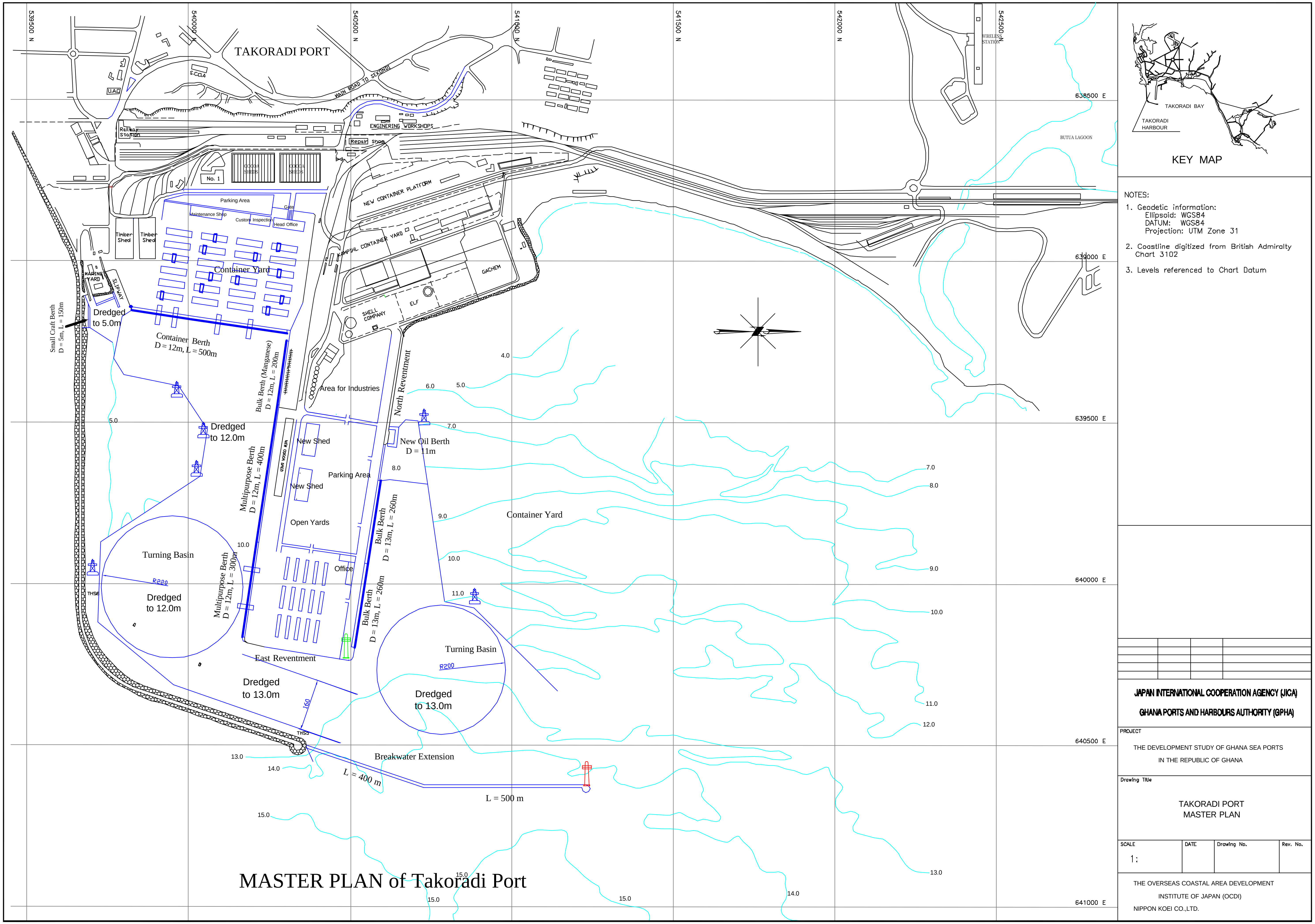
APPENDIX


TAKORADI PORT
MAIN ROAD TO SEKONDI
Railway Station
ENGINEERING WORKSHOPS
Repair Shop
No. 1
NEW CONTAINER PLATFORM
KAMPUL CONTAINER YARD
GACHEM
SHELL COMPANY
ELF
Parking Area
Maintenance Shop
Custom Inspection
Gate
Head Office
Timber Shed
Timber Shed
MARINE YARD
SLIPWAY
Container Yard
Dredged to 5.0m
Small Craft Berth D = 5m, L = 150m
Container Berth D = 12m, L = 500m
Bulk Berth (Manganese) D = 12m, L = 200m
Area for Industries
North Revetment
Dredged to 12.0m
New Shed
New Oil Berth D = 11m
Parking Area
New Shed
Multipurpose Berth D = 12m, L = 400m
Open Yards
Bulk Berth D = 13m, L = 260m
Container Yard
Turning Basin
R220
Dredged to 12.0m
Multipurpose Berth D = 12m, L = 300m
Office
Bulk Berth D = 13m, L = 260m
East Revetment
Turning Basin
R200
Dredged to 13.0m
Dredged to 13.0m
160
Breakwater Extension
L = 400 m
L = 500 m
BUTUA LAGOON
WIRELESS STATION
539500 N
540000 N
540500 N
541000 N
541500 N
542000 N
542500 N
638500 E
639000 E
639500 E
640000 E
640500 E
641000 E
MASTER PLAN of Takoradi Port
KEY MAP
TAKORADI BAY
TAKORADI HARBOUR
NOTES:
1. Geodetic information:
Ellipsoid: WGS84
DATUM: WGS84
Projection: UTM Zone 31
2. Coastline digitized from British Admiralty Chart 3102
3. Levels referenced to Chart Datum
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
GHANA PORTS AND HARBOURS AUTHORITY (GPHA)
PROJECT
THE DEVELOPMENT STUDY OF GHANA SEA PORTS
IN THE REPUBLIC OF GHANA
Drawing Title
TAKORADI PORT
MASTER PLAN
SCALE
1:
DATE
Drawing No.
Rev. No.
THE OVERSEAS COASTAL AREA DEVELOPMENT
INSTITUTE OF JAPAN (OCDI)
NIPPON KOEI CO.,LTD.

Appendix

Draft Environmental Impact Statement

for Short-Term Development Plan

of Takoradi Port

Table of Contents

Chapter 1 Introduction

1.1 Project Background and Objectives

1.1.1 Background

The original Takoradi Port was constructed in the 1920s as the base of navy operations and trade (1^{st} Stage). From 1947-1953, major parts of the present breakwaters were constructed (2^{nd} Stage). From 1953-1958, breakwaters together with berths were extended to complete the present framework of the Port.

Takoradi Port is located about 250km west of Accra, and has played an important role as an export gateway of Ghana. Most of the main export products of Ghana such as bauxite, manganese, wood, and cocoa are shipped from this port.

Main port facilities of Takoradi Port include 9 berths, Berth No.1 to No.6, an Oil Berth, a Bauxite Berth and a Clinker Jetty. There are 2 public sheds and one private shed for the export of the bulk cocoa beans on Lee Breakwater, and 2 Cocoa sheds, 2 Timber sheds and one shed in the inner port area. The existing port layout plan of the Takoradi Port is shown in Figure 6.2.1 of the Main Report.

Increasing cargo handling volume requires a considerable scale of expansion of capacity of the Port. The cargo handling volume will reach to 5 million tons and 9 million tons in 2010 and 2020, respectively, while it remains around 3 million tons at present. In particular, container cargo is estimated to increase more than 4 times and 10 times in 2010 and 2020 (see Table 13.1.1 of the Main Report).

In order to respond to the increasing demand of cargo volume, the provision of deep berths is indispensable and urgent. At the same time, the space for the cargo handling operation should be provided considering the requirement from the local residents.

1.1.2 Objectives

JICA Study Team proposed a development plan of Takoradi Port, in response to the request from the Government of Ghana to Government of Japan, to accelerate and support the economic development of Ghana. Based on the Scope of Works signed by JICA and Government of Ghana on July 20^{th}, 2000, the study team carried out an EIA study for the short-term development plan of Takoradi Port with a target year of 2010.

Takoradi short-term development plan comprised of the following components:
- Creation of new berths through reclamation replacing the existing lee breakwater
- Extension of main breakwater
- Reclamation at head of the existing port basin
- Dredging in the existing port basin and entrance area
- Container and other cargo handling operation on the reclaimed land
- Increase in the cargo transportation

In compliance with the Environmental Protection Agency (EPA) Act, Act 490 of 1994, the plan must be registered with the EPA by GPHA, the project proponent. Under the Ghana Environmental Assessment Regulations, 1999 (LI 1652), port expansion projects with the increase of cargo handling volume of 25 % or more fall within the category of Environmental Critical Undertakings for which EIA is mandatory.

The objective of the environmental study in this report is to prepare the technical parts of the EIS for the short-term development plan of Takoradi Port, which in due course, GPHA will complete for the implementation of the plan.

1.2 Legal, Administrative and Policy Consideration

The relevant policies and the regulatory conditions that must be considered for the successful implementation of the project have been reviewed and are discussed below.

The laws considered include:
- Environmental Protection Agency Act, 1994 (Act 490)
- Environmental Assessment Regulation, 1999 (LI 1652)
- Ghana Ports and Harbours Authority Law, 1986 (PNDC Law 160)
- Merchant Shipping Act, 1963 (Act 183)
- Port Regulations, 1964 (LI 352)
- Ghana Free Zones Act, 1995 (Act 504)

In addition, the followings were considered, though under consideration of the Government of Ghana:
- Draft National Maritime Authority Act, 2000
- Draft Landlord Ports Act, 2000
- Draft Port Regulations, 2000

The Environmental Assessment Regulations, 1999 (LI 1652) enacted under the provisions of the EPA Act, set out the procedures governing EIA in Ghana. Under Schedule 2 Regulation 3 (10) of these regulations, the proposed port development project falls under the undertakings for which EIA is mandatory as it is expected to result in an appreciable increase in port handling capacity.

Section 5 of the Ghana Ports and Harbours Authority Law, empowers the GPHA to build, develop, manage, maintain, operate and control all ports in Ghana. The law also charges the Authority to maintain and deepen as necessary the approaches to the port and also to provide cargo storage/handling facilities such as warehouses etc.

The Ministry of Road and Transport is responsible for Government policy issues related to the Maritime sector. Currently the Merchant Shipping Act, 1963 (Act 183) and the Port Regulations, 1964 (LI 352) have been revised as part of an overall restructuring of the Maritime Administration in Ghana. These revised laws are yet to be approved by Parliament.

Apart from the administrative and policy issues, various legislation and guidelines concerning safety, pollution etc. have also been considered. Among these are:

- EPA Quality Guidelines (Effluents, Air Quality and Noise)
- Radiation Protection Instrument, 1993 (LI 1559)
- National Oil Spill Contingency Plan
- Various international maritime conventions (MARPOL, SOLAS, OPRC, IMDG codes etc.)

These are discussed in relevant details in the sections later where they are applicable.

1.3 Scope of Study

In prior to the preparation of the short-term plan, the study team made a master plan for Takoradi Port development (see Interim Report (1)). In accordance with the EIA procedure in Ghana, Scoping work was also done to identify the environmental elements with possible impact, and in due course of the said procedure, TOR for EIA on the master plan prepared (Appendix AA-1).

Here, the Study Team applies the TOR for EIA on the master plan to the EIA on the short-term plan, since the master plan's components of construction work and operational activity entirely contain those of the short-term plan. Hence it can be said that the TOR for EIA on the master plan cares all of the possible environmental impacts of the short-term development plan of Takoradi Port.

In accordance with the Environmental Assessment Regulations, 1999, the EIA of the Takoradi Port short-term development plan include:

- A description of the proposed undertaking and an analysis of the need/reason for the undertaking;
- Objectives of the undertaking;
- Other options for carrying out the undertaking;
- Alternatives to the undertaking;
- A description of the present environment that would be affected, directly, or indirectly;
- A description of the future environment, predicting its condition if the undertaking did not take place;
- Impacts that may be caused to the environment by the undertaking;
- Proposed measures to prevent or mitigate all adverse impacts;
- Evaluation of opportunities and constraints to the environment of the undertaking;
- Proposal for an environmental management program to cover constructional, operational and decommissioning stages of the undertaking;
- Proposal for a program of public information

Chapter 2 Description of Proposed Development Plan

The short-term development plan of Takoradi Port comprised of the following components:
- Dredging in the port basin and entrance area
- Extension of bauxite and clinker jetty
- Extension of main breakwater
- Reclamation at head of the existing port basin

2.1 Preparation Phase

Since GPHA has already owned the necessary areas for the port expansion, it will not need further land acquisition and relocation of facilities.

2.2 Construction Phase

The short-term development plan of Takoradi Port is drawn as in Figure 16.3.1. The schedule of the construction works is planned as in Figure 18.3.2.

2.2.1 Dredging

The port entrance channel and turning basin will be deepened to 12 – 13 m. The dredging will be carried out by a dredge cutter boat and a pump-dredge boat.

The dredged materials will be used for the reclamation in the proposed plan. The materials to be dredged is estimated to be about 1.66 million m^3 while the area to be reclaimed will require about 1.14 million m^3. Considering a loss of dredged material of 30 % during the operation, the volume of dredged material will meet the demand of landfill.

2.2.2 Extension of Bauxite/Clinker Jetty

The existing bauxite/clinker jetty will be extended offshore to obtain a deeper berth. The new berth of 260 m long will employ the pile structure, similarly to the existing one, and will be sheltered by a breakwater to be extended.

2.2.3 Extension of Breakwater

The breakwater will be extended 400 m to ensure a calm and wide port area and consequent safe navigation at the port entrance. The structure will be same as the existing breakwater, using rocks which are available from the quarry site.

2.2.4 Reclamation for New Container Yard

The head of the existing port basin will be reclaimed with materials both dredged in the port area and transported from the quarry site. The reclamation of the area of 140,000 m^2 requires 1.14 million m^3 of filling materials. The reclaimed area will be used for berths and a yard for container handling.

2.2.5 Demolishing Existing Facility

North and West Lighter Wharves and neighboring Docks No. 1 and 2 will be demolished to create a new container yard. The loading/unloading facility on the clinker/bauxite jetty will also be shifted offshore.

2.3 Operation Phase

2.3.1 Extended Bauxite/Clinker Jetty

A new clinker/bauxite jetty will handle 1.0 and 0.99 million $m^3$of bauxite and clinker, respectively, while the existing facility treats 0.44 and 0.76 million m^3 per year only. Loading/unloading site will be shifted 300 m offshore from the location of the existing facility.

