Technical studies extract from Draft TEFR for proposed Deep-Sea Port at Tajpur, West Bengal

West Bengal Industrial Development Corporation (WBIDC)

2019-2020

pwc

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1. Preliminary site assessment

1.1. Preliminary Soil Report Approach

As a part of feasibility stage survey & investigation, geotechnical investigation by drilling borehole has been conducted. Altogether fourteen (14) boreholes have been drilled. Out of fourteen boreholes, three boreholes have been drilled at beach and eleven boreholes have been drilled in the open sea.



The approach followed for the surveys is elaborated down below:

Bathymetric survey has been conducted in Bay of Bengal. Bathymetric survey is the measurement of depth of water in various waterbodies like lake, sea, ocean etc.


Field Work

Bathymetric has been conducted by using dual frequency echo-sounder (GPS MAP 85; make – Garmin) and hand GPS. The survey has been conducted using motor boats. Bathymetric survey has been conducted in a triangular shaped area, please refer Annexure 1.1 – 1.5: *Technical survey drawings and details*. Distance of the vertex of the triangle from the coast line is about 25 km. Bathymetry data has been collected over about 250-line kilometer.

Field work has been conducted during 'high tide' and duration of survey is about 10 days (22.09.2019 to 01.10.2019)

Data Processing & Drawing Preparation

Bathymetry data collected was downloaded and analyzed. Based on analyzed data, bathymetric survey drawings have been prepared. Drawings has been presented Annexure 1.1 – 1.5: *Technical survey drawings and details*. Drawing has been prepared with the aid of various drawing software. For 2D and 3D mapping GIS software has been used.

1.2. Topography, Geology and Geomorphology

Topographically the site area is sloping gently to flat ground. Geology of this area is characterized by unconsolidated sedimentary deposit of Quaternary period. The site area falls under deltaic plains of Bengal. The deltaic plain of Bengal is characterized by thick piles of unconsolidated sediments. The project area falls under the Ganga basin. Geomorphologically, the area is characterized by deltaic plains of Bengal. The site is gently sloping. Elevation difference within the test site is less.

1.3. Seismicity

The site area falls under the Seismic zone III (as per IS: 1893; Part -1: 2002). This area is moderate damage risk zone. No epicenter of any major earthquake has been located nearby the site.

1.4. Details of Methods of Investigation

1.4.1. General

This section presents details about the investigations that had been carried out at site and at the laboratory.

1.4.2. Boring

Since the site is located on sedimentary deposit, boreholes of 150 mm diameter were advanced into the soil, adopting shell & auger boring method. The tool consists of augers and shell. Boring has been done using a mechanized rig. Boring rods were raised and lowered by means of shear legs and a power winch. The casing is advanced by driving by means of a "monkey" suspended from winch. Open sea boreholes were advanced into the soil adopting rotary mud boring method. The method consists in first driving a casing through which a hollow drill rod with a sharp chisel at the lower end is inserted. Water is forced under pressure through the drill rod, which is alternatively raised and dropped and rotated. The resulting of this chopping and jetting action with washing, forced to the soil up to the ground surface in the form of soil-water slurry through annular space between the drill rods and casing. This process is advanced until the specified depth of sampling is reached. All boreholes were systematically logged, and boring data were noted. Borehole logs and bore hole positions are presented in the Annexure 1.1 and Annexure 1.3 at the end of this report

1.4.3. Standard Penetration Test (SPT)

Standard penetration tests were conducted in all the exploratory bore holes at regular intervals as per as the provision laid down in IS: 2131 - 1981. The split spoon sampler used for such tests was of standard design and dimensions as stipulated in IS: 9640-1980. The split spoon sampler in the entire test had been adapted to lower end of drill rods taken up-to specific depth of test. The split spoon sampler was advanced by driving a drop hammer, weighing 63.5 kg. falling freely through a height of 75 cm. A record of number of blows required for penetration of 30 cm after penetration of first 15 cm as seating drive at the specific depth of test in each bore hole was recorded as 'N' values for corresponding test depths in the respective bore holes.

The disturbed soil samples, collected from the split spoon sampler after completion of each test had been subsequently used for visual identification and classification of the subsurface deposits and for preparation of the borehole logs, and for laboratory test.

1.4.4. Undisturbed Sample (UDS)

The undisturbed samples were collected by means of a two tier 100 mm internal diameter and 450 mm length open drive sampling assembly confirming to IS 2132: 1986. Before sampling, the boreholes were thoroughly cleared. The sampling assembly was driven to the required depth manually with the help of jarring link. After sampling operations, undisturbed soil samples were retained in the samplers and molten wax was then poured on each end in several layers so as to give an end sealing about 25 mm thick. The undisturbed soil samples were then sent to the laboratory for conducting appropriate laboratory tests pertaining to the subsurface deposit types, encountered with at the respective borehole locations.

1.4.5. Water Table Observation

Water levels in the boreholes were observed during and after completion of boring operation. The final water levels were recorded in the field and are shown in the individual logs.

1.4.6. Laboratory Investigation

Following laboratory tests for index and engineering properties, as applicable to the subsurface deposit, were conducted as per the provision of various sections of relevant IS codes (IS: 2720).

(a) Grain size analysis.

(b) Test for liquid limit, plastic limit.

(c) Test for water content.

(d) Test for bulk density.

(e) Tri-axial / direct shear test for c and ϕ.

(f) Consolidation test.

Laboratory test results have been presented in Annexure 1.2

Sample Computation of Safe Bearing Capacity for Shallow Foundation are presented in Annexure 1.4

1.5. Results of the Surveys

1.5.1. Sub-soil Profile

Fourteen boreholes have been drilled at this site. Depending on field observation and laboratory test results, the sub-soil deposits revealed at borehole locations are classified into different strata. The borehole data indicate similar sub-soil stratification; two strata have been identified. Stratum wise description has been presented below.

Stratum I

This stratum consists of blackish grey, moist to wet, soft, clayey silt mixed with some sand. This stratum has been significantly encountered in all boreholes. This stratum is most important from sub-soil point of view.

Stratum II

This stratum consists of brownish to yellowish grey, moist, loose to medium dense, sand. This stratum has been significantly encountered in only two beach boreholes.

1.5.2. Sub-soil Properties

Mainly one stratum has been encountered in boreholes – clayey silt. It can be said that the sub-soil profile (up to the depth of exploration) is comprised of only one stratum – clayey silt (stratum I). Hence, sub-soil properties of stratum I will lead to understanding of the sub-soil profile characteristics.

Generalized sub-soil properties of stratum I have been presented below:

Table 1: Sub-soil Properties

Stratum I	
IS Classification	MI
Average N value	5
Consistency	Soft
Water Content	38.0%
Unit Weight	1.7 t/m^3
Cohesion	2 t/m^2
Angle of internal friction	9^o

Source: Survey results

It may be summarized that the sub-soil profile is comprised of soft clayey silt with high water content (unconsolidated sediments) having low consistency and strength.

1.5.3. Topography Plan

Topographical survey started with fixing of benchmark. Four (4) benchmarks have been set up with Differential Global Positioning System (DGPS). With this setting up starting co-ordinates and elevation were known. They are:

Table 2: Topo Survey Co-ordinates (UTM Zone 45 Q)

Benchmark	Easting	Northing	Elevation (m)
TBM – 1	563311.020	2393649.863	7.517
TBM – 2	563104.374	2393604.649	7.140
TBM – 3	560773.808	2393076.273	5.253
TBM – 4	560126.605	2392867.592	7.510

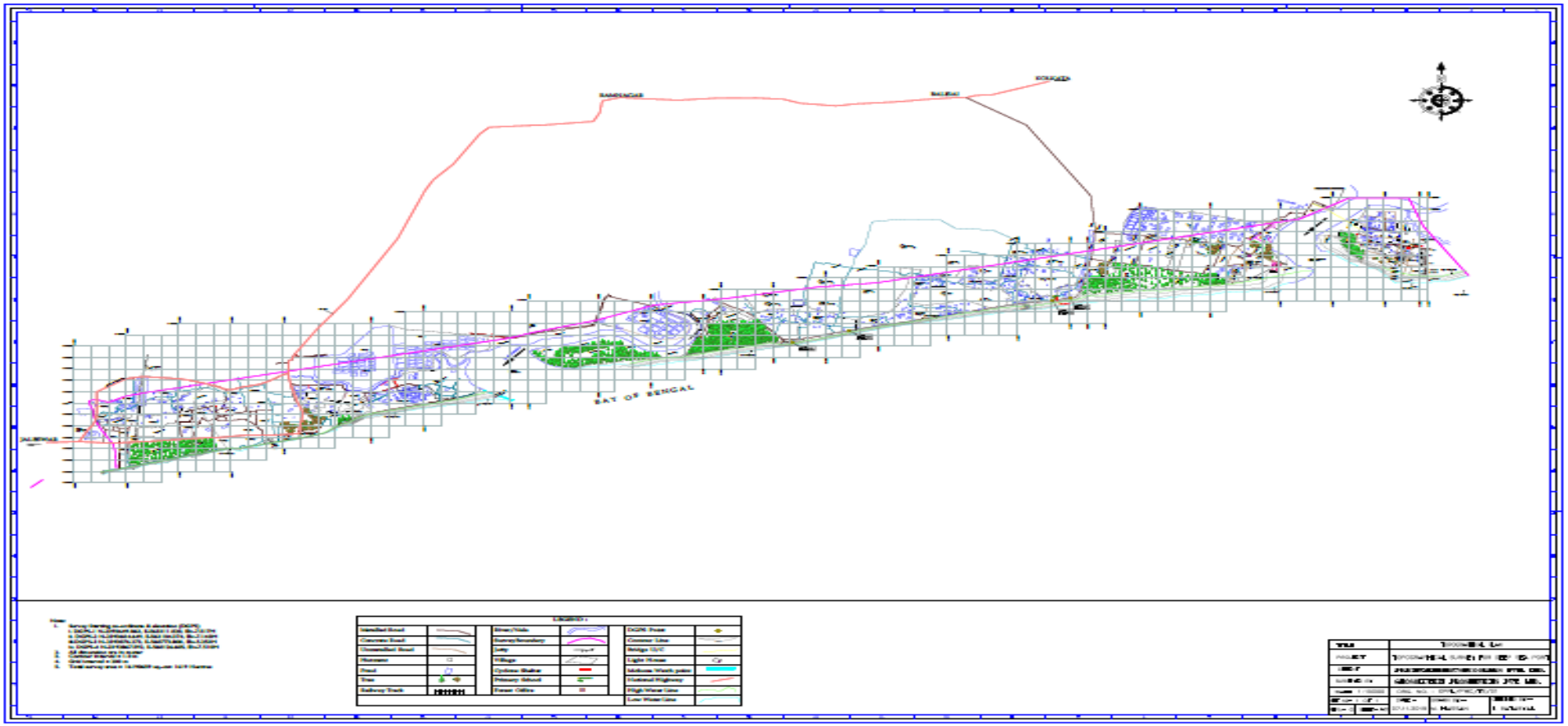
Source: Survey team

After setting up of benchmark field survey has been conducted with help of electronic Total Station instrument, Auto Level and hand GPS.

Drawing Preparation

Topographical survey plan has been presented in drawing in the next page (GPPL/PWC/TS/01). Drawing has been prepared by AutoCAD Civil 3D software. Scale of drawing is 1:15000. Total area surveyed is 1619 Hectares. Grid interval is 200m x 200m and the contour interval is 1.0 m.

The topography survey done showed the following results:

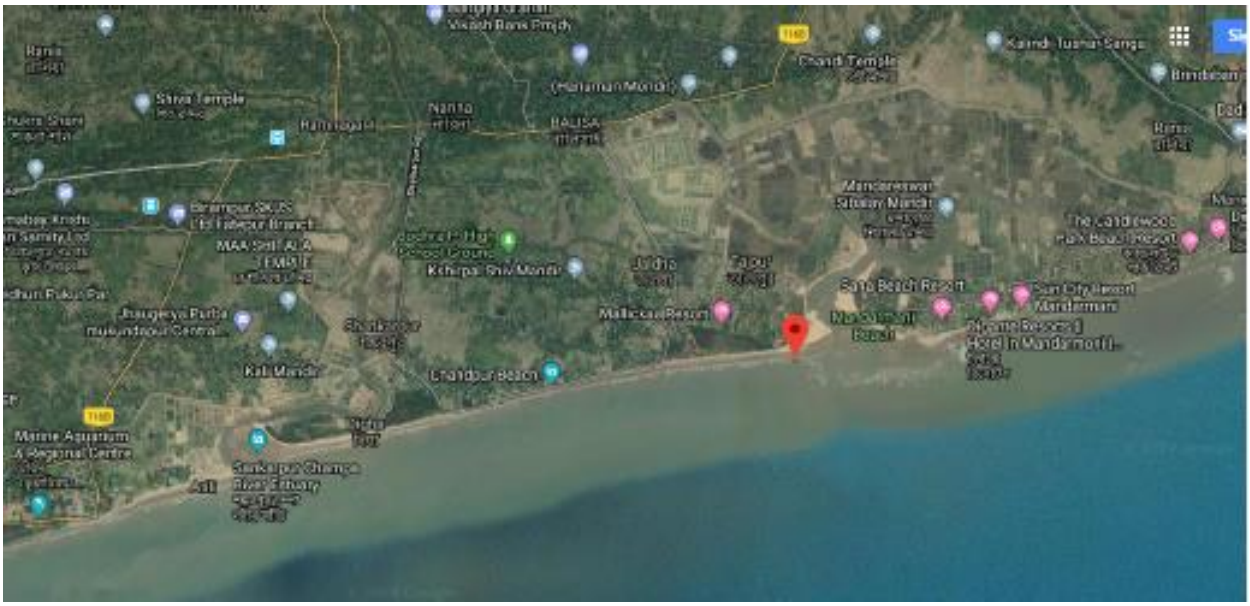


Source: Survey team

1.5.4. Tidal observations

Study on the tidal activity at the proposed site was also carried out to effectively asses the nature of tidal support that can be envisioned while laying out the dredging requirement and the conceptual master planning. The tidal observation points are shown in the figure below:

Figure 1: Tide Observation Points



Source: Survey Consultants

Methodology:

- Tide observation is done at Off Tajpur Beach. Tidewater height is measured using the Tide gauge placed beyond Low Tide Line (LTL).
- Tide gauge is a measuring staff made up of PVC. It was grounded in the location shown in google map (Co-ordinate: E 565468.147, N 2393652.238 (UTM Zone 45 Q). Elevation of the observation point is 1.80 M above MSL
- Tide data is observed from 14/10/19 to 12/11/2019 with daily observation timing from 8:00 hrs. to 17:00 hrs. Measurements are observed regularly as shown in the excel graph.
- Microsoft Excel is used to create the daily tide level variation curves.
- Three to four data sets were taken daily during maximum high and low tide times. The tidal variation curve on diurnal basis is prepared using the trend obtained from the observation points fitted in 6th order polynomial in Microsoft Excel. This process might inherit extrapolation from the actual observation within permissible limit of 0.1 M

Tide observation point location: Off Tajpur Beach

Co-ordinate: E 565468.147, N 2393652.238 (UTM Zone 45 Q)

Elevation: 1.80 M above MSL

Benchmark Details

DGPS Benchmark (DGPS 1)

Co-ordinate: E 563311.020, N 2393649.863, Elevation: 7.517 M

Observation Duration: 14/10/19 to 12/11/2019

Daily Observation Timing: 8:00 hrs. to 17:00 hrs.

