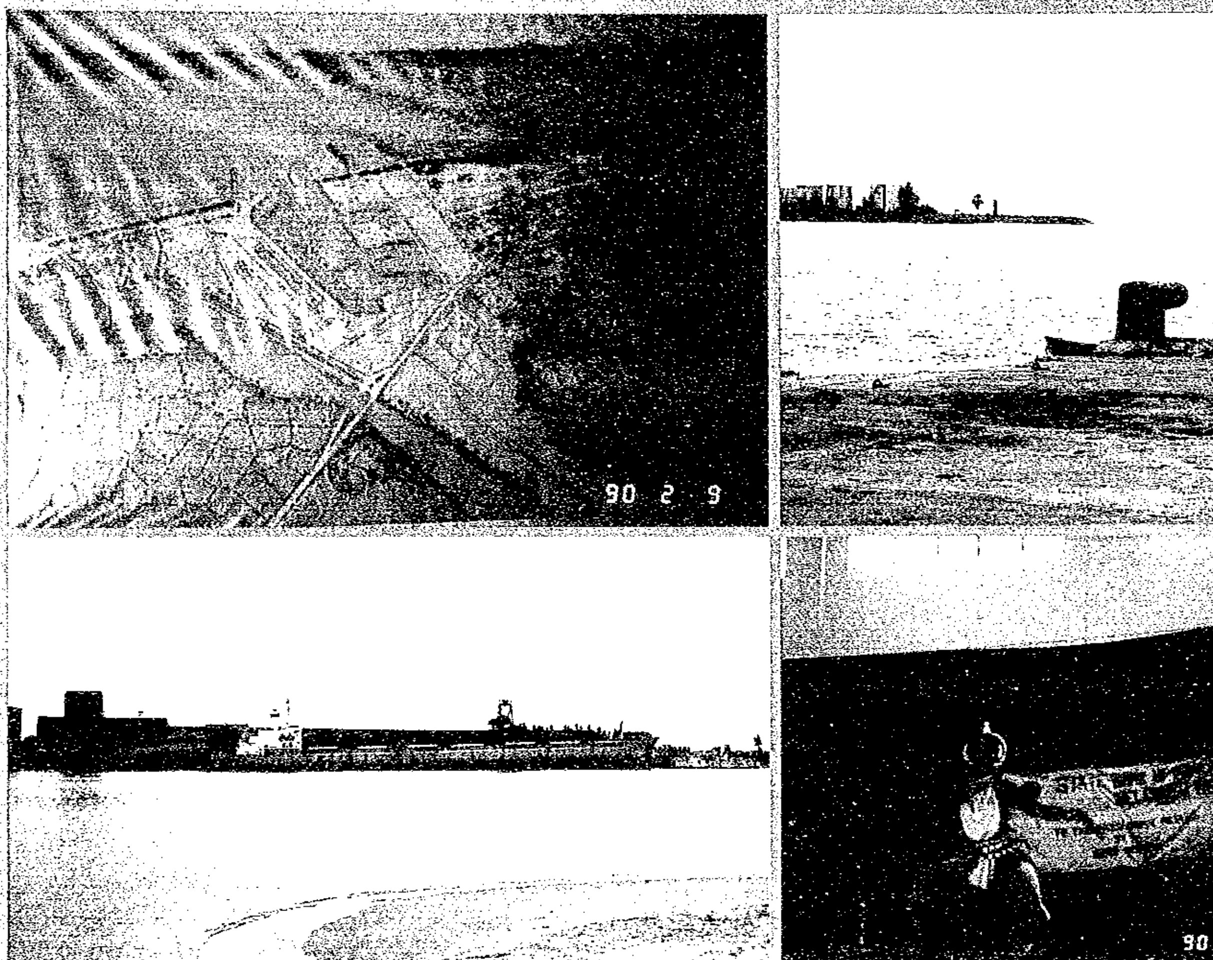
社会開発調査部報告書

No. 62

I N D I A
NEW MANGALORE PORT

THE FEASIBILITY STUDY ON THE INPROVEMENT PLAN
of
NEW MANGALORE PORT



FINAL REPORT AUGUST 1990

J I C A
JAPAN INTERNATIONAL COOPERATION AGENCY

SSF
CR(3)
90－103

FINAL REPORT
THE FEASIBILITY STUDY ON THE IMPROVEMENT PLAN
of NEW MANGALORE PORT
AUGUS

107
61.7
SSF

JICA LIBRARY
1086708[3]
21795

INDIA

NEW MANGALORE PORT

THE FEASIBILITY STUDY ON THE IMPROVEMENT PLAN
of
NEW MANGALORE PORT

FINAL REPORT AUGUST 1990

国際協力事業団
21795

PREFACE

In response to a request from the Government of India, the Japanese Government decided to conduct a study on the Feasibility Study on the Improvement Plan of New Mangalore Port and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to India a survey team headed by MR. Haruo Okada and composed of members from the Overseas Coastal Area Development Institute of Japan (OCDI) and Yachiyo Engineering Co., Ltd, three times from September, 1989 to July, 1990.

The team held discussions with the concerned officials of the Government of India, and conducted field surveys. 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 India for their close cooperation extended to the team.

August, 1990

Kensuke Yanagiya
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

August, 1990

Mr. Kensuke Yanagiya
President
Japan International cooperation Agency

Dear Mr. Yanagiya:

It is my great pleasure to submit herewith the Report for the Feasibility Study on the Improvement Plan of New Mangalore Port.

The Study Team which consists of the Overseas Coastal Area Development Institute of Japan and the Yachiyo Engineering Co., Ltd., headed by myself, conducted a survey in India from September 1989 to July 1990 at the contract of the Japan International Cooperation Agency.

The findings of this survey were fully discussed with the Indian couterparts to formulate the Master Plan for the period up to the year 2004/05 and to formulate and examine the feasibility of the Short-term Plan for the period up to the year 1994/95 and were then compiled into this report. As a result of the Study, the implementation of the projects herein proposed is regarded as crucial not only to the socioeconomic development of the southern region of India centered by the State of Karnataka and also regarded as viable from economic and financial viewpoints.

I earnestly wish that the Plan herein proposed will be implemented at the possible earliest by the Government of India.

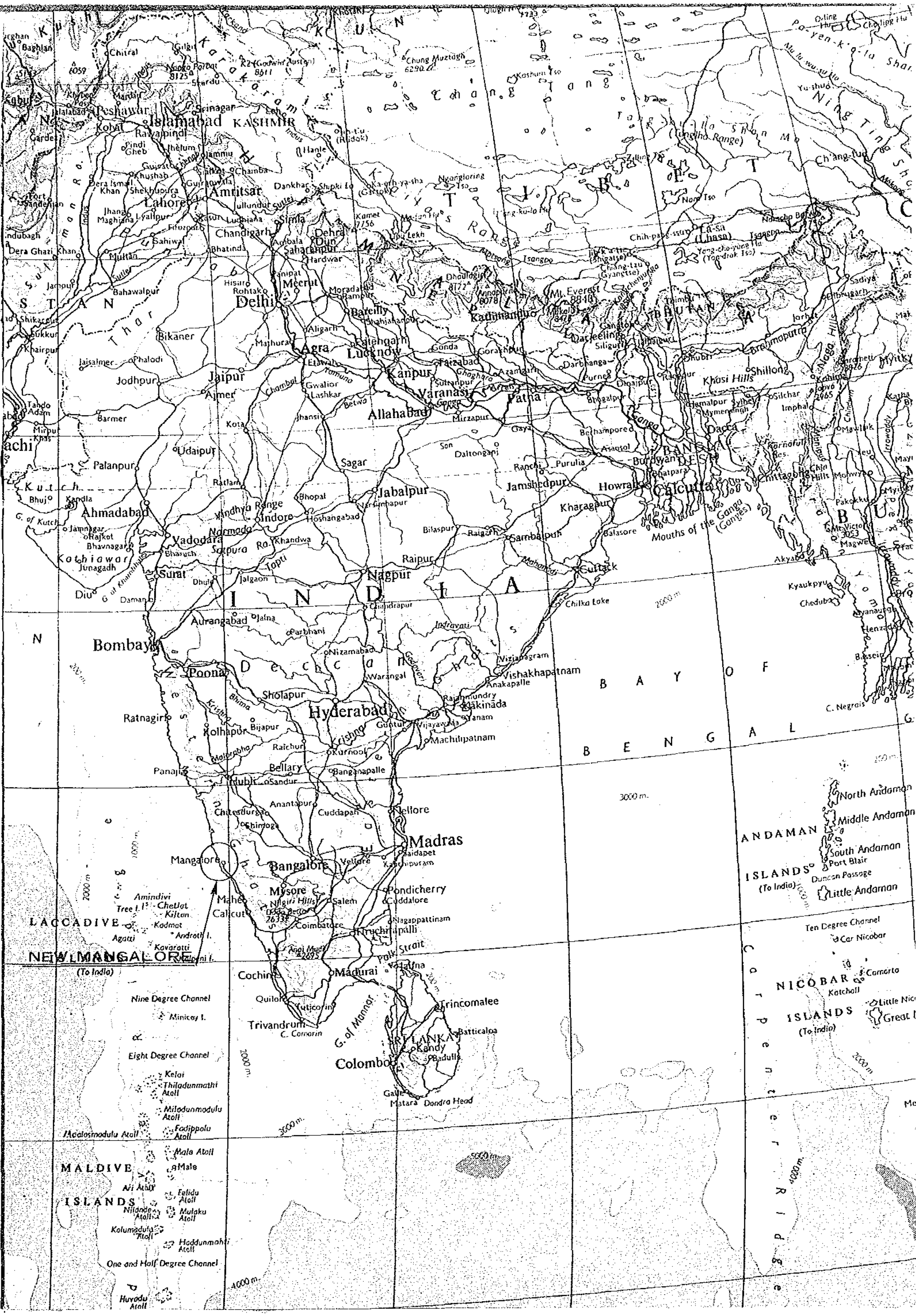
On behalf of the Study Team, I would like to express my deepest appreciation to the Government of India, the New Mangalore Port Trust and the various organizations concerned with the Study for their brilliant cooperation and assistance and for the heartfelt hospitality which they extended to the Team during their stay in India.

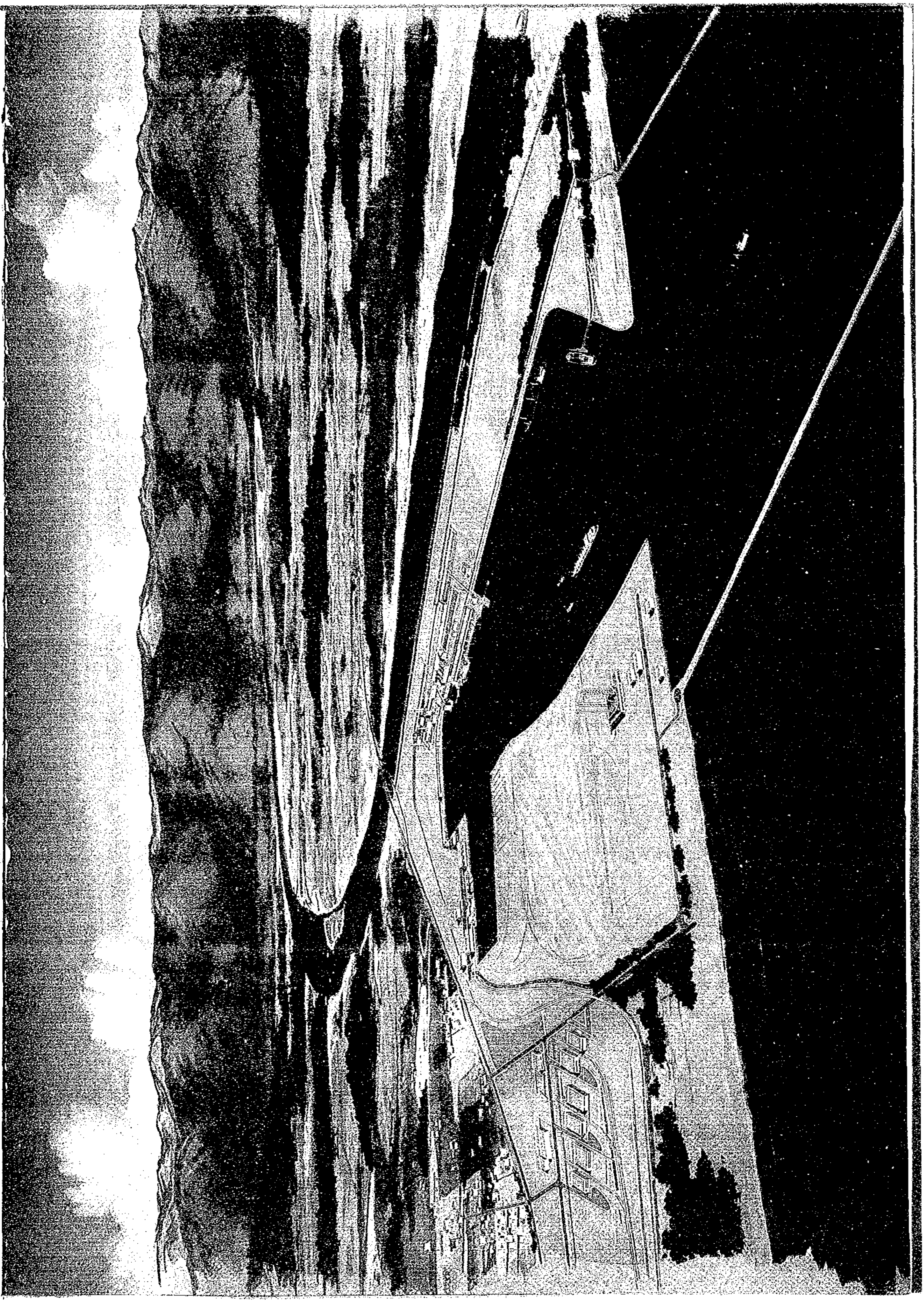
I am also greatly indebted to the Japan International Cooperation Agency, the Ministry of Foreign Affairs, the Ministry of Transport, the Japanese Embassy and the JICA Office in India for giving us valuable suggestions and assistance during the field surveys and the preparation of this report.

Respectfully,

H. Okada

Haruo Okada
Leader
Japanese Team for the Feasibility
Study on the Improvement Plan
of New Mangalore Port
(Exective Director, the Overseas Coastal Area Development Institute of Japan)


NEW MANGALORE
(To India)
INDIA
BAY OF BENGAL
BANGLADESH
BHUTAN
TIBET
KASHMIR
Islamabad
Rawalpindi
Peshawar
Srinagar
Amritsar
Lahore
Chandigarh
Simla
Delhi
Meerut
Bareilly
Agra
Lucknow
Kanpur
Varanasi
Allahabad
Patna
Kathmandu
Mt. Everest
Darjeeling
Shillong
Khasi Hills
Dacca
Calcutta
Howrah
Jamshedpur
Kharagpur
Mouths of the Ganga (Ganges)
Cuttack
Sambalpur
Raipur
Nagpur
Jabalpur
Bhopal
Indore
Sagar
Jhansi
Gwalior
Jaipur
Ajmer
Jodhpur
Bikaner
Udaipur
Ahmadabad
Vadodara
Surat
Bombay
Poona
Aurangabad
Sholapur
Hyderabad
Warangal
Vishakhapatnam
Kakinada
Machilipatnam
Kurnool
Bellary
Hubli
Panaji
Ratnagiri
Kolhapur
Bijapur
Nellore
Madras
Bangalore
Mysore
Mangalore
Calicut
Coimbatore
Pondicherry
Cuddalore
Tiruchchirapalli
Madurai
Cochin
Quilon
Trivandrum
C. Comorin
Palk Strait
G. of Mannar
Jaffna
Trincomalee
Batticaloa
SRI LANKA
Kandy
Colombo
Galle
Matara
Dondra Head
Deccan
Thar
Kutch
G. of Kutch
Kathiawar
Chilka Lake
LACCADIVE
Minicoy I.
Nine Degree Channel
Eight Degree Channel
MALDIVE ISLANDS
Male
One and Half Degree Channel
ANDAMAN ISLANDS (To India)
North Andaman
Middle Andaman
South Andaman
Port Blair
Duncan Passage
Little Andaman
Ten Degree Channel
Car Nicobar
NICOBAR ISLANDS (To India)
Carpenter Ridge
Chittagong
Akyab
C. Negrais
Lhasa
Karakoram



ABBREVIATION

ADB	Asian Development Bank
CFC	Conversion Factor for Consumption
CWPRS	Central Water and Power Research Station
DWT	Dead Weight Tonnage
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GRT	Gross Ragistered Tonnage
IBRD	International Bank for Reconstruction and Development
ICD	Inland Container Depot
IPA	Indian Ports Association
JICA	Japan International Cooperation Agency
KIOCl	Kudremukh Iron Ore Company Limited
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MOST	Ministry of Surface Transport
MCF	Mangalore Chemicals & Fertilizer Limited
MOST	Ministry of Surface Transport
NMP	New Mangalore Port
NMPT	New Mangalore Port Trust
NTPC	National Thermal Power Plant
OCDI	Overseas Coastal Area Development Institute of Japan
OECF	Overseas Economic Cooperation Fund
PHRI	Port and Harbour Research Institute, Ministry of Transport, Japan
POL	Petroleum, Oil and Lubricant
Rs	Rupees
SCF	Standard Conversion Factor
SCI	Shipping Corporation of India
TEU	

EXCHANGE RATE

$ 1 = Rs. 16.75

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Background of the Study

New Mangalore Port (NMP) is one of the eleven major ports of India. The port has been developed by New Mangalore Port Trust, established in 1980, and plays an important role in the iron ore trade together with Mormugao Port, Visakhapatnam Port and Madras Port. NMP handles 7.1 million tons of cargo in total in 1988-89, over 70% of which is iron ore exported to Japan and Eastern European countries.

NMP has a -13.5m-deep, 5.5km-long navigational channel and a -13.0m-deep turning basin, which require 3 -4 million m^3 of dredging every year to maintain the depth.

Other major ports in India accommodate iron ore vessels of 130,000-150,000 DWT size and there are plans to enlarge the handling facilities to accept 170,000 DWT vessels. However, the present iron ore terminal of NMP can receive vessels of 60,000 DWT size at most, and NMP would be behind other ports in the iron ore market without improvement of the facility.

Moreover, an oil refinery plant plan is being prepared by Mangalore Refinery & Petrochemicals Ltd., and a construction plan for a crude oil handling facility is also included in the existing Master Plan. Also, a feasibility study on a coal handling facility plan for a proposed coal thermal power plant (30km north from NMP) is being executed.

Accordingly, the main subjects for NMP are as follows:

(1) Formulation of an improvement plan for the iron ore handling facility.

(2) Review of the existing plan for the oil handling facility.

(3) Review of the existing Master Plan.

1.2 Objectives of the Study

The objectives of the Study are:

(1) to review the Master Plan of New Mangalore Port with a long-term perspective for the period up to the year 2005.

(2) to formulate an Improvement Plan for New Mangalore Port for accommodating larger size iron ore and oil vessels in accordance with the

investment profile for the 8th Five-Year Plan (1990/1995) of the Government of India.

(3) to determine the technical, economic, and financial feasibility of the Improvement Plan.

1.3 Scope of the Study

In order to achieve the objectives mentioned above, the Study shall cover the following items:

(Review and Field Survey)

(1) to collect and review available information and reports relevant to the Study.

(2) to conduct field surveys for evaluating the present conditions of the Port.

(Observation of Natural Conditions)

(1) boring investigation

(2) sonic prospecting and seismic survey for identifying sea-bed rocks

(3) bottom sediments sampling

(4) wave observation

(5) current observation

(Review of the Master Plan)

(1) to review and examine the future functions of the Port.

(2) to review and examine the layout plan of major port facilities.

(Formulation and Evaluation of Alternative Improvement Plans for the Iron Ore Handling Facility)

(1) to forecast the port traffic for iron ore.

(2) to forecast the size of vessels likely to call at the Port.

(3) to evaluate the structual design of the existing iron ore berthing facilities.

(4) to prepare improvement plans suitable for different sizes of vessels in phased stages.

(5) to assess the capital and maintenance dredging volume for each alternative.
(6) to determine the optimum improvement plan.

(Review and Examination of the Plan for the Oil Handling Facility)
(1) to review the existing plan for oil handling facilities in light of the improvement plan described above.
(2) to examine the layout plan and facilities plan of the oil handling facilities.
(3) to make the necessary recommendations on development and improvement of the oil handling facilities.

(Feasibility Study on Improvement Plan for Iron Ore Handling)
(1) to formulate a detailed facilities improvement plan, including cargo handling systems.
(2) to consider environmental impacts in qualitative terms.
(3) to carry out preliminary design.
(4) to estimate initial and maintenance costs.
(5) to prepare an implementation programme.
(6) to carry out economic analysis.
(7) to carry out financial analysis.
(8) to carry out additional economic and financial analyses taking account of benefits and costs for both iron ore and oil handling.
(9) to prepare recommendations on operation and maintenance systems.

The study was carried out according to the flow chart shown in Figure-1.1.1.

