JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF TRANSPORT AND COMMUNICATIONS
THE REPUBLIC OF MOZAMBIQUE

No. 52

社会開発調査部報告書

FINAL REPORT

THE STUDY FOR MAINTENANCE AND IMPROVEMENT PLAN OF ACCESS CHANNEL OF BEIRA PORT IN THE REPUBLIC OF MOZAMBIQUE

MARCH 1998

TETRA CO., LTD.
OVERSEAS SHIPBUILDING COOPERATION CENTER

SSF
JR
98-025(2/2)

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF TRANSPORT AND COMMUNICATIONS
THE REPUBLIC OF MOZAMBIQUE

FINAL REPORT

THE STUDY FOR MAINTENANCE AND IMPROVEMENT PLAN OF ACCESS CHANNEL OF BEIRA PORT IN THE REPUBLIC OF MOZAMBIQUE

MARCH 1998

CURRENCY EXCHANGE RATE

1 US Dollar = 11,300 Mozambican Meticals
= 116.84 Japanese Yen

(As of February, 1997)

PREFACE

In response to a request from the Government of the Republic of Mozambique, the Government of Japan decided to conduct a study for Maintenance and Improvement Plan of Access Channel of Beira Port in Mozambique and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent a study team to Mozambique four times between January 1997 and February 1998. The study team was headed by Dr. Shoji Sato and composed of members of Tetra Co., Ltd. and Overseas Shipbuilding Cooperation Center.

The team held discussions with the officials concerned of the Government of Mozambique and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

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

March, 1998

Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

March, 1998

Mr. Kimio Fujita
President
Japan International Cooperation Agency

Dear Mr. Fujita

It is my great pleasure to submit herewith the Report for the Study for Maintenance and Improvement Plan of Access Channel of Beira Port in Mozambique.

The study team which consists of the Tetra Co., Ltd. and Overseas Shipbuilding Cooperation Center, headed by myself, conducted a survey in Mozambique from January 1997 to February 1998 as per the contract with the Japan International Cooperation Agency.

The findings of this survey were fully discussed with the officials of the Ministry of Transport and Communications and other authorities concerned to formulate the Siltation Analysis and Maintenance Dredging Plan of the Access Channel and to formulate and examine the feasibility of the introduction of a new dredger, and were then compiled into this report.

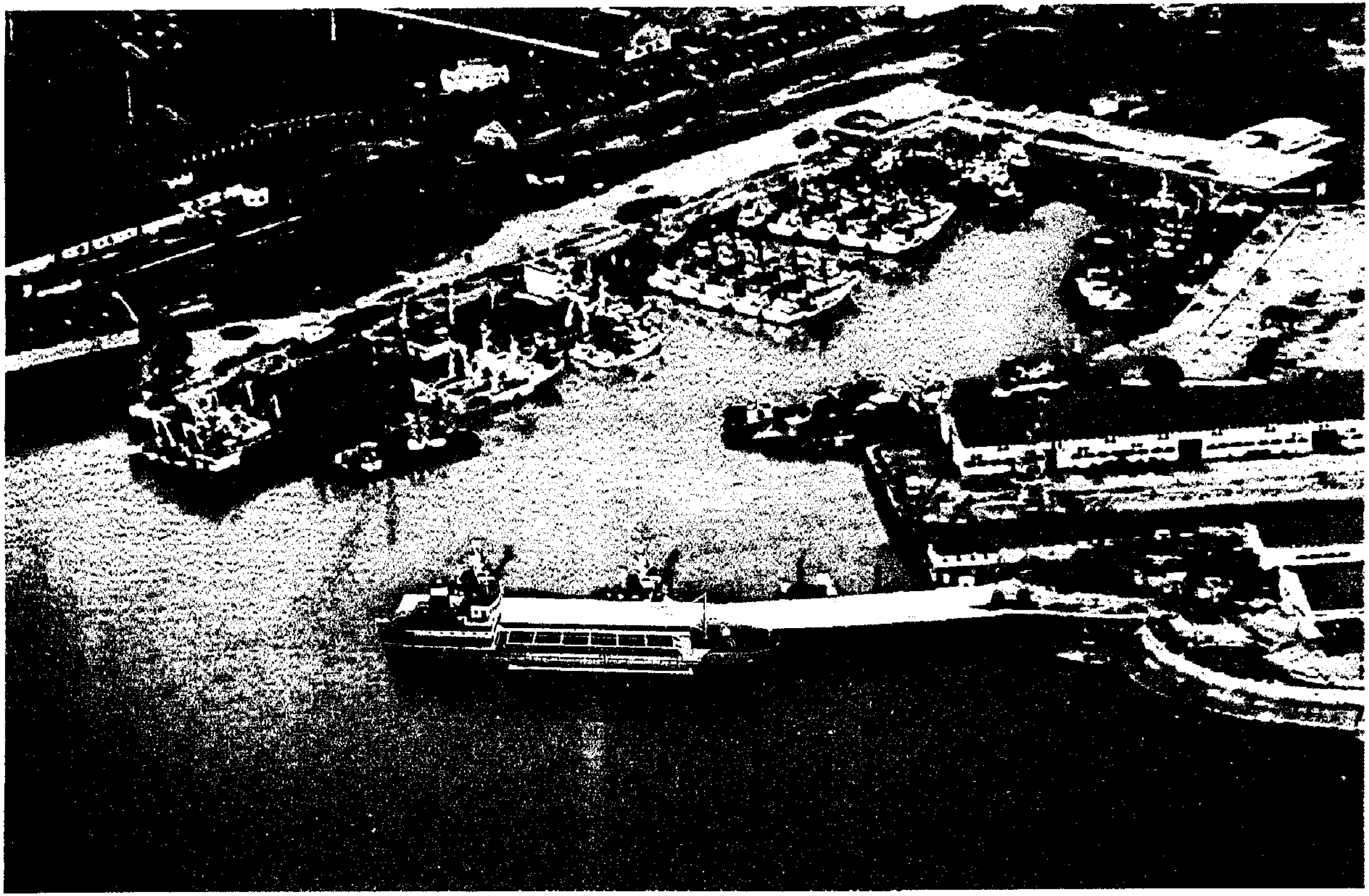
On behalf of the study team, I would like to express my deepest appreciation to the Government of Mozambique and other authorities concerned for their brilliant cooperation and assistance and for the heartfelt hospitality which they extended to the study team during the stay in Mozambique.

I am also greatly indebted to the Japan International Cooperation Agency, the Ministry of Foreign Affairs, the Ministry of Transport and the Embassy of Japan in Zimbabwe for giving us valuable suggestions and assistance during the preparation of this report.

Respectfully,

Shoji Sato
Leader of the Study Team for
the Study for Maintenance and Improvement
Plan of Access Channel of Beira Port

Beira Port and Access Channel



New Dredger and Berthing Jetty

ABBREVIATIONS

AM	Air Malawi
AZ	Air Zimbabwe
BCA	Beira Corridor Authority
BPTS	Beira Port Transport System
B/S	Balance Sheet
CA	Board of Management, CFM
CDL	Chart Datum Level
CFC	Conversion Factor for Consumption
CFL	Conversion Factor for Labor
CFM	Mozambique Ports and Railways
CFM-C	Mozambique Ports and Railways-Center
CFM-N	Mozambique Ports and Railways-North
CFM-S	Mozambique Ports and Railways-South
CFM-Z	Mozambique Ports and Railways-Zambezia
CIF	Cost, Insurance and Freight
DAC	Development Assistance Committee, OECD
DGPS	Global Positioning System in Differential Mode
DWT	Dead Weight Tonnage
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate and Return
EMODRAGA	Mozambique Dredging Company
FIRR	Financial Internal Rate of Return
FOB	Free on Board
GCT	General Cargo Terminal
GDP	Gross Domestic Product
GOJ	Government of Japan
GOM	Government of the Mozambique
GPS	Global Positioning System
HAT	Highest Astronomical Tide
IEE	Initial Environmental Examination
INAHINA	National Institute of Hydrography and Navigation
LAM	Mozambique Airline
LAT	Lowest Astronomical Tide
Loa	Length Overall
Lpp	Length between Perpendiculars
MCT	Multipurpose and Container Terminal
MHWN	Mean High Water Neap Tide
MHWS	Mean High Water Spring Tide
MLWN	Mean Low Water Neap Tide
MLWS	Mean Low Water Spring Tide
MSC	Mediterranean Shipping Company
MSL	Mean Sea Level
MT	Mozambique Meticals
MTC	Ministry of Transport and Communications
m-ton	Metric Ton
ODA	Official Development Assistance

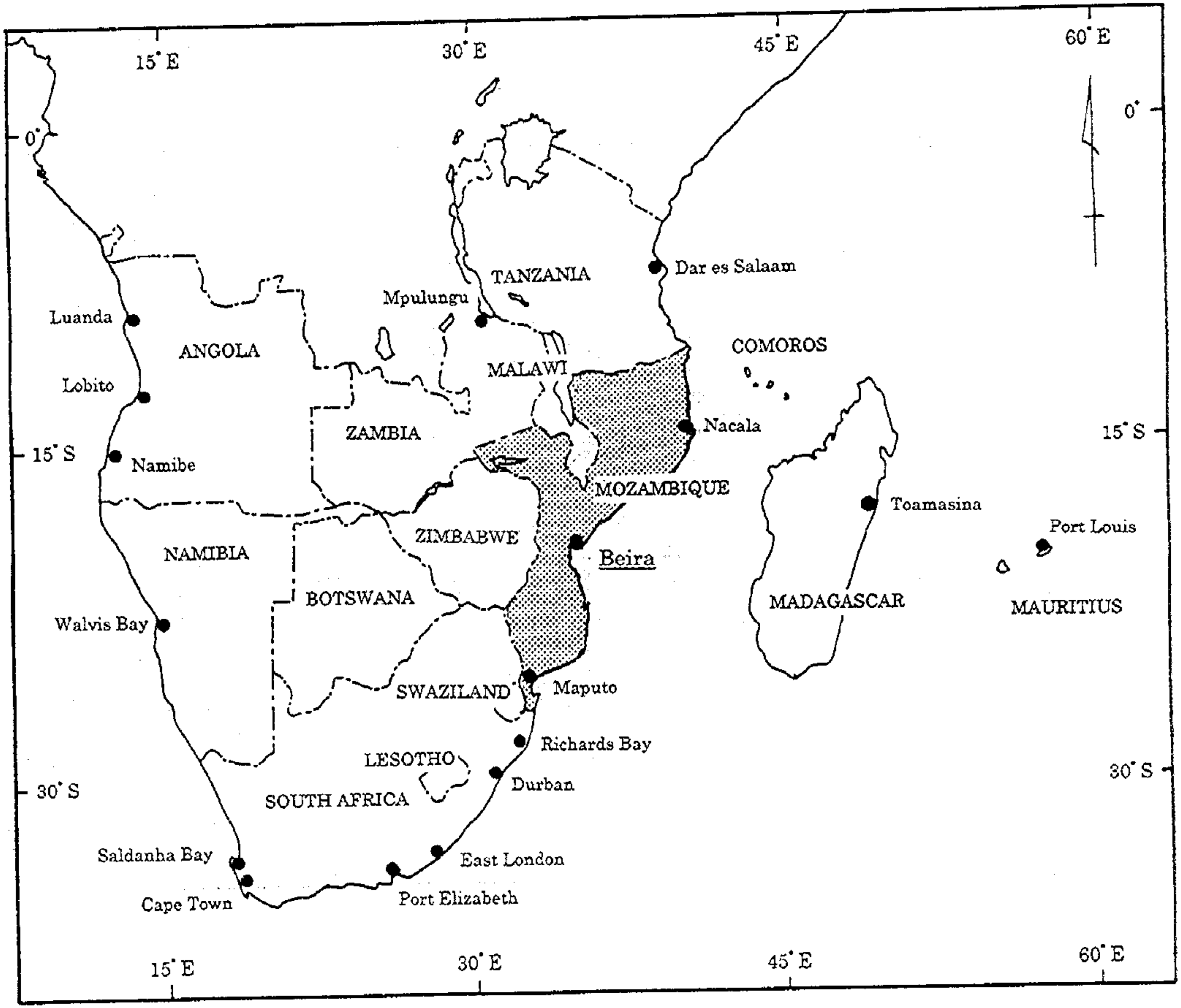
OECD	Organization for Economic Cooperation and Development
P/L	Profit and Loss
POL	Petroleum, Oil and Lubricant
RSA	Republic of South Africa
SADC	Southern Africa Development Community
SATCC	Southern Africa Transport and Communication Commission
SCF	Standard Conversion Factor
TEU	Twenty Footer Equipment Unit
UK	United Kingdom
US$	United States Dollar
USA	United States of America
UTM	Universal Traverse Mercator
ZA	Zambia Airline
Z$	Zimbabwe Dollar

