The People's Republic of Bangladesh
Ministry of Power, Energy & Mineral Resources
The Coal Power Generation Company Bangladesh Limited

Preparatory Survey Report for the Construction and Operation of Imported Coal Transshipment Terminal Project in Matarbari Area in the People's Republic of Bangladesh (PPP infrastructure project)

Final Report (Public Version)

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Japan International Cooperation Agency

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Abbreviation

ADB	Asian Development Bank
BBS	Bangladesh Bureau of Statistics
BERC	Bangladesh Energy Regulatory Commission
BFD	Bangladesh Forest Department
BNBC	Bangladesh National Building Code
BOT	Build-Operate-Transfer
BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
BPDB	Bangladesh Power Development Board
CCEA	Cabinet Committee on Economic Affairs
CFPP	Coal Fired Power Plant
COD	Commission Operation Date
CPGCBL	Coal Power Generation Company Bangladesh Limited
CTSA	Coal Transshipment Services Agreement
CTT	Coal Transshipment Terminal
DAM	Department of Agricultural Marketing
DOE	Department of Environment
DOF	Department of Fisheries
DWT	Dead Weight Ton
ECA	Ecologically Critical Area
ECC	Environmental Clearance Certificate
ECR	Environmental Conservation Rules
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environmental Management Plan
EMoP	Environmental Monitoring Plan
EPC	Engineering, Procurement and Construction
FIRR	Financial Internal Rate of Return
GOB	Government of Bangladesh
GRC	Grievance Redress Committee
ICC	International Chamber of Commerce
IEE	Initial Environmental Examination
IFI	International Financial Institutions

IPP	Independent Power Producer
IMF	International Monetary Fund
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JV	Joint Venture
LAO	Land Acquisition Officer
MoPEMR	Ministry of Power, Energy and Mineral Resources
MOU	Memorandum of Understanding
ODA	Official Development Assistance
O/M	Operation and Management
PPP	Public-Private Partnership
PSPGP	Power Generation Policy of Bangladesh
PSIF	Private Sector Investment Finance
PSMP	Power System Master Plan
RAP	Resettlement Action Plan
RFP	Request for Proposal
RFQ	Request for Qualification
RSMC	Regional Specialised Meteorological Centre
SDR	Social Discount Rate
SIAC	Singapore International Arbitration Centre
SPC	Special Purpose Company
TOR	Terms of Reference
UNCTAD	United Nations Conference on Trade and Development
USAID	United States Agency for International Development
USC	Ultra Super Critical
WASA	Water Supply and Sewerage Authority
WB	World Bank

Summary

(Background of the Project)

As Bangladeshi economy grows, its demand for energy has steeply increased. The domestic energy supply in 2013 is about 180% of the supply in 2000. According to the draft of Power System Master Plan 2015 (draft PSMP2015), Bangladeshi economy is estimated to grow at 6.0-6.5% per year toward 2041. To cover this economic growth, the power source needs to be developed progressively. The draft PSMP2015 estimates that the power demand will grow from 15,475 MW in 2015 to 57,000MW in 2041. The draft PSMP2015 also estimates that the total demand for coal in 2041 will be 80,728 thousand ton, of which 97.5% i.e. 79,500 thousand ton will be imported. However, it is difficult to import fuel coal to each coal fired power plant (CFPP) directly by large-scale coal carrier since most of the coastal area of Bangladesh has a shoaling beach. It is also inefficient to transport imported coal by small vessels which can pass through existing channels to each power plant in terms of economy and stable coal supply. Therefore, the construction of a coal transshipment terminal (CTT) that can accommodate large-scale coal carriers is indispensable to the realization of the above-mentioned CFPPs. As the Matarbari area in Cox’s Bazar District in Chittagong Division is the only promising site that has easy access to the deep sea area and has limited adverse impact on the surrounding environment, construction of the CTT with deep sea-port that can accommodate large coal carriers at the Matarbari area and realising the economic and efficient imported coal supply to the CFPPs constructed in the country are considered imperative.

This study aimed to improve the stable supply of imported coal by constructing CTT as a common infrastructure for Bangladesh where many CFPPs are planned to be constructed. This study also aimed to develop the assistance plan assuming the participation of Japanese investor and to develop a project implementation program in which the utilisation of official development assistance (ODA) loan and the Japan International Cooperation Agency (JICA) overseas investment loan was considered. For these aims, this study focused on the following two issues;

(1) To develop the coal logistics system to satisfy the imported coal demand for planned CFPPs

(2) To formulate the CTT plan to secure the returns of the investment from the CTT operation and to make this investment as a meaningful investment.

(Coal Demand)

Annual coal handling volume at CTT was estimated based on the future development plan of CFPPs. The Power System Master Plan 2015 (draft PSMP2015) Study, which is being studied under JICA, estimates the total electric power demand in 2041to be 52,000 MW. According to the draft PSMP2015’s scenario, the proportion is as follows: natural gas: 35%; coal: 40%; oil: 5%, and others (nuclear: 8% and imported power: 12%). The draft PSMP2015 estimates that the total demand for coal in 2041 will be 80,728 thousand ton, of which 97.5% i.e. 79,500,000 t will be imported. It also

estimates that 86.5% of coal will be used for the power sector. The coal demand was also considered based on the draft PSMP 2015.

The maximum annual coal handling volume was determined based on the planned CFPPs using imported coal for which the Bangladeshi government has signed a memorandum of understanding (MOU). Development of CFPPs using imported coal started in 2012 with a capacity of 1,320 MW and consuming 3.82 Mt of coal per year. The capacity will reach 23,691 MW with 68.7 Mt of coal per year in 2041. However, it is difficult to make a precise estimate of the commencement date of operation. Therefore, phased development plan of CTT was recommended to have enough flexibility, i.e., to expand the CTT when the power generation program develops and the realistic commission operation date (COD) becomes certain.

As the first phase of the CTT will commence operation in 2025, the object of the 1st Phase will include these power stations that will commence operation by 2029 and use the CTT. The total generating capacity of these units will be 3,800 MW. The following 2nd Phase, which is planned to commence operation in 2030, targets those plants with COD later than 2030, and the total generating capacity will be 5,240 MW.

(Coal Logistics)

It was assumed to procure coal from Australia and Indonesia in the CTT project, although procurement plan of coal for CFPPs has not been decided and loading ports have not been specified yet. Australia and Indonesia are main supplying countries of coal and the distances from Australia and Indonesia are more efficient than from other coal producing countries. Transit time from Australian coal loading ports to Matarbari is about 19 days, and transit time from Indonesian loading ports is about eight days.

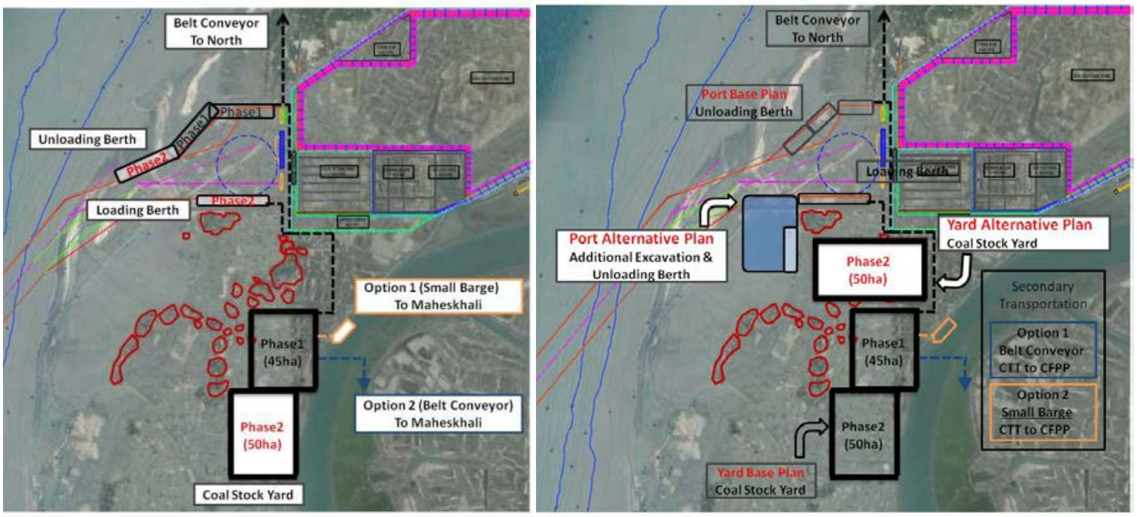
From the view-point of loading operation and chartering vessels, vessel size for imported coal is Panamax size which is the acceptable maximum size for channel of Matarbari CFPP. Considering the current conditions of canal, secondary transportation through conveyor is used in the 1st Phase, and secondary transport vessels of 5,000 DWT are considered in the 2nd Phase.

(CTT Layout Plan)

The capability of expansion, impacts on the surrounding environment, construction cost, construction work impact and others were considered for the determination of the layout of CTT. The CTT facilities include coal unloading berth, coal loading berth, expansion of inner harbour for Matarbari CFPP, coal stock yard and belt conveyor from unloading berth to coal stockyard. Secondary transportation facilities to the surrounding CFPPs are not within the scope of CTT but under the CFPPs.

The layout plan in the 1st Phase was mainly considered to minimize the effect to the surrounding society and environment, since early start of operation is required in Bangladesh.

There are several options for the determination of the layout plan in the 2nd Phase depending on the existence or non-existence of resettlement before the implementation of the 2nd Phase. In this study, the case where resettlement has not been conducted until the start of the 2nd Phase study is employed as the base case. If resettlement has been conducted based on other applicable studies, alternative plan is also considered.



Source：JICA Study Team

Figure CTT Layout Plan (Left：Base Plan, Right：Alternative Plan)

(Port Plan)

The above mentioned coal import ships and secondary transport ships were considered for the determination of the port plan. Survey results of existing facilities and dimensions of coal transport ships were considered for the determination of the capacity of the coal unloader and two continuous coal unloader of 2,500 t/h per berth with unloading efficiency of 75% were selected. Based on a similar study, one loader of 1,500 t/h per berth with loading efficiency of 90% was selected. Considering the existing CTT, annual operation days of 350 days and working hours of 18 hours were considered.

The recommended berth occupancy ratios shown in “Port Development – A handbook for planner in developing countries” issued by the United Nations Conference on Trade and Development (UNCTAD) as well as the above mentioned conditions were considered for the determination of the required number of coal unloading berths. Average waiting time of vessels computed by queuing theory and other factors were also referred for the determination of the required number of unloading berths.

(Terminal Plan)

The outdoor coal storage was proposed as the coal storage type in this study from the perspective of safety control against spontaneous combustion in handling sub-bituminous coal because it may cause serious damage by fire accident unless appropriate measures against spontaneous combustion are provided. The outdoor coal storage such as that involving stockpile, stackers, and reclaimers is used for piling and delivering the coal because of its advantage in terms of expenses and handling operation convenience, including its measure against spontaneous combustion. However, it requires appropriate coal dust control such as installation of dust-control fence and sprinkling of water because it may affect the surrounding environment.

For general operation in the CFPP, 1 to 2 month's coal stock is required in the CFPP stockyard. In this study, one month stock is necessary to operate stably. The effect of rough wave conditions during the monsoon season on berth working ratio was considered in determining the necessary coal stockyard area for the case of offshore unloading berths without breakwater.

(Outline of Execution Plan and Schedule for Construction Works)

The outline of execution plan for the construction works was prepared based on the proposed phased development plan of this project. Outline of construction schedule was prepared based on the conceptual design for each development phase as well as the above mentioned execution plan. Tentative overall project schedule was also presented based on the phased development plan and outline of execution plan and schedule of construction works.

This information includes trade secrets.

Source：JICA Study Team

Figure Tentative Overall Project Schedule (Original Plan)

The possibility of earlier opening of CTT was studied according to the request of the Coal Power Generation Company Bangladesh Limited (CPGCBL). The recommended countermeasures were mentioned for the construction stage and preparation stage. When all the countermeasures are applied, it is possible to open half of the area of the CTT after 36 months from the commencement of construction, which is 12 months earlier than the original plan. Construction schedules and the project schedule as a result of the study shown in this section are the earliest schedules and the actual required time of opening CTT is not considered. Reasonable time of opening and the possibility of the recommended countermeasures shall be studied in the next stage.

This information includes trade secrets.

Source：JICA Study Team

Figure Tentative Overall Project Schedule (Shorter Plan)

(Terminal Management)

In order to make the project successful, it is important to determine the project risk assignment between the government and the private sector. For this reason, the application of Japanese ODA, which the government manages, is expected for the lower part of the infrastructure for unloading berth, loading berth, and coal stockyard, and for the CTT project including the investment for the upper part of the infrastructure, the private sector consisting of both Japanese and Bangladeshi firms shall set up a special purpose company (SPC) and invest and operate the terminal. For the performance of each work, it was expected that reliable companies will be selected for each work and the work will be performed under subcontract arrangement. For the organisation of SPC, the following scheme was investigated.

This information includes trade secrets.

Source: JICA Study Team

Figure Relation of SPC and other related organization and firms

The running cost of CTT operation was obtained from personnel expenses, utilities expenses, water charge, depreciation cost, maintenance cost of coal handling equipment, insurance cost, land usage fee, maintenance cost for the lower infrastructure and other necessary expenses which were obtained by considering the anticipated project scheme and the features of the organisations and the port and terminal.

(Financial Analysis)

Construction cost, maintenance cost and operation cost for each phase have been obtained and financial and economic analysis has been done. Several general conditions such as application of normal market price at the project site, negligence of price fluctuation and interest of rent money, and inclusion of consultant fee for detailed design and supervision of construction works were applied for obtaining the construction cost. The estimation of terminal operation cost is obtained from above studies. Feasibility is evaluated by calculating terminal handling charge (THC) per tonne which fulfills the equity internal rate of return (IRR) of the special purpose company (SPC) required by the public investor. It is common to calculate the minimum rate of return on a capital investment project (hurdle rate) for investment as “capital cost plus spread between domestic and overseas interest rates”.

The term of the project is from 2021 to 2055, and the financial analysis was considered from the commencement of the construction work. Thirty percent of the total project cost was assumed to be financed by the investors’ equity from both Japan and Bangladesh and the rest of the project cost was assumed as loan under the JICA “Private Sector Investment Finance (PSIF)”.

The THC is assumed to be based on take or pay mechanism, which consists of capacity charge (fixed charge for installed capacity of CFPP) and variable charge. Fluctuation of capacity charge, which includes the cost of compensation for the financing cost, its interest and capital cost including dividend and tax cost, and compensation for the fixed operation and management (O/M) cost such as labour cost and periodic maintenance during the project period, was considered based on the idea that phased development is employed in accordance with the increase of coal demand. The THC is based on the assumption that the capacity charge guarantees the agreed income amount of SPC as long as CTT maintains its performance, which is mutually agreed in advance. In other words, the price in each phase was obtained based on the assumption that the coal demand in each phase will not increase during the project term.

(Economic Analysis)

The “With Project Case”, wherein the CTT project will be conducted, and the “Without Project Case”, in which coals from Indonesia and Australia will be imported and transshipped form large vessels to small barge offshore, and transported up to 5,000 DWT for other CFPPs, were considered in the economic analysis. The benefit is considered as the difference between the total project cost for the “With Project Case” and “Without Project Case”.

An economic internal rate of return (EIRR) of more than 12% was obtained from the economic analysis and this is larger than the social discount rate (SDR) of 12%, which is employed in similar study in Bangladesh indicating that the project will be feasible from the perspective of the national economy.

(Concerned Local Laws and Regulations)

Currently, projects developed jointly by the private and public sector, whether as build-operate-transfer (BOT), build-own-operate (BOO), build-own-operate-transfer (BOOT) or otherwise, are generally subject to Bangladeshi Law. Whilst exemptions may be negotiated with the government on a project by project basis, e.g. with respect to public procurement, transfer restrictions, and foreign exchange rules. there is currently not yet a dedicated legal regime for public-private partnership (PPP) projects.
Based on the indicative time schedule of the project, it is likely that the PPP Law would have been passed by the time the CTT project is being tendered, but it is uncertain to what extent secondary legislation would have been promulgated at that point.

Implementing a large infrastructure project such as the CTT project will involve various kinds of project risks such as country/political risks, natural risks, legal risks and commercial risks. These are the typical types of risks which investors would carefully consider and which should be carefully allocated between the government and the private investor in order to ensure the commercial viability and bankability of the CTT project.

(PPP Project Plan)

The SPC is supposed to be formed through the joint investment of the government entity and private company to fund the construction of the upper infrastructure of the CTT. It was recommended that the SPC, which raises funds, constructs, manages, and operates the upper infrastructure of the CTT, should have an experience of operating and managing the CTT in Bangladesh or some other countries and of procuring and supplying coal domestically and internationally and is a coal user, such as independent power producers (IPPs) operators.

Debt financing under the JICA private sector investment finance (PSIF), which is long term and low interest non-recourse project finance is the most probable option to improve the profitability of the project. Then, SPC will be responsible for its management and operation after completion of the construction.

(Proposed Plan of CTT)

The recommendation plan was proposed for the efficiency of the CTT project. The plan is to manage the coal handling facilities of Matarbari CFPP No.1 and No.2 and the CTT integrally. The Matarbari CFPP No.1 and No.2 plan to construct coal unloading berth and coal stockyard whose capacity has leeway for operation. Therefore, it is possible to make the operation more efficient through the unified management of the CFPP and CTT.

(Environmental and Social Considerations)

The current study was categorised by JICA as category B because the environmental impacts are not significantly critical adverse impacts and they are site specific and mitigable by normal mitigation measures. Considering the case with small-scale resettlement at the planning stage, the study covers the environmental study at the initial environmental examination (IEE) level and the framework of the resettlement action plan (RAP) and the terms of reference (TOR) for the required study such as environmental impact assessment (EIA) and RAP. The environmental study to meet the requirement under the official process for the EIA should be continued by the implementation agency after the current JICA study through the submission of the IEE report and TOR for EIA to obtain the approval of the Department of Environment (DoE).

Chapter 1. Introduction

1.1. Background of the Project

As Bangladeshi economy grows, its demand for energy has steeply increased. The domestic energy supply in 2013 is about 180% of the supply in2000. As a result of development of natural gas fields since 2000 and production of domestic coal since 2005, the domestic energy production also increased considerably. The domestic production is about 190 % of that in 2000. According to the Power System Master Plan (draft PSMP2015), Bangladeshi economy is estimated to grow at 6.0-6.5% per year toward 2041. To cover this economic growth, the power source needs to be developed progressively. The draft PSMP2015 estimates that the power demand will grow from 15,475 MW in 2015 to 57,000MW in 2041.

Bangladesh has mainly depended on thermal power generation using domestic natural gas. As the domestic natural gas production is believed to decrease in the near future and increase of domestic coal production is difficult, Bangladesh has a plan to raise the proportion of thermal power plant using imported liquefied natural gas (LNG) and imported coal. Although the draft PSMP2015 does not show the balance (proportion) of future energy source at this moment, it is estimated that no single energy source will be more than 50% and that coal and natural gas will cover 70%-75% of power source in 2041. Based on this basic principle, many thermal power generation plants are planned by power generation companies under the Ministry of Power, Energy and Mineral Resources (MoPEMR) and independent power producers (IPPs) and some other joint investment plants with other countries. The total electric power generation capacity of 22,260 MW by many coal fired power plants (CFPPs) is planned.

However, it is difficult to import fuel coal to each CFPP directly by large-scale coal carrier, since most of the coastal area of Bangladesh has a shoaling beach. It is also inefficient to transport imported coal by small vessels which can pass through existing channel to each power plant in terms of economy and stable coal supply. Therefore, the construction of a coal transshipment terminal (CTT) that can accommodate large-scale coal carriers is indispensable to the realisation of the abovementioned many CFPPs.

As the Matarbari area in Cox’s Bazar District in the Chittagong Division is the only promising site that has easy access to the deep sea area and has limited adverse impact on the surrounding environment, construction of the CTT with deep seaport that can accommodate the large coal carriers at the Matarbari area and realising the economic and efficient imported coal supply to the CFPPs constructed in the country are considered imperative.

In Japan’s official development assistance (ODA) policy for Bangladesh, “*accelerating sustainable economic growth with equity and bringing people out of poverty towards becoming a middle-income country*” are mentioned as basic principles of the assistance, and “*to increase electricity supply* *through the development of power plants and transmission and distribution grids"* is promoted as one of the priority areas. Actually, Japan has supported the feasibility study (F/S) on the implementation of the Haripur Combined Thermal Power Plant near Dhaka, Bheramara Combined Thermal Power Plant located southwest of Dhaka and Matarbari Coal Power Plant located south of Chittagong and made positive contribution to the elimination of power shortage in Bangladesh. Because the major objective of this project is to supply imported coal efficiently to the CFPP and to contribute to the stable electric power supply in the country, this project corresponds to the Japanese and JICA's assistance policy to the power generation sector in Bangladesh.

The "Policy and Strategy for Public-Private Partnership (PPP), 2010" is an infrastructure-related legislative system in Bangladesh. Related infrastructural fields of coal supply and electric power generation were considered as one of the priority sectors in this legislative system and the CTT project that supplies imported coal to the CFPP is considered to be in line with the basic policy of this legislative system. So far, no port infrastructure project has been undertaken under the PPP scheme; this CTT project would be the first PPP infrastructure project in Bangladesh.

1.2. Objectives of the Study

This study aims to improve the stable supply of imported coal by constructing CTT as a common infrastructure in Bangladesh where many CFPPs are planned to be constructed. This study also aims to develop the assistance plan assuming the participation of Japanese investor and to develop a project implementation program in which the utilisation of ODA loan and JICA's overseas investment loan will be considered. For these aims, this study will focus on the following two issues:

(1) To develop the coal logistics system to satisfy the imported coal demand for the planned CFPPs.

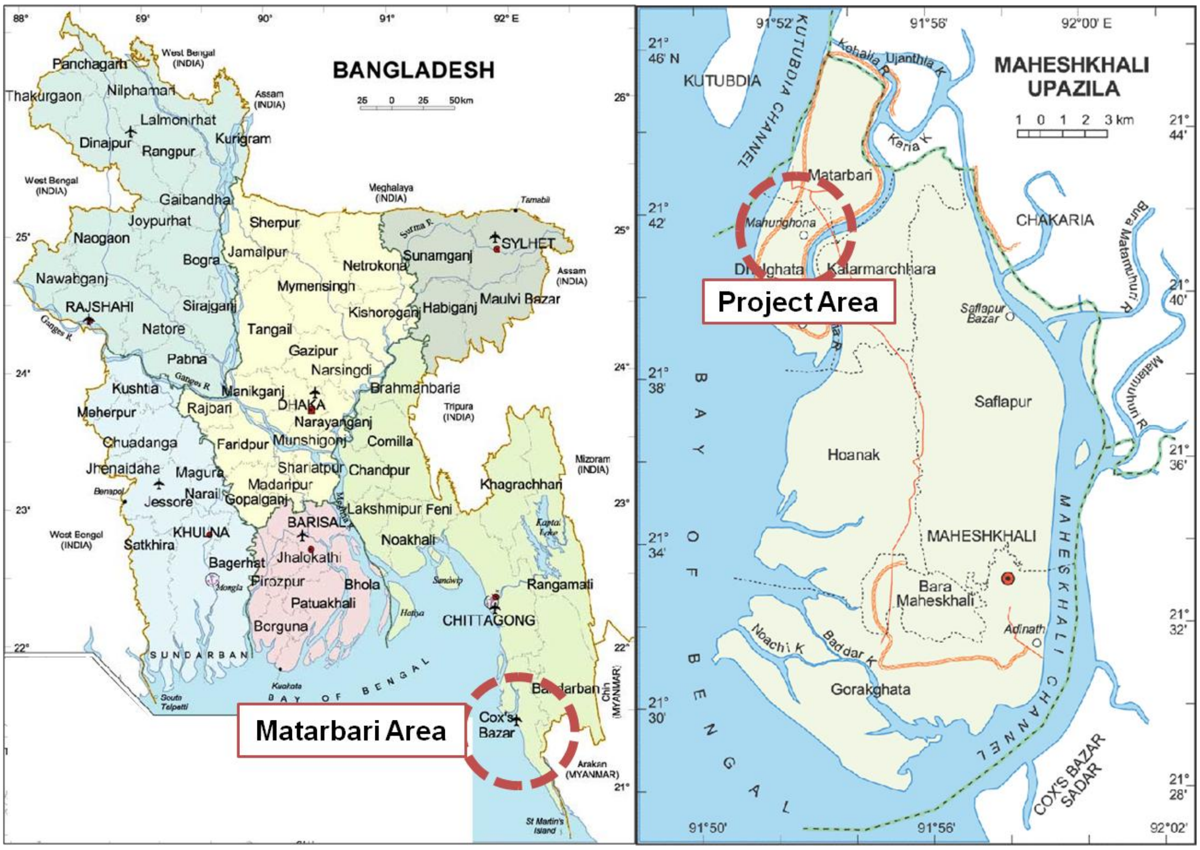
(2) To formulate the CTT plan to secure the returns of the investment from the CTT operation and to make this investment a meaningful investment.

Annual handling volume of coal supply at CTT will be studied in this F/S and applicability of phased development plan of CTT will be studied by considering the gradual increase of coal demand.

1.3. Project Site

Country: Bangladesh; District: Matarbari

Currently, the construction of Matarbari CFPP No.1 and No.2 and deep seaport for accommodating large coal import ships is in the planning stage. In this study, use of this deep seaport for importing coal and secondary transport of coal to the anticipated CFPP by CTT were assumed. Ship operation for coal import to Matarbari CFPP No.1 and No.2 and future land use concept of this region were also considered in the study.



Source：http://www.in2bangla.com/upazilaMap.php?id=293

Figure 1.3.1 Project Site

Chapter 2. Current Status of the Region

2.1. Natural Conditions of the Region

2.1.1. Topographical Feature

The People’s Republic of Bangladesh is located at the east side of the Indian subcontinent facing the Bay of Bengal. Most part of Bangladesh is located in the world’s biggest delta of the Ganges River (Padma River in Bengali), the Brahmaputra River (Jamuna River in Bengali), the Meghna River, and their distributaries. The project area is located about 150 km south of Chittagong in the southeastern part of Bangladesh, and on the coast near Cox’s Bazar.

2.1.2. Climate

(1) Outline

Bangladesh has a tropical climate which changes by season. During the summer season from March to June, it is hot and humid and the maximum temperature is about 24-35 ℃, and occasionally over 40 ℃. During the monsoon season from June to October, the temperature decreases due to rainfall. The winter season from October to March is warm. The yearly average rainfall in Bangladesh is about 2,300 mm and the rainfall from June to September accounts for 80% of the total rainfall.

(2) Temperature

Weather observation stations are located in Cox’s Bazar and Kutubdia near the project area. Annual changes of temperature in both areas are not so different, and seasonal change is nearly fixed. The temperature in January is 19-21 ℃. After January, the temperature is getting higher and higher and it is 28-29 ℃ in April. During April and October, the temperature remains at 27-29 ℃. However, the temperature during July and October gets cooler than that during April and June. During November and December, the temperature is getting cooler and the temperature in December is 21-23 ℃. The maximum monthly average temperature in Kutubdia is 29.4 ℃ in May 2010, and that in Cox’s Bazar is 29.9 ℃ in April 2010. On the other hand, the minimum monthly average temperature in Kutubdia is 18.9 ℃ in January 2003, and that in Cox’s Bazar is 19.6 ℃ in January 2003.

(3) Rain fall

The yearly average rainfall in Kutubdia is 4,321-5,905 mm, and that in Cox’s Bazar is 5,286-6,707 mm. Most of the rainfall is during May and October. On the other hand, it has never rained in some months such as November and April. In this way, the rainy season is obviously different from the monsoon season.

(4) Humidity

Annual change of humidity in Kutubdia and Cox's Bazar is calm, and seasonal change is nearly fixed. Throughout the year, the humidity is 65-90%. In the rainy season from May to October, the humidity is 75-90%. And in the other season from November to April, the humidity is 65-85%.

(5) Wind

In Cox's Bazar, the wind is usually "calm (less than 0.5 m/s)". Especially during September and March, the wind is "calm" for more than 50% of the day. However, in the other points, the features of wind directions are same in both areas. In January and February, prevailing wind direction is northerly. However, there is no especially strong wind. During March and October, prevailing wind direction is southerly, and it is significant especially during April and September. In July and August, the wind speed of southwesterly is slightly strong. Apart from it, however, the speed of strong wind is not significant. In October, wind direction changes from south to north, and the wind speed of southwesterly tends to be strong. In November and December, prevailing wind direction is northerly. However, wind speed of southwesterly tends to be strong.

2.2. Socio-economic Condition of the Project Area

2.2.1. Location

Project site is located between Matarbari Union and Dhalghata Union in Maheshkhali Upazila in Cox's Bazar District of Chittagong Division.

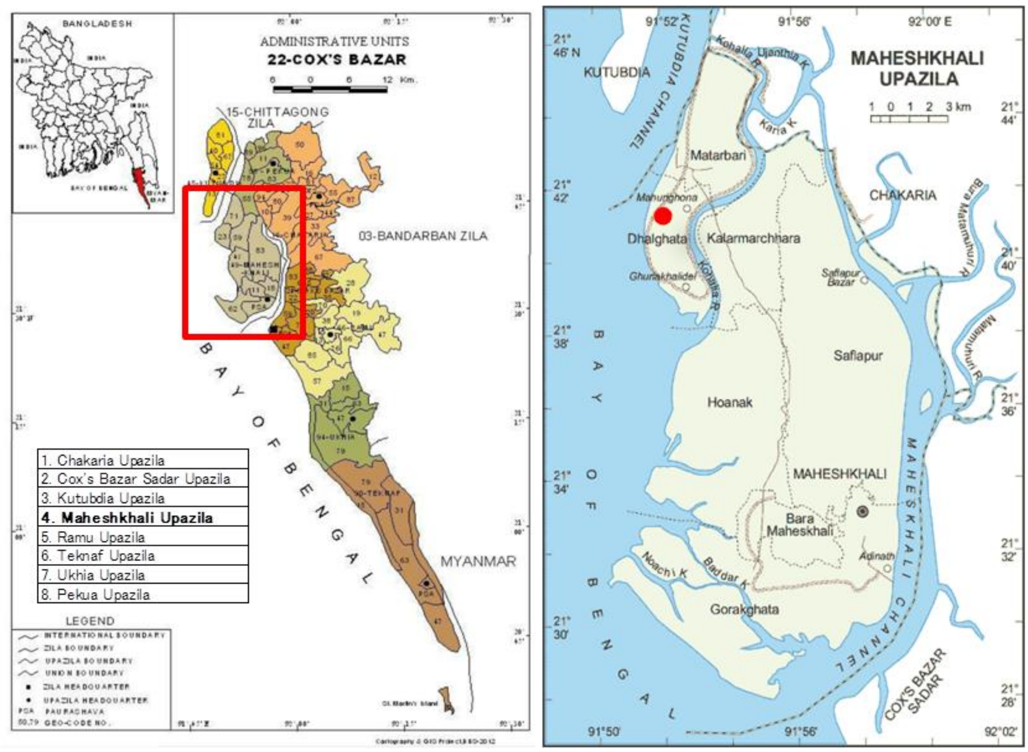


Figure 2.2.1 Cox's Bazar District

2.2.2. Population

The population of Bangladesh is 142 million people, and the population density is very high at about 1,000 people/km^2 (March 2011, Bangladesh Bureau of Statistics). Almost all of the people in Bangladesh are Bengali, but in the Chittagong Hill tracts next to the border of Myanmar, there are minority Buddhist people, e.g., Chakma people. The official language is Bengali. Literacy rate of adult (over 15) is 56% (2011). The state religion of Bangladesh is Islam (89.7%). Other religions of Bangladesh are Hindu (9.2%), Buddhism (0.7%), and Christianity (0.3%).

According to the Census of 2011, the population of Matarbari Union is 8,168 households (44,936 people, 5.5 people/household). Population density is about 1,662 people/km^2. The population of Dhalghata Union is 2,250 households (12,877 people, 5.7 people/household). Population density is about 6,441 people/km^2. Table 2.2.1 shows the population and number of households in Cox's Bazar District in 2011.

Table 2.2.1 Population of Cox's Bazar District in 2011

Upazila	Household	Population			Average size of household	Density per sq. km.
		Male	Female	Total		
Chakaria	88,391	239,198	235,267	474,465	5.4	942
Cox's Bazar Sadar	82,683	241,637	217,445	459,082	5.3	2,011
Kutubdia	22,587	64,093	61,186	125,279	5.5	581
Moheshkhali	58,177	165,693	155,525	321,218	5.5	887
Pekua	31,944	86,310	85,238	171,538	5.4	1,229
Ramu	47,904	135,000	131,640	266,640	5.5	681
Teknaf	46,328	133,106	131,283	264,389	5.7	680
Ukhia	37,940	104,567	102,812	207,379	5.4	792
Total	415,954	1,169,604	1,120,386	2,289,990	5.5	919

Source: Bangladesh Bureau of Statistics District Statistics 2011

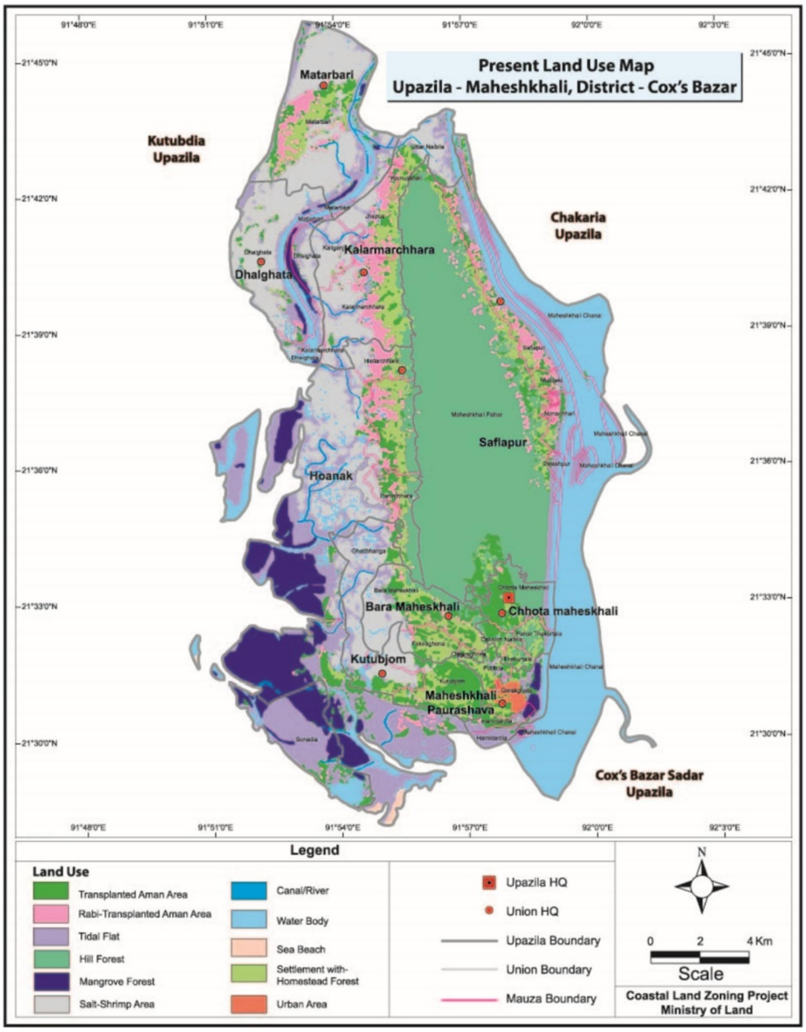
2.2.3. Land Use

Table 2.2.2 shows the land area of Cox's Bazar District. The area of Bangladesh is 147,000 km^2 and the area of Cox's Bazar is 2,500 km^2. Figure 2.2.2 shows the land use in Moheshkhali Upazila. Over 50% of the land use of the proposed area is for salt field and cultivation area of shrimp.

Table 2.2.2 Area of Cox's Bazar District

Upazila	Total Area (km^2)	Land Area (km^2)	Reserve Forest (km^2)	Riverine Area (km^2)
Chakaria	503.83	327.06	136.25	40.47
Cox's Bazar Sadar	228.23	196.05	-	3.50
Kutubdia	215.79	199.15	-	-
Moheshkhali	362.18	249.80	-	112.38
Pekua	139.68	135.41	2.25	2.02
Ramu	391.71	246.42	145.29	-
Teknaf	388.66	227.60	159.80	1.36
Ukhia	261.80	137.77	155.14	0.91
Total	2,491.85	1,719.26	598.73	160.61

Source: Bangladesh Bureau of Statistics (BBS) District Statistics 2011



Source: Ministry of Land's Land Use Map

Figure 2.2.2 Land Use of Moheshkhali Upazila

2.2.4. Industry

Fishery, salt production, and shrimp aquaculture have been developed.

In Maheshkhali Upazila, many people work in salt marsh. Usually, they are poor, and do not own the land. Thus, they usually rent the land. The average area of salt marsh is about 0.62 ha. The elevation of the area is so low that storm surge often occurs. Storage facilities of salt are insufficient. Hence, salt is often lost due to heavy rain and storm surge.

Chapter 3. Coal Demand Forecasting

3.1. Overview of Energy in Bangladesh

As Bangladeshi economy grows, its demand for energy has steeply increased. The domestic energy supply in 2013 is 33,870 thousand ton of oil equivalent (toe), which is about 180% of the supply in2000 (18,602 thousand toe). As a result of development of natural gas fields since 2000 and production of domestic coal since 2005, the domestic energy production also increased considerably. The domestic production is 28,727 thousand toe in 2013, which is 190 % of that in 2000. Natural gas production is 18,957 thousand toe, which occupies 66% of the total production. Table 3.1.1 shows the Energy Balance of Bangladesh (International Energy Agency). (Note: JCIA's Power System Master Plan 2015 (draft PSMP2015) will cover the country's primary energy growth estimate. However, the examination work started in December 2015, and the estimate will be available only in June 2016. This subchapter, therefore, uses the data of IEA.)

Table 3.1.1 Energy Balance in Bangladesh

Unit: thousand ton of oil equivalent (1,000toe)

		2000	2005	2010	2011	2012	2013
Production							
	Coal	–	–	385	333	417	427
	Oil	97	98	93	242	239	254
	Naturai Gas	7,271	10,806	16,490	16,745	17,574	18,957
	Hydro	76	111	63	75	67	77
	Biofuel and waset etc	7,603	8,296	8,730	8,785	8,890	8,999
	Total (a)	15,048	19,311	25,760	26,180	27,187	28,727
Net Imports (Note)							
	Coal	330	350	519	415	486	508
	oil	3,321	4,624	4,570	4,764	4,974	4,843
	Total	3,554	4,876	4,996	4,937	5,221	5,640
(Total Primary							
Energy Supply)	Coal	330	350	904	748	903	988
	Oil	3,321	4,624	4,570	4,764	4,974	4,843
	Natural Gas	7,271	10,806	16,490	17,320	18,338	18,950
	Hydro	76	111	63	75	67	77
	Biofuel and waset etc	7,603	8,296	8,730	8,785	8,890	8,999
	Total(b)	18,602	24,187	30,756	31,692	33,172	33,870
	Self Supply ratio (=(a)/(b))	1	1	1	1	1	1
Total Final Consumption							
	Coal	330	350	654	516	666	652
	Oil	2,824	3,957	3,754	3,938	3,960	3,631
	Natural Gas	3,538	5,436	6,693	7,532	7,637	7,875
	Electricity	951	1,686	3,014	3,167	3,719	3,667
	Biofuel and waste etc	7,603	8,296	8,730	8,785	8,890	8,835
	Total	15,246	19,726	22,846	23,938	24,872	24,660

Note: Net Imports include stock change.

