JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF NATURAL RESOURCES
TUVALU

BASIC DESIGN STUDY REPORT ON THE RECONSTRUCTION PROJECT OF THE FISHERIES HARBOUR AT VAITUPU IN TUVALU

JANUARY 1995

NIPPON TETRAPOD CO., LTD.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF NATURAL RESOURCES
TUVALU

BASIC DESIGN STUDY REPORT
ON
THE RECONSTRUCTION PROJECT
OF
THE FISHERIES HARBOUR AT VAITUPU
IN
TUVALU

JANUARY 1995

NIPPON TETRAPOD CO., LTD.

PREFACE

In response to a request from the Government of Tuvalu, the Government of Japan decided to conduct a basic design study on the Reconstruction Project of the Fisheries Harbour at Vaitupu and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Tuvalu a study team headed by Mr. Takeru Kato, Deputy Director, Fishing Port Construction Division, Fishing Port Department, Fisheries Agency, and constituted by members of Nippon Tetrapod Co., Ltd., from August 13 to September 15, 1994.

The team held discussions with the officials concerned of the Government of Tuvalu, and conducted a field study at the study area. After the team returned to Japan, further studies were made, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between the two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Tuvalu for their close cooperation extended to the team.

January, 1995

Kimio Fujita
President
Japan International Cooperation Agency

January, 1995

Mr. Kimio Fujita,
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Reconstruction Project of the Fisheries Harbour at Vaitupu in Tuvalu.

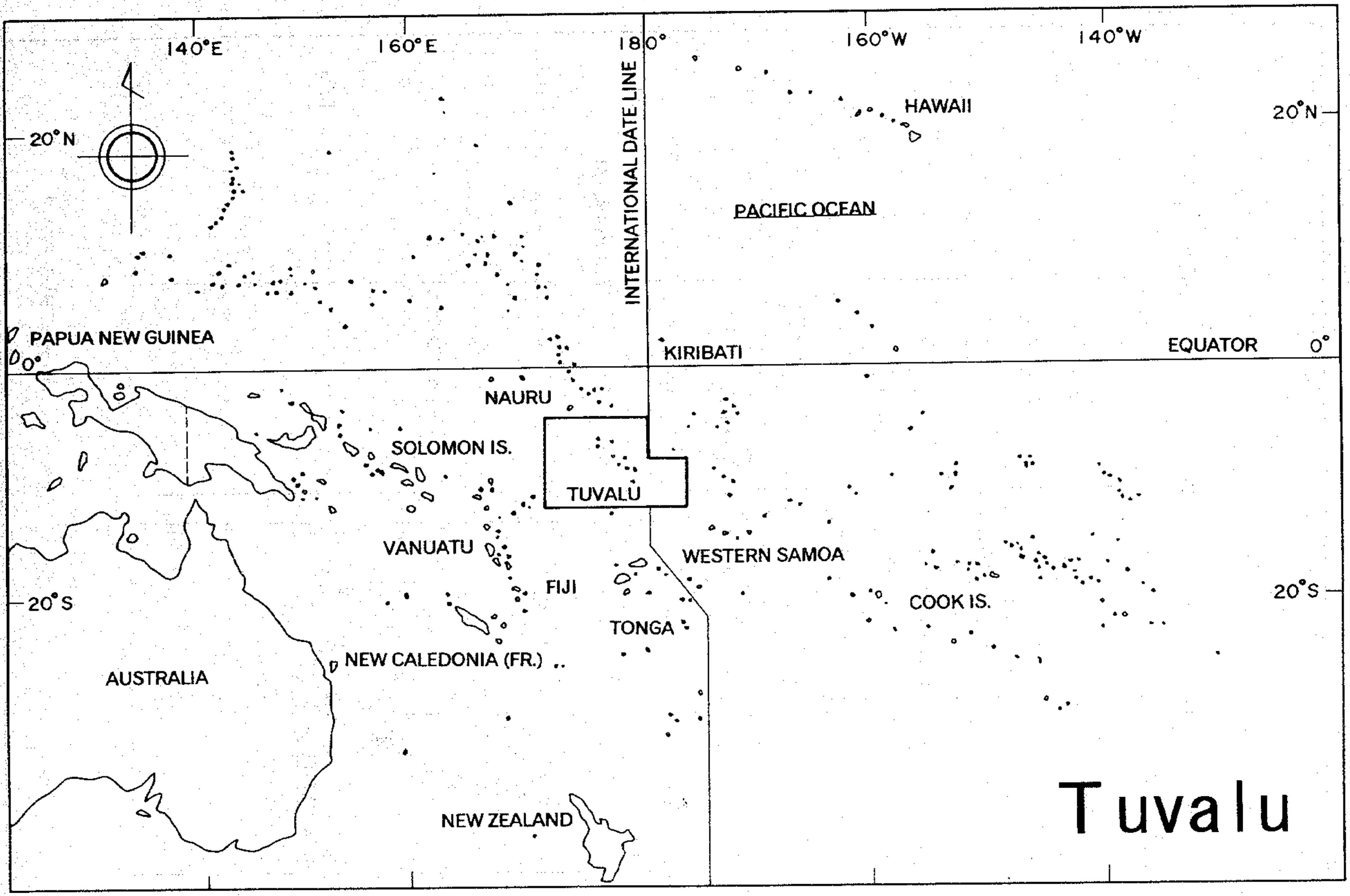
This study was conducted by Nippon Tetrapod Co., Ltd., under a contract to JICA, during the period from August 10, 1994 to January 26, 1995. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Tuvalu and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs, and the Ministry of Agriculture, Forestry and Fisheries. We would also like to express our gratitude to the officials concerned of the Ministry of Natural Resources of Tuvalu, JICA Fiji Office and the Embassy of Japan in Fiji for their cooperation and assistance throughout our field survey.

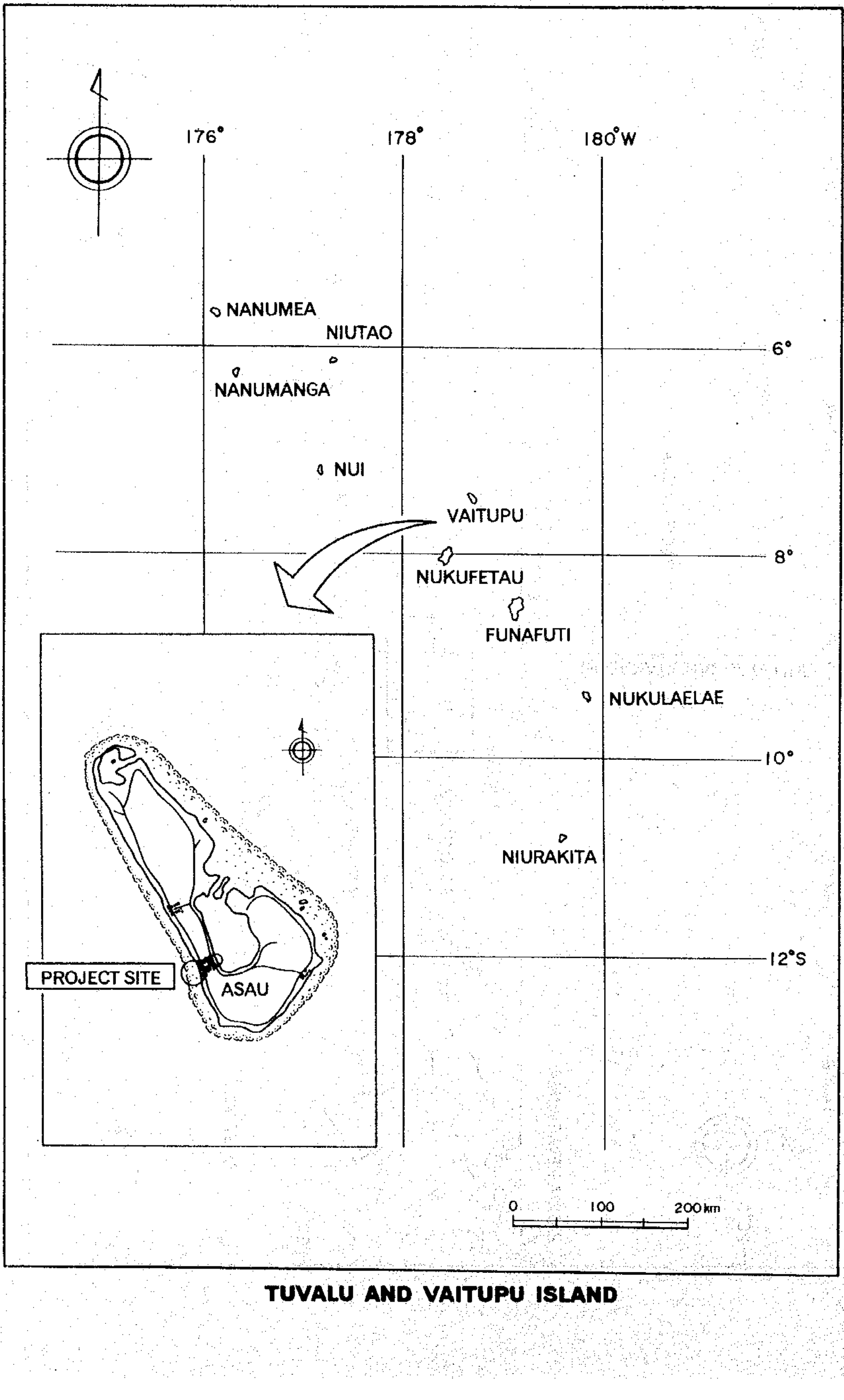
Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

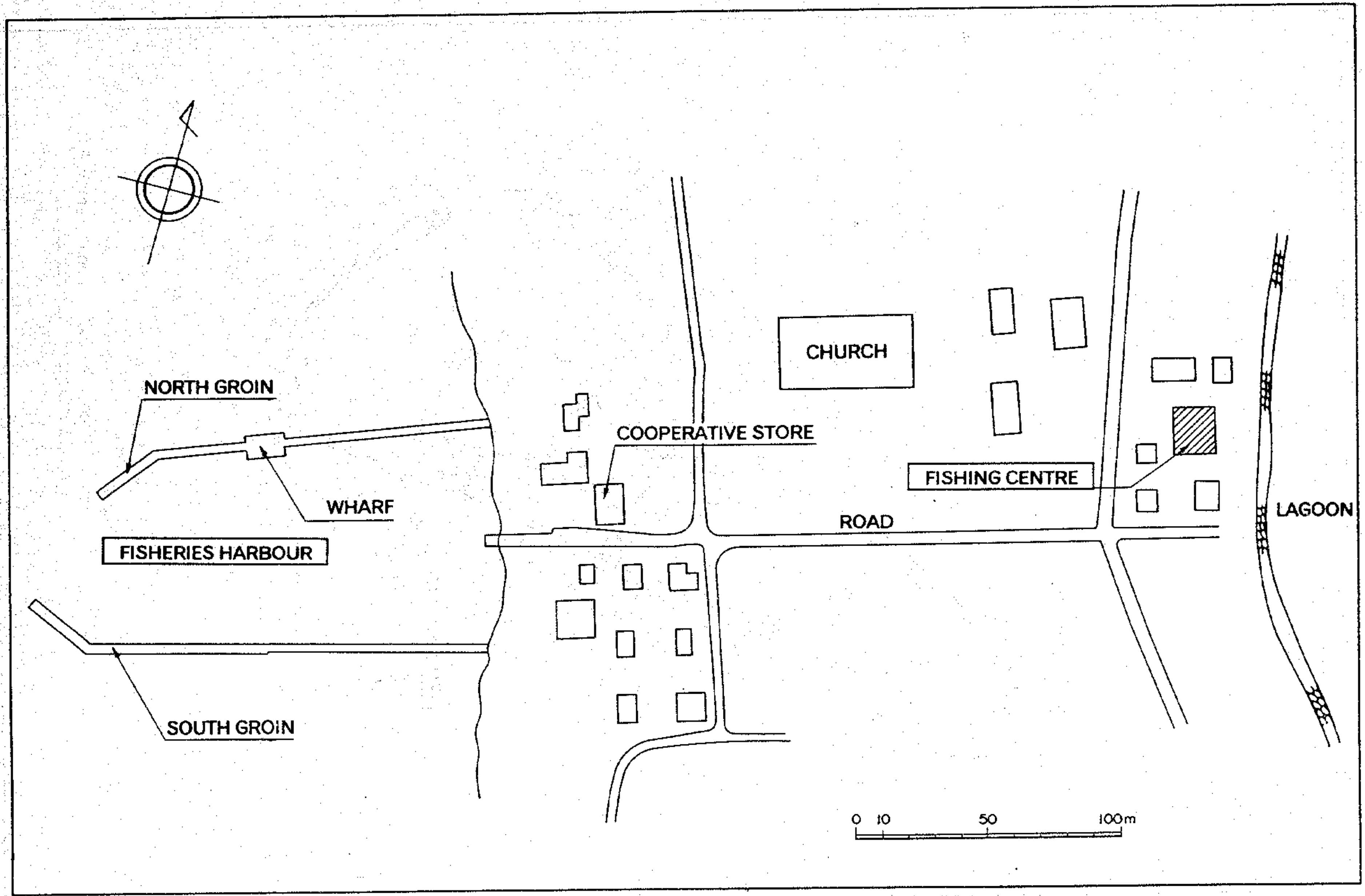
Tatsuo Fuke,
Project Manager
Basic Design Study Team on
the Reconstruction Project of the
Fisheries Harbour at Vaitupu in Tuvalu
Nippon Tetrapod Co., Ltd.