CONTENTS

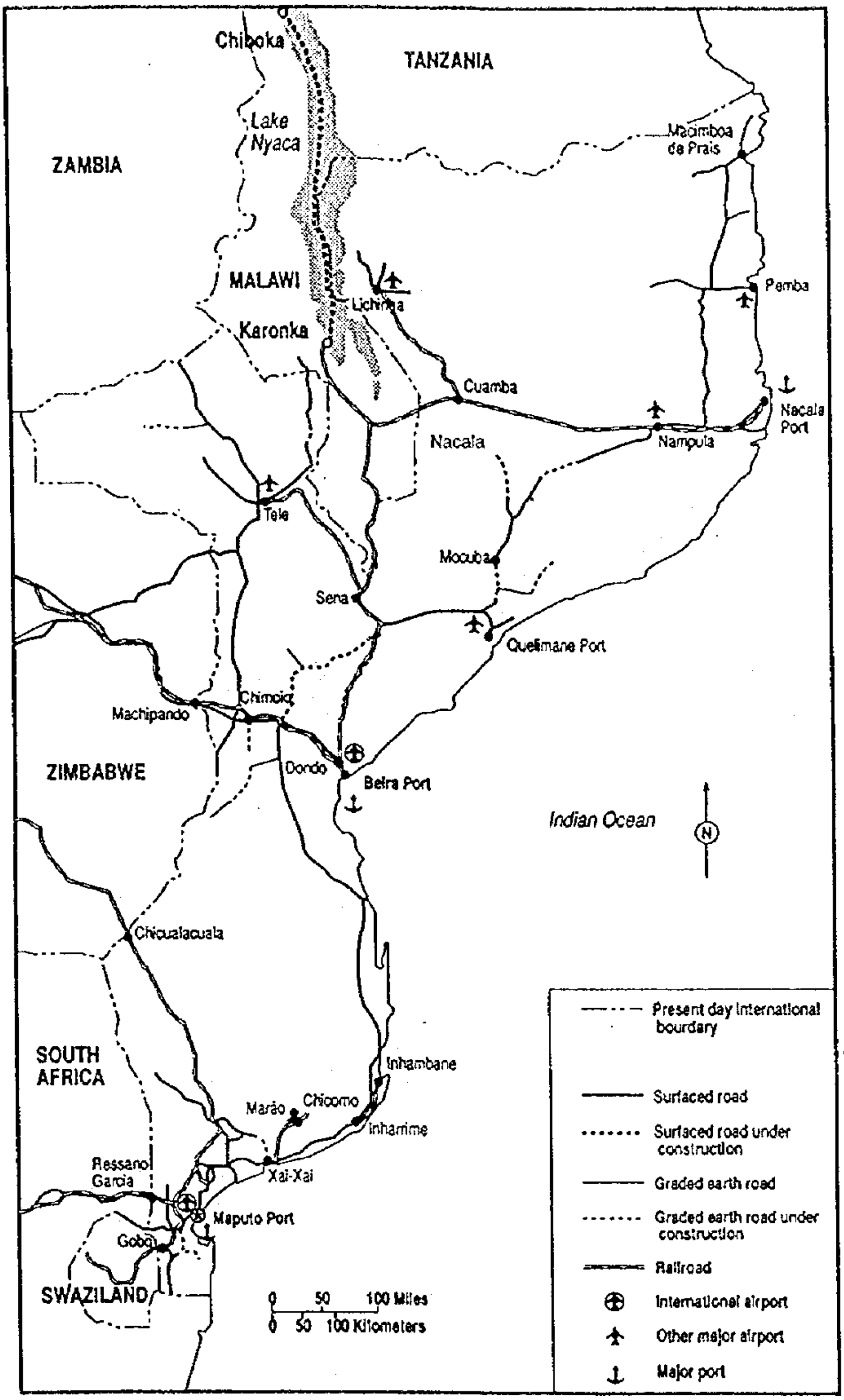
List of Tables

List of Figures

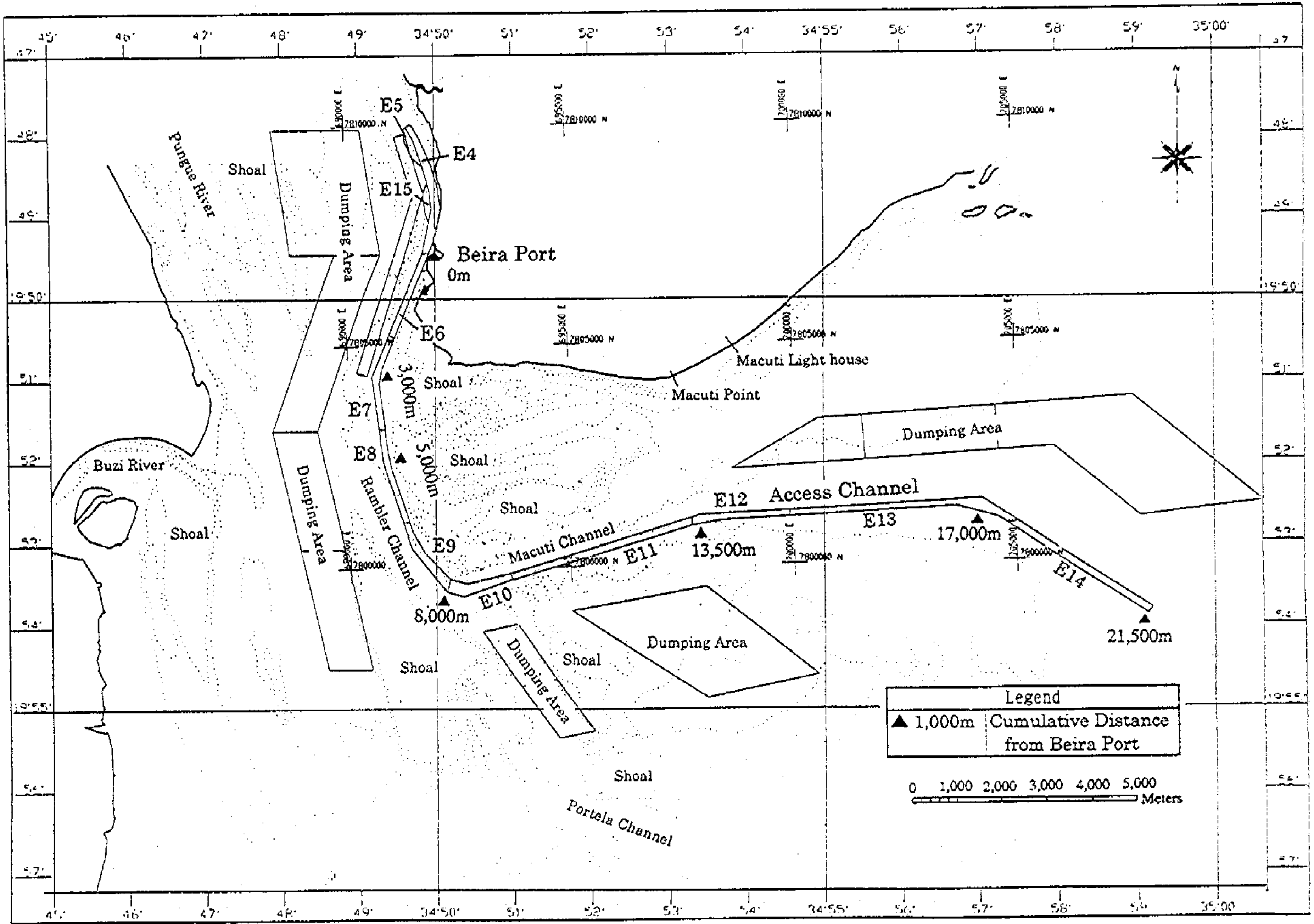
LOCATION MAPS AND PHOTOS



Location of Beira

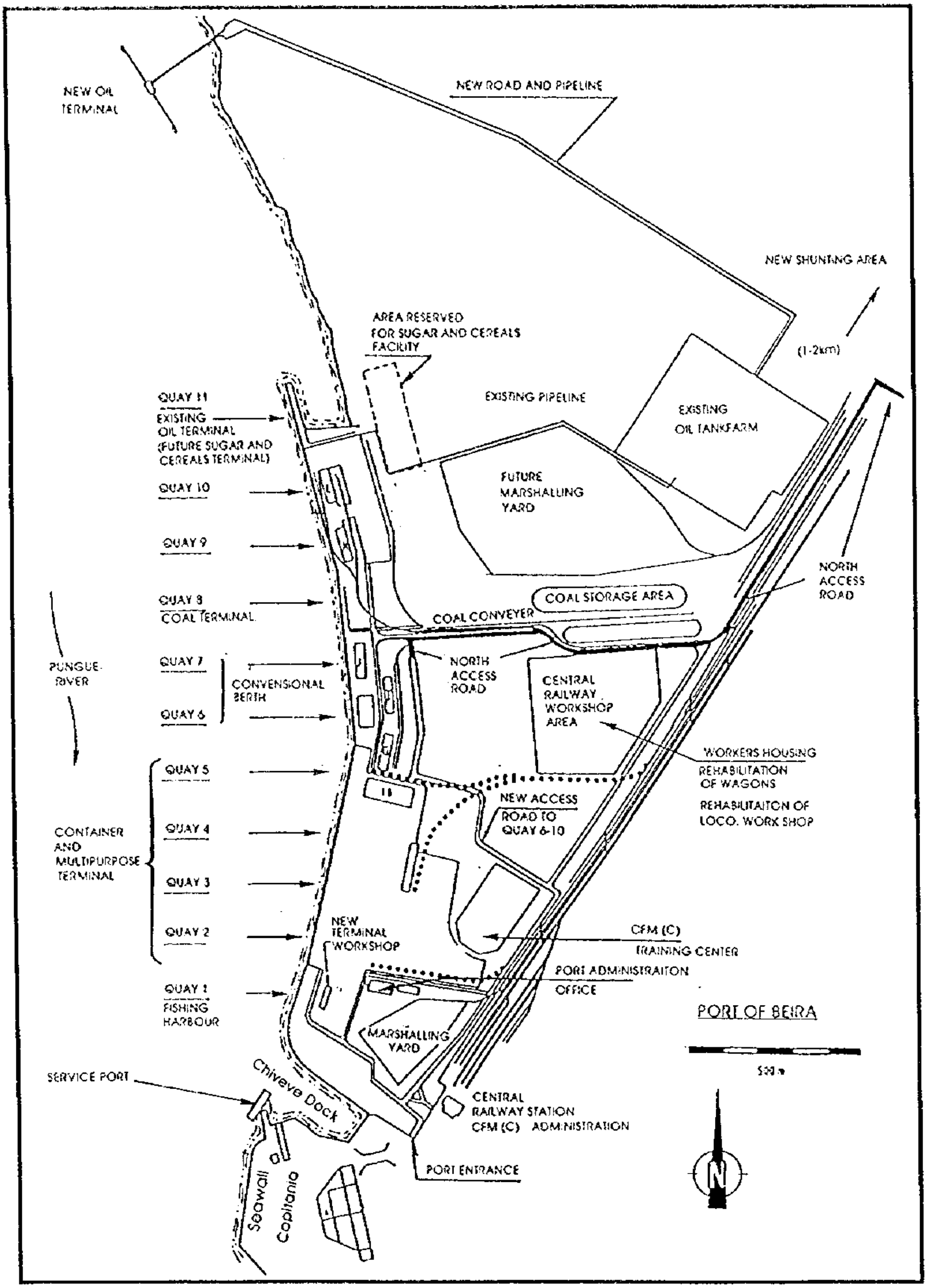


Transportation Network in Mozambique



Source : Map of Approaches to Porto da Beira No.1003

Location of Beira Port and the Access Channel



Facility Layout of Beira Port

Photo - 1
Overview of
Beira Port,
Access Channel
and Shoals

Photo - 2
Shoals along
Access Channel

Photo - 3
Macuti Shoal
during Low Tide

Photo - 4
Overview of
Beira Port

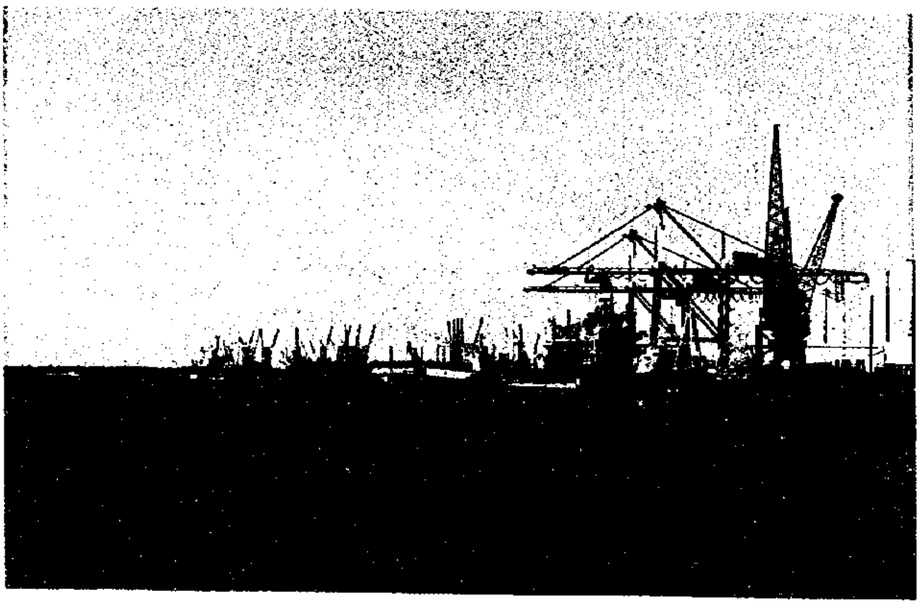


Photo - 5
Quays of Beira
Port

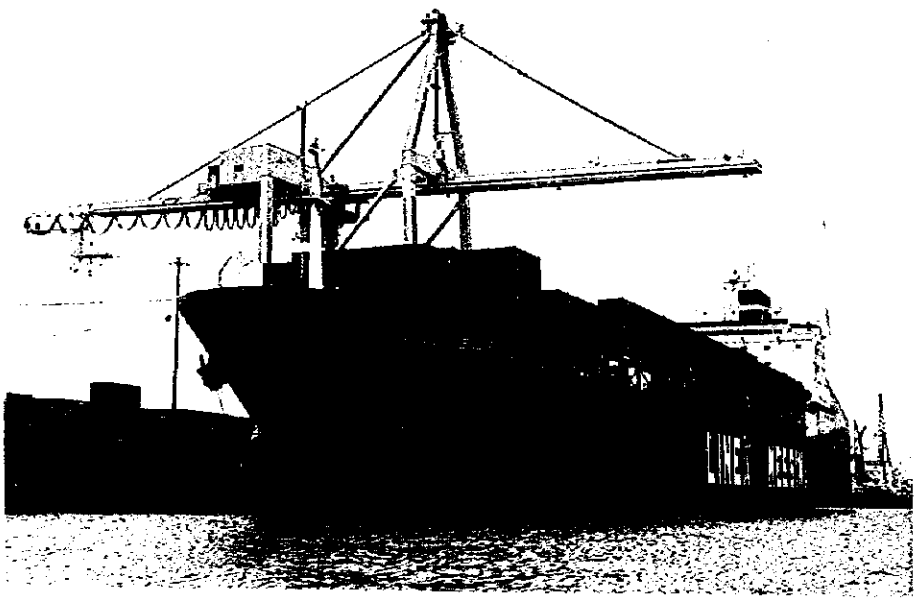


