ENVIRONMENTAL ASSESSMENT FOR PROPOSED DREDGING OPERATIONS IN YAP LAGOON

RONALD D. STRONG, RICHARD H. RANDALL, THOMAS L. SMALLEY,

BEN BUMOON & OTTO BOWOO

Prepared For

DEPARTMENT OF PUBLIC UTILITIES AND CONTRACTS
FEDERATED STATES OF MICRONESIA
YAP, WCI

Prepared By

PACIFIC BASIN ENVIRONMENTAL CONSULTANTS, INC.

In Cooperation With

UNIVERSITY OF GUAM MARINE LABORATORY

UNIVERSITY OF GUAM MARINE LABORATORY

Technical Report No. 78

January 1982

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

We would like to thank Governor John A. Mangefel who invited us to a Council of Chiefs. At this meeting the scope of work for the study was explained to the various Chiefs and other leaders of the Districts of Yap that we worked in. Governor Mangefel and the Council of Chiefs kindly permitted access to their districts and provided us with valuable background information and history of some of the study sites.

Mr. Richard Folta, Director of Public Utilities and Contracts, and other members of his staff were most helpful from the time we first stepped off the plane, upon our arrival, to the minute we boarded back to Guam. Richard Folta graciously provided us sleeping accommodations in his house and assisted in locating all the field study sites. His knowledge of the past history and customary usage of the various sites was very useful to us as well as the easy and friendly manner in which he furnished us all our various wishes and needs.

Our co-authors Mr. Ben Bumoon and Mr. Otto Bowoo were especially helpful in navigating our boat quickly and safely through the channels and bays and over shallow reef areas. Because of their interests in and knowledge of the valuable natural resources of Yap, it is hoped that they could become more actively involved within the government agency responsible for the use and development of Yap's natural resources.

We are also grateful for the discussion and assistance provided to us by Mrs. Margie Falanruw of the Yap Institute of Natural Science, and for accompanying us to the lagoon sand dredging site.

Without the logistic support of the Department of Marine Resources, in providing us with water transportation, the field work for the project could never have been completed on schedule.

The Department of Land Management was most helpful to us in providing background information, maps and copies of other publications.

A final note of appreciation goes to the people of Yap who were both friendly and helpful to our team.

INTRODUCTION

The State of Yap, Department of Public Utilities and Contracts (PUC), expressed an interest in obtaining a proposal for Yap Lagoon Impact Study to evaluate potential and existing dredging sites scattered around the island. Initial inquiries were sent to the University of Guam Marine Laboratory (UGML) and to Pacific Basin Environmental Consultants (PBEC) in early March 1981. It was decided that PBEC would act as the prime contractor and use the expertise of the UGML as a subcontractor. A formal proposal was prepared and sent to Richard C. Folta, Director of PUC for the State of Yap on April 22, 1981.

Due to excellent cooperation by PUC in providing housing, transportation and other support services, the State of Yap was able to fund the project without outside assistance. A contract was prepared by PBEC and signed by all parties involved in late May 1981.

The field studies were conducted on Yap during the period June 26-July 1, 1981. The three man team from Guam included the following:

Ronald D. Strong, President PBEC, Project Coordinator; Fishes, Currents.

Richard H. Randall, Assistant Professor of Biology, UGML; Corals, Geology.

Thomas Smalley, UGML, Graduate Student; Invertebrates, General Assistance.

In addition to the investigating team members (above) from Guam, two Yapese were observers and assisted with portions of the field evaluations. Mr. Ben Bumoon and Mr. Otto Bowoo received practical training in monitoring currents, sedimentation rates and general biological impacts of activities such as dredging. It is hoped that one or both of these men will be able to work for the government and continue with monitoring and baseline data collection in the lagoonal areas of Yap.

Mr. Richard Folta accompanied the authors to all of the sites which were visited during the five days in the field. In addition, Mrs. Margie Falanruw of the Yap Institute of Natural Science joined the team for one day in the field and provided valuable information pertinent to the study.

The suitability of reef, lagoon, and mangrove areas in Yap for various types of development have been outlined by Tsuda et al. (1978)[1]. The areas studied for this report were restricted to their mangrove, seagrass, and enclosed lagoon habitats, and in general we are in agreement with their suggested uses of these habitats for dredging and filling types of development.

---

1 Tsuda, R. T. [ed.]. 1978. Marine biological survey of Yap Lagoon. Univ. of Guam Marine Lab. Tech. Rept. No. 45. 169 p.

METHODOLOGY

The State of Yap is very interested and concerned about preserving the integrity of its biological systems, particularly in the lagoonal areas which provide subsistence fishing for the majority of the Yapese. Since Yap has no exposed limestone or other suitable rocks for available fill material for roads and other construction activities, most materials must be dredged from the lagoon. In addition to the lagoonal deposits, the government also conducts sand-dredging operations in a shallow part of the lagoon just north of Tomil Channel.

In order to determine the suitability of several locations for obtaining fill material, the investigators visited each site and conducted brief biological and physical studies. At each site, a general reconnaissance was conducted to ascertain the biological community (corals, fishes, macroinvertebrates and marine plants) in and around the proposed or existing dredge area. The shoreline features were noted as well and briefly evaluated for possible impact from dredging operations. In addition, the general suitability of the substrate for use as road base material and for other construction uses was determined where feasible.

Wind direction and currents were noted at most sites, but these were only single or duplicate measurements and not a 24 hour current analysis. Therefore, additional investigation of the current and water movement patterns needs to be accomplished before further dredging or construction of the revetment moles is begun. The use of flourescein dye proved to be the most appropriate technique because of shallow water encountered in most of the locations. Refer to Appendix A for a brief description of how to measure currents using flourescein dye.

The following areas were visited and surveyed for potential (or continuing) use as dredge sites (Figure 1).

1. Kanif (Gaatamoon)
2. Meerur
3. Ngof
4. Balabat
5. Magachaguill (Old Airport Dredge Site)
6. Keng (New Hospital)
7. Dugor
8. Rumw (Northern Yap Island)
9. German Channel
10. Map Bridge
11. Map School
12. Lagoon Sand Dredge Area

The Mitsui Corporation dredging site in Colonia was also visited but no biological or current data were taken. At the time of the survey, (June 26-July 1) a large hole (or holes) was present in the silt curtain used to contain suspended sediments. A large suspended sediment plume was observed moving east and southeast from the silt curtain. The Mitsui Corp.

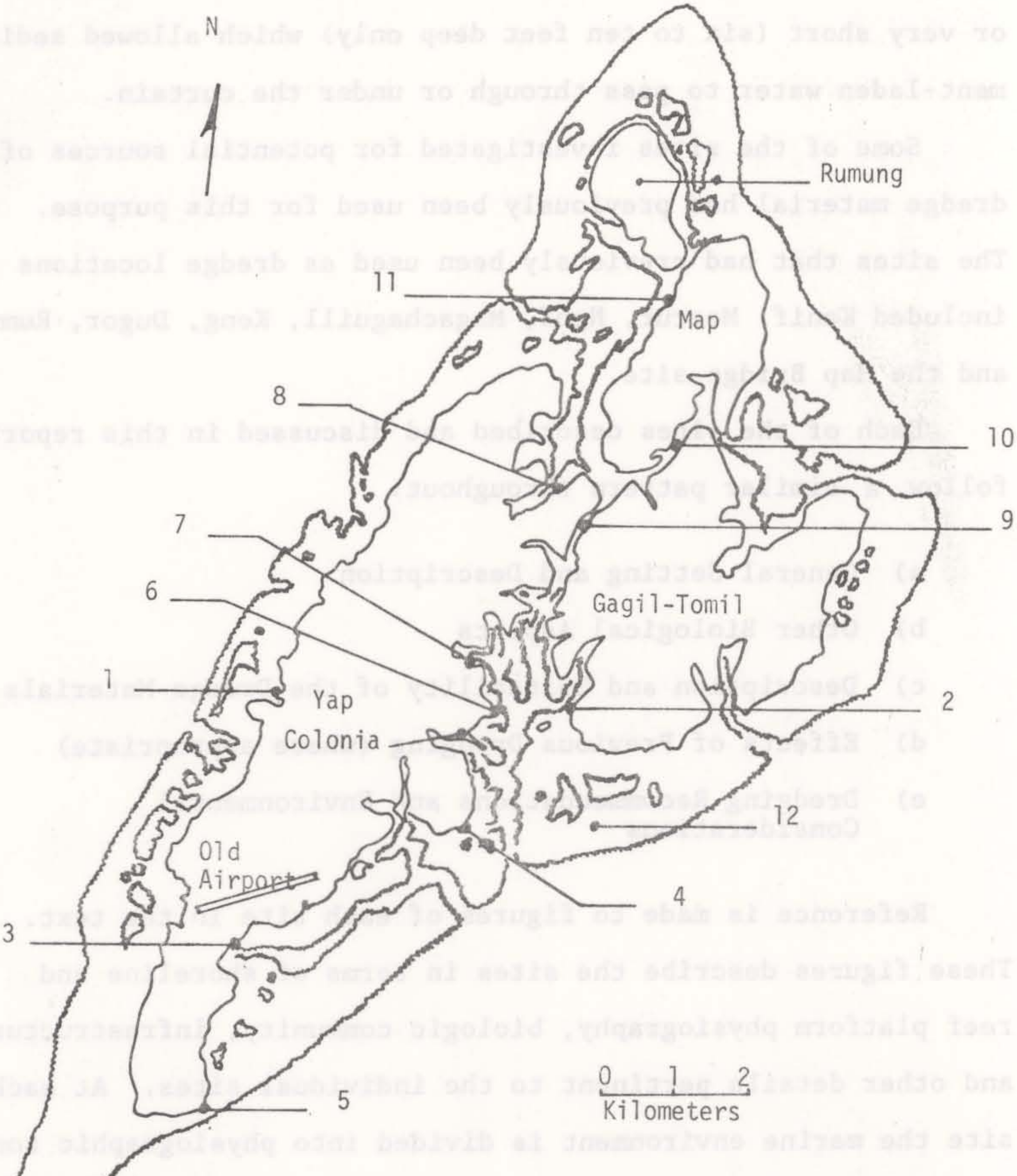

Figure 1. Map of Yap showing study site locations 1-12.

crew appeared to have fixed the problem the next day but many sections of the silt screen were still found to be defective or very short (six to ten feet deep only) which allowed sediment-laden water to pass through or under the curtain.

Some of the sites investigated for potential sources of dredge material had previously been used for this purpose. The sites that had previously been used as dredge locations included Kanif, Meerur, Ngof, Magachaguill, Keng, Dugor, Rumw and the Map Bridge site.

Each of the sites described and discussed in this report follow a similar pattern throughout:

a) General Setting and Description
b) Other Biological Aspects
c) Description and Suitability of the Dredge Materials
d) Effects of Previous Dredging (where appropriate)
e) Dredging Recommendations and Environmental Considerations

Reference is made to figures of each site in the text. These figures describe the sites in terms of shoreline and reef platform physiography, biologic community, infrastructure and other details pertinent to the individual sites. At each site the marine environment is divided into physiographic zones depending on the geologic and biologic nature of the area. Vertical profiles, and in some cases substrata columns, are provided for greater detail and understanding of each site. The sections on Dredge Materials Suitability, Effects of

Previous Dredging and Recommentations contain details necessary to make policy decisions regarding future operations. See Table 1 for a summary of considerations regarding the suitability of each site for dredging operations.

SITE DESCRIPTIONS

SITE 1 - KANIF (Gaatamoon)

General Setting and Description

Site 1 is located on a lagoon fringing reef flat platform along the northwest coast of Yap Island about 2.9 miles north of the old airport area (Figs. 1 and 2). According to Yap Public Works this site was previously dredged to supply calcareous reef deposits for road construction about one year ago. A mole composed of dredged reef platform deposits presently extends outward from the shore approximately 100 meters from the terminus of a road at the shoreline. The outer part of the mole has been partly removed, leaving two small islets with a shallow intertidal zone connecting them to the mole proper. A dredged zone forms a channel around the periphery of the mole about three meters deep at low tide. North and south of the mole a thick veneer of rubbly beach deposits overlies greenschist metamorphic rocks of the Yap formation at the shoreline. Somewhat more distant from the mole the beach deposits grade into a mangrove swamp fringe along the shoreline.

The lagoon fringing reef flat platform is divided into three physiographic zones as follows: 1) an intertidal muddy fringe along the shoreline 2) a wide sandy stretch dominated by seagrasses and algae, and 3) the dredged channel around the periphery of the mole. The physiographic zones, water depth, general characteristics of the reef platform

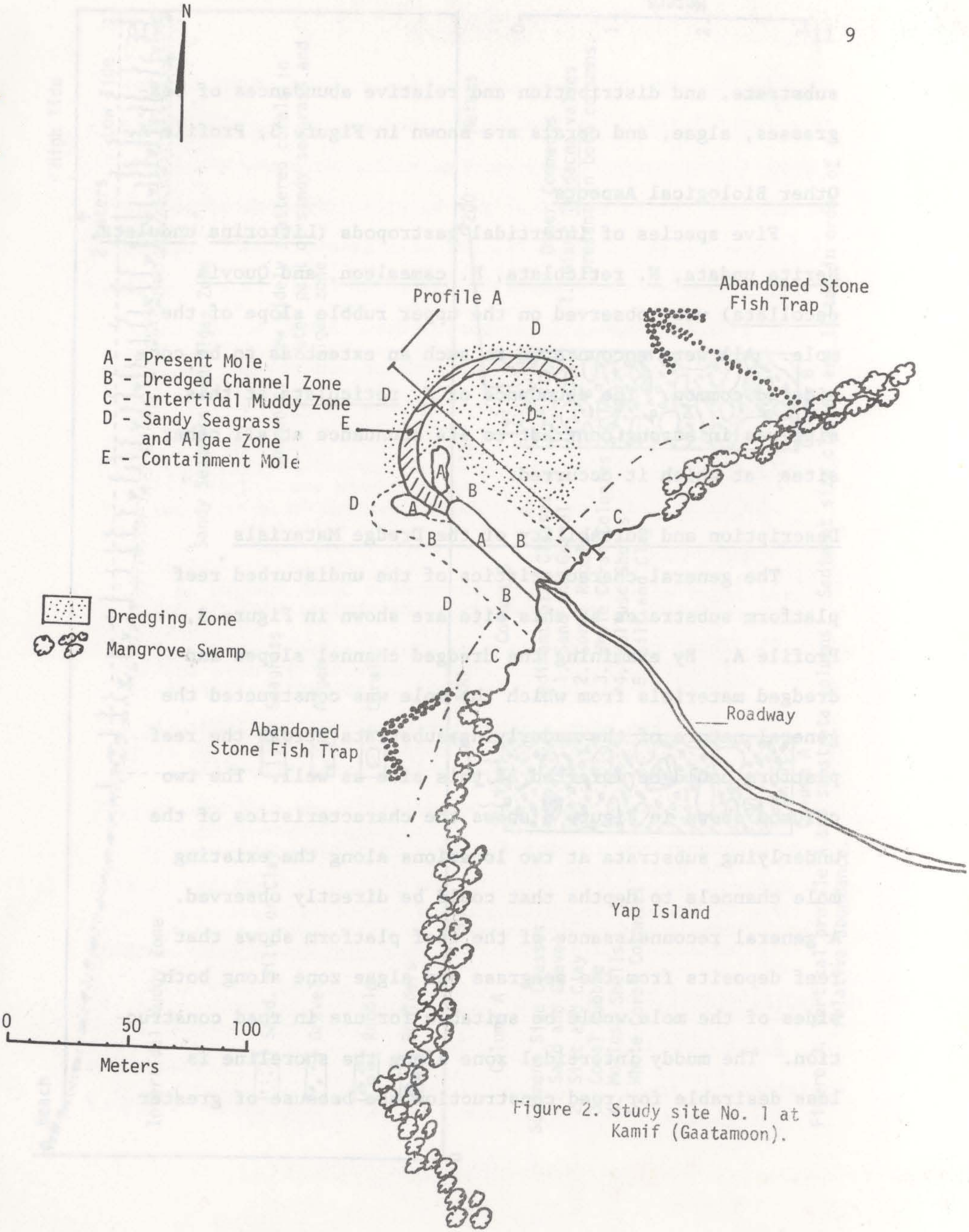

Figure 2. Study site No. 1 at Kamif (Gaatamoon).

substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 3, Profile A.

Other Biological Aspects

Five species of intertidal gastropods (Littorina undulata, Nerita undata, N. reticulata, N. camealeon, and Quoyia decollata) were observed on the upper rubble slope of the mole. All were encountered to such an extent as to be considered common. The abundance of N. reticulata at this site was in strong contrast to its abundance at all other sites at which it occurred.

Description and Suitability of the Dredge Materials

The general characteristics of the undisturbed reef platform substrates at this site are shown in Figure 3, Profile A. By examining the dredged channel slopes and dredged materials from which the mole was constructed the general nature of the underlying substrata across the reef platform could be inferred at this site as well. The two columns shown in Figure 3 shows the characteristics of the underlying substrata at two locations along the existing mole channels to depths that could be directly observed. A general reconnaissance of the reef platform shows that reef deposits from the seagrass and algae zone along both sides of the mole would be suitable for use in road construction. The muddy intertidal zone along the shoreline is less desirable for road construction use because of greater

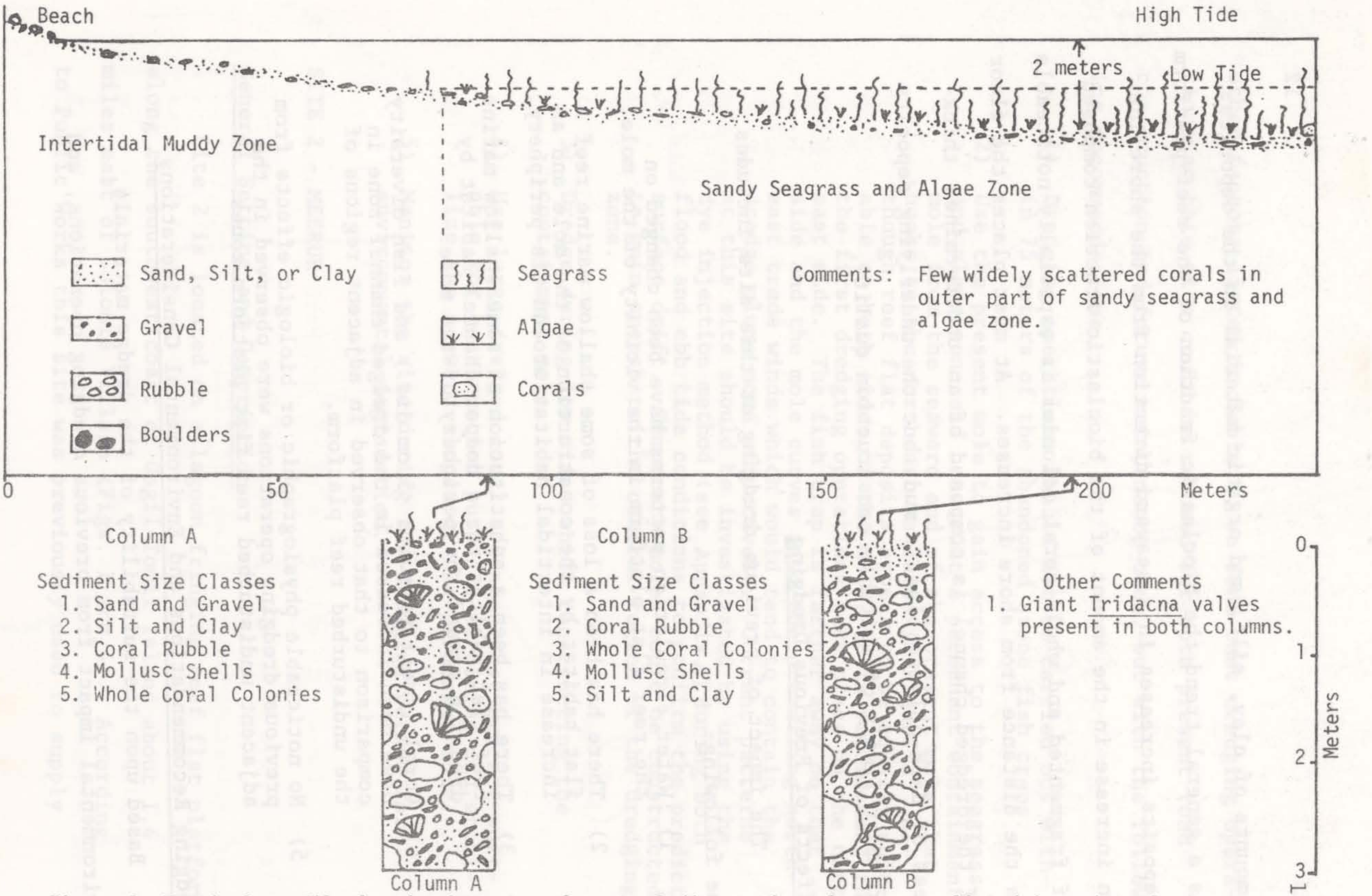

Figure 3. Vertical profile A and substrata columns. Sediment size classes are listed in order of relative abundance.

amounts of clay, silt, and organic material in the deposits. As a general trend the bioclastic fraction of the reef platform deposits increases in a seaward direction from the shoreline. An increase in the amount of the bioclastic fraction composed of fragmented and whole coral colonies is especially noticeable as the distance from shore increases. At most places the floor of the dredged channel is composed of an undetermined thickness of dark-colored plastic mud, but the underlying deposits are most likely of suitable construction quality.

Effects of Previous Dredging

The impact of previous dredging at this site includes the following:

1) Water circulation patterns have been changed on the reef flat platform in the vicinity of the mole.

2) There has been a loss of some shallow marine reef flat habitat by the construction of the mole and an increase in intertidal habitat around its periphery.

