13.6 Preliminary Design

13.6.1 Design Criteria and Conditions

(1) Design Codes and Standards for Port Facilities

In Ghana no design code/standard for the port facilities is available, however generally related British Standards (B.S) are used when necessary. Thus the following standards are referred to in the design.

- Technical Standards for Port and Harbor Facilities in Japan
- British Standard Code of Practice for Maritime Structures (B.S 6349 Part 1 to Part 7)

(2) Oceanographic Conditions

From the collected data on the natural conditions of Takoradi Port area (ref. Chapter 3 Natural Conditions in and around Ghana Sea Ports) the following oceanographic conditions are applied;

(a) Tides

- Design High Water Level (H.W.L) : C.D + 1.50 m (MHWS)
- Design Low Water Level (L.W.L) : C.D ± 0.00 m

(b) Waves

<u>Deep Water Waves</u>

Based on the offshore wave data (ref. Chapter 3: Natural Conditions in and around Ghana Sea Ports), the following probable deep water waves are estimated.

Table 13.6.1 Probable Deep Water Waves

All Direction

Return Period (year)	5	10	20	30	40	50	100
Wave Height Ho (m)	4.70	4.93	5.19	5.35	5.47	5.56	5.86
Wave Period To (sec)	8.35	8.60	8.88	9.05	9.18	9.29	9.62
Wave Length Lo (m)	108.77	115.38	123.01	127.77	131.47	134.63	144.37

<u>Design Waves</u>

Over the whole coastal area of Ghana, the predominant wave direction is between SW and SE. The design waves to determine the structural sections of the required port facilities are estimated at –18.0 m water depth line computing wave transformation coefficients, due to refraction and shoaling, with a use of “Energy Balance Equation”. The applied probable deep water waves are 50 years return-period waves with the wave period (To) of 9 sec ~ 11 sec.

Table 13.6.2 Design Waves at –18.0 m Depth

Wave Characteristics	Deep Water Wave Direction		
	SW	S	SE
Deep Water Waves			
Ho (m)	5.10	5.40	4.80
To (sec)	9 ~ 11	9 ~ 11	9 ~ 11
Lo (m)	126.4 ~ 188.8	126.4 ~ 188.8	126.4 ~ 188.8
Design Waves			
$K_d \cdot K_\gamma \cdot K_s$	0.724	0.818	0.921
H 1/3 (m) ($Ho*K_d \cdot K_\gamma \cdot K_s$)	3.70	4.40	4.40

Note: $K_d \cdot K_\gamma$: coefficient of diffraction and refraction, K_s: Shoaling coefficient

(c) Current

- Max Tidal current velocity : 1.0 m/sec

(2) Subsoil Conditions

Most of the area for the master plan including the existing port area is geologically rock formation represented by sandstone or siltstone having a very thin overburden of sandy/silty deposit (0.0 ~ 1.0 m) at relatively deep water area. The Characteristic strength of the rock is expected between 10 to50 MPa, except at the southern part of the existing port basin area where the characteristic strength is of the order of 80 MPa.

Based on the above, the following subsoil conditions are applied for the master plan design;

Table 13.6.3 Subsoil Conditions

Location	Design Parameters of Subsoil
Southern Part of the existing port basin	Sandstone Unit Weight : 24.5 KN/m^3 Compressive Strength : 80 MPa
Other areas	Sandstone/siltstone Unit Weight : 24.5 KN/m^3 Compressive Strength : 10 to 50 MPa

(4) Seismic Conditions

Due to recent earthquake experiences (at least 5 times in these 10 year, magnitude 3.1 ~ 4.4), a new guideline for seismic conditions for buildings design is being discussed. Taking the above situation in Ghana, the seismic force coefficient of 0.15 is applied in the design.

(5) Objective Vessels

The following objective vessels are considered in the design;

Table 13.6.4 Objective Vessels for Takoradi Port

Vessel Type	DWT	Length Overall (L.O.A) m	Breadth (B) m	Max. Draft (Df) m
Bulk Carrier	40,000	200	29.9	11.8
General Cargo Ship	30,000	185	27.5	11.0
Container Ship	30,000	220	30.2	11.1
Ro/Ro Ship	28,000	210	-	11.0
Oil Tanker	20,000	158	25.8	9.6

(6) External Loads

Based on the requirements of the "Technical Standards for Port and Harbor Facilities in Japan" the flowing external loads are used in the design;

(a) Tractive Force

Table 13.6.5 Tractive Forces of Ships

Gross Tonnage	Tractive Force on Bollard (KN)
200 ~ 500	150
501 ~ 1,000	250
1,001 ~ 2,000	350
2,001 ~ 3,000	350
3,001 ~ 5,000	500
5,001 ~ 10,000	700
10,001 ~ 20,000	1,000
20,001 ~ 50,000	1,500
50,001 ~ 100,000	2,000

Source: Technical standards for Prt and Harbon Facilities in Japan

(b) Crane Load and Surcharge

	Normal Condition	Seismic Condition
Crane Load	400 KN/wheel	400 KN/wheel
Surcharge	20 KN/m^2	10 KN/m^2

13.6.2 Structural Design of Main Facilities

(1) Breakwater

In the Master Plan the existing breakwater is to be extended towards NNE to N direction in order to obtain a necessary calmness of the new bulk berths. The total length of the breakwater extension is approximately 900 m and the water depth of the area is about –14.0 m.
The structural type of the existing breakwater is rubble mound type and the max water depth is around –13.0 m.

In the vicinity of Takoradi, a several operating quarries or possible quarry sites are available where some suitable rock materials for the breakwater can be produced.

In order to examine the appropriateness of the structural type of the planned breakwater, an alternative case study has been carried out. The selected alternative structural type for the comparison with the existing structural type (rubble mound) is a concrete caisson type as this type is typically adopted when a breakwater is to be constructed in deep water areas.

The examination conditions and the results are shown in Table 13.6.6. From the results of the examination the rubble mound type is recommended under the following reasons;

- Costwise no significant difference or slightly more economical than the concrete caisson type.
- Possible to maximize utilization of locally available material.
- Construction method is simple and easier than caisson type.

It should however be noted that the armor stone size is to be increased so as to cope with the estimated design wave conditions as the currently used armor stone size may not sufficiently satisfy the required stability against the possible wave height.
The recommended cross section of the breakwater is indicated in Figure 13.6.1.

(2) New Berths for Bulk and Container and General Cargoes

The following new berths are planned in the Master Plan;

Usage	Length	Water Depth	Design Vessel Size
New Bulk Berths	520 m	-13.0 m	40,000 DWT
New Container/Berth	500 m	-12.0 m	30,000/28,000 DWT

(a) Berth Crown Height

New bulk berths are located outside the existing port basin whilst new container/Ro-Ro berth is at inner harbor where well sheltered by the existing breakwaters. Generally, berth crown height is determined from the following recommended clearance above MHWS;

	Tidal Range 3.0 m or more	Tidal Range less than 3.0 m
Water Depth 4.5 m or more	0.5 ~ 1.5 m	1.0 ~ 2.0 m
Water Depth less than 4.5 m	0.3 ~ 1.0 m	0.5 ~ 1.5 m

Source: Technical Standards for Port and Harbor Facilities in Japan

Taking the above recommendation and site conditions of each berth location, the following berth crown heights are recommended;

- New Bulk Berths : +3.50 As located outer area of the existing port basin where exposed to higher waves
- New Container/Berths : +3.00 Same elevation with the existing main berths

(b) Alternative Structural Types for New Berths

The following alternative types have been examined to determine a recommendable structural type for the new berths.

- Alt. a : Concrete block type
- Alt. b : Concrete caisson type
- Alt. c : Steel pipe pile type

The examination results are indicated in Table 13.6.7 and Concrete Caisson type structure is recommended from the comparison results.

(3) Main wharf Improvement

In the Master Plan, it is proposed to improve the existing main wharf (Berths No. 1 to No. 6; total length 900 m) by deepening the wharf front water depth up to –12.0m below C.D.

The exiting structural designs are concrete block type (Berth No. 4, 5 & 6), and pipe supported open deck type (Berth No. 1, 2 &3).

A several options may be possible to deepen the front water depth of the existing wharf ranging from a just deepening of the water depth by seabed excavation with extended wharf coping concrete to a provision of almost new wharf structure.

Due to, however uncertainty of the existing wharf capacity on stability against the increased external forces by calling ships and deepened water depth, the following structures are considered and examined.