Photo - 6
Container
Carrier Berthing
at Multipurpose
and Container
Terminal

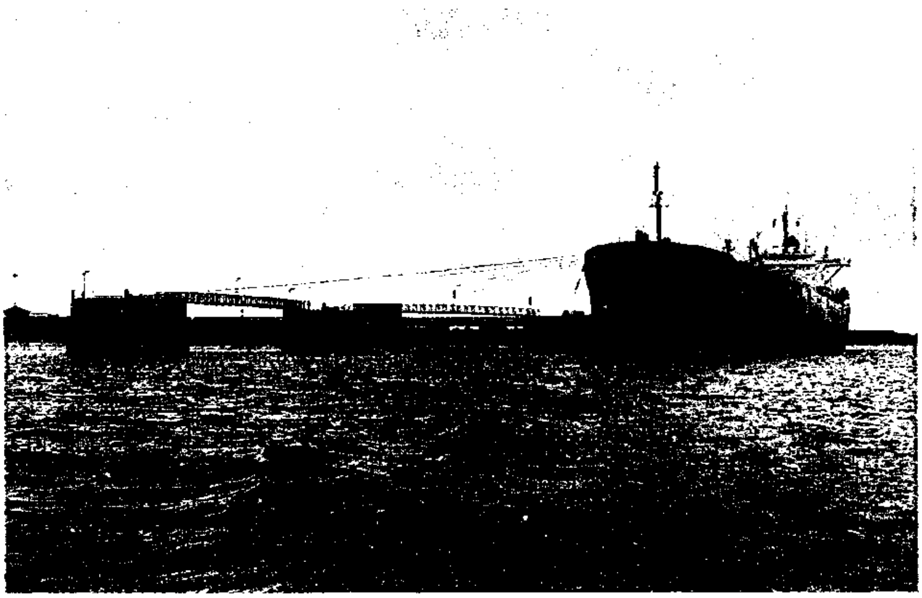


Photo - 7
Tanker Berthing
at Oil Terminal

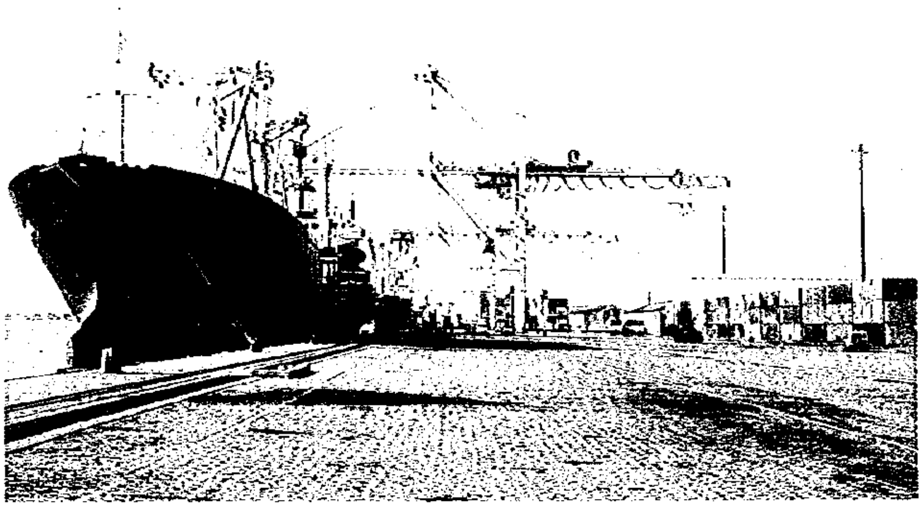


Photo - 8
On-land
Facilities of
Multipurpose
and Container
Terminal

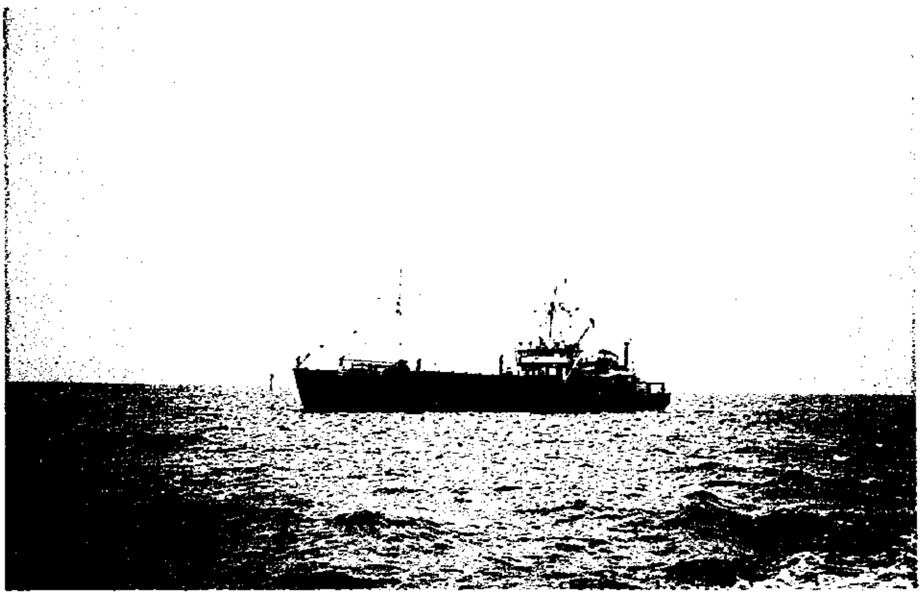


Photo - 9
EMODRAGA
Dredging Fleet,
Trailing Suction
Hopper Dredger,
"Rovuma"

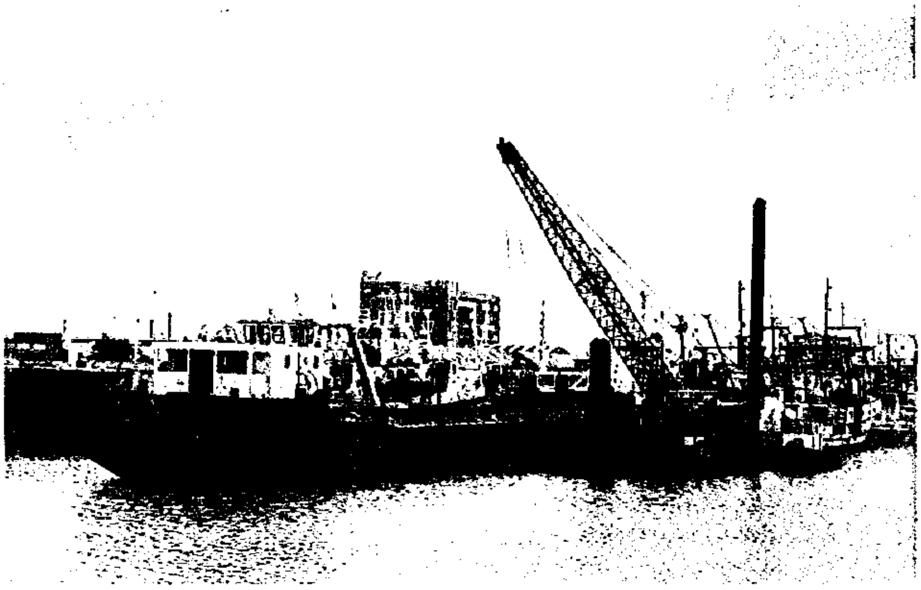


Photo - 10
EMODRAGA
Dredging Fleet,
Grab Dredger
and Split Barges

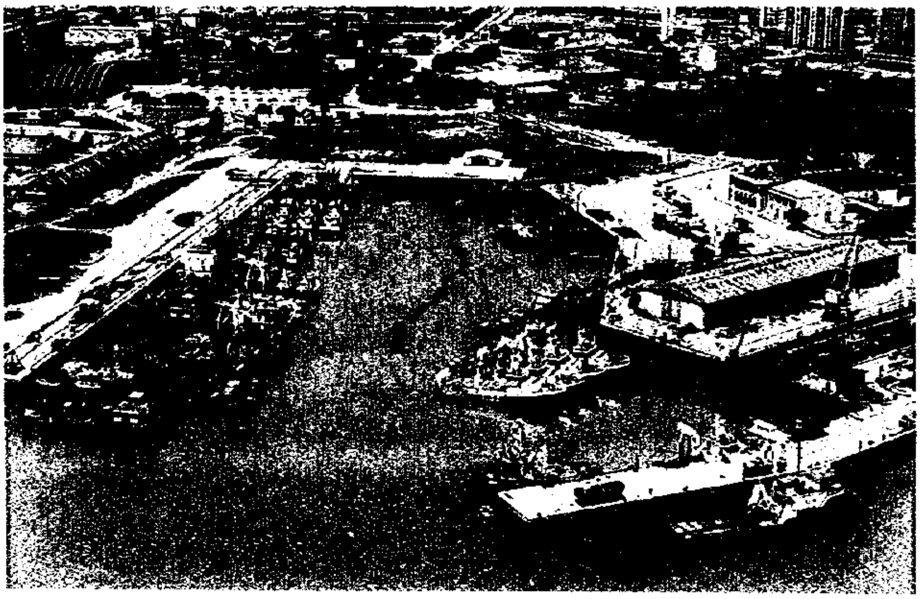


Photo - 11
Chiveve Dock
and Service Boat
Jetty

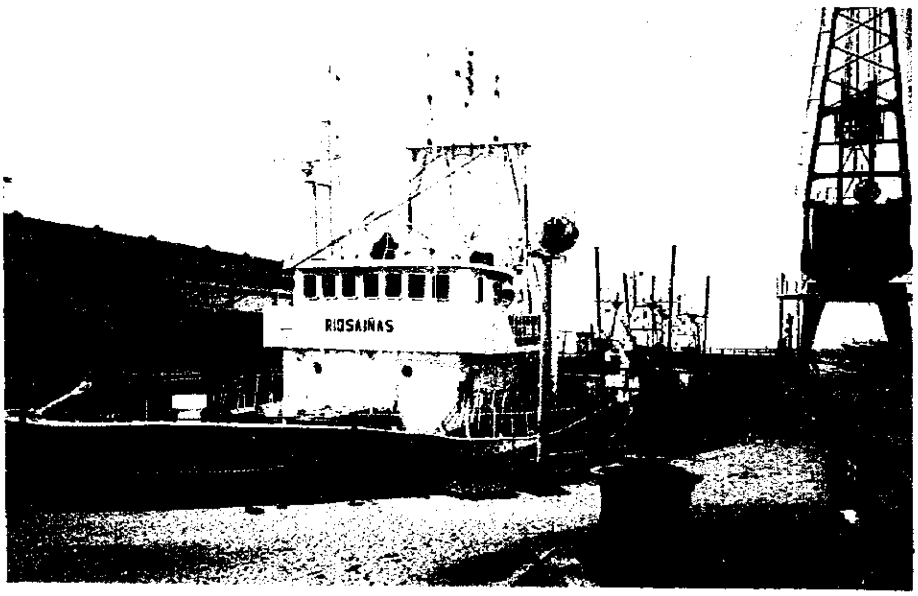


Photo - 12
Dry Dock in
Beira Port
"Beiranave"