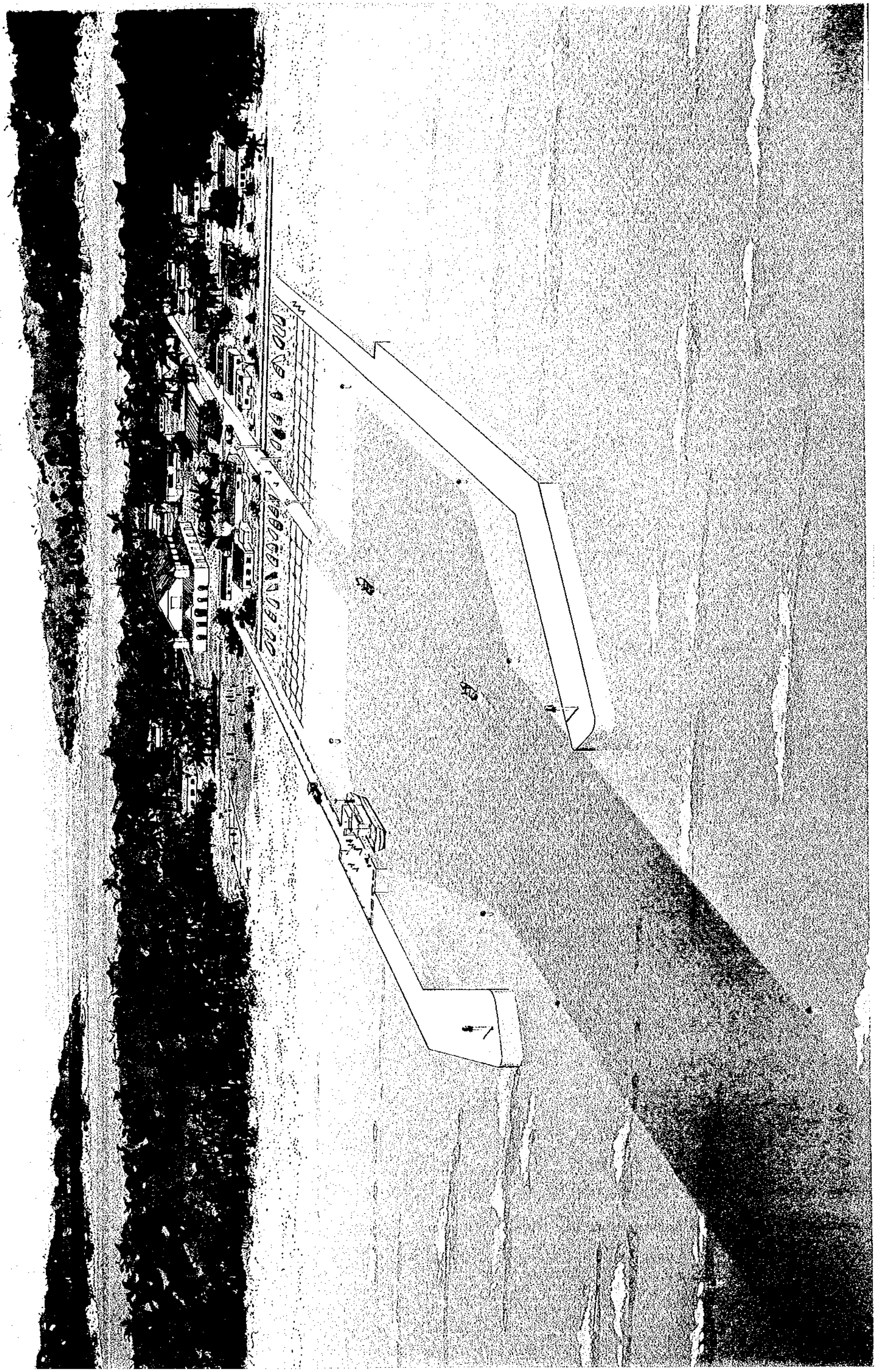
LOCATION OF TUVALU

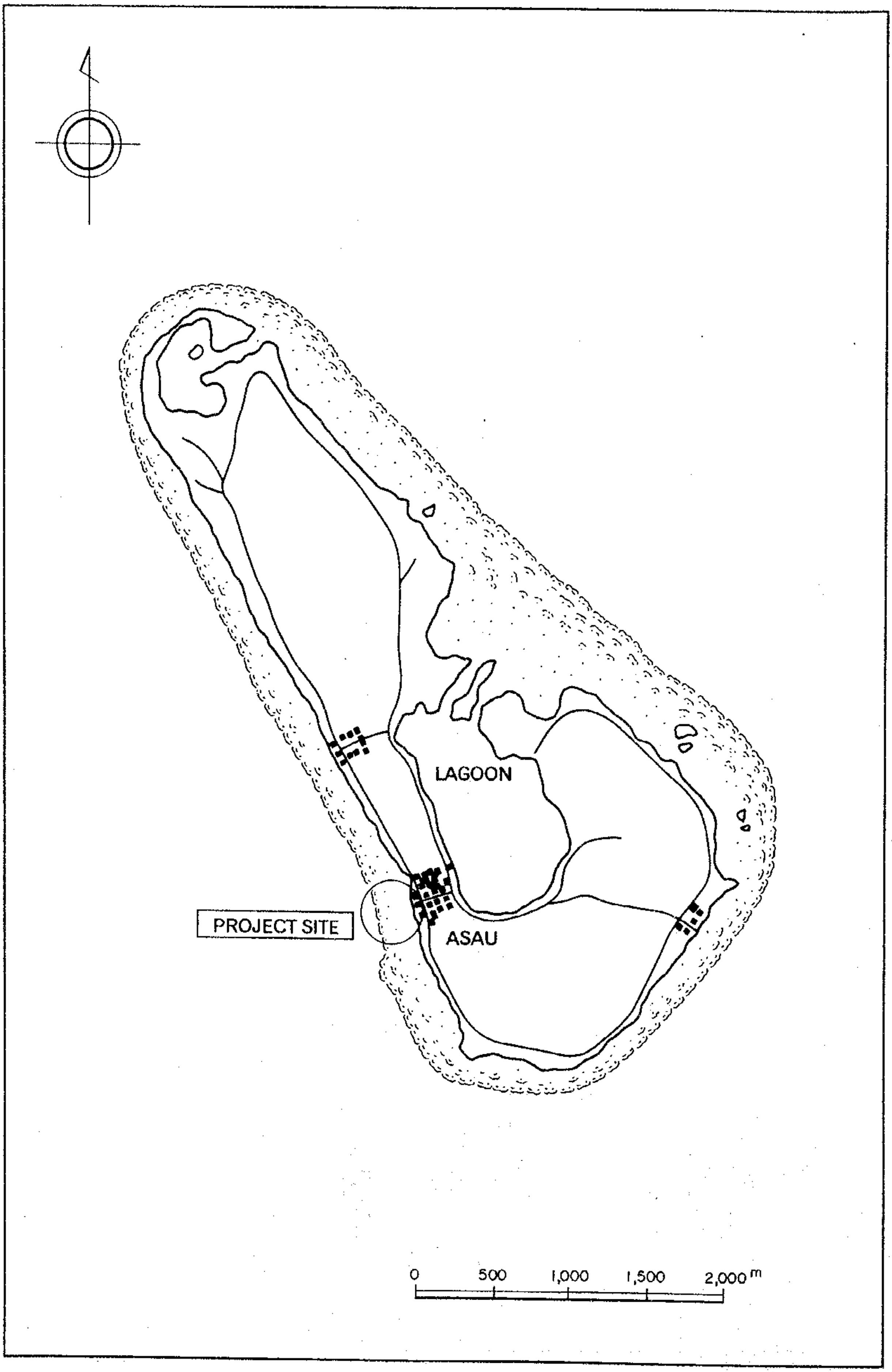


TUVALU AND VAITUPU ISLAND

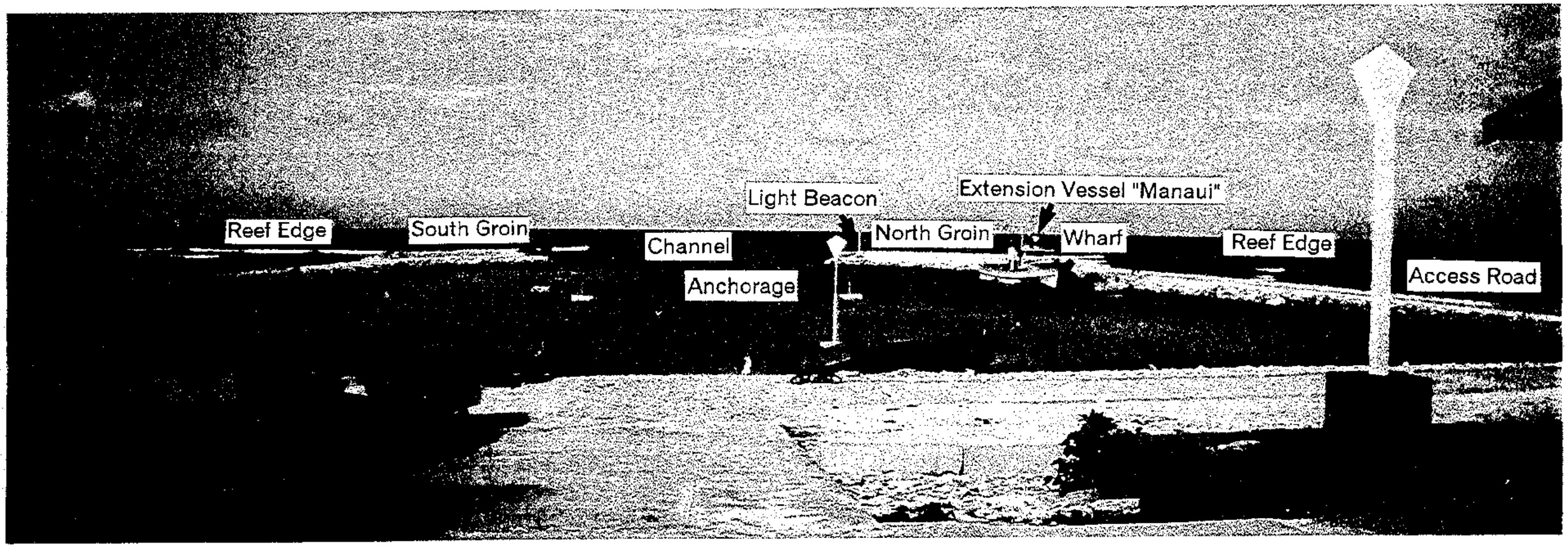


LOCATION OF FISHERIES HARBOUR AND FISHING CENTRE

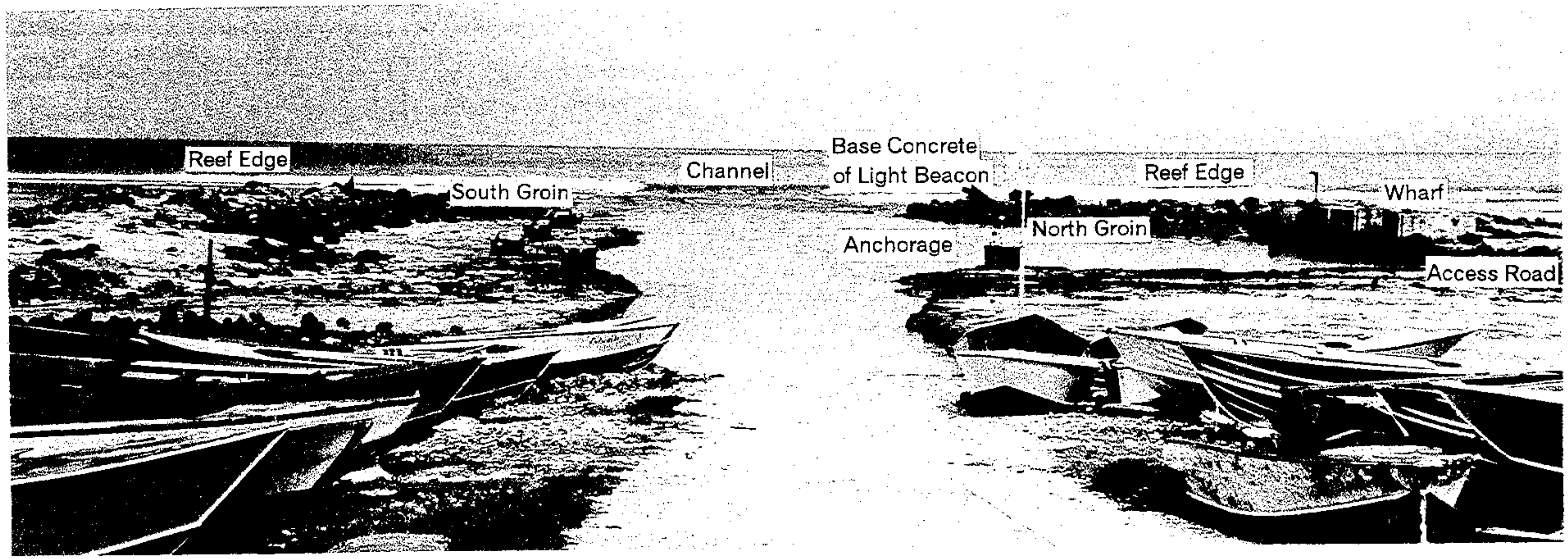




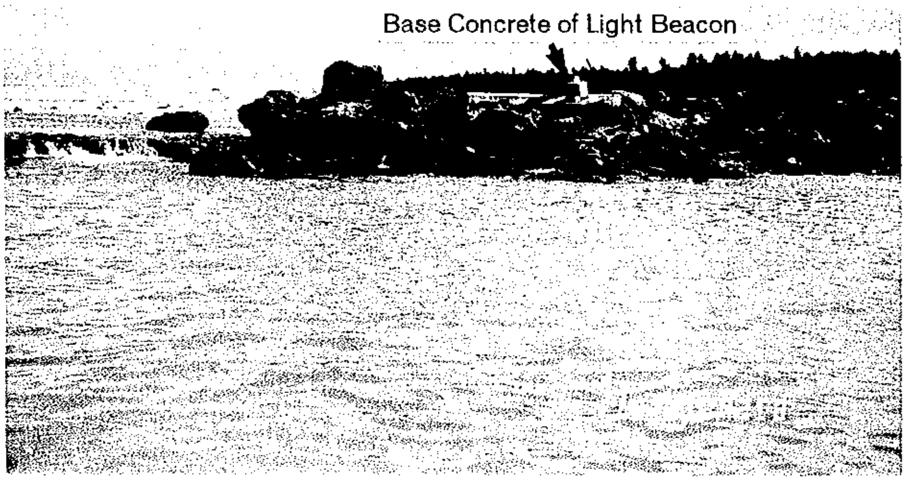
VAITUPU ISLAND



Photo① Fisheries Harbour before Cyclones

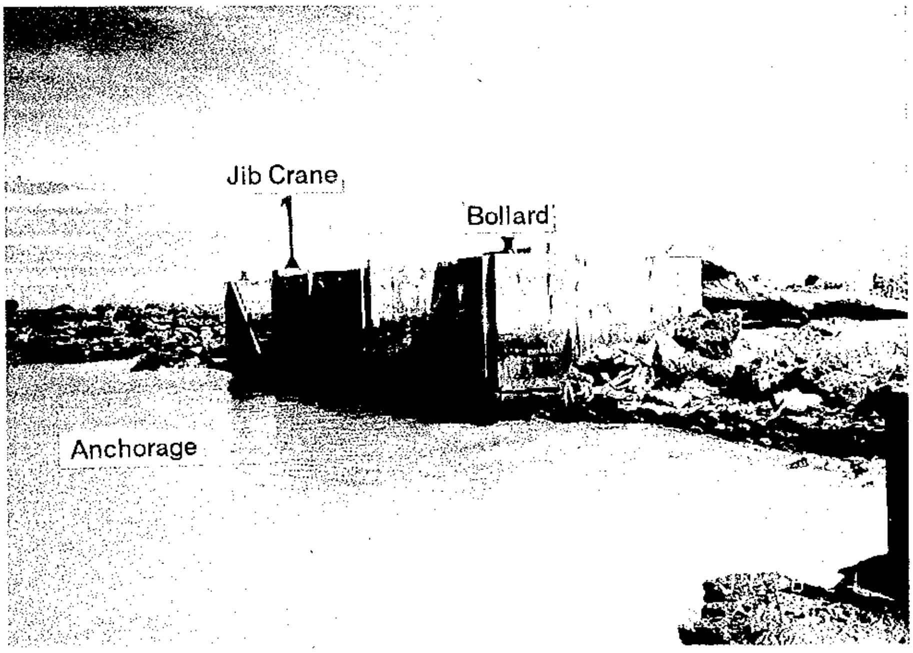


Photo② Fisheries Harbour After Cyclones

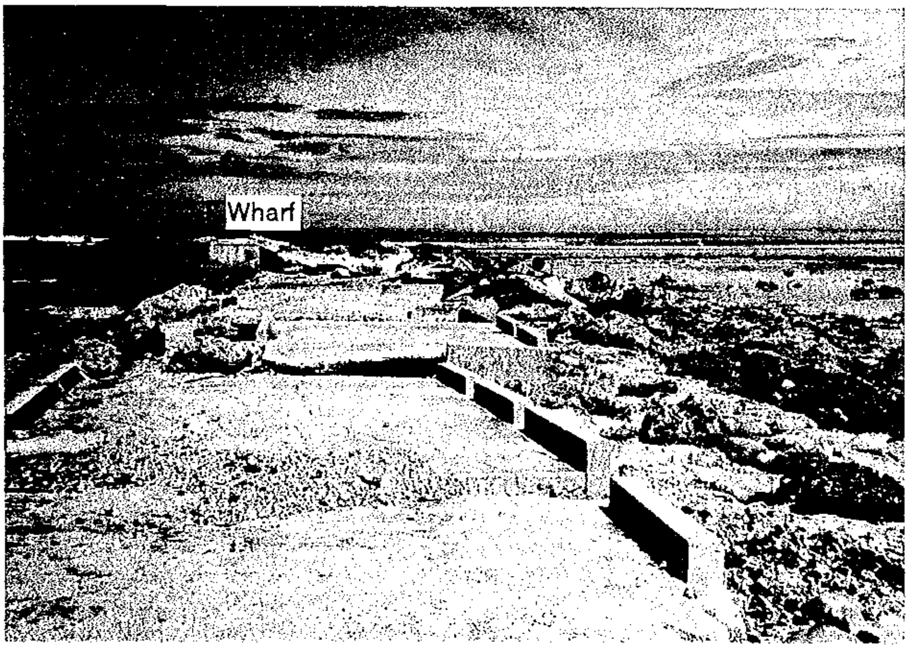


Photo③ Top of North Groin

Photo④ Top of South Groin



Photo⑤ Wharf



Photo⑥ Access Road

Summary

Summary

Tuvalu is an archipelago consisting of three islands and six atolls in the south of the mid-Pacific Ocean. They are small and flat coral islands situated at less than 5 m above the sea level with hardly any soil suitable for afforestation. The country has a population of about 9,600 inhabitants (1993), with a total land area of about 25.6 km2 and the exclusive economic zone (EEZ) of 750,000 km2.

Its national economy depends on the production of small-scale agriculture and fishery, and its per capita GDP amounts to AS$1,200. The country relies also on import for most of its needs for commodities, equipments and foodstuffs, and its trade balance has been in deficit for many years. Small amounts of foreign currencies can be earned through remittance from expatriate communities, postage stamp sales, license fees for piscatory rights in national waters paid by foreign vessels, and also through the export of copra.

With such geographical background, Tuvalu has given the priority to the fishery development as its development objective along with its neighboring countries. For its Third National Development Programme (1984–1987), the Government of Tuvalu has decided to promote fishery as its main objective, but due to poor conditions of the wharf, distribution facilities, fishermen training vessels, etc., good results could not be achieved. In response to the request of the Government of Tuvalu under the "Fishery Development Plan", the Government of Japan proposed the "Fishing Communities Development Project" aimed at improving the training equipments and materials, wharf, and infrastructure for fishing villages, and provided the following grant aids from 1987 to 1991.

Phase I : Provision of equipments and six fishermen training vessels
Phase II : Provision of an extension vessel "Manaui"
Phase III : Improvement of Funafuti Fisheries Centre
Phase IV : Construction of Vaitupu Fisheries Centre
and improvement of the existing channel

Fishery facilities such as the groins and channel in Asau, Vaitupu Island, which were constructed in Phase IV Project, have been seriously damaged soon after completion by the waves attributable to two large cyclones, "Kina" and "Nina", and most of their functions have been lost, hindering thus the fishing activities.

With the urgency of the needs for reconstruction and for a rehabilitation of the damaged facilities, the Government of Tuvalu requested another grant aid from Japan in February, 1994. In response, the Government of Japan organized a basic design study team which conducted a field survey for 34 days from August 13 to September 15, 1994.

The request concerned the rehabilitation and reconstruction of the following facilities in the fisheries harbour.

Facility	Rehabilitation Status	Reconstruction/ Material
A. North Groin	Totally damaged except concrete wharf. Complete rehabilitation required.	Concrete and armour stone structure
B. South Groin	Totally damaged. Complete rehabilitation required.	Concrete and armour stone structure
C. Slipway	Some damage. Repair required.	Concrete structure
D. Beach Protection	Some damage. Repair required.	Stone pitching
E. Channel and Anchorage	Re-excavation and removal of coral debris required.	Dredging of coral reef
F. Light Beacons	Totally damaged. Complete rehabilitation required.	Rehabilitation
G. Jib Crane	Totally damaged. Complete rehabilitation required.	Rehabilitation

The study team conducted the following field surveys:

(1) Discussion with the Government Officials of Tuvalu

- Explanation and discussion of the Inception Report
- Confirmation of the damages, background of the project and the content of request
- Confirmation of the extent of costs to be borne by the Tuvalu Government
- Discussion and signing of the Minutes

(2) Surveys of the Damages to the Fisheries Harbour Facilities and Natural Conditions

- Survey of damages to the facilities and equipments, gathering information for the Project
- Gathering information about the related development plans
- Maintenance and management of the facilities after reconstruction
- Gathering materials and information on construction
- Survey of natural conditions

Following on-site surveys and discussions in Japan, the study team prepared a facility reconstruction plan covering substantially all the requests.

Outline of the Planned Facilities

Facility(Structure)		Contents and scale
Removal of existing groins		Removal of broken south and north groins, about 5,000m3
	Gravity-type concrete	
South groin	Length x Crown width	Base 80 m x 4 m, Middle 70 m x 6 m, Top 25 m x 8 m
North groin	Length x Crown width	Base 80 m x 4 m, Middle 55 m x 6 m, Top 30 m x 8 m
Wharf	Water depth	-3.0 m
	Length x Apron width	Extension 5 m x 10 m
Jib crane		One
Bollard		One
Fender		One set
Channel	Bottom width x Depth	26 m x -3.5 m
Anchorage	Width x Depth	64 m x -3.0 m
Light beacons	Solar type	Two
Navigation aids	Concrete anchor type	Seven buoys (channel and anchorage), Two beacons (land)
Lighting facilities	Solar type	Two
South seawall	Gravity-type concrete	75 m
North seawall	Gravity-type concrete	40 m
Access road	Concrete pavement	Width 4 m x Length 20 m
Slope protection	Armour stones with concrete filling	20 m x 40 m, 2 Slope faces
Slipway	Concrete pavement	Length 10 m

Regarding the reconstruction of facilities, the study team established the following basic design policies.

(1)Policy regarding Natural Conditions

Hindcasting the design waves represents an important tool for the basic design of facilities. To this end, the study team chose the ten largest cyclones which occurred within the past 30 years and caused big waves to the planned construction area, and as for their courses and scales, obtained the relevant weather charts and hindcasted the respective waves by the spectrum method. It also conducted the statistical analysis on the offshore waves for 11 cases including cyclones "Kina" and "Nina", and obtained the design offshore wave height with a return period of 50 years for the current plan.

(2) Policy regarding the Socio-economic Conditions

Although Tuvalu is an independent country, most of its commercial activities are supported through aids from developed countries. Even though the country is able to build facilities and equipments making good use of foreign aids, it lacks funds for maintenance and management and its facilities are badly maintained. It is therefore proposed to design structures that are maintenance-free as much as possible.

(3) Policy regarding the Construction and Labour Conditions