Source: IEA, Energy Balances of Non-OECD Countries

According to the draft PSMP2015, Bangladeshi economy is estimated to grow at 6.0-6.5% per year toward 2041. To cover this economic growth, the power source needs to be developed progressively. Regarding the natural gas, which currently plays a key role in domestic energy production, the production of the current gas fields in eastern part of the country is declining, and the development of offshore gas fields is planned. Regarding the development of the coal, which will be explained in detail in following sections, there are five prospective mine fields, but only Barapukuria Mine will continue operation in future. It is not expected that the other four sites will be developed due to strong opposition by residents, difficulty of mining, high cost and so on.

draft PSMP2015 estimates that the power demand will grow from 15,475 MW in 2015 to 57,000MW in 2041 and that the incremental power source will rely on import of natural gas (LNG) and coal, while domestic gas production will be developed. Although the draft PSMP2015 does not show the balance (proportion) of future energy source at this moment, it is estimated that no single energy source will be more than 50% and that coal and natural gas will cover 70%-75% of power source in 2041.

3.2. Coal Industry in Bangladesh

3.2.1. Coal Reserve and Utilization in Bangladesh

In Bangladesh, coal deposit exists in the north-west of the country between Jamuna River and Padma River. The coal, called Gondwana Coal, is bituminous originating in the Paleozoic and Cenozoic eras, or sub-bituminous in the Tertiary era or lignite. According to the exploration result, the deposits are observed in five coal mines.

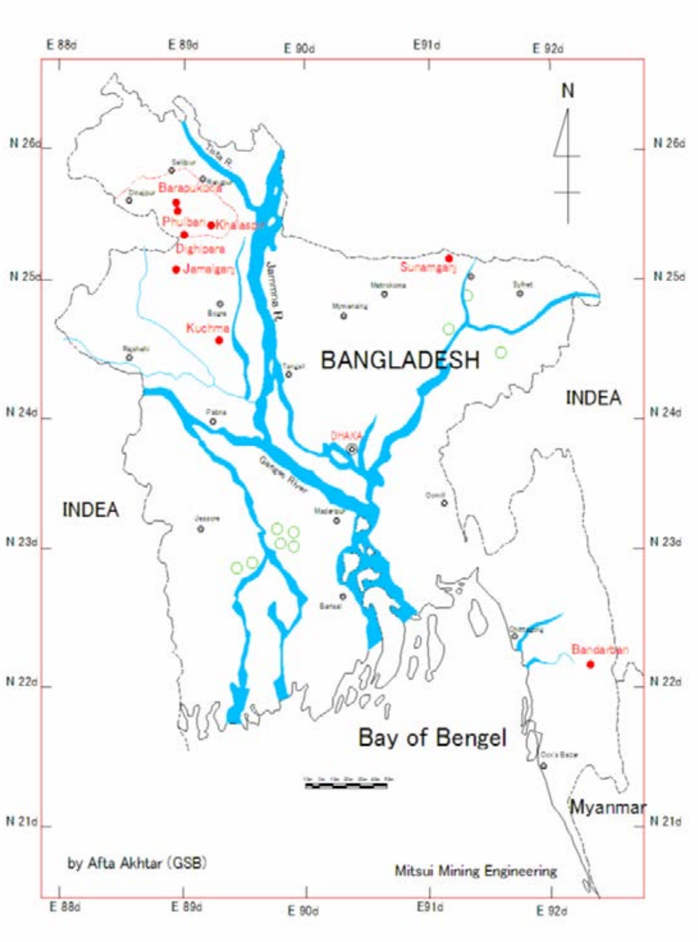
Coal in Bangladesh is characterized as low ash and low sulfur, and thus is of high quality with small environmental impact. Most of the coal is bituminous and has similar characteristics as the coal used in Japanese power plants. Bangladeshi coal is also used in the steel industry, and this coal has quite high commercial value.

The confirmed and estimated reserve of coal is 3,300 million tones (Mt). The Draft Coal Policy published in 2007 estimates the confirmed coal reserve at 1,168 Mt, which can be explored in the near future, whilst the policy excludes Jamalgonji Coal deposit because it is comparatively deep. As more new coal mines will be explored in the future, the coal reserve will increase. Table 3.2.1 shows the total coal reserves in Bangladesh, and Figure 3.2.1 shows the location of the coal mines.

Table 3.2.1 Coal Reserves in Bangladesh

	Coal field name	Exploration Year;	Depth(m)	No. of Layers	Average Thickness(m)	Confirmed Amount (in million ton)	Confirmed and Estimated Amount (in million ton)
1	Barapukuria(Dinajpur)	1985 -87	118 -506	6	51	303	390
2	Phulbari, (Dinajipur)	1,997	150 -240	2	15-70	572	572
3	Khalaspir, (Rangpur)	1989 -90	257 -483	8	42	143	685
4	Dighipara,(Dinajipur)	1994 -95	328 -407	5	62	150	600
5	Jamalgonji, (Bogra)	1,962	640-1158	7	64	1,053	1,053
6	Kuchma, (Bogra)	1,959	2,380-2,876	5	52	–	0
Total						2,221	3,300

Source: draft PSMP2015 (as of Jan 2016)



Source: Petrobangla

Figure 3.2.1 Location of Coal Mines

(1) Production of Domestic Coal

The only coal mine developed in Bangladesh is Barapukuria Coal Mine. The mine uses underground mining method, and the coal is bituminous with low ash and low sulfur, which means that it has environmental advantage.

Based on the management, production, maintenance and provisioning services (MPM&P) contract, signed between Petrobangla and XMC-CMC, a Chinese corporation, XMC-CMC started mine exploration in 1994. By introducing mechanized long-wall top coal caving (LTCC) production method, the corporation has achieved stable production in this first coal mine with underground mining technology in Bangladesh. The first contract was for 71 months starting from September 2005, during which the production amounted to 3.65 Mt ton whilst the contractual target was 4.75 Mt. Furthermore, the second contract was awarded to XMC-CMC and MPM&P, and was signed in December 2012 (available retroactively from August 2011) as a result of international bidding. The second contract targets 5.5 Mt production. This contract also applied LTCC technology, which enables thick layer production.

As the second layer production technology for thick layers, which has long been a problem, becomes stable by introduction of LTCC since 2012, coal production in 2014 was 950 thousand ton. In 2015, the production reduced considerably because of facility trouble. However, the trouble was already recovered, and it is expected that the production level will soon reach the targeted of 1 million ton per year. Table 3.2.2 shows the recent annual production of Barapukuria Coal Mine.

The current mining facility is made in China. With the vertical shaft of 300m and skipping capacity of 3,300 t/day, this production is at the full level at the moment, and the maximum annual production could reach up to 1.2 Mt. It can be increased to 1.5 Mt if the facility is reinforced, for example, by increasing vertical shafts.

Table 3.2.2 Recent annual production of Barapukuria Coal Mine

Year	Production (t)
2005-2006	303,016
2006-2007	388,376
2007-2008	677,098
2008-2009	827,845
2009-2010	704,568
2010-2011	666,635
2011-2012	835,000
2012-2013	854,804
2013-2014	947,124
Total	6,382,647

Source: Barapukuria Coal Mining Co.Ltd

(2) Usage of Domestic Coal

Most of the coal produced in Barapukuria Mine is supplied to Barapukuria CFPP (125 MW x 2 units), which is owned by the Bangladesh Power Development Board (BPDB) and is next to the mine, and some amount is supplied for industries including brick factories. The Barapukuria Power Station consumes 400,000-500,000 t/yr, depending on load factor. BPDB plans to construct the third unit. The production and usage of domestic coal, i.e., Barapukuria, are shown in Table 3.2.3.

Table 3.2.3 Production and Usage of Domestic Coal

Year	Production (t)	Sale (t)	
		BPDB	Others
2005-2006	303,016	209,235	45,603
2006-2007	388,376	460,231	6,523
2007-2008	677,098	491,354	11,630
2008-2009	827,845	532,488	259,244
2009-2010	704,568	501,132	320,368
2010-2011	666,635	463,923	108,616
2011-2012	835,000	499,972	333,360
2012-2013	854,804	643,687	289,398
2013-2014	947,124	524,143	338,618
Total	6,382,647	4,326,458	1,850,560

Source: Petrobangla Coal Mining Co.Ltd

The BPDB column in Table 3.2.3 denotes the sales to Barapukuria CFPP. As mentioned earlier, Barapukuria Coal Mine always stores coal for two to three months. The mine increased production through the LTCC facility since 2013, and the production is stable now. The mine, with the current facility, is expected to achieve the original goal of 1 Mt/yr soon.

The selling price of coal is USD 130/t for BPDB’s power stations (available from May 2015) and BDT 13,680/ton (about US$175, assuming 1 US$=78BDT) for other local buyers. These prices are higher than Australian coal of similar quality at mine mouth, which is currently USD50-60/t in March 2015. The prices are set high because the prices include the fee for coal mining technology transfer and because there is no other competitor in the international bidding.

In response to the increasing demand for electric power, it is necessary to plan and develop new power stations. Since domestic natural gas, which is currently a major energy resource in Bangladesh, will be depleted, it is estimated that coal will be an important energy source. However, since domestic coal is expensive and new development of coal mines is unlikely, it is estimated that the coal-fired power stations using imported coal will be the major power source.

3.3. Utilization of Imported Coal in Bangladesh

The only coal currently used for power production in Bangladesh is the coal from Barapukuria Mine. Since it is not expected that this coal mine will increase production drastically, the CFPP to be constructed in the future will have to rely on imported coal. Current usage of imported coal is explained below.

According to Bangladesh Bureau of Statistics (BBS), Bangladesh imports 4-5 Mt of coal per year, whilst domestic production is several hundred tonnes per year. Table 3.2.1 shows the amount of imported coal. As all the imported coal is used for industries, no imported coal is used for power generation.

Imported coal is categorised into two kinds. One type is coke and semi-coke that are used in foundry (casting) and smithery (forging), and the other is for brick factories and charcoal briquettes for household use.

Bangladesh is a major delta region with some rivers flowing in a few countries. Since the land is flat in most areas of the country, it has abundant sand with small diameter, but it is difficult to collect aggregates (stones and gravels with larger diameter).

These aggregates are used for high strength concrete and are inevitable materials for the surface of roads. They are produced from natural stones in the northeastern mountain area and carried to flat areas like Dhaka, but transportation distance and price are some of the concerns.

Thus, bricks once made in brick factories are crushed into pieces and used for materials for strengthening of ground and for road surface.

Comparing the natural stone-oriented aggregates with high transportation cost and the crushed bricks, the latter is more economical. As more roads are developed in accordance with economic growth, the demand for brick is increasing, and the production of brick is expected to increase.

According to a research by a coal trading company, the coal for brick production is imported from Indonesia, India, and China. Indonesian coal is dominantly used now. Quality of these coals is classified into three: 5,000 kcal/kg, 6,500 kcal/kg, and 7,500 kcal/t.

Selling prices depend on the quality and seasonal demand, but they are currently BDT 7,000-9,500 (USD 90-122)/t for Indonesian coal, and BDT 10,000 (USD 125)/t for Indian coal. Considering the freight and conveying/shifting cost, they are appropriate, i.e., competitive against domestic coal. Annual import is 20,000-30,000 tonnes.

As primary transportation, the imported coal is transported by handy max vessels (DWT 30,000-50,000 tonnes) from the exporting port to Chittagong Port.

Brick factories, where most imported coal is consumed, concentrate on regions at the river mouth of any major river, and some regions have several tens of factories.

The secondary transportation from Chittagong Port to brick factories is by small vessels and barges. Each brick factory is expected to consume 700 tonnes of coal over a normal 6-month work period.

Estimating that there are 5,000 factories in Bangladesh, the coal demand for brick industry together with other consumers coincides with the annual import of 4 Mt as shown in the statistics.

Table 3.3.1 Amount of Imported Coal

use application	2010/2011		2011/2012	
	amount of import (t)	import figures (BDT)	amount of import (t)	import figures (BDT)
Coke and Semi-coke of Coal	59,778	4,768,131	56,636	4,116,081
Coal & Briquette	4,473,929	104,317,797	3,903,230	103,100,496

Source：Bangladesh Bureau of Statistics (BBS)

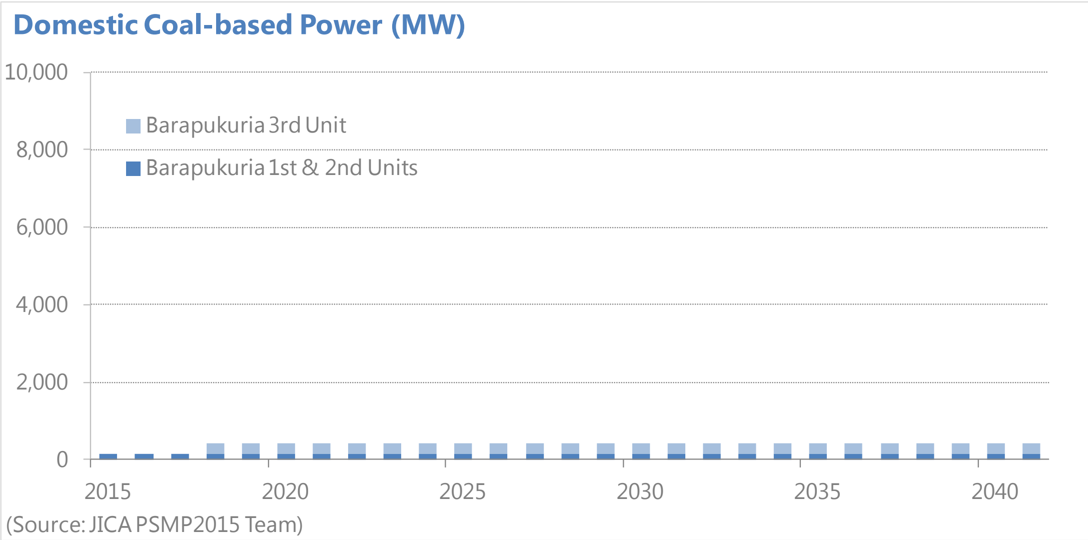
3.3.1. Estimates of Coal Demand in Bangladesh

(1) Existing Coal Development Plan

Barapukuria Coal Mine is the only existing domestic mine in Bangladesh and produces about 1 Mt/yr. The coal produced is supplied to Barapukuria Power Station and others including brick factories. In the future plan, the production will be limited up to 1.5 Mt/yr. On the other hand, the coal will be purchased by already fixed customers, and thus, there is little possibility that the mine can supply to other new power stations.

The Phulbari Coal Mine, which is a possible candidate for development, is known by its abundant reserve capacity, but the government refrains from developing the mine because the development would entail the relocation of many people and the local residents strongly oppose the development.

Since it is hardly expected that the domestic coal production will increase whilst the future demand for coal is expected to increase, the government plans to expand the use of imported coal. Figure 3.3.1 shows the existing coal-fired power development plan.



Source: Draft PSMP2015 (as of Jan 2016)

Figure 3.3.1 Existing Coal-fired Power Development Plan

(2) New Coal Development Plan

The draft PSMP 2015, which is being studied under JICA, estimates the total electric power demand in 2041 will to be 52,000 MW. 57,000MW including reserve margin. Whilst the draft PSMP2015 has not yet fixed the estimate of its breakdown, a scenario of the draft PSMP2015 estimates that the coal will account for about 40%.

Table 3.3.2 shows the coal demand forecast in Bangladesh, Figure 3.3.2 shows the estimate of coal demand whilst Figure 3.3.3 shows the demand and supply of coal.

In forecasting the coal demand, the JICA Study Team has some Limitations because the capacity and size of the planned power stations are yet to be decided and the procurement of coal, e.g., types of coal and caloric value. is also not yet decided. Therefore, the JICA Study Team assumed in the forecasting that the plants will adopt highly efficient technology like ultra-super critical (USC) or super critical type (average energy efficiency of 43%) and the plants will use either bituminous or sub-bituminous coal and the average calorie is 5,100 kcal/kg. This is the same assumption as in the draft PSMP2015. Annual coal consumption will be 2,900 t/MW.

The draft PSMP2015 estimates that the total demand for coal in 2041 will be 80.7 Mt, of which 97.5%, i.e., 79.5Mt, will be imported. It also estimates that 86.5% of coal will be used for the power sector.

Development of CFPPs using imported coal started in 2012 at 1,320 MW. This consumes 3.82 Mt of coal per year, and will reach 23,691 MW with 68.7 Mt of coal per year in 2041.

The first project is Rampal Power Station developed by the Joint Venture between BPDB and India's NTPC Limited, which plans to transship coal from large vessel to barge (8,000-10,000 DWT) off Bengal Bay.

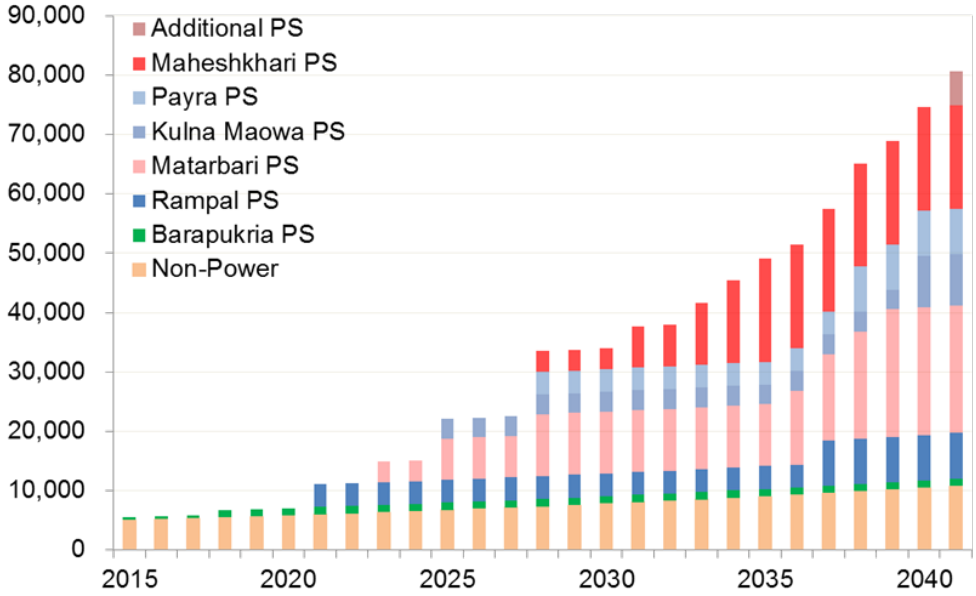
The plan of Matarbari Thermal Power Station, developed in Matarbari Region, Chittagong Prefecture in southern Bangladesh through Japanese ODA, is to construct two units of 600 MW USC with a very deep bay and port that will enable Panamax vessel (80,000 DWT) to call directly. The coal will be imported from Australia, Indonesia, or South Africa using large vessels, which is efficient in terms of transportation cost.

For reference, the values under the "Domestic, Amount (ktonne)" column in Table 3.2.2 indicate the estimated amount of coal (produced in Barapukuria Mine, which is the only domestic coal mine) that will be used for Barapukuria Mine-mouth Power Station.

Table 3.3.2 Coal Demand Forecast in Bangladesh

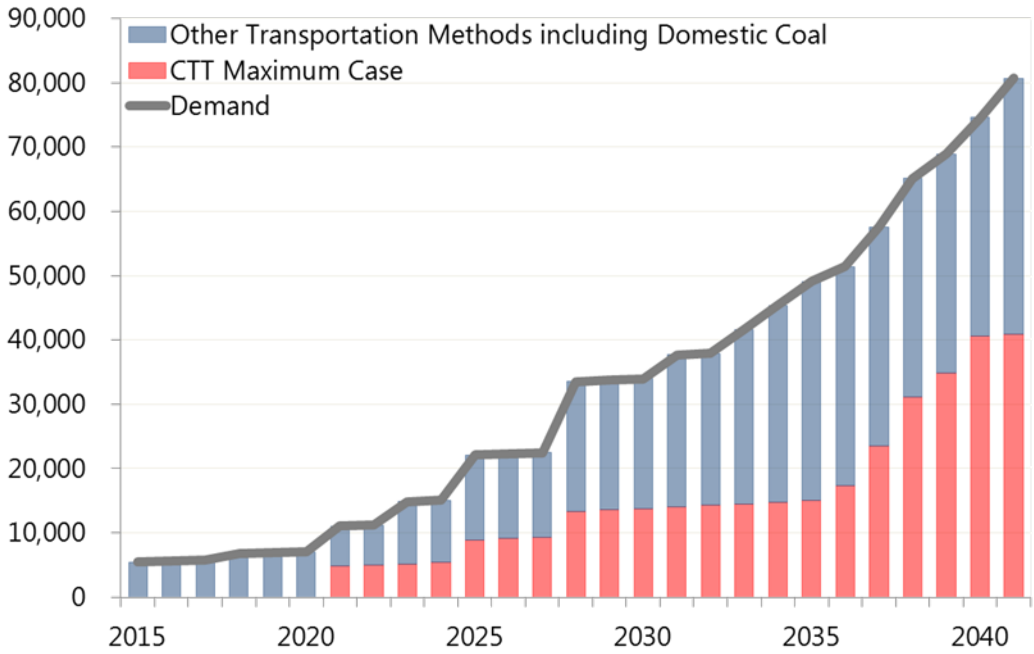
YEAR	Import Coal				Domestic				
	Power Sector		Non-Power	Total	Power Sector(Barapukuria)				Total
	Capacity	Amount			Capacity			Amount	
					# 1,#2	#3	Total		
	(MW)	(kton)	(kton)	(kton)	(MW)	(MW)	(MW)	(kton)	(kton)
2014	0	0	0	0	154		154	447	447
2015	0	0	5,000	5,000	154		154	447	5,447
2016	0	0	5,150	5,150	154		154	447	5,597
2017	0	0	5,305	5,305	154		154	447	5,752
2018	0	0	5,454	5,454	154	274	428	1,241	6,695
2019	0	0	5,628	5,628	154	274	428	1,241	6,869
2020	0	0	5,796	5,796	154	274	428	1,241	7,037
2021	1,320	3,828	5,970	9,798	154	274	428	1,241	11,039
2022	1,320	3,828	6,149	9,977	154	274	428	1,241	11,218
2023	2,520	7,308	6,334	13,642	154	274	428	1,241	14,883
2024	2,520	7,308	6,524	13,832	154	274	428	1,241	15,073
2025	4,872	14,129	6,720	20,849	154	274	428	1,241	22,090
2026	6,072	17,609	6,921	24,530	154	274	428	1,241	25,771
2027	6,072	17,609	7,129	24,738	154	274	428	1,241	25,979
2028	8,592	24,917	7,343	32,260	154	274	428	1,241	33,501
2029	8,592	24,917	7,563	32,480	154	274	428	1,241	33,721
2030	8,592	24,917	7,790	32,707	154	274	428	1,241	33,948
2031	9,792	28,397	8,024	36,421	154	274	428	1,241	37,662
2032	9,792	28,397	8,264	36,661	154	274	428	1,241	37,902
2033	10,992	31,877	8,512	40,389	154	274	428	1,241	41,630
2034	12,192	35,357	8,768	44,125	154	274	428	1,241	45,366
2035	13,392	38,837	9,031	47,868	154	274	428	1,241	49,109
2036	14,092	40,867	9,301	50,168	154	274	428	1,241	51,409
2037	16,112	46,725	9,581	56,306	154	274	428	1,241	57,547
2038	18,632	54,033	9,868	63,901	154	274	428	1,241	65,142
2039	19,832	57,513	10,164	67,677	154	274	428	1,241	68,918
2040	21,691	62,904	10,465	73,369	154	274	428	1,241	74,610
2041	23,691	68,704	10,783	79,487	154	274	428	1,241	80,728

Source: Draft PSMP2015 (as of Jan 2016)



Source: Draft PSMP2015 (as of Jan 2016)

Figure 3.3.2 Forecast of Coal Demand Increase (kt)



Source: Draft PSMP2015 (as of Jan 2016)

Figure 3.3.3 Coal Supply and Demand Balance (kt)

3.3.2. Coal Transshipment Terminal (CTT)

(1) Necessity of Coal Terminal

The draft PSMP2015 shows the long term development of CFPP using imported coal. According to the draft PSMP2015, most of the future CFPPs will be constructed in Matarbari area. However, the seashores are generally shallow and could not be reached by large vessels without modifications. Transportation method is not yet determined except that for Matarbari Units No.1 and No.2.

Therefore, in order to import coal for these power stations in Matarbari area, it is necessary to dredge vessel routes and harbors so that large vessels can pass and anchor and to construct a large-scale CTT to temporarily store coal for supply to the CFPPs. It is not economically advantageous to import coal to each power station by small vessels or to construct an off-shore coal storage facility and transport coal by barges.

When a very deep bay and port are completed in Matarbari Region and large vessels like Panamax (80,000 DWT) can have direct access to the port, the speed of developing new power stations will possibly increase. However, to reach the Moheshkhali CFPPs, it is necessary to extend the route from Matarbari. In this case, there are many problems including construction cost of route extension, treatment of soil and sand resulting from construction works, and other environmental concerns; therefore, it is uncertain when the route extension will be completed.

Regarding Maowa, Khulna, Rampal, and Payra project sites, the shores of Bengal Bay and the rivers for transportation are too shallow with sand from upstream for large vessels like Panamax to supply coal. In order to realise the long-term power development plan, on-shore (land) CTT should be considered from the viewpoints of transportation method and cost.

A concept flow of transportation using CTT is shown in Table 3.3.3.

Table 3.3.3 Concept flow of transportation using CTT

Producer Country ⇒	Primary Transportation ⇒	CTT ⇒	Secondary Transportation ⇒ Power Station
●Austlalia ●Indonesia ●Africa ●Others	【Type of Vessel】 ●Panamax 80,000DWT Class	【Proposed Site】 ●Chittagon Div. Matarbari Area	【Khulna、Chittagon】 ●Barge；5000t～10,000t 【Matarbari、Moheshkhali】 ●Belt Conveyor

Source: JICA Study Team

(2) Examination of Power Stations Using CTT

The maximum annual treatment amount of the CTT is determined by the development plan. The draft PSMP2015 assumes that the power development plan is based on the power demand forecast, that the off-shore coal transportation route will be extended to Moheshkali Region based on the previous preliminary research on South Chittagong Regional Development, and that coal transportation to Moheshkali Region will not use the CTT as large vessels will have direct access to the port adjacent to the power stations.

In general, in order to make the coal terminal plan, factors such as power station sites, commencement year, type of generation, generating capacity, and fuel type need to be determined. Secondly, based on these assumptions, power stations that the plan targets will be selected and design conditions will be determined. The CTT plan refers to the scenario shown in the draft PSMP2015 and also considers the requests of the Bangladeshi government.

The Bangladeshi government expects the early completion of the CTT as it will contribute to the development of infrastructure and the enhancement of investment into IPP projects. In this regard, the JICA Study Team will assume and evaluate the case of early completion and a more realistic case based on the power development plan proposed in the draft PSMP2015.

3.3.3. Planned Coal-Fired Power Stations Using Imported Coal

Regarding the planned coal-fired power stations using imported coal, the projects for which the Bangladeshi government signed a memorandum of understanding (MOU) are listed in Table 3.3.4. These MOUs have been signed by the Bangladeshi government and sponsors who eagerly consider investing in the project. However, the details including site selection, land acquisition, environmental and social impact assessment, detailed design, and contract procedure need to be discussed and determined before the commencement of construction.

Table 3.3.4 List of Power Projects with MOU with the Bangladeshi Government

Area	Power Plant	Cap(MW)		COD(FY)	Company/Sponsor
【Government project】					
Khulna Barisal	BIFPCL, Rampal, Coal Fired Power Plant #1	660		2018	NTPC+BPDB
	BIFPCL, Rampal, Coal Fired Power Plant #2	660		2019	NTPC+BPDB
	Payra,Patuakhali Coal Based Power Plant #1	660		2023	CMC(China)+NWPGCL
	Payra,Patuakhali Coal Based Power Plant #2	660	2640	2024	CMC(China)+NWPGCL
Ashuganj	Ashuganj Coal based power plant #1	660		2024	
	Ashuganj Coal based power plant #2	660	1320	2025	
Dhaka	Munshiganj	800	800	tbd	
Chittagong	Chittagong Anowara #1	660		tbd	Undesided
	Chittagong Anowara #2	660	1320	tbd	Undesided
Matabari	Matarbari USC Coal thermal #1	600		2023	Japan ODA,(COD;2023)
	Matarbari USC Coal thermal #2	600		2024	Japan ODA,(COD;2023)
	Matarbari 700 MW Coal Power Plant	700		tbd	Singapole(IN Enterprise)
	Matarbari USC Coal thermal#3	600		tbd	ODA or IPP
	Matarbari USC Coal thermal#4	600		tbd	ODA or IPP
	Matarbari USC Coal thermal#5	600		tbd	IPP
	Matarbari USC Coal thermal#6	600	4300	tbd	IPP
Moheshkhali	Moheskhali 1200 MW Coal Power Plant	600		tbd	JV with Huadian
	Moheskhali 1200 MW Coal Power Plant	600		tbd	JV with Huadian
	Moheshkhali 1320 MW Joint Venture #1	660		tbd	ECA Funding
	Moheshkhali 1320 MW Joint Venture #2	660		tbd	ECA Funding
	Moheshkhali Coal Based Power Plant #1	660		tbd	Malaysia
	Moheshkhali Coal Based Power Plant #2	660		tbd	Malaysia
	Moheskhali 1320 MW Coal Power Plant	660		tbd	ADB Funding
	Moheskhali 1320 MW Coal Power Plant	660		tbd	ADB Funding
	1320 MW Power Plant with South Korea #1	660		tbd	KEPCOSouth Korea
	1320 MW Power Plant with South Korea #2	660	6480	tbd	KEPCOSouth Korea
Government Project Total		16,860			
【Private Project】					
Khulna	Khulna 630 MW IPP	630		2015	Orion Khulna Power Ltd.
Maowa	Maoa Munshiganj 522 MW IPP	522		2016	Orion Dhaka Power Ltd.
Meghnaghat	Dhaka 635 MW	635		tbd	Orion Dhaka Power Ltd.
	Dhaka 282 MW	282		tbd	Orion Dhaka Power Ltd.
Chittagong	Chittagong Anowara 282 MW IPP	282		tbd	Orion Dhaka Power Ltd.
	Chittagong 612 MW	612		tbd	S Alam Group
	Chittagong 612 MW IPP8	612		tbd	S Alam Group
	Mirersorai Chittagong 150 MW Commercial Power Plant	150		tbd	Chittagong Power Co Ltd. (BSRM)
Bashkhali	Bashkhali 600 MW	600		tbd	Bangladesh Machine Tools Factory Ltd. (BMTFL)
Private Project Total		4,325			
Total		21,185			

Table 3.3.5 shows the power development plan based on Table 3.3.4 and the draft PSMP2015 based coal-fired power generation development plan as well as the plan of the CTT. Locations of the planned coal-fired power stations using imported coal are shown in Figure 3.3.4.

he Matarbari USC CFPP Units No. 1 and No. 2 (600 MW each), the construction of which will start soon, are planned to commence operation in 2023. This power station will provide direct access for Panamax size vessel due to the development of very deep bay and port; therefore, it will not be an object of this CTT study.

For other power stations, there is a possibility to use this CTT if cost and stability of coal procurement are judged satisfactory. However, this survey does not consider power stations that do not clearly express the possibility to use CTT in the future.

Rampal Power Station Units No. 1 and No. 2, located in Khulna Region, are planned to commence operation in 2018, and are the first target of the CTT. Since this plan precedes the completion of CTT, it examines a plan to tranship coal from large vessel to barge (8,000-10,000 DWT) off shore. However, if the completion of CTT precedes the start of the Rampal Project operation or the fee to use the CTT is lower than the offshore transshipment cost, the plan may consider using the CTT.

Table 3.3.5 Draft PSMP2015's Generation Plan and CTT-based Coal-Fired Power Plan

Government MOU Based Project				(Draft PSMP2015)				CTT				
Power Plant	(MW)	COD (FY)	Company/Sponsor	MW	COD (FY)	CTT	Coal (kton)	COD(FY) PSMP	MW	～2029 1st Phase	2030～ 2nd Phase	
Matarbari Island							19,720		**5,000**			
Matarbari#1	600	2023	Japan ODA,(COD;2023)	600	2023		1,740	2023	600			
Matarbari#2	600	2024	Japan ODA,(COD;2023)	600	2023		1,740		600			
Matarbari#3	600	tbd	ODA or IPP	600	2025		1,740	2025	600	○		1,740
Matarbari#4	600	tbd	ODA or IPP	600	2025		1,740	2025	600	○		1,740
Matarbari#5	600	tbd	IPP	600	2026		1,740	2026	600	○		1,740
Matarbari#5	600	tbd	IPP	600	2026		1,740	2026	600	○		1,740
Matarbari North #7	700	tbd	Singapole(IN Enterprise)	700	2036	○	2,030	2036	700		○	2,030
Matarbari North #8				700	2037	○	2,030	2037	700		○	2,030
Matarbari North #9				600	2038	○	1,740	2038	600		○	1,740
Matarbari North				600	2038	○	1,740	2038	600		○	1,740
Matarbari North				600	2039	○	1,740	2039				
Matarbari North				600	2039	○	1,740	2039				
Moheshkhali Island							15,660		**1,200**			
Moheshkhali#1	600	tbd	JV with Huadian	600	2028		1,740	2028	600	○		1,740
Moheshkhali#2	600	tbd	JV with Huadian	600	2028		1,740	2028	600			1,740
Moheshkhali#3	660	tbd	ECA Funding	600	2033		1,740	2033				
Moheshkhali#4	660	tbd	ECA Funding	600	2033		1,740	2033				
Moheshkhali#5	660	tbd	Malaysia	600	2034		1,740	2034				
Moheshkhali#6	660	tbd	Malaysia	600	2034		1,740	2034				
Moheshkhali#7	660	tbd	ADB Funding	600	2031		1,740	2031				
Moheshkhali#8	660	tbd	ADB Funding	600	2031		1,740	2031				
Moheshkhali#9	660	tbd	KEPCOSouth Korea	600	2035		1,740	2035				
Moheshkhali#10	660	tbd	KEPCOSouth Korea	600	2035		1,740	2035				
Khulna							5,742		**1,980**			
Rampal#1	660	2018	NTPC+BPDB	660	2021	○	1,914	2021	660		○	1,914
Rampal#2	660	2019	NTPC+BPDB	660	2021	○	1,914	2021	660		○	1,914
Rampal#3				660	2037	○	1,914	2037	660			
Rampal#4				660	2037	○	1,914	2037	660			
Patuakhali							5,742	0	**1,320**			
Payra#1	660	2023	CMC(China)+NWPGCL	660	2028	○	1,914	2028	660		○	1,914
Payra#2	660	2024	CMC(China)+NWPGCL	660	2028	○	1,914	2028	660		○	1,914
Payra#3				660	2038	○	1,914	2038				
Payra#4				660	2039	○	1,914					
Others							8,732		1,152			
Khulna	630	2015	Orion Khulna Power Ltd.	630	2025	○	1,827	2025	630			
Maowa	522	2016	Orion Dhaka Power Ltd.	522	2025	○	1,514	2025	522			
Dhaka	800	tbd		635	2040	○	1,842	2040				
Chittagong #1	660	tbd	Undesided	612	2040	○	1,775	2040				
Chittagong#2	660	tbd	Undesided	612	2040	○	1,775	2040				
Ashuganj#1	660	2024										
Ashuganj#2	660	2025										
Meghnaghat#1	635	tbd	Orion Dhaka Power Ltd.									
Meghnaghat#2	282	tbd	Orion Dhaka Power Ltd.									
Chittagong#1	282	tbd	Orion Dhaka Power Ltd.									
Chittagong#2	612	tbd	S Alam Group									
Chittagong#3	612	tbd	S Alam Group									
Chittagong#4	150	tbd	Chittagong Power Co (BSRM)									
Bashkhali	600	tbd	Bangladesh Machine Tools Factory Ltd. (BMTFL)									
Total Power							55,596		10,652			
Total for CTT+CTT							35,064					
Total Non-Power							5,783					
Total Coal Supply/Deamnd				21,691			**61,379**	1st Phase		3,600		10,440
								2nd Phase			5,240	**15,196**

Source: Draft PSMP2015 and JICA Study Team (as of Jan 2016)

Source: JICA Study Team

Figure 3.3.4 Location of Coal-fired Power Stations Using Imported Coal

Regarding the coal transportation for the planned power stations in Maowa and Khulna regions, it is considered to import coal by 5,000 DWT-class barge via Chittagong Port. However, the maximum depth at Chitaggong Port is shallow at merely 9.1 m and cannot accept Panamax vessels which need at least 15 m depth. Therefore, these power stations may switch to the utilisation of CTT.

The draft PSMP2015 assumes only the power stations in Matarbari North area as the targets of CTT, but the Coal Power Generation Company Bangladesh Limited (CPGCBL) plans to use CTT for all plants except Matarbari Units No.1 and No.2. Therefore, this feasibility study assumes that CTT will target all Matarbari Region's projects except Units No.1 and No.2 and will bring coal directly to their own coal storage facility.

The Moheshkhari area has several issues including construction cost for route extension, treatment of soil and sand due to the construction work and other environmental concerns. Since the timing of routs extension is uncertain, the JICA Study Team will examine the utilization of belt conveyor system for Moheshkhari Units No.1 and No.2, which is requested by CPGCBL. Regarding Units No.1 and No.2, the operation will start in 2018 and the concrete plan is yet to be made. However, CPGCBL expressed a likely option to transport coal from the CTT to power stations using a belt conveyor system. Furthermore, at the workshop with CPGCBL in Dhaka, Bangladesh expressed an interest to use CTT for all the planned units of Maheshkhali CFPPs. Bangladesh also indicated to be willing to consider using CTT for Rampal and Payra CFPPs if the use of CTT is beneficial, although those CFPPs planned to import fuel coal in their own way. (The 1st Phase of the project will target the original 3,600 GW of coal-fired generating units. However, the 2nd Phase of the project, which will start operation five year later of the 1st Phase, will be able to flexibly consider the amount of coal that CTT will treat. If the concrete projects and needs are indicated, it will be possible to examine the timing of the development of 2nd Phase.) For non-power sector utilization like brick factories, the coal will be supplied using 5,000DWT barge via Chittagong Port.

3.3.4. Examination of Coal Transshipment Terminal (CTT)

The MOUs signed between the Bangladeshi government and the sponsors regarding the commencement date of operation of the planned coal-fired power stations using imported coal are simply non-binding tentative agreements. Since most of the feasibility studies are executed after signing the MOUs, MOU-based commencement date of operation (COD) does not generally coincide with the COD based on actual construction procedure.

This study of CTT will consider the basis of the draft PSMP2015, the intention of the counterpart, and the estimated progress of infrastructure development. Table 3.2.6 lists the power stations in the draft PSMP2015 and the CTT plan that may use CTT.

