BASIC DESIGN STUDY REPORT
ON
THE FISHING COMMUNITY DEVELOPMENT PROJECT
IN
THE REPUBLIC OF PALAU

FEBRUARY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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P R E F A C E

In response to the request of the Government of the Republic of Palau, the Government of Japan has decided to conduct a Basic Design Study on the Fishing Community Development Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Palau a study team headed by Mr. Masaru Okamoto, Deputy Director, Office for Overseas Fishery Cooperation, International Affairs Division, Oceanic Fisheries Department, Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries, from October 18 to November 11, 1987.

The team had discussions on the Project with the officials concerned of the Government of Palau and conducted a field survey in the Project areas. After the team returned to Japan, further studies were made, a draft report was prepared and, to explain and discuss it, a mission headed by Mr. Yoshinori Ugajin, Inspector, Fishing Port Construction Division, Fishing Port Department, Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries, was sent to Palau from 17 to 26 January, 1988. As a result, the present report has been prepared.

I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

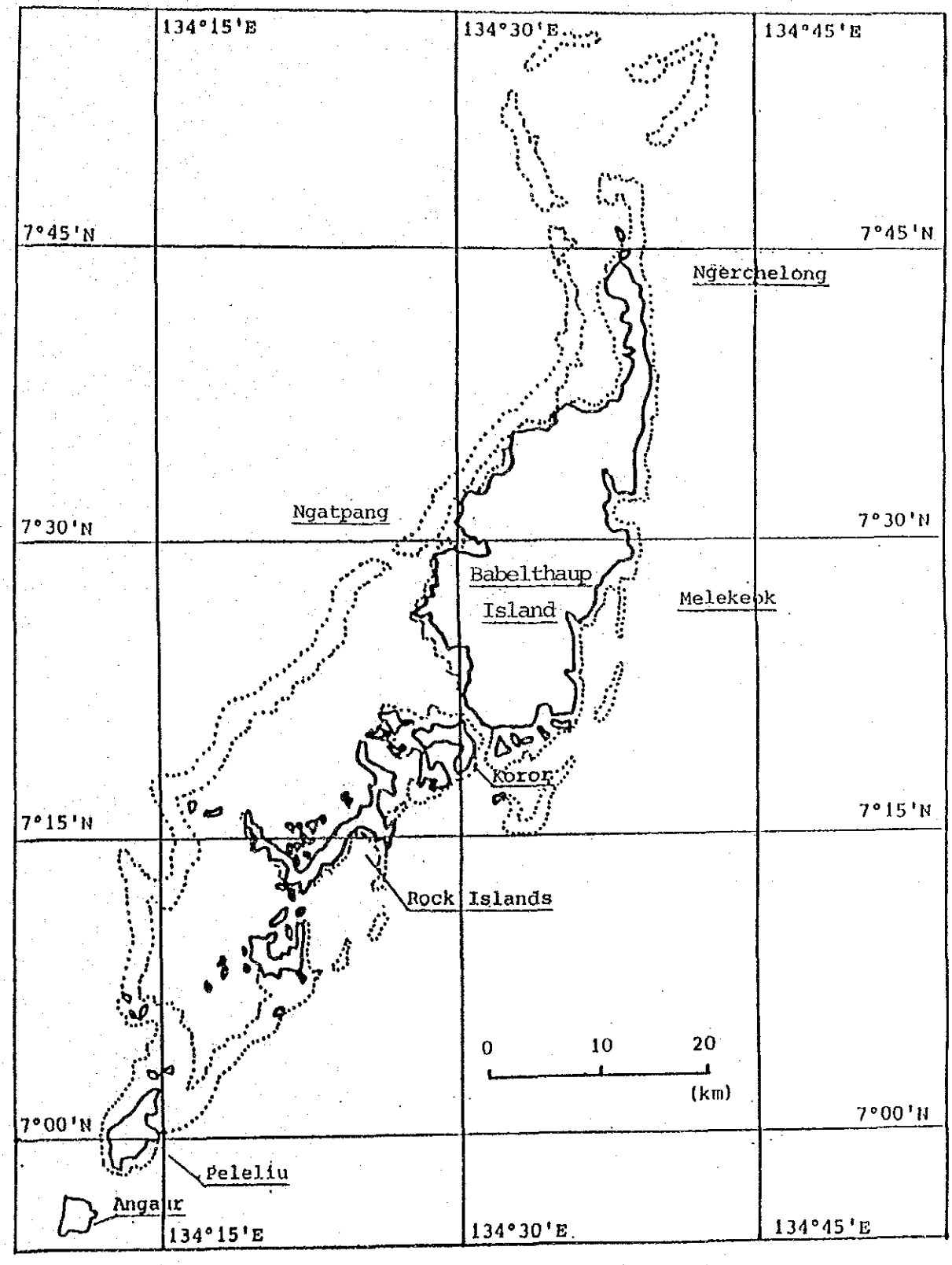
I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Palau for their close cooperation which they extended to the team.

20 February, 1988

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

PALAU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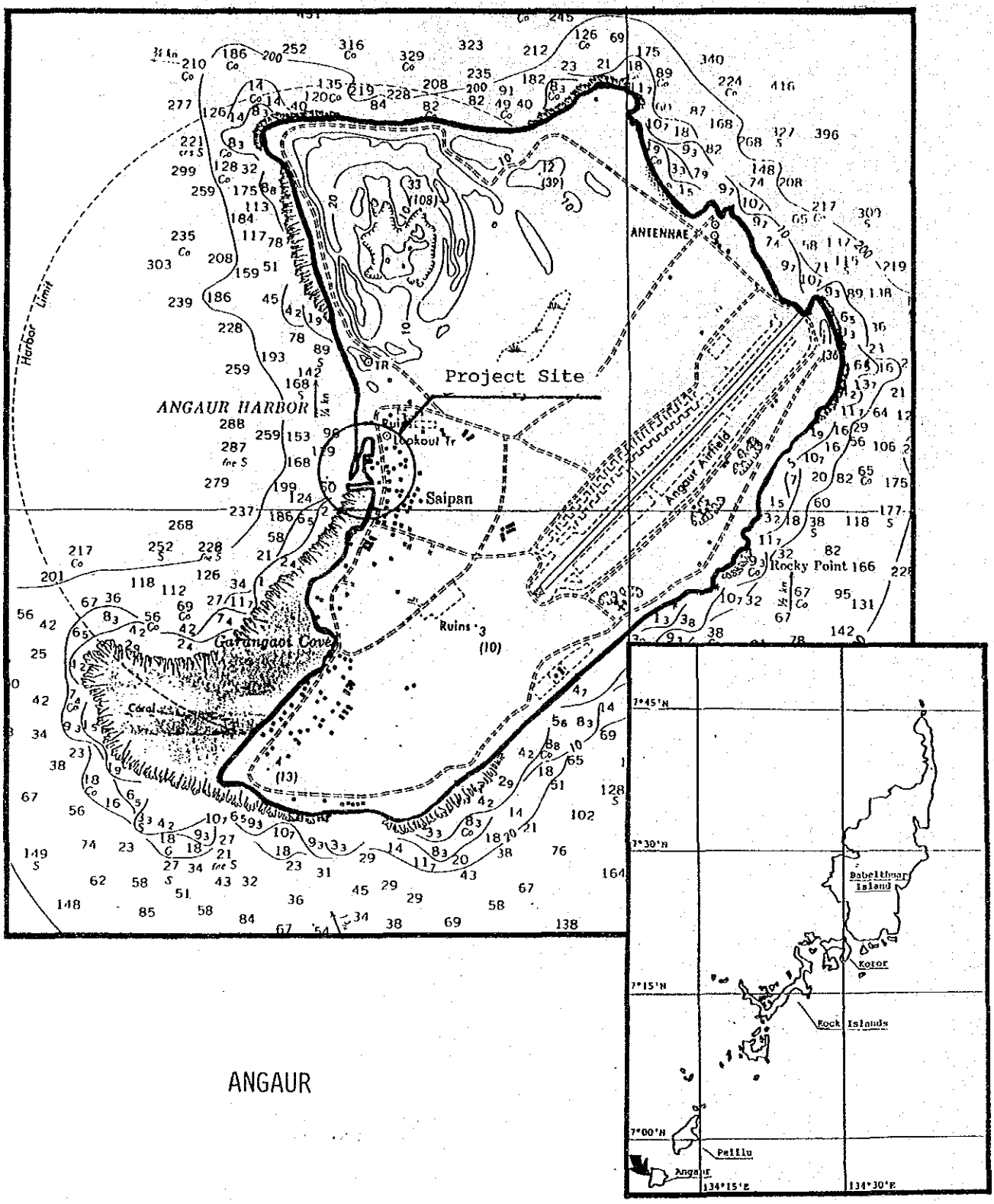
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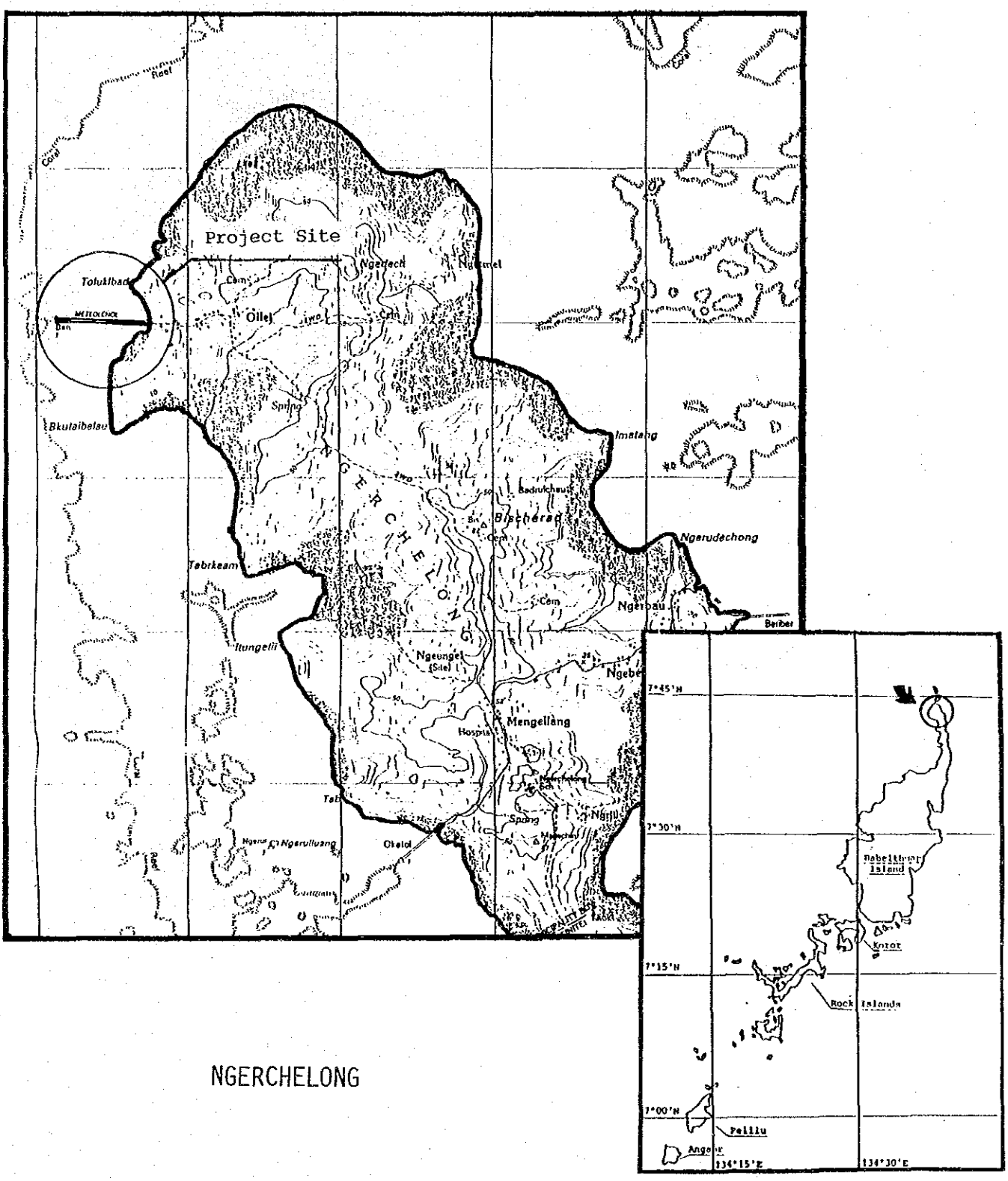

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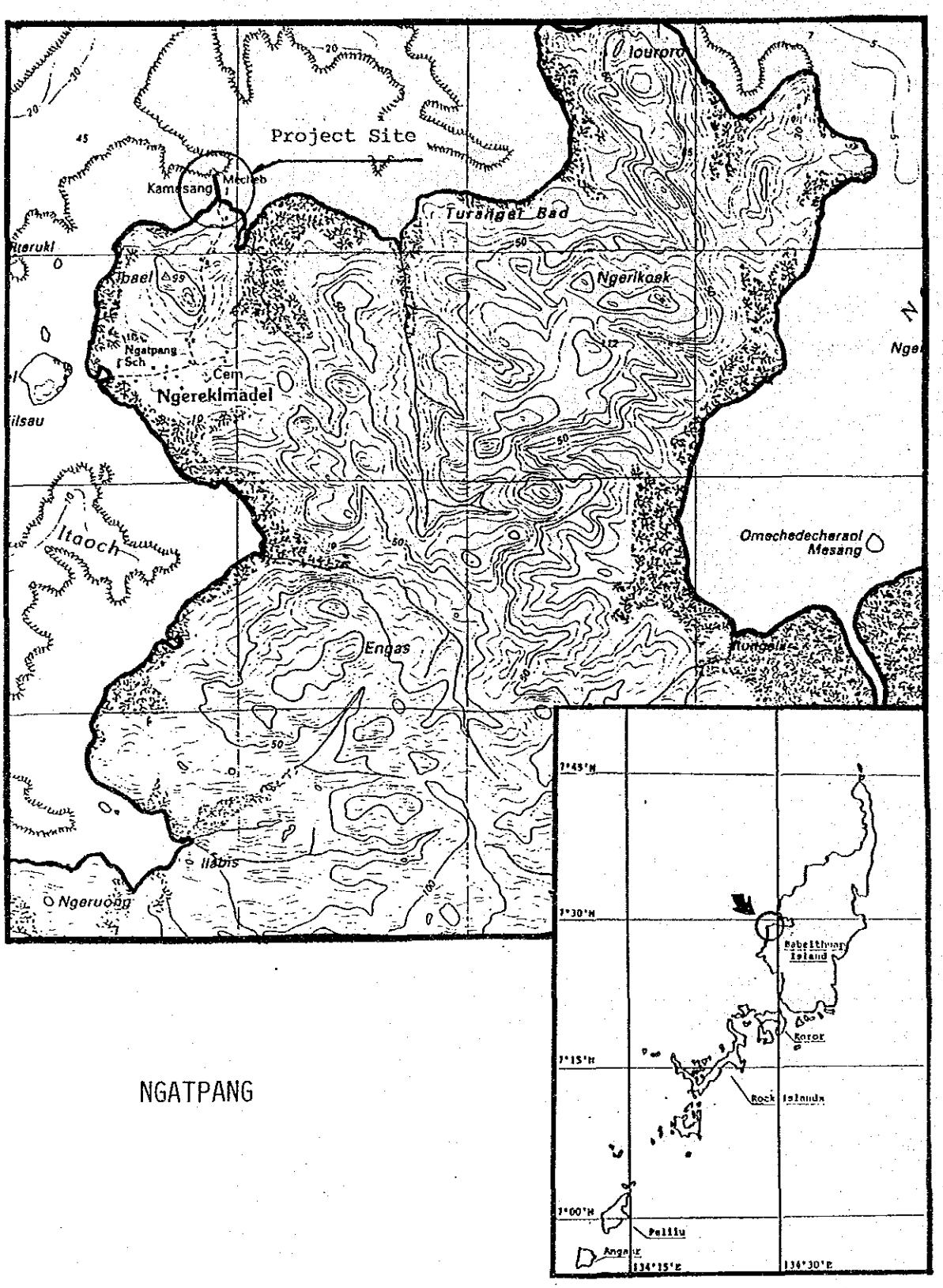
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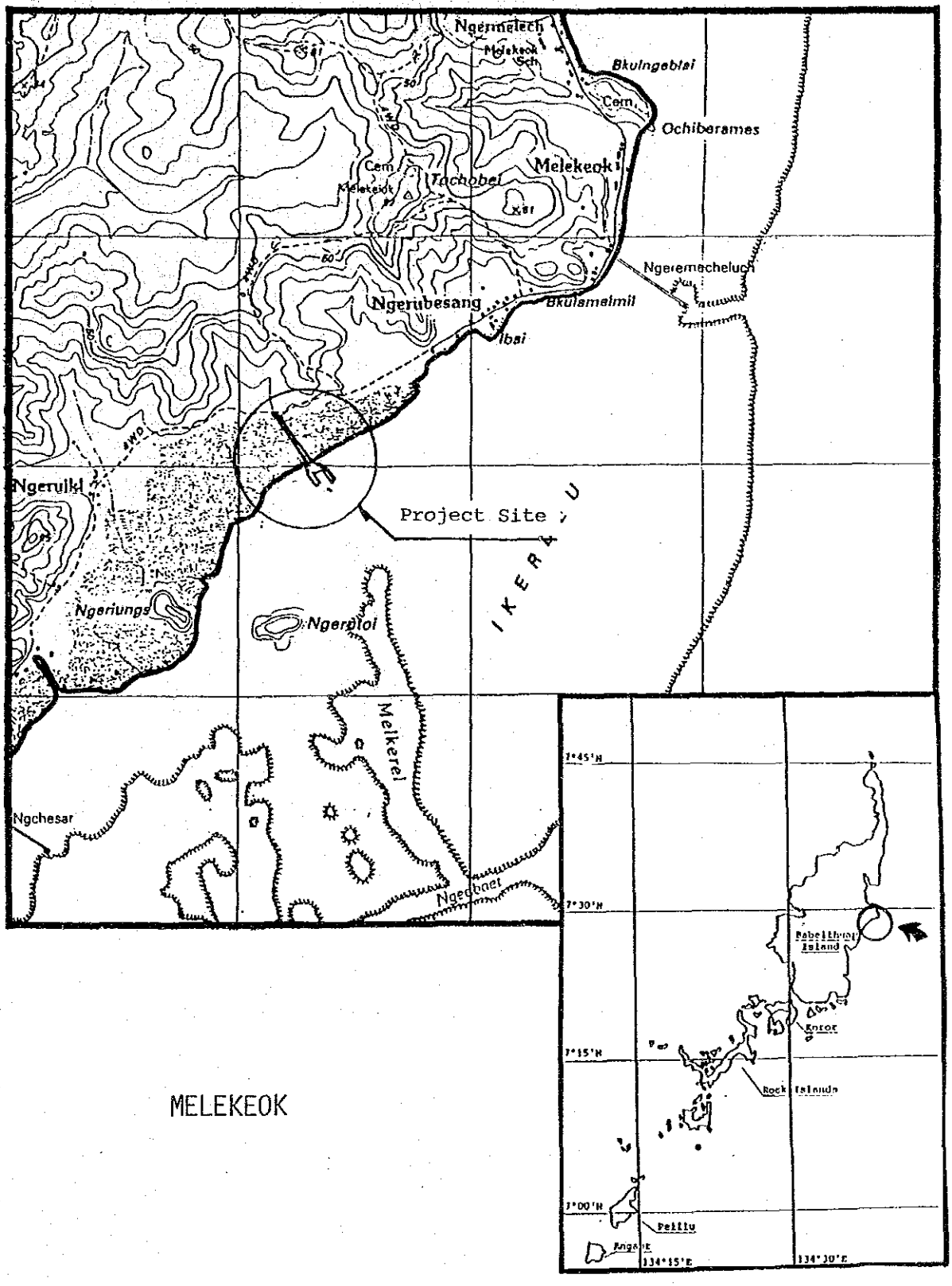
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SUMMARY