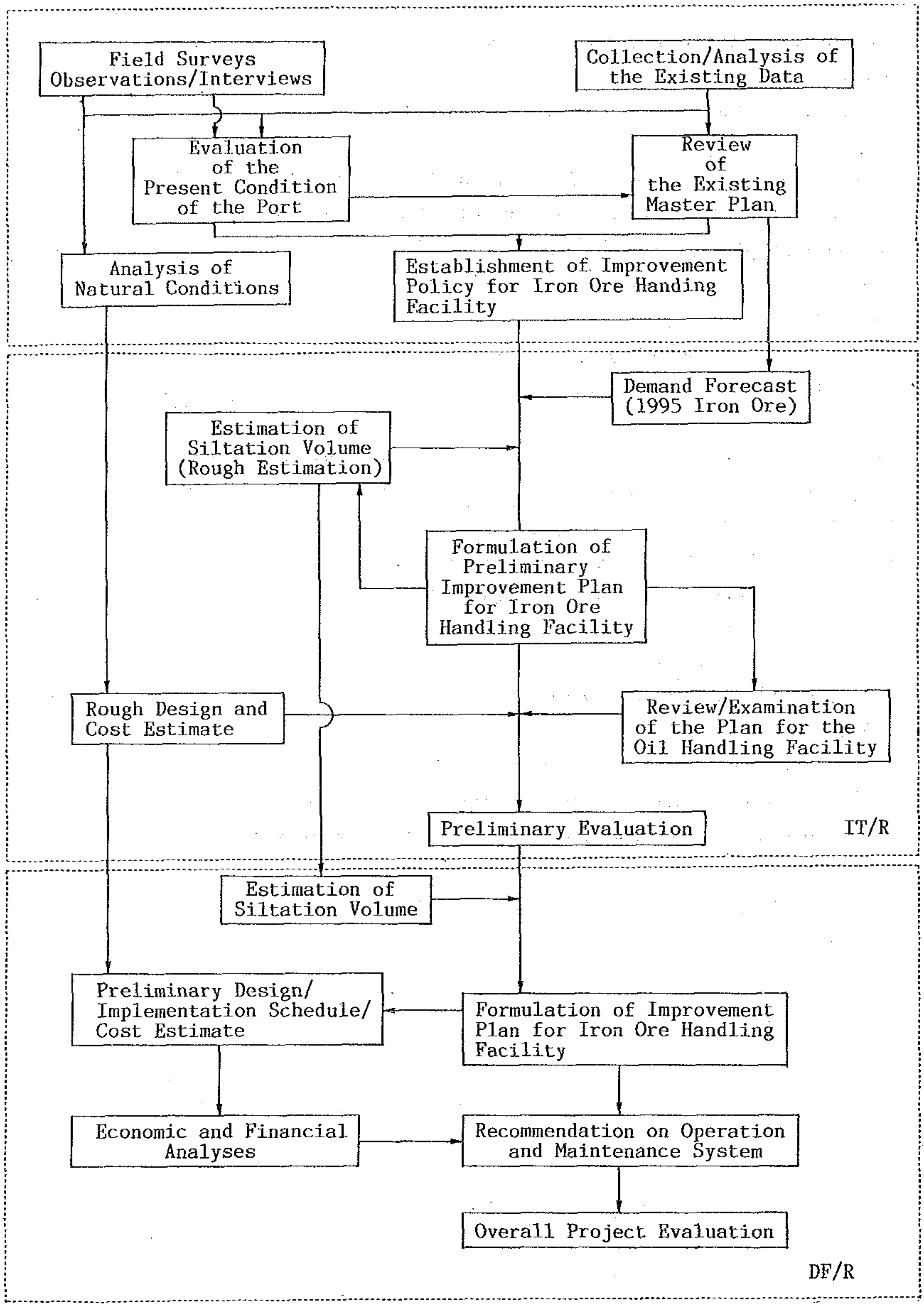
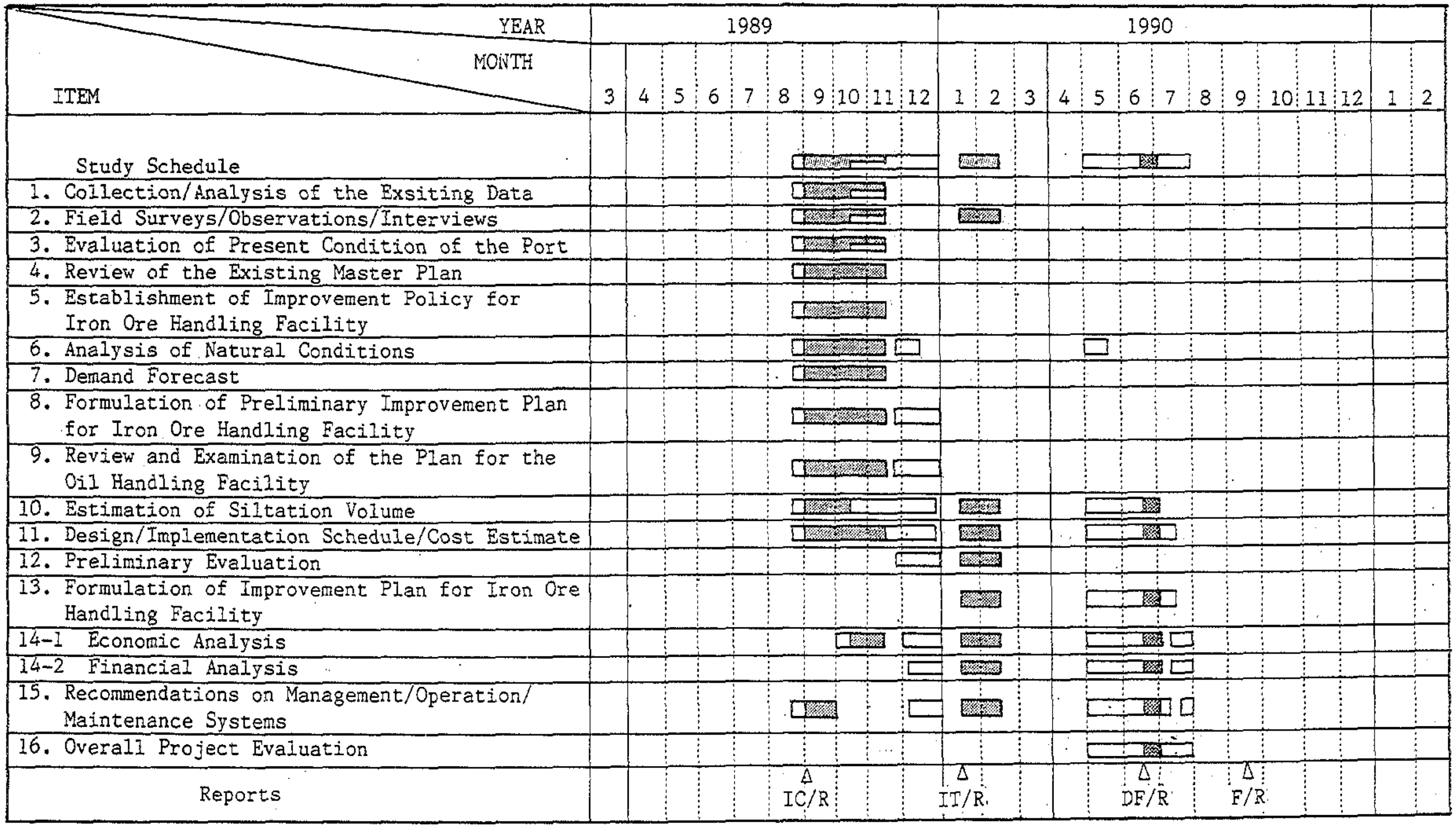


Figure-1.1.1 Working Procedure of the Study

1.4 Study Schedule



Legend; Work in India   Work in Japan
IC/R: Inception Report   IT/R: Interim Report   DF/R: Draft Final Report   F/R: Final Report

1.5 Organization of the Study Team

The Study Team consists of twelve experts. Their names and responsibilities are listed below.

Name	Responsibility
Haruo OKADA	Leader
Hiroshi HORIKAWA	Port Planning/Demand Forecast
Yukio KAMEI	Countermeasures Against Siltation/ Dredging Planning
Kenji HATTORI	Economic Analysis
Yutaka YOSHIMORI	Operation Planning/Financial Analysis
Yuzuki MUROGA	Cargo Handling System Planning
Mitsuo IGARASHI	Natural Conditions (Oceanographic)
Katsutoshi SUZUKI	Natural Conditions (Soil)
Touru WATANABE	Natural Conditions (Soil)
Masao ITOI	Siltation Volume Estimation
Shuji SEKIGUCHI	Facilities Design
Takahisa SOGABE	Construction Method/Cost Estimation

2. PRESENT SITUATION OF THE PORT

2.1 Profile of New Mangalore Port

New Mangalore Port is located at Panambur, Mangalore in Karnataka state, on the West Coast of India, 170 nautical miles south of Marmagao Port and 191 nautical miles north of Cochin Port (Figure-2.1.1). Its hinterland area, 69,930 km^2, includes Bangalore and Mysore and is connected with the port by National Highway No.17 and State Highway No.48.

New Mangalore Port was declared India's 9th major port in 1974 and started operation in 1975. Then New Mangalore Port Trust was formed in 1980. The port area is 2,350 acres (950 ha), including the water area, and is located between the shore-line and the Gurpur River (Figure-2.1.2).

The port handled about 7 million tonnes of cargo in the 1988-89 period. This was mainly composed of iron ore (over 70 %) as well as P.O.L, granite stone, timber, etc., at one 60,000 DWT-class iron ore berth, one oil jetty, four general cargo berths and one shallow berth.

The main firms adjacent to the port are Kudremukh Iron Ore Company Limited (KIOCL) and Mangalore Chemicals & Fertilizers Limited (MCF). Moreover, in the near future, an oil refinery and a coal thermal power plants will be constructed 10 km and 35 km from the port, respectively, and will consume and/or generate much cargo through the port. Mazagon Dock Limited has established a pipe coating plant and an offshore fabrication yard in the area and is exporting coated pipes and fabricating offshore structures for Bombay High.

New Mangalore Port has a long navigational channel and a siltation problem like that of other ports on India's West Coast. Three million to four million cubic meter of silt must be dredged every year.

2.2 Locational Condition and Hinterland

(1) Introduction

The land area of Karnataka is 191,757 square kilometers (approximately 6% of the total land area of India: 3.29 million square kilometers) and is situated in the western part of the Deccan Peninsula between 11.5°N and 19°N latitudes and 74°E and 78°E longtitudes. The state

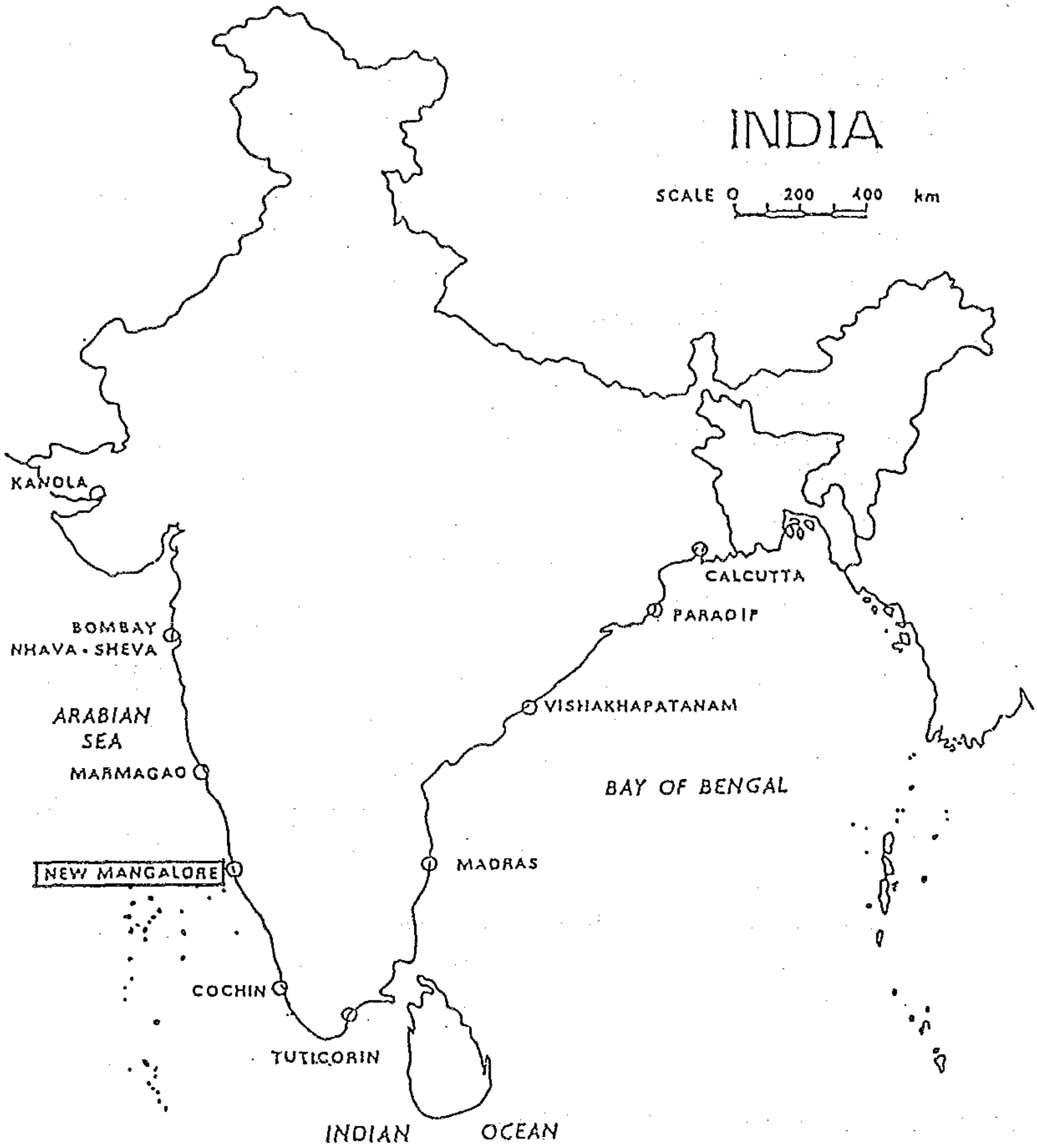


Figure-2.1.1 Major Ports in India

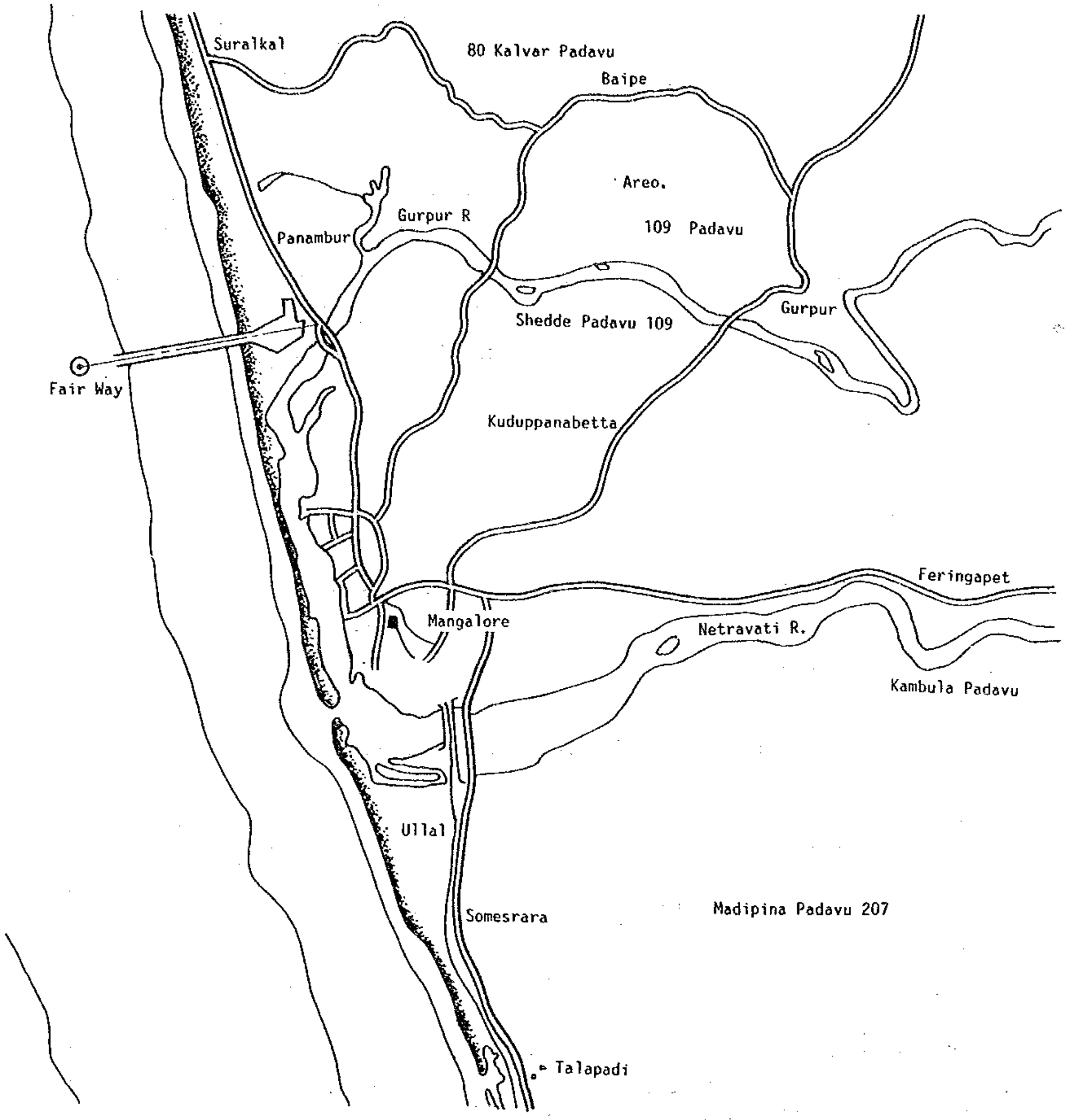


Figure-2.1.2 New Mangalore Port and Vicinity is bounded by the state of Maharashtra in the north and the union territory of Goa and the Arabian Sea in the west. It borders the state of Andhra Pradesh on the east and the states of Tamil Nadu and Kerala on the south. Physiographically, the state may be divided into four regions, viz., (i) Coastal Region, (ii) Malnad Hilly Country lying east of the Western Ghats, (iii) The northern Trappeanless Undulating Plateau and (iv) The southern broad Archaean Undulating Plateau.

When we discuss about demand forecast at Chapter 7, the economic hinterland of New Mangalore Port covers not only Karnataka state but also part of Kerala state and Andra Pradesh state as the secondary hinterland.

In this Chapter, however, it is very difficult to pick up population, GDP etc. of a part of Kerala state and Andra Pradesh state. Therefore, we discuss here only Karnataka state of primary hinterland for demand forecast.

(2) Population

According to the 1981 census Karnataka had a population of 37,135,714 with a density of 194 per square kilometer and ranks in population as the eight state in India.

Table-2.2.1 Population in Karnataka

(Unit: Million)

				Annual Growth Rate(%)	
	1971	1981	1986	1981/71	1986/81
India	547.9	645.2	761.1	2.3	2.1
Karnataka	18.9	37.1	41.1	7.0	2.2
Share of Karnataka of India's population (%)	3.4	5.4	5.4		

Source: A Social and Economic Atlas of India

(3) Economy

(i) Gross domestic product at factor cost (at 1970-71 Prices) of Karnataka is as follows:

Table-2.2.2 GDP of Karnataka

(Unit: Million Rs.)

Year	1970/71	1780/81	1986/87	Annual Growth Rate(%) 1981/71	1987/81
GDP(Karnataka)	18,581	25,240	33,358	3.1	4.8
GDP(India)	367,360	506,230	681,074	3.3	5.1
Share of Karnataka(%)	5.1	5.0	4.9		

(ii) Per capita GDP (at 1970-71 Prices) of Karnataka is as follows:

Table-2.2.3 Per Cpaita GDP of Karnataka

(Unit:Rs)

Year	1970/71	1980/81	1986/87
Karnataka	641	681	799
India	633	698	798

(iii) Sectorial distribution of GDP (at 1970-71 Prices) of Karnataka is as follows:

Table-2.2.4 Sectorial Distribution of GDP of Karnataka

(Unit:%)

		Karnataka	India
1970-71	Agriculture	54.2	49.2
	Manufacturing	15.4	13.4
	Other	30.4	37.4
1980-81	Agriculture	44.5	41.6
	Manufacturing	21.1	14.6
	Other	34.4	43.8
1986-87	Agriculture	41.5	N.A.
	Manufacturing	21.6	N.A.
	Other	36.9	N.A.

Agriculture forms the backbone of the economy of Karnataka. The state produces 5.66 million tonnes of cereals and 0.69 million tonnes of pulses, totaling 6.35 million tonnes of food grains in 1987-88.

Karnataka is one of the leading state in India in plantation and garden crops. It is the largest producer of coffee in the country.

Karnataka produced 130 thousand tonnes of coffee in 1985-86 (the share of Karnataka of India's coffee output is approximately 70%).

Sugar cane is also an important crop in Karnataka. The state produced 12.8 million tonnes of this product in 1985-86 (about 7.3% of India's total sugar cane production.)

The state is blessed with a large number of metallic and non-metallic mineral resources, which has contributed to its industrial development. The major minerals are iron ore, manganese, limestone, chromate, bauxite, gold and so on.

There were 513 major and medium industries and 67,972 small scale industries in Karnataka as of 1985-86. According to the latest Annual Survey of Industries (1981-82), there are 5,694 factories in the state. The number of people employed in this sector was 3.67 thousand, the value of its output Rs 30,180 million and value added was Rs. 6,740 million. Per capita value added works out to Rs 182. Karnataka is in seventh place in terms of per capita value added among the states in the country.

(4) Transportation

(i) Roads

The total road length in the state as of March 1986 was 112,923 km of which national highways accounted for 1,968 km, state highways 7,912 km, major district roads 15,999 km, other district roads 7,072 km and village roads 45,495 km. According to a sample survey conducted in 1985-86, the annual rate of increase of road traffic on National highway was 32.9%, state highways 16.8%, major district roads 15.9%, other district roads 24.0% and on village roads 12.7%. According to the present traffic trends, road traffic in the state is expected to double in the next 20 years.

Motor vehicles on the road by the end of December 1985 numbered 742,490 in which 471,428 (63.6%) were two-wheelers, 90,903 (12.2%) cars, 15,753 (2.1%) jeeps, 27,658 (3.7%) autorickshaws, 6,985 (1%) taxis, 16,870 (2.3%) buses, 43,073 (5.8%) goods carriers, 28,633 (3.8%) tractors, 29,588 (4%) trailers and 11,599 (1.5%) other vehicles.

