center, 1981). Data from the U.S. Coast Guard Station in the southeastern portion of the island indicate an average annual precipitation of 76.6 inches (recent 10 year period) ranging from a low of 58.85 inches to a high of 102.23 inches.

Wind

In the vicinity of Saipan, the steadiest winds occur when the winter monsoon and the northeast trades reinforce each other. Between November and April, northeasterly to easterly winds prevail approximately 70 percent of the time at a velocity of 10-12 knots (kn) (8.7 - 10 mph) (Hinz, 1980). Easterly winds predominate 47.7 percent annually with a mean speed of 12.0 kn (10 mph) while northeasterly winds occur 24.9 percent of the year with a mean speed of 12.5 kn (11 mph) (U.S. Naval Weather Service Command, 1971). The calmest months of the year are July - September when winds typically average less than 6 kn (5 mph).

Water Surface Temperature

The mean surface sea temperature for Saipan is 28.6° C (83.4°F). The mean minimum temperature of 27.3° C (81.1°F) occurs during February, while August has the highest mean temperature of 29.6° C (85.2°F) (U.S. Naval Weather Service Command, 1971).

Tropical Disturbances and Typhoons

Saipan is in an area where many tropical disturbances occur. Tropical storms become typhoons if surface winds at some time during the progress of the storm reach a speed of 64 kn (55 mph) or greater. Although the storm tracks are often erratic when in the vicinity of Saipan, they generally move towards the WNW.

Tropical disturbances occur most often between July and November and are least likely to occur from January to April. One source shows an average of one storm a year originating in or passing over this area (Hinz, 1980). Guam data (1959 - 1981) shows the occurance of all tropical cyclones (depressions, storms and typhoons) was greatest during the months of August (6.3 cyclones) and September (5.9) and the least frequent during February (0.3), January (0.6) and March (0.7) (U.S. Naval Oceanography Command Center, 1983). The frequency of typhoons follows the exact same monthly pattern, ranging from a low of 0.04 typhoons in February to a high of 3.4 in August.

Oceanic Temperature and Salinity Profiles

Temperatures at the proposed OTEC site appear to follow a well defined profile typical in the Western Pacific, i.e., a warm, well mixed surface layer of nearly constant temperature, a thermocline region where temperature declines with increasing depth and a deep cold layer (Figure 12). The depth at which these regions or zones occur vary on a global scale with latitude and season. At lower latitudes (0°-15° north or south) the thermocline depth begins much shallower than that found at mid-latitudes: usually related to frequency of storm activity. Typically, the lack of storm activity and lower air temperatures in spring result in a shallow, highly angular thermocline. Increased air temperatures and more frequent storms in late summer and fall tend to create a deeper mixed layer thus increasing the thermocline depth and smoothing the shape of the profile.

Water temperature was measured at the surface and four depths as follows (229, 305, 381 and 457 m) (Figure 13). Temperature decreased from

28.4° C (83.1° F) at the surface to 22.5° C (72.5° F) at 229 m (Table 5, Appendix A). Between 229 m and 457 m the temperature decreased to 7.4°C (45.3° F). Although we did not actually measure the temperature between 457 and 550 m we did extrapolate the temperatures based on similar observations in the region. The temperatures at 525 and 550 m were extrapolated to be 6.4° C (43.5° F) and 4.4° C (39.9° F) respectively.

Salinity is the most frequently measured chemical parameter in seawater. It is the single measurable parameter which can be used in conjunction with temperature and pressure to calculate other properties of seawater, e.g. density. A change of 1 percent in salinity has a much larger effect on density than a 1°C change in temperature. However, the wider range in temperature variation dominates the density profile.

The salinity profile off the proposed OTEC site is similar in shape to that shown in Lassuy (1979) and corresponds well with Williams (1962) and Gregg (1973) for the Mid-Pacific region. Craig, et. al. (1977) reported average surface salinities of 34.5 percent and a maximum of 34.9-35.1 percent between 150 and 200 m (492-656 ft) for ocean water near Guam. These coincide with observed values at similar depths of the Bahia Laulau OTEC site (Table 5, Appendix A). There appears to be a salinity inversion between the surface and 300 m (1,000 ft). This inversion is typical and has been reported in nearshore waters surrounding Guam and other islands of the Marianas archipelago (Lassuy, 1979).

Bottom Profile

Figure 13 identifies the site where bathymetric studies took place. Figure 14 illustrates the profile and degree of slope. It is evident from this profile that the slope is extreme ($\bar{x}$ = 45%) from the surface to a depth of approximately 550 m (1,800 ft) only 1.1 km (0.7 miles) offshore. From this

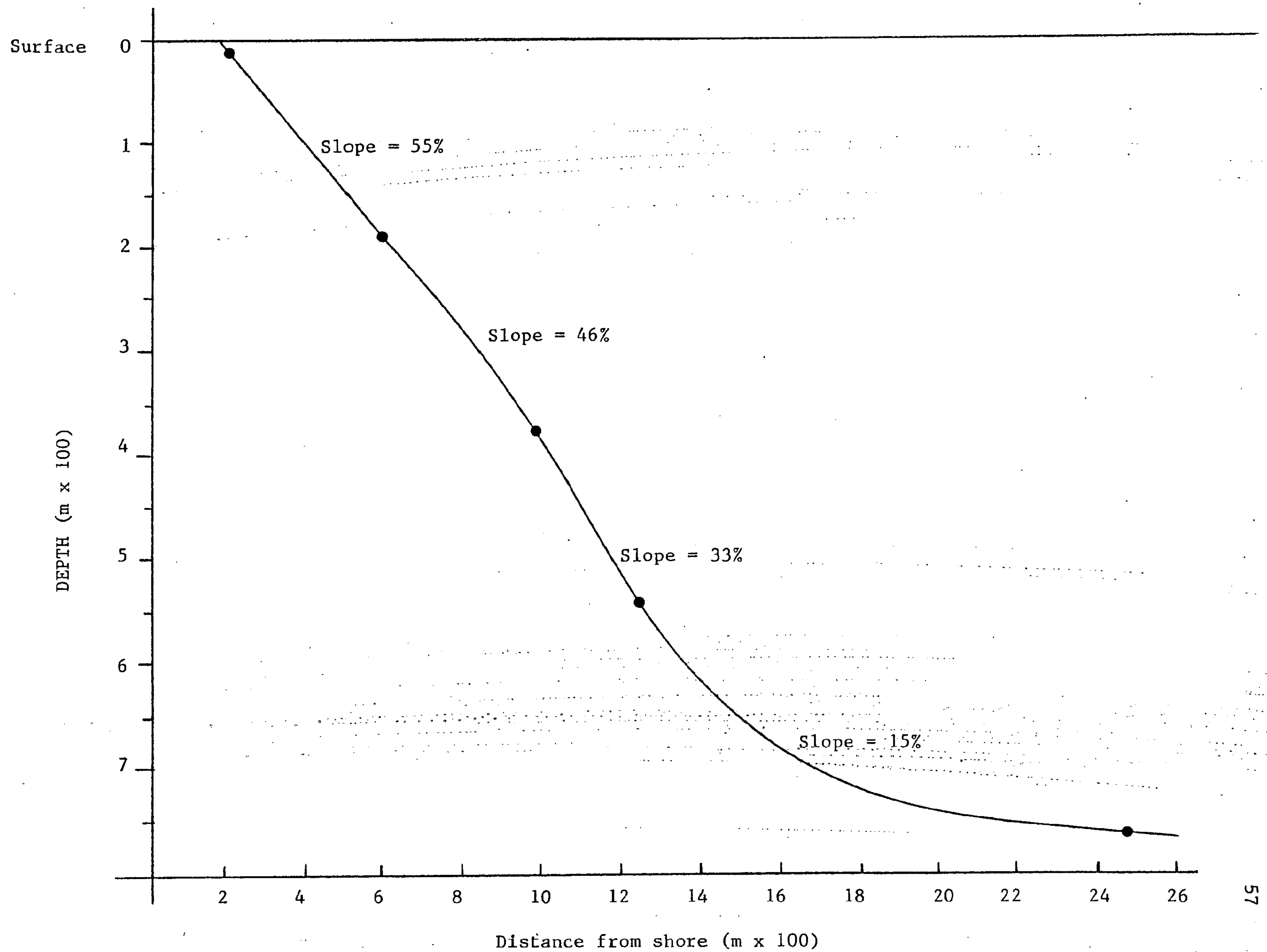


Figure 14. Bottom profile from shoreline to a depth of 730 m (2400 ft) off proposed OTEC site. Average slope = 37 percent.

depth, the slope smooths out gradually to 15 percent at a depth of approximately 700 m (2,400 ft) 1.8 km (1.1 miles) offshore along the profile.

Although bathymetric studies were not conducted in other areas of Bahia Laulau, examination of hydrographic charts indicates that the 100 fathom contour (600 ft) runs closest to shore (0.5 km, 1,584 ft) along the Hagman peninsula. This contour runs nearly as close to the shore along the northwestern coast of Naftan Point, the southern extreme of Bahia Laulau. The 100 and 20 fathom contour lines are fairly uniform in terms of distance from shore. With the exception of Hagman and Naftan Points, bathymetric profiles within central Bahia Laulau are more gradual with less degree of slope, and shallower further offshore. Once offshore, depth increases drastically in the direction of the Marianas Trench. Having adequate depths so close to shore at Hagman Point suggests a significant resource in terms of OTEC development and energy production.

Current Patterns

The currents in Bahia Laulau are not well known. Historically, no previous work has been done anywhere in the Bay regarding water movement. Fishermen who fish along the cliffs or 100-fathom contour from station 1a to the northeastern tip of Bahia Laulau (Puntan Hagman) frequently report the current running along the contour to the east, opposite in direction to prevailing wind and surface waves. It has been postulated that an overall circular current pattern may exist in Bahia Laulau with large volumes of water entering the southern portion of the Bay then traveling along the inside contours until it exits at the northeastern opening (Figure 15). The following are results from current studies in Bahia Laulau.

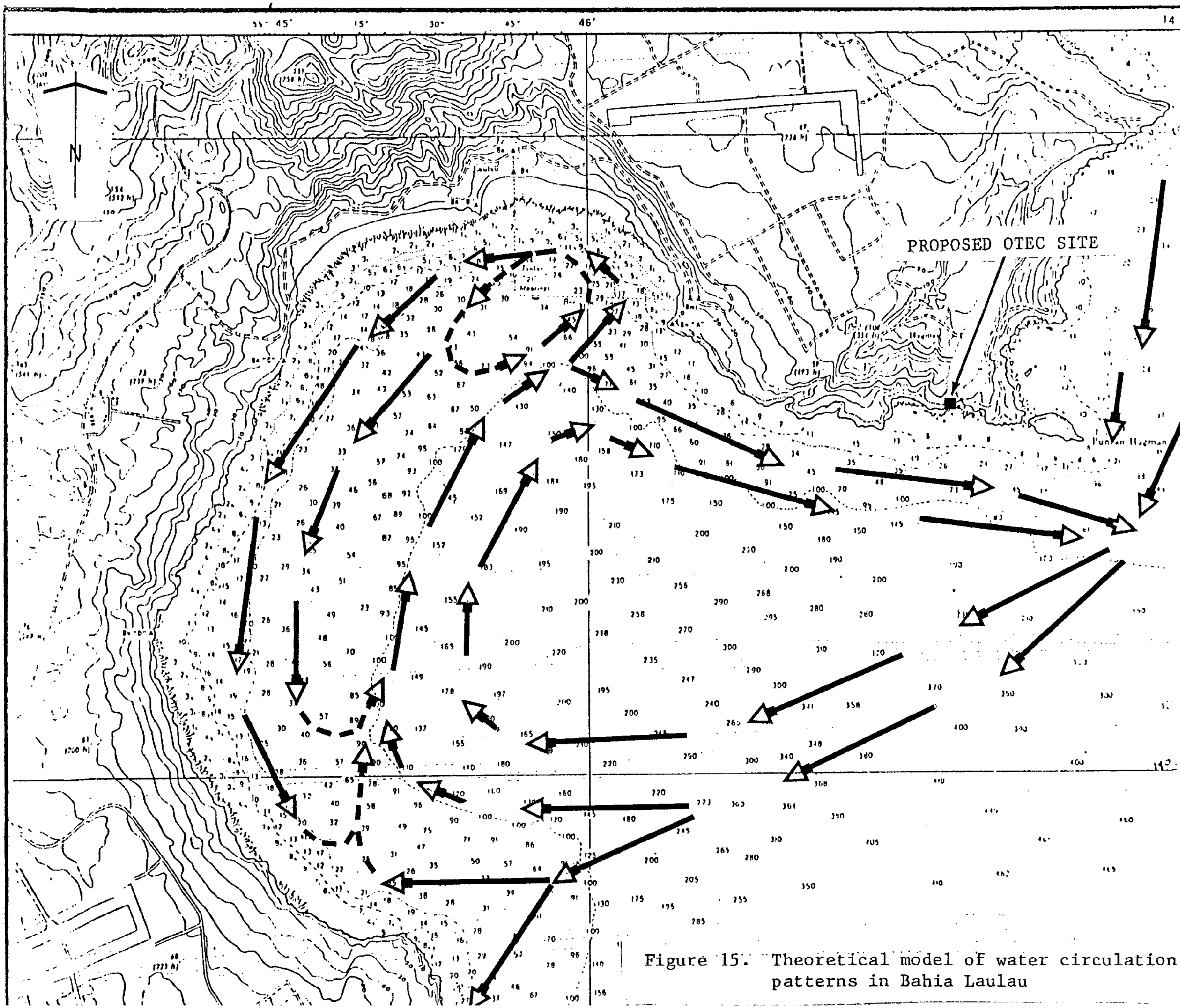


Figure 15. Theoretical model of water circulation patterns in Bahia Laulau

Results

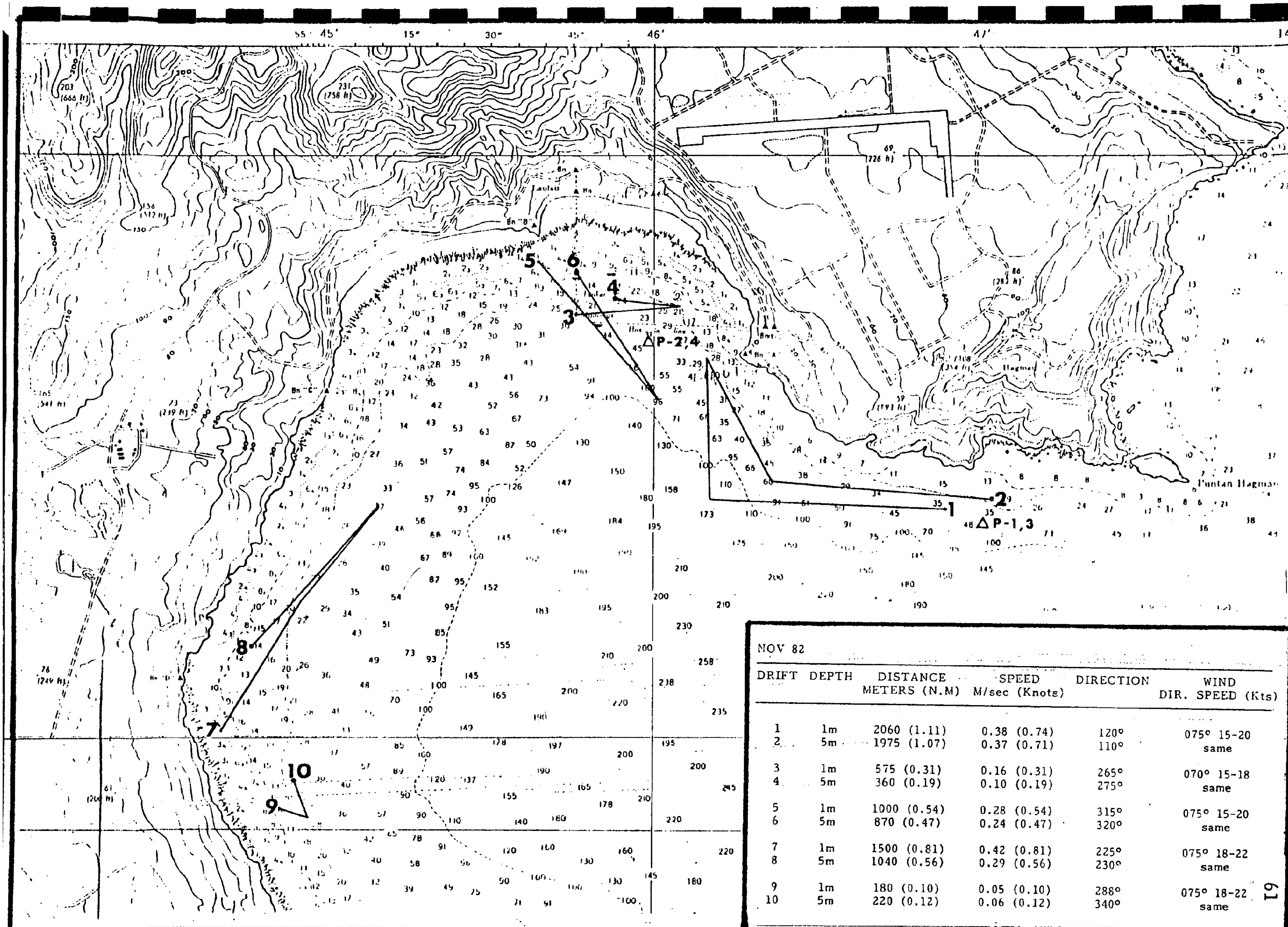
Offshore

A. November 1982, February 1983, May 1983 and September 1983

The results of the offshore current studies conducted November 5 - 6, 1982, February 9, May 10 - 11 and September 29-30, 1983 are shown in Figures 16 a,b,c,d. Extremely strong winds and heavy seas restricted drogue placement in the vicinity of Sites 1, 1a, and 2 during November, but drogue releases were completed at all sites in February, May and September 1983. In addition, a mid-bay release was conducted during the May survey.

Although current patterns were not clearly established by this survey, some general trends have been noted. It seems likely that the majority of the water enters Bahia Laulau from the northeast (prevailing wind direction) and splits apart at Dandan Point at the southern part of the bay. This would form a rather consistent and strong clockwise water pattern within the center of Bahia Laulau. The leading edge of this water mass likely moves along or near the 100 fathom (600 ft) contour eventually emerging in the northern part of the bay at Puntan Hagman. Here it would enter deeper water and/or merge with the overall water mass moving to the southwest (Figure 15).

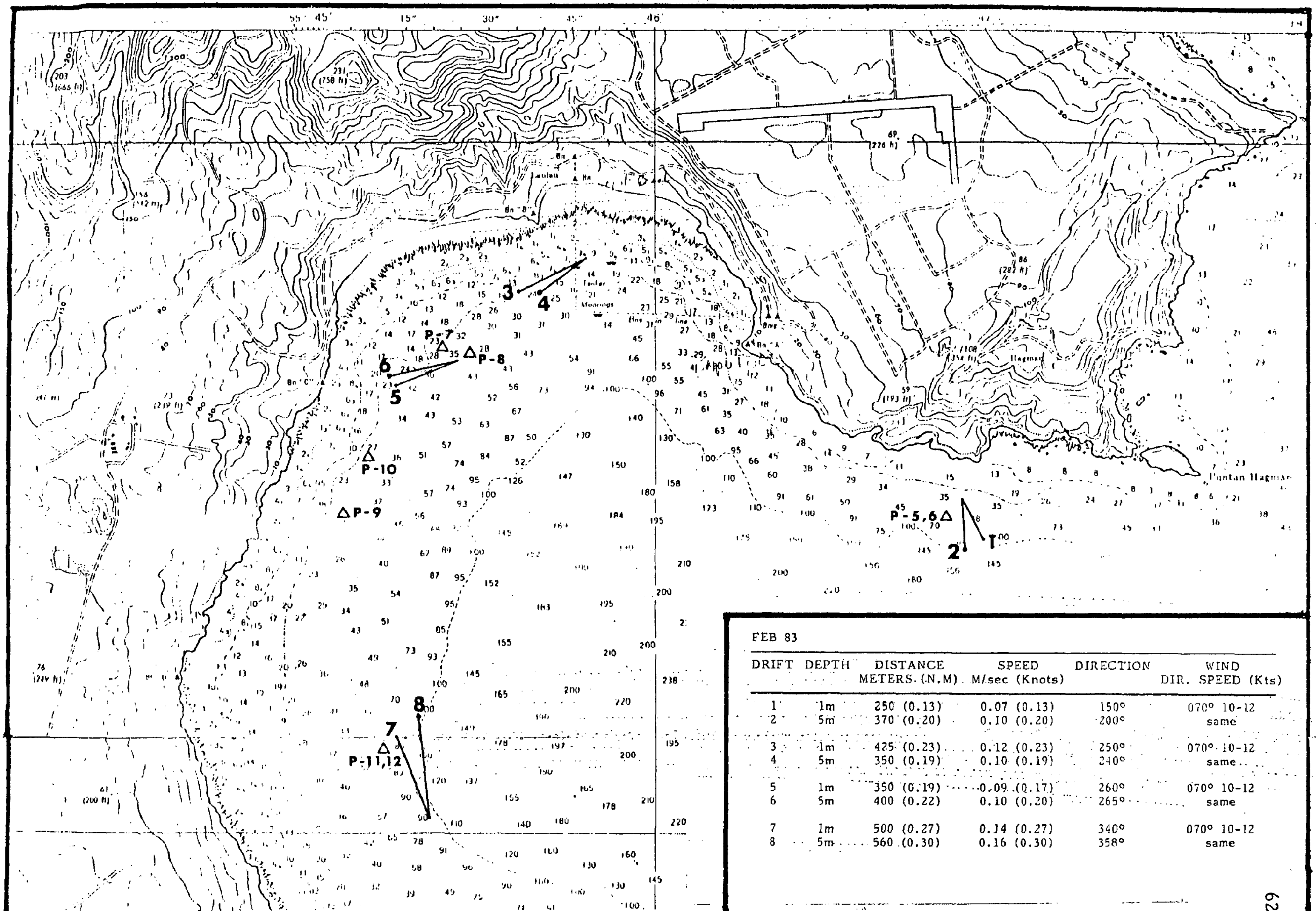
Near-shore water circulation patterns of Bahia Laulau inside the 100 fathom (600 ft) contour are much more complex and seasonally variable. They are influenced more by the prevailing winds and seas and preliminary data suggest they may run counter to the deeper water circulation by following the shoreline. Several small eddies may also form in more enclosed areas such as the cove-like embayments found at Sites 2 and 3. Most of the drogues that were released close to shore traveled along the shore or



NOV 82

DRIFT	DEPTH	DISTANCE METERS (N.M)	SPEED M/sec (Knots)	DIRECTION	WIND DIR. SPEED (Kts)
1	1m	2060 (1.11)	0.38 (0.74)	120°	075° 15-20
2	5m	1975 (1.07)	0.37 (0.71)	110°	same
3	1m	575 (0.31)	0.16 (0.31)	265°	070° 15-18
4	5m	360 (0.19)	0.10 (0.19)	275°	same
5	1m	1000 (0.54)	0.28 (0.54)	315°	075° 15-20
6	5m	870 (0.47)	0.24 (0.47)	320°	same
7	1m	1500 (0.81)	0.42 (0.81)	225°	075° 18-22
8	5m	1040 (0.56)	0.29 (0.56)	230°	same
9	1m	180 (0.10)	0.05 (0.10)	288°	075° 18-22
10	5m	220 (0.12)	0.06 (0.12)	340°	same

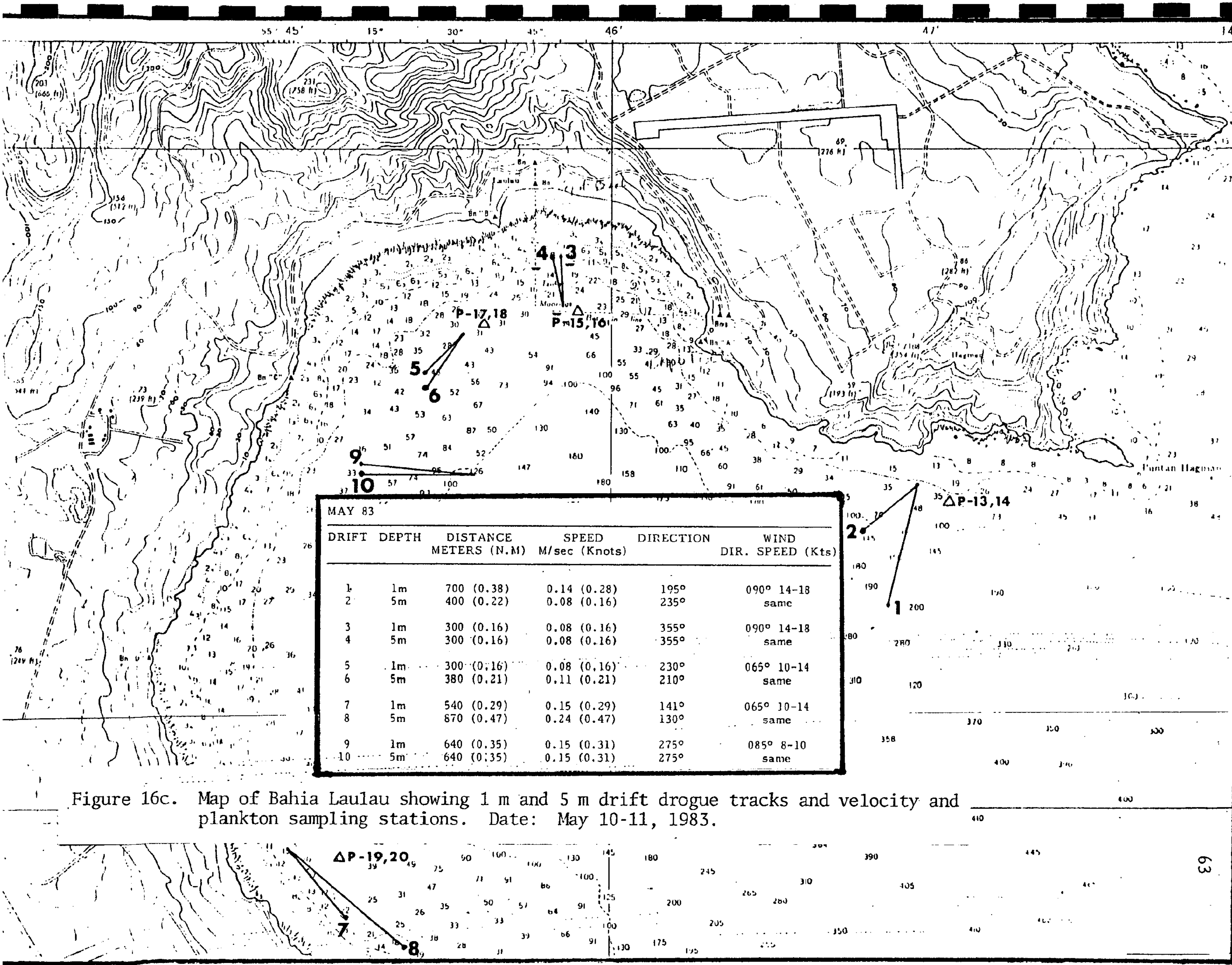
Figure 16a. Map of Bahia Laulau showing 1 m and 5 m drift drogue tracks and velocity and plankton sampling stations. Date: November 5-6, 1982.



FEB 83

DRIFT	DEPTH	DISTANCE METERS (N.M)	SPEED M/sec (Knots)	DIRECTION	WIND DIR. SPEED (Kts)
1	1m	250 (0.13)	0.07 (0.13)	150°	070° 10-12
2	5m	370 (0.20)	0.10 (0.20)	200°	same
3	1m	425 (0.23)	0.12 (0.23)	250°	070° 10-12
4	5m	350 (0.19)	0.10 (0.19)	240°	same
5	1m	350 (0.19)	0.09 (0.17)	260°	070° 10-12
6	5m	400 (0.22)	0.10 (0.20)	265°	same
7	1m	500 (0.27)	0.14 (0.27)	340°	070° 10-12
8	5m	560 (0.30)	0.16 (0.30)	358°	same

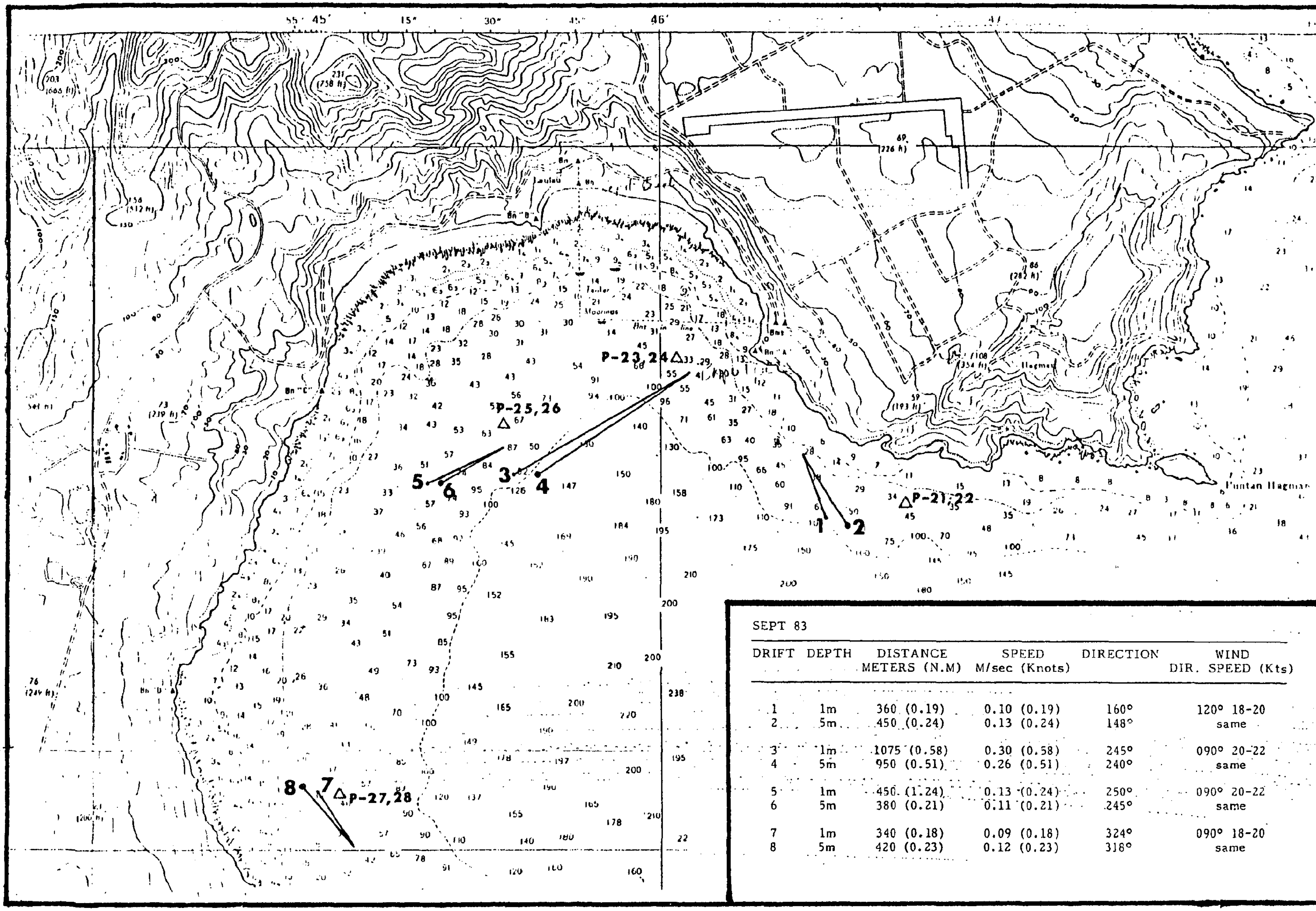
Figure 16b. Map of Bahia Laulau showing 1 m and 5 m drift drogue tracks and velocity and plankton sampling stations. Date: February 9, 1983.



