JAPAN INTERNATIONAL COOPERATION AGENCY

THE REPUBLIC OF MALDIVES

THE MINISTRY OF FINANCE AND TREASURY
THE MINISTRY OF CONSTRUCTION AND PUBLIC WORKS

No. 1

BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR SEAWALL CONSTRUCTION
IN
MALE' ISLAND
IN
THE REPUBLIC OF MALDIVES

OCTOBER 1993

INA CORPORATION
PACIFIC CONSULTANTS INTERNATIONAL

BASIC DESIGN STUDY REPORT ON THE PROJECT FOR SEAWALL CONSTRUCTION IN MALE' ISLAND IN THE REPUBLIC OF MALDIVES
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Preface

In response to a request from the Government of the Republic of Maldives, the Government of Japan decided to conduct a basic design study on the Seawall Construction Project for Male' Island and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Maldives a study team headed by Mr. Yuji Ogura, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs, and constituted by members of INA Corporation / Pacific Consultants International Joint Venture, from August 19 to September 2, 1993.

The team held discussions with the officials concerned of the Government of Maldives, and conducted a field study on West Coast of Male' Island. 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 the friendly relations between our two countries.

I wish to express my sincere gratitude to the officials concerned of the Government of the Republic of Maldives for their close cooperation extended to the team.

October, 1993

Kensuke Yanagiya

Kensuke Yanagiya
President,
Japan International
Cooperation Agency

October 1993

Mr. Kensuke Yanagiya,
President,
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Project for Seawall Construction in Male' Island in the Republic of Maldives.

This study was conducted by INA Corporation in cooperation with Pacific Consultants International, under a contract to JICA, during the period August 13, 1993 to October 29, 1993. In conducting the Study, we have examined the feasibility and rational of the Project with due consideration to the present situation in Maldives and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

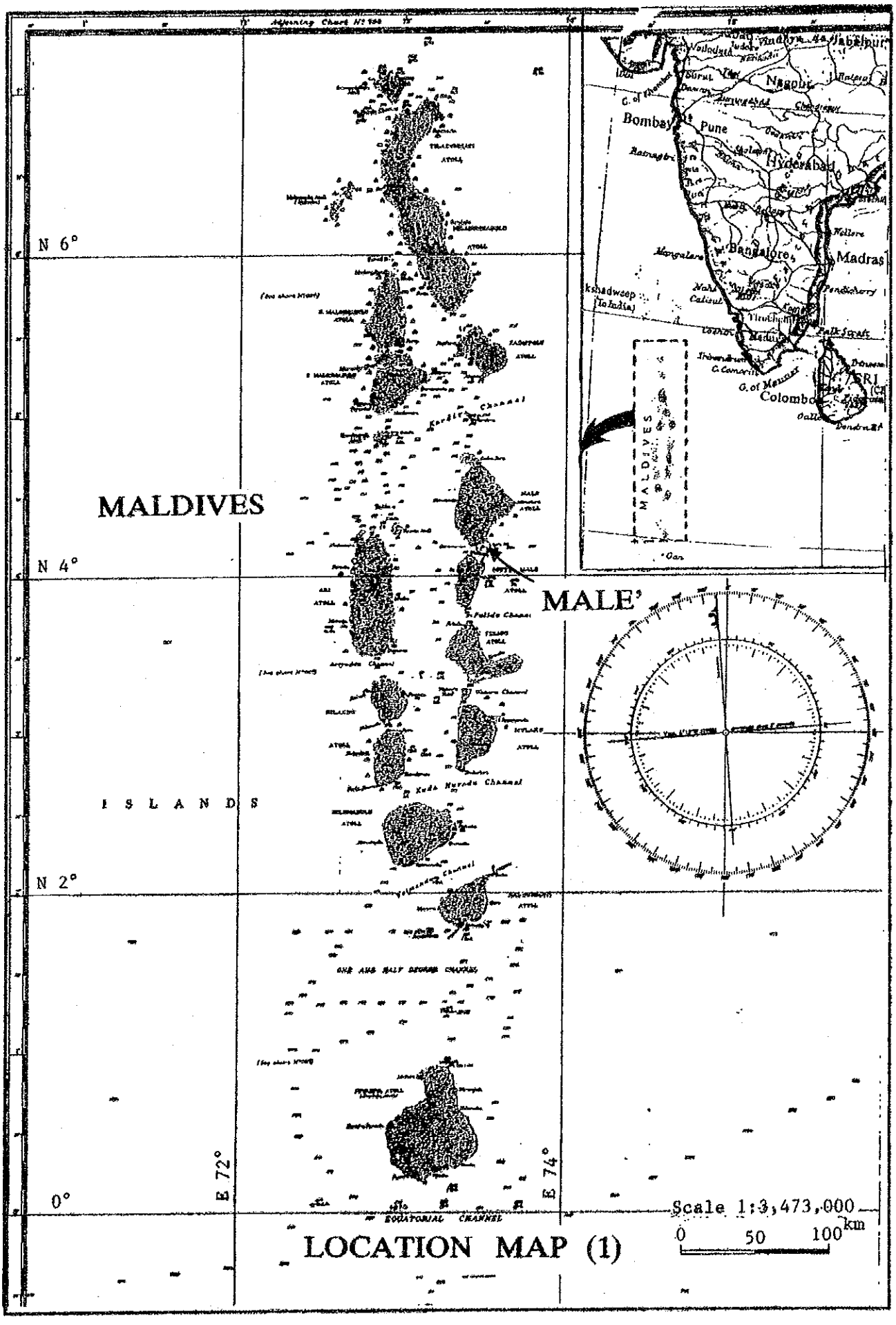
We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs, and the Ministry of Construction. We would also like to express our gratitude to the officials concerned of the Ministry of Foreign Affairs, the Ministry of Public Works and Labour in Maldives, the JICA Sri Lanka office, the Embassy of Japan in Sri Lanka 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,

H. Sakuramoto

Hiroshi Sakuramoto
Project Manager,
Basic design study team
on the Project for Seawall
Construction in Male' Island,
INA Corporation



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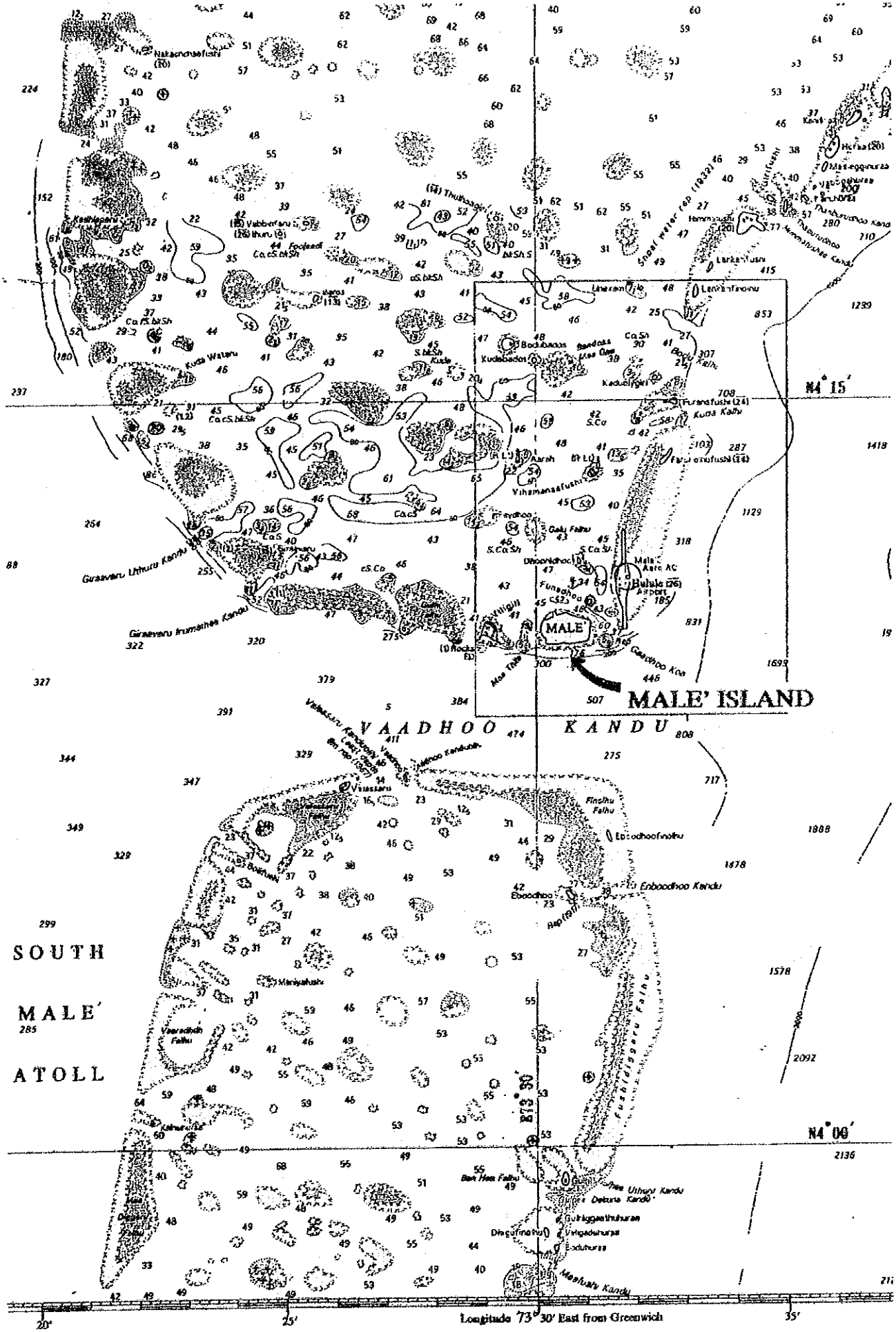

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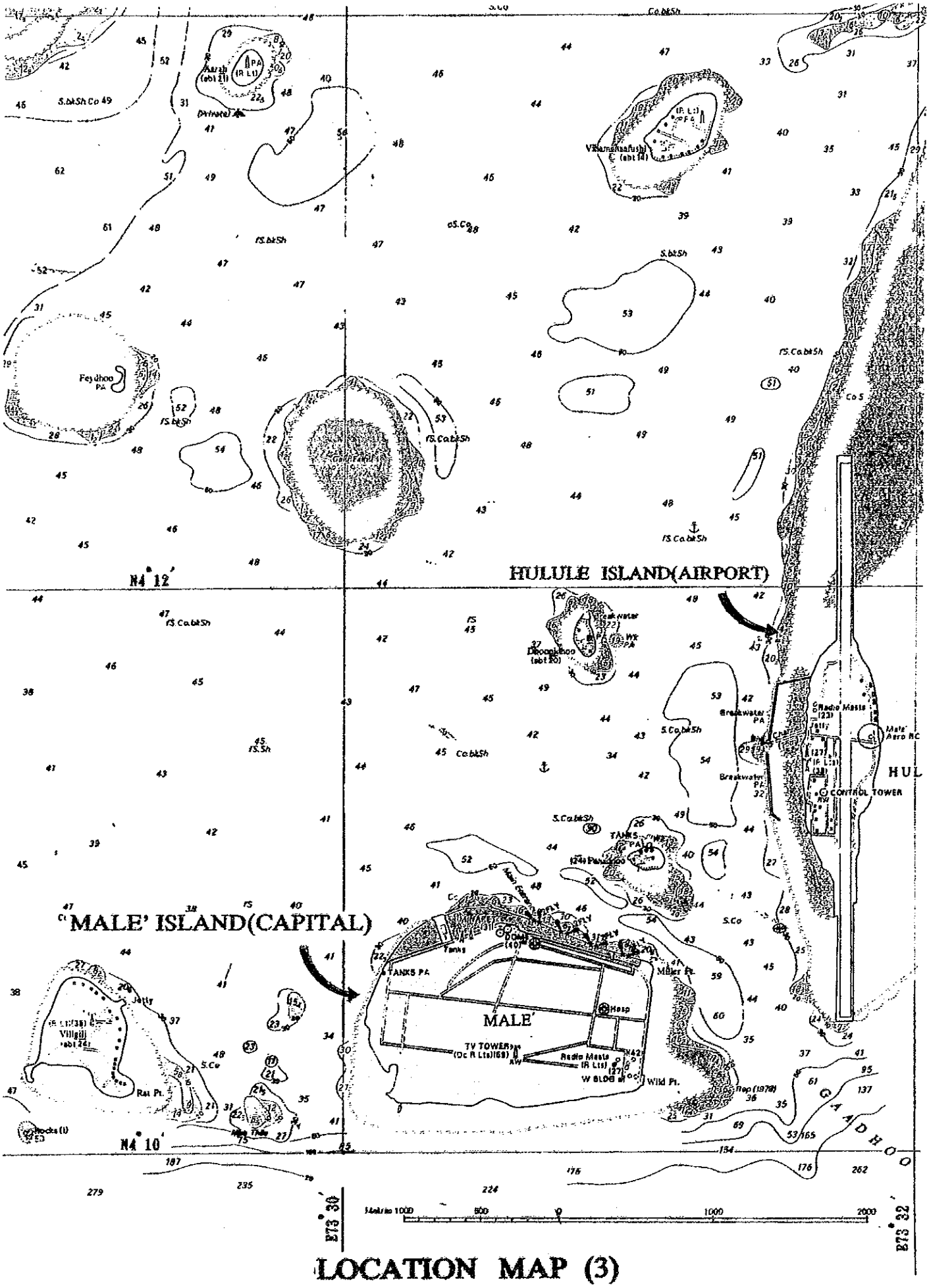

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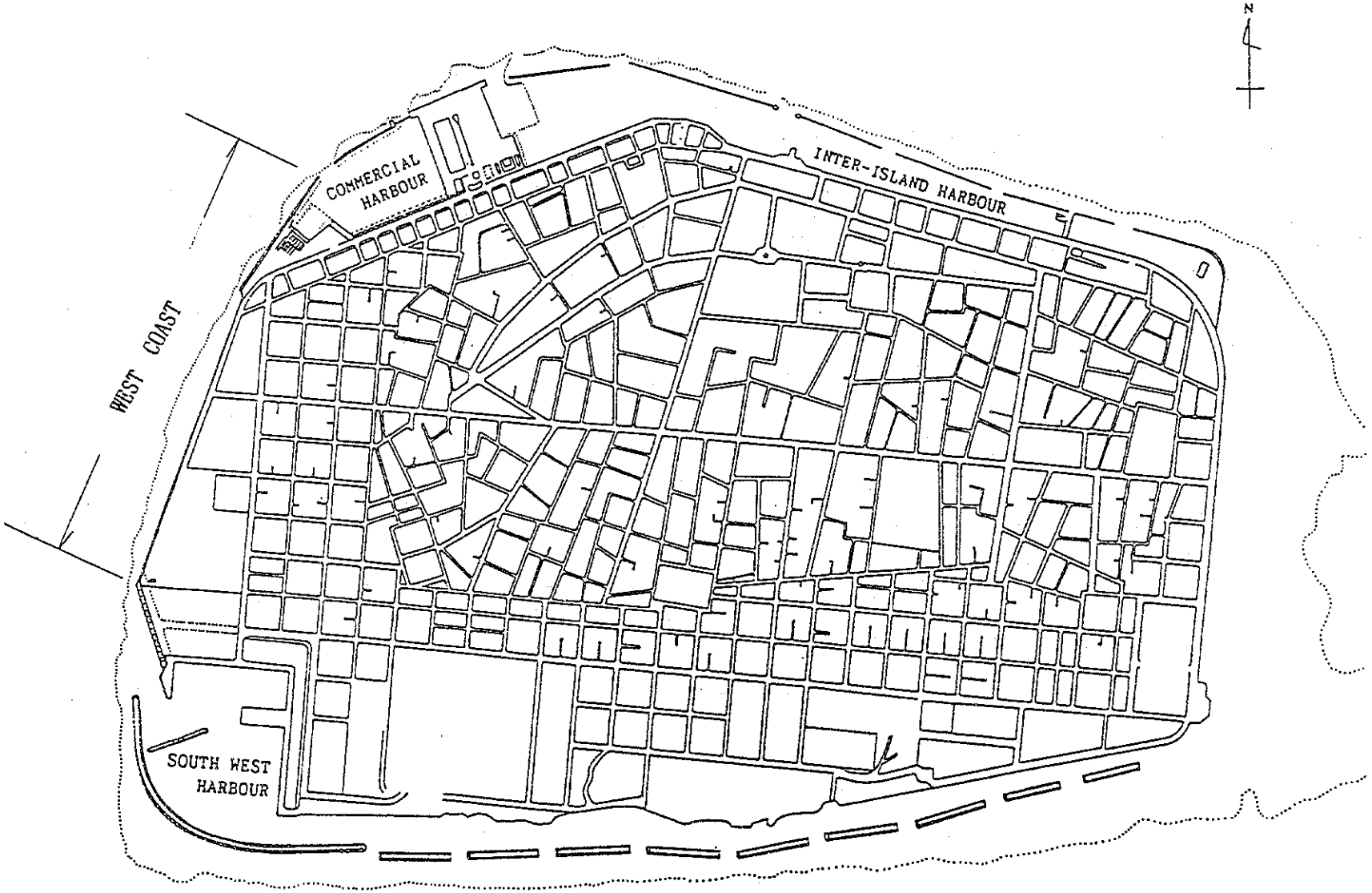

LOCATION MAP (4)

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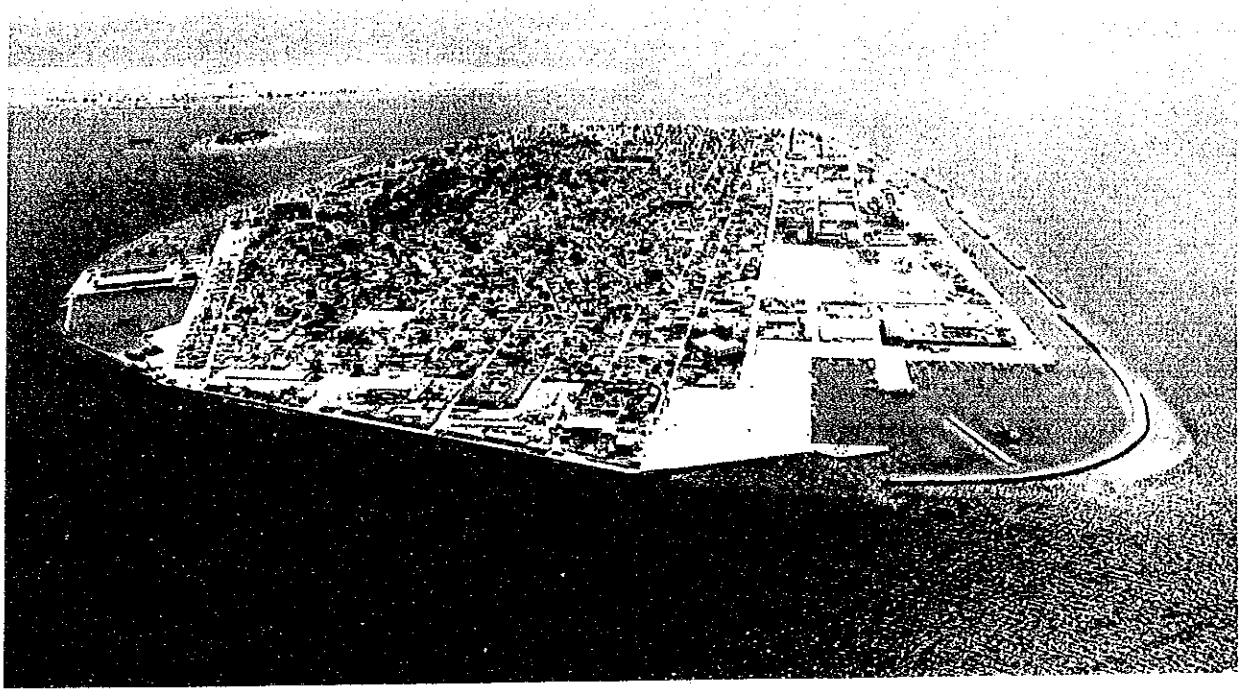