Observations

- The highest observed tide water level (MSL) is 5.15 M, which was observed on 30/10/2019.
- The lowest observed water level (MSL) recorded is 1.60 M, measured on 29/10/2019.
- The tidal fluctuation between high and low tides is varying on day to the basis.
- Maximum and minimum high tide levels noted are 5.15 M and 4.3 M, revealing a variation of 0.85 M within high tide water level.
- Minimum and maximum low tide levels noted are 1.6 M and 2.9 M, indicating a fluctuation of 1.3 M within low tide water level.
- LAT (Lowest Astronomical Tide) CD = 0.00 m

Findings

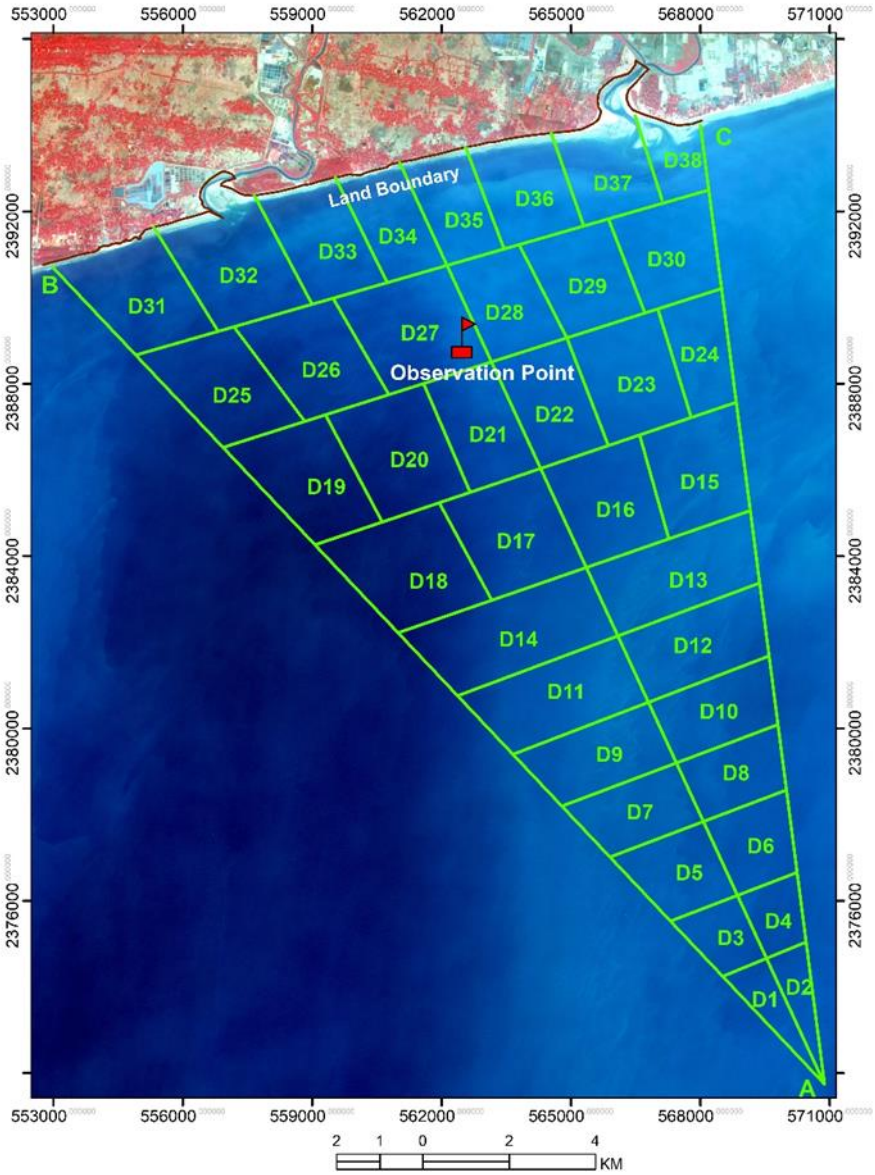
- Semidiurnal tidal cycles are observed.
- This region shows the property of a variable fluctuation of tidal activity within both inter- and intra-tidal water level

Details about the tidal observations are provided in Annexure 1.5

1.5.5. Wave and Current observations

As part of site survey, study on wave and current observations study was carried out. Total domain area was about 180 square km. Because there was a limitation in DHI Mike 21 in demo mode, the domain was divided into 38 small domains (Figure below). A separate hydrodynamic flow model and spectral wave model was computed for each domain. The parameters such as Water level, wave height, wave period and wind velocity were measured for point A and those values were applied for the D1 model domain. For other model domain the input data sets were interpolated from the share boundary of that domain. The observation point is situated in D27 domain. For that domain the parameters of shared boundaries with D20, D21, D26 and D28 are used as the input datasets. The methodology for which has been described as below:

Figure 2: Methodology for Wave and Current observations



Input Datasets:

- From Bathymetry: the xyz data for the whole domain is measured by on field survey.
- Water Level Data: dataset is collected from the Global Tide Model.
- Wind Data: Collected from https://www.meteoblue.com/.

Methodology:

- From the measured bathymetry data, a mesh was generated for every domain in Mike Zero Mesh Generator tool.
- Water level values of A point is calculated from Global Tide Model by Mike 21 toolbox.
- In DHI Mike 21 FM tools (Demo) the input datasets are initially processed in D1 domain. For other domains the linear output of each boundary from adjacent domains are used as input parameter. From is model water level, Current Speed and Direction of required time interval was generated.

- Similar processes are applied for DHI Mike 21 SW tools (Demo). This model is used to calculate significant wave height, wave period, and wave direction.
- From the numerical model (Both FM and SW) of D27 a point output is generated by using DHI Mike Zero Data Extraction tool.
- The output datasets are plotted graphically.

Detailed diagrams are represented in the Appendix 1.5. Observations on Current, Wave and Wind study are provided below:

Current – The current in the area are predominantly from the South and North-East side and the magnitude varies between 0.16 m/s to 0.28 m/s.

Wave – The wave in the surveyed area are predominantly from the South and South-West and the magnitude varies between 0.6 m to 1.00 m.

Wind – The wind in the surveyed area are predominantly from the South and the magnitude varies between 2.5 m/s to 5.5 m/s.

The above-mentioned observations are made based on historical information[1] available on tide, current, wave and wind data, which was further substantiated/ calibrated for local effects, using the surveys undertaken as part of this study (surveys were conducted for a limited period of 30 days, which can be considered indicative in nature). The private player is advised to undertake its own due-diligence and analysis over a larger sample period for more detailed assessment.

1.5.6. Bathymetric Survey

Bathymetric survey was also carried out to assess the seabed contour and analyze various draft levels at incremental distances from the Coast.

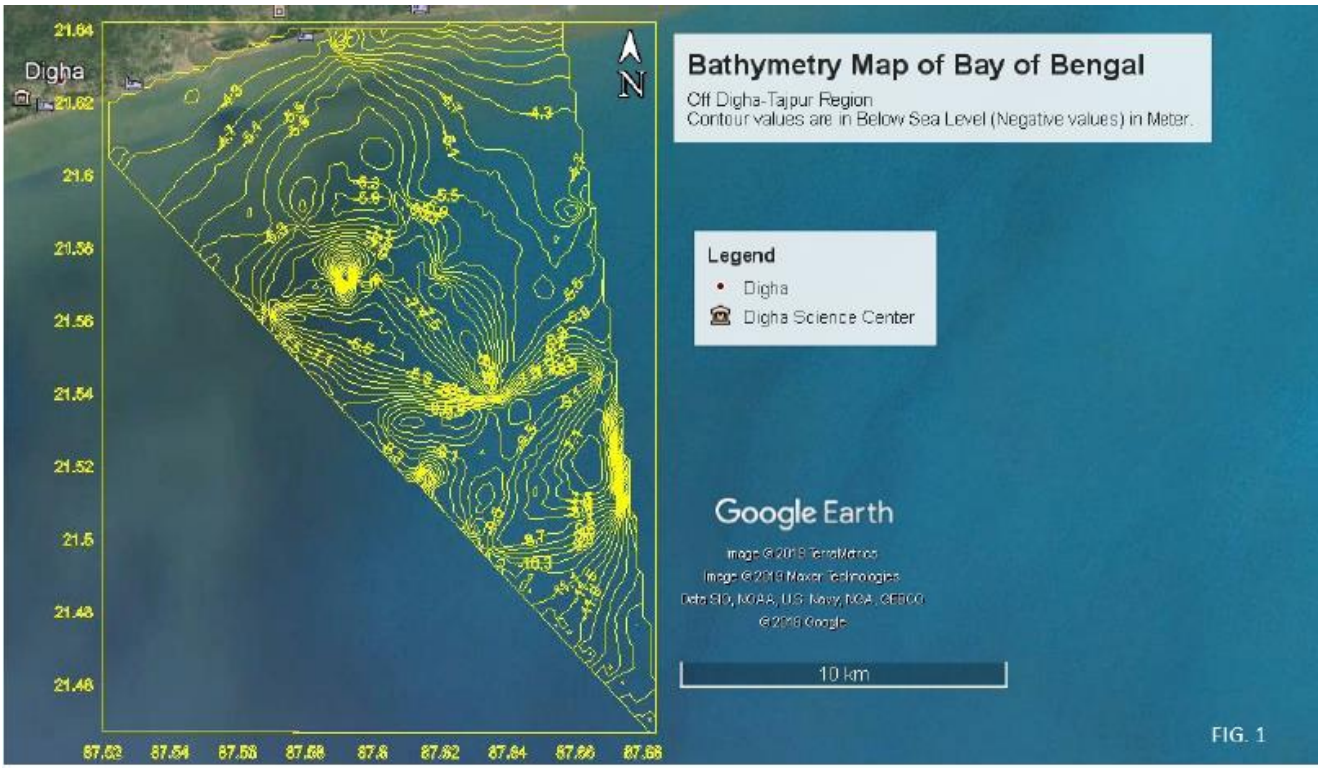
Bathymetric has been conducted by using dual frequency echo-sounder (GPS MAP 85; make – Garmin) and hand GPS. The survey has been conducted using motorboats. Bathymetric survey has been conducted in a triangle shaped area, please refer figure below. Distance of the vertex of the triangle from the coastline is about 25 km. Bathymetry data has been collected over about 250-line kilometer. Field work has been conducted during 'hh tide' and duration of survey is about 10 days (22.09.2019 to 01.10.2019).

Bathymetry data collected was downloaded and analyzed. Based on analyzed data, bathymetric survey drawing has been prepared. Drawing has been presented in fig. 2 to fig. 4. Drawing has been prepared by various drawing software. For 2D and 3D mapping GIS software has been used.

The diagram below shows the details of the bathymetry survey:

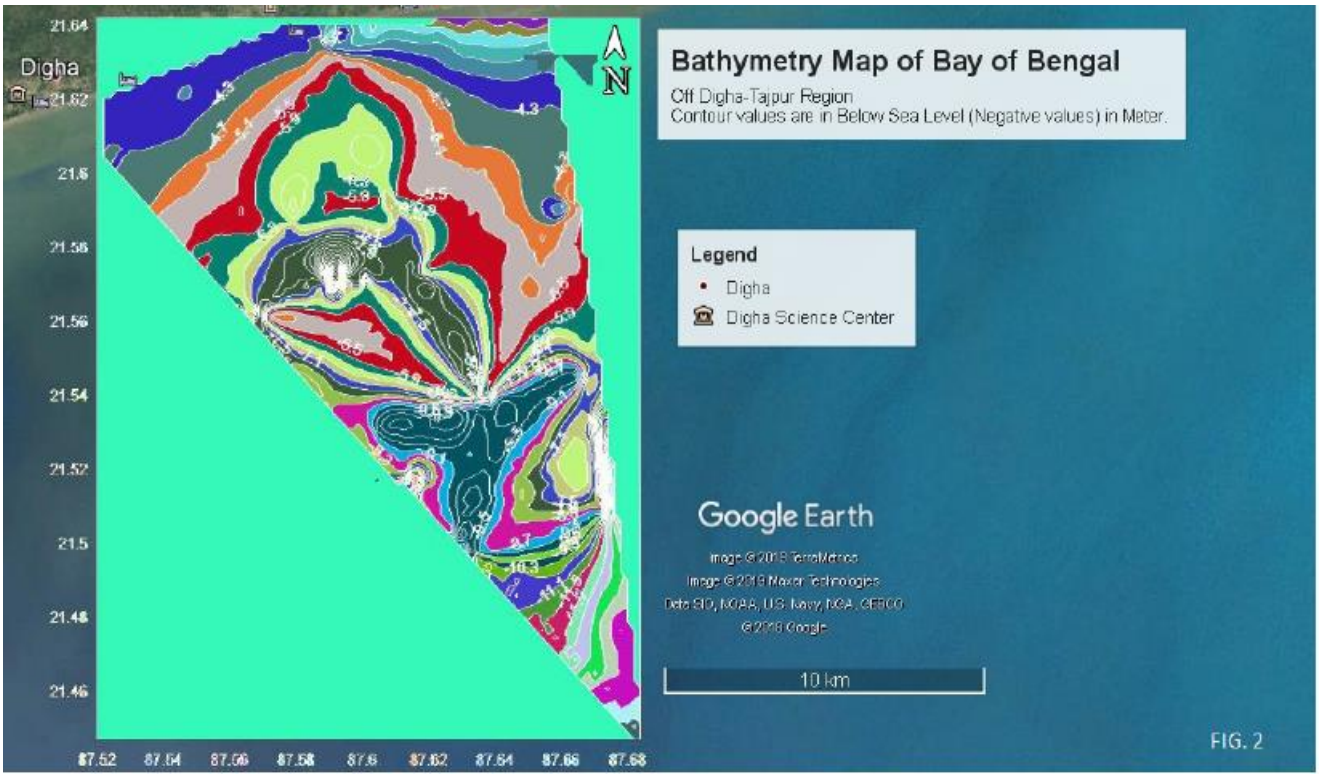
[1] Information provided by WBIDC; https://tides4fishing.com/as/india/sagar-island#_tides

Figure 3: Bathymetry Survey (1)



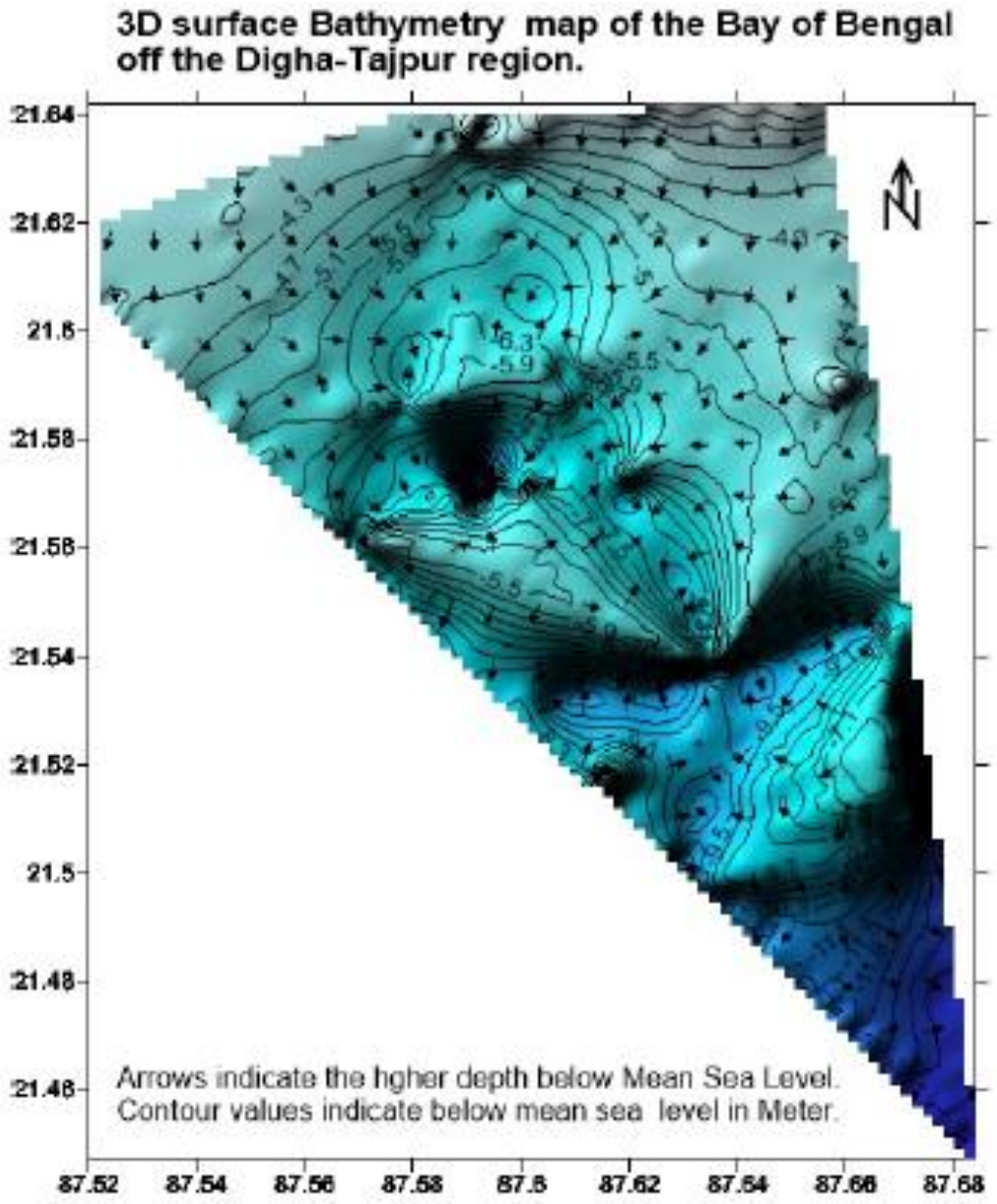
Source: Survey team

Figure 4: Bathymetry survey (2)



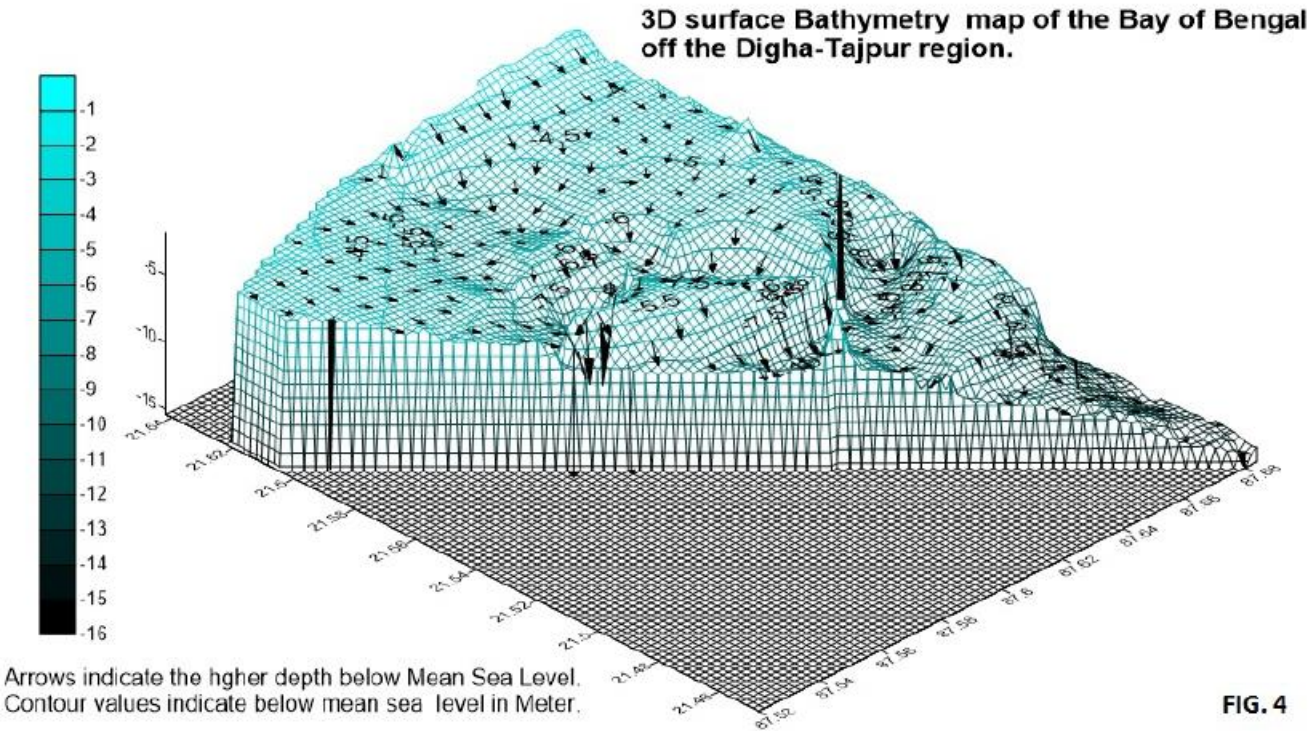
Source: Survey team

Figure 5: Bathymetry survey (3)