MAY 83

DRIFT	DEPTH	DISTANCE METERS (N.M)	SPEED M/sec (Knots)	DIRECTION	WIND DIR. SPEED (Kts)
1	1m	700 (0.38)	0.14 (0.28)	195°	090° 14-18
2	5m	400 (0.22)	0.08 (0.16)	235°	same
3	1m	300 (0.16)	0.08 (0.16)	355°	090° 14-18
4	5m	300 (0.16)	0.08 (0.16)	355°	same
5	1m	300 (0.16)	0.08 (0.16)	230°	065° 10-14
6	5m	380 (0.21)	0.11 (0.21)	210°	same
7	1m	540 (0.29)	0.15 (0.29)	141°	065° 10-14
8	5m	870 (0.47)	0.24 (0.47)	130°	same
9	1m	640 (0.35)	0.15 (0.31)	275°	085° 8-10
10	5m	640 (0.35)	0.15 (0.31)	275°	same

Figure 16c. Map of Bahia Laulau showing 1 m and 5 m drift drogue tracks and velocity and plankton sampling stations. Date: May 10-11, 1983.



SEPT 83

DRIFT	DEPTH	DISTANCE METERS (N.M)	SPEED M/sec (Knots)	DIRECTION	WIND DIR. SPEED (Kts)
1	1m	360 (0.19)	0.10 (0.19)	160°	120° 18-20
2	5m	450 (0.24)	0.13 (0.24)	148°	same
3	1m	1075 (0.58)	0.30 (0.58)	245°	090° 20-22
4	5m	950 (0.51)	0.26 (0.51)	240°	same
5	1m	450 (1.24)	0.13 (0.24)	250°	090° 20-22
6	5m	380 (0.21)	0.11 (0.21)	245°	same
7	1m	340 (0.18)	0.09 (0.18)	324°	090° 18-20
8	5m	420 (0.23)	0.12 (0.23)	318°	same

Figure 16d. Map of Bahia Laulau showing 1 m and 5 m drift drogue tracks and velocity and plankton sampling stations. Date: September 29-30, 1983.

towards shore in a general south to southwest direction. A generalized model of currents in Bahia Laulau is shown in Figure 15.

Inshore

The inshore (reef-flat) current patterns are typical of any reef flat that is influenced by winds and tidal changes. Since depth of water covering the reef-flat areas varies from almost zero at very low tides to as much as one meter or more at high tide, the prevailing winds usually dictate the direction and velocity of the water movement. The majority of the dye releases at Sites 2 and 3 resulted in movement parallel to the shoreline, with the general water movement to the west at Site 2 and to the south or southeast at Site 3. During incoming (flood) or outgoing (ebb) tides, the water tends to move towards a channel, cut or low area in the reef flat where the majority of the water mass is entering or leaving the reef. This strong tidal flow usually overpowers the wind-driven water movement unless they happen to be in similar directions. This is particularly evident at Site 2 where the cut in the reef accounts for much of the water flow into and out of the reef flat.

Water movement was generally faster during periods of high tides than low. The rate of water movement ranged from 0.1 m/sec (0.19 kn) to 0.35 m/sec (0.68 kn), with a mean of 0.13 m/sec (0.25 kn).

During low tides, slack water (no tidal movement) or light trade winds, water movement along the reef flats was generally slower. At times, there was little or no water movement due to light winds and/or minimal drainage of the reef flat during low tides. When dye was released during these conditions it would either move very slowly or eddy in a circular pattern showing very little if any along shore movement. Water movement at low tides and light wind conditions ranged from no movement to 0.12 m/sec (0.23 kn), with a mean of 0.07 m/sec (0.13 kn).

Direction of water movement at Site 2 averaged 265° (westerly movement), with the majority of the dye releases traveling parallel to the shoreline. The only exception to this general pattern was when a dye release was close to the cut (boat channel) in the reef during an outgoing tide. Water movement at these times was towards the cut, but only if the dye release was very close (a few meters) to the channel.

Dye release studies at Site 3 also showed strong along shore movement, with an average direction of movement at 170°, almost due south. More eddying was observed at this site, especially in dye releases that were located midway between the shore and the reef crest and during periods of low tides. This was probably due to Site 3 being both shallower and wider than the reef flat at Site 2.

Water Quality

Review of literature indicates that very little chemical water quality data exists from Bahia Laulau. Simple physical water quality parameters such as temperature have been evaluated in this report and salinity is the only chemical parameter examined in this study. Early discussions with the CNMI Department of Environmental Quality resulted in the expansion of their water quality monitoring program to include approximately 10 stations in Bahia Laulau. This program began in January 1983 by examining marine waters in Bahia Laulau for total and fecal coliform bacteria.

Marine waters were sampled in Bahia Laulau for fecal coliform on February 16, 1983. Ten (10) stations were monitored from the south end near the quarry below the runway and north to the extent of vehicle passage (Figure 13). The following are results from this initial survey.

LOCATION	TOTAL COLIFORM	FECAL COLIFORM
South end of Laulau Bay (Unai Tuturan)	10	0
61 m (200 ft) North of (Unai Tuturan)	32	0
61 m (200 ft) North of #2 near ditch	18	10
Farm Area	6	0
30 m (100 ft) South of cave near center of Bay	12	2
91 m (300 ft) South of old Laulau Lounge	15	2
30 m (100 ft) South of old Laulau Lounge	24	4
Adjacent to old Laulau Lounge	30	20
30 m (100 ft) North of old Laulau Lounge	TNTC	66
61 m (200 ft) North of old Laulau Lounge	TNTC	17

NOTE: TNTC = Too numerous to count

Refer to Figure 13 for location of sampling sites

Total and fecal coliforms are counted as a number per 100 ml of water collected. Normally, in high quality water, coliform count is extremely low since these bacteria are an indication of unsanitary conditions. The preceeding table indicates that marine waters from the majority of stations sampled are clean. Stations near the northern sector of Bahia Laulau suggest polluted conditions which can be traced to a farm located nearby. Most likely, farm animal wastes are being washed down to the bay where total coliform counts are too numerous to count and fecal coliform counts increase radically over other stations sampled.

DISCUSSION AND CONCLUSIONS

As one would expect, weather conditions in the Bahia Laulau area are consistent with prevailing conditions of the south-central Marianas. Although no actual temperatures were taken in the Bahia Laulau area, it is tropical with a uniformally warm climate and a high average relative humidity. A recent 10 year rainfall average at the Coast Guard Station in San Antonio measured 76.6 inches annually. Winds in the Bahia Laulau area follow the prevailing east-northeast direction at an average 10 - 12 kn (8.7 - 10 mph) during the period November to April. Wind direction remains easterly to northeasterly during the summer months, May - October, but drops considerably to an average 6 kn (5 mph). Tropical storms generated in the Western Pacific typhoon belt have a strong possibility of passing near Saipan. In the vicinity, these storms move from the southeast to the north-west. Bahia Laulau is directly exposed to powerful typhoon generated winds and waves. Evidence of these previous storms can be seen where heavy boulders, mooring buoys and other debris have been thrown up on high ground.

Bahia Laulau is a deep bay approximately 731 m (2,400 ft) midway on a line between Hagman and Dandan Points. Deeper depths exist further offshore in the direction of the Marianas Trench. These depths so close to shore represent a significant resource in terms of OTEC development and energy production.

Offshore oceanic temperature follows a well-defined profile typical of the Western Pacific, i.e., a warm well mixed surface layer of nearly constant temperature (28.4° C, 83.4° F), a deep thermocline region (150 - 229 m) (500 - 757 ft) of decreasing temperatures (22.5° - 7.4° C) (72.5° - 45.3°F) and a deep (525 -550 m) (1,700 -1,800 ft) layer (6.4° - 4.4° C) (43.6° - 39.9° F). These depths and corresponding temperatures represent one of the most significant temperature differentials in the world close to shore and suggest a strong possibility for OTEC development at least from the perspective of physical paramaters alone.

Currents offshore of the 100 fathom contour (600 ft) follow an overall circular pattern with water entering the bay from the northeast splitting apart at Dandan Point. Water entering the bay forms a consistent and strong clockwise pattern within the center of Bahia Laulau. The leading edge of the water mass moves along or near the 100 fathom contour emerging with oceanic water at Hagman Point. Inside the 100 fathom contour currents are more complex and seasonally variable influenced more by the prevailing wind and seas. Studies indicate that this current runs counter to the prevailing clockwise outer current following the shoreline and creating small eddies here and there. Currents inside the reef flat are mainly influenced by surface winds, tidal movements and water depth. Water movement is almost always parallel to shore except where incluenced by a channel, cut or low area.

Water quality in the bay appears to be excellent overall except where localized pollution exists. Only total and fecal coliform, an indicator of animal wastes, have been evaluated nearshore. Other common water quality parameters are to be initiated in the area by the CNMI Department of Environmental Quality.

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TERRESTRIAL FLORA AND FAUNA

FLORA

INTRODUCTION

Prior to this study very little, if any, scientific work had been undertaken on the identification of flora in the Bahia Laulau area. In fact, very little botanical data had been collected from all of Saipan until recently. Major works such as Fosberg (1960) and Stone (1970) dealt primarily with Guam, although mention is made in each of these works regarding the general vegetation of the Marianas. Recently, however, a team of botanists from the U.S. Forest Service along with Margie Falanruw have been mapping the vegetation of Saipan.

Bahia Laulau is a highly diverse region of Saipan in terms of vegetation. Within the bay can be found nearly every type of vegetative cover existing in Saipan from savanna grasslands, to the unique beach strand and into the climax limestone forest. Because of the Bay's southeast exposure, portions of the bay (Hagman and Dandan Points and portions of the coastline out to these points) are depauperate and poorly vegetated. Only the most tolerant forms of vegetation florish here.

It is evident that the composition of vegetation on large parcels of land, particularly on the Hagman and Dandan promontories, has been totally modified from the original or climax stage of development. This is true for much of Saipan and is the result of wartime activities. Both the Hagman and Dandan promontories were sites of military air installations which required extensive clearing operations. Bombing and subsequent burning in these areas have left scars on the vegetation that may never allow it to return to its natural climax state. Relics of ancient Chamorro villages and farms in the LauLau area also indicate the drastic modification of vegetative cover from primary to secondary in nature. In spite of the scars left by historic and wartime activities, the area is highly diverse and represents a truly tropical setting.

METHODS

Maps, aerial photographs, photography by boat and from prominent vistas provided information on the general type of plant community and where transects should be located.

Four (4) study area were established in the vicinity of each project site (Figure 13). Transects within study areas were chosen so as to represent a cross-section of the flora in the vicinity of each site. Transects at each site represented the same area covered and the sampling period was similar at each site. Species lists and counts were made during transect walks within study areas. Sampling occured on four field visits (11/82, 2/83, 5/83 and 9/83) and each site was evaluated twice. Relative abundance was calculated for each species as an indicator of its in composition. The following categories were used:

ABUNDANT - Indicates the number of individuals of that species is greater than 500

COMMON - Indicates the number of individuals of that species is greater than 100 but less than 500

SELDOM - Indicates that the number of individuals of that species is greater than 10 but less than 100

RARE - Indicates that the number of individuals of that species is less than 10

This method does not provide statistical data like quadrats or nearest-neighbor programs would. Nonetheless, these relative values are more than purely subjective since they are based on actual counts.

RESULTS

Site 1

Flora at Site 1 is comprised mostly of low scrub forms dominated by Leucaena leucocephala (tangantangan) and Miscanthus floridulus (swordgrass) (Neti). Other common forms in the vicinity are a variety of shrub like plants, small trees or vines, i.e. Colubrina asiatica (Gasoso), Bikkia mariannensis (Gausali), Cassytha filiformis (Mayagas), Clerodendrum inerme (Ladugao), Myrtella bennigseniana. Common weeds, grasses and ferns include Bidens pilosa (beggar's tick), Dimeria chloridiformis (grass) and Dicranopteris linearis (savannah fern) (Mana). A few larger trees are scattered about but considered rare in the vicinity of Site 1. Usually these trees are clumped together in one area and include the following: Casuarina equisetifolia (ironwood) (Gago), Pandanus fragrans (Kafu) and Pandanus dubius (pandanus) (Pahong).

Environmental pressure at Site 1 is intense due to heavy and constant winds and waves causing the air to be filled with salt spray. These conditions beat down the flora considerably and only the most resilient plants flourish here. This accounts for the low profile of vegetation at this site.

Sites 2 and 3

Flora at Sites 2 and 3 is quite similar and for this reason they are discussed together. Flora found at Sites 2 and 3 can be typified as associates of the limestone or modified-limestone forest. The limestone forest on either side of the access road is typical of the central valley portion of Bahia Laulau. Limestone forests are dense and variety is extreme. It is difficult to identify a particular form as dominant; however, numerous forms are common. In addition, this limestone forest is considered modified in the vicinity of the road and along the beach strand since these are transition zones, either man-made or natural, in the succession of the forest.

Low limestone areas called terraces typify the central coastline of Bahia Laulau. Harsh conditions prevail due to high evaporation rate, rapid water drainage and exposure to salt spray. Pemphis acidula (Nigas) is abundant nearest the ocean. This is followed by Scaevola taccada (Nanaso) and Messerschmidia argentea (Hunig) a small tree. Away from the water are found Pandanus sp., Hibiscus tiliaceus (Hibiscus) (Pago) and Ochrosia mariannensis (Langiti). Bikkia mariannensis (Gausali) is a common form found on steep cliffs.

Further back in the limestone forest we find larger trees comprising the upper story of the forest. These forms include Artocarpus sp. (breadfruit) (Dugdug), Ficus prolixa (banyan) (Nana), Cocos nucifera (coconut) (Niyog), Ochrosia mariannensis (Langiti) and Mammea odorata (Chopak). Various smaller forms, either lianas, epiphytes or weeds make up most of the understory vegetation. These include the following: Leucaena leucocephala and L. gaumense (tangantangan), Hibiscus tiliaceus (Hibiscus) (Pago), Pluchea indica, Neisosperma oppositifolia (Fago), Cycas circinalis (cycad) (Fadang), Davallia solida (fern) (Pugua Machena), Caesalpinia major (Ife), Piper guahamense (wild piper) (Pupula-n-Aniti), Phymatodes scolopendria (kahlao), Morinda citrifolia (Indian mulberry) (Lada), Psychotria mariana (Aplokatina), Triphasia trifolia (limeberry) (Lemon-China) and Cestrum diurnum (China inkberry) (Tintan-China).

Sites 2 and 3 also include a ravine community dissecting the upper savanna forming valleys and gullies in which water and moisture accumulates. Although the flora varies slightly, one always finds Hibiscus tiliaceus (hibiscus) (Pago), Cycas circinalis (cycad) (Fadang), Areca cathecu (betel-nut palm) (Pugua Machena), Ficus prolixa (banyan) (Nana), several lianas and numerous epiphytes such as ferns.

Beach Strand

Since these islands are small, nearly all vegetation can be considered "strand vegetation." However, in the context of this report it is taken to mean those plants most often found growing in the immediate vicinity of the sea. With very few exceptions, plants growing on the strand can be found elsewhere on Saipan. However, not as a dominant form like on the strand.

Within central Bahia Laulau, as in most strand communities, numerous trees grow close to the sea and provide deep shade where mosses, ferns, lianas and epiphytes of many kinds abound. Some of these larger trees include the following: Casuarina equisetifolia (ironwood) (Gago), Messerschmidia argentea (Hunig), Hernandia nymphaeifolia (Nonak), Cassytha filiformis (Mayagas), Thespesia populnea (Banalo) and Cocos nucifera (coconut) (Niyog). Smaller forms of vegetation can be found in the understory shaded by the larger trees or growing out in the open along the beach. Understory shrubs and bushes include the following: Scaevola taccada (Nanaso), Pluchea indica, Desmodium umbellatum (Palaga Hilitai), Sophora tomentosa, Colubrina asiatica (Gasoso), Bikkia mariannensis (Gausali), Allophylus timorensis (Nger), Triphasia trifolia (limeberry) (Lemon China) and Cestrum diurnum (china inkberry) (Tinta'n-China). A few plants obviously more salt tolerant than others grow out along the beach as vines and creep toward the water. These include the following: Ipomoea pes-caprae (beach morning glory) (Alalag-Tasi), Wedelia biflora (beach sunflower), Vigna marina (Akangkang Manulasa), Clerodendrum inerme (lodugao) and Abrus precatorius (coral bean) (Kolales). Where rocky outcrops exist (Sites 2 and 3) or where rugged uplifted limestone forms a border between the ocean and the inner coast, very few plants are found. Environmental conditions are extremely harsh here. In these strand areas

Pemphis acidula (Nigas) provides a thick cover along a narrow band near the shore. Along the highly exposed shore this plant is scrub-like and bent shoreward with gnarled trunks and twisted roots solidly embeded in the limestone.

Site 4

Flora at Site 4 is dominated by a thick cover of Leucaena leucocephala (tangantangan). Also found in this section of Bahia Laulau is the local tangantangan Leucaena insularum var. guamense. Associated with the thick cover of tangantangan can be found various weeds, grasses and vines i.e. Bidens pilosa (beggar's tick), Stachytarpheta indica (false verbena), Mucuna gigantea (small seabean) (Gayidikike) and Clerodendrum inerme (Lodugao). Pemphis acidula (Nigas) also provides a thick cover along the coastline here. A few small shrubs stand out here and there but not in great numbers. These include: Colubrina asiatica (Gasoso), Bikkia mariannensis (Gausali), Triphasia trifolia (limeberry) (Lemon-China), Cestrum diurnum (China inkberry) (Tinta'n-China) and the small fern Dicranopteris linearis (Savannah fern) (Mana).

A complete checklist of flora by site is given in Table 6 (Appendix A).

DISCUSSION AND CONCLUSIONS

Diversity and species composition of flora at sites two and three are quite similar, this being the only major similarity between the four sites. A very well defined limestone forest covers the majority of central Bahia Laulau and comprises the majority of species found at these two sites.

Each of the other two sites (one and four) are unique in terms of species composition but diversity is low compared with the sites in central Bahia Laulau. Comparatively speaking, sites one and four are depauperate as a result of intense environmental pressures i.e. high winds and surf, salt air and rugged terrain. Sites two and three are protected from harsh environmental pressures which seems to allow for greater diversity. Table 6 (Appendix A) is a checklist of flora from Bahia Laulau. Scientific names are given in each case with associated common and Chamorro names where appropriate.

On the whole, the flora of Bahia Laulau can be characterized as a highly diverse botanical community having lush limestone forests, upland savannah grasslands and low scrub rocky cliffs with modifications where human activities existed or now exist. Major modifications are evident at Dandan and Hagman Points where wartime activities existed.

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FAUNA

INTRODUCTION

The fauna of Saipan has not been well defined, particularly in the Bahia Laulau area and other areas along the east coast of the island. The avifauna has been described by Baker (1951) and more recently by Owen (1977). Additional recent accounts of the avifauna have mostly concentrated in the lake Susupe and wetland areas of the island (Shallenberger and Ford, 1978 and Tenorio and Associates, 1979).

In his checklist of the birds of Micronesia, Owen (1977) lists a total of 91 species reported for the Marianas. These include residents, migrants, vagrants and introduced species and take into account all reliable records known for the area up to 1977. This compares with his listing of 191 species reported for all of Micronesia.

Although no overall or island-wide study has been published on Saipan's birds, the wetland regions, especially the lake Susupe area, have been fairly well documented. Shallenberger and Ford (1978) recorded a total of 30 species of birds within the lake Susupe area. These included migratory waterbirds, seabirds, marsh associated species as well as several birds commonly found in the limestone forest areas of Saipan.

In an ornithological survey of the wetlands of Saipan (Tenorio and Associates, 1979), the investigators observed a total of 28 species of birds in the seven study sites, with the lake Susupe site being the most diverse with 19 species. This report described Saipan's overall bird population as stable and in good condition in terms of species diversity, geographic distribution and general population levels. Tenorio and Asso. (1979) observed a total of three species that were currently on the endangered species list. These included the Marianas Mallard (Anas oustaleti), Nightingale Reed-warbler (Acrocephalus luscinia) and the Micronesian Megapode (Megapodius laperouse).

Eighteen genera of terrestrial reptiles are known from Micronesia (Brown, 1956), with the greatest variety being in the skink (Scincidae) and gecko (Geckonidae) families. The most common skink is a small brown species (Emoia sp) and this was observed at all sites. Other common skinks are the blue-tailed variety (Emoia cyanura) and a larger, green-tailed skink (Lamprolepis smaragdina). A few Anole (Anolis carolinensis) were observed.

Three species of rats and one species of mouse are known from the Mariana Islands, and all are widely distributed throughout the islands. The Norway rat (Rattus norvegicus) is found mostly in urban areas of the islands, but may be present in the limestone forest areas of Bahia Laulau.

METHODS

The fauna of Bahia Laulau was sampled along the shoreline, along four transects perpendicular to the beach into the forested areas of each site and from vehicles along the access road. Sampling was conducted during the early morning (sunrise to one hour after sunrise), daytime and early evening (one hour before and until sunset). This would insure that the time of greatest activity for all animals, particularly birds, would be observed and sampled. All transects were sampled three times, November 1982, February 1983 and September 1983. The transects sampled are the same as those used for the flora investigations (Figure 13).

All animals were censused by naked eye sightings and a checklist of all species was made. Walks were made along the transect at a reasonably slow pace. Rocks were turned over and tracks were noted for signs of animals not usually seen. In the case of birds, binoculars were used to verify sightings along with audible calls to identify those not actually seen.

Frequently, in the dense vegetation, it is impossible to see many animals particularly birds. However, approximate numbers can be estimated by auditory means. Because of the adequate numbers of birds observed at each site, relative abundances were used in conjunction with the checklist. Calculating densities and actual abundances statistically would have required more transects and replicate counts, neither of which were practical for the scope of work. In addition, many birds in the tropics are difficult to quantify due to their secretive behavior, low numbers and habitat preference (dense vegetative cover). For a measure of relative abundance of birds, four categories were used:

(A) Abundant- The species was noted in numbers greater than 20

(C) Common - The species was noted between 10 and 20 times

(O) Occasional - The species was noted between 3 and 9 times

(R) Rare - The species was noted 1 to 2 times

In addition, based on habitat and birds previously recorded from the Marianas, a species was noted as expected (E) to occur in the area if it was not actually observed or heard but was thought likely to occur if more intensive sampling were done.

RESULTS

Avifauna

Table 7 (Appendix A) includes a checklist of all species of birds observed or heard at all study sites including the access road that runs along Bahia Laulau and includes species that were not observed or heard but that could reasonably be expected to be found at the sites. The avifauna was surveyed from the beach and shore area landward to the more densely vegetated forest area. All sites were surveyed a minimum of four times, including early morning, midday and late afternoon times.

The total number of species actually observed at all sites was 29, with a total of 34 species observed and expected to occur in the bay area. All sites were similar in total number of species observed with the exception of Site 4, where only 13 species were observed. This is not unusual since Site 4 respresents the smallest site area and contained relatively few shorebirds since the beach and reef flat areas were also quite small and limited in space. Vegetation is also less diverse at Site 4 accounting for fewer species of birds. The low-profile vegetation at Site 1 likely accounted for the second-lowest number of species being sighted there (17 species).

The most abundant bird species encountered at the four sites include the Fantail (Chichirika), White-eye (Nossak), Philippine Turtle-dove (Paluman senesa), Eurasian Tree Sparrow (Gaga Pale') and Noddy Tern (Fahang). Species that could be considered common for the bay area include the Yellow Bittern (Kakkag), Collared Kingfisher (Sihig), Cardinal Honeyeater (Egigi), Golden Plover (Dulili), Starling (Sali), White Tern (Chunge) and the Reef Heron (Chuchuko).

Reptiles and Amphibians

The blind snake (Typhlops braminus) has been recorded from Saipan but none were seen during this survey. There are no records of the Philippine rat snake (Boiga irregularis) in the Marianas, although it is very common on Guam. In March 1983 a Saipan resident killed what was believed to be a rat snake but was later identified as a California bull snake. The snake probably arrived aboard a ship or was transported as a pet from the U.S.

The largest reptile in the Marianas is the Indian monitor lizard (Varanus indicus). Originally introduced by the Japanese to control rats, the monitor lizard has spread throughout Guam and the Marianas. It reaches a length of 5-6 feet and has had a negative impact on the native bird population since it eats eggs and the juveniles. Chicken farmers regard the monitor lizard as a pest which is hunted and killed regularly if seen around farms. Three individual monitor lizards were observed in the forested areas surrounding Bahia Laulau and two more were seen on the access road during the early morning hours.

The most widespread amphibian in the Pacific Basin is the giant marine toad (Bufo marinus). These are more common around lakes, swamps and marshes, but are also commonly found within limestone forests and in areas of dense tangantangan growth. Their abundance increases dramatically as the rainy season arrives, which triggers their reproductive response and provides standing water for the tadpoles. This toad was seen at each of the study sites particularly at Sites 2 and 3 and along the access road.

Mammals

Both the roof rat (Rattus rattus) and the Polynesian rat (Rattus exulans) were observed in the study area and these are the two most common rats found on Guam and in the Mariana Islands. Rats can climb and often are seen in trees, especially the larger roof rat. They are considered potential predators of bird eggs and small birds, especially those species that build their nests on or near the ground. Mice (Mus musculus) are common around residences in Saipan and would be expected in the limestone forest and shoreline areas within the study site.

The musk shrew (Suncus murinus) was originally introduced to Guam and has since spread to Rota, Tinian and Saipan (Shallenberger and Ford, 1978). They live near human habitations, in secondary growth and can be found in both swampy as well as grassy and rocky habitats. They are likely found in the vicinity of Bahia Laulau although none were observed.

Feral dogs (Canis familiaris) and cats (Felis catus) and pigs (Sus scrofa) are found throughout the islands although they tend to inhabit areas bordering more densely urbanized zones or near family dwellings and/or farms. A few dogs were seen in the survey site but no cats were observed during the study.

Habitat conditions, especially in the limestone forest areas of Sites 2 and 3, are favorable for reasonable populations of pigs. Based on current field observations and information from wildlife biologists from the Division of Fish and Wildlife and local interviews, wild pigs are not present on Saipan. They say it appears that wild pigs have been absent for many years. However, it is likely that escaped or loose domestic pigs or descendants of domestic pigs that have interbred with the original wild stock many years ago roam the limestone forest areas of Saipan. A few observations in the limestone forest of Bahia Laulau (shoreward at Sites 2 and 3) revealed holes that were dug-up or rooted by some kind of animal. Although there are typical signs of pigs searching for food, the holes could have been made by another animal. Since no pigs were actually observed and based on the field work by local Fish and Wildlife biologists, the pig is not been included in the checklist of fauna for the Bay.

The Marianas or Sambar deer (Cervus unicolor marianus) is an inhabitant of the limestone forest regions throughout Saipan. The cliff line areas surrounding Bahia Laulau provide excellent habitat for this animal and signs indicative of deer and pig were observed in various locations, although no animals were actually seen.

Possibly the only true native mammals in the Mariana Islands are the bats. The Marianas fruit bat (Pteropus mariannus) is found on Saipan in limited numbers. Populations have declined drastically and their status is in question. However, it is still hunted illegally as a source of food since the Guam and Marianas bats are considered a delicacy and are preferred over bats from other islands such as Yap and Palau. No fruit bats were observed around the cliffs of Bahia Laulau. However, the habitat and suitable foods are present there. Since bats move about from area to area, either in small groups or larger colonies, it is reasonable to expect that fruit bats do frequent this area from time to time. The most likely areas would be between sites 1 and 2, along the cliffline and inland to the limestone forest. The status and occurence of the insectivorous bat (Emballonura semicaudata) is unknown on Saipan at the present time.

DISCUSSION AND CONCLUSIONS

In general, Saipan has a relatively healthy bird population, especially in the more densely vegetated limestone forest areas of the island. Compared to Guam, Saipan avifauna is more diverse and numerous even though the total land area is smaller. This is due in part to a smaller human population, less developed areas (urban sprawl), fewer natural predators (rat snakes, feral dogs and cats) and possibly fewer pesticides and diseases within the environment.

Birds represent the most abundant type of fauna in the Bahia Laulau area with a total of 29 species observed out of an expected 34. All sites were similar in total numbers with the exception of Site 4 where only 13 species were observed. However, this site was the smallest in size and is relatively depauperate of flora.

At the present time, CNMI regulations require a hunting license for the taking of birds. The legal hunting season runs from July 1 through July 31. The following species may be taken: Philippine Turtledove (bag limit = 10, season limit =40); Ground Dove (bag limit = 2, season limit = 6); Fruit Dove (bag limit = 3, season limit = 9); and the Micronesian Starling (bag limit = 10, season limit = 40).

The blind snake Typhlops braminus, although not seen at any of the study sites, is expected to occur here. It has previously been recorded from Saipan. There is no evidence that the larger Philippine Rat Snake

(Bioga irregularus) exists in the area although it is common on Guam and likely to be found in other islands of the southern Marianas.

A total of five monitor lizards (Varanus indicus) was observed in the limestone forest region of Bahia Laulau. These individuals were at least two feet in total length but less than three feet. It was extremely difficult to get near these animals as they are not accustomed to being around humans.