The Republic of Palau established its first constitutional government under the new constitution on 1 January 1981 in order to achieve complete independence from US trusteeship. In February 1986, the Palauan people approved the Compact of Free Association with the United States of America, and the Republic of Palau is making attempts to promote local industries with the objective of realizing economic independence after the expiration of the trusteeship. Tourism and fisheries are the most important industries of the country, and particularly the latter is attaining steady progress in terms of both coastal fishing and offshore fishing thanks to the abundant resources available in its waters. Especially the reef fishes caught in the nearby waters are being highly appraised not only on the domestic market but also on overseas markets in such places as Saipan, Guam, and Hawaii, and exports are growing at a sound pace.

On the other hand, it must be borne in mind that the fishing villages in Palau, which are the mainstays of the country's coastal fishing industry, are depopulated areas and that the basic infrastructure of these villages has been long ignored. Under the circumstances, the recruitment of young people into the fisheries sector has long since fallen off, the fishing ports are poorly equipped and catches are not smoothly marketed.

The First National Development Plan (1987-1991) is aiming at improving the local fishery facilities, activating the fishing industry and promoting the export of marine products; thereby upgrading the livelihood of the fishing communities. This Fishing Community Development Project (hereinafter referred to as the Project) is intended to improve

the fishing villages of Angaur, Ngerchelong, Ngatpang and Melekeok that are the bases for fisheries development in the Eastern, Western, Southern and Northern sea areas of Palau. These fishing villages are provided with some harbor facilities but such items as passages, anchorages, wharves, and slipways are not in condition to function properly as fishing ports.

However, it will be possible to promote fisheries and increase the marine production of Palau, and thereby enrich the income of fishermen and improve the livelihood of the fishery communities by excavating the passages of the ports to enable the fishing boats to enter and leave the harbors without being influenced by the tides and by improving port facilities for safe mooring and proper maintenance of the vessels as well as timely fish handling.

In August 1987, the Republic of Palau requested the Government of Japan to implement the said Fishing Community Development Project under grant aid. In response to that request the Government of Japan has decided to conduct a Basic Design Study and has entrusted it to the Japan International Cooperation Agency (JICA). JICA sent the Basic Design Study Team headed by Mr. Masaru Okamoto, Deputy Director, Office for Overseas Fishery Cooperation, International Affairs Division, Oceanic Fisheries Department, Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries, to the Republic of Palau. The said study team stayed in the Republic of Palau from 18 October to 11 November, 1987 where it held discussion on the contents of the request and carried out such work as field surveys, collection of materials and the relevant analyses. After the team returned to Japan, further studies were made, a draft report was prepared and, to explain and discuss it, a mission headed by Mr. Yoshinori Ugajin, Inspector, Fishing Port Construction Division, Fishing Port Department, Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries, was

sent to the Republic of Palau from 17 to 26 January, 1988.

The following facts were found as a result of the survey on natural conditions of the project sites.

1. There is no probability of obstruction of the passages and anchorages of any project site which might be caused by the accumulation of drift.

2. The construction of stable structures is practicable at the various project sites irrespective of their geological conditions.

3. The functions of all fishing ports can be improved by properly equipping their facilities; thereby contributing to the development of the fishing villages.

The following facilities and equipment are the outline of the basic design formulated as a result of the examination of the contents of the request of the Republic of Palau and the Basic Design Study carried out.

1) Angaur Harbor
   - Anchorage dredging : 2,370 m^2
   - Wharf : 70 meters long, concrete block system
   - Ancillary facilities : Navigation light, multipurpose house, toilet/shower

2) Ngerchelong Harbor
   - Passage dredging : 4,800 m^2
   - Anchorage dredging : 3,200 m^2
   - Wharf : 70 meters long, concrete block system

- Ancillary facilities : Navigation light, slipway multipurpose house, ice making machine, toilet/shower
- Surplus soil reclamation area : 5,000 m^2

3) Ngatpang Harbor
- Anchorage dredging : 2,400 m^2
- Wharf : 70 meters long, sheet pile system
- Sand dike : 50 meters long
- Ancillary facilities : Slipway, multipurpose house, toilet/shower
- Surplus soil reclamation area : 2,000 m^2

4) Melekeok Harbor
- Passage dredging : 6,125 m^2
- Anchorage dredging : 10,500 m^2
- Wharf : 50 meters long, sheet pile system
- Sand dike : 30 meters long
- Revetment reinforcement : 40 meters long
- Ancillary facilities : Multipurpose house, toilet/shower
- Surplus soil reclamation area : 6,000 m^2

5) Spare parts for fishing boats, ice making machine, fishing gear, etc.

The construction works of the Project will be executed as described in the following.

Taking into consideration the national priority on port construction and saving on the construction costs, the whole project will be divided into the following three phases:

Phase I	Angaur Harbor
Phase II	Ngerchelong Harbor
Phase III	Ngatpang/Melekeok Harbors

The office in charge of the implementation of the Project is the Division of Marine Resources of the Ministry of National Resources, but the facilities will be handed over to the state governments after their completion and the routine management will be taken charge of by the local fishing associations of the states. The necessary labor for maintenance work is to be supplied by the village communities. Currently the maintenance of the existing harbor facilities is being taken charge of by the village communities and the same is presumed to occur in connection with the said fishing ports.

Fishing boats will be allowed to enter and leave the harbor irrespective of high and low tides as a result of the implementation of the Project, and this will bring about such benefits as longer fishing hours, shorter waiting time, and shorter catch transportation time. More catch means more income for the fishermen, and this will contribute to improving the livelihood of the communities. Furthermore, shortening the domestic distribution time will contribute to improving the quality of the fish, making it possible to export more fish, and this is expected to bring about more foreign currency income which is badly needed by Palau. Moreover, the Project is expected to bring about more benefits such as a smoother supply of living commodities and more active inter-island movement of the people, which will promote the settlement of the population on the local islands.

Implementation of the Project is regarded as extremely significant and it is very desirable to realize it as soon as possible.

CONTENTS

CHAPTER I

INTRODUCTION

CHAPTER I INTRODUCTION

The Republic of Palau has drawn up and is making efforts to implement the First National Development Plan (1987-1991) aiming at attaining complete independence from US trusteeship and establishing an independent economy. The development of fisheries making use of the abundant marine resources available in the exclusive economic zone of the Republic of Palau is particularly important for the country because it is not blessed with many natural resources, and the matter is given top priority among plans regarding investments for development.

In promoting fisheries development, the Government of Palau regards the Fishing Community Development Project as a matter of top priority for the sake of nurturing a safe and stable fishing industry by properly outfitting the basic fishing infrastructure of the local fishing communities. Consequently the Government of Palau has asked the Government of Japan for grant aid cooperation that provides the financial resources required to realize the said project. In response to the request of the Government of Palau the Government of Japan has decided to carry out a Basic Design Study, and the Japan International Cooperation Agency (JICA) sent a Basic Design Study Team led by Mr. Masaru Okamoto, Deputy Director, Office for Overseas Fishery Cooperation, International Affairs Division, Oceanic Fisheries Department, Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries to the Republic of Palau during the 25 day period from 18 October to 11 November, 1987. The said Study team held consultations on the contents of the request with the authorities concerned of the Republic of Palau and conducted field surveys covering such matters as the actual state of the fisheries industry, natural conditions, and the activities of the Palau Fishing Authority, with the objective of checking the appropriateness of the contents of the Project, deciding the scale and the contents of

the facilities to be installed in each village, etc.

The matters agreed upon by the Government of Palau and the Basic Design Study Team during the field survey period were summarized in the form of the Minutes of Discussions which was signed by both parties. Upon its return to Japan, the Study team has analyzed and examined the results of the survey, has drawn up the Basic Design related to the implementation of the Project, and has prepared the Basic Design Study draft report with the object of providing materials required to implement the grant aid cooperation.

For the explanation and discussion of this draft report, a mission headed by Mr. Yoshinori Ugajin, Inspector, Fishing Port Construction Division, Fishing Port Department, Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries, was sent to Palau from 17 to 26 January, 1988. The Government of Palau and the mission finally agreed as described in the Minutes of Discussions.

The Minutes of Discussions, the members and the study schedule of both the Basic Design Study Team and the draft report explanation team are attached to this report along with the names of the officials which the study teams held consultations with.

CHAPTER II

PROJECT BACKGROUND

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2.1 Marine Resources

Palau's living marine resources include inshore and offshore vertebrate species such as reef fish, pelagic fish, bottom fish, turtles, birds, crocodiles and marine mammals; invertebrate species such as shrimp, clams, trochus, lobsters, pearl oysters, crabs, octopus, corals and others as well as a wide variety of marine plants. Palau's coral reef ecosystem is widely recognized as one of the richest and most diverse in the world and as such it is one of the nation's most valuable natural resources.

2.2 Fisheries

Fisheries in Palau can be subclassified into coastal fisheries and offshore fisheries.

Coastal fisheries are commonly established within the fishing grounds in the lagoon area of about 1,455 Km^2 surrounded by a long reef of about 400 Km. Artisanal coastal fishing is also conducted in Peleliu and Angaur Islands and the Southwest Islands.

Fishing within the reef is commonly conducted on a subsistence or semi-subsistence scale, with the catch being distributed along well established lines of kinship or friendship. Techniques used for subsistence level fishing range from simple collecting of sea cucumbers, sea urchins, clams and other species at low tide, often by women and children, to hook and line fishing, underwater spear fishing, cast net fishing and trolling conducted almost exclusively by men. These latter activities often involve the use of outboard motor boats, typically from 16 feet to 25 feet in length. Most

extended families at least have indirect access to power boats of this type, and it is estimated that 400 to 500 men actively engage in subsistence fishing. The sale of fish to Koror Island and other villages surrounding it has recently developed largely through the utilization of fishing associations.

Beyond the outer reef, the bulk of onshore commercial fishing is done with ten locally operated displacement hull diesel craft (35 feet in length) which were donated to Palau by the Government of Japan in 1983. These vessels and other smaller, locally owned power craft produced a commercial catch of 331 tons in 1985.

Offshore fishing for pelagic species, especially tuna-type fish, is conducted primarily by foreign vessels which must pay the Republic of Palau for fishing licenses. Revenues realized from this source totaled about $375,000 in 1983 and $365,000 in 1984. In addition to these foreign vessels, one locally owned and operated pole and liner (23 gt, 200 HP) supplies fresh tuna for domestic consumption.

Fishing for commercial button shell, trochus, is a seasonally significant source of revenue for many local fishermen. Average annual catches during June collecting season range from 100 to 300 tons, with a fishermen's value of $60,000 to $180,000. The raw product is exported to Japan and other Asian countries for processing.

2.3 Fishery Related Organizations

National government agencies concerned with marine resources exploitation and development include the Ministry of National Resources and the Ministry of State.

Within the Ministry of State, the Palau Maritime Authority (PMA) is responsible for negotiating and issuing

fishing licenses to foreign entities. The PMA's jurisdiction extends from the 12- to the 200-mile limit. The PMA is responsible for the development, conservation and management of migrating species of fish within both the territorial seas and the 200-mile fisheries zone. Inside the 12 mile waters, individual state governments have the authority to exploit and manage their own resources. Trade negotiations are handled by the Bureau of Foreign Affairs, and the Division of Foreign Relations oversees matters involving international boundaries.

The Ministry of National Resources includes the Bureau of Resources and Development, which directs the activities of the Division of Marine Resources and the Micronesian Mariculture Demonstration Center. The main functions of the Division of Marine Resources include transfer of fisheries technology, advisory services, statistical monitoring and technical support to fishermen. The Micronesian Mariculture Demonstration Center conducts research and development on commercially important mariculture species, such as clams, turtles, and trochus, and conducts training programs and serves as a base of operations for visiting international researchers.

A fishermen's cooperative, the Palau Federation of Fishing Associations (PFFA), was established in 1975 to offer onshore facilities and services to local fishermen. PFFA suffered financial losses and was declared insolvent in 1982. In 1983 the PFFA was taken over by the national government, and is currently managed as a quasi government agency by the Palau Fishing Authority (PFA), a nonprofit corporation. These entities oversee the operation of a 100 gt cold storage facility and three ice machines with a combined production capacity of 16 tons per day. In addition, PFA and PFFA manage ten 35-foot diesel vessels donated by the Government of Japan, and provide fishing gear at cost to local fishermen.

Enforcement and surveillance of Palau's 200-mile

extended economic zone is currently undertaken by the Attorney General's Office, which maintains a 60 foot diesel patrol boat and crew of contracted deputies.

2.4 Fishery Production

Precise data on total landings and marine products are generally lacking mainly due to the incomplete system of collecting data on subsistence fishing and direct landings to private retailers/processors/consumers other than the Palau Federation of Fishing Association. The records of the Palau Fishing Authority show fishing purchases from 1976 to 1981 varying between 112 tons and 50 tons during these six years. The total in 1983 was 215 tons, and in 1984, 287 tons, representing a value of $199,000 in 1983 and $272,000 in 1984 (Appendix V-9-1, V-9-2).

There is another estimation of fish production which indicates a yield of about 2,000 tons of fish for coastal fisheries inside the reefs, 700 to 800 tons of which are marketed in the domestic market and for exports and the remaining 1,200 to 1,300 tons of which are consumed by the fishermen and their villages.

The number of fishermen is estimated to be 400 to 500 persons including 195 full-time fishermen and other part-time fishermen. Their major target species are bottom fish such as snappers, groupers, parrot fish, rabbit fish, unicorn fish, and pelagic fish such as skipjack, yellowfin tuna, and dolphin fish. Mangrove crabs and lobsters are also valuable targets.

Inland or brackish water fisheries are not well developed in Palau. Some quantity of milkfish is landed to PFFA by fishermen from Ngatpang.

In aquaculture, the Micronesian Mariculture Demonstration Center (MMDC) plays a key role in mariculture research and development especially for giant clams and turtles. MMDC also conducts trial hatching of the fresh water prawn, Macrobrachium. Two culture ponds for Macrobrachium have been constructed by private investors. Since its establishment in 1973, MMDC has produced 700,000 pieces (equivalent to 30 tons of biomass) of seed clams, which have been distributed to twelve countries in the South Pacific area for experimental culture activities.