Tuvalu has no construction companies, and it is therefore necessary to procure all the construction machinery from other countries. Since there are no skilled labours either, the study team recommend to adopt construction methods which require small-scale use of machinery or skills. Unskilled labour, however, is available in this country.

(4) Policy regarding Local Procurement of Materials

Only stones (coral stones) and sea sand (coral sand) can be procured in Vaitupu, and all other construction materials must be imported.

Based on the above mentioned principles, the study team undertook a comparative study on the materials and construction methods. For the North and South Groins, three types (armour stone, gravity and steel sheet pile) were chosen first and the gravity-type with in-situ concrete has been adopted finally.

Most of the materials and equipments for the present project will be imported from Japan or other countries as follows:

(1) Materials procured

locally:	stones, crushed stones, sand, fuel
from Japan:	steels, steel moulds, light beacons, lighting facilities, fenders, jib crane, bollard, buoys, anchors, ropes, etc.
from Fiji:	reinforcing bars
from New Zealand:	cement, timbers, plywood moulds, gunpowder

(2) Construction Machinery procured

from Fiji:	tugboat, pontoon
from Japan:	high-speed ferry boat between Funafuti and Vaitupu, boat with outboard engine, other construction machinery, materials for temporary works

The effects that can be expected upon the implementation of this project are shown below. The Asau Fisheries Harbour will be able to recover its primary functions as a fisheries harbour. Along with the smooth implementation of the National Development Programme, the harbour will play an important part for the national fishery industry.

Effect from the Implementation of this Project

Current Situation	Countermeasures	Effect/ Improvement expected
Damaged groins lost functions	Design a groin which will not damage other facilities at the time of big waves	Effective prevention of disaster recurrences
Boats unable to berth at the wharf	Dredge the front area and expand the wharf Use fenders and bollard	Securing safe berthing
Shoaling and narrowing of the channel	Redredge and expand channel width for safe navigation	Securing safe navigation even at night
Shoaling and narrowing of the anchorage	Redredge anchorage and expand width for safe turning	Securing safe anchoring
Poor access road conditions	Connect with the access road	Improving transportation
Construction of seawalls	Protect houses in hinterland and prevent cyclone damages	Improving people's life
Lack of lighting facilities and light beacons	Aim at safe loading/ unloading at night in harbour	Improving safety in the harbour
Slope protection	Armour stones cover the slope with concrete to prevent scouring	Preventing disaster recurrence
Debris disposal	Transport to appropriate places	Preventing disaster recurrence Preventing re-shoaling of the channel and anchorage

Though small boats with outboard engines can enter the harbour thanks to the emergency repairs undertaken after the disaster, scattered debris may cause another shoaling of the channel and anchorage.

It is necessary to rehabilitate the harbour on a full-scale basis as soon as possible, by adopting a suitable design which takes into account experiences from former disaster.

The rationale for the grant aid in the framework of this project is discussed as follows;

(1) The harbour damaged by unprecedented cyclones was originally built with the grant aid from the Government of Japan.

(2) The project will benefit poor people and will basically stabilize their livelihood.

(3) With the implementation of this project, the maintenance and management operations undertaken for the harbour will be made easier.

(4) The project concurs with another one for the Vaitupu Island under the Fourth National Development Programme (1988-1990).

(5) Undesirable effects are not foreseen on the environment.

The study team would like to make the following requests to the Government of Tuvalu for a smooth and effective implementation and management of this project:

(1) Full-scale Cooperation in Construction

Cyclones "Kina" and "Nina" not only destroyed the fisheries facilities of the island but also ravaged its residential areas. As the implementation of this project requires a full understanding and cooperation from the Vaitupu Island Council and the islanders, the study team requests the Government of Tuvalu to take an active initiative for a smoother operation.

(2) Thorough Maintenance and Management

The study team has designed structures that require little maintenance, with the full knowledge that jib crane, light beacons or lighting facilities, however, essentially need maintenance. Regular and adequate maintenance and management alone will be able to extend their capacity. The study team recommends to allocate sufficient budgets for their maintenance.

(3) Development of Human Resources

The lack of civil engineers in the country has delayed reconstruction process following the disaster caused by both cyclones. The study team recommends to take this opportunity by training engineers who will be good counterparts in this project as well as qualified experts for the fisheries harbour of Tuvalu.

Contents

Page

Contents

Page

List of Figures

List of Tables

CHAPTER 1

BACKGROUND OF THE PROJECT

[illegible]

CHAPTER 1 BACKGROUND OF THE PROJECT

1-1 Background of the Project

Tuvalu is an archipelago consisting of three islands and six atolls in the south of the mid-Pacific Ocean. They are small and flat coral islands situated at less than 5 m above the sea level with hardly any soil suitable for afforestation. The country has a population of about 9,600 inhabitants (1993), with a total land area of about 25.6 km2 and the exclusive economic zone (EEZ) of 750,000 km2.

Its national economy depends on the production of small-scale agriculture and fishery, and its per capita GDP amounts to AS$1,200. The country relies also on import for most of its needs for commodities, equipments and foodstuffs, and its trade balance has been in deficit for many years. Small amounts of foreign currencies can be earned through remittance from expatriate communities, postage stamp sales, license fees for piscatory rights in national waters paid by foreign vessels, and also through the export of copra.

With such geographical background, Tuvalu has given the priority to the fishery development as its development objective along with its neighboring countries. For its Third National Development Programme (1984-1987), the Government of Tuvalu has decided to promote fishery as its main objective, but due to poor conditions of the wharf, distribution facilities, fishermen training vessels, etc., good results could not be achieved. In response to the request of the Government of Tuvalu under the "Fishery Development Plan", the Government of Japan proposed the "Fishing Communities Development Project" aimed at improving the training equipments and materials, wharf, and infrastructure for fishing villages, and provided the following grant aids from 1987 to 1991.