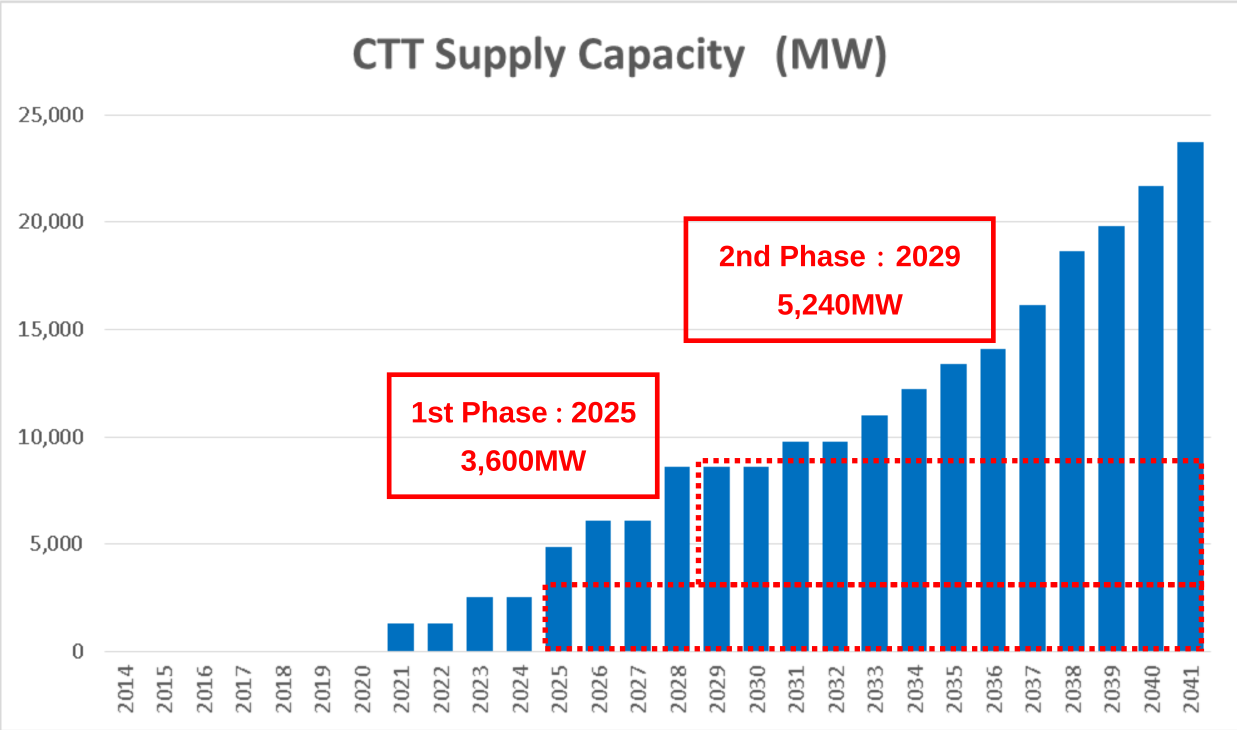
As explained above, the governmental plan does not coincide with the realistic date of operation commencement, and thus it is desirable to adopt a two-stage development plan so that the project can deal with the gradually increasing demand. In this Study, (as the first phase of the CTT will commence operation in 2025,) the object of 1st Phase will include the power stations that will commenced operation by 2029 and use CTT. The total generating capacity of these units will be 3,800 MW. The following 2nd Phase, which is planned to commence operation in 2030, targets plants with COD later than 2030, and the total generating capacity will be 5,240 MW.

Figure 3.3.5 shows the generating capacity (in MW) of power stations (units) that CTT will supply coal to, and Figure 3.3.6 shows the estimated amount of imported coal planned by the Bangladeshi government.

Table 3.3.6 List of Power Stations of the draft PSMP2015 and CTT Plan that May Use CTT

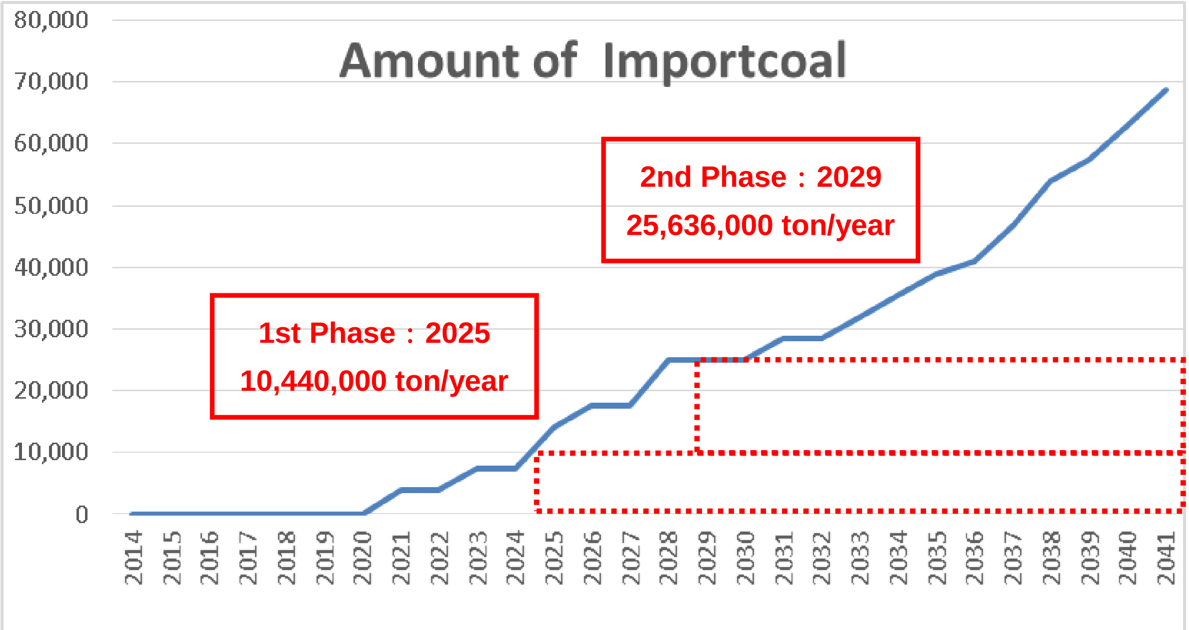
Name of Power Plant	Category	Capacity	COD	
Matarbari 1200 MW (Unit 3 & 4)	Public	1,200	2025	Phase-1
Matarbari 1200 MW (Unit 5 & 6)	Public	1,200	2026	Phase-1
Matarbari North 700 MW (Unit 7)	Public	700	2036	Phase-2
Matarbari North 700 MW (Unit 8)	Public	700	2037	Phase-2
Matarbari North 1200 MW (Unit 9& 10)	Public	1,200	2038	Phase-2
Moheskhali 1200 MW (Unit 1 & 2)	IPP	1,200	2028	Phase-1
Rampal 1320 MW (Unit 1 & 2)	Public	1,320	2021	Phase-2
Payra 1320MW (Unit 1 & 2)	Public	1,320	2028	Phase-2
Phase -1 total	MW	3,600		
Phase-2 total	MW	5,240		
Total	MW	8,840		

Source：JICA Study Team based on draft PSMP2015 (as of Jan 2016)



Source: JICA Study Team based on draft PSMP2015 (as of Jan 2016)

Figure 3.3.5 Generation Capacity of Power Generation Plan Using Imported Coal based on PSMP2015



Source: JICA Study Team based on draft PSMP2015 (as of Jan 2016)

Figure 3.3.6 Amount of Imported Coal Planned by Bangladeshi Government

The construction program for a new coal-fired power station using imported coal must satisfy important factors such as site acquisition, consent of local residents, various technical issues, procurement of construction cost, fuel procurement, and transportation. Thus, it is difficult to make a precise estimate of the commencement date of operation. Therefore, it is recommended to have enough flexibility, for example, to expand the CTT when the power generation program is developed and the realistic COD becomes certain.

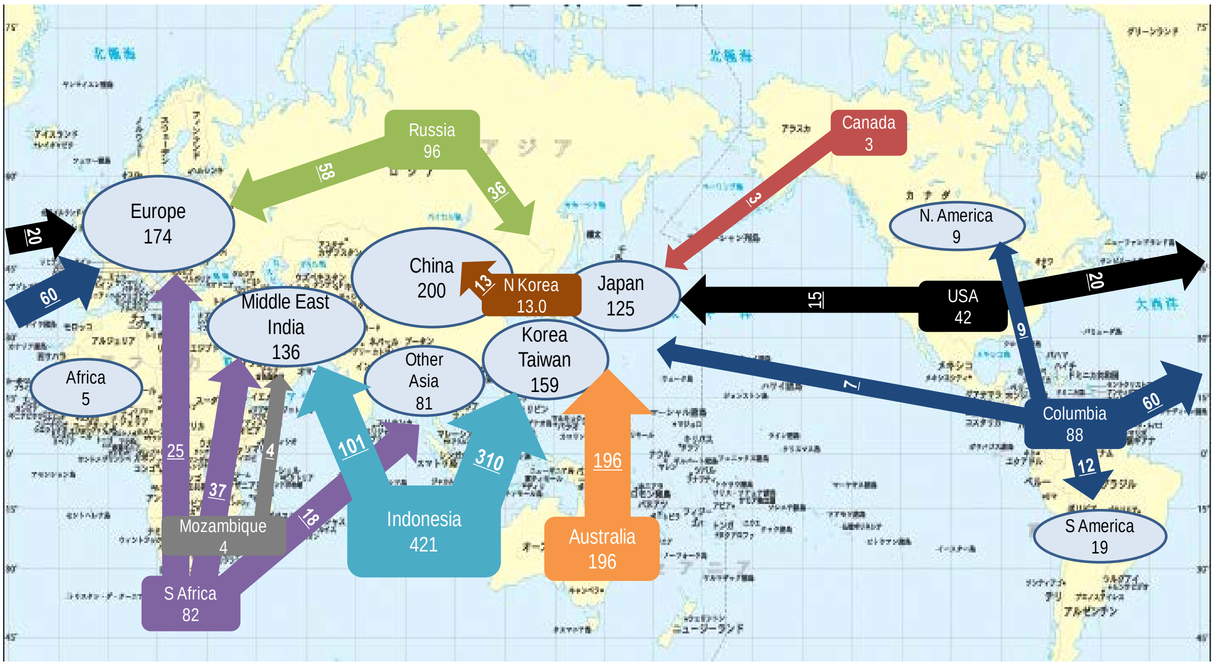
Chapter 4. Proposal of Optimum Planning of CTT

4.1. Coal Logistics Plan

4.1.1. Seaborne Market Supply and Demand as of 2014

As a starting point for the Coal Logistics Plan, the current and future production supply capacities of potential coal exporting countries are being studied.

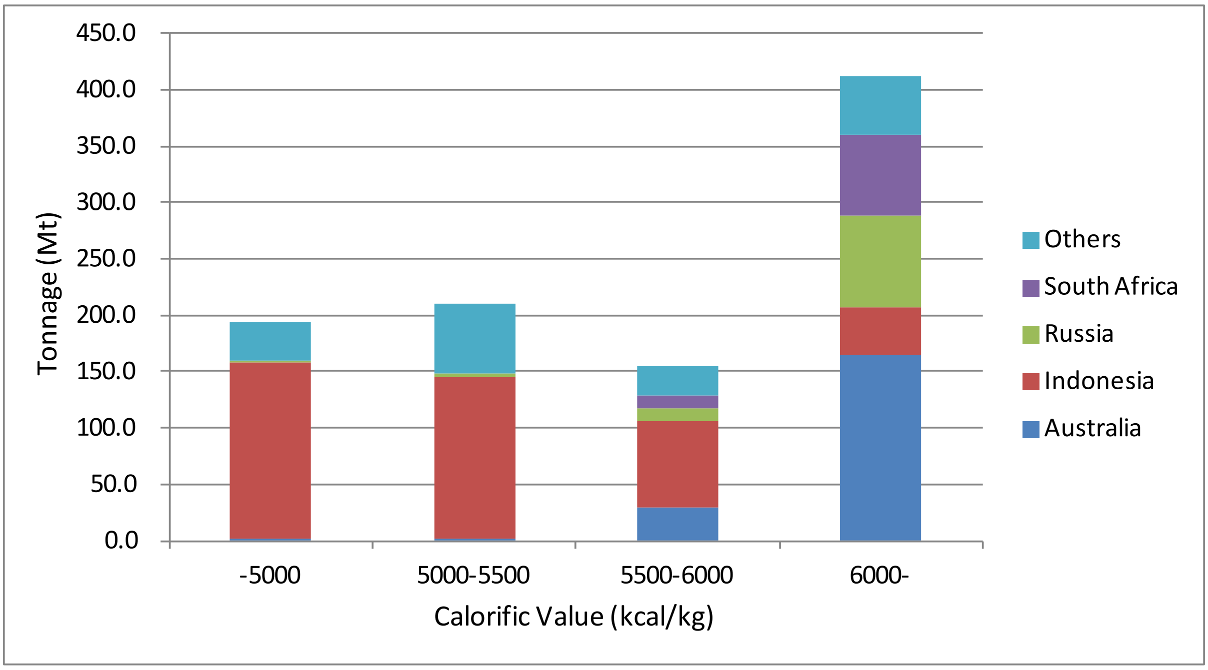
In 2014, the seaborne market of thermal coal is around 970 Mt. The largest exporter is Indonesia with export tonnage of 420 Mt, followed by Australia, Russia, Columbia, and South Africa. The cargo flow for 2014 is shown in Figure 4.1.1.



Source: JICA Study Team

Figure 4.1.1 Thermal Coal Seaborne Cargo Flow

The above tonnage is for the entire seaborne thermal coal and includes both bituminous and sub-bituminous coal. Main exporting countries and tonnages by calorific value range are shown in Figure 4.1.2. Coal that has a calorific value of 6,000kcal/kg or above has approximately 42% share of the entire seaborne market, however, for the largest exporter, i.e., Indonesia, only 10% of its tonnage has a calorific value of 6,000 kcal/kg or above, whereas more than 70% of its coal has a calorific value of less than 5,500 kcal/kg. This trend of decreasing production of higher calorific value coal should accelerate in the coming years.



Source: JICA Study Team

Figure 4.1.2 Thermal Coal Production in Calorific Values

4.1.2. Future Trend of Global Thermal Coal Supply and Demand

Until around 2020, Southeast Asian and South Asian countries such as India will face increase in demand, whilst this will be offset by decrease in Europe due to change of energy source from coal to renewable energy. This will lead to a slight increase in the total seaborne market volume, up to approximately 1 billion tones (bnt). Post 2020, the demand increase of approximately 50 Mt is expected year after year, bringing the seaborne market volume up to approximately 1.3 bnt in 2025, and 1.5bnt in 2030.

The breakdown of this 500 Mt increase towards 2030 is shown in Table 4.1.1.

Table 4.1.1 Coal Production Increase Towards 2030

Australia	210 Mt
Indonesia	120 Mt
United States	100 Mt
Columbia	50 Mt
Mozambique	10 Mt
South Africa	10 Mt
Canada	10 Mt
Russia	▲20Mt

Source: JICA Study Team

However, considering the location of Bangladesh, the United States, Canada and Colombia will be less competitive due to distance/freight, and the natural source will be Australia, Indonesia, Mozambique, and South Africa.

Australia has significant reserve and resource, and considering its quality, (although it may deteriorate from its current calorific value), it will be competent to produce coal in the range of 5,700 kcal/kg – 6,000kcal/kg. Subject to infrastructure construction such as rail and port, Australia will be capable of supplying the 210Mt mentioned above by opening up new coal basins such as Galilee Basin and Surat Basin.

On the other hand, as previously mentioned, the decrease of bituminous coal reserve is unavoidable. Although the production volume is expected to increase by approximately 120 Mt, the quality may further deteriorate. As a result, there is even a possibility that Indonesian coal will only be the imported sub-bituminous coal.

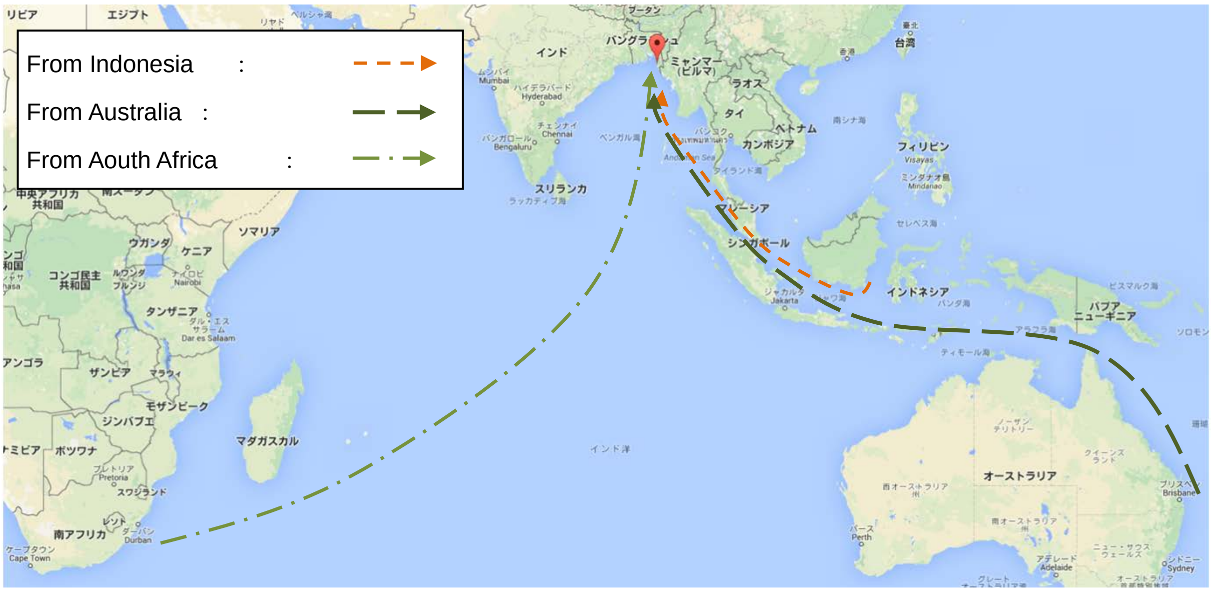
4.1.3. Coal Transportation Plan

(1) The coal supply sources, transportation from supply sources to CTT, type of vessels to be used and freight are studied.

1) Coal Loading Ports

Since the coal procurement policy of the Bangladesh government has not been fixed yet, the coal loading ports could not be specified. However, this study assumes that the coal will be imported from Australia, Indonesia, and South Africa (Mozambique is included in South Africa in terms of the transportation) as described above.

It will take about 19 days from the loading port of Australia, 8 days from Indonesia, and 17 days from South Africa up to CTT by ocean transportation.



Source : Google Map

Figure 4.1.3 Seaway from Australia, Indonesia, and South Africa

2) Vessel Type

Considering loading/unloading efficiency, it would be appropriate to have a certain amount of volume to be loaded. Therefore, this study is based on the assumption that vessels over 30,000DWT will be used for coal transportation. The type of vessel will be roughly as follows;

Cape Size	:	130,000-180,000 DWT
Panamax	:	63,000-80,000 DWT (Post Panamax: 100,000 DWT)
Handy	:	30,000-55,000 DWT (30,000 DWT vessel is smaller than the general Handy, however, the vessel from 30,000-55,000DWT is called Handy in this study because the freight would be the same level.)

Many coal loading ports are designed for larger vessels than Panamax and therefore, the port equipment is designed to accommodate Cape Size and Panamax which do not have vessel crane. Since vessel crane can be an obstacle in changing the holds during loading and unloading, it is normal that vessel with crane is not allowed to enter into the ports in Australia.

Currently, the gateway port of Bangladesh, Chittagong Port, is not handling coal. Even if Chittagong Port will handle coal, the vessel size should be limited to 20,000 DWT due to the shallow draft. In case of coal transportation to Bangladesh by 20,000 DWT vessels, 700 trips/yr to import 14 Mt of coal per year in the 1st Phase and 1,450 trips for 29 Mt of coal in the 2nd Phase would be necessary, making it impractical to import coal using 20,000 DWT vessels.

3) Ocean Freight Cost

The rough estimation of the ocean freight cost is shown in Table 4.1.2. Although Cape Size is not supposed to be used for CTT, this rough estimation of the ocean freight cost is for Cape Size and Panamax vessels.

Table 4.1.2 Ocean Freight COST by Vessel Type

This information includes trade secrets.

Source：JICA Study Team

The above figures are calculated based on the vessel operational costs and are higher compared with the figures based on the current maritime market. Although the actual freight cost should be subject to the maritime market, it would be practical to calculate based on the operational costs from the long-term perspective. The ocean freight cost is fluctuating according to oil price but the freight cost difference between the vessel types will not change. Therefore, the larger size vessel will basically lead to reduce the ocean freight cost per tonne. The estimated figures above do not include both the loading fees at the loading port and the unloading fees at CTT.

For the chartering cost, which is necessary to calculate the ocean freight cost, the market prices at the time of this report are around USD 4,000/day and USD 6,000/day for Handy and Panamax, respectively. The market trend for the past 10 years is shown in Figure 4.1.4 and seeing this, the current market price is at a rather low level. In this section, the ocean freight cost is calculated based on the assumption that the chartering costs are USD 15,000/day and USD 20,000/day for Handy and Panamax, respectively, considering the shipbuilding cost.

This information includes trade secrets.

Source: JICA Study Team

Figure 4.1.4 Chartering Cost per Day

Table 4.1.3 shows the summary of the ocean freight cost per year based on the assumed yearly coal volume to be transported to CTT for the 1st Phase and 2nd Phase.

Table 4.1.3 Ocean Freight Cost/year (Comparison Between Vessel Type）

This information includes trade secrets.

Source：JICA Study Team

This information includes trade secrets.

Table 4.1.4 Number of Vessels and Capacity at the end of 2014

DWT	10,000 - 40,000		40,000 - 65,000		65,000 - 100,000		100,000 +	
	No. of vessel	000DWT	No. of vessel	000DWT	No. of vessel	000DWT	No. of vessel	000DWT
Total	**2,415**	**69,476**	**2,793**	**149,069**	**2,240**	**177,639**	**1,545**	**288,805**

Source：JICA Study Team

Amongst the abovementioned 10,000-40,000 DWT vessels, about 200 units of 20,000 DWT-30,000 DWT vessels are supposed to be operating in Southwest Asia. On the other hand, if 29 Mt/yr of coal will be imported to Bangladesh, it is necessary to dedicate 120 numbers of 20,000 DWT vessels with the assumption of 12 round trips per year (21 days per one round trip). Even if such numbers of vessels can be arranged, the dedication of these vessels to this CTT project is quite significant, which may affect the maritime market. Also, considering the necessity to expand the number of berths at CTT and the demurrage occurring due to congestion, 20,000 DWT vessels would be an impractical option.

Taking into consideration of the analysis above, the practical way of coal delivery would be the transshipment at CTT, which is the deploy of Panamax or Handy size vessels from coal loading ports to CTT and then delivery by small vessels and/or belt conveyor from CTT to each CFPP. The chartering contract will be concluded to secure the Panamax or Handy size vessels for the certain term and numbers. Since there’s enough supply in the market, no problem is expected to secure the vessels if the necessary preparation is made with the appropriate timing.

4.1.4. Secondary Transportation Plan

(1) Secondary Transportation

The imported coal will be stored at the CTT for a certain period of time and then will be transported to power plants near CTT by belt conveyor during the 1st Phase and to power plants far from the CTT by small vessels and/or barges with tug boat during the 2nd Phase. The coal transportation to the far power plants from CTT during the 2nd Phase by vessels and/or barges is called as secondary transportation and is studied in this section. However, since the secondary transportation is assumed to be under each coal-fired power plant’s (CFPP) scope, this study should be for reference purpose only.

Amongst the CFPPs which need secondary transportation, Rampal CFPP and Payra CFPP in Khulna are selected to be studied as described in Chapter 3. The study for Maowa CFPP and Mushunganj CFPP along the Megha River and Chittagong CFPP should be for reference purpose only.

It would be efficient if secondary transportation can be done by large vessels; however, as a result of the hearing from the local shipping companies, river transportation in Bangladesh is through small vessels which are mainly 1,000 DWT and the available maximum capacity is 3,200 DWT. Therefore, it is difficult to find similar example in Bangladesh as a reference for the CTT project’s secondary transportation. The desirable vessel for practical and efficient secondary transportation would have the following points:

i) Large vessel as much as possible
ii) Stability which can allow outer sea navigation (Bengal Bay)
iii) Shallow draft which can allow river navigation

In order for the stable navigation, the draft of the vessel should be deep to some extent, on the other hand, the deep-draft vessel has a difficulty in the river navigation.

Also, for the efficient operation and cost minimization of the secondary transportation, the vessels should be as large as possible. In this sense, the suitable vessel for the secondary transportation should be selected considering the climate condition of Bengal Bay, draft of the river, and the limitation of the navigation due to river width.

In addition to the next section (2), as a result of the survey of the limiting factors for river navigation, the suitable vessel type is considered as per Table 4.1.5 below. It is assumed that self-propelled vessels are deployed for the safe navigation on the Bengal Bay. The vessel types under this section are considered to be suitable just from the viewpoint of the limiting factors for navigation and the design of CTT is made under the assumption that 5,000 DWT vessels will be deployed.

Table 4.1.5 Suitable Vessel Type for each CFPP

	Rampal	Payra	Maowa / Mushunganj	Chittagong
DWT	6,100	8,500	2,000	20,000
Draft	5m	7.5m	3.6m	8.5m
LOA	128m	90m	82m	140m
Width	No limitation	No limitation	13m	No limitation

Source: JICA Study Team

(2) Hydrographic Conditions in Bangladesh

The Mongla Port and Chittagong Port, which are the main ports of Bangladesh, were closed for 31-40 days per year (about 10%) from 2007 to 2011 according to the data from the Bangladesh Inland Water Transport Authority (BWTA), which means that about 90% of 365 days would have loading and unloading operations at the port.

Bangladesh is located in an area affected by frequent tropical cyclones. Although it varies year by year, according to the Regional Specialised Meteorological Centre (RSMC) of India Meteorological Department (IMD), cyclones occur for 3-10 days/yr from 2005 to 2014 and 0-3 cyclones/yr might affect the river navigation. It is impossible to measure and predict the disturbance of the navigation because the scale, wind directions, and period will vary from time to time. But assuming that cyclone disturbance would be for about 5 days and three cyclones occur per year, it seems that the disturbance due to cyclone will be about 15 days/yr.

Table 4.1.6 Number of Closed Days of Mongla Port (2007-2011)

SI No	Month	Number of Closed Days				
		2007	2008	2009	2010	2011
1	January - March	0	0	0	0	0
2	April	4	3	2	4	1
3	May	6	5	3	5	5
4	June	8	6	5	7	5
5	July	5	5	7	8	6
6	August	3	6	5	3	4
7	September	6	4	4	6	6
8	October	4	3	4	5	4
9	November	…	1	2	…	…
10	December	…	…	…	…	…
Total days in a year		36	33	32	38	31
Percent (%) of a year		9.9	9.0	8.8	10.4	8.5

Source：JICA Study Team

Table 4.1.7 Number of Closed Days of Chittagong Port（2007 - 2011）

SI No	Month	Number of Closed Days				
		2007	2008	2009	2010	2011
1	January - March	0	0	0	0	0
2	April	4	3	3	4	1
3	May	6	5	5	5	5
4	June	8	6	7	7	5
5	July	5	5	7	8	6
6	August	3	6	6	3	4
7	September	6	4	5	6	6
8	October	4	3	5	5	4
9	November	…	1	2	…	…
10	December	…	…	…	…	…
Total days in a year		36	33	40	38	31
Percent (%) of a year		9.9	9.0	10.7	10.4	8.5

Source：JICA Study Team

Table 4.1.8 Number of Cyclones that Occurred in Bengal Bay

	LAND	D	DD	CS	SCS	VSCS	SuCS	Total	Number of Cyclonic Disturbance Which Might Affect Bangladesh River Operation
2005	1	2	3	4	0	0	0	10	0
2006	1	5	2	1	0	1	0	10	2
2007	0	3	4	1	0	1	0	9	3
2008	1	1	2	3	0	1	0	8	3
2009	0	0	2	2	1	0	0	5	3
2010	0	2	1	0	2	1	0	6	2
2011	1	2	2	0	0	1	0	6	2
2012	0	0	2	1	0	0	0	3	1
2013	1	3	0	1	1	3	0	9	3
2014	2	2	1	0	0	1	0	6	N/A
Total	7	20	19	13	4	9	0	72	

LAND: Any tropical depression formed on the land.

D: Depression with wind speed between 17 and 27 kt (31 and 51 km/h)

DD: Deep Depression with wind speed between 28 and 33 kt (52 and 61 km/h)

CS: Cyclonic storm with wind speed between 34 and 47 kt (62 and 88 km/h)

SCS: Severe cyclonic storm with wind speed between 48 and 63 kt (89 and 118 km/h)

VSCS: Very severe cyclonic storm with wind speed between 64 and 119 kt (119 and 221 km/h)

SuCS: Super cyclonic storm with wind speed 120 kt (222 km/h) and above

Source：JICA Study Team

(2) Trial Calculation of the Secondary Transportation

This information includes trade secrets.

This information includes trade secrets.

4.2. Preliminary Site Selection of the CTT

4.2.1. Basic Policy for the Basic Layout Plan of Major Port Facilities

(1) Consistency with the Land Use Plan of the Surrounding Area

The layout plan should match the development plan of the CFPPs in the surrounding area, residential areas, environmental reserve areas, inundation areas during floods, and soil condition. Above all, the effect to the existing habitat should be minimized.

(2) Availability of Future Expansion

There is a future development plan of the commercial port. Accordingly, the layout plan of the port facilities of the CTT should not constrain future expansion. The south area of the main channel is to be left for future expansion and the additional quay walls are mainly to be located at the north side of the main channel. In case additional quay walls have to be located on the south side of the main channel, they are to be aligned so as to maintain the possibility of future development.

(3) Economic Efficiency

Since a large amount of excavation or dredging is required for construction of a port of this type, the layout plan of the port facilities should be designed so as to minimize the water area in the port. The main channel of the CFPP would be commonly used for the CTT in order to avoid additional maintenance dredging or anti-sedimentation measures.

(4) Efficiency of Operation

For the improvement of port operational efficiency, the movement of vessels in the port should be minimized. To enhance efficiency and safety, the maneuvering area for large vessels and the one for small vessels should be separated as much as possible. The distance between the berths and stock area should also be minimized for efficient land side operation.

4.2.2. Site Selection of the CTT

(1) Scope of CTT Facilities

The CTT facilities are as follows:

- Coal unloading berth
- Coal loading berth
- Expansion of inner harbour for Matarbari CFPP
- Coal stockyard
- Belt conveyor from unloading berth to coal stock yard

Although secondary transportation facilities to surrounding CFPPs are not within the scope of CTT but of the CFPPs, they are studied conceptually in this study to consider more efficient operation of the CTT project.

(2) Layout of the CTT Facilities

1st Phase

The layout plan for the 1st Phase is especially considered to minimize the effect to the surrounding society and environment, since early start of operation is required in Bangladesh. Each facility is explained below.

1) Coal Unloading Berth

It is possible to allocate the coal unloading berth at the northern side and southern side of the inner harbour for Matarbari CFPP. However, the southern side of the harbour area is limited since there are many habitats, and expansion of the existing harbour area is required to develop new unloading berth. In order to avoid resettlement of inhabitants in the southern side of the harbour, it is recommended to allocate new coal unloading berth at the northern side of the inner harbour.

In order to install the unloading berth, it is required to expand the inner harbour for the Matarbari CFPP for maintaining enough space in the inner harbour.

2) Coal Loading Berth

The coal loading berth for large barge is not installed in the 1st Phase because coal is only supplied to nearby CFPPs such as Matarbari area or Moheshkali area. Although secondary transport methods to CFPPs should be studied for each CFPP, it is recommended to use belt conveyor or small barge which can navigate behind the river.

The expected secondary transportation methods are shown in Figure 4.2.1 and Figure 4.2.2. In case small barges will be used, construction of small facilities for coal loading and dredging works for broadening and deepening the Kohelia River are required. In case of using conveyor belt, more than 5-6 km long conveyor belt will be necessary to connect the CTT with the CFPPs.

Figure 4.2.1 Expected Loading Facilities and Small Barges

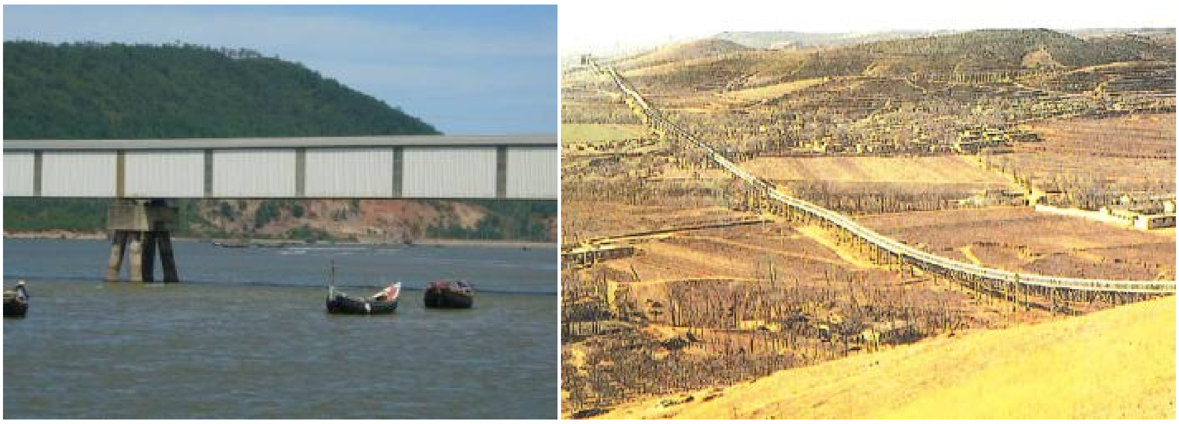


Figure 4.2.2 Examples of Conveyor Belt

3) Coal Stockyard

As mentioned in Chapter 4.4, coal stockyard of about 45 ha is required for the 1st Phase. Three locations of coal stockyard for the 1st Phase are selected as candidates

1. Northern Side of Inner Harbour for Matarbari CFPP

There are many habitats around the site. It is required to conduct reclamation of the sea area in order to avoid resettlement of the habitats. However, sea reclamation is not employed because of environmental problem.

2. Seaside at the Southern Side of Inner Harbour for Matarbari CFPP

There are also many habitats around the southern side of the turning basin for Matarbari CFPP, but it is possible to ensure enough area at the seaside without resettlement of the habitats. However, according to the environmental impact assessment (EIA) of the Matarbari CFPP, a habitat of sea turtle, which is listed as endangered species, exists in the area. Therefore, large environmental impact is expected.

3. Riverside at the Southern Side of Inner Harbour for Matarbari CFPP

Although there are also many habitats around the southern side of the turning basin for Matarbari CFPP, it is possible to ensure enough area at the riverside without resettlement of the habitat. Large-scale involuntary resettlement is not estimated since applicable countermeasures such as layout or dust protection wall will be employed.

As a result, No. 3 site is selected. According to the preparatory social survey shown in Chapter 11.2, it was confirmed that there are four villages with 467 households and 2,576 people in the south side of Matarbari CFPP. The layout and coordinates of the coal stockyard without large-scale involuntary resettlement are considered as shown in Table 4.2.1 below. Therefore, involuntary resettlement are not occurred. The details of the environmental and social consideration study are mentioned in Chapter 11.

Table 4.2.1 Coordinates of Coal Stockyard Location for 1st Phase

Point	Latitude	Longitude
1－A1	21°41'16.54"N	91°52'19.51"E
1－A2	21°41'16.54"N	91°52'23.44"E
1－A3	21°41'22.66"N	91°52'23.44"E
1－B1	21°41'00.72"N	91°52'19.51"E
1－B2	21°41'00.72"N	91°52'24.66"E
1－B3	21°40'55.68"N	91°52'24.66"E
1－C	21°40'55.68"N	91°52'36.94"E
1－D	21°41'22.66"N	91°52'36.94"E

Source: JICA Study Team based on Google Earth Pro

Figure 4.2.3 Layout of Coal Stockyard for the 1st Phase

4) Belt Conveyor from Unloading Berth to Coal Stockyard

In order to transport imported coal from the unloading berth allocated at the northern side to the stockyard at the southern side, belt conveyor is installed in front of Matarbari CFPP. The belt conveyor is located so as not to disturb the operation of the CFPP. Type of belt conveyor is closed type to avoid dust.

5) Layout of CTT Facilities

The following Figure 4.2.4 shows the layout plan of the CTT in the 1st Phase. Required facilities for the CTT are shown below.

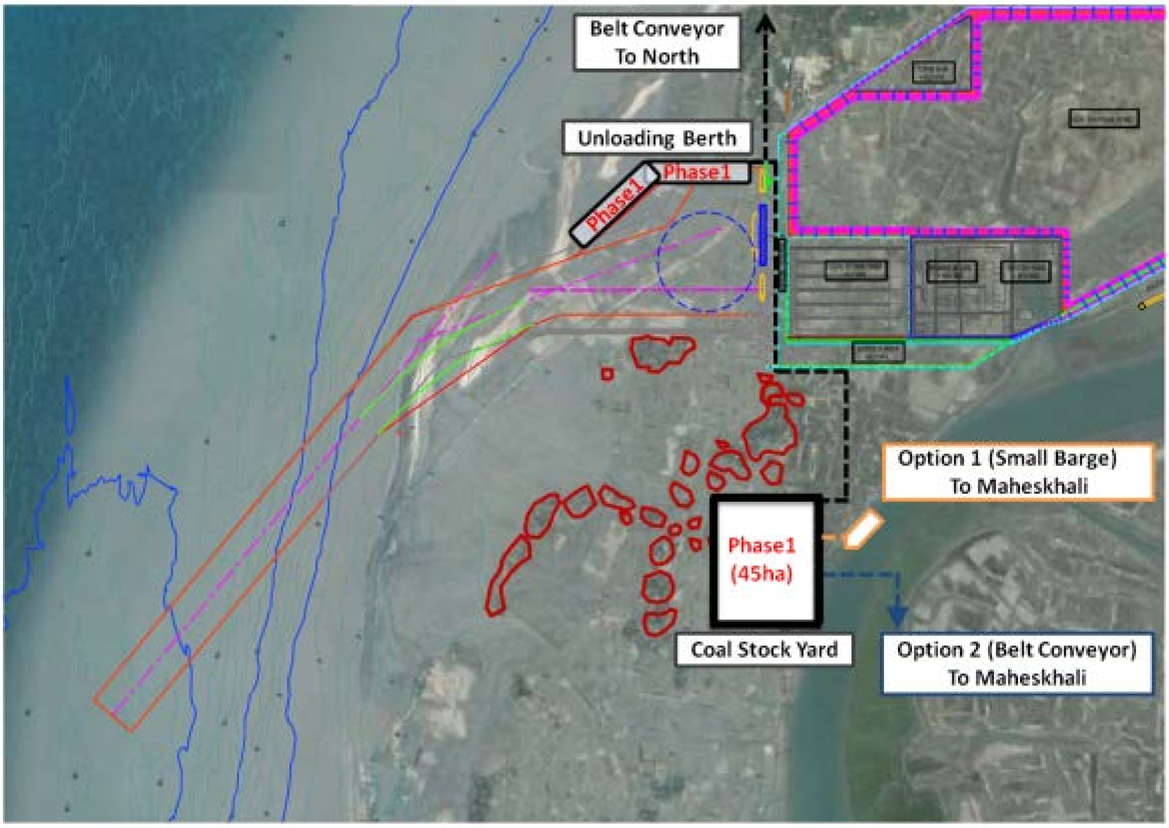


Figure 4.2.4 Layout Plan in the 1st Phase

2nd Phase

The required facilities are additional facilities to those of the 1st Phase and coal loading berth to transport to faraway CFPPs in Bangladesh.

There are several options for the determination of the layout plan for the 2nd Phase depending on the requirement or non-requirement of resettlement before the implementation of the 2nd Phase. In this study, the case where resettlement has not been conducted until the start of the 2nd Phase study is employed as the "Base Case". If resettlement has been conducted based on other applicable studies, alternative plan is also considered.

(A) Base Case: "Resettlement has not been conducted until the start of the 2nd Phase study."

1) Coal Unloading Berth

Unloading berth is allocated at the northern side of the inner harbour for Matarbari CFPP to avoid adverse environmental impact on residents at the southern side of the turning basin for Matarbari CFPP.