EXECUTIVE SUMMARY

Executive Summary

1 Background

Beira Port located in the central Mozambique, Maputo Port in the south and Nacala Port in the north are the major ports in Mozambique, each functioning as a gateway for national and international routes of transport connecting Mozambique and inland countries of Southern Africa. Beira Corridor has been developed as the most efficient route to Zimbabwe, where improvements of infrastructures such as railways, roads and pipelines are being carried out.

Beira Port is situated at the river mouth of the Pungue River and has 10 berths of general cargo and container of 1,680 m in total length and an oil berth. However, sedimentation in the Access Channel and the basin is the most serious problem in port management. The water depth of the Access Channel is shallower than 5 m below CDL at some parts, so that large vessels must enter and leave the Port during high tide.

Under these circumstances, the Government of Mozambique requested the Government of Japan for a grant aid of a dredger. In February 1996, a preliminary study mission was dispatched to Mozambique under the grant aid scheme. Although the need and urgency of offering a dredger were acknowledged, it was judged necessary to study the sedimentation phenomena and to make a plan of improvement of the Access Channel based on a long range view. Therefore, the Government of Mozambique requested the Government of Japan for the cooperation in planning maintenance and improvement of the Access Channel in Beira Port.

In response to the request of the Government of Mozambique, the Government of Japan has executed "Study for Maintenance and Improvement Plan of Access Channel of Beira Port" through the Japan International Cooperation Agency from December 1996.

2 Present Situation of Beira Port

Beira Port is situated in an advantageous location for transportation to neighboring land-locked countries as shown in Figure 2-1 and has been playing an important role for sea transport not only for Mozambique but also for such countries as Zimbabwe, Malawi, Zambia, etc. The onshore port facilities and road/rail connection are shown in Figure 2-2 and are in a comparatively good condition.

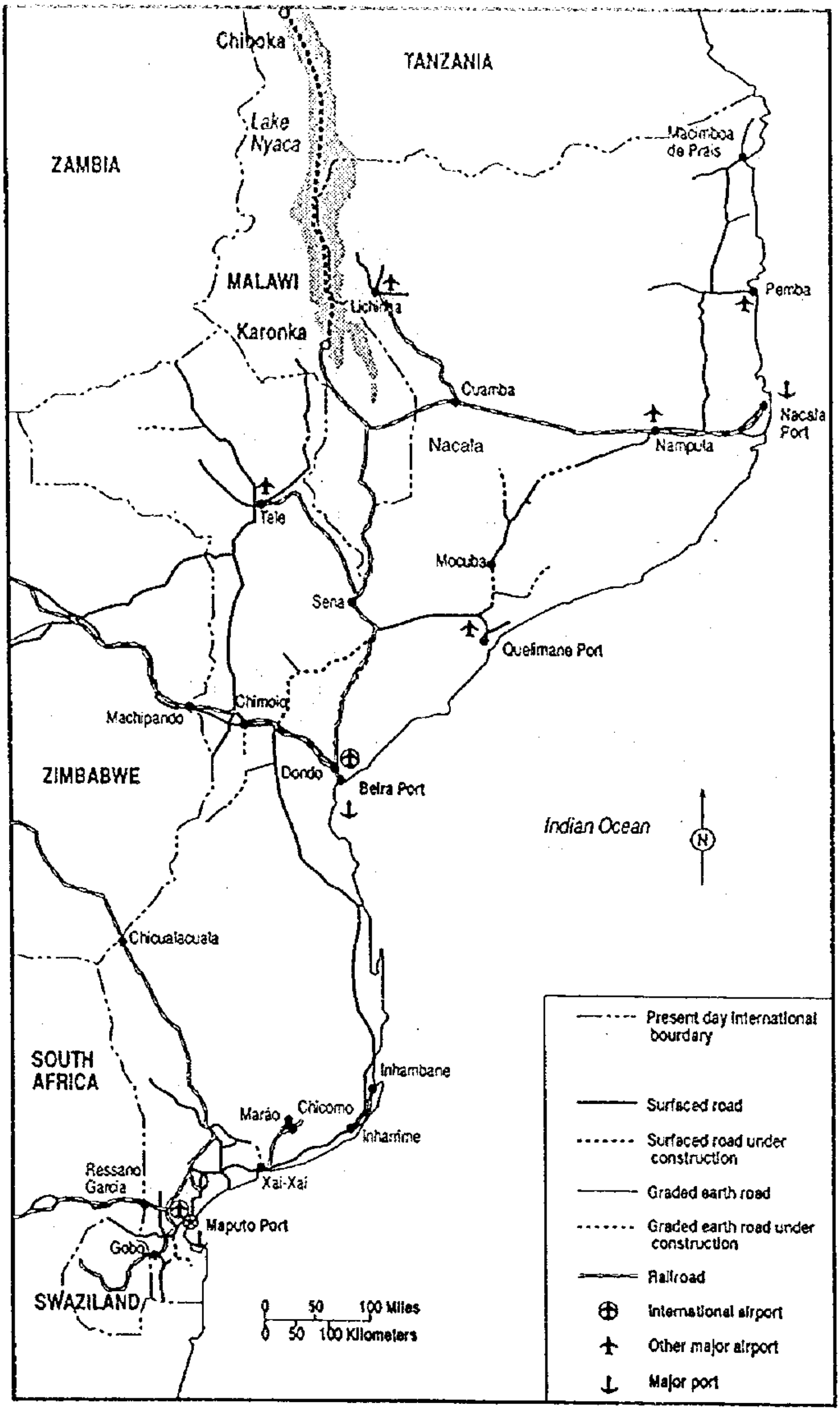


Figure 2-1 Transportation Network in Mozambique

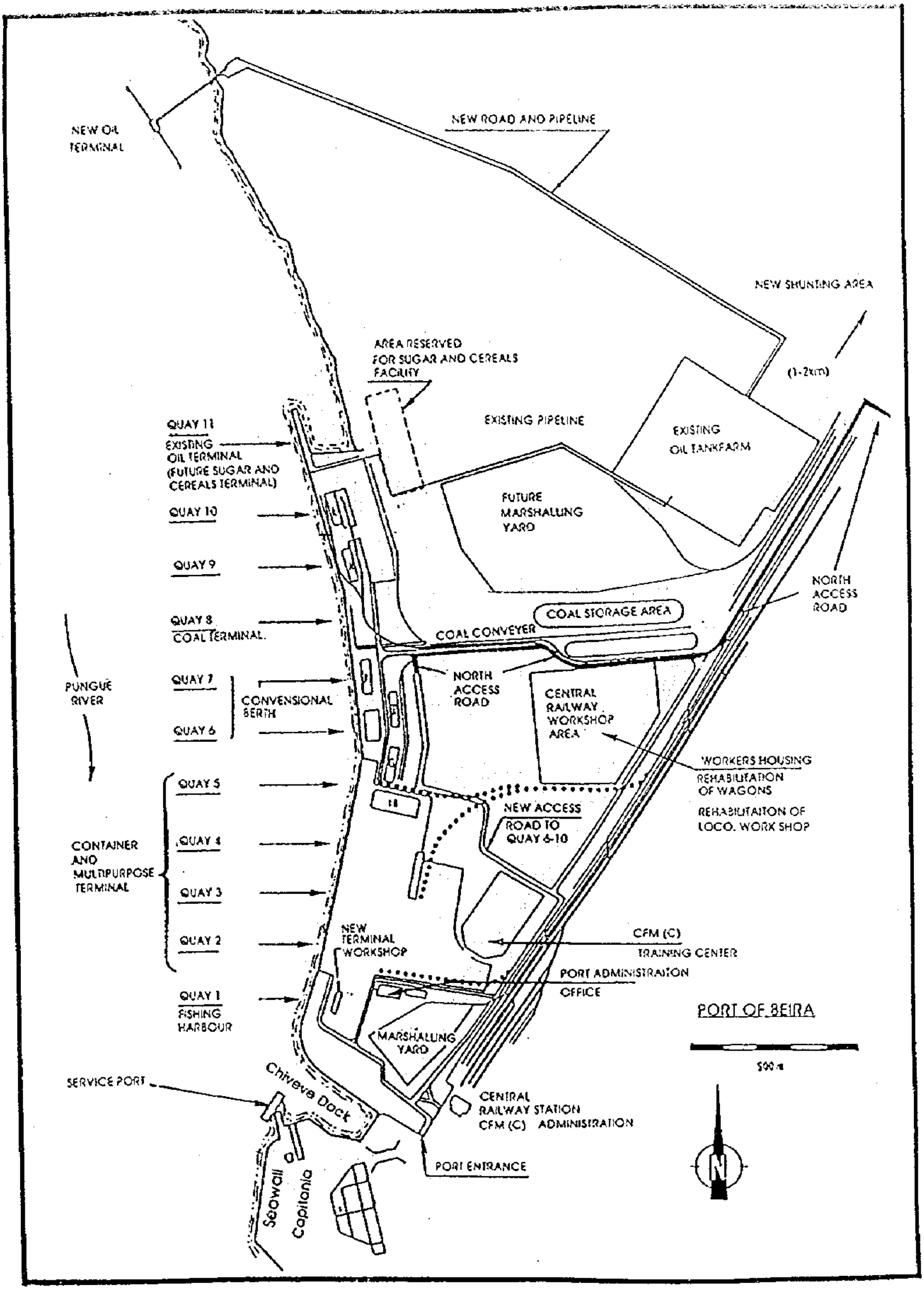


Figure 2-2 Outline of Existing Port Facility of Beira Port

For the period from 1983 to 1988, the Channel was being dredged at an average annual rate of 0.33 million m^3 by the trailing suction hopper dredger "Rovuma", and the quay front areas and the fishery port at that of 0.08 million m^3 by the backhoe dredger "Sofala" for 8 years from 1983 to 1990.

The major bottle neck of Beira Port has long been recognized as its shallow approach channel which is under serious sedimentation all the time. Improvement of the Channel to Beira Port was studied in "Access Channel Study" in 1982 and then the study of "Master Plan Study for the Port of Beira" was carried out by NEDECO to deepen the Channel from 6.0 m below CDL in 1984. The design ship size for the Channel is determined as a 30,000 DWT tanker and cargo carrier. During the period from March 1989 to August 1990, the existing channel to Beira Port was, as shown in Figure 2-3, deepened to 8.0 m below CDL from the previous depth of 6.0 m below CDL under the contract PA-1. Since then, no substantial maintenance dredging works have been carried out.

In the last 5 years, the cargoes including oil products handled at Beira Port was around 2.5 million metric tons a year with a steady increase, of which about 80 % were transit cargoes to and from the inland countries. In 1996, the maximum dead weight tonnage of calling ships to Beira Port was 30,611 tons of an oil tanker and the number of ocean going ships' calls was 322.

At present, most of the large sized ships entering Beira Port have to wait until the tide level to reach the necessary water depth for sailing through the Channel. Recent waiting time of calling ships is getting longer and, in 1996, 69.9% of total calling ships with a draft more than 5 m had the tide waiting time of 15 hours in average.