Photo-1 MALE' ISLAND (Oct. 1992)

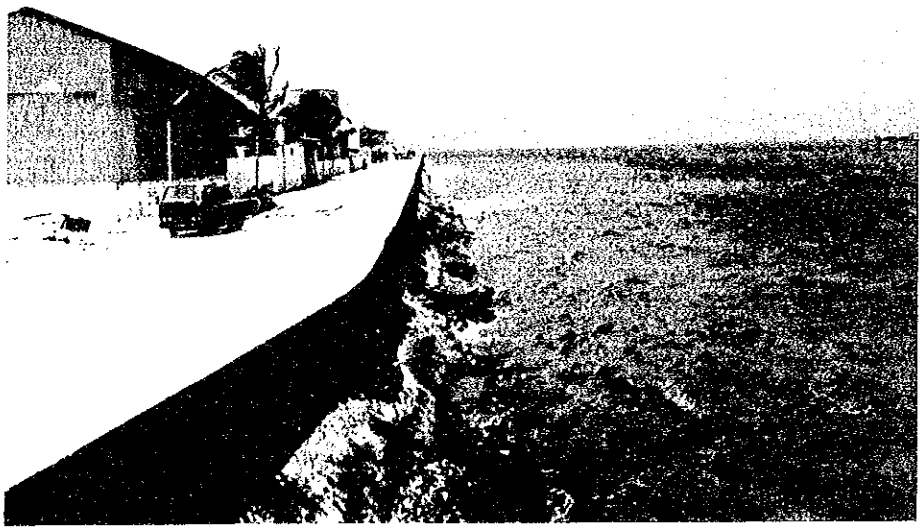


Photo-2 Exisiting Seawall on the west coast (Aug. 1993)

SUMMARY

The Republic of Maldives is a typical island nation set in the Indian Ocean and consisting of approximately 1,190 coral islands. The Island of Male', the capital of the Republic of Maldives, is a small island with a total land area of about 1.8 km^2 and is home to approximately 55,000 people, or 23% of the total population, giving an extremely high population density. In 1987, a major storm surge due to high waves coming into from the Indian Ocean occurred on the Island of Male', resulting in major damage, which was, in financial terms, estimated to amount to approximately US$ 6 million.

The Government of the Republic of Maldives made a request to the Government of Japan for an emergency aid to relieve the disaster brought about by the abnormal storm surge. In response to this request, the Government of Japan dispatched Japan Disaster Relief (JDR), and carried out the construction of detached breakwaters along the South Coast of Male' Island between 1987 and 1990. However, while the emergency construction of the detached breakwaters had now been completed, the existing coastal protection facilities still remained in an undeveloped state. Consequently, the Government of the Republic of Maldives made a request to the Government of Japan to carry out a study with a view to the establishment of a coastal disaster prevention plan, in the form mainly of the construction of new seawall facilities. In response to this request, the Japan International Cooperation Agency (JICA) carried out the development study on the Seawall Construction Project for Male' Island in the Republic of Maldives between 1991 and 1992. It was on the basis of the results of this study, that the Government of the Republic of Maldives made a request to the Government of Japan in February 1993 for a grant aid cooperation for the construction of seawalls along the West Coast of Male' Island where the utmost urgency of the construction was indicated by the results of the development study.

In response to this request, the Government of Japan has decided to carry out a basic design study in connection with the coastal disaster prevention plan for the Island of Male', and JICA dispatched a basic design study team between 19th August and 2nd September, 1993.

The study team held a series of discussions with their counterparts in the Ministries of Foreign Affairs and of Public Works and Labour in the Government of the Republic of Maldives, and conducted various studies, including field surveys at the project site and supplementary topographical surveys together with the collection of information on construction methods. The results of the above surveys basically confirmed the necessity and propriety of the request comprising mainly of the construction of the seawall facilities, the propriety of which had already been confirmed by the development study.

The results of the field surveys were analyzed further in the home country to review the necessity and propriety of the project. As a result, the essential features of the project were decided as shown below.

1) Executing agencies

① Implementation of project: Ministry of Foreign Affairs

② Operation and management of project: Ministry of Public Works and Labour

2) Project area (length of the Western Coast: 774 m)

① Northern Section : length: 254 m

② Southern Section : length: 520 m

3) Outline of Protection Facilities

① Northern Section

* Type	: seawalls with wave dissipation blocks
* Crest elevation	: D.L. +3.00 m
* Crest blocks	: 2 rows
* Weight of block	: 1 ton Tetrapod
* Face line of seawalls	: 5 m inland from present face line (after removal of the existing seawalls)

② Southern Section

* Type	: seawalls with wave dissipation blocks
* Crest elevation	: D.L. +2.60 m
* Crest blocks	: 3 rows
* Weight of block	: 1 ton Tetrapod
* Face line of seawalls	: 2.2 m seaward from present face line (in consideration of widening of the coastal road)

4) Project schedule

In implementing the project, a period of 5 months and 18 months is required for detailed design and construction works, respectively.

The seawalls to be constructed under this project will provide protection to the West Coast and the land behind it, which calls for urgent implementation of appropriate countermeasures and makes up around 10% of the total area of Male' Island, from storm surge disasters, which means that the 6,000 or so people who live in these areas will be able to lead their lives in security. In concrete terms, the following economic benefits are expected to result from the project: one, the safety of the public facilities situated along the coastline, including a hospital, a social education centre, primary schools, harbour facilities and a coastal road, are securable; two, the private housing, the small shops and household goods can be protected from storm surge disasters; and three, safety for the passing traffic can be guaranteed. Besides the above economic benefits, the

project is also expected to result in the social benefits, to be more specific, the improvement of the living conditions for the local residents by providing them with the guarantee of safety in their everyday lives and while travelling to the schools and the hospitals, as well as the psychological effects on them in the form of a sense of security. It is deemed appropriate to implement the project under grant aid cooperation from the Government of Japan in view of the following:

* Technical transfer regarding seawall construction is expected.

* The project may be considered a disaster prevention project which is required for protection of the facilities constructed under the development plan for Male' Island (hospital, harbour facilities, coastal road etc.).

* The construction work are feasible without any major difficulties.

In order to implement the project effectively, the following measures are proposed to be undertaken by the Maldivian Government.

1) This project covers only the areas along the West Coast of the entire coastal area of Male' Island where urgent implementation of appropriate countermeasures is called for. In order to confirm the technical effects of the project and to improve the knowledge of storm surge disaster prevention, it is important to monitor the wave runup height and the conditions of wave overtopping after the completion of the proposed seawalls, as well as to collect data on the above items at other coastal areas to establish a system that facilitates the formulation and implementation of future disaster prevention plans.

2) In Maldives, an island nation set in the Indian Ocean, islands other than Male' will also likely suffer from storm disasters in the future. Consequently it is expected to acquire knowledge of coastal engineering and to master construction technology to be used in this project so as to enable the Maldivians to devise coastal disaster prevention plans by their own in future.

CONTENTS

ABBREVIATIONS

JICA	:	Japan International Cooperation Agency
F / S	:	Feasibility Study
Mrf	:	Maldivian Rufiyaa
US$	:	American Dollar
¥	:	Japanese Yen
GDP	:	Gross Domestic Products
GNP	:	Gross National Products
ADB	:	Asian Development Bank
OPEC	:	Organization of Petroleum Exporting Countries
DWT	:	Deadweight ton
D. H. W. L.	:	Design High Water Level
H. W. L.	:	High Water Level
M. S. L	:	Mean Sea Level
L. W. L.	:	Low Water Level
L. A. T.	:	Lowest Astronomical Tide
Max.	:	Maximum
E / N	:	Exchange of Notes
M / D	:	Minutes of Discussions
MPWL	:	Ministry of Public Works and Labour
DIB	:	Department of Information and Broadcasting
IECA	:	International Engineering Consultants Association
UNCDF	:	United Nations Capital Development Fund

CHAPTER 1 INTRODUCTION

1-1 Objectives of Study

A major storm surge occurred on the Island of Male', where the capital of the Republic of Maldives is located, and on the surrounding islands between 10th and 15th April 1987, resulting in major damage to the seawalls, private housing, airport and other facilities. The damage, in financial terms, was estimated to amount to approximately US$ 6 million. Most of the damage was concentrated in the densely populated areas along the South Coast of Male' Island and around the international airport on Hulule Island. When storm surges occur on Male' Island, the duration of the inundation is prolonged by the low, flat profile of the island and the inadequacy of the drainage system. In 1987, the prolonged inundation and high temperatures resulted in the spread of contagious diseases. The Government of the Republic of Maldives made a request to the Government of Japan for an emergency aid to combat the disaster brought about by the abnormal storm surge. In response to this request, the Government of Japan dispatched an international emergency relief team, and between 1987 and 1990, carried out the construction of detached breakwaters along the South Coast of Male' Island.

However, while the emergency construction of the detached breakwaters had now been completed, the existing coastal protection facilities still remained in an underdeveloped state. Consequently, the Government of the Republic of Maldives made a request to the Government of Japan to carry out a study with a view to the establishment of a coastal disaster prevention plan, in the form mainly of the construction of new seawall facilities. In response to this request, JICA implemented the development study on the Seawall Construction Project for Male' Island in the Republic of Maldives between 1991 and 1992. It was on the basis of the results of this study, that the Government of the Republic of Maldives made a request to the Government of Japan for a grant aid cooperation for the construction of seawalls along the West Coast of Male' Island in February 1993.

The study reported here was implemented in response to this request, with the objectives of investigating the social and economic impact of the project and the appropriateness of implementing the project under grant aid cooperation from the Government of Japan, as well as of collecting the information and documents required for the basic design of the facilities and the equipment that were necessary for and best suited to the proposed plan.

1-2 Dispatch of Study Team

In response to the request from the Government of the Republic of Maldives, JICA dispatched a basic design study team, headed by Mr. Yuji Ogura (Grant Aid Division, Economic Cooperation

Bureau, Ministry of Foreign Affairs) and made up of two other members from INA Corporation of a private consultant firm, to the Republic of Maldives. (See Appendix 1.)

The study team left Japan on 19th August 1993 and, after visiting the Japanese Embassy and the JICA Office in the Democratic Socialist Republic of Sri Lanka on 20th August, arrived in the Republic of Maldives later on the same day. Starting from 21st August, the study team conducted field reconnaissance, held a series of discussions with their counterparts in the Ministries of Foreign Affairs and of Public Works and Labour in the Government of the Republic of Maldives, and implemented data collection, supplementary topographical surveys and other surveys. The Minutes of Discussions (Appendix 4) were concluded on 29th August 1993 and the study team returned to Japan on 2nd September. The details of the schedule for this study trip are given in Appendix 2.

1-3 Scope of Study

The field study conducted in accordance with the objectives of the Basic Study discussed above covers the following items.

1) Presentation/explanation of and consultation on the Inception Report and the Questionnaire
2) Explanation of and consultation on the system of grant aid cooperation from the Government of Japan
3) Confirmation of the background of the project and the scope of the request
4) Consultation on and cooperation for transportation of the construction materials and equipment
5) Procurement of the construction and working space and cooperation therefor
6) Disposal methods for the waste materials generated by the demolition of the existing seawalls and procurement of the disposal sites
7) Request for cooperation and understanding of the local residents
8) Study of the operation and management structure
9) Supplementary topographical surveys on the West Coast
10) Study of the construction conditions on Male' Island
11) Collection of related documents

After the completion of the field study, the documents obtained were analysed in Japan for investigations on the scope of the project requested by the Maldivian Government and on the appropriateness of implementing the project under grant aid cooperation from the Japanese Government.

The list of those interviewed in Maldives during the field study trip and the list of the documents collected are given, respectively, in Appendices 3 and 5.

CHAPTER 2 BACKGROUND OF PROJECT

2-1 Outline of the Republic of Maldives

(1) Location, Topography and Area

The Republic of Maldives is a typical island nation, situated on the Indian Ocean, approximately 600 km south of India and 670 km to the southwest of Sri Lanka, and consisting of 26 circular coral reefs (atolls) of various sizes scattered through an area stretching 823 km from north to south, between the latitudes of 7°9' north and 0°45' south, and 130 km from east to west. These atolls are made up of a total of approximately 1,190 islands, of which 198 are inhabited.

The total land area is approximately 298 km^2 (total area including the atolls: 90,000 km^2).

(2) Population and Population Increase

According to the interim reports of the 1993 census, the population of the Republic of Maldives stands at 238,363. The annual average increase over the six-year period from 1985 to 1990 was 3.4%.

The capital city/island of Male', a small island with an area of about 1.8 km^2, is home to approximately 55,000 people, or 23% of the total population, giving an extremely high population density of 31,000 per km^2.

(3) National Budget and Industries

The soil in this country made up of coral reefs is unsuitable for cultivation, nor is there enough space for agriculture. Agricultural production, as a result, is negligible, and the principal industries are tourism, distribution and fisheries.

The national budget for 1992 (fiscal year) was MRF 25,431,458 (US$ 2,311,950 at the 1992 exchange rate, or, in Japanese currency, ¥ 299,274,000)

The GDP was MRF 970 million in 1990 and 1,121 million in 1992 (at the 1992 exchange rate, MRF 1,121 million x [10.5 MRF/US$] = US$ 106,762,000).

Of the principal industries, tourism accounts for 17.5% of the GDP, followed by the distribution industry at 17.1% and fisheries at 15.7%, these three industries together making up approximately 50% of the GDP.

(4) Finances and Economy

As a national development plan, the Third National Development Plan (1991-1993) is in progress at present. Continuing the policies underlying the Second National Development Plan, this programme is aimed at the three objectives of "improvement of the national standard of living," "elimination of the social disparities between the capital and the outlying regions" and "achievement of self-reliance, which is essential for future growth."

According to the statistics for 1992, the inflation on domestic commodities was 16.8%.

The national income stood at MRF 720 million, while the national expenditure stood at 1,267 million by the 1992 statistics. The principal trading partners are the U.S.A., Thailand, Sri Lanka, Japan, Germany, Canada and Singapore. The principal items of import and export are listed below.

Import (x MRF 1,000)		Export (x MRF 1,000)	
Consumer goods	997,493	Marine products	332,158
Petroleum products	242,132	Other products	84,524
Intermediate and capital goods	761,900		

The total amount of aid from foreign countries and international organisations in 1992 was MRF 185.9 million, most of which was in the form of grant aid.

2-2 Outline of Coastal Protection

The coastal protection facilities found today on Male' Island may be classified into the old-type seawalls constructed by the Maldivian Government and the detached breakwaters constructed along the South Coast under grant aid from the Japanese Government after the storm surge disaster of 1987.

The existing seawalls are found along more or less the whole of the coastline on the island and are made of coral stones 10 to 20 cm in diameter, which have been piled up and bound together by coating on the surface with mortar. Because of the lack of construction materials, local coral sand is often used as the aggregate for the mortar. The shortage of cement and the use of salt water for mortar mixing make the structures thus constructed extremely weak. Exposure of the seawalls to waves and tides quickly result in deterioration and rupture of the surface mortar, hollowing of the seawalls and collapse of the coral stones inside, shortening the service lives of these seawalls.

Ten detached breakwaters were constructed along the reef edge on the South Coast of the island under Japanese grant aid after the storm surge disaster of 1987. The Maldivian Government has plans to construct quaywalls behind these detached breakwaters to create a space for mooring and cargos for small boats, and this plan has been included in the Development Study.

The Commercial Harbour is located on the western part of the North Coast of the island, while a new, small harbour for inter-island ferries has recently been constructed on the southwestern side of the island. Besides these, the North Coast is used as an anchorage for government-owned boats, coast guard boats, tourist boats and *dhoni*. All these anchorages are protected by breakwaters constructed right on the edge of the coral reefs. The quaywalls on the North Coast are being replaced by new quaywalls with sheet pile foundations, whose completion will open the way for the improvement of the harbour facilities.

The crest elevations of the existing seawalls and breakwaters on Male' Island are as follows.

	Seawalls	Quaywalls	Breakwaters
East Coast	D.L. +2.8 m		—
South Coast	D.L. +2.1 m		D.L. +4.1 m
Southwest Coast	D.L. +3.1 m	(+1.8 m)	D.L. +3.5 m
West Coast	D.L. +2.6 m		—
North Coast	D.L. +2.0 m	(+1.8 m)	D.L. +2.1 m

2-3 Outline of Related Plans

1. National Development Plan (1991-1993)

The Maldivian Government has adopted a development plan, setting down as the ultimate goal of all the development work implemented by it the advancement and improvement of both the material and non-material status of the Maldivian people, including the balanced increase of incomes, provision of better housing, access to quality health and education services and increased opportunities for recreational activities, and has been endeavouring to achieve the targets of this plan. The plan is aimed at the same time at the improvement of the standards of well-being rooted in respect for social and cultural values, environmental conservation and continuation of the stable and harmonious society.

The principal objectives of the plan are as follows.

(1) Improvement of the living standards and quality of life for all Maldivians

(2) Equal distribution of the benefits of development

(3) Achievement of greater self-reliance, essential for future growth

While the above objectives were specified as the guiding principles for the development work up until this year, the formulation of these policies was accompanied by the clarification of the priorities. As a result of a detailed review of the policies and plans to date, 30 such priority items were identified and these were classified under the following five headings.