The common marine toad (Bufo marinus) was found in abundance particularly in shaded, forested or damp areas of the bay. They were observed at all four sites and were particularly abundant at Sites 2 and 3. We did not notice a large population increase during the rainy season due to the dryness experienced during 1983. However, populations of this toad normally increase dramatically when the rainy season arrives triggering the reproductive response.

A number of mammals common in the southern Marianas were observed. The roof rat (Rattus rattus) and the polynesian rat(Rattus exulans) were observed on the ground and in the trees. Numerous feral dogs were observed in the area. These animals may belong to a land owner in the area and it is common for them to run wild.

Areas surrounding the bay are open to hunting and it is suspected that a reasonable amount of illegal hunting also occurs in the limestone forest and cliffline habitats. Both deer and pigs may be hunted with a license from September 1 through December 31. The bag and season limit for deer is one (1), while for pig the bag limit is two (2), with a season limit of six (6).

The Marianas fruit bat (Pteropus mariannus) is found on Saipan in limited numbers. Although the population on Saipan is not included in the Federal Endangered Species List, populations have declined drastically and their status is in question. It is estimated that the total population on Saipan is less than 50 individuals (Division of Fish and Wildlife).

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MARINE FLORA AND FAUNA

MARINE PLANTS

INTRODUCTION

Marine plants have been studied in the Saipan Lagoon (Fitzgerald et al., 1974) and (Tsuda et al., 1977 a and b). However, these studies did not concern themselves with the Bahia Laulau area. The only previous work on marine plants in the Bahia Laulau area is a very brief mention by Cloud in the Military Geology of Saipan.

METHODS

Reconnaissance dives were made at all sites utilizing snorkel and/or scuba equipment during November 1982. Where conditions permitted, semiquantitative 100 m (328 ft) transects were established perpendicular from the shore (Sites 2 and 3 only). These data reflect changes in algal distribution (Table 8) but do not reflect percent cover or density.

For purposes of this study, turfs were considered to be any marine algae whose growth form produced a low relief upright habitat. Species of red algae, especially in the orders Gelidiales, Corallinales and Cryptonemiales were the principal turf formers. Turfs provide both microhabitats and substrata for numerous epiphytic plant and animal taxa. In contrast to turfs, larger fleshy algae made up the overstory, e.g., Sargassum and Galaxaura species.

RESULTS

During this survey sixty-nine species of marine algae representing four divisions were recorded. One species of seagrass, Enhalus acoroides, was also recorded. A list of the recorded taxa can be found in Table 8

(Appendix A). Two narrow fringing reefs (Sites 2 and 3), one reef margin and reef face (Site 2), three shallow submarine terraces (Sites 1a, 2 and 3) and two deeper submarine terraces (Sites 1 and 4) were investigated. A range of habitats including sand floors, reef flat holes, cryptic overhangs, vertical walls and limestone terraces were present at the various sites.

Site 1. Site 1 was characterized by a scoured and rubble strewn submarine topography. Only 15 species of algae were recorded. Red algal turfs composed chiefly of Gelidium species predominated. The blue-green algae, Microcoleus lyngybaceus and Schizothrix calcicola were also abundant. Scattered patches of Galaxaura, Mastophora and Neomeris species were observed in crevices and overhangs. In general, this site can be described as extremely depauperate.

Site 1a. Site 1a is located in a protected area surrounded by steep limestone cliffs and narrow cut benches. This area was very calm and quite luxuriant in marine life. A highly variable topography and rich coral community provided a variety of habitats for benthic algae. Thirty-seven species were recorded, 14 of which were green algae. Patches of Chlorodesmis fastigiata and Bryopsis pennata were particularly common. Low relief turf forming coralline algae, especially Amphiroa species were abundant and provided a substrate for many epiphytic red and green algal species. Cryptic species such as Boergesenia forbesii and Dictyosphaeria versluysii were common as well.

Site 2. Site 2 consists of a narrow reef flat (approx. 150 m, 482 ft wide) cut by numerous surge channels extending through the reef margin. In addition to general reconnaissance dives, a perpendicular transect was set up across the reef flat, reef margin and submarine terraces to a depth of

10m (33 ft). The submarine terrace transect parallelled an old pipeline. Calm surf conditions permitted work on the reef margin and face.

The reef flat was divided into an inner and outer zone. Because of its narrow width and windward exposure, it did not exhibit the sharp zonation patterns characteristic of wider windward flats. The substrate consisted of scoured limestone coral rubble and sand with scattered holes and Porites colonies. In the inner zone, small patches of the seagrass Enhalus acoroides were found in association with several other species of algae, notably, Sargassum polycystum, Turbinaria ornata, Dictyota bartayresii and Padina minor. These patches varied from 1 - 3 m (3.3 - 9.8 ft) in width. Scoured and rubble-strewn surfaces had sparse turf consisting of Cladophoropsis membranacea and Amphiroa fragilissima. Occasional clumps of Halimeda opuntia and Mastophora rosea were noted in sandy areas. Neomeris annulata was patchily abundant on coral rubble. Vertical walls in sand holes contained additional species. The outer reef flat was covered by a more luxuriant turf consisting of Amphiroa fragilissima and A. foliacea in association with Cladophoropsis membranacea, Gelidiella acerosa, Sporolithon sp., Porolithon sp., and Mastophora rosea. Five species of Caulerpa were recorded. Patches of Sargassum cristaefolium were also abundant in this area. In all, 33 species of marine benthic algae and one species of seagrass were noted on the reef flat.

The reef face and submarine terrace habitats were characterized by a diverse assemblage of algae totaling 54 observed species. Turfs, as well as overstory species were interspersed among corals. Cover ranged from approximately 20-100 percent (or greater in selected areas). Rich turfs of Amphiroa fragilissima, A. foliacea, Cladophoropsis membranacea, Boodlea composita intertwined with five Caulerpa species, Tolypiocladia glomerulata, Leviellea jungermannioides and others were luxuriant. Large patches (1 m, 3.3 ft or more) of Halimeda opuntia and Mastophora rosea were also common. Three species of Galaxaura were noted as were Chlorodesmis fastigata and Bryopsis pennata. In general, the variable terrain of the site provided numerous types of habitats for algal species in addition to corals and other marine organisms.

Site 3. Site 3 consisted of a very narrow reef flat (approx. 100 m, 328 ft wide). Large waves prevented access to the reef margin and face although these habitats are probably comparable to those studied at Site 2. In addition to reconnaissance dives, a transect was established on the reef flat. A subtidal reconnaissance dive was also made to 10 m (33 ft).

Because of its narrow width and uniform topography, the reef flat did not exhibit sharp zonations typical of more extensive reef flats. Large expanses of sand and coral rubble alternated with stretches of scoured limestone and Porites colonies. From 1 - 10 m (3.3 - 33 ft) seaward of the shoreline only occasional patches of Padina minor were noted. From 10 - 50 m (33 - 164 ft) out, patches of the fleshy brown algae Sargassum cristifolium, Turbinaria ornata and Padina minor were more common, accounting for approximately 25 percent of the surface cover in places. Beyond 50 m (164 ft), turf algae were dominant. A combination of Cladophoropsis membranacea and Amphiroa fragilissima provided the substrate for numerous epiphytic algae. The blue-green alga Schizothrix calcicola was ubiquitous, often overtopping the algal turfs and some larger species below. This phenomenon is common during the winter (Nov-Jan) when minus tides and exposure create favorable conditions for opportunistic blue-greens. In the occasional reef flat hole or vertical surface of a coral head, Halimeda opuntia and Mastophora rosea were common. The coralline red alga

Sporolithon sp. was also common. Gelidiella acerosa became progressively more abundant on the outer reef flat, though it was consistently less abundant than Amphiroa fragilissima. Both are characteristic of high wave impact zones.

The submarine terrace was accessible only by boat. One reconnaissance dive was made to depths ranging from 5 - 10 m (16 - 33 ft). Poor visibility and heavy surge limited the investigation at this site. In general, however, there was evidence that the area is seasonally calm. Deep surge channels extended for long distances creating a labryinth of vertical walls and overhangs. Seven species of the stoloniferous green alga Caulerpa were recorded, often in luxuriant carpets covering entire walls. Caulerpa filicoides and C. verticillata were especially dominant. Halimeda velasquezii and three species of Galaxaura were also common. Ceramium gracillium, Leveillea jungermannioides and Tolypiocladia glomerulata were common turf forms. A total of 45 species were recorded.

Site 4. Site 4 consisted of a deep sloping submarine terrace with crevices, coral pillars and sand channels. One reconnaissance dive was made covering depths from 10 - 20 m (33 - 66 ft). Conditions were so rough that even at 20 m (66 ft) the surge could be felt.

The algal community was remarkably similar to that seen at Site 2 though fewer species were recorded. Of particular interest was the abundant growth of a usually cryptic and uncommon green algal species, Rhipilia orientalis. Throughout the dive this was the visually dominant alga. In all 28 species of algae were recorded.

DISCUSSION AND CONCLUSIONS

Each of the five sites examined in Bahia Laulau presented somewhat different algal communities. This is largely a function of exposure to the fetch of the open sea and local coastal topography (i.e., reef flats vs. cut benches and cliffs). Sites 1 and 4 experience the most regular and severe disturbances due to their direct exposure to windward ground swells. Site 1a is the most protected area and Sites 2 and 3 are seasonally variable. Moreover, Sites 2 and 3 have fringing reefs, while the other sites do not. Strictly from the marine botanical perspective, the algal communities are typical of those seen on windward exposures in the southern Marianas (cf. Pago Bay, Guam and bays south).

With respect to reef flats, Sites 2 and 3 had very narrow reef flats and thus did not exhibit distinct zones of seagrass and the brown alga Sargassum. At Site 2 only small irregular patches of these taxa were present. Consistent with the narrow reef flats were the lack of moat development and other physiographic features that result in a more patterned benthic algal community. However, the 33 and 25 species recorded respectively from these sites indicates a moderately high diversity, despite low percent cover (probably less than 5 percent in most places). It is important to note that seasonality is a critical factor in the distribution and abundance of benthic algae on the reef flat. During the summer and fall months, low tides, desiccation stress and exposure lead to massive die-offs and low percent cover. Ephemeral species can be expected to increase diversity slightly as the winter and spring seasons begin along with a concomitant decrease in blue-green taxa. However, percent cover and overall standing crop will increase substantially. Based on the author's experience with similar habitats on Guam, by March and algal reef flat bloom will alter percent cover to nearly 100 percent in many areas. A green carpet of Cladophoropsis species can be expected. This is a natural phenomenon and not an indicator of pollution.

The submarine terrace algal communities at all the study sites reflected differences in response to various disturbance conditions. With respect to marine plants these are both physical and biological. Rough water conditions and barren substrate can inhibit algal recruitment and subsequent survival. Integrally, the presence of herbivorous grazing fishes and echinoderms (for which there was strong evidence, e.g., scrape marks on rocks) may have further reduced the standing crop of algae present. Site 1 exemplified this situation. However, the presence of grazers can also enhance algal diversity and standing crop depending on other ecological parameters. Measurement of these factors is experimental in nature and was beyond the scope of this survey. In general, however, Sites 2, 3 and 4 presented typically diverse tropical reef habitats, while Site 1 presented a high disturbance area resulting in a depauperate seaweed community.

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PLANKTON

INTRODUCTION

Plankton has only recently been sampled or studied within the Bahia Laulau area (Birkeland et al., 1984 in press). Plankton has been sampled in other areas of the Marianas particularly Guam, Saipan and a few offshore banks (Amesbury, 1978). Planktonic larval behavior and geographic distribution of coral reef asteroids in the Indo-west Pacific was studied by Yamaguchi in 1977. The zooplankton of Tanapag Harbor was analyzed as part of the marine survey of the power barge "Impedance" (Doty and Marsh, 1977).

METHODS

Two each, horizontal and oblique, plankton tows were conducted from the M.V. Bahia Laulau on November 5, 1982. These tows were located offshore just to the north of site 2. On February 9, May 10-11 and September 29-30, 1983 a series of horizontal and oblique tows were conducted offshore at all four sites. Refer to Figures 16 a,b,c,d for the location of all the plankton tows. Equipment consisted of a 0.5 m (1.65 ft) diameter plankton net with a mesh size of 0.020 inch (500 microns), a towing bridle and line and sampling jars. All samples were fixed in 5% buffered formalin.

Horizontal tows were run just below the surface for a total of 5 minutes at a boat speed of four 3.5 kn (4 mph) during November 1982. Gusty winds and moderate seas prevented a slower tow speed. Oblique tows were started from a depth of 35 m (112 ft). For the February, May and September tows, a slower boat speed 1.7 kn (2 mph) was possible and all tows were run for a total of 10 minutes each.

RESULTS AND DISCUSSION

Results of the plankton tows completed on November 5, 1982 and February 9, May 10-11 and September 29-30, 1983 are shown in Tables 9-9c (Appendix A).

For the plankton tows done during November, there was at least a three-fold increase in the total abundance of zooplankton collected in the surface tows than in the oblique tows. Mysids were the predominant taxa, representing 20 to 30 percent of the total number of zooplankton collected. All taxa except chaetognaths were more abundant at the surface than at the deeper depth (3.5 m, 11.5 ft). Other predominant taxa were calanoid copepods, veliger capsules, shrimp mysis and fish larvae. The fish larvae were predominantly members of the following families: Apogonidae, Gobiidae and one Sygnathidae larvae.

Variation between tows was great for veliger capsules and calanoid copepods; however, patchiness is an intrinsic characteristic of plankton and it is a universal problem in sampling methods. The total composition of zooplankton is similar to the zooplankton collected off Luminao Reef, Guam, another potential OTEC site.

For the eight tows conducted during February (4 surface and 4 oblique), the predominent taxa was the class Radiolaria which comprised 94 percent of the total plankton collected (all tows). The class Copepoda was the most diverse with 11 species. Although there were slight increases in total numbers of plankton and species diversity between surface and oblique tows, these differences were only significant at Sites 2 and 4. Site 4 showed almost a 15-fold increase in total numbers for the surface tow compared to the oblique tow. However, this was due almost entirely to a great number of Radiolarians. The oblique tow, however, was more diverse

(11 species versus 9 species). At Site 2, the most diverse site sampled, the surface tow showed an approximate 33 percent increase in total numbers and one more species than the oblique tow.

For the four surface and four oblique tows conducted during May 1983, the predominant groups included invertebrate eggs (55.5 % of the total plankton collected), the class Malacostraca (mainly shrimp mysis and crab zoeae, 14.3 %), class Copepoda (mostly Calanoid sp., 11.7 %) and the class Cladocera (Evadne sp., 10.0 %). Fish eggs comprised less than 1 % of the total plankton collected.

Species diversity did not vary greatly between sites or between surface versus oblique tows. Site 2 had the greatest number of species collected, a total of 19 for both tows, followed by Site 1 (18), Site 4 (17) and Site 3 (15). Site 4 was the only location where a significant difference in total species was obtained between the surface tow (16 species) and the oblique tow (10 species). Site 4 had the greatest numbers of individuals collected with a total of 3,903 representing 45.3 % of the total for all four sites. Fish eggs and larvae were most abundant at Site 1 where they comprised 2.9 % of the total plankton sampled.

The predominent groups for the four surface and oblique tows conducted during September 1983 included the invertebrate eggs (35.1% of the total), copepods (26.1%) and shrimp and crabs (3.8%). These major groups are similar to results obtained in the previous plankton samples, except for the high percentage of fish larvae and eggs. Previously, this group normally comprised less than 1% of the total, with a high value of 2.9% at Site 1 during May. In the September samples, fish eggs and larvae ranged from a high of 32.9% (Site 1) to a low of 10.8% (Site 2), and reached 49.7% for a single tow at Site 1.

Comparison of results from other studies on plankton around Saipan and Guam indicate that, while overall densities are low in Bahia Laulau, the predominant groups and relative abundances are quite consistent with seasonal variability. Only one other plankton survey has been conducted in the Bahia Laulau area (Birkeland et al, 1984 in press) Exact locations were not recorded but four tows were conducted in various parts of the bay. However, none were done in close to the reef. Predominant groups included invertebrate eggs, Calanoids, Chaetognaths, Eucheaia and shrimp and crab larvae. Fish eggs and larvae varied from 0.9% to 3.2% of the total plankton. This compares with results of the Laulau study except for the high values recorded in September ($\bar{x}$ = 19.8%).

The only other planktonic data from Saipan was done in Tanapag Harbor (Doty and Marsh, 1977). They obtained similar results in terms of major groups of organisms but as is usually the case when sampling in an enclosed lagoon or harbor, densities were higher. Relative abundance of fish eggs and larvae ranged from 0.2% to 19%.

On Guam, Amesbury (1978) sampled several locations along the west coast over a one year period. He found the highest densities of fish eggs and larvae occured in July and August (91.1% maximum) but was as low as 2.7% at other times of the year. The sites with the greatest densities were enclosed bays or areas near extensive reef and/or mangrove areas such as Agana Bay, Agat Bay and Ajayan Bay (near Cocos Island). No sampling was done on the windward side of the island or offshore. Randall and Eldredge (1982) sampled plankton off Cabras Island, Guam as part of an assessment for a potential OTEC facility. Although no sampling was done during the summer, they reported relative abundances of fish eggs and larvae ranging from less than 1% to a high of 43.5% (March). These ranges are comparable to the results for Bahia Laulau and one would suspect that the site at Cabras would be more similar to Laulau than other locations sampled around Guam and Saipan. The Cabras study also reported high densities of Radiolarians, a group which is more commonly found offshore than in near-shore or lagoon environments.

Species diversity in the September samples was quite consistent between sites, with 21 species at Sites 1, 2 and 3 and 18 species at Site 4. Previous sampling generally showed the lowest diversity at Sites 1 and 4. This would be expected as these two sites are closer to the points (eastern boundaries) of Bahia Laulau and thus would likely contain fewer planktonic species than the sites that are closer to species-rich reef-flat areas of the Bay.

CONCLUSIONS

When all four plankton tows are analyzed together, Sites 1, 3 and 4 had the lowest mean numbers of species with 12, 11 and 12 respectively. Site 2 had the greatest species diversity with an average of 18 species per tow. In terms of total planktonic organisms per tow, Site 4 averaged 1,506, followed by Site 3 (1,201), Site 2 (867) and Site 1 (587). These results generally support what would be expected when looking at the current patterns and lack of a reef flat area along the cliffs out to Puntan Hagman. Sites 2, 3 and 4 (particularly Sites 2 and 3) would be expected to be rich in plankton considering the current patterns, eddies, shallow areas and extensive reef areas present.

In terms of gross impacts on the planktonic community, an OTEC plant would have the least negative impact in the area of Site 1 and would potentially affect Site 2 the most. The impact on planktonic species would be dependent upon the size of the mixing zone of the cold effluent, both in terms of temperature differential (dilution) and the actual size

(3-dimensional) of the effluent plume from the discharge point. Both surface and subsurface currents would affect the size and shape of the mixing zone and it is likely that mixing and dilution would be more rapid and extend over a larger area at Site 1 due to the strong currents and submarine topography.

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CORALS

INTRODUCTION

Reef-building scleractinian, octocorallian and hydrozoan corals are sessile invertebrates with potentially long life spans and distribution patterns that depend upon the particular environmental setting found from one habitat to another. Their stony calcium carbonate skeletons are major contributors to both *in situ* framework and detrital reef development in the shoal-water environments like that of Bahia Laulau. Characteristic coral communities develop in response to the variable environmental conditions found within an area, ranging from conditions completely unfavorable for corals to optimum conditions where corals are the dominant organisms in the community. Corals are sensitive to many environmental variables; particularly light intensity, suspended materials in the water column, sediment accumulation on the substrate upon which they grow, water currents and agitation, seawater dilution from surface drainage and groundwater discharge, temperature fluctuations, emersion on shallow platforms during low tides, predation by other organisms and various forms of pollution from toxic substances like thermal, storm drain and sewage discharges.

Until recently, the coral community of Bahia Laulau had been evaluated from the point of view of degree of difficulty in landing military troops from the ocean (Cloud, 1959) and a generalized concept of where coral is found along the shoreline to the reef margin (Eldredge and Randall, 1980). Very little was done to identify species, community structure, zonation and distribution in these studies. Cloud (1959) did identify common named coral types in the vicinity of selected approaches to the beach. These were commonly referred to as "staghorn or brain coral types." Gawel (1974) and

Gordon (1974) made preliminary surveys of corals in the Saipan Lagoon on the west coast of Saipan but did no work in the Bahia Laulau area.

Assessment of the present coral communities in Bahia Laulau will establish baseline data from which changes in the quality of the reef environment can be determined or predicted. These data will be useful in establishing sound planning practices and management of these reef areas in relation to future development (OTEC or otherwise).

The principal objectives of this part of the study are to determine the distribution and community structure of corals in Bahia Laulau from the shoreline to 10 m (33 ft) depth along four transect locations shown in Figure 13.

METHODS

The coral communities of Bahia Laulau were studied at five sites as shown in Figure 13. At each site, observations were primarily limited to a 20 m (66 ft) wide band that extended from the shoreline to a depth of 10 m (33 ft). High waves and rough surf conditions, that persisted for the duration of the study period, prevented direct observations from being made at the seaward edge of the fringing reef platform (reef margin zone) at Site 4. Strong bottom surge also prevented quantitative studies from being made on the submarine slope at Site 1 and on the forereef slope at Sites 3 and 4.

Where possible, coral communities were quantitatively analyzed within physiographic zones discriminated at each site by using the point-centered or point-quarter technique of Cottam et al. (1953). Three physiographic zones consisting of the reef-flat platform, reef margin and forereef slope were discriminated at Sites 2, 3 and 4. At Site 1a, the fringing reef-flat platform and reef margin zones were very similar physiographically and therefore lumped together. At Site 1 only the submarine slope zone was distinguished since active reef development and a fringing reef-flat platform are absent. Sample areas were selected by randomly tossing a hammer within the 20 m (66 ft) wide band of each physiographic zone. At the intersection of the hammer handle and head a reference point was established. Reference lines extended along the long axes of the hammer handle and divided the sample area into four quadrants. Corals nearest the sample point (junction of hammer handle to head) in each quadrant were identified and the following data collected: diameter of the colony (a maximum length and width measurement) and the distance from the colony center to the sample point. From this point-quarter data the following calculations were used to estimate community structure of the corals in each physiographic zone.

$$\text{Total Density of all Species} = \frac{\text{unit area}}{(\text{mean point-to colony distance})^2}$$

$$\text{Relative Density} = \frac{\text{individuals of a species}}{\text{total individuals of all species}} \times 100$$

Total Percent Coverage = total density of all species X average coverage value for all species

Percent Coverage = density of a species X average coverage value for the species

$$\text{Relative Percent Coverage} = \frac{\text{percent coverage for a species}}{\text{total coverage for all species}} \times 100$$

$$\text{Frequency} = \frac{\text{number of points where a species occurs}}{\text{total number of points}}$$

Importance Value = relative frequency + relative density + relative percent coverage

$$\text{Density} = \frac{\text{relative density of a species}}{100} \times \text{total density of all species}$$

Colony Size Distribution Data (n = number of data, Y = arithmetic mean, s = standard deviation, and w = size range) were also calculated from point-quarter data.

The coral species encountered during the point-quarter analysis indicate the predominant and common species within a zone. The presence of uncommon or rare species not encountered during the point-quarter analysis was determined by making 20 minute observations within a 20 m (66 ft) wide band in each zone. In zones not analyzed by using the point-quarter method, species lists were compiled by making 20 minute observations within a 20 m (66 ft) wide band. An overall list of species is compiled for each zone within a site from both the point-quarter and dive data in Table 10 (Appendix A). Quantitative data from the point-quarter analysis are presented in Table 11 (Appendix A).

Vertical profile sections shown in Figure 4b indicate the zonation patterns discriminated, water depth, sediment distribution and the relative abundance of corals for each study site.

RESULTS

Description of Reefs and Coral Communities

Zonation

Vertical profile sections (Figure 4b, Appendix B) that extend from the shoreline to 10 m (33 ft) depth indicate the general inshore submarine topography and physiographic zonation patterns discriminated, water depth, sediment distribution and relative abundance of corals at each of the five study sites. Some reef zones have no corals at all, while other areas support communities ranging from a few widely scattered colonies and species (reef-flat platform at Sites 2 and 3) to regions where the substrate is dominated by a relatively rich diversity of species (forereef slope zone at

Site 2). Although less noticeable, considerable community variation also occurs within the same zones from one site to another (Tables 10 and 11).

Coral Distribution

Ninety-eight species of corals representing 34 genera were recorded from the five study sites along the Laulau embayment (Table 10). Considerable variation occurred in species richness, size distribution, frequency of occurence, density and percentage of substrate coverage between the five sites and among the various zones discriminated at each site (Tables 10 and 11).

DISCUSSION AND CONCLUSIONS

One of the most noticeable aspects of the coral communities studied at the five sites in Bahia Laulau is their unequal distribution from the inner reef-flat platform to the 10 m (33 ft) depth contour on the forereef slope. Much of the regional variation found in the community structure of corals on the reef-flat platform zones is attributable to exposed platforms during low spring tides. Corals are unable to survive long periods of emergence, particularly when low spring tides coincide with extreme drying effects of the mid-day sun, and are thus restricted to parts of the reef-flat platforms that retain water during such times. Low tide exposure accounts for lower species diversity, general low density and percentage of substrate coverage recorded for the reef-flat platforms zones at Sites 2 and 3. The few species of corals that were recorded on these periodically exposed platform zones were confined to small scattered holes which retain water during low tides. An exception to poor coral community development on the reef-flat platform zones was found at Site 1a (53 species recorded) where the reef platform zone remains completely submerged during low tides and at Site 4 (30 species recorded) where an extensive reef flat depression creates a low-tide moat that retains up to a meter or more of water during such times.

In contrast to poor coral community development observed on the low-tide exposed reef-flat platforms at Sites 2 and 3, species richness, density and substrate coverage increased dramatically where low-tide exposure is not a factor in the reef margin zones at Sites 1a and 2 (no reef margin development at Site 1) and at all sites in the forereef slope zones (comparable to inner slope and submarine terrace zones at Site 1). Low density and substrate coverage values recorded in the reef margin at Site 3 (Table 11) are thus a reflection of observations being restricted to the inner part where it grades into the exposed reef-flat platform zone.

Substrate composition is another important factor that influences community structure and distribution of corals. Most corals require a hard rocky surface or a relatively stable unconsolidated substrate to settle upon and successfully grow. On the intertidal reef-flat platform zones at Sites 2 and 3 the relatively flat reef rock pavement surface areas are swept free of sediments by strong currents and storm waves. The only significant deposits of sediment observed consisted of poorly sorted mixtures of sand, gravel and rubble in some of the larger holes, troughs and depressions. At Sites 1a and 4 the subtidal reef-flat platform sediments were similarly restricted to holes and depressions. Except for a few patches of gravel, rubble and boulders lodged in the bottom of channels and fissures, sediments on the wave-swept reef margin and upper forereef slope zones were absent. Sediment deposits observed on the coral-covered lower forereef slopes at Sites 1a, 3 and 4 were restricted to the floors of shallow channels and troughs that funnel sediment downward to deeper forereef submarine terraces and slopes. The only significant sediment deposit observed was at Site 2 where a broad submarine terrace interrupts the forereef slope. Here extensive patches of sand, gravel, rubble and some boulders are found between coral-covered knobs, pinnacles, mounds and ridges. Although a few coral colonies are found on relatively stable boulders, most of the sediment covered areas of the submarine terrace are unstable and thus free of coral growth. However, it was most likely these small oases of coral growth on scattered boulders in the sediment covered areas of the terrace that were the forerunners of the abundant knobs and pinnacles of coral growth now found there.

Although considerable suspended sediment was observed in the water column, both on the shallow reef platform, reef margin and forereef slope zones, it did not appear to have much affect on the coral communities or accumulate on the living coral tissues. Most likely this is because of strong currents and water agitation present during periods of normal Northeast Tradewinds. Suspended sediment was particularly noticeable in the rich coral zones at Site 2. Water transported onto the reef platform by waves and swell returns to the open sea via a shallow channel that cuts across the reef-flat platform and reef margin zones.

Because of constant submergence and water circulation, normal annual and diurnal seawater temperature fluctuations that occur in the reef margin and forereef slope zones have little or no affect on the coral communities growing there. On the intertidal reef-flat platforms of Sites 2 and 3, and to some extent in the moat at Site 4, lethal or sublethal elevated temperatures may exist during low spring tides when water circulation is cut off and exposure to midday sunlight occurs.

Although some small streams discharge freshwater and some terrestrial sediment into the reef environment along the shoreline, it appeared to have little effect upon adjacent coral communities.

Since Site 1 is indicated as the preferred location for the proposed OTEC plant a more detailed description of this region is given.

Fringing reef development is absent along the wave-assaulted section of the coast at Site 1. As shown in the Site 1 profile (Figure 4b) the inner part of the submarine slope is steep which at about 5 - 8 m (16 - 26 ft) depth grades outward into a more gentle downward-sloping terrace. Bottom topography is irregular and humpy and cut here and there by large erosion channels and smaller grooves and fissures. The channel walls are steep to vertical, locally overhanging, scoured and undercut near the bottom. The channel floors show considerable evidence of scouring and in most places along their length are strewn with large angular blocks, rounded boulders and patches of coarse sand and gravel.

Although fringing reef development was not observed at this site, a moderately diverse coral community consisting of 36 species (Table 10) was found growing on nonabraided surfaces of the steep inner slope, outer submarine terrace, mounds and upper walls of channels and fissures. Corals were also observed on the upper surfaces of large stable blocks and boulders, but were generally absent on smaller ones that are apparently moved about by storm waves. Except for a few small stunted colonies, corals were also absent on the floors of channels and fissures and other locations where surface abrasion by loose sediments was evident. Percentage of surface coverage on nonscoured substrates at Site 1 was estimated to range from 10-30 percent. Predominant coral species include seven in the family Pocilloporidae, ten in the family Acroporidae and nine in the family Faviidae (Table 10). Corals from Site 1 that were not observed at other sites in Bahia Laulau include Pocillopora ankeli, Scapophyllia cylindrica and Stylaster profundiporus.

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MACROINVERTEBRATES

INTRODUCTION

Conspicuous macroinvertebrates were collected at four coastal sites along Bahia Laulau on the east coast of Saipan. The only previous study in that area was conducted between October 1948 and July 1949 (Cloud, 1959). Cloud described the shallow-water shore areas of Bahia Laulau as "intertidal to very shallow shore benches that are subject to nearly similar conditions of heavy surf and to abrupt and extreme variations of temperature and salinity" (p. 385). Cloud's Station 13a coincides quite nearly to Site 3 of this study. He did not consider the parts of the reef seaward of the reef margin.