The major arterial roads in Karnataka state are as follows:

There are seven national highways with a total length of about 2,000 kilometers. They are shown in Figure-2.2.1.

i) Kolar-Bangalore-Belgawn (NH-4)

ii) Hosur-Bangalore-Bagepalli (NH-7)

iii) Sholapur-Hyderabad Road through Bidar District (NH-9)

iv) Chitradurga-Sholapur (NH-13)

v) Belgaum-Panjim

vi) West Coast Road-Goa to Capecomorin (NH-17)

vii) Bangalore-Mangalore via Hassan (NH-48)

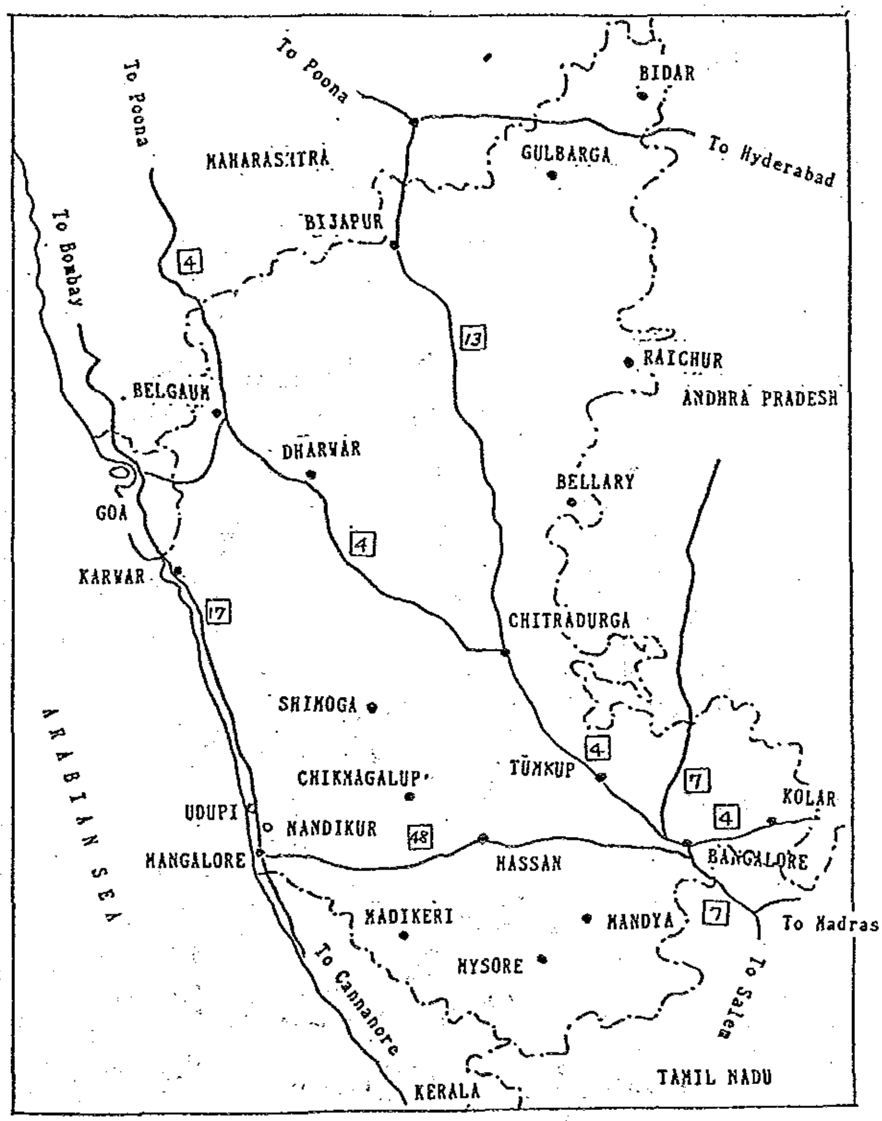


Figure-2.2.1 Highway Network in Karnataka

(ii) Railways

The routes length of railways in the state as on date is 3,024 km as against 2,634 km, as of November 1956, which meant an increase of 390 km over 31 years. The important railways in Karnataka state are described as follows. Railways found in the state are shown in Figure-2.2.2.

i) Bangalore-Mysore
ii) Hassan-Mangalore
iii) Chikjajur-Chitradurga
iv) Birur-Talaguppa
v) Bangalore-Pune
vi) Hubli-Sholapur
vii) Hubli-Guntakal
viii) Hospet-Kottur metregauge
ix) Mangalore-Salem

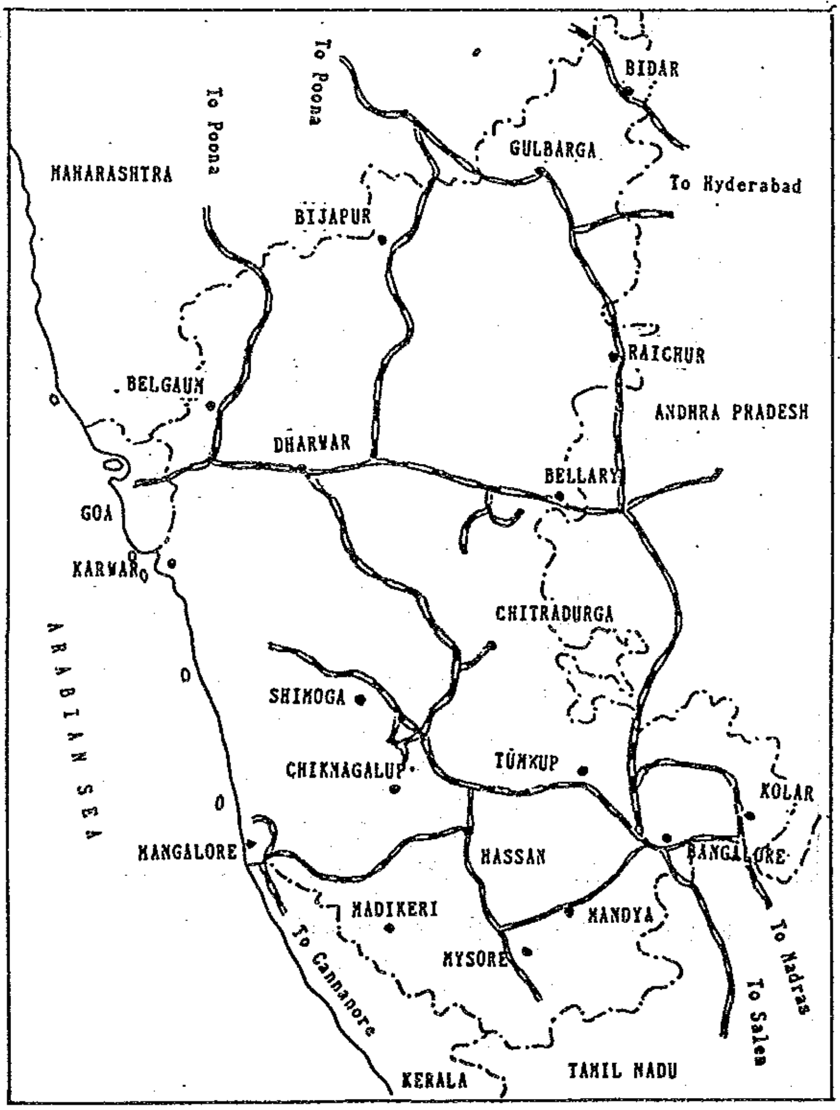


Figure-2.2.2 Railway Network in Karnataka

(iii) Air Transport

The India Airlines Corporation (IAC) maintains two airports in the state: one at Bangalore and the other at Mangalore. Mangalore is connected with Bombay and Bangalore. Bangalore is connected with all the state capitals of India.

(iv) Ports

Karnatáka is a maritime state with a coastal belt of 287 km covering the Uttara Kannada and Dakshina Kannada districts, with a total of 20 ports. Except Karwar Port, all other ports are riverine ports situated near the junction of the river in question with the Arabian Sea. Excluding New Mangalore Port, the handling capacity of 1.2 million tonnes. There are 15 lighthouses in the state (Figure-2.3.1).

2.3 Land Use

As stated in section 2.1, only two major firms, KIOCL and MCF, are located next to the port. A railway marshalling yard, a commercial area where the New Mangalore Port Trust Administration Office is located and a residential area for staff members of the Port Trust occupy the northern part of the port area. Additionally, the oil storage and distribution terminal of the Indian Oil Corporation is located at the south edge of the area (Figure-2.3.2).

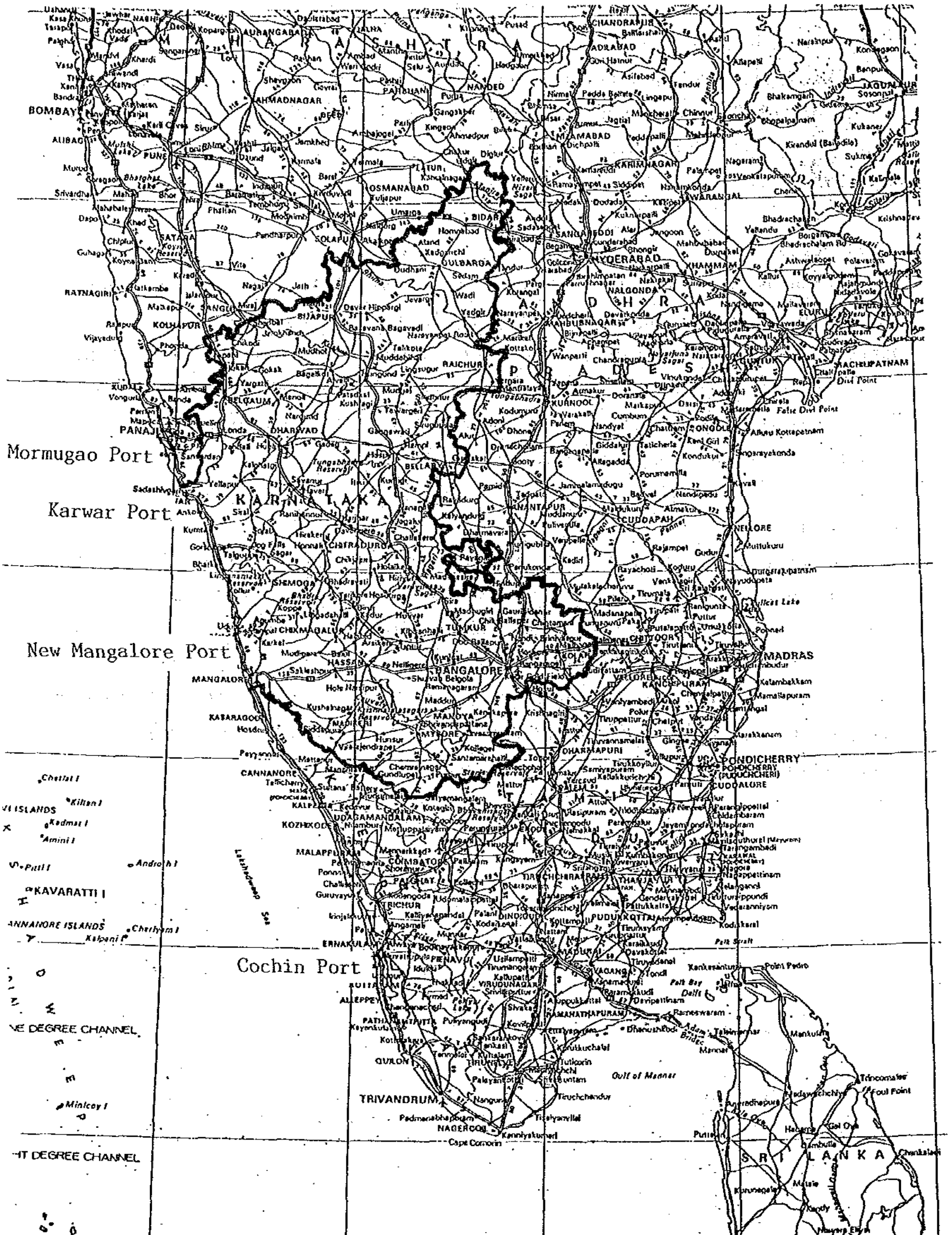


Figure-2.3.1 Neighbouring Ports of New Mangalore Port

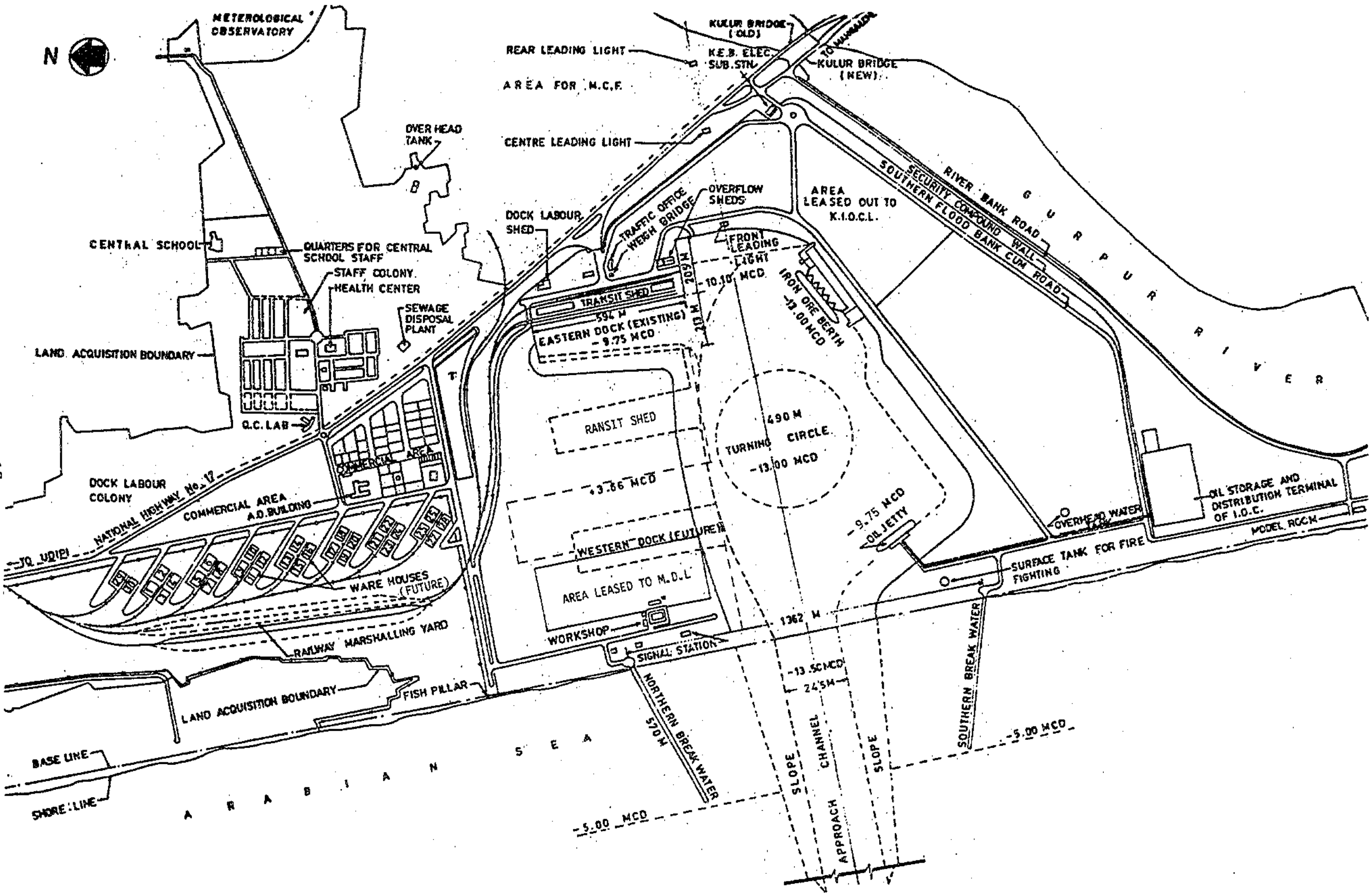


Figure-2.3.2 Land Use in and around New Mangalore Port

2.4 Existing Port Facilities

The present condition of the port facilities at New Mangalore port is described below.

2.4.1 Mooring facilities

New Mangalore Port now has six berths, four for break-bulk/dry-bulk cargo, one for iron ore one for handling POL products, and a shallow-water berth is available for handling reefer and coastal cargoes.

A brief description of these facilities following table.

Table-2.4.1 Berth Particulars

Sl. No.	Description of berth	Draught (in meters)	Length of berths(in meters)	Remarks
1.	Berth No. 1	9.45	198	a straight
2.	Berth No. 2	9.45	198	continuous wharf
3.	Berth No. 3	10.10	198	594 meters in length
4.	Shallow Berth	6.50	125	
5.	Oil Jetty	9.75	330	Length between centers of extreme moorings
6.	Iron Ore Berth	12.50	285	With mechanized shiploader
7.	Additional Berth	9.15	250	

(1) General cargo berth

There are four berths for handling general cargo.(Berth No.1, Berth No.2, Berth No.3 and Shallow Berth)

The main commodities being handled at these berth are fertilizers, manganese ore, logs, cement and others.

The type of construction of these berths in the eastern dock is partly monoliths founded at various depths and partly piles and diaphragm walls.

(2) Iron Ore berth

The iron ore berth is a open type pier with a length of 285 m and a front depth of -13.0 m. The maximum berthing vessel size is 60,000 DWT. The shiploader with 6,000 t/h is equipped for handling concentrate and pellets from the Kudremukh Iron Ore Company.

(3) Oil jetty berth

The oil jetty berth is an open type pier with a length of 250 m and a depth of -9.75 m. The maximum size of vessel that can enter the berth is 30,000 DWT.

Presently, oil products (naphtha and fuel oil) and molasses are handled using rubber hoses.

(4) Container berth

The container berth is of a diaphragm type with a length of 250 m and a depth of -9.75 m. Container cargoes are handled by crane and pick & carry.

Railways for handling container cargo are to be established behind this berth in the near future.

2.4.2 Cargo handling equipment

The port has various types of cargo handling equipment. This consists of 3 wharf cranes with capacities ranging from 3 to 10 tonnes, 4 mobile cranes with capacities from 5 to 22 tonnes, 2 crawler-mounted cranes with capacities from 18 to 30 tonnes and two forklift trucks with capacities of 3 tonnes. The iron ore berth has a shiploader with a loading capacity of 6,000 tonnes per hour.

The existing cargo handling equipment are shown in the following table:

Table-2.4.2 Cargo Handling Equipment

Sl. No.	Description of Equipment	Capacity	No. available
1.	"JESSOP" Electrical level luffing wharf cranes	3 Tons	3
2.	"JESSOP" Electrical level luffing wharf cranes	6 Tons	1
3.	"Braithwaite" Electrical level luffing wharf crane (can be converted into grab crane of 4 tons payload)	10 Tons	4
4.	"Coles" Mobile Crane	5 Tons	1
5.	"Coles" Mobile Crane	7.5 Tons	2
6.	"Coles" Mobile Crane	16 Tons	1
7.	"Coles" Hosky 680S Mobile Crane	26.35 M.T.@ 6M Radis (Pick & Carry)	1
8.	"Tata" P & H Crawler Crane	30 Tons	1
9.	"Tata" P & H Crawler Crane	18 Tons	1
10.	Godrej Low Mast Forklift Trucks	3 Tons	2
11.	Voltas 'Yale' Forklift Trucks	3 Tons	2
12.	Tractor Trailer unit for transportation of containers	-	1
13.	Dockside bagging & stitching equipments (for fertilizer/urea/NP/NPK)	3 Tons Per	3
NOTE:	These units are operated and maintained by M/s. Mangalore Chemicals & Fertilizers Limited		
14.	Mechanized iron ore loading equipment at Kudremukh Iron Ore Berth	6000 to 8000 Tons/Hr.	1
NOTE:	This equipment is operated and maintained by M/s. Kudremukh Iron Ore Company Limited		

2.4.3 Storage facilities

The port has 5 single storely transit sheds at various locations as described below.

One transit shed with an area of 5,574 sq.m. at Berth No.1 for fertilizers, with a storage capacity of 10,000 M.T.

Two transit sheds with areas of 2,190 sq.m. each, with a storage capacity of 4,000 M.T. each.

Two transit sheds with an area of 4,380 sq.m. each, with a storage capacity of 8,000 M.T. each.

The total covered area of transit sheds is 12,144 sq.m.

In addition, one more transit shed of 4,920 sq.m. is under construction at a location adjacent to Berth No.4.

Two warehouses with areas of 2,190 sq.m. each (60mx36.5m) are also available.

2.4.4 Harbor craft

The port's fleet of harbor craft comprises launches, barges, tugs, etc., as shown in Table.

Table-2.4.3 Specification of Marine Craft Owned by New Mangalore Port Trust

No.	TYPE & NAME OF SHIP	YEAR BUILT	OVERALL LENGTH (M)	MOULDED BREADTH (M)	MOULDED DEPTH (M)	LOADED DRAUGHT (M)	FREE SPEED (KNOTS)	OUTPUT OF ENGINE (HP)(RPM)	STATIC PULL (TONS)	YEAR OF REPLACEMENT
1	TUGBOAT	1975	30.30	8.50	4.40	2.50	12.0	2,000	30.0	1990
	DCI TUG IV							375		
2	TUGBOAT	1976	30.30	8.50	4.40	2.50	12.0	2,000	30.0	1991
	DCI TUG V							375		
3	TUGBOAT	1988	30.00	9.00	3.60	2.70	12.0	1,350	22.5	2018
	M.V. HEMAVATHI							900		
4	GRAB DREDGER		55.17	13.41	3.35	2.13	8.5	401		
	MANGALORE							1,800		
5	SURVEY LAUNCH	1967	15.24	4.27	1.83	1.23	12.0	2x 165		1997
	M.L. KULUR									
6	PILOT LAUNCH	1969	17.25	4.60	2.10	1.15	14.0	2x 156		1999
	P.L. SUMANGALA									
7	WOODEN MOORING LAUNCH	1976	9.14	2.76	1.22	0.75		49		1991
	M.L. NANDINI									
8	FRP MOORING LAUNCH	1984	9.70	2.97	1.82	0.99		108		2004
	M.L. PADMINI									
9	25 TON BUOY LAYING		18.28	6.09	1.82					
	TENDER									

DCI:DREDGING CORPORATION OF INDIA
NMPT:NEW MANGALORE PORT TRUST

NOTES;1. DCI TUG IV & V WERE TRANSFERED FROM DIC TO NMPT IN APR. 1988.
2. THE MOT DUMP BARGE BUILT IN 1967 WAS CONVERTED INTO THE SELF-PROPELLED GRAB DREDGER 'MANGALORE' IN 1984.
3. THIS DREDGER IS EQUIPPED WITH A GRAB BUCKET OF 1.91 M3 AND a HOPPER OF 750 TONS CAPACITY.
4. MAXIMUM DREDGING DEPTH IS 15 METERS.

2.4.5 Channel and basin

The approach channel and the turning basin are shown in Fig. This drawing also shows the location of the northern and southern breakwaters.

Approach channel

Length	:5430 m
Width	: 245 m
Depth of water below chart datum	: 13.5m
Permissible draught	: 12.5m

Turning basin

Diameter	: 490 m
Depth of water below chart datum	: 13.0m
Permissible draught	: 12.5m

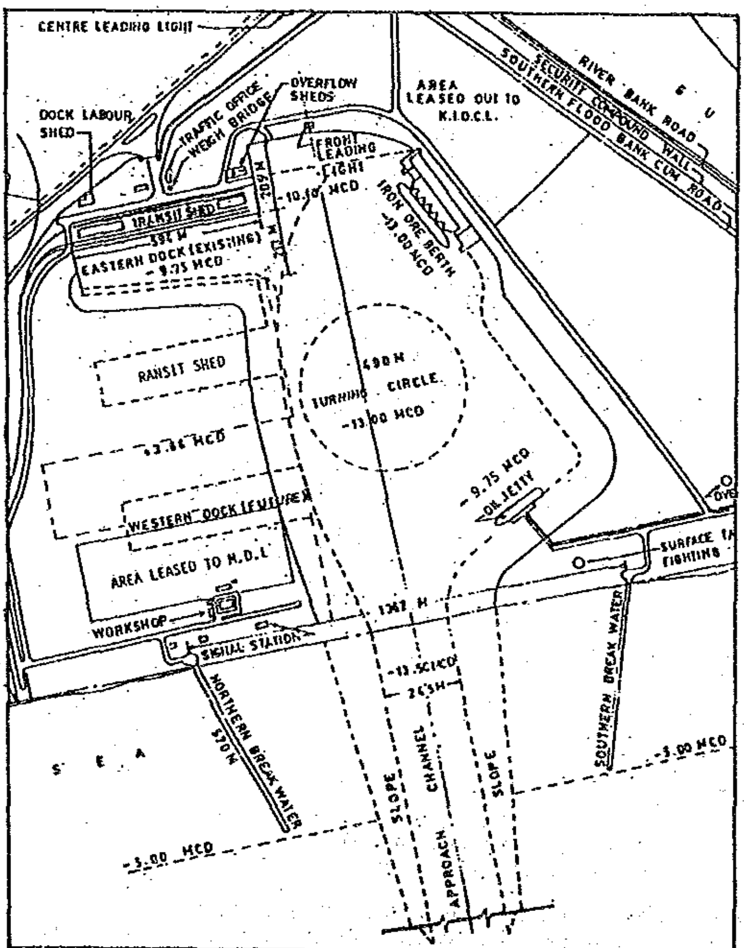


Figure-2.4.1 The Channel and the Basin

2.4.6 Breakwater

Breakwaters are located around the month of the port with a length of 570m each, to the depth of -5m.

However the tranquilility of the channel and the basin is not ensured against waves in monsoon season because the breakwaters aren't long enough.