Source: Survey team

Figure 6: 3D Surface Map



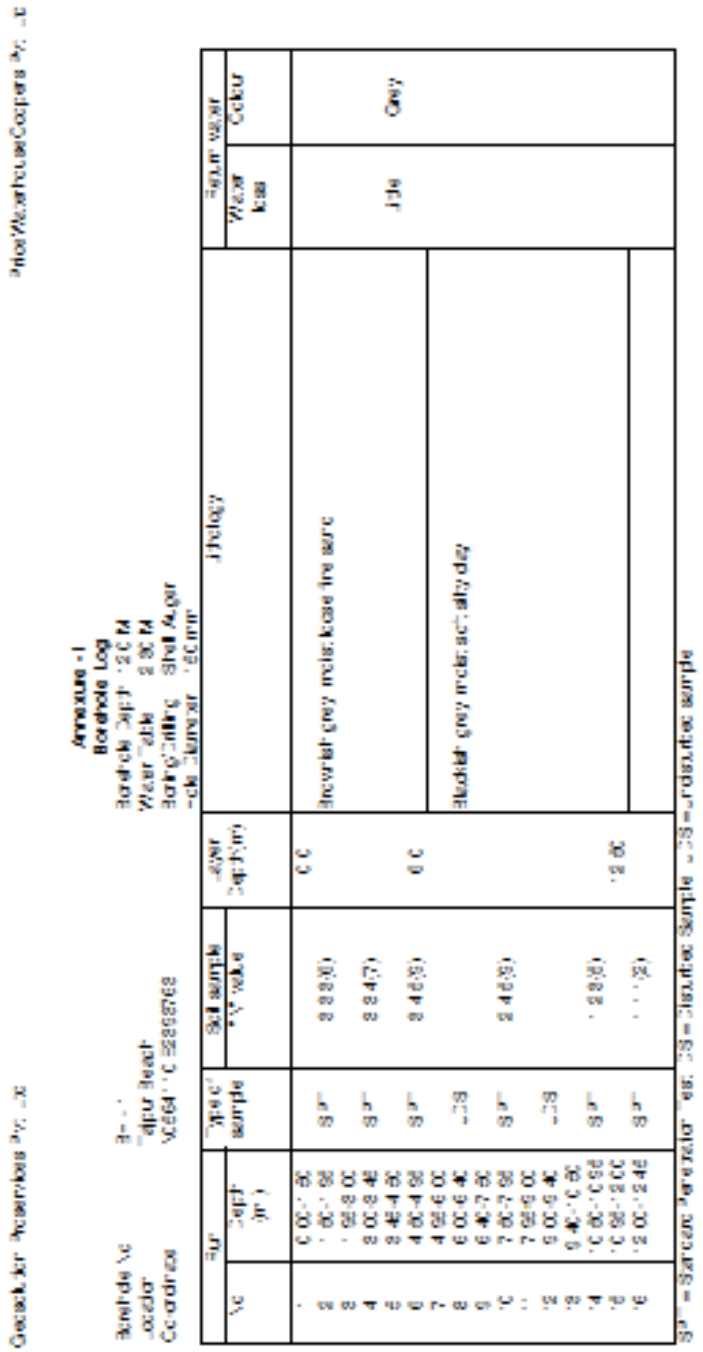
Source: Survey team

The survey carried out brings to the forefront favorable features for a deep-sea port development. Basis the above findings from the borehole, tide, bathymetry and soil investigation surveys, the conceptual master plan has been formulated as illustrated in the next few sections. Additional analysis and other surveys might be required at DPR stage for a detailed assessment and actual designing/ master planning of port.

1. Annexures – Technical Studies

1.1 Bore Log details

(1)



(2)

Geosolution Proservices Pvt. Ltd.   PriceWaterhouseCoopers Pvt. Ltd.

Annexure - I
Borehole Log

Borehole No: BH - 2
Location: Tajpur Beach
Co-ordinates: N0622144 E8889400

Borehole Depth: 12.0 M
Water Table: 1.50 M
Boring/Drilling: Shell Auger
Hole Diameter: 150 mm

Run		Type of sample	Soil sample	Layer Depth (m)	Lithology	Return water	
No	Depth (m)		'N' value			Water loss	Colour
1	0.00-1.50			0.00	Brownish grey to blackish grey moist soft silty clay	Nil	Grey
2	1.50-1.95	SPT	1 1 2(3)				
3	1.95-3.00						
4	3.00-3.45	SPT	1 1 1(2)				
5	3.45-4.50						
6	4.50-4.95	SPT	1 1 1(2)				
7	4.95-6.00						
8	6.00-6.45	SPT	1 2 2(4)				
9	6.45-7.50						
10	7.50-7.95	SPT	1 1 2(3)				
11	7.95-9.00						
12	9.00-9.45	SPT	1 2 2(4)				
13	9.45-10.50						
14	10.50-10.95	SPT	2 2 3(5)				
15	10.95-12.00						
16	12.00-12.45	SPT	1 3 3(6)	12.50			

SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample

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(3)

Geosolution Proservices Pvt. Ltd | PriceWaterhouseCoopers Pvt. Ltd

Annexure - I
Borehole Log

Borehole No	[illegible]	Borehole Depth	12.0 M
Location	Shankarpur Beach	Water Table	2.70 M
Co-ordinates	[illegible]	Boring/Drilling	Shell Auger
		Hole Diameter	150mm

Run		Type of sample	Soil sample	Layer Depth (m)	Lithology	Return water	
No	Depth (m)		"N" value			Water loss	Colour
1	0.00-1.50			0.0	Yellowish grey moist medium dense silty sand	Little	Grey
2	1.50-1.95	SPT	4 6 12 (18)				
3	1.95-3.00						
4	3.00-3.45	SPT	6 8 12 (20)				
5	3.45-4.50						
6	4.50-4.95	UDS					
7	4.95-6.00			6.0			
8	6.00-6.45	SPT	3 3 4 (7)		Blackish grey moist soft silty clay		
9	6.45-7.50						
10	7.50-7.95	UDS					
11	7.95-9.00						
12	9.00-9.45	SPT	3 3 5 (8)				
13	9.45-10.50						
14	10.50-10.95	UDS					
15	10.95-12.00						
16	12.00-12.45	SPT	4 4 5 (9)	12.50			

SPT = Standard Penetration Test; DS = Disturbed Sample; UDS = Undisturbed Sample

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Bore Hole Logs

Borehole Log						
Borehole No.		BH - 1 (Beach)			Borehole Depth	12.0 M
Location		Tajpur Beach			Water Table	2.30 M
Co-ordinate		N0564110,E2393763			Boring/Drilling	Shell Auger
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.0		
2	1.50-1.95	SPT	3,3,3(6)		Brownish grey, moist loose fine sand	
3	1.95-3.00					
4	3.00-3.45	SPT	3,3,4(7)			
5	3.45-4.50					
6	4.50-4.95	SPT	3,4,5(9)	6.0		
7	4.95-6.00					
8	6.00-6.40	UDS	--		Blackish grey, moist soft silty clay	
9	6.40-7.50					
10	7.50-7.95	SPT	2,4,5(9)			
11	7.95-9.00					
12	9.00-9.40	UDS	--			
13	9.40-10.50					
14	10.50-10.95	SPT	1,2,3(5)			
15	10.95-12.00			12.50		
16	12.00-12.45	SPT	1,1,1(2)			
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbe Sample.					Undisturbed sample	

Borehole No.		BH - 2 (Beach) Tajpur			Borehole Depth Water	12.0 M
Location		Beach			Table	1.50 M
Co-ordinate		N0562144,E2393405			Boring/Drilling	Shell Auger
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	1,1,2(3)			
3	1.95-3.00					
4	3.00-3.45	SPT	1,1,1(2)			
5	3.45-4.50					
6	4.50-4.95	SPT	1,1,1(2)		Brownish grey to blackish grey,moist, soft silty clay	

7	4.95-6.00					
8	6.00-6.45	SPT	1,2,2(4)			
9	6.45-7.50					
10	7.50-7.95	SPT	1,1,2(3)			
11	7.95-9.00					
12	9.00-9.45	SPT	1,2,2(4)			
13	9.45-10.50					
14	10.50-10.95	SPT	2,2,3(5)			
15	10.95-12.00					
16	12.00-12.45	SPT	1,3,3(6)	12.50		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbe Sample.					Undisturbed Sample	

Borehole No.		BH - 3 (Beach)			Borehole Depth	12.0 M
Location Co-ordinate		Shankapur Beach N0560213,E2392881			Water Table	2.70 M
					Boring/Drilling	Shell Auger
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.0		
2	1.50-1.95	SPT	4,6,12(18)			
3	1.95-3.00					
4	3.00-3.45	SPT	6,8,12(20)		Yellowish grey, moist, medium dense silty sand	
5	3.45-4.50					
6	4.50-4.90	UDS	--			
7	4.90-6.00			6.0		
8	6.00-6.45	SPT	3,3,4(7)			
9	6.45-7.50					
10	7.50-7.90	UDS	--			
11	7.90-9.00				Blackish grey,moist soft silty clay	
12	9.00-9.45	SPT	3,3,5(8)			
13	9.45-10.50					
14	10.50-10.90	UDS	--			
15	10.9-12.00					
16	12.00-12.45	SPT	4,4,9(13)	12.50		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbe Sample.					Undisturbed Sample	

Borehole No.		1 (1 km from shoreline)			Borehole Depth	10.95 m
Location		1KM (From Beach)			Water Depth	3.30 m
Co-ordinate		E565217,N2392870			Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	1,1,1 (2)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.45	SPT	1,1,2 (3)			
5	3.45-4.50					
6	4.50-4.90	UDS	--			
7	4.90-6.00					
8	6.00-6.45	SPT	1.2.3 (5)			
9	6.45-7.50					
10	7.50-7.90	SPT	2.2.2 (6)			
11	7.90-9.00					
12	9.00-9.45	SPT	2,3,5 (8)			
13	9.45-10.50					
14	10.50-10.95	SPT	3.4.6 (10)			
				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.		2 (1 km from shoreline)			Borehole Depth	10.95 m
Location		1KM (From Beach)			Water Depth	4.00 m
Co-ordinate		E563353,N2393581			Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	0,1,1 (2)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.45	SPT	1,1,2 (3)			
5	3.45-4.50					
6	4.50-4.90	UDS	----			
7	4.90-6.00					
8	6.00-6.45	SPT	2.1.2 (3)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.2.2 (4)			
11	7.90-9.00					

12	9.00-9.45	SPT	2.3.3 (6)			
13	9.45-10.50					
14	10.50-10.95	SPT	2.4.5 (9)			
				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.		3 (1 km from shoreline)			Borehole Depth	10.95 m
Location		1KM (From Beach)			Water Depth	4.70 m
Co-ordinate		E561433,N2392197			Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	1.1.1 (2)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.45	SPT	1.1.2 (3)			
5	3.45-4.50					
6	4.50-4.95	SPT	2.2.2 (4)			
7	4.95-6.00					
8	6.00-6.45	SPT	2.2.3 (5)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.2.4 (6)			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.4 (7)			
13	9.45-10.50					
14	10.50-10.95	SPT	2.4.5 (9)			
				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.		4 (1 km from shoreline)			Borehole Depth	10.95 m
Location		1KM (From Beach)			Water Depth	4.70 m
Co-ordinate		E559443,N2391736			Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	0.1.1 (2)		Blackish grey,wet, soft, clayey silt	

3	1.95-3.00					
4	3.00-3.45	SPT	1.1.2 (3)			
5	3.45-4.50					
6	4.50-4.90	UDS	----			
7	4.90-6.00					
8	6.00-6.45	SPT	1.2.3. (5)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.2.4 (6).			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.4 (7)			
13	9.45-10.50					
14	10.50-10.95	SPT	2.3.6 (9)			
				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.	1 (2 km from shoreline)				Borehole Depth	10.95 m
Location	2KM (From Beatch)				Water Depth	4.20 m
					Boring/Drilling	Rotary Mud Boring
Co-ordinate	E564524,N2391828					
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	0.0.1 (1)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.45	SPT	1.1.1 (2)			
5	3.45-4.50					
6	4.50-4.95	SPT	1.2.2 (4)			
7	4.95-6.00					
8	6.00-6.45	SPT	1.3.3 (6)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.3.4 (7)			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.5 (8)			
13	9.45-10.50					
14	10.50-10.95	SPT	2.4.6 (10)	11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.	2 (2 km from shoreline)				Borehole Depth	10.00 m
Location	2KM (From Beach)				Water Depth	5.40 M
Co-ordinate	E562608,N2391450				Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	0.1.2 (3)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.40	UDS	----			
5	3.40-4.50					
6	4.50-4.95	SPT	1.2.2 (4)			
7	4.95-6.00					
8	6.00-6.45	SPT	1.2.3 (5)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.3.4 (7)			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.5 (8)	10.0		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.	3 (2 km from shoreline)				Borehole Depth	10.95 m
Location	2KM (From Beach)				Water Depth	5.9 m
Co-ordinate	E560645,N2390942				Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	0.1.1 (2)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.45	SPT	1.1.2 (3)			
5	3.45-4.50					
6	4.50-4.95	UDS	----			
7	4.95-6.00					
8	6.00-6.45	SPT	1.2.3 (5)			
9	6.45-7.50					
10	7.50-7.90	SPT	1.2.2 (4)			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.4 (7)			
13	9.45-10.50					
14	10.50-10.95	SPT	2.4.5 (9)			

				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.		1 (3 km from shoreline)			Borehole Depth	10.95 m
Location		3KM (From Beach)			Water Depth	4.50 m
Co-ordinate		E565436,N2390892			Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	0.1.1 (2)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.45	SPT	1.1.2 (3)			
5	3.45-4.50					
6	4.50-4.90	UDS	----			
7	4.90-6.00					
8	6.00-6.45	SPT	2.2.3 (5)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.3.4 (7)			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.5 (8)			
13	9.45-10.50					
14	10.50-10.95	SPT	2.4.6 (10)			
				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.		2 (3 km from shoreline)			Borehole Depth	10.95 m
Location		3KM (From Beach)			Water Depth	5.40 m
Co-ordinate		E563769,N2390661			Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	1.1.1 (2)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.40	UDS	----			
5	3.40-4.50					
6	4.50-4.95	SPT	1.1.2 (3)			

7	4.95-6.00					
8	6.00-6.45	SPT	2.2.3 (5)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.3.3 (6)			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.4 (7)			
13	9.45-10.50					
14	10.50-10.95	SPT				
				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.		3 (3 km from shoreline)			Borehole Depth	10.95 m
Location		3KM (From Beach)			Water Depth	6.40 m
Co-ordinate		E561909,N2390267			Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	
No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	0.1.2 (3)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.45	SPT	1.1.1 (2)			
5	3.45-4.50					
6	4.50-4.95	UDS	----			
7	4.95-6.00					
8	6.00-6.45	SPT	2.2.3 (5)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.3.3 (6)			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.5 (8)			
13	9.45-10.50					
14	10.50-10.95	SPT	3.4.5 (9)			
				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

Borehole No.		4 (3 km from shoreline)			Borehole Depth	10.95 m
Location		3KM (From Beach)			Water Depth	6.0 m
Co-ordinate		E559887,N2389765			Boring/Drilling	Rotary Mud Boring
					Hole Diameter	150 mm
Run		Type of	Soil sample	Layer	Lithology	

No.	Depth (m.)	sample	"N" value	Depth(m)		
1	0.00-1.50			0.00		
2	1.50-1.95	SPT	0.1.1 (2)		Blackish grey,wet, soft, clayey silt	
3	1.95-3.00					
4	3.00-3.45	SPT	1.2.2 (4)			
5	3.45-4.50					
6	4.50-4.95	SPT	1.2.3 (5)			
7	4.95-6.00					
8	6.00-6.45	SPT	2.3.3 (6)			
9	6.45-7.50					
10	7.50-7.95	SPT	2.3.4 (7)			
11	7.90-9.00					
12	9.00-9.45	SPT	2.3.5 (8)			
13	9.45-10.50					
14	10.50-10.95	SPT	2.4.5 (9)			
				11.00		
SPT = Standard Penetration Test, DS = Disturbed Sample, UDS = Undisturbed Sample.						

1.2 Lab Data

Laboratory Test Result

BH No.	Depth (m.)	Sample Type	Grading (%)				Liquid Limit	Plastic Limit	Water Content (%)	Unit Weight (gm/cc)	Shear Test		Consolidation Test	
			Gravel	Sand	Silt	Clay					Cohesion (Kg/sq.cm)	Angle of Friction (Degree)	Consolidation Pressure (kg/sq.cm)	Co-eff. of vol decrease (sq.cm/kg)
1	3	SPT	0	93	7	0	N	P	21.9	1.88	0.15	36	---	---
1	4.5	SPT	2	73	25	0	N	P	28.7	1.85	0.11	30	---	---
1	6	UDS	0	3	57	40	31	21	22.4	1.84	0.28	8	0.25-0.5	0.0711
1	9	UDS	0	5	55	40	36	22	30.1	1.87	0.25	11	0.25-0.5	0.0724
2	3.0	SPT	0	4	51	45	40	19	27.9	1.86	0.28	7	---	---
2	6.0	SPT	0	3	53	44	38	20	28.9	1.82	0.29	9	---	---
2	7.5	SPT	0	5	60	35	41	22	23.3	1.88	0.32	10	---	---

2	9.0	SPT	0	3	59	38	44	21	29.80	1.89	0.31	9	---	---
3	3.0	SPT	2	80	18	0	N	P	30.90	1.89	0.11	24	---	---
3	7.5	UDS	0	5	60	35	46	20	31.70	1.86	0.20	0	0.25-0.5	0.0813
3	9.0	SPT	0	10	70	20	43	24	29.80	1.88	0.26	10	---	---
3	10.5	UDS	0	12	69	19	42	22	20.60	1.70	0.29	12	0.25-0.5	0.0219
SPT = Standard Penetration Test sample, UDS = Undisturbed Sample.														