- Alt. a : Concrete block wall structure
- Alt. b : Steel pipe pile structure

The examination results are indicated in Table 13.6.8 and a concrete block type structure is recommended.

(4) Other Facilities

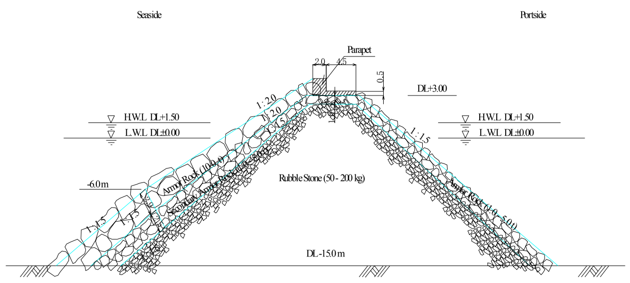
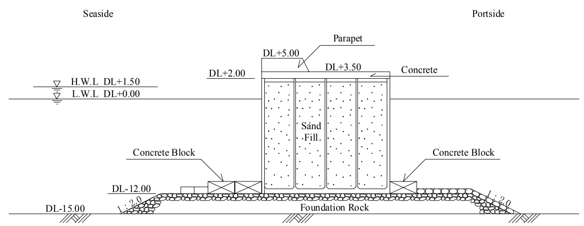
(a) Revetment

Rubble stone revetment is considered for all the revetment works proposed in the Master Plan as rock materials are available locally and are generally economical.

(b) Yard Paving

In Takoradi Port, most of the pavings for yards and roads including wharf aprons are made with concrete blocks. Taking this situation and relatively easy maintenance into account, concrete block paving is adopted.

Table 13.6.6 Comparison of Breakwater Alternatives

Items	Alt. a Rubble Mound Type	Alt. b. Concrete Caisson Type
1. Examination Conditions - Applied Design Wave: $H_{1/3}$ 4.00 m $T_{1/3}$ 9 sec - Design Water Depth: -15.0 m - Subsoil Condition: Rock (20~50 Mpa)		
2. Construction Aspects - Construction Equipment	- Floating crane (50~70 t) - Gutt barges for rubble mound - Tug boat / Anchor boat	- Floating dock (5,000~6,000 DWT) for caisson fabrication - Tug boats for towing / Anchor boat - Gutt barge for rubble foundation - Sand pump barge
- Features	- Locally available material can be used. - Similar structural type with the existing breakwater, thus relatively easy. - Max. Rock size will be limited (abut. 10 t/pc) - Production capacity of rock be checked - If water depth is increased, the required rock volume increases sharply, thus environmental issue occurs.	- A calm and deep water area is required for mooring Floating dock(s). - When construction scale is large, very effective and economical, but if Q'ty is small it takes longer period and not so economical.
3. Cost Index	100	100
Evaluation	Recommended	-

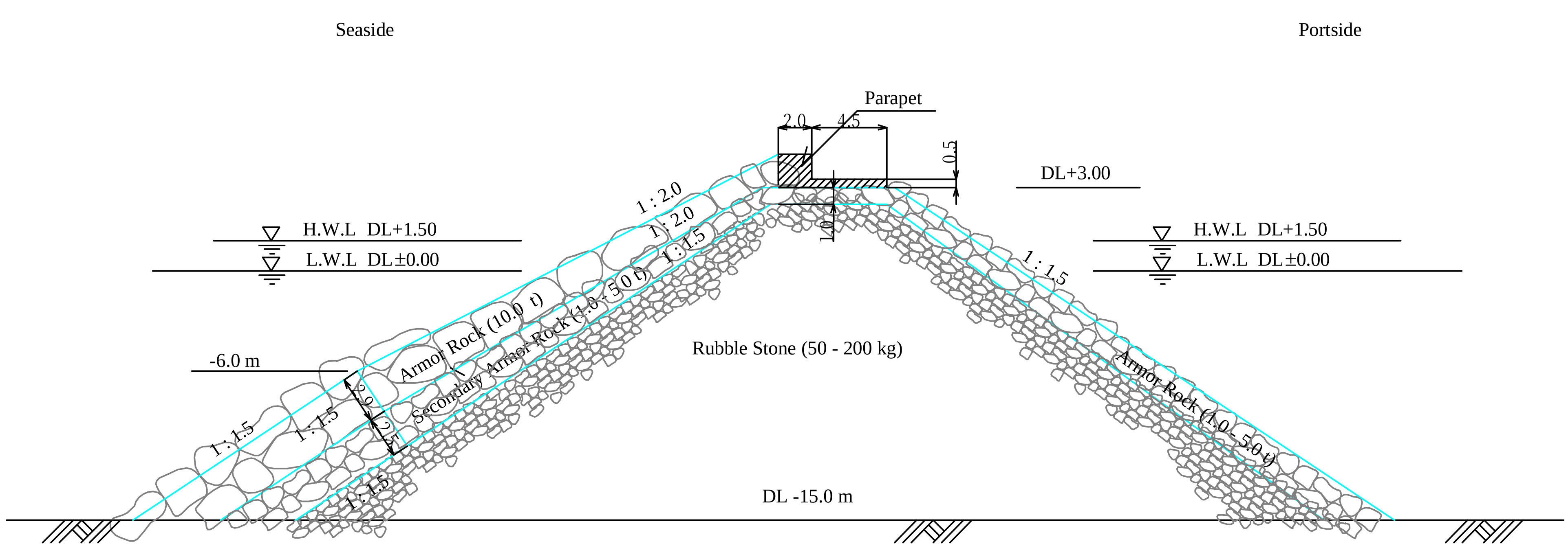
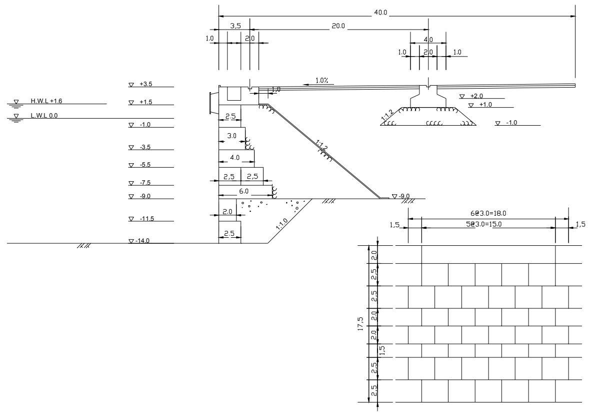
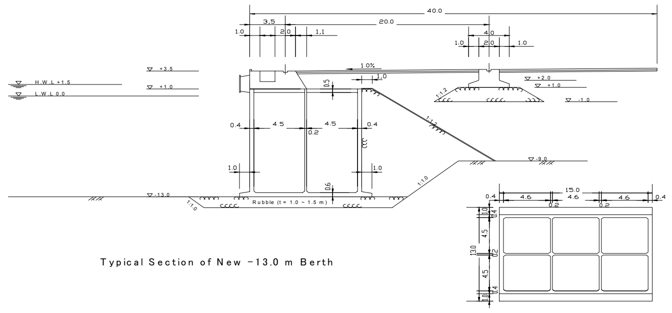
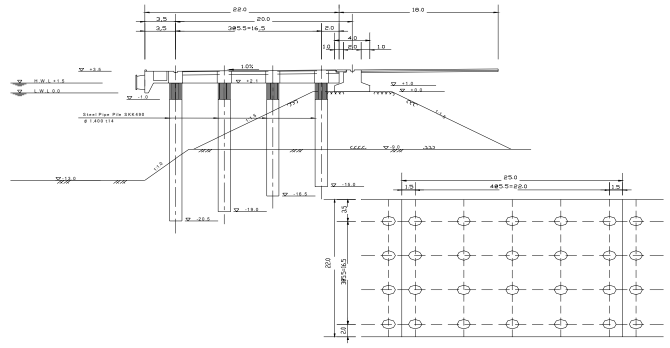


Figure 13.6.1 Typical Section of Breakwater (Rubble Mound Type)