2.5 Fishing Fleet

The major part of the fishing fleet of Palau consists of outboard engine fishing boats which are of 5 to 8 m in length and equipped with 50 to 120 HP outboard engines. These boats are usually used for fishing and transportation purposes. GRP or wooden inboard engine fishing boats equipped with 12-70 HP engines also play a key role in coastal fisheries in Palau. Their total number is less than that of outboard engine boats. These boats include eleven GRP boats (11 m in length, 70 HP, 3.2 gt) supplied by a Japanese fisheries grant aid project in 1983. The Palau Fishing Authority holds title to these GRP boats and lends them to local fishermen. Fish landings by these boats to contributes much to PFFA total fish purchases. In addition, there is one big fishing vessel in operation, a GRP made pole and liner of 23 gt with a 200 HP engine.

The Division of Marine Resources estimates there are a total of 120 fishing boats and vessels in operation for fishing activities. Other than the motor powered fishing fleet, fishing from bamboo rafts and traditional canoes still exists, but their role is getting smaller.

2.6 Infrastructure

Malakal fishing port located on Malakal island, adjacent to Koror island, is the biggest landing place with such related facilities as block ice and plate ice plants, a fish wholesaler area, cold storage and freezing plants. The PFA and PFFA main offices are located in this port.

Major local landing sites are located in Peleliu, Kayangel, Ngatpang, Ngeremlengui, Ollei and Ngaraard. These landing sites generally consist of a landing jetty, fuel supply facility and flake ice plants (1 ton/day).

2.7 Fish Marketing

Palauan patterns of fish consumption are based on common customs seen in tropical areas. They eat fish in baked form, smoked form, dried form and as soup. They also eat sashimi style fish (raw fish eating) with soy sauce and some seasonings such as horse radish.

Mainly because of the lack of retailers' facilities for frozen fish, sashimi eating customs, and the limited marketing range both in villages and town areas, fish is marketed fresh basically in the domestic market. Some frozen fish is marketed to small scale processors for fried and smoked fish processing in poor fishing seasons.

In Palau, there exists no fish wholesale market. PFFA plays an important role in fish marketing as wholesaler cum retailer in Koror and adjacent islands, where more than 60% of the population is concentrated. PFFA purchases fish both from its member fishermen and others. However, undersize fish (less than about 12 cm), damaged fish, and nonmarketable fish species are rejected for purchase. PFFA sells purchased fish in its retail space to local consumers, private fish

processors, processors cum retailer, retailers, hotels, and restaurants mainly in fresh form. In poor fishing seasons and periods, PFFA sells its frozen stock from the good fishing seasons or periods mainly to fried fish processors, restaurants and hotels. Fish handling of PFFA has been growing since its establishment. In 1986, PFFA purchased 295 tons of fish and sold 155.5 tons in the local market (Appendix V-9-1, V-9-2, V-10). Though PFFA's fish purchase and sale prices have been adjusted in its management, at the time of this study PFFA marketed fish by demarcating fish into three groups in accordance with Palauan preference and marketing conditions (Appendix V-11, V-12). Major fish purchased by PFFA are snapper and parrot fish followed by rabbit fish, grouper, unicorn fish, jack and skipjack. These are also common fish in coastal fisheries in Palau. Market preference is for most of these fish species. However, preference for some species of red snapper and grouper seems to be relatively low. As fish is sold by weight, customers select larger sizes of fish in consideration of the ratio of the edible portion against the whole fish weight. PFFA's fish stock which remained unsold amounted to 84.5 tons in 1986. According to PFFA, the major portion of this stock consisted of grouper (mainly Epinephelus sp., Plectropoma sp.), red snapper (mainly Lutjanus bohar), small size (less than 25 cm) blue parrot fish and white snapper. Skipjack was also included in this unsold stock because its production is seasonally concentrated due to its migrating habits and the availability of bait fish for fishing.

Other than PFFA fish marketing, fishermen sell fish directly to their customers such as retailers, restaurants, hotels, fish processors, etc. There are around five fish retail shops in Koror. Some of them deal fish occasionally. The retail spaces of these shops are smaller than that of PFFA. Including PFFA, these retailers commonly display fish in ice slurry water. On local islands, fishermen distribute fish in their village areas. Detailed fish marketing data by these private retailers and local fishermen are not available.

PFFA also plays a key role in fish exports. PFFA exports fish by itself and often assists persons who buy fish in the PFFA retail shop for export. PFFA export handling including these two types of dealings amounted to 74 tons or 77% of total fish exports of 95.8 tons in 1984 (Appendix V-13). Exported fish is put in a plastic bag and packed in an insulated polystyrene container with covering ice. Destinations of exports are concentrated to Guam and Saipan. In 1984, 61.7% of total exports were for Guam and 33.2% for Saipan (Appendix V-14).

2.8 Fish Processing

Fish processing in Palau is conducted on a small scale. There are one smoked skipjack processing factory and freezing facilities of Palau International Traders Incorporated. However, the former is not well operated and the latter has just initiated reoperation. Other than a fish processing plant, a trochus shell processing factory is operated periodically.

Fish is mainly processed at a retail stage in fried and smoked form by small-scale processors or retailer cum processors. For smoking fish, processors use handmade traditional smoking kilns and small smoking houses. The smoking kiln is commonly made of secondhand drum cans, steel nets and galvanized iron plate. A typical kiln has a smoking capacity of 15 to 30 lbs. per one process cycle. Large size smoking houses can smoke 90 lbs. of fish per cycle. Local pine trees and mangroves are preferred as smoking wood. However, other woods are also used because smoking wood is not marketed and processors often feel it is difficult and time consuming to get wood by themselves. Various species of fish are smoked. According to one of the major processors, market preference is for grouper, snapper, blue parrot fish, unicorn fish and yellowfin tuna. Processors usually smoke larger fish mainly

because smoked fish is sold by weight at a retail price of from $1.75/lb. to $2.50/lb. Smaller fish are utilized in frying processing considering the difference in weight loss due to processing. However, many processors mention that there is a strong preference for smoked fish and one of the major processors mentions that at least 50 lbs. of smoked fish can be sold to his customers. He also processed 100 to 150 lbs. of fried fish daily when material was available. There are good smoked fish sales in the evening and in the morning just before international flights depart for Guam because people prefer to take smoked fish as souvenirs.

CHAPTER III

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3.1 Object of the Project

The Republic of Palau has established the following development objectives in its First National Development Plan (1987-1991):

1) lay the foundations for achieving the long-term goal of self-reliance based on a free market economy;
2) develop the full potential of natural resources through controlled exploitation, to expand exports to earn foreign exchange and thus meet increased domestic demands for improved living standards;
3) develop, to the maximum extent possible, manpower resources through increased training programs and job creation;
4) achieve balanced growth and development among the states as well as income generating opportunities for the population; and
5) protect the environment and preserve the cultural heritage of the Palauan country.

The Government's strategy for fisheries sector development is based on the recognition that the ocean is the most valuable natural resource and that it may offer the best potential for long-term economic development and the attainment of economic self-sufficiency. Accordingly, the Government has established the following development objectives in the fisheries sector:

1) increase fisheries sector employment;
2) develop environmentally sensitive resource management;
3) improve the fisheries related infrastructure;
4) increase exports of marine products; etc.

Coastal fisheries in Palau have been undergoing change of a structural nature in recent years as a result of the introduction of small modern fishing boats. Until very recently people of Palau used to catch fish with harpoons and spears and to gather trochus shells and giant clams by diving under their self-subsistence economy. The catch was used exclusively for home consumption in the households and any surplus was distributed to the neighborhood.

The modernization of fishing gear and equipment through the motorization of the fishing boats through the introduction of outboard engines and the introduction of energy saving fishing by means of inboard engine craft and net fishing, etc., replaced the wooden canoes and bamboo rafts used until recently. The catch increased as a result, and it became possible not only to cope with domestic consumption but also to sell marine products to the outside. On the other hand, concurrent with the motorization of the fishing boats, it became necessary to purchase fuel with cash. Under these circumstances, fishermen began to sell their catches on the Koror market besides consuming it in the local villages.

Since 1983 the Government of Palau has been taking measures to promote the export of fish, which are gathered from the various local islands of the country, to overseas markets through the Palau Fishing Authority besides distributing it for domestic consumption. The growth of exports is especially conspicuous, particularly to such markets as Hawaii, Guam, Saipan, etc., thanks to the increasing demand for fresh fish resulting from the growing number of tourists visiting those places. For instance, most of the fresh fish sold in Guam reportedly comes from Palau. This is attributable to the frequent contamination of reef fish near Guam with ciguatoxic. Such advantages as the safety and relatively low price of the reef fish of Palau renders it more competitive than products of other countries, even taking into consideration the air freight. Furthermore, the supply of fresh fish of stable

quality, thanks to the technical guidance given by the government for the sake of improving the quality, is contributing to the high appraisal of fish exported from Palau.

As can be seen, fisheries dealing with reef fish found inside the reefs has been growing rapidly in recent years, and the Government of Palau has given top priority to the development of the trade in view of its strategic importance as a source of foreign currency.

Such equipment and materials as cold stores, ice, insulated fish boxes, etc., are required for the sake of gathering in Koror high-grade fresh fish for export, as well as for their subsequent sorting out, storage and delivery. On the other hand, the establishment of an appropriate system for the supply of ice, as well as for landing, ice packing and swift handling of the catch and smooth operation of the vessels is indispensable in the various local harbors. It must be borne in mind, however, that the fishing boats rely heavily on tide conditions to enter and leave the local fishing ports and furthermore, the fishing hours and return hours are subject to severe restrictions because of the extremely shallow draft occurring in the harbors.

Moreover, night fishing is a very dangerous job because the harbors are not equipped with nautical mark lights and the like, and this results in the risk of such accidents as grounding, collision, etc. Development of such resources as pelagic and migratory fishes outside the reefs, besides the conventional coastal fishing practiced inside the reefs, is indispensable for the sake of further expanding fisheries production in the future. Operation of Lejabil-class craft (70 ft overall length, 23 gt) becomes indispensable in this connection.

As noted, the improper equipment of the fisheries

infrastructure in the various local areas is obstructing the development of the fishing industry in Palau. Such measures as proper outfitting of the various local fishing ports, the construction of facilities required to secure the operating safety of the fishing boats, supply of decent equipment and a positive living environment related to fisheries, and hygienic handling of the catch are indispensable to solving the problem.

Besides the aforementioned matter of infrastructure outfitting for the sake of promoting the fishing industry, the equipment of local fishing ports is a problem whose solution is long overdue for Palau also from the standpoint of regional development. As things now stand, 68% of the population of the Republic of Palau is concentrated around Koror, its capital city, and the provincial areas of the country are extremely underpopulated. This imbalance is basically attributable to the backwardness of the social infrastructure in the various states of the country.

In the 1930's and 1940's, the supply of goods to the various villages was reportedly smooth. On the other hand, such local commodities as copra, pineapples, sugar, giant clams, trochus shells etc., were gathered and exported via Koror. The harbors of the various villages were constructed by the local people, and furthermore maintenance and control were carried out by the local communities. After the Second World War, however, most of the population of the villages emigrated to Koror, the regular ferry transport service was abolished, the maintenance and control conditions of the quays, passages, anchorages and the like became very obsolete and in some cases became disabled and unusable.

Dispersion of the population to the provincial areas is also regarded as a top priority theme in the First National Development Plan of the Government of Palau (1987-1991), and outfitting of the local infrastructure is also badly needed in this connection.

This project is aimed at constructing fishing harbors and installing their ancillary facilities on Babelthaup Island and on Angaur Island for the sake of smooth distribution of fishing catches and improving the living environment in the fishing villages; thereby promoting the development of the fishing industry in these states of Palau.

On the other hand, the fishing boats, fishing gear and the like donated by the Government of Japan in 1983 are effectively functioning under the control of the Palau Fishing Authority and are making substantial contributions to the promotion of fisheries in the country. These boats are being operated by local fishermen under a leasing arrangement. It must be remembered, however, that the Palau Fishing Authority does not have the financial capability to operate them with a sufficient stock of spare parts because the leasing charge is being kept very cheap. It is indispensable to keep a sufficient stock of spare parts for the fishing boats, fishing gear, etc., and to supply them to the fishermen for the sake of satisfactory operation and maintenance of the coastal fishing industry of Palau.

Provision of the spare parts which are in shortage is included within the scope of this project, because the supply of equipment and materials required to maintain and to increase catches is regarded as an important factor in the development of fishing communities.

3.2 Outline of the Project Sites

The Government of Palau selected Angaur, Ngerchelong, Ngatpang and Melekeok as sites for implementation of the Project. There are facilities there suitable only for mooring small boats. The fishing communities selected as sites for implementation of the Project have the characteristics mentioned in the following.

ANGAUR (Angaur Island)

Angaur State is an island with a population of approximately 220 located in the southern part of the Republic of Palau. In the past phosphate mining used to be an important trade for this island. The main island is located outside the Palau reef, and the harbor is regarded as a base for offshore fisheries in the southern sea of the Republic of Palau. As things now stand there are barely 2 boats used exclusively for fishing on the island, but most of the households possess canoes or small boats. Also, casting fishing from the shore is very popular and this fishing method is sufficient to supply most of the fish for home consumption. The abundant resources existing in the southern sea areas of Palau are still unexploited, and much hope is being placed on their development. In particular, this harbor is expected to become a base for developing fisheries in the sea areas in the vicinity of Hatohobei Island and Sonsorol Island.

NGERCHELONG - OLLEI HARBOR (Babelthaup Island)

The State of Ngerchelong is located in the northernmost part of Babelthaup Island and has a population of 272. This state consists of four villages. Ollei is the only fishing community. This harbor was opened for the sake of lighthouse building about 1930. It is located at the northernmost tip of Babelthaup Island, close to the vast reef fishing ground of the northern sea areas of the country. Furthermore, it is at a strategic position for the transit of catches coming from Kayangel Island located to the north. The number of fishing boats of Ngerchelong State amounts to 26, and most of them use this harbor as a base for their operations. The catch of the fishing boats is gathered in this port and then shipped together to Koror. There is considerable consumption of ice, and

ships transporting the catch to Koror are used to take ice back on their return trip for the sake of the storage of fresh fish.

NGATPANG - VILLAGE HARBOR (Babelthaup Island)

The state of Ngatpang is located in the central western part of Babelthaup Island and has a population of approximately 220. This state consists of two villages, Ibobang and Ngatpang, and Village Harbor is located adjacent to Ngatpang village. It is a fishing port constructed in 1967. It is located at the western part of Babelthaup Island and is also close to the passage outlet of the western channel. Moreover, mangrove crabs are found in abundance in this area because of the existence of dense formations of mangrove. As things now stand there are only two households in the Village district fishing as their principal occupation, but in the Ibobang district there are many households possessing small boats and these people catch mangrove crabs and fish inside the reef. This is a natural harbor with superior characteristics because the existing wharf faces a water route with a depth of more than 8 meters depth. Furthermore the inner water is shielded from the SW winds.

MELEKEOK (Babelthaup Island)

The state of Melekeok is located in the central eastern part of Babelthaup Island and has a population of 255. There are plans to transfer the capital of the country to this state in the near future. This harbor is located in the eastern part of the island. At the beginning it was a depression left as a result of the excavation of sand used as subbase course material for the construction of roads in the state of Melekeok and later on it was outfitted as an ordinary harbor. In the village of Melekeok each

household is outfitted with approximately one small boat or canoe for fishing, but these craft are landed on the beach in the vicinity of their houses because they are small vessels. Just a few fishing boats use the harbor at the present time. Reef fishing is not popular in the eastern part of the island because there is little reef in this part of the country, but fishing outside this area is regarded as promising because of the short distance to the fishing grounds. As things now stand there are no fishing boats left moored in the harbor because the place is unsafe in view of the absence of houses nearby. Craft that are landed at the village are expected to moor in the harbor should it become inhabited in the future.

As can be seen, these four project sites have the characteristics of fisheries development bases for the eastern, western, southern and northern sea areas of the Republic of Palau, and are playing a leading role within the context of the type of fishing practiced in each area. Under the circumstances, invigorating the fishing activities and stabilizing the livelihood of the local fishing folk by outfitting the proper facilities at these sites are regarded as very important for the sake of promoting the development of the local economy.

3.3 Planned Facilities

Properly outfitting the fishing ports is regarded as the most important factor for the sake of improving the infrastructure of the fishing community. As things now stand, it is indispensable for ships to take into consideration the tide conditions to enter and leave all harbors in the Republic of Palau with the exception of Koror. The said problem occurs because the water in the harbors becomes too shallow at low tide, making it impossible for craft, with the exception of rafts and small boats with very shallow drafts, to access the

harbor. Under the circumstances, tide level tables for each month are at the disposal of the parties concerned at the PFA office in Koror, and fishermen take them back and use them for the sake of operating safety in their trade.

It is indispensable to broaden and to deepen the existing passages by excavating them for the fishing boats to navigate with safety. Furthermore, it is also necessary to secure anchorages with sufficient depth and which are protected from the strong eastern and western winds for the sake of executing such work as the loading of fishing gear, unloading of catches and maintenance of the fishing boats with sufficient safety. As things now stand fishing boats are being moored at random. In reality it is necessary to provide proper mooring facilities for the craft so that they may be anchored in an orderly manner for the sake of safety. On the other hand, repair and maintenance of the vessels are not satisfactory because no proper slipways are available at the present time.