Laboratory Test Result

BH No.	Depth (m.)	Sample Type	Grading (%)				Liquid Limit	Plastic Limit	Water Content (%)	Unit Weight (gm/cc)	Shear Test	
			Gravel	Sand	Silt	Clay					Cohesion (Kg/sq.cm)	Angle of Friction (Degree)
1(1km)	4.5	UDS	0	9	67	24	47	21	42.20	1.65	0.22	9
1(1km)	6.0	SPT	0	8	72	20	49	27	41.70	1.67	0.20	8
2(1km)	4.5	UDS	0	9	59	32	45	21	43.00	1.72	0.19	9
2(1km)	7.5	SPT	0	5	60	35	46	22	44.00	1.68	0.21	8
3(1km)	3.0	SPT	0	7	54	39	45	23	41.00	1.69	0.20	9
3(1km)	6.0	SPT	0	8	52	40	48	21	43.20	1.70	0.21	9
4(1km)	4.5	UDS	0	9	65	26	44	21	40.80	1.69	0.19	8
4(1km)	1.5	SPT	0	9	57	34	45	22	41.7	1.7	0.22	10
1(2km)	3	SPT	0	12	59	29	46	21	40.9	1.68	0.22	9

1(2km)	4.5	SPT	0	10	57	33	44	23	41.8	1.66	0.21	8
2(2km)	3.0	UDS	0	9	59	32	46	20	43.5	1.68	0.19	9
2(2km)	6.0	SPT	0	8	62	30	43	23	42.8	1.69	0.20	8
3(2km)	4.5	UDS	0	7	55	38	45	25	41.70	1.67	0.21	10
3(2km)	7.5	SPT	0	8	56	36	43	24	43.50	1.72	0.23	9
SPT = Standard Penetration Test sample, UDS = Undisturbed Sample.												

BH No.	Depth (m.)	Sample Type	Grading (%)				Liquid Limit	Plastic Limit	Water Content (%)	Unit Weight (gm/cc)	Shear Test	
			Gravel	Sand	Silt	Clay					Cohesion (Kg/sq.cm)	Angle of Friction (Degree)
1(3km)	4.5	UDS	0	9	60	31	49	27	45.80	1.67	0.22	8
1(3km)	7.5	SPT	0	8	61	31	52	29	49.30	1.65	0.20	8
2(3km)	3.0	UDS	0	8	56	36	54	28	42.70	1.69	0.19	10
2(3km)	6.0	SPT	0	9	59	32	55	26	44.80	1.70	0.21	9
SPT = Standard Penetration Test sample, UDS = Undisturbed Sample.												

1.3 Site photographs for bore hole locations

BH 1 (Beach)

BH 2 (Beach)

BH 3 (Beach)

BH 1 (1 km from shoreline)

BH 2 (1 km from shoreline)

BH 3 (1 km from shoreline)

BH 4 (1 km from shoreline)

BH 1 (2 km from shoreline)

BH 2 (2 km from shoreline)

BH 3 (2 km from shoreline)

BH 1 (3 km from shoreline)

BH 2 (3 km from shoreline)

BH 3 (3 km from shoreline)

BH 4 (3 km from shoreline)

1.4 Sample Computation of Safe Bearing Capacity for Shallow Foundation

For shallow foundation placed in stratum I

Ultimate bearing capacity of a stratum can be computed as per Terzaghi - Peck

equation based on the following expression as per IS: 6403 - 1981

$q_{ult} = c\, N_c\, s_c + q\,(N_q - 1)\, s_q + \frac{1}{2}\, B\, \gamma\, N_\gamma\ \ s_\gamma\ \ w'$

Open foundation for the proposed structure of footing size 2.0 m. x 2.0 m. placed at 3.0 m. depth below EGL in clayey, silt horizon (Stratum – I)

Therefore, D_f = 3.0 meter, B = 2.0 meter

Average stratum parameter for Stratum I

Cohesion (c) = 2 t/m^2

Bulk density (γ) = 1.70 t/m^3

Angle of friction (ϕ) = 9^o

Applying local shear failure

Cohesion (c) = 1.3 t/m^2

Angle of friction (ϕ) = 6^o

N_c = 6.81, N_q = 1.72, N_γ = 0.57,

Here, s_c = 1.30, s_q = 1.20, s_γ = 0.80

Reduction factor for water table w' = 0.5

Then, q_{ult} = 13.71 t/m²

Safe bearing capacity (q_{safe}) = q_{ult}/FOS

Taking factor of safety (FOS) = 3.0

Safe bearing capacity (q_{safe}) = 13.71/3.0 = 4.57 t/m² ≈ 5 t/m²

1.5 Tidal, Wave and Current Observations

Tide observation point location: Off Tajpur Beach

Co-ordinate: E 565468.147, N 2393652.238 (UTM Zone 45 Q)

Elevation: 1.80 M above MSL

Benchmark Details

DGPS Benchmark (DGPS 1)

Co-ordinate: E 563311.020, N 2393649.863, Elevation: 7.517 M

Observation Duration: 14/10/19 to 12/11/2019

Daily Observation Timing: 8:00 hrs. to 17:00 hrs.

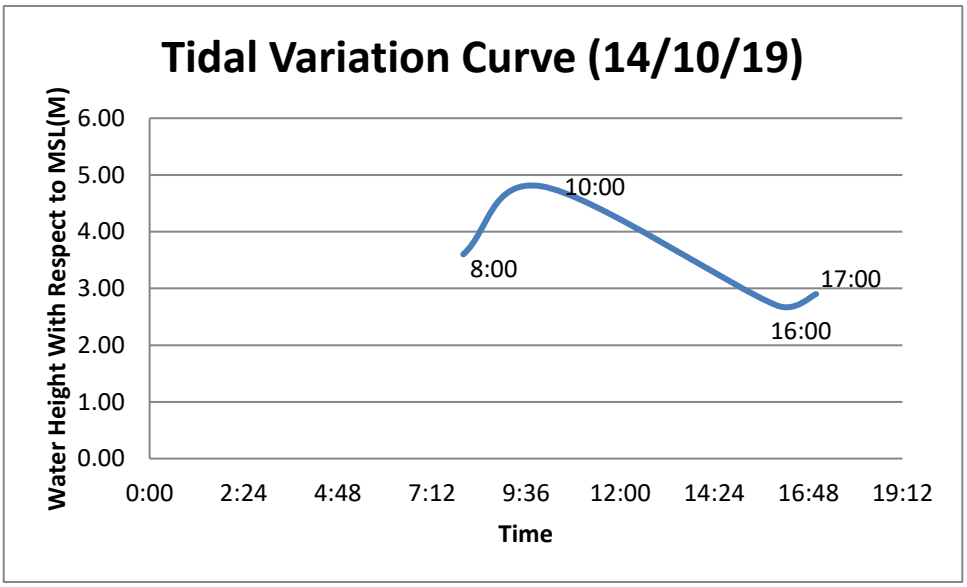
Highest observed water level (MSL): 5.15 M

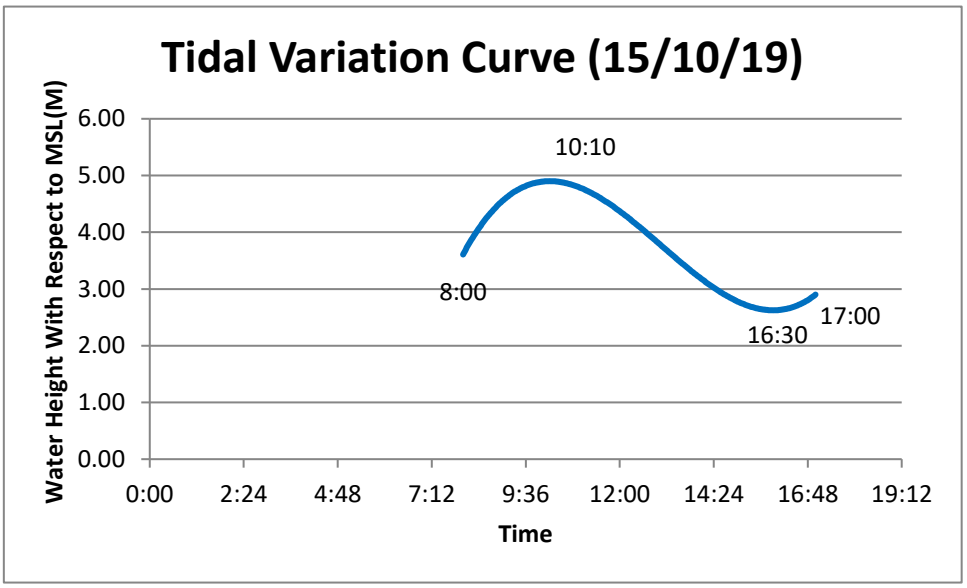
Highest observed water level date: 30/10/2019

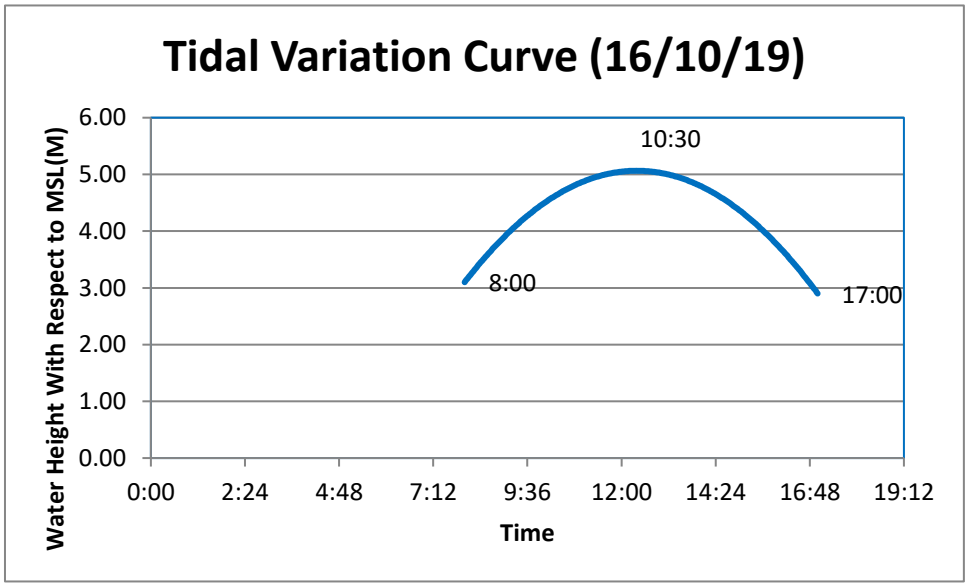
Lowest observed water level (MSL): 1.60 M

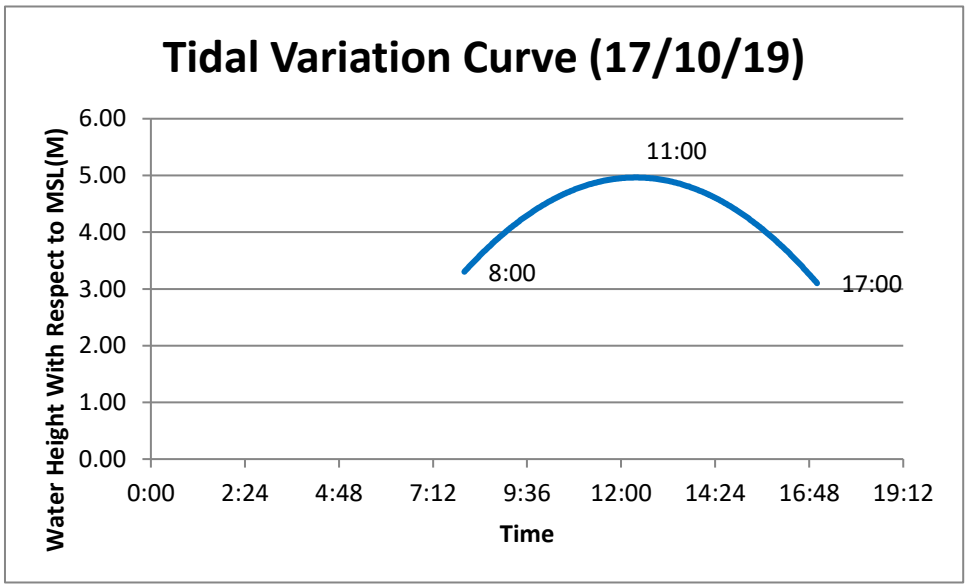
Lowest observed water level date: 29/10/2019

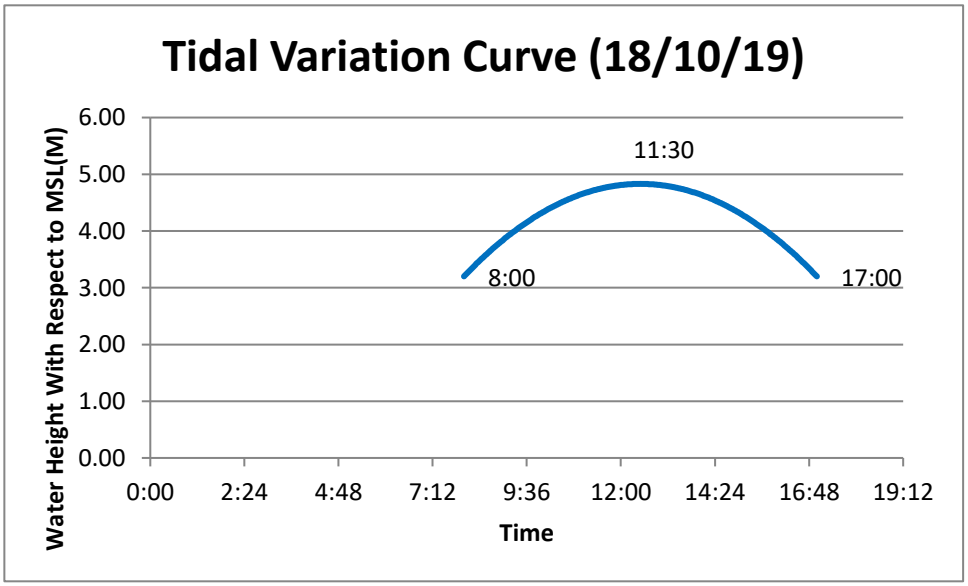
Tidal variation curves have been presented below:

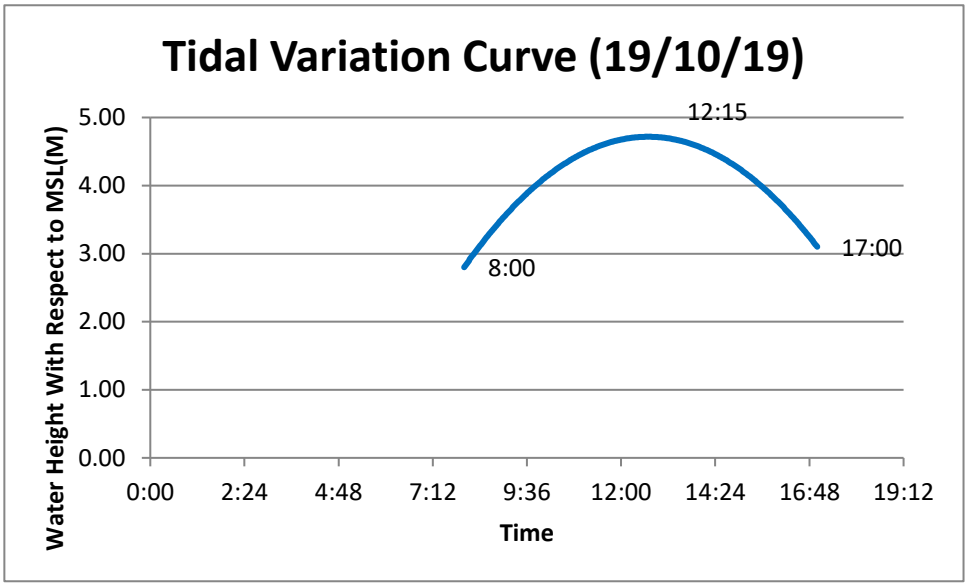

Tidal Variation Curve (14/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
10:00
8:00
17:00
16:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

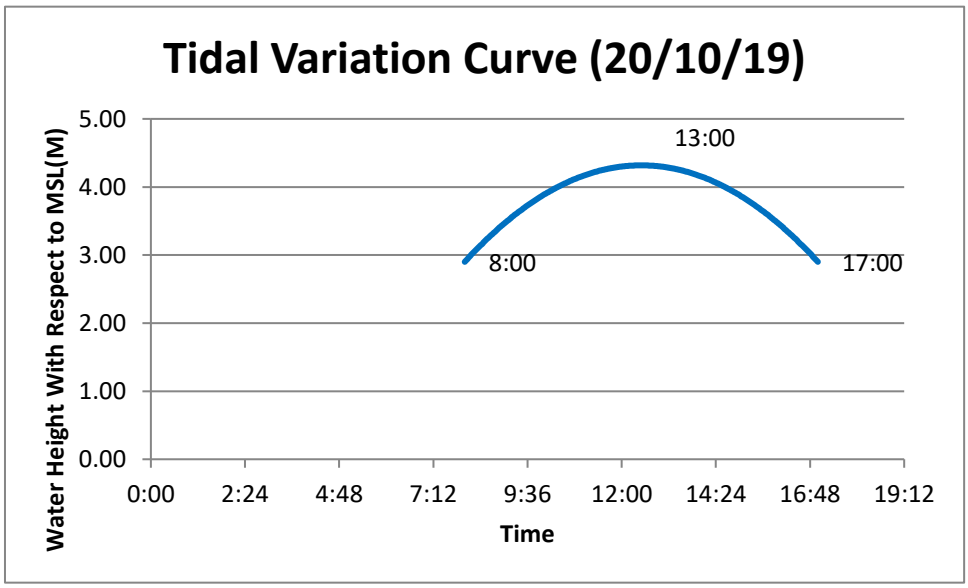

Tidal Variation Curve (15/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
10:10
8:00
17:00
16:30
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

