# A MARINE SURVEY
# FOR THE PROPOSED
# MERIZO MARINA



BY

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70

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## INTRODUCTION

### Background

Mr. Juan Reyes of Merizo, Guam is submitting a proposal to the Department of Land Management, Government of Guam; the U.S. Department of Interior; and the Corp of Engineers to construct a small boat marina on submerged lands. These lands are located seaward of lot no. 240 new-4 within the municipality of Merizo, in an area generally known as Pigua, Territory of Guam (Fig. 1 and 2). It is necessary for Mr. Reyes to file an Environmental Impact Statement and obtain permission from the above governmental agencies. He contacted the authors of this report through his engineering consultant Mr. Juan Tenorio and requested an environmental assessment of the construction site. The results of our survey are contained herein.

This report does not constitute a complete Environmental Impact Statement. Instead it is an environmental impact survey or assessment from which Mr. Reyes may extract details for his final statement.

The report is based upon drawings by Juan C. Tenorio and Associates, entitled; Proposed Marina, Merizo, Guam. Figures 1 to 4 are from this proposal.

### The Proposal

The proposal consists of two parts, one inshore and one offshore. The inshore portion consists of a parking lot, a two-story building with offices and a restaurant, an outdoor bar and restrooms, a boat repair shop, boat ramp, and sewage treatment plant. Except for the boat ramp, all the above facilities will be located above the mean high water mark and will not be considered in detail herein.

The offshore development consists of a protected boat basin approximately 500ft. by 200 ft. with protection provided by two parallel causeway-jetty structures, constructed of steel sheet piles and filled with rock and earth (Fig. 3).Dredging will be necessary within the basin and entrance to the basin (Fig. 4). Space will be provided for 100 boats of varying sizes moored to floating docks and driven pilings within the basin. Although the plans do not show one, we suspect some type of retaining wall will be necessary at the shoreline to prevent erosion.

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[1] This work and the opinions contained herein are those of the authors and not necessarily those of the University of Guam, the Marine Laboratory, or the Government of Guam. The project is considered a community service and the work was conducted by the authors on their own time.

Potential modification of the marine environment includes the following:

1. Seawall construction and boat ramp will cover the present seawater-land interface (shoreline).

2. Dredging will physically remove the extant benthic habitat of the lagoon fringing reef flat and part of the Mamaon Channel slope and bottom (Fig. 4).

3. Dredge silt may affect downstream benthic organisms.

4. The causeways will cover benthic organisms of the fringing lagoon reef flat.

5. The causeways may divert the seaward flow of the Geus River and alter the lagoon seawater currents in the immediate vicinity.

6. Circulation within the enclosed basin may be restricted.

## RESULTS

### Description of Study Area

General Land Forms and Geology:

The study area is located along the shore of Cocos Lagoon near the mouth of the Geus River (Figs. 2 and 5). The Geus River empties into the Cocos Lagoon about 150 feet east of the project site. The project site is located on the seaward margin of the Geus River alluvial valley. This valley trends in a northeast direction from the shoreline. The head of the valley originates on the steep southwest slopes of Mt. Schroeder, Mt. Finasantos, and Mt. Sasalaguan. The sides of the valley are bordered by steep dissected hills, comprised of the lower slopes of the above mountains. Geologically these mountains and foothills are part of the Umatac formation. The rocks of this formation are of volcanic origin and on the surface, at most places, are deeply weathered and altered into clay. The vegetation of this volcanic upland consists mostly of savanna type growth. Some dense jungle woodland occupies the lower parts of the steep mountain valleys.

At the project site the alluvial plain is elevated about three feet above the mean high tide level. The alluvium consists mostly of volcanic clay, sand, and gravel derived from the steep mountain slopes bordering the valley plain. A small fraction of the alluvium along the shoreline consists of bioclastic materials derived from carbonate secreting marine organisma of the adjacent lagoon. The alluvium at the project site appears to be a thin mantle covering an older limestone platform. At present the shoreline is a zone of accretion. The alluvial valley floor is occupied by residential dwellings and farmland. Vegetation consists of coconut trees; ornamental grasses, trees, and shrubs around the residential areas; and weed communities, vegetable gardens, and grazing pastures in the farmland areas. The inshore part of the project site is at present a grazing pasture which extends from the shoreline to Route 4 (Fig. 5). Strand vegetation at the site consists of a mixed grass and weed community with three or four scattered trees and shrubs. The beach zone shows considerable evidence of past disturbance in the form of rock fill and trash accumulation.

Intertidal Zone:

This zone consists of a broad fringing lagoon platform that extends outward to Mamaon CHannel (Fig. 5e). During minus tides, the entire platform (Fig. 9) is exposed to the channel margin. At the project site, the platform consists mostly of a black plastic mud, high in organic content; some fine sand and gravel; and a small fraction of bioclastic materials. This unconsolidated material forms a layer of variable thickness over a limestone platform.

To the east of the project site the Geus River empties onto the intertidal platform (Fig. 5g). A small mangrove community occupies the river banks at the mouth. Several small patches of mangrove trees are located near the shore between the river mouth and the project location, but none of these will be disturbed as they lay outside the construction boundaries. The river divides into several shallow tributaries as it makes its way across the intertidal platform to the head of Mamaon Channel. There are two principal channels, one of which cuts across the construction site (Fig. 5f). These river channels are quite shallow, usually less than a foot in depth, and show evidence of meandering about as sediment deposition builds up on various parts of the intertidal platform. The channels are submerged at high tide and exposed at minus tides. During floods the river deposits, tree limbs, leaves, roots, and other forms of organic material on the platform. The most easterly of the river channels marks the boundary of the dark-colored intertidal sediments found in the construction area. The platform region east of the river channels (Fig. 5h) and around the head of Mamaon Channel, (Fig. 5j) have sediments composed mostly of light-colored bioclastic materials and a smaller fraction consisting of nonbioclastic material of alluvial origin. This sediment distribution pattern and water current data indicate that flood waters of the Geus River flow out onto the intertidal platform and then to the west across the project site. These waters sweep into Mamaon Channel at its head and all along the edge of the intertidal mud flats to the west.

Down current from the river and project site, the intertidal platform is covered by a thin layer of dark-colored mud and sand. The fraction of bioclastic material contained within these sediments increases slightly along the channel, which is due to the presence of Halimeda segments (a green calcareous alga). The segments are contributed by scattered Halimeda opuntia patches growing on the upper surfaces of dead microatoll coral colonies. A shallow tidal channel less than a foot in depth originates at the east side of the project site about 50 feet from the shore. It then turns across the intertidal platform west of the project site in a southwest direction to the margin of Mamaon Channel (Fig. 5m).

Mamaon Channel Margin, Slopes, and Floor:

At the project site Mamaon Channel margin slopes downward, 30 to 40 degrees to the 10 to 12 foot depth where it grades into the channel floor (Fig. 6g). Both the channel margin and slope are composed of the same type of unconsolidated sediments as those found on the fringing intertidal platform. The channel margin and slope are rather featureless, except for scattered pieces of river borne debris embedded in the muddy sediments.

Profile No. 1 shows the depth from the outer end of the east causeway, across the head of the channel to the channel margin and slope on the other side (Figs. 6g and 7). The channel floor near the construction site is composed of unconsolidated sediments similar to those found on the channel slope and margin at the project site. The amount of bioclastic material steadily increases across the channel floor, from the project site to the opposite margin. These bioclastic sediments are derived from the intertidal platform east of the study area (eel grass community) and from the lagoon regions around the head of the Mamaon Channel (coral community) lying southeast of the fish trap (Fig. 5i). The channel slope and margin are quite different on the lagoon side of the profile from that found on the project side. The communities there have developed under conditions of less silt sedimentation. The channel slope is composed of large massive and ramose coral colonies. There is much less silt accumulation all along the lagoon side of the channel margin when compared to the landward side. This indicates that the silt laden flood water from the Geus River is more or less restricted to the central and landward side of Mamaon Channel as it moves west to the Philippine Sea. The lagoon side of the channel increases in amount coral coverage and development toward the location of Profile No. 2 (Figs. 6f and 8).

West of the project site a reef patch projects outward into the Mamaon Channel (Fig. 6e). The upper surface of this patch is mostly exposed at low tide. It consists of a cluster of coral microatolls which are mostly dead except for a few small basal patches. The channel slopes around this reef patch have good coral development on the channel side and rather poor development on the embayment side. Silt accumulation is quite heavy among the coral colonies on these slopes and the species present are those which are commonly found around regions where rivers empty onto reef platforms. Coral diversity and development increases in a westward direction along the landward side of Mamaon Channel.