Table 13.6.7 Comparison of New Berths Alternatives

Items	Alt. a. Concrete Block Type	Alt. b. Concrete Caisson Type	Alt. c. Steel Pipe Pile Type
1. Examination Conditions - Wharf deck elevation: +3.50 m - Design Water Depth: -13.0 m - Design Max. Vessel: 40,000 DWT · Tractive force: 2,000 kN · Crane load: 400 kN/wheel - Seismic Force Coefficient: 0.15			
2. Construction Aspects - Construction Equipment	- Floating crane (100-150 t) - Mobile cranes (70-100 t) - Trailer for transportation - Gutt-barge	- Floating dock(s) 5,000~6,000 DWT - Tug boat / Anchor boat - Gutt-barge for Foundation - Floating crane (50-100 t)	- Pile driving barge and hammer - Tug boat / Anchor boat - Boring machine with stage - Crane barge or mobile crane - Flat barge (300-500 t)
- Features	- Locally available material can be used. - Large yard for block fabrication is required - A quite long construction period is required to fabricate a huge number of blocks. - This type is normally not applied for deep water wharves (over –12.0 m).	- Almost locally available material can be used. - For effective construction well-skilled techniques are required for caisson fabrication and installation. - Construction period is shorter than concrete block type	- Steel pipe piles be imported - Piling work is fast, but pre-drilling is required when subsoil condition is rock which requires a longer period. - Corrosion protection is required
3. Cost Index	105	100	112
Evaluation		Recommended	

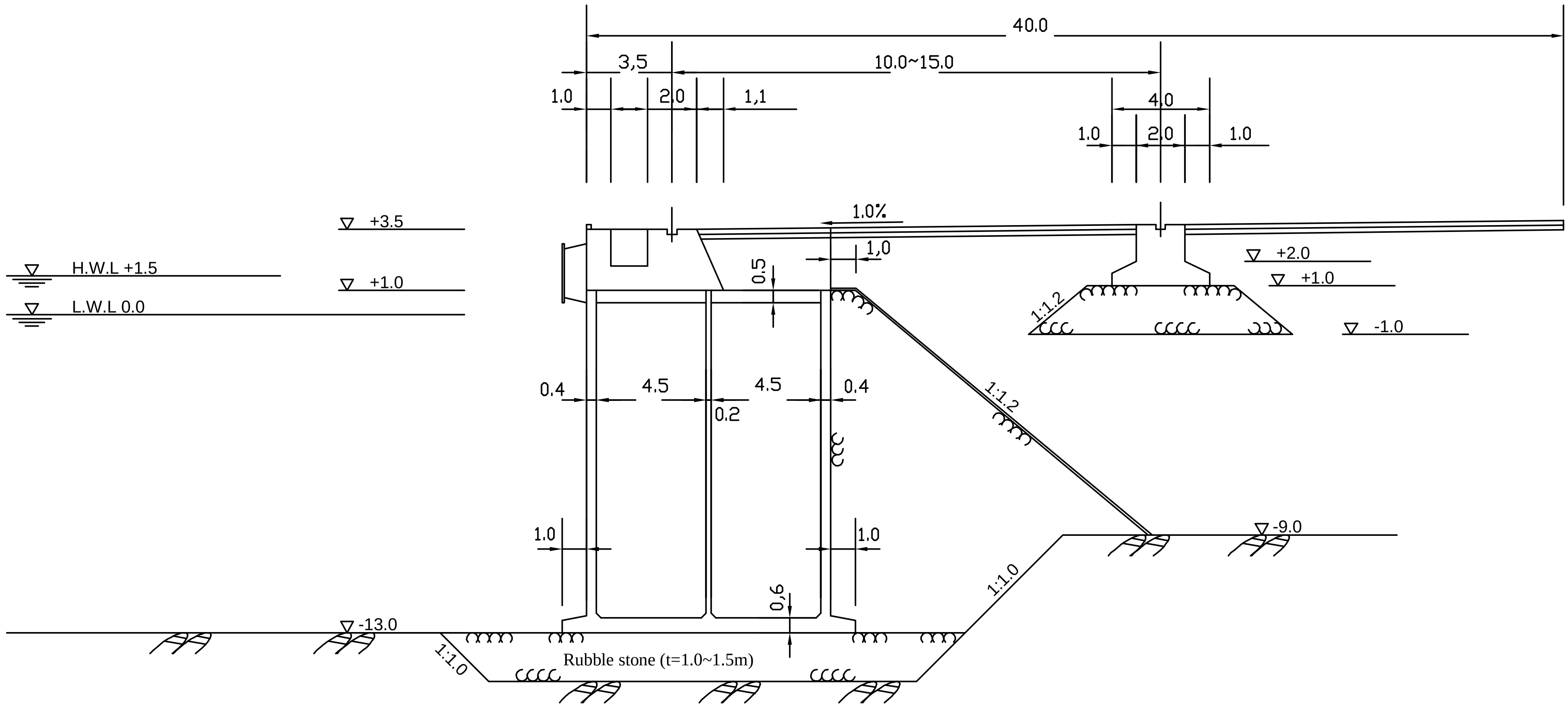


Figure 13.6.2 Typical Section of Concrete Caisson Type New Wharf (-13 m)

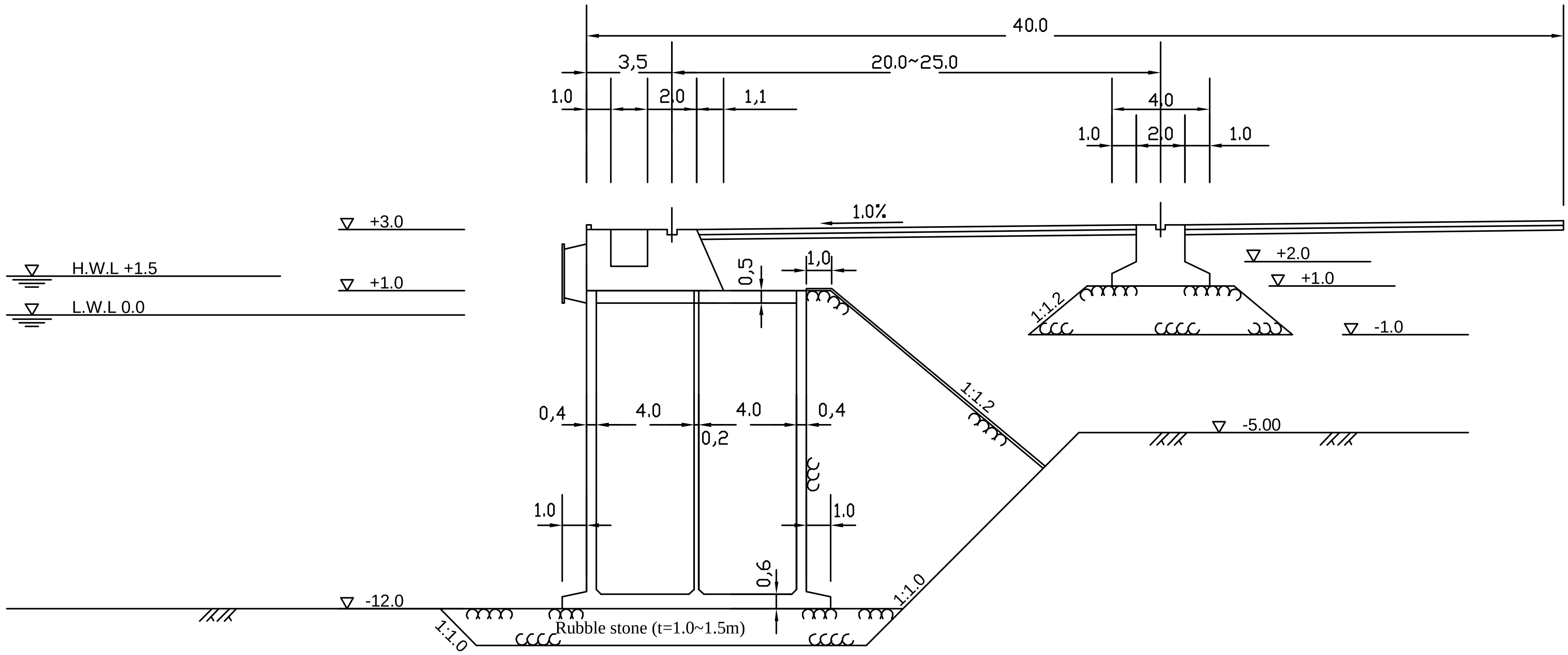
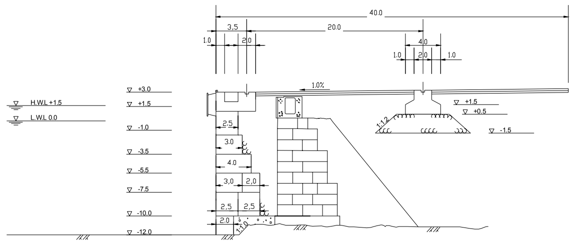
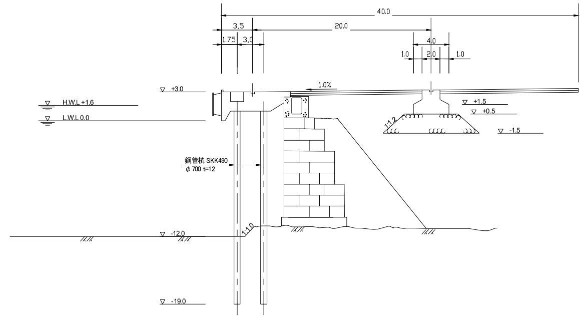