METHODS

Specimens were collected from five stations during November 5, 6, and 7, 1982. Specimens were collected during all reconnaissance scuba dives by all team members. Dr. Eldredge collected specimens in the intertidal and reef flat areas. No quantitative data were attempted for conspicuous macroinvertebrates except for major forms like Acanthaster planci. To the east and protected from the rough water Site 1a allowed collecting on the narrow reef flat and in the block-and-boulder intertidal zone. Specimens were also collected here at a depth of 9 m (30 ft). At Site 2 specimens were collected on the reef flat, reef front and at a depth of 9 m (30 ft). Similarly at Site 3, specimens were collected on the reef flat and at depths of 9 - 18 m (30 - 60 ft). Intertidal specimens were collected at Site 4, as well as from the reef flat and at depths of 12 - 15 m (40 - 50 ft). Specimens collected are listed in Table 12 (Appendix A).

RESULTS

Gastropods were the most commonly collected group totaling 88 species. Among these, 22 species belong the family Conidae, ten to the Muricidae, nine to the Mitridae and seven to the Cypraeidae. Only two species, Astraea rhodostoma and Vasum turbinellus were collected at all sites.

Intertidal zonation is typical of that found in the southern Marianas. The pulmonate Melampus flavus represents the greatest abundance in the community. Another gastropod, Littorina coccinea is also a very high in abundance and occurred in especially large numbers at Site 4. The remaining intertidal gastropods, Littorina undulata, Cellana radiata and N. plicata were found at Site 4 and at the low headlands immediately south of Site 2. Of interest was the occurrence of the large muricid Drupa morum on the seaward erosion platform at Site 4 and the cone Conus planorbis has not yet been reported from Guam.

Nine species of bivalves were collected. Voucher specimens of all the gastropods and bivalves have been deposited at the Dickinson Memorial Mollusk Collection at the University Marine Laboratory.

DISCUSSION AND CONCLUSIONS

Cloud (1959) reported ten gastropods from his Site 13a which included three cowries. One of his species names is an Indian Ocean form and is unidentifiable. Of the six cone shells reported, one is also unidentifiable. All of the remaining forms and one vasid were also collected again during this study.

Although no specimens were observed during this study, the spiny lobster (Panularus sp.) and slipper lobster (Family Scyllaridae) are important resources of Bahia Laulau. Divers regularly harvest lobsters from the area, particularly at night. During appropriate tides and moon phases, harvesting also occurs along the extensive shallow reef-flats.

Twelve echinoderm species were observed during the study. They are large and readily identifiable forms. Healthy populations of Acanthaster planci were observed at all sites. The size of each herd (greater than 100 large individuals) was unexpected but prevalent throughout Bahia Laulau particularly in the vicinity of coral-rich Sites 2 and 3. Some individuals represented the largest individuals (50 cm, 20 in) that have been recorded anywhere particularly in recent years.

The significance of large populations of Acanthaster planci is evident from previous outbreaks in the Western and South Pacific regions. Reefs in Micronesia and Australia's Great Barrier Reef suffered extreme damage by Acanthaster between the late 1960's and mid 1970's. The history and early development of Acanthaster was studied by Cheney (1972) and Tsuda (1971 and 1972). However, while these studies were going on teams of divers were waging war on the huge populations that threatened to destroy coral reefs throughout the Pacific Basin (Chesher, 1969) and (Yamaguchi, 1971). Marsh and Tsuda (1973), and Marsh et al (1971) surveyed the Mariana and Caroline Islands to determine the population levels of this particular coral killing animal. Randall (1973) provides the best account of a reef prior to destruction by Acanthaster. By 1974 spawning and characteristic aggregation of Acanthaster had been exhaustively studied (Cheney, 1974). However, it was not until Birkeland's 1982 paper linking heavy rainfall after a dry period to increased populations that an understanding was gained into how such large populations seem to appear overnight in areas where none were previously noticed.

Two foraminiferid forms, Margonipora vertebralis and Baculogypsina sphaerulata were commonly seen in beach and reef flat sands. Both were previously reported by Cloud (1959).

The reef flats at Sites 2 and 3 were more similar to one another than to those at Sites 1a and 4 and all the intertidal zones were similar to each other. In summary, the conspicuous macroinvertebrates collected and observed represent a typical reef flat and embayment area for a southern Mariana island. With the inclusion of such large numbers of Acanthaster we can honestly say that the area resembles similar bays and reefs in Micronesia in the late 1960's to mid 1970's. This find does not represent a healthy short-term picture for the submarine ecology of Bahia Laulau.

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FISHES

INTRODUCTION

Previous to this work no other assessment of fish resources in the Bahia Laulau area had been done. Bahia Laulau is a unique and valuable asset to Saipan's recreational and subsistence fishery. This large windward bay contains a wide range of habitats which have the potential to accommodate many important species of fish. Despite this, and the bay's reputation of being a good diving and fishing spot, very little is known of the fishes that live there. The objectives of this study were to investigate the species composition, distribution and general density of the fishes seen on the reef flat and shallow forereef slope. The data presented here provide baseline information on Bahia Laulau that will be useful in assessing its reef community as a whole and in gaining a better understanding of its reef fishery potential.

METHODS

The conspicuous shallow-water fish fauna of Bahia Laulau was surveyed between November 3-7, 1982. Reef flat reconnaissance was done with mask and snorkel and SCUBA was used to survey the forereef slope. Species checklists were compiled at five study Sites (1, 1a, 2, 3 and 4). Line transect counts of fishes were made on the reef flat and forereef slope at Sites 2 and 3. Fishes observed along these transects were counted only if they were within 1 m (3 ft) of either side of the line and less than 2 m above it.

Rough ocean conditions at Sites 1 and 4 limited the investigation to single 45-minute reconnaissance dives on the forereef slope. Site 1 fishes were observed to approximately 21 m (70 ft), and Site 4 species were surveyed down to 18 m (60 ft).

Greater time was spent at Sites 2 and 3 since they were more protected and contained accessible reef flats. Care was taken to sample fishes in both the shallow and depressed areas of the reef flat. At Site 2, fishes were surveyed during a 45-minute swim and counted along a 50 m (164 ft) transect line placed within a depressed area near an old pipeline. Site 3 fishes were counted along a 100 m (328 ft) transect line that traversed mostly along shallow pavement. Together, these transects covered eight 10 m (33 ft) sections of depressed reef flat and seven 10 m (33 ft) sections of shallow pavement.

On the forereef slope at Sites 2 and 3, reconnaissance as well as 100 m (328 ft) transect counts of fishes were made at 9 and 18 m (30 and 60 ft.) These transects traversed substrate that was uniformly covered with coral and algae-covered rocks at both depths at Site 3. At Site 2, however, the transects extended across substrate that varied from extensive sand/rubble areas containing isolated rocks and coral heads to areas almost completely covered by coral. Fish densities calculated from the transect data were converted to a standardized form to reflect densities per 10 m (66 ft) of transect line or 20 m^2 (215 ft^2) of substrate.

RESULTS

Species Diversity

Table 13 (Appendix A) lists the fish species seen at the four study sites. Altogether, 200 species belonging to 35 families were recorded. The most well represented families included the Labridae (33 spp), Pomacentridae (23 spp), Acanthuridae (19 spp), Chaetodontidae (17 spp) and Scaridae (13 spp). These five families contributed 52 percent of the total number of observed species, while the Labrids alone accounted for 16 percent of the total.

Although the ocean surface at Site 1 was rough, below 10 m (33 ft) the surge diminished rapidly and visibility was fairly good. A total of 107 species representing 23 families were observed. Approximately 10 percent of the total number of species recorded at all sites were seen exclusively at this location. Reconnaissance at Site 4 was more difficult and less fruitful. Not only was the surface very rough, but there were also a strong surge and much reduced visibility down to 18 m (60 ft). Only 73 species comprising 19 families were observed. Only two percent (4) of the total recorded species were observed exclusively at this site.

Not surprisingly, the greatest numbers of species were recorded at Sites 2 and 3. At Site 2, a total of 130 species belonging to 31 families were seen on the reef flat and forereef slope. Approximately 12 percent (34) of the total recorded species were observed solely at this site. A slightly lesser number of species were observed at Site 3 where 125 species representing 28 families were recorded. Approximately 10 percent (21) of the total recorded species were seen exclusively at this site. The combined reef flat data for Sites 2 and 3 yielded a total of 42 species representing 23 families. These species are listed in Table 14 (Appendix A).

Juvenile Fishes

The presence of juvenile fishes was recorded during both the reconnaissance and transect dives. These species are listed in Table 15. Based on the abundance of the smallest individuals, none of these species showed evidence of recent large-scale recruitment. Within both the reef flat and forereef slope zones the largest numbers of observed juveniles belonged to the family Pomacentridae. Juveniles belonging to the familes Labridae and

Acanthuridae were also among the most numerous. In all, juveniles were recorded among 31 species within 9 famlies. More than half of these species are herbivorous.

Food Fishes

At least 38 percent (75) of the recorded species are known to be desirable food fishes. These species have potentially important economic and recreational value and are identified in Table 13 by an asterisk.

About 33 percent (35) of the Site 1 species are listed as desirable food fishes. The majority of these species belong to the families Acanthuridae (34%), Lutjanidae (11%), Mullidae (11%) and Scaridae (11%). Some of the more important species seen at mid-depth were the emperor, Lethrinus semicinctus (Mafute); several surgeonfish species of the genus Naso, including Naso unicornis (Tataga); and the rabbitfish, Siganus argenteus (Hiting). The largest individual food fishes seen during the entire study were recorded at Site 1 near the 21 m (70 ft) depth. These included the snappers, Aprion virescens, Lutjanus bohar (Tagafi), Lutjanus rivulatus, Lutjanus russelli; and the groupers, Plectropomus leopardus (Godao) and Variola louti.

At Site 4 only 27 food species were recorded, yet these made up 37 percent of the total number of species seen there. The major food fish families included the Acanthuridae (37%), Scaridae (18%), Labridae (15%) and Lethrinidae (11%). Among the most important food species were Lethrinus semicinctus (Mafute) and Siganus argenteus (Hiting); the emperor, Lethrinus harak (Mafute); the snapper, Macolor niger; the surgeonfishes, Naso hexacanthus (Gausa) and Naso lituratus (Hangun); the goatfish, Parupeneus bifasciatus (Salmoniti); and several parrotfish species, including Scarus rubroviolaceus (Lagua).

Desirable food fishes composed 39% (51) of the Site 2 species, and were most represented by the Acanthuridae (22%), Scaridae (16%), Mullidae (14%) and Holocentridae (12%). The most abundant food species seen on the reef flat were small schools of the surgeonfish, Acanthurus triostegus (Kechu); the goatfish, Mulloides flavolineatus (Tiao); and the rabbitfish, Siganus spinus (Seyun). Other important reef flat species included Lethrinus harak (Mafute); the jack, Caranx melampygus (Tarakito); and the snapper, Lutjanus fulvus (Kakaka). The principal food species observed on the forereef slope consisted of Lethrinus harak (Mafute) and Mulloidichthys flavolineatus (Tiao); several surgeonfishes, including Naso lituratus (Hangun); the squirrelfishes, Adioryx caudimaculatus (Suksuk), Adioryx spinnifer (Sesiok), Myrpristis berndti (Sagsag) and Myrpristis murdjan (Sagsag); the jack, Caranx sexfasciatus (Mamulon); several wrasses, including Cheilinus undulatus (Tanguisun); the grouper, Epinephelus merra (Gadao); the sweetlips, Plectorhynchus orientalis (Hamala); and several parrotfishes, including Cetoscarus bicolor and Scarus gibbus (Lagua), both of which attain relatively large sizes.

Nearly 31 percent (38) of the Site 3 species are considered desirable food fishes. The prominent food fish families were the Acanthuridae (26%), Scaridae (15%), Lutjanidae (13%), Holocentridae (10%) and Labridae (10%). The major food species recorded on the reef flat included Acanthurus triostegus (Kechu), Mulloidichthys flavolineatus (Tiao) and Siganus spinus (Seyun). Other important reef flat food species were Adioryx spinnifer (Sesiok) and the grouper, Cephalopholis sonneratus (Gadao). On the forereef slope, the important food species included the following: Lethrinus harak (Mafute); Lutjanus bohar (Tagafi), Lutjanus fulvus (Kakaka) and Macolor niger; Adioryx spinnifer (Sesiok), Myrpristis berndti (Sagsag) and

Myrpristis murdjan (Sagsag); several surgeonfishes, including Naso lopezi, Naso hexacanthus (Guasa) and Naso lituratus (Hangun); the snapper, Aphareus furcatus and several parrotfishes, including Scarus gibbus (Lagua).

Fish Density

Fish density at Bahia Laulau was investigated along line transects at Sites 2 and 3. Density values calculated from these data are presented in Table 16 (Appendix A). The reef flat breakdown by site shows similar densities of species between sites, but a much higher density of individuals occurring at Site 2. However, the latter is misleading and is probably largely the result of transect placement rather than to significant differences between sites (see Methods). A better way to use these data would be to compare fish densities between the shallow pavement and depressed areas of the reef flat (Table 17, Appendix A). These values do indicate real differences and help explain why the density of individuals at Site 2 was so high.

Fish densities calculated for the forereef slope are broken down by site and depth in Table 16. Overall, the density on the forereef slope was about twice that found on the reef flat. Within each study site, similar densities were found at both depths. However, quite different densities were found between study sites. The fish density at Site 3 was consistently higher. At 9 m (30 ft), a 36 percent greater species density, as well as a 52 percent greater density of individuals were found. At 18 m (60 ft), Site 3 showed a 57 percent greater species density and a 41 percent greater density of individuals. As in the case of the reef flat, substrate variability appears to be related to the density differences observed on the forereef slope (see Methods). It is evident from Table 17 that fish density at Site 2 increases with substrate complexity at both depths. It is also interesting to note the high degree of similarity between the densities at Site 3 and those over the coral-covered areas at Site 2.

DISCUSSION

Considering the limitations imposed on this investigation by time and nature, Bahia Laulau was found to contain a fairly diverse shallow-water fish fauna. In general, the fish communities observed at each study site appeared to be healthy. The numbers of species that were found to be unique to a single study site were relatively low, ranging from 2-16 percent ($\bar{x}$ = 10%) of the total recorded species. This is an indication of widespread recruitment of species within the bay. More extensive reconnaissance throughout the bay, especially at depths greater than 18 m (60 ft), and within the vicinities of Sites 1 and 4, would undoubtedly reveal the presence of several other important species. A thorough survey of the more cryptic, burrowing, nocturnal and pelagic species would also increase the overall species list significantly.

Furthermore, the overall abundance of shallow-water coral reef fish is known to fluctuate seasonally largely as a result of reproductive activities. In the Mariana Islands, peak fish abundance occurs from April through July. Several studies support the belief that coral reef fishes increase in abundance in the spring and early summer months due to both spawning peaks and increases in recruitment (see Johannes, 1978 and 1979; Kock, 1982 and Molina, 1982). Had the same survey techniques been employed during the peak season, it is likely that a greater number of species as well as juveniles, would have been encountered. In addition, the ratio of carnivores to herbivores among juveniles may also shift seasonally with the former being more abundant during the late spring and early summer months.

The percent of desirable food species seen during the survey was fairly uniform across study sites. These species ranged from 31-39 percent of the total number of species recorded at each site. These figures should be regarded as minimums when viewed in relation to the bay's fishery potential. In addition, better diving conditions and more extensive reconnaissance would have resulted in the identification of other important food fishes, especially among the more secretive and deeper living species.

The bay does have a significant reef fishery potential for a variety of fishing methods. The reef flats offer cast net (talaya), gill net (tekin) and limited surround net (chinchulun umesugan) possibilities. A more diverse array of species are taken with the latter two methods since their catch is limited primarily by the location and mesh size of the net. Species commonly caught by gill and surround nets include many wrasses, snappers, emperors, jacks, parrotfishes, rabbitfishes, surgeonfishes and goatfishes. Cast netting, on the other hand, is a selective method usually used to target in on specific species such as Acanthurus triostegus (Kechu), Caranx melampygus (Ee), Mulloidichthys flavolineatus (Tiao), Naso unicornis (Tataga) and Siganus spinus (Seyun).

Angling with hook and line is another method commonly employed on the reef flat. This method may also be selective when used along the shore to catch schooling juvenile jacks such as Caranx melampygus (Ee) and Caranx sexfasciatus (Mamulon), or from the reef margin to catch fishes over the reef front, such as Naso unicornis (Tataga). Much of the selectivity of this method is determined by the reef zone or depth that is fished and by the type of bait and tackle that is used. Over the forereef slope, deeper dwelling species such as the larger snappers, emperors, wrasses, jacks, sweetlips and squirrelfishes may be caught with hook and line from a boat.

Spearfishing is another selective method that has a high potential on the forereef slope. Species that are highly desirable by spearfishers include; Adioryx spinnifer (Sesiok), Caranx melampygus (Tarakito), Cheilinus undulatus (Tanguisun), Naso unicornis (Tataga), and the larger snappers, emperors, sweetlips and parrotfishes.

Local fishermen consider that the fish populations close to the reef flats have declined as a result of the pressure from heavy fishing in recent years. However, fishing in the bay as a whole is still considered to be excellent.

Other important species seen within the bay include four species of Caesionidae (fusiliers). These relatively unexploited species have potential as food and as baitfish for tuna. Unfortunately, their abundance was not observed to be high, but this may be because they are only indirectly associated with the reef.

Relatively few of the reef fishes traditionally regarded as dangerous to humans were seen during this survey. Those observed included a large adult stingray (Taeniura melanospilos) (Hafula) seen at 9 m (30 ft) at Site 3, a young black-tip shark (Charcharhinus melanopterus) (Haluu) and a moray eel (Lycodontis sp.) (Titugi) recorded on the reef flats at Sites 2 and 3 respectively.

The transect data yielded calculated fish densities that may be used to partly characterize the reef flat and forereef slope fish communities. Differences in the fish densities within each of these zones appear to be related to differences in substrate complexity. More complex substrates have a greater potential for accommodating larger numbers of species and individuals per area than less complex substrates. This was well illustrated on the forereef slope at Site 2, partially explaining why the densities at Sites 2 and

3 were so different. The density values presented here may be useful in obtaining gross estimates of the demersal fish resources existing within the bay down to 18 m (60 ft).

CONCLUSIONS

The fish community in Bahia Laulau down to 21 m (70 ft) is fairly diverse and appears to be in a relatively healthy state. This, and the wide range of habitats found there, makes it a location potentially valuable for ecological studies of reef fish. Many important species of food fishes are present and the potential for recreational and subsistence fishing is also high. The replenishment of harvested food species should not be a problem since the bay is large and inaccessible to fishing by rough seas during most of the year. The more remote regions of the bay should be excellent sources of new recruits for the more heavily fished areas.

Although Bahia Laulau represents a significant recreational subsistence fishery for the island, preliminary data provides no basis for the support of an intensive commercial fishery here. However, based on observations made during this study, we feel that the resources contained within the bay could support a limited commercial fishery for reef fishes. In this regard, spearfishing and shallow-water hook and line fishing have the greatest potential. There may be some species of fish that are not being utilized from Bahia Laulau at the present time. These may represent an excellent, though perhaps seasonal, resource (pelagic types, ie. tuna and mahi-mahi). In any event, the reef and reef associated fishery resources should continue to be utilized for recreational and subsistence fishing until more data are available to support demands for additional fishery development.

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MARINE TURTLES AND MAMMALS

INTRODUCTION

Both the green sea turtle (Chelonia mydas) and the hawksbill turtle (Eretmochelys imbricata) are known to occur in the waters of Bahia Laulau. Interviews with local fishermen and divers, as well as sightings by team members during this study indicate that the green sea turtle is a frequent inhabitant of the bay, while the endangered hawksbill turtle is more seldomly seen. According to information from Ben Concepcion, a local diver and fisherman, no noticeable decline in the turtle population in Bahia Laulau is evident. He normally sees one or two green turtles on every dive he makes, spotting them either underwater or on the surface from a boat. He says that "turtles are more numerous around the points, such as Hagman and Dandan and in the waters surrounding Forbidden Island."

Marine mammals, particularly porpoise, are known to occur in Bahia Laulau (personal observations of Ben Concepcion). However, no record of sightings or other scientific works verify these sitings. Porpoise of an unknown variety were observed moving through the bay on two field visits (February and May 1983) during this study. It is expected that porpoise venture into Bahia Laulau for feeding and protection during migration. There did not appear to be a resident population of porpoise in Bahia Laulau while our survey was going on. There is no known record of whale sitings in Bahia Laulau and none were observed during this study.

METHODS

Prior to each field visit all research participants were instructed to look for marine turtles and mammals while on their respective surveys. Separate transects or observations were not run since we did not expect to observe great numbers of these animals. Instead, we made a point to keep an eye out for these animals wherever a research participant went either by boat, car or while diving. Observations were made by boat, underwater by scuba and skin diving and from observation points high above the bay. In addition, knowledgeable locals were surveyed regarding their personal observations recently and over the past few years.

RESULTS

Turtles were spotted at different locations throughout Bahia Laulau on each of the four field surveys. Sightings were made from observation points above Hagman Point (Site 1), Chamorro Village (Site 3) and the Quarry (Site 4). Turtles were also sighted while working underwater at all sites. A total of 9 turtles were observed during the study. More turtles were observed on the surface at Sites 1 and 4 than at the other sites either on the surface or underwater. Two green sea turtles (Chelonia mydas) and one hawksbill Eretmochelys imbricata) were observed floating on the surface from our observation post above Site 1. Three green sea turtles (Chelonia mydas) were observed floating off Site 4 from our quarry observation post. One each of the green and hawksbill turtles were observed underwater at Site 2 and one Hawksbill at Site 3.

Turtle nesting has been observed along the beaches which occur within Bahia Laulau. Information from Mr. Concepcion and a few residents in the area revealed that they have observed green turtle nests at beaches below the airport and quarry site in southern Bahia Laulau (Site 4 of our survey). Recently Mr. Concepcion observed a few nests at Dandan Beach. Ben Sablan, Fisheries specialist at the Division of Fish and Wildlife, recorded two nests at Puntan Hagman during 1982. He reports that in the mid-1970's, scuba divers were harvesting turtles regularly at Naftan Point, Forbidden Island and the Grotto.

DISCUSSION AND CONCLUSIONS

Because of the rather extensive development of the shoreline and beach areas along the west coast of Saipan, there is a shortage of protected nesting areas for turtles. Even some of the nesting sites on the east coast are visited frequently by fishermen and tourists. Disturbing and robbing eggs from these nests has seriously affected the reproductive efforts of the turtles. This situation makes the few relatively inaccessible nesting beaches in Bahia Laulau very important for the continued survival and conservation of these animals. Nesting sites need to be better protected during the nesting season (March-July) and laws protecting the turtle nests need to be enforced. At the present time, all marine turtles are considered to be either threatened or endangered in the CNMI. Continued education is essential to enlighten the public as to the steps necessary in protecting and conserving this precious biological resource.

Although both the green and hawksbill turtles are protected by the Federal Endangered Species Act, CNMI residents are exempted from the provisions of this act and allowed to take green turtles for subsistence purposes only. Subsistence taking is defined as "customary, traditional taking of restricted game to provide sustenance for the taker and his or her immediate family when no other means of providing sustenance is available or when curtailment would result in severe malnutrition." Only one green turtle may be taken per season (September 1-November 30) and only CNMI citizens may take a turtle after purchasing a $5.00 license. However, the CNMI government may pass more stringent laws or regulations in regards to the taking of endangered species. To this end the Director of Natural Resources may grant exemptions from limits for subsistence taking of wildlife.

Additional regulations state that green turtles less than 34 inches in length measured across the top of the carapace may not be taken, taking of green turtles inshore of the mean low tide mark is prohibited, no person shall disturb or take eggs from a nest, green turtles may not be transferred, sold or exported and the taking of green turtles must be customary and traditional.

OTEC DEVELOPMENT

INTRODUCTION

The CNMI government recognizes the importance of OTEC development as a part of its renewable energy program in order to reduce its dependence on imported fossil fuels. In their OTEC pilot plant program technical proposal the CNMI concluded that "OTEC is one of its few alternatives as a baseload electric power source." OTEC represents a capital-intensive approach to the production of electric power. Although the fuel is free and renewable, the high initial capital costs plus the lack of sufficient demonstration of the technology and economics on a large scale have been a barrier to the rapid commercialization of OTEC.

Four small OTEC applications represent the bulk of technological advancement in the field: Mini-OTEC, OTEC-1, Seacoast Test Facility and the Nauru plant. In July 1979 the Mini-OTEC plant was deployed off Keahole Point on the island of Hawaii and became the world's first successful closed-cycle OTEC plant producing an average of 18 kW net electricity during its 620 hours of operation. OTEC-1 is a converted T-2 tanker renamed Ocean Energy Converter and was deployed off Keahole Point in September 1980. The Seacoast Test Facility is a land-based OTEC plant from which biofouling and corrosion experiments are being conducted. The 100kW Nauru OTEC plant was placed in operation in October of 1981 and a continuous operation test was carried out for ten days in November 1981. This test proved the reliability and performance of the plant under continuous operation and valuable data applicable to future commercial OTEC plants was obtained. Due to successful completion of the 100 kW Nauru pilot plant the developers are now willing to undertake construction of a 2,500kW commercial plant.

Significant potential for OTEC application exists in tropical and subtropical zones between 20° S and 20° N latitude where delta T exceeds 20°C. Figure 17 illustrates this resource in terms of the average of monthly temperature differential. A comprehensive list of 98 potential OTEC nations and territories has been developed from basic OTEC criteria (Table 18). These criteria are based on significant monthly delta T within 370 kilometers (200 miles) from shore, also known as the Exclusive Economic Zone (EEZ). These nations and territories can be categorized as follows.

1. Developed nations - 3 (U.S., Japan, Australia)
2. Territories of developed nations - 29 (U.S., Japan, France, UK, Netherlands and NZ).
3. Developing nations with free-market economies - 63.

Perhaps the greatest OTEC potential is in developing nations and territories. Table 19 illustrates the key oceanographic resource parameters for 67 of these nations and territories (excluding territories of developed nations except Guam, Trust Territory of the Pacific, Virgin Islands and American Samoa and the centrally planned economic nations). These 67 nations and territories combined have a projected installed electrical capacity of approximately 284,000 MW in 1990 and a potential 1,460,000 MW by the year 2010. Much of this could be supplied by OTEC.

The Saipan location and Bahia Laulau site represents one of the best OTEC resources in the world with the average of monthly temperature difference between the warm surface and cold deep ocean waters exceeding 21°C. There are two estimates of the thermal resource available in the Marianas; Lassuy (1979) University of Guam and Dames and Moore (1979) in

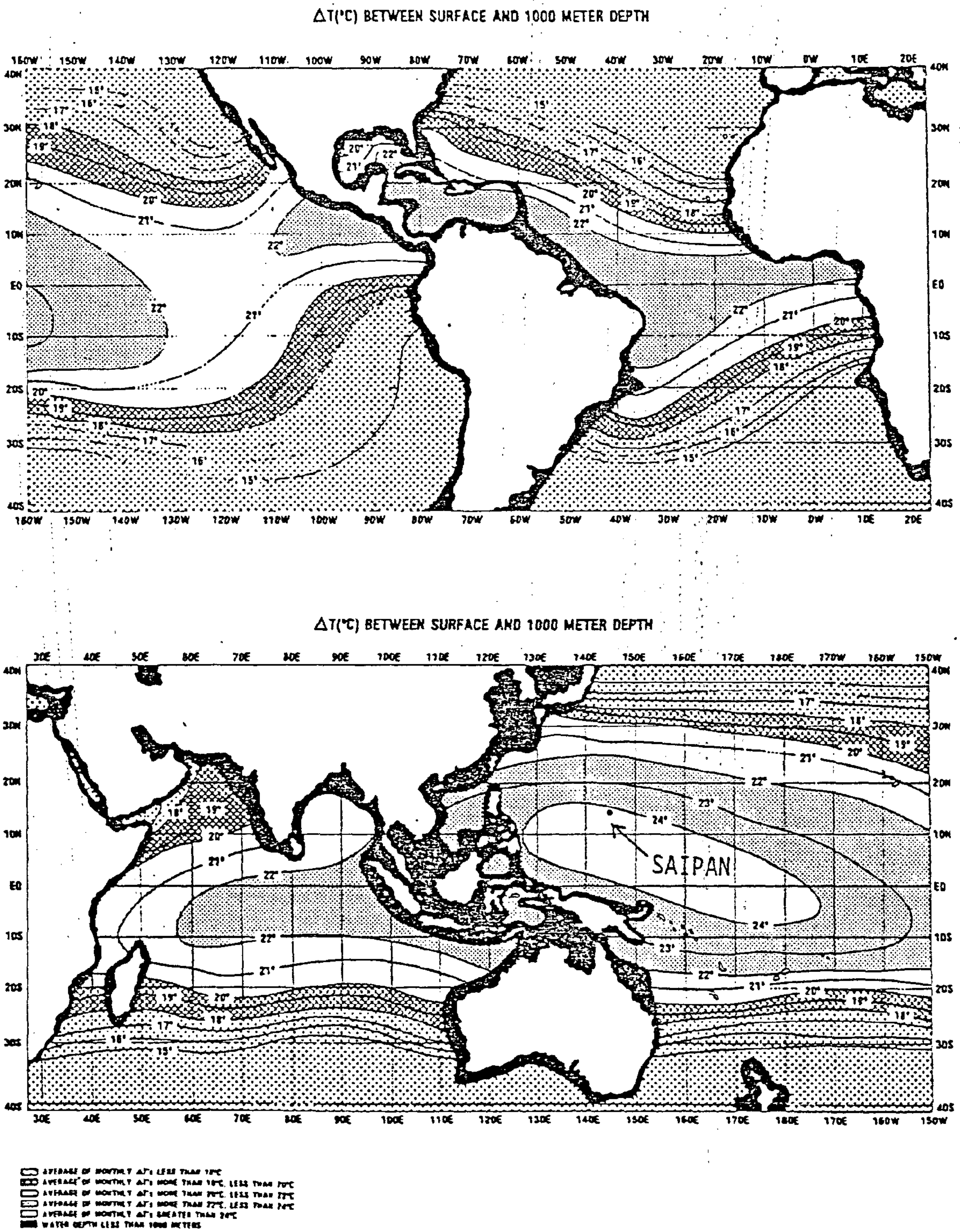

Figure 17. Potential OTEC Thermal Resource.