In Beira, EMODRAGA currently renders dredging services with the dredging fleet of one grab dredger, three soil barges, two tug boats and one survey boat. The existing dredging fleet of EMODRAGA are obsolescent and far below the capacity required to maintain the Access Channel to the original design depth.

The draft limitation imposed to the ships calling the Port leads to an eventual uneconomical arrangement of ship operators to use either a smaller ship with full loaded cargo or a large ship with partially loaded cargo for shallower draft.

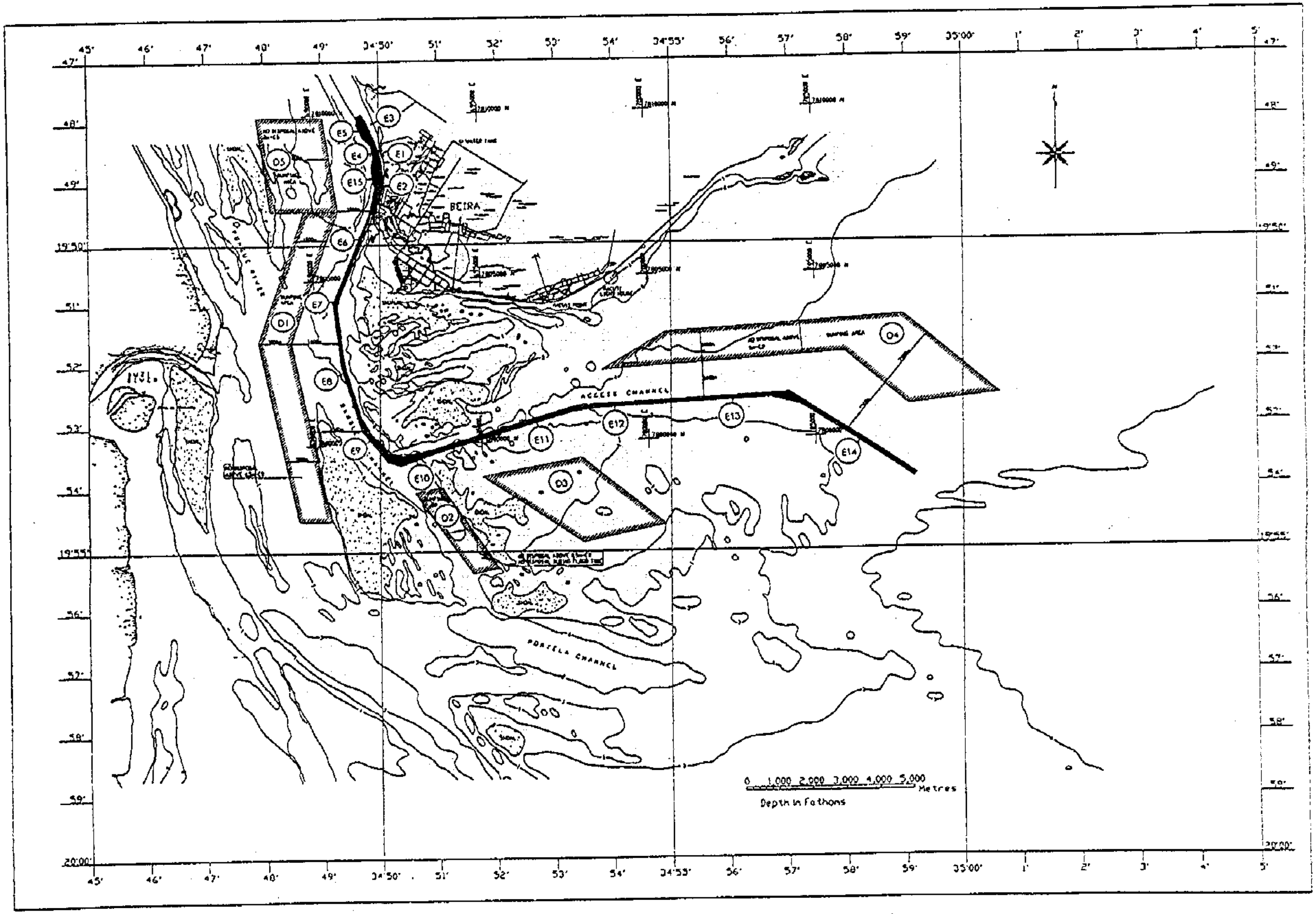


Figure 2-3 Layout of the Access Channel and Dumping Areas

3 Natural Condition

3.1 Meteorological Condition

The City of Beira is located in the tropical zone which is characterized by the wet season from November to April and the dry season from May to October.

According to the statistics during the last 25 years, frequency of wind more than 10 m/s is very small, being less than 1 % from February to August and 1～2 % from September to January excluding October of 2.4 %. The most predominant direction of wind is from ENE to SE. Cyclones are generated in the South-Western Indian Ocean from November to April which affect Beira especially in February and March.

3.2 Sea Condition

In order to obtain characteristics of sea condition, bathymetric survey, tide observation, wave observation, and current and turbidity survey were executed. The survey were conducted during January to April in the wet season and during July to September in the dry season.

The tide condition in Beira is of typical semi-diurnal and its excursion range is very large. Mean high water and mean low water at spring tide are respectively +6.5 and +0.9 m above CDL.

Wave Buoys 1 and 2 were installed at the point 13 m deep near the entrance of the Access Channel and at the land-ward side near Section E11 of the Access Channel, respectively. The wave observation was conducted during from the February 9 to April 9 in 1997. The maximum significant wave was generated by Cyclone "Lisette" and observed as 4.2 m in height and 10.7 seconds in period at Wave Buoy 1. This cyclone was the largest in last ten years. While the maximum significant wave height at Buoy 2 was of 2.2 m. Frequency of significant wave height at Buoy 1 was 51.6 % for 0.5 to 1 m in height, 35.5 % for 1.0 to 1.5 m, 8.8 % for 1.5 to 2.0 m and 3.9 % for more than 2.0 m. The predominant wave direction was from E to SE.

Most of strong currents along the Access Channel were slightly faster in the wet season than in the dry season. Ebb currents were observed generally faster than flood currents and the observed maximum current velocity was 2.5 m/s.

In spring tide, the maximum turbidity value appeared at the ebb tide level. In neap tide, turbidity did not show significant difference between flood and ebb tides. The turbidity is higher in the wet season than that in the dry season and was observed at about 2000 mg/l at maximum in the wet season.

Regarding the bottom sediments condition along the Access Channel, sand was predominant except Sections E6, E7, E8 and E14 where silt mostly was found. Coarse sand existed particularly at the bending corner of the Access Channel. In the offsore side of the Access Channel entrance, fine sand is predominant, and silt existed more in the north side than in the south side of the Access Channel.

3.3 Littoral Drift and Sedimentation

The Access Channel to Beira Port is developed through the extensive shoal area. Sand drift in this area is mainly supplied along the north coast from the mouths of the Zambeze Rivers and other rivers, and from the Pungue and Buzi Rivers.

Figure 3-1 shows an overview of littoral drift in the vicinity of the Access Channel, which is presumed from past sounding maps and the preceding sea conditions. Sediments discharged from the estuary of the Pungue River, in general, seem to be fine sand and clay owing to their flat bottom slope except in strong flood time. These sediments mostly seem to deposit in its wide estuary area excluding the narrow part along the quay front and in the south of the Access Channel, although some part of them flows in the Access Channel.

Along the Macuti Coast located in the east of Beira Port, sand transport toward the Pungue River is predominant, since most of waves come from an easterly direction against the perpendicular to the coast line and tidal currents also are prevailing in the direction toward the Pungue River on the Macuti Coast. And some parts of them move toward the Port along the left bank of the Pungue River and others deposit in Sections E6 to E8 of the Access Channel or are

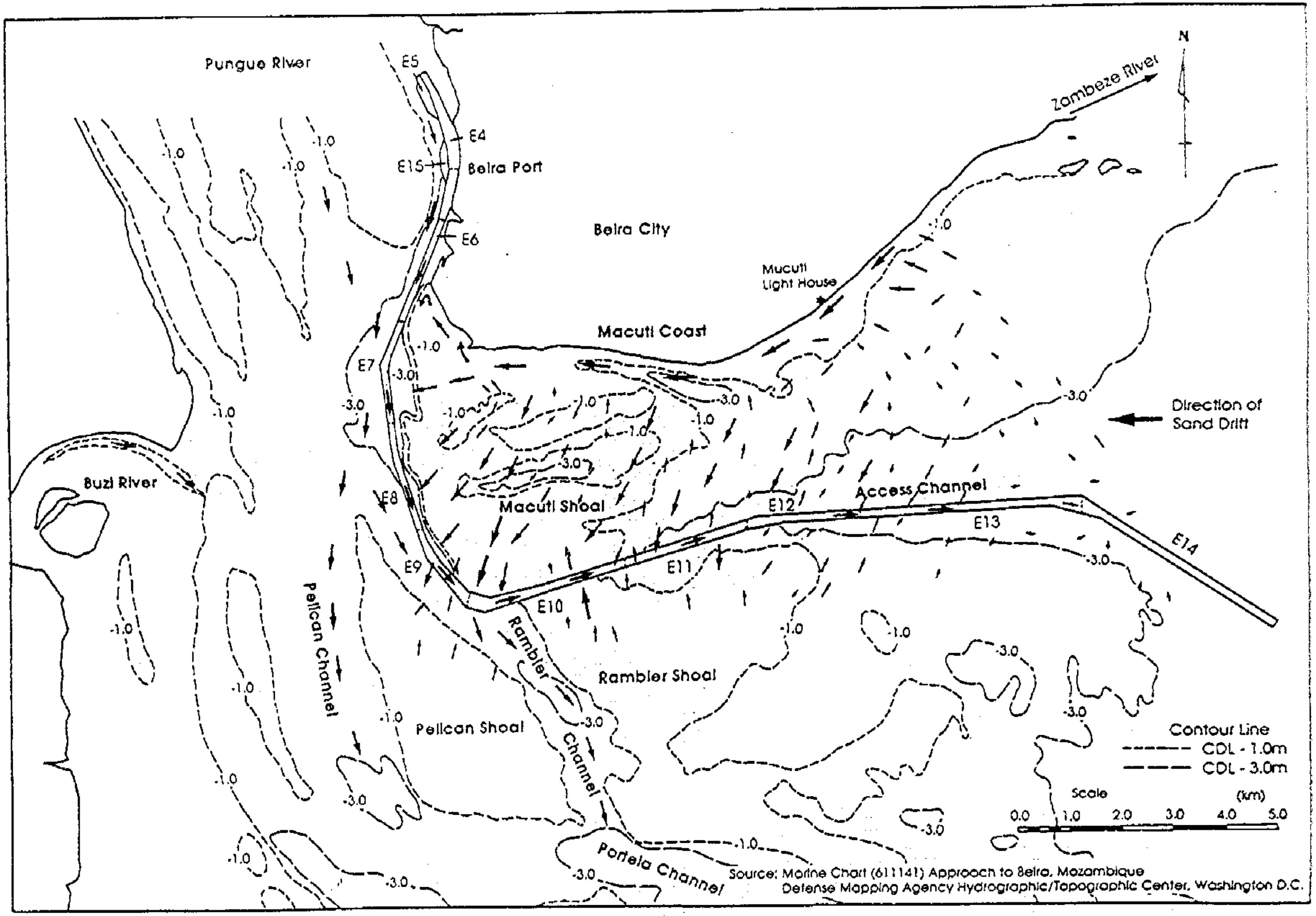


Figure 3-1 Image of Littoral Drift in the Vicinity of the Access Channel

transported through the Channel by strong tidal currents.

Moreover, suspended sand by waves on the Macuti Shoal is transported obliquely seaward by offshore ward currents, besides in parallel with the coastline. Some part of sand can not reach Sections E6 to E8 during the period of strong ebb-currents along the Channel, forming sand banks toward the bending corner and entering into the Channel.

Some sand also enters into the Access Channel from the direction of the Pelican and Rambler Shoals by waves and tidal currents. Sand transported through the Channel untill the entrance of the channel deposits widely in its vicinity, a part of which is moved by waves toward the coast. But, this sand transport to the Macuti Beach is supposed to be a little in volume as compared with the sand going out from the beach.

The above mentioned characteristics of sand transport is also confirmed by the results of the chemical element analysis of bottom sediments.

