URBAN DEVELOPMENT DIRECTORATE (UDD)

Government of the People's Republic of Bangladesh

Mobilization Report

ON

Geological Study And Seismic Hazard Assessment

Under

Preparation of Development Plan for Mirsharai Upazila, Chittagong District: Risk Sensitive Landuse Plan (MUDP)

Package No. 2 (Two)

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Submitted by

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EXECUTIVE SUMMARY

Urban Development Directorate (UDD) has decided to introduce suitable development plan for Mirsharai upazila. As such, UDD has initiated the project titled 'Preparation of Development Plan for Mirsharai Upazila, Chittagong District: Risk Sensitive Landuse Plan'. Geological Study and Seismic Hazard Assessment is one of the important development module of this project. In this development plan, subsurface geological and geotechnical information's consider as an important tool for a durable and sustainable urbanization.

To know the subsurface soil condition of the study area, several Geophysical and Geotechnical surveys will be carried out up to 30 meters depth. To accomplish geological study and seismic hazard assessment following investigations should be execute: geo-morphological survey; drilling of boreholes and preparation of borehole logs; collection of undisturbed and disturbed soil sample as per standard guide line; conducting standard penetration tests (SPTs); drilling of boreholes and casing by PVC pipe for conducting Down-hole seismic test; conducting Down-hole seismic test, Multi-Channel Analysis of Surface Wave (MASW) and single Microtremor Measurment. Laboratory test of soil samples such as Grain Size analysis, Natural moisture Content, Atterberg Limits, Direct Shear Test, Unconfined Compression strength, Triaxial (Uncosolidated Undrain) etc. need to be performed, which will give more qualitative and quantitative information about the subsurface. Regarding these, tentatively 85 numbers boreholes, 20 nos of MASW, 30 nos of Microtremor Measurement and 15 nos of Down-hole seismic survey sites have been selected in the Mirsharai Upazila.

Field and laboratory investigation data will be analyzed and result will be integrated with all information's in a module which can generate geomorphologic map, sub-surface litho-logical 3D model of different layers, engineering geological mapping based on AVS30, Seismic Hazard Assessment Map (risk sensitive micro-zonation maps), soil type map, seismic intensity map, Peak Ground Acceleration (PGA) and Peak Ground Velocity (PGV) map, recommended building height maps for both high rise building and low rise building, liquefaction and Slope Stability Map etc.

From above geotechnical and geological data base would give a clear idea about the geo-hazard status of particular landscape where newly urban developing activities or any other mega infrastructure project is going on and these mentioned investigation also gives an idea about the vulnerability of existing build up infrastructure of a particular area. Based on these results, proper management techniques as well as other necessary adaptation process could be addressed before or after the development activities in the studied area. On the other hand, if the infrastructures are built according to this risk informed physical land-use plan, the long-term maintenance cost will be reduced and the developed structure will withstand against the potential natural hazards.

CONTENTS

LIST OF FIGURES

1. INTRODUCTION

1.1. Background

Bangladesh can earn money in local and also in foreign exchange by opening a tourist resort at Mirsharai. The spot, if properly developed will become an excellent holiday resort and tourist center. The rowing facility can be arranged easily; fishing and hunting facilities are already there. The success of developing Mirsharai as a tourist center and Special Economic Zone depends much on good communication facilities and availability of modern amenities. Moreover, the proposed Special Economic Zone would generate many industries related new activities including huge vehicular traffic such as air, rail, road and water. This phenomenon would have both positive and negative impacts on the socioeconomic condition and existing land use pattern of the region. The proposed planning package would guide such probable changes in the socio-economic condition and land use pattern of the region, and would also address the adverse impact of such changes.

Landuse planning is an impotent component for a modern urban development. But practicing urban development using a proper landuse plan is not developed in Bangladesh. Prior to landuse planning it is very essential to access surface and subsurface geological conditions and the relevant geological hazard and risk in and around the site of future urban development. Therefore a rigorous geological and geotechnical site characterization, including a potential risk analysis need to carry out for a risk resilient urban development.

Urban development is being increasing very fast in Bangladesh. The government has planned to develop Mirsharai as a tourist center and Special Economic Zone. However, risk sensitive urban planning is very important in such a disaster prone country like Bangladesh for a risk resilient urban development in these cities and surrounding area. In those cities Mirsharai is most disaster prone area because of this city is located near one of the most seismo-tectonically active zones of the earth. So this area covers the assessment and management of earthquake, landslide, and hydrometorological hazards in pre-dominantly urban context. Considering the earthquake threat of the populated urban and rural areas of the project, UDD will have to be taken many initiatives for earthquake preparedness of the 16 (Sixteen) unions, including Ichhakhali, Wahedpur, Osmanpur, Karerhat, Katachhara, Khaiyachhara, Zorwarganj, Durgapur, Dhum, Maghadia, Mayani, Mithanala, Mirsharai, Saherkhali, Haitkandi and Hinguli Under Mirshari Upazila Development Plan (MUDP).

Slope stability assessment is very important for any development plan. While the study area is located near and/or in the hilly area, this assessment should be performed before any development plan. In this project our study area is along with hill track, slope stability assessment need to be conducted to protect slope failure and landslide. Geological, Geotechnical and DEM data should be compiled to accomplish this assessment.

Therefore the geological and geotechnical site characterization of the areas including potential seismic hazard and risk analysis is an important component for rick sensitive landuse planning of the populated urban and rural area. In here, Environmental & Geospatial Solutions (EGS) has been entrusted to conduct this project work.

1.2. Client: About Urban Development Directorate (UDD)

Urban Development Directorate (UDD) was established through a government order in 17th July 1965. This directorate is working under the Ministry of Housing and Public Works. Since its inception, UDD is contributing in developing Master Plan/Land Use Plan for small, medium and large town and cities of Bangladesh. Thus it is contributing in development of the localities and lifestyle of peoples of Bangladesh in direct and indirect ways.

vision of UDD is to augment the quality of life of the people by improving the environment through planned development activities for adequate infrastructure, services and utility provision, to make optimum utilization of resources especially land and to ensure a geographically balance urbanization. It also aims to reduce local and regional disparity by alleviating poverty and to create good governance in the country through people participation and empowering of woman.

1.3. Location and Accessibility

Mirsharai Upazila (CHITTAGONG DISTRICT) area 482.88 sqkm(BBS)/509.80sqkm, located in between 22°39' and 22°59' north latitudes and in between 91°27' and 91°39' east longitudes. It is bounded by TRIPURA state of India, CHHAGALNAIYA and FENI SADAR upazilas on the north, SITAKUNDA upazila and BAY OF BENGAL on the south, FATIKCHHARI upazila on the east, SONAGAZI and COMPANIGANJ (NOAKHALI) upazilas on the west.Mirsharai Thana was formed in 1901 and it was turned into an upazila in 1983. Mirsharai Upazila consists of 2 Municipality, 16 Union and 103 Mouza(Location of Project Area Figure1.1).

Mirsharai, the combination of lake and hilly area contains attractive scenic beauty on the southernmost part of Bangladesh. The most important attraction of the upazila is that one can travel Mohamaya Chara Lake by speed boat and explore hilly area and can enjoy Khoiyachora, Baghbiani, Napitachora, Sonaichora, Mithachora and Boyalia waterfalls. This area is located 192.2 km far from DHAKA and 4.5hour bus journey. Anyone can travel by rail and it is 197 km of rail journey and it takes 4.5 hour from Dhaka to Mirsharai Upazila. 56 km from the CHITTAGONG Divisional headquarters and takes 1.5 hour travel by bus. The Bangladesh Road Transport Corporation introduced a direct bus service from Dhaka to *Mirsharai* via comilla.(Source: Banglapedia, 2012)

At Mirsharai Upazila main river is Feni; Sandwip Channel is notable; canal 30, most noted of which are Feni Nadi, Isakhali, Mahamaya, Domkhali, Hinguli, Moliaish, Koila Govania and Mayani Khal. The hills range on the northern and eastern side of this upazila along the bank of the Feni River extended up to Chittagong and the Chittagong hill tracts

Table 01: Name and Area of Ten Unions under Mymensingh Strategic Development Plan (MUDP) Area.

Municipality	Union	Mouza	Village	Population		Density (per sq km)	Literacy Rate (%)
				Urban and Other Urban	Rural		
2	16	103	208	31206	367510	826	55.1

Source: BBS, 2001 and GIS Lab, MSDP, UDD, September, 2011

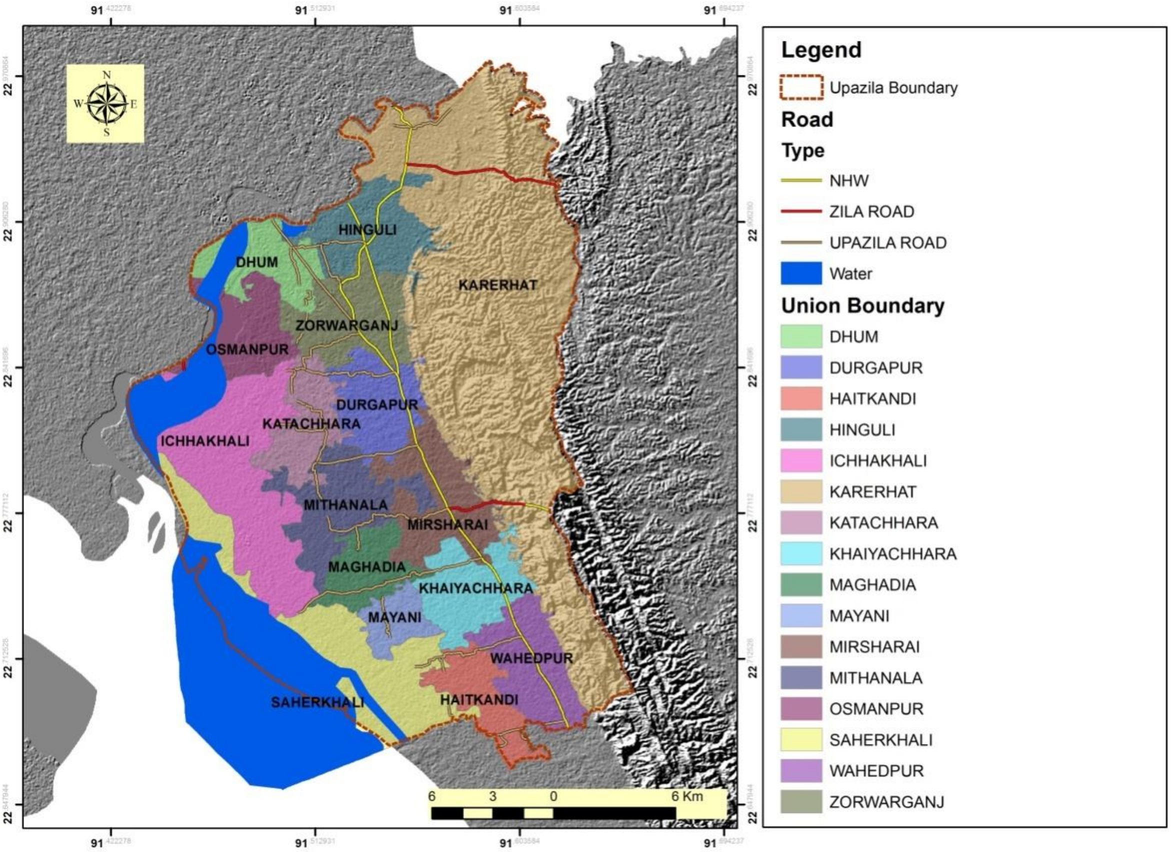


Figure 1.1 Location map of the project area

2. AIMS AND OBJECTIVES

The main objective of the research is to carry out a seismic hazard analysis of the 16 (Sixteen) unions, including Ichhakhali, Wahedpur, Osmanpur, Karerhat, Katachhara, Khaiyachhara, Zorwarganj, Durgapur, Dhum, Maghadia, Mayani, Mithanala, Mirsharai, Saherkhali, Haitkandi and Hinguli Under Mirshari Upazila Development Plan (MUDP). The main objective will be achieved through accomplishment of the following sub-objectives:

i. Geological and geomorphologic map a the study area
ii. Sub-surface lithological 3D model development
iii. Soil classification map using geophysical and geotechnical investigations
iv. Engineering geological map development based on AVS30
v. Foundation layers delineation and developing engineering properties of the sub-soil
vi. PGA, Sa (T) Maps of 5% damping at 0.3 and 1.0 second periods values of 10% exceedance probability during next 50 years for local site condition.
vii. Risk Sensitive Building Height
viii. Landslide vulnerable zones will be identified from the study.
ix. Liquefaction susceptibility map will be constructed from study data.
x. Formulation of Policies and plans for mitigation of different types of hazards, minimizing the adverse impacts of climate change and recommend possible adaptation strategies for the region.