Profile No. 2 (Figs. 6f and 8) shows the general configuration of Mamaon Channel west of the project site. At the base of the channel slope the coral development abruptly stops and the unconsolidated sediments of the channel floor are encountered. The channel floor at this location has a greater fraction of bioclastics present than at Profile No. 1 (Figs. 6g and 7). The floor is rather featureless, except for the presence of conspicuous mounds which have a relief of about one foot. The mounds are formed by the activity of some type of burrowing marine organism. The lagoonward channel slope and margin, like those at Profile No. 1, are considerably richer in coral diversity and development than the landward side.

## Biological Studies

Table 1 is a compilation of all the organisms observed in the study area.

The intertidal zone is dominated by burrowing organisms. Organic matter introduced with river borne sediments results in a reducing environment throughout most of the region. The fish Periopthalmus koelreuteri (mudskipper), at least two species of the fiddler crab (Genus Uca), one or more species of the mud crabs (Xanthidae) and one species of swimming crab (Portunidae) were the most ubiquitous organisms in the intertidal within the construction site. The mudskipper and fiddler crabs were by far the most dominant organisms. Their abundance increases from the channel margin shoreward, reaching a maximum biomass in a band about 50 feet wide along the shore. Most of these animals leave obvious burrows in the black mud. Some blue green algal mats were found in the area but these were thin and widely scattered. The mud seems to be devoid of micromolluscs, worms and other organisms that are usually common in sandy areas. We suspect this is due to the reducing environment.

The intertidal area to the west of the construction site is down current and will receive some sedimentation during construction (Fig. 6d). This region is basically the same as the above except that the mud has a higher fraction of bioclastic material that increases toward the channel margin and to the west. In addition to the above organisms, this area has a population of holothurians and several species of benthic algae (Table 1).

The channel margin in the construction area is a steep slope composed of mud, organic debris, and wreckage washed down the river from Pigua village (Fig. 6a). This is a very poor area biologically due to the shifting nature of the mud slope. Table 1 lists the organisms that occur here. The table shows 21 fish species along the slope. This is an artifact because the species are attracted to the scattered wreckage. Except for the gobies, there would be far fewer fishes here without the wreckage to provide artificial cover. In any event, the fish biomass is low and would not amount to more than five to ten pounds in the entire area.

Corals first make their appearance along the channel margin just west of the construction site. They are widely scattered here and the species are, for the most part, adjusted to high sedimentation areas. A small patch reef projects from the channel margin as shown on Figure 6e. The upper surface of this patch reef is composed of microatolls. Most of these structures are dead except near the basal parts. The sides of the patch reef show an increase in the degree of coral development and coverage. The south side of the patch is considerably richer in corals than the east. The north and west sides are heavily silted and coral growth patchy. A coral transect was run from the surface to the bottom of the patch reef on the south side (Fig. 6j). This transect, Table 2, shows that 35 percent of the slope is covered with living corals which is surprising in an area dominated by heavy siltation from the Geus River. The dominant corals are Porites mathai, and P. (Synarea) convexa.

The channel margin continues on to the west beyond the patch reef (Fig. 6c). The edge of the channel margin on the surface is composed of microatolls that are dead except near the basal portions as in the case of the patch reef. This zone is about 10 to 15 feet wide and gives way shoreward to mud flats. The channel slope is steep and the upper 20 feet at transect 2 (Fig. 6k) is similar in coral species and coverage to that found at transect 1 (Table 2). From 20 feet to 40 feet, the channel floor, the coral coverage is much less and consists of widely scattered coralla and patches. Since transect 2 is deeper and the lower portion has a poor coral coverage, the overall percentage of coral cover of 16.5 percent is less than half that at transect 1. The dominant corals are the same as at transect 1.

The number of fish species increases considerably in both these areas due to the presence of cover offered by the coral community. Table 1 lists the dominant species of the channel margin walls.

Profile 1 shows the configuration of the head of Mamaon channel opposite the study site (Figs. 6g and 7). The channel floor was almost entirely barren of marine orgainisms except for scattered patches of the green algae Arainvillia, Halimeda macroloba, and several species of burrowing gobioid fishes. Profile 2 shows the configuration of Mamaon channel farther to the west (Figs. 6f and 8). This area is deeper than the above and completely barren except for the burrowing gobies and mounds made by some as yet unidentified organism. These mounds are conspicuous and in some cases have a relief of over one foot. Attempts to dig up these organisms were unsuccessful.

The area to the east of the construction site lies outside of the normal pattern of sedimentation (Figs. 5h and 6b). This area is much richer biologically than the construction site but since it is not likely to be damaged, it will not be reported on further. Table 1 lists the organisms observed in this area.

## Current Patterns

It should be pointed out that a picture of the current patterns in the study area is based on very few samples. The data taken are shown on Figure 10 and in Table 3. The current sweeps through the study area from east to west. This condition predominates at all stands of the tide. All of the water flowing through the study area eventually enters Mamaon Channel and moves westward to the Philippine Sea. These data are in agreement with a similar study conducted by Randall and Jones (1972), in an area along Mamaon Channel and farther to the west. On January 13 we encountered a weak west wind which is rare in the study area. The result of this wind was a reduction in current velocity (Table 3). During flood tides and strong west winds, there may be a current reversal in Mamaon Channel and water may then sweep from west to east across the study area.

One series of dye releases was made along the west causeway boundary (Table 3). The two inshore stations showed a confused oscillating pattern that was related to translatory surge from the Cocos lagoon reef margin. The inshore one third of the study area is sheltered from prevailing winds. Except during southeast and southwest winds, there is little wave action here.

# CONCLUSIONS

It is apparent that the dredging of the marina basin and construction of the causeways will remove or cover about 100,000 square feet of mud flat habitat. The primary community disturbed will be that of the mud-skipper/fiddler crab complex. The most dense portion of this community lies along the shore and consists of about 10,000 square feet. The community is common all along the southeast corner of Guam. The dredging of the basin entrance will probably be minimal due to the existing depths of Mamaon Channel (Fig. 7). This area (Fig. 6a) was found to be biologically depauperate.

If the basin is provided with adequate circulation, we would predict a replacement of the existing community with one that is considerably richer in terms of species composition. The causeway and associated pier structures along with the deepening of the area can be expected to provide cover that does not now exist in the immediate construction site. These structures will attract a considerable fouling community as well as a much richer fish community. The possible success of the latter is evident from the present association of fishes with wreckage on the channel margin and floor. The gobioid fishes will probably recolonize the basin floor after construction and the stabilization of the bottom sediments.

The downstream community consists of more of the same kind of mud flat as well as the coral rich margins of Mamaon Channel. These communities have developed in and are adjusted to a considerable silt load from the Geus River. It is doubtful that these communities will be significantly affected by dredging activities. There is no way, however, that this could be predicted with certainty. It would be wise to monitor the coral communities during and after construction to provide data for evaluating the impact of future projects of this nature.

Figure 10 shows that the construction area will block the present tidal channels of the Geus River. This will deflect the flow around the end of the east causeway into Mamaon Channel. Some accretion of material can be expected along the east side of the east causeway. The deflection of silt into Mamaon Channel may ease the present amount of sedimentation of the mud flats and the coral rich channel margins west of the construction site. This might well result in a richer marine community in the present mud flat area similar to that up current from the mouth of the Geus River.

There is a permanent government licensed fish trap off the end of the east causeway. The construction boundaries do not encroach on the trap, but it is not known what effect the proximity of the marina and river diversion will have on the catch rate of the trap.

We feel that this marina site is well chosen from a biological point of view. Siltation from the Geus River results in a biologically poor area within the construction boundaries. If properly engineered for circulation in the basin the project may well enhance the immediate construction site biota.

## RECOMMENDATIONS

1. Under no circumstances should dredging be done when unusual conditions reverse the flow of currents in Mamaon Channel.

2. The basin design should allow adequate flushing to avoid anaerobic conditions.

## REFERENCES

Randall, R. H. and R. S. Jones. 1972. A Marine Environmental Impact Survey for the Proposed Merizo Pier, Environmental Survey Report No. 1. 13p.