The breakwaters are of the rubble-mound type with side berms.

A sectional diagram of the breakwaters is provided below:

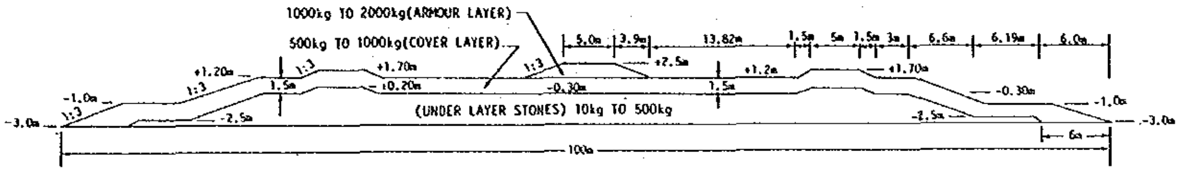


Figure-2.4.2 Section of the Breakwater at -3.0m C.D

2.5 Structures of the Port Facilities

2.5.1 Mooring facilities

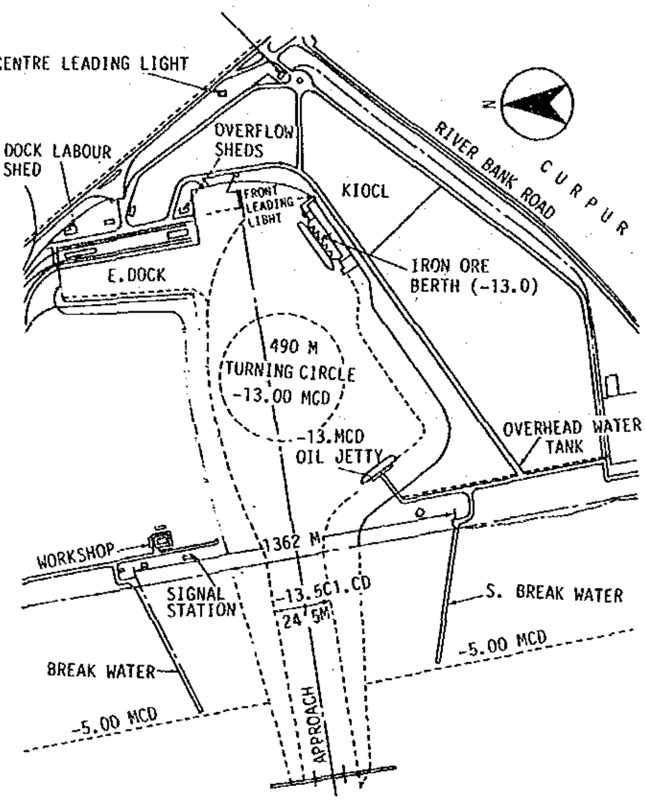


Figure-2.5.1 Plan of Existing Basin

1) Iron Ore Berth

a) Location and General Description of the Iron Ore Berth

Figure-2.5.1 shows the location of mooring facilities at the iron ore berth and the oil jetty.

The iron ore berth, with its associated handling system, was designed to enable 60,000 DWT ships to load iron ore concentrate. Provision for the accommodation of larger ships is not sufficient without major modifications. The handling system is also inadequate for pellets and sponge iron.

The present specifications of the iron ore berth, including the layout and size of piles, are shown in Figures-2.5.2 (a) and (b).

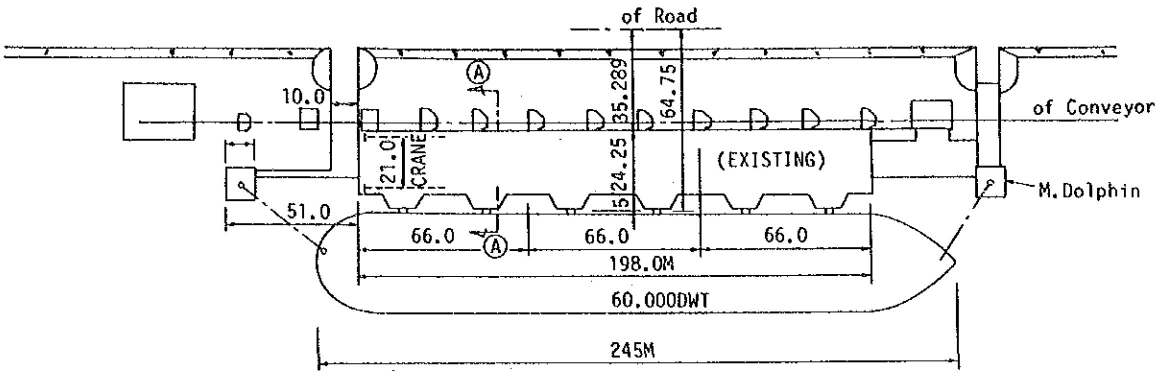


Figure-2.5.2(a) Layout of Existing Iron Ore Berth

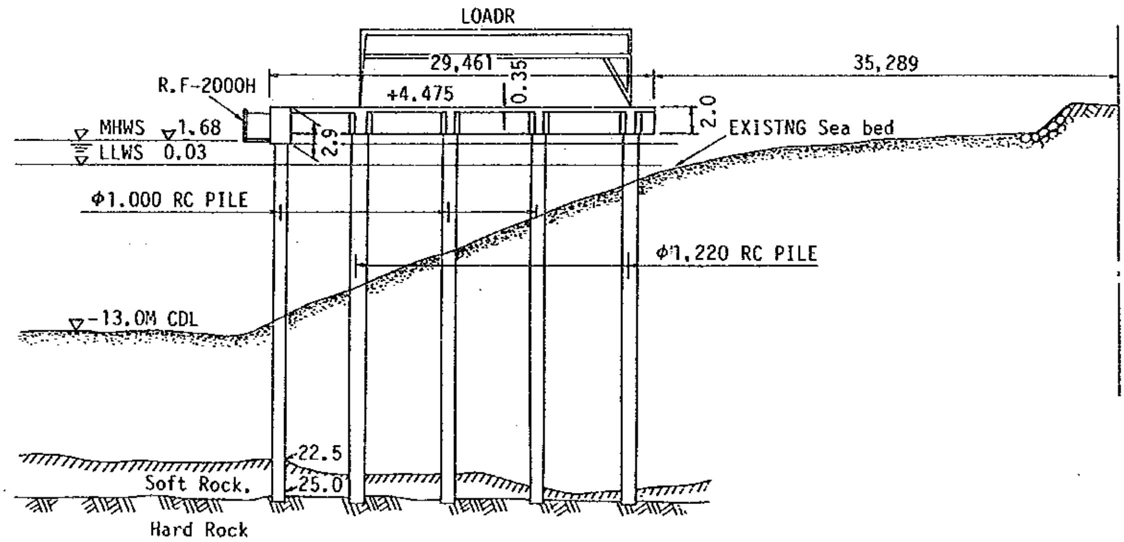


Figure-2.5.2(b) Standard Section of the Berth

b) General Features of the Berth

- No. of berth	: 1 no. for iron ore concentrate/pellet/ sponge iron
- Orientation	: South-east of the basin
- Type	: Open type structure with breasting and mooring dolphins founded on vertical cast-in-situ RCC piles.
- Length	: Ore berth - 198 m Mooring dolphin to mooring dolphin - 228 m
- Maximum LOA of ships permissible	: 245 m
- Depth of water below chart datum	: 13.0 m
- Permissible draught	: 12.5 m
- Height of deck above chart datum	: 4.475 m
- Fenders	: H-Type Seibu Heavy Duty Dock Fenders, size 1700 H x 1460 L - 6 units.
- Mooring facility	: six units. 100 T pull on breasting dolphins, & 2 units. 200 T pull on mooring dolphins (total : 8 units.)
- Height of mooring dolphin from chart datum	: 4.475 m
- Maximum size of ship the berth can handle	: 60,000 DWT

Berth Structure

As already explained, the iron ore berth consists of :

- open type main ore berth,
- two (2) mooring dolphins,
- one platform on the western side of the berth,
- two (2) approach bridges connecting land to berth (one on each side), and
- one (1) catwalk connecting mooring dolphin and approach on the eastern side.

c) Present Condition of the Berth

Results of sounding survey

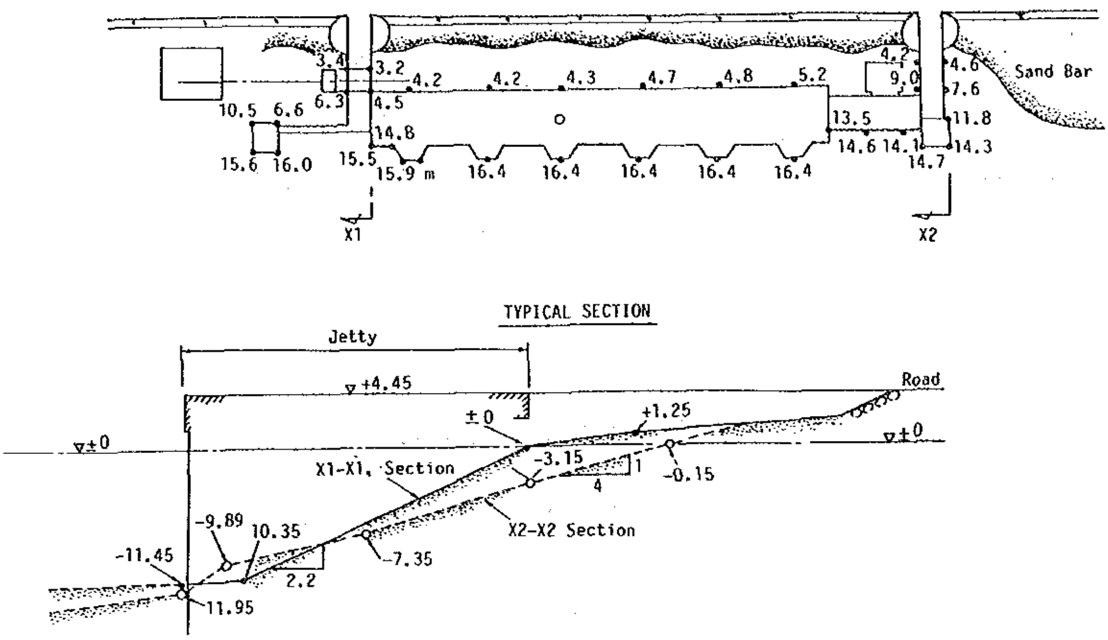


Figure-2.5.3 Sounding Survey at the Irom Ore Berth

Sounding survey for the iron ore berth was executed in September 1989 and the results are shown in Figure-2.5.3.

The numbers mentioned in the plan show the depth from the deck Level of +4.45m C.D.L.

As shown in the cross section, the slope of the sea bed seems to be steep compared with the original design slope.

This fact shall be taken into consideration when structural analysis is made.

Damages to the Berth

A visual survey was executed on the damage to the structures which had been constructed in 1980.

The survey revealed that no serious damage such as cracks in the concrete members or partial sinking of beams and slabs was observed. Partial damage was found, however, on some slabs added as working decks between convex spots for the purpose rubber fender installation purpose. But the damage occurred in secondary members of the structure, therefore they will not be crucial from the stability point of view.

Some rubber fenders are also damaged, so they should be replaced with new ones.

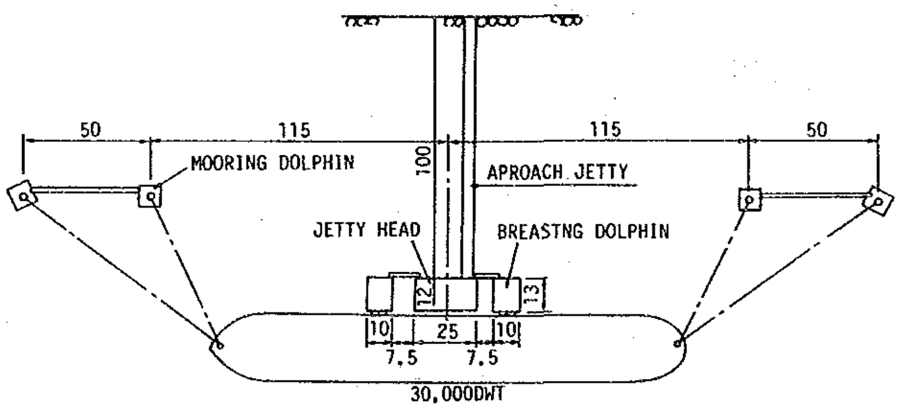
2) Oil Jetty

a) Location and General description of Oil Berth

The existing oil berth is shown in Figure-2.5.1.

The present jetty is capable of receiving 35,000 DWT vessels. The details of the existing oil berth with the layout and typical section are shown in Figure-2.5.4.

[PLAN OF EXISTING OIL BERTH]



[TYPICAL SECTION OF THE BERTH]

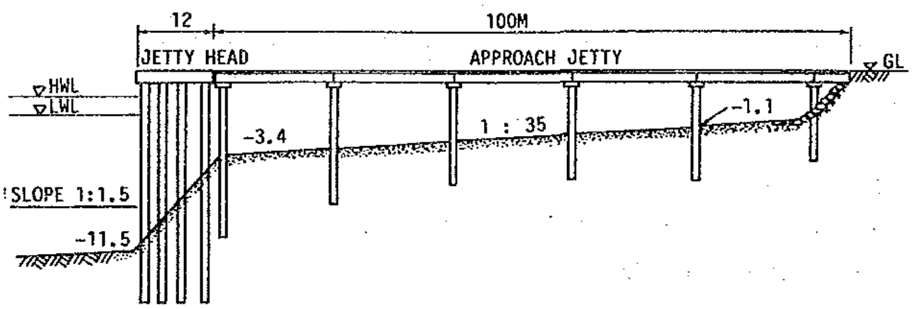


Figure-2.5.4 Existing Oil Berth

Berthing dolphins are constructed on ϕ 1,200 vertical cast-in-situ RCC piles with a 2.0 meters thick concrete slab. Mooring dolphins are founded on ϕ 800 and ϕ 600 RCC rake piles with a 1.0 meter thick concrete slab, and the jetty head consists of ϕ 750 vertical RCC piles with a 0.7 meter thick concrete slab.

b) General Features of the Oil Berth

- No. of berth	: One unit for crude oil		
- Orientation	: South-west of the basin		
- Type	: Jetty type structure with breasting and mooring dolphins, founded on vertical and rake cast-in-situ RCC piles		
- Length	: Jetty head - 25.0 m x 10.0 m		
	Between two Breasting dolphins	- 50.0 m	
	Between two Mooring dolphins	- 330.0 m	
- Maximum LOA of ships permissible	: 200 m		
- Depth of water below chart datum	: 10.4 m		
- Permissible draught	: 9.75 m		
- Height of deck above chart datum	: 3.66 m		
- Fenders	: Temporary Fenders		
- No. of structures	: Breasting dolphin	2 - units	
	Mooring dolphin	4 - units	
	Jetty head	1 - units	
	App. Jetty	1 - units	
	Catway	4 - units	
- No. of piles	: Breasting dolphin	16 units	ϕ1,200(Vertical)
	Mooring dolphin	10 units	ϕ 800(Rake)
		6 units	ϕ 650(Rake)
	Jetty head	18 units	ϕ 750(Vertical)

C) Present Condition of Oil Jetty

Results of sounding survey

[Sounding Survey of Oil Jetty]

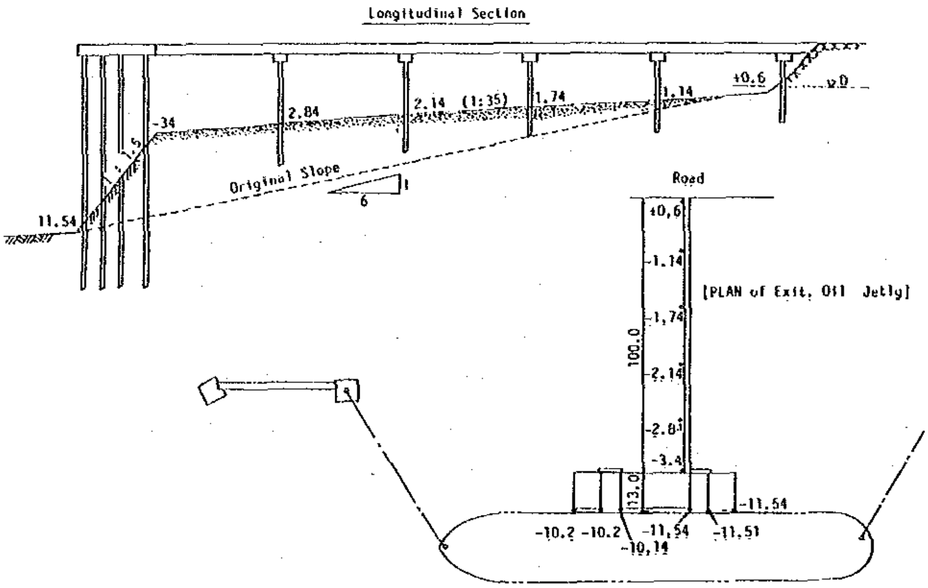


Figure-2.5.5 Sounding Survey at the Oil Berth

Sounding survey for the Oil Jetty was carried out in September 1989, and the results are shown in Figure-2.5.5.

The water depth at the face line of the Jetty was -10.2m - -11.5m.

In front of the southern breasting dolphin, the depth was shallower than that of the northern breasting dolphin by 1.5m.

The sea bed slope from the face line of the berth to back site of the jetty head is very steep compared with the slope originally planned. Therefore this fact should be taken into consideration when the facilities will be designed.

Damages to the structures

The structures which were constructed in 1975 heve become partially superannuated and some repair works are being executed at present.

Damage of some piles of breasting dolphins was observed visually, therefore more careful repair work for the existing structures shall be planned and carried out when the whole improvement plan is formulated.

2.5.2 Handling equipment

New Mangalore Port has various handling equipment, all of which except the equipment on the iron ore berth are light and simple. Here, only the equipment on the iron ore shiploading system are presented here.

Using this system, both ground/concentrated ore (concentrate) and pelletized ore (pellets) are handled and loaded onto ships. The system is depicted in Figure-2.5.6.

Concentrate is reclaimed from the concentrate stockyard by reclaimers RK01 or RK02, loaded on belt conveyers CB85 or CB86, transported through conveyers CB89 and CB92, and loaded onto ships by the shiploader on the berth.

Pellets are reclaimed from the pellet stockyard by the reclaimer for pellets, loaded on belt conveyer CB434, transported through conveyers CB89 and CB92 and loaded onto ships by the shiploader.

The shiploader is of the boom shuttling and derricking type, as shown in Figure-2.5.7. The nominal shiploading capacity is 6000t/h for concentrate and the chute max. radius is 32m from the seaside rail, so it can load onto 60,000 DWT class ships.

The nominal handling capacity of the existing equipment and stockyard capacity are shown in Table-2.5.1 below.

Table-2.5.1 Nominal Handling Capacity of Existing Equipment

Equipment	Capacity t/h	Concentrate	Pellet
Shiploader	Boom conveyor	6,800	3,500
Conveyor	Wharf CB92	6,800	3,500
	Cross CB89	6,800	3,500
	Outgoing CB85,86	3,000 x 2	
	Outgoing CB434		6,600
Reclaimer	RK01,02	3,500 x 2	
	RK		5,000
Stockyard	Capacity t	200,000 x 2t	150,000 t

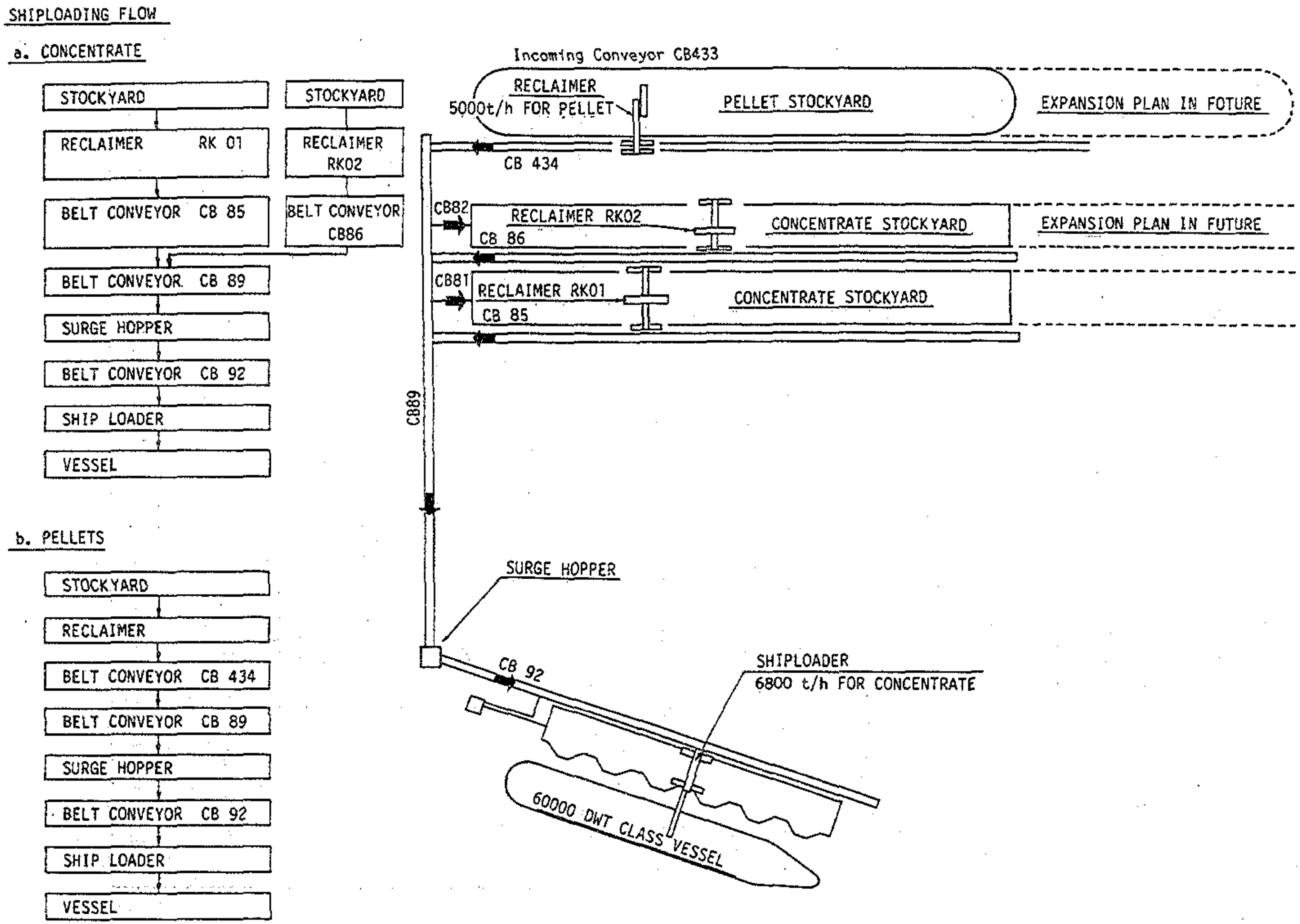


Figure-2.5.6 Layout of Ore Shiploading System (Existing)