3. METHODOLOGY

3.1. Approach

The method of study can be divided into following components:

1) Collection of relevant existing data, topo sheets, reports, maps, DEM of the study area;
2) Section of all the geotechnical and geophysical tests/survey location base on the existing data and geomorphological units of the project area;
3) Collection of both geotechnical and geophysical data in field. Following investigations given in Table 02 that will be conducted for the preparation of engineering geological maps for rural part of MUDP Project area:

Table 02: Geotechnical and geophysical investigation will be carried-out in the rural part of MUDP Project Area

Name of Union	Name of investigations			
	Borelog with SPT *(upto 30m)*	PS logging *(30m depth)*	MASW *(30m depth)*	Single Microtremor *(Vs>100m depth)*
Ichhakhali, Wahedpur, Osmanpur, Karerhat, Katachhara, Khaiyachhara, Zorwarganj, Durgapur, Dhum, Maghadia, Mayani, Mithanala, Mirsharai, Saherkhali, Haitkandi and Hinguli	85	15	20	30

4) Laboratory test of 10 numbers of boreholes will be conducted for investigating geotechnical properties of soil samples.
5) Geophysical data (PS Logging, MASW,and Microtremor survey) analysis for calculating AVS30 will be done by using some types of advanced international software's.
6) Preparation of engineering geological map is to develop the geotechnical and geophysical characteristics of the soft sub-surface sedimentary deposits. In this investigation, the GIS technique, the advanced international software andhardware will be used, which makes the system′s performance steady with good expansibility. These information are often used for foundation engineering, seismic hazard assessment. The purpose of engineering geological investigations is to generate AVS30 maps for the targeted areas. The investigated area will be differentiated

intonumber of potential grid sizes. AVS30 will be calculated for each grid of the targeted areas.

7) Seismic hazard assessment using engineering seismological information in and around the project area.

8) Organization of workshop and seminarto present the research findings to different professionals.

9) Report writing.

3.2. Strategic Methodology

The methodology consists of both field and laboratory investigations. To conduct this project work, geomorphological, geotechnical and geophysical data of soil will be collected, analysed and interpreted. Geomorphological data will be collected from satellite image of the study area to prepare a geomorphological map. Geotechnical data will be collected from field investigations *i.e.*, boring, standard penetration test (SPT), and laboratory investigations *i.e.*, soil physical properties test, consolidation test, direct shear test and triaxial test of undisturbed soil sample. Geophysical data will be collected from down-hole seismic test (PS logging) and Multi-channel analysis of surface wave (MASW) and Singles Microtremor survey. The total works will be conducted by the following methodology-

The method of testing/surveying, application, Instrumentation and previous works of Geophysical and Geotechnical investigation are given below-

3.2.1. Test Detail And Procedure Of Downhole Seismic Test (Ps Logging)

Seismic down hole test is a direct measurement method for obtaining the shear wave velocity profile of soil stratum. The seismic down hole test aims to measure the travelling time of elastic wave from the ground surface to some arbitrary depths beneath the ground. The seismic wave was generated by striking a wooden plank by a 7kg sledge hammer. The plank was placed on the ground surface at around 3 m in horizontal direction from the top of borehole. The plank was hit separately on both ends to generate shear wave energy in opposite directions and is polarized in the direction parallel to the plank.

The shear wave emanated from the plank is detected by a tri-axial geophone. The geophone was lowered to 1 m below ground surface and attached to the borehole wall by inflating an air bladder. Then, the measurements were taken at every 1 m interval until the geophone was lowered to 30 m below ground surface. For each elevation, 6 records were taken and then used to calculate the shear wave velocity. The first arrival time of an elastic wave from the source to the receivers at each testing depth can be obtained from the downhole seismic test.

Figure 3.1 Field Data Acquisition by PS logger

Two geophones are lowered in the hole by keeping them 1.5m apart. There exists two ways of moving geophone either upward or downward. Say, if the hole is 30m then the bottom geophone is kept at 30m and then the top geophone will be at 28.5m and then we bring these geophones upward by taking reading after each meter and for downward is vice versa. In Downhole Seismic, an accelerometer mounted to a wooden plank source is used to trigger data collection.

Figure3.2 Main Component of the Freedom Data PC

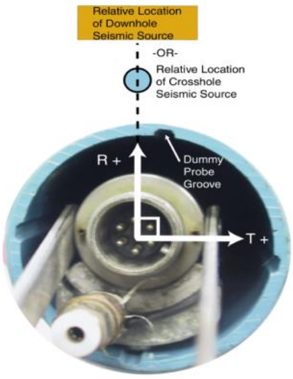


Figure 3.3 Receiver Orientation in Sinco casing

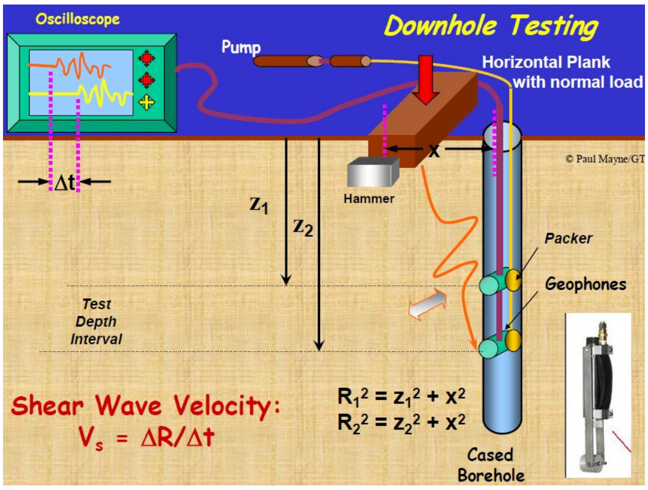


Figure 3.4 Calculation of Shear Wave Velocity by Down hole Seismic, where R_1=Distance between source to top geophone and R_2=Distance between source to bottom geophone

Figure 3.5 To set the wooden plank and sand bag 3.0 meters from a borehole

Figure 3.6 To attach the trigger to a hammer.

Figure 3.7 To connect the air pump with a battery.

Figure 3.8 To connect the computer with cables which are connected to the geophone.

Figure 3.9 Make sure that the air bag at the geophone works. Then, put the geophone into the borehole and fix the safety rope with the holder

Figure 3.10 Hit the wooden plank in 3 directions which are on the left, right and vertical directions.

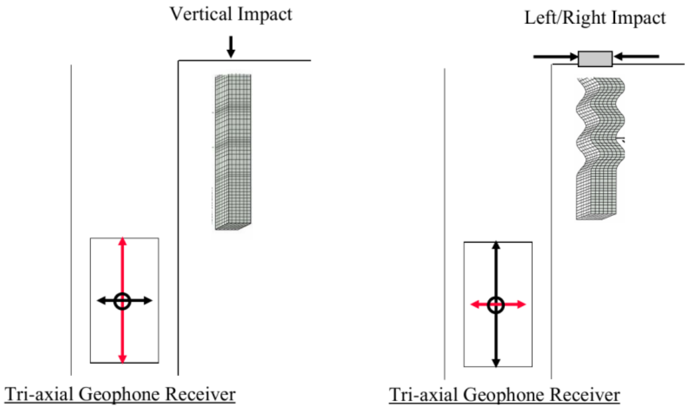


Figure 3.11 Triaxial geophone behavior.

Analysis and Calculation from PS Logging

P-wave travel time is calculated by the first arrival of either peak or trough in the seismic trace and P-wave is characterized by higher frequency and lower amplitude. On the other hand, shear wave is characterized by lower frequency but high amplitude.

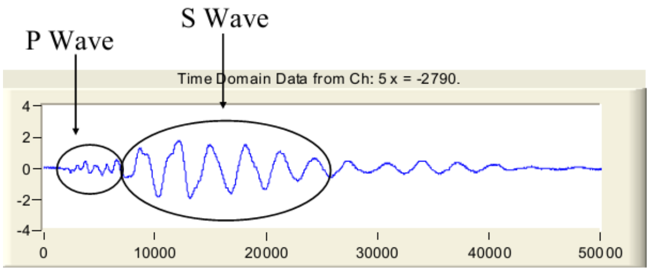


Figure 3.12 P wave and S wave in the Computer Window

S wave travel time is calculated from the first cross as we hit in both direction of the wooden plank so there generate opposite phase shear waves in radial and transverse direction and cross at some points.

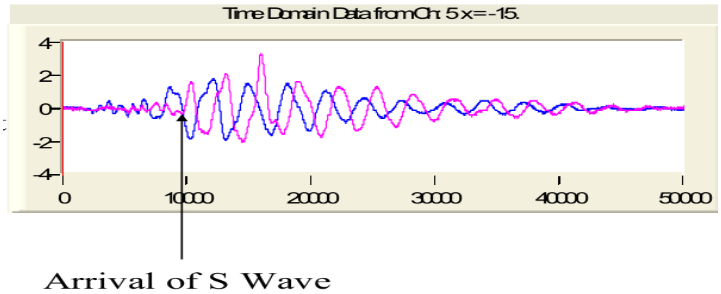


Figure 3.13 Arrival of S wave

Moreover, bounty of engineering geological parameters of soil can be determined whenever shear wave and compressional wave velocity is known. The Shear Modulus (G), Constrained Modulus (M) , Poisson Ratio (ν) and Young Modulus(E) of the soil profiles are calculated using the following formula:

$$G = \rho V_S^2$$
$$M = \rho V_P^2$$
$$\nu = [0.5(\frac{V_P}{V_S})^2 - 1]/[(\frac{V_P}{V_S})^2 - 1]$$
$$E = 2G(1+\nu)$$

Where, *p*is the local soil mass density (unit weight divided by gravity) obtained from the boring log information is taken 2 gm/cc for based on SPT results.

Besides, the average shear wave velocity upto 30 m depth has been determined using the following equation.

$$T_{30} = \sum \frac{Hi}{Vi}$$
$$AVS\ 30 = \frac{30}{T_{30}}$$

Where, Hi : Thickness of i th layer and $30 = \sum Hi$

Vi: S-wave velocity of i th layer

Instrument List

The PS logging test equipments are listed below-

1. One Freedom NDT PC
2. Two High Sensitive Tri-axial Geophones.
3. Two set Cable/Air lineSpool
4. Wooden Plank.
5. 7kg weight Hammer.

Figure 3.14 Freedom Data PC with P-SV Downhole Source and 1 Tri-axial Geophone Receiver used in Crosshole Seismic Investigations

Application of PS Logging Test

Downhole Seismic (PS Logging) system is useable for providing information on dynamic soil and rock properties for earthquake design analyses for structures, liquefaction potential studies, site development, and dynamic machine foundation design. The investigation determines shear and compressional wave depth versus velocity profiles. Other parameters, such as Poisson's ratios and moduli, can be easily determined from the measured shear and compressional wave velocities. The PS Logging is a downhole method for the determination of material properties of soil and rock.