Moreover, the construction of covered spaces as protection from the glaring tropical sunlight is regarded as indispensable for the sake of improving the efficiency of such work as maintenance and repair of fishing gear, processing of the catch, preparations to sail out for fishing, etc. Facilities of this kind could be used not only as working spaces but also as a place for the exchange of technical information, communal meetings and other purposes.

The contents of the request of the Government of Palau related to this project are summarized in the following.

(1) HARBOR OUTFITTING

1) ANGAUR

- Mooring wharf : 70 meters long, concrete block system

- Levee crest finishing: 30 meters long
- Passage : -2.5 m, 1,070 m^2

2) NGERCHELONG

- Passage excavation : -1.5 m, 500 m x 20.2 m
- Wharf : -2.0 m, 40 meters long, concrete block system
- Revetment : 170 meters long
- Anchorage : -1.5 m, 3,700 m^2
- Land leveling : 5,600 m^2 (70 m x 80 m)
- Slipway : 10 m x 10 m

3) NGATPANG

- Wharf : 80 meters long,
  : concrete block system
- Slipway : 10 m
- Groyne revetment : 50 m
- Dredging : -2.5 m, 2,000 m^2

4) MELEKEOK

- Passage broadening : -1.3 m, B 7.5 m x 700 m
- Anchorage : -1.5 m, Approx. 6,000 m^2
- Wharf : 60 meters long

(2) FACILITIES REQUIRED IN THE VARIOUS HARBORS

Warehouse to store the catch, fish processing shop, fuel storage facilities, workshop, waiting room, multipurpose community center, etc.

(3) EQUIPMENT AND MATERIALS FOR COASTAL FISHERIES

1) Spare parts for FRP fishing boats 1 lot
2) Spare parts for ice making machines 1 lot
3) Fishing gear such as fishing nets, etc. 1 lot

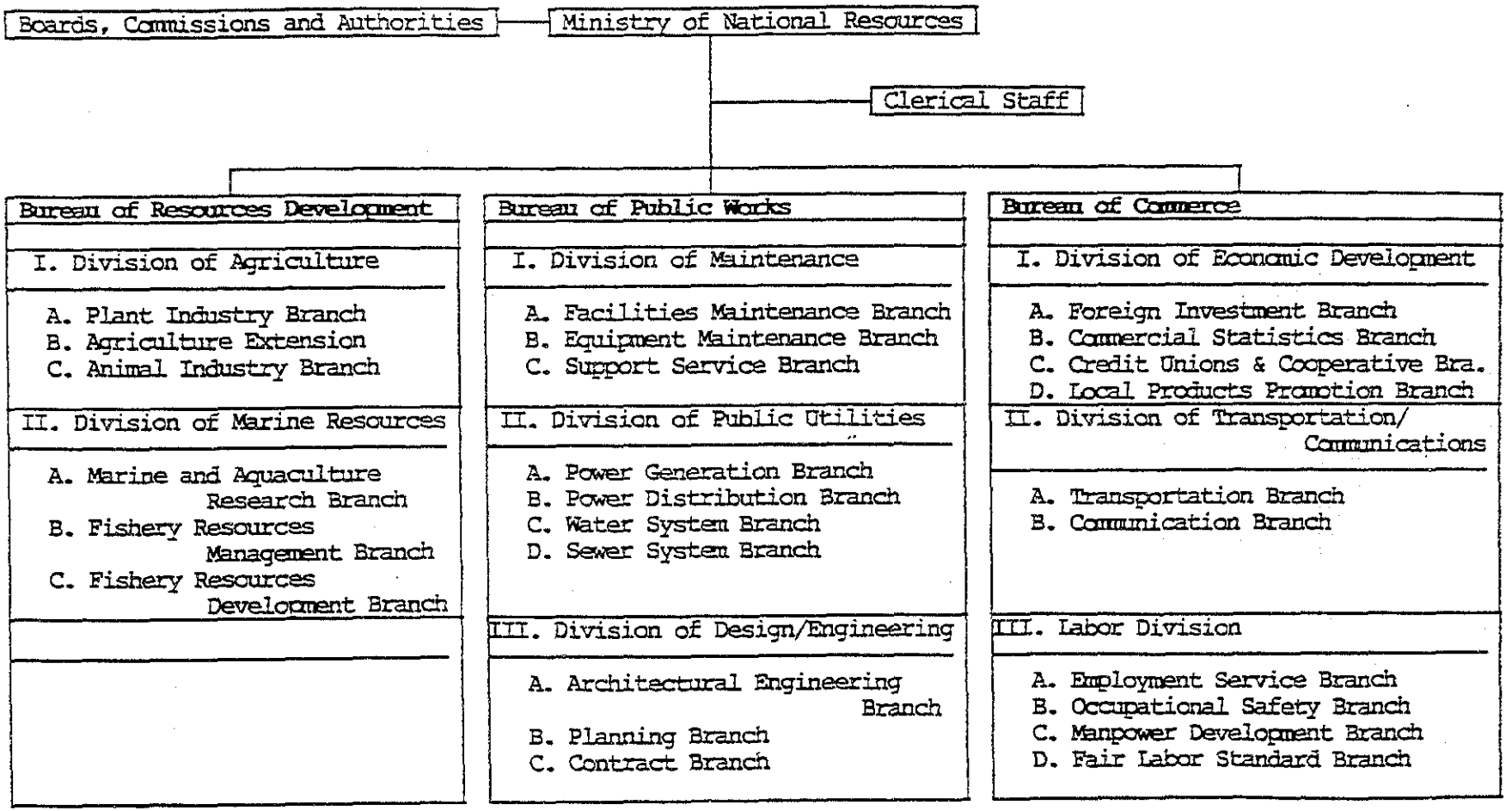
3.4 Office in Charge of the Implementation of the Project and Operation System

The Bureau of Resources and Development of the Ministry of National Resources of the Republic of Palau is the office in charge of the implementation of this project. The Division of Marine Resources, Bureau of Resources and Development, is the office in charge of the administrative affairs related to fisheries. That being so, the Bureau of Resources and Development is in close contact with people of the various states engaged in fisheries. It is this office which registers the demands and requests of the local people. On the other hand, the Bureau of Public Works, Ministry of National Resources, is the office in charge of the control of public works. It will give advice on this project from the standpoint of civil engineering. The Ministry of National Resources has the organization shown in Figure 3-1.

The Chief of the Bureau of Resources and Development, the Governor of the State of each Project site, and the Chief of the Bureau of Public Works will form a three member committee to promote the implementation of the project. The facilities that will be constructed within the context of this project will be handed over to the various states after their completion, and their operation and control will be taken charge of by the fishing associations of the various states.

The Ministry of National Resources has 250 persons on its staff and is operated on an annual budget of $7,500,000. About 40 of this staff are working in the Bureau of Resources and Development, and, prior to the project implementation, the Government will appoint 2 persons as the counterpart who will take charge of project promotion. The fisheries related projects which are scheduled to be carried out in the first year (1987) of the First National Development Plan (1987-1991) have a budget of $640,000.

Figure 3-1 Organization Chart of the Ministry of National Resources



CHAPTER IV

OUTLINE OF THE PROJECT SITES

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4.1 Natural Conditions

4.1.1 Topography and Geology

The topography and the geology of the Palau Islands are roughly divided into volcanic rock type topography in the northern part of the archipelago beginning from Malakal Island and the calcareous type topography of the southern part of the archipelago beginning from Rock Island and have various different aspects. In the portion of the archipelago north of Malakal Island, the inland areas have either low mountainous topography or hilly topography consisting of tuffbreccia, which is the bedrock of this archipelago. On the other hand, the shoreline consists of unconsolidated sediments of calcareous matter that are marine alluvia covering the bedrock. There is no transportation of earth to the shore because there are no major rivers, and as a consequence the Palau Islands have practically no plains. The absence of terrace structures like those observed in Guam is presumably attributable to the absence of major diastrophism and marine tectonism.

The tuffbreccia composing the bedrock does not have uniform characteristics, and presents many distinct lithofacies instead. In the southern part of the archipelago it consists of andesite characterized by quartz and glass matter, but on the other hand, in the eastern and northern parts such as Melekeok and Ngerchelong, it contains gravel of holocrystalline basalt in which the presence of pyroxene and hornblende is observed. The rubble itself has various distinct lithofacies varying from small ones consisting mainly of gravel on the order of 5 mm - 50 mm to large ones consisting mainly of gravel on the order of 100 mm - 400 mm. It must be borne in mind, however, that the matrix portion breaks with ease because

it has a medium degree of consolidation, and therefore can by no means be regarded as an aggregate suited for construction use. This shortcoming is observed also in connection with wave erosion. In the coastal areas there are many mushroom shaped small islands with conspicuous erosion in the vicinity of the water surface.

On the other hand, the marine alluvia contains clayey silt, boulder gravel, shell and coral fragments, and is presumed to have areas in which the stratum thickness surpasses 20 meters. There are very loose strata in some parts, and special attention is required when constructing structures in these areas.

Peleliu Island and Angaur Island located south of the Rock Islands consist of elevated limestone, and the topography is generally flat without high mountains. The geology consists of limestone bedrock with a considerable degree of consolidation. In the coastal portion there is distribution of alluvia consisting of materials ranging from sand through boulder gravel distributed over a narrow range, but this stratum is not so thick as that of Babelthaup Island. As for earthquakes, frequent cases of this phenomenon are reported to occur in the Mariana Islands, but as far as the interview survey carried out this time in Palau is concerned, they are not so frequent in this archipelago and furthermore, their scale seems to be relatively small, although no accurate observation data are available at the present time.

4.1.2 Oceanographic Conditions

Coral reef is found everywhere in the Palau Islands, but generally speaking barrier reefs are well developed in the western and northern parts but not so developed in the eastern part of the islands. By the way, it must be remembered that

there is no barrier reef at all at Angaur Island. The space between the barrier reef and the land consists of a shallow fringing reef, but there are waterways with sufficient depth located everywhere to provide access to the outer sea. It must be noted that overall oceanographic conditions do not necessarily coincide with the specific oceanographic conditions prevailing at each individual place because the said coral reef topography exerts conspicuous influence on the tidal and ocean currents, waves and other relevant aspects.

The system of ocean currents prevailing in the vicinity of the Nanyo Islands consists of the Northern Equatorial Current and the Southern Equatorial Current flowing in a westward direction and the Equatorial Counter Current located between them and flowing in an eastward direction. The Palau Islands are located nearly in the middle of the Equatorial Counter current. It must be remembered, however, that the northern portion of the archipelago projects into the Northern Equatorial Current. Therefore ocean currents at the border area have a very complicated pattern. The Equatorial Counter Current is approximately 300 miles wide, normally located within the 4°N - 8°N latitudes, and flows in an eastward direction with a speed on the order of 0.4 - 1.5 knots, but depending on the place it reaches 2 - 3 knots. It has variable intensity depending on the season, being reportedly strong in the December - February and July - August periods and weak in the March - May period.

As for wind waves and swell, the southwestern portion of the Nanyo Islands, where the Republic of Palau is located, has the mildest conditions compared with the eastern and the northern parts. Their directions are practically coincident with the predominant wind direction of each month. During the winter they have a northeastern direction; during the springtime they have a rather eastern direction; during the

summer they have a southwestern direction; and in the autumn they return to the northeastern direction. The number of days in which the wave height surpasses 0.9 meter amounts to barely a few percent of the year. Depending on the month the number of calm days surpasses 10%. As for swell, the number of days with 0.9 - 1.5 m swell increases a little during the winter due to the influence of the monsoon, but at all other times it has the same direction and height as the wind waves (Figure 4-1, 4-2).

It must be remembered, however, that surf is caused not only by ocean waves but also by the least swell, and special attention is required in the southern part of the archipelago where barrier reefs are not developed.

4.1.3 Meteorological Conditions

The meteorological conditions of the Palau region have oceanic and tropical characteristics, and are influenced by the easterly trade winds and the intertropical convergence zone. In other words, Palau is characterized by the occurrence of cyclic meteorological conditions that repeat every year because the said meteorological phenomena repeat periodic north - south movements with an annual cycle. Meteorological data referring to the Republic of Palau mentioned in the following are based on those of the NOAA (National Oceanic and Atmospheric Administration) of Koror, because the only meteorological observatory of the country is located in Koror.

According to data collected in the last 10 years, the prevailing wind direction is northeasterly in January - May and the southerly component increases in June (Reference V-15-1). During the summer it turns southerly and during the July - October period it becomes practically westerly, but in November the north- easterly component increases considerably. Finally

Figure 4-1 Chart of Swell

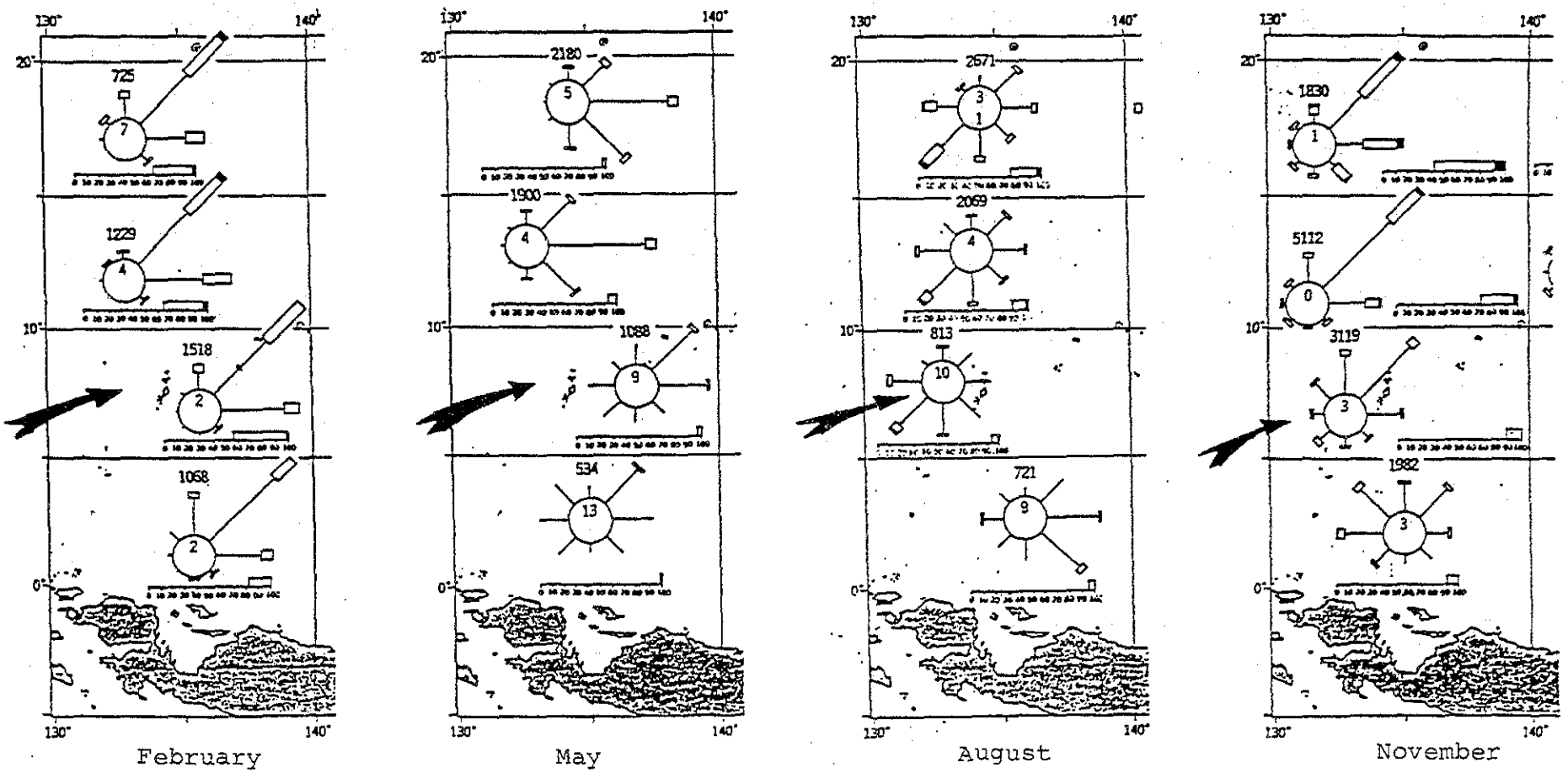
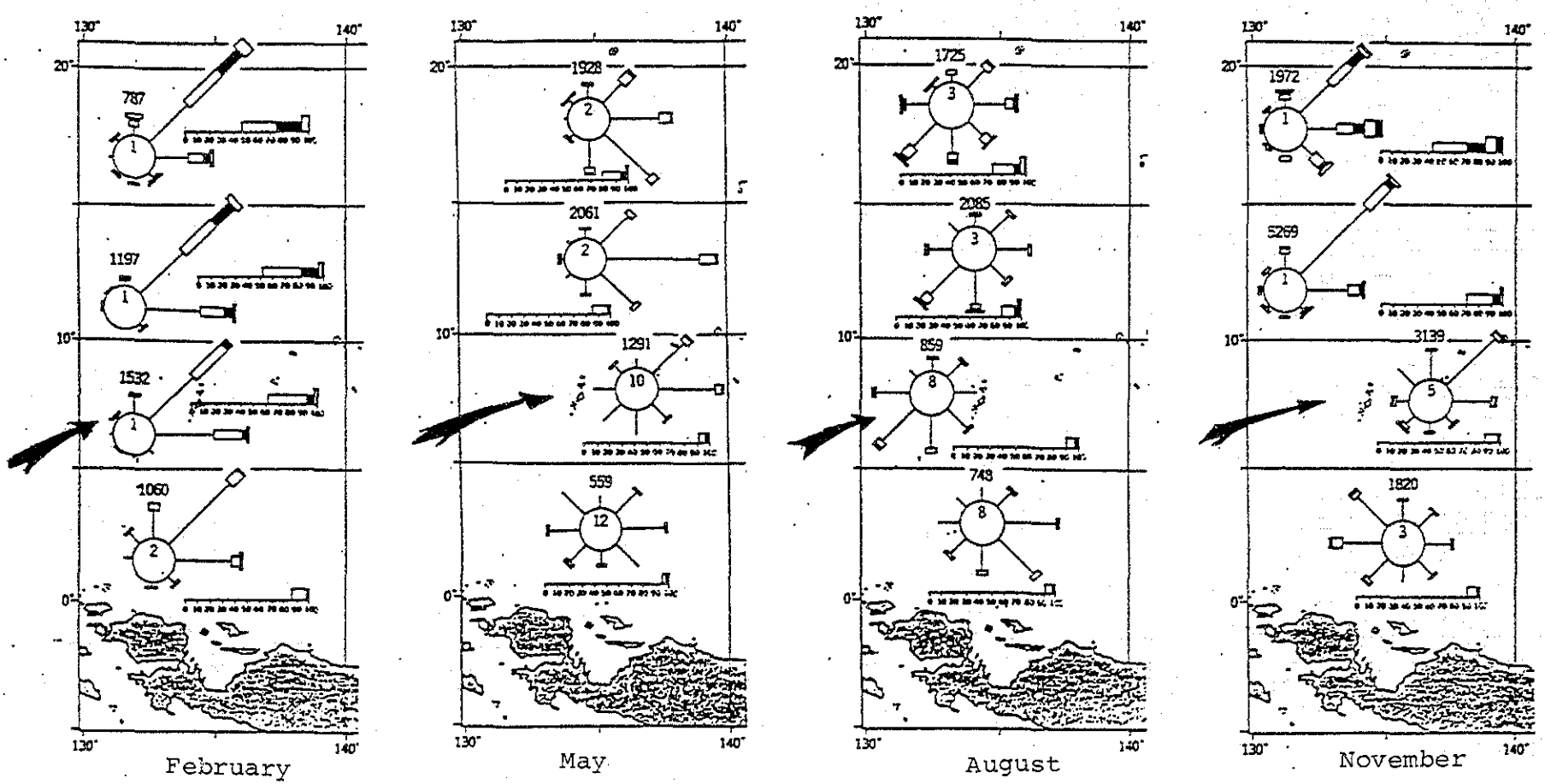


