No. 1

BASIC DESIGN STUDY REPORT
ON
THE PROJECT
FOR
REHABILITATION OF CYCLONE-DAMAGED PORTS
AND
CONSTRUCTION OF QUARRY PLANT
IN
WESTERN SAMOA

November, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

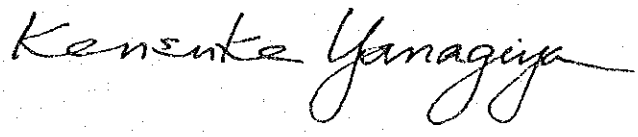
In response to the request from the Government of Western Samoa, the Government of Japan has decided to conduct a Basic Design Study on the Project for Rehabilitation of Cyclone-damaged Ports and Construction of Quarry Plant and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Western Samoa a survey team headed by Mr. Toshiro TSUTSUMI, Senior Port Inspector, Port Construction, the Third District Port Construction Bureau, Ministry of Transport, from June 12 to July 21, 1990.

The team exchanged views with the officials concerned of the Government of Western Samoa and conducted a field survey. After the team returned to Japan, further studies were made. Then, a mission was sent to Western Samoa in order to discuss the draft report and the present report was prepared.

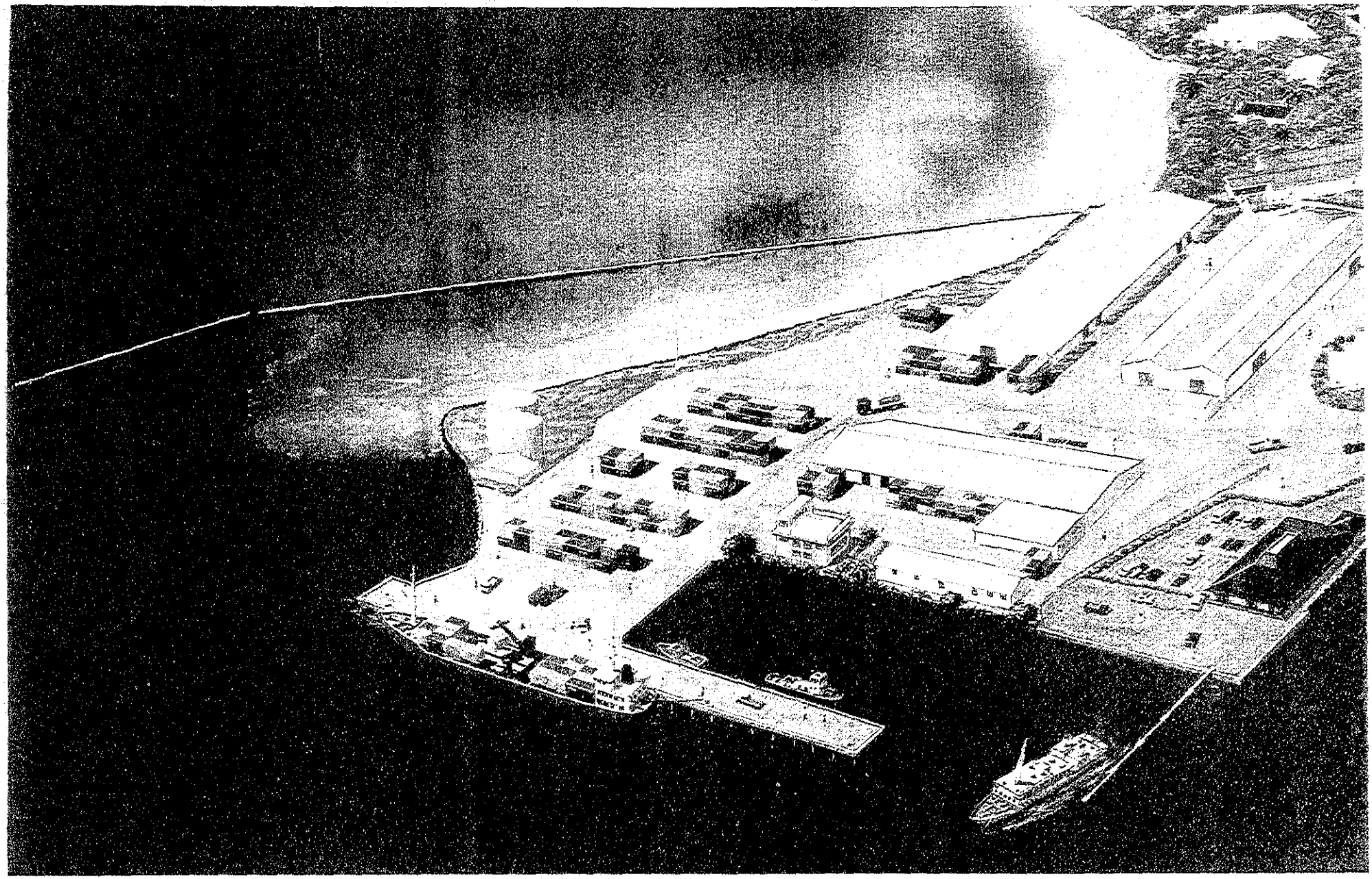
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

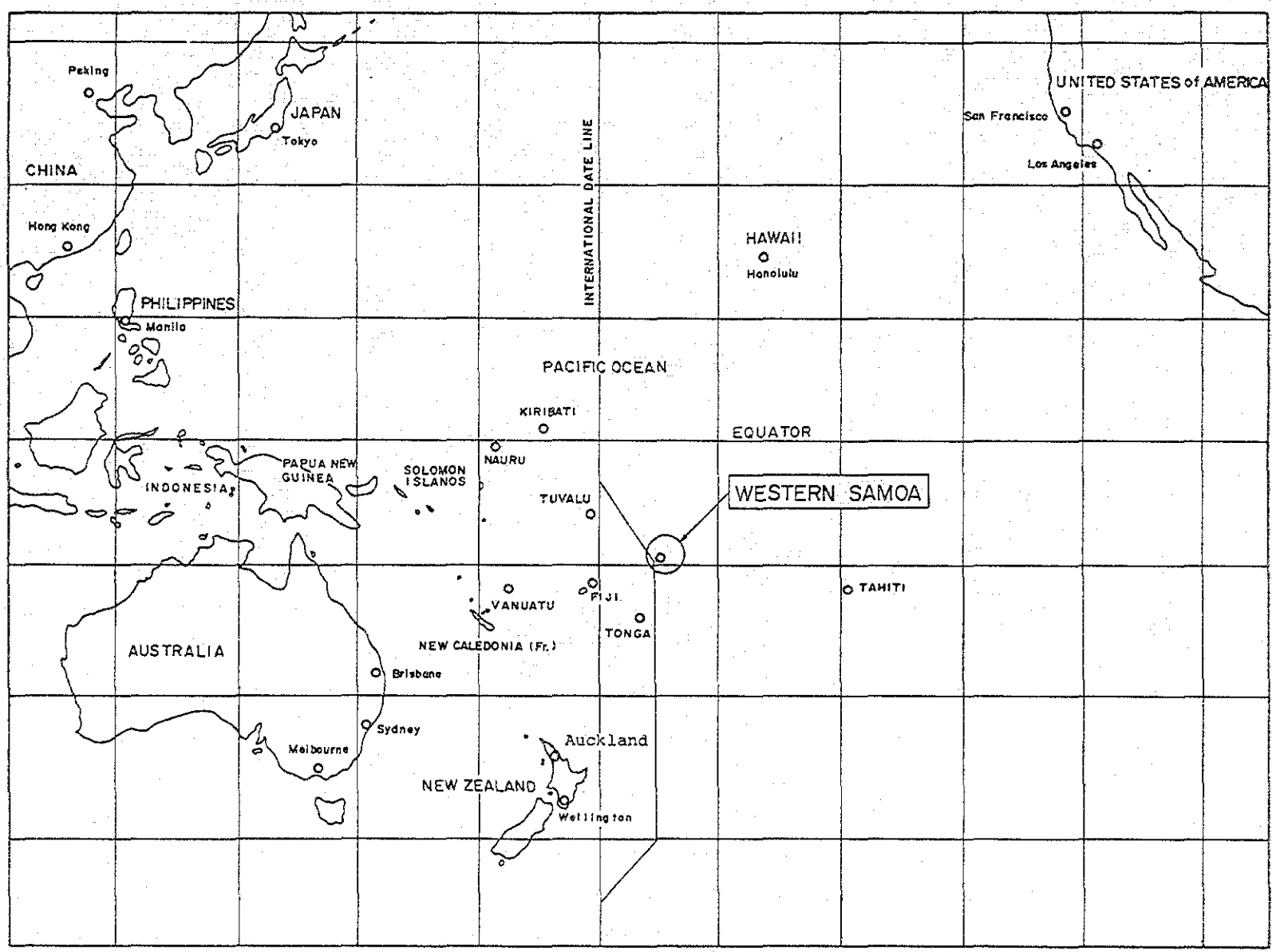
I wish to express my sincere appreciation to the officials concerned of the Government of Western Samoa for their close cooperation extended to the teams.

November 1990



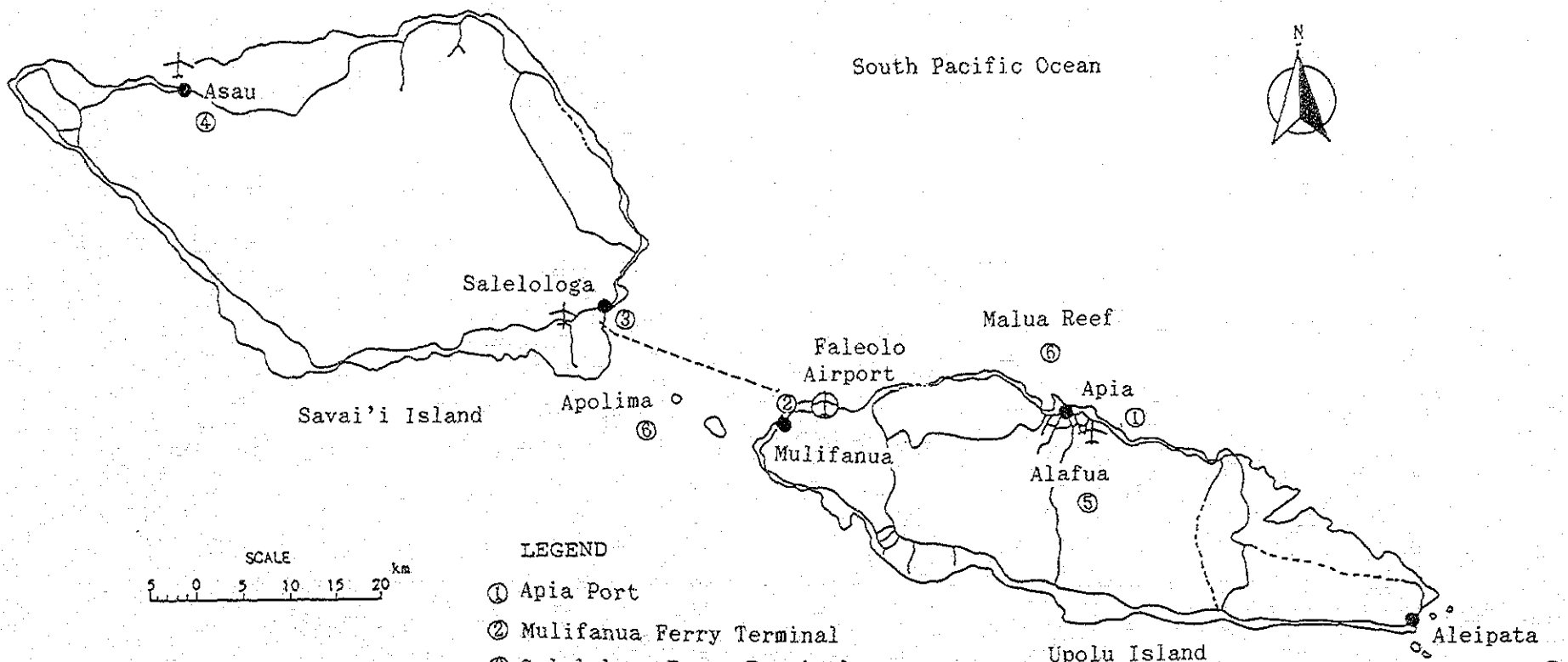
Kensuke Yanagiya
President
Japan International Cooperation Agency