3.2.2. Test Detail And Procedure Of Multi-Channel Analysis Of Surface Wave (MASW)

MASW utilizes the frequency dependent property of surface wave velocity, or the dispersion property, for Vs profiling. It analyses frequency content in the data recorded from a geophone array deployed over a moderate distance.

The processing of MASW is schematically summarized in Figure 3.20. The principle MASW is to employ and arrange a number of sensors on the ground surface to capture propagating Rayleigh waves, which dominates two-thirds of the total seismic energy generated by impact sources. If the tested ground is not homogeneous, the observed waves will be dispersive, a phenomenon that waves propagate towards receivers with different phase velocities depending on their respective wavelength (see Figure 3.16).

From field observation, the data in space-time domain is transformed to frequency-velocity domain by slant-stack and Fast Fourier transform using

$$S(\omega,c)=\int e^{-i\frac{\omega}{c}x}U(x,\omega)dx$$

where $U(x,\omega)$ is the normalized complex spectrum obtained from the Fourier transform of $u(x,t)$, ω is the angular frequency, c is the testing-phase velocity and $S(\omega,c)$ is the slant-stack amplitude for each ω and c, which can be viewed as the coherency in linear arrival pattern along the offset range for that specific combination of ω and c. When c is equal to the true phase velocity of each frequency component, the $S(\omega,c)$ will show the maximum value. Calculating $S(\omega,c)$ over the frequency and phase-velocity range of interest generates the phase-velocity spectrum where dispersion curves can be identified as high-amplitude bands. The dispersion curve is, then, used in inversion process to determine the shear wave velocity profile of the ground.

In theory, a phase-velocity spectrum can be calculated for a known layer model **m** and the field setup geometry. This process is called forward modeling. The inversion process tries to adjust assumed layer model as much as possible through several iterations in order to make the calculated spectrum looks similar to the dispersion curve obtained from the field test. Once the algorithm can match the calculated with the measured one, the assumed model will be considered as the true profile.

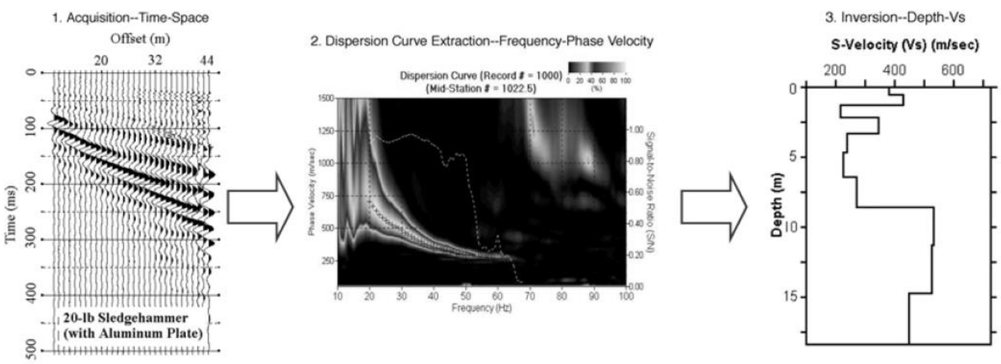


Figure 3.15 MASW data processing (Park et al., 1999)

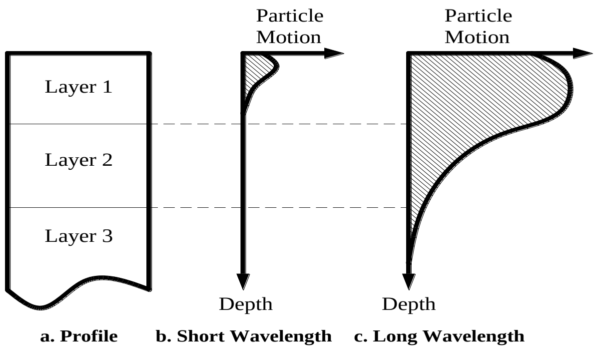


Figure 3.16 Rayleigh wave dispersion in layer media (Rix, 1988)

Active Source Data Acquisition

The active MASW method was introduced in GEOPHYSICS in 1999. This is the most common type of MASW survey that can produce a 2D VS profile. It adopts the conventional mode of survey using an active seismic source (e.g., a sledge hammer) and a linear receiver array, collecting data in a roll-along mode. It utilizes surface waves propagating horizontally along the surface of measurement directly from impact point to receivers. It gives this VS information in either 1D (depth) or 2D (depth and surface location) format in a cost-effective and time-efficient manner. The maximum depth of investigation (z max) is usually in the range of 10–30 m, but this can vary with the site and type of active source used.

Seismic energy for active source surface wave surveys can be created by various ways, but we used a sledgehammer to impact a striker plate on the ground since it is a low-cost, readily available item. To signal to the seismograph when the energy has been generated, a trigger switch is used as the interface between the hammer and the seismograph. When the sledgehammer hits the ground, a signal is sent to the seismograph to tell it to start recording.

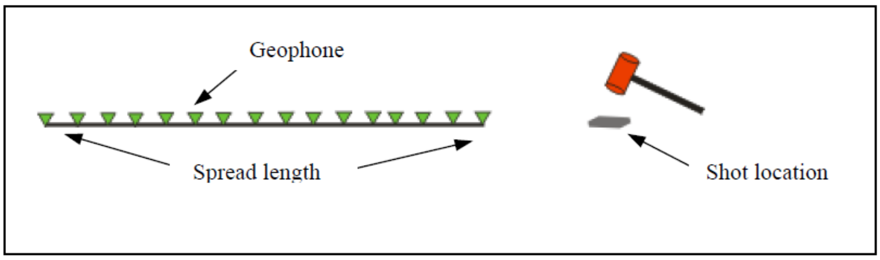
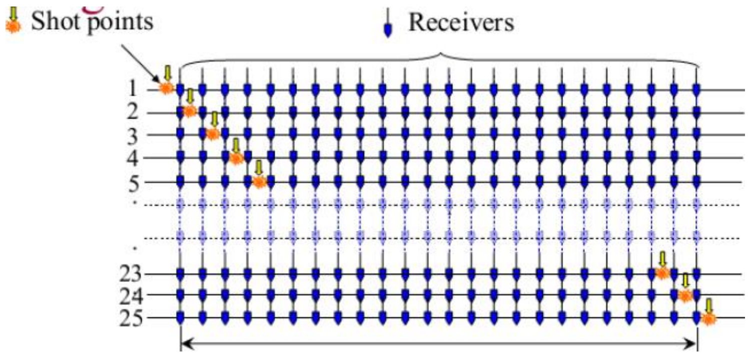


Figure 3.17 Schematic of linear active source spread configuration

During our field work we used 12 channels with 3m interval, 6 m source (sledge hammer) offset, 0.125 ms sample interval, 2 seconds record length and auto trigger option. But the geophone interval was kept 4m in Station 28 and 90. And the active source spread configuration for the station 20 was like below:



Survey Line Length

(Number of Sources= Number of Receivers + 1)

Figure 3.18 MASW Field Data Acquisition

At every station one data was acquired by stacking (6 times hammer hit) to enhance the data quality.

Analysis of MASW

In the phase velocity analysis, SPAC (Spatial Autocorrelation) method (Okada, 2003) is employed. Okada (2003) shows Spatial autocorrelation function $\rho(\omega, r)$ is expressed by Bessel function.

$$\rho(\omega, r) = J_0(\omega r / c(\omega)) \quad \text{-------------------}(1)$$

Where, r is the distance between receivers, ω is the angular frequency, c(ω) is the phase velocity of the waves, J_0 is the first kind of Bessel function. The phase velocity can be obtained at each frequency using equation (1). Figure 3-20 shows an example of dispersion curve of the survey, the frequency range between 15 and 50 Hz.

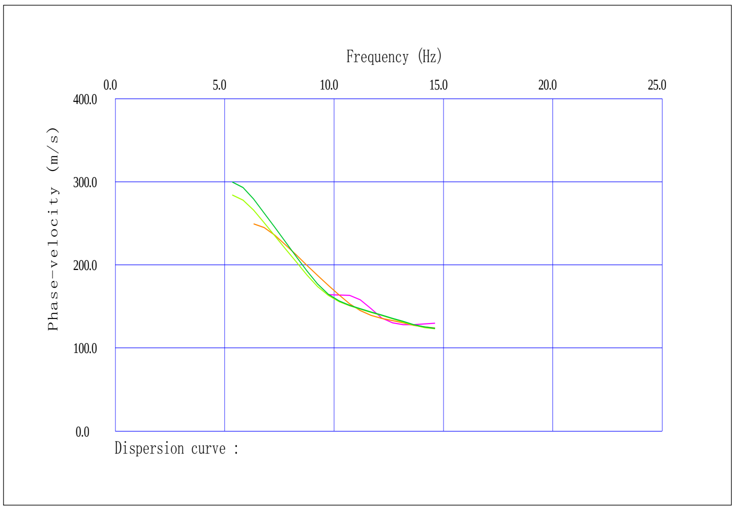


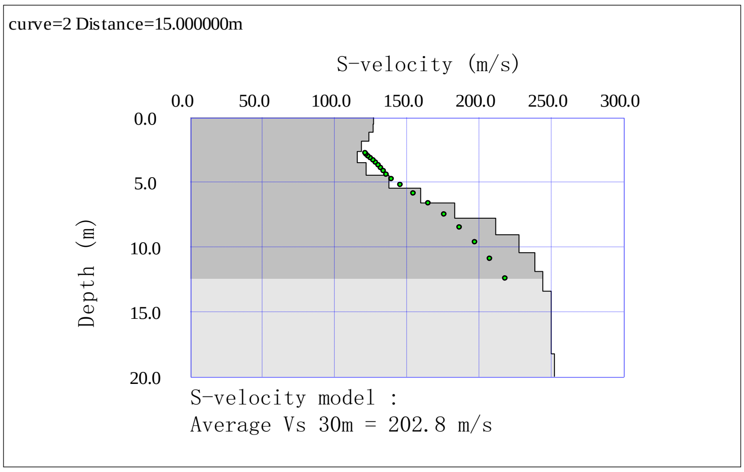
Figure 3.19 Dispersion Curve

A one-dimensional inversion using a non-linear least square method has been applied to the phase velocity curves. In the inversion, the following relationship between P-wave velocity (Vp) and Vs (Kitsunezaki et. Al.., 1990):

$$Vp = 1.29 + 1.11Vs \quad \text{-------------------------} (2)$$

Where Vp and Vs are the P-wave velocity and S-wave velocity respectively in (km/sec).

These calculations are carried out along the measuring line, and the S-wave velocity distribution section was analyzed, then summarized to one dimensional structure; SeisImager software can also give a 2-D velocity model (for active), a sample of which is shown in Fig. 3-20.



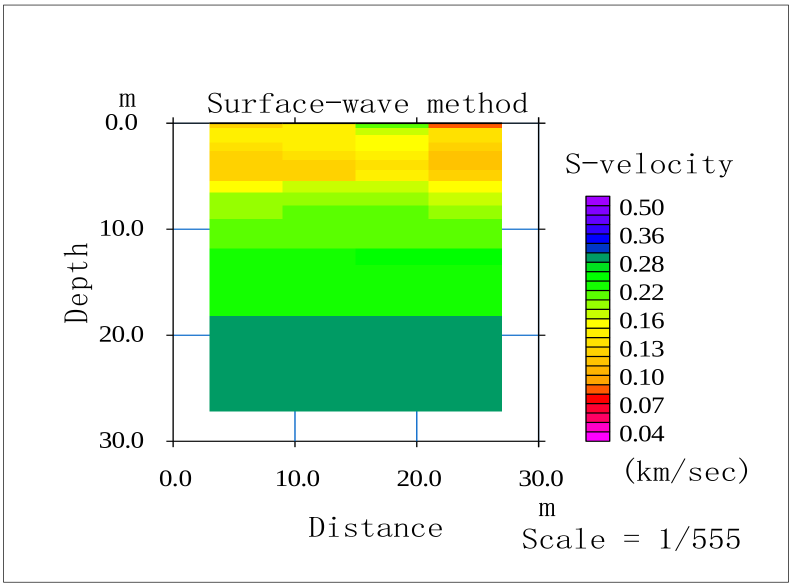


Figure 3.20 One dimensional Velocity Structure and 2 D velocity Model

Figure 3-21 shows an example of dispersion curve for passive MASW and phase velocity versus frequency as a sample. A one dimensional inversion using a non-linear least square method has been applied to the phase velocity curves and one dimensional S-wave velocity structures down (Figure 3-22).