Table 18. Nations and Territories with Thermal Resource (Mean) Annual ΔT >20°C @1000 M Depth within 200 nm EEZ)

GEOGRAPHICAL AREA	MAINLAND		ISLAND	
LATIN AMERICA	MEXICO	GUYANA	CUBA	GUADALOUPE (FR)
	BRAZIL	SURINAM	HAITI	MARTINIQUE (FR)
	COLOMBIA	FRENCH GUIANA(Fr)	DOMINICAN REP.	BARBADOS
	COSTA RICA	NICARAGUA	JAMAICA	DOMINICA
	GUATEMALA	EL SALVADOR	VIRGIN IS. (US)	ST. LUCIA
	HONDURAS	BELIZE (UK)	GRENADA	ST. KITTS (UK)
	PANAMA	UNITED STATES	ST. VINCENT	BARBUDA (UK)
	VENEZUELA		GRAND CAYMAN (UK)	MONTSERRAT (UK)
			ANTIGUA (UK)	THE GRENADINES (UK)
			PUERTO RICO (US)	CURACAO (NETH)
			TRINIDAD AND TOBAGO	ARUBA (NETH)
			BAHAMAS	
AFRICA	NIGERIA	GABON	SAO TOME AND PRINCIPE	
	GHANA	BENIN	ASCENSION (UK)	
	IVORY COAST	ZAIRE	COMOROS	
	KENYA	ANGOLA	ALDABRA (UK)	
	TANZANIA	CAMEROON	MADAGASCAR	
	CONGO	MOZAMBIQUE		
	GUINEA	EQ. GUINEA		
	SIERRA LEONE	TOGO		
	LIBERIA	SOMALIA		
INDIAN/PACIFIC OCEAN	INDIA	AUSTRALIA	INDONESIA	AMERICAN SAMOA (US)
	BURMA	JAPAN	PHILIPPINES	TRUST TERRITORIES (US)
	CHINA	THAILAND	SRI LANKA	GUAM (US)
	VIETNAM	HONG KONG (UK)	PAPUA NEW GUINEA	KIRIBATI
	BANGLADESH	BRUNEI (UK)	TAIWAN	FRENCH POLYNESIA (FRANCE)
	MALAYSIA		FIJI	NEW CALEDONIA (FRANCE)
			NAURU	DIEGO GARCIA (UK)
			SEYCHELLES	TUVALU
			MALDIVES	WAKE IS. (US)
			NEW HEBRIDES (UK/FR)	SOLOMON ISLANDS
			SAMOA	MAURITIUS
			TONGA	OKINAWA (JAPAN)
			COOK IS. (NZ)	WALLIS & FUTUNA IS. (FR)
TOTALS:	44		54	

Table 19. Oceanographic Resource Parameters

Geographical Area	Nation	Thermal Resource (°C)	User Proximity (km)	Thermal Resource Size (km)	Frequency of Severe Storms*	Currents (m/sec)
Indian/Pacific Ocean	Indonesia	22-23	10-50	>1000	0-0.1	0.2-0.4
	Papua New Guinea	23-24	<10	>1000	0.1-0.5	0.4-0.6
	Kiribati	>24	<10	250-500	0-0.1	0.4-0.6
	Tuvalu	>24	<10	250-500	0-0.1	0.2-0.4
	Solomon Islands	23-24	<10	500-1000	0.1-0.5	0.4-0.6
	Nauru	>24	<10	100-250	0-0.1	0.4-0.6
	Trust. Terr. Pacific	>24	<10	500-1000	1.0-3.0	0.2-0.4
	American Samoa	23-24	<10	100-250	0.1-0.5	0.1-0.2
	Samoa	23-24	<10	100-250	0.1-0.5	0.1-0.2
	Philippines	>24	<10	>1000	>3.0	0.2-0.4
	Tonga	20-21	<10	100-250	0.1-0.5	0.1-0.2
	India	21-22	50-100	>1000	1.0-3.0	0.2-0.4
	Guam	>24	<10	100-250	1.0-3.0	0.2-0.4
	Fiji	21-22	10-50	250-500	0.1-0.5	0.1-0.2
	Sri Lanka	21-22	10-50	500-1000	0.5-1.0	0.6-0.9
	Maldives	21-22	<10	500-1000	0-0.1	0.4-0.6
	Mauritius	20-21	<10	250-500	1.0-3.0	0.1-0.2
	Seychelles	21-22	10-50	250-500	0-0.1	0.4-0.6
	Taiwan	21-22	10-50	250-500	>3.0	0.4-0.6
	Burma	21-22	10-50	100-250	0.5-1.0	0.2-0.4
	Malaysia	23-24	100-370	100-250	0.5-1.0	0.2-0.4
	Bangladesh	21-22	200-370	<100	1.0-3.0	0.2-0.4
Africa	Liberia	22-23	10-50	250-500	0-0.1	0.6-0.9
	Ivory Coast	22-23	10-50	250-500	0-0.1	0.6-0.9
	Ghana	22-23	10-50	250-500	0-0.1	0.6-0.9
	Nigeria	22-23	50-100	250-500	0-0.1	0.6-0.9
	Togo	22-23	10-50	<100	0-0.1	0.6-0.9
	Benin	22-23	10-50	<100	0-0.1	0.6-0.9
	Cameroon	22-23	50-100	100-250	0-0.1	0.6-0.9
	Gabon	21-22	50-100	250-500	0-0.1	0.6-0.9
	Mozambique	20-21	10-50	500-1000	0.5-1.0	0.6-0.9
	Sao Tome & Principe	22-23	10-50	<100	0-0.1	0.6-0.9
	Eq. Guinea	22-23	10-50	<100	0-0.1	0.6-0.9

* Number per 5° Latitude - Longitude Square

their preliminary EIS for a Guam OTEC. The consensus of these data conclude that a year round temperature differential over 21° C (69.8° F) exists at a depth of 550 m (1,800 ft) and a 23° C (73.4° F) differential can be obtained at a depth of 900 m (2,952 ft).

Siting of OTEC plants must consider existing competing ocean uses to avoid conflicts that could delay approval by local and federal agencies. Extensive U.S. offshore oil activities, with a large number of existing platforms, pipelines, operations of drilling and logistics vessels do not exist in the regions of most Pacific Islands. In contrast to the coastal areas of the U.S. continent and, to a reduced degree, of Hawaii and Puerto Rico, there are only a few ocean uses in the vicinity of the Pacific Islands. Therefore, the potential for conflict with existing competing ocean uses is considerably reduced for the small Pacific Island OTEC pilot plant program.

The competing ocean uses on which OTEC facilities may be expected to impact in the Commonwealth of the Northern Marianas are fisheries, navigation and possible deepwater port development. However, the location of any OTEC facility can be planned to cause the minimum of interference with shipping and port development. The only ocean use that could realistically be affected in the foreseeable future is that of fisheries.

At present, the fisheries of the Northern Marianas are largely of the subsistence variety with some recreational fishing and a small local commercial industry. Nevertheless, there is a high potential for development of a commercial fishing industry as has been shown by the successful efforts achieved by the Japanese, Taiwanese, Korean and more recently large U.S. purse seiners in Marianas waters. The development of a viable commercial fishing industry is of central importance to CNMI economic independence and self-sufficiency and is recognized as such in the recent Draft Fisheries

Development Plan, FY 1981-85. The recently enacted Marine Sovereignty Act of 1980 stresses the dependence of the people of the Northern Mariana Islands on the resources of the sea "for their economic, social and political survival and growth" and the consequent need to establish control over marine resource exploitation. The Act inter alia establishes a 370 kilometer (200 mile) economic zone for this purpose.

The effect of an OTEC facility on fisheries relates to the displacement of warm, shallow water with cold, deep water and the resulting modification of temperature, salinity, density, dissolved oxygen, nutrients, carbonates and particulates. This "artificial upwelling" caused by an OTEC operation can result in an increased fish population and therefore higher yields. However, the overall impact of a small OTEC plant is likely to be minimal.

Another aspect currently under consideration is the feasibility of a multi-purpose OTEC consisting of a mariculture plant utilizing the nutrient-rich discharged sea water and possibly a desalination plant and air conditioning facility. An OTEC/mariculture/desalination/air conditioning complex of this nature would be an efficient application particularly for small scale OTEC plants.

In summary, the island of Saipan, particularly Bahia Laulau, as a potential OTEC site looks very promising from a physical environmental point of view. The thermal resources available are close to shore making the concept of a coastal OTEC plant a very viable one. Caution, however, needs to be exercised in the actual site selection to position the plant in an area least exposed to adverse physical conditions such as faults, typhoon generated waves and proximity to shore.

POTENTIAL ENVIRONMENTAL IMPACTS RELATED TO OTEC DEVELOPMENT

Evaluation of potential environmental impacts associated with Pilot Plant deployment and operation is presently a matter of conjecture since little data has been collected near an operating OTEC plant. During the first deployment of Mini-OTEC at Keahole Point, Hawaii, the number and species of fish attracted to the platform were monitored (Nolan, 1980). Environmental monitoring for the OTEC preoperational platform (OTEC-1), also near Keahole Point, has also been completed (Menzies et al., 1980).

Several reports have preliminary data regarding potential environmental impacts associated with OTEC plants. The full range of environmental issues surrounding OTEC development, demonstration and commercialization was described in the DOE OTEC Environmental Development Plan (DOE, 1979a). An Environmental Assessment (EA) was prepared by DOE (1979b) for OTEC-1. The OTEC Programmatic Environmental Analysis considered the environmental effects of the development, demonstration and commercialization of several OTEC technological designs, plant configurations and power usages (Sands, 1980).

The OTEC Pilot Plant may potentially affect air quality, the terrestrial environment and the marine ecosystem in the vicinity of the deployment and operation site. Atmospheric effects or climatic alterations from carbon dioxide release and sea-surface temperature cooling are not anticipated to result from Pilot Plant operation. Construction of a Land-Based Pilot Plant may necessitate the total destruction of the existing terrestrial habitat. Grading for roads, utility corridors and the central utility terminus may result in a change of land use from natural to improved (developed) land.

The majority of environmental effects associated with Pilot Plant deployment and operation center on the marine ecosystem since it is the source of evaporating and condensing waters and receiver of effluent waters used by the plant. Marine environmental effects associated with the various Pilot Plant configurations being considered can be categorized as: (1) major (those causing significant environmental impacts), (2) minor (those causing insignificant environmental disturbances and (3) potential (those occuring only during accidents). Pilot Plant characteristics and their corresponding environmental effects include:

1. Major Effects of Deployment and Oper.	Source of Pollution
Attraction of fish, invertebrates and birds	Platform presence
Organism impingement and entrainment	Withdrawal of surface and deep-ocean waters
Effects on nontarget organisms	Discharge of biocides
Redistribution of ocean properties, particularly nutrients and planktonic organisms	Discharge of waters at or near the thermocline
Toxic effects on resident organisms	Protective hull coating release

2. Minor Effects of Deployment and Oper.	Source of Pollution
Effects from trace constituent release on resident organisms	Power cycle erosion and corrosion
Habitat destruction and turbidity during dredging	Implantation of cold-water pipe and transmission cable

3. Potential Effects from Accidents	Source of Pollution
Toxic effects of released working fluid on resident organisms	Potential working fluid release from spills or leaks
Toxic effects of oil on resident organisms	Potential oil releases

The Pilot Plant will serve as an artificial reef and provide a habitat for a large number of organisms. The increased population near the plant will compound environmental impacts by exposing greater numbers of organisms to the effects associated with routine plant operation, such as entrainment and impingement and risk of nonroutine events such as spills.

Preliminary (order-of-magnitude) estimates indicate that the most serious marine ecosystem effects caused by Pilot Plant operation are associated with the seawater intake and discharge. The Pilot Plant will withdraw and dischage approximately 100 times more water than a similarly sized fossil-fuel or nuclear power plant. The potential impacts associated with seawater withdrawal and discharge include entrainment of larval stages, impingement of ecologically and commercially important species, toxic substance release and ocean water redistribution.

1. Entrainment of ichthyoplankton (fish eggs and larvae) and meroplankton (benthic invertebrate eggs and larvae) may reduce adult populations downstream of the plant. Around islands the maintenance of a larval population near the spawning site is vital to adult population existence.

2. Impingement of organisms on the intake screens may reduce the population of ecologically or commercially important species in the vicinity of the plant. Data on platform attraction rates, species affected by impingement, impingement rates and mortality rates have been collected during operation of OTEC-1, a converted T-2 tanker that tested various OTEC plant components off Keahole Point, Hawaii in 1981.

3. Biocides (chlorine and its seawater-reaction products) and protective hull coatings released from the Pilot Plant may be toxic to resident organisms or taken up in the tissues of ecologically or commercially important species (Rowley, 1980). Descriptive studies on the seawater chemistry of chlorine, acute/chronic toxicity studies and food-chain investigations are required for evaluating the effects of these releases.

4. The release of working fluids and oil during a catastrophic accident could significantly impact the marine environment. The risk of accident occurrence should be assessed and a spill contingency plan prepared.

5. The discharge of nutrient-enriched deep waters within the surface layers of the water column may increase the primary productivity of the receiving waters. Data for evaluating nutrient redistribution effects on the ecosystem includes physical-model predictions, phytoplankton uptake rates and food-chain investigations. Results of physical models will provide estimates of the plume stabilization depth, downstream nutrient concentrations and area affected. Phytoplankton uptake rates and food-chain investigations are important for estimating the increase in biomass and its resulting effect on trophic level structures.

To assess the potential effects of Pilot Plant deployment and operation the ecological, physical and chemical characteristics of the site must be determined prior to plant deployment and an environmental monitoring plan (for evaluation of plant operational effects) prepared. After Pilot Plant deployment, environmental monitoring data must be obtained and used for determining the long-range environmental effects associated with the Pilot Plant operation. These data will be used in regulatory compliance reporting, but should also be compared with environmental predictions made prior to deployment in order to validate theoretical results.

RISK OF CREDIBLE ACCIDENTS RELATED TO OTEC DEVELOPMENT

Operations in the marine environment present several unique hazards or potential for accidents. Collisions, extreme weather conditions, military or political terrorism and human error may endanger the safety of the platform crew and the population served by the Pilot Plant. Pilot Plant crew members, population adjacent to the plant and communities served by the plant will be exposed to potential accidents and power failures.

Ship traffic around the Pilot Plant must be carefully monitored to minimize the potential for collisions. Large volumes of working fluid (ammonia) will be stored aboard the Pilot Plant and present certain health hazards should a collision or large leak occur. A spill contingency plan should be prepared after the Pilot Plant platform and deployment sites have been selected.

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GENERAL DISCUSSIONS

PHYSICAL RESOURCES

Physical resources in Bahia Laulau include the reef, beaches and isolated mineral deposits. Reefs and associated flora and fauna are one of the most valuable resources islands have to offer and this is exemplified by the available resources of Bahia Laulau. The most important resources on the reef are the edible fishes as well as numerous other edible flora and fauna. Food fishes are described in the fish section of this report. In addition, the coral community represents an important resource for without it most other forms would not congregate here. Beaches represent a significant physical resource both from an aesthetic point of view as well as the potential for sand mining. A reasonable sized deposit of Manganese is located on the Hagman Point side of the bay. Details of these mineral deposits are discussed the Geology section. One important resource not to be overlooked in Bahia Laulau is the temperature differential between deep cold water and warm surface water. This temperature differential is the basis for OTEC development and the premise upon which this study was undertaken.

BIOLOGICAL RESOURCES

Biological resources include fishing and harvesting of algae, coral and clams. Fishing represents the single largest biological resource for the people of Saipan. Harvesting coral, algae and other forms such as clams is a viable resource in Bahia Laulau. However, strict regulations and limits must be placed on these resources since they can be depleted rapidly leaving an irreparable condition. At the present time, harvesting of coral is illegal in the CNMI except by permit.

RECREATIONAL RESOURCES

Recreational uses of Bahia Laulau include all activities associated with the beach and ocean. These include boating, fishing, diving, sunbathing, picknicking or just appreciating the natural beauty of this idyllic bay. Observations during our field trip indicate that the bay is used by fishermen both from boats and on the reef including netting and spearfishing. Small boats can also be launched on the beach or over the reef near the small channel at Site 2, weather permitting. Numerous scuba divers were observed during our field trips. Sunbathing is an ideal recreational use for Bahia Laulau.

Snorkeling and Scuba Diving

Bahia Laulau is one of the favorite areas for recreational and tourist-related diving and it affords one of the only sites along the east coast of Saipan where divers and spearfishermen can make an easy beach entry. A well-protected cove (near Unai Bapot) with a narrow cut through the reef provides an entry and exit point for divers and small boats.

Dive shop owner and scuba instructor Ben Concepcion reports that all dive tours to Saipan (mostly from Japan and Guam) make at least one dive in Bahia Laulau. He estimates a total of 75-100 tourist divers visit this site each month. In addition to this number, local residents frequent the Bay for spearfishing, lobstering and other recreational uses.

Fishing and Boating

Observations by team members during this study, information from the local Fish and Wildlife Division and interviews with Mr. Ben Concepcion and other local fishermen all indicate that Bahia Laulau is important and frequently used for subsistence and light commercial fishing. The reef flat is extensively utilized for talaya (throw-net) fishing, gill nets, pole casting from the reef edge, octopus hunting and lobstering and crabing at night.

A limited number of fishermen bottom fish and troll in the Bahia Laulau area. According to local fishermen, more fishing would occur if a better boat launching site and channel were available in the Bay. At the present time, only small boats can be launched via the cut in the reef. The trip around the southern tip of the island and Naftan Point up to Bahia Laulau is long and usually rough and it is costly in terms of time and fuel. Both boaters and divers expressed a desire to have the present channel (cut) widened and deepened which would result in increased use of the Bay for fishing and recreation.

RESOURCE DEGRADATION

Some damage to the coral community throughout Bahia Laulau is presently underway as a result of an influx of Acanthaster planci (crown-of-thorns starfish). Numerous individuals (more than 100 large individuals) were observed at each site with the majority inhabiting the lush coral community at Sites 2 and 3. Individuals collected during our survey measured nearly 50 cm (20 in) representing some of the largest specimens observed anywhere, particularly in these waters. Damage to the coral reef is evident which suggests the condition has been progressing for sometime now.

An Acanthaster outbreak for Saipan was predicted for the summer of 1981 on the basis of heavy rains in August 1978 (Birkeland, 1982). This outbreak was observed in August 1981 by Joaquin Villagomez, then chief of the Division of Marine Resources, Saipan. The starfish were first observed in southern Saipan and they were described as "a moving front comprised of several thousand individuals." It is likely that the Acanthaster which now inhabit the reefs of Bahia Laulau are from this 1981 infestation as the large size reported (up to 50 cm) would be expected in a $4\frac{1}{2}$ year-old population (settled out of the plankton to form juveniles in August 1978).

Minor degradation to the coral community offshore and on the reef flat has also resulted from sediment runoff particularly in the vicinity of Site 2. Storm water drainage carrying large quantities of silt pours into the bay near Site 2 through a small drainage fitted with what appears to be a box culvert constructed sometime during the Japanese occupation. Water quality analysis indicates a higher degree of turbidity from suspended solids pouring into the bay at this point. In addition, total and fecal coliform counts are higher here than in other areas of the bay.

The increased use of Bahia Laulau and intensive subsistence fishing and trampling of corals on reef flats has contributed to the gradual decline of food fishes in the area. Local fishermen note that fish populations on the reef flats or close to the shore have gradually declined in the last ten years or so as a result of increased fishing in the area.

UNIQUE AREAS AND FEATURES

Bahia Laulau is a unique bay in itself both from the resource and aesthetic point of view. Specific unique areas include Forbidden Island and Hagman Point, the reef flat and beaches between Sites 1 and 2, natural cut in reef at Site 2 where boats can enter and exit the bay and the protected cove at Site 1a. These areas are unique because of their natural beauty and aesthetic value as well as their value as a resource for enjoyment or livelihood.

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CONCLUSIONS

GENERAL

- Bahia Laulau has highly diverse terrestrial and marine ecological communities.

- Bahia Laulau is important for subsistence fishing and various recreation uses for local residents and tourists alike.

- Ancient Chamorros and military personnel (both Japanese and American) have utilized the bay which is rich in resources.

- Bahia Laulau is known as a mating ground and the isolated beach areas are utilized as nesting sites for sea turtles.

- Water quality within the bay is generally excellent with some localized degradation following heavy rains.

RESOURCES

- The entire bay is rich in resources which may play an important role in the future development of Saipan and the Northern Mariana Islands. These resources include the following:

  - Manganese
  - Limestone
  - Beach sand
  - Tropical forest lumber (Breadfruit, Ifil, Kamachile)
  - Cold deep water and warm shallow water close to shore

-The tagpochou formation cropping out immediately north of Beach Road at Unai Bapot appears to possess the requisite density required for construction aggregate.

OTEC

- Adequate near-shore cold water exists at appropriate depths for the proposed OTEC facility at the Hagman Point site.

- Providing that effluent is not discharged in the vicinity of the near-shore reef area, impact to the marine environment due to effluent discharge would be minimal since currents at the discharge point move out to sea.
- The site is poor from an engineering point of view because of instability due to faults in the area and heavy surf and constant wind activity from the prevailing east-northeast direction.

- Accessibility to the proposed OTEC site is non-existent and would pose severe problems during the development of infrastructure because of its general isolation.

- Highly fractured bedrock, steeply dipping soft and weathered volcanic strata, extremely steep slopes, high relief, sparse vegetation and low-level shock waves from earthquakes and storm swells contribute to lessen safety factors at Site 1. Many slopes at Puntan Hagman are barely stable from the construction point of view.

- Tropical storms and typhoons would probably attack the base of Site 1 directly promoting active coastline retreat and generating sufficient submarine instability to initiate submarine slides directly off the site.

- Engineering and construction costs to build an OTEC facility would be extremely high because of its isolated nature and the general geologic constraints of the site.

- General working conditions for offshore pipe placement would be extremely poor and limited to only a few weeks a year due to rough water conditions.

RECOMMENDATIONS

General

- Control development within Bahia Laulau to preserve its natural beauty and water quality.

- Properly manage and conserve all resources in Bahia Laulau for their ultimate future protection.

- Subsistence, recreational and small scale commercial fishing should be supported and expanded for under-utilized species.

- Access for boating through the existing natural cut at Bapot Beach should be improved.

- Continue water quality monitoring within the Bahia Laulau area.

Resources

- Further studies to determine the quantity and quality of manganese deposits at Hagman Point should be undertaken.

- Limestone deposits throughout the bay should be studied to determine the nature and extent of future quarry sites.

OTEC

Providing the OTEC facility is approved, the following are needed:

- Detailed engineering studies to determine the suitability of the OTEC site at Hagman Point.

- Specific detailed current studies at the OTEC site to determine the zone of mixing. This would include shallow to deep underwater current studies over a one year period.

- Additional bottom profiles at the OTEC site to determine precise bottom profile for pipe placement.

- Heavy construction planned for sites on Marianas and Tanapag formations should be preceeded by thorough subsurface investigations including geophysical surveying and borings.

APPENDICES

Appendix A

Tables 1, 2, 4-17

Table 1. Rock units mapped in the vicinity of Bahia Laulau, Saipan.

Name[1]	Map Symbols[1]	General Lithologic Descriptions[1]	Engineering Designation[2]	General Engineering or Construction Considerations[2]	Laulau Sites Where Unit Occurs
Beach Deposits	Qrb	Intertidal and low supertidal sand and gravels including recently cemented beachrock. Predominantly calcareous, bioclastic, and poorly sorted. East coast Qrb may contain significant volcanics.	Beach sand	Easily excavated waterworn poorly graded shell and coral fragments. Bearing capacity good if dry. Satisfactory construction material.	1 and 4: scarce 2 and 3: abundant
Emerged Limesands	Orl	Poorly sorted calcareous sands and gravels occurring as supratidal storm deposits; may be mixed with alluvium washed off local slopes.	Beach sand	Same as above	Same as above
Alluvium	Qa	Presently accumulating gravelly alluvium transported off hilly terrain by deeply incised ephemeral streams. Includes significant clay lenses and occasional debris flows.	Alluvium	Easily excavated; very poor grading. Non clay material too weathered for aggregate. Crumbly.	2 and 3
Colluvium	Ql, Qor Qx	Deposits formed by mass wasting. Slide blocks, slump blocks, landslides, soil creep and talus.	Colluvium	Some rockslides may have appreciable aggregate-quality material.	3 and 4: scarce 2: common 1: abundant
Tanapag	Qta	Coralgal reef limestone and detrital limestone. Partially recrystallized, highly fossiliferous, tan to white, porous. Outcrops discontinuous. Forms lowest 2-10 m, benches where it rests on eroded Mariana or Tagpochau abrasion terraces.	Firm Porous Limestone	Pinnacled, cavernous surface on very cavernous subsurface. May be compact or friable. Excavations require drilling and blasting. Adequate only for construction.	1: one small previously unmapped outcrop. 2, 3 and 4: common
Terrace Deposits	Qp	Well-stratified reddish argillaceous sandstone composed of reworked volvolcanic pebbles.	Partially Weathered Andesite	Friable and easily excavated. Very limited outcrops. Generally unsatisfactory engineering material.	1: scarce

Table 1. Continued.

Mariana	Qmh, Qmm Qmr	Coarse to fine-grained massive (Qmm), rubbly (Qmr), sometimes Halimeda-rich (Qmh) lagoonal white to tan limestone with occasional reefal units. Major terrace former throughout CNMI. 100-150 m thick.	Firm Porous Limestone	Compact to friable, often cavernous. Faults and joints prevalent. Good to excellent construction material if compact	1, 3, and 4: abundant
Tagpochau	Tti, Ttt Ttd, Ttm	White to pink, often variagated, generally compact, lagoonal and off-reef limestone; significant deepwater sandy units (the Donni member (Ttd)). Inequigranular (Tti), marly (Ttm), and transition members (Ttt). May be argillaceous and tuffaceous. Thickness about 200 m.	Very Compact Limestone (Tti, Ttt)	Limestones are very firm and compact; Excellent construction aggregate and decorative stone.	1, 2, and 3: common
unconformity	Ttr		Clayey Volcanic Sediments (Ttd)	Very bad qualities: Expandable clays; no bearing strenght; unstable. Slopes	1 and 2 common 3: scarce
Densinyama	Tdcq	Interbedded well-stratified tuffaceous quartzose sandstones and conglomer ates. Hematic, reddish-brown cherty matrix. Grains mostly volcanics, quartz and chert. Sulfides. Thickness about 30 m.	Weathered Andesitic Sandstone and Conglomerate	Vuggy; porous to compact, friable. Pebblesweathered. Quartzose material hard and abrasive. Generally unsatisfactory construction material.	1: scarce
Hagman	Thc, Thb	Volcanoclastics: Volcanic-derived tuffaceous sandstones, lapilli-tuff, medium tuff, breccia, conglomerate, andesite glass and rock fragments. Pebbles and boulders are porphyritic. Dark gray, pink, olive: thickness about 300 m.	Partly Weathered Andesitic Sandstone and Conglomerate	Loose, fresh to partly weathered volcanic detritus and altered tuffaceous matrix. Easily excavated boulders and cobbles make excellent aggretage. Expandable clays make some slopes unstable.	1 and 2: common

Footnotes

[1]Geologic mapping, names, symbols, and formation thickness after Cloud, et. al., 1956.

[2]Engineering designation and qualities after Nicol, 1956.

Table 2. Soil units mapped in vicinity of Bahia Laulau, Saipan.[1]

NAME[1]	General Description[1]	Construction Considerations[2]	Laulau Sites Where Unit Occurs
Saipan - Chacha Association	Mostly deep clays; neutral, firm yellowish brown, on gently sloping hilly terrain over limestone.	Unsuited for heavy construction. Slow drainage. High shrinkage sticky clays with limestone boulders. Good subgrade fill.	1, 2, and 3: sporadic 4: above quarry
Dandan Soils	Mostly clay loam; moderately deep, neutral to alkaline, friable, brown; on gently sloping terrain over limestone.	Fair for light structures, Unsuited for heavy construction. Good subgrade, excellent topsoil.	1
Lito-Akina-Dago Association	Deep clays; acid, firm, reddish, on gently sloping to hilly terrain over volcanic rocks.	Poor for heavy structures. High shrinkage; Sticky: Poor drainage.	1 and 2: sporadic
Chinen Soils	Mostly clay loam; shallow, alkaline, stony, on gently sloping to steep terrain over limestones.	Fair for light structures, Slow drainage, high shrinkage, fair topsoil.	1, 2, 3, 4
Shioya Soils	Mostly loamy sand; deep, calcareous, light colored, on nearly level coastal flats.	Good for light structures. Very rapid drainage. Good compaction, good subgrade and fill. Poor topsoil.	2 and 3
Rough Stonyland on Limestone	Very shallow stony solid; mostly on hilly and steep terrain, numerous limestone outcrops.	Too shallow to rate. Bedrock excellent for structures (if sited properly).	1, 2, 3, 4
Rough Broken Land	Clays; shallow and very shallow, acid, reddish, highly weathered volcanic rocks, many gullies.	Fair for light structures, high shrinkage. Slow drainage.	1,2
Quarries	No soil cover; limestone quarries	Not applicable.	1.4

Footnote:
[1] Soil mapping, names, and descriptions taken from McCracken and Zarza (1954)
[2] Engineering soil data from McCracken (1955)

Table 4. Site comparison summary.

Geologic Evaluation Criteria	SITE 1 Sabanan Kagman	SITE 2 Unai Bapot	SITE 3 Unai Laulau	SITE 4 Unai Dandan	Most Favorable Site Based Upon Criterion
Rock Units (composition and structure)	Volcanics and limestones. Many joints and faults. Very complex.	Volcanics and limestones. Normal stratigraphic sequence. No faulting. Abundant jointing.	Limestones. Normal stratigraphic sequence. Minor faulting.	Limestones: Terraced and pinnacled Tanapag and Mariana. Joints	2 or 3
Soil Units	Mostly shallow and rocky.	Sticky clays upslope. Shallow and rocky downslope. Limesands.	Shallow and rocky. Some deep pockets of clay.	No soil. Essentially bedrock.	4
Slope Stability	Extremely unstable slopes. Rapidly changing slopes and coastline.	Fair. Volcanics upslope show slumping and creep.	Good	Excellent	4
Danger of Flooding	Low	High. Vulnerable to typhoon-related swells and flash flooding.	Moderate. Somewhat vulnerable to flash flooding and waves.	None	4
Alluvial Processes	Active gullying and soil removal from steep terrain.	Active transport of boulders, sand and clay down ephemeral streams.	Minor alluvial transport.	None	4
Subsurface	Very porous limestones from faulting and solution.	Very porous limestones on low porosity volcanics.	Very porous limestones.	Very porous limestones.	None
Coastal Configuration	Faces south cliff; and headlands vulnerable to typhoons.	Faces south; beach and road vulnerable to typhoons.	Faces southeast; beach vulnerable to typhoons cliffline receding	Faces northeast; Vulnerable to constant tradewind energy.	4
Economic Resources	Manganese; Scenic	Recreational	Recreational	Aggregate; Scenic	4

Table 5. Temperature and Salinity at the Listed Depths with Corresponding Calculated Density (November 4, 1982). m = meters, °C = degrees centigrade, ppt = parts per thousand, g/cm³ = grams per cubic centimeter. Temperature, salinity and density values were extrapolated where noted by an asterisk.

