Ministry of Power, Energy and Mineral Resources
People's Republic of Bangladesh

Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh

Final Report
on
Power Plant / Port /
Transmission Line / Access Road /
Execution Survey of Natural Condition

Book 3
For Publishing

March 2015

Japan International Cooperation Agency (JICA)
Tokyo Electric Power Services Co., LTD
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Chapter 16

Plan and Design of Access Road

Chapter 16 Plan and Design of Access Road

16.1 Basic policy and Design Concept

16.1.1 Basic policy on preliminary planning of road and bridge (route planning and structural study)

1) Avoiding or Minimizing Negative Social and Environmental Impacts

It is the basic and fundamental policy tenet to avoid or to minimize any negative impacts on the livelihoods of the people by giving every possible priority to avoiding any forced relocations in selecting the access road route.

Accordingly the following order of priority is adopted:

･To use existing road facilities to the maximum possible degree

･To limit improvements on existing roads at the minimum level as to avoid or minimize any relocations of the people. Provision of bypass roads is considered to avoid or minimize relocations of the people. Notably, in terms of environmental aspects, all consideration will be taken to avoid or minimize the impacts on the rare bird species found in the area.

2) To Grasp the Actual Utilization Conditions and Needs

A traffic analysis will be conducted to reflect the results in road planning. The actual present day road utilization conditions, along with needs for the future must be considered in the road planning.

3) To Determine Route and the Structures of the Roads and Bridge Based on a Comprehensive Perspective

Route and the structural specifications of the road and bridge will be determined based on a comprehensive perspective that includes project cost, user-friendliness, effectiveness, construction period, ease of operations and maintenance, with the priority focus on avoiding or minimizing negative social and environmental impacts.

16.1.2 Basic policy on preliminary road design

To provide a preliminary design for the road under the coordination of LGED and RHD, it is not only based on the design standards and the best practices in Bangladesh but also consider the existing road utilization and flood risk management issues, with perspectives based on the Japan road construction ordinance and current Euro-American design standards.

16.1.3 Basic policy on preliminary bridge design

To provide preliminary design of the bridge under the coordination of LGED and RHD, not only based on the design standards and the best practice in Bangladesh, but that also considers existing road and river utilization, with perspectives based on Japan road bridge design standards and Euro-American design standards. A preliminary bridge design will be prepared that duly considers environmental aspect, social aspect, construction costs, ease of construction, ease of operations and maintenance, construction period, and providing no less than four alternatives.

16.1.4 Basic policy on environmental and social considerations

1) To ensure a proper environmental and social considerations study, in line with the Project's classification as a Category B project.
2) To consider consistency and compliance with the findings of the preparatory survey for the Plant: special consideration will be given to promote the efficiency and supplementing requirements, consideration of an execution scheme that incorporates use of dredged or excavated fill for the construction of access road are considered, where applicable to share or overlap needs.
3) To prepare an environmental assessment report in line with the "JICA Guidelines for Environmental and Social Considerations (April 2010)" (hereinafter referred to as JICA Environmental Guideline (April 2010), and the contents of the World Bank Safe Guard Policy OP 4.01 Annex B.
4) To prepare unavoidable relocation plans based on the JICA Environmental Guideline (April 2010) and content of the World Bank Safe Guard Policy OP4.12 as per the Resettlement Plan of Annex B. The specific preparation procedures will be set based on the "World Bank Involuntary Resettlement Source Book Planning and Implementation in Development Projects"

16.2 Route Selection

16.2.1 Requirements for the access road

1) From national highway No. 1 to Maheshkhali, maximum use of existing roads should be considered. Where repairs or improvement are necessary due to damage or insufficient width of the existing roads to service for the thermal power plant, repair or improvement plans will be proposed in the study at the minimum feasible scope.

2) Repair, improvement, or new construction of roads (mountainside or canal-side routes) from Maheshkhali Island to the power plant site will be considered, as necessary.

3) As criteria to determine the elevation of new road constructions, the high water marks for 10, 25, and 50-year floods will be estimated in light of flooding histories and conditions of existing roads compared to the necessary vehicle transit volume for operations and maintenance.

4) Methods to re-use the excavated sediment (dredged sediments) in the proposed roads will be determined based on sediment quality.

16.2.2 Route selection for access road

(1) Candidate Routes

The candidate routes of access road are in the area from the national highway running between Chittagong and Cox's Bazar to the Power Plant site. Basically, existing road facilities will be utilized wherever possible. It is envisioned that the route segments to join the national highway in the north and the route from Maheskhali Island to the Power Plant site will involve new road and bridge construction.

Candidate Route 1

From **Chakoria** via Regional Highway R172, Badarkhali Bridge and new road & bridge to the Power Plant Site

This route is the shortest route from the National highway to the Power Plant Site, and need new bridge construction.

Candidate Route2

From Chakoria via Regional Highway R172, Badarkhali Bridge, Upazilla road, Matarbari Road Bridge, Matarbari Bridge and Union road to the Power Plant Site.

This route is composed of existing roads only to be shorter from the national highway to the Power Plant Site.

<u>Candidate Route 3</u>

From **Ekata Bazar** via Zilla road Z1125, Pekua Bazar, via R170, Eidmoni, R172, Badarkhali Bridge and <u>new road & bridge</u> to the Power Plant Site

This route is an alternative of Candidate 1 to avoid the congestion of Chakoria intersection and select good condition route.

<u>Candidate Route 4</u>

From **Ekata Bazar** via Zilla road Z1125, Pekua Bazar, R170, Eidmoni, R172, Badarkhali Bridge, <u>Upazilla road, Matarbari Road Bridge, Matarbari Bridge and Union road</u> to the Power Plant Site

This route is an alternative of Candidate 2 to avoid the congestion of Chakoria intersection and select good condition road.

<u>Candidate Route 5</u>

From (<u>**Chittagong** via Regional Highway R170 or via National highway NH1, Ekata Bazar, Z1125)</u> **Pekua Bazar** and, Upazilla road (Pekua), new bridge, Upazilla road (Maheshkhali), and Union road to the Power Plant Site.

This route is an alternative of the section between Pekua and Power Plant Site considering the transmission line route and connection with Regional road 170 instead of the national highway.

(Source: LGED, modified by JICA Study Team)

Figure 16.2-1 The Candidate Routes of Access Road

Table 16.2-1 shows sectional distance of candidate routes.

Table 16.2-1 Sectional Distance of Candidate Routes

Candidate Route	Candidate 1	Candidate 2	Candidate 3	Candidate 4	Candidate 5
Ekata～Chakoria	9.00km	9.00km			
Chakoria～Eidmoni	8.00km	8.00km	-	-	-
ReconstructionBr.(Chakoria)	0.20km	0.20km			
Ekata～Pekua	-	-	11.80km	11.80km	-
Pekua～Eidomoni	-	-	10.90km	10.90km	-
Eidomoni～Badarkhali Br.	7.40km	7.40km	7.40km	7.40km	-
Badarkhali Br.~Janata Bazar	1.35km	1.35km	1.35km	1.35km	
Janata Bazar～Thallatoli Inter.	0.30km	0.30km	0.30km	0.30km	-
Thallatoli Inter.~Yunuskhali Inter.	1.60km	-	1.60km	-	
Yunushkhali Inter.～New Br.	2.56km	-	2.56km	-	-
New Bridge(Kohelia river)	0.64km	-	0.64km	-	-
West end of New Bridge~ Power Plant	1.25km	-	1.25km	-	-
Thallatoli Inter.～New Matarbari Br.	-	1.80km	-	1.80km	-
New Matarbari Br.	-	0.06km	-	0.06km	-
New Matarbari Br.~Matarbari Br.	-	1.90km	-	1.90km	-
Matarbari Br.(Reconstruction)	-	0.44km	-	0.44km	-
Matarbari Br.~ Power Plant	-	5.60km	-	5.60km	-
Pekua～Katahari Br,	-	-	-	-	3.73km
Katahari Br,	-	-	-	-	0.10km
Katahari Br,~New Br.(Kohelia river)	-	-	-	-	8.34km
New Br,(Kohelia river)	-	-	-	-	0.50km
New Br,(Kohelia)~Matarbari Mogdail Bazar	-	-	-	-	5.10km
Matarbari Mogdail Bazar～Power Plant	-	-	-	-	9.73km
TOTAL DISTANCE	32.30km	36.15km	37.80km	41.85km	27.50km

(Source: JICA Study Team)

(2) Current Condition of Each Section

1) From Chakoria to Eidmoni via Regional highway R172 (Candidate 1, 2)

Chakoria intersection is so congested that some improvement measures will be required.

There are some narrow sections following to the intersection, and some structures along the road should be removed for improvement.

About 2km west from Chakoria, there is a steel bridge (bridge length is 200m) which should be replaced, because the width is out of standard of Regional highway, and the weight limit is only 5 ton. The reconstruction works will be started after rainy season of 2013.

In this entire section, houses are concentrated along the road, and there are so many narrow and winding spots that the traffic safety measurements will be necessary.

2) From Ekata to Pekua via Zilla road Z1125 (Candidate 3, 4)

This section has been improved with the regional highway standard to mitigate the congestion at Chakoria intersection and westward transportation in 2009. Entire section is well maintained. The width is enough in the entire section, so no land acquisition will be required.

3) From Pekua to Eidmoni via Regional highway R170 (Candidate 3, 4)

The width is enough in the entire section, so no land acquisition will be required. On the other hand, the road condition is not well maintained,.and improvement works will be required.

4) From Eidmoni to Badarkhali Bridge via Regional highway R172 (Candidate 1-4)

No improvement work will be required.

There are two congested places, one bazar and the bridge guard, but both of them will be managable.

5) From Badarkhali Bridge to Janata Bazar via Regional highway R172 (Candidate 1-4)

The road condition near Janata Bazar is not good, and improvement works will be required.

The traffic safety measurements will be required around Janata bazar.

6) From Janata Bazar to Yunuskhali Bazar via Zilla road Z1104, and from Yunushkhali to the Jetty via Village road, and from the jetty to Power Plant Site (Candidate 1, 3)

The condition of Zilla road section is not good, and the entire section should be improved. Especially the drainage system including drain ditch and causeway should be considered. As the record of ROW is not confirmed, the width of rad should be remained in actual condition.

The width of Village road is 3.0 m, so widening and land acquisition will be required in the most of section, but no resettlement will be required. There is graveyard of Kararmachara union near the Yunushkhali intersection.

To cross Kohelia River, new bridge should be constructed, and land acquisition for new road in Matarbari side will be required. But there will be no resettlement in Matarbari side

This route will benefit wide area, such as Karamachara Union, Matarabari Union and Dalghata Union.

7) From Janata Bazar to Matarbari Bridge via Upazilla road, and to Power Plant Site via Union road (Candidate 2, 4)

The most parts of this section should be widened, and a large culvert should be replaced. And Matarbari Bridgeshould be improved. Therefore land acquisition will be required between Matarbari and BWDB embankment.

In the section between Matarbari Bridge and BWDB embankment huge resettlement will be occued, and on the embankment used for union road there are many houses.

8) From Pekua to west via Zilla road Z1125, and to Power Plant Site in Matarbari via Upazilla road (Pekua), new bridge crossing Kohelia River, BWDB embankment and Union road (Candidate 5).

Zilla road section after Pekua intersection is very congested, and it seemes to be hard to manage the traffic and keep safety.

There is a broken bridge under consruction between Zilla road and Upazilla road.

The length of Upazilla road is 9.0km, and its width is 2.9m. Basically land acquisition will be required along Zilla road., and also resettlement will be required.

To cross Kohelia River, a bridge should be constructed. The length will be about 600m.

In the Matarbari, no land acquisition will be required, but a large resettlement will be occurred within the ROW of BWDB embankment.

(3) Comparison of Canndidate Routes

1) Environemntal and Social Aspects

Table 16.2-2 shows a comparison of environmental and social aspects on each candidate route. Based on this comparison, Candidate 3 is the most suitable route which is less congested in traffic, less condenced in residence, the least land acquisition and no resettlement, if the impact on mangrove forest in Kohelia River is avoidable.

Table 16.2-2 Comparison of Environmental and Social Aspects on Each Candidate Route

<table>
<tr><th>Candidate Route</th><th>Candidate 1</th><th>Candidate 2</th><th>Candidate 3</th><th>Candidate 4</th><th>Candidate 5</th></tr>
<tr><td colspan="6">1. Environmental Aspect</td></tr>
<tr><td rowspan="2">1.1 Living Environment</td><td colspan="2">In the section between Chakoria and Eidmoni the impact of construction works and traffic will be significant.</td><td colspan="2">In the section between Ekata and Eidmoni the impact of construction works and traffic will not be so significant</td><td rowspan="2">In the section between Pekua and Matarbari impact of construction works and traffic will be significant.</td></tr>
<tr><td>In the section between Janata Bazar and Yunushkhali the impact of construction works and traffic will not be so significant.</td><td>In the section between Janata Bazar and Matarbari the impact of construction works and traffic will be significant.</td><td>In the section between Janata Bazar and Yunushkhali the impact of construction works and traffic will not be so significant.</td><td>In the section between Janata Bazar and Matarbari the impact of construction works and traffic will be significant.</td></tr>
<tr><td rowspan="2">1.2 Natural Environment</td><td>Along the all road section any important natural environment is not observed.</td><td>A Along the all road section any important natural environment is not observed.</td><td>Along the all road section any important natural environment is not observed.</td><td>Along the all road section any important natural environment is not observed.</td><td>Along the all road section any important natural environment is not observed.</td></tr>
<tr><td>Mangrove forest is observed along the Kohelia</td><td>No sensitive biota is observed near</td><td>Mangrove forest is observed along</td><td>No sensitive biota is observed near</td><td>No sensitive biota is observed near</td></tr>
</table>

	River near the expected point of new bridge.	Matarbari Bridge which will be rehabilitated.	the Kohelia River near the expected point of new bridge.	Matarbari Bridge which will be rehabilitated.	the expected point of new bridge.
2. Social Aspect					
2.1 Land Acquisition (m^2)	134,782 Land acquisition will not be significant.	248,530 Land acquisition will not be significant, but more than Candidate 1.	118,532 Land acquisition will be least.	242,280 Land acquisition will not be significant, but more than Candidate 3.	272,500 Land acquisition will be most.
2.2 Resettlement (PAPs)	Approx. 500 In Chakoria area, resettlement will be required, but not significant comparing with Candidate 2, 4, 5.	Approx.4,100 In Chakoria and Matarbari area huge resettlement will be required,	None	Approx.3,500 In Matarbari area huge resettlement will be required,	Approx.4,200 In Pekua and Matarbari area huge resettlement will be required,
2.3 Benefit to Local People	New bridge construction will increase safety, communication capacity and broad economic effect.	Economic effect will be highest, but restrictive in Matarbari.	New bridge construction will increase safety, communication capacity and broad economic effect.	Economic effect will be highest, but restrictive in Matarbari.	New bridge will increase travel convenience, but restrictive in Matarbari.

(Source: JICA Study Team)

2) Construction Aspects

Table 16.2-3 shows a comparison of construction aspects on each candidate route.

Table 16.2-3 Comparison of Construction Aspects on Each Candidate Route

Candidate Route	Candidate 1	Candidate 2	Candidate 3	Candidate 4	Candidate 5
1. Total length (km)	31.44km Maintenance will be least.	36.15km	36.94km	41.85km Maintenance will be most.	27.50km +11.80 km =39.30 km (from Ekata)
2. New or reconstructed road (km)	2.95 km The construction period will be shortest and the impact of construction will be the least.	9.3 km The construction period will be longer than Candidate 1	2.95 km The construction period will be shortest and the impact of construction will be the least.	9.3 km The construction period will be longer than Candidate 1	23.17 km The construction period will be the longest.
3. New or reconstructed bridge	0.64 km (minimum) -1.370 km (maximum)	0.44 km	0.64 km (minimum) -1.370 km (maximum)	0.44km	0.50 km

(Source: JICA Study Team)

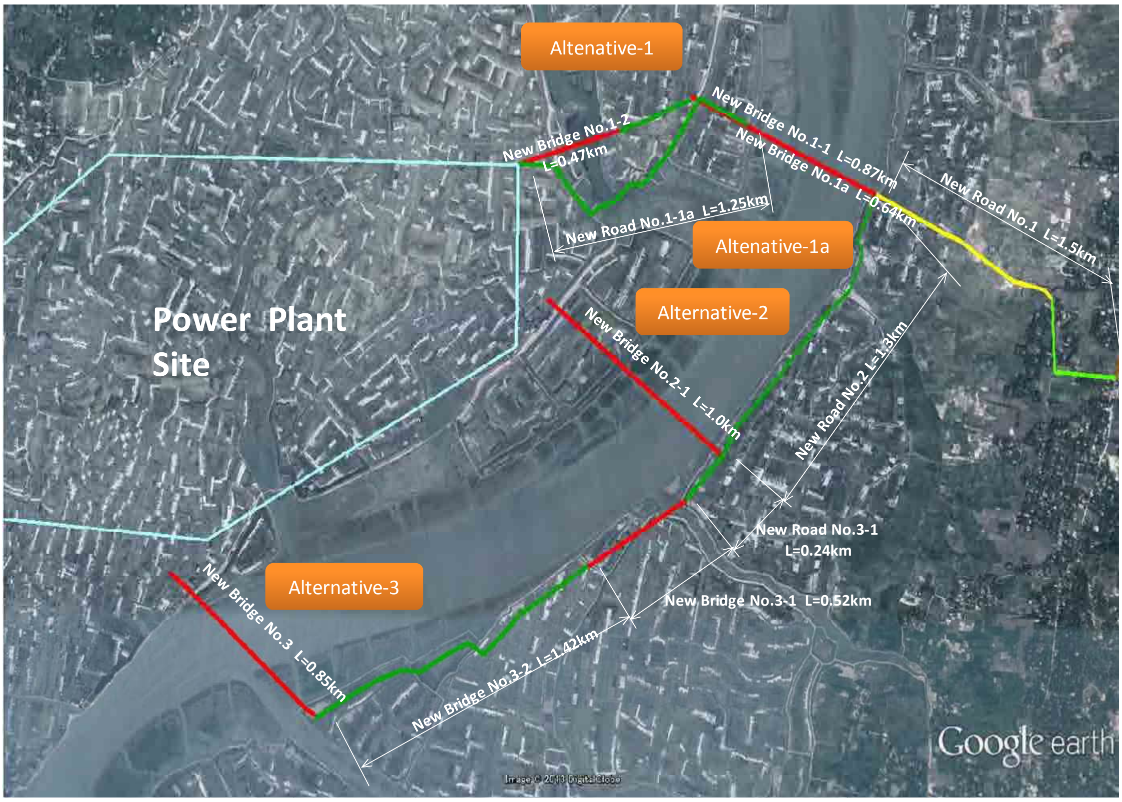
Regarding the new bridge on Candidate 1 and 3, the length will influence not only the bridge cost, but also total cost. And the bridge location will influence the mangrove forest and tidallat. Therefore the following bridge locations shown in Figure 16.2-2 have been considered, and the comparison of altanatives are shown in Table 16.2-4.

1) Alternative-1 is to avoid impacts on the mangrove forest, but it needs two bridges.

2) Alternative-1a is to avoid impacts on the mangrove forest, and to minimize bridge length, land acquisition and cost by utilizing BWDB embankment.

3) Alternative-2 is the shortest bridge with minimized new road, but it passes between mangrove forests.

4) Alternative 3 is another way to avoid impacts on mangrove forest, but it also needs two bridges and long road.



(Source: JICA Study Team)

Figure 16.2-2 The New Bridge Alternatives over Kohelia River for Candidate 1 and 3

Table 16.2-4 Comparison of Construction Aspects on Each Candidate Route

Candidate Route	Alternative -1	Alternative-1a	Alternative-2	Alternative-3
1. Total bridge length (m)	1,340 m	640 m	1,000 m	1,370 m.
2. New road between the jetty and Power Plant (km)	2.56 km	1.25 km	1.4 km	3.06 km
3. Impact on the mangrove forest	Avoidable	Avoidable	Not avoidable	Avoidable
4. Social aspect		Land acquisition will be the least		Land acquisition will be the most.
5. Technical issue				Soft ground measures will be the most
6. Ascending order of cost	4	1	3	2
EVALUATION		Most suitable		

(Source: JICA Study Team)

Table 16.2-5 shows comparison of rough estimation of total construction cost. The total construction cost is lowest in Candidate 3, because of well-ballanced cost among road, bridge and other structure portion.

Table 16.2-5 Comparison of Total Construction Cost (Unit : ratio to the lowest)

Candidate Route	Candidate 1	Candidate 2	Candidate 3	Candidate 4	Candidate 5
1. Road	1.00	1.18	1.56	1.74	1.54
2. Bridge	1.67	1.40	1.27	1.00	1.19
3. Other Structure	1.00	1.57	1.06	1.57	2.25
Total	1.05	1.06	1.00	1.28	1.15

(Source: JICA Study Team)

3) Conclusion

According to the comparison of environmental, social and construction aspects and cost, Candidate 3 is the most suitabel for the access road.

Table 16.2-6 shows the inventory of selected route.

Table 16.2-6 Inventory of Selected Route

<table>
<tr><th>Section</th><th>Managed by</th><th>Distance</th><th>Current condition</th></tr>
<tr><td>Existing Road</td><td colspan="3">35.05 km</td></tr>
<tr><td>Ekata – Pekua</td><td>RHD
(Zilla road Z1125)</td><td>11.80km</td><td>Well maintained</td></tr>
<tr><td>Pekua - Eidmoni</td><td>RHD
(Regional highway R170)</td><td>10.90km</td><td>Spot holes, cracks, etc.</td></tr>
<tr><td>Eidmoni – Badarkhali Bridge</td><td>RHD
(Regional highway R172)</td><td>7.40km</td><td rowspan="2">Spot holes, cracks, etc.</td></tr>
<tr><td>Badarkhali Bridge – Janata Bazar</td><td rowspan="3">RHD
(Zilla road Z1004)</td><td>1.35km</td></tr>
<tr><td>Janata Bazar – Thallatoli Intersection</td><td>0.30km</td><td rowspan="2">Damaged all through the road</td></tr>
<tr><td>Thallatoli Inter. – Yunuskhali Intersection</td><td>1.60km</td></tr>
<tr><td>Yunuskhali Intersection – Jetty</td><td>LGED
(Village road 4013)</td><td>1.70km</td><td>Out of Requirement</td></tr>
<tr><td>New road</td><td colspan="3">1.25 km</td></tr>
<tr><td>Government land between two embankments in Matarbari</td><td>Government (DC Office)</td><td>0.24km</td><td>Salt field/ Shrimp farm</td></tr>
<tr><td>Embankment</td><td>BWDB</td><td>0.60 km</td><td></td></tr>
<tr><td>Partial dyke</td><td>BWDB</td><td>0.24 km</td><td></td></tr>
<tr><td>Private land</td><td>Private</td><td>0.17 km</td><td>Salt field/ Shrimp firm</td></tr>
<tr><td>New Bridge</td><td colspan="3">0.64 km</td></tr>
<tr><td>New Bridge
(Fly-over Kohelia River)</td><td>Government (River)</td><td>0.64km</td><td>Jetty built by community (Maheshkhali side)</td></tr>
<tr><td colspan="2">TOTAL</td><td>36.94 km</td><td></td></tr>
</table>

(Source: JICA Study Team)

16.3 Preliminary Road and Bridge Design

16.3.1 Natural condition survey

(1) Topographic Survey

1) Purpose of Survey

The main purpose of the survey works is to produce the topographic plan maps, road profiles and cross sections which can be utilized for the project road design.

2) Location

The project site is located about 90km from Chittagong city and close toBay of Bengal in the district of Cox’s Bazar under Maheskhali Upazilla in Bangladesh.

Conducting topographic survey along selected route between Badarkhali bridge and northeast side of the power plant and three (4) intersections. Centerline survey, profile leveling survey and cross section survey are conducted from Pekua intersection to the power plant site.

Figure 16.3-1 Location of Topographic Survey

3) Bench Mark Installation

Survey starts from an arbitrary reference point which was finally connected with a permanent national BM located at Chakaria, and establish site TBMs.

The TBM and TP have been installed as follows;

Table 16.3-1 Location of TBM and TP

Point	Easting (m)	Northing (m)	Elevation (mMSL)	Chainage (m)
TP-01	390842.395	2401740.592	5.601	0032.00
TP-02	388878.134	2400391.606	6.935	3046.00
TP-03	388861.704	2400311.195	7.148	3030.00
TBM-01	388228.235	2400903.419	3.023	4197.00
TBM-02	386766.173	2401167.288	2.291	5800.00

4) Bathymetric Survey

The bathymetric survey have been conducted at Kohelia River along centerline of the bridge and upstream and downstream of bridge.

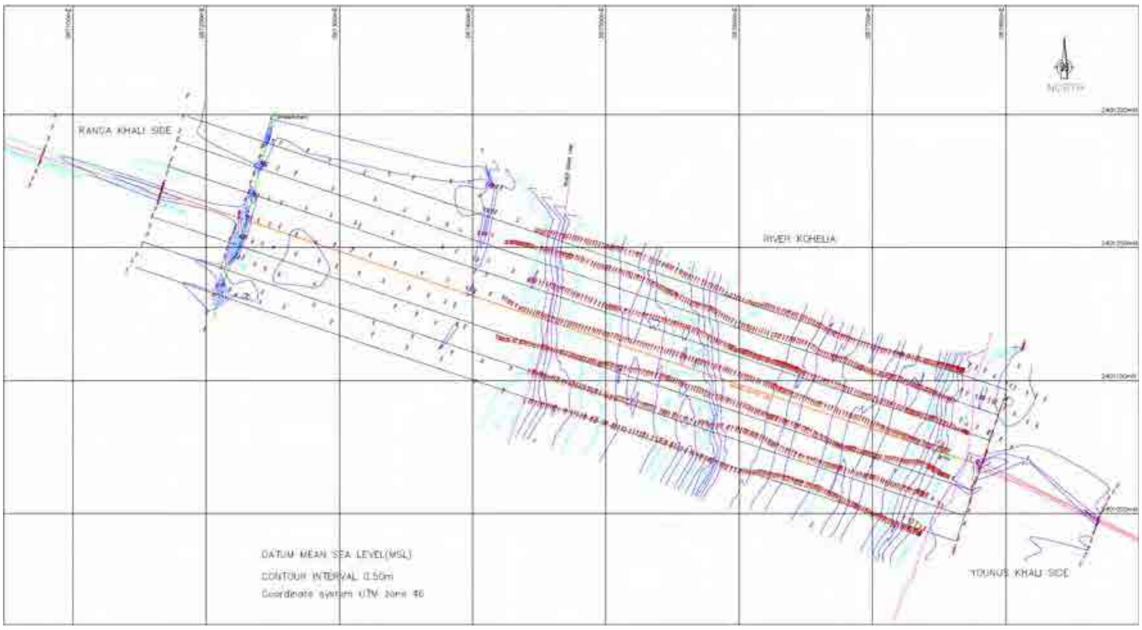


Figure 16.3-2 Location of Bathymetric Survey

(2) Geotechnical Survey and Laboratory Test

1) Purpose of Survey

The purposes of the survey are collection of geotechnical data and analyses for design of bridge and other structural items

2) Location

The location of geotechnical boring are as follows;

Table 16.3-2 Coordinate Value of Boring

No.	Latitude	Longitude	Note
New Br-1E	21°42'33.28"N	91°54'53.77"E	Nayaghata jetty
New Br-1C1	21°42'36.43"N	91°54'45.39"E	Streamway of river
New Br-1C2	21°42'38.25"N	91°54'39.37"E	Mudland
New Br-1W	21°42'41.63"N	91°54'33.80"E	Mudland
Existing Box-1	21°42'09.68"N	91°55'32.42"E	Yunuskhali intersection
Existing Box-2	21°42'18.96"N	91°55'22.46"E	
Existing Box-3	21°42'32.91"N	91°54'15.69"E	Sluice-gate at branch channel
New Rd-1	21°42'38.78"N	91°54'23.08"E	Road on embankment
New Rd-2	21°42'35.44"N	91°54'19.99"E	Water area
New Rd-3	21°42'30.00"N	91°54'10.00"E	Road on embankment

Figure 16.3-3 Location Map of Boring

3) Evaluation

The bearing capacity of both shallow and deep foundation are determined from the parameters of soil, such as the values of cohesion and the angle of internal friction. Allowable bearing capacity of the shallow foundation and allowable load bearing capacity for piles foundation have determined from laboratory soil results.

Deep foundation may be appropriate for the Kohelia bridge. At detail design stage, the load bearing capacity of pile should be confirmed by the static load test results.

Evaluation of soil samples collected from roadway and soft-soil counter measures

The improvement of the existing RHD road could be executed through traditional practices of RHD as there are no anticipated hazards during execution. But the stretch from Yunuskhali village to Power-plant through salt fields and low lying area might face some challenges during construction as the stretch appears to be problematic as the area inundates due to flood or sea tide. Following special features may be adopted in designing the high road embankment.

1. Use of lightweight materials
2. Partial or total removal of undesirable material.
3. Use of stage construction and surcharge fill.
4. Use of sand drains.

Considering the cost and duration of construction, the feature items 2,3 or 4 above might be adopted but the use of sand drains is most common in Bangladesh.

Evaluation of soils sample as suitable materials for embankment construction

The desirable properties of good fill materials is that it should have high stability and strength and for that it should not exhibit large change of volume with change of moisture content, have good drainage properties, not contain much organic matter and not favor capillary rise of water. In India and Bangladesh, following criteria are adopted in selecting soils for road embankment:-

- Soils having a maximum dry density less than 1,440 kg/cum are ordinarily considered unsuitable for embankment construction.
- Soils having a maximum dry density less than 1,520 kg/cum are ordinarily considered unsuitable for use in embankments exceeding 3 m in height or in embankments in any height subject to long periods of inundation.
- Top 0.5 m of the embankment should preferably constructed with soils having maximum dry density greater than 1,650 kg./cum.

However, following are test results and anticipated embankment performance based on I. S. classification and PRA classification.
So, as per the test results, soils from test pit# 2 area could not be used as embankment materials. As per general practice of RHD, during executing, contractor might be asked to construct embankment with carried earth of specified quality and from approved borrow pit.

(3) Soft Ground Countermeasure Works
1) Boring Survey
Boring survey has been conducted along the new road section at the points shown in Figure 16.3-4 in order to confirm the existing ground condition.

Figure 16.3-4 Locations of Boring Survey

Among these boring data, data of New Br-1E and Existing Box-2 are used as reference soil data for road embankment at Yunusikhali side, and data of New Rd-1, New Rd-2 and New Rd-3 are used as soil data of road embankment at Matarbari side for the study. A preliminary study to evaluate the existing ground condition and to consider about the applicable soft ground countermeasure has been conducted based on the above data. It is recommended that a thorough investigation shall be conducted in the detailed design stage to draw out more specific countermeasure works.

According to the boring survey result, soft ground layer at each location is summarized as .

Table 16.3-3 Summary of Soft Ground Layer at Each Location

	Depth (m)	Soil Type	Field SPT Value	Corrected STP Value	Effective Over Burden Pressure P'(kN/m^2)	Cohesion C_u(kN/m^2)	Adhesion Factor α
New Br-1E	9.0	Silty CLAY	1	0~0	12.3~73.7	0~12	0.99~1
Existing Box-2	1.5	Silty CLAY	1	2	12.3	12	0.99
New Rd-1	10.5	Silty CLAY	2~5	3~4	12.3~86.0	18~24	0.97~0.98
New Rd-2	7.5	Silty CLAY	2~3	2~4	12.3~61.4	12~27	0.97~0.99
New Rd-3	10.5	Silty CLAY	1~5	1~8	12.3~86.0	6~48	0.94~0.99

2) Soft ground countermeasure works

The boring survey data reveals that soft layers in the salt field of Yunuskhali side and the BWDB embankment section in Matarbari side are formed by silt sedimentation of 1.5m ~10m thick with N-value from 1 to 5 range.

In this regard, following countermeasure works can be considered.

Sand Mat Works

Sand mat shall be constructed with 1.0m thick with following objectives.

i) to provide the upper drainage layer for consolidation of soft soil layer

ii) to provide the underground drainage layer to intercept rise of groundwater into embankment

iii)to provide the load bearing layer to ensure trafficability of construction machinery

Thickness of sand mat shall be determined by taking into consideration of trafficability of construction machinery. Also the sand mat layer will have a function to provide underground drainage layer as well. The total thickness of the sand mat layer has been set at 100 cm that consisted of 50 cm for minimum requirement as drainage layer and additional 50 cm for securing trafficability of construction machinery. At the detailed design stage, it is necessary to confirm the cone bearing capacity (kN/m2) of the layer and set the actual required thickness of the sand mat.

Material for sand mat shall be of passing material with less than 3% of 75 μ m mesh.

Vertical Drain Work

Vertical drain work is a method that sets drainage materials at soft ground layer vertically to accelerate consolidated-drain by shortening drainage path and also aim to increase shear strength of the ground. There are two main types of sand drain methods as shown in the Table 16.3-5.

For this project, standard sand drain work is adopted that will not require any special materials.

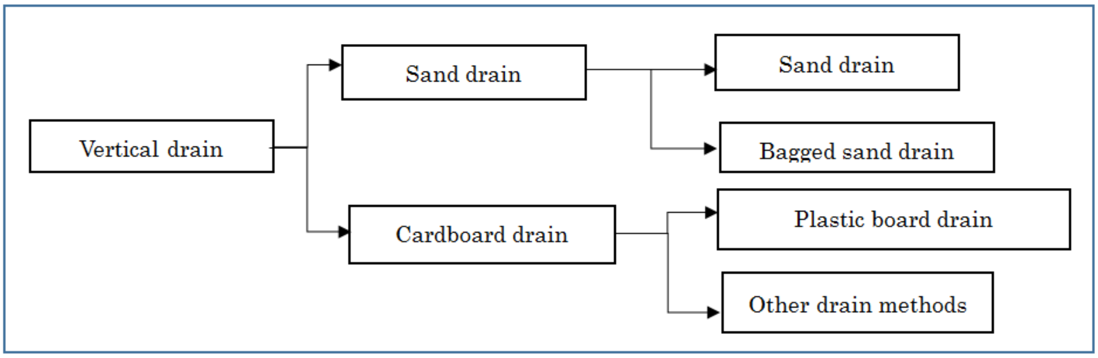


Figure 16.3-5 Types of Vertical Drain Work

It is assumed that longer period will be required as consolidation time with the silt layer at the salt field section.
In view of this, Sand Drain Method is adopted as work to accelerate consolidation.
At the detail design stage, it is preferred to carry out following operation.
- conduct more detailed survey
- set an appropriate construction schedule of earth filling works based on the soil property data
  (Note: the schedule should not affect the overall project implementation schedule)
- design detailed sand drain layout, pitch and size

Slow Banking Work

To avoid collapse of ground caused by rapid construction of embankment, embankment shall be constructed slowly by well controlled manner.
Construction of embankment shall be carried out slower than 5cm/day in accordance with the following points of attention.

Points of Attention

i) Upon construction, based on data of construction management, the earth fill rate shall be controlled.
That is, to construct each layer with a thin layer compaction and if ground stability is ensured by observation and inspection during construction works, the construction speed shall be accelerated or shorten the leave-to-stand period.
If it is noted that ground is unstable, slower earth filling rate or taking sufficient leave-to-stand period shall be considered. In case the condition becomes more critical, removal of earth fill will become necessary. Such an emergency treatment shall be prepared in advance.
ii) Within the possible range, fast earth filling may be meritorious if the ground is stable because subsidence of the embankment after the completion becomes smaller. However, this fast earth filling may cause the destruction of the foundation ground during construction works. An attentive work control is necessary.
iii)Install necessary equipment such as settlement gauge, displacement gauge and other instruments to monitor the status of lateral deformation and ground subsidence. The purpose of installation of the equipment is to manage the speed of the earth fill during construction according to the progress of the compaction and stability of the embankment.

Leave to Stand Period

Set the standing period of the ground foundation until the compaction index becomes 80-90%. In the area the appropriate period shall be more than one year.

Surcharge Method

Surcharge method shall be considered to accelerate the subsidence by adding more load than the design load of the embankment, to increase apparent settlement rate and also to reduce residual settlement against design load.

Settlement required to be secured during construction (target settlement) shall be determined as acceptable residual settlement with less than 30 cm in 30 years after completion.

Thickness of embankment to ensure target settlement rate during construction work shall be determined based on the survey result and data analysis which will be conducted during the detailed design stage.

3) Preliminary Analysis of Soft Soil Ground

Although laboratory test such as consolidation test was not conducted during the preparatory survey, a preliminary basic analysis of soft soil ground for the section of the new road has been conducted. The analysis was conducted based on the assumed soil property utilizing data such as N-value which became available by the boring survey.

Studied Sections

Locations of the studied sections are shown in the Figure 16.3-6. The study has been conducted for two sections; Yunuskhali salt field and BWDB Embankment section.

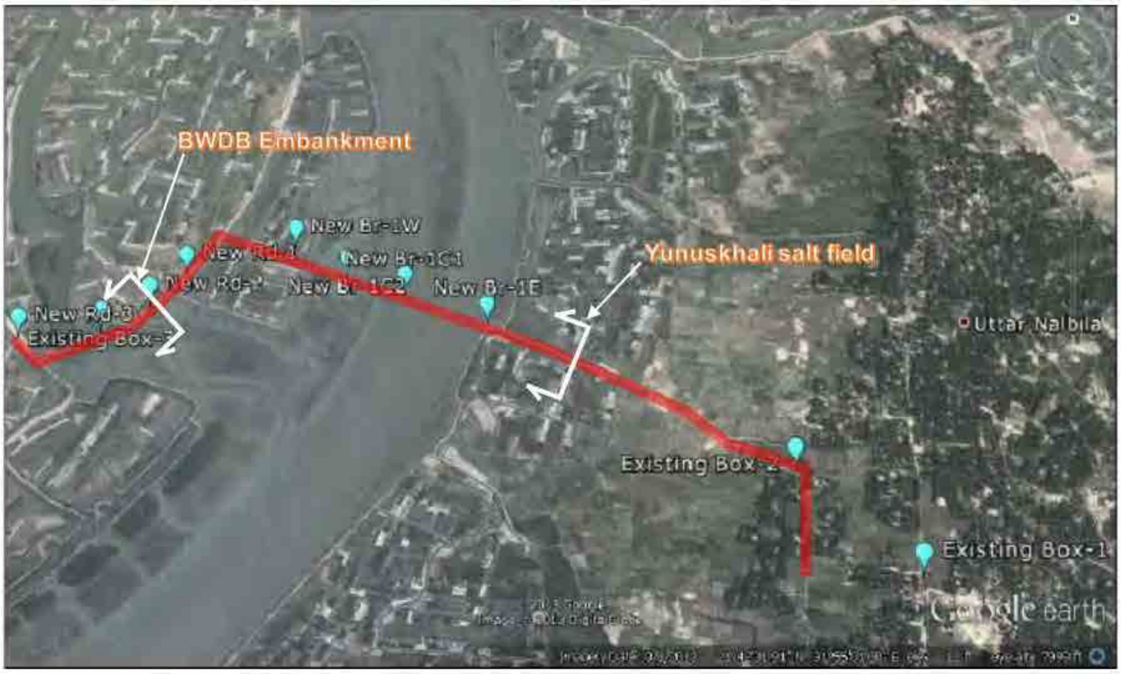


Figure 16.3-6 Locations of the Studied Sections

Analysis Result

According to the preliminary analysis result, at Yunuskhali salt field, 886 days will be required to achieve 80% degree of consolidation and at BWDB embankment, 1535 days will be required to achieve 80% degrer of consolidation. Time required for resettlment is long, so countermeasure works to promote consolidation settlement will be necessary.

Consideration of soft ground countermeasure works

A settlement analysis has been conducted by adopting sand drain method which is effective in promoting consolidation settmelement. In sand drain which was utilized in analysis of flatland configuration: square arrangement, arrangement distance:5.0m and drain diameter: 40cm.

Recommendation

It was confirmed that implementation of sand drain work enables to shorten the number of required days for achieving 80% degree of consolidation from 1583 days (approximately 4.3 years) to 273 days (approx. 9 months). From the result, “sand drain work” shall be adopted as consolidation promoting work for the area if necessary.

.

(4) Dynamic Cone Penetrometer (DCP) Test

1) Purpose of Survey

The main purpose of the Works is to analyze and evaluate the characteristic of existing road condition. The CBR value worked out from this tests have been recorded for design of the pavement.

2) Location

The locations of DCP test are shown in Figure 16.3-7.

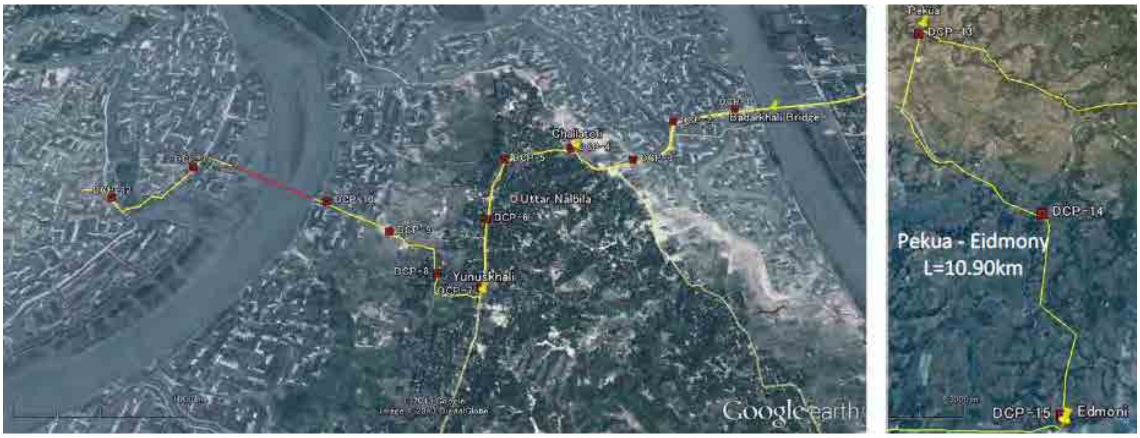


Figure 16.3-7 Location Map of DCP Test

3) Test Result

Table 16.3-4 Result of DCP Test

Test Point	Surface Condition		Pavement Strength		
	Type	Moisture	CBR (%)	SN	SNP
1	Hot mix asphalt	n/a	6	2.98	3.66
2	Hot mix asphalt	n/a	45	2.94	4.62
3	Hot mix asphalt	n/a	34	2.47	4.29
4	Hot mix asphalt	n/a	22	2.70	4.54
5	Hot mix asphalt	n/a	32	2.65	4.67
6	Hot mix asphalt	n/a	45	2.44	4.42
7	Hot mix asphalt	n/a	24	2.80	4.33
8	Hot mix asphalt	n/a	14	1.89	3.48
9	Unpaved	0.51 (dry)	9	1.02	2.14
10	Unpaved	0.71 (moderate)	5	0.12	0.30
11	Unpaved	0.71 (moderate)	-	0.90	0.82
12	Unpaved	0.71 (moderate)	-	0.98	0.90
13	Hot mix asphalt	n/a	50	1.37	3.65
14	Hot mix asphalt	n/a	38	3.30	5.16
15	Hot mix asphalt	n/a	50	3.31	4.79

(5) Existing Road Material Sampling

1) Location

Existing road material sampling have been done along the route between Yunuskhali intersection and the power plant site.

2) Evaluation of Soil

The desirable properties of good fill materials is that it should have high stability and strength and for that it should not exhibit large change of volume with change of moisture content, have good drainage properties, not contain much organic matter and not favor capillary rise of water. In India and Bangladesh, following criteria are adopted in selecting soils for road embankment.

- Soil having a maximum dry density less than 1,440 kg/cum are ordinarily considered unsuitable for embankment construction.
- Soil having a maximum dry density less than 1,520kg/cum are ordinarily considered unsuitable for use in embankment exceeding 3m in height or in embankment in any height subject to long periods of inundation.
- Top 0.5m of the embankment should preferably constructed with soils having maximum dry density greater than 1,650kg/cum.

As per the test results, soil from test pit No.2 area could not be used as embankment materials.

Table 16.3-5 Evaluation of Existing Road Material

Test Pit	No. 1	No. 2	No. 3
Location (chainage m)	4445	5235	6205
Visual description	Silt clay	Silt clay	Clayey silt
PRA Classification	A6	A5	A4
Max. dry density (kg/cum)	1560 – 1650	1480 – 1600	1570 - 1710
OMC (%)	19	23	18
Anticipated embankment performance	Poor to good	Unsatisfactory	Poor to good

16.3.2 Hydrological and morphological analysis

(1) General

The purposes of the analyses are to fix of Design High Water Level (DHWL) and scour depth. for design of the proposed new bridge.

Considering normal practice all the analyses have been presented in Public Works Department (PWD) datum values. Figure 3.2-1 shows the relationship between PWD and Mean Sea Level (MSL). PWD = MSL + 0.46 m

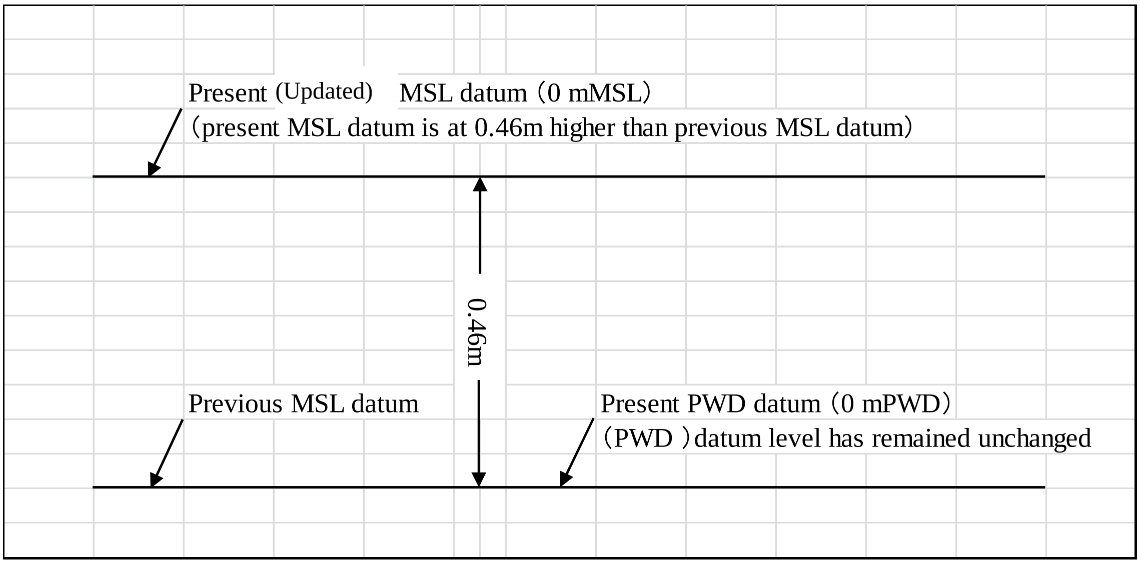


Figure 16.3-8 Schematic Relationship between MSL and PWD Datum Values

(2) Design High Water Level (DHWL)

RHD made an overall hydraulic analysis for the Bangladesh region in 1992 for bridge design purpose under Road Master Plan Project (RMPP). The RMPP Study Report (vol-V; hydrology) recommended 50 years flood frequency analyses for construction of road bridges on stretches of land exposed to direct over-spill from large rivers. The study also recommended use of normal high tide level for design purpose in case of roads located within active tidal zone. Fixations of DHWL considering different criteria are detailed below.

- Tidal level
- Long-term observed highest water level
- HWL considered for BWDB embankment
- Frequency analysis

1) Tide level

The Kohelia river is in active tidal zone being connected to Bay of Bengal directly at one end and through Kutubdia channel at the other end. Mean High Water Spring (MHWS) is the highest level to which spring tide reaches on the average over a period of time. MHWS value of nearby BIWTA measuring station Cox’s Bazar is 3.785m CD[1] (=2.880 mPWD).

2) Long term highest water level

The nearest available water level station is Shaflapur water gauge station of BWDB. Observed yearly maximum and minimum water levels for the period of 1971 to 2012 is shown in the

[1] BIWTA Tide Table-2013

Table 3.2-1. Highest recorded water level during the period 1971 - 2012 is 4.36 mPWD and lowest recorded water level is (-) 2.17 mPWD.

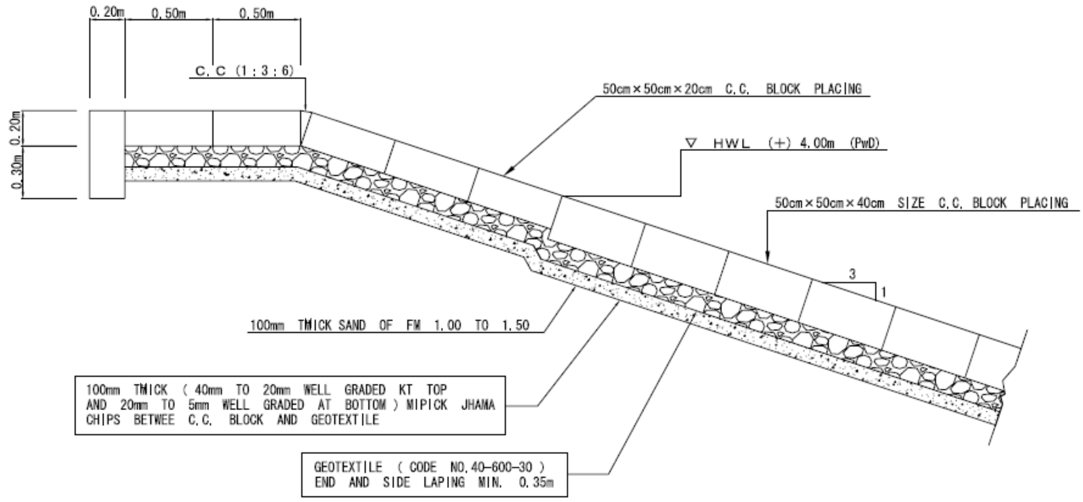
Table 16.3-6 Water Level Data (1971 – 2012)

Year	Water level (mPWD)		Year	Water level (mPWD)	
	Max	Min		Max	Min
1971	3.23	-1.68	1992	3.33	-2.10
1972	3.05	-1.77	1993	3.56	-1.88
1973	3.17	-1.80	1994	3.16	-1.64
1974	3.75	-1.74	1995	3.74	-1.55
1975	2.74	-1.68	1996	3.88	-1.35
1976	3.16	-0.39	1997	3.75	-1.40
1977	3.35	-1.67	1998	3.20	-1.30
1978	2.59	-1.68	2004	3.45	-1.60
1983	4.21	-1.91	2005	3.70	-1.80
1984	3.65	-1.55	2006	2.80	-1.70
1985	**4.36**	-1.20	2007	-	-1.80
1986	3.60	-1.20	2008	3.84	-
1987	4.20	-1.50	2009	3.98	-
1988	4.20	-1.50	2010	3.95	-
1989	4.20	-1.86	2011	3.88	-
1990	3.76	-1.86	2012	3.97	-
1991	3.13	**-2.17**			

Source : Hydrology Directorate, BWDB

3) HWL considered in BWDB embankment

HWL for the design of BWDB embankment at Matarbari (Polder-70) is 4.00 mPWD. Figure 16.3-9 shows the typical cross section of BWDB embankment at Matarbari (Polder-70).



Source : BWDB Cox's Bazar

Figure 16.3-9 Typical Cross Section of BWDB Embankment at Matarbari

4) Frequency analyses of HFL

Frequency analysis of HFL on the basis BWDB data of Bakkhali River near Cox's Bazar was done by Cyclone Protection Project-II (CPP-II)[2]. They calculated peak water levels as:

- 1 : 20 year : 3.63 mPWD
- 1 : 50 year : 3.74 mPWD

5) Cyclone storm surge levels

Storm surge heights resulting from cyclones along Bangladesh coast have been collected by Bangladesh Meteorological Department (BMD). Institute of Water Modelling (IWM) reported 100 year surge level to be around 5.5m MSL (5.96mPWD) near Sonadia Island of Cox's Bazar[3].

6) Recommended DHWL

The findings of discussions made above can be summed up as:

- Tidal Mean High Water Spring (MHWS) : 2.88 mPWD
- Observed highest water level : 4.36 mPWD
- HWL considered for BWDB embankment : 4.00 mPWD
- Frequency analysis of HFL (50 year) : 3.74 mPWD

Considering all the above mentioned facts, the recommended DHWL for design of new bridge is 4.36 mPWD, which is the highest observed water level of Shaflapur, Maheshkhali.

[2] BWDB Systems Rehabilitation Project, Feasibility Report, Polder-70 Sub-project, 1994.6
[3] Coastal and Hydraulic Study for Deep Sea Port, IWM, 2008.11

(3) Design Discharge

No historical data or information as to the discharge of Kohelia River was available. Discharges for the main channel flow and over-land flow are shown in Table 3.2-2 using discharge equation, measured cross section areas and observed velocity. Total design discharge is 4,137m^3/sec

Table 16.3-7 Design Discharge

	Level (mPWD)	Area (m2)	V (m/sec)	Q = A x V (m^3/sec)
Main channel flow	4.36	2,323.33	1.7[4]	3,950
Over-land flow	4.36	109.93	1.7	187
Design Discharge				4,137

(4) Water Way Opening

Required water way opening is calculated using Lacey's formula.

$$Ws = 4.75 \sqrt{Q}$$

$$= 4.75\sqrt{4137}m = 305.52m$$

where, Ws : required water way opening (m)

Q : design discharge (m^3/sec)

Present water way width of the river is 578m and the new bridge width including viaduct is 640m. So the proposed bridge width is safe from water way opening consideration.

(5) Anticipated Scour Depth

River bed scour can be general deepening of river bed and local scour. General deepening of river bed may take place due to long term hydrologic and morphologic changes in the river where as local bed scour takes place due to obstruction in flow passage.

1) Scour in the Main Channel

a General Scour

General scour in main channel will be calculated using Lacey's Formula.

$$d = 0.473 (Q/fs)^{1/3}$$

$$= 0.473(3950 / 0.5)^{1/3} = 9.44m$$

where, d : Normal depth of scour below DHWL (m)

Q : Discharge (m^3/s)

fs : Silt factor ($1.76 \times \sqrt{(D_{50})} = 1.76 \times \sqrt{0.08} = 0.5$)

b Local Scour

There are some empirical formulae and methods for calculation of local scour. The formulae and methods have been developed from empirical consideration and are site specific. Indian

[4] Hydraulic Modeling Study for Rehabilitation of Affected Seven High Risk Coastal Polders, IWM, 2004.11

Road Congress (IRC) has recommended doubling the normal depth of scour (d_{max} = 2.0d) to determine maximum river bed scour. Furthermore, using of 1.5d for scour depth under abutment and 2.0d for pier has suggested[5].

c Anticipated Depth of Scour in Main Channel

- Below piers in main channel : 2.0d = 2.0 x 9.44 = 18.88m below DFL
- Below eastern side abutment : 1.5d = 1.5 x 9.44 = 14.16m below DFL

2) Scour in Flood Plain

a General Scour

General scour in main channel will be calculated using Lacey's Formula.

$$d_{fp} = 0.473\ (Q/fs)^{1/3}$$
$$= 0.473(187 / 0.5)^{1/3} = 3.41\text{m below DHWL}$$

b Local Scour

General formula for calculation of local scour below pile is:

- 2.25 x pile dia : when flow depth is 5 m or more
- 1.50 x pile dia : when flow depth is less than 5 m

As maximum depth of flow in flood plain will be less than 5m, local scour below pile in flood plain will be 1.5 x 1.2 = 1.80m.

c Anticipated Depth of Scour in Main Channel

- Below piers in flood plain : $2.0d_{fp}$ = 2.0 x 3.41 = 6.82m
  : d_{fp} + local scour = 3.41 + 1.80 = 5.21m
  : Recommended scour depth is 6.82m
- Below western side abutment : $1.5d_{fp}$ = 1.5 x 3.41 = 5.12m

3) Anticipated Scour Depth & Level

i)	Below pier in main channel	: 18.88m below DHWL i.e up to	-14.52mPWD
ii)	Below eastern abutment	: 14.16m below DHWL i.e up to	-9.80mPWD
iii)	Below pier in flood plan	: 6.82m below DHWL i.e up to	-2.46mPWD
iv)	Below western abutment	: 5.12m below DHWL i.e up to	-0.76mPWD

(6) Navigation Clearance

Table 3.2-3 shows navigation clearance as per Bangladesh Inland Water Transport Authority (BIWTA) regulation. In case of non-classified waterway like Koheria river, at least one span must be kept wide enough to accommodate intended river traffic. The absolute minimum vertical clearance should be 1.50m above DHWL.

[5] Design of Bridge Structure, T. R. Jagadeesh and M. A. Jayaram, Prentice Hall, India

Table 16.3-8 Navigation Clearance

Classification of waterways	Min. vertical clearance (m)	Min. horizontal clearance (m)
Class-I	18.30	76.22
Class-II	12.20	76.22
Class-III	7.62	30.48
Class-IV	5.00	20.00

Source : Bridge design standards for RHD, 2004.1

On the basis of evaluation of ground realities and consideration of future generated traffic as outcomes of power station establishment as well as construction of approach road; it is recommended that at least 1 span of the bridge should have minimum 20m horizontal clearance and minimum 5m vertical clearance.

16.3.3 Road component

(1) Basic Road Design Approach

The design works of the Access Road include following items:

- Geometric design
- Pavement design
- Road ancillary structures design
- Drainage design
- Embankment design

The survey and investigation works have been conducted, and a series of technical meetings were held with RHD and BWDB. Following steps have been adopted in designing works.

1) Establishment of the class and terrain of the road

The selected road is of around 37 km including a new bridge out of which around 33 km is the existing RHD road. A broad discussion among the project stakeholders happened regarding functional class of the road and finally decided it to be a Regional Highway as it is existing RHD Road of plain terrain through which it passes. It was decided that the design aspects covered by RHD's design guides could be adopted in designing.

2) Geometric design of RHD roads

Road cross-section standards is shown in Table 16.3-9, and RHD's typical design speed is shown in Table 16.3-10.

It is determined for road design and correlation of the physical features of the highway. As per physical condition of existing roads of the route and RHD classification of Regional Highway, the assumed design speed is 40 km.ph. for the existing road and new construction road as well.

(Source: RHD Geometric Design Standards).

Table 16.3-9 Road Cross-Section Standards

Design Type	Design year traffic volume PCU / peak hour (typical MV AADT)	Cross-section widths in metres Crest width	Carriageway (no. of lanes)	Paved shoulders	Indicative Road Classification
1	4500 – 8500 (19,000–36,000)	36.2	2 x 11 (6)	1.8	
2	2100 - 4500 (7,000 – 19,000)	21.6	2 x 7.3 (4)	1.8	National
3	1600 – 2100 (5,000 – 7,000)	16.3	7.3 (2)	1.5	Regional
4	800 – 1600 (1,000 – 5,000)	12.1	6.2 (2)	1.5	
5	400 – 800 (500 – 1,000)	9.8	5.5 (2)	1.2	Feeder
6	<400 (<500)	9.8	3.7 (1)	1.2	

Table 16.3-10 Typical Design Speeds

Design Type	Design Speed (km/h) Plain	Rolling	Hilly
1 - 2	80 –100	80	-
3	80	65	50
4	65	50	40
5 - 6	50	40	30

Notes
Terrain: typical cross-slopes
Plain: 0 – 10%
Rolling: 11 – 25%
Hilly: >25%

Table 16.3-11 Speed Related Design Parameters

Design Speed (km/h)	Sight Distance (m) SSD	ISD	OSD	Minimum Curvature Values Horizontal curve (radius (m))	Vertical curve (K value)
Two lane roads					
30	30	60	120	35	2
40	45	90	180	65	4
50	60	120	250	120	9
65	90	180	360	250	18
80	120	250	500	500	35
100	180	360	720	1000	70
Single lane roads					
30		60		120	4
40		90		250	9
50		120		500	18
65		180		1000	35

Notes:
1. This is a summary table – refer to the appropriate sections of the manual before using these parameters
2. Sight distances (see Section 2.6) SSD – Stopping Sight Distance; ISD - Intermediate Sight Distance; OSD – Overtaking Sight Distance
3. Horizontal curves (see Section 5) The radii are those needed to achieve SSD with 5% superelevation (3% for the 1000m radius curve)
4. Vertical curves (see Section 6) Two lane roads: K values are those needed to achieve SSD; Single lane roads: K values are those needed to achieve ISD
5. For parameters relating to dual carriageway roads refer to the appropriate sections of the manual

(RHD's Geometric Design Standard)

a Selection of the Pavement Design Life and traffic Growth:

As per Regional Highway of RHD, the design life and the traffic growth are assumed 20 years and 7% respectively. (Source: RHD's Pavement Design Guide,Table-2, page-5)

b Selection of cross-sectional elements:

The existing RHD road is Regional Highway of carriageway width of 5.50 m. It was decided through discussion with RHD design unit that the new road along with the existing roads should be of same standard having carriageway width of 5.5 m with 9.8 m crest width including 1.2 m hard shoulders except 2 sections of limited ROW in built-up area. The thickness of pavement layers have been decided based on RHD guides with requisite checks with AASHTO and TRRL, UK. (Source: RHD's Geometric Design Standard)

c Selection of Design standards:

The geometric design standard for cross-sectional parameters and speed related parameters are based on RHD design guides (For pavement design and geometric design). RHD has developed these guides based on AASHO and TRRL, UK Guides to suit physical, traffic and climatic conditions of Bangladesh.

d Designing the alignment and profile:

Horizontal and vertical alignments of the existing RHD roads have not been changed and the new road has been designed to suit the topography of the area with due regards to RHD road design standards.

e Designing surface drainage, erosion control and cross-drainage structure:

Surface drainage: The geometric design aspects that affect the quality of drainage have been studied thoroughly. Camber/cross slope have been provided for quick disposal of rain –water from the road surface. Road-side ditch and drains have been provided as per requirement. Protection of road-embankment from erosion and wave action has been ensured by pitching of CC blocks over geotextiles. cross-drainage structures like culverts, sluice gate, causeway and regulator have been provisioned. Retaining walls are planned to put in place of limited ROW and ponds.

f Designing road junctions:

There are 4 junctions along the route situated in built-up areas. The junctions are at present capable of catering medium trucks and buses but the semi-trailers need to be sided or slowed down while plying through the junctions having inadequate space for expansion. The semi-trailers will have some difficulty to pass through the intersections. They will scrape the existing building structures.

g Traffic factors:

Types of traffic plays important role in designing roads. Wheel load, impact and repetition of wheel load across the pavement have been duly considered in designing the road. Classified traffic counts have been conducted to assess the traffic plying through the road (Source: RHD's Geometric Design Standard).

The summary traffic volumes are shown below:

Table 16.3-12 Summary Traffic Volume

Name of road stretch	Dry Season		Rainy Season		Current	Future	Highest Peak- hour PCU (10%)	Design Traffic (Cumulative traffic within 20 years)
	Average Daily Traffic(ADT)	Passenger Car Unit(PCU) of a Day	Average Daily Traffic(ADT)	PCU of a Day	Annual Average Daily Traffic(AADT)	Annual Average Daily Traffic(AADT) at 20years later		
Ekata to Pekua	342.2	6782.5	236.55	6433.25	289.37	1119.77	678	4329945.95
Pekua to Eidmoni	298.59	6760.25	42.34	2883.75	170.46	659.63	676	2550653.44
Eidmoni to Janata Bazar	171.83	4223.75	342.11	3614.75	256.97	994.39	422	3845133.26
Challatoli to Yunuskhali	42.94	1498.25	8.41	1340	25.67	99.33	150	384109.32
Challatoli to Matarbari	6.37	571.75	140.11	2037	73.24	283.42	203	1095916.10

Future traffic volume can be obtained by following calculation process.

Annual Average Daily Traffic (AADT) at 20years later = AADT*(1+r)^n

r: Traffic growth rate, r= 0.07

n: year, n=20

In Ekata - Pekua case;

Annual Average Daily Traffic(AADT) at 20years later

=AADT*(1+r)^n

AADT= 289.37, r=0.07, substitute n=20

=289.37* (1+0.07)^20

=289.37*3.869684
=4329945.95

Design Traffic can be obtained by following calculation;
Design traffic（Cumulative）= 365*AADT*((1+r)^n-1)/r

h Traffic Volume for the new road from Yunuskhali to Matarbari Power-plant:

1) Existing traffic is nil as there is no functional road there. People of Matarbari union and Dhalghata union use Challatoli-Matarbari road and Challatoli/Janata Bazar to Maheskhali road via Yunuskhali. It could be assumed that 50% of the existing traffic of these two roads will be diverted to this new road after opening. So, total traffic of the road at the time of opening could be calculated as following:-
2) Existing traffic= 0.00 ESL
3) Diverted traffic= (73.24+25.67) X 50%= 49.45 ESL and (1340+2037) X50% PCU=1688.5 PCU.
4) Generated traffic: Soon after opening the road, some heavy trucks will be plying to transport materials for construction of the proposed power-plant as well as for transporting salt and fish produced in the area. Following vehicles are likely to ply daily at the opening period:-

Table 16.3-13 Traffic Volume for the New Road from Yunuskhali to Matarbari Power Plant

Vehicle	ESA	Number	Total ESA	Total PCU
Heavy trucks(Dual axle)	4.8	5	24	15
Large Trucks(single axle)	4.62	7	32.34	21
Truck(8160 Kg)	1	5	5	15
Bus	0.5	6	3	9
Minibus/Small truck/Goods van	0.2	10	2	10
Total			66.34	70

So, the total average annual daily traffic (AADT) after completion of the road will be as following:-
Traffic after completion of the road construction in the year of 2020=
49.45(1+.07) ^7=79.40 ESA (AADT).
Also there will be generated traffic, as above, 66.34 ESA (AADT).

So, total traffic in the year of 2020(The year of opening) = 0+79.4+66.34= 145.79 ESA (AADT). Cumulative Standard Axle (W-18) Calculation

AADT= 145.79 ESA

Design life, n= 20 Years
Traffic growth rate, r=7% 0.07

(1+r) 1.07 (1+r)^n 3.869684 (1+r)^n-1 2.869684 ((1+r)^n-1)/r 40.99549

So, Cumulative standard axle (design traffic)= 365*AADT*((1+r)^n-1)/r
2181507
So, Cumulative standard axle (design traffic) in design lane,75%= 1636131 ESL
Equal to= 1.64 million ESL

i Climatic factors:
Climate plays an important role to the life of pavement. Pavement suffers damage due to excessive rainfall, frost heave and loss subgrade support during the thawing period. There is possibility of heavy rainfall in almost every year but here is no possibility to reach temperature to freezing point along the route. Much attention has been paid to climatic factors as above for designing pavement layers.

(2) Design and Construction Concept

The design shall be in compliance with the relevant regulations of Bangladesh, American/European Road Standards (AASHTO/TRRL) and Japanese Road Structure Ordinance. Table 3.3-6 shows applicable standard. In Bangladesh about the design of road structure like culvert, bridge, etc., AASHTO LRDF latest version is followed in every department RHD, LGED, RAJUK etc. Specifically, the design Standard of RHD shall be adopted in this project as a basic criteria.

In addition, for the new road constructed on BWDB embankment the road standard mentioned above will be adopted to pavement, and BWDB design standard will be adopted to basement (embankment) and other specific structures in embankment such as sluice gate and regulator.

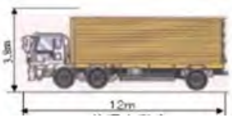
Table 16.3-14 List of Applicable Standards

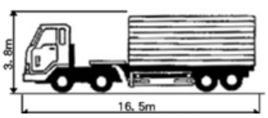
<table>
<tr><th></th><th>RHD</th><th>Japan (Road structure Ordinance) (2004.2)</th></tr>
<tr><td>1. Road type</td><td>The access road will be a Regional Highway according to RHD's classification guideline and connect to the National Highway-1.</td><td>Road is classified by “type of road” and “region of which road exists”.
Road is classified by “kind of road” , “topography of the area” and “planned traffic volume” .
<table>
<tr><th>Area where road exist / Type of road: Highway road and Limited highway or other road</th><th>Region</th><th>City</th></tr>
<tr><td>Highway and limited high way</td><td>Type 1</td><td>Type 2</td></tr>
<tr><td>Other roads</td><td>Type 3</td><td>Type 4</td></tr>
</table>
City: areas developed downtown or areas expected to become developed downtown
Region: areas exclude City
<table>
<tr><th>Planned traffic volume / Topography of area road / Kind</th><th>Over 20,000</th><th>Over 4,000 to under 20,000</th><th>Over 1,500 to under 4,000</th><th>Over 500 to under 1500</th><th>Under 500</th></tr>
</table>
</td></tr>
</table>

<table>
<tr><th></th><th>RHD</th><th>Japan (Road structure Ordinance) (2004.2)</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>of road</td><td>exist</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">National road</td><td>Flat land</td><td>Class 1</td><td>Class 2</td><td colspan="3">Class 3</td></tr>
<tr><td>Mountain</td><td>Class 2</td><td>Class 3</td><td colspan="3">Class 4</td></tr>
<tr><td rowspan="2">Regional road</td><td>Flat land</td><td colspan="2">Class 2</td><td colspan="3">Class 3</td></tr>
<tr><td>Mountain</td><td colspan="2">Class 3</td><td colspan="3">Class 4</td></tr>
<tr><td rowspan="2">Municipal roads</td><td>Flat land</td><td colspan="2">Class 2</td><td>Class 3</td><td>Class 4</td><td>Class 5</td></tr>
<tr><td>Mountain</td><td colspan="2">Class 3</td><td colspan="2">Class 4</td><td>Class 5</td></tr>
</table>
According to the above table, access road is classified as "Type 3, Class 4".
</td></tr>
<tr><td>2.Vehicle design</td><td>Minimum axle load: For single axle-8160 Kg, for Tandem axle-14500 Kg.
Vehicle length: 9.15 m (Single unit truck which requires minimum turning radius of 12.8 m (Outside) and 8.61 m (Inside radius).
As per the existing ROW and building condition at road junctions, semi-trailer will affect the existing structures at the corner.</td><td>Size of vehicle is fundamental condition for determining road width configuration, widening of curved part, design of intersection, vertical slope, sight distance etc. Therefore, dimension of design vehicle is established.

Road structure ordinance article 4
Type 1, Type 2, Type 3 class 1, Type 4 class 1 road: compact car , semi-trailer
Other road: compact car, ordinary vehicles
<table>
<tr><th>Designed vehicle / Dimension</th><th>compact car</th><th>ordinary vehicles</th><th>articulated road train</th></tr>
<tr><td>Length</td><td>4.7m</td><td>12m</td><td>16.5m</td></tr>
<tr><td>Width</td><td>1.7m</td><td>2.5m</td><td>2.5m</td></tr>
<tr><td>Height</td><td>2m</td><td>3.8m</td><td>3.8m</td></tr>
<tr><td>Front top overhang</td><td>0.8m</td><td>1.5m</td><td>1.3m</td></tr>
<tr><td>wheelbase</td><td>2.7m</td><td>6.5m</td><td>Front wheelbase 4m
Rear wheelbase</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th></th><th>RHD</th><th>Japan (Road structure Ordinance) (2004.2)</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td></td><td></td><td></td><td>9m</td></tr>
<tr><td>Rear top overhang</td><td>1.2m</td><td>4m</td><td>2.2m</td></tr>
<tr><td>Minimum rotation radius</td><td>6m</td><td>12m</td><td>12m</td></tr>
</table>
Compact car


Ordinary vehicle


Semi-trailer


According to the above table, access road is classified as for “compact car”, "ordinary car".
</td></tr>
<tr><td>3.Design speed</td><td>The design speed of regional highway is V=40~60 Km./h
Design speed of 40 Km/h has been adopted considering traffic safety based on the discussion with RHD’s design unit.</td><td>○ In the road structure ordinance, design speed is established for each class as fundamental condition for road design.
<table>
<tr><td>Category</td><td colspan="2">Design speed(1km per 1 unit hour)
(left column: defined value ,right column: special value)</td></tr>
<tr><td>Class 1</td><td>60</td><td>50 or 40</td></tr>
<tr><td>Class 2</td><td>60, 50 or 40</td><td>30</td></tr>
<tr><td>Class 3</td><td>50, 40 or 30</td><td>20</td></tr>
<tr><td>Class 4</td><td>40,30 or 20</td><td></td></tr>
</table>
According to the above table, design speed of access road is determined as V = 40 km/h.
</td></tr>
<tr><td>4.Width configuration</td><td>Crest width will be 9.8 m including 5.5 m</td><td>○Regarding road width, there are regulations for “carriageway” and “pavement etc.” and “orbit”,</td></tr>
</table>

<table>
<tr><th></th><th>RHD</th><th>Japan (Road structure Ordinance) (2004.2)</th></tr>
<tr><td></td><td>carriageway and 1.2 m hard shoulders and 0.95 m verges
Reference:
Table-2.1,page-3 RHD Manual</td><td>“greening” also. Road cross section configuration is determined with combinations of these regulations.
○ Regarding road, regulations including “lane number”, “Width of road”, “central zone” and “road shoulder” are determined by planned traffic volume and category. There are regulations for “Additional passing lane”, “lanes for slower traffic” and “Sub lane” which is installed when it is required.

○Regarding pavement etc., regulations are established in different system from the perspective of safety for pedestrian and bicycle.</td></tr>
<tr><td>5.Roadway width</td><td>See 6. Traffic lane</td><td>○ In the road structure ordinance, the idea that traffic road is comprised of traffic lanes is adopted. Width of traffic road is determined by kind of road, traffic volume, design speed etc.</td></tr>
<tr><td>6. Traffic lane</td><td>Standard
Carriageway width= 5.5 m
Reference:
Table-2.1,page-3 RHD Manual</td><td>○ Number of lanes is required condition to determine the width configuration and determined by planned traffic volume and standard of traffic volume per one lane.
-Number of lanes are determined by ratio of design standard traffic volume and planned traffic volume (per day) in consideration of road category and topographic condition.
<table>
<tr><th colspan="2">Category</th><th>Topography</th><th>Design standard traffic volume(Unit vehicles per 1 day)</th></tr>
<tr><td rowspan="5">Type 3</td><td>Class 2</td><td>Flat land</td><td>9,000</td></tr>
<tr><td rowspan="2">Class 3</td><td>Flat land</td><td>8,000</td></tr>
<tr><td>Mountain</td><td>6,000</td></tr>
<tr><td rowspan="2">Class 4</td><td>Flat land</td><td>8,000</td></tr>
<tr><td>Mountain</td><td>6,000</td></tr>
</table>

Number of lanes: 2 Lane</td></tr>
<tr><td>7. Traffic Lane width</td><td>Standard for regional highway is 2 (Two) lanes</td><td>○It is generally assumed that ration of heavy traffic is differ according to road class, with of traffic lane of each class is determined with estimated design speed, traffic volume, ratio of heavy truck.</td></tr>
</table>

<table>
<tr><th></th><th>RHD</th><th>Japan (Road structure Ordinance) (2004.2)</th></tr>
<tr><td></td><td>-</td><td>
<table>
<tr><td colspan="2">Road category</td><td>Lane width of ordinary road (Unit: m) Inside of () is special value</td><td colspan="2">Road category</td><td>Lane width of ordinary road (Unit: m) Inside of () is special value</td></tr>
<tr><td rowspan="4">Type 1</td><td>Class 1</td><td>3.50(3.75)</td><td rowspan="4">Type 3</td><td>Class 1</td><td>3.50</td></tr>
<tr><td>Class 2</td><td>3.50(3.75)</td><td>Class 2</td><td>3.25(3.50)</td></tr>
<tr><td>Class 3</td><td>3.50</td><td>Class 3</td><td>3.00</td></tr>
<tr><td>Class 4</td><td>3.25</td><td>Class 4</td><td>2.75</td></tr>
<tr><td rowspan="2">Type 2</td><td>Class 1</td><td>3.50(3.25)</td><td rowspan="2">Type 4</td><td>Class 1</td><td>3.25(3.50)</td></tr>
<tr><td>Class 2</td><td>3.25</td><td>Class 2,3</td><td>3.00</td></tr>
</table>
Width of a lane: w = 2. 75 m</td></tr>
<tr><td>8. Separation of lanes</td><td>Lane separation has not been considered for the limited carriageway width of 5.5 m. Also the design speed has been limited to 40 km/h for the inseparable lane.
Reference: RHD Regional Highways do not have lane separator</td><td>○ Regarding road with large traffic volume and high design speed such as limited highway, deviation to the oncoming lane often lead to serious accident, therefore separation of lanes are established as principle.

○ Separation of lanes: do not separate</td></tr>
<tr><td>9. Shoulder width (road width)</td><td>Shoulders will be 2.15 m including 1.2 m hard shoulders
Reference:
Table-2.1,page-3 RHD Manual</td><td>○Regarding width of road shoulder, required width is determined in coordination with function of road such as protection of road main structures, space for disordered vehicles, room for side etc.
<table>
<tr><td colspan="2">Type and class category</td><td colspan="2">Width of road shoulder of left side of ordinary road</td><td>Width of road shoulder of right side of ordinary road</td></tr>
<tr><td rowspan="2">Type 1</td><td>Class 1,2</td><td>2.5</td><td>1.75</td><td>1.25</td></tr>
<tr><td>Class 3,4</td><td>1.75</td><td>1.25</td><td>0.75</td></tr>
<tr><td colspan="2">Type 2</td><td>1.25</td><td></td><td>0.75</td></tr>
<tr><td>Type 3</td><td>Class 1</td><td>1.25</td><td>0.75</td><td>0.5</td></tr>
</table></td></tr>
</table>

<table>
<tr><th></th><th>RHD</th><th>Japan (Road structure Ordinance) (2004.2)</th></tr>
<tr><td></td><td></td><td><table><tr><td rowspan="2"></td><td>Class 2-4</td><td>0.75</td><td>0.5</td><td rowspan="2"></td></tr><tr><td>Class 5</td><td>0.5</td><td></td></tr><tr><td colspan="2">Type 4</td><td>0.5</td><td></td><td>0.5</td></tr></table>
Road shoulder width: w = 0. 5 m</td></tr>
<tr><td>10. Construction limit</td><td>NA</td><td>○ Construction limit is established as constant height and range where installation of structure is prohibited to avoid structures etc. affect vehicle or pedestrian's safety or smooth.
○ Height is set as 4.5m considering height of "ordinary vehicles" "semi-trailers"; 3.8m and room for rocking etc. of vehicles.
○ When vehicles entering road shoulder, it basically slow or stopped. Therefore at road berm, it is accepted to reduce 3.8m height excluding room height.
Construction limit: H = 4. 5 m</td></tr>
<tr><td>11.Curve radius</td><td>Radius for ISD is 250 m for 2 lane regional highway. But due to site constraints SSD radius is to be used which is 65 m.
Reference:
Table-5.1,page-25 RHD Manual</td><td>○From perspective of securing traffic safety and smoothness, at curve part of road, minimum radius of curve is established for stable driving.
○Regarding minimum radius is established as to forces acting on horizontal such as centrifugal force does not exceed forces generated by friction between tire and road surface and also balance between centrifugal force act on driver and ride quality.<table><tr><td>Design speed</td><td colspan="2">Curve radius (m)</td></tr><tr><td>120</td><td>710</td><td>570</td></tr><tr><td>100</td><td>460</td><td>380</td></tr><tr><td>…</td><td>…</td><td>…</td></tr><tr><td>20</td><td>15</td><td></td></tr></table>
○Minimum curve radius: R = 50 m</td></tr>
<tr><td>12.Curve part incline</td><td>To be confirmed</td><td>○ Curve part incline is established as to realize safety driving of vehicles and mitigate uncomfortable due to centrifugal force by mitigating forces acting on horizontal.
○ However, when curve part incline is too steep, it may lead to cause passing obliquely with low speed and slop with snow. Therefore maximum values is established.<table><tr><td>Category</td><td>Area road exist</td><td>Maximum incline(%)</td></tr></table></td></tr>
</table>

<table>
<tr><th></th><th>RHD</th><th>Japan (Road structure Ordinance) (2004.2)</th></tr>
<tr><td></td><td></td><td><table><tr><td rowspan="3">Type 1,2 and 3</td><td rowspan="2">Snow covered frigidity area</td><td>Significant area</td><td>6</td></tr><tr><td>Other area</td><td>8</td></tr><tr><td colspan="2">Other area</td><td>10</td></tr><tr><td>Type 4</td><td colspan="2"></td><td>6</td></tr></table>1 Maximum incline: i =10%</td></tr>
<tr><td>13.Widening of curve part</td><td>For assumed speed of 40 Km/h and 65 m of radius, the extra widening at curves would be 1.5 m
Reference:
Table-5.4,page-26 RHD Manual</td><td>○Widening of curve part is established because curved part requires wider road width than straight part because front wheel and rear wheel draw different path at curved part.</td></tr>
<tr><td>14. Transition section</td><td>There will be transition sections adjacent to horizontal curve sections</td><td>○From perspective of securing traffic safety and smoothness, installation of transition section is established in coordination with design speed to avoid sudden action of handles and impact to drivers due to sudden change of linear.</td></tr>
<tr><td>15. Vertical slope</td><td>There will be 3% longitudinal gradient as proposed by and RHD agreed.
Remarks: For the new construction from Yunuskhali to the power plant site, longitudinal gradients will be only at bridge approaches.</td><td>○From perspective of securing traffic safety and smoothness, vertical gradient is established to avoid reduction of traffic capacity and traffic safety due to significant decrease in speed.
○Value is established as to passenger vehicle could climb with average speed and tracks could climb with a half of design speed.</td></tr>
<tr><td>16.Vertical radius</td><td>K-value for the vertical curves shall be 4
Reference:
Table-2.3,page-3, RHD Manual</td><td>○From perspective of securing traffic safety and smoothness, installation of vertical curves etc. is established as to secure sight distance and mitigate impact due to rapid change of incline at part where vertical incline is changing.</td></tr>
<tr><td>17.Sight distance</td><td>SSD=60 m;ISD=120m;OSD=250</td><td>○Form perspectives of securing traffic safety and smoothness, sight distance are established as distance</td></tr>
</table>

	RHD	Japan (Road structure Ordinance) (2004.2)
	m Reference: Table-5.4,page-26 RHD Manual	vehicle could recognize obstacle etc. in front and stop with brake to avoid clash in accordance with design speed.
18... Paved constitution	Under carriageway: Base course=200 mm; Sub-base=200mm; Improved Subgrade=300 mm. Reference: This is minimum requirement of RHD Regional Highways standard	○Installation of pavement and vehicle wheel load standard is established to secure traffic safety and smoothness by avoiding splash at rainy time and dry dust at dry time, improve road flatness and secure appropriate resistance for slip. ・Road, central zone (exclude separation zone), road shoulder connected to road, bicycle road and side walk must be paved. However, when there is special reason such as little traffic volume etc., it could be excluded. ・Pavement of road and side zone, must be structures which satisfy established regulation of Ministry of Land, Infrastructure, Transport and Tourism, considered planned traffic volume, vehicle weight, road bed condition, weather system and standard as it can secure traffic safety and smoothness with 49 kN as wheel load of vehicle standard
19. Cross-fall	Terrain of the route is mostly plain; so, cross slope of 3% for carriageway and 5% for earthen shoulders is used Reference: As per AASHTO and RHD Manuals	○ Incline for transverse direction is required to guide surface rain water to side ditch or gutter. ○When incline is too steep, it may lead to oblique motion or slip when it snow. ○Considering above reasons, minimum and maximum value is established as standard transverse gradient. ○Regarding permeable pavement road, drainage is considered in structure, gradient could be reduced. ○Transverse gradient: i = 1. 5 %
20. Combined gradient	Not applicable Reference: As the terrain is plain from Yunuskhali to power plant	○Gradient which combined transverse gradient and vertical gradient is established as combined gradient which is the maximum gradient on road. ○When gradient is too steep, it may cause slip etc. of vehicles when it snows or with reduced speed, therefore maximum value is established. Especially, in region where freezing and snow cover occurs often very strict value is established. <table><tr><td>Design speed (Unit : km per one</td><td>Combined gradient(unit %)</td></tr></table>

<table>
<tr><th></th><th>RHD</th><th>Japan (Road structure Ordinance) (2004.2)</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>hour)</td><td></td></tr>
<tr><td>120</td><td rowspan="2">10</td></tr>
<tr><td>100</td></tr>
<tr><td>80</td><td rowspan="2">10.5</td></tr>
<tr><td>60</td></tr>
<tr><td>40</td><td rowspan="3">11.5</td></tr>
<tr><td>30</td></tr>
<tr><td>20</td></tr>
</table>
○ Maximum combined gradient: i = 11.5%</td></tr>
<tr><td>21. Traffic safety facilities</td><td>Cautionary signs, signals, road markings, guard post, railings and boundary walls have been considered to increase traffic safety.</td><td>○Traffic safety facilities are required facilities to avoid traffic accidents along with road structure itself and to secure traffic safety and smoothness of vehicle and pedestrian. Therefore regulation regarding installation is established.