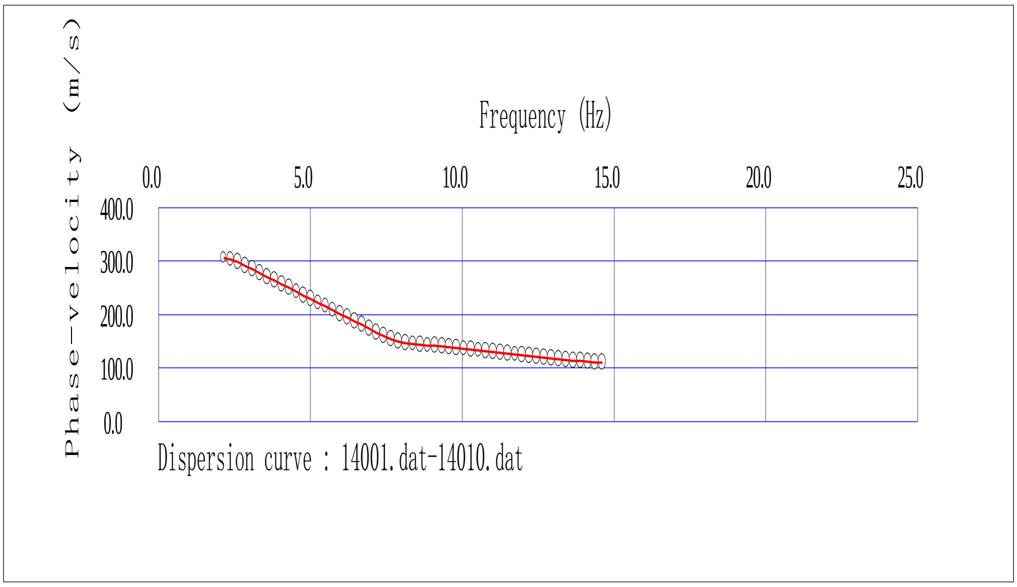


Figure 3.21 Dispersion Curve for Passive MASW

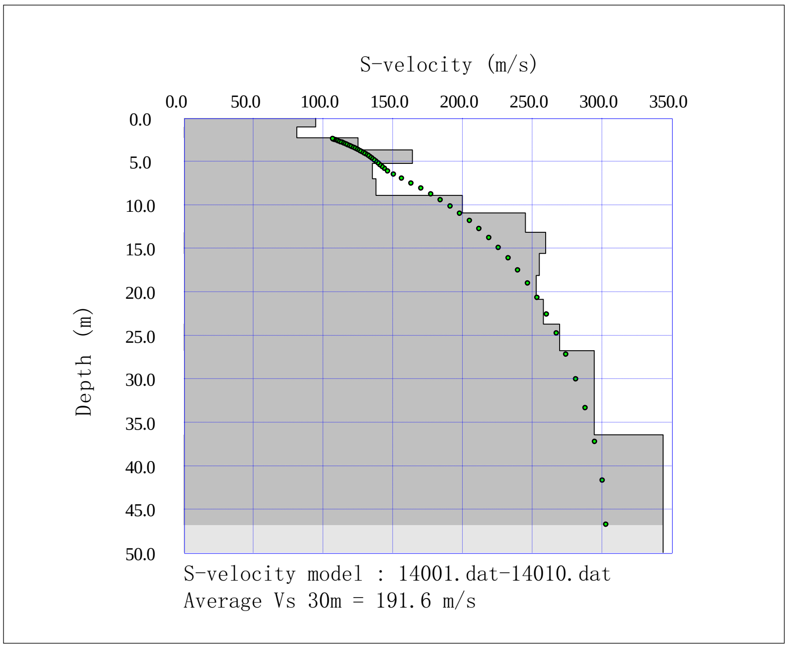


Figure 3.22 One dimensional velocity structure for Passive MASW

Calculation of AVS 30

The AVS30 can be calculated as follows:

$T_{30} = \sum(Hi/Vi)$

AVS 30= (30/ T_{30})

Where, Hi= Thickness of the i th layer and ∑Hi= 30

Vi= S wave velocity of the I th lay

3.2.3. Test Detail And Procedure Of Microtremor Measurement (Single Microtremor)

Microtremor method is a practical and economical seismic survey since it has potential to explore deep soils without a borehole. Microtremors are the phenomenon of very small vibrations of the ground surface even during ordinary quiet time as a result of a complex stacking process of various waves propagating from remote man-made vibration sources caused by traffic systems or machineries in industrial plants and from natural vibrations caused by tidal and volcanic activities. Observation of microtremors can give useful information of dynamic properties of the site such as predominant period, amplitude, peak ground acceleration and shear wave velocity.

Single Microtremor observation

Method

1) The transfer function of surface layer

$$S_T = \frac{\text{Hor. spectrum at surface}}{\text{Hor. spectrum at base}} = \frac{S_{HS}}{S_{HB}}$$

2) Vertical component of MT is affected by Rayleigh wave at surface, but no effect at base and no amplification of vertical waves.
Define the effect of Rayleigh wave as;

$$E_S = \frac{\text{Ver. spectrum at surface}}{\text{Ver. spectrum at base}} = \frac{S_{VS}}{S_{VB}}$$

3) To eliminate the effect of Rayleigh wave, define new transfer function as;

$$S_{TT} = \frac{S_T}{E_S} = \left(\frac{S_{HS}}{S_{VS}}\right) x \left(\frac{S_{VB}}{S_{HB}}\right) = \left(\frac{S_{HS}}{S_{VS}}\right)$$

1.0

$$H/V spectrum = \frac{Hs}{Hv} = \frac{\sqrt{F_{NS} x F_{EW}}}{F_{UD}}$$

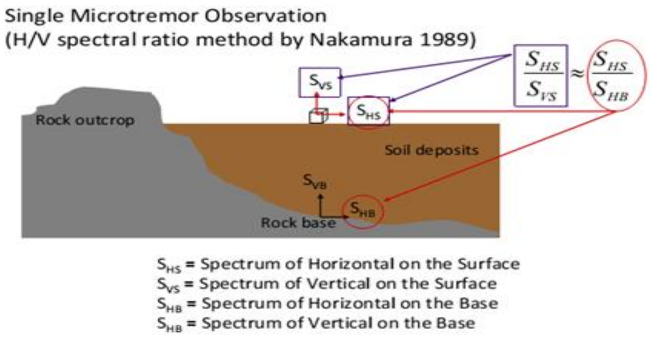


Figure 3.23 Fundamental of SingleMicrotremor observation

Field Data Acquisition System

Microtremor observations are performed using portable equipment, which is equipped with a super-sensitive sensor, a wire comprising a jack in one site and USB port in another site, and a laptop computer is also used. The microtremor equipment has been set on the free surface on the ground without any minor tilting of the equipment. The N-S and E-W directions are properly maintained following the directions arrowed on the body of the equipment. The sampling frequency for all equipments is set at 200Hz. The low-pass filter of 40Hz is set in the data acquisition unit. Like the seismometer or accelerometer, the velocity sensor used can measure three components of vibrations: two horizontal and one vertical. The natural period of the sensor is 2 sec. A global positioning system (GPS) is used for recording the coordinates of the observation the available frequency response range for the sensor is 0.5-20Hz. sites. The length of record for each observation was 20~30 min.In all fields of this project this data acquisition system has be applied.

Figure 3.24 Field data acquisition of Single microtremor

3.2.4. Standard Penetration Test (SPT) Method

The Standard Penetration test (SPT) is a common in situ testing method used to determine the geotechnical engineering properties of subsurface soils. The test procedure is described in the British Standard BS EN ISO 22476-3, ASTMD1586. A short procedure of SPT N-value test is described in the following paragraph.

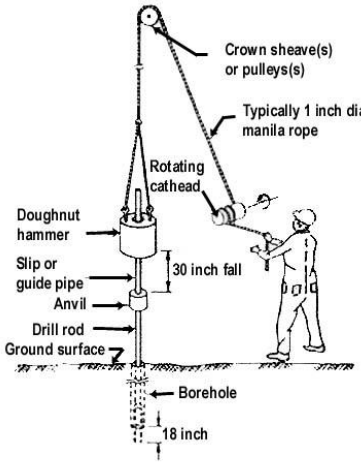


Figure 3.25 The SPT sampler in place in the boring with hammer, rope and cathead (Adapted from Kovacs, et al., 1981)

The test in our field uses a thick-walled sample tube, with an outside diameter of 50 mm and an inside diameter of 35 mm, and a length of around 650 mm. This is driven into the ground at the bottom of a borehole by blows from a slide hammer with a weight of 63.5 kg (140 lb) falling through a distance of 760 mm (30 in). The sample tube is driven 150 mm into the ground and then the number of blows needed for the tube to penetrate each 150 mm (6 in) up to a depth of 450 mm (18 in) is recorded. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance" or the "N-value". In cases where 50 blows are insufficient to advance it through a 150 mm (6 in) interval the penetration after 50 blows is recorded. The blow count provides an indication of the density of the ground, and it is used in manyempirical geotechnical engineering formulae.

The main objective of SPT is as follows:

a) Boring and recording of soil stratification.
b) Sampling (both disturbed and undisturbed).
c) Recording of SPT N-value
d) Recording of ground water table.

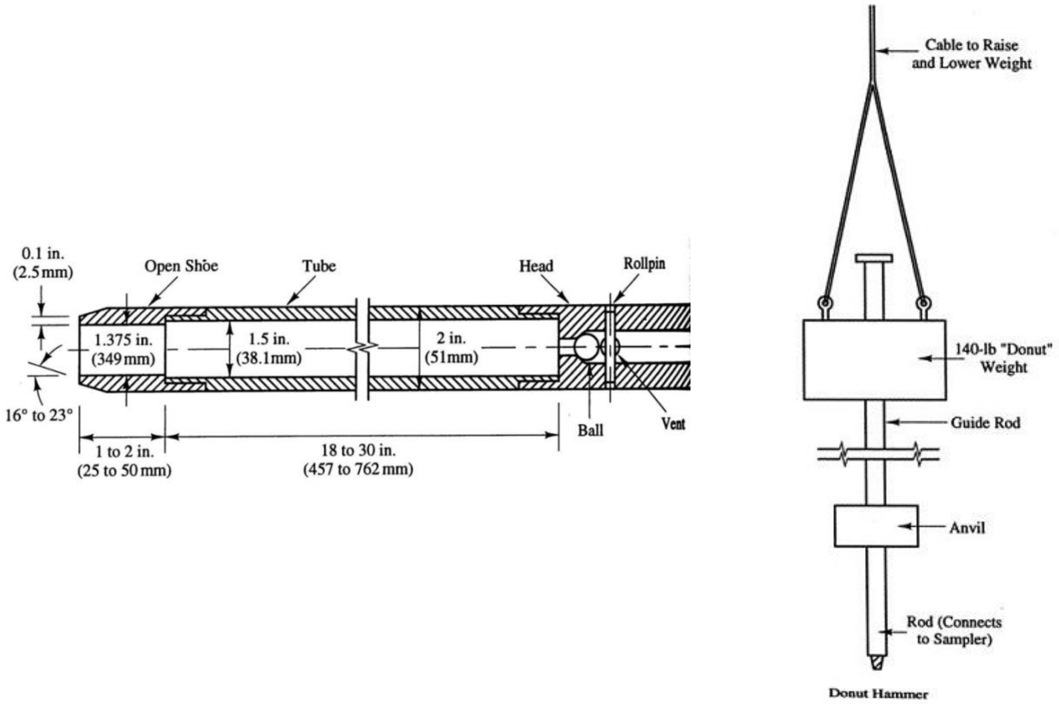


Figure 3.26 SPT Sampler and Donut Hammer

3.2.5. Grain Size Analysis (Sieve And Hydrometer Analysis)

Purpose:

This test is performed to determine the percentage of different grain sizescontained within a soil. The mechanical or sieve analysis is performed todetermine the distribution of the coarser, larger-sized particles, and the hydrometermethod is used to determine the distribution of the finer particles.

