GHANA PORTS AND HARBOURS AUTHORITY

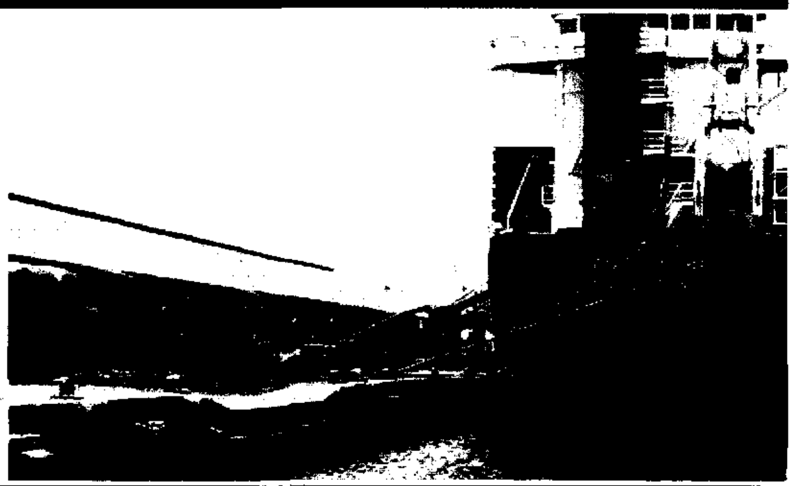
Feasibility Study for the Ghana Ports of Tema and Takoradi

Master Plans

VOLUME 2

April 2010

Submitted by Halcrow Engineers, PC



Task 3a: Master Plan Container Facilities Tema

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1000 Wilson Boulevard • Suite 1600 • Arlington, VA 22209-3901
Phone: 703-875-4357 • Fax: 703-875-4009 • Web site: www.ustda.gov • email: info@ustda.gov

Feasibility Study for the Ghana Ports of Tema and Takoradi Master Plans

VOLUME 2

Task 3a: Master Plan Container Facilities Tema

Halcrow Engineers, PC
22 Cortlandt Street
New York, NY 10007
Phone: 212-608-3990
Fax: 212-566-5059
Jens Korsgaard

Nathan Inc.
Two Colonial Place
2101 Wilson Boulevard, Suite 1200
Arlington, VA 22201
Phone: 703-516-7700
Paul Kent, Vice President

Environmental Solutions Limited
P.O. Box LG 239
Legon, Accra
Ghana
Phone: +233 (0)24-4771707
A.K. Armah, President

Planconsult
Total House, 4th Floor
25 Liberia Road
P.O. Box CT 1367
Cantonments, Accra
Ghana
Phone: 233-21-669-165
Ebow Bannerman, President

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Chapter 1 - Introduction

This report constitutes the activities conducted described in our proposal for the development of the master plan for the container facilities in the port of Tema. The report has been developed in conformance with Amendment 1 to our contract dated October 28, 2009.

In the report for task 1, a forecast was developed for future container traffic at Tema. Three different forecasts were developed which predicted future traffic; optimistic, best estimate, and low forecast. All three forecasts developed show that there is a need to increase the container handling capacity in the port of Tema.

The report was developed taking into consideration the existing container terminal operations agreement between Meridian Ports Services and the Port.

This report focuses on the expansion of the existing container facilities within the breakwater. A companion report addresses the case of adding a new container terminal outside the breakwater area.

The recommendation is to add additional berths within the breakwater area, perform reclamation of the land to the west of the port and develop that area as container yards, and in the event the high forecast materializes modifications to the existing main breakwater would be necessary to handle the volume.

Chapter 2 – Container Facility Requirements at the Port of Tema

2.1 Present Facilities

The Port of Tema has 12 berths designated to handle general cargo, bulk, and containers. In addition there is a berth designated for use by the Aluminum Company (VALCO) for the handling of alumina and a petroleum/liquid bulk berth operated by the Oil Company. Please refer to Figure 2.1. In 2009 the approximate water depth at Berths 1 & 2 was 12 meters, Berth 3 11 meters, Berth 4 9 meters, and Berth 5 through 12 8.5 meters.

There is a project to deepen Berths 10, 11, and 12 to 12 meters, however this project may or may not be executed.

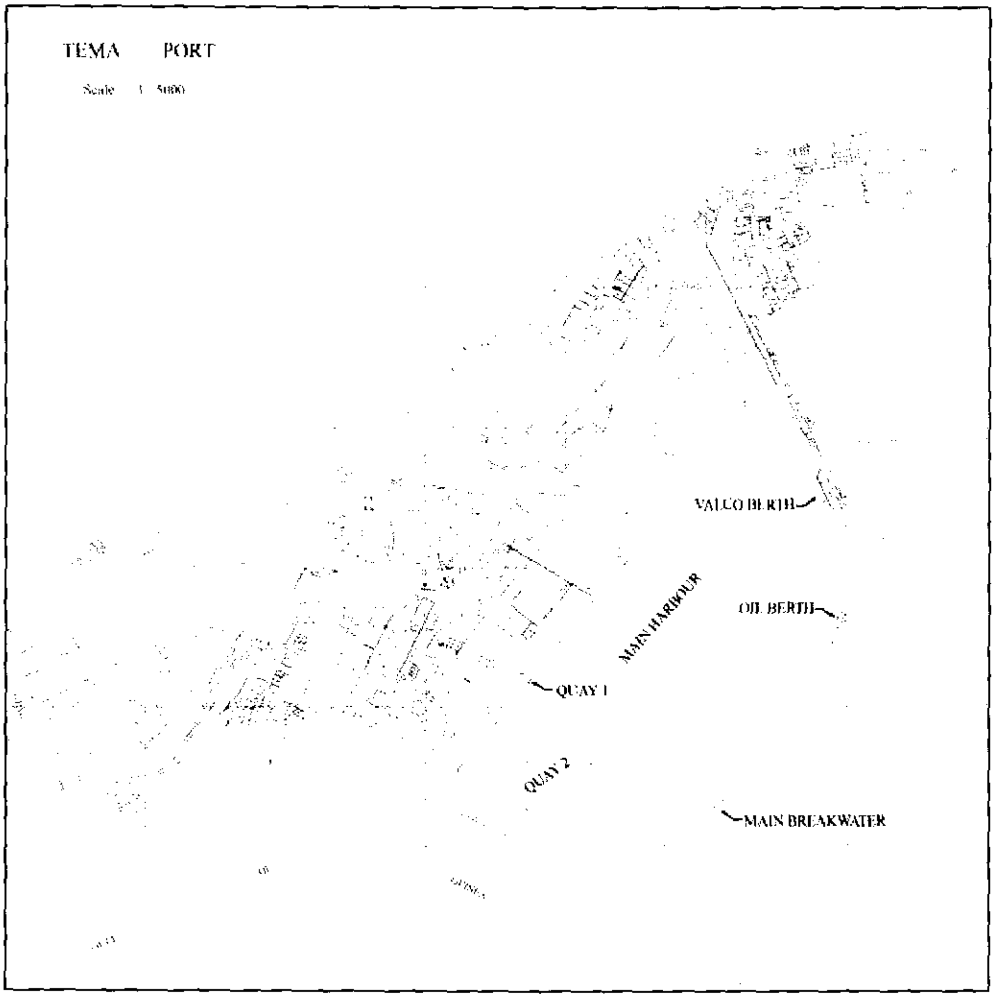
Berths 1 & 2 are dedicated for containers. The two berths (600 m) are equipped with three 18 meter gauge container gantry cranes. It is anticipated that one more container crane will be placed on these berths in the future.

From time to time containers are however handled at the other berths at the port i.e. Berth 3 through 12. At these berths containers are generally handled by geared ships or Ro-Ro ships relying on their own equipment to transfer the containers.

The terminal at Berths 1 & 2 is operated by Meridian Port Services (MPS). Meridian Port Services is a company that is understood to be partly owned by APM Terminals, Bollore, and by GPHA.

MPS, based on a contract entered into in 2004, commenced to operate a dedicated container terminal on berths 1 and 2 in conjunction with a dedicated modern container storage yard to the northwest. In return the company was granted exclusive rights to handle all container cargo inside the Port of Tema until the year 2024. Although they seem to have a monopoly it is not absolute. Other companies handling a small number of containers per ship call can operate independently within the port without restriction. In addition to the MPS container yard there is a container yard behind Berths 10, 11, and 12 which could be used for containers as well.

Figure 2-1
Present Facility Plan



A significant quantity of the containerized cargo is transferred to ordinary trucks for transport to and from the hinterland. The transfer of these goods to/from containers takes place at a dedicated facility at Tema operated by the Golden Jubilee Terminal. This company has a dedicated yard approximately 2km west of the port. Consequently, stuffing and un-stuffing of containers does not normally take place on the port premises.

2.2 Future Container Facilities needs

The master plan for the Port of Tema Container Terminal has been developed based on the updated optimistic cargo forecast provided in Volume 1 as presented in Table 2-1 below.

In August 2009 containers were being handled in the MPS container yard to the west of the port and in the areas behind berths 10 to 12. One way to increase the volume of containers handled in the port would be to enlarge the container storage area behind berths 10 to 12 and to dedicate the berths exclusively to containers. Plans exist whereby dredging would take place at berths 10 to 12 increasing the depth from 8.5m to 12 m. This would allow the same size vessels calling berths 1 and 2 to call berths 10-12. Unfortunately there has been no decision to carry out the deepening project as of the time of this report.

Table 2-1 Container Traffic Forecast Tema (TEU)

YEAR	Optimistic	Best Estimate	Pessimistic
2008	566,500	552,000	539,000
2009	641,845	609,408	581,042
2010	727,210	672,786	626,363
2011	823,929	742,756	675,220
2012	933,511	820,003	727,887
2013	1,051,367	900,910	781,750
2014	1,177,005	984,995	836,473
2015	1,309,713	1,071,674	891,680
2016	1,448,542	1,160,674	946,964
2017	1,592,310	1,249,993	1,001,888
2018	1,739,599	1,339,993	1,055,990
2019	1,888,769	1,429,326	1,108,790
2020	2,037,982	1,516,991	1,159,794
2021	2,185,226	1,601,942	1,208,505
2022	2,328,359	1,683,107	1,254,429
2023	2,465,150	1,759,408	1,297,079
2024	2,593,338	1,829,785	1,335,991
2025	2,728,191	1,902,976	1,376,071
2026	2,870,057	1,979,095	1,417,353
2027	3,019,300	2,058,259	1,459,874
2028	3,176,304	2,140,589	1,503,670

**Note: Heavy Lines indicate need for expansion*

Presently berths 10 through 12 handle other types of cargo than just containers.. Berth 12 handles the import of clinker for the Ghana Cement Company (GHACEM). If these berths were to be dedicated to containers the existing non-container operations would need to be relocated. This would require additional berths to be developed outside the Port of Tema Harbour. Some of this traffic could be diverted to Takoradi or it could be relocated to the ship repair facility or the fishing harbour.

Widening of the container yards behind berths 10 through 12 can only be done by removing the existing warehouses and/or by relocating the Eastern Gate. Both of these alternatives would be disrupt operations and be very expensive to complete.

Converting the ship repair facility to port traffic use was by direction of GPHA not to be considered in this present study. Relocating some of the traffic to the fishing harbour would create yet another set of disruptions to that facility.

Container throughput in year 2007 was 495,000 TEU. Numbers shown for the years 2008 to 2028 are projected.

In order to determine the number of container berths required to meet the projected cargo throughput, it has been assumed that:

1. The annual berth capacity in the first year of operations is 1,000 TEU per linear meter of berthing front. Therefore, for each of the two existing 300-m long MPS berths (Berths No.'s 1 and 2) the initial throughput capacity is 300,000 TEU per year.

2. Each of the new berths, identified as Berths No.'s C3 through C7 and assumed to be 320 m long, has a throughput capacity projection of 320,000 TEU per year.

3. Due to improvements of container handling procedures, introduction of new technology, and improved training of the port personnel, the annual berth capacity in the subsequent years of operations grows. This growth has been assumed to be 5% of the initial capacity per year, for the first four years, after which it will remain constant.

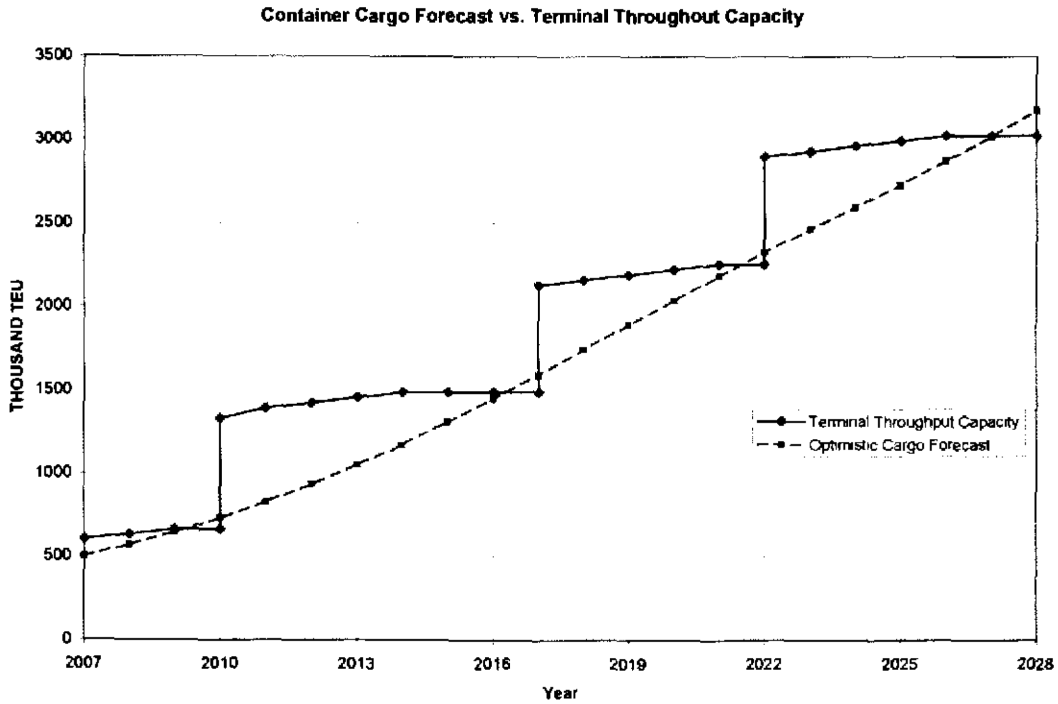
4. When the projected container throughput reaches the estimated terminal capacity two new berths shall be constructed and placed into operations.

The container terminal volume for the years 2008 to 2028 has been estimated and is presented in Table 2-2 below.

Table 2-2 Capacity Development Tema Container Terminal

YEAR	HIGH FORECAST THO.TEU	BERTH ANNUAL THOUGHPUT CAPACITY, THO. TEU				
		BERTH 1-2	BERTH 3-4	BERTH 5-6	BERTH 7-8	TOTAL
2007	495	600				600
2008	566	630				630
2009	642	660				660
2010	727	690	640			1,330
2011	824	720	672			1,392
2012	934	720	704			1,424
2013	1051	720	768			1,456
2014	1177	720	768			1,588
2015	1310	720	768			1,488
2016	1449	720	768			1,488
2017	1592	720	768	640		2,128
2018	1740	720	768	672		2,160
2019	1889	720	768	702		2,192
2020	2038	720	768	736		2,224
2021	2185	720	768	768		2,256
2022	2328	720	768	768	640	2,896
2023	2465	720	768	768	672	2,928
2024	2593	720	768	768	702	2,960
2025	2728	720	768	768	736	2,992
2026	2870	720	768	768	768	3,024
2027	3019	720	768	768	768	3,024
2028	3176	720	768	768	768	3,024

Figure 2-2
Container Cargo Forecast vs. Terminal Throughput Capacity



As noted in Table 2-2 above, two new berths would need to be built and put into operations in the years 2010, 2017, and 2022. In the year 2028, the projected cargo throughput will slightly exceed the estimated terminal capacity but for planning purposes was ignored. Evident also shows that terminal capacity will exceed demand for a few years after the new berths are put in operation, specifically in the years 2010 to 2014, 2017 to 2020, and 2022 to 2024. Although transshipment cargo was not analyses for this project, the extra capacity could be used for such work potentially reducing the extra space and increasing revenue. A graphical representation of the cargo forecast and terminal throughput capacity over time is shown in Figure 2-2 above.

Terminal development staging based upon the high forecast is summarized in Table 2-3 below. After completion of the projected development the terminal will have a total of 8 berths including the two existing MPS berths, 6 of which will be new berths developed by the year 2022.

Table 2-3 Staging of Container Terminal Development

STAGE NO.	YEAR	NUMBER OF BERTHS	
		ADDED	TOTAL
Existing	-	-	2
1	2010	2	4
2	2017	2	6
4	2022	2	8

2.3 Other needs

This report is limited to assessing the container terminal in Tema. The taking of berths 3,4, and 5 for the exclusive use for container ships will displace the current non-container cargo which will need to be accommodated at other berths within the port of Tema.

Some of the container operations taking place at berths 6 through 12 will be accommodated at the container terminal thereby opening up capacity that can be used to meet the needs of vessels no longer able to access berths 3 through 5.

Although not considered in this report, berths 6 through 12 may require improvements to the re efficiency and capacity.

Chapter 3 - Physical Conditions at the Port of Tema

3.1 Physical Environment

The description of the physical environment has been obtained through existing reports and publications. No field investigations were made. However, a walkthrough inspection of the port was made in April 2008.

3.1.1 METROLOGICAL CONDITIONS

The Tema area is one of the moderate rainfall parts of the Ghana. The main rainy season is in May and June, followed by a late minor rainy season lasting from October to November. The dry season lasts from around December to around March.

Details of data on Temperature, Relative Humidity, Rainfall and Wind are presented in the following sections.

a) *Temperature*

The hottest periods of the year in Tema are in the months of February and March with daytime temperatures reaching up to 35°C. This is the period preceding the onset of the minor rains. The mean monthly temperature during this time is about 29°C. July and August are relatively cooler months with mean temperatures of 26°C. Table 3-1 shows monthly average temperatures.

Table 3-1 The Monthly Average Temperatures - Tema

(Unit:°C)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	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 Department, Tema (from JICA)

b) Relative Humidity

The variation in Relative Humidity 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 3-2 gives the monthly average Relative Humidity at Tema.

Table 3-2 Relative Humidity Data for Tema

(Unit: %)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	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 Department, Tema (from JICA)

c) Rainfall

The minor rainy season begins around March and reaches its peak of about 300 mm / month at Tema in the month of June, when the region comes under the influence of the moisture-laden South-West winds. Rainfall declines after June to August after which it starts rising again and reaches to about and about 100 mm / month at Tema in October.

The monthly average rainfalls for the period 1961-2000 recorded at the Tema Meteorological station are shown in the Table 3-3.

Table 3-3 Monthly Rainfall (mm/month)– Tema

(Unit:%)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Tot.
61-97	20.2	32.0	62.7	110.1	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 Department, Tema (from JICA)

d) Wind

The North-East Trade and the South-West Monsoon are the major winds which influence the project area. In addition to this is the daily changes in the wind direction, resulting from the differential heating and cooling of the land and sea, During the day, the local breeze is therefore from off-shore and the reverse occurs in the night. The prevailing wind influencing the area is from south to south-west.

Table 3-4 below gives the monthly average wind velocity for the period 1973-1999 at Tema expressed in m/sec.

Table 3-4 Monthly Average Wind Speed and Direction (1973-99) – Tema

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	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 Department, Tema (from JICA)

3.1.2 HYDROGRAPHIC CONDITIONS

a) Tide Levels

The tide in Ghana is semidiurnal with two high and low tide levels each day. There is no time difference between Takoradi and Tema Ports. The tide levels of the Ports in Ghana are referenced to the port of Takoradi. The datum of the Nautical Chart is approximately referenced to lowest Astronomical Tide (LAT). The tidal levels are referenced to this and are shown in Table 3-5.

Table 3-5 Tide Levels of Tema Port

(Unit: m)

	MHWS	MHWN	MLWN	MLWS
GPHA	1.6	1.3	0.7	0.3

Tema Port: 5° 38′ N.0° 01′E

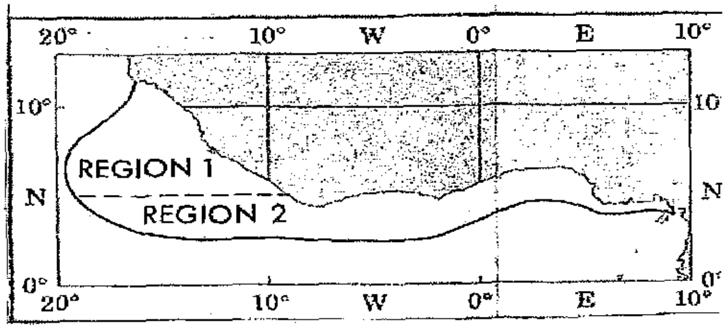
Source: US Chart 57082 Port of Tema and Accra Roads 3rd Edition Nov.17, 1990

b) Currents

The offshore current in Ghana flows toward the east and is driven by the Guinea Current. The Guinea current is reduced in magnitude near the coast due to the friction at the sea bed. Super imposed on the eastward Guinea current are very weak tidal currents. Neither of these currents impact navigation to and from the Port of Tema.

During the northern summer the Guinea Current begins at about 14° W as the eastern extension of the well-established Atlantic Equatorial Countercurrent. Table 3-6 shows the constancy of the prevailing current within the boundaries shown in Figure 3.1.

Figure 3-1
Extent of Guinea Current



Source: US Defense Mapping Agency Publication 121 (1988)

Table 3-6 Speed of Offshore Guinea Current (July, August, and September)

Dir.	SPEED (Knots) 0.2	0.5	0.8	1.1	1.4	1.8	2.2	2.7	3.2	3.7	>4.0	Mean Speed Knots	Frequency (%)
NE	2.9	4.1	4.0	1.7	2.1	1.5	0.9	0.6	0.3	0.1	0	1.0	18.2
E	3.3	8.4	8.1	7.8	6.7	5	3.6	1.7	0.9	0.1	0.1	1.2	45.7
SE	2.4	3.0	3.3	2.6	1.8	0.9	0.5	0.1	0	0	0	0.9	14.6

All other directions 5 percent or less
Source: US Defense Mapping Agency Publication 121 (1988)

The prevailing direction is east and the mean speed 1.2 knots; the general flow is between northeast and southeast more than 75 percent of the time, with a maximum speed of about 4.0 knots. The Guinea Current appears constant in direction except from December through February, when easterly winds reduce the speed and cause the current to become variable and at times to reverse. When reversed the flow seldom exceeds 1 knot. During the northern winter (January through March), when the Atlantic Equatorial Countercurrent is not well established or has disappeared, the Guinea Current, mainly influenced by the Canary Current, widens considerably between 10° and 20° W. This current is of interest to the region but presents no problems in entering or leaving the port of Tema.

c) Wave Conditions

The JICA report states the following:

"There is no wave observation data available locally for Tema and Tema Ports."

The wave characteristics for this study are derived during latest 40 years from The Global Wave Statistics published by British Maritime Technology.

It is found that the predominant waves came from the South to South-West direction (about 60 % of the time). Most of the waves are between 1 ands 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 waves (1960 -2000) is shown in Table 3-7.

Table 3-7 Frequency Distribution of Wave at offshore of Ghana (1960-2000)

(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	1L03	38.92	20.72	11.15	7.54	100.00

Number of Observations: 267,326
Source: "The Global Wave Statistics" published by British Maritime Technology (from JICA)

Table 3-7 implies that the extreme waves for which the breakwater armor rock should be designed are on the order of 6 meters or more. A review of the breakwater rock that exists on the exterior breakwater at Tema indicates that the size of the armor rock typically does not exceed 8-10 tons. The breakwater has been in existence with minor damage for more than 50 years. It may therefore be concluded that a reasonable design wave is one which would call for breakwater armor rock of a size of approximately 5-10 tons. Applying the Hudson formula from the Shore Protection Manual to this problem indicates that the corresponding design wave height is in the order of 3 to 4 meters.

APM terminals contracted with the Danish Hydraulics Institute (DHI) in connection with a project in Takoradi in 2005 and 2006. One of the objectives of the DHI studies was to establish a proper design wave for revetments facing the open sea. The DHI recommendation was to use a significant wave height of approximately 3.0 meters as the design wave height. This number corresponds well with the reverse engineering calculations above of the performance of the breakwater at Tema. It then can be concluded that the frequency distribution given in Table 3-7 overstates the occurrences of waves higher than 3.0 meters.

Table 3-7 indicates that 97% of the waves are below Hs=3.0 meters. In reality, it will be near 100%. These are very mild wave conditions and indicate that relatively small defensive works will be required to provide proper protection for all ships that are in the lee of the breakwater.

For purposes of evaluating the operational down time in Tema, it is believed that Table 3-7 is reliable is as far as the distribution of wave heights between 0 meters and 3.0 meters.

d) Littoral Drift

The West African coast extending from Cape Palmas to the Niger Delta generally has an accretion tendency in the western section near Cape Three Points in Ghana and an erosion tendency in the East near the Niger Delta. Shoreline recession has been recorded at various locations along the East Coast of Ghana. The worst hit areas are the shores of Atorkor and Ada. The shoreline was found to have receded about 10 m in some areas, and erosion of another area was about 7 m in Ada.

3.1.3 GEOLOGICAL & GEOTECHNICAL CONDITIONS

For the Tema site, geotechnical information is available from the following sources (See Fig. 3.2):

I. Conterra Limited Consulting Engineers (2004)
II. Rhein Ruhn (2001)
III. JICA Site Investigation
IV. Boskalis International BV (1992)

I. Site Investigation by Conterra Limited Consulting Engineers (2004)

From February 2 to 11th, 2004 three successful boreholes (MD1, MD2, and MD3) were drilled on the landside in the location of the creek to supplement borings C1, C2, and C3 made during the site investigation by Rhein Ruhr.

In general, rock recovery was low with a maximum of 23% of the core returning to the surface. Boring MD1 discovered weak and highly weathered schist and gneiss until elevation -10.1m. Below this elevation, weak to moderately strong and moderately weathered gneiss was found until the termination at -11.6m. Boring MD2 extended to -9.4m and returned weak to moderately strong gneiss. Boring MD3 extended to -9.7m and terminated in a vein of strong to very strong quartz.

Geotechnical Assessment Report by Interbeton Delta Marine Consultants (2004)

This report reviews the three previously conducted geotechnical reports and estimates soil and rock parameters based on the information provided. The report refers to the following documents:

- Alluvial Mining Site Investigation for Boskalis, April 1992. This investigation included two boreholes drilled at the location of the proposed Marine Dock.
- Minerex Site Investigation for Boskalis, November 2000. Provided as part of contract documents, this investigation included three boreholes drilled at the location of the marine dock.
- Conterra Site Investigation for Interbeton, February 2004. This investigation provided further data to compliment and confirm findings from previous boreholes, and provided three new boreholes as described in the previous section.

Alluvial Mining Site Investigation

Two boreholes were drilled offshore in the vicinity of the marine dock. BH9 extended from -4.2m to -7.9m. BH10 extended from -2.6m to -6.6m and both holes consisted of highly weathered gneiss with moderately strong to strong rock in the bottom 1.5 - 2m. Point load tests were performed on the recovered rock cores.

Minerex Site Investigation

Three boreholes were drilled onshore in the vicinity of the proposed wall extension. The recovery and quality of the rock cores were affected by contractor difficulties, and cuttings were used to infer rock description in the highly fractured zone.

Boring C1 extended to elevation -12.9m and terminated in moderately weak to moderately strong, moderately weathered, weakly foliated gneiss. The boring did show a very weak, highly weathered layer between -10.8 and -11.5m.

Boring C2 extended to elevation -9.8m and terminated in moderately strong to strong and moderately weathered weakly foliated gneiss.

Boring C3 extended to elevation -13.4m and terminated in weak to moderately strong, slightly weathered, weakly foliated gneiss and becoming strong highly fractured quartz rose gneiss in the bottom of the hole.

Conterra Site Investigation

This site investigation was previously described above.

A report by Interbeton Delta Marine report drew the following conclusions:

- The underlying rock is generally gneiss with high mica content, and this trend is found in all boreholes within the port as well as exposed rock in the area. The weathering varies with depth and location, and a highly weathered layer is generally found between -6 and -7m.

- A 1.0m layer of soft sediment covers the seabed.
- The rock is heavily fractured. Additional fractured rock and loose debris material due to dredging could be found in the trench.
- Fractures in previous boreholes are thought to have been caused by drilling procedures. Fractures were generally clean with infilling of mica, and some decomposition of the material is observed at pre-existing fractures.
- At the marine dock, (next to Berth 12) there appears local decomposition into a stiff, clayey material, which does not appear to be the same clayey material found in boreholes near the Quay 2 extension. The material is high in quartz and the decomposition does not appear to be complete, having less affect on the rock mass parameters.
- In situ fill appears to be large cobbles in sandy, silty gravel. The properties of the general fill indicate that it could be used for cobble fill material for the purpose of design.

The report also estimated engineering design properties for in-situ rock. A conservative value for the joint friction angle of 22 degrees is recommended given the observation of mica. The joint roughness value of 10 has been selected as an average value (upper end of 12 and lower end of 8). Joint compressive strength is approximately equal to 1/3 of the unconfined compressive strength, with the UCS equal to 10Mpa and the JCS conservatively estimated at 3 Mpa. A friction angle of 31 degrees and a cohesion of 8kPa were deemed appropriate and offering the required degree of conservatism.

While DMC recommended using a single set of parameters for in-situ rock, general fill and rock fill were assigned the following parameter:

Table 3-8 Geotechnical Design Values Recommended by Delta Marine in the Vicinity of Berth 12

Layer	Unit Weight Above Water Table (kN/m^3)	Unit Weight Below Water Table (kN/m^3)	Internal Friction Angle (degrees)	Apparent Cohesion (kPa)
General fill (block wall)	18.5	19.5	37	0
General fill (slope stability)	18.5	19.5	35	0
Rock fill	N/A	19	40	0
Gneiss	N/A	23	31	8

II. Rhein Ruhn (2001)

From November 8 to 29th, 2000 sixteen boreholes were drilled in Tema Harbor. The investigation was conducted to determine the ground conditions at the site of the Quay 2 extension, the existing Quay 1 and Quay 2 berths, and in the Creek area for a Pilot Boat Harbor. A previous 1992 investigation provided supplemental data in assessing the cuttability for dredging.

Detailed results of the investigation can be found in the tender document titled "Quay Extension Works at the Port of Tema" produced for the Ghana Ports and Harbors Authority.

The dredge ability of the area can be analyzed by the depth of the seabed and the type of material. The depth of the seabed increases from north to south with elevations ranging from -5m at the creek entrance to -12m at the harbor entrance. At Quay 1, the seabed is relatively flat and ranges from -8m to -9m. South of Quay 2 and in the harbor, the seabed ranges from -10m and -12m.

The top of the rock surface is either the top of the basement rock or of cemented sediment such as cap rock. The rock surface is similar in shape and follows the elevation of the seabed within the dredging areas. Marine sediment layers are relatively thin and range from 0.5m to 2.0m thick in the turning circle, and 1m or less in front of Quay 1. The unconsolidated sediment consists of micaceous silty fine sand, silt, and silty clays.

Basement rock consists mainly of gneiss with well-defined quartz, mica and feldspar, with strengths ranging from very weak to strong, and is generally highly fractured. Within the northern section of the turning circle, strong but highly fractured rock quartz bands with the gneiss basement rock with elevations between -9.1m to -11.3m.

In the Quay 2 extension area (Berths 2 and 3) trench dredging along the northern and eastern sides extends to -11.9m and along the south side extends to -13.7m. Unconsolidated sediment layer is approximately 0 to 0.8m thick, and a rock layer of 2.15 and 3.45m can be expected in the Quay 2 extension area to achieve the -13.7m dredging limit. Boreholes within the area had poor quality and poor recovery to -13m depth, consisting of weak, highly fractured quartz rose micaceous gneiss. Competent rock can be found at -13.6m.

Competent rock was found between -15.2 and -16.4m at the south east side of Quay 2. At lower elevations, rock quality and strength significantly increase. Cores were found to be highly fractured with no clay zones. Rock strength is described as moderately strong to strong ranging from 50 to 100Mpa.

At the north end of Quay 1, very weak fractured rock extended to -17.46m, the depth limit of the boreholes within the immediate area. Competent rock should be found below this level. In the center of Quay 1, borings showed thin clay shears between -13.8m and -15.2, but competent rock should be found below -16.5m. At the south end, core drilling found mostly clay free rock material with competent rock found below -16m

III. Site Investigation by JICA (2002)

Seismic profiling and geotechnical investigation by rock coring were conducted in 2002 by Japan International Cooperation Agency (JICA) (4). The survey area of the seismic profiling was 2 km x 8 km. The boring location is illustrated on Figure 3.2.

Of the 4 borings, No.1 through No.4, two were drilled in the water and two were on the land. The results are summarized in Table 3-11.