Depth (m)	Temperature (°C)	Salinity (ppt)	Density (g/cm³)
Surface	28.4	34.4	1.022
229	22.5	35.1	1.025
305	12.3	34.5	1.027
381	9.3	34.4	1.028
457	7.4	34.5	1.028
525*	6.4	34.3	1.026
550*	4.4	34.1	1.022

Table 6. Checklist of plants by site. A = Abundant, C = Common, S = Seldom, R = Rare. Plant Type, (T) Tree, (S) Shrub, (B) Bush, (F) Fern, (V) Vine, (W) Weed, (G) Grass. Dates: 11/82, 2/83, 5/83, 9/83

SCIENTIFIC NAME	Common Name	Chamorro Name	Plant Type	Site 1	Site 2	Site 3	Site 4	Beach Strand
Leucaena leucocephala	Tangan-tangan		(T)	C	S	S	S	S
Leucaena insularum var. guamense	Tangan-tangan		(T)	C	R	R	C	R
Casuarina equisetifolia	Ironwood	Gago	(T)	S	S	S		C
Miscanthus floridulus	Sword-grass	Neti	(G)	A				
Scaevola taccada		Nanaso	(S)		C	C		C
Bidens pilosa	Beggar's-Tick		(W)	C	C	C	C	C
Stachytarpheta indica	False Verbena		(W)	C	C	C	C	
Hibiscus tiliaceus	Hibiscus	Pago	(B)		C	C		C
Ipomoea pes-caprae	Beach Morning-Glory	Alalag-Tasi	(V)					C
Pluchea indica			(S)		C	C		C
Wedelia biflora	Beach Sunflower		(V)		C			C
Hernandia nymphaeifolia		Nonak	(T)		C	C		C
Cassytha filiformis		Mayagas	(T)	C				C
Barringtonia asiatica	Fish-kill-tree	Puting	(T)		R	R		R
Desmodium unbellatum		Palaga Hilitai	(S)					C
Mucuna gigantea	Small Seabean	Gayi Dikike	(V)					R
Sophora tomentosa			(S)	R			R	R
Vigna marina		Akangkang Manulasa	(V)					C
Pemphis acidula		Nigas	(S)		A	A		C
Thespesia populnea		Banalo	(T)					R
Cocos nucifera	Coconut	Niyog	(T)		S	S		R
Colubrina asiatica		Gasoso	(S)	C			C	C
Bikkia mariannensis		Gausali	(S)	C			C	C
Allophylus timorensis		Nger	(S)					C
Calliparpa candicans		Masiksik						C
Clerodendrum inerme		Lodugao	(V)	C			C	C
Guamia mariannae		Pai-pai	(T)		C	R		R
Ochrosia mariannensis		Langiti	(T)		C	C		
O. oppositifolia		Fago	(T)		C	C		
Asplenium nidus	Birds-nest-Fern	Galak Feda	(T)		R	R		
Cycas circinalis	Cycad	Fadang	(T)		R	R		
Davallia solida		Pugua Machena	(F)		C	C		

Table 6. Continued

SCIENTIFIC NAME	Common Name	Chamorro Name	Plant Type	Site 1	Site 2	Site 3	Site 4	Beach Strand
Macaranga thompsonii		Pengua	(T)		C	C		
Melanolepis multiglandulosa		Alom	(T)		C	C	R	
Phyllantus marianus		Gaogao-Uchan	(S)	R	R			
Flagellaria indica	False Rattan	Bejuco-halomtano	(G)		C	C		R
Mammea odorata		Chopak	(T)		C	C		
Abrus precatorius	Coral Bean	Kolales	(V)		R	R		R
Caesalpinia major	Wait-a-Bit	Pakao	(V)		C	C		
Cynometra ramiflora		Gulos	(T)		R	R		
Intsia bijuga		Ifet	(T)		R	R		
Artocarpus sp.	Breadfruit	Lemai	(T)		C	C		
Ficus prolixa	Banyan	Nana	(T)		R	R		
Pisonia grandis		Umumu	(T)	R	R	R		
Pandanus dubius	Pandanus	Pahong	(T)	R	R	R		
P. fragrans	Pandanus	Kafu	(T)	R	C	C		
Piper guahamense	Wild Piper	Pupulu-n-Aniti	(S)		C	C		
Microsorum punctatum	Strapleaf Fern	Galak Dalalai	(F)		C	C		
Phymatodes scolopendria		Kahlao	(F)		R	C		
Guettarda speciosa		Panao	(T)		C			R
Morinda citrifolia	Indian Mulberry	Lada	(B)		C	C		R
Psychotria mariana		Aplokatina	(T)		C	C		
Randia cochinchinensis		Sumac	(T)		C	C		
Cestrum diurnum	China Inkberry	Tintan-china	(B)	R	C	C	R	R
Dicranopteris linearis	Savannah Fern	Mana	(F)	R			R	
Dimeria chloridiformis	Grass		(G)	C				
Pennisetum polystachyon	Foxtail		(G)	R	R	R		
Myrtella bennigseniana			(S)	C				
Messerschmidia argentia		Hunig	(T)		C	C		
Annona reticulata	Custard-Apple		(T)		C	C		
Uvaria odorata		Ilang-Ilang	(T)		C	C		
Aglaia mariannensis		Mapuano	(T)		C	C		
Areca cathecu	Betel-Nut Palm	Pugua	(T)		C	C		
Annona muricata	Soursop	Laguanaha	(T)	R	C	C	R	R
Carica papaya	Papaya	Papaya	(T)		C	C	R	
Musa sp.	Banana	Chotda	(T)		C	C		

Table 7. Checklist of terrestrial vertebrate fauna in the vicinity of Bahia Laulau, Saipan. For occurance, A = abundant, C= common, O = occasional, R = Rare, E = expected to occur but not observed. Dates: 11/82, 2/83 and 9/83.

Common Name	Species	Chamorro Name	Site 1	Site 2	Site 3	Site 4
AVIFAUNA						
Bittern, Yellow (Chinese)	Ixobrychus sinensis	Kakkag	C	C	C	O
Booby, Brown	Sula leucogaster	Luao Attilong	O	-	-	-
Booby, Red-footed	Sula sula	Luao Talisai	E	-	-	-
Curlew, Bristle-thighed	Numenius tahitiensis	Kalalang	E	R	R	-
Dotteral, Mongolian	Charadrius mongolus	Dulili	E	R	O	-
Dove, Fruit	Ptilinopus roseicapilla	Totot	O	O	E	R
Dove, Ground	Gallicolumba xanthonura	Paluman Apaka/Fachi	R	O	E	E
Dove, Philippine-turtle	Streptopelia bitorquata	Paluman Senesa/Apu	C	A	C	O
Egret, Cattle	Bubulcus ibis	Chuchuko	E	-	-	-
Egret, Plumed	Egretta intermedia	Chuchuko	E	-	E	-
Egret, Reef (Heron)	Egretta sacra	Chuchuko Attilong	E	O	C	E
Fantail, Rufous-fronted	Rhipidura rufifrons	Chichirika, Naabak	A	A	A	C
Honeyeater, Cardinal	Myzomela cardinalis	Egigi	O	C	O	O
Honeyeater, Golden	Cleptornis marchei	Kanario	O	O	E	O
Kingfisher, Collared	Halcyon chloris	Shihig	E	C	C	E
Mannikan, Chestnut	Lonchura malacca		C	O	E	O
Plover, Golden	Pluvialis dominica	Dulili	O	C	C	O
Plover, Grey	Pluvialis squatarola	Dulili	-	E	R	-
Reed-warbler, Nightingale	Acrocephalus luscinia	Kaga Karisu	E	R	O	E
Sandpiper, Common	Actitis hypoleucos	Dulili	-	R	R	-
Sandpiper, Sharp-tailed	Calidris acuminata	Dulili	-	E	R	-
Sparrow, Eurasian Tree	Passer montanus	Gaga Pale'	C	A	C	O
Starling, Micronesian	Aplonis opaca	Sali	C	O	O	O
Swiftlet, Vanikoro	Collocalia vanikorensis	Yayaguag, Chuchaguak	E	-	-	-
Tattler, Grey-tailed	Heteroscelus brevipes		-	E	R	-
Tattler, Wanderling	Heteroscelus incanus		-	E	O	E
Tern, Common	Sterna hirundo		O	E	E	E
Tern, Brown Noddy	Anous stolidus	Fahang	A	E	E	O
Tern, White	Gygis alba	Chunge	C	C	C	O
Tropicbird, Red-tailed	Phaethon rubricauda	Utag, Fagpi Agaga	E	-	-	-
Tropicbird, White-tailed	Phaethon lepturus	Utag, Fagpi Apaka	O	-	-	-
Turnstone, Ruddy	Arenaria interpres	Dulili	E	R	O	E
Whimbrel	Numenius phaeopus	Kalalang	-	E	R	-
White-eye, Bridled	Zosterops conspicillata	Nossak, Nosa	O	C	C	C
	Total Species Observed		17	20	21	13
	Total Species Observed/Expected		28	27	28	20
	Total Species Observed (All Sites)		29			
	Total Species Observed/Expected (All Sites)		34			

Table 7. Continued.

Common Name	Species	Chamorro Name	Site 1	Site 2	Site 3	Site 4
REPTILES AND AMPHIBIANS						
Anole	Anolis carolinensis		E	O	O	E
Lizard, Monitor	Varanus indicus		E	O	O	E
Skink, Blue-tailed	Emoia cyanura		O	C	C	O
Skink, Brown	Emoia sp		O	C	C	C
Skink, Green-tailed	Lamprolepis smaragdina		E	E	E	E
Snake, Blind	Typhlops braminus		E	E	E	E
Toad, Marine	Bufo marinus		O	C	C	O
MAMMALS						
Bat, Marianas Fruit	Pteropus mariannus	Fanihi	E	E	-	-
Cat, Feral	Felis catus		E	E	E	E
Deer, Sambar	Cervus unicolor mariannus	Benado	E	E	E	-
Dog, Feral	Canis familiaris		O	O	E	-
Mouse, House	Mus musculus	Chaca	E	O	E	-
Rat, Norway	Rattus norvegicus	Chaca	E	E	E	E
Rat, Polynesian	Rattus exulans	Chaca	E	E	E	E
Rat, Roof	Rattus rattus	Chaca	E	E	E	E
Shrew, Musk	Suncus murinus		E	O	E	E

Table 8. Checklist of benthic algae and seagrasses at five sites in Bahia Laulau, Saipan, November 1982. IRF - inner reef flat, ORF = outer reef flat, RM/RF - reef margin and reef face, ST = submarine terrace.

SITES	1	1a		2			3		4
SPECIES	ST	3-6m ST	IRF	ORF	RM/RF	ST	RF	10-5m ST	20-10m ST
CYANOPHYTA (Blue-green algae)									
Anacystis sp.			x						
Calothrix sp.						x		x	
Microcoleus lyngbyaceus			x			x		x	x
Schizothrix calcicola	x	x	x	x		x	x	x	x
S. mexicana	x	x	x	x		x	x	x	
CHLOROPHYTA (Green algae)									
Enteromorpha clathrata			x	x			x		
Chaetomorpha crassa		x		x	x				
Microdictyon okamurai		x		x	x	x		x	x
Bryopsis pennata		x		x	x	x		x	
B. hypnoides						x		x	x
Caulerpa cupressoides				x		x	x	x	
C. filicoides								x	
C. racemosa		x		x		x	x	x	x
C. serrulata				x		x		x	x
C. sertularioides		x		x		x		x	x
C. urvilliana				x		x		x	
C. verticillata								x	
Chlorodesmis fastigiata		x		x	x	x	x	x	x
Halimeda discoidea		x			x	x			
H. opuntia		x	x		x	x	x	x	x
H. valasquezii						x		x	x
Rhipilia orientalis									x
Tydemannia expeditionis						x			
Udotea argentea	x	x				x		x	x
U. geppi						x		x	x
Boergesenia forbesii		x			x				
Boodlea composita		x		x	x	x	x	x	
Cladophoropsis membranacea			x	x	x			x	
C. sundanensis				x			x		
Dictyosphaeria verluysii		x			x	x		x	
Acetabularia moebii						x	x	x	x
Neomeris annulata		x	x			x	x		
N. vanbosseae	x					x		x	x

Table 8. Continued

SITES	1	1a	2			3			4
SPECIES	ST	3-6m ST	IRF	ORF	RM/RF	ST	RF	10-5m ST	20-10m ST
PHAEOPHYTA (Brown algae)									
Dictyota bartayresii		x				x	x	x	
D. friabilis						x		x	
Lobophora variegata		x			x	x		x	
Padina minor			x	x			x		
P. tenuis								x	
Sargassum cristaefolium			x	x			x		
S. polycystum			x				x		
Turbinaria ornata				x	x	x	x	x	
RHODOPHYTA (Red algae)									
Actinotrichia fragilis	x	x				x		x	x
Galaxaura filamentosa	x				x	x	x	x	
G. marginata	x	x			x	x		x	x
G. oblongata	x	x			x	x	x	x	x
Gelidiella acerosa			x	x		x	x		
Gelidium crinale	x				x	x	x	x	
G. pusillum	x			x	x	x			
Liagora sp.		x				x			x
Pterocladia parva x	x				x			x	
Amphiroa fragilissima	x	x		x	x	x	x	x	x
A. foliacea		x		x	x	x			x
Jania capillacea			x			x			
J. decussato-dichotoma		x							
Mastophora rosea	x	x		x	x	x		x	x
Porolithon onkoides	x	x	x	x	x	x	x	x	
Sporolithon sp.				x	x	x	x	x	
Champia parvala		x				x			x
Rhodymenia sp.	x	x			x	x		x	x
Acanthophora spicifera		x	x				x		
Caloglossa sp.		x				x			
Centroceras clavulatum						x		x	x
Ceramium gracillimum		x				x		x	
Laurencia sp.		x				x		x	
Leveillea jungermannioides		x			x	x		x	x
Polysiphonia sp.		x			x	x		x	
Spyridia filamentosa				x	x				
Tolypiocladia glomerulata		x						x	x
ANTHOPHYTA (Seagrasses)									
Enhalus acoroides			x						
TAXA RECORDED	15	37	15	26	26	50	25	45	28
GRAND TOTAL - 69									

Table 9. Total number of planktonic organisms per sample. NOVEMBER 1982.

Date: 11-82 Taxa	Location Sampling Number	Surface P-1	Surface P-2	Oblique P-3	Oblique P-4
Chrysophyta					
Bacillariophyceae (Diatoms)					
Centrales					
Coscinodiscus sp. A		2	2	0	0
Protozoa					
Foraminifera					
Orbulina universa		30	3	0	6
Radiolaria					
Species A		8	4	13	11
Cnidaria					
Siphonophora		32	1	6	1
Medusae		1	1	0	0
Annelida					
Polycheate larvae		2	3	0	0
Arthropoda/Crustacea					
Cladocera					
Evadne sp. A					
Ostracoda					
Euconchoecia sp. A		0	0	0	2
Cypridina sp.		14	3	2	9
Copepoda					
Unidentified species		146	19	40	40
Calanoid sp. A					
Calanoid sp. B					
Euchaeta sp.					
Candacia sp.					
Acartia sp.					
Eucalanus sp.					
Centropagus					
Oncea sp.					
Copilia sp.					
Coryceaus sp.					
Sapphirina sp.					
Unidentified Cylcopoidid		2	0	3	2
Malacostraca					
Mysidacea sp. A		400	300	44	73
Mysidacea sp. B		224	188	6	20
Cumacea sp. A		1	0	0	1
Isopoda sp. A		2	2	0	2
Amphipoda sp. A		10	12	0	0
Decapoda/Shrimp mysis sp.		66	12	11	16
Decapoda/Crab zoeae sp.		4	0	0	1
Decapoda/Crab megalops sp.		10	6	2	4

Table 9. Continued.

Date: 11-82 Taxa	Location Sampling Number	Surface P-1	Surface P-2	Oblique P-3	Oblique P-4
Mollusca					
Gastropoda					
Gastropod veliger larvae		2	3	1	0
Pteropoda					
Cresius acicula					
Unidentified sp. A		1	0	0	0
Unidentified veliger capsules		16	200	55	17
Cephalapoda (squid)					
Chaetognatha					
Sagitta sp. A		4	0	4	15
Heteropoda					
Chordata					
Urochordata					
Thaliacea (Salpa)					
Salpa sp. A		8	0	0	0
Vertebrata					
Osteichthyes					
Fish larvae		42	15	11	8
Fish eggs "round"		20	12	4	5
Fish eggs "oval"					
Miscellaneous		1	0	0	0
#Individuals/cubic meter		10.11	7.58	1.95	2.25
Total Species		25	18	14	18
Total No.		1048	786	202	233

Table 9a. Total number of planktonic organisms per sample. FEBRUARY 1983.

Date: 2-83 Taxa	Location Sampling Number	Surface P-5	Oblique P-6	Surface P-7	Oblique P-8	Surface P-9	Oblique P-10	Surface P-11	Oblique P-12
Chrysophyta									
Bacillariophyceae (Diatoms)									
Centrales									
Coscinodiscus sp. A								5	
Protozoa									
Foraminifera									
Orbulina universa									
Radiolaria									
Species A		100	100	1000	650	1000	2400	3000	200
Cnidaria									
Siphonophora				3	3			2	1
Medusae									
Annelida									
Polycheate larvae									
Arthropoda/Crustacea									
Cladocera									
Evadne sp. A							2		1
Ostracoda									
Euconchoecia sp. A									
Cypridina sp.									
Copepoda									
Unidentified species									
Calanoid sp. A				8	9				
Calanoid sp. B				1	2				
Euchaeta sp.				6	2				
Candacia sp.				1	2				
Acartia sp.		1	1	2	2				
Eucalanus sp.				1	1				
Centropagus								3	1
Oncea sp.				15	4				
Copilia sp.				2	3				
Coryceaus sp.		8	0	5	6				1
Sapphirina sp.		1		7				2	
Unidentified Cylcopoidid									

Table 9a. Continued.

Date: 2-83 Taxa	Location Sampling Number	Surface P-5	Oblique P-6	Surface P-7	Oblique P-8	Surface P-9	Oblique P-10	Surface P-11	Oblique P-12
Malacostraca									
Mysidacea sp. A				8	6				1
Mysidacea sp. B									
Cumacea sp. A									
Isopoda sp. A									
Amphipoda sp. A				1					1
Decapoda/Shrimp mysis sp.		1		6	8		4		1
Decapoda/Crab zoeae sp.				4	4	2	2		18
Decapoda/Crab megalops sp.									
Mollusca									
Gastropoda									
Gastropod veliger larvae		1		7	13	21	30	3	
Pteropoda									
Cresius acicula									
Unidentified sp. A				2	1				
Unidentified veliger capsules				75	70				
Cephalapoda (squid)				1	1		1		
Chaetognatha									
Sagitta sp. A				13	16				
Heteropoda				1	1				
Chordata									
Urochordata									
Thaliacea (Salpa)									
Salpa sp. A									
Vertebrata									
Osteichthyes									
Fish larvae					3				1
Fish eggs "round"				43	22			6	
Fish eggs "oval"				115	85		5	1	1
#Individuals/cubic meter		1.08	0.97	12.80	8.81	9.86	23.57	29.14	2.91
Total Species		6	3	24	23	3	7	8	11
Total No.		112	101	1327	914	1023	2444	3022	227

Table 9b. Total number of planktonic organisms per sample. MAY 1983

Date: 5-83 Taxa	Location Sampling Number	Surface P-13	Oblique P-14	Surface P-15	Oblique P-16	Surface P-17	Oblique P-18	Surface P-19	Oblique P-20
Chrysophyta									
Bacillariophyceae (Diatoms)									
Centrales									
Coscinodiscus sp. A									
Protozoa									
Foraminifera									
Orbulina universa		45	84		16			16	
Radiolaria									
Species A				70					
Cnidaria									
Siphonophora			48			20	34	4	
Medusae									
Annelida									
Polycheate larvae					2				
Arthropoda/Crustacea									
Cladocera									
Evadne sp. A			60		20	6		400	375
Ostracoda									
Euconchoecia sp. A									
Cypridina sp.				4		8			
Copepoda									
Unidentified species									
Calanoid sp. A		66	400	2	36	24	30	160	24
Calanoid sp. B		20			100			8	
Euchaeta sp.			40						
Candacia sp.									
Acartia sp.				2					
Eucalanus sp.									
Centropagus									
Oncea sp.					2			4	4
Copilia sp.		1			4				
Coryceaus sp.			4			2	2	4	4
Sapphirina sp.		2	6	2				16	40
Unidentified Cyclopoid									

Table 9b. Continued.

Date: 5-83 Taxa	Location Sampling Number	Surface P-13	Oblique P-14	Surface P-15	Oblique P-16	Surface P-17	Oblique P-18	Surface P-19	Oblique P-20
Malacostraca									
Mysidacea sp. A			4				30		
Mysidacea sp. B									
Cumacea sp. A									
Isopoda sp. A									
Amphipoda sp. A		2			4			4	8
Decapoda/Shrimp mysis sp.		4	20	16	24	16	35	24	
Decapoda/Crab zoeae sp.		10	48	115	132	200	200	200	140
Decapoda/Crab megalops sp.									
Mollusca									
Gastropoda									
Gastropod veliger larvae		8	20		21	21	8		30
Pteropoda									
Cresius acicula									
Unidentified sp. A		1	2				2	8	
Unidentified veliger capsules									
Cephalapoda (squid)								5	1
Chaetognatha									
Sagitta sp. A		12	52	6		30	30	20	
Heteropoda									
Miscellanious Invertebrate Eggs		100	150	1000	350	400	400	800	1600
Chordata									
Urochordata									
Thaliacea (Salpa)									
Salpa sp. A									
Vertebrata									
Osteichthyes									
Fish larvae				4		6	2	4	
Fish eggs "round"		12	24	8		5	15		
Fish eggs "oval"									
#Individuals/cubic meter		2.73	9.28	11.85	6.86	7.12	7.60	16.17	21.47
Total Species		13	15	11	12	12	12	15	10
Total Number		283	962	1229	711	738	788	1677	2226

Table 9c. Total number of planktonic organisms per sample. SEPTEMBER 1983.

Date: 9-83 Taxa	Location Sampling Number	Surface P-21	Oblique P-22	Surface P-23	Oblique P-24	Surface P-25	Oblique P-26	Surface P-27	Oblique P-28
Chrysophyta									
Bacillariophyceae (Diatoms)									
Centrales									
Coscinodiscus sp. A									
Protozoa									
Foraminifera									
Orbulina universa									
Radiolaria									
Species A									
Cnidaria									
Siphonophora		53	32	90	90	29	60	1	6
Medusae							2		
Annelida									
Polycheate larvae							4		
Arthropoda/Crustacea									
Cladocera									
Evadne sp. A		2		50	26	18	12	6	
Ostracoda									
Euconchoecia sp. A						1		1	
Cypridina sp.			1						
Copepoda									
Unidentified species		1							
Calanoid sp. A and B		6	17	127	99	58	72	36	64
Euchaeta sp.				4		2	1	1	12
Candacia sp.					2				
Acartia sp.		1	6	1		2			14
Eucalanus sp.									
Centropagus		321	273	58	26	35	50	360	468
Oncea sp.		2	2	2			1	6	
Copilia sp.				3	4				
Coryceaus sp.		4	9	1		3	2	4	3
Sapphirina sp.		2	3	7	9	2	4		
Unidentified Cylcopoidid		1							

Table 9c. Continued.

Date: 9-83 Taxa / Location Sampling Number	Surface P-21	Oblique P-22	Surface P-23	Oblique P-24	Surface P-25	Oblique P-26	Surface P-27	Oblique P-28
Malacostraca								
Mysidacea sp. A								
Mysidacea sp. B								
Cumacea sp. A								
Isopoda sp. A								
Amphipoda sp. A	4		6	2			2	
Decapoda/Shrimp mysis sp.	16		21	13	7	1	6	8
Decapoda/Crab zoeae sp.	3	6	48	115	33	20	6	4
Decapoda/Crab megalops sp.								
Mollusca								
Gastropoda								
Gastropod veliger larvae	36	16	57	94	137	86	52	21
Pteropoda								
Cresius acicula								
Unidentified sp. A				2		2		
Unidentified veliger capsules								
Cephalapoda (squid)		2	1	2	2			
Chaetognatha								
Sagitta sp. A	11	5	77	87	22	74	1	
Heteropoda								
Miscellanious Invertebrate Eggs	357	192	405	450	600	608	130	200
Chordata								
Urochordata								
Thaliacea (Salpa)								
Salpa sp. A					2			
Vertebrata								
Osteichthyes								
Fish larvae	1	1	2	2			1	
Fish eggs "round and oval"	117	543	95	141	70	191	204	68
Fish eggs (Scarid)	2	14					120	84
#Individuals/cubic meter	9.06	10.82	10.17	11.22	9.86	11.48	9.04	9.18
Total Species	19	16	19	17	17	17	17	12
Total Number	940	1122	1055	1164	1023	1190	937	952

Table 10. Species list of corals for Stations 1-4 in Bahia Laulau. List compiled from corals observed within a 20 meter band from the shore to 10 meter depth. FS = Forereef Slope, RF = Reef-Flat Platform, RM = Reef Margin,

Date: November 1982	Sta. 1	Sta. 2			Sta. 3			Sta. 4			Sta. 1A	
	FS	RF	RM	FS	RF	RM	FS	RF	RM	FS	RF	FS
Class - Anthozoa												
Order - Scleractinia												
Suborder - Astrocoeniina												
ASTROCOENIIDAE												
Stylocoeniella armada (Ehrenberg, 1834)				x							x	x
THAMNASTERIIDAE												
Psammocora contigua (Esper, 1797)			x								x	
P. digitata Milne-Edwards and Haime, 1851										x	x	x
P. superficialis Gardiner, 1898			x									
POCILLOPORIDAE												
Stylophora mordax (Dana, 1846)	x			x			x			x		x
Seriatopora crassa Quelch, 1886				x			x			x		
S. hystrix Dana, 1846				x								
Pocillopora ankeli Scheer and Pillai, 1974	x											
P. damicornis (Linnaeus, 1758)				x				x				x
P. danae Verrill, 1864				x			x				x	x
P. elegans Dana, 1846	x			x			x			x	x	x
P. eydouxi Milne-Edwards and Haime, 1860	x			x			x			x		x
P. liqulata Dana, 1846				x			x					
P. setchelli Hoffmeister, 1929	x		x	x			x	x			x	x
P. verrucosa (Ellis and Solander, 1786)	x		x	x			x				x	x

Table 10. Continued.

	Sta. 1	Sta. 2			Sta. 3			Sta. 4			Sta. 1A	
	FS	RF	RM	FS	RF	RM	FS	RF	RM	FS	RF	FS
ACROPORIDAE												
Acropora cerealis (Dana, 1846)	x			x		x	x	x			x	x
A. humilis (Dana, 1846)	x			x			x			x	x	x
A. irregularis (Brook, 1892)				x			x			x		x
A. monticulosa (Bruggemann, 1879)				x			x				x	x
A. nasuta (Dana, 1846)	x		x					x		x	x	x
A. ocellata (Klunzinger, 1879)												x
A. palifera (Lamarck, 1816)				x								
A. quelchi (Brook, 1893)				x								
A. smithi (Brook, 1893)				x								x
A. squarrosa (Ehrenberg, 1834)						x	x	x		x	x	x
A. studeri (Brook, 1893)								x			x	x
A. surculosa (Dana, 1846)	x		x	x		x	x	x		x	x	x
A. tenuis (Dana, 1846)	x			x			x	x		x	x	x
A. valida (Dana, 1846)				x			x	x				
A. variabilis (Klunzinger, 1879)			x	x		x	x	x			x	x
A. wardi Verrill, 1901	x			x							x	x
A. (corymbose sp. 1)							x			x		
Astreopora myriophthalma (Lamarck, 1816)				x			x			x	x	
Montipora berryi Hoffmeister, 1925				x								
M. cf. M. caliculata (Dana, 1846)				x								x
M. ehrenbergii Verrill, 1875			x	x			x	x			x	x
M. elschneri Vaughan, 1918	x			x			x	x			x	x
M. foveolata (Dana, 1846)	x			x			x	x				
M. hoffmeisteri Wells, 1954	x			x			x				x	x
M. planiuscula (Dana, 1846)											x	
M. tuberculosa (Lamarck, 1816)				x								x
M. verrilli Vaughan, 1907	x			x			x	x			x	x
M. verrucosa (Lamarck, 1816)							x				x	
M. (foveolate sp. 1)				x								
M. (tuberculate sp. 1)							x			x		
M. (tuberculate sp. 2)				x			x	x				x

Table 10. Continued.