(1) Economic management and development

(2) Infrastructure development

(3) Social development

(4) Institutional development

(5) The environment

2. Regional Development Plans

(1) Male' Land Reclamation Project

The reclamation project was begun in April 1979 and was completed in July 1986. The project was aimed at the reclamation of the reef flats on the southern and western sides of the island to create 59.7 ha of new land as sites for private housing and such public facilities as schools, a hospital, a power plant, a domestic port and a sports complex. The land area on Male' Island, which was approximately 108 ha at the commencement of the project, was increased by 56% to 168 ha at the completion of the project. The newly-created land has been handed over to and are being used by private house-owners and relevant governmental agencies. The soil used for reclamation was produced mainly by dredging the harbour on the North and South Coast of the island.

(2) Port Development for Inter-Island Transport

The harbour on the North Coast of the island, used as an anchorage for government-owned boats, including coast guard patrol boats, tourist speed boats, *dhoni*, small cargo boats and cargo lighters, is small and congested. A new harbour has been constructed on the southwestern side of the island to alleviate this congestion and to provide an anchorage for inter-island ferries and fishing boats. The construction, under financial assistance from ADB, UNCDF and OPEC, was begun in April 1991 and was completed in August 1992.

(3) Second Male' Port Project

This is the second phase of the project for expanding Male' International Port, implemented by ADB. The water depth in Male' International Port at present is 3.5 m, which is too shallow to allow international liners to enter the port, with the result that the cargo has to be transferred to barges from the liners moored offshore. The project, devised in response to the increasing volume of cargo, involves the construction of a pier accessible to 15,000 DWT class ships. The project is at the detailed design stage. Construction work is due to begin in the latter half of 1994, aiming at completion in the first half of 1996.

(4) Marine Drive Expansion Project

The Maldivian Government has a plan to widen the road running along the West Coast of the island from 7.5 m to 10.5 m to cope with the increased traffic generated by the construction of the Southwest Harbour. This road widening project affects the positions of the seawalls to be constructed. The positions of the road sites mean that the face line of the seawalls will have to be moved approximately 2.2 m at its maximum towards the sea from the present face line.

(5) Swimming Pool Project

This project is just a conceptual idea at present stage. In view of the maritime nature of the country, the Maldivian Government is interested in promoting swimming among the public and in training swimmers capable taking part in the Olympic and other international and national games, and has a plan to construct a freshwater swimming pool. Reclaimed land on the East Coast of the island has been proposed as the project site.

(6) Southern Area Coastal Fisheries Promotion Project

With the aim of promoting the development of fisheries in the southern parts of the Maldive Islands, a fishing port (to accommodate local fishing boats and fresh-fish carriers: 2.5 m deep quaywalls with a length of 110 m and breakwaters) is being constructed together with a refrigeration facilities and a cold storage (300 tons) on the island of Maandhoo in Laamu Atoll under grant aid from the Japanese Government. The construction work, in progress at present, is due for completion in March 1994.

(7) Other Relevant Projects

The following related projects are also in progress at present.

① Garbage Collection and Management Plan
② Power Plant Project (incl. regional electrification)
③ Water Supply and Sewage Development Projects
④ Indira Gandhi Memorial Hospital Project

2-4 Background and Scope of Request

The population increase on the capital/city island of Male' has pushed the reclamation area almost as far as the reef edge, while the average ground elevation in this area is approximately only 1 m above sea level, raising fears that the existing seawalls will not provide adequate defence against such abnormal storm surges as that of 1987. It was under these circumstances that the Development Study was implemented by JICA between 1991 and 1992 with the aim of devising a coastal protection plan, aimed at ensuring the safety of the facilities at the nerve centre the Republic of Maldives and of the local residents. According to the results of the Development Study, which covered the whole coastline of Male' Island, the sides of the island may be ranked as follows according to the urgency of improvement on the protection facilities.

1) West Coast (length: 774.00 m)
2) East Coast (length: 1,088.45 m)
3) South Coast (length: 1,508.83 m)
4) North Coast (length: 1,291.00 m)

It was on the basis of the Development Study that the Government of the Republic of Maldives made a request for cooperation in implementing as an emergency project the construction of seawalls on the West Coast, which has been ranked first in the list above, taking into account also the fact that the important public facilities (Indira Gandhi Memorial Hospital, Social Education Centre and two schools) are located close to the coastline here.

The particulars of the seawall facilities requested by the Government of the Republic of Maldives, as confirmed during the Basic Design Study, are as follows.

1) Project area: 774 m stretch on the West Coast
   - ① Northern section : 254 m
   - ② Southern section : 520 m

2) Protection facilities type : seawalls, with wave dissipation blocks installed in front of upright seawalls
   - ① Northern section : crest elevation - D.L. +3.00 m; 2 rows of crest blocks
   - ② Southern section : crest elevation - D.L. +2.60 m; 3 rows of crest blocks

3) Face line of seawalls
   - ① Northern section : 5 m inland from present face line
   - ② Southern section : 2.2 m seaward from present face line

CHAPTER 3 OUTLINE OF PROJECT AREA

3-1 Location

The capital/city island of Male', where the project area is found, is situated at the southern tip of the North Male' Atoll, which is located more or less at the centre of the 26 widely scattered atolls making up the Republic of Maldives. To the northeast of this island is the island of Hulule, the airport island, while to the north is the island of Funadhoo, used for storage of petroleum consumed on Male' Island.

The area covered in the Basic Design Study is the West Coast of Male' Island. The study covered a 774 m stretch of the coast from the western side of the entrance to the Commercial Harbour in the northwestern part of the island to the northern side of the local port at the southern end.

3-2 Meteorology and Oceanography

1. Meteorology

The year in Maldives may be divided into the northeast monsoon season between December and March, and the southwest monsoon season from the end of April to October.

There is little temperature variation throughout the year, the hottest month being April with an average temperature of 31.7°C and the coolest being September with an average temperature of 25.1°C.

According to the records taken at the airport on Hulule Island, the average annual rainfall is approximately 1,900 mm. The average monthly rainfalls exceed 200 mm during the five months of June, August, September, October and December.

The wind directions vary with the monsoons, northeasterly winds occurring between December and February and westerly winds occurring between May and September.

Humidity is high throughout the year, the average being 75%.

The climate may be said generally to be stable and to show little variation.

2. Oceanography

(1) Current

The patterns of the currents on the Indian Ocean vary with the seasons, the current flowing westwards in the vicinity of Maldives during the northeast monsoons and eastwards during the southwest monsoons.

The tidal currents flow eastwards during rising tides and westwards during ebbing tides. The flow velocity varies according to the positions of the islands.

(2) Tides

The harmonic constants at Male' Island, according to "Tide Tables, Vol. 2, 1991," published by the Hydrographer of the U.S. Navy, are as follows.

Constant	Z_0	M_2	S_2	K_1	O_1
(m)	0.65	0.24	0.14	0.12	0.06

H.W.L.	D.L +1.34 m
M.S.L.	D.L. +0.64 m
Chart datum line	D.L. +0.08 m
L.A.T.	D.L. +0.00 m

(3) Waves

Measurements were taken on the wave heights and flow velocities on the East, South and West Coasts during the Development Study using water-pressure wave height gauges and electromagnetic current meters.

The results indicate that the West Coast was in a calm period during the observation period, with wave heights of 20 to 30 cm being recorded. The period of the waves was relatively long at around 10 seconds, judging from the fact that the angle of incidence was slightly to the south, the waves observed may regarded as "swell" waves from the Indian Ocean affected by refraction and diffraction.

The Maldivian Government commissioned Lanka Hydraulic Institute Ltd. of Sri Lanka to carry out wave observation in the seas around Maldives between 1988 and 1989.

The occurrence probabilities of wave heights exceeding 0.4 m, at which it becomes difficult to carry out construction work on the sea, as calculated on the basis of this study and the observation results on the West Coast, are given below.

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
%	0.0	0.0	0.0	0.0	1.6	0.3	0.1	0.0	3.3	0.3	0.0	0.0

* Waves exceeding 0.6 m occur only in September and their occurrence probability of 1.6% accounts for 1/2 of the occurrence probability of waves exceeding 0.4 m.

3-3 Topography

Although bathymetric surveys were carried out around the whole of the island during the Development Study, the measurement pitch was large and, especially because of the reefs, there were no detailed survey data for the submarine topography near the coast. Supplementary surveys were carried out during the Basic Design Study, as more detailed data were required on the coastal topography for the purpose of drawing up the basic design of the facilities.

As relatively large waves were observed along the West Coast during the bathymetric surveys, rendering the survey work dangerous, small barge towboats were used as supports, and the surveys were carried out moving outwards from the existing seawalls at 5 m intervals within a 20 m section, which corresponded to the design range for the planned facilities, while also confirming the positions of the reef edges. Surveys were also carried out on land on such items as the positions of the public facilities and other facilities for assessment and confirmation of the conditions behind the planned seawalls.

3-4 Geology

1. Geology of Male' Island

Male' Island, located at the southern tip of the North Male' Atoll, consists of a horseshoe shaped coral reef and an island standing in the reef lagoon. The coral reef is made up of the reef edges, where broken masses of corals are observed near the sea surface, and the reef flats found inside the reef edges.

2. Physical Properties of Seawall Foundations

The geological conditions on Male' Island were studied through boring surveys carried out during the Development Study. The results indicate that the West Coast, located on the reef edge, consists of loose native corals. The *N*-values range from 2 to 50, and uniaxial compression tests indicated strengths of 5 to 135 kgf/cm^2 (average: 70 kgf/cm^2). The ultimate bearing capacity was found to range between 45 and 60 t/m^2.

It was observed during the Development Study that, in some sections of the West Coast, the lower parts of the coral flats had been gouged out and caved in landward at the reef edges. When the seawalls and wave dissipation blocks have been constructed, the weight of these structures will be considerable, but they will be safe as the construction work under the design on this occasion will not extend as far out as the positions of these hollows.

CHAPTER 4 SCOPE OF PROJECT

4-1 Objectives

On the West Coast of Male' Island, where the project is to take place, important public facilities are found close to the shoreline as shown in Figure 4.1. The aim of this project will, therefore, be to provide protection against storm surge disasters in the form, for example, of wave overtopping, collapse of sea dykes and inundation of the land area due to the high waves that occur during the southwest monsoons, and the project will be implemented to achieve the following concrete objectives through the construction of seawalls.

① To ensure the safety of the public facilities located in the southern section (Indira Gandhi Hospital, Social Education Centre and primary schools)
② To ensure the safety of the Commercial Harbour and the boat repair yard in the northern section
③ To ensure the safety of the lives of local residents in this densely populated area
④ To ensure the safety of vehicles travelling on the Marine Drive, a trunk transportation route, whose construction is planned behind the seawalls

Since the seawalls to be constructed under this project are semi-permanent structures with little need for maintenance work after their completion, they may be expected to make a major contribution to the promotion of social and economic activities in the western parts of Male' Island.

4-2 Examinations on Request

As shown in Figure 4.1, important facilities are located along the West Coast of Male' Island. Furthermore, the area where roads can be seen running in grids consists of low-lying ground with an average elevation of 1 m above sea level, which was created by reclamation, as shown in Figure 4.2, and has been subject to inundation damage due to high waves on several occasions in the past. According to the results of hydraulic tests implemented during the Development Study, with the existing seawalls, the occurrence of the design wave (wave height: 1.2 m, period: 4.6 sec.) at the design tide level (D.L. +1.34 m) will result in a run-up height of D.L. +6.5 m and an overtopping rate of 0.034 m^3/m.sec., which is approximately three times the standard permissible overtopping rate of 0.01 m^3/m.sec. for densely-populated areas in Japan, meaning that the land areas are liable to damage due to high waves with the existing seawalls. It is judged, therefore,

that the construction of seawalls, the appropriate scale for which has been studied in the Development Study, are indispensable in order to ensure the safety of the lives and properties of people in the land areas.

From the foregoing, it is judged appropriate, in principle, to implement under grant aid from the Government of Japan the construction of the seawalls on the West Coast of Male' Island, the request for cooperation in whose construction as urgently needed facilities has been made by the Government of the Republic of Maldives and the appropriateness of whose scale and scope has been investigated in the Development Study.

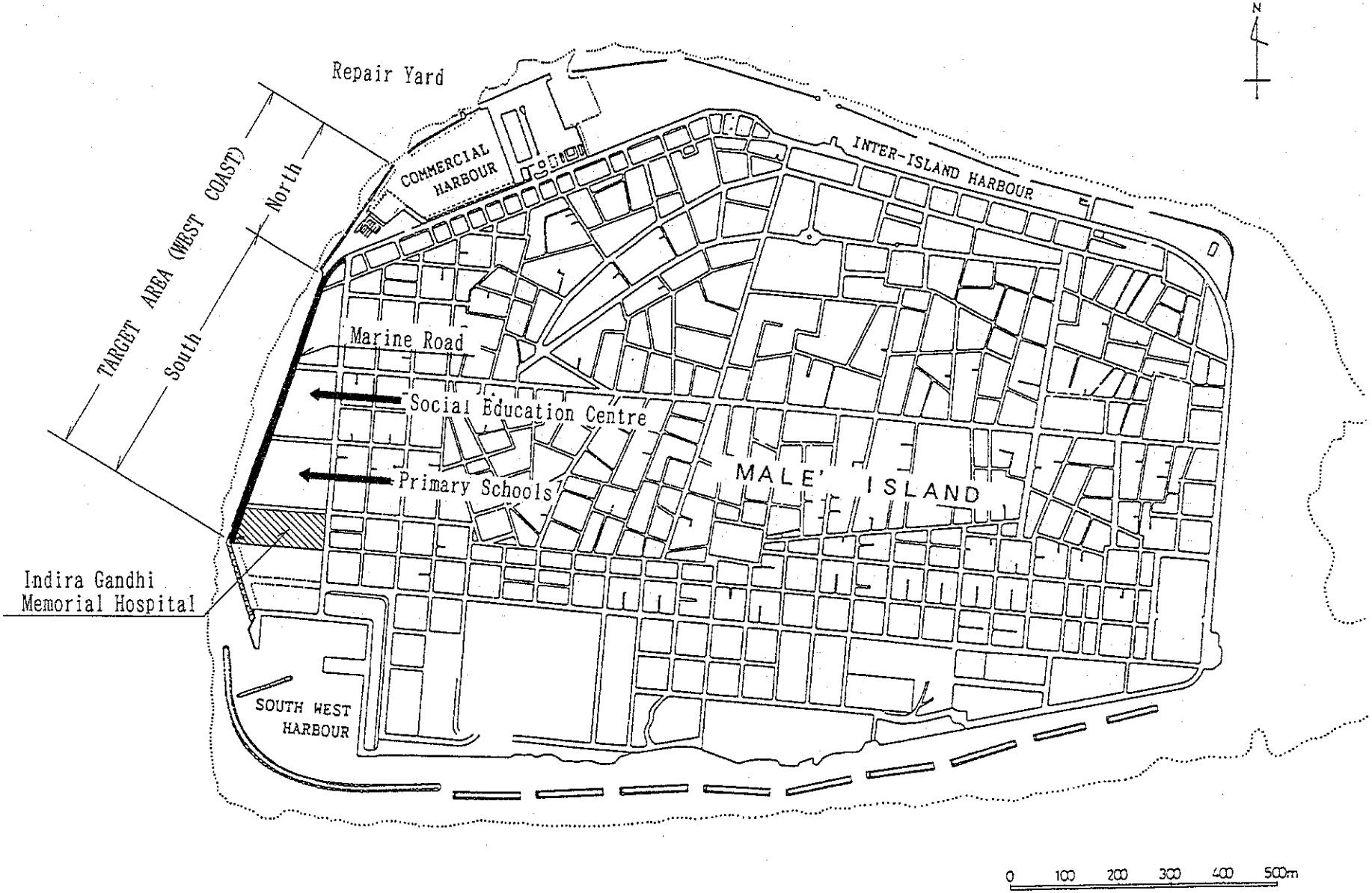


Figure 4.1 Coastal Use Map on the West Coast

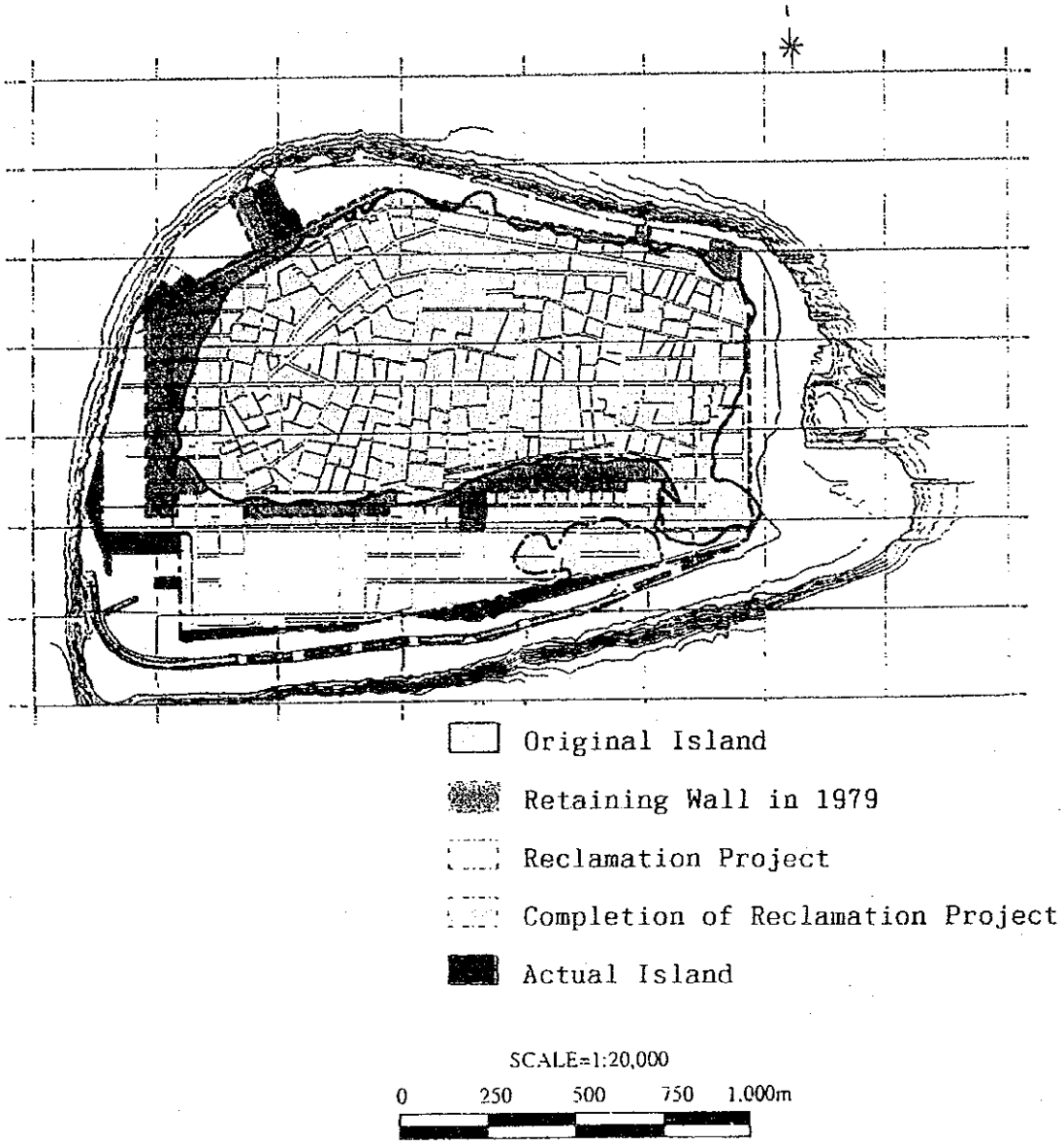


Figure 4.2 Progress of Land Reclamation in Male' Island

4-3 Project Description

4-3-1 Executing Agencies and Operational Structure

Should the Project be implemented under grant aid from the Government of Japan, the following bodies will responsible for the implementation and operation of the Project in the Government of the Republic of Maldives.