When it is required to prevent traffic accident, pedestrian bridge etc., fence, lighting facilities, safety post, emergency contact and other facilities which are specified in the Ordinance of the Ministry of Land, Infrastructure and Transport facilities will be provided.
〇Traffic facilities to be installed
-3D cross facility
-Protection fence
-Lighting installations
-Delineators
-Road reflector Etc.</td></tr>
</table>

Design and construction concept is shown in Table 3.3-7, and the adopted standard cross-section is shown in Figure 3.3-1. Figure 3.3-2 shows a typical cross section of BWDB embankment restoring in Matarbari.
Overview of road construction and rehabilitation is shown in Table 16.3-16.

Table 16.3-15 Design Concept for the Road Component of Access Road

Item	Description
Road Design	
Crest Width	9.80 m
Carriage Way Width	5.50 m
Shoulder	2.15 m (Hard: 1.25 m, Soft: 0.90 m) x 2
Surge Load in the Coastal Area	4.26 m (14 feet) from Mean Sea Level (MSL)
Crest Level of road on embankment	4.54 m from MSL (PWD standard)
Maximum Vehicle	Medium Truck (Category 2 in RHD guideline)

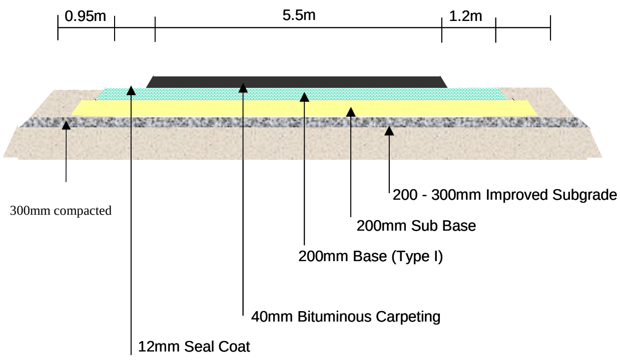
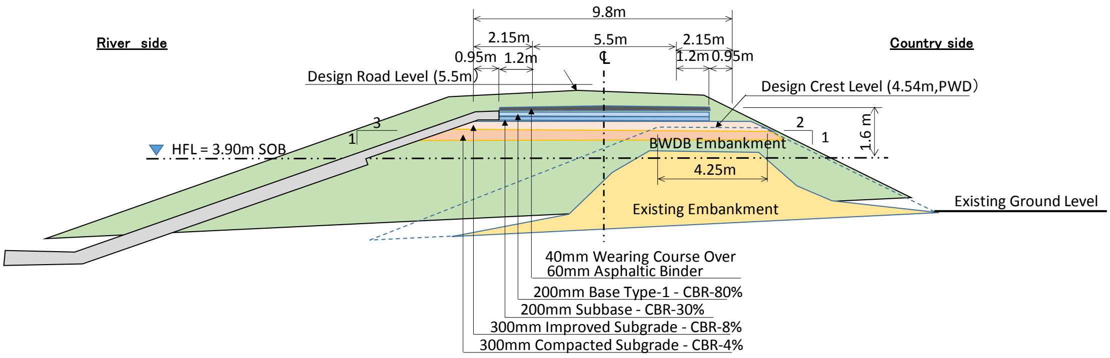


Figure 16.3-10 Standard Cross-Section for Normal Road



(Source: BWDB & JICA Study Team)

Figure 16.3-11 Typical Cross Section of BWDB Embankment Restoring in Matarbari and Model of New Road

Table 16.3-16 Overview of Road Construction and Rehabilitation

Section	Current Jurisdiction	Distance	Major Construction/ Rehabilitation	Land Acquisition
Existing Road		35.05 km		
Eakata – Pekua	RHD (Zilla road Z1125)	11.80km	1) Surface sealing 2) Make-up and repair shoulders 3) Repair rain cuts 4) Restore damaged shoulders **5)** Patching potholes and depressions with bituminous materials **6) Uniform Overlay Finishing**	NOT necessary
Pekua - Eidmoni	RHD (Regional highway R170)	10.90km	1) Bituminous overlay 2) Restore damaged shoulders and broken edges (20% area) with provision of brick on end edging. 3) Restore damaged slopes 4) Repair large defective areas (potholes/depression patching with bituminous materials) 5) **Uniform Overlay Finishing**	NOT necessary
Eidmoni – Badarkhali Bridge	RHD (Regional highway R172)	7.40km	1) Bituminous overlay 2) Restore damaged shoulders (30% area) with provision of brick on end edging 3) Restore damaged slopes 4) Repair large defective area (potholes patching)	NOT necessary

			5) **Uniform Overlay Finishing**	
Badarkhali Bridge – Janata Bazar	RHD (Zilla road Z1004)	1.35km	1) Widening of carriageway width to 5.5 m. 2) Bituminous overlay 3) Restore damaged shoulders(50% area) 4) Restore damaged slopes 5) Repair large defective area (potholes patching) 6) **Uniform Overlay Finishing**	NOT necessary
Janata Bazar – Thallatoli Intersection		0.30km		NOT necessary
Thallatoli Intersection – Yunuskhali Intersection		1.60km	1) Scarifying of existing bituminous layer 2) Replacing existing unspecified road-base materials and formation preparation 3) Addition of Road-base Type-1 4) Widening of carriageway width to 5.5 m and providing asphaltic layer finish. 5) Restore damaged shoulders 6) Providing surface drains as and where required. 7) **Uniform Overlay Finishing**	NOT necessary
Yunuskhali Intersection – Jetty	LGED (Village road 4013)	1.70km	1) Construction of earthen road embankment of 9.8 m crest width 2) Construction of 5.5 m carriageway and shoulders 3) Pavement layers: Asphalt finish 4) 200 mm road-base type-1 5) 250 mm sub-base 6) 300 mm improved sub-grade **7) Uniform Overlay Finishing** 8) Soft ground countermeasure work shall be considered	Necessary
New road			1.25 km	
Government land between two embankments in Matarbari	DC Office	0.24km	1) Construction of earthen road embankment of 9.8 m crest width 2) Construction of 5.5 m carriageway and shoulders 3) Pavement layers: Asphalt finish 4) 200 mm road-base type-1 5) 250 mm sub-base 6) 300 mm improved	Necessary

			sub-grade 7) **Uniform Overlay Finishing** 8) Soft ground countermeasure work shall be considered	
Embankment	BWDB	1.60m	1) Reconstruction of BWDB embankment according to BWDB Standards 2) Pavement of crest of embankment according to RHD Standards 3) **Uniform Overlay Finishing** 4) Soft ground countermeasure work shall be considered	NOT necessary
Partial dyke	BWDB	0.24 km		NOT necessary
Private land	Private	0.17 km	1) Construction of earthen road embankment of 9.8 m crest width 2) Construction of 5.5 m carriageway and shoulders 3) Pavement layers: Asphalt finish 4) 200 mm road-base type-1 5) 250 mm sub-base 6) 300 mm improved sub-grade 7) **Uniform Overlay Finishing** 8) Soft ground countermeasure work shall be considered	Necessary
TOTAL		36.20 km		

(Source: JICA Study Team)

(3) Assumption for Planning and Design

Major section of the selected route will utilize existing road which starts from National Highway 1. Based on the basic policy of road planning in this project, the existing road facilities shall be used to the maximum possible degree.

In Bangladesh, the carriageway width of single lane is 3.7 m and double lane is 7.3 m respectively. So carriageway width of 5.5 m is an intermediate lane width of one and two lane/s road that is very common in most of the regional highways in Bangladesh.

The proposed road (new construction portion) runs through remote rural and low lying area where carriageway width of 3.7 m appears ind\adequate. On the other hand, as per traffic volume forecast and to avoid excessive agricultural land acquisition, it is not feasible to construct a two-lane highway of 7.3 m carriageway.

Dimensionally, the existing road facilities can pass up to medium trucks without problem. In Bangladesh, medium trucks categorizes in Category 2 of RHD Guideline. It meets the basic road planning policy to plan the access road by taking into consideration of passage of Category 2 medium trucks.

1) Maximum Vehicles (RHD's category)

Category: 2

Type: Medium Truck

All 2-axle rigid trucks with over three tons of payload capacity. Typical medium trucks are the Hindustan Bedford, "English" Bedford and Hino trucks of about 10 tons gross vehicle weight. Agricultural tractors and trailers are also included in this category. RHD agreed that Medium Truck of category 2 shall be a maximum passable vehicle for the access road in the technical meeting in June 2013 when the Interim Report was submitted and explained the consultant's design approach. And the preliminary design has been made based on medium truck as a maximum possible vehicle with smooth and safety traffic for access road. In this regard, appropriate traffic control will be done by measures such as traffic control by Safety Traffic Police and Safety Sign Signals. Even though there is a possibility that heavy truck may come in to access road due to township development and to carry bulky cargo for fishing industry.

Table 16.3-17 shows the list of Manual Traffic Counts Instruction Guide, RHD gives a brief description of the vehicles to be included in each category.

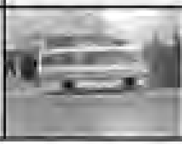
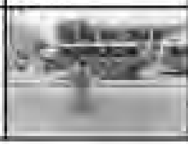
Table 16.3-17 Vehicle Classification

Category	**Type**	**Description**
1.	Heavy Truck	Three or more axles. Includes multi-axle tandem trucks, container carriers and other articulated vehicles.
2.	Medium Truck	All 2-axle rigid trucks over three tones payload. Typical medium trucks are the Hindustan Bedford, "English" Bedford and Hino trucks of about 10 tones gross vehicle weight. Agricultural tractors and trailers are also included in this category.
3.	Light Truck	Small trucks up to 3 tone payload. The most typical example is the Jeep based conversion.
4.	Large Bus	More than 40 seats on 36 foot or longer chassis.

Category	Type	Description
		chassis. Includes double decker buses.
5.	Minibus	Between 16 and 39 seats. Typical minibuses are the TATA 909 and Hindustan Mascot.
6.	Microbus	Up to 16 seats. Typical microbuses are the 12/15 seat Toyota Hi-ace, and the Mitsubishi L300.
7.	Utility	Pick-ups, jeeps and four wheels drive vehicles, such as Pajero's and Land Rover's.
8.	Car/Taxi	All types of car used either for personal or taxi services.
9.	Baby-taxi	Includes Babytaxi and Mishuks
10.	Tempo	Auto-Tempo and Auto-Vans.
11.	Motor Cycle	All two wheeled motorised vehicles.
12.	Bicycle	All pedal cycles.
13.	Rickshaw Standard	Three wheeled cycle rickshaws (not rickshaw vans)
14.	Rickshaw Van	Rickshaw vans
15.	Cart	All animal and manually drawn/pushed carts.

(Source: RHD)

Table 16.3-18 Vehicle Identification Sheet

No.	CATEGORY	CHARACTERISTICS	TYPICAL VEHICLES			
1	HEAVY TRUCK	3 OR MORE AXLES				
2	MEDIUM TRUCK	2 AXLES OVER THREE TONNES UNLOADED WEIGHT				
3	LIGHT TRUCK	2 AXLES UNDER THREE TONNES UNLOADED WEIGHT				
4	LARGE BUS	OVER 39 SEATS				
5	MINI BUS	16-39 SEATS				
6	MICROBUS	LESS THAN 16 SEATS				
7	UTILITY	PICK UPS AND FOUR WHEEL DRIVE VEHICLES				
8	CAR	ALL CARS AND TAXIS				
9	BABY TAXI	BABY TAXIS AND MISHUKS				
10	TEMPO	AUTO TEMPOS AND AUTO VANS				

(Source: RHD)

No.	CATEGORY	CHARACTERISTICS	TYPICAL VEHICLES			
11	MOTOR CYCLE	ALL TWO WHEELED MOTORISED VEHICLES				
12	BICYCLE	PUSH BICYCLE				
13	RICKSHAW STANDARD	ALL THREE WHEELED NON MOTORISED VEHICLES				
14	RICKSHAW VAN	ALL THREE WHEELED NON MOTORISED VEHICLES				
15	CART	ALL ANIMAL AND PERSON DRAWN/PUSHED CARTS				

2) Road specification (basic)

1) Carriageway width: 5.5m

2) Shoulder:2.15 m x 2

3) Crest width: 9.8 m

(4) Analysis of Traffic Counts Data

Traffic counts for pavement design purposes have been obtained by manual counts. To obtain a sufficient estimate of average traffic flow, the manual count is carried out for a relatively long period of 12-hours (From 6 AM to 6 PM).

The manual counts have been carried out by observers situated at predetermined observation points to each candidate routes and selected route. The observers have recorded the number of vehicles of each type and as for simplicity and quick estimation the traffic counts have been conducted for two days of a week one in working day and one in holiday.

1) Weekly variation of traffic

We know traffic flow differs in working day and holiday. In Bangladesh it is considered that there are five working days and two holidays in a week. So, for determination of a “seven day count", we have calculated as following:

7-day count =5 x one working day counts + 2 x one holiday counts

2) Daily variation of traffic

We know that there is hourly variation of traffic in a day. Bangladesh is a tropical country. As per normal practice of tropical countries we have conducted a 12-hour period traffic counts and assumed that 80% of whole day traffic (24-hours) flows within 6.00 AM to 6.00 PM.

3) Seasonal variation of traffic

Volume of traffic varies upon month/season. As per Road Note-40 of TRRL of UK for traffic counts, we can assume a factor of 0.82 for the traffic counts we conducted in the month of February.

4) Passenger-Car-Unit (PCU)

It is observed that there is mix-traffic flow in our candidate routes and selected route. Slow moving traffic/vehicle in a traffic stream affects the overall free flow of the traffic. A way of interaction of various kinds of traffic/vehicle is to express the capacity of a road in terms of a common or single unit is adopted as Passenger-Car-Unit (PCU). The following table of PCU factors is commonly adopted in Bangladesh:

Table 16.3-19 PCU Factors

Vehicle Type	PCU Factor
Heavy Truck/Truck	3
Large bus/Bus	3
Minibus	3
Pickup	1
Car	1
Auto rickshaw	0.75
Motorcycle	0.75
Bicycle	0.5
Rickshaw	2
Bullock-cart	4

5) Equivalent-standard-Axle (ESA)

In the design methods of Road Note-31 and AASHTO it is customary to express axle load of all vehicles in terms of Equivalent-standard-Axle (ESA) of 8160 Kg. For accurate determination of Equivalent-standard-Axle (ESA), we had to engage weigh bridges but application of weigh-bridge was beyond our limited scope. However, according to Road Note-31 and Axle Load Survey report of Bangladesh (Road Material and standard Study, Bangladesh, (RMSS)) it is in practice to use Table 16.3-20.

Table 16.3-20 ESA Table for Design Purposes

Vehicle	ESA
Large Truck/Trailer of 3-Axle(10000 Kg)	2.5
Truck(8160 Kg)	1
Bus	0.5
Minibus/Small truck/Goods van	0.2

6) Traffic growth calculation & traffic forecasting

For designing a new road pavement or rehabilitating an existing one, the measurement of current traffic levels is an important step in the process. It is also important to estimate the future traffic that the pavement will carry in over its design life.

It is to be noted that all the roads in candidate routes and the selected route are the existing roads except the road stretch of Yunuskhali to the proposed bridge over Kohelia River to Power Plant site which is to be newly constructed. All the roads except this portion belong to Roads and Highways Department of Bangladesh. However, as observed during reconnaissance survey, the stretch from Janata Bazar to Yunuskhali(1.6 Km) that belongs to RHD needs rehabilitation. Considering geographic conditions, socioeconomic conditions and future development of the area the following traffic growth and forecast could be assumed.

a. All the roads in candidate routes and selected route will have traffic growth of 8% annually in next 15 years.

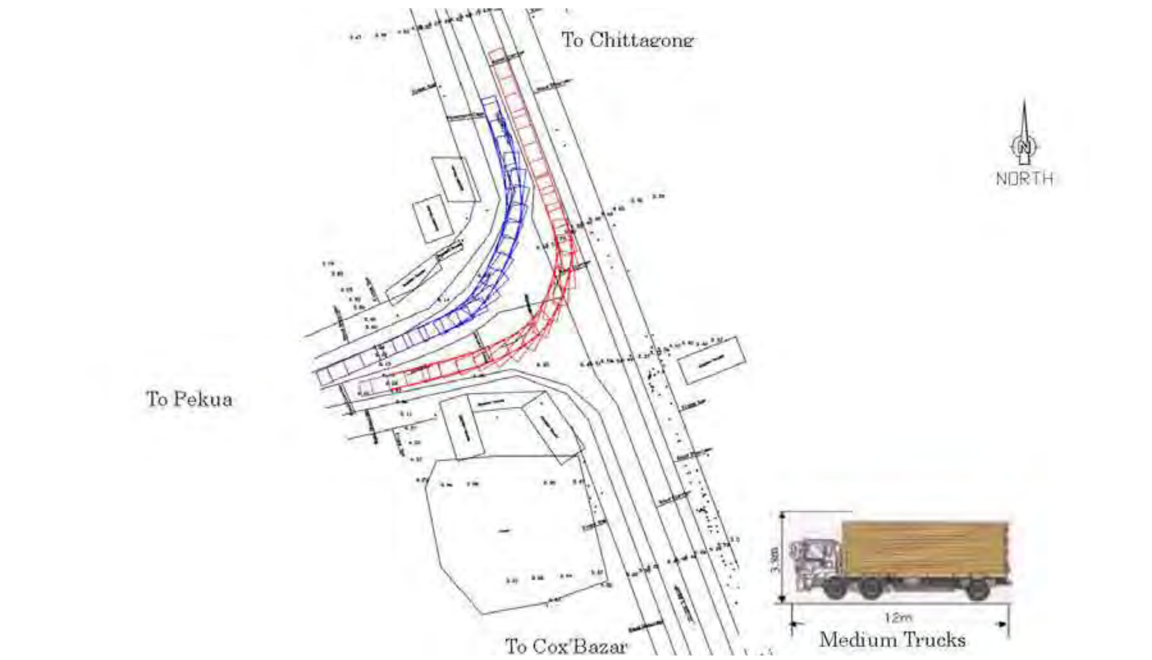
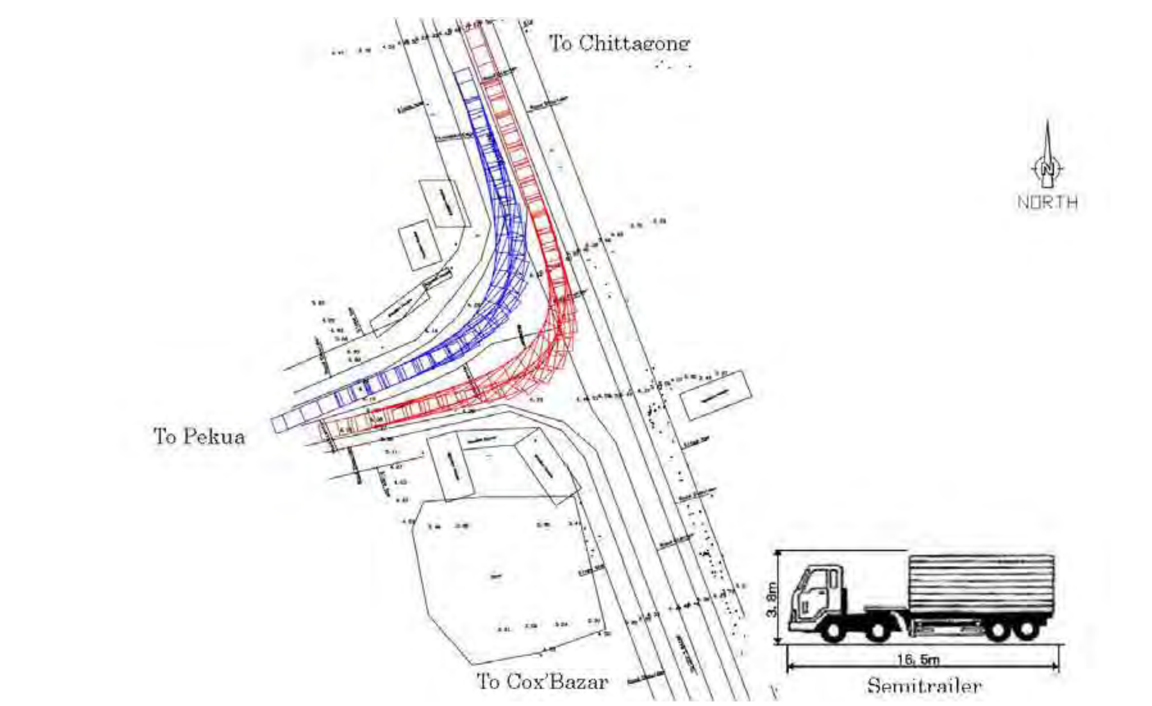
b. For Yunuskhali to Plant site at Matarbari, present traffic volume is nil as there is no functional road there. However, the existing traffic that the road from Janata Bazar to Matarbari (Belongs to LGED and under construction) is carrying, will be shared (around 50%) with the proposed new constructed road along with 30 % increase as generated traffic in the year of opening the new road. In next 10/15 years, the likely traffic growth will be 10%.

7) Vehicle Path Swept Simulation

A vehicle path swept simulation has been conducted in order to confirm the pass possibility of both Medium Truck and Semi-trailer at the four existing intersections on the proposed Access Road route.

The simulation results are shown in the following figures.

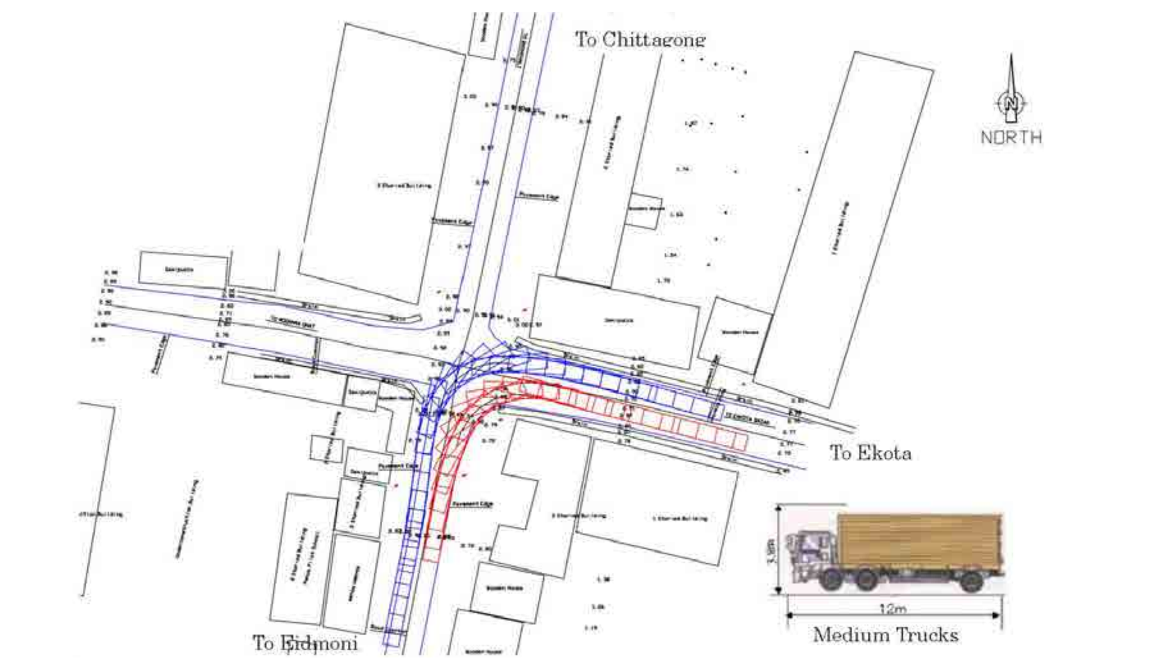
The simulation results show that medium trucks can pass all the intersections without problem. However semi-trailers will touch the existing structures as shown in the above figures. To secure a smooth and safe traffic on the access road, the road design should be based on the condition that the maximum appropriate vehicle is medium truck.

Ekata Intersection (Medium Trucks)

Ekata Intersection (Semitrailer)


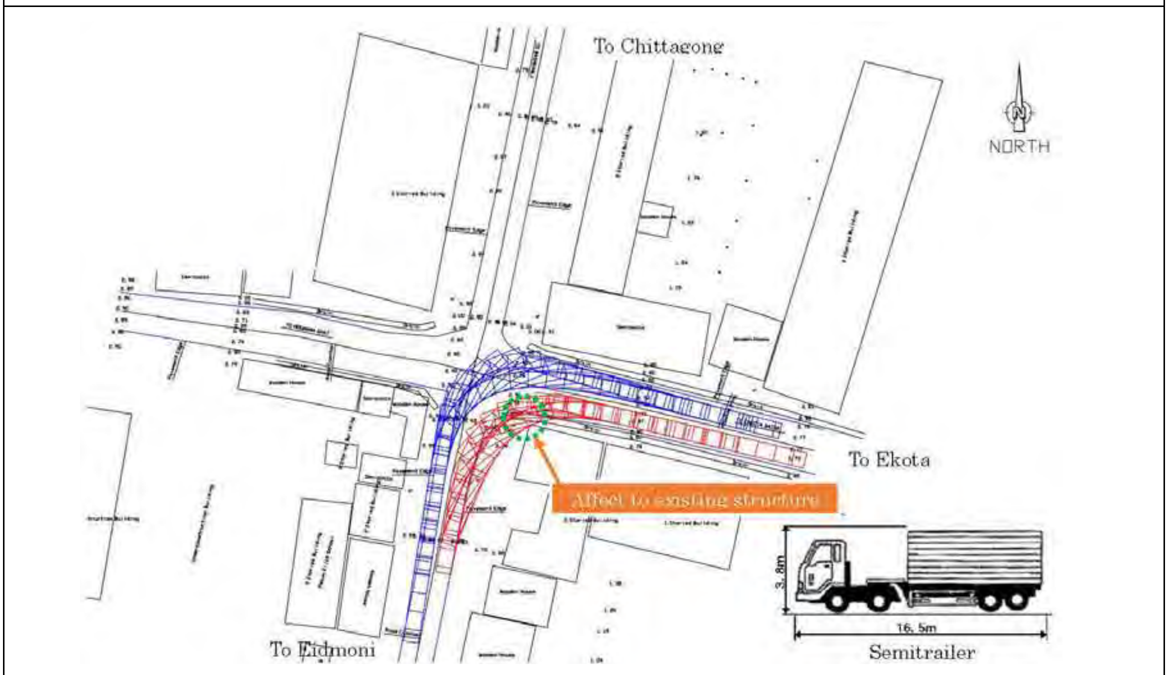
(Source: JICA Study Team)

Figure 16.3-12 Vehicle Run Trace 1

Pekua Intersection(Medium Trucks)



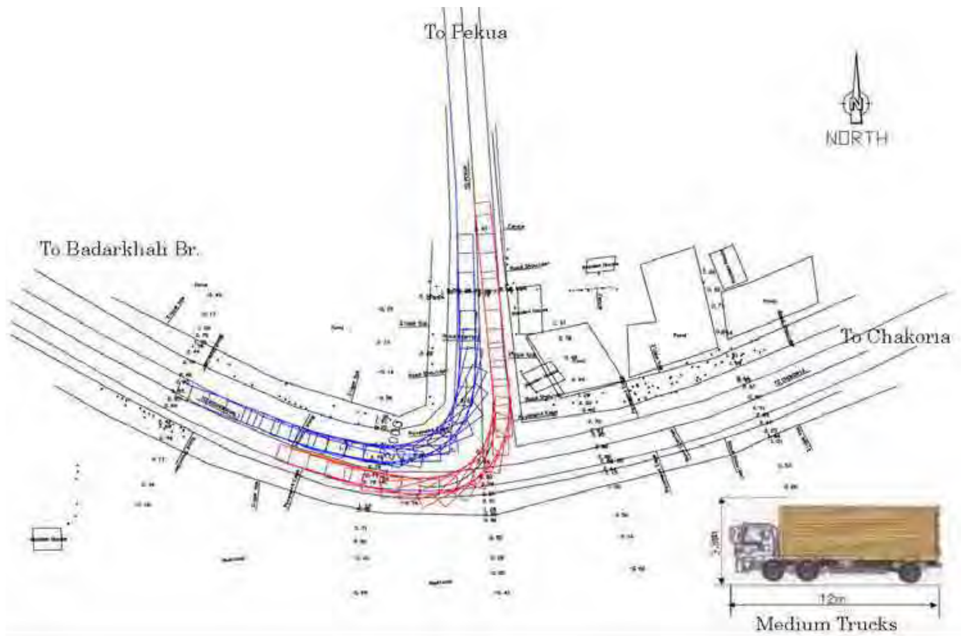
Pekua Intersection (Semitrailer)



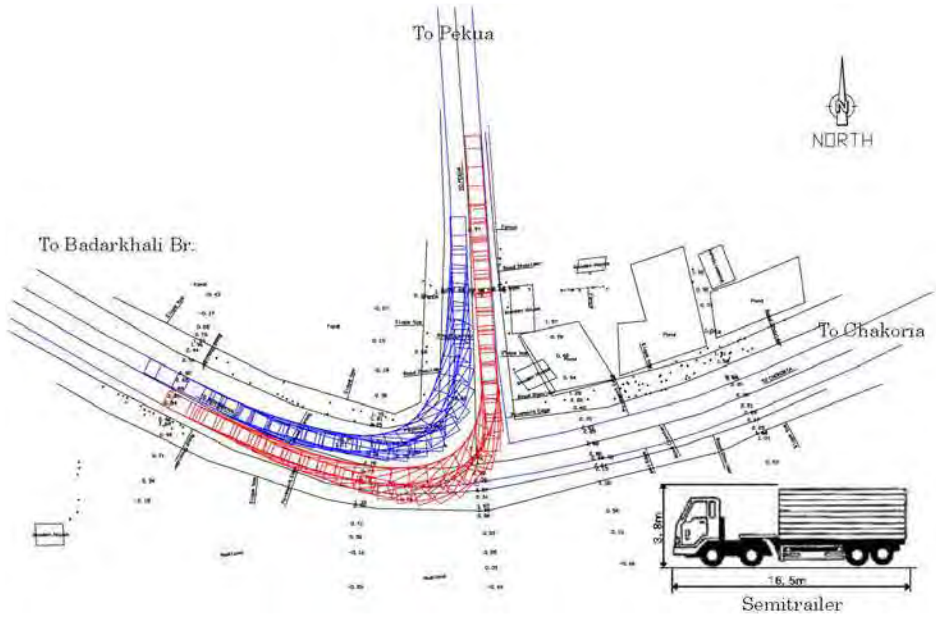
(Source: JICA Study Team)

Figure 16.3-13 Vehicle Run Trace 2

Eidmoni Intersection (Medium Trucks)



Eidmoni Intersection (Semitrailer)

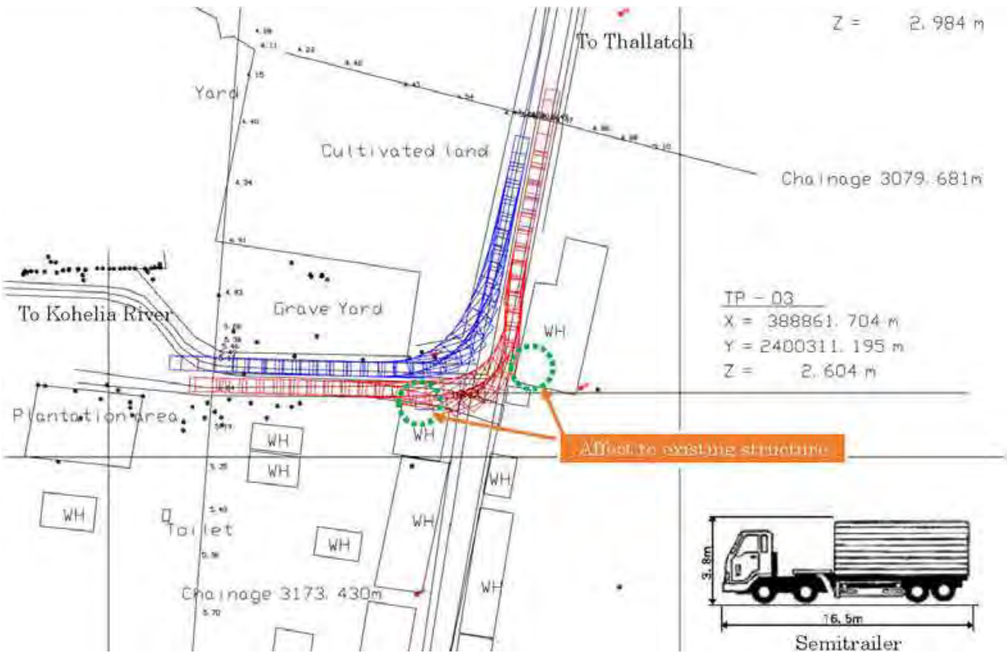


(Source: JICA Study Team)

Figure 16.3-14 Vehicle Run Trace 3

Yunuskhali Intersection (Medium Trucks)

Yunuskhali Intersection (Semitrailer)



(Source: JICA Study Team)

Figure 16.3-15 Vehicle Run Trace 4

(5) Road Construction and Rehabilitation Works

1) Outline of Works

a Make-Up and Repair Shoulders

Sometimes earthen shoulders do not have correct slopes and levels. It require little filling, re-compaction and bring back to correct slopes and provision of turfing.

b Restore Damaged Slopes

Sometimes existing slope loses correct shape due to sliding and rainwater. It requires clearing & grubbing, earth filling and compaction and turfing.

c Surface Sealing

Normally before the monsoon starts it requires sealing the asphaltic surface. It is done by providing 12 mm seal coat.

d Repair Large Defective Area (Potholes/Depression Patching)

Sometimes potholes, depressions and rut forms on road surface. It requires patch repairing by bituminous materials(up to 75 mm) and filling of road-base materials followed by patching with bituminous materials. If holes depth greater than 75 mm.

e Bituminous Overlay

When the asphaltic surface in the carriageway develops cracks of larger width and looks hungry due to insufficient bitumen binder it requires asphaltic overlay. Normally it is done of 40- 50 mm thickness.

2) Relative Major Structures

Relative major structures are considered as follows. Those locations are shown in Figure 3.3-7.

a Improvement of the Drainage System in the Hill Area

In the hill area after Janata Bazar, the drainage system along Zilla Road (Z1004) does not function. It should be improved and replaced to V-shaped gutter.

b Improvement of the Existing Causeway Near Yunuskhali Intersection

The existing causeway functions to drain rainwater from hill side to downstream, but it doesn’t function for smooth driving because the longitudinal slope is too steep. So, it should be reconstructed with gentle slope.

c Box Culverts in Kalarmachara, Maheshkhali

- At the Yunuskhali intersection road widening should be constructed on the waterway to avoid the graveyard at the opposite side.
- A existing small culvert at the out of residential area shall be replaced to larger one.
- In the salt field a new box culvert shall be constructed to keep water flow.

d Side Wall

Side wall shall be required at many section, especially in Kararmachara to minimize land acquisition and protect slope.

e Box Culverts in Matarbari

- In the salt field of the government land at least two box culverts should be constructed to keep seawater flow.
- In the salt field of the private land one box culvert should be constructed to keep seawater flow and drain rainwater from hill(west) side.

f Regulator

A new regulator should be constructed for flood control in the BWDB embankment.

g Sluice Gate

A new sluice gate should be constructed to keep seawater exchange.

h Causeway in the hill area

There is an existing causeway in this stretch. It was constructed long before and it was of very simple design without smooth and good approaches. Discussing with RHD and local people, it was confirmed that the structure was very useful to ensure discharge to the existing irrigation canal. In view of the above, a new causeway has been designed with provision for adequate drainage path and good approaches.

(1) Kararmachara Side

(2) Matarbari Side

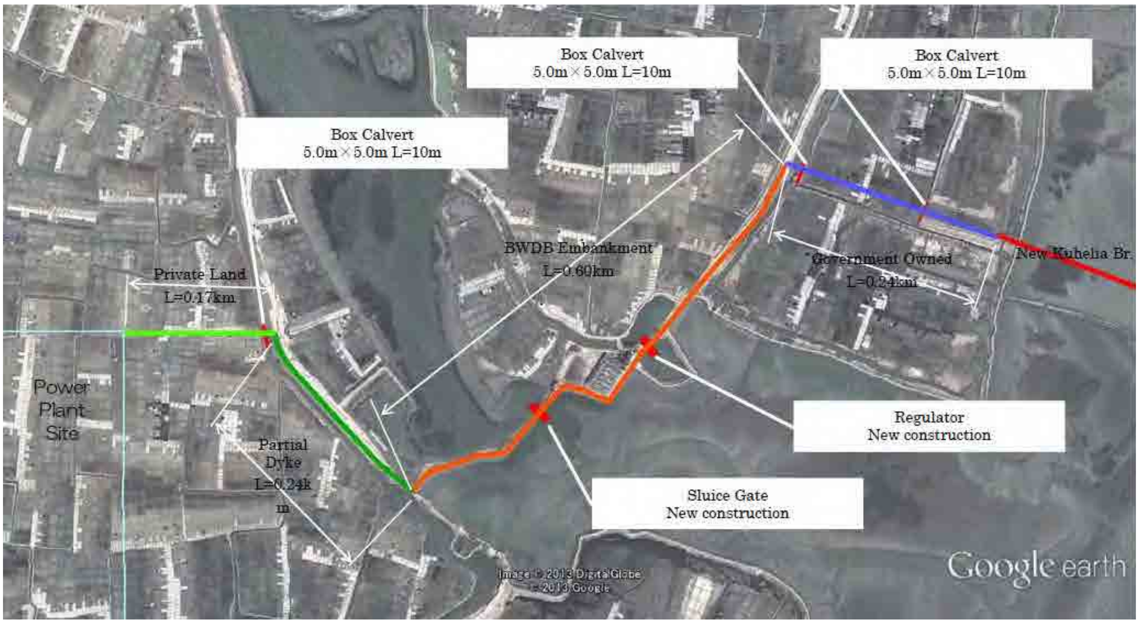


Figure 16.3-16 Locations of Relative Major Structures

The details of the proposed pavement structures are as shown in Table 16.3-21.

Table 16.3-21 Pavement Details

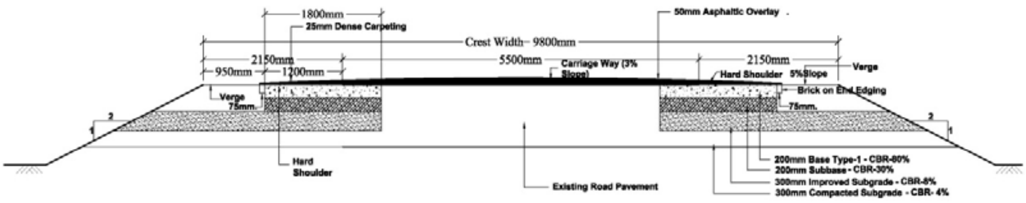
Sl#	Section	Length (Km)	Proposed work	Proposed design		Reference Cross Section
				Carriageway	Construction of hard Shoulder	
1.	Ekata- Pekua	Total Length= 11.8 Km Applicable Length= 5.9 Km(Ch- From 0+000 to 5+900)	Asphaltic overlay and construction of hard shoulder	Asphaltic overlay	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	1. (a) As attached below
2.	Pekua- Ekata	Total Length= 11.8 Km Applicable Length= 5.9 Km(Ch- From 5+900 to 11+800)	Partial reconstruction	40 mm asphaltic wearing course;60 mm asphalt binder course;200mm road base type-1	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	1. (b) As attached below
3.	Pekua-Eidmoni	Total Length= 10.9 Km	Partial reconstruction	40 mm asphaltic wearing course;60 mm asphalt binder course;200mm road base type-1	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	2. As attached below
4.	Eidmoni-Janata Bazar	Total Length= 8.6 Km	Asphaltic overlay and construction of hard shoulder	Asphaltic overlay	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	3. As attached below
5.	Janata Bazar-Yunuskhali	Total Length= 1.9 Km	Full re-construction	40 mm asphaltic wearing course;60 mm asphalt binder course;200mm road base type-1; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	4. As attached below

				subgrade		
6.	Yunuskhali-Power Plant	Total Length= 6.56 Km Applicable Length= 1.071 Km(through Yunuskhali village)	New construction	40 mm asphaltic wearing course;60 mm asphalt binder course;200mm road base type-1; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	5. (a) As attached below
7.	Yunuskhali-Power Plant	Total Length= 6.56 Km Applicable Length= 0.452 Km(through salt field at Yunuskhali end)	New construction	40 mm asphaltic wearing course;60 mm asphalt binder course;200mm road base type-1; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	5. (b) As attached below
8.	Yunuskhali-Power Plant	Total Length= 6.56 Km Applicable Length= 0.234 Km(through salt field from Bridge to BWDB Embankment)	New construction	40 mm asphaltic wearing course;60 mm asphalt binder course;200mm road base type-1; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	6. (a) As attached below
9.	Yunuskhali-Power Plant	Total Length= 6.56 Km Applicable Length= 0.606 Km(along	New construction	40 mm asphaltic wearing course;60 mm asphalt binder	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over	6. (b) As attached below

		BWDB Embankment at Matarbari end)		course;200mm road base type-1; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	300 mm compacted subgrade	
10.	Yunuskhali-Power Plant	Total Length= 6.56 Km Applicable Length= 0.257 Km(along BWDB Dyke at Matarbari end)	New construction	40 mm asphaltic wearing course;60 mm asphalt binder course;200mm road base type-1; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	6. (c) As attached below
11..	Yunuskhali-Power Plant	Total Length= 6.56 Km Applicable Length= 0.170 Km(through salt field from BWDB Dyke to Power Plant)	New construction	40 mm asphaltic wearing course;60 mm asphalt binder course;200mm road base type-1; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	Providing 25 mm dense carpeting over road-base type-1 ; 200 mm sub-base ; 300 mm Improved subgrade over 300 mm compacted subgrade	6. (d) As attached below

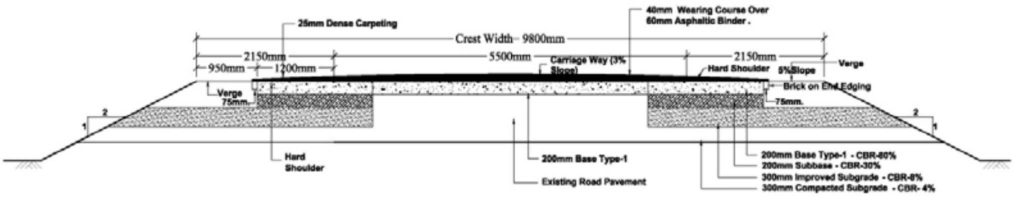
(Source; JICA Study Team)

1. (a)Ekota Bazar to Pekua Intersection, 5.90 Km. to be Asphaltic Overlay



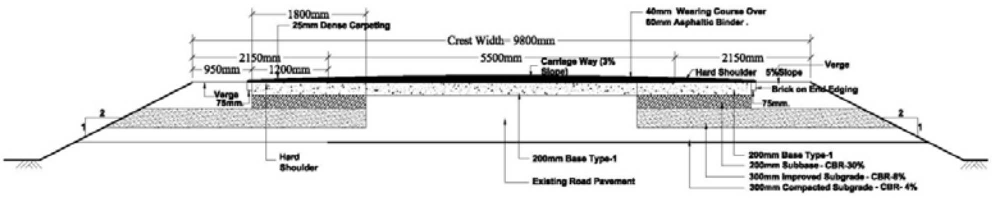
Section: Ekota Bazar to Pekua Intersection, from Km. 0.00 to 5.90 (Length Approx. 5.90 Km.)

1. (b)Ekota Bazar to Pekua Intersection, 5.90 Km to be Partial Reconstruction



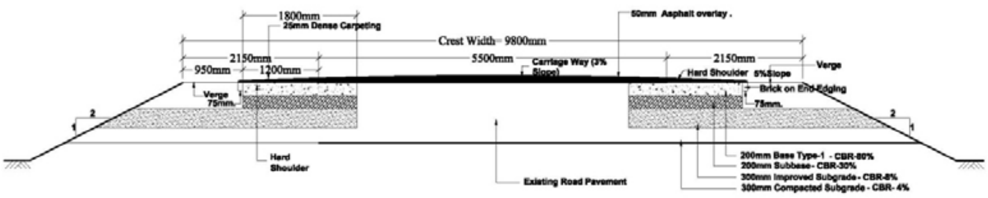
Section: Ekota Bazar to Pekua Intersection, From Km. 5.90 to 11.80 (Length 5.90 km.)

2. Pekua Intersection to Eidmoni Intersection Partial Reconstruction



Section: Pekua Intersection to Eidmoni Intersection (Length Approx. 10.90Km)

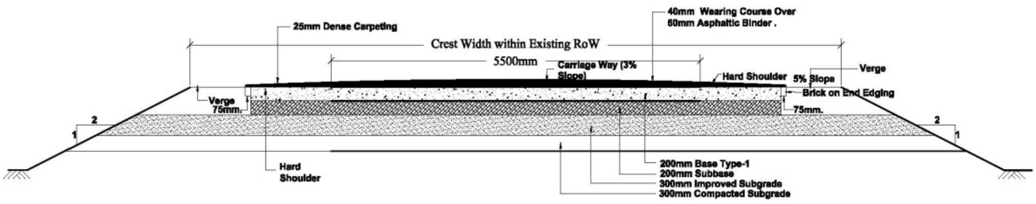
3. Eidmoni Intersection to Janata Bazar Aspahaltic Overlay



Section: Eidmoni Intersection to Janata Bazar (Length Approx. 8.6Km)

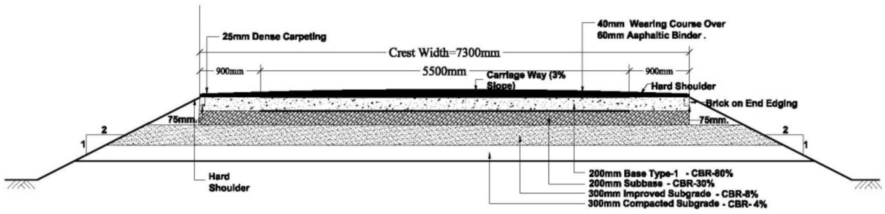
Figure 16.3-17 Cross Sections of Existing and New Roads

4. Janata Bazar to Yunuskhali Intersection Full Reconstruction



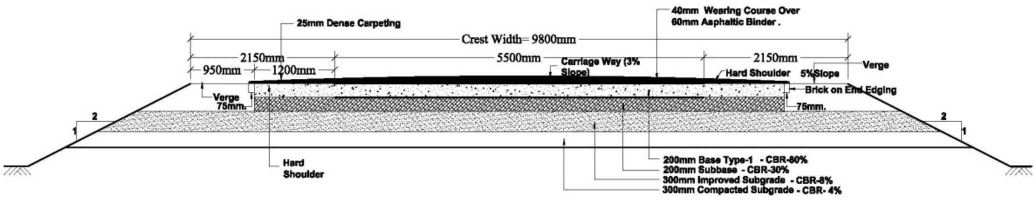
Section: Janata Bazar to Yunuskhali Intersection (Length Approx. 1.9Km)

5. a. Yunuskhali End New Construction



Section: ThroughYunuskhali village.(Length Approx. 1071.44 m, Ch-3125.56m to 4197m)

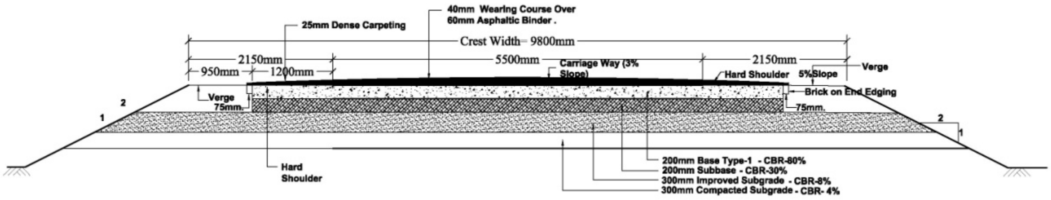
5. b. Yunuskhali End New Construction



Section: New Construction through Salt Field at Yunuskhali End (Length Approx. 452m, Ch-4194.84 to 4647.84)

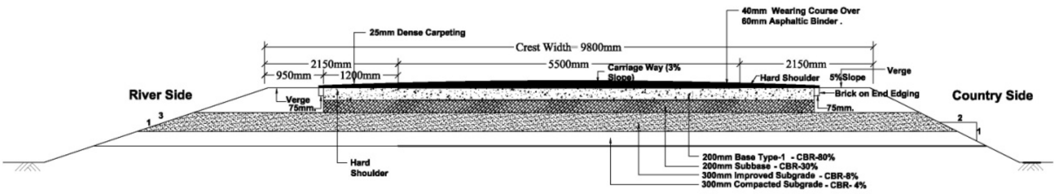
Figure 16.3-18 Cross Sections of Existing and New Roads

6. (a) New Construction through Salt Field at Matarbari End



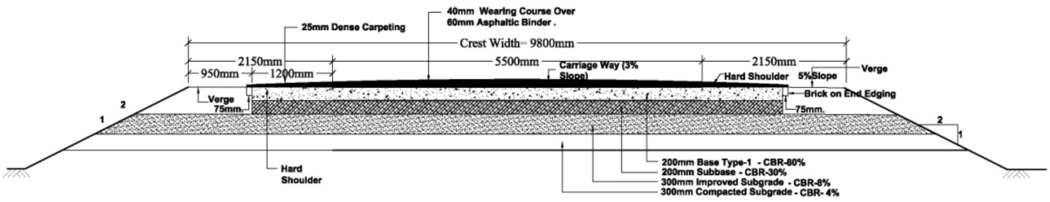
Section: New Construction through Salt Field from Bridge to BWDB Embankment (Length 0.234 Km.)

6. (b) New Construction along BWDB Embankment



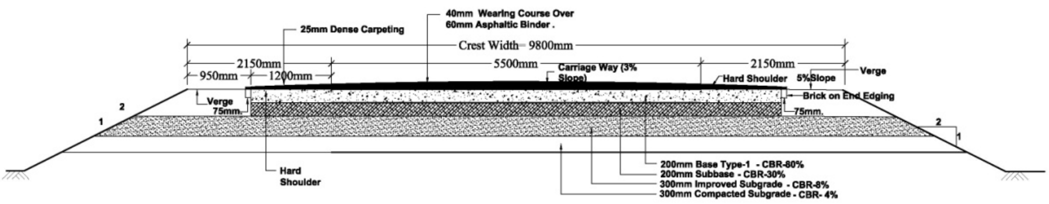
Section: New Construction along BWDB Embankment (Length Approx.605.75m)

6. (c) New Construction Along BWDB Dyke



Section: New Construction along BWDB Dyke (Length 0.257 Km.)

6. (d) New Construction through Salt Field from Dyke to Power-plant



Section: New Construction through Salt Field from Dyke to Power-plant (Length 0.170 Km.)

(Source: JICA Study Team)

Figure 16.3-19 Cross Sections of Existing and New roads

16.3.4 Bridge component

(1) Design and Construction Concept

The analysis and design of the bridge will be in accordance with American Association of State Highway and Transportation Officials (AASHTO) standard Specification for Highway Bridges latest edition presently used in Bangladesh (LRFD 2007). The Design method LFD (Load Factor Design) is adopted in Design. The design specification for loading has been considered as per AASHTO HS 20-44 with the provision of IRC class 'A 'Loading. Design standards such as RHD Design Standard, AASHTO, Indian Road Congress Standard and Japan Road Association Standard were discussed in the technical meetings with RHD. Reference standards are shown in Table 16.3-22.

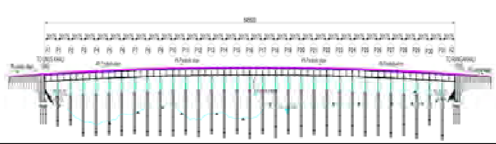
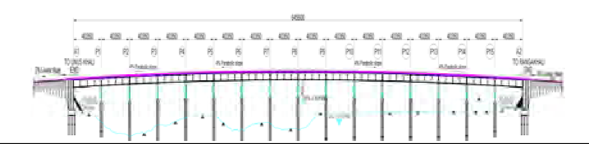
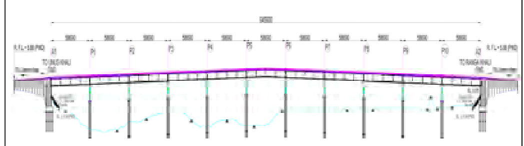
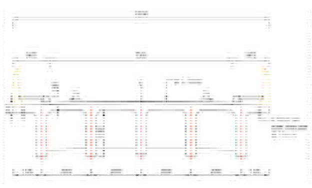
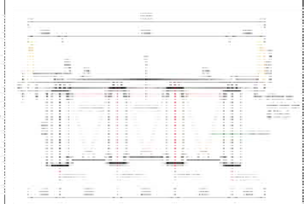
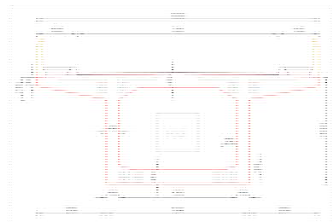
Table 16.3-22 Reference Design Standards

Soil condition		① RHD		② AASHTO		③ IRC		④ JRA	
Bearing layer		sandy soil (N>15) cohesive soil (N>20)		sandy soil (N>15) cohesive soil (N>20)		sandy soil (N>15) cohesive soil (N>20)		sandy soil (N>30) cohesive soil (N>20)	
Dead load		① RHD		② AASHTO		③ IRC		④ JRA	
① steel		78.5	KN/m^3	78.5	KN/m^3	78.5	KN/m^3	77.0	KN/m^3
② reinforced concrete		24.0	KN/m^3	24.0	KN/m^3	24.0	KN/m^3	24.5	KN/m^3
③ prestressed concrete		24.0	KN/m^3	24.0	KN/m^3	24.0	KN/m^3	24.5	KN/m^3
④ plain concrete		23.0	KN/m^3	23.0	KN/m^3	23.0	KN/m^3	23.0	KN/m^3
⑤ asphalt pavement		22.0	KN/m^3	22.0	KN/m^3	22.0	KN/m^3	22.5	KN/m^3
Live load		① RHD		② AASHTO		③ IRC		④ JRA	
①For a deck slab design	Load on wheel	Truck load 32.5 Lane load 3.1	kN kN/m2	Truck load 32.5 Lane load 3.1	kN kN/m2	Class-A=554.0 Class-AA=700.0	kN kN	100 (axle load=200KN)	KN
	Width							200×500	mm
	impact coefficient	0.33		0.33		A/(B+L) L=span, A=4.5, B=6.0		20/(50+L) L=span	
②For a girder design	Track load	Truck load 32.5	kN	Truck load 32.5	kN	Truck C-A 554.0	kN	L-load(245KN)	KN
	Distributed load	Lane load 3.1	kN/m2	Lane load 3.1	kN/m2	Truck Class-A=554, Class-AA=700	kN	—	kN/m
	Reduction coefficient	1-Lane 1.0 2-Lane 0.85 3-Lane or more 0.80		1-Lane 1.0 2-Lane 0.85 3-Lane or more 0.80		-	-	—	
	impact coefficient	0.33		0.33		A/(B+L) L=span, A=4.5, B=6.0		7/(20+L) L=span	

		① RHD	② AASHTO	③ IRC	④ JRA	
Earthquake force		As per BNBC code for zone II	As per AASHTO code zone wise	Zone I = 0.01, II = 0.02, III=0.04,	Earthquake motion level I	kh=0.20
		c = 0.15	Zone-1 = 0.09, zone-2 = 0.19, zone-3 = 0.29, zone-4 = >0.29	IV = 0.05, V = 0.08	Earthquake motion level II	kh=0.75
		① RHD	② AASHTO	③ IRC	④ JRA	
Wind load		AS per BNBC, V = 180 kM/h	Vb = 160 kM/h	According to height, (0 to 25.0m), V = (80 to 142 kM/h)	Concrete bridge 0.75～3.0KN/m^2 Steel bridge less 6.0KN/m^2	
		① RHD	② AASHTO	③ IRC	④ JRA	
Temperature load		Temp. difference = 48 degree considered.	For moderate : -12 to 27 deg. C, and for cold : -18 to 27 deg. C	Thermal co-eff : 11.7x10^{-6}/c for steel and 10.8x10^{-6}/c for concrete.	Concrete bridge -5℃～+35℃ Steel bridge -10℃～+40℃	
		① RHD	② AASHTO	③ IRC	④ JRA	
Combination of load And a load coefficient		As per LRFD, STRANGTH-I, II, III, IV, V and EVENT-I, II and SERVICE-I, II, III, IV	As per LRFD, STRANGTH-I, II, III, IV, V and EVENT-I, II and SERVICE-I, II, III, IV	As per IRC, I, IIA, IIB, IIA, IIIB, IV, V, VI, VII, VIII & IX	・Normal(dead load+live load) ・Temperature(dead load+live load+temperature load) ・Earthquake(dead load+earthquake load)	
		① RHD	② AASHTO	③ IRC	④ JRA	
concrete	main girder	For RCC f'c = 25 Mpa but for PC, f'c = 40 Mpa	For RCC f'c = 25 Mpa but for PC, f'c = 40 Mpa	For RCC, Grade M-35 Mpa but for PC, Grade M-40 Mpa	40	N/mm^2
	cross beam	For RCC f'c = 25 Mpa but for PC, f'c = 30 Mpa	For RCC f'c = 25 Mpa but for PC, f'c = 30 Mpa	For RCC, Grade M-20 Mpa but for PC, Grade M-30Mpa	30	N/mm^2
	cast-in-place slab	For RCC f'c = 25 Mpa but for PC, f'c = 35 Mpa	For RCC f'c = 25 Mpa but for PC, f'c = 30Mpa	For RCC, Grade M-30Mpa but for PC, Grade M-35Mpa	24	N/mm^2
	abutment	f'c = 30Mpa	f'c = 25Mpa	f'c = 30Mpa	24	N/mm^2
	pier	f'c = 30Mpa	f'c = 25Mpa	f'c = 30Mpa	24	N/mm^2

Table 16.3-23 shows comparison of bridge structure. Accordingly, PCT Girder has been selected.

Table 16.3-23 Comparison of Bridge Structure

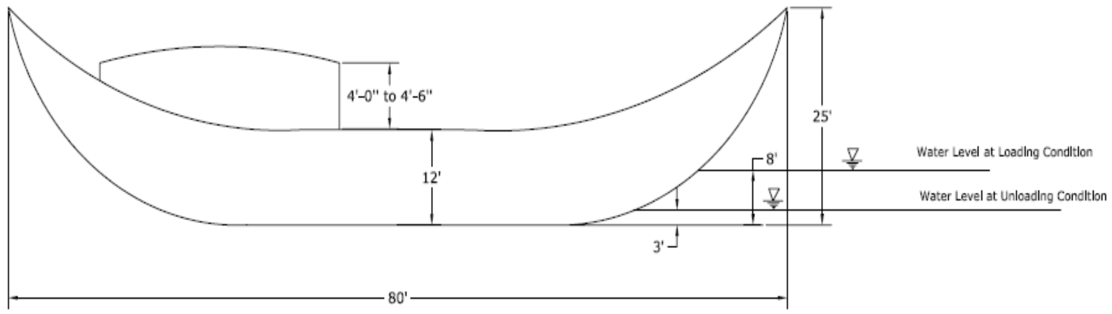
	RCT Girder Bridge	**PCT Girder Bridge**	Steel Girder Bridge	PC Box Girder Bridge
Evaluation Items	20 m Span	**40 m Span**	40 m Span	60 m Span
Typical Side View				
Typical Sectional View				
Environmental Consideration	River water flow will be obstructed more which will cause the constricted scour which will affect the environment.	It will not cause serious scour with appropriate foundation and sub-structure design.	It will not cause serious scour with appropriate foundation and substructure design.	For construction of this type of bridge, land acquisition will be required more for construction yard which may be affect surrounding environmental conditions.
Social Consideration	Due to small span length, it will afffect river navigation and then affect regional movement of people and goods.	This type of bridge provides enough navigational clearance. It will secure smooth river traffic and it will not cause negative impact to the region.	This type of bridge provides enough navigational clearance. It will secure smooth river traffic and it will not cause negative impact to the region.	For construction of segmental box, land acquisition will be required more for construction yard to casting segmental box which will affect affect the cultivated land and then affect farmers in the area.
Construction Cost				

(Source: JICA Study Team)

Construction Works	From technical easiness & availability of equipment, RCC girder bridge construction	PCT girder construction is widely constructed in Bangladesh. Construction equipment & accessories are available and local contractor are well trained & capable to construct PCT girder Bridge.	Steel girder is pre-fabricated and to be procured from out side of Bangladesh. Only the foundation & sub-strucrure is constructed. Installation and setting is done by the manufac-turer's company. Now a days steel girder is not constructed in Bangladesh. Before 25 to 30 years back RHD constructed steel girder bridges for long span more than 20.0m. Because during that time PC girder was not constructed widely in Bangladesh. Skilled manpower, construction cost, and construction equipment was not available. Now RHD and also LGED donot construct any steel girder Bridge.	For construction of PC segmental box girder, equipment and materials are not available. So heavy equipment & other accessories related to construction work will be required to procure from abroad. Also the local contractor are not capable to construct this type of bridge.
Construction Period	For easiness of construction, availability of equipment and materials, a resonable (moderate) time will be required but on the other hand due to small span length, number of pier will be more as well as foundation which will increase construction time compared PCT girder.	Due to large span length, number of pier will be required less than that of RCCT. So time for construction of sub-structure & foundation will be required less compared to RCCT bridge.	For procurement of steel girder from out side of country, an additional time will be required.	For procurement of construction equipment, accessories and construction materials from out side of the country, an extra time will be required. Total construction time will be required more than other type.
Operation & Maintenance	Above 25.0m span, RCCT girder is not economical. For provid-ing small span length, number of pier will be increased. After all river water flow will be obstructed more which will cause the constricted scoure of river. Not only that due to small span length horizontal nevigational clearance could not be maintained. So RCCT type bridge will not be feasible. For smaller length of RCCT girder and more number of span maintenance cost will be more compared to PCT girder. Beacause after 25 to 30 years if expansion joint or bearing pad is needed to replace then there may have to replace more number. So maintenance may be more than other.	PCT Girder Bridge is widely constructed both in RHD & LGED. of PCT girder, both horizontal and vertical nevigational clearance could be maintained. All the prestressing equipment, accessories and skilled manpower are available. For providing of large span length compare to RCCT type girder, number of pier will be required less. So river flow obstruction will be less. For less number of span, number of bearing pad and expansion joint will be required a minimun. So maintenance cost will be required minimum in future if needed to be creplaced.	There is no any international standard manufacturer company to produce quality base steel girder in Bangladesh. So steel girder to be procured from out side of Bangladesh. Also for installation & setting skilled of girder skilled manpower to be required from out side.	For construction of PC segmental box, local contractor, construction equipment and accessories etc. are not available. Construction equipent & accessories will be required to procure from outside of country. For construction of segmental box, land aquisation will be required more for condtruction yard to casting segmental box which will effect the cultivated land of the farmer. But PCT girder can be constructed inplace by making some arrangement and using errection, shifing & lifting method. In case of segmental box pot bearing is normally used. So for provision of pot bearing, maintenance cost may be required more than normal type.
Overall Evaluation Result	Not feasible for horizontal nevigational clearance dut to short span length.	As per site condition, construction facilities, material availibility, nevigational clearance, type & size of river traffic movement, economic consideration and also from social & environmental consideration PCT girder bridge is more feasible and viable than other type of Bridges.	For procurement of girder from out side, cost will be more. It's maintenance cost will be more compared to PCT girder. If any repair or maintenance is required for steel girder then it will be required to get help from manufacturer's company. Even yearly anti corrosive emulsion paint to be provided on the structure to protect from causung corrosiveness. Considering all diffulculties, more construction cost and for long time maintenencee cost, steel girder is not feasible.	Not feasible for more construction cost, nonavailability of construction equipment, accessories and materials.

(Source: JICA Study Team)

A brief water traffic survey was conducted to grasp rough traffic volume, kind of ships and size of ships which navigate the water way at the proposed bridge point.



BOAT WIDTH = 20 Ft.

Length of Boat= 80ft	<u>Survey Date: 27 June 2013</u>
Width of Boat= 20ft	River Traffic survey
Height at Front Side of Boat= 25ft	Location: Matarbari Bridge
Height at Middle Side of Boat= 12ft	Weather condition: Rainy
Draft at Loading Condition= 17ft(5.198 m)	Time: 7 a.m.- 6 p.m.
Draft at Unloading Condition= 22ft.(6.7 m)	Large Boats: 7 ea.
Height of Shed=4~4'-6" over deck	Medium Boats: 4 ea.
	Small Boats: 8 ea.

(Source: JICA Study Team)

Figure 16.3-20Measurement of the Largest Boat Spotted During a Brief Water Traffic Survey

Table 16.3-24 Design Concept for the Bridge Component of Access Road

Item	Description
Live Load	AASHTO IRC Class A
Type	Pre-stressed Concrete Girder
Length	640 m
Total Width	10.25 m
Carriage way Width	7.30 m (Double lanes)
Foot pass	1.475 m x 2
Span Length	40.0 m
Surfacing Thickness	50 mm
Alignment	R =∞
Crest Level	10 m from Mean Sea Level
Concrete Strength	Superstructure σ ck=40N/ mm2 Substructure σ ck=30N/ mm2
Reinforcement	fy = 410 Mpa (Grade-60)
PC Steel Material	Grade-270
Navigational Clearance	8 m from Highest High Tide Level River traffic survey result shows that the tallest boat is 25’-0”, about 7.62 m. During unloading condition draft is 3’-0”, about 0.91 m. Net height is about 6.71 m. Safety allowance 1.0 m shall be considered. Total height becomes (6.71 + 1.0) m = 7.71 m, then rounded to 8 m.
Design References	AASHTO Standard Specification for Highway Bridge

	Design Indian Road Congress (IRC) RHD bridge Designer’s Handbook Geometric Design Standard of RHD

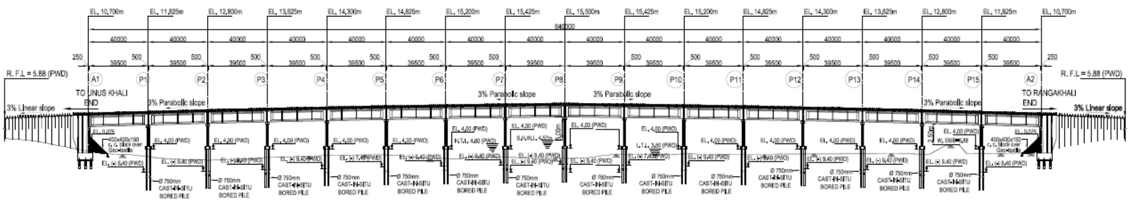
(Source: JICA Study Team)

(2) Bridge Design

Longitudinal section and cross section of the proposed bridge are shown in (Source: JICA Study Team)

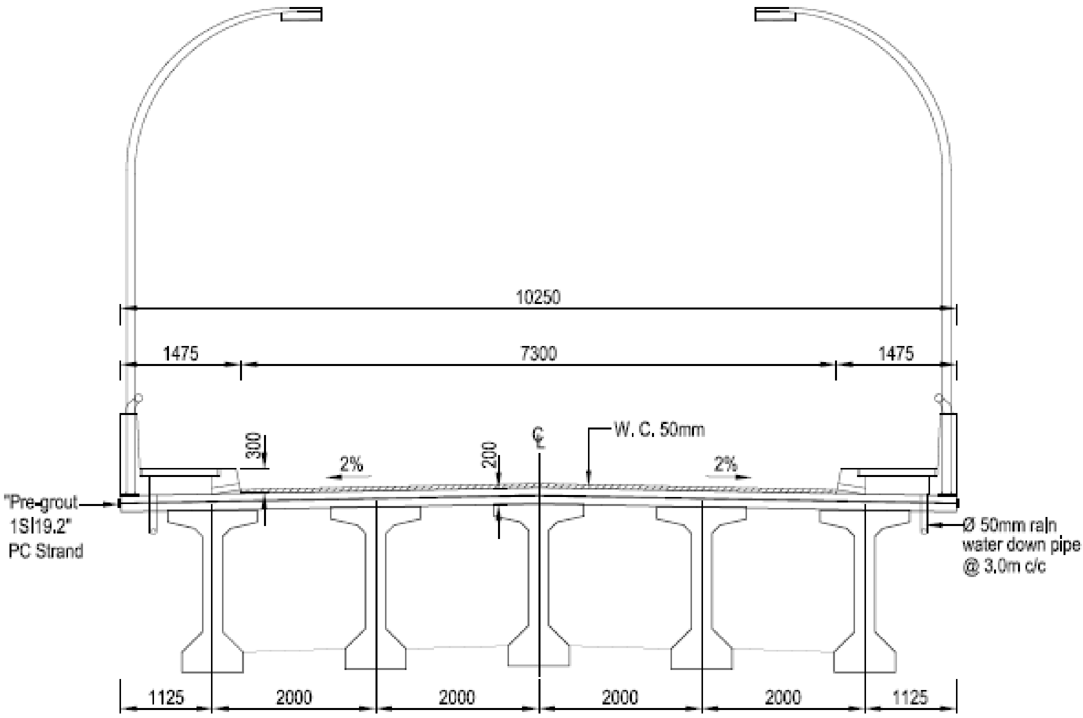
Figure 16.3-21, (Source: JICA Study Team)

Figure 16.3-22



(Source: JICA Study Team)

Figure 16.3-21 Longitudinal Section of the Proposed Bridge over the Kohelia River



(Source: JICA Study Team)

Figure 16.3-22 Cross Section of the Proposed Bridge over the Kohelia River

16.3.5 Assumed load

For Bridge design HL-93, loading is considered. During analysis, the latest version of AASHTO LRFD 2007 is followed. It includes following loads.

(1) Dead load

Dead load includes any structure which to be designed is combination of its own weight & superimposed load which comes on it.

(2) Live load

4.07 kN/sq.m

Here it means human being move on the Bridge footpath. AASHTO recommended this value.

(3) Impact

33%

This impact factor value was adopted as per latest version of LRFD 2007 & later version of AASHTO. Before LRFD version it was 30% maximum. In previous version there was a formula like,

IMP = [15.24/(L+38)] in SI unit.

If the calculated value comes more than 30%, then it is considered max. 30%.

(4) Braking force

As per Latest version of LRFD 2007, Braking force (BF) recommended value to be maximum is as follows:

Case-I: 25% of (Truck Load + Tendom Load)

Case-II: 5% of (Truck Load+ Lane Load)/ OR 5% of (Tendom Load+Lane Load)

Maximum value of above was considered.

(5) Truck Load

As per Latest version of LRFD 2007 loading pattern is like bellow:

1) Truck Load : HS20-44 Load (Front wheel 35 kN, Middle wheel 145 kN & Rear wheel 145 kN), each wheel 4.26m apart from each other along traffic direction. But in Transverse direction of Traffic, distance between the wheel is 1.83m.
2) Tandem Load : In Latest version of LRFD this loading is adopted. Each Axle 110 kN each.

3) Lane Load : 9.3 kN/m2 is adopted per 3.0m width of Lane in LRFD.

(6) Tandem Load

Especially in LRFD, this loading is adopted. Axle 110kN each

(7) Seismic Load (Force)

In Bangladesh, there are 3 seismic zones which is described in BNBC (Bangladesh National Building Code). The project location falls on Zone II (2), So zone co-efficient = 0.15 to be considered as per BNBC code of Bangladesh.

(8) Wind Load

In Bangladesh, it is based on BNBC. In this project, guideline for Cox's bazar district shall be adopted.

As per BNBC code of Bangladesh wind speed of Cox’s bazar is: 260 kM/h.

(9) Temperature effect

In RHD they follow in accordance with the provision of AASHTO standard specification.

(10) Current load

The Hydrologist found out the maximum velocity of the channel of our project. Using the maximum velocity in formula suggested by AASHTO it is possible to decide the current force developed on submerged pile or substructure. AASHTO Load is also considered. In the final design submission will be determined.

(11) Surge load for costal area

BNBC code suggest to consider the surge load on structure in coastal area, 14’ (4.26m) height of surge water load from Mean Sea Level (MSL) to be considered.

(12) Geometric Design Criteria of the Bridge: Standard Bridge Cross-Section

Based upon the RHD’s approved Geometric Design Standard Manual (Revised), June 2005, a typical bridge cross section has been designed. The adopted width of the bridge cross section is 10.30m including footpath. Carriageway width is 7.3m, exclusive of footpath and railing. The width of the pedestrian footpath is 1.50m inclusive of 0.25m parapet width.

(13) Longitudinal Gradient:

The longitudinal gradient of the bridge has been taken 4.0% Parabolic in main Bridge whereas for approach road of Bridge is 3% linear.

(14) Deck Cross-fall:

2% cross slope has been considered as per Sl. No. 5.3 of Bridge Design Standards of RHD, January 2004.

(15) Navigational Clearance:

The Navigational Clearance has been considered in accordance with the current Bangladesh Inland Water Transport Authority (BIWTA) requirements. Table 16.3-25 below has been given for information purposes only and gives the present minimum vertical and horizontal Navigation Clearance as per BIWTA. To determine the minimum vertical clearance for the new bridge, consideration shall be given to the local requirement for passage of fishing vessels, boats, trawlers, barges, etc. Since the proposed bridge may be on a non-classified route, the minimum vertical clearance shall be decided based on the local requirement and substantial discussion with RHD and other agencies.

Table 16.3-25 Present Minimum Vertical and Horizontal Navigation Clearance as per BIWTA

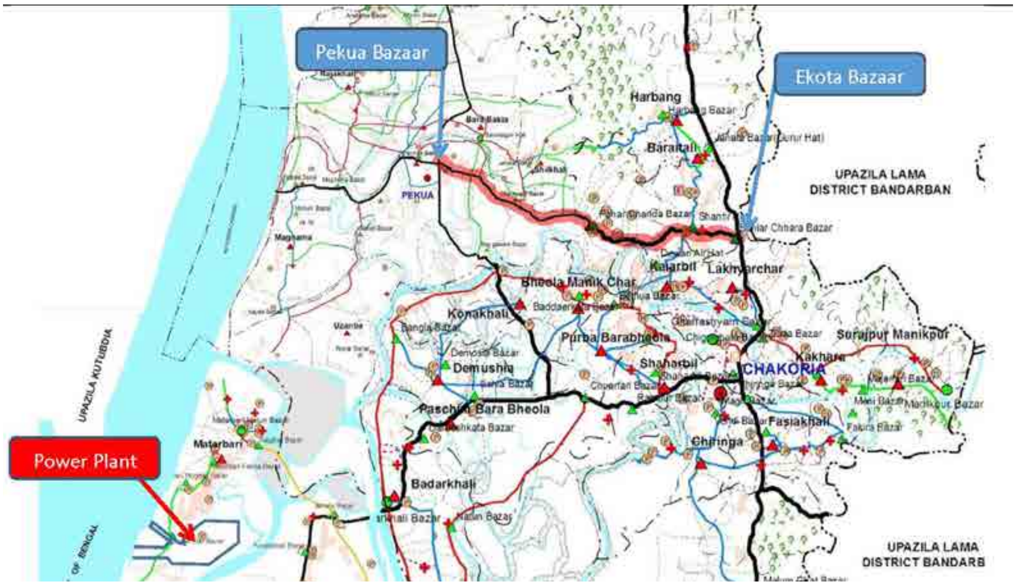
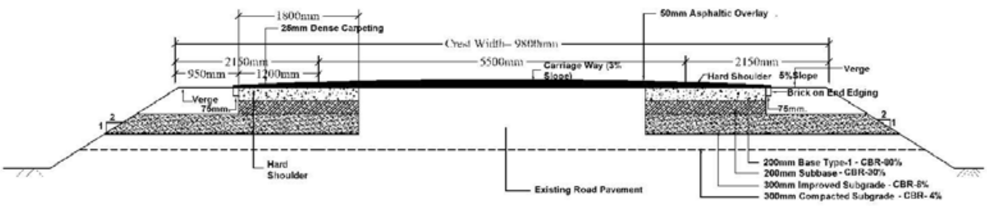
Sl. No.	Classification of Waterways	Minimum Vertical Clearance (m)	Minimum Horizontal Clearance
1	Class – I	18.30	76.22
2	Class – II	12.20	76.22
3	Class – III	7.62	30.48
4	Class – VI	5.00	20.00

(Source: JICA Study Team)

16.3.6 Scope of works

Following sheets describe the outline of the planned general scope of works.