Phase I : Provision of equipments and six fishmen training vessels
Phase II : Provision of an extension vessel "Manaui"
Phase III : Improvement of Funafuti Fisheries Centre
Phase IV : Construction of Vaitupu Fisheries Centre
and improvement of the existing channel

Fishery facilities such as the groins and channel in Asau, Vaitupu Island, which were constructed in Phase IV Project have been seriously damaged soon after completion by the waves attributable to two large cyclones, "Kina" and "Nina", which attacked the country in January, 1993 and most of their functions have been lost, hindering thus the fishing activities.

With the urgency of the needs for reconstruction and for a rehabilitation of the damaged facilities, the Government of Tuvalu requested another grant aid from Japan. In response, the Government of Japan conducted a survey for the basic design study of this project.

The implementing organ for the project will be the Fisheries Department, Ministry of Natural Resources in Tuvalu.

1-2 Outline of the Request and Main Components

Objectives of the requested project by the Government of Tuvalu are shown below.

(1) Short-term objectives

- To restore the fisheries harbour to its original function
- To provide the people of Vaitupu with a means of safely unloading/ loading goods and cargo within the anchorage of the fisheries harbour
- To provide the extension vessel "Manaui" with a safe anchorage

(2) Medium and long-term objectives

- To invigorate the fishing activities in order to achieve the aims of the Fishing Communities Development Project of improving the living standard of the people
- To achieve success in the Vaitupu fisheries, which will serve as a model of fisheries promotion for other islands

The request concerned the rehabilitation of the following facilities which had been destroyed.

Table 1-1 Contents of the Request

Facility	Rehabilitation Status	Reconstruction/ Material
A. North Groin	Totally damaged except concrete wharf. Complete rehabilitation required.	Concrete and armour stone structure
B. South Groin	Totally damaged. Complete rehabilitation required.	Concrete and armour stone structure
C. Slipway	Some damage. Repair required.	Concrete structure
D. Beach Protection	Some damage. Repair required.	Stone pitching
E. Channel and Anchorage	Re-excavation and removal of coral debris required.	Dredging of coral reef
F. Light Beacons	Totally damaged. Complete rehabilitation required.	Rehabilitation
G. Jib Crane	Totally damaged. Complete rehabilitation required.	Rehabilitation

CHAPTER 2

OUTLINE OF THE PROJECT

CHAPTER 2 OUTLINE OF THE PROJECT

2-1 Objectives of the Project

In line with the objectives of the previous grant aid for the "Fishing Communities Development Project", this project aims at restoration and rehabilitation of the Asau Fisheries Harbour which had been devastated by cyclones.

2-2 Study and Examination on the Request

Because of its geographical background, Tuvalu is endeavoring to promote fishery development as the first-priority national objective along with its neighboring countries.

Its Medium-term Economic Framework Programme(1992-1994) places emphasis on the fishery industry, especially the following topics in relation to the current project:

(1) To provide fishery products and protein supply regularly and continuously to all of its people
(2) To develop small-scale export industry
(3) To activate small-scale fisheries in remote islands

The Fourth National Development Plan (1988-1990) points out that in order to expand the fishery production volume by artisanal and commercial fishermen in Vaitupu Island, the Government should finance the fishery infrastructure, transportation means and fishing boats and integrate the foreign and domestic distribution systems for rational distribution of fishery products.

The Government of Japan offered the following grant aids from 1987 to 1991:

Phase I : Provision of equipments and six fishermen training vessels
Phase II : Provision of extension vessel "Manaui"
Phase III: Improvement of Funafuti Fisheries Centre

Phase IV: Construction of Vaitupu Fisheries Centre
and improvement of the existing channel

The aid in Phase IV aimed to construct the Fisheries Centre and improve Asau Fisheries Harbour in Vaitupu Island and was in accordance with the Fourth National Development Programme.

On Vaitupu Island, 1,600 people live self-sufficiently on coconuts, plaka and taro and raise a small number of chickens and pigs. As the main supply source of protein, people depend on fish caught by the fishing activities which also serves as the only source of income for the islanders. The aid for Phase IV was thus welcomed by the people as most appropriate.

Two large cyclones which attacked the island in January, 1993 damaged the groins, the channel and the anchorage in Asau Fisheries Harbour in Vaitupu which had been built by the grant aid in Phase IV. The Government of Tuvalu judged that the reconstruction and rehabilitation of the facilities were urgently needed in order not to deter the promotion of fisheries and requested Japan for another grant aid.

The Government of Japan dispatched a study team from August to September, 1994 in order to study the damages and the validity of reconstruction plans. The result is shown below.

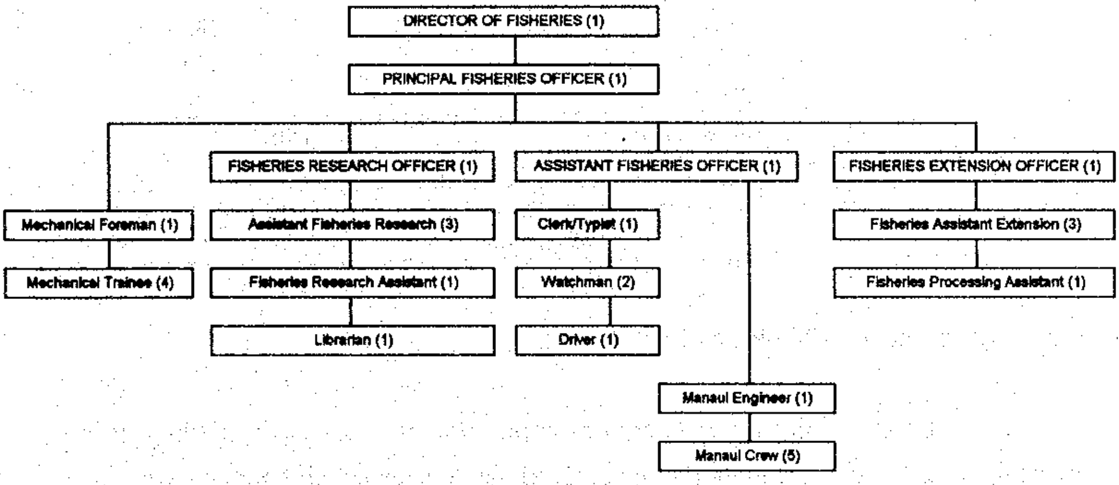
(1) The functions of Asau Fisheries Harbour had been grossly damaged by the disaster
(2) To leave the situation unrectified would be contrary to the development policies of the Government and the island.
(3) If left unattended, the debris, etc. are likely to induce another disaster quite easily.

Based on the above, it is concluded that the request is meaningful and should be urgently addressed as a part of the long term grant aids programme offered by Japan.

2-3 Project Description

2-3-1 Operational Structure

The organization chart of the Fisheries Department, Ministry of Natural Resources (as of September, 1994) is shown below.



Note: ( ) shows the number of staffs.

Fig. 2-1 Organization of Fisheries Department

The Fisheries Department of the Ministry of Natural Resources will be responsible for maintenance and management of the fisheries harbour facilities at Vaitupu when they are restored. As of September, 1994, the Department has about 30 staffs, one of whom is stationed at the Vaitupu Fisheries Centre since the time of completion of the Phase IV project of the grant aid offered by Japan previously. This staff is in charge of overall maintenance and management of the fisheries facilities of the island. There is, therefore, no need to appoint a new staff for this job, and the current organization is believed to be capable of maintenance and management.

The annual maintenance and management cost is approximately A$700 and the department is believed to be sufficiently capable of paying the cost.

Table 2-1 Estimate of Maintenance Cost

1. Material costs (Unit: AS$)

Facilities		Consumable life (year)	Unit price
Light beacons(2)	Bulbs	1	150
	Batteries	3	330
Solar lights(2)	Bulbs	5	50
	Batteries	3	600
Jib crane	Chassis grease	3	50
	Paint	3	250
	Pulley	3	100
	Pin	3	50
Annual costs of materials:		620	
2. Personnel expense			
Skilled-worker (caretaker) x 3 days		80	
	Annual costs	700	

2-3-2 Location and Condition of Project Site

Vaitupu Island has the land area of approximately 5.24 km2, the largest in the country, and there is a lagoon at its approximate center which connects with the ocean. The land is substantially flat and less than 5 m above sea level, and consists of coral soil. Palm trees, breadfruit trees and taro potatoes grow indigenously. The Island Council is in charge of politics in three main villages of Motofua, Tumaseu and Asau.

(1) Climatic Conditions

Tuvalu belongs to the typical tropical oceanic climate zone. The climatic data available for Vaitupu Island are limited to those on temperature and rainfall collected in Funafuti, the country's capital located 150 km to the south.

1) Temperature

Fig. 2-2 shows changes in daily average maximum and minimum temperatures in Funafuti. The average temperature fluctuates only slightly and remains between 28 and 29 degrees. The daily average maximum and minimum temperatures are 31～32 degrees and 26 degrees respectively.

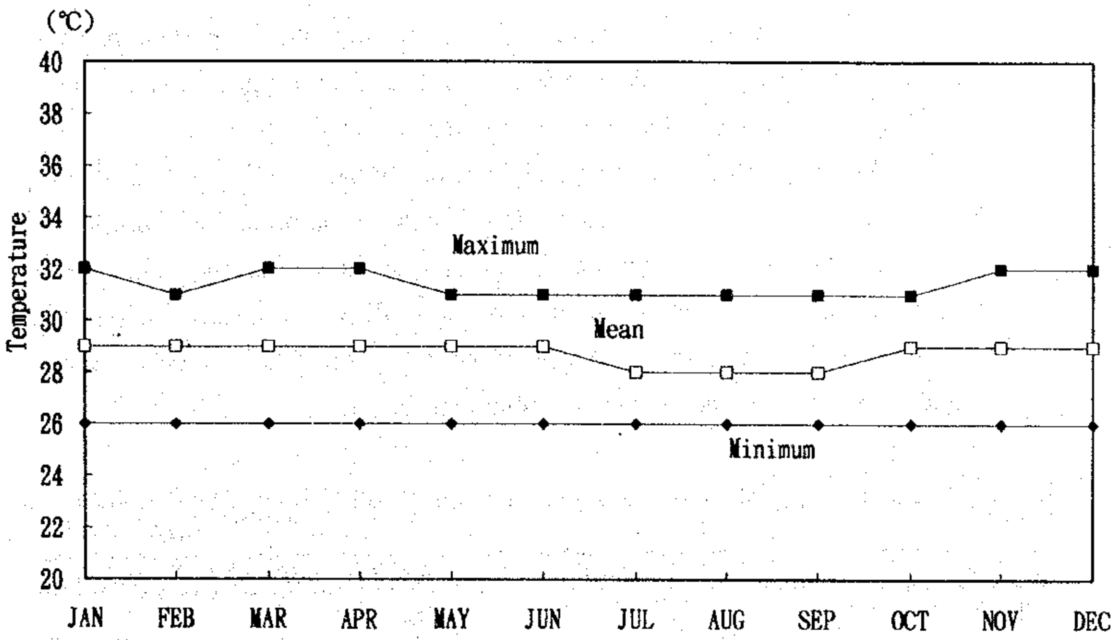


Fig. 2-2 Changes in Mean Temperature in Funafuti

2) Rainfall

Fig. 2-3 shows monthly changes in the rainfall in Vaitupu Island. The yearly average rainfall is generally high at 3,200 mm and accounted for mostly by squalls. There may be droughts in some years. The distinction between the dry and the rainy seasons is not clear.

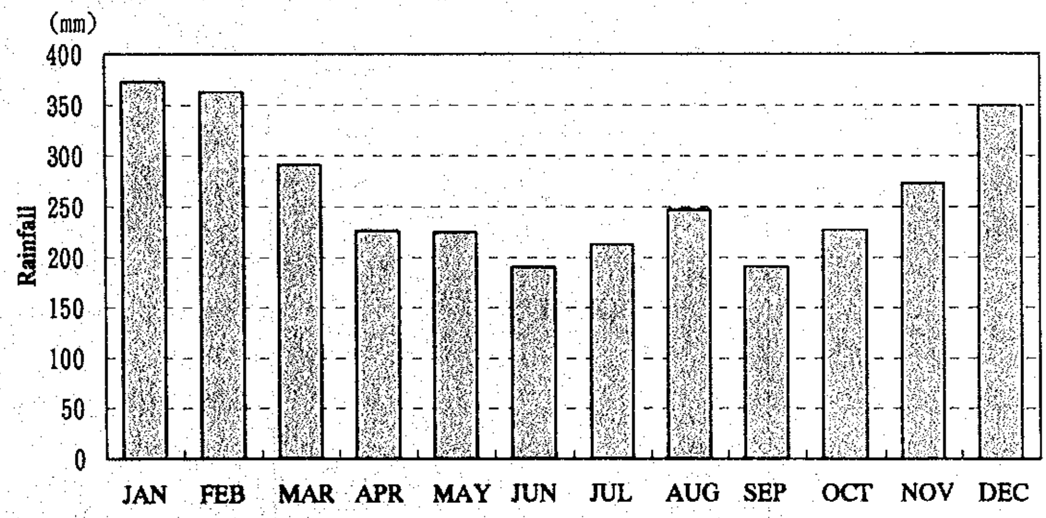


Fig. 2-3 Changes in Mean Rainfall (1948-1992)

3) Wind direction and velocity

Tuvalu is in the trade wind region in the southwest Pacific and the wind tends to blow in N-E directions. Table 2-2 and Fig. 2-4 show the wind frequency distribution and the wind rose respectively.

According to them, the yearly average wind velocity is 7.6 knot (about 3.8 m/s) and the frequency of the wind velocity beyond 22 knots (11 m/s) is 0.7 %, showing remarkable calmness throughout the year. The wind in the N-E direction prevails at about 70 %. As Asau Fisheries Harbour is located on the west side of the island and faces the ocean, the land breeze blows predominantly throughout the year.