1) Implementation of Project : Ministry of Foreign Affairs

2) Operation and management of construction work : Ministry of Public Works and Labour

An organizational chart of the Ministry of Public Works and Labour is given in Figure 4.3.

International Project and Operation Sections of Public Works Division consisting of 15 staffs are responsible for the operation and maintenance of the Project. The 1993 fiscal year maintenance budget for the existing coastal facilities (breakwaters and seawalls) of the Ministry of Public Works and Labour is MRF1,200,000 (approx. ¥11,700,000).

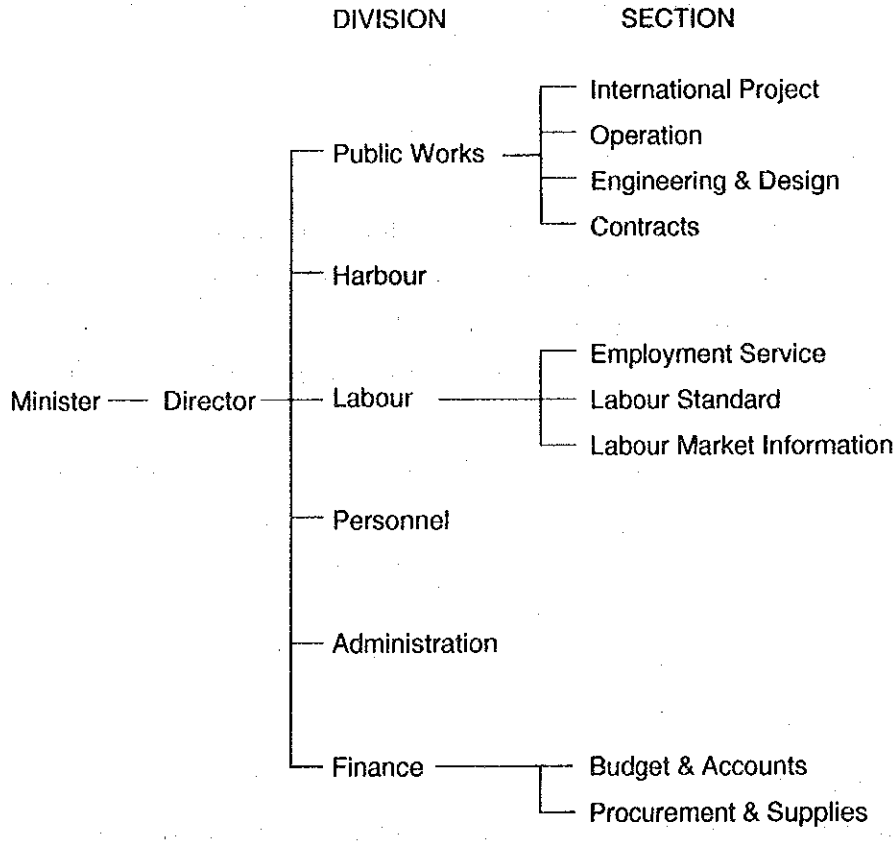


Figure 4.3 Organization of the Ministry of Public Works and Labour

4-3-2 Coastal Protection Plan

In drawing up shore protection plans, there is a need to study the various conditions relating to the coast, such as the conditions of the waves, tide levels, topography, use of the coast, related development projects and wishes of the local residents. It has been confirmed during the field study trip for the Basic Design Study that the scope of the request from the Maldivian Government is based on the plans proposed in the Development Study. The outline of these proposals is given below.

1) Design Conditions

The same datum level (D.L.) and tide level conditions shall be used in the design for the seawall construction project as for the ports to facilitate distinction between sea and land areas and for ensuring congruity with port and harbour plans. This datum line corresponds to 99.80 cm in the reference elevation used by the Ministry of Public Works and Labour. The mean sea level (M.S.L.) is D.L. +0.64 cm and the high water level (H.W.L.) is D.L. +1.34 m.

The design high water level (D.H.W.L.) and design wave conditions are as follows.

① Design wave (offshore waves): wave height = 1.2 m, period = 4.6 sec.

② D.H.W.L.: D.L. +1.34 m

2) Request from Maldivian Government concerning Coastal Protection Facilities

The requests from the Maldivian Government have to be considered to ensure the convenience for various activities on the part of the local residents. The principal items of the request concerning the protection plan for the West Coast are as follows.

① The seawall crest elevation should be lowered to allow a view of the horizon from the land side.

② Sufficient space should be secured behind the seawalls for a coastal road with a width of 10.5 m, whose construction is planned along the West Coast.

③ Drainage facilities should be provided behind the seawalls.

3) Planned Facilities

The results of hydraulic tests indicate that, with the seawall facilities as they stand today without wave dissipation blocks in front of them, high waves on the scale of the design waves, when they reach and collide with seawalls, will rise to a significant height and overflow in large quantities on to the land behind the seawalls. Given the intense use that is

being made of the land behind the seawalls on the West Coast and the low elevation of the ground in this area, inundation on a large scale here must be prevented. When the technical considerations and the wishes of the Maldivian Government are taken into account, together with the presence of shallow reef flats in front of the seawalls, the best method for protecting the areas behind the seawalls on the West Coast from the incoming waves is judged to be the use of seawalls with wave dissipating blocks, which are capable of absorbing the energy of the waves with efficiency and are the most commonly used type of seawalls throughout the world.

In accordance with the results of hydraulic tests, the seawalls for the southern section of the West Coast will be given a crest elevation of D.L. +2.60 m and three rows of crest blocks, and those for the northern section a crest elevation of D.L. +3.00 m and two rows of crest blocks.

4-3-3 Outline of Protection Facilities

In view of the circumstances surrounding construction work in Maldives, the seawalls should be given as simple a structure as possible, be made of readily available construction materials and be easy to maintain. The basic specifications for the coastal protection facilities for the West Coast of Male' Island, as designed in line with these conditions and on the basis of the investigations on their appropriateness from the point of view of hydraulics and the requests from the Maldivian Government, are as follows.

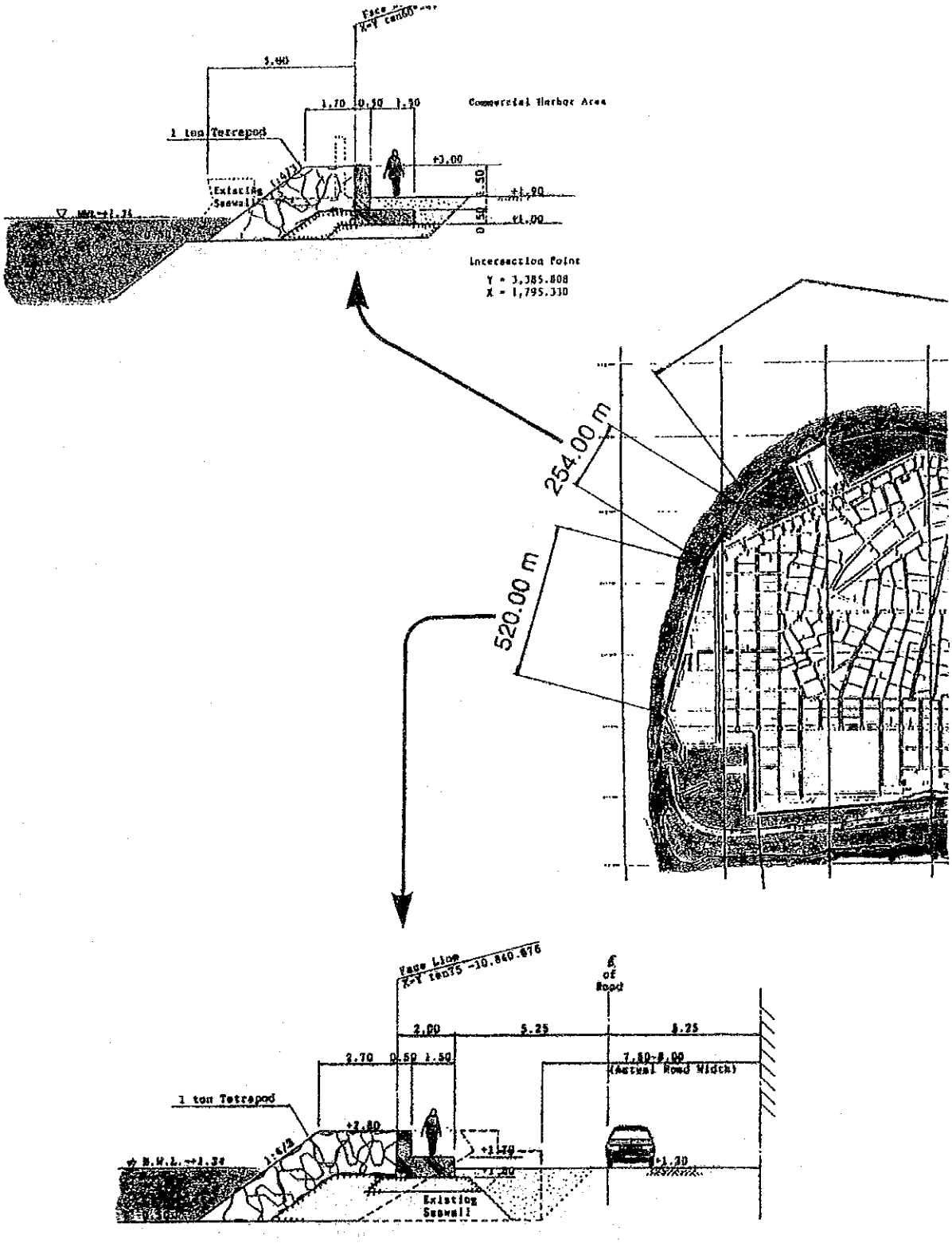
1) Northern Section (length: 254 m)

Type	:	seawalls with wave dissipation blocks
Crest elevation	:	D.L. +3.00 m
Crest blocks	:	2 rows

2) Southern Section (length: 520 m)

Type	:	seawalls with wave dissipation blocks
Crest elevation	:	D.L. +2.60 m
Crest blocks	:	3 rows

Typical sections of the seawalls are shown in Figure 4.4.



Note 2: Drainage system behind all seawalls will be provided.

Figure 4.4 Plan of Shore Protection Facilities on the West Coast

4-3-4 Operation and Maintenance Plan

The Ministry of Public Works and Labour is responsible at present for the operation and maintenance of the detached breakwaters along the South Coast, the Southwest Harbour and the existing seawalls, and after their completion, the seawalls are to be maintained by the Ministry of Public Works and Labour.

The detached breakwaters along the South Coast retain their shapes and functions as they were at the time of completion in 1989 without marked scattering and subsidence of the concrete blocks. All of the operation and maintenance budget of the Ministry of Public Works and Labour are being used for the repair of the existing seawalls due to deterioration. The seawalls to be constructed consist of upright concrete walls fronted with wave-dissipating blocks, so falling-off of these blocks is a major concern from the aspect of the maintenance of the seawalls. The foundation of these seawalls, however, will be solid enough to support the seawalls, as has been verified by the detached breakwaters along the South Coast. It is also considered that the stability of the seawalls can be secured if the blocks, which are designed to have an adequate durability against wave with a return period of 50 years, are arranged with care by skilled engineers. Consequently, it is assumed that the Ministry of Public Works and Labour will require almost no budget for the maintenance of these seawalls with relatively simple, semi-permanent structures.

As has been mentioned above, the seawalls to be constructed are simple and solid structures, nevertheless, it will be an important part of the maintenance work after their completion to conduct visual inspections of the seawalls every month or so for detection of abnormalities and for preparation of records on such items as the effects of the seawalls in reducing overtopping due to high waves, so as to accumulate data and to deepen the knowledge of overtopping which can be used in future planning.

CHAPTER 5 BASIC DESIGN

5-1 Design Policy

The project is one of the shoreline protection facilities planned for the capital city of Male' Island, the purpose of which is to construct permanent shoreline protection facilities on the west coast of the island. The characteristics of the west coast, which is the subject of this project, are as follows:

1) There are public facilities along the coast road (called the Marine Drive) including Boat Repair Yard, a Social Education Centre, two Primary Schools, and a Hospital, which are all important to the entire Male' Island.

2) The waves that attack the west coast are swells from the south, and waves generated by the wind within North Male' Atoll. During the May to October southwest monsoon season, there are waves that overtop the existing seawalls and flood the roads, and sprays that damage buildings further inland.

3) The edge of the reef is close to the seawall, and outside this there is a steep drop, so there are areas where there is no space to install wave dissipation blocks.

4) The Government of Maldives plans to widen the west coast road which connects the Commercial Harbour in the north with the Inter-Island Harbour in the southwest.

5) The two Primary Schools, Social Education Centre and Hospital are located close to the coastline, and when the weather is good many people walk in the vicinity.

6) Almost no one swims or plays on the shoreline of the west coast.

7) The living areas along the west coast are on reclaimed land with the lowest elevations on Male' Island, and for this reason the area is subject to frequent flooding in rain.

Due to the above characteristics, and in accordance with the design policy in the Development Study, the Basic Design for the West Coast Shoreline Protection facilities is as follows:

1) The project site on the west coast of Male' Island extends approximately 774 meters from the seawall for the Inter-Island Harbour in the southwest to the Commercial Harbour in the north, and includes part of the Commercial Harbour breakwater.

2) Wave overtopping will be reduced as far as possible.

3) The height of the seawall will be kept as low as possible so that the horizon may be seen from the road.

4) The line of the seawall will be decided upon having first considered the road widening (width 10. 5 m) plans.

5) In areas where it is too difficult to place wave dissipation blocks in front of the seawall, the face line of the seawall will be moved inland.

6) The landward side of the seawall will be provided with space for walking, similar to that in the existing seawall.

7) No one is assumed to go down to the sea from the seawall.

8) Future maintenance of the structure to be unnecessary.

9) Further excavation of coral is forbidden, so construction materials will be imported. However, coral taken from the demolition of existing structures will be as far as possible re-used as fill material.

10) It should be noted that this project will not cause any significant damage to the environment either during or after the construction of the new facilities.

5-2 Design Conditions

5-2-1 Design Water Level and Datum

The tidal level indices used in the design are taken from measurements by the British Royal Navy Hydrographic Department. This data has been used for the Male' Harbour Project financed by the Asian Development Bank. For the Male' Harbour Project, the Low Water Level was established at 99. 8; however for this project the Low Water Level was established at 0. 00m.

High Water Level (H. W. L.)	:	+ 1. 34 m	(101. 14)
Mean Sea Level (M. S. L.)	:	+ 0. 64m	(100. 44)
Low Water Level (L. W. L.)	:	+ 0.00m	(99.80)

5-2-2 Design Wave Height and Period

Based on data taken by the Lanka Hydraulic Institute Ltd. of Sri Lanka from February 1988 to May 1989, the significant wave heights were established for each recurring wave on the west coast, as shown below. For this project, the 50 year wave was adopted for the design.

Recurring Period (Year)	Height of Significant Wave (m)	Period (sec)
1	0.95	4.6
2	1.00	4.6
5	1.05	4.6
10	1.10	4.6
20	1.15	4.6
50	1.20	4.6
100	1.25	4.6

5-2-3 Permissible Wave Overtopping Rate

For the level of permissible wave overtopping, it is necessary to consider the seawall structure, the duration of the high waves, the land use behind the seawall, and the water drainage behind the seawall.

Goda (1990: Wave Design for harbour Structures) has established the following figures for wave overtopping rates based on observations taken of seawalls during typhoons:

	Wave Overtopping Rate (m^3 / m / sec)
Without Protection	Less than 0.05
With Protection	Less than 0.2

The Ministry of Transport of Japan has established their design criteria based on the importance of the land use behind seawalls. According to these Standards, in areas with a concentration of residences and public facilities behind seawalls, and where much damage is expected from overtopping or spray, the permissible wave overtopping rate is 0.01 m^3 / m / sec. This value has been used in this project too.

5-2-4 Subsoil Condition

In the Development Study one test drilling was carried out in the vicinity of the existing seawall on the west coast. The results from this drilling are as shown in Fig. 5. 1. The new seawall will be in almost the same position as the existing seawall, and it will have almost the same structural form so the stability of the bearing capacity of the site is considered substantiated.

5-2-5 Sea Bottom Profile

The profile of the sea bottom on the west coast shows a steep drop. For this reason, it is considered that the waves will break directly on the seawalls with no dissipation. There are areas where there is no shallow reef flat in front of the seawalls, and it is necessary to move the face line inland from the existing seawalls.

5-2-6 Seismic Considerations

As there is no record of earthquakes occurring in the Maldive Islands, seismic loadings are not considered in the design.