Standard Reference:

ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils

Significance:

The distribution of different grain sizes affects the engineering properties ofsoil. Grain size analysis provides the grain size distribution, and it is required inclassifying the soil.

Equipment:

Balance, Set of sieves, Cleaning brush, Sieve shaker, Mixer (blender), 152HHydrometer, Sedimentation cylinder, Control cylinder, Thermometer, Beaker,Timing device.

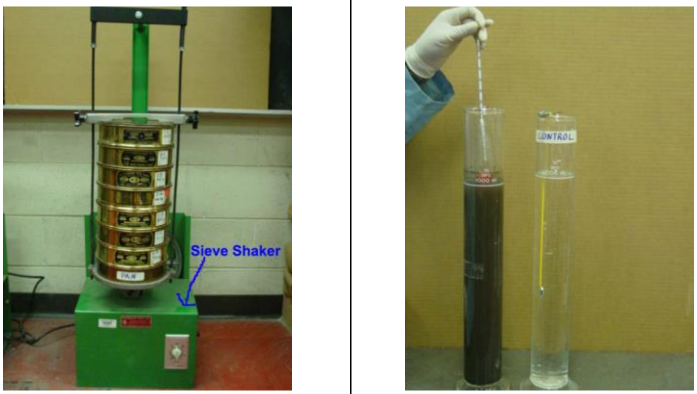


Figure 3.27 Grain size analysis test equipment

3.2.6. Specific Gravity Determination

Purpose:

This lab is performed to determine the specific gravity of soil byusing a pycnometer. Specific gravity is the ratio of the mass of unit volumeof soil at a stated temperature to the mass of the same volume of gas-freedistilled water at a stated temperature.

Standard Reference:

ASTM D 854-00 – Standard Test for Specific Gravity of Soil Solidsby Water Pycnometer.

Significance:

The specific gravity of a soil is used in the phase relationship of air,water, and solids in a given volume of the soil.

Equipment:

Pycnometer, Balance, Vacuum pump, Funnel, Spoon.

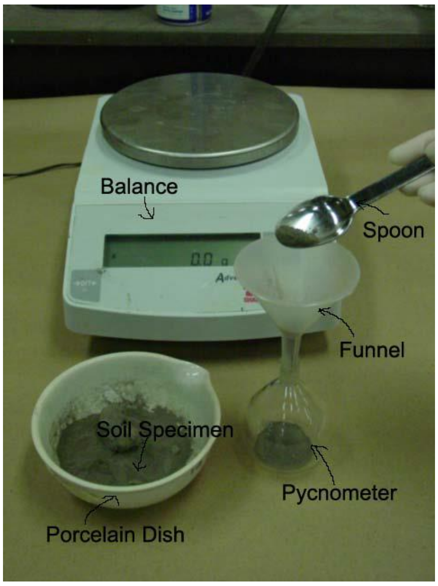


Figure 3.28 Specific gravity test equipment

3.2.7. Atterberg Limits Determination

Purpose:

This lab is performed to determine the plastic and liquid limits of a finegrainedsoil. The liquid limit (LL) is arbitrarily defined as the water content, inpercent, at which a pat of soil in a standard cup and cut by a groove of standarddimensions will flow together at the base of the groove for a distance of 13 mm (1/2in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standardliquid limit apparatus operated at a rate of two shocks per second. The plastic limit(PL) is the water content, in percent, at which a soil can no longer be deformed byrolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

Standard Reference:

ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and

Plasticity Index of Soils

Significance:

The Swedish soil scientist Albert Atterberg originally defined seven “limits ofconsistency” to classify fine-grained soils, but in current engineering practice onlytwo of the limits, the liquid and plastic limits, are commonly used. (A third limit,called the shrinkage limit, is used occasionally.) The Atterberg limits are based onthe moisture content of the soil. The plastic limit is the moisture content thatdefines where the soil changes from a semi-solid to a plastic (flexible) state. Theliquid limit is the moisture content that defines where the soil changes from a plasticto a viscous fluid state. The shrinkage limit is the moisture content that defineswhere the soil volume will not reduce further if the moisture content is reduced. Awide variety of soil engineering properties have been correlated to the liquid andplastic limits, and these Atterberg limits are also used to classify a fine-grained soilaccording to the Unified Soil Classification system or AASHTO system.

Equipment:

Liquid limit device, Porcelain (evaporating) dish, Flat grooving tool with gage,Eight moisture cans, Balance, Glass plate, Spatula, Wash bottle filled with distilledwater, Drying oven set at 105°C.

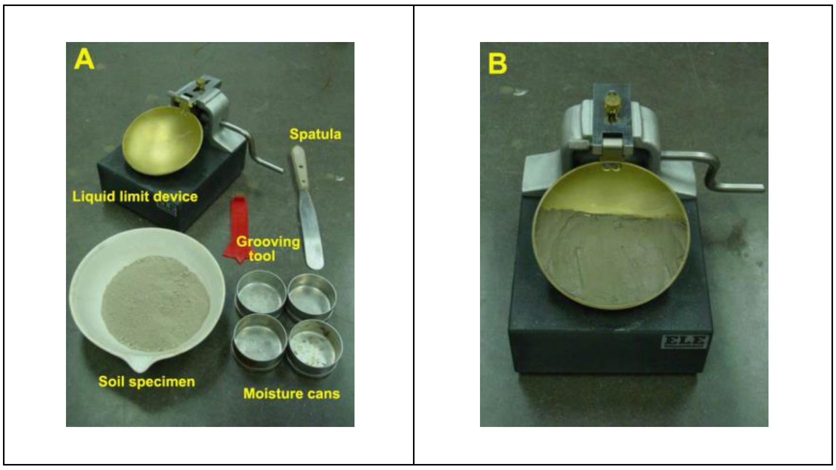


Figure 3.29 Atterberg limits test equipment

3.2.8. Direct Shear Determination

Purpose:

To determine the shearing strength of the soil using the direct shear apparatus.

Standard Reference:

ASTM D 3080- to measure the shear strength properties of soil.

Significance:

In many engineering problems such as design of foundation, retaining walls, slab bridges, pipes, sheet piling, the value of the angle of internal friction and cohesion of the soil involved are required for the design. Direct shear test is used to predict these parameters quickly. The laboratory report cover the laboratory procedures for determining these values for cohesionless soils.

Equipment:

Direct shear box apparatus, Loading frame (motor attached), Dial gauge, Proving ring, Tamper, Straight edge, Balance to weigh upto 200 mg, Aluminum container and Spatula.

3.2.9. Unconfined Compression Test

Purpose:

To determine shear parameters of cohesive soil.

Standard Reference:

ASTM D2166- To determine shear parameters of cohesive soil.

Significance:

It is not always possible to conduct the bearing capacity test in the field. Some times it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remoulded soil sample. Now we will investigate experimentally the strength of a given soil sample.

Equipment:

Loading frame of capacity of 2 t, with constant rate of movement. Proving ring of 0.01 kg sensitivity for soft soils; 0.05 kg for stiff soils. Soil trimmer, Frictionless end plates of 75 mm diameter (Perspex plate with silicon grease coating), Evaporating dish (Aluminum container).
Soil sample of 75 mm length, Dial gauge (0.01 mm accuracy), Balance of capacity 200 g and sensitivity to weigh 0.01 g, Oven, Sample extractor and split sampler, Dial gauge (sensitivity 0.01mm), Vernier calipers.

3.2.10. Triaxial (Unconsolidated – Undrained) Test

Purpose:

To find the shear of the soil by Undrained Triaxial Test.

Standard Reference:

ASTM D2850-70- To find the shear of the soil by Undrained Triaxial Test.

Significance:

The standard consolidated undrained test is compression test, in which the soil specimen is first consolidated under all round pressure in the triaxial cell before failure is brought about by increasing the major principal stress.It may be perform with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

Equipment:

3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes, Rubber ring, An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side, Stop clock, Moisture content test apparatus, A balance of 250 gm capacity and accurate to 0.01 gm.

3.2.11. Slope Stability Assessment

The dynamic stability of a slope is related to its static stability; therefore, the static factor of safety for each point (e.g. in-situ field measurements on slope) must be determined. For the purpose of regional analysis, we use a relatively simple limit equilibrium model of infinite slope in a material having both frictional and cohesive strength. The generalized equation pertaining to the safety factor of slope and a generalized flow chart pertaining to the study are given below:

$$F = \frac{s}{t} \text{.........................} (1)$$

Where, F= factor of safety, S= shear strength and t= shear stress

Safety factor eventually infers the terrains stability is the ratio between the forces that make the slope failand those that prevent the slope from failing. F values larger than 1indicate stable conditions, and F values smaller than 1 unstable. At F=1 the slope is at the point of failure. The approach of safety factor determination is involved number of data extraction from field as well as remote sensing techniques. However, the analysis of slope safety factor determination depends on geotechnical parameters. The detail of data extraction is given below

Step-1:

A digital elevation model (DEM) of around 10 meter resolution was employed for slope map creation. From the DEM slope map in degree was created in ArcGIS interface.

Step-2:

In the second step, using unit weight, cohesion, angle of friction and slope height from the following equation value for $\lambda_{c\varphi}$ has been calculated (Cousins,1978)

$$\lambda_{c\varphi} = \frac{\gamma H \tan \varphi}{c} \text{.....................} \quad (2)$$

Where γ = unit weight, H = Slope Height φ = Angle of Friction and c = cohesion of soil

Step-3:

Stability number (NF) was determined by using Cousins (1978) stability chart and the Factor of safety (FS) for slope was calculated from the equation no (3):

$$F = N_F \frac{c}{\gamma H} \text{............................} \quad (3)$$

Where, NF = Stability Number, γ = unit weight, H = Slope Height and c = cohesion of soil

3.3. Expected Outcome

a) Geological and Geomorphologic Mapping

Using aerial photographs, high resolution satellite images and field investigation both the regional and local geological maps will be prepared to delineate the surface and near-surface outcrops and attitudes of geological structures. On the other hand for preparing geomorphologic map, using digital elevation model (DEM) satellite and different image such as Spot images, Landsat images, Satellite images etc. The geomorphologic map is verified by field auger test and collecting of relevant existing data. This map will provide all background information for the preparation of the hazard maps and environmental aspects of the project site.