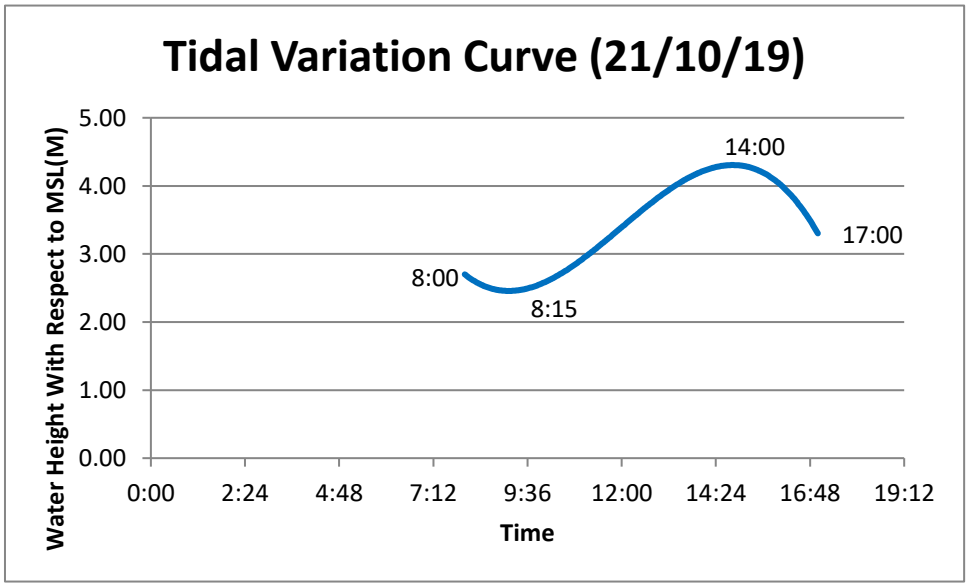

Tidal Variation Curve (16/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
10:30
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

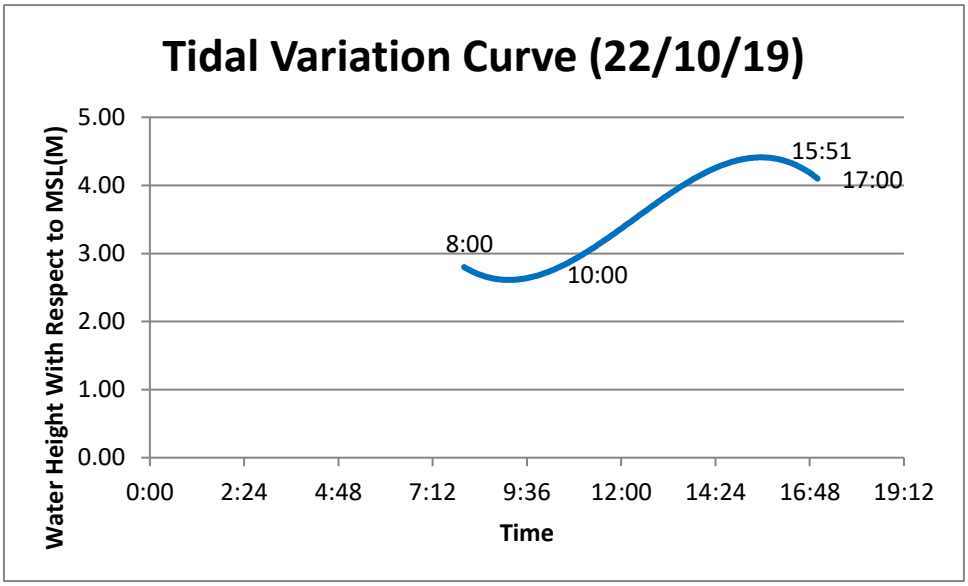

Tidal Variation Curve (17/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
11:00
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

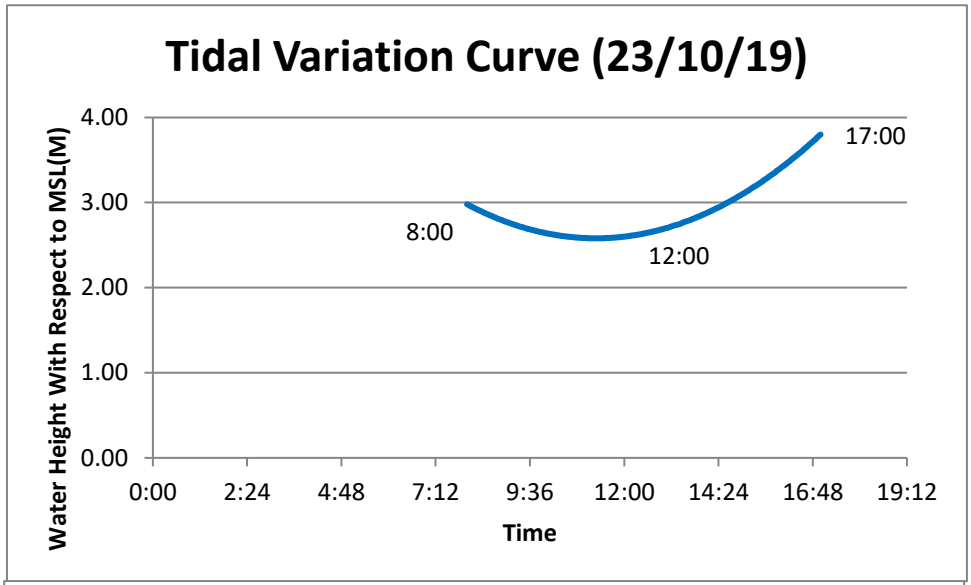

Tidal Variation Curve (18/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
11:30
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

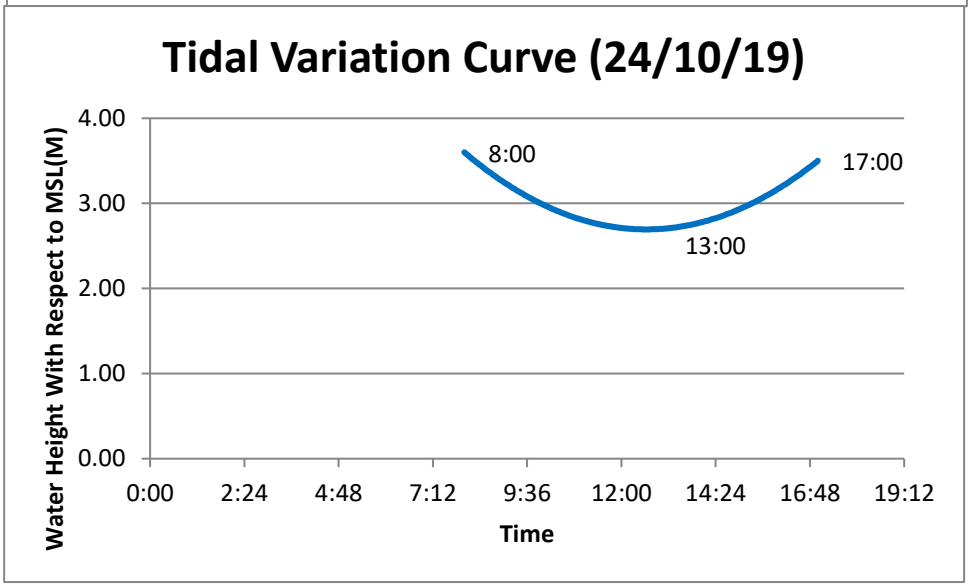

Tidal Variation Curve (19/10/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
12:15
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

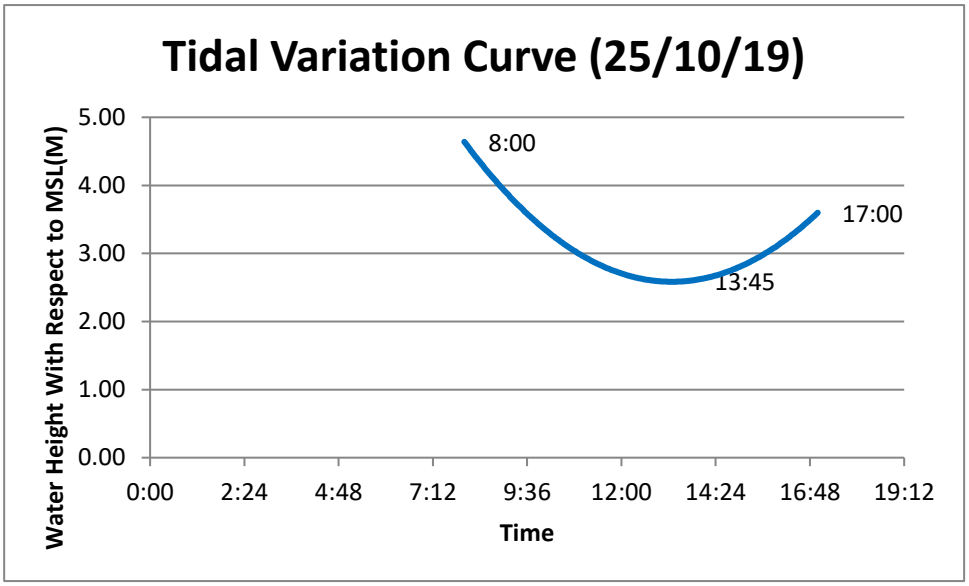

Tidal Variation Curve (20/10/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
13:00
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

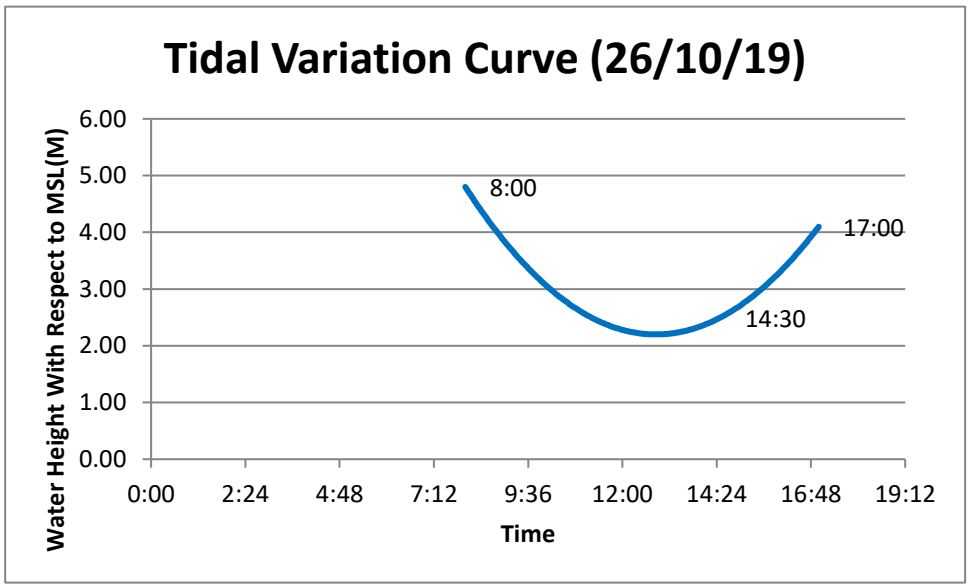

Tidal Variation Curve (21/10/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
14:00
17:00
8:00
8:15
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

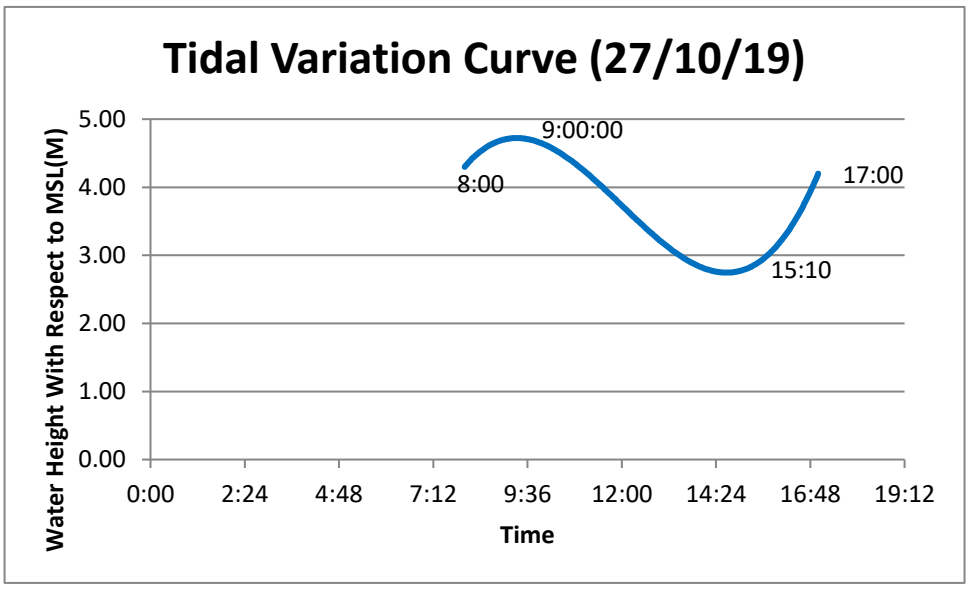

Tidal Variation Curve (22/10/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
15:51
17:00
8:00
10:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

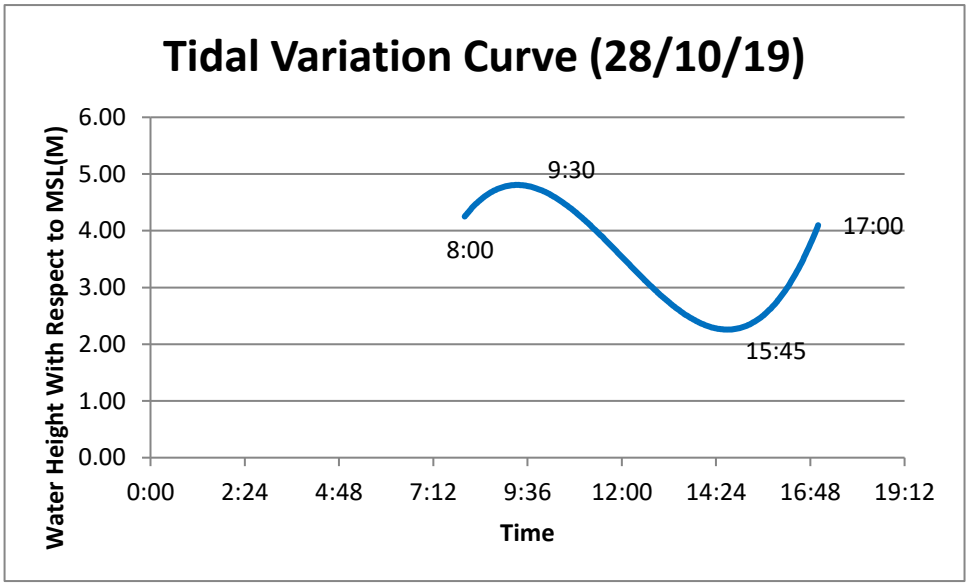

Tidal Variation Curve (23/10/19)
Water Height With Respect to MSL(M)
4.00
3.00
2.00
1.00
0.00
17:00
8:00
12:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

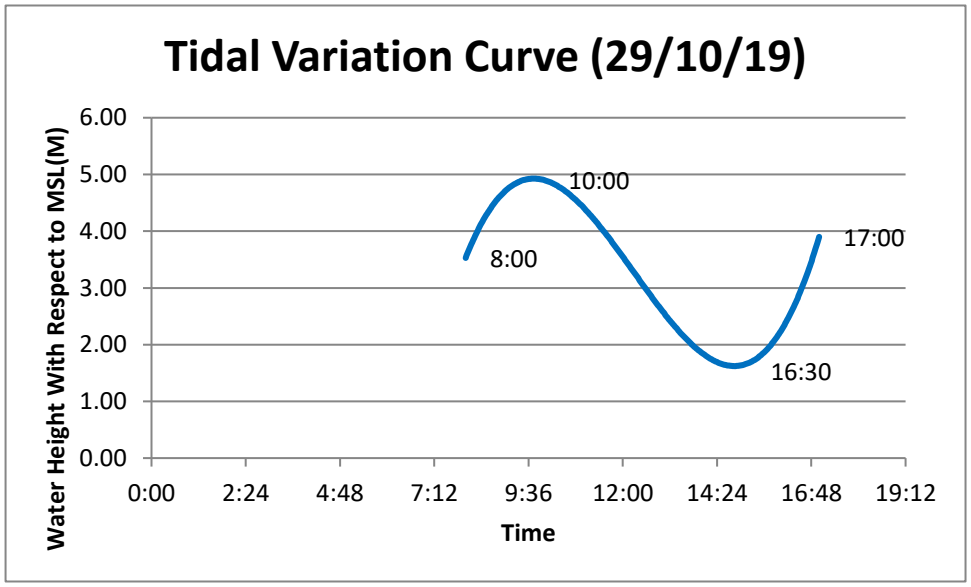

Tidal Variation Curve (24/10/19)
Water Height With Respect to MSL(M)
4.00
3.00
2.00
1.00
0.00
8:00
17:00
13:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