4 Siltation Analysis of the Access Channel

4.1 Analysis of Sounding Maps

Through analysis of the past and present available sounding survey maps, water depth change and sedimentation volume of the Access Channel have been investigated in detail. As a result, the characteristics of sedimentation along the Access Channel have been estimated as follows :

(a) The annual sedimentation volume is greatly influenced by the fluctuation of river flows of the Pungue River and cyclones attacking Beira,

(b) The most remarkable sedimentation occurs at Sections E9 and E10 adjacent to the bending corner and E8 follows them. Sections E11 to 13 are smaller in sedimentation compared with their vicinity area,

(c) In the area of the distances 8,700 m and 10,700 m of E10, sedimentation occurs so that the slope of land side and the slope of sea side shift inside of the Channel, respectively,

(d) The Channel seems to have a tendency to be scoured in the wet season and shoaled in the dry season. Therefore, in the wet season, sediments transported in the vicinity of the Channel from the rivers and the northern coast seem to deposit in the estuary area and the shoal area around the Access Channel and to enter comparatively early in the dry season into the Channel.

(e) In the vicinity of E14, a tendency of erosion in the wet season and sedimentation in the dry season is observed clearly.

Sedimentation volume of the Access Channel was calculated as 3,871 $\times 10^3$ m^3 in the period from August 1990 to August 1991 immediately after the capital dredging. It is nearly equal to 3,735 $\times 10^3$ m^3 calculated by BCA. The average annual sedimentation volume in the period from August 1990 to April 1996 was estimated as 2,137 $\times 10^3$ m^3 from the sounding maps and the dredging volume in this period.

4.2 Computer Simulation

Numerical Simulation on the sedimentation has been carried out for Sections E6 to E11 of the Access Channel, using the distributions of tidal currents and waves. These distributions are calculated in the area shown in Figure 4-1 under the condition of the mean spring tide of 2.8 m in amplitude and storm waves of 2.0 m in height and 10 seconds in period at the offshore.

Bijker's model was applied in the simulation of sedimentation volume in the Access Channel. After checking the reliability of this simulation using the analyzed sedimentation volume during August 1990 and August 1991, the sedimentation volume has been simulated for different channel depths.

4.3 Consideration on Maintenance Dredging Volume

The average maintenance sedimentation volume has been estimated as 2,500,000 m^3 for 8M Access Channel, taking into consideration the annual sedimentation volume of 3,735,000 m^3 just after the capital dredging, in which over dredging more than one meter was included additionally in almost all Sections, and the average annual volume of 2,137,000 m^3 during August 1991 to

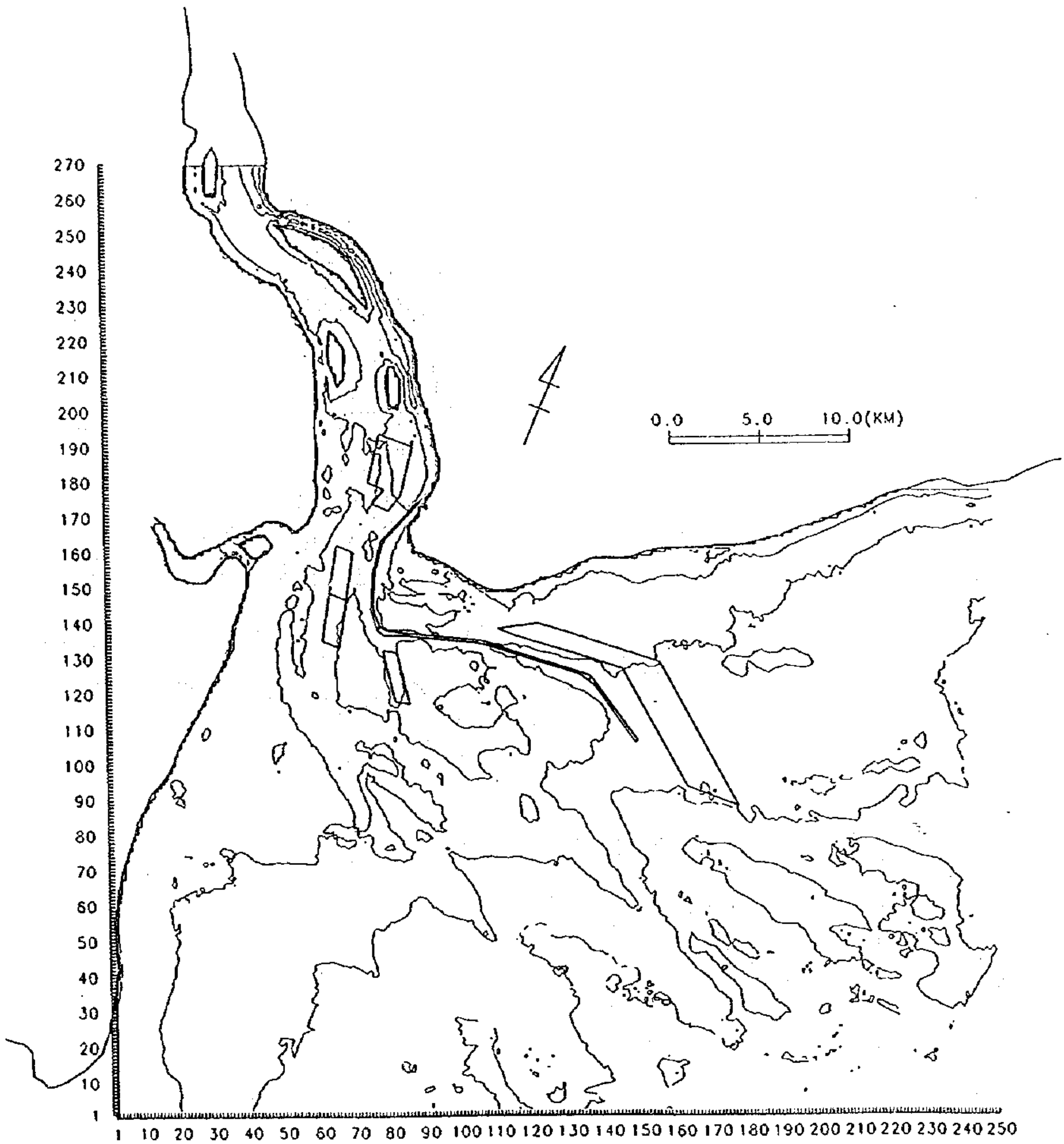


Figure 4-1 Grid Layout and Bathmetry of Simulation Model

April 1996. Moreover, based on this 2,500,000 m^3, the annual average maintenance dredging volumes for the Access Channel with different channel depths have been estimated as shown in Table 4-1.

Table 4-1 Maintenance Dredging Volume by Channel

	Maintenance Dredging Volume (m^3)				
Channel	9M	8M	7M	6M	5M
Ratio 1	1.506	1.000	0.478	0.111	0.000
Ratio 2	1.188	1.000	0.808	0.615	0.441
E4	415,876	276,146	131,998	30,652	
E5	181,455	120,488	57,593	13,374	
E15	281,630	187,005	89,388	20,758	
E4+E5+E15	878,962	583,640	278,980	64,784	
E6	170,264	113,057	54,041	12,549	
E7	193,816	128,696	61,517	14,285	
E8	224,127	148,823	71,137	16,519	
E6+E7+E8	588,207	390,576	186,695	43,354	
E9	321,783	287,820	232,559	177,009	126,929
E10	687,523	614,958	496,886	378,199	319,778
E11	112,975	101,051	81,649	62,146	52,547
E9+E10+E11	1,122,281	1,003,829	811,094	617,355	521,991
E12	77,201	30,637	24,755		
E13	317,553	62,313	50,349		
E14	498,582	429,005	346,636		
E12+E13+E14	893,336	521,955	421,740		
Total	3,482,786	2,500,000	1,698,509	725,493	521,991

5 Design of the Access Channel

5.1 Ship Traffic Forecast

According to the trend on the cargo volume of Beira Port from 1978 to 1997, the average growth rate of cargo volume per annum is obtained at 7.4 % during 1987 to1996. The actual cargo volume of Beira Port in 1996 including the drought relief was 2,603,300 tons in total, comprising Mozambican traffic of 357,100 tons (13.7 %) and transit traffic of 2,246,200 tons (86.3 %).

According to the cargo demand forecast of Beira Port made by SATCC, the total cargo of Beira Port is 2,976,400 tons in 2002, 3,398,900 tons in 2007 and 4,874,900 tons in 2017. Adding the cargo shift expected from Harare-Maputo to Harare-Beira route to the above values, the total cargo demand of Beira Port is forecast as 3,274,400 tons in 2002, 3,737,650 tons in 2007 and 5,100,095 tons in 2017 as shown in Figure 5-1.

The annual ships' calls during from 2000 to 2025 have been calculated by multiplying the ships' call of each category in 1996 by the respective increment ratios of cargoes, which is shown in Figure 5-2. Forecast numbers of total calling ships are 557 in 2000, 681 in 2007, 841 in 2017 and 959 in 2025.

The waiting time to enter and to leave the Port has been estimated as shown in Figure 5-3 by the channel traffic simulation. Ships in the simulation model are categorized based on the calling ships forecast. Although the waiting times of 5 and 6 m channel water depth are significantly very long, the waiting times of the channel depth more than 8 m are reduced drastically to a small number of hours and to be within the permissible limit.

5.2 Design of the Access Channel

The water depth of the Access Channel is calculated by a fully loaded draft of the design ship, the channel depth and an additional tide level of wide excursion range. The nautical vessel depth of 30,000 DWT cargo carriers and 50,000 DWT of tankers are calculated with a tolerance for squat, trim and wave motion of ship. The required water depths for 30,000 DWT cargo carriers and 50,000 DWT