Table 1. Checklist of marine organisms from study area. Letters a-e are study transects (Fig. 6).

| ALGAE: | a | b | c | d | e |
|---|---|---|---|---|---|
| *Acanthophora spicifera* | o | x | o | o | o |
| *Amphiroa fragilissima* | o | x | x | o | o |
| *Arrainvillea obscura* | x | x | o | x | o |
| *Caulerpa filicoides* | x | x | x | o | o |
| *C. racemosa* | x | x | x | o | o |
| *C. sertularioides* | x | o | o | o | o |
| *C. taxifolia* | x | x | x | o | x |
| *Dictyota* sp. 1 | x | x | x | x | x |
| *Enteromorpha intestinales* | o | o | o | x | o |
| *Galaxaura* sp. 1 | x | x | x | o | x |
| *Halimeda macroloba* | x | o | o | x | o |
| *H. micronėsica* | o | x | x | o | o |
| *H. opuntia* | x | x | x | x | x |
| *Hormothamnion enteromorphoides* | o | x | x | o | o |
| *Lobophora variegata* | o | x | x | o | o |
| *Microcoleus lyngbyaceus* | x | x | x | x | x |
| *Neogoniolithon frutescens* | o | x | x | o | x |
| *Neomeris annulata* | o | o | x | o | o |
| *Oscillatoria* sp. 1 | o | o | o | x | o |
| *Padina boryana* | x | x | x | x | x |
| *Peyssonelia* sp. 1 | o | x | x | o | o |
| *Porolithon gardineri* | o | o | x | o | o |
| *P.* sp. 1 | x | x | x | x | x |
| *P.* sp. 2 (yellow) | x | x | x | o | o |
| *Schizothrix mexicana* | x | x | x | x | x |
| *Spyridia velasquezii* | o | x | o | o | o |
| TOTAL | 14 | 20 | 19 | 10 | 9 |

| ANGIOSPERMS (marine): | a | b | c | d | e |
|---|---|---|---|---|---|
| *Enhalus acoroides* | o | x | o | x | o |
| *Halophila minor* | x | o | o | x | o |
| TOTAL | 1 | 1 | 0 | 2 | 0 |

| PROTOZOA: | a | b | c | d | e |
|---|---|---|---|---|---|
| *Homotrema rubrum* | o | x | x | o | o |
| *Marginopora vertebralis* | o | x | o | o | o |
| TOTAL | 0 | 2 | 1 | 0 | 0 |

Table 1. (continued)

| PORIFERA: | a | b | c | d | e |
|---|---|---|---|---|---|
| *Cinachyra australiensis* | o | x | o | x | o |
| "Sponge" sp. 1 | o | x | x | o | o |
| "Sponge" sp. 2 | o | x | o | o | o |
| "Sponge" sp. 3 | o | x | o | o | o |
| "Sponge" sp. 4 | o | x | o | o | o |
| "Sponge" sp. 5 | o | x | o | o | o |
| TOTAL | 0 | 6 | 1 | 1 | 0 |

CNIDARIA:
Anthozoa:

| | a | b | c | d | e |
|---|---|---|---|---|---|
| *Acrhelia horrescens* | o | o | x | o | x |
| *Acropora aspera* | o | x | o | o | o |
| *A. formosa* | o | x | o | o | x |
| *Astreopora myriophthalma* | o | x | x | o | o |
| *Galaxea fascicularis* | o | o | x | o | o |
| *Goniastrea retiformis* | o | x | x | o | o |
| *Heliopora coerulea* | o | x | x | o | o |
| *Lobophyllia corymbosa* | o | o | x | o | o |
| *Montipora lobulata* | o | x | x | o | x |
| *M. ehrenbergii* | o | o | x | o | x |
| *M. granulosa* | o | o | x | o | x |
| *M. hoffmeisteri* | o | o | x | o | x |
| *M. patula* | o | o | x | o | x |
| *M. verrilli* | o | x | x | o | x |
| *Pachyseris speciosa* | o | o | x | o | o |
| *Pocillopora damicornis* | x | x | x | o | x |
| *Porites andrewsi* | x | x | x | o | x |
| *P. cocosensis* | x | x | x | o | x |
| *P. lobata* | o | x | x | o | x |
| *P. lutea* | x | x | x | o | x |
| *P. (Synaraea) convexa* | o | x | x | o | x |
| *P. (Synaraea) horizontalata* | o | o | x | o | x |
| *P. (Synaraea) iwayamaensis* | o | x | x | o | x |
| *Plerogyra sinuosa* | o | o | x | o | o |
| *Psammocora contigua* | x | o | x | o | o |
| TOTAL | 5 | 14 | 23 | 0 | 16 |

Alcyonaria:

| | a | b | c | d | e |
|---|---|---|---|---|---|
| *Sarcophyton* sp. 1 | o | x | o | o | o |
| TOTAL | 0 | 1 | 0 | 0 | 0 |

Table 1. (continued)

| Hydrozoa: | a | b | c | d | e |
|---|---|---|---|---|---|
| "Hydroid" sp. 1 | o | o | x | o | x |
| TOTAL | 0 | 0 | 1 | 0 | 1 |
| ANNELIDA: | | | | | |
| *Sabellastarte* sp. 1 | o | x | x | o | o |
| *Spirobranchus* sp. 1 | o | x | x | o | o |
| TOTAL | 0 | 2 | 2 | 0 | 0 |
| MOLLUSCA: | | | | | |
| *Bursa* sp. 1 | o | x | o | o | o |
| *Cerithium* sp. 1 | x | x | x | x | x |
| *C.* sp. 2 | o | x | o | o | o |
| *Conus pulicarius* | x | x | x | o | o |
| *Coralliophila violaiea* | o | x | x | o | o |
| *Cypraea erosa* | o | x | o | o | o |
| *C. moneta* | o | x | x | o | o |
| *Drupa nodus* | o | x | x | o | x |
| *Littorina* sp. 1 | x | o | o | o | o |
| *Mitra stictica* | o | x | o | o | o |
| "Opisthobranchia" sp. 1 | o | o | o | o | x |
| "Opisthobranchia" sp. 2 | o | o | o | o | x |
| *Terebra maculata* | o | o | x | o | o |
| *Tridacna maxima* | o | x | o | o | o |
| "Vermetidae" sp. 1 | o | x | x | o | x |
| TOTAL | 3 | 11 | 7 | 1 | 5 |
| CRUSTACEA: | | | | | |
| Amphipoida: | | | | | |
| "Amphipod" sp. 1 | o | x | o | o | o |
| TOTAL | 0 | 1 | 0 | 0 | 0 |
| Decapoda: | | | | | |
| "Portunid" | x | o | o | x | o |
| "Grapsid" sp. 1 | x | o | o | x | o |
| "Grapsid" sp. 2 | x | o | o | x | o |
| *Uea* sp. 1 | x | o | o | x | o |
| TOTAL | 3 | 0 | 0 | 3 | 0 |

Table 1. (continued)

| ECTOPROCTA: | a | b | c | d | e |
|---|---|---|---|---|---|
| "Bryozoa" sp. 1 | o | x | o | o | o |
| TOTAL | 0 | 1 | 0 | 0 | 0 |
| ECHINODERMATA: | | | | | |
| Echinometra mathaei | o | x | x | o | o |
| Echinothrix diadema | o | x | x | o | o |
| Holothuria argus | o | x | o | o | o |
| H. atra | x | x | x | x | x |
| H. sp. 1 | x | x | o | o | o |
| H. sp. 2 | x | x | x | x | x |
| Opheodesoma godeffroyi | o | x | x | o | x |
| "Ophiuroid" sp. 1 | o | o | x | o | o |
| Stichopus chloronotus | o | x | x | o | o |
| S. sp. 1 | o | o | x | o | o |
| TOTAL | 3 | 8 | 8 | 2 | 3 |
| FISHES: | | | | | |
| Acanthuridae: | | | | | |
| Acanthurus xanthopterus | o | x | x | o | x |
| A. triostegus | o | x | x | o | x |
| Ctenochaetus striatus | o | x | x | o | x |
| Zebrasoma flavescens | o | o | x | o | o |
| Z. veliterum | o | x | x | o | o |
| Apogonidae: | | | | | |
| Apogon sp. | o | o | x | o | x |
| A. variegatus | o | o | o | o | x |
| Paramia quinguelineata | x | x | x | o | x |
| Balistidae: | | | | | |
| Rhinecanthus aculeatus | o | o | o | o | x |
| Blenniidae: | | | | | |
| Meiacanthus atrodorsalis | o | x | x | o | x |
| Canthigasteridae: | | | | | |
| Canthigastei solandri | x | x | o | o | o |
| C. bennetti | x | o | o | o | o |