Table 3-9 Results from JICA Geotechnical Investigations in Tema

Bore Hole No.	Ground Elv. / End of Drill (C.D.)	Rockhead Level	Specific Gravity	Compressive Strength (MPa)	Rock Type Description
No. 1	-4.50 -13.80	-12.90	(No core sample recovered)		Completely to highly weathered Gneiss
No. 2	-5.50 -14.00	-9.50	(No core sample recovered)		Completely to highly weathered Gneiss
No. 3	+4.00 -6.20	-	2.72	4.4~13.8	Granitic Gneiss boulder - bouldery
No. 4	-2.50 -1.30	+1.70	2.67~2.73	2.9~32.4	Completely to highly weathered Gneiss

Source : Study Team

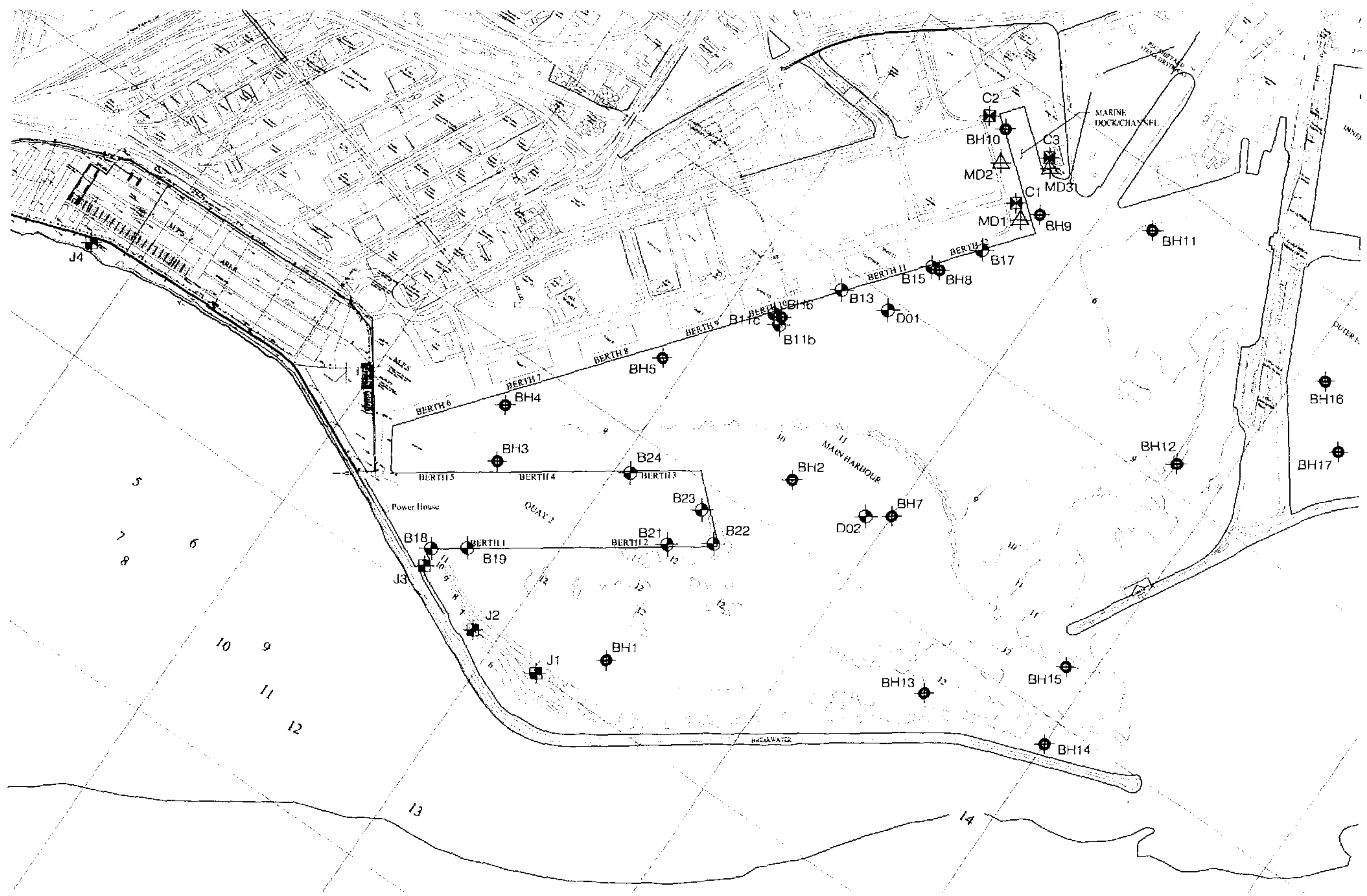
IV. Site Investigation by Boskalis International BV (1992)

Boskalis drilled 16 boreholes in the port of Tema shown as BH-1 through BH-16 and Figure 3.2.

<u>Summary</u>

Core recovery and quality was low, due to the high degree of weathering and fracturing. Only 10 suitable samples could be collected for unconfined compressive strength tests, from which 4 failed on pre-existing cracks.

The hard ground in the Port of Tema consists mainly of gneisses. The gneisses can be subdivided into 3 main groups. An estimate for the occurrence of the rock types is drawn in Appendix 3.



NOTE:

DEPTHS IN METERS

LEGEND:

- EXISTING BORINGS BY BOSKALIS (1992)
- EXISTING BORINGS BY JICA (2002)
- EXISTING BORINGS BY RHEIN-RUHR (2001)
- EXISTING BORINGS BY CONTERRA
- EXISTING BORINGS BY MINEREX/BOSKALIS (2000)

1:10000 — 100 0 600 m

GHANA PORTS AND HARBOURS AUTH.
PORT OF TEMA

EXISTING SOILS BORINGS

FIG 3–2

Halcrow

S:\G\GGHAN130\Figure\Report-2\GGHAN130-GPHA-F003-2.dwg 01/07/10 09:50 PortalatinA

Rock Type A1:

Micaceous quartz gneiss occurs in the inner part of the port. It has a very platy character, causing fault development in the mica, often weathered to chlorite, rich zones. The weathering index is generally 4, but varies from place to place. To evaluate the weathering distribution more drill holes in a regular grid are necessary.

Volumetric weight:	2500 Kg/m^3
Mean compressive strength:	38.2 MPa
Max. Compressive strength:	58.9 MPa

Rock Type A2:

Leucocratic granitic gneiss occurs probably in a narrow NNE - SSW trending zone (lee-breakwater and in the port entrance). Foliation is not well developed in this rock type. Fracturing is intense and increases in NNE direction. Larger un-fractured zones occur. The weathering index is generally 3.

Volumetric weight:	2650 Kg/m^3
Mean compressive strength:	253 MPa
Max compressive strength:	253 MPa

Rock Type A3:

Felsic quartz gneiss. The high content of Felsic minerals results in a high volumetric weight. The hardest parts occur probably in the vicinity of rock type A2. More remote it gradually starts to resemble rock type A1. This rock type occurs in the east part of the port. Weathering index varies in the different boreholes from 2 to 6.

Volumetric weight:	3050 Kg/m^3
Mean compressive strength:	152 MPa
Max compressive strength:	152 MPa

Rock Type A4:

Only near the port entrance, BH 13 and 15 a 1.5 to 2 m thick porous bioclastic limestone, containing lithic breccia elements was encountered on top of the gneissic basement.

A summary of the location of these rock types is presented in Table 3-12.

Table 3-10-Summary of Boskalis Results (1992) Boring Program

Summary of Boskalis (1992) Boring program

Elevations in meters below to chart datum

Boring Number	Rock Type A1		Rock Type A2		Rock Type B1		Rock Type B2	
BH-	Micaceous Gneiss		Granitic Gneiss		Felsic-Quartz Gneiss		Bioclatic Limestone	
	Top elev.	Bottom el.	Top elev.	Bottom el.	Top elev.	Bottom el.	Top elev.	Bottom el.
1	10.5	14.34						
2	8.6	13.18						
3	8.86	12.79						
4	8.92	13.26						
5	8.98	13.15						
6	8.96	13.64						
7	9.1	13.06						
8					9	13		
9					4.2	7.85		
10					2.64	6.58		
11					5.6	9.41		
12			11.5	15.61				
13					13.78	17.23	12.36	13.78
14					11.85	14.34		
15			14.3	15.52			12.48	14.3
16			8.1	10.88				
17	8.78	12.71						

3.1.4 SOURCES OF FILL MATERIALS

Suitable fill material comprises gravel and sand. The existing port of Tema was partly built on fill in the 1950's. The fill material was obtained at the Shai Hills quarry located some 35km from the port. Although the quarry is not presently active, it has been reported that unlimited quantities of suitable fill may be available reopening the quarry for port projects in Tema.

An alternative means of obtaining suitable fill is by dredging. Any dredging project in the port is likely to generate suitable fill material because the seabed is comprised of cohesion less sediments or rock. A third potential source would be reclaiming offshore suitable deposits of sand and/or gravel. It is not known if such offshore deposits exist near Tema. If they exist within 20km of the port, such deposits can be reclaimed by a trailing hopper suction dredge and pumped to shore from the dredge to the landfill area. If suitable deposits exist, this would be the lowest cost means of obtaining fill material for Tema.

Offshore soil investigations do not exist except for the soil investigations made by the West African Gas Pipeline project. The West African Gas Pipeline Company has furnished the project team results from the soil investigations made in the vicinity of Tema and Takoradi. The maps provided by West African Gas Pipeline Company are shown in Appendix B.

The purpose of the soil investigations made by the West African Gas Pipeline Company was to assess the technical feasibility of placing a gas pipeline on the seabed in a relatively narrow corridor. See the maps in Appendix B. The maps indicate that in water depths of 30 to 40m offshore Tema; there is an existing silty sand layer on the seabed with a thickness of approximately 3m. The surveyed area is along the pipeline trajectory and is 1 km wide. Thus the actual surveyed area comprises only a very small fraction of the total potential area from which sand can possibly be reclaimed.

During the last Ice Age, the sea level was approximately 120 m lower than today. It is highly possible that the sand deposits found during the pipeline survey were beach formations during the lowering to or the rise of the sea level from the last ice age. If this is so, then there will be a reasonably high expectation of finding such sediments everywhere along the Ghanaian coast in 30 to 40m water depths. However, to determine this with certainty, a survey is required for the purpose of identifying such sources of fill materials.

3.2 Existing Port Facilities

This section provides a brief history of the construction of the Tema Port and discusses the existing waterfront infrastructure facilities. The results of the rapid above water inspection are discussed and a summary of the existing conditions of the existing facilities is provided, along with recommendations for further action.

3.2.1 INTRODUCTION

The initial development of the Tema Port commenced in 1954 and continued through to the commissioning of the port in 1962. Located approximately 30 km east of the capital city of Accra, the port was originally planned and developed as part of the Volta River Project along with the Akosombo Dam and the Aluminum Smelter at Tema. The primary structures of the Main Harbor – Quay 1, Quay 2, and the Valco and Oil Berths – were added during an expansion of the port between 1970 and 1975.

Over the next 30 years, no major rehabilitation or development projects were undertaken and the overall condition of the port facilities deteriorated with use and exposure to the harsh tropical, marine environment. In the early part of the 21st century, circa 2003, a major development program undertaken at the port included the extension of Quay 2 by 200 m to support increasing container activity 3.2.2 Tema Port Waterfront Structures

3.2.2 GENERAL DESCRIPTION

The Ghana Ports and Harbour Authority (GPHA) handles cargo at fourteen berths within the port zone. Berths 1 through 5 at Quay 2, Berths 6 through 12 at Quay 1, and the Oil Berth and the Valco Berth at the South Breakwater. The shallow water Outer Harbour is utilized primarily by the local fishing fleet. See Figure 3-3

A summary of the port's key marine facilities is provided in Table 3-13 and a facility plan illustrating the location of these facilities within the port is provided in Figure 3-3.

Table 3-11 Tema Port Waterfront Facilities

Facility/Structure	General Dimensions
INNER HARBOUR	
Berth No 1	Length 283m Depth 11.6m CD
Berth No 2	Length 283m Depth 12.0m CD
Berth No 3	Length 189m Depth 11.5m CD
Berth No 4	Length 189m Depth 10.5m CD
Berth No 5	Length 189m Depth 9.5m CD
Berth No 6	Length 183m Depth 8.5m CD
Berth No 7	Length 183m Depth 8.5m CD
Berth No 8	Length 183m Depth 8.5m CD
Berth No 9	Length 183m Depth 8.5m CD
Berth No 10	Length 183m Depth 8.5m CD
Berth No 11	Length 183m Depth 8.5m CD
Berth No 12	Length 183m Depth 8.5m CD
Oil Berth	Length 175m Depth 9.8m CD
Valco Berth	Length 183m Depth 9.6m CD
BREAKWATERS	
Main Breakwater	Length 1,905m
South Breakwater	Length 1,100m
Channel	Approach channel 240m wide dredged depth 10.6m CD

Sources: The Development Study of Ghana Sea Ports in the Republic of Ghana (JICA, February 2002) &corrected as per NIRAS drawings No.13 2007.06.20

Figure 3-3
Tema Port Facility Plan

3.2.3 Waterfront Structures

A preliminary above water waterfront structures at the port was performed in April 2008. The inspection took place over a two day period and consisted of a topside inspection of all of the waterfront structures. Personnel from GHPA attended the waterside inspection of the accessible structures with the use of a GPHA vessel. Access to the wharf face of several of the berths was limited due to the presence of vessels. However, sufficient access across all inspection activities was possible and was enough to form a general condition rating of the condition of each of structures.

The inspection was performed as described below and the facilities classified for discussion based upon the location within the areas described:

- Main Harbour - Comprises the deep water berths (Berths 1 through 12). A partial visual inspection of the Oil Berth and the Valco Berth was included within the scope of this investigation.
- Breakwaters - Comprises the Main Breakwater and South Breakwater; only a partial visual inspection of the breakwaters was included in the scope of this investigation.
- Outer Harbour - Comprises the Fishing Harbour and Outer Fishing Harbour; *these facilities were not inspected as part of this study.*

The above water inspection was performed in keeping with best industry practices for an evaluation of this scope and duration. A Condition Assessment rating has been assigned to each of the inspected structures in accordance with The American Society of Civil Engineers Manual and Report on Engineering Practice No. 101, 2001. All evaluations, comments, and condition ratings apply solely to the visible above water elements accessible at the time of the inspection. Further above water and underwater investigation is required to fully evaluate the conditions of the structures and to develop a complete understanding of required repair actions.

3.2.4 Existing Conditions

Main Harbour

Operations are generally concentrated at the deep water berths at Quays 1 and 2, with dedicated container operations at the south face of Quay 2 (Berths 1 and 2) and bulk cargo and limited container operations in the remainder of the main harbor at Quay 1 and along the north face of Quay 2. These structures are of similar closed quay wall construction and are generally in a condition that makes operations safe and practicable. The construction of the Valco Berth and Oil Berth varies however the condition of the structures remains sound. In general the existing condition of all the structures of the Main Harbour is in keeping with the expected condition of structures of this age, construction type, exposure, and operating conditions.

A brief description of each of the structures and the existing condition of the structural elements evaluated follows and a summary of this information is provided in Table 3-13. The layout and location of all of the structures of the Inner Harbour is shown in Figure 3-3.

3.2.5 BERTHS 1 TO 5 (QUAY 2)

Quay 2, originally built during the late 20th century port expansion and extended circa 2003, is a large earth fill structure laterally retained by precast concrete block quay walls (Figs. 3-4 through 3-6). Berths 1 and 2 serve as the primary deep water berths for container operations at the port, while Berths 3, 4, and 5 serve for general cargo handling and limited container operations.

Figure 3-4
Quay 2: Typical Section

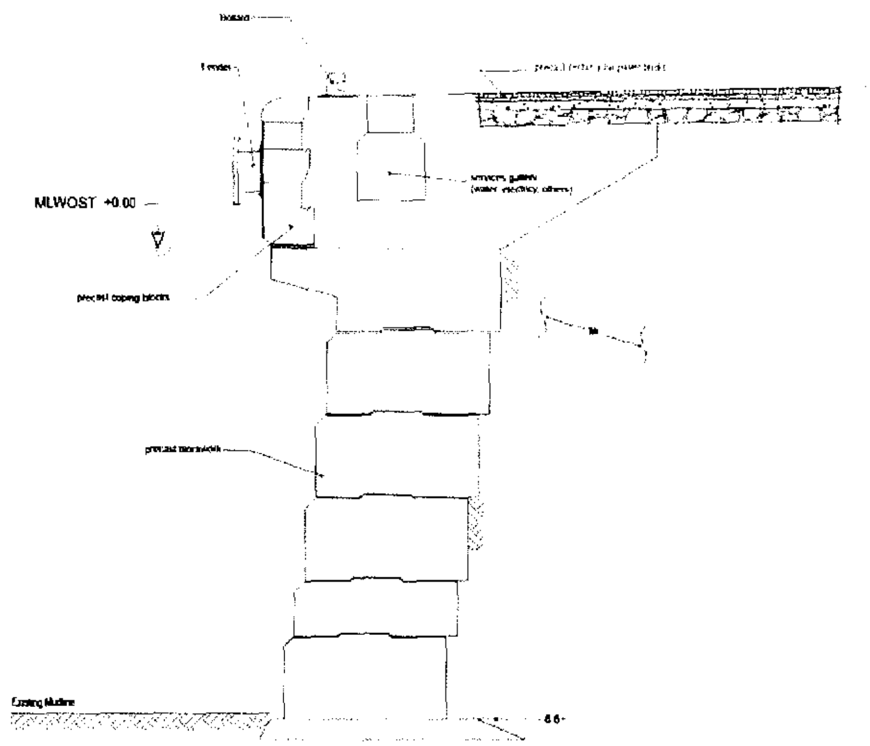


Figure 3-5 *General view of Berth 2, Southeast Elevation.*

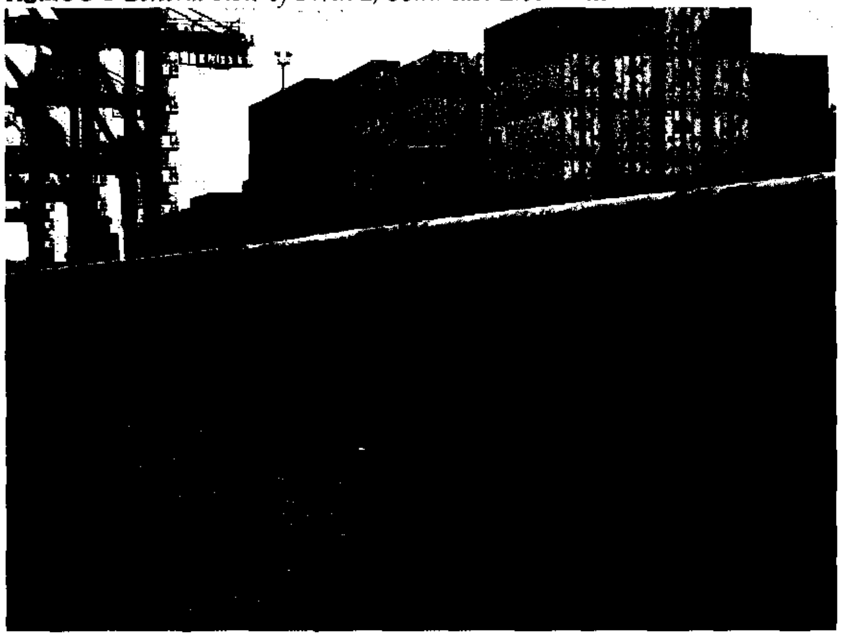
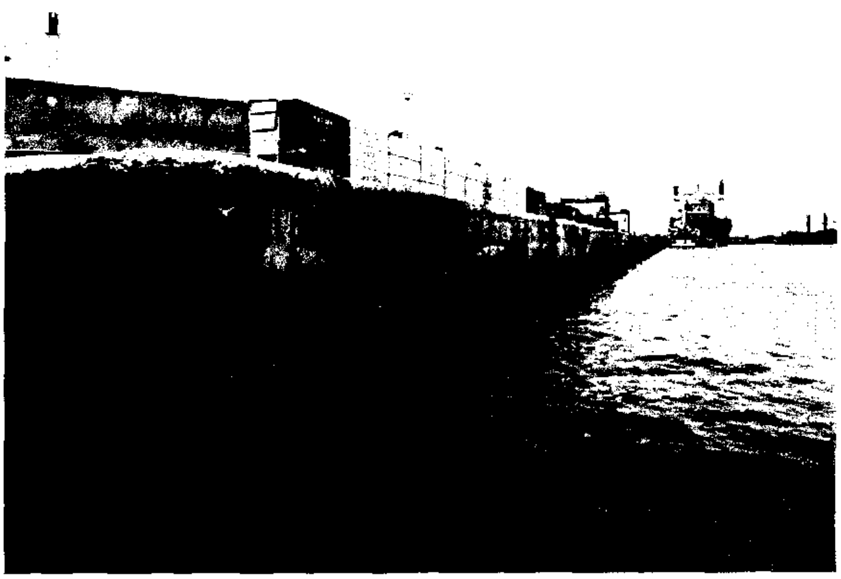


Figure 3-6
General view of Berth 3, Northeast Elevation



The structure is in **Satisfactory** condition overall with deterioration generally found near and above the low water elevation and the along the concrete cope. Typical defects include erosion and spalling of the concrete, minor cracking, and mechanical damage (Figs. 3-7 and 3-8).

Figure 3-7
Berth 1. Minor Deterioration of Precast Concrete Blocks within the Tidal Zone.

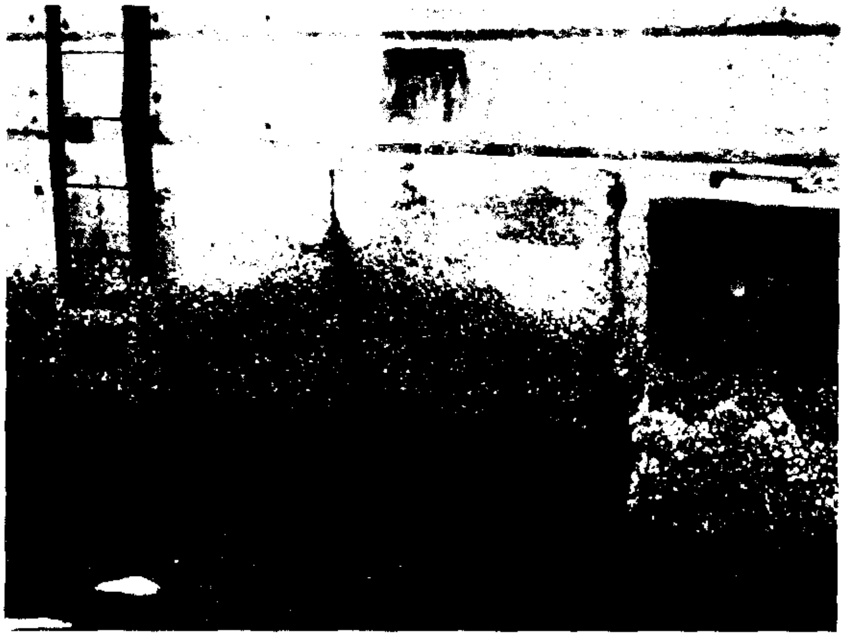
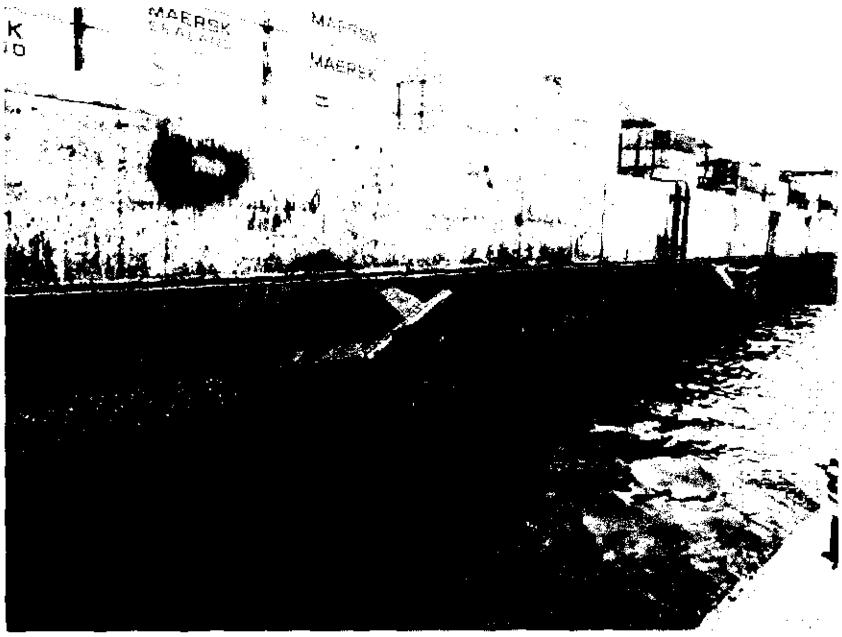


Figure 3-8
Berth 5. Mechanical Damage and Cracking in Concrete above the Low Water Elevation..

The fender system along the berths is in satisfactory condition. The fenders consist of rubber unit elements, or modular rubber, fenders supporting a polyethylene fender shield. The fenders are typically in-place and in reasonably good condition, however defects in the hardware of a number of the units have resulted in a lack of proper connection (Figs. 3-10 and 3-11).

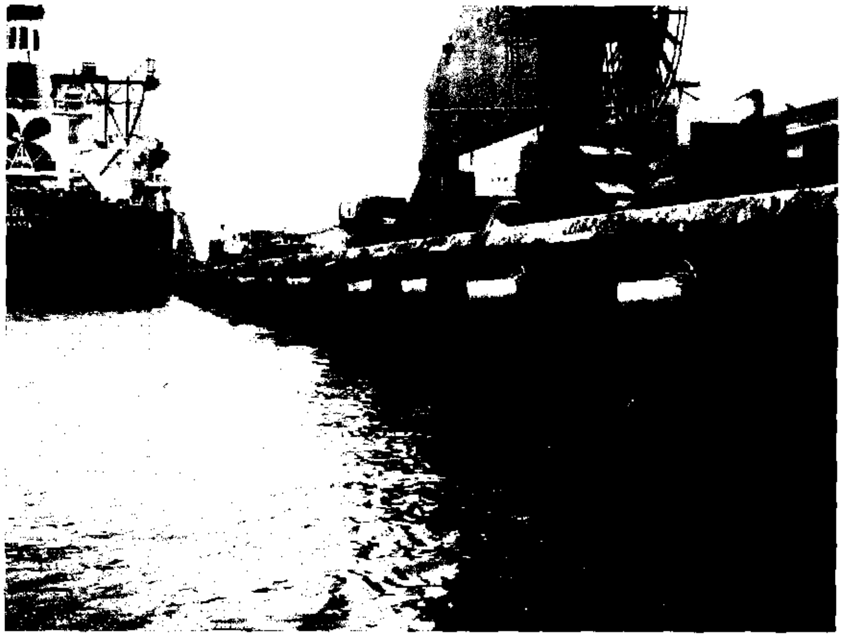
Figure 3-9
Berth 3. Isolated Defects in Fender System.



3.2.6 BERTHS 6 TO 12 (QUAY 1)

Quay 1 is a closed wharf constructed of precast concrete block quay walls (Figs. 3-4 and 3-10). Berths 6 through 11 serve as the primary deep water berths for general cargo handling and Berth 12 is utilized for limited small-scale container operations.

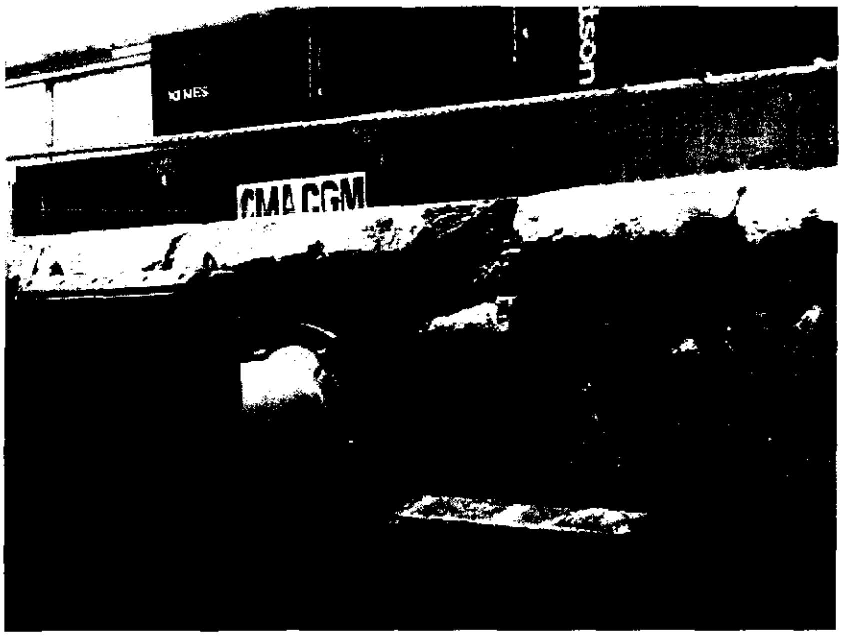
Figure 3-10
General View of Berth 10, South Elevation.



The structure is in **Satisfactory** condition overall with deterioration generally found near and above the low water elevation and the along the concrete cope. Typical defects in the concrete include erosion and spalling, minor cracking, and minor to moderate mechanical damage (Figs. 3-11 and 3-12). It is clear that the most significant mechanical damage resulted from lack of fender protection prior to the installation of the current fender system.

Figure 3-11
Berth 9. Moderate Mechanical Eamage along the Concrete Cope.

Figure 3-12
Berth 12. Moderate Mechanical Damage along the Concrete cope.



The fender system along the berths is in **Satisfactory** condition. The fenders consist of rubber cell fenders supporting a steel fender panel with polyethylene wearing pads. The fenders are typically in-place and in reasonably good condition, however a small number of fenders are missing (Fig. 3-13). Additionally, damage to the rubber of the cell fenders is evident, this damage results from the lack of existing weight chains and from the aging and weathering of the rubber (Figs. 3-14 and 3-15).

Figure 3-13
Berth 10. Missing Fender Unit.

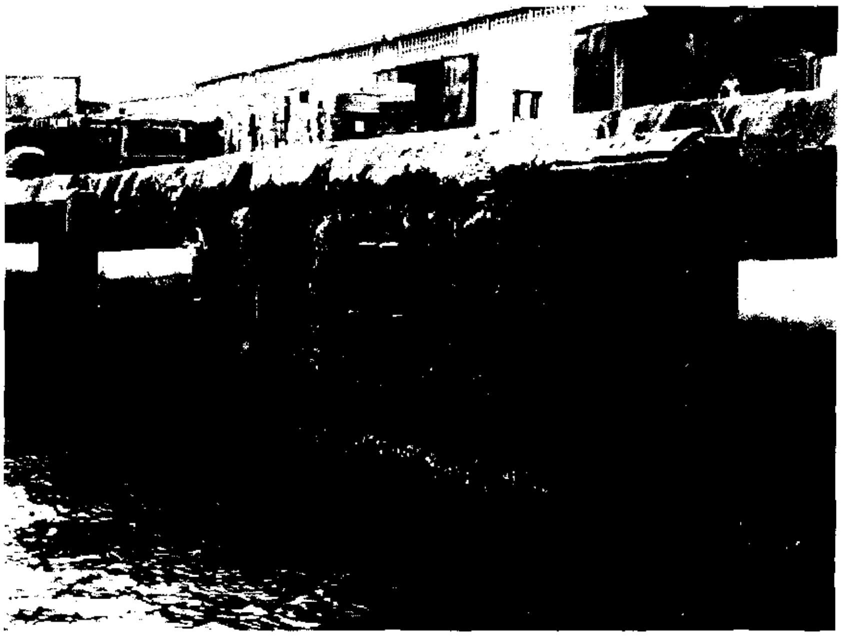
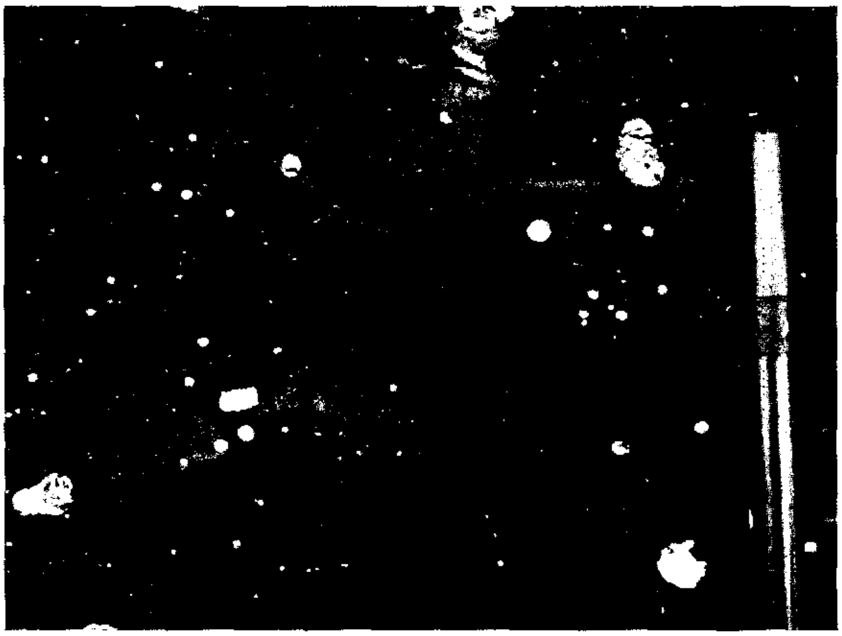


Figure 3-14
Berth 11. Cracking in RubberCcell Fender due to the Lack of Existing Weight Chains.

Figure 3-15

Berth 11. Aging and Cracking in Surface of Rubber Cell Fender.



3.2.7 OIL BERTH

The Oil Berth is located along the western (leeward) side of the South Breakwater and serves as a fuel loading and unloading facility. The structure is constructed of mass concrete mooring and berthing dolphins (Figs 3-16 and 3-17).

Figure 3-16
General View of Oil Berth, North Elevation..