3) There has been a substitution of some shallow marine reef flat habitat for a deeper channel habitat by dredging around the periphery of the mole.

4) Coral (small recruits <5 cm dia.) and fish diversity have been increased in the dredged channel zone in comparison to that observed in adjacent regions of the undisturbed reef platform.

5) No noticeable physiographic or biologic effects from previous dredging operations were observed in the adjacent undisturbed reef flat platform zones.

Dredging Recommendations and Environmental Considerations

Based upon the suitability of the dredge materials, environmental impact from previous dredging operations, and other factors listed in Table 1, we find that dredging operations at this site could be resumed for both present road construction and future maintenance uses, but with the following recommendations:

1) Dredging operations should not be carried out within 75 meters of the abandoned stone fish traps.

2) Use the present mole to gain access to the seagrass and algae zone and construct a permanent containment mole from the seaward end of the present mole that hooks to the northeast as shown in Figure 2. Although reef flat deposits appear to be equally suitable on both sides of the mole, it is recommended that the first dredging operations take place on the northeast side. The fish trap is farther away on that side and the mole curves into the prevailing northeast trade winds which would tend to contain the dredge plume more effectively. Current patterns at this site should be investigated by using the dye injection method (see Appendix A) during both flood and ebb tide conditions to confirm the predicted surface drift. Temporary moles could be constructed to gain access to the central region of the dredging zone.

3) Dredge during low tides while constructing the containment mole.

4) Use large dredged coral colonies that are not suitable for construction purposes to riprap and stabilize the seaward slopes of the permanent mole.

5) Monitor the site during the dredging period for environmental degradation.

SITE 2 - MEERUR

<u>General Setting and Description</u>

Site 2 is located on a lagoon fringing reef flat platform along the southwest coast of Gagil-Tomil Island about 1.4 miles east of Colonia Village (Figs. 1 and 4). According to Public Works this site was previously used to supply

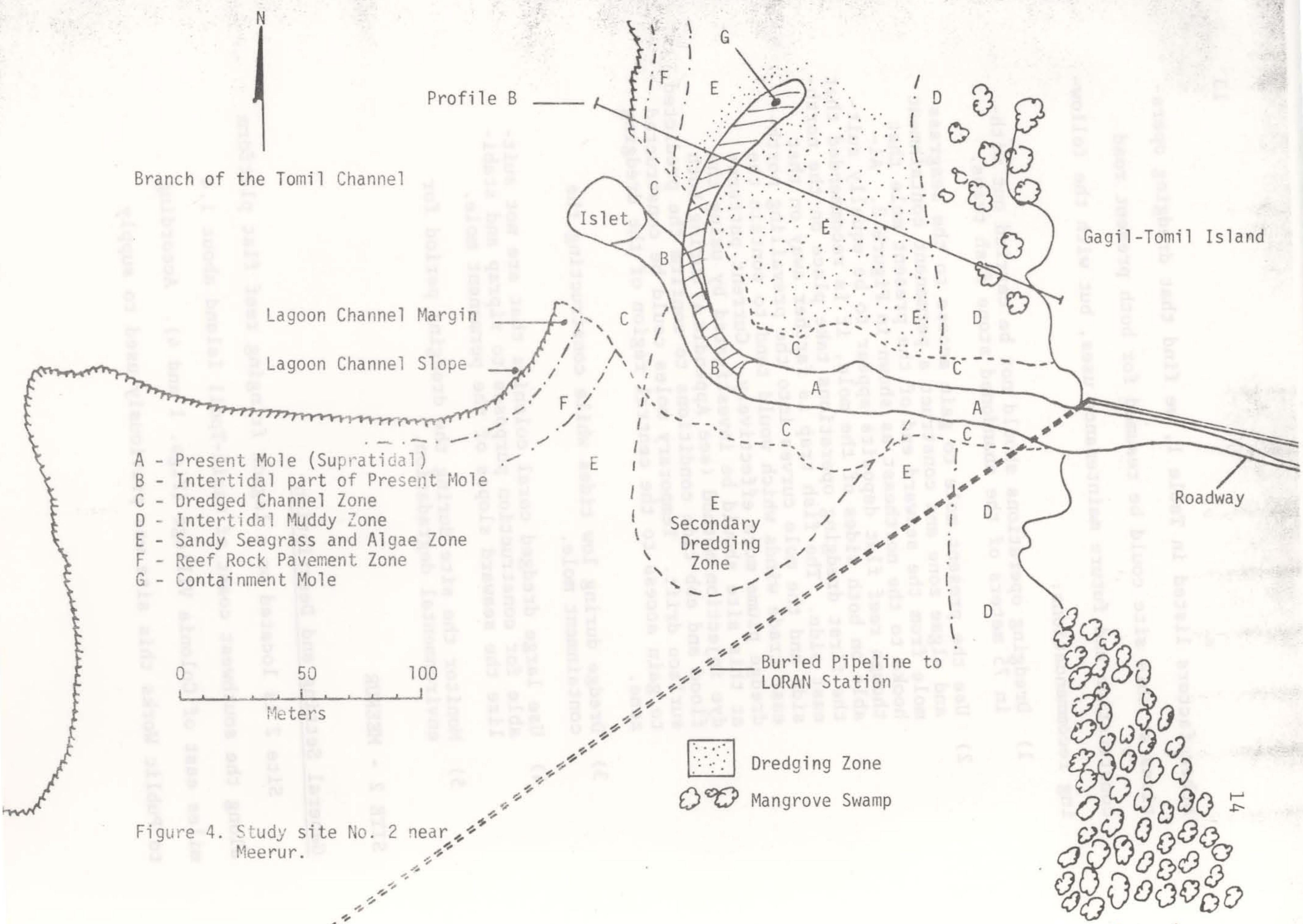

Figure 4. Study site No. 2 near Meerur.

calcareous reef deposits for road construction about four to five years ago. A mole composed of dredged reef platform deposits presently extends 235 meters outward from the shore. The outer half of the mole is covered during high tides and at the extreme seaward end a pile of dredge material forms a small supratidal islet. A dredged zone forms a channel around the periphery of the mole, which at the outer end connects with a branch of the Tomil Harbor Channel. Along the outer half of the mole the channel is three to four meters deep and at the islet where it grades into the Tomil Channel the depth increases to five or six meters. The dredged zone along the south side of the mole serves as a channel and anchorage area for small boats. Several dwellings occupy the immediate shoreline south of the mole. A roadway terminates shoreward of the mole. A burried pipeline that supplies oil to the U. S. Coast Guard LORAN station cuts diagonally across the reef flat platform from the shoreward end of the mole to a tanker terminal pier in the deeper water of Tomil Channel (Fig. 4). The presence of this pipeline reduces considerably the size of the area available for dredging on the south side of the mole. A narrow band of mangrove swamp occupies much of the intertidal coastal platform south of the mole. At the shoreline the mangrove fringe grades into the weathered Tomil volcanics of southern Gagil-Tomil Island. The substrate in the mangrove fringe consists of a marly black muck high in organic content.

The lagoon fringing reef flat platform can be divided into five physiographic zones as follows: 1) an intertidal band dominated by mangrove swamp, 2) a narrow partly intertidal muddy fringe along the mangrove swamp, 3) a wide sandy stretch dominated by scattered seagrass, algae, and a few widely scattered corals that retains a few centimeters of water during low spring tides, 4) a narrow region of reef rock pavement veneered with a thin layer of sand and scattered corals that fringes the rich coral growth along the lagoon slope of Tomil Channel, and 5) the mole and dredged channel around its periphery. The five physiographic zones, water depth, general characteristics of the substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 5, Profile B.

Other Biologic Aspects

The most conspicuous macroinvertebrates were the echinoderms. The most abundant of these were the holothuruian Stichopus variegatus followed the echinoid Protoreaster nodosus. Less common were the holothurians Holothuria atra and H. edulis as well as the echinoid Culcita novaeguineae. The greatest numbers of these species occurred on the south and southwest side of the mole on the rubble covered slope of the dredged channel. In addition Lambis lambis was observed on the rubble covered slope. Stichopus variegatus and P. nodosus were the only two echinoderms observed on the opposite side of the mole in an adjacent seagrass bed and on the rubble covered

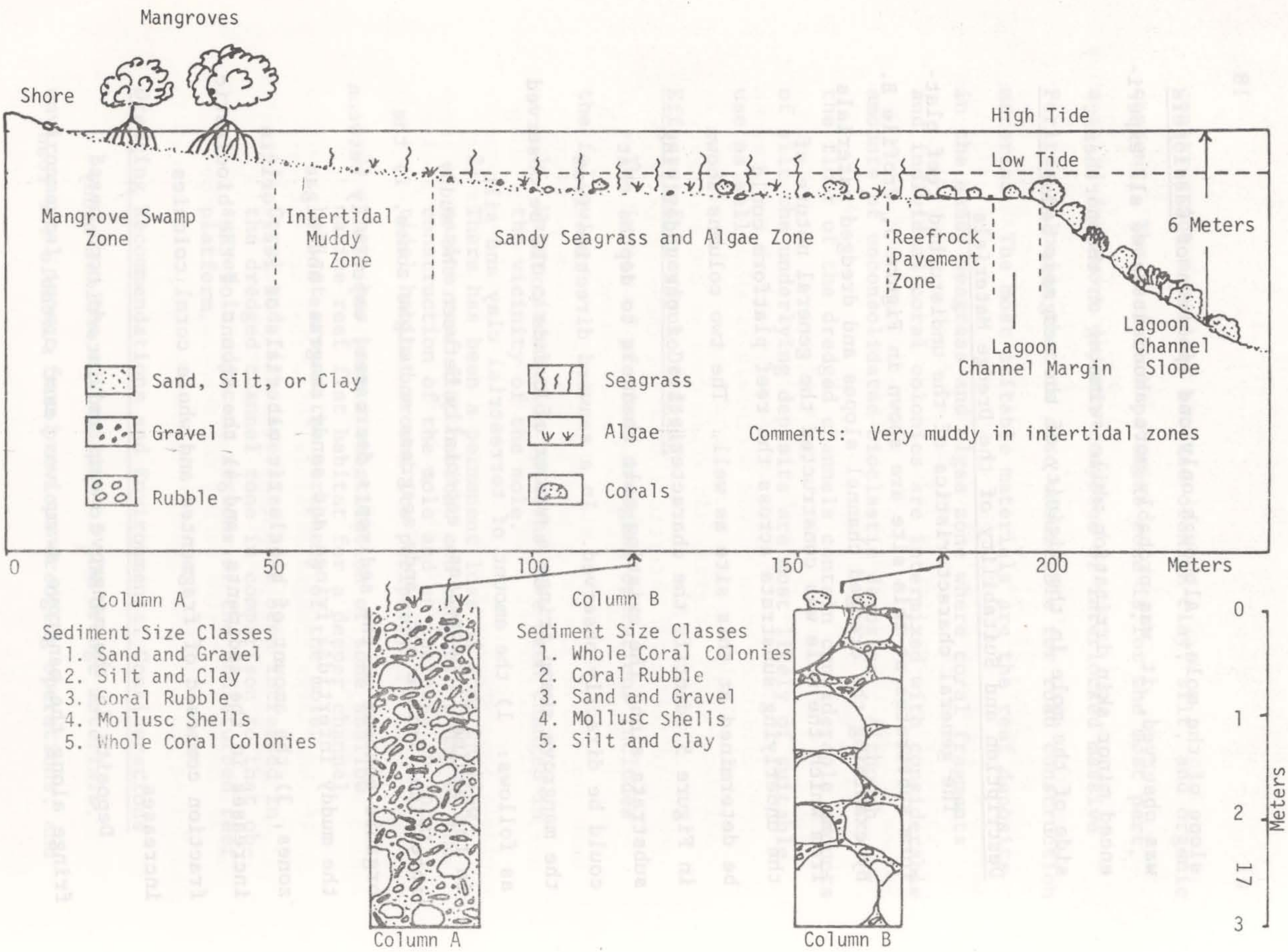

Figure 5. Vertical profile B and substrata columns. Sediment size classes are listed in order of relative abundance.

slope of the mole. Although only one specimen of Cassiopeia was observed, it was probably more abundant as we all experienced minor skin irritation while swimming on the northeast side of the mole in the vicinity of the seagrass beds.

Description and Suitability of the Dredge Materials

The general characteristics of the undisturbed reef platform substrates at this site are shown in Figure 5, Profile B. By examining the dredged channel slopes and dredged materials from which the mole was constructed the general nature of the underlying substrata across the reef platform could be determined at this site as well. The two columns shown in Figure 5 identify the characteristics of the underlying substrata along the existing mole channels to depths that could be directly observed. In a seaward direction from the mangrove swamp fringe a number of trends could be observed as follows: 1) the amount of terrestrial clay and silt in the sediments decreases, especially between the muddy intertidal fringe and sandy seagrass and algae zones, 2) the organic content of the sediments decreases, especially between the muddy intertidal fringe and sandy seagrass and algae zones, 3) the amount of bioclastic materials of reef origin increases in the sediments, and 4) the amount of the bioclastic fraction composed of fragmented and whole coral colonies increases.

Deposits in the mangrove swamp and intertidal muddy fringe along the mangrove swamp are least suitable for road construction materials because of high clay, silt, and organic content. The reef rock pavement zone is, for the most part, a solid framework deposit composed of interlocked massive Porites colonies that is also unsuitable for road construction material. The most suitable materials are the reef deposits in the sandy seagrass and algae zone where coral fragments and individual coral colonies are intermixed with considerable amounts of unconsolidated bioclastic deposits. Although the floor of the dredged channels contain considerable amounts of silt, the underlying deposits are most likely of suitable use as well.

Effects of Previous Dredging

The impact of previous dredging operations includes the following:

1) Water circulation patterns have been changed in the vicinity of the mole.

2) There has been a permanent loss of some shallow marine reef flat habitat and mangrove swamp by the construction of the mole and an increase in intertidal habitat around its periphery.

3) There has been a substitution of some shallow marine reef flat habitat for a deeper channel habitat around the periphery of the mole.

4) Coral and fish diversity have been increased in the dredged channel zone in comparison to that observed in adjacent regions of the undisturbed reef platform.

Dredging Recommendations and Environmental Considerations

Based upon the suitability of the dredge materials, environmental impact from previous dredging operations, and other factors listed in Table 1, we feel that dredging operations at this site could be resumed for both present road construction and future maintenance uses, but with the following recommendations:

1) Because of the presence of the buried LORAN pipeline on the southeast side of the present mole it is recommended that dredging operations be first carried out on the north side, and if further materials are needed limited dredging can be conducted in the south side. If the south side is used, clearly mark the route of the pipeline and dredge no closer than 20 meters of it.

2) Use the present mole to gain access to the sandy seagrass and algae zone and construct a permanent containment mole from the seaward end of the present mole that hooks to the northeast as shown in Figure 4. Dredging operations should be restricted to the sandy seagrass and algae zone as the sediments contain too much clay, silt and organic material in the muddy intertidal zone and there is too much solid reef framework development in the reef rock pavement zone. The mole hooked either to the northeast or southeast will protect the rich coral growth found on the outer part of the reef rock pavement zone and lagoon slope from the dredge plume. Additional current studies should be conducted by using the dye injection method (see Appendix A) during both flood and ebb tide conditions to confirm the predicted surface drift. Temporary moles could be constructed to gain access to the central region of the dredging zone.

3) Dredge during low tides while constructing the containment mole.

4) Use large dredged coral colonies that are not suitable for construction purposes to riprap and stabilize the seaward slope of the permanent mole.

5) Monitor the site during the dredging period for environmental dregadation.

SITE 3 - NGOF

General Setting and Description

Site 3 is located on a lagoon fringing reef flat platform along the southeast coast of Yap Island about 0.8 miles south of the present airport runway (Figs. 1 and 6). A fringe of mangrove swamp and a few small isolated mangrove islets occupy much of the intertidal coastal platform. At the shoreline the mangrove fringe is boardered by a narrow alluvial zone which in turn grades into the weathered Tomil volcanics of southern Yap Island farther inland. The alluvial zone is composed mostly of a marly clay high in organic content and predominantly covered with forest growth, but with some local mucky and swampy patches present as well.

According to Public Works this site was previously used to supply calcareous reef deposits for airstrip construction about ten years ago. A mole composed of dredged reef platform deposits presently extends 400 meters outward from the shore. The outer end of the mole hooks toward the north and presently is in the process of being removed to sea level by Navy Seabee construction crews to obtain road building materials. A dredged zone forms a channel around the peripery of the mole, which at the outer end connects with the shallow southwestern branch of the Gobach Channel. During low tides the peripheral dredged channel ranges in depth from six to eight meters at the seaward end of the mole to a meter or less where it

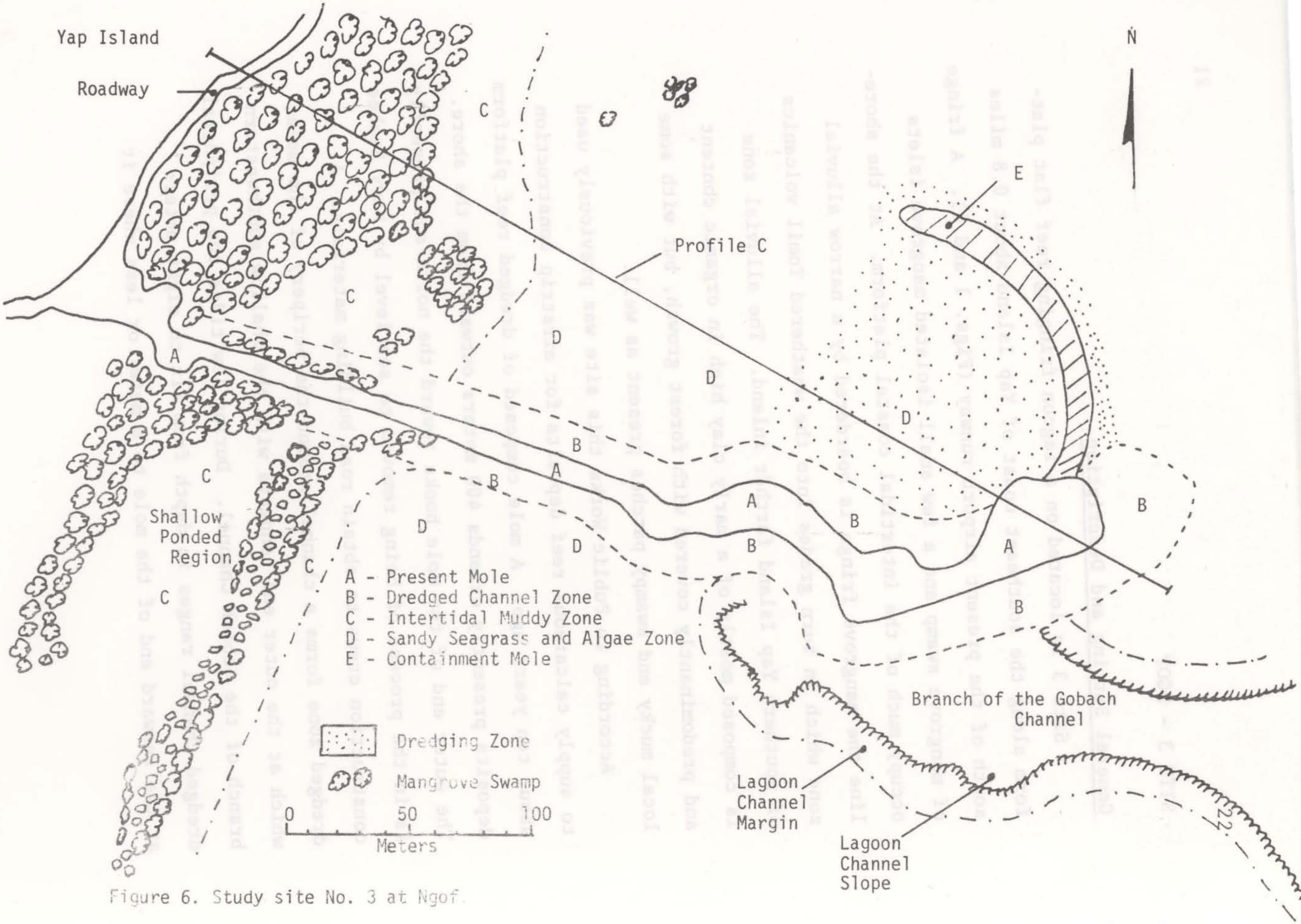

Figure 6. Study site No. 3 at Ngof.

grades into mangrove swamp near the shore. An old, badly deteriorated seawall, now extensively covered with mangrove growth, extends outward from the south side of the mole forming a shallow ponded region between it and the mangrove fringe along the shoreline. According to Edward Falanruw this seawall is of pre Japanese construction and was probably used as an access to the Gobach Channel. Near the mole the old seawall is constructed mostly of massive Porites colonies. Mangrove growth has also become established at a number of locations on the lower sides of the mole along the shoreward third of its length as well.

The lagoon fringing reef flat platform can be divided into four physiographic zones as follow: 1) an intertidal band dominated by mangrove swamp, 2) a narrow partly intertidal muddy fringe along the mangrove swamp (including the ponded region on the south side of the mole), 3) a wide sandy stretch dominated by seagrass and algae which for the most part retains a few centimeters of water during low spring tides, and 4) the mole and deeper dredged channels around its periphery. The four physiographic zones, water depth, general characteristics of the substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 7, Profile C.