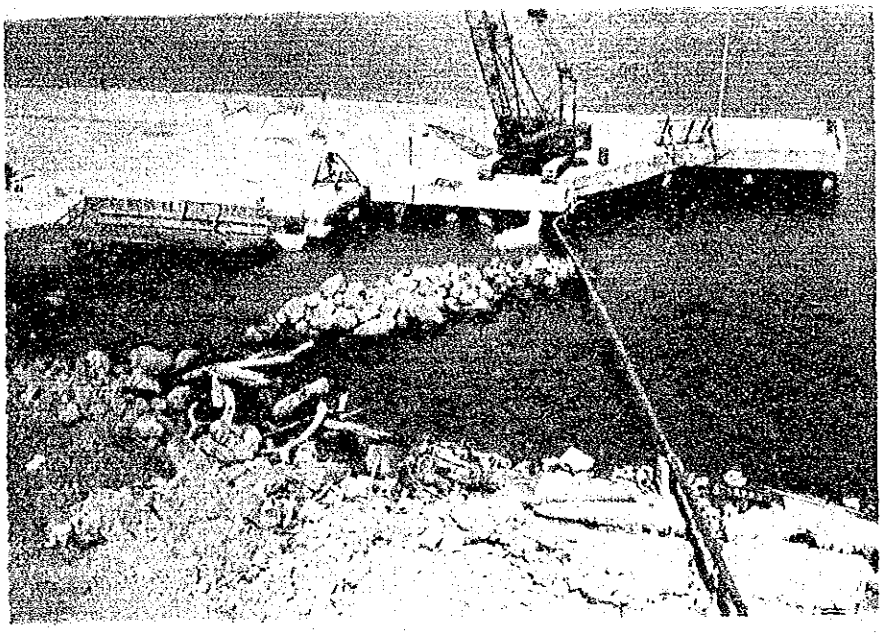




Location of Western Samoa

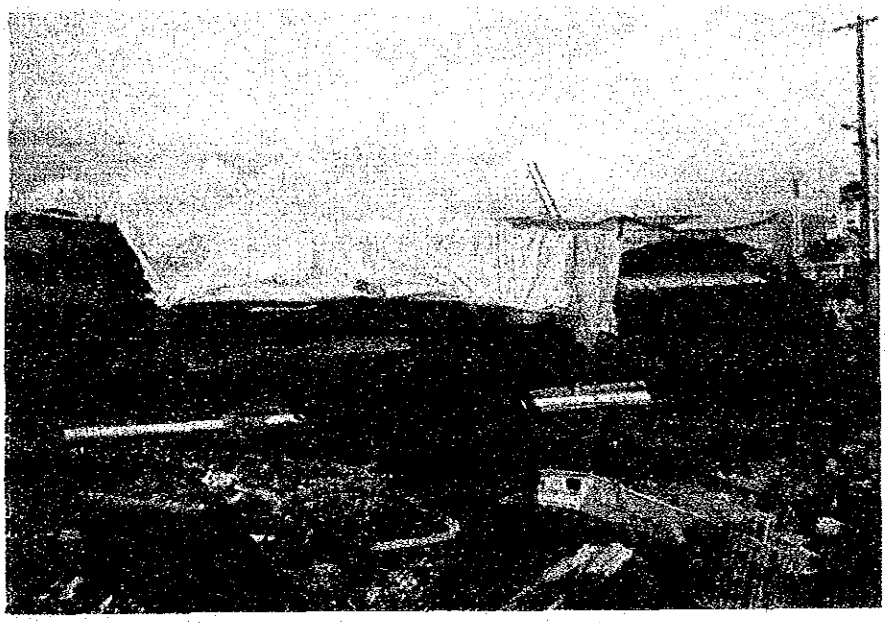
Location of Project Site



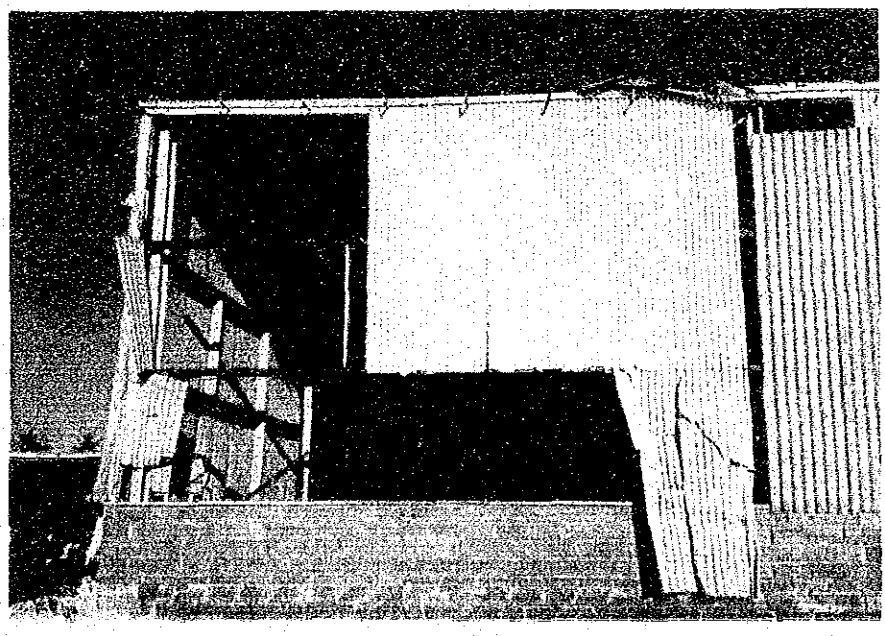


Cyclone-damages
in Apia Port

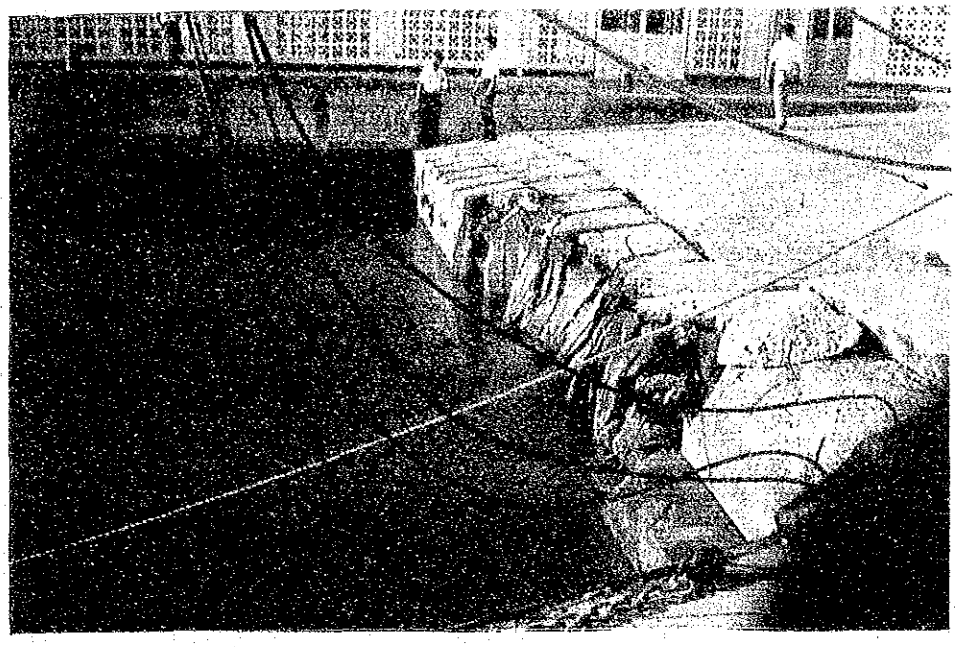
The causeway has
been washed away
and access to the
main wharf is lost.



The Marine Office
has been damaged
beyond repair.

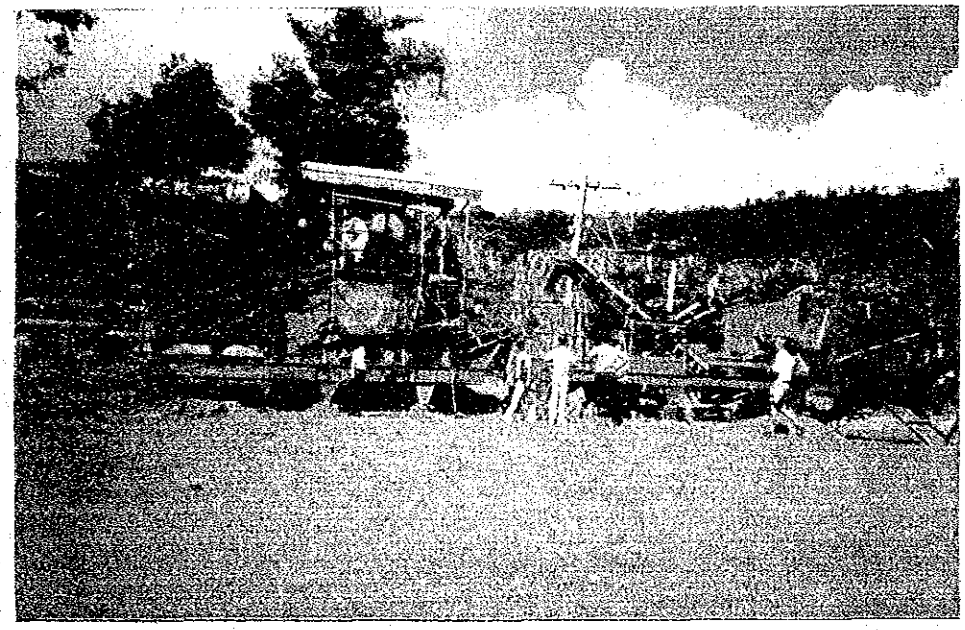


The Shed No.3 has
been damaged on
its roof and wall
and is partly
unserviceable



Cyclone-Damages
in Mulifanua Port

The ferry ramp
has been damaged
on its concrete
coping and apron.



The Existing
crusher in Alafua
is out of operation
due to serious
deterioration.

The road in Savaii
Island has been
washed away by
cyclone waves.

SUMMARY

SUMMARY

Western Samoa is an insular country located in the central South Pacific with a national land area of 2,936 km^2 and a population of about 160,000. Given its geographical condition, Western Samoa's national life and economic activities largely depend on maritime transportation, making ports crucial components of basic social infrastructure. While road facility is the most important means in domestic transportation, and many road improvement projects are planned in the sixth national development plan to complete an efficient road network for promotion of national and regional economy.

Western Samoa was attacked by the large cyclone "Ofa" in February, 1990 which caused extensive damage making 25,000 people homeless. The port facilities which are the basis of sea transportation also sustained such heavy damages as collapse of breakwater and wharfs, siltation of a navigation channel and loss and damage of navigation aids, etc. In the case of Apia Port which is the key port for both domestic and foreign trade, safe and efficient port operation must be urgently restored, demanding the urgent implementation of rehabilitation works.

An urgent rehabilitation plan is currently being prepared for a total of about 50 km of coastal road sections, which were washed away on Upolu and Savaii Islands, in order to secure efficient and safe land transportation.

From this background, the Government of Western Samoa made a request to the Government of Japan for a grant aid to restore the port facilities and to introduce the quarry plant to supply stone material for the road restoration works.

In response to the request by the Government of Western Samoa, the Government of Japan decided to carry out the basic design of the project and the Japan International Cooperation Agency (JICA) sent the Study Team

to Western Samoa for a period of 40 days from June 12th to July 21st, 1990 to conduct a field study. In the course of the study period, the Study Team collected relevant data and information, and discussed with officials of the Government of Western Samoa. The draft final report was presented and discussed in Western Samoa from 16th to 24th September 1990.

Based on the results of the field study and the discussions with the officials of the Government of Western Samoa, the optimal basic design consisting of the following project components has been worked out through due consideration of the request of the Government of Western Samoa. The implementation of the project is divided into two phases and the project components requiring urgent restoration are included in the first phase.

(1) Port Facilities

	I Phase	II Phase	
Apia Port	Causeway Seawall	Breakwater Navi. Aids Sheds No.1 & 3	Pilot/Work Boats Marine Office Wooden Fender
Mulifanua Port		Channel Dredging - 3.5 m Wharf Navi. Aids	Ferry Ramp Seawall
Salelologa Port		Navi. Aids	
Navigation Aids		Lighthouses in Aleipata, Apolima and Malua Reef	

(2) Quarry Plant

The quarry plant and related equipments are urgently required for restoring the damaged roads and is included in the first phase.

Drills	63-90 m/m	2 Nos.
Bulldozer	35 ton	1 No.
Crusher	100 t/h	1 No.
Generator	270 KVA	1 No.
Wheel-Loaders (for raw rock)	2.4 cu-m	2 Nos.
Dump Trucks	12 ton	4 Nos.
Wheel-Loader (for crushed stone)	1.7 cu-m	1 No.
Pick-Up Trucks	1 ton	2 Nos.
Station Wagon	4,000 cc	1 No.

The implementation of the project will require 3 months for detailed design and 7.5 months for construction works for the first phase and 3 months for detailed design and 12 months for construction works for the second phase.

The executing agencies of this project are Ministry of Transport (MOT) and Public Works Department (PWD).

Apia Port and the other ports are planned to be administered and operated by a proposed new organization "Port Authority" after the completion of this project. Also it is planned that the quarry be operated on a self-financing basis by a public corporation to be established under the jurisdiction of the PWD. Both agencies have sufficient experiences and staffs to operate the project facilities and further efficient operation and management will be achieved by introducing the above corporations.

Benefits expected to be brought about by implementation of this project are listed below :

by restoration of the port facilities

(1) Improvement of efficiency and safety in sea transportation and cargo handling

(2) Improvement of safety of navigation and

by introduction of the quarry plant

(1) Improvement of efficiency of construction works by smooth and sufficient supply of crushed stone

(2) Reduction of transportation cost and improvement of safety of transportation by restoration of the damaged roads.

The urgent restoration of the port facilities and introduction of the quarry plant are considered to be essential for recovery of the national life and economic activities of Western Samoa and, therefore, the urgent implementation of the project as a grant aid assistance of the Government of Japan is judged to be highly significant and appropriate.

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Abbreviations

ADB	Asian Development Bank
AIDAB	Australian International Development Assistance Bureau
DP6	Sixth Development Plan
FS	Feasibility Study
GDP	Gross Domestic Product
IDA	International Development Association
JIS	Japanese Industrial Standards
MOT	Ministry of Transport
PFL	Pacific Forum Line
PWD	Public Works Department
UNDP	United Nations Development Programme
US$	United States Dollar
WSSC	Western Samoa Shipping Corporation
WS$	Western Samoa Dollar (or Tala)
¥	Japanese Yen

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Request

Western Samoa is an insular country located in the central South Pacific Ocean with a national land area of 2,936 km^2 and a population of about 160,000. Given its geographical condition, Western Samoa's national life and economic activities largely depend on maritime transportation, making ports crucial components of basic social infrastructure. While road facility is the most important means in domestic transportation, and many road improvement projects are planned in the sixth national development plan to complete an efficient road network for promotion of national and regional economy.

Western Samoa was attacked by the large cyclone "Ofa" in February, 1990 which caused extensive damage and made 25,000 people homeless. The port facilities which are the basis of sea transportation also sustained such heavy damages as collapse of breakwater and wharfs, siltation of a navigation channel and loss and damage of navigation aids, etc. In the case of Apia Port which is the key port for both domestic and foreign trade, safe and efficient port operation must be urgently restored, demanding the urgent implementation of rehabilitation works. A similar urgent rehabilitation plan is currently being prepared for a total of about 50 km of coastal road sections, which were washed away on Upolu and Savaii Islands, in order to secure efficient and safe land transportation. A large volume of stone material is required in the restoration works to be done all over the country, however all the crushing plants in Western Samoa, being extremely obsolete, are insufficient to meet a large demand of crushed rock. A new crushing plant with production capacity enough to provide the crushed rock is imperative to implement restoration works and should be urgently developed.