Table 1. (continued)

| | a | b | c | d | e |
|---|---|---|---|---|---|
| Chaetodontidae: | | | | | |
| *Chaetodon auriga* | x | x | x | o | x |
| *C. ephippium* | x | o | x | o | x |
| *C. falcula* | o | o | x | o | o |
| *C. lunula* | o | o | x | o | x |
| *C. melannotus* | o | x | o | o | o |
| *C. mertensii* | o | o | x | o | x |
| *C. ornatissimus* | o | o | x | o | o |
| *C. trifasciatus* | o | o | x | o | x |
| *Heniochus permutatus* | x | x | x | o | o |
| Gobiidae: | | | | | |
| *Acentrogobius triangularis* | x | x | o | x | x |
| *Amblygobius albimaculatus* | x | x | o | x | x |
| *A. decussatus* | x | x | o | x | x |
| *Asterropteryx semipunctatus* | x | x | x | o | x |
| *Gnatholepis deltoides* | x | x | o | o | x |
| *Oxyurichthys guibei* | x | o | o | x | x |
| *Periopthalmus koelreuteri* | o | o | o | x | o |
| *Trimma caesiura* | o | x | x | o | x |
| Holocentridae: | | | | | |
| *Myripristes kuntee* | o | o | x | o | x |
| *M.* sp. | o | o | o | o | x |
| Labridae: | | | | | |
| *Cheilinus fasciatus* | o | o | o | o | x |
| *C.* sp. 1 | o | x | x | o | x |
| *Epibulus insidiator* | o | x | o | o | o |
| *Halichoeres trimaculatus* | o | x | x | o | x |
| *Hemigymnus melapterus* | o | o | x | o | x |
| *Labroides bicolor* | o | o | o | o | x |
| *L. dimidiatus* | o | o | x | o | x |
| Leiognathidae: | | | | | |
| *Gerres* sp. | x | o | o | o | x |
| *Leiognathus equulus* | o | o | o | o | x |
| Lutjanidae: | | | | | |
| *Lethrinus* sp. | o | x | x | o | x |
| *Lutjanus kasmira* | x | o | o | o | o |
| *L. vaigiensis* | x | x | x | o | x |
| Mugilidae: | | | | | |
| *Mugil* sp. | x | x | o | x | x |

Table 1. (continued)

| | a | b | c | d | e |
|---|---|---|---|---|---|
| Mullidae: | | | | | |
| _Mulloidichthys samoensis_ | o | x | o | o | o |
| _Parupeneus barberinus_ | x | o | o | o | o |
| _P. pleurostigma_ | o | o | x | o | o |
| _P. porphyreus_ | o | x | x | o | o |
| _P. trifasciatus_ | o | x | o | o | o |
| Muraenidae: | | | | | |
| _Gymnothorax_ sp. | o | o | o | o | x |
| Ostraciontidae: | | | | | |
| _Ostracion cubicus_ | o | x | o | o | o |
| _O. meleagris_ | o | o | o | o | x |
| Pomacentridae: | | | | | |
| _Abudefduf sexfasciatus_ | o | x | x | o | x |
| _A. curacao_ | o | o | x | o | x |
| _Chromis_ sp. 1 | o | o | x | o | x |
| _Dascyllus aruanus_ | x | x | x | o | x |
| _D. trimaculatus_ | x | o | o | o | o |
| _Pomacentrus lividus_ | o | x | o | o | x |
| _P. pavo_ | x | x | x | o | x |
| Scaridae: | | | | | |
| _Scarus lepidus_ | o | x | x | o | o |
| _S. sordidus_ | o | x | x | o | x |
| Serranidae: | | | | | |
| _Epinephelus merra_ | o | x | o | o | x |
| Sygnathidae: | | | | | |
| _Corythoichthys_ sp. 1 | x | x | x | o | x |
| Synodontidae: | | | | | |
| _Synodus_ sp. | o | x | o | o | o |
| Teuthididae: | | | | | |
| _Siganus spinus_ | o | x | o | o | o |
| Zanclidae: | | | | | |
| _Zanclus cornutus_ | o | x | x | o | x |
| TOTAL | 21 | 37 | 36 | 6 | 45 |

Table 2. A - Coral transect #1. Data are from a single line transect which starts at the channel margin downward across the channel slope to the channel floor. Each line section is one meter in length. Line length occupied, is the length of the transect line occupied by a living coral colony. (Fig. 6j)

| Line Section | Zone | Corals: Name | Corals: Line length occupied in cm |
|---|---|---|---|
| 1 | channel margin | _Porites andrewsi_ | 10-12 |
| 2 | channel slope | none | |
| 3 | " | _Porites andrewsi_<br>_Porites (s.) convexa_ | 18-10<br>40 |
| 4-5 | " | none | |
| 6-7-8-9 | " | _Porites (s.) convexa_ | 185-105 |
| 10 | " | none | |
| 11 | " | _Porites cocosensis_ | 32 |
| 12-13 | " | _Porites (s.) convexa_ | 78 |
| 14-15-16-17 | channel floor | _Porites (s.) convexa_ | 105 |

$$\frac{\text{Total line length occupied by living coral}}{\text{Total line length of transect}} \quad \frac{595\text{cm}}{1700\text{cm}} = 35\% \text{ living coral coverage}$$

Table 2. B - Coral transect #2. (Fig. 6k)

| Line Section | Zone | Corals: Name | Line length occupied in cm |
|---|---|---|---|
| 1 | channel margin | none | |
| 2 | " | Porites lutea | 15 |
| 3-4 | channel slope | Porites cocosensis | 10-40 |
| 5-6 | " | none | |
| 7 | " | Porites (s.) convexa | 32-60 |
| 8-9-10 | " | Porites andrewsi | 64-32 |
| 11-12 | " | Porites (s.) iwayamaensis | 25 |
| 13-14 | " | none | |
| 15 | " | | |
| 15 | " | Porites (s.) convexa | 10 |
| 17-18-19 | " | none | |
| 20-21-22 | channel floor | Porites (s.) horizontalata | 75 |

| | | |
|---|---|---|
| Total line length occupied by living coral | 363cm | = 16.5% living coral coverage |
| Total line length of transect | 2200cm | |

| Date | Location | Time | Magnetic Bearing | Speed in Knots | Wind Direction | Wind Speed Kts. | Tide |
|---|---|---|---|---|---|---|---|
| Jan. 13, 1973 | Fig. 10-a. | 1440 | 270 | 0.18 | 290 | 4-5 | near turn, flood/ebb |
| Jan. 14, 1973 | " | 1017 | 285 | 0.25 | 125 | 8-10 | flood |
| " | " | 1152 | 285 | 0.23 | " | " | flood |
| " | " | 1600 | 297 | 0.38 | " | " | ebb |
| " | Fig. 10-b. | 1200 | 281 | 0.36 | 115 | 10-12 | flood |
| " | " | 1210 | 332 | 0.23 | " | " | " |
| " | " | 1215 | 292 | 0.42 | " | " | " |
| " | " | 1218 | 340 | 0.25 | " | " | " |
| " | " | 1221 | 293 | 0.23 | " | " | " |
| " | " | 1225 | 108-288 oscillatory | -- | " | " | " |
| " | " | 1229 | " | -- | " | " | " |
| Jan. 19, 1973 | Fig. 10-a. | 2100 | 292 | 0.27 | 100 | 4-5 | ebb |
| " | " | 2200 | 289 | 0.26 | " | " | " |
| " | " | 2300 | 230 | 0.27 | " | " | " |
| Jan. 20, 1973 | " | 0100 | No current, area dry, low tide (-0.6 feet) | | | | " |
| " | " | 0200 | " | " | " | " | " |
| " | River Channel | 0230 | 260 | 0.30 | 100 | 4-5 | " |
| " | Fig. 10-a. | 0800 | 0 | 0 | 110 | 5-6 | flood |
| " | " | 1000 | 284 | 0.07 | " | " | " |