Other Biologic Aspects

The hermit crab, Calcinus laevimanus, was the most conspicuous and abundant macroinvertebrate at the dredge site,

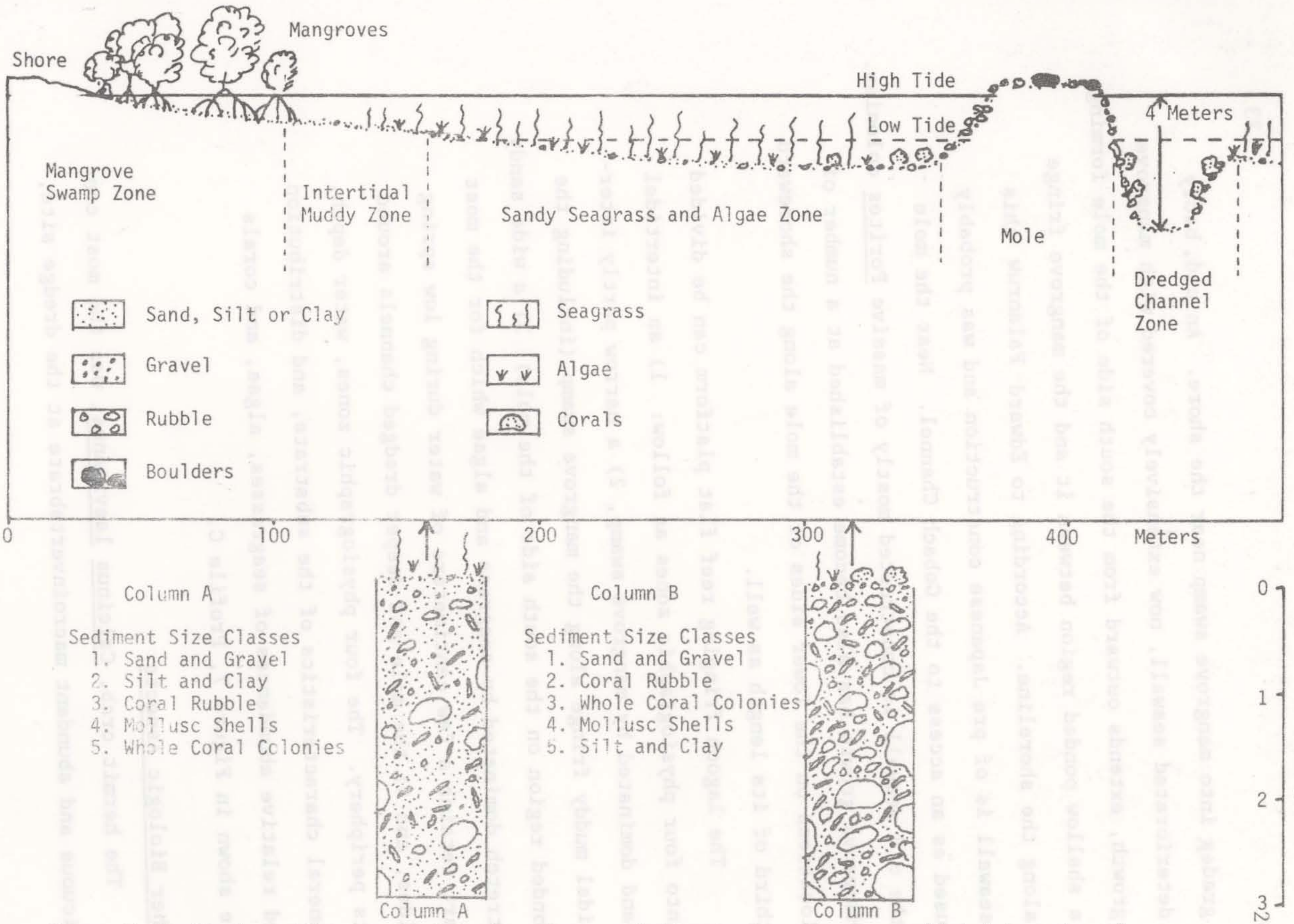

Figure 7. Vertical profile C and substrata columns. Sediment size classes are listed in order of abundance.

occurring among rubble between the high and low water marks on the mole. Four species of intertidal gastropods were also moderately common on the shore of the mole; Nerita plicata, N. undata, Littorina undulata and Quoyia decollata.

At its landward end the mole bisects a stand of mangroves composed of at least two Rhizophora species and the large white mangrove Sonneratia alba. Inhabiting the mangrove and restricted to the root system were four species of gastropods. Of these Clypeomorus patulus and C. trailii were the most common while Littorina scabra and Nerita greyana were rather uncommon. In addition, the hermit crab Clibinarius striolatus was also common on the roots, inhabiting the shells of C. patulus and C. traillii.

The extensive seagrass beds, composed of Enhalus acoroides and Thalassia hemprichii, provided a habitat for a number of macroinvertebrates, the most conspicuous and common of which were Holothuria atra, H. edulis, Cypraea tigris and Cassiopeia (cf. medusa Light).

Description and Suitability of Dredge Materials

The general characteristics of the undisturbed reef platform substrates at this site are shown in Figure 7, Profile C. By examining the dredged channel slopes and dredged materials from which the mole was constructed the general nature of the underlying substrata along the reef platform could be determined at this site as well. The two columns shown in Figure 7 give the characteristics of the underlying substrata along the existing mole channels to depths that could be directly observed. In a seaward direction from the mangrove swamp fringe a number of trends can be observed as follows: 1) the amount of terrestrial clay and silt in the sediments decreases, 2) the organic content of the sediments decreases, 3) the amount of bioclastic materials of reef origin increases, and 4) the amount of the bioclastic fraction composed of fragmented and whole coral colonies increases.

Deposits in the mangrove swamp and narrow intertidal muddy fringe zones are least suitable for road construction materials because of high clay, silt, and organic content. The remaining reef deposits of the wide zone dominated by seagrasses and algae are the most suitable, especially those from the outer half of the zone where coral rubble constitutes a large fraction of the sediments. Although the dredged channel floor is composed of an undetermined thickness of dark colored plastic mud, the underlying deposits are most likely of suitable construction quality as well.

Effects of Previous Dredging

The impact of previous dredging at this site include the following:

1) Water circulation patterns have been changed on the reef flat platform in the vicinity of the mole.
2) There has been a loss of some shallow marine reef flat habitat and mangrove swamp by the construction of the mole and an increase in intertidal habitat around its periphery.

3) There has been a substitution of some shallow marine reef flat habitat for a deeper channel habitat by dredging around the periphery of the mole.

4) The original mangrove swamp area removed by dredging has been recolonized by mangroves as well as part of the intertidal region along the inner third of the mole.

5) Coral and fish diversity have been increased in the dredged channel zone in comparison to that observed in adjacent regions of the undisturbed reef platform.

6) No noticeable physiographic or biologic effects from previous dredging operations were obeved in the adjacent reef flat platform zones.

Dredging Recommendations and Environmental Considerations

Based upon the suitability of the dredge materials, environmental impact from previous dredging operations, and other factors listed in Table 1, we feel that dredging operations at this site could be resumed for both present road construction and future maintenance uses, but with the following recommendations:

1) Dredging operations be conducted on the north side of the mole in the wide seagrass and algae zone. This side is shallower, has fewer scattered corals, and the substrate is less silty than the south side.

2) Use the present mole to gain access to the wide seagrass and algae zone to construct a permanent containment mole from the seaward end of the present mole that hooks to the northwest as shown in Figure 6. We recommend hooking this mole to the northwest because currents on the shallow reef platform were found to be primarily influenced by the direction of the wind (assuming that the NE Trades are the prevailing winds). Additional current patterns should be investigated by using the dye injection method (see Appendix A) during both flood and ebb tide conditions. Hooking the containment mole to the northwest would also tend to restrict movement of the dredge plume into Goback Channel where extensive coral growth was found. Temporary moles could be constructed outward from the permanent mole to gain access to the central region of the dredging site.

3) Dredge during low tides while constructing the containment mole.

4) Use large dredged coral heads that are not suitable for construction purposes to riprap and stabilize the seaward slopes of the permanent moles.

5) Monitor the site during the dredging period for environmental degradation

SITE 4 - BALABAT

General Description and Setting

Site 4 is located on a lagoon fringing reef flat platform along the eastern coast of Yap Island about 1.2 miles south of Colonia (Figs. 1 and 8). There has been no previous dredging at this site. The coastline forms a small embayment about 100 meters across. At the head of the embayment the shoreline has been disturbed somewhat by road construction. A narrow beach composed of a rubbly mixture of bioclastic and greenschistose deposits border the shoreline at the head of the bay. The beach deposits in turn grade into metamorphic rocks of the Yap formation along the coast. Several green-schist outcrops were noted along the shoreline and at two locations similar rocks form rocky islets on the reef flat platform. Within the small embayment the water had a foul smell and contained considerable amounts of organic material and floating trash. Emptying into the bay were several small ditches that drain inhabitated areas along the shore and appeared to be carrying significant amounts of sewage.

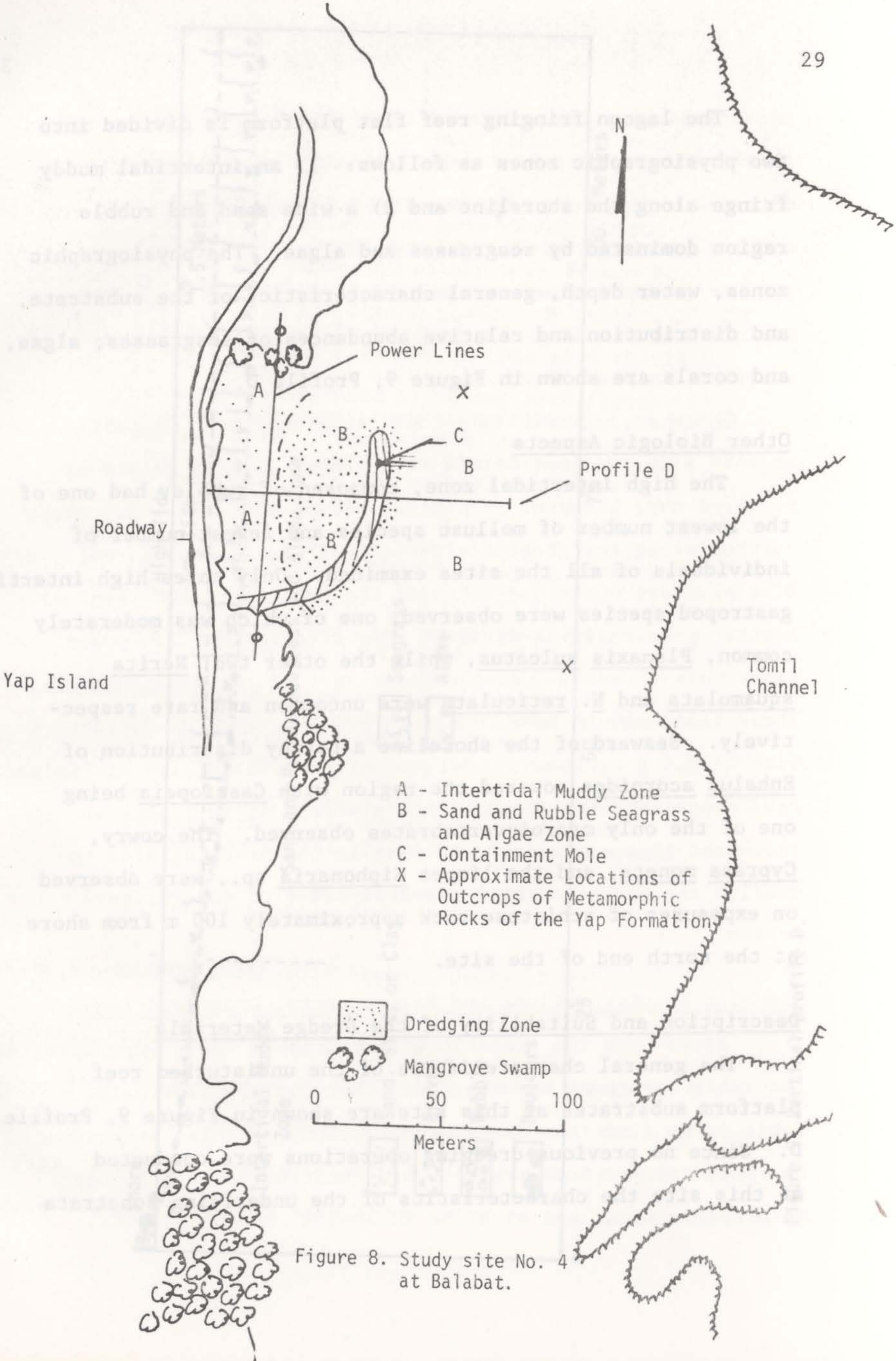

Figure 8. Study site No. 4
at Balabat.

The lagoon fringing reef flat platform is divided into two physiographic zones as follows: 1) an intertidal muddy fringe along the shoreline and 2) a wide sand and rubble region dominated by seagrasses and algae. The physiographic zones, water depth, general characteristics of the substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 9, Profile D.

Other Biologic Aspects

The high intertidal zone, composed of rubble, had one of the lowest number of mollusc species and fewest number of individuals of all the sites examined. Only three high intertidal gastropod species were observed, one of which was moderately common, Planaxis sulcatus, while the other two, Nerita squamulata and N. reticulata were uncommon and rare respectively. Seaward of the shoreline a patchy distribution of Enhalus acoroides covered the region with Cassiopeia being one of the only macroinvertebrates observed. The cowry, Cypraea moneta, and the limpet Siphonaria sp., were observed on exposures of schistose rock approximately 100 m from shore at the north end of the site.

Description and Suitability of the Dredge Materials

The general characteristics of the undisturbed reef platform substrates at this site are shown in Figure 9, Profile D. Since no previous dredging operations were conducted at this site the characteristics of the underlying substrata

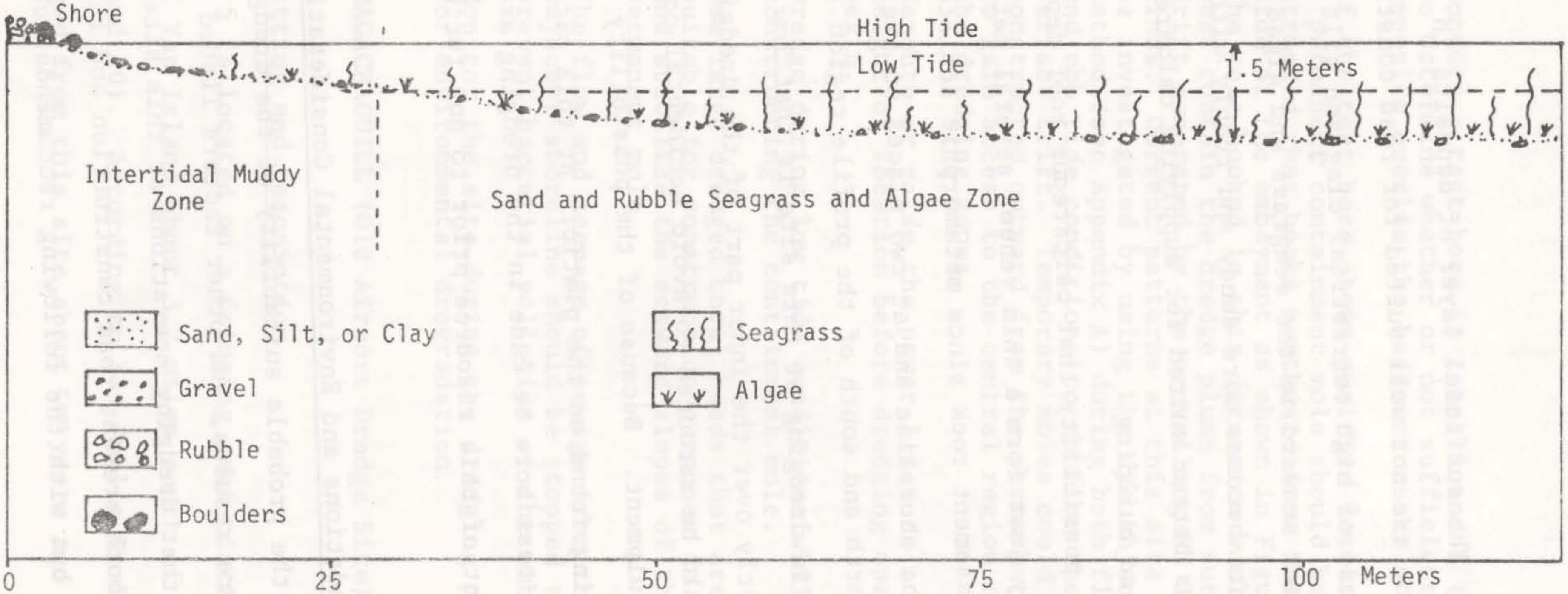

Figure 9. Vertical profile D.

are not known. The surficial layer of deposits in the intertidal muddy zone are not well suited for road construction materials because of high terrestrial clay and silt and organic content. Farther seaward in the seagrass and algae zone surface sediments becomes more sandy and rubbly with less mud and are thus better suited for supplying calcareous deposits for road building.

There is a possibility that calcareous reef deposits at this site may just form a thin veneer several meters or so thick over basement rock since metamorphic schistose rocks outcrop along the shoreline and at two places on the reef flat platform north and south of the profile region (Fig. 8). Another problem in dredging at this site is that low power lines pass directly over the inner part of the dredging area. These lines should be rerouted to avoid accidental contact with dredging equipment. Because of the possibility of limited reef deposits being found on the platform at this site we recommend that a test bore be made in the dredging area to confirm the extent of this resource prior to any further action.

Dredging Recommendations and Environmental Considerations

Based upon the probable suitability of the dredge materials, favorable test bore results, and other factors listed in Table 1, we find that dredging operations at this site could be conducted for both present road construction and future maintenance uses, but with the following recommendations:

1) Conduct a test bore in zones A and B (Fig. 8) to determine whether or not sufficient reef deposits overlie the basement rocks.

2) If the test bore shows positive results a permanent containment mole should be constructed that hooks northward from the south side of the embayment as shown in Figure 8. The mole hooked in this direction would best contain the dredge plume from surface drift generated by the prevailing NE Trade winds. Current patterns at this site should be investigated by using the dye injection method (see Appendix A) during both flood and ebb tide conditions to confirm the predicted surface drift. Temporary moles could be constructed outward from the permanent mole to gain access to the central region of the dredging zones.

3) Reroute or raise the power lines to a safe height or location before dredging operations begin.

4) Dredge during low tide conditions while constructing the containment mole.

5) Use large dredged coral heads that are not suitable for construction purposes to riprap and stabilize the seaward slopes of the permanent mole.

6) The flow and seepage of sewage from the adjacent shoreline should be stopped to prevent bacterial pollution of the embayment.

7) Monitor the site during the dredging period for environmental dregradation.

SITE 5 - MAGACHAGUILL (Old Airport Dredge Site)

General Setting and Description

Site 5 is located on a fringing reef platform at the southern tip of Yap Island about 3.2 miles south of the old airport (Figs. 1 and 10). According to Yap Public Works, reef deposits were dredged from this site about ten years ago in conjunction

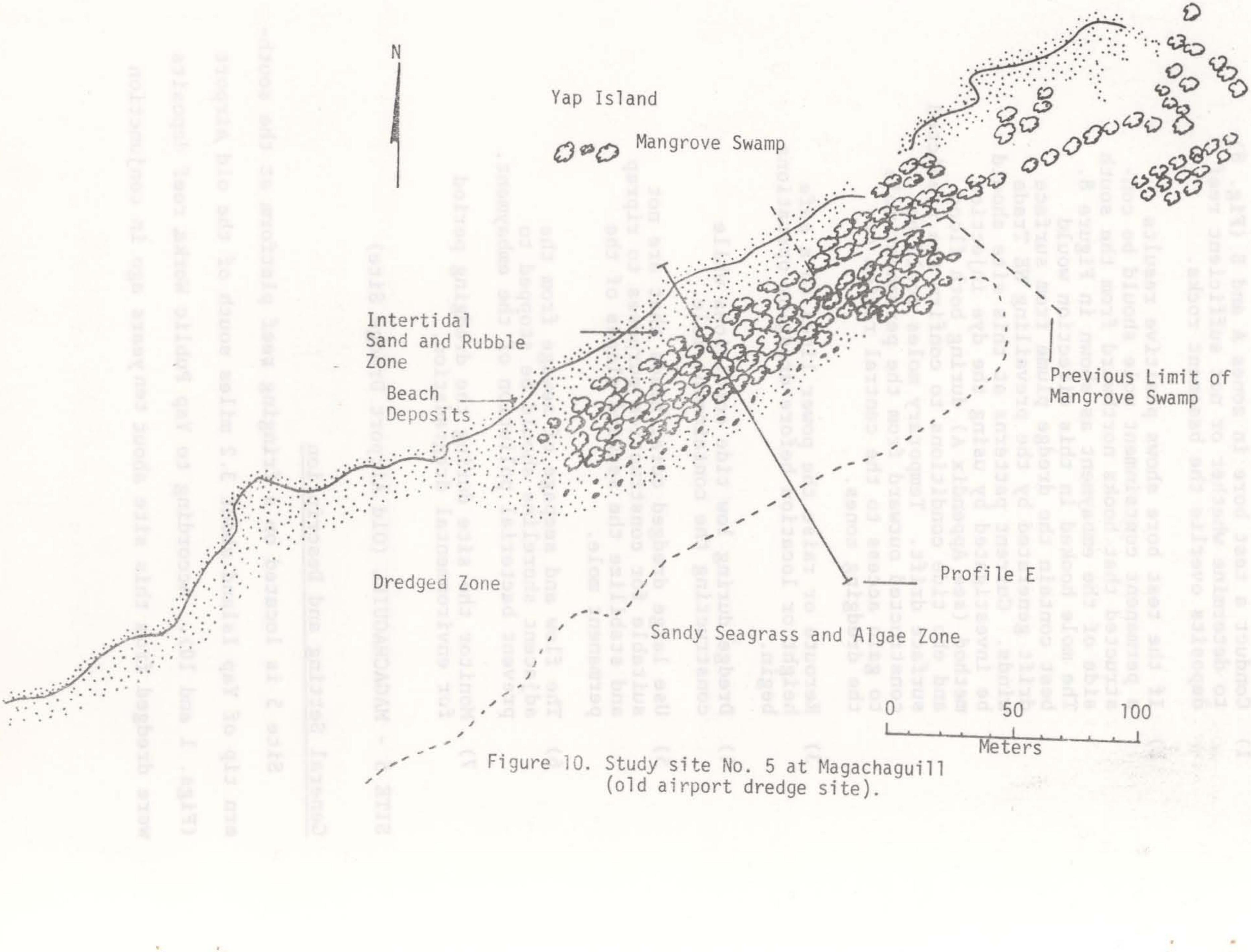

Figure 10. Study site No. 5 at Magachaguill (old airport dredge site).

with the construction of the old airport. Although no new dredging is being considered at this site, a reconnaissance of the general area was made to assess the effects of dredging on the shallow reef flat platform ten years ago.