Figure 13.6.3 Typical Section of Concrete Caisson Type New Wharf (-12 m)

Table 13.6.8 Comparison of Exist. Wharf Alternatives

Items	Alt. a Concrete Block Type	Alt. b. Steel Pipe Pile
1. Examination Conditions - Wharf deck elevation: +3.00 m - Design Water Depth: -12.0 m - Design Max. Vassal: 30,000 DWT - Tractive force: 1,500 kN - Crane Load: 400 kN/wheal - Seismic Force Coefficient: 0.15		
2. Construction Aspects - Construction Equipment - Features	- Mobil crane (10~70 t) - Trailers for transportation - Locally available material can be used. - Similar construction is already experienced - Large yard for concrete block fabrication, stockpiling is required. - Generally a quite long construction period is required due to many numbers of blocks required.	- Pile driving barge/Boring machine - Tug boat/Anchor boat - Flat Barge - Steel pipe piles be imported. - Piling work is generally very fast but in this design, drilling by boring machine is required before piling due to rock conditions. - Corrosion protection is required.
3. Cost Index	100	108
Evaluation	Recommended	-

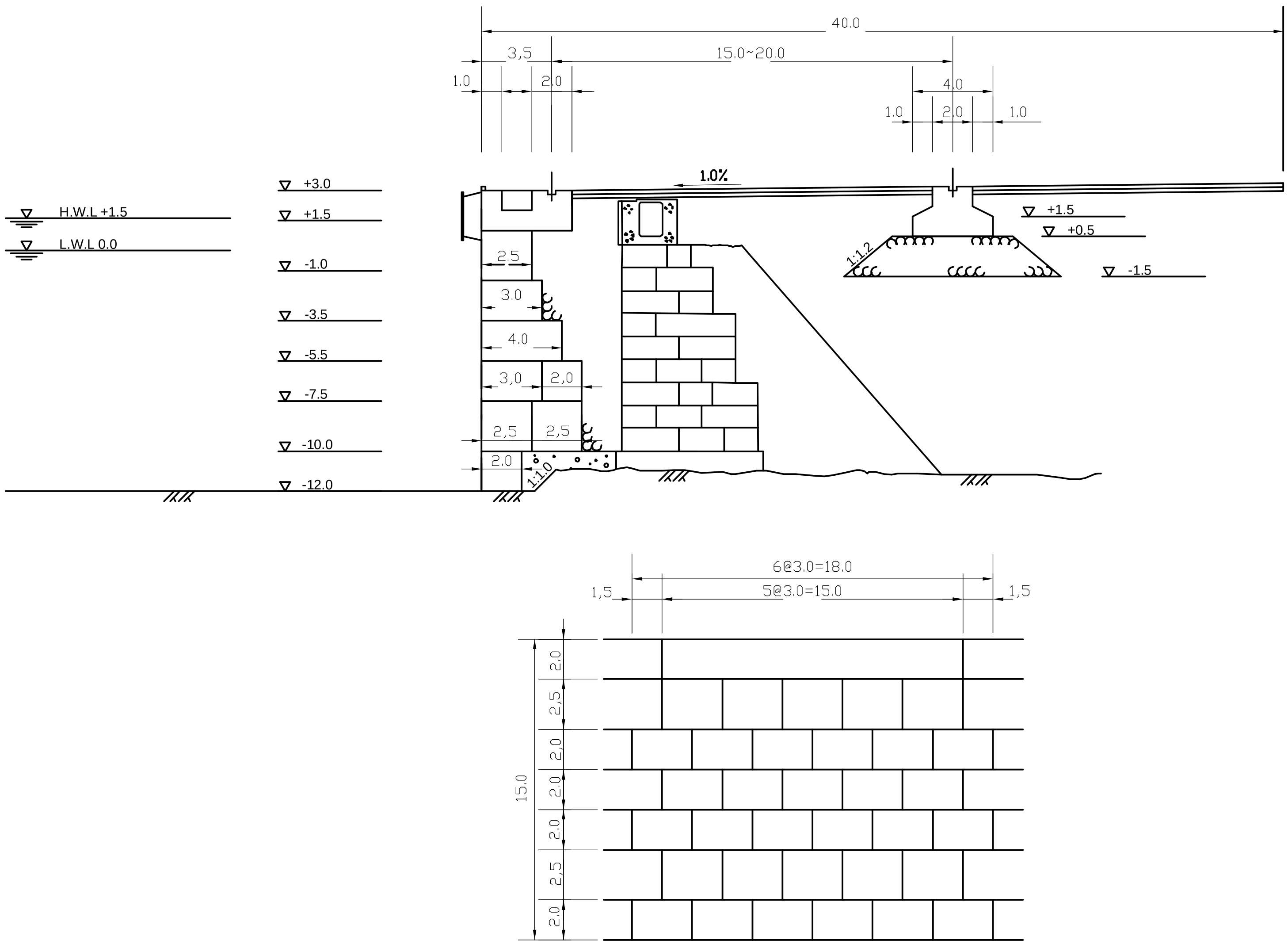
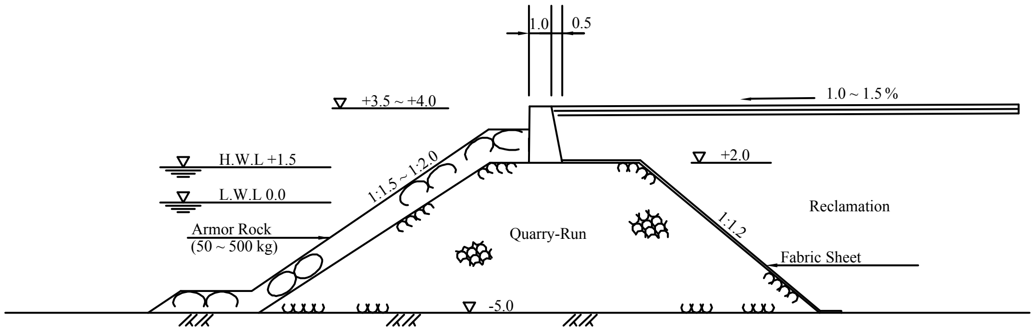
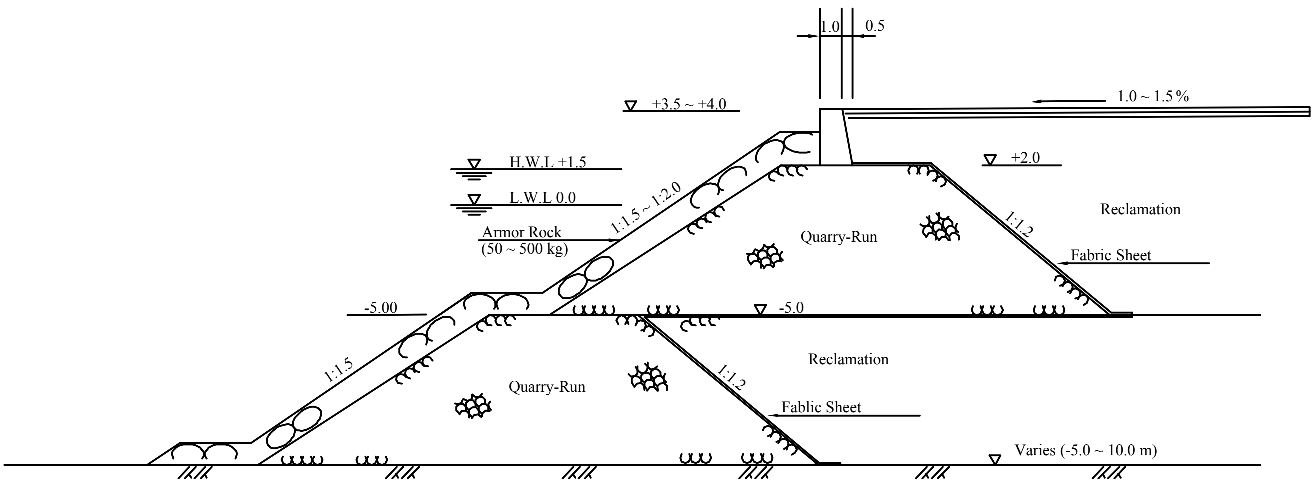