	Sta. 1	Sta. 2			Sta. 3			Sta. 4			Sta. 1A	
	FS	RF	RM	FS	RF	RM	FS	RF	RM	FS	RF	FS
Suborder - Fungiina												
AGARICIIDAE												
Pavona divaricata (Lamarck, 1816)											x	
P. duerdeni Vaughan, 1907	x			x			x	x		x	x	x
P. maldivensis (Gardiner, 1905)												x
P. varians Verrill, 1864				x							x	
P. venosa (Ehrenberg, 1834)						x					x	
P. (encrusting sp. 1)				x								
Leptoseris mycetoseroides Wells, 1954										x		
FUNGIIDAE												
Fungia (Fungia) fungites (Linnaeus, 1758)				x								
F. (Pleuractis) scutaria Lamarck, 1816										x		
Herpolitha limax (Houttuyn, 1772)										x		
PORITIDAE												
Goniopora tenuidens (Quelch, 1886)				x								
Porites australiensis Vaughan, 1918	x				x	x	x	x				
P. lichen Dana, 1846	x									x		
P. lutea Milne-Edwards and Haime, 1851	x	x	x	x	x	x	x	x		x	x	x
P. murrayensis Vaughan, 1918	x							x		x	x	x
P. superfusa Gardiner, 1898			x									
P. (Synaraea) convexa Verrill, 1864				x			x	x		x	x	x
P. (Synaraea) iwayamaensis Eguchi, 1938			x	x			x			x	x	x
Alveopora sp. 1												
Suborder - Faviina												
FAVIIDAE												
Favia favus (Forskal, 1775)				x			x	x		x	x	x
F. matthai Vaughan, 1918				x			x	x		x	x	x

Table 10. Continued

	Sta. 1	Sta. 2			Sta. 3			Sta. 4			Sta. 1A	
	FS	RF	RM	FS	RF	RM	FS	RF	RM	FS	RF	FS
F. pallida (Dana, 1846)	x		x	x		x	x	x		x	x	x
F. rotumana (Gardiner, 1899)											x	
F. stelligera (Dana, 1846)			x	x		x	x			x	x	x
Favites abdita (Ellis and Solander, 1786)			x					x			x	
F. flexuosa (Dana, 1846)				x								
F. russelli (Wells, 1954)				x								
Oulophyllia crispa (Lamarck, 1816)				x			x			x		
Goniastrea edwardsi Chevalier, 1971	x						x				x	x
G. pectinata (Ehrenberg, 1834)				x								
G. retiformis (Lamarck, 1816)	x	x	x	x	x	x	x	x			x	x
Platygyra daedalea (Ellis and Solander, 1786)				x			x				x	x
Platygyra pini Chavalier, 1975	x			x			x				x	x
Leptoria phrygia (Ellis and Solander, 1786)	x			x		x	x	x		x	x	x
Hydnophora microconos (Lamarck, 1816)				x			x				x	x
Montastrea curta (Dana, 1846)	x		x	x		x	x	x			x	x
Diploastrea heliopora (Lamarck, 1816)				x								
Leptastrea purpurea (Dana, 1846)	x			x				x			x	
L. transversa Klunzinger, 1879	x			x								
Cyphastrea chalcidicum (Forskal, 1775)	x						x					
OCULINIDAE												
Galaxea fascicularis (Linnaeus, 1767)			x							x	x	x
MERULINIDAE												
Scapophyllia cylindrica Milne-Edwards and Haime, 1848	x											
MUSSIDAE												
Acanthastrea echinata (Dana, 1846)	x			x		x		x			x	x
Lobophyllia corymbosa (Forskal, 1775)										x		
L. hemprichii (Ehrenberg, 1834)				x			x				x	x

Table 10. Continued.

	Sta. 1	Sta. 2			Sta. 3			Sta. 4			Sta. 1A	
	FS	RF	RM	FS	RF	RM	FS	RF	RM	FS	RF	FS
PECTINIIDAE												
<u>Echinophyllia</u> <u>aspera</u> (Ellis and Solander, 1786)											x	x
Order - Coenothecalia												
HELIOPORIDAE												
<u>Heliopora</u> <u>coerulea</u> (Pallas, 1766)				x								
Class - Hydrozoa Order - Milleporina												
MILLEPORIDAE												
<u>Millepora</u> <u>dichotoma</u> Forskal, 1775				x								
<u>M.</u> <u>latifolia</u> Boschma, 1948											x	x
<u>M.</u> <u>platyphylla</u> Hemprich and Ehrenberg, 1834	x			x				x			x	x
<u>M.</u> <u>tuberosa</u> Boschma, 1966											x	
Order - Stylasterina												
STYLASTERIDAE												
<u>Stylaster</u> <u>profundiporus</u> Broch, 1936	x											
Total Species for Reef Zones	36	2	17	65	3	13	47	30		32	53	52
Total Genera for Reef Zones	18	2	10	26	2	8	18	13		18	21	19
Total Species for Stations	36		71			49			50		63	
Total Genera for Stations	18		28			19			24		22	

Total Species for Reef Stations Combined - 98
Total Tenera for Reef Stations Combined - 34

Table 11. Coral size distribution, frequency, relative frequency, density, relative density, percent of substrate coverage, relative percent of substrate coverage and importance value (sum of the three relative values) for Stations 2, 3, and 4 in Bahia Laulau. Species are listed in order of their importance values.

Date: November 1982	Size Distribution of Colony Diameters (cm) n	y	s	w							
Stations 1 and 1A	(Corals not quantitatively analyzed)										
Station 2											
Reef-Flat Platform Zone											
Porites lutea	9	13.7	10.1	6-30	.30	60.00	.01	69.23	.02	86.96	216.19
Goniastrea retiformis	4	8.3	5.6	3-14	.20	40.00	.005	30.77	.003	13.04	83.81
Totals	13	12.8	8.5	3-30			.015		.023		
Station 2											
Reef Margin Zone											
Pocillopora setchelli	10	9.9	4.8	3-18	.70	20.59	1.91	25.00	1.84	12.79	58.38
Goniastrea retiformis	4	18.0	11.4	5-31	.40	11.76	.76	10.00	2.51	17.44	39.20
Montipora verrilli	3	21.7	6.4	17-29	.30	8.82	.57	7.50	2.30	15.98	32.30
Porites lutea	3	19.7	14.2	10-36	.20	5.88	.57	7.50	2.37	16.47	29.85
Acropora nasuta	4	13.5	7.0	5-21	.30	8.82	.76	10.0	1.38	9.59	28.41
A. surculosa	2	16.5	16.3	5-28	.20	5.88	.38	5.00	1.21	8.41	19.29
A. variabilis	3	8.7	0.6	8-9	.30	8.82	.57	7.50	.35	2.43	18.75
Porites (S.) iwayamaensis	2	12.5	9.2	6-19	.20	5.88	.38	5.00	.61	4.24	15.12
Montipora ehrenbergii	1	28.0	-	-	.10	2.94	.19	2.50	1.17	8.13	13.57
Pocillopora verrucosa	2	7.0	1.4	6-8	.20	5.88	.38	5.00	.15	1.04	11.92
Galaxea fascicularis	2	6.0	1.4	5-7	.20	5.88	.38	5.00	.11	.76	11.64
Psammocora contigua	2	7.0	2.8	5-9	.10	2.94	.38	5.00	.15	1.04	8.98
Favia pallida	1	12.0	-	-	.10	2.94	.19	2.50	.20	1.39	6.83
Montastrea curta	1	5.0	-	-	.10	2.94	.19	2.50	.04	.28	5.72
Totals	40	13.0	8.4	3-36			7.61		14.39		

Table 11. Continued.

	Size Distribution of Colony Diameters (cm) n	y	s	w							
Station 2											
Forereef Slope Zone											
Goniastrea retiformis	18	27.3	18.1	5-58	.53	18.79	2.28	30.00	14.66	28.68	77.47
Montipora ehrenbergii	6	51.0	33.8	14-99	.27	9.57	.76	10.00	21.26	41.56	61.16
M. verrilli	9	25.9	12.2	5-46	.47	16.67	1.14	15.00	7.19	4.28	35.95
Pocillopora setchelli	3	12.0	1.7	11-14	.20	7.09	.38	5.00	.44	.86	12.95
Acropora tenuis	2	32.0	24.0	15-49	.13	4.61	.25	3.33	2.54	4.97	12.91
Montipora hoffmeisteri	3	17.7	10.6	8-29	.13	4.61	.38	5.00	1.14	2.23	11.84
Pocillopora verrucosa	2	23.5	4.9	20-27	.13	4.61	.25	3.33	1.11	2.17	10.11
P. damicornis	2	18.0	14.1	8-28	.13	4.61	.25	3.33	.87	1.70	9.64
Acropora cerealis	2	15.0	5.7	11-19	.13	4.61	.25	3.33	.50	.98	8.92
Leptoria phrygia	1	47.0	-	-	.07	2.48	.13	1.67	2.24	4.38	8.53
Acropora variabilis	3	7.3	2.1	5-9	.07	2.48	.38	5.00	.17	.33	7.81
A. surculosa	1	42.0	-	-	.07	2.48	.13	1.67	1.79	3.50	7.65
Favia favus	2	14.0	8.5	8-20	.07	2.48	.25	3.33	.45	.88	6.69
Montipora elschneri	1	35.0	-	-	.07	2.48	.13	1.67	1.23	2.41	6.56
Acanthastrea echinata	1	14.0	-	-	.07	2.48	.13	1.67	.20	.39	4.54
Porites (S.) iwayamaensis	1	12.0	-	-	.07	2.48	.13	1.67	.14	.27	4.42
Montipora tuberculosa	1	9.0	-	-	.07	2.48	.13	1.67	.08	.16	4.31
Acropora wardi	1	9.0	-	-	.07	2.48	.13	1.67	.08	.16	4.31
Pocillopora danae	1	5.0	-	-	.07	2.48	.13	1.67	.03	.06	4.21
Totals	60	24.4	18.7	5-99			7.61		56.12		
Station 3											
Reef-Flat Platform Zone	(No corals encountered)										
Station 3											
Reef Margin Zone											
Goniastrea retiformis	7	17.6	12.7	5-34	.40	26.67	.06	29.17	.23	59.28	115.12
Porites lutea	10	10.8	5.5	5-20	.50	33.33	.09	41.67	.10	25.77	100.77

Table 11. Continued.

	Size Distribution of Colony Diameters (cm) n	y	s	w							
P. australiensis	3	10.3	3.1	7-13	.20	13.33	.03	12.50	.02	5.15	30.98
Pavona venosa	1	18.0	-	-	.10	6.67	.01	4.17	.02	5.15	15.99
Acropora nassuta	1	12.0	-	-	.10	6.67	.01	4.17	.01	2.58	13.42
Acropora variabilis	1	7.0	-	-	.10	6.67	.01	4.17	.004	1.03	11.87
Favia pallida	1	7.0	-	-	.10	6.67	.01	4.17	.004	1.03	11.87
Totals	24	12.75	8.28	5-34			.22		.388		
Station 3 Forereef Slope Zone	(Weather prohibited quantitative analysis)										
Station 4 Reef-Flat Platform Zone											
Acropora squarrosa	16	10.81	4.5	4-19	.80	30.79	1.54	40.00	1.66	14.78	85.55
Montipora verrilli	2	39.0	32.5	17.62	.10	3.85	.19	5.00	3.12	27.78	36.63
Acropora sp. 1	3	30.7	3.2	27.33	.20	7.69	.29	7.50	2.13	18.97	34.16
A. surculosa	3	20.7	8.5	11-27	.30	11.54	.29	7.50	1.08	9.62	28.66
A. variabilis	4	11.8	4.9	8-19	.20	7.69	.39	10.00	.50	4.45	22.14
Goniastrea retiformis	3	12.3	6.1	7-19	.20	7.69	.29	7.50	.41	3.65	18.84
Pocillopora setchelli	2	16.0	5.7	12-20	.20	7.69	.19	5.00	.41	3.65	16.34
Acropora cerealis	2	10.5	0.7	10-11	.20	7.69	.19	5.00	.17	1.51	14.20
Porites murrayensis	1	30.0	-	-	.10	3.85	.10	2.50	.68	6.06	12.41
Montastrea curta	2	11.5	7.8	6-17	.10	3.85	.19	5.00	.25	2.23	11.08
Favia pallida	1	25.0	-	-	.10	3.85	.10	2.50	.47	4.19	10.54
Acropora humilis	1	21.0	-	-	.10	3.85	.10	2.50	.35	3.12	9.47
Totals	40	16.1	10.7	4-62			3.86		11.23		
Station 4 Reef Margin and Forereef Slope Zones	(Weather prohibited quantitative analysis)										

Table 12. Conspicuous macroinvertebrates collected or observed at Bahia Laulau, Saipan, Nov. 1982.

Protozoa
  Foraminiferida (Foraminiferan)
    Baculogypsina sphaerulata (Parker and Jones) Site 2 and 3, sands
    Marginopora vertebralis Blainville Site 2 and 3, sands

Porifera (Sponges)
    Cinchyra sp. Site 1a, reef flat; 2, reef flat; 4, reef flat

Arthropoda
  Crustacea (Crustaceans)
    Coenobitidae (Land Hermit Crab)
      Coenobita sp. Site 2, beach

    Grapsidae (Grapsid Crab)
      Grapsus tenuicrustatus (Herbst) Site 1a; 2, 4, high intertidal

    Ocypodidae (Ghost crab)
      Ocypode sp. Site 2 and 3, beach

    Xanthidae (Xanthid Crab)
      Carpilius maculatus (Linnaeus) Site 2, reef flat

Mollusca
  Gastropoda (Snails)

  Pulmonata
    Ellobiidae
      Melampus flavus (Gmelin) Site 4, high intertidal

  Prosobranchia
    Patellidae (Limpets)
      Cellana radiata orientalis (Pilsbry) Site 2, high intertidal; 4, reef flat and high intertidal

    Trochidae (Trochids, Topshells)
      Tectus pyramis (Born) Site 3, 30 ft.
      Trochus intextus Kiener Site 3, 30 ft.
      T. niloticus Linnaeus Site 1a, reef flat

    Turbinidae (Turban Shells)
      Astraea rhodostoma (Lamarck) Site 1, 30 ft.; 1a, 20-30 ft.; 2, 30 ft.; 3, 30 ft.; 4, 40-50 ft.
      Turbo argyrostomus Linnaeus Site 1, 30 ft.; 3, 60 ft.; 4, 30-50 ft.
      T. petholatus Linnaeus Site 4, 30-50 ft.
      T. setosus Gmelin Site 2, reef flat

    Neritidae (Nerites)
      Nerita albicilla Linnaeus Site 2, high intertidal
      N. plicata Linnaeus Site 2, high intertidal; 4 high intertidal

Table 12. Continued.

Neritopsidae
Neritopsis radula (linnaeus) Site 2, 30 ft.

Littorinidae
Littorina coccinea (Gmelin) Site 4, high intertidal
L. undulata Gray Site 2, high intertidal; 4, high intertidal

Modulidae
Modulus tectum (Gmelin) Site 1, 30 ft.

Cerithiidae
Cerithium moras Lamarck Site 2, high intertidal
C. mutatum Sowerby Site 1a, 20-30 ft.; 3, 60 ft.
C. nodulosum Brugiere Site 1a, 20-30 ft.; 3, reef flat
Rhinoclavis articulatus (Adam and Reeve) Site 1, 30 ft.
R. aspera (Linnaeus) Site 1a, 20-30 ft.
R. sinensis (Gmelin) Site 4, 30-50 ft.

Strombidae (Conchs)
Lambus chiragra (Linnaeus) Site 1, 30 ft.; 1a, 20-30 ft.; 3, 30 ft.
L. lambis (Linnaeus) Site 3, 30 ft.
Strombus dentatus Linnaeus Site 1, 30 ft.; 1a, 20-30 ft.
S. luhuanus Linnaeus Site 1a, 20-30 ft.
S. mutabilis Swainson Site 1, 30 ft.; 1a, reef flat and 20-30 ft.; 3, reef flat

Hipponicidae
Hipponix conicus (Schumacher) Site 1, 30 ft.; 3, 30 and 60 ft.; 4, 30-50 ft.

Cypraeidae (Cowries)
Cypraea caputserpentis Linnaeus Site 1, 30 ft.
C. depressa (Gray) Site 1, 30 ft.
C. helvola Linnaeus Site 3, 20 ft.

C. isabella Linnaeus Site 1a, 20-30 ft.
C. Lynx Linnaeus Site 1a, reef flat
C. moneta Linnaeus Site 1a, reef flat; 2, reef flat and reef front; 4, reef flat
Cypraea sp. (Juvenile) Site 1a, 20-30 ft.

Tonnidae (Tonn shells)
Tonna perdix (Linnaeus) Site 2, beachwashed

Cymatiidae
Cymatium nicobaricum (Roeding) Site 1a, reef flat; 2, reef front
Distorsio anus (Linnaeus) Site 1a, reef flat

Bursidae
Bursa bufonia (Gmelin) Site 3, reef flat

Table 12. Continued.

Muricidae
- Drupa (Roeding) Site 1, 30 ft.
- D. morum Roeding Site 4, reef flat
- D. ricinus (Linnaeus) Site 2, reef front; 4, reef flat and 30-50 ft.
- Drupella elata (Blainville) Site 3, 30 and 60 ft.
- D. ochrostoma (Blainville) Site 3, 30 ft.
- Morula biconica (Blainville) Site 1a, 20-30 ft.
- M. granulata (Duclos) Site 4, reef flat
- M. uva (Roeding) Site 1a, reef flat, 2 reef flat
- Muricodrupa funiculus (Wood) Site 1, 30 ft.; 1a reef flat
- Thais armigera (Link) Site 1, 30 ft.; 1a, reef flat; 3, 30 ft.

Faciolariidae
- Latirus nodatus (Gmelin) Site 1a, 20-30 ft.; 3, 30 ft.
- L. polygonus (Gmelin) Site 1a, 20-30 ft.; 2 reef flat and reef front
- Peristernia nassatula (Lamarck) Site 1a, reef flat; 2 reef front

Nassariidae
- Nassarius graniferus (Kiener) Site 1a, 20-30 ft.

Vadidae
- Vasum turbinellus (Linnaeus) Site 1, 30 ft., 1a, reef flat and 20-30 ft.; 2 reef flat and reef front; 3, reef flat; 4, reef flat

Olividae (Olives)
- Oliva annulata (Gmelin) Site 1a, 20-30 ft.

Mitridae (Miters)
- Mitra cucumerina Lamarck Site 2, reef flat
- M. eremitarum Roeding Site 2, 30 ft.
- M. ferruginea Lamarck (juvenile) Site 1a, reef flat
- Mitra Site 3, 60 ft.
- Neocancilla Papilio (Link) Site 2, 30 ft.
- Vexillum cadaverosum Reeve) Site 1a, 20-30 ft.
- V. coronatum (Helbling) Site 1a, 20-30 ft.
- V. exasperatum (Gmelin) Site 2, 30 ft.
- V. modestum (Reeve) Site 1a, 20-30 ft.

Conidae (Cones)
- Conus aulicus Linnaeus Site 1a, 20-30 ft.
- C. balteatus Sowerby Site 1a, reef flat; 3, 30 ft.
- C. coronatus Gmelin Site 1a, reef flat
- C. distans Hwass Site 1, 30 ft.; w. 30 ft.; 4, 40-50 ft.
- C. ebraeus Linnaeus Site 2, 30 ft.
- C. eburneus Hwass Site 1a, reef flat; 2, reef flat
- C. flavidus Lamarck Site 1a, reef flat; 2, reef flat; 4, reef flat
- C. generalis Linnaeus Site 2, 30 ft.
- C. geographis Linnaeus Site 1a, 20-30 ft.
- C. litoglyphus Hwass Site 1, 30 ft.; 2, 30 ft.
- C. lividus Hwass Site 3, reef flat and 30 ft.
- C. miles Linnaeus Site 1a, 20-30 ft.; 2, reef front; 3, 30 ft.
- C. miliaris Hwass Site 1a, reef flat and 20-30 ft.
- C. moreleti Crosse Site 1a, 20-30 ft.
- C. musicus Hwass Site 1a, 20-30 ft.

Table 12. Continued.

C. planorbis Born Site la, 20-30 ft.
C. pulicarius Hwass Site la, 20-30 ft.
C. rattus Hwass Site la, reef flat
C. sponsalis Hwass Site 2, reef flat
C. striatus Linnaeus Site la, 20-30 ft.; 2, 30 ft.
C. tessulatus Born Site la, 20-30 ft.
C. virgo Linnaeus Site la, 20-30 ft.

Terebridae (Auger Shells)
Terebra subulata (Linnaeus) Site 2, 30 ft.

Bivalvia (Clams)
Arcidae
Arca Site la, reef flat
Barbatia Site 3, reef flat

Limidae
Lima annulata Lamarck Site 2, 30 ft.; 3, 30 ft.

Chamidae
Chama Site 2, 30 ft.

Carditidae
Cardita variegata Brufiere Site 3, 30 ft.

Cardiidae
Fulvia tenuicostata (lamarck) Site la; 20-30 ft.; 3, 30-60 ft.; 4, 30-50 ft.

Tridacnidae (Giant Clams)
Tridacna maxima (Roeding) Site 1, 30 ft.; 2 reef flat; 4, 30-50 ft.

Veneridae
Lioconcha Site la, 20-30 ft.
Periglypta puerpera (Linnaeus) Site 4, 30-50 ft.

Echinodermata (Schinodermos)

Holothuroidea
Holothuriidae (Sea Cucumber)
Actinopyga echinites (Jaeger) Site 2, reef flat
A. mauritiana (Quoy and Gaimard) Site 2, reef flat
Bohadschia argus Jaeger Site 2, reef flat; 4, reef flat
Holothuria atra Jaeger Site 2, reef flat; 4 reef flat
H. edulis Lesson Site 4, 30-50 ft.
H. leucospilota (Brandt) Site la, reef flat; 2 reef flat; 4 reef flat

Stichopidae
Stichopus cholorontus Brandt Site la, reef flat; 2 reef flat
Thelenota ananas Site 1, 30-50 ft.

Echinoidea (Sea Urchin)
Diadematidae
Echinothrix diadema Site 3, 30 ft.

Table 12. Continued.

Echinometridae
Echinometra mathaei (Blainville) Site 2, reef flat; 3, reef flat

Asteroidea (Sea Stars)
Acanthasteridae
Acanthaster planci (Linnaeus) Site 1, 30-50 ft.; 3, reef front

Oreasteridae
Culcita novaeguineae Muller and Troschel Site 1, 30-50 ft.; 3, reef front

Not Observed, But Known To Be An Important Resource Of Bahia Laulau

Panularus sp. (Spiny Lobster, 3 species)

Scyllaridae (Slipper Lobster, 8 genera)

Table 13. Fish species observed at Bahia Laulau, Saipan, November 3-7, 1982. Asterisks indicate generally desirable food species.

FAMILY/SPECIES	Chamorro Name	Site 1	2	3	4
ACANTHURIDAE (Surgeonfishes)					
* *Acanthurus achilles* Shaw				x	
* *A. glaucoparieus* Cuvier	Hugupau	x	x	x	x
* *A. lineatus* (Linnaeus)	Hiyuk	x	x	x	x
* *A. mata* (Cuvier)		x	x		x
* *A. nigricaudus* Dunker and Mohr					x
* *A. nigrofuscus* (Forsskal)	Hugupau	x	x	x	x
* *A. olivaceus* Bloch and Schneider	Hugupau	x		x	x
* *A. pyroferus* Kittlitz		x	x		x
* *A. thompsoni* (Fowler)			x		
* *A. triostegus* (Linnaeus)	Kechu	x	x	x	
* *Ctenochaetus binotatus* Randall			x		
* *C. striatus* (Quoy and Gaimard)	Hugupau	x	x	x	x
* *Naso brevirostris* (Valenciennes)		x	x		
* *N. hexacanthus* (Bleeker)	Guasa	x		x	x
* *N. lituratus* (Bloch and Schneider)	Hangun	x	x	x	x
* *N. lopezi* Herre				x	
* *N. unicornis* (Forsskal)	Tataga	x			
Paracanthurus hepatus (Linnaeus)		x			
Zebrasoma flavescens (Bennett)	Ababang	x	x		
APOGONIDAE (Cardinalfishes)					
Apogon novemfasciatus Cuvier	Lansi	x	x	x	
A. sp.	Lansi		x		
Cheilodepterus macrodon (Lacepede)	Lansi		x		
AULOSTOMIDAE (Trumpetfishes)					
Aulostomus chinensis (Linnaeus)	Badyak		x		
BALISTIDAE (Triggerfishes)					
Balistipus undulatus (Park)		x	x	x	x
Melichthys vidua (Solander)	Pulunun	x	x	x	x
Odonus niger (Ruppell)	Pulunun	x			
Rhinecanthus aculeatus (Linnaeus)	Pulunun		x	x	
R. echarpe (Lacepede)				x	
Sufflamen bursa (Bloch and Schneider)	Pulunun	x		x	x
S. chrysopterus (Bloch and Schneider)	Pulunun	x	x	x	x
BLENNIIDAE (Blennies)					
Exallias brevis (Kner)	Maching			x	
Meiacanthus atrodorsalis (Gunther)	Maching	x	x	x	
Plagiotremus tapeinosoma (Bleeker)	Maching			x	
Salarias fasciatus (Bloch)	Maching			x	

Table 13. Continued.

FAMILY/SPECIES	Chamorro Name	Site 1	2	3	4
Blenniid sp. 1	Maching			x	
Blenniid sp. 2	Maching			x	
CAESIONIDAE (Fusiliers)					
Caesio caerulaureus Lacepede	Bonita	x	x	x	x
C. tile Cuvier and Valenciennes	Bonita	x			
C. xanthonothus Bleeker	Bonita		x	x	
Pterocaesio chrysozona Cuvier	Bonita	x		x	x
CARANGIDAE (Jacks, Pompanos)					
* *Caranx melampygus* Cuvier	Ee, Tarakito		x	x	
* *C. sexfasciatus* Quoy & Gaimard	Mamulon		x		
CHARCHARHINIDAE (Requiem Sharks)					
Charcharhinus melanopterus	Haluu	x			
CHAETODONTIDAE (Butterflyfishes)					
Chaetodon auriga Forsskal	Ababang		x	x	x
C. bennetti Cuvier	Ababang				x
C. citrinellis Cuvier	Ababang	x	x	x	
C. ephippium Cuvier	Ababang	x	x	x	
C. lineolatus Cuvier	Ababang			x	
C. lunula (Lacepede)	Ababang	x	x	x	x
C. mertensii Cuvier	Ababang		x		x
C. ornatissimus Cuvier	Ababang	x	x	x	x
C. punctatofasciatus Cuvier	Ababang	x	x	x	x
C. quadrimaculatus Gray	Ababang	x		x	x
C. reticulatus Cuvier	Ababang	x	x	x	x
C. trifasciatus Park	Ababang		x		x
C. ulietensis Cuvier	Ababang		x	x	x
C. unimaculatus Bloch	Ababang	x	x	x	
Forcipiger flavissimus Jordan and McGregor	Ababang	x		x	x
F. longirostris (Broussonet)	Ababang	x			
Megaprotodon trifascialis (Quoy and Gaimard)	Ababang	x	x	x	x
CIRRHITIDAE (Hawkfishes)					
Cirrhitichthys falco Randall		x		x	
Neocirrhites armatus Castelnau		x		x	
Paracirrhites arcatus (Cuvier)		x	x	x	x
P. forsteri (Bloch and Schneider)		x	x	x	x
DASYATIDAE (Stingrays)					
Taeniura melanospilos Bleeker	Hafula			x	

Table 13. Continued

FAMILY/SPECIES	Chamorro Name	Site 1	2	3	4
GOBIIDAE (Gobies)					
Amblyeleotris steinitzi (Klausewitz)	Maching	x	x		
Nemateleotris magnifica Fowler	Maching	x		x	
Pogonoculius zebra Fowler	Maching	x		x	
Ptereleotris evides (Jordan and Hubbs)	Maching			x	
Valencienna puellaris (Tomiyama)	Maching		x		
V. strigatus (Broussonet)	Maching	x	x	x	
HAEMULIDAE (Sweetlips)					
* Plectorhynchus orientalis (Bloch)	Hamala		x		
HEMIRAMPHIDAE (Halfbeaks)					
* Hemiramphus dussumieri (Valenciennes)	Anko, Hankut		x		
HOLOCENTRIDAE (Squirrelfishes)					
* Adioryx caudimaculatus (Ruppell)	Suksuk	x			
* A. ruber (Forsskal)	Suksuk		x		
* A. spinnifer (Forsskal)	Sesiok		x	x	
* Flammeo opercularis (Valenciennes)	Chalak		x		
* F. sammara (Forsskal)	Chalak		x	x	
* Myrpristis berndti Jordan and Evermann	Sagsag		x	x	
* M. murdjan (Forsskal)	Sagsag		x	x	
LABRIDAE (Wrasses)					
Anampses caeruleopunctatus Ruppell	Aaga	x	x	x	x
A. meleagrides Valenciennes	Aaga		x		
A. twistii (Bleeker)	Aaga		x	x	
Bodianus axillaris (Bennett)			x		
* Cheilinus celibicus Bleeker	Aaga		x		
* C. unifasciatus Streets	Aaga	x	x	x	x
* C. trilobatus Lacepede	Lalatsa-Mamati		x	x	x
* C. undulatus Ruppell	Tanguisun				
* Cheilio inermis (Forsskal)	Aaga		x		
Cirrhilabrus sp.	Aaga		x	x	
Coris aygula Lacepede	Aaga	x		x	
C. gaimard (Quoy and Gaimard)	Aaga	x		x	
* Epibulus insidiator (Pallas)	Aaga	x	x		x
Gomphosus varius Lacepede	Aaga	x	x	x	x
Halichoeres biocellatus Schultz	Aaga	x		x	
H. hortulanus (Lacepede)	Aaga	x	x	x	x
H. margaritaceus (Valenciennes)	Aaga	x	x	x	x
H. marginatus Ruppell	Aaga		x	x	
H. scapularis (Bennett)	Aaga	x			
H. trimaculatus (Quoy and Gaimard)	Aaga		x	x	
* Hemigymnus fasciatus (Bloch)	Aaga	x	x	x	x

Table 13. Continued.