Table 16.3-26 Scope of Work to Access Road (1)

Section	Ekata bazar to Pekua Bazar		
Road Classification	Z1125	Distance	11.80km
			
Major items of work	• Earth work on shoulder and slopes • Aggregate road base course • Construction of hard shoulders with bituminous surface sealing • Asphalt work		
Section 1. (a) Ekata Bazar to Pekua Intersection, 50% Length to be Asphaltic Overlay  1. (b) Ekata Bazar to Pekua Intersection 50%Partial Reconstruction			

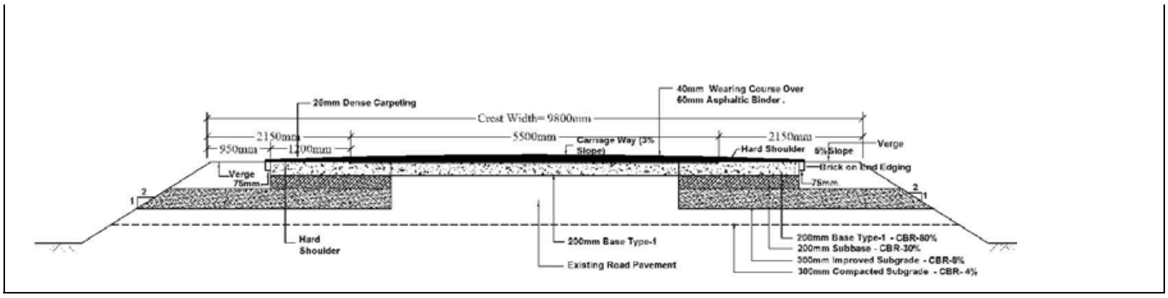
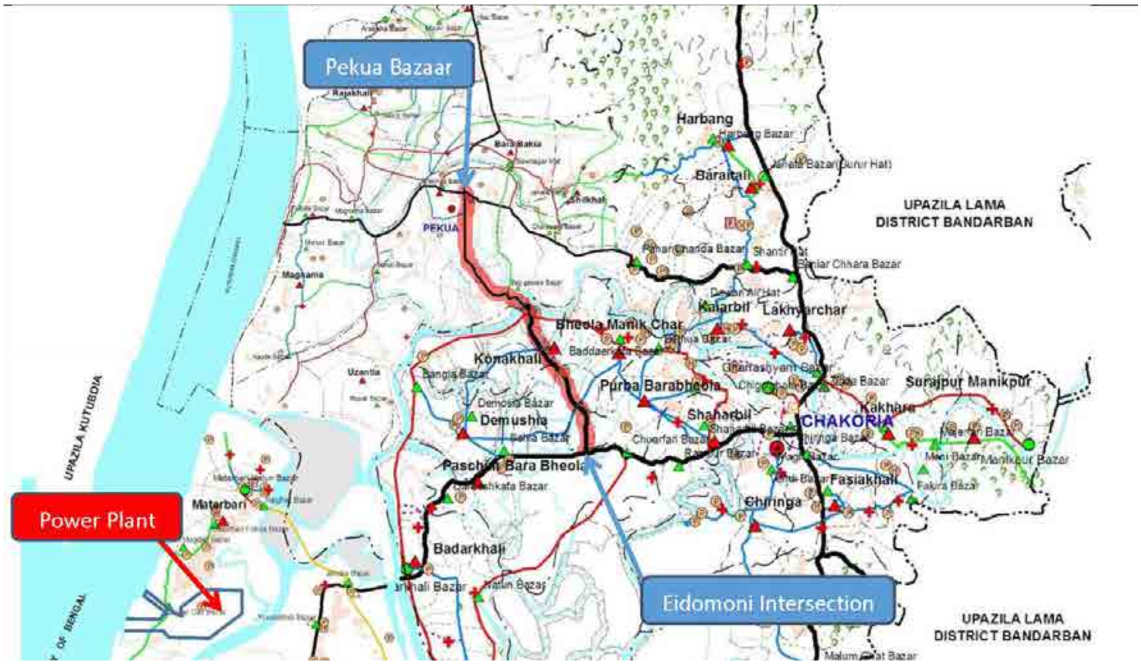

40mm Wearing Course Over
60mm Asphaltic Binder .
20mm Dense Carpeting
Crest Width= 9800mm
2150mm
5500mm
2150mm
950mm
1200mm
Carriage Way (3% Slope)
Hard Shoulder
5% Slope
Verge
Brick on End Edging
Verge
75mm
75mm
2
1
2
1
Hard Shoulder
200mm Base Type-1
Existing Road Pavement
200mm Base Type-1 - CBR-80%
200mm Subbase - CBR-30%
300mm Improved Subgrade - CBR-8%
300mm Compacted Subgrade - CBR- 4%

Figure 16.3-23 Photos of Selected Route (Ekata Bazar to Pekua Bazar)

Table 16.3-27　Scope of Work to Access Road (2)

Section	Pekua Bazaar to Eidmoni Intersection		
Road Classification	Z170	Distance	10.90km



Major items of work	• Earth work on shoulders and slopes • Aggregate road base course • Construction of hard shoulders with bituminous surface sealing • Asphalt work

Section

2. Pekua Intersection to Eidmoni Intersection Partial Reconstruction

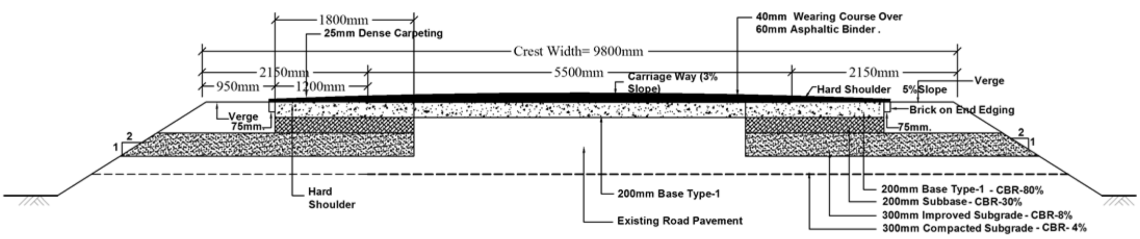
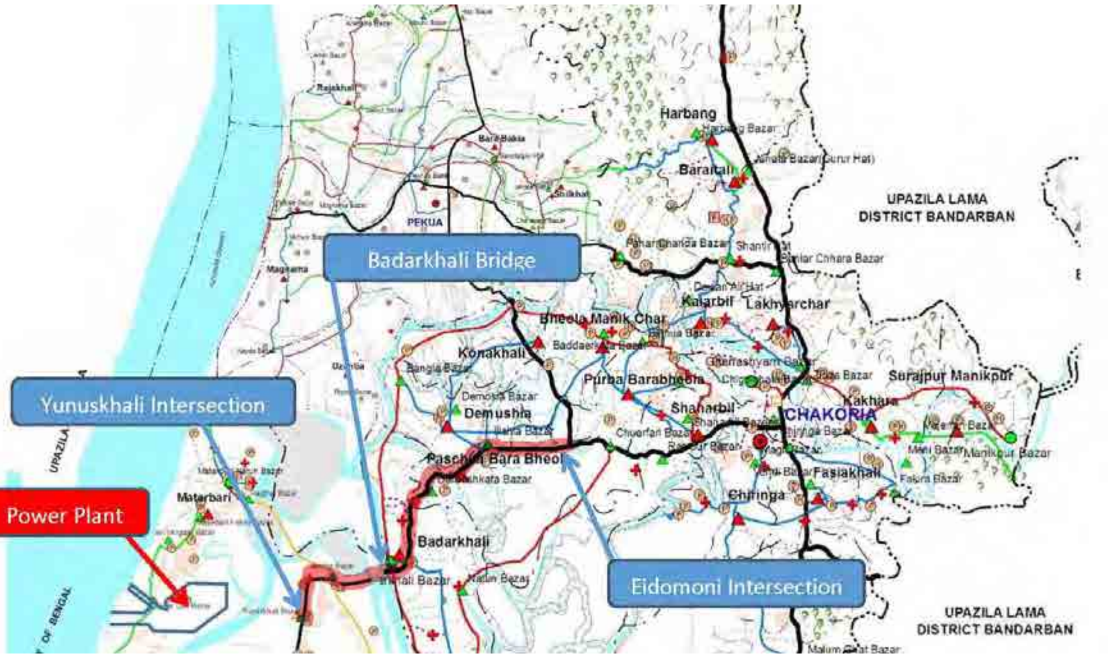


Figure 16.3-24 Photos of Selected Route (Pekua Bazar to Eidmoni Intersection)

Table 16.3-28 Scope of Work to Access Road (3)

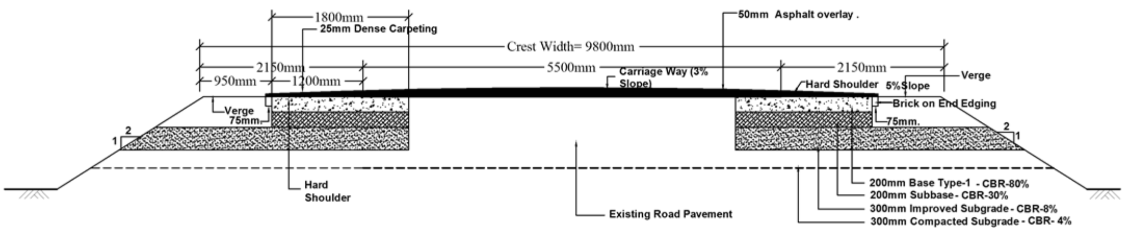
Section	Eidomoni Intersection to Badarkhali Br. to Yunuskhali Intersection		
Road classification	Z170/Z1004	Distance	10.65km



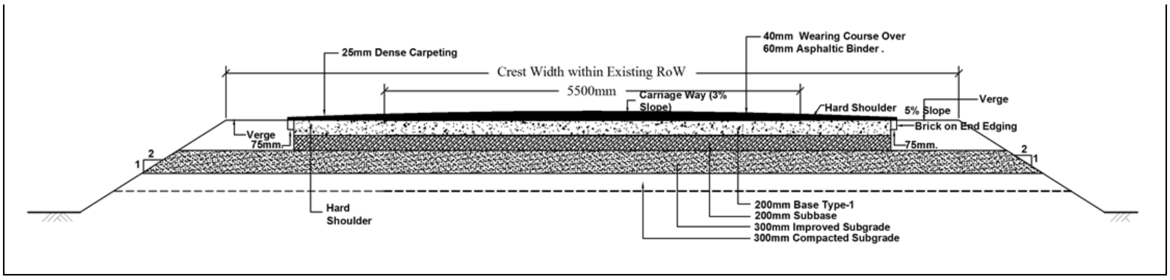
Major items of work	・Repairing potholes ・Earth work on shoulders and slopes ・Construction of hard shoulders with bituminous surface sealing ・Asphaltic overlay ・Aggregate subbase course, road base course ・Providing surface drains; Construction of a causeway

Section

3. Eidomoni Intersection to Janata Bazar Asphaltic Overlay



4. Janata Bazar to Yunuskhali Intersection Full Reconstruction


40mm Wearing Course Over
60mm Asphaltic Binder .
25mm Dense Carpeting
Crest Width within Existing RoW
5500mm
Carriage Way (3%
Slope)
Hard Shoulder
5% Slope
Verge
Brick on End Edging
Verge
75mm.
75mm.
2
1
2
1
Hard
Shoulder
200mm Base Type-1
200mm Subbase
300mm Improved Subgrade
300mm Compacted Subgrade

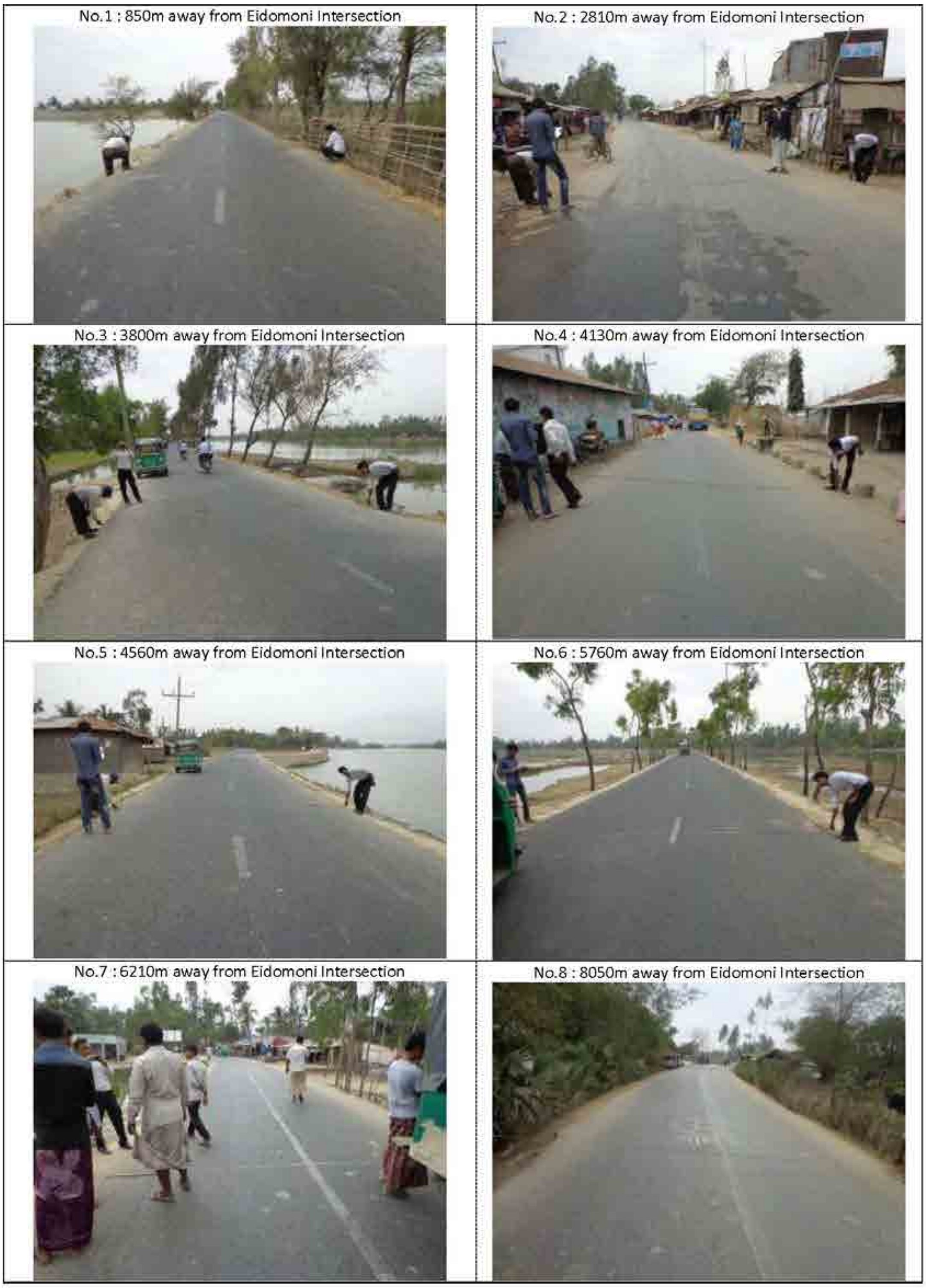
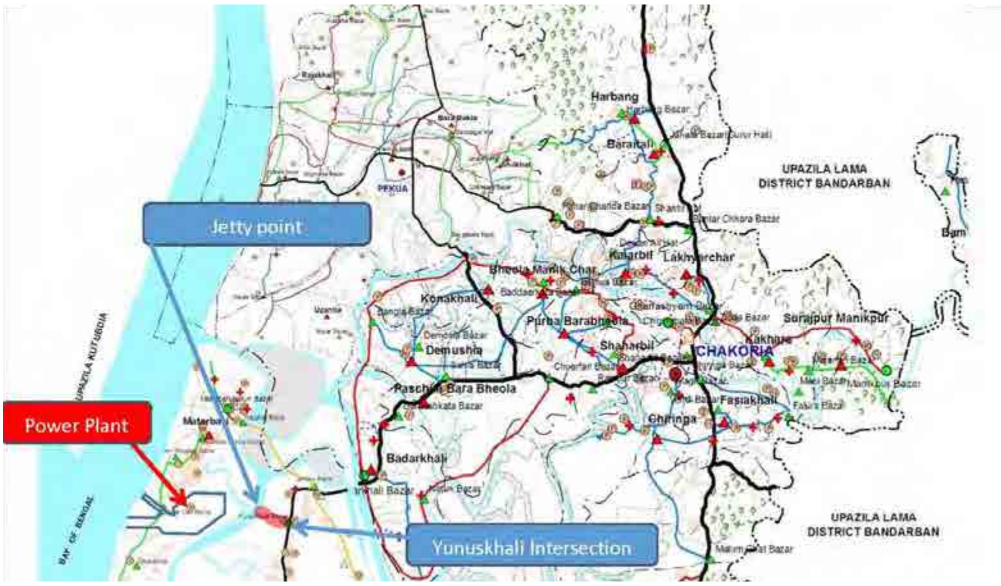
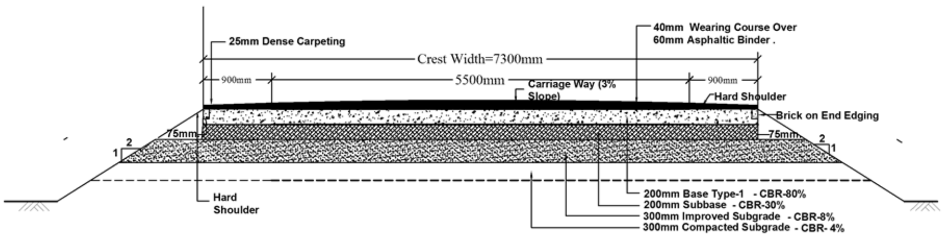


Figure 16.3-25 Photos of Selected Route (Eidmoni Intersection via Badarkhali Bridge to Yunuskhali Intersection)

Figure 16.3-26 Photos of Selected Route (Eidmoni Intersection via Badarkhali Bridge to Yunuskhali Intersection)

Table 16.3-29 Scope of Work to Access Road (4)

Section	Yunuskhali Intersection to Jetty point		
Road classification	Village Road	Road classification	Village Road
			
Major items of work	・Earth work on shoulders and slopes ・Aggregate subbase course, road base course ・Construction of hard shoulders with bituminous surface sealing ・Asphalt work ・Providing irrigation drains ; Construction of Earth-retaining wall; Slope protection works by CC/RCC ・Soft ground countermeasure work shall be considered		
Section 5. Yunuskhali End New Construction  5. Yunuskhali End New Construction			

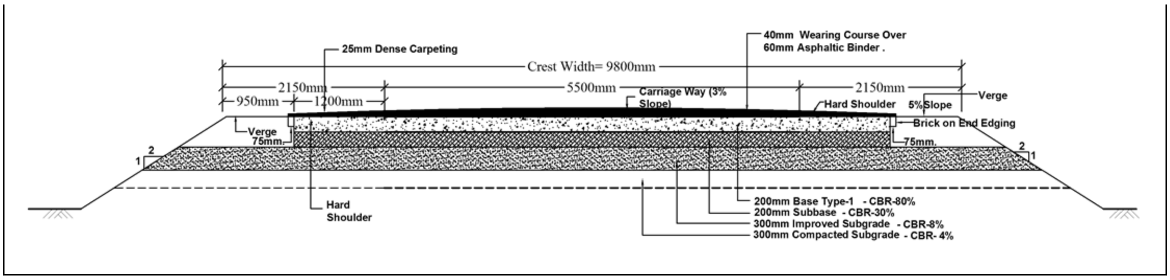
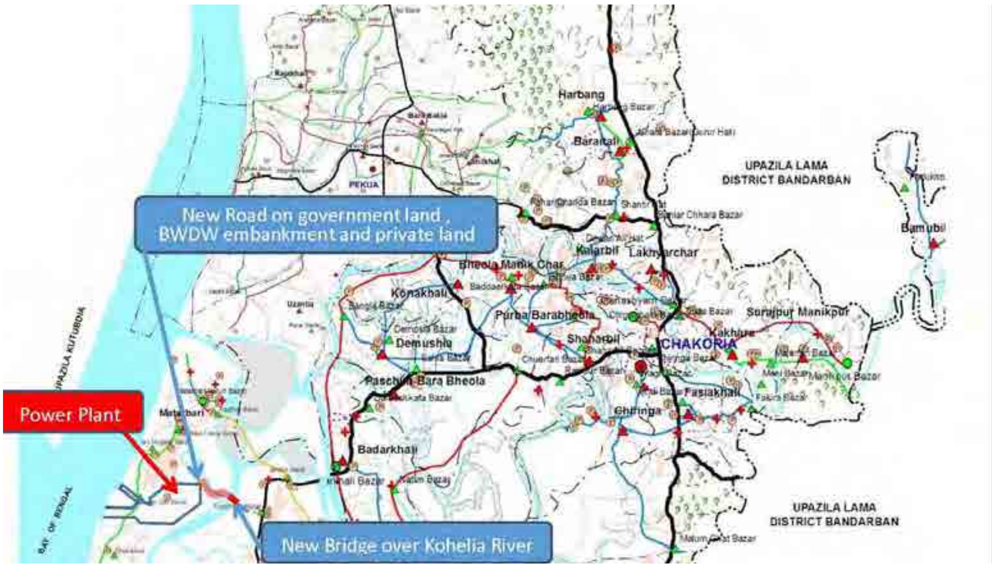

25mm Dense Carpeting
40mm Wearing Course Over
60mm Asphaltic Binder .
Crest Width= 9800mm
2150mm
5500mm
2150mm
950mm
1200mm
Carriage Way (3% Slope)
Hard Shoulder
5% Slope
Verge
Brick on End Edging
Verge
75mm.
75mm.
2
1
2
1
Hard Shoulder
200mm Base Type-1 - CBR-80%
200mm Subbase - CBR-30%
300mm Improved Subgrade - CBR-8%
300mm Compacted Subgrade - CBR- 4%

Figure 16.3-27 Photos of Selected Route(Eidmoni Intersection via Badarkhali Bridge to Yunuskhali Intersection)

Table 16.3-30　Scope of Work to Access Road (5)

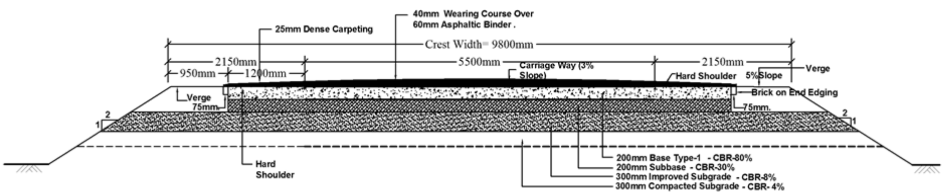
Section	New Road on government land , BWDB embankment and private land		
Road classification	BWDB embankment	Distance	1.25km



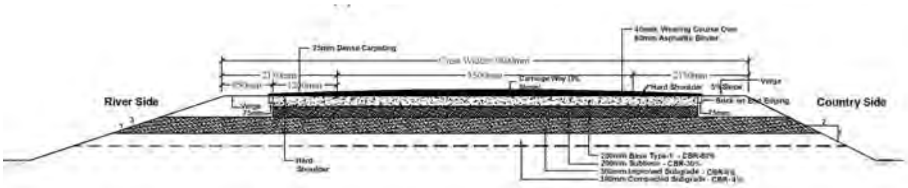
Major items of work	• Construction of Earth Embankment • Aggregate subbase course , road base course • Construction of hard shoulders with bituminous surface sealing • Asphalt work • Providing irrigation drains ; Construction of Earth-retaining wall; Slope • protection works by CC/RCC • Soft ground countermeasure work shall be considered

Section

6. (a) New Construction through Salt Field



6. (b) New Construction over BWDB Embankment



Section: New Construction over BWDB Embankment (Length Approx.605.75m)

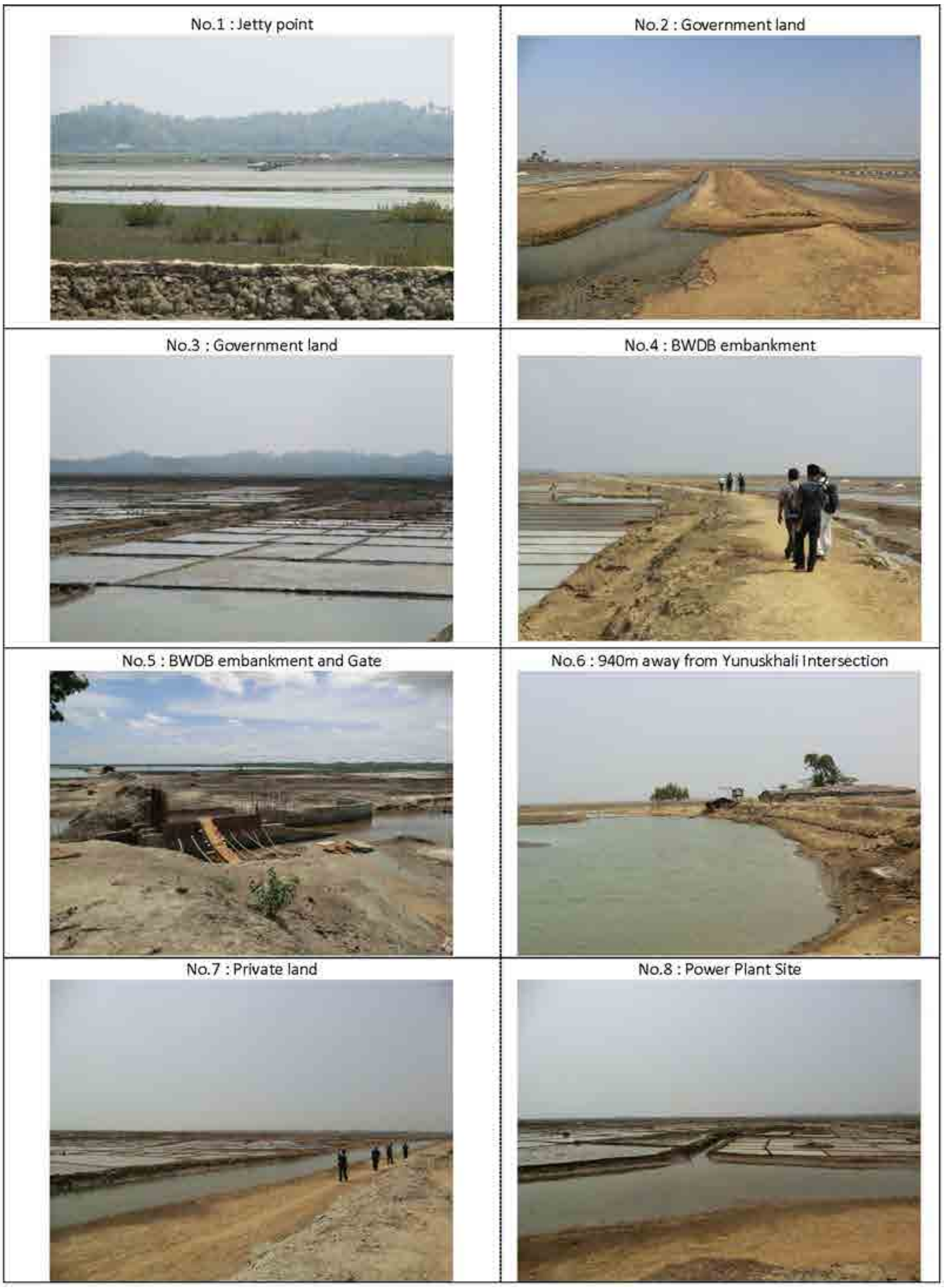


Figure 16.3-28 Photos of Selected Route (Eidmoni Intersection via Badarkhali Bridge to Yunuskhali Intersection)

16.4 Project Implementation

16.4.1 Project cost estimation

(1) Items

(a) Construction cost

(b) Consulting services

(c) Vehicle cost

(d) Land acquisition of cost

Table 16.4-1 shows the base cost of access road project. The cost has been estimated with two currencies. One is Bangladesh Taka as for local currency. The other is Japanese Yen as for foreign currency.

1) Construction Cost

Construction costs have been calculated on the basis of the quantities and unit prices given in Table 16.4-2. The unit prices for the different types of works have been estimated from market prices given by the contractors in Bangladesh. The work items have been itemized on the base of the work items on the "Schedule of Rate" of RHD.

2) Consulting Services

The cost of consulting services has been calculated on the basis of the number of engineer-hours and staff-hours required for remuneration, and direct cost quantities and unit prices. The unit rates for the different engineers and staff have been estimated from JICA guideline. These costs have been divided into a portion in foreign currency and portion in local currency. Table 16.4-3 gives details of the costs associated with consulting services, and Table 16.4-4 gives the expected timetable for the services.

Cost for the consulting services was estimated on the basis of consulting schedule.

The contents of the consulting main services are as follows.

- Detailed design
    - Supplementary investigation for the preparation of execution drawings
    - Preparation of drawings
    - Preparation of quantities
    - Preparation of pre-qualification documents
    - Preparation of tender documents
    - Supporting works for tender

- Supervising for the works
    - Checking for the execution drawings
    - Supervising
    - Quantity control
    - Progress control
    - Claim work
    - Safety and environmental control
- Portion in foreign currency
    - Remuneration of foreign staff
    - International travel fee
    - Shipping fee
    - Foreign material purchase
- Portion in local currency
    - Remuneration of local staff
    - Administration fee
    - Office management expenses

3) Vehicle for Construction Supervision Works

Four cars (two jeep type 4WDs and two pickup trucks) shall be provided for the purpose of construction supervision works by the implementation agency. The cost is borne by Bangladesh side, because this fee is likely the item of non-eligible items of financing.

4) Land Acquisition Cost

Land acquisition fee has been estimated on the basis of the results of the calculation of area. Land acquisition fee is borne by Bangladesh side, because this fee is likely the item of non-eligible items of financing.

(2) Exchange Rate

In accordance with the specifications of JICA, the exchange rate has been set at 1.28 Yen = 1 BDT.

(3) Road Repair Work Cost during Construction

16.4.2 Maintenance budget

After completion of the access road, there will be two types of maintenance needed;

a) Recurrent: This is repetitive in nature and will be needed every year (routine). This includes: routine maintenance outside carriageway, patching potholes, crack sealing, edge repair, etc.

b) Periodic: this type of maintenance work is needed periodically. Normally 5-7 years after completion of a periodic overlay is needed. The maintenance need is determined by analyzing the road data through HDM analysis. If the road is designed for 20 years it needs at least 2 periodic treatments in its life cycle.

Table 16.4-1 Base Cost of Access Road Project

(This table has been removed because of confidential information.)

Table 16.4-2 Quantity of Main Item for Bridge and Road

Bridge

(This table has been removed because of confidential information.)

Road

(This table has been removed because of confidential information.)

Table 16.4-3 Breakdown of Consulting Services Costs

(This table has been removed because of confidential information.)

Table 16.4-4 Manning Schedule for the Consulting Services

(This table has been removed because of confidential information.)

16.4.3 Implementation plan

- Pledge of loan agreement
- Detailed desig
- Construction

Table 16.4-5 Implementation Schedule

(This table has been removed because of confidential information.)

The main procedure of the establishment of the construction schedule
The depth of the half area of the river adjacent to the alignment of the new bridge is not sufficient or shallow for the navigation because of the sedimentation. Another half of the river shall be kept the way for the navigation during the whole day. Therefore to divide the area of the river with sufficient depth with two portions in consideration of the navigation is the appropriate method.
The Access Road is not the critical work for the Plant construction. Considering the costwise of the project, the optimum method of the bridge construction is to conduct the construction with the one way execution method.

Table 16.4-6 Construction Schedule

(This table has been removed because of confidential information.)

Table 16.4-7 Consultant Schedule

(This table has been removed because of confidential information.)

16.4.4 Procurement method

(1) General

The project will be done under ICB. And also JICA recommend ICB on the guideline of procurement. Some similar projects, the project for Laning of Dhaka-Chittagong Highway Project under RHD financed by GOB and the project for Eastern Bangladesh Bridge Improvement Project under RHD financed by JICA have been doing with ICB basis. Therefore the project for the Access Road will be recommendable by ICB. Detailed information for these projects is shown on the table of “Similar project”.

Each ministry and department is publishing the “Schedule of Rate”. RHD, executing agency, also publishes it, and has been reviewing each year.

The cost for the projects under RHD with GOB finance that could be LCB base project will be estimated in accordance with the schedule of rate of RHD.

However the project for the Access Road will be adopted ICB. Accordingly prospective tenderers will estimate the tender price on the base of market prices after gathering the quotation from local contractors in Bangladesh. Therefore cost estimation for the survey has been done on the base of the market prices in Bangladesh.

(2) Procurement of Manpower, Materials and Equipment

1) Manpower

a. Capability of Recruit of Engineers and Workers

Most of engineers are graduated from universities in Bangladesh. There are some engineers taken the favor of scholarship for study abroad at each ministry. Some of them graduated from Japanese universities, certified of engineering, and returned to Bangladesh to be assigned some important post. On the other hand, there are many technicians and workers to cultivate their skills in foreign countries. Meanwhile they are bearing the part of the governmental revenue by remittance through working abroad.

There are a lot of human resources in Bangladesh.

b. Labor Law and Regulations

Labor law has been published as the Bangladesh Labor Act 2006.

In this law, there are the prime regulations for workers for the construction as follows;

1. Normal working hours over a week are restricted within 48 hours
2. Longest working hours shall not exceed 60 hours over a week.

(3) Material

Basic plan for procurement of the main materials for the project is as follows;

- Cement and re-bar are manufactured in Chittagong area. It is available to procure these things locally. Production volume are well accommodated to needs.
- Aggregate and sand for pavement and concrete are procured from Sylhet located north east

of Bangladesh. Needs are growing gradually, price are increasing accordingly.

- Sand for filling will be purchased from adjacent hill of Janata Bazar at Maheskhali island. Production will be accommodated to needs.
- Filling materials for embankment will be purchased from the adjacent borrow pit.
- PC strand/wire and ancillary will be imported from Japan, China, India and so on.
- Bituminous for pavement will be purchased from Singapore and so on.

Table 16.4-8 Purchase of Main Materials

(This table has been removed because of confidential information.)

(4) Equipment

Basic plan of procurement of the equipment for the project is as follows;

- Primary equipment will be purchased from national. Most of contractors owned this kind of primary equipment.
- Erection girder and ancillary will be imported from Japan as the planning tentatively.

Table 16.4-9 Purchase of Main Equipment

(This table has been removed because of confidential information.)

1) Shipping

Shipping and packing plan for the materials and equipment will be done as follows.

Chittagong port is the biggest river port in Bangladesh located along the estuary of Karnaphuli River. It is facilitated six berths for general cargo and eleven berths for container. Annual shipping volume on 2010/2011 year was 45 million F/T. Water depth is over eight meters for which it is available to navigate ships of the displacement volume are 30,000 ton.

Chittagong port	
	
National highway No. 1 From Chittagong to Cox's Bazar	
	

Figure 16.4-1 Chittagong Port and National Highway N1

Imported materials and equipment will be firstly custom clearance at port, and then transported to the site by boat or track.

(5) Custom Clearance

Duration of the custom clearance will be needed for about 3 days at Chittagong port.

1) Shipping

a From Yokohama to Chittagong

Materials and equipment exported from Japan will be shipped from Yokohama to Chittagong. Duration of the shipment is about 20 days. On the other hand, duration of the shipment from

Mumbai of India to Chittagong is about 10 days.

b From Chittagong to the site

Inland Transportation

Route for the inland transportation is firstly pass through Chittagong city center to National highway N1, then driving down to the south to Ekata junction that the beginning point of the Access Road. Distance from Chittagong to Ekata junction is 85km. From Ekata junction to Yunuskhali Bazar is 30km.Total distance from Chittagong port to the site is about 115km. At present there is not available to drive with normal size of track for transportation from Yunuskhali bazar to the site. It is 2.5km. Until the completion of the road from Yunuskhali to the site, inland transportation will be restricted. Time for the inland transportation from Chittagong to the Yunuskhali Bazar is about 5 hours.

By Vessel

Vessel navigate to the south from Chittagong port through Bengal Bay about 80 km, then coming up from the cape of Matarbari island along the Kohelia River about 10km to the site. Kohelia River has much capacity of navigation of the vessels and barges for the depth and width. Shipping hour is about 6 hours.

Figure 16.4-2 Transportation Route: from Chittagong Port to the Site

16.4.5 Construction plan

(1) Sectors

The works involved in the access road is divided into two sectors of road and bridge as shown in Table 16.4-10.

Table 16.4-10 Sector List of Access Road

Sector	Sub-lot	Description	Quantity
Road	Section 1	From Ekata Bazar to Pekua intersection	11.80km
	Section 2	From Pekua intersection to Eidmoni intersection	10.90km
	Section 3	From Eidmoni intersection to Badakhali bridge	7.40km
	Section 4	From Badakhali bridge to Janata Bazar	1.35km
	Section 5	From Janata Bazar to Thallatoli Inter.	1.60km
	Section 6	From Thallatoli Inter. To Yunuskhali Bazar	0.3km
	Section 7	From Yunusukhali Bazar to Nyaghata Jetty point	2.56km
	Section 8	From Kohelia bridge to Power Plant	1.25km
Bridge	Kohelia bridge	PCT girder simple beam	L=640m (16span) Span length=40m Width=10.3m

Source: JICA study team

(2) Construction Methods

1) Direct Work

In consideration of the rain falls which are more than 10mm/day, during the rainy season from May to October, the implementation for the road will be suspended. Implementation of the bridges will be executed continually through the year.

Matarbari side (Site condition of approach road section near abutment)

Dry season

Rainy season

Maheshkhali side (Site condition of Yunuskhali to Jetty)

	
Dry season	Rainy season

Figure 16.4-3 Site Condition of Dry and Rainy Season

2) Development for the construction yard

The construction yard will be developed at both sides of the Kohelia River, Maheskhali island side and Matarbari island side. Figure 16.4-4 shows location of temporary yard, jetty and dredging area

After the completion of the project, the developed area will be retrieved to the initial feature.

a Development for the bridge construction yard

At the Maheskhali island side, the area of the girder fabrication yard for the bridge construction has been assumed 4,000m^2 including for the area for warehouse, material stocking, motor pool, site office and so on. The yard will be established on and along the future alignment of the Access Road.

At the Matarbari island side, the area for the bridge construction has been assumed 2,000m^2 for the area for warehouse, material stocking, motor pool, site office and so on. The yard will be established on and along the future alignment of the Access Road.

The elevation of the yard will be constructed as same as the elevation of the Access Road, which is MSL +5.5m, for the sake of avoiding the submergence during the rainy season.

In consideration of the bearing of the traffic for heavy vehicles and safety work for the heavy equipment, the present field for the construction yard shall be improved with sand up to CBR 8%, and then filling to the prospective elevation of the yard. After the filling, placing the aggregate and compacted, bearing ratio of the yard will be assured more than CBR 80% as same as the CBR of base course of the Access Road, and DBS surface course will be conducted as temporally.

Most of the materials will be transported by vessels and partially by inland transportation to the site. Accordingly temporary jetty shall be constructed at the both sides of the river at the south of the prospective alignment of the new bridge in consideration of the transportation of vessels.

b Development for the road construction yard

The road construction yard will be had jointly with the bridge construction yard.

Materials will be transported by the vessels and by the inland transportation to the site.

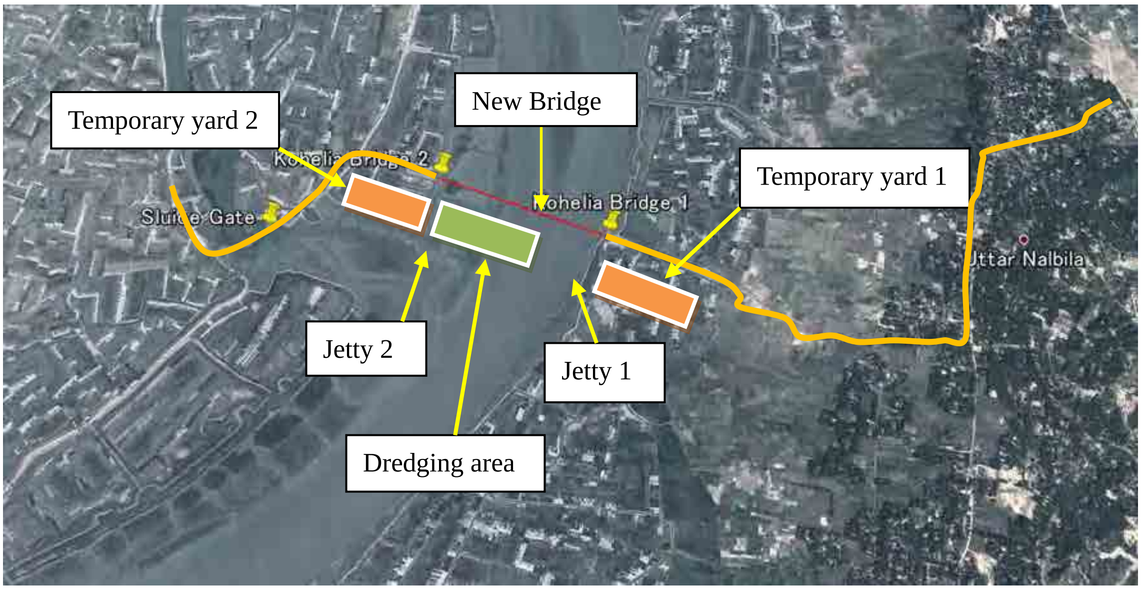


Figure 16.4-4 Location of Temporary Yard, Jetty and Dredging Area

3) Road construction

The Access Road will be constructed for the purpose of the traffic for the execution of the Plant, the management of the Plant and the public.

Road structure profile is as follows;

- Width of the carriage way : 5.5m, two lanes
- Width of the shoulder : 2.15m or 0.9m, both side
- Total crest width : 9.8m or 7.3m

As mentioned in Table 16.4-10 above, access road is classified with two portions that are the existing road portion and new construction portion. The existing portion is from Ekata Bazar to Yunuskhali Bazar. The new construction portion is from Yunuskhali Bazar to Nyaghata Jetty point and between new bridge and Power Plant.

And on the aspect of the repairing, widening and new construction, Access Road is classified eight sections. Figure 16.4-5 shows the alignment of whole Access Road from Ekata Bazar to the Power Plant.

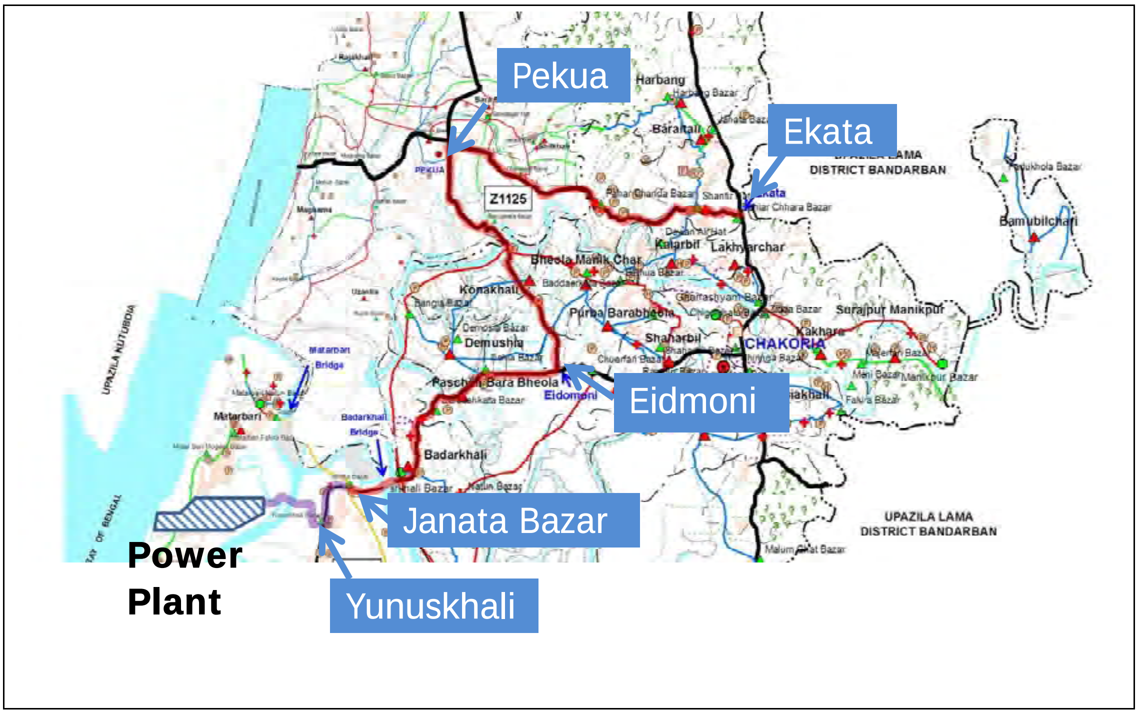


Figure 16.4-5 Access Road Route and Major Junctions

The road works for each sections are as follows.

a Ekata Bazar to Pekua intersection

This section has been maintained properly. The width of the carriage way is fulfilled for the standard of the Bangladesh. This section will be paved with over lay.

b Pekua intersection to Eidmoni intersection

There are pot holes, cracks and roughness of the bituminous surface along the road. Ordinary maintenance work will be needed. This section will be paved with over lay. The width of the carriage way is fulfilled for the standard of the Bangladesh. This section will not be needed widening works.

c Eidmoni intersection to Badarkhali bridge

There are pot holes, cracks on the bituminous surface along the road. Ordinary maintenance work will be needed. This section will be paved with over lay. The width of the carriage way is partially not fulfilled for the standard of the Bangladesh. This section will not be needed widening works in consideration of practical traffic situation.

d Badarkhali bridge to Janata Bazar

There are pot holes, cracks on the bituminous surface along the road. Besides there are some areas where the edges of the surface of pavement have been demolished. Ordinary maintenance work will be needed. The width of the carriage way is not fulfilled for the standard of the Bangladesh. This section will not be needed widening works in consideration of practical traffic situation.

e Janata Bazar to Thallatoli Intersection

Entire repair work will be needed. The width of the carriage way is not fulfilled for the standard of the Bangladesh. This section will be need widening works. Side filling and pavement work will be done for the widening work. During the construction, the public traffic has to be opened. For the widening the existing culverts will be done after demolish of the inlet and outlet of the culverts.

f Thallatoli Intersection to Yunuskhali Bazar

Entire repair work will be needed. The width of the carriage way is not fulfilled for the standard of the Bangladesh. This section will need widening works. Side filling and pavement work will be done for the widening work. During the construction, the public traffic has to be opened. For the widening the existing culverts will be done after demolish of the inlet and outlet of the culverts. Drainage system shall be done along the hill area.

g Yunuskhali Bazar to Nyaghata Jetty point

This section is the new construction section. Firstly soil improvement for the present ground surface will be needed by sand to assure the bearing capacity against the settlement. Along the habitats area, guide wall, with which the width of the embankment will be shortened, will be constructed along the both side of the embankment.

In consideration of the drainage and crossing the road with under way, culverts will be constructed with proper interval.

h Between New Bridge and Power Plant

This section is the new construction section. Firstly soil improvement for the present ground surface will be needed by sand to assure the bearing capacity against the settlement.

In consideration of the drainage, culverts will be constructed with proper intervals.

Sluice gate will be constructed in consideration of the difference of the elevation of the upper-side reservoir and the downside river. Before the execution of sluice gate, cofferdam will be constructed for the dewatering of the reservoir.

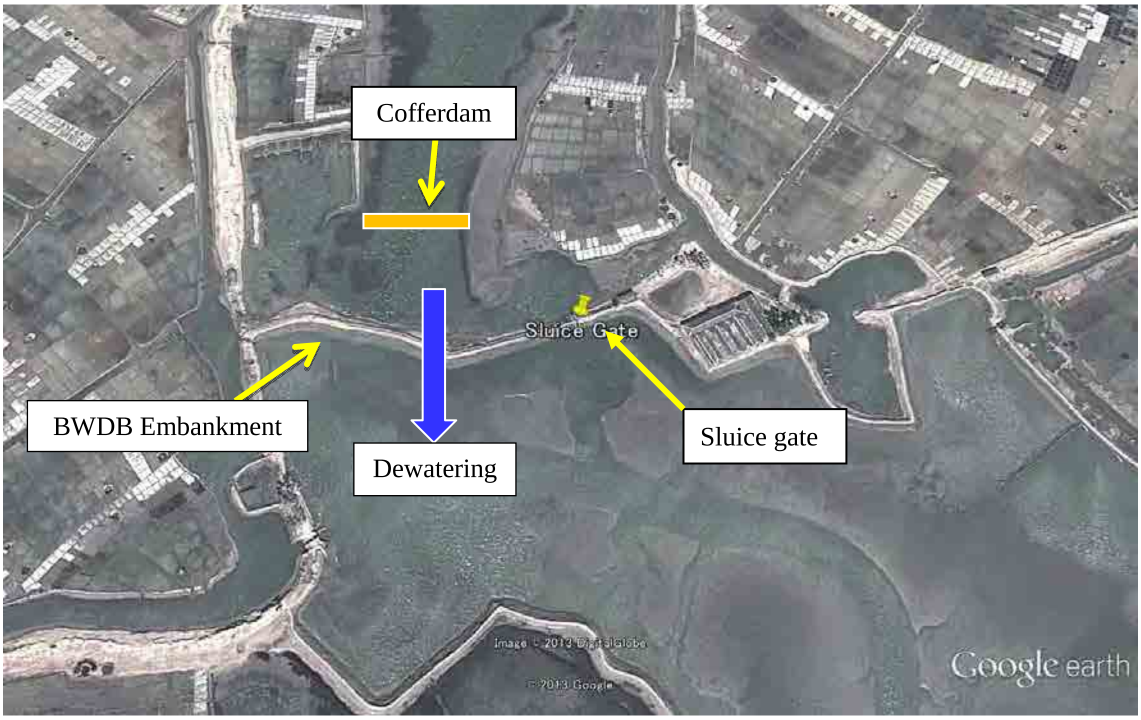


Figure 16.4-6 Location of the Sluice Gate

i Repair work during construction period

Repair work for the damaged area attributed to the construction shall be done by contractor during construction period for the whole access road.

4) Bridge construction

Kohelia River is current canal existing between Mahesikhali island and Matarbari island.

The type of the bridge has been studied through the appropriate factors with which are economical, landscape, easiness of the execution, environment and so forth. Finally the type of the superstructure of simple beam PCT Girder Bridge has been decided. The erection girder method is recommended for the erection method. The type of the substructure has been decided as Pile Vent method, it is the most economical and easiest way for substructure.

Piling method that is cast-in-situ for the substructure will be established in consideration of the feature of the river bed, length of pile, soil condition, velocity and water flow volume and past experience of piling.

Piling work cast-in situ will be done by barge after dredging work.

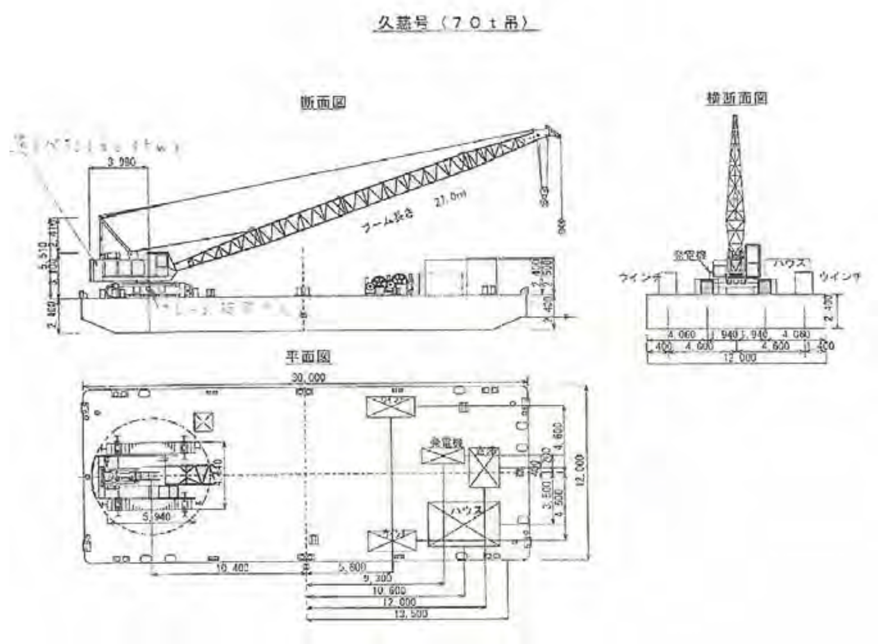


Figure 16.4-7 Schematic View of Barge

a Substructure work

a) Abutment

Piling work will be done with inland work. Piling will be done with the cast-in-situ method. Excavation will be done to the proper depth, reclaim the foundation bed, placing the lean concrete and then structure work.

Piling will be done with the cast-in-situ method.

b) Pier

In the river, piling work and structure work will be done by barge. Regarding the dredging work for the river, the area of the dredging work will be done for about a half of the river from the Matarbari side to keep the proper depth for floating of the barge. To protect the getting muddy of the river during the dredging work, the protection sheet for the muddying shall be placed with proper area.

Cast-in-situ piling work for the foundation for the substructure will be done by the reverse piling machine recommendable and set on the artificial inland and barge.

c) Structure Work

The artificial island will be made in the river as the scaffolding.

Fabricated re-bar and materials for the form work will be transported by boat from the work shop and assembled using the barge with crane.

Materials for the form work are plywood, form-tie, separator, and so on.

Batching plant for the concrete will be established at the yard. Green concrete will be transported by boat and placed by the barge with crane.

b Superstructure work

a) Main girder

Design strength of the concrete for PCT girder is 40 N/mm2. In consideration of the length of the span and the water volume of the river, erection girder method is recommendable.

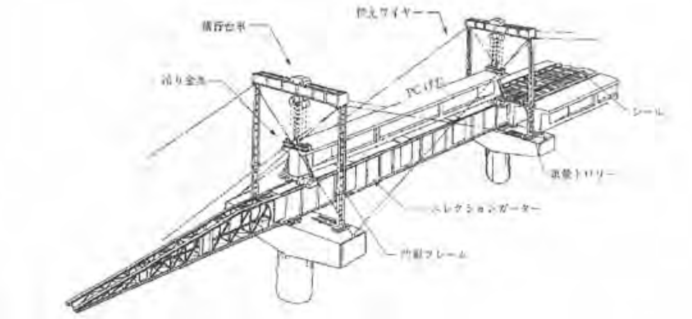


Figure 16.4-8 Reference Sketch of The Erection Girder Method

Figure 16.4-9 Reference Pictures of Erection Girder Method

Figure 16.4-10 shows a flow chart for the superstructure work.

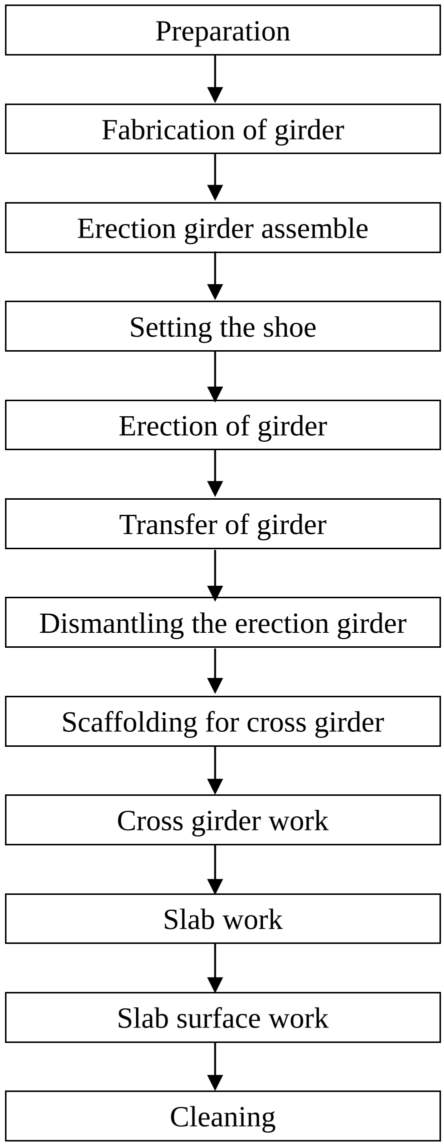


Figure 16.4-10 Flow Chart for the Superstructure Work

c Cross girder work

After the erection of main girder, the cross girder work will start.

d Slab work

After the cross girder work, the slab work will start. Transversal prestressing will be done.

e Shoe work

After the pier work, shoe work will start. Rubber bearing shoe will be set.

f Expansion joint

After the slab work, the expansion joint work will start. Strip seal joint will be set.

g Drainage

After the slab work, the drainage work will start.

h Water proof

After the slab work, the water proof work will start.

i Bridge rail

After the felloe work, the bridge rail work will start.

j Foot path/Curb

After the felloe work, the foot path/ curb work will start.

k Asphalt pavement

After the works from a) to j), asphalt pavement work will start.

l Name plate

Finally name plate will be installed both side of the bridge.

m Revetment

Potential erosion by the water flow for the abutments will be protected by the revetment surfaced by concrete flat blocks.

n Jetty

Temporary jetty will be constructed for the loading from the river at the south of the prospective alignment of the bridge.

16.4.6 Similar project

(1) List of Similar Project

Four similar projects are selected as listed on the Table 5.5-1.

Main items for each project for comparison as the similar projects are as follows;

- Unit costs for bridge for two lanes: 2.15mil BDT/m, 2.19mil BDT/m.
- Procurement: ICB or LCB
- General condition: FIDIC(ICB)
- Design/Specification: Bangladesh Highway Standard
- Contract: BOQ
- Payment: Monthly
- Performance security: 10%(ICB)
- P/Q: Yes (ICB) or Not applicable (LCB)
- Supervision: Consultant(ICB) or RHD directly(LCB)
- Duration of construction: 215.7m/24 months(Laning of Dhaka-Chittagong Highway Project)

Table 16.4-11 Comparison Table of the Similar Projects

Eastern Bangladesh Bridge Improvement Project: Loan Agreement 7,824mil Yen (JICA)							
	Scope of works	Implementation period		Required method for Design & Specification	PQ and Tender	Condition of contract	Supervision of construction
	Contract No. EBBIP/Dhaka/CP-01 Reconstruction and replacement of 31 bridges	22 months		-Bangladesh Highway Standard -Bored Cast-in-situ Piles -Casting of piles Caps under water for piers -Vertical static pile load test -Methodology for superstructure elements	1. P/Q: -Historical Contract -Non-performance -Financial situation for previous 5 years -Average Annual construction Turnover for last 5 years -Financial resources -Current contract commitments /Works in progress 2. Tender: March 2011 3. ICB	1. G.C. FIDIC 2. BOQ 3. Work item: RHD code 4. Payment: - Advanced payment 10% - Monthly interim payment 5. Performance security 10%	National Consultant
	Contract No. EBBIP/Chittagong/CP-02 Reconstruction and replacement of 40 bridges	22 months					
	Contract No. EBBIP/Comilla/CP-03 Reconstruction and replacement of 16 bridges	20 months					
	Contract No. EBBIP/Sylhet/CP-04 Reconstruction and replacement of 18 bridges	22 months					
Laning of Dhaka – Chittagong highway Project: Contract Amount BDT1,368,281,344-(including Tax 10.5%) BDT2.38mil/linear m							
	Bridge Package B2 Lalpul Bridge(progress 85% as of June 2013) L=22.1m(22.1m) two lanes	From 14/02/2012 to		-Bangladesh Highway Standard -Bored Cast-in-situ Piles -Casting of piles Caps under water	1. PQ: 2. Tender - Six Indians	1. G. C. FIDIC 2. BOQ	National Consultant

	Lamua Bridge(progress 45% as of June 2013) L=93.3m(28.6m+36.1m+28.6m) two lanes Muhuri Bridge(progress 50% as of June 2013) L=188.6m(18.1m+29.6m+35.1m+40.1m+35.6m +30.1m) two lanes Dhumghat Bridge(progress -) L=215.7m(28.1m+28.6m+28.1m+30.1m+48.1m +29.1m+23.6m) two lanes Chittagong Rail Crossing L=53.9m(11.0m+31.9m+11.0m) two lanes	14/02/2014 M 24 months		for piers -Methodology for superstructure elements	- Two China - Two national 3. ICB: -Indian Contractor won the bid	3. Work item: RHD code	
Eidgah Bridge: BDT 70 crocre(BDT700,000,000-)		BDT2.19mil/linear m					
	Cox's – Chittagong Bypass Road, National highway No. 1 L=320m two lanes PCI girder, simple beam 40m@8 spans	From 2004 to 2013 7 years (The project has been suspended after the completion of the substructures)		-Bangladesh Highway Standard -Bored Cast-in-situ Piles -Casting of piles Caps under water for piers -Methodology for superstructure elements	1. PQ: not applicable 2. LCB	BOQ	RHD
Badarkhali Bridge:							
	65km from Cox's Bazar PCT simple beam L=360m. two lanes 40m@9 span	-		-Bangladesh Highway Standard -Bored Cast-in-situ Piles -Casting of piles Caps under water for piers Methodology for superstructure elements	1. PQ: not applicable 2. LCB	BOQ	RHD

Muhuri Bridge: on-going project for Laning of Dhaka-Chittagong Highway project

Table 16.4-12 Overview of the Muhuri Bridge Project

Executing Agency	RHD	
Highway	National highway Route No. 1	
Location	13 km from Feni	
Type of Bridge	PCT simple beam	
Bridge length	188.6m	
Lanes	2 lanes	
Span length	18.1m+29.6m+35.1m+40.1m+35.6m+30.1m	
Design	Bangladesh Highway Standard	

	
Over view 1: exiting bridge	**Over view 2: Before piling work**
	
Over view from abutment	**Substructure: pier work in land**

Figure 16.4-11 Overview of the Muhuri Bridge Project

Lamua Bridge: On-going project for Laning of Dhaka-Chittagong Highway

Table 16.4-13 Overview of the Lamua Bridge Project

Executing Agency	RHD	
Highway	National highway Route No. 1	
Location	10 km from Feni	
Type of Bridge	PCT simple beam	
Bridge length	93.3m	
Lanes	2 lanes	
Span length	28.6m+36.1m+28.6m	
Design	Bangladesh Highway Standard	

Over view: Existing Bridge

Piling work in the river

Figure 16.4-12 Overview of the Lamua Bridge Project

Eidgah Bridge: BDT2.19mil/linear m

Table 16.4-14 Overview of the Eidgah Bridge Project

Executing Agency	RHD	
Highway	Cox's – Chittagong Bypass Road National Highway Route No. 1	
Location	5km from Cox's Bazar	
Type of Bridge	PCT simple beam	
Bridge length	320m	
Lanes	2 lanes	
Span length	40m@8 span	
Design	National Highway Standard	

Over view 1

Over view 2

Substructure

Superstructure

Figure 16.4-13 Overview of the Eidgah Bridge Project

Badarkhali Bridge (Maheshkhali River)

Table 16.4-15 Overview of the Badarkhali Bridge Project

Executing Agency	RHD	
Highway	Regional way	
Location	65km from Cox's Bazar	
Type of Bridge	PCT simple beam	
Bridge length	360m	
Lanes	2 lanes	
Span length	40m@9 span	
Design	Bangladesh Highway Standard	

	
Over view 1	**Over view 2**
	
Substructure	**Superstructure**

Figure 16.4-14 Overview of the Badarkhali Bridge Project

Chapter 17

Execution Survey of Natural Condition

Chapter 17 Execution Survey of Natural Condition

Executive Summary

As a result of the Preparatory Survey on the Chittagong Area Coal Fired Power Plant Development Project (hereinafter referred to as "the Project"), the excavated port was planned. In addition, the site is situated in lowland, approximately 1m above sea level. Therefore, a land formation that develops an embankment to protect the power plant against flooding due to the high tide was proposed, along with reusing the dredged soil in the construction of the port and navigational channel. For the purpose of deeper depth of data collection in the Preparatory Survey, JICA decided to employ a supplemental environmental survey (hereinafter referred to as "the Environment Survey"), which aimed to collect additional data and analyze the natural conditions at the site in February 2014.

The following prioritized subjects were included in the Environmental Survey. The analysis and assessment of these with issues and/or concerns that arose when creating the detailed design were addressed therein.

1) The range and amount of the sand deposits at the area and depth of the dredging.

2) The physical properties of the sand deposits at the area and depth of the dredging, and an assessment of whether this sand could be used as material for the embankment.

3) The impact of coastal drift sand or siltation at the port and access channel.

4) The range and thickness of the soft soil layer deposits at the power plant area.

5) The physical properties (including the consolidation characteristics and shear strength) of the soft soil deposits and foundation layer at the power plant area.

During the Environmental Survey period, information on the procurement of construction material was investigated as a contingency for the potentially inadequate amounts of dredged soil, and also as information that could be beneficial to the detailed design.

In this investigation, 45 exploratory drillings, 46 Swedish weight sounding tests, marine seismic surveys on 15 survey lines, and laboratory tests at the site and in Singapore on the specimens from both the disturbed and undisturbed samplings were carried out. On top of this, a topographical survey of the 632ha covering the Project site was also included.

The results of the Environmental Survey are as follows:

1) It was found that the As-1 and As-2 alluvial sandy soil layers were distributed within the Project site, and that the quantity of these layers, from a comparison between the amount of dredged sand and filling sand, equated to a well-balanced soil at the site.

2) The physical properties of the soil layers encountered were obtained (as referred to in 17.5 (8)). It was found with reference to the domestic and overseas codes and standards that the A_{s-1} and A_{s-2} in the existing ground layers could potentially be used as filling material for the power plant. The densities of the pollutants in the existing ground were found to be within this criteria.

3) It was revealed through the simulations on the littoral drift that waves did not significantly affect the topography of the channel, and sedimentation in the channel tended to occur during the high wave period with a smaller grain size and at a higher SS concentration. Based on these findings, the following measures are recommended.
   - Dredging should be conducted regularly to maintain a sufficient depth in the channel.
   - Breakwaters should be constructed along the channel to prevent the entry of suspended sediments into the channel.

   It is also recommended to conduct additional surveys in the future, including wave observation surveys (at regular intervals), flow-direction/flow-velocity distribution surveys (at regular intervals), bottom sediment surveys (in the rainy and dry seasons), and concentration distribution surveys (in the rainy and dry seasons).

4) It was found that the Ac-1, Ac-2, and Ac-3 alluvial clayey soil layers with thicknesses ranging from 6m to 14m were distributed within the power plant site; the physical properties of these layers were also obtained and a rough estimation of the settlement of the consolidation was conducted. It is suggested on the basis of this estimation that a soil improvement program must be carried out on the existing soft layers in order to potentially avoid an adverse effect on the power plant construction schedule in the future.

5) It was revealed that the Dc diluvial clayey soil layer with an N-value of over 30 was distributed within the existing ground, and that below this was the corresponding Ds layer

with an N-value of over 50; both these seem to be the bearing layer. The physical properties of these layers were obtained.

6) It was found through the material procurement survey that although there was a potential risk in procuring boulders/stone (used for the training dyke/quay wall), there was little/minimal risk in procuring construction materials other than these.

   For the procurement of boulders/stone it is advised that quarries be sourced as close as possible from the Project site, and that studies be undertaken into the possibilities of conducting the design without using - or with minimum use of - boulders/stone. In terms of the construction materials in general, further investigations and studies are recommended to obtain the detailed cost of these, as well as making efforts to secure the cooperation of public testing laboratories or institutes in Bangladesh, to conduct physical tests on the materials, and to obtain information on the delivery of these via land routes including India.

In advance of the Environmental Survey, CPGCBL issued an entry permit letter. Upon the issuance of the permit, for security purposes policemen guarded the site on a 24 hour basis day and night. Coastal guards kept watch over the site during the daytime only, and at nighttime when required to prevent equipment and machinery from being damaged or stolen, as well as to protect all the allocated engineers and the onshore and offshore subordinate personnel.

The Environmental Survey did not include some works carried out in the detailed design, such as the: 1) additional information required in the detailed design at the implementation phase; 2) determination of the design parameters; and 3) review or study of countermeasures for technical issues and other matters.

17.1 Background and Purpose

As the result of the Preparatory Survey on the Chittagong Area Coal Fired Power Plant Development Project (hereinafter referred to as "the Project"), a candidate site at the Matarbari district was selected. In the planning of the coal fired power plant, a port and navigational channel shall be arranged for safe access and accommodation of a coal carrier which will deliver vital fuel (importing coal in this Project). Since an outer jetty for that purpose was judged inappropriate from an environmental point of view, the excavated port was planned instead. In addition, the site is situated in the lowland, approximately 1m above sea level. Therefore, a land formation that develops an embankment to protect the power plant against flooding due to the high tide was proposed, along with re-using the dredged soil in the construction of the port and navigational channel.

The Preparatory Survey started in July 2012, and the Draft Final Report was submitted to JICA in September 2013 with the draft EIA report and LARAP (Land Acquisition and Resettlement Action Plan), which reflected upon the comments of the Advisory Committee of Environmental and Social considerations. The Preparatory Survey included studies on the basic design, the operation and its organization, the delivery of coal, the transmission lines, the environmental and social considerations (including the observation of the endangered species), and the access roads that apply to the state of the art USC coal fired power plants of 2x600MW.

Although the Project will be the first large-scale coal fired power plant in Bangladesh, as no new port construction has been carried out over the last few decades, major development projects by the government or systematic investigations have not been realized.

Since the depth of data collection in the Preparatory Survey was insufficient, JICA decided to employ a precedent environmental survey (hereinafter referred to as "the Environment Survey"), as a supplement to the Preparatory Survey, which aimed to collect additional data and analyze the natural conditions at the site in February 2014.

17.2 Plan of the Environmental Survey

On the basis of the above background, the purpose, and appropriate interface with the subsequent engineering works in the implementation phase, the Environmental Survey team has prioritized the considerations (or precedent subjects) detailed below in order to effectively complete the survey within the required period of time.

In constructing the port and the land formation, the dredging, embankment work, and ground improvement work will require the most time. It was estimated that in total approximately 17 million m^3 of sand will be dredged, with 9 million m^3 of this sand being required for the land formation. This dredging and land formation, which is to be covered by the BOQ contract, will be the most time consuming and, given its potential to delay the power plant construction schedule, one of the most critical tasks in this Project.

Furthermore, the results of the Preparatory Survey indicate that soft soil is being deposited on the surface layer of the power plant area and that this soft layer is likely to cause a settlement of the embankment. Thus, the exact range and physical properties of the soft soil should be confirmed.

Meanwhile, since sand transport or siltation in coastal areas will affect the progress of construction and maintenance of the port after dredging, adequate attention should be paid to such factors given the major impact of this to coastal change.

Given the above factors, the following prioritized subjects have been included in the Environmental Survey. The analysis and assessment of these with issues and/or concerns that arise when creating the detailed design have also been addressed therein.

1) The range and amount of the sand deposits at the area and depth of the dredging.
2) The physical properties of the sand deposits at the area and depth of the dredging, and an assessment of whether this sand can be used as material for the embankment.
3) The impact of coastal drift sand or siltation at the port and access channel.
4) The range and thickness of the soft soil layer deposits at the power plant area.
5) The physical properties (including the consolidation characteristics and shear strength) of the soft soil deposits and foundation layer at the power plant area.

However, the Environmental Survey does not include some works carried out in the detailed design, such as the: 1) additional information required in the detailed design at the implementation phase; 2) determination of the design parameters; and 3) review or study of countermeasures for technical issues and other matters.

During the Environmental Survey period, information on the procurement of construction material was investigated as a contingency for potentially inadequate amounts of dredged soil, and also as information beneficial to the detailed design.

17.3 Content and Method of the Investigations

17.3.1 Soil Investigation

As shown in section 17.1, the purposes of the soil investigation are: (i) to confirm the existence of the dredging sand inside the area of the planned dredging work; (ii) and to understand the properties of the dredged soil material; and (iii) to confirm the bearing capacity of ground and the soil properties at the planned power plant area. The following section explains about the content and methods regarding the soil investigation.

(1) Drilling survey

1) Drilling position

The drilling survey, in accordance with each drilling purpose to be carried out based on the Matarbari power plant layout, set the respective drilling positions and depths for this. That is, in the dredging area, the drilling position was arranged on the channel centerline and the range edge over the whole length and breadth of the planned dredging area in order to roughly confirm the existence of the dredging sand. Moreover, in the shallow sea area, several of the drillings were set in a parallel direction with the shore line (for the south to north direction) in order to cover the outside of the planned dredging area.

On the other hand, in the planned power plant area, the drilling position was arranged with regard to the following three purposes (and in consideration of the solidity, the ground situation and the foundation type of the structure design).

- Drilling to confirm a soft layer.
- Drilling to confirm a load bearing layer for the power plant buildings and facilities.
- Drilling to confirm the ground situation under the load bearing layer (up to 50m in depth).

Regarding the drilling to confirm the soft layer, this was arranged evenly in the coal stock yard and power block area to broadly understand the distribution of the soft layer. The drilling to confirm the load bearing layer for the power plant buildings and facilities was arranged on the jetty for the coal vessel, the coal-storage yard, and the power block’s main building. The drilling to confirm the ground situation underneath the load bearing layer was arranged at the east and west edges the power block, as well as at its center.

The number of the drillings is shown in Table 17.3-1, and the positions, coordinates, and borehole depth(s) of these are shown in Figure17.5-1 and Table17.5-1 in section 17.5.1 – results of soil investigation.

Table 17.3-1 Quantity of Drilling

<table>
<tr><td colspan="2">Investigation area</td><td>The number of drillings</td></tr>
<tr><td colspan="2">Port and harbors dredging area</td><td>25</td></tr>
<tr><td rowspan="4">Coal stock yard
and
Power block area</td><td>To confirm the soft layer</td><td>11</td></tr>
<tr><td>To confirm the load bearing layer</td><td>6</td></tr>
<tr><td>To confirm underneath the load bearing layer</td><td>3</td></tr>
<tr><td>Subtotal</td><td>20</td></tr>
<tr><td colspan="2">Total</td><td>45</td></tr>
</table>

2) Rules for the drilling work of borehole depth

The depth of the borehole was set in accordance with the purposes of the drilling surveys; with the survey teams carrying out the drilling work up to the required depth in compliance with the following rules.

・Port and harbors dredging area

To drill under the seabed up to the M.S.L-20m including 2m additional depth from the planned bottom level for the dredging.

・Drilling to confirm the soft layer

To drill under the ground that can be confirmed with more than 20 times of N-vale and more than 2m continuous depth over the soft layer.

・Drilling to confirm the load bearing layer for the power plant buildings and facilities

To drill under the ground that can be confirmed with more than 50 times of N-vale and more than 5m continuous depth on the sand layer.

・Drilling to confirm the ground situation underneath the load bearing layer

To drill under the ground up to 50m in depth from the existing ground level.

3) Working barge and drilling rig

a. Working barge

The drilling works have been taking places in salt farm areas with sea water all around. The survey team made the best possible use of pontoons to carry out the drilling work effectively, as well as the drilling rig and its parts that were installed on a ship. For the land areas, the drilling team made use of two pontoons.

On the other hand for the work in the sea areas, a floating-working ship (drilling ship) was equipped with a drilling rig and its parts. In addition, drilling work in the shallow sea areas was done using a tower-type platform. Figure 17.3-1, Figure 17.3-2, and Figure 17.3-3 show photographs of these working conditions.

b. Drilling rig

The drilling work team was adopted two types of the drilling rigs - a rotary drilling dig and a percussion drilling rig. The rotary drilling rig was used mainly for work in the land areas to clarify the soil layer, conduct in-situ tests and standard penetration test, and also sampling. To remove the slime in the borehole and to prevent the borehole wall from collapsing, a casing pipe was installed into the borehole, and when the drilling was promoted muddy water was used and circulated through the borehole.

For the sea areas, due to difficult sea-related conditions the drilling work fell behind schedule, so more drilling rigs were required. Therefore, for this reason percussion drilling was undertaken in parts of the sea area drilling. Percussion drilling - a drilling technique in which a heavy drill bit attached to rope or cable is repeatedly raised and lowered, impacting soil and rock, and making a hole deeper - is more suited for drilling in sea areas, as unlike rotary these in no need for cohesive soil samples. The Environment Survey Team must add that there is no difference in between rotary drilling and percussion drilling for evaluating the results of the relevant drilling surveys. Percussion drilling was carried out on the borehole numbered OF-05-1a, OF-05-1b, OF-05-3a, and OF-05-3b.

Figure 17.3-1 Floating Stage for the Shallow Water Drilling

Figure 17.3-2 Floating Stage for the Deep Water Drilling

Figure 17.3-3 Stationary Platform for Drilling

(2) Standard penetration test

The standard penetration test was carried to measure the N value, which became the target criteria of the soil conditions, and also to obtain the samples that were taken for laboratory tests for the composition stratum aiming. In accordance with ASTEMD1586, the SPT was carried out, except for the sampling depth, at an interval of 1m in drilling the borehole from ground surface until the drilling finished. More specifically, a cylindrical sampler was set up in the location of the borehole, the steel-made drive hammer of 63.5±0.5kg was dropped from the height of 76±1cm freely, and sank a sampler into the ground. The total depth of the testing was 45cm - 15cm for the preliminary test and 30cm for the actual test. Then, the inspector recorded a hammering frequency not only for the preliminary test but also for the actual test. The test adopted a fixed number of hammerings, that is, the SPT could be brought in the actual test if the hammering frequency was occurred more than 50 times.

The soil conditions of the samples obtained by the standard penetration test, were judged by the naked eye directly, and were organized according to the order of the samples.

(3) Sampling

The aim of the sampling investigation is to collect soil samples for laboratory tests. The laboratory tests to confirm the soil characteristics (including the mechanical characteristic) of the samples were carried out for undisturbed sample and disturbed samples, respectively.

The undisturbed samples were collected at intervals of 3m from the target for the soft layer (cohesive soil and silty soil). Here, a hydraulic piston was used for the sampling.

The disturbed samples were collected at intervals of 3m from the target for the sand layer. The sample revealed the relevant soil compaction and classifications of the samples. Here, a open drive sampler was used for the sampling.

(4) Marine seismic survey

The marine seismic survey was carried out to understand the geology tectonics and that condition in front of the Matarbari power plant area. In particular, the sandy soil distribution can be clarified on closer examination with the sea area drilling results. A marine seismic survey can chart the structural geology of sea areas through producing sound waves that continuously penetrate the stratum and bounce back to and are measured by reflection receivers towed by a sea vessel. Based on the obtained the marine seismic survey results, the stratum structure and geology are shown as the soil profiles compared with the drilling results.
As shown schematically in Figure 17.3-4, the marine seismic survey was equipped with a sound

wave inquiry device using a frequency 200 kHz set in the main inboard and the electric wire that reported this sailed from the stern at a depth of 30m seawater. The echo sounder transmitter and the echo sounder receiver were installed in the point of the electric wire, and the position of survey vessel on the sea was decided by using GPS and an electric wave distance meter together.

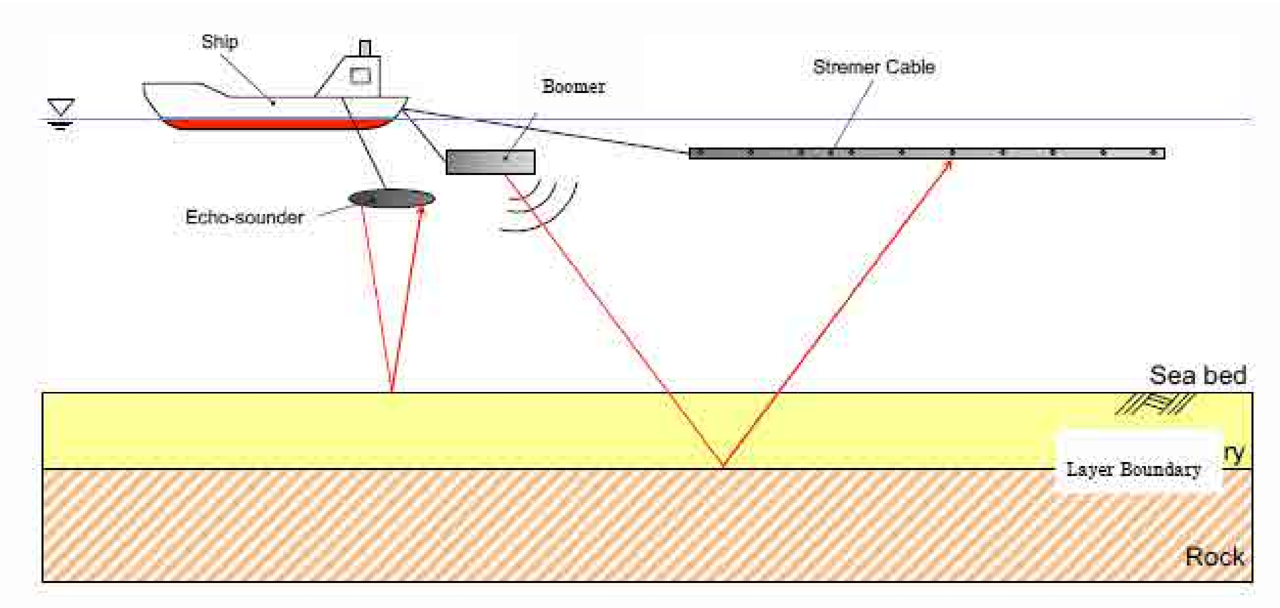


Figure 17.3-4 Schematic of the Marine Seismic Survey Operation System

(5)Electric exploration

The electric exploration is to understand the geological structure and the distribution in the land area by analyzing the specific resistance value of the ground. The method of the electric exploration is facilitated by inserting the electrode at equal intervals in surface of the ground and injecting the current between the electrodes. This survey was planned to understand the soft layer distribution in the power plant area. However, the electric exploration was unable to be carried out because the land area has been used as a salt field and was covered with sea water during the investigation period (from September to November). As an alternative investigation to the electric exploration, the Environment Survey Team carried out the Swedish weight sounding test (SWS) as shown in the following clause.

(6) Swedish weight sounding test (SWS)

The SWS is used to understand the distribution and thickness of the soft layer in land area. On the basis of JIS A 1221 (similar to ASTM), the SWS method is facilitated initially by inserting a rod into the ground with loading within 100kgf weights on the tip of the rod to record the loaded weight. Next, when the rod stopping fall down, then the rod revolves into the ground at 25cm and converts the number of turns into relevant N-values. Finally, the investigator charts the investigation record by analyzing the N-values and the depth. As the SWS is an effective sounding test to confirm the surface ground, it serves as a suitable substitute for the electric exploration. Figure 17.3-5 shows the execution condition of the SWS.

Figure 17.3-5 Swedish Weight Sounding Test

(7) Sea bottom sediment and sea water test

As shown in 17.7 section, the Environment Survey Team carried out the simulation regarding the shoring of port and harbor. The purpose of the sea bottom sediment and sea water sampling is to increase the accuracy of the simulation model that takes into consideration shoring characteristic modeling the seabed configuration in front of the power plant and also the sedimentation characteristics underneath the dredged port and channel condition.

The laboratory test results data for the sea bottom sediment and sea water sampling, this included the amount of soil particles in the samples, was input into the simulation model.
Table 17.3-2 shows the number of points where these tests were carried out.

Table 17.3-2 Sea Bottom Sediment and Sea Water Test

Test item	Investigation time	No. of points
Bottom sediment test	・Rainy season (September) ・Dry season (November)	61 points
Sea water test	・Rainy season (September)	14 points

(8) Chemical property test

As for the dredged sandy soil, it is planned to use this for the site filling material at the power plant. The silt and cohesive soils are similarly assumed to be reclamation at the ash pond of the power plant site. In light of the potential environmental impact, a chemical property test was carried out to confirm whether the existing ground soil contains harmful pollutants or not.

The chemical property test is based on the environmental quality standards (EQSs) for soil pollution stipulated in a notification (no.14 of 1973) issued by Japan’s Environment Agency. The EQSs are meant to ensure the smooth implementation of surveys and countermeasures, as well as for evaluating the dredged soil for the land reclamation and marine disasters. The Environment Survey Team is considering applying these EQSs to the filling material on the Project plan. The details for this are shown in Table17.3-3.

Table17.3-3 Summary of Chemical Analysis Standards (EQS)

	Pollutant	Allowable contents* (per test solution 1L otherwise stated)
1	Alkyl mercury compound	Not be detected
2	Mercury and its compounds	0.005mg or less
3	Cadmium and its compounds	0.1mg or less
4	Lead and its compounds	0.1mg or less
5	Organic phosphorus compound	1mg or less
6	Hexavalent chromium compound	0.5mg or less
7	Arsenic and its compounds	0.1mg or less
8	Cyanides	1mg or less
9	Polychlorinated biphenyls (PCBs)	0.003mg or less
10	Copper and its compounds	3mg or less
11	Zinc and its compounds	2mg or less
12	Fluorides	15mg or less
13	Trichloroethylene	0.3mg or less
14	Tetrachloroethylene	0.1mg or less
15	Beryllium and its compounds	2.5mg or less
16	Chromium and its compounds	2mg or less
17	Nickel and its compounds	1.2mg or less
18	Vanadium and its compounds	1.5mg or less
19	Organochlorine compound	40mg or less per sample 1kg
20	Dichloromethane	0.2mg or less
21	Carbon tetrachloride	0.02mg or less
22	1,2 - dichloroethane	0.04mg or less
23	1,1 - dichloroethylene	1mg or less
24	Cis-1 ,2 - dichloroethylene	0.4mg or less
25	1,1,1 - trichloroethane	3mg or less
26	1,1,2 - trichloroethane	0.06mg or less
27	1,3 - dichloropropene	0.02mg or less
28	Thiuram	0.06mg or less
29	Simazine	0.03mg or less
30	Thiobencarb	0.2mg or less
31	Benzene	0.1mg or less
32	Selenium and its compounds	0.1mg or less
33	1,4 - dioxane	0.5mg or less
34	Dioxins	10pg-TEQ or less

(9) Laboratory soil tests

The laboratory soil tests were carried out by using samples obtained from the soil investigation in accordance with the ASTM standards shown in the table below.

Table 17.3-4 Laboratory Soil Test and Applied Standards

Samples	No.	Types		Applied Standard
From Exploratory Drilling	1	Physical Property Tests	Natural Water Content	ASTM D2216-10
	2		Specific gravity	ASTM D854-10
	3		Unit Weight	ASTM D7263-09
	4		Atterberg limit determination (LL + PL)	ASTM D4318-10
	5		Grain size (Sieve analysis only)	ASTM D422-63
	6		Grain size (with Hydrometer Test)	ASTM D422-63
	7	Mechanical Property Tests	Unconfined Compression Test	ASTM 2166-06
	8		UU Triaxial Test	ASTM D2850-03a
	9		CU Triaxial Test	ASTM D4767-11
	10		CD Triaxial Test	ASTM D7181-11
	11		One Dimensional Consolidation Test	ASTM D2435-11
	12		Compaction Tests by 10cm diameter mold	ASTM D698-07 or D1557-09
	13	Chemical Property Tests	Metal contents to be checked for the waste for reclamation, The Prime Minister's Office Ordinance No. 6, 1973 and Dioxins	Appropriate JIS See individual data sheets.
From Sea Bottom	14		Grain size (Sieve analysis only)	ASTM D422-63
Seawater	15		Total Suspended Solids	ASTM D5907-13

A detailed explanation about the mechanical property tests are shown below.

a. Compaction test

Regarding the filling material, to be effective for its purpose this should have good compactibility as well as a high level of dry density and shearing strength. In the laboratory soil tests, the Environment Survey Team carried out the compaction test to understanding the characteristics of the dredging sand adopted as a filling material, and also to verify the compaction curve that can be confirmed in the relation between the moisture content and the dry density. More specifically, the compaction curve was made by the moisture content and the dry density parameters – this was done through the tamping method, loosely based on ASTM D698-07, by dropping the rammer of 2.5kg from a height of 30cm.

The collected dredging soil samples were assumed to cover each borehole over the broad area for the dredging plan.

Moreover, the unconfined compression test samples assumed an admixture soil as shown in Table17.3-5.

Table 17.3-5 Soil Compaction Test

Sampling position	Type	Type of soil	
		Sandy soil	Silty soil
Shown in Table17.5-9	Type A	100%	0%
LD2-13-2	Type B	90%	10%
	Type C	80%	20%

b. Shearing characteristics of the filling material

A triaxial compression test was carried out to understand the shearing characteristics of the filling material made by the compaction test samples. The triaxial compression test provides shearing characteristics, c and ϕ.

c. Shearing characteristics of the existing ground

It is planned along the channel area to construct the embankment to a height of M.S.L+6.5m, and the power plant area to a height of M.S.L+1.0m. A triaxial compression test was carried out to understand the shearing characteristics of the existing ground. The triaxial compression test provides shearing characteristics, c and ϕ. The unconsolidated-undrained triaxial test is subject to the silty and cohesive soil, and the consolidated- drained triaxial test is subject to the sand using a remolding disturbed soil sample applied with lateral pressure.

d. Consolidation test

A consolidation test was carried out to understand the consolidation characteristics and parameters - e-log curve, Cc,Po and Cv - as well as the shearing characteristics of the existing ground.

17.3.2 Land Survey

The topographical survey was carried out for the purpose of confirming the current state of the geographical landscape/conditions at the power plant area. The permanent benchmark was established at the site based on the equivalent national benchmark. In addition, several temporary benchmarks were also set up. Following this, in accordance with the said benchmarks, the Environment Survey Team carried out the land survey to acquire all the relevant coordinates and elevation readings for all the drilling points and the topographical survey.

The land survey matters, the applied standards, and the survey instruments are shown below.

< Land survey >

1) SI points setting out (onshore and offshore)
2) Permanent benchmark establishments
3) Temporary benchmark
4) Topographic survey

< Applied standards >

The survey was performed in accordance with the following standards and documents.