From this background, the Government of Western Samoa made a request to the Government of Japan for a grant aid to restore the port facilities and to construct a crushing plant to supply stone material for the road restoration works.

1.2 Dispatch of the Study Team

In response to the request by the Government of Western Samoa, the Japan International Cooperation Agency (JICA) sent the Study Team headed by Mr. Toshiro Tsutsumi, Senior Inspector, Port Construction, the Third District Port Construction Bureau, Ministry of Transport, to Western Samoa for a period of 40 days from June 12th to July 21st, 1990 to conduct a field study. In the course of the study period, the Study Team collected relevant data and information, consulted with officials of the Government of Western Samoa and signed the Minutes of Discussion on June 22nd. The further study was made in Japan and the draft final report was prepared and presented from 16th to 24th September 1990 in Western Samoa.

The list of the Study Team members, study schedule, list of main interviewees and the Minutes of Discussion are attached in the Appendices of this report.

1.3 Scope of the Study

The objectives of the study are to work out the basic design for the restoration project requested by the Government of Western Samoa through detailed study on the background, scope and effect of the project. The study team conducted the following studies to formulate an adequate project plan.

1) confirmation of project background and contents of the request
2) confirmation of project priorities
3) inspection on project sites
4) confirmation of cyclone damages to port and road facilities
5) confirmation of current operation and maintenance of the existing crushing plants
6) natural condition survey (topography, sounding, boring, etc.)
7) study on availability of local construction material and equipment
8) scope of works to be borne by the Government of Western Samoa

The present report presents the results of project study on the project components, facility layout, structural design, project cost, management system and overall project suitability based on the above study.

CHAPTER 2

BACKGROUND OF THE PROJECT

CHAPTER 2 BACKGROUND OF THE PROJECT

2.1 Outline of Western Samoa

2.1.1 Geographical Conditions

Western Samoa is located between latitude $13^{o}S$ and $14^{o}S$ and between longitude $171^{o}W$ and $173^{o}W$ at almost the centre of the South Pacific Ocean, some 3,700 km SSW of Hawaii and 2,900 km NNE of Auckland.

Western Samoa has a total national land area of 2,936 km^2 with the two main islands of Upolu (1,122 km^2) and Savaii (1,714 km^2) accounting for 95% of the total land area and a few small islands comprising the remainder. The islands are protected from rough seas by coral reefs which are more developed around Upolu Island than Savaii Island. Both the main islands are of volcanic origin. Savaii Island has a thin deposit layer and many lava outcrops especially in the northern coastal areas, and its population of some 40,000 is only one-third of that of Upolu Island, mainly because of the poor land fertility.

2.1.2 Socioeconomic Conditions

1) Industry

The GDP of Western Samoa in 1985 was 98.6 million WS$ in 1980 price and the growth rate from 1981 to 1985 was approximately 1.6%. The GDP per capita in 1985 was 622 WS$.

The GDP share by sector in 1983 showed a predominant 48% for agriculture, forestry and fisheries followed by 36% for service, mainly public service, sector. The industrial sector accounted for only 8%. Main agricultural products are copra, taro, cocoa and banana while main industrial products are coconut oil, beer, tobacco, match, soap and sawn timber.

2) Trade

Economy of Western Samoa is a typical monoculture economy which is dependent on export of such agricultural products as copra, taro and cocoa with exports of these three products accounting for about 80% of total export value. As international market prices of copra and cocoa have been sluggish, improvement of export earnings has been attempted by developing export of coconut oil. Balance of trade has been mostly in red and the import value for the last three years exceeded the export value by more than three times despite relatively high import duties, restrictions on import items and stagnation of economic growth.

Structural trade deficit is compensated for by transfer of money from Western Samoans working abroad and also by capital account surplus. Government budget shows a large deficit due to steady increase of expenditure in development projects. Some 60% of development funds are met by foreign assistances to ease a burden of the Government of Western Samoa.

2.2 Outline of Transportation Sector

2.2.1 Marine Transportation

Marine and air transportation play an important role in Western Samoa due to country's geographical conditions. Marine transportation in particular is essential, not only for foreign trade but also to maintain vital link between Upolu and Savaii Islands.

(1) Ports in the Country

Economy and national life of Western Samoa depend on marine transportation due to its geographical conditions as previously described. Four major ports are outlined below and shown in Fig. 2-1 - Fig. 2-5.