Description of the Reef Platform Prior to Dredging

The general nature of the marine environment at this site before dredging was reconstructed by making observations along the undisturbed inner part of the reef platform and shoreline northeast of the dredged zone and on the undisturbed platform on the seaward side of the dredged zone. Several residents from an adjacent village also provided information about the region before dredging. The marine habitat apparently consisted of a shallow fringing reef flat platform dominated by seagrasses and algae. Bioclastic deposits of reef origin formed a narrow beach and intertidal sand zone along the shoreline instead of mangrove swamp. The unstable intertidal sand zone and paucity of terrestrial clay and silt in the deposits probably prevented mangroves from becoming established.

Effects of Previous Dredging

Dredging operations at this site were conducted from the shoreline or from temporary moles that paralleled the shoreline, rather than from moles that extended outward onto the reef platform. Such methods of dredging are not feasible at most locations on Yap because mangrove swamp borders much of the shoreline.

Changes in the marine environment are most noticeable at the northeast end of the dredged channel where a sizeable stand of mangroves have become established. The physiographic zones, water depth, general characteristics of the substrate, and distribution and relative abundances of seagrasses, algae, and corals for the northeastern end of the dredged channel are shown in Figure 11, Profile E. An assessment of the dredged regions revealed the following:

1) The dredge zone forms a channel three to five meters deep that parallels the shoreline. The channel floor is composed of a dark-colored plastic mud and is somewhat undulatory because of bioturbation. Both the landward and seaward sides of the dredged channel are relatively steep and mostly composed of sand-sized sediments intermixed with abundant coral boulders and rubble, mollusc shells, and Halimeda segments.

2) Along the northeast end of the dredged channel mangrove trees up to eight meters in height have become established over an intertidal zone of dredged rubble and boulders. Substrate stability of this rocky intertidal zone has probably allowed mangroves to become established. Mangroves have failed to become established in the less stable intertidal sand and rubble zone.

3) Corals are absent in the undisturbed sand seagrass and algae zone, but in the deeper waters of the dredged channel ten species have colonized the boulder and rubble substrates where the channel slopes are stable. Colonies up to 50 cm in diameter were observed in the vicinity of Profile E. Fleshy algae is also present on channel slopes.

4) Fish diversity is higher in the channel than on the adjacent shallow reef flat platform.

5) At a few places seagrasses have become established on the channel slopes and a few widely scattered clumps were also observed on shallower parts of the muddy channel floor.

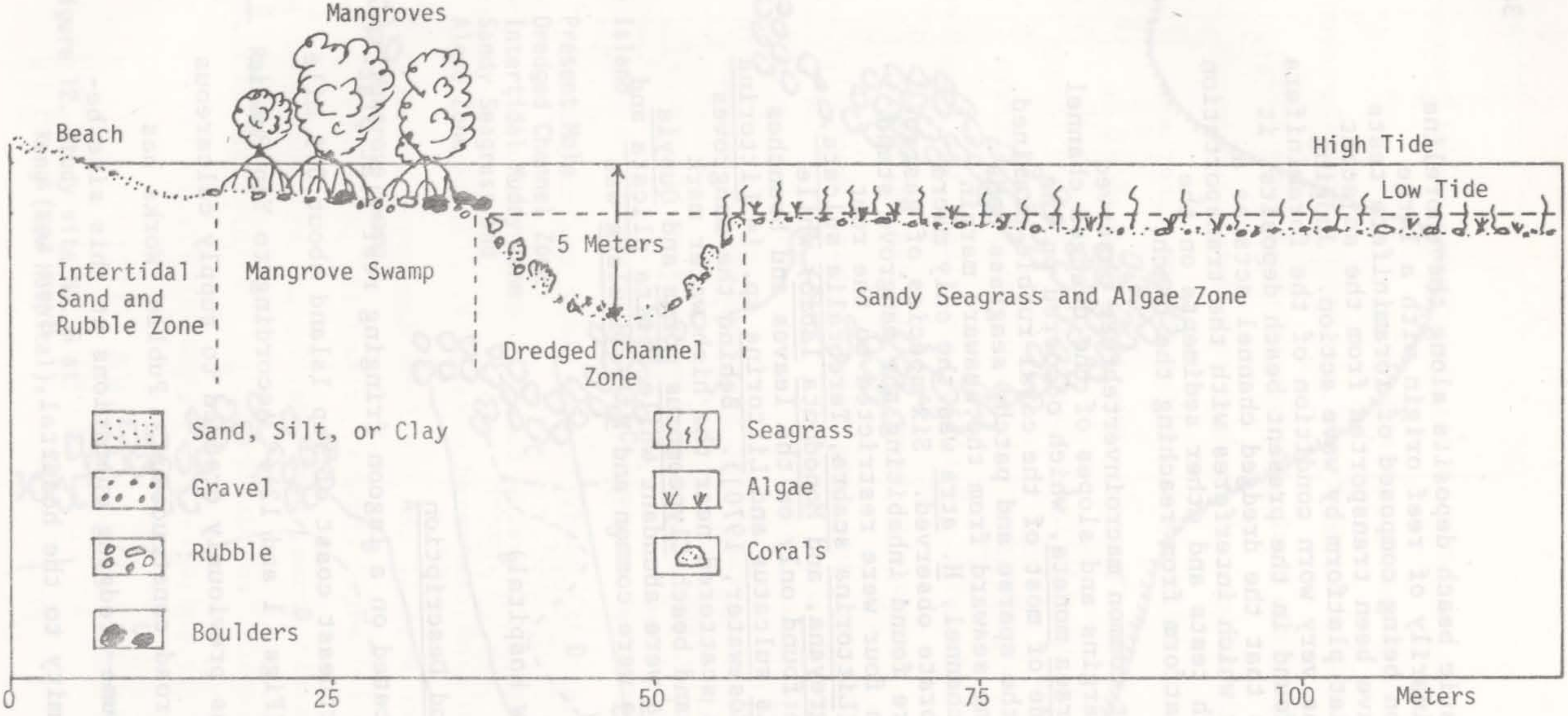

Figure 11. Vertical profile E.

6) Bioclastic beach deposits along the shoreline are primarily of reef origin with a large fraction being composed of foraminifera tests that have been transported from the adjacent reef flat platform by wave action. Judging from the very worn condition of the foraminifera tests found in the present beach deposits, it appears that the dredged channel acts as a barrier which interferes with the transportation of fresh tests and other sediments on the reef platform from reaching the beach.

7) The most common macroinvertebrate observed on the margins and slopes of the dredged channel was Cypraea moneta, which occurred on the underside of most of the coral rubble examined. Within the sparse and patchy seagrass beds extending seaward from the seaward margin of the channel, H. atra was the only macroinvertebrate observed. Six species of gastropods were found inhabiting the mangrove stand of which four were restricted to the root system (Littorina scabra, Terebralia sulcata, Nerita greyana, and Monodonta labio) while two were found only on the leaves and branches (Planaxis sulcatus and Littorina sp. [= Littorina scabra Rosewater, 1970]). Behind the mangroves on rocks scattered near the high water mark on the sand beach Clypeomorus morus and Quoyia decollata were abundant while Nerita plicata and N. undata were common and N. reticulata was rare.

SITE 6 - KENG (New Hospital)

General Setting and Description

Site 6 is located on a lagoon fringing reef flat platform along the northeast coast of Yap Island about 0.5 mile north of Colonia (Figs. 1 and 12). According to Yap Public Works this site was previously dredged to supply calcareous reef deposits for road construction. Public Works has decided not to resume dredging operations at this site because of its proximity to the hospital. Even so, a

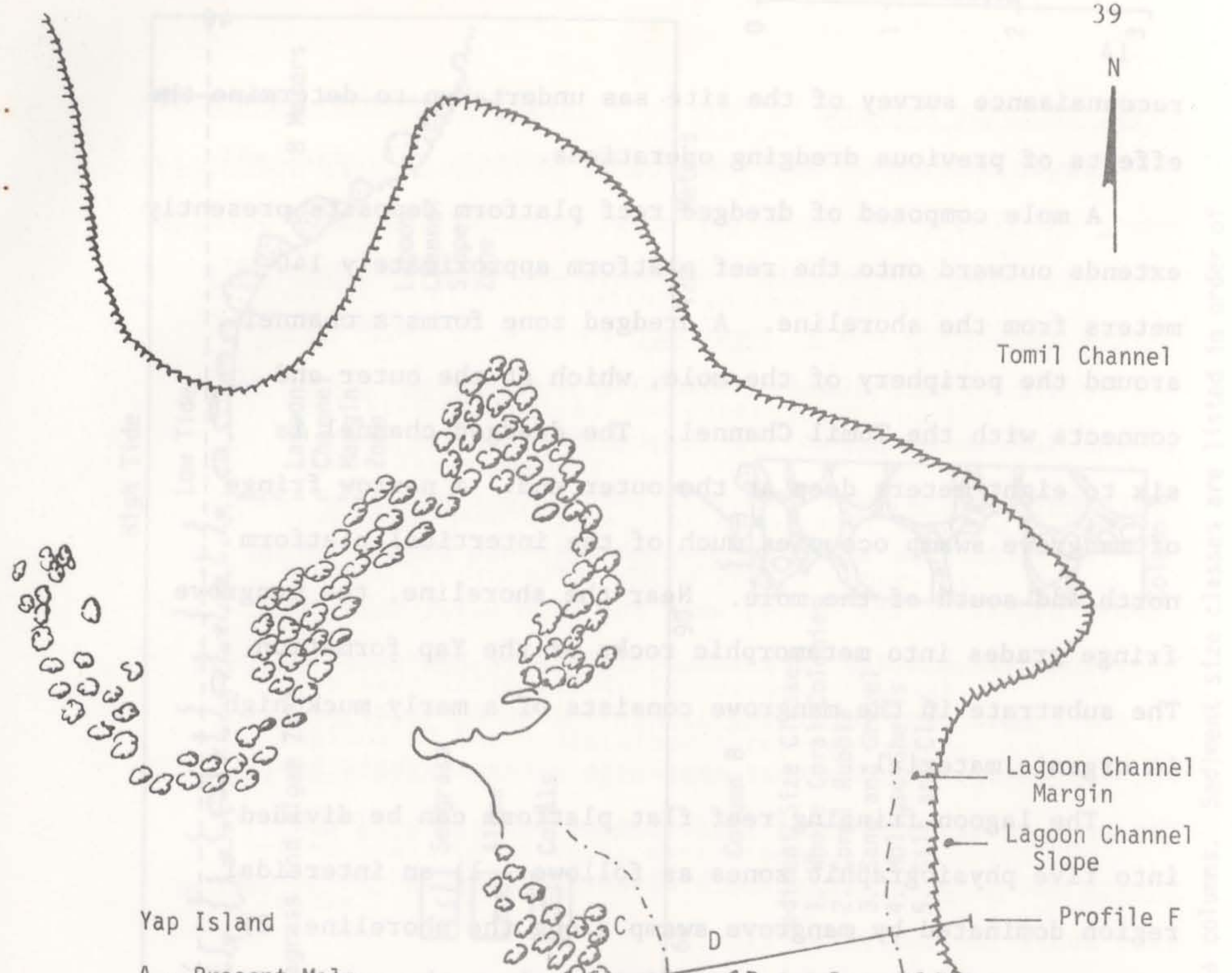

Figure 12. Study site No. 6 at Keng (New Hospital).

reconnaisance survey of the site sas undertaken to determine the effects of previous dredging operations.

A mole composed of dredged reef platform deposits presently extends outward onto the reef platform approximately 140 meters from the shoreline. A dredged zone forms a channel around the periphery of the mole, which at the outer end connects with the Tomil Channel. The dredged channel is six to eight meters deep at the outer end. A narrow fringe of mangrove swamp occupies much of the intertidal platform north and south of the mole. Near the shoreline, the mangrove fringe grades into metamorphic rocks of the Yap formation. The substrate in the mangrove consists of a marly muck high in organic material.

The lagoon fringing reef flat platform can be divided into five physiographic zones as follows: 1) an intertidal region dominated by mangrove swamp along the shoreline, 2) a narrow partly intertidal muddy fringe along the outer edge of the mangrove swamp, 3) a wide sandy stretch dominated by seagrass, algae, and scattered corals, 4) a lagoon channel margin at the outer edge of the platform dominated by corals, and 5) the mole and dredged channel around its periphery. The five physiographic zones, water depth, general characteristics of the substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 13, Profile F.

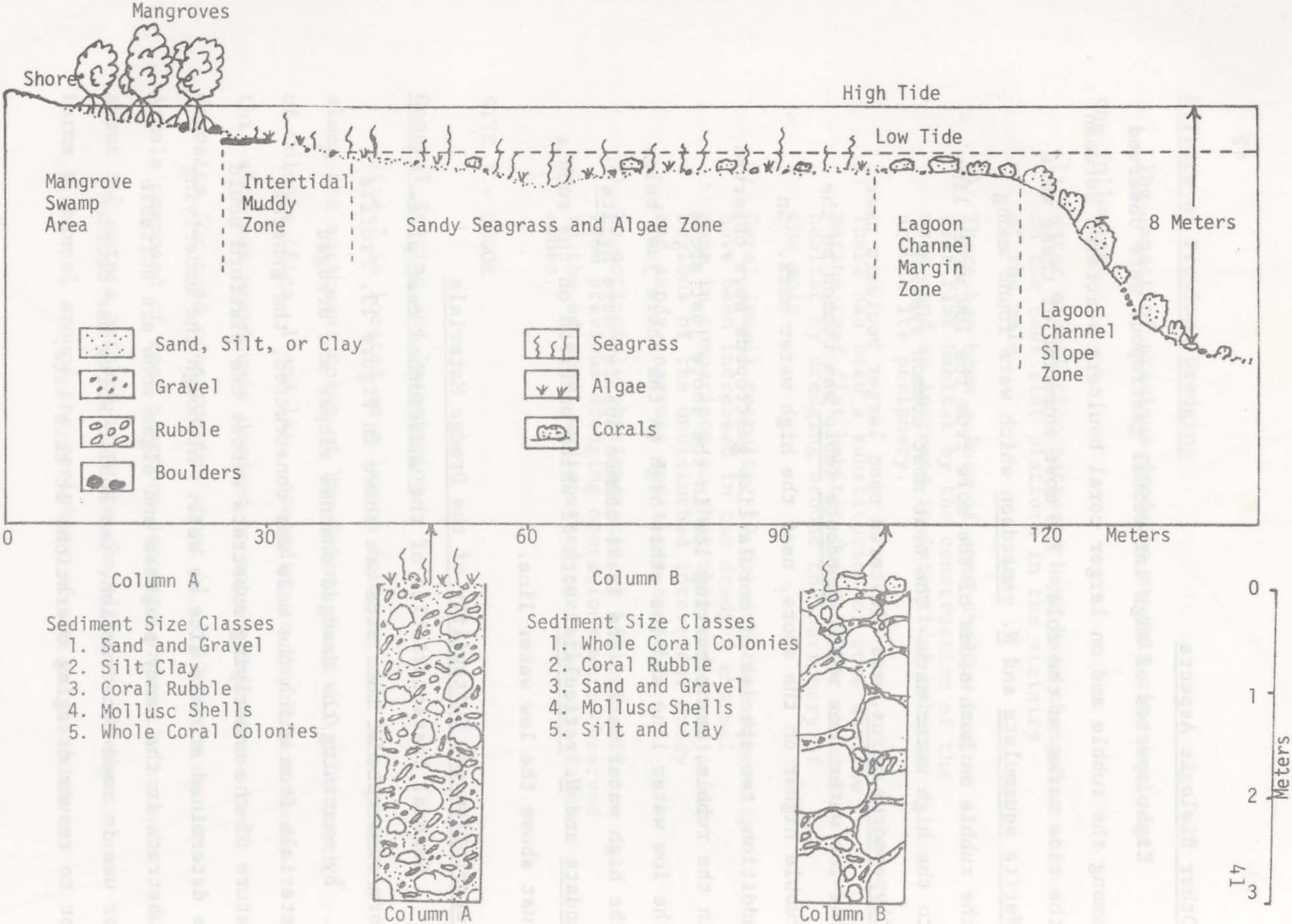

Figure 13. Vertical profile F and substrata columns. Sediment size classes are listed in order of relative abundance.

Other Biologic Aspects

Eight species of high intertidal gastropods were observed among the rubble and on larger coral boulders scattered between the tide marks on the mole. The most abundant of these were *Nerita squamulata* and *N. camaedeon* which were found among the rubble on both sides of the mole from the low water line to the high water mark. The next most common species, *Clypeomorus morus*, was clustered upon larger boulders near the low water line while *Monodonta labio* was common on the rubble higher on the shore, near the high water mark. In addition, two species of morula-like gastropods were observed in the rubble, one occurring low in the shore just above the low water line and the other high on the shore just below the high water mark. The least common species were *Nerita undata* and *N. reticulata*, both of which occurred on the rubble just above the low water line.

Description and Suitability of the Dredge Materials

General characteristics of the undisturbed reef platform substrate at this site are shown in Figure 13, Profile F. By examining the dredged channel slopes and dredged materials from which the mole was constructed, the general nature of the underlying substrata across the platform could be determined at this site as well. Although the underlying substrata in the sandy seagrass and algae zone are suitable for use in road construction, Yap Public Works has decided not to resume dredging operations at this site.

Effects of Previous Dredging

The impact of previous dredging at this site includes the following:

1) Water circulation patterns have been changed on the reef flat platform in the vicinity of the mole.

2) There has been a loss of some shallow marine reef flat habitat by the construction of the mole, and an increase in intertidal habitat around its periphery.

3) There has been a substitution of some shallow marine reef flat habitat for a deeper channel habitat by dredging around the periphery of the mole.

4) Coral (small recruits <10 cm) and fish diversity have been increased in the dredged channel zone in comparison to that observed in adjacent regions of the undisturbed intertidal muddy and sandy seagrass and algae zones.

5) No noticeable physiographic or biologic effects from previous dredging operations were observed in the adjacent undisturbed reef flat platform zones.

SITE 7 - DUGOR

General Setting and Description

Site 7 is located on a lagoon fringing reef flat platform along the northeast coast of Yap Island about 1.0 mile north of Colonia (Figs. 1 and 14). According to Yap Public Works this site was previously dredged to supply calcareous reef deposits for road construction about 11 or 12 years ago. A mole composed of reef platform deposits presently extends about 140 meters outward from the shoreline. A dredged zone forms a channel around the periphery of the mole, which at

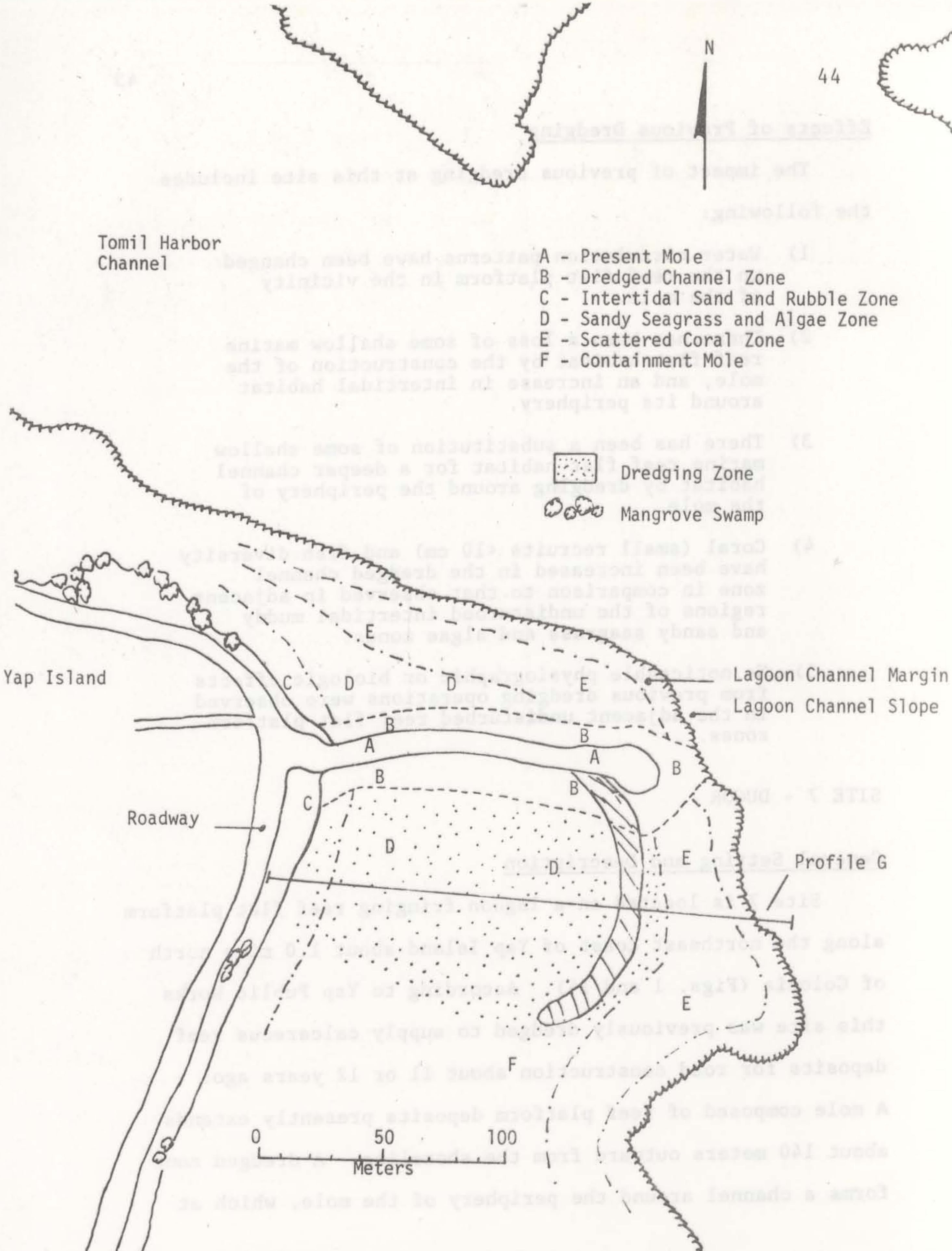

Figure 14. Study site No. 7 at Dugor.

the outer end connects with the Tomil Harbor Channel. At its outer end the dredged channel is three to four meters deep. North and south of the mole a thin veneer of rubbly beach deposits overlies metamorphic rocks of the Yap formation at the shoreline.