1) ISO/TC 211 Geographic information/ Geomatics.
2) GB 50026-2007 Code for Engineering Surveying.
3) BS 5964: 1st issued 1990 - Building setting out and measurement. Methods of measuring, planning and organization and acceptance criteria.
4) BS 5964: 2nd issued 1996 - Building setting out and measurement. Measuring stations and targets.
5) BS 5964: 3rd issued 1996 - Building setting out and measurement. Check-lists for the procurement of surveys and measurement services.
6) Letter No: Ph 02-9131193 Coordinates, Heights and Location of Geodetic Control Points issued at 04 Sep 2014 from the Survey of Bangladesh for National Benchmark information

< Survey instruments >

1) Static GPS:
- Horizontal error of the GPS receiver 5mm+2 ppm RMS
- Number of healthy satellites ≧5
- Satellites vertical 750 (elevation mask 15°)
- Time of the data record(s) ≧2 hours
- Centering error ≦1mm
- Reading of the antenna height 1mm

2) Total station:
- Number of distance measurements: 8 times
- Difference between each distance measurement: 2mm
- Input the temperature, humidity, air pressure for atmospheric corrections.

The baseline data from the static GPS and the total station were combined and processed by software and met all the accuracy requirements and technical references. Some of the main results are shown below:

Root mean square weighting unit error : Mo = 2.16(")
Mean square of position error:
Maximum: (TBM1) = 0.014(m)
Minimum: (TBM4) = 0.002(m)
Precision ratio:
Maximum: (TBM4 - PBM1) = 1/ 67200
Minimum: (TBM7 - PBM1) = 1/ 594300
Azimuth mean square error:
Maximum: (TBM1 - TBM2) = 1.45(")
Minimum: (TBM7 - PBM1) = 0.66(")

17.4 Organization and Achieved Schedule

Several skills, including the analysis of investigation results, the supervision of field surveys, and the execution of progress and quality controls, are required to acquire the field data that can be used for engineering and the detailed design in order to implement the Environmental Survey. Furthermore, it is essential to minimize the effect of exploratory boring on the environment and adequately consider the welfare of local inhabitants. Based on these necessities, the Environment Survey team decided to dispatch a team of skilled engineers from a sub-contracted Japanese soil investigation firm to work on a full-time basis at the site. Specialists from the

Environment Survey team also visited the site for to supervise the relevant works.
In accordance with JICA's "Guidelines for Local Consigned Contract under Consultancy Contract", Kiso Jiban Consultants, Inc. (KJC) was selected through a competitive tender (based on provided quotations) of appointed firms.

After obtaining the entry permit through CPGCBL - the Project implementation entity that became the owner of the whole site on August 2014 - the site works were started on 25 August 2014 and completed on 30 November 2014. The actual work schedule is indicated in Figure 17.4-1 and the team allocations for the Environmental Survey team and KJC are indicated in Figure 17.4-2 and 17.4-3, respectively.

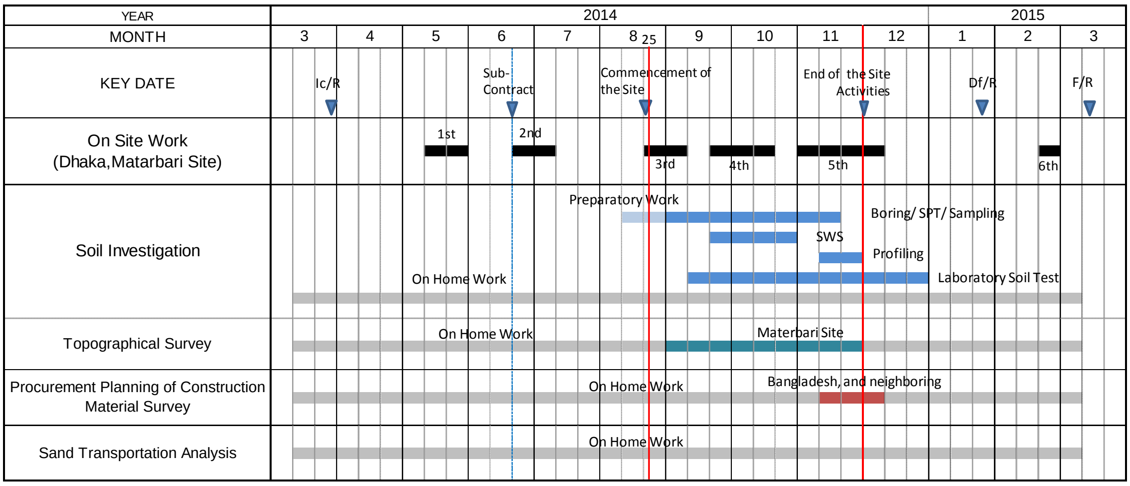


Figure 17.4-1 Actual Work Schedule

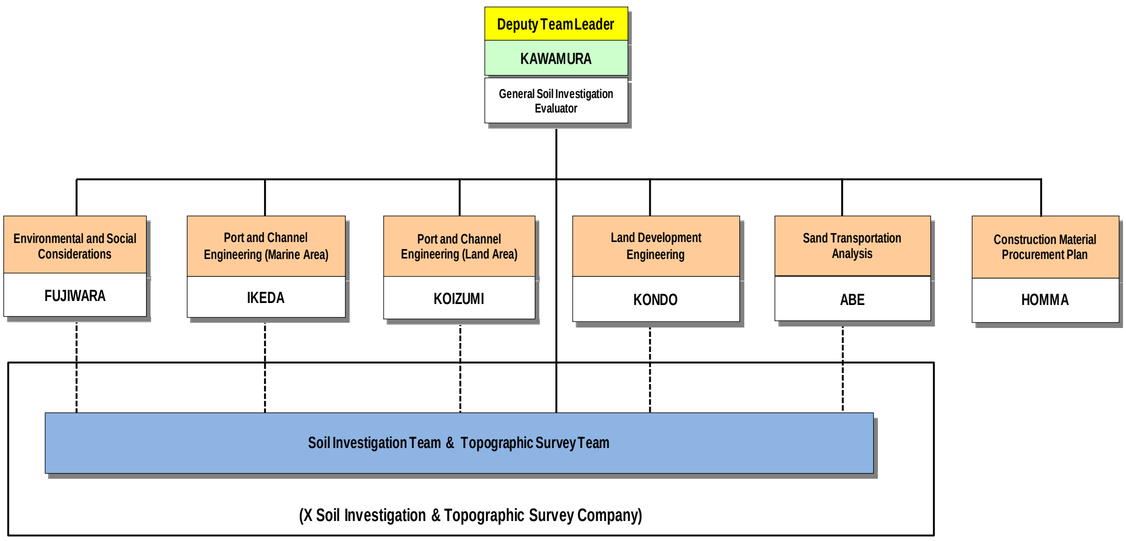


Figure 17.4-2 Team Allocation for the Environmental Survey Team

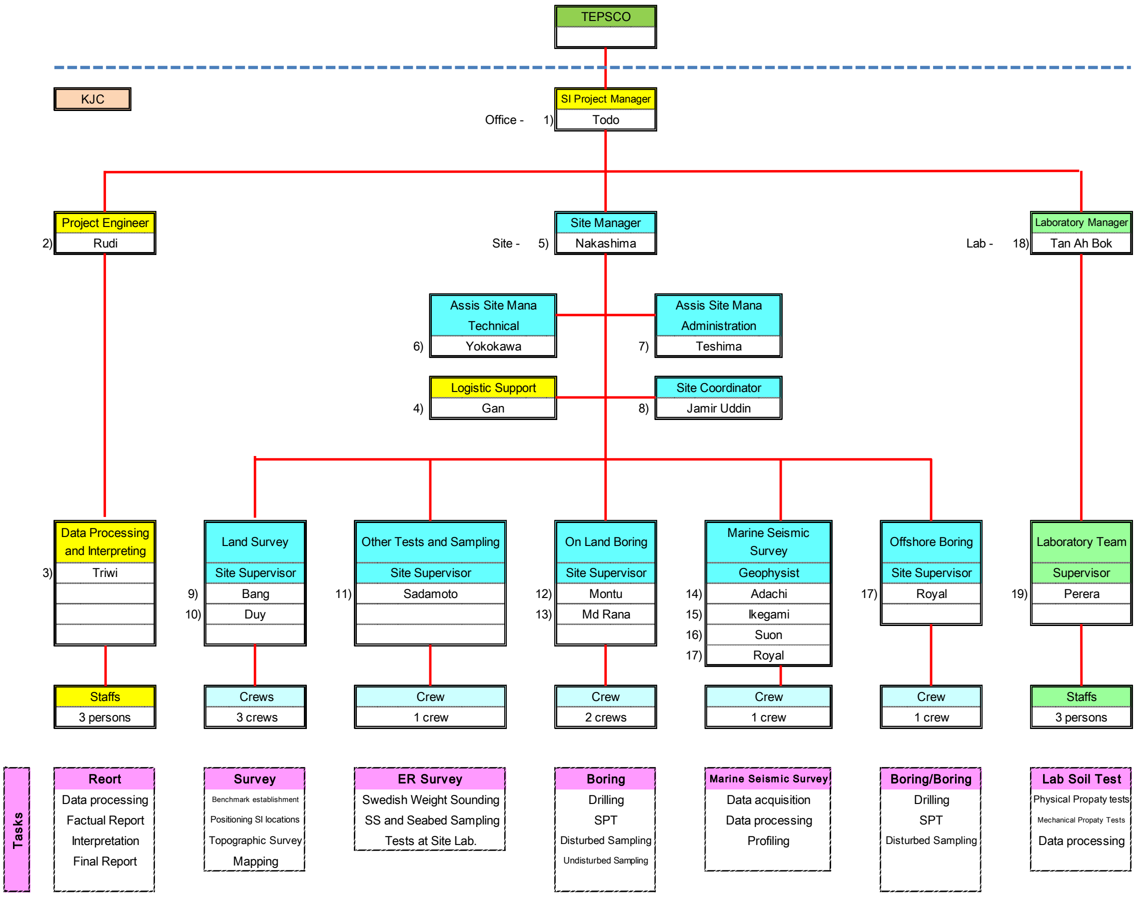


Figure 17.4-3 Team Allocation for KJC

17.5 Environmental Survey Results

17.5.1 Results of Soil Investigation

(1) Soil investigation

In this investigation, 45 exploratory drillings, 46 Swedish weight soundings, and marine seismic surveys on 15 survey lines were carried out. All quantities and locations together with previous investigation points are shown in Table 17.5-1 and Figure 17.5-1.

Table 17.5-1 Quantities of Boring, SPT, and Sampling

		BH No.	Coordinates		Elevation	Water Level	Location	Symbol	Line	Rig	Completed on	Bor Length (m)			Test / Sampling Done (nos)					
												Done			SPT		D-sampling		HP-sampling	
			North(m)	East(m)	MSL(m)	G.L(+m)						Total	0-30m	30-60m	0-30m	30-60m	0-30m	30-60m	0-30m	30-60m
Approach Area	1	OF-02-1	2,399,700.61	380,826.80	-15.24	15.24	Offshore	Bulue C	Chanel C	S-1	2014/11/15	11.90	11.90	0.00	7		4			
	2	OF-03-1	2,399,923.31	381,302.17	-11.83	11.83	Offshore	Bulue C	Chanel C	S-1	2014/11/16	13.45	13.45	0.00	9		4			
	3	OF-03-1a	2,400,316.93	381,415.04	-11.26	11.26	Offshore	Purple C		S-1	2014/11/11	9.45	9.45	0.00	7		2			
	4	OF-03-1b	2,400,713.36	381,558.04	-10.50	10.50	Offshore	Purple C		S-1	2014/11/17	10.45	10.45	0.00	7		3			
	5	OF-03-1c	2,399,514.59	381,154.28	-13.36	13.36	Offshore	Purple C		S-1	2014/11/2	7.45	7.45	0.00	5		1			
	6	OF-04-1	2,400,320.20	381,830.85	-6.99	6.99	Offshore	Bulue C		S-1	2014/11/10	13.45	13.45	0.00	8		3		1	
	7	OF-04-2	2,400,124.00	381,751.56	-8.00	8.00	Offshore	Bulue C	Chanel C	S-1	2014/11/7	18.95	18.95	0.00	11		5			
	8	OF-04-3	2,399,925.55	381,685.21	-6.94	6.94	Offshore	Bulue C		S-1	2014/11/13	13.45	13.45	0.00	9		4			
	9	OF-05-1	2,400,309.57	382,227.53	-1.04	1.04	Offshore	Bulue C		L-2	2014/10/31	19.45	19.45	0.00	12		8			
	10	OF-05-1a	2,400,717.48	382,356.12	-1.38	1.38	Offshore	Purple C		S-3	2014/11/17	19.45	19.45	0.00	14		6			
	11	OF-05-1b	2,401,124.50	382,494.71	-1.94	1.94	Offshore	Purple C		S-2	2014/11/14	18.45	18.45	0.00	14		4			
	12	OF-05-2	2,400,114.54	382,171.45	-0.06	0.06	Offshore	Bulue C	Chanel C	L-2	2014/10/28	26.45	26.45	0.00	15		11			
	13	OF-05-3	2,399,933.03	382,085.86	-0.99	0.99	Offshore	Bulue C		L-2	2014/10/30	21.45	21.45	0.00	14		7			
	14	OF-05-3a	2,399,517.85	381,960.07	-0.15	0.15	Offshore	Purple C		S-2	2014/11/7	20.45	20.45	0.00	17		3			
	15	OF-05-3b	2,399,110.71	381,819.92	-1.71	1.71	Offshore	Purple C		S-2	2014/11/2	19.45	19.45	0.00	15		4			
	Subtotal											243.70	243.70	0.00	164	0	69	0	1	0
Channel Area	1	LD-12-1	2,400,120.42	383,068.87	1.43	0.25	Wetland	Black C	Chanel C	L-2	2014/9/27	34.30	30.00	4.30	21	5	6		1	
	2	LD2-10a-1	2,400,119.95	382,463.85	0.45	0.40	Offshore	Green C	Chanel C	L-2	2014/10/14	21.30	21.30	0.00	15		4		2	
	3	LD2-11-1	2,400,120.34	382,669.58	1.50	0.30	Offshore	Green C	Chanel C	S-1	2014/9/19	39.30	30.00	9.30	22	10	3		4	
	4	LD2-11-1a	2,400,362.62	382,669.30	0.16	0.65	Offshore	Hadairo C		L-2	2014/10/9	21.45	21.45	0.00	14		4		3	
	5	LD2-11-1b	2,399,921.61	382,669.21	1.64	0.20	Offshore	Hadairo C		L-2	2014/10/1	22.45	22.45	0.00	15		3		3	
	6	LD2-12-1a	2,400,362.70	383,069.83	0.94	0.30	Wetland	Hadairo C		L-2	2014/9/21	22.45	22.45	0.00	16		4		1	
	7	LD2-12-1b	2,399,921.47	383,069.02	1.33	0.40	Wetland	Hadairo C		L-1	2014/10/31	23.45	23.45	0.00	15		6		1	
	8	LD2-13-1	2,400,518.79	383,469.98	1.38	0.40	Wetland	Green C		L-2	2014/10/14	22.45	22.45	0.00	16		3		3	
	9	LD2-13-2	2,400,120.52	383,473.46	1.34	0.35	Wetland	Green C	Chanel C	L-1	2014/9/2	25.45	25.45	0.00	20		5		1	
	10	LD2-13-3	2,399,680.09	383,469.28	1.06	0.45	Wetland	Green C		L-1	2014/11/1	22.95	22.95	0.00	15		7		1	
	Subtotal											255.55	241.95	13.60	169	15	45	0	20	0
Plant Area	1	PP-14-1	2,400,522.22	383,758.29	1.27	0.25	Wetland	Black C		L-1	2014/10/30	28.45	28.45	0.00	24		1		3	
	2	PP-14-2	2,400,120.09	383,745.41	1.02	0.45	Wetland	Black C	Plant C	L-1	2014/9/8	33.45	30.00	3.45	21	4	4		3	
	3	PP-14-3	2,399,680.04	383,757.14	1.26	0.25	Wetland	Black C		L-1	2014/11/6	50.28	30.00	20.28	23	21			6	
	4	PP-17-1	2,400,112.76	384,144.80	1.35	0.20	Wetland	Black C	Plant C	L-1	2014/9/10	26.45	26.45	0.00	22		1		3	
	5	PP-21-1	2,400,362.66	384,791.13	0.57	0.65	Wetland	Black C		L-1	2014/10/25	41.13	30.00	11.13	25	12	1		3	
	6	PP-21-2	2,400,114.87	384,808.77	1.12	0.30	Wetland	Black C	Plant C	L-1	2014/10/7	50.25	30.00	20.25	24	15	3		3	
	7	PP-21-3	2,399,801.12	384,785.11	1.03	0.30	Wetland	Black C		L-2	2014/10/24	45.28	30.00	15.28	24	16	3		2	
	8	PP-24-1	2,400,120.10	385,294.22	0.68	0.65	Wetland	Black C	Plant C	L-1	2014/10/18	50.26	30.00	20.26	24	16	3		2	
	9	PP3-15-1	2,400,362.64	383,867.15	1.08	0.30	Wetland	Yellow C		L-1	2014/10/28	7.45	7.45	0.00	5				2	
	10	PP3-15-2	2,399,802.40	383,860.15	1.32	0.10	Wetland	Yellow C		L-1	2014/11/8	17.45	17.45	0.00	11				6	
	11	PP3-17-1	2,400,362.66	384,179.15	1.00	0.20	Wetland	Yellow C		L-1	2014/10/27	12.95	12.95	0.00	8				4	
	12	PP3-17-2	2,399,802.42	384,179.17	0.97	0.50	Wetland	Yellow C		L-1	2014/11/9	16.45	16.45	0.00	12				4	
	13	PP3-19-1	2,400,363.25	384,491.45	1.25	0.10	Wetland	Yellow C		L-1	2014/10/27	17.45	17.45	0.00	11				6	
	14	PP3-19-2	2,400,120.46	384,491.55	0.87	0.55	Wetland	Yellow C	Plant C	L-1	2014/9/14	37.29	30.00	7.29	24	8	1		4	
	15	PP3-19-3	2,399,802.41	384,491.11	1.08	0.40	Wetland	Yellow C		L-1	2014/11/10	14.45	14.45	0.00	11				3	
	16	PP3-23-1	2,400,362.68	385,091.13	0.73	0.30	Wetland	Yellow C		L-1	2014/10/21	13.45	13.45	0.00	10		1		2	
	17	PP3-23-2	2,400,120.44	385,111.24	0.20	0.70	Wetland	Yellow C	Plant C	L-1	2014/10/10	14.45	14.45	0.00	10		2		2	
	18	PP3-23-3	2,399,786.85	385,101.27	-0.15	0.70	River	Yellow C		L-2	2014/10/16	9.45	9.45	0.00	7				2	
	19	PP3-24-1	2,400,366.09	385,292.70	0.95	0.35	Wetland	Yellow C		L-1	2014/10/20	13.45	13.45	0.00	10		1		2	
	20	PP3-24-2	2,399,904.30	385,281.19	0.89	0.55	Wetland	Yellow C		L-1	2014/10/19	12.45	12.45	0.00	9		1		2	
	Subtotal											512.29	414.35	97.94	315	92	22	0	64	0
Total							Offshore and River					357.65	348.35	9.30	237	10	83	0	15	0
							On-land (Wetland)					653.89	551.65	102.24	411	97	53	0	70	0
							Channel and Plant Areas					767.84	656.30	111.54	484	107	67	0	84	0
							All					1,011.54	900.00	111.54	648	107	136	0	85	0

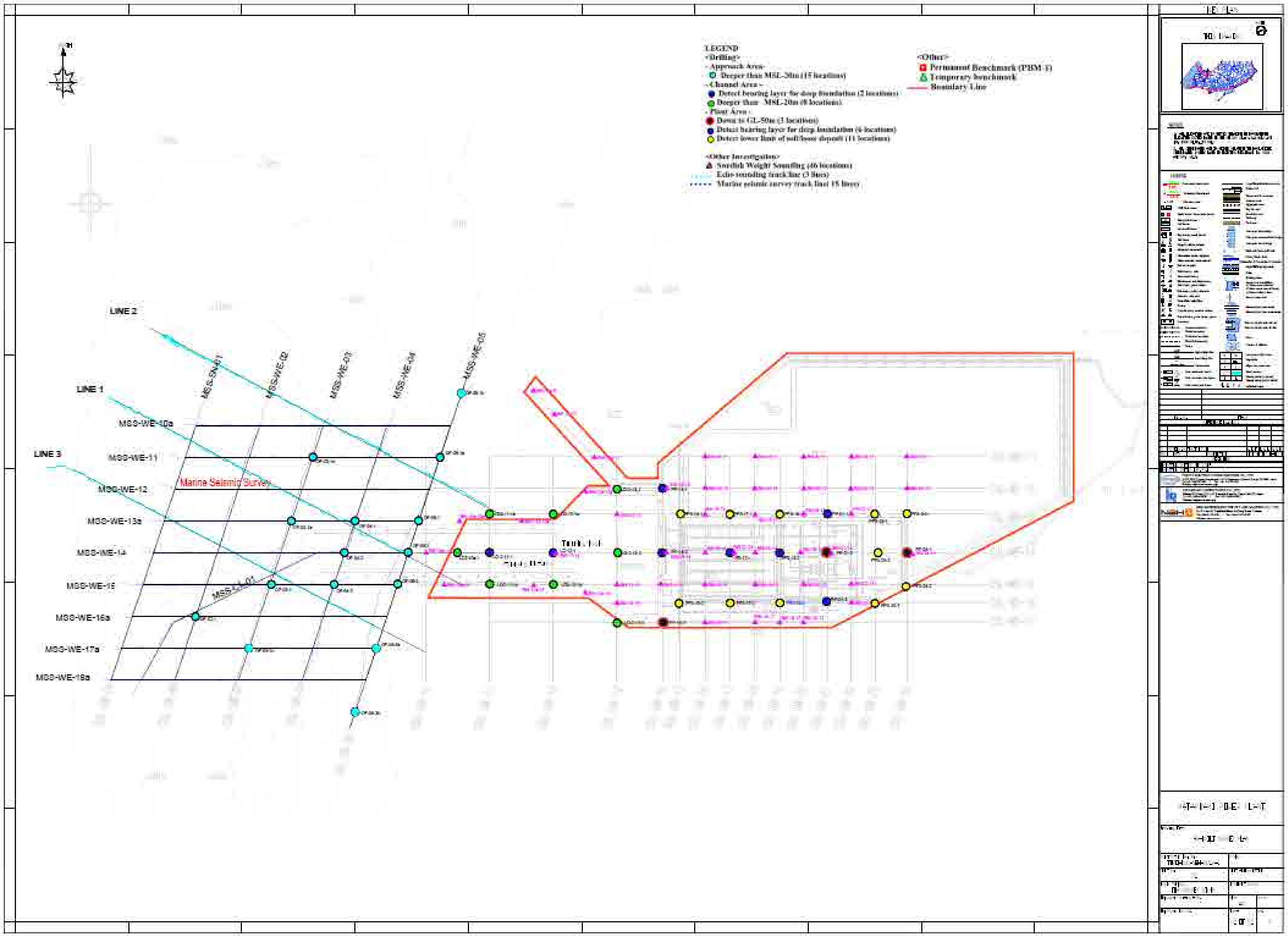


Figure 17.5-1 Location for the SI Works

(2) Stratification

Based on the results of soil investigation, some soil profiles have been prepared to provide a better understanding of the sub-soil conditions at the site and are shown in Figures 17.5-2 to 17.5-12. As can be seen from these soil profiles, soil layers under the site are classified and named as follows:

a) Beach Sand Layer: Bs
b) Alluvial Clayey Soil Layers: Ac-1, Ac-2 and Ac-3
c) Alluvial Sandy Soil Layers: As-1 and As-2
d) Diluvial Clayey Soil Layers: Dc
e) Diluvial Sandy Soil Layers: Ds

Some characteristics of each layer are described below:

1) Beach Sand (Bs)

Beach Sand (hereinafter referred as “Bs”) was encountered only on the offshore area of the coast lines. The Bs layer is a fluid material, and the sand is influenced by tidal fashion. The Bs layer was deposited on the Ac layer and As layer with thicknesses ranging from 0.6m to 2.6m. The Bs layer is loose to medium dense in consistency as indicated by the SPT N-values of 4 to 24. It is brown, grey in colour, and contains sea shell fragments, organic matter, and mica fragments.

2) Alluvial Clayey Soil (Ac-1, Ac-2 and Ac-3)

Alluvial clayey soil was encountered throughout the entire area of the Project site. The types of this soil were: alluvial clayey soil -1 (hereinafter referred as “Ac-1”), alluvial clayey soil-2 (hereinafter referred as “Ac-2”), and alluvial clayey soil-3 (hereinafter referred as “Ac-3”).

The thicknesses of the Ac-1 layer ranged from 0.8 to 12.7m. A contour map of the thicknesses of the Ac-1 layer is shown in Figure 17.5-13. In relation to the distribution of the Ac-1 layer, It is thinly distribution in offshore area and east of the power plant area; and it is thickly distributed on land in the central part of the site. The thickest layer of the Ac-1 is 12.7 m at PP-14-3 in the relevant soil investigation presented below. The Ac-1 layer is very soft to soft in consistency as indicated by the SPT N-values of 4 or less. It is grey, greenish grey, brownish grey in colour, and contains some traces of organic matters, mica fragments, and sea shell fragments.

The Ac-2 layer was found underneath the Ac-1 layer with thicknesses ranging from 0.9m to 8.7 m. The Ac-2 layer is medium stiff to stiff in consistency as indicated by the SPT N-values of 4 to 15. It is grey, yellowish brown in colour, and contains organic matter, mica fragments, sea shell fragments, and fine grained sand.

The Ac-3 layer was found as a pocket in and also underneath the As-2 layer with thicknesses ranging from 1.1m to 9.0 m. The Ac-3 layer is very stiff in consistency as indicated by the SPT N-values of 15 to 30. It is grey in colour, and contains organic matter, mica fragments, sea shell fragments, and fine grained sand.

3) Alluvial Sandy Soil (As-1 and As-2)

Alluvial sandy soil was encountered throughout the entire area of the site. The types of this soil ware : alluvial sandy soil-1 (hereinafter referred as “As-1”) and alluvial sandy soil-2 (hereinafter referred as “As-2”). Alluvial sandy soil is mainly fine grained sand.

The As-1 layer was found underneath the Ac-1 or Ac-2 layers at the power plant area and at the top side of the As-2 layer by the land area with thicknesses ranging from 1.1m to 6.0m. The As-1 is very loose to loose in consistency as indicated by the SPT N-values of 0 to 10. It is grey, brown in colour, and contains organic matter, mica fragments, and sea shell fragments.

The As-2 layer was found underneath the Ac-1 and Ac-2 layers with thicknesses ranging from 0.75m to 21.85m. The As-2 layer is medium dense to dense in consistency as indicated by the SPT N-values of 10 to 30. It is light grey, grey, brownish grey and yellowish grey in colour, and contains sea shell fragments, organic matter, mica fragments, and occasionally laminated silt.

4) Diluvial Sandy Soil (Dc)

Diluvial clayey soil (hereinafter referred as “Dc”) was encountered the land area and power plant area of the Project site.

The Dc layer was found underneath the As-2 layer. The Dc layer is hard in consistency as indicated by the SPT N-values of more than 30. It is grey in colour, and contains fine grained sand, sea shell fragments, organic matter, mica fragments, and occasionally lenses of sand and laminated silty sand.

5) Diluvial Sandy Soil (Ds)

Diluvial sandy soil (hereinafter referred as “Ds”) was encountered the land area and power plant area of the project site.

The Ds layer was found underneath the Dc layer. The Ds layer is very dense in consistency as indicated by the SPT N-values of more than 50. It is light grey, grey and yellowish gray in colour.

A contour map for the elevation of the top of the diluvial soil is shown in Figure 17.5-14. The top of elevation ranges from about 15m to 24m and gradually becomes deeper from the east area of the power plant to the land area. The deepest elevation of the top of the diluvial soil is 24.60m at PP-14-3.

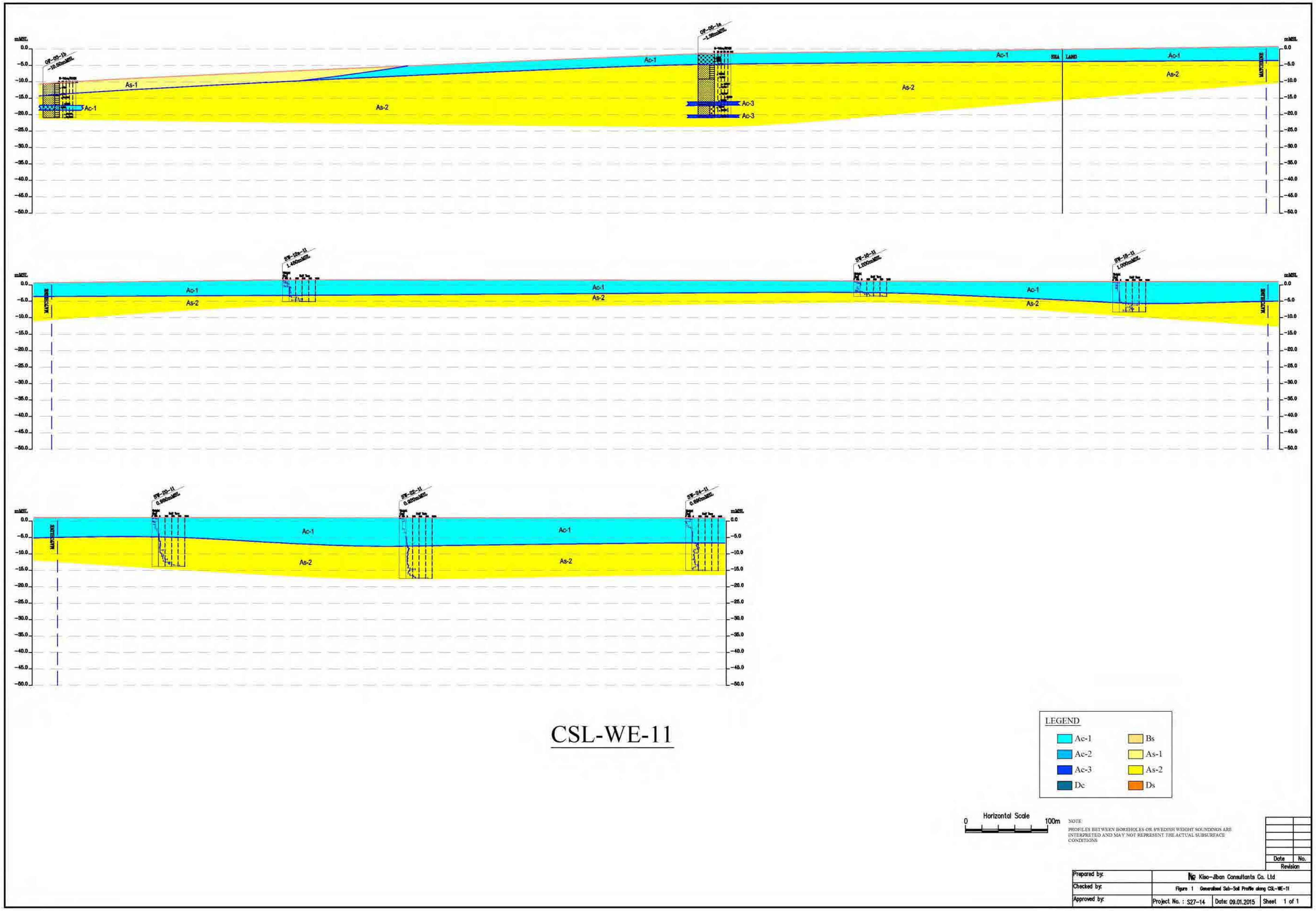


Figure 17.5-2 Soil Profile for CSL-WE-11

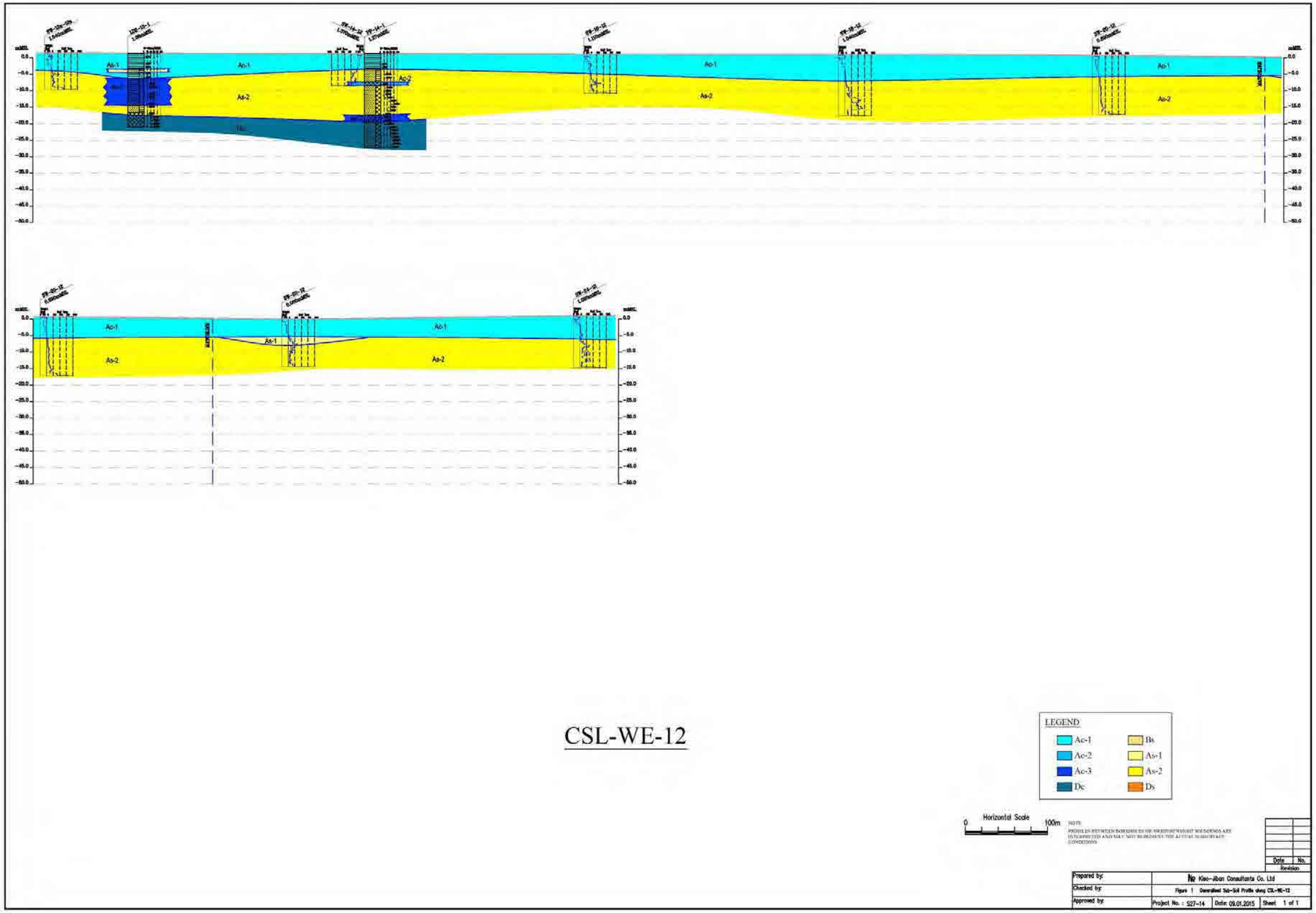


Figure 17.5-3 Soil Profile for CSL-WE-12

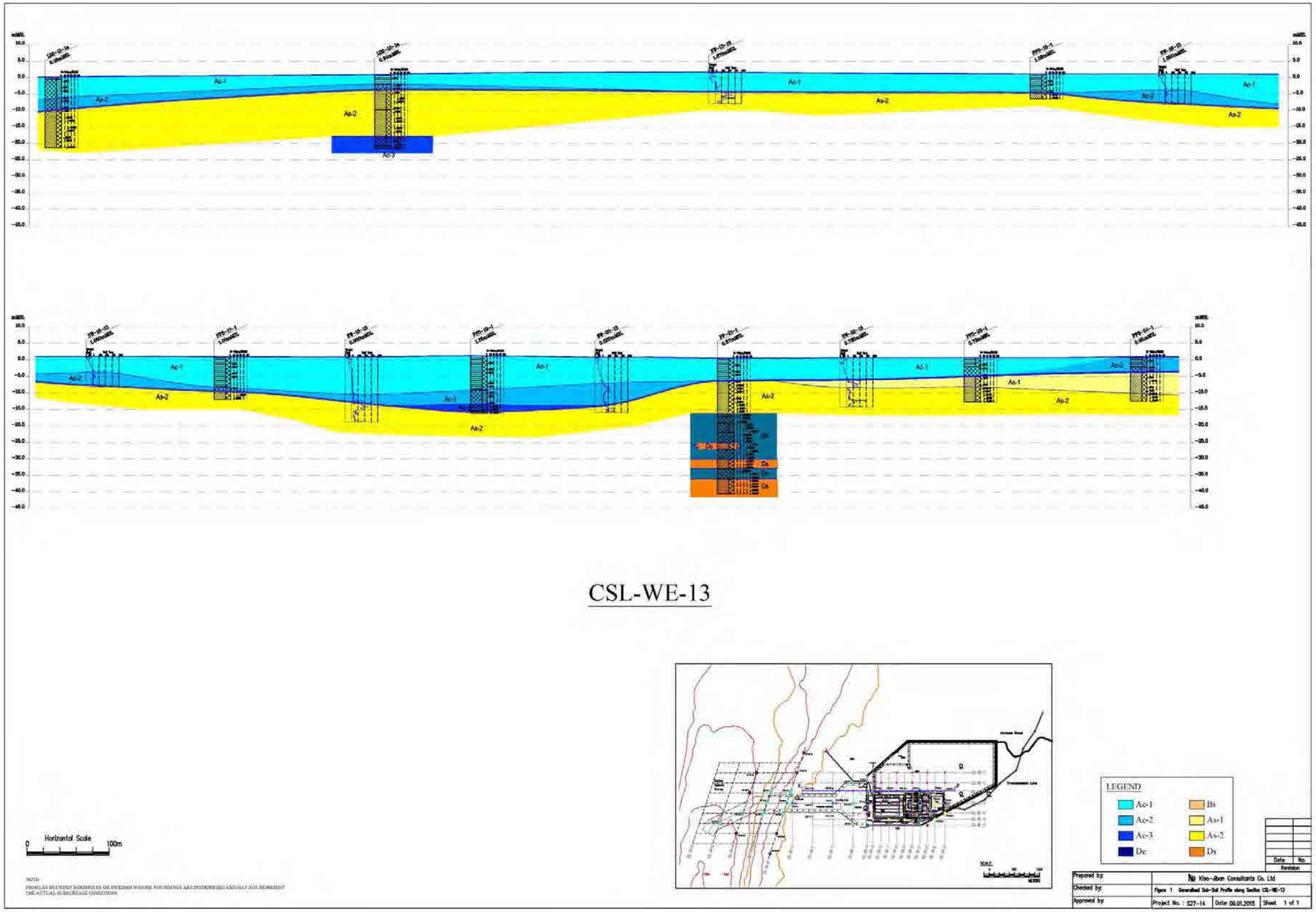


Figure 17.5-4 Soil Profile for CSL-WE-13

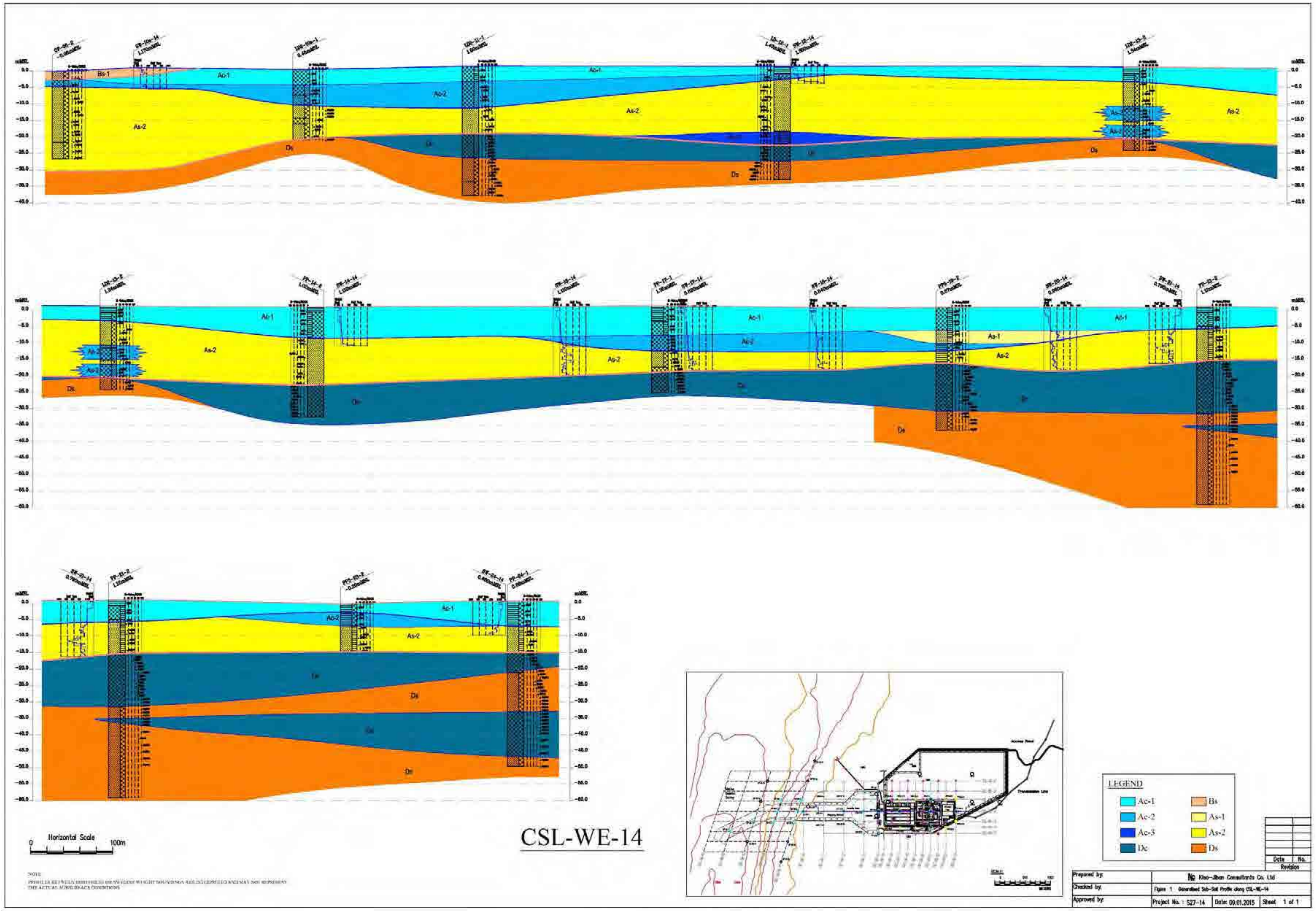


Figure 17.5-5 Soil Profile for CSL-WE-14

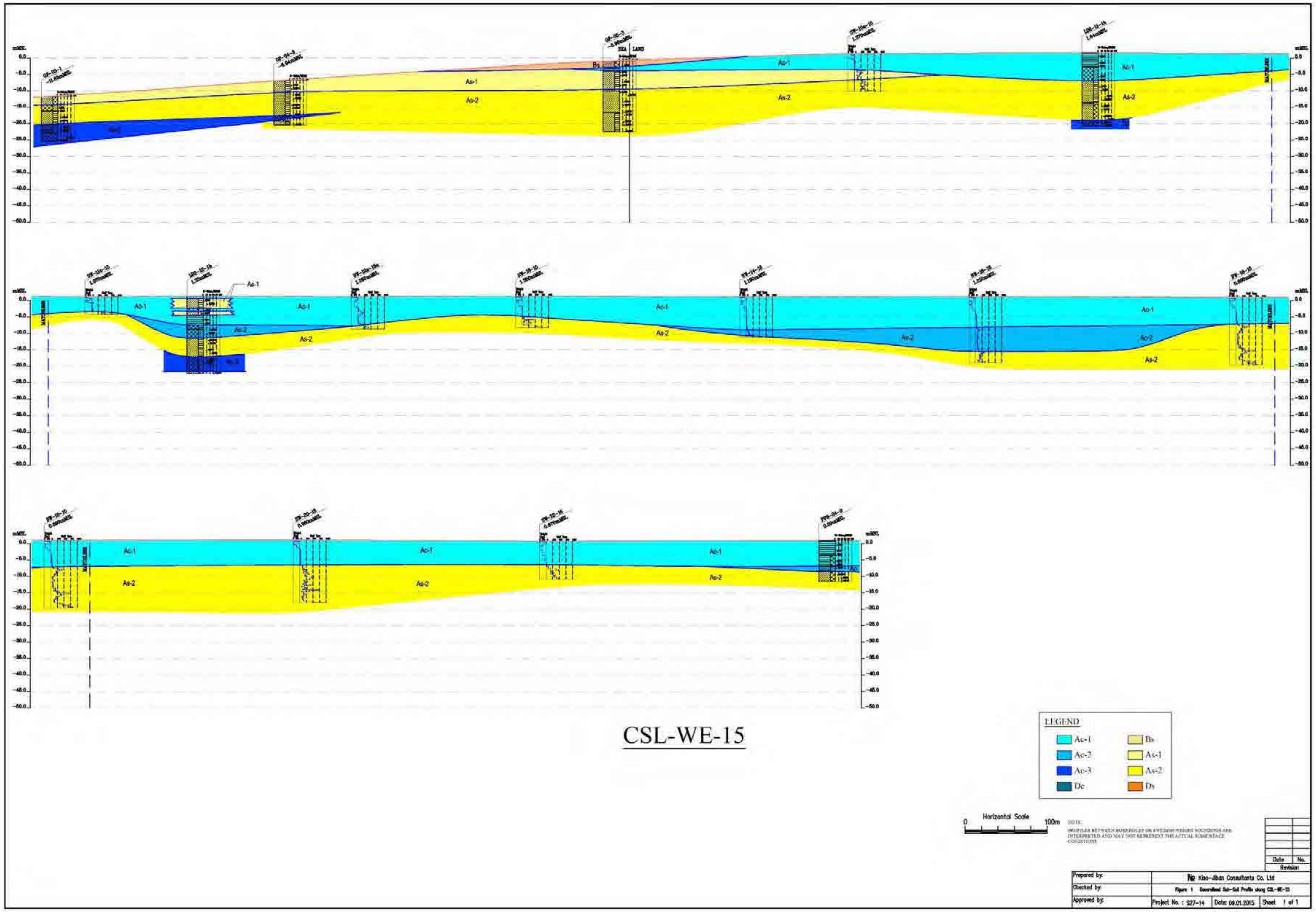


Figure 17.5-6 Soil Profile for CSL-WE-15

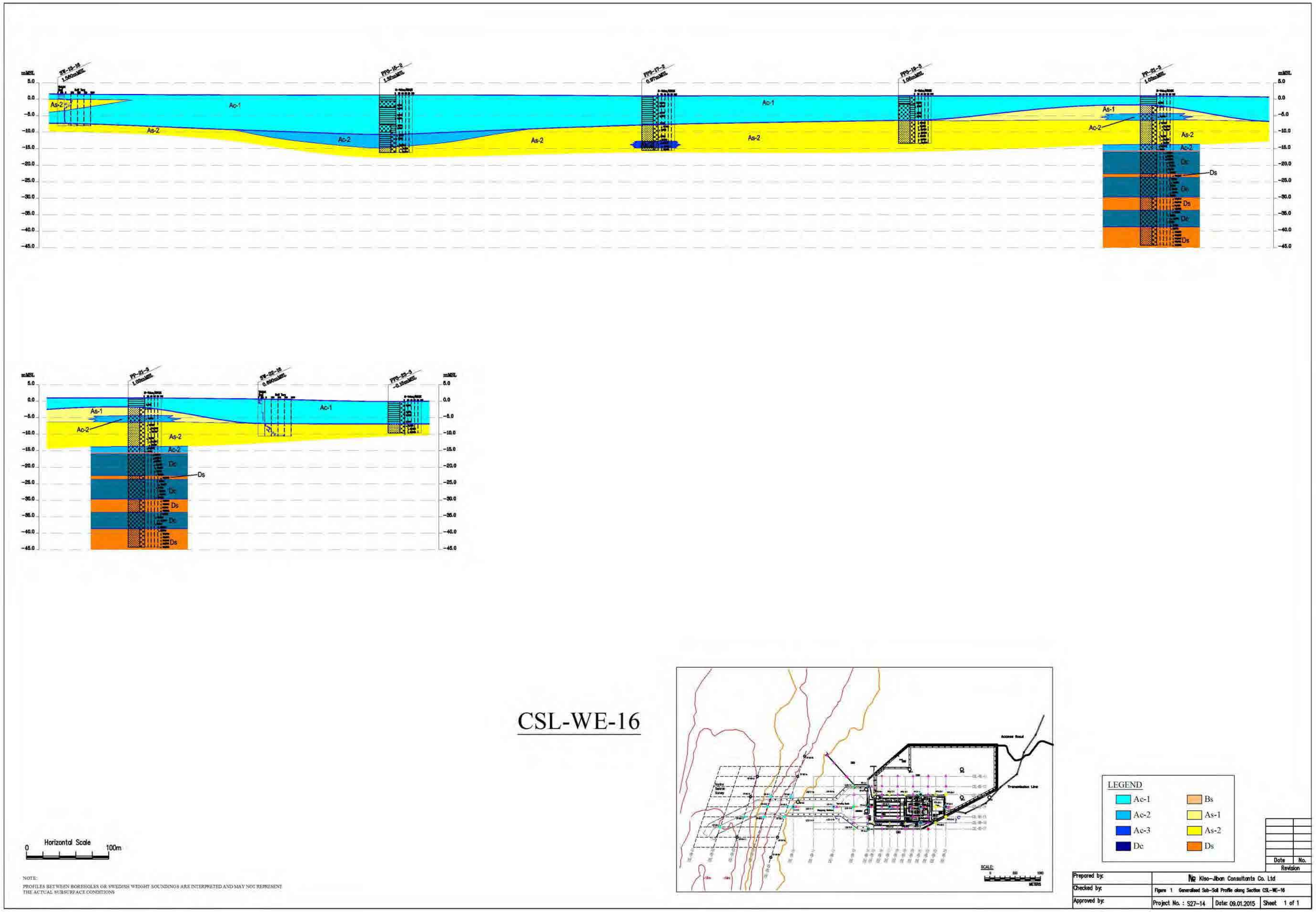


Figure 17.5-7 Soil Profile for CSL-WE-16

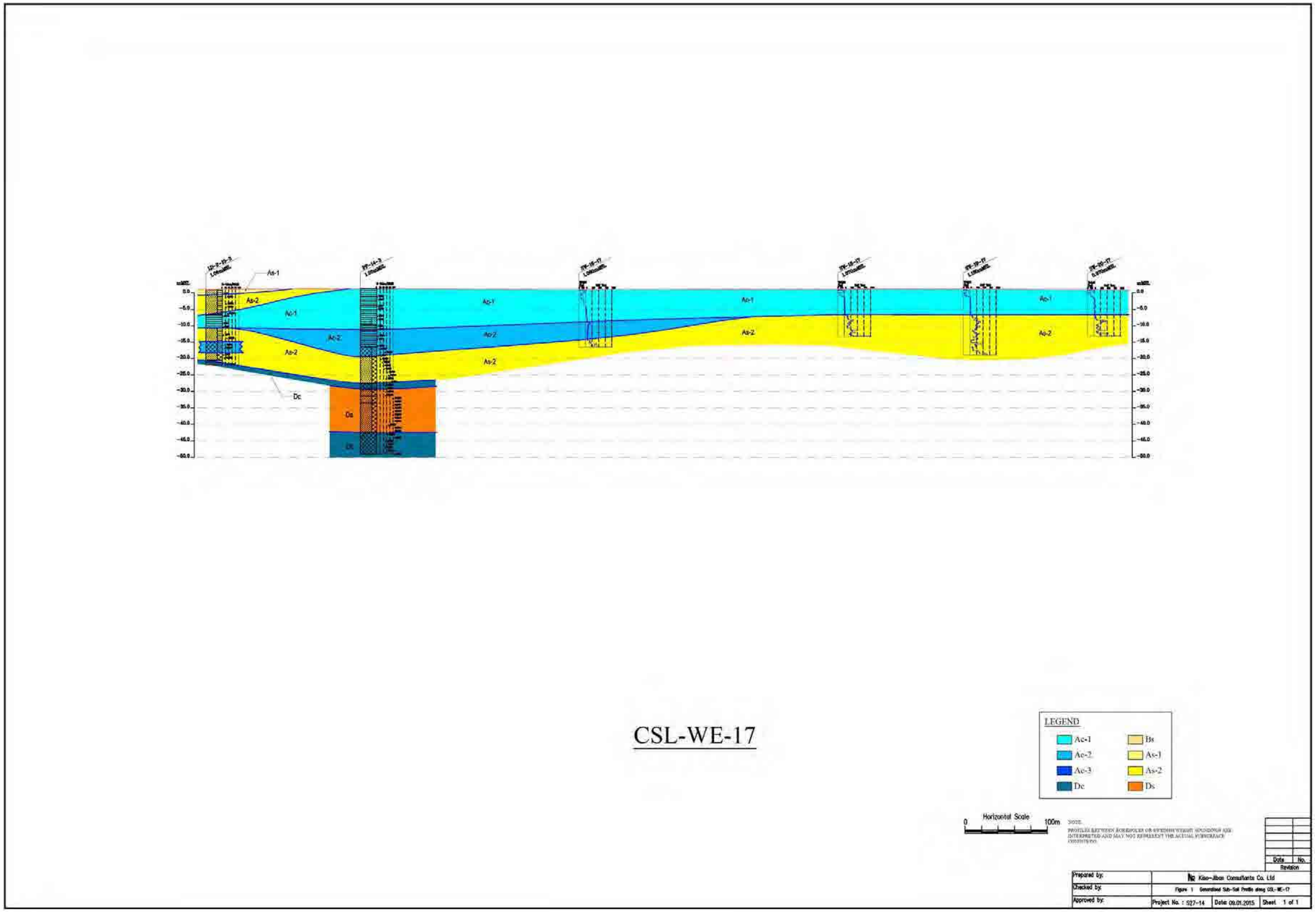


Figure 17.5-8 Soil Profile for CSL-WE-17

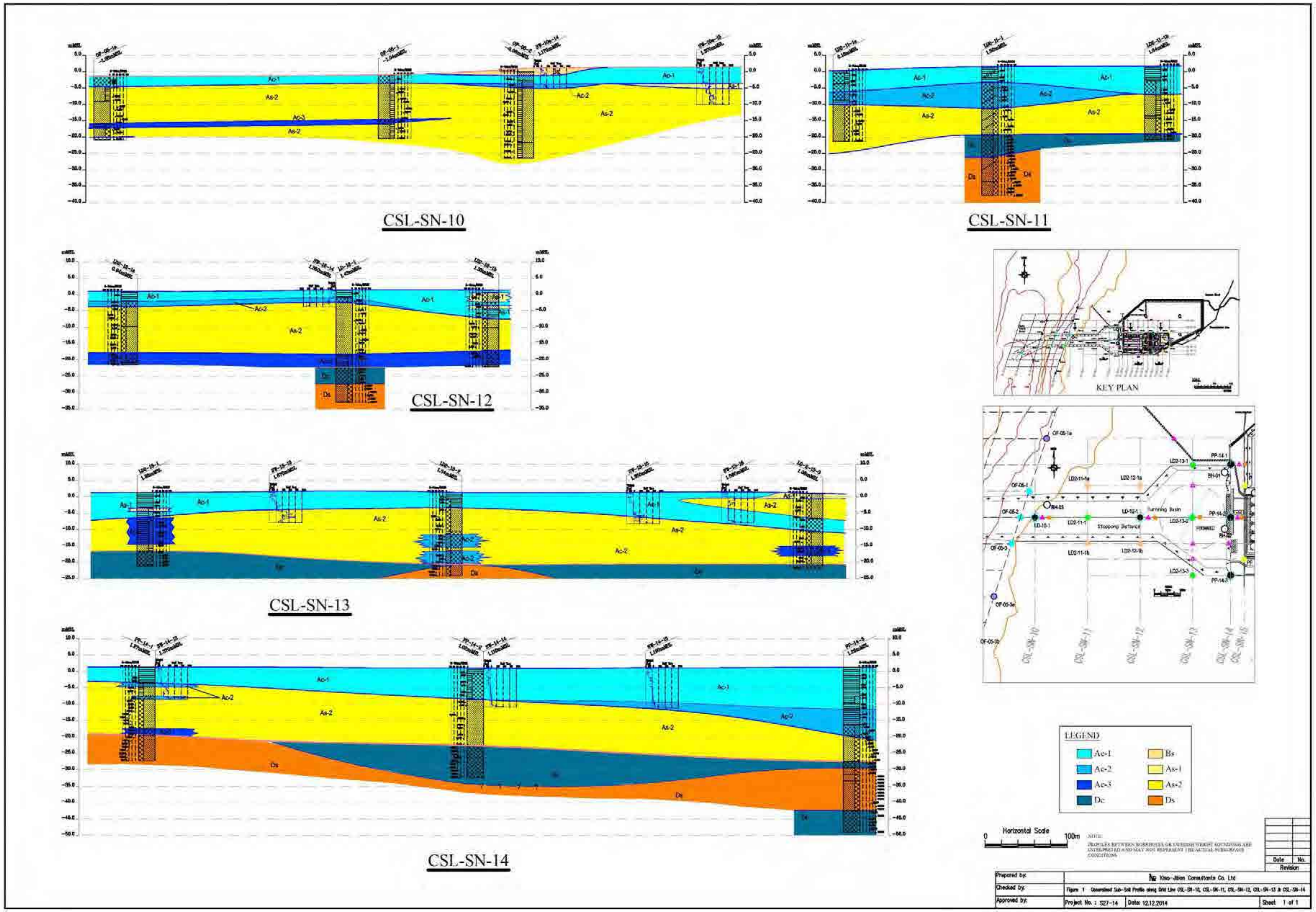


Figure 17.5-9 Soil Profile for CSL-SN-10 and CSL-SN-14

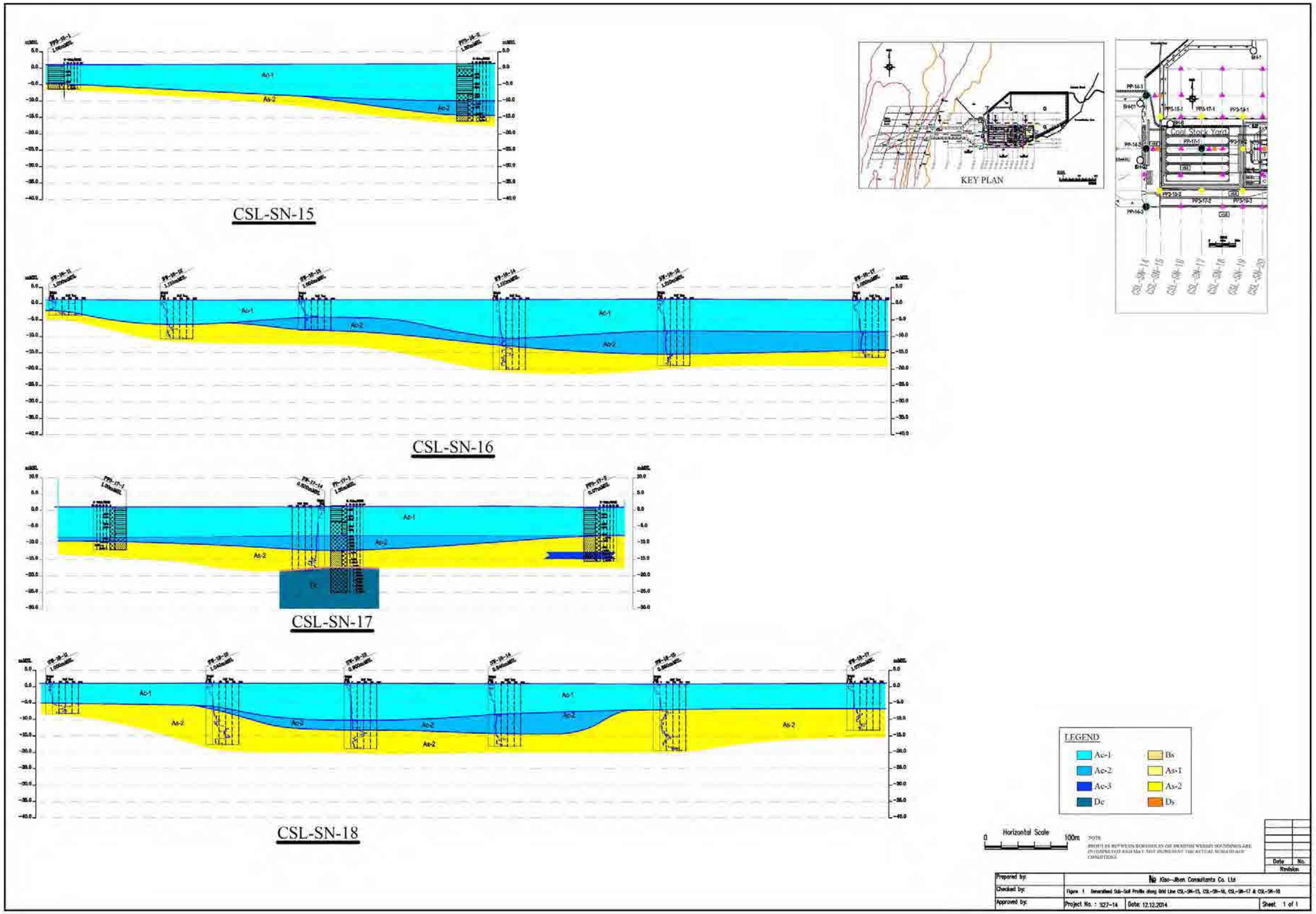


Figure 17.5-10 Soil Profile for CSL-SN-15 and CSL-SN-18

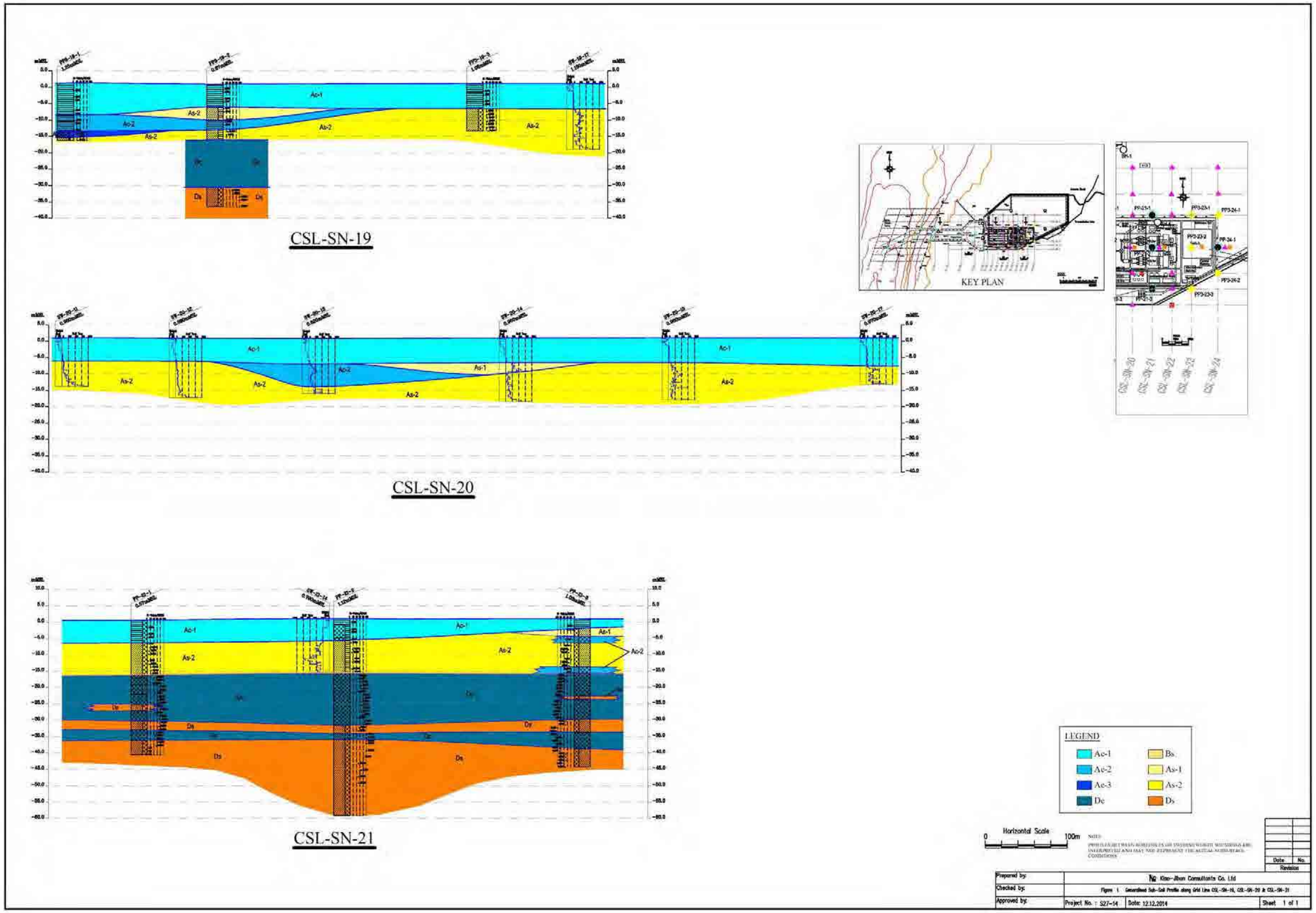


Figure 17.5-11 Soil Profile for CSL-SN-19and CSL-SN-21

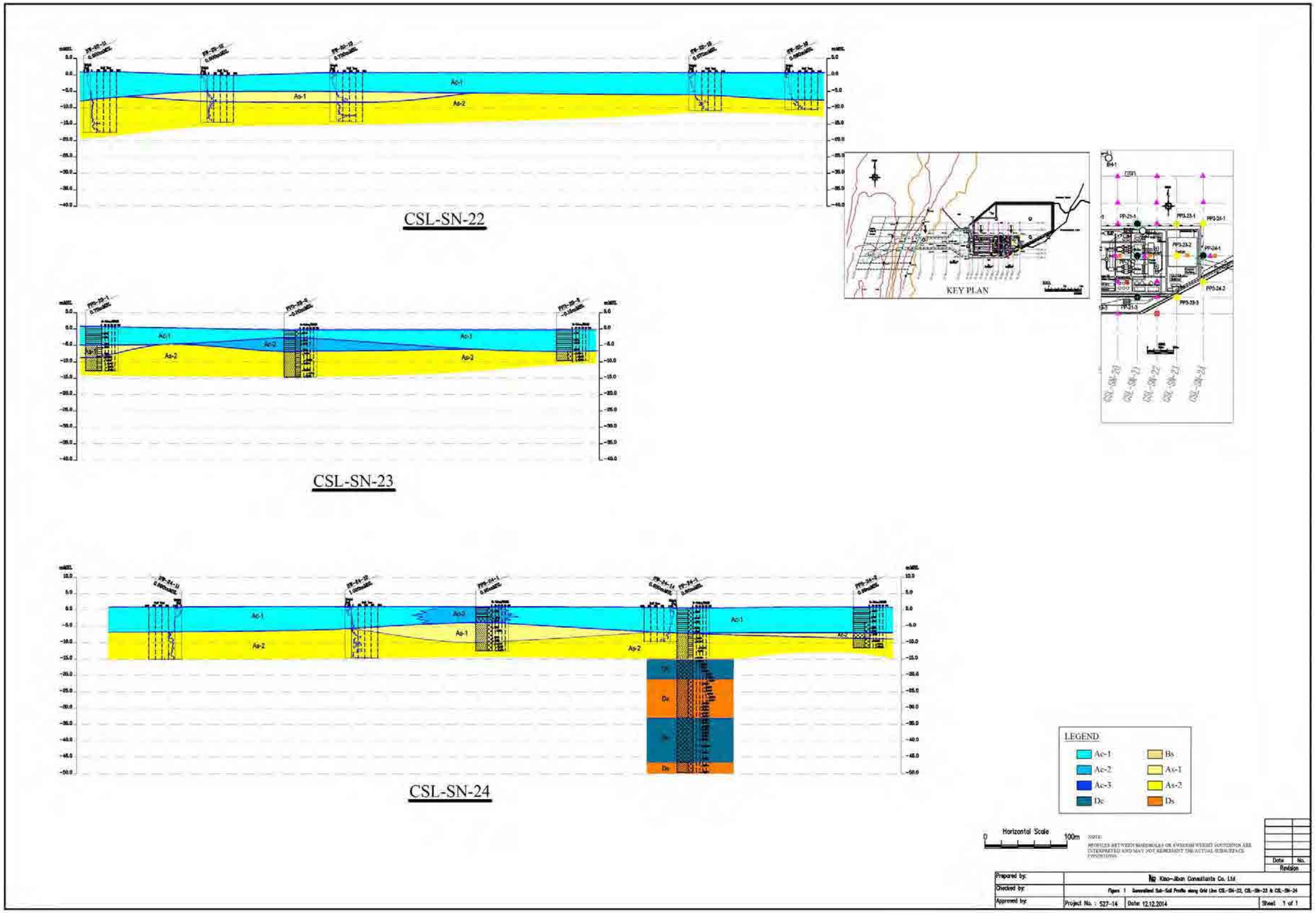


Figure 17.5-12 Soil Profile for CSL-SN-22 and CSL-SN-24

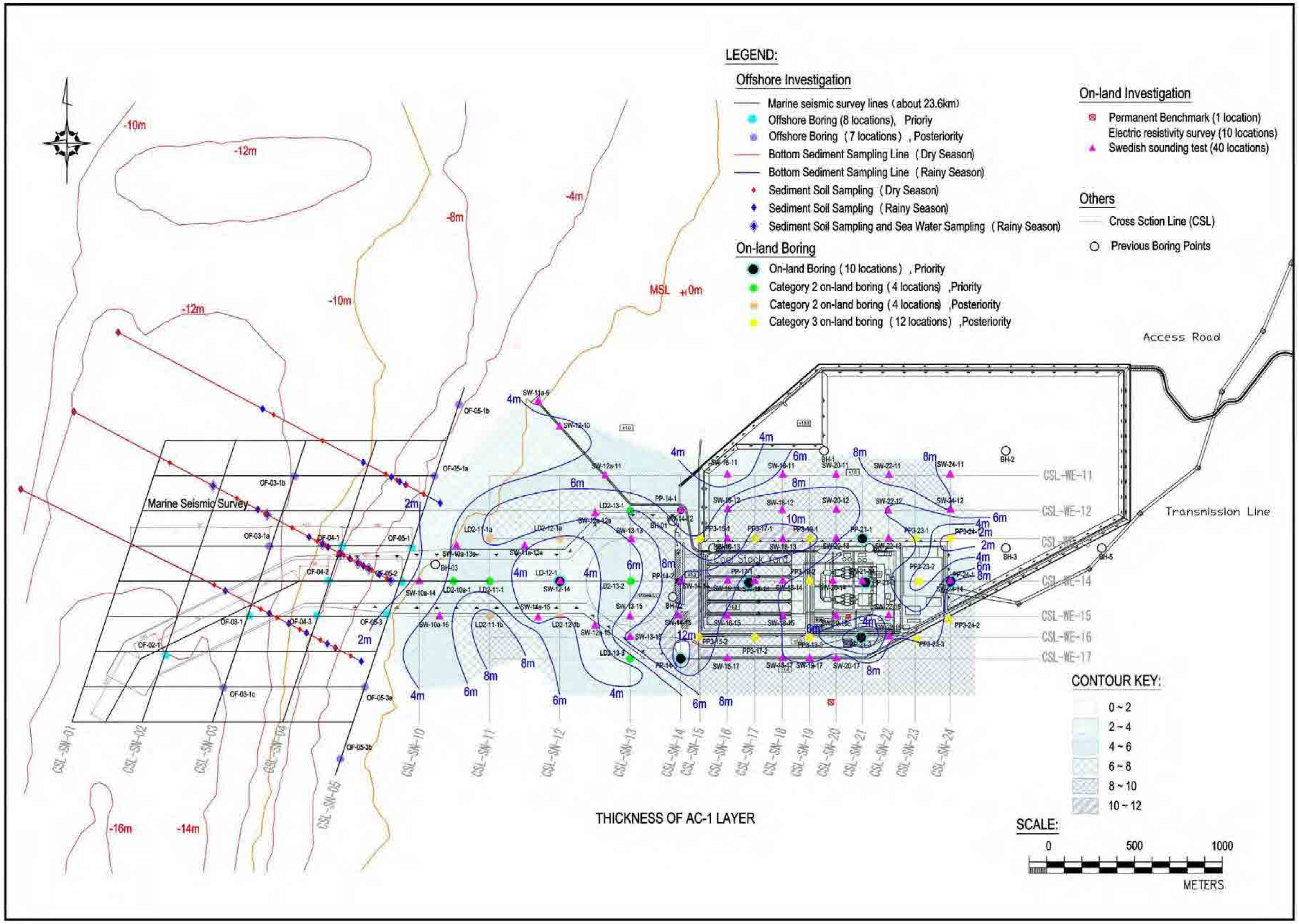


Figure 17.5-13 Contour Map for the Thickness of the Ac-1 Layer

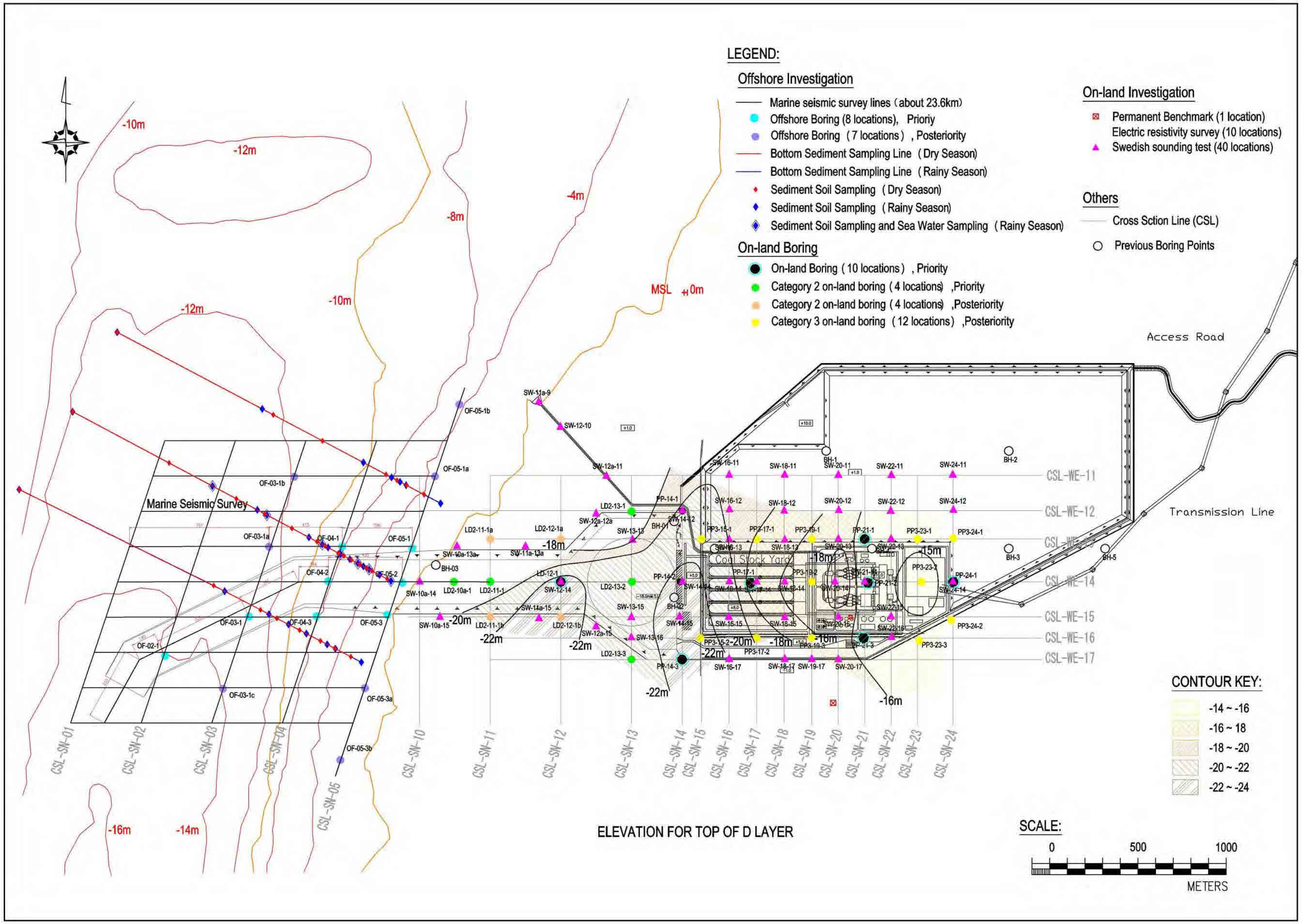


Figure 17.5-14 Contour Map for the Elevation of the Top of the Dilvial Soil

The results of each boring point are shown in the Appendix of the drilling log. The stratigraphic correlation of the Project site is summarized as follows:

Table 17.5-2 The Stratigraphic Correlation of the Project Site

Layer	Distribution of Area	Thickness of Layer (m)	Color	Relative Density or Consistency	Material	N value
Bs	Land Offshore	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
Ac-2	Land Power Plant Offshore	0.9 to 8.7	Grey	Medium Stiff to Stiff	Clayey Soil	4 to 15
Ac-3	Land Power Plant Offshore	1.1 To 9.0	Grey	Stiff to Hard	Clayey Soil	15 to 30
As-1	Land Power Plant Offshore	1.1 to 6.0	Grey	Very Loose to Loose	Sandy Soil	0 to 10
As-2	Land Power Plant Offshore	0.7 to 21.9	Light Grey, Brownish Grey, Yellowish Grey,	Medium Dense to Dense	Sandy Soil	10 to 50
Dc	Land Power Plant	1.4 to 17.3	Grey	Hard	Clayey Soil	≥ 30
Ds	Land Power Plant	0.5 to 13.2	Light Grey, Grey, Yellowish Grey	Very Dense	Sandy Soil	≥ 50

The SPT N-values of each layer are summarized as follows:

Table 17.5-3 Range of N-value for Each Layer

Layer	SPT-N Value	Term
Ac-1	0 to 4	Very Soft to Soft
Ac-2	4 to 15	Medium Stiff to Stiff
Ac-3	15 to 30	Stiff to Hard
As-1	0 to 10	Very Loose to Loose
As-2	10 to 50	Medium Dense to Dense
Dc	More than 30	Hard
Ds	More than 50	Very Dense
Bs	4 to 24	Very Loose to Medium Dense

(3) Standard penetration test

Each layer was separated according to the plotted N-value results. The SPT N-values were plotted against depth and elevation in Figure 17.5-15.

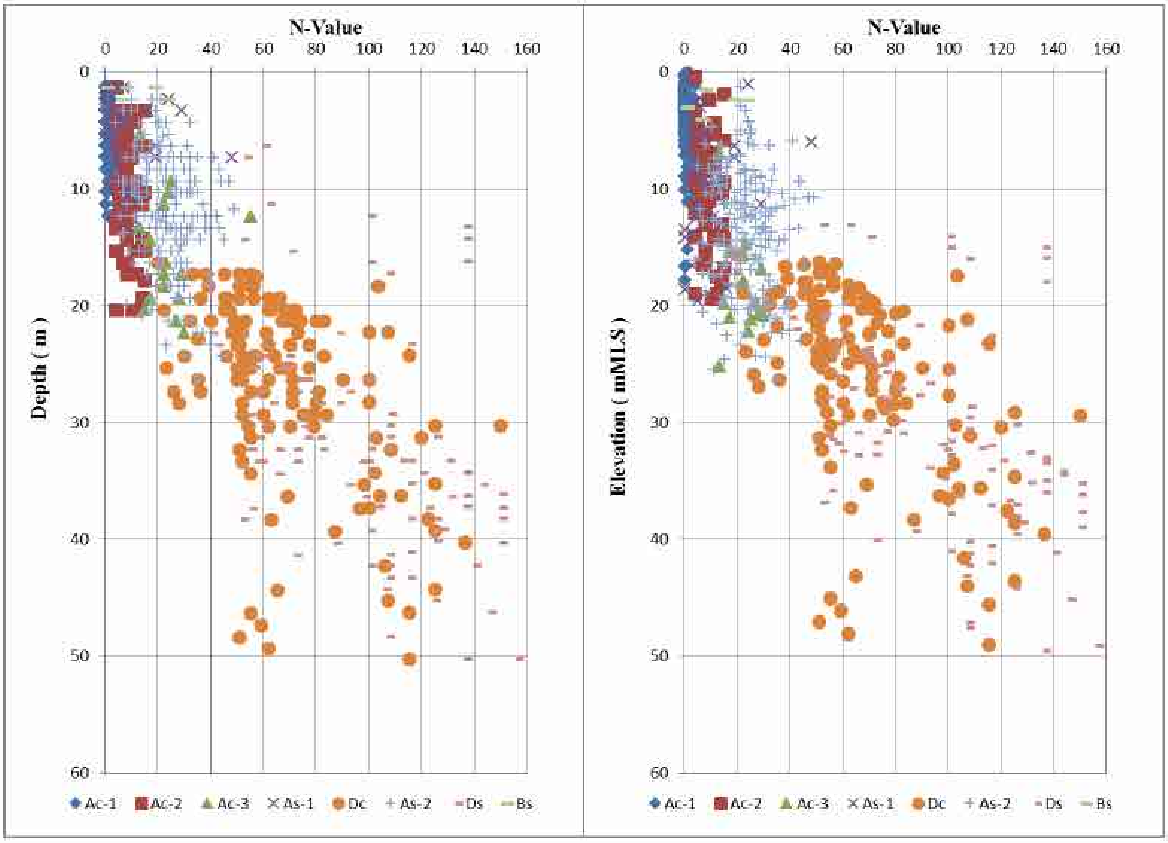


Figure 17.5-15 N-value Plotted against Depth and Elevation

(4) Marine seismic surveys

In order to understand the relevant geological characteristics, marine seismic surveys (MSS) were carried out on 15 survey lines. The quantities of the surveys are shown in Table 17.5-4, with the locations of the surveys in Figure 17.5-16, and the results of the surveys for each line in Figure 17.5-17 (lines 1-15).