Figure 4-2 Chart of Wind Waves



the easterly trade component increases considerably. The easterly trade wind stabilizes once again from December, and this pattern repeats every year with regularity.

The maximum wind speed of the various months coincides very well with the prevailing wind direction of the same period (Reference V-15-2). By the way, the maximum wind speed recorded so far is 32.5 m/sec. (south) in 1967, and the maximum instantaneous wind speed in the last 10 years is 24 m/sec. (SW) in July 1986. The mean wind speed recorded in the 23 year period since 1963 is barely 3.2 m/sec., but wind speeds of the order of 7 - 8 m/sec. were observed very often during the survey carried out this time.

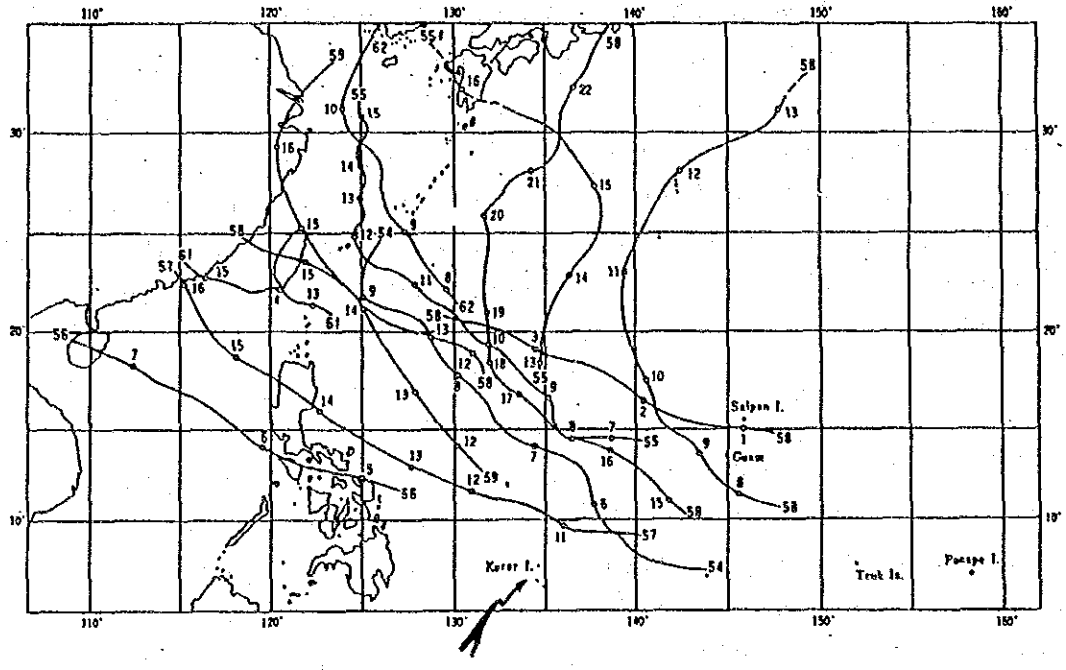
The zone contained within the 5°N - 20°N, 130°E - 170°E limits is regarded as the area in which tropical cyclones (typhoons) are generated, but the occurrence of this kind of phenomenon is rare in Palau because this archipelago is located in the southernmost border area of the said zone. Figure 4-3 shows the trajectories of the summer and winter typhoons.

As for temperatures, there is a conspicuous influence of the oceanic characteristics in view of the small size of the islands, and the average temperature is 27.8°C during the winter and 28.9°C during the summer. As for the daily temperature variation, the diurnal range is on the order of 6°C during the summer. As for the daily temperature variation, the diurnal range is on the order of 6°C, with a mean maximum temperature of 30.8°C and mean minimum temperature of 24.1°C. The maximum and minimum temperatures recorded so far are 35°C in June 1967 and 20.5°C in April 1979, respectively.

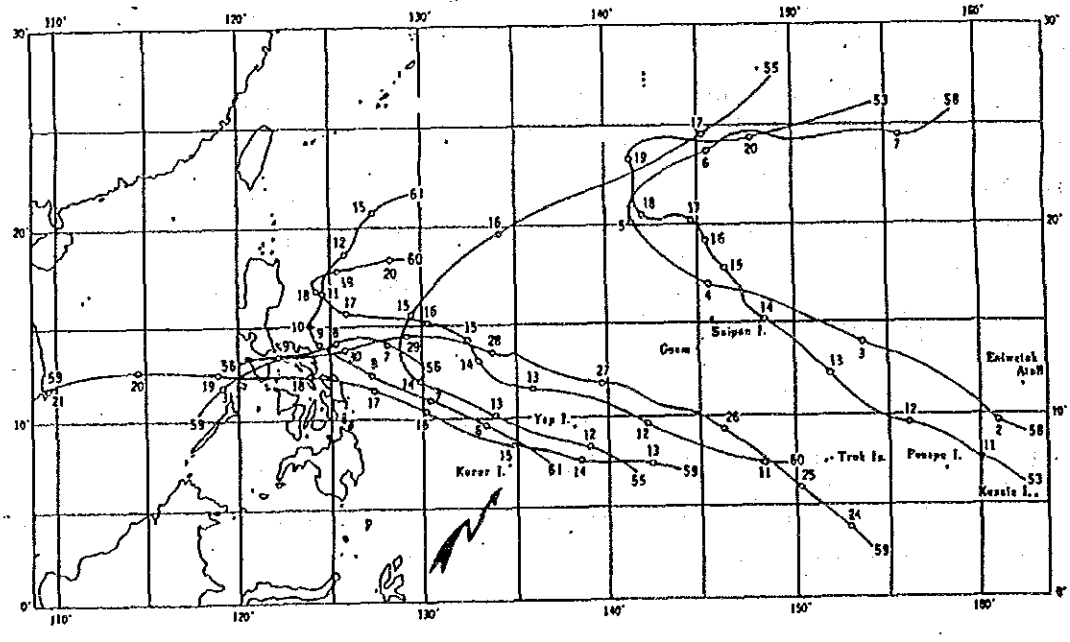
Precipitation is very great, reaching an annual average of 3,800 mm since 1957, but in the northern part of Babelthaup Island it reportedly reaches 5,000 mm. In terms of annual variation pattern, the precipitation becomes relatively

Figure 4-3 Trajectory of Typhoons

From 1 to 16 July (1953-1962)



December (1953-1962)



little in February and March, beginning to increase in April and reaching the peak level in July. After that it declines a little but in December and January it reaches a new peak level. The rainfall pattern is a typical shower type. As soon as the beat of the first drops is heard, the rainfall becomes hard at once, but in most cases it goes away within 20 or 30 minutes and the weather returns to clear skies.

4.2 Natural Conditions at Each Site

(1) ANGAUR

Angaur is an island consisting of upheaved calcareous rock having a point with an altitude of 60 meters at its northwestern portion, but the island as a whole is flat. It must be remembered, however, that the island has such features as limestone caves and sharp sawtooth shaped undulations at some places due to the characteristics of the calcareous rocks. At one time phosphorite was mined on this island and shipped from the harbor examined in this survey, but nowadays the mine is abandoned, and the only vestiges of the past are the ruins of the facilities, a wharf, etc.

Calcareous rock in the vicinity of the harbor examined in this survey is white through gray white and has a fair degree of consolidation, but it is porous due to weathering and erosion, and the surface has very sharp notches. The method of work to be adopted for the sake of dredging the entrance of the port must be examined with special care because of the said calcareous rock outcrops therein, resulting in characteristics different from those of the alluvial sediments. The soil of the wharf construction site consists of an alluvial sand gravel stratum and alternations consisting of such materials as fine through coarse sand of coral origin, granule sand through pebble gravel, coral fragments, etc., are

distributed down to depths of 10 meters from the ground surface. The degree of compactness is fairly good, and the N-value is at least 23 and normally on the order of 30 - 40.

The meteorological conditions of this area have the same characteristics as those of Koror. The interior of the harbor is calm irrespective of the wind direction because it is surrounded by land and trees on all sides, but the harbor entrance faces west, and there is nothing to shut off westerly winds. Furthermore, the island is subject to the direct influence of the wind waves and swell of the outer sea because there is no barrier reef in its vicinity. Under the circumstances, the frequent occurrence of surf and the narrowness of the harbor entrance makes it difficult for small vessels to enter and leave the harbor under bad sea conditions. In particular, the situation becomes quite bad during the westerly wind season ranging from the summer to the autumn.

The currents in the vicinity of this island are reported to be very unstable, presenting frequent changes, but the shoreline consists mostly of exposed rocks, and there are practically no sediments that could result in littoral drift. No trace of littoral drift was observed during the study carried out this time.

(2) NGERCHELONG

Ngerchelong is located on the western side of the northern part of Babelthaup Island. The eastern side of the site consists of a hilly district, and the village of Ollei is located at its foot. A masonry breakwater with a length of 800 meters in the E-W direction stretches through this project site, but in reality its ends are completely broken and as things now stand the available breakwater length is on the order on 700 meters. The existence of a

cliff of tuffbreccia is observed in the vicinity of the foot of the breakwater, but the wharf construction site is in the sea approximately 400 meters off this foot, and the soil of this area consists exclusively of alluvium sediment.

As for the geological structure at the site, the upper stratum with approximately a 4-meter thickness consists of loose silty sand, but a boulder stratum consisting of clayey rocks begins at a depth of approximately 6 meters. The latter stratum has a confirmed thickness of 2 meters, but it continues down to greater depths, and it can be regarded as having sufficient strength to bear structures. As for the location of the anchorage at the southern side or at the northern side of the existing breakwater, the former alternative seems to be the better choice by taking into consideration the prevailing wind direction (NE) during the year. This choice was regarded as appropriate also by the authorities concerned of Palau in view of the more frequent occurrence of northerly winds. As a matter of fact, the southern side is being used at the present time. It must be borne in mind, however, that the area in question is widely open in the western direction, being completely defenseless against western winds. According to meteorological data collected so far, westerly winds prevail in the August - October period, and furthermore the maximum wind speeds of the various months also have a westerly direction. Under the circumstances, some protective measures will be required in the anchorage.

In connection with the influence of the outer sea, both barrier reefs and fringing reefs are well developed in the vicinity of this site and such phenomena as swell and the like are not expected to exert a direct influence. However, there are long stretches of shallow water with flat topography at the bottom of the sea before reaching the fairway. That means a huge volumes of earthwork to

clear the passages and secure the safe sailing of ships, and the disposal of surplus earth are factors to be taken into consideration in connection with the works. The soil at the bottom of the sea consists of silty sand containing shell and coral fragments. Seaweed is abundant and there is no trace of littoral drift.

(3) NGATPANG

The project site faces approximately north, and its southern and eastern sides are surrounded by mountains. It consists of sedimentation from alluvial stratum projecting conspicuously out from the land, and the harbor is located at the tip of the projection. The mountainous areas in the background consist of the tuffbreccia generally found on Babelthaup Island, and have mountainous topography with a rather sharp configuration compared with the gentle hilly slopes found in other areas. Neatly oval shaped boulders 1 m - 4 m in diameter that consist of hard portions of tuffbreccia which has withstood weathering are found very often in these hilly districts.

The alluvial sediment at the project site has considerable thickness and furthermore it has a very loose consistency. According to the results of the boring survey carried out at the wharf construction site, the soil consists of a stratum of silt containing clayey pebble gravel down to approximately 4 meters from the ground surface, and at greater depths there is a silty sand stratum containing pebble gravel down to 11 meters from the ground surface, and at even greater depths there is a silty sand stratum containing pebble gravel down to 11 meters and more from the ground surface. Both strata are very loose and have a low degree of compactness. The result of the standard penetration test was barely N = 2 - 8 in both cases.

There is a small breakwater at the western end of the anchorage site. It is desirable to design the position of the wharf so as to make the most of this breakwater as a means to cope with the westerly winds. As things now stand it is not necessary to excavate the passage. Dredging the anchorage instead is sufficient, because the fairway is already reaching part of the anchorage. A sand dike is required at the eastern side of the anchorage because earth sedimentation therein comes to the point of cropping out during the spring tide. The soil at the bottom of the sea consists of silty sand, pebble gravel, coral fragments and shell. There is abundant growth of seaweed and there is no trace of littoral drift. Barrier reef and fringing reef are well developed at the western side of the site and have the function of shutting off the waves of the outer sea.

(4) MELEKEOK

Of the four project sites taken into consideration in this study, Melekeok is the only one located on the eastern side of the archipelago. There is a flat area with a width on the order of a few dozen meters to 100 meters along the shoreline, and the village is located therein. The adjacent hinterland is a direct extension of the central mountainous district of Babelthaup Island. The soil of this zone consists of tuffbreccia with basic characteristics comparable to the Koror area, and gravel with a size of 2 cm - 15 cm is very common. The degree of consolidation is medium, and the matrix portion can be chipped off with a hammer pick. As for the degree of weathering, the breccia itself is fairly hard but the material as a whole falls into pieces with a moderate hammer stroke. It is of the CM class according to the method of rock classification by KIKUCHI & SAITO.

There is alluvial sedimentation with considerable

thickness at the construction site, and there are tidal flats up to several hundred meters offshore. Results of the boring survey indicate that the alluvial stratum has a thickness of 22.5 m at the wharf construction site. As for the composition of the soil, the upper part of the stratum contains much boulder gravel of coral limestone but the portion corresponding to the construction foundation consists of calcareous silty sand, pebble gravel, shell, etc., with a low degree of consolidation and loose consistency with an N-value on the order of 2 - 9. Under the circumstances, special attention must be paid to the method of construction if this stratum is to be used to bear the heavy weight of the wharf. The harbor examined in this survey is provided with a breakwater in the N - S direction and it is quite effective in protecting against the prevailing winds (NE). Also, the background mountainous districts provide protection against the N and NW winds. In connection with the meteorological conditions there is no peculiarity worth special mention, and this site can be regarded as similar to Koror.