The lagoon fringing reef flat platform is divided into five physiographic zones as follows: 1) an intertidal sand and rubble fringe along the shoreline, 2) a wide sand and rubble stretch dominated by seagrasses, algae, and a few scattered corals, 3) a narrow region similar to zone two but with more corals, 4) a reef rock pavement fringe thinly veneered with sand and rubble and dominated by corals at the lagoon channel margin, and 5) the dredged channel around the periphery of the mole. The various physiographic zones, water depth, general characteristics of the substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 15, Profile G.

Other Biologic Aspects

The two most conspicuous macroinvertebrates were a red frondose sponge and a bright red starfish (Echinaster) commonly with five arms but also observed with six and eight arms. Neither were common, but stood out due to their color and the fact that they were not observed at any other site during the study.

Stichopus variegatus was common and Culcita novaeguineae was uncommon on the outer slope of the channel and into the

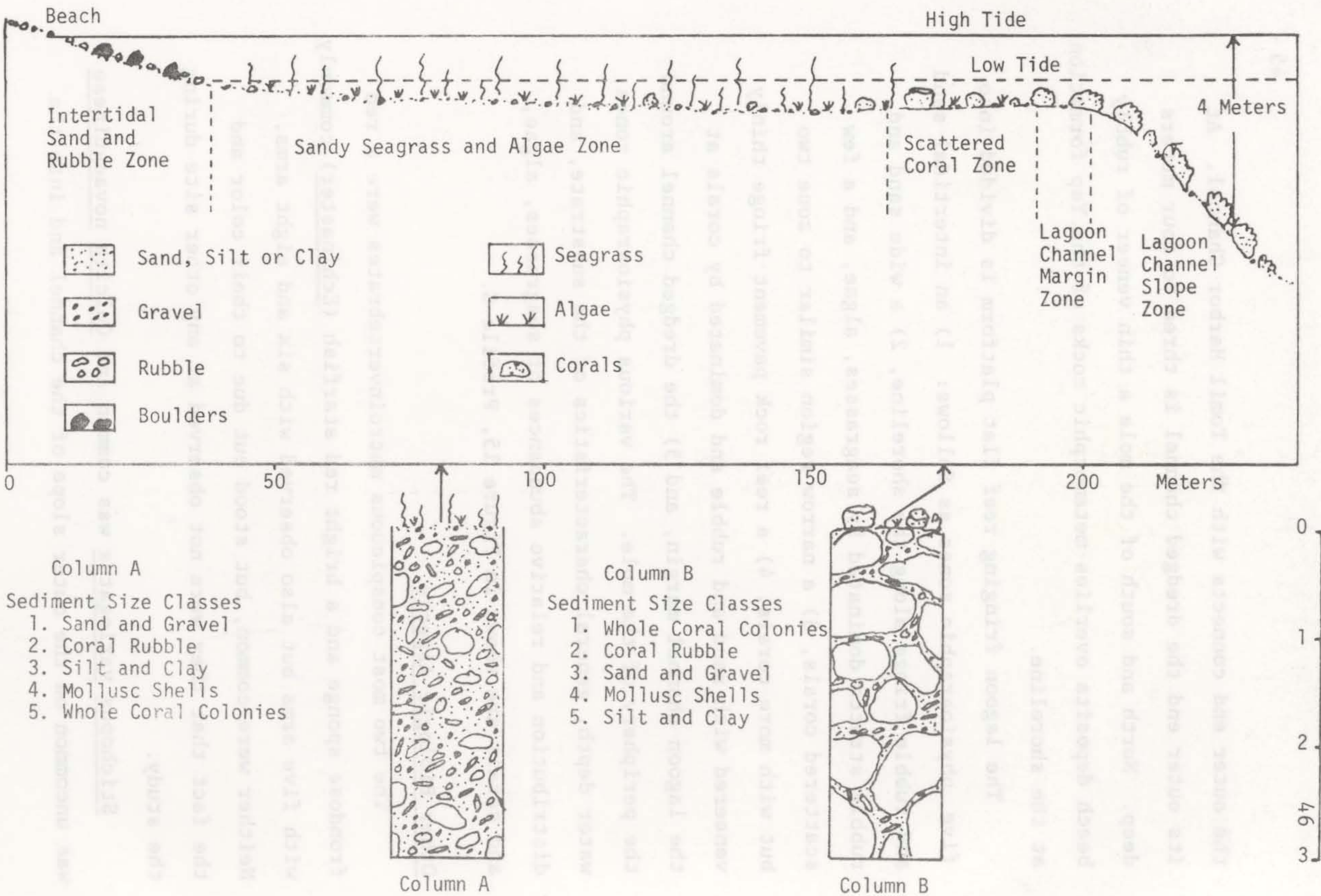

Figure 15. Vertical profile G and substrata columns. Sediment size classes are listed in order of relative abundance.

seagrass bed on the south side of the mole. Two species of cerithids, Clypeomorus morus and Clypeomorus sp., were common on the north side of the mole among the rubble on the slope of the mole and in the fine sediment of the dredged channel respectively.

Description and Suitability of the Dredge Materials

The general characteristics of the undisturbed reef platform substrates at the site are shown in Figure 15, Profile G. By examining the dredged channel slopes and dredged materials from which the mole was constructed the general nature of the underlying substrata across the reef platform could be inferred at this site as well. The columns shown in Figure 15 indicate the characteristics of the underlying substrata at two locations along the existing mole channels to depths that could be directly observed. A general reconnaissance of the reef platform shows that reef deposits from the intertidal sand and rubble zones and sandy seagrass and algae zone along both sides of the mole would be suitable for use in road construction. The coralline reef deposits along the intertidal sand and rubble zone may not be very thick as schistose rocks outcrop along the beach at several locations. Because of the small area of reef platform north of the present mole it is recommended that dredging operations be conducted on the south side. As a general trend the bioclastic fraction of the reef platform deposits increases in a seaward direction from the shoreline. An increase in the amount of the bioclastic fraction composed of fragmented and whole coral colonies is also noticeable as the distance from the shoreline increases. In the scattered coral zone the underlying substrata is mostly composed of large massive coral colonies that are less suitable for road construction. The most suitable materials are those in the sandy seagrass and algae zone where coral fragments and individual coral colonies are intermixed with considerable amounts of sand and gravel sized bioclastic deposits.

Effects of Previous Dredging

The impact of previous dredging at this site includes the following:

1) Water circulation patterns have been changed on the reef flat platform in the vicinity of the mole.

2) There has been a loss of some shallow marine reef flat habitat by the construction of the mole and an increase in intertidal habitat around its periphery.

3) There has been a substitution of some shallow marine reef flat habitat for a deeper channel habitat by dredging around the periphery of the mole.

4) Coral (colonies to 30 cm dia.) and fish diversity has been increased in the dredged channel zone in comparison to that observed in adjacent regions of the undisturbed reef platform.

5) No noticeable physiographic or biologic effects from previous dredging operations were observed in the adjacent undisturbed reef flat platform zones.

Dredging Recommendations and Environmental Considerations

Based upon the suitability of the dredge materials, environmental impact from previous dredging operations, and other factors listed in Table 1, we find that dredging operations at this site could be resumed for both present road construction and future maintenance uses, but with the following recommendations:

1) Dredging operations be conducted on the south side of the mole in the sandy seagrass and algae and intertidal sand and rubble zones.

2) Use the present mole to gain access to these zones by constructing a permanent containment mole near the seaward end of the present mole that hooks southwest as shown in Figure 14. Hooking the mole to the southwest will tend to restrict movement of the dredge plume across the scattered coral zone, lagoon channel margin and lagoon slope zones where extensive coral growth was observed. There is a possibility that surface drift generated by the prevailing NE Trade winds might carry the dredge plume southward across the reef platform. Current patterns should be investigated in the dredging zones by using the dye injection method (see Appendix A) during both flood and ebb tide conditions. If the current direction is southward the dredge plume would tend to be contained in the intertidal sand and rubble and sandy seagrass and algae zones. This part of the reef platform is dominated by seagrasses which can apparently tolerate considerable amounts of suspended silt in the water column. If the current direction is southeastward toward Tomil Channel, the dredge plume would be carried across the rich coral zones on the outer part of the reef platform. Movement of the plume across these coral rich zones could be prevented by further extension of the containment mole toward the shore or possibly by dredging during low tide conditions. Temporary moles could be constructed outward from the containment mole to gain access to the central region of the dredging zone.

3) Dredge during low tides while constructing the containment mole.

4) Use large dredged coral heads that are not suitable for construction purposes to riprap and stabilize the seaward slopes of the permanent mole.

5) Monitor the site during the dredging period for environmental dregradation.

SITE 8 - RUMW (Northern Yap Island)

General Setting and Description

Site 8 is located on a lagoon fringing reef flat platform along the northern coast of Yap Island near the head of the southern branch of Mil Channel (Figs. 1 and 16). According to Yap Public Works this site was previously dredged to supply calcareous reef deposits for road construction. A mole composed of dredged reef platform deposits presently extends outward from the shore approximately 115 meters from the terminus of a road at the shoreline. The outer part of the mole has been partly removed, leaving a small islet with a shallow intertidal zone connecting it to the mole proper. A dredged zone forms a channel around the periphery of the mole that ranges from one to four meters deep at low tide. A fringe of mangrove swamp occupies much of the intertidal coastal platform. At the shoreline the mangrove swamp grades into steep slopes composed of weathered Tomil Volcanic rocks of northern Yap Island.

The lagoon fringing reef flat platform is divided into three physiographic zones as follows: 1) a narrow intertidal band along the shoreline dominated by mangrove swamp, 2) an

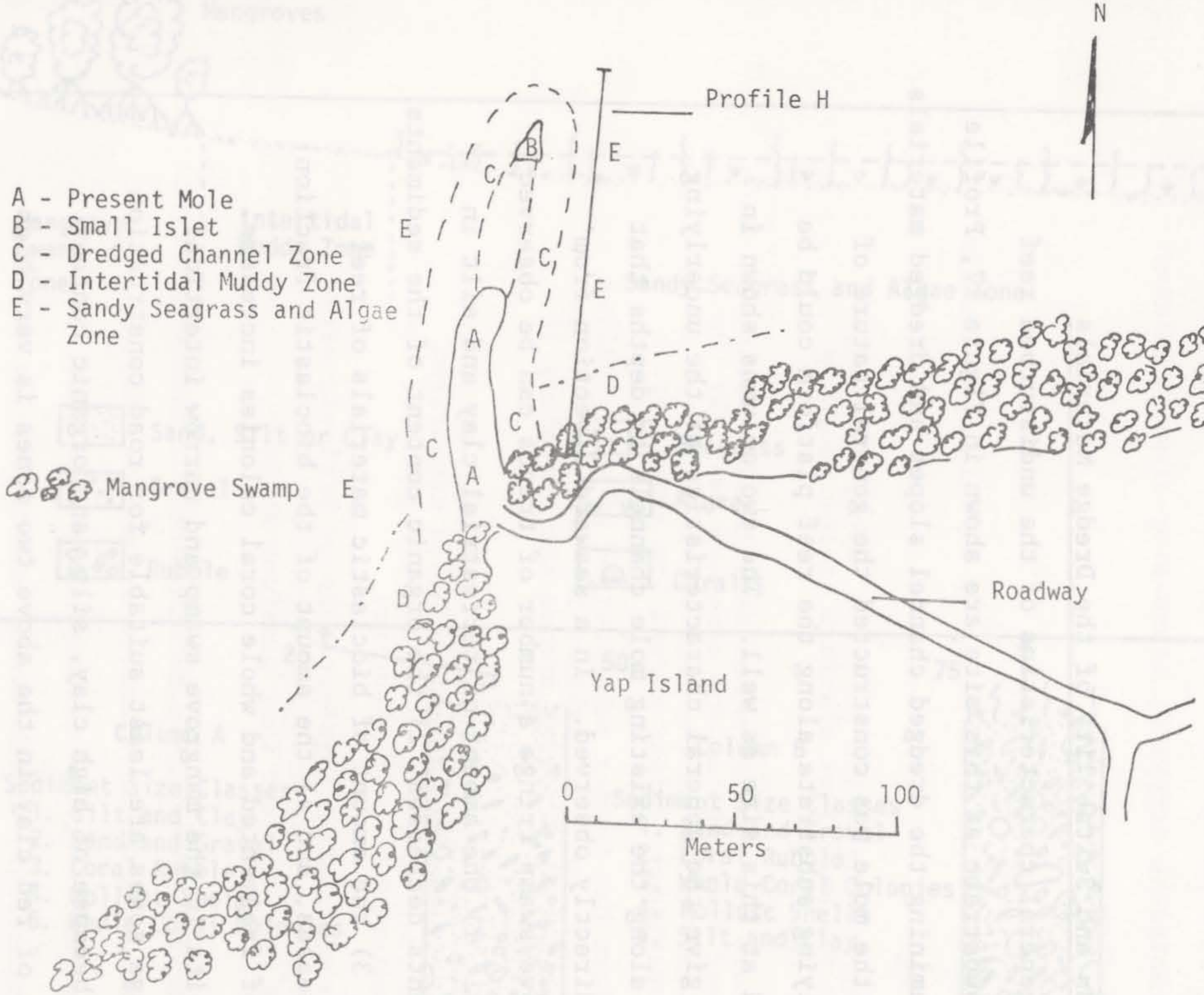

Figure 16. Study site No. 8 at Rmuw.

intertidal muddy fringe along the mangrove swamp, and 3) a wide sandy stretch dominated by seagrass and algae (inner part intertidal at places). The water depth, general characteristics of the substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 17, Profile H.

Description and Suitability of the Dredge Materials

The general characteristics of the undisturbed reef platform substrate at this site are shown in Figure 17, Profile H. By examining the dredged channel slopes and dredged materials from which the mole was constructed the general nature of the underlying substrata along the reef platform could be determined at this site as well. The two columns shown in Figure 17 give the general characteristics of the underlying substrata along the existing mole channels to depths that could be directly observed. In a seaward direction from the mangrove swamp fringe a number of trends can be observed as follows: 1) the amount of terrestrial clay and silt in the sediments decreases, 2) the organic content of the sediments decreases, 3) the amount of bioclastic materials of reef origin inceases, and 4) the amount of the bioclastic fraction composed of fragmented and whole coral colonies increases.

Deposits in the mangrove swamp and narrow intertidal muddy fringe zones are least suitable for road construction materials because of high clay, silt, and organic content. The amount of red clay in the above two zones is very high

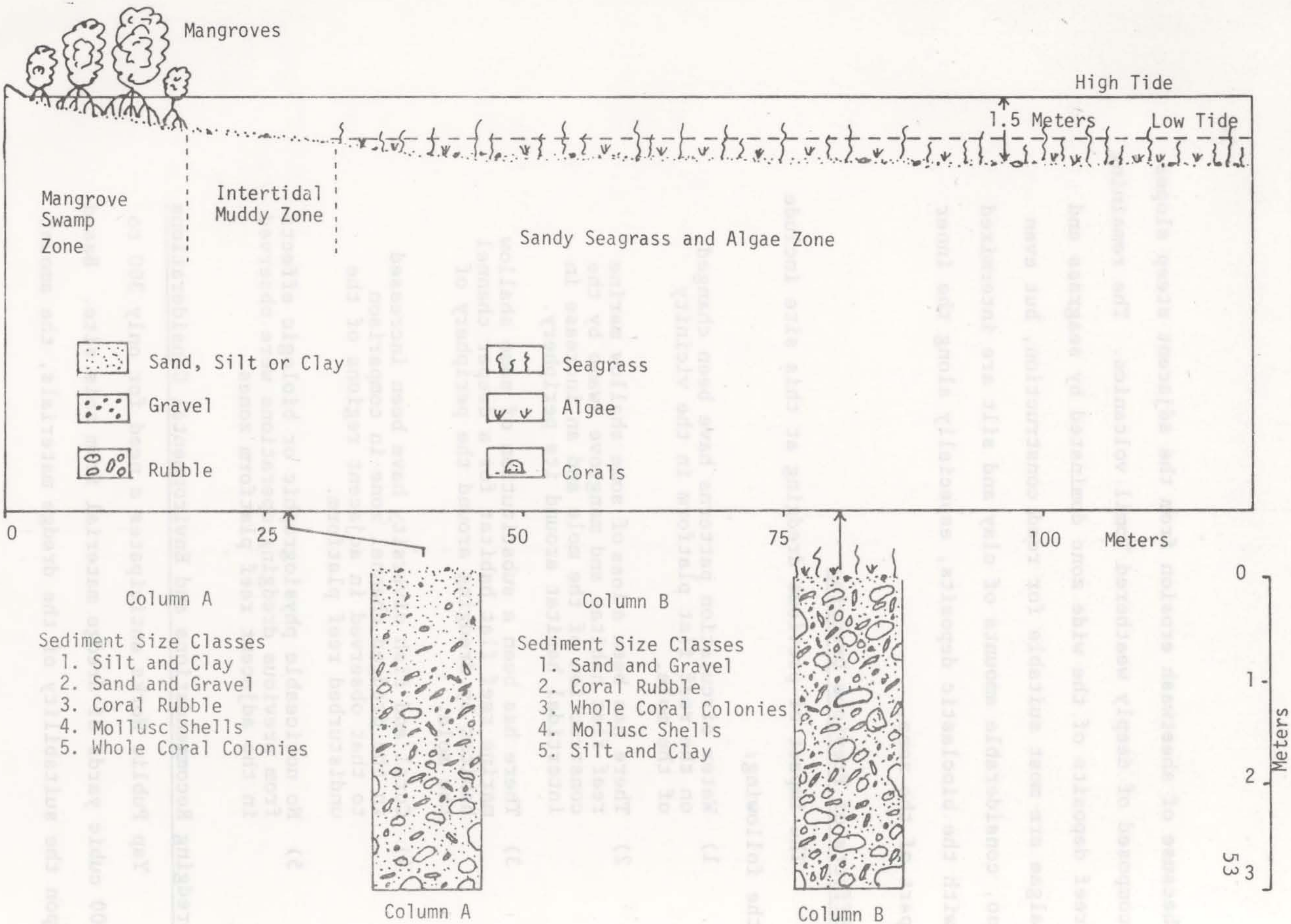

Figure 17. Vertical profile H and substrata columns. Sediment size classes are listed in order of relative abundance.

because of sheetwash erosion from the adjacent steep slopes composed of deeply weathered Tomil volcanics. The remaining reef deposits of the wide zone dominated by seagrass and algae are most suitable for road construction, but even so, considerable amounts of clay and silt are intermixed with the bioclastic deposits, especially along the inner part of the zone.

Effects of Previous Dredging

The impact of previous dredging at this site include the following:

1) Water circulation patterns have been changed on the reef flat platform in the vicinity of the mole.

2) There has been a loss of some shallow marine reef flat habitat and mangrove swamp by the construction of the mole and an increase in intertidal habitat around its periphery.

3) There has been a substitution of some shallow marine reef flat habitat for a deeper channel habitat by dredging around the periphery of the mole.

4) Coral and fish diversity have been increased in the dredged channel zone in comparison to that observed in adjacent regions of the undisturbed reef platform.

5) No noticeable physiographic or biologic effects from previous dredging operations were observed in the adjacent reef platform zones.

Dredging Recommendations and Environmental Considerations

Yap Public Works anticipates a need for only 300 to 400 cubic yards of dredge material from this site. Based upon the suitability of the dredge materials, the amount of dredge materials needed, environmental impact from previous dredging operations, and other factors listed in Table 1, we feel that dredging operations could be resumed for present road construction uses, but with the following recommendations:

1) Since a limited amount of materials is needed from this site, dredging operations should be restricted to removing just the reef deposits already stockpiled in the present mole.

2) If the mole is removed to subtidal levels the effects of generated plume on the adjacent reef flat community can be reduced by dredging during low tide conditions.

3) Monitor the site during the dredging period for environmental degradation.

SITE 9 - GERMAN CHANNEL

General Description and Setting

The German Channel is a man-made canal that connects Tomil Channel with Mil Channel between Yap and Tomil-Gagil Islands (Figs. 1 and 18). The canal is quite shallow and many outboard boats have difficulty in passing through it during low tide. Yap Public Works is considering deepening the canal, particularly in its shallowest part in the vicinity of the bridge. Our team was asked to conduct a reconnaissance of the canal and comment on the probable environmental impact as a result of dredging.