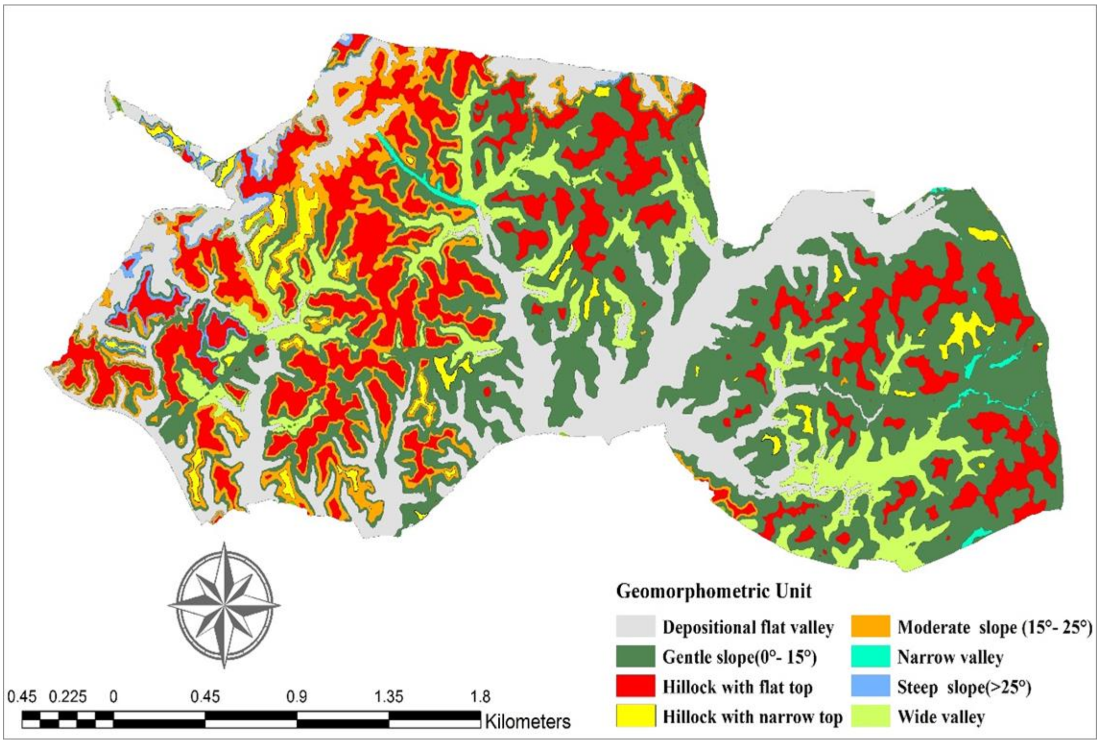


Figure 3.30 Geomorphological map

b) Sub-surface 3D model of different layers through geo-technical investigation

According to 200m × 200m grid pattern, Standard penetration test locations are selected and drilling for identifying the geological characteristic of sub-surface soft sedimentary rocks. Description of different layer of the soil, its sedimentary characteristics, structure, lithology etc will be reflected in 3D model. Engineering properties of different soil layer: SPT value, soil strength and foundation layer etc are also being described. Computing all the results of soil properties and geotechnical properties preparation of 3D model for sub surface information of different layers of the area can be done using GIS and other software.3D subsoil modeling will illustrates the sub-soil condition and behavior if over-burden pressure and dynamic load are given in a specific site.

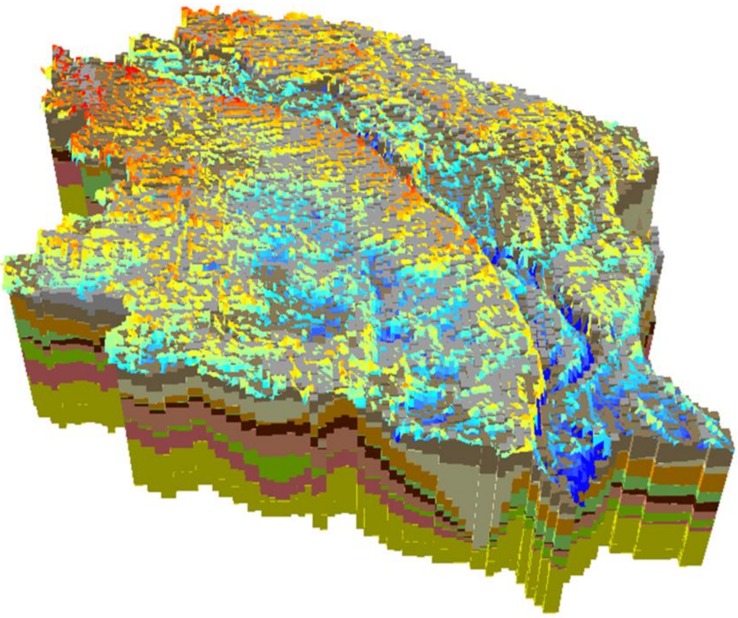


Figure 3.31 Subsurface Lithological 3D Model

c) Engineering geological mapping based on AVS30

In this investigation, Geophysical data will be collected by using PS Logging, Multi-channel Analysis of Surface Wave (MASW), Small Scale Microtremor Measurement(SSMM) and Microtremor test/survey in the field and analyses those data for identifying average shear wave velocities (Vs) in a project area. The purpose of identifying average shear wave velocities (Vs) is to generate AVS30 maps for the targeted areas. This information's are often used for foundation engineering and seismic hazard assessment.

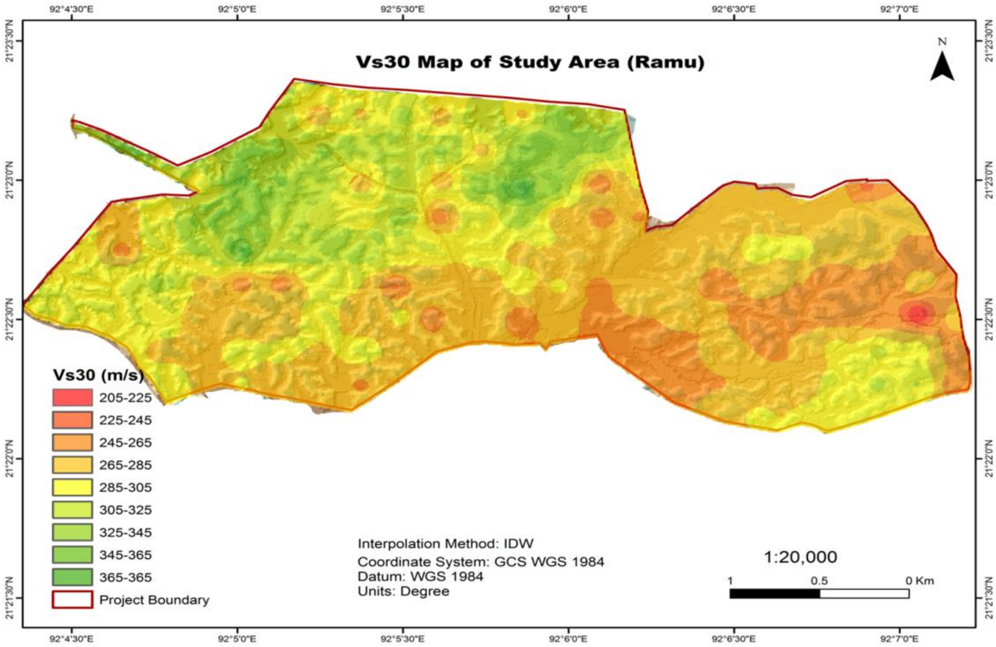


Figure 3.32 Engineering geological mapping based on AVS30

d) Seismic hazard assessment

The purpose for the preparation of localized seismic hazard maps is to make the structural design and to address other mitigation options following seismic intensity. For preparation of seismic hazard maps, historical earthquake data and damage information are needed. The response of the soil layers in-term of the amplification factor of the soft-soil need to be developed based on the engineering properties of the sub-soil. The main outcomes of the seismic hazard assessment are Peak Ground Acceleration (PGA), Response Spectrum Sa(T) of 5% damping at 0.3 and 1.0 second periods values of 10% exceedance probability during next 50 years for upper soft local soil by using these amplification factor. Liquefaction and Ground Failure Map is also conducted from PGA, water level and triaxial test. Liquefaction is addressed by high-moderate- low zone in round from 100m*100m to 250m*250m grid size. Finally intensity map is prepared and also the vulnerable zones for high rise and low rise building will be identified.

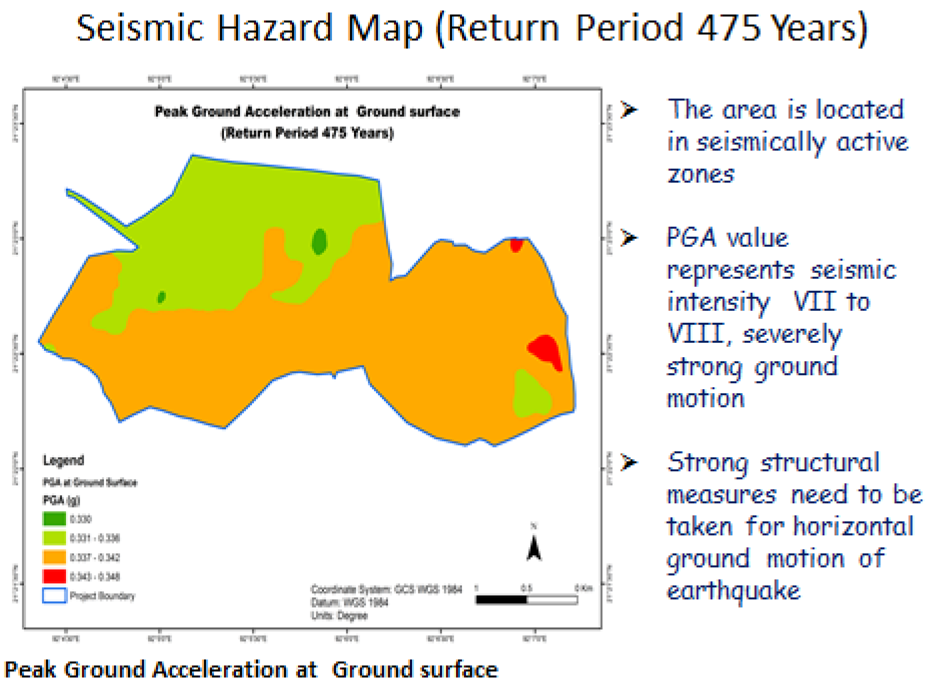


Figure 3.33 Seismic Hazard Map (Return Period 475 Years)

e) Slope stability assessment

Slope stability analysis is one of the prime prerequisites prior to any development work.Since slope failure (e.g. slides, flows and falls) often produce extensive property damage, and occasionally result in loss of life, therefore this particular issue should be in mind among the authorities those are involved in infrastructural works. For a risk sensitive land use planning as well as infrastructural development, slope stability analysis should be used for sustainable development activities. To minimize the slope related hazard, a slope stability map of thestudy area was prepared for sustainable urban development.

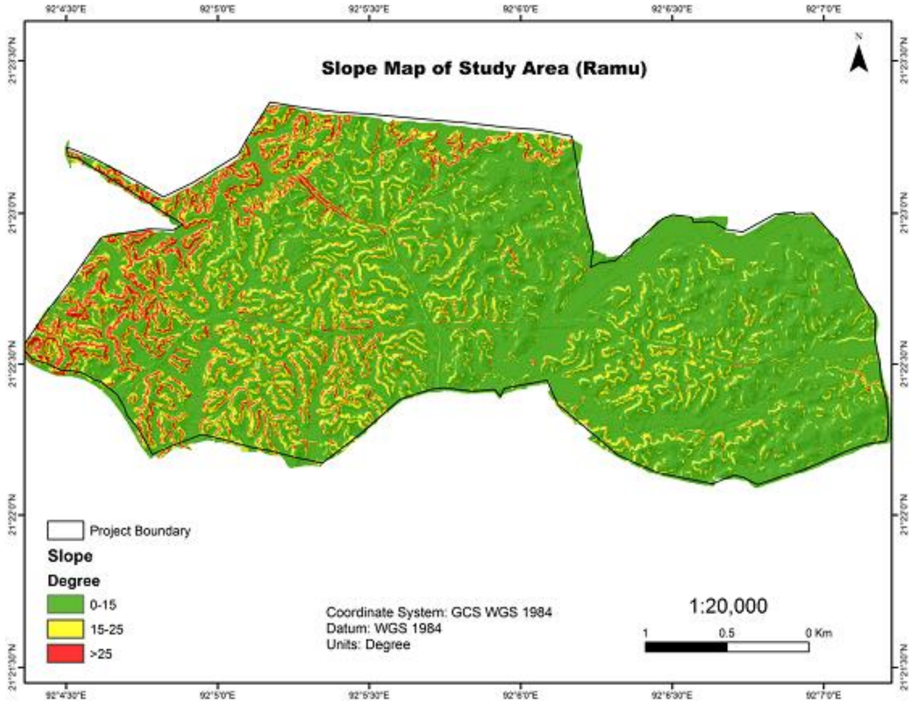


Figure 3.34 DEM based Slope Map

f) Training/Workshop

On-the-job training, sometimes called direct instruction, is one of the earliest forms of training (observational learning is probably the earliest). It is a one-on-one training located at the job site, where someone who knows how to do a task shows another how to perform it. It will be arranged during the investigation time.