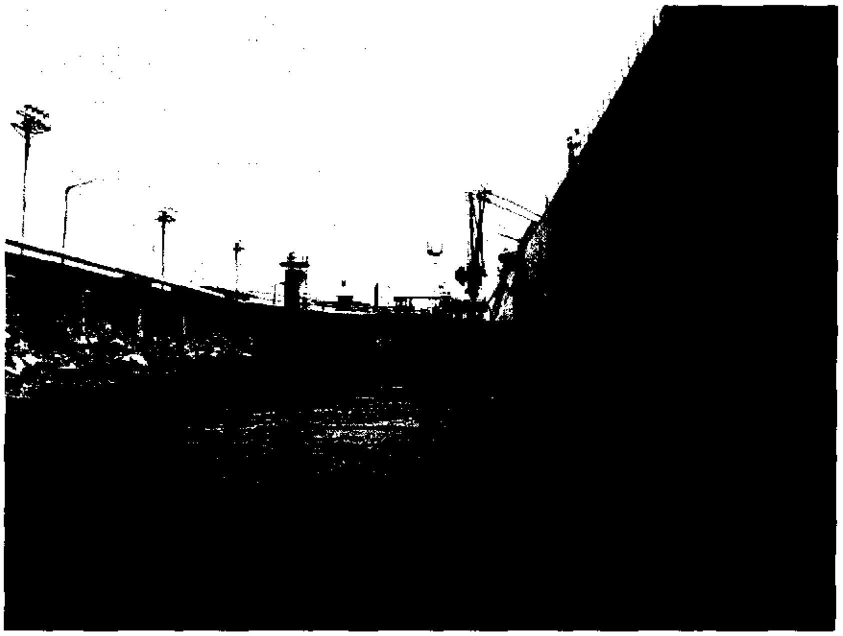
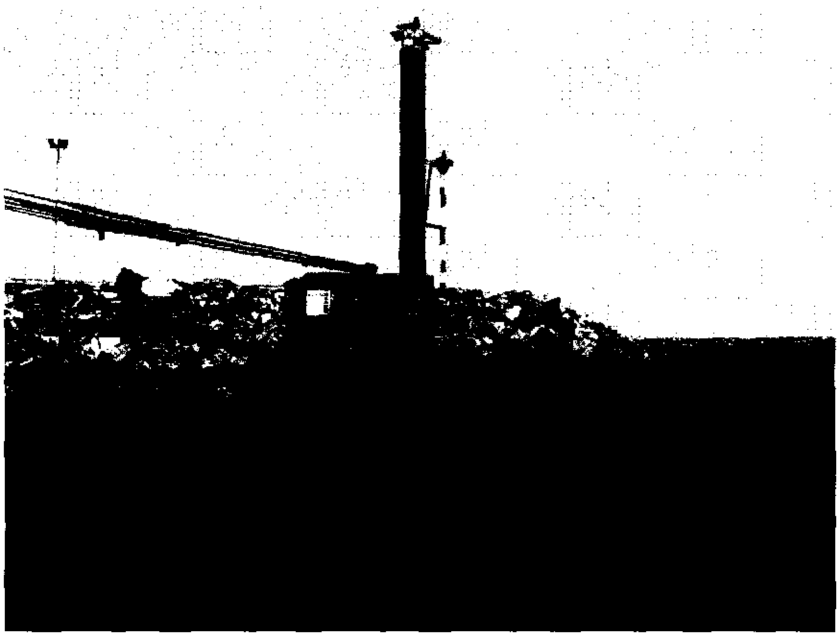


Figure 3-17
General View of Oil Berth Mooring Dolphin, West Elevation.

Note minor undermining of rock slope beneath dolphin.



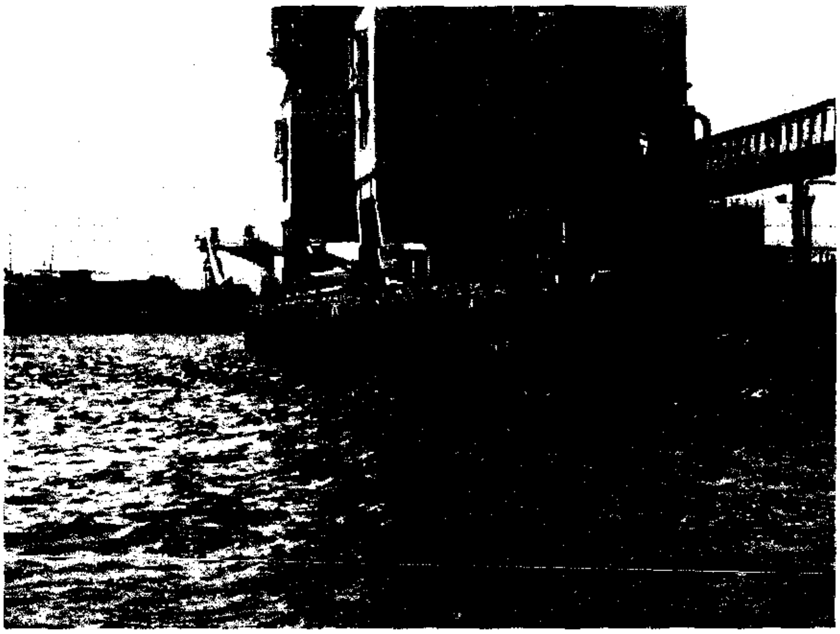
The structure is in **Satisfactory** condition overall. Damage is generally confined to minor concrete deterioration and undermining of the stone slope beneath the mooring dolphins. The berthing dolphins were inaccessible for inspection due to presence of a visiting vessel.

The fender system at the berth consists of rubber element fenders supporting steel fender panels.

3.2.8 VALCO BERTH

The Valco Berth is located along the western (leeward) side of the South Breakwater and serves as loading and unloading facility for the alumina operations at the port. The structure is constructed of mass concrete quay wall (Fig. 3-18).

Figure 3-18
General view of Valco Berth, Southwest Elevation



The concrete wharf is in **Satisfactory** condition overall. Minor cracking and mechanical damage exists along the offshore berthing face of the facility.

The fender system, consisting of chain suspended cylindrical fenders, is in **Satisfactory** condition overall.

Table 3-12 Tema Port Existing Condition Summary

Facility	Construction	Condition Assessment*	Description of Defects/Comments
Berths 1 through 5 (Quay 2)	Precast Concrete Quaywall	Satisfactory	• Minor damage to concrete walls and cope.
Berths 6 through 12	Precast Concrete Quaywall	Satisfactory	• Minor to moderate damage to concrete walls and cope.
Oil Berth	Concrete block mooring and berthing dolphins	Satisfactory	• Minor undermining of stone slope at mooring dolphins
Valco Berth	Concrete Block Quaywall	Satisfactory	• Minor defects in concrete wall.

** As defined in ASCE Manual and Report on Engineering Practice No. 101*

3.2.9 Breakwaters

The main breakwater protects the Main Harbour berths from the southerly and south westerly waves which predominate at Tema. The South Breakwater protects the Main Harbour from the east and provides protection to the Oil Berth and Valco Berth (Fig. 3-3). Both of these breakwaters are very substantial structures with the physical characteristics outlined in Table 3-15.

The Main Breakwater has been previously repaired during the port rehabilitation works. This repair work consisted largely of breakwater re-profiling along with the addition of concrete cubes in areas where the rock had either been displaced or settled. It should be noted that despite the significant age of these breakwaters, the slope of the main structures have remained consistent to the slope as originally constructed.

The visual inspection of the top layer of armour also identified that an acceptable amount of the armour rock appears to be interlocked and also has a reasonably satisfactory void ratio and packing density.

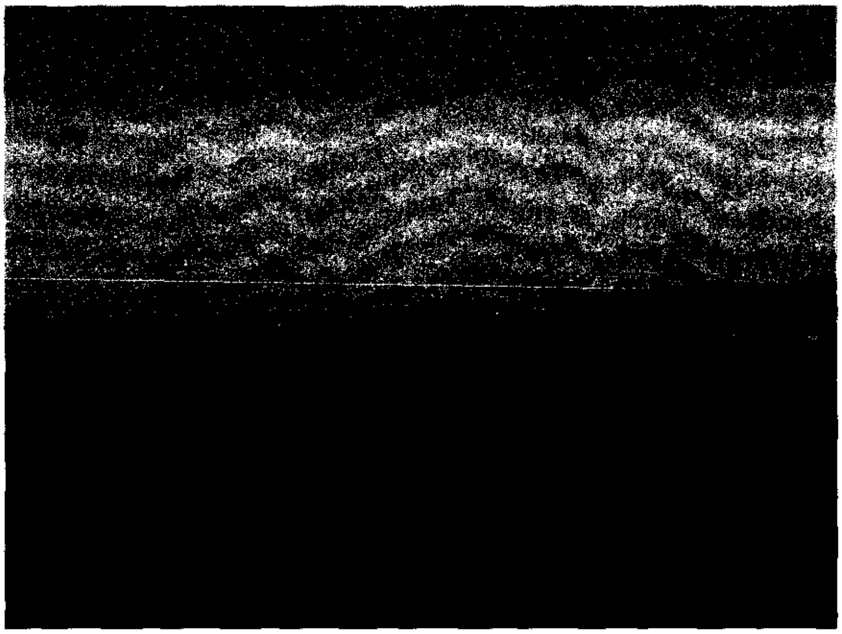
Whilst the rock slope has been reworked in periods of extreme conditions, the material itself has only sustained minor damage.

A brief description follows of the structures and the existing condition of the structural elements evaluated along with a summary of this information is provided in Table 3-16.

3.2.10 MAIN BREAKWATER

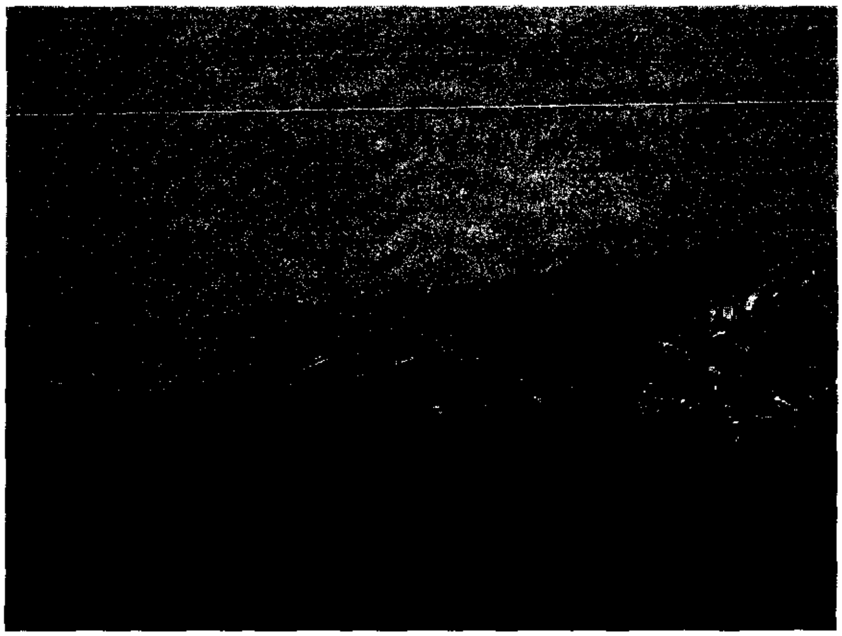
The Main Breakwater is in **Satisfactory** condition overall. While the seaward side of the breakwater is generally well graded and well armored (Figs. 3-19 and 3-20), isolated areas of deterioration and damage exist along the length of the structure.

Figure 3-19
General view of Main Breakwater, Leeward Side.



The access roadway and wave wall atop the breakwater are generally in reasonable condition, however exposure to marine elements and wave overtopping have caused minor weathering of the concrete blocks of the wave wall and damaged the concrete surface of the concrete roadway.

Figure 3-20
Main Breakwater,LleewardSside. Existing repair area near root of breakwater.



3.2.11 SOUTH BREAKWATER

The Lee Breakwater is in **Good** condition overall with a well graded and well armoured seaward side.

Table 3.13 Tema Port Condition Summary, Breakwaters

Structure	Construction, Primary Armor Type and Slope	Condition Assessment	Description of Defects/ Comments
Main Breakwater	Rubble mound construction	Satisfactory	Damage to wave walls and evidence of previous repair of slope settlement
Lee Breakwater	Rubble mound construction	Good	No noted defects

* *As defined in ASCE Manual and Report on Engineering Practice No. 101*

3.3 Conclusions and Recommended Actions

In general, the condition of the structures of the port is in keeping with what may be expected for structures of the age and construction encountered at the Tema Port.

A summary of recommended actions that are required to address the existing defects and conditions observed during the course of the inspection, and to maintain the safe operating conditions of the structures as currently utilized, is provided in Table 3-16. All of these recommendations apply solely to the visible above water defects visible at the time of the inspection. Further above water and underwater investigation is required to develop a comprehensive understanding of required repair actions and to develop a well planned rehabilitation program.

Table 3-14 Summary of Recommended Actions

Facility	Recommended Actions	Urgency of Action
Berths 1 through 5	Perform Routine Above Water and Underwater Inspection and Engineering Evaluation	Low Priority
Berths 6 through 12	Perform Routine Above Water and Underwater Inspection and Engineering Evaluation	Low Priority
Oil Berth Wharf	Perform Routine Above Water and Underwater Inspection and Engineering Evaluation	Low Priority
Valco Berth	Perform Routine Above Water and Underwater Inspection and Engineering Evaluation	Low Priority
Main Breakwater	Perform Routine Above Water and Underwater Inspection and Engineering Evaluation	Low Priority
Lee Breakwater	Perform Routine Above Water and Underwater Inspection and Engineering Evaluation	Low Priority

Chapter 4 – Develop Master Plan for Container Facilities at Tema

4.1 Preliminary Alternatives Options

The master plan for the container facilities at the Port of Tema has been developed based on the cargo forecast from 2009 to 2028 and the corresponding requirements for the port facilities, as addressed in Chapter 2. A summary, of the new berths to be added to the existing port by the year 2028 is shown in the Table 4-1 below.

Table 4-1 Recommended Schedule for required number of Container Berths

	Forecast		
No. of Berths	**High**	**Best**	**Low**
2	Now	Now	Now
4	2010	2011	2012
6	2015	2018	2024
8	2020	NA	NA

Additionally, the following facilities shall be added to the port, as required:

- Breakwater modification
- Additional container storage,
- Paved operating areas,

As of August 2009 containers were handled in the MPS container yard to the west of the port and in an area behind berths 10 to 12. One way of increasing the ability to handle containers in the port of Tema would be to enlarge the container yard behind berths 10 to 12 and to dedicate these berths to containers. See Figure 4.1. There is an exiting project to deepen these berths to 12 m depths, which would make them able to handle the same size ships that can presently be handled at berths 1 and 2. However, this project may or may not be carried out.

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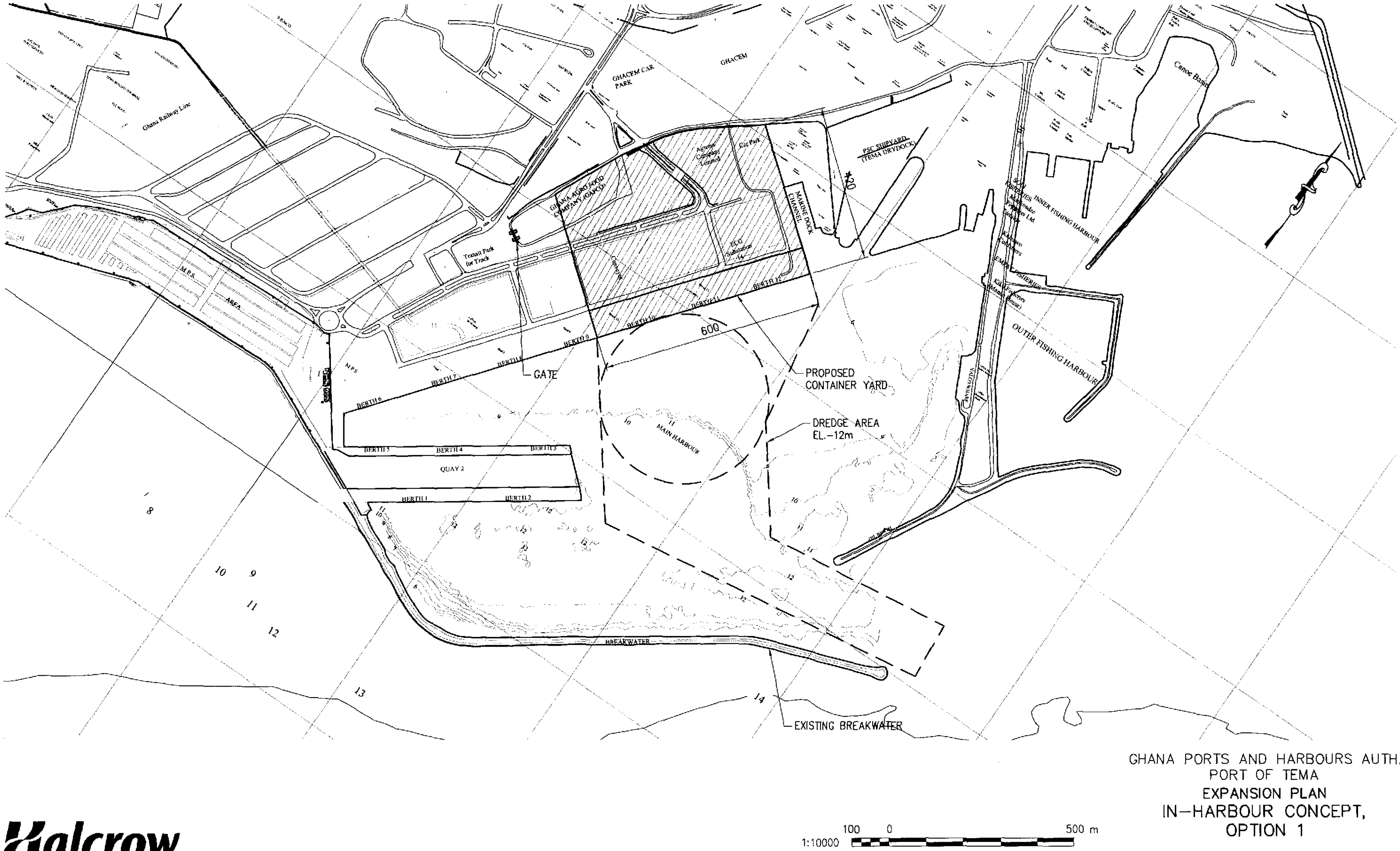

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PORT OF TEMA
EXPANSION PLAN
IN-HARBOUR CONCEPT,
OPTION 1

FIG 4–1

Halcrow

The berths 10 through 12 handle more than containers. For example berth 12 handles the imports of clinker for GHACEM. If these berths were to be dedicated to containers, existing non-container operations would need to be relocated. This would without doubt require berths to be located elsewhere outside the existing Tema Harbour. Some of this traffic could possibly be diverted to Takoradi, be relocated to the ship repair facility, or the fishing harbour.

Widening of the container yards behind berths 10 through 12 can only be done by removing the existing warehouses and/or by relocating the Eastern Gate. Either or both of these undertakings would be extremely disruptive and expensive.

Converting the ship repair facility to port traffic use was by direction of GPHA not to be considered in this present study. Relocating some of the traffic to the fishing harbor would create yet another set of disruptions to that facility, and is not considered.

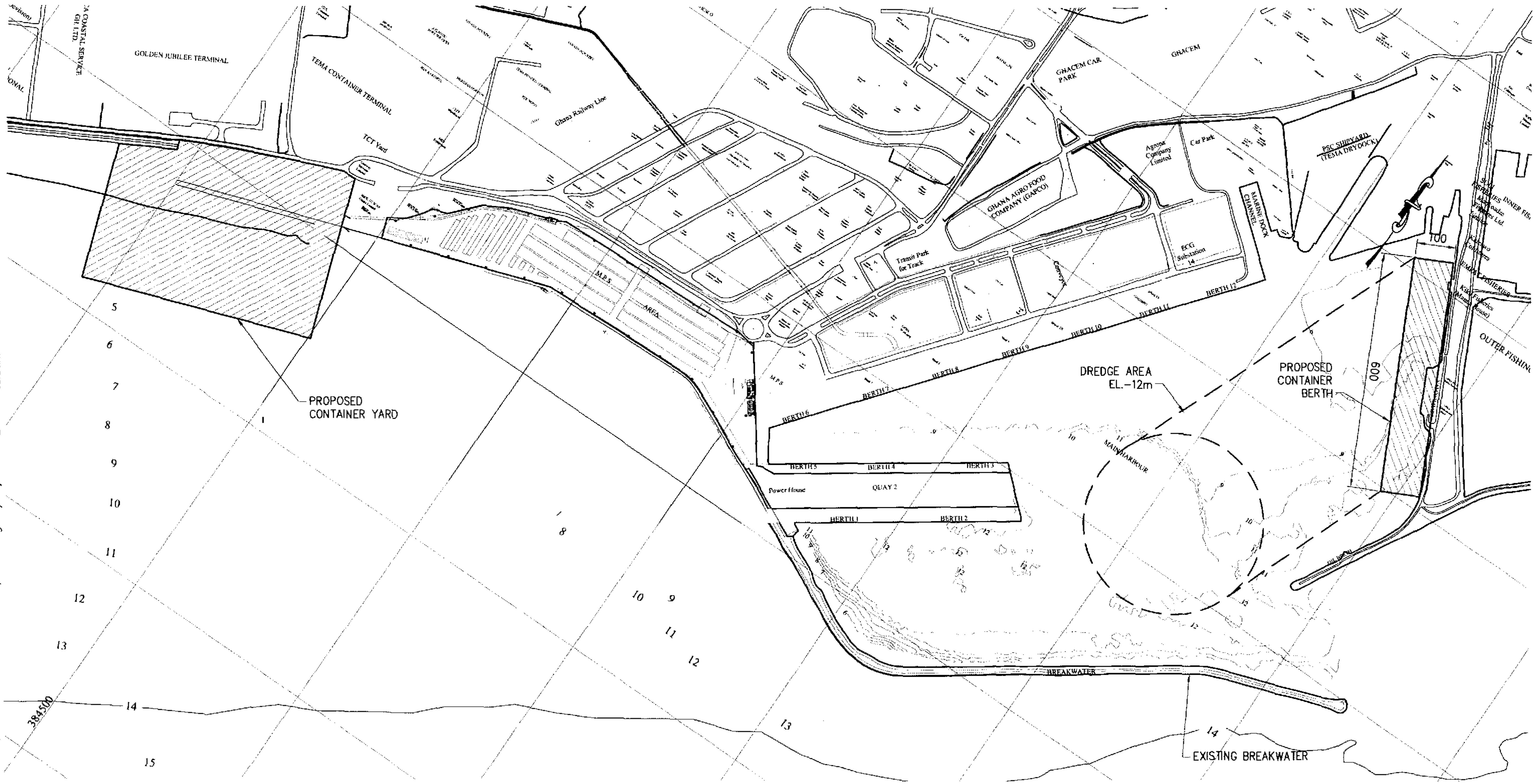
Considering the wide scope of these disruptions these possibilities were not considered further in this master plan.

There is no room within the existing breakwater to increase the number of container berths with the exception of the area of the VALCO berth. This area could be developed into a two berths container facility if the VALCO berth may be abandoned. See Figure 4.2. This option was not considered further for two reasons:

- There is no present plan to abandon the VALCO berth
- The transfer of containers between the container yard to the west of the port and this berth is difficult and expensive.

For these reasons, the choice for expanding the facility to handle the container ships was focused on the lee side of the breakwater and on converting Berths 3-5 to container service. The reduced draft that is available at berths 3 to 5 is an inconvenience and a drawback. However, Berth 3 can accommodate almost the same size container ship as is presently accommodated at Berths 1 and 2. However, Berth 5 needs to be dedicated to low draft feeder ships only.

Additional berths can be developed on the inside of the breakwater. See Figure 4.3. These berths can conveniently be connected to the existing container yard by a new road that needs to be constructed as part of the project. A significant advantage of this proposal is that new internal traffic will not further congest the port or interfere with any existing port traffic.



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OPTION 2

FIG 4–2

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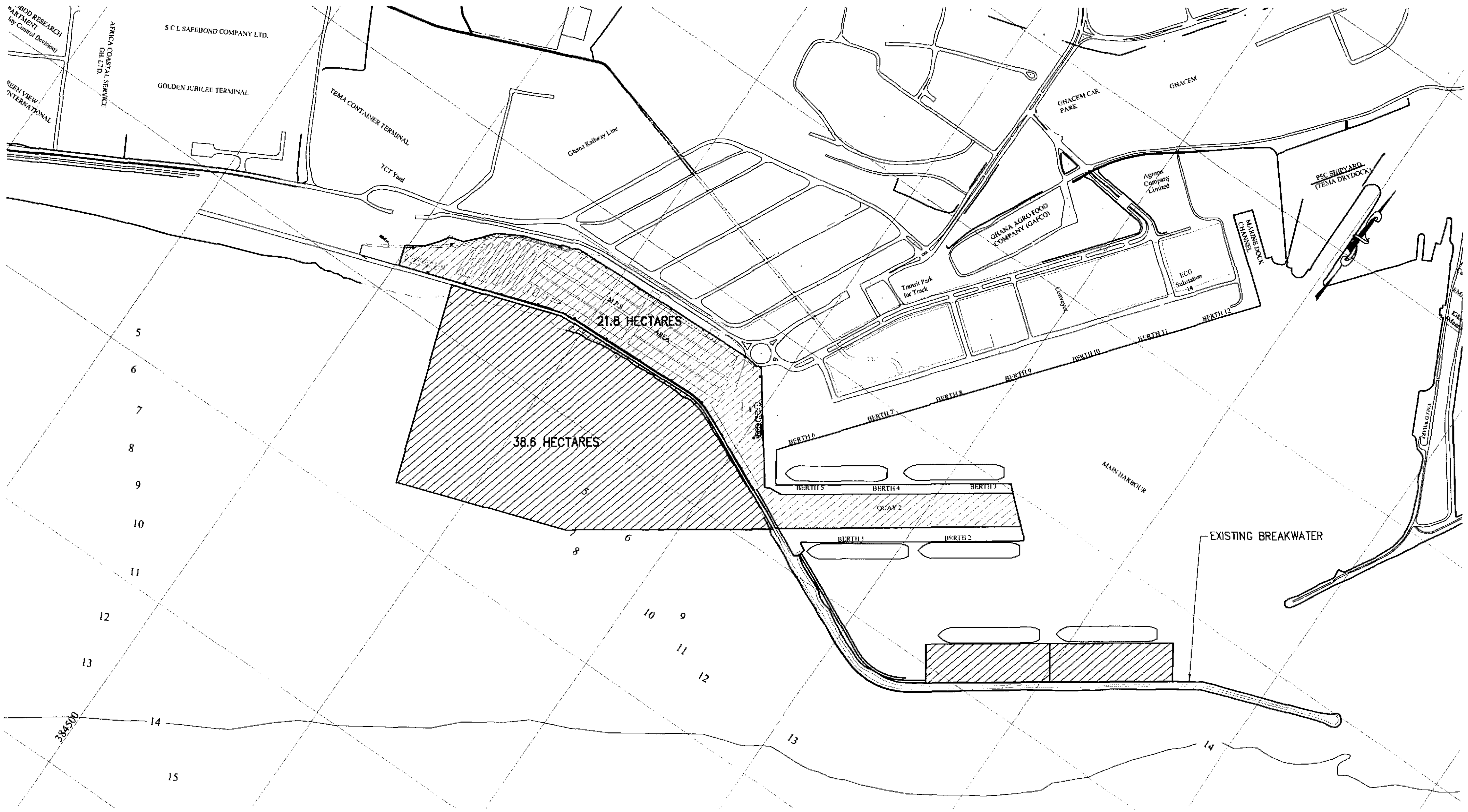

NOTE

ALL UNITS IN METERS AND ELEVATION IN METERS.

1:10000 100 0 500 m

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PORT OF TEMA
EXPANSION PLAN
IN-HARBOUR CONCEPT,
OPTION 3

FIG 4-3

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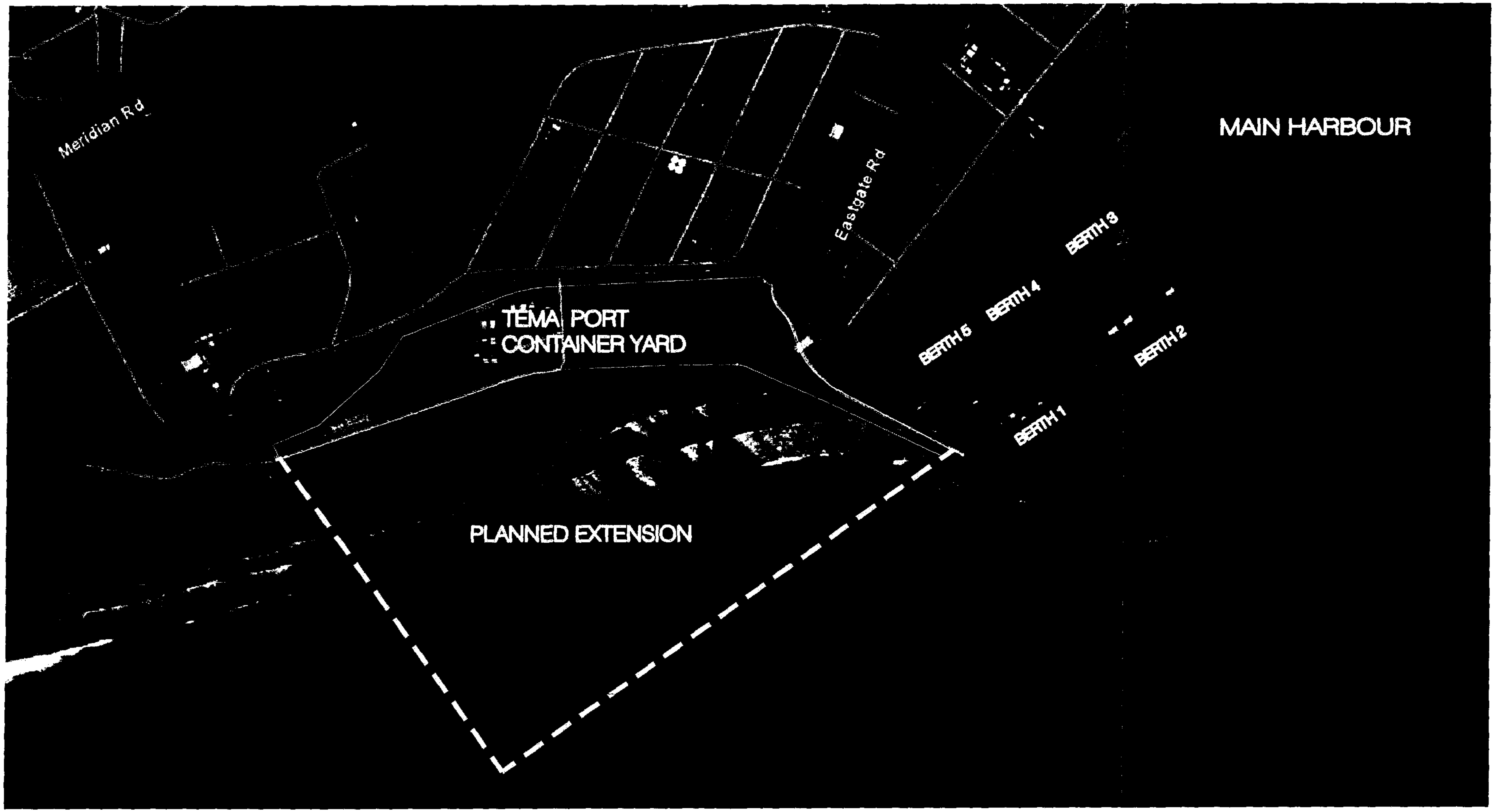
4.2 Recommendation for Container Yard development

MPS operates a modern efficient container yard immediately to the west of the port. GPHA has a planned expansion of the port to the west by filling the sea next to the existing container berths 1 and 2. This fill is proposed by GPHA to be partly sourced from dredging in the main harbor by a project which may or may not be carried out. Even if the proposed deepening the main harbor at berths 10-12 to 12m depth is carried out, the quantity of fill to be generated from this project is far from sufficient to fill the area that GHPA plans to fill. See Figure 4.4.

The planned expansion augments and extends the area of the Tema container terminal and yard. The extension does not interfere with any existing port facilities, roadway, or rail line. Therefore from a technical point of view, there is no impediment to fill this area provided that the fill will be properly protected against the sea by revetments.

The only known source of fill that with near certainty can be employed to fill this area is the Shai Hills quarry. This quarry was used to fill areas of the existing harbor when it was constructed in the 1950's.

The soil investigation made in the connection with the West African Gas Pipeline project indicated that in water depths around 30m to 40m offshore Tema there may be suitable sand or gravel deposits that can be reclaimed by dredging and which can be used for fill for the container yard. If this is so, then the unit costs of the fill material for the planned extension can be much reduced compared to the unit cost of the material obtained in the Shai Hills quarry. See Section 3.1.4 and Section 5.5 for further details.



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EXPANSION PLAN

GPHA PLANNED EXTENSION

FIG 4–4

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4.3 Staging of the Master Plan

The first stages of the plan do not require new breakwaters or new revetments except for the expansion to the 8th berth late in the forecasting period. For this modification to the breakwater, it does not make any sense to consider a different design than the one that has been successfully in place for 50 years.

The roadway between the container wharfs and the container yard will need to be widened. Offshore the exiting berths 1 & 2, this will be done by widening the breakwater leeward in the direction of the port basin. The protection of this roadway will be accomplished by removing the existing leeside armor while the road is being widened and then replacing the armor on the new slope. It may be necessary to build a seawall seaward of this road to protect against spray and overtopping on bad weather days.

Northward of the existing berths 1 & 2, the roadway will be widened by expanding the roadway into the sea. Also in this section, existing armor will be reused. Therefore during the construction, the existing armor will first be removed, the roadway widened, and the armor replaced on the slope.

The container facilities in Tema can most logically be expanded inside the breakwaters by first taking into use Berths 3-5 exclusively for containers and then subsequently expand by placing the new berths on the inside of the breakwater on Figure 4.5.

The proposed first expansion is shown on Figure 4.5. It includes the entire Quay 2 in Tema supported by a 21.8 ha container yard immediately to the west. Further expansion, phase 2, is shown on Figure 4.6 making two additional berths on the inside of the breakwater. These berths are equivalent to the existing berths 1 and 2 and backed up by an additional 38.6 ha of container yard.

This expansion is the limit of expansion within the breakwaters without modifying the breakwaters. Therefore in phase 3 shown on Figure 4.7, the existing breakwater is extended to the west thereby enlarging of the harbor. This new area will be dredged to 12m water depth as for the existing container berths 1 and 2.