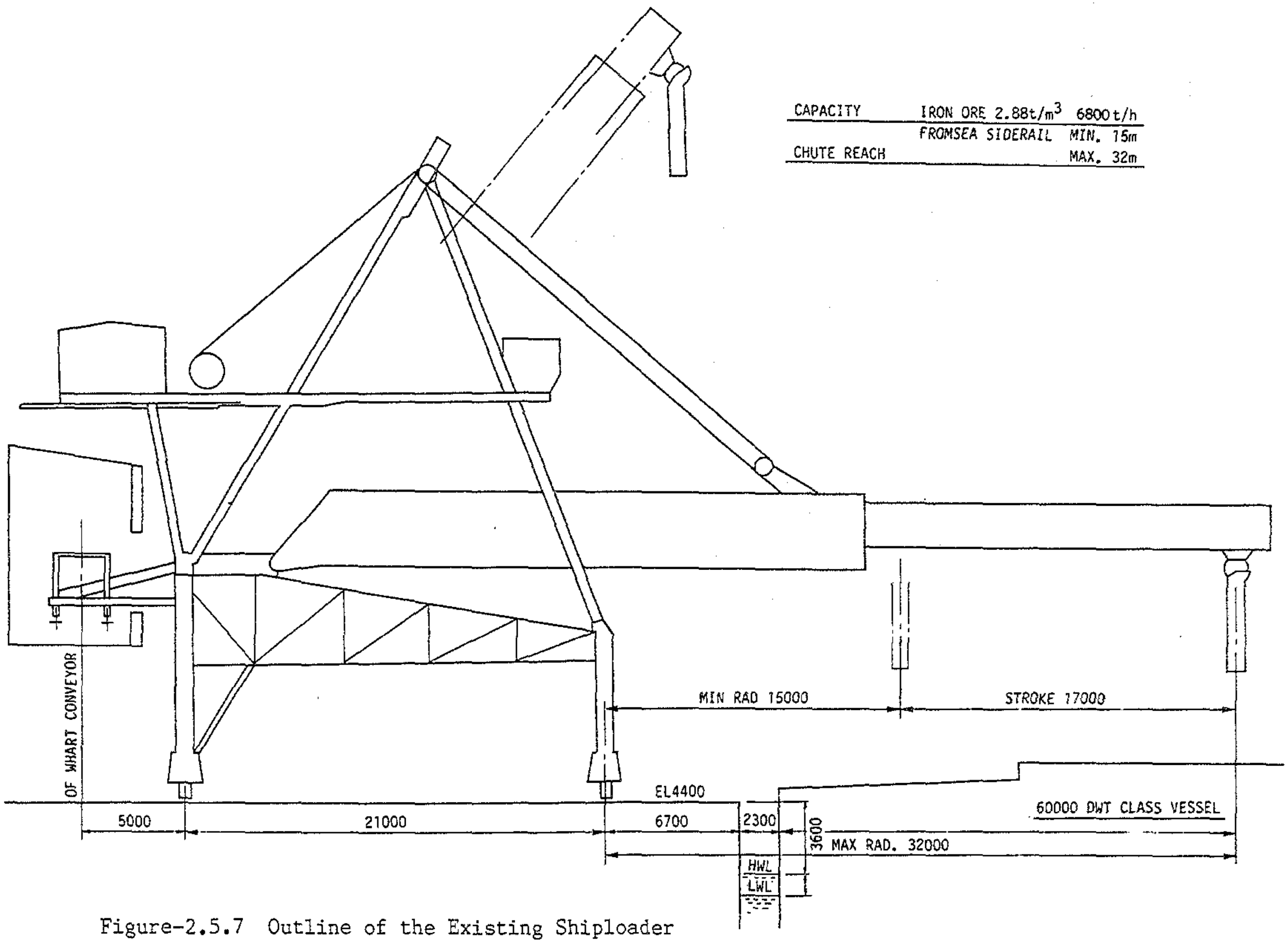


Figure-2.5.7 Outline of the Existing Shiploader

2.5.3 Breakwater

a) General

At first, two breakwaters on either side of the entrance channel, each 360 meters long extending down to the - 3.60m contour, were constructed in 1975 as shown in Figure-2.5.8.

Originally it was planned to provide breakwaters on either side of the entrance channel extending down to the -6.0m contour; however, 3 - dimensional comprehensive wave model studies indicated that, in view of the long approach channel and the flat side slopes, considerable wave energy reduction was experienced, as one proceeded along the channel towards the basin. Therefore, from the point of view of tranquillity the breakwaters would play only a minor role.

However, for preventing the direct entry of littoral material in the entrance channel or the basin, provision of short lengths of breakwaters would be advantageous.

Accordingly, the breakwaters were constructed on either side of the channel down to the - 3.60m contour, over which portion the major littoral drift takes trafic place. Afterwards, both general cargo and iron ore was expected to increase. Providing facilities and dredging the entrance channel were required for large ore carriers using the port.

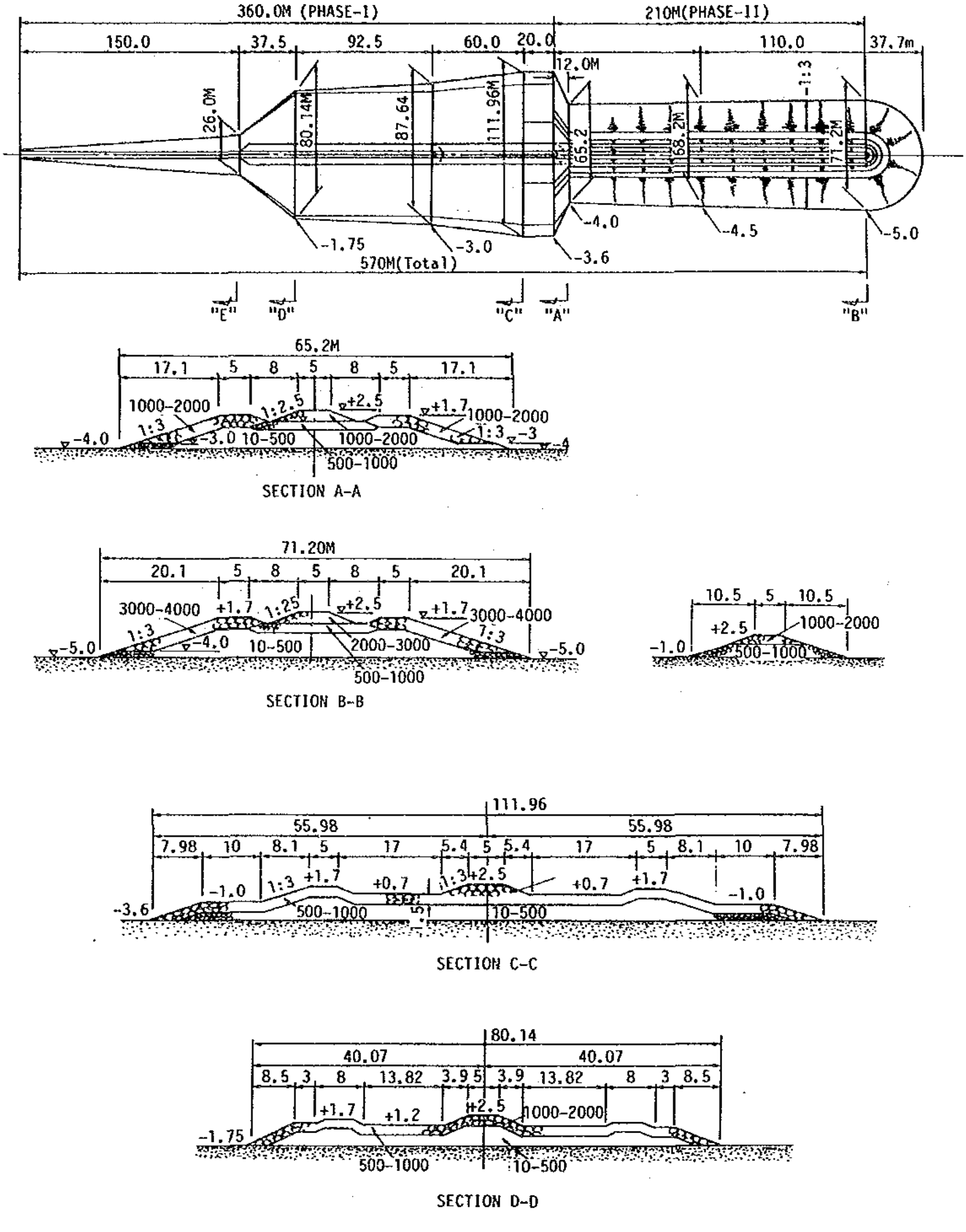


Figure-2.5.8 Section of Breakwaters

Further more, it was also proposed by the Port Authorities to extend the breakwaters down to the -5.0m contour (length becomes 570 meters as shown in Figure-2.5.1) in order to provide adequate stopping distance along this channel upto the turning circle in the basin. The construction of the breakwater was carried out in 1980.

The layout of the breakwater and typical sections are shown in Figure-2.5.1 and 2.5.8.

b) General Features of the Breakwater

- No. of Breakwater : Two units for south and north breakwater
- Type : Rubber mound breakwater
- Length : 570m (upto -5.0m contour)
- Depth of water : 0 - -5.0m C.D.L
- Height of crest : +2.5 m (+1.7m at berm)
- Armor stone size : 3 - 4t for the section -4 to -5.0m
  1 - 2t for the section upto -4m
  3 - 4t for the tip roundhead

2.6 Natural Condition

2.6.1 Topography condition

New Mangalore Port is situated at 12°55'6.2" latitude south and 74°66'17.6" East in the Karnataka state on the West coast mid-way between Mormugao and Cochin in India.

The port is located on the alluvial plain and about 10 km south of the mouth of the Gurpur and the Netravati rivers.

The hinterland of New Mangalore port consists of flat land and rolling, hilly areas.

The flat land is mainly utilized as paddy fields and Mangalore city is located in the rolling area.

Figure-2.6.1 shows the location of New Mangalore Port.

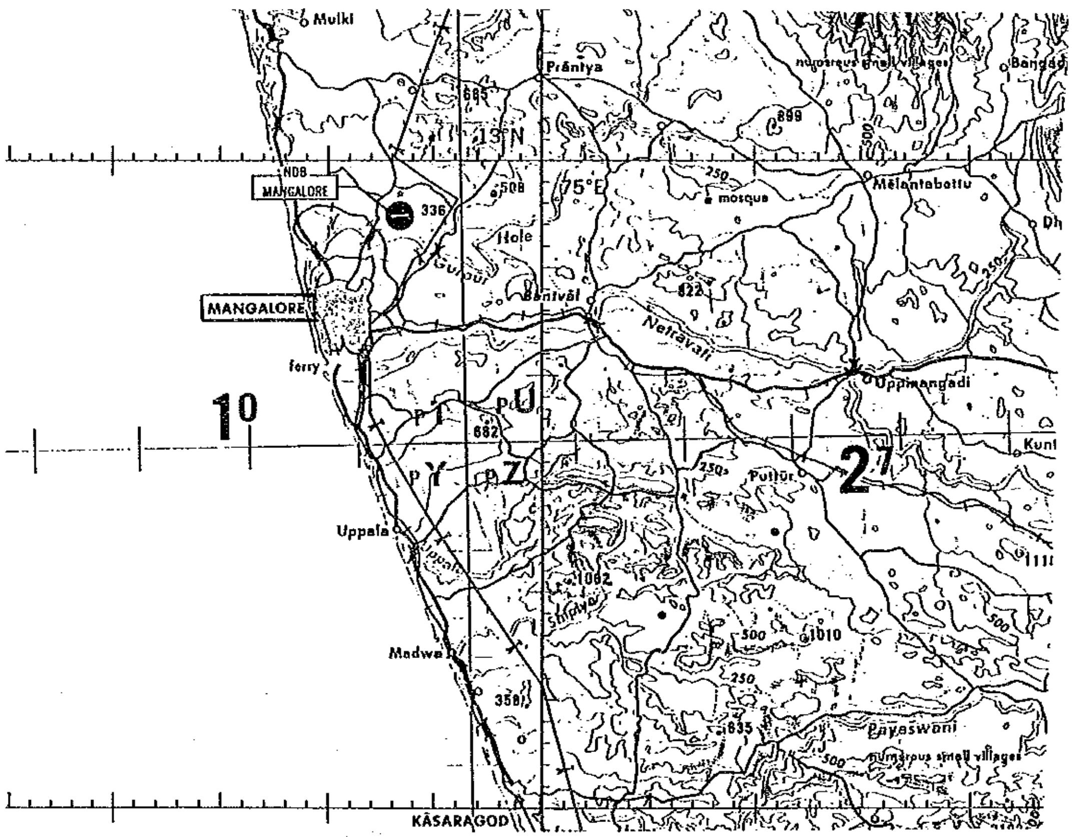


Figure-2.6.1 Location of New Mangalore Port

2.6.2 Meteorology

(1) General

The climate of Mangalore has a regular variation on account of the alternating SW and NE monsoon. The main season with their principal characteristics are given below:

- The cool season (December to March), when winds are NE and the weather is dry with little cold except in the Southern area.

- The hot season (April and May), winds are light and variable with sea breezes on the land. Tropical cyclonic storms (cyclones) may cross the Arabian Sea in this season.

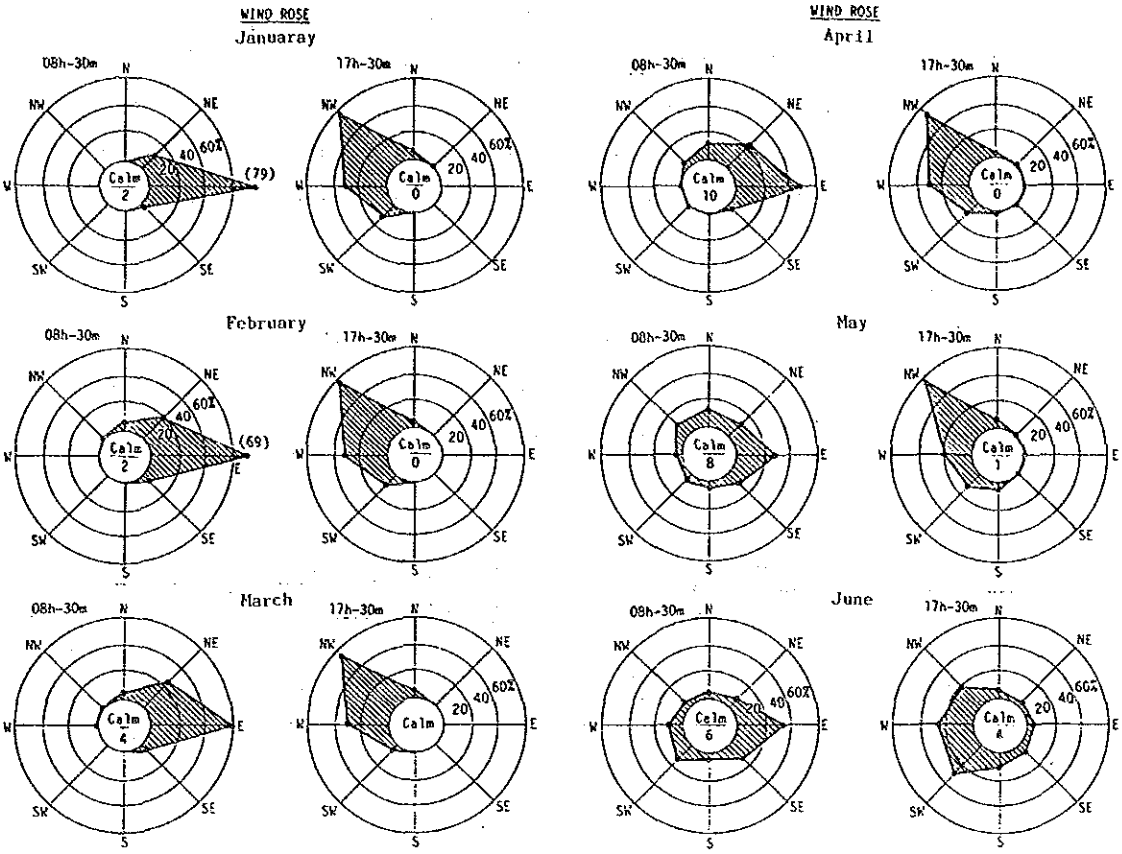
- The SW monsoon or rainy season(June to September). The wind over the sea is between SW and W, but mainly W to NW along the coast.

- The interim period (October and November) is marked by light winds the with land and sea breezes. Occasional tropical cyclones occur in the Arabian Sea in this period. In much of the Mangalore area, most rainfall occurs during the SW monsoon. While the average frequency of cyclonic storms in the Arabian Sea is about one per year, there have been years in which two or three have occurred, and also periods of one or two years without one, based on the Meteorological records of the past 30 years.

(2) Wind

The winds in the monsoon months of June, July and August are predominantly from SW and W with a maximum intensity of from 20 to 61 Km.p.h. The winds in the remaining months of the year are predominantly from NW and the maximum intensity during this period is also 20 to 61 Km.p.h.

Consolidated wind diagrams are shown in Figure-2.6.2. Land and sea breezes are experienced at most times of the year except during the SW monsoon. The land breeze is well developed during the NE monsoon, especially from November to February, and may persist by day where



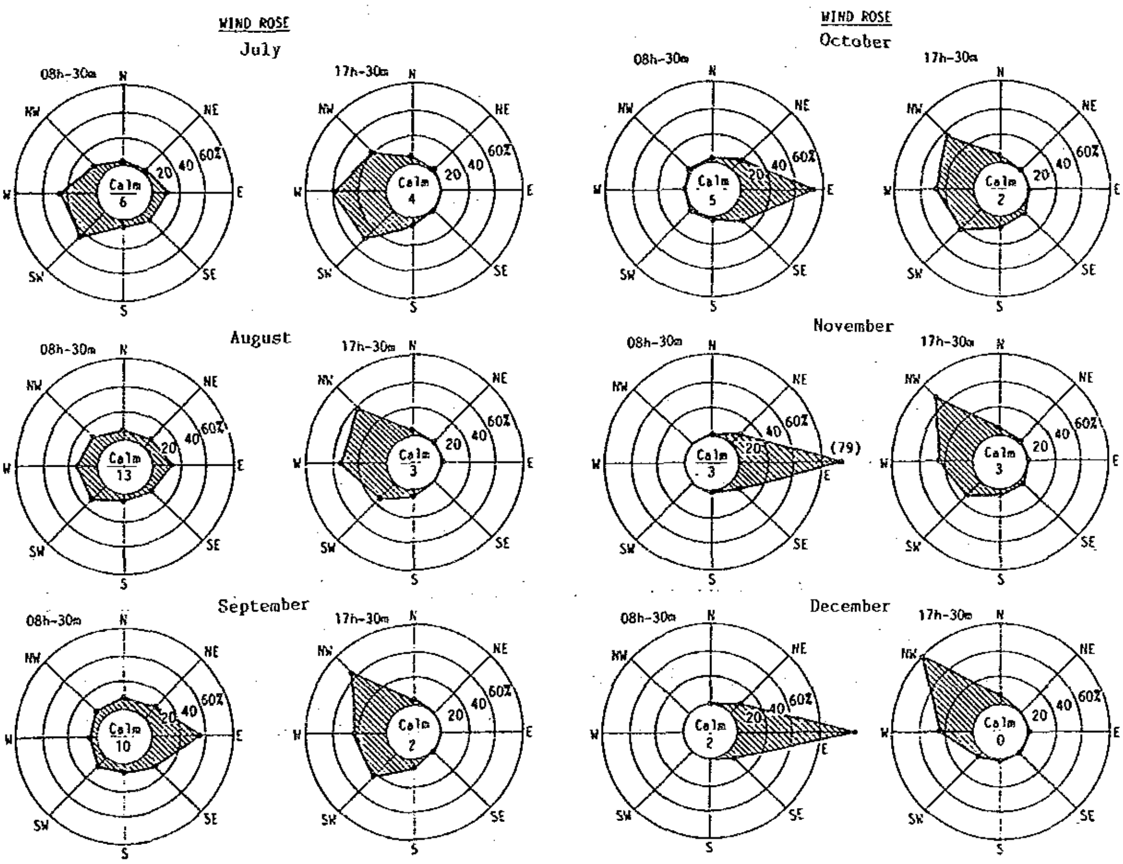


Figure-2.6.2 Wind diagrams

funneling occurs through gaps in the mountains.

The land breezes decrease in strength and duration from April when sea breeze develop during afternoons. In September, the weather moderates, and towards the end of the month, or in October, strong E or S squalls, sometimes called "Elephants", and thunder-storms indicate the approaching end of the monsoon.

Figure-2.6.3 gives the No. of days with wind speed (Km.p.h.).

There is little seasonal variation of wind speed, and are mainly light, Around Mangalore, 92% of all winds have speeds less than 19km p.h., and the average wind speed is 8.4 Km p.h.

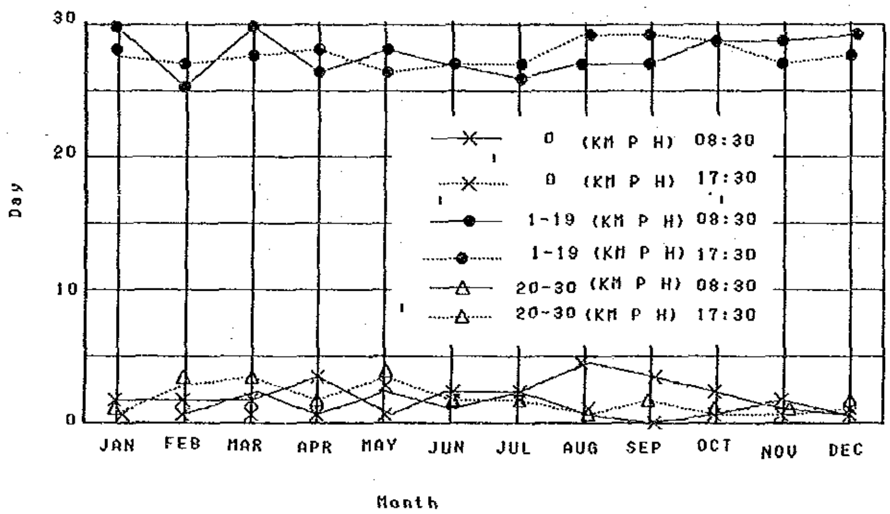


Figure-2.6.3 No of days wind speed

(3) Rainfall

The average annual rainfall is approximately 3467.0mm. The rainfall is concentrated in the SW monsoon months of June, July, August and September during which period the average rainfall is as much as 84% of the total annual rainfall as shown in Figure-2.6.4.

The maximum rainfall is in July(1102.7mm), and decrease gradually to 1.9mm in February.

The Maximum falls recorded over 24 hour periods was 27 cm from June to September. The average total number of rainy days in the year is 122.7.