2) Coal loading berth

As mentioned in Chapter 4.3, four loading berths are required for the transportation to faraway CFPPs. The loading berth is allocated at the southern side of the channel for Matarbari CFPP.

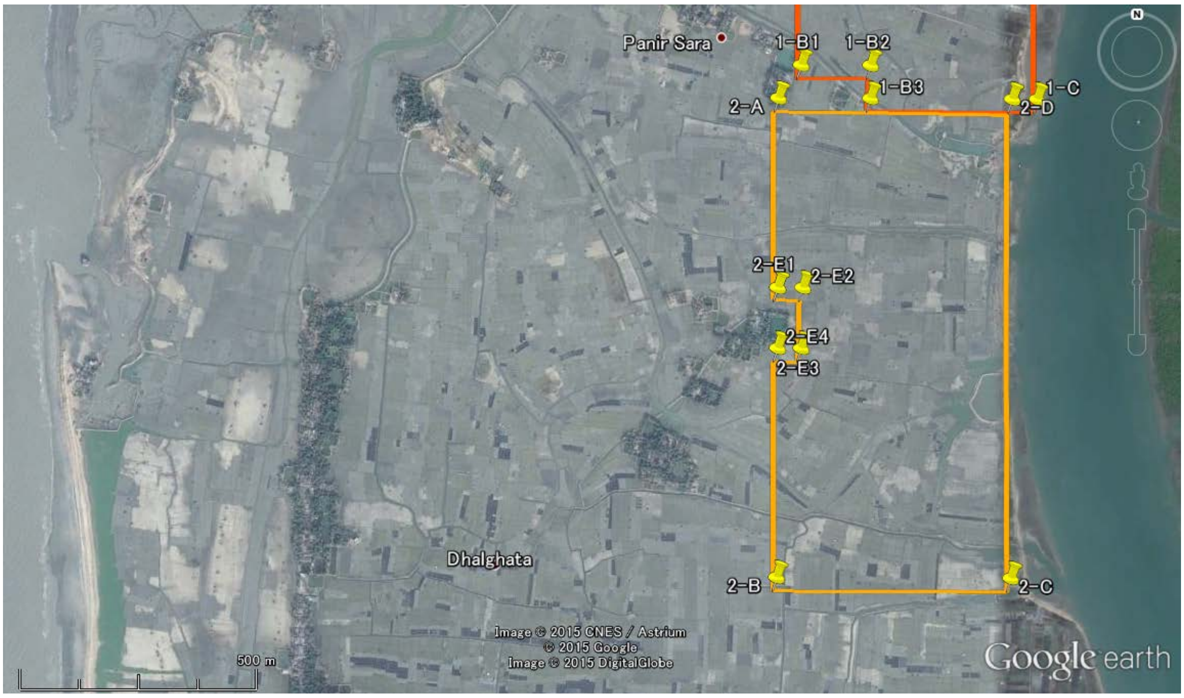
3) Coal stock yard

As mentioned in Chapter 4.4, the required area of the coal stockyard in the 2nd Phase is 50 ha. The concept of the layout is the same as for the 1st Phase which is considered to avoid negative impact on the surrounding environment. Therefore, the coal stockyard in the 2nd Phase is allocated at the southern side of the 1st Phase yard. The coordinates and layout are respectively shown in Table 4.2.2 and Figure 4.2.5 below.

Table 4.2.2 Coordinates of Coal Stockyard Location in 2nd Phase

Point	Latitude	Longitude
2－A	21°40'55.68"N	91°52'17.91"E
2－B	21°40'23.00"N	91°52'17.91"E
2－C	21°40'23.00"N	91°52'35.10"E
2－D	21°40'55.68"N	91°52'35.10"E
2－E1	21°40'42.76"N	91°52'17.91"E
2－E2	21°40'42.76"N	91°52'19.75"E
2－E3	21°40'38.63"N	91°52'19.63"E
2－E4	21°40'38.63"N	91°52'17.91"E

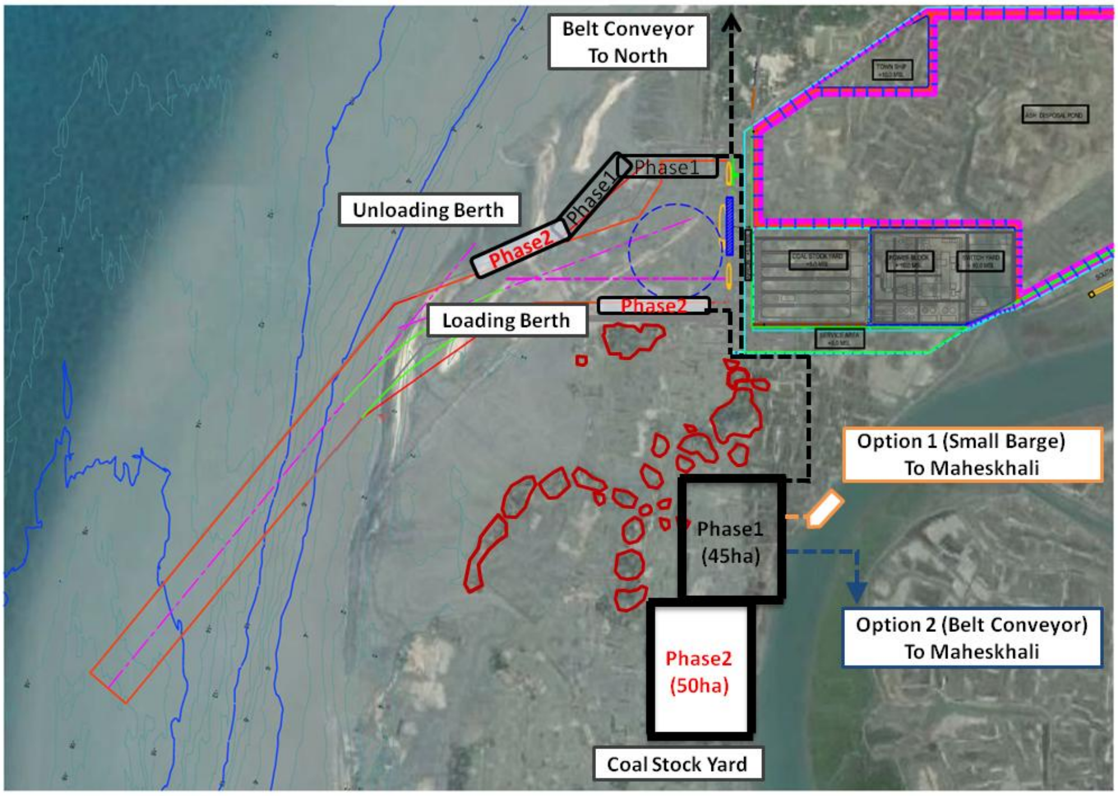
Source: JICA Study Team



Source: JICA Study Team Based on Google Earth Pro

Figure 4.2.5 Layout of Coal Stockyard in the 2nd Phase

The following Figure 4.2.6 shows the CTT layout plan in the 2nd Phase.



Source: JICA Study Team based on Google Earth Pro

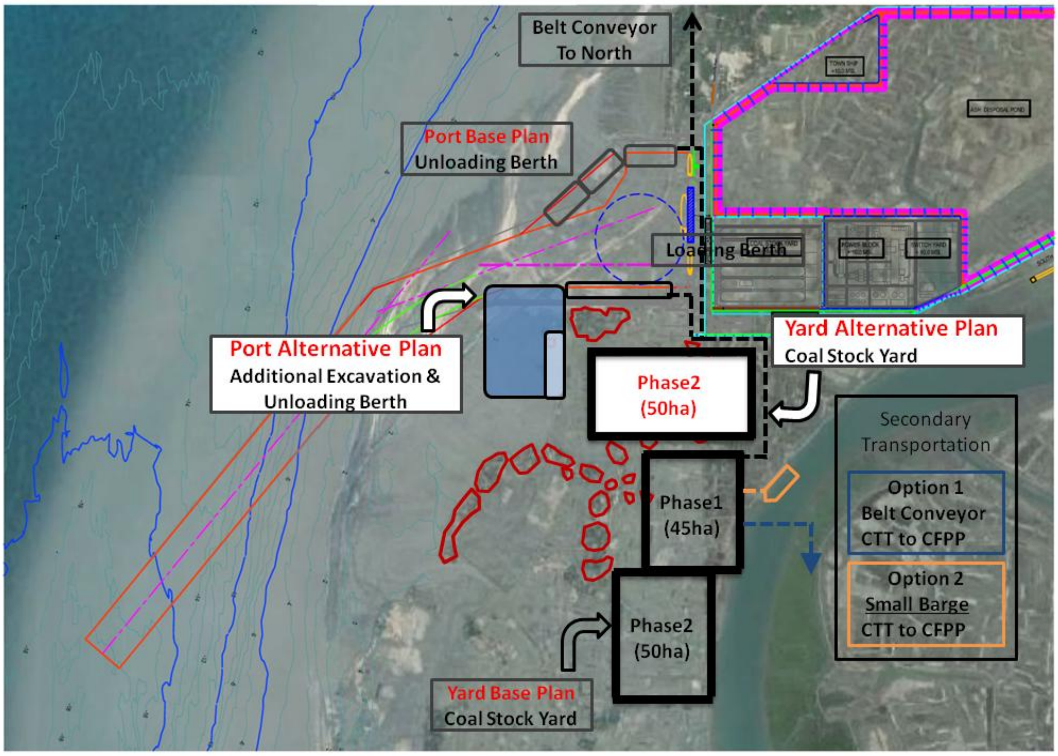
Figure 4.2.6 Layout of CTT in the 2nd Phase

<u>(B) Alternative Plan: “Resettlement has been conducted before the start of the 2nd Phase.”</u>

In case that resettlement has been conducted before the start of the 2nd Phase, large ship berths can be located along the south side of the main channel. The new berth should be developed by expanding the main channel southward as shown in Figure 4.2.7. Future expansion is possible by excavating further southward. The distance between the new berth and the coal stockyard would be longer than in the other layout plan. However, additional cost of dredging works is expected.

In the study and verification survey on the comprehensive development of southern Chittagong Region in Bangladesh, the proposed site is planned to develop as energy basis. If the plan will progress, it will require large-scale resettlement in the Matarbari area. Therefore, the alternative plan is adopted depending on the progress of these projects.

As mentioned in chapter 6, the construction in the 2nd Phase is estimated to start from 2025. Therefore, it is necessary to judge the adoption of this alternative plan before 2021. As mentioned in the preparatory social survey shown in Chapter 11.2, there are four villages with 467 households and 2,576 people in the south side of Matarbari CFPP. Therefore, the project proponent should formulate the land acquisition and resettlement action plan (LARAP) after having thoroughly surveyed in light of Bangladesh legal requirement as well as JICA Guidelines for Environmental and Social Considerations. The required action in detail is shown in Chapter 11.5.



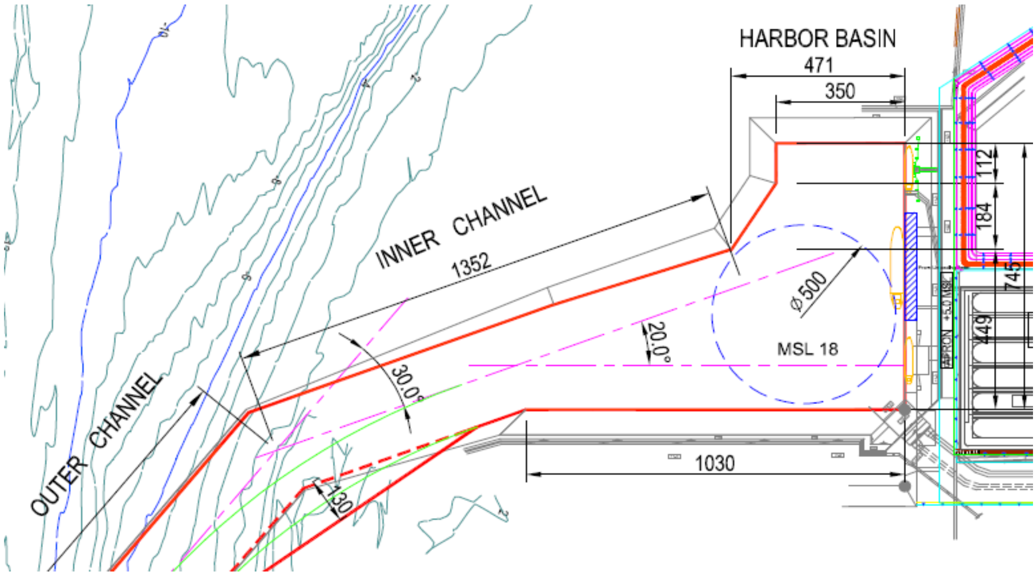
Source: JICA Study Team

Figure 4.2.7 Alternative Layout of CTT in the 2nd Phase

4.3. Determination of Port and Terminal Layout Plan

4.3.1. Port Development Plan of the Matarbari CFPP Project

The port facilities of the CTT are to be developed by fully utilizing the basic facilities such as the main channel, and basin, which are being developed in the Matarbari CFPP Project.



Source: Report of Basic Design for Matarbari Coal Fired Power Plant

Figure 4.3.1 Layout Plan of Deep Sea Port for Matarbari CFPP

In the feasibility study of the CFPP, the target vessel type for deciding the size of the port facilities is proposed as follows:

Class (DWT)	80,000
Length L (m)	230
Breadth B (m)	37.0
Draft D (m)	14.5

The following basic port facilities are included in the CFPP Project:

Main Channel:	Breadth	250 m (1L)
	Length	Excavation of land area 1,350 m (5L)
		Dredging water area 2,500 m
	Depth	-18.0m MSL
Basin:	Turning basin with a diameter of 500 m (2L) is located in front of the coal berth.	
	Depth -18.0 m MSL	
Coal Unloading Berth:		
	Length	300 m
	Depth	-18.0 m MSL
Oil Berth:	Length	150 m
	Depth	-7.5 m
Unloader:	Capacity	800 t/h 2 unit

There is only one coal unloading berth for large vessels in the port. When a large coal carrier is berthing at the port, no other large coal carrier is allowed to enter the access channel. It is estimated to take four days for a large vessel from the time it enters the access channel to the time it exits the entrance channel. In this way, a large vessel does not encounter another large vessel in the channel.

In the previous Japanese Standard, the width of a single-way waterway should be more than 0.5 L (L: the overall length of the ship =250 m). The proposed plan complies with this standard. There are many other standards related to the width of the waterway based on B (breadth of ships). The majority of these standards stipulate that the necessary width of single-way waterway should be 4~6 B (=150 m ~ 224 m). The proposed plan also satisfies such standards. The proposed width of 250 m (1 L) is expected to be sufficient as a single-way waterway.

In the previous Japanese Standard, the area of the basin for turning the bow of a ship should exceed the area of a circle with a radius of 1.0 times the overall length of the ship in case of using an anchor or tugboats. The turning basin could be placed just in front of the coal berth since no other vessel is berthing when a vessel turns in the basin.

Regarding the calmness of the basin, the critical wave height in front of the berthing facilities is designed as 1.0 m with a calmness factor of 96%. This is in line with the previous Japanese Standard which states that the critical wave height for cargo handling by a large vessel should be 0.7~1.5 m, and that cargo handling should be possible 95~97.5% or more of the year. The critical wave height of the entrance of the channel is evaluated as 1.5 m with a calmness factor of 96%.

There is no description for the target vessel type for the oil berth or the number of vessels expected to be accommodated.

In the feasibility study of the CFPP, the annual volume of imported coal is estimated as 373,000 t. The average capacity of the coal carriers calling at the port is estimated as 76,000 t/yr. Consequently, the average number of vessel calls is calculated at 49/yr. If the average dwell time for a coal carrier in the port is four days, the berth occupancy rate will be 55% (4.0 x 49/356 = 0.55), which is rather high compared with the United Nations Conference on Trade and Development (UNCTAD) standard (40%). The average waiting time for entering the port is estimated as 2.5~5.0 days which would be unacceptable for merchant vessels such as container ships. In the case of coal carriers, however, it may be within an acceptable range considering that it takes more than 50 days for one navigation cycle for importing coal from Australia.

	λ (=49/356)	μ (=1/4.0)	ρ	wQ
M/M/1	0.138	0.25	0.55	4.93
M/D/1	0.138	0.25	0.55	2.46

Since the number of operators of coal carriers calling at the port is limited, the average waiting time could be lowered by arranging the optimum calling schedule. In addition, the average berthing time could be curtailed by introducing an additional unloader or by replacing the current unloader with one with a greater handling capacity. This would also contribute to decreasing the average waiting time. More efficient utilisation of the port facilities by combining operations of the CTT with the CFPP would also lead to shorter average waiting times.

Although there is no description in the feasibility study of the CFPP, it is necessary to secure the water area outside the port for anchorage of vessels waiting to enter the access channel of the port. According to the previous Japanese Standard, a basin used for anchorage or mooring should have a water area exceeding the area of a circle with a radius of L+6D+30 m (=250+6x16+30=376 m) for one vessel. Judging from the nautical chart, it seems possible to secure the required anchorage area.

4.3.2. Condition for Port Layout Planning

(1) Handling Volume of Coal in Target Years

Forecast volumes of coal imports described in Chapter 3.3.3 are used in planning of port facilities for the CTT. Transshipment coal volume of 8Mt is for planned CFPPs at Rampal and Payra as are shown in Chapter 3.3.3 which have four units of 600MW. Matabari CFPP No.1 and No.2 have their own coal import facilities and thus, coal from the CTT is not required; however, the other CFPPs planned in the vicinity of the CTT are supposed to be supplied from the CTT through belt conveyors. Table 4.3.1 shows the import and transshipment volumes of coal to plan the port facilities.

Table 4.3.1 Import and Transshipment Volumes of Coal (Unit: Mt)

Year	Import Volume	Supply by Land Transportation	Transshipment Volume
2025	10.40	10.40	0.00
2029	25.60	17.60	8.00

Source: JICA Study Team

The CTT project will be developed based on a phased plan. According to the increment of coal volume, the target year of the 1st Phase is 2025 and that of the 2nd phase is 2029.

(2) Design Vessel

1) Vessel for Coal Importation

The CTT is expected to utilize basic port facilities such as the channel and basin constructed for the CFPP project. Accordingly, the design vessel for the CTT is assumed to be the same level with that of the CFPP. The design vessel adopted for the Matabari CTT project is the 80,000 DWT class Panamax-type with the following specifications.

DWT	80,000
LOA (m)	230.0
Beam (m)	37.0
Draft (m)	14.5

2) Vessel for Transshipment

A vessel of 5,000 DWT is planned to be introduced for the transshipment to the CFPPs in the other areas from CTT, considering the size of the domestic shipping fleet, efficiency of transshipment, and navigability of the access channel to the CFPPs. Therefore, design vessel for the loading berth is set as follows:

Specifications of the design vessel

DWT	5,000
LOA (m)	109.0
Draft (m)	6.4
Beam (m)	17.0

Specifications of the coal loading berth

Length (m)	130.0
Depth of Water (m)	7.5

(3) Conditions on Coal Handling

1) Capacity of Unloader and Loader

The capacity of the unloader and loader installed at the quayside is generally determined by the handling volume of coal, scale of the stockyard, and economic efficiency. Generally, unloaders with a capacity of 1,000~2,500 t/h are deployed. In the feasibility study of the CFPP, two unloaders with the capacity of 800 t/h are equipped for one berth. More than one unloader will be necessary for each berth considering regular maintenance and repair in case of trouble. Given the projected cargo volume of 3.75 Mt/yr, this plan is appropriate.

In case the volume of coal increases further, there are two choices: one is to increase the capacity of the unloaders, whilst the other is to increase the number of berths. As the coal volume being handled at the berths increases, the capacity of the belt conveyor and stacker/reclaimers should also be increased. Life cycle cost including operation and maintenance cost should be considered when upgrading the facilities

It will be necessary to construct new berths if there is no other existing berth which could be utilised for coal handling. This is a far costlier option than increasing the capacity of unloaders. According to a preliminary estimation, in case two unloaders with a capacity of 800 t/h are deployed for each berth, three berths in total will be necessary in 2025, and six berths in 2029. On the other hand, in case of deploying unloaders with a capacity of 2,500 t/h, only two berths would be necessary in 2025, and three berths in 2029. Investment cost for berth construction could be greatly reduced.

In this study, considering the result of the design vessel, the unloader should meet the following conditions:

Capacity: 2,500 t/h for unloading
Unloading Efficiency: 70% (Based on the result of the feasibility study of the CFPP)
Number: Two unloaders per berth

Considering the result of the feasibility study of the CFPP and the size of the design vessel, the loader for transshipment should meet the following conditions:

Capacity: 1,500 t/h for loading
Loading Efficiency: 90%
Number: One loader per berth

Table 4.3.2 Specification of Coal Handling Equipment

	Unloader		Loader
	Matabari CFPP	CTT	CTT
Capacity (t/h)	800	2,500	1,500
Number / Berth	2	2	1
Efficiency (%)	70	70	90

Source: JICA Study Team

2) Operational Days per Year and Working Hours per Day

A coal loading/unloading port is usually operated through the year on a round-the-clock basis. Although the operation of the CTT should be examined in consideration of the rules and regulations of Bangladesh, the following conditions are set in this study:

i) Operation days per year

Operation days per year are usually determined in consideration of days of rough weather, days for maintenance, and special holidays in the case of other bulk terminals. In this study, operation days per year are set at 350 days. However, operation days per year of the coal loading facilities are set at 300 days in consideration of the annual operation rate of the barges for coal transshipment.

ii) Working hours per day

Based on a three-shift working system, working hours per day are usually determined in consideration of time for meal breaks, resting, takeover, and maintenance and so on in the case of other bulk terminals. In this study, working hours per day are set at 18 hours.

(4) Calmness of the port

Considering the operating rate of coal handling and stability of mooring, 97.5% calmness is determined. The planning area is excavated into the land area and enclosed by land. Accordingly, a calmness factor of 97.5 % or more is secured in the water area.

4.3.3. Port Facilities Planning

(1) Method of Determining the Required Number of Berths

The number of berths to cope with the handling volume is calculated using the following formula.

Number of berths = Berthing days per year / (Operation days per year x Berth occupancy ratio)

Hereto;

Berthing days per year = Number of calling vessels per year x Average berthing days per vessel
Number of calling vessels per year = Handling volume per year / Average carrying volume per vessel
Average berthing days per vessel = (Average carrying volume per vessel /Average handling capacity per day) + Idling days

(Note: as this method uses the average value, the peak ratio is sometimes not adequately taken into account.)

Regarding berth occupancy ratio, "Port Development – A handbook for planner in developing countries" issued by UNCTAD indicates the advisable berth occupancy ratios as shown in Table 4.3.3 in the case of break bulk cargo berth. These ratios should not be exceeded.

Table 4.3.3 Berth Occupancy Ratio

Number of Berth	Berth Occupancy Ratio
1	40 %
2	50 %
3	55 %
4	60 %
5	65 %
6 - 10	70 %

Source: "Port Development − A handbook for planner in developing countries -) by UNCTAD

In this study, the required number of berths is to be determined from a comprehensive point of view taking into account the above figures, average waiting time of vessels computed by a queuing theory and other factors.

(2) Required Number of Coal Unloading Berths

1) 1st Phase: Handling volume of coal is 10,400,000 t/yr.

Average carrying volume of a Panamax vessel is set as 76,000 t with an estimated loading efficiency of 0.95. These figures are the same as in the feasibility study of the CFPP.

Required hours for unloading 76,000 t of coal are calculated as follows. The preparation time between the shifts is set at 2 hours and other idling time is set at 6 hours, which includes procedures for entering and departing the port, vessel maneuvering in the port, and mooring and unmooring.

Number of shifts: 4 (76,000 / (2,500 x 2 x 0.7 x 6) = 3.6)
Average berthing hours: 35.7 hours (1.49 days) (76,000 / (2,500 x 2 x 0.7) + 2 x 4 + 6 = 35.7)

4h	2h	6h	2h	6h	2h	6h	2h	3.7h	2h

Total number of calling vessels is calculated as follows:

Number of calling vessels per year: 137 (10,400,000 / 76,000 = 136.8)

In case there is only one berth, the berth occupancy rate is calculated as follows:

137x 1.49 / 350 = 0.583

This far exceeds the advisable berth occupancy ratio by UNCTAD (40%). Average waiting time of vessels is estimated to fall within the range of 0.96 to 1.91 days. This is too long considering the average service time for vessels (1.49days) and thus not acceptable

Two berths are necessary to meet the UNCTAD standard. The berth occupancy rate is 29.2% (0.583/2=0.292) and the average waiting time drops between 0.06～0.13days.

	λ (=137/350)	μ (=1/1.49)	ρ	wQ
M/M/1	0.391	0.671	0.583	1.911
M/D/1	0.391	0.671	0.583	0.956
M/M/2	0.391	0.671	0.583	0.128
M/D/2	0.391	0.671	0.583	0.064

2) 2nd Phase: Handling volume of coal is 25,600,000 t.

Design vessel and the method to determine the number of berths are the same as in the 1st Phase.

Average berthing days: 1.49 days
Number of calling vessels per year: 337 (25,600,000/76,000 = 336.8)
Number of berths: 3 ((337 x 1.49 / 350 = 1.43) / 3 = 0.478)

Therefore, the required number of coal unloading berths in the 2nd Phase is set as three and berth occupancy ratio becomes 47.8 % which satisfies the criteria of UNCTAD. The average waiting time of vessels is calculated to fall within a range of 0.10～0.20 days.

	λ (=337/350)	μ (=1/1.49)	ρ	wQ
M/M/2	0.963	0.671	0.717	1.562
M/D/2	0.963	0.671	0.717	0.781
M/M/3	0.963	0.671	0.478	0.202
M/D/3	0.963	0.671	0.478	0.101

(3) Required Number of Coal Loading Berths

The method to examine the required number of coal loading berths is the same as that used for unloading berths. However, due to the incremental weather condition in the monsoon season, operational days for the transshipment by barges or small vessels would be limited to 300 days.

1) 1st Phase: Transshipment volume of coal is zero tonne per year.

All imported coal is expected to be transported to the nearby CFPPs with belt conveyors. No loading berth is required.

2) 2nd Phase: Transshipment volume of coal is 8,000,000 t/yr.

Idling time for a 5,000 DWT transshipment vessel is much less compared with unloading vessels because such vessels are used for domestic shipping only. Therefore, idling time is set at around 2 hours. The number of berths is calculated as follows:

Average berthing time: 0.32 days ((5,000 / (1,500 x 0.90) + 2 = 5.7 hr) / 18 = 0.317)

1.5h	3.7h	1.5h

Number of calling vessels per year: 1,600 (8,000,000/5,000 = 1,600)
Number of berths: 4 ((1,600 x 0.317 / 300 = 1.691) / 4 = 0.423)

The number of berths is four and berth occupancy ratio becomes 42.3%, which is far lower than the criteria of UNCTAD. Average waiting time of vessels is estimated to fall within the range of 0.02 to 0.04 days, which is a relatively short period of time compared with the average berthing time of 0.32 days. In case that the number of berths is two, berth occupancy ratio becomes 55.9%, which exceeds the criteria of UNCTAD and average waiting time of vessels is estimated to range from 0.06 to 0.13 days. This means that the figures exceed the average berthing time so it may not be possible to cope with the demand. Therefore, the required number of coal loading berths in the 2nd phase is four.

	λ (=1,600/300)	μ (=1/0.317)	ρ	wQ
M/M/3	5.33	3.15	0.564	0.075
M/D/3	5.33	3.15	0.564	0.038
M/M/4	5.33	3.15	0.423	0.015
M/D/4	5.33	3.15	0.423	0.007

Remarks: Average waiting time of vessels in this report is calculated using the computational function in the website (http://queueingtoolpal.org/). Under the assumption that distribution of the arrival ratio follows Poisson distribution and that of the berthing time follows exponential distribution or constant, computational calculation is conducted. Although no data on port activities are obtained because facilities are still in the planning stage, actual waiting time of vessels seems to fall within the range of the two figures.

(4) Capacity of Approach Channel

The capacity of the approach channel shall be examined as follows;

In the channel, two large ships are allowed to pass each other. Vessels entering the port transit the channel and turn in the turning basin and come alongside the berth. During this transit time, the next vessel should not enter the channel. In case of departing the port, vessels leave berths, turn in the turning basin and progress out the channel. During this transit time, no other vessel shall leave the berth. The average waiting time for a large vessel to enter the access channel could be estimated by queueing theory under the assumption that distribution of the arrival ratio follows Poisson distribution and that the berthing time is constant.

Necessary time for a vessel from the entrance of the access channel to come alongside the berth (transit time) could be estimated as 1.0 hr for both large and small vessels.

In the 2nd Phase plan, the annual number of vessels entering the port is 337 large vessels, 1,600 small vessels, and 1,937 in total. If large vessel calls as well as small vessel calls are concentrated within 300 days in the year, the channel occupancy rate is estimated as 35.9%.

The average waiting time for entry to the access channel is estimated as 23 min by M/D/1, and 46 min by M/M/1 model.

	λ (=1,937/300)	μ (=18/1.0)	ρ	wQ
M/M/1	6.46	18.0	0.359	0.031
M/D/1	6.46	18.0	0.359	0.016

In case two large ships are not allowed to pass each other, the channel occupancy rate will further increase. To estimate this effect, one large ship is assumed to be equivalent to two small ships. The converted number of the ships comes to (337 x 2 + 1,600) = 2,274 and the channel occupancy rate becomes 2,274 / (18 x 300) = 0.421 whilst the average waiting time is estimated as 32 min (0.022 x 24 x 60) by M/G/1 model and 62 min (0.040 x 24 x 60) by M/M/1.

	λ (=2,350/300)	μ (=18/1.0)	ρ	wQ
M/M/1	7.83	18.0	0.435	0.043
M/D/1	7.83	18.0	0.435	0.022

The average transit time consists of channel transit time and turning time as estimated below;

Channel outside the port: 2.5 km / (5 kt = 9 km/h) = 0.28 h
Channel inside the port: 1.4 km/ (2 kt = 3.6 km/h)= 0.38 h
Turning and mooring: 0.3 h

Actual transit time is expected to be less than 1 hr.

In the estimation above, calls of large ships are concentrated within 300 days; however, they are actually distributed within 350 days. This alleviates congestion to some extent.

In addition, the estimated time above treats the transit time of small vessels the same as that of large vessels; however, small vessels could turn and moor before the turning basin if berths for small vessels are located close to the entrance of the port. Accordingly, the transit time could be considerably shortened for small vessels.

Accordingly, the capacity of the access channel is sufficient even in the long-term stage.

(5) Impact on Existing Plan of Matarbari CFPP

It is required to expand the inner harbour in the existing plan of Matarbari CFPP since CTT is necessary to be installed at the expansion area of the inner harbour. Although it is expected to remove the constructed revetment for Matarbari CFPP in case the construction of CFPP started earlier than CTT, it is possible to proceed without the removal of the revetment by discussing the construction plan with Matarbari CFPP.

Construction of CTT is estimated not to impact on the operation of Matarbari CFPP, because the COD of Matarbari CFPP is in September 2013 and the construction of the unloading berth for CTT is almost completed.

4.3.4. Staged Development Planning

The staged plan for port and terminal planning is proposed as follows. The plan is divided into two phases based on increasing coal demand.

(1) 1st Phase Development Plan

The 1st Phase development plan for the target year of 2025 is shown in Table 4.3.4.

Table 4.3.4 1st Phase Development Plan (Excluding the CFPP)

Coal Demand		10.40 Mt	
Port Facility		Unloading Berth	Loading Berth
	Design Vessel	Over Panamax (80,000 DWT)	-
	Berth (Number, Length Depth)	(2,300 m,16 m)	(-,-,-)
	Approach Channel (Breadth, Depth)	(250 m,16 m)	—
	Turning Basin (Depth)	16.0 m	-
	Handling Equipment	Unloader 4 Capacity 2,500 t/h	
Layout of Port and Terminal		Figure 4.3.2	

Source: JICA Study Team

The coal unloading berths (300 m x 2) can be located at the north side of the turning basin as shown in Figure 4.3.2. Since all the large ship berths will face the turning basin, effective berthing/leaving is possible. The distance between the berths and coal stockyard could be minimised. Since more than one large vessel will stay in the port, it is necessary to secure a turning basin that is 50 m apart from the quay wall in order to let a large vessel turn whilst another vessel is at berth. Expansion of the water area of 8.5 ha including 1.7 Mt of dredging is necessary.

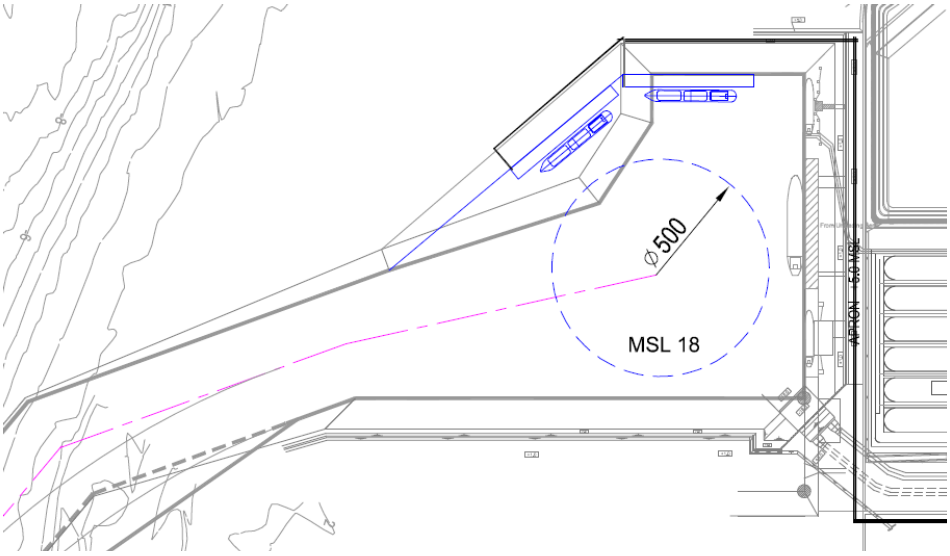


Figure 4.3.2 Layout Plan of Coal Unloading Berth in the 1st Phase

(2) 2nd Phase Development Plan

The 2nd Phase Development Plan for the target year of 2029 is shown in Table 4.3.5.

Table 4.3.5 2nd Phase Development Plan (Excluding the CFPP)

Coal Demand		25.56 Mt	
Port Facility		Unloading Berth	Loading Berth
	Design Vessel	Over Panamax (80,000 DWT)	5000 DWT
	Berth (Number, Length Depth)	(3,300 m,16 m)	(4,130 m, 7.5 m)
	Approach Channel (Breadth, Depth)	(250 m,16 m)	—
	Turning Basin (Depth)	(16.0 m)	(7.5 m)
	Handling Equipment	Unloader 6 Capacity 2,500 t/h	Loader 4 Capacity 1,500 t/h
Layout of Port and Terminal		Figure 4.3.3, Figure 4.3.4 and Figure 4.3.5	

1) Layout Plans of the Coal Unloading Berths

In the 2nd Phase Development Plan, one more coal unloading berth is required in addition to the one constructed under the 1st Phase Development Plan. It is possible to secure the necessary length of the water front line and water area of the mooring basin for the new berth as shown in Figure 4.3.3.

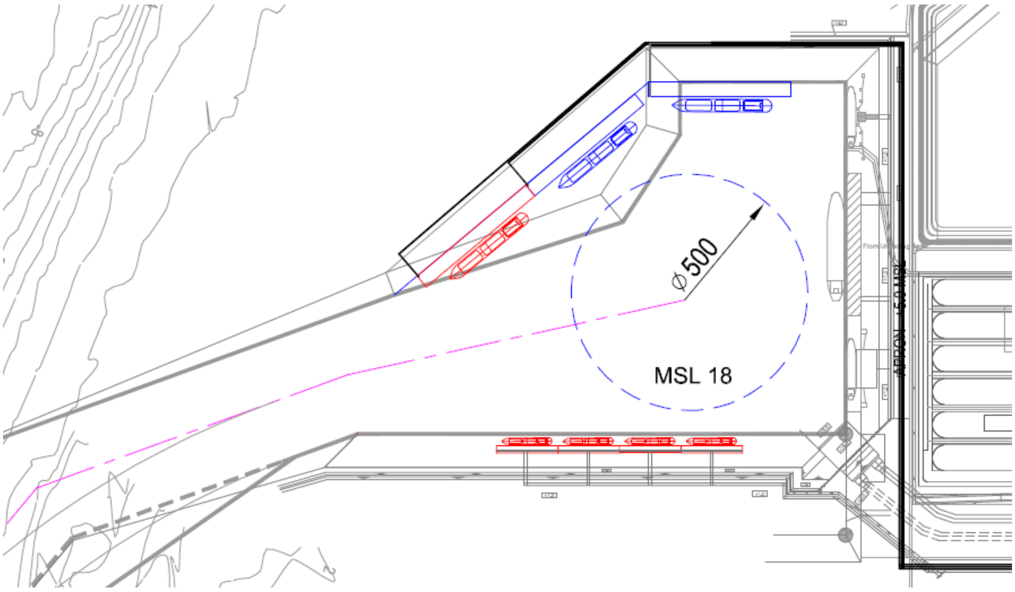


Figure 4.3.3 Layout Plan of Coal Unloading Berth in the 2nd Phase

In case that resettlement has been conducted before the start of the 2nd Phase, large ship berths can be located along the south side of the main channel. The new berth should be developed by expanding the main channel southward as shown in Figure 4.3.4. Future expansion is possible by excavating further southward. The distance between the new berth and the coal stockyard would be longer than in the other layout plan.

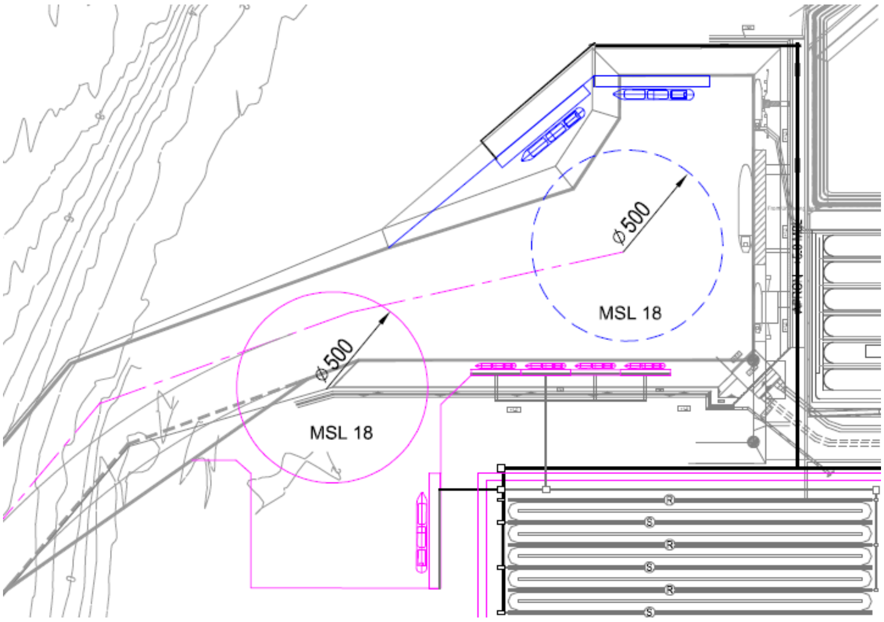


Figure 4.3.4 Alternative Layout Plan of Coal Unloading Berth in the 2nd Phase

2) Layout Plans of the Coal Loading Berths

Four coal loading berths are required in the 2nd Phase Development Plan. The coal loading berths could be located at the inner basin. It is relatively easy to secure the necessary space. However, further expansion of the unloading berths southward which could hinder future expansion should be considered.