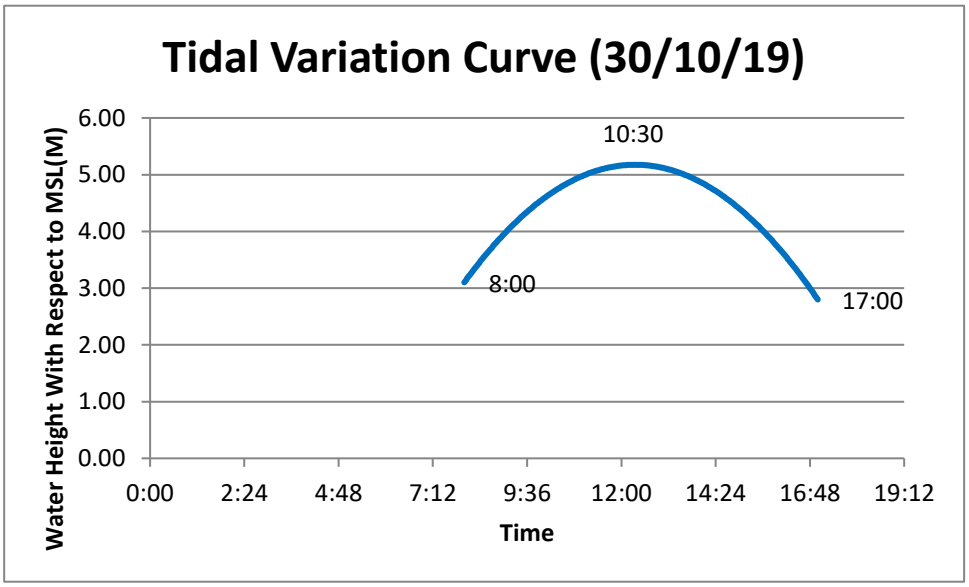

Tidal Variation Curve (25/10/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
8:00
17:00
13:45
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

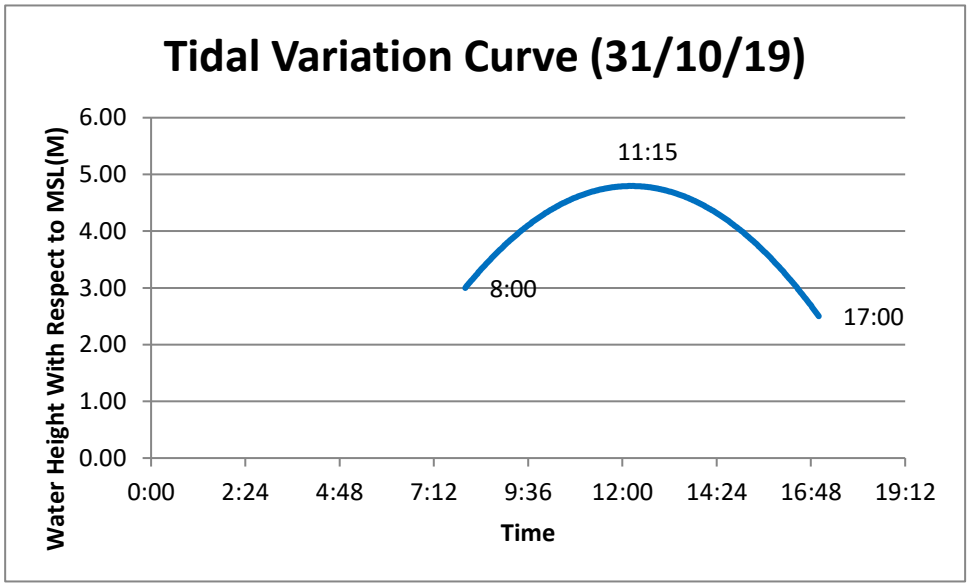

Tidal Variation Curve (26/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
8:00
17:00
14:30
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

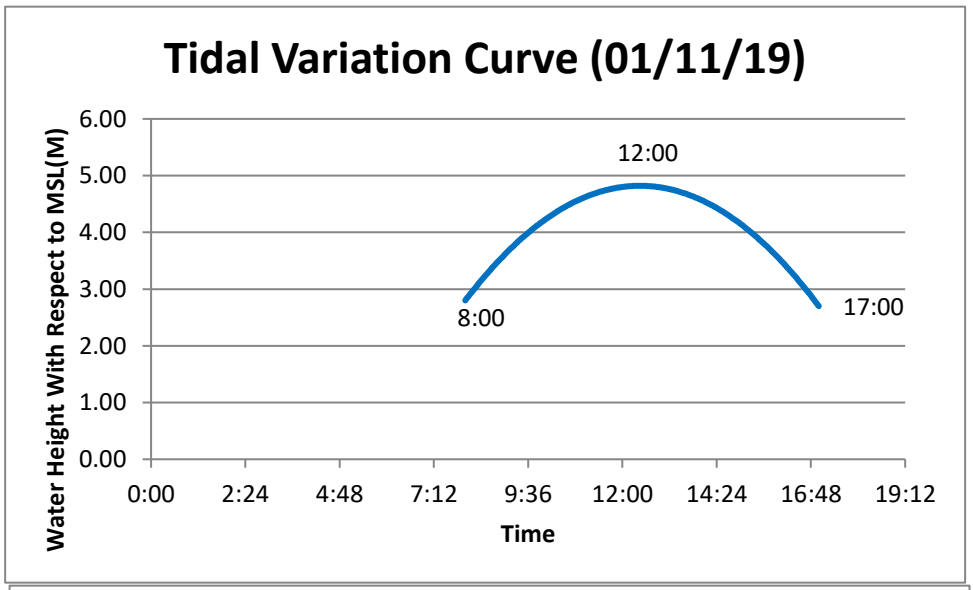

Tidal Variation Curve (27/10/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
9:00:00
8:00
17:00
15:10
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

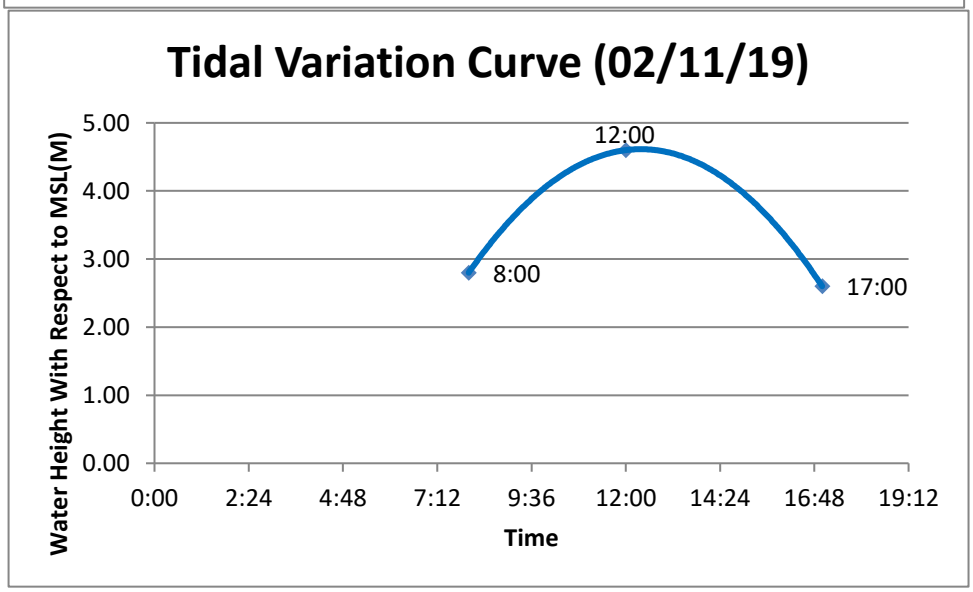

Tidal Variation Curve (28/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
9:30
8:00
17:00
15:45
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

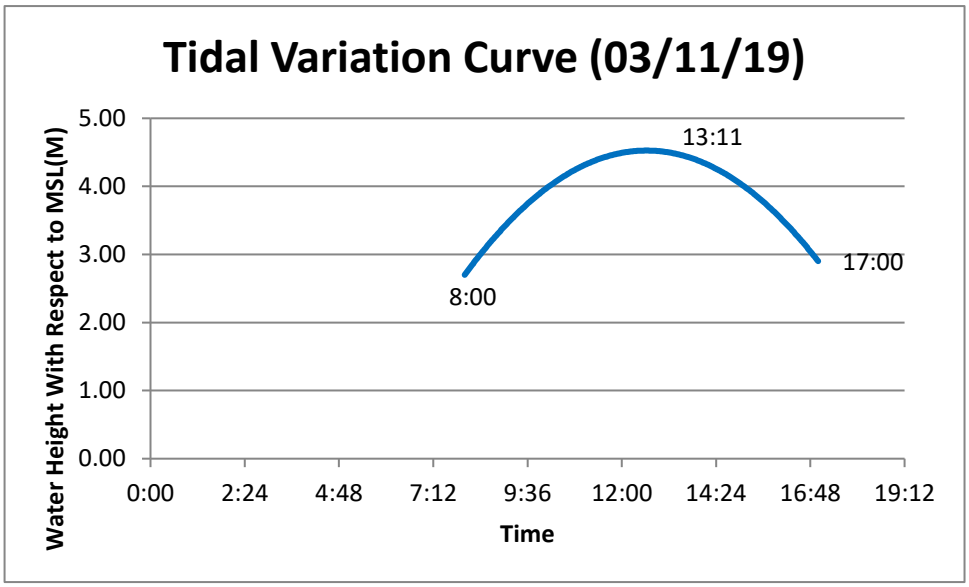

Tidal Variation Curve (29/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
10:00
8:00
17:00
16:30
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

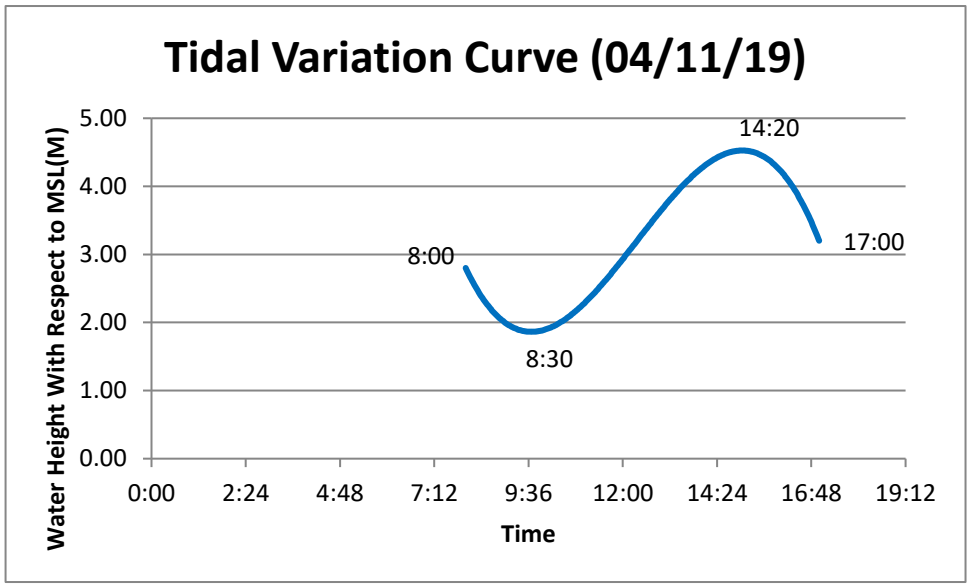

Tidal Variation Curve (30/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
10:30
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

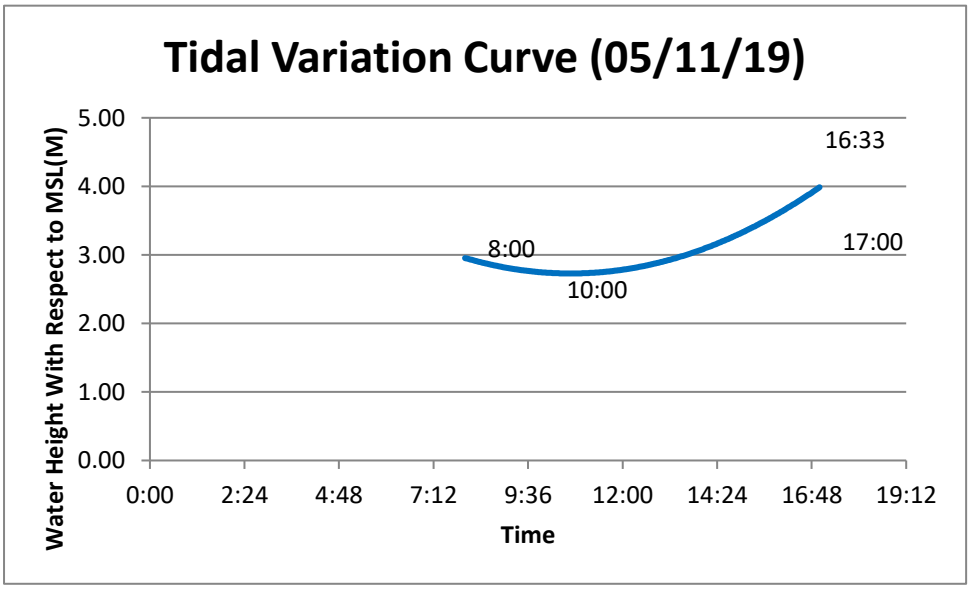

Tidal Variation Curve (31/10/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
11:15
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

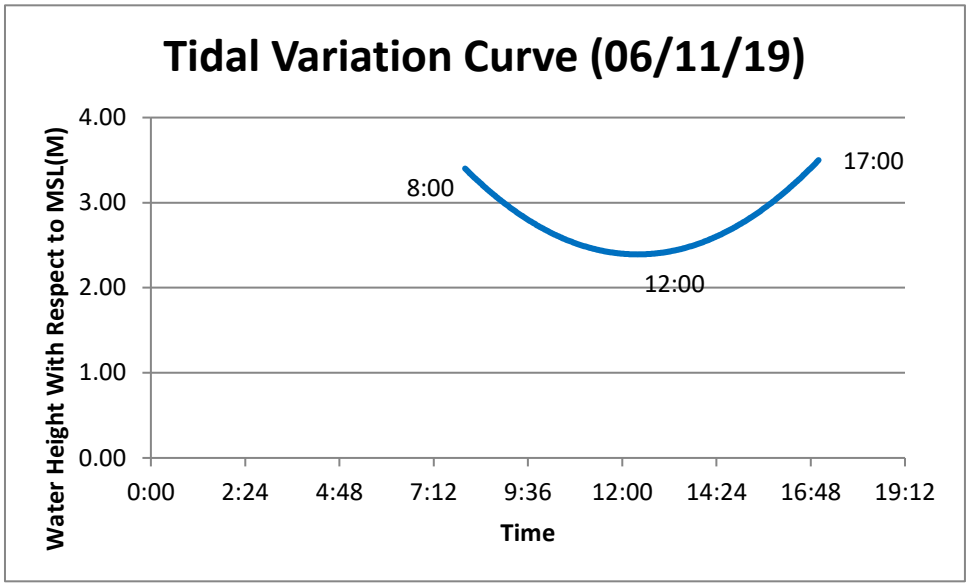

Tidal Variation Curve (01/11/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
12:00
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

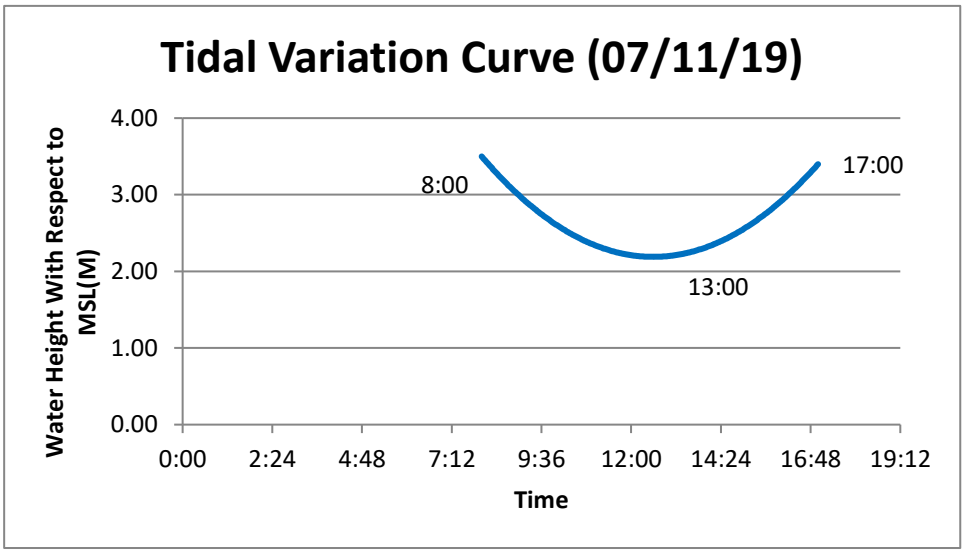

Tidal Variation Curve (02/11/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
12:00
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

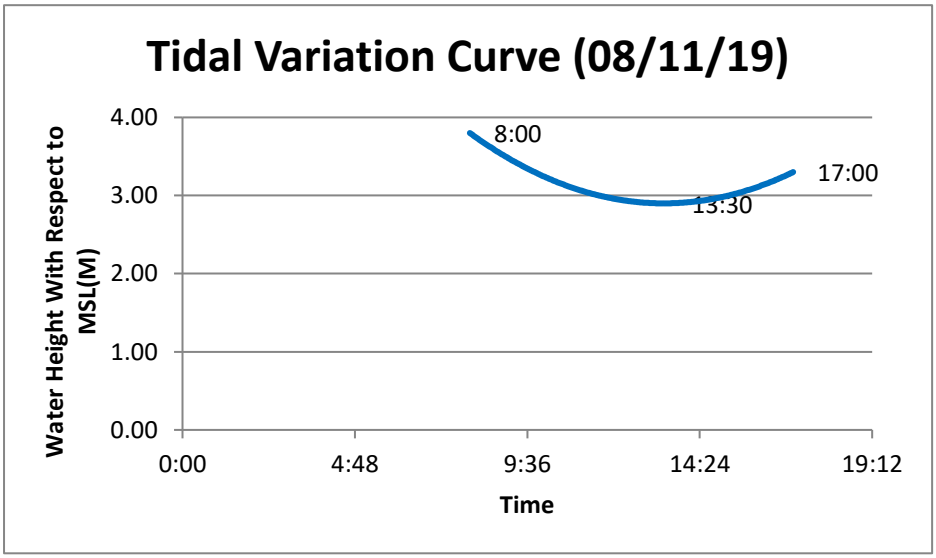

Tidal Variation Curve (03/11/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
13:11
8:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