2.3.2 Container Berth/Yard

The new container berths and yard which would be constructed through reclamation will handle a total of 150,000 TEU of containers. Cranes and other container handling equipment will be introduced. Light facility will also be set up to ensure the safe work and the security.

More port workers will be needed to carry out an efficient container handling.

2.3.3 Deepened Multi-purpose Berth

Deepening the port basin and berth enable to accommodate the larger ship and larger volume of cargoes. This will achieve 16 % of increase of cargo-handling volume to reach 935,000tons.

2.3.4 Ship Berthing/Navigation

Pilots and tugboats will work properly for navigation in the port area and berthing, as same as at present.

2.4 Demolition Phase

The port structures should be long-life assets and will form the basement for future expansion of the port. Therefore, demolishing port is not reality, though the future port development work may demolish partly some port structure.

Chapter 3 Existing Environmental Condition

3.1 Climate Conditions

3.1.1 General

The study area lies within the tropical zone in which each year has rainy and dry seasons and belongs to dry Equatorial climatic region of Ghana. Climate is characterized with constant high temperature and moderate rainfall.

The main rainy season in Takoradi is May and June, followed by a late minor rainy season in October and November. The dry season lasts from around December to around March.

3.1.2 Temperature

The hottest periods of the year in Takoradi are in the months of February and March with daytime temperatures reaching up to 35 ℃. This is the period preceding the onset of the minor rains. The mean monthly temperature during this time is about 28 ℃. July and August are relatively cooler months with mean temperatures of 25 ℃ (Table 3.1.1).

Table 3.1.1 Monthly Average Temperature - Takoradi (Unit: ℃)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Av.
61-97	26.6	27.7	27.7	27.7	27.3	26.4	25.2	24.9	25.3	26.0	26.8	26.8	26.5
1998	27.6	28.9	29.5	29.3	28.0	26.9	25.7	25.0	25.8	26.7	28.0	27.8	27.4
1999	27.5	27.5	28.0	27.9	27.6	26.9	25.8	24.8	25.2	25.8	27.0	27.7	26.8
2000	27.0	27.5	28.3	27.6	27.4	26.3	24.9	24.6	25.2	26.3	27.4	27.1	26.6

Source: Meteorological Services, Takoradi

3.1.3 Relative Humidity

The variation in relative humidity in Takoradi area is minimal and sometimes erratic due to the daily influence of the sea and the land breezes. The values range between 80 % during the night to about 60 % at daytime, and falls to less than 30 % during the dry season (Dec. – Jan.), when the dry North-east Trade winds reach the coastline. The highest humidity is experienced around August after the rainy season and the lowest in December(Table 3.1.2).

Table 3.1.2 Relative Humidity in Takoradi (Unit: %)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Av.
61-97	70.7	73.5	73.6	74.5	77.5	81.7	82.0	83.0	82.5	79.4	75.2	73.8	77.5
1998	68.0	72.0	71.0	73.0	78.0	79.0	81.0	79.0	79.0	78.0	72.0	72.0	75.1
1999	76.0	69.0	74.0	75.0	75.0	79.0	81.0	81.0	82.0	79.0	74.0	71.0	76.3
2000	75.0	62.0	72.0	75.0	77.0	81.0	81.0	82.0	82.0	77.0	71.0	73.0	75.7

Source: Meteorological Services, Takoradi

3.1.4 Rainfall

The minor rainy season begins around March and reaches its peak of about 300 mm in Takoradi in the month of June, when the region comes under the influence of the moisture-laden South-west winds. Rainfall figures decline from June to August after which it starts rising to about 100 mm at Takoradi in October. The monthly average rainfall figures for the past 37 years and for the recent 3 years recorded at the Takoradi Meteorological Station is shown in Table 3.1.3.

Table 3.1.3 Monthly Total Rainfall in Takoradi (Unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
61-97	20.2	32.0	62.7	110.4	190.4	312.2	107.8	61.1	85.0	111.1	69.8	22.1	1185
1998	12.5	7.6	22.7	134.6	101.5	107.7	34.5	10.0	5.5	324.4	23.4	41.8	826
1999	55.4	25.5	58.2	218.1	112.4	192.0	195.1	103.1	15.4	58.7	89.4	20.5	1144
2000	27.2	0.0	68.0	145.1	194.9	296.3	24.7	34.1	33.3	42.1	30.2	155.2	1051

Source: Meteorological Services, Takoradi

3.1.5 Wind

Wind data compiled by Meteorological Services Department are based on the records for the last 28 years at Takoradi (Table 3.1.4), and reveal that the mean wind speed is 3.6 knots. In relatively calm season, the mean wind speed is weakened to 2 knots. The Southwest Monsoon prevails influencing the project area (Table 3.1.4 and 3.1.5, Figure 3.1.1). In addition, the diurnal change is observed in the wind direction, resulting from the differential heating and cooling of the land and sea. The local breeze is therefore offshore during the daytime, and reverse occurs at night (Appendix AA-2).

Table 3.1.4 Monthly Average Wind Speed and Direction during 1973 – 99, and 2000 in Takoradi

(Unit: knot)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Av.
Dir.	S	S	SW	SW	S	S	SW	SW	SW	SW	S	S	SW
Vel.	2.8	3.8	4.1	3.7	3.1	3.7	3.8	4.0	4.5	4.2	3.0	2.3	3.6
Dir. (2000)	SW	SW	SSW	SSW	SSW	SW	SW	SW	SW	SW	SW	SSW	SW
Vel. (2000)	4.0	3.0	4.0	3.0	4.0	3.0	3.0	4.0	5.0	4.0	4.0	2.0	3.6

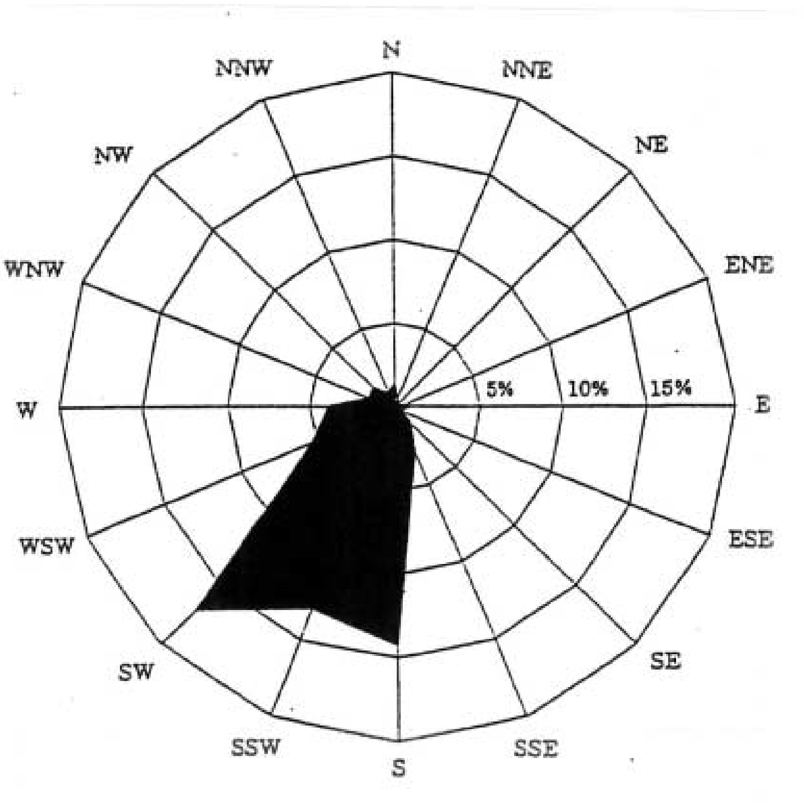
Source: Meteorological Services, Takoradi

Table 3.1.5 Frequency of Wind Direction and Velocity during 1973 – 93 in Takoradi

Speed(knot) / Direction	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-	Total %	Mean wind speed
N	0.9	0.2	0.1	+	-	-	-	-	-	-	1.3	3.1
NNE	0.1	0.1	0.1	+	+	+	-	+	+	-	0.4	11.4
NE	0.2	0.1	+	-	-	-	-	-	-	-	0.3	3.9
ENE	0.1	+	+	-	+	-	-	-	-	-	0.1	4.5
E	0.4	0.4	0.1	+	+	-	-	-	-	-	1.0	4.7
ESE	0.1	0.2	0.1	+	-	-	+	-	-	-	0.5	5.7
SE	0.5	0.5	0.1	+	-	-	-	-	-	-	1.2	4.2
SSE	1.0	1.0	0.6	+	-	-	-	-	-	-	2.7	4.8
S	4.0	5.8	3.6	0.8	+	+	-	+	-	+	14.2	5.6
SSW	2.8	4.2	4.7	1.2	+	+	+	+	-	-	13.0	6.4
SW	3.8	5.7	5.4	1.9	0.1	-	-	-	+	+	17.0	6.5
WSW	1.6	1.7	1.5	0.3	+	-	-	-	+	+	5.2	6.0
W	2.1	1.2	0.4	0.1	+	-	+	-	-	-	3.8	4.0
WNW	0.8	0.4	0.1	+	-	+	-	-	-	+	1.4	4.2
NW	1.2	0.4	0.1	-	+	-	-	-	-	-	1.7	3.1
NNW	0.6	0.2	0.1	-	-	-	-	-	-	-	0.8	2.9
CLM	-	-	-	-	-	-	-	-	-	-	35.6	-
ALL	20.1	22.3	17.1	4.5	0.2	+	+	+	0.1	0.1	100	3.7

+: percent < 0.05

Source: Meteorological Services, Takoradi



Source: Meteorological Services, Takoradi

Figure 3.1.1 Wind Rose through the Year

3.2 Marine Hydrological Condition

3.2.1 General

The seashore in Ghana is faced on the Guinea Gulf of the Atlantic Ocean. Atlantic Ocean and Monsoon wind directly influence the marine hydrological condition of the Ghana's coast.

3.2.2 Tide Level

Tides are resulted from the rise and fall in seawater levels caused by the pull between the earth and other heavenly bodies, mainly the moon. The relative positions of these bodies determine the level of tide at any particular point. There are normally two high tide levels and two low levels within a day (i.e. semi-diurnal). Ghanaian coast also has the semi-diurnal tide. There is no time difference between Tema and Takoradi Ports. The tide levels of Ports in Ghana are corrected to standard port of Takoradi. Daily tidal predictions are computed and have been published annually by GPHA.

Since the tide level observation stopped three (3) years ago in Takoradi Port, the Study Team conducted the tide level observation in Takoradi Port from mid-January to mid-February 2001. The tide level of Takoradi Port is shown in the Table 3.2.1.

Table 3.2.1 Tide Level of Takoradi Port (Unit: m)

	MHMS	MHWN	MLWN	MLWS
JICA	1.75	1.40	0.85	0.52
GPHA	1.5	1.2	0.6	0.2

Takoradi Port: 4 ° 53 ′ N. 1 ° 45 ′ W

Source: Tide Tables 2,001 (GPHA)

3.2.3 Current Flow

Currents in the sea composed of many components including ocean current, wind-driven current, upwelling, tidal current, etc. In the immediate coastal sea area, tidal current plays an important role to transport and disperse materials in the seawater. The velocity of the tidal current is less than 0.1 m/sec. The maximum velocity of tidal current is about 0.5 m/sec which was observed on the day of strong winds.

3.2.4 Wave Condition

There are no wave observation data available locally for Takoradi Port. The wave characteristics during latest 40 years for this study is derived from The Global Wave Statistics publish Maritime Technology.

It is found that the predominant waves flow in the South to Southwest direction (about 60 % of the time). Most of the waves are between 1and 2 meters in height. Wave heights during the rainy season (June-September) when the Monsoon winds predominate may exceed 2 meters more frequently.

The frequency distribution of the concluded wave is shown in Table 3.2.2. South and Southwest waves prevail with a composition rate of nearly 60 % and have relatively large height.

Table 3.2.2 Frequency Distribution of Wave at Offshore of Ghana (1985-1990)

(Unit: %)

Height	N	NE	E	SE	S	SW	W	NW	Total
0.0-1.0	2.45	2.00	1.84	4.38	10.55	10.30	7.48	3.98	42.97
1.0-2.0	1.69	0.84	0.92	5.04	19.85	7.82	2.98	2.84	41.98
2.0-3.0	0.24	0.17	0.19	1.36	6.93	2.15	0.60	0.62	12.44
3.0-4.0	0.07	0.02	0.03	0.22	1.36	0.41	0.08	0.09	2.28
4.0-5.0	0.00	0.00	0.00	0.02	0.19	0.04	0.01	0.01	0.29
5.0-6.0	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04
Total	4.63	3.04	2.99	11.03	38.92	20.72	11.15	7.54	100.00

Number of Observations: 267,326

Source: “The Global Wave Statistics” publish Maritime Technology

3.3 Pollution

3.3.1 Water Quality

Field reconnaissance surveys clarified that, during low tides, innermost part of the port showed water pollution caused by the wastewater from nearby residential areas and the port area, while the entrance of the port had good water quality. Considerable number of staff and workers in the port area give rise to proportionate amount of sewage, though most of it is collected from the septic tanks and transported to a dumpsite at the coast east of the town.

The low tide brought about turbid water. The principal causal factor of turbidity resulted from not the sewage but the re-suspension of soil particles deposited along the main breakwater and re-suspended by the wave action. The transparency measured by a Secci disc was 3 – 4 meters in the head of the port water and more than 10 meters at the entrance.

The water quality in the port largely changes with the tide. High tide replaced the entire port water with the clear offshore water and brought highly transparent water showing the transparency exceeding 10 meters even in the innermost part of the port. The port owes such a high water exchange rate to the proportion of the harbor, shallow water depth, size of the harbor entrance, and the adequate tidal range.

Based on the above observation, a field survey was carried out in the time zone of the low water on 25th January 2001 to know the worst water quality condition. The location of the sampling is shown in Figure 3.3.1. The surface water was collected and brought to a laboratory for chemical analyses.

The water quality obtained from four (4) sampling stations showed the moderately polluted condition in general, and no significant difference between the locations (Table 3.3.1).