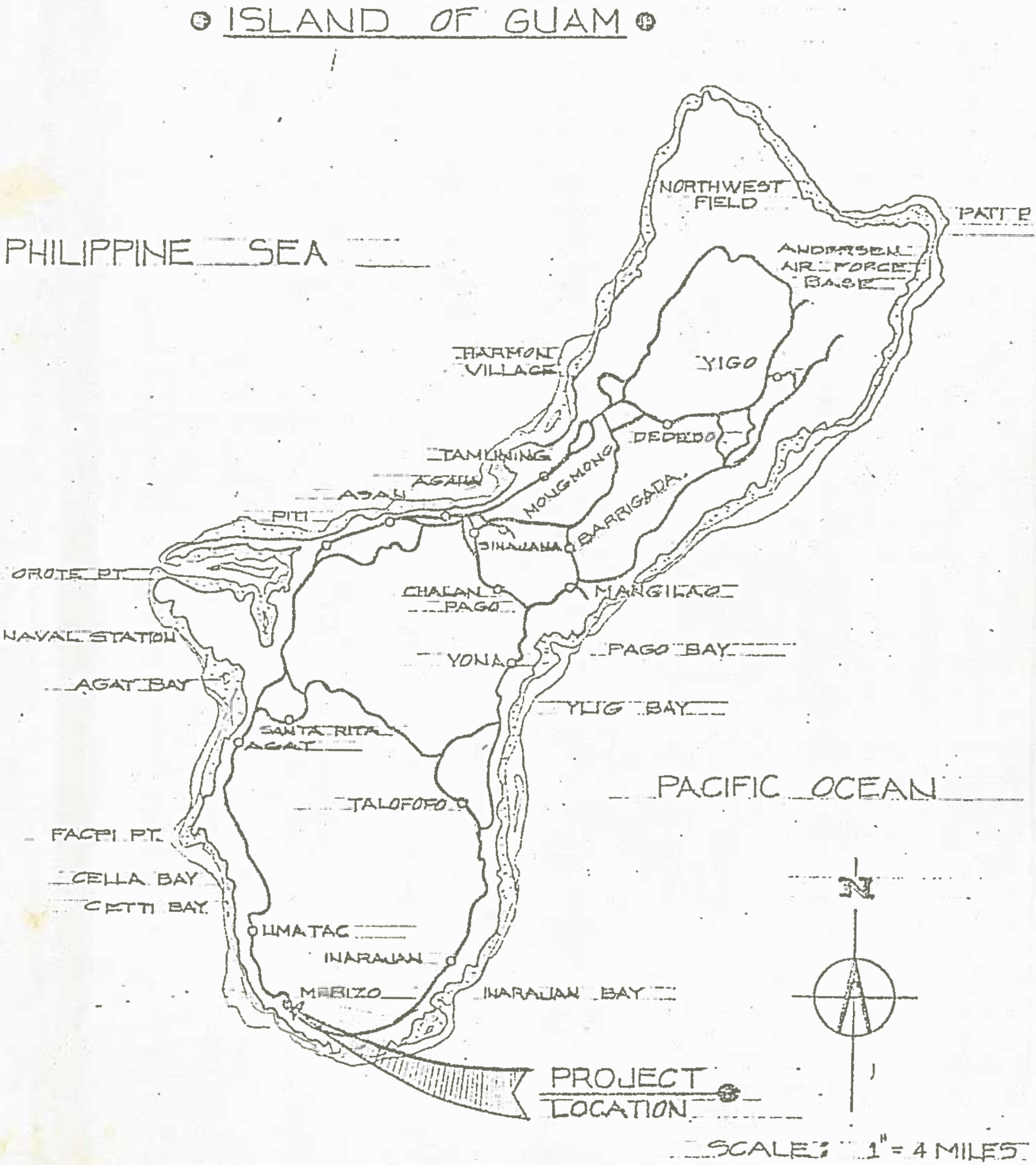


Figure 1

LOCATION MAP

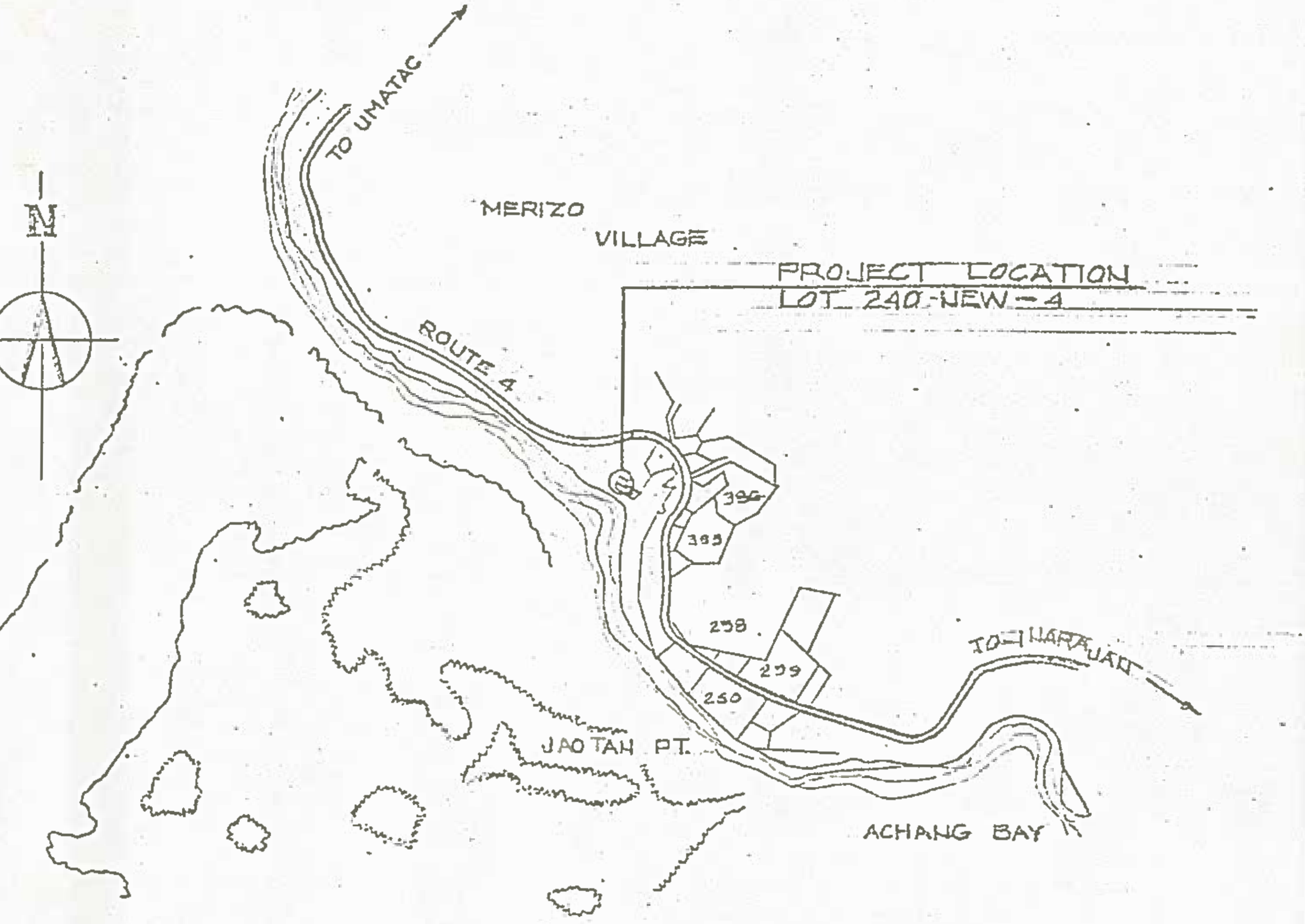


Figure 2 VICINITY MAP
NOT TO SCALE