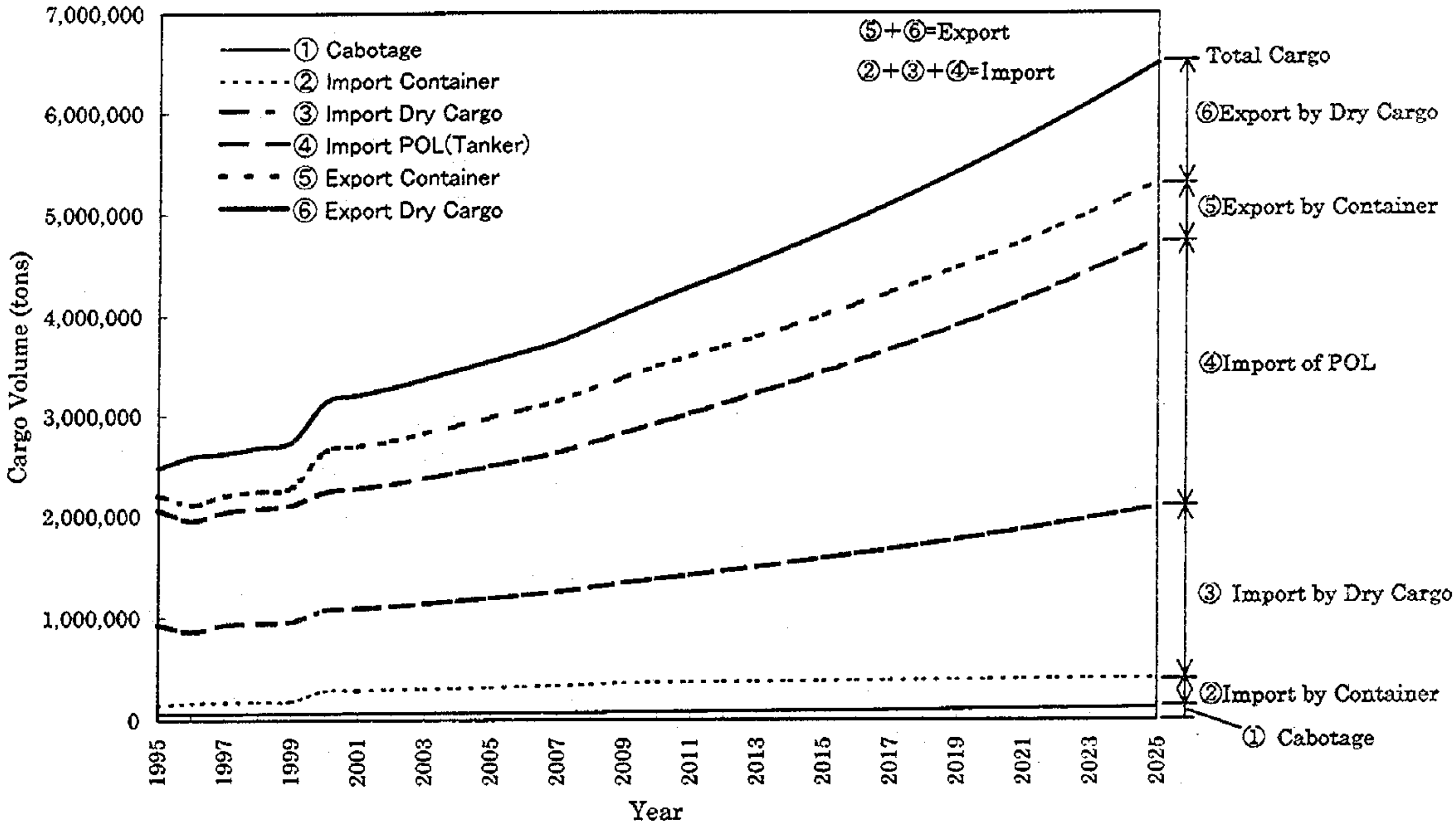


Figure 5-1 Trend in Cargo Forecast of Beira Port

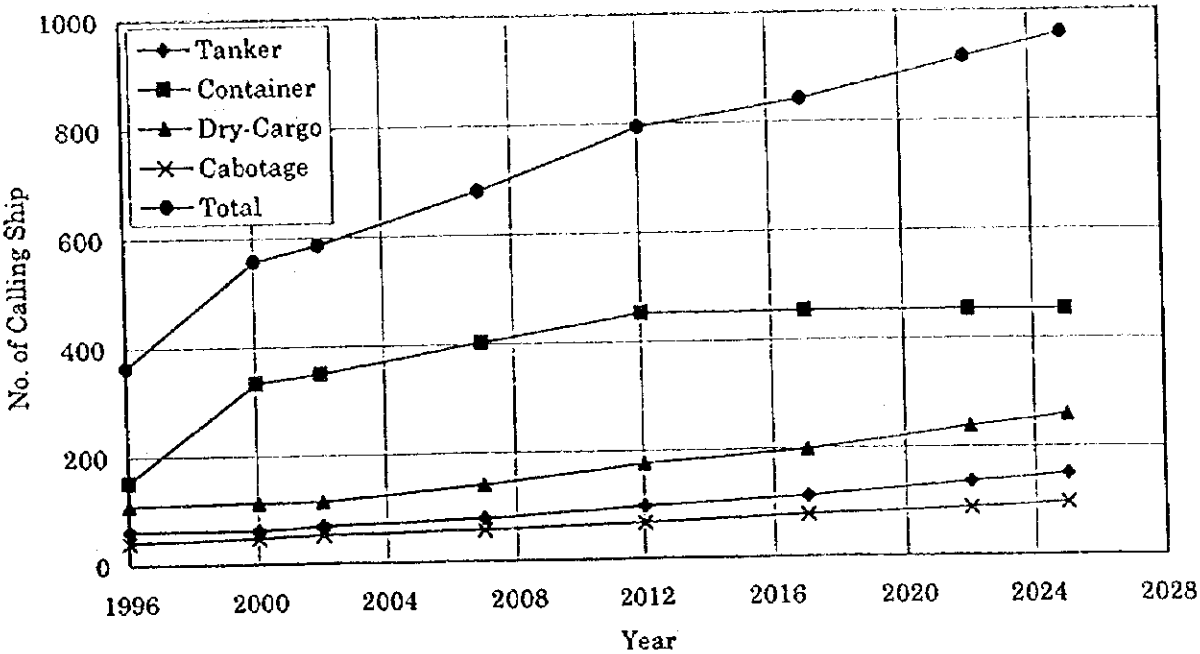


Figure 5-2 Forecast Number of Ship's Call in 1996 to 2025

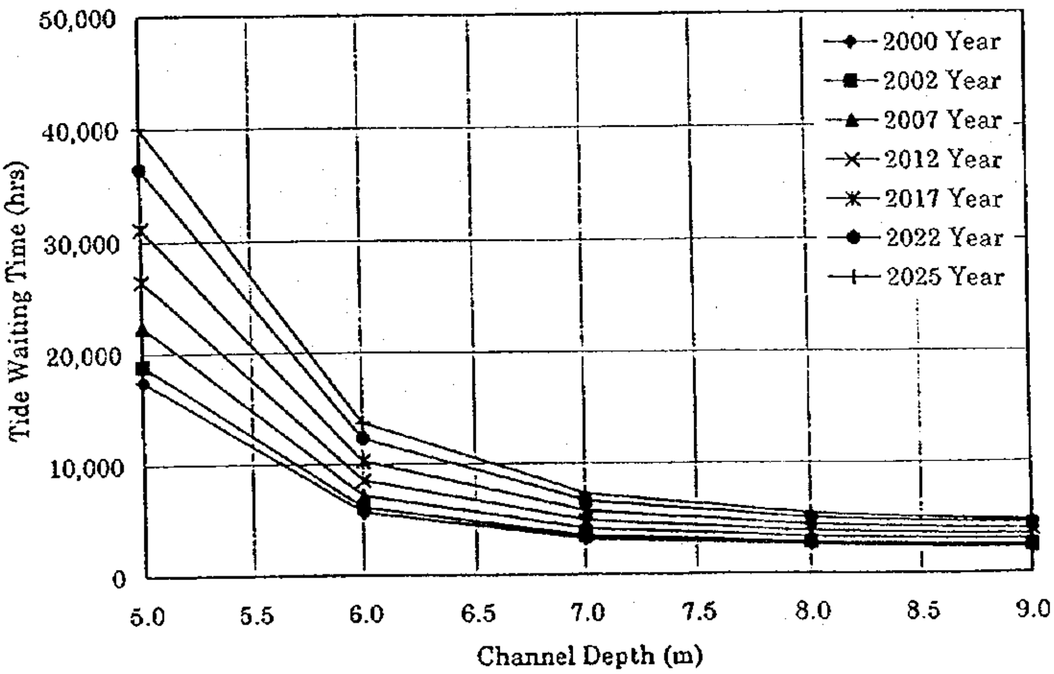


Figure 5-3 Forecast of Tide waiting Time of Total Ship's Call

tankers have been determined respectively at CDL -8.0 m and CDL -10.0 m. The water depth of CDL -8.0 m have been concluded to be more appropriate and reasonable for Beira Port.

The design water depth has been determined with an additional tolerance for wave motion of each sections as shown in Table 5-1, where the water depth is set at CDL -8.0 m for Sections E6 to E8, -8.5 m for E9 to E11 and -8.7 m for E12 to E14.

Table 5.1 Design Water Depth along the Access Channel

	Design Water Depth		
Channel Section	E6, E7, E8	E9, E10, E11	E12, E13, E14
Location	Near Port	Bending Point	Near Entrance
Required Water Depth	8.0 m	8.0 m	8.0m
Additional Tolerance	---	0.5 m	0.7 m
Design Water Depth	8.0 m	8.5 m	8.7 m

The width of the Access Channel is determined as same as the original design width stipulated in "Beira Port Study, Access Channel Study, NEDECO". The width of each channel section is shown in Table 5.2.

Table 5.2 Design Width of the Access Channel

Channel Basin	E6, E7, E8, E9	E10, E11	E12, E13	E14
Design Width	135 m	155 m	140 m	160 m

6 Improvement and Maintenance of the Access Channel

The basic direction of maintenance and improvement of the Access Channel in this Project is to restore the existing shoaled channel to the dimensions which allow a safe navigation for the design ship calling the Port.

A trailing suction hopper dredger with hopper capacity of 2,000 m^3 is considered to be an optimal option for the purpose of maintaining the Access Channel at the depth of 8 m with annual dredging volume of 2.5 million m^3.

The concept of the above mentioned dredger of 2,000 m^3 is as follows:

Length overall	about 83 m
Length between perpendiculars	80 m
Breadth moulded	15 m
Depth moulded	6.2 m
Dead weight	about 3,650 tons
Hopper capacity	about 2,000 m^3
Speed at full load	10.2 knots
at empty hopper	10.8 knots
at dredging on full load	6.5 knots
Accommodation	For 48 persons
Propulsion plant	2 engines and 2 propellers
Crew member	3 gangs (one gang consists of 24 person)

Water depth of the dumping area is not always deep enough for dumping operation during low tide. Two dredging methods of i) to dredge a certain section until a required depth is reached, while dumping at remote and deeper dumping area at low tide, and ii) to dredge a section close to a deeper dumping area at low tide and dredge a section close to shallow dumping area at high tide, are compared in Tables 6.1 and 6.2. The latter gives efficiency higher by 3 % than the former.

The new dredger with hopper capacity of 2,000 m^3 has an annual dredging capacity of 2.5 million m^3 with total annual working time of 4,224 hours under a working condition of 5 days a week, 44 weeks a year and working efficiency of 0.8.

The total annual required working hour for the trailing hopper suction dredger of 2,000 m^3 hopper capacity is 3,921 hours giving the ratio of 0.93 less than 1.0 against workable hours, which means that the hopper capacity of 2,000 m^3 is appropriate for dredging work of 2.5 million m^3 with acceptable allowance. Annual average cycle time is calculated as 2.02 hours and annual total required number of dredging cycles is calculated as 1940.

Location and depth of dumping sites are key factors governing the efficiency of dredging operation so that the sounding survey covering wide area shall be carried out in order to evaluate the appropriateness of current sites and to find better alternate sites based on the results of the survey.

Table 6-1 Maintenance Dredging Plan (1)

(soil to be dumped at a distant site at low tide)

Hopper Capacity = 2000 m3 | Ship speed full 10.2 kt., ballast 10.8 kt

Dredging Time Silt 1.00 hr Sand 1.25 hr Turning Time 0.25 hr

Section	E5		E15		E4		E6		E7		E8		E9		E10		E11	E12	E13	E14	Total
Siltation Vol m^3/y	120,488		187,005		276,146		113,057		128,696		148,823		287,820		614,958		101,051	30,637	62,313	429,005	2,499,999
Siltation Vol %	5		7		11		5		5		6		12		25		4	1	2	17	100
Silt'n Thickness m/y	0.78		1.20		0.57		0.33		0.38		0.43		1.11		1.13		0.26	0.09	0.09	0.72	
Soil: Silt or Sand	Silt		Silt		Silt		Silt		Sand		Sand		Sand		Sand		Sand	Sand	Sand	Silt	
Dred'g/Turn'g Time hr	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.25	
Soil in Hopper %	55		55		55		55		75		75		75		75		75	75	75	55	
Soil in Hopper m3	1,100		1,100		1,100		1,100		1,500		1,500		1,500		1,500		1,500	1,500	1,500	1,100	
Dumping Area	D1 (75%)	D4	D1 (75%)	D4	D1 (75%)	D4	D1 (75%)	D4	D1 (60%)	D4	D1 (60%)	D4	D2 (85%)	D4	D2 (85%)	D4	D4	D4	D4	D4	
Sailing Distance km	11.0	16.8	9.2	15.0	9.7	15.5	6.9	12.8	4.9	10.7	3.0	8.5	2.7	6.4	1.7	4.3	1.8	1.5	1.5	1.5	
Sailing Time to DA hr	0.58	0.89	0.48	0.79	0.51	0.82	0.37	0.68	0.26	0.57	0.16	0.45	0.14	0.34	0.09	0.23	0.10	0.08	0.08	0.08	
Dumping Time hr	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.15	
Sailing Time fm DA hr	0.55	0.84	0.46	0.75	0.48	0.78	0.35	0.64	0.24	0.54	0.15	0.43	0.14	0.32	0.08	0.21	0.09	0.08	0.08	0.08	
Cycle Time hr	2.53	3.13	2.34	2.95	2.39	3.00	2.11	2.71	2.25	2.85	2.06	2.63	2.03	2.41	1.92	2.19	1.94	1.90	1.90	1.55	
Av Cycle Time hr	2.68		2.49		2.54		2.26		2.49		2.29		2.09		1.96						
Required No of Cycle	110		170		251		103		86		99		192		410		67	20	42	390	1940
Req'd Working Hour hr	293.4		423.9		638.9		232.4		213.7		226.8		400.1		803.6		130.4	38.9	79.1	606.3	4,087
Working Hour Ratio %	7.2		10.4		15.6		5.7		5.2		5.5		9.8		19.7		3.2	1.0	1.9	14.8	100.0
T.Dred/Turn'g Time hr	136.9		212.5		313.8		128.5		128.7		148.8		287.8		615.0		101.1	30.6	62.3	487.5	2,653.5
Sailing Time hr	140.1		185.9		287.4		88.5		63.6		53.2		64.3		86.2		12.5	3.2	6.4	60.3	1,051.4
Dumping Time hr	16.4		25.5		37.7		15.4		21.4		24.8		48.0		102.5		16.8	5.1	10.4	58.5	382.6
																				Total	4,037.5

Silt/Sand Ratio %
Silt 45
Sand 55

Average Cycle Time
2.11 hr

Annual Working Hours
Week 44
Day 5
Hour 24
Efficiency 0.8
4,224 hr

Annual Required Working Hours

Dred'g/Turn'g Time	2,654 hr	65%
Sailing Time	1,051 hr	26%
Dumping Time	383 hr	9%
Total	4,087 hr	100%