4. PROJECT PERSONNEL

i) Professional Staff				
Name of Staff	Firm/Organization	Area of Expertise	Position Assigned	Task Assigned
1. Nasim Ferdous	Environmental & Geospatial Solutions (EGS)	Geophysics, Engineering Geology & Geo-technical engineering	Geologist	(i) To conduct and supervise boreholes for geological surveys for the study area; (ii) To prepare seismic hazard, vulnerability, damage and risk assessment map for the area, (iii) To prepare micro zonation map for the area. (iv) To provide land use based interpretation of seismic hazard map for developing guidelines to prepare risk sensitive land use plan (v) Any other related jobs assigned by PD.
2. Dewan Md. Enamul Haque	Advisor, EGS; Assistant Professor, University fo Dhaka	Geologist; Natural Hazards and Climate Related Risk Assessment and Management Specialist	Geologist	(i) To conduct and supervise boreholes for geological surveys for the study area; (ii) To prepare seismic hazard, vulnerability, damage and risk assessment map for the area, (iii) To prepare micro zonation map for the area. (iv) To provide land use based interpretation of seismic hazard map for developing guidelines to prepare risk sensitive land use plan (v) Any other related jobs assigned by PD.
3. Atikul Haque Farazi	Advisor, EGS; Lecturer, University fo Barisal	Geophysics, Engineering Geology & Geo-technical engineering	Geologist	(i) To check and monitor the accuracy of the borehole preparation process, collected sample and data for the geological survey; (ii) To conduct lab test of the collected samples and interpretation of the results of lab test; (iii) Any other related jobs assigned by PD.
4. Md. Abdus Samad	Environmental & Geospatial Solutions (EGS)	Geophysics, Engineering Geology	Associate Geologist	(i) To assist the geologist in conducting and supervising boreholes for geological surveys for the study area; (ii) To assist the geologist in checking and monitoring the accuracy of the borehole preparation process, collected sample and data for the geological survey; (iii) To assist the geologist in conducting lab test of the collected samples and interpretation of the results of lab test;

Name of Staff	Firm/Organization	Area of Expertise	Position Assigned	Task Assigned
5. Musabbir Ahmed Khan	Environmental & Geospatial Solutions (EGS)	Geophysics, Hydro-Geology	Associate Geologist	(i) To assist the geologist in preparation of seismic hazard, vulnerability, damage and risk assessment map for the area, (ii) To assist the geologist in preparation of micro zonation map for the area. (iii) To assist the geologist for land use based interpretation of seismic hazard map for developing guidelines to prepare risk sensitive land use plan (iv) Any other related jobs assigned by PD.
6. Biplob Hossain	Environmental & Geospatial Solutions (EGS)	Engineering Geology	Geological Survey Technician	(i) To prepare boreholes for geological surveys for the study area; (ii) To collect samples and data for the geological survey; (iii) Any other related jobs assigned by PD
7. Sanjida Sharmeen	Environmental & Geospatial Solutions (EGS)	Engineering Geology	Geological Survey Technician	(i) To assist the geologist in conducting lab test of the collected samples; (ii) Any other related jobs assigned by PD

5. PROJECT OFFICE

5.1. Client

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5.2. Consultant

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6. WORK PLAN

Within the outcomes of Mirshari Upazila Development Plan (MUDP), risk reduction is a potential thematic area that comprise of reducing risk for urban & rural populations through structural and non-structural interventions, improved awareness of natural hazard events that targeted the specifically extreme poor. Considering the earthquake threat of the populated urban and rural areas of the project, UDD will have to be taken many initiatives for earthquake preparedness of the Project area. So geotechnical and geophysical investigations are essential tools for seismic risk assessment in this project area. The geophysical investigations include PS-logging, and Multi-channel Analysis of Surface Wave (MASW). The geotechnical investigations will contain geotechnical boreholes with Standard Penetration Test (SPT) and sample collection (disturbed and undisturbed samples). The geotechnical laboratory tests, such as Atterberg limits, grain size analysis, direct shear, Unconfined compression strength and triaxial tests will be conducted to prepare subsurface geological and geotechnical model for bearing capacity and settlement estimation. The average shear wave velocity up to the depth 30 m (AVS 30) will be determined interpreting the geophysical and geotechnical SPT data and geological and geotechnical subsurface model. An engineering geological map using AVS 30 will be prepared for site specific seismic hazard assessment. Finally the risk sensitive landuse planning map will be prepared based the seismic risk map.

The union based geotechnical and geophysical investigations of the proposed project are listed in below table-

S/N	Paurashava/ union name	Area (sqkm)	Name of investigations			
			Bore-log with SPT	PS logging *(30m depth)*	MASW *(30m depth)*	Single Micro Tremor Measurement
1	Ichhakhali	51.25	15	1	2	3
2	Wahedpur	19.37	5	1	1	2
3	Osmanpur	17.77	4	1	1	2
4	Karerhat	25.27/130	5	1	1	1
5	Katachhara	14.1	3	1	2	2
6	Khaiyachhara	17.76	4	1	1	2
7	Zorwarganj	21.01	6	1	1	2
8	Durgapur	16.59	3	1	2	2
9	Dhum	16.71	3	1	1	1
10	Maghadia	12.27	2	1	1	2
11	Mayani	7.67	3		1	1
12	Mithanala	21.68	4	1	1	2
13	Mirsharai	22.45	13	1	2	4
14	Saherkhali	25.55/57.08	7	1	1	2
15	Haitkandi	13.13	3	1	1	1
16	Hinguli	20.14	5	1	1	1
17	**Total area**	**459.00**	**85**	**15**	**20**	**30**

Standard Penetration Test (SPT) Locations

BH_ID	Union_Name	BH No. Each Union	Lat	Long
BH-M01	Karerhat	5	22.9440313972	91.5468582392
BH-M02			22.9353047945	91.5633735652
BH-M03			22.9156742412	91.5722965440
BH-M04			22.9497442879	91.5858235983
BH-M05			22.9340905029	91.5814487688
BH-M06	Hinguli	5	22.9164482972	91.5401911740
BH-M07			22.8980432489	91.5454913397
BH-M08			22.8912617850	91.5290730588
BH-M09			22.9026831978	91.5583404292
BH-M10			22.9025486254	91.5207936353
BH-M11	Dhum	3	22.8986794094	91.4966303568
BH-M12			22.8885667001	91.4758100730
BH-M13			22.8824383569	91.5091849763
BH-M14	Zorwarganj	6	22.8662252066	91.5420415158
BH-M15			22.8614124619	91.5209665964
BH-M16			22.8747374435	91.5279860063
BH-M17			22.8766410123	91.5485683440
BH-M18			22.8495554360	91.5547164249
BH-M19			22.8552661424	91.5349668985
BH-M20	Osmanpur	4	22.8407988601	91.4766901744
BH-M21			22.8500426874	91.5016484801
BH-M22			22.8714600208	91.4962368915
BH-M23			22.8555542705	91.4878381003
BH-M24	Durgapur	3	22.8141801609	91.5419058532
BH-M25			22.8304007749	91.5598322661
BH-M26			22.8333751011	91.5411534972
BH-M27	Katachhara	3	22.8384607316	91.5160222912
BH-M28			22.8191870974	91.5175689408
BH-M29			22.8024923562	91.5049137587
BH-M30	Ichhakhali	15	22.7653389220	91.4874420942
BH-M31			22.7623645958	91.5005291298
BH-M32			22.7492775602	91.4951753425
BH-M33			22.7992416119	91.4833604761
BH-M34			22.8305315241	91.4561156475
BH-M35			22.7365428144	91.5050135712
BH-M36			22.8253781522	91.4756732043
BH-M37			22.7935304886	91.4653616998
BH-M38			22.7471698878	91.5114572764
BH-M39			22.7802583488	91.4917430889
BH-M40			22.7859690552	91.4787750264
BH-M41			22.8105246921	91.4691701002
BH-M42			22.8169492368	91.4972477400
BH-M43			22.8201021896	91.4506393384
BH-M44			22.8312856563	91.4970388280
BH-M45	Mirsharai	13	22.8151865410	91.5678668772
BH-M46			22.8042210265	91.5734666800
BH-M47			22.8042242580	91.5634118212
BH-M48			22.7914941416	91.5823285362
BH-M49			22.7672236394	91.5932740568
BH-M50			22.7787640253	91.5901807575
BH-M51			22.7606245057	91.5575831905
BH-M52			22.7964456419	91.5523421277
BH-M53			22.7708664360	91.5666188938
BH-M54			22.7791868500	91.5780028162
BH-M55			22.7916790203	91.5708644332

BH-M56			22.7691817240	91.5828183972
BH-M57			22.7785787070	91.5567234964
BH-M58	Mithanala	4	22.7788997606	91.5231330103
BH-M59			22.7627194258	91.5164705195
BH-M60			22.7854232846	91.5405111450
BH-M61			22.7990382486	91.5303621793
BH-M62	Maghadia	2	22.7482974738	91.5316084336
BH-M63			22.7639269674	91.5444959357
BH-M64	Saherkhali	7	22.7290966474	91.5272450627
BH-M65			22.7169256825	91.5062715463
BH-M66			22.7103821647	91.5300661563
BH-M67			22.6919413419	91.5621888799
BH-M68			22.7411154739	91.4810397802
BH-M69			22.7703714545	91.4662248079
BH-M70			22.7137383946	91.5620772837
BH-M71	Khaiyachhara	4	22.7512579419	91.5777520815
BH-M72			22.7322222538	91.5783469467
BH-M73			22.7518899209	91.6027755729
BH-M74			22.7429479995	91.5882621235
BH-M75	Mayani	3	22.7157571134	91.5448768914
BH-M76			22.7281160792	91.5552035102
BH-M77			22.7417979800	91.5582968095
BH-M78	Wahedpur	5	22.6991019573	91.6227890801
BH-M79			22.7308808017	91.6043276122
BH-M80			22.7200542541	91.6171767016
BH-M81			22.7073241378	91.6107521569
BH-M82			22.6868645043	91.6186873335
BH-M83	Haitkandi	3	22.6702049875	91.6057672759
BH-M84			22.7131568071	91.5821668730
BH-M85			22.6918492413	91.5965002980