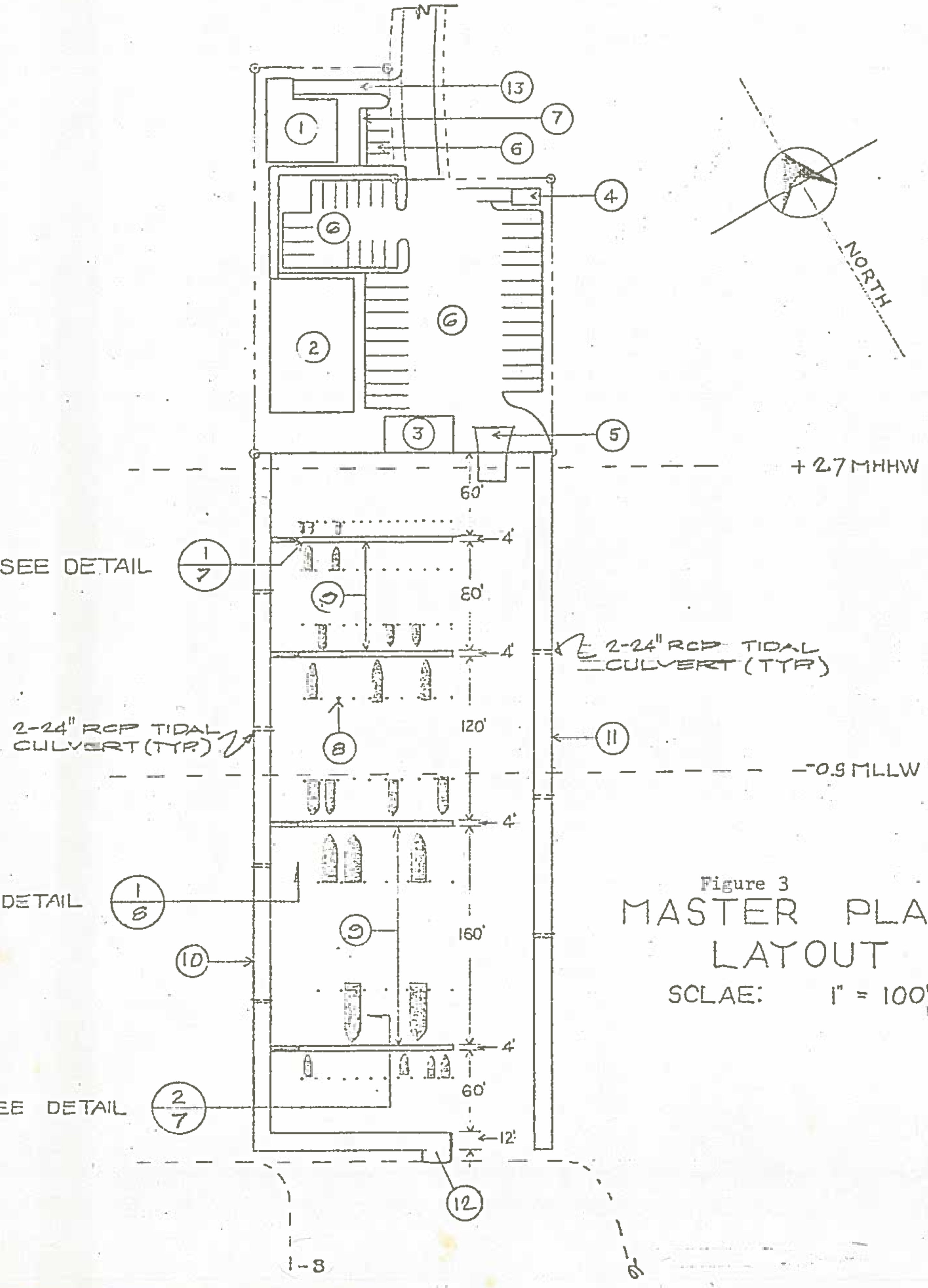


Figure 3
MASTER PLAN
LAYOUT
SCLAE: 1" = 100'

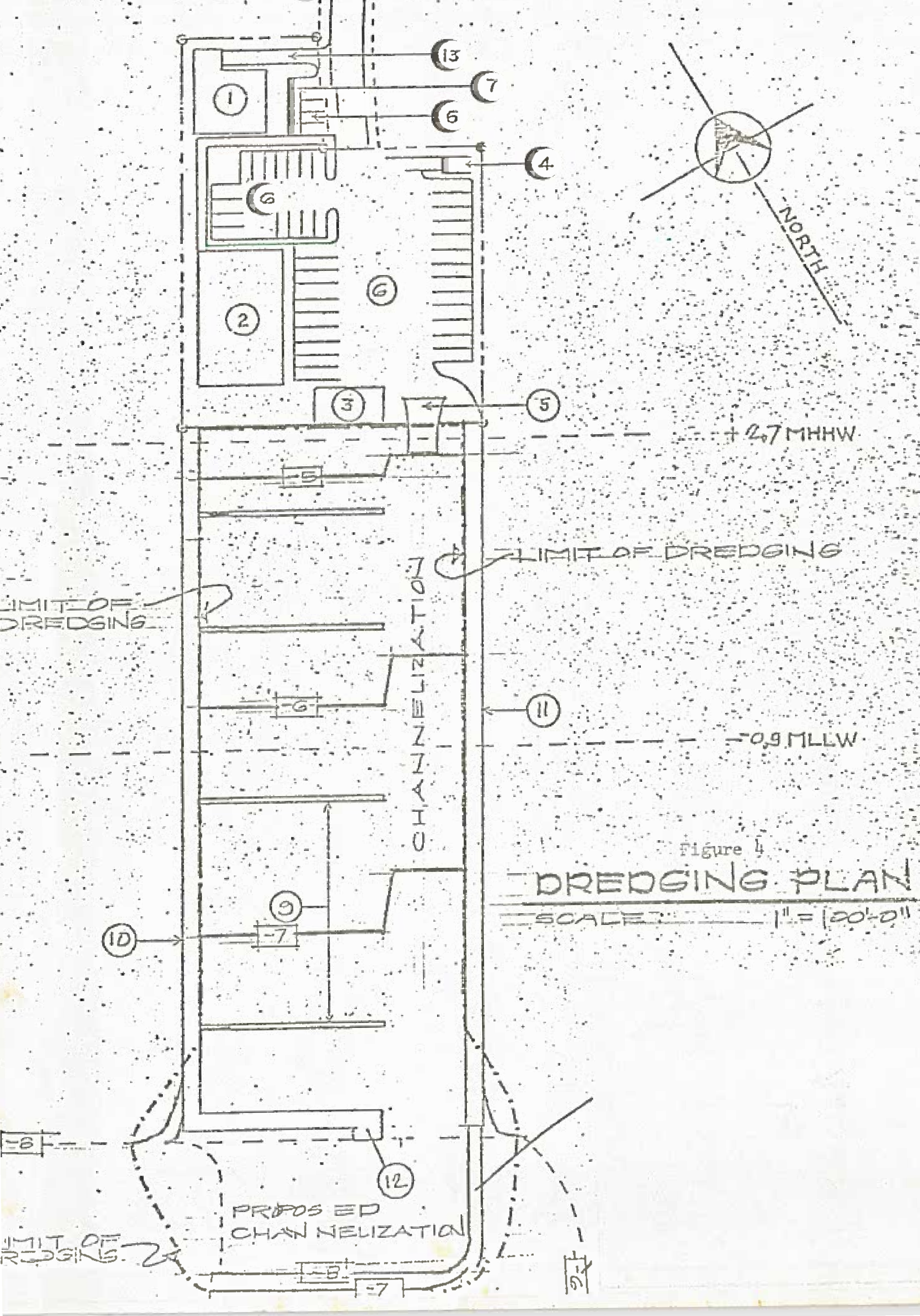


Figure 4

DREDGING PLAN

SCALE: 1" = 100'-0"