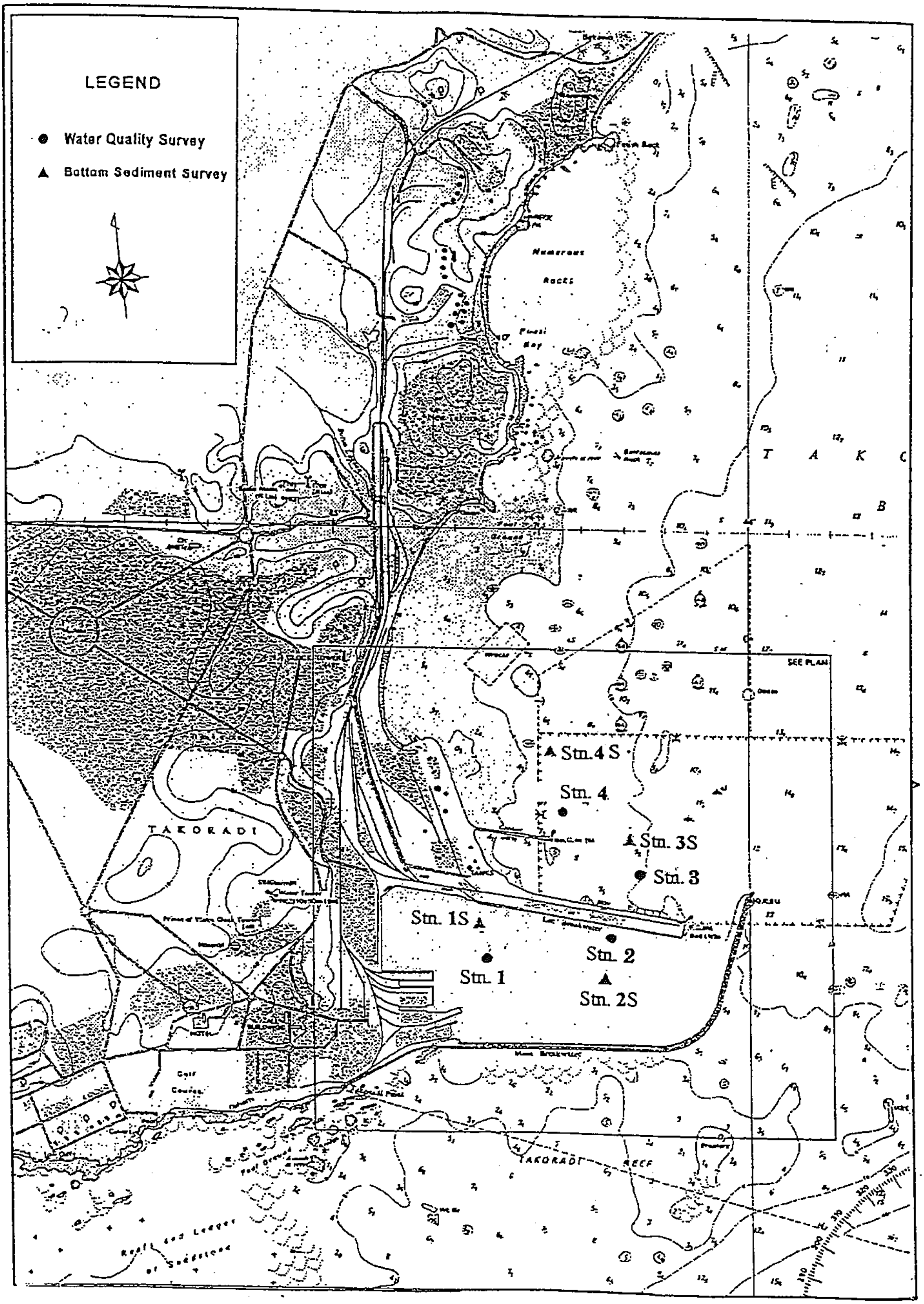


Figure 3.3.1 Locations of Water and Bottom Sediment Sampling in Takoradi Port (25 Jan. 2001)

Table 3.3.1 Result of the Water Quality Analysis of Takoradi Port

Station	Unit	1	2	3	4	AEC*
Date		25 Jan. 2001	25 Jan. 2001	25 Jan. 2001	25 Jan. 2001	
Time		10:15	10:50	11:15	11:45	
Latitude		4°52'55"N	4°52'59"N	4°53'08"N	4°53'16"N	
Longitude		001°44'38" W	001°44'20" W	001°44'16" W	001°44'28" W	
Whether	-	fine	Fine	fine	Fine	
Air temp.	℃	32.0	30.0	29.0	27.8	
Wind dir.	-	SW	SW	SW	SW	
Wind speed	kt	5	5	5	5	
Depth	m	6.0	10.8	10.2	9.8	
Water color	-	Olive yellowish green	Olive green	Olive green	Olive green	
Smell	-	no	no	no	no	
Transparency	m	4.0	3.4	3.8	3.7	≧1
Oil film	-	no	no	no	no	
Floatable	-	no	no	no	no	
Surface temp.	℃	29.1	28.2	27.8	27.8	
Salinity	-	37.93	36.13	36.49	34.14	
PH	-	7.9	8.0	8.0	8.0	6.5 – 9.0
DO	mg/L	6.5	7.6	7.7	7.6	≧3
BOD	mg/L	0.8	1.1	1.6	1.2	≦20
COD_{Cr}	mg/L	18.6	48.1	48.1	18.6	≦40
TOC	mg/L	1.3	1.2	1.1	1.2	
Oil & grease	mg/L	11.0	16.0	15.0	9.0	≦10
SS	mg/L	10.5	7.0	9.0	8.3	
Turbidity	NTU	3.3	1.9	3.1	2.9	
Pb	mg/L	0.001	0.001	0.001	0.002	≦0.05
Cd	mg/L	<0.001	<0.001	<0.001	<0.001	≦0.01
Cu	mg/L	<0.001	0.005	0.002	0.002	≦1
Zn	mg/L	0.004	0.011	0.010	0.029	≦2

* "AEC" (Assumed Environmental Criteria) is conveniently cited as a quality reference value derived from "Environmental Assessment Handbook for Port Development Projects." OCDI, 1993.

Since Ghana has not established an ambient water quality standards, a series of quality reference value for selected parameters were introduced in Table 3.3.1 as an Assumed Environmental Criteria (AEC). This was tentatively set up based on the examples of criteria for port waters in tropical and subtropical eight (8) countries. This helps the understanding the water quality situation objectively.

Comparing with AEC, it should be noted that oil and grease concentration revealed high value exceeding the criteria for ordinary sea ports, though other parameters showed concentrations that meet the AEC. Management of oil spill and leakage should take the first priority for water quality control in Takoradi Port.

3.3.2 Bottom Sediment Quality

A past report stated that the sediment consisted of silt with shell and rock fragments and that the sand contents in the silt got higher near the entrance and in samples behind the main breakwater. And the report suggested that latter observation might confirm that quantities of sediment are passing through or over the breakwater.
No data has been obtained, however, on the chemical quality of the sediment in the port basin. Therefore, a field survey on the bottom sediment quality was conducted at the same time as the water quality survey. The sampling locations are also shown in Figure 3.3.1.

The bottom sediment quality revealed the heavily polluted condition in the entire survey area (Table 3.3.2). Particularly, the innermost part of the port showed the most severe pollution both in organic matters indicated with COD, and the heavy metal.

AEC for the sediment quality was introduced as the reference values to evaluate the bottom sediment condition. This was tentatively set up based on the examples of criteria in U.S.A., Canada, Germany, Netherlands, Belgium, and Hong Kong. These are criteria for offshore dumping of dredged sediments. (The contaminated sediments that do not meet the criteria should be disposed to carefully designed dumping sites.) The highest (loosest) values among 6 examples were adapted for every parameter.

Lead (Pb) concentration at station 1S exceeded the AEC largely. Total mercury (T-Hg) also showed high concentrations at all sampling locations, which exceeded the AEC. This fact means that dredging and other sediment-disturbing activities will require careful consideration to prevent the contamination by harmful substances.

Table 3.3.2 Result of Sea Bottom Sediment Analysis in Takoradi Port

Station	Unit	1S	2S	3S	4S	AEC*
Date		25 Jan. 2001	25 Jan. 2001	25 Jan. 2001	25 Jan. 2001	
Time		10:35	11:05	11:35	12:05	
Latitude		4°53’01”N	4°52’53”N	4°53’13”N	4°53’26”N	
Longitude		001°44’39”W	001°44’21”W	001°44’17”W	001°44’28”W	
Color		Grayish black	Grayish black	Grayish black	Grayish black	
Smell		no	no	no	no	
Grain size		Coarse sand	Medium sand	Coarse sand	Fine sand	
COD_{Cr}	mg/g dry	188	129	107	196	
T-S	mg/kg dry	10.0	21.0	6.0	39.0	
Ignition loss	%	16.5	19.5	15.0	11.3	
Pb	mg/kg dry	200.4	68.2	60.1	83.1	≦100
Cd	mg/kg dry	0.73	0.26	0.25	0.19	≦2.5
As	mg/kg dry	16.7	15.11	9.16	5.22	≦30
T-Cr	mg/kg dry	930.1	395.6	337.5	220.7	
T-Hg	mg/kg dry	6.54	2.55	3.62	1.08	≦1.0
Mg	mg/kg dry	60.69	52.06	50.66	36.76	

- AEC: see Table 3.3.1.

3.3.3 Air Quality

The air quality in and around Takoradi Port does not show the serious situation as a whole, though the nuisance due to the dust from the clinker for GHACEM appears at and around the cement processing facilities. GHACEM has taken measures not to spill the clinker dust out of the belt-conveyor using an emission control system. The dispersion of the clinker dust, however, is still obvious in the adjacent area. Bauxite does not bring the dust problem because of its coarse grain. Gas concentration, such as SOx, NOx, and CO, seems to be low due to the relatively low accumulation of industries, though the ambient air quality monitoring system, which commenced in December 2000, has not provided any data yet.

Thus, the Study Team carried out a field survey focussing on the dust concentration at locations in Figure 3.3.2. Two (2) Paschal 9000 – dust monitor were employed for the fieldwork. Detailed methodology is described in Appendix AA-3. Table 3.3.3 shows the result of the survey. Sites near manganese loading facility and the clinker jetty revealed high concentration, though they still did not exceed the EQS.

Table 3.3.3 Total Suspended Particulate and PM_{10} (1 hr value) Measured in August 2001.

(Unit: $\mu g/m^3$)

Site No.	TSP			PM_{10}		
	13 Aug	14 Aug	Mean	13 Aug	14 Aug	Mean
1	15.2	19.4	17.3	7.0	8.9	7.5
2	40	42	41	29	27	28
3	41.2	40	40	25	20	22.5
4	38.4	39.1	38.9	28	32	30
6	10.5	10.8	10.7	5.0	5.2	5.1
8	6.8	7.3	7.1	3.0	3.6	3.3
9	6.1	6.2	6.1	2.7	2.4	2.5
10	5.8	5.7	5.7	2.1	2.0	2.0
EQS*	In industrial area: 230 for 24 hrs 75 for 1 yr			70 for 24 hrs		

*: National Environmental Quality Standards (draft), EPA

3.3.4 Noise

The Study Team carried out a field survey on noise at locations in Figure 3.3.2, using a Castle 1800 Type 19-a noise meter. Detailed methodology and obtained field data are introduced in Appendix AA-3 and 4, and the summarized result in Table 3.3.4.

All measurement sites were located in the port area or the commercial/industrial area neighboring the port. Obtained noise levels met the Environmental Quality Standards (EQS) value in Ghana. The fact that GPHA has not received any complaints from local residents on the noise nuisance also shows the relatively quiet condition in and around the Port.

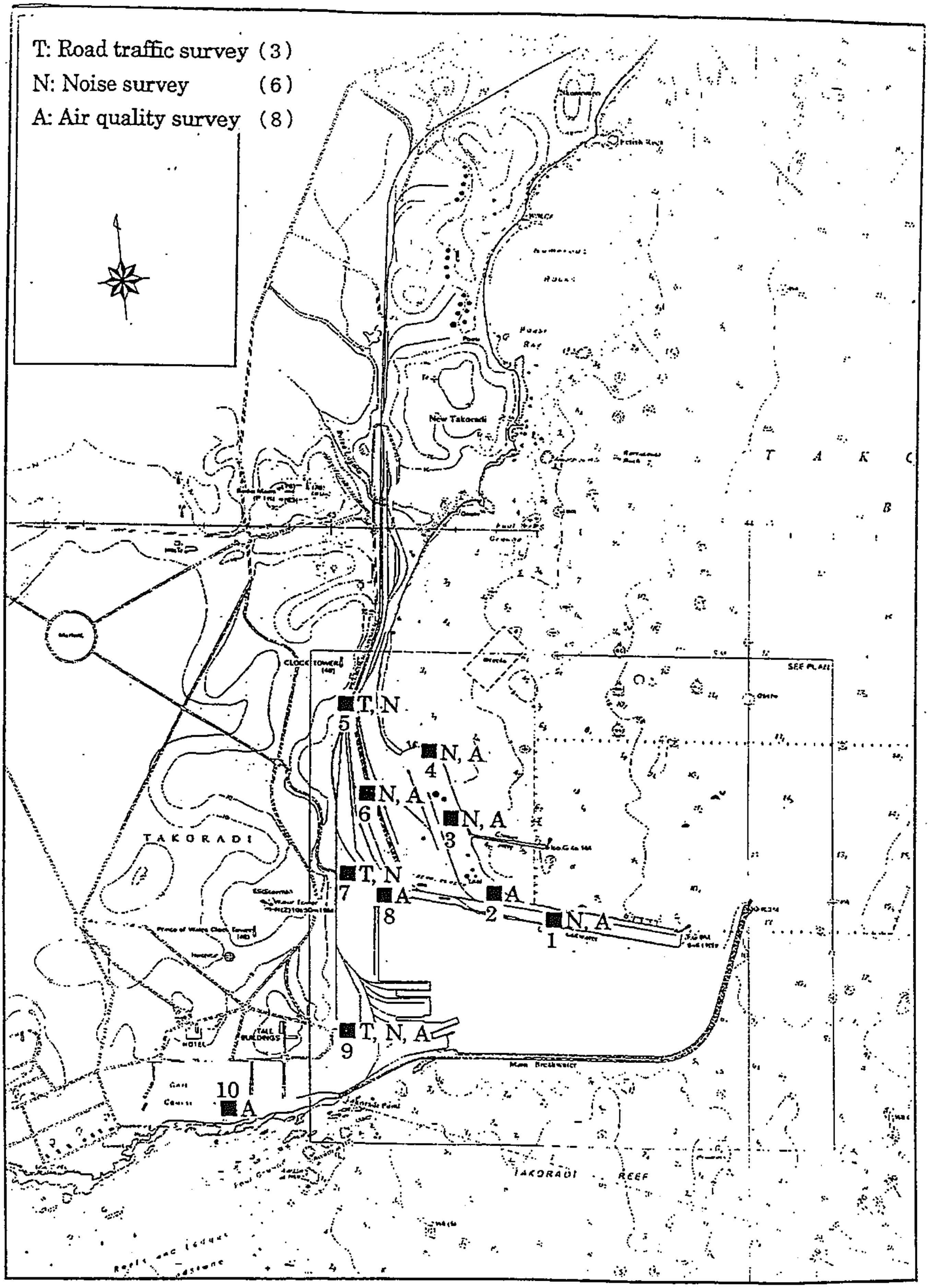


Figure 3.3.2 Sampling and Monitoring Sites for Air Quality, Noise and Road Traffic (13 – 16 August 2001)

Table 3.3.4 Summary of Noise Measured in August 2001.