Figure 13.6.4 Typical Section of Exist. Wharf Improvement



Water Depth Less Than -5.0 m



Water Depth -5.0 m ~ -10.0 m

Figure 13.6.5 Typical Sections of Revetment

13.7 Implementation Plan and Preliminary Cost Estimate

13.7.1 Implementation Plan

(1) Construction Component of Master Plan

The following facilities construction is planned in the Master Plan;

Table 13.7.1 Construction Component of Master Plan

Facilities	Description	Quantity
1. Dredging and Reclamation		
1) Dredging	Rock and Soil	1,980,000 m^3
2) Reclamation		4,500,000 m^3
2. Breakwater (-14.0 ~15.0 m)	Rubble Mound	L = 900 m
3. Wharf and Berth		
1) New Bulk Berth (-13.0 m)	Concrete Caisson	L = 520 m
2) New Container/Ro-Ro Berth (-12.0 m)	Concrete Caisson	L = 500 m
3) Exist. Wharf Improvement (-12.0 m)	Concrete Block	L = 900 m
4) New Oil Berth (-11.0 m)	Dolphins	1 berth
5) Small Craft Berth (-5.0 m)	Concrete Block	L = 150 m
4. Revetment		
1) North Revetment	Rubble Mound	L = 480 m
2) East Revetment	Rubble Mound	L = 270 m
5. Paving/Miscellaneous Works	Yard, Road, Drainage	1 set
6. Buildings and Utilities	Gate, Maintenance shop, Electrical/Mechanical Works	1 set

Note: Procurement of Equipment is excluded

(2) General Considerations of Construction Methods and Procedures

The following assumptions and considerations are made for the construction of the required facilities planned in the Master Plan.

(a) Dredging and Reclamation

The dredging volume is in the order of 2.0 million m^3, and the most of the materials to be dredged are rocks represented by sandstone or siltstone. The characteristics of the rocks expressed in terms of compression strength are between 20 MPa and 80 MPa, which is generally regarded as a soft rock. It is however difficult to judge whether dredging can be done without blasting (soft rock) or required (hard rock) since this very depends on the degree of weathering or fracturation and rock types.

In this design an assumption which defines the dredgability of rocks is made as follows;

- Hard rock : blasting is required ; compressive strength not less than 50 MPa

- Soft rock : blasting not required ; compressive strength less than 50 MPa

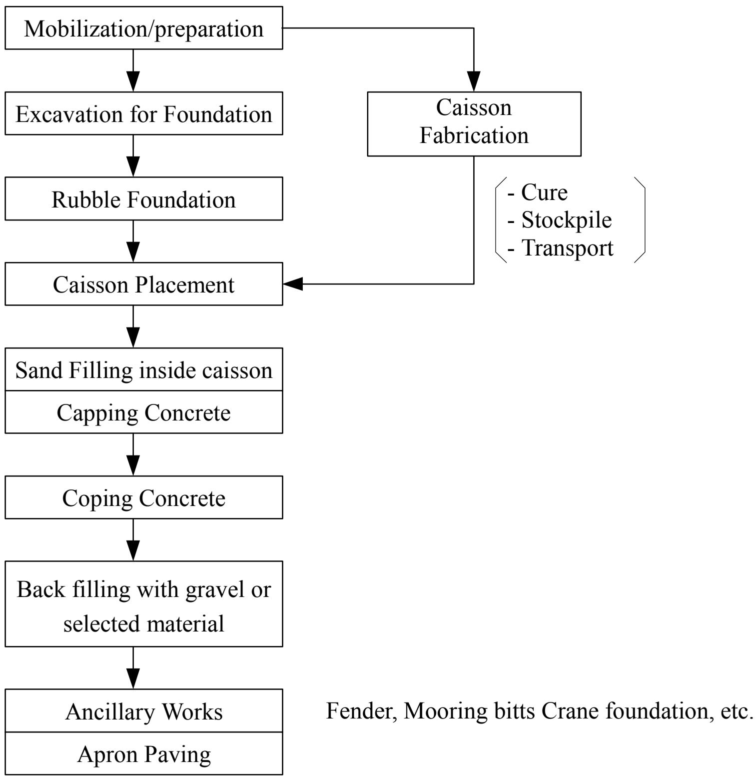
Dredging work is to be made employing cutter suction dredger(s) or grab dredger(s).

The dredged materials are to be used for reclamation work as much as possible, thus the dredged material will be transported and discharged through pipeline or by use of hopper barges.

The reclamation other than utilization of dredged materials is to be made from land side with materials transported from available quarries or other borrow areas in the vicinity of Takoradi.

(b) New Berths Construction

Concrete caisson type structures are selected for the construction of the new berths. The construction of the new berths will be done under the following sequence;



A several fabrication methods for caissons are possibly adopted depending on the site conditions. In this design a floating dock method is considered as recommendable since no appropriate dry dock or slipway facility is available in the vicinity of Takoradi Port.

(c) Existing Wharf Improvement

A concrete block type structure is selected for the improvement of the existing main wharf by deepening the water depth of the wharf. The maximum weight of a unit of concrete blocks is designed to be less than 50 tons which required about 100 ~ 150 tons capacity crane. It is however possible to place the concrete blocks without employing any floating cranes, from this the concrete blocks installation work will be eased and generally more economical.

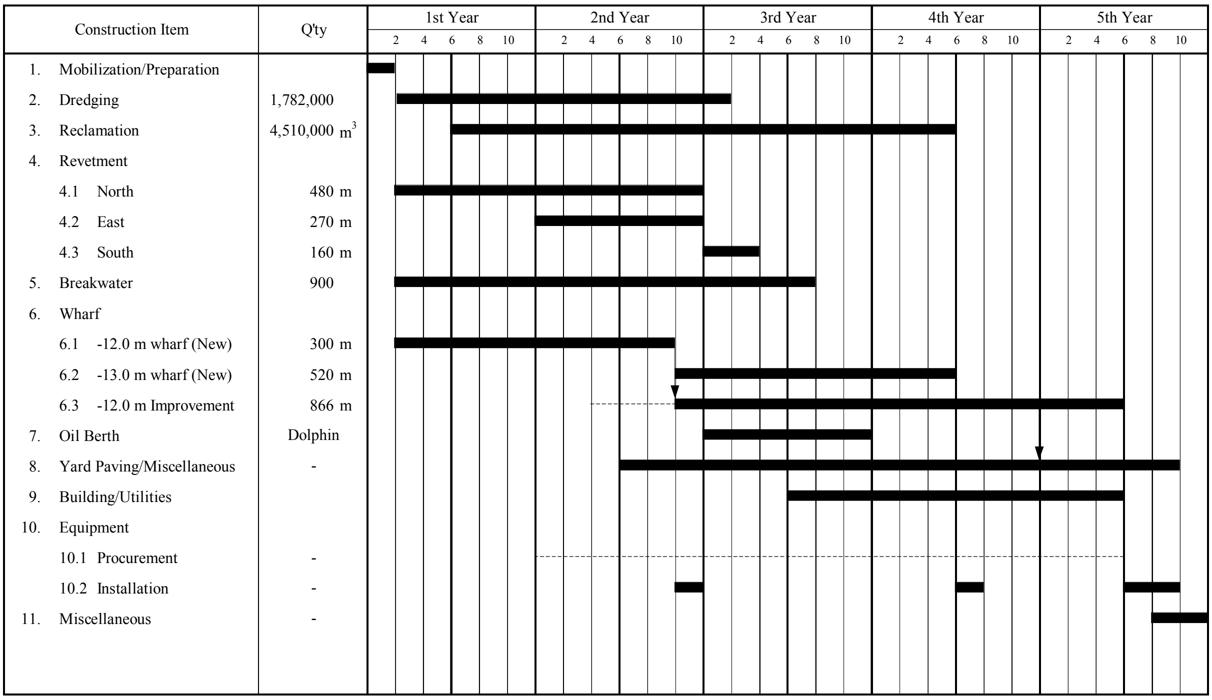
(d) Construction of Revetment

Revetment is designed with a rubble mound type structure. The construction of revetment is required to be proceeded sufficiently ahead of the reclamation work. In order to optimize the required construction time of revetment it is necessary to work from bothsides (i.e. landside and seaside) using dump trucks and gutt barges respectively.