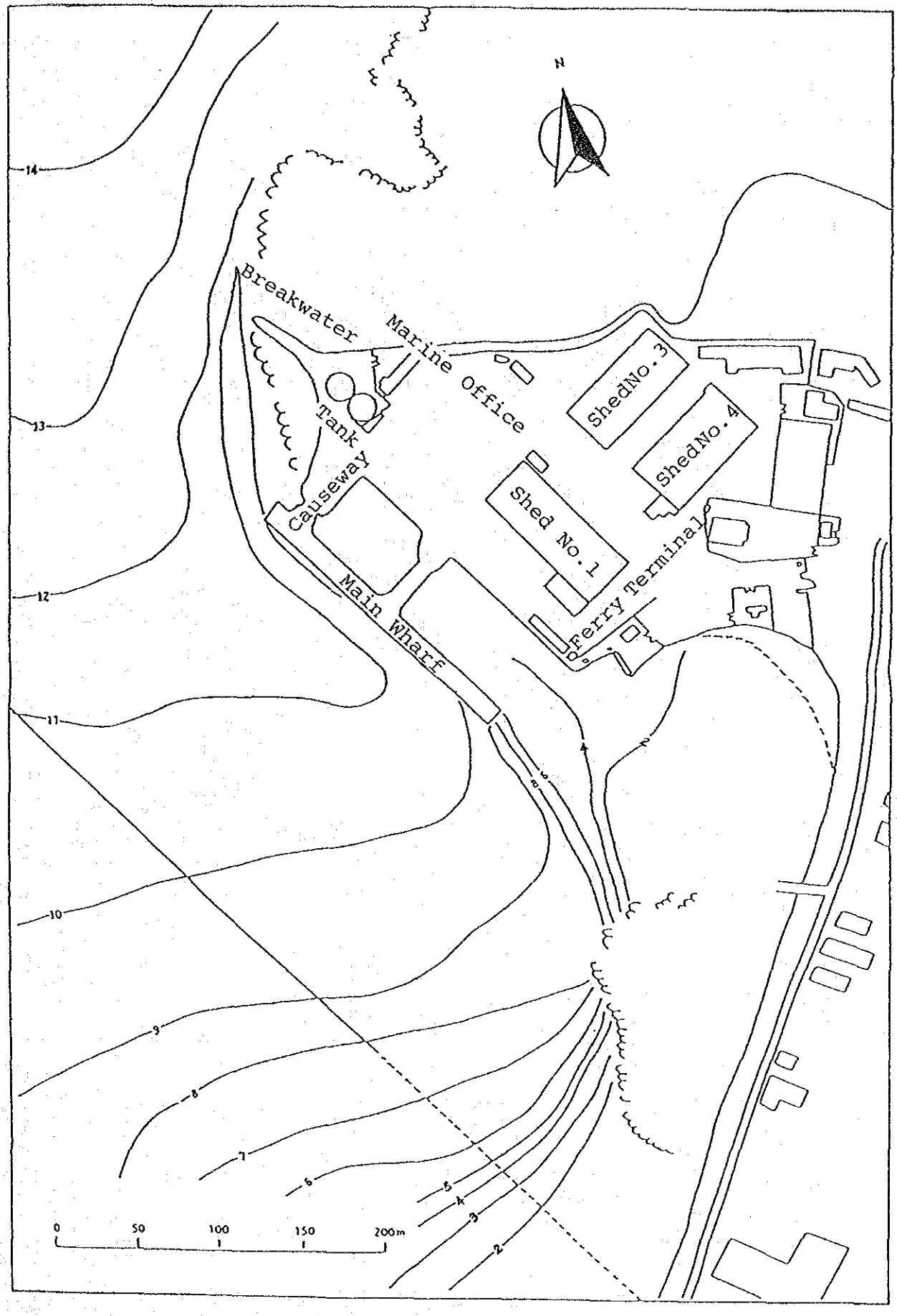


Fig. 2-1 Layout Plan, Apia Port

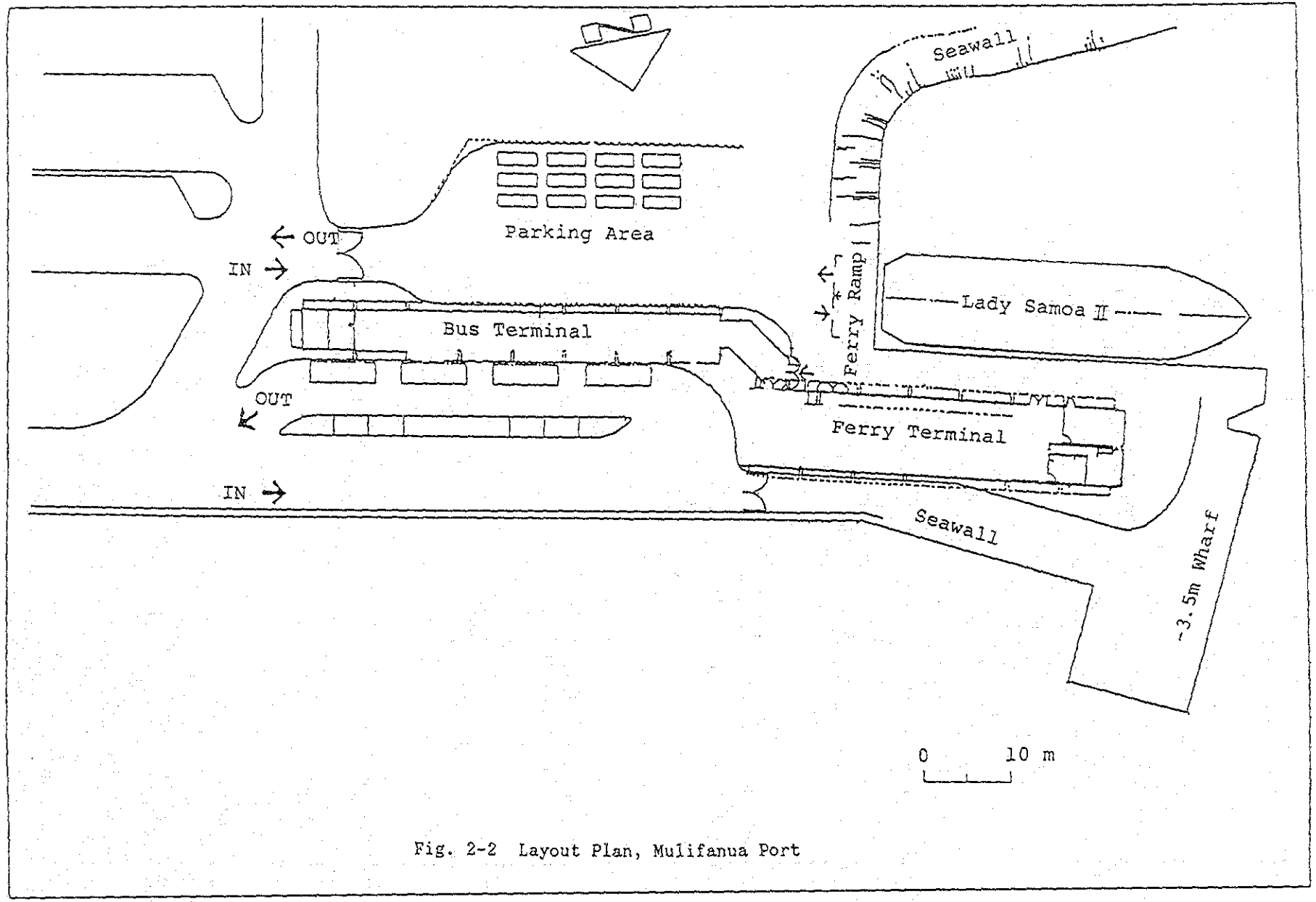


Fig. 2-2 Layout Plan, Mulifanua Port

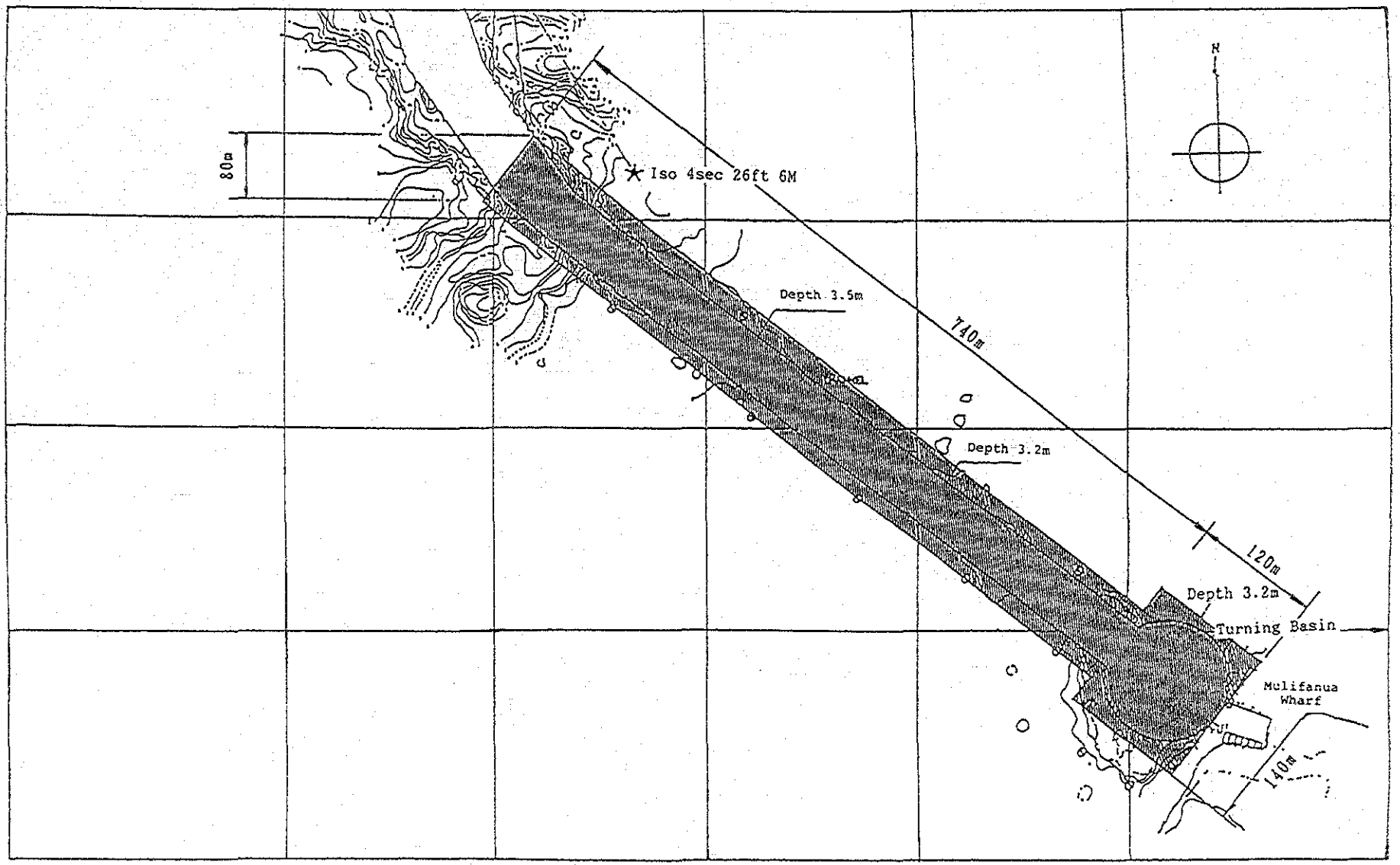


Fig. 2-3 Navigational Channel, Mulifanua Port

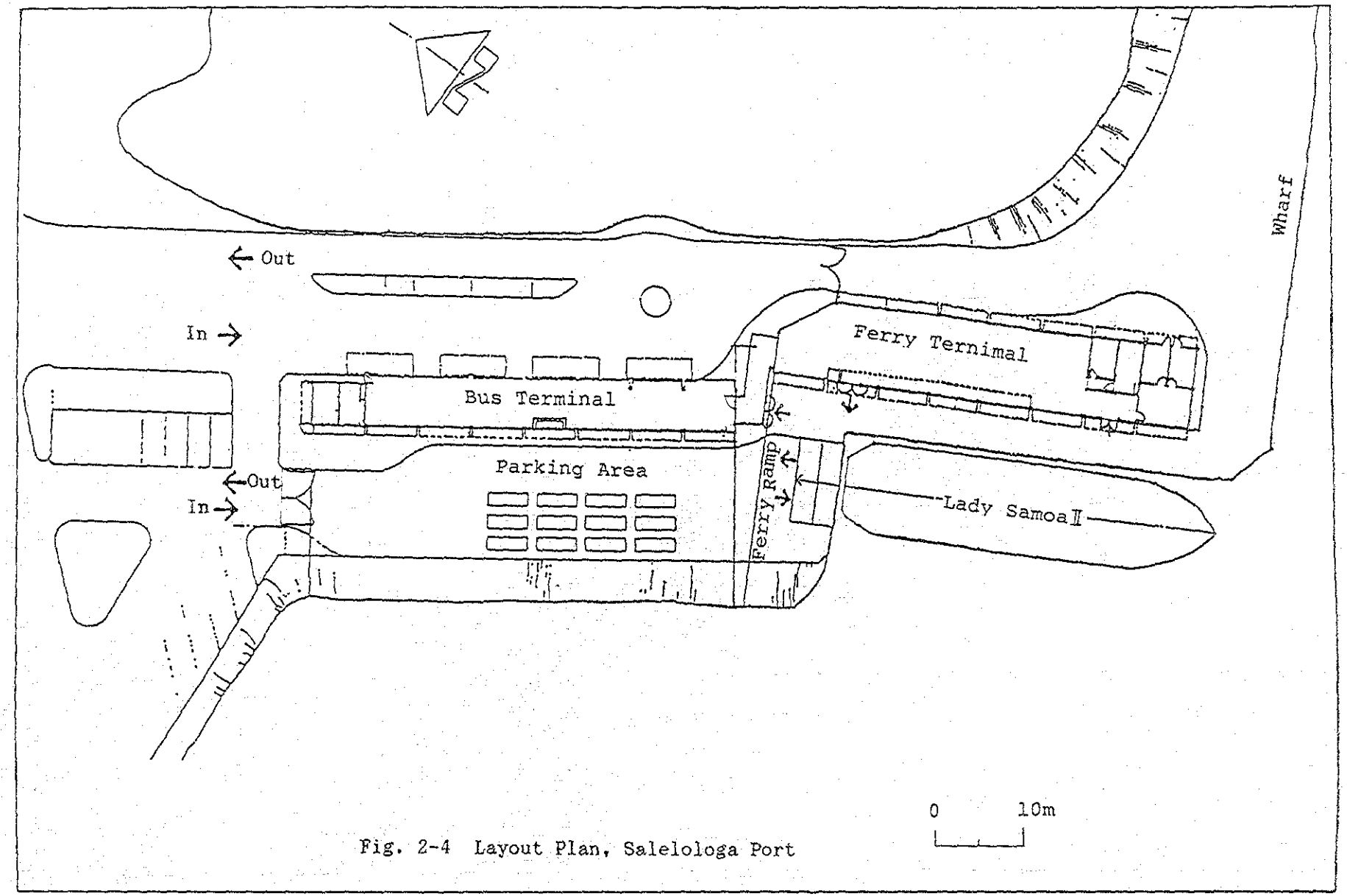


Fig. 2-4 Layout Plan, Salelologa Port

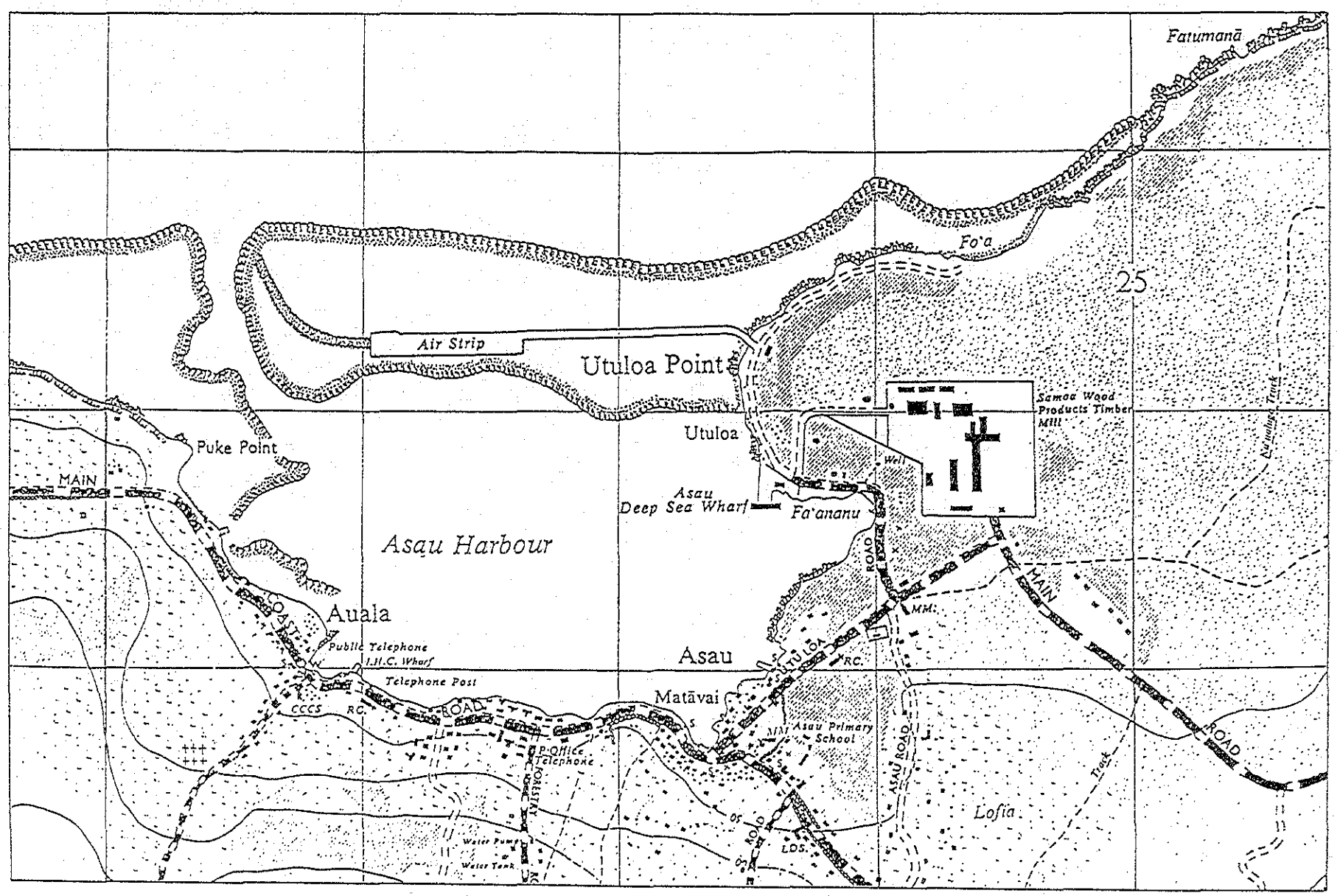


Fig. 2-5 Layout Plan, Asau Port

Apia Port

Handles some 97% of foreign trade (approximately 180,000 tons) and also acts as a ferry base connecting Western Samoa and American Samoa.

Asau Port

Acts as an export base for timber produced in Savaii Island (3,000 - 5,000 tons/year).

Mulifanua and Salelologa Ports

Act as domestic ferry bases connecting Upolu and Savaii Islands and were improved by Japanese assistance in 1985.

(2) Activities of Apia Port

Apia Port is connected with such other countries in the South Pacific as New Zealand and Australia and with Far Eastern countries, including Japan, the U.S.A. and Europe, by 9 liner services of semi-container ships and Ro-Ro ships. In the South Pacific region in particular, the Pacific Forum Line (PFL) established in 1977 by member countries of the South Pacific Forum to facilitate marine transportation in the region provides a shipping service to Apia Port with 2 container ships.

A regular ferry service (approximately 2 trips/week) is provided by the Western Samoa Shipping Corporation (WSSC) between Apia Port and Pago Pago Port in American Samoa which carries 20,000 - 30,000 passengers/year.

Irregular services are provided by cargo vessels and oil tankers, and passenger boats cruising the South Pacific call at Apia Port several times a year.

The activities of Apia Port are outlined as follows.

1) The number of ship's call is 190 - 200/year.

2) The annual cargo volume is about 180,000 tons, of which 150,000 tons are handled through the main wharf. And 20,000 tons and 10,000 tons are handled through a buoy berth and a ferry wharf respectively.

3) The number of passengers handled through the ferry wharf is 20,000 - 30,000 in a year.

2.2.2 Land Transportation

A total number of registered vehicles in 1989 is about 4,900 and a daily traffic volume at the center of Apia city is about 20,000. A total length of road in 1989 is 2,089 km with paved section of 286 km. A road network in Upolu Island consists of a circumferential road running along the coast and three roads crossing the Island north to south. While, a road network in Savaii Island consists of a circumferential road and several secondary roads. The Government of Western Samoa has improved the road network by allocating about 3% of the national budget each year. The conditions of pavement and length of these roads in the last 5 years (1985 - 1989) are shown in Table 2-1.

Table 2-1 shows that there has been no extension of national roads in these 5 years but that rural roads have been paved at a rate of 6.2 km a year. As of 1989, a total length of paved first class national roads is 246 km, while a length of unpaved section is 150 km. Rural and plantation roads are not paved at all and have been extended at a rate of about 14 km a year and their total length in 1989 is 1,290 km.

The number of registered vehicles by type (1985 - 1989) is shown in Table 2-2.

Table 2-1 Length of Paved/Unpaved Road (1985 -1989)(km)

Road Grade	Year	1985	1986	1987	1988	1989
First Class National Road	Paved	221	226	231	236	246
	Unpaved	175	170	165	160	150
	Sub-Total	396	396	396	396	396
Second Class National Road	Paved	40	40	40	40	40
	Unpaved	363	363	363	363	363
	Sub-Total	403	403	403	403	403
Rural/ Plantation Road	Paved	0	0	0	0	0
	Unpaved	1,234	1,250	1,265	1,280	1,290
	Sub-Total	1,234	1,250	1,265	1,280	1,290
Total	Paved	261	266	271	276	286
	Unpaved	1,772	1,783	1,793	1,803	1,803
	Total	2,033	2,049	2,064	2,079	2,089

Table 2-2 Number of Registered Vehicles by Type

Type \ Year	Number of Registered Vehicles				
	1985	1986	1987	1988	1989
Passenger Cars	3,698	3,701	3,761	3,878	4,219
Trucks	432	353	391	346	313
Buses	192	156	212	196	212
Tractors	50	50	39	72	35
Motorbikes	165	138	149	150	140
Total	4,537	4,398	4,552	4,642	4,919

2.2.3 Outline of the Existing Quarry Plants

Crushed stone is one of the most important construction materials in various construction project for concreting work in port rehabilitation, subgrade and pavement in road construction, etc.

(1) Existing Quarry Plants

The PWD currently has two quarries in Upolu Island and one quarry in Savaii Island, though the latter is out of operation due to deterioration. The plants in Upolu Island have also been extremely deteriorated and the rated production capacity of 30 t/h has dropped to about 5 t/h which is hardly capable of meeting the demand of stone materials in Western Samoa.