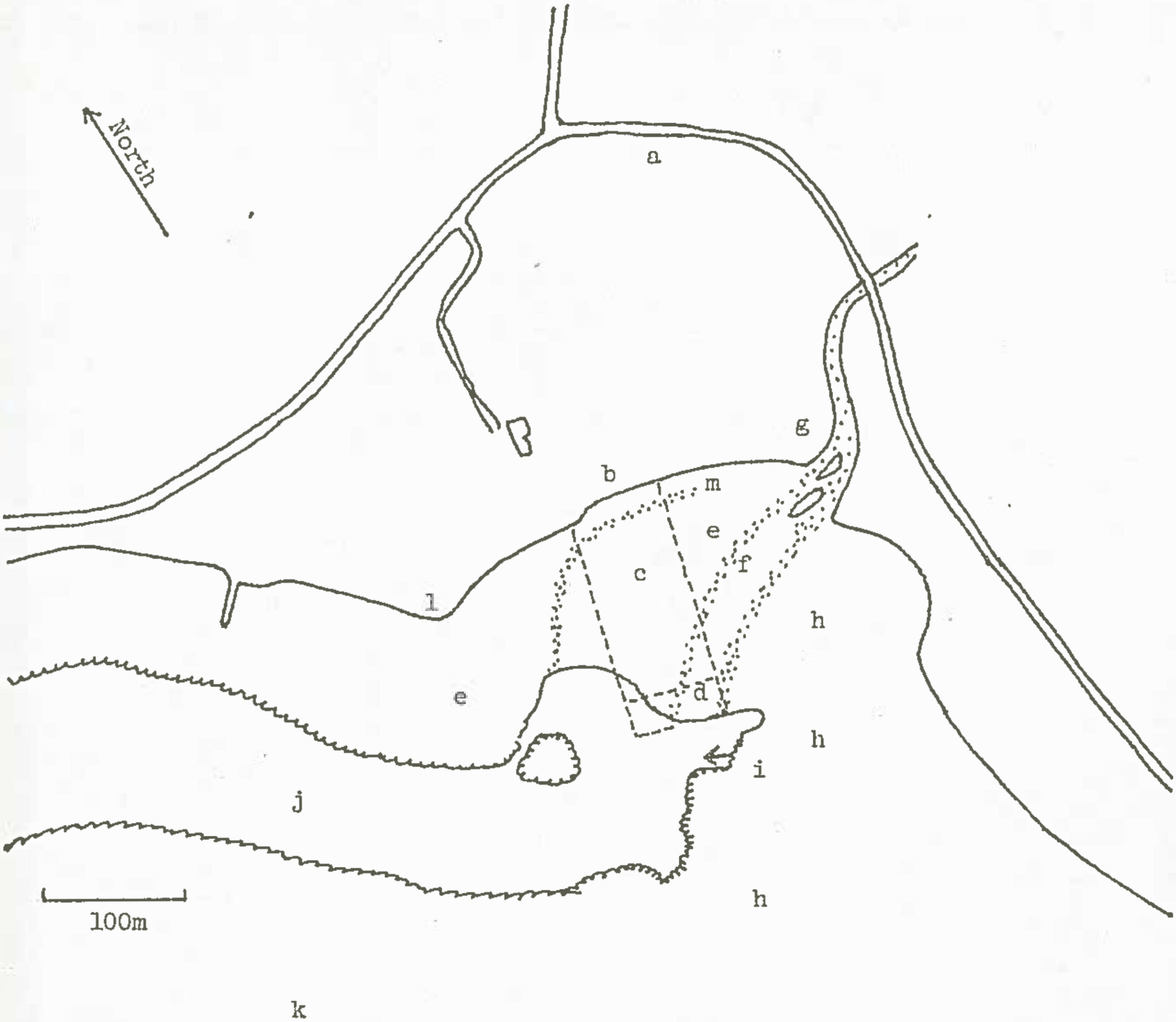


Figure 5. Site map for orientation of major features of study area.

(a) Route 4
(b) location of shore development
(c) marina basin
(d) dredge site for basin entrance
(e) intertidal mud flats
(f) subtidal channels of Geus River
(g) Geus River
(h) intertidal sand flats
(i) fish trap
(j) Mamaon Channel
(k) Cocos Lagoon
(l) shoreline
(m) tidal channel

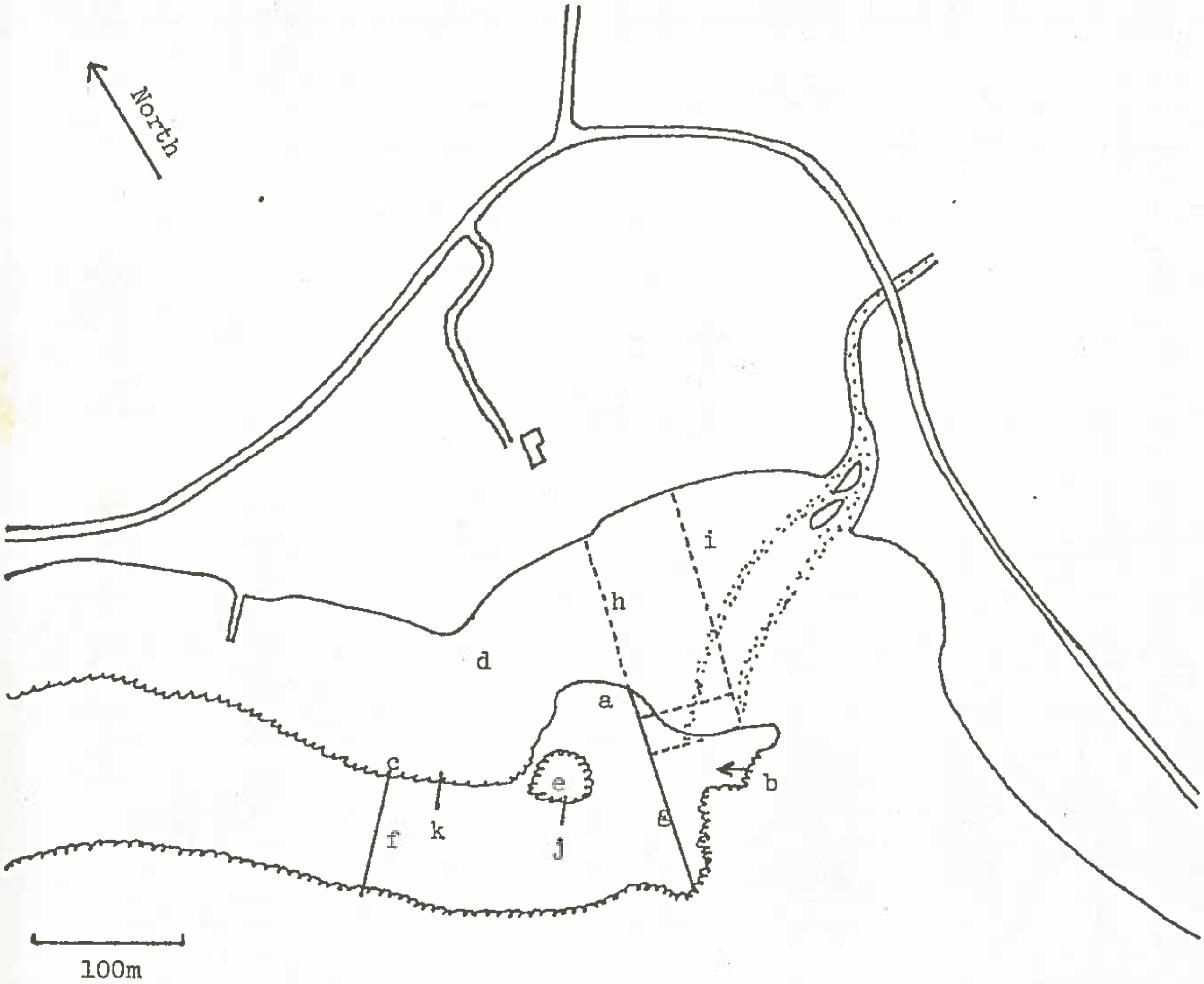


Figure 6. Site map showing location of transects, profiler, and biological surveys.

Biological surveys conducted at (a) through (e).

Profiles conducted at (f) through (i).

Coral cover transects conducted at (j) and (k).

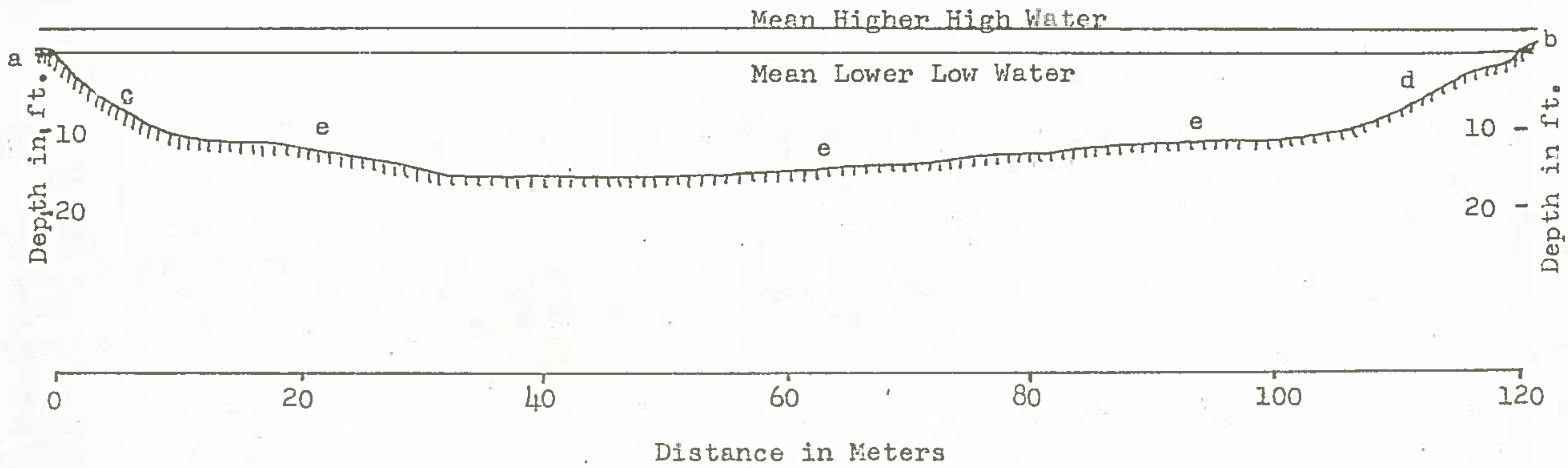


Figure 7. Profile No. 1, across the head of Mamaon Channel, from the channel margin at the west causeway to the opposite lagoonward channel margin (Fig. 6g).