FAMILY/SPECIES	Chamorro Name	Site 1	2	3	4
* *H. melapterus* (Bloch)	Aaga		x		
Hologymnosus doliatus (Lacepede)	Aaga	x		x	x
Labrichthys unilineatus (Guichenot)	Aaga		x		
Labroides dimidiatus (Valenciennes)	Aaga	x	x	x	
Macropharyngodon meleagris (Valenciennes)	Aaga	x	x	x	x
Novaculichthys taeniourus (Lacepede)	Aaga	x	x	x	x
Pseudocheilinus evanidus	Aaga			x	
P. hexataenia (Bleeker)	Aaga	x	x	x	x
Stethojulis bandanensis (Bleeker)	Aaga	x	x	x	x
Thalassoma fuscum (Lacepede)	Aaga	x	x	x	
T. lutescens (Lay and Bennett)	Aaga	x	x	x	x
T. quinquevittatum (Lay and Bennett)	Aaga	x	x	x	x
LETHRINIDAE (Emperors)					
* *Gnathodentex aureolineatus* (Lacepede)	Salagai	x		x	x
* *Lethrinus harak* (Forsskal)	Mafute		x	x	
* *L. semicinctus* Valenciennes	Mafute	x			x
* *Monotaxis grandoculis* (Forsskal)	Matanhagon	x	x	x	x
LUTJANIDAE (Snappers)					
* *Aphareus furcatus* (Lacepede)			x	x	
* *Aprion virescens* Valenciennes		x			
* *Lutjanus bohar* (Forsskal)	Tagafi	x		x	
* *L. fulvus* (Bloch and Schneider)	Kakaka		x	x	
* *L. rivulatus* (Cuvier and Valenciennes)		x			
* *L. russelli* (Bleeker)			x		
* *Macolor niger* (Forsskal)			x	x	x
MALACANTHIDAE (False Whitings)					
Malacanthus brevirostris Guichenot		x			
M. latovittatus (Lacepede)			x		
MONACANTHIDAE (Filefishes)					
Cantherhines pardalis (Ruppell)		x	x	x	
Oxymonacanthus longirostris (Bloch and Schneider)	Hagonfa Ha		x		
Pervagor melanocephalus (Bleeker)				x	x
MUGILOIDIDAE (Sand Perches)					
Parapercis cephalopunctata (Seale)		x	x	x	x
P. clathrata Ogilby		x	x	x	

Table 13. Continued

FAMILY/SPECIES	Chamorro Name	Site 1	2	3	4
MULLIDAE (Goatfishes)					
* Mulloides flavolineatus (Lacepede)	Tiao or		x	x	
* M. vanicolensis (Valenciennes)	Salmonete		x		
* Parupeneus barberinus (Lacepede)	Salmoniti	x			
* P. bifasciatus (Lacepede)	Salmoniti	x	x	x	x
* P. chryseredros (Lacepede)	" Amariyu		x		
* P. pleurostigma (Bennett)		x	x		
* P. poryphyreus Jenkins			x		
* P. trifasciatus (Lacepede)	Salmoniti	x	x	x	x
MURAENIDAE (Moray Eels)					
Lycodontis sp.	Titugi			x	
NEMIPTERIDAE (Monacle Breams)					
* Scolopsis cancellatus (Cuvier)	Sihig		x		
OPICHTHIDAE (Snake Eels)					
Myrichthys colubrinus (Boddaert)	Hagman-Lisado			x	
PEMPHERIDAE (Sweepers)					
Pempheris oualensis Cuvier				x	x
POMACANTHIDAE (Angelfishes)					
Apolemichthys trimaculatus (Cuvier)	Ababang	x			
Centropyge flavissimus (Cuvier)	Ababang	x		x	x
C. hearaldi Woods and Schultz	Ababang	x			
C. shepardi Randall and Yasuda	Ababang	x		x	x
Pygoplites diacanthus (Boddaert)	Ababang	x	x		
Pomacanthus imperator (Bloch)	Ababang			x	
POMACENTRIDAE (Damselfishes)					
Abudefduf septemfasciatus (Cuvier)	Doddo		x	x	
A. vaigiensis (Quoy and Gaimard)	Fohmo		x		x
Amblyglyphidodon aureus (Cuvier)	Fohmo	x	x	x	x
Amphiprion clarkii (Bennett)	Fohmo	x	x		
Chromis acares Randall and Swerdloff	Fohmo	x	x		
C. agilis Smith	Fohmo		x		
C. caerulea (Cuvier)	Fohmo		x		
C. margaritifer Fowler	Fohmo	x			
C. xanthura (Bleeker)	Fohmo	x	x	x	
Chrysiptera biocellatus (Quoy and Gaimard)	Fohmo		x	x	
C. glaucus (Cuvier)	Fohmo			x	

Table 13. Continued

FAMILY/SPECIES	Chamorro Name	Site 1	2	3	4
C. leucopomus (Lesson)	Fohmo	x	x	x	
C. traceyi (Woods and Schultz)	Fohmo		x	x	
Dascyllus aruanus (Linnaeus)	Fohmo		x		
D. reticulatus (Richardson)	Fohmo	x		x	
D. trimaculatus (Ruppell)	Fohmo	x			
Plectroglyphidodon dickii (Lienard)	Fohmo		x	x	x
P. imperipennis (Valliant and Sauvage)	Fohmo			x	
P. johnstonianus Fowler and Ball	Fohmo			x	x
P. lacrymatus (Quoy and Gaimard)	Fohmo	x	x	x	x
Pomacentrus vaiuli Jordan and Seale	Fohmo	x	x	x	x
Pomachromis guamensis Allen and Larson	Fohmo	x		x	
Stegastes fasciolatus (Ogilby)	Fohmo	x	x	x	x
SCARIDAE (Parrotfishes)					
* *Cetoscarus bicolor* (Ruppell)		x	x		
* *Scarus brevifilis* (Gunther)				x	
* *S. frenatus* Lacepede	Lagua				x
* *S. frontalis* Valenciennes	Lagua		x		
* *S. gibbus* Ruppell	Lagua		x	x	
* *S. oviceps* Valenciennes	Lagua		x		
* *S. psittacus* Forsskal	Palagsi		x	x	x
* *S. rubroviolaceus* (Bleeker)	Lagua		x	x	x
* *S. schlegeli* (Bleeker)	Lagua	x	x	x	x
* *S. sordidus* Forsskal	Lagua	x	x	x	x
* *S. tricolor* Bleeker	Lagua	x			
S. sp.	Lagua	x			
S. sp.	Lagua				x
SERRANIDAE (Groupers)					
* *Cephalopholis urodelus* (Bloch & Schneider)	Gadao	x			x
* *C. sonneratus* (Cuvier)	Gadao			x	
* *Epinephelus merra* Bloch	Gadao		x		
* *Plectropomus leopardus* (Lacepede)	Gadao	x			
* *Variola louti* (Bleeker)		x			
SIGANIDAE (Rabbitfishes)					
* *Siganus argenteus* (Quoy and Gaimard)	Hiting	x			x
* *S. spinus* (Linnaeus)	Seyun		x	x	
SYGNATHIDAE (Pipefishes)					
Corythoichthys intestinalis (Ramsey)	Hilitsi-Tasi			x	
SYNODONTIDAE (Lizardfishes)					
Saurida gracilis (Quoy and Gaimard)	Pipipu	x	x		
Synodus variegatus (Lacepede)	Pipipu			x	

Table 13. Continued

FAMILY/SPECIES	Chamorro Name	Site 1	Site 2	Site 3	Site 4
TETRAODONTIDAE (Smooth Puffers)					
Canthigaster amboinensis (Bleeker)	Botati		x	x	
C. bennetti (Bleeker)	Botati		x		
C. solandri (Richardson)	Botati		x	x	x
C. valentini (Bleeker)	Botati		x		
ZANCLIDAE (Moorish Idols)					
Zanclus cornutus (Linnaeus)	Ababang	x	x	x	x

TOTAL NO. FAMILIES = 35	23	31	28	19
TOTAL NO. SPECIES = 200	107	130	124	73
TOTAL NO. FOOD SPECIES = 75	35	51	38	27

Table 14. Fish species observed on the reef flat at Sites 2 and 3, Bahia Laulau, Saipan, November 3-7, 1982.

FAMILY/SPECIES	CHAMORRO NAME
ACANTHURIDAE (Surgeonfishes)	
Acanthurus nigrofuscus	Hugupau
A. triostegus	Kechu
APOGONIDAE (Cardinalfishes)	
Apogon novemfasciatus	Lansi
BALISTIDAE (Triggerfishes)	
Rhinecanthus aculeatus	Pulunun
BLENNIIDAE (Blennies)	
Salarias fasciatus	Maching
CARANGIDAE (Jacks, Pompanos)	
Caranx melampygus	Ee, Tarakito
CHARCHARHINIDAE (Requiem Sharks)	
Charcharhinus melanopterus	Haluu
CHAETODONTIDAE (Butterflyfishes)	
Chaetodon auriga	Ababang
C. citrinellis	Abagang
C. lunula	Ababang Lonnat
HOLOCENTRIDAE (Squirrelfishes)	
Adioryx spinnifer	Sesiok
Flammeo opercularis	Chalak
LABRIDAE (Wrasses)	
Cheilinus trilobatus	Lalatsa-Mamati
Cheilio inermis	Aaga
Halichoeres hortulanus	Aaga
H. marginatus	Aaga
H. trimaculatus	Aaga
Stethojulis bandanensis	Aaga
LETHRINIDAE (Emperors)	
Lethrinus harak	Mafute

Table 14. Continued.

FAMILY/SPECIES	CHAMORRO NAME
LUTJANIDAE (Snappers)	
Lutjanus fulvus	Kakaka
MULLIDAE (Goatfishes)	
Mulliodes flavolineatus	Tiao, Salmonete
Parupeneus trifasciatus	Salmoniti, Acho
P. poryphyreus	
MURAENIDAE (Moray Eels)	
Lycodontis sp.	Titugi
OPICHTHIDAE (Snake Eels)	
Myrichthys colubrinus	Hagman-Lisado
POMACANTHIDAE (Angelfishes)	
Pomacanthus imperator	Ababang
POMACENTRIDAE (Damselfishes)	
Abudefduf septemfasciatus	Fohmo, Doddo
Chrysiptera biocellatus	Fohmo
C. leucopomus	Fohmo
C. glaucus	Fohmo
Pomacentrus vauili	Fohmo
SCARIDAE (Parrotfishes)	
Scarus oviceps	Lagua
S. psittacus	Palagsi
S. schlegeli	Lagua
S. sordidus	Lagua
SERRANIDAE (Groupers)	
Cephalopholis sonneratus	Gadao
SIGANIDAE (Rabbitfishes)	
Siganus spinus	Manahak, Seyun
SYGNATHIDAE (Pipefishes)	
Corythoichthys intestinalis	Hilitsi-Tasi

Table 14. Continued.

FAMILY/SPECIES	CHAMORRO NAMES
SYNODONTIDAE (Lizardfishes)	
Saurida gracilis	Pipipu
TETRAODONTIDAE (Smooth Puffers)	
Canthigaster bennetti	Botati
C. solandri	Botati
ZANCLIDAE (Moorish Idols)	
Zanclus cornutus	Ababang Gupalao

Table 15. Juvenile fishes observed during reconnaissance and transect dives at Bahia Laulau, Saipan, November 3 - 7, 1982. Numbers are based on transect dives only. RF = Reef Flat; RS = Forereef Slope; Trophic groups: C = Carnivore, H = Herbivore, O = Omnivore.

SPECIES	TOTAL NUMBER	RF#	RS#	TROPHIC GROUP
Acanthuridae (Surgeonfishes)				
Acanthurus glaucoparieus	1		1	H
Acanthurus nigrofuscus	1		1	H
Acanthurus thompsoni	1	1		H
Acanthurus triostegus	1	1		H
Ctenochaetus striatus	1		1	H
Ctenochaetus binotatus	1		1	H
Naso lituratus	3		3	H
Apogonidae (Cardinalfishes)				
Apogon novemfasciatus	4	4		C
Apogon sp	6		6	C
Blenniidae (Blennies)				
Meiacanthus atrodorsalis	1		1	C
Plagiotremus tapeinosoma	1		1	C
Labridae (Wrasses)				
Cori aygula	1		1	C
Gomphosus varius	3		3	C
Halichoeres hortulanus	1		1	C
Halichoeres marginatus	3	3		C
Halichoeres trimaculatus	3	3		C
Labrichthys unilineatus	2		2	C
Stethojulis bandanensis	3	3		C
Lutjanidae (Snappers)				
Lutjanus russelli	1		1	C
Pomacanthidae (Angelfishes)				
Pomacanthus imperator	1		1	H

Table 15. Continued

SPECIES	TOTAL NUMBER	RF#	RS#	TROPHIC GROUP
Pomacentridae (Damselfishes)				
Chrysiptera briocellatus	21	21		H
Chrysiptera leucopomus	5	1	4	H
Chrysiptera traceyi	1		1	H
Plectroglyphidodon lacrymatus	4		4	H
Pomacentrus vaiuli	5		5	O
Stegastes fasciolatus	1		1	H
Scaridae (Parrotfishes)				
Scarus schlegeli	1		1	H
Scarus sordidus	5	2	3	H
Scarus sp 1	1		1	H
Scarus sp 2	1		1	H
Synodontidae (Lizardfishes)				
Saurida gracilis	2	1	1	C

TOTALS	NUMBER	PERCENT OF TOTAL
Number of Individuals	86	
Number of Species	31	
Number of Families	9	
Number of Herbivores	17	55
Number of Carnivores	13	42
Number of Omnivores	1	3

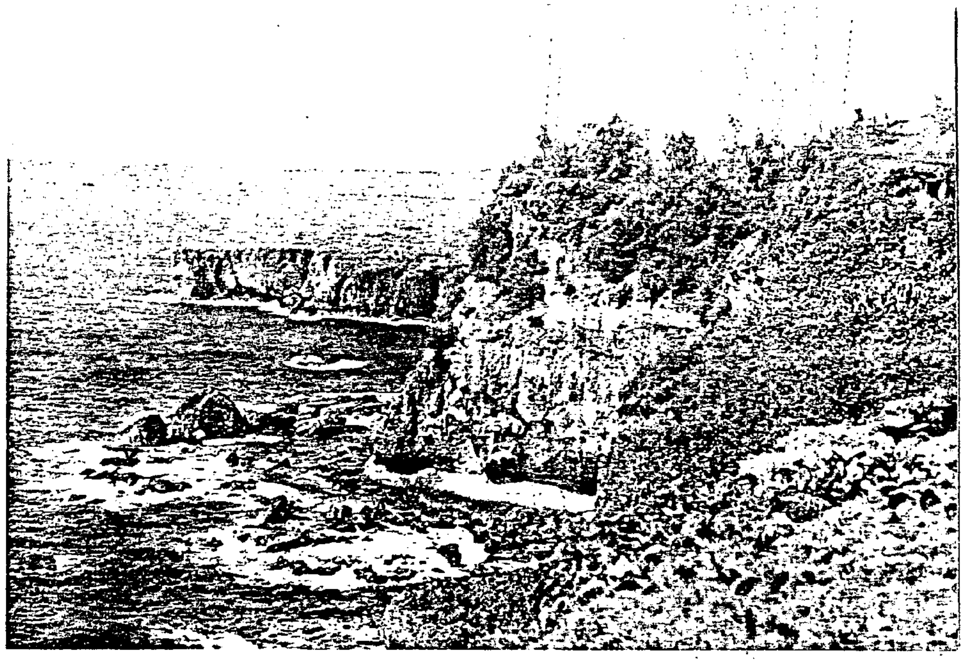
Table 16. Fish densities calculated for different depths and general reef zones from line transect data compiled at Sites 2 and 3, Bahia Laulau, Saipan, November 3-7, 1982.

Study Site	Depth (m)	Transect Length (m)	#spp/20 m²	#indiv/20 m²
REEF FLAT:				
Site 2	1	50	4.8	13.6
Site 3	1	100	3.2	5.6
Sites 2 and 3	1	150	3.7	8.3
FOREREEF SLOPE:				
Site 2	9	100	6.1	11.8
Site 3	9	100	9.5	22.8
Sites 2 and 3	9	200	7.8	17.3
Site 2	18	100	5.4	11.4
Site 3	18	100	9.4	27.6
Sites 2 and 3	18	200	7.6	19.5
Site 2	9 and 18	200	5.8	11.6
Site 3	9 and 18	200	9.4	25.2
Sites 2 and 3	9 and 18	400	7.7	18.4

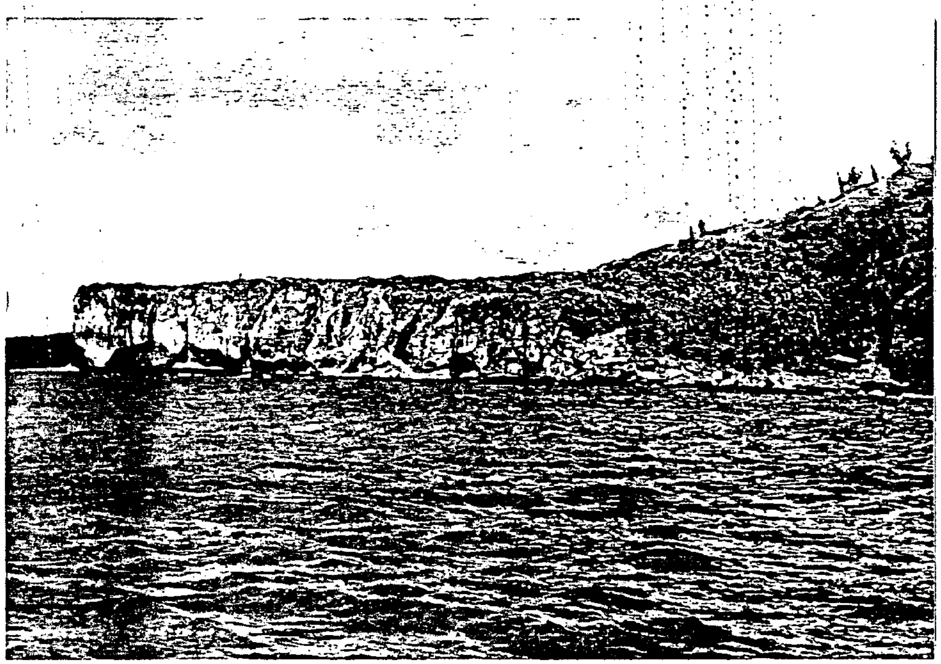
Table 17. Fish densities calculated for different substrate categories from line transect data compiled at Sites 2 and 3, Bahia Laulau, Saipan, November 3-7, 1982.

STUDY SITE	Depth (m)	Transect Length (m)	#spp/20 m²	#indiv/20 m²
REEF FLAT: (Sites 2 and 3)				
Shallows	0.3	70	1.3	1.6
Depressions	0.3, 1	80	5.9	14.0
FOREREEF SLOPE: (Site 2)				
Sand/Rubble	9	30	2.0	2.0
Sand/Rubble	18	20	1.5	1.5
Sand/Rubble	9&18	50	1.8	2.0
Sand/Rubble with Rocks or Coral	9	40	5.0	11.0
Sand/Rubble with Rocks or Coral	18	50	4.5	6.2
Sand/Rubble with Rocks or Coral	9&18	90	4.7	8.3
Coral	9	30	11.7	23.7
Coral	18	30	10.3	25.3
Coral	9&18	60	11.0	24.5

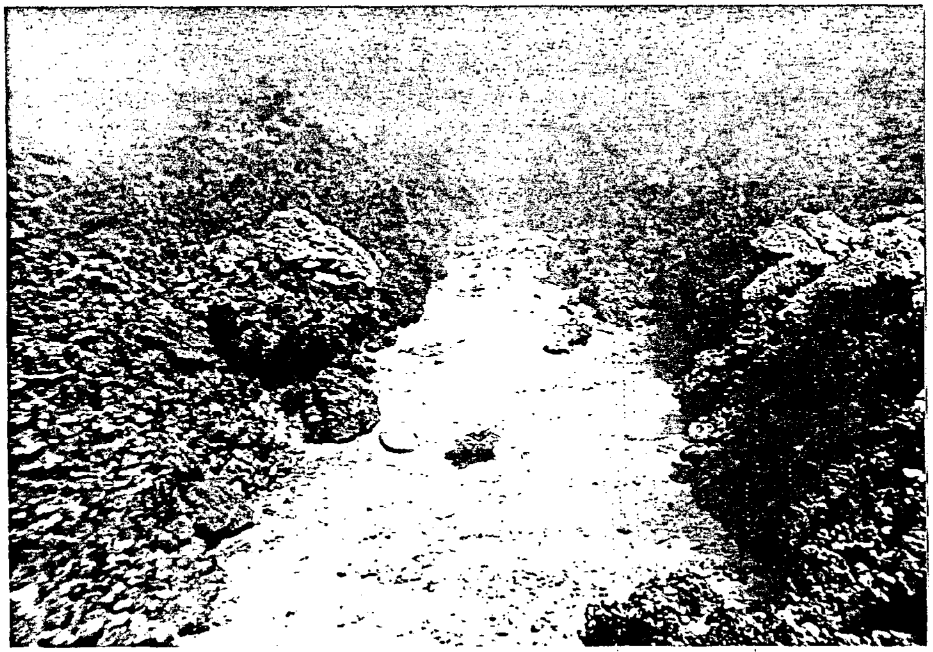
Appendix B
Plates



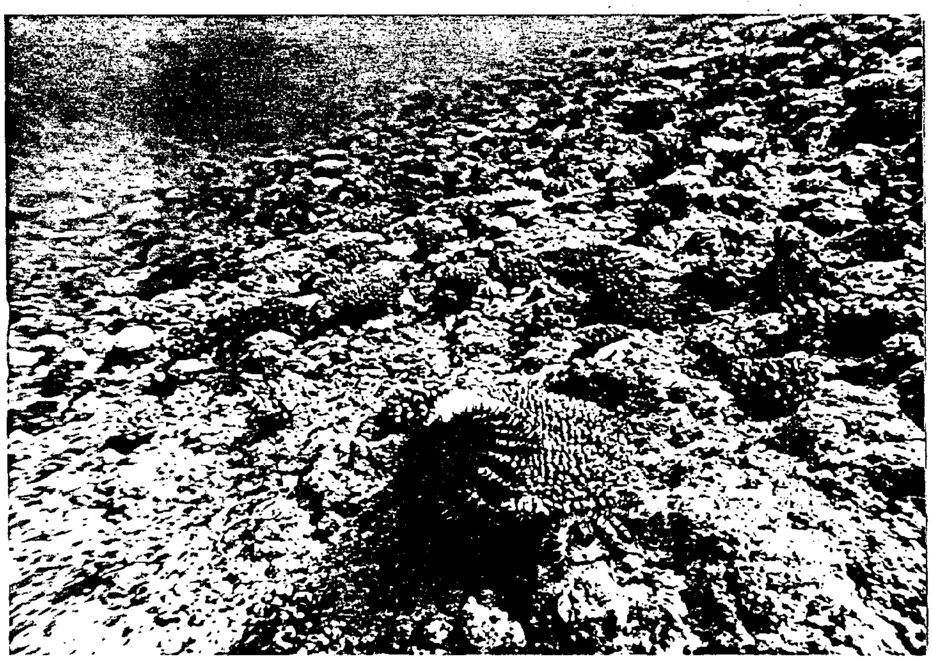
1. View from Puntan Hagman looking down at Site 1, the potential site for the OTEC facility.



2. View from seaward looking in at the potential OTEC site. This was a very calm day with little wave assault.



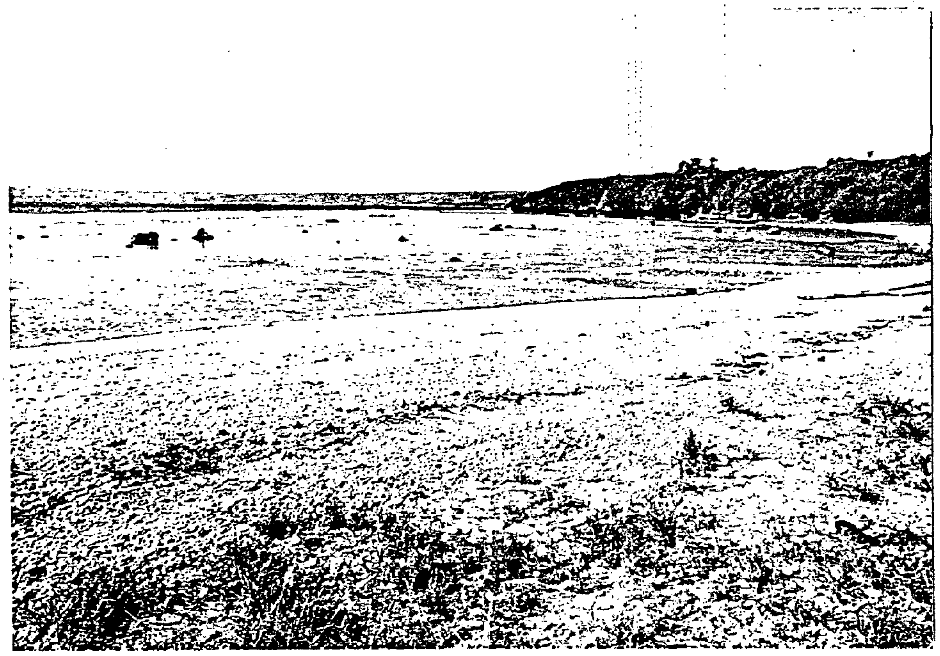
3. One of the numerous sand channels which run perpendicular out from Site 1. The depth here is approximately 60 feet.



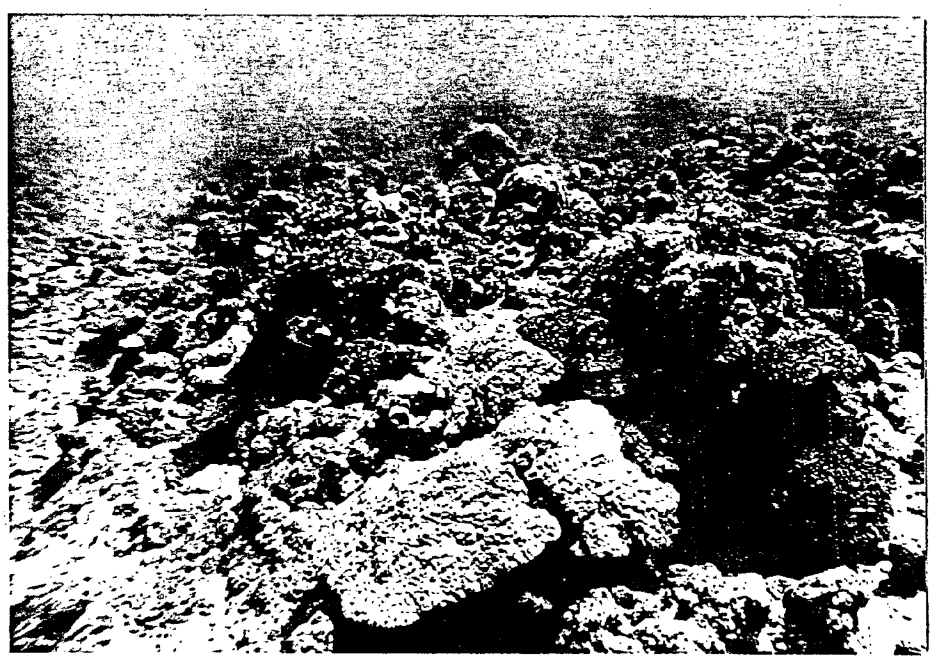
4. The seaward slope just offshore of Site 1. Three *Acanthaster planci* can be seen feeding on the coral in the foreground. Depth here is approximately 30 feet.

5. Site 1a looking north across the reef flat to the sand beaches along the shore.

6. Typical coral formations found at a depth of 25 feet at Site 1a.



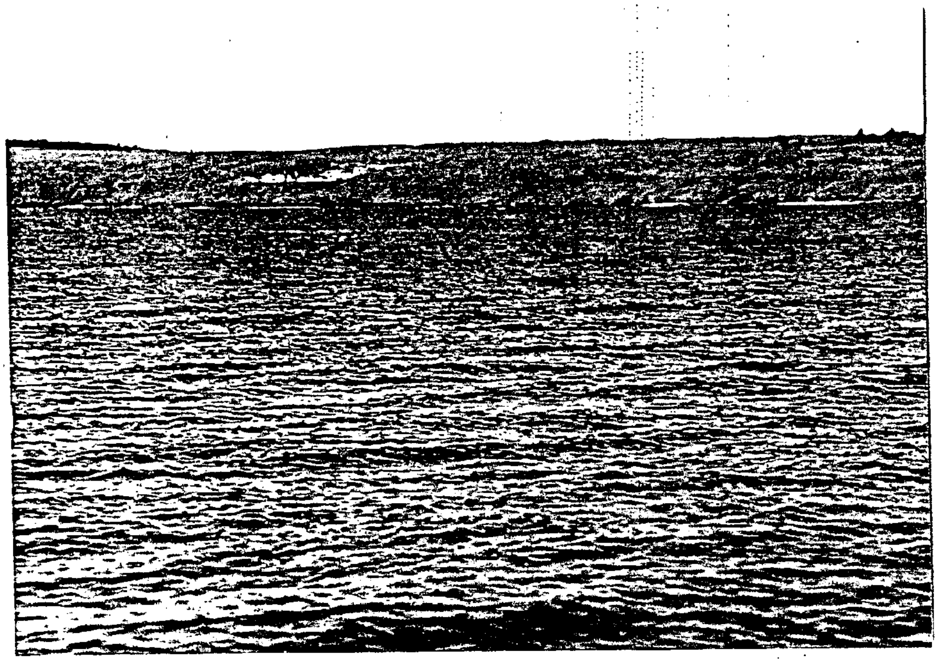
7. Site 2 looking southeast across Bahia Laulau. The cut used for boat and diver access is located between the larger rocks in the left side of the photo.



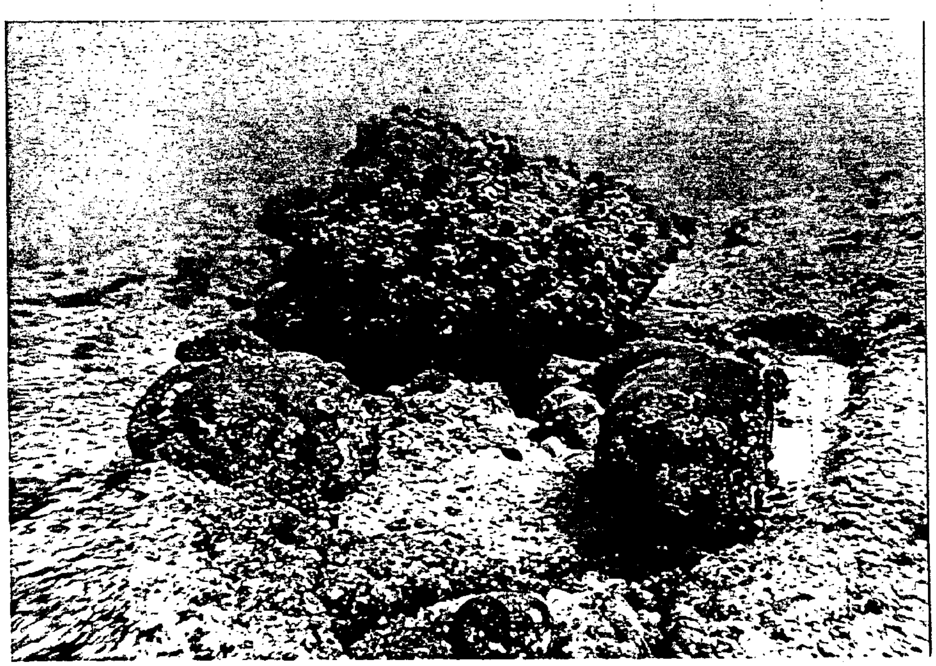
8. Typical coral coverage at Site 2 taken at a depth of 30 feet.

9. Site 3 looking southeast across Bahia Laulau. Chamorro Village restaurant can be seen on the top of the cliff to the right.

10. Typical underwater view taken at a depth of 40 feet at Site 3.



11. Looking south across Bahia Laulau to Site 4. The quarry below the airport is just to the right of Site 4.



12. Underwater view of Site 4 taken at a depth of approximately 50 feet.