The facilities of the existing two plants in Upolu Island are outlined below.

a.	Jacques Primary and Secondary Crushers (30 t/h)	2 Nos.
b.	Loader (Caterpillar 930)	1 No.
c.	Trackavators	2 Nos.
d.	Toyota Tip Truck ($4m^3$)	1 No.
e.	Track Rock Drill	1 No.
f.	Compressor (750 c.f.m.)	1 No.

All the above equipment were purchased some 15 years ago and are currently in serious deterioration with frequent breakdowns.

The structure of the Jacques Crusher is shown in Fig. 2-6. The primary crusher is a jaw crusher of 25" x 15" and the secondary crusher is a hammer mill type while the screening machine is a 3 deck of 8 feet x 4 feet.

1) Alafua Quarry

The Alafua quarry is located on the ridge between Papaseea River and Samoi River, some 6 km southwest of downtown Apia as shown in Fig. 2-7. This quarry was constructed following a survey conducted in 1976. The quarry was not in operation at the time of field survey due to deterioration of machinery. The layout of the quarry is shown in Fig. 2-7.

Various preparation works for introduction of a new crushing plant are currently in progress under the supervision of an expert dispatched to Western Samoa by the Australian Government. The works include land preparation for a stock yard, repair of crusher and transportation and loading equipment, improvement of an office building and removal of surface soil on blasting area.

2) Olo Quarry

The Olo quarry is located at the foot of Mt. Olo, some 8 km south of Mulifanua Port. Stone materials for construction of the Faleolo Airport were supplied from this quarry due to its proximity to the Airport.

The crushing machine used is the same model as that of the Alafua Quarry but is mobile equipped with wheels. The production of crushed rock has been suspended due to deterioration of the machinery. Unlike the Alafua quarry plant, rock is taken in open cutting in the Olo quarry.

3) Vaiata Quarry

The Vaiata quarry is located on flat land some 12 km north of Salelologa Port in Savaii Island. The open cutting method is used as in the case of the Olo quarry. The primary crusher is a jaw crusher while the secondary crusher is a hammer mill type. Both are out of operation

due to deterioration. The rated production capacity is estimated to be in order of 20 t/h.

(2) Production Record of Crushed Stone

As already described, the operations of all the existing quarries were suspended several years ago and no detailed production records are available. Their past production activities are outlined below based on available monthly reports.

1) Alafua Quarry

According to production record for 1979 - 1987 in the Alafua quarry, the maximum hourly production rate in 1979 was 36.4 t/h which exceeded the rated capacity of 30 t/h. The total production volume of 17,880 m^3 recorded for the same year could represent the maximum production volume of this quarry. The actual production volume decreased annually with deterioration of machinery and the hourly production rate in 1987 was only 1.4 t/h.

2) Olo Quarry

The production rate of the Olo quarry after 1983 was far below its rated capacity of 30 t/h as in the case of the Alafua quarry. While there are no production records in 1980 in the Olo quarry, it can be assumed that a volume similar to that of the Alafua quarry was produced because of the use of the same crusher. The mean hourly production rate in 1987 of 1.8 t/h is similar to that recorded in the Alafua quarry.

3) Vaiata Quarry Plant

No production records are available for the Vaiata quarry and the rated production capacity is judged to have been about 20 t/h based on the facility size.

From the above, the production capacity of crushed rock in Western Samoa around 1980 could have been 80 t/h as calculated below.

Alafua Quarry	30 t/h
Olo Quarry	30 t/h
Vaiata Quarry	20 t/h

The actual production capacity depends on size of aggregates. The above figure for a maximum stone size of 20 mm can be converted to 115 t/h for aggregate of a maximum stone size of 38 mm.

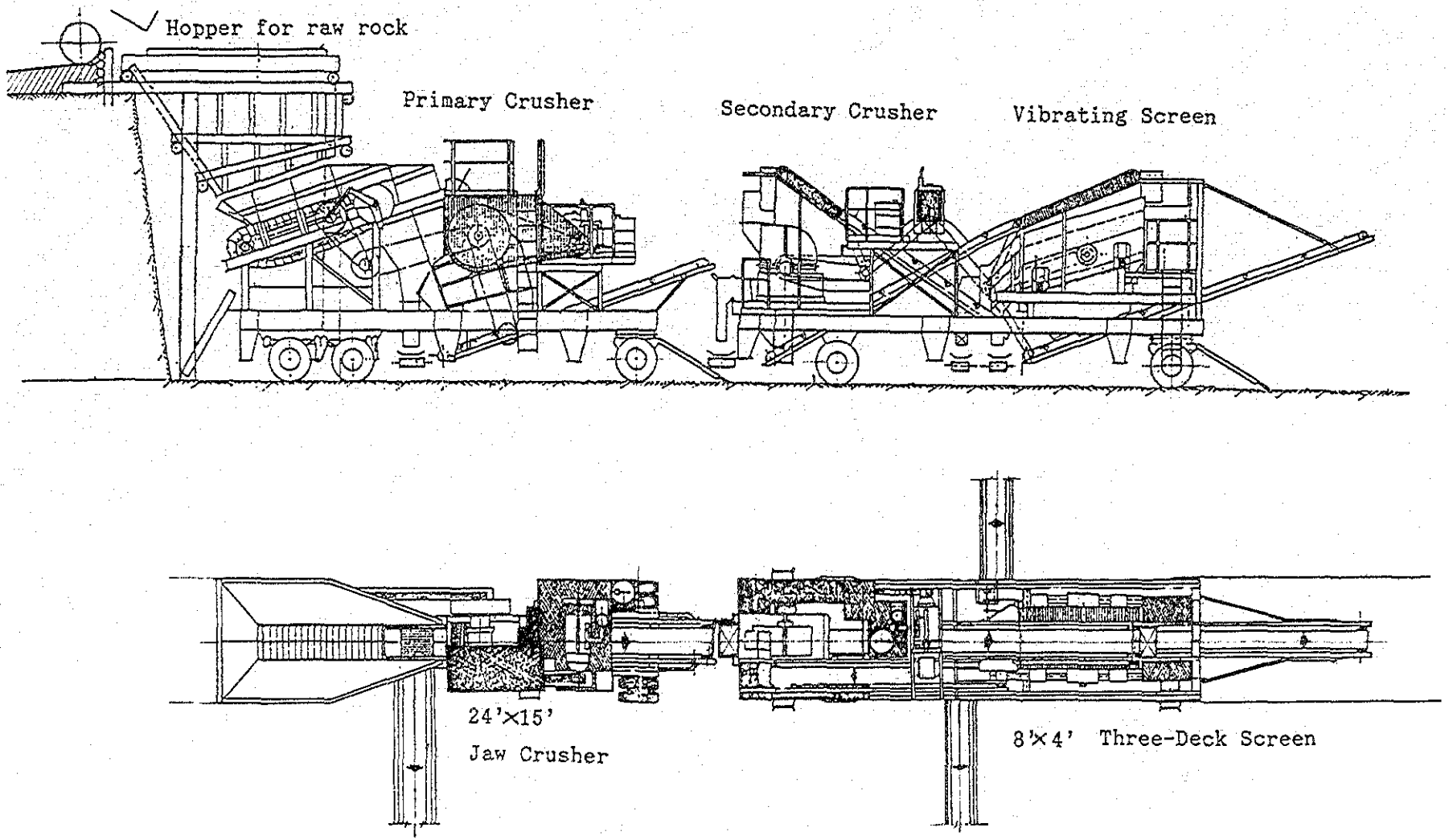


Fig. 2-6 Structure of Existing Crusher

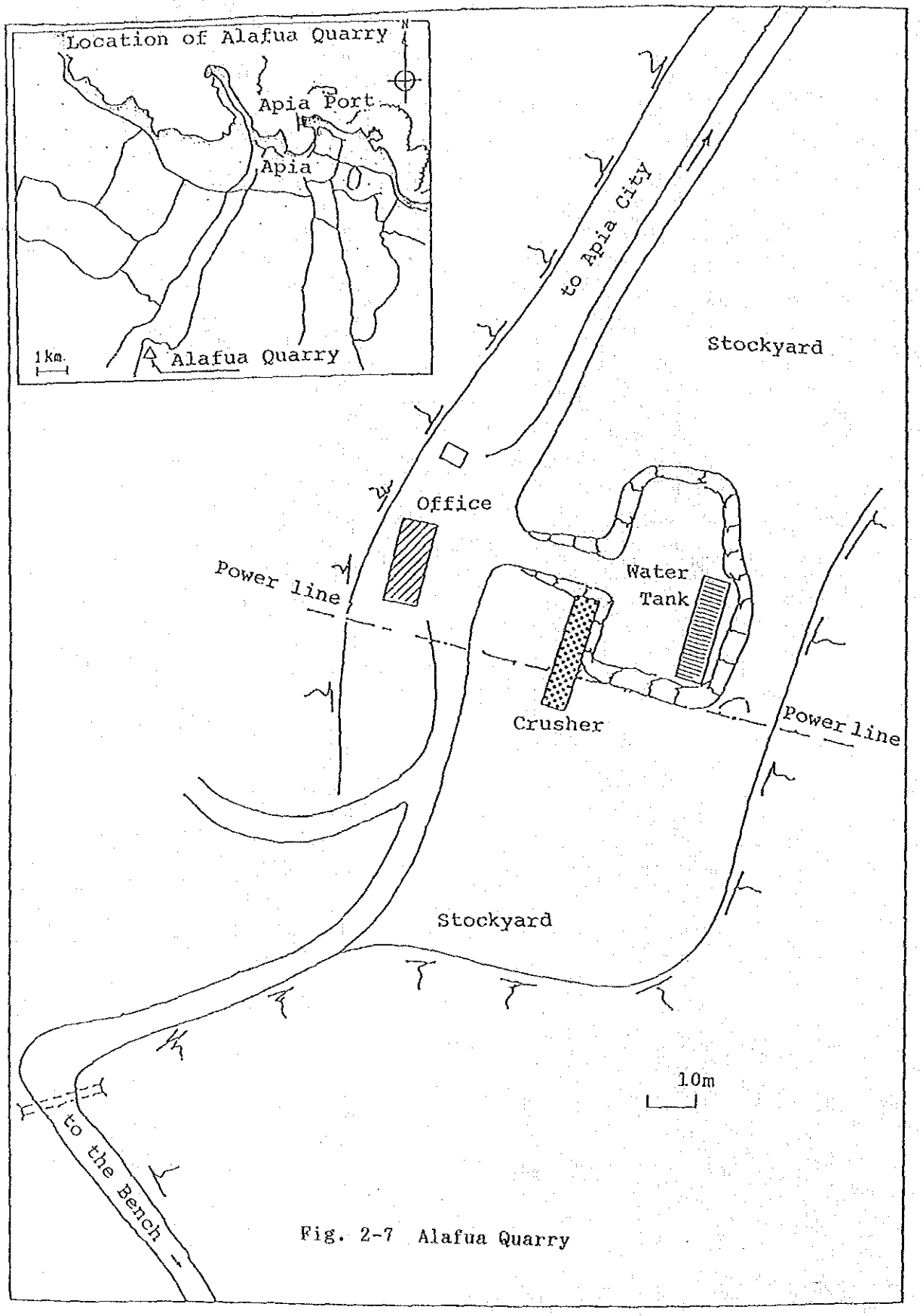
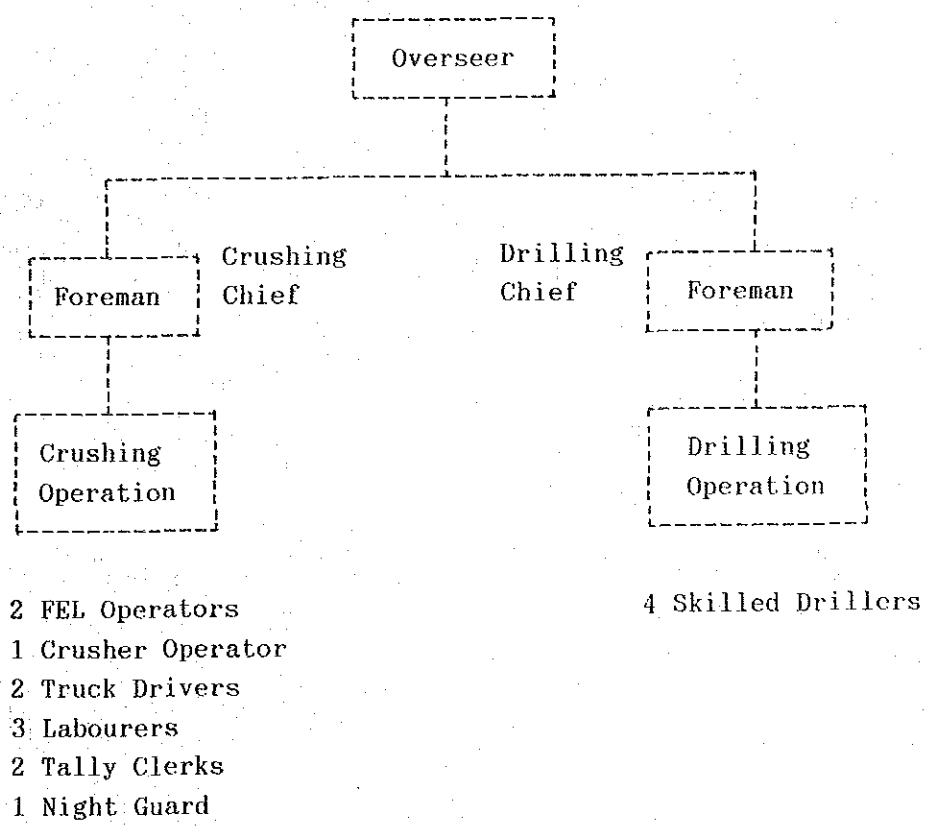


Fig. 2-7 Alafua Quarry

(3) Organization of Quarry

The present administrative organizations of the Alafua and Olo quarries are shown in Fig. 2-8. The two groups of drilling and crushing are controlled by respective foremen under an overall control of a plant overseer. The drilling group consists of 4 drillers while the crushing group consists of 2 loader operators, 1 crusher operator, 2 truck drivers, 3 labourers, 2 tally clerks and 1 night guard. Each quarry, therefore, has a total of 18 employees, including the overseer and two foremen. The quarries are under control of the PWD and are managed under instruction of the Chief Civil Engineer.