(3) Construction Duration

At least 5 years will be necessary for the construction of the facilities required under the Master Plan when to be carried out in one (1) construction package (as shown in Figure 13.7.1).

Figure 13.7.1 Implementation Plan for Takoradi Port (Master Plan)



13.7.2. Preliminary Cost Estimate

(1) Conditions for Cost Estimate

- The cost estimates are based on the recommended/selected designs of the required facilities/equipment and the assumed construction methods described in the previous sub-sections.

- Implementation period is 5 years.

- Construction/procurement costs are expressed in terms of U.S. dollars and include direct/indirect costs.

- Exchange rates used are; 1 U.S.D = 6,700 Cedis

- Costs for land acquisitions or any compensations are not considered.

- No price escalation is considered.

- V.A.T. which may be imposed on the contracts is excluded.

- The following physical contingency rates are applied;

For Civil/Building Construction	:	8 %
For procurement of equipments	:	4 %

(2) Estimated Implementation Costs of the Master Plan

The total cost required for the implementation of the Master Plan is estimated as approximately U.S. $ 250 Million.

The breakdown of the implementation cost is indicated in Table 13.7.2.

Table 13.7.2 Implementation Cost of Master Plan for Takoradi Port

Item	Description			Construction Cost
	Type/Material	Unit	Quantity	(USD)
1. Civil & Building Works				
1.1 Dredging and Reclamation				
・Dredging work	Rock/Soil	m^3	1,980,000	49,509,000
・Reclamation work		m^3	4,500,000	25,979,000
1.2 Breakwater				
・Breakwater extension(-14.0m)	Rubble mound	m	900	26,550,000
1.3 Wharf & Berth				
・-12m New Container/Berth	R.C. Caisson	m	500	15,800,000
・-13m New Bulk Berth	R.C. Caisson	m	520	17,784,000
・Exist. Berth Improvement (-12m)	Concrete block	m	900	19,800,000
・New Oil Berth	Dolphin	L.S	1	6,000,000
・Small Craft Berth	Concrete block	m	150	1,500,000
1.4 Revetment				
・North revetment	Rubble mound	m	480	4,800,000
・East revetment	Rubble mound	m	270	4,860,000
1.5 Paving & Miscellaneous works		L.S	1	12,500,000
1.6 Buildings & Utilities Works		L.S	1	5,200,000
Sub-total				**190,282,000**
2. Equipment				
2.1 Cargo Handling Equipment		L.S	1	31,000,000
2.2 Other Equipment		L.S	1	2,300,000
Sub-total				**33,300,000**
Total				**223,582,000**
3. Phisical Contingency	8% of 1,4% of 2	L.S	1	16,554,560
4. Engineering Cost	5% of Item 1	L.S	1	9,514,100
Grand Total				**249,650,660**

13.8 Initial Environmental Examination

13.8.1 Background

The steadily growing economy of Ghana over the past two decades has resulted in the rapid increase in import/export shipping load, while the existing ports are struggling in handling the load efficiently. The Ghanaian government under the Ghana Vision 2020 program and Port Development Policy, intends on making Ghana Sea Ports the gateway of Western Africa by modifying the outdated sea ports into more advanced and efficient facilities.

13.8.2 Location and Description of Takoradi Port

Takoradi Port is located about 250km west of Accra, adjacent to a residential area. The port is the second largest in Ghana, mainly functioning as an export port. It is divided into 2 harbour areas, an inner and an outer harbour. The inner harbour is protected from waves by 2 breakwaters, main and lee breakwaters, which enclose an area of approximately 220 acres. There are total of 9 berths with 6 berths located along the lee breakwater (main wharf) and the other 3 berths are located on the outer harbour. Water depth around the main wharf ranges between 8 to 9.5m. To maintain water depth, dredging was last carried out in 1992. The water depth is, however, gradually decreasing, due to siltation especially around the inmost part of the harbour.

13.8.3 Description of the Proposed Master Plan

- Expansion of port area to achieve more efficient cargo handling, through land reclamation and reconstruction of port structure.
- Construction of new berths for handling export products of manganese, bauxite, cocoa, timber, oil products, container, wheat and other products. Berth area for mineral products shall be separated from other berths.
- Construction of breakwaters.
- Dredging along berth to secure sufficient water depth for large vessels.
- Reconstruction of access roads to relieve traffic congestion.
- Land clearing to secure space for stock and container yards.

Two alternative project plans have been proposed to satisfy the above objectives. The environmental evaluation was done for both alternatives as stated in Section 13.3.2 (6).

13.8.4 Identification of Potential Environmental Impacts

As a part of the scoping process, key issues of pollution, social and biophysical environmental concerns in respect of the harbour development project in Takoradi have been identified. Based on the Master Plan of Takoradi Port, 14 environmental factors were identified for the EIA. Environmental factors with the ratings A, B or C in Table 13.8.1 should be subject to the EIA.

Table 13.8.1 Scoping Checklist

Environmental factors		Rating	Justification
Pollution	Air quality	B	Increase in numbers of calling ships and vehicle traffic.
	Water quality	B	Dredging, landfill, breakwater, increase in port activity
	Bottom sediment quality	B	Dredging, landfill, stagnation of water in the port
	Noise/vibration	B	Increase in vehicle traffic, port activity
	Odor	B	Smell from commodities
	Land subsidence	D	Stable substrate (bed rock)
Biophysical environment	Topography, geology, soils	D	No important topography and geology
	Erosion	B	Active littoral drift at present
	Groundwater	D	No influence to the groundwater
	Lake/River flow	D	No lakes or rivers in the surrounding vicinity
	Coast/sea area	D	No important coastline
	Flora/fauna	B	Impacts on the aquatic ecosystem
	Landscape	D	No scenic value due to the existing port structure
Social environment	Economic activities	B	Increase in revenue of local community and employment opportunity
	Resettlement	C	Possible minor relocation of residential area and factories located near the port
	Infrastructure	C	Upgrade of infrastructure is expected accompanied with port expansion
	Cultural assets	D	No significant cultural assets in and around the port area
	Fisheries	B	Minor extinction of fishing ground for local fisherman
	Land use	C	Minor change expected
	Natural disaster	D	No influence to the occurrence of natural disaster
	Waste	B	Increase in calling ships and port activity
	Public health and safety	B	Possible traffic accidents

A Significant potential impact

B Potential impact of less significance

C Undecided (Possible impact in the future)

D No potential impact

The above scoping list can apply for both Master Plan and Short-term Plan because both plans have the same project components, though the scale of the Short-term Plan is smaller than that of the Master Plan. Based on the table above, TOR for EIA was prepared and attached to the Appendix A.

13.9 Preliminary Economic Analysis

13.9.1 Methodology

(1) Purpose

The purpose of the preliminary economic analysis is to appraise the economic feasibility of the master plan for the study ports before a feasibility study on the short-term plan can proceed. The preliminary economic evaluation of a project should show whether the project is justifiable from the viewpoint of the national economy by assessing its contribution to the national economy.

(2) Methodology

An economic analysis was carried out applying the following method. Master plan for Takoradi Port was defined, and it was compared to the "Without" case. All the benefits and costs accruing from the difference between "With" and "Without" cases were calculated in market prices. Here, the economic internal return (EIRR) based on a cost-benefit analysis was used to appraise the feasibility of the project.

13.9.2 Prerequisites of Analysis

(1) Base Year

The "Base Year" here means the standard year in the estimation of costs and benefits. Taking into consideration the base year in cost estimation of construction, 2001 is set as the base year for this study.

(2) Project Life

Taking into consideration the depreciation period of the main facilities of 30 years and the construction period of 5 years, the period of calculation (project life) in the economic analysis is assumed to be 35 years from the beginning of construction.

(3) Foreign Exchange Rate

The exchange rate adopted for this analysis is US$ 1.00 = 6,700 Cedi, the same rate as used in the cost estimation.

(4) "With" Case

In an economic analysis, benefits are mainly brought about by improvements and expansions in capacity. Therefore, the "With" case scenario includes all improvements in productivity and all expansions of port facilities for the master plan.