Table 2-2 Frequency Distribution of Daily Average Wind Velocity (1981-1985)

(Unit: %)

		DEC-FEB	MAR-MAY	JUN-AUG	SEP-NOV	Annual
Direction	N	29.3	22.1	9.9	15.6	19.2
	NE	20.2	22.7	24.3	27.7	23.8
	E	11.3	23.6	36.3	31.8	25.8
	SE	2.9	3.2	7.1	5.1	4.6
	S	5.1	8.4	12.5	9.2	8.7
	SW	4.9	7.1	5.6	4.6	5.4
	W	12.6	9.0	4.2	5.2	7.7
	NW	12.4	2.9	0.3	1.2	4.3
	Calm	11.3	0.9	0.0	0.0	0.5
Mean Speed(knots)		8.0	6.6	7.6	7.8	7.6
Over 22 knots		0.7	0.0	1.1	0.9	0.7

(Source: National Institute of Water and Atmospheric Research Limited)

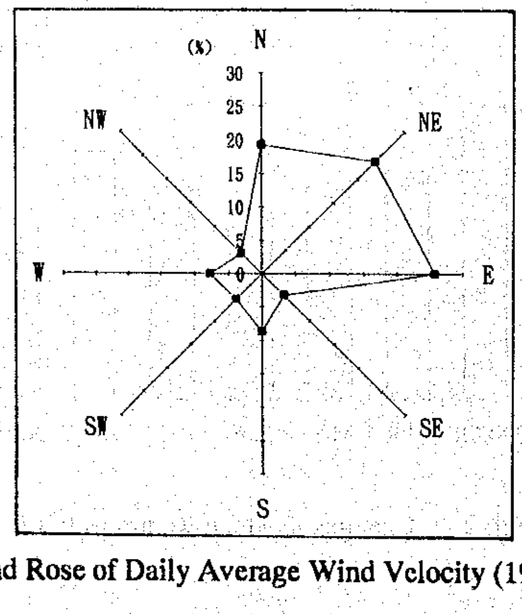


Fig. 2-4 Wind Rose of Daily Average Wind Velocity (1981 - 1985)

(2) Topography

In order to learn the topography of the land and the sea depth in the vicinity of the fisheries facilities, the topographic and bathymetric surveys were conducted in the hinterland and at 500 m offshore for 500 m along the coast. Figs. 2-5 and 2-6 show the results. In the survey of the sea depth, the basic data required for calculation of wave deformations were obtained in shallow water and a reef flat in the on-site wave hindcasting which shall be referred to later.

(3) Oceanographic Conditions

1) Tidal level

To study the tidal levels in the surrounding sea, the study team conducted continual observations for 15 consecutive days using a tide gauge. Fig. 2-7 shows the tide conditions.

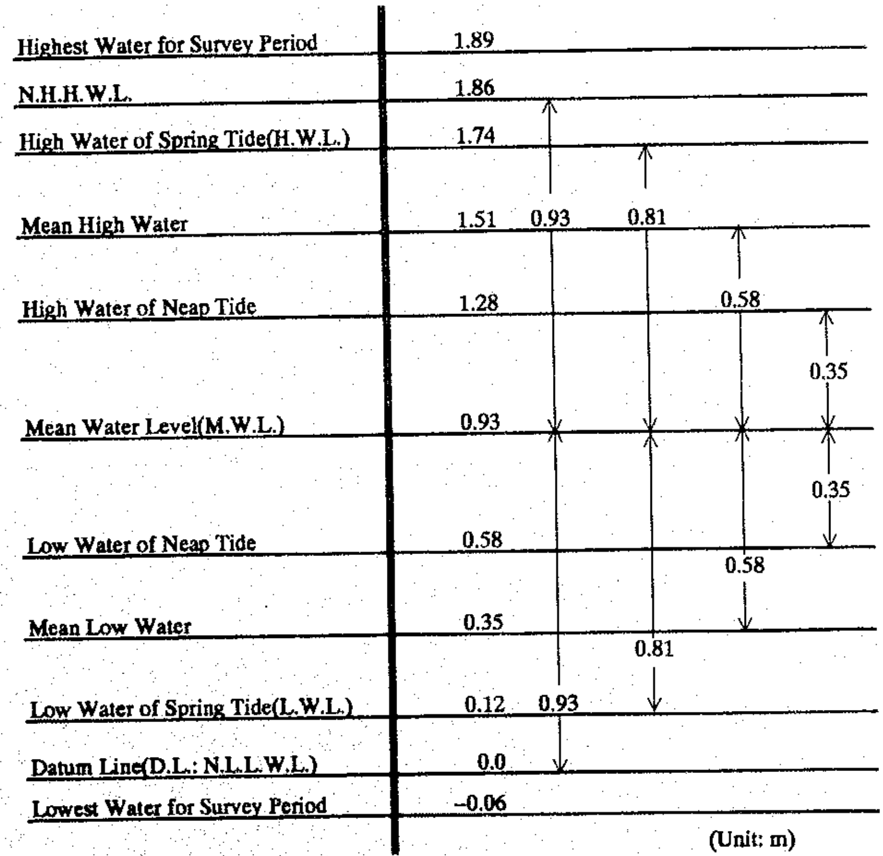


Fig. 2-7 Tide Condition for Survey Period at the Asau Fisheries Harbour

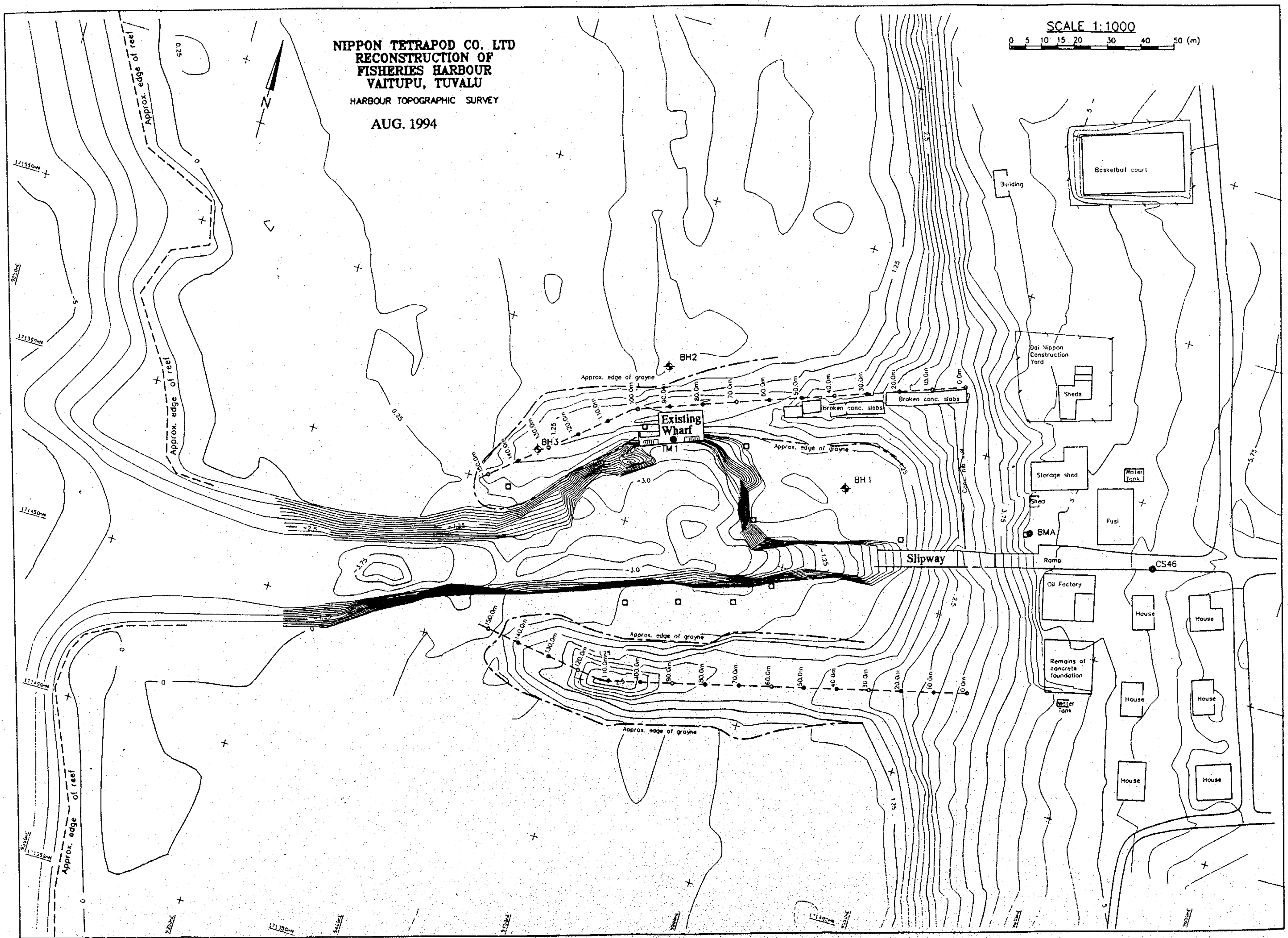


Fig. 2-5 Topography in the Vicinity of the Asau Fisheries Harbour

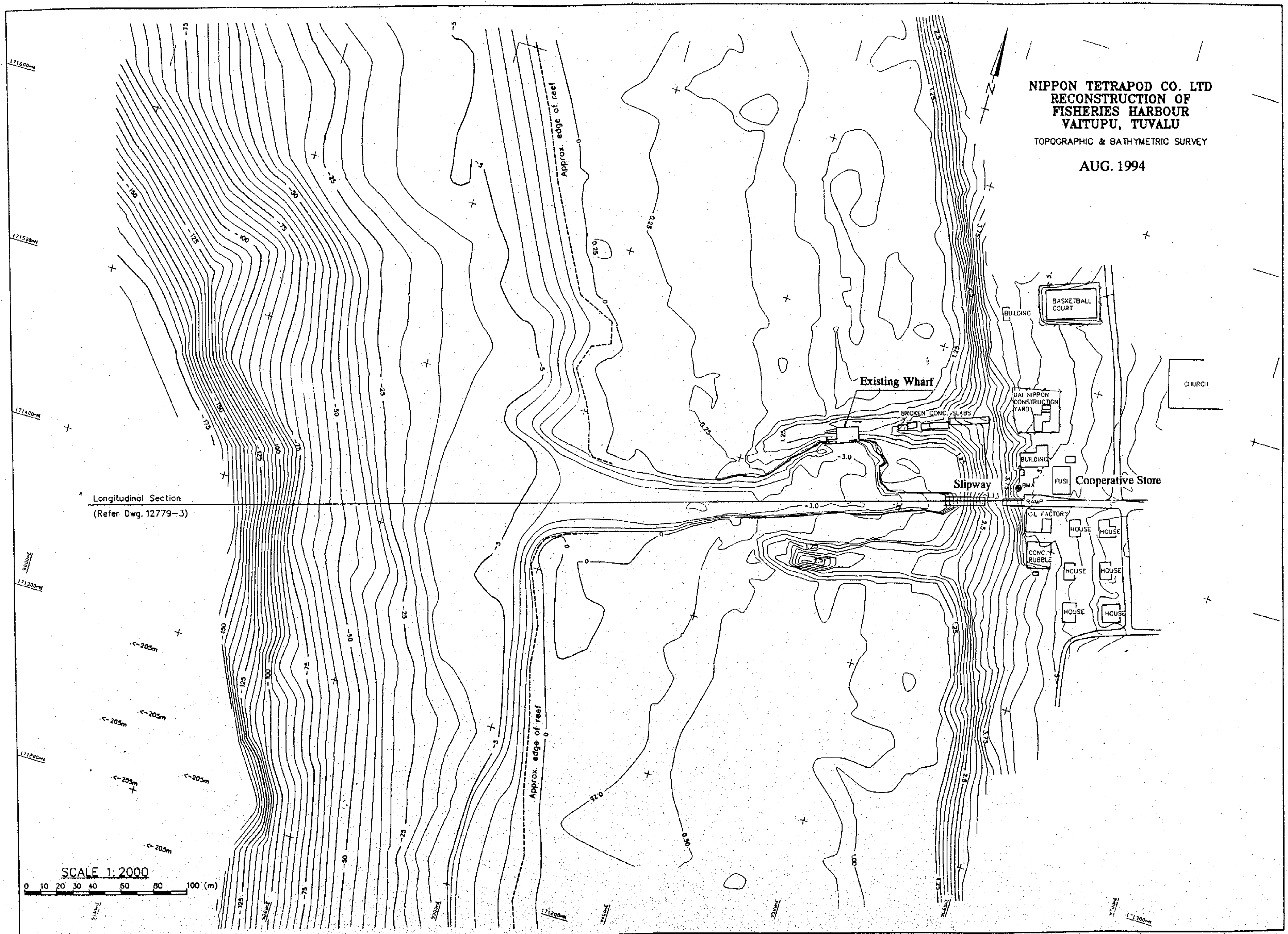


Fig. 2-6 Result of Sounding Survey in the Vicinity of the Asau Fisheries Harbour

2) Tidal current

The direction and speed of the tidal current were measured by using an electromagnetic current meter at spring and neap tide at about 50 cm from the sea bottom in the existing channel which had been open-cut by excavating the reef in the harbour. The current speed was about 0.3 m/s maximum and there was no prevailing current direction. The daily maximum current speeds are shown in Table 2-3.

Table 2-3 Daily Maximum Current Speed at the Channel

Date	Time	Max.speed (m/sec)	Remarks
AUG. 28	20:15	0.22	
AUG. 29	22:15	0.25	at Neap
AUG. 30	01:15	0.18	
SEP. 04	13:55	0.18	
SEP. 05	18:25	0.21	at Spring
SEP. 06	06:05	0.30	
SEP. 07	06:55	0.23	

3) Littoral drift and coast process

There was no supply source of littoral drift such as a river nor was there any sand on the reef flat. Near the shoreline at the bases of the south and the north groins, however, there was sand with a gentle slope. Similar sand was observed in the bottom of the existing channel. Table 2-4 shows the specific gravity and the settling velocity while Fig. 2-8 shows the grain size distribution of these sand. These figures show that sand near the fisheries harbour was mostly fine and coarse sand, containing hardly any silt or clays, and that it was larger grain sand with higher terminal speeds.

It was not possible to estimate the presence/absence or the volume of littoral sand in the present study because of the short study period.