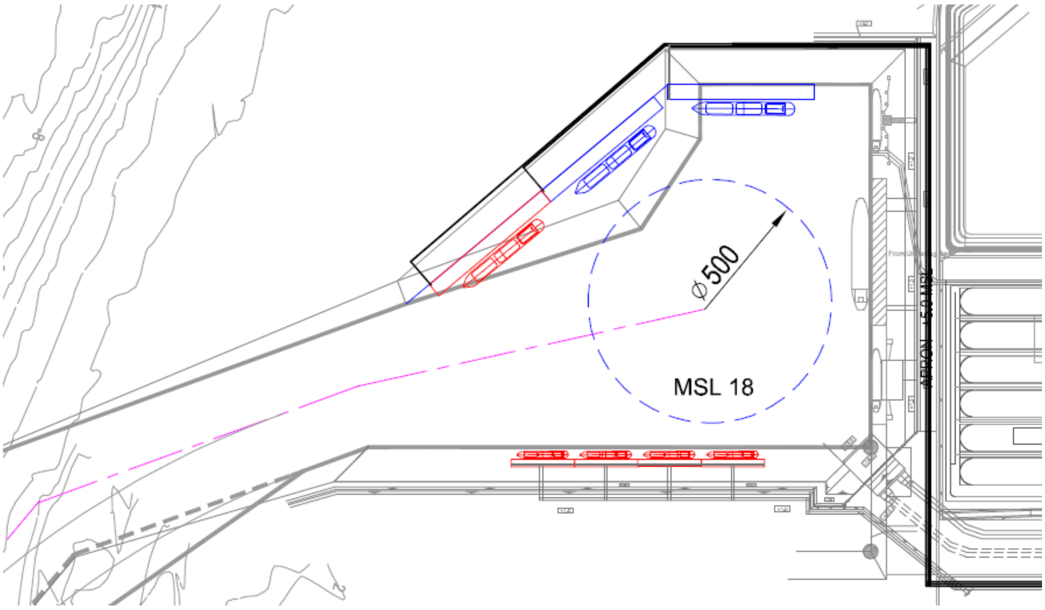


Figure 4.3.5 Layout Plan of Coal Loading Berth in the 2nd Phase

4.4. Determination of Terminal Layout Plan (Including Coal Handling and Conveying Equipment)

4.4.1. Coal Storage Facility

The coal storage facilities are roughly classified into two types, namely, outdoor coal storage and indoor coal storage. The outdoor coal storage is the appropriate type of stockyard for the project especially from the perspective of safety control against spontaneous combustion in handling sub-bituminous coal. (If bituminous coal such as Australian coal is the main coal source, the risk of spontaneous combustion is reduced. Therefore, the indoor coal storage type could be a candidate, although it is inferior from the viewpoint of cost competitiveness and required land space.)

(1) Type of Coal Storage

1) Indoor Coal Storage

For indoor storage facility, there are silo coal storage and roofed longitudinal coal yard as shown in Figure 4.4.1 below. Silo coal storage is adopted by plants with limited space and/or those with concern on the neighborhood environment. Roofed longitudinal coal yard is mainly adopted by plants with concern on the neighborhood environment.

However, the disadvantage of the silo coal storage type is greater construction and operation cost compared with outdoor coal storage type. The cost of the roofed longitudinal coal yard is smaller than that of the silo yard; however, the required land space is bigger than outdoor coal yard. The most important disadvantage of these indoor coal storage facilities is that they may cause a serious damage due to fire accident unless appropriate measures against spontaneous combustion are provided.

Silo Coal Atorage

Source：J-Power HP

Roofed Longitudinal Coal Yard

Source：Sakata Kyodo Power (Japan)

Figure 4.4.1 Indoor Coal Storage Facilities

2) Outdoor Coal Storage

Outdoor coal storage, such as that involving a stockpile, stackers, and reclaimers, is used for piling and delivering coal because of its advantage in terms of cost and convenience of handling operation, including its measure against spontaneous combustion. Therefore, this type of storage is used in many cases by steelworks and thermal power generation plants on large sites.

Disadvantage of the outdoor coal storage is that it requires appropriate coal dust control by equipping dust-control fence and by sprinkling with water. Besides, it requires bigger land space for coal storage than silo storage. (Required land space of outdoor storage is smaller than that of roofed longitudinal coal yard.)

Table 4.4.1 Comparison of Advantages and Disadvantages of Coal Storage Types

	Outdoor (Open Yard)	Indoor (Roofed Longitudinal)
Cost increase in relation to open yards of the same size	○：100%	△：220%
Land space increase in relation to open yards	△：100%	×：130%
Dust control	△：Appropriate measures are required	○：Very low
Safety control	○：Easy to control	△：Difficulty in handling of sub-bituminous coal (spontaneous combustion)

Source : JICA Study Team

(2) Spontaneous Combustion

When storing coal for an extended period of time, attention must be paid to the possibility of spontaneous combustion. The temperature inside a pile immediately after the piling is approximately 30 ℃ to 40 ℃, but it rises gradually due to the heat generated by the low-temperature oxidation of the coal. The temperature of a pile is determined by the balance of the heat of coal oxidation, the latent heat of water evaporation, and the heat dissipated from the pile by air flow. It is considered that the temperature continues to rise at a spot where heat generation dominates, which eventually leads to spontaneous combustion.

There are internal and external factors based on the characteristics of stored coal such as the size distribution, the amount of sprinkled water, and ambient temperature. It has been known that coal with strong oxidising properties, such as a high O/C ratio (the ratio of oxygen to carbon contained in coal), and large specific surface area is more prone to spontaneous combustion.

Coal with high O/C ratio such as brown coal and sub-bituminous coal is more prone to spontaneous combustion, and coal with low O/C ratio such as anthracite coal does not cause spontaneous combustion. Therefore, strict control against spontaneous combustion is required in this CTT since sub-bituminous coal is supposed to be mainly used.

(3) Spontaneous Combustion Management

As a spontaneous combustion management, appropriate prevention, monitoring and corrective actions are required. Unlike handling low O/C ratio coal such as typical Australian bituminous coal or Vietnamese anthracite coal, some preventive actions are required for typical Indonesian sub-bituminous coal; i.e. moist control by sprinkling water while loading coal, press compaction with dozer to reduce inflow of oxygen. However, these preventive actions are insufficient especially for Indonesian sub-bituminous coal, thus monitoring and corrective cooling actions are also required. As a cooling action, some measures are taken in a gradual manner based on temperature of coal stockpile; i.e. sprinkling water, injecting water to stockpile, removal of hot coal by shovel, removal and re-storage of whole coal stockpile.

As mentioned above, flexible stock management and strict safety control are required since serious damage may result in case spontaneous combustion occurs. Therefore, it is common to choose outdoor coal storage for handling sub-bituminous coal. Main coal type for indoor coal storage is generally limited to bituminous coal or anthracite coal. Therefore, usage of sub-bituminous coal is very restrictive with segregated management from bituminous coal in indoor storage.

Source: IEA Clean Coal Center Homepage

Source: Blair Athol Coal Mine

Figure 4.4.2 Spontaneous Combustion Accident

(4) Dust Control and Environmental Measures

For environmental preservation efforts for outdoor coal storage, it is required to reduce coal dust pollution by using dust proofing fences, net sheets, and automatic sprinkler system in addition to maintaining a wastewater treatment facility.

One coal center in Japan, i.e., Chubu Coal Center, established an environmental management system which complies with ISO 14001 in 2003 and has been operating according to that system to be a more socially responsible corporation.

Chubu Coal Center (Japan)

Dust Proofing Fence

Automatic Sprinkler System

Vacuum Dumper

Wastewater Treatment System

"Environmental Management System (EMS)" Registration Certificate

Source：Chubu Coal Centre

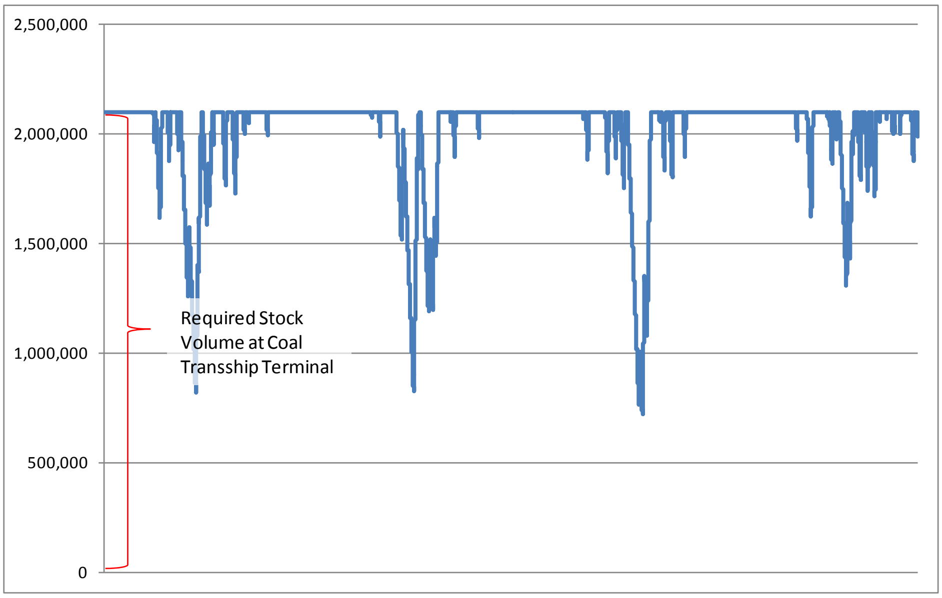
Figure 4.4.3 Environmental Measures in Chubu Coal Centre

4.4.2. Required Coal Stock Volume at Terminal

The following conditions for terminal planning are used.

- Coal handling volume at the terminal (stock): 10.40 Mt/yr for the 1st Phase, 23.60 Mt/yr for the 2nd Phase
- Specific gravity: 0.9
- Coal stock volume at terminal: 30 days
- Yard operation efficiency: 0.75
- Unloader: continuous type 2,500 t/h
- Ship loader: 1,500 t/h
- Stacker / reclaimer: 5,500t/h, 3,000 t/h
- Belt conveyor (unloading): 6,000 t/h
- Belt conveyor (discharging): 3,600 t/h

Figure 4.4.4 shows the examination results of required coal stock volume considering four-year offshore wave data from 2006 to 2010. It says 30-day coal stock can be sufficient for stable coal supply under the given wave condition. The threshold wave height for ship operation is determined to be 2.0 m based on the interview with a Japanese shipping company. Coal stock volume for the 2nd Phase is computed to be 2.10 Mt/month, which is 25.6 Mt/yr divided by 12 months, based on a 30-day coal stock.



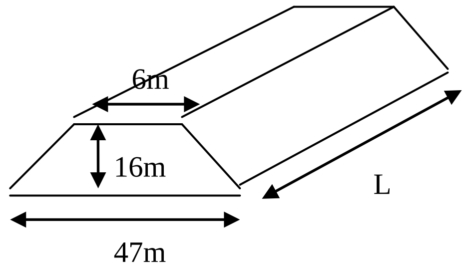
Source: JICA Study Team

Figure 4.4.4 Examination of Required Coal Stock Volume for the 2nd Phase Based on Wave Condition

4.4.3. Staged Development Planning

(1) Terminal Layout for the 1st Phase

The dimensions of the stockpile are determined as illustrated below.



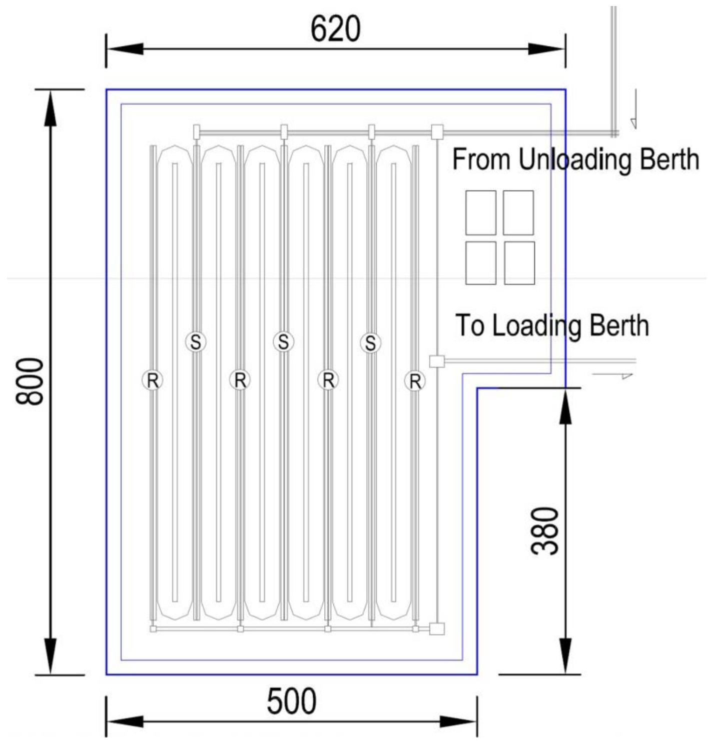
The sectional area is calculated as follows: A = (6 + 47) x 16 ÷ 2 = 424 m^2.

The coal stock volume, length, and number of stock piles, and required terminal areas for the 1st Phase plan are summarised in Table 4.4.2 below. It is assumed that coal will be transported through belt conveyor from the unloading berth to the CFPP, which a Singaporean enterprise has a plan to invest in and develop. Terminal layout is shown in Figure 4.4.5.

Table 4.4.2 Required Area of Coal Stockyard (1st Phase)

Coal Stock Volume (mil ton)	Yard Operation Efficiency	Length of Stockpile (m)	Number of Stockpile	Required Area of Coal Stockyard (ha)
0.90	0.75	600	6	45

Source: JICA Study Team



Source: JICA Study Team

Figure 4.4.5 Terminal Layout (1st Phase)

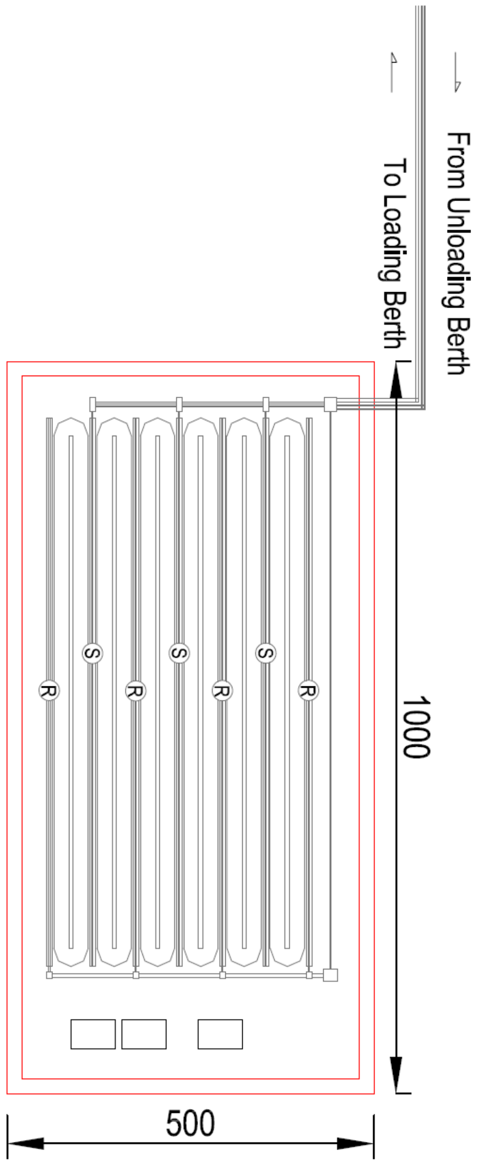
(2) Terminal Layout for the 2nd Phase

The coal stock volume, length, and number of stock piles, and required terminal areas for the 2nd Phase plan are summarised in Table 4.4.3 below. Terminal layout is shown in Figure 4.4.6.

Table 4.4.3 Required Area of Coal Stock Yard (2nd Phase)

Coal Stock Volume (mil ton)	Yard Operation Efficiency	Length of Stockpile (m)	Number of Stockpile	Required Area of Coal Stockyard (ha)
1.13	0.75	700	6	50

Source: JICA Study Team



Source: JICA Study Team

Figure 4.4.6 Terminal Layout (2nd Phase)

(3) Coal Handling and Conveying Equipment

The number and capacity of coal handling and conveying equipment in each phase are summarised in Table 4.4.4 below.

Table 4.4.4 Summary of Coal Handling and Conveying Equipment

		1st Phase	2nd Phase (to be newly installed)
Annual handling volume		10.4 Mt	13.2 Mt
Unloader	Continuous type 2,500t/h	4 nos	2 nos
Shiploader	1,500t/h	—	3 nos
Stacker	5,500t/h	4 nos	4 nos
Reclaimer	3,000t/h	3 nos	3 nos
Belt conveyor (unloading)	6,000t/h	3.9 km	8.4 km
Belt conveyor (discharging)	3,600t/h	8.9 km	6.5 km

Source: JICA Study Team

Maximum of three lines of belt conveyor are installed in this study. Each berth has one line belt conveyor for back up. The length of the belt conveyor is shown in Table 4.4.5 below.

Table 4.4.5 Belt Conveyor for 1st Phase

Belt Conveyor (m)		Length	nos	total
Unloading	Berth	350	1	350
		650	1	650
	Berth to Stock Yard	2,500	2	5,000
	Stock Yard	400	2	800
		700	3	2,100
Loadeing	Stock Yard	700	4	2,800
		400	1	400
		700	1	700
			Total	**12,800**

Source: JICA Study Team

Table 4.4.6 Belt Conveyor for 2nd Phase

Belt Conveyor (m)		Length	nos	total
Unloading	Berth	1,050	1	1,050
	Berth to Stock Yard	2,500	1	2,500
		800	1	800
	Stock Yard	400	2	800
		800	3	2,400
Loadeing	Stock Yard	800	4	3,200
		400	1	400
		800	2	1,600
	Stock Yard to Berth	2,100	1	2,100
			Total	**14,850**

Source: JICA Study Team

Chapter 5. Conceptual Design of Port and Terminal Facilities

Conceptual design is conducted to assess project costs of the main port and terminal facilities based on collecting data, or design planning from this study and "Matarbari Coal Fired Power Plant Study Report (hereinafter called Matarbari CFPP Study). At the stage of basic design or detailed design, it is necessary to survey in more detail and to revise design conditions or project planning based on the detailed survey results.

The studied main facilities for CTT are coal unloading berth, coal loading berth, reclamation and soil improvement for coal stock yard, foundation for coal handling equipment, dust protection fence, and pavement for yard and road. It is out of scope to design security fence, drainage facilities, drainage treatment facilities, water supply facilities, and buildings. Although these facilities are considered in cost estimation, the design of these facilities should be studied in the basic and detailed design stage after determining the detailed plan.

The design is based on Japanese design standard for port structure and British Standard (BS), rock manual or related standard in Bangladesh are used as reference.

5.1. Design Conditions

Design conditions include commonly applicable conditions at the site and specifically applied conditions for each specific structure. Commonly applicable natural conditions and design conditions at the site are shown in this section.

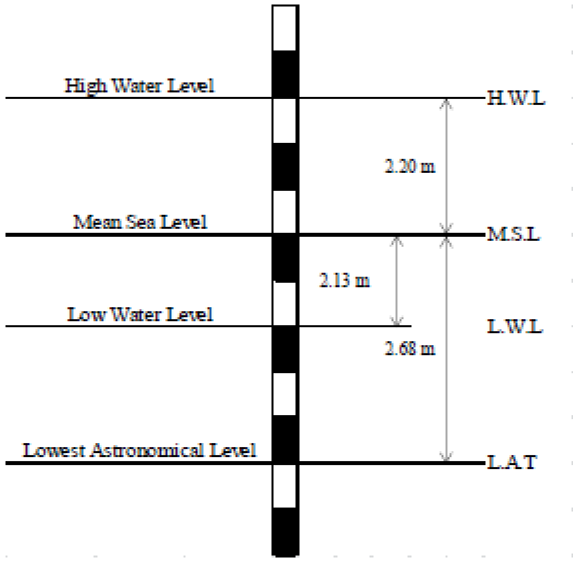
The natural conditions in this study set up the survey results of Matarbari CFPP Study.

5.1.1. Natural Conditions

1) Tidal level

According to the study for the Matarbari CFPP Study, the tidal levels based on the tidal observation from 9th September to 17th April, are shown in Figure 5.1.1 below. The relation between chart datum level (CDL) and national datum level in Bangladesh (PWD=EL=MSL) are also shown in Figure 5.1.1.

		CDL	EL(MSL)
HWL	:	+4.33m	+2.20m
MWL	:	+2.13m	0.00m
LWL	:	-0.00m	-2.13m
LLWL	:	-0.55m	-2.68m



Source: Matarbari CFPP Study

Figure 5.1.1 Relation between Chart Datum Level (CDL) and National Datum Level

2) Tidal current

The port type of Matarbari CFPP is the artificially excavated port. The location of coal wharf in this port was about 1.5 km landward from the harbour entrance. Therefore, the tidal current is not significant that current affects for the structure is not taken into account in the conceptual design.

3) Waves

The simulation results of the **calmness** in Matarbari CFPP Study show the wave height ratio at the north and south side in Table 5.1.1. From the result, offshore wave of 50 years return period is shown in Table 5.1.2. The maximum wave height based on 50 years return period of inner harbour is estimated as $H_{1/3}$ = approximately 2.6 m. Port facilities for CTT are planned to employ pile typed pier. It is estimated that waves are not significantly affected to piles. Therefore, it is not considered to affect the waves in this conceptual design for CTT.

Table 5.1.1 Wave Height Ratio at the Port

Area	Incident wave	$T_{1/3}$=6s	$T_{1/3}$=9s	$T_{1/3}$=12s
North Side	SW	0.37	0.48	0.47
	W	0.32	0.32	0.26
	WSW	0.40	0.42	0.45
South Side	SW	0.11	0.10	0.09
	W	0.08	0.12	0.06
	WSW	0.09	0.09	0.09

Source: JICA Study Team

Table 5.1.2 Significant Wave with Return Period of 50 Years

Wave direction	Significant wave height	Significant wave period
SW	5.45m	9.4s
SSW	6.69m	10.2s
S	6.03m	9.8s

Source: Matarbari CFPP Study

4) High Tide

According to the Matarbari CFPP Study, Matarbari area, southern Bangladesh, is a region that storm surge caused by infestation of cyclone occurs. The recorded storm surges by cyclones and the Bangladesh National Building Code (BNBC), and the height of the storm surge by statistical analysis are shown in Table 5.1.3 .

Table 5.1.3 Design Storm Surge Height

Range	25-year Return Period	50-year Return Period	Actual Result in period of near50 years	Remarks
Maximum	8.0 m	9.0 m	-	Statistical analysis results (Conservative Condition)
↕	-		7.6 m	Previous highest Record* (April 1991,Chittagong Patenga)
	-	7.1m	-	Standard of Bangladesh national code
Minimum	6.2m	7.0 m	-	Statistical analysis results (Critical Condition)

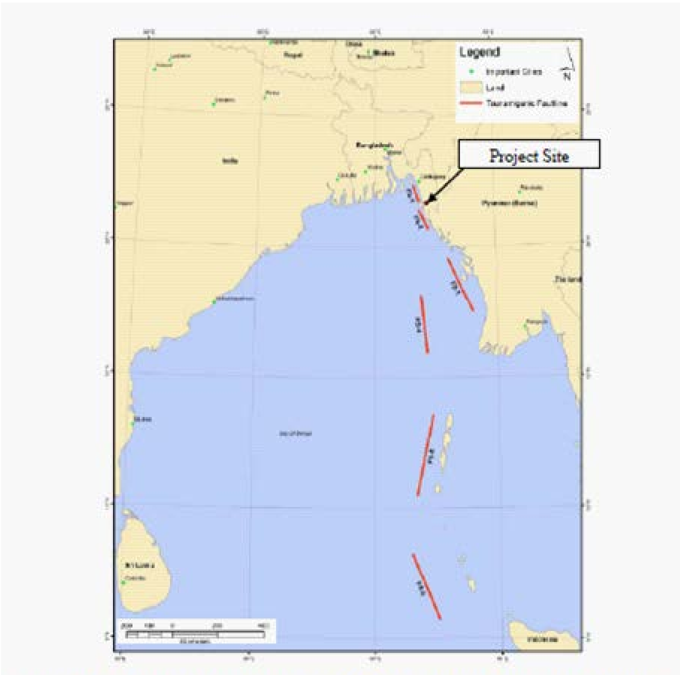
* the worst cyclone in 50 years observed November 1970 in Chittagong, Sarankhola-Bhola Noakhali is not adopted, since it is geographically so far from Matarbari site that it didn't strike,

Although storm surges cause inundation of port facilities such as quay, the effect of the pile structures such as piers is not considered as the schematic design of pier because the flow is assumed to be not so large.

5) Tsunami

According to the Matarbari CFPP Feasibility Study (F/S) Report, the maximum tsunami wave height is expected to be from 1~3 m in the simulation of the tsunami caused by an earthquake that occurred in the fault of the Bay of Bengal.

Fault of the Bay of Bengal is shown in Figure 5.1.2 below.



Source : Matarbari CFPP F/S Study

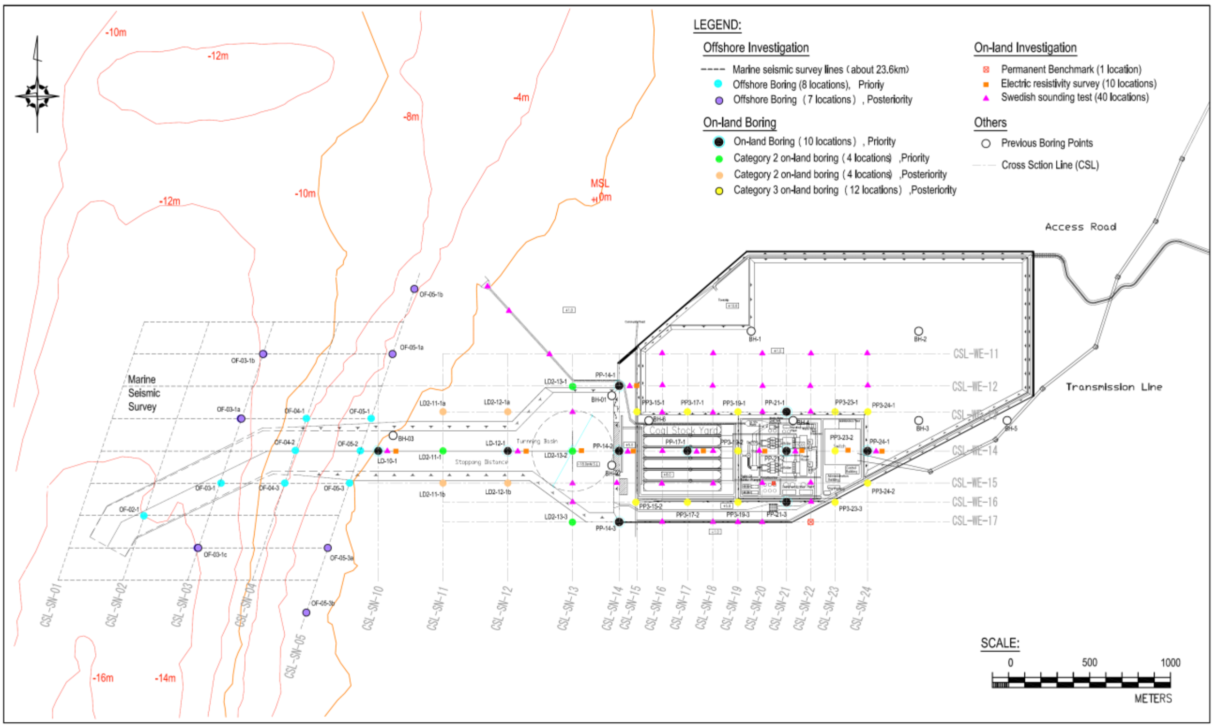
Figure 5.1.2 Fault of the Bay of Bengal

The impact of the pier pile of such structures by wave force of the tsunami will not be considered in this conceptual design because it is assumed that the wave force is not so large compared with other external forces.

6) Soil Conditions

According to the Matarbari CFPP F/S Report, the JICA Study Team has done geological survey by 45 points in the planning area.

The location of boring surveys and their results are shown in Figure 5.1.3 below.



Source: Matarbari CFPP F/S Study

Figure 5.1.3 Location of Boring Surveys

There are five borehole logs in the north area and four borehole logs in the south area, which correspond to the planning area of coal terminal in Matabari CFPP F/S. Applicable boring survey point is as follows.

North area

LD2-11-1a, LD2-12-1a, LD2-13-1, LD2-11-1, LD-12-1,

South area

LD2-11-1b, LD2-12-1b, LD2-13-3, LD2-14-3,

Fig.

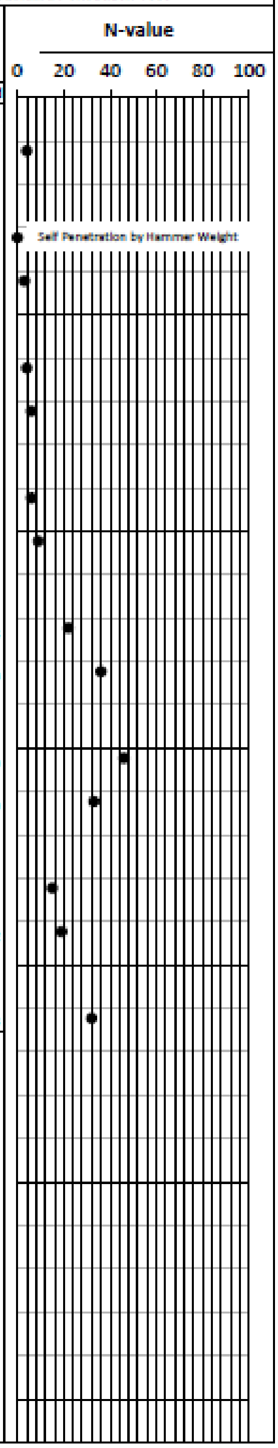
Drilling Log

Hole Number: LD2-11-1a

Project No.	827-14	Project Name:	Matarbari PP	Sheet:	1
Supervisor:	Royal	Coordinate	N:2400362.62 E:382660.30	Elevation:	MSL+0.16 m
Driller:	Mizan	Date Started:	20141003	Water Table:	GL+0.65 m
Type of Drilling Rig:	Rotary:KJC-L-2	Date Terminated:	20141009	Remarks:	Offshore:Final casing depth GL-4m

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
0.16	0.00	0.60	Silty Sand	Grey	Loose	Fine to medium grained sand. With sea shell fragments, mica fragments
-0.44	0.6	3.20	Clayey Silt	Grey	Very Soft to Soft	With few organic matter.
-3.64	3.80	5.10	Sandy Silt	Grey	Soft to Medium Stiff	With some fine grained sand, few organic matter. lenses of sand at lower portion.
-8.74	8.9	1.30	Clay	Grey	Medium Stiff to Stiff	with little fine grained sand.
-10.04	10.2	11.25	Silty Sand	Grey	Medium Dense to Dense	Fine to medium grained sand. With trace of organic matter and mica fragments. Sandy clay at 20.20 to 20.60m.
-21.29	21.45		END OF BH			

Sampling: Depth in m From	To	C'ter	Sample No.	SPT: N-value blows/30cm	Blows per each 15 cm: 1st	2nd	3rd
1.00	1.45	1.23	SPT-1	4	1	2	2
2.00	2.85	2.43	HP-1		REC:85/85		
3.00	3.45	3.23	SPT-2	0	0	0	0
4.00	4.45	4.23	SPT-3	3	0	1	2
5.00	5.90	5.45	HP-2		REC:90/90		
6.00	6.45	6.23	SPT-4	4	1	2	2
7.00	7.45	7.23	SPT-5	6	2	2	4
8.00	8.90	8.45	HP-3		REC:90/90		
9.00	9.45	9.23	SPT-6	6	2	3	3
10.00	10.45	10.23	SPT-7	9	2	4	5
11.00	11.80	11.40	D-1		REC:65/80		
12.00	12.45	12.23	SPT-8	22	4	9	13
13.00	13.45	13.23	SPT-9	36	5	16	20
14.00	14.60	14.30	D-2		REC:60/60		
15.00	15.45	15.23	SPT-10	46	10	17	29
16.00	16.45	16.23	SPT-11	33	12	14	19
17.00	17.80	17.40	D-3		REC:70/80		
18.00	18.45	18.23	SPT-12	15	5	7	8
19.00	19.45	19.23	SPT-13	19	4	7	12
20.00	20.70	20.35	D-4		REC:60/70		
21.00	21.45	21.23	SPT-14	32	7	14	18



Source:Matarbari CFPP F/S

Figure 5.1.4 Boring Holes at Survey Point BH1

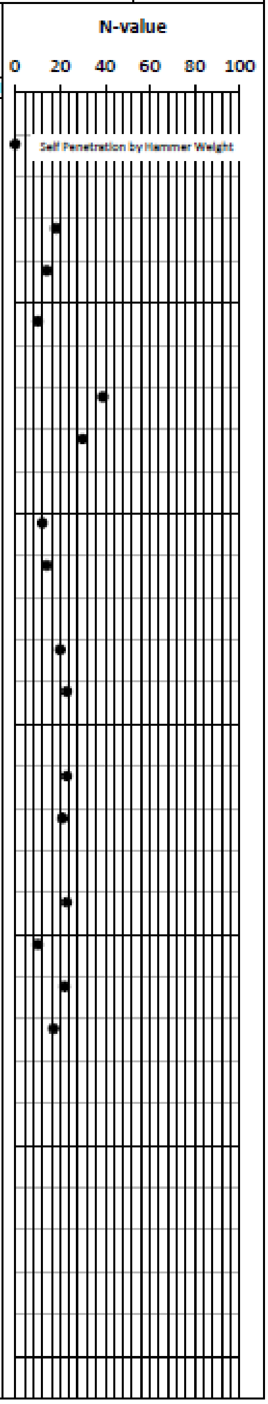
Fig. Drilling Log

Hole Number: **LD2-12-1a**

Project No.	827-14	Project Name:	Matarbari PP	Sheet:	1
Supervisor:	Royal	Coordinate	N:2400362.70 E:383060.83	Elevation:	MSL+0.94 m
Driller:	Abul	Date Started:	20140916	Water Table:	GL+0.30 m
Type of Drilling Rig:	Rotary:KJC-L-2	Date Terminated:	20140921	Remarks:	Wetland:Final casing depth GL-1.5m

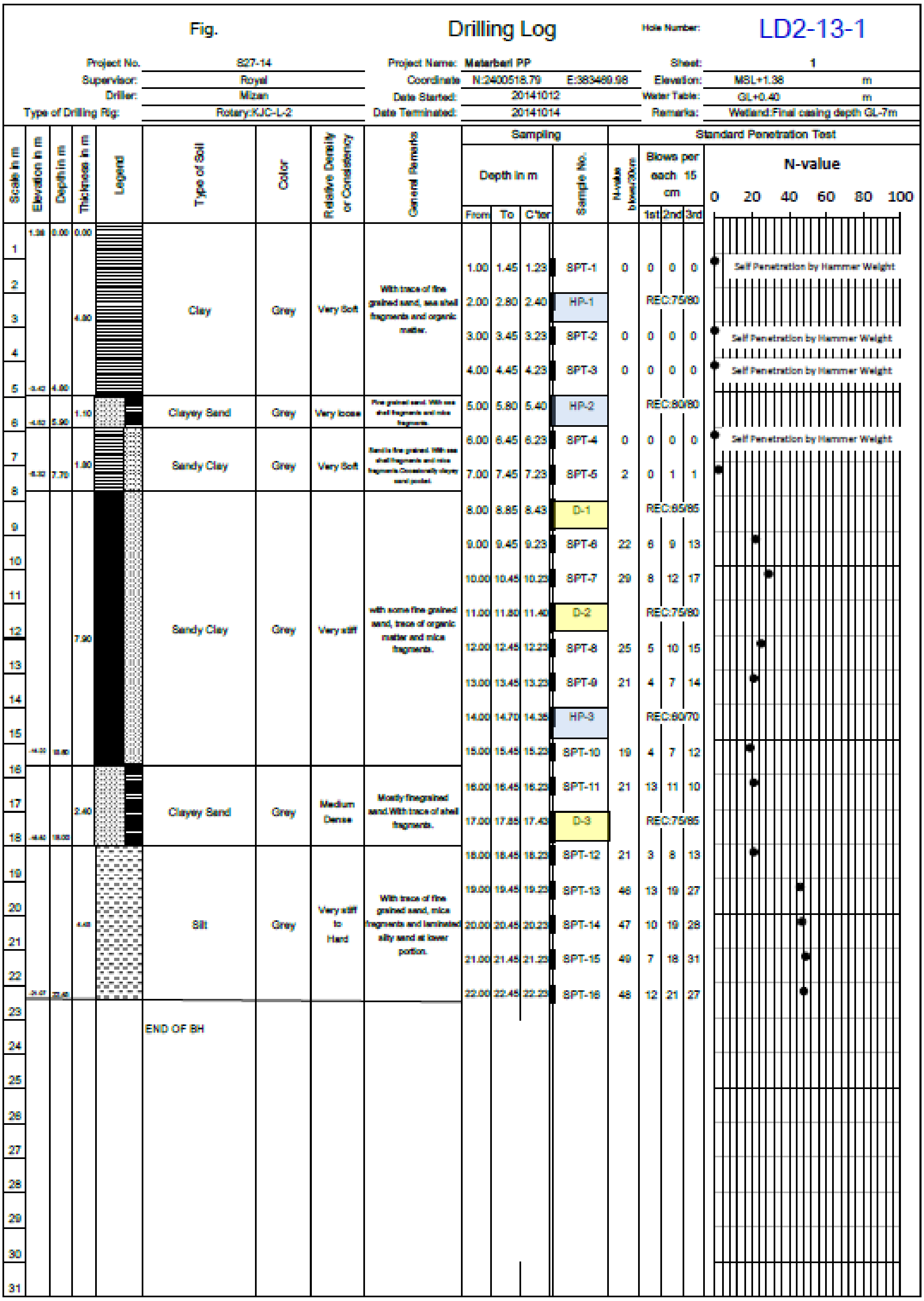
Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
0.94	0.00	0.00				
-2.06	3.00	3.00	Clay	Grey	Very Soft	With little sand. Sand is fine grained. With trace of organic matter
-3.76	4.70	1.70	Sandy Silt	Grey	Stiff to Very Stiff	Sand is fine grained at top, medium grained at bottom. With organic matter, sea shell fragments, mica fragments
-7.96	8.90	4.20	Sand	Grey	Medium Dense to Dense	Fine to medium grained sand. With sea shell fragments, organic matter, mica fragments
-11.36	12.30	3.40	Sandy Clay	Grey	Stiff	With some fine to medium grained sand, few sea fragments, organic matter and trace of mica fragments.
-17.76	18.70	6.40	Clayey Sand	Grey	Medium Dense	Fine to medium grained sand. With trace of organic matter, sea shell fragments, mica fragments and lenses of silt at lower portion.
-20.76	21.70	3.00	Sandy Silt	Grey	Stiff to Very Stiff	With some fine grained sand.
-21.51	22.45	0.75	Silt	Grey	Very Stiff	With very fine grained sand
			END OF BH			