Table 17.5-4 Quantities of the Marine Seismic Surveys

		Line No	point	Planned Coordinate		Completed on	Direction	GPS Antenna Position (m)			Profile, Single (m)			Profile, Multiple (m)			Record	Reference Borehole	Remarks
				North (m)	East (m)			North or West Point	South or East Point	Length	North or West Point	South or East Point	Length	North or West Point	South or East Point	Length			
SN Direction Lines	1	MSS-SN-01	n	2,400,920	380,825	2014/11/30	sn	-164.0	1,736.0	1,900.0	-142.9	1,757.1	1,900.0	-142.7	1,792.4	1,935.1	24 ch	-	Completion
			s	2,399,320	380,292														
	2	MSS-SN-02	n	2,400,920	381,225	2014/11/27	ns	-200.0	1,789.7	1,989.7	-220.5	1,769.2	1,989.7	-256.0	1,686.5	1,942.5	24 ch	OF-02-1	Started
			s	2,399,320	380,692														
	3	MSS-SN-03	n	2,400,920	381,625	2014/11/29	ns	-57.0	1,829.0	1,886.0	-77.5	1,805.7	1,883.2	-112.0	1,807.0	1,919.0	24 ch	OF-03-1b,1a,1,1c	
			s	2,399,320	381,092														
	4	MSS-SN-04	n	2,400,920	382,025	2014/11/28	sn	-114.0	1,706.0	1,820.0	-93.5	1,726.5	1,820.0	-92.6	1,762.4	1,855.0	24 ch	OF-04-1,2,3	
			s	2,399,320	381,492														
	5	MSS-SN-05	n	2,401,220	382,525	2014/11/28	ns	-288.4	2,030.0	2,318.4	-308.5	2,011.3	2,319.8	-344.8	2,009.5	2,354.3	24 ch	OF-05-1b,1a,1,2,3,3a,3b	
			s	2,399,020	381,791														
		Subtotal				5				9,914.1			9,912.7			10,005.9			
WE Direction Lines	6	MSS-WE-10a	w	2,400,920	380,825	2014/11/28	we	-80.0	1,413.5	1,493.5	-100.5	1,392.2	1,492.7	-117.7	1,392.2	1,509.9	12 ch	-	
			e	2,400,920	382,425														
	7	MSS-WE-11	w	2,400,720	380,758	2014/11/28	ew	-100.0	1,300.0	1,400.0	-77.6	1,320.5	1,398.1	-79.5	1,336.7	1,416.2	12 ch	Of-03-1b,Of-05-1a	
			e	2,400,720	382,358														
	8	MSS-WE-12	w	2,400,520	380,692	2014/11/28	we	-100.0	1,409.0	1,509.0	-120.5	1,377.3	1,497.8	-136.6	1,384.3	1,520.9	12 ch	-	
			e	2,400,520	382,292														
	9	MSS-WE-13a	w	2,400,320	380,625	2014/11/28	ew	-100.0	1,377.0	1,477.0	-68.2	1,397.5	1,465.7	-75.8	1,414.7	1,490.5	12 ch	OF-03-1a,OF-04-1,OF-05-1	
			e	2,400,320	382,225														
	10	MSS-WE-14	w	2,400,120	380,558	2014/11/28	we	-80.0	1,385.0	1,465.0	-100.5	1,359.7	1,460.2	-117.7	1,359.5	1,477.2	12 ch	OF-04-2,OF-05-2	
			e	2,400,120	382,159														
	11	MSS-WE-15	w	2,399,920	380,492	2014/11/29	ew	-149.0	1,290.0	1,439.0	-128.5	1,310.5	1,439.0	-128.5	1,326.5	1,455.0	12 ch	OF-03-1,OF-04-1,OF-05-3	
			e	2,399,920	382,092														
	12	MSS-WE-16a	w	2,399,720	380,425	2014/11/29	we	-52.0	1,323.0	1,375.0	-72.5	1,302.5	1,375.0	-88.7	1,302.5	1,391.2	12 ch	OF-02-1	
			e	2,399,720	382,025														
	13	MSS-WE-17a	w	2,399,520	380,358	2014/11/29	ew	-158.0	1,251.0	1,409.0	-134.5	1,264.5	1,399.0	-133.6	1,288.7	1,422.3	12 ch	OF-03-1c,OF-05-3a	
			e	2,399,520	381,958														
	14	MSS-WE-18a	w	2,399,320	380,292	2014/11/29	we	-53.0	1,319.0	1,372.0	-73.5	1,298.5	1,372.0	-90.7	1,295.4	1,386.1	12 ch	-	
			e	2,399,320	381,892														
		Subtotal				9				12,939.5			12,899.5			13,069.3			
CC Line	15	MSS-CC-01	a	2,399,320	380,482	2014/11/30	sw-ne	-147.0	1,416.5	1,563.5	-100.8	1,416.5	1,517.3	-126.5	1,416.5	1,543.0	12 ch	OF-02-1,OF-03-1,	Channel Center Line
			b	2,399,520	380,593														
			c	2,399,679	380,881														
			d	2,400,120	381,585														
			d	2,400,120	381,585	2014/11/30	we	1,416.5	1,609.0	-	1,416.5	1,835.5		1,416.5	1,645.6	-	12 ch	OF-04-2,OF-05-2	
			e	2,400,120	382,159														
			f	2,400,120	382,869														
		Subtotal				1				1,563.5			1,517.3			1,543.0			
		Total				15	lines			24,417.1			24,329.5			24,618.2			

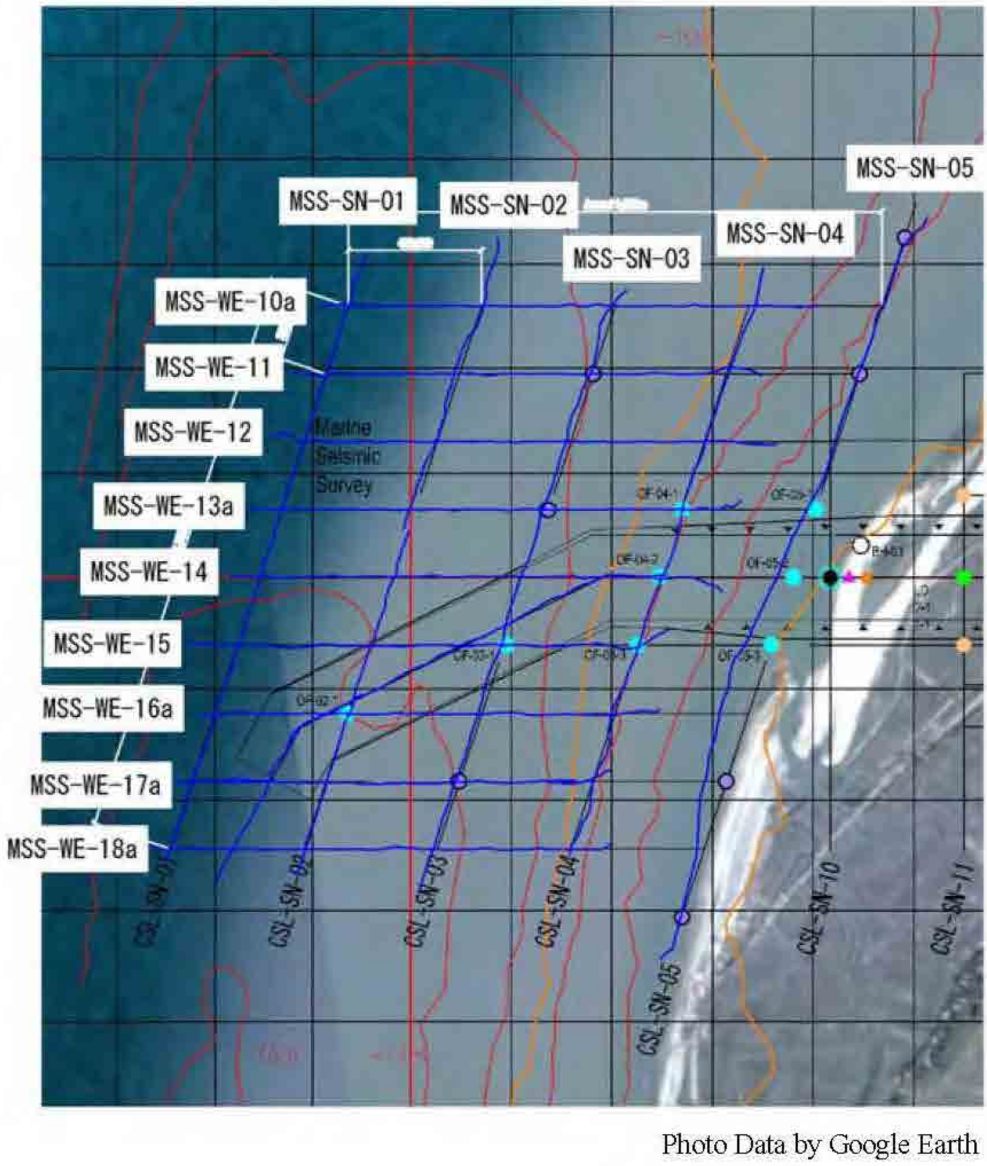


Figure 17.5-16 Locations of the Survey

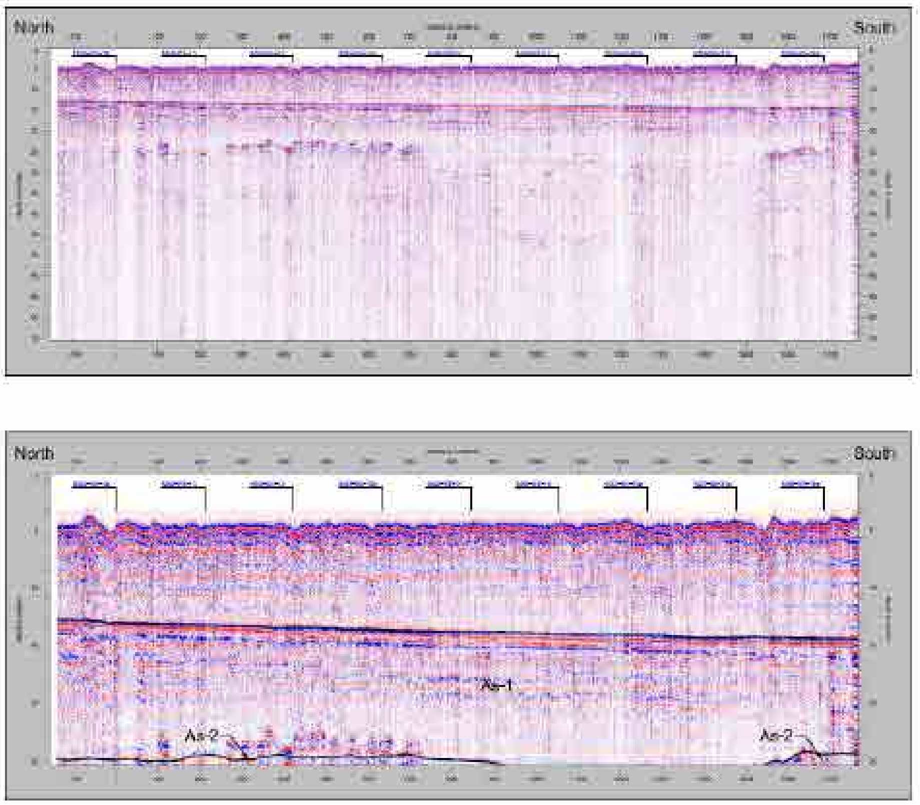


Figure 17.5-17(1) Soil Profile (Survey Line：MSS-CL-01)

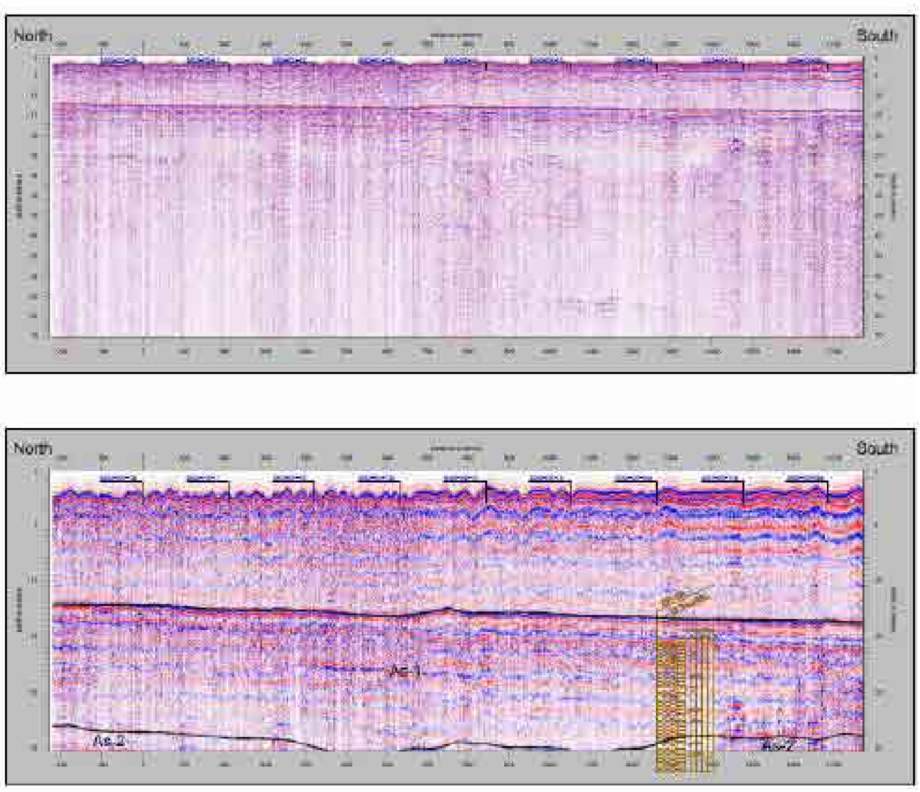


Figure 17.5-17(2) Soil Profile (Survey Line：MSS-CL-02)

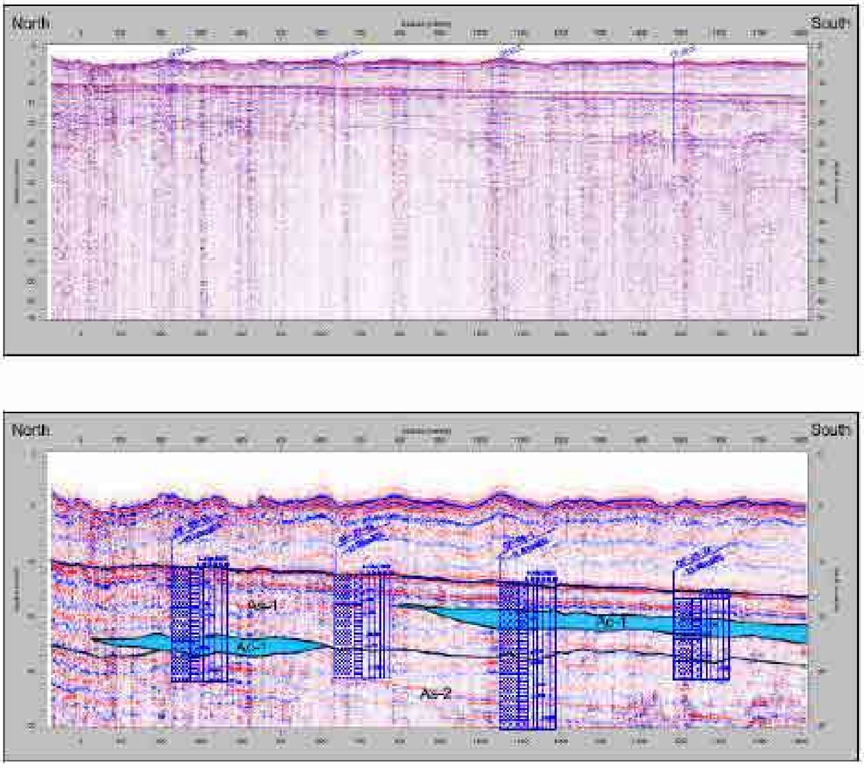


Figure 17.5-17(3) Soil Profile (Survey Line：MSS-SN-03)

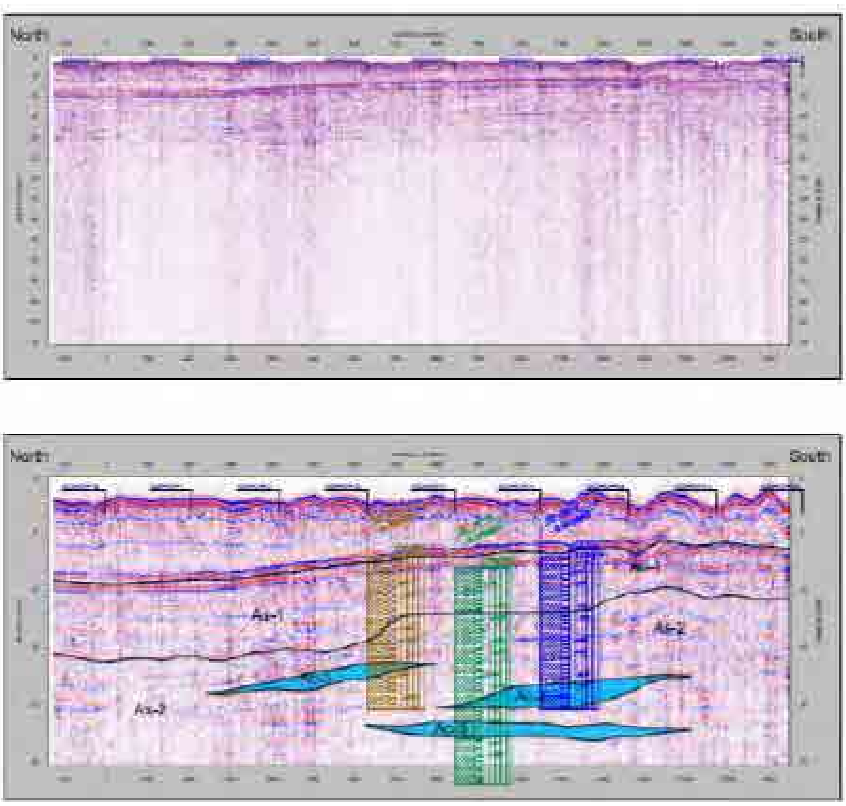


Figure 17.5-17(4) Soil Profile (Survey Line：MSS-SN-04)

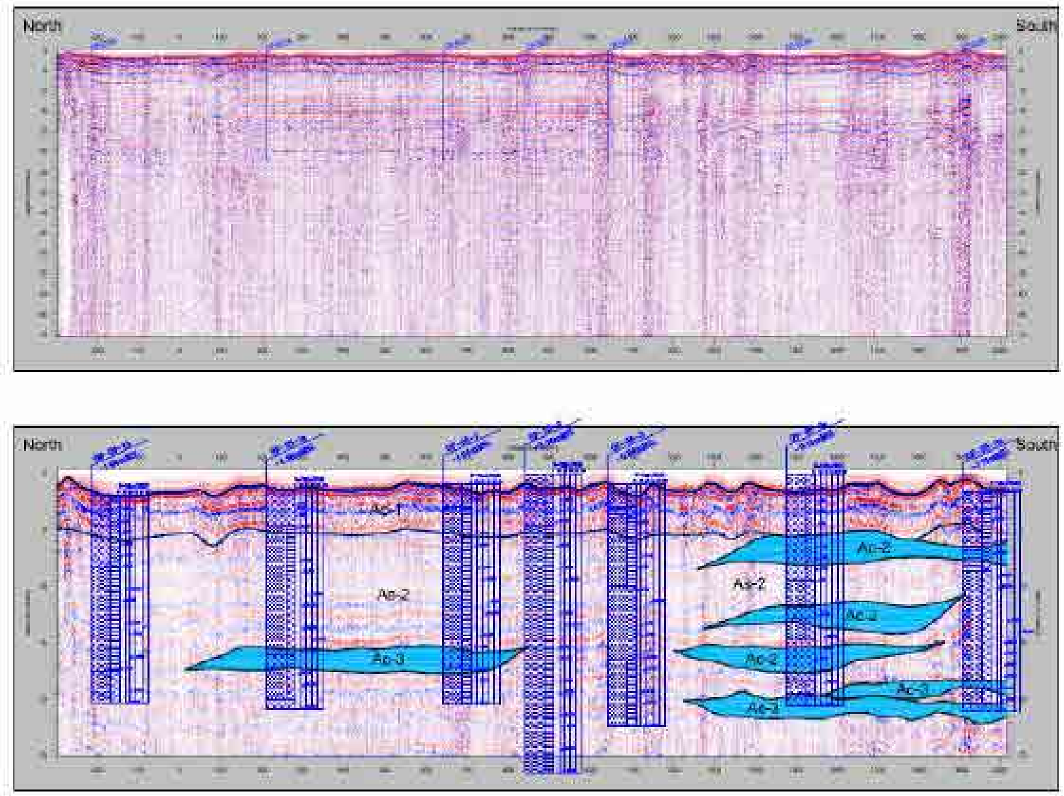


Figure 17.5-17(5) Soil Profile (Survey Line：MSS-SN-05)

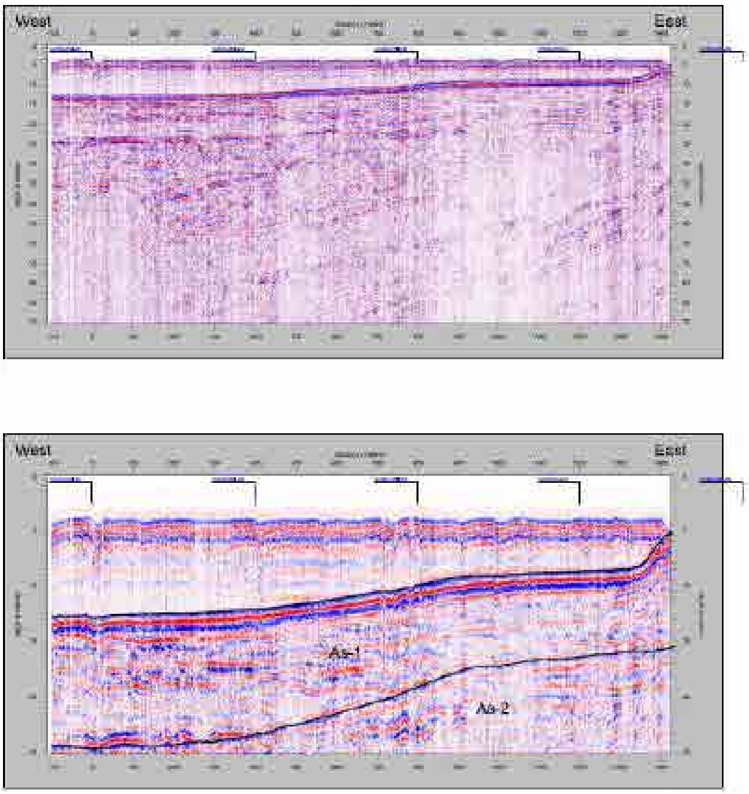


Figure 17.5-17(6) Soil Profile (Survey Line：MSS-WE-10a)

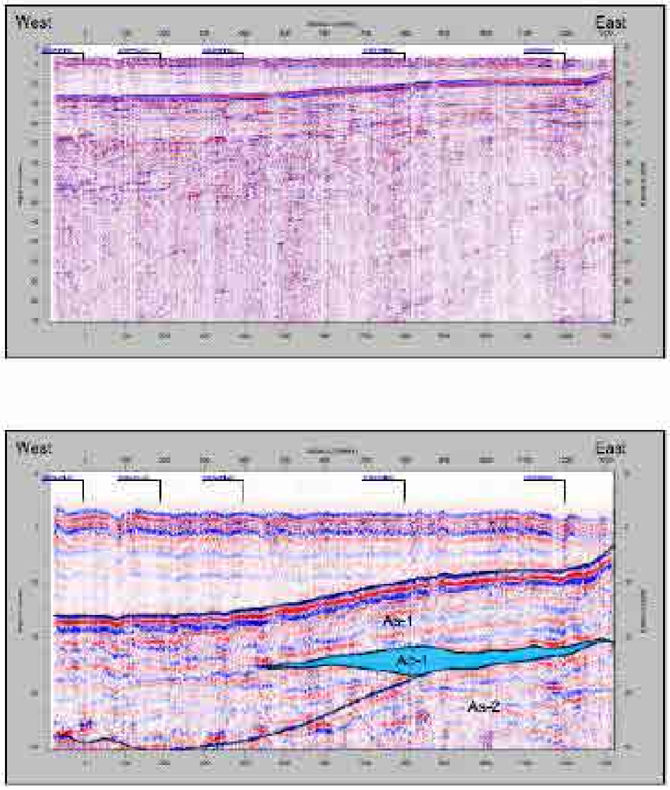


Figure 17.5-17(7) Soil Profile (Survey Line：MSS- WE-11)

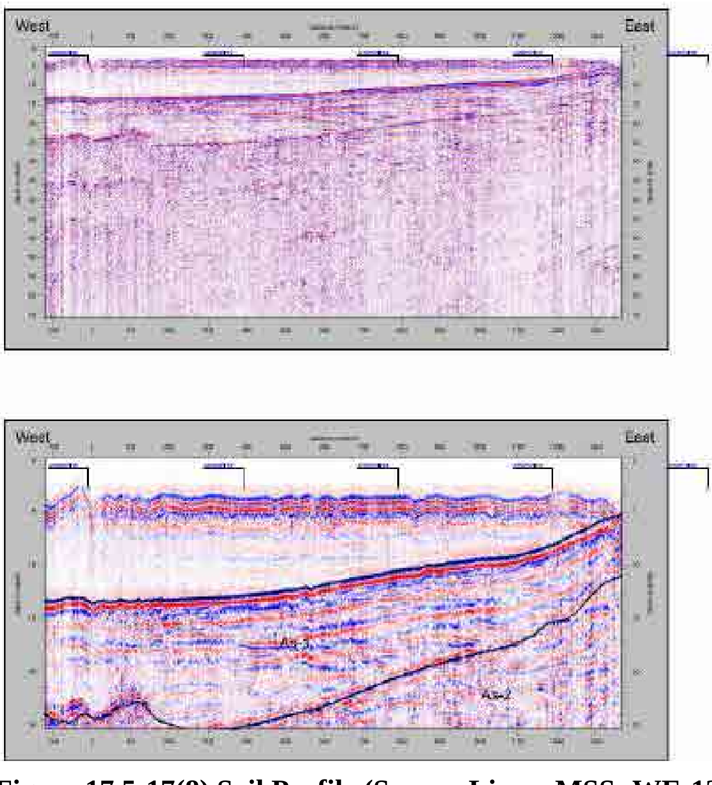


Figure 17.5-17(8) Soil Profile (Survey Line：MSS- WE-12)

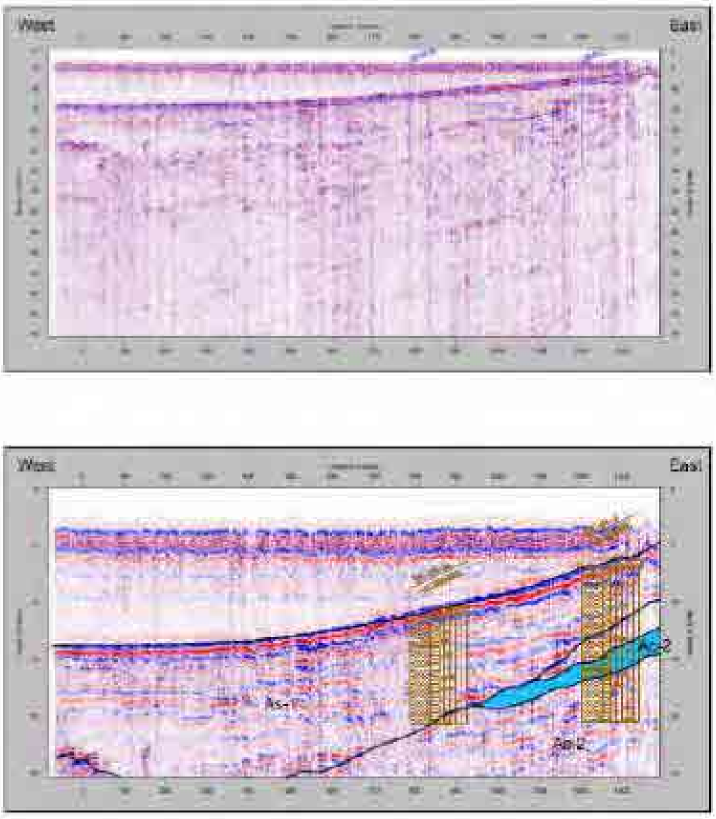


Figure 17.5-17(9) Soil Profile (Survey Line：MSS- WE-13)

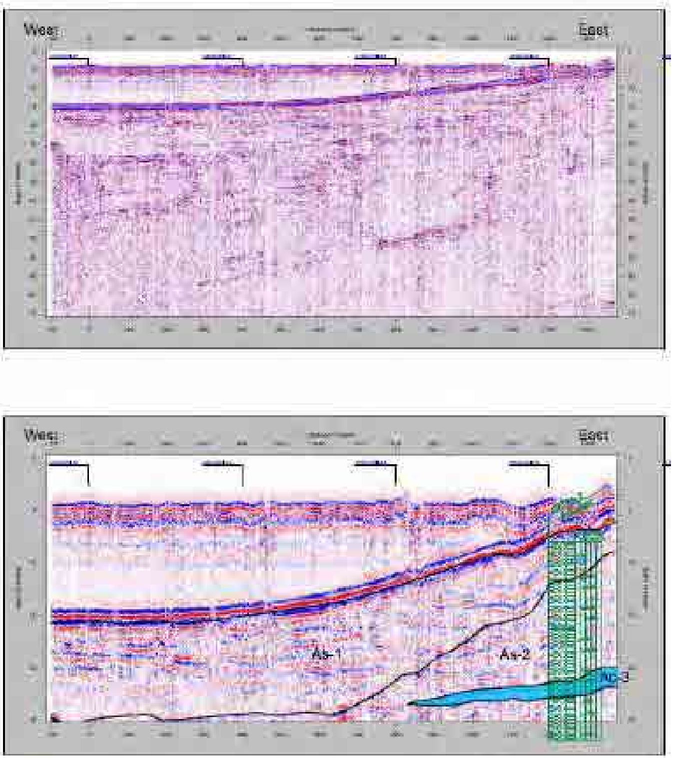


Figure 17.5-17(10) Soil Profile (Survey Line：MSS- WE-14)

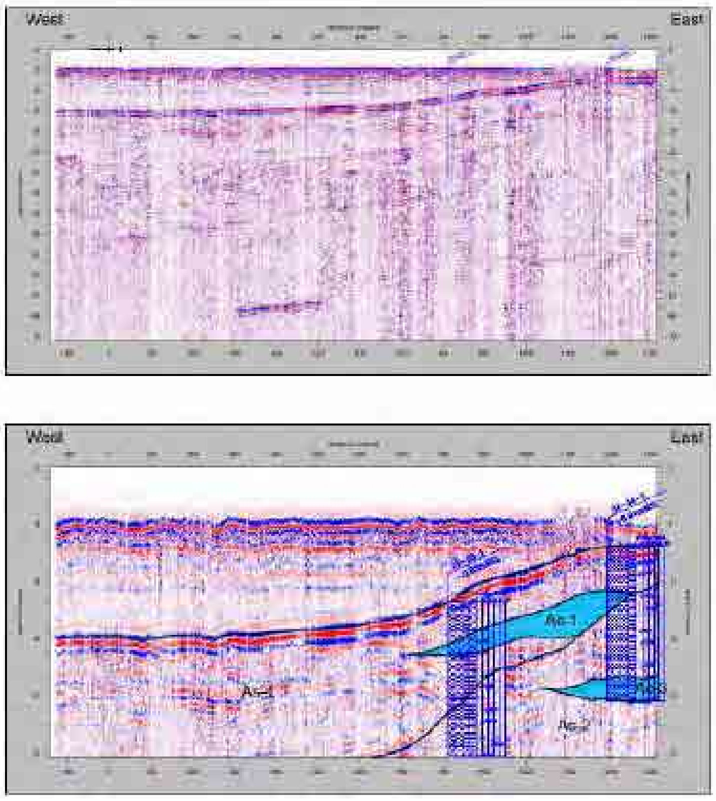


Figure 17.5-17(11) Soil Profile (Survey Line：MSS- WE-15)

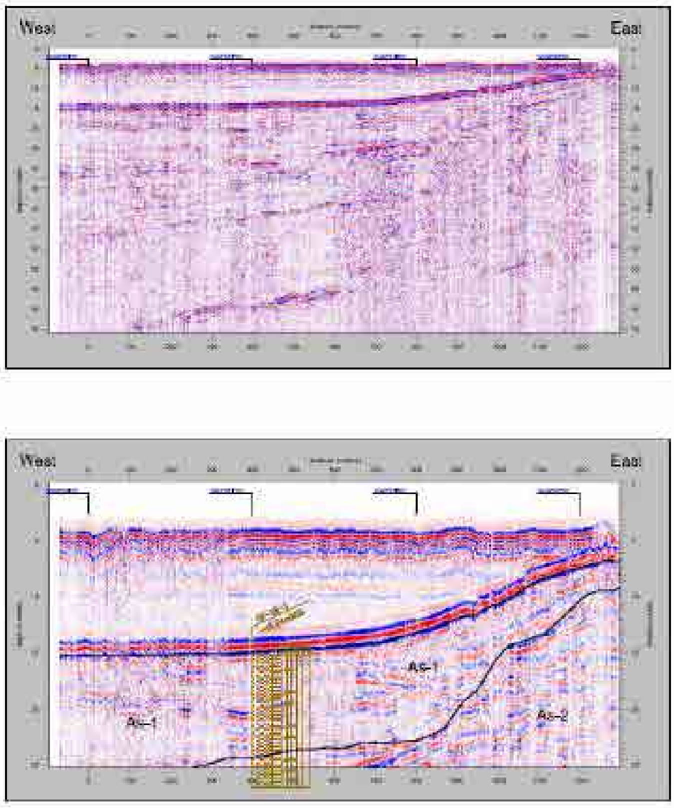


Figure 17.5-17(12) Soil Profile (Survey Line：MSS- WE-16a)

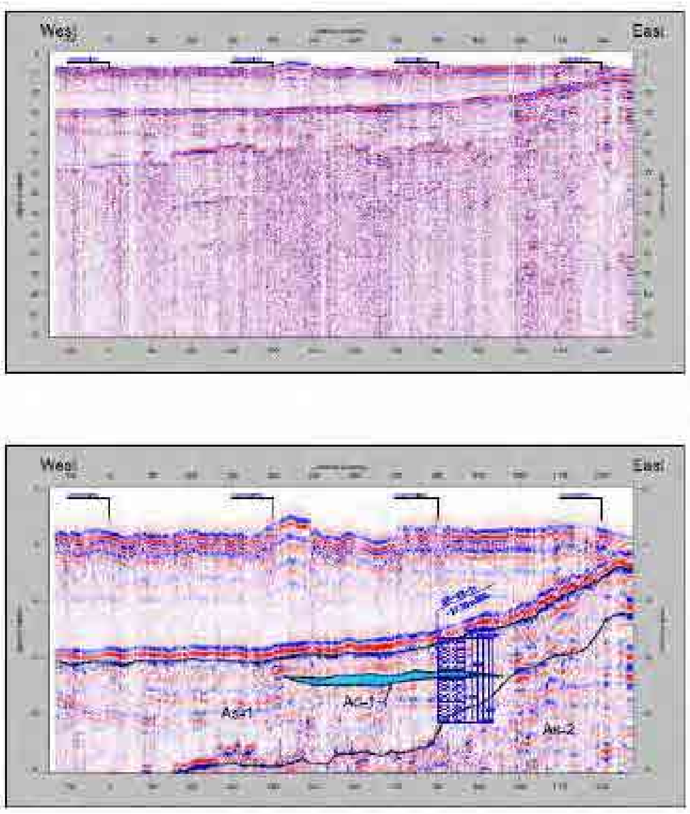


Figure 17.5-17(13) Soil Profile (Survey Line：MSS-WE-17a)

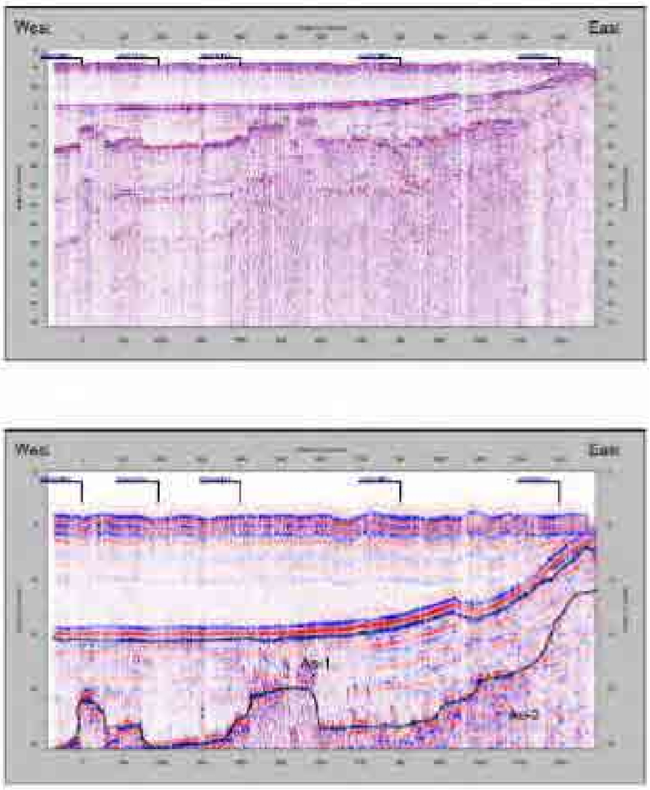


Figure 17.5-17(14) Soil Profile (Survey Line：MSS- WE-18a)

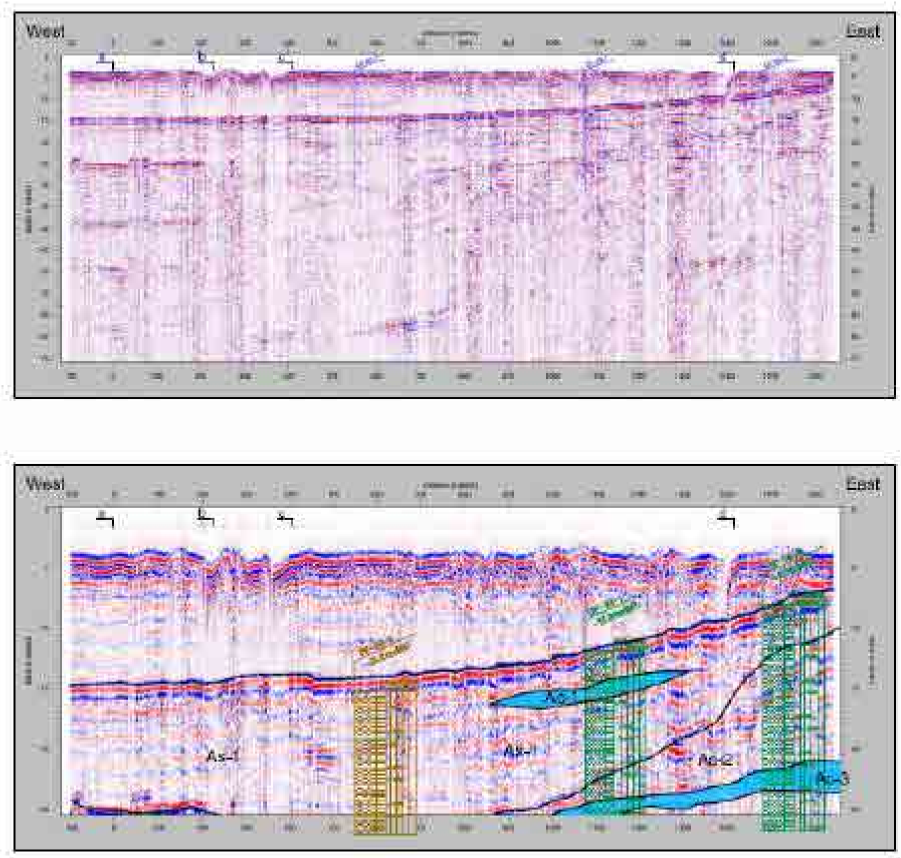


Figure 17.5-17(15) Soil Profile (Survey Line：MSS- CC-01)

(5) Swedish weight soundings

As a complement between the boring survey points and also to find out the sandy soil emergence depth, Swedish weight soundings were carried out at 46 locations. The quantities of the soundings are shown in Table 17.5-5, the locations of the soundings in Figure 17.5-1, and the thickness of the Ac-1 layer and elevation of dilvial soil in Figure 17.5-13 and Figure 17.5-14, respectively.

Table 17.5-5 Quantities of the Swedish Weight Soundings

		SW No	Line	Coordinates		GL (MSL m)	Completed on	Final Depth (m)
				Easting (m)	Northing (m)			
Approach & Channel Area	1	SW-10a-13a		382,480.85	2,400,321.06	0.42	2014/10/27	12.58
	2	SW-10a-14	Chanel Center	382,270.29	2,400,119.57	1.17	2014/10/2	6.39
	3	SW-10a-15		382,384.63	2,399,919.98	1.37	2014/10/28	11.50
	4	SW-11a-09		382,944.51	2,401,138.27	-0.78	2014/10/1	7.37
	5	SW-11a-13a		382,869.29	2,400,319.97	1.53	2014/10/30	13.92
	6	SW-11a-15		382,945.54	2,399,912.91	1.07	2014/10/24	5.20
	7	SW-12-10		383,076.73	2,400,996.10	1.87	2014/9/30	16.28
	8	SW-12-14	Chanel Center	383,069.75	2,400,120.04	1.35	2014/9/28	5.14
	9	SW-12a-11		383,327.49	2,400,718.41	1.48	2014/9/29	6.59
	10	SW-12a-12a		383,269.33	2,400,605.14	1.54	2014/10/31	11.16
	11	SW-12a-15a		383,269.28	2,399,866.59	1.26	2014/10/24	9.88
	12	SW-13-13		383,475.69	2,400,356.68	1.67	2014/9/27	9.60
	13	SW-13-15		383,469.07	2,399,919.28	1.35	2014/9/26	9.53
	14	SW-13-16		383,469.25	2,399,803.75	1.56	2014/9/26	9.69
	Subtotal						14	134.73
Plant Area	15	SW-14-12		383,758.03	2,400,522.67	1.37	2014/9/25	9.82
	16	SW-14-14	Plant Center	383,758.15	2,400,120.10	1.11	2014/9/22	11.93
	17	SW-14-15		383,742.37	2,399,922.10	1.19	2014/9/25	12.30
	18	SW-16-11		384,023.23	2,400,724.61	1.20	2014/10/8	4.72
	19	SW-16-12		384,024.99	2,400,526.71	1.11	2014/10/7	11.79
	20	SW-16-13		384,023.21	2,400,357.63	1.05	2014/10/7	9.19
	21	SW-16-14	Plant Center	384,024.51	2,400,120.13	1.11	2014/9/22	21.20
	22	SW-16-15		384,020.89	2,399,918.38	1.21	2014/10/3	20.05
	23	SW-16-17		384,023.40	2,399,681.52	1.08	2014/10/3	17.48
	24	SW-17-14	Plant Center	384,179.12	2,400,120.00	0.82	2014/9/20	19.25
	25	SW-18-11		384,338.02	2,400,724.93	1.00	2014/10/22	9.24
	26	SW-18-12		384,334.91	2,400,523.71	1.04	2014/10/21	18.63
	27	SW-18-13		384,337.66	2,400,358.21	0.90	2014/10/20	19.69
	28	SW-18-14	Plant Center	384,337.61	2,400,120.17	0.84	2014/9/20	19.00
	29	SW-18-15		384,338.04	2,399,919.02	0.89	2014/10/18	20.43
	30	SW-18-17		384,338.12	2,399,681.50	1.07	2014/10/17	14.35
	31	SW-19-17		384,491.12	2,399,680.61	1.13	2014/10/17	20.06
	32	SW-20-11		384,642.02	2,400,723.56	0.98	2014/10/8	14.80
	33	SW-20-12		384,643.55	2,400,525.67	0.89	2014/10/9	16.11
	34	SW-20-13		384,642.32	2,400,361.98	0.82	2014/10/9	16.80
	35	SW-20-14	Plant Center	384,622.92	2,400,120.58	0.96	2014/9/19	19.35
	36	SW-20-15		384,641.54	2,399,921.60	0.98	2014/10/10	16.93
	37	SW-20-17		384,641.96	2,399,680.00	0.97	2014/10/11	14.20
	38	SW-21-14	Plant Center	384,791.12	2,400,119.98	0.79	2014/9/18	16.95
	39	SW-22-11		384,942.53	2,400,723.40	0.92	2014/10/15	18.43
	40	SW-22-12		384,938.19	2,400,522.42	0.00	2014/10/15	14.47
	41	SW-22-13		384,940.34	2,400,362.21	0.73	2014/10/14	15.03
	42	SW-22-15		384,940.92	2,399,923.67	0.67	2014/9/17	11.55
	43	SW-22-16		384,943.27	2,399,805.42	0.69	2014/10/16	11.29
	44	SW-24-11		385,290.26	2,400,725.39	0.89	2014/10/14	16.03
	45	SW-24-12		385,293.53	2,400,525.82	1.02	2014/10/13	15.80
	46	SW-24-14	Plant Center	385,292.18	2,400,120.01	0.68	2014/10/12	10.30
	Subtotal						32	491.20
Total							46	625.93

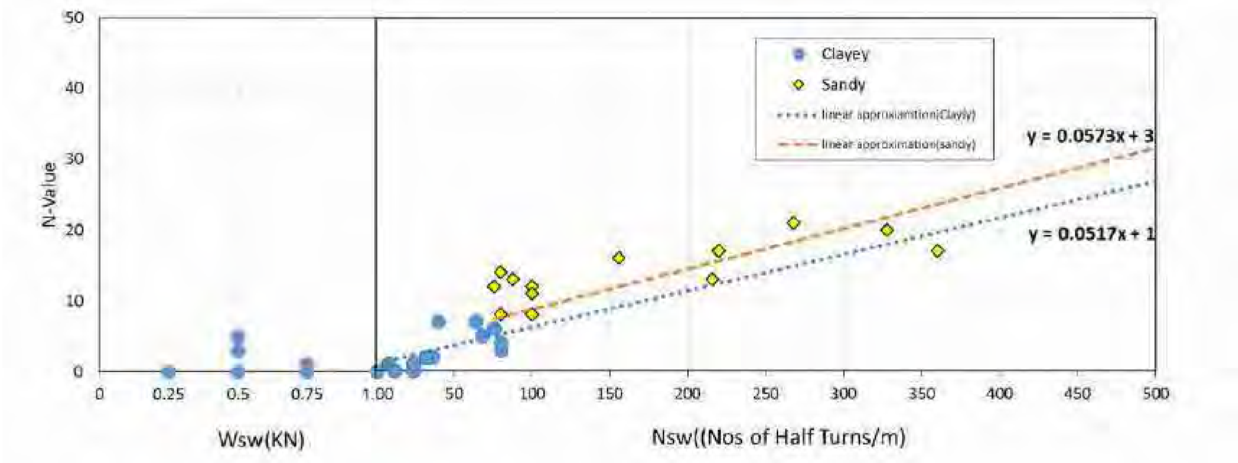


Figure 17.5-18 Correlation Wsw, Nsw and N-value

(6) Sea bottom sediment and sea water sampling

In addition to the original plan sea bottom sediment and sea water sampling and testing were also carried out. The sea bottom sediment samplings were carried out in both the rainy season (September) and the dry season (November). The samples were collected along 3 lines and tested as shown in Table 17.5-6 and Figure 17.5-19.

Table 17.5-6 Quantities of the Sea Bottom Sediment and Sea Water Sampling

Line	Point		Coordinates		Rainy Season (Sampling on 11 to 15 September)				Dry Season (Sampling on 4th to 8th November)		Remarks
	No	Name	N (m)	E (m)	Elevation* (MSL m)	Water Sampling** Top	Water Sampling** Bottom	Sediment Sampling**	Elevation*** (MSL m)	Sediment Sampling**	
Line 1	1	Start of Line	2,400,376	382,744	1.56				1.56		
	2	SL-1-0	2,400,102	382,150	0.00				0.05	1	****
	3	SL-1-1	2,400,125	382,107	-1.00	1	1	1	-0.79	1	
	4	SL-1-2	2,400,159	382,042	-2.00			1	-1.51	1	
	5	SL-1-3	2,400,191	381,983	-3.00	1	1	1	-2.52	1	
	6	SL-1-4	2,400,208	381,951	-4.00			1	-3.31	1	
	7	SL-1-5	2,400,224	381,919	-5.00	1	1	1	-4.33	1	
	8	SL-1-6	2,400,249	381,874	-6.00			1	-5.23	1	
	9	SL-1-7	2,400,276	381,821	-7.00	1	1	1	-6.46	1	
	10	SL-1-8	2,400,314	381,750	-8.00			1	-7.77	1	
	11	SL-1-9	2,400,332	381,717	-9.00	1	1	1	-8.23	1	
	12	SL-1-10	2,400,372	381,642	-10.00			1	-9.27	1	
	13	SL-1-11	2,400,499	381,404	-11.00	1	1	1	-10.28	1	
	14	SL-1-12	2,400,527	381,350	-12.00			1	-11.05	1	
	15	SL-1-13	2,400,662	381,095	-13.00	1	1	1	-12.32	1	
	16	SL-1-end	2,401,084	380,303	-12.63			1	-12.39	1	
	Subtotal					7	7	14		15	
Line 2	1	Start of Line	2,399,904	382,520	2.54				2.54		
	2	SL-2-0	2,400,424	382,654	0.00				0.11	1	****
	3	SL-2-1	2,400,564	382,388	-1.00			1	-0.43	1	
	4	SL-2-2	2,400,641	382,243	-2.00				-1.60		
	5	SL-2-3	2,400,668	382,193	-3.00			1	-3.08	1	
	6	SL-2-4	2,400,676	382,177	-4.00				-3.69		
	7	SL-2-5	2,400,686	382,158	-5.00			1	-4.39	1	
	8	SL-2-6	2,400,699	382,134	-6.00				-5.25		
	9	SL-2-7	2,400,712	382,110	-7.00			1	-6.15	1	
	10	SL-2-8	2,400,734	382,068	-8.00				-7.42		
	11	SL-2-9	2,400,796	381,950	-9.00			1	-8.48	1	
	12	SL-2-10	2,400,957	381,646	-10.00				-9.47		
	13	SL-2-11	2,401,099	381,377	-11.00			1	-11.02	1	
	14	SL-2-12	2,401,114	381,349	-12.00				-11.21		
	15	SL-2-end	2,401,534	380,555	-12.38			1	-11.32	1	
	Subtotal					0	0	7		8	
Line 3	1	Start of Line	2,399,493	382,269	1.76				1.76		
	2	SL-3-0	2,399,653	381,962	0.00				0.37	1	****
	3	SL-3-1	2,399,665	381,939	-1.00			1	-0.50	1	
	4	SL-3-2	2,399,709	381,854	-2.00				-1.66		
	5	SL-3-3	2,399,741	381,792	-3.00			1	-2.92	1	
	6	SL-3-4	2,399,751	381,772	-4.00				-3.54		
	7	SL-3-5	2,399,765	381,745	-5.00			1	-4.32	1	
	8	SL-3-6	2,399,794	381,689	-6.00				-5.47		
	9	SL-3-7	2,399,827	381,627	-7.00			1	-6.02	1	
	10	SL-3-8	2,399,855	381,573	-8.00				-7.17		
	11	SL-3-9	2,399,879	381,526	-9.00			1	-8.00	1	
	12	SL-3-10	2,399,903	381,480	-10.00				-8.65		
	13	SL-3-11	2,399,937	381,415	-11.00			1	-10.06	1	
	14	SL-3-12	2,399,983	381,326	-12.00				-11.25		
	15	SL-3-13	2,400,067	381,165	-13.00			1	-12.23	1	
	16	SL-3-end	2,400,643	380,000	-12.42			1	-12.00	1	
	Subtotal					0	0	8		9	
	Total					7	7	29		32	

: Sampling Point

* Elevations were measured by echo sounder and land survey from 11 to 15 September.

** All the samples were subjected to laboratory tests.

Sediments were to sieve analysis and water samples were to Total Suspended Solid determination.

*** Elevations were measured by echo sounder on 22 November/

**** Additional Sampling on 22 November.

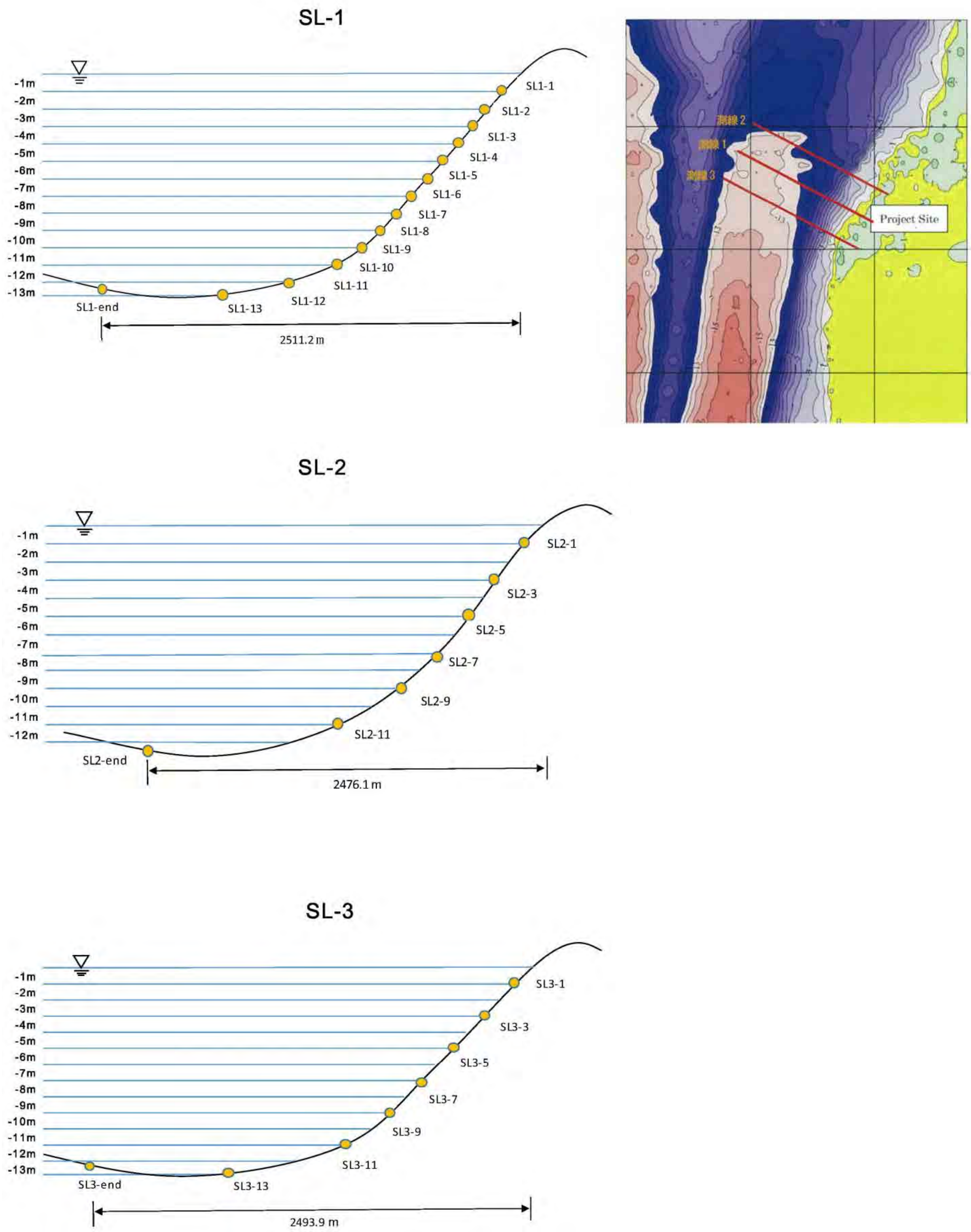
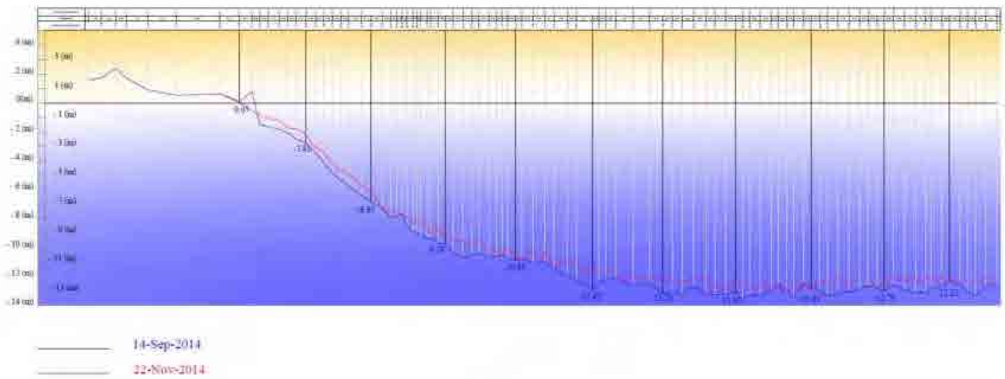
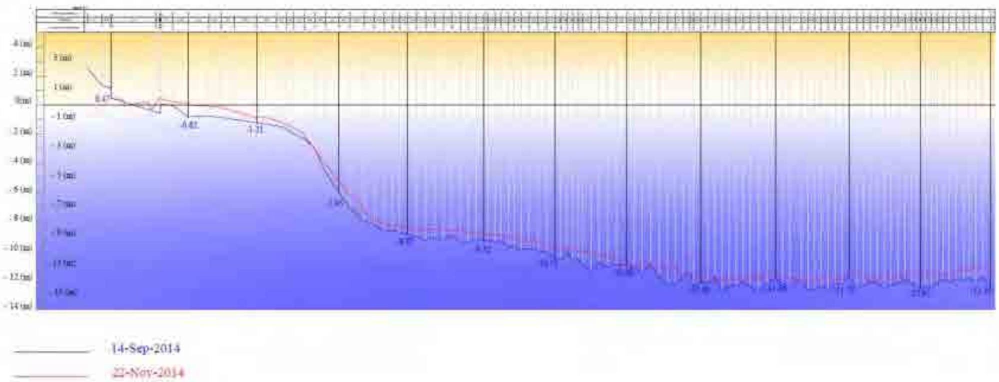


Figure 17.5-19 Locations of the Sampling

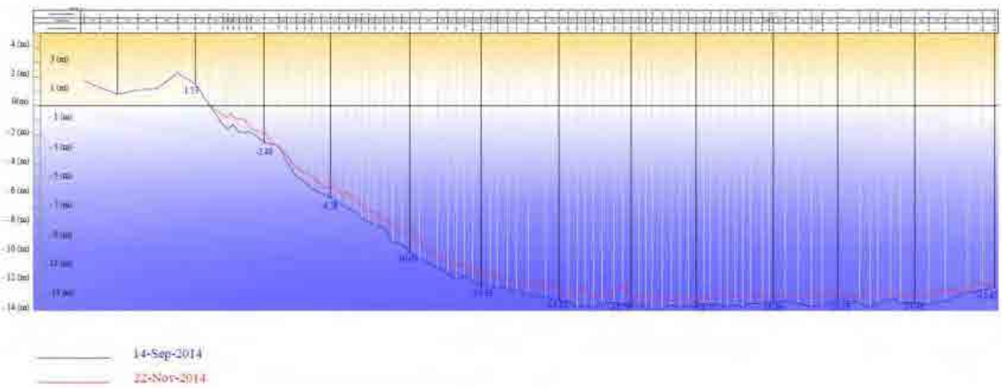
The echo soundings were carried out along 3 lines in both the rainy season (September) and the dry season (November) to determine the seabed elevation. The cross sections from the echo soundings are shown in Figure 17.5-20.



Line-1



Line-2



Line-3

Figure 17.5-20 Results of the Echo Soundings

The grading and texture (rainy season and dry season) at the Project site is shown in Table17.5-7.

Table17.5-7 Summary of Test Results on Soil and Seawater Samples from Sea Bottom Sediments and Seawater Sampling

Line	Points		Coordinate		Rainy Season (Sampling on 11 to 15 September)					Dry Season (Sampling on 4th to 8th November)					Remarks
	No	Name	N (m)	E (m)	Elevation* (MSL m)	Contents (%) Clay & Silt	Sand	Gravel	D50 (mm)	Elevation** (MSL m)	Contents (%) Clay & Silt	Sand	Gravel	D50 (mm)	
Line 1	1	SL-1-0	2,400,102	382,150	0.00	-	-	-	-	0.05	1.5	98.5	0.0	0.265	***
	2	SL-1-1	2,400,125	382,107	-1.00	0.9	99.1	0.0	0.276	-0.79	5.9	94.1	0.0	0.155	
	3	SL-1-2	2,400,159	382,042	-2.00	46.8	53.2	0.0	0.077	-1.51	21.5	78.5	0.0	0.095	
	4	SL-1-3	2,400,191	381,983	-3.00	27.6	72.4	0.0	0.088	-2.52	41.2	58.8	0.0	0.080	
	5	SL-1-4	2,400,208	381,951	-4.00	21.6	78.4	0.0	0.096	-3.31	19.6	80.4	0.0	0.125	
	6	SL-1-5	2,400,224	381,919	-5.00	19.6	80.4	0.0	0.101	-4.33	18.7	81.3	0.0	0.106	
	7	SL-1-6	2,400,249	381,874	-6.00	23.3	76.7	0.0	0.088	-5.23	14.7	85.3	0.0	0.102	
	8	SL-1-7	2,400,276	381,821	-7.00	21.6	78.4	0.0	0.088	-6.46	15.3	84.7	0.0	0.091	
	9	SL-1-8	2,400,314	381,750	-8.00	21.3	78.7	0.0	0.086	-7.77	14.2	85.8	0.0	0.094	
	10	SL-1-9	2,400,332	381,717	-9.00	21.0	79.0	0.0	0.087	-8.23	10.8	89.2	0.0	0.099	
	11	SL-1-10	2,400,372	381,642	-10.00	20.7	79.3	0.0	0.093	-9.27	15.7	84.3	0.0	0.099	
	12	SL-1-11	2,400,499	381,404	-11.00	13.5	86.5	0.0	0.100	-10.28	31.3	68.7	0.0	0.084	
	13	SL-1-12	2,400,527	381,350	-12.00	21.5	78.5	0.0	0.092	-11.05	30.0	70.0	0.0	0.084	
	14	SL-1-13	2,400,662	381,095	-13.00	23.2	76.8	0.0	0.115	-12.32	64.4	35.6	0.0	-	
	15	SL-1-end	2,401,084	380,303	-12.63	22.9	76.7	0.4	0.287	-12.39	89.9	10.1	0.0	-	
Line 2	1	SL-2-0	2,400,424	382,654	0.00	-	-	-	-	0.11	45.8	54.2	0.0	0.088	***
	2	SL-2-1	2,400,564	382,388	-1.00	1.4	98.6	0.0	0.161	-0.43	4.6	95.4	0.0	0.146	
	3	SL-2-3	2,400,668	382,193	-3.00	7.8	92.2	0.0	0.144	-3.08	20.5	79.5	0.0	0.103	
	4	SL-2-5	2,400,686	382,158	-5.00	2.7	97.2	0.1	0.175	-4.39	11.3	88.7	0.0	0.162	
	5	SL-2-7	2,400,712	382,110	-7.00	13.9	86.1	0.0	0.101	-6.15	13.2	86.8	0.0	0.130	
	6	SL-2-9	2,400,796	381,950	-9.00	20.5	79.5	0.0	0.087	-8.48	9.4	90.6	0.0	0.116	
	7	SL-2-11	2,401,099	381,377	-11.00	1.7	98.3	0.0	0.124	-11.02	24.1	75.9	0.0	0.088	
	8	SL-2-end	2,401,534	380,555	-12.38	98.1	1.9	0.0	-	-11.32	94.0	6.0	0.0	-	
Line 3	1	SL-3-0	2,399,653	381,962	0.00	-	-	-	-	0.37	2.3	97.7	0.0	0.276	***
	2	SL-3-1	2,399,665	381,939	-1.00	7.3	92.7	0.0	0.241	-0.50	14.5	85.5	0.0	0.098	
	3	SL-3-3	2,399,741	381,792	-3.00	25.0	75.0	0.0	0.091	-2.92	9.0	91.0	0.0	0.130	
	4	SL-3-5	2,399,765	381,745	-5.00	14.6	85.4	0.0	0.164	-4.32	9.2	90.8	0.0	0.105	
	5	SL-3-7	2,399,827	381,627	-7.00	20.4	79.6	0.0	0.093	-6.02	8.7	91.3	0.0	0.106	
	6	SL-3-9	2,399,879	381,526	-9.00	24.7	75.3	0.0	0.090	-8.00	9.4	90.6	0.0	0.116	
	7	SL-3-11	2,399,937	381,415	-11.00	23.9	76.1	0.0	0.087	-10.06	11.7	88.3	0.0	0.112	
	8	SL-3-13	2,400,067	381,165	-13.00	15.1	84.9	0.0	0.108	-12.23	30.4	69.6	0.0	0.084	
	9	SL-3-end	2,400,643	380,000	-12.42	38.9	61.1	0.0	0.123	-12.00	8.4	91.6	0.0	0.176	

* Elevations were measured by echo sounder and land survey from 11 to 15 September.

** Elevations were measured by echo sounder on 22 November

*** Additional Sampling on 22 November.

The results of total suspended soilds (TSS) at the Project site are shown in Table 17.5-8.

Table 17.5-8 Results of the Total Suspended Soilds (TSS) in Seawater

Sample Depth (m)		Cup No	Cup+ Filter (mg)	Sample Volume (ml)	SS+Cup+ Filter (mg)	TSS (mg/L)	Remarks
1.00	Top	1	12831.00	102	13172.00	3343.14	
1.00	Bottom	2	12777.00	50	12943.00	3320.00	
3.00	Top	3	12582.00	88	12680.00	1113.64	
3.00	Bottom	4	12580.00	75	12695.00	1533.33	
5.00	Top	5	12602.00	60	12672.00	1166.67	
5.00	Bottom	6	12820.00	70	13067.00	3528.57	
7.00	Top	7	12566.00	72	12625.00	819.44	
7.00	Bottom	8	12850.00	40	12967.00	2925.00	
9.00	Top	9	12476.00	186	12510.00	182.80	
9.00	Bottom	10	12615.00	100	12917.00	3020.00	
11.00	Top	11	12671.00	118	12692.00	177.97	
11.00	Bottom	12	12674.00	68	12764.00	1323.53	
13.00	Top	13	12572.00	149	12595.00	154.36	
13.00	Bottom	14	12918.00	50	12988.00	1400.00	

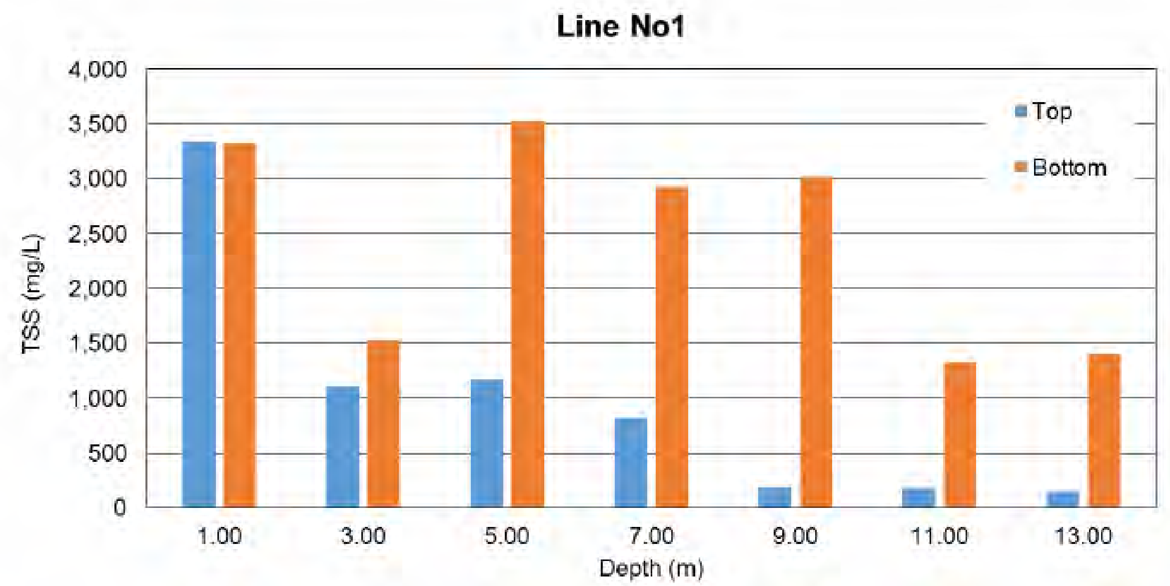


Figure17.5-21 Results of the Total Suspended Soilds(Tss) in Line No.1

(7) Chemical properties of the pollutant

The chemical properties of the soil and TSSs were determined by laboratory chemical tests. The details of the test results are shown in Table 17.5-9.

Table 17.5-9 Chemical Test Results

	Pollutant	Allowable contents* (per test solution 1L otherwise stated)		Result of Analysis (mg/L)							Detection Limit)
			Borehole No.	OF-05-2			LD-2-13-2				
			Sample No.	D-1	D-2	D-4	SPT-2	D-3	SPT-10	D-5	
			Depth from	1.00	3.00	7.00	2.00	9.00	14.00	18.00	
			to (m)	1.80	3.80	7.80	2.45	9.90	14.45	18.80	
1	Alkyl mercury compound	Not be detected		ND	ND	ND	ND	ND	ND	ND	0.0005
2	Mercury and its compounds	0.005mg or less		ND	ND	ND	ND	ND	ND	ND	0.0005
3	Cadmium and its compounds	0.1mg or less		ND	ND	ND	ND	ND	ND	ND	0.001
4	Lead and its compounds	0.1mg or less		ND	ND	ND	ND	ND	ND	ND	0.01
5	Organic phosphorus compound	1mg or less		ND	ND	ND	ND	ND	ND	ND	0.1
6	Hexavalent chromium compound	0.5mg or less		ND	ND	ND	ND	ND	ND	ND	0.04
7	Arsenic and its compounds	0.1mg or less		ND	0.008	ND	0.005	ND	0.007	0.012	0.005
8	Cyanides	1mg or less		ND	ND	ND	ND	ND	ND	ND	0.1
9	Polychlorinated biphenyls (PCBs)	0.003mg or less		ND	ND	ND	ND	ND	ND	ND	0.0005
10	Copper and its compounds	3mg or less		ND	ND	ND	ND	ND	ND	ND	0.02
11	Zinc and its compounds	2mg or less		0.005	0.006	0.087	ND	0.008	ND	ND	0.005
12	Fluorides	15mg or less		ND	0.1	ND	0.2	ND	ND	ND	0.1
13	Trichloroethylene	0.3mg or less		ND	ND	ND	ND	ND	ND	ND	0.002
14	Tetrachloroethylene	0.1mg or less		ND	ND	ND	ND	ND	ND	ND	0.0005
15	Beryllium and its compounds	2.5mg or less		ND	ND	ND	ND	ND	ND	ND	0.05
16	Chromium and its compounds	2mg or less		ND	ND	ND	ND	ND	ND	ND	0.04
17	Nickel and its compounds	1.2mg or less		ND	ND	ND	ND	ND	ND	ND	0.01
18	Vanadium and its compounds	1.5mg or less		ND	0.02	ND	0.02	0.01	0.02	0.03	0.01
19	Organochlorine compound	40mg or less per sample 1kg		ND	ND	ND	ND	ND	ND	ND	4mg/kg-wet
20	Dichloromethane	0.2mg or less		ND	ND	ND	ND	ND	ND	ND	0.002
21	Carbon tetrachloride	0.02mg or less		ND	ND	ND	ND	ND	ND	ND	0.0002
22	1,2 - dichloroethane	0.04mg or less		ND	ND	ND	ND	ND	ND	ND	0.0004
23	1,1 - dichloroethylene	1mg or less		ND	ND	ND	ND	ND	ND	ND	0.002
24	Cis-1 ,2 - dichloroethylene	0.4mg or less		ND	ND	ND	ND	ND	ND	ND	0.004
25	1,1,1 - trichloroethane	3mg or less		ND	ND	ND	ND	ND	ND	ND	0.0005
26	1,1,2 - trichloroethane	0.06mg or less		ND	ND	ND	ND	ND	ND	ND	0.0006
27	1,3 - dichloropropene	0.02mg or less		ND	ND	ND	ND	ND	ND	ND	0.0002
28	Thiuram	0.06mg or less		ND	ND	ND	ND	ND	ND	ND	0.0006
29	Simazine	0.03mg or less		ND	ND	ND	ND	ND	ND	ND	0.0003
30	Thiobencarb	0.2mg or less		ND	ND	ND	ND	ND	ND	ND	0.002
31	Benzene	0.1mg or less		ND	ND	ND	ND	ND	ND	ND	0.001
32	Selenium and its compounds	0.1mg or less		ND	ND	ND	0.004	0.002	ND	ND	0.002
33	1,4 - dioxane	0.5mg or less		ND	ND	ND	ND	ND	ND	ND	0.05
34	Dioxins	10pg-TEQ or less		0.00021	0.086	0.0012	0.012	0.00058	0.018	0.000087	-

*Allowable metal contents in the waste to be used for reclamation, The Prime Minister's Office Ordinance No. 6, 1973

ND indicates value below the detection limit.

(8) Laboratory test results

For the purpose of revealing the soil characteristics of the Project site, the Environment Survey Team carried out laboratory tests on the undisturbed samples that were obtained from the cohesive soil layer as well as on the disturbed samples that were obtained from the sandy soil layer. The data sheets are attached to Appendix for Chapter 17, types and quantity of tests for each exploratory drilling and survey lines are shown in Table 17.5-10 and test results are shown in Table 17.5-11.

Table17.5-10 Types and Quantity of Tests for Each Exploratory Drillings and Survey Line

Lab Test Plan

At Off-Site Laboratory

Area	BH No	Test Item: Physical Poperty Tests: Gt*	Wn	Gs	LL & PL	Sieve	Hydro	QU	Triaxial Tests: UU	CU bar	CD	Cons	Compaction Tests	Chemical Pro. Tests	TSS	Remarks
Approach Area	OF-02-1		4	4		4	4									
	OF-03-1		4	4	2	4	4									
	OF-03-1a		2	2		2	2									
	OF-03-1b		3	3		3	3									
	OF-03-1c		1	1		1	1				1		1			
	OF-04-1	1	4	4	2	4	4									
	OF-04-2		5	5		5	5				1		1			
	OF-04-3		4	4		4	4									
	OF-05-1		8	8	2	8	8									
	OF-05-1a		6	6	1	6	6									
	OF-05-1b		4	4		4	4									
	OF-05-2		11	11		11	11				3		3	3		
	OF-05-3		7	7	2	7	7									
	OF-05-3a		3	3		3	3				1		1			
	OF-05-3b		3	3	1	3	3				1		1			
Channel Area	LD-12-1	1	7	7	1	7	7		1		4	1	3			
	LD2-10a-1	2	6	6	2	6	6									
	LD2-11-1	4	7	7	2	7	7		3	1	1	3	1			
	LD2-11-1a	3	7	7	3	7	7				1		1			
	LD2-11-1b	3	6	6	2	6	6		1	1						
	LD2-12-1a	1	6	6	3	6	6		2		3	2				
	LD2-12-1b	2	8	8	2	8	8				1		1			
	LD2-13-1	3	6	6	3	6	6				1		1			
	LD2-13-2	1	7	7	3	7	7	1			4	1	5	4		
	LD2-13-3	1	8	8	3	8	8				2		2			
Power Plant Area	PP-14-1	3	4	4	2	4	4									
	PP-14-2	3	7	7	5	7	7	2	4		2	4				
	PP-14-3	6	6	6	6	6	6									
	PP-17-1	3	4	4	4	4	4		3	2		4				
	PP-21-1	3	4	4	4	4	4		2	1	1	2				
	PP-21-2	3	6	6	3	6	6	1	2	1	1	2				
	PP-21-3	2	5	5	2	5	5		1		1	1	1			
	PP-24-1	2	5	5	2	5	5		2		1	2				
	PP3-15-1	2	2	2	2	2	2									
	PP3-15-2	6	6	6	6	6	6									
	PP3-17-1	3	4	4	4	4	4									
	PP3-17-2	4	4	4	4	4	4									
	PP3-19-1	6	6	6	6	6	6									
	PP3-19-2	3	5	5	3	5	5		2	1		3				
	PP3-19-3	3	3	3	3	3	3									
	PP3-23-1	2	3	3	1	3	3									
	PP3-23-2	2	4	4	2	4	4		2			2				
	PP3-23-3	2	2	2	2	2	2									
	PP3-24-1	2	3	3	1	3	3									
	PP3-24-2	2	3	3	2	3	3									
SBS Samples						3	3									Sediment soil sample
Additional						2	2									From outcrops
Total		84	223	223	98	228	228	4	25	7	30	27	22	7	0	

*Gt: All the bulk density measurements were done at the site laboratory.