Table 2-4 Specific Gravity and Settling Velocity

Location of sampling	Shoreline①	Shoreline②	Shoreline③	Shoreline④	Channel	Average	Remarks
Specific gravity	2.67	2.71	2.69	2.71	2.69	2.69	
Settling velocity(m/h)	70		150		60	93	10% contained

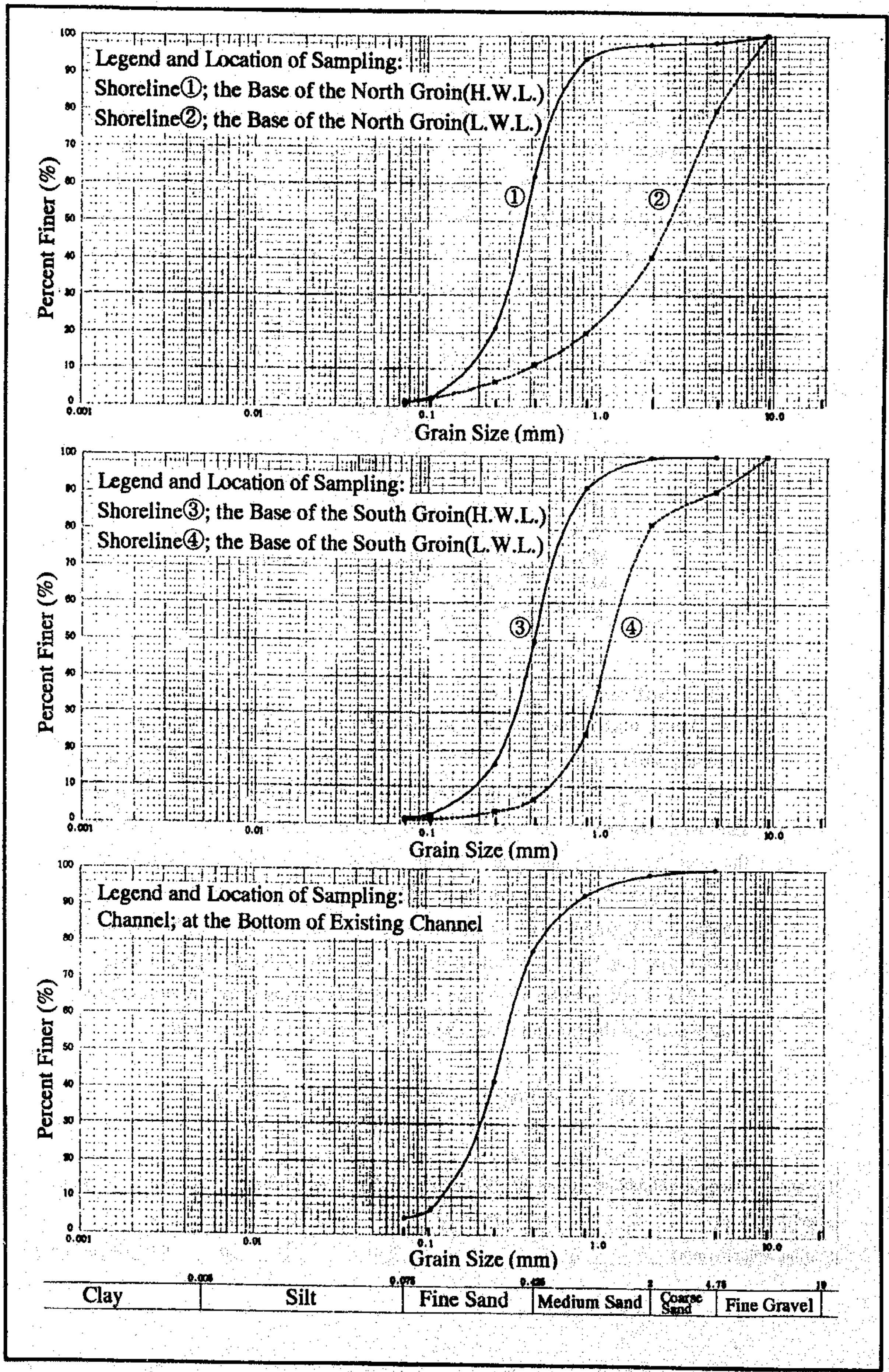


Fig. 2–8 Grain Size Distribution of Sand at the Asau Fisheries Harbour

(4) Hindcasting of Waves Attributable to "Kina" and "Nina"

Table 2-5 shows statistics concerning frequency distribution of waves in the sea surrounding Tuvalu. The wind waves which are 0 to 1.5 m high account for 81 % and those 1.5 m to 3.0 m high 16 %, and the swells of 0 to 1.5 m account for 33 % and those of 1.5 to 3.0 m 60 %, indicating that the swells are more frequent rather than the wind waves. The principal direction of the waves is reported to be E-NE.

Table 2-5 Frequency Distribution of Waves

(Unit: %)

		SEP-NOV	DEC-FEB	MAR-MAY	JUN-AUG	Annual
Wind waves	Class height(m)					
	0 -1.5	85	83	87	74	81
	1.5-3.0	14	17	12	23	16
	3.0-6.0	2	0	1	4	2
	Over 6.0	-	-	-	-	-
	Modal direction	E 35	E 20	E 34	E 52	E 36
Swell	Class height(m)					
	0 -1.5	37	36	38	23	33
	1.5-3.0	57	58	56	67	60
	3.0-6.0	6	6	6	10	7
	Over 6.0	-	-	-	-	-
	Modal direction	E 36	NE 24	E 26	E 38	E 30

(Source: National Institute of Water and Atmospheric Research Limited)

1) Gists of cyclones "Kina" and Nina"

In the sea of Tuvalu, 24 cyclones are reported since 1940. Those which are officially recorded as having affected the country occurred in February 1891, January 1958 and October 1972. Although not confirmed officially, the cyclone which occurred in November 1957 is said to have inflicted tremendous damages to the land. As shown, very few cyclones generate in the area and the above mentioned two cyclones which had brought disasters to Vaitupu are considered very rare. Fig. 2-9 shows the tracks of the two cyclones and Figs. 2-10 and 2-11 show time series of their wind and waves.

"Nina" was born in the Sea of Arafa in the north of Australia, headed east while retaining the ordinary force although it remained small in size, reached the point about 500 km SSW of Vaitupu Island on January 3,

1993. "Kina" was born on the sea 1,000 km southwest of Vaitupu on December 27, 1992 and passed the Fiji Islands and the south of the Kingdom of Tonga. This cyclone was large and remained powerful and proceeded in the southeastern direction at 1,000 km distance from Vaitupu.

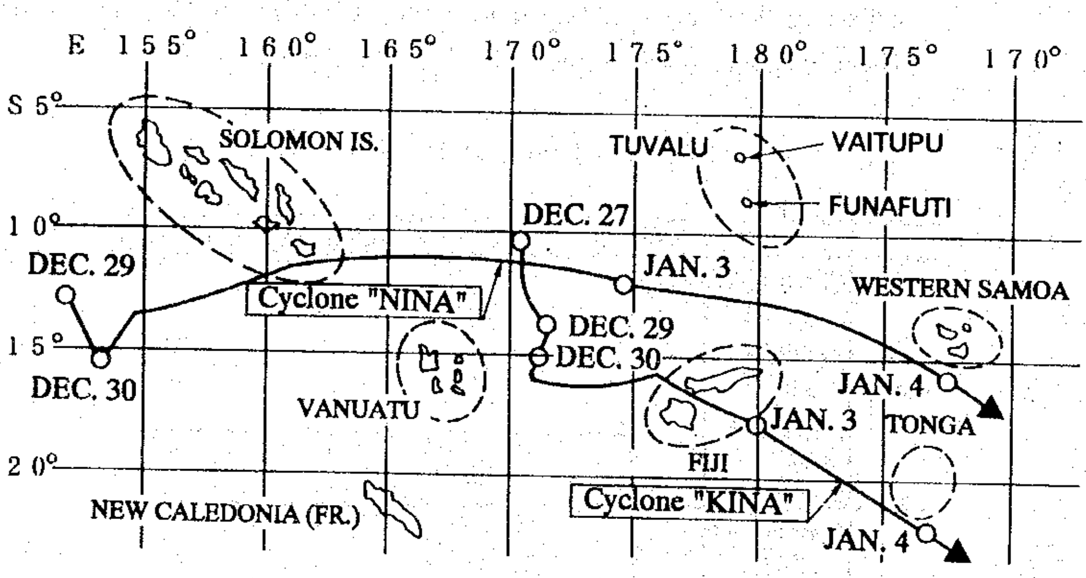
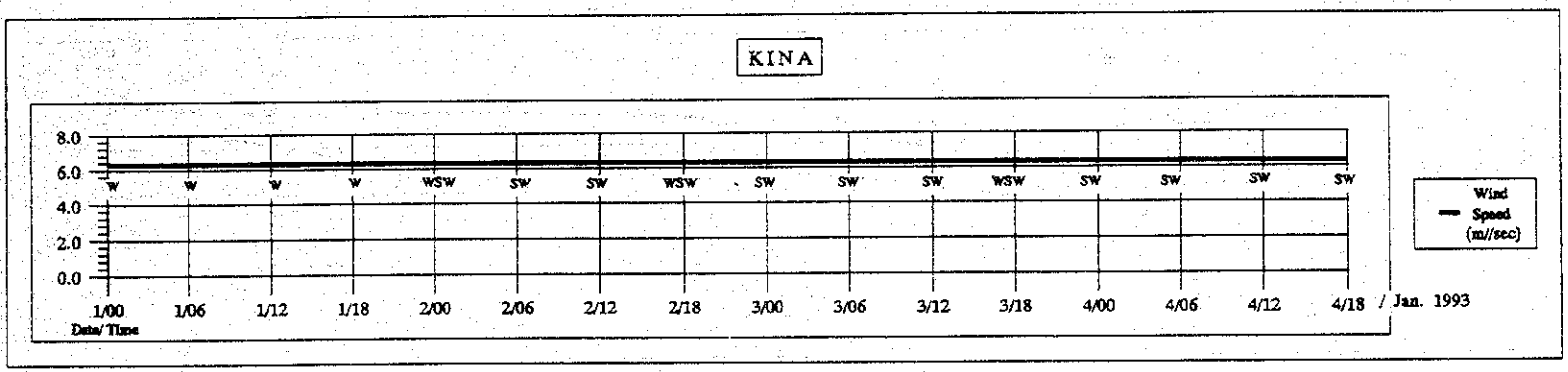


Fig. 2-9 Cyclone Tracks of "Kina" and "Nina"

The cyclones advanced in the southeastern direction between January 1 and 4 in 1993 generating strong WNW winds and the waves generated in these fetches respectively departed the fetches and propagated to Vaitupu as swells with respective periods while interfering with each other's energy.



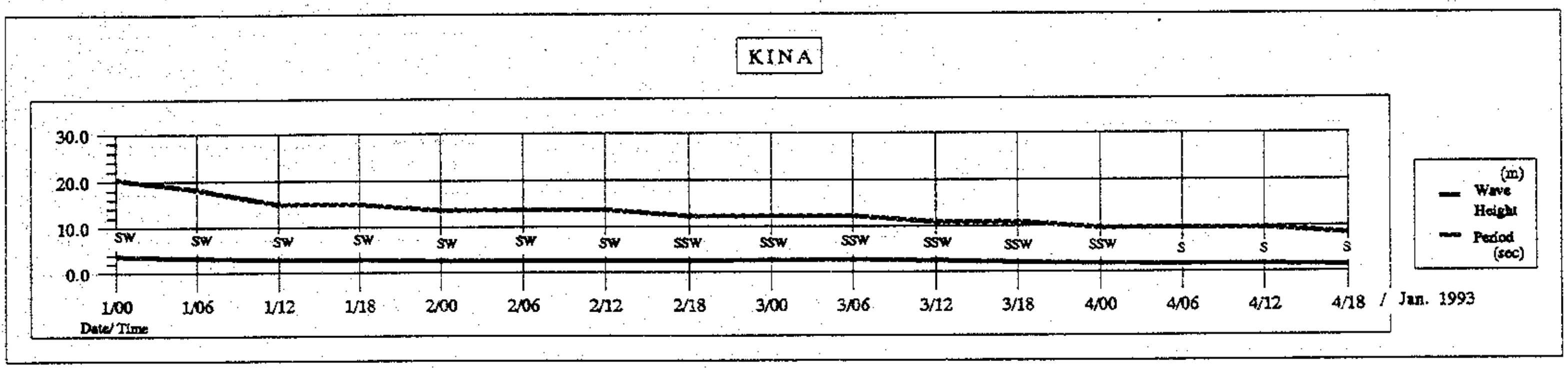


Fig. 2–10 Time Series of Wind and Waves(Kina)

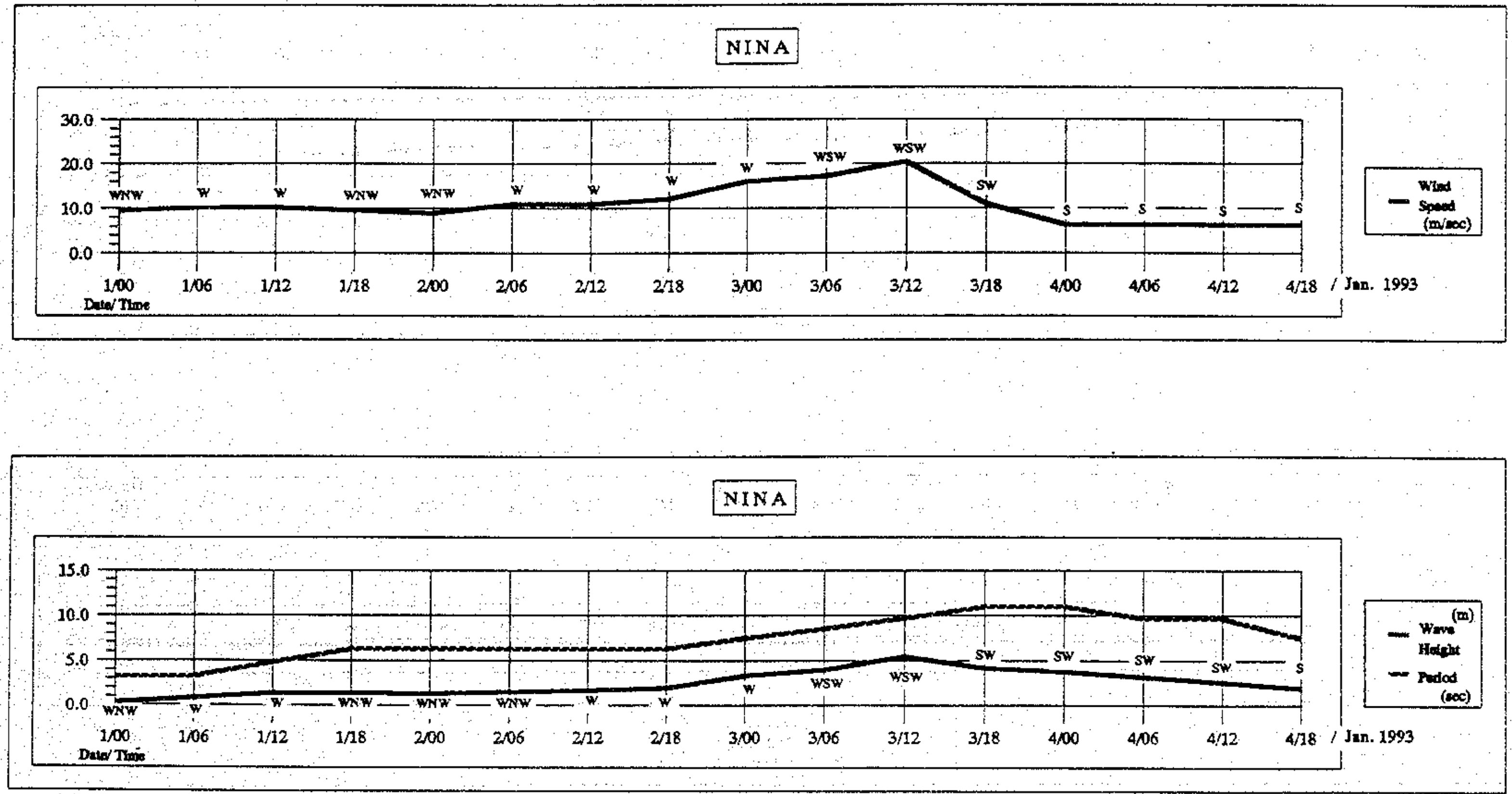


Fig. 2–11 Time Series of Wind and Waves(Nina)

2) Hindcasting of offshore waves

Fig. 2-12 shows the steps for hindcasting the offshore waves.