The layout on figure 4.7 permits two additional berths to be placed inside of the new breakwater and extending the existing berth 1 and 2 to the west. Two new berths will be backed up by a container yard of 56.1 ha as shown on figure 4.7.

The ultimate expansion plan as shown on Figure 4.7 will enable Tema to handle the projected optimistic case container throughput in the year of 2028. If this forecast does not materialize and the most likely forecast materializes then the expansion shown on figure 4.6 is adequate to handle the container traffic in the year 2028.

The proposed sequence of expansion uses Quay 2 to its maximum extent before building new berths on the inside of the breakwater as shown in Figure 4.5. It is however possible to make the first expansion of the container facilities by building new berths on inside the breakwater and then subsequently take existing berths 3, 4, and 5 into use for containers. If the rest of the port is faced with congestion and limited capacity, this may be a more attractive option. This may also be a more attractive option from the point of view that the new berths inside the breakwater can handle all sizes of ships that can presently be handled at berths 1 & 2. When expanding on Quay 2 one berth, berth 5, is limited to handle feeder vessels only.

Whether or not the sequence of expansion is as described in this section Figure 4.7, shows the master plan for expanding container facilities within the existing harbor.

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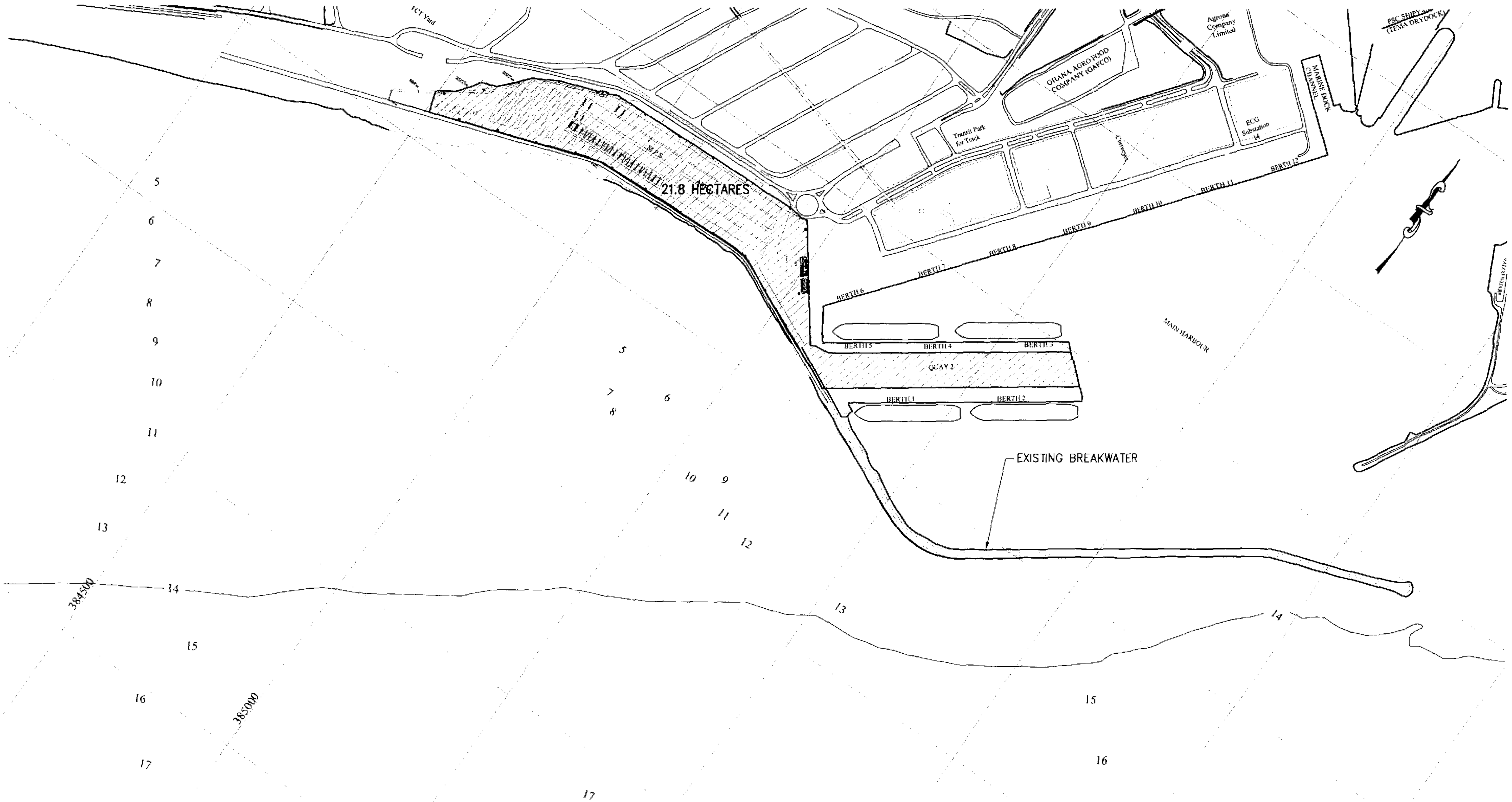

NOTE

ALL UNITS IN METERS AND ELEVATION IN METERS.

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PORT OF TEMA
EXPANSION PLAN
IN-HARBOUR CONCEPT,
PHASE 1

FIG 4–5

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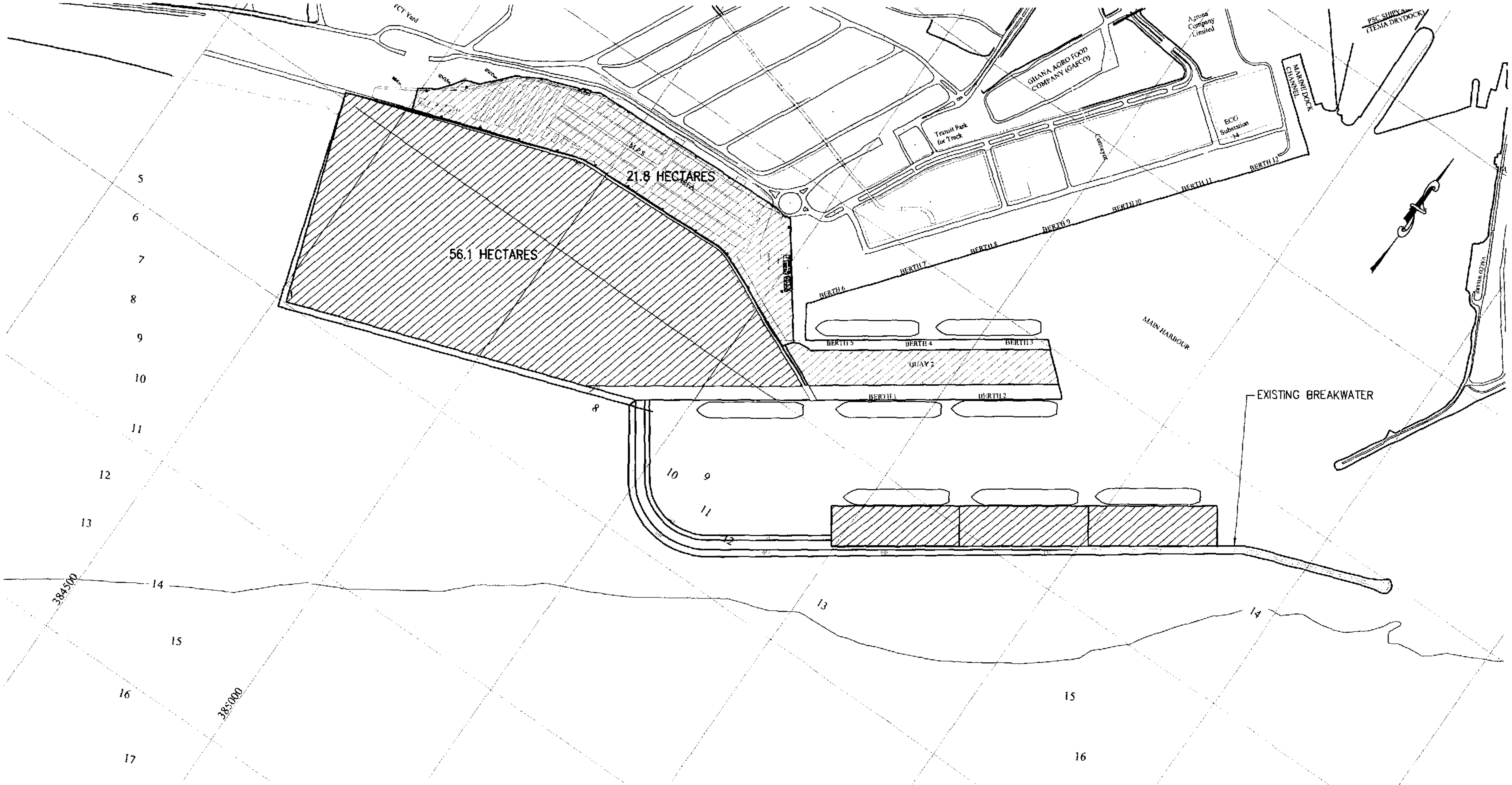

NOTE

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GHANA PORTS AND HARBOURS AUTH.
PORT OF TEMA
EXPANSION PLAN
IN-HARBOUR CONCEPT,
PHASE 3

FIG 4-7

Chapter 5 - Facilities Engineering & Cost Development

5.1 Dredging and Wharf Structures

The present plan does not contain a proposal to deepen the port beyond the existing 12m water depth relative to chart datum. The existing berths 1 & 2 can not be depended further without structural reinforcement. Berths 3, 4 & 5 similarly can not be deepened without modifications to the structure.

The new structures to be built on the leeward side of the breakwater can be built to 12m depth without any dredging in the harbor basin. Nonetheless, it would be prudent to plan these structures for an increase of the depth of 1m in the harbor basin. Therefore it is proposed to build the new container wharf structures on the leeward side of the breakwater to a future water depth of 13m.

The existing port is facing horizontal constraints if a ship requiring a depth of more than 13m is considered. This is because the deeper draft ships not only require more water depth but also require more space horizontally as they are longer. The existing layout imposes constraints on the ship size. Modifying the exiting port to accommodate much larger ship will require extensive and expensive modifications to the breakwater, dredging inside the port basin, dredging of an entrance channel, and possibly modifications to the wharfs. It could therefore be advantageous to build an entirely new port possibly at a different location remote from Tema, if such larger ships were to be accommodated.

5.2 Landfills

Landfills are required for the expansion for the container yard and also for the container berths to be placed on the leeward side of the breakwater. In addition, a smaller amount of fill will be required to widen and create the roadway between the container yard and the berths.

Because the plan contemplates no dredging, all landfill materials must be obtained from land sources. Existing evidence from nautical charts and from the soil borings, principally from inside the port, show that rock is very close to the surface or at the surface in the immediate vicinity of the port. Therefore it does not seem possible to gain suitable fill material by dredging cohesion less soils in the vicinity of the port. If such material is available; this would be the cheapest source of fill material.

The port was originally built with fill obtained from the Shai Hills quarry. The material was transported from the quarry to the port by railroad. It is believed that the right of way of this railroad still exists and can easily be rehabilitated. This quarry contains a very large quantity of materials. The quarry has not been investigated as part of this project however it has been reported that for purposes of this project, unlimited quantities of materials are available.

The quarry is 35km distant from the port. It would be feasible to use truck transportation for this material. However, Tema is already very congested with trucks. It is therefore believed that the best option for transporting the materials from the Shai Hills quarry to the port will be the railroad. This railroad is assumed rehabilitated for the project solely for the purpose of transporting this fill material.

It is noted that supplemental armor rock may be required for the revetments or the breakwater; this rock can also be obtained in the quarry and be transported by the railroad.

The soil investigations made by the West African gas pipeline project indicate that suitable soils might be available offshore in water depth of 30-50 meters

Therefore it is recommended that an offshore exploration survey to be initiated to identify potential sources of landfill materials. It is recommended to survey a 40km stretch of the coast centered on Tema and water depths between 25m and 50m.

5.3 Geotechnical Field Surveys

To support the design of the expansion recommended by this master plan, it is proposed that geotechnical surveys be made underneath the new wharfs. The recommended extent of these surveys is shown in Figure 5.1.

A draft specification of these surveys is enclosed as Appendix A.

5.4 Preliminary Design Criteria

Preliminary designs for each concept were developed using the below preliminary criteria. It is anticipated that final design criteria may differ somewhat from the criteria used for this analysis. Such differences may affect the actual cost of the quay wall, but they would not affect the conclusion regarding which is the preferred alternative for this application. The preliminary design criteria are as follows:

- Mooring and berthing for container vessels ranging from feeders to Panamax
- Rail mounted Panamax gantry cranes with an outreach of approximately 32 m, and a rail gage of 18 m
- A uniform live load of 150 kN/m^2 waterside of the waterside crane rail and a uniform live load of 50 kN/m^2 inshore of the waterside crane rail
- The waterside crane rail is located 5 m from the face of the quaywall
- Top of quay wall elevation is +2.5 m, and dredge depth elevation at the quaywall is -12.5 m
- The quay wall will be founded on rock
- Loads are vehicles for containers and heavy load transport such as lift trucks, mobile cranes, straddle carriers, and tractor trailers
- Consideration of wave, wind, and current forces
- Consideration of lateral earth pressure and slope stability
- Consideration of erosion and corrosion

A number of internationally recognized design manuals and construction standards were used in developing these conceptual designs including:

- American Association of State Highway and Transportation Officials (AASHTO)
- American Concrete Institute (ACI)
- American Institute of Steel Construction (AISC)
- American Petroleum Institute (API)
- British Standard Code of Practice for Maritime Structures
- International Navigation Association for Development of Modern Marine Terminals (PIANC)
- United States Naval Facilities Engineering Command Military Design Handbooks

The alternatives evaluated are presented below, with discussions of design, schedule, and cost considerations.

5.4.1 CONCRETE BLOCK

The concrete block gravity structure concept is illustrated in Fig 5.2. After dredging, a gravel foundation bed is placed, followed by installation of large prefabricated concrete block units. Both unreinforced solid and hollow blocks have been considered. Unreinforced concrete blocks have the advantage over reinforced concrete blocks in that there will be no reinforcement subjected to corrosion, and they would thus result in a less maintenance intensive product with a long life expectancy. Hollow blocks may also be considered since they can be made larger than solid blocks without substantially increasing their weight. Therefore, for the same weight as a solid block, the hollow block creates a larger surface area of wall, resulting in fewer blocks being lifted with heavy-lift equipment. The hollow vertical cavities may be filled with either crushed stone or reinforced concrete, which could be installed using lower cost equipment. The blocks are typically sized with a design weight of approximately 70 tonnes. However, the contractor would have the option to fabricate larger, heavier blocks to suit the capacity of his construction equipment.

Blocks will be sufficiently large and heavy enough to withstand lateral loads resulting from soil pressure combined with additional surcharge, uniform live loads, mooring loads, crane loads, and wave loads. Scour protection at the toe would be provided. Geotechnical considerations for design include ground bearing pressure, lateral earth pressure, safety against sliding and overturning, and appropriate fill material and compaction methods behind the wall.

For comparison purposes only, the bare cost per linear meter of quay wall founded at -13m, based upon using the solid precast blocks, is approximately USD $40,000.00.

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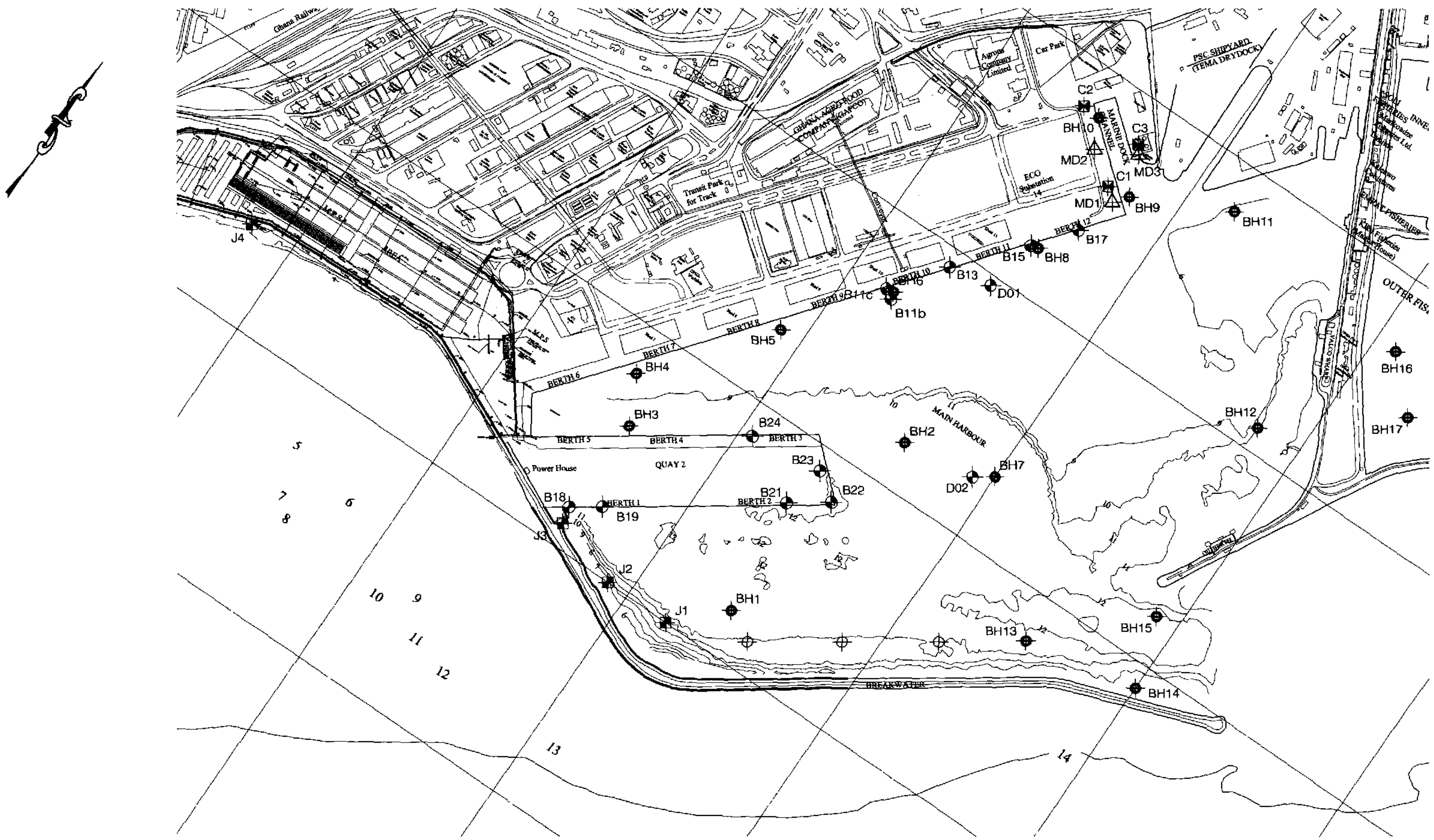

LEGEND:

- EXISTING BORINGS BY BOSKALIS (1992)
- EXISTING BORINGS BY JICA (2002)
- EXISTING BORINGS BY RHEIN-RUHR (2001)
- EXISTING BORINGS BY CONTERRA
- EXISTING BORINGS BY MINEREX/BOSKALIS (2000)
- PROPOSED BORINGS

NOTE:

DEPTHS IN METERS

1:10000 100 0 500 m

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PORT OF TEMA

SOILS BORINGS

FIG 5-1

Fig 5.2

Concrete Block Quaywall

(Illustration only, not applicable to Tema)

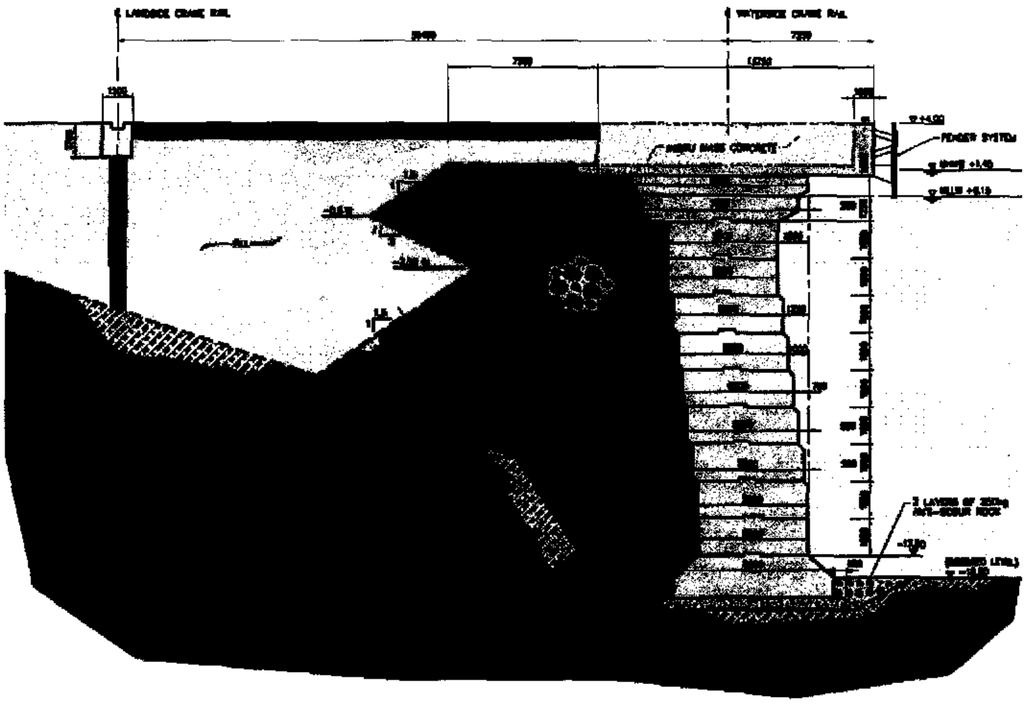
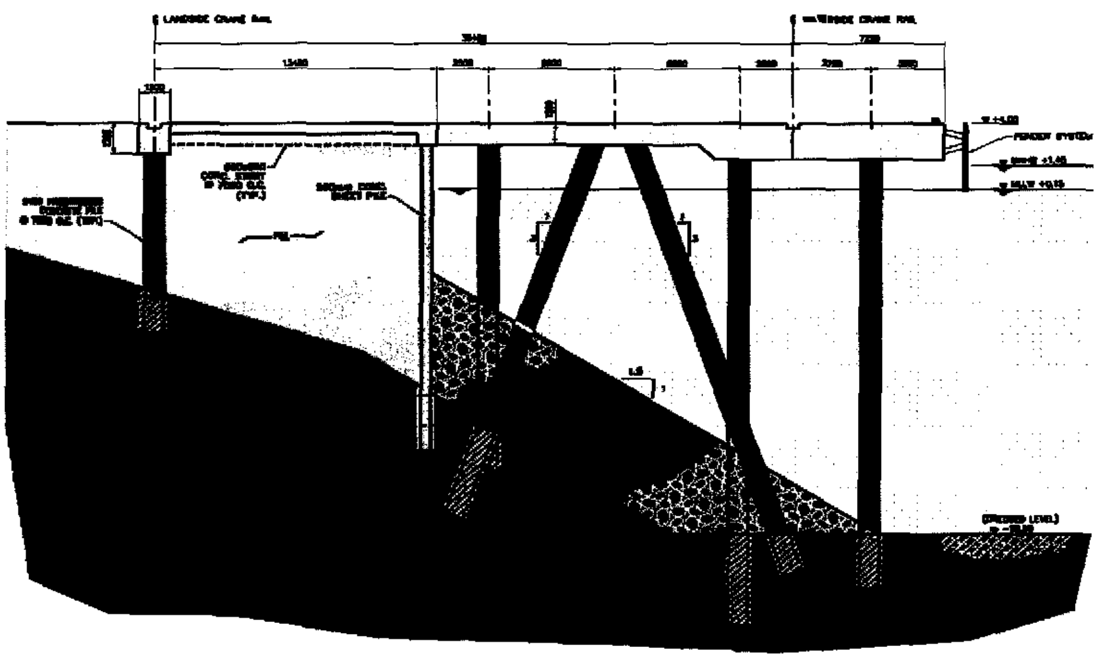


Fig 5.3

Pile-Supported Platform Quaywall

(Illustration only, not applicable to Tema)



5.4.2 Pile-Supported Platform

A pile-supported platform type quay wall is illustrated in Fig 5-3. It includes 915-mm diameter vertical and battered piles, with vertical pile loads distributed to all piles and lateral loads resisted almost entirely by the battered piles. The piles are precast and prestressed hollow concrete. The estimated bent spacing of the piles and pile caps is 7 m on center. Suitable expansion joints along the length of the superstructure would be provided.

This alternative requires that piles be embedded into the existing rock strata. Oversized holes must be predrilled to the established depth of embedment. The piles would then be secured in the holes using high strength grout, providing adequate bonding strength to resist design loads. The remaining superstructure construction could begin after the grout has properly cured.

The superstructure consists of either a continuous, monolithic, reinforced concrete flat slab, or pile caps with a composite deck slab. The flat slab concept is illustrated. Moment resisting connections have been integrated at the tops of all piles. Also, a thickened section has been incorporated to act as the crane rail beam. The composite deck slab option includes prefabricated, prestressed concrete planks topped with cast-in-place reinforced concrete.

The pile-supported platform quay wall alternative incorporates an appropriate underwater slope constructed from fill material. Graded riprap armor stone provides protection against erosion from wave action and turbulence from bow thrusters and stern propellers.

A sheet pile cut-off wall is also required for this design. The sheet pile used for the budget estimate is 500-mm thick precast concrete.

Some disadvantages of this concept are the requirements for steel reinforcement, and concrete pre-casting requirements. Steel reinforcement could present long-term corrosion problems, especially with prestressed elements. Precast products may also be difficult to obtain locally. Steel sheet piling, if used instead of concrete sheet piling, would also present a corrosion problem, and/or additional maintenance costs in terms of cathodic protection requirements.

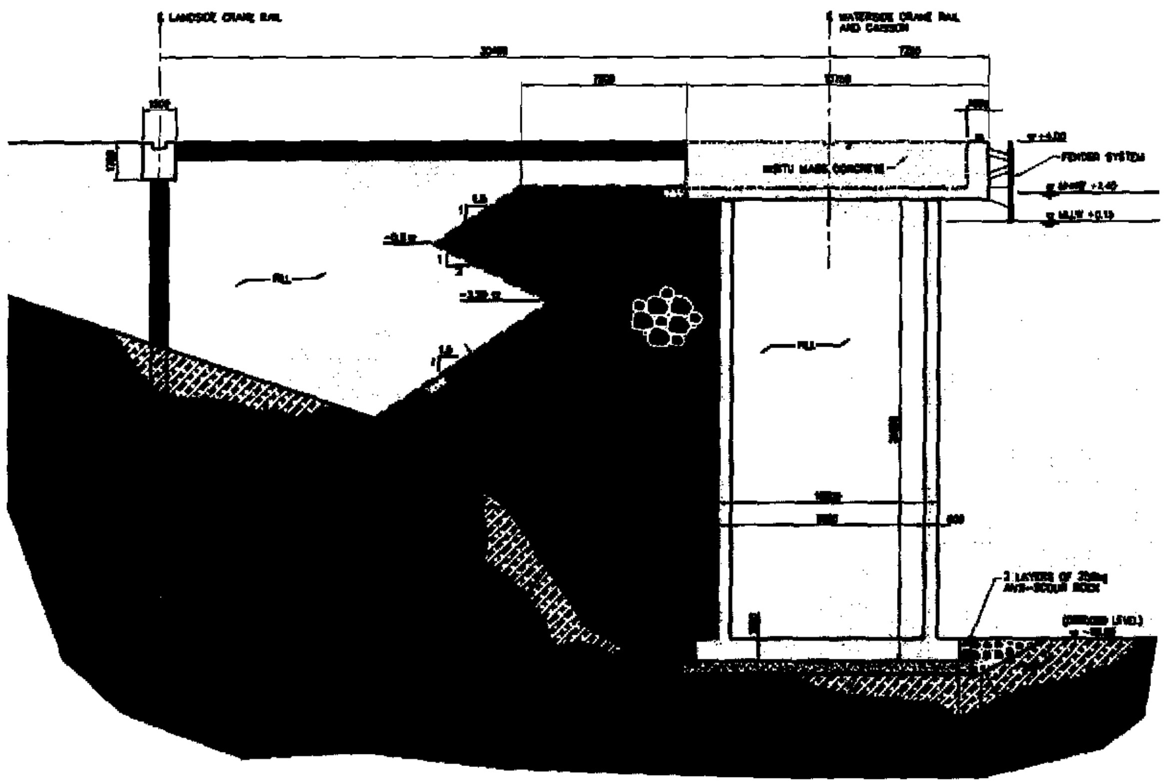
This concept provides the advantage of a wave dissipating slope, which would tend to reduce the wave disturbance.

The approximate bare cost per linear meter of quay wall, for comparison purposes only, based upon using the pile-supported platform with 500-mm thick precast concrete sheet piling, is USD $50,000.00.

5.4.3 PRECAST CONCRETE CAISSON

The concept which features large pre-fabricated concrete caisson units positioned on a gravel foundation bed is illustrated in Fig 5.4. The caissons would be prefabricated at a nearby location either inside the harbor basin in Tema or in the graving dock in Tema, towed to the site, lowered into position by controlled flooding, and filled with sand or gravel. After backfilling and compaction of fill material is complete, the top of the caisson units would be fabricated with reinforced cast-in-place concrete, followed by the crane rail support beam. The caisson units would be designed to resist lateral soil pressure combined with additional surcharge, uniform live loads, mooring loads, and crane loads. Scour protection along the toe of the caisson units is included in the design.

Fig 5.4
Concrete Caisson Quaywall



(Illustration only, not applicable to Tema)

This concept has the potential for requiring significant maintenance due to corrosion of the steel reinforcement in the caisson walls if proper quality control is not assured. Delivery and installation schedules could also be impacted by weather conditions and/or storm events due to the sensitivity of the installation procedure and the possible requirement for floating in the prefabricated units from a considerable distance away from the site.

The linear meter estimate of the cost of the caisson concept was developed based upon the same assumptions used for the other concepts. The cost reflects the need to provide work areas to fabricate the caissons and also includes the associated costs for outfitting the work barges to include the resources necessary for completing the work. The bare linear meter cost of the quaywall, for comparison purposes only, is approximately USD $55,000.00.

5.4.4 Evaluation of Concepts

The various quay wall concepts were evaluated based on their relative costs, their technical advantages and disadvantages, and their ability to allow completion of construction within the time frame permitted for the overall project.

The recommended method of construction for the quay wall is a concrete block wall. At this time, it cannot be definitively stated whether the wall should be of solid or hollow block construction since, based on the information in hand, they are of approximately equal relative cost and the minimal differences in construction procedures do not differentiate their construction schedules. It is possible that the final design would be based on the solid block option but would permit the construction contractors to submit alternative tenders based on the hollow block option if that option is more suitable for their equipment and proposed procedures.

The concrete block type of quay wall construction is common to the area. It is familiar to the international contractors operating in the general vicinity of this project. In addition, the block wall construction maximizes the use of local materials and minimizes the need to rely on imported material.

5.4.5 Fuel Bunkering

No bunkering is provided.

5.5 Preliminary Cost Estimates

Construction costs were estimated on the basis that construction is let on the basis of fully developed plans and tendered to international contractors. The cost basis is prevailing costs in West Africa in 2009.