(Unit: dB(A))

Site No.	$L_{Aeq}=L_{50}+(L_{10}-L_{90})^2/57$		
	13 Aug	14 Aug	EQS's Permissible Noise Level For Predominantly Commercial Areas 75 in daytime (0600 – 2200) 65 at night (2200 – 0600) EPA categorized Port Areas into predominantly commercial areas in the classification.
1	65.4	69.0	
3	58.6	67.4	
4	60.3	61.1	
5	75.5	60.4	
6	57.8	69.1	
7	69.0	64.4	
9	55.3	56.1	

3.3.5 Odor

The odor caused by the water/sediment quality could not be detected through the repeated field reconnaissance. The smell of cacao beans from sheds, however, seemed to be a nuisance to some of port workers. The smell was not sensible for most of local people in the town area.

3.4 Biophysical Environment

3.4.1 Littoral Drift

The West African coast extending from Cape Palmas to The Niger Delta generally has an accretion tendency in the western section up to Cape Three Points in Ghana and an erosion tendency in the east. Takoradi is located east to Cape Three Points.

In the port area, considerable sand accretion has occurred along the main breakwater. The accreted sand seemed to have come from a beach south to the port being carried over and/or have passed through the breakwater made of rocks and stones.

On the other hand, erosion has been obvious along the north side of the lee breakwater and along the revetment of the northern part of the port. The eroded stones have been carried northward.

3.4.2 Fauna/Flora

(1) Aquatic Biota

Green algae dominated the aquatic flora on the quay wall in the innermost part of the port, indicating the deteriorated water quality condition. On the other hand, brown and red algae were predominant on the breakwaters at the entrance of the port. Here, sea urchin showed high individual numbers of 10 – 20 inds./m^2, which fed on these algae.

The composition of fish community in the inner part of the port appeared also different from that in the port entrance. Fry and small pelagic fish characterized the inner part, and were abundant in the vicinity of the outlets of drains, while schools of big fish exceeding 80 cm long and various ornament fish species contributed to diversified aquatic fauna in the entrance area. The main breakwater obviously has a habitat function for reef-associated fish.

No coral reef exists on the coast of Ghana, though it is known that dense communities of soft corals and sea fans with its associated fish fauna have been formed on the hard substrate of deeper sea bottom off Takoradi.

Sea turtles are present two to three months prior to nesting activities in the Shama Bay area, about 20 km east to Takoradi, though which species they were have not been specified yet. Takoradi area seems to be located out of their habitat, probably due to the intensive human activity which prevents sea turtles from approaching.

(2) Terrestrial Biota

There is very little significant natural vegetation around the Takoradi Port, because the town surrounds it. In the port area, no green area exists. The high level of human activity both in the port and town has resulted in the disappearance of most of the wildlife. Interviews with local residents indicated the distribution of only several species as follows.

- Rodents (squirrels and rat / mouse),
- Lizards,
- Snakes, and
- Crabs (found along the sandy beach strip)

3.5 Social Environment

3.5.1 Population Distribution

The Metropolis has a population strength of 357,431, and a daily floating population of 8,000 made up of people that commute from the neighbouring districts and suburbs, into the city for trade, industry and other civic activities. It has a growth rate of 2.9% per annum, and offers a large skilled labour force, as well as a major potential market.

The demographic structure is that of a young and a growing population. The economically active population constitute 51.9 % of the total population, while the school going age forms 44.8 %. Men constitute 51 % of the total population and women 49 %. The population density of the city is generally high and stands at 1,069 persons per sq. km.

3.5.2 Ethnicity and Religion

The metropolis has its roots from the Ahantas (Table 3.5.1). It has however become cosmopolitan with the following as the major ethnic groups. Nzema-Ahantas, Fantes Guans, Gas and Ewes. In term of religion, Christians form 86.1 %, while Moslems and traditionalist constitutes 8.1 % and 0.3 % respectively. The remaining are atheists, who form 5.5 %.

Table 3.5.1 Ethnicity by Percentage

Ethnic Group	Percentage
Ashantis	4.1
Fantes	20.5
Other Akans (Ahantas, Nzemas)	41.1
Ga-Adangbe	4.5
Ewe	3.3
Guans	16.0
Dagomba	1.1
Grussi/Frafra	0.8
Dagarti	0.5
Other tribes (Kukomba,Mamprusi etc)	8.1
Total	100.0

Within the last 10 years the Sekondi-Takoradi metropolis has not recorded any major conflict between the ethnic groups. There have however been issues of litigation and chieftaincy dispute between the natives in the communities.

3.5.3 Economic Activity

Takoradi Port is the second largest port facility in Ghana. It was established in 1927 and started operation a year after. Since that time it has earned the distinction of being the gateway and a springboard for the economic and industrial development of Ghana.

Takoradi is a cosmopolitan city with people engaged in various forms of economic activity that has linked to the Port directly or indirectly. Port-related industries include manufacturing, repairing, transportation, fishing and other wide range of services.

3.5.4 Infrastructure

(1) Water Supply System

The Sekondi-Takoradi Metropolis obtains its water supply from two main sources: River Anankwari at Inchaban, a suburb of Sekondi and the Pra River at Daboasi, where the two water treatment plants which serve the entire Metropolis are located. At full capacity the two stations generate between 8 – 10 million gallons of water per day for the metropolis, which has between 60 –70 % of the population having access to pipe-borne water. Alternative sources of water include bore-holes and drilled wells.

Though water shortage within the metropolis is rare, minor incidents have been recorded during dry seasons. This has been attributed to a reduction in the water levels at the source rivers, power fluctuation and deterioration of existing supply system. Tanker services are employed in the event of an acute shortage.

(2) Sewerage

The sewerage of the Metropolis is managed by the Waste Management Department of the SAEMA. The system is obsolete and inadequate to meet the demands of the increasing population and housing infrastructure within the metropolis. This condition is typical of the old towns within the metropolis. SAEMA has in place a house-to-house sewerage tankers are however available to drain septic tanks for disposal at appropriate sites.

(3) Other Infrastructure

The Metropolis is well equipped with a road network of 331 km in total length including the highest quality road of 62 km. Railroad has also contributed to the transportation since 1927, just after the completion of the Takoradi Port. The fact that freight traffic increased from 743,000 tons in 1991 to over 850,000 tons in 1997, though the passenger traffic increased only 1.5 % during the same period shows the railway system mainly supports the freight transportation and the passenger traffic relies on the road transportation.

Communication facilities and electricity have also developed in the Metropolis area. The Port is being supported by the reliable and efficient communication and data-exchange measures.

3.5.5 Road Traffic

There are three (3) access roads to the Port. Lines of articulated vehicles and trucks parking and waiting for the loading/unloading were sometimes observed on the main access roads. Local people say that, since the gates of the port area are very close to the town, the lines of such vehicles sometimes causes a traffic problem and a nuisance for taxies waiting for passengers.

The Study Team carried out a road traffic survey at three (3) locations which were arranged one (1) each on three access roads to the Port (see Figure 3.3.2). The survey was conducted throughout continuous 72 hours on 13 – 16 August 2001 (see Appendix AA-5).

The result is summarized in Table 3.5.2. Inbound and outbound traffic counted 4,548 and 4,425 vehicles per day, respectively, including trailers and trucks of 391 and 403 vehicles for in- and outbound. Peak hours appeared in 0700 – 1500 for inbound traffic and in 0900 – 1800 for outbound traffic. South Gate Road (St. 9) accommodated more than half of the total vehicle traffic to/from the Port, while trailers and trucks utilized North Gate Road most intensively.

Table 3.5.2 (1) Summary of Road Traffic Survey on 13 – 16 August 2001 (All Types of Vehicles)

Hour	Inbound				Outbound			
	St. 5	St. 7	St. 9	Total	St. 5	St. 7	St. 9	Total
00-01	4.3	2.3	2.0	8.7	5.3	1.3	2.7	9.3
01-02	2.3	1.0	0.3	3.7	4.0	1.3	2.7	9.3
02-03	2.0	0.7	0.3	3.0	1.7	1.3	0	3.0
03-04	2.0	2.0	2.0	6.0	3.0	2.3	1.7	7.0
04-05	3.7	6.0	5.3	15.0	8.7	3.7	6.0	18.3
05-06	27.7	20.3	30.7	78.7	11.3	12.7	27.3	51.3
06-07	45.0	26.3	64.7	136.0	40.3	19.0	55.0	114.3
07-08	110.7	88.7	143.7	343.0	52.3	38.3	96.7	187.3
08-09	65.7	113.7	192.0	374.7	66.0	71.3	149.0	286.3
09-10	79.3	81.3	204.0	364.7	76.0	74.0	184.3	334.3
10-11	80.7	84.7	189.7	355.0	81.3	67.3	193.0	341.7
11-12	79.7	102.0	177.0	358.7	79.0	73.7	207.0	359.7
12-13	76.0	87.3	174.7	338.0	115.3	81.0	216.3	412.7
13-14	94.0	96.3	169.0	359.3	68.3	58.7	181.0	308.0
14-15	82.0	100.0	181.0	363.0	94.3	60.7	214.3	369.3
15-16	69.0	85.7	167.7	322.3	66.7	56.0	179.3	302.0
16-17	57.3	90.3	148.7	296.7	88.0	68.0	203.0	359.0
17-18	52.7	84.7	116.0	253.3	71.0	81.7	204.0	356.7
18-19	22.3	45.3	141.3	209.0	43.0	43.3	146.3	232.7
19-20	20.3	14.7	149.3	184.3	24.3	20.7	136.0	181.0
20-21	14.7	13.3	60.3	88.3	18.0	6.7	67.0	91.7
21-22	15.3	5.0	26.7	47.0	12.3	7.0	27.0	46.3
22-23	8.0	8.7	8.7	25.3	15.0	4.0	7.0	26.0
23-00	5.3	5.7	7.0	18.0	4.3	8.7	8.3	21.3
Total	1,020.0	1,166.3	2,362.0	4,548.3	1,049.7	862.7	2,512.7	4,425.0

Table 3.5.2 (2) Summary of Road Traffic Survey on 13 – 16 August 2001 (Trailer and Truck)

Hour	Inbound				Outbound			
	St. 5	St. 7	St. 9	Total	St. 5	St. 7	St. 9	Total
00-01	3.0	0	0.3	3.3	3.3	0	0.7	4.0
01-02	0.7	0	0	0.7	3.0	0	0	3.0
02-03	1.7	0	0	1.7	1.3	0	0	1.3
03-04	0.3	0	1.0	1.3	1.3	0.3	0	1.7
04-05	2.0	0	0	2.0	2.3	0	0	2.3
05-06	8.0	0.3	1.3	9.7	4.3	0.7	1.0	6.0
06-07	6.0	1.7	6.7	14.3	4.7	3.7	1.7	10.0
07-08	10.3	8.3	8.0	26.7	5.0	1.0	1.7	7.7
08-09	6.3	10.7	16.3	33.3	11.0	4.0	12.0	27.0
09-10	16.3	8.3	16.3	41.0	12.0	9.3	14.7	36.0
10-11	10.7	9.0	11.7	31.3	12.0	7.7	10.0	29.7
11-12	13.7	9.7	9.3	32.7	15.0	13.0	12.0	40.0
12-13	10.3	7.7	23.3	41.3	18.0	13.3	10.0	41.3
13-14	14.3	4.7	3.7	22.7	12.7	6.0	9.0	27.7
14-15	12.0	9.3	5.7	27.0	16.3	6.7	14.7	37.7
15-16	11.3	7.0	6.7	25.0	13.0	6.0	8.7	27.7
16-17	12.3	6.7	8.3	27.3	16.7	12.0	12.7	41.3
17-18	9.0	2.0	4.0	15.0	8.0	6.3	6.0	20.3
18-19	6.7	2.0	5.3	14.0	8.0	3.0	1.3	12.3
19-20	6.7	1.7	1.3	9.7	6.0	0.7	4.0	10.7
20-21	4.0	0.3	2.0	6.3	5.0	0.3	0.3	5.7
21-22	2.0	0	0.3	2.3	4.0	0	0	4.0
22-23	1.3	0	0	1.3	4.7	0	0	4.7
23-00	1.7	0	0	1.7	1.3	0	0	1.3
Total	170.7	89.3	131.7	391.7	189.0	94.0	120.3	403.3
*1 Daily ave. transportation (A)				33.1				
*2 Daily peak transportation (B)				82.6				
β (B/A)				2.5				

3.5.6 Waste

No significant problem was observed concerning the waste treatment in the port area, though the open dumping of solid waste had been conducted at the concealed places in the port area. Most of the solid wastes are carried to an open dumping site in Sekondi-Takoradi town area. This open-dumping site, however, has almost come to the end of its capacity. World Bank has supported a construction project of a solid waste treatment facility in Sekondi-Takoradi. The completion of this project will help the waste handling capacity of the Port to prevent the visual nuisance in the port area.

The solid waste at the port premises is usually garbage generated by calling vessels and port users (workers and visitors). An average of 5 tons of solid waste is generated per month. This amount is however dependent on the ship calls per month.

Garbage is collected into 25 large size garbage bins, which have been strategically placed within the Port and along its periphery. Disposal is carried out daily (weekdays) and costs between ¢ 15000 - 25000 per trip.

Sewage is generated on board vessels and by the port users (visitors and workers). The Port's waste management division has two sewerage disposal tanker vehicles, which siphon the sewerage tanks of vessels (on request) and dispose off at designated point within the Takoradi metropolis. These tankers are also responsible for collection of domestic sewerage from places of convenience that have been adequately provided to serve 12 people per time. This provision is made for every berth at the port.

Oil wastes are usually generated from the calling ships and they may pose a treat to the environment within the port area. The Ghana Port and Harbours Authority has no facility for ships to discharge oil waste at Takoradi Port. However in the event of spillage, pumps and a skimmer are mobilised at short notice for clearing the spillage.

3.5.7 Fishing Industry

All villages along the coast of Western Region are actively involved in fishing. These include New Takoradi, which directly overlooks the port, Poasi, European town and Shama all to the east and Adjua, Dixcove, Axim and Half Assin to the west of the port.