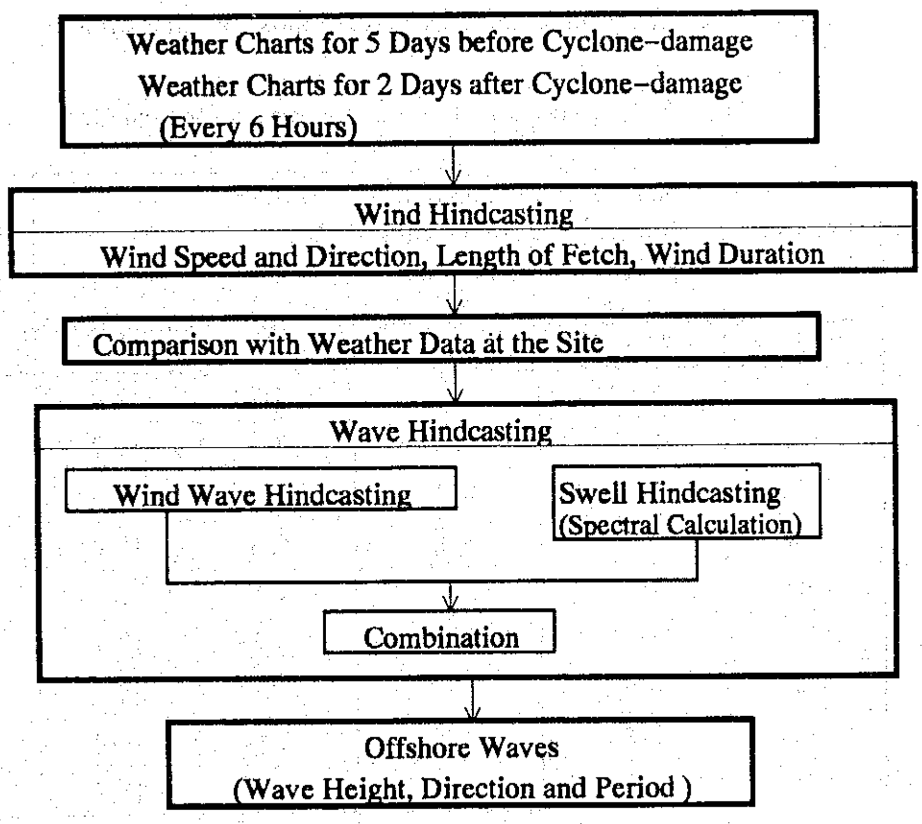


Fig. 2-12 Flow of Design Offshore Wave Hindcasting

Table 2-6 shows the result of hindcasting of offshore waves for each cyclone. The combined offshore waves attributable to "Nina" and "Kina" (the highest site significant wave height; 6.0 m, the maximum wave height; 11.2 m) are remarkably larger than those of other cyclones.

Table 2-6 Hindcasting of Offshore Waves for each Cyclone

Cyclone Name	Highest Site 1-Minutes Wind Speed (m/s)	Highest Site Significant Wave Height (m)	Maximum Wave Height (m)	Wave Period (s)	Wave Direction (degrees)
Nina/Kina	20.4	6.0	11.2	9.9 *	220
TC17	7.1	2.0	3.7	11.0	230
TC03	12.1	4.8	8.9	13.7	140
TC21	8.3	2.8	5.2	11.0	190
HINA	---	3.1	5.8	13.0	245
TC06P	12.7	2.6	4.8	7.5	170
RAJA	---	2.3	4.3	13.7	157
TC04	8.9	---	---	---	---
ANNE	8.3	3.2	6.0	14.9	246
OFA	---	2.7	5.0	13.7	195
SINA	---	3.8	7.1	14.9	205
JONI	11.5	3.2	6.0	16.4	203

NB 1) Asterisk(*) shows the wave period of combined waves of "Nina" and "Kina".

2) The wave period and direction are the average values if there are two periods and directions.

3) The columns without figures for "Hina", "Raja", "Ofa" and "Sina" indicate that no remarkable wind speeds were observed at the study site even though they were among the worst ten cyclones with very high wave heights.

4) The columns without figures for "TC04" indicate that its wave height was not high enough to be included in the worst ten list excluding "Nina/ Kina" even though it brought the strong wind of 8.9 m/s to the study site.

3) Hindcasting of wave deformation

Fig. 2-13 is a sketch of wave deformation in shallow waters. The steps of calculation are shown below.

①Hindcasting of wave deformation in shallow waters

Based on the result of the on-site sounding survey, the deformation of the offshore waves in the shallow waters was calculated using the energy balance equation to obtain the equivalent offshore waves (Ho', Lo').

②Hindcasting of wave breaking and wave deformation on the reef flat

Deformation of the breakers and the waves on the reef flat was calculated to obtain the design wave height which had reached the south and the north groins. As for the wave breaking deformation (between points a and b), the changes in the wave height and the sea level due to wave breakings were taken into consideration. These deformations were calculated using Goda's method of calculating wave heights in the surf zone. That method takes into account the changes in the mean sea level due to radiation stresses and to surf beat. The wave deformation on the reef flat (between points b and c) was calculated assuming the water level elevations on the reef flat near the south and the north groins to be 1.5 m and 2.0 m respectively.

Table 2-7 shows the result of hindcasting of wave heights attributable to the two cyclones. The result indicates that the wave height changes remarkably by the rise in the sea level at that time because of the wave deformation in the shallow waters, the surf zone and on the reef flat. If the water level rises as much as 2.0 m, the maximum wave height becomes 3.7 m.

Table 2-7 Hindcasting of Wave Height Attributable to Cyclones "Kina" and "Nina"

Offshore Wave Height : H(m)=6.0
Offshore Wave Period : T(s)=9.9
Offshore Wave Direction: SW

	Wave Setup(m)	
Site Wave Height(m)	1.5	2.0
H1/3	2.5	2.8
Hmax	3.3	3.7

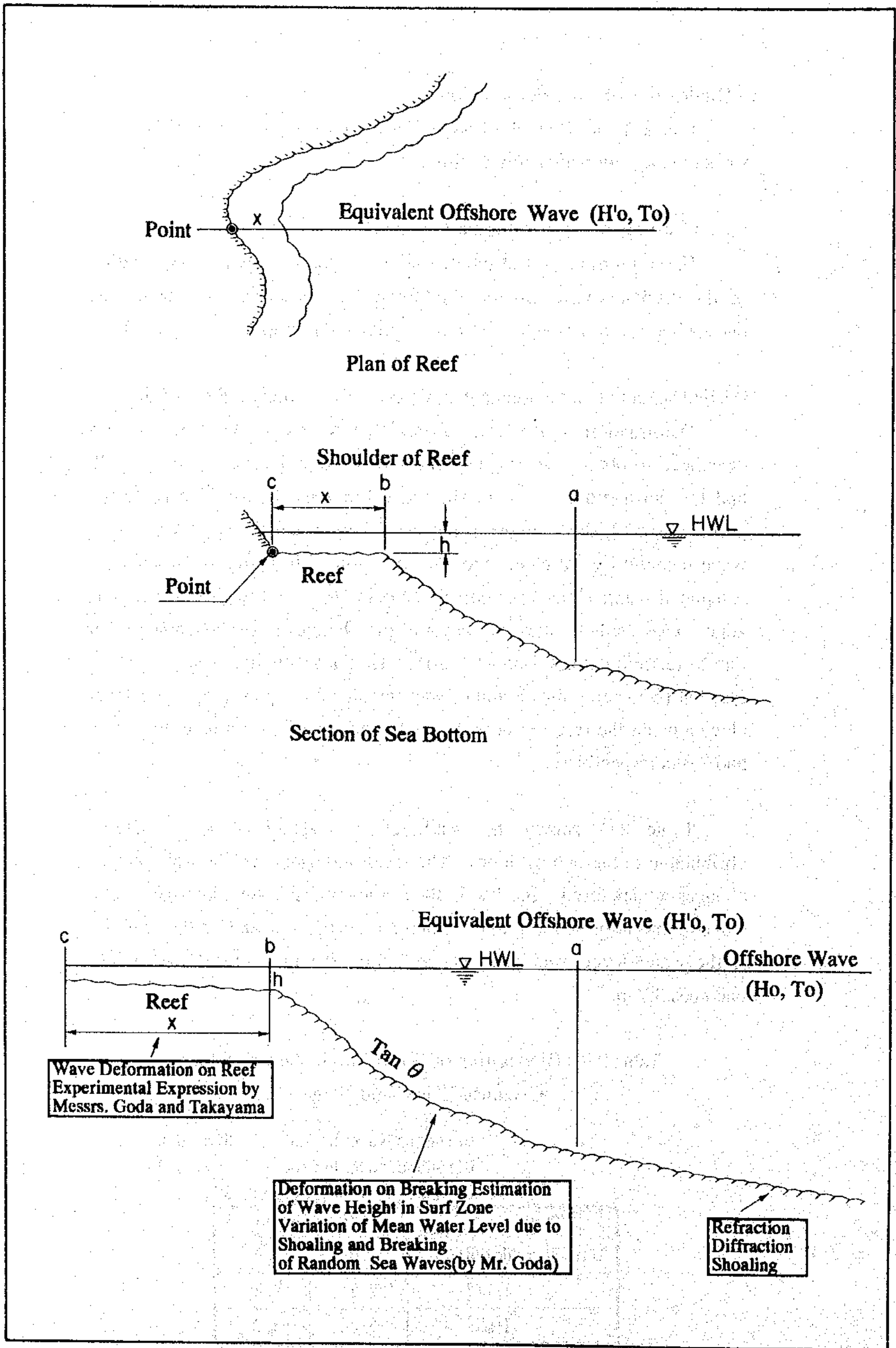


Fig. 2-13 Sketch of Wave Deformation

(5) Hindcasting of Offshore Waves at Site

1) Offshore wave height with a return period

Fig. 2-14 shows the steps for hindcasting of offshore wave heights with a return period.

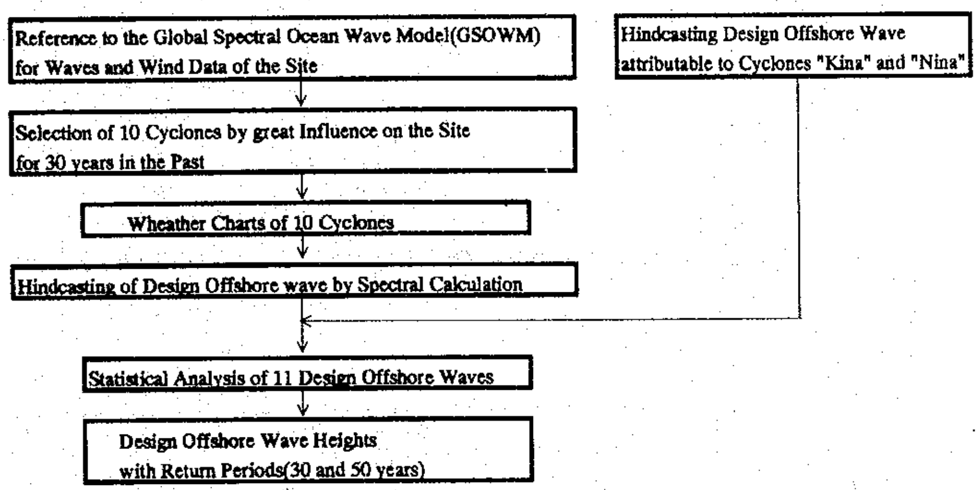


Fig. 2-14 Flow of Hindcasting of Offshore Wave Height with a Return Period

Fig. 2-15 shows the relation of the equivalent offshore wave heights with periods and Fig. 2-16 that with directions. As shown by the arrows, the periods for cyclone waves are likely to be 12 to 14 seconds and the wave direction SW-SSW. The mean period and the direction by visual observation during the study period were 12 to 13 seconds and SW-SSW respectively.

Fig. 2-17 shows the result of hindcasting of design offshore wave height with return periods in respect of 11 cyclones shown in Table 2-6. Table 2-8 shows those of design offshore wave height with return periods of 30 and 50 years as well as the direction and period of waves affecting the study site. Fig. 2-17 shows the combined wave attributable to cyclones "Kina" and "Nina" has the return period of about 60 years.