At Site Laboratory

Area	BH No	Test Item: Physical Poperty Tests: Gt	Wn	Gs	LL & PL	Sieve	Hydro	QU	Triaxial Tests: UU	CU bar	CD	Cons	Compaction Tests	Chemical Pro. Tests	TSS	Remarks
SBS	SL-1					28									14	
	SL-2					14										
	SL-3					16										
Drilling	LD2-11-1					16										
	LD2-13-2				6	14										
	PP-14-2					11										
	PP-21-2					14										
AD	Additional					3										From outcrops
Total		0	0	0	6	116	0	0	0	0	0	0	0	0	14	

Total

Area	BH No	Test Item: Physical Poperty Tests: Gt	Wn	Gs	LL & PL	Sieve	Hydro	QU	Triaxial Tests: UU	CU bar	CD	Cons	Compaction Tests	Chemical Pro. Tests	TSS	Remarks
Total		84	223	223	104	344	228	4	25	7	30	27	22	7	14	

Table 17.5-11 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 Offshore	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	29.3 to 77.6	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	38 to 40	0	0.82 to 1.93	35 to 190	0.22
Ac-2	Land Power Plant Offshore	0.9 to 8.7	Grey	Medium Stiff to Stiff	Clayey Soil	4 to 15	25.2 to 37.9	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	37	0 to 4	0.69 to 1.05	260 to 450	0.16 to 0.22
Ac-3	Land Power Plant Offshore	1.1 To 9.0	Grey	Stiff to Hard	Clayey Soil	15 to 30	22.0 to 41.6	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 Offshore	1.1 to 6.0	Grey	Very Loose to Loose	Sandy Soil	0 to 10	19.3 to 30.8	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 Offshore	0.75 to 21.85	Light Grey, Brownish Grey, Yellowish Grey,	Medium Dense to Dense	Sandy Soil	10 to 50	13.9 to 33.6	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	1.45 to 17.3	Grey	Hard	Clayey Soil	≥ 30	23.1 to 31.0	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	0.55 to 13.2	Light Grey, Grey, Yellowish Grey	Very Dense	Sandy Soil	≥ 50	12.9	1.97	2.69	94	6	0	-	-	-	-	-	-	-	-	-	-

1) Soil Physical Properties

①Specific Gravity

The specific gravities of each layer were plotted against depth and elevation in Figure 17.5-22. These are summarized as follows:

Table 17.5-12 Range of Specific Gravity for Each Layer

Layer	Range of Specific Gravity
Ac-1	2.68 to 2.78
Ac-2	2.71 to 2.74
Ac-3	2.69 to 2.74
As-1	2.66 to 2.72
As-2	2.67 to 2.72
Dc	2.71 to 2.73
Ds	2.69

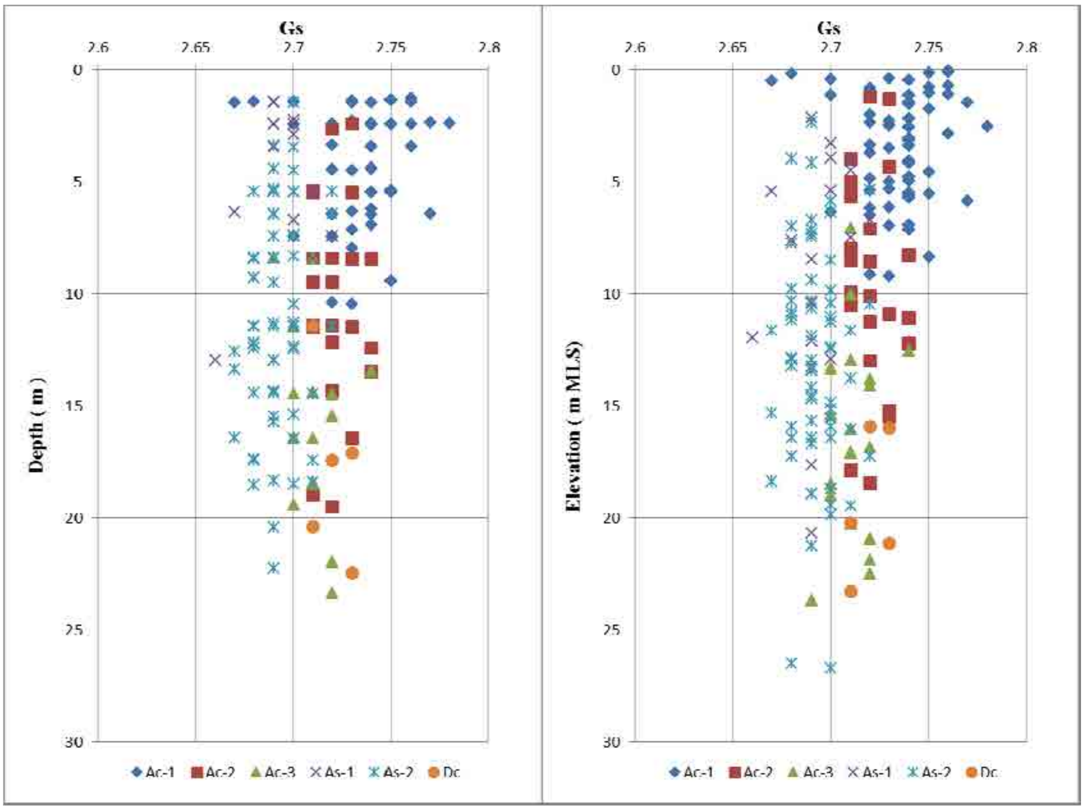


Figure 17.5-22 Specific Gravity Plotted against Depth and Elevation

②Water Content and Wet Density

The natural water content of each layer were plotted against depth and elevation in Figure 17.5-23. The natural water content results are summarized as follows:

Table 17.5-13 Range of the Natural Water Content for Each Layer

Layer	Range of Natural Water Content (%)
Ac-1	29.3 to 77.6
Ac-2	25.2 to 37.9
Ac-3	22.0 to 41.6
As-1	19.3 to 30.8
As-2	13.9 to 33.6
Dc	23.1 to 31.0
Ds	12.9

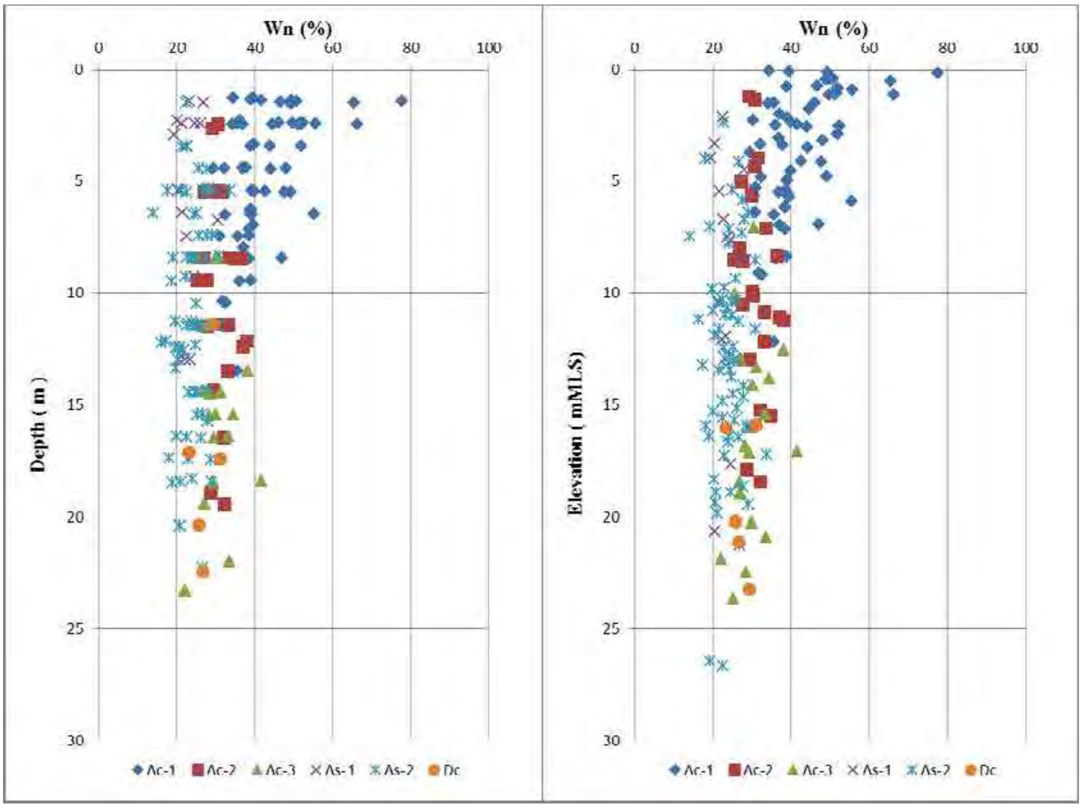


Figure 17.5-23 Natural Water Content Plotted Against Depth and Elevation

The wet densities of each layer were plotted against depth and elevation in Figure 17.5-24. These are summarized as follows:

Table 17.5-14 Range of Wet Density for Each Layer

Layer	Range of Wet density (g/cm^3)
Ac-1	1.52 to 1.93
Ac-2	1.75 to 2.02
Ac-3	1.77 to 2.04
As-1	1.71 to 2.05
As-2	1.79 to 2.12
Dc	1.83 to 2.12
Ds	1.97

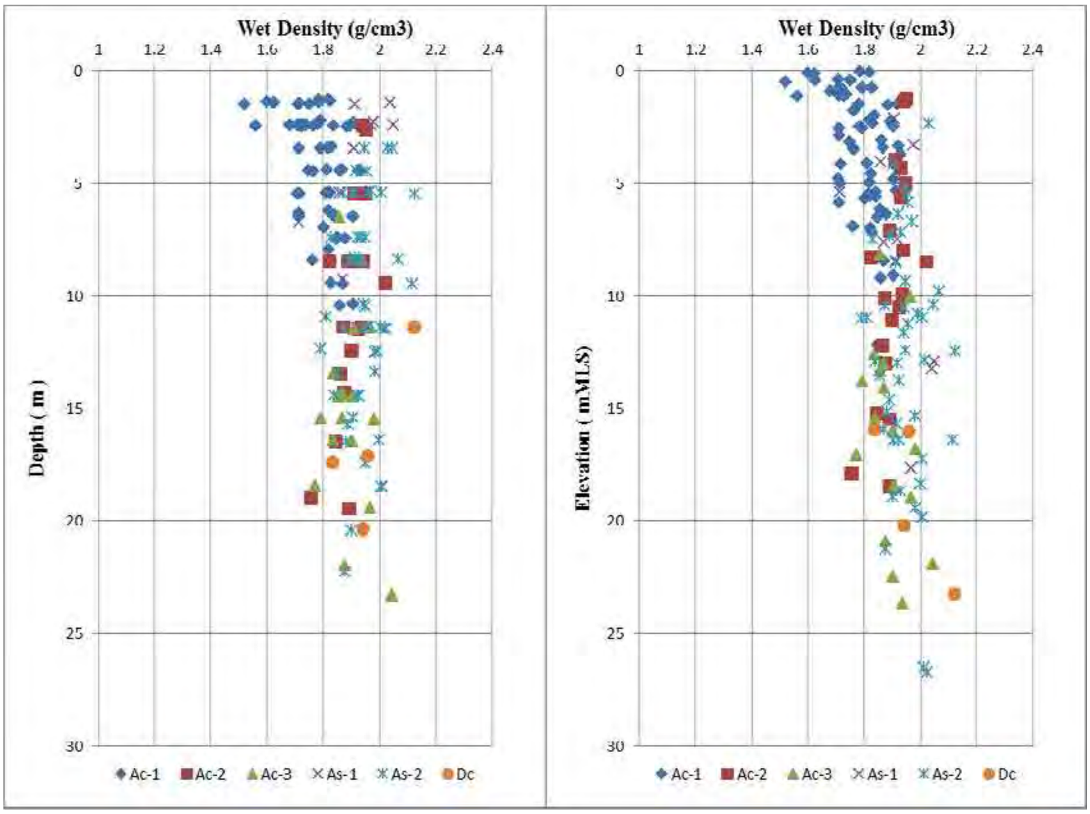


Figure 17.5-24 Wet Density Plotted against Depth and Elevation

③Grained Size Analysis

The grained size analyses of each layer were plotted against depth and elevation in Figures 17.5-25, 17.5-26, and17.5-27. These are summarized as follows:

Table 17.5-15 Range of the Grain Size Content for Each Layer

Layer	Range of Sand Content (%)	Range of Silt Content (%)	Range of Clay and Colloid Content (%)
Ac-1	1 to 41	31 to 57	25 to 67
Ac-2	2 to 47	24 to 50	23 to 43
Ac-3	8 to 49	25 to 57	21 to 49
As-1	53 to 97	2 to 22	10 to 28
As-2	50 to 96	4 to 30	11 to 28
Dc	13 to 48	24 to 59	23 to 34
Ds	94	6	0

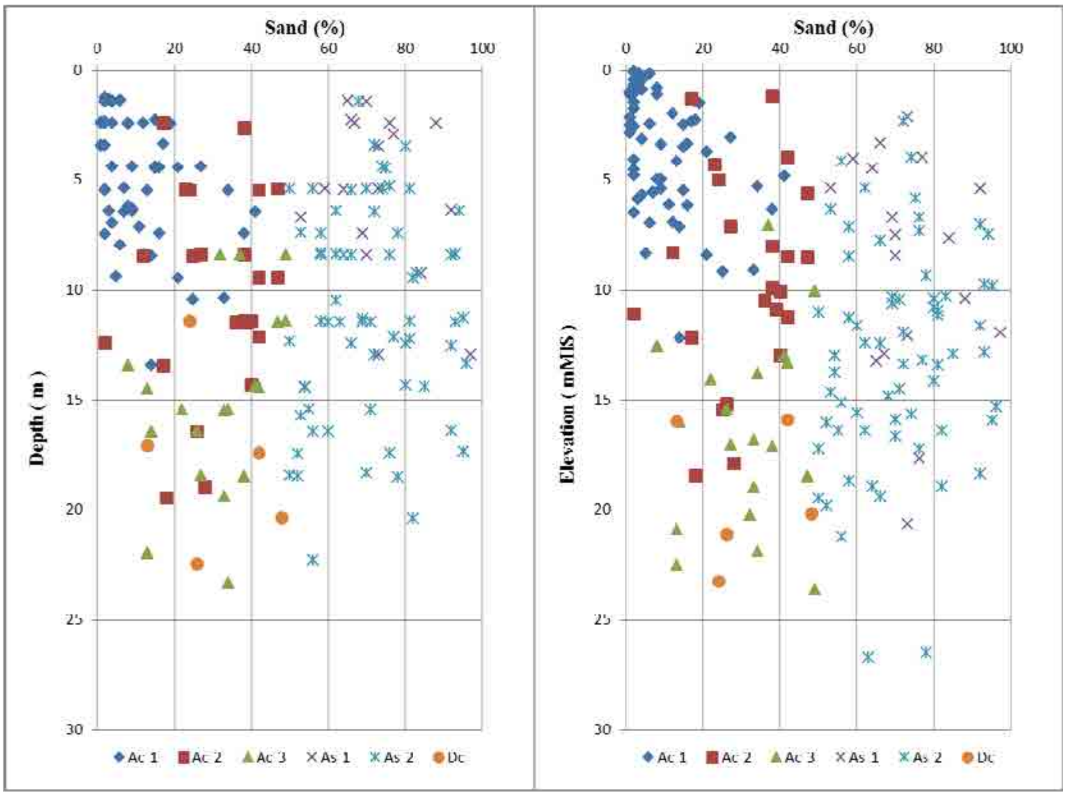


Figure 17.5-25 Sand Content Plotted against Depth and Elevation

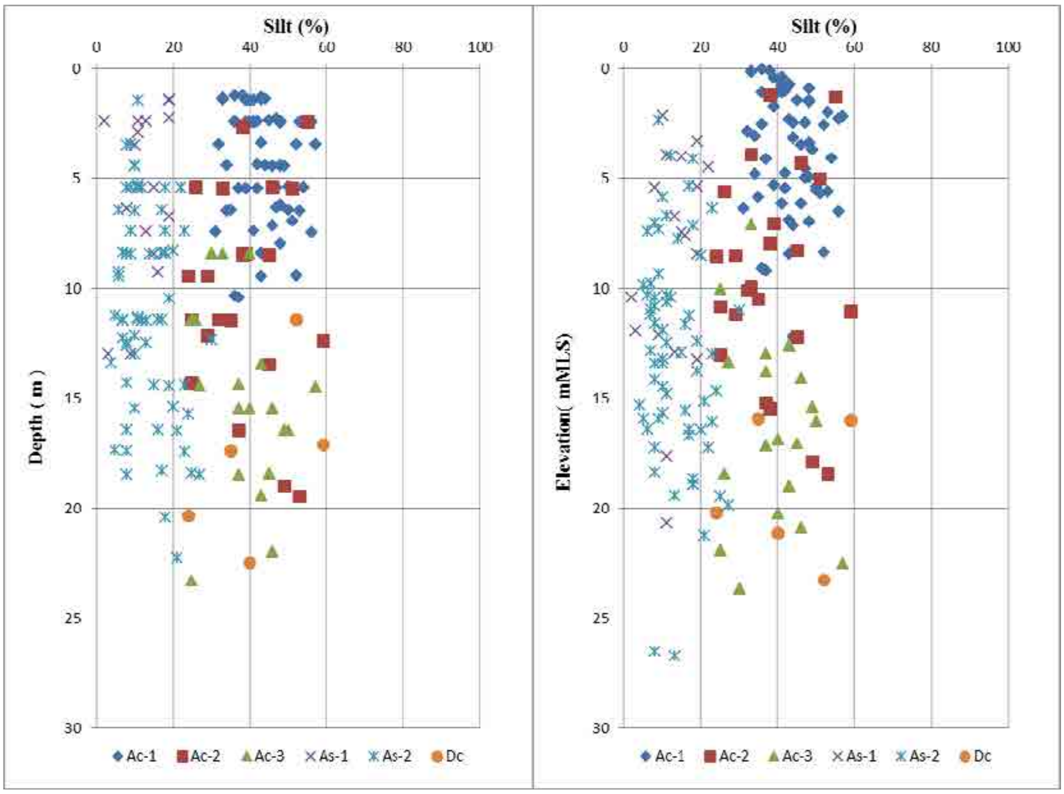


Figure 17.5-26 Silt Content Plotted against Depth and Elevation

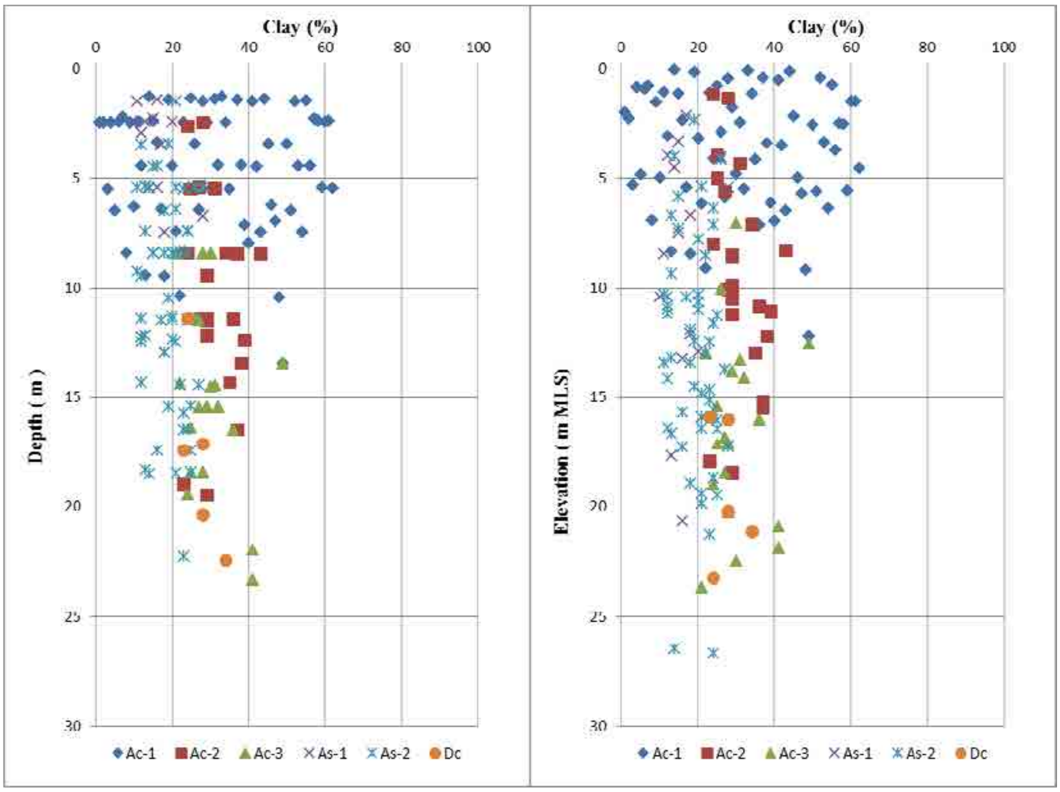


Figure 17.5-27 Clay and Colloid Content Plotted against Depth and Elevation

④Consistency Limits

The liquid limit was plotted against the plasticity index in Figure 17.5-28. As can be seen from the plasticity chart: almost all of the Ac-1 layer is categorized within CL or OL to CH or OH: the Ac-2 layer is categorized in CL or OL; the Ac-3 layer is categorized in CL-ML to CL or OL; and the Dc layer is categorized in CL or OL.

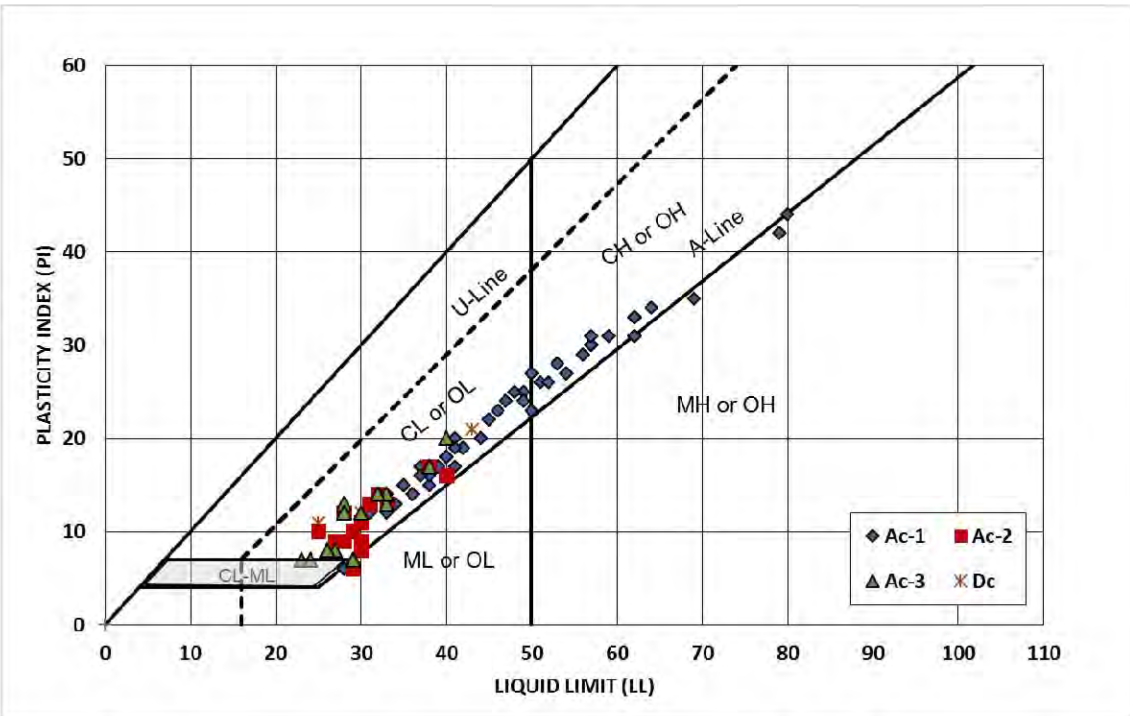


Figure 17.5-28 Liquid Limit Plotted against the Plasticity Index

2) Mechanical property

①Compression Strength

i) Unconfined Compression Strength

The unconfined compression strengths of each layer were plotted against depth and elevation in Figure 17.5-29. These are determined by unconfined compression tests (QU) and summarized for each layer as follows:

Table 17.5-16 Range of the Unconfined Compression Strength for Each Layer

Layer	Range of Unconfined Compression Strength qu/2 (kPa)
Ac-1	8.6 to 9.8
Ac-2	-
Ac-3	29.2
Dc	227.0

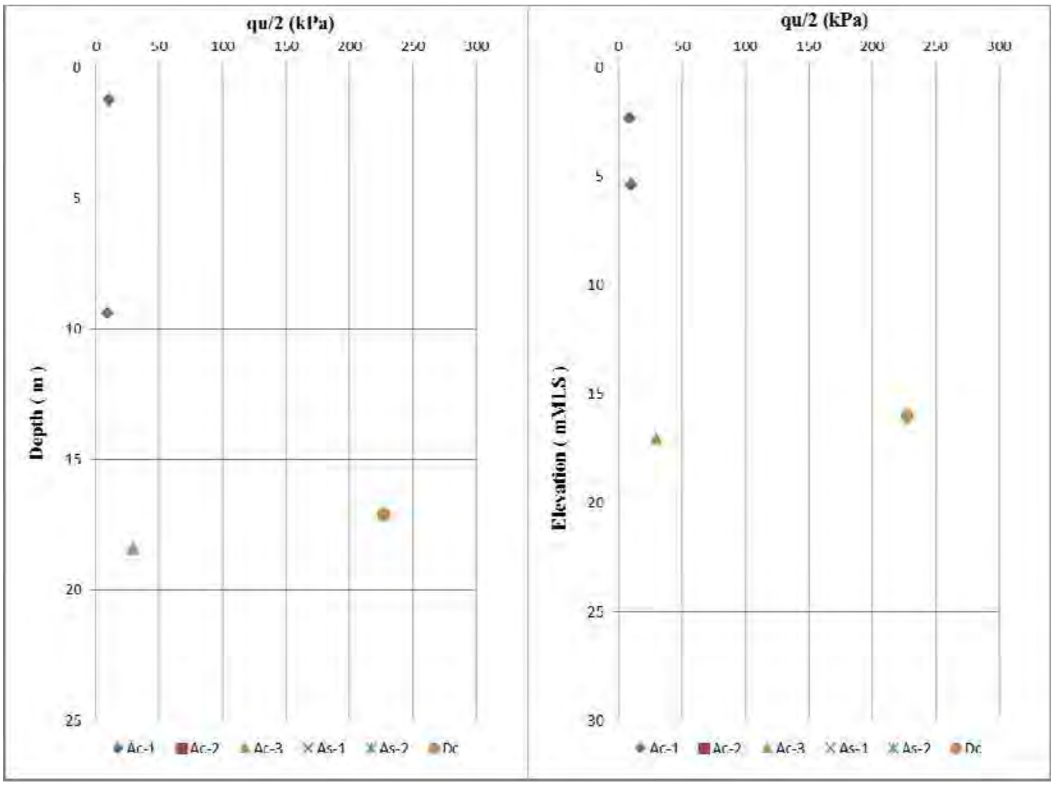


Figure 17.5-29 Unconfined Compression Strength Plotted against Depth and Elevation

ii) Undrained Shear Strength

The undrained shear strength of each layer was plotted against depth and elevation in Figure 17.5-30. These were determined by the unconsolidated undrained (UU) triaxial compression tests and are summarized for each layer as follows:

Table 17.5-17 Range of the Undrained Shear Strength for Each Layer

Layer	Range of Undrained Shear Strength (kPa)
Ac-1	10 to 35
Ac-2	44 to 71

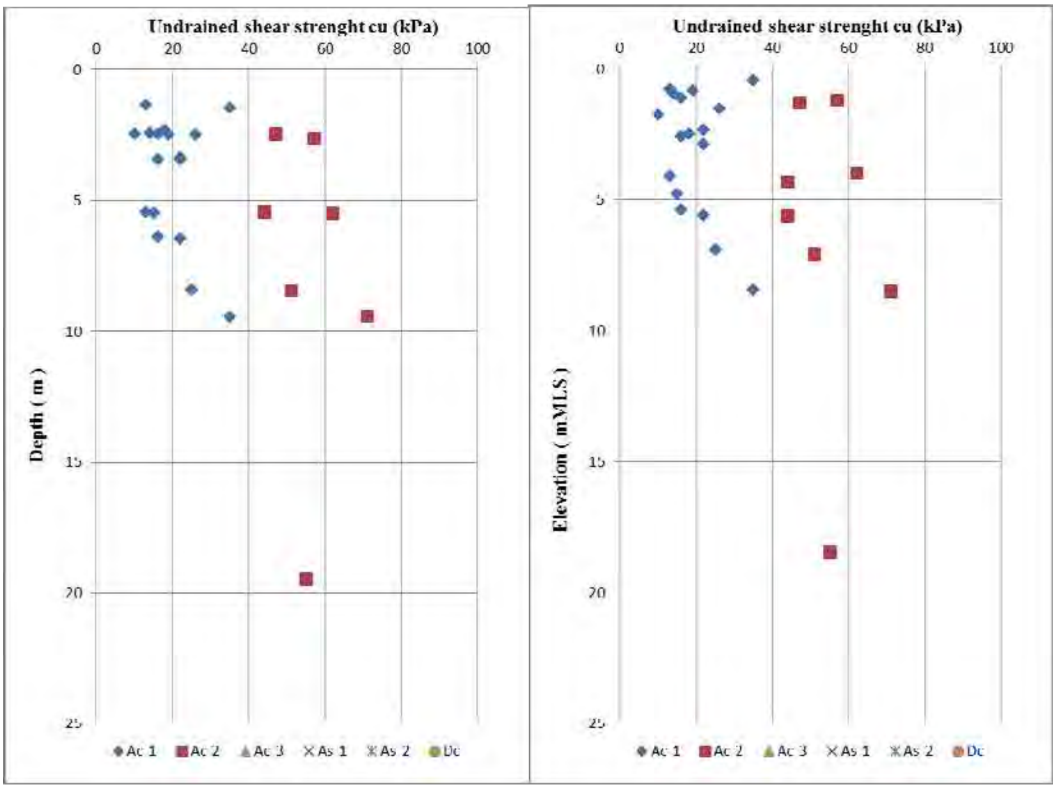


Figure 17.5-30 Undrained Shear Strength Plotted against Depth and Elevation

iii) Consolidated Undrained Triaxial Test (CU bar)

The undrained shear strength versus mean principal stress was plotted in Figure 17.5-31. The angle of internal friction and cohesion intercept were determined by the consolidated undrained triaxial tests and are summarized for each layer as follows:

Table 17.5-18 Range of Cohesion Intercept and the Angle of Internal Friction

Layer	Range of c' (kPa)	Range of ϕ' (deg)
Ac-1	0	38 to 40
Ac-2	0 to 4	37

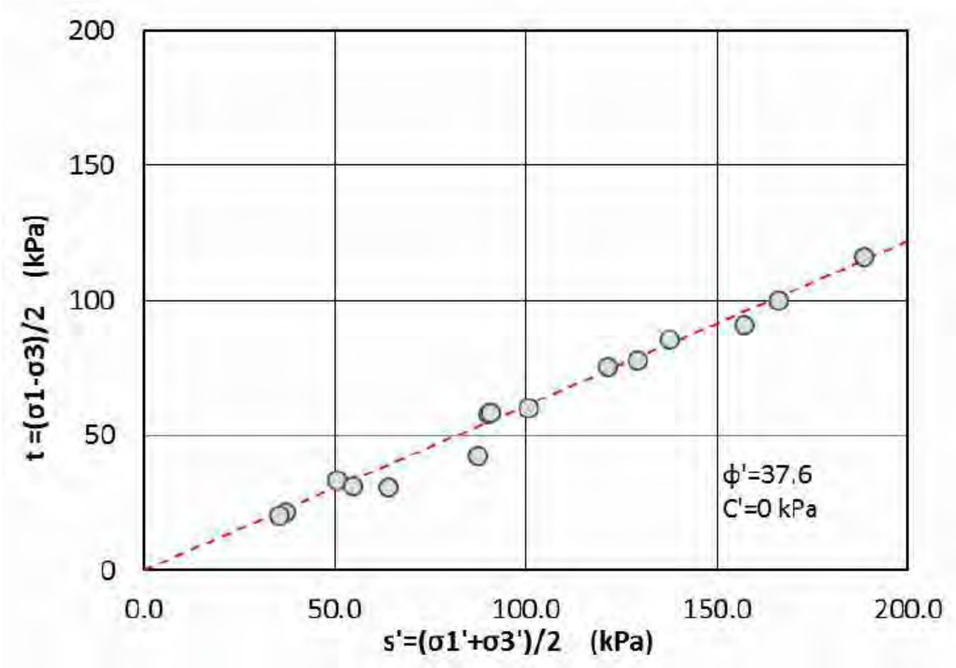


Figure 17.5-31 Undrained Shear Strength Plotted Mean Principal Stress from CU Test

iv) Consolidated Drained (CD) Triaxial Test

The angle of internal friction and cohesion intercept determined by the consolidated drained triaxial tests are summarized for each layer as shown in Table 17.5-19.

Table 17.5-19 CD Test Results

Layer	Range of c_d (kPa)	Range of ϕ_d (deg)
As-1	0	36 to 39
As-2	0	30 to 41
Ds	0	35

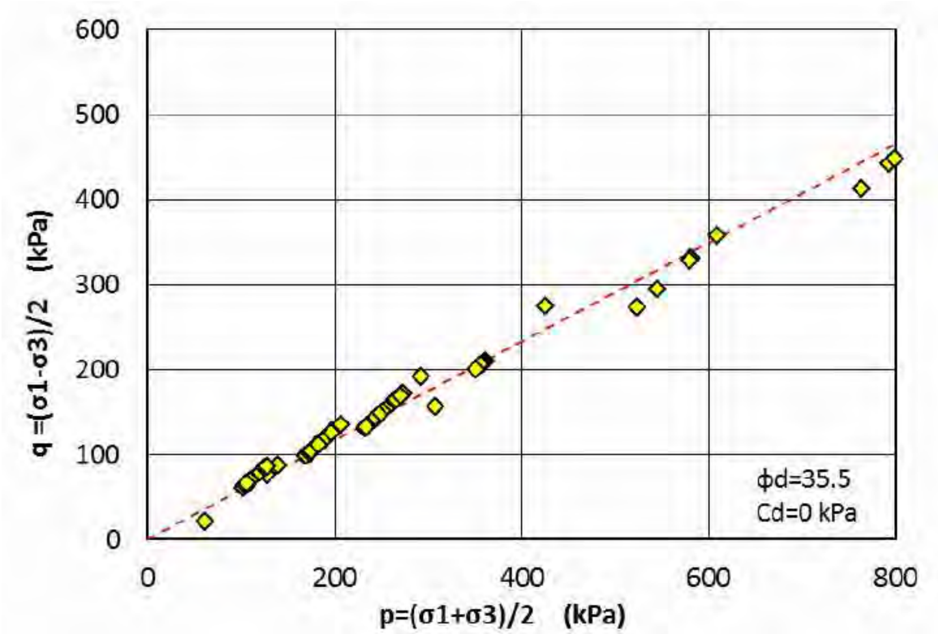


Figure 17.5-32 Shear Strength Plotted Mean Principal Stress from CD Test

③ Consolidation Characteristics

The void ratio, preconsolidation pressure Pc, and compression index Cc were plotted against depth and elevation in Figure 17.5-33～Figure 17.5-41 respectively, and their values are summarized as follows:

Table 17.5-20 Range of the Void Ratio, Preconsolidation Pressure Pc, and Compression Index Cc

Layer	Range of Initial Void Ratio e_0	Range of Preconsolidation Pressure Pc (kPa)	Range of Compression Index Cc
Ac-1	0.82 to 1.93	35 to 190	0.22
Ac-2	0.68 to 1.05	260 to 450	0.16 to 0.22
Ac-3	0.63 to 1.17	190	0.19
As-1	0.73 to 1.06	-	-
As-2	0,61 to 0.88	-	-
Dc	0.72 to 0.94	-	-

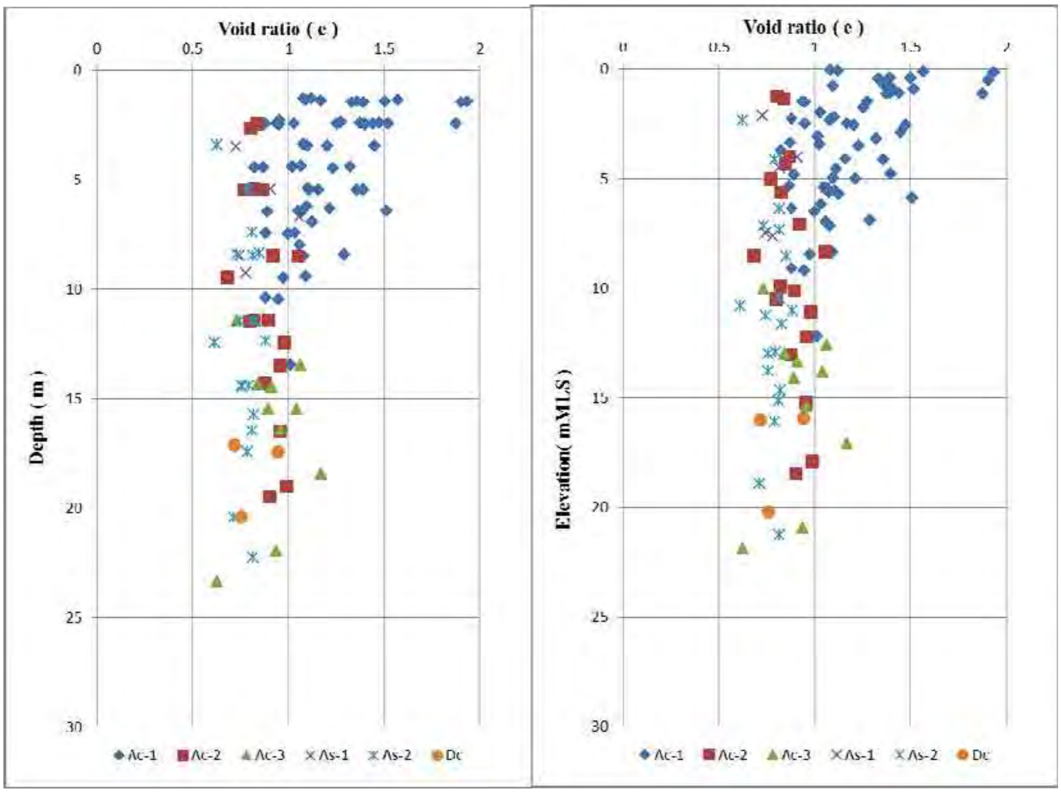


Figure 17.5-33 Void Ratio Plotted against Depth and Elevation

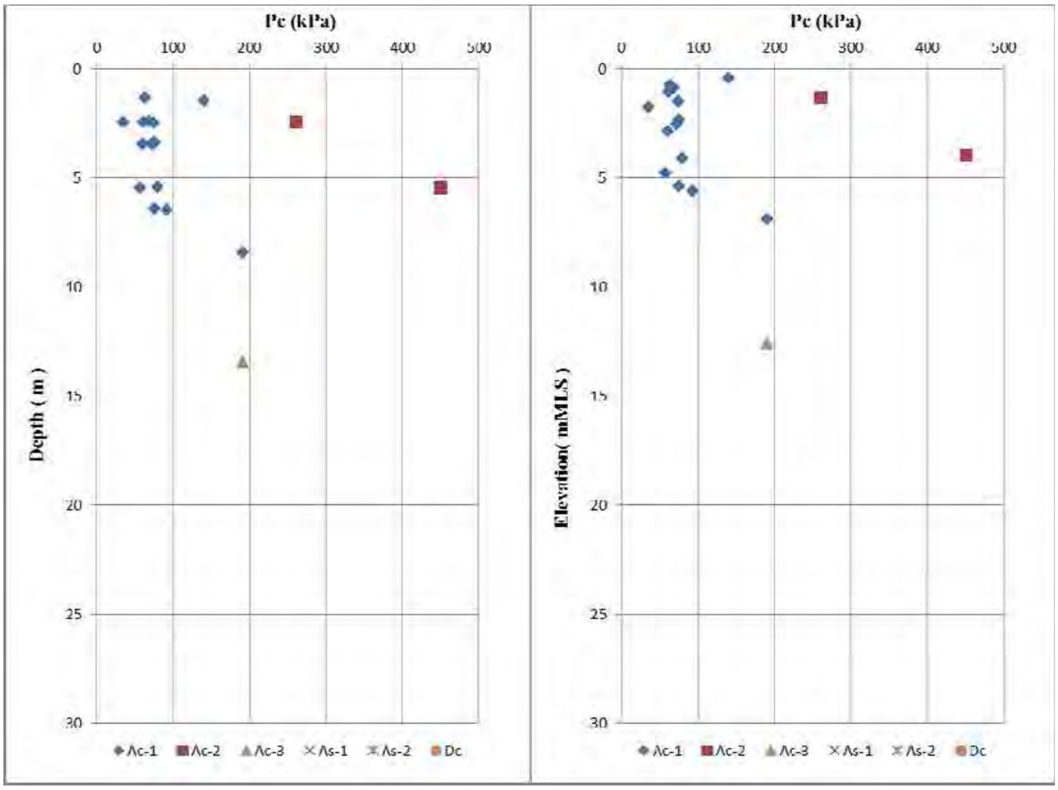


Figure 17.5-34 Preconsolidation Pressure Plotted against Depth and Elevation

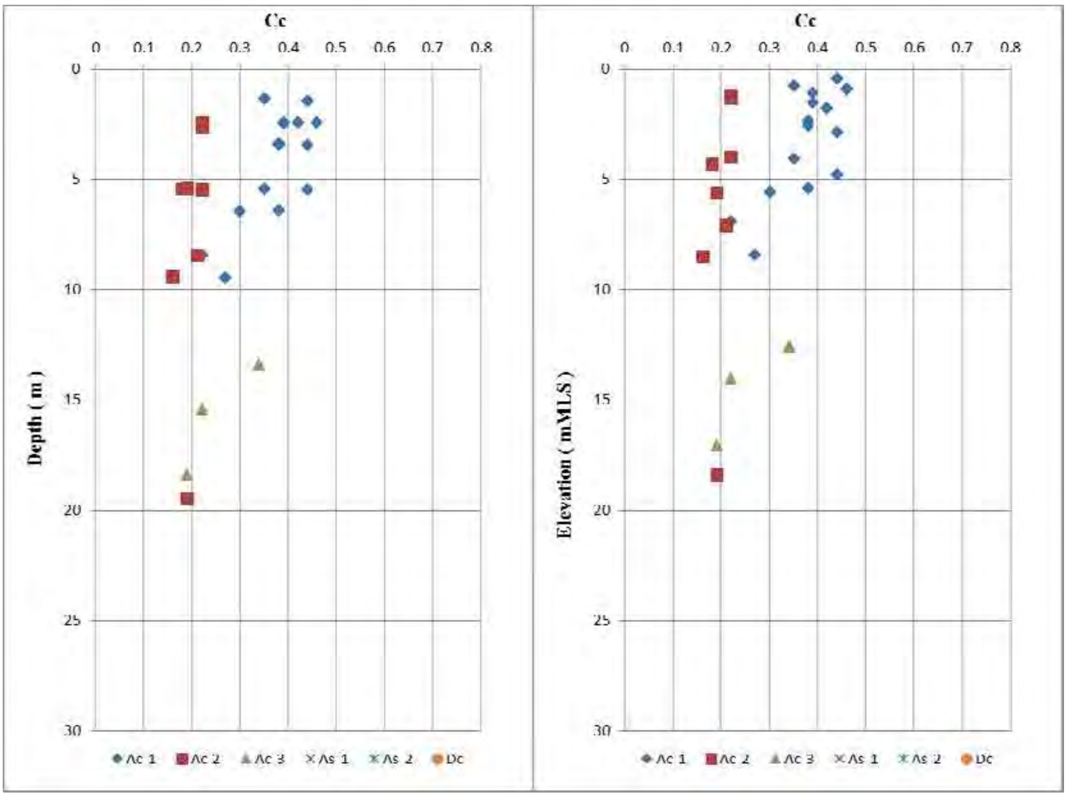


Figure 17.5-35 Compression Index Plotted against Depth and Elevation

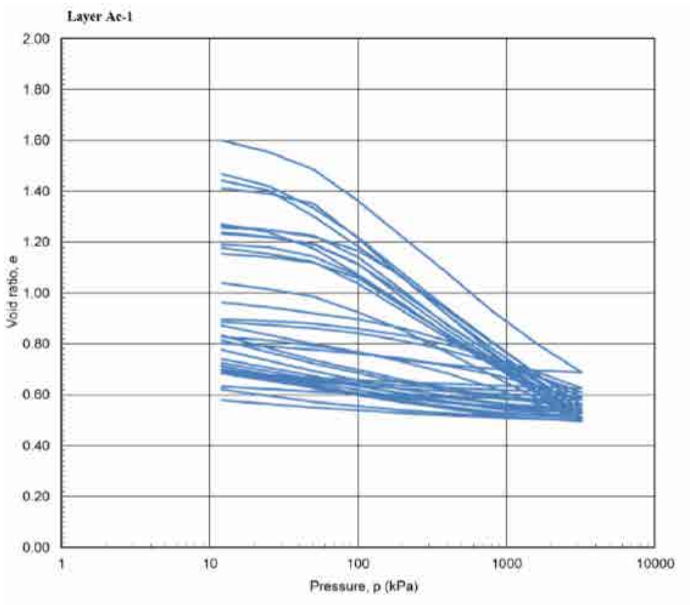


Figure 17.5-36 E-log P Curve for Ac-1 Layer

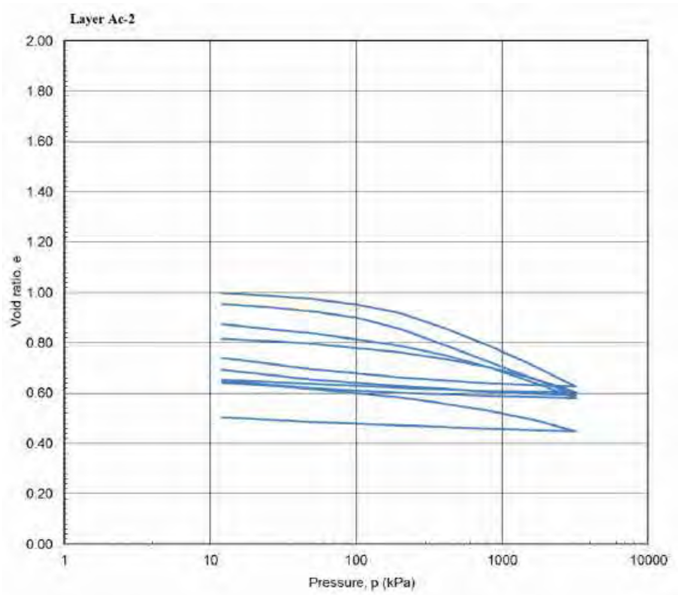


Figure 17.5-37 E-log P Curve for Ac-2 Layer

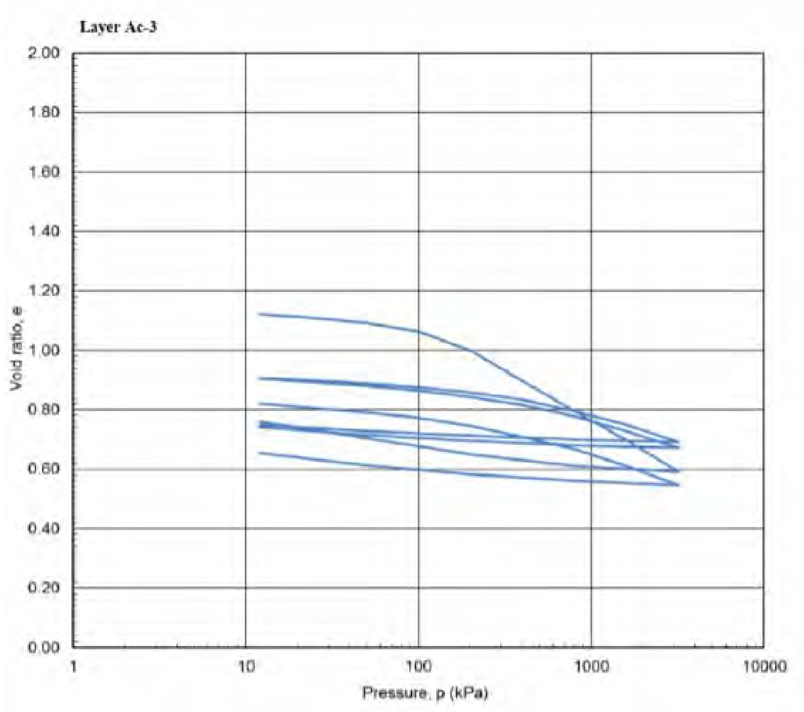


Figure 17.5-38 E-log P Curve for Ac-3 Layer

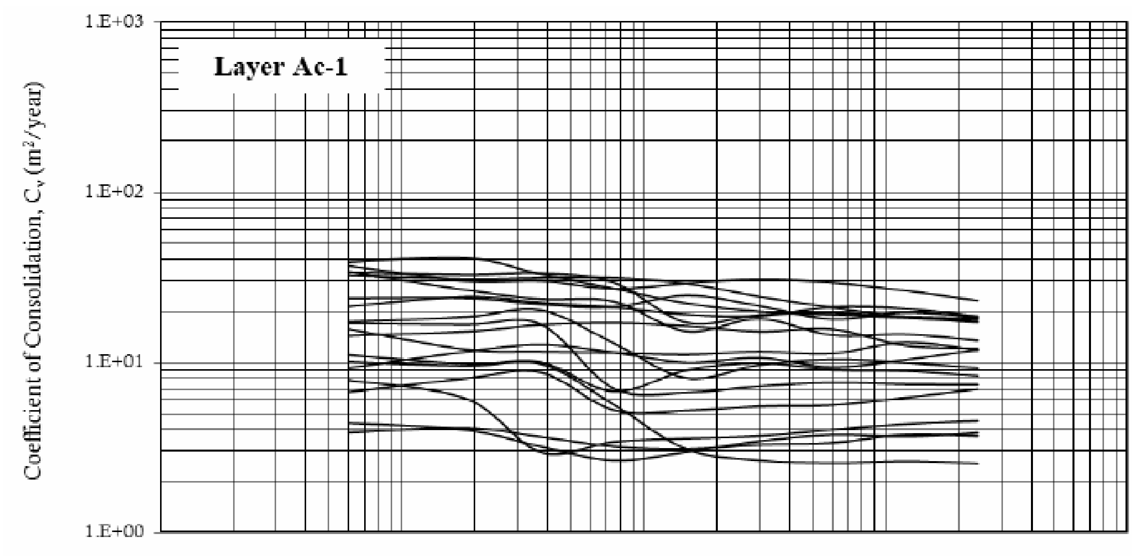


Figure 17.5-39 Cv Curve for Ac-1 Layer

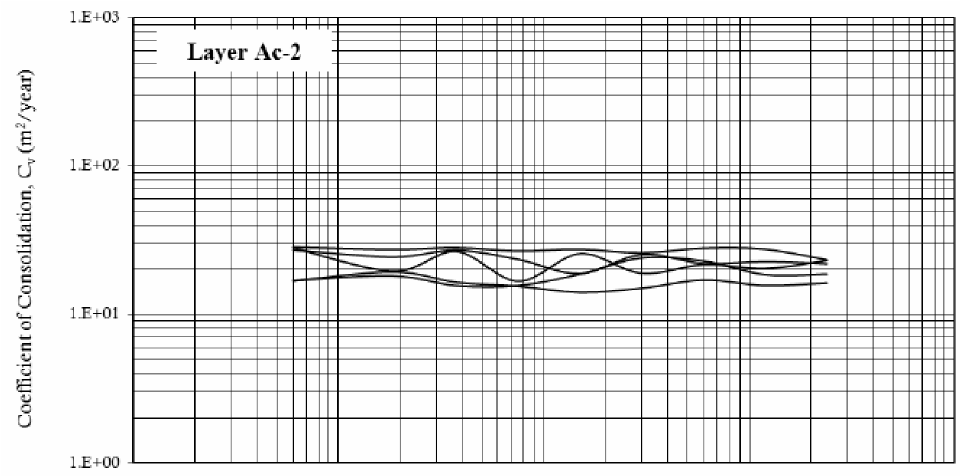


Figure 17.5-40 Cv Curve for Ac-2 Layer

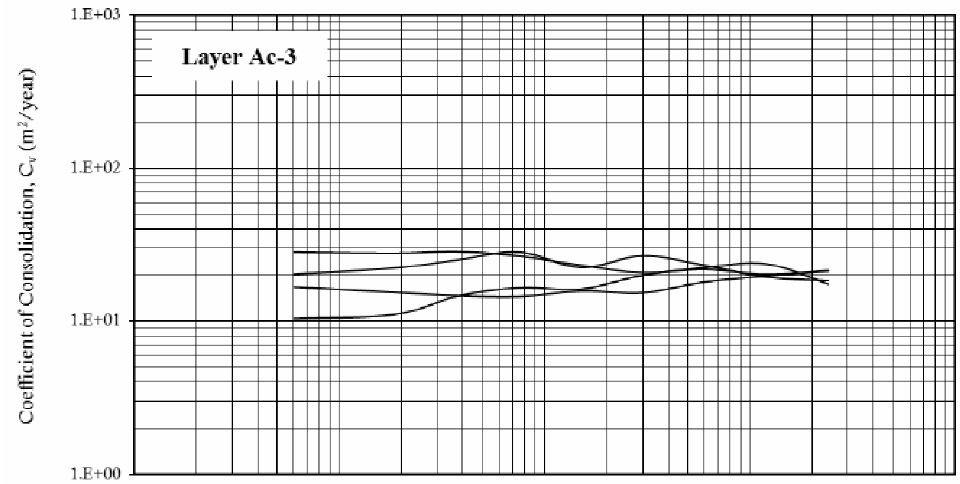


Figure 17.5-41 Cv Curve for Ac-3 Layer

④ Compaction Characteristics

The standard proctor compaction test was conducted on samples from the sand layers. The maximum dry density and optimum water content determined by the test are as follows:

Table 17.5-21 Compaction Test Results

Layer	Range of Maximum Dry Density (g/cm^3)	Range of Optimum Water Content (%)
As-1	1.73	14.4
As-2	1.60 to 1.91	11.6 to 17.8
Ds	1.67	16.5

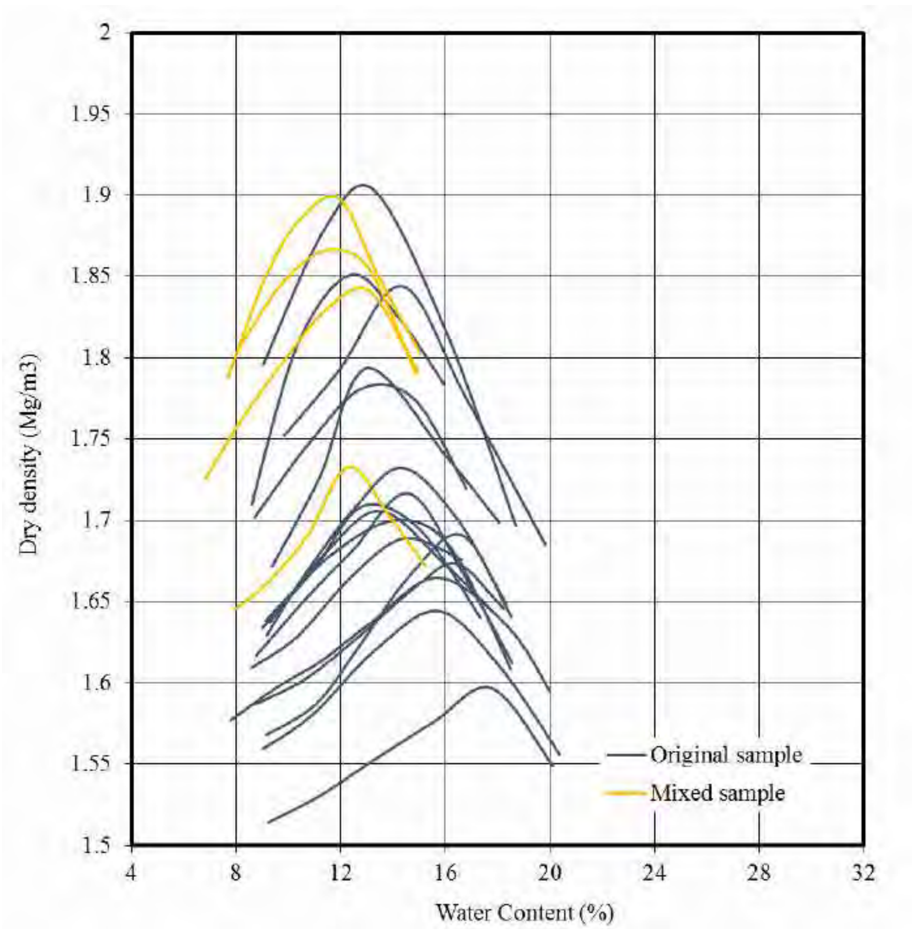


Figure 17.5-42 Compaction Curve of All Test Results

17.5.2 Land Survey Result

(1) Survey Quantity

Table 17.5-22 shows the quantity of the land survey.

Table 17.5-22 The Survey Quantity

No	Item	Quantity
1	SI points setting out (onshore and offshore)	91 points
2	Permanent benchmark establishments	1 station
3	Temporary benchmark	10 TBMs
4	Topographic survey	632 hectares*1

For details of the SI (Site Investigation) points setting out, please refer to the drilling works result section.

*1 The survey area covers the total area of the power plant with a 50m fringe.

(2) Establishment of the Benchmarks

1) Coordinates system employed

For this a site independent coordinate system was chosen with the center point of the turning basin being the UTM grid north (based on the UTM coordinates system). The coordinates for the center point of the turning basin are shown in Table 17.5-23.

Table 17.5-23 UTM Coordinates of Turning Basin Center

Point name	North (m)	East (m)
LD2-13-2	2,400,120.000	383,470.000

2) National benchmark

The Environment Survey Team carried out a field investigation in relation to the national bench mark established by the Survey of the Bangladesh Department at the nearest point to the site. Table17.5-24 shows the coordinates and elevation regarding the national bench mark that was the quotable bench mark at the site’s surroundings.

A control point of coordinates are referred to as BM6010 and BM8508, and a control point of elevation is referred to as GPS322 (these are shown in Table17.5-24).

Table 17.5-24 National Bench Marks

No	Point name	North (m)	East (m)	Elevation (m)	For
1	GPS322	2395895.991	404305.717	4.6373	Elevation
2	BM6010	2402479.557	384669.838	2.4344	Coordinates
3	BM8508	2398788.388	383295.616	2.1853	Both

Source: Survey of the Bangladesh Department

3) Temporary benchmarks (TBM)

There are 10 TBMs (named from TBM-1 to TBM-10, respectively) were established at specific locations surrounding the site that had a clear sight and stable ground conditions. The TBM network is shown in Figure 17.5-43 and TBM’s relevant coordinates and elevations are shown in Table 17.5-25. The TBM blocks were cast in concrete and stainless steel centers, and then installed at their specifically chosen locations. The structure of the TBM and the photographs are shown in Figure 17.5-44 and Figure 17.5-45, respectively.

Figure 17.5-43 Location of the Land Survey Work with the National Bench Mark and TBM Positions

Table17.5-25 Coordinates and Elevations of the TBMs

Point name	Coordinates		Elevation
	North(m)	East(m)	
TBM-1	2401350.247	386334.862	1.669
TBM-2	2400394.681	386194.220	4.551
TBM-3	2399852.390	385325.010	3.411
TBM-4	2399450.376	384737.737	3.398
TBM-5	2400383.835	384398.821	1.572
TBM-6	2399545.161	383786.929	1.746
TBM-7	2399973.651	382940.210	3.696
TBM-8	2400584.367	383595.037	3.046
TBM-9	2401414.231	384422.094	2.320
TBM-10	2400780.709	385047.194	1.730

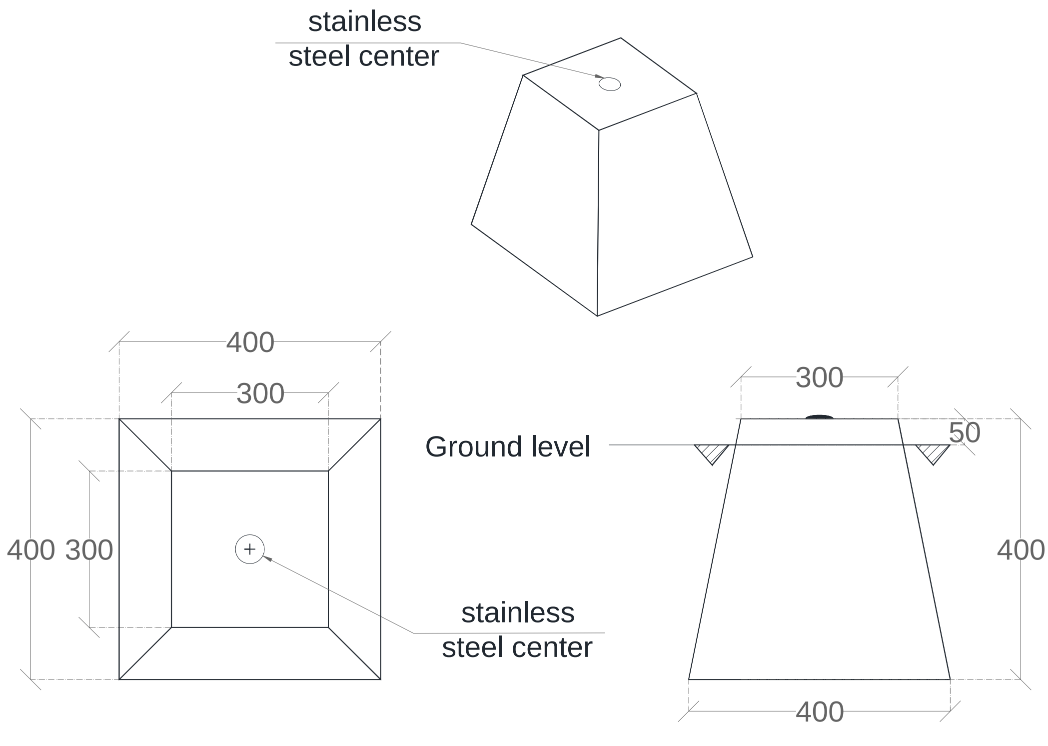


Figure 17.5-44 Temporary Benchmark Structures

Casting TBM core center　　　　TBM-04 at site

Figure 17.5-45 Temporary Benchmark at the Site

4) Elevation and the coordinate network

High precise leveling was carried out to connect the elevation from SoB GPS No 322 and BM 8508 to PBM. The elevation transverse made a loop: starting from the PBM, going round all the respective TBMs, and then returning to the PBM. The accuracy of the elevation network was proofed by some results as shown below:

Root mean square weighting unit error	: Mo = 0.002(m/Km)
Maximum mean square of height	: (TBM3) = 0.004(m)
Minimum mean square of height	: (TBM7) = 0.002(m)
Maximum mean square of measurement value	: (GPS322 - TBM) = 0.004(m)
Minimum mean square of measurement value	: (TBM4 - PBM) = 0.001(m)

The coordinates were transferred from **BM 8508** and **BM 6010** to PBM by a combination of the static GPS and total station methods to obtain a highly precise and certain result. After that the TBMs were connected to the PBM by the total station traverse network.

5) Permanent benchmark

① Coordinates and elevation

After establishing the coordinate system, the coordinates and the elevation of the PBM was surveyed and determined as shown in Table 17.5-26.

Table 17.5-26 Coordinates and Elevation of PBM-1

Point name	Coordinates		Elevation
	North(m)	East(m)	
PBM	2399433.796	384612.764	3.845

② Structure

The installation of the PBM was carried out as follows:

1) A hole was drilled into the ground using a drilling machine at the chosen position.
2) The borehole was washed to the bottom after its stable layer (44.2 m from ground level) was reached.
3) The SPT N-value at the bottom was confirmed as more than 50, and then the borehole was washed to the bottom again.
4) Steel pipes – each with a diameter of 100mm - were inserted in the borehole and connected together by a thread to reach the stable layer.
5) After reaching the stable layer, the “connected” pipe was then hit by a SPT hammer so it penetrated a few centimeters into the stable layer.
6) The area between the pipe and the borehole wall was backfilled with bentonite and cement grout.
7) The ground around the pipe was excavated for a pile cap with designed dimensions.
8) Cast leveling concrete was applied.
9) Reinforcement steel bars were installed.
10) The PBM head and the force center parts at the top of the D100 steel pipe were welded together.
11) A framework with designed dimensions was made and casted with concrete.
12) A framework for the working slab was made and casted with concrete.
13) A manual excavation was undertaken for protective poles at the four corners.
14) A framework for the base was made and casted with concrete.
15) D60 pipes were inserted at the four corners.
16) The borehole was backfilled with soil to ground level and compacted around the PBM area.
17) A chain was linked up between the pipes at the four corners.
18) The site was cleaned.
19) The PBM was handed over to the client

The depth of the borehole and the pipes installed at the PBM are shown in Table 17.5-27. A photograph of the PBM installed is shown in Figure 17.5-46 and the structure is shown in Figure 17.5-47.

Table 17.5-27 Depth of Drill Hole and Pipe Installed at PBM

Point name	Depth of borehole before SPT (from ground level) (m)	Length of steel pipe prepared /installed (from ground level) (m)	Difference (m)	Remark
PBM	44.20	44.44 / 44.20	0.00	Pipe cut off

Figure 17.5-46 Permanent Benchmark Installed

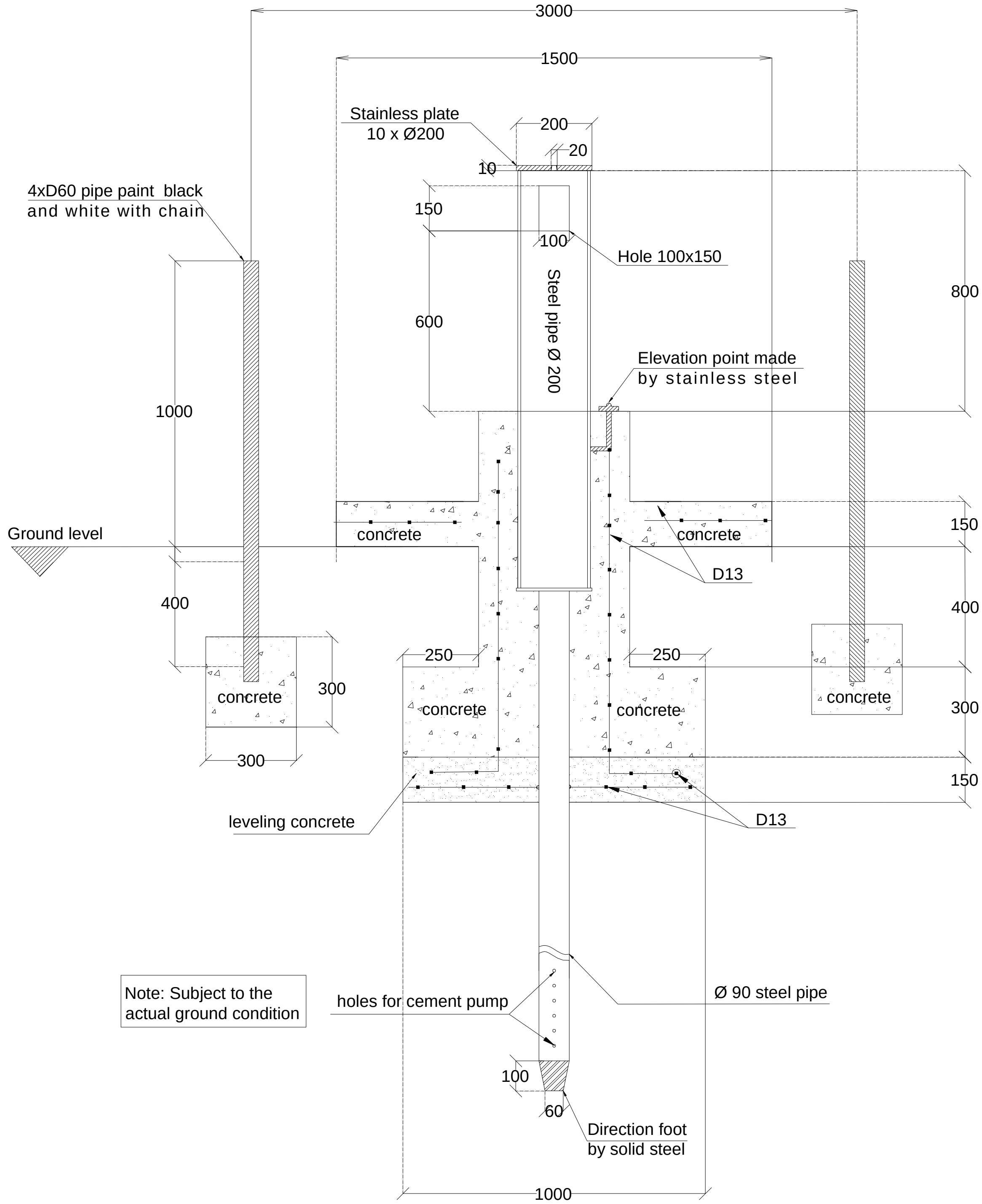


Figure 17.5-47 Permanent Benchmark Structure

(3) Topographic survey result

The coordinates and elevation adopted were from the site independence coordinates system based on aforesaid national benchmark and the mean seawater level. All dimensions are in metric.

The topographical survey on the land was carried out using a combination of the total stations and the RTK GPS method. The survey area was based on the boundary line which was shown in the AutoCAD drawing planned by the Environment Survey Team. The survey covered an area with a 50m fringe at each side of the boundary; in total the survey area became 623 hectares.

All structures and objects were surveyed and drawn to satisfy all the technical requirements for a 1/5000 scale topographic map. Contour lines, if shown, are in 0.5m intervals.

The said topographic map produced is shown in Figure 17.5-48 and the full size map was submitted separately.

The topographic map and the power plant layout were combined based on the match point refer to center of the turning basen on Table 17.5-23. The north direction of the power plant layout is follow to UTM coordinates system.

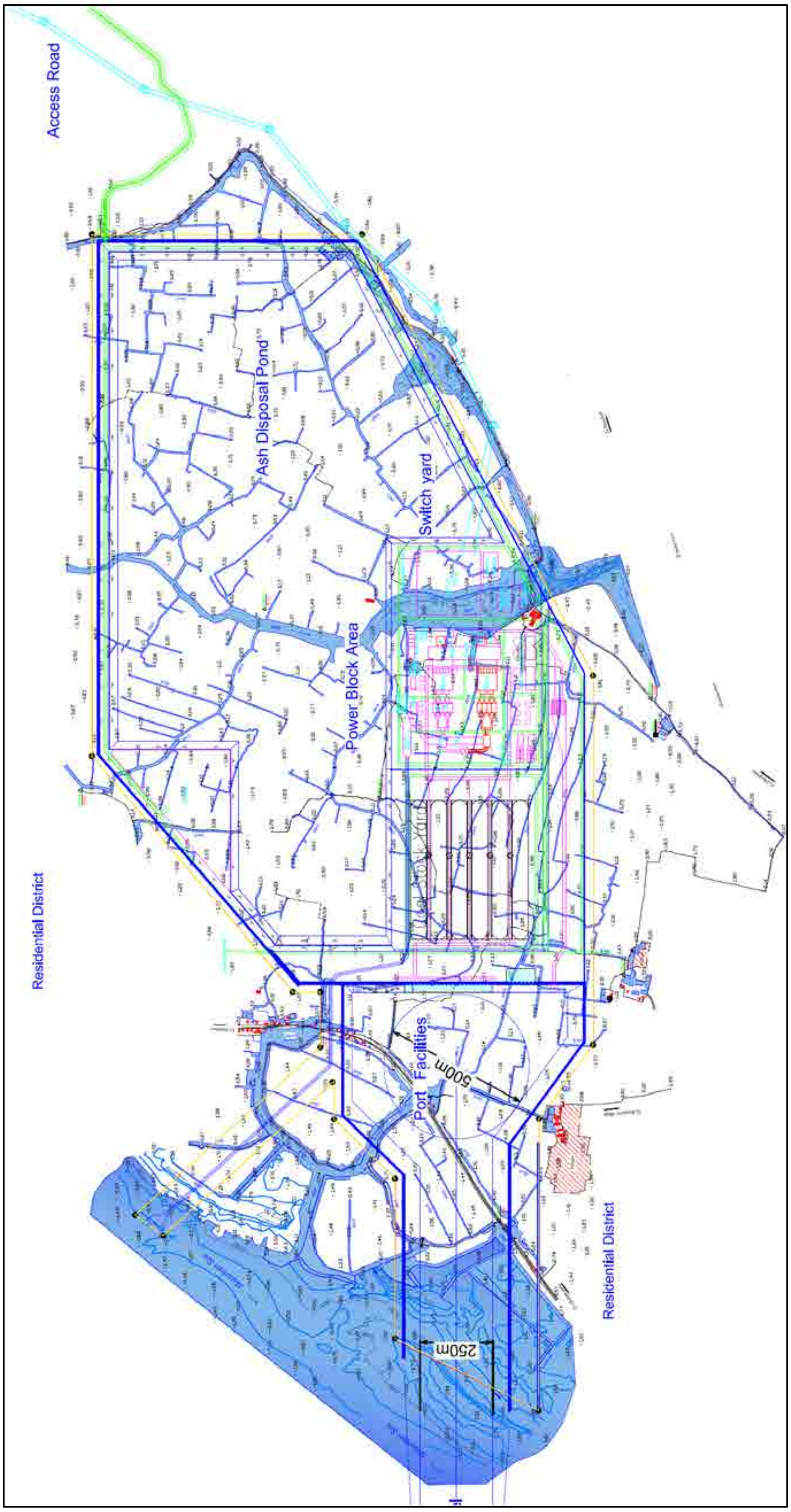


Figure 17.5-48 Topographic Map Produced

17.5.3 Environmental and Social Considerations related to the Environmental Survey

・Local Authorities related to the Environmental Survey

The primary local contact for inquiries and consultations concerning the natural environment is the Department of Environment (DOE) office of Cox's Bazar district. This office is headed by the Assistant Director and is one of the district level offices of the Ministry of Environment and Forest. The Deputy Commissioner's (DC) office of Cox's Bazar district and the Maheskhali Upazila Nirbahi office exclusively handle matters related to land acquisition, as well as coordinating with relevant organizations, and dealing, on behalf of the Government of Bangladesh (GOB), with grievances from Project-affected people and parties. The DC and Upazila Nirbahi Officer (UNO) are appointed and deployed by the GOB to provide civil services to the local residents.

Apart from the said professional and administrative bodies of the GOB, there are also local government bodies such as the Upazila Parishads (sub-district councils) and Union Parishads (town/union councils) which are represented by the Parishad members that the local populous elects. These bodies were established for promoting decentralization and monitoring the civil service as stipulated by the Constitution and the Local Government Act. At the Upazila-level, it is the Upazila Parishad which has the authority to make final decisions. Whereas, at union-level, as there are no administrative bodies allocated from the central government for this purpose, the Union Parishad chairman and its members possess the absolute authority to make such decisions.

The diagram inserted on the last page of this section shows the interrelations between the relevant authorities in this survey.

・Acquisition of the Entry Permit, and the Request for and Provision of Security Guards and Defense

CPGCBL issued an entry permit letter on 11th August 2014 , which allowed the Environmental Survey team to conduct the survey commencing from 24th August 2014 until completion.

For security purposes local policemen and coastal guards were deployed to prevent equipment and machinery from being damaged or stolen and to protect all the allocated engineers and the onshore and offshore subordinate personnel. Engineers from Kiso-Jiban Consultants commenced their field activities on 25th August 2014, with the policemen and coastal guards being deployed two days later. The policemen guarded the site day and night for 24 hours, and the coastal guards kept watch over the site during the daytime only, and nighttime when required.

・Local Directions During the Environmental Survey Period

<Natural Environment>

The Environmental Survey team visited the DOE office of Cox's Bazar district on 30th June 2014 to present the survey plan and schedule, and on 1st December in the same year for reporting the survey conclusion.

The survey, based on civil engineering, was to be conducted within the Project site; this was covered in the EIA approved by the Ministry of Environment and Forest in October 2013, which was still effective. The DOE office of Cox's Bazar district fully understood this position, and thereby extended a favorable opinion to the Environmental Survey team.

<Land Acquisition and Standing Crop Compensation>

The budget for land acquisition - allocated by the GOB for the payment, mandated by law, of cash compensation to parties that have their land acquired - was transferred from CPGCBL to the DC office on 30th June 2014. The DC office has been fully mandated to deal with the payment procedures (including compensation for standing crops) and negotiations with the affected people and parties. In early July 2014 the DC declared the land acquisition for the Project site. Here the main people and parties to be compensated for the land acquisition were those involved in shrimp cultivation, which was the main activity conducted on the Project site prior to the DC's said declaration.

Based on the official assessment by the DC's office, approximately 1,600 acres (the equivalent to 650 ha) of land was to be acquired, out of which almost 200 acres (80 ha) was public land that belonged to the Bangladesh Water Development Board (BWDB).

On 24th August 2014, the DC's office handed over the Project site to CPGCBL – this was widely reported in the local media, including through photos and articles in newspapers. In attendance at the handing over ceremony were around 400 villagers, UP members, the UNO, the Upazila Parishad chairman, and staff from the district's inland revenue department.

The DC office has been implementing the payment of compensation to the relevant landowners since the end of November 2014. The DC office staff in charge of this matter handle the landowners' claims at the office, which includes going through the payment procedures, dealing with grievances, and advising on inquiries. At this time the DC predicted that it would take another few months until the land compensation payments are fully complete. On top of the difficult issue of identifying landowners, the DC office has also been faced with a more complex situation in having to identify those people and parties who actually ran shrimp cultivation businesses on the Project site. As of the end of November 2014, the DC office was actively still trying to track these down.

<Salt Cultivation>

The Project site was used mainly as a salt farm during the dry season. The peak season for salt cultivation is between December and February every year. Typically, following the end of the rainy season in August and September every year, local businesses and workers begin to transport the salt they have excavated and stocked at the bottom of the salt field. In 2014 local workers took salt from the Project site during the survey period up until November, however, this did not affect the survey itself.

In fact, one of the salt factories located at a corner of the Project site, was declared closed on 27th August 2014 by the UNO. Part of the factory was offered as the field office for KJC to monitor the progress of the field work until the completion of the Environmental Survey.

Figure 17.5-49 Salt Factory Sealed by UNO

Figure 17.5-50 Salt Stocked in the Salt Factory

・Remarks concerning the Engineering Service

<Environmental Issues>

In case the implementation of the Engineering Service goes beyond the scope and content of the approved EIA, it is recommended to consult with the DOE of the Dhaka Headquarters for directions.

In light of this. if it becomes necessary to revise or change any part of the Environmental

Management Plan or the Environmental Monitoring Plan in order to effectively implementing them, it is also desirable to consult with the said DOE for further instructions.

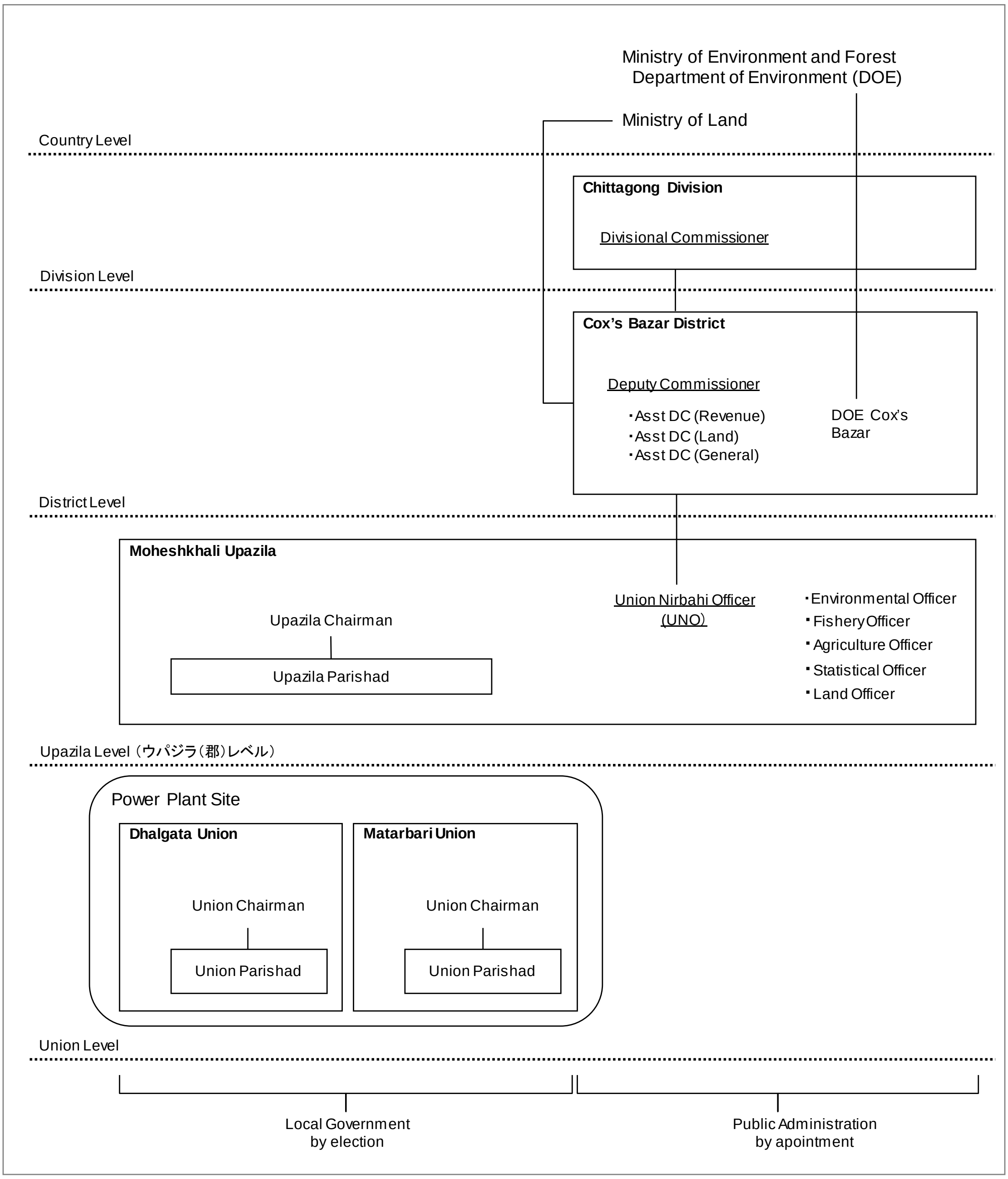


Figure 17.5-51 Diagram of the Relevant Authorities to the Environmental Survey

17.6 Analysis and Evaluation

17.6.1 Availability of Dredging Soil for the Embankment and Volume Analysis

(1) Availability of the Dredging Soil

For reuse of the dredged soil for the necessary embankment, its availability was studied with regard to international standards (AASHTO, and BS) and Japanese standards (Japan Road Association, and Railway Technical Research Institute), that are commonly applied to many projects overseas and in Japan.

1) AASHTO Standards

The classifications and ratings of soil specified in AASHTO M145 are shown in Table17.6-1. The granular materials (35% or less passing 0.075mm) were rated as “Excellent to Good”, which means these are suitable for subgrade. AASHTO M80 also stipulates that material classified in the A-1, A-2-4 and A-2-5 or A-3 groups may be used for the embankment when suitable.

Table 17.6-1 Classification and Usage of AASHTO M145

	Granular Materials (35 Percent or Less Passing 0.075mm)							Silt-Clay Materials (More than 35 Percent Passing 0.075mm)			
	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5,6
Sieve analysis, percent passing:											
2.00mm(No.10)	≦50%	—	—	—	—	—	—	—	—	—	—
0.425mm(No.40)	≦30%	≦50%	51%≦	—	—	—	—	—	—	—	—
0.075mm(No.200)	≦15%	≦25%	≦10%	≦35%	≦35%	≦35%	≦35%	36%≦	36%≦	36%≦	36%≦
Characteristics of fraction passing 0.425mm(No.40)											
Liquid limit	—	—	—	≦40%	41%≦	≦40%	41%≦	≦40%	41%≦	≦40%	41%≦
Plasticity index	≦6%	≦6%	NP	≦10%	≦10%	11%≦	11%≦	≦10%	≦10%	11%≦	11%≦
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General ratings as subgrade	Excellent to Good							Fair to poor			

The range of grain size contents for each layer are shown in Table17.6-2. The range of silt, clay and colloid contents for the Ac-1,Ac-2,Ac-3, and Dc layers exceeds 35%. Therefore, these layers were as “Fair to poor” in the "Silty-Clay Materials" classification of Table17.6-1.

The As-1, As-2, and Ds layers were rated as “Excellent to Good” in the "Granular Materials" classification of Table17.6-1. Therefore, these layers are suitable as material for the embankment. However, as for some As-1 and As-2 layers the range of their silt, clay and colloid contents exceeds 35%. Therefore, a detailed evaluation of the soil is necessary in the detailed design.

The group A-2 requires the characteristics of fraction passing through 0.425mm with LL and PI. Table17.6-3 shows LL and PI for each layer. The As-1, As-2, and Ds layers are non-plastic materials. Therefore, these are denoted with the mark "-" in Table17.6-3 meaning they are “not available” for the LL and PI tests. In Table17.6-1, the evaluation of LL and PI is intended for materials passing 0.425mm.

For example, as a sample of the As-1, As-2, and Ds layers, the Environment Survey Team refers to D-1/D-2 of PP3-23-2 and D-3/D-4 of LD2-11-1a. By a particle size distribution test result, the ingredients less than 0.425mm more than 0.075mm are 40% - 90%. These results show much sand a thing. Therefore, because there was much sand, the consistency examination was impossible to properly conduct. From the above, we think that it is classified in A-3 by the classification of AASHTO.

However the above the results show that more than 10% of the particles were 0.075mm or less. Therefore an examination is necessary for the detailed design.

Table 17.6-2 Range of the Grain Size Content for Each Layer

Layer	Range of Sand Content (%) ≧0.075mm	Range of Silt, Clay and Colloid Content (%) ＜0.075mm
Ac-1	1 to 41	59 to 99
Ac-2	2 to 47	53 to 98
Ac-3	8 to 49	51 to 92
As-1	53 to 97	3 to 47
As-2	50 to 96	4 to 50
Dc	13 to 48	52 to 87
Ds	94	6

Table 17.6-3 Range of the Liquid Limit and Plasticity Index for Each Layer

Layer	Liquid Limit(LL)	Plasticity Index(PI)
Ac-1	28 to 80	6 to 44
Ac-2	25 to 40	6 to 17
Ac-3	23 to 40	7 to 20
As-1	-	-
As-2	-	-
Dc	25 to 43	11 to 21
Ds	-	-

2) BS 6349

Below are general descriptions about the materials for land reclamation from Clause 8.3.2 of BS 6349 part 5 (Code of practice for dredging and land reclamation).

- An economic material is well graded, free-draining sand with particle sizes in the range of 0.1 mm to 0.6 mm.
- Materials that are finer than 0.10 mm may be subject to excessive losses during dredging, handling and placing.
- The maximum percentage of fines that is acceptable in materials for land reclamation depends to some extent on the overall grading of the material.
- A difficulty that arises whenever significant percentages of fines are present is the natural tendency for the fine to segregate during hydraulic placing.

The particle size of most specimen obtained from the As-1, As-2, and Ds layers ranges between 0.1 mm and 0.6 mm. Therefore, these layers are thought to be suitable for land reclamation according to the above descriptions. However, for the same issues in relation to the fine contents (as previously stated), the maximum percentage of the fines should be examined in the detailed design stage. Although it may be possible that such contents could be eliminated through pumping delivery at the reclamation works.

3) Japan Road Association

Table17.6-4 shows the height and the range of slope for the materials of embankment as specified generally by the Japan Road Association: (Dourodokou, 2010).

Table 17.6-4 Classification by the Japan Road Association

Embankment Materials	Height(m)	Ratio of the inclined plane	Application
Fine sand(S) , gravel and silty or clayey gravel (G)	≦5m	1:1.5～1:1.8	・Apply to the embankment: -bearing capacity of a ground is enough -no influence of water -satisfy the compaction management value ・ （）: representative group ・other than a ratio of the indication, need a calculation
	5～15m	1:1.8～1:2.0	
Sand ,bad distribution(SG)	≦10m	1:1.8～1:2.0	
Rock(include blasted rock)	≦10m	1:1.5～1:1.8	
	5～15m	1:1.8～1:2.0	
Silty or clayey sand(SF), hard clayey soil, hard clay(hard clayey soil of diluvium, clay, Kanto loam etc.)	≦5m	1:1.5～1:1.8	
	5～10m	1:1.8～1:2.0	
volcanic cohesive soil(V)	≦5m	1:1.8～1:2.0	

When the As-1, As-2, and Ds layers with some mixing of fine contents are considered, categories 1 and 3 in Table17.6-4 may be applicable. In the project it is planned to install the embankment with a height of 10m, therefore, the slope range of 1.8~1:2.0 should be adopted. Although this slope will be subject to the actual design calculations.

4) Japan Railway Technical Research Institute

Table17.6-5 the shows soil groups available for use in embankment as specified generally by the Railway Technical Research Institute (Tetsudou Kouzoubutu Tou Sekkei Hyoujun: 2007, Japan). The upper side embankment means a thickness of 3m from the top. The lower side embankment means the part under the upper side embankment.

Table 17.6-5 Soil Groups Classified and Suitable for Embankments

Group	Soil and rock	Suitable for the upper side embankment	Suitable for the lower side embankment
〔A〕	(GW) (GP) (G-M) (G-C) (G-V) (GM) (SW) (S-M) (S-C) blasted hard rock(remove a fissile rock)	Suitable	・Basically, the soil which occurred will put to use. ・As a general rule, you must not use D2 group. ・You must not use : a) distensible soil and rock, e.g. bentonite, acid clay, solfataric clay b) serpentine and mudstone that the weathering is remarkable by the absorbing water expansion. c)high compressible soil, e.g. highly organic soil d)frozen soil
〔B〕	(G-O) (GC) (S-V) (S-O) (SP) (SM) (SC) blasted hard rock(remove a fissile rock), blasted soft rock, blasted fragile rock(remove a material, that belongs D1 group)	Suitable	
〔C〕	(GO) (GV) (SV) (ML) (CL)	Need a soil stabilization	
〔D1〕	(MH) (CH), blasted fragile rock(argillation material, the materials which weathering moved in after construction or the materials which become the mud under compaction)	Need a soil stabilization	
〔D2〕	(SO) (OL) (OH) (OV) (Pt) (Mk)	Not suitable	
〔V 〕	(VH_1) (VH_2)	Need a soil stabilization	

The content of silt, clay, and colloid of the samples from the As-1 and As-2 layers ranged within 50%. Therefore, these are classified as (SM) or (SC) in the group B in Table17.6-5. For the Ds layer, the range of silt, clay and colloid contents were around 6%. Therefore, the Ds layer is classified as (S-M) or (S-C) in group A in Table17.6-5. According to these classifications, the As-1, As-2 and Ds were suitable as material of embankment. In addition, the other layers were classified in group D1, so these are suitable for use in the lower side embankment.