Table 5.1 Capital Cost Estimate

Port of Tema Expansion Plan
Ghana Ports and Harbors Authority
Tema, Ghana

Halcrow
Project No.: DGGHAN
07-Dec-09

Conceptual Estimate Breakdown

Cost in $US

ITEM DESCRIPTION	Quantity	Unit	Unit Cost	Total Cost
Phase 1				114,386,242
Phase 2				291,784,168
Phase 3				327,170,518
Total Phased Project Costs				*733,340,928*
Transshipment Concept				
Option No. 1: Caisson Construction, Quarry Fill				800,110,761
Option No. 2: Caisson Construction, Offshore Borrow Fill Material				753,425,145
Option No. 3: Rubble Breakwater Constr., Quarry Fill, Block Quay				811,280,265

Note: Cost represent Conceptual Level Design and should be considered accurate on the level of +/-30 %

Mark-Up Included

General Conditions	8%
Mobilization	8%
Overhead	10%
Profit	15%
Design Contingency	25%
Construction Contingency	25%

Port of Tema Expansion Plan
Ghana Ports and Harbors Authority
Tema, Ghana

Halcrow
Project No.: DGGHAN
07-Dec-09

Conceptual Estimate Breakdown

Cost in $US

ITEM DESCRIPTION	Quantity	Unit	Unit Cost	Total Cost
Phase 1				114,386,242
Land Reclamation				30,395,362
Pavement				14,827,006
Cargo Handling Equipment				69,163,875
			Phase 1	114,386,242
Phase 2				291,784,168
Land Reclamation				109,420,644
Pavement				36,946,477
New Roadway				21,786,621
Quay Wall at New Berth				54,466,552
Yard Handling Equipment				69,163,875
			Phase 2	291,784,168
Phase 3				327,170,518
Land Reclamation				49,128,830
Pavement				19,063,293
Removal of Existing Breakwater				12,680,044
Construction of New Breakwater				88,760,306
Dredging				37,942,178
Quay Wall at New Berth				50,431,992
Cargo Handling Equipment				69,163,875
			Phase 3	327,170,518
	Total Phased Project Costs			*733,340,928*

Port of Tema Expansion Plan
Ghana Ports and Harbors Authority
Tema, Ghana

Halcrow
Project No.: DGGHAN
07-Dec-09

Conceptual Estimate Breakdown

Cost in $US

ITEM DESCRIPTION	Quantity	Unit	Unit Cost	Total Cost
Phase 1				**114,386,242**
Land Reclamation				**30,395,362**
Fill Material Acquisition	1,286,250	cu m	5	5,930,802
Fill Material Processing	1,286,250	cu m	7	8,896,203
Fill Material Transportation	1,286,250	cu m	10	12,602,955
Fill Material Handling at Reclamation	1,286,250	cu m	2	2,965,401
	1,286,250	*cu m*	*24*	*30,395,362*
Pavement				**14,827,006**
Pavement	183,750	sq m	81	14,827,006
	183,750	*cu m*	*81*	*14,827,006*
Cargo Handling Equipment				**69,163,875**
Cargo Handling Equipment	1	ls	69,163,875	69,163,875
	1	*ls*	*69,163,875*	*69,163,875*
			Phase 1	**114,386,242**
Phase 2				**291,784,168**
Land Reclamation				**109,420,644**
Fill Material Acquisition	4,630,388	cu m	5	21,350,369
Fill Material Processing	4,630,388	cu m	7	32,025,554
Fill Material Transportation	4,630,388	cu m	10	45,369,535
Fill Material Handling at Reclamation	4,630,388	cu m	2	10,675,185
	4,630,388	*sq m*	*24*	*109,420,644*
Pavement				**36,946,477**
Pavement	457,875	sq m	81	36,946,477
	457,875	*sq m*	*81*	*36,946,477*
New Roadway				**21,786,621**
New Roadway	630	m	34,582	21,786,621
	630	*m*	*34,582*	*21,786,621*
Quay Wall at New Berth				**54,466,552**
Quay Wall at New Berth	675	m	80,691	54,466,552
	675	*m*	*80,691*	*54,466,552*
Yard Handling Equipment				**69,163,875**
Yard Handling Equipment	1	ls	69,163,875	69,163,875
	1	*ls*	*69,163,875*	*69,163,875*
			Phase 2	**291,784,168**

Port of Tema Expansion Plan
Ghana Ports and Harbors Authority
Tema, Ghana

Halcrow
Project No.: DGGHAN
07-Dec-09

Conceptual Estimate Breakdown

Cost in $US

ITEM DESCRIPTION	Quantity	Unit	Unit Cost	Total Cost
Phase 3				327,170,518
Land Reclamation				**49,128,830**
Fill Material Acquisition	2,079,000	cu m	5	9,586,113
Fill Material Processing	2,079,000	cu m	7	14,379,170
Fill Material Transportation	2,079,000	cu m	10	20,370,490
Fill Material Handling at Reclamation	2,079,000	cu m	2	4,793,057
	2,079,000	***cu m***	***24***	***49,128,830***
Pavement				**19,063,293**
Pavement	236,250	sq m	81	19,063,293
	236,250	***sq m***	***81***	***19,063,293***
Removal of Existing Breakwater				**12,680,044**
Removal of Existing Breakwater	550	m	23,055	12,680,044
	550	***m***	***23,055***	***12,680,044***
Construction of New Breakwater				**88,760,306**
Construction of New Breakwater	1,100	m	80,691	88,760,306
	1,100	***cu m***	***80,691***	***88,760,306***
Dredging				**37,942,178**
Dredging	1,097,168	cu m	35	37,942,178
	1,097,168	***cu m***	***35***	***37,942,178***
Quay Wall at New Berth				**50,431,992**
Quay Wall at New Berth	625	m	80,691	50,431,992
	625	***m***	***80,691***	***50,431,992***
Cargo Handling Equipment				**69,163,875**
Cargo Handling Equipment	1	ls	69,163,875	69,163,875
	1	***ls***	***69,163,875***	***69,163,875***
			Phase 3	**327,170,518**
	Total Phased Project Costs			***733,340,928***

5.6 Offsite Road Improvements

5.6.1 MAJOR ASSUMPTIONS

The existing gates will be expanded and the existing traffic pattern will be maintained. As directed by GPHA the container traffic will use the existing roads as indicated on Figure 5.5.

5.6.2 LANDSIDE ACCESS

The following baseline assumptions have been made in establishing the port related traffic:

- The port will, in general, operate 24/7/365
- No consolidation or "stuffing" of containers will occur within the port
- Container moves within the port will be primarily accomplished using yard handling equipment

Based on the baseline assumptions and shipping forecast, an estimation of the vehicular traffic (mainly truck traffic) demand for the port has been generated. These estimates deal solely with traffic generation from the port itself, and do not address traffic issues beyond the port gate.

The land access to Tema is heavily congested at the present time. The expansion of container traffic will without doubt add to this congestion.

GPHA indicated that the containers will enter or leave Tema via Harbour road as shown in Fig 5.5. This road will need to be widened to handle the harbour traffic, however, this by itself will not solve the traffic congestion in Tema.

A major study of the entire road system at Tema is recommended. Such study should aim not only alleviate the present congestion but provide for the near and far future unimpeded access to the port and to the many industrial facilities now operating in Tema. Such study is beyond the scope of this report.

5.7 Rail Improvements

The railroad has ample operational areas in Tema for potential future operations.

The railroad is currently not operating in Tema. However, the railroad operations areas exist and the right of ways and in many cases the tracks exist. It can therefore be foreseen that if the proper business case for rehabilitating the railroad exists, this will be done.

It is assumed that the railroad in Tema may begin to transport containers. The containers will in this case be transferred between the container yards and railroad marshalling area, which is immediately north of the port by using yard tractors. It is not foreseen that integration between the railroad operations and the container yard operations will be undertaken. However, the plan provides for such a possibility.

Consequently, it will be possible for the railroad to offer in the future the transportation of containers directly from the container yard at Tema to destinations served by the railroad provided it acquires the appropriate rolling stock and upgrades the track beds to provide reliable service.

5.8 Electrical Supply

The port is within the industrial city of Tema with easy access to the national electrical grid. It is assumed that power will be obtained from this grid and distributed within the project area at an intermediate voltage of 11kv.

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Halcrow

GHANA PORTS AND HARBOURS AUTH.
PORT OF TEMA
EXPANSION PLAN

CONTAINER FACILITY ACCESS ROAD

FIG 5–5

Chapter 6 – Implementation Planning

6.1 Key Success Factors

The expense of the container facilities at Tema is driven by need arising from import and export volumes generated by the economy of Ghana. The only alternative port for container export or import in Ghana is Takoradi. Takoradi only handles a negligible portion of import/export of containers in Ghana. Therefore, expansion of the container facilities at Tema in proportion to the increase in foreign trades in Ghana is a necessity.

Nevertheless, the manner in which the container facilities at Tema are expanded is important. At the present time in 2009, the container handling at Tema is being consolidated in a modern efficient container yard immediately to the rest of the port. GPHA has plans of expanding the area of this container yard as the need arises by filling the sea immediately seaward of the existing container yard. The plan in this document endorses this concept. The Port of Tema provides many other services beyond handling containers. It is important that these services continue to be provided in an efficient manner. The plan proposed in this document minimizes interference with other port functions, both during construction of the expansion of the container facilities and the operations.

Because the existing operator MPS is assumed to continue to operate the expanded facilities, they assume a dominant position in the Port of Tema. It is therefore of utmost importance that an agreement be reached with MPS as to the tariffs and sharing of costs of developing the expanded facilities. It is recommended that a tariff be negotiated with MPS that allows a reasonable return on the investments to be made by MPS and at the same time permits the existing contract to expire in 2024 as foreseen in the existing contract.

Chapter 7 – Environmental Impact Analyses

7.1 Summary

The Ghana Ports and Harbours Authority (GPHA) has embarked on a Port Development Strategy (PDS) aimed at transforming from an operating Port Authority to a Land-lord Port Authority. As part of the PDS, a master plan is being prepared for the modernization of its commercial port at Tema. The three components of this feasibility study for the master plan are: 1. Analytical Assessment of Ghana's Port Capabilities, Performance, and Market, 2. Review and Realignment of Ghana, Port Goals and Strategies, 3. Development of a Master Plan for the Tema Container Terminal.

At the Port of Tema, the following activities are expected to be carried out in part or in whole in the process of providing access to the larger container vessels to the Port of Tema:

- Deepened and possibly widened entrance channel
- Deep end port basins
- Larger turning basins
- Possibly new and extended breakwaters
- Wharves designed and extended for the new depths
- Larger container cranes
- Larger container yards

In compliance with the Ghana Environmental Protection Agency (GEPA) environmental regulations, this report provides preliminary environmental impact analysis of the biophysical and socioeconomic environment of the projects as conceived in the Master Plans. The objective of this preliminary environment report (PER) include, *inter alia*:

- Provide the proponents with the major potential environmental issues and baseline conditions (where available) for the proposed activities.
- Identify potential impacts and possible mitigation measures.
- Propose plans to manage the identified impacts resulting from the project.

It is anticipated that the port expansion activities would have some impacts on the environment. Depending on the scale and magnitude of identified issues, a full environmental impact assessment (EIA) study will be recommended and an environmental assessment (EA) report as required by EPA Act 1994 (Act 490) and Environmental Assessment Regulations, 1999 (LI 1652) will have to be prepared.

The expansion works is expected to follow the normal three-tier project life cycle of the construction, operational and termination / decommissioning phases. At Tema Port, the key construction activity will be the extension of the container berths of Quay 2 and possibly deepening of berths 11 and 12.

Environmental issues assessed in this PER for Tema Port are land uses, water uses, socioeconomic impacts, traffic and transportation, geology and hydrogeology, water and sediment quality, marine and terrestrial ecology, fisheries resource, air quality, noise and visual intrusion.

7.2 Tema Port

The assessment of the existing situation identified the following environmental data gaps:

1. Hydrogeological. Data on aquifers and any subterranean flows/seepages into the sea.
2. Current and wave dynamic information. Long term information on wave and current dynamics for modeling of extent of impacts of storm surges and inform diffusion and dispersal of pollutants entering the harbour and its environs etc.
3. Sediment and Water quality data. Sediment characteristics within the harbour and surrounding areas quality for toxicity, heavy metal levels and organic pollutants (PAH and TPH).
4. Biological indicators of pollution. Phytoplankton and zooplankton biodiversity and abundance; microbiological contamination levels particularly fecal coliforms and other pathogenic microbes; macrobenthic fauna abundance and diversity (within harbour and vicinity, intertidal and near shore between 1-20 m depth).
5. Socio-economic information of the Port. Data on employment level and induced development in Tema due to changes in port infrastructures and activities.
6. Air quality data. Diurnal variation and seasonal data to capture reversals in wind direction for periods of offshore winds (night breeze) and onshore winds (day breeze) as well as in dry season (January) and wet season (July).
7. Traffic and transport. Traffic and parking survey data for the key access roads including locations and quantities of parked trucks.

8. Land uses. Shoreline recession rates from beach profile monitoring data.

7.3 Identified impacts and amelioration

In a number of cases, identified impacts would require consultations with stakeholders with the port authorities. Impacts related to land uses, water uses, fisheries resources fall under this category. Community expectations need to be managed, especially with regard to existing poor urban environment of some local townships such as Tema Manhean. Ameliorative measures have been proposed for the other impacts identified irrespective of level of severity. Key surveys (which could include marine ecology, water and sediment quality, and coastal processes and sediment transport etc) may need to be undertaken early in the study process to ensure early environmental permit approval. Surveys to fill data gaps may be worthwhile even if only to dismiss any potential environmental impact.

7.4 Conclusion

The PER was prepared according to GEPA assessment regulations derived from EPA Act 490 and LI 1652. The environmental assessment identified moderate to minimal impacts affecting land use, water uses, socioeconomic impacts, traffic and transportation, geology and hydrogeology, water and sediment quality, marine and terrestrial ecology, fisheries resource, air quality, noise and visual intrusion, occupational health and safety.

In order to reduce and/or mitigate the identified impacts, GPHA will have to conduct a full scale EIA into the existing environment of the proposed project to identify the nature and extent of the identified impacts and the probable effects they may have on natural systems and society. An effective and rigorous environmental management plan will then be implemented to mitigate the effects of identified impacts.

7.5 Background

The Government of Ghana (GoG) is currently supporting a Port Development Strategy (PDS) which addresses private participation in the ports, development of Freeport zones, modernization of customs practices, and transportation infrastructure modernization and alignment. The Ghana Ports and Harbours Authority (GPHA) is integral to the implementation of the PDS. In order to execute its responsibilities most effectively, GPHA is transitioning from an operating Port Authority to a Land-lord Port Authority. As a Land-lord

Port Authority, GPHA would own the physical infrastructure of the port, but work with private investors to operate those assets. As part of the PDS, a Master Plan is being prepared for the modernization of Tema port. The modernization works is envisaged to bring the existing infrastructure and facilities to a state-of-the-art level, which would include extensive physical development work.

7.5.1 PORT OF TEMA

Tema is located about 25 km east of Accra in the Greater Accra Region of Ghana. The area falls within Latitude 5°38'1"N and Longitude 0°0'47"E and lies within the coastal savannah zone. The port of Tema has a total area of 5.5 km^2 out of which 3.9 km^2 is land. The Ghana Ports and Harbour Authority (GPHA) is mandated by Ghana Ports and Harbour Authority Law, 1986 (PNDC Law 160) to manage the Ports in Ghana. Presently, over 90% of Ghana's international Trade is sea borne, and about 80% occurs through the Port of Tema. The container throughput at Tema Port has more than doubled since 1998. Over the years, the Port of Tema has seen significant increases in the level of cargo traffic and is poised to become a maritime hub in the West Africa sub-region.

The Port has good anchorage from 1.5 km to 4 km ENE to SW off the main harbour entrance in depths of 9 m to 18 m with good holding ground. Deep draft vessels enter only at high tide to avoid the effect of heavy swells which causes vessels to roll heavily up to 40-80 during the monsoon season from April to September. Re-fuelling of all marine craft is carried out by the Ghana Bunkering Services from the Fishing Harbour. Heavy bunkers are available from the oil berth located on the south end of the main eastern breakwater. A total of 19,000 m^2 storage area for transit cargo is available at Berths 1,2,3,4,5,7,9, and11. There is storage capacity for cocoa in 4 sheds for a capacity of 60,000 tonnes. Overall, the port has a total of 53,270 m^2 covered and 92,200 m^2 of open storage. The Port maintains a 24 hr watch on VHF Channels 14 and 16 which can reach vessels within a radius of 140 km and during Harmattan conditions, vessels can hear the signal 400 km from port. The Oil berth accommodates tankers up to 244 m in length and 9.7 m in draft. The Port operates four tugs fitted with pumps and monitors for fire-fighting. Towage is compulsory within the harbour.

The Port boasts of a state-of-the-art container handling facility comprising ship-to-shore and rubber-tyred gantry cranes. The total quay length of the new container terminal is 570 km with a draft of 11.50 m. The new container on-dock and near dock operations is under the management of Meridian Port Services Limited (MPS), a joint venture of APM Terminals International, Bollore Group and GPHA. Various off dock container terminals exist as well as car parks run by private operators. The Golden Jubilee Terminal (GJT), an off-dock container devanning terminal was commissioned in March, 2007. The construction of the terminal was undertaken to overcome space constraints posed by large volumes of containerized cargoes which required stuffing and un-stuffing as well as parking space for imported vehicles. The GJT is located 300 m from the western gate of the Tema main harbour and is linked by an excellent road system.

Transshipment is another important growing component of the core activities of the Port. There has been significant advance in the performance of transshipment since 2005. The tonnage of goods rose from 71,083 in 2004 to 327,648 tonnes in 2006. Key players in the transshipment business are Hull-Blyth, Maersk Line, ISAG, MOL and Messina Lines. The increase in transshipment volumes is attributable to the provision of a dedicated container terminal and the use of the ship-to-shore gantry cranes as well as good port management practices including cargo security. There is immense potential for growth in transit trade through Ghana to the landlocked countries in the sub-region. The total volume of transit cargo traffic stood at 887,325 tonnes in 2006. A 100,000 dwt dry dock and slipway facility is available at the Port and operated by PSC Tema Shipyard Ltd.

A separate fishing harbour with cold-storage and marketing facilities is east of the lee breakwater. The fishing Harbour comprises of an Inner Harbour, Outer Harbour, Canoe Basin and a Commercial Area. The Inner Fishing Harbour was commissioned alongside the main harbour in 1962 to provide landing facilities for semi-industrial and industrial fishing vessels and to promote the development of the Ghanaian fishing industry. The Outer Fishing Harbour was added in 1965 to provide deeper draft for larger vessels of the national fishing fleet. More recently, a tuna wharf was commissioned in 1995 to accommodate larger tuna fishing vessels to encourage landing of tuna in Ghana.

7.6 Project Objectives and Justification

7.6.1 OVERVIEW AND JUSTIFICATION OF THE PROJECT

The proposed project aims at providing master plans for the Port of Tema. The master plan has three main components comprising:

1. Analytical Assessment of Ghana's Port Capabilities, Performance, and Market,

2. Review and Realignment of Ghana Port Goals and Strategies,

3. Development of Master Plan for Tema Container terminal and

The Master Plan would involve infrastructural expansion of the Tema container terminal. A significant aspect of the Master Plan would be the expansion of the facilities to accommodate larger vessels and also aim at eliminating the draft limitations of the new container terminal at the Port of Tema.

The improvements to the port of Tema is justified not only by the rapidly increasing traffic and demand for services at Ghana's ports, but also by the more private sector approach to infrastructure development that the Government of Ghana has embraced. Over $100 million in public and private investment has been spent on port facilities in Ghana in recent years, demonstrating the high priority being given to port facilities by the Government, and the high level of interest from the private sector.

Ghana is one of the rapidly growing economies in West Africa. The nation's seaborne traffic has grown substantially since 1999 when violence erupted in neighboring Cote d'Ivoire causing much traffic to be moved through Ghana as an alternative route. The Government of Ghana views an efficient port system as crucial to its plans to become the trade and investment gateway to West Africa.

The proposed project will provide huge benefits to the country. Besides economic gains, there would be significant social benefits including the provision of jobs and job security to several Ghanaians during the constructional and operational phases of the project.

7.6.2 PORT OF TEMA

The following activities are expected to be carried out in part or in whole in the process of providing access to larger vessels at the Port of Tema:

- Deepened and possibly widened entrance channel
- Deepened port basins
- Larger turning basins
- Possibly new and extended breakwaters
- Wharves designed and extended for the new depths
- Larger container cranes
- Larger container yards

The envisaged recommendations in the master plan would result in the development of up to four berths, eight gantry cranes, and cargo handling equipment as well as improved cargo storage facilities.

The above proposed developments will take into consideration the GPHA plans to redevelop Quay 1 to enhance cargo handling which will involve dredging and redevelopment of Berths 10-12 to enable it receive vessels drawing up to 11.5 m draft. The deep draft berth (berths 1 and 2 with depth of 11.0-11.5m) at Quay 2 handles the deep draft vessels of about 30,000 DWT.

7.7 Purpose and Objectives of the Preliminary Environmental Assessment

The port expansion activities would have some impacts on the environment. The purpose and objective of the Preliminary Environmental Report (PER) is to identify and examine the core environmental issues associated with project implementation based on the proposed tasks in the Master Plan. Depending on scale and magnitude of identified issues, a full environmental impact assessment (EIA) study will be recommended and an environmental assessment (EA) report as required by EPA Act 1994 (Act 490) and Environmental Assessment Regulations, 1999 (LI 1652) will be prepared.

7.8 Legal and Regulatory Requirements

Ghana has introduced environmental assessment legislation and regulations that enable the Government to limit and control developments that can be considered to have, or be capable of having, a significant effect on the environment. The relevant Ghanaian laws and legislative instruments relevant to the proposed development are:

- Ghana Ports and Harbours Authority Law 1986, PNDC Law 160;
- Ghana Investment Promotion Centre Act 1994, Act 478;
- Environmental protection Agency Act 1994, Act 490;
- Environmental Assessment Regulations 1999,LI 1652;
- Environmental Assessment Regulations (Amendment) 2002, LI 1703;
- Ports Regulations, 1964, LI 352;
- Factories , Offices and Shops Act 1970, Act 328
- Factories, (Docks Safety) Regulations, 1960;
- The New Labour Act 2003, Act 651;
- The Fire Precaution (Premises) Regulations 2003, LI 1724;
- Ghana Maritime Authority Act 2002,Act 630;
- Ghana shipping Act 2002, Act 645.
- Oil in Navigable Waters Act 1964, Act 235; and

- Relevant international conventions such as MARPOL, ISPS etc

The key documents include:

Environmental Protection Agency Act 1994

This Act covers the establishment of the GEPA, powers of the GEPA (particularly regarding environmental enforcement and control), establishment and operation of a national environmental fund, and general administration and operation of the GEPA.

Environmental Assessment Regulations 1999

This is the key environmental assessment Regulation as it outlines the requirements for registration of projects and issue of Environmental Permits (EPs), along with the procedures for the submission and review of EIA Scoping Studies, Preliminary Environmental Reports (PERs), and Environmental Impacts Statements (EISs). It also covers key issues such as allowable period for the determination of an application, requirements for a public hearing, validity period for an EP, and requirements for Environmental Certificates, Environmental Management Plans (EMPs), and annual Environmental Reports. Schedule 2 of the Environmental Assessment regulation 1999, requires a mandatory EIA for projects that are involved in dredging, coastal land reclamation, construction of ports and any port expansion involving an increase of 25% or more in annual handling capacity.

Environmental Assessment (Amendment) Regulations 2002

This Regulation amends the Environmental Assessment Regulations 1999 by providing updated information on environmental processing charges, permit fees, and certificate fees that need to be paid by a project proponent at various stages within the EIA approval process.

Ghana Maritime Authority Act 2002, Act 630

The Ghana Maritime Authority Act 2002, Act 630 has been enacted establishing the Ghana Maritime Authority which will advise government on Maritime matters and assist the Ministry of Harbour and Railways to formulate policies, monitor, regulate and coordinate activities and programs of the various sub-sectors in the maritime industry.

Ghana Shipping Act 2002, Act 645

The Ghana shipping Act 2002, Act 645 has been enacted to replace the erstwhile Merchant Shipping Act 1963, Act 183. These are all geared towards the overall restructuring of maritime administration in the country and implement the provisions enshrined in the Port regulations 1964, LI 352.

Ghana Ports and Harbours Authority Law 1986, PNDC Law 160

The Ghana Ports and Harbours Authority Law 1986, PNDC Law 160 mandates the Ghana Ports and Harbours Authority (GPHA) to plan, build, develop, manage, maintain, operate, and control Ports in Ghana. The law enjoins the GPHA among other functions to:

- Provide port facilities as appear to it to be necessary for the efficient and proper operation of the port
- Maintain the port facilities and extend and enlarge any such facilities as it shall deem fit;
- Regulate the use of any port and of the port facilities; and
- Maintain and deepen as necessary the approaches to, and the navigable waters within and outside the limits of any port, and also maintain lighthouses and beacons and other navigational services and aids as appear to it to be necessary.

These regulations ensure that environmental and socioeconomic management decisions are integrated at the planning stage of projects, aiding in the early identification of potential impacts and the mitigation of any adverse impacts.

In compliance with the GEPA environmental regulations, this report provides preliminary environmental impact analysis of the biophysical and socioeconomic environment of the projects as conceived in the Master Plans. The objective of this preliminary environment report (PER) include, *inter alia:*

- Providing the proponents with the major potential environmental issues and baseline conditions (where available) for the proposed activities.
- Identify potential impacts and possible mitigation measures.
- Propose plans to manage the identified impacts resulting from the project.

The project proponent and its consultants are expected to be committed to the environmental issues identified within the framework of local, national and international rules and regulations governing undertakings. This commitment includes carrying out the undertaking in such a manner as to leave minimal adverse environmental footprints whiles maximizing positive impacts of the project.

7.9 Site and Project Description

7.9.1 TEMA PORT

The water-enclosed area of the port measures 1.7 million square meters and the total land area are 3.9 million square meters. There are 5 km of breakwaters, 12 deepwater berths, an oil-tanker berth, and a dockyard, warehouses, and transit sheds.

Figure 7.1 shows the layout of the Port of Tema depicting the two main quays with 12 multipurpose berths. In addition to the main quay berths are the Volta Aluminum Company (VALCO) berth and oil berth for oil tankers that supply the Tema Oil Refinery (TOR). The access channel of the port has been dredged to 12.5 m while the harbour basin is dredged to 11.5 m. The transfer of container traffic to the new terminal, Quay 2, has led to a restriction of operation on it requiring the handling of bulk cargo vessels at Quay 1. The depth of each of the three berths is 0.8 m CD. It is the intention of the GPHA to redevelop Quay 1 which will include reconstruction of the quay wall to enhance cargo handling, also dredging and redevelopment of Berth 10-12 on Quay 1 to enable it receive vessels drawing up to 11.5 m draft. The deep draft berth (berths 1 and 2 with depth of 11.0-11.5 m) at Quay 2 handles the deep draft vessels of about 30,000 DWT. The western section of the port holds a Container Terminal consisting of a new devanning area, cocoa shed, cement bagging company and vehicle parking lots.

Figure 7.1
Layout of Port of Tema
(Source: GPHA).

7.10 Project Life Cycle

The description below for the life-cycle of the project is indicative and only provides in broad terms anticipated issues that may crop up. A more specific description will be provided when the final engineering plans are completed for the project.

The expansion works at the Tema port are expected to involve extensive physical development including dredging operations and constructional activities. It is also anticipated that during normal operation after construction, there will be an increase in maritime traffic at the ports, resulting in significant increases in utility consumption, human populations and pressure on natural systems. The potential impacts at each stage of the project cycle for the Tema port is discussed in the proceeding sections.

7.10.1 CONSTRUCTION PHASE

The constructional phase of the proposed project at Tema is expected to include construction and dredging activities. The key activities that are expected to be undertaken include dredging to deepen the port basin and widen port entrance, increase turning basins, construction of new breakwaters, extension of existing breakwaters, construction of new wharves, construction of new container berths, bulk goods berths and other berths as deemed necessary. The port will also be equipped with facilities for handling cargo including the installation of state-of-the-art cranes and new container terminals. It is also anticipated that there will be filling of port area with dredged materials, thus extending port seaward.

7.10.2 OPERATION PHASE

The operational phase will see an increase in vessel activity in the ports. Significant increases are also expected in cargo volumes and the workforce in the ports. Increases are also expected in utilities (such as water and electricity) consumed and the amount of wastes generated from the facility.

7.10.3 Termination/Decommissioning Phase

The expansion of the ports will include fixed and mobile structures which are expected to have lifespan of several decades. However, should any of the structures and the facility become dysfunctional; these are expected to be de-commissioned in conformity with internationally acceptable practice.

7.11 Baseline Data and Assessment Methodology

7.11.1 Existing Environmental Data and Information

The existing environmental data and information from Port of Tema was obtained from literature of existing studies including the *Development Study of Ghana Sea Ports in the Republic of Ghana* (JICA, February 2002), *WAGP Draft Final EIA* (WAPCo, October 2004), Scoping reports for proposed development of Quay 1: berths 10–12, Sunon-Asogli Thermal Power Plant EIS (2008), the Ghana Ports and Harbours Authority website as well as observations by the authors.

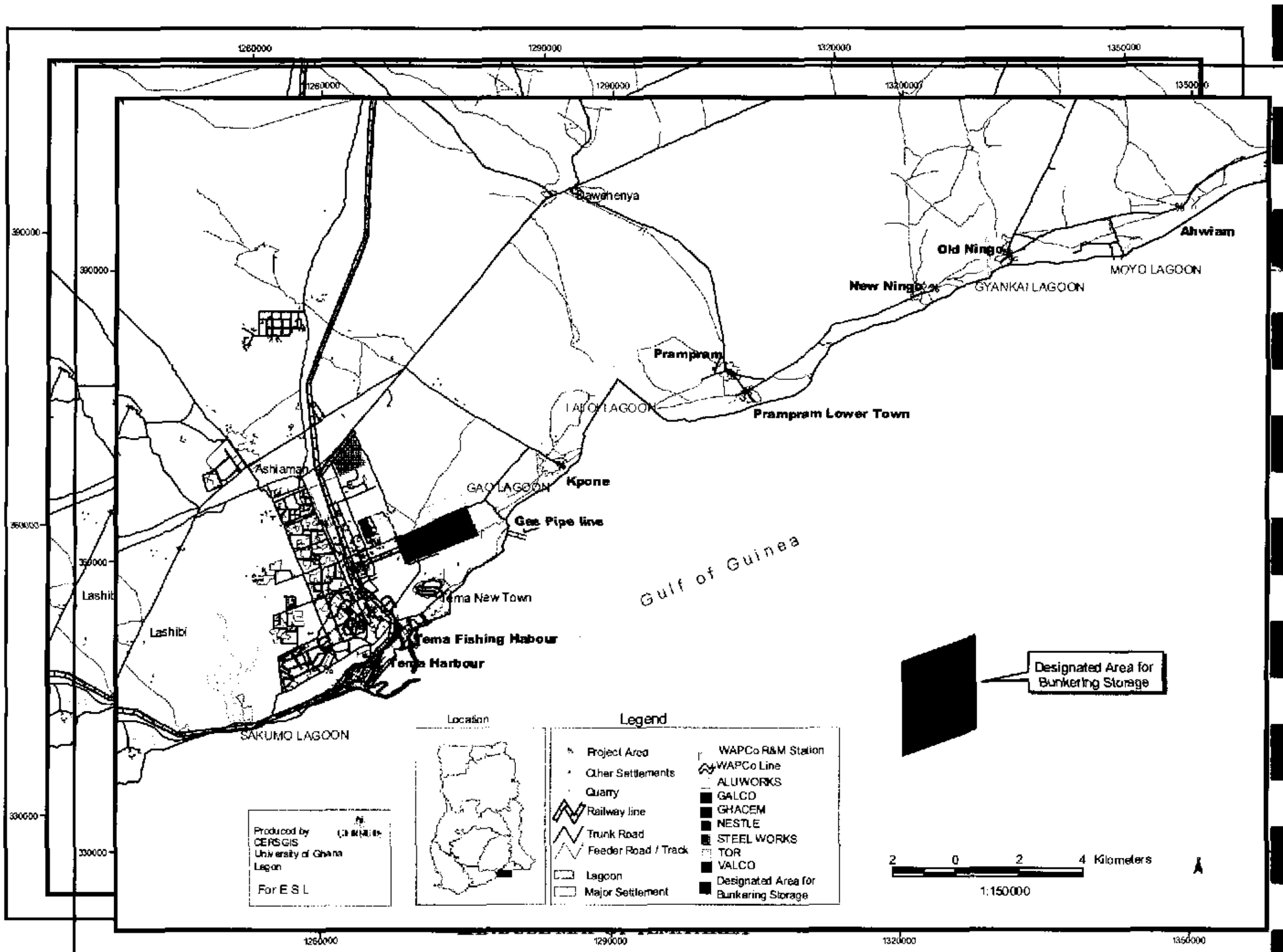
7.11.2 Land Use

The Tema Development Corporation (TDC) is the only entity with authority to convey legal title to lands in the Municipality though lands on the outskirts are also owned by families. Most of the land within the immediate vicinity of Tema port is owned by the Ghana Ports and Harbor Authority. Fig. 7.2 shows the layout of Tema Municipality and the land use features. Eastward of the Tema port is located two important coastal lagoons; the Chemu (highly polluted with industrial and domestic wastes) and Gao lagoons. At the western portion is the Sakumo II Ramsar site, which supports diverse populations of migratory and residence shorebirds.

Land uses within Tema are diverse including industrial, residential, agriculture, commercial, fishing and recreational facilities. Around the port, land uses include a wide range of industrial and commercial companies, producing or handling among others petroleum products, cement, food items, iron and steel, aluminum products and textiles. Most of the country's chief export, cocoa beans, is shipped from Tema. Manufacturing industries include aluminum, steel, oil refinery, soap, and fish processing, chocolate, textiles, cement, and chemicals factories.

Figure 7.2

Land-use Map of Tema Municipality and Adjoining areas.



LANDUSE MAP OF TEMA AREA

The eastern side of the harbour (towards the Gao lagoon) is characterized with developments including a berm crossing constructed by the West African Gas Pipeline project (Figure 7.3). This area is also traversed by a number of small pipelines carrying refined and crude oil to the refinery at Tema. Others pipelines in the area are intended for cooling water for power plants currently under construction. In addition, there is an old sewer outfall pipe which discharges wastes from the Tema Municipality into the ocean.

Figure 7.3
The West African Gas Pipeline Berm Crossing Constructed for the Laying of Pipeline for the Transport of Natural Gas.

This rocky breakwater, located between Tema New Town and the Gao lagoon, has a number environmental issues associated with it. These include erosion of adjacent shoreline, disruptions in sediment movement and deposition patterns, changes in near shore hydrology, biodiversity and impacts on the Gao Lagoon.

Within the vicinity of the lagoon is a 25 m. Right of Way (ROW) for the gas pipeline that passes through maritime strand, coastal scrub, and grassland vegetation types for a distance of about 800 m from the shoreline to the regulating and metering (R&M) station of WAPCO.

Much of the area is used as farmland where vegetables, grains, and pulses are grown on a small scale.

7.11.3 WATER USES

The main water uses are shipping vessels related to the Port and fishing vessels ranging from canoe to steel hulled dragnet fishing boats. Single point moorings (SPM) for petroleum products loading and offloading are installed east of the harbour. Conflict between large and small vessels may occur especially when the smaller fishing canoes drift near the port entrance or when they fish near the SPMs and gas pipeline.

7.11.4 SOCIO-ECONOMIC ENVIRONMENT

The Tema municipality has a total land area of approximately 396 square kilometers. It is a recipient of a large number of migrants. The population of the Municipality stood at 506,400 in 2000 when the census was conducted. Less than 10% of the population lives in rural communities. Several communities have come into being in the last decade or so with the development of housing estates. In addition, communities that might have been described as hamlets have registered dramatic increases in population. The urban area of the Municipality includes Ashaiman, Tema Manhea and Tema Township. The Tema Municipality is the traditional home of the Ga-Dangme. However, because it is a popular destination of migrants, several ethnic groups can be found. Three groups dominate. These are the Akan, Ga-Dangme and Ewe. Other fairly well represented groups are the Mole-Dagbani and the Guans

The Municipality has well developed network of roads and most areas are provided with electricity. The total length of the urban road network is over 400 kilometers. Thirty-nine percent of the roads are in poor condition whilst 36% and 24.8% of the road network is in good and fair condition. About 87% of the feeder roads are motorable. Some communities, such as Ashaiman, have experienced an improvement in access due to improved road conditions. The Municipality has many industries and therefore ranks as the highest electrical power consumer in the country. The Tema fishing harbour located to the east of the main harbour is the principal landing port for fish catches and exports. The fishing harbour therefore caters for the fishing vessels, trawlers and inshore boats.