5-2-7 Structural Conditions

(1) Construction Materials

Fill Materials:	Angle of Internal Friction:	$\phi = 30°, \delta = 15°$
Rock Mound Foundation:	Angle of Internal Friction:	$\phi = 40°$
Unit Weight :	Reinforced Concrete:	2.45 t / m^3 (in air)
		1.45 t / m^3 (in water)
	Plain Concrete :	2.30 t / m^3 (in air)
		1.30 t / m^3 (in water)

(2) Coefficient of Static Friction

Between precast concrete and rock mound foundation 0.6

(3) Safety Factors

Sliding : 1.2 (ordinary case)

Overturning : 1.2 (ordinary case)

(4) Allowable Stresses

Deformed Reinforcing

Bar : 1,800 kgf / cm^2 (SD295A)

Reinforced Concrete : 240 kgf / cm^2 (standard design strength)

90 kgf / cm^2 (allowable bending compressive strength)

9 kgf / cm^2 (allowable shear strength)

Plain Concrete : 180 kgf / cm^2 (standard design strength)

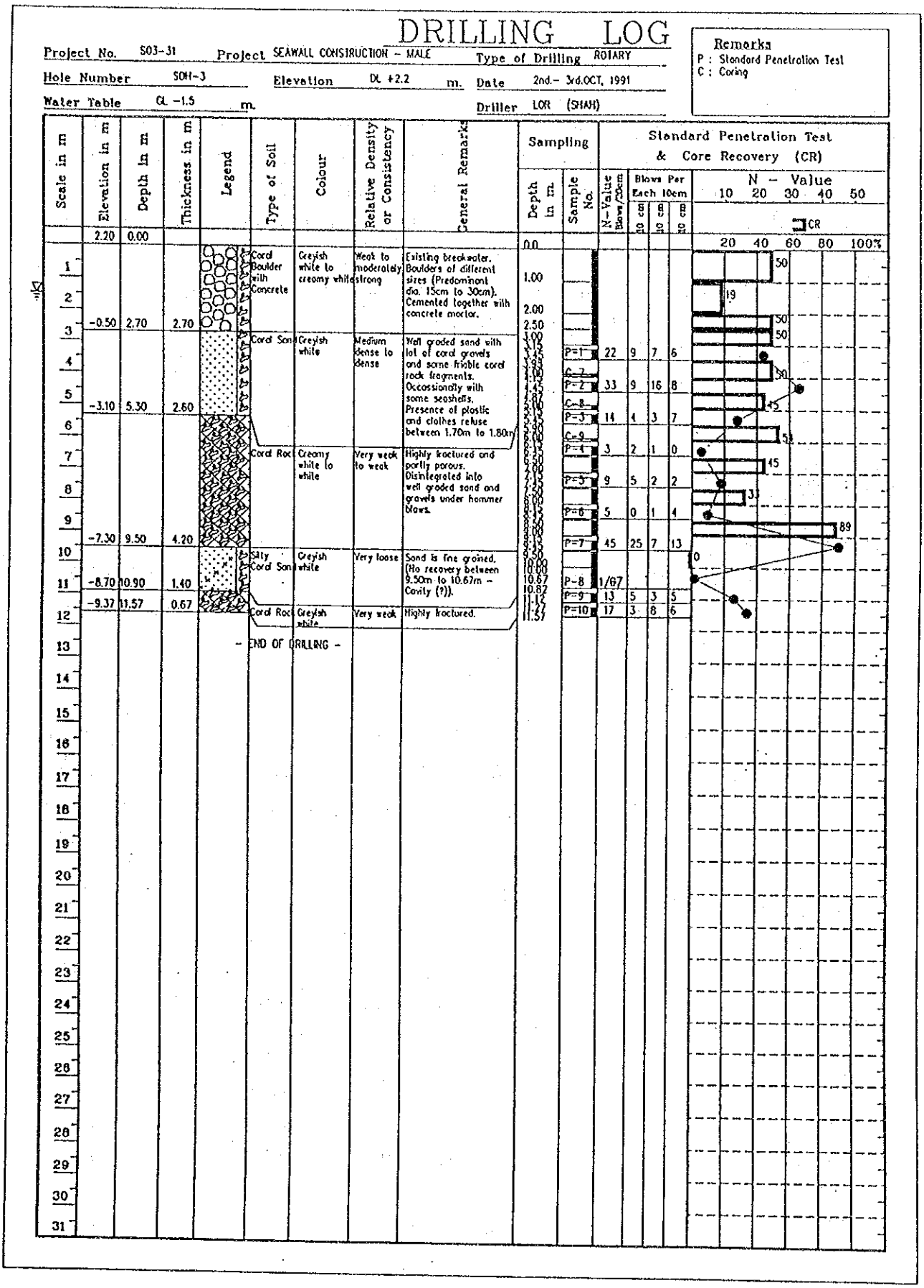


Figure 5.1 Soil Characteristics on the West Coast

5-3 Basic Plan

5-3-1 Layout

The west coast can be divided into two sections from the profile of the seabed in front of the seawall. The first in the south (520m) where the coral reef is comparatively wide, and the second in the north (254m) where the coral reef is close to the existing seawall.

The face line of the new seawall was determined, having considered the coast road widening plans of the Government of Maldives, as follows.

Southern Section (520m) : With the road widening, the new seawall will be 2.2 m seaward from the existing seawall.

Northern Section (254m) : The existing seawall will be demolished and the new seawall will be 5.0 m inland.

5-3-2 Structural Design

(1) Cross-Section Design

The cross-sections of the shore protection facilities (type, crown height and block arrangement) have been determined based upon the results of the 3-dimensional model hydraulic tests carried out in the Development Study.

a. Type of Seawall

Having observed the overtopping with the existing seawall (only dissipation blocks), and considering the importance of the public facilities behind the seawall (Social Education Centre, Primary Schools, Hospital) a gravity type seawall with wave dissipation blocks is recommended.

b. Crest Height and Number of Dissipation Blocks

The results from the model tests are shown in Table 5. 1 and summarized below.

	Elevation of Seawall	Blocks (Crown Height)	Overtopping Rate	Run Up Height
Existing Seawall	+2.6	-	0.034	6.5m
Plan 1	+3.0	2 rows (+1.5)	0.005	4.4m
Plan 2	+3.0	2 rows (+1.5)	0.004	4.1m
Plan 3	+3.0	2 rows (+3.0)	0.002	2.7m
Plan 4	+3.0	2 rows (+3.0)	0	-
Plan 5	+3.0	2 rows (+3.0)	0	-

With the dissipation blocks (height +3.0m) in 2 rows at a crest height +3.0m the overtopping wave rate, 0.002, is sufficiently below the permissible value. Accordingly, this was set as the standard cross-section. However, the crest height of the existing seawall is +2.6m. At this height it is possible to see the horizon from the road, and the Government of Maldives strongly desire to keep this possible.

To lower the seawall elevation, the crest width of the dissipation blocks was increased. With the 2 rows in the test model changed to 3 or more rows, it was possible to set the seawall elevation at +2.6m. The relationship between the seawall elevation and the crest width of the dissipation blocks (standard: 2 rows) is shown in Fig 5.2. With the overtopping wave rate in the test model at zero and from an economical view, sufficient protection ability was surmised with 3 rows of dissipation blocks. Thus the crest height and number of dissipation blocks will be as below:

Along Coast Road (520m)	:	+2.6 m Blocks, 3 Rows
Within Harbour Area (254m)	:	+3.0 m Blocks, 2 Rows

c. Weight of Dissipation Blocks

The weight of the dissipation blocks is given by the Hudson formula.

$$W = \frac{\gamma_r \cdot H_D^3}{K_D \cdot (\gamma_r / W_0 - 1)^3 \cdot \cot \alpha} = \frac{2.3 \times 1.2^3}{8.3\,(2.3 / 1.03 - 1)^3 \times 4/3} \fallingdotseq 0.2t$$

where W : Weight of Block (tf)

γ_r : Unit Weight of Block (2.3t / m^3)

w_o : Unit Weight of Seawater (1.03t / m^3)

α : Angle of Slope ($\cot \alpha = 4/3$)

K_D : Coefficient depending on Block Type (Tetrapod = 8.3)

H_D : Design Wave Height (1.2m)

In the southwest Harbour shore protection, one ton type tetrapods were employed, so for harmony this project will also use one ton tetrapods.

(2) Structure Design

Having considered the points below, typical structural sections for the proposed seawalls, consisting of reinforced concrete on a rock mound with wave dissipation blocks on the seaward face, are shown in Fig. 5.5.

1) In general sheet piling and concrete were considered. However fresh water for Male' Island is taken from deep wells, and to isolate the fresh water from the sea water it was decided not to use sheet piling.

2) The existing seawall was constructed on rubbish and stone reclaimed land with coral. The reclaimed land and the existing seawall will be demolished to -0.5m including the estimated layers of previous corral reef, and above the rock mound layer a foundation of reinforced concrete for the seawall will be set.

3) Work will be carried out under usual wave conditions. To avoid concrete works in sea water, the bottom of the concrete should be at +1.0m.

4) The wave dissipation blocks will be in two layers with two or three rows.

(3) Construction Materials

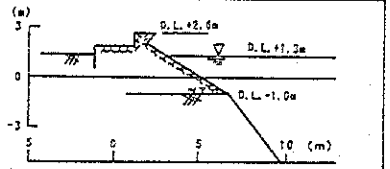
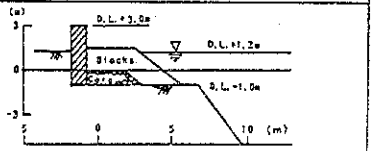
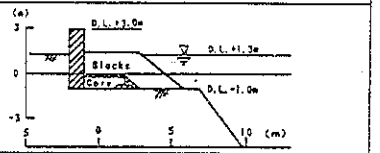
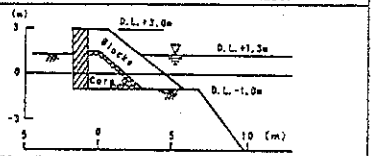
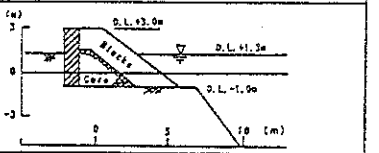
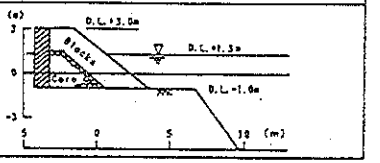
The construction materials required for the proposed seawalls are as follows.

Rock (Max. 50kg)	:	5,800m^3
Armour Rock (50-100kg)	:	3,500m^3
Wave Dissipation Blocks (1 ton)	:	9,700 units
Reinforced Concrete	:	1,600m^3
Steel Reinforcement	:	50tons
Geotextile Sheets	:	8,200m^2

5-3-3 Basic Design Drawings

The basic design drawings for the proposed seawall are shown in Fig.5.5.

Table 4.1 Experimental Results for the West Coast

TYPE	ELEVATION OF SEAWALL (D.L.+m)	BLOCK MOUND		CROWN HEIGHT OF BLOCKS (D.L.+m)	INCIDENT WAVE		TIDE LEVEL (D.L.+m)	OVERTOPPING RATE ($m^3/m\ s$)	RUNUP HEIGHT (D.L.+m)	REMARKS
		Num. of Row	Num. of Layer		Ho(m)	T(sec)				
PRESENT CONDITION	2.6	——	——	——	1.2	4.6	1.34	0.034	6.5	
PLAN-(1)	3.0	4	2	1.5				0.005	4.4	
PLAN-(2)	3.0	4	3	1.5				0.004	4.1	
PLAN-(3)	3.0	5	2	3.0				0.002	2.7	
PLAN-(4)	3.0	5	3	3.0				0.0	——	
PLAN-(5)	3.0	5	3	3.0				0.0	——	

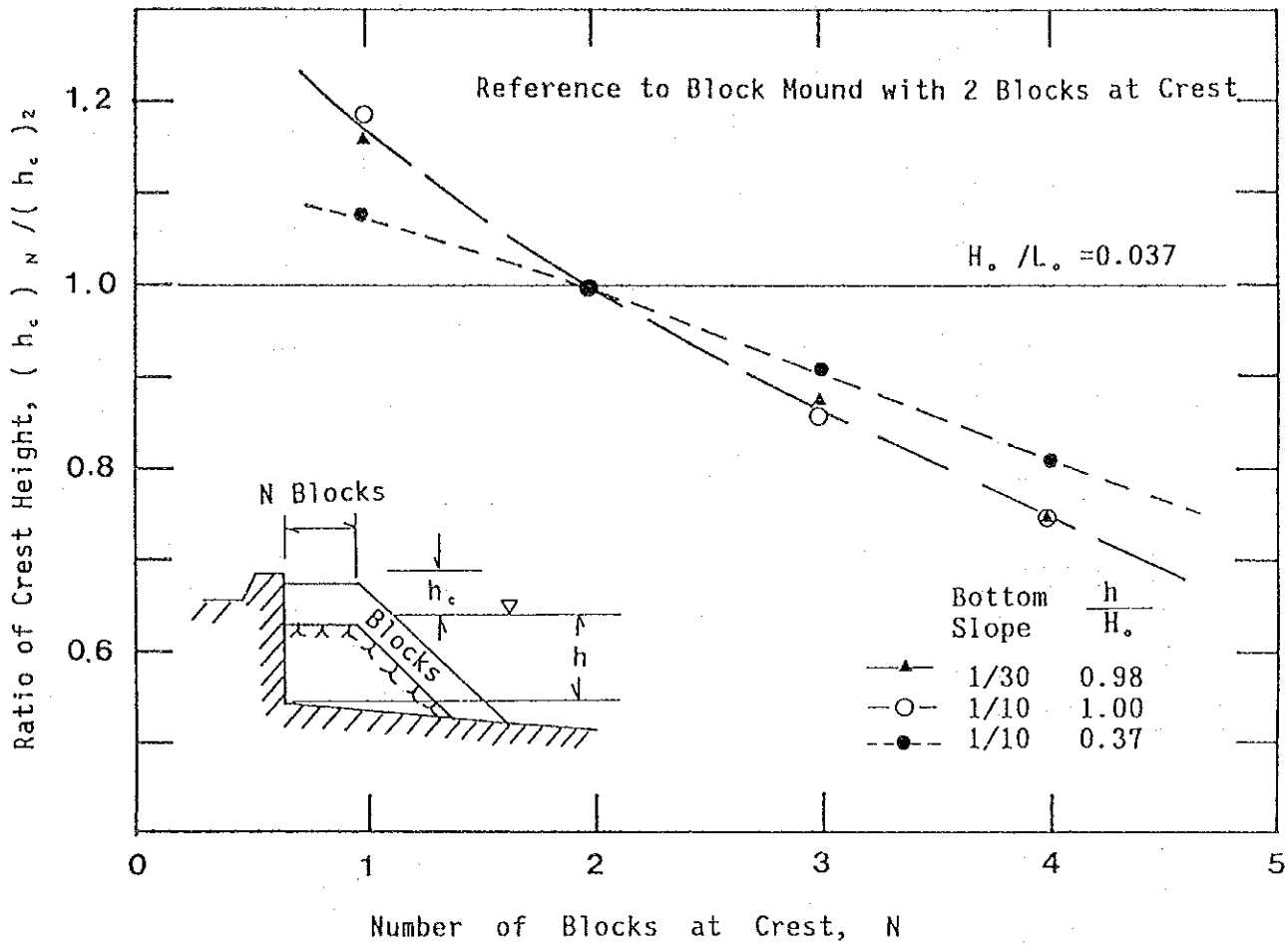


Figure 5.2 Ralation between Ratio of Crest Height and Crown Width of Blocks

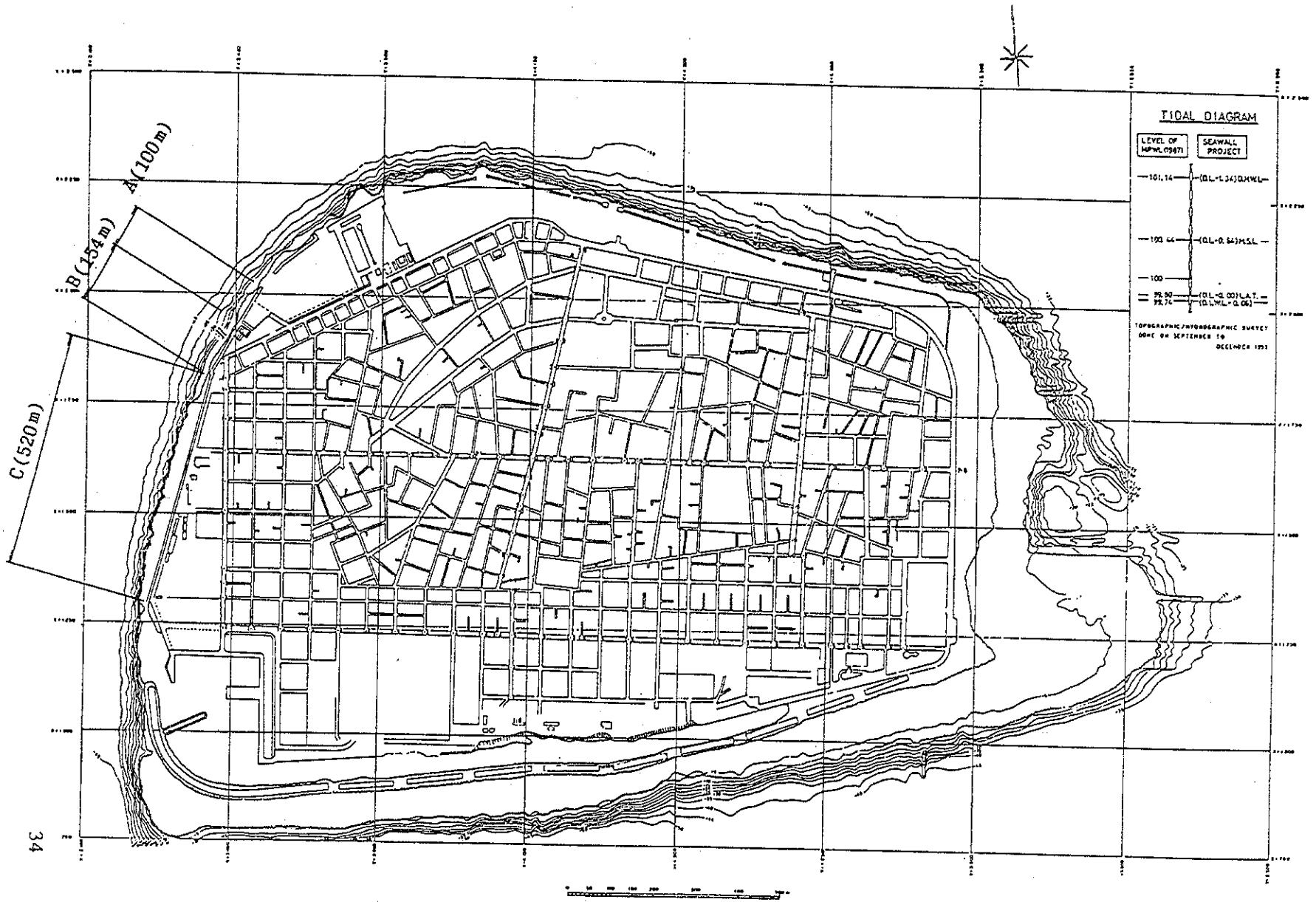
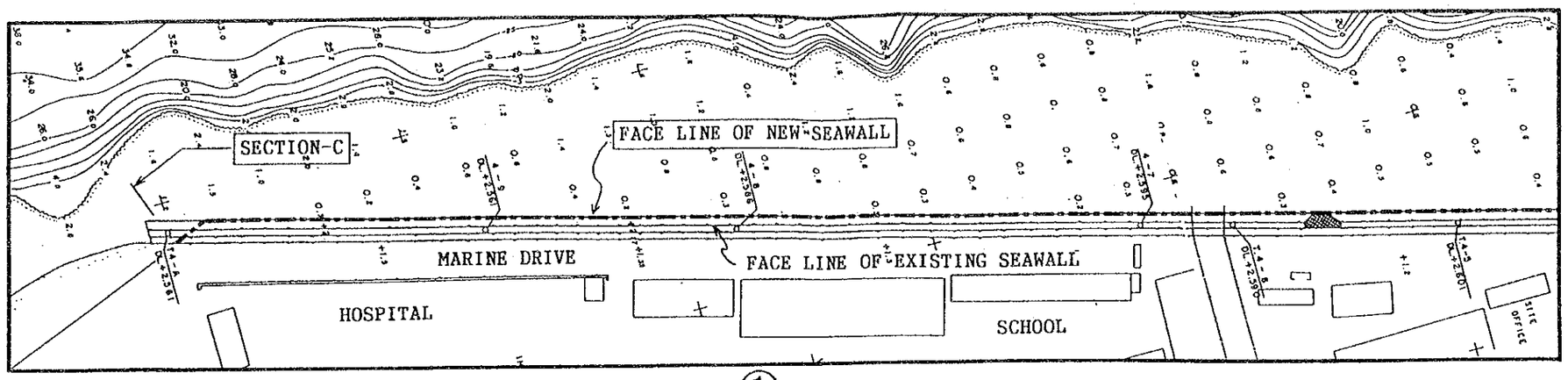