(2) Estimated the amount of dredged sand

The results of the application to the filling material mentioned the previous section found from a qualitative perspective that the A_{s-1} and A_{s-2} existing ground layers can potentially be used as filling material for the power plant. Fortunately, according to the relevant soil profiles, these sand layers are deposited over all power plant area. Thus, from a quantity viewpoint, the Environment Survey Team tried to estimate the amount of dredged sand available here for the Project. The calculation method used for this was the multiplication of the partial cross-section of the dredging area by a partial length.

Figure7.4-4 shows the Matarbari power plant layout, and Figure17.5-2～Figure17.5-14 show the soil profiles.

The rough estimate of the amount of dredged sand was 9,700,000 m^3.

This value was calculated as the net volume. In terms of the amount of the soil that can be actually used, it was assumed that the value will change depend on the classification of the sand based on the bulking factor and the detailed design policy in the pre-construction stage.

On the other side, the rough estimate for the amount of the filling sand was 9,000,000 m^3.

This value was formulated base on a hypothetical case by taking into account the soil compression factor and subsidence factor. Thus, the accuracy of this value will be calculated based on several coefficients of variation in terms of the final design.

From a comparison between the amount of dredged sand and filling sand, it was found that the quantity of As-1 and As-2 will be a well-balanced soil at the project site.

17.6.2 Consolidation Characteristics of the Existing Ground in the Power Plant

The soil investigation results found that a soft layer, silt and cohesive soil, were deposited on the existing ground of the power plant area. In consideration of the storm surge height in order to avoid any flood damage, it is reported that the ground level for the power plant area shall be higher than the water level. For example, the port revetment area will fill up to M.S.L.+5.0m, the coal stock yard to M.S.L.+8.0m, and the power block area to M.S.L+10.0m. (for reference, the existing ground level is M.S.L.+1.0m). Ordinarily, in the case of a development on soft subsoil, it is necessary pay particular attention to the consolidation.

This section is to study about a settlement of consolidation and whether it will be possible or not to fill up on the existing ground without soil improvement works, through using the consolidation characteristic that had been obtained from laboratory tests

(1) Method

The purpose of this study is to give an overview of the consolidation regarding the existing ground of the power plant area. The Environment Survey Team performed preliminary calculations concerning the matter of consolidation settlement degree by using the soil investigation results. The preliminary calculations are based on the one dimensional consolidation model.

1) Study case

The soil profile of the power plant area is shown in Figure17.5-2～Figure17.5-14. The Environment Survey Team made two study cases for the preliminary calculations: the first concerns the coal stock yard area, which is the thickest point of the soft layer in the power plant area; and the second concerns the power block area, which is the highest filling level point in the power plant area.

Table 17.6-6 Preliminary Study Case Calculations concerning the Settlement

Case	Existing ground level (M.S.L.)	Filling plan		Thickness of the soft layer		
		Ground elevation (M.S.L.)	Height	Ac-1 layer	Ac-2 layer	Total
Case A (Coal Stock Yard area)	+1.0m	+8.0m	7.0m	8.0m	6.0m	14.0m
Case B (Power block area)	+1.0m	+10.0m	9.0m	6.0m	-	6.0m

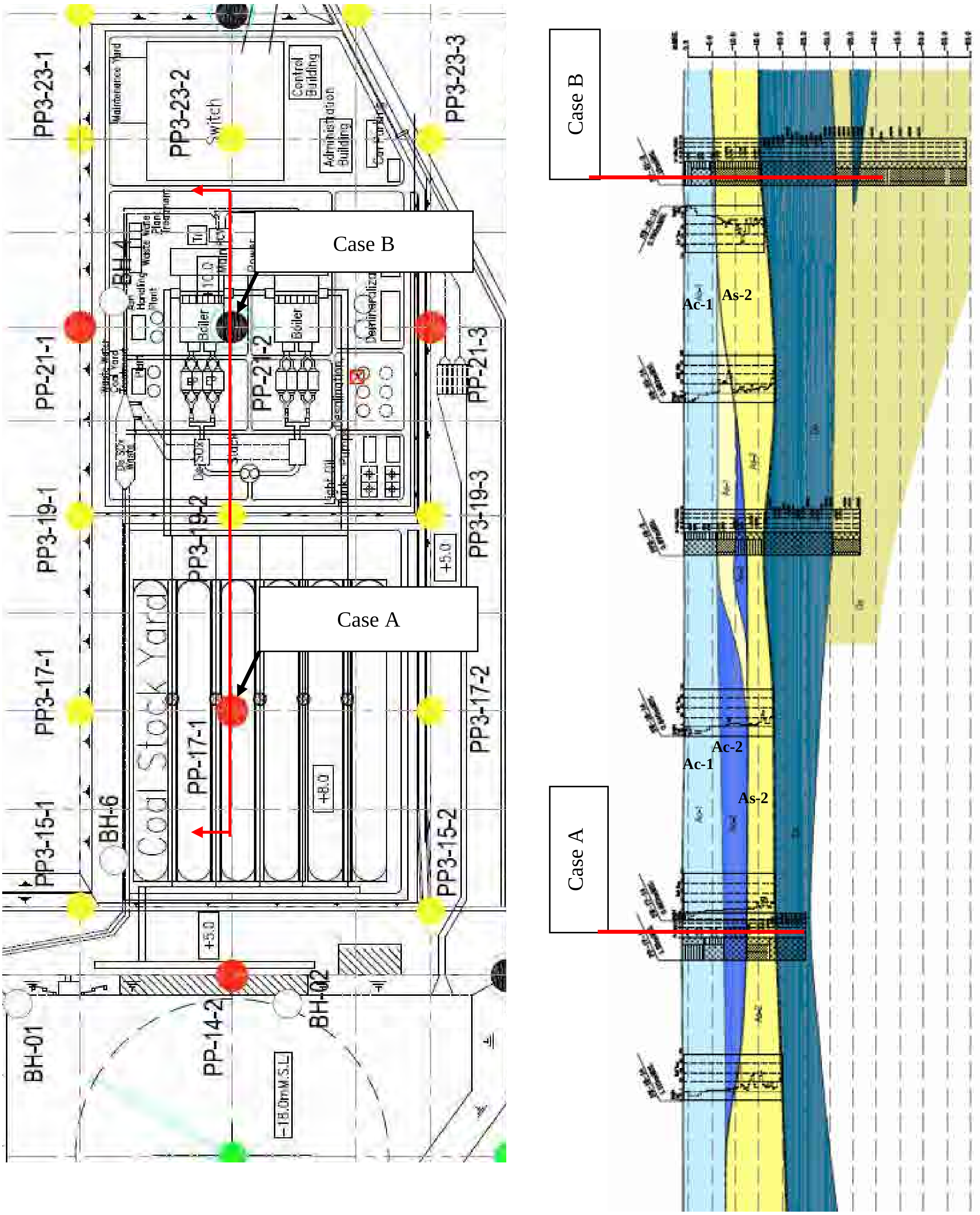


Figure17.6-1 The Location of the Preliminary Study Case Calculations

2) Calculation conditions

a. Unit weight of the material for filling

The unit volume weight assumed the following value in this calculation for the dredging sand to be used in the filling process.

・Unit weight γ_s=19 kN/m^3

b. Construction speed for raising the ground level

The construction speed for raising the ground level assumed the following value based on the intended construction method and schedule.

・Speed to fill up 2 cm/day

c. Consolidation characteristics

The Consolidation characteristic C_c and C_v is set as the following value based on the laboratory soil test results.

・Cc= 0.35 (Ac-1 layer) , 0.20 (Ac-2 layer), as shown in Figure 17.6-2

・C_v :the curve as shown in Table17.6-7

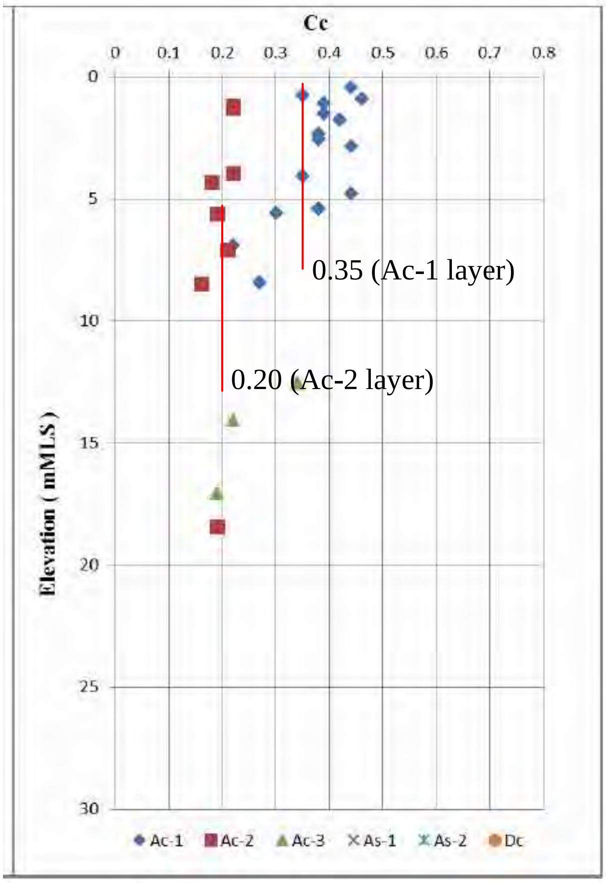
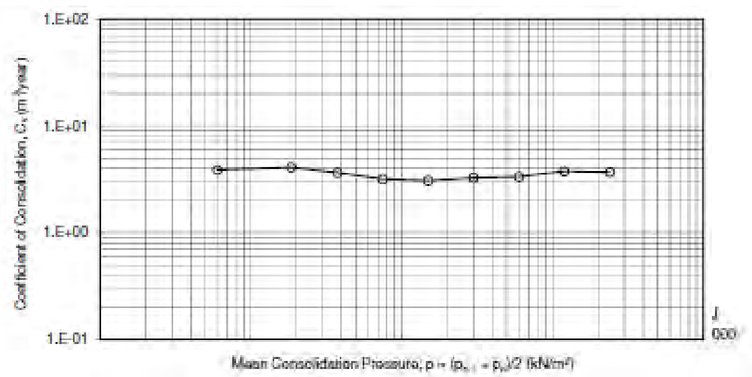
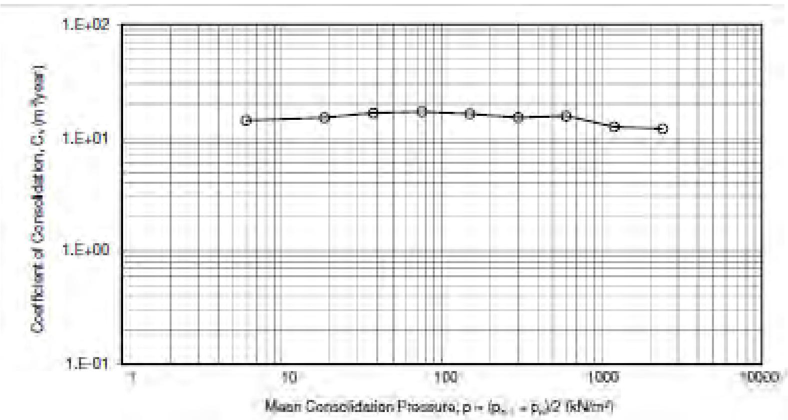


Figure 17.6-2 Compression Index Plotted against Depth and Levation

Table 17.6-7 Coefficient of Consolidation, C_v (m^2/year)

Ac-1 layer	
Ac-2 layer	

Source: Consolidation Test Result of the Boring No.PP-17-1 (Coal Stock Yard Point)

(2) Calculation model

The thickness of the soft layer based on the soil profile of the power plant area is as shown in Figure 17.6-1. According to the soil profile, it is possible to deduce from this thickness that the back area of the port facility is about 9m, the coal stock yard is about 14m, and the power block area is about 14m. The calculation model should be adjusted to take into account the changing thickness of the soft layer, with the height of the filling ground level also needing to be considered. These site plan conditions provide two calculation models as shown below.

a) Case A model: coal stock yard area

The case A model shows the situation regarding the thickest layer in the power plant area. The model is located at the center of the coal stock yard which, as shown in Figure17.6-1, is near the drilling point no. PP-17-1. The groundwater level was assumed to be M.S.L+1.0m.

Table 17.6-8 Calculation Model (Case A)

Soil layer	Bottom level (M.S.L)	Layer thickness (m)	Unit weight γs (kN/m^3)	Consolidation characteristic
Ground level M.S.L+8.0m, Groundwater level M.S.L+1.0m*1				
Fill layer	+ 2.0 m	6.0 m	19.0	-
Sand Mat	+1.0 m	1.0 m	19.0	-
Ac-1 layer	- 7.0 m	8.0 m	16.8*1	Cc=0.35, Cv = Shown by Table17.6-7
Ac-2 layer	- 13.0 m	6.0 m	18.5*1	Cc=0.20, Cv = Shown by Table17.6-7
As-2 layer	-20.0 m	7.0 m	18.3*1	-

*It is based on the laboratory test result of borehole No. PP-17-1.

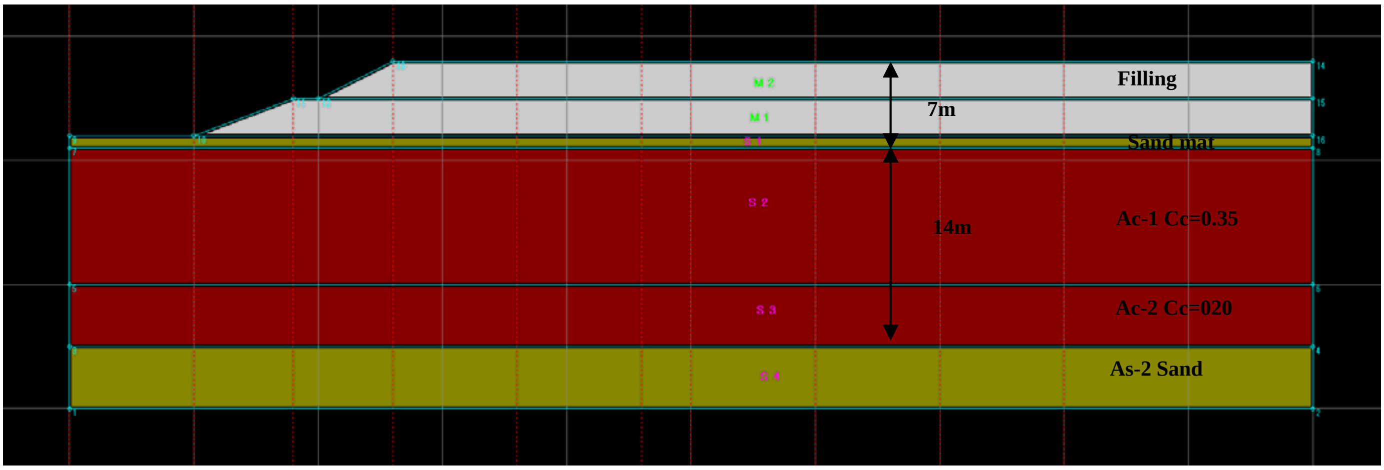


Figure 17.6-3 Soil Layer Model (Case A)

b) Case B model: power block area

The case B model shows the highest level of the filling ground in the power plant area. The model is located at the center of the power block area which, as shown in Figure17.6-1, is near the drilling point no. PP-21-2. The groundwater level was assumed to be M.S.L+1.0m.

Table 17.6-9 Calculation Model (Case B)

Soil layer	Bottom level (M.S.L)	Layer thickness (m)	Unit weight γs (kN/m^3)	Consolidation characteristic
Plan ground side M.S.L+10.0m and groundwater level M.S.L+1.0m*1				
Fill layer	+2.0 m	8.0 m	19.0	-
Sand mat	+1.0 m	1.0 m	19.0	-
Ac-1 layer	-6.0 m	7.0 m	18.9*1	Cc=0.35, Cv = Shown by Table17.6-7
As-2 layer	-15.0 m	9.0 m	18.1*1	-

*1: It is based on the laboratory test result of borehole No. PP-21-2.

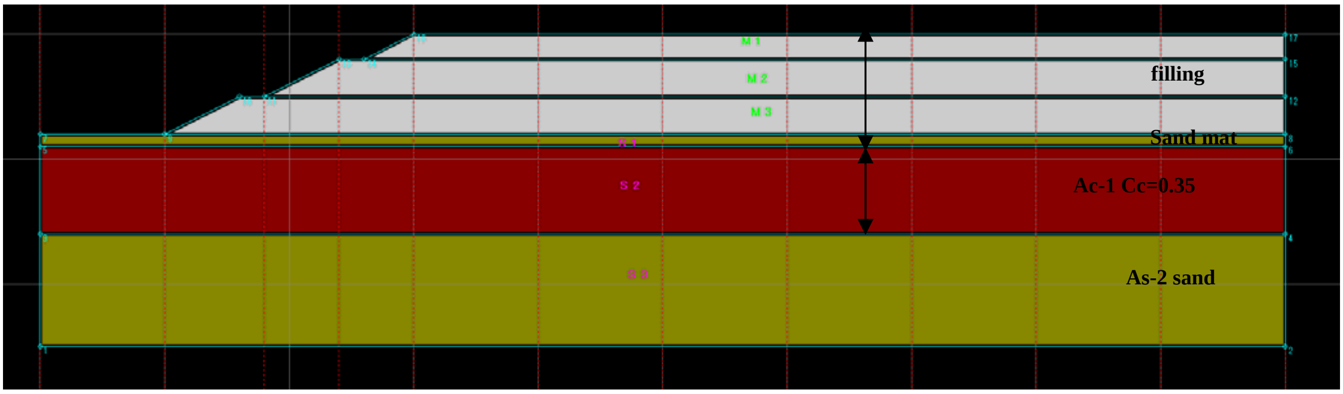


Figure 17.6-4 Soil Layer Model (Case B)

(3) Results

On the basis of the calculation conditions, the Environment Survey Team made a rough estimation of the settlement of the consolidation as shown in Table17.6-10.

The results show that the coal stock yard area shall be settled at about 1.9m and the power block area at about 1.5m. Moreover, something to bear in mind about the term from to the filling work (around 720 days or two years), is that there has been an excess of the 90% degree consolidation days in both of the said calculation models. That is, due to a continuously consolidation it may be that it will take over two years to fill the ground. The degrees of consolidation are 20% and 50%, respectively.

According to the calculation results, a settlement of consolidation shall occur on the existing soft ground. Thus, as this may have an adverse effect on the power plant construction schedule in the future, the Environment Survey Team suggests that a soil improvement must be carried out on the existing soft layers (Ac-1 and Ac-2) in order to potentially avoid this outcome.

Table 17.6-10 Consolidation Characteristics

Item	Case A Model (Coal Stock Yard)	Case B Model (Power Block)
Amount of the final subsidence	1.9m	1.5 m
90% consolidation days	11,000 day (30 year)	1640 day (4.5 year)
Compaction index (720day*1)	20 %	50 %

*1,720 days refers to the construction schedule or filling the power plant ground.

It should, however, be added that it is possible to change the degree of settlement greatly because these calculation conditions contain many assumptions, like the groundwater parameters or the unit weight parameters for filling the ground.

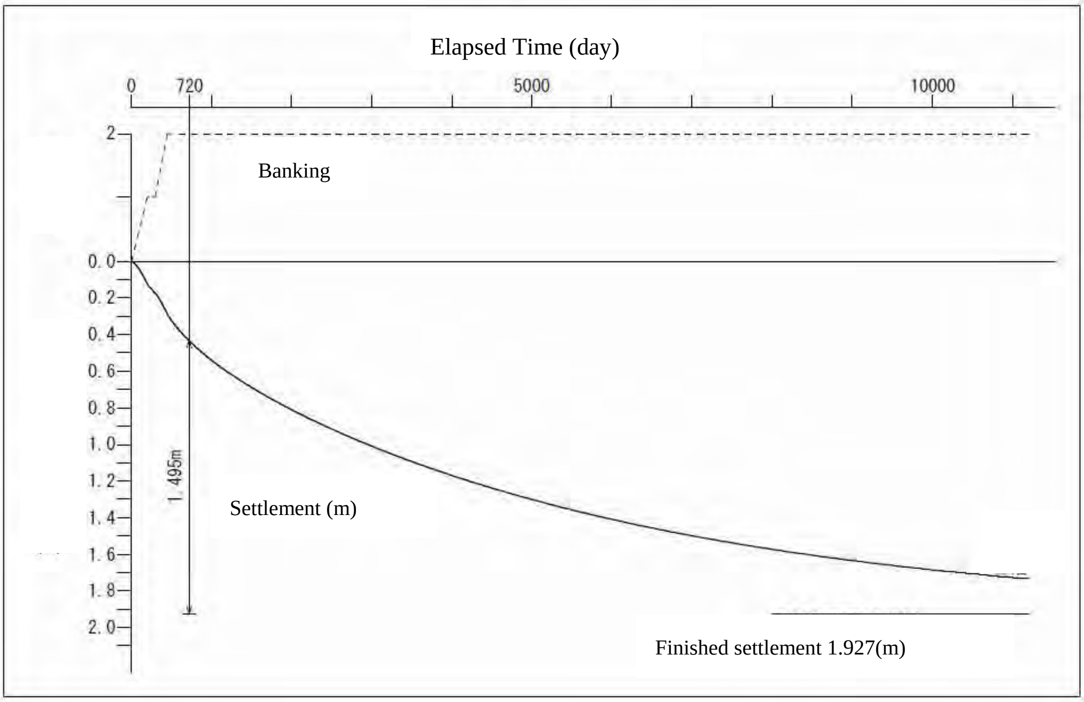


Figure 17.6-5 Elapsed Time and Amount of Subsidence (Case A Model)

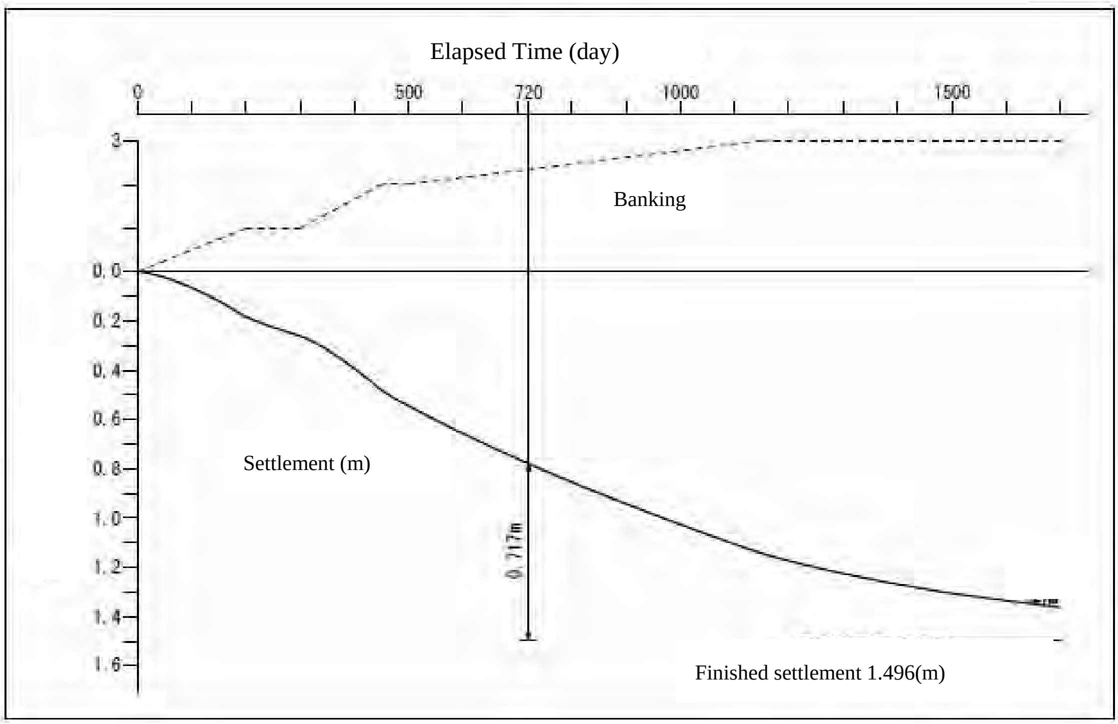


Figure 17.6-6 Elapsed Time and Amount of Subsidence (Case B Model)

17.6.3 Reconsideration of construction procedure for dredging and land development

As shown in the section 8.2.8, the Critical Path of the construction procedure about the dredging work and the land development was examined based on the preconditions related to the dredged sand material.

In this section, the construction schedule mentioned in Figure 10.1-1 was checked based on the latest natural condition investigation results.

(1) The main factors affecting to Critical Path Process

The evaluation for the dredged sand including a lot of fine fractions (the silt) or the silt layers lay in the sand layer was obtained according to the results of the detailed soil investigation.

The dredged sand properties will affect the construction schedule and costs. The dredged sand that contains a lot of silts will be difficult to temporarily store, because, as a filling material, it cannot easily be classified as sand or silt. Therefore, it will not be possible for the dredged sand to used directly as filing materials, - for this purpose it would require a longer period to drain away the moisture weight. Furthermore, the handling efficiency of the carriage from the temporary storage yard to the land development area will become lower.

(2) Possibility of modifications to the construction schedule and costs

In consideration of the dredged sand properties, it is likely that a separate construction procedure and method to those stipulated in 8.2.8 shall be adopted. Therefore, the detailed design should be conducted a thorough study of all matters relating to a receiving facility of the dredged sand and the critical path process.

17.7 Study of Sedimentation in Navigation Channel

In this Study, littoral drift patterns after the completion of the port and navigation channel are simulated to identify and analyze key factors that cause sedimentation in the port and channel. Based on the simulation results, the possibility of sedimentation in navigation channel and the necessity of countermeasures are examined and additional field surveys recommended.

17.7.1 Contents and Method of the Study

(1) Mechanisms of Littoral Drift Patterns and Sedimentation in Navigation Channel

1) Potential Littoral Drift Patterns

The coastal area, where the analysis zone is located, lies in a flood plain of a river, where the topography of the delta at the mouth of the river is constantly changing. However, the analysis zone, though it is situated in sand bar of river mouth, seems more topographically stable than other parts of the estuary as suggested by the relatively steep foreshore slope. Since the bottom sediments of the delta are mostly fine sand, it was decided to focus on the movement of sand while dismissing siltation of silt components as temporary phenomena occurring only during floods.

2) Mechanism of Sedimentation in Navigation Channel

Figure 17.7-1 is a simplified depiction of the mechanism of sedimentation in navigation channel due to transport of sand.

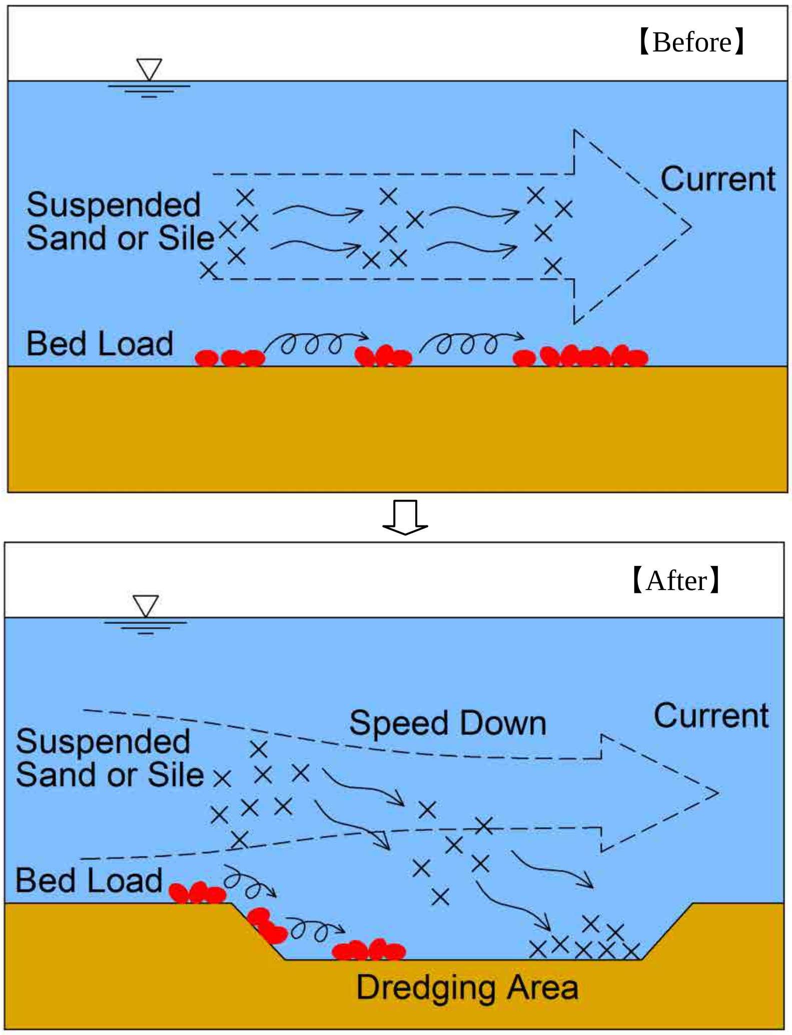


Figure 17.7-1 Schematic of Sedimentation in Navigation Channel

(2) Simulations

1) Simulation on Littoral Drift Caused by Waves

The flow of littoral drift simulation is shown in Figure17.7-2.

The analysis method used in the littoral drift simulation is outlined in Table17.7-1.

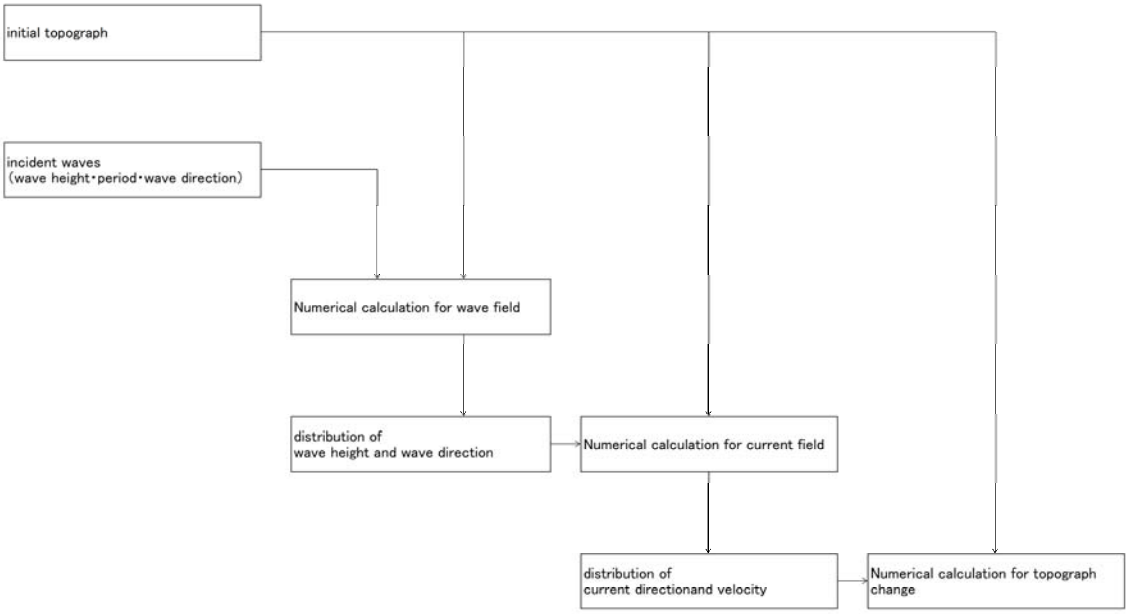


Figure17.7-2 Flow of Simulation on Littoral Drift Caused by Waves

Table17.7-1 Outline of the Simulation Method for Analyzing Littoral Drift Caused by Waves

Numerical Calculation for wave field	basement equation： Energy balance equation［Karlsson（1969）］ ・・・refraction，wave shoaling diffraction： angular spreading method wave breaking： numerical model for random breaking process［Goda（1975）］
Numerical Calculation for current field	basement equation： equation of continuity and motion for mean flow calculation method： Time-dependent equation considered time dependent , advection , pressure , bottom friction , horizontal diffusion and exerting force term（radiation stress by wave） , equation of continuity and motion for mean flow
Numerical Calculation for topograph change	basement equation： equation of continuity for sediment transport equation of local sediment transport rate ： equation of Watanabe et al.（1984） sediment transport rate・・・power model Evaluation of bottom shear stress ： Tanaka and Shuto（1980）

2) Simulation on Littoral Drift Caused by Tides

The flow and schematic image of the simulation are shown in Figures 17.7-3 and 17.7-4, respectively.

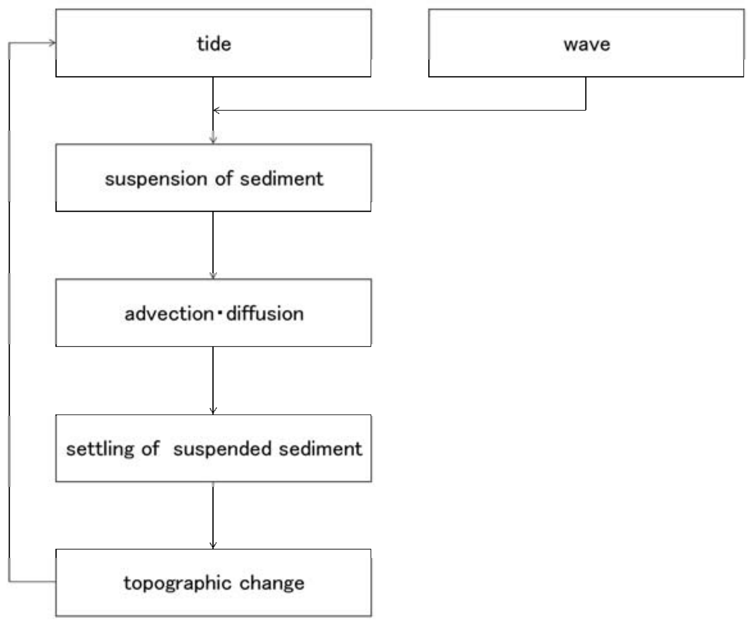


Figure17.7-3 Flow of Simulation on Littoral Drift Caused by Tides

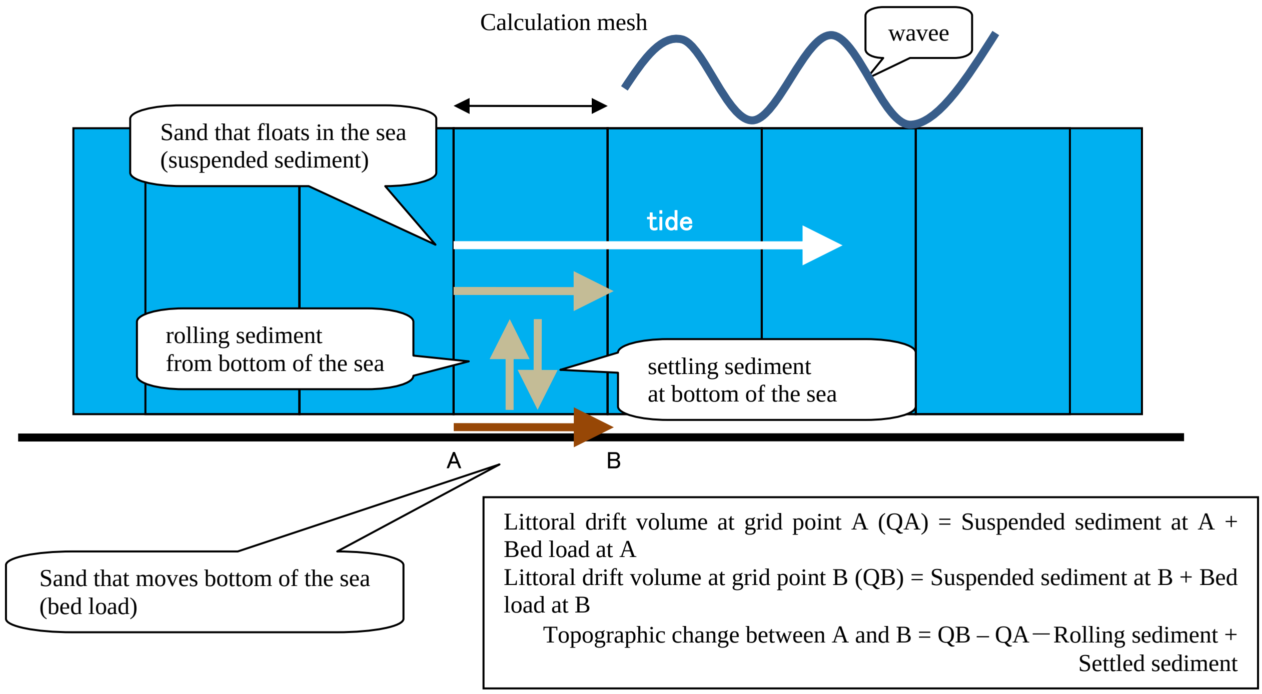


Figure17.7-4 Schematic of Computation of Topographic Change Caused by Tides

17.7.2 Results of the Simulation on Littoral Drift

(1) Simulation on Littoral Drift caused by Wave

1) Examination condition

The examination condition of Simulation on Littoral Drift caused by wave is shown in Table 17.7-2.

Table 17.7-2 Examination Condition of Simulation on Littoral Drift caused by Wave

Item	Examination condition				
analysis zone (Figure17.7-5)	wave field	on-offshore 47,600m×shore71,300m			
	wave field/ topographic change	on-offshore 8,500m×shore 11,150m			
bottom topography	Figure17.7-6				
wave condition (Table 17.7-3)		wave height Ho'	period T1/3	wave direction	remarks
	highest wave per year	3.40m	8.5sec	SSW	high rank 1% wave
	mean wave per year	1.22m	8.2sec	SSW	high rank 50% wave
tide level	H.W.L＝M.S.L.＋2.2m				
calculation condition of wave and current field	calculation mesh	Δx＝10m			
	time step	Δt＝0.01sec			
	friction coefficient	Cf＝0.02			
	horizontal diffusion coefficient	N＝0.01			
	boundary condition	open boundary of side and offshore land：normal element of velocity = 0			
calculation condition of topographic change	calculation mesh	Δx＝10 m			
	time step	Δt＝0.5hr			
	littoral drift rate coefficient	Ac＝1.0, Aw＝0.2（reference value）			
	on-offshore judgment coefficient	Fd＝1.0			
	topographic change coefficient	ε＝10.0			
	sand grain size	D_{50}＝0.20mm［assumed dry season］ D_{50}＝0.10mm［assumed rainy season］ （Table 17.7-4 result of sediment survey）			
	action days	3days			
	boundary condition	open boundary of side and offshore land：normal element of littoral drift = 0			

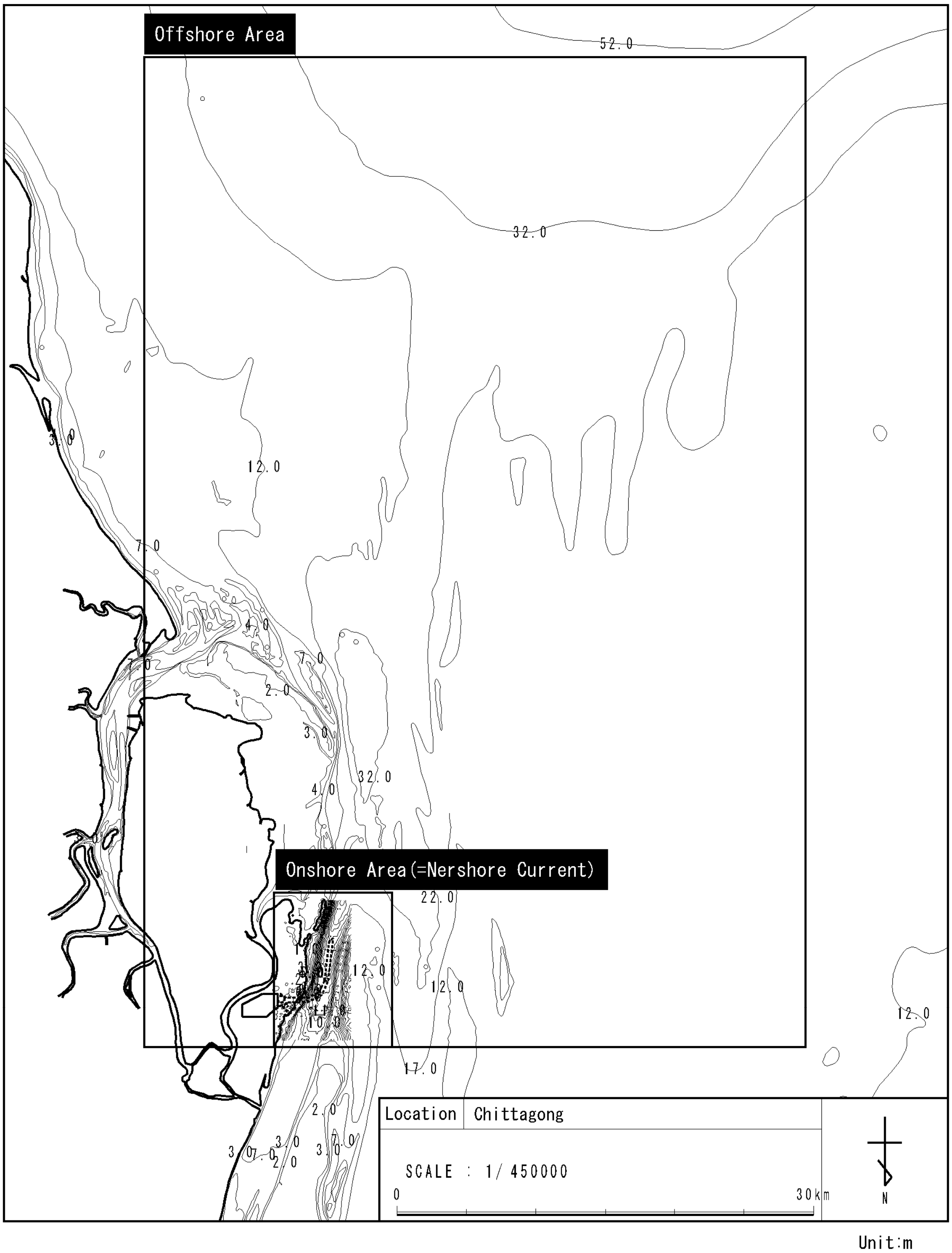
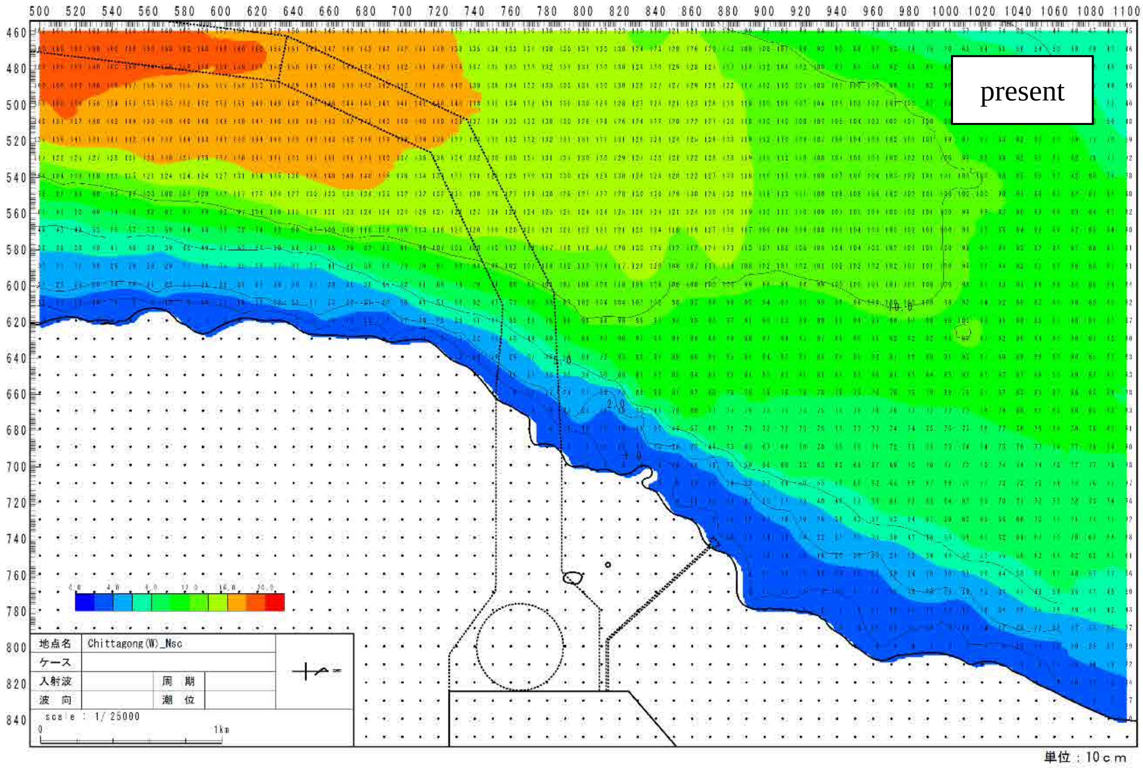


Figure17.7-5 Analysis Zone



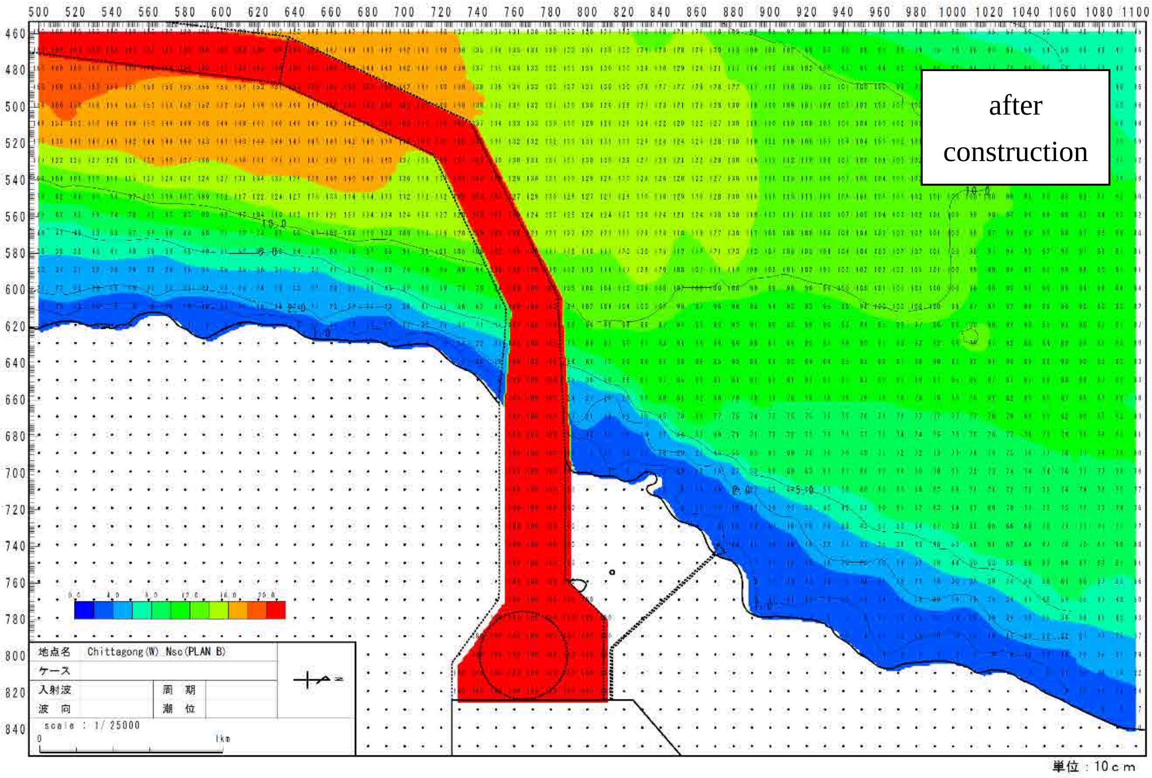


Figure17.7-6 Bottom Topography

Table 17.7-3 Occurrence Rate of Ocean Waves

(Results of 2006 – 2011 ocean wave predictions by Japan Weather Association)

Point : E91.5 , N20.5
Term : 2006.1.1 ～ 2010.12.31
Wave Direction : ALL

Height (m) \ Period (s)	～ 2.9	3.0 ～ 3.9	4.0 ～ 4.9	5.0 ～ 5.9	6.0 ～ 6.9	7.0 ～ 7.9	8.0 ～ 8.9	9.0 ～ 9.9	10.0 ～ 10.9	11.0 ～ 11.9	12.0 ～ 12.9	13.0 ～ 13.9	14.0 ～ 14.9	15.0 ～	Sum	Total amount
～ 0.49			18 (0.0)	75 (0.2)	187 (0.4)	323 (0.7)	378 (0.9)	346 (0.8)	131 (0.3)	17 (0.0)					1475 (3.4)	1475 (3.4)
0.50 ～ 0.99		6 (0.0)	255 (0.6)	948 (2.2)	1729 (3.9)	2533 (5.8)	3765 (8.6)	3280 (7.5)	1734 (4.0)	484 (1.1)	189 (0.4)	19 (0.0)	13 (0.0)		14955 (34.1)	16430 (37.5)
1.00 ～ 1.49			186 (0.4)	590 (1.3)	1089 (2.5)	2579 (5.9)	2952 (6.7)	1929 (4.4)	1389 (3.2)	917 (2.1)	350 (0.8)	110 (0.3)	18 (0.0)		12109 (27.6)	28539 (65.1)
1.50 ～ 1.99				144 (0.3)	1295 (3.0)	2644 (6.0)	2617 (6.0)	1209 (2.8)	609 (1.4)	122 (0.3)	61 (0.1)	70 (0.2)	4 (0.0)		8775 (20.0)	37314 (85.1)
2.00 ～ 2.49				14 (0.0)	765 (1.7)	1560 (3.6)	1158 (2.6)	462 (1.1)	129 (0.3)	67 (0.2)	42 (0.1)				4197 (9.6)	41511 (94.7)
2.50 ～ 2.99					267 (0.6)	681 (1.6)	369 (0.8)	173 (0.4)	28 (0.1)	13 (0.0)	26 (0.1)				1557 (3.6)	43068 (98.3)
3.00 ～ 3.49					13 (0.0)	256 (0.6)	128 (0.3)	13 (0.0)	1 (0.0)	13 (0.0)					424 (1.0)	43492 (99.2)
3.50 ～ 3.99						131 (0.3)	36 (0.1)	9 (0.0)							176 (0.4)	43668 (99.6)
4.00 ～ 4.49						34 (0.1)	35 (0.1)	6 (0.0)							75 (0.2)	43743 (99.8)
4.50 ～ 4.99						2 (0.0)	17 (0.0)	10 (0.0)							29 (0.1)	43772 (99.9)
5.00 ～ 5.49							13 (0.0)	4 (0.0)	2 (0.0)						19 (0.0)	43791 (99.9)
5.50 ～ 5.99							6 (0.0)	7 (0.0)	4 (0.0)						17 (0.0)	43808 (100.0)
6.00 ～ 6.49								5 (0.0)	5 (0.0)						10 (0.0)	43818 (100.0)
6.50 ～ 6.99									6 (0.0)						6 (0.0)	43824 (100.0)
7.00 ～															0 (0.0)	43824 (100.0)
Sum	0 (0.0)	6 (0.0)	459 (1.0)	1771 (4.0)	5345 (12.2)	10743 (24.5)	11474 (26.2)	7453 (17.0)	4038 (9.2)	1633 (3.7)	668 (1.5)	199 (0.5)	35 (0.1)	0 (0.0)	43824 (100.0)	
Total amount	0 (0.0)	6 (0.0)	465 (1.1)	2236 (5.1)	7581 (17.3)	18324 (41.8)	29798 (68.0)	37251 (85.0)	41289 (94.2)	42922 (97.9)	43590 (99.5)	43789 (99.9)	43824 (100.0)	43824 (100.0)		

upper : frequency , (lower) : ratio

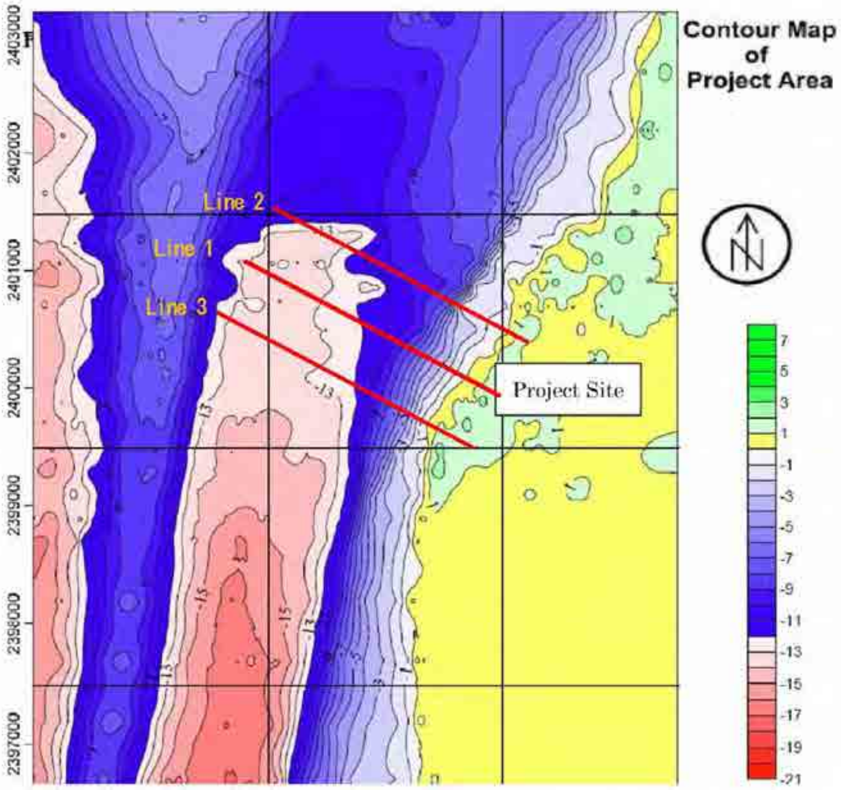
Point : E91.5 , N20.5
Term : 2006.1.1 ～ 2010.12.31

Height (m) \ Direction	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	Sum
～ 0.49	10 (0.0)	1 (0.0)	1 (0.0)		1 (0.0)	3 (0.0)	66 (0.2)	890 (2.0)	375 (0.9)	52 (0.1)	19 (0.0)	23 (0.1)	17 (0.0)	12 (0.0)	3 (0.0)	2 (0.0)	1475 (3.4)
0.50 ～ 0.99	55 (0.1)	3 (0.0)	1 (0.0)	2 (0.0)		7 (0.0)	37 (0.1)	2921 (6.7)	8670 (19.8)	1486 (3.4)	288 (0.7)	251 (0.6)	239 (0.5)	317 (0.7)	389 (0.9)	289 (0.7)	14955 (34.1)
1.00 ～ 1.49	15 (0.0)					7 (0.0)	39 (0.1)	816 (1.9)	8201 (18.7)	1781 (4.1)	182 (0.4)	105 (0.2)	92 (0.2)	138 (0.3)	424 (1.0)	309 (0.7)	12109 (27.6)
1.50 ～ 1.99						11 (0.0)	40 (0.1)	532 (1.2)	6711 (15.3)	1396 (3.2)			2 (0.0)	3 (0.0)	28 (0.1)	52 (0.1)	8775 (20.0)
2.00 ～ 2.49						12 (0.0)	86 (0.2)	353 (0.8)	2906 (6.6)	838 (1.9)	2 (0.0)						4197 (9.6)
2.50 ～ 2.99						1 (0.0)	74 (0.2)	125 (0.3)	847 (1.9)	508 (1.2)	2 (0.0)						1557 (3.6)
3.00 ～ 3.49							17 (0.0)	73 (0.2)	258 (0.6)	76 (0.2)							424 (1.0)
3.50 ～ 3.99							33 (0.1)	22 (0.1)	80 (0.2)	41 (0.1)							176 (0.4)
4.00 ～ 4.49							22 (0.1)	5 (0.0)	35 (0.1)	13 (0.0)							75 (0.2)
4.50 ～ 4.99							5 (0.0)	9 (0.0)	15 (0.0)								29 (0.1)
5.00 ～ 5.49							7 (0.0)	6 (0.0)	6 (0.0)								19 (0.0)
5.50 ～ 5.99								7 (0.0)	10 (0.0)								17 (0.0)
6.00 ～ 6.49								6 (0.0)	4 (0.0)								10 (0.0)
6.50 ～ 6.99								1 (0.0)	5 (0.0)								6 (0.0)
7.00 ～																	0 (0.0)
Sum	80 (0.2)	4 (0.0)	2 (0.0)	2 (0.0)	1 (0.0)	41 (0.1)	426 (1.0)	5766 (13.2)	28123 (64.2)	6191 (14.1)	493 (1.1)	379 (0.9)	350 (0.8)	470 (1.1)	844 (1.9)	652 (1.5)	43824 (100.0)

upper : frequency , (lower) : ratio

Table 17.7-4 Result of Sediment Survey

	Dry season			Rainy season		
depth(m)	Line1 D_{50}(mm)	Line2 D_{50}(mm)	Line3 D_{50}(mm)	Line1 D_{50}(mm)	Line2 D_{50}(mm)	Line3 D_{50}(mm)
−1	0.15	0.15	0.10	0.28	0.16	0.24
−2	0.10			0.08		
−3	0.08	0.10	0.13	0.09	0.14	0.09
−4	0.13			0.10		
−5	0.11	0.09	0.11	0.10	0.18	0.16
−6	0.10			0.09		
−7	0.09	0.12	0.11	0.09	0.10	0.09
−8	0.09			0.09		
−9	0.10	0.13	0.12	0.09	0.09	0.09
−10	0.10			0.09		
−11	0.08	0.16	0.11	0.10	0.12	0.09
−12	0.08			0.09		
−13	—		0.08	0.12		0.11
end	—	—	0.18	0.19	—	0.12



［Location of measurement line］

2) Simulation case

The simulation case is shown in Table 17.7-5.

Table 17.7-5 Simulation Case

structure	wave	calculation for topograph change	
		dry season (D_{50}=0.2mm)	rainy season (D_{50}=0.1mm)
present	highest wave per year	○ Table17.7-6(1)	○ Table17.7-6 (3)
	mean wave per year	○ Table17.7-6 (2)	○ Table17.7-6 (4)
after construction	highest wave per year	○ Table17.7-6(1)	○ Table17.7-6(3)
	mean wave per year	○ Table17.7-6(2)	○ Table17.7-6(4)

3) Result

The numerical results at present and after construction are shown in Table17.7-6.

Present

- The results of topographic change simulations showed that sedimentation in the coastal area under the highest wave per year conditions was slightly greater than that under the mean wave per year conditions.
- While different sand grain sizes resulted in different topographic changes both under the mean wave and the highest wave per year conditions, the differences were negligible.

After Construction

- The results of topographic change simulations showed that sedimentation in the coastal area under the highest wave per year conditions was slightly greater than that under the annual mean wave per year conditions.
- While different sand grain sizes resulted in different topographic changes both under the mean wave and the highest wave per year conditions, the differences were negligible.

The above observations suggest that ocean waves will not likely cause significant topographic changes in the analysis zone.

Table17.7-6 (1) Topographic Change (present：highest wave per year ,dry season ,D_{50}=0.2mm)

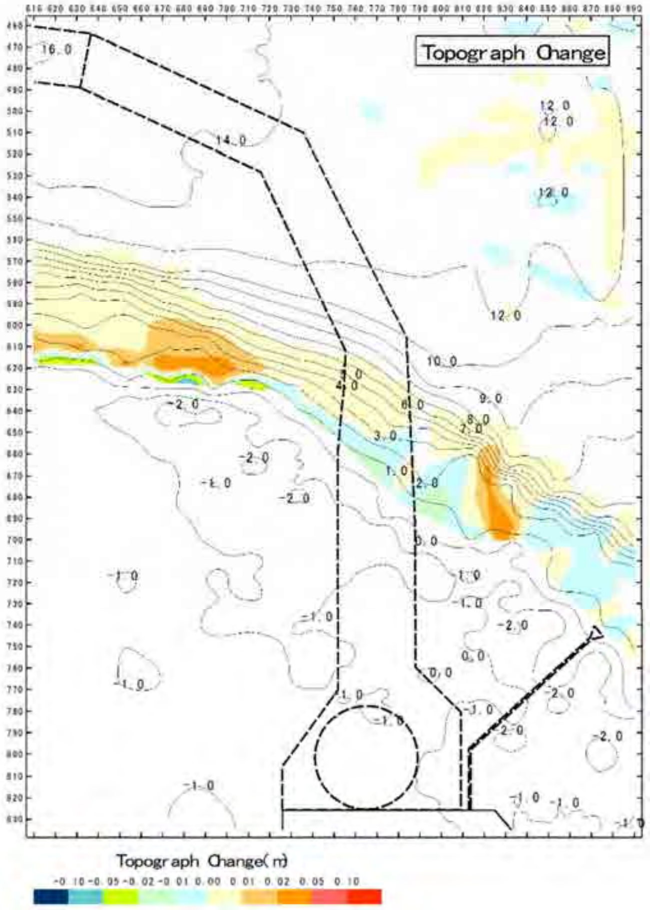
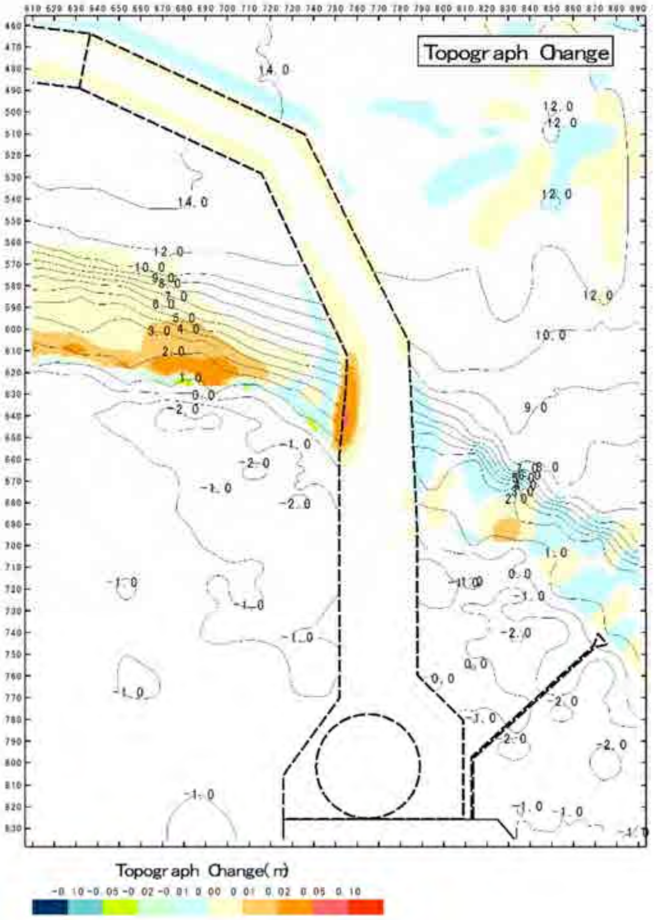
present	after construction
	

Table17.7-6 (2) Topographic Change (present：mean wave per year ,dry season ,D_{50}=0.2mm)

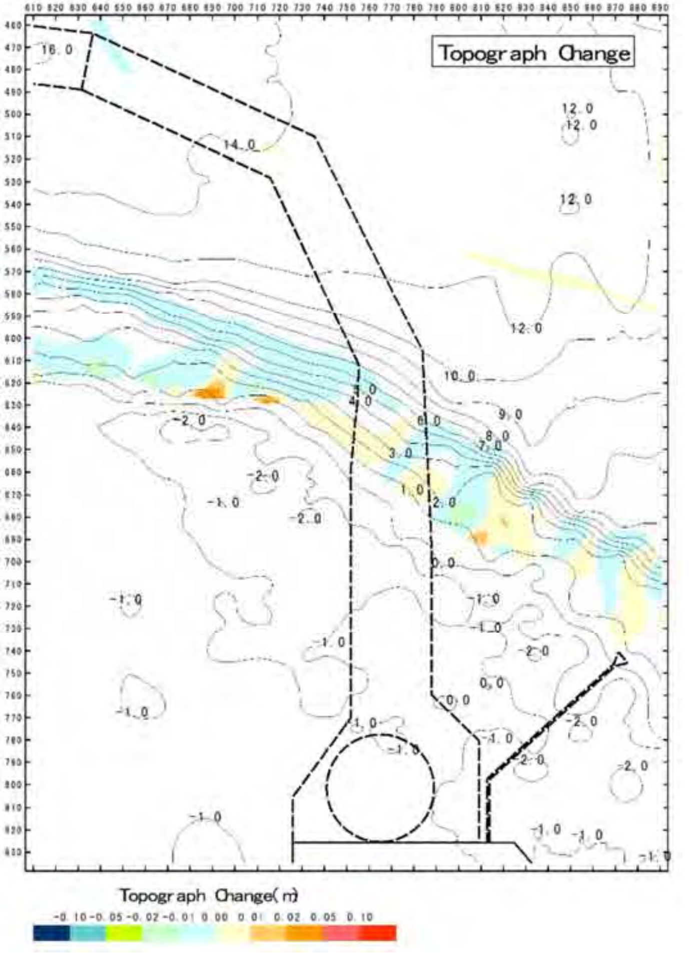
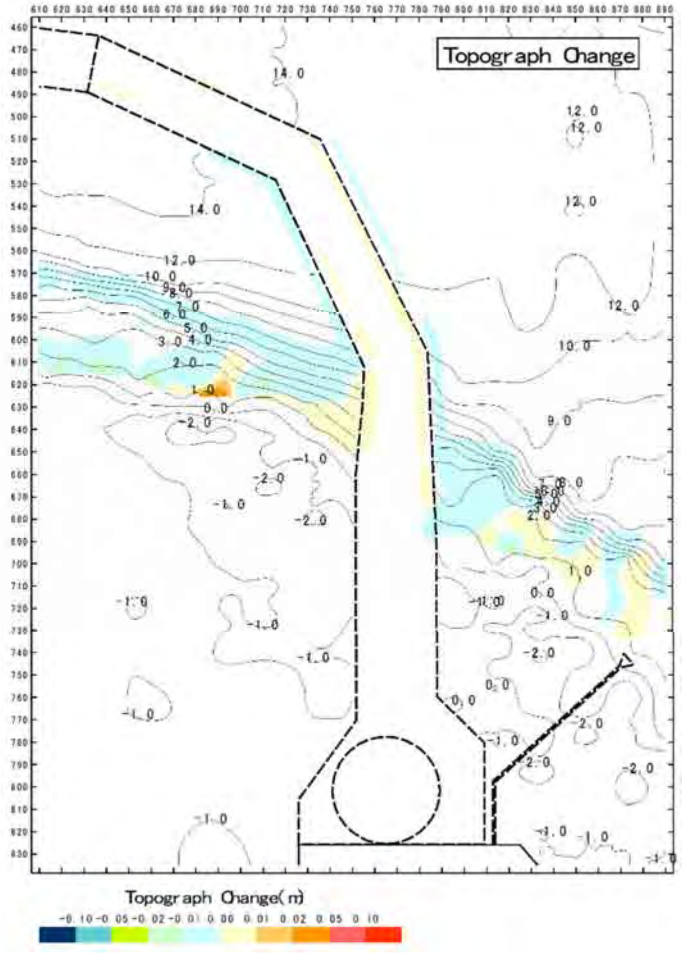
present	after construction
	

Table17.7-6 (3) Topographic Change (present：highest wave per year ,rainy season ,D_{50}=0.1mm)

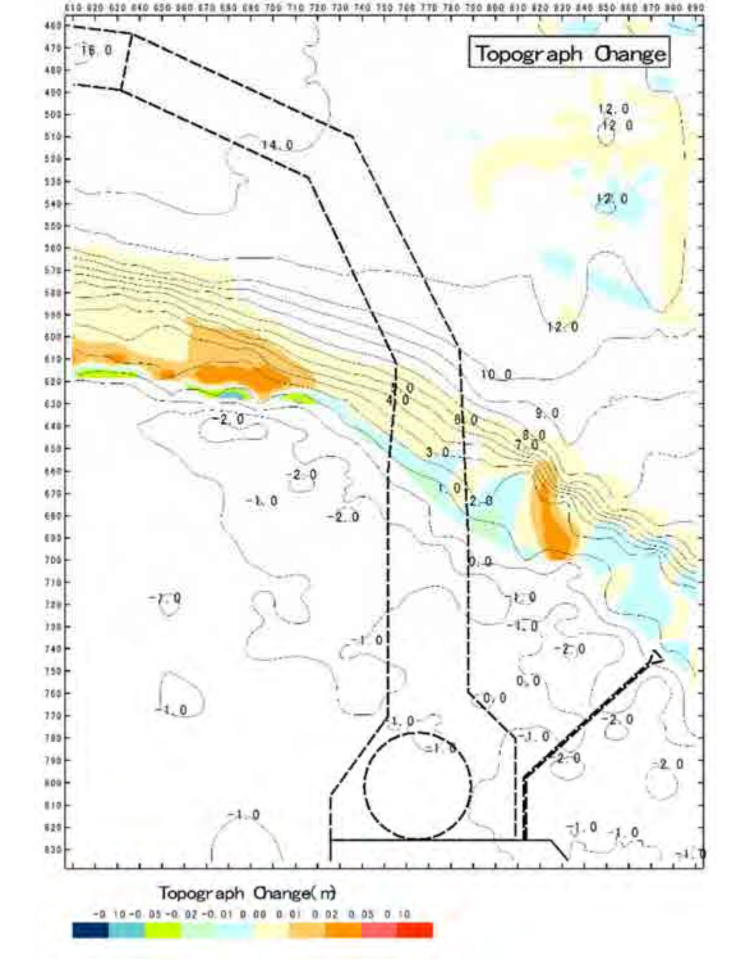
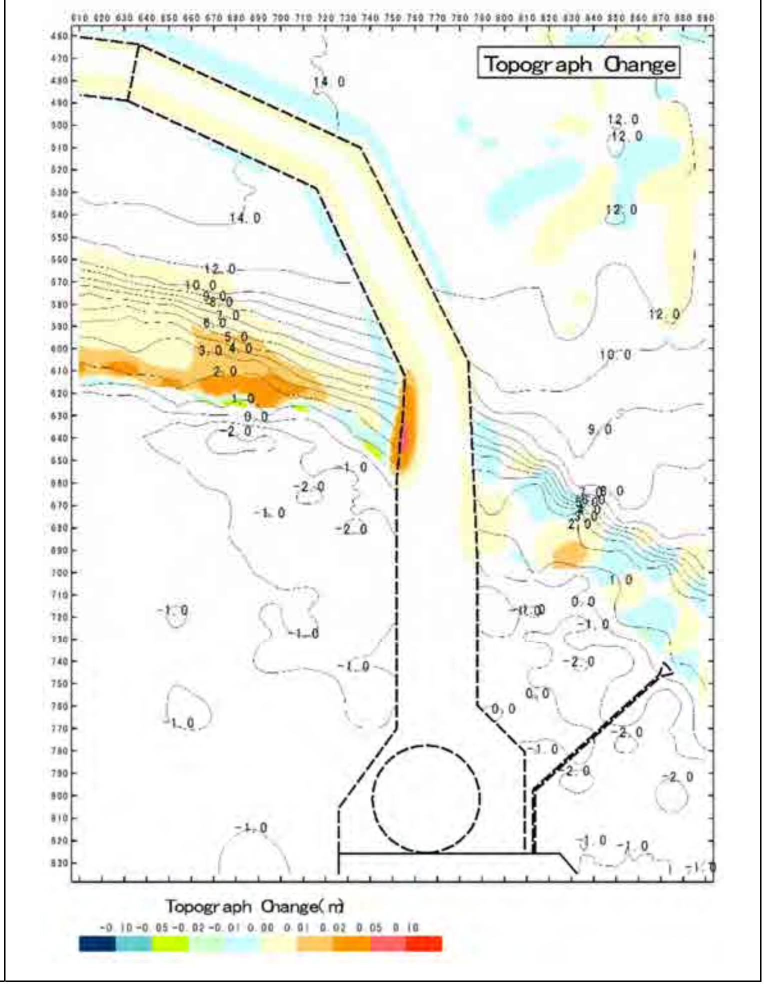
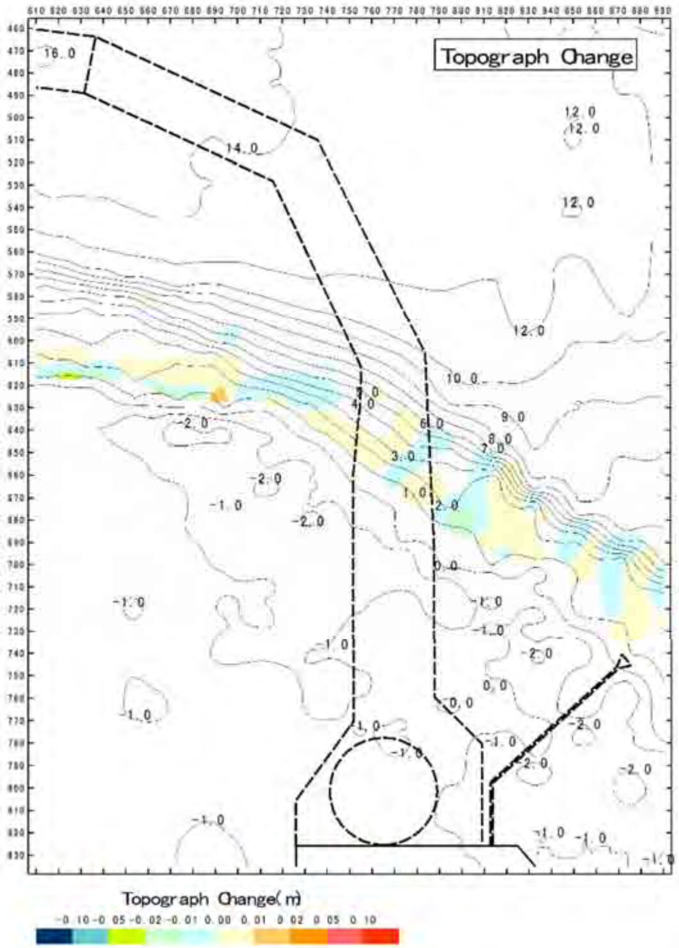
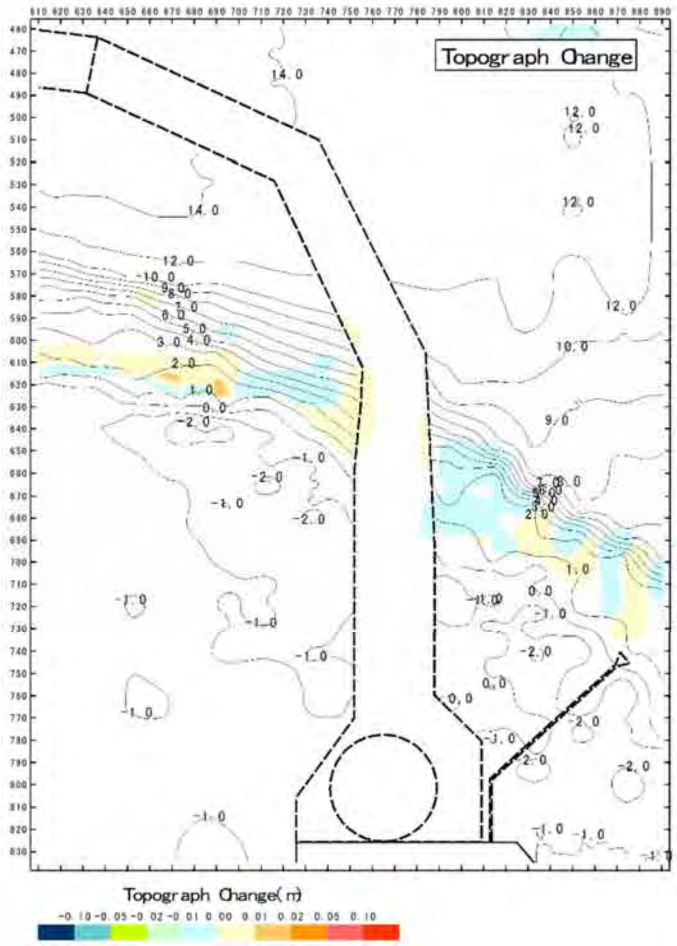
present	after construction
	

Table17.7-6 (4) Topographic Change (present：mean wave per year ,rainy season ,D_{50}=0.1mm)

present	after construction
	

(2) Simulation on Littoral Drift caused by tides

1) Examination condition

The examination condition of Simulation on Littoral Drift caused by tides is shown in Table 17.7-7.

Table 17.7-7 (1) Examination Condition of Simulation on Littoral Drift caused by Tides

Item		Examination condition	Remarks
boundary condition	return flow stress of boundary	fluctuation of surface elevation	
	number of tides	10tides	
	reproduction condition	velocity ：1.45m/s wave direction：NNE	results of last year
		velocity ：1.20m/s wave direction：SSW	
analysis zone		on-offshore15km×shore25km	analysis zone （Figure17.7-7） Water depth （Figure17.7-8）
tidal current	analysis model	Nonlinear long waves equation	
	calculation mesh	25m	
	roughness coefficient	0.025	reference value
	horizontal eddy viscosity coefficient	1.00	reference value
	analysis model	Nonlinear long waves equation	

river flow rate	river1	3500m^3/s	results of last year
	river2	350m^3/s	
intake rate	cooling water equipment	50 m^3/s	2unit
wave1	wave height	1.22m	high rank 50% wave
	period	8.2s	
	wave direction	SSW	
wave2	wave height	3.40m	high rank 1% wave
	period	8.5s	
	wave direction	SSW	

Table 17.7-7 (2) Examination Condition of Simulation on Littoral Drift caused by Tides

Item		Examination condition		Remarks
tide level		H.W.L＝M.S.L.＋2.2m		
topographic change	sand grain size	D_{50}=0.10mm（Off Shore）		assumed rainy season
		D_{50}=0.20mm（Off Shore）		assumed dry season
	bed load rate coefficient	10.0		reference value
	diffusion coefficient	1.0		reference value
	sediment pickup rate coefficient	0.01		1% of bed load
	settling velocity	0.09mm/s		
	SS concentration	rainy season	600mg/L 1300mg/L	result of survey （Table 17.7-7）
		dry season	0mg/L	

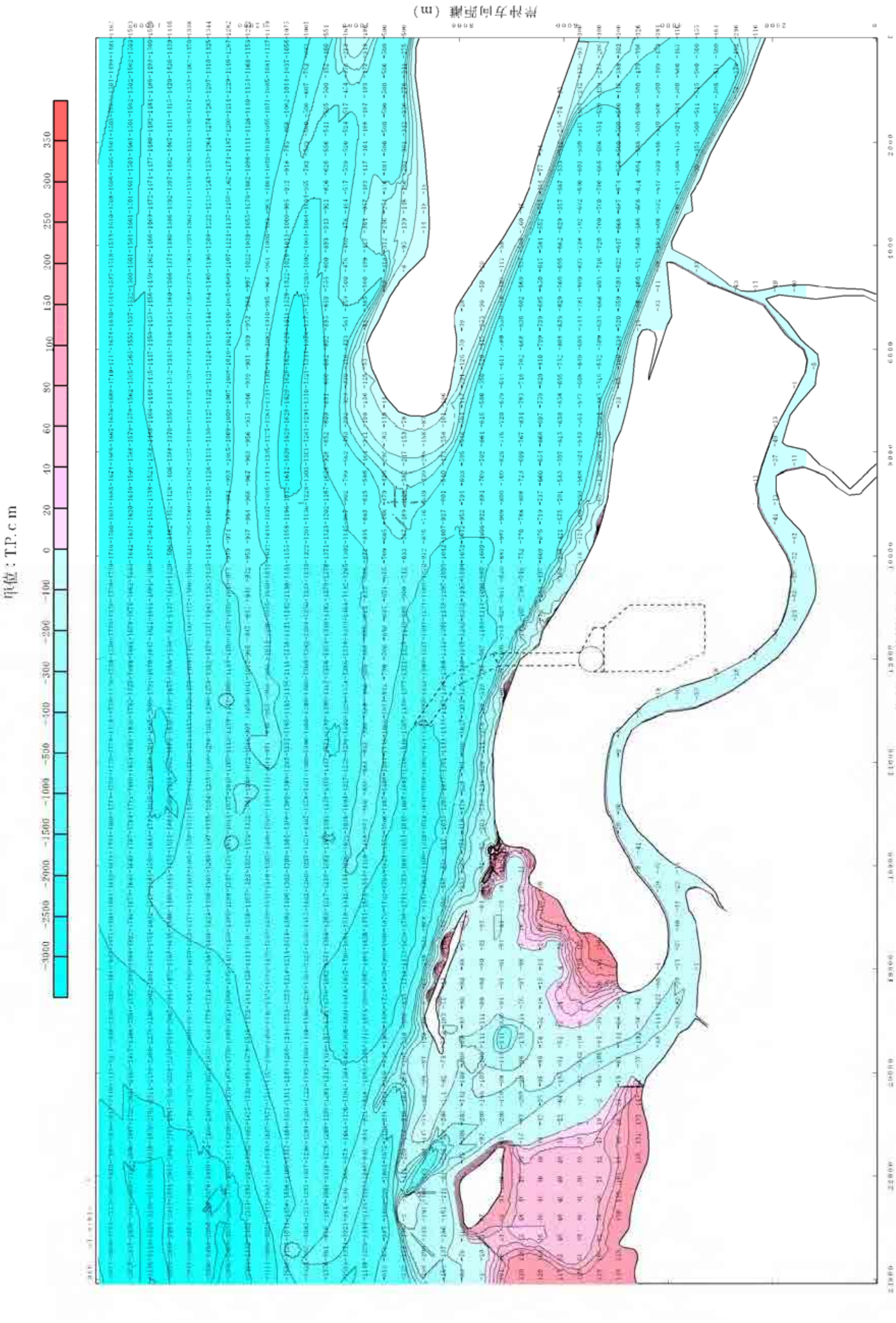


Figure17.7-7 Analysis Zone

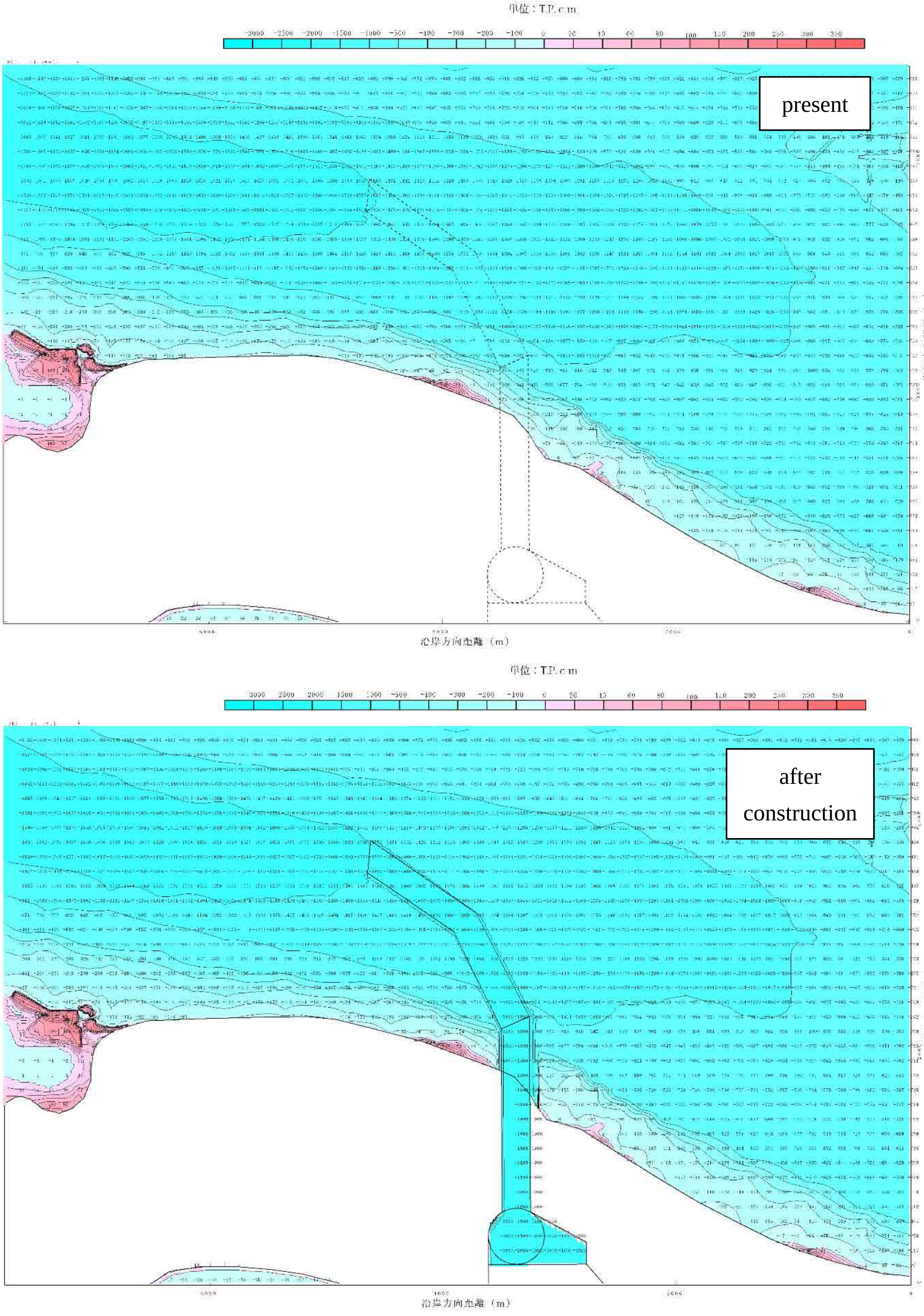


Figure17.7-8 Water Depth

Table 17.7-8 SS Concentration

unit：mg/L

depth (m)	survey		median of surface and bottom	mean value on which weight is put by depth on surface	mean value on which weight is put by depth on median
	surface	bottom			
1	3343	3320	3332	3343	3332
3	1114	1533	1324	3342	3971
5	1167	3529	2348	5835	11740
7	819	2925	1872	5733	13104
9	183	3020	1602	1647	14414
11	178	1324	751	1958	8261
13	154	1400	777	2002	10101
average	994	2436	1715	**487**	**1325**

2) Simulation case

The simulation case is shown in Table 17.7-9.