A barrier reef is developed approximately 1,500 meters off the shoreline. This prevents waves of the outer sea from reaching the interior of the harbor. A shoaling beach stretches up to 100 meters off the shoreline, but a -2.5 meter passage provides access to the harbor. The influence of littoral drift on this passage can be neglected in view of the facts mentioned in the following.

1) Results of the analysis carried out with samples of the soil at the bottom of the sea in the passage indicate that the soil consists of silty material containing gravel, coral fragments and shell, and therefore it does not have the uniform composition observed in littoral drift.

2) Growth of seaweed is observed in some parts of the passage, indicating the stable nature of the soil at the bottom of the sea in the passages.

3) Topographic characteristics suggesting the occurrence of littoral drift are observed in some places, but they were found to be unexcavated portions through the interview survey carried out with local contractors.

4) Three years have passed since the excavation of these passages, but there is practically no change in the depth of the water with the exception of some places. Reduction in the depth of the water was observed at some parts of the eastern side of the passage as a result of the comparison with the results of the sounding carried out in September 1985, but it is not known whether these changes are attributable to unexcavated portions or to natural sedimentation.

5) There are no plans that could bring about future changes in the material of the bottom of the sea and in the tidal currents.

In view of the aforementioned facts, the conclusion is that the harbor presents no risk of being clogged within a short period of time.

4.3 Results of Boring Tests

Two boring tests were carried out at each site. The results of these boring tests, numbering 8 in total, are summarized in Table 4-1 and in Figure 4-4. The results of the tests carried out with the soil samples collected on the occasion of the boring are summarized in Table 4-2. According

Table 4-1 Summary of Bore Hole Tests

Location	Borehole Designation	Boring Depth (m)	Thickness of Fill Mat.	Thickness of Overburden	Type of Over-burden Material	Redrock Classification	Type of Sea-bed Material
Angaur	BH-1	9.80	2.80	5.50	Calcareous sand & gravel	Consolidated calcareous stone	Coarse grain beach
	BH-2	6.70	Shoreline	5.10	Shells & coral fragments	Coral reef	Sandy mat.
Ngerchelong	BH-3	6.73	1.25	5.23	Calcareous sand & gravel	Ibid	Medium to very fine sand
	BH-4	7.75	1.80	6.29	Ibid (slightly weathered)	Ibid	Ibid
Ngatpang	BH-5	10.80	2.40	>10.80	Ibid (highly weathered)	-	Loose sand
	BH-6	10.80	2.45	>10.80	Ibid	-	Decayed coral reef
Melekeok	BH-7 (1')	11.00	2.55	>11.00	Ibid	-	Ibid
	BH-8 (2')	22.50	2.55	>22.50	Ibid	-	Loose sand

Figure 4-4
Boring Test Results

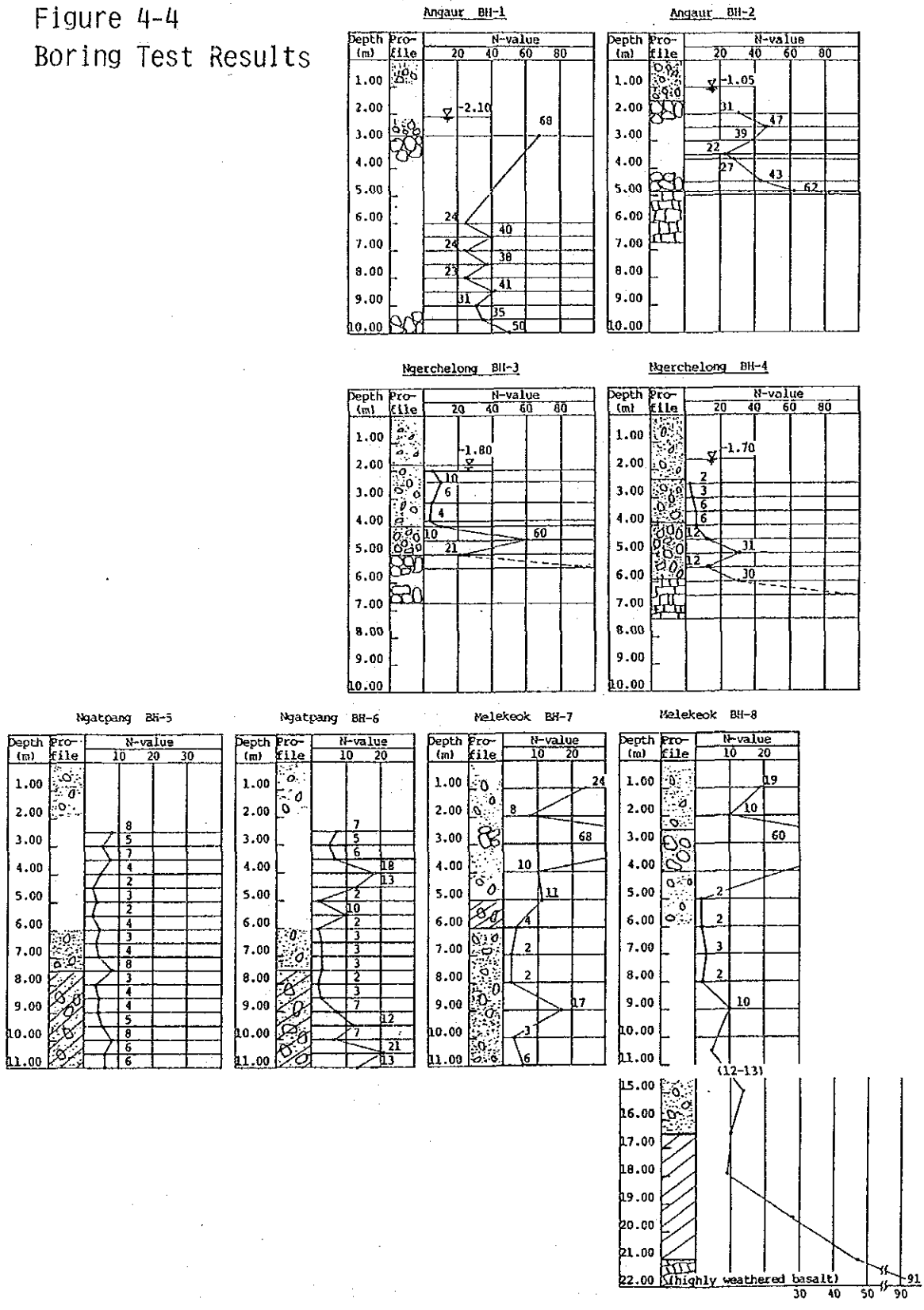


Table 4-2 Soil Test Results

Site	Boring hole and sample number	Sample collecting depth (m)	Soil classi-fication	Wet unit weight** (t/m3)	Soil composition (% wt)			Remarks
					Gravel (2mm<)	Sand (2mm-74μ)	Silt (<74μ)	
Malekeok	BH-2'/5	5.55-6.00	SM	1.41	55	36	9	
	BH-2'/6	6.55-7.00	SM	1.60	40	35	25	
Ngerchelong	BH-4/3	3.00-3.30	SM	1.56	30	55	15	
	BH-4/4	3.50-3.80	SM	1.72	27	58	15	
	BH-4/8	5.50-5.80	SM	1.57	37	43	20	
	BH-4/A	6.27-7.75	Core*	wet 1.61	Qu = 53.7 kg/cm2			Wo = 22%
	BH-4/B	Ibid	Core*	wet 1.28	Qu = 68.8 kg/cm2			Wo = 20%
Ngatpang	BH-5/5	4.00-4.30	SM	1.59	53	33	14	
	BH-5/9	6.00-6.30	SM	1.43	53	42	5	
	BH-5/12	2.50-7.80	SM	1.47	32	58	10	

Note:
* According to ASTM-2938(76).
Qu = Unconfined compression strength (ø ∓ 5cm, L = 10cm)
Wo = Water absorption rate
** Stirring sample
SM: Sand mixed with silt

to Table 4-1 the overburden stratum has a thickness on the order of 0 m - 3 m, and in all cases the soil contains coral fragments. The soil is basically sand mixed with silt, and is similar to the material found at the bottom of the sea. No pit earth (laterite type clay or mangrove area humus) was found in the boring sample. The depth of the hard bedrock is 5.10 m - 5.50 m in Angaur and 5.23 m - 6.27 m in Ngerchelong, but it reaches 10 meters or more in Ngatpang and in Melekeok. Information referring to the soil of the project sites, obtained from the results of the sampling and the standard penetration test as well as the tests carried out with the soil samples, are summarized in the following.

(1) ANGAUR

The area in which the passage dredging work is to be carried out corresponds to the boring position (BH-2), and the surface stratum consisting of sand mixed with gravel (GM) has a modest thickness on the order of 1 meter. Beneath the surface stratum there is a bed (depth of 2 m-5 m under the bottom of the sea) consisting of gravel of large diameter (approximately 30 cm), and its N-value is on the order of 20-50. Bedrock consisting of clayey material is found at depths of 5 meters or more under the bottom of the sea.

As things now stand, the passage and the anchorage have a shallow depth because they are filled with earth. However, most of these areas can be dredged by means of a dragline because the fill materials consist of boulders and sand mixed with small diameter gravel used as fill for part of the peripheral breakwater.

The place where the wharf is to be constructed corresponds to the boring position (BH-1). The bottom surface of the wharf (approximately 5 meter/depth) consists of a gravel

layer with an N-value on the order of 20-70, and is suited for grab dredging. Further, the soil under the wharf bottom surface consists of the same gravel stratum with an N-value on the order of 23-50. Therefore, it is expected to have sufficient strength as bedrock to bear a concrete block type wharf.

(2) NGERCHELONG

It was decided that the boring tests (BH-3, BH-4) should be carried out on the northern side of the breakwater because ground leveling of the passage site was being planned at that side before the present study. Anyway, there is presumably no major geological difference between the northern and the southern sides of the breakwater because the bottom of the sea is flat and shallow on both sides. At the boring position (BH-4), which corresponds to the passage dredging site, the surface stratum has a thickness of approximately 2.5 meters, and the soil consists of loose sand mixed with silt having an N-value under 10 at depths down to 4 meters. From the standpoint of the grading, composition gravel accounts for the largest proportion, on the order of 27%-57%, but it consists mostly of coral fragments sized less than 5 cm and the proportion of gravel of a larger size is negligible. Under the circumstances, dragline dredging is presumed to be applicable with ease in this case.

The surface stratum soil (ground surface at the bottom of the sea) contains a fairly large proportion (15%-20%) of silty components. This component is presumed to keep the sand particles together with a loose degree of consolidation, reducing the risk of the passage being filled due to the drift of the earth suspended in the water to the bottom of the sea.

At the boring positions (BH-3, BH-4) corresponding to the place where the wharf is to be constructed, there is a gravel stratum (GM) mixed with sand having a thickness on the order of 1 m - 2 m at depths of 4 meters and more. There is clayey bedrock beneath that gravel stratum. Under these circumstances, dragline and grab are suited to excavate the bottom of the sea at the place where the wharf is to be constructed (a depth of approximately 5 meters) when the gravel size is under 30 cm and 50 cm or more, respectively. On the other hand, it may be necessary to break the bedrock depending on the place, but an ordinary bob plumb or rock drill can be used to break the rock because the bedrock has a relatively modest strength (axial compression strength under 70 kg/cm^2). After the rock breaking operation, the excavation can be carried out by using either a grab or dipper.

(3) NGATPANG

The boring positions (BH-5, BH-6) correspond only to the wharf construction site. At both places the soil consists of strata of loose sand mixed with silt (SM) and gravel mixed with sand (GM) having N-values under 10 that stretch down to a depth of 10 meters and more, but at some points there is a bed consisting of large sized gravel with an N-value on the order of 20. Under the circumstances, the excavation of the anchorage can be carried out with ease by using a dragline. It must be remembered, however, that the said soil is inadequate as a foundation for the wharf, and a careful study on the wharf structure comprising such aspects as subsoil stabilization, sheet pile structure, backfill material, etc. will be required prior to executing the work.

(4) MELEKEOK

The boring positions (BH-8, BH-9) correspond only to the wharf construction site, in the same way as in Ngatpang. At depths surpassing 4 meters the soil consists of loose sand mixed with gravel (GM) having N-values under 10, similar to that of Ngatpang. At places with a relatively small depth (approximately 3 meters) corresponding to the bottom of the sea, however, there is a hard gravel stratum with a thickness on the order of 1 meter having an N-value surpassing 60, and coral blocks with a size of 30 cm or more are found on the flat bottom during low tide periods.

Under the circumstances, the excavation of the wharf construction site is presumably practicable by using a grab. It must be considered, however, that the strength of the foundation ground is presumably insufficient to bear a gravity type wharf. Nevertheless, if an alternative such as a steel sheet pile type wharf should be adopted in this project, troubles are expected to occur when driving the sheet piles. Therefore, a careful study on wharf structure comprising such aspects as subsoil stabilization, sheet pile structure, backfill material, etc. will be required prior to starting the construction, the same as in the case of Ngatpang.

By the way, coral sand has a porous nature (20% water absorption rate) and a low dry density (1.41 - 1.72 t/m^2) as can be shown from the soil test results summarized in Table 4-2. Therefore, from the standpoint of the sliding stability of the wharf, it is advantageous as backfilling earth to be used behind the wharf.

On the other hand, coral sand is presumed to have considerable shearing strength (internal friction angle)

in spite of the field N-values observed in Ngatpang and in Melekeok because it consists of gravel containing many coral fragments with diameters on the order of 1 cm and lengths on the order of 5 cm (gravel component proportion on the order of 1%-55%).

4.4 Tide Levels and Tidal Currents

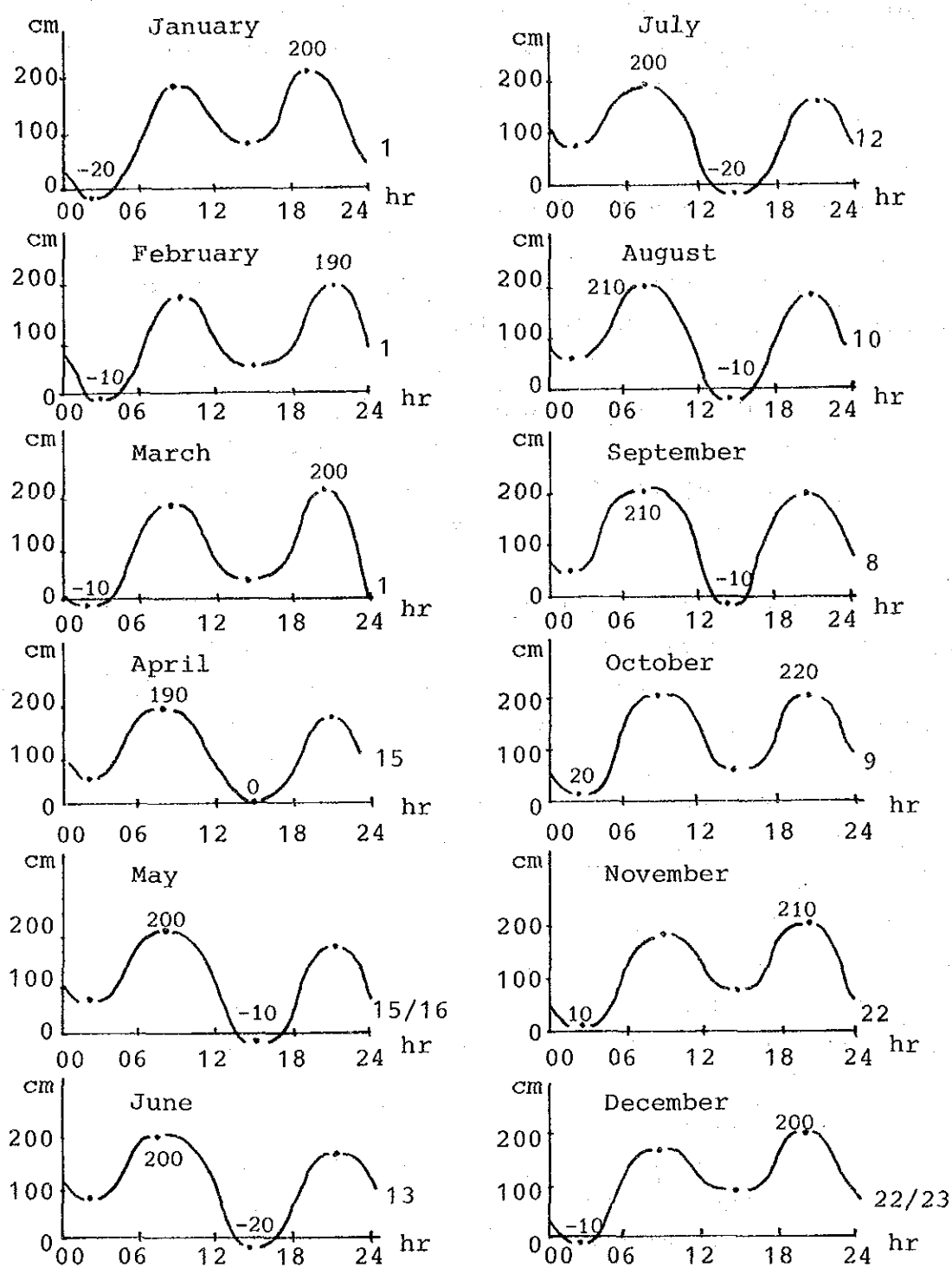
The Chart Datum Level (C.D.L) in harbor works is defined as shown in the following.