We passed through the canal during low tide with a 25 HP outboard boat and at several locations we could not operate the engine, but by tilting the motor up the boat could be poled over the shallow regions. Mangrove swamp fringes both

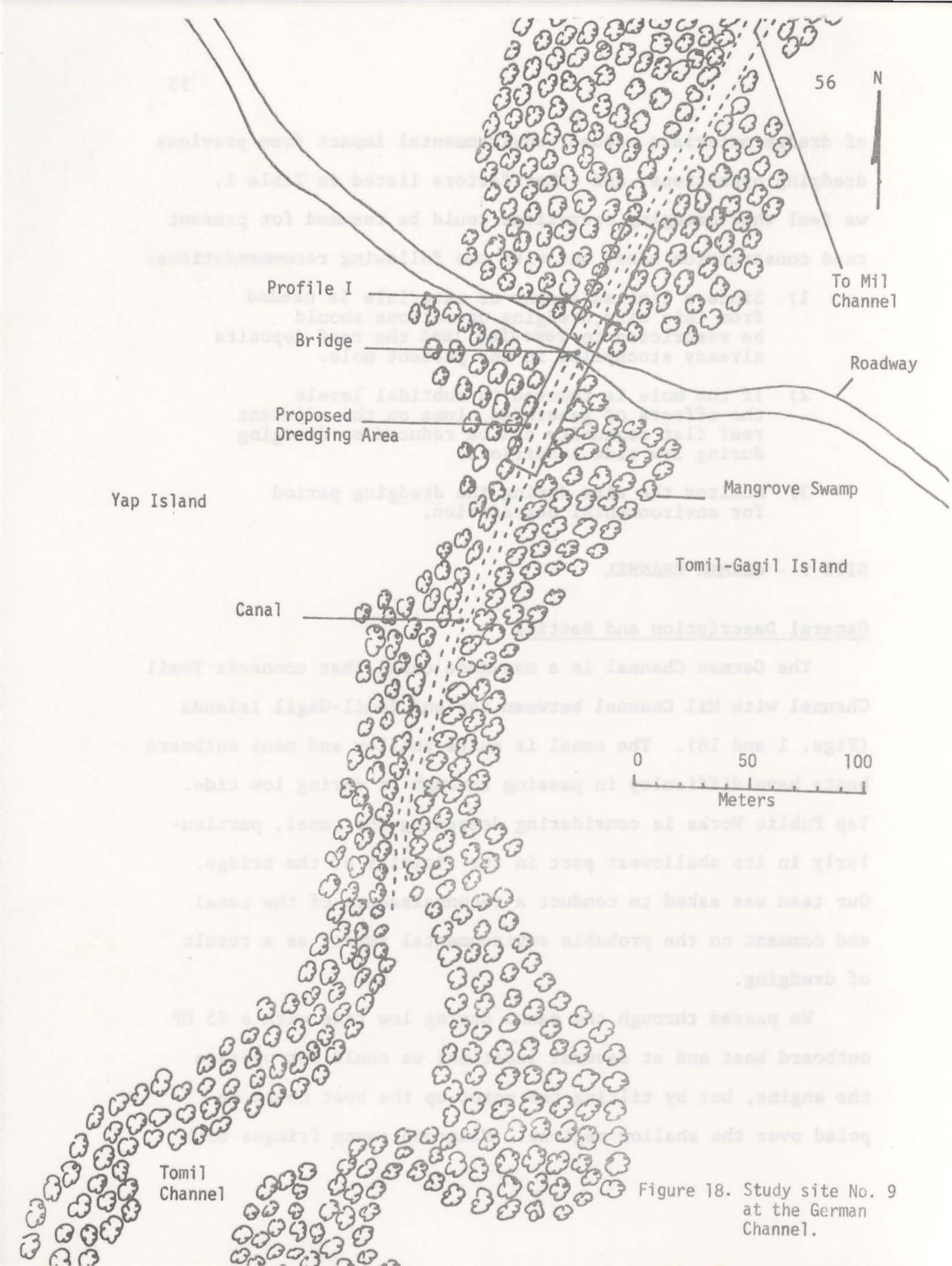

Figure 18. Study site No. 9 at the German Channel.

region on the north side of the mole. At the shoreline this mangrove fringe is bordered by an alluvial zone which in turn grades into volcanic rocks of the Map formation farther inland. On the south side of the mole a number of isolated mangrove islets occupies part of the channel reef platform area. The fringing reef flat platform at the site is divided into three physiographic zones as follows: 1) an intertidal band along the shoreline and intertidal islets in the main channel dominated by mangrove swamp, 2) the shallow rubbly floored reef platform areas of the main channel dominated by seagrasses and algae, and 3) the deeper dredged channel around the periphery of the mole. The three physiographic zones, water depth, general characteristics of the reef platform substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 21, Profile J.

The southern site is located on a shallow fringing reef flat platform about 85 meters southwest of the highway bridge. Although no previous dredging operations for construction materials have been conducted at this site a shallow dredged channelway bisects the proposed dredge site and a landfilled area extends from the shore through a zone of mangroves to the open water of the main channel. A fringe of mangrove swamp occupies the intertidal coastal region. At this shoreline the mangrove fringe grades into the weathered volcanic rocks of the Map formation. The fringing reef flat platform at sides of the canal except for a short rocky stretch near the bridge. In the vicinity of the bridge a strong current was flowing from Tomil Channel to Mil Channel. Where the canal grades into the two channels the canal floor is composed of a black plastic muck intermixed with some boulder rubble. Toward the central part of the canal the floor is composed of less muck and at the bridge it consists entirely of boulder-rubble cemented together by sponge growth (Figure 19, Profile I). A strong current prevents sediments from setting out in the vicinity of the bridge and probably promotes the abundant sponge growth observed. Although the rubble-sponge framework was excavated by hand to a depth of 15 to 25 cm, its total thickness was not determined. It was doubtful though that it is much thicker than 25 cm. Water in the canal was quite turbid and at no time could the bottom be observed directly. Most hard rocky surfaces and mangrove roots along the sides of the canal had a thin film of silt and organic material covering them. Other than the rubble-sponge framework in the central part of the canal and molluscs and crabs among the rocks and mangrove roots along the sides of the canal, there were no other conspicuous macroinvertebrates noticed. Scattered corals, consisting of nodular masses of yellow <u>Porites</u> colonies, first appeared at the end of canal where it grades into the Tomil and Mil Channels. Seagrasses and large fleshy and calcareous algae also first appeared with the scattered corals.

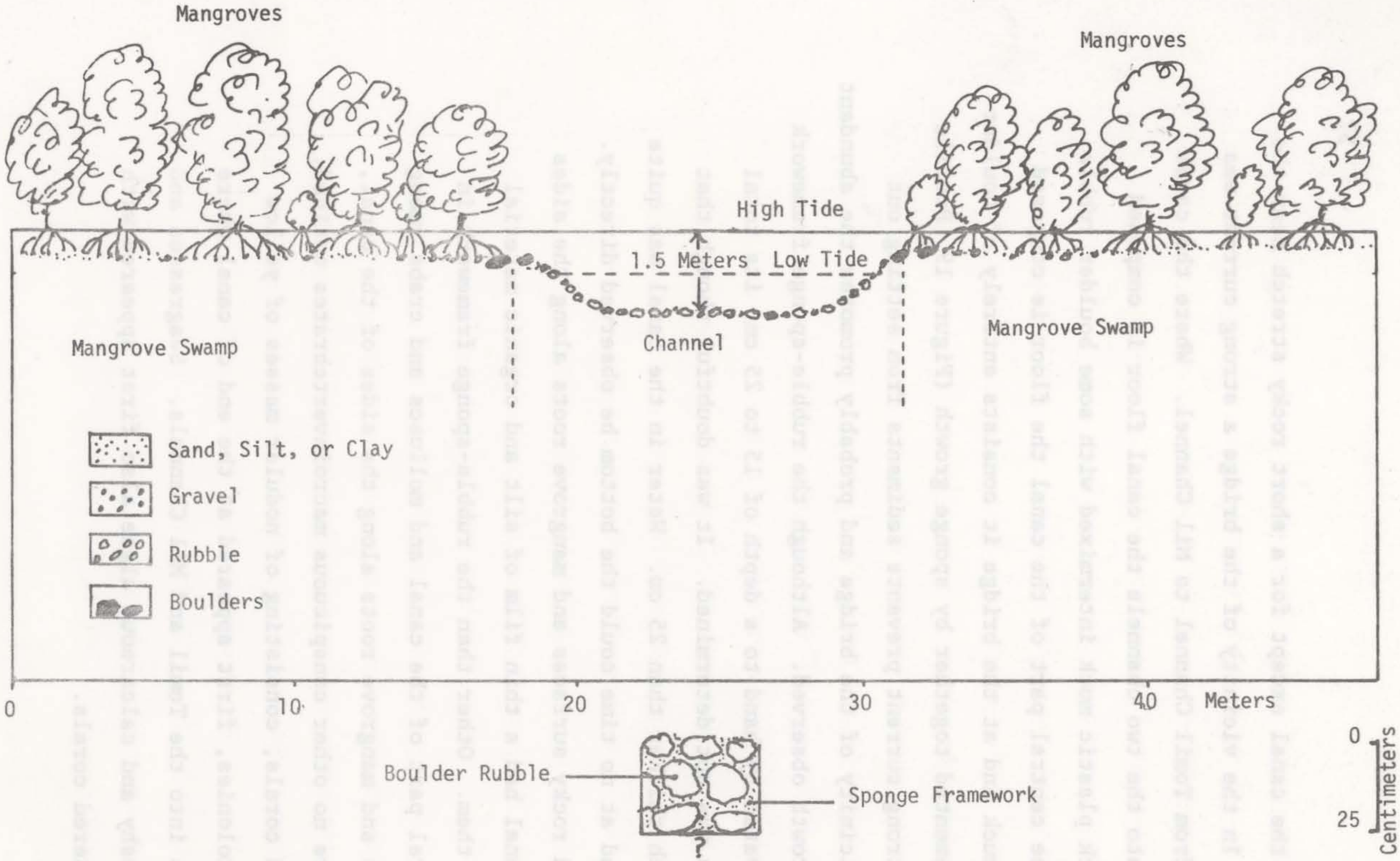

Figure 19. Vertical profile I at the German Channel and substratum column.

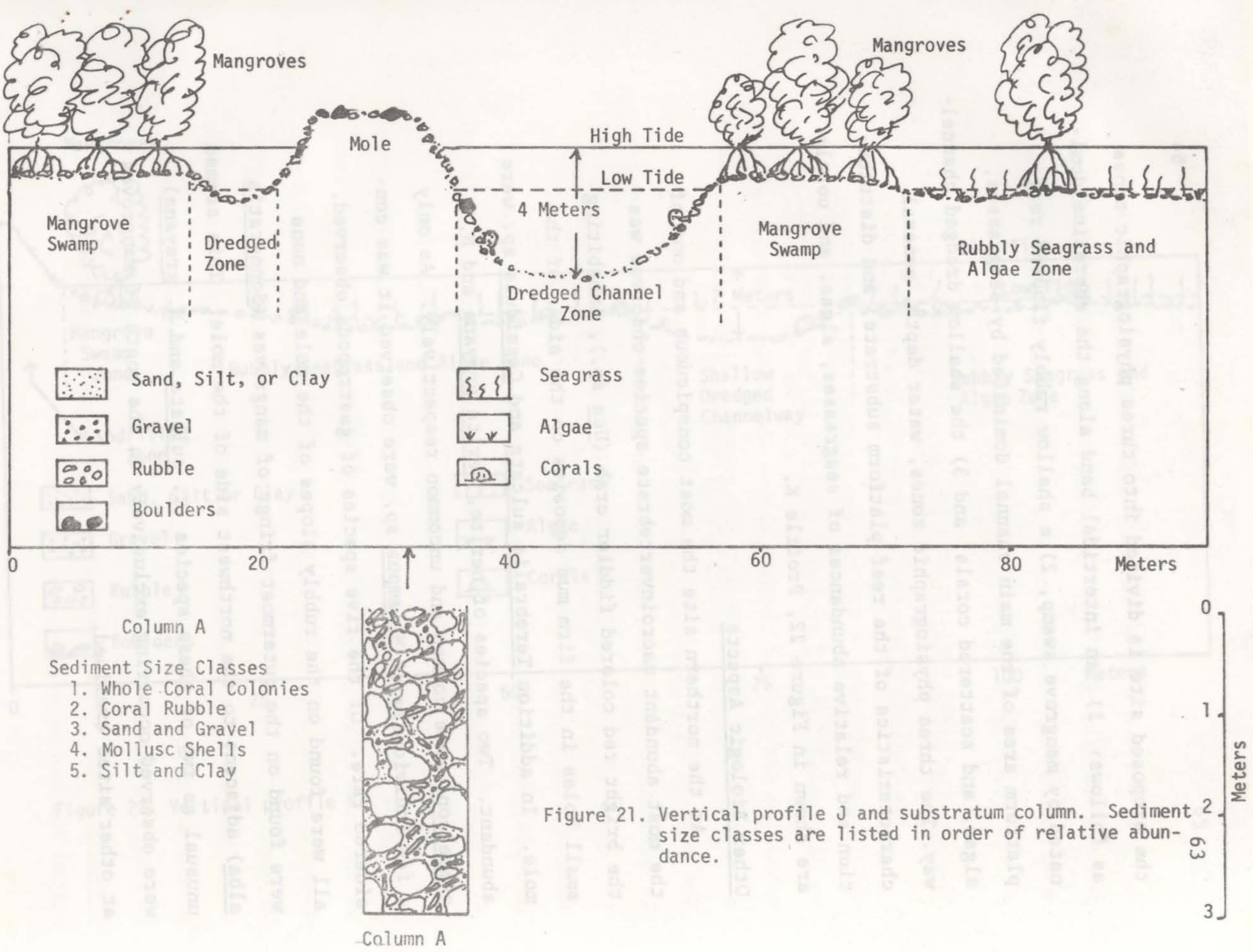

Figure 21. Vertical profile J and substratum column. Sediment size classes are listed in order of relative abundance.

Probable Marine Biologic Impact of Dredging the German Channel

Effects of deepening the canal will depend to a considerable extent upon the volume of floor material removed and the duration of the dredging operation. At the present time, Yap Public Works is considering deepening only the central rocky part of the canal approximately one meter. Comments about the biologic impact will be based upon this limited dredging operation.

The most direct impact would be the removal of the rubble-sponge community in the floor of the canal. Most likely a similar sponge community will develop on the newly dredged canal floor. If the dredged material is disposed along the sides of the canal there will be some impact to the intertidal mangrove swamp community. A secondary impact would result from the movement of the dredge plume, generated at the central dredging zone, to the scattered coral, seagrass and algae zones where the canal grades into Tomil and Mil Cannels. Although some Porites now thrive in the turbid water at the heads of these two channels, additional stress from sedimentation might cause some to die, especially if they are presently living near their upper turbidity and sedimentation tolerance levels. The seagrass and algae community appears to be able to tolerate a much higher level of turbidity and sedimentation than corals and would less likely be affected by the dredge plume. The impact of the dredge plume would affect both channel areas by dredging during both ebbing and flooding tide conditions, presuming that the tide current in the canal reverses with a changing tide. On the other hand impact to the channel communities could be restricted to one location by dredging only during one tide condition. If dredging is confined to the rubble and boulder floored central region of the canal there may be only a small amount of material that will be carried away as a plume. If this is the case, the coral communities might be able to tolerate the increased sediment and turbidity levels during the dredging period.

SITE 10 - MAP BRIDGE

General Setting and Description

Site 10 is located on a narrow channel fringed by mangrove where the highway bridge connects Gagil-Tomil and Map Islands (Figs. 1 and 20). Two dredging areas have been identified at this site - one on the north side of the bridge on Map Island and the other on the south side of the bridge on Gagil-Tomil Island.

At the northern site a mole composed of dredged reef platform deposits presently extends outward approximately 90 meters from the highway onto a fringing reef flat platform and mangrove swamp. A dredged zone forms a channel around the outer end and south side of the mole that is several meters deeper than adjacent undisturbed reef platform areas. A fringe of mangrove swamp occupies the intertidal coastal the proposed site is divided into three physiographic zones as follows: 1) an intertidal band along the shoreline dominated by mangrove swamp, 2) a shallow rubbly floored reef platform area of the main channel dominated by seagrasses, algae, and scattered corals, and 3) the shallow dredged channelway. The three physiographic zones, water depth, general characteristics of the reef platform substrate, and distribution and relative abundances of seagrasses, algae, and corals are shown in Figure 22, Profile K.

Other Biologic Aspects

At the northern site the most conspicuous and one of the most abundant macroinvertebrate species observed was the bright red colored fiddler crab (Uca sp.), inhabiting small holes in the firm mud deposits on the sides of the mole. In addition Terebralia sulcata and Cassidula sp. were abundant. Two species of nerite, Nerita greyana and N. camaeleon, were common and uncommon respectively. As only a few individuals of Melampus sp. were observed it was considered rare. Of the five species of gastropods observed, all were found on the rubbly slopes of the mole and none were found on the outermost fringe of mangroves (Sonneratia alba) adjacent to the northwest side of the mole. This seemed unusual as two of these species (T. sulcata and N. greyana) were observed occurring exclusively on the roots of mangroves at other sites examined.

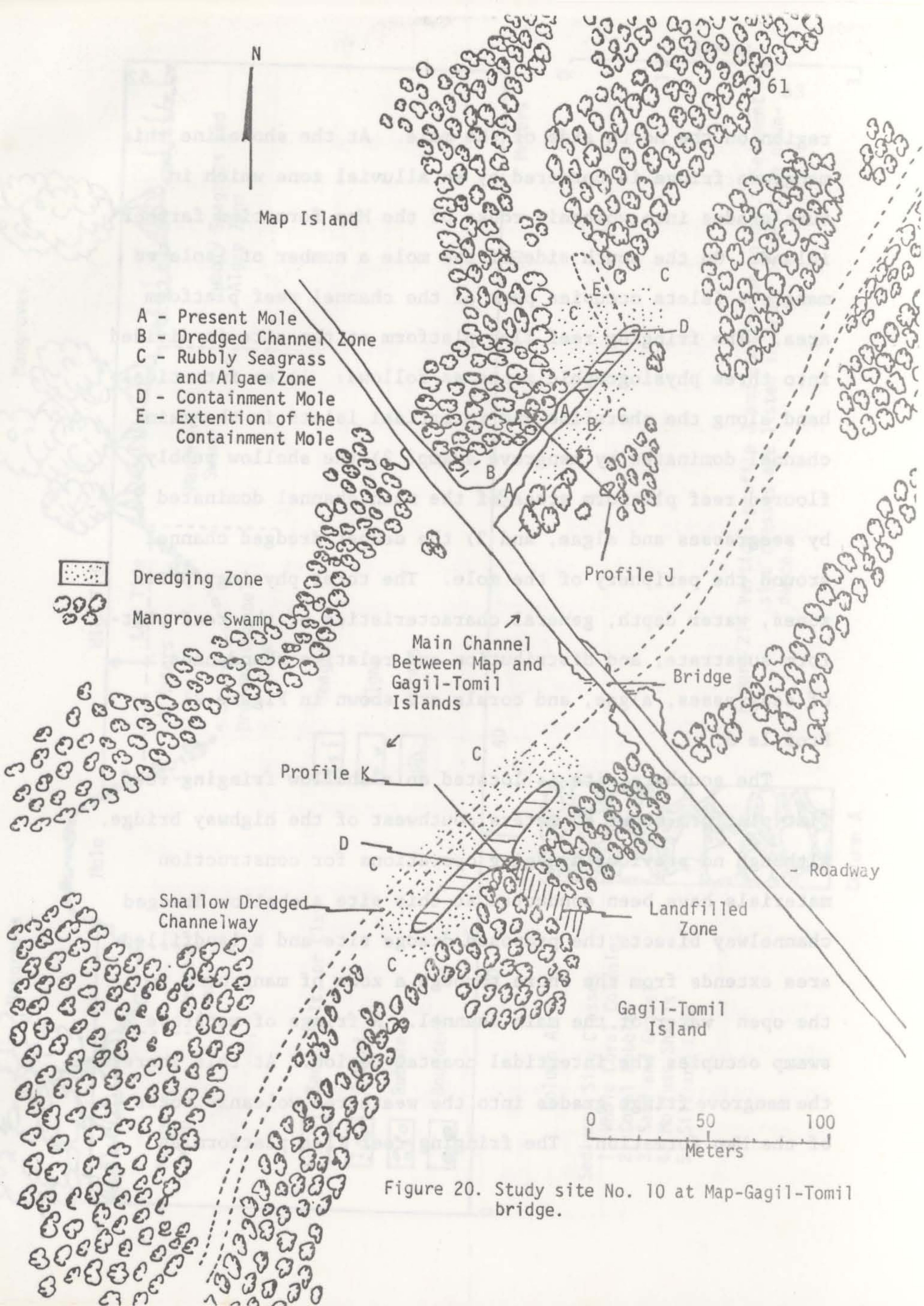

Figure 20. Study site No. 10 at Map-Gagil-Tomil bridge.