Fig. 2-8 Organization Chart, Existing Quarry



2.3 Outline of Related Projects

2.3.1 National Development Plan

The 6th National Development Plan (DP6) for 1988 - 1990 indicates the following three development objectives.

(i) Economic growth in agriculture, forestry, fisheries and industry

(ii) Improved productivity and establishment of firm economic policies for stable growth

(iii) Manpower development

With regard to the agriculture, forestry and fisheries sector, the following three main targets are introduced.

(i) Effective use and development of national land

(ii) Improved productivity of existing plantations

(iii) Diversification of agricultural products

The following four targets are introduced for development of port facilities which play a crucial role in maritime transportation for both foreign and domestic trade.

(i) Improvement of safety and efficiency of foreign and domestic maritime transportation

(ii) Development of safe and efficient facilities to handle containers in Apia Port

(iii) Introduction of port management system for efficient cargo handling operation

(iv) Development of manpower capable of operating systems and facilities to be introduced as part of the port management system

The projects shown in Table 2-3 are listed as maritime transportation projects in the DP6.

Table 2-3 Maritime Transportation Projects Implementation Plan (DP6)

(unit: 1,000 WS$)

Project \ Year	1988	1989	1990	Total	Foreign Aid	Donor Organization
Container Facility at Apia Port	1,900	-	-	1,900	1,900	ADB
Ferry Facility (Passengers/Vehicles)	8,000	-	-	8,000	8,000	Japan
Tug Boat	3,500	-	-	3,500	3,500	Japan
Training and Manpower Development	90	90	45	225	200	UNDP
Apia Port Development	-	806	13,487	14,293	12,162	Japan
Total	**13,490**	**896**	**13,532**	**27,918**	**25,762**	

Road facility is considered to be the most basic infrastructure serving all types of economic activities and the following 3 projects are planned in the DP6 to save transportation cost and to increase agricultural productivity through road improvement.

(i) Rural road improvement work (eastern coastal road in Upolu Island)

(ii) Apia municipal road improvement work

(iii) Extension of plantation roads (Upolu and Savaii Islands)

The road improvement projects planned in the DP6 are shown in Table 2-4.

Table 2-4 Road Improvement Projects (DP6)

(unit: 1,000 WS$)

Project \ Year	1988	1989	1990	Total	Foreign Aid	Donor Organization
Richardson Road (Eastern Coast on Upolu)	6,600	4,400	-	11,000	11,000	ADB
Upolu West Coast Rd. (Apia - Faleolo)	-	-	1,500	1,500	1,000	Australia
Matafele Reclaimed Area	300	-	-	300	-	-
Leone Bridge	-	400	-	400	-	-
Plantation Road Improvement Work	100	150	150	400	-	-
Feasibility Studies	-	250	250	500	500	Australia
Total	**7,000**	**5,200**	**1,900**	**14,100**	**12,500**	

2.3.2 Restoration Plan of Cyclone Damages

(1) Cyclone "Ofa"

According to the weather maps obtained from the Fiji Meteorological Service, the tropical low pressure born off Tuvalu Island on January 30 changed its course to the south and then to the southeast by south through the sea area of Western Samoa and Tonga while gradually growing as shown in Fig. 2-9.

As it passed Western Samoa, the cyclone "Ofa" was still growing and, the central air pressure was around 980 mb which is not particularly strong compared to typhoons attacking Japan from time to time. The main characteristic of the

cyclone "Ofa", however, was its wind velocity which was almost the strongest ever recorded in the century and most of the damages were caused by the wind.

The available meteorological data were mostly observed at Apia and sorted by the New Zealand Meteorological Service. Fig. 2-10 shows hourly observation record of the maximum mean wind velocity. The maximum mean wind velocity recorded was 42 m/sec and wind velocity of 30 m/sec or more continued about 58 hours, indicating that the cyclone "Ofa" was a cyclone of the largest scale. Fig. 2-11 shows wave observation data from February 1st to February 3rd when "Ofa" attacked Samoa, recorded by the wave gauge installed between Upolu and Savaii Islands for regular observation. According to these data, the highest significant wave height was about 8 m with a 10 second period. The higher waves concentrated between the night of February 3rd and the following morning. In consideration of the topographical conditions of the area around the wave gauge, however, these waves can differ from those attacked Apia Port and this is verified by calculating the wave characteristics which had been generated by the cyclone "Ofa".

(2) Condition of Cyclone Damages

The cyclone "Ofa" passed from north to south on the western side of Western Samoa, damaging port facilities and roads along the northern coast of Upolu and Savaii Islands by high waves from the north, generated by strong northerly wind. The cyclone damages are summarized below.

1) Port Facilities

Damages to the port facilities in Apia and Mulifanua are shown in Fig. 2-12 and 2-13.

Apia Port

- Causeway

  Back-filling material along the entire length of the causeway connecting the main wharf and the container yard was completely lost due to waves at the time of the cyclone. Armour stone weighing 1 ton covering the slope of the causeway were pushed inwards up to 20 m. Part of the back fill material in the reclamation area has been moved to and deposited in the small boat basin at the back of the main wharf. The causeway was scoured about 1 m below sea level and completely lost its function as a connecting road.

  The coconut oil loading pipeline laid along the causeway was also damaged and a temporary pipeline has currently been installed on steel piles driven into the sea bed.

  While the Apia Port Development Project currently in progress plans to improve cargo handling efficiency by reclaiming the area between the two causeways behind the main wharf, the loss of the off-shore side causeway has made construction of a temporary revetment necessary to complete the reclamation work. About 90% of the back-filling work has so far been completed at the back of the main wharf.

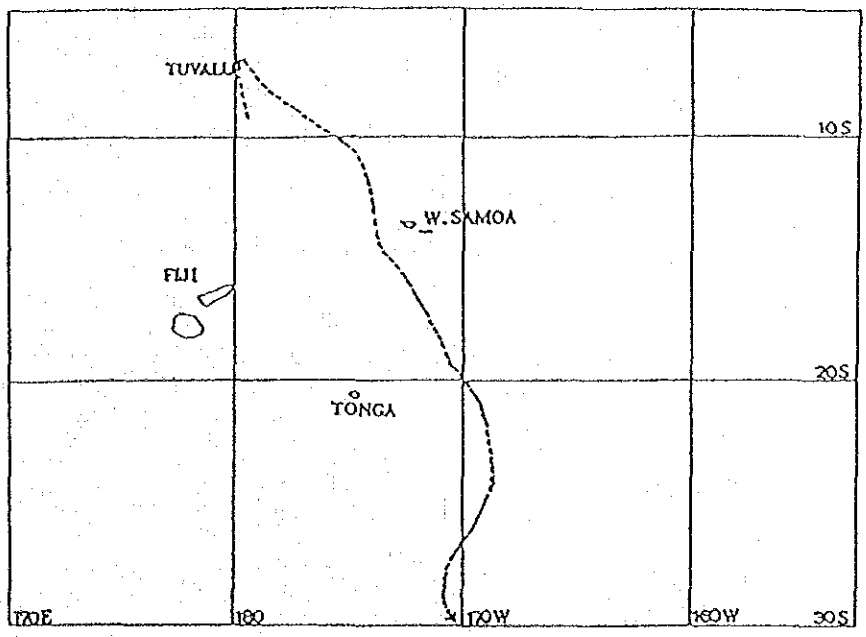


Fig. 2-9 Track of the Cyclone "Ofa"

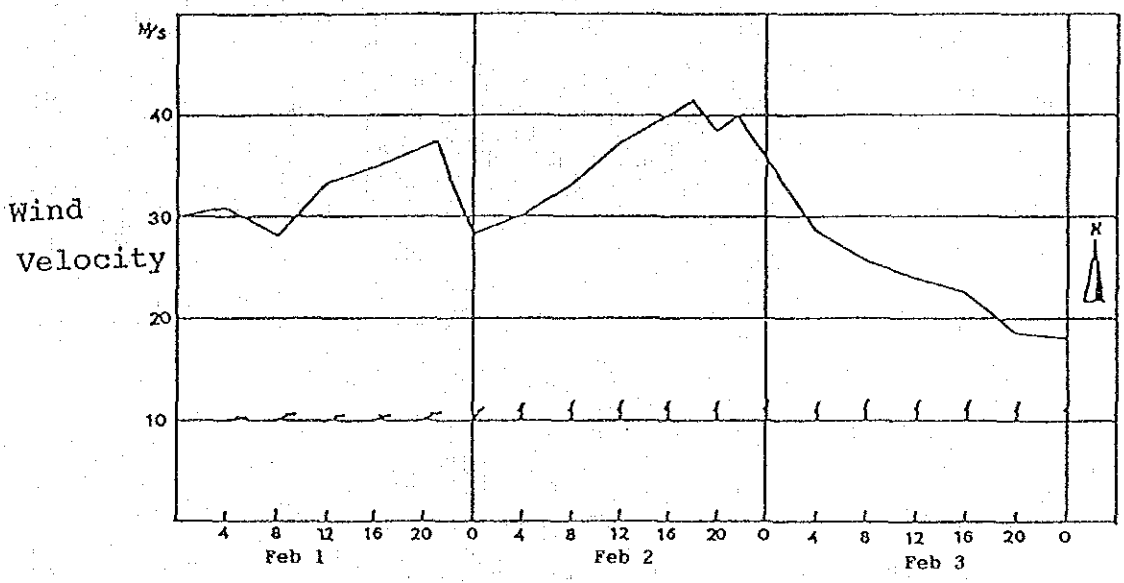


Fig. 2-10 Wind Record (Apia City)

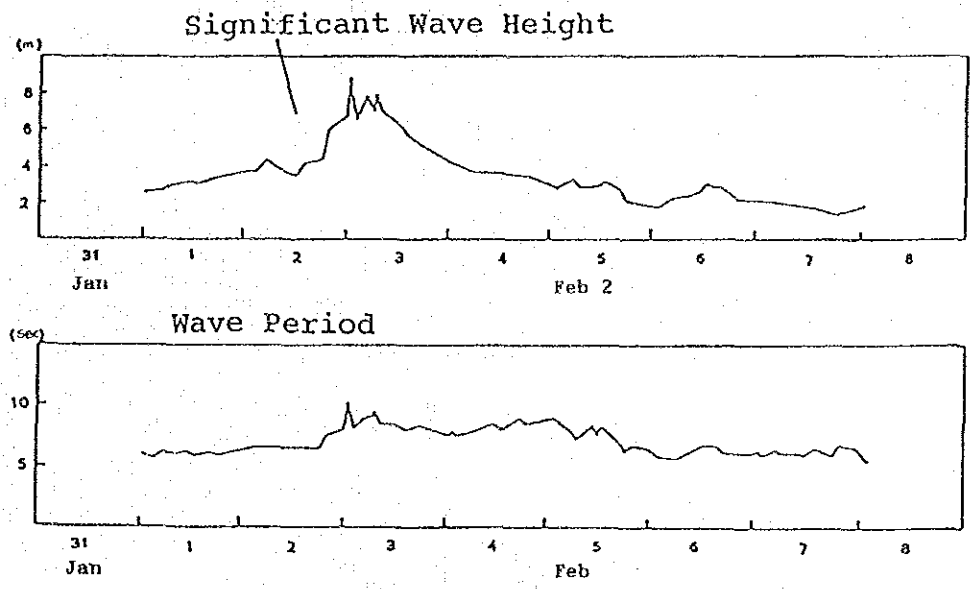


Fig. 2-11 Wave Record

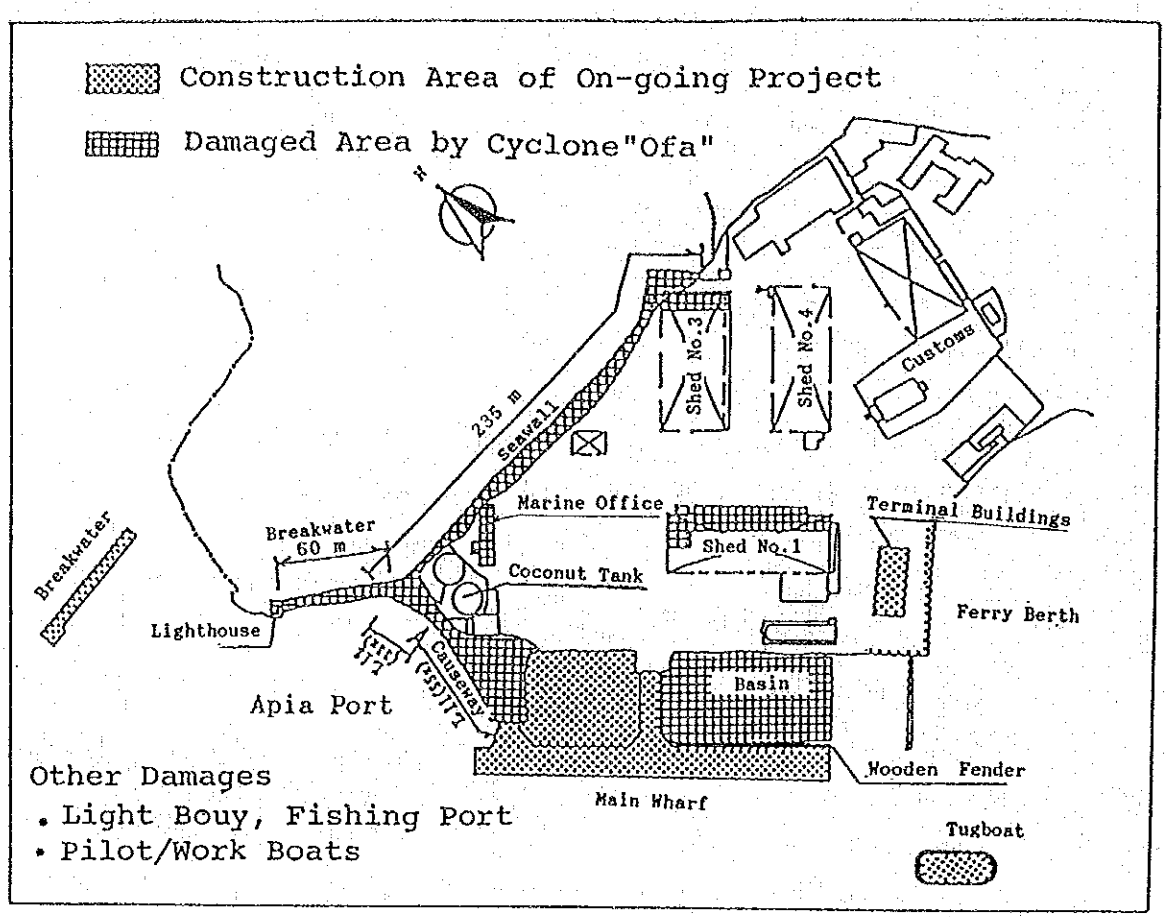


Fig. 2-12 Cyclone Damages, Apia Port

- Seawall

  The overflow of waves during the cyclone washed away the back-filling material of the revetment, destroyed the slope and moved armour stones weighing between 500 kg and 1 ton inwards by a maximum of 10 m. The copra shed located near the causeway has been demolished, as the foundation was scoured and the shed was seriously damaged beyond repair.