Sampling Depth From (m)	To (m)	C'ter (m)	Sample No.	N-value blows/30cm	Blows per each 15 cm: 1st	2nd	3rd
1.00	1.45	1.23	SPT-1	0	0	0	0
2.00	2.90	2.45	HP-1		REC:90/90		
3.00	3.45	3.23	SPT-2	18	6	8	10
4.00	4.45	4.23	SPT-3	14	6	6	8
5.00	5.20	5.10	D		REC:0/20		
5.20	5.65	5.43	SPT-4	10	7	5	5
6.00	6.70	6.35	D-1		REC:70/70		
7.00	7.45	7.23	SPT-5	39	10	18	21
8.00	8.45	8.23	SPT-6	30	8	13	17
9.00	9.70	9.35	D-2		REC:70/70		
10.00	10.45	10.23	SPT-7	12	9	4	8
11.00	11.45	11.23	SPT-8	14	5	7	7
12.00	12.80	12.40	D-3		REC:80/80		
13.00	13.45	13.23	SPT-9	20	4	7	13
14.00	14.45	14.23	SPT-10	23	8	10	13
15.00	15.70	15.35	D-4		REC:55/70		
16.00	16.45	16.23	SPT-11	23	5	9	14
17.00	17.45	17.23	SPT-12	21	4	8	13
18.00	18.70	18.35	D		REC:0/70		
19.00	19.45	19.23	SPT-13	23	7	9	14
20.00	20.45	20.23	SPT-14	10	2	4	6
21.00	21.45	21.23	SPT-15	22	3	9	13
22.00	22.45	22.23	SPT-16	17	3	8	9



Source:Matarbari CFPP F/S

Figure 5.1.5 Boring Holes at Survey Point BH2



Source:Matarbari CFPP F/S

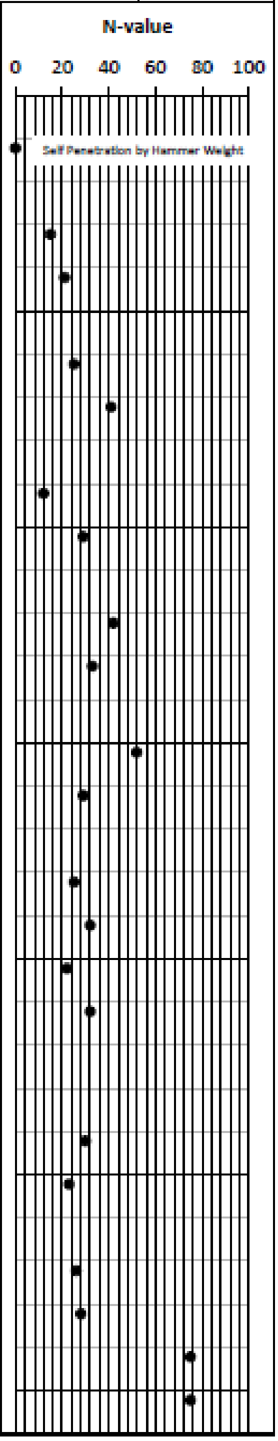
Figure 5.1.6 Boring Holes at Survey Point BH2

Fig. **Drilling Log** Hole Number: **LD-12-1**

Project No.	827-14	Project Name:	Matarbari PP	Sheet:	1
Supervisor:	Royal	Coordinate:	N:2400120.42 E:383068.87	Elevation:	MSL+1.43 m
Driller:	Abul	Date Started:	20140922	Water Table:	GL+0.25 m
Type of Drilling Rig:	Rotary:KJC-L-2	Date Terminated:	20140927	Remarks:	Wetland:Final casing depth GL-1.5m

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
1.43 / -0.92	0.00 / 2.35	0.00 / 2.35	Clay	Grey	Very Soft	With trace of fine grained sand, sea shell fragments and organic matter
-2.27	3.70	1.35	Sandy Silt	Grey	Stiff	Sand is fine grained
-9.27	10.70	7.00	Clayey Sand	Grey	Medium Dense to Dense	Fine to medium grained sand. With organic matter and decomposed wood. Occasinally Clayey Sand. Occasionally brownish grey
-18.27	19.70	9.00	Sand	Grey	Medium Dense to Very Dense	Fine to medium grained sand.With trace of organic matter and mica fragment and occasionally lenses of clayey soil. Silty sand at 14.00 to 14.30m.
-22.27	23.70	4.00	Sandy Clay	Grey	Very Stiff to Hard	Sand is fine to medium grained with mica fragments
-27.27	28.70	5.00	Silt	Grey	Very Stiff to Hard	With fine grained sand
		5.80	Silty Sand	Grey to yellowish brown	Very Dense	Fine to medium grained sand. With thinly lenses of silt

Sampling Depth in m From	To	C'ter	Sample No.	SPT N-value blows/30cm	Blows per each 15 cm 1st	2nd	3rd
1.00	1.45	1.23	SPT-1	0	0	0	0
2.00	2.90	2.45	HP-1		REC:90/90		
3.00	3.45	3.23	SPT-2	15	4	6	9
4.00	4.45	4.23	SPT-3	21	4	7	14
5.00	5.80	5.40	D-1		REC:80/80		
6.00	6.45	6.23	SPT-4	25	5	10	15
7.00	7.45	7.23	SPT-5	41	10	16	25
8.00	8.85	8.43	D-2		REC:80/85		
9.00	9.45	9.23	SPT-6	12	2	4	8
10.00	10.45	10.23	SPT-7	29	4	12	17
11.00	11.50	11.25	D-3		REC:40/50		
12.00	12.45	12.23	SPT-8	42	5	15	27
13.00	13.45	13.23	SPT-9	33	14	14	19
14.00	14.80	14.40	D-4		REC:50/80		
15.00	15.45	15.23	SPT-10	52	11	24	28
16.00	16.45	16.23	SPT-11	29	5	10	19
17.00	17.60	17.30	D-5		REC:60/60		
18.00	18.45	18.23	SPT-12	25	5	10	15
19.00	19.45	19.23	SPT-13	32	6	11	21
20.00	20.45	20.23	SPT-14	22	8	10	12
21.00	21.45	21.23	SPT-15	32	9	13	19
22.00	22.70	22.35	HP		REC:0/70		
23.00	23.60	23.30	D-6		REC:60/60		
24.00	24.45	24.23	SPT-16	30	7	13	17
25.00	25.45	25.23	SPT-17	23	6	9	14
26.00	26.45	26.23	SPT-18	35	6	14	21
27.00	27.45	27.23	SPT-19	26	7	12	14
28.00	28.45	28.23	SPT-20	28	6	13	15
29.00	29.45	29.23	SPT-21	75	19	31	44
30.00	30.45	30.23	SPT-22	75	20	31	44



Source:Matarbari CFPP F/S

Figure 5.1.7 Boring Holes at Survey Point BH2

Fig.

Drilling Log

Hole Number: **LD-12-1**

Project No.	S27-14	Project Name:	Matarbari PP	Sheet:	2
Supervisor:	Royal	Coordinate:	N:2400120.42 E:383068.87	Elevation:	MSL+1.43 m
Driller:	Abul	Date Started:	20140922	Water Table:	GL+0.25 m
Type of Drilling Rig:	Rotary:KJC-L-2	Date Terminated:	20140927	Remarks:	Wetland:Final casing depth GL-1.5m

Scale in m	Elevation in m	Depth in m	Thickness in m	Legend	Type of Soil	Color	Relative Density or Consistency	General Remarks	Sampling: Depth in m From	To	C'ter	Sample No.	Standard Penetration Test: N-value blows/30cm	Blows per each 15 cm: 1st	2nd	3rd
31																
32			5.60		Silty Sand	Grey to yellowish brown	Very Dense	Fine to medium grained sand.	31.00	31.30	31.15	SPT-23	50 /15cm	25	50	
33									32.00	32.45	32.23	SPT-24	82	20	38	44
34	-32.87	34.30							33.00	33.45	33.23	SPT-25	97	25	45	52
35			END OF BH						34.00	34.30	34.15	SPT-26	50 /15cm	25	50	
36																
37																
38																
39																
40																
41																
42																
43																
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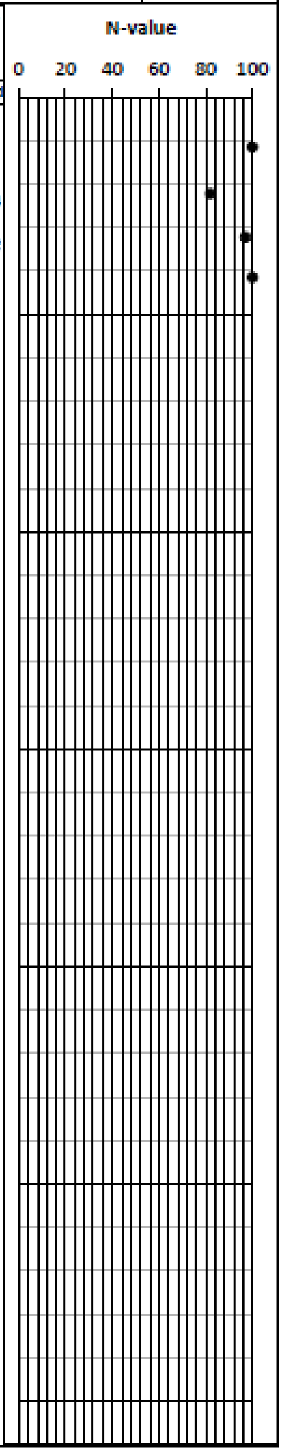


Source:Matarbari CFPP F/S Study

Figure 5.1.8 Boring holes at survey point BH2

Fig. Drilling Log

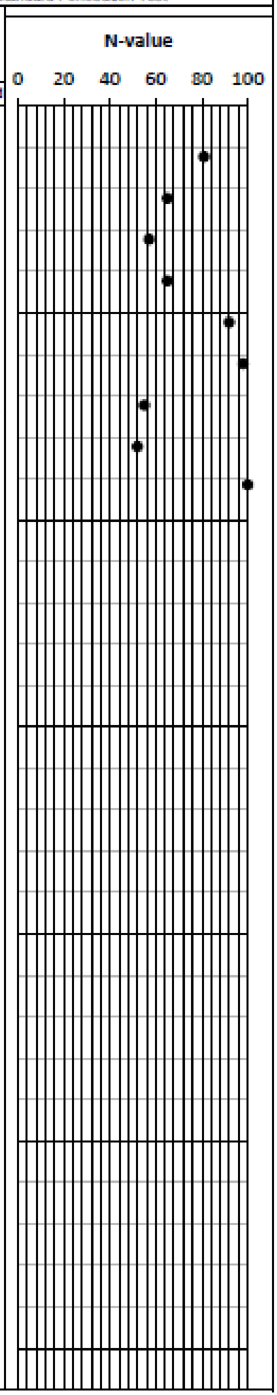
Hole Number: **LD2-11-1**

Project No.	827-14	Project Name:	Matarbari PP	Sheet:	2
Supervisor:	Royal	CordinateCoordinate	N:2400120.34 E:382669.58	Elevation:	MSL+1.50 m
Driller:	Matab	Date Started:	20140911	Water Table:	GL+0.30 m
Type of Drilling Rig:	Rotary:KJC-S-1	Date Terminated:	20140919	Remarks:	Offshore:Final casing depth GL-6m

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
-33.80	35.30	7.30	Silty Sand	Yellowish brown	Very Dense	Fine to medium grained sand
-37.80	39.30	4.30	Silty Sand	Grey	Very Dense	Fine to medium grained sand.With trace of organic matter

Depth in m From	To	C'ter	Sample No.	N-value blows/30cm	Blows per each 15 cm 1st	2nd	3rd
31.00	31.45	31.23	SPT-24	81	22	36	45
32.00	32.45	32.23	SPT-25	65	18	28	37
33.00	33.45	33.23	SPT-26	57	18	22	35
34.00	34.45	34.23	SPT-27	65	22	50	15
35.00	35.45	35.23	SPT-28	92	15	34	58
36.00	36.45	36.23	SPT-29	98	14	35	63
37.00	37.45	37.23	SPT-30	55	13	21	34
38.00	38.45	38.23	SPT-31	52	17	24	28
39.00	39.30	39.15	SPT-32	50 /15cm	27	50	

Scale in m: 31–61



Source:Matarbari CFPP F/S

Figure 5.1.9 Boring Holes at Survey Point BH2

Fig.

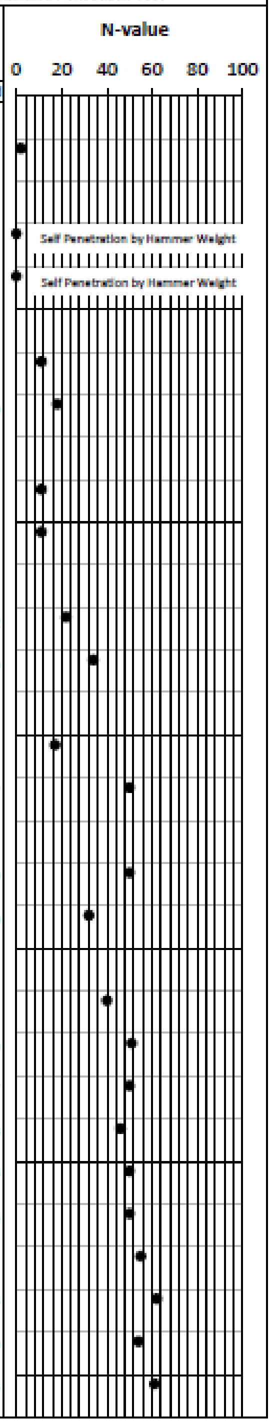
Drilling Log

Hole Number: LD2-11-1

Project No.	827-14	Project Name:	Matarbari PP	Sheet:	1
Supervisor:	Royal	CordinateCoordinate	N:2400120.34 E:382689.58	Elevation:	MSL+1.50 m
Driller:	Matab	Date Started:	20140911	Water Table:	GL+0.30 m
Type of Drilling Rig:	Rotary:KJC-S-1	Date Terminated:	20140919	Remarks:	Offshore:Final casing depth GL-6m

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
1.50	0.00	0.00				
-3.30	4.80	4.80	Clay	Greenish Grey	Very Soft	With trace of fine grained sand, sea shell fragments, organic matter and decomposed wood
-10.50	12.00	7.20	Sandy Silt	Grey	Stiff to Very Stiff	Sand is fine to medium grained. With trace of mica fragments. Clay at 8.00 to 8.90m. Silty sand at 9.00 to 9.45m
-19.40	20.90	8.90	Silty Sand	Grey	Medium Dense to Dense	Fine to medium grained sand. With trace of mica fragments. Sandy silt at 17.00 to 17.80m
-22.00	23.50	2.60	Sandy Silt	Grey	Hard	Sand is fine to medium grained. With trace of mica fragments
-24.30	25.80	2.30	Silty Sand	Grey, Yellowish Brown	Dense to Very Dense	Mostly fine grained sand. With trace of mica fragments.
-26.20	27.70	1.90	Sandy Silt	Grey	Hard	Sand is fine to medium grained. With trace of mica fragments
		7.30	Silty Sand	Yellowish brown	Very Dense	Fine to medium grained sand

Sampling Depth in m From	To	C'ter	Sample No.	N-value blows/30cm	Blows per each 15 cm 1st	2nd	3rd
1.00	1.45	1.23	SPT-1	2	1	1	1
2.00	2.80	2.40	HP-1		REC:80/80		
3.00	3.45	3.23	SPT-2	0	0	0	0
4.00	4.45	4.23	SPT-3	0	0	0	0
5.00	5.90	5.45	HP-2		REC:90/90		
6.00	6.45	6.23	SPT-4	11	3	4	7
7.00	7.45	7.23	SPT-5	18	7	8	10
8.00	8.90	8.45	HP-3		REC:90/90		
9.00	9.45	9.23	SPT-6	11	2	3	8
10.00	10.45	10.23	SPT-7	11	3	5	6
11.00	11.80	11.40	HP-4		REC:79/80		
12.00	12.45	12.23	SPT-8	22	5	10	12
13.00	13.45	13.23	SPT-9	34	7	14	20
14.00	14.80	14.40	D-1		REC:50/80		
15.00	15.45	15.23	SPT-10	17	1	6	11
16.00	16.45	16.23	SPT-11	50	17	23	27
17.00	17.80	17.40	D-2		REC:75/80		
18.00	18.45	18.23	SPT-12	50	10	21	29
19.00	19.45	19.23	SPT-13	32	4	12	20
20.00	20.80	20.40	D-3		REC:70/80		
21.00	21.45	21.23	SPT-14	40	15	19	21
22.00	22.45	22.23	SPT-15	51	16	22	29
23.00	23.45	23.23	SPT-16	50	14	23	27
24.00	24.45	24.23	SPT-17	46	12	20	26
25.00	25.45	25.23	SPT-18	50	15	25	25
26.00	26.45	26.23	SPT-19	50	16	22	28
27.00	27.45	27.23	SPT-20	55	10	24	31
28.00	28.45	28.23	SPT-21	62	19	24	38
29.00	29.45	29.23	SPT-22	54	18	25	29
30.00	30.45	30.23	SPT-23	61	16	28	33



Source:Matarbari CFPP F/S

Figure 5.1.10 Boring Holes at Survey Point BH2

Fig.

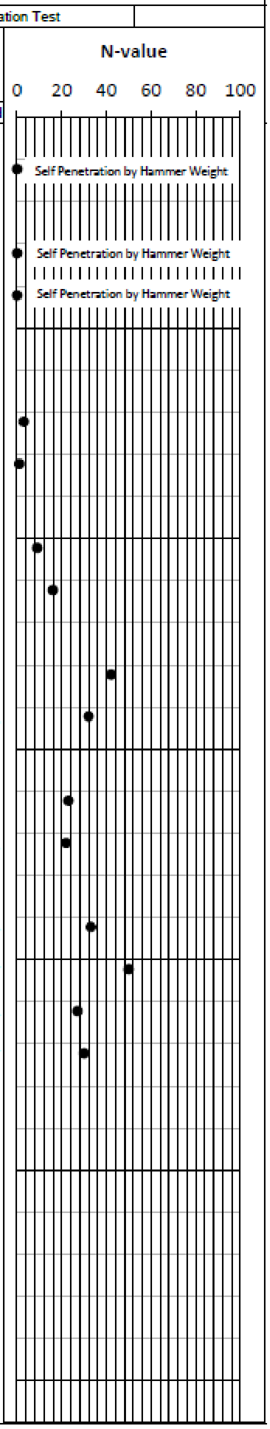
Drilling Log

Hole Number: **LD2-11-1b**

Project No.	S27-14	Project Name:	Matarbari PP
Supervisor:	Royal	Coordinate	N:2399921.61 E:382669.21
Driller:	Mizan	Date Started:	20140929
Type of Drilling Rig:	Rotary:KJC-L-2	Date Terminated:	20141001
Sheet:	1		
Elevation:	MSL+1.64 m		
Water Table:	GL+0.20m m		
Remarks:	Wetland:Final casing depth GL-7m		

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
1.64 / -2.86	0.00 / 4.50	4.50	Clay	Grey	Very Soft	With trace of fine grained sand, organic matter. At top mottled with yellowish brown
-7.06	8.70	4.20	Sandy Silt	Grey	Very Soft to Soft	With lots of fine grained sand
-13.46	15.10	6.70	Clayey Sand	Grey	Medium Dense to Dense	Fine to medium grained sand. With trace of sea shell fragments
-14.26	15.90	0.80	Sandy Clay	Grey	Very Stiff	Sand is fine grained .
-19.06	20.70	4.80	Silty Sand	Grey	Medium Dense to Dense	Fine to medium grained sand. With trace of sea shell fragments. Color is Brownish Grey at 20.00 to 20.45m.
-20.81	22.45	1.75	Sandy Silt	Grey	Very Stiff	With trace of fine grained sand
			END OF BH			

Depth From (m)	Depth To (m)	C'ter	Sample No.	N-value blows/30cm	1st	2nd	3rd
1.00	1.45	1.23	SPT-1	0	0	0	0
2.00	2.90	2.45	HP-1		REC:90/90		
3.00	3.45	3.23	SPT-2	0	0	0	0
4.00	4.45	4.23	SPT-3	0	0	0	0
5.00	5.85	5.43	HP		REC:0/85		
6.00	6.90	6.45	HP-2		REC:90/90		
7.00	7.45	7.23	SPT-4	3	0	1	2
8.00	8.45	8.23	SPT-5	1	0	0	1
9.00	9.50	9.25	HP-3		REC:50/50		
10.00	10.45	10.23	SPT-6	9	2	4	5
11.00	11.45	11.23	SPT-7	16	3	8	8
12.00	12.85	12.43	D-1		REC:65/85		
13.00	13.45	13.23	SPT-8	42	13	18	24
14.00	14.45	14.23	SPT-9	32	7	14	18
15.00	15.85	15.43	D-2		REC:60/85		
16.00	16.45	16.23	SPT-10	23	13	12	11
17.00	17.45	17.23	SPT-11	22	6	9	13
18.00	18.60	18.30	D-3		REC:60/60		
19.00	19.45	19.23	SPT-12	33	6	13	20
20.00	20.45	20.23	SPT-13	50	20	23	27
21.00	21.45	21.23	SPT-14	27	7	12	15
22.00	22.45	22.23	SPT-15	30	8	13	17



Source:Matarbari CFPP F/S

Figure 5.1.11 Boring Holes at Survey Point BH2

Fig.

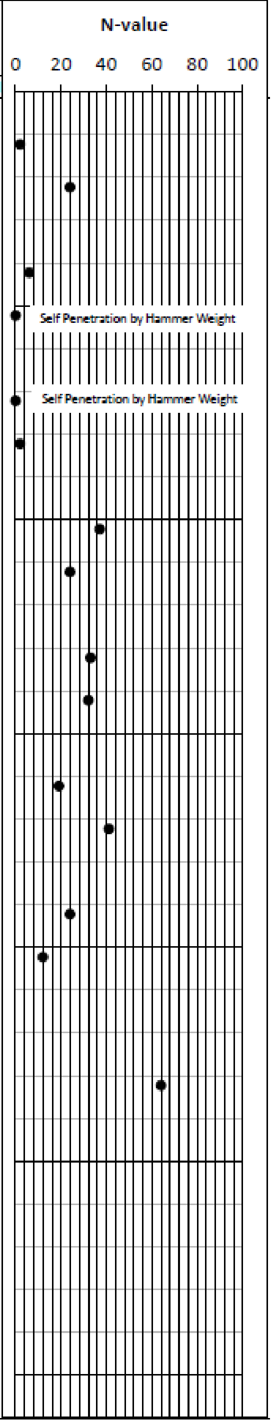
Drilling Log

Hole Number: **LD2-12-1b**

Project No.	S27-14	Project Name:	Matarbari PP
Supervisor:	Royal	Coordinate	N:2399921.47 E:383069.02
Driller:	Matab	Date Started:	20141030
Type of Drilling Rig:	Rotary:KJC-L-1	Date Terminated:	20141031
Sheet:	1		
Elevation:	MSL+1.33 m		
Water Table:	GL+0.40 m		
Remarks:	Wetland:Final casing depth GL-8m		

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
1.33 / 0.53	0.00 / 0.80	0.00 / 0.80	Clay	Grey	Very Soft	With trace of fine grained sand, sea shell fragments, organic matter
-2.27	3.60	2.80	Clayey Sand	Grey	Dence	Fine grained sand. With sea shell fragments, organic matter, mica fragments
-3.37	4.70	1.10	Sandy Silt	Grey	Medium Stiff	Sand is fine grained. With organic matter, sea shell fragments, mica fragments
-4.47	5.80	1.10	Silty Sand	Grey	Very Loose	Fine to medium grained sand. With sea shell fragments, organic matter ,mica fragments
-7.47	8.80	3.00	Clay	Grey	Very Soft	with trace of fine grained sand, sea shell fragments, organic matter
-8.67	10.00	1.20	Clayey Silt	Grey	Very Soft	with little fine grained sand, trace of organic matter.
-11.47	12.80	2.80	Silty Sand	Brown	Dense	Fine to medium grained sand. With trace of sea shell fragments
-17.07	18.40	5.60	Clayey Sand	Grey	Medium Dense to Dense	Fine grained sand. With sea shell fragments,organic matter,mica fragments
-21.57	22.90	4.50	Sandy Silt	Grey	Stiff to Very Stiff	Sand is fine grained. With sea shell fragments, organic matter. Occasionally clay with sand .x Clay with sand at 22.00 to 22.60m.
-22.12	23.45	0.55	Silty Sand	Yellowish brown	Very Dense	Fine to medium grained sand. With mica fragments
			END OF BH			

Sampling Depth in m From	To	C'ter	Sample No.	N-value blows/30cm	Blows per each 15 cm 1st	2nd	3rd
1.00	1.45	1.23	SPT-1	2	0	1	1
2.00	2.45	2.23	SPT-2	24	7	9	15
3.00	3.90	3.45	D-1		REC:90/90		
4.00	4.45	4.23	SPT-3	6	2	3	3
5.00	5.45	5.23	SPT-4	0	0	0	0
6.00	6.80	6.40	HP-1		REC:80/80		
7.00	7.45	7.23	SPT-5	0	0	0	0
8.00	8.45	8.23	SPT-6	2	1	1	1
9.00	9.65	9.33	D-2		REC:65/65		
10.00	10.45	10.23	SPT-7	37	6	16	21
11.00	11.45	11.23	SPT-8	24	3	9	15
12.00	12.65	12.33	D-3		REC:65/65		
13.00	13.45	13.23	SPT-9	33	5	15	18
14.00	14.45	14.23	SPT-10	32	8	15	17
15.00	15.90	15.45	D-4		REC:75/90		
16.00	16.45	16.23	SPT-11	19	7	9	10
17.00	17.45	17.23	SPT-12	41	13	21	20
18.00	18.90	18.45	D-5		REC:75/90		
19.00	19.45	19.23	SPT-13	24	6	8	16
20.00	20.45	20.23	SPT-14	12	3	2	10
21.00	21.90	21.45	D		REC:0/90		
22.00	22.90	22.45	D-6		REC:70/90		
23.00	23.45	23.23	SPT-15	64	15	26	38



Source:Matarbari CFPP F/S

Figure 5.1.12 Boring Holes at Survey Point BH2

Fig.

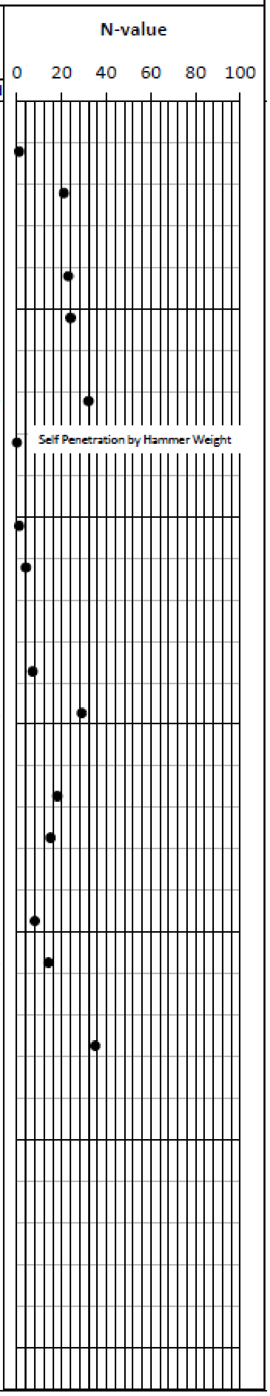
Drilling Log

Hole Number: **LD2-13-3**

Project No.	S27-14	Project Name:	Matarbari PP	Sheet:	1
Supervisor:	Royal	Coordinate:	N:2399680.09 E:383469.28	Elevation:	MSL+1.06 m
Driller:	Matab	Date Started:	20141031	Water Table:	GL+0.45 m
Type of Drilling Rig:	Rotary:KJC-L-1	Date Terminated:	20141101	Remarks:	Wetland:Final casing depth GL-2m

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
1.60 / -0.64	0.00 / 1.70	0.00 / 1.70	Clayey Sand	Grey	Very Loose	Fine to medium grained sand. With sea shell fragments, organic matter, mica fragments
-6.64	7.70	6.00	Clayey Sand	Grey	Medium Dense to Dense	Fine to medium grained sand. With sea shell fragments, organic matter, mica fragments
-10.74	11.80	4.10	Clay	Grey	Very Soft to Soft	With trace of fine grained sand, sea shell fragments, organic matter
-14.94	16.00	4.20	Clayey Sand	Grey	Loose to Medium Dense	Fine grained sand. With organic matter, sea shell fragments. Silty sand at 15.50 to 16.00m
-18.24	19.30	3.30	Sandy Silt	Grey	Stiff to Very Stiff	Sand is fine grained. With trace of organic matter, sea shell fragments.Occasionally silt with sand. Silt with sand at 18.50 to19.20m.
-20.44	21.50	2.20	Silty Sand	Grey	Loose to Medium Dense	Fine to medium grained sand. With sea shell fragments, organic matter
-21.89	22.95	1.45	Clay	Grey	Hard	With few sand .Sand is fine grained sand. With trace of sea shell fragments, organic matter
			END OF BH			

From	To	C'ter	Sample No.	N-value blows/30cm	1st	2nd	3rd
1.00	1.45	1.23	SPT-1	1	1	0	1
2.00	2.45	2.23	SPT-2	21	5	9	12
3.00	3.80	3.40	D-1		REC:80/80		
4.00	4.45	4.23	SPT-3	23	5	10	13
5.00	5.45	5.23	SPT-4	24	6	10	14
6.00	6.80	6.40	D-2		REC:80/80		
7.00	7.45	7.23	SPT-5	32	8	13	19
8.00	8.45	8.23	SPT-6	0	0	0	0
9.00	9.80	9.40	HP-1		REC:80/80		
10.00	10.45	10.23	SPT-7	1	1	0	1
11.00	11.45	11.23	SPT-8	4	1	2	2
12.00	12.45	12.23	D-3		REC:45/45		
12.50	13.40	12.95	D-4		REC:79/90		
13.50	13.95	13.73	SPT-9	7	2	3	4
14.50	14.95	14.73	SPT-10	29	2	11	18
15.50	16.40	15.95	D-5		REC:80/90		
16.50	16.95	16.73	SPT-11	18	3	6	12
17.50	17.95	17.73	SPT-12	15	2	6	9
18.50	19.40	18.95	D-6		REC:80/90		
19.50	19.95	19.73	SPT-13	8	2	2	6
20.50	20.95	20.73	SPT-14	14	2	4	10
21.50	22.40	21.95	D-7		REC:80/90		
22.50	22.95	22.73	SPT-15	35	9	14	21



Source:Matarbari CFPP F/S

Figure 5.1.13 Boring Holes at Survey Point BH2

Fig.

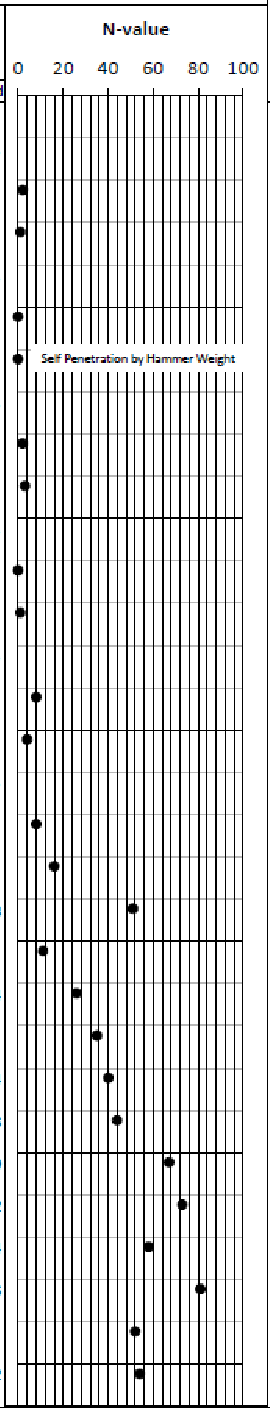
Drilling Log

Hole Number: **PP-14-3**

Project No.	S27-14	Project Name:	Matarbari PP
Supervisor:	Royal	Coordinate:	N:2399680.04 E:383757.14
Driller:	Kowser	Date Started:	20141101
Type of Drilling Rig:	Rotary:KJC-L-1	Date Terminated:	20141106
Sheet:	1	Elevation:	MSL+1.26 m
Water Table:	GL+0.25 m	Remarks:	Wetland:Final casing depth GL-6m

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
1.26	0.00	0.00				
-3.64	4.90	4.90	Clay	Grey	Very Soft	With trace of fine grained sand, sea shell fragmnets, organic matter, decomposed wood. Occasionally clayey silt.
-7.44	8.70	3.80	Clay	Grey	Very Soft	With few fine grained sand, sea shell fragments and organic matter.
-9.64	10.90	2.20	Sandy Clay	Grey	Soft	With some sand. Sand is fine grained.With trace of organic matter.
-11.44	12.70	1.80	Clay	Grey	Very Soft	With trace of fine grained sand, sea shell fragments, organic matter. Occasionally sandy silt.
-16.44	17.70	5.00	Clay	Grey	Medium Stiff	With little sand. Sand is fine grained. With sea shell fragments, organic matter.
-19.44	20.70	3.00	Sandy Silt	Grey	Stiff to Hard	Sand is fine to medium grained.
-27.44	28.70	8.00	Silty Sand	Yellowish Brown	Medium Dense to Very Dense	Fine to medium grained sand.
-29.44	30.70	2.00	Sandy Silt	Grey	Hard	With trace of fine grained sand.

Sampling Depth From (m)	To	C'ter	Sample No.	N-value blows/30cm	Blows per each 15 cm 1st	2nd	3rd
1.00	1.80	1.40	HP-1		REC:80/80		
2.00	2.45	2.23	SPT-1	2	1	1	1
3.00	3.45	3.23	SPT-2	1	1	0	1
4.00	4.80	4.40	HP-2		REC:80/80		
5.00	5.45	5.23	SPT-3	0	1	0	0
6.00	6.45	6.23	SPT-4	0	0	0	0
7.00	7.80	7.40	HP-3		REC:80/80		
8.00	8.45	8.23	SPT-5	2	1	1	1
9.00	9.45	9.23	SPT-6	3	1	1	2
10.00	10.70	10.35	HP-4		REC:70/70		
11.00	11.45	11.23	SPT-7	0	1	0	0
12.00	12.45	12.23	SPT-8	1	0	0	1
13.00	13.90	13.45	HP-5		REC:80/90		
14.00	14.45	14.23	SPT-9	8	3	3	5
15.00	15.45	15.23	SPT-10	4	1	1	3
16.00	16.90	16.45	HP-6		REC:85/90		
17.00	17.45	17.23	SPT-11	8	2	3	5
18.00	18.45	18.23	SPT-12	16	3	7	9
19.00	19.45	19.23	SPT-13	51	16	28	23
20.00	20.45	20.23	SPT-14	11	4	4	7
21.00	21.45	21.23	SPT-15	26	6	12	14
22.00	22.45	22.23	SPT-16	35	6	14	21
23.00	23.45	23.23	SPT-17	40	7	16	24
24.00	24.45	24.23	SPT-18	44	13	18	26
25.00	26.45	25.23	SPT-19	67	17	28	39
26.00	26.45	26.23	SPT-20	73	23	31	42
27.00	27.45	27.23	SPT-21	58	20	24	34
28.00	28.45	28.23	SPT-22	81	16	35	46
29.00	29.45	29.23	SPT-23	52	8	21	31
30.00	30.45	30.23	SPT-24	54	12	22	32



Source:Matarbari CFPP F/S

Figure 5.1.14 Boring Holes at Survey Point BH2

Fig.

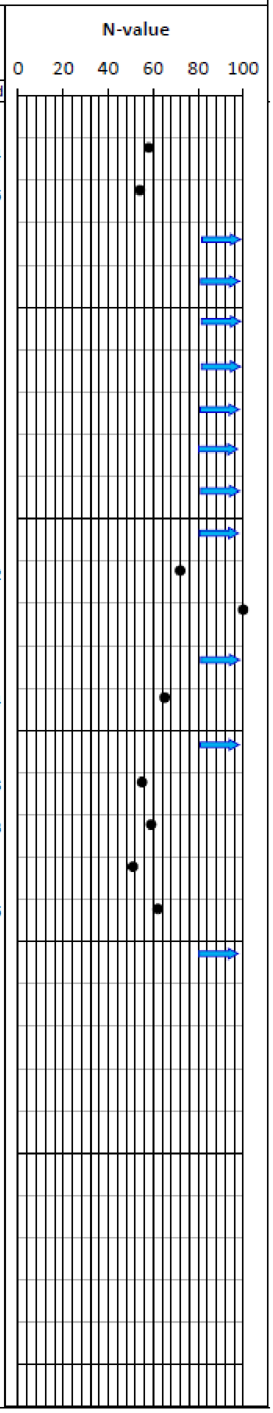
Drilling Log

Hole Number: **PP-14-3**

Project No.	S27-14	Project Name:	Matarbari PP
Supervisor:	Royal	Coordinate:	N:2399680.04 E:383757.14
Driller:	Kowser	Date Started:	20141101
Type of Drilling Rig:	Rotary:KJC-L-1	Date Terminated:	20141106
Sheet:	2		
Elevation:	MSL+1.26 m		
Water Table:	GL+0.25 m		
Remarks:	Wetland:Final casing depth GL-6m		

Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
-29.44	30.70	2.00	Sandy Silt	Grey	Hard	With trace of fine grained sand
-31.44	32.70	2.00	Silty Sand	Light Greenish Grey	Very Dense	Fine grained sand
-33.44	34.70	2.00	Silty Sand	Brown	Very Dense	Fine to medium grained sand
-42.44	43.70	9.00	Silty Sand	Grey to yellowish Brown	Very Dense	Fine to medium grained sand
-49.02	50.28	6.58	Silt	Grey	Hard	With trace of fine grained sand
			END OF BH			

Depth From	Depth To	C'ter	Sample No.	N-value blows/30cm	1st	2nd	3rd
31.00	31.45	31.23	SPT-25	58	16	24	34
32.00	32.45	32.23	SPT-26	54	12	19	35
33.00	33.28	33.14	SPT-27	50 /13cm	36	50 /13cm	
34.00	34.26	34.13	SPT-28	50 /11cm	44	50 /11cm	
35.00	35.28	35.14	SPT-29	50 /13cm	26	50 /13cm	
36.00	36.26	36.13	SPT-30	50 /11cm	24	50 /11cm	
37.00	37.26	37.13	SPT-31	50 /11cm	31	50 /11cm	
38.00	38.27	38.14	SPT-32	50 /12cm	28	50 /12cm	
39.00	39.27	39.14	SPT-33	50 /12cm	27	50 /12cm	
40.00	40.25	40.13	SPT-34	50 /10cm	25	50 /10cm	
41.00	41.45	41.23	SPT-35	72	13	30	42
42.00	42.30	42.15	SPT-36	50 /15cm	20	50 /15cm	
43.00	43.28	43.14	SPT-37	50 /13cm	26	50 /13cm	
44.00	44.45	44.23	SPT-38	65	12	21	44
45.00	45.29	45.15	SPT-39	50 /14cm	23	50 /14cm	
46.00	46.45	46.23	SPT-40	55	13	19	36
47.00	47.45	47.23	SPT-41	59	17	26	33
48.00	48.45	48.23	SPT-42	51	11	20	31
49.00	49.45	49.23	SPT-43	62	17	27	35
50.00	50.28	50.14	SPT-44	50 /13cm	21	50 /13cm	



Source:Matarbari CFPP F/S

Figure 5.1.15 Boring Holes at Survey Point BH2

Table 5.1.4 shows the geological test results conducted in Matarbari CFPP F/S.