Figure 5.3 Project Site for Shore Protection



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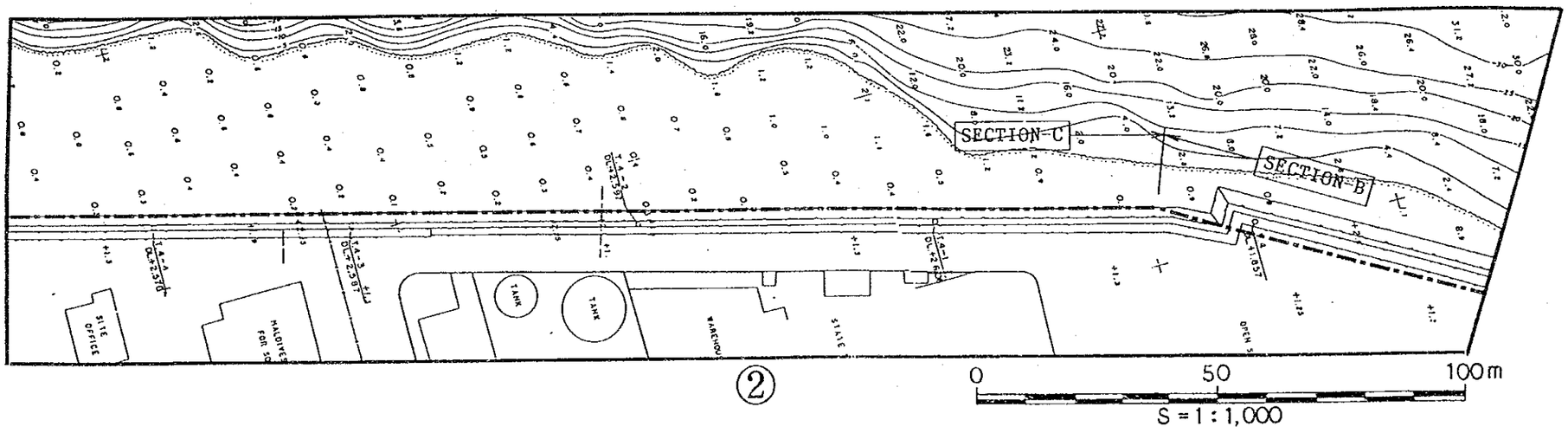

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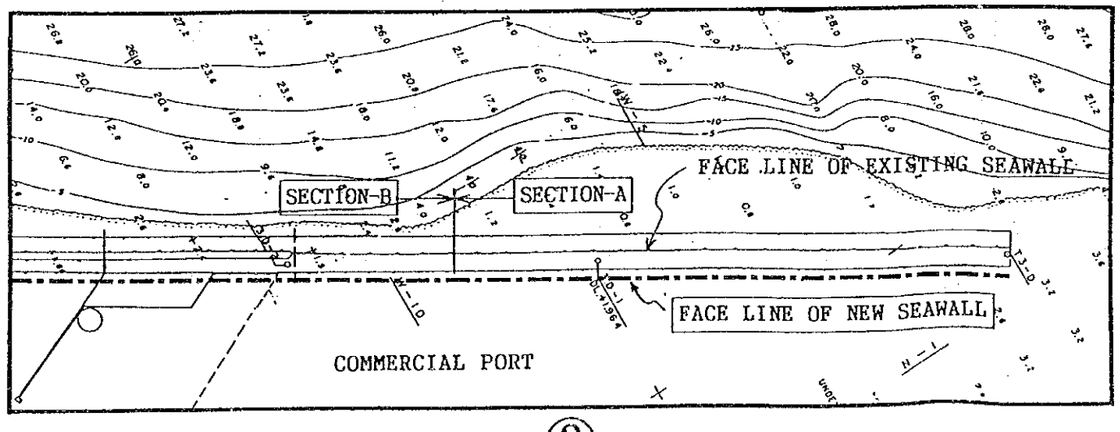

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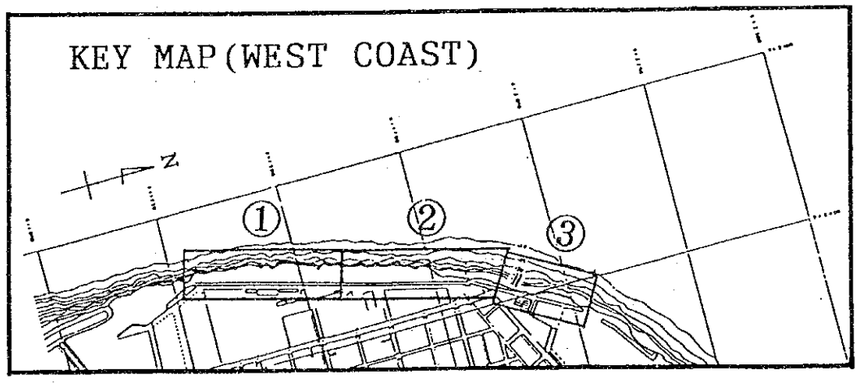
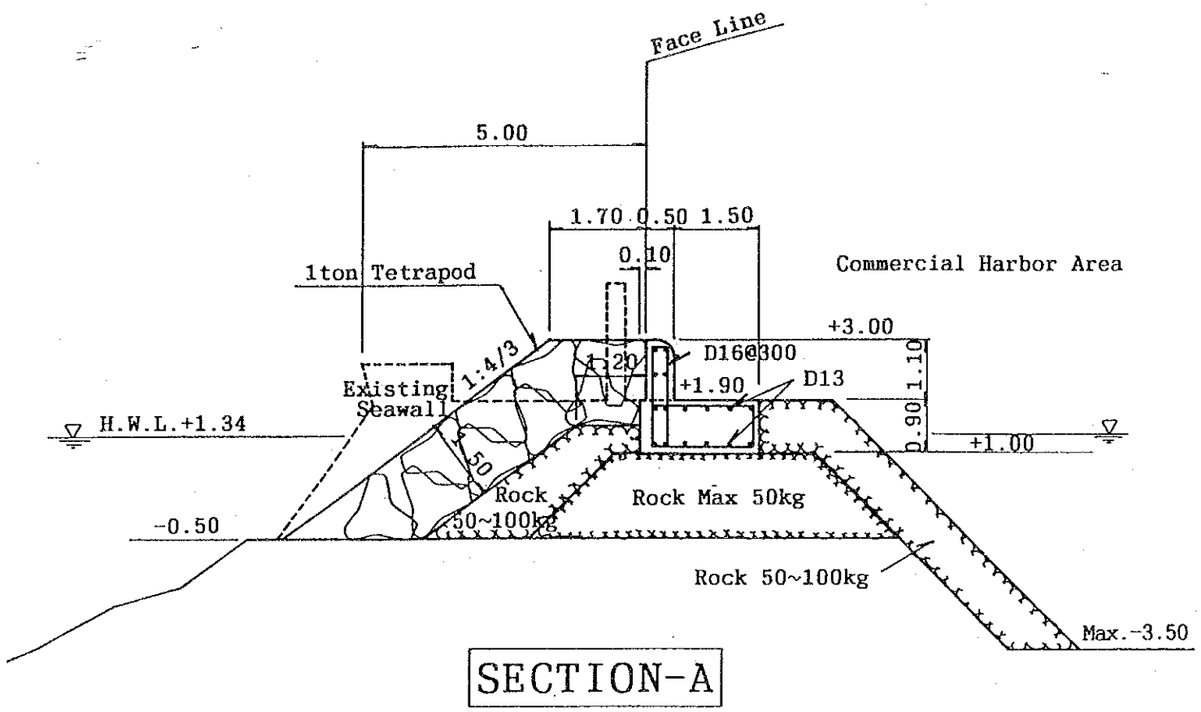
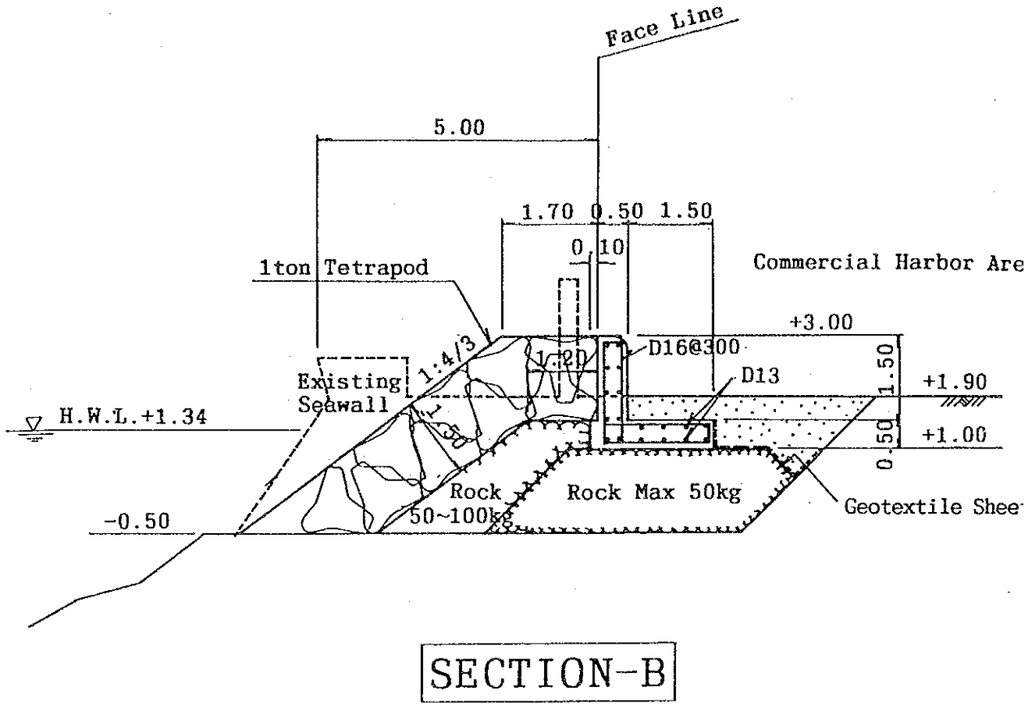


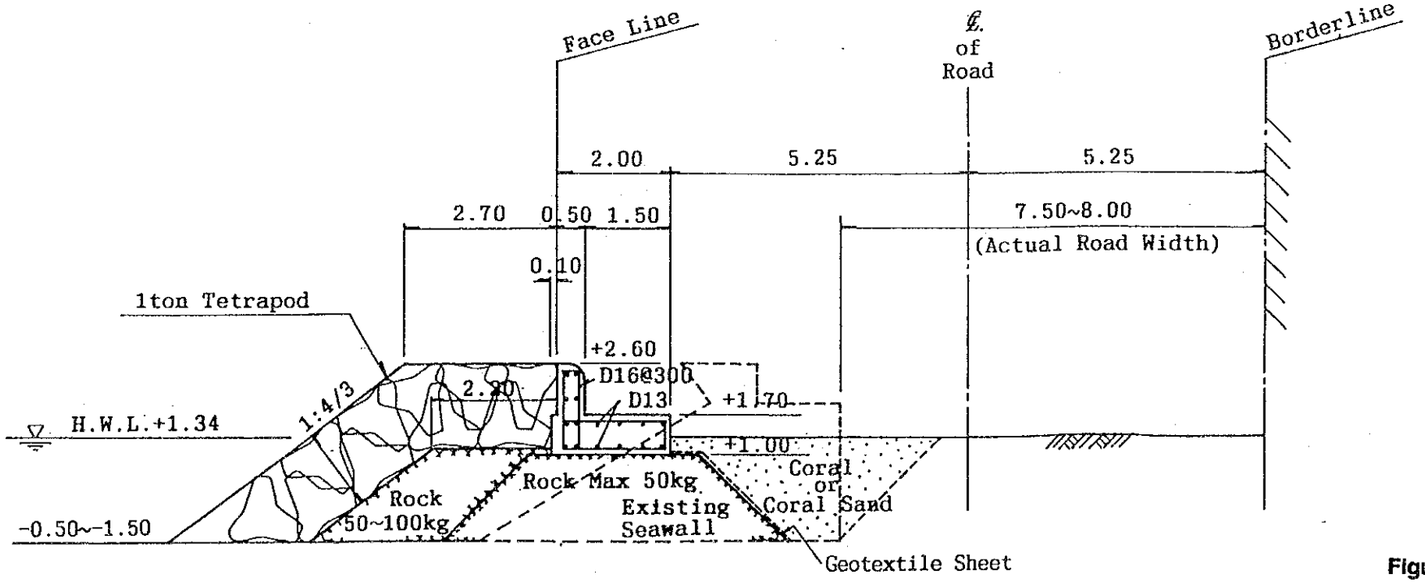
Figure 5.4 Layout of Shore Protection Facilities on the West Coast



SECTION-A



SECTION-B



SECTION-C

Figure 5.5 Typical Section of Shore Protection Facilities

5-4 Implementation Plan

5-4-1 Implementation Policies

1. Execution Method

Following the Exchange of Notes, the Government of the Republic of Maldives will conclude an agreement with an authorised foreign exchange bank in Japan concerning the authorization to pay for the grant aid funds from the Government of Japan required for the implementation of the present project. It will also select a Japanese execution design and construction management consultant and a contractor for implementation of the construction work.

2. Execution Plan

<Preparatory Works (Temporary Works)>

(1) A large number of important facilities, such as schools, a hospital, a social education centre, private housing and warehouses, are situated behind the project area on the West Coast of Male' Island, while the road running behind the planned seawalls plays an important role in the lives of the islanders.

It has been decided, therefore, that, in drawing up the execution plan, adequate attention should be paid to the preservation of the environment during the construction work, for example, through reduction of noise and vibration and guarantee of safety during the passage of the construction vehicles.

At the same time, rationalisation of the work should be ensured as far as possible to reduce the construction period, since the construction work is to take place along the coast with the existing seawalls for protection against waves removed during the construction work.

The construction work will be executed in accordance with the flowchart given in Figure 5.6.

① Of the construction materials and equipment required, only coral stones, oil and fuel can be procured in the Maldives and other materials and equipment will have to be procured elsewhere, while the local technicians and labourers too cannot be hired in the Maldives. The plan will therefore be to procure and import construction materials and equipment from third countries and to hire technicians and labourers also from third countries.

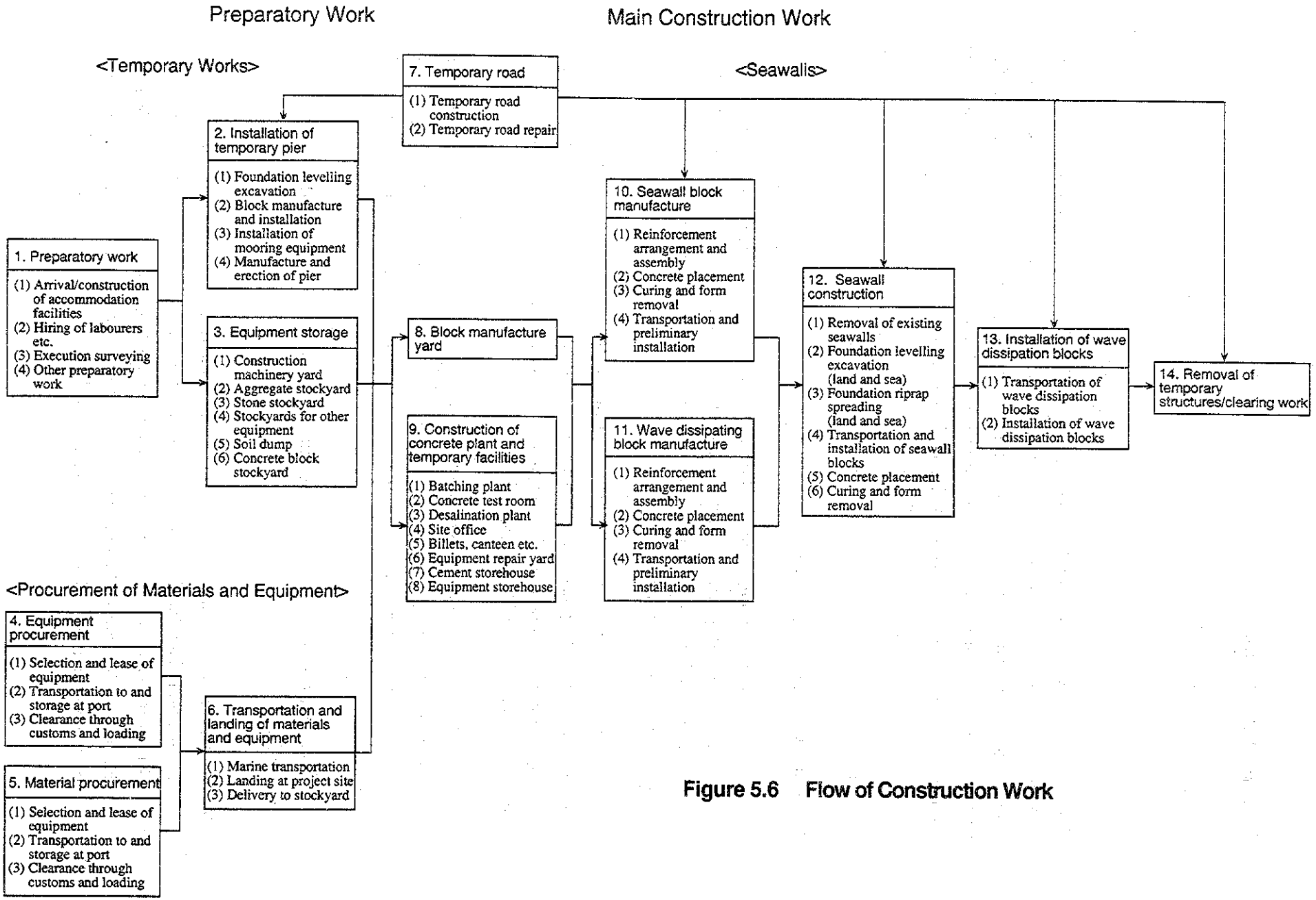


Figure 5.6 Flow of Construction Work

② With respect to the importation of construction materials and equipment, the small tonnage of the regular commercial liners calling at Maldives and the shortage of the unloading equipment there prevent the transportation of large quantities of materials and equipment in one go, presenting problems in terms of schedule management. For this reason, it has been decided that a large barge (5,000 ton class) and a towboat should be chartered in a third country for bulk transportation of all the materials and equipment in several trips.