The continental shelf extends up to 80 km broad off the eastern to central part of Ghana. From Takoradi and eastwards, important fishing grounds of gill net fishing and purse seine fishing spread in a coastal zone up to 40 km from the coastline (Figure 3.5.1). According to the Fisheries Department of Western Region, there are spawning and fishing grounds for shrimps off Takoradi at water depths between 20 and 50 m, and spawning and feeding grounds for the Round Sardinella from 30 m and outwards on the shelf.

In spite of a regulation prohibiting the all types of fishing operation within the vicinity of the port, many canoes of various sizes in operation were observed during the field reconnaissance.

3.5.8 Existence of Slums and Illegally Occupied Areas

Slums and illegally occupied areas are a common feature in the suburban areas within the metropolis. Prominent areas include the New Takoradi and Kwesimintsim townships in the Takoradi sub-metropolis and in Sekondi, the part of European township can be considered as such.

3.5.9 Land Use

Town of Takoradi has been formed on a hilly area separated by a small cliff from Atlantic Ocean. Three slope roads lead materials and commodities down to the Port from the town. The port area therefore has relatively small area with distinct circumstances from the town itself. The port area surrounded by the cliff is used almost all by port facilities, companies exporting and importing materials, and railroads.

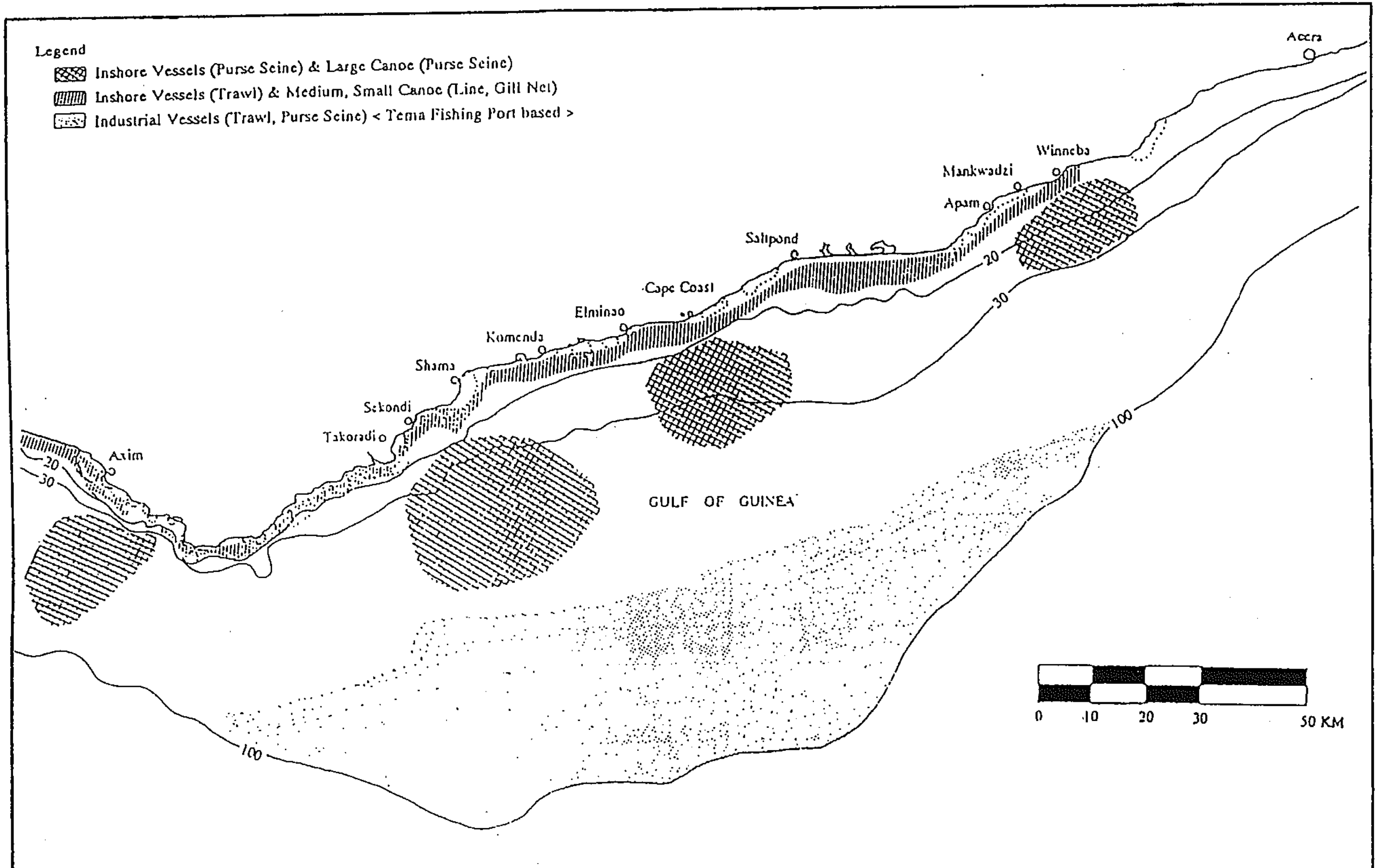


Figure 3.5.1 Fishing Grounds along Ghana's Coast

Source: Proposed Sekondi Fishing Port. Environmental Impact Statement. GPHA (1997)

Public Health and Safety

Takoradi Port and its surrounding town area has not suffered from significant health and safety hazards, though New Takoradi area has only deteriorated living condition. Provided with upgraded sewerage and sophisticated waste management system, the quality of life will be greatly improved.

Chapter 4 Assessment of Impact

Fourteen (14) environmental elements needed to be assessed on the impacts, as shown in the TOR for EIA. The impacts on these elements were identified for every phase of the project, i.e. preparation phase, construction phase and operation phase. Every activity likely to have impacts on the environment was listed up and its environmental impacts were evaluated. The result is summarized in Table 4.1.1.

It is not reality for the port development to assume demolishing port structure. When demolition becomes necessary, it will be to implement the further development of the port. In the present study, therefore, the demolition phase was not considered. Instead, impacts of the demolition of existing facilities during the construction phase were taken into account.

In Table 4.1.1, the significance of the environmental impact was evaluated from the viewpoint of "Importance" and "Magnitude". "Importance" was classified into five (5) ranks positively or negatively (second row of Table 4.1.1). The classification was based on the following points of view:

- How local people and/or port workers value the environmental element to be affected.
- Whether or not the environmental element has a value of national/regional/global level which the local people are not aware of.
- Whether or not improving the situation of the environmental element leads the poverty reduction in the local community.

Thus, "Importance" is the property of the environmental elements for local people, port workers and other relevant persons/parties/organizations, regardless of the contents and scale of the development activity involved.

"Magnitude" was also classified into five (5) ranks (top of each cell of Table 4.1.1). Criteria for the classification include the followings:

- Degree and/or scale of the impact on the environmental element
- Whether the impact is temporal, residual or permanent.
- Whether the impact is reversible or irreversible.

Thus, "Magnitude" is determined through the extent of the environmental alteration by the proposed development activity.

Finally, the evaluation of the significance of the environmental impact was made multiplying "Importance" by "Magnitude". The obtained values were put on the bottom of each cell of Table 4.1.1.

Justification on the ratings for each element is shown below.

- Progress of air pollution (AP): Although, Ghana has an Environmental Quality Standard for air quality, air pollution is still causing various health hazards and nuisance and is a major concern for the local people.
- Progress of water pollution (WP): Despite the poor water quality in the Takoradi port basin and the surrounding coastal waters, no Environmental Quality Standards for recipient water

has yet been established in Ghana. Local people do not show the concern on the seawater quality.

- Bottom sediment pollution (SP): Though the local people might be unaware of sediment pollution, high concentration of heavy metal substances have been recorded in the port area, which could potentially have an adverse affect on the health of local residents through biological accumulation.
- Noise generation (Noi): Noise is not a major concern for the local people as yet, with GPHA receiving no noise complaints so far. However, noise level in the port area sometimes exceeded the Ghana Environmental Quality Standards.
- Odor generation (Odr): Despite the unique smell emitted from cacao beans, odor complaints from local residents and port workers are uncommon. Future import or export commodities are not expected to emit any odor.
- Progress of Erosion (Ero): Erosion is occurring along the seaward side of the lee breakwater and up towards the industrial zone.
- Deterioration of Fauna/Flora (F/F): Natural vegetation is scarce and no significant fauna is observed in Takoradi area.
- Promotion of Economic Activities (EA): The livelihood of the local people is intimately linked to the presence of the port. The local people are engaged in various forms of port related activities, which could either be directly or indirectly related. Indirect port related activities include manufacturing, repairing, transportation and fishing. Increased port activity will lead to the poverty reduction in Takoradi.
- Resettlement (RES): Resettlement of port facilities could disturb the efficiency of port workers.
- Development of Infrastructure (INF): With many unpaved roads and inadequate sewage systems, improvement of infrastructure is a key issue among the local people. Improvement in the infrastructure will lead to the poverty reduction.
- Promotion of Fisheries (Fsh): Fisheries is an important industry for Takoradi and has contributed to the poverty reduction. A strong interest in fisheries exists among the local people.
- Rational Land Use (LU): Land use must be carefully planned, due to the limited land area in Takoradi.
- Waste generation (Wst): The importance of waste management is strongly emphasized in the Ghana EIA guideline, since many disposal sites are approaching its full capacity.
- Promotion of Public Health and Safety (HS): There is a strong interest in Public Health and Safety among the local people, but poverty reduction is their first priority.

Table 4.1.1 Environmental Impact Matrix

Element / Importance / Activity	AP	WP	SP	Noi	Odr	Ero	F/F	EA	Res	Inf	Fsh	LU	Wst	HS
Importance	-3	-1	-3	-1	0	-2	0	+5	-3	+5	+1	+1	-3	+2
Preparation Phase (no activity)														
Construction Phase														
Dredging & other marine works		2 -2	-2 +6	1 -1							0 0		1 -3	
Construction machines, and vehicles/vessels	1 -3	0 0		1 -1				1 +5			0 0		1 -3	-1 -2
Reclamation	1 -3	1 -1					0 0				0 0		-1 +3	
Demolition of existing facilities	1 -3			1 -1					0 0				1 -3	
Employing construction workers		1 -1						2 +10					2 -6	
Operation Phase														
Altered port configuration		0 0	1 -3			-2 +4					0 0			
Increased ship-call		0 0						2 +10			0 0		2 -6	
Increased cargo-handling	2 -6	0 0		3 -3	0 0			2 +10					2 -6	-1 -2
Increased port workers		0 0						3 +15					2 -6	
Port-associated development										2 +10				
Rearrangement of facilities							0 0					0 0		
Increased land transportation	1 -3			3 -3			0 0	2 +10						-2 -4
Demolition Phase (not applicable)														

top: Magnitude of impact
bottom: Significance of impact (importance × magnitude)

AP: Progress of air pollution
WP: Progress of water pollution
SP: Bottom sediment pollution
Noi: Noise generation
Odr: Odor generation
Ero: Progress of Erosion
F/F: Deterioration of Fauna/Flora
EA: Promotion of Economic Activities
Res: Resettlement
Inf: Development of Infrastructure
Fsh: Promotion of Fisheries
LU: Rational Land Use
Wst: Waste generation
HS: Promotion of Public Health and Safety

4.1 Air Quality

Since Takoradi area has no accumulated industrial area, it has not suffered from air pollution resulted from gas emission. The area seemed to have enough capacity to receive gases emitted by port construction and operation activities. The evaluation of impact on the air quality, therefore, focused on the dust generation by the development activities.

4.1.1 Construction Phase

The construction activities that give rise to dust generation include the followings:
- Activity of dump truck, bulldozer and other machines
- Landfill
- Demolition of wharves and docks

At the peak time of the construction work, it is presumed that three (3) dump trucks, three (3) bulldozers and a few other machines will be operated at the same time. The presumed impact of these machines will be small, and considering the present situation of the dust concentration (Table 3.3.3), it will meet the permissible noise level of Environmental Quality Standards.

Landfill and demolition of existing facilities would have a smaller impact further. Because landfill will use dredged wet materials and will result in small amount of dust. Demolition will generate dust only momentarily.

4.1.2 Operation Phase

(1) Methodology

Impact of the future port activity on the air quality, particularly the dust concentration was evaluated using the method shown in Figure 4.1.1. In this analysis, all the impacts caused by increased ship-call, cargo-handling and land transportation were considered together.

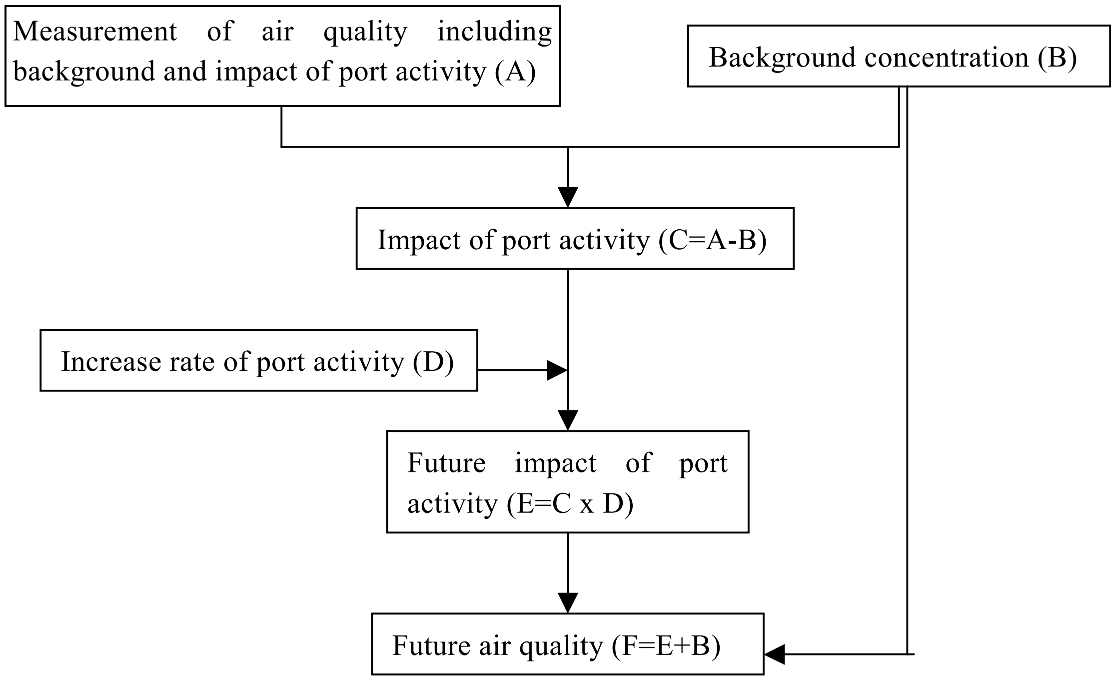


Figure 4.1.1 Flow chart of air quality modeling

1) Measurement at survey site (A). Background concentration also measured at a site with no impact of port activity (B).
2) Present impact of port activity on air quality calculated by subtracting the background concentration from the measured air quality value (C).
3) Future impact of port activity on air quality then estimated by multiplying the rate of emission increase to the magnitude of impact obtained in 2) (E).
4) Future air quality concentration obtained by adding the value in 3) to the background concentration (F).
5) Figures of annual cargo-handling volume were used to obtain (D).