Required Working Hours
4,087 hr

Required/Annual Working Hours Ratio 97 %

Table 6-2 Maintenance Dredging Plan (2)
(Sections E11-E14 to be dumped at low tide)

Hopper Capacity = 2000 m3 | Dredging Time Silt 1.00 hr | Sand 1.25 hr | Turning Time 0.25 hr
Ship speed full 10.2 kt. | ballast 10.8 kt

Section	E5	E15	E4	E6	E7	E8	E9	E10	E11	E12	E13	E14	Total
Siltation Vol m^3/y	120,488	187,005	276,146	113,057	128,696	148,823	287,820	614,958	101,051	30,637	62,313	429,005	2,499,999
Siltation Vol %	5	7	11	5	5	6	12	25	4	1	2	17	100
Soil: Silt or Sand	Silt	Silt	Silt	Silt	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Silt	
Dred'g/Turn'g Time hr	1.25	1.25	1.25	1.25	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.25	
Soil in Hopper %	55	55	55	55	75	75	75	75	75	75	75	55	
Soil in Hopper m3	1,100	1,100	1,100	1,100	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,100	
Dumping Area	D1	D1	D1	D1	D1	D1	D2	D2	D4	D4	D4	D4	
Sailing Distance km	11.0	9.2	9.7	6.9	4.9	3.0	2.7	1.7	1.8	1.5	1.5	1.5	
Sailing Time to DA hr	0.58	0.48	0.51	0.37	0.26	0.16	0.14	0.09	0.10	0.08	0.08	0.08	
Dumping Time hr	0.15	0.15	0.15	0.15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.15	
Sailing Time fm DA hr	0.55	0.46	0.48	0.35	0.24	0.15	0.14	0.08	0.09	0.08	0.08	0.08	
Cycle Time hr	2.53	2.34	2.39	2.11	2.25	2.06	2.03	1.92	1.94	1.90	1.90	1.55	
Av Cycle Time hr													
Required No of Cycle	110	170	251	103	86	99	192	410	67	20	42	390	1940
Req'd Working Hour hr	276.9	398.3	601.0	217.0	193.0	204.3	389.2	787.1	130.4	38.9	79.1	606.3	3,921
Working Hour Ratio %	7.1	10.2	15.3	5.5	4.9	5.2	9.9	20.1	3.3	1.0	2.0	15.5	100.0
T.Dred/Turn'g Time hr	136.9	212.5	313.8	128.5	128.7	148.8	287.8	615.0	101.1	30.6	62.3	487.5	2,653.5
Sailing Time hr	123.6	160.3	249.6	73.1	42.9	30.7	53.4	69.7	12.5	3.2	6.4	60.3	885.4
Dumping Time hr	16.4	25.5	37.7	15.4	21.4	24.8	48.0	102.5	16.8	5.1	10.4	58.5	382.6
												Total	3,921.4

Silt/Sand Ratio %	
Silt	45
Sand	55

Average Cycle Time 2.02 hr

Annual Working Hours	
Week	44
Day	5
Hour	24
Efficiency	0.8
	4,224 hr

Annual Required Working Hours		
Dred'g/Turn'g Time	2,654 hr	68%
Sailing Time	885 hr	23%
Dumping Time	383 hr	10%
Total	3,921 hr	100%

Required Working Hours 3,921 hr

Required/Annual Working Hours Ratio 93 %

The dredging fleet formation of two 1,000 m^3 dredgers is not recommended due solely to higher capital and running costs. However, besides an economic viewpoint, a 1,000 m^3 dredger has essential and valuable advantages such as a possibility of phased purchase/introduction, a lower effect to operation by low tide, thereby the higher efficiency and safety of dredging/dumping operation and the higher flexibility of docking/repair scheduling. Phased introduction allows lower financial and managerial burden, while shallower draft improve productivity and safety of dredging works.

Therefore, in the case that any difficulty or delay in financial and personnel arrangement is expected, the fleet formation of two 1,000 m^3 dredgers shall be given through consideration from overall viewpoints of economical, financial and operational aspects.

The original interim dredging plan has been changed as 0.5 million m^3 to be dredged in 1997 and 1.5 million m^3 each in 1998 and 1999. The interim dredging is planned assuming that the new dredger will dredge 3.23 million m^3 with the operation of 6 days a week and 44 weeks a year. The new dredger has to work 6 days a week for the first 5 years to clear the backlog up and from 2005 onward the channel will be maintained to the depth of 8.0 m with constant annual volume of 2.5 million m^3.

Annual dredging cost of the new dredger is estimated at about 3.4 million US$ which exceeds the current budget of EMODRAGA. CFM shall allocate this operating cost to EMODRAGA to ensure efficient operation of the new dredger.

7 Environmental Assessment

Marine environmental surveys were carried out to investigate water quality and seaded materials in the two seasons and also benthic macrofaunal community structuere in the dry season. As a result, it is concluded that this project would not be expected to generate any significant damaging impact to the environmental condition of Beira.

8 Economic and Financial Analysis

8.1 Economic Analysis

This Project is evaluated by means of cost-benefit analysis, comparing the case of achievement of the Project(with-case) with the present case of non-achievement of the Project(without-case). In "without-case", the channel water depth is maintained to CDL -5.0 m as same as in 1997 by dredging 0.52 million m^3 per annum under the outside contract. In "with-case", one new dredger of 2,000 m^3 hopper capacity will be introduced to dredge 2.5 million m^3 per annum with operation by EMODRAGA so that the channel water depth is maintained to CDL -8.0 m.

In comparison of "with and without cases", the following points are identified as major benefits of the Project:

(a) Saving in the ship staying cost of 8 M Channel is estimated as US$ 3.5 million in 2002,

(b) Saving in the cost up of transportation by using other ports is estimated as US$ 1.5 million in 2002,

(b) Saving in the cost of transportation by larger tankers is estimated as US$ 0.8 million in 2002,

(c) Saving in the dredging cost to maintain the channel water depth of 5 m is estimated as US$ 1.6 million every year.

The capital investment costs comprising costs of a new dredger, spare parts and training etc. is estimated as US$ 27 million. In order to dredge soil of 2.5 million m^3, the annual operation cost amounts to US$ 2.4 million in the shadow price. In the year from 2000 to 2004 after the Interim Dredging, the dredging volume amounts to 3.2 million m^3 to clear the backlog and the annual operation cost increases to US$ 2.6 million in the shadow price.

The EIRR of the Project of 8 M Channel is calculated as 24.38 % at the shadow price. The EIRR of 24.38 % at the shadow price is much higher than the estimated opportunity cost of capital (12 %). The effect of investment to the Project is considered to be very high and the best in comparison with other alternatives. Further, the EIRR is the best, even taking into consideration the fluctuations of the investment costs and project life. Therefore, this Project is judged to be feasible from economic viewpoints.

8.2 Financial Analysis

The expenses of this Project are assumed to be paid to EMODRAGA by the Port Department of CFM-C, which consist of fixed revenues equivalent to the fixed cost (labor costs, maintenance costs, repair costs, administration costs and depreciation costs) of EMODRAGA and variable costs in proportion to the dredged soil volume of US$ 0.57 /m^3. Thus the income of EMODRAGA is calculated so as to amount to US$ 3.9 million including 10 % of the profit.

The capital investment cost in 2000 is estimated as US$ 27 million. The annual operation cost is estimated as US$ 2.8 million during 2000 to 2004 and US$ 2.5 million during 2005 to 2024.

The FIRR is calculated at 2.28 % that CFM-C will pay a full fixed cost of US$ 2.4 million and a variable cost of US$ 1.4 million plus profit. At the end of project life, this Project is to gain Current Assets of US$ 29 million, which can recover the initial investment of US$ 27 million, and EMODRAGA also can use the new funds of US$ 5 million. Therefore, this Project is evaluated to be feasible enough in spite of the low level of FIRR.

According to the trend of Profit and Loss on the Port Section of CFM-C during 2000 to 2024 and their Source of Fund, from which the operation and maintenance cost of this Project can be paid for, the rate of expense for new dredging (= Revenues of EMODRAGA of this Project) against the Source will decrease from 19.7 % in 2000 till 9.8 % in 2024 by the effect of increasing cargo volume of Beira Port.

9 Implementation Plan

For the construction of the new dredger, approximately 20 months are required after contracting. And further 3 months will be necessary for mobilization to Beira Port and for delivery. Moreover, it is important to pay attention on survey boats, navigation aids, management and operation system and training of crews.

10 Recommendation

As the countermeasure for the maintenance and improvement of the Access Channel to Beira Port, it is recommended urgently to introduce the above mentioned dredger with hopper capacity of 2,000 m^3 and to recover and maintain the Access Channel to -8 m below CDL.

Recruit and training of new crews and shift of existing experienced crews shall be planned and implemented well before introducing the new dredger. The training program of dredger crews and engineers in charge of dredging plan and oceanographic survey should be appropriately arranged and should be begun before introducing the new dredger.

Moreover, the extensive hydraulic surveys in the Access Channel including its surrounding area shall be executed in the wet and dry seasons every year, in order to make clear the seasonal and yearly change of sedimentation phenomena in the Access Channel and to serve for establishing an appropriate plan of dredging works.

The location of dumping areas is an important factor governing the efficiency of dredging operation. Therefore, sounding surveys of the dumping areas shall be conducted as often as possible in order to establish the appropriate dredging and damping plan.

The dredging works are executed under the contract between CFM and EMODRAGA. The contract forms after the introduction of the new dredger should be studied in full between them beforehand in order to secure the sound finance of EMODRAGA.

INTRODUCTION

INTRODUCTION

This report is the result of "The Study for Maintenance and Improvement Plan of Access Channel of Beira Port in the Republic of Mozambique" which was conducted from December 1996 to March 1998.

1 Background of the Study

Beira Port located in central Mozambique, Maputo Port in the south and Nacala Port in the north are the major ports in Mozambique, each functioning as a gateway for national and international routes of transport connecting Mozambique and inland countries of Southern Africa. The Beira Corridor is the most efficient route to Zimbabwe, where improvements of infrastructure such as railways, roads and pipelines are being carried out.

Beira Port is situated at the river mouth of the Pungue River and has 10 berths with a total berth length of 1,632 m and water depth of 10.0 - 12.0 m and a new oil terminal with water depth of 13.5 m. Cargo volume currently handled at the port was about 2.6 million metric tons in the year 1996, of which domestic cargo amounts to only 360,000 metric tons with most of the remainder in transit of Zimbabwe.

In Beira Port, siltation of the Access Channel is presenting the most serious problem in port management. The water depth of the Access Channel is 5.0 m below CDL at some portion, as a result that large vessels must enter and leave the port during high tide. In order to secure the safety of vessels calling at the port, it is necessary to dredge and maintain the Access Channel.

All maintenance dredging work in Mozambique has been conducted by EMODRAGA, utilizing one obsolescent trailing suction hopper dredger and other small dredging vessels. The existing dredging equipment owned by EMODRAGA, however, does not have enough capacity to properly dredge the huge amount of silted material in many ports in Mozambique; thus Beira, Maputo and Quelimane Ports are suffering serious siltation problems.

Under these circumstances, the Government of Mozambique requested the Government of Japan for a grant aid for a dredger. In February 1996, a preliminary study mission was dispatched to Mozambique under the grant aid scheme. Although the need and urgency of offering a dredger were acknowledged, it was deemed necessary to study the siltation phenomena before formulating countermeasures against siltation based on a long range view. In March 1996, the country requested again the Government of Japan for cooperation in planning, maintenance and improvement of the Access Channel at Beira Port.

2 Study Objective

In accordance with the conditions described above and in response to a request from the Government of the Republic of Mozambique, the objectives of the study are listed as follows.

1) To formulate a maintenance and improvement plan of the Access Channel and Basin in order to maintain the port functions at Beira Port.
2) To transfer the related technology to Mozambique counterpart through the survey studies.

3 Scope of the Study

To achieve the objectives mentioned above, the study shall cover the following items.

1) Investigation on the present conditions of the port, the Access Channel and dredging activities
2) Preparation of effective countermeasures against the shoaling problem in the port
3) Formulation of maintenance and improvement plan of the Access Channel and basin

4 Study Execution

The study was conducted as follows.

1) Presentation of Inception Report, the first field survey and presentation of the Progress Report; January - March 1997.
2) The second field survey on natural conditions; April - May 1997.
3) Presentation of the Interim Report and the third field survey; July - September 1997.
4) Presentation of the Draft Final Report and the forth field survey; January - February 1998.

The final report is produced on the basis of the comments on the Draft Final Report provided by the Government of the Republic of Mozambique.