③ On Male' Island goods are transferred by small barges for landing from the vessels anchored offshore. This method may result in confusion when the construction materials and equipment are unloaded together with other cargo. Furthermore, there is not suitable facilities for unloading of heavy construction machinery and large quantities of stone materials. A temporary pier needs, therefore, to be constructed for unloading of the construction materials and equipment with the barge moored directly on to it.
The temporary pier is, in principle, to be removed after the completion of the project.

④ Because of the large quantities of materials and equipment, stockyards need to be constructed individually for storage to ensure safety and efficiency.
A total area of around 2,000 m^2 will be required for the stockyards for materials and equipment.

⑤ Because of the shortage of accommodation facilities on the island, temporary facilities, such as the billets for the large number of technicians and labourers from third countries, will be constructed.
A total area of around 8,400 m^2 will be required for these temporary facilities.

⑥ A concrete plant will be constructed for manufacturing the large quantities of concrete required in the project. To ensure satisfactory quality control, the concrete plant will be provided with storehouses for cement and for reinforcement steels and a concrete strength test room. In view of the lack of freshwater on the island, a desalination plant will also be provided for production of water for use in concrete mixing and curing.
The area required for the installation of the concrete plant, together with the concrete block manufacture yard mentioned below, will be 14,000 m^2.

⑦ Parts of the ordinary roads on the island will be used, as mentioned above, for transportation of the materials and equipment, as well as concrete blocks, from the stockyards and the manufacture yard to the construction sites. Pavement repair etc. will be carried out on the roads in advance as temporary construction roads to prevent damage to the roads due to transportation of heavy loads. The construction roads will be repaired whenever they are damaged.

⑧ The sites of the temporary facilities (stockyards for materials and equipment, concrete plant, temporary buildings) and the routes of the temporary construction roads are shown in Figure 5.7.

<Seawalls>

① Removal of Existing Seawalls

The existing seawalls are made of coral stones, used as the core materials and bound by coating with mortar. The seawalls can be dismantled with machinery installed on land.

As the Maldivian Government has plans to use the waste materials (concrete masses, coral stones, earth etc.) generated by the removal work for reclamation on the East Coast, the waste materials will, in principle, be transported to and disposed of on the East Coast. If, however, the seawalls etc. for preventing the outflow of the earth cannot be completed in time on the East Coast, the waste materials will be stored temporarily at other sites on the island, as the outflow of earth may result in the deterioration of the coastal environment.

The coral stones could also be used in the foundations of the planned seawalls. The best stones will be selected and will be reused where possible.

② As in the removal work, the parts of the levelling excavation work and riprap spreading work for the seawall foundations above the water surface will be implemented from the land side, while the parts of the work below the water surface will be implemented from the sea.

Since the quality of the foundation work will affect the strength of the seawall structures, divers will be deployed for finished form control in the work implemented from the sea.

③ The superstructures, which comprise the main structural parts of the seawalls, will be L-shaped reinforced concrete structures. Care will be taken to ensure the alignment of the face lines and crests of the seawalls.

The seawall construction work will be implemented in the following order: removal of existing seawalls → foundation levelling excavation → foundation riprap spreading → seawall construction. During the construction of the foundations, when the existing seawalls have been removed, the coastline will be exposed directly to the waves coming in from the west. To minimise this period of exposure, the lower parts (horizontal sections) of the seawalls will be manufactured in advance in the form of blocks at the block manufacture yards and will be installed as soon as the spreading of riprap is completed in each section to allow the construction of the vertical sections of the L-shaped walls to start immediately.

④ One-ton tetrapods will be used for the wave dissipation blocks. These will be manufactured in advance at the manufacture yards and will be stored in the stockyards. The wave dissipation blocks will be installed as soon as the seawalls are completed in each section. To ensure efficiency, they will be installed from the land side using large cranes.
The locations of the block manufacture yard and stockyard are shown in Figure 5.7.

<Procurement Plan for Construction Materials and Equipment>

Under the proposed project, in which large quantities of materials and equipment are used and for which a large number of labourers will be employed from third countries, efficient procurement of high quality materials is desired from the point of view of schedule control. All materials and equipment, other than fuel oil, will be procured in third countries as follows.

① Cement, wood, reinforcing bar and other steel materials will be procured in Singapore.
② Materials such as waterproof sheets and steel concrete forms will be procured in Japan.
③ Stones and concrete aggregate materials will be procured in Malaysia.
④ Most of the construction machinery will be procured in Singapore. Machinery used continually over long periods of time, however, such as the batching plant and desalination plant, will be procured in Japan.

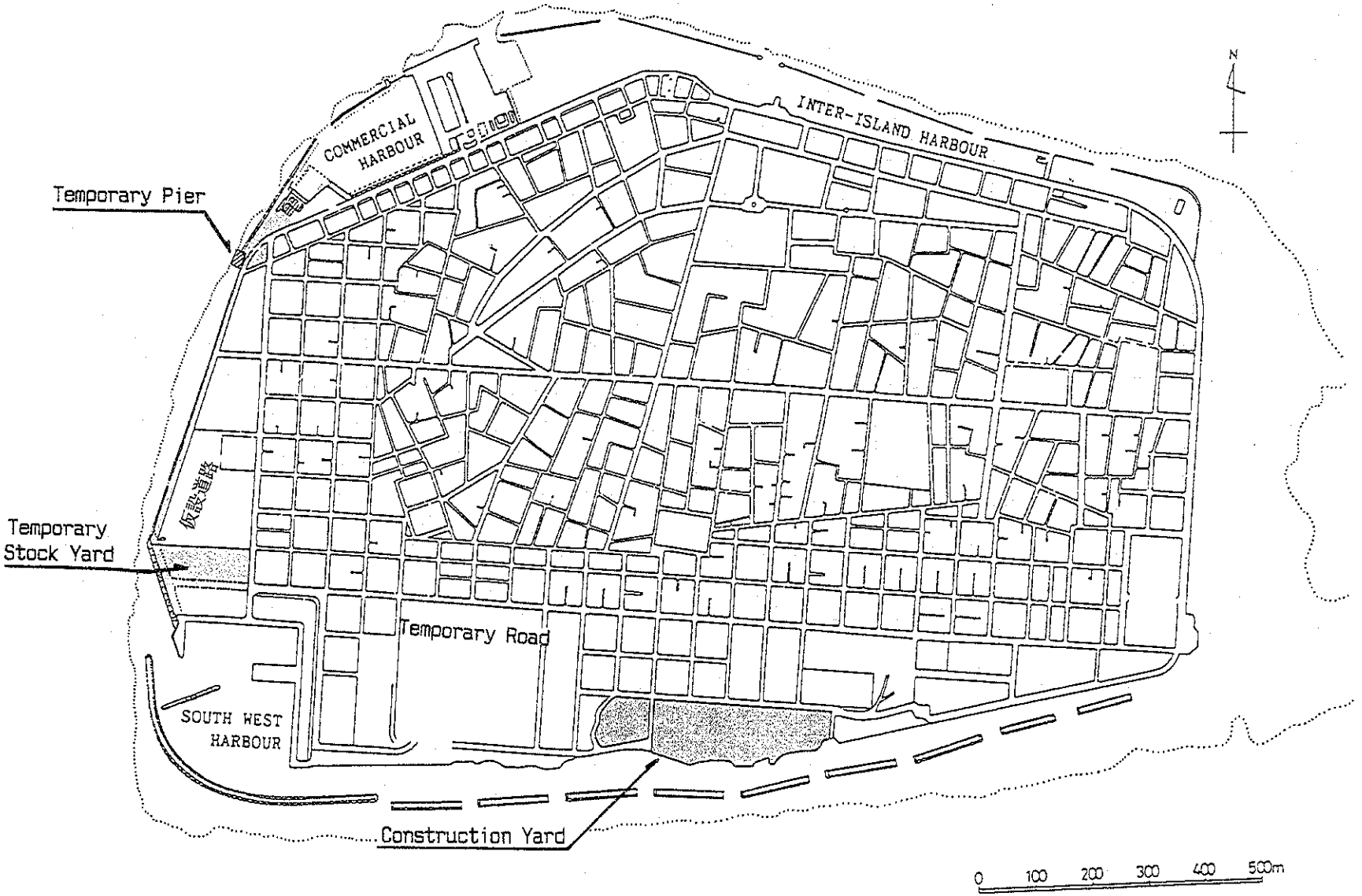


Figure 5.7 Location Map of Temporary Works

5-4-2 Construction Conditions

(1) Labour Conditions in Maldives

The small population of Maldives means that the working population too is small, making it difficult to secure the site staff and labourers required for the project within Maldives. Site staff and labourers for construction projects in Maldives are brought in from neighbouring countries. Under the present project too, labourers will be hired mainly from neighbouring countries.

(2) Procurement of Construction Materials and Equipment in Maldives

Most of the principal construction materials and equipment required for the project are not produced in Maldives and therefore cannot be procured there. The procurement conditions for the principal construction materials and equipment in Maldives are discussed below.

① Cement

Importation of cement produced in India is very little used in Maldives because of its low quality to secure the design strength. As a result, cement imported from Malaysia and Indonesia is used in construction work in Maldives.

② Concrete Aggregate

Stable supply of aggregate from India is hindered by the problems relating to the cargo collection system in the country, including transportation to and storage at the ports, which produce elements of uncertainty, such as the difficulty of delivering the required quantities of materials by the set date.

Sri Lanka restricts exportation of stones including aggregate materials. Sri Lanka is therefore excluded from the prospective procurement sites for concrete aggregate.

③ Other Materials (reinforcement steels, joint materials, plywood, crushed stones etc.)

(a) Reinforcement steels

Because of the quality of the products from India and Sri Lanka, most of the reinforcement steels used in Maldives are imported from Malaysia and Singapore.

(b) Other steel materials (flat plates, H steels, L steels, channel steels etc.)

Imports from Malaysia and Singapore also account for the majority of the other steel materials because of the product quality of neighbouring countries.

(c) Concrete joint materials, suction prevention materials

Japanese products provide the best quality, but materials procured in Singapore are adequate.

(d) Plywood (for concrete forms), wood

These are procured in Singapore. They mostly come from Malaysia.

(e) Stones (crushed stones, riprap)

As in the case of concrete aggregate materials, exportation of stones is restricted in Sri Lanka. Supply of stones from India is unstable and their use is impractical. As a result, most of the stones used for construction work in Maldives are imported from Malaysia. While coral stones can be procured within Maldives, there are restrictions on their collection.

(3) Marine Transportation in Maldives (esp. with reference to construction materials and equipment)

① The regular cargo liners calling at Maldives are small vessels with displacement tonnages of 1,000 to 2,000 tons, and the capacities of their unloading derricks are small. The port facilities too are underdeveloped and there are no piers for direct berthing of the cargo boats, with the result that the cargo arriving in Male' have to be transferred to barges and *dhoni*.

② The unloading equipment on the 1,000 to 2,000 ton cargo boats are capable of lifting loads up to only around 5 tons, meaning that large construction machinery, such as crawler cranes and bulldozers, will have to be dismantled into parts for unloading.

③ The materials and equipment could be transported in bulk using regular cargo liners. Cargo liners arrive in Maldives once every two months or so from India and twice a month from Singapore. Boats from Singapore, however, do not normally leave until they are fully loaded, hindering a stable supply of the goods. A 1,000 ton class boat could be chartered in India, but the shortage of vessels with adequate derrick and other equipment makes this option impractical.

5-4-3 Construction Supervision Plan

In accordance with the rules for grant aid from the Government of Japan, a design and construction supervision contract will be concluded between a Japanese consultant and the Ministry of Foreign Affairs of the Maldivian Government. The construction supervision work under this contract will involve cooperation relating to the conclusion of an appropriate construction contract and fair supervision of the contractor with a view to the achievement of the intentions of the design to ensure that the construction work is implemented in accordance with the contract.

1. Assistance to construction contract

   Preparation of tender and contract documents, examination of itemised statements, attendance at conclusion of contract

2. Examination of drawings and other documents

   Examination of drawings, materials and equipment etc. submitted by the contractor

3. Instruction in construction work

   Instruction in execution, scheduling, and quality and safety planning and control; submission of progress reports to the client

4. Payment approval

   Cooperation for investigations on the contents of the statements etc. and procedures for the payments made during and after the construction work

5. Inspections

   Inspections on the construction works

The consultant will have completed its services when, after the completion of the construction work and confirmation that the conditions of the contract have been fulfilled, it has attended the delivery of the work and has obtained the approval of the owner.

5-4-4 Implementation Schedule

The overall schedule for the project, including the construction work, is given in Figure 5.8. Each of the items is discussed below.

1. Consultant contract

MOFA will conclude a contract with a consultant concerning design and management work. After the conclusion of the contract, the consultant will have the contract approved by the Government of Japan.

2. Detailed design

After the conclusion of the contract, the consultant will carry out the detailed design on the basis of the Basic Design Report and will prepare the tender documents. The consultant will hold preliminary, interim and final discussions with the relevant personnel in the Maldivian Government during the period of three months allotted for this purpose.

The consultant will obtain the approval of MPWL for the tender documents prepared in the detailed design.

3. Tendering

Using the documents approved by MPWL, the consultant will explain the drawings and the site conditions to Japanese tenderer and invite them to tender. A period of around three months has been allocated for the tendering work, which will include ① tender announcement, ② qualifications of the tenderers, ③ examination and evaluation of the tender documents, and ④ conclusion of construction contract.

4. Construction

After the conclusion of the construction contract, the construction work will commence upon approval from the Japanese Government. A period of 18 months has been allotted for the construction work, on the basis of the scale and scope of the project and the site conditions.

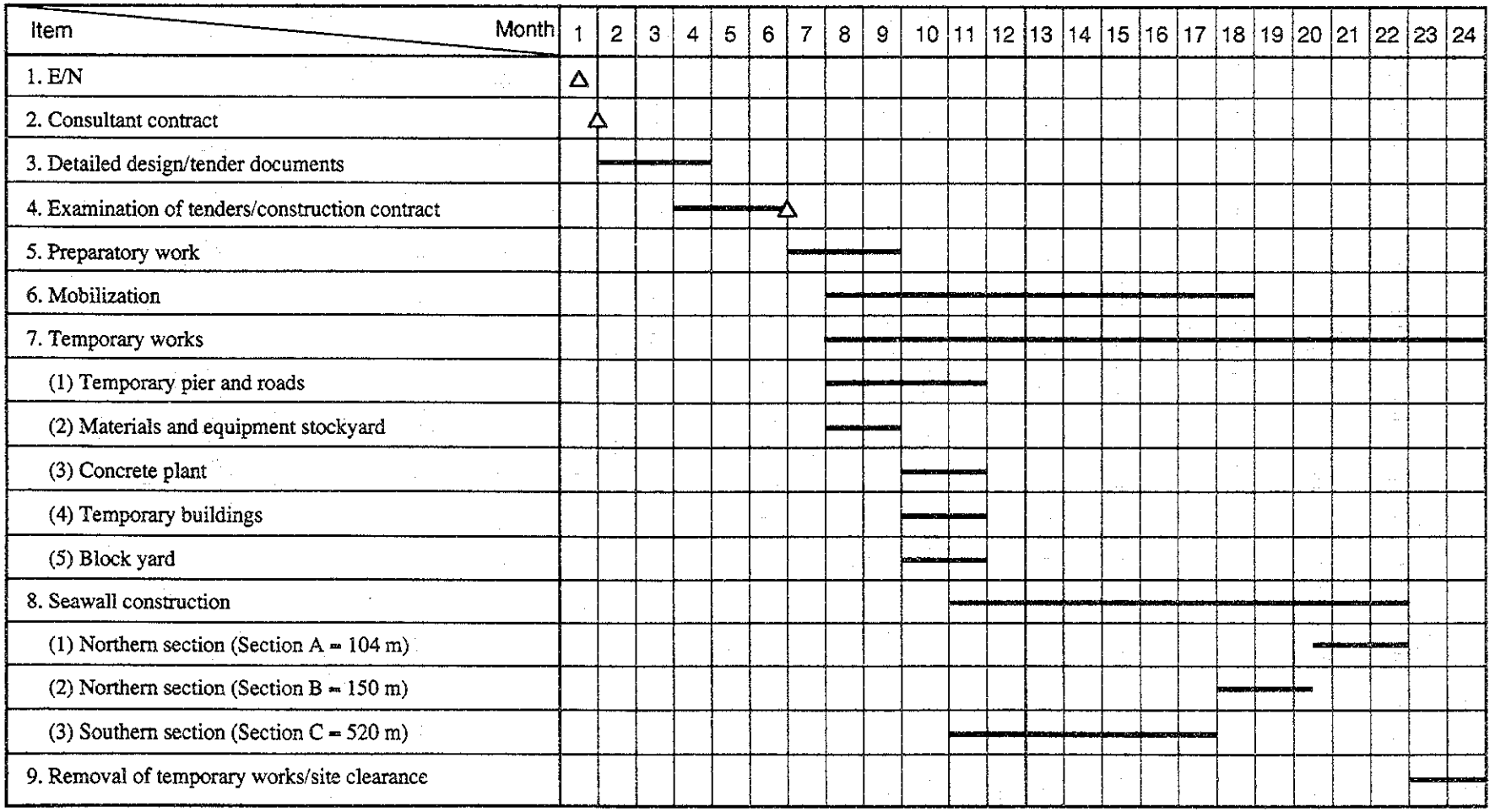


Figure 5.8 Project Schedule

5-4-5 Scope of Works

Scope of Works to be undertaken by the Government of Maldives are as follows.

(1) To secure land for the seawalls and other related facilities.

(2) To provide temporary land for the construction office, warehouse, stock yard etc. during the construction period.

(3) To provide accessible roads to the project site from the construction office.