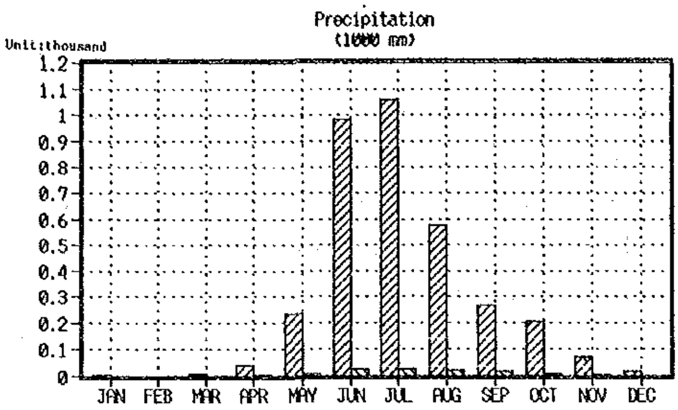


Figure-2.6.4 Annual rainfall

(4) Temperature

Air temperature is high throughout the year as shown in Figure-2.6.5. This Figure shows that the mean temperature in the hottest month, which generally occurs just before the onset of the SW monsoon, is from 33°C to 34°C.

temperature ever recorded in a year was 37°C and lowest temperature 16.7°C.

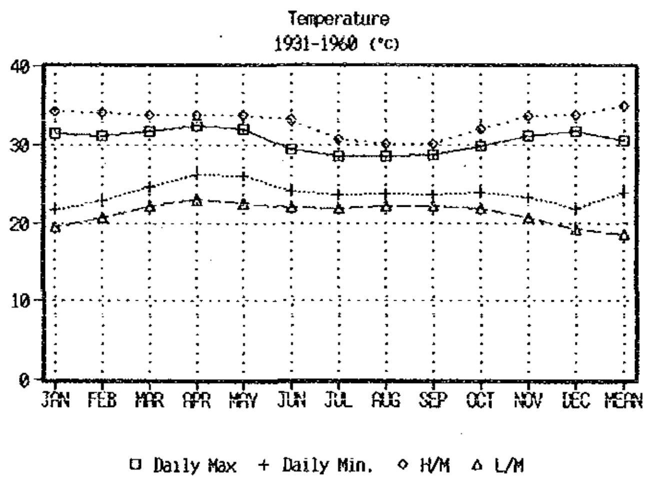


Figure-2.6.5 Annual temperature

(5) Humidity

Humidity is fairly high at all times and seasons. There is a large range from the damp conditions in early mornings in the wet season to the drier conditions in the afternoon in the dry season. Daily variation is least during the SW monsoon as shown in figure 2.7.6. The maximum relative humidity observed during monsoon period is 92% (August). The minimum relative humidity during non-monsoon period is 60% (December and January).

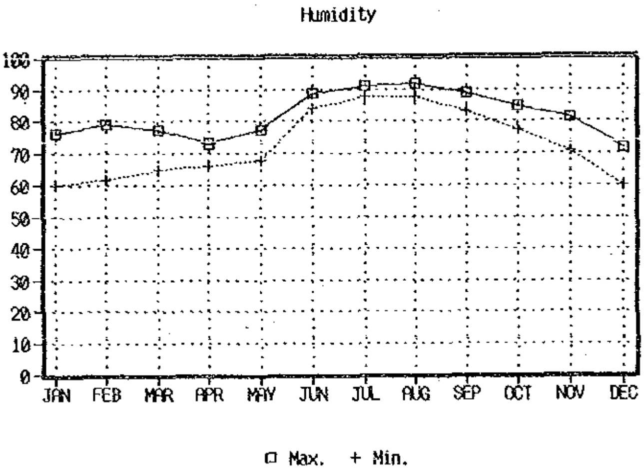


Figure-2.6.6 Humidity

(6) Visibility

Mist sometimes develops on the coast after a calm and clear night but soon disperses after sunrise. In Mangalore, during the SW monsoon (from June to September), thick haze develops. However, the maximum number of foggy days in a year is only 3. The number of days and degree of visibility observed are shown in Figure-2.6.7.

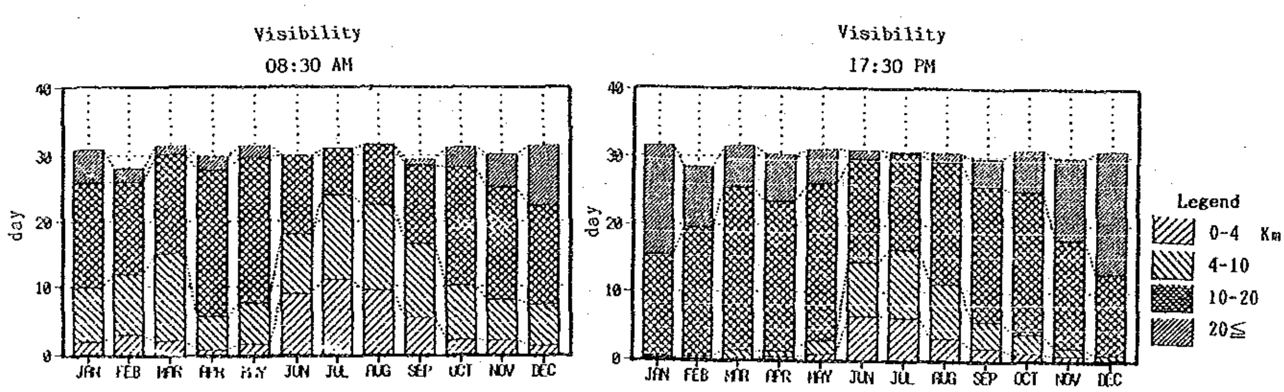


Figure-2.6.7 Visibility

(7) Cyclone

While the average frequency of cyclonic storms in the Arabian Sea is about one per year, there have been years in which two or three have occured, and also periods of one or two years without one.

The maximum wind speed so far recorded has not exceeded 62km.p.h.(16.9m/s), except once during a storm in 1965 when the maximum speed recorded was 97 km.p.h.(26.9m/s).

2.6.3 Oceanography

(1) Wave

The predominant direction of waves at New Mangalore Port Vicinity during monsoon months of June, July and August is West and South West whereas the predominant direction during the fair months is North-West and North. High waves are experienced only during the monsoon month of June to September.

Wave data was collected by the CWPRS with the help of waverider Buoys during the years 1974 and 1975. The positions of the Waverider Bouys installed in 1974 and 1975 are shown as "Position A" and "Position B" respectively in Figure-2.6.8.

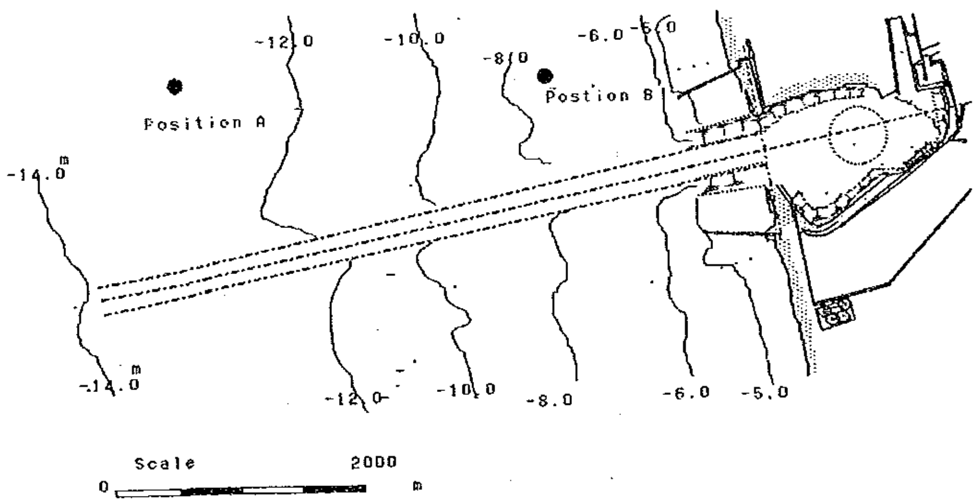


Figure-2.6.8 Location of the Wave Observation Points

1) Wave Data Collection:

Wave data collection at "Position A" in 1974

a) Period of collection 3-7-1974 to 28-8-1974

b) Latitude of position A 12°-55'-43.8"N

c) Longitude of Position A 74°-46'-0.18"E

d) Location of Buoy

1,250m North of approach channel and about 4.2km in line with North Breakwater.

e) Depth of water at the Buoy 12m

f) No. of observations recorded 445

Wave data collected at "Position B" in 1975

a) Period of collection 8-7-1975 to 6-11-1975

b) Latitude of position B 12°-55'-59"N

c) Longitude of Position B74°-47'-30"E

d) Location of Buoy 1.200m North of approach channel

e) Depth of water at the Buoy 7.5m

f) No. of observation recorded 905

2) Wave data for 1974 and 1975.

The following information indicates the range of variation of significant wave heights and period:

Month	Range of Wave hights Hs (m)	Range of Wave periods Ts (sec)	Hmax (m)	Corres.-period (sec)
July(1974)	1.07-3.21	6.5-13.2	5.0	12
Aug.(1974)	1.04-2.74	6.3-10.8	5.2	9
			5.2	11
July(1975)	0.86-1.96	6.3-11.9	3.2	10
Aug.(1975)	0.92-3.33	6.3-13.4	5.5	11
Sept.(1975)	0.34-1.19	4.6-11.0	3.1	9
Oct.(1975)	0.34-1.19	4.6-11.0	2.3	8
Nov.(1975)	0.40-1.06	5.6-8.2	1.8	7

The analysis of 15 minute records of 1974 from 3/7/74 to 28/8/74 indicated that the maximum significant wave height was 3.21m and the largest single wave in that wave train was 4.7m. However, in another wave train, the largest single wave height was 5.2m, in which the corresponding significant wave height was 2.55m.

The analysis of the 15 minute record 8/7/75 to 6/11/75 indicated that the maximum significant wave height was 3.33m and the largest single wave height in that wave train was 5.5m.

3) Frequency distribution for wave data in 1974 and 1975.

Table-2.6.1 shows the frequency distribution of the waves in the of July 1974, and all of them had significant wave heights less than 3.5m and corresponding significant period between 6 to 12 sec. By Table-2.6.2, it can be seen that for the month of August 1974, 100 % of the waves had significant wave heights less than 3.0m and corresponding significant period between 6 to 11 sec.

For the month of July 1975, it can be noted that 100% of the waves had significant wave heights less than 2.0m and corresponding significant periods between 6 to 12 sec. (cf. Table-2.6.3).

For the month of August 1975, 100% of the waves had significant wave heights less than 3.5m and corresponding significant period between 6 to 12 sec (cf. Table-2.6.4).

For the month of September 1975, 100% of the waves had significant wave heights less than 2.5m and corresponding significant period between 6 to 11 sec (cf. Table-2.6.5).

For the month of October 1975, 100% of the waves had significant wave heights less than 1.5m and the corresponding period between 4 to 11 sec (cf. Table-2.6.6).

For the month of November 1975, 100% of the waves had significant wave heights less than 1.5m and the corresponding significant period between 5 to 9 sec.

The yearly maximum significant wave heights observed during the recording time in 1974 and 1975 were 3.21m and 3.33m respectively.

In the date of 1974, the recording time duration of the waves, exceeding 3.0m in height is only 9.35 hours (cf. Table-2.6.7).

In the data of 1975, the recording duration time of the waves exceeding 3.0m in height is only 12 hours (cf. Table-2.6.8).

Table-2.6.1 Frequency Distribution of Wave
(July, 1974) No. of three hourly observations - 222

H1/3 / T	0.00 - 0.49 (m)	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	2.50 - 2.99	3.00 - 3.49	3.50 3.99	Total
(sec) 3.0 - 3.9	-	-	-	-	-	-	-	-	-
4.0 - 4.9	-	-	-	-	-	-	-	-	-
5.0 - 5.9	-	-	-	-	-	-	-	-	-
6.0 - 6.9	-	-	-	0.45	1.35	-	-	-	1.80
7.0 - 7.9	-	-	0.45	3.60	3.15	-	0.45	-	7.65
8.0 - 8.9	-	-	0.90	15.77	9.01	1.35	0.90	-	27.93
9.0 - 9.9	-	-	1.35	24.33	18.02	4.06	-	-	47.76
10.0 - 10.9	-	-	-	3.60	9.46	0.45	-	-	13.51
11.0 - 11.9	-	-	-	-	0.90	-	-	-	0.90
12.0 - 12.9	-	-	-	-	-	-	-	-	-
13.0 - 13.9	-	-	-	-	0.45	-	-	-	0.45
Total	-	-	2.70	47.75	42.34	5.86	1.35	-	100.00

Table-2.6.2 Frequency Distribution of Wave
(August, 1974) No. of three hourly observations - 223

H1/3 / T	0.00 - 0.49 (m)	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	2.50 - 2.99	3.00 - 3.49	3.50 3.99	Total
(sec) 3.0 - 3.9	-	-	-	-	-	-	-	-	-
4.0 - 4.9	-	-	-	-	-	-	-	-	-
5.0 - 5.9	-	-	-	-	-	-	-	-	-
6.0 - 6.9	-	-	3.59	-	-	-	-	-	3.59
7.0 - 7.9	-	-	6.28	4.04	1.79	-	-	-	12.11
8.0 - 8.9	-	-	8.97	11.66	9.42	1.35	-	-	31.40
9.0 - 9.9	-	-	8.07	13.00	18.83	1.79	-	-	41.69
10.0 - 10.9	-	-	1.79	5.38	3.59	0.45	-	-	11.21
11.0 - 11.9	-	-	-	-	-	-	-	-	0.90
12.0 - 12.9	-	-	-	-	-	-	-	-	-
13.0 - 13.9	-	-	28.70	34.08	33.63	3.59	-	-	100.00
Total	-	-	-	-	-	-	-	-	-

Table-2.6.3 Frequency Distribution of Wave
(July, 1975) No. of three hourly observations - 153

H1/3 / T	0.00 - 0.49 (m)	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	2.50 - 2.99	3.00 - 3.49	3.50 3.99	Total
(sec) 3.0 - 3.9	-	-	-	-	-	-	-	-	-
4.0 - 4.9	-	-	-	-	-	-	-	-	-
5.0 - 5.9	-	-	-	-	-	-	-	-	-
6.0 - 6.9	-	-	0.65	1.31	-	-	-	-	1.96
7.0 - 7.9	-	-	1.96	1.96	-	-	-	-	3.92
8.0 - 8.9	-	-	13.07	4.58	-	-	-	-	17.65
9.0 - 9.9	-	7.84	25.49	21.57	-	-	-	-	54.90
10.0 - 10.9	-	1.31	7.19	6.53	-	-	-	-	15.03
11.0 - 11.9	-	1.31	5.23	-	-	-	-	-	6.54
12.0 - 12.9	-	-	-	-	-	-	-	-	-
13.0 - 13.9	-	-	-	-	-	-	-	-	-
Total	-	10.46	53.59	39.95	-	-	-	-	100.00

Table-2.6.4 Frequency Distribution of Wave
(August, 1975) No. of three hourly observations - 245

H1/3 / T	0.00 - 0.49 (m)	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	2.50 - 2.99	3.00 - 3.49	3.50 3.99	Total
(sec) 3.0 - 3.9	-	-	-	-	-	-	-	-	-
4.0 - 4.9	-	-	-	-	-	-	-	-	-
5.0 - 5.9	-	-	-	-	-	-	-	-	-
6.0 - 6.9	-	-	0.82	-	-	-	-	-	0.82
7.0 - 7.9	-	-	4.90	2.86	-	-	-	-	7.76
8.0 - 8.9	-	0.82	13.06	8.16	4.49	0.41	-	-	26.94
9.0 - 9.9	-	-	15.10	14.28	12.24	4.90	-	-	46.52
10.0 - 10.9	-	0.41	0.82	3.67	7.34	2.86	1.22	-	16.32
11.0 - 11.9	-	-	-	0.41	0.82	-	-	-	1.23
12.0 - 12.9	-	-	-	-	-	-	-	-	-
13.0 - 13.9	-	-	-	-	-	1.41	-	-	0.41
Total	-	1.23	34.70	29.38	24.89	8.58	1.22	-	100.00

Table-2.6.5 Frequency Distribution of Wave
(September 1974) No. of three hourly observations - 230

H1/3 (m) / T (sec)	0.00 - 0.49	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	2.50 - 2.99	3.00 - 3.49	3.50 3.99	Total
3.0 - 3.9	-	-	-	-	-	-	-	-	-
4.0 - 4.9	-	-	-	-	-	-	-	-	-
5.0 - 5.9	-	-	-	-	-	-	-	-	-
6.0 - 6.9	-	1.30	2.61	-	-	-	-	-	3.91
7.0 - 7.9	-	8.70	13.48	0.43	-	-	-	-	22.61
8.0 - 8.9	-	20.87	14.35	1.30	-	-	-	-	36.52
9.0 - 9.9	-	10.87	17.83	2.61	0.43	-	-	-	31.74
10.0 - 10.9	-	1.74	3.05	-	-	-	-	-	4.97
11.0 - 11.9	-	0.43	-	-	-	-	-	-	0.43
12.0 - 12.9	-	-	-	-	-	-	-	-	-
13.0 - 13.9	-	-	-	-	-	-	-	-	-
Total	-	43.92	51.31	4.34	0.43	-	-	-	100.00

Table-2.6.6 Frequency Distribution of Wave
(October 1975) No. of three hourly observations - 223

H1/3 (m) / T (sec)	0.00 - 0.49	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	2.50 - 2.99	3.00 - 3.49	3.50 3.99	Total
3.0 - 3.9	-	-	-	-	-	-	-	-	-
4.0 - 4.9	-	-	-	-	-	-	-	-	-
5.0 - 5.9	-	-	-	-	-	-	-	-	-
6.0 - 6.9	-	-	3.59	-	-	-	-	-	3.59
7.0 - 7.9	-	-	6.28	4.04	1.79	-	-	-	12.11
8.0 - 8.9	-	-	8.97	11.66	9.42	1.35	-	-	31.40
9.0 - 9.9	-	-	8.07	13.00	18.83	1.79	-	-	41.69
10.0 - 10.9	-	-	1.79	5.38	3.59	0.45	-	-	11.21
11.0 - 11.9	-	-	-	-	-	-	-	-	0.90
12.0 - 12.9	-	-	-	-	-	-	-	-	-
13.0 - 13.9	-	-	28.70	34.08	33.63	3.59	-	-	100.00
Total	-	-	-	-	-	-	-	-	-

Table-2.6.8 Wave Duration Table 1975

Month and Year	Duration and number of events	Ware height (m) Hs 0.5	1.0	1.5	2.0	2.5	3.0	3.5
July 1975	Maxmum hours	559.00	342.00	113.00	-	-	-	-
(from 8/7/75	Average hours	559.00	51.11	21.15	-	-	-	-
to 31/7/75)	No. of events in a month	1	10	12	-	-	-	-
	Maxmum hours	744.00	554.00	396.00	126.00	51.00	5.67	-
August 1975	Average hours	744.00	183.75	31.33	18.12	9.46	4.34	-
	No. of events in a month	1	4	15	14	8	2 -	-
September	Maxmum hours	720.00	74.00	17.25	3	-	-	-
	Average hours	720.00	21.69	7.65	3	-	-	-
1975	No. of events in a month	1	19	9	1	-	-	-
	Maxmum hours	365.00	12.00	-	-	-	-	-
October 1975	Average hours	65.50	6.00	-	-	-	-	-
	No. of events in a month	10	5	-	-	-	-	-
Nov. 1975	Maxmum hours	80.00	3.00	-	-	-	-	-
(from 1/11/75	Average hours	22.20	3.00	-	-	-	-	-
to 18/11/75)	No. of events in a month	5	2	-	-	-	-	-

Table-2.6.7 Wave Duration Table 1974

Month and Year	Duration and number of events	Ware height (m) Hs 0.5	1.0	1.5	2.0	2.5	3.0	3.5
July 1974	Maxmum hours	684.75	684.75	359.75	74.17	18.25	9.35	-
(from 3/7/74	Average hours	684.75	684.75	166.69	16.22	6.46	9.35	-
to 31/7/74)	No. of events in a month	1	1	4	22	7	1	-
Aug. 1974	Maxmum hours	659.00	659.00	309.00	111.00	3.00	-	-
(from 1/8/74	Average hours	659.00	659.00	51.89	12.60	2.64	-	-
to 28/8/74)	No. of events in a month	1	1	9	19	9	-	-

4) Ship Observation Data

The analysis of ship observed data between latitude 11°N to 15°N and longitude 71°E to 75°E from 1978 to 1987.

The monthly and consolidated wave rose diagrams are shown in Figure-2.6.9. The predominant direction of waves occuring during the SW monsoon season (from June to September) is West, which percentage is about 51%, and maximum wave height is from 4.0m to 6.0m class. The next predominat wave direction is South-West, which percentage is about 19% and maximum wave heights are about 4.0m to 6.0m in June and July, and 2 to 3m in September. The wave heights are mainly small in October. After October the predominant wave direction with a decrease in energy changes to NE and the maximum wave height is 2 to 2.5m.

Wave data ever recorded were too short to use for desinging the harbour faciliteis, the harbour design was, therefore, based on the ship data. It is used for design that 2.44m external wave height is for normal conditions and 3.66m, for extreme conditions.

The analysis made by CWPRS has recorded that significant wave heights were 3.13m for normal and 3.3m for extreme conditions.

These are less than the wave height of 3.66m considered for the design of the facilities.

These ship observation data can be also used to establish conditions for the tranquillity analysis of the harbour.

5) Other Wave Data

At the time of designing the New Mangalore Harbour Project, a wave observations were performed from 1968-1969 for a period of about 18 months (IMOBCO International Inc., Report of wave & current studies pertinent to an offshore terminal site at Mangalore). The observation period included all months of the southwest monsoon season, June to September. Therefore, this wave data has been used to establish wave conditions in the estimation of siltation volume and harbour tranquillity. No significant differences of wave characteristics between 1968 and 1974-1975 could be observed.