Physical access to health facilities in the Municipality is high with 94% of households in the Municipality having to travel less than half an hour to arrive at a health facility. This definition of access does not take into account the range and variations in the quality of health services that the facility provides. The Tema general hospital and urban health centers as well as other public clinics and privately owned ones are located in the Tema Township.

Compared to the national average, a much larger proportion of houses in the Municipality have facilities such as an inside tap, electricity for lighting and water closets.

Fishing is one of the major economic ventures in the Tema Metropolitan Assembly (TMA). Artisanal, semi-industrial and industrial fishing activities are very prominent in the TMA. The number of canoes increased from 472 in 1995 to 500 in 2007. The breakdown of the canoes is as follows:

Purse seines	199
Beach Seine	6
Set Nets	34
Hook & Line	326
Drift Gill Net	35
Total	**500**

Out of 230 semi-industrial vessels operating nationally, 150 operate from the port of Tema. In addition, there are 60 industrial trawlers, 6 shrimpers and 40 tuna vessels base in the port of Tema.

The Port of Tema provides ideal landing and marketing facilities for the industry. It is estimated that there are 15,250 active fishermen in the TMA as follows:

Artisanal fishermen	5000
Semi-Industrial fishermen	4500
Industrial Trawler	3000
Shrimpers	250
Tuna	2500
Total	**15,250**

Fisheries in the TMA support directly some industries. There are 3 tuna canneries based in Tema which processed 55,000 metric tons of tuna in 2007. The 3 canneries employ over 3000 people. Export earning from canned tuna in 2007 was US$99 million. Fish and feed mills based in Tema, depend on the fish waste from the canneries as raw materials. There are 70 cold stores and ice making plants operating from TMA for storage of and preservation of fish both at sea and on land. The Tema Boatyard depends on repair of semi-industrial fishing craft for their survival while the Tema Drydock offers repair services to the industrial trawlers, shrimpers and tuna vessels.

More than half of the economically active population is employed in the services sector. Employment in agriculture and related activities in the Municipality is not as widespread as in other parts of the country because of the concentration of industry in the Municipality. In recent years agriculture activity may be described as coming under threat. In those communities that may be described as peri-urban, a major concern is the loss of agriculture land to new developers. Women are concentrated in the wholesale and retail trade sectors. The majority of workers are self-employed and this is especially the case for women of whom about 76% are self-employed.

Unemployment rate in the Municipality was estimated at 11.7% in 2003. This is higher than the national unemployment rate of 5.5%. During periods of unemployment the most frequently used support mechanism was support from household members.

7.11.5 CULTURAL HERITAGE AND ARCHAEOLOGY

Located around the Gao lagoon at the eastern portions is a sacred grove comprised of undisturbed neem trees and baobab tree, which serves as a shrine for the people of the area. Rites are performed at this shrine during festive periods and other important occasions to seek for the blessings of the gods and deities, and to usher in a new year. A similar tree near the Meridian Hotel is also regarded as a deity by the traditional people of Tema. The Chemu lagoon and Sakumo II lagoon are also worshipped as deities with annual rites.

7.11.6 TRAFFIC AND TRANSPORT

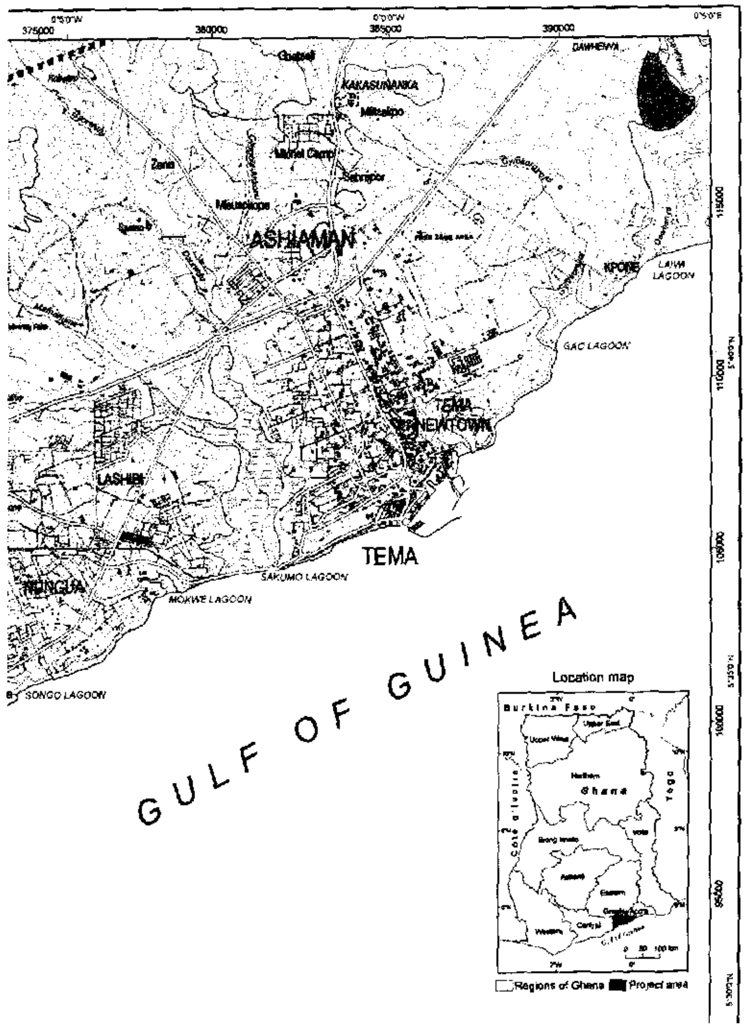
Port statistics show that the traffic passing through the Port of Tema has been increasing over the years. Available data show that of 4.29 million tons of total imports registered from January to September of 2000, the Tema port accounted for 80 percent of the cargo. For exports, Tema port registered 26 percent of the total cargo volume.

There are 220 km of roads in the Tema municipality. The road network in the Tema municipality and the suburban Tema Manhean or Tema New Town is fairly dense although some streets are in poor condition. A coastal road (Paradise Beach Road) from Tema Township passes through Tema Manhean and extends to the Gao lagoon. There is a diversion from the coastal road to the next town of Kpone. The Port of Tema has access to good roads. However, there is significant traffic congestion on routes serving the port. The public transport system in the Tema Township is fairly developed, with buses of different sizes providing services within and to other towns and cities. Two first class roads including a motorway link Tema to the capital, Accra. Tema is also accessed by a third first class road from the East linking Ghana and Togo. Articulated trucks for hauling goods to the hinterland and Burkina Faso have become a traffic issue near the port. The number of such trucks has increased tremendously in recent times due to diversion of transit cargo to Burkina Faso from Abidjan port to Tema.

7.11.7 Geology and Hydrogeology

The Tema Harbour area is underlain by the Dahomeyan System of rocks consisting of heterogeneous assemblage of sericitic, bioitic or chloritic quartz schist. In some areas, many small amphibolite dikes occur in the rocks. Primary porosity as well as fracturing of the massive paragneiss is very low. The groundwater potential is poor. Generally, groundwater protection is of less concern in the Dahomeyan formation. The geological map of the Tema port is shown in Figure 7.4.

Figure 7.4
Geological Map of Tema



The topography of the project area is generally flat with gentle slope towards seaward of the Gulf of Guinea in the southwestern direction. The area lies in the Accra plains and falls under the Dahomeyan Precambrian formation. The decomposed weathered rocks are predominantly sandy clay. The lithological composition of the Dahomeyan System indicates that it represents a metamorphosed sedimentary or volcano-sedimentary sequence. The proposed project site forms part of the middle Precambrian Dahomeyan rock system consisting of basic and acidic gneisses and schist with occasional bands of quartzite, which are hard, foliated and folded. The basic gneiss and/or gneiss schist on the project site depict fresh state and fully competent with high bearing capacity.

The residual soil within the site consists of dark gray calcareous clay/sandy clay in areas of poor drainage, and sandy/clayed sand in areas of good drainage. The clay soil has the potential to exhibit swelling and shrinking characteristics if the moisture content changes and this may cause cracking damages to even light structures if their foundations are laid on this soil.

The available records show that most earthquakes and major tremors in the country had their epicenters either along the Akwapim fault zone (in the Akwapim range), which turns approximately NE-SW in the location of west Accra, or along the coastal boundary faults which lies some 3 Km offshore and runs almost parallel to the coastline of Accra. Tema lies between these two fault zones. Information from the proposed project site did not indicate any evidence of geological instability or major geological discontinuities like fault. Further, the area falls within isoseismic line of intensity VI (developed for the country based on Modified Mercalli scale I-X, with X the highest and shows high risk of seismic damage), which qualifies the site as low risk seismic damage area.

Messrs Alluvial Mining and Shaft Shifting Company Limited conducted underwater investigation of the harbour basin on behalf of GPHA in the 1990s under the supervision of Messrs Boskalis International BV. The geotechnical survey involved drilling of 17 boreholes to an average depth of 4m, using a pilkton Traveller P.N.4 hydraulic rotary rig with a triplex pump, to obtain a reliable impression of the soil and rock conditions. The 17 boreholes and their positions (BH 1-17) are shown in Figure 7.4. The findings from the investigation are presented below. The harbour basin has a general hard ground consisting of mainly metamorphic rock (light/dark banded gneisses), subdivided into rock types A1, A2, A3 and A4.

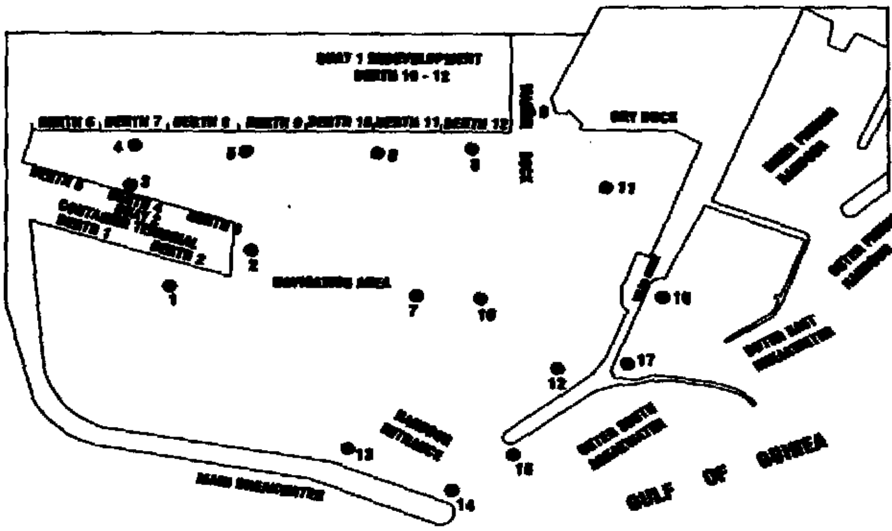
Rock type A1

This rock type consists of micaceous gneiss which occurs in the inner part of the port basin and is predominant around the berthing areas (BH 1 to7) and around the fishing harbor entrance (BH17). This rock type is moderate to strong foliated medium grained gneiss, having distinct micaceous bands of approximately 1mm. The opaque quartz bands (1-20mm) give the rock a platy appearance.

The platy character of the mica causes fault development which weathers in to chlorite. Large elongated, lens shaped quartz fragments are also common in the mica rich bands. The mica content varies from 10% to 40% with high amounts recorded in BH 2.5, and 6. The rock has quartz-filled veins occurring parallel to the foliation. A sub-vertical and steep dipping (70 degrees) fracture is also common, with iron and clay materialization fractured surfaces.

Figure 7.5

Borehole Geology of the Main Tema Harbour



Rock Type A2

This includes the Leucocratic granitic gneiss that forms the predominant rock at the port entrance. These are predominant around the main Harbour entrance (BH 12 and 15) and at the Fishing Harbour entrance (BH 16). These are medium to coarse grained granite with elongated lens shaped crystal, forming a weak foliation. It has a characteristic opaque purple quartz (30%) and pinkish, green weathering feldspar with few dark minerals. BH 15 has the lowest mica content with no elongated crystals and insignificant foliation. The mica content is however highest in BH16. The rock samples from BH 16 were very hard and compact with the highest mica content. These rocks have fractures developed at 60 degrees sub-vertical and along foliation. The fractured surfaces also have a covering of iron oxide and clay minerals.

Rock Type A3

These are felsic-quartz gneiss which form the predominant rock underlying the eastern part of the port, (BH 8, 9, 10, 11) and at the entrance (BH 13and 14). They have fine grained gneisses with light quartz bands (50%) with lenses alternated by dark felsic minerals. They also contain biotites and amphiboles. Rock samples from BH 14 have almandine granite garnet which makes them hard and dense, showing no fracture. In the westerly direction, this rock type seems to grade in to rock type A1 with relatively more quartz and mica.

Rock Type A4

These include the bioclastic limestone found exclusively near the port entrance (BH 13 and 15). These have a high porosity due to dissolution of shell fragments. They have high amounts of lithic clasts with sub-rounded, poorly sorted irregular shaped fragments ranging between 1-50mm of rock type A. They have a layer of dark grey silt as surface soil.

Seismicity

The coastal zone extending from Accra through to Kpone is known to lie in an earthquake zone. Significant earthquake activity has been reported in the coastal region of the country, that is, southern Ghana along the Gulf of Guinea, where earthquakes up to magnitude 5.5 to 6.5 according to the Richter scale have been historically recorded (in 1906 and 1939) and occur on repetitive periods of between 50 and 140 years.

Seismic activity in southern Ghana is believed to be caused by movement along two active fault systems; the Akwapim Fault along the Akwapim mountain range which trends approximately NE-SW and is located about 20km west of Accra and the Coastal Boundary Fault which lies some 3 km offshore and runs almost parallel to the coastline in the vicinity of Accra.

It was reported after the Accra Earthquake of June 1939, which measured 6.5 on the open ended Richter scale, those portions of the Tema area was located in the Isoseismic V intensity zone. In recent, times seismic events on minor scales between 2 and 4 on the Richter scale, have been measured three or four times a year; and it is likely that the coastal fault is renewed with each event.

Building foundations, water and sewage pipes, oil pipelines and power cables might therefore be affected in the event of a major earthquake of the magnitude of that of 1939. The seismic factor should be taken into consideration in the development of quay extension structures.

7.11.8 Coastal Processes and Sediment Transport

The Marine conditions of the Tema Port are directly influenced by the Atlantic Ocean and the South Westerly Monsoon wind. The principal oceanic factors that influence the coastline of the project area include tides, currents and waves. Information on waves and currents in the Accra-Tema area are scarce since there are no quantitative measurements of these covering a sufficiently long periods.

Currents

The hydrography of the area, which is within the Gulf of Guinea, is influenced largely by subtropical gyres of the north and south Atlantic oceans. The major current influencing the area is the Guinea Current flowing from west to east. This current runs opposite to the south westerly equatorial current between Africa and South America. The Guinea Current reaches a maximum between May and July during the strongest South-West Monsoon Winds when it peaks at 1 to 2 knots. For the rest and greater part of the year, the current is weaker. Near the coast, the strength of the current is attenuated by locally generated currents and winds. The current is less persistent near-shore than farther offshore. Geostrophic effects induce the tendency of Guinea Current to drift away from the coast especially during its maximum strength.

It is however subject to periodical and usually short-term reversals. The reversal of the Guinea current is probably due to the effects of the varying strengths of the Equatorial Current and the waters of Benguela origin. The general dynamics of the ocean currents in the Gulf of Guinea depends on the large-scale oceanic climatic seasonal exchanges which occur in the oceans and the morphology of the shelf and the orientation of the coast.

The coastal surface currents are predominantly wind-driven and are confined to a layer of 10–40 m thickness. Littoral drift, which is the main driving forces in coastal circulation in this area is generated by breaking waves. These littoral drifts, generally flowing in an eastward direction, flows at rates less than 1 ms-1, but are responsible for transporting large volumes of littoral sediments. The direction of tidal current around the coast of Ghana is mostly North or North-East. The velocity of the tidal current is generally less than 0.1 m/s. the maximum velocity of tidal current observed in a day of strong winds is about 0.5 m/s. The wave induced longshore currents are generally in the west to east direction which is an indication of the direction the waves impinge the shoreline. The longshore currents may average bout 1m/s and vary between 0.5 and 1.5 m/s. The magnitude increases during rough sea conditions.

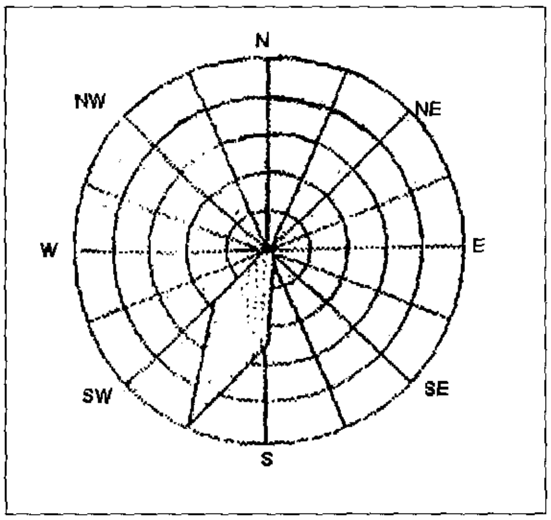
Tide Level

The tide in Ghana is semidiurnal pattern which has generally two high and low tide levels each day. Average tidal heights of 1.6 m at MHMS and 1.3 m at MLWS and 0.7 m at MLWN are recorded twice daily. Tema has no tide gauge at present and any expansions to the port will need to seriously consider creating a tide gauge house for installing one.

Waves

Waves reaching the shores of Ghana consist of swells originating from the oceanic area around the Antarctica Continent and seas generated by locally occurring winds. The significant height of the waves generally lies between 0.9 m and 1.4 m and rarely attains 2.5 m or more. The most common amplitude of waves in the region is 1.0 m but annual significant swells could reach 3.3 m in some instances. Swells attaining heights of 4.8-6 m, however, occur with a 10-20 year periodicity. The peak wave period for the swells generally falls in the range of 7 to 14s. The swell wave direction is almost always south or south-west (Figure 7.5).

Figure 7.5
Wave Rose Indicating Predominant Swell Wave Direction



Other observations on the wave climate include a long swell of distant origin and with wavelengths varying between 160 and 220 m. This swell has a primary period of 12 seconds and a relatively regular averaged height between 1.0 and 2.0 m. The swells generally travel from southwest to northeast.

Sediment transport

The sediments along the coastline are redistributed primarily by the eastward longshore current, in the form of littoral drifts and, less importantly, tidal currents. The sediment grain size investigations along the proposed route of the WAGP carried out by ESL identified that, with a few exceptions, most fine-grained stations occurred at depths exceeding 37m. Sandy and/or hard cobble/ancient coral bottoms were found throughout the entire depth of the investigated proposed pipeline route. All of the stations sampled for the pipeline route have either sandy sediments or hard/cobble bottoms, which reflect the relatively high energy regimes in the area.

The near shore sediment of Tema could be described as being sandy and the offshore as sandy-mud. Pockets of muddy sediments occur in water depths between 30 – 40 m. Erosion of the shore line is quite prominent in areas where the onshore land consist of unconsolidated material. There is significant erosion to the east and west of the Port of Tema. Notable areas are Tema New Town (Manhean) and the west of the Port between Tema and Nungua. Near the Sakumo II outfall, armored rocks have been used to construct revetments to check the erosion.

7.11.9 WATER AND SEDIMENT QUALITY

The quality of seawater within the port and the surrounding water mass is expected to change depending on the activities taking place. The effect may be pronounced in semi-enclosed areas where residence time is low. In general, the water quality has immense implications for aquatic organisms. Water quality (especially suspended solids and oil spills) near shore is likely to be affected by the proposed project especially if dredging will be involved. Most of the effects may be short-lived but could also have the potential of long term adverse impacts on rare biota. Sources of contamination of harbour water and sediment may be derived from ship-borne wastes, port activities and storm water outside the port premises and emptying into the harbour basin. The results of water samples collected in the main harbour drain in March 2007 to determine the quality and impact of municipal and wastewater that flows into the marine waters are shown in Table 3.1.

Table 7.1 Wastewater Quality of the Tema Harbour Main Drain

Parameter /Sampling point (Location)	Meridian Road crossing at Community 2 (outside Port premises) (Upstream)	By the railway line near Cottage Grove (within Port premises) (Midstream)	Near harbour station (within Port premises) (Downstream)
Table text			
Ph	7.99	7.55	7.64
Temperature (oC)	28.4	28.1	27.3
TDS (mg/L)	401	659	596
Conductivity (µs/cm)	805	1316	1194
Total Suspended Solids (mg	164	176	185
BOD (mg/L)	380	855	390
COD (mg/L)	438	1330	563
Nitrate (mg/L)	<0.005	<0.005	<0.005
Phosphate (mg/L)	2.42	4.91	3.63
Oil	6.5	11.5	8.0

Values for the midstream samples showed elevated levels for BOD, COD, Oil and phosphates. There were no upstream to downstream trends in the variables determined. The quality of the midstream sample analyzed could be a reflection of local peculiar factors.

Outside the main harbour, the burgeoning population density and industrial activity, year by year, increase the amounts of untreated domestic waste and industrial effluent discharged into the nearby marine waters. It is on record that there has been concurrent fecal and nutrient increase in the marine coastal waters near Tema. The polluted Chemu II Lagoon lies to the east of the harbour and is the main channel for industrial effluents from Tema to the sea.

Water quality data collected from the Gao Lagoon which is open to the sea indicated generally good water quality due to tidal flushing. Moderately elevated heavy metal concentrations in the water and sightings of apparent oil and grease in the lagoon were observed. Elevated levels of coliforms and fecal coliforms bacteria provide confirm contamination in the lagoon and that contact with the water should be avoided (Source: WAPCo Reports).

7.11.10 MARINE AND TERRESTRIAL ECOLOGY

The project area is within the coastal zone of Ghana. A number of sensitive habitats occur on the eastern and western adjoining coast of the Tema port. These include high diversity rocky shores and intertidal areas supporting high biodiversity of both flora and fauna that may be impacted by the project by sediment plumes arising from dredging activities (Figure 7.6; Table 7.2).

Figure 7.7
Rocky Shore Habitats near Tema showing Sea Urchin (Echinometra lucunta) and some Microalgae (Ulva Fasciata etc.)

Table 7.2 Inventory of Intertidal Rocky Shore Fauna and Microalgae in the vicinity of Tema Port

Faunistic group	Floristic group
Gastropod	***Blue green algae***
Echinolittorina pulchella	*Cladophora vagabunder*
Echinolittorina cingulifera	*Ulva fasciata*
Echinollitorina. Granosa	*Enteromorpha flexuosa*
Thais nodosa	*Chaetomorpha linum*
Thais haemastoma	*Hydropuntia dentata*
Semifusus monroi	*Botrisia radicans*
Nerita atrata	*Ralfsia expansa*
Patella safiana	*Centrocera clavulatum*
Siphonaria pectinata	*Sargassum vulgare*
Bivalvia	*Bachelotia antillarum*
Ostea tulipa	*Hypnea muciformes*
Brachydontes sp.	*Lithothamnia spp.*
Perna perna	
Crustacea	
Grapsus grapsus	
Cthamalus dentata	
Panopeus sp.	
Echinodermata	
Cidaroidea sp.	
Echinometra lucunter	

(Source: ESL 2008)

The sandy shore areas at the eastern and western sections of the Tema port serve as sites for sea turtles. Good numbers of sea turtles have been reported to nest along the sandy beaches from Ningo-Prampram all the way to the Volta Estuary. The sandy shores are also habitats to macrobenthic fauna, mainly ghost crabs of the Genus Ocypoda.

The onshore terrestrial plant communities fall under three categories. These are the coastal strand vegetation, coastal scrub vegetation, and grassland vegetation. The terrestrial areas adjacent to the port have very few tall trees. Some mangroves however could be found on the banks of the Gao lagoon.

7.11.11 FISHERIES RESOURCES

The traditional artisanal inshore fishery in Ghana is well developed and provides about 70 percent of the total marine production in the country. The fishery is usually all year round but shows definite peaks (periods of bumper harvests) and troughs (the lean or off season when landings are very poor) in the course of the year. While the fish landings from any one lagoon or estuary may be comparatively small, these water bodies provide reasonable quantities of fish products for subsistence purposes. Fishing generally is banned within the main harbour area and therefore no fishing activities are observed in the near-shore area of the project site. However, fishing canoes could be seen a distance beyond and outside the harbour area. Such fishers normally landed their catch at the canoe basin of the fishing harbour.

The Artisanal Fishery in the Tema Metropolitan Assembly (TMA) and adjoining Districts

The artisanal fishery is a highly patronized industry with a high number of people dependent on it. The Tema harbour area is influenced by the activities of artisanal fishermen from Dangme East, Dangme West Districts and the Tema and the Accra Metropolitan Assemblies. This includes fishing villages from Faanaa to the west of Accra to as far East as Ada at the Volta estuary. The activities of the fishermen are not confined to one location but tend to follow the fish movements from one village to the other hence the wide area that their fishing activities cover.

The Greater Accra Region has about forty-four (44) fishing villages giving it about sixty-two (62) fish landing sites. There are about 2957 active canoes in the area out of which about 65% are motorized. The area provides jobs for about 41,026 people who are involved directly in the fishing activity. Among the gears employed by the fishermen in the area are beach seine, purse seine, line, lobster net, Ali net, drift net, nifa and other form of set nets. The most dominant gear used in the area is the purse seine with the nifa being the least used gear.

The Dangbe East has the highest number of landing beaches and fishing villages in the Greater Accra Region. It employs about 12,041 fishermen who are mainly into purse seining. Over 90% of the vessels in this District use motors. The key fishing villages in terms of number of fishermen and canoes are the Azizanya (Mataheko landing beach), Pute (Pute landing beach), Anyamam (Ayamam landing beach) and Akplabanya (Akplabanya landing beach). Other fishing villages are Kewunor. Lolonyakope, Otrokpe, Totimekope, Ocanseykope and Totope among others.

The Dangbe West District also has 11,744 fishermen who are mainly into line fishing with about 51.5% of their vessels having motors. Fishing activity is intense in villages like Lekpogunor (Zongo and Anasi landing beaches), Old Ningo (Old Ningo landing beach), and

Lower Prampram (Lighthouse landing beach). Lekpogunor, Wekumagbe, Mangotsonya and Ahwiam are other fishing villages in the area with good numbers of canoes and fishermen.

The Tema Municipality has its fishing activities concentrated at Ahamang and Awudun landing beaches (all in Tema) and Sege landing beach in Kpone. The Municipality has about 5,195 fishermen; about 57.0% of the vessels motorized and employ line fishing as the major fishing type. The coastal area under the Accra Metropolitan Assembly (A.M.A) has purse seining as the major fishing type practiced in the area with about 76.5% of the vessel in the area motorized.

The fishing activity in the Accra Metropolitan Assembly is concentrated in Accra (Jamestown harbour) and Chorkor (Wolei and Mantsuru landing beaches). The area has about 10,263 fishermen, 852 fishing vessels of which 76.5% use motors and purse seining as the dominant fishing practice.

The near shore marine environment is known to be a nursery area for many demersal and pelagic fish species (Nunoo *et al.*, 2006). Typically the catch from the near shore area is dominated by juveniles and few adult individuals that are usually either gravid with eggs/milt or spent. Such vulnerable fish populations are easily disturbed by sudden discharges of large quantities of pollutants into the water. The fin and shellfish catch from the area is known to be dominated by species from the taxonomic families Clupeidae, Carangidae, Sciaenidae, Sparidae, Cynoglossidae, Polynemidae, Haemulidae, Sepiidae and Penaeidae.

7.11.12 Air Quality

Within harbour establishments, aerial pollution may come from operational activities including exhaust fumes from vehicles and machines as well as from idling vessels. Where large industries are located close to the harbour, such as the cement factory (GHACEM), and food processing companies (flour milling and tuna processing) such as occurs at Tema, these may contribute to elevated levels of pollutants in the air. Additionally, the phenomenon of land and sea breezes can change the concentrations of particulates in the course of a single day.

Studies conducted over several years indicate that air pollution in the Tema harbour and its immediate environs are not alarming. For example, values obtained in 2000 and 2007 appear to be within acceptable levels (Table 3.3 and Table 3.4). The regular strong onshore winds and the early morning land breeze which flow in the opposite direction generally tend to dissipate any local build ups of aerial pollutants.

Table7.3 Air Auality Variables within the Main Tema Harbour area (May, 2000)

Location	Sampling point	Mean values of pollution indicaters monitored/ ugm^{-3}				
		SO_2	NO_2	CO/mgm^{-3}	PM_{10}	TSP
Quay 1	Shed 6	28	10	2	23	10
	Shed 6	34	11	1	23	13
	Shed 6	37	11	2	25	13
	Shed 8	56	26	3	20	42
	Shed 8	45	23	4	31	44
	Berth 11	92	67	5	15	13
	Berth 12	81	48	5	21	23
Quay 2	Berth 2	87	55	6	17	19
	Berth 3	87	54	4	19	19
EPA Guideline values		900	400	100	70	230

SOURCE: *Refast /GPHA (2000): EIS for Tema Port Development project.*

Table 7.4 Air Quality in the vicinity of Tema Harbour (2006 and 2007)

Location	Sampling point	Mean values of pollution indicators monitored/ ugm^{-3}				
		SO_2	NO_2	CO/mgm^{-3}	PM_{10}	TSP
Fishing harbour (measured Dec 2006)	Near generating set	12.5	Below detection level	24	55	200
VRA new substation behind TOR(site for proposed power plant for consortium of mining companies) (measured Feb.2007)	North-west of plant site	116	Below detection	2.8	58.1	241
	South of plant site	114	Below detection	2.8	56	205
EPA Guideline values		900	400	100	70	230

SOURCE: *Environmental Laboratories (Gh) Ltd: Air quality monitoring.*

Evidence from results carried out by Environmental Laboratories (Gh) limited in the main port area indicate elevated values close to the Ghana EPA guidelines for respirable dust (PM10) and Total Suspended Solids (TSP). Results for the sulphur oxides(SO2), nitrous oxides (NO2) and carbon monoxide (CO) are all well below the Ghana EPA guideline threshold.

7.11.13 NOISE

The major source of noise within the Tema Port area are associated with construction activities, vehicular traffic, marine craft/equipment movement, human/operational activities such as loading and unloading, and opening of containers as well as sea waves. Average between 64 dB to 72 dB had been reported in the main harbour area in April 2007.

7.11.14 LANDSCAPE AND VISUAL ASPECTS

The topography of the project area is generally flat with a gentle slope towards the seaward edge of the Gulf of Guinea in the southwestern direction. Three lagoons characterize the immediate outskirts of the Port. The larger Ramsar designated Sakumo II lagoon lies about 1 km to the West of the Port and the polluted and almost silted Chemu lagoon, which serves as the major effluent drain for the majority of the industries of Tema abuts the Canoe basin of the Fishing Harbour. The third is the Gao lagoon located 3 km further east of the Port. The Gao lagoon is slowly getting silted and polluted by the emerging new industries in its vicinity. Of the three lagoons, the Sakumo II is a tourist point for seabird watching and also is a source of livelihood for fishers. It is broadly comprised of a coastal brackish-saline lagoon whose main habitats are open lagoon, surrounding floodplains, freshwater marsh, and coastal savanna grassland, with a narrow connection to the sea through culverts. The site is a temporary home to rare and endangered migratory palearctic bird species annually. The dominant fish in the lagoon is the black-chin tilapia. Fishing is the main livelihood of the communities around the lagoon, but some minor industrial activities occur near the site. The Ramsar Convention is an international treaty for the conservation and sustainable utilization of wetlands: i.e. to stem the progressive encroachment on and loss of wetlands now and in the future, recognizing the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value.

Other features include the disused Meridian Hotel and the Lighthouse close to the Naval base. The VALCO aluminum smelting tower and the flares of the Tema Oil Refinery are significant skyline features. Littering the beach east of the harbour are derelict fishing vessels left to rust at the mercy of the waves.

7.11.15 IDENTIFIED ENVIRONMENTAL DATA GAPS

- Hydrogeology of Tema port
  - — Hydro-geological data of the port area needs to be assessed in terms of aquifers and any subterranean flows/seepage into the sea.
- Current and wave dynamic information
  - — Long term information on wave and current dynamics for modelling of extent of impacts of storm surges and inform diffusion and dispersal of pollutants entering the harbour and its environs etc.
- Sediment and Water quality data
  - — Sediment characteristics within the harbour and surrounding areas for toxicity, heavy metal levels and organic pollutants (PAH and TPH) as well as grain size distribution.
- Biological factors: phytoplankton and zooplankton biodiversity and abundance; microbiological contamination levels particularly faecal coli forms and other pathogenic microbes; macro benthic fauna information (within harbour and vicinity, intertidal and near shore between1-20 m depth).
- Socio-economic information of the Port
  - — Employment level and induced development in Tema due to changes in port infrastruture and activities.
- Air quality data
  - — Diurnal variation data to capture reversals in wind direction for periods of offshore winds(night breeze) and onshore winds (day breeze)as well as in dry season (January) and wet season (July).

7.12 Assessment Methodology

All impacts were evaluated within the context of the proposed harbour expansion project and information currently available from similar projects in the study areas. Assessments were based on potential impacts arising during constructional phase and normal operational phase of the projects. Considerations for potential impacts are derived from ISO 14001, which gives the following definitions for environmental aspects and impacts:

- Impacts: Any change to the environment, whether adverse or beneficial, wholly or partly resulting from an organization's activities, products or services.
- Aspects: Any element of an organization's activities, products or services which can interact with the environment.