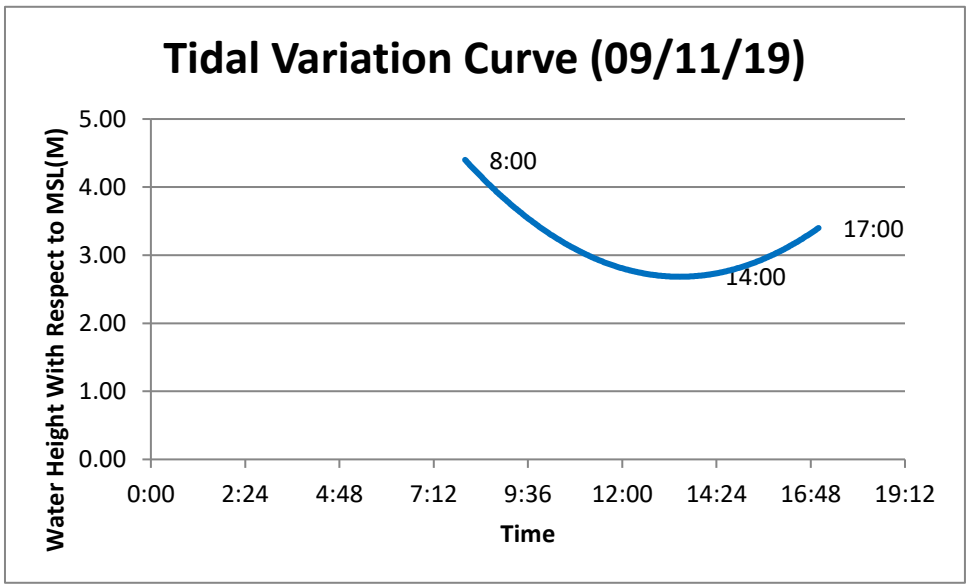

Tidal Variation Curve (04/11/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
14:20
8:00
17:00
8:30
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

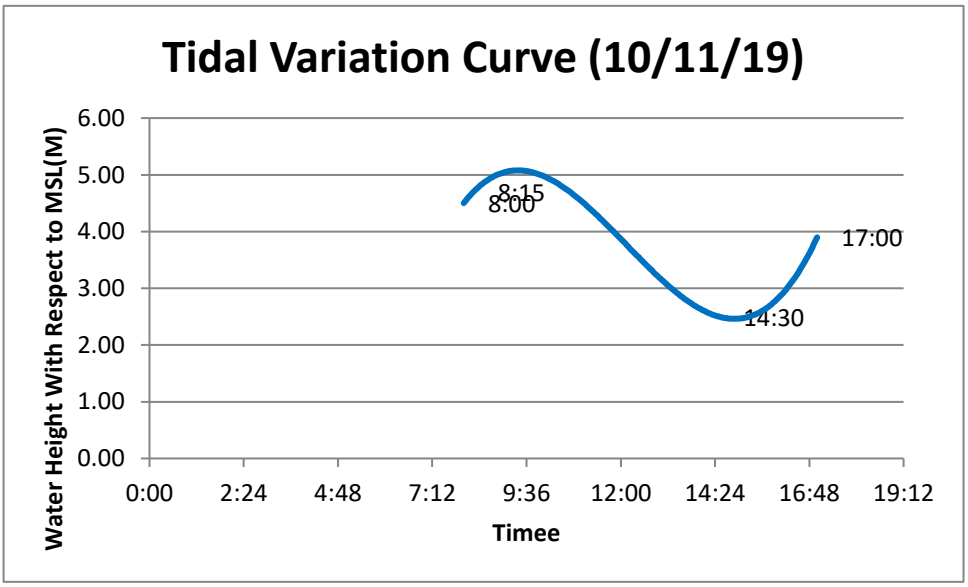

Tidal Variation Curve (05/11/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
16:33
8:00
17:00
10:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

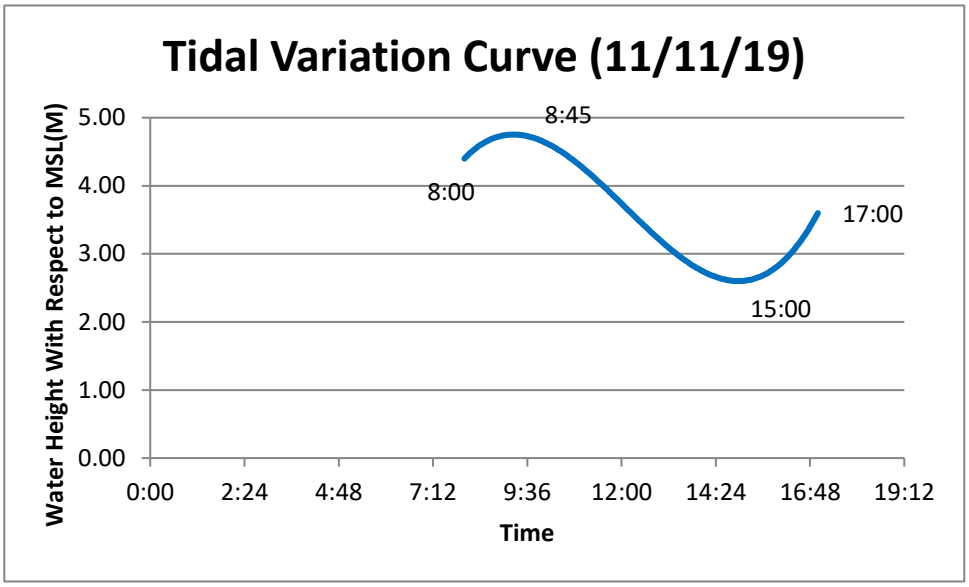

Tidal Variation Curve (06/11/19)
Water Height With Respect to MSL(M)
4.00
3.00
2.00
1.00
0.00
8:00
12:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time


Tidal Variation Curve (07/11/19)
Water Height With Respect to MSL(M)
4.00
3.00
2.00
1.00
0.00
8:00
13:00
17:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time


Tidal Variation Curve (08/11/19)
Water Height With Respect to MSL(M)
4.00
3.00
2.00
1.00
0.00
8:00
13:30
17:00
0:00
4:48
9:36
14:24
19:12
Time


Tidal Variation Curve (09/11/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
8:00
17:00
14:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time


Tidal Variation Curve (10/11/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
8:15
8:00
17:00
14:30
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Timee


Tidal Variation Curve (11/11/19)
Water Height With Respect to MSL(M)
5.00
4.00
3.00
2.00
1.00
0.00
8:45
8:00
17:00
15:00
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

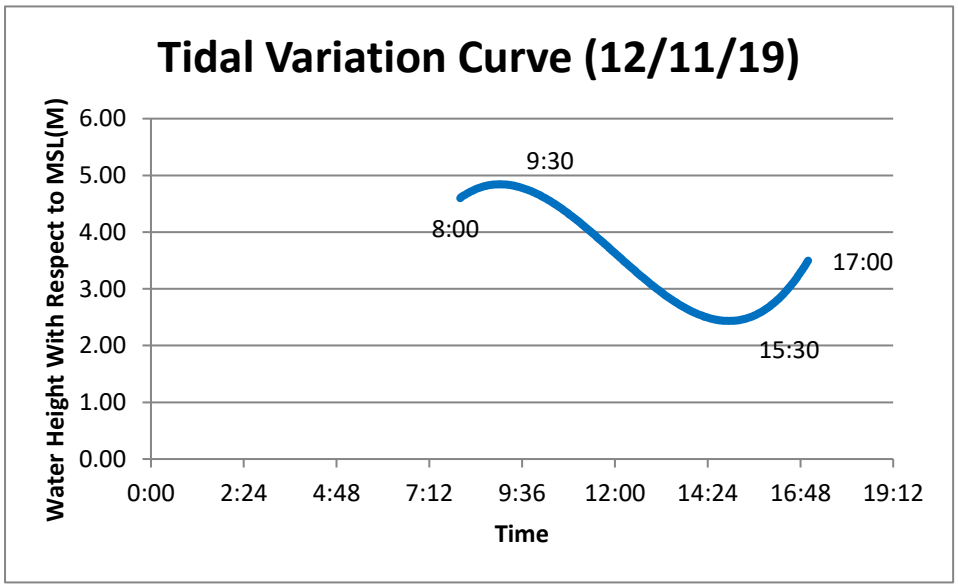
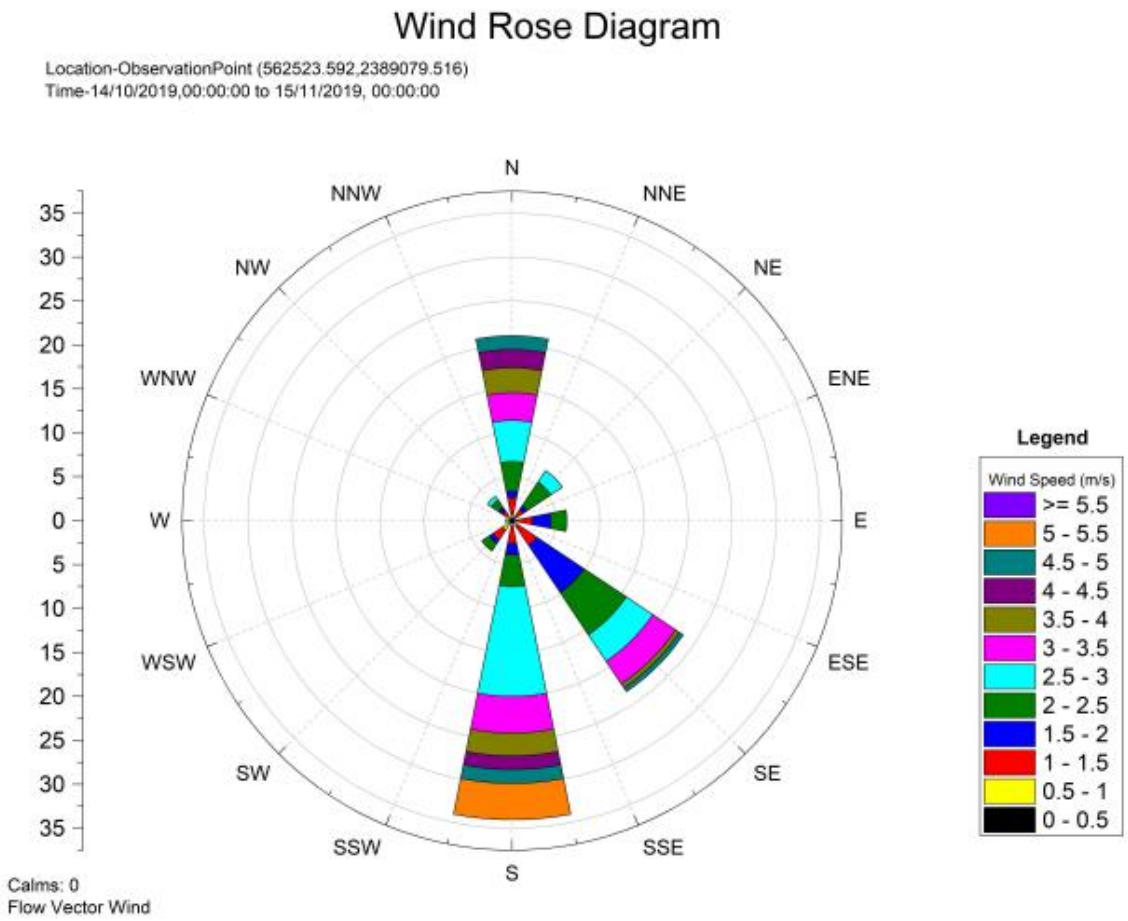
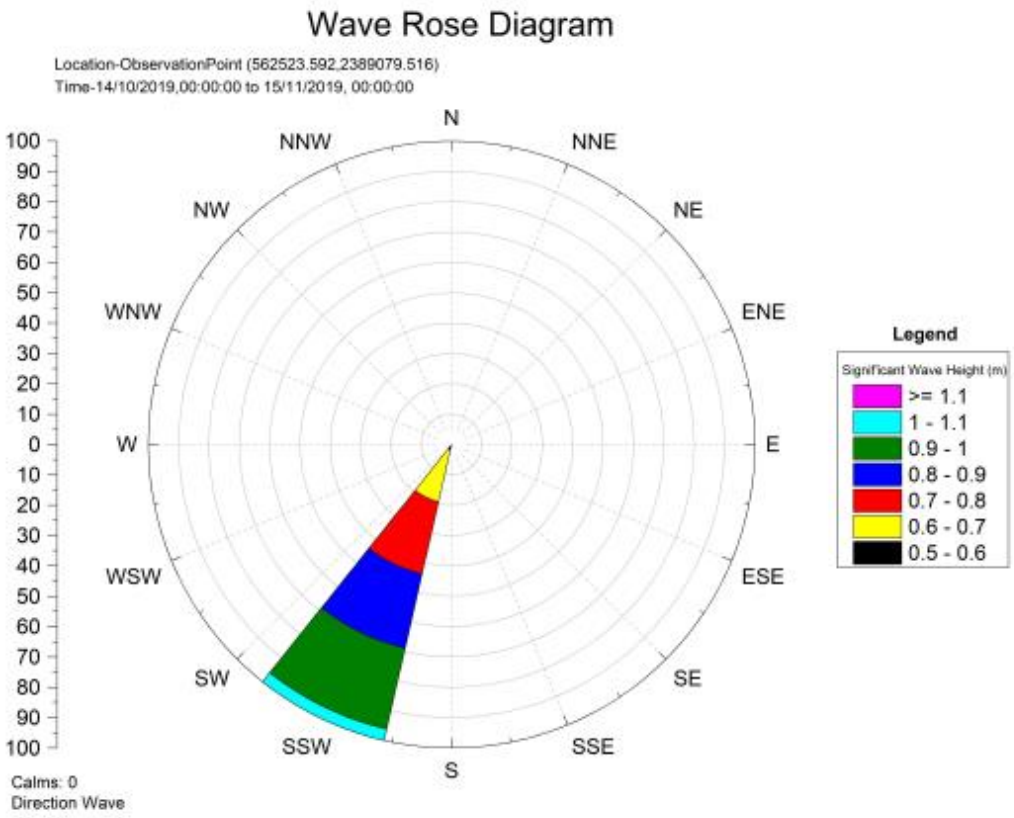

Tidal Variation Curve (12/11/19)
Water Height With Respect to MSL(M)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
9:30
8:00
17:00
15:30
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
Time