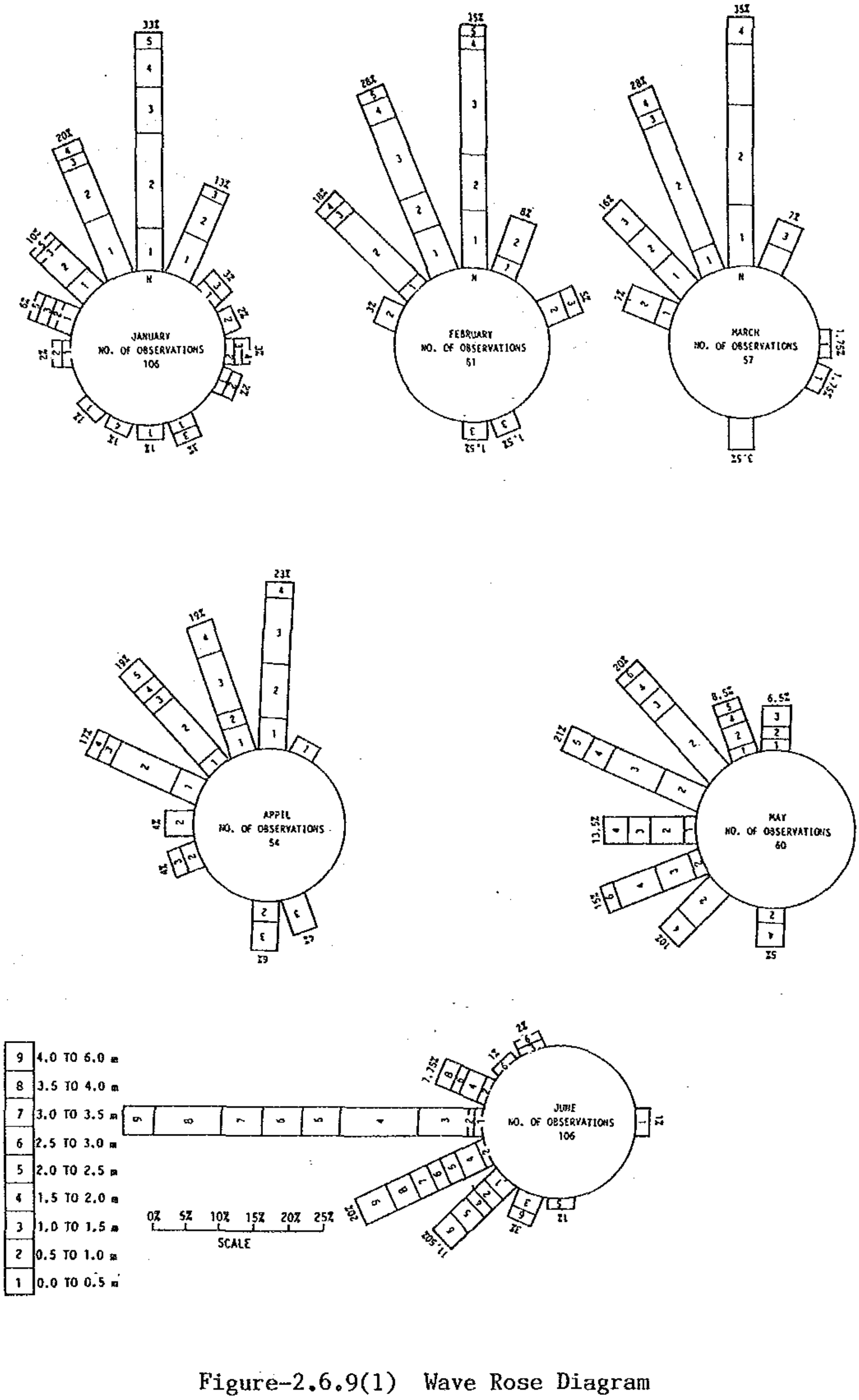


Figure-2.6.9(1) Wave Rose Diagram

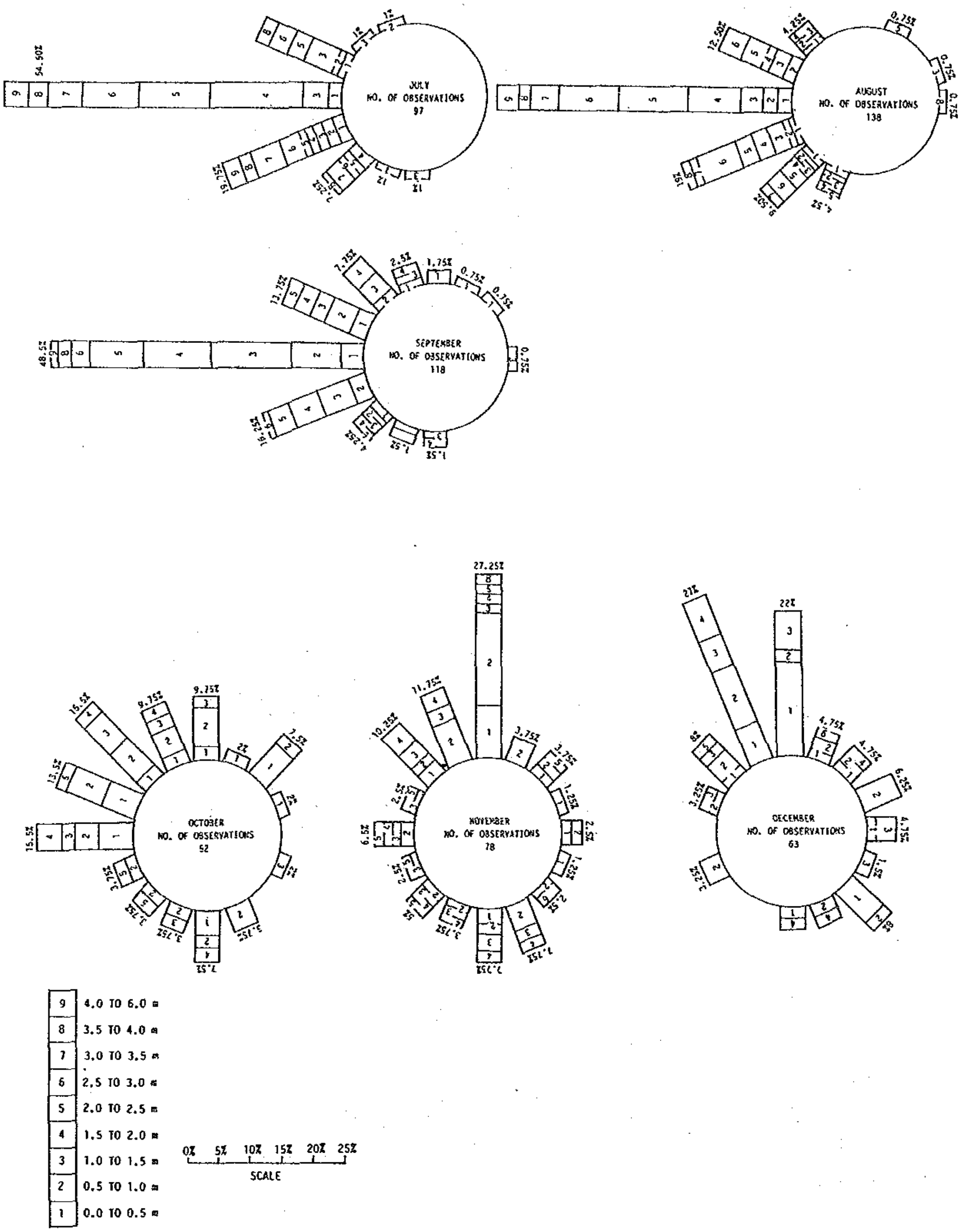


Figure-2.6.9(2) Wave Rose Diagram

(2) Tide

Tidal particulars at New Mangalore Port are as follows:

Highes high water level (HHWL)	+1.68m
Mean higher high water (MHHW)	+1.48m
Mean lower high water (MLHW)	+1.26m
Mean sea level (MSL)	+0.95m
Mean higher low water (MHLW)	+0.77m
Mean lower low water (MLLW)	+0.26m
Lowest low water level (LLWL)	+0.03m

The above figures are with reference to Chart Datum. The type of the tide in New Mangalore Port is mixed tide comparing with the bellow figures.

$$\frac{K_1 + O_1}{M_2 + S_2} = 0.76,\ 0.25 \leq \frac{K_1 + O_1}{M_2 + S_2} < 1.5$$

An automatic recording tide gauge has been installed by "Survey of India" (Various Hydrographic Surveys Dehia Dun, Naval Hydorgraphic Office) in the vicinity of the Oil Jetty area of the Port, inside the lagoon.

(3) Current

The current along the coast during the SW monsoon (from February to September) is generally towards the South (from 160° to 200°) with a velocity of 0.22 to 0.80 knots. During the NE monsoon (from November to January) the current in general is towards the North (from 0° to 40° and 320° to 360° bearing) with a velocity of 0.22 to 0.60 knots.

In the approach channel region protected by breakwater, the current direction lags 6° to 8° behind the coastal current. The current in the lagoon area further lags behind the approach channel on an average leads the surface current by 10° to 15°.

The magnitude of the current outside the lagoon area during the monsoon is about 1 to 1.5 knots as experienced by pilots. The data collected from the surveys will be used for computing the tidal current.

(4) Site Survey Results in This Study

1) General

The following oceanographical site serveys were carried out on OCT/'99.

- wave observation
- current observation
- Sea bed observation by "SPM-III"
- Soil sampling test

The locations of each survey are shown in Figure-2.6.10, and their time schedule is shown in Figure-2.6.11.

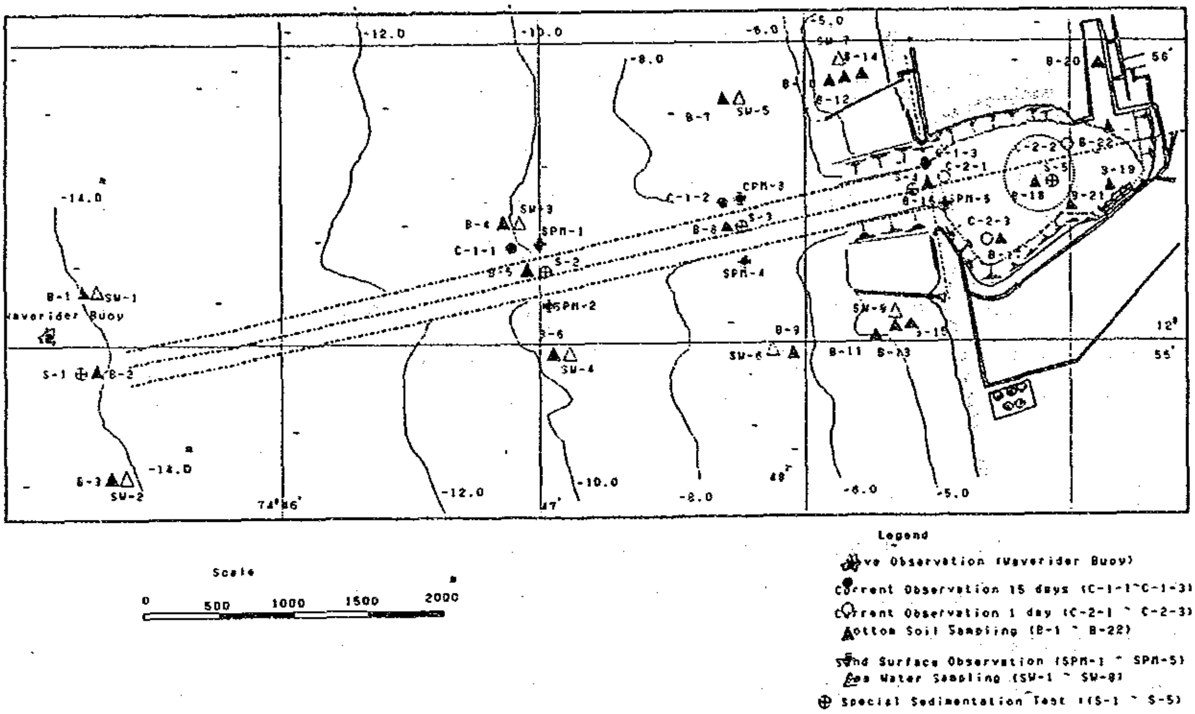


Figure-2.6.10 Location of Each Survey

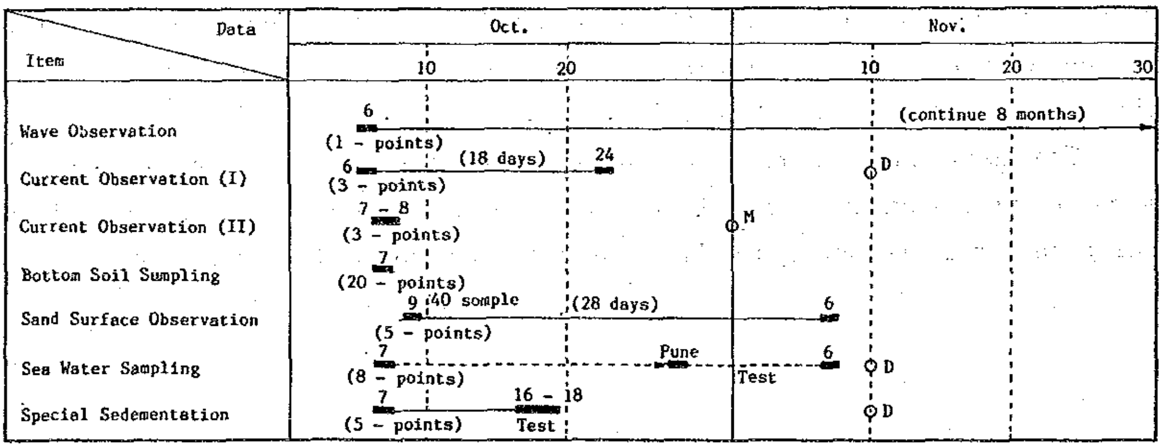


Figure-2.6.11 Survey Schedule

2) Wave observation

A wave rider buoy (70cm dia) was installed at the extremity of the channel where the depth of water is about -15m. Observations were made from OCT/'89 to be end of May/'90 for 8 months.

In this survey period a monsoon season, in which high waves are expected to occur, is not included, but the records of 1974 and 1975 in the monsoon season is available as supplementary data.

The data obtained from October 1989 to February 1990 are summarized as follows.

a. Wave height and frequency

In Octorber, at the end of the monsoon season, the wave heights were comparatively high 0.5 - 0.99m accounting for 78%. Wave heights of more than 1.0m were measured accounting for 9%. In November and December, the sea is generally very calm and in November the wave heights were 0.0 - 0.49m and 0.5 - 0.99 accounting for 75% and 25% respectively. In December waves of 0.5 - 0.99m height appeared accounting for 57 - 78%.

Interim period of cool seasons to SW monsoon (April to May) the wave height become higher gradualy. In May, the wave height 0.55 - 0.99m were accounting for 30%, 1.00 - 1.49 and 1.50 - 1.99 were accounting for 36% and 31% respectively. In partigular high wave of 2.00 to 2.49m were appeared accounting for 3.3%.

The frequency of wave distinguished in 6.0 - 8.0 sec. In this period, the significant wave height was H1/3=2.14 (T=7.4 sec) and the maximum height was Hmax=3.1m (Tmax=10 sec).

<u>Wave direction</u>

The predominant wave direction was distinguished as from the west (280°) in this period. South-west (220°) direction waves followed predominant west direction.

Table 2.6.9 - 2.6.17 shows the relation of wave heights and wave frequency.

The frequency distribution graphs are shown in Fig.2.6.12 - Fig.2.6.20.

Table 2.6.18 shows each wave direction and its graph is shown in Fig.2.6.21.

Table-2.6.9 Frequency Distribution of Wave (7-31, Oct.1989)

(70%)

Hs(m) / T(sec.)	0.00 - 0.49	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	Total(%)
4.0 - 4.9						
5.0 - 5.9						
6.0 - 6.9	2.22	5.19	1.48			8.89
7.0 - 7.9	1.48	5.19	2.96			9.63
8.0 - 8.9	2.22	17.79	2.96			22.97
9.0 - 9.9	2.96	12.59				15.55
10.0 -10.9	2.22	16.30	0.74			19.26
11.0 -11.9		9.64	0.74			10.38
12.0 -12.9	0.74	2.22				2.96
13.0 -13.9	0.74	4.44				5.18
14.0 -14.9		2.96				2.96
15.0 -15.9		1.48				1.48
16.0 -16.9	0.74					0.74
Total(%)	13.32	77.80	8.88			100.00

Table-2.6.10 Frequency Distribution of Wave (1-12, Nov.1989)

(50%)

Hs(m) / T(sec.)	0.00 - 0.49	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	Total(%)
4.0 - 4.9	4.17					4.17
5.0 - 5.9	4.17					4.17
6.0 - 6.9	27.08	8.33				35.41
7.0 - 7.9	8.33	4.17				12.50
8.0 - 8.9	16.67	8.33				25.00
9.0 - 9.9	2.08	4.17				6.25
10.0 -10.9	6.25					6.25
11.0 -11.9	6.25					6.25
12.0 -12.9						
13.0 -13.9						
14.0 -14.9						
15.0 -15.9						
16.0 -16.9						
Total(%)	75.00	25.00				100.00

Table-2.6.11 Frequency Distribution of Wave (5-31, Dec.1989)

(77%)

Hs(m) / T(sec.)	0.00 - 0.49	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	Total(%)
4.0 - 4.9	0.91					0.91
5.0 - 5.9	7.27	13.64				20.91
6.0 - 6.9	10.91	13.64				24.55
7.0 - 7.9	7.27	6.36				13.63
8.0 - 8.9	7.27	8.18				15.45
9.0 - 9.9	5.45	10.00				15.45
10.0 -10.9	2.73	4.55				7.28
11.0 -11.9	1.82					1.82
12.0 -12.9						
13.0 -13.9						
14.0 -14.9						
15.0 -15.9						
16.0 -16.9						
Total(%)	43.63	56.37				100.00

Table-2.6.12 Frequency Distribution of Wave (1-31, Jan.1990)

(100%)

Hs(m) / T(sec.)	0.00 - 0.49	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	Total(%)
4.0 - 4.9						
5.0 - 5.9	2.06	6.19				8.25
6.0 - 6.9	2.06	17.01				19.07
7.0 - 7.9	7.73	13.40				21.13
8.0 - 8.9	7.73	12.37				20.10
9.0 - 9.9	2.06	8.76				10.82
10.0 -10.9	4.12	10.31				14.43
11.0 -11.9	2.58	2.06				4.64
12.0 -12.9	1.04					1.04
13.0 -13.9	0.52					0.52
14.0 -14.9						
15.0 -15.9						
16.0 -16.9						
Total(%)	29.90	70.10				100.00

Table-2.6.13 Frequency Distribution of Wave (1-28, Fev.1990)

(96%)

Hs(m) / T(sec.)	0.00 - 0.49	0.50 - 0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	Total(%)
4.0 - 4.9		13.94				13.94
5.0 - 5.9	0.82	14.75				15.57
6.0 - 6.9	4.92	14.75	0.82			20.49
7.0 - 7.9	4.92	14.75				19.67
8.0 - 8.9	6.55	9.03				15.58
9.0 - 9.9	1.64	6.55				8.19
10.0 -10.9	2.46					2.46
11.0 -11.9	1.64					1.64
12.0 -12.9	0.82					0.82
13.0 -13.9	1.64					1.64
14.0 -14.9						
15.0 -15.9						
16.0 -16.9						
Total(%)	25.41	73.77	0.82			100.00

Table-2.6.14 Frequency Distribution of Wave (1-31, Mar.1990)

(100%)

Hs(m) / T(sec)	0.00 ~ 0.49	0.50 ~ 0.99	1.00 ~ 1.49	1.50 ~ 1.99	2.00 ~ 2.49	Total (%)
4.0 ~ 4.9		4.35	1.45			5.80
5.0 ~ 5.9		7.25				7.25
6.0 ~ 6.9		5.80	4.35			10.15
7.0 ~ 7.9		10.14	2.89			13.03
8.0 ~ 8.9		13.04	5.80			18.84
9.0 ~ 9.9		15.94	1.45			17.39
10.0 ~10.9		8.69				8.69
11.0 ~11.9		5.80				5.80
12.0 ~12.9		4.35				4.35
13.0 ~13.9		2.90	1.45			4.35
14.0 ~14.9		4.35				4.35
15.0 ~15.9						
16.0 ~16.9						
Total (%)		82.61	17.39			100.00

Table-2.6.15 Frequency Distribution of Wave (2-7, 24-30, Apr.1990)

(43%)

Hs(m) / T(sec)	0.00 ~ 0.49	0.50 ~ 0.99	1.00 ~ 1.49	1.50 ~ 1.99	2.00 ~ 2.49	Total (%)
4.0 ~ 4.9						
5.0 ~ 5.9						
6.0 ~ 6.9		4.47				4.47
7.0 ~ 7.9		11.94				11.94
8.0 ~ 8.9		17.91				17.91
9.0 ~ 9.9	1.50	22.38				23.88
10.0 ~10.9	1.50	14.93				16.43
11.0 ~11.9		5.97				5.97
12.0 ~12.9		7.46				7.46
13.0 ~13.9		7.46				7.46
14.0 ~14.9						
15.0 ~15.9						
16.0 ~16.9		2.98				2.98
17.0~17.9		1.50				1.50
Total(%)	3.00	97.00				100.00

Table-2.6.16 Frequency Distribution of Wave (1-31, May.1989)

(100%)

Hs(m) / T(sec)	0.00 ~ 0.49	0.50 ~ 0.99	1.00 ~ 1.49	1.50 ~ 1.99	2.00 ~ 2.49	Total (%)
4.0 ~ 4.9		4.92	2.47			7.39
5.0 ~ 5.9		7.37	7.38	1.64		16.39
6.0 ~ 6.9		5.74	13.93	7.38		27.05
7.0 ~ 7.9		3.27	7.38	18.03	2.46	31.14
8.0 ~ 8.9		4.92	3.27	4.10	0.82	13.11
9.0 ~ 9.9		0.82	1.64			2.46
10.0 ~10.9		0.82				0.82
11.0 ~11.9		0.82				0.82
12.0 ~12.9		0.82				0.82
13.0 ~13.9						
14.0 ~14.9						
15.0 ~15.9						
16.0 ~16.9						
Tota (%)1		29.50	36.07	31.15	3.28	100.00

Table-2.6.17 Frequency Distribution of Wave (Oct.1989-May.1990)

(79.5%)

Hs(m) / T(sec)	0.00 ~ 0.49	0.50 ~ 0.99	1.00 ~ 1.49	1.50 ~ 1.99	2.00 ~ 2.49	Total (%)
4.0 ~ 4.9	0.35	3.00	0.46			3.81
5.0 ~ 5.9	1.73	6.81	1.04	0.23		9.81
6.0 ~ 6.9	4.38	10.50	2.65	1.04		18.57
7.0 ~ 7.9	4.04	9.11	1.73	2.53	0.34	17.75
8.0 ~ 8.9	4.84	11.42	1.38	0.58	0.12	18.34
9.0 ~ 9.9	2.08	9.69	0.35			12.12
10.0 ~10.9	2.42	7.27				9.69
11.0 ~11.9	1.38	3.11				4.49
12.0 ~12.9	0.46	1.38				1.84
13.0 ~13.9	0.46	1.49	0.12			2.07
14.0 ~14.9		0.81				0.81
15.0 ~15.9		0.23				0.23
16.0 ~16.9	0.12	0.23				0.35
17.0 ~17.9		0.12				0.12
Total (%)	22.26	65.17	7.73	4.38	0.46	100.00

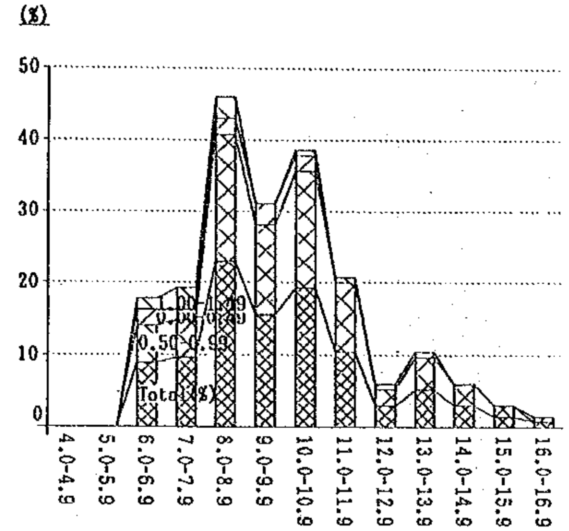


Figure-2.6.12 Frequency Distribution of Wave (7-31, Oct.1989)