The significance of an aspect on the environment is determined by the significance of the associated impacts, where each aspect may have more than one impacts. The significance of impacts is largely based on:

- Scale of impact
- Severity of impact
- Probability of occurrence
- Duration of impact

Based on the above, during the determination of impacts of project aspects on the natural and socioeconomic environment, the methodology used for this assessment was to:

- Identify project aspects which may impact on environment through desk study, stakeholder consultations and field visits to the project sites,
- Determine the spatial and temporal extent of impacts using professional judgment and other studies in similar environments.

7.13 Consultations

Public involvement in the environmental assessment was considered as one of the most important sources for impact identification and mitigation. A major reason for consultations for this project was to gather data and information on the likely impacts of the project and also to identify potential conflicts between the proponent, stakeholders, interested and affected communities. In line with this, preliminary consultations were held with the following major stakeholders:

- EPA official at Tema
- GPHA officials at Tema
- Ghana Highways Authority personnel at Tema
- Physical Development Unit of the Tema Metropolitan Assembly

Other stakeholders and interested parties that consultations will subsequently be held with include chiefs and clan heads in the development areas, utility providers, security services, heads of municipal services and the interested community in the area. These consultations should be held during the impact assessment stage of the project.

7.14 Assessment of Environmental Impacts

7.14.1 LAND USES

Minimal direct land-use impacts are anticipated at Tema. The project is currently envisages a seaward expansion to the harbour. However, some landward expansion may occur as a result of expansion of the container terminal. Tema in general and the port in particular, is a planned area with land for the port clearly demarcated, and owned by the port authority. Hence no significant land-use conflicts are anticipated. Other land-use impacts anticipated include indirect effects of increases in worker community in Tema and surrounding areas, leading to increases in squatter communities. A new settlement currently exists near Tema (called Ashaiman) which arose as a result of the construction of the Tema port. This community may increase due to the project.

The identified indirect land-use impacts are likely to occur and the effects may be severe. However, the impacts are expected to be localized to the Tema municipality. Cumulative effects will be on utilities and socioeconomic environments.

7.14.2 WATER USES

Water-use impacts anticipated include resource use competitions among the various stakeholders and interested parties within the port area. These groups include artisanal fishers and small trawler operators that also use water space near the harbour for navigation. These groups make use of the fishing harbour adjacent to the main harbour and routinely navigate near the main harbour. It is however identified that little or no fishing activity occurs within the vicinity of the harbour.

Potential conflicts include an increased risk of collision, particularly during the operational phase of the project, when maritime activity is expected to significantly increase within the port area. The impact however is limited to the immediate vicinity of the project.

7.14.3 SOCIO-ECONOMIC IMPACTS

The development is expected to create job opportunities for both skilled and unskilled labour segments. This is expected to boost income levels of the large number of labour that currently inhabit Tema and surrounding communities of Ashaiman and Kpone.

Secondary, indirect and cumulative potential impacts include pressure on utilities, land-use and water sources within the Tema metropolis. Particular impacts are expected on waste disposal facilities, water sources and road networks. The temporal aspect of this identified impact is expected to persist through the operational phase of the project. It was previously identified that Ashaiman is a new settlement that arose as a result of the construction of the Tema harbour, and the expansion of the harbour is expected to further exacerbate impacts at Ashaiman.

7.14.4 TRAFFIC AND TRANSPORT

Some impacts on traffic and transportation are anticipated during the constructional and operational phases of the project. The constructional phase impacts are expected from heavy goods vehicles that are expected to transport constructional material to the development site. Operational phase impacts are expected from an increase in cargo volumes delivered to the port, which will result in increases in vehicular traffic, as several large goods vehicles will be involved in transporting imports to the rest of the country and neighboring landlocked countries. These increases in vehicular traffic might increase the traffic situation in the metropolis, leading to frequent traffic jams.

Other impacts identified include increased stress on road networks from increases in tonnage of vehicles using roads, especially for transshipment to land-locked countries. The effects of these include rapid degradation of road network.

7.14.5 GEOLOGY AND HYDROGEOLOGY

Minimal impacts are anticipated on the geology and hydrogeology of the development area. Primary effects on geology include dredging/blasting activities within the harbour basin. Other effects are anticipated from the disposal of dredged materials on land. In this case, contaminants from dredged materials could potentially pollute soil, and may percolate into groundwater sources and potentially contaminating them. Effects on geology and hydrogeology are however limited to the constructional phase of the development and localized to the port area or the area identified for disposal of dredged materials.

7.14.6 Coastal Processes and Sediment Transport

It is likely that the project may impact on the sediment transport within the immediate vicinity of the port area. Extension to the breakwaters could lead to potential erosion at the leeward side, since this may be deprived of sediments, leading to erosion if substrate. Generally, substrate types to the leeward side of the harbour at Tema are of unconsolidated materials interspersed with rocky outcrops, which are liable to erosion.

The shoreline to the leeward side of the harbour is identified in the Ghana Environmental Sensitivity Atlas as a habitat for selected marine organisms including protected species such as turtles and shore birds. Potential erosion of this coastline is however expected to impact on the habitats of these organisms. The impacts are however expected to be localized to Tema and surrounding communities, but may persist during the operational phase of the project.

7.14.7 Water and Sediment Quality

Identified potential impacts on water quality include the development of turbidity plumes in waters within the immediate vicinity of the port area as a result of construction works. There is also the likelihood of re-suspension of chemicals contaminants into the water arising from dredging/blasting operations. Other constructional phase impacts include the leaching of chemical pollutants from fill materials that other constructional materials used in the construction works. These impacts are however expected to be localized to the constructional areas.

Water and sediment quality may also be affected, particularly during the operational phase of the project from minor oil spills and antifouling agents leaching from ships. This kind of pollution usually occurs within large harbors, and the effects are usually localized.

Other potential sources of impacts to water and sediment quality are from solid and domestic wastes that may be generated during the constructional and operational phases.

7.14.8 Marine and Terrestrial Ecology

The anticipated impacts on marine ecology as a result of the port expansion constructional and operational activities include:

- Dredging activities which may directly impact on benthic fauna.
- Increases in suspended matter in water, which may impact on benthic organisms, fishes and other aquatic fauna.

- Increased levels of pollutants in water, which may probably arise from re-suspended sediment, which may have effects on aquatic flora and fauna.
- Modifications to the hydrological regime, which may directly and/or indirectly impact on aquatic biota.
- Habitat modifications/segregations as a result of the development.
- Leaching of anti-biofouling chemicals into the water from marine vessels.
- Spillages of fuels and bunkering oils into the water from marine and dock operations.
- Potential contamination of water with domestic and industrial wastes produced from the operation of the port facility.

In summary, the main anticipated impacts are those arising from the re-suspension of sediment as a result of constructional activities or normal operation of port facility after the expansion project, which may alter water quality. The expected modifications of the hydrological regime may impact on the highly diverse rocky intertidal biota, modifying the community structure.

The effects of the port expansion project on terrestrial ecology are anticipated to be largely indirect. This is expected to arise as a result of encroachment on natural habitats by human population, which is expected to increase as a result of the project. The anticipated direct impact on terrestrial ecology may arise from disposal of dredge spoil on land, in which case impacted terrestrial environment is limited to disposal site.

7.14.9 FISHERIES RESOURCES

Some impacts are expected on the biological environment which may invariably impact on the fishery resource. Constructional activities (e.g. dredging) which may create turbidity plume will affect biological resources although the effect may be localized. For instance, benthic organisms may be smothered in addition to impacts on fish breeding grounds. Plankton populations may be affected through changes in water quality and changes in food supply. It is also anticipated that re-suspended pollutants, such as heavy metals may accumulate in fish tissues, rendering them unsuitable for human consumption. These impacts may however be transient and therefore the fishery may be re-established after the cessation of project activities.

7.14.10 AIR QUALITY

Air pollution indicators, particularly the concentration of dust particles in the area may increase slightly above ambient levels during the construction phase. Other alteration in air quality will be as a result of activities such as vehicular and marine vessel movements.

Emissions from diesel engines and the anticipated large numbers of container ships in the harbour during the operational phase will result in impacts on air quality.

7.14.11 NOISE

The constructional activities are expected to increase noise within the harbour areas. Also, increases in ship numbers coupled with increases in container handling works at the expanded terminal is expected to further increase noise levels within the port area. The haulage of materials by goods vehicles and power generators will add to noise levels. Site workers may be exposed to some risk hazards associated with noise pollution, and other forms of vibration.

7.14.12 VISUAL ASPECTS

No major visual impacts are expected with the development. The expansion of the port facilities will alter the layout of the existing port. But this is not expected to visually impact negatively on residents living near the harbour area. The operational phase may also result in more lights within the port area during night time operations.

7.15 Impact Mitigation and Amelioration

This section proposes mitigation for the identified impacts in the preceding section. It is identified that extensive analysis needs to be carried out to identified specific mitigation and amelioration measures, which are largely beyond the scope of this report. Such study is effectively carried out in an EIA which is expected to follow from this document.

7.15.1 LAND USES

Adequate consultations with key stakeholders, development authorities, chiefs and local communities are required to reduce any potential impacts on land use. It is anticipated that that land use impacts as a result of the development will be minimal, however, the potential for the spread of squatter communities as a result of influx of workers needs to be addressed through an adequate socioeconomic study.

7.15.2 WATER USES

Any potential conflict relating to water needs to be addressed through appropriate delimitation of the inshore areas of the Tema Port. Consultations need to be held with various stakeholders and special interest groups so as to forestall any future conflict within the development area.

7.15.3 SOCIO-ECONOMIC IMPACTS

Early consultations with the Tema Metropolitan Authorities should take place to adequately identify and account for the expected rise in the human population. Urban and municipal plans will have to be updated to accommodate the anticipated population rise while facilities and facility standards will also have to be updated.

7.15.4 TRAFFIC AND TRANSPORT

Improved port management during the operation phase should reduce the waiting time of vehicles and improve the congestion near the port area. Future plans for road development should take into consideration the tonnage of the vehicles likely to transit the roads within the urban metropolis. It is expected that heavy vehicles will not use side roads and country lanes whereby reducing the impact on the roads.

Future plans should also take into account the requirements to upgrade the railway network between Tema and the rest of the country to ease pressure on road transport.

7.15.5 GEOLOGY AND HYDROGEOLOGY

Geologic effects are expected to be minimal and localized to development area. Since it is anticipated that dredging/blasting would be minimal and limited to the development area, the impacts are expected to be localized.

The effects of dredged spoil in contaminating groundwater sources can also be minimized by adequately researching and selecting a dumping site where the risk of contamination are minimized.

7.15.6 COASTAL PROCESSES AND SEDIMENT TRANSPORT

The effect of any altered hydrological regime within the development area can largely be minimized by modeling the direct impact of any preferred engineering design of breakwaters on the adjacent coastline. Modeling should take into consideration the zone of influence, current state of the shoreline and the magnitude of impacts, if any.

7.15.7 Water and Sediment Quality

It is recommended that sediment quality assessment be carried out prior to constructional works to determine the precise nature of contaminants within the sediment. After this, water circulation models should be setup to determine the potential direction and concentration of suspended matter and pollutants within the development area.

Modeling will give a fair idea of the dispersion of potential contaminant within the project area. It is recommended that fishing activities be limited in the area during the constructional phase of the project to limit potentials for human uptake of contaminated fish.

7.15.8 Marine and Terrestrial Ecology

The effect of modifications to the hydrological regime should be investigated through modelling prior to project implementation. This will give a fair idea of the exact environmental receptacles of impacts. Modifications to the coastline can be minimized or mitigated though adequate design of breakwater so that leeward side erosion may be minimized.

The effect of the project on coastal and terrestrial ecology should be adequately investigated, particularly potential impacts on marine turtle nesting sites and avifauna sites to the east of the Tema port. Other anticipated impacts on terrestrial ecology as a result of disposal of dredge waste should also be adequately investigated.

7.15.9 Fisheries Resources

Direct impacts on fishery resource are expected to be minimal due to the localized nature of anticipated impacts. However, it is important that adequate consultations are held with stakeholders, interested and affected parties to minimize potential conflicts that may arise from resource use and resource sharing.

7.15.10 Air Quality

Sulphur oxides (SO_x), nitrous oxides (NO_x), volatile organic compounds (VOCs) smoke, carbon monoxide (CO) and other gaseous pollutants will constitute major sources of emissions from machinery and diesel engines. Best industrial practices are recommended, including regular maintenance and use of proper fuels to reduce the potential impacts of these sources of atmospheric pollution. It is anticipated that adequate dispersion of gases will occure in view of prevailing wind speed that exists throughout the year.

Air quality monitoring should be conducted routinely to measure particulate and emissions concentrations. During the construction phase, dust and particulate matter likely to be generated should be controlled by regular sprinkling of water within the vicinity to suppress visible dust emissions. All potable emission sources (e.g., portable diesel engine) should be positioned as far as practical from sensitive receptors. The project should ensure that speed limits are controlled on all haul routes and also minimise vehicle idling. Fill material should be transported by covered vehicles. Finally, the project should establish a complaint monitoring, reporting and response program.

7.15.11 NOISE

Noise and vibration minimization should follow best industry practice. Machinery should be housed as much as possible in noise proof facilities to reduce atmospheric noise levels. Care should be taken in the maintenance of heavy equipment to ensure reduced noise levels. Mufflers and other noise reduction devices should be fitted and should be in good condition. If possible, there should be the installation of temporal noise barriers around compressors pumps and other stationary sources of loud noise. It is also recommended that loud and noisy construction activities be restricted to daylight hours, where practical.

7.15.12 VISUAL ASPECTS

The aesthetics of the port layout may reduce any negative visual aspect of the project. The effects of strong lights during night time operations are also noted. However, this aspect may have to be balanced with trade offs and the overall economic benefits of redeveloping and expanding the port.

7.16 Environmental Monitoring

A provisional environmental plan will be implemented during the constructional phase of the project, in accordance with GEPA guidelines and GPHA's Environmental Policy. The environmental plan will be based on potential constructional phase impacts identified through the PER stage and the EIA stage and will consider potential impacts to land use, water uses, socioeconomic impacts, traffic and transportation, geology and hydrogeology, water and sediment quality, marine and terrestrial ecology, fisheries resource, air quality, noise and visual intrusion.

These aspects of the project will be monitored on an agreed schedule as a way of providing feedback to management as to the direct and indirect effects of constructional activities on the natural and social environments.

7.17 Environmental Management Strategy

The environmental management strategy will consist of structures that outline responsibilities for environment management within the framework of the project development. The structure shall consist of an environment officer (EO) who shall be part of management. The EO will be tasked to co-ordinate and monitor project activities and advice management on the various impacts associated with the activities on site. The functions of the EO will include the following:

- Responsibility for implementing the environmental policies of GPHA with respect to the project.
- Liaise with public and stakeholders on all such matters of environmental concern affecting the project.
- Work closely with management and other project technical officers to co-ordinate all activities bearing on the environment, occupational health and safety.
- Coordinating monitoring activities during construction and responsible for reporting and communications with regulating agency.
- Consult with management to decide the role of external consultants in the environmental management programs of the company.

A budget shall also be prepared indicating the commitment of GPHA to various components of the provisional environmental management plan.

7.18 Reporting

A periodic report shall be compiled of the analyses of monitoring data according to EPA statutory requirements (EPA Act 490) and in accordance with GPHA environmental policy. This shall be submitted on an agreed schedule to the GEPA.

7.19 Environmental Management Plan

In consonance with GEPA regulations, an Environmental Management Plan (EMP) shall be prepared one year after the implementation of the project.

7.20 Conclusion

The PER was prepared according to GEPA assessment regulations derived from EPA Act 490 and LI 1652. The environmental assessment identified moderate to minimal impacts affecting land use, water uses, socioeconomic impacts, traffic and transportation, geology and hydrogeology, water and sediment quality, marine and terrestrial ecology, fisheries resource, air quality, noise and visual intrusion, occupational health and safety.

In order to reduce and/or mitigate the identified impacts, GPHA will have to conduct a full scale EIA into the existing environment of the proposed project to identify the nature and extent of the identified impacts and the probable effects they may have on natural systems and society. An effective and rigorous environmental management plan will then be implemented to mitigate the effects of identified impacts.

Chapter 8 – Financial & Economic Impact Analyses

8.1 Economic Analysis

Background to the Economic Analysis

The proposed port expansion for the in-harbor case in Tema is primarily considered as a way to provide additional capacity for Ghana's foreign trade, i.e. import/export shipments by containers which are expected to grow as per the forecasts presented earlier.

Ports are a link in the total foreign trade chain. As such, they are a necessary but not sufficient condition to carry on foreign trade. Foreign trade starts with marketing efforts to sell goods to overseas customers, the support of banks and communications links, factories to produce the goods, movement through domestic transport links such as trucks and highways or railroads, or both, into the port itself, then onto ships, then ports on the other end, and so on for final delivery to customers. Port services, while a necessary element of the trade chain, account for only a small fraction of the total costs of foreign trade. The port must exist to achieve the benefits of foreign trade, along with all the other links in the chain. As such it is not appropriate, or even possible, to perform a meaningful economic cost benefit for just the port in isolation—the appropriate benefit is the benefit of conducting foreign trade, and the cost that benefits must be compared with is the cost of the entire foreign trade chain. Such an analysis is beyond the scope of this study, and in any case is not necessary or appropriate to its needs. To the extent that increased port capacity is needed to support foreign trade, it is clearly economically justified to provide it, and charges for its use are properly set at whatever level is needed to recover the required investments and other costs.

However, that said it is important that the needs of foreign trade be met in the most efficient and least costly manner possible, including port services. Consequently, economic analysis to determine the best way to go about providing the required port capacity is appropriate and needed. In this section is presented an economic analysis of the alternatives available to provide the necessary port capacity in Tema to support Ghana's containerized foreign trade. This is supplemented with consideration of the impact that transshipment cargo may have on the determination of the optimal development approach.

8.2 Alternative Port Development Scenarios

The engineering studies in this and other reports have determined there are two potential lines of development for container facilities in Tema (port expansion scenarios):

- Phased development of additional container facilities inside the existing breakwater, which is the subject of this report
- Development of new facilities outside the breakwater, similar to the solution proposed previously by JICA, which is the subject of a parallel report; the emphasis there is on transshipment cargo, but there is no technical or economic bar to such a port facility being used for import/export cargo

8.3 Plan of the Economic Analysis

The economic analysis presented here is for the purpose of determining the optimal development track for providing container handling facilities in Tema in support of Ghana's foreign trade. The initial step is to determine the optimal port development strategy understanding the absence of significant transshipment volume, that is, purely to accommodate Ghana's own cargo flows.

There are several points of comparison between the two port expansion scenarios. The JICA solution is an "all-or-nothing" approach from the technical perspective. If it is to be built, the civil works should be completed in one single project even though the terminals utilization may be low during the early years. The in-harbor solution is a phased approach whereby the development better matches the capacity growth. The JICA solution supports the needs of larger containerships since it involves greater depths. Greater depths may become increasingly important in the future. Given its sheer magnitude, the JICA solution will likely require more construction time whereby volume will increase faster than the development of the terminal proper. The in-harbor solution builds on the availability and experience of the existing container handling operation, so integration and implementation may be easier and smoother. How the two scenarios would be meshed institutionally with the existing terminal operation in Tema, which is being carried out under an existing concession contract, is unclear.[1] It should be noted that the in-harbor development plan assumes that the current container yard operated by MPS would continue to operate in whole or part for cargo worked at the expanded facilities. In addition, the existing concessionaire has the right to access and

[1] Some aspects of the current concession contract (MPS Terminal) relative to port development at Tema were discussed in the parallel report.

utilize the area proposed for the Phase 1 development on the north side of the existing quay area.

The capacity increment associated with the two projects is roughly similar. The in-harbor project as presented earlier brings additional capacity of 1.7 million annual TEU's; the capacity of the JICA project depends upon the assumption regarding the split between transshipment cargo and import/export cargo; if it were strictly import/export, thus making it comparable to the in-harbor solution, its end-point capacity would be greater than that of the in-harbor solution, but not by a margin that is significant for the results of the economic analysis here.

The optimal development track, other things held equal, is the least cost track that also provides the needed capacity. Thus, the main approach of the analysis here is to measure the economic cost of the two basic proposals, focusing on the net present cost presented by each.

8.4 The Model and Data

In order to perform the economic analysis, a customized spreadsheet model was created to evaluate the NPV of the cost of the two basic scenarios.

The key data and assumptions used in the model are as follows:

- Whichever scenario is selected, the costs of port equipment, stevedoring and cargo handling generally, and operating overheads (insurance, utilities, accounting, management, etc.) would be essentially the same, since either way these would be added as needed to handle the actual volume. As such, the only costs that will differ will be the actual hard and soft construction costs, and maintenance of facilities over time. Therefore, the quantitative analysis presented here is limited to consideration of these latter costs.
- For the JICA solution, the construction and maintenance costs assumed here, and the timing of those costs, are the same as were used in the parallel report.
- For the in-harbor solution, the construction costs are those presented earlier in this report (Table 5.1).
- Since the scope of each phase of the in-harbor solution is smaller than the JICA scope, it is assumed that construction of each phase could be completed in two rather than three years, with expenditures of 40% the first year and 60% the second form each phase.

- Design costs for the in-harbor solution are assumed to be incurred the first year, while supervision costs are incurred in proportion to the annual construction expenditures.
- M&R costs for the JICA solution are the same as assumed in the parallel report; M&R for the in-harbor solution are assumed at $300,000 per year for the first ten years of each stage, and 1% of the hard investment cost after that.
- For purposes of the analysis, it is nominally assumed that construction starts in 2010 for either option; this would result in the facilities being ready earlier in the case of the in-harbor solution.

8.5 Results of the Model and Preliminary Conclusions

The NPV's of the total project costs were calculated for each of the two development scenarios, discounted to the present. The results, at various discount factors, are presented in the following table:

Table 8.1 Results of the Model and Preliminary Conclusion

Discount Factor	NPV In-harbor scenario	NPV JICA scenario
8%	$300.6 million	$606.2 million
10%	$260.6 million	$579.4 million
12%	$227.5 million	$555.1 million
14%	$199.9 million	$532.9 million
16%	$176.8 million	$512.5 million

Based on the calculations shown, it is clear that the in-harbor solution has the lower NPV, by a substantial margin, about $300+ million. This means that the in-harbor solution is, from the standpoint of costs/economics, the preferred strategy, particularly at the higher discount factors (interest costs) where the delay in investment associated with the in-harbor approach is more strongly relevant; even at the lowest discount factor shown, 8%, the NPV associated with the in-harbor solution is half the economic cost of the JICA solution.

8.6 A Hybrid Scenario

In addition to the two scenarios above, there is nothing to prevent undertaking an early phase or phases of the in-harbor scenario and later switching to the JICA scenario if conditions and opportunities warrant it. This approach would take advantage of the comparatively inexpensive first phase of the in-harbor scenario, would defer the major investments associated with the JICA approach and thus improve the NPV of the overall growth path, would provide additional time to assess the prospects for success of the potential transshipment business as well as time to work with potential users to develop the necessary long term commitment that would justify the facility, and through the above materially reduce the risk associated with the investment.

The table below adds the NPV of a hybrid approach, under which the first step is Phase 1 of the in-harbor strategy, followed by the JICA strategy with construction delayed 4 years, until 2014, so that the capacity increment is available in 2017, the same as with Phase 2 of the in-harbor strategy:

Table 8.2 NPV of a Hybrid Approach

Discount Factor	NPV in-harbor scenario	NPV JICA scenario	NPV hybrid scenario
8%	$300.6 million	$606.2 million	$487.0 million
10%	$260.6 million	$579.4 million	$436.7 million
12%	$227.5 million	$555.1 million	$393.0 million
14%	$199.9 million	$532.9 million	$354.9 million
16%	$176.8 million	$512.5 million	$321.4 million

Examination of the results shows that the hybrid strategy yields improved results when compared with the JICA scenario. It clearly has a further advantage, in that it represents the first phase of the in-harbor strategy, meaning that without question it can be adopted as the preferred strategy; a decision about whether to jump to the more expensive JICA strategy can be deferred for several years while further information is acquired about the prospects for large volume transshipment that would justify that extra expense, and only after that a final decision made about continuing on the in-harbor development path or switching to the JICA path.

8.7 Overall Conclusions

The results above lead to the following conclusions:

- In the absence of a major and firm commitment(s) for transshipment services in Tema, the best track for providing additional port capacity to handle containers is the in-harbor strategy. The relative cost of expansion following the track of the JICA strategy appears on its face far too high to swerve the needs of import/export cargo alone; however, if sufficient transshipment cargo becomes part of the mix, it may justify the JICA approach on capacity and/or technical grounds.
- Under any set of circumstances related to demand, including the expectation of significant transshipment volume, it is clear from examination of the hybrid strategy that the best initial step for providing more capacity in Tema is to implement Phase 1 of the in-harbor strategy. It provides the least expensive increment to capacity and very likely the shortest construction time, and is needed in view of the growth of import/export cargo assumed in this analysis.
- In general, even under the robust import/export demand growth assumptions made for purposes of this analysis, the in-harbor scenario is capable of providing the needed capacity for the foreseeable future.
- At such time as either significantly increased capacity for import/export is needed, and/or concrete demand for transshipment emerges, a determination can be made whether to continue with later phases of the in-harbor track or to shift to the JICA track.
- When and if very heavy and firm (i.e. robust) demand for transshipment service materializes, it may be appropriate to shift to the JICA track; this possibility was explored in the parallel report. The JICA approach may have an additional advantage since it brings the capability to better serve the needs of the very large container vessels that may be associated with transshipment cargoes moving in large volume.

Chapter 9 – Developmental Impact Analyses

9.1 Economic Impact Analysis for the Proposed Tema In-Harbor Port Development (Task A)

The construction and operation of the proposed in-harbor project for the Port of Tema, when and if implemented, will bring about an increase of economic activity and jobs in Ghana's economy. The method used to determine this effect is called economic impact analysis. The specifics of this infrastructure, in terms of civil works, berths, breakwaters, yard storage space, equipment, buildings, etc., were presented earlier in this report. The impact of the construction and operation of these facilities will have, i.e. the economic effect they are expected to have on Ghana, is the subject of this section.

9.2 The Source of Economic Impacts

Economic impacts are effects on the level of economic activity in a given area. They can be viewed in terms of (1) business output (or sales volume), (2) gross regional product, (3) wealth (including property values), (4) personal income (including wages), and/or (5) jobs. Any of these measures can be an indicator of improvement in the economic well being of area residents, which is usually the major goal of economic development efforts.

Economic impacts start when new funds are injected into a defined locality, from outside that locality. For example if, as in this analysis, the defined locality is a country, then the country's exports result in the injection of funds into the locality (the country) because those exported goods and/or services are paid for by buyers from outside (foreign customers). Similarly, if a project is financed with outside funds, then the purchases in the locality associated with that project constitute new funds injected into the locality.

The funds initially coming into the locality make up the first, or primary, stage of economic impact, which is called the "direct impact." However, the impact does not stop there. The receivers of the funds (e.g. the companies that sell the exported goods) will in turn re-spend some of the funds locally, some with other local businesses and some with local households (i.e. salaries and wages). This next stage of spending is termed "secondary" impacts, and includes indirect impacts (spending with businesses) and induced impacts (spending with households). Thus the direct impact is increased by some amount—this factor is less than 1.0 because some of the spending will "leak" out of the locality or not be spent at all; the exact pattern depends upon the structure of the local economy. Then, the portion of the impact that stays in the locality will again be re-spent, creating still another "secondary" cycle of indirect and induced effects, which in turn creates another cycle, theoretically without end. When the total of all the later cycles is compared with the original direct impact, the ratio is called the "multiplier." Once the multiplier is known for a specified locality and type of direct activity, the total economic impact for a specific investment can be determined.

9.3 Analytical Approach

The direct impact of the proposed project is estimated by reference to the project budget presented earlier, with an estimate for the various cost categories of the portion that will be spent on local vs. foreign purchases for materials, labor, services, utilities, equipment, etc. The indirect and induced impacts can then estimated through use of applicable input-output data for Ghana.

Input-output data for Ghana are available the Ghana Social Accounting Matrix (SAM) for 2005[2], which is a structured representation of the flow of economic transactions that occur within the Ghanaian economy. The transactions are real observed data recorded by various Ghanaian agencies and represent actual economic relationships. The SAM contains all of the necessary information to develop an input-output matrix, which in turn can be used to calculate direct, indirect, and induced effects of a particular investment stream. In order to convert the SAM into a suitable form, it was first reworked to include only domestic expenditures. Then a series of matrix algebra calculations were applied to convert it into a working input-output model, which formed the basis of the results presented below. In particular, the direct and total requirement tables for goods and services are derived, and these yield the proportion of inputs required by an industry from contributing industries to produce one cedi of output, thus ultimately calculating indirect and induced effects in the regional economy.

The input-output model function is represented in the following diagram Figure 9.1. An increase in final demand is input into the model, and the model is capable of producing

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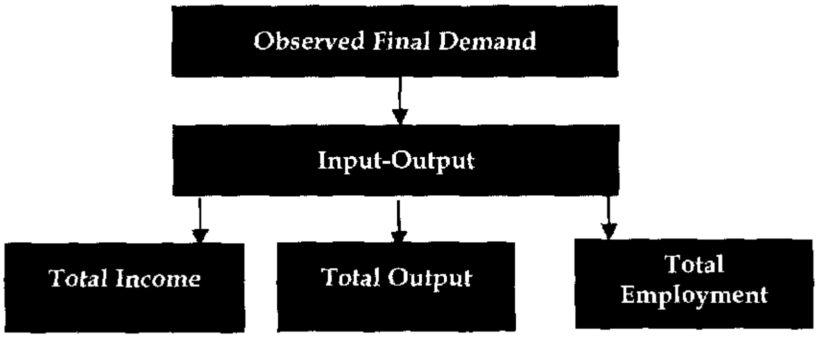
[2] *2005 Social Accounting Matrix (SAM) For Ghana. Produced by the Ghana Statistical Services (GSS), International Food Policy Research Institute (IFPRI) and Ghana Strategy Support Program (GSSP).*

estimated direct, indirect and induced output of an economy in terms of output, income and jobs.

Figure 9.1
Input-Output Model Process



9.4 Direct and Secondary Impacts Estimation

9.4.1 Overview of Requirements Tables

Through mathematical processing of the SAM table for Ghana cited above, the Halcrow/Nathan project team produced estimates of the direct and total requirements for the Ghanaian economy. The table 9.1 below provides a sampling of the factors that indicate direct, indirect/induced, and total requirements, equivalent to economic impacts, for a range of selected economic activity types in Ghana; the key sectors for our purpose are shown in red. The results contained in the table, which represent each stage of impact, are based on observed data. For estimating the impact of various industries, it is assumed that households can proxy for labor, which is an average of rural and urban households. The construction industry line is representative of the domestically-sourced portion of the build phases. The information contained in the table includes the induced effects from extra wages spent in the local economy. For example, by using table, it can be seen that for every 1 Cedi increase in demand for local construction industry services (highlighted in red), a total of 1.50 Cedis of output is generated, equivalent to the total economic impact. Of the total, 0.50 Cedi of the output is indirect and induced effects.

Table 9.1 Total Requirement Table for a Sample of Sectors

Industry	Direct	Indirect/Induced	Total Requirement
Households (Rural-Urban Mean)	1.00	1.41	2.41
Rural households (Labor Proxy)	*1.00*	*1.41*	*2.41*
Urban households (Labor Proxy)	*1.00*	*1.42*	*2.42*
Mining	1.00	0.63	1.63
Construction	1.00	0.50	1.50
Other services	1.00	1.07	2.08
Diesel	1.01	0.67	1.68
Capital goods	1.01	0.06	1.08
Petrol	1.02	0.64	1.66
Wood products	1.02	1.01	2.03
Trade services	1.02	0.87	1.89
Transport services	1.03	1.23	2.26
Metal products	1.05	1.17	2.22
Business services	1.05	0.30	1.35
Communication	1.06	0.36	1.42
Real estate	1.07	0.45	1.52
Utilities	1.08	0.73	1.81
Paper products, publishing and print	1.19	0.28	1.47
Average	**1.04**	**0.75**	**1.79**

By applying these factors to relevant capital and labor costs as estimated in the project budget, the economic impact of the project can be derived.[3]

9.4.2 Economic Impact of Project Construction

The table below shows the Tema in-harbor port redevelopment project budget as was estimated earlier in this report (Table 5.1). Engineering estimates of the domestic (i.e. local Ghanaian) portion of the various cost categories are provided, yielding the direct impact of the project on the local Ghanaian economy. As was noted, the development of the facilities would be carried out in three phases, and the budgets as well as domestic portion (primary impact) and secondary impacts are shown for each phase.

Taking the total of all three phases of the project, equipment and dredging services are expected to be provided by foreign firms, and thus the domestic share of direct expenditures accounts for 42%. Based on the factor shown above for the construction industry, the indirect/induced effects related to capital expenditures produce an additional $106.9 million or 35.1%, while an additional $129.2 million or 42.4% is produced by labor expenditures. Thus the total indirect and induced impacts on the domestic economy are an additional 77.5% expenditure over the direct amount, achieving an overall effect of $540.5 million.

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[3] It may be noticed that for some industries the direct impact is shown as being greater than 1.0. This results from the fact that for those industries the primary impact results in purchases from other firms categorized in the same industry. While these are secondary impacts from a conceptual standpoint, they are recorded in the mathematical formulation of the input-output matrix as if they were primary. Since this equally reduces the impacts that would have otherwise been recorded as secondary, it has no effect on the total economic impact ultimately calculated.