(4) To provide facilities for the distribution of electricity, telephone lines and other incidental facilities to the office.

(5) To ensure the speedy unloading, tax exemption, custom clearance at ports of disembarkation in the Maldives as to the products purchased under the grant aid cooperation from the Government of Japan.

(6) To bear the commissions to a Japanese foreign exchange bank for the banking services based upon the Banking Arrangement.

(7) To accord Japanese Nationals whose services may be required in connection with the supply of the products and under the verified contract to enter into Maldives and to stay therein for the performance of their works.

(8) To maintain properly the seawalls constructed under the grant aid cooperation.

Scope of Works to be undertaken by the Government of Japan are as follows.

(1) To construct the seawalls between a section of 774 meters on the west coast of Male' Island.

(2) To procure equipments, materials and the labour force required for the construction of the seawalls.

CHAPTER 6 PROJECT EVALUATION AND CONCLUSION

6-1 Project Evaluation

The benefits expected to result from the project are summarized as follows:

(1) The seawalls to be constructed under the project will provide protection against inundation damage from storm surge caused by high waves during the southwest monsoons to the buildings within the 18 ha of reclaimed area along the West Coast, which makes up around 10% of the total area of Male' Island.

(2) They will provide protection against direct destructive damage due to the overtopping waves to the public facilities situated along the coastline, including the Social Education Centre, two primary schools, a hospital and the boat repair yard for the Commercial Harbour, as well as the warehouses of the State Trading Organization (STO).

(3) The construction of a 10.5 m-wide trunk road is planned behind the proposed seawalls to connect between the Southwest Harbour and the Northern Commercial Harbour, so that the guarantee of safety for the passing traffic from the overtopping waves will be secured by the project.

(4) They will enable the prevention of the spread of contagious diseases, such as that observed during the storm surge disaster of 1987.

The benefits of the project are summarized in Table 6.1.

Table 6.1 Summary of the Benefits of Project

Benefits	Beneficiary
1) Guarantee of safety for public facilities (hospital, social education centre, primary , schools, harbour facilities, road) 2) Protection of housing, shops, household goods in the land area from disasters 3) Guarantee of safety for traffic on a trunk road 4) Prevention of contagious diseases	1) Direct beneficiary area: 18 ha 2) Direct beneficiary population: approx. 6,000 Note: The area benefiting directly covers approximately 10% of the total area of Male' Island.

Resulting the above, the following points are concluded.

① A large number of local residents will be benefited from the project.

② The project will contribute to the improvement of living conditions for the local residents.

③ The project will not place any major financial burden on the Maldivian Government, which will be responsible for the maintenance, operation and management of the seawalls after their construction.

④ The project is considered as a basic disaster prevention project which is required for protection of the facilities constructed under the development plans for Male' Island (hospital, harbour facilities, coastal road etc.).

⑤ The construction work can be implemented without any major difficulties.

6-2 Conclusion and Recommendations

The implementation of the project will protect the west coast and the land behind it calling for urgent implementation of appropriate countermeasures, which accounts nearly 10% of the total area of the Male' Island from storm surge disasters due to high waves; consequently, 6,000 or so local residents will be able to lead their lives in security. To be more specific, the safety of the public facilities situated along the coastline, including a hospital, a social education centre, primary schools, harbour facilities and coastal road can be secured. Moreover, the buildings in these area, including private housing and small shops, as well as household goods will be protected from storm surge disasters due to high waves. Economic benefits are also expected to result from seawall construction, namely, safety for the passing traffic on the coastal road can be guaranteed. Besides the above economic benefits, social benefits are also expected as follows: the improvement of the living conditions for the local residents by providing them with the guarantee of safety in their everyday lives and while travelling to and from schools and the hospitals; and, the psychological effects on them in the form of a sense of security. In view of other benefits mentioned below, it is deemed appropriate to implement the project under the grant aid cooperation from the Government of Japan.

* Technical transfer regarding seawall construction is expected.
* The project may be considered a disaster prevention project which is required for protection of the facilities constructed under the development plans for Male' Island (hospital, harbour facilities, coastal road etc.)
* The construction work can be implemented without any major difficulties.

In order to implement the project effectively, the following measures are proposed to be undertaken by the Maldivian Government.

1) This project covers only the areas along the west coast of the entire coastal area of Male' Island where urgent implementation of appropriate countermeasures is called for. In order to confirm the technical effects of the project and to improve the knowledge of storm surge disaster prevention, it is important to monitor the wave runup height and the conditions of wave overtopping after the completion of the proposed seawalls, as well as to collect data on the above items at other coastal areas to establish a system that facilitates the formulation and implementation of future disaster prevention plans.

2) In Maldives, an island nation set in the Indian Ocean, islands other than Male' will also likely suffer from storm surge disasters in the future. Consequently it is expected to acquire knowledge of coastal engineering and to master construction technology to be used in this project so as to enable the Maldivians to devise coastal disaster prevention plans by their own in future.

Appendix

1. Member List of Study Team

Name	Duty	Position/Affiliation
Yuji Ogura	Leader	Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs
Hiroshi Sakuramoto	Manager, Coastal protection	INA Corporation
Kazuo Unoki	Construction planning, Cost estimate	INA Corporation

2. Survey Schedule

Date order	Date	Itinerary	Work/Activity
1	Aug.19 (Thu.)	Tokyo—Colombo (UL-457)	Travel
2	Aug. 20 (Fri.)	Colombo—Male' (UL-101)	Visit JICA office and the Japanese Embassy
3	Aug. 21 (Sat.)	Male'	Site investigation
4	Aug. 22 (Sun.)	Male'	Visit (consultation) Ministry of Foreign Affairs Visit (consultation) Ministry of Public Works and Labour
5	Aug. 23 (Mon.)	Male'	Consultation with the Ministry of Public Works and Labour Supplementary topographical survey
6	Aug. 24 (Tue.)	Male'	Consultation with the Ministry of Public Works and Labour Supplementary topographical survey
7	Aug. 25 (Wed.)	Male'	Site investigation Consultation with the Ministry of Public Works and Labour on M/M Supplementary topographical survey
8	Aug. 26 (Thu.)	Male'	Collect data Supplementary topographical survey
9	Aug. 27 (Fri.)	Male'	Pigeonhole data Supplementary topographical survey
10	Aug. 28 (Sat.)	Male'	Consultation on M/D (Ministry of Public Works and Labour/Ministry of Foreign Affairs)
11	Aug. 29 (Sun.)	Male'	Signing of M/D Pigeonhole data
12	Aug. 30 (Mon.)	Male'	Pigeonhole data
13	Aug. 31 (Tue.)	Male'—Colombo (UL-102)	Travel Visit the Japanese embassy to report on returning home
14	Sep. 1 (Wed.)	Colombo—	Visit JICA to report on returning home Travel
15	Sep. 2 (Thu.)	—Tokyo	Travel

3. Member List of Personnel Concerned

Persons concerned with the Government of the Republic of Maldives

Ministry of Foreign Affairs

Mr. Mohamed Shihab	Director of External Resources,
Mr. Mohamed Naseer	Assistant Undersecretary

Ministry of Public Works and Labour

Mr. Ibrahim Maniku	Director of Public Works
Mr. Ahmed Ashraf	Assistant Undersecretary
Mr. Ismail Ibrahim	Civil Engineer

Persons concerned with the Government of Japan

Hiroyuki Kinomoto	Third secretary, The Japanese Embassy at Sri Lanka
Yoshiaki Sakamaki	Resident Representative, Sri Lanka Office of the Japan International Cooperation Agency
Mitsuyoshi Kawasaki	Assistant Resident Repressentative, Sri Lanka Office of the Japan International Cooperation Agency
Akihito Sakamoto	Civil engineer, Member of Japan Overseas Cooperation Volunteers in Maldives

4. Minutes of Discussion

Minutes of Discussions
Basic Design Study on
the Project for Seawall Construction
in Male' Island
in The Republic of Maldives.

In response to the request from the Government of the Republic of Maldives, the Government of Japan decided to conduct a Basic Design Study on the Project for Seawall Construction in Male' Island (hereinafter referred to as "the Project") and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Republic of Maldives a study team, which is headed by Mr. Yuji OGURA, Ministry of Foreign Affairs, Government of Japan from Aug. 20, 1993 to Aug. 31, 1993.

The team held discussions with the officials concerned of the Government of the Republic of Maldives and conducted a field survey.

As a result of the discussions and field survey, both parties have confirmed the main items described on the attached sheets.

Male', Aug. 29th, 1993

Mr. Yuji OGURA
Leader,
Basic Design Study Team,
JICA

Mr. Mohamed SHIHAB
Director of External Resouces
Ministry of Foreign Affairs
Government of Republic of Maldives

Mr. Ibrahim MANIKU
Director of Public Works
Ministry of Public Works and Labour
Government of Republic of Maldives

1. Objective

The objective of the Project is to construct Seawall structure at the west coast of Male' Island to ensure a safe livelihood for the residents of Male' Island in The Republic of Maldives.

2. Project site

The site of the Project is located at the west coast of Male' Island. The location map of the site is shown in ANNEX-I.

3. Executing agency

The Ministry of Foreign Affairs is the executing agency for this project and the Ministry of Public Works and Labour is the responsible agency for implementing this project.

4. Items requested by Maldivian side

After discussions with Basic Design Study Team, the following items were requested by the Maldivian side:

(1) To construct Seawall structure at the west coast of Male' Island.
(2) To divide target areas into north area with the length of 254 meters and south area with the length of 520 meters.
(3) To construct the seawall of armor blocks with vertical wall of the following basic dimensions:
    1. crown elevation of D.L.+3.00 meters and two rows of blocks at crest in the north area and
    2. crown elevation of D.L.+2.60 meters and three rows of blocks at crest in the south area.
(4) To situate face line of the proposed seawall as follows:
    1. to retreat in five meters landward from the position of existing seawall in the north area.
    2. to advance in two meters seaward from the position of existing seawall in the south area.

However, the final components of the Project will be decided after further studies.

5. Major Point of Discussions

(1)Maldivian side will secure the working road for smooth transportation of materials, equipments and products, and space for proposed seawall by removing or demolishing obstacle facilities prior to commencement of the construction.

(2)Maldivian side will offer working space of about 20,000 m² of land on the southern coast of Male' for stocking materials and equipments, producing concrete products and for various other activities.

(3)Waste materials produced by the demolition work of the existing seawall will be deposited on certain allocated area of land provided by the Maldivian Government or the east coast of Male' on condition that Maldivian side takes proper measures preventing above mentioned materials from being washed away by waves.

6. Japan's Grant Aid System

(1)Maldivian side has understood the system of Japan's Grant Aid explained by the team.

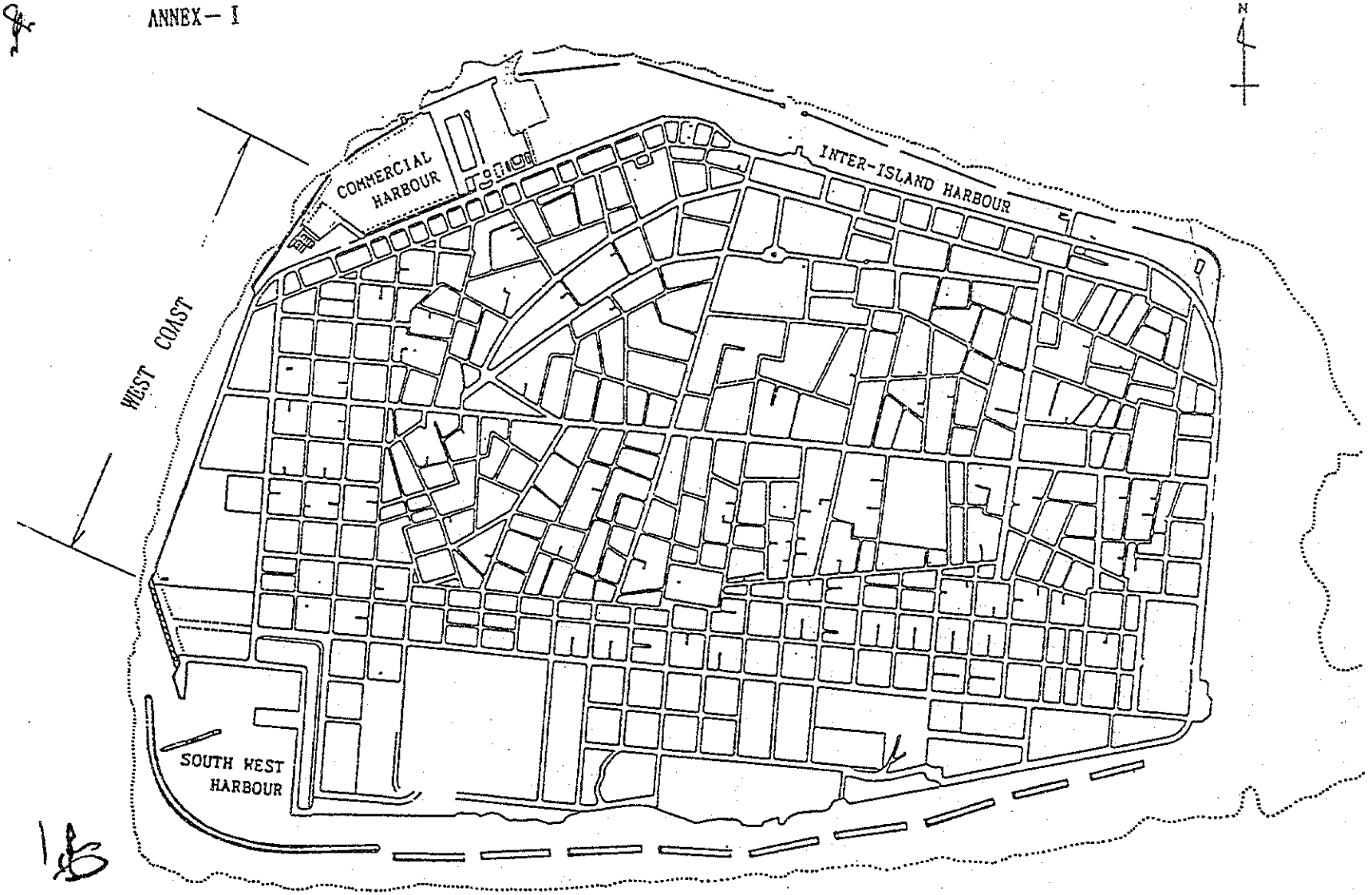
(2)Maldivian side will take the necessary measures described in ANNEX-II for smooth implementation of the Project, on condition that the Grant Aid Assistance by the Government of Japan is extended to the Project.

7. Schedule of the Study

(1)The consultants will proceed to field survey in The Republic of Maldives until Aug. 31, 1993.

(2)Based on the Minutes of Discussions and technical examination of the study results, JICA will complete the final report and sent it to the Government of Maldives by Nov., 1993.

ANNEX – I



LOCATION MAP

(9)

ANNEX-II

Major undertakings and necessary measures to be taken by the Maldivian side in case Japan's Grant Aid is executed.

(1)To provide data and information necessary for the Project.

(2)To secure land for the site, working space, a dump for industrial wastes and stock yard for materials and products.

(3)To take proper measures to prevent the destruction of the environment.

(4)To clear the sites prior to commencement of the construction.

(5)To bear the commissions to the Japanese foreign exchange bank for the banking services based upon the banking arrangement.

(6)To exempt taxes and take necessary measures for customs clearance of the material and equipment brought for the Project at the port of disembarkation in Maldives.

(7)To accord Japanese nationals whose services may be required in connection with supply of the products and services under the verified contracts, such facilities as may be necessary for their entry into Maldives and stay therein for the performance of their work.

(8)To assign the necessary staff for operation and maintenance of the facilities constructed and equipment purchased under the Grant Aid.

(9)To maintain properly the facilities constructed under the Grant Aid.

(10)To bear all the expenses other than those to be borne by the Grant Aid necessary for construction of the facilities as well as for the transportation and installation of the equipment.

(11)To explain the outline of the Project to local residents for obtaining their understandings and cooperations.

(12)To control the trafic for the road safety if necessary.

5. List of Collected Documents

No.	Title of material	Publisher
1	INTRODUCING MALDIVES	DIB
2	AN ECONOMIC BRIEF	DIB
3	MALE' THE CAPITAL	DIB
4	THE NATIONAL MUSEUM	DIB
5	HISTORY	DIB
6	FISHING	DIB
7	AGRICULTURE	DIB
8	YOUTH	DIB
9	EDUCATION	DIB
10	WOMEN	DIB
11	HEALTH	DIB
12	THE PRESIDENTIAL PALACE	DIB
13	TOURISM	DIB
14	PHYSICAL FEATURES	DIB
15	CONSTITUTIONAL HISTORY	DIB
16	NATIONAL EMBLEMS	DIB
17	ENVIRONMENT	DIB
18	MALDIVES A Nation of Islands	Media Transas ia Ltd.
19	STRATEGIES FOR THE FUTURE AND THE IMPORTANCE OF COASTAL ZONE MANAGEMENT IN THE CONTEXT OF SEA-LEVEL RISE	Dr. Alasdair J. Edwards
20	FIELD MEASUREMENT PROGRAMME ON TIDES AND WAVES IN THE REPUBLIC OF MALDIVES (FINAL REPORT SEPT. 1989)	MPWL
21	HIGH AND LOW WATER PREDICTION	University of Hawaii
22	CHANGES IN THE TOPOGRAPHY OF THE MALDIVES	Hassan Ahmed Maniku
23	International Coastal Resources Management Project — High Waves in the Maldives in 1987	University of Rhode Island
24	THE IMPLICATIONS SEA-LEVEL RISE FOR THE REPUBLIC OF MALDIVES	Dr. Alasdair J. Edwards
25	PRELIMINARY STUDY REPORT ON SEAWALL CONSTRUCTION PROJECT IN MALE' ISLAND	IECA

No.	Title of material	Publisher
26	COASTAL PROTECTION SCHEME FOR MALE' ISLAND	UNITED NATIONS DEVELOPMENT PROGRAMME
27	MALE LAND RECLAMATION AND SHORE PROTECTION WORK CONCERNED	UNITED NATIONS DEVELOPMENT PROGRAMME
28	SITE INVESTIGATION REPORT—Male' Port Development Project	MPWL
29	FIELD MEASUREMENT PROGRAMME ON TIDES AND WAVES IN THE REPUBLIC OF MALDIVES (REPORT ON DATA JUNE 1989-JANUARY 1990)	JICA
30	Preliminary study report on coastal protection project in Male' Island, the Republic of Maldives	JICA
31	Republic of Maldives Implications of Sea-Level Rise	Delft Hydraulics

* Abbreviations

DIB : Department of Information and Broadcasting

IECA : International Engineering Consultants Association

MPWL : Ministry of Public Works and Labour

JICA