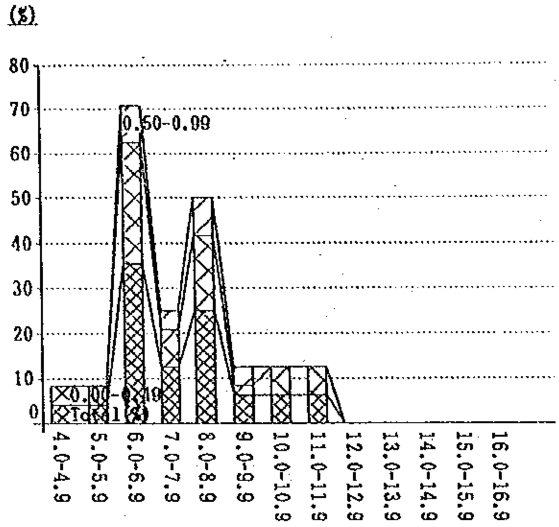


Figure-2.6.13 Frequency Distribution of Wave (1-12, Nov.1989)

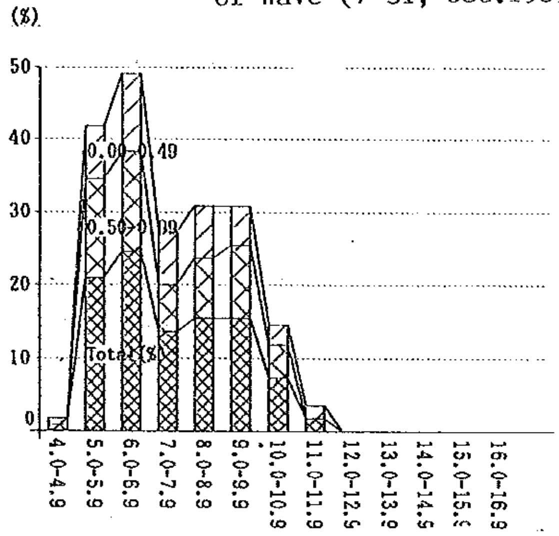


Figure-2.6.14 Frequency Distribution of Wave (5-31, Dec.1989)

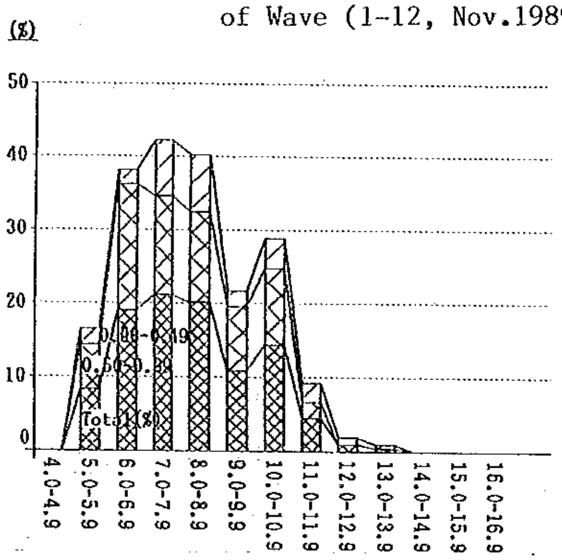


Figure-2.6.15 Frequency Distribution of Wave (1-31, Jan.1990)

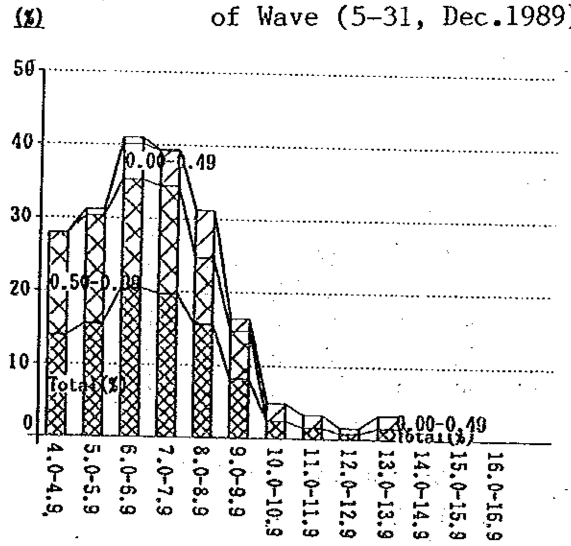


Figure-2.6.16 Frequency Distribution of Wave (1-28, Fev.1990)

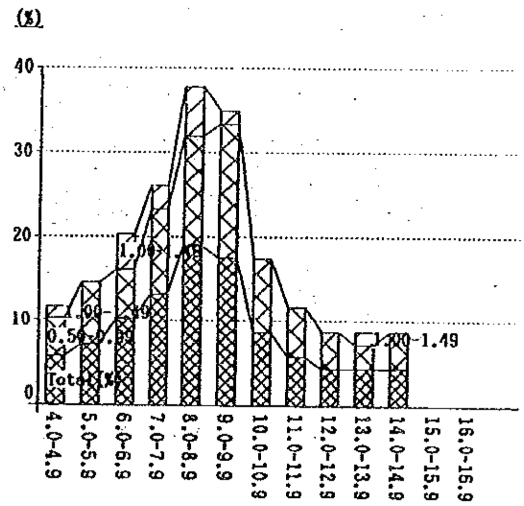


Figure-2.6.17 Frequency Distribution of Wave (1-31, Mar.1990)

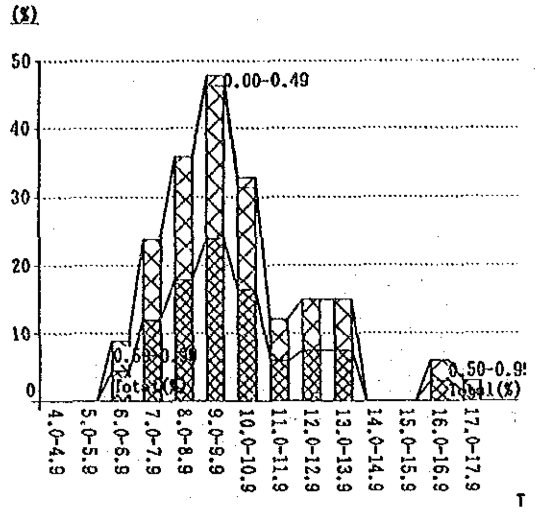


Figure-2.6.18 Frequency Distribution of Wave (2-7, 24-30, Apr.1990)

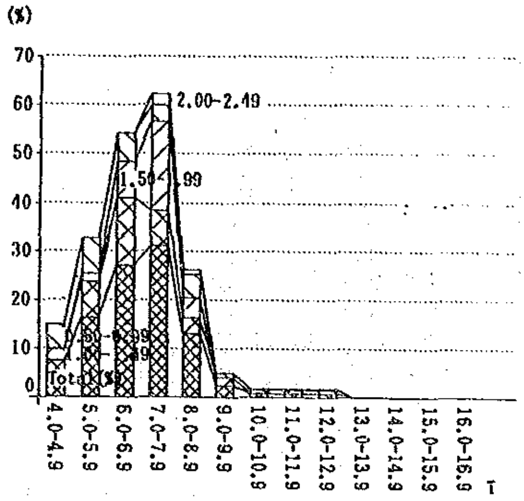


Figure-2.6.19 Frequency Distribution of Wave (1-31, May.1990)

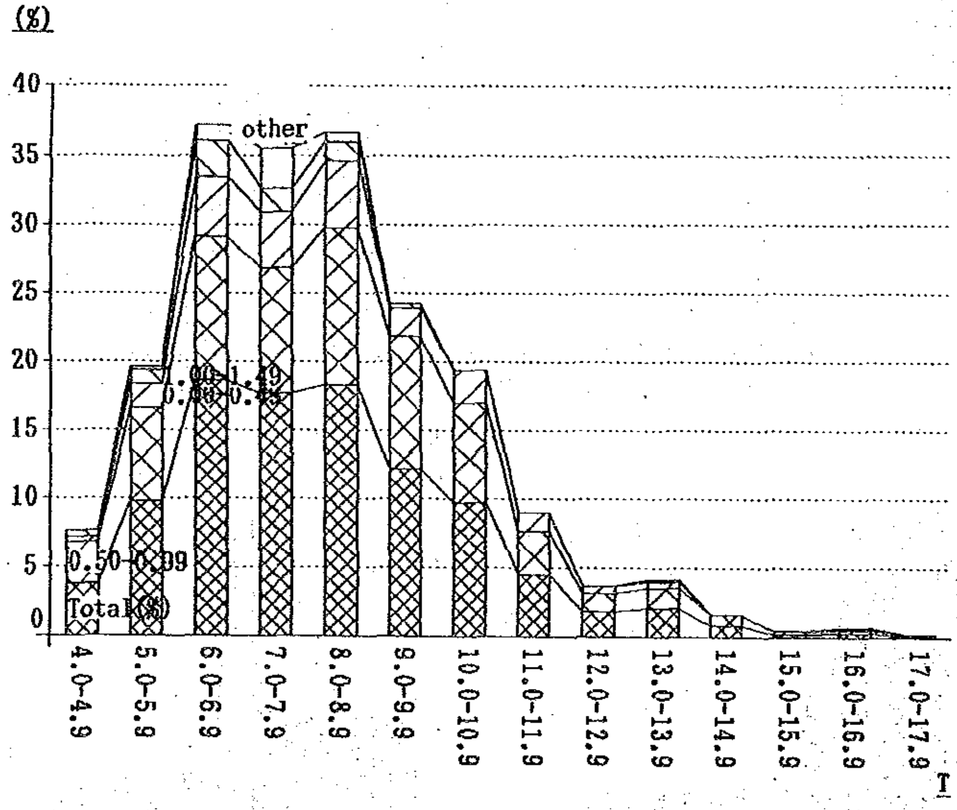


Figure-2.6.20 Frequency Distribution of Wave (Oct.-May, 1989-1990)

Table-2.6.18 Wave Direction (Oct.-Feb. 1989-1990)

D.	0.00-0.49	0.50-0.99	1.00-1.49	1.50-1.99	Total(%)
160	0.48	0.97	0.48	0	1.93
180	0.97	2.42	0	0	3.38
200	3.38	7.25	0	0	10.63
220	4.35	9.18	0.97	0	14.49
240	2.90	9.66	0	0	12.56
260	3.38	5.80	0.97	0	10.14
280	8.70	13.50	0.97	0	23.19
300	2.42	9.66	0.48	0	12.56
320	0.48	3.86	0	0	4.35
340	0	0.97	0	0	0.97
360	0.97	4.35	0.48	0	5.80
Total(%)	28.02	67.63	4.35	0	100.00

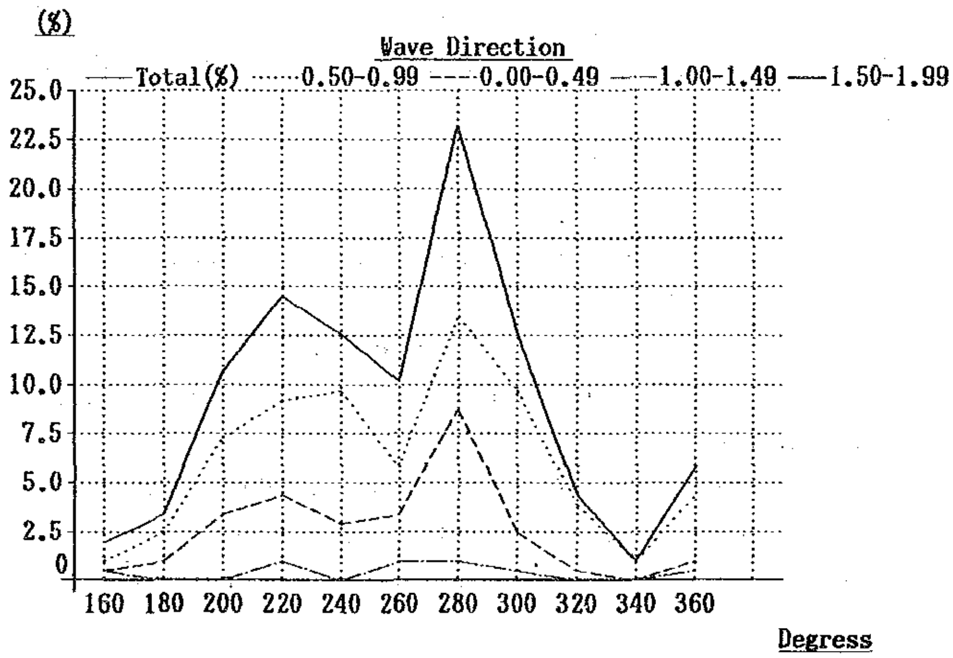


Figure-2.6.21 Wave Direction

3) Tidal current observation

Tidal current observations were carried out in two ways. First, three sets of "BERGEN" type currentmeters were installed with anchor buoys in the outer port as shown in the Figure-2.6.10. The observations were conducted for 15 days. Second, at three points inside the basin, tidal currents were observed for twenty four (24) hours by one currentmeter on a small boat. The results of current observation for 15 days are shown in Appendix 2.6.3.

Outer Port

Generally, the tidal current is weak and its velocity is less than 10 cm/sec at the point C-1-1 in -10m contour area (Figure-2.6.22).

The maximum velocity is 24.3cm/sec (about 0.5kt) in the NE - SW direction (parallel to the shore line) and the direction is gradually changing clockwise.

The maximum current velocity is 25.8cm (about 0.5kt) with the direction of WNW - ESE (parallel to the navigation channel) at the C-1-2 point in the -8m contour area.

The current direction is also changing clockwise. At the C-1-3 point near the port entrance, current velocity is strong and it is 57.2cm/sec (about 1.1kt) with a direction paralled to the navigation channel.

Basin

Tidal current in the basin is weak and its velocity is less than 0.15cm/sec (about 0.3kt).

The current direction is distinguished as WNW - NW.

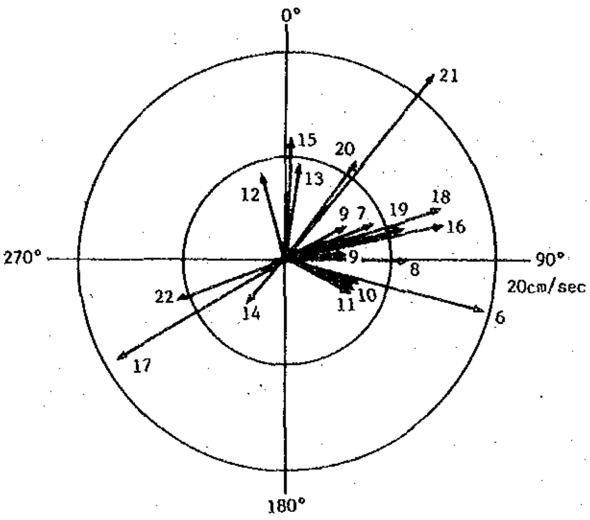
The current pattern near the general cargo berth is normal, changing gradually clockwise.

The current pattern at the front area of the Oil jetty shows the E - NWN direction in the shape of an ellipse. Generally, at any points current velocity is stronger at the surface than below the surface.

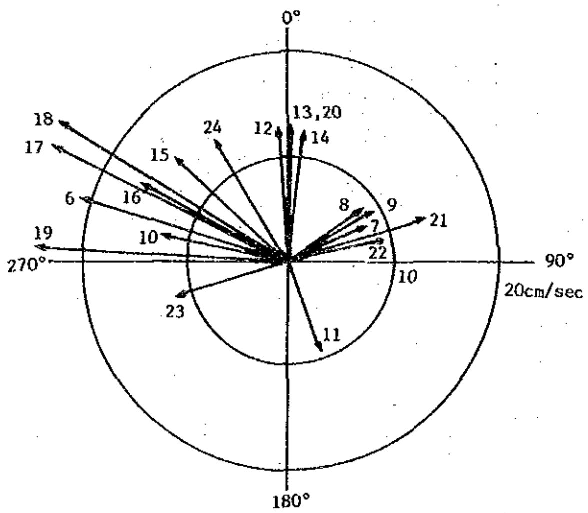
Table-2.6.19 Daily Maximum Tidal Current (6/10 - 24/10)

C-1-1			C-1-2			C-1-3		
DAY H.M.	DIR.	VLT.	DAY H.M.	DIR.	VLT.	DAY H.M.	DIR.	VLT.
6 16-10	104	20.0	6 15-10	288	20.6	6 14-30	274	57.2
7 00-10	62	7.8	7 11-00	66	8.7	7 20-10	278	18.2
8 01-50	90	12.1	8 23-20	56	8.7	8 15-10	264	15.3
9 00-00	86	5.2	9 00-10	60	9.5	9 08-20	252	13.9
10 23-00	106	6.9	10 18-00	284	12.1	10 03-20	249	14.2
11 17-40	109	6.6	11 23-40	162	9.2	11 15-40	265	13.6
12 17-00	344	8.9	12 17-00	357	13.0			
13 05-00	8	9.2	13 04-30	1	13.3			
14 20-20	222	6.0	14 16-40	6	12.7			
15 19-30	1	10.7	15 23-30	313	14.8			
16 20-50	77	15.0	16 02-40	301	15.9			
17 22-30	240	19.7	17 23-40	297	25.8			
18 05-10	73	15.3	18 00-00	303	25.8			
19 08-10	74	11.3	19 17-30	274	24.3			
20 23-40	36	12.1	20 19-30	1	13.9			
21 00-20	38	24.3	21 02-20	74	13.9			
22 04-10	249	11.0	22 12-50	77	10.4			
23 06-50	67	8.7	23 21-50	254	11.0			
			24 01-50	329	13.3			

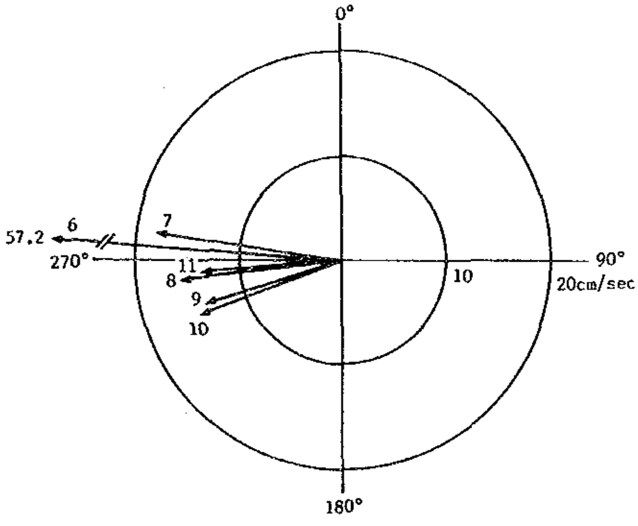
※ 1) CURRENT MAGNITUDE IS IN CM/SEC 2) CURRENT DIRECTION IS IN DEGREES MAGN



C-1-1



C-1-2



C-1-3

Figure-2.6.22 Didal Current Direction

4) Sea bed observation by SPM-III

The optical sand surface survey equipment "S.P.M-III" were prepared and installed by a diver at five (5) points on the seabed of the navigation channel and the basin as shown in Figure-2.6.10 and withdrawn after 28 days.

Specifically, the data of installation was 9th October 1989 and the date of withdrawal was 6th November 1989. Three (3) of the total five (5) were lost perhaps due to the very soft soil which appears to have flushed away the equipments.

Only two out of the five sand surface meters could be retrieved in this manner. Data from one of the two was abnormal due to some accident such as water intrusion into the equipment. Only one set of normal data was obtained at the location of SPM-5 in Figure-2.6.10. This data is characterized as follows. No change of the sea bed height was observed from 9th October, the date of installation, to 25th October. An increase of sea bed height of 0.3m (the depth become shallower) took place from eleven to twenty oclock 26th October. After that, the level of the sea bed was out of the range measurable by this equipment untill its withdrawal. This sudden change of the sea bed level seems to have occured due to a dredging operation worked during the observation period.

5) Soil sampling test

Soil sample were taken from the seabed at 22 points in the navigation channel and the basin. Samples were taken two at a time at each point therefore they were 44 in number totally.

The soil samples were tested by mechanical grain size analysis. Intermediate grain sizes D_{50} of each sample were from 0.17mm to 0.004mm and the locations where each sample was collected are shown in Figure-2.6.23 together with D_{50} respectively.

From the result, comparative larger grain sizes exist in the western side of the channel compared with the eastern side, so it may be reasoned that siltation material is coming from the western side.

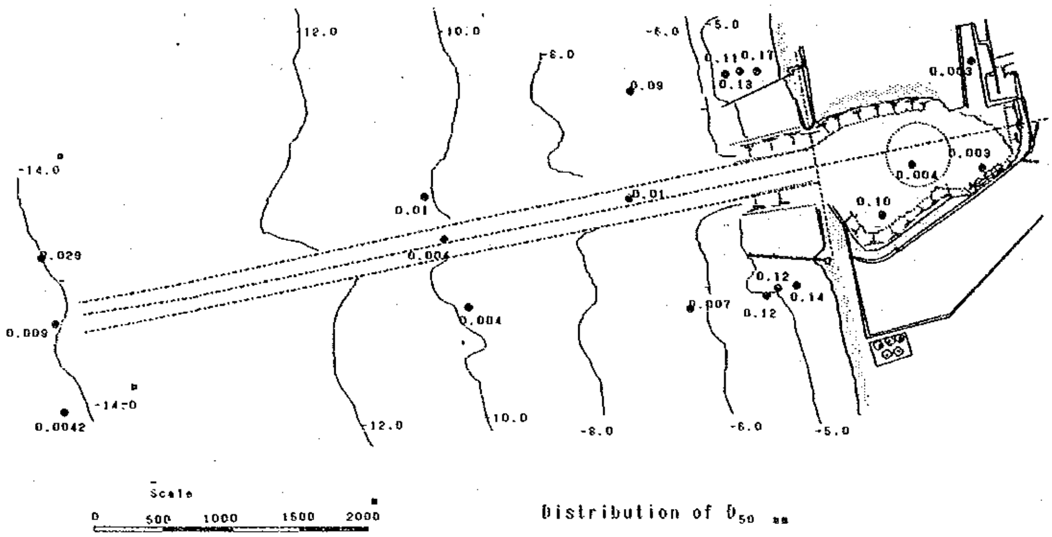


Figure-2.6.23 Distribution of D50

6) Sea water sampling test for measuring suspended substance

Seawater sample were taken at 8 points in the navigation channel and the basin. At each point such samples were taken at the level of 1.0m, 2.0m above the seabed and at the middle of sea depth. The results are shown in Table-2.6.20.

Table-2.6.20 Seawater Sampling for Suspended Substance

Location	Depth	Suspended substance gms/litre
1	Mid-depth	0.022
	2 m above bed	0.041
	1 m above bed	0.052
3	Mid-depth	0.041
	2 m above bed	0.048
	1 m above bed	0.073
4	Mid-depth	0.027
	2 m above bed	0.029
	1 m above bed	0.043
6	Mid-depth	0.047
	2 m above bed	0.113
	1 m above bed	0.077
7	Mid-depth	0.045
	2 m above bed	0.071
	1 m above bed	0.073
9	Mid-depth	0.062
	2 m above bed	0.058
	1 m above bed	0.065
12	Mid-depth	0.068
	2 m above bed	0.116
	1 m above bed	0.092
13	Mid-depth	0.043
	2 m above bed	0.048
	1 m above bed	0.078