(5) "Without" Case

A cost-benefit analysis is conducted on the difference between the "With" and "Without" investment cases. In this study, the following conditions are adopted as the "Without" case.

1) No investment is made for the port.

2) Berthing facility use models are made based on the present condition. (Table 13.9.1) Model-0 is the prototype model assuming that all the berthing facilities are available to any calling vessels. Model-1 could be applicable to the master plan.

3) In the model-1, berthing facilities are divided into the 5 groups. Berthing time and waiting time are estimated by the group.

4) As for the container cargo, ships' waiting time is set within about three hours, because container ships should not wait long time due to the competition with the neighboring major ports. The overflowed container cargoes are assumed to be handled in a foreign port and transported by land between Takoradi Port and a foreign port.

5) As for the other cargoes, the upper limit of berth occupancy ratio is assumed to be 0.82. The overflowed dry bulk cargoes are to be handled in a foreign port and carried by land between Takoradi Port and a foreign port.

6) The distribution of ships and the working efficiency of cargo handling are the same as that in the year 2000. (Table 13.9.2)

Table 13.9.2 Ave. Cargo Volume and Time at Berth by Ship Type in Both Cases
Takoradi Port

Berth	Ship Type	W/O.			
		Ave.Ship Size (GRT)	Ave.Ship Size (DWT)	Ave. Cargo Vol/Ship (MT/Ship)	Time at Berth (Hrs/Ship)
Bauxite	BU(B)	20,739	33,000	21,991	86.93
Manganese	BU(M)	20,739	33,000	22,276	86.93
Clinker	BU(C)	20,739	33,000	22,075	86.93
Oil Berth	TK	3,299	6,000	3,067	46.80
	GC	8,315	13,000	937	46.80
	RO	32,859	43,000	3,703	46.80
	CM	13,875	20,000	1,564	46.80
	CO	14,442	20,000	1,628	46.80
	BU	20,739	33,000	2,337	86.93

Berth	Ship Type	W/.			
		Ave.Ship Size (GRT)	Ave.Ship Size (DWT)	Ave. Cargo Vol/Ship (MT/Ship)	Time at Berth (Hrs/Ship)
Bauxite	BU(B)	20,739	33,000	28,588	86.93
Manganese	BU(M)	20,739	33,000	28,959	86.93
Clinker	BU(C)	20,739	33,000	28,698	86.93
Oil Berth	TK	3,299	6,000	3,987	46.80
	GC	8,315	13,000	1,218	46.80
	RO	32,859	43,000	4,814	46.80
	CM	13,875	20,000	2,033	46.80
	CO	14,442	20,000	2,116	46.80
	BU	20,739	33,000	3,038	86.93

BU: DWT/GRT=1.6
TK: DWT/GRT=1.7
Others: DWT/GRT=1.5

Table 13.9.1(1) Facility Use Model (2020) - W/O. (1)

Items	Unit	***Model-0***	***Model-1***				
		All Facilities	Oil Berth	Bauxite	Manganese	Clinker	Other Facilities W2,3,4,5,6
Nos. of Berth	Berth	8	1	1	1	1	4
Nos. of Calling Ships	Ship	2,714	119	68	76	73	2,531
Ave. Ship Size	GRT	18,294	3,299	20,739	20,739	20,739	18,863
Cargo Handling Volume	MT	10,540,230	366,154	1,500,000	1,690,000	1,604,196	5,379,880
Ave. Cargo Volume per Ship	MT/ship	3,884	3,067	21,991	22,276	22,075	2,126
Berthing Time per Ship	Hrs/ship	50.8	46.8	86.9	86.9	86.9	47.5
Berthing Time per Year	Days	5,744	233	247	275	263	5,008
		5,744	6,026				
Berth Occupancy Ratio	-	2.05	0.67	0.71	0.79	0.75	3.58
Waiting Time Factor *($M/E_2/n$)**	-	-	1.48	1.80	2.75	2.20	-
Waiting Time per Year	Days	-	345	445	756	579	-
		-	-				

** Random arrivals, Erlang 2-distributed service time*

Table 13.9.1(2) Facility Use Model (2020) - W/O. (2)

Items	Unit	***Model-0***	***Model-1***				
		All Facilities	Oil Berth**	Bauxite	Manganese	Clinker	Other Facilities W2,3,4,5,6
Nos. of Berth	Berth	8	1	1	1	1	4
Nos. of Calling Ships	Ship	1,085	119	68	76	73	637
Ave. Ship Size	GRT	18,294	3,299	20,739	20,739	20,739	18,866
Cargo Handling Volume	MT	4,213,070	366,154	1,500,000	1,690,000	1,604,196	1,353,479
Ave. Cargo Volume per Ship	MT/ship	3,884	3,067	21,991	22,276	22,075	2,126
Berthing Time per Ship	Hrs/ship	50.8	46.8	86.9	86.9	86.9	47.5
Berthing Time per Year	Days	2,296	233	247	275	263	1,260
		2,296	2,278				
Berth Occupancy Ratio	-	0.82	0.67	0.71	0.79	0.75	0.90
Waiting Time Factor *($M/E_2/n$)**	-	0.27	1.48	1.80	2.75	2.20	1.43
Waiting Time per Year	Days	620	345	445	756	579	1,802
		620	3,926				
Navigation Time per Year	Days	75	8	5	5	5	44
		75	68				
Staying Time at Port per Year	Days	2,991	586	697	1,036	847	3,106
		2,991	6,271				

** Random arrivals, Erlang 2-distributed service time*

Table 13.9.1(3) Facility Use Model (2020) - W/.

Items	Unit	***Model-0***	***Model-1***				
		All Facilities	Oil Berth	Bauxite	Manganese	Clinker	Other Facilities W2,3,4,5,6
Nos. of Berth	Berth	11	1	1	1	1	7
Nos. of Calling Ships	Ship	2,093	92	52	58	56	1,698
Ave. Ship Size	GRT	18,296	3,299	20,739	20,739	20,739	20,303
Cargo Handling Volume	MT	10,540,230	366,154	1,500,000	1,690,000	1,604,196	5,379,880
Ave. Cargo Volume per Ship	MT/ship	5,036	3,987	28,588	28,959	28,698	2,975
Berthing Time per Ship	Hrs/ship	22.6	46.8	86.9	86.9	86.9	16.1
Berthing Time per Year	Days	1,971	179	190	211	202	1,213
		1,971	1,996				
Berth Occupancy Ratio	-	0.51	0.51	0.54	0.60	0.58	0.50
Waiting Time Factor *($M/E_2/n$)**	-	0.00	0.74	0.84	1.08	1.00	0.02
Waiting Time per Year	Days	0	133	160	228	202	24
		0	747				
Navigation Time per Year	Days	146	6	4	4	4	118
		146	136				
Staying Time at Port per Year	Days	2,117	318	353	444	409	1,356
		2,117	2,879				

** Random arrivals, Erlang 2-distributed service time*

13.9.3 Costs of the Projects

The items that should be considered as costs of the projects are construction costs and maintenance costs.

(1) Construction Costs

Construction costs are divided into such categories as civil costs and mechanical costs. Main mechanical costs are purchasing of cargo handling equipment.

(2) Maintenance Costs

The costs of maintaining of port facilities are estimated as a fixed proportion (1 % for structures, 4 % for handling equipment) of the original construction costs excluding the costs of dredging and reclamation costs.

(3) Renewal Investment Costs

The renewal costs for cargo handling equipment after their economic durable periods should be considered. The economic durable periods of equipment are planned as follows.

Table 13.9.3.1 Economic Durable Periods and Costs of Equipment

Equipment	Durable Periods	Costs('000US$)
Gantry Crane, Transfer Crane, Tug Boat	20 Years	33,300

Table 13.9.3.2 Costs of the Projects for Master Plan – Takoradi Port

(Unit: Thousand US$)

Items	Costs
Civil Works	190,282
Equipment	33,300
Total	223,582
Maintenance Costs for Structure	1,072
Maintenance Costs for Equipment	1,332
Total (per year)	2,404

13.9.4 Benefits of the Projects

(1) Benefit Items

As benefits brought about by the master plan of the study port, the following items are identified.

1) Savings in staying costs of ships

2) Savings in water transportation cost by increase of cargo volume per ship

3) Savings in land transportation costs

4) Earnings of foreign currency in handling transshipment cargoes

5) Savings of costs in cargo handling

6) Savings in interest of cargo costs

7) Reduction of cargo damage and accidents at the port

8) Promotion of regional economic development

9) Increase in employment opportunities and incomes

Of the above, items 1) to 4) are considered as tangible benefits in terms of the cost-benefit analysis in this study.