- Zero level of navigation charts
- Datum level for ordinary harbor works (Japan)
- In the materials of the NOAA it is defied as "1 foot below mean low water springs"

According to the tide table of the NOAA, the Malakal Harbor has tides as shown in Figure 4-5, and the tide range during the spring tide is in the order of 2.20 m - 1.90 m, but when the C.D.L. is taken as datum level we have the Highest H.W.L. = 2.20 m and the Lowest L.W.L. = -0.20 m, and the annual difference between H.H.W.L. and L.L.W.L. is 2.40 m. It must be remembered, however, that the object of the basic design is a fishing port, and that there is no important construction in the hinterland. Under the circumstances an average tide range of 2.0 m is adopted at the various sites and the C.D.L. for the sake of measurement of the water depth is determined as shown in the following based on the tide table of Malakal Harbor.

- Angaur
  (1 hour lead --- taken into consideration)
- Ngerchelong
  (1 hour delay --- taken into consideration)
- Ngatpang/Melekeok
  (30 minute delay --- neglected)

Figure 4-5 High and Low Waters at Malakal Harbor (1987)



NOTE: 1) Meridian: 135°E
2) Height: 00 cm = chart datum of soundings
≒ 1 foot below mean low water springs

On the other hand, in connection with the tidal flow, the 3 harbors of Babelthaup Island (Ngerchelong, Ngatpang, Melekeok) are located inside the reef and are provided with passages/anchorages surrounded by shallows accessing natural fairways instead of having closed harbor entrances, and as a consequence the tidal flow due to the tide range is relatively small (on the order of 0.5 knot). Furthermore, the sea areas adjacent to the passages and anchorages are shallows with L.W.L. on the order of 0 cm in all three harbors. That being so, flow due to wind waves is presumed to be negligible because it is not easy for this kind of wave crossing the shallows to develop under the said conditions.

4.5 Estimation of Waves

(1) EXPECTED VALUE OF THE MAXIMUM WIND SPEED AND ESTIMATION OF WIND WAVES

The annual maximum wind speeds (1 minute average) in the directions at each site (navigation direction ±45°) are calculated on the bases of the wind statistics referring to the 20 year period (1967-1986) recorded at the Koror Meteorological Station. And the expected value of the maximum wind speed repeated once every 50 years is estimated from the ranking probability obtained as a result of the said calculation by using Gummel's Extreme Value Probability Graph as shown in Appendix V-16. The relevant results are summarized in Table 4-3.

It should also be considered that, in connection with the wind wave estimation by means of SMB, the fetch length (F) up to the peripheral reef measured on the navigation chart is relatively short. Under the circumstances, the significant height of the wind wave (offshore wave) has a small value falling under H1/3=1.0 m at all harbors with

Table 4-3 Expected value of the maximum wind speed, fetch length, estimated values of the fetch time and offshore wind waves

Site	Passage direction	Calculated wind direction	Expected value occurring once every 50 years U (m/sec)	Fetch length F (km) (1)	Fetch time T (hr) (2)	Wind wave height H (m) (3)
Angaur	W	NW-SW	28.3	- 10^3	10	7.5
Ngerchelong	W	NW-SW	28.3	2.0	10	0.9
Ngatpang	NE	N-E	25.8	1.0	10	0.6
Melekeok	S	SE-SW	32.5	2.0	10	1.0

1. Distance up to the peripheral reef measured in the passage direction on the navigation chart (a hypothetical fetch distance is adopted for Angaur)
2. Assumed
3. SMB Method

the exception of Angaur even when the strong wind fetch time is overestimated as 10 hours.

(2) ESTIMATION OF THE WAVE HEIGHT INSIDE THE HARBORS

The deformation coefficients of the waves due to such phenomena as refraction, diffraction and shoring are Kr=Kd=Ks=1 in all harbors except Angaur, and therefore the offshore waves access directly the interior of the harbors. In Angaur the water depth changes suddenly from 30 m to 5 m within a distance of 70 meters from the outer sea to the shallow reef area. Under the circumstances the offshore waves are amplified up to Ks=1.32 due to shoring

as they reach the harbor entrance, but the offshore wave height is presumed to be reduced to approximately 50% (standard) in the vicinity of the harbor entrance due to the action of the breakers. Furthermore, the wave height at the anchorage is attenuated to approximately 1/10 of that of the harbor entrance due to diffraction because the anchorage is located at a deep position perpendicular to the harbor entrance direction. Therefore, it is presumed that sufficient safety can be secured by assuming that the significant wave height in front of the wharf is H1/3≒1.0 m even in the case of the strong winds occurring once every 50 years.

Nevertheless, there is no sign suggesting that the 1 - 2 ton stone blocks piled up beside the southern breakwater of the harbor entrance were moved by the waves, and this fact indicates the effectiveness of these stone blocks as a material to reinforce the breakwater. Under the circumstances, stone quarried from the hinterland of Angaur can be used to reinforce the northern breakwater of the harbor entrance.

CHAPTER V

BASIC DESIGN

CHAPTER V BASIC DESIGN

5.1 Basic Design Policy

The economy of the Republic of Palau is being shaken by the prospect of enforcement of the Compact of Free Association with the United States of America. The enforcement of the said agreement is due soon, and a big step is expected to be taken in the process leading to the construction of an independent economy. So far investments in the public sector have been strongly biased toward the education and the social welfare fields, but hereinafter it will be indispensable to change course toward a direction that places greater importance on socioeconomic development. The environment for private investment is expected to improve, and such trades as fisheries, agriculture, tourism, etc., are expected to grow as basic industries of the country by supplying the necessary infrastructure all over the country and by encouraging the development of the regions lagging behind.

The basic design is drawn up by taking into consideration the said status of the country, as well as the matters mentioned in the following that are aimed at realizing the most appropriate facilities within the context of the grant-in-aid to be provided by the Government of Japan.

(1) DESIGN WITH APPROPRIATE PROJECT SCALE

1) The scale of the facilities of each harbor should be defined on the basis of a proper forecast of the demand.

2) The contents of the facilities should be practicable within the scope of the financial resources provided by the grant aid.

3) The maintenance and control costs after the Project's completion should be as modest as possible.

4) The construction works should be properly designed to eliminate any waste.

(2) DESIGN TAKING INTO CONSIDERATION THE NATURAL CONDITIONS

1) Such factors as weather, topography, geology, tide current, tide level, etc., of each site should be taken into consideration in the design.

2) Attention should be paid to preventing any harmful influence on the environment during and after the completion of the works.

3) The peculiarities of each site should be taken into consideration in the design.

(3) THE STRUCTURE, MATERIALS AND CONSTRUCTION METHODS TO BE ADOPTED SHOULD FIT THE CONDITIONS AT THE SITE

1) The structure should be as simple as possible to facilitate maintenance and control.

2) The materials and construction methods available in the Republic of Palau should be given priority.

3) Attention should be paid to landscape conservation.

In fact, the norms and standards mentioned in the following issues are taken into consideration for the sake of the design.

- TECHNICAL STANDARDS FOR PORT AND HARBOR FACILITIES IN JAPAN; 1980 THE OVERSEAS COASTAL AREA DEVELOPMENT INSTITUTE OF JAPAN
- ROAD PAVING STANDARDS; JAPAN ROAD ASSOCIATION
- SOIL TEST METHODS; SOIL ENGINEERING INSTITUTE OF JAPAN
- CONCRETE TEST METHOD; CIVIL ENGINEERING INSTITUTE OF JAPAN
- OTHER ASPECTS AND MATERIALS; JIS (JAPANESE INDUSTRIAL STANDARDS)

5.2 Design of Fishing Port Facilities

The basic facilities (passage, anchorage, wharf), the functional facilities (slipway, landing yard, multipurpose house, toilet/shower, ice making machine, nautical marks) and accessory facilities (manual crane, mooring post) required at each fishing port are selected as described in the following items by taking into consideration such factors as the siting conditions, natural conditions and social conditions of each fishing port as well as their relation with the plans for future development of the Republic of Palau as a whole, and by hearing the requests related to fisheries of the authorities of the various state governments.

A. ANGAUR

The navigation channel, the anchorage and the area in front of the wharf of Angaur Harbor are designed with a uniform water depth of -2.5 m because in the near future it will probably be the base for medium sized fishing boats engaged in coastal fishing (outside the reef). Also, according to the results of the soil study mentioned before, there are no big stone blocks that must be broken in order to secure the required navigation channel width (approximately 15 m as bottom width). The soil of this

area consists of sedimentary calcareous gravel with diameters under 50 cm and grab dredging is presumed to be sufficient to carry out the work, including the excavation down to the base of the wharf. The soil corresponding to the wharf bottom position has bearing strength sufficient to be used as the foundation of a concrete block structure because it consists of gravel with an N-value as high as 30 or more as mentioned before.

The works related to the functional facilities to be provided at this site are (1) repair of the existing slipway (for LSD landing), (2) provision of a landing yard located behind the wharf, (3) a simplified lighthouse at the tip of the southern jetty, and (4) a multipurpose house and toilet/shower. On the other hand, the works related to the ancillary facilities will be (1) removal of the existing manual crane and (2) installation of mooring posts.

Dredged earth will be used for backfilling behind the wharf and any surplus earth will be carried to the backyard and used for road material because there is no sea area susceptible for reclamation.

B. NGERCHELONG

The basic facilities or works required at this site are the passage, anchorage, wharf and land leveling (including revetment), besides the breakwater shown. The position of the passage is selected at the south side of the existing passage by taking into consideration the collapsed state of the southern side of the existing breakwater (presumably attributable to the return of the overhead wind waves coming from the north and the suction of earth from the masonry revetment), the conditions of use of the fishing boats (normally coming alongside the southern side of the breakwater) used by the local fishermen and the wind statistics data stretching over 20 years. The

breakwater (stretching in an E - W direction and pointing NNE) is required to keep the anchorage calm even when there are wind waves (maximum H 1/3 0.9 m) caused by strong winds coming from the SW side during the winter period (June - November) so as to provide safety to all small and medium fishing boats taking refuge.

Nevertheless, the locations of the anchorage, wharf and reclaimed area are considerably shifted to the offshore side by taking into consideration the balance between the volume of earth to be dredged and the volume of earth required for of reclamation. In this connection the crest width (5.6 meters) the existing breakwater is regarded insufficient as an access road, and it becomes necessary to increase its width. Furthermore, the water depth of the passage, anchorage and the area in front of the wharf is set for future use of the harbor by medium sized fishing boats. This site is already a major fisheries base of northern Palau, and is expected to develop as an important interreef fisheries base also in the future.

The functional facilities regarded as necessary at this site are the slipway, landing yard, multipurpose house and toilet/shower besides the nautical mark lights (it was learned that the existing breakwater was originally aimed at being used for the sake of construction of the lighthouse atop the mountain in back of the village) and the ice making machine. On the other hand, the ancillary facilities consist of the manual winch and the mooring posts the same as in other sites.

The geological bedrock has a relatively shallow depth on the order of 5.5 m - 6.5 m, which corresponds approximately to the base of the wharf. With this, it is decided to adopt the concrete block type wharf structure which is the safest, most reliable and durable one.

C. NGATPANG

Malakal Harbor located in Koror, the capital city, will be diverted to uses different from its current uses after the enforcement of the Compact of Free Association. Under the circumstances, it is very probable that Ngatpang Harbor and Melekeok Harbor, which are close to Koror and are located on the west and east side of the island, respectively, will become the bases for small and medium fishing boats operating outside the reef in place of Malakal Harbor. Under the circumstances, fisheries base facilities (sand dikes, anchorage, wharf, functional facilities, slipway, landing yard, multipurpose house, toilet/shower) are regarded as necessary. Furthermore, mooring posts and manual cranes are added as ancillary facilities by taking into consideration their convenience of use. The installation of the lighthouse is omitted because the lights of the village are visible from the sea when it is dark.

On the other hand, a background area of approximately 4,000 m^2 will be reclaimed anew by using dredged earth. That reclaimed area added to the existing area (approximately 3,000 m^2) will be used for the construction of social infrastructure that will be needed in the future.

D. MELEKEOK

Melekeok is expected to become the new capital city of the Republic of Palau in the near future, and a considerable part of the population around Koror is expected to move to Melekeok and to Ngatpang (existing population; approx. 2,000 persons in Ngatpang, 4,000 persons in Melekeok). The basic facilities consisting of a wharf with a water depth of -2.0 m water depth and passage and anchorage with a water depth of -1.5 m water depth are regarded as

insufficient when the future importance of the fishing port and ordinary harbor are taken into consideration. As a result, the construction of harbor facilities with a water depth of -2.5 m the same as in the other sites will be undertaken.

In the study concerning the influence of littoral drift on the navigation channel, it is concluded that the said influence is negligible in view of the following reasons.

(1) No structure with the risk of changing the tide flow will be constructed anew.

(2) The surface stratum at the bottom of the sea consists of sandy material and it contains some silt (approximately 5%), perhaps due to the proximity of mangrove wood. Under the circumstances, the soil is loosely agglomerated, making it difficult to be suspended.

(3) The area in the vicinity of the navigation channel is so shallow that it becomes dry beach at low tide, and no flow of sea water is expected in the navigation channel direction and in the direction crossing the channel even under strong wind conditions.

(4) There exists no tide current passing and returning through the fairway.

(5) The obstacle (shoal) in the transversal direction of the navigation channel, located on its eastern side, gives the impression of littoral drift when seen on aerial photographs but according to people concerned with channel dredging it consists of lumps of hard material. Therefore it is presumed to be remnant

material left behind when the navigation channel was excavated by means of a drag line.

Although the soil of this site consists of gravel stratum containing coral fragments, the poor subsoil stratum with an N-value under 5 has considerable thickness. Under the circumstances, the most appropriate type of wharf structure was selected after a careful study in the same way as in the case of Ngatpang.

Nevertheless, it must be remembered that the existing wharf adjacent to the one to be constructed anew has no revetment and has collapsed. If things should be left untouched, the existing anchorage (-2.5 m) would risk being filled by earth coming from the land side. Under the circumstances it was decided to restore the existing wharf and to provide it with a revetment. Furthermore, it was concluded that the sand dike adjacent to the tip of the new wharf is also indispensable for the sake of maintaining the water depth of the new anchorage. As for the area of land to leveled in the background of the wharf, it will be on the order of 6,000 m^2 so as to match the volume of earth to be dredged from the navigation channel and from the anchorage.

The functional facilities required at this site are the slipway, landing yard, multipurpose house and toilet/shower because the lighthouse and ice making machine are already provided. The ancillary facilities are the manual winch (500 kg hoisting capacity) and mooring post (5 ton/unit), the same as in Ngatpang.

5.3 Design Policy of Mooring Facilities

The mooring facilities are classified as shown in the following in terms of structures and types. The detached

piers and dolphins, which handle large bulk carries and petroleum tankers, are not taken into consideration in the study because this project refers to mooring facilities aimed at small fishing boats. However, it must be borne in mind that cell type wharves are not appropriate as mooring facilities for small fishing boats with modest drafts because they are structures suited of places with great water depth.

CLASSIFICATION OF STRUCTURES OF THE MOORING FACILITIES

1. Gravity type mooring wharf
   - Caisson type
   - L-block type
   - Cellular block type
   - Block type
   - Cast in place concrete type
2. Sheet pile type mooring wharf
   (Classification in terms of type of stay work)
   - Stayed straight pile type
   - Stayed combined pile type
   - Stayed slab type
   - Stayed sheet pile type
3. Rack type mooring wharf
4. Cell type mooring wharf
   - Steel sheet pile cell type
   - Steel plate cell type
5. Landing pier type mooring wharf
6. Shore bridge type mooring wharf
   - Straight pile type
   - Inclined combined pile
7. Side shore bridge type mooring wharf
   - Straight pile type
   - Inclined combined pile
8. Detached pier
9. Dolphin

10. Others

- Slipway
- Floating pier
- Mooring buoy

On the other hand, rack type mooring facilities and landing pier type mooring facilities are suited for places with poor subsoil, where upright wall type structures (gravity type, sheet pipe type) are not practicable from the structural standpoint because they consist of pile structures supporting the superstructure load, but they are not suited for the three harbors (Ngatpang, Ngerchelong, Melekeok) of Babelthaup Island because they require reclamation of the background area.

Floating piers are suited to moor small vessels in anchorages with small waves and a large tidal range, and have an extensive record of use in harbors handling yachts, motorboats and small fishing boats. It must be recalled, however, that floating piers require mooring facilities (posts, chains, ropes, etc.) to fix the pier itself and furthermore they have problems related to the durability and maintenance of the movable bridge used to access the floating pier from the land. That being so, they are not suited for this project because of their incompatibility with the requirements of long life and the maintenance free characteristics of the basic facilities of the Project.