  The concrete fence erected along the revetment at the coconut oil tank yard collapsed by a direct action of the waves, and a new concrete fence has been erected inward from the old fence. The oil tanks were fortunately undamaged.

- Breakwater

  The entire breakwater was washed away by the waves caused by the cyclone and armour stones of 500 kg - 1 ton were moved scattering on the toe of the slope of the causeway.

  While the 100 ton bollard located at the far end of the breakwater was undamaged, the light beacon installed in the same place collapsed.

- Marine Office

  The concrete block walls collapsed on the north and west sides due to the strong wind and waves with the storage and toilet located on the west side of the office completely losing their walls and roofs. Vinyl sheets are currently being used as temporary walls and roofs to allow these facilities to function in a smaller scale.

The eastern half of the office which was protected from the strong wind by the coconut oil tanks suffered relatively minor damage.

- Cargo Sheds

Of the 3 sheds, the sheds No. 1 and No. 3 directly subjected to the strong wind were seriously damaged. In the case of the shed No. 1, the roofing materials on the north and west sides were blown off. The north wall and roof of the No. 3 shed were also blown off. In addition, containers stored in the shed No. 3 were moved and damaged the pillars of the shed. The damage to the northernmost part of the shed No. 3 was serious and this part is no longer in use for cargo storage. In those places where the damage is not so serious, vinyl sheets are being used to cover cargoes. As the doors to the sheds were also damaged, security against pilferage becomes serious.

- Wooden Fender

The wooden fender installed along the back of the eastern side of the main wharf to moor such small boats as tug boats consists of wooden piles of 30 cm in diameter placed at intervals of 3 m, connected by wooden beams at the top and fixed to the concrete apron by bolts. The fender shows signs of deterioration due to natural aging and is damaged by the cyclone. Two wooden piles were broken and about one third of the beams on the east side were either lost or deformed, requiring urgent repair.

Mulifanua Port

- Ferry Ramp

The ferry ramp was damaged in the upper section of the sheet pile structure and the concrete apron behind it due to grounding of the ferry boat, the Lady Samoa II which mooring ropes were cut by the strong wind at the time of the cyclone. The concrete coping was lost for the section of about 5 m, exposing top of the sheet piles and the back-filling material of the ferry ramp was washed away.

The sheet piles were pushed inland by a maximum of 1 m and were buckled. The slabs were broken by the ship load and subsided by a maximum of 50 cm. The space under the slab, including the section of a gravity type, becomes hollow.

The concrete blocks laid at the top of the gravity type wharf next to the sheet pile type wharf were pushed inland by a maximum of 55 cm, moving the concrete slabs behind the blocks.

Upper fixing bolts of a rubber fender were also lost and the fender suspends with the lower bolts fixed.

The rubble revetment next to the gravity type wharf was also damaged and about one third of it on the the off-shore side was washed away.

- 3.5 m Wharf

This wharf was constructed in 1957 using concrete piles. Its detailed structure before the cyclone is unknown because of lack of relevant structural drawings. The damages are outlined below.

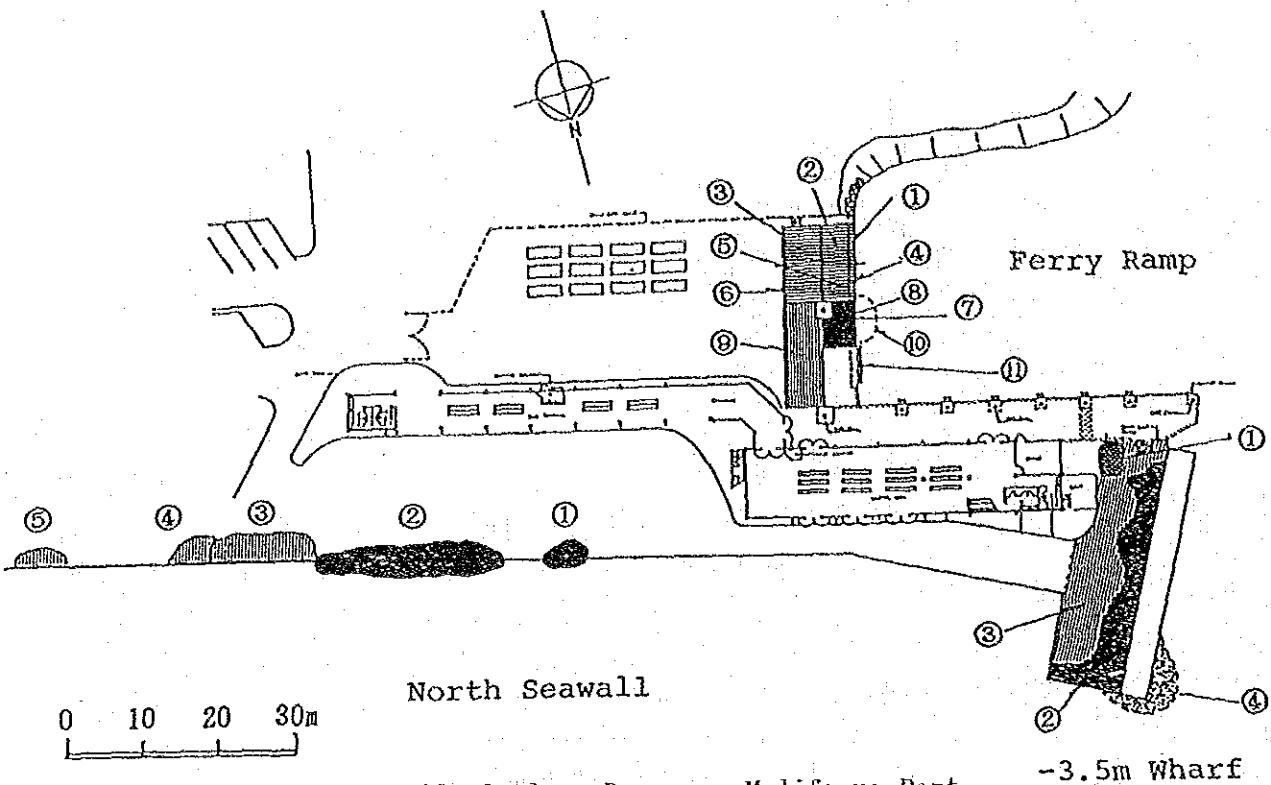


Fig. 2-13 Cyclone Damages, Mulifanua Port

Ferry Ramp		Damage
Section 1	Concrete block	Small displacement, not serious
2,3	Concrete apron	Subsidence of 10-20 cm, cavity underneath
4	Concrete block	Displacement of 40-50 cm
5,6	Concrete apron	Displacement of 40-50 cm, subsidence of 10-20 cm
7	Concrete coping	Buckling of pile head, displacement of 50 cm
8	Concrete apron	Subsidence of 50 cm for 5 m section
9	Concrete apron	Cavity of 10-20 cm
10	Backfill sand	Washed away and deposited in front of ramp
11	Rubber fender	Suspending with fixing bolts broken

-3.5 m Wharf		Damage
Section 1	Oil tank	Unserviceable with foundation damaged
2	Concrete apron	Broken into pieces and subsided about 1.0 m
3	Concrete apron	Broken with many cracks
4	Backfill scoria	Scoured and deposited in front of wharf

Seawall	Damage
Section 1	Damaged and subsided about 1.0 m
2	Concrete pavement broken 5 m in width
3	Concrete pavement broken 5 m in width
4	Concrete pavement cracked
5	Concrete pavement subsided about 20 cm

All 8 concrete piles have cracked at the joints with the upper concrete deck.

While no cracks are observed on the concrete deck, uneven subsidence has taken place resulting in disjoints of up to 5 cm. The central part of the deck has subsided and the deck generally tilts towards the sea.

A 3 m concrete pavement immediately behind the deck was broken into pieces by the lifting force of the waves. The pavement further behind it suffered only minor damage but shows many cracks. The wharf is much damaged at the seaward end and the concrete slabs have fallen into the sea.

The back fill of scoria of about 10 kg was scoured out by about 1.5 m in depth and 3 m in width scattering in front of the wharf.

The concrete beams retaining backfill were damaged by waves and some fell down onto the front rubble slope. A 3 m section immediately behind the deck and at the end of the wharf were seriously damaged with most of them broken.

The concrete foundation for the oil tank located at the back of the wharf and used by ferry boats was damaged and caused the tank unserviceable. The revetment next to the -3.5 m wharf was seriously damaged as it was directly subject to the waves. The wooden office built on the slope of the revetment was completely washed away. One lane of a 50 m section of the concrete paved road behind the revetment was broken.

Salelologa Port

Salelologa Port is protected from northerly waves by reef and therefore no damage occurred to the onshore port facilities. The navigation channel is not silted but most of the marking posts are lost and the lanterns of the beacons are damaged or lost.

Navigation Aids

- Asau Port

There were 18 navigation aids in Asau Port before the cyclone, including 4 marking posts each on both sides of the channel entrance, 5 beacons at the innermost part of the bay and 5 beacons on the coast. The foundation of the marking posts were made of drums filled with concrete and buried in a shallow sea bed. A steel pipe of 10 cm in diameter was erected at a centre of the drum with a triangular mark on its top. All these posts were lost by the waves and scouring of the sea bed. The layout of the beacons was unique in that 5 each were located in front and at the back so that any slight deviation of ship caused by strong current crossing the channel could be accurately detected.

The beacons installed in the sea are steel H piles (30 cm x 30 cm) with top marks but have heavily corroded. The top marks of 4 beacons were lost and the remaining beacon collapsed together with its pile. Of the 5 ground beacons, the central beacon has a white wooden top mark on top of the 8 m high steel tower. The remaining side beacons with a white triangular top mark on top of the 2.5 m high (11 cm in diameter) steel pipe have all been lost.

- Apolima Lighthouse

  The Apolima lighthouse is a stainless steel structure about 4.5 m high from the ground. The lantern at the top fell down as the fixing bolts were broken by the strong wind. The hinges of the door were also broken and the door is out of position. Some of the foundation stones of the concrete base were washed away due to torrential rain.

- Malua Reef Lighthouse

  The foundation concrete was placed in the shallow reef and the lighting device was installed on the top of the 10 m high concrete tower. This lighting device was damaged by the strong wind, and the lamp and batteries, etc. were lost.

- Aleipata Lighthouse

  The Aleipata lighthouse is the same structure as the Apolima lighthouse. The top lantern was damaged and the door, with hinges broken, is lost. The concrete foundation is not damaged.

- Mulifanua Port

  All the 11 marking posts along the channel were lost due to the strong waves. Of the sea beacons, the front beacon was lost and the lantern of the rear beacon was also damaged by the strong wind. The beacon near the coast and the ground beacons are not damaged. The approach channel to Mulifanua Port is currently marked by 15 ball floats which show the southern half of the channel where the siltation is not serious. The ferry boat with shallow draft operate daily at high tide.

2) Road Facilities

Road sections damaged by the cyclone are shown in Fig. 2-14.

Upolu Island

- Upolu East Coast Road

The 19 km section between Moataa at the eastern end of Apia city and Saluafata was seriously damaged because of its proximity to the coast and low ground level. Both seawall and road were washed away, leaving boulders, coral and gravel scattered. All the 6 bridges located in this section are in a dangerous situation with their piers scoured.

Emergency repair work has made this section passable at present though its gravel surface has caused traffic accidents due to skidding and traffic restrictions are frequently made for road surface improvement work, necessitating urgent implementation of rehabilitation work to secure safe and efficient use of the roads.

- Upolu West Coast Road

The damage to the 34 km section between Apia and Mulifanua was relatively small since it has a better protection by well developed off-shore reef. The Upolu West Coast Road is an important trunk road which connects Apia city with the Faleolo International Airport as well as the Mulifanua Ferry Terminal.

The ground elevation of this section is less than 1 m above sea level and the damage was severe in the section between Faleasiu and Fasitoouta in the Mulifanua side where no seawall was provided. The road and land at the back in this section were scoured by about 10 m in width and 1.5 m in depth. Construction of new road is necessary for a 2 km section while seawall and road shoulder should be reconstructed for a 3 km section.