(2) Calculation of Benefits

1) Savings in staying costs of ships

In accordance with the implementation of the projects, the total ship staying time, namely ship waiting time for berthing and ship mooring time for unloading/loading in the port, will be greatly decreased. The reduction of the ship staying time under the "With" case is one of the major benefits of the projects. The benefits that will accrue to Ghana from the projects can be calculated by the following formula.

Savings in ships' staying costs = Difference in staying time between "With" and "Without" cases x Ships' staying cost (unit cost) x Share of benefits accruing to Ghana (= 0.5)

Whereby,

Savings in ships' staying costs = *(6,271-2,879)days x 7,608$/day x 0.5 = 12,903,168US$*

Ship cost is estimated by accumulating the component factors of cost such as depreciation, wages, maintenance cost and so forth. Although it is conceivable to estimate ship cost based on charter rate, this rate has been fluctuating so much according to the market conditions that it is not appropriate for economic price of ship cost.

Table 13.9.4.1-2 shows the ship waiting cost estimated by the Study Team based on the estimation made by some Japanese shipping companies. These data are used as unit cost of ship staying.

Table 13.9.4.1 Ship Cost by Ship Size (General Cargo)

(Unit: US$ per day)

DWT	Tons	Navigation	Anchorage	Knot
5,000	4,500	7,442	6,067	13.0
8,000	7,200	7,883	6,533	13.0
10,000	9,000	8,100	6,775	13.0
20,000	18,000	8,925	7,608	13.0
30,000	27,000	9,550	8,183	13.0

Table 13.9.4.2 Ship Cost by Ship Size (Container Cargo)

(Unit: US$ per day)

DWT	TEUs	Navigation	Anchorage	Knot
4,500	200	9,042	7,917	12.0
5,900	300	10,800	9,475	13.0
8,800	500	15,008	12,975	15.0
22,000	1,200	29,250	23,433	20.0
35,000	2,000	40,258	32,450	22.0

The savings in staying costs of vessels are primarily realized by shipping companies. Since Ghana has no national shipping company at present, these benefits accrue to other countries. However, some portion of these benefits should be returned to Ghana after some time lag. It is possible for Ghana to acquire some of the benefits by, for instance, decreasing freight rates reflecting the reduced incidence of delays at the port. In this Study, it is assumed that 50% of the benefits attributed to foreign ship operators will be transferred to the Ghana economy.

2) Savings in water transportation cost by increase of cargo volume per ship

At present, calling ships at Takoradi Port cannot transport the cargoes fully loaded due to the shallow berths. When the deep-water berths are materialized in the master plan, they can call at Takoradi with full load. Therefore, average cargo volume per ship will increase resulting the lower water transportation cost. These savings are marked in the container and general cargoes.

Savings in water transportation costs = Difference in water transportation costs between "With" and "Without" cases (unit cost) x Total cargo volume x Share of benefits accruing to Ghana (= 0.5)

Whereby,

Savings in water transportation costs $= (67.41 - \frac{67.41}{1.3})\$/MT \times 0.2 \times 6{,}513{,}829MT \times 0.5$

$= 10{,}133{,}013 US\ \$$

3) Savings in land transportation costs

In the following two cases, it is assumed that the cargoes will be handled in other foreign ports and then be transported to Ghana by land.

- Handling volume reaches the maximum volume of handling capacity of the port.
- As for the container cargoes excluding transshipment cargoes, ships' waiting time is over three hours.

In accordance with the implementation of the projects, it is not necessary to transport the cargoes by land. The benefit that will accrue to Ghana from the projects can be calculated by the following formula.

Savings in land transportation costs = Difference in handling cargo volume between "With" and "Without" cases x Land transportation cost (unit cost)

Whereby,

Savings in land transportation costs =(*10,540,230-6,513,829-31,909*)MT x 9.14US$/MT*
*= 36,509,657 $ * Transit cargo (See, Table 20.2.2(1))*

4) Earnings of foreign currency in handling transshipment cargoes

In "Without" case, transshipment cargoes will be handled in the competitive foreign ports due to the lack of sufficient facilities and the increase of waiting time. The benefit that will accrue to Ghana from the projects can be calculated by the following formula.

Earnings of foreign currency = Difference in handling cargo volume between "With" and "Without" cases x Cargo handling fee per TEU

Whereby,

Earnings of foreign currency = *1,813TEU* x 127.98$/TEU = 232,028 US$*
** Transit cargo (See, Table 20.2.2(1))*

(3) Calculation Result of Benefits

Benefits of the projects are summarized in the following table.

Table 13.9.4.3 Benefits of the Projects for Master Plan – Takoradi Port
(Unit: thousand US$)

Items	Benefits
Ships' Staying	12,903
Water Transportation	10,133
Land Transportation	36,509
Earnings of Foreign Currency	232
Total	59,777

13.9.5 Evaluation of the Projects

(1) Calculation of the EIRR

The economic internal rate of return (EIRR) based on a cost-benefit analysis is used to appraise the economic feasibility of the project.
The EIRR is the discount rate which makes the costs and benefits of a project during the project life equal. It is calculated by using the following formula.

$$\sum_{i=1}^{n} = \frac{B_i - C_i}{(1+r)^{i-1}} = 0$$

Where, n: Period of economic calculation (project life)
Bi: Benefits in I-th year
Ci: Costs in I-th year
R: Discount rate

The EIRR of the master plan is calculated as 17.8%. The results of calculation are shown in Table 13.9.5.1.

(2) Evaluation

It is generally recognized that the project is feasible if the EIRR exceeds the opportunity cost of capital. Usually, the opportunity cost of capital is considered to range from 8% to 10% according to the degree of development in each country. It is acceptable that a project with an EIRR of more than 8% is economically feasible for infrastructure or social service projects.
As for this project, even though the economic calculation only takes into account the items which are easily quantified, the EIRR exceeds 8%. Therefore, this master plan development project is feasible from the viewpoint of the national economy.

Table 13.9.5.1 Cost/Benefit Analysis of Master Plan for Takoradi Port

Name of Port: :Takoradi
Table ____ (1/1)
Economic Evaluation
(In constant 2000 prices, 1000US$)

Year	Costs			Benefits	Net Benefits
	Investment	O&M	Total	Total	
2015	44,716	-	44,716	-	(44,716)
2016	44,716	-	44,716	-	(44,716)
2017	44,716	-	44,716	-	(44,716)
2018	44,716	-	44,716	-	(44,716)
2019	44,716	-	44,716	-	(44,716)
2020		2,404	2,404	59,777	57,373
2021		2,404	2,404	59,777	57,373
2022		2,404	2,404	59,777	57,373
2023		2,404	2,404	59,777	57,373
2024		2,404	2,404	59,777	57,373
2025		2,404	2,404	59,777	57,373
2026		2,404	2,404	59,777	57,373
2027		2,404	2,404	59,777	57,373
2028		2,404	2,404	59,777	57,373
2029		2,404	2,404	59,777	57,373
2030		2,404	2,404	59,777	57,373
2031		2,404	2,404	59,777	57,373
2032		2,404	2,404	59,777	57,373
2033		2,404	2,404	59,777	57,373
2034		2,404	2,404	59,777	57,373
2035	16,650	2,404	19,054	59,777	40,723
2036	16,650	2,404	19,054	59,777	40,723
2037		2,404	2,404	59,777	57,373
2038		2,404	2,404	59,777	57,373
2039		2,404	2,404	59,777	57,373
2040		2,404	2,404	59,777	57,373
2041		2,404	2,404	59,777	57,373
2042		2,404	2,404	59,777	57,373
2043		2,404	2,404	59,777	57,373
2044		2,404	2,404	59,777	57,373
2045		2,404	2,404	59,777	57,373
2046		2,404	2,404	59,777	57,373
2047		2,404	2,404	59,777	57,373
2048		2,404	2,404	59,777	57,373
2049		2,404	2,404	59,777	57,373
Total	**256,880**	**72,120**	**329,000**	**1,793,310**	**1,464,310**
Economic Internal Rate of Return (EIRR):					**17.8%**

Sensitivity Analysis

	EIRR	Increase in Investment Cost		
	17.8%	0%	10%	20%
Decrease Benefits	0%	17.8%	16.5%	15.4%
	10%	16.4%	15.1%	14.0%
	20%	14.9%	13.7%	12.6%