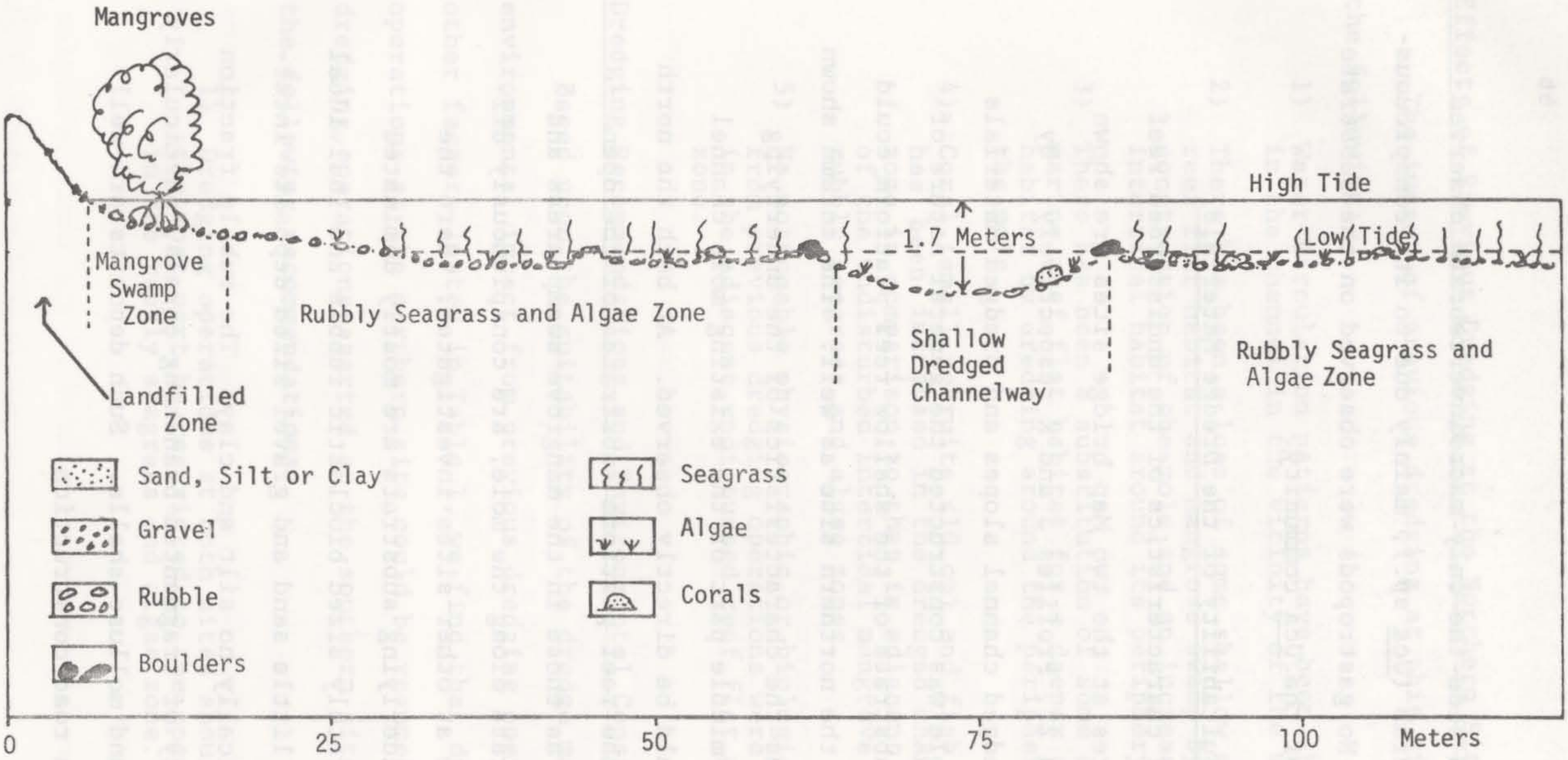

Figure 22. Vertical profile K.

At the south side the only macroinvertebrate observed was the fiddler crab (Uca sp.), mainly due to its conspicuousness red color. No gastropods were observed on the substrate on the vicinity of the Uca community.

Description and Suitability of the Dredge Materials

The general characteristics of the undisturbed reef platform substrates at the two Map bridge sites are shown in Figures 21 and 22, Profiles J and K respectively. By examining the dredged channel slopes and dredged materials from which the mole was constructed the general nature of the underlying substrata of the shallow reef platform could be determined at the northern site as well. The column shown in Figure 21 gives the characteristics of the underlying substrata at the middle part of the existing mole channel to depths that could be directly observed. At both the north and south sites the reef platform substrates of the open channel, as well as those in the mangrove swamp areas and underlying substrata along the mole, are conspicuously different from those at other sites investigated. Here the substrates and underlying substrata are mostly dominated by small to moderately sized bioclastic rubble and individual coral heads with little sand and gravel sized deposits intermixed, and practically no silt and clay. The rubble fraction is composed mostly of fragmented branching corals, particularly Acropora stems, and mollusc shells. Such deposits are well suited for use in road construction.

Effects of Previous Dredging at the Northern Site

The impact of previous dredging at this site includes the following:

1) Water circulation patterns have been changed in the channel in the vicinity of the mole.

2) There has been a loss of some shallow marine reef flat habitat and mangrove swamp by the construction of the mole and an increase in intertidal habitat around its periphery.

3) There has been a substitution of some shallow marine reef flat habitat for a deeper channel habitat by dredging around the periphery of the mole.

4) Coral (small recruits <10 cm) and fish diversity has been increased in the dredged channel zone in comparison to that in adjacent regions of the undisturbed intertidal mangrove and rubbly seagrass and algae zones.

5) No noticeable physiographic or biologic effects from previous dredging operations were observed in the adjacent undisturbed reef flat platform zone.

Dredging Recommendations and Environmental Considerations

Based upon the suitability of the dredge materials, environmental impact from previous dredging operations, and other factors listed in Table 1, we find that dredging operations at the northern site could be resumed and new dredging operations started at the southern site, but with the following recommendations:

1) Dredging operations at both sites should, for the most part, be restricted to the open channel in the rubbly seagrass and algae zone.

2) At the north site use the present mole to gain access to the dredging zones by constructing a permanent mole as shown in Figure 20. If more dredge materials are needed from this site the permanent mole could be extended and hooked toward the northwest into a secondary channelway present there. Hooking the mole in this direction would tend to prevent the dredge plume from entering the main channel areas. Current patterns should be investigated in the dredging zones by using the dye injection method (see Appendix A) during both flood and ebb tide conditions. The most suitable time to dredge would be when the current in the main channel is flowing toward the southwest as the dredge plume would then be somewhat contained on the north side of the mole.

3) At the south site construct a containment mole outward from the shoreline at the landfilled zone that hooks both to the northeast and southwest as shown in Figure 20. By hooking the mole in two directions the dredge plume could be somewhat contained by dredging within the northeastern part when the current in the channel is flowing to the southwest and in the southwestern part when the current is flowing to the northeast.

4) Dredge during low tides while constructing the containment moles.

5) Use large dredged coral heads that are not suitable for construction purposes to riprap and stablize the slopes of the permanent moles.

6) Monitor the site during the dredging period for environmental dregradation.

SITE 11 - MAP SCHOOL

General Description and Setting

Site 11 is located on a lagoon fringing reef flat platform along the northwestern tip of Map Island near the village school (Figs. 1 and 23). There has been no previous dredging at this site. Conglomerate and breccias of the Tomil volcanics

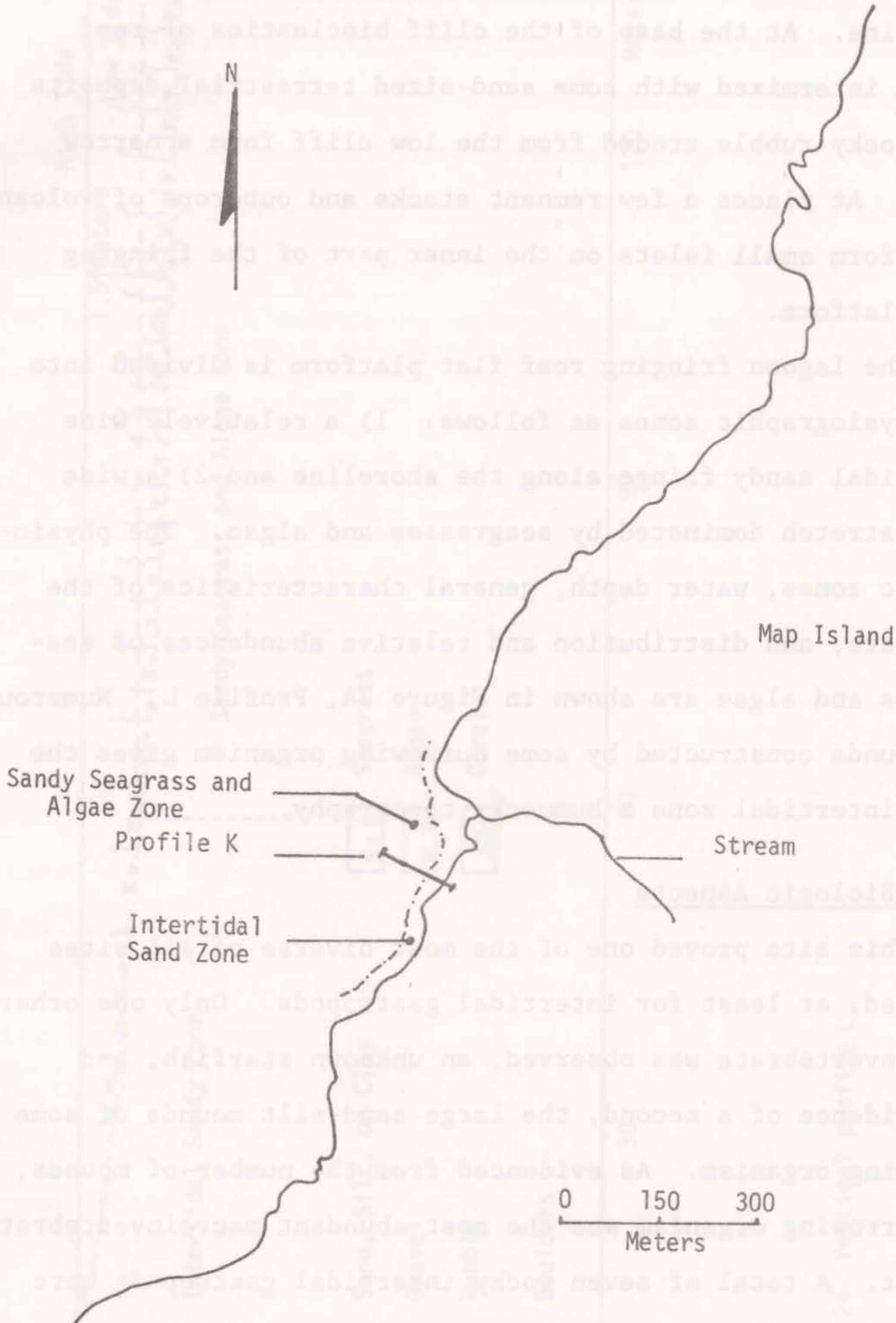

Figure 23. Study site 11 at Map School.

forms a low cliff up to ten meters or more high along the shoreline. At the base of the cliff bioclastics of reef origin intermixed with some sand-sized terrestrial deposits and blocky rubble eroded from the low cliff form a narrow beach. At places a few remnant stacks and outcrops of volcanic rocks form small islets on the inner part of the fringing reef platform.

The lagoon fringing reef flat platform is divided into two physiographic zones as follows: 1) a relatively wide intertidal sandy fringe along the shoreline and 2) a wide sandy stretch dominated by seagrasses and algae. The physiographic zones, water depth, general characteristics of the substrate, and distribution and relative abundances of seagrasses and algae are shown in Figure 24, Profile L. Numerous low mounds constructed by some burrowing organism gives the sandy intertidal zone a hummocky topography.

Other Biologic Aspects

This site proved one of the most diverse of all sites examined, at least for intertidal gastropods. Only one other macroinvertebrate was observed, an unknown starfish, and the evidence of a second, the large sand-silt mounds of some burrowing organism. As evidenced from the number of mounds, the burrowing organism was the most abundant macroinvertebrate present. A total of seven rocky intertidal gastropods were observed, five of them occurring on two large conglomerate boulders about 75 meters from the shore (*Nerita costata*,

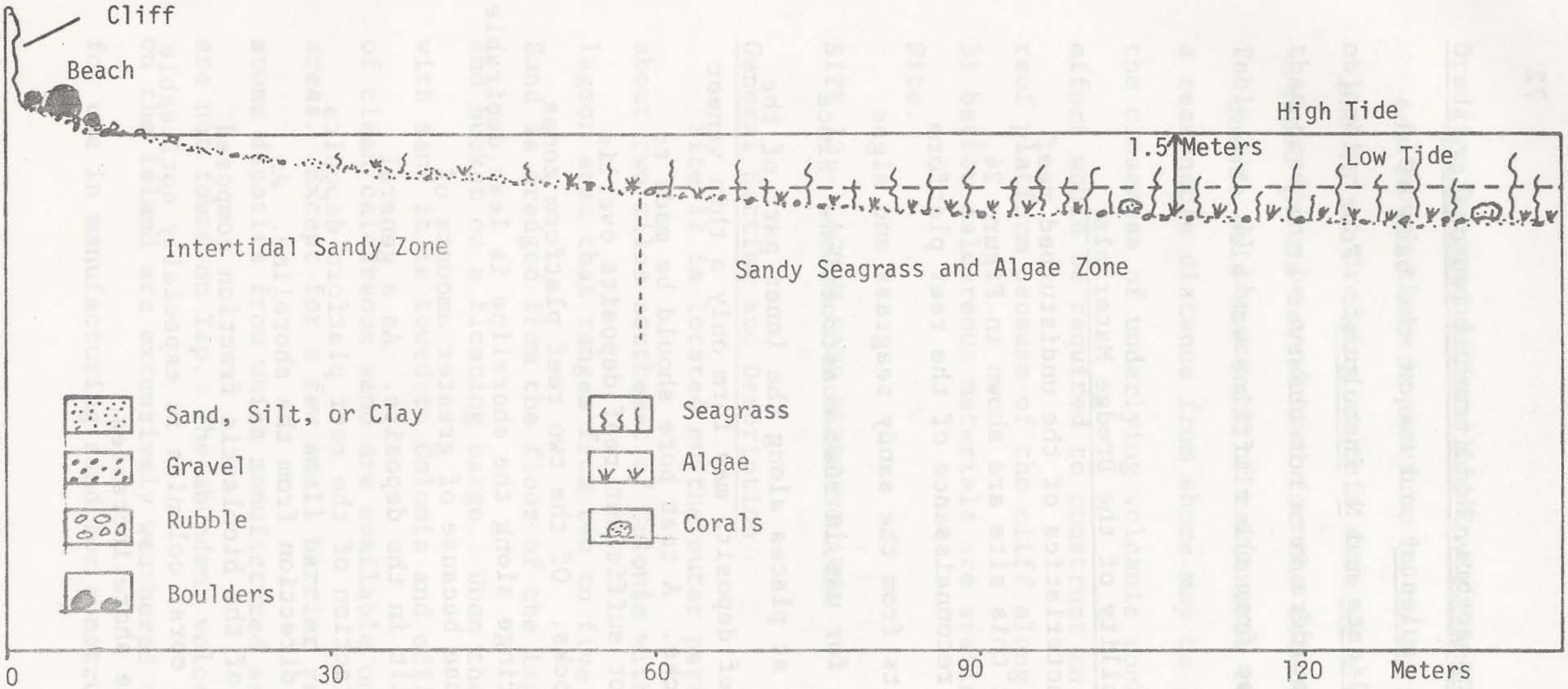

Figure 24. Vertical profile L.

N. albicilla, Littorina scabra, Noddittorina leucosticta feejeensis, and Thais aculeata) and two at the base of the shoreline cliff (N. plicata and N. insculpta). Four of the five species on the boulders were not observed at any other site while one of those from the cliffline was also absent from the other sites.

Description and Suitability of the Dredge Materials

The general characteristics of the undisturbed reef platform substrates at this site are shown in Figure 24, Profile L. A general reconnaissance of the reef platform shows that reef deposits from the sandy seagrass and algae zone would be suitable for use in road construction. Since volcanic rocks outcrop at places along the inner part of the platform calcareous reef deposits may form only a thin veneer over Tomil basement rocks. A test bore should be made to determine whether or not sufficient reef deposits overlie the nonreef basement rocks. Of the two reef platform zones the sandy intertidal fringe along the shoreline is less desirable for road construction use because of greater amounts of terrestrial clay and silt in the deposits. As a general trend the bioclastic fraction of the reef platform deposits increases in a seaward direction from the shoreline. An increase in the amount of the bioclastic fraction composed of fragmented and whole coral colonies is especially noticeable as the distance from the shore increases.

Dredging Recommendations and Environmental Considerations

Although there appears to be no serious environmental objection to dredging at this site we are not recommending that dredging be conducted for the following reasons (see Table 1): 1) the amount of calcareous reef deposits within a reasonable distance from shore may be limited because of the closeness of underlying volcanic rocks, 2) considerable effort would be required to construct an accessway to the reef platform because of the cliff along the shoreline, and 3) better calcareous materials are available at the Map Bridge Site.

SITE 12 - LAGOON SAND DREDGING AREA

General Setting and Description

Site 12 is located on the outer part of barrier reef about two miles southeast of Colonia within a large secondary lagoon area that ranges from two to five meters deep (Fig. 1). Sand is dredged from the floor of the lagoon by using a crane and bucket on a floating barge. When the barge is loaded with sand it is towed to Colonia and offloaded. Large amounts of clean calcareous sand are available only from such lagoonal areas. Except for a few small barrier reef islets, hard limestone deposits from which manufactured sand could be made are not found on Yap. The abundant volcanic rocks exposed on the island are extensively weathered or are not suitable for use in manufacturing sand for construction uses.

Considering the high cost of importing sand to the island, Yap has little choice but to use its abundant lagoonal resource.

In deeper parts of the sand dredging site the lagoon floor is somewhat undulatory and barren, particularly where it is undergoing bioturbation by burrowing organisms. Moderately deep regions are also somewhat undulatory with scattered patches of seagrass and algae. Shallower parts of the lagoon are for the most part dominated by a contiguous mat of sea-grasses and algae. Holothurians are the most conspicuous and abundant macroinvertebrate observed on the lagoon floor. Corals are restricted to a few widely scattered knolls and mounds. Where these oases of coral were found in regions of intense dredging they appeared to be healthy and thriving. Observation during dredging revealed that a surprisingly small plume was generated and that within 150 meters downcurrent of the operation most of the suspended sediments had settled to the lagoon floor. At the dredge site the lagoon deposits contain mostly sand-sized sediments with little lime mud present, which accounts for the small dredge plume observed. Wave transport of water across the barrier reef generates currents at the dredge site that carries most of the mud-sized particles farther lagoonward where they settle out in deeper quieter water. Inspection of rich coral zones around the perimeter of the sand dredge site revealed no damage that could be attributed to sedimentation generated by the dredging operation.

Based upon observations made during our short reconnaissance of the lagoon sand dredging site we recommended the following: 1) sand dredging operations be restricted to shallow lagoon areas (two to five meters deep) near the outer barrier reef where the sediments contain little lime mud, 2) sand dredging operations be conducted no closer than 200 meters of the rich coral regions around the perimeter of the dredge site, 3) a more extensive study of the sand dredging operation be conducted, and 4) monitor the site periodically for environmental degradation.

Table 1. Overall Evaluation of Existing and Potential Dredge Sites.

	SITE											
CRITERIA	1 Kanif (Gaatamoon)	2 Meerur	3 Ngof	4 Balabat	5 Magachaguill	6 Keng	7 Dugor	8 Rumw	9 German Channel	10 Map Bridge	11 Map School	12 (Sand)
Shoreline Type	Mangrove Swamp	Mangrove Swamp	Mangrove Swamp	Rubbly Beach	Bioclastic Beach	Mangrove Swamp	Rubbly Beach	Mangrove Swamp	Mangrove Swamp	Mangrove Swamp	Rubbly Beach	N/A
Marine Impact	Moderate	Moderate	Low-Mod	Low	Moderate	High	Low-Mod	Low	Moderate	Low	High	Low-Med
Accessibility	Good	Excellent	Excellent	Excellent	Moderate	Moderate	Good	Moderate	Poor	Excellent	Poor	N/A
Suitability of Substrate	Excellent	Exc-Poor	Excellent	Unknown	Good	Excellent	Excellent	Poor-Good	N/A	Excellent	Good	Excellent
Recommended Size	Med-Large	Medium	Large	Small-Med	Small	Small	Med-Large	Small	N/A	Large	Small	Large
Quantity of Suitable Material	Large	Medium	Large	Unknown	Moderate	Moderate	Large	Moderate	N/A	Large	Moderate**	Large
Impact of Previous Dredging (if applicable)	Low	Low	Low	N/A	Changed Shore- from Beach to Mangrove	Moderate	Low	Low	Low	Low	N/A	Low
Rare or Endangered Species	None Observed	None Observed	None Observed	None Observed	None Observed	None Observed	None Observed	None Observed	None Observed	None Observed	None Observed	None Observed
Overall Suitability as a Dredge Site	Excellent	Good	Excellent	Good**	Poor*	Not recommended due to Hospital proximity	Good	Good for limited use only	Recommend deepening and widening	Excellent	Poor**	Excellent

* Not recommended because of public opposition.

** Thickness of reef deposits over the underlying volcanic basement rocks is unknown.

APPENDIX A

MEASURING WATER MOVEMENTS (CURRENTS) USING FLOURESCEIN DYE OR DRIFT DROGUES

In order to obtain data regarding the direction and velocity of water movements (currents), two methods are employed depending upon water depth and other physical parameters. In very shallow water (less than 1-2 meters) or where bottom contours may rise up to that depth, flourescein dye is generally used. In deeper water or where currents need to be measured for long distances, surface-floated drift drogues are used to measure both the surface currents as well as the deeper, non-wind influenced currents (5 meters or so below the surface). Both methods are relatively simple to use and the materials are quite inexpensive.