(2) Application of Air Quality Model to Takoradi Port

(a) Present Impact of Port Activity on Air Quality

Present impact of port activity on the air quality was calculated by subtracting the background concentration from the measured air quality value (see Table 3.3.3). The value of St. 10 was set as the background concentration. Present impact of port activity was obtained as shown in Table 4.1.2.

Table 4.1.2 Present Impact of Port Activity on Air Quality in Takoradi Port

($\mu g/m^3$)

	1	2	3	4	6	8	9
TSP(1hr)	11.6	35.3	34.3	33.2	5.0	1.4	0.4
PM_{10}(1hr)	5.5	26.0	20.5	28.0	3.1	1.3	0.5

2) Increase Rate of Future Activity

Based on the annual cargo volume, intensity of future port activity was estimated by the following formula.

$I = (Vf / Vp) \times \alpha \times \beta$

Where, I: Increase rate
Vf: Annual cargo volume in 2010
Vp: Annual cargo volume in 2000
α: Monthly change rate (monthly peak transportation / monthly average transportation
β: Daily change rate (daily peak transportation / daily average transportation)

For Sts. 3 and 4, clinker transportation was applied, while other commodities than clinker and bauxite was assumed for Sts. 1, 2, 6, 8 and 9. Vf / Vp will be 1.31 (991,760 / 755,525 tons)for Sts. 3 and 4, and 1.74 (3,381,000 / 1,879,662 tons) for other Stations. α of 1.52 for Sts. 3 and 4, and 1.34 for other Stations were obtained based on the port statistics in 2000. For β, road traffic data of trailers/trucks (Table 3.5.2) were used as an indicator of diurnal fluctuation of port activity. Obtained β were 2.28 for Sts. 3 and 4, and 3.36 for other Stations.

Table 4.1.3 Monthly change rate (α) of transportation in Takoradi Port

Monthly transportation	Station 3,4	Station 1,2,6,8,9
JAN	69,473	83,883
FEB	44,738	161,960
MAR	55,955	139,146
APR	70,631	85,776
MAY	45,546	205,737
JUN	68,464	183,309
JUL	67,190	142,743
AUG	68,634	208,188
SEPT	50,888	155,226
OCT	88,085	187,512
NOV	28,913	176,751
DEC	35,857	128,088
Total	694,374	1,858,319
Monthly ave. transportation	57,864.50	154,859.92
Monthly peak transportation	88,085	208,188
α	1.52	1.34

Increased rate was calculated as below:
For Sts. 3 and 4: 4.54
For Sts. 1, 2, 6, 8 and 9: 7.83

3) Future Impact of Port Activity

Future impact of port activity on air quality was estimated by multiplying the Increase rate and present impact obtained in Table 4.1.2. Calculated future impact is shown in Table 4.1.3.

Table 4.1.3 Future Impact of Port Activity on Air Quality in Takoradi Port

(μ g/m^3)

	1	2	3	4	6	8	9
TSP(1hr)	90.8	276.4	155.7	150.7	39.2	11.0	3.1
PM_{10}(1hr)	43.1	203.6	93.1	127.1	24.3	10.2	3.9

4) Future Air Quality Concentration

Rising dust concentration may become an adverse impact to port workers. Ambient air quality in the future was estimated as shown in Table 24.4.2. Environmental Quality Standards (EQS) has set the TSP and PM_{10} values for industrial area as 24-hr value or 1-yr value. As estimation carried out here is based on the 1-hr value, the immediate comparison is not reasonable. Considering the fact that the ratio of 1-hr value to 24-hr value falls into 3:1 to 4:1 in most case of environmental standards of various countries, the assumed EQS (1 hr) would be about 700 for TSP and 250 for PM_{10}. Obtained air quality (1 hr) will meet the EQS, barely in some locations. Proper mitigation measures will be necessary for loading/unloading facilities of manganese and clinker to reduce dust concentration.

Table 4.1.4 Estimated Air Quality in Takoradi Port (2010)

(μ g/ m^3)

	1	2	3	4	6	8	9	EQS
TSP(1hr)	96.5	282.1	161.4	156.4	44.9	16.7	8.8	24 hr: 230, 1 yr: 70
PM_{10}(1hr)	45.1	205.6	95.1	129.1	26.3	12.2	5.9	24 hr: 70

4.2 Water Quality

4.2.1 Construction Phase

The following activities will affect the water quality in and around the port area:

- Dredging and other marine works will generate turbid water.
- Work boats will discharge bilge and other waste water.
- Reclamation work will squeeze turbid water to the receipt water area.
- Construction workers will generate waste water through the daily life.

Among these, dispersion of turbid water caused by dredging activity seemed to have the most significant impact. The suspended solid (SS) concentration, therefore, was predicted using hydrodynamic and diffusion modeling.

(1) Methodology

Tidal currents of Takoradi Port are modeled by numerical model of hydrodynamics. The model describes time-varying water levels and depth-averaged circulation of seawater. This type of model is appropriate for Takoradi Port area because vertical gradients of physical properties are relatively small. The basic equations of the model are:

<Equation of Continuity>

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad \cdots\cdots (1)$$

<Equation of Motion>

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{1}{\rho_0}\frac{\partial p}{\partial x}+\frac{\partial}{\partial z}\left(K_M\frac{\partial u}{\partial z}\right)+F_X \quad \cdots\cdots (2)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{1}{\rho_0}\frac{\partial p}{\partial y}+\frac{\partial}{\partial z}\left(K_M\frac{\partial v}{\partial z}\right)+F_Y$$

Transport and diffusion of contaminants are modeled by numerical model of diffusion. The diffusion model describes the movement of contaminants based on the current field obtained by the hydrodynamic model. The basic equation of the model is:

<Equation of Diffusion>

$$\frac{\partial S}{\partial t}+u\frac{\partial S}{\partial x}+v\frac{\partial S}{\partial y}+w\frac{\partial S}{\partial z}=\frac{\partial}{\partial z}\left(K_H\frac{\partial S}{\partial z}\right)+F_S \quad \cdots\cdots (3)$$

where,

x,y,z	: right hand coordinate
u,v,w	: x,y,z component of currents [cm/s]
p	: pressure [g/cm/s^2]
f	: Coriolis parameter[1/s]
ρ_0	: representative density [g/cm^3]
K_M	: eddy viscosity [cm^2/s]
K_H	: eddy diffusivity [cm^2/s]
F_X, F_Y	: other forces [cm/s^2]
S	: concentration [mg/L]
F_S	: loads [mg/s]

(2) Application of Hydrodynamic Model to Takoradi Port

Hydrodynamic model was applied to Takoradi Port for the present condition and Y2010 condition. The data used for the model are shown below.

- Model area: 5000 m by 5000 m (see Figure 4.2.1)
- Grid size: 100 m
- Bathymetry: Bathymetry was set up based on the marine chart updated in Y2000. Present condition is shown in Figure 4.2.2 and Y2010 condition is shown Figure 4.2.3. Y2010 condition adds two changes to the present condition. They are 1) bathymetry change by dredging inside and outside of the port and 2) extension and new construction of breakwaters.
- Boundary conditions:
    1) Water levels on open boundaries were forced by semidiurnal oscillation (M_2) of 44 cm observed in Takoradi (Admiralty Tide Tables Vol. 2, 1999).
    2) River discharges and surface runoff were set as shown in Figure 4.2.4 estimated from the average precipitation.
    3) Wind frictions were included in F_X , F_Y based on the average summer wind condition of SW 4.1 knot (Meteorological Services, Takoradi, 1973–99).

(3) Results of Hydrodynamic Model

Current vectors are shown in Figure 4.2.5 for the present condition and in Figure 4.2.6 for Y2010 condition. Eastward or northward currents dominated in both rising tide and ebb tide due to SW wind conditions. Tidal currents were relatively small and dominantly found near the mouth of Takoradi Port due to water exchange between breakwaters. Validation of the results by field survey data is expected if the data are available.

(4) Application of Diffusion Model to Dredging Impact Assessment

Dredging impacts to suspended solid (SS) concentrations during dredging works were predicted by the diffusion model. Two cases were considered as 1) dredging inside Takoradi Port and 2) dredging outside Takoradi Port.

Pollution loads of SS by dredging works were estimated based on the following conditions.

- 200,000 m^3 of sediment is dredged per month. 400,000 m^3 as a total of two months.
- 24 hour operation everyday
- One suction dredger of 3,000 to 6,000 horsepower operates
- Silt screen is used to reduce impacts
- Grain size composition of the sediment is derived from the field survey

Based on the conditions, pollution loads were estimated as 3,643 kg/day inside the port and 5,828 kg/day outside the port referencing unit loads of similar dredger in Japan. Settling velocities were estimated for three ranges by Stokes law based on grain size distributions obtained at sampling locations in Figure 3.3.1. The grain size distributions are shown in Figure 4.2.7. The estimated settling velocities are shown in Table 4.2.1.

Table 4.2.1 Settling Velocities

Range	Grain size (mm)	Settling velocity (m/h)
Range 1	0.01 to 0.1	0.28
Range 2	0.1 to 1.0	28
Range 3	1.0 to 10.0	2800

(5) Results of Diffusion Model on Dredging Impacts

Predicted SS distributions are shown in Figure 4.2.8 for inside Takoradi Port and in Figure 4.2.9 for outside the Port. Both results suggested the impacts would be very limited to nearby dredging points mainly due to large settling velocities of the sediments. The mud particle to be diffused, however, is contaminated with heavy metals (lead and mercury). This requires special attention to minimize the diffusion.

Other impact than dredging would be smaller taking the situation of severely polluted seawater in the coastal area into account.

4.2.2 Operation Phase

In the operation phase, increased ship-call, cargo-handling and port workers will give more pollution load to the sea than the present. Altered port configuration may also effect on the water quality distribution. Considering all these imapcts, a diffusion model was employed to predict the future water quality distribution, based on the results of the hydrodynamic model introduced in the previous section.

(1) Application of Diffusion Model to Impact Assessment of Port Extension

Impacts of port extension to key water quality parameter, COD, were predicted by the diffusion model. Two cases were considered to estimate impacts: 1) present condition and 2) Y2010 condition. Impacts were expressed by difference of the two cases.

Pollution loads of COD from coasts were estimated as below based on field reconnaissance in the study and existing statistics. Discharge location numbers correspond to those in Figure 4.2.4.

Table 4.2.2 Pollution Loads of COD (unit: kg/day)

Location	Present	Y2010
Butua Lagoon	250	250
1	68	82
2	9	9
3-1	3	3
3-2	13	13
3-3	13	13
3-4	10	10
3-5	26	26
4	22	22

(2) Results of Diffusion Model on Impacts to COD

Predicted COD distributions are shown in Figure 4.2.10 for the present condition and in Figure 4.2.11 for Y2010 condition. Field survey data in the study are indicated in Figure 4.2.10 for comparison. The data ranged more than 200 % within 1 km and showed lower values (18.6 mg/L) inside the port and close to the coast. This suggested the possibility of polluted water from offshore. The simulated distribution corresponded such trend.

Compared with the simulated present distribution, the predicted Y2010 distribution changed in north of the port. This is considered due to the dominant northward currents shown in Figures 4.2.5 and 4.2.6.

To highlight impacts of port extension, the difference between the simulated present values and Y2010 values (Y2010 - present) was obtained as shown in Figure 4.2.12. COD values decreased in western side of the extended breakwater and increased in eastern side although pollution loads to the Port increased in Y2010. This suggested the extension of the breakwater would reduce the intrusion of offshore water of high COD concentration and prevent the port basin from the progress of the water pollution.