Table 17.7-9 Simulation Case

structure	wave	D_{50} (mm)	SS concentration (mg/L)	intake rate (m^3/s)	Remarks
present	mean wave per year	0.1	600	－	Figure17.7-9 (1)
	highest wave per year	0.1	600	－	Figure17.7-9 (2)
	highest wave per year	0.2	600	－	Figure17.7-9 (3)
	mean wave per year	0.1	0	－	Figure17.7-9 (4)
	mean wave per year	0.1	1300	－	Figure17.7-9 (5)
after construction	mean wave per year	0.1	600	50	Figure17.7-9 (1)
	highest wave per year	0.1	600	50	Figure17.7-9 (2)
	highest wave per year	0.2	600	50	Figure17.7-9 (3)
	mean wave per year	0.1	0	50	Figure17.7-9 (4)
	mean wave per year	0.1	1300	50	Figure17.7-9 (5)

3) Result

The numerical result is shown in Figure 17.7-9.

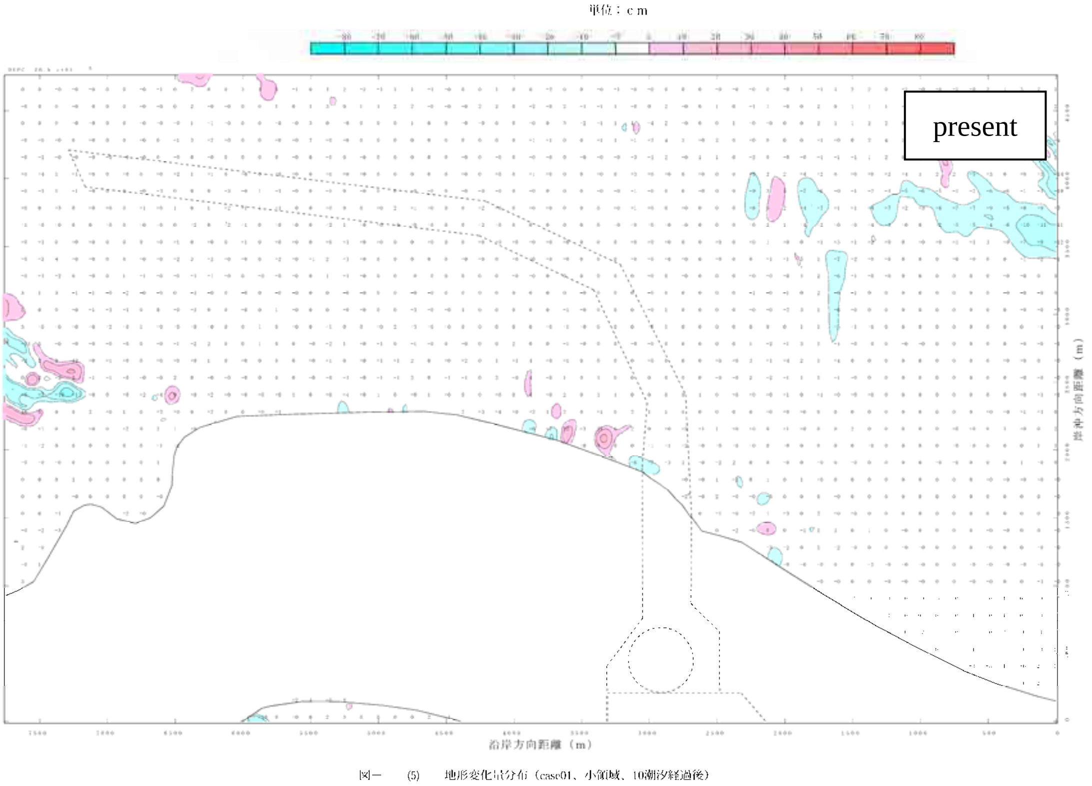
Present

- The simulation results indicated no significant difference in topographic change between the mean wave and the highest wave per year.
- The results of topographic change simulation under the highest wave per year conditions showed that the larger grain size led to slightly greater coastal erosion than the smaller grain size.
- Under the mean wave per year conditions, there was no significant difference in topographic change between when SS concentration was not taken into account and when the concentration was 600mg/L.
- When SS concentration was 1300mg/L under the mean wave per year conditions, sedimentation tended to occur over the entire sea area.

After Construction

- The simulation results indicated that greater sedimentation in the channel occurred under the highest wave per year conditions than under the mean wave per year conditions.
- Under the highest wave per year conditions, the smaller grain size tended to cause greater sedimentation in the channel than the larger grain size.
- Under the mean wave per year conditions, greater sedimentation occurred in the channel at SS concentration of 600mg/L than 0mg/L.
- Under the mean wave conditions, sedimentation tended to occur over the entire sea area at SS concentration of 1300mg/L. Sediments tended to accumulate in and around the same localized spots inside the channel both at 600mg/L and 1300mg/L.

The above observations indicate certain tendencies in topographic change as summarized below.
Greater sedimentation in the channel tends to occur during high wave period.
Greater sedimentation in the channel tends to occur with smaller grain size, suggesting that suspended sediments are carried by currents and settled in the channel.
Greater SS concentration tends to cause sedimentation in the whole sea area, which means that the channel will also be affected by it.



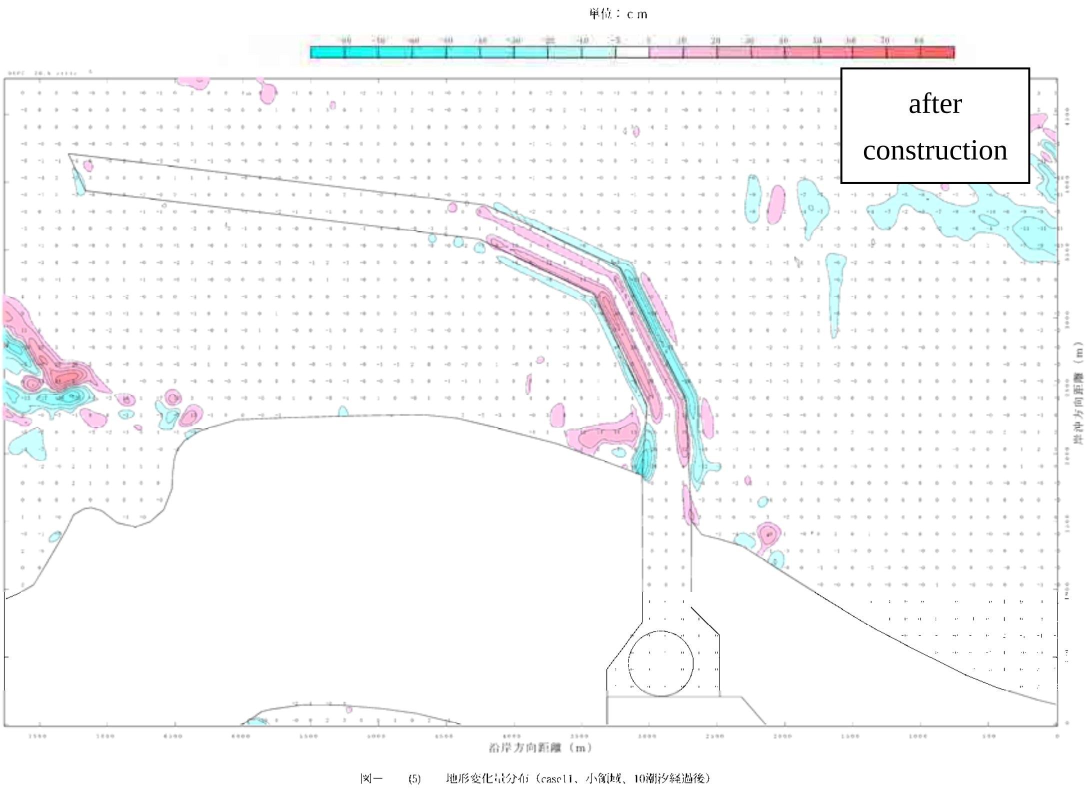
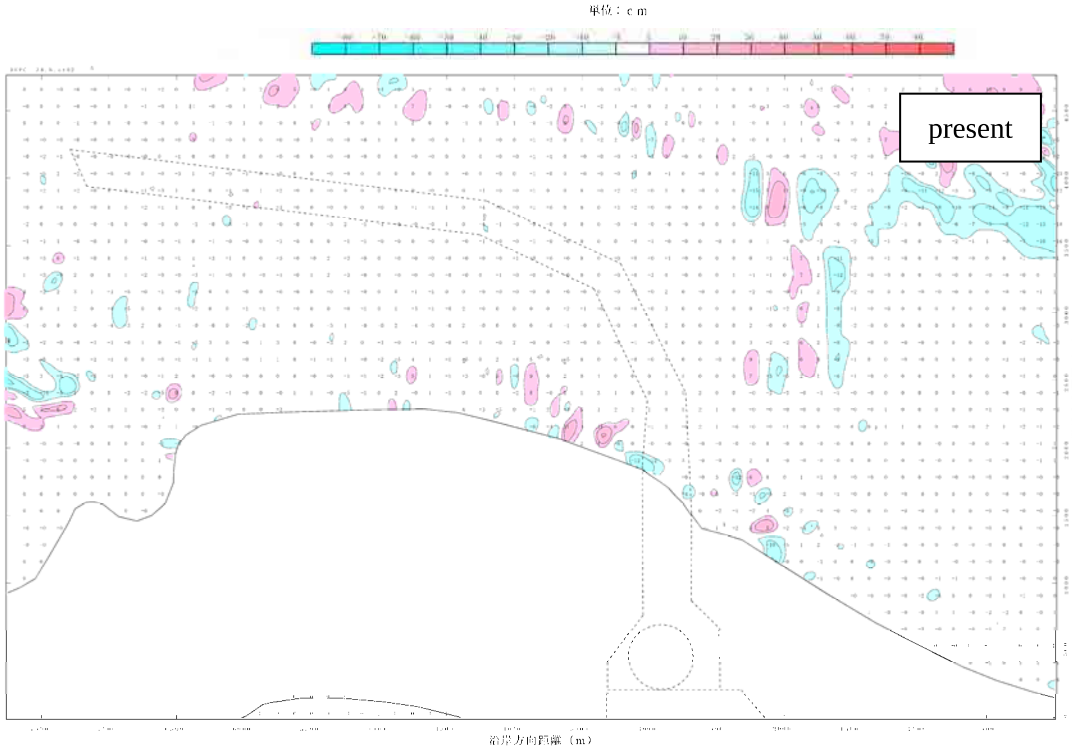
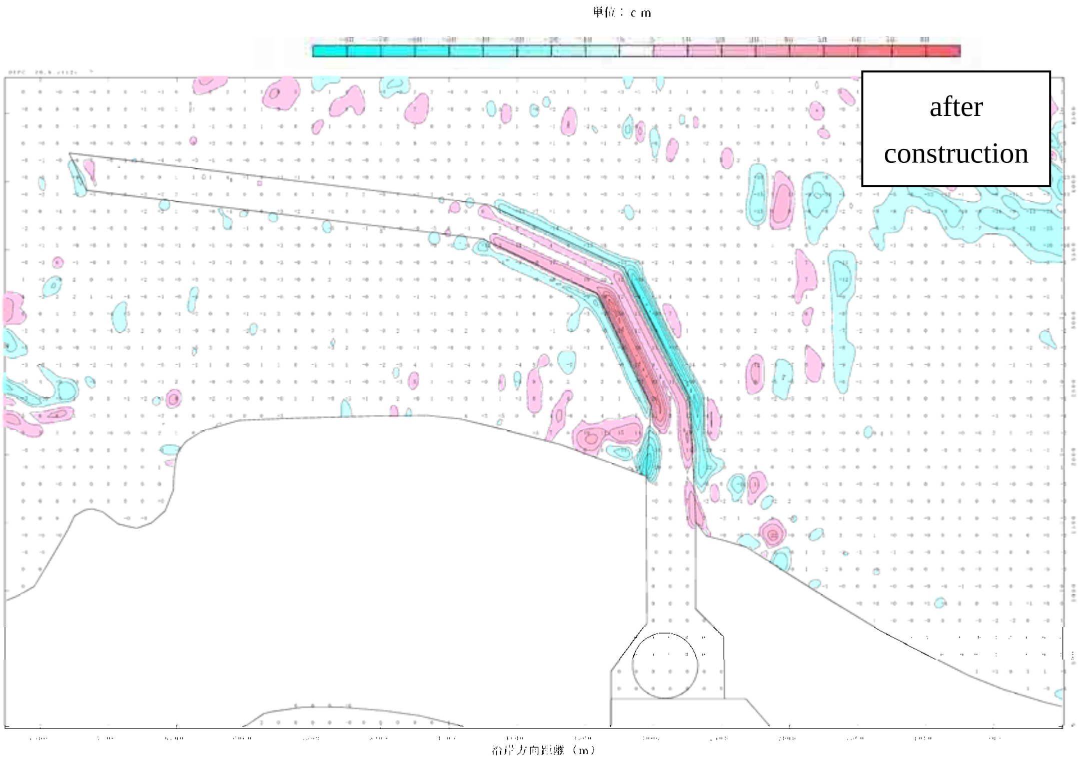


Figure17.7-9 (1) Topographic Change

(mean wave per year ,rainy season ,D_{50}=0.1mm,SS 600mg/L)



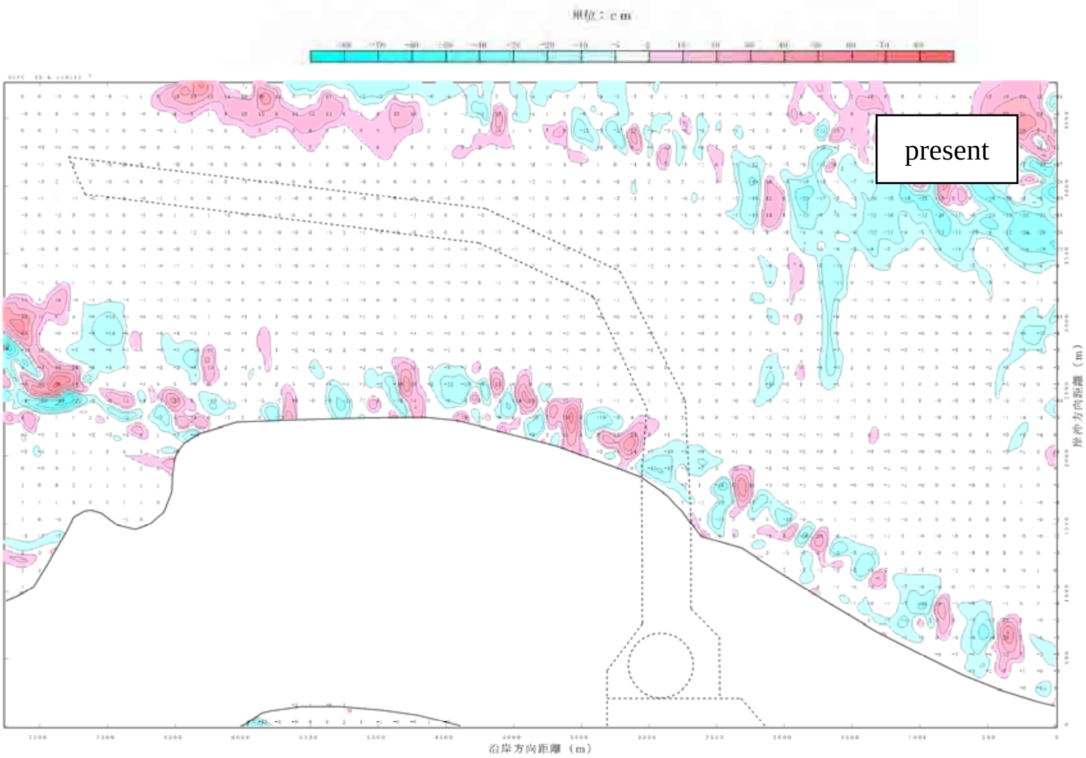
図－　(5)　地形変化量分布（case02、小領域、10潮汐経過後）



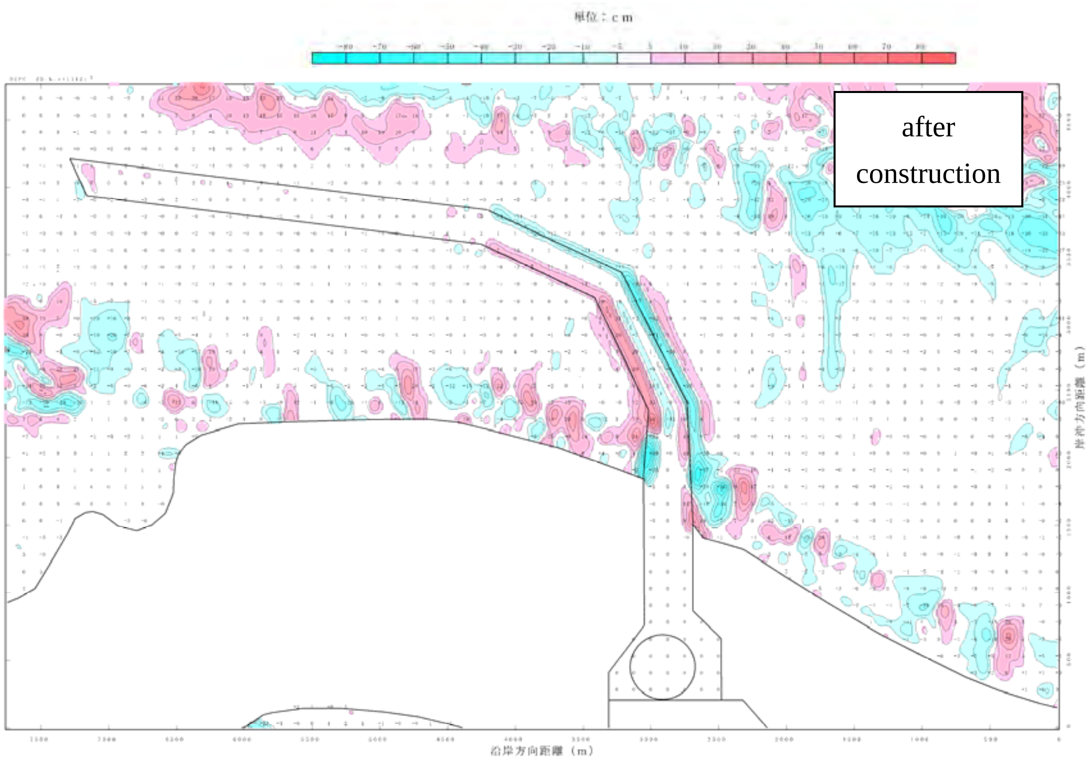
図－　(5)　地形変化量分布（case12、小領域、10潮汐経過後）

Figure17.7-9 (2) Topographic Change

(highest wave per year ,rainy season ,D_{50}=0.1mm,SS 600mg/L)



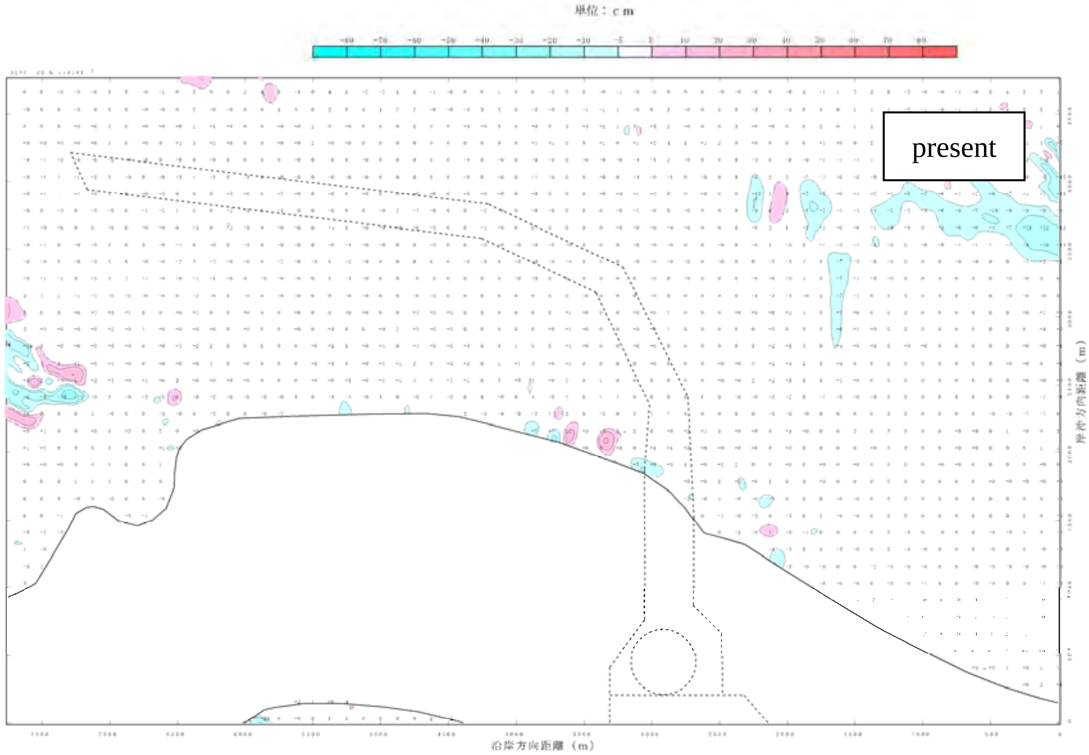
図ー (5) 地形変化量分布（case0112、小領域、10潮汐後）



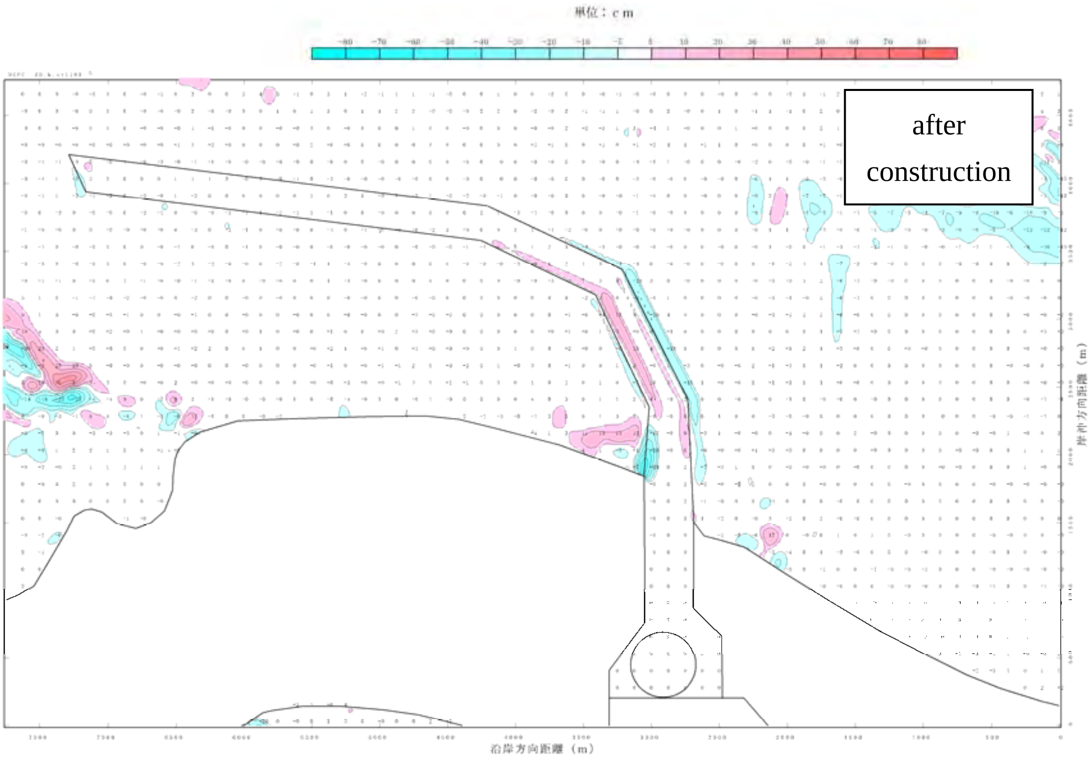
図ー (5) 地形変化量分布（case1112、小領域、10潮汐後）

Figure17.7-9 (3) Topographic Change

(highest wave per year ,dry season ,D_{50}=0.2mm,SS 600mg/L)



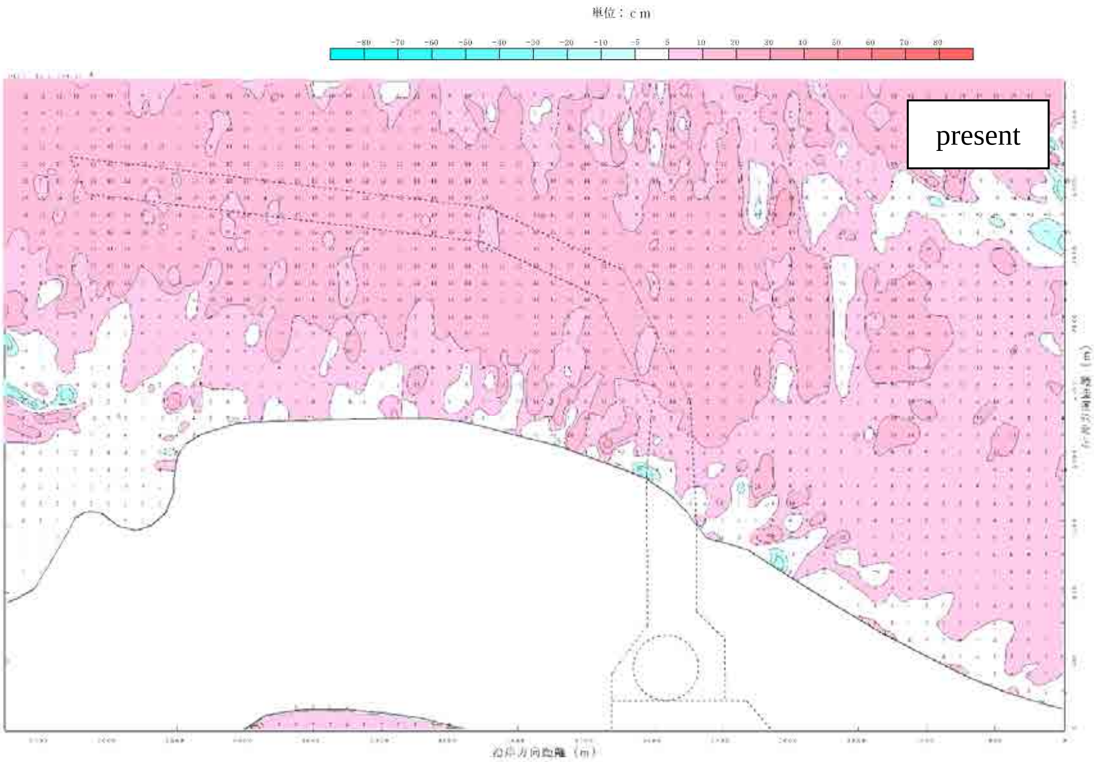
図一　(5)　地形変化量分布（case0101、小領域、10潮汐後）



図一　(5)　地形変化量分布（case1101、小領域、10潮汐後）

Figure17.7-9 (4) Topographic Change

(mean wave per year ,rainy season ,D_{50}=0.1mm,SS 0mg/L)



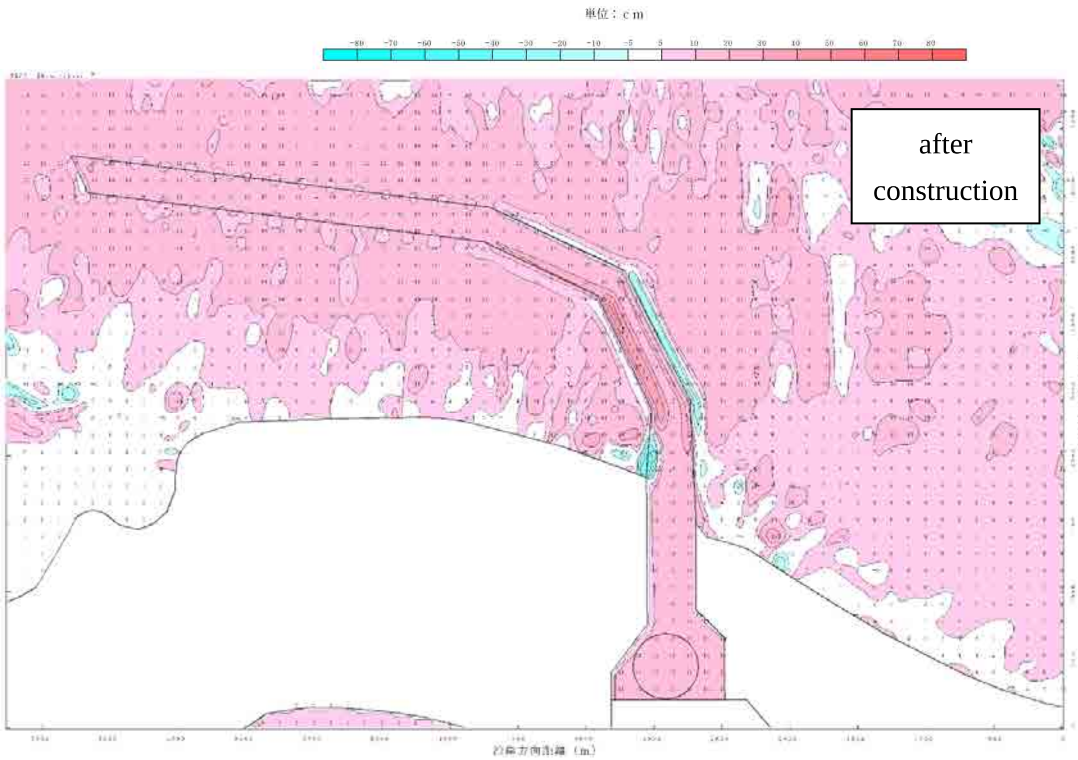


Figure17.7-9 (5) Topographic Change

(mean wave per year ,rainy season ,D_{50}=0.1mm,SS 1300mg/L)

17.7.3 Analysis Result by Simulation on Littoral Drift

(1) Key Factors of Sedimentation in Navigation Channel Based on Simulation on Littoral Drift

Simulations were performed on littoral drift caused by waves and that caused by tides to ascertain how the topography would change as a result of construction of the navigation channel.

Simulation on littoral drift caused by waves indicated that waves did not significantly affect the topography of the channel.

Simulation on littoral drift caused by tides indicated that sedimentation in the channel tended to occur during the high wave period with smaller grain size and at higher SS concentration.

(2) Sensitivity Analysis of Various Factors

1) Simulation on Littoral Drift caused by Waves

The results of sensitivity analysis on wave height and grain size suggested no significant correlation to topographic change.

2) Simulation on Littoral Drift Caused by Tides

The results of sensitivity analysis on wave height, grain size, and SS concentration suggested that greater sedimentation occurred in the channel with the smaller grain size.

This suggests that smaller grains were carried by currents and settled in the channel.

Sedimentation tented to occur throughout the sea area at a high SS concentration, which means that the channel will also be affected by it.

(3) Consideration on Measures Against Sedimentation in Navigation Channel

As it was suggested that currents cause sedimentation in the channel, the following measures are recommended.

・Conduct dredging regularly to maintain a sufficient depth in the channel.

・Construct breakwaters along the channel to prevent entry of suspended sediments into the channel.

(4) Additional Site Surveys Related to Sedimentation in Navigation Channel

In this analysis, simulation on littoral drift were performed based on the predominant wave conditions and two different grain sizes obtained by geotechnical survey, which was conducted once during rainy season and again during dry season.

Toward performing more accurate simulations on littoral drift that incorporate more detailed information on local characteristics, it is recommended to conduct the following additional surveys in future:

・Wave observation survey (at regular intervals)

・Flow-direction/flow-velocity distribution (at regular intervals)

・Bottom sediment survey (rainy and dry seasons)

・Concentration distribution (rainy and dry seasons)

17.8 Procurement Material Study

The main construction materials to be used in this Project are currently being studied regarding their suitability to the principle of local procurement. However, up until the present time in Bangladesh, there are no large, high-efficiency coal-fired power plants, coal imports are sparse, and there has been no large deep sea port developments; also, the Project site is located in remote areas. Thus, this Project has a high risk with regard to construction material procurement. The Environment Survey Team has studied the current situation by conducting interviews on prices, the quality of the main construction material, and the amount of supply in Bangladesh. In addition, the possibility of procurement from neighboring countries to minimize material procurement risk is being considered.

(1) Material Procurement Study Item

The Environment Survey Team studied following item - which is the main construction material in this Project - the supply of cement, rebar, fine aggregates (sand), coarse aggregates, reclamation sand, ground improvement material (prefabricated vertical drain – “PVD”), and boulders/stone (for the training dyke/quay wall). A general material procurement survey is being carried out in Bangladesh, but procurement of the following two materials in the country is assumed to be difficult based on the preliminary survey conducted in neighboring countries. A field survey for ground improvement material (PVD) is being carried out in Malaysia. There are many manufacturing and construction projects in Southeast Asia. In addition, a field survey for boulders/stone (training dyke/quay wall) is being carried out in Myanmar. There is a deep sea port construction site near this Project site. The countries of investigation and the outline study content for the main construction materials are shown below.

Table 17.8-1 Procurement Item

Main Procurement Material	Country	Outline Study Contents
Cement	Bangladesh	Quality, manufacturing location, production volume, transportation method, construction results, price, etc.
Rebar		Quality, manufacturing location, production quantity, transportation method, construction result, price, etc.
Fine aggregates (sand)		Quality, quarry, supply, transportation method, price, etc.
Coarse aggregates		Quality, quarry, supply, transportation method, price, etc.
Reclamation sand		Quality, quarry, supply, transportation method, price, etc.
Ground improvement material (PVD)	Malaysia	Quality, production quantity, transportation method, delivery time, price, etc.
Boulders/stone	Myanmar	Quality, quarry, supply, transportation method, price, etc.

Source：The Environment Survey Team

(2) Material Quality Control

The manufacturers produce construction materials based on a standard specification and minimum quality requirement for each product. Each product in general is shipped with a certificate as proof that it has passed the quality test conducted by testing institutions and/or the manufacturers' own private testing organizations. In addition, each manufacturer in Bangladesh performs product inspection conducted by public testing institutions as a countercheck, and there are many cases that have they have done so as proof of further quality check.

There are six public testing institutions within Bangladesh, which are stated below.

- Bangladesh University of Engineering and Technology (BUET) (this is the most widely used)
- Chittagong University of Engineering and Technology (CUET)
- Dhaka University of Engineering and Technology (DUET)
- Khulna University of Engineering and Technology (KUET)
- Rajshahi University of Engineering and Technology (RUET)
- Bangladesh Council of Scientific and Industrial Research (BCSIR)

Items that can be tested and inspected in each of the above public testing institutions might be different. Thus, it is better to confirm this in advance during the design and construction period.

(3) The Import of Construction Materials to Bangladesh

1) Import item regulations and area regulations

There are various import item regulations and area regulations for imported materials in Bangladesh. It is not possible to import an item from other regions because of such regulations.

It is necessary to confirm whether the items to be imported are acceptable for importation.

a. Import item regulations: The items are described in the "Import Policy Order 2012-2015" established by the Department of Commerce.
   The latest information is confirmed in http://www.mincom.gov.bd/Polices.php.
b. Import area regulations: Goods produced and imported from Israel as well as third country goods imported using Israeli-flagged vessels are not allowed for importation.

Table 17.8-2 Import Item Regulations and Area Regulations for Construction Materials

Main procurement material	a. Import item regulation	b. Import area regulations
Cement	Not applicable	Positive for local material
Rebar	Not applicable	Positive for local material
Fine aggregates (sand)	Not applicable	Positive for local material
Coarse aggregates	Not applicable	Positive for local material
Reclamation sand	Not applicable	Positive for local material
Ground improvement material (PVD)	Not applicable	To be confirmed at the time of importation
Boulders/stone	Not applicable	To be confirmed at the time of importation

Source：The Environment Survey Team

There is a chance that PVD for ground improvement and boulders/stone will be imported as construction materials, but this is not covered by the above import item regulations.
It is necessary to describe in the contract and specifications when the use of local materials is impossible, when imported materials will be needed, and whether import item regulations and import area regulations will apply to these imported materials.

2) Tariff system

General tariff rates in Bangladesh are different based on the specific imported item. The calculation method for tax items will be described below. Tax adjustment is complicated. Depending on the import and export destination and due to the fact that there is a "Preferential Special Measures" region, it is necessary to examine the tariff rate for future import items in more detail.

Import tariffs in Bangladesh:
a. Custom Duty（CD）
b. Regulatory Duty（RD）
c. Supplementary Duty（SD）
d. Value Added Tax（VAT）
e. Advanced Income Tax（AIT）
f. Advance Trade VAT（ATV）

＜Supplementation＞
a. CD is divided into five levels - 0%, 2%, 5%, 10%, and 25%. CD for some of the local industry protected items ranges from 150% to 4,000%.

b. RD is fixed at 5%, non-taxed item.

c. SD is 20% to 500%. There are high tax rate items subject to local industry protection.

d. VAT is fixed at 15%, non-taxed item.

e. AIT is fixed at 5%, non-taxed item.

f. ATV is fixed at 4%, non-taxed item.

Source：The website of JETRO and Summary of Taxation Rules in Bangladesh 2013-14

(4) Confirmation of the Main Construction Materials

Imperial units have been widely used as the unit of volume in Bangladesh, i.e., cft. The Environment Survey Team used the metric system and the conversion rate of 1 cft = 0.02832 m^3. In addition, a currency conversion rate of USD 1 = BDT 77.8 is used with respect to the exchange rate of January 2013.

1) Cement

a. Product and type

There are 72 cement manufacturers that are registered in the country, only 36 of which are currently engaged in the manufacture of cement (this was information from acquired from an interview with Seven Rings Cement). Five manufacturers, which are the country’s leading cement manufacturing companies, that were interviewed have respective domestic market shares of 5% to 8%.. The cement is produced in accordance with the national standard BDS-EN-197 or the international standard ASTM C150. BDS-EN-197 is a standard that is based on international standard the EN-197. Therefore, when the supplier follows BDS-EN-197, the cement has been manufactured in compliance with international standards.

Major cement manufacturers have produced mainly two types of cement: ordinary Portland cement (OPC) and Portland composite cement (PCC).

b. Production of cement

Bangladesh does not have enough main raw materials such as limestone. Therefore, each supplier imports clinker from Thailand, Vietnam, and China. Slag has been mainly imported from Japan and India, and fly ash has been imported from India. Limestone has been imported from Japan, Thailand, and domestic quarries (near the border with India). Gypsum has been imported from Thailand.

There is a manufacturing plant for producing cement using imported raw materials in Bangladesh. Therefore, suppliers are not limited to the supply of raw materials from one country. Imported raw materials are unloaded at Chittagong Port, then feeder vessels transport the raw material to each production factory.

Factories of a popular cement brands are located in large domestic consumption areas near Dhaka, Chittagong, and Khulna. Cement produced by these factories has been exported to neighboring India.

Figure17.8-1 Unloading of Clinker

Figure17.8-2 Production of Cement

c. Production rate of cement

The annual domestic cement production amount is said to be approximately 23.5 million tons/year (2014) (this information was acquired from an interview with Seven Rings Cement). Each interviewed company produces 3,000-9,500 tons/day of cement.

d. Domestic distribution

If it is possible for heavy vehicles to load and unload these deliver cement to the concrete batching plants and cement silos. However, the quality of the roads in Bangladesh is not so high. Once off of the main roads, there are many traffic difficulties for long vehicles and trucks due to narrow roads. Often cement is deliveries to retail shops and construction sites in bags (50 kg/bag). This is also delivered by barges when there are jetties on the rivers and coasts.

Figure17.8-3 Bulk Vehicle Transport

Figure17.8-4 Container Transport

Figure17.8-5 Truck Transport

Figure17.8-6 Barge Transport

e. Domestic construction results

Major manufacturers in Bangladesh have experienced a number of large hotel constructions funded with foreign capital. Also foreign companies have constructed large bridges, power plants, and water purification plants.

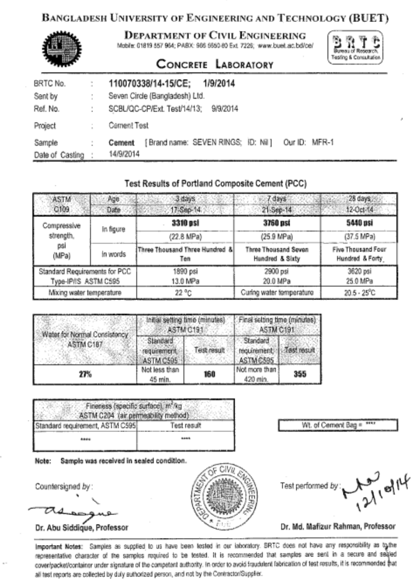
f. Transportation and price

In recent years, the cement price in Bangladesh for: OPC has been about BDT 430/bag (50 kg) <USD 110.5/ton>; and PCC has been about BDT 400/bag (50 kg) <USD 102.8/ton> (VAT included). Prices have remained constant during this study time <November 2014>.

Separately, the transportation cost from the factory near Dhaka City to the Project site is BDT 60/bag (50 kg) <USD 15.4/ton>. This transportation cost will vary depending on the distance to each factory. Furthermore, in case of prices at surveyed retail stores, the local price in Badarkhali <November 2014> was BDT 445-475/bag (50 kg) <USD 5.7-6.1/bag> (VAT included).

g. The test results by public testing institutions

In general, cement has been inspected to comply with ASTM standards in BUET. OPC has been inspected/tested using ASTM C150 and PCC has been inspected/tested using ASTM C595. There are different testing criteria for the BDS-EN-197 test method; therefore, it is necessary to confirm whether there are in conformance with national standards.



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Mobile: 01819 557 964; PABX: 966 5650-80 Ext. 7226; www.buet.ac.bd/ce/
CONCRETE LABORATORY
BRTC Bureau of Research, Testing & Consultation

BRTC No. : 110070338/14-15/CE; 1/9/2014
Sent by : Seven Circle (Bangladesh) Ltd.
Ref. No. : SCBL/QC-CP/Ext. Test/14/13; 9/9/2014
Project : Cement Test
Sample : Cement [Brand name: SEVEN RINGS; ID: Nil] Our ID: MFR-1
Date of Casting : 14/9/2014

Test Results of Portland Composite Cement (PCC)

ASTM C109	Age / Date	3 days / 17-Sep-14	7 days / 21-Sep-14	28 days / 12-Oct-14
Compressive strength, psi (MPa)	In figure	3310 psi (22.8 MPa)	3760 psi (25.9 MPa)	5440 psi (37.5 MPa)
	In words	Three Thousand Three Hundred & Ten	Three Thousand Seven Hundred & Sixty	Five Thousand Four Hundred & Forty
Standard Requirements for PCC Type-IP/IS ASTM C595		1890 psi 13.0 MPa	2900 psi 20.0 MPa	3620 psi 25.0 MPa
Mixing water temperature		22 °C	Curing water temperature	20.5 - 25°C

Water for Normal Consistency ASTM C187	Initial setting time (minutes) ASTM C191		Final setting time (minutes) ASTM C191	
	Standard requirement, ASTM C595	Test result	Standard requirement, ASTM C595	Test result
27%	Not less than 45 min.	160	Not more than 420 min.	355

Fineness (specific surface), m^2/kg ASTM C204 (air permeability method)	
Standard requirement, ASTM C595	Test result
****	****

Wt. of Cement Bag = ****

Note: Sample was received in sealed condition.

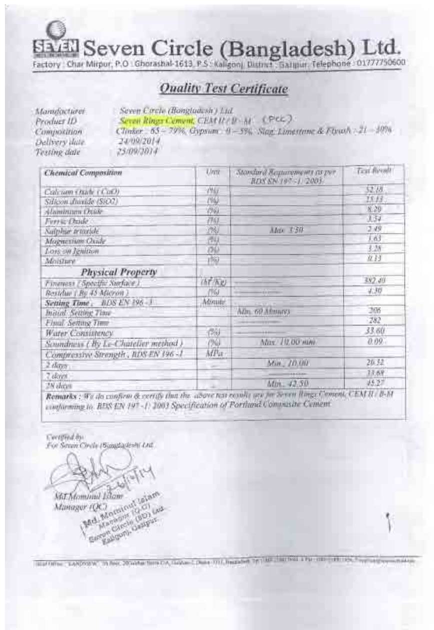
Countersigned by: Dr. Abu Siddique, Professor

DEPARTMENT OF CIVIL ENGINEERING

Test performed by: 12/10/14 Dr. Md. Mafizur Rahman, Professor

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports are collected by duly authorized person, and not by the Contractor/Supplier.

Figure17.8-7 Sample of the Test Results (BUET)



SEVEN Seven Circle (Bangladesh) Ltd.
Factory : Char Mirpur, P.O : Ghorashal-1613, P.S : Kaligonj, District : Gazipur, Telephone : 01777750600

Quality Test Certificate

Manufacturer : Seven Circle (Bangladesh) Ltd.
Product ID : Seven Rings Cement, CEM II / B-M (PCC)
Composition : Clinker : 65 – 79%, Gypsum : 0 – 5%, Slag, Limestone & Flyash : 21 – 30%
Delivery date : 24/09/2014
Testing date : 25/09/2014

Chemical Composition	Unit	Standard Requirements as per BDS EN 197-1: 2003	Test Result
Calcium Oxide (CaO)	(%)		52.18
Silicon dioxide (SiO2)	(%)		25.13
Aluminium Oxide	(%)		8.20
Ferric Oxide	(%)		3.54
Sulphur trioxide	(%)	Max. 3.50	2.49
Magnesium Oxide	(%)		1.63
Loss on Ignition	(%)		3.28
Moisture	(%)		0.13
Physical Property			
Fineness (Specific Surface)	(m^2/Kg)	————	382.40
Residue (By 45 Micron)	(%)	————	4.30
Setting Time, BDS EN 196-3	Minute		
Initial Setting Time		Min. 60 Minutes	206
Final Setting Time		————	282
Water Consistency	(%)	————	33.60
Soundness (By Le-Chatelier method)	(%)	Max. 10.00 mm	0.09
Compressive Strength, BDS EN 196-1	MPa		
2 days	–	Min. 10.00	26.32
7 days	–	————	33.68
28 days	–	Min. 42.50	45.27

Remarks : We do confirm & certify that the above test results are for Seven Rings Cement, CEM II / B-M conforming to BDS EN 197-1: 2003 Specification of Portland Composite Cement.

Certified by
For Seven Circle (Bangladesh) Ltd.

Md. Mominul Islam
Manager (QC)

Figure17.8-8 Sample of the Test Results

(Manufacturer's Inspection Result for BDS- EN-197)

h. Summary of the minutes of the manufacturers' interviews

Information from the interviews with the cement manufacturers are shown in the following table:

Table 17.8-3 Summary of Interviews (Cement)

Interview company of Cement Manufacturer

Manufacturer	Production name	Type	Standard Specification		Productivity (ton/Day)	Factory Place	Price Include transport
Confidence Cement	Lion Brand	OPC	BDS EN 197-1:2003	CEM-I	3,000	Chittagong	420-460BDT/Bag(50Kg)
	Lion	PCC		CEM-II/B-M(S-V-L)			
Crown Cement	N/A	OPC	BDS EN 197-1:2003	CEM-I 52.5N	5,800	Munshigonj (Dhaka)	445-475BDT/Bag(50Kg) @Badarkhali shop
	N/A	OPC		CEM-I 42.5N			
	N/A	PCC		CEM-II/A-M(S-V-L) 42.5N			
	N/A	PCC		CEM-II/B-M(S-V-L) 42.5N			
Holcim	Holcim Red	OPC	ASTM C150	TYPE-I	6,600	Meghnaghat*2No's (Dhaka) Mongla	
	Holcim Strong Structure	PCC	BDS EN 197-1:2003	CEM-II/B-M(S-V-L) 42.5N			
Ruby Cement/ Scan Cement	N/A	OPC	BDS EN 197-1:2003	CEM-I 52.5N	6,000	Kanchpur (Dhaka) Chittagong	
	N/A	PCC		CEM-II/B-M(S-V-L) 42.5N			
Seven Rings Cement	Seven Ring Special	OPC	BDS EN 197-1:2003	CEM-I 52.5N	9,580	Gazipur (Dhaka) Khulna	490BDT/Bag(50Kg)
	Seven Ring Gold	PCC		CEM-II/A-M(S-V-L) 42.5N			460BDT/Bag(50Kg)
	Sulphate Resisting Cement	SRC	ASTM C150	TYPE-V			N/A

Note:
Ordinary Portland Cement (OPC)
Portland Composite Cement (PCC)
Sulphate Resisting Cement (SRC)

Source：The Environment Survey Team

2) Rebar

a. Product and type

There are 297 rebar manufacturers that are registered in the Bangladeshi market (this information was acquired from an interview with BSRM). The Environment Survey Team investigated the products of three leading manufacturers with large respective production capacities and market shares.

In the Bangladeshi market, rebars are manufactured in compliance with the national standard BDS-ISO-6935 or the international standard ASTM A615. BDS-ISO-6935 is a standard that is based on the international standard ISO-6935. Therefore, when the supplier follows BDS-ISO-6935, the rebars have been manufactured in compliance with the international standards. However, quality is a different condition depending on each manufacturer’s product policy.

The major rebar manufacturers produce mainly two types of rebar. One type complies with BDS-ISO-6935 - a yield strength of 500 Mpa, a tensile strength of 575 Mpa, and an elongation of 14% or more. The other complies with ASTM A615 - a yield strength of 420 Mpa and a tensile strength of 620 Mpa.

Rebar diameters are different depending on the specific manufacturer. However, D8, D10, D12, D16, D20, D25, D28 and D32 (mm) are the flagship products. Some manufacturers have been manufacturing D40 and D50. Rebars are manufactured in 12m lengths.

Figure17.8-9 Production Line
Photo source：BSRM

Figure17.8-10 Production Furnace
Photo source：BSRM

b. Rebar manufacture

There are no iron ores in Bangladesh, but there is a large ship breaking yard in the Chittagong region. There is large amount of scrap iron outside the ship breaking yard. The scrap iron will be re-purified into billets at a steel plant. Some rebars are made from these billets and some manufacturers import good quality billets from Turkey and Korea.
In light of the the above reasons, there are many rebar manufacturing factories located in the Chittagong region. Some rebars are exported to neighboring countries like India.

Figure17.8-11 Storage of Billet
Photo source：BSRM

c. Production rate of rebar

The annual domestic rebar production amount is said to be 4 million tons/year (from this information was acquired from an interview with BSRM). Each of the interviewed companies produces rebars at around 400-2,000 ton/day.

d. Domestic distribution

Between main cities, rebars can be transported in a long trailer. With good access to a construction site, it is possible for these to be delivered in their manufactured length of 12m. However, the quality of the road conditions is not well in Bangladesh is not so high. Once out off of the main roads, there are many traffic difficulties for long vehicles and trucks due to narrow roads. The rebars are bent in half and carried by medium-sized trucks to retail shops and project sites.

There are many cases of deliveries to retail shops and construction sites by medium-sized trucks for rebars that are bent in half.

Figure17.8-12 Rebar Delivered by Long Trailer

Figure17.8-13 Rebar Delivered by Medium-Sized Truck

Photo source：BSRM

e. Domestic construction result

Like cement, the actual use of rebars produced by the leading manufacturers in Bangladesh is widespread.

f. Transportation and price

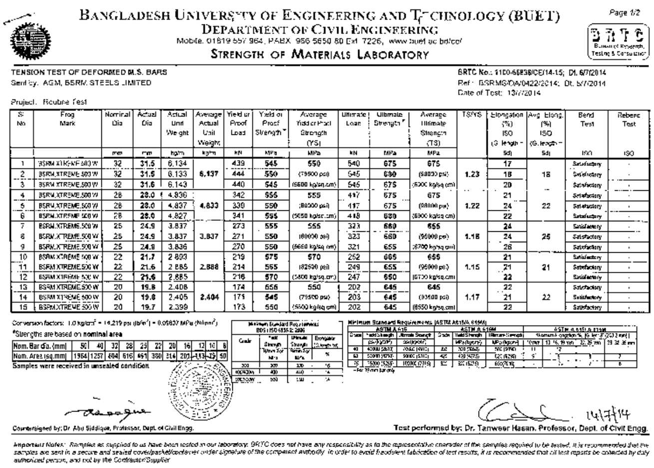
Many of the leading manufacturers have posted the market price on their homepages/websites. Recently in Bangladesh <November 2014> this rebar price has been BDT 55,500-58,000/ton <USD 713.3-745.3/ton> (excluding VAT). This cost is free on board (FOB).

The land transportation cost is also shown on the manufacturers' homepages/websites. The major manufactures have their factories near Chittagong. The land transportation cost from the factory to the Matarbari Project site is BDT 720-1,500/ton <USD 9.3-19.5/ton> (excluding VAT). This cost covers only transportation by long trailer to near the Matarbari area; further cost is required for the rebar to be transported on narrow rural roads (i.e. this involves smaller vehicles).

The Environment Survey Team conducted a survey of the waterway transportation cost using barges up to the Matarbari Project site from the factory. This cost at BDT 720-1,500/ton <USD 9.3-19.5/ton> (excluding VAT), is almost the same as for land transportation. Nevertheless, if the jetty facility is located near the site, waterway transportation does not require the separate cost of transportation on narrow rural roads.

g. The test results by public testing institutions

Rebar has been inspected to comply with ISO standards. Rebar testing results of major manufacturers are compliant with BDS-ISO-6935 and ASTM A615.



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Page 1/2

BRTC Bureau of Research, Testing & Consultation

TENSION TEST OF DEFORMED M.S. BARS
Sent by: AGM, BSRM STEELS LIMITED
Project: Routine Test

BRTC No.: 1100-66838/CE/14-15; Dt. 6/7/2014
Ref: BSRMS/DA/0422/2014; Dt. 5/7/2014
Date of Test: 13/7/2014

Sl No	Frog Mark	Nominal Dia	Actual Dia	Actual Unit Weight	Average Actual Unit Weight	Yield or Proof Load	Yield or Proof Strength*	Average Yield or Proof Strength (YS)	Ultimate Load	Ultimate Strength*	Average Ultimate Strength (TS)	TS/YS	Elongation (%) ISO (G. length - 5d)	Avg. Elong. (%) ISO (G. length - 5d)	Bend Test	Rebend Test
		mm	mm	kg/m	kg/m	kN	MPa	MPa	kN	MPa	MPa				ISO	ISO
1	BSRM XTREME 500 W	32	31.5	6.134		439	545	550	540	675	675		17		Satisfactory	-
2	BSRM XTREME 500 W	32	31.5	6.133	6.137	444	550	(79500 psi)	545	680	(98000 psi)	1.23	18	18	Satisfactory	-
3	BSRM XTREME 500 W	32	31.6	6.143		440	545	(5600 kg/sq.cm)	545	675	(6900 kg/sq.cm)		20		Satisfactory	-
4	BSRM XTREME 500 W	28	28.0	4.836		342	555	555	417	675	675		21		Satisfactory	-
5	BSRM XTREME 500 W	28	28.0	4.837	4.833	339	550	(80000 psi)	417	675	(98000 psi)	1.22	24	22	Satisfactory	-
6	BSRM XTREME 500 W	28	28.0	4.827		341	555	(5650 kg/sq.cm)	418	680	(6900 kg/sq.cm)		22		Satisfactory	-
7	BSRM XTREME 500 W	25	24.9	3.837		273	555	555	323	660	655		24		Satisfactory	-
8	BSRM XTREME 500 W	25	24.9	3.837	3.837	271	550	(80000 psi)	323	660	(95000 psi)	1.18	24	25	Satisfactory	-
9	BSRM XTREME 500 W	25	24.9	3.836		270	550	(5650 kg/sq.cm)	321	655	(6700 kg/sq.cm)		26		Satisfactory	-
10	BSRM XTREME 500 W	22	21.7	2.893		219	575	570	252	665	655		21		Satisfactory	-
11	BSRM XTREME 500 W	22	21.6	2.885	2.888	214	565	(82500 psi)	249	655	(95000 psi)	1.15	21	21	Satisfactory	-
12	BSRM XTREME 500 W	22	21.6	2.885		216	570	(5800 kg/sq.cm)	247	650	(6700 kg/sq.cm)		22		Satisfactory	-
13	BSRM XTREME 500 W	20	19.8	2.408		174	556	550	202	645	645		22		Satisfactory	-
14	BSRM XTREME 500 W	20	19.8	2.405	2.404	171	545	(79500 psi)	203	645	(93500 psi)	1.17	21	22	Satisfactory	-
15	BSRM XTREME 500 W	20	19.7	2.399		173	550	(5600 kg/sq.cm)	202	645	(6550 kg/sq.cm)		22		Satisfactory	-

Conversion factors: 1.0 kg/cm² = 14.219 psi (lb/in²) = 0.09807 MPa (N/mm²)
*Strengths are based on nominal area

Nom. Bar dia. (mm)	50	40	32	28	25	22	20	16	12	10	8
Nom. Area (sq.mm)	1964	1257	804	616	491	380	314	201	113	79	50

Samples were received in unsealed condition.

Minimum Standard Requirements BDS ISO 6935-2: 2006

Minimum Standard Requirements (ASTM A615/A 615M)

Countersigned by: Dr. Abu Siddique, Professor, Dept. of Civil Engg.

14/7/14

Test performed by: Dr. Tanweer Hasan, Professor, Dept. of Civil Engg.

Important Notes: Samples as supplied to us have been tested in our laboratory. BRTC does not have any responsibility as to the representative character of the samples required to be tested. It is recommended that the samples are sent in a secure and sealed cover/packet/container under signature of the competent authority. In order to avoid fraudulent fabrication of test results, it is recommended that all test reports be collected by duly authorized person, and not by the Contractor/Supplier.

Figure17.8-14 Sample of the Test Results (BUET)

h. Summary of the minutes of the manufacturers' interviews

Information from the interviews with the rebar manufacturers are shown in the following table:

Table 17.8-4 Summary of Interviews (Rebar)

Interview company of Re-bar Manufacturer

Manufacturer	Production name	Size (mm)	Standard Specification	Yield(min) Strength	Tensile(min) Strength	Elongation (min)	Productivity (ton/Day)	Factory Place	Price
BSRM	Xtreme-500W	8-50	BDS ISO 6935	500Mpa	575Mpa	14%	2,000	Chittagong	57400-58000BDT/Ton
	Grade-60		ASTM A615	420Mpa	620Mpa	7-9%			
KSRM	Grade-500W	8-40	BDS ISO 6935	500Mpa	575Mpa	14%	1,700	Chittagong	56500-57500BDT/Ton
	Grade-60		ASTM A615	420Mpa	620Mpa	9%			
GPH ispad ltd.	GPH TMT 500W	8-40	BDS ISO 6935	500Mpa	575Mpa	14%	400	Chittagong	55500-56500BDT/Ton
	GPH G60-400		ASTM A615	415Mpa	620Mpa	14%			

Source：The Environment Survey Team

3) Fine aggregates (sand)

a. Product and type

River sand from the Sylhet district in the northeast of Bangladesh has been distributed nationwide as a good quality fine aggregate sand to be used in concrete or other construction materials in the Bangladeshi market.

b. Sand quarry

This fine aggregate sand is taken manually and pumped from the riverbed in the Sylhet District.

c. Quantity of the sand

The Sylhet river sand has been distributed nationwide as good quality fine aggregate sand to be used in concrete or other construction materials in the Bangladeshi market.

There are such sand many suppliers, but no official statistical data of the amount supplied from the Sylhet district is available. According to supplier interviews, around 57 million m^3/year of Sylhet river sand is exported from the district.

Each supplier supplies about 1,500-4,000 m^3/month. Also, 4.7 million m^3/month is the estimated annual supply amount from this district.

d. Domestic transportation

The fine aggregate sand is transported from Sylhet via overland and waterways; overland, the sand is moved by heavy vehicles that are approximately 30-40m^3 in size. In general the journey from Sylhet to Chittagong takes around three days. Therefore, for suppliers to make deliveries to directly to the Project site in the Matarbari area, it will take around 4-5 days. In addition, in order to overcome the difficult passage of heavy vehicles when they enter rural roads, it is necessary to carry out the delivery by transshipment using small trucks.

Figure17.8-15 Transportation by Heavy Vehicle

Figure17.8-16 Transportation by Small Barge

In the case of transport using the waterway, aggregates have been transported from the Sylhet district to the site by using a small barge (500 m^3 capacity).

Rivers from the Sylhet Region flow downstream to shallow water, where the depth can be only around 2.0m. Each barge has to adjust its loading volume during rainy season and dry season depending on water depth. Generally travel from Sylhet to Chittagong takes by water takes approximately 4-5 days. According to the suppliers, transportation to the Project site in the Matarbari area will take around 5-6 days.

On the way to Matarbari, the small barges cross the Bay of Bengal coastline, however, there are concerns about the rough sea conditions and waves that may affect the operation of these barges.

e. Domestic use
Sylhet river sand is used as fine aggregate sand for concrete throughout Bangladesh.

f. Transportation methods and price
Recent unit prices for fine aggregates in Bangladesh, regardless of the classification of sand, have been around BDT 17-24/cft <USD 7.7-10.9/m^3> (VAT included) <November 2014 >. Th price covers only the local delivery price in the Sylhet district (FOB). The transportation to Matarbari will incur separate costs, with the study results showing that:

by land this cost is around BDT 78-82/cft <USD 35.4-37.2/m^3> (VAT included); and by water it is around BDT 69-71/cft <USD 31.3-32.2/m^3> (VAT included) (this includes transportation up to the temporary jetty near the Matarbari site). The total combined amount of the materials and transportation costs are shown below.

Land transportation：BDT 95-106/cft <USD 43.1-48.1/m^3> (VAT included)

Water transportation：BDT 86-95/cft <USD 39.0-43.1/m^3> (VAT included)

g. Material test results

Suppliers do not perform material testing of sand. It is common for buyers to check the material test results before purchasing. In many projects, the decision to purchase is made by bringing in sand for inspection and testing to the public institutions such as BUET. Sand from the Sylhet district has no problem in terms of quality, since it is used in most domestic concrete structures.

h. Summary of the interviews

Information from the interviews with the suppliers of fine aggregates (sand) is shown below.

Table 17.8-5 List of Interviews (fine aggregates)

Interview company of fine aggregate/sand supplier

Supplier	Origin	Quality	Supply ability (m3/Month)	Material cost	Transportation cost by waterway	Transportation cost by land way	Total Cost By waterway	Total Cost By land way
Mohammed Eunus & Brothers Pvt. Ltd.	Syhlet	Coarse sand	4,000	19.0-21.0BDT/cft	69.0BDT/cft	78.0BDT/cft	88.0-90.0BDT/cft	97.0-99.0BDT/cft
Grace Builders	Syhlet	Coarse sand	1,400	20.0-24.0BDT/cft	71.0BDT/cft	82.0BDT/cft	91.0-95.0BDT/cft	102.0-106.0BDT/cft
K.K Enterprise	Syhlet	Coarse sand	1,700	18.0-22.0BDT/cft	70.0BDT/cft	80.0BDT/cft	88.0-92.0BDT/cft	98.0-102.0BDT/cft
Quality Engineering	Syhlet	Coarse sand	1,500	17.0-21.0BDT/cft	69.0BDT/cft	78.0BDT/cft	83.0-90.0BDT/cft	95.0-99.0BDT/cft
Tasnia Enterprise	Syhlet	Coarse sand	n/a	30.0BDT/cft	90.0BDT/cft	100.0BDT/cft	120.0BDT/cft	130.0BDT/cft
Ali & Brothers	Syhlet	Coarse sand	2,800	30.0BDT/cft	80.0-90.0BDT/cft	90.0BDT/cft	110.0-120.0BDT/cft	120.0BDT/cft
Average			1,400-4,000	17.0-24.0BDT/cft	69.0-71.0BDT/cft	78.0-82.0BDT/cft	86.0-95.0BDT/cft	95.0-106.0BDT/cft

Note
Exception (general discussion only)

Source：The Environment Survey Team

4) Coarse aggregates (crushed stone)

a. Product and type

Like fine aggregates (sand), coarse aggregates (crushed stone) from Sylhet district is widely used in Bangladesh. The type of stone is granite.

b. Quarry

This raw material comes from large river stones – which can be as large as a human's head size - extracted from riverbeds in the Sylhet district. The required grade of granite stone is produced by crushing these river stones with a crusher. Typically, crushers that are used for concrete and civil construction work are suitable for producing and supplying granite stones of around 20mm-100mm size.

Figure 17.8-17 Workers at a Quarry

Photo source：Khaja Construction

Figure 17.8-18 Production of Crushed Stone

Photo source：Khaja Construction

c. Production volume

Sand suppliers often handle coarse aggregates. Like fine aggregates, statistical data about the annual supply amount from the Sylhet district is poor, but according to interviews with the suppliers there is a production of 85 million m^3/year in the district.

Each supply company produces around 1,500-8,000 m^3/month. It is estimated from the annual supply that 7 million m^3/month is supplied from the Sylhet district.

d. Domestic transportation

The same as for fine aggregate (sand) distribution.

e. Domestic use

The same as for fine aggregate (sand) distribution.

f. Transportation methods and price

Recent unit prices for coarse aggregate in Bangladesh, regardless of the size of crushed stone, have been around BDT 102-120/cft <USD 46.3-54.4/m^3> (VAT included) <November 2014 >. Th price covers only the local delivery price in the Sylhet district (FOB). Like with fine aggregates (sand), the transportation to Matarbari will incur separate costs. The total combined material and transport price is shown below.

Land transportation：BDT 80-202/cft <USD 81.7-91.7/m^3> (VAT included)
Water transportation：BDT 171-191/cft <USD 77.6-86.7/m^3> (VAT included)

g. Material test results

Suppliers produce crushed stone sized in accordance with each order received. Like with fine aggregates (sand), it is common in Bangladesh for buyers to check the material test results before purchasing. In many projects, the decision is made by choosing a quarry for inspection and testing by the public institutions such as BUET. Crushed stone from Sylhet district has no problem in terms of quality, since it is widely used in domestic concrete structures and basic crushed stone.

h. Summary of interviews

Information from the interviews with the suppliers of coarse aggregates is shown below.

Table 17.8-6 List of Interviews (coarse aggregate)

Interview company of Coarse aggregate supplier

Supplier	Origin	Quality	Supply ability (m3/Month)	Material cost	Transportation cost by waterway	Transportation cost by land way	Total Cost By waterway	Total Cost By land way
Mohammed Eunus & Brothers Pvt. Ltd.	Syhlet	Crashed stone (Granite)	8,000	110.0-118.0BDT/cft	69.0BDT/cft	78.0BDT/cft	179.0-187.0BDT/cft	188.0-196.0BDT/cft
Grace Builders	Syhlet	Crashed stone (Granite)	4,000	114.0-120.0BDT/cft	71.0BDT/cft	82.0BDT/cft	185.0-191.0BDT/cft	186.0-202.0BDT/cft
K.K Enterprise	Syhlet	Crashed stone (Granite)	3,000	110.0-120.0BDT/cft	70.0BDT/cft	80.0BDT/cft	180.0-190.0BDT/cft	190.0-200.0BDT/cft
Quality Engineering	Syhlet	Crashed stone (Granite)	3,000	108.0-120.0BDT/cft	69.0BDT/cft	78.0BDT/cft	177.0-188.0BDT/cft	185.0-198.0BDT/cft
Tasnia Enterprise	Syhlet	Crashed stone (Granite)	n/a	102.0-110.0BDT/cft	90.0BDT/cft	100.0BDT/cft	192.0-200.0BDT/cft	202.0-210.0BDT/cft
Ali & Brothers	Syhlet	Crashed stone (Granite)	2,800	110.0BDT/cft	80.0-90.0BDT/cft	90.0BDT/cft	190.0-200.0BDT/cft	200.0BDT/cft
Average			2,800-8,000	102.0-120.0BDT/cft	69.0-71.0BDT/cft	78.0-82.0BDT/cft	171.0-191.0BDT/cft	180.0-202.0BDT/cft

Note
Exception (general discussion only)

Source：The Environment Survey Team

5) Sand (for landfill)

Many reclamation works have been carried out in Bangladesh. From interviews with the relevant contractors, landfill sand is basically supplied near the construction site. Since there is a concern with the inadequate supply of landfill sand and using dredged sand to resolve this, a study was made to prepare for this situation in this Project.

a. Type

According to interviews with landfill contractors, landfill sand used for reclamation work in Bangladesh is generally supplied from neighboring rivers, and coastal and mountainous areas.

b. Sand pit

It is difficult to determine the physical properties and reserves of sand to be collected by dredging without a detailed field survey such as a soil investigation. In this study, sand collected by the dredging of rivers in the suburbs of Chittagong near the Project site, and mountain sand collected in the hilly areas that extend from north Chittagong through to Cox's Bazar was investigated. From the sand screening test results, the silt content (passing through a 0.075 mm sieve) of the dredged sand from the said rivers was 1.2%.

And, the silt content of the mountain sand collected in the hilly areas that extend from Cox's Bazar to Chakaria area was 1.5%. From these results, it is estimated that both sands can be used for land reclamation.

Figure17.8-19 Sand Collection from the River (Chittagong)

Figure17.8-20 Sand Collection from the Hills (Cox's Bazar)

c. Amount of sand supply

From the fact that maintenance dredging in the Chittagong River has been continuously carried out, and Bangladesh's geography divides the coastline and the hilly areas of north Chittagong to Cox's Bazar as beach and dune sand, it is assumed that there are sufficient reserves for replenishment of the shortfall.

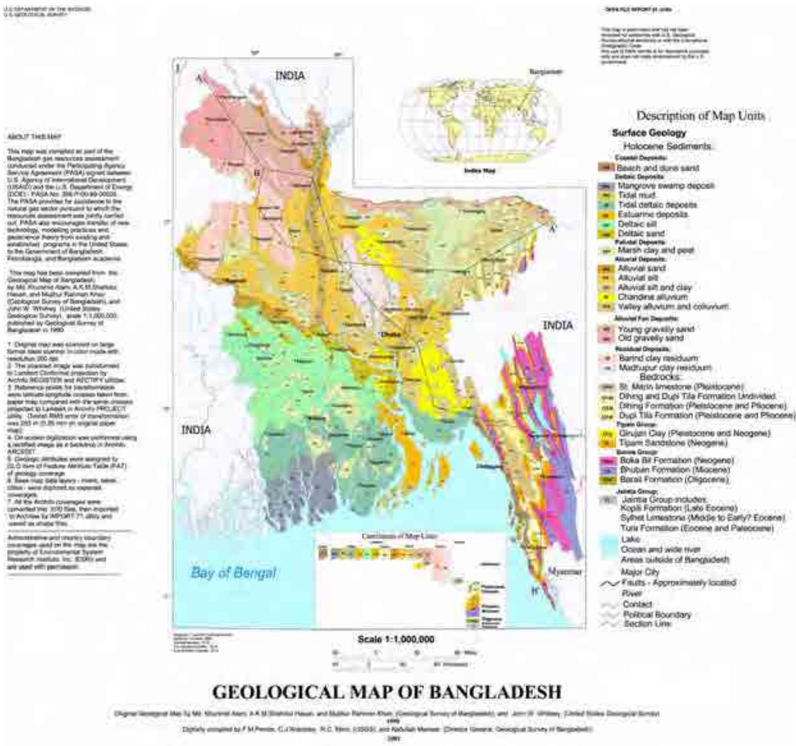

Figure 17.8-21 Bangladesh Geological Map

Source：Website: Ministry of Power, Energy and Mineral Resources

d. Transportation and price

The transportation price of dredged sand from Chittagong is inferred from the interviews with the dredging contractors. In around 2010, one of the contractors previously collected dredged sand near the Dhaka suburbs and transported them to a piece reclaimed land 70 km away at a cost of BDT 23-29/cft <about USD 10.4-13.2/m^3> (VAT included). Because the distance from Chittagong to the Matarbari area is around the same as this, it may be inferred that the price is similar to said amount. In addition, information from a contractor that performed coastal sand dredging and landfill from Chittagong to Matarbari, with a transportation distance of about 40 km, resulted in a price of BDT 25/cft <about USD 11.3/m^3> (VAT included). Then, the price for Cox's Bazar hilly area mountain sand, including transportation to Matarbari area, was BDT 27-33/cft <about USD 12.3-15.0/m^3> (VAT included）.

Figure17.8-22 Dredging and Landfill Workers

Photo source：Citadel Dredgers Limited

e. Summary of the interviews

Information from the interviews with the experienced traders for reclamation work is shown below.

Table 17.8-7 List of Interviews (landfill sand)

Interview company of dreading/local sand contractor

Contractor	Work experience Location	Quality	Access	Transport Distance	Supply ability (m3/day)	Material cost (Including transport)
Citadel Dredgers Ltd	Narayanganj River sand	Sand	Barge	70km	3,000	23.0-29.0BDT/cft
Tasnia Enterprise	Bashkhali Coastal sand	Sand	Barge	40Km	1,400	25.0BDT/cft
Ali & Brothers	Bashkhali Coastal sand	Minimum sand	Barge	40Km	5,600	25.0BDT/cft
Bismilah Construction	Bashkhali Coastal sand	Sand	Barge	40Km	n/a	25.0BDT/cft
Prime International	Local mountain Sand	Mountain Sand	Track	50km	n/a	29.0-33.0BDT/cft
Fardia Enterprise	Local mountain Sand	Mountain Sand	Track	50km	n/a	27.0-30.0BDT/cft

Source：The Environment Survey Team

6) Soil improvement material (PVD)

When carrying out ground improvements to a landfill construction, the loading embankment construction method combined with the PVD method is often adopted. There is a construction project using the PVD method in Bangladesh. However, a PVD production and construction management trader does not exist. Thus research was conducted on the high performance PVD method being used in the construction industry in nearby Malaysia (this covered PVD production, material procurement possibility and price research).

a. Product and type

The three companies which were interviewed had PVD export and construction experience in Bangladesh. Each company has 2-3 types of major products and there are many construction projects with these specifications.

PVD is generally manufactured in a roll 100mm wide and 300m long. PVDs are manufactured according to ASTM standards.

b. PVD manufacturing

PVD is made up of a polypropylene core and filter. It is commercialized by rolling the core and filter in a manufacturing plant.

In Southeast Asia, countries such as Malaysia, Thailand, and Indonesia manufacture PVD. Many of the companies perform both manufacturing and construction, and have a number of overseas construction projects.

c. Production rate of PVD

PVD can be manufactured in a relatively small factory. One production lane can produce 1.0 million m/month. Although there are differences in the capacity of production lanes, each company has a monthly production volume of 1.0-7.0 million m/month.

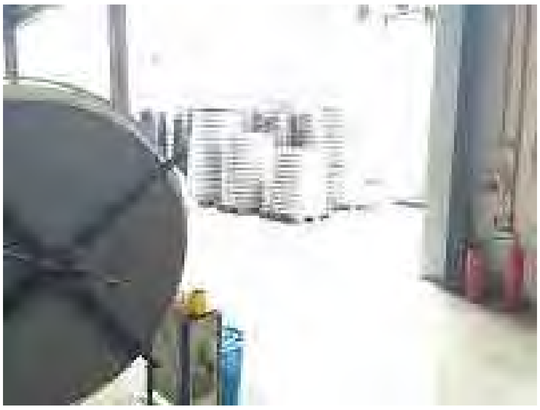

Figure17.8-23 PVD Manufacture

Figure17.8-24 PVD Storage

d. Export method

Exports from Malaysia of PVD is typically done by ship and packed in a container.

e. Domestic use performance

Examples of projects in Bangladesh that involved the three interviewed companies are referred below.

・Lekamage Associates(PVT) LTD, Chittagong: 2010, Ce Teau
・Bangladesh Project Builders, Chittagong: 2010, Ce Teau

・Al-Amin, Chittagong: 2007, Ce Teau
・Dhaka North Power Plant Project: 2005, Emaskira
・Construction of the Double Line Track from Tongi to Bhairab Bazar: 2003, K-Plast
・Jamuna Bridge Railway Link Project (Contract1): 1999, K-Plast
・Haco Site Haripur 365 MW Combined Cycle Power Plant Project: 1999, K-Plast

f. Price

The PVD price is USD 0.30-0.35/m (CIF price) in Bangladesh. <November 2014>

g. The test results by public testing institutions

Based on the practical application of the PVD method in Bangladesh and experience, PVD material testing is carried out in BUET. It is necessary to confirm the in detail the test content.

h. Summary of the interviews

Information from the interviews with the PVD manufacturers and traders is shown below.

Table 17.8-8 List of Interviews (PVD)

Interview company of PVD Manufacturer

Manufacturer	Production name	Width (mm)	Thickness (mm)	Standard Specification	Tensile Strength	Productivity (m/month)	Factory Place	Material Price
CeTeau	N/A	100	various	ASTM	various	7mil	Malaysia	0.3-0.4USD/lm
Emas Kiara Industries (Tencate)	HB63	100	3.5	ASTM	2500N	5mil	Malaysia	N/A
	HB65		5.0	ASTM	2800N			0.30USD/lm
K-Plast technology (Creative Polymer)	FD 747w	100	3.3	ASTM	2000N	1mil	Malaysia	0.35USD/lm
	FD 767w		N/A	ASTM	N/A			N/A

Note

Exception (general discussion only)

Source：the Environment Survey Team

7) Stone

When carrying out port construction, stones weighing about 200kg to 1000kg are used for the construction of the quay walls and training dyke foundations.

Crushed stone from the Sylhet Region has been widely used for general civil engineering work in Bangladesh. However, only 100kg river stones are locally available and there is no choice but to rely on imports from third countries for big rubble stone to be used in the port construction.

For a third-country study, it was decided to carry out a survey of deep sea port construction work in the neighborhood of this Project area. Information was gathered that a deep sea port development work was in progress in Myanmar's Kyaukpyu Port, located about 310 km southeast of the planned Project site.

In the Kyaukpyu deep sea port, crushed stone and stone material from Mawlamyine, in Myanmar's Mon State (about 850km south, across the coast from Kyaukpyu), is transported by barge. The Environment Survey Team studied the quality and supply potential of the stone material used there.

a. Quarry and type of stone

The interview was carried out with a company that has a delivery record of stone materials to Kyaukpyu Port, and a field study was carried out in the quarry of Myanmar Mon State in order to ensure the quality and supply. In the quarry, granitic stone has been quarried. The specific gravity of the stone is about 2.70 g/cm^3. From this region, it has been widely transported to Yangon and used as crushed stone for concrete aggregate and civil engineering.

In the mountain quarry area, there are areas operated and quarried by the government sector, and areas where the private sector may quarry with government permission. Currently, the demand for stone in Myanmar is low, so although the majority of the work is manual without using large machinery, where necessary to increase production efficiency heavy equipment is are on standby in the quarry workshops.

Figure17.8-25
Rock Quarry (Inn Myaung)

Figure17.8-26
Production (Mayagone)

b. Production volume of stone

The Kyaukpyu port construction project requires approximately 170,000 m^3 of stone material, of which 120,000 m^3 has been delivered in the last year. The scale of the stony zone in Mon State is large so it is possible to have a stable supply for the Project.

c. Transportation method

There is a quarry from Kyaikto to Motama and it is quarried in the areas approximately 25 to 130 km away from Mawlamyine Port. The shipments of stoneinvolves dump trucks transporting stones from the quarry to the port and loading them on the barge. The road conditions from the quarry to the shipment field are good. Since large vehicles can pass, transportation can be done without problems. In addition, transportation by train to the port is also possible because there is an adjacent track, although this is dependent on the distance to the quarry.

Figure17.8-27 Shipping Port Stock Yard

Photo source：Rockwell Mining

Figure17.8-28 Track Usage

Photo source：Rockwell Mining

d. Export

The exportation of stone from Myanmar to Bangladesh had not been done up until now. In the future, although there will be a need for consultation between the governments, it will be possible because the import and export of non-stone materials has been widely done. When exporting stone material, there is a customs house in Mawlamyine Port and the current situation for facilitating this in Myanmar situation is favorable.

Figure17.8-29 Shipment Lamp

Photo sauce：Rockwell Mining

Figure17.8-30 Barge Loading Work

Photo sauce：Rockwell Mining

e. Price

Loading only stone price to barge (FOB price) in Mawlamyine Port is about USD 36.5/m^3 <November 2014> and survey results, including shipping costs and custom duties, was USD 80/m^3.

f. Price of stone in other nearbycountries

From the stone price survey conducted in Bangladesh, Vietnamese stone is about USD 84/m^3 <November 2014 >. Basically, it would be more effective to use Myanmar stone, if available, in order to ensure the supply of necessary material sources and to reduce the construction costs.

Figure17.8-31 Cutout Stone