1. Flourescein Dye Injection Method

Materials necessary to calculate direction and velocity of currents using dye injection include flourescein dye (powder), small squeeze bottle or similar container, tape measure or measured length of line, hand-bearing compass and a stop-watch or regular watch with a second hand.

The dye is diluted in sea water (if being used in a lake or river dilute in fresh water) so that it will be the same density as the surrounding water and the location for release is chosen. The bottle should be held a few inches under the surface of the water when the dye is released.

As the dye is released, the timing of the movement begins. When the cloud of dye reaches the end of the predesignated distance (usually 5 or 10 meters) the time is noted. At that time, a compass heading is determined by sighting along the dye path from the point of release to the end point (see Figure A-1). Calculate the velocity of the dye movement in the following manner:

$$\frac{\text{Distance traveled (m)}}{\text{Time in seconds}} = \text{Velocity in meters/second}$$

You will then have both the velocity and direction of the current at that particular time. Since this is a fairly easy task, it is recommended that it be repeated one or two times in the general area under study.

One should be aware that dye injection current velocities are usually greatly affected by surface winds, especially if they are very strong. If the water is deep enough, sometimes the dye can be released 0.5-1 meter below the surface and compared with the surface release. Normally, however, the wind influences currents from the surface down to a depth of 0.5-2 meters.

2. Drift Drogue Method

To measure both surface and deeper currents, or to measure currents over long distances, drift drogues are commonly used. The drogues themselves contain two basic parts, a float which is attached to a sheet metal cross to catch the current. The floats may be as simple as a chlorox bottle or a commercial foam float which often contains a pole or other device to attach a light for tracking at night during 24-hour current studies. The exposed part of the float should be as small as possible to minimize the effect of the wind on the drogue (see Figures A-3 and A-4).

The float is attached by line or cable to the sheet metal cross which gets carried by the current. The cross is suspended below the float to a depth appropriate to the current that is being measured.

Unlike the dye which is measured on the spot by a line and compass, the drift drogues must be tracked by boat and their location plotted on a chart by using a hand-bearing compass and a 3-arm protractor (see Figure A-2).

Although it depends upon the area and velocity of the current, drift drogues are usually released from a predetermined point (or points) and then tracked (plotted) hourly or so. When they reach a certain distance or location they are plotted and removed from the water, and started again.

To establish a fix (location) for a drift drogue, a boat usually sits alongside it while three compass headings are taken on known points along the shoreline. These three headings are used to fix the location of the buoy on a chart. From these locations, the direction of current and distance (and therefore velocity) of drift can be calculated. The fix is established as follows:

a. Three compass headings are taken on known locations on shore using a hand-bearing compass.

b. The middle heading is compared with the one to the left and the difference in degrees is set on the protractor.

c. The difference in degrees between the center and right heading is set on the protractor.

d. The protractor is moved on the chart until the three arms fall over the three locations that the headings were taken on. The hole in the protractor (center) is the location of the drift drogue.

By measuring distances between the fixed locations of the drift drogues and knowing the time between the fixes the velocity of the current may be calculated.

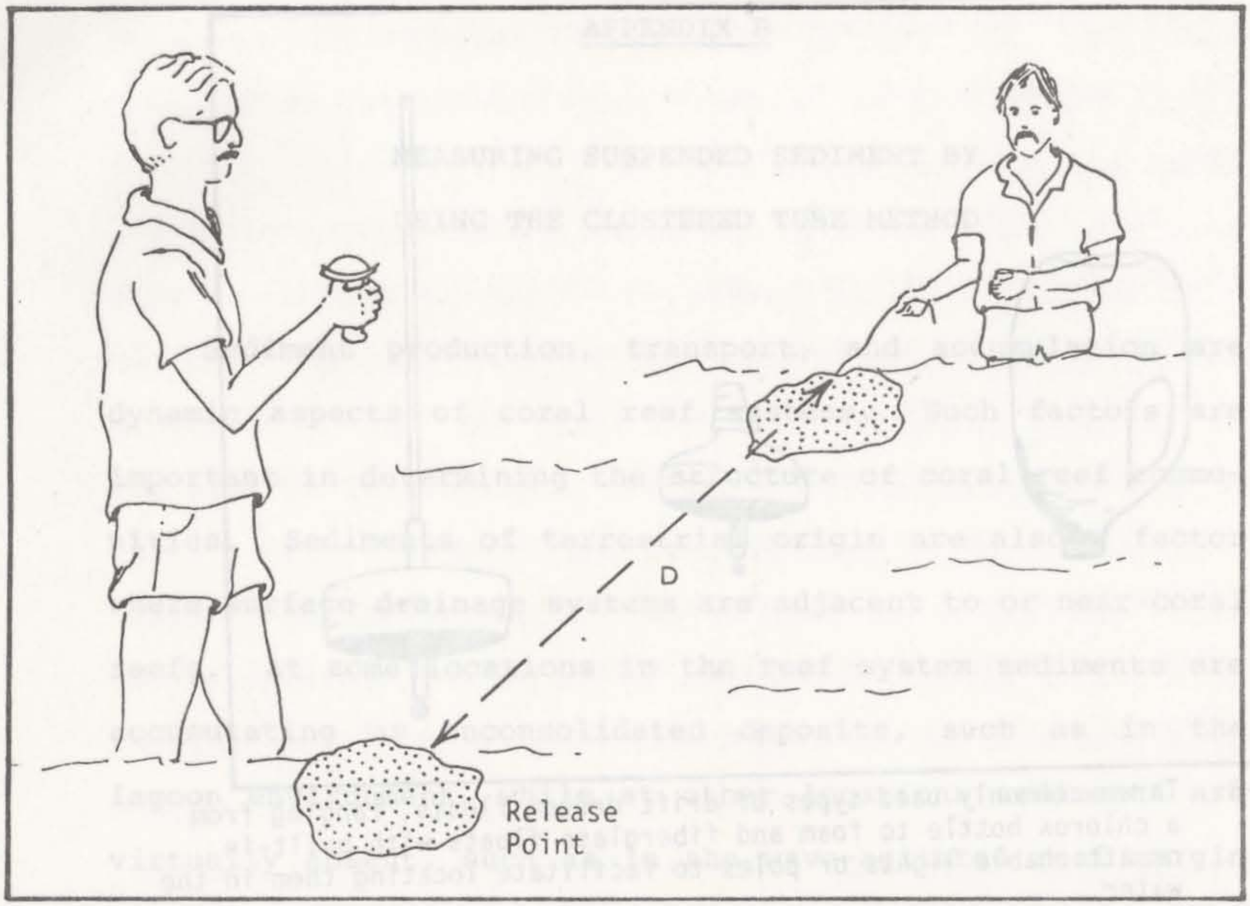

Figure A-1. The flourescene dye release method of determining current velocity and direction. The movement of the leading edge of the dye cloud is timed over a measured distance (D) for velocity. A compass reading along the path of dye travel gives the current direction.

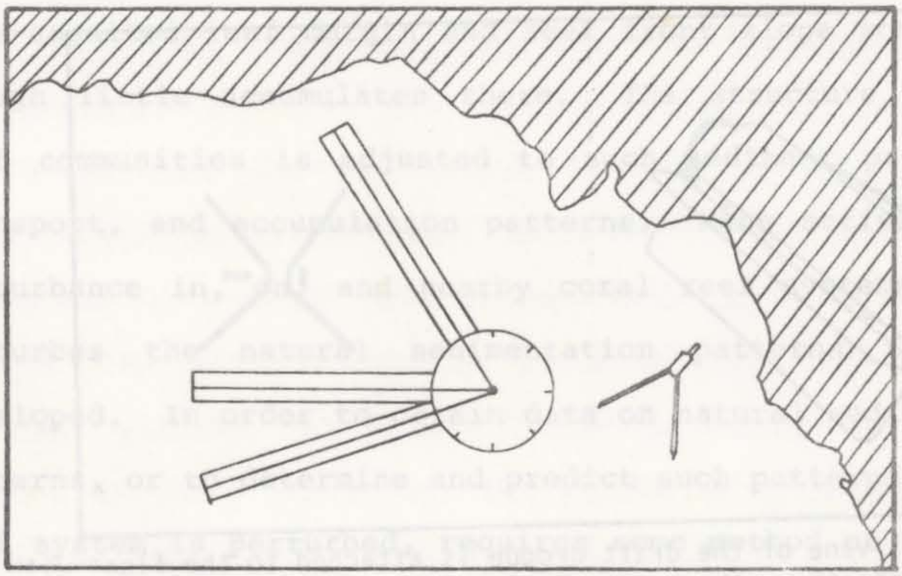

Figure A-2. Use of the three-arm protractor and dividers for determining drogue location based on three compass headings to known locations on shore. A fix of the drogues position is then obtained.

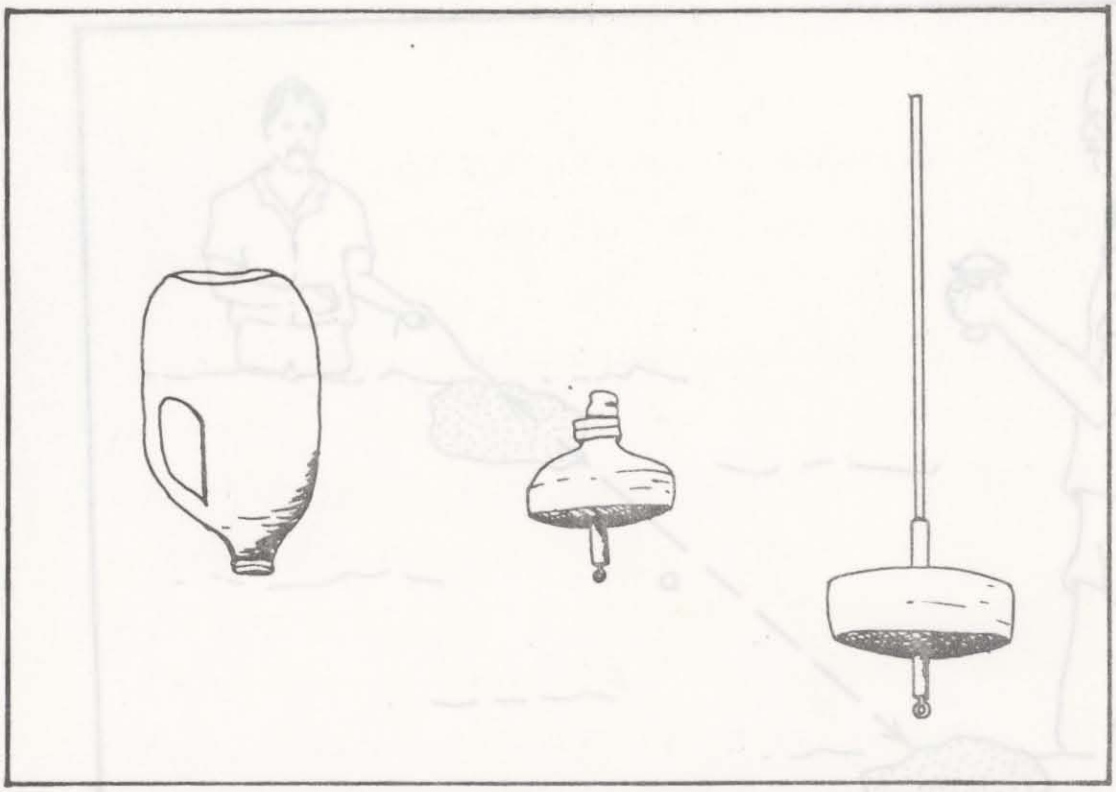

Figure A-3. Three commonly used types of drift drogue floats, ranging from a chlorox bottle to foam and fiberglass floats with built-in or attachable lights or poles to facilitate locating them in the water.

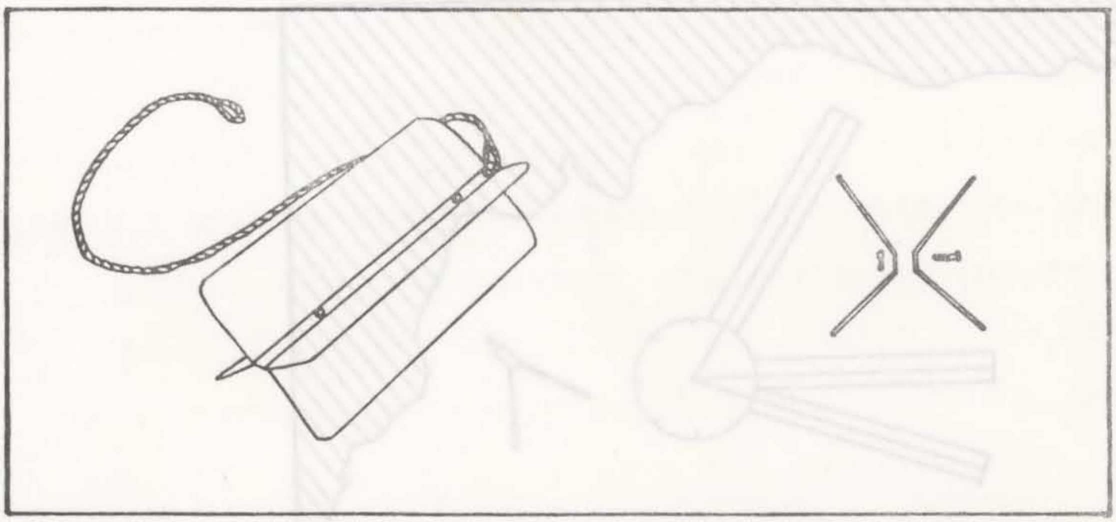

Figure A-4. The metal vane of the drift drogue is attached to the float with a cable or line. The cross section (top) view shows how they are disassembled for ease in transporting and reassembled with a bolt and wing nut.

APPENDIX B

MEASURING SUSPENDED SEDIMENT BY USING THE CLUSTERED TUBE METHOD

Sediment production, transport, and accumulation are dynamic aspects of coral reef systems. Such factors are important in determining the structure of coral reef communities. Sediments of terrestrial origin are also a factor where surface drainage systems are adjacent to or near coral reefs. At some locations in the reef system sediments are accumulating as unconsolidated deposits, such as in the lagoon environment, while at other locations sediments are virtually absent, such as in the wave-agitated reef margin and reef front slope zones. A considerable amount of sediment is transported as suspended particulates in the water column. A large amount of sediment fluxes through the wave-assalted reef margin and reef front slope zones, even though little accumulates there. The structure of coral reef communities is adjusted to such sediment production, transport, and accumulation patterns. Mans activities and disturbance in, on, and nearby coral reef systems usually perturbes the natural sedimentation patterns that have developed. In order to obtain data on natural sedimentation patterns, or to determine and predict such patterns when the reef system is perturbed, requires some method of quantitative measurement. A relatively simple, quick, and inexpensive method employing clustered tubes was used to obtain sediment data by Randall and Birkeland (1978) in Guam.

The clustered tubes used by Randall and Birkeland (1978) consist of four PVC (polyvinyl chloride) pipes strapped together as shown in Figure B-1. The length of the tubes used in the Guam study was 41 cm (16 in.). The tubes can be longer or shorter than 41 cm (16 in.), but should be no shorter than six times the aperature diameter. In shallow locations the shorter tubes may be used so they will remain submerged during low tides. The original pipe aperature diameter was about 2.4 mm (.94 in.), but other diameters can be used as well. For ease of handling, cost, and weight the PVC pipe ranging from 3/4 to 1 inch (inside diameter) is well suited for use in shallow coral reef habitats. In the Guam study there was no significant difference in sampling results from using either a beveled or square cut aperature end. It is probably more convenient to use the square cut aperatures as illustrated in Figure B-1. Before taking the tubes into the field the aperatures at one end of the clustered set should be tightly closed off with rubber or cork stoppers. At the sediment collecting station a length of steel rod (rebar used in reinforced concrete construction, No. 4 or 1/2 in. diameter size) is hammered into the reef surface and a set of clustered tubes (central cavity formed at the center of the clustered set) slipped onto the free end. This secures the sediment tubes in a vertical upright position. Do not let the rebar protrude above the aperature openings as this could interfere with water movement. After a period of time the tubes are collected by first closing the open aperature ends with cork or rubber stoppers (to prevent loss of sediment in handling and transporting) and then slipping the clustered set of pipes off the rebar rod. If continued sampling at the station is desired a new set of clustered pipes can be slipped onto the rebar rod at this time. The length of a sampling period should not be so long as to let the tubes fill completely. A period of time which results in sediment accumulation of less than three-forths of the pipe length is best.

Next the tubes are brought into the laboratory. Processing of the sediment samples should start immediately as biologic activity can alter the sediments within the stoppered tubes. The sediment should be rinsed from each tube into clean containers that have been previously weighed and labeled. Fresh or distilled water is then poured into the containers and the sample allowed to settle for 24 hours. The water is then decanted. This procedure is continued for a total of five days (rinsing periods) to get rid of the salts from the seawater collected with the sediment sample. After the fifth decanting the sediment samples in their containers are placed in a drying oven at 80°C for four days. On the fifth day, the containers are placed in a desicator overnight and allowed to reach room temperature. The container with the dried sediment is then weighed and the weight of the empty container subtracted. If desired, the sediment samples can be analyzed for other characteristics such as; grain size, composition, and other statistical parameters by following standard procedures in various references (see Folk, 1974).

Some factors to consider in collecting reliable sediment data are: 1) be consistent in the size of the clustered pipes used (aperature diameter and length), 2) sampling periods should be consistent, 3) when comparing similar habitats be consistent in the depth at which the tubes are placed, and 4) recording of weather conditions is helpful in explaining variation in rates of sedimentation (especially wind and rainfall if the station is influenced by terrestrial sediments brought to the reef by rivers and streams).

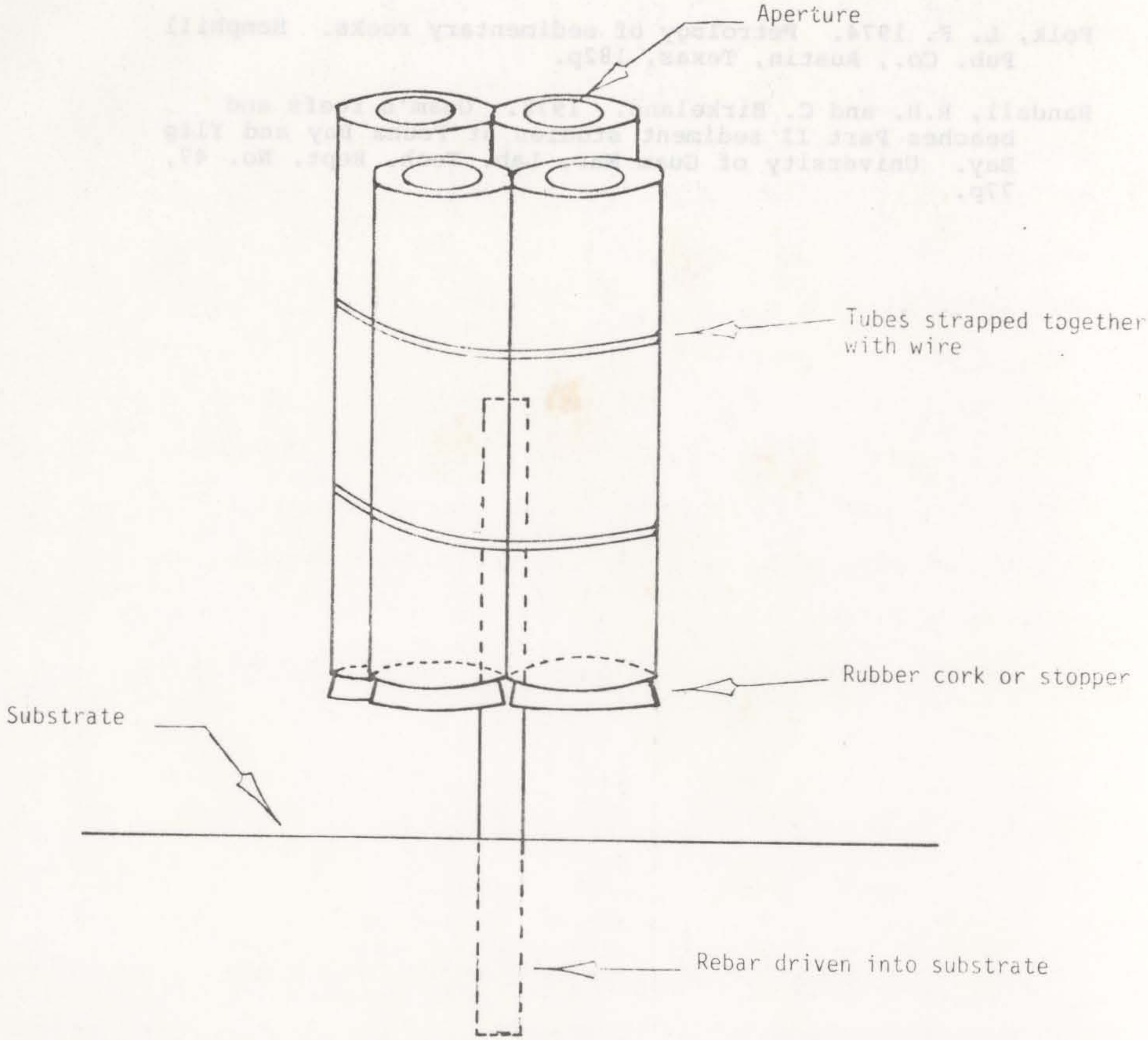

Figure B-1. Clustered sediment tubes used to measure suspended sediment.

REFERENCES

Folk, L. F. 1974. Petrology of sedimentary rocks. Hemphill Pub. Co., Austin, Texas, 182p.

Randall, R.H. and C. Birkeland. 1978. Guam's reefs and beaches Part II sediment studies at Fouha Bay and Ylig Bay. University of Guam Mar. Lab. Tech. Rept. No. 47, 77p.