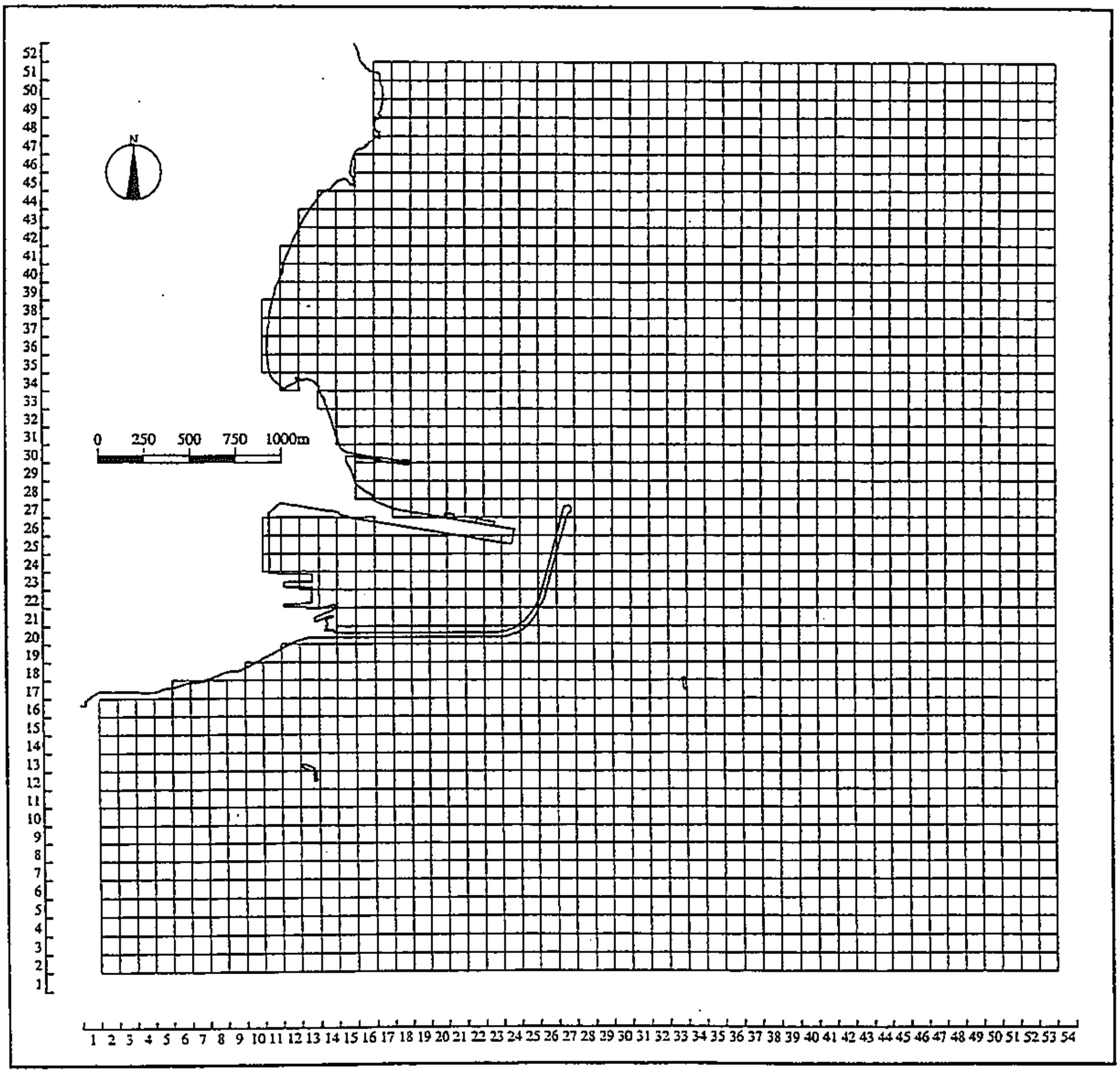


Figure 4.2.1 Model Area

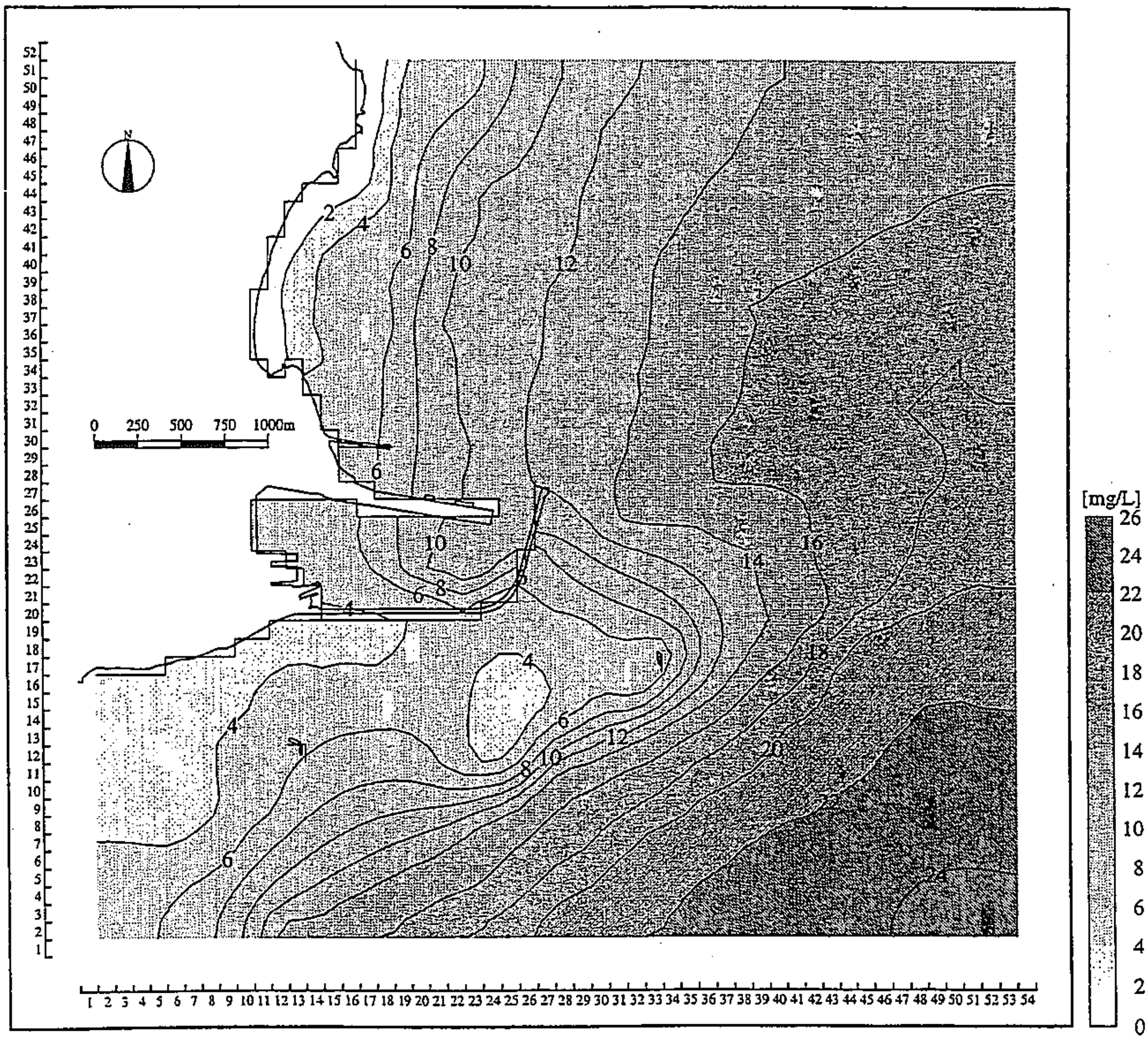


Figure 4.2.2 Bathymetry (Present)

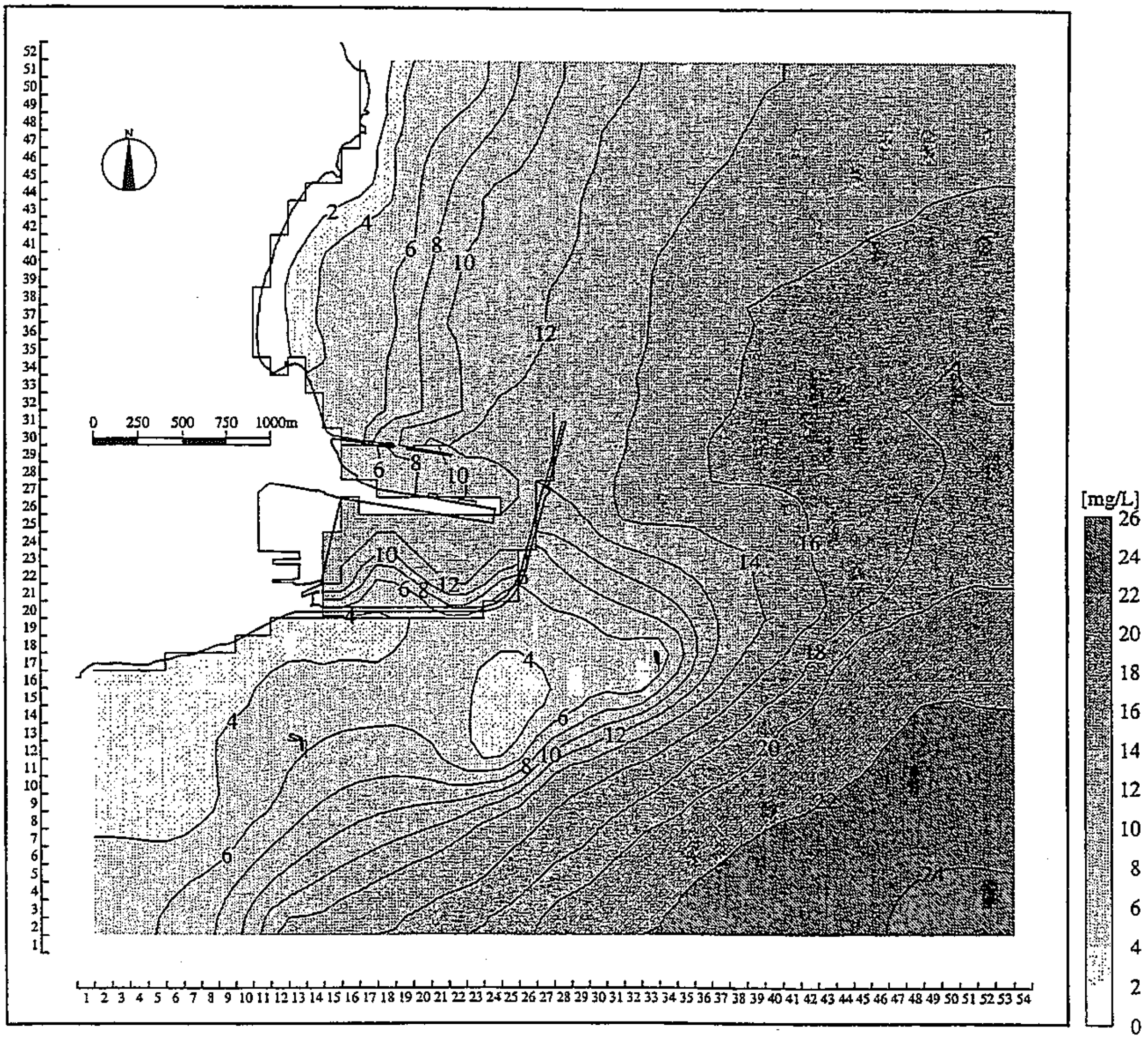
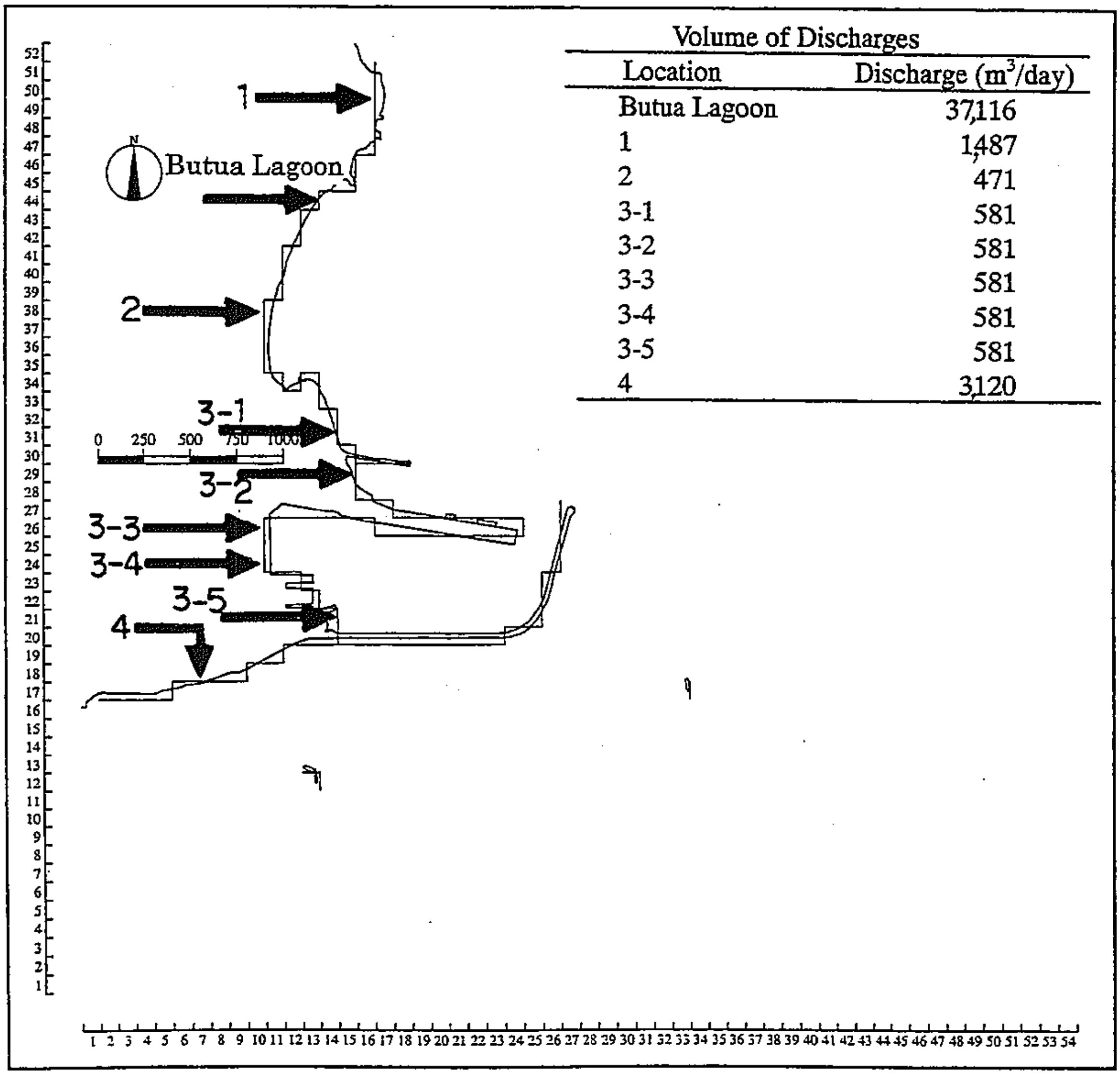


Figure 4.2.3 Bathymetry (Y2010)



Volume of Discharges

Location	Discharge (m^3/day)
Butua Lagoon	37,116
1	1,487
2	471
3-1	581
3-2	581
3-3	581
3-4	581
3-5	581
4	3,120