(a) Landward channel margin.
(b) Lagoonward channel margin.
(c) Landward channel slope.
(d) Lagoonward channel slope.
(e) Channel floor.

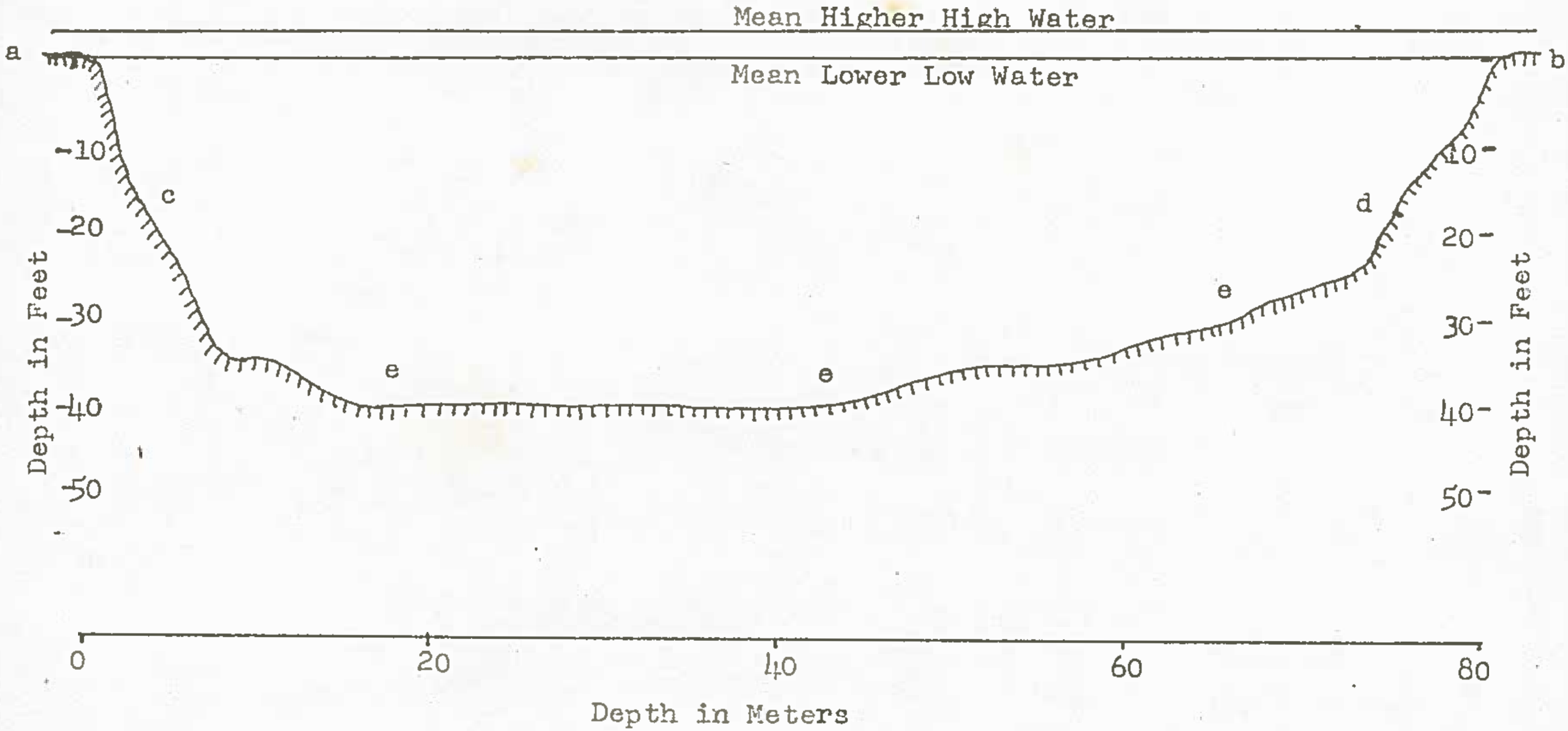


Figure 8. Profile No. 2, across Mamaon Channel downcurrent from the project site (Fig. 6f).

(a) Landward channel margin.
(b) Lagoonward channel margin.
(c) Landward channel slope.
(d) Lagoonward channel slope.
(e) Channel floor.

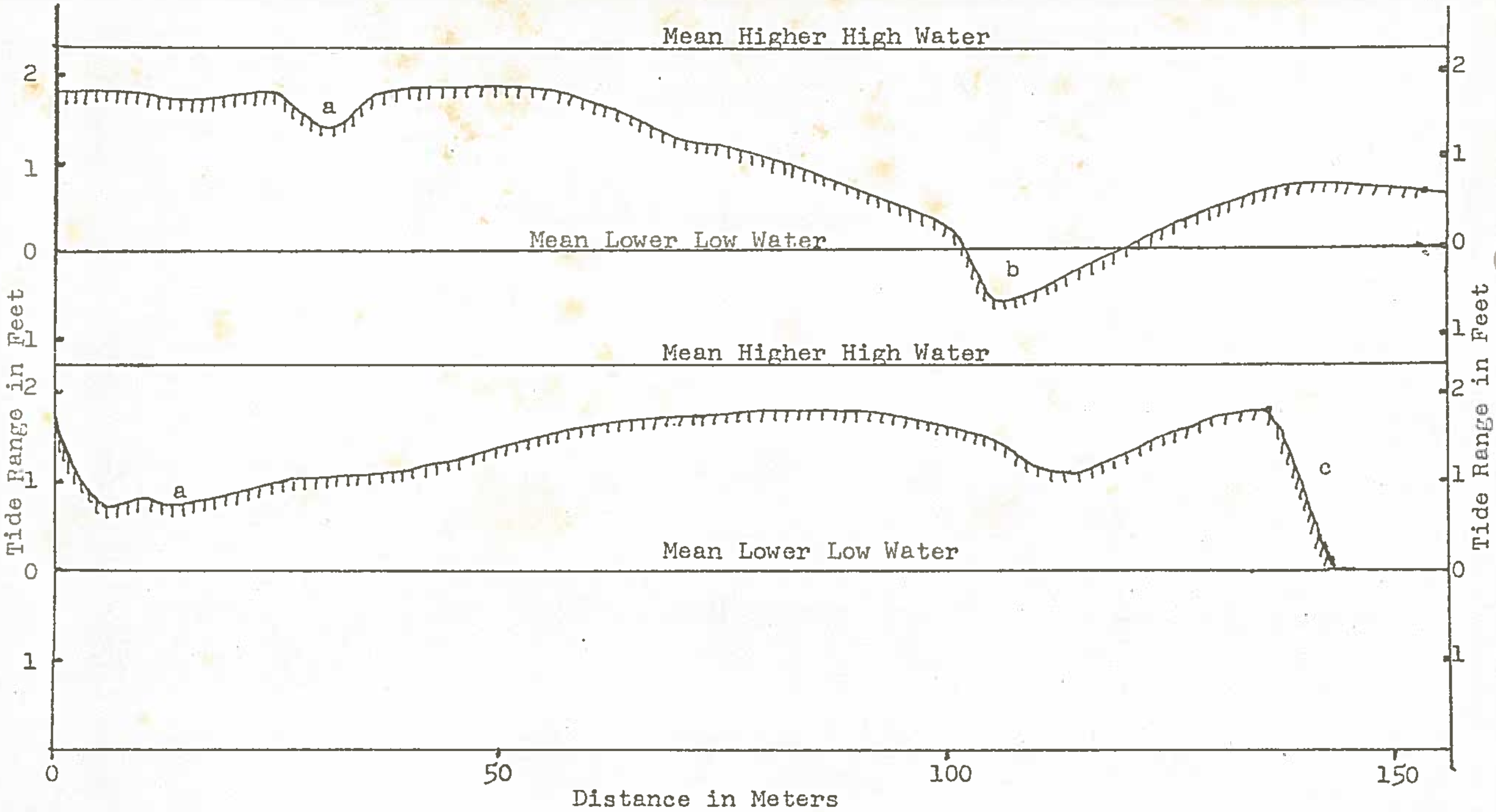


Figure 9. Profiles No. 3 and 4, at the project site. Profile No. 3 is located on the east causeway (Fig. 6i). Profile No. 4 is located on the west causeway (Fig. 6h).

(a) Tidal channel (Fig. 5m).
(b) Subtidal channel of the Geus River (Fig. 5f).
(c) Mamaon Channel margin (Fig. 5).


Figure 10. Current Map.

(a) Primary sample point.

(b) Series of stations along west boundary at 10m intervals.

(c) This station was taken in the river channel at a minus tide.

(d) Two releases in Mamaon Channel.