Table 9.2 –Estimated Generic Economic Impacts by Phase of Construction

		Direct		Indirect and Induced Impacts	
Item	Cost ($)	DOM (%)	Domestic	Capital ($)	Labor ($)
Phase 1	114,386,243	28%	31,729,793	11,138,740	13,464,420
Land Reclamation	30,395,362	80%	24,316,290	8,536,231	10,318,527
Pavement	14,827,006	50%	7,413,503	2,602,509	3,145,893
Cargo handling Equipment	69,163,8	0%			
Phase 2	*291,784,169*	49%	*144,136,340*	*50,599,046*	*61,163,722*
Land Reclamation	*109,420,644*	80%	87,536,515	30,729,684	37,145,796
Pavement	36,946,477	50%	18,473,239	6,485,028	7,839,050
New Roadway	21,786,621	50%	10,893,311	3,824,095	4,622,536
Quay Wall at New Berth	54,466,552	50%	27,233,276	9,560,238	11,556,340
Yard handling equipment	69,163,875	0%			
Phase 3	*327,170,518*	39%	*128,574,895*	*45,136,202*	*54,560,297*
Land Reclamation	49,128,830	80%	39,303,064	13,797,336	16,678,110
Pavement	19,063,293	50%	9,531,647	3,346,083	4,044,719
Removal of Existing Breakw	12,680,044	80%	10,144,035	3,561,062	4,304,584
Construction of New Breakv	88,760,306	50%	44,380,153	15,579,648	18,832,553
Dredging	37,942,178	0%			
Quay Wall at New Berth	50,431,992	50%	25,215,996	8,852,073	10,700,314
Cargo handling Equipment	69,163,875	0%			

		Direct		Indirect and Induced Impacts	
Item	Cost ($)	DOM (%)	Domestic	Capital ($)	Labor ($)
All Phases	*733,340,930*	42%	*304,441,028*	*106,873,988*	*129,188,439*
Land Reclamation	188,944,836	80%	151,155,869	53,063,251	64,142,433
Pavement	70,836,776	50%	35,418,388	12,433,621	15,029,662
Removal of Existing Breakw	12,680,044	80%	10,144,035	3,561,062	4,304,584
New Roadway	21,786,621	50%	10,893,311	3,824,095	4,622,536
Construction of New Breakv	88,760,306	50%	44,380,153	15,579,648	18,832,553
Dredging	37,942,178	0%			
Quay Wall at New Berth	104,898,544	50%	52,449,272	18,412,311	22,256,654
Yard handling equipment	69,163,875	0%			
Cargo handling Equipment	138,327,750	0%			

9.4.3 Operations

For each level of containerized throughput, the Port of Tema will require a certain level of employment. As tonnage grows with the port expansion projects this will allows for the increase in direct jobs in the port will grow, and through secondary effects will cause jobs will create increased employment outside the port, in the general economy. Generally, every one unit of additional direct employment in the port will result in an associated 1.41 additional indirect and induced employment.[4] This is approximately 0.6 indirect/induced employments per 1000 TEUs of throughput.

Aside from simple employment numbers, the technological advancement of equipment and operations may have long term benefits for the skill composition of Ghana's overall workforce. Among the most prevalent beliefs in development economics is the potential of technological transfer and productivity augmentation through a learning-by-doing process.[5] Workers improve their skill and capabilities through regularly practicing a type of action, and by achieving improved levels of efficiency and perfection. To further strengthen long term growth, technology transfer is accompanied by knowledge transfer, which leads to human capital generation and potential innovation spillovers.

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[4] Assumes that inter -industry wage differentials between maritime/port transport and indirect/induced industries are negligible. Also, foreign induced employment is determined to be negligible due to small size of employed.

[5] This effect has been cited by Kenneth Arrow and Robert Lucas, Jr. in explaining increasing returns to human capital and endogenous growth

Table 9.3 Indirect Employment Impacts given Various Level of Output

Tema (Plan A)				
		Labor		
ID	Annual TEL ('000)	Local Direct	Local Indirect/ Induced	Foreign
1	800	363	512	10
2	900	388	547	10
3	1,000	420	592	10
4	1,100	503	709	10
5	1,200	528	745	10
6	1,300	560	790	10
7	1,400	643	907	10
8	1,500	668	942	10
9	1,600	700	987	10
10	1,700	783	1,104	10
11	1,800	808	1,140	10
12	1,900	840	1,185	10
13	2,000	923	1,302	10
14	2,100	948	1,337	10
15	2,200	980	1,382	10
16	2,300	1,063	1,499	10
17	2,400	1,088	1,535	10
18	2,500	1,120	1,580	10

Chapter 10- Concession/Franchise Recommendations

The operation of container facilities within the port of Tema is subject to an existing contract between GPHA and Meridian Port Services (MPS) that gives MPS near monopoly of handling containers within the existing port.

The cost of abrogating the contract with MPS cannot be reasonably established. Consequently a recommendation for doing so and providing opportunities for third parties to handle containers within the port cannot be provided.

In the companion report (Task 3B) a detailed recommendation for a franchise arrangement for the container port outside the existing port is provided. Reference is made to this report.

Appendix A

Draft Specification of Soils Boring Program

Please note that this draft needs to be updated when a specific project is decided upon.

DRAFT SPECIFICATION

The specification shall be the *Specification for Ground Investigation,* published by Thomas Telford Services Ltd in 1993, (ISBN 0-7227-1984-X) with information, amendments and additions as described in the following schedules.

Schedule 1	Information
Schedule 2	Exploratory Holes
Schedule 3	Amended Clauses
Schedule 4	Additional Clauses

Schedule 1: Information

Name of Contract	S1.1	The project is Takoradi Port Expansion, and Geotechnical Site Investigation.
Description of site	S1.2	The Takoradi Port and Container Terminal is situated on the Gulf of Guinea (Atlantic Ocean) in Southern Ghana, 228 Km west of Accra, the capital city of Ghana and 300 Km east of Abidjan, capital city of Cote d'Ivoire. The port of Takoradi is a harbor protected b y two major structures. At the south side of the harbor, the main breakwater extends in west-east direction about 1.5 km to offshore , curving at the outboards end towards north with a length of about 700 m and thus protecting the harbour from the prevailing south and southeast waves. The lee side breakwater located at the northern side of the port is a combine breakwater , oriented towards the east and extends about 700 m to offshore.
Main works proposed and purpose of this contract	S1.3	The Takoradi geotechnical investigation is the main investigation for the following key activities expected to be undertaken : i) development of a new deep water container/hub terminal to the north of the existing Takoradi port and ii) the refurbishing, modernizing and operating of the existing Takoradi port. The main works within the phased Takoradi terminal development will include i) construction of an extension of the existing xxxx breakwater to provide sheltered water alongside berths, ii) construction of new container handling quays and container staking

areas, iii) dredging shipping channels and berths areas, iv) purchase and installation of cranes.

Scope of investigation S1.4

The scope of the Takoradi geotechnical investigations consist of performing marine and land based boreholes. However, the majority of the investigation work will consist of advancing marine boreholes. Both the marine and land based boreholes shall consist of soil drilling, rock coring, and associated in-situ sampling and testing. Laboratory testing will be required, along with the provision of preliminary and final factual reports.

Geology and ground conditions S1.5

The following assessment of the geology of the site and ground conditions has been inferred from available information. No assurance is given to its accuracy.

Site geology in undredged and unreclaimed areas is expected to comprise of superficial sand, silt, clay and gravel deposits, overlying Takarodi Sandstone (mix of sandstone, mudstone and siltstone). Site geology in dredged areas is expected to comprise alluvial sand and disturbed dredge material, overlying Takarodi sandstone and cemented sands. In reclaimed areas, site subsurface conditions are expected to comprise of sand and gravel fill gained from dredging operations, overlying Takarodi sandstone, and cemented sands.

Tidal data for the Takoraid Port is as follows:

MHWS – +1.6m CD

MHWN – +1.1m CD

MLWS – +0.3m CD

MLWN – +0.7m CD

Where MHWS= Mean high Water Springs

MHWN= Mean high Water Neaps

MLWN= Mean Low Water Neaps

MLWS= Mean high Water Springs

The datum refers to the World Geodetic System 1984 (WGS-84). Sea Levels are referenced to the Chart

Datum (CD).

Schedule of drawing(s) and documents	S1.6	Fig. 1: Takoradi Port and Container Terminal, Borehole and PCPT – Location Plan.
Particular Contract restrictions	S1.7	Investigation work shall be completed in areas, in the following order: <u>Takoradi Site</u> Dredging Areas **(list borings)** Quay Wall and Revetment Areas (**list borings**). Upland Areas within the Reclaimed Island (**list borings**) Contractor's schedule shall target completion of the field work for the various site areas in accordance with the requirements provided above. No upland hole shall be backfilled without the Engineer's approval. Contractor shall be responsible for clearing and avoiding all utilities, including underground and above ground piping, drainage systems, and underground structures. Contractor shall backfill on land boreholes with cement/bentonite grout. Existing surfaces on land shall be reinstated to their original condition.
Particular General requirements	S1.8	Full time professional attendance will be required in accordance with **Clause 3.12**. Contractor shall designate a lead geotechnical engineer on the project site at all times, with experience equivalent to category (f) as described in **Clause 2.2**. The lead geotechnical engineer shall direct the Contractor's personnel, and be authorized to accept, and act upon, any instructions from the Engineer in accordance with these specifications. Contractor shall also provide for the full time attendance of an engineer with experience equivalent to category (d) as described in **Clause 2.2**, for each drilling rig or PCPT rig operating, throughout the duration of the investigation. Contractor shall furnish uninterrupted access to and from borehole locations for his plant, materials and personnel. Where temporary access roads are to be built, the Contractor shall determine the route to the drill location, and shall obtain the necessary permission for access, if required.

Contractor shall furnish sufficient number of boats for uninterrupted access to and from the marine borehole locations for his plant, materials, and personnel, including the Engineer and Employer's Representatives.

For the marine boreholes, the Contractor shall provide a stahle platform and sink boreholes through conductor pipe spanning between the working platform and the seabed. The design of the platform is to take into account fluctuating water levels due to tides, waves, and swell conditions. It is essential that such construction be sufficiently strong for borehole operations to resist waves, tidal flow, and other currents and floating debris. Due consideration is to be given to safety requirements, navigational warning, and regulations of governmental departments and other authorities. Necessary readings of water levels and tidal gauges are to be made to enable seabed elevation at location of marine boreholes to be referred to the specified project datum (CD) and elevations of various strata to be determined accurately.

Exploratory holes on land and PCPTs shall be set out to within 1 m of proposed locations. Exploratory holes overwater shall be set out to within 3 m of proposed locations. All final boreholes and PCPT locations shall be recorded to an accuracy of 0.1 m in the vertical direction and in the horizontal direction.

Contractor is responsible for obtaining all permits and permissions pertinent to the works, and shall post notices to mariners for all marine works as required by Ghana Ports and Harbour Authority (GPHA).

Particular borehole requirements — S1.9 — Auger boring is not permitted. Boreholes shall be advanced using either cable-tool percussive or rotary techniques.

Rotary drilling in soil shall be performed at the applicable rates for boring as listed in the Bill of Quantities.

For marine boreholes, payment shall be made for soil drilling below seabed only.

Particular rotary drilling — S1.10 — Rotary drilling, in soil only, shall be accomplished

requirements (Section 5)		using bentonite mud or other Engineer approved drilling mud, to prevent collapse of the hole. Rock coring shall be in accordance with BS 5930 or ASTM D2113. Minimum core size shall be "P" size. Rock cores shall be digitally photographed, in accordance with **Clause 5.6.** Minimum core recovery shall be 95%. Should recovery fall below 95%, the drilling methods are to be amended (e.g., drill runs reduced to 50% of the previous run) until recovery improves. For marine drill holes, payment shall be made for soil drilling below seabed only.
Particular pit and trench requirements (Section 6)	S1.11	Not required
Particular sampling requirements (Section 7)	S1.12	Small disturbed samples shall be taken from each SPT split spoon. Bulk disturbed samples shall be obtained from each soil type. Undisturbed samples shall be obtained from within each cohesive deposit encountered, at the direction of the Engineer, using thin walled piston or push type-samplers in accordance with ASTM D1587 or BS 5930. Soil sample identification and rock core logging of borings shall be performed either on site in the Contractor's secure logging facility, or on-board the drilling platform. Subsequently, the samples shall be transported the Contractor's laboratory for final logging, laboratory testing, and final storage. Samples shall be examined and described in accordance with **Clause 7.11**. Should the Contractor require to store the soil and rock core samples temporarily on-site then a secure, weatherproof facility shall be provided at an on-site upland location to be identified by the Contractor. Storage facilities utilized prior to testing of the soil samples and rock cores, whether on site or at the Contractor's laboratory facility, shall be climate controlled (cooled). After completion of the laboratory testing, soils and rock core samples shall be stored at the Contractor's warehouse facility as per **Clause 7.13**, except that

		samples shall be retained for 365 days. Following the storage period, the Contractor shall make provision to deliver any remaining samples to a location to be identified by the Engineer.
Particular in situ testing requirements (Section 8)	S1.13	As per Clause 7.6 except that SPTs shall be carried out at 0.5 m centres within the upper 5 m, and at 1.5 m centres thereafter, in both cohesive and non-cohesive deposits. Tests shall be carried out in accordance with BS1377 or ASTM D1586, Cone Penetration Tests shall be carried out in accordance with BS1377 or ASTM D5778 and shall be include as a minimum, tip resistance, sleeve friction, friction ratio and excess pore water pressure. PCPTs shall be advanced to the maximum capacity of the equipment, or refusal, whichever is sooner. PCPT equipment shall be capable of exerting minimum 20 tonnes reaction force.
Particular instrumentation and monitoring requirements (Section 9)	S1.14	No instrumentation is required
Particular daily report requirements (Section 10)	S1.15	Per Clause 10.2
Particular laboratory testing requirements	S1.16	Laboratory testing shall be carried out in accordance with ASTM D2216, ASTM D4318, ASTM D422 and ASTM D1140, ASTM D2435, ASTM D2850, ASTM D2938, ASTM D3148, ASTM D3967, and ASTM D5731, or the equivalent appropriate section of BS1377. Samples shall be transported in accordance with ASTM D4220 or BS 5930. Contractor shall prepare blank lab testing schedule for each borehole and forward to the Engineer for completion. All laboratory testing shall be undertaken by the Contractor's own NAMAS/UKAS accredited laboratory, unless otherwise approved by the Engineer.
Particular reporting requirements (Section 12)	S1.17	Preliminary Data Reports for each investigated area at shall be provided within 7 calendar days after completion of the fieldwork. The Preliminary Data

Reports shall include details of all boreholes, and in-situ testing. Interpreted soil strata profiles shall be provided, with PCPT results, where applicable, in accordance with **Clause 12.2.5**.

Interim laboratory testing shall be provided on a weekly basis.

A Draft Final Factual Report shall be provided 21 days after the completion of the fieldwork. The Draft Final Factual Report shall include all borehole logs, and field testing with classification corrected based on the laboratory testing, and results of all laboratory testing conducted.

Final Factual Report shall be required within 30 days of completion of fieldwork, and shall take full account of Engineers comments. Contractor shall provide both PDF and hard copies of the Final Factual Report.

Digital data is required and shall include digital copies of the factual reports and tabulated data from cone penetration tests shall also be provided as described in **Clause 12.4 and Appendix III.**

Schedule 2: Exploratory Boreholes

Locations of the exploratory marine and on land boreholes are provided on the attached drawings.

Borehole Location	Type	Approximate Existing Ground Elevation (m CD)	Scheduled Termination Elevation (m CD)

Schedule 3: Amended Clauses

The following clauses are amended

Clause

3.6 *Add the following*

The Contractor shall take all necessary precautions to avoid causing any damage to access roads, tracks, land, buildings, and other features and shall deal promptly with any complaints by owners or occupiers.

Care shall be taken to preserve the natural amenities of the area and to avoid damaging any trees, bushes, hedges or walls in the vicinity of the Site Operations.

No excavations shall be left open outside the Contractor's working hours.

3.12 *Add the following*

The professional attendant shall be responsible for informing all personnel on site employed by the Contractor of the specific requirements of this Specification.

3.14 *Add the following*

No boring or excavation shall commence until the location has been marked by the Contractor and approved by the Engineer on site.

4.1 *Delete "Auger boring" from the list in the second paragraph*

5.2 *Delete and replace with the following*

Where drilling in rock, drilling fluid shall be selected to maximize core recovery and ensure stability of the borehole wall. Drilling fluid may be clean water, air, or air mist, although bentonite mud or other similar fluid shall be used where necessary to ensure against collapse of the borehole wall.

Where using rotary drilling to advance the borehole through soil, drilling mud shall be used to stabilize the borehole. Drilling mud shall be made from bentonite, guar gum or similar product, subject to approval by the Engineer.

5.3.3 *Delete and replace with the following*

The first drill run in each hole shall not exceed 1 m in length. Subsequent drill runs shall not normally exceed 3 m in length and the core barrel shall be removed from the drill hole as often as is required to obtain the best possible core recovery. When any recovery is less than 90% from a drill run then the next drill run shall be reduced to 50% of the previous length, unless otherwise directed by the Engineer, and so on down to a minimum length of 0.5 m. The Engineer may specify in situ testing between drill runs.

5.3.5 *Delete Sub-clause 3 and replace with the following*

3. Depth shall be indicated on the core box by durable markers at one metre intervals and at all significant changes of strata and at the end of each drill run. Where there has been failure to achieve 100% recovery, core spacer pieces of appropriate size clearly indicating the missing lengths, shall be placed in the boxes. The location, exploratory hole number and the depth of coring relating to the contents of each box shall be clearly indicated in indelible ink on labels, inside the box, on the top and on each end of the box. All markers and labels shall be such as to facilitate subsequent photography. All core boxes other than those to be retained by the Employer shall remain the property of the Contractor.

5.3.6

- 4 Access for the inspection of the cores by the Engineer shall be provided by the Contractor for the duration of the Contract.

5 The cores shall be sealed after examination and before laboratory testing by wrapping in plastic as approved by the Engineer.

7.1 *Delete this clause and add the following:*

Small disturbed samples weighing not less than 1 kg shall be placed in jars with air tight lids. The jar shall be fully filled to leave no free space within the jar. The jar shall be clearly labelled using indelible ink on waterproof labels, one placed inside the jar and the other securely attached to the outside.

Schedule 4: Additional Clauses

The following clause is added to the specification

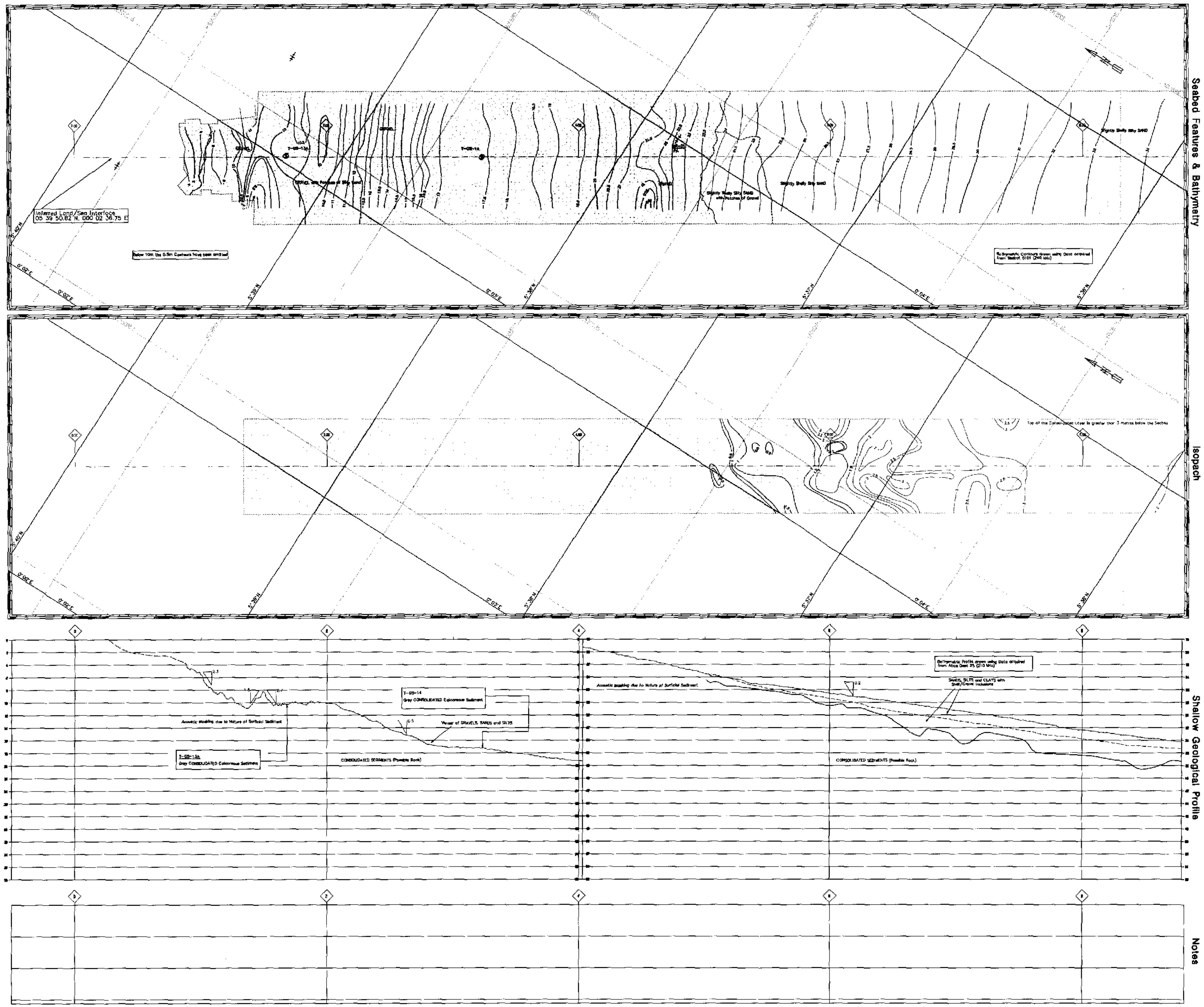
Clause
3.26 Core Storage and Logging Facilities

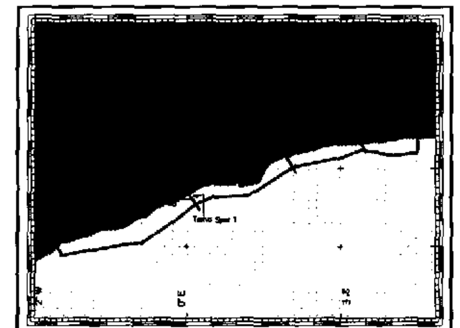
As part of the Contractor's offices and stores, the Contractor shall provide secure and weatherproof facilities on site for the purpose of core storage and logging. The logging facilities shall be suitable for the purpose of preparation of the core for examination (Clause 5.36), photography and examination of the core.

The logging facilities shall be equipped with a table or work-bench suitable for placing the core boxes during examination and adequately lit. A measuring tape shall also be provided. Water shall be provided for the purpose of hand washing.

Appendix B

West African Gas Pipeline Project
Geotechnical Survey





LOCATION CHART

LEGEND

Proposed Piperoute with KP's — Amended Piperoute with KP's

Seabed Features and Bathymetry

- Bathymetric Contour (M.S.L.), 1-m Interval, 0.5-m interval in less than 30-m water depth
- Limits of Side-Scan Sonar Coverage
- Seabed Sediment Boundary
- Seabed Scar
- In Service Cable (SAT 3, Proposed), from Global Marine Database
- Out of Service Cable, from Global Marine Database
- Seabed Depression, less than 5 metres Diameter unless otherwise stated
- Possible Sonar Contact with Dimensions (Length x Width x Height)
- Observed Shipwreck (Coloured Black where not observed, Position derived from Admiralty Chart)
- Magnetometer Contact
- Core/Grab Sample, GS = Grab Sample, DC = Drop Core
- CONSOLIDATED SEDIMENTS
- GRAVEL
- Sandy GRAVEL
- Gravelly SAND
- Shelly SAND
- Silty SAND
- Clayey SAND
- Sandy SILT
- Gravelly CLAY
- Sandy CLAY
- Silty CLAY
- Ripples = W=Wavelength (m), h=Height (m)

Isopach to top of the Consolidated Layer

- Extent of Sub-Bottom Coverage
- Isopachytes, interpreted down to 3-m Sub-Seabed
- Top of Consolidated Layer is within 1.5 metres of the seabed

Shallow Geological Profile

- Seabed (M.S.L.), Inferred where Dashed
- Sub-Seabed Reflector
- Sub-Seabed Internal Reflector
- Consolidated Sediment Reflector
- Possible Gas Front
- Seabed Gradient Triangle, Gradient measured in Degrees

NOTES

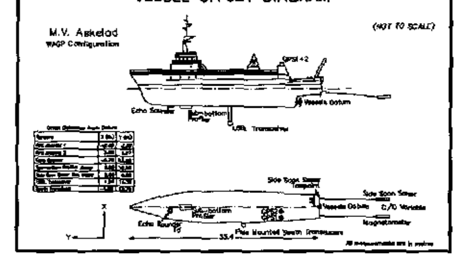
1) All KP's are Calculated using Great Circle Computations
2) All KP's are relative to the Main Route, where KP 0.0 is the Nigerian Shore Landing Site
3) Bathymetric Data acquired using a Seabat 8101 (240 kHz) & an Atlas Deso 25 (210 kHz)
4) Side-Scan Data acquired using a Geoacoustics 1590 Fish
5) Sub-Bottom Data acquired using a Geoacoustics 134 4x4 Pinger Array
6) Bathymetric Contours drawn to limit of the Swath Coverage
7) Isopach drawn to top of the Interpreted Consolidated Layer to a maximum thickness of 3 metres
8) Multibeam Swath Data & Echosounder Profiles may not always directly compare. See Chapter 2 of Volume 1, Survey Results for Discussion

SCALE

Horizontal Scale 1:10,000 Vertical Scale 1:200

VESSEL OFFSET DIAGRAM

M.V. Askelad
WAGP Configuration
(NOT TO SCALE)



GEODETIC INFORMATION	
Projection	T.M.
Spheroid	WGS-84
Datum	WGS-84
Latitude of Origin	00° 00' 00" North
Central Meridian	00° 40' 00" East
False Easting	500 000m
False Northing	0m
Scale Factor on C.M.	0.9996
Unit of measurement	International metre

NAVIGATION SYSTEM

Thales SkyFix DGPS Solution
Reference Station: Abidjan, Port Harcourt, Port Gentil
Navigation Software: QINSy v2.48

VERTICAL DATUM

Reduced to C.D. using Chartx Co-tidal model, utilising the Tidal Harmonics of ATT; Vol.2, Pt.2 (2002).
Tidal Ports: Takoradi, Sekondi, Accra, Tema, Lome, Cotonou & Lagos Bar

WEST AFRICAN GAS PIPELINE PROJECT

WAGP

FOR

CHEVRONTEXACO

BY

THALES
THALES GEOSOLUTIONS LTD.

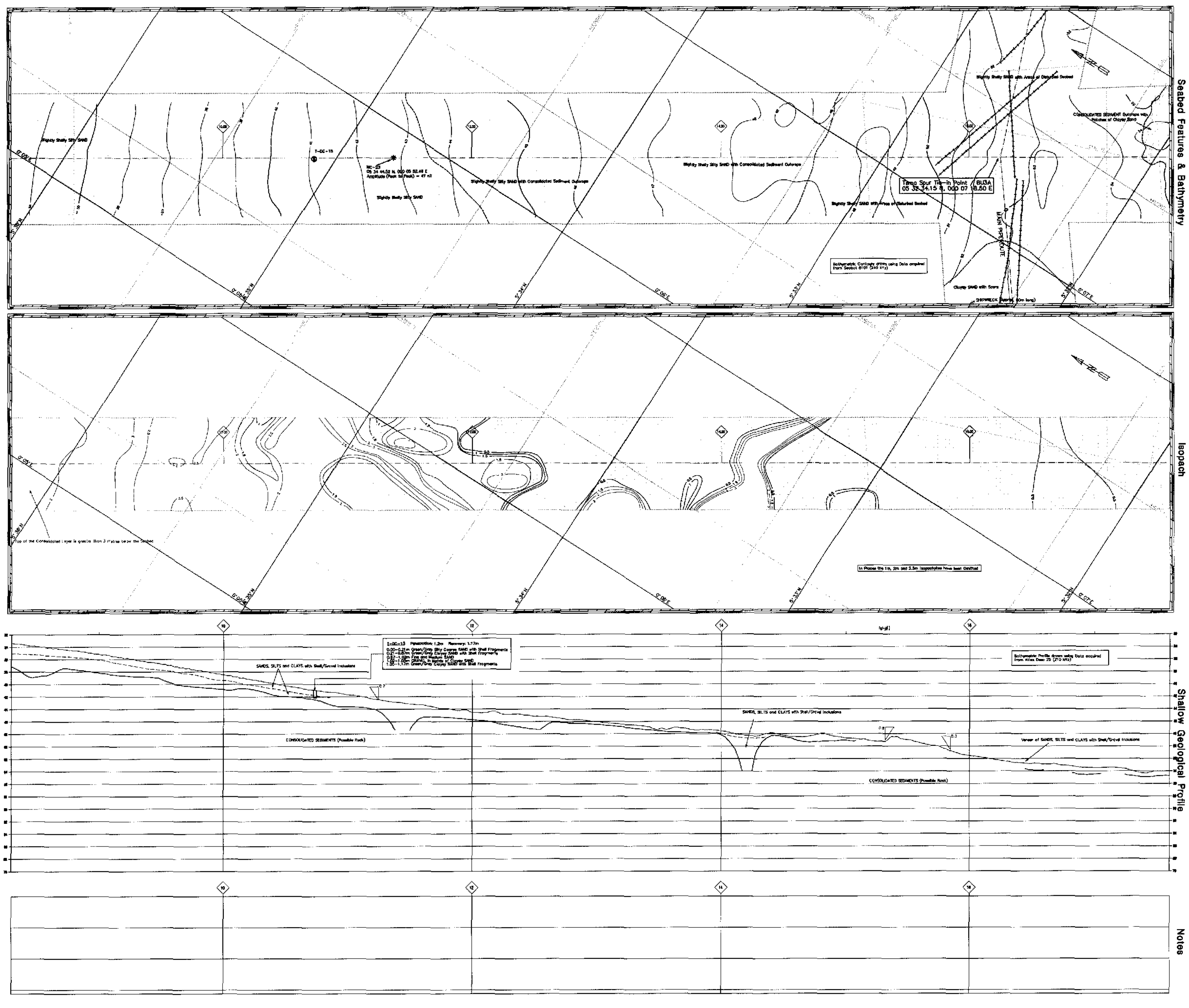
Seabed Features, Bathymetry, Isopach and Shallow Geological Profile

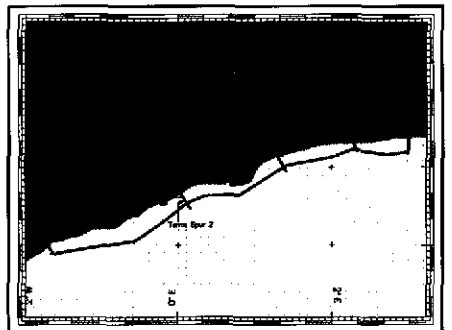
TEMA SPUR
Alignment Chart 01 of 03
(KP 000.000 to KP 008.793)

Project Manager: Dave Stephens
Thales GeoSolutions Ltd.
Newark House
26-45 Cheltenham Street
Bath BA2 3EX
United Kingdom
Telephone +44 (0) 1225 486500
Fax +44 (0) 1225 486597
www.Thales-GeoSolutions.com

Revision	Comment	Checked	Checked	Approved
02	Client Final Copy	AAR/FMC	DST	NCA
01	Client Draft Copy	AAR/FMC	DST	NCA
00	Internal Review	AAR/FMC	DST	NCA

Date: 6th February 2003 — Drawn by: Aaron Armstrong & Graham Corley





LOCATION CHART

LEGEND

Proposed Piperoute with KP's — Amended Piperoute with KP's

Seabed Features and Bathymetry

- Bathymetric Contour (M.S.L.), 1-m interval, 0.5-m interval in less than 30-m water depth
- Limits of Side-Scan Sonar Coverage
- Seabed Sediment Boundary
- Seabed Scar
- In Service Cable (SAT 3, Proposed), from Global Marine Database
- Out of Service Cable, from Global Marine Database
- Seabed Depression, less than 5 metres Diameter unless otherwise stated
- Possible Sonar Contact with Dimensions (Length x Width x Height)
- Observed Shipwreck (Coloured Black where not observed, Position derived from Admiralty Chart)
- Magnetometer Contact
- Core/Grab Sample, GS = Grab Sample, DC = Drop Core
- CONSOLIDATED SEDIMENTS
- GRAVEL
- Sandy GRAVEL
- Gravelly SAND
- Shelly SAND
- Silty SAND
- Clayey SAND
- Sandy SILT
- Gravelly CLAY
- Sandy CLAY
- Silty CLAY
- Ripples = W=Wavelength (m), h=Height (m)

Isopach to top of the Consolidated Layer

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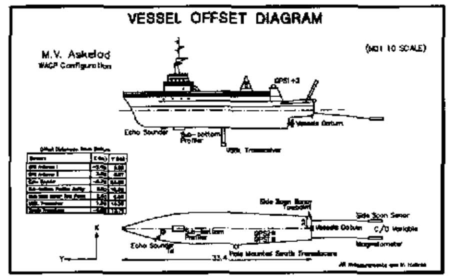
WAGP Configuration
(NOT TO SCALE)



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Scale Factor on C.M.	0.9996
Unit of measurement	International metre

NAVIGATION SYSTEM

Thales SkyFix DGPS Solution
Reference Station : Abidjan, Port Harcourt, Port Gentil
Navigation Software: QNS II v2.46

VERTICAL DATUM

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Tidal Ports : Takoradi, Sekondi, Accra, Tema, Lome, Cotonou & Lagos Bar

WEST AFRICAN GAS PIPELINE PROJECT

WAGP

FOR

CHEVRONTEXACO

BY

THALES
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Seabed Features, Bathymetry, Isopach and Shallow Geological Profile

TEMA SPUR
Alignment Chart 02 of 03
(KP 008.306 to KP 017.593)

Project Manager: Dave Stephens
Thales GeoSolutions Ltd.
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26-45 Cheltenham Street
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Date: 6th February 2003 — Drawn by: Arron Armstrong & Graham Corley