In view of the aforementioned points, only the upright wall type structure (gravity type, sheet pile type), that can function both as wharf and as revetment of the background reclamation area are taken into consideration as mooring facilities of this project, including Angaur Harbor. Moreover, out of the various choices of gravity type mooring wharf alternatives it is decided to adopt the block type and the cast-in-place concrete type alternatives, that consist of plain concrete, instead of the caisson type, L-block type and cellular block type alternatives, whose members consist of

reinforced concrete, because of their merits regarding durability. In reality only the concrete block type was picked up as the ultimate choice out of the existing alternatives of gravity type mooring wharves, however, because it is safe, reliable and has a good track record regarding both manufacture and installation and because the cast-in-place concrete system requires sophisticated construction techniques to effect watertight concrete with high durability. Furthermore, only modest experience is available in connection with such aspects as work with submerged concrete forms, submerged concreting work, prepacked concrete, etc.

5.4 Determination of the Scale of the Facilities

(1) VESSELS USING THE FACILITIES

Small FRP fishing boats of 5 m - 6 m with outboard engines are the kinds of craft that will use these facilities most frequently. Larger vessels are inboard diesel engine types, and small fishing boats of this category provided through a grant aid project from Japan are operating in the various parts of Palau by using the harbors of the fishing communities as bases. Furthermore, the JABIL, a fishing boat belonging to the Palau Fishing Authority, is working outside the reef by calling at the various ports of the archipelago.

In Melekeok state the ferry boat is providing regular service for the sake of the supply of living commodities and for trips by the local residents. Should the various harbors be properly outfitted in the future, the said vessel would provide regular service accessing all of them.

On the other hand, a Landing Ship, Tank (LST) under the control of the Government of Palau is being operated for

the massive transportation of goods. Such items as machinery for public works of the various states, fuel for power generation, etc., are being transported by means of these vessels. The dimensions of the ships using the facilities to be provided within the context of this project are mentioned in the following.

Type of vessel	Gross Tonnage	Dimensions [L(m)xB(m)xD(m)]
Small fishing boat *1	approx. 5 t	11.8x3.3x1.6
Medium fishing boat JABIL *2	approx. 23 t	23x4.95x1.81
Ferry boat	approx. 40 t	20x4.5x2.19
Landing Ship, Tank (LST)	approx. 100 t	33x 11x1.98

*1 Provided under Japanese grant aid project.
*2 operating in outer reef area

It is presumed that for the time being the vessels using the target harbors of the Project will be limited to the aforementioned ones.

The larger the size of the ships expected to use the target harbors of the Project, the larger the scale of the basic facilities of the fishing ports, and that would result in more expensive construction costs. Because of this, the ships which are objects of the Project are restricted to fishing boats and the facilities are designed, assuming their use by vessels of the size of the JABIL.

(2) SELECTION OF THE REQUIRED FACILITIES

The basic facilities and the functional facilities required at fishing ports are listed in Table 5-1. The facilities mentioned in Table 5-2 are selected for the four harbors which are the objects of the Project, however, by comparing such factors as the siting conditions, natural conditions, social conditions, etc., by carrying out the field survey and by holding consultations with people concerned.

SAND DIKE AND BREAKWATER

Sand dikes will be provided in Ngatpang and in Melekeok because the wharf site and the anchorage are located close to mangrove woods and the anchorage is at risk of being filled by earth from the land side. On the other hand, Ngerchelong will be provided with a breakwater on the western side of the anchorage by taking into consideration the safety of ships taking shelter in the case of a strong west wind.

NAVIGATION CHANNEL (Figure 5-1)

The navigation channel is designed with a -2.5 m water depth by taking into consideration some margin of safety for the design draft (1.8 m) of the fishing boats and the draft (2.1 m) of freight ships using the harbor at the present time. The channel is designed with a 15 m breadth (B) by taking into consideration the planned fishing boats (breadth = 8 m). The channel length depends on the state of things in the various districts, and is the distance required to interconnect the deep natural fairway with the anchorage.

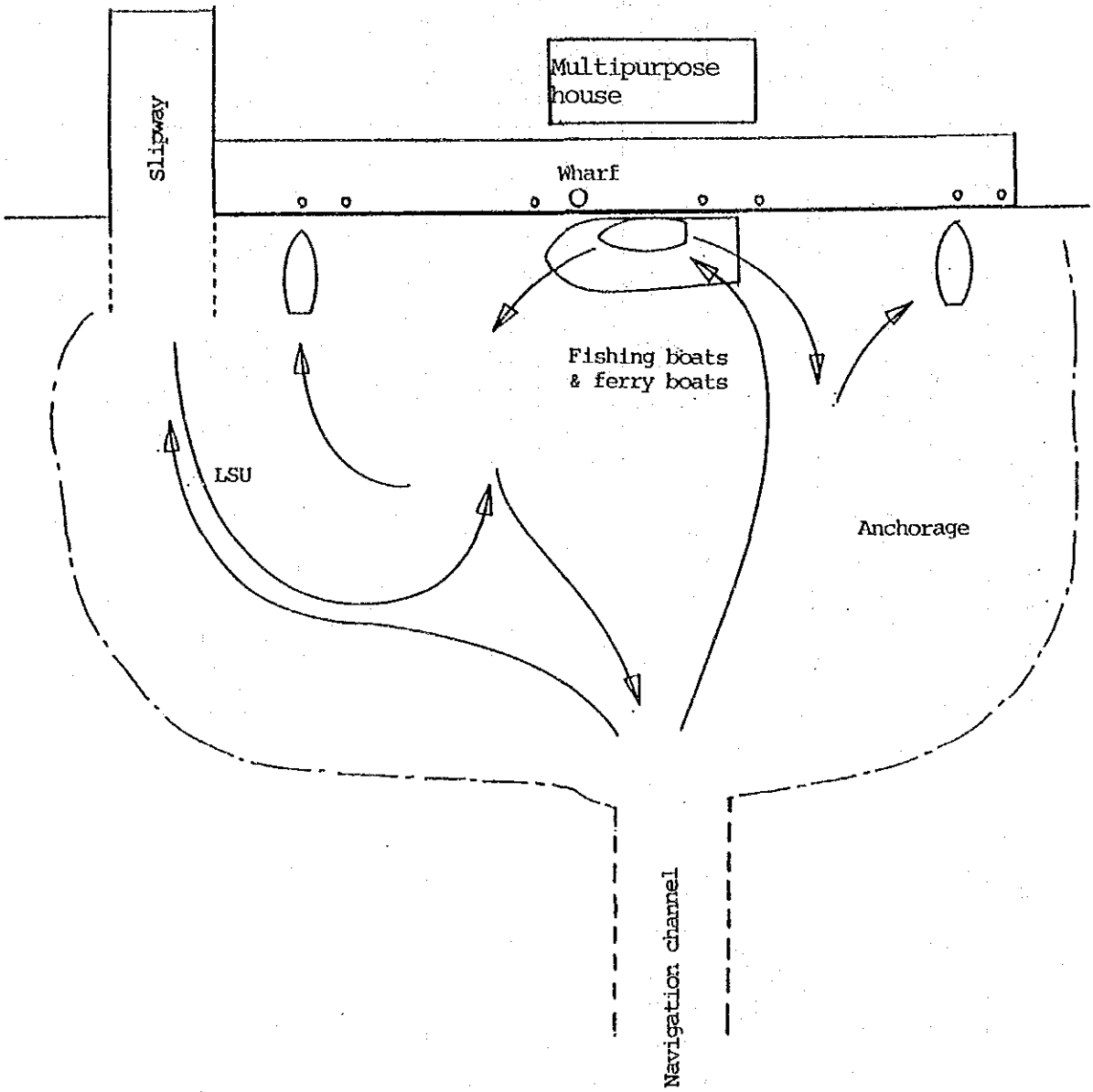
Table 5-1 Classification and Nomenclature of the Fishing Port Facilities

Classification		Nomenclature	Remarks
Basic facilities	Peripheral facilities	breakwater, sand dike, training dike, revetment, jetty, gate, lock, embankment, breast wall	Facilities aimed at protecting the mooring facilities, water area facilities, functional facilities, etc. from the effect of the waves, littoral drift, flow of rivers, tidal current, etc.
	Mooring facilities	wharf, landing yard, floating pier, mooring post, mooring mark	Facilities to land catches, to supply the required goods, and to moor and to land the boats for rest
	Water area facilities	navigation channel and anchorage	Water area used for the ships to enter and leave the harbor and to anchor with safety
Functional facilities	Transportation facilities	railways, tracks, roads, bridges and canals	The basic facilities alone are not sufficient for the harbor to give full play to its functions. These functional facilities are required in this connection.
	Navigation aid facilities	navigation channel marks, signals for the ships to enter and leave the harbor and lighting facilities	
	Fishing boat & fishing gear conservation facilities	fishing boat repair shop, fishing boat engine repair shop and fishing gear drying yard	
	Supply facilities	facilities to supply water, fuel, ice, etc. to the fishing boats	
	Facilities for handling, storage and processing of catches	Sorting yard, loading/unloading machinery, warehouse, storage yard, ice-making facilities, freezing facilities, cold store facilities and processing plant	
	Communication facilities for fisheries	land radiotelegraph facilities, land radio telephone facilities and meteorological signal station	
	Welfare facilities for fishermen	lodging facilities, shower, clinic and fishermen's hall	
	Administrative facilities of fishing port	administrative office and watching station	
	Fishing port cleaning facilities	water-conveyance facilities and other cleaning facilities to prevent environmental pollution	
	Waste oil processing facilities	facilities for processing of waste oil generated in the fishing port	
	Site for fishing port facilities	Site required for the sake of the aforementioned facilities	

Table 5-2 Design Scale of the Facilities

Site	ANGAUR (Angaur District)	NGERCHELONG (Ollei District)	NGATPANG (Village District)	MELEKEOK (Ngerabesang District)
(Civil Works)				
1) Navigation channel dredging work	Maintenance of the existing one (-2.5 m x 15 m)	-2.5m x 15m x (-300m) (D) (W) (L)	(Natural fairway)	Enlargement of the existing one (-2.5mx5m) (-2.5m x 15m) x 550m
2) Anchorage	Maintenance of the existing one (-2.5 m x 5,000 m2) especially on slipway side	-2.5 m x 3,600 m2	-2.5 m x -3,500 m2	Existing one (-2.5 m x 3,500 m2) + new one (5,500 m2)
3) Wharf (with stairway)	-2.5 m x (20+50)m (block)	-2.5 m x (50+10)m (block)	-2.5 m x (60+10)m (sheet pile)	-2.5 m x (40+10)m (sheet pile)
4) Landing yard	10 m x 70 m	10 m x 50 m	10 m x 60 m	10 m x 50 m
5) Slipway	Repair of the existing one (20m x 30m)	10 m x 18 m	10 m x 21 m	10 m x 21 m
6) Breakwater	Existing	50 m x 40 m	-	Existing
7) Sand dike	-	-	50 m (Wire cylinder)	30 m (Wire cylinder)
8) Road	Existing	Enlargement (5.6m - 11.0m wide) x (-350m) Revetment (incl.-350m)	Existing	Existing
9) Reclamation	-	5,600 m2 (150 m revetment)	Existing 3,000 m2 + new (-4,000m2)	- 6,000 m2
10) Facilities				
a) lighthouse	To be installed anew (pole/battery & lamp)	To be installed anew (pole/battery & lamp)	Not required	Existing
b) hand crane	Removal of existing winch	Hoisting capacity 300 kg x 1 unit	Hoisting capacity 300 kg x 1 unit	Hoisting capacity 300 kg x 1 unit
c) mooring poles	1 T/unit x 7 units	1 T/unit x 6 units	5 T/unit x 6 units	5 T/unit x 6 units
(Construction Work)				
1) Multipurpose house	108 m2	144 m2	108 m2	108 m2
2) Toilet/shower	72 m2	72 m2	72 m2	72 m2
3) Icemaking plant (2 stories)	-	To be constructed anew 36 m2, 2 stories	-	-

Figure 5-1
Conceptual Diagram of the Navigation Channel of the Ships



MOORING

Required lengths of the mooring facilities at each project site are determined based on the following formula.

Required length of mooring facilities $= \sum \frac{N}{r} L$

where:

L: Length occupied by each ship (berth length)

N: Daily standard number of ships using the mooring facilities

r: No. of turns of the berth

= (Standard permissible time - Approx. 3 hours)/(Time at the mooring wharf per ship)

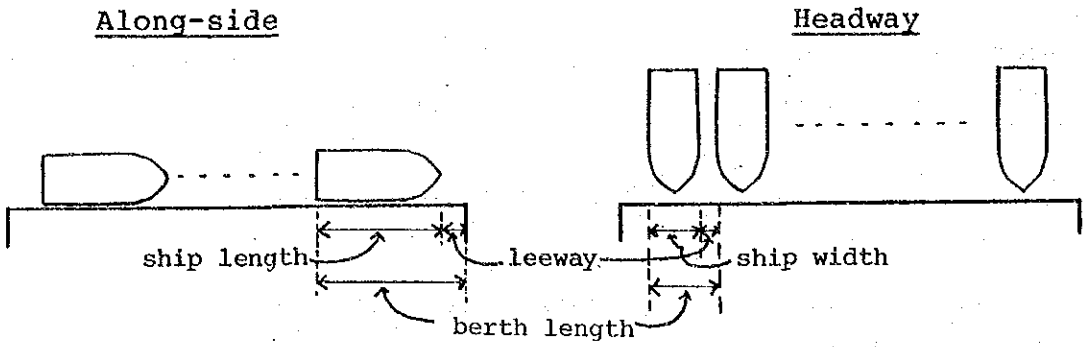
a. Number of boats using the fishing port

		Catch (ton)	Mooring wharf using time(min)	Anga-ur	Nger-chel-ong	Ngat-pang	Mele-keok
Base of fishing boats & other ships	Outboard engine boat	0.1	20	10	20	20	20
	Inboard engine boat	0.25	50	5	16	5	10
	Launch	1	70	5	-	5	-
	Ferry boat	20	120	*	*	*	*
	Freight ship	150	1 day	*	*	*	*

b. Berth Length per boat and mooring pattern

The along-side berth length per ship shown in Figure 5-2 is used to examine the required mooring wharf length.

Figure 5-2 Mooring Method



c. Dimensions and required berth length by type of boat

	Project boat dimensions (m)		Berth length per boat	
	L	B	Along-side	Headway
Outboard engine boat	7.0	2.0	8.5	3.0
Inboard engine boat	11.2	2.7	13.0	4.0
Launch	15.0	5.0	17.3	7.5

From the above-shown three basic criterias the required berth length for mooring at each fishing port is calculated as below.

Angaur

Type of boat	Length per berth	No. of boats	Service time per boat (hr)	No. of turns of berth	Required berth length(m)	No. of berths
Outboard engine	3	10	0.3	10	3	3
Inboard engine	13.0	5	0.8	4	17	1.3
Launch	17.3	5	1.2	2	44	2.5
					3+17----20 44----50	

Ngerchelong

Type of boat	Length per berth	No. of boats	Service time per boat (hr)	No. of turns of berth	Required berth length(m)	No. of berths
Outboard engine	3	20	0.3	10	6	2
Inboard engine	13.0	16	0.8	4	52	4
					6----10 52----60	

Ngatpang

Type of boat	Length per berth	No. of boats	Service time per boat (hr)	No. of turns of berth	Required berth length(m)	No. of berths
Outboard engine	3	20	0.3	10	6	2
Inboard engine	13.0	5	0.8	4	17	1.3
Launch	17.3	5	1.2	2	44	2.5
					6----10 17+44----60	

Melekeok

Type of boat	Length per berth	No. of boats	Service time per boat (hr)	No. of turns of berth	Required berth length(m)	No. of berths
Outboard engine	3	20	0.3	10	6	2
Inboard engine	13.0	10	0.8	4	33	2.5
					6----10 33----40	

Therefore, the berth length at each fishing port is designed as follows:

Angaur : 70 m
Ngerchelong : 70 m
Ngatpang : 70 m
Melekeok : 50 m

The wharf is designed with a -2.5 m water depth, which is the same as the navigation channel depth determined by adding some margin of safety to the draft of the largest boats using the harbors. The depth is determined irrespective of the types of boats because the fishing port and the anchorage are of a small size.

ANCHORAGE

The anchorages are designed with the sizes shown in Table 5-2 by taking into consideration the factors mentioned in the following.

(1) Safety access for the fishing boats
(2) Sufficient area to accommodate the fishing boats
(3) Safe anchoring of fishing boats in stormy weather
(4) Volume of dredged earth matching the volume of earth required for backfilling and reclamation of the wharf background area and construction of roads.

The anchorage is designed with a -2.5 m depth, which is the same as navigation channels and the wharf water.

RECLAMATION & ROAD

It was decided that a new land area midway in the jetty of Ngerchelong should be created because there is no room to open new areas on the land side and because the existing jetty is very long. Furthermore, it was decided to broaden the access road (jetty) between the reclaimed area and the land side to cope with future increases in the volume of catches to be handled in the harbor.

The reclamation areas of the 3 harbors of Babelthaup Island, excluding Angaur Harbor, are properly designed so as to keep balance with the volumes of earth excavated from the navigation channels and anchorages.

The areas reclaimed this time provide room for the construction of facilities of various kinds, besides