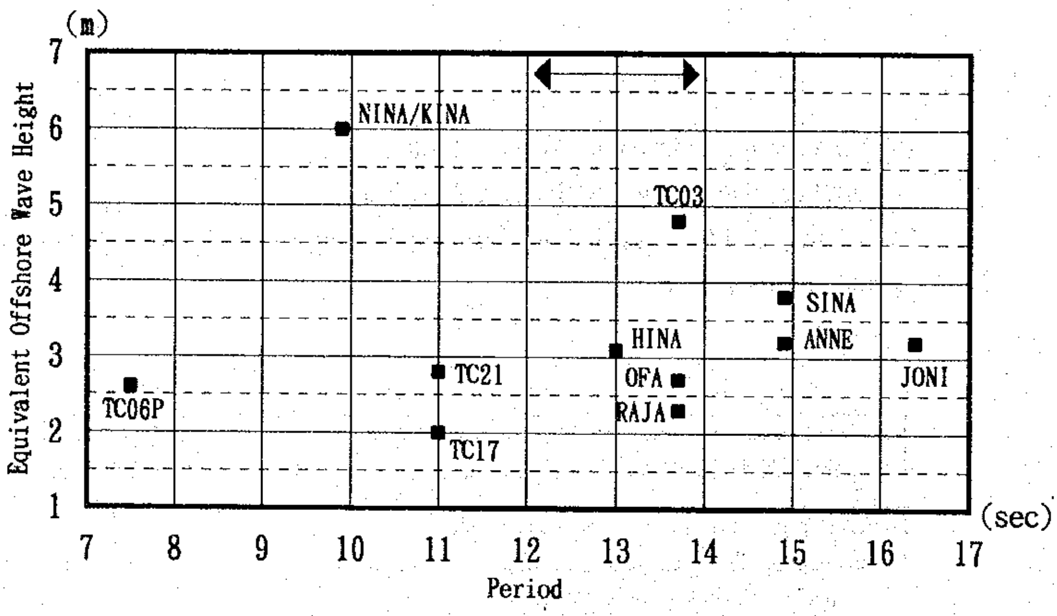


Fig. 2-15 Relation Between Offshore Wave Heights and Periods

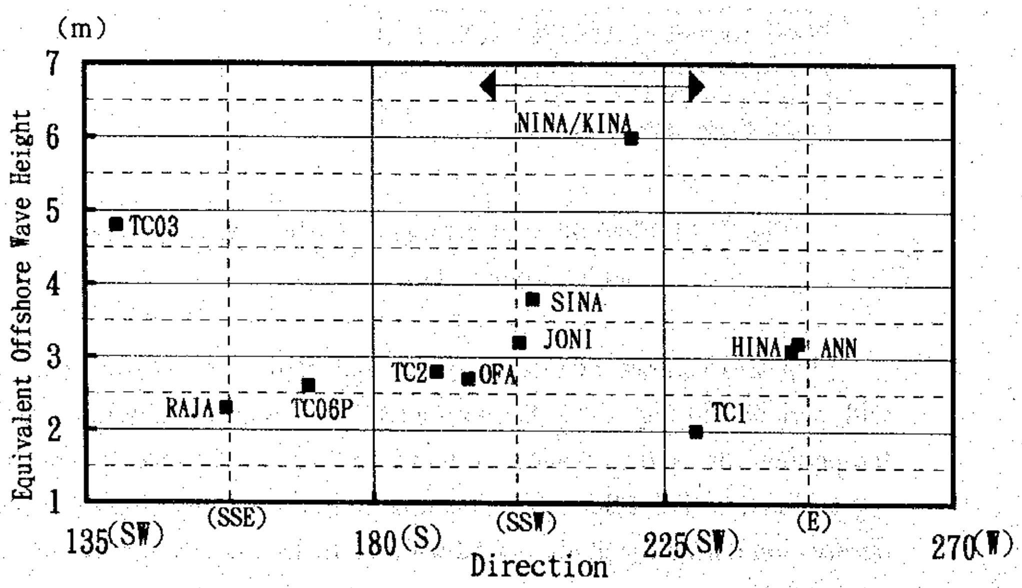


Fig. 2-16 Relation Between Offshore Wave Heights and Directions

Table 2-8 Offshore Wave Height with a Return Period

Return Period	30 Years	50 Years
Wave Direction	SW – SSW	SW – SSW
Wave Height(m)	5.1	5.8
Wave Period(s)	12 – 14	12 – 14

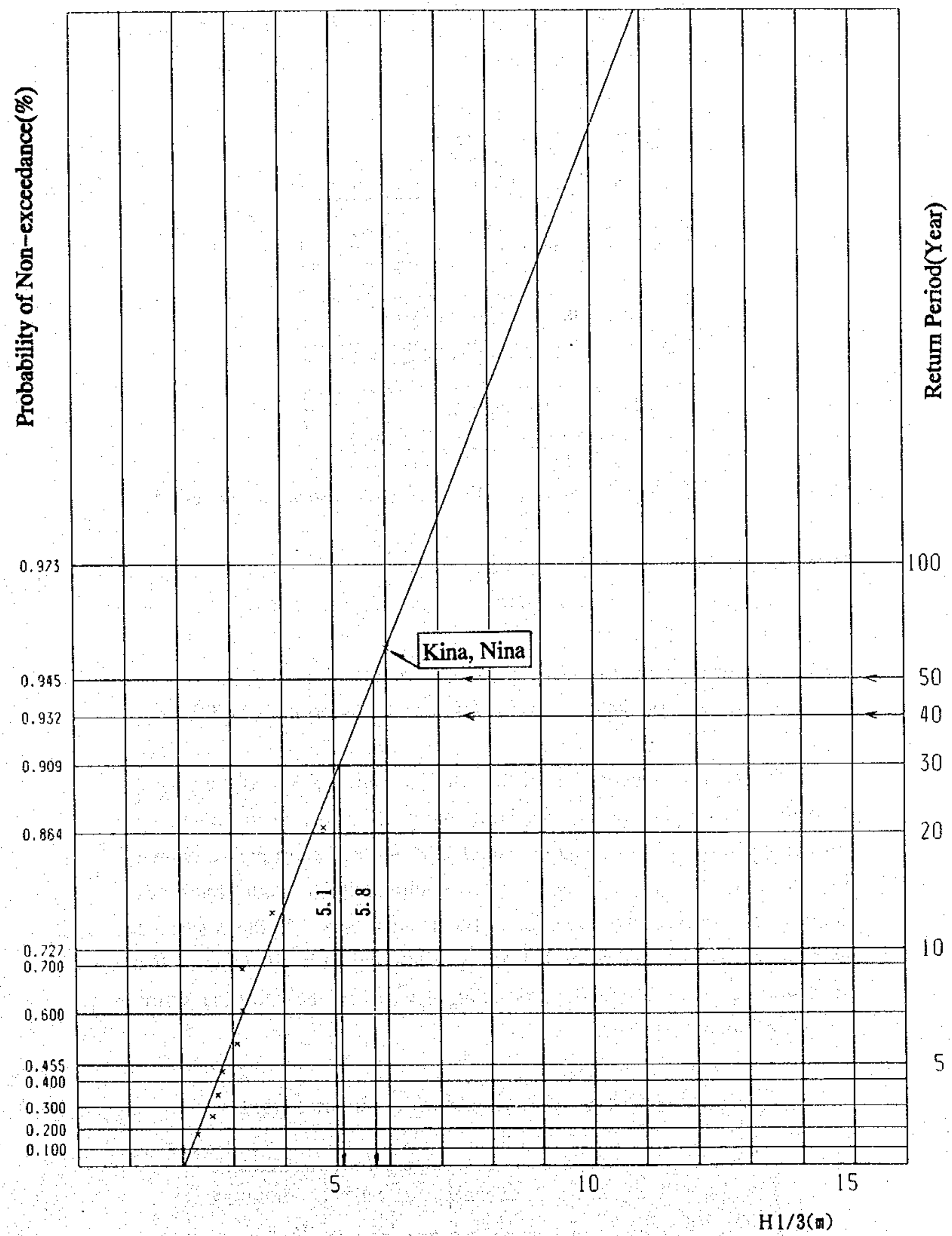


Fig. 2-17 Return Period

2) Design wave height with a return period

Fig. 2-18 shows the steps for hindcasting of design wave height with return periods at the proposed site.

Offshore Wave Heights with the Return Periods(30 and 50 Years)

↓

Wave Deformation in the Shallow Area

↓

Calculation of Wave Breaking and Wave Deformation on the Reef Flat

↓

Design Wave Heights with the Return Periods(30 and 50 Years)

Fig. 2-18 Flow of Hindcasting of Design Wave Height with a Return Period

①Wave deformation in shallow waters

The steps for hindcasting are the same as discussed in (4) 3) ①.

②Wave deformation in the surf zone and on the reef flat

The steps for hindcasting are the same as discussed in (4) 3) ②.

The result of hindcasting of the wave direction SW and the period 14.0 seconds which would affect the planned site is shown in Table 2-9 for comparison with the offshore wave height with a return period shown in Table 2-8. The rise in the sea level by cyclones "Kina" and "Nina" was abnormally large at above 1.5 m according to this study. As the combined wave height had the return period of about 60 years, the elevation of the sea level was set at 1.5 m for hindcasting of wave heights with the return periods of 50 and 30 years.

Table 2-9 Design Wave Height with a Return Period

Return Period	30 Years	50 Years	Remarks
Wave Height(m)	5.1	5.8	Wave
Design Wave Height(m)	2.5	2.6	Setup=1.5m

(6) Soil Conditions

At the groin reconstruction site, the soil exploration was conducted by boring at sea and by laboratory test. Three holes were driven into the depth of 10 m. The survey sites and the profile of boreholes are shown in Fig. 2-19. The soil conditions at the site are discussed below.

1) Except the surface layer on the coral reef, the site consists of very hard coral rocks with N value of generally above 100 according to the standard penetrating test.

2) Although there are some gravels and sandy soil in the voids between the coral rock layers, the soil conditions are comparatively good with N value of above 20.

3) The surface layer for about 50 cm at BH-3 consists of sandy coral pieces which are the debris of the damaged groins.

(7) Material Tests

The result of the tests on the aggregate materials for use as concrete materials is shown in Table 2-10. Concrete samples were prepared using these aggregates and the unit volume weight of concrete was found to be very light at about 1.87 g/cm3.

Table 2-10 Test Results of Water Content, Dry Density and Unconfined Compressive Strength

Test Item ＼ Sample Name	Water Content (%)	Dry Density (t/m3)	Compressive Strength (kg/cm2)	Remarks
Sand ①	33.8	1.10	-	White Sand No Silt contained
Sand ②	18.7	1.14	-	
Sand ③	19.9	1.48	-	
Average	24.1	1.24	-	
Coral Debris ①	1.1	2.12	351	Dark Gray Outer Light Pink-White Inner
Coral Debris ②	1.1	2.24	622	
Average	1.1	2.18	487	

(8) Seismic Condition

As there were no seismic data available in Vaitupu, the study team used the data supplied by the International Seismic Center in London. The data indicated that there were hardly any earthquakes near the island, the maximum acceleration for the seismic movements was 10 gal (10 cm/s2). Therefore, there is no need to consider any effect of earthquakes.

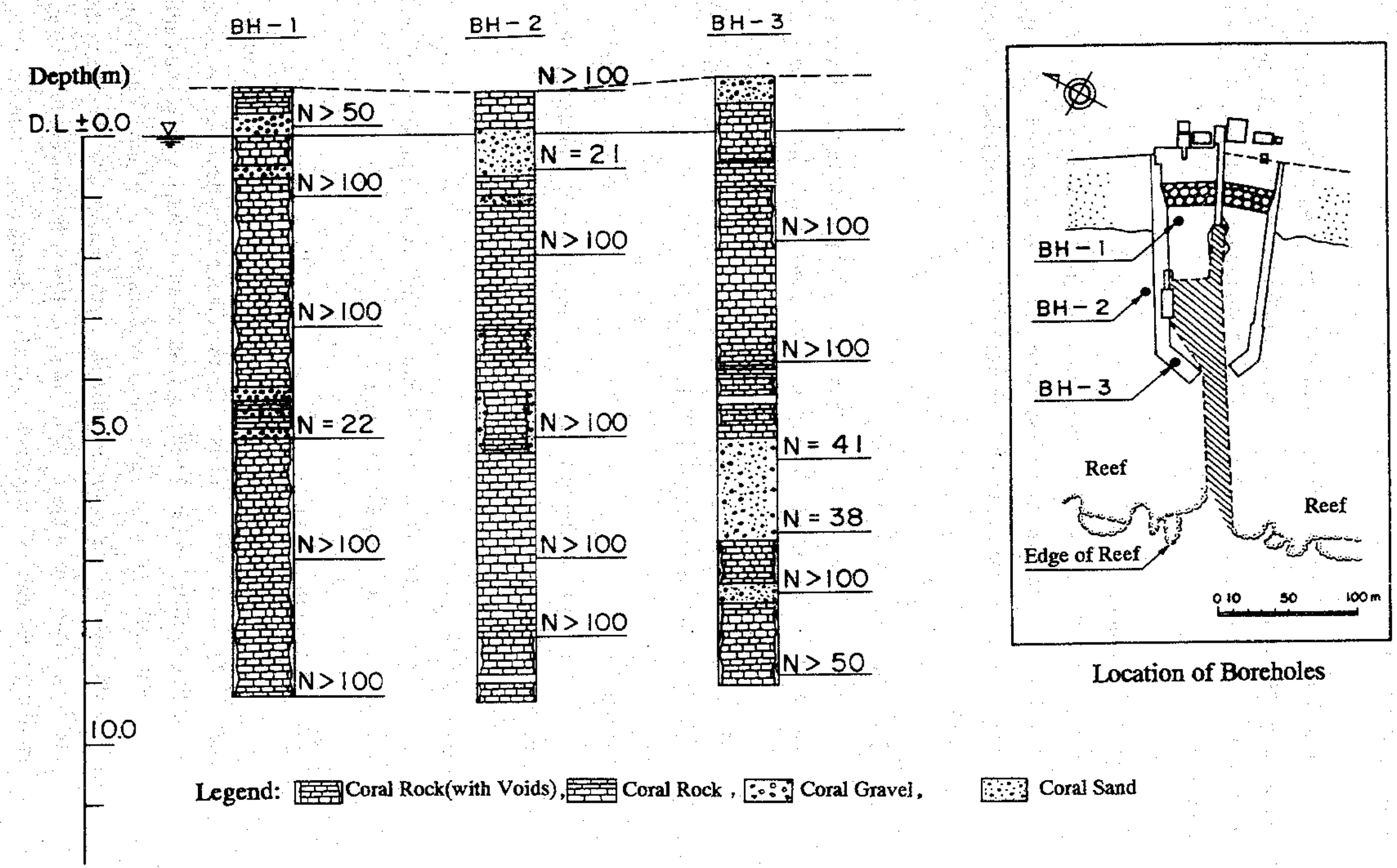


Fig. 2-19 Profile of Boreholes

2-3-3 Infrastructure

Vaitupu Island is about 150 km north of Funafuti Island where the country's capital is located. The only means of transportation to the island are the three inter-island ships owned by the Government. This section shall now discuss the infrastructure.

(1)Road Conditions

The island has a one-lane unpaved road running parallel to the coastline from the fishery harbour to some parts of the island. Many local people walk the road and small old trucks, tractors, small buses and motor bikes go past them occasionally.

(2)Electricity and Communications

There is no public power generator to supply energy to all parts of the island. All private houses use kerosene lamps and some public facilities have solar type small generators. For communication, they have wireless phones which they can use for about one hour on weekdays. Telephone communication is quite impractical.

(3)Water

As there is no public water system, people drink rain water. There are some villages which have wells.

(4)Medical Care

There is no modern medical care facility. A local nurse is stationed full time at what appears to be a clinic.

(5) Area for the Project Site

Behind the site for the fishery harbour, there is a cooperative store, a church and some private houses. On the lagoon side there are the Island Council's facilities and the Fisheries Centre built by the previous grant aid.

The entire area for the project belongs to the Island Council and there are no problems regarding sites for restoration as was the case in the previous grant aid project. The request from the Government stated similar points which we were able to confirm during the site survey.