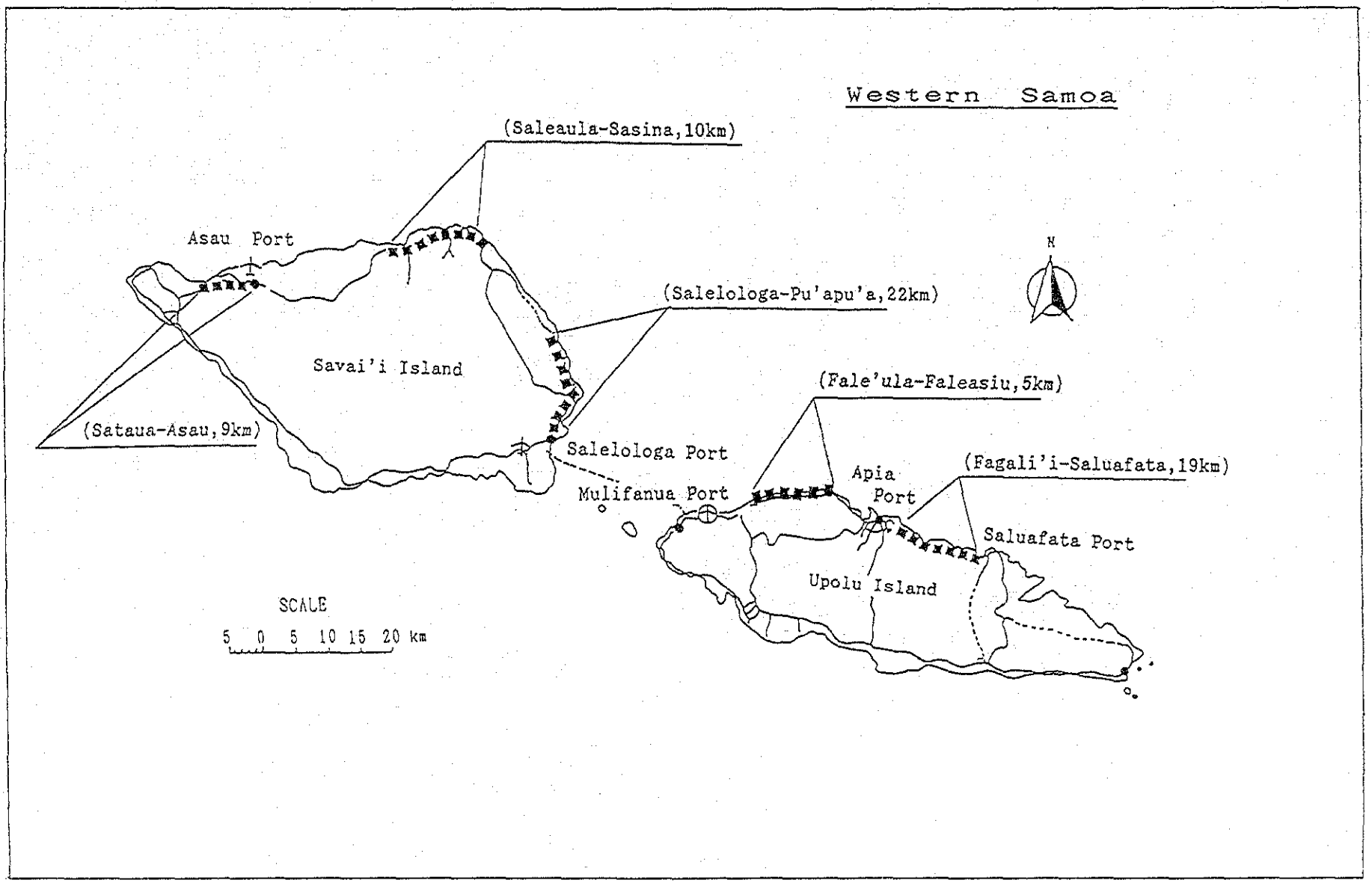


Fig. 2-14 Damaged Road Section

- Savaii Island

The road along the north coast of Savaii Island suffered from extensive damage for a total length of 35 km consisting of a 10 km section between Tuasivi and Puapua, a 15 km section between Saleaula and Sasina, a 15 km section between Saleaula and Sasina, a 9 km section between Sataua and Asau and a 1 km section of the south coast road.

Of the 35 km of damaged road, construction of a new road is required for 15 km and a major repair work is required for 12 km. Complete repavement is also required for the remaining 8 km. At some points, the coastline has retreated up to 100 m inland and, therefore, a new road has to be constructed several hundred meters back from the present coastline to avoid damages by cyclone waves in future. The damages of road in Savaii Island are summarized below.

Required Rehabilitation Work

Section	Reconst-ruction	Major Repair	Repaving	Total
Tuasivi-Puapua	5 km	5 km		10 km
Saleaula-Sasina	7 km	3 km	5 km	15 km
Sataua-Asau	3 km	3 km	3 km	9 km
Salelologa-Sataua		1 km		
Total	15 km	12 km	8 km	35 km

In those sections where the roads were washed away, beaches consisting of boulders, coral and gravel, etc. are used for traffic. Traffic restrictions, including one-way traffic, have been introduced, calling for an urgent implementation of rehabilitation work to secure safe and efficient land transportation. The 11 km section between Sasina and Avao has recently been reopened.

(3) Rehabilitation Plan

1) Port Facilities

As the Government of Western Samoa intends to implement the entire rehabilitation work for the damaged port facilities with the grant assistance of the Government of Japan, no full-scale rehabilitation work has so far commenced. However, some emergency measures have been taken as described below.

Apia Port

- Port Office Building and Sheds

  Vinyl sheeting is being used for covering the roofs, walls and cargoes to prevent damage by rain.

- Coconut Oil Tank

  The collapsed concrete fence of the tank yard has been removed and a new fence has been erected inside. A temporary pipeline has been laid above the seawater to replace the damaged pipeline which was formerly laid along the causeway.

- Causeway

  Minor sand filling work has been conducted but slope works facing the sea have been left damaged.

- Anchorage for Small Boats

  The sunken containers have been removed and the minimum water area for the anchorage of tug boats has been secured.

- Port Communication Equipment

  The wireless equipment on board the tug boat is being temporarily used. The request for emergency assistance to the U.N. has been approved for replacing the damaged equipment.

Mulifanua Port

- Ferry Channel

  The western half of the channel where the deposit of sand was not extensive is marked by ball floats. Ferry boats with shallow draft are operating at reduced frequency at high tide in this newly marked channel.

2) Road Facilities

Following the disaster caused by the cyclone "Ofa", the IDA Study Team surveyed the conditions of cyclone damage over the entire road network in Western Samoa. The Government of Western Samoa is planning the following Road Project in consultation with the IDA taking the findings of the above Study Team into consideration.

Project Name - Emergency Road Rehabilitation Project

Executing Agency - PWD

Project Cost - 35.5 million WS$

Financing

Western Samoan Government	4.0 million WS$
IDA Loan	27.0 million WS$
not fixed	4.5 million WS$

Construction Period - 3 years

Project Commencement Date - June, 1990 (provisional)

Project Scope

1) Upolu Island East Coast Road Rehabilitation Work
   Fagalii - Saluafata (19 km)

2) Savaii Island North Coast Road Rehabilitation Work
   Salelologa - Puapua (22 km)
   Saleaula - Sasina (20 km)
   Sataua - Asau (9 km)

3) Apia Urban Road and Seawall Rehabilitation Work (1.2 km)

The commencement date of the project was planned at June 1990, however delay of about one year is expected because of PWD's incapability of supplying stone materials.

2.3.3 Apia Port Development Plan

(1) Apia Port Master Plan

With regard to development of Apia Port, a Master Plan with a target year of 2005 has been prepared by the Japanese Study Mission dispatched to Western Samoa in 1987 in response to a request by the Government of Western Samoa. The First Phase Plan of this Master Plan consists of those project components requiring urgent implementation.

The Apia Port Master Plan has been prepared taking the following requirements/conditions into consideration in order to solve the current problems and to meet an increasing demand for cargo handling.

1. Improvement of cargo handling efficiency, especially for container cargoes.

2. Improvement of navigational safety.

3. Improvement of safety by means of separating cargo and passenger areas and by other means.

4. Efficient use of available land area.

5. Obsolescence of the existing facilities

6. Natural conditions (geography, currents and waves).

7. Efficient administration and operation of port

Based on the consideration of the above factors, the improvement of port facility is proposed in the Master Plan as listed in Table 2-5 and shown in Fig. 2-15.

Those project components requiring urgent implementation have been selected to form the First Phase Plan of the Apia Port Master Plan as shown in Fig. 2-16 and their expected effects are as follows.

1. Construction of a new breakwater (100 m long) with a lighthouse to minimize wave disturbance in Apia Port in order to secure a working ratio of 95% or over even in the rainy season.

2. Application of anti-corrosion measure to the steel piles of the existing main wharf to extend its service life.

3. Improvement of the ferry terminal to increase safety and efficiency of port operation and cargo handling.

4. Expansion of the cargo handling yard at the back of the main wharf to improve loading and unloading operation to and from the main wharf.

5. Introduction of a new tug boat and a provision of lighting to tanker buoys to secure navigational safety.

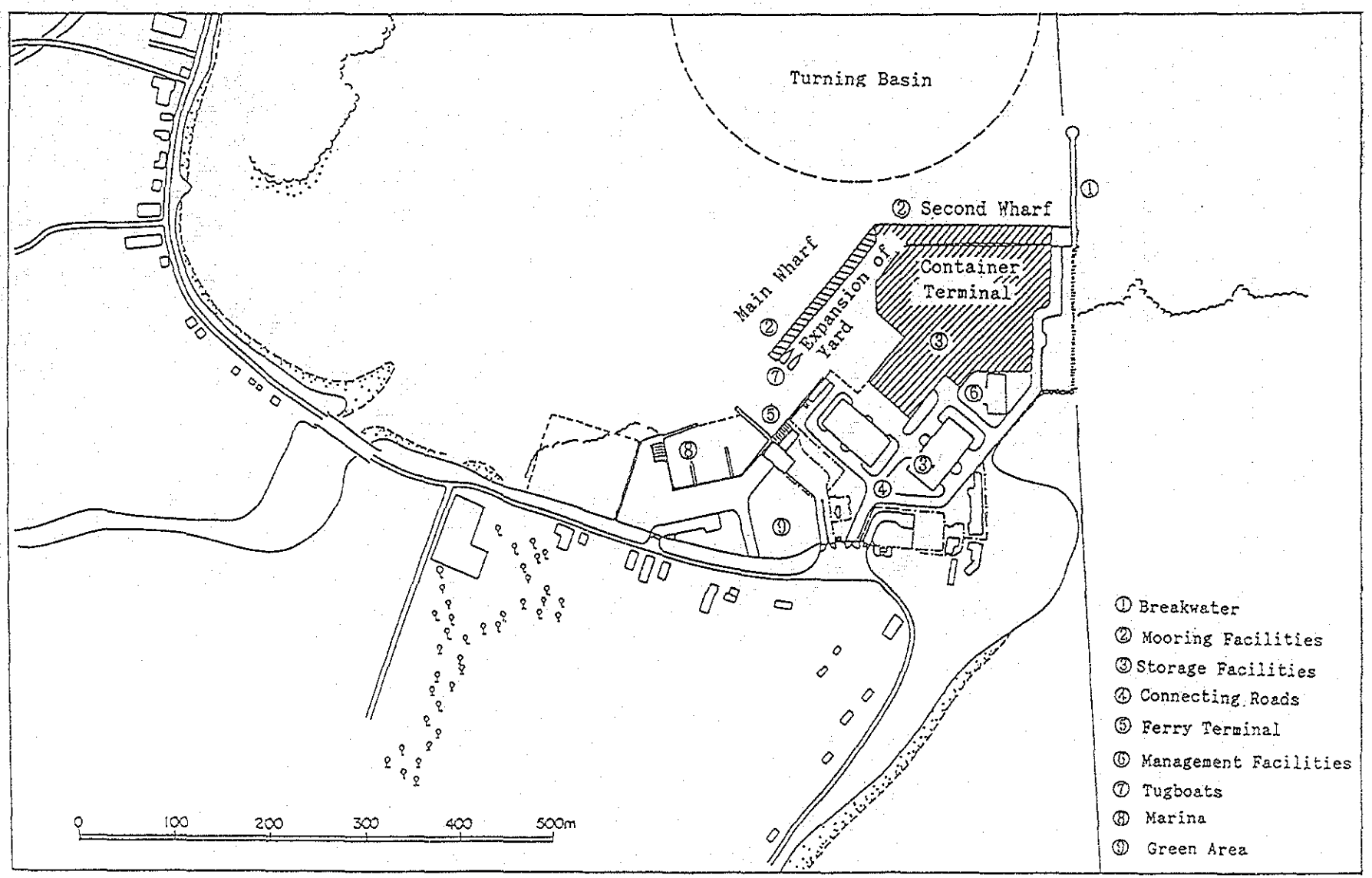


Fig. 2-15 Master Plan, Apia Port

Table 2-5 Apia Port Master Plan

Facility	Function	Dimension or Contents
1) Basins	(a) Turning basin	Diameter = 400 m, Depth (D) = -11 m
	(b) Mooring basin	D = -11 m
2) Breakwater		Length (L) = 100 m
3) Mooring facilities	(a) Main Wharf	Minor repairs
	(b) New Wharf	L = 200 - 225 m D = -11 m
	(c) Ferry berth	L = 50 m
	(d) Wharf for small vessels	Improvement for the coastline
4) Storage	(a) Expansion of yard	Behind the main wharf
	(b) Container terminal	Area 263 slots
	(c) CFS	30 m x 40 m = 1,200 m^2
	(d) Maintenance shop	200 m^2
	(e) Transit sheds	2,500 m^2
	(f) Coconut oil tanks and she	Replacement
5) Ferry Terminal		710 m^2
6) Port management facilities	(a) Main office	1,500 m^2
	(b) Pilot office	200 m^2
7) Tugboats		Replace (2 boats)

(2) On-going Projects

Based on the Master Plan described in the previous section, the Government of Western Samoa requested the Government of Japan a grant aid assistance for the following three objectives.

1 Modernization of Apia Port

2 Improvement of navigational safety

3 Improvement of port management and administration