Figure 4.2.4 River Discharges and Surface Runoff

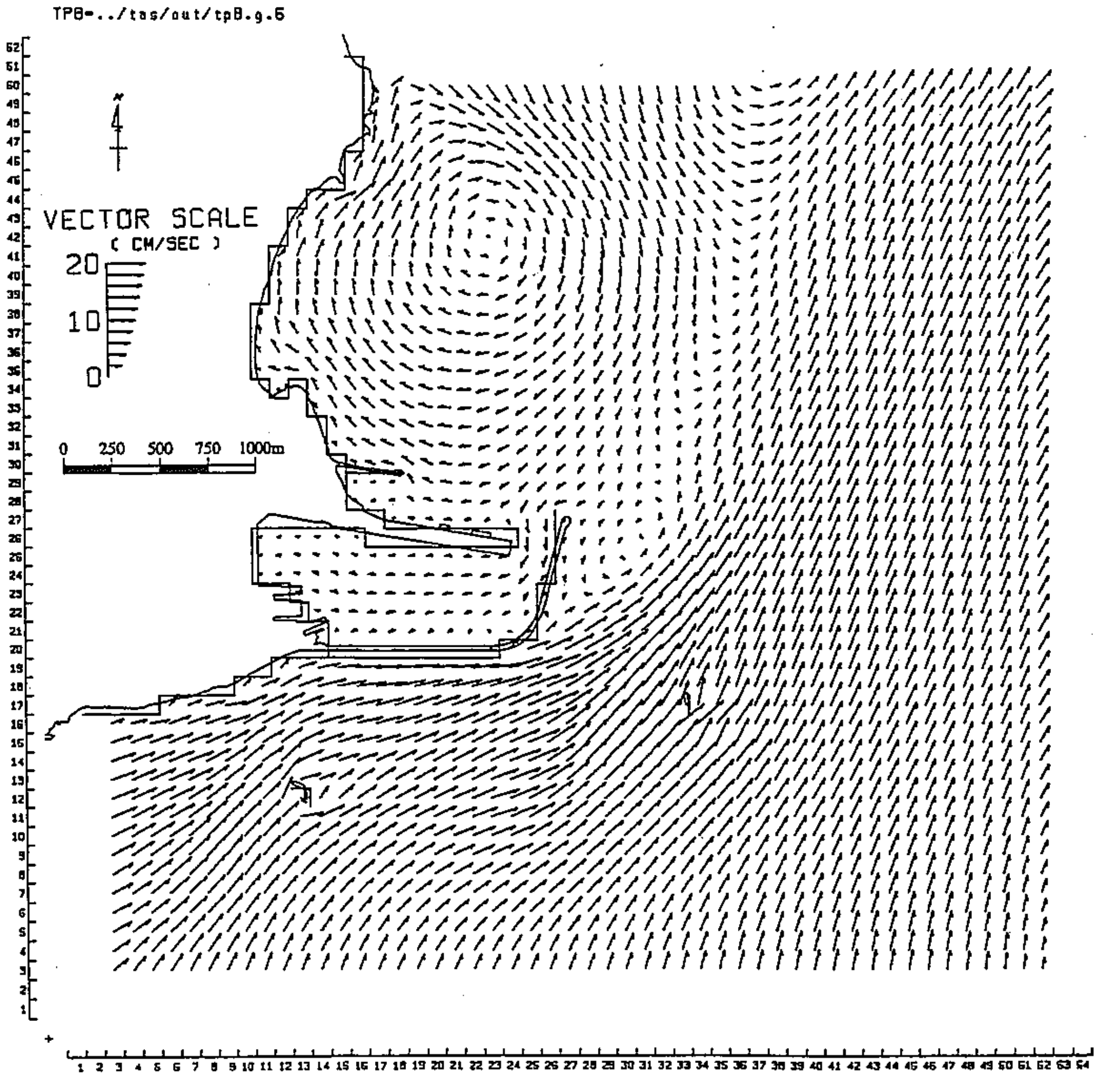


Figure 4.2.5(1) Simulated Current Vectors of Rising Tide (present)

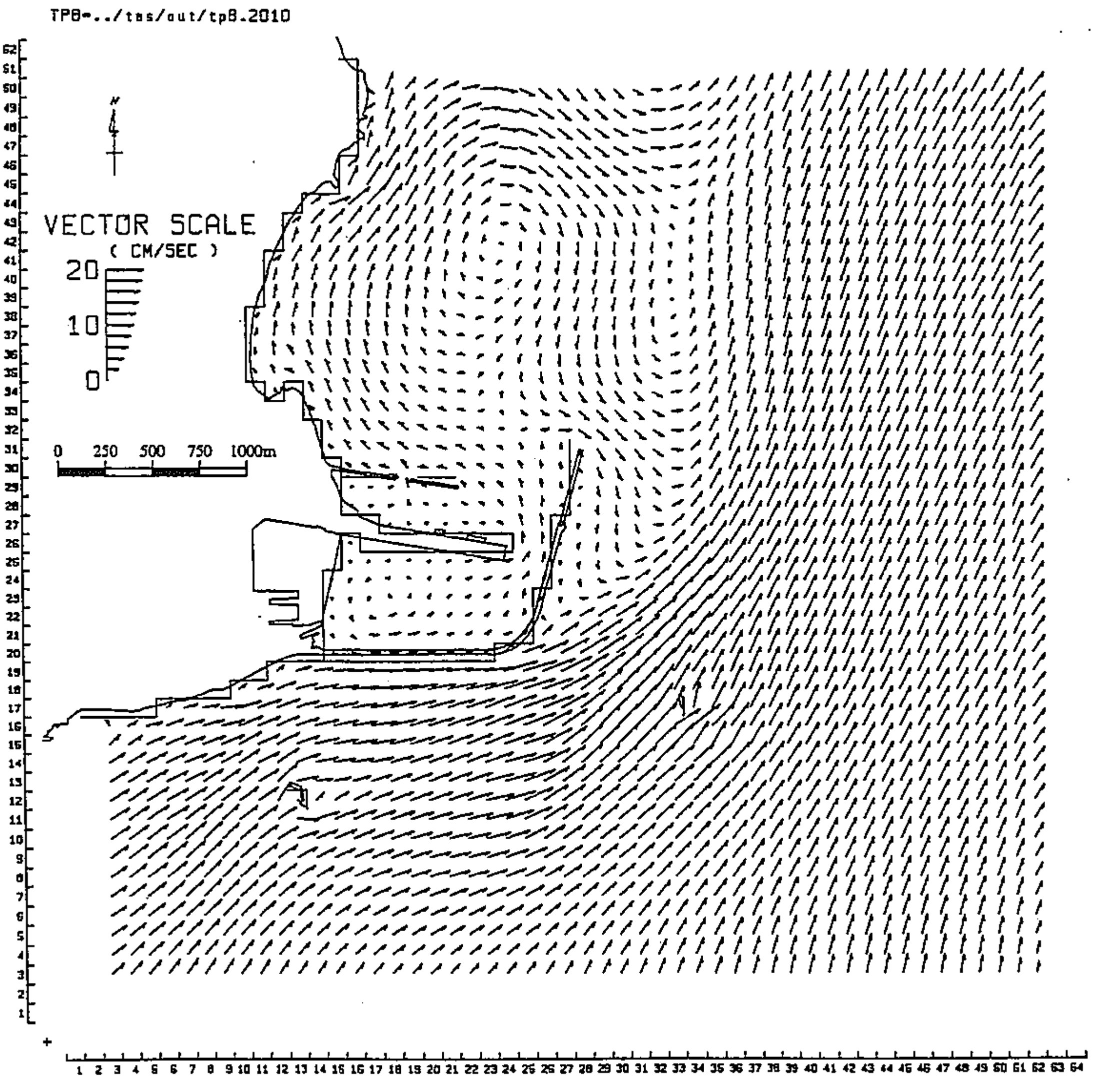


Figure 4.2.5(2) Simulated Current Vectors of Ebb Tide (present)

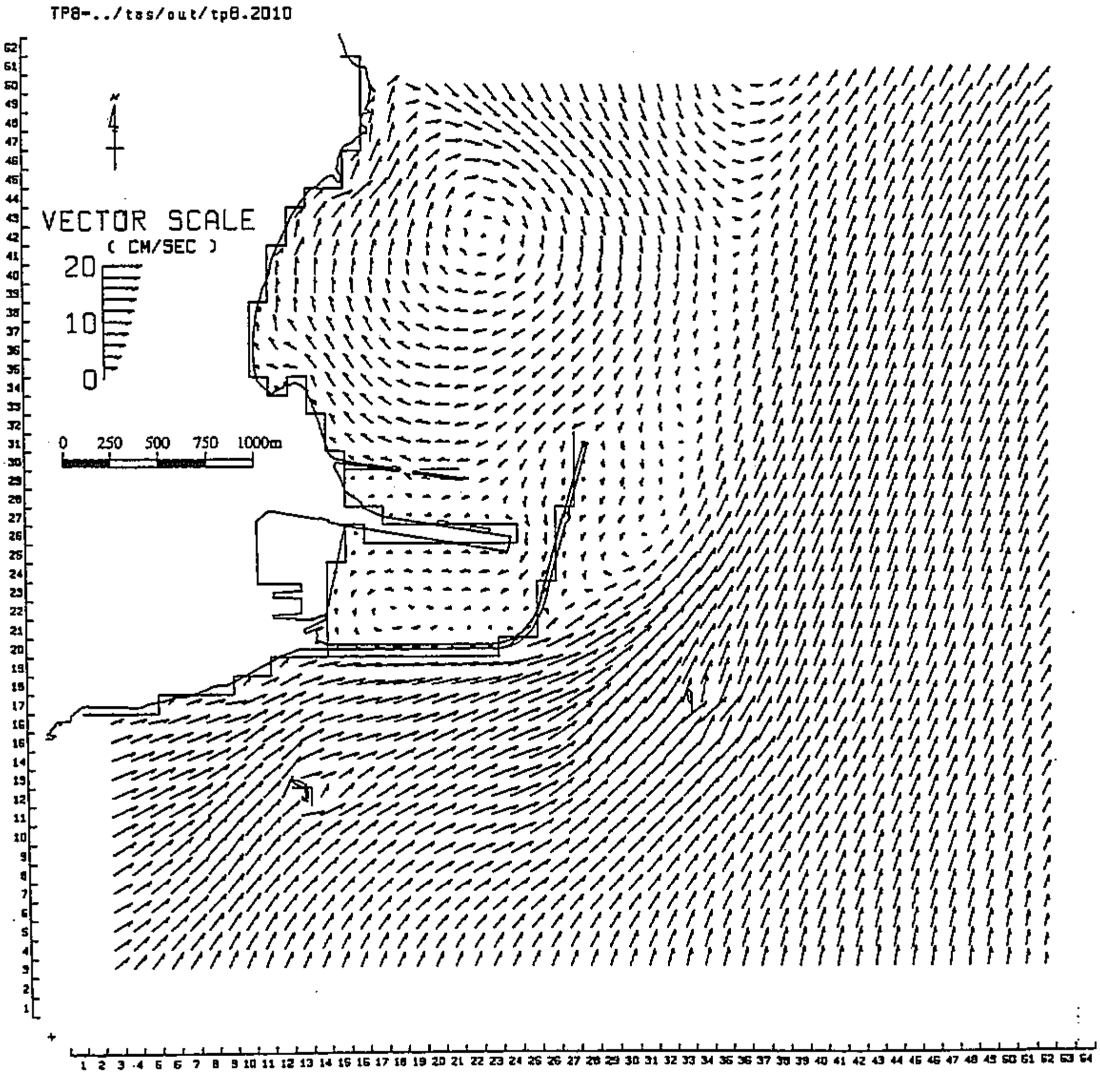


Figure 4.2.6(1) Predicted Current Vectors of Rising Tide (Y2010)

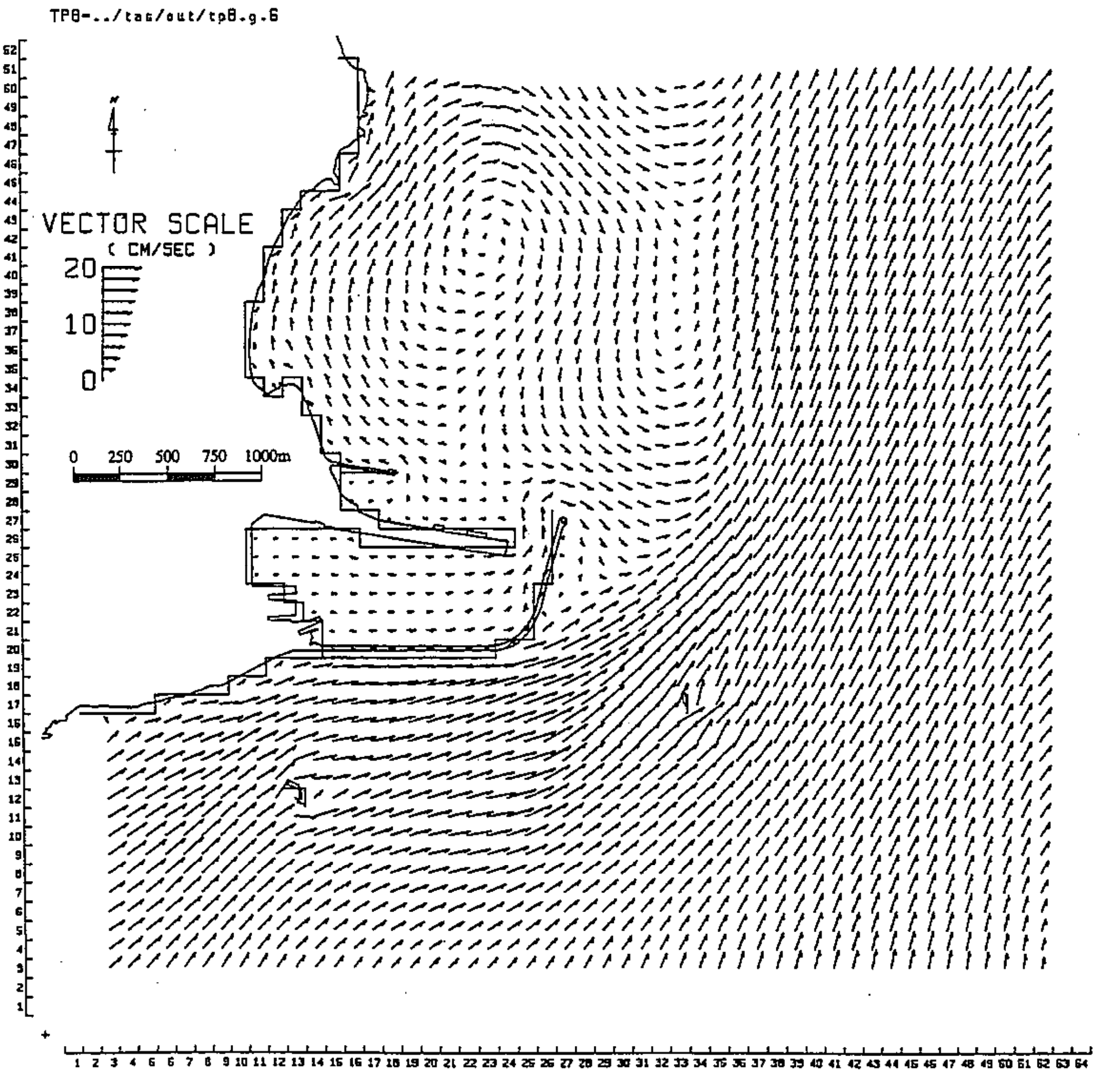


Figure 4.2.6(2) Predicted Current Vectors of Ebb Tide (Y2010)