Table 5.1.4 Laboratory Test Results

Table 5.13 Summary Table of Soil Property

Layer	Distribution of Area	Thickness of Layer (m)	Color	Relative Density or Consistency	Material	N value	Wn (%)	Wet Density (g/cm3)	Gs	Grained Size			LL	PL	PI	qu/2 (kPa)	cu (kPa)	C (kPa)	φ (deg)	e	Pc (kPa)	Cc
										Sand (%)	Silt (%)	Clay and Colloid (%)										
Bs	Land Off-shore	0.6 to 2.6	Brown, Grey	Loose to Medium dense	Sandy Soil	4 to 24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ac-1	Land Power Plant	0.8 to 12.7	Grey, Greenish grey, Brownish grey	Very soft to Soft	Clayey Soil	0 to 4	29 to 78	1.52 to 1.93	2.68 to 2.78	1 to 41	31 to 57	25 to 67	28 to 80	19 to 37	6 to 44	8.6 to 9.8	10 to 35	0	38 to 40	0.82 to 1.93	35 to 190	0.22
Ac-2	Land Power Plant Off-shore	0.9 to 8.7	Grey	Medium stiff to Stiff	Clayey Soil	4 to 15	25 to 38	1.75 to 2.02	2.71 to 2.74	2 to 47	24 to 50	23 to 43	25 to 40	15 to 24	6 to 17	-	44 to 71	0 to 4	37	0.69 to 1.05	260 to 450	0.16 to 0.22
Ac-3	Land Power Plant Off-shore	1.1 To 9.0	Grey	Stiff to Hard	Clayey Soil	15 to 30	22 to 42	1.77 to 2.04	2.69 to 2.74	8 to 49	25 to 57	21 to 49	23 to 40	15 to 22	7 to 20	29.2	-	-	-	0.63 to 1.17	190	0.19
As-1	Land Power Plant Off-shore	1.1 to 6.0	Grey	Very loose to loose	Sandy Soil	0 to 10	19 to 31	1.71 to 2.05	2.66 to 2.72	53 to 97	2 to 22	10 to 28	-	-	-	-	-	-	-	0.73 to 1.06	-	-
As-2	Land Power Plant Off-shore	0.7 to 21.9	Light grey, Brownish grey, Yellowish grey,	Medium dense to Dense	Sandy Soil	10 to 50	13 to 34	1.79 to 2.12	2.67 to 2.72	50 to 96	4 to 30	11 to 28	-	-	-	-	-	-	-	0.61 to 0.88	-	-
Dc	Land Power Plant	1.4 to 17.3	Grey	Hard	Clayey Soil	≥ 30	23 to 31	1.83 to 2.12	2.71 to 2.73	13 to 48	24 to 59	23 to 34	25 to 43	14 to 22	11 to 21	227	-	-	-	0.72 to 0.94	-	-
Ds	Land Power Plant	0.5 to 13.2	Light grey, Grey, Yellowish grey	Very dense	Sandy Soil	≥ 50	12 to 13	1.97	2.69	94	6	0	-	-	-	-	-	-	-	-	-	-

Source: JICA "Matarbari CFPP F/S

Table 5.1.5 Soil Parameter for Design

Item				Layer									
				Embankment (Sand)	Ac-1 (Clay)	Ac-2 (Clay)	Ac-3 (Clay)	Ac-4 (Clay)	As-1 (Sand)	As-2 (Sand)	As-3 (Sand)	Dc (Clay)	Ds (Sand)
N-value				-	1	6	13	22	7	22	37	68	85
Specific Gravity		Gs		-	2.73	2.73	2.72	2.71	2.70	2.69	2.69	2.72	2.68
Wet Density		γt	(kN/m^3)	18.0	17.9	18.7	19.1	19.1	19.4	19.4	19.4	19.1	20.0
Saturated Density		γsat	(kN/m^3)	20.0	17.9	18.9	19.2	19.2	19.8	19.7	20.0	19.2	20.2
Void Ratio		eo		-	1.18	0.95	0.87	0.86	0.74	0.74	0.69	0.86	0.65
Liquid Limit		W_L	(%)	-	46.2	33.6	30.8	29.8	-	-	-	36.5	-
Plasticity Index		I_P		-	21.9	13.8	12.0	10.4	-	-	-	16.5	-
Undrained Shear Strength	Cohesion	Su	(kN/m^2)	-	15	40	60	100	-	-	-	200	-
	Internal Friction Angle	φu	(degree)	-	0	0	0	0	-	-	-	0	-
Drained Shear Strength	Cohesion	Cd	(kN/m^2)	0	-	-	-	-	0	0	0	-	0
	Internal Friction Angle	φd	(degree)	25	-	-	-	-	24	31	36	-	45
Rate of Strength Increase		m		-	0.19	0.16	0.15	0.15	-	-	-	0.17	-
Consolidation Parameters	Coefficient of Volume	mv	(m^2/kN)	-	$0.0565P^{-0.906}$	$0.00818P^{-0.7005}$	-	-	-	-	-	-	-
	Coefficient of Consolidation	Cv	(cm^2/day)	-	200	500	-	-	-	-	-	-	-

Note (1): The value of γsat is calculated using Gs and eo with the saturation of 100%
Note (2): The value of φd of sand layer is calculated using Dunham's equation of "φd = 15 + SQRT(12N)"
Note (3): The value of rate of strength increase (m) is calculated using Skempton's equation of "m = 0.11 + 0.0037I_P"

Source: JICA "Matarbari CFPP F/S

The geological conditions for the coal terminal have been set as follows.

EL(MWL)	Soil Name	N-value
+1.0m		
	Ac1	1
-3.7m		
	As-1	7
-4.7m		
	Ac1	1
-6.7m		
	Ac4	22
-14.7m		
	As2	22
-17.0m		
	Dc	68

Source: JICA Study Team

Figure 5.1.16 Coal Unloading Pier Ground Configuration.

EL(MWL)	Soil Name	N-value
+1.0m		
		1
+0.0m		
	As-2	22
-2.0m		
	Ac1	1
-3.0m		
	As1	7
-4.5m		
	Ac1	1
-7.5m		
	As-2	22
-8.8m		
	As3	37
-17.0m		
	Ac4	22
-21.5m		
	Ds	85

Source: JICA Study Team

Figure 5.1.17 Coal Shipment Pier and Stockyards Ground Configuration

7) Meteorological conditions

There are two weather stations around the planning area, Kutubdia which is located 10 km north and Cox's Bazar is 30 km south.

(Source: JICA Study Team)

Figure 15.1-4 Locations of Meteorological Observatories

Figure 5.1.18 Weather Stations Around the Planning Area, Kutubdia 10 km North and Cox's Bazar 30 km South

Weather conditions in the surrounding area of Matabari CTT are set based on the observations in these weather stations.

i) Wind

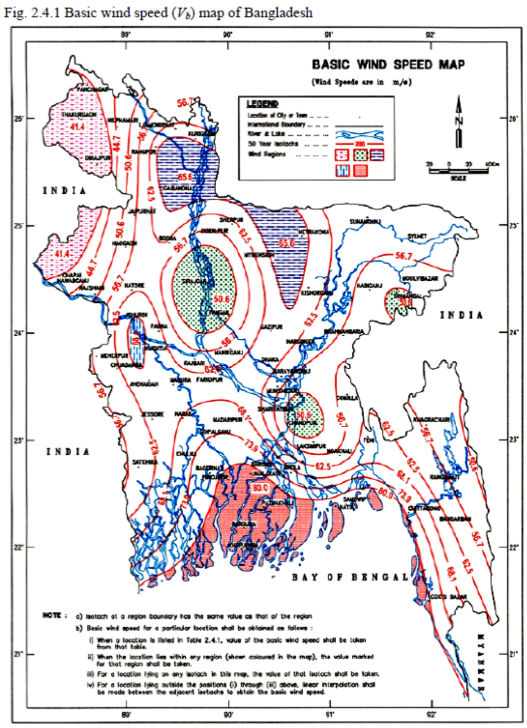
Table 5.1.6 Wind Data Observed Nearby the Project Site (1999 - 2008)

Wind speed (m/s)	1 - 2	2 - 4	4 - 7	7 - 9	9 - 12	12 - 16	> 16
Frequency (%)	99.3	96.3	82.4	48.1	23.4	3.3	0.04

Source: JICA Study Team

According to the observations, the wind from west-southwest and east-northeast caused by monsoon are affected, and wind from other direction is not affected. The frequency of wind speed over 16 m/s is very low. Therefore, it is expected that the effect on the facilities is not significant.

According to the wind speed distribution diagram of the BNBC, the maximum moment wind speed is about 80 m/s around this area. The design maximum wind speed applied for handling equipment is 55 m/s based on Japanese equipment design, since the probability maximum wind speed has not been analysed.

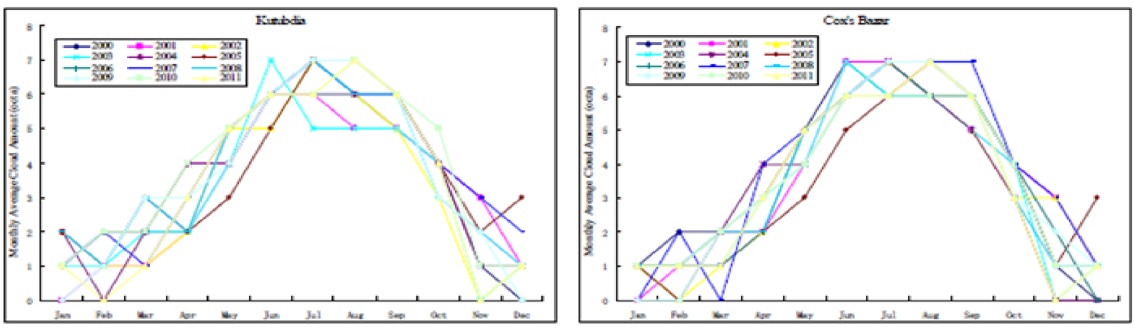


Source: BNBC 2012

Figure 5.1.19 : Basic Wind Speed (Velocity) Map of Bangladesh

ii) Rainfall

Annual rainfall in Kutubdia is 4,321 ~ 5,905mm, and in Cox's Bazar is 5,286 ~ 6,707mm.



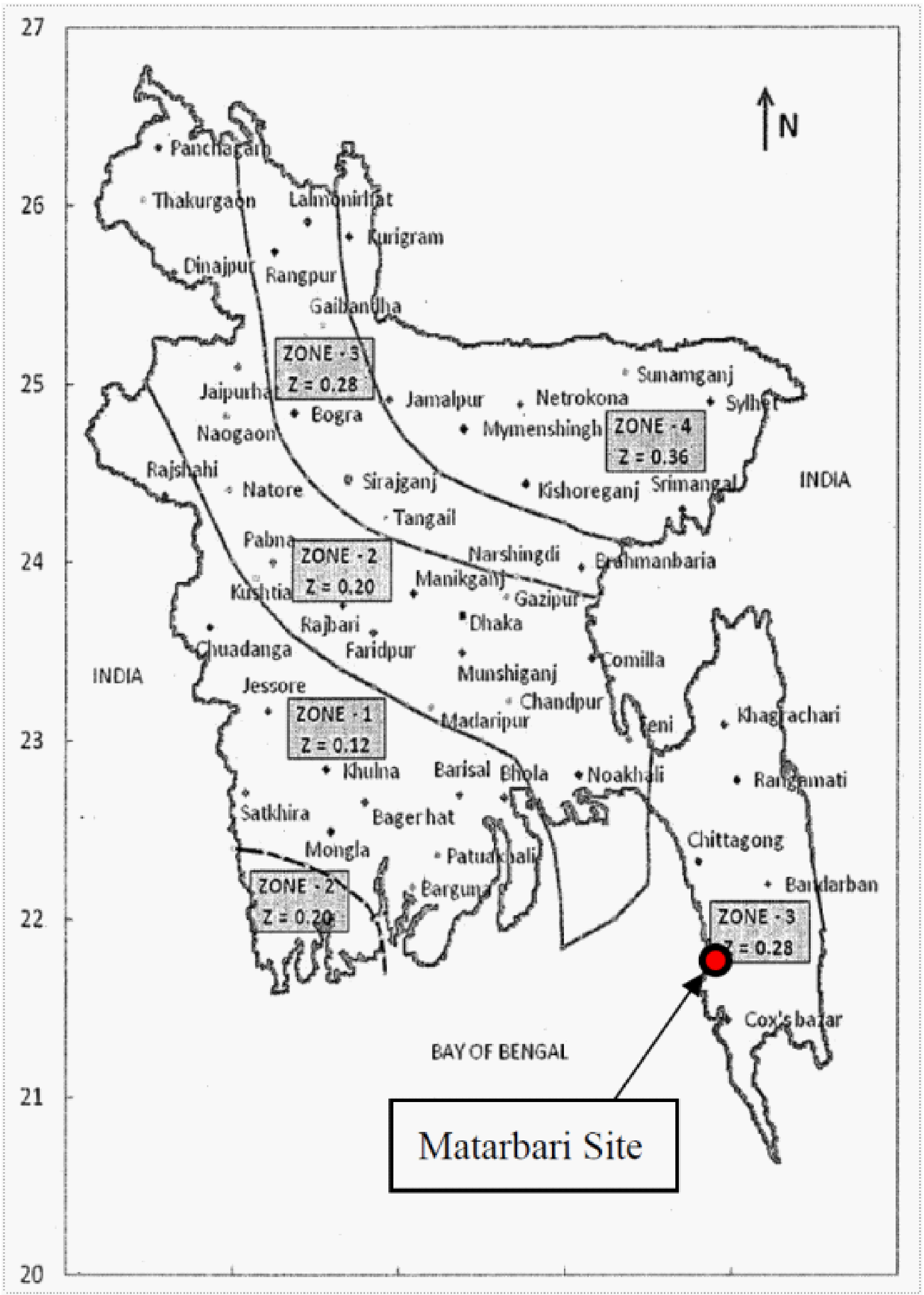
(Prepared based on the data of the meteorological observatories)

Source: JICA Matarbari CFPP F/S

Figure 5.1.20 Rainfall in Kutubdia and Cox's Bazar

8) Earthquake

Seismic coefficient in Bangladesh was defined by the BNBC 2012 as shown in Figure 5.1.21. According to this figure, the seismic coefficient at the site is 0.28. Earthquake coefficients for the design are considered based on technical criteria in the BNBC 2012.



Source: BNBC 2012

Figure 5.1.21 Seismic Coefficient in Bangladesh

Seismic coefficient formula is shown by BNBC 2012 as follows:

$$S_a = \frac{2}{3}\frac{ZI}{R}C_s \quad (2.5.4)$$

where,

S_a = Design spectral acceleration (in units of g), which shall not be less than 2/3*ZI*β.

β = coefficient used to calculate lower bound for S_a. Recommended value for β is 0.2.

Z = Seismic zone coefficient, as defined in Section 2.5.6.2

I = Structure importance factor, as defined in Section 2.5.7.1

R = Response reduction factor which depends on the type of structural system given in Table 2.5.7. The ratio I/R cannot be greater than one.

C_s = Normalized acceleration response spectrum, which is a function of structure (building) period and soil type (site class) as defined by Equations 2.5.5a-d

$$C_s = S\left(1 + \frac{T}{T_B}(2.5\eta - 1)\right) \quad \text{for} \quad 0 \le T \le T_B \quad (2.5.5a)$$

$$C_s = 2.5S\eta \quad \text{for} \quad T_B \le T \le T_C \quad (2.5.5b)$$

$$C_s = 2.5S\eta\left(\frac{T_C}{T}\right) \quad \text{for} \quad T_C \le T \le T_D \quad (2.5.5c)$$

$$C_s = 2.5S\eta\left(\frac{T_C T_D}{T^2}\right) \quad \text{for} \quad T_D \le T \le 4\,\text{sec} \quad (2.5.5d)$$

C_s depends on S and values of T_B, T_C and T_D, (Fig. 2.5.2) which are all functions of the site class. Constant C_s value between periods T_B and T_C represents constant spectral acceleration.

S = Soil factor which depends on site class and is given in Table 2.5.4

T = Structure (building) period as defined in Section 2.5.9.2

T_B = Lower limit of the period of the constant spectral acceleration branch given in Table 2.5.4 as a function of site class.

T_C = Upper limit of the period of the constant spectral acceleration branch given in Table 2.5.4 as a function of site class

T_D = Lower limit of the period of the constant spectral displacement branch given in Table 2.5.4 as a function of site class

η = Damping correction factor as a function of damping with a reference value of η=1 for 5% viscous damping. It is given by the following expression:

$$\eta = \sqrt{10/(5+\xi)} \ge 0.55 \quad (2.5.6)$$

where, ξ is the viscous damping ratio of the structure, expressed as a percentage of critical damping. The value of η cannot be smaller than 0.55.

Type of soil at the site is SD by following the table below.

Table 2.5.1: Site classification based on soil properties

Site Class	Description of soil profile up to 30 meters depth	Average Soil Properties in top 30 meters		
		Shear wave velocity $\bar{V}_s$ (m/s)	Standard Penetration Value, $\bar{N}$ (blows/30cm)	Undrained shear strength, $\bar{S}_u$ (kPa)
SA	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	--	--
SB	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250
SC	Deep deposits of dense or medium dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
SD	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
SE	A soil profile consisting of a surface alluvium layer with V_s values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with V_s > 800 m/s.	--	--	--
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	--	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types SA to SE or S_1	--	--	--

Therefore, S, TB (s), Tc, are shown in the table below.

Table 2.5.4 : Site dependent soil factor and other parameters defining elastic response spectrum

Soil type	S	T_B(s)	T_C (s)	T_D (s)
SA	1.0	0.15	0.40	2.0
SB	1.2	0.15	0.50	2.0
SC	1.15	0.20	0.60	2.0
SD	1.35	0.20	0.80	2.0
SE	1.4	0.15	0.50	2.0

CTT facilities correspond to Category II from the table below.

Table 1.2.1 Occupancy Category of Buildings and Other Structures for Flood, Surge, Wind and Earthquake Loads

Nature of Occupancy	Occupancy Category
Buildings and other structures that represent a low hazard to human life in the event of failure, including, but not limited to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities	I
All buildings and other structures except those listed in Occupancy Categories I, III, and IV	II
Buildings and other structures that represent a substantial hazard to human life in the event of failure, including, but not limited to: • Buildings and other structures where more than 300 people congregate in one area • Buildings and other structures with daycare facilities with a capacity greater than 150 • Buildings and other structures with elementary school or secondary school facilities with a capacity greater than 250 • Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities • Health care facilities with a capacity of 50 or more resident patients, but not having surgery or emergency treatment facilities • Jails and detention facilities Buildings and other structures, not included in Occupancy Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure, including, but not limited to: • Power generating stations[a] • Water treatment facilities • Sewage treatment facilities • Telecommunication centers Buildings and other structures not included in Occupancy Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.	III
Buildings and other structures designated as essential facilities, including, but not limited to: • Hospitals and other health care facilities having surgery or emergency treatment facilities • Fire, rescue, ambulance, and police stations and emergency vehicle garages • Designated earthquake, hurricane, or other emergency shelters • Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response • Power generating stations and other public utility facilities required in an emergency • Ancillary structures (including, but not limited to, communication towers, fuel storage tanks, cooling towers, electrical substation structures, fire water storage tanks or other structures housing or supporting water, or other fire-suppression material or equipment) required for operation of Occupancy Category IV structures during an emergency • Aviation control towers, air traffic control centers, and emergency aircraft hangars • Water storage facilities and pump structures required to maintain water pressure for fire suppression • Buildings and other structures having critical national defense functions Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing highly toxic substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction.	IV

[a] Cogeneration power plants that do not supply power on the national grid shall be designated Occupancy Category II.

Importance factor of Category II is 1.0 according to the following table.

Table 2.5.5 Importance Factors for Buildings and Structures for Earthquake design

Occupancy Category	Importance factor I
I or II	1.0
III	1.25
IV	1.5

Source: National Building Code 2012

b) The building period T (in secs) may be approximated by the following formula:

$$T = C_t (h_n)^m \tag{2.5.8}$$

where,

h_n = Height of building in metres from foundation or from top of rigid basement. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected.

C_t and m are obtained from Table 2.5.8

Table 2.5.8 Values for coefficients to estimate approximate period

Structure type	C_t	m
Concrete moment-resisting frames	0.0466	0.9
Steel moment-resisting frames	0.0724	0.8
Eccentrically braced steel frame	0.0731	0.75
All other structural systems	0.0488	0.75

NOTE:
Consider moment resisting frames as frames which resist 100% of seismic force and are not enclosed or adjoined by components that are more rigid and will prevent the frames from deflecting under seismic forces.

Source：Bangladesh National Building Code

The seismic coefficient is calculated from these formulae:

hn= 23m (CD-16.0m～MSL+5.0m,MSL=DL+2.02m)

T=0.0488 x 23 x 0.75 = 0.513

η = 1.0

Cs = 2.5 x 1.35 x 1.0 = 3.375

Z = 0.28

I = 1.0

R =3

Sa = 2/3(0.28 x 1.0 x 3.375)/ 3 = 0.21

Horizontal seismic coefficient、 Kh = 0.21

Vertical seismic coefficient、 Kv = 0.00 （JDSOPF）

5.1.2. Conditions for use

1) Design vessels

i) Coal import vessels and its dimensions

Design vessels for coal import vessels are shown in Table 5.1.6. For the 1st phase and 2nd phase design target is 80,000DWT.

Table 5.1.7 Coal import Vessels and its Dimensions

Phase	Vessels (DWT)	L_{oa} (m)	Draft (m)	Beam (m)
1・2	80,000	230	14.5	37.0

Source: JICA Study Team

ii) Secondary transport vessels of coal

Design vessels for secondary transport vessels of coal are shown in Table 5.1.7. For the 2nd phase, design target is 5,000DWT.

Table 5.1.8 Secondary Transport Vessels of Coal and its Dimensions

Vessels (DWT)	L_{oa} (m)	Draft (m)	Beam (m)
5,000	110	6.5	17.0

Source: JICA Study Team

2) Coal handling equipments

The design conditions of the coal handling equipments are determined based on the specifications reported by the maker. In this study, 20% more of the load of coal handling equipment is applied in consideration with the difference of the maker.

i) Unloader

Handling capacity	2,700 t/h
Total weight	1,775t
Rail gauge	25.0 m
Wheel base	22 m
Number of wheel	front : 12 wheels/coner rear : 8 wheels/coner
Wheel span	900 mm
Unit wheel load	Table 5.1.8.

Table 5.1.9 Unit Wheel Load of Unloader

		Unit Front Wheel Load (kN/wheel)	Unit Rear Wheel Load (kN/wheel)
Vertical load	Under operation (wind velocity 16m/s)	510	550
	Storm condition	650	700
	Seismic condition (Kh=0.21)	670	720
Horizontal load	Under operation (wind velocity 16m/s)	51	55
	Storm condition	65	70
	Seismic condition (Kh=0.21)	67	72

Source: JICA Study Team

ii) Ship loader

Handling capacity	2,500 t/h
Total weight	540t
Rail gauge	14.0 m
Wheel base	8 m
Number of wheel	6 wheels/corner x 2 arms
Wheel span	680 mm
Unit wheel load	Table 5.1.9.

Table 5.1.10 Unit Wheel Load of Ship Loader

		Maximum Unit Wheel Load (kN/wheel)
Vertical load	Under operation (wind velocity 16m/s)	260
	Storm condition	280
	Seismic condition (Kh=0.21)	270
Horizontal load	Under operation (wind velocity 16m/s)	260
	Storm condition	280
	Seismic condition (Kh=0.21)	290

Source: JICA Study Team

iii) Belt conveyor

Table 5.1.11 Dimensions of Belt Conveyor Considered in this Design Section

	Unloading Line (Offshore Side)	Loading Line (Land Side)
Handling capacity	5,500 t/h (2 line)	3,300 t/h (2line)
Width of belt	2,200mm	1,600mm
Speed of belt	240m/min	240m/min
Weight of conveyor	21kN/m	21kN/m

Source: JICA Study Team

iv) Stacker and Reclaimer

Handling capacity	6,500/2,500 t/h
Coal stock pile height	16m
Coal stock pile width	47m
Rail span	8m
Wheel base	10.0m
Wheel formation	8 wheel / corner
Unit wheel load	250kN/wheel (working condition)
	280kN/wheel (seismic condition)
Total weight	10,000 kN (Main body 7,500kN + Tripper 2,500kN)

3) Load conditions

i) Dead load

Unit weight of super structure concrete is assumed as follows.

Reinforced concrete: 24k N/m3
Unreinforced concrete: 23k N/m3

ii) Vertical Load conditions

Apron

On the berth：vertical load of 2 t/m^2
(Unloading/loading of equipment is considered separately)

Trestle

Management aisle：” A live load” in Specification of highway bridge.

iii) Other load conditions

Specific weight of coal

Coal mass : 7.8kN/m3

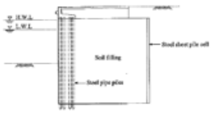
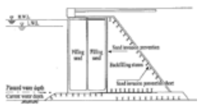
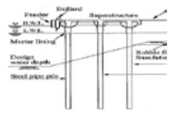
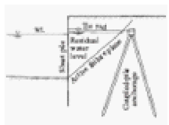
Coal powder : 9.8kN/m3

5.2. Coal Unloading Berth

(1) Selection of the structure type

The candidates of berth structure type are cell type, caisson type, jetty type and sheet pile type considering the deep water depth of -16m at berth front for larger size vessels. Comparing the soil conditions at the site, easiness of construction and cost efficiency, jetty type is considered as most appropriate candidate. Table 5.2.1 shows the comparison of four candidate type of structure for berth structure.

Table 5.2.1 Comparison of Four Candidate Type of Berth Structures

	Cell Type	Caisson Type	Jetty Type	Dolphin Type
Schematic structural figure				
For the case of soft soil conditoin	No necessity of soil improvement work A	Appropriate soil improvement work is necessary C	No necessity of soil improvement work A	No necessity of soil improvement work A
Installation of unloading equipment	Possible on the superstructure A	Possible on the superstructure A	Possible on the superstructure A	Another base structure is necessary. B
Easiness of construction	Large scale temporally working site and equipments are necessary C	Large scale temporally working site and equipments are necessary C	No necessity of large scale working site A	No necessity of large scale working site A
Cost efficiency	Steel type cell structure and comparatively expensive C	Conventional concrete and rock material work and not so expensive B	Steel pipe pile and concrete works and comparatively cost efficient A	Steel sheet pile and steel pipe pile works and most cost efficient B
Judge	Not applicable D	Not applicable C	Applicable A	Applicable B

Source: JICA Study Team

(2) Design conditions

Design conditions of coal unloading berth are shown as below.

1) Natural conditions

Natural conditions are shown in "5.1.1 Design Conditions". The design soil conditions near the shore location are shown in Table 5.1.16 and were considered for unloading berth.

2) Conditions for use

Conditions for use are shown in "5.1.1 Design Conditions". Major issues are shown below.

i) Design vessels

- For the 1st and 2nd Phase：80,000DWT

ii) Load conditions of coal handling equipment

Two unloaders are installed in each unloading berth.

iii) Vertical load conditions

Uniform vertical load of 20kN/m2 is considered for the entire area of berth.

(3) Dimensions of structure

1) Berth top surface level

Surface level of berth top is determined by considering the local tide condition and size of design vessel. According to Table 5.2.2 by the Japanese design standard for port structure, which shows the relation between HWL and top surface level of berth, 0.5 m to 1.5 m are considered appropriate.

+2.2 m+0.5 m~+2.2 m+1.5 m=+2.7 m~+3.7 m

Considering the standard and effect of storm surge, top surface level of MSL+5.0 m is employed. However, it is required to confirm the top surface level depending on the frequency of storm surge and coal handling equipment on unloading berth in the basic and detailed design stage.

Table 5.2.2 Threshold of Berth Top Surface Level by Considering the Local Tide Condition and Size of Design Vessel

	Tidal range 3.0m or more	Tidal range less than 3.0m
Wharf for large vessels (water depth of 4.5m or more)	+0.5–1.5m	+1.0–2.0m
Wharf for small vessels (water depth of less than 4.5m)	+0.3–1.0m	+0.5–1.5m

Source: Japanese Design Standard for Port Structure

2) Berth length

Berth length is determined as follows in Section 5.2.2

1st and 2nd Phase 80,000DWT：1 berth=300m

3) Berth allocation

Berths are allocated on one side of jetty based on the unloader type in port planning.

4) Width of berth

Total width of 29.5m is employed by considering the unloader’s rail span of 25m, interval between sea side rail and front side end of berth of 2.5m and interval between landside rail and back side of berth of 2.0m.

Access road on the berth and installation space of belt conveyor is allocated within the rail span of unloader.

5) Water depth in front of the berth

Water depth in front of the berth is planned as follows.

For 1st and 2nd Phase: 80,000DWT, 16.0m water depth

(4) Design force

1) Wave, tide and tsunami forces

These forces are not considered at this stage of work, because the wave, tide and tsunami forces are comparatively small with other dominant forces such as berthing of design vessels or earthquake forces.

2) Earthquake force

Seismic force was applied to the parallel and the perpendicular direction of the berth.
Horizontal design seismic intensity was Kh = 0.21

3) Berthing forces

i) Berthing velocity

Figure 5.2.1 shows the relation between the berthing velocity and DWT of the vessels. Berthing velocity of 5 cm/s which is the maximum value for largest ship in the Figure 5.2.1 is selected as the design berthing velocity for 80,000DWT vessel. Fender interval of 10m is assumed.

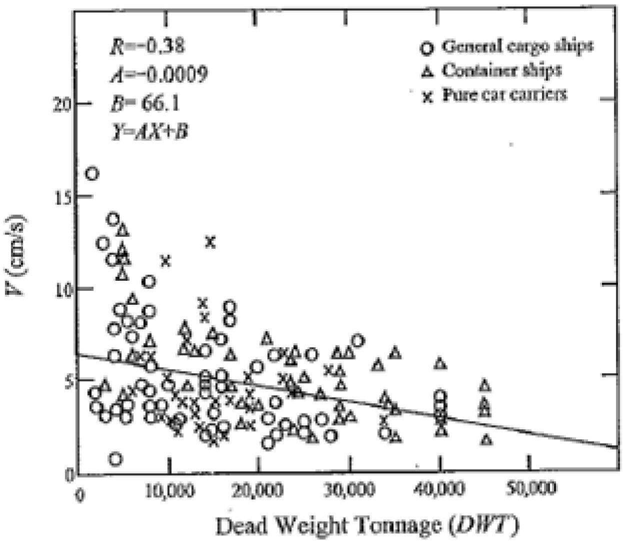


Fig. 2.2.5 Relationship between Dead Weight Tonnage and Berthing Velocity [5)]

ii) Berthing forces

Berthing forces are determined based on the Japanese design standard for port structure. The results are shown below.

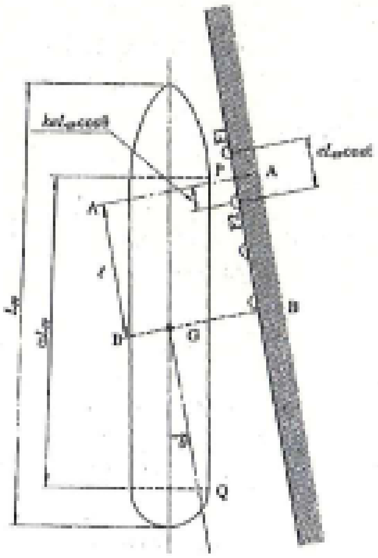
For the 1st and 2nd Phase: 1560kN/location (design vessel=80,000 DWT, berthing velocity=5cm/s)

Table 5.2.3 Calculation of Berthing Energy for 80,000DWT Vessels

Calculation of Berthing Energy

Key-in Data

Type of Vessel		Bulk Carrier Vessel		
Deadweight Ton	DWT	80,000	ton	
Length (over all)	Loa	230.0	m	
Length (between perpendiculars)	Lpp	225.0	m	(Assumed)
Breadth	B	37.0	m	
Depth	D	28.0	m	
Draft (full)	d	14.5	m	
Displacement	Ws	95400	ton	(Assumed)
Berthing Angle	TH	5	degree	(Assumed)
Hydrodynamic coefficient	Cm	1.802		Cm=1+(pai/2Cb)(d/B)
Block coefficient	Cb	0.767		Cb=Ws/(LppXBXdX1.03)
Eccentricity coefficient	Ce	0.676		Ce =1/(1+(l/r)^2)
Radius of gyration	r	57.55	m	r=(0.19Cb+0.11)Lpp
Distance alongside the water line from the center of gravity of vessel to the berthing point	l	39.83 min(l1,l2)	m	l1=(0.5a+e(1-k))LppXcos(TH) l2=(0.5a-ek)LppXcos(TH)
Fender Spacing	Lf	10.00	m	(Assumed)
Coefficient of parallel side	a	0.40		
Coefficient of Fender interval	e	0.045		e=Lf/(LppXcosTH)
Coefficient of berthing point	k	0.50		
Block coefficient	Cb	0.767		Cb=Ws/(LppXBXdX1.03)
Softness coefficient	Cs	1.0		
Berth configuration coefficient	Cc	1.0		
Berthing Velocity	V	0.05	m/sec	(Assumed)
Berthing Energy	E	145.3	kN-m	E=0.5XWsXV^2XCmXCeXCsXCc
Safety factor	Sf	1.10		(Assumed)
Abnormal Berthing Energy	Ea	159.9	kN-m	Ea = E × Sf



Source: JICA Study Team

4) Mooring forces

Mooring forces are obtained from Table 5.2.3. Bollard force of 1,000kN for 80,000DWT (about 45,000GT) is selected from Table 5.2.4.

Table 5.2.4 Relationship Between Gross Tonnage of Ship and Mooring Force

Gross tonnage of ship (t)	Tractive force acting on mooring post (kN)	Tractive force acting on bollard (kN)
Over 200 and not more than 500	150	150
Over 500 and not more than 1,000	250	250
Over 1,000 and not more than 2,000	350	250
Over 2,000 and not more than 3,000	350	350
Over 3,000 and not more than 5,000	500	350
Over 5,000 and not more than 10,000	700	500
Over 10,000 and not more than 20,000	1,000	700
Over 20,000 and not more than 50,000	1,500	1,000
Over 50,000 and not more than 100,000	2,000	1,000

Source: JICA Study Team

(5) Design structures

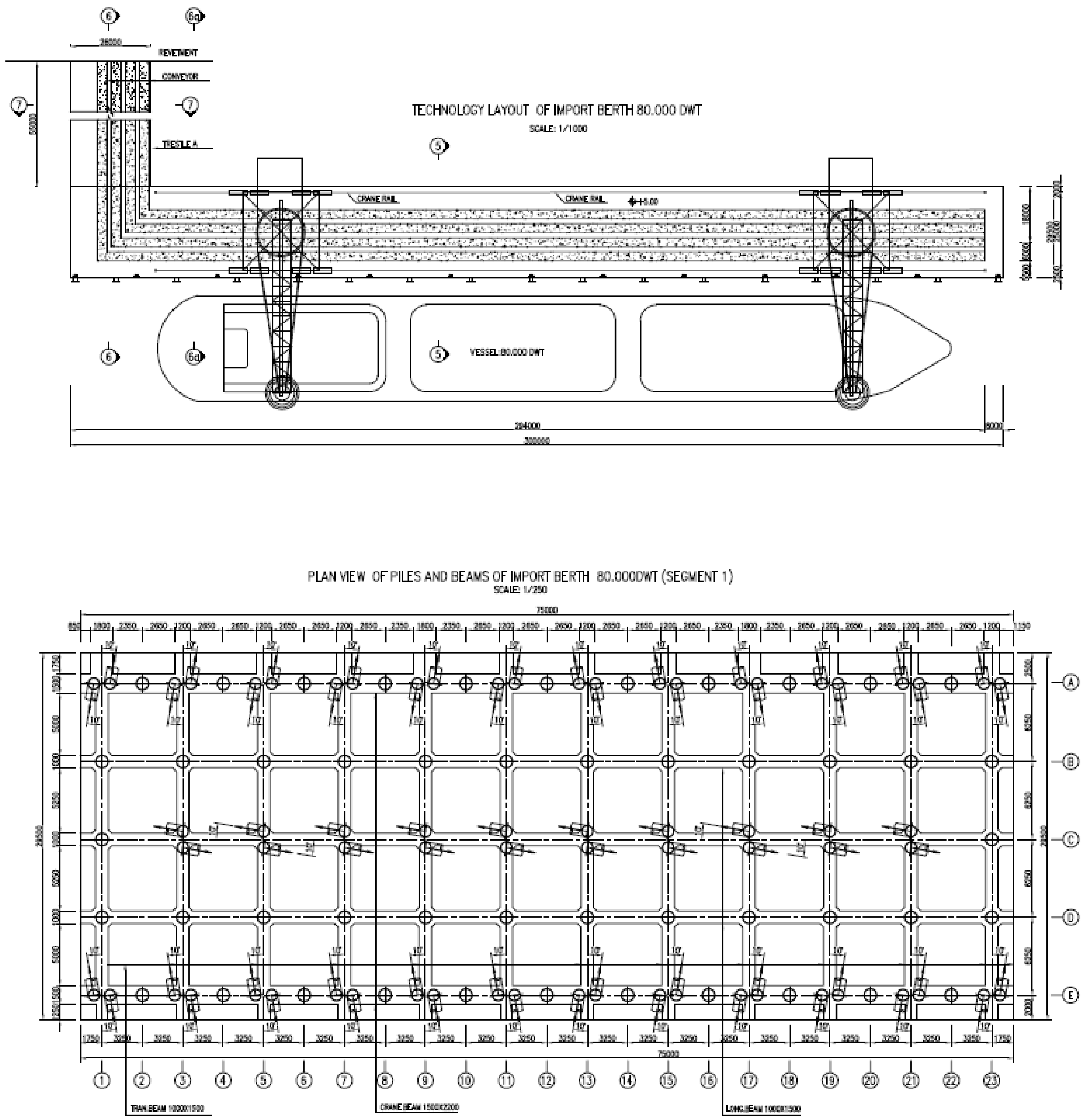
Location of pile: Two sets of pile casting are allocated to resist the strong horizontal berthing forces. Pile interval of 6.25 m to 6.5 m is determined by considering the use of reinforced concrete (RC) beam. Supporting piles just underneath the rail for unloader are allocated because of heavy vertical load. The interval of the piles is 3.25 m. The piles are allocated at the intermediate RC beam under rail for unloader.

Type of pile: Steel pipe pile is selected by considering the necessity of long pile due to subsurface soft soil conditions. Corrosion protection is considered.

Superstructure: RC type structure is considered.

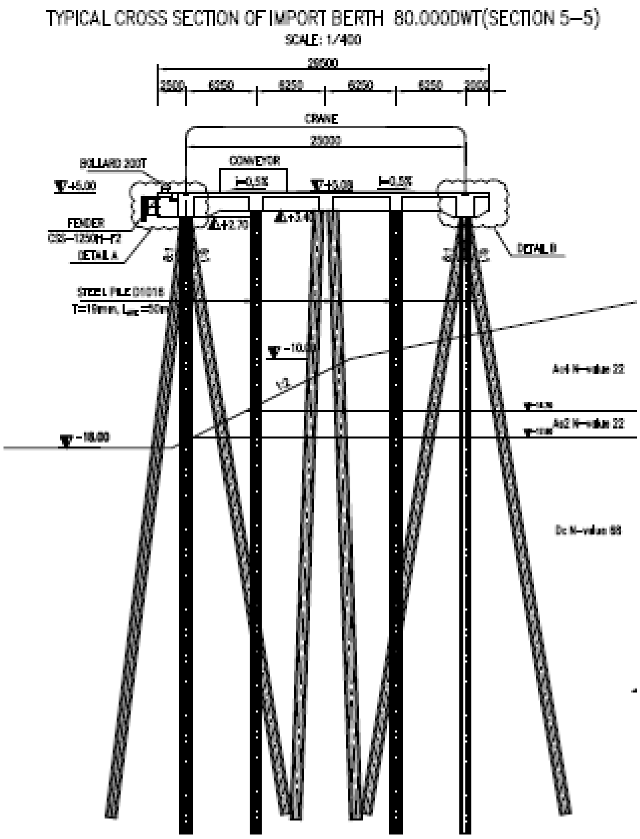
(6) Design drawings

For 80,000DWT berth



Source: JICA Study Team

Figure 5.2.2 Front View and Side View of the Berth for 80,000 DWT



Source: JICA Study Team

Figure 5.2.3 Typical Cross Section of the Berth for 80,000 DWT

5.3. Coal Loading Berth

(1) Selection of the type of structure

Jetty type structure for the coal loading berth same as the coal unloading berth is selected.