Figure 7: Wind Rose Diagram



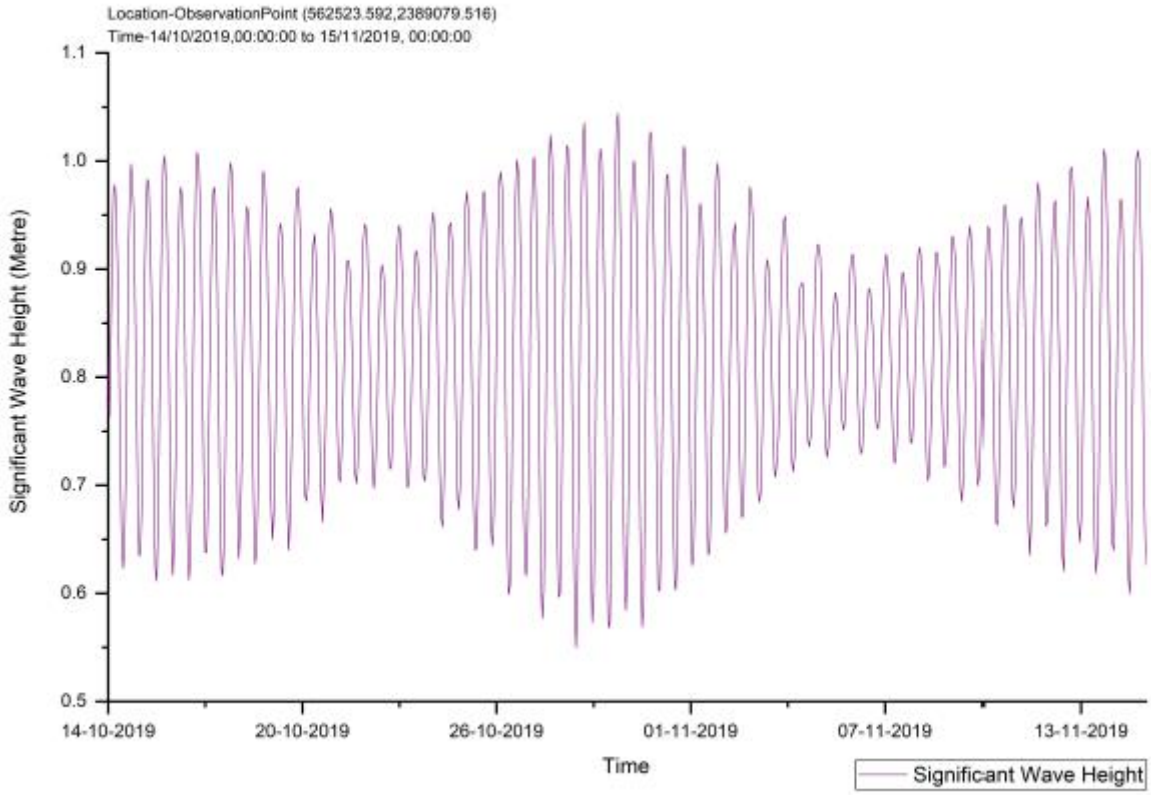
Source: Survey Team

Figure 8: Wave Rose Diagram



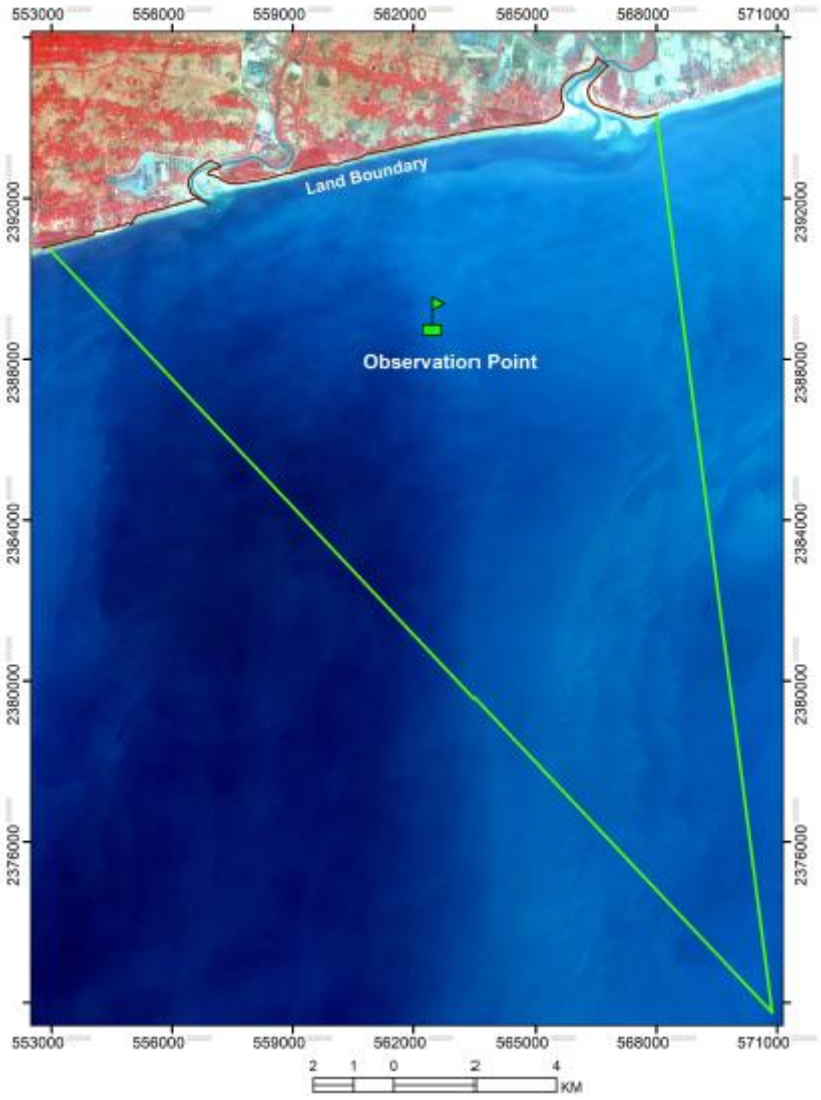
Source: Survey Team

Figure 9: Wave Height



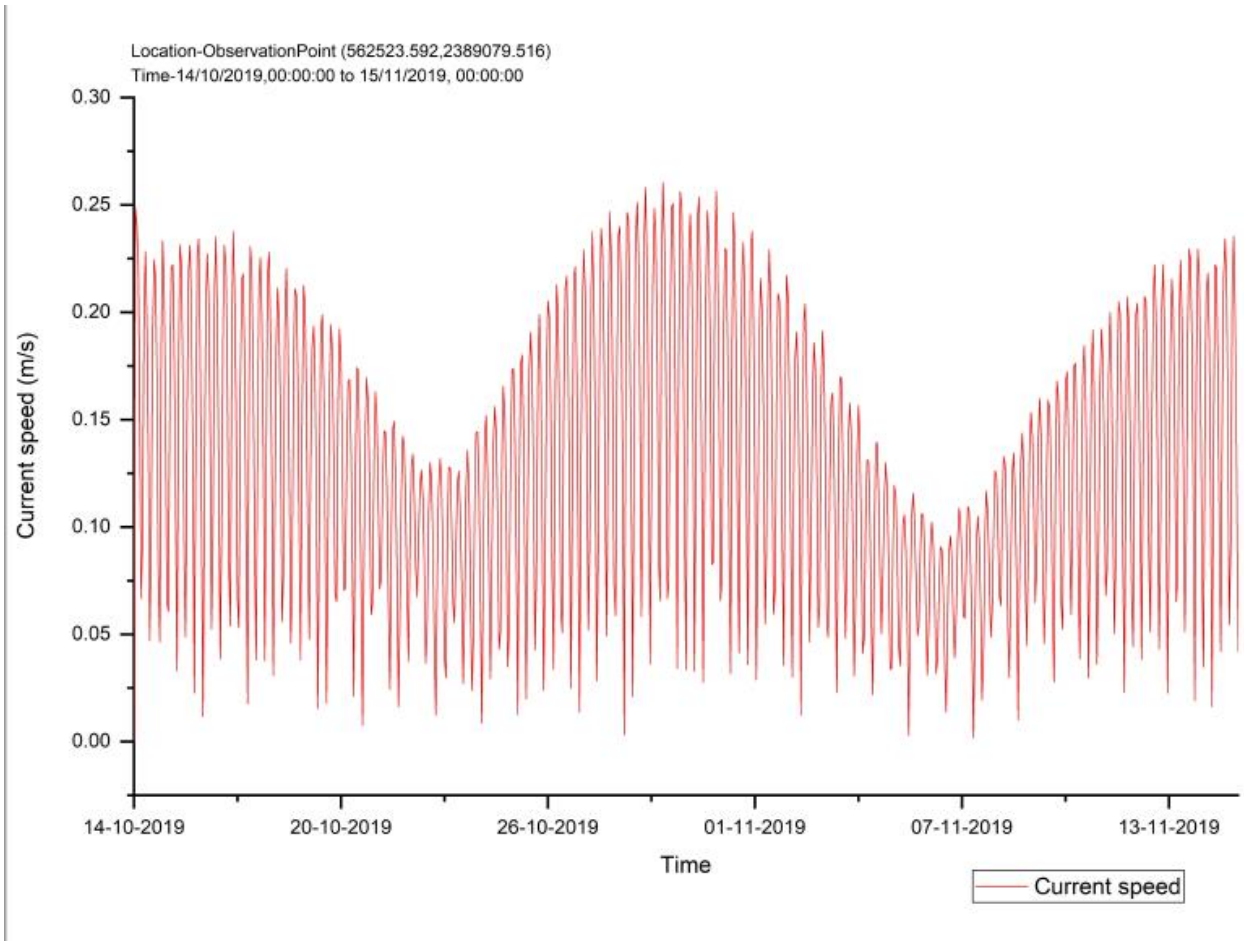
Source: Survey Team

Figure 10: Wave and Current Observation Point Location



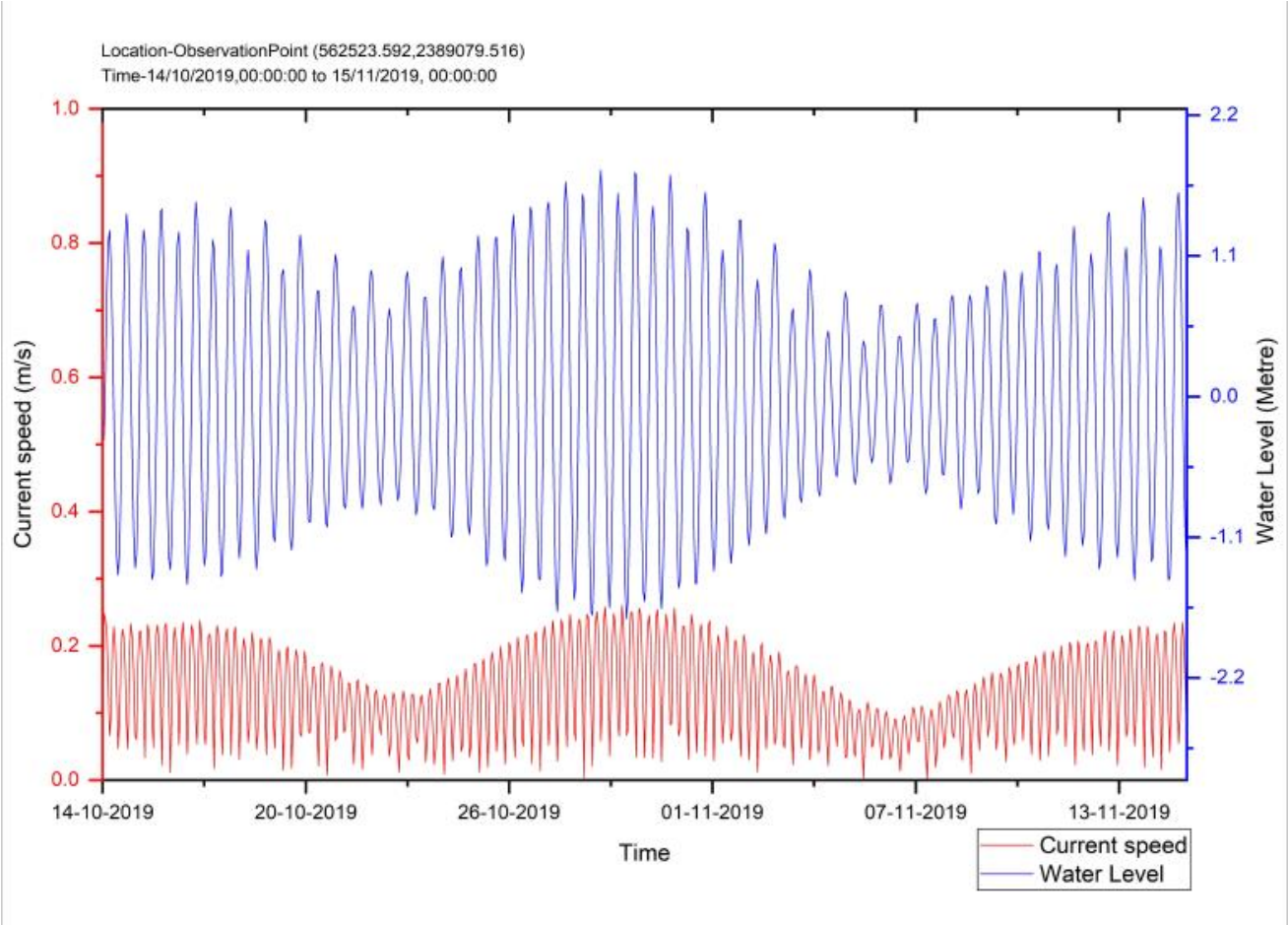
Source: Survey Team

Figure 11: Current Speed



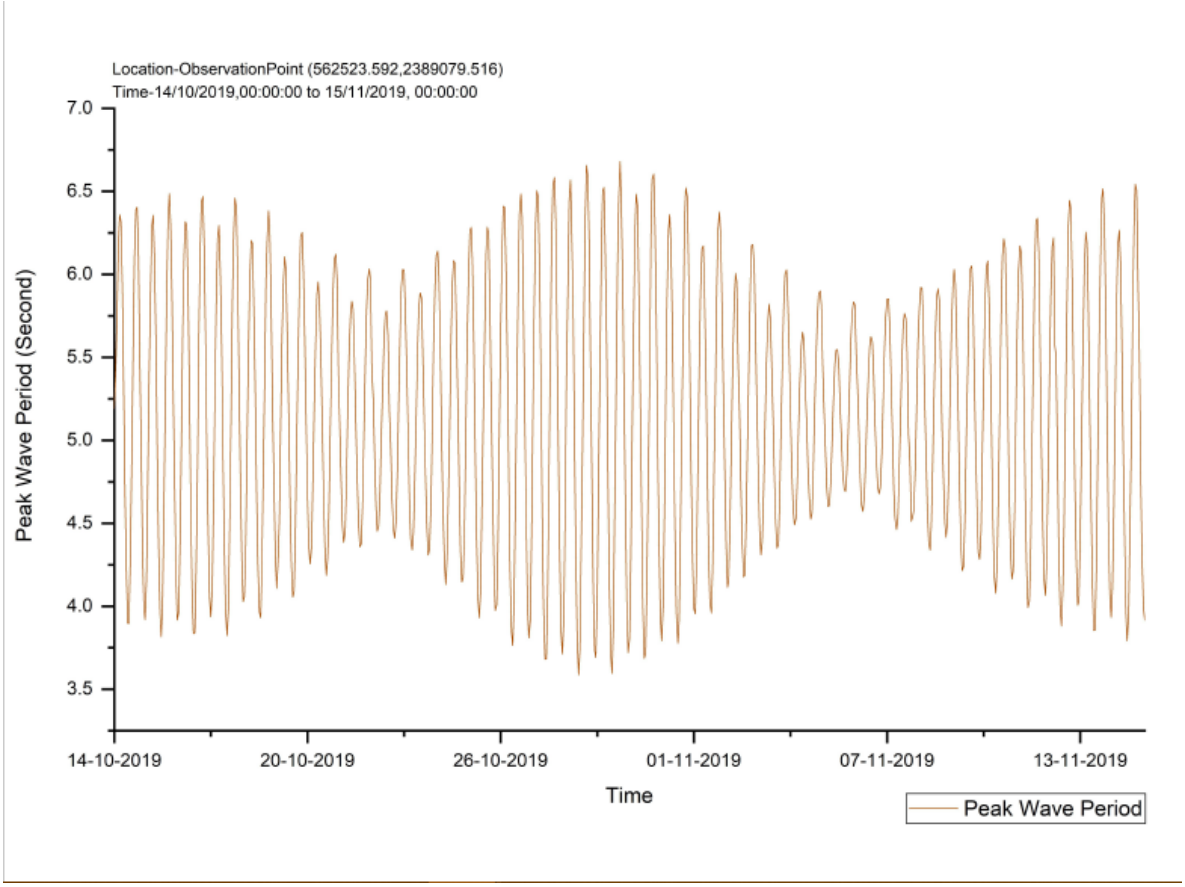
Source: Survey Team

Figure 12: Water Level and Current Speed



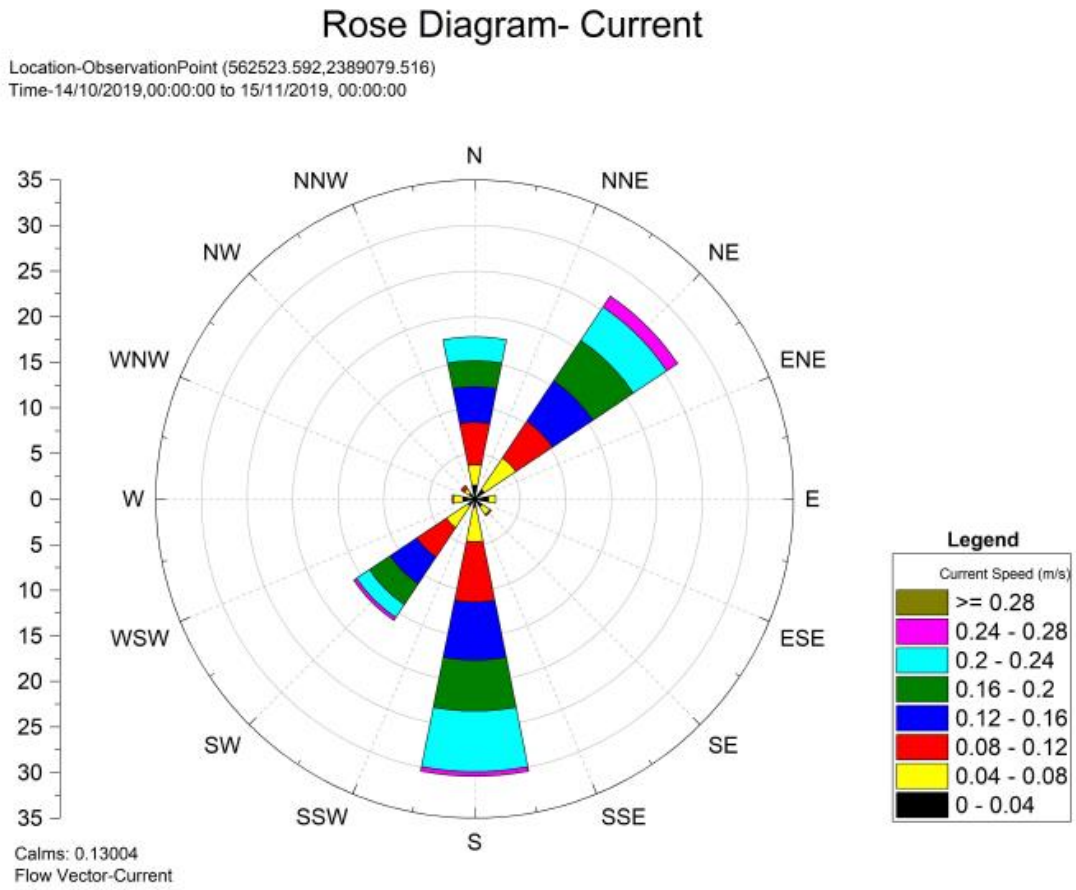
Source: Survey Team

Figure 13: Peak Wave Period



Source: Survey Team

Figure 14: Current Rose Diagram



Source: Survey Team

1.6 Baseline Monitoring Photographs

Soil Sampling

Ground Water Sampling

Air Quality Monitoring

Noise Level Monitoring

Surface Water Sampling

Marine Water Sampling