(2) Design conditions

1) Design condition for the facility

i) Natural conditions

Natural conditions are shown in “5.1.1 Design Conditions”. The design soil conditions at near shore location shown in Table 5.1.17 was considered for loading berth.

ii) Conditions for use

Conditions for use and major items are shown below.

Uniform vertical load of 20 kN/m^2 is considered for the entire area of berth.

A 5,000 DWT barge is considered to be used in the planning. However, the specifications of the barges are not clear because there are plans that barges will be newly built. Therefore, the specifications of 5,000 DWT vessels are considered for this design. In the stage of basic design and detailed design, it is necessary to determine the specification of the barges.

(3) Dimensions of structure

i) Berth top surface level

Berth top surface level of MSL+5.0m, same value of unloading berth, is selected by considering the tide conditions and design vessel size.

ii) Berth length

Berths are allocated at one side of jetty based on the port planning. A ship loader is also allocated at each berth.

iii) Berth allocation

Berths are allocated one side of jetty based on the port planning. A Ship loader is also allocated at the each berth.

iv) Width of berth

Total width of 18.0 m is determined by considering the loader’s rail span of 14.0 m, berth front side of 2.5 m, and rear side of 1.5 m. Access road on the berth and installation of conveyor belt are allocated within the rail span of loader.

v) Water depth in front of the berth

Water depth in front of the berth is MSL-7.5m

(4) Design forces

1) Wave, tide and tsunami forces

These forces are not considered at this stage of work, because the wave, tide and tsunami forces are comparatively small with other dominant forces such as berthing of design vessels, and earthquake forces.

2) Earthquake force

Seismic force was applied to the parallel and the perpendicular direction of the berth.
Horizontal design seismic intensity was Kh = 0.21

3) Berthing forces

i) Berthing velocity

According to Figure 5.2.1, the berthing velocity of targeted ship of 5,000 DWT is 10.0 cm/s, which was selected considering the variation of data. Fender allocation interval of 10 m is also assumed.

ii) Berthing force

Berthing force is determined based on the Japanese design standard for port structure. The 53 kN/location is obtained for the design ship of 5,000 DWT.

4) Mooring force

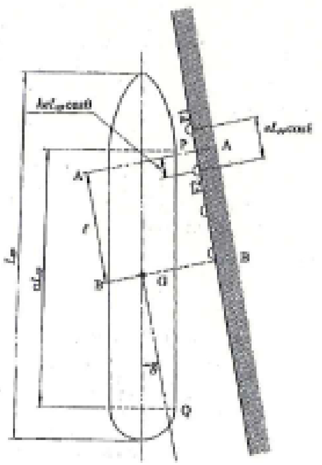
Mooring force is obtained from Table 5.3.1. Bollard force of 350 kN/location is considered. Bollard interval of 10 m is selected.

Table 5.3.1 Calculation of Berthing Energy for 5,000DWT Vessels

Calculation of Berthing Energy

(Key-in Data)

Type of Vessel		Bulk Carrier Vessel		
Deadweight Ton	DWT	5,000	ton	
Length (over all)	Loa	110.0	m	
Length (between perpendiculars)	Lpp	101.0	m	(Assumed)
Breadth	B	17.0	m	
Depth	D	8.7	m	
Draft (full)	d	6.5	m	
Displacement	Ws	6950	ton	(Assumed)
Berthing Angle	TH	5	degree	(Assumed)
Hydrodynamic coefficient	Cm	1.993		Cm=1+(pai/2Cb)(d/B)
Block coefficient	Cb	0.605		Cb=Ws/(LppXBXdX1.03)
Eccentricity coefficient	Ce	0.693		Ce =1/(1+(l/r)^2)
Radius of gyration	r	22.71	m	r=(0.19Cb+0.11)Lpp
Distance alongside the water line from the center of gravity of vessel to the berthing point	l	15.12 min(l1,l2)	m	l1=(0.5a+e(1-k))LppXcos(TH) l2=(0.5a-ek)LppXcos(TH)
Fender Spacing	Lf	10.00	m	(Assumed)
Coefficient of parallel side	a	0.40		
Coefficient of Fender interval	e	0.099		e=Lf/(LppXcosTH)
Coefficient of berthing point	k	0.50		
Block coefficient	Cb	0.605		Cb=Ws/(LppXBXdX1.00)
Softness coefficient	Cs	1.0		
Berth configuration coefficient	Cc	1.0		
Berthing Velocity	V	0.10	m/sec	(Assumed)
Berthing Energy	E	48.0	kN-m	E=0.5XWsXV^2XCmXCeXCsXCc
Safety factor	Sf	1.10		(Assumed)
Abnormal Berthing Energy	Ea	52.8	kN-m	Ea = E × Sf



Source: JICA Study Team

(5) Design structure

Layout: Coal loading berth is planned to be installed in the harbour.

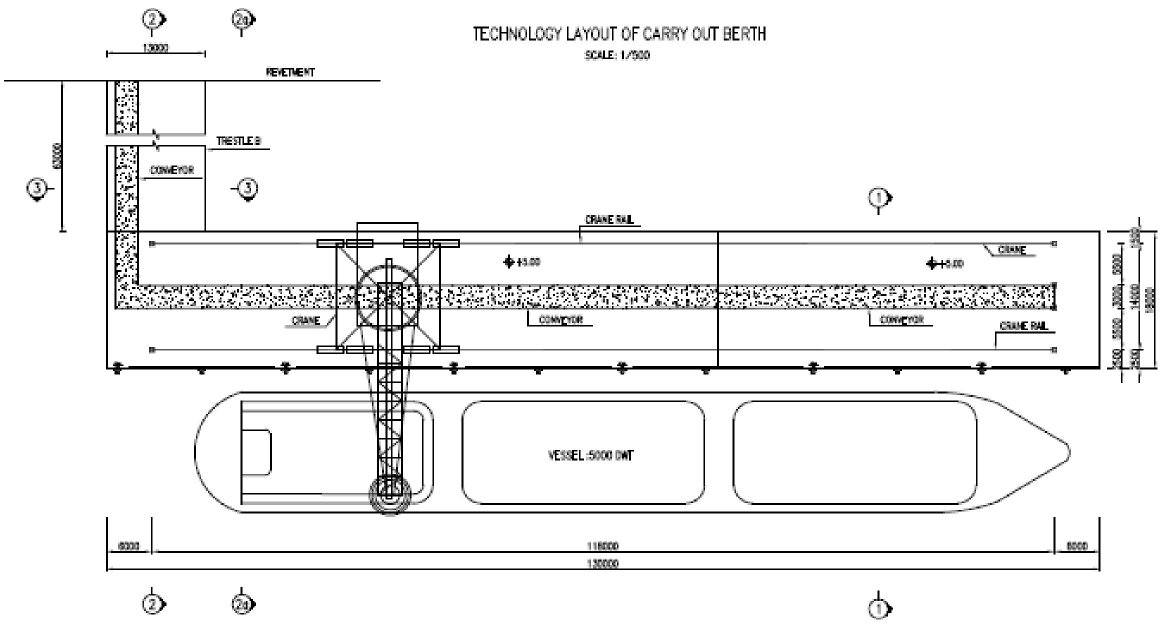
Location of pile: Two set of pile casting are allocated at the centre to resist the horizontal berthing forces. Supporting piles just underneath the rail for loader are allocated. Pile interval of 7m is selected by considering the dimensions of rail span.

Type of pile: Steel pipe pile is employed by considering the necessity of long pile due to subsurface soft soil conditions. Corrosion protection is considered.

Superstructure: RC type structure is selected.

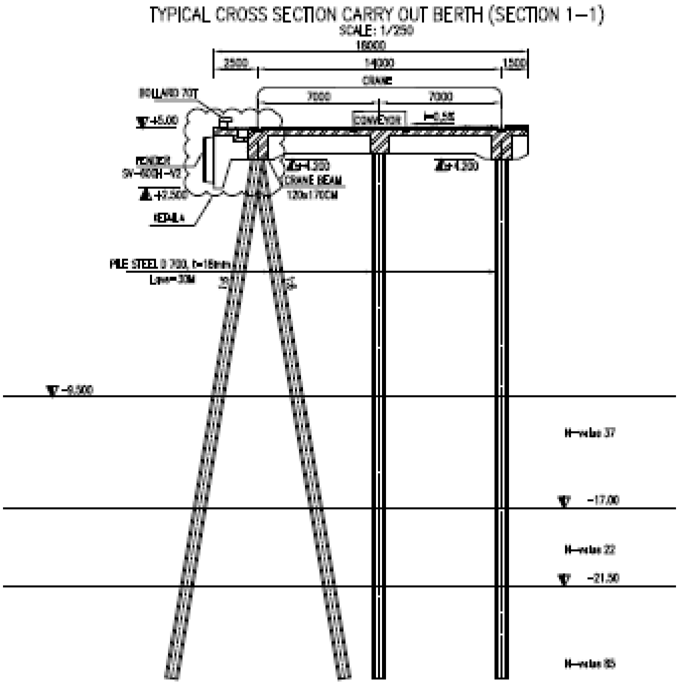
(6) Design drawings

For 5,000DWT berth



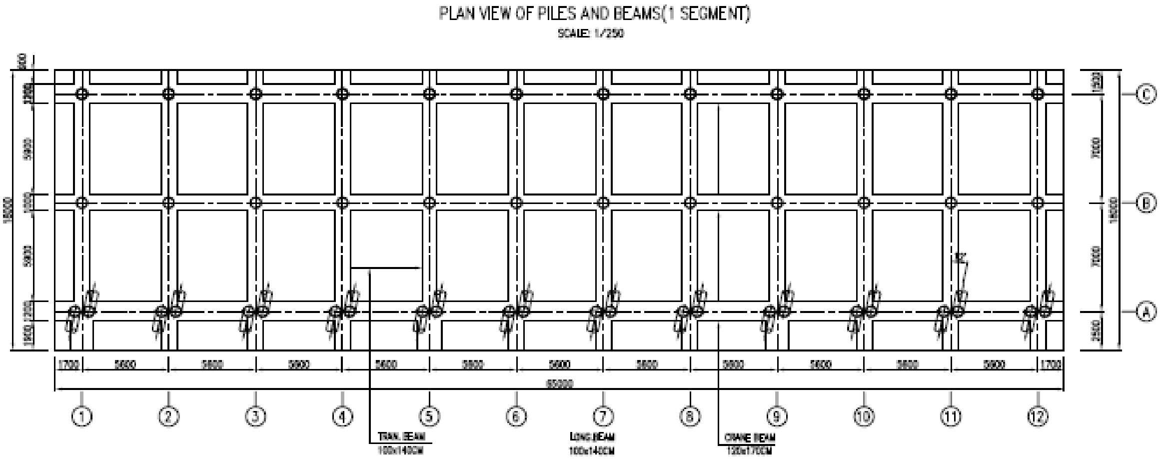
Source: JICA Study Team

Figure 5.3.1 Layout of Berth for 5,000DWT



Source: JICA Study Team

Figure 5.3.2 Typical Cross Section of the Berth for 5,000 DWT



Source: JICA Study Team

Figure 5.3.3 Pile Plan of the Berth for 5,000 DWT

5.4. Trestle

Trestle consists of Trestle A for unloading and Trestle B for loading. Both cross sections are considered for parallel access road.

1) Design conditions

i) Natural conditions

Natural conditions are shown in “5.1.1 Design Conditions”.

ii) Conditions for use

Trestle A

Belt conveyor: Unloading berth belt conveyors with four lanes in the 1st Phase and six lanes in the 2nd Phase are considered for transfer of import coal to coal stock yard. The width of belt conveyor is 2,200 mm.

Trestle B

Belt conveyor: Loading berth belt conveyors with one lanes of one berth in the 2nd Phase, is considered for transfer of coal from coal stock yard to loading berth. The width of belt conveyor is 1,600 mm.

Access road

Two-lane access road for management purpose are considered. Width of the access road is 8.0 m. Live load of large sized vehicle of 20 kN/m^2 is applied.

2) Selection of the type of structure

Bridge type is selected by considering the length, water depth, waves, and impact on the sea environment.

PC hollow slab girder is selected for the access road and steel truss bridge is employed for belt conveyor. The truss structure of belt conveyor will be studied in more detail at the determination of conveyor structure. Steel pile for bridge pier is selected because the load of bridge pier is not so large and long pile is expected. Covers for belt conveyor are considered to protect the environment.

3) Dimensions

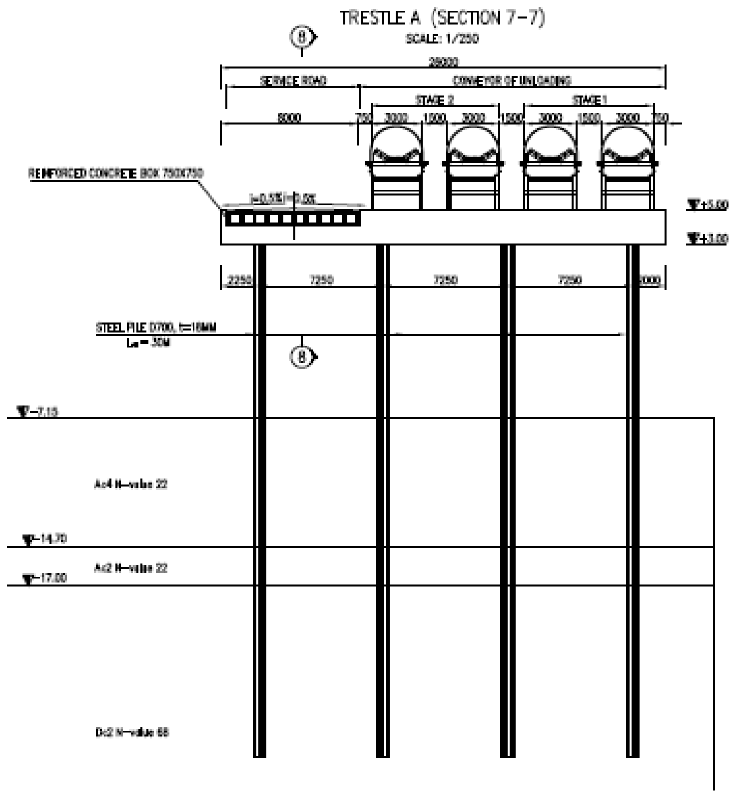
Width: The width of 26.0m for Trestle A and 13.0m for Trestle B are determined by considering the access road for management and four lanes belt conveyor.

Span of the bridge: The span of 20 m is determined by considering its balance with the dead load of superstructure.

Top surface elevation: The elevation of MSL+5.0m is determined by considering the extreme wave conditions at the time of HWL.

4) Design Drawings

Trestle A



Source：JICA Study Team

Figure 5.4.1 Typical Cross Section of Trestle A

Trestle B

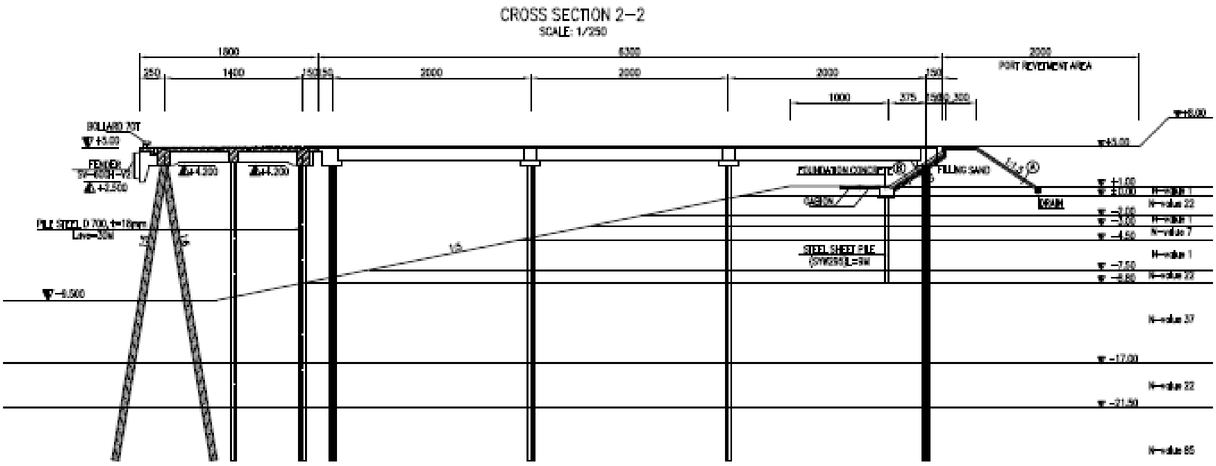


Figure 5.4.2 Side Cross Section of Trestle B

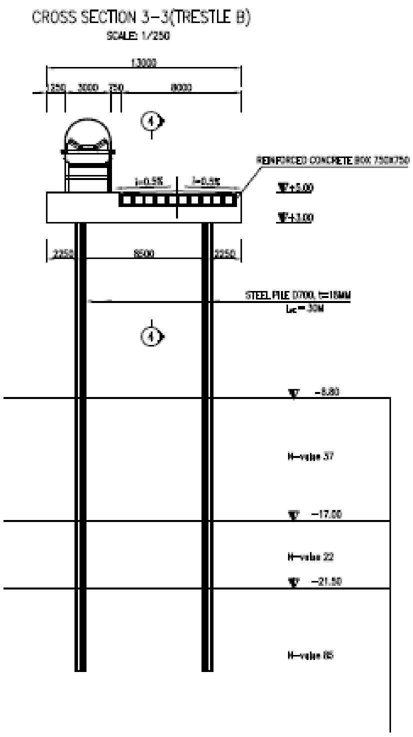


Figure 5.4.3 Typical Cross Section of Trestle B

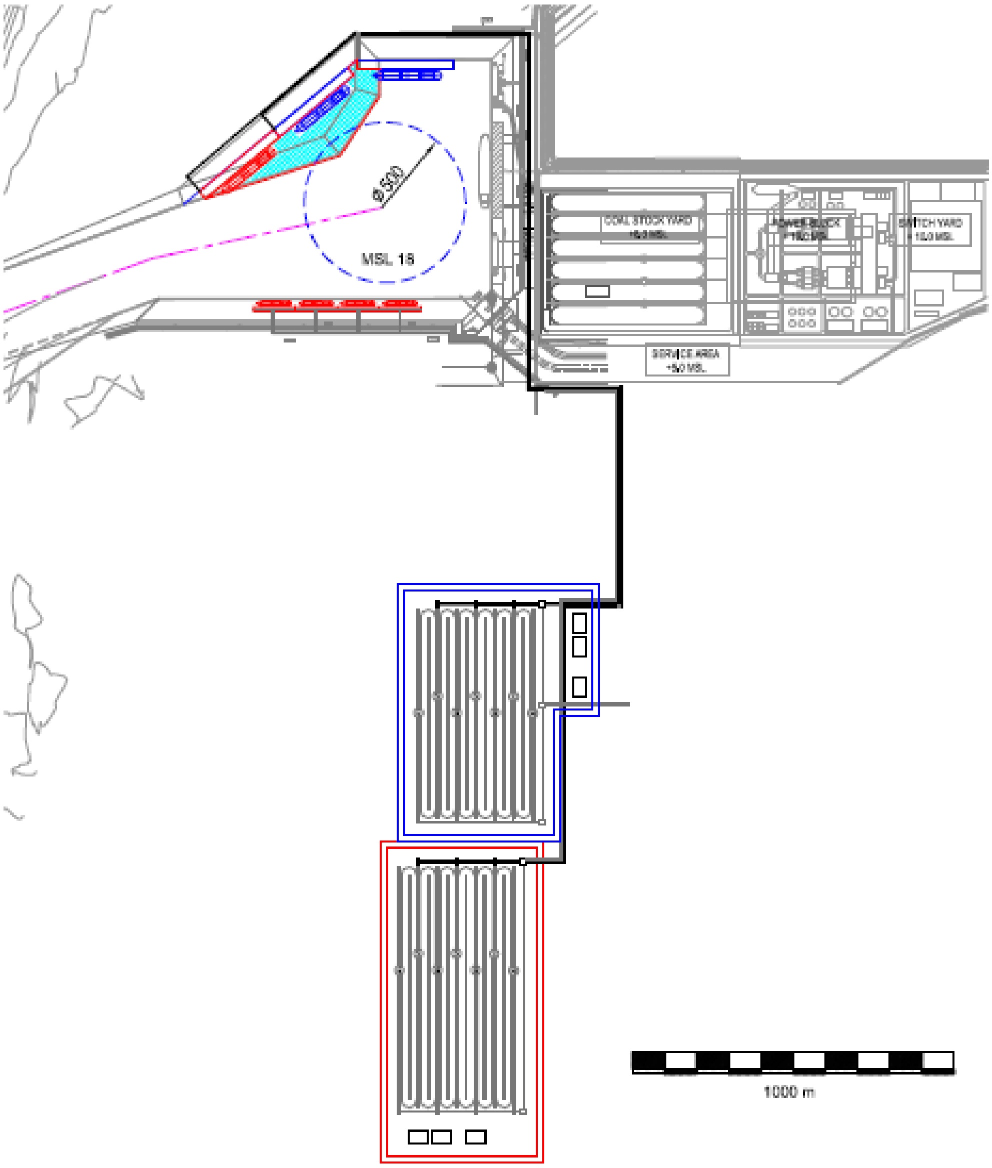
5.5. Coal Stockyard

(1) Selection of the structure type

Development plan from the 1st Phase to 2nd Phase is considered. Required areas of stockyard are as follows:

1st Phase: 45ha
2nd Phase: 50ha

The layout of stockyard is shown in Figure 5.5.1 below.



Source：JICA Study Team

Figure 5.5.1 Layout of Planned Coal Stockyard

Designed structures and facilities are shown as below.

i) Reclamation
ii) Base of stacker reclaimer
iii) Soil improvement
iv) Pavement
v) Dust protection fence

As mentioned before, other facilities such as utility of drainage or water treatment are studied in cost estimation.

(2) Design conditions

1) Natural conditions

Land elevation: Land reclamation is conducted from MSL+1.0 m current average elevation to MSL+8.0 m considering the prevention of storm surge damage. In the case that a risk of severe storm surge caused by low frequent cyclone is acceptable, elevation of land reclamation is determined at MSL+5.0 m. Therefore, MSL+8.0 m and MSL+5.0 m of reclamation elevation are designed in this study.

Reclamation material: The material to be used for land reclamation is soil, which will be dredged in the construction work of Matarbari CFPP. The height of land reclamation is necessary to be reconsidered based on the quality and quantity of material and cyclone risk. The height should be studied in more detail in the detailed design stage.

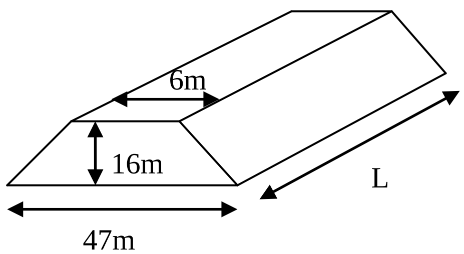
Soil conditions: The design conditions shown in Table 5.1.17 are applied.

2) Conditions for use

Current average elevation at the site is about MSL+1.0 m. The elevation after land reclamation will be at MSL+8.0 m and MSL+5.0 m considering the prevention of storm surge and drainage water from the facilities.

The typical cross section of coal stock pile is determined by considering the past examples and capacity of stacker reclaimer as follows.

Cross section of coal stock pile: trapezoid
Slope gradient: 40°
Height of coal stock pile: 16.0m
Width of top surface: 6.0m
Width of bottom: 47.0m



Source：JICA Study Team

Figure 5.5.2 Dimensions of Coal Stockpile

3) Structure results

i) Reclamation

The stockyard elevation of MSL+8.0 m and MSL +5.0 m, which are higher than the current elevation, is determined by considering the wave or drainage. An average of 7.0 m and 4.0 m height of the reclamation is considered. The dredged soil placed temporally at the ash pond is used for reclamation.

ii) Basement of rail for stacker reclaimer

The beams under the ground supported by steel pile are considered as basement of rail for stacker reclaimer. The grid span of 10m connecting with both sides of beams was considered to ensure the rail span. The height of basement is 1.2m higher than coal stock yard to protect rail from sedimentation by coal.

iii) Soil improvement

Weight from the height of coal stock pile of 16.0 m and reclamation of 7.0 m and 4.0 m are expected. Maximum of about 1.0 m consolidation settlement of clay soil layer is expected because there is a soft clay layer with about 7.0 m depth in current soil. Therefore, soil improvement for control of settlement is required at the whole of reclamation area.

Soil improvement aims less than 30 cm of residual settlement and 80% of final settlement during six months of surcharge period. Pre-loading method with PVD is expected as the most cost efficient. Square configuration of PVD with 1.3 m interval is determined. The surcharge height of 3.0 m is considered and over 90% of final volume of consolidation settlement is expected for eight months.

Ground settlement and stability of slope should be considered. To prevent from circular slip of slope, 1:3 slope gradients are employed for reclamation. Small embankment with 1.0 m height and 10 m width are also considered at the end of slope. A 20 m of offset distance from top of slope of land reclamation are ensured because large weight from stock coal affects the yard.

iv) Pavement

Wheel loader, reclaimer or bulldozer for transfer of coal stock pile is considered for the design of pavement. Concrete slab with thickness of 30cm, upper road bed with thickness of 20cm and lower road bed with thickness of 30cm for capacity of wheel loader of 2.0 m3 are considered. About 2% gradient is selected to drain water from sprinkler for dust or fire protection.

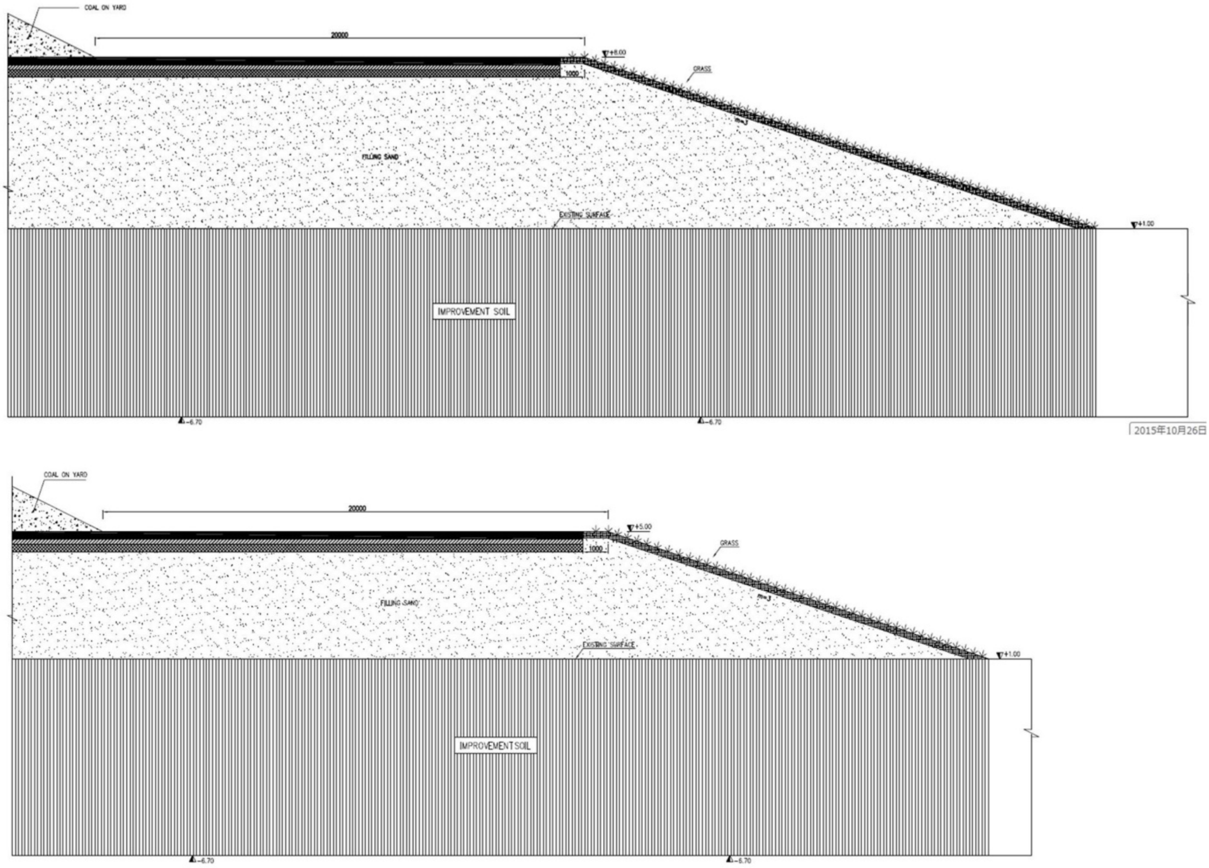
v) Dust protection fence

The dimensions of dust protection fence are expected that the height of fence is 16m and the height of

base is 2.0m, which are same as Chubu Coal Center in Japan. PC piles, L=20m, Ø=400m and t=65mm, are considered as the base of the fence. The dust protection fence is planned to be installed at the border of coal stock yard on land side until the 2nd Phase.

4) Design drawings

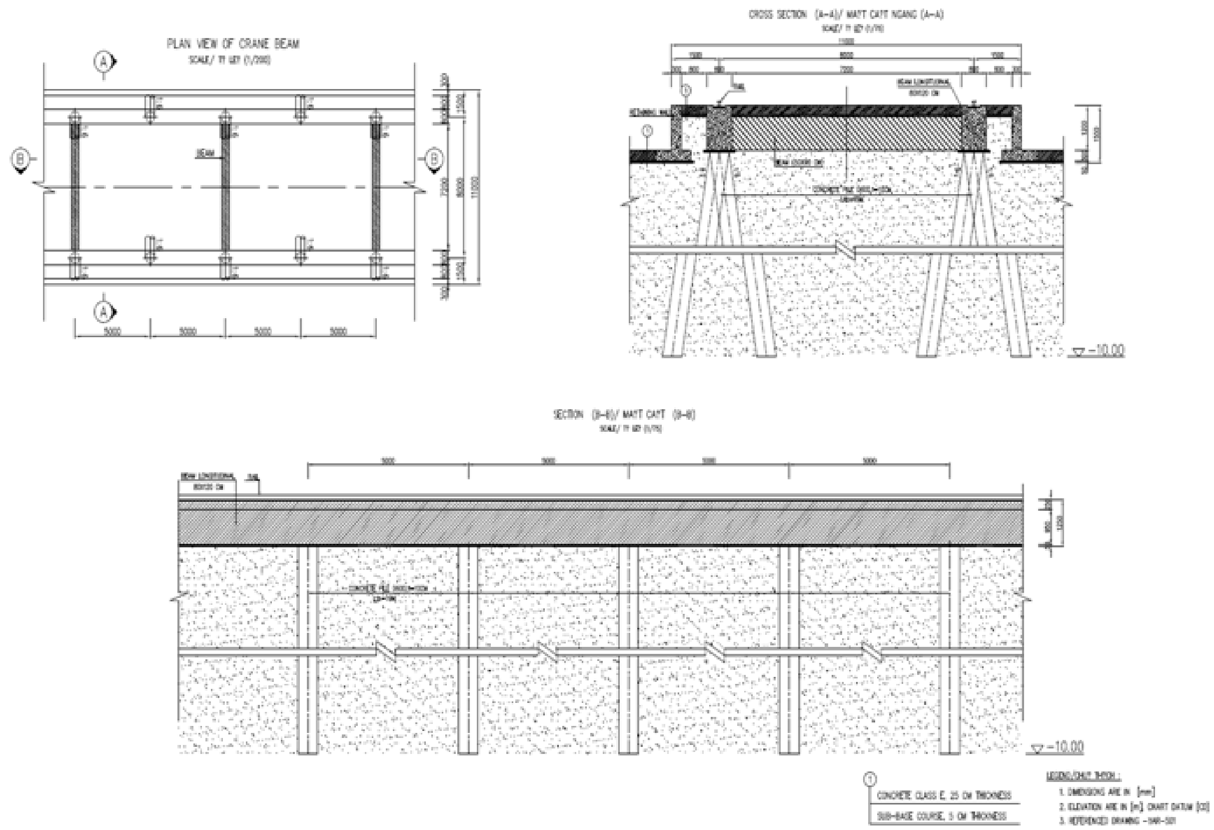
i) Reclamation slope on the land side



Source: JICA Study Team

Figure 5.5.3 Typical Cross Section of Reclamation Slope on the Land Side

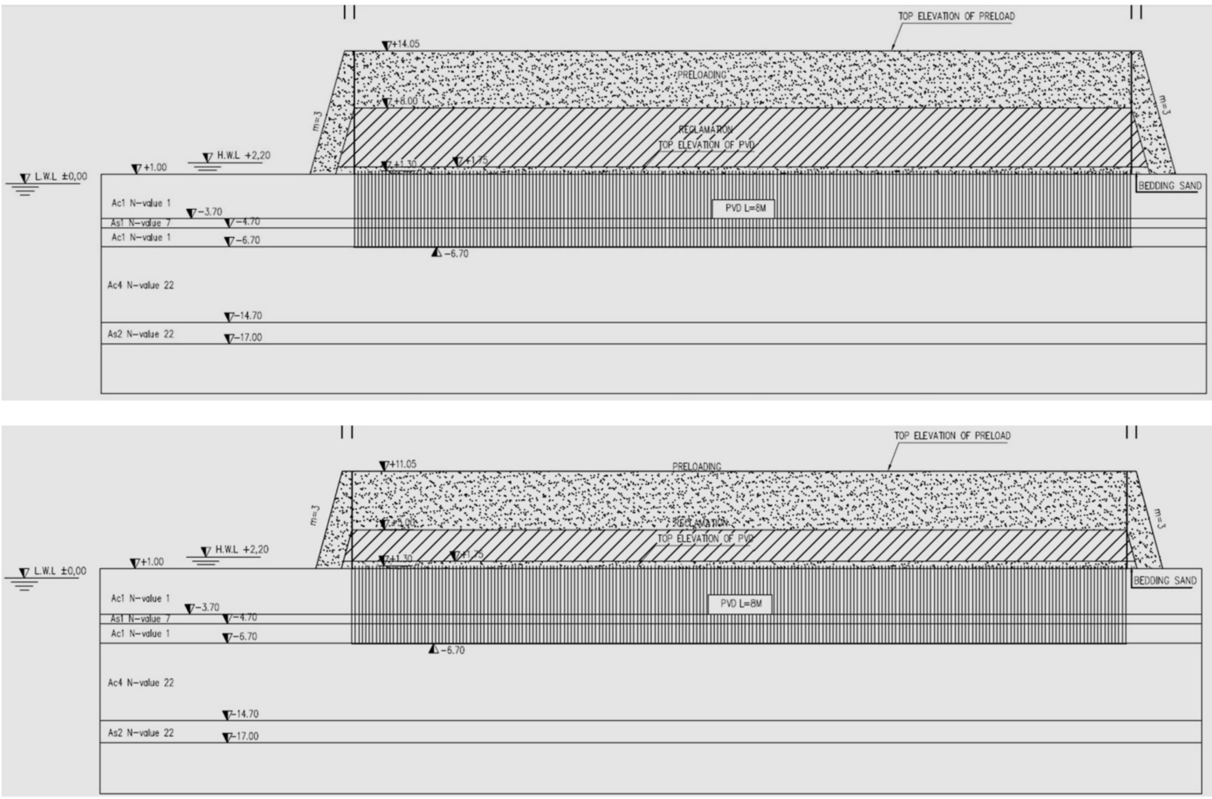
ii) Basement for stacker reclaimer



Source: JICA Study Team

Figure 5.5.4 Drawings of Basement for Stacker Reclaimer

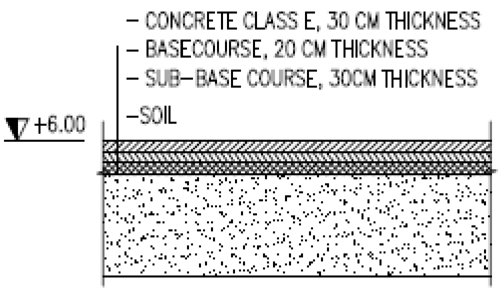
iii) Soil improvement of the coal stock yard



Source: JICA Study Team

Figure 5.5.5 Cross Section of Soil Improvement

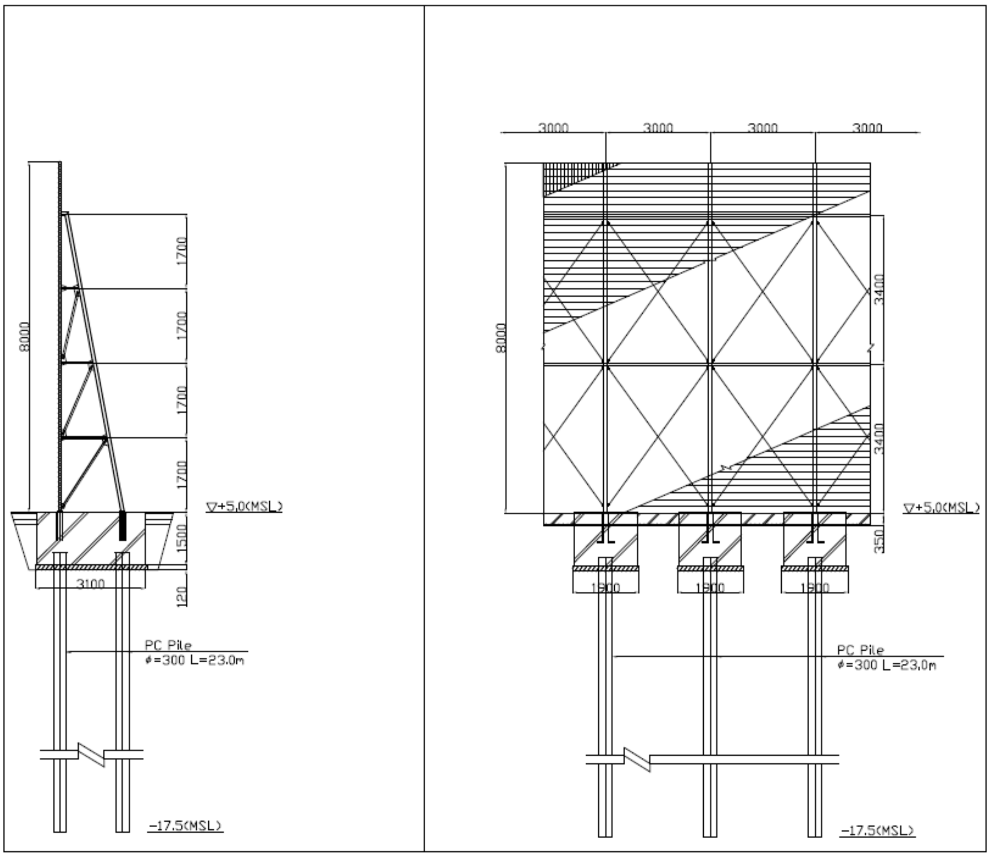
iv) Pavement



Source: JICA Study Team

Figure 5.5.6 Cross Section of Pavement

v) Dust protection fence



Source: JICA Study Team

Figure 5.5.7 General Layout of Dust Protection Fence

5.6. Basement of Facilities on Land Side

(1) Structure

Belt conveyor is designed with steel truss type and MSL+10.0 m height in order to consider crossover to other facilities. PC concrete piles are expected as basement of facilities on land side such as belt conveyors or buildings.