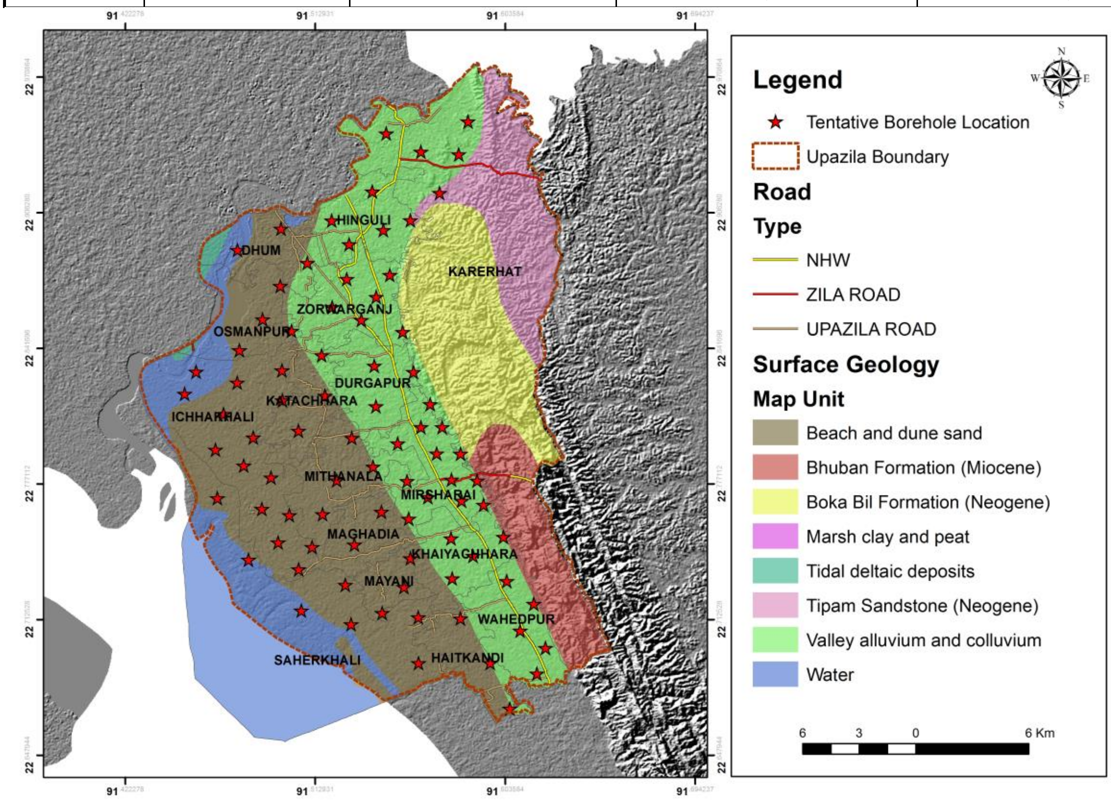

Figure 6.1Tentative sites location for Borehole(SPT test)

MASW Survey Locations

ID_MASW	Union_Name	Test No. Each Union	Lat	Long
MASW01	Hinguli	1	22.9164482972	91.5401911740
MASW02	Zorwarganj	1	22.8662252066	91.5420415158
MASW03	Osmanpur	1	22.8684829427	91.4900708143
MASW04	Durgapur	2	22.8261765967	91.5432900573
MASW05			22.8304007749	91.5598322661
MASW06	Katachhara	2	22.8312937992	91.5101584374
MASW07			22.8048836547	91.5041883009
MASW08	Ichhakhali	2	22.7874861881	91.4717544474
MASW09			22.7492775602	91.4951753425
MASW10	Dhum	1	22.8938639880	91.4949923133
MASW11	Karerhat	1	22.9505812633	91.5756407513
MASW12	Mirsharai	2	22.8018059011	91.5591002511
MASW13			22.7926859921	91.5734666800
MASW14	Mithanala	1	22.7899733936	91.5282084254
MASW15	Maghadia	1	22.7570640999	91.5371452501
MASW16	Mayani	1	22.7230984295	91.5475467233
MASW17	Saherkhali	1	22.6897030013	91.5537958881
MASW18	Khaiyachhara	1	22.7337246896	91.5800590884
MASW19	Wahedpur	1	22.6991019573	91.6227890801
MASW20	Haitkandi	1	22.6702049875	91.6057672759

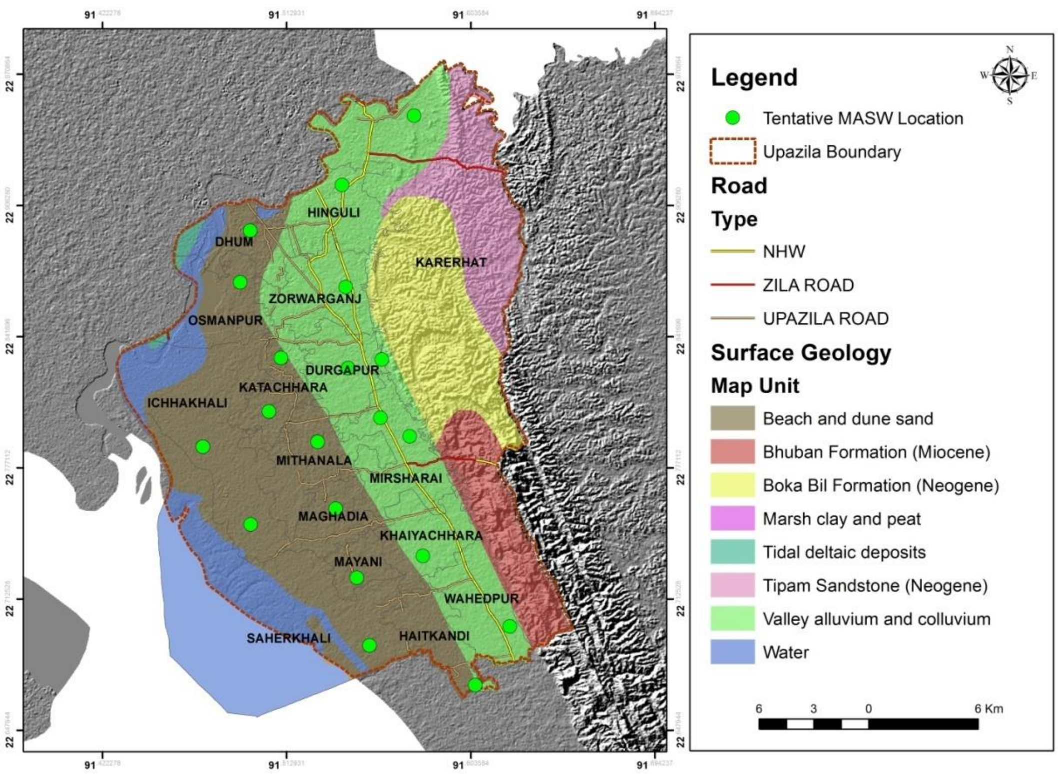

Figure 6.2Tentative sites location for MASW survey

PS Logging Test Locations

PS_ID	Union_Name	Test No. Each Union	Lat	Long
PS-M01	Karerhat	1	22.9353047945	91.5633735652
PS-M02	Hinguli	1	22.8980432489	91.5454913397
PS-M03	Dhum	1	22.8824383569	91.5091849763
PS-M04	Zorwarganj	1	22.8552661424	91.5349668985
PS-M05	Osmanpur	1	22.8555542705	91.4878381003
PS-M06	Durgapur	1	22.8141801609	91.5419058532
PS-M07	Katachhara	1	22.8191870974	91.5175689408
PS-M08	Ichhakhali	1	22.8105246921	91.4691701002
PS-M09	Mirsharai	1	22.7791868500	91.5780028162
PS-M10	Mithanala	1	22.7788997606	91.5231330103
PS-M11	Maghadia	1	22.7482974738	91.5316084336
PS-M12	Khaiyachhara	1	22.7512579419	91.5777520815
PS-M13	Saherkhali	1	22.7219256825	91.5152715463
PS-M14	Wahedpur	1	22.7308808017	91.6043276122
PS-M15	Haitkandi	1	22.6918492413	91.5965002980

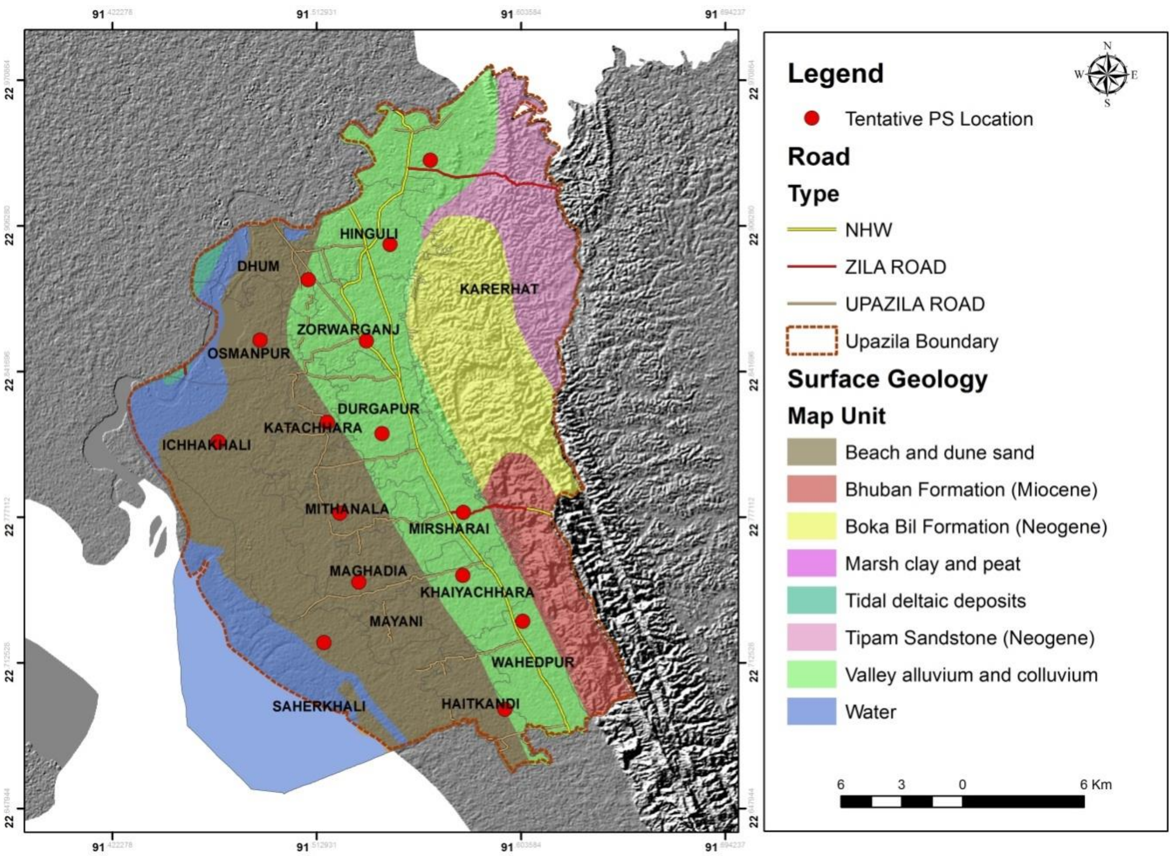

Figure6.3Tentative sites location for PS Logging test

Single microtremor survey Locations

Micro Tremor_ID	Union_Name	Test No. Each Union	Lat	Long
MT01	Karerhat	1	22.9440313972	91.5468582392
MT02	Hinguli	1	22.9164482972	91.5401911740
MT03	Dhum	1	22.8986794094	91.4966303568
MT04	Zorwarganj	2	22.8662252066	91.5420415158
MT05			22.8614124619	91.5209665964
MT06	Osmanpur	2	22.8407988601	91.4766901744
MT07			22.8500426874	91.5016484801
MT08	Durgapur	2	22.8141801609	91.5419058532
MT09			22.8304007749	91.5598322661
MT10	Katachhara	2	22.8384607316	91.5160222912
MT11			22.8191870974	91.5175689408
MT12	Ichhakhali	3	22.7653389220	91.4874420942
MT13			22.7623645958	91.5005291298
MT14			22.7492775602	91.4951753425
MT15	Mirsharai	4	22.8151865410	91.5678668772
MT16			22.8042210265	91.5734666800
MT17			22.8042242580	91.5634118212
MT18			22.7914941416	91.5823285362
MT19	Mithanala	3	22.7788997606	91.5231330103
MT20			22.7627194258	91.5164705195
MT21			22.7482974738	91.5316084336
MT22	Maghadia	1	22.7639269674	91.5444959357
MT23	Saherkhali	2	22.7290966474	91.5272450627
MT24			22.7169256825	91.5062715463
MT25	Khaiyachhara	2	22.7512579419	91.5777520815
MT26			22.7322222538	91.5783469467
MT27	Mayani	1	22.7157571134	91.5448768914
MT28	Wahedpur	2	22.6991019573	91.6227890801
MT29			22.7308808017	91.6043276122
MT30	Haitkandi	1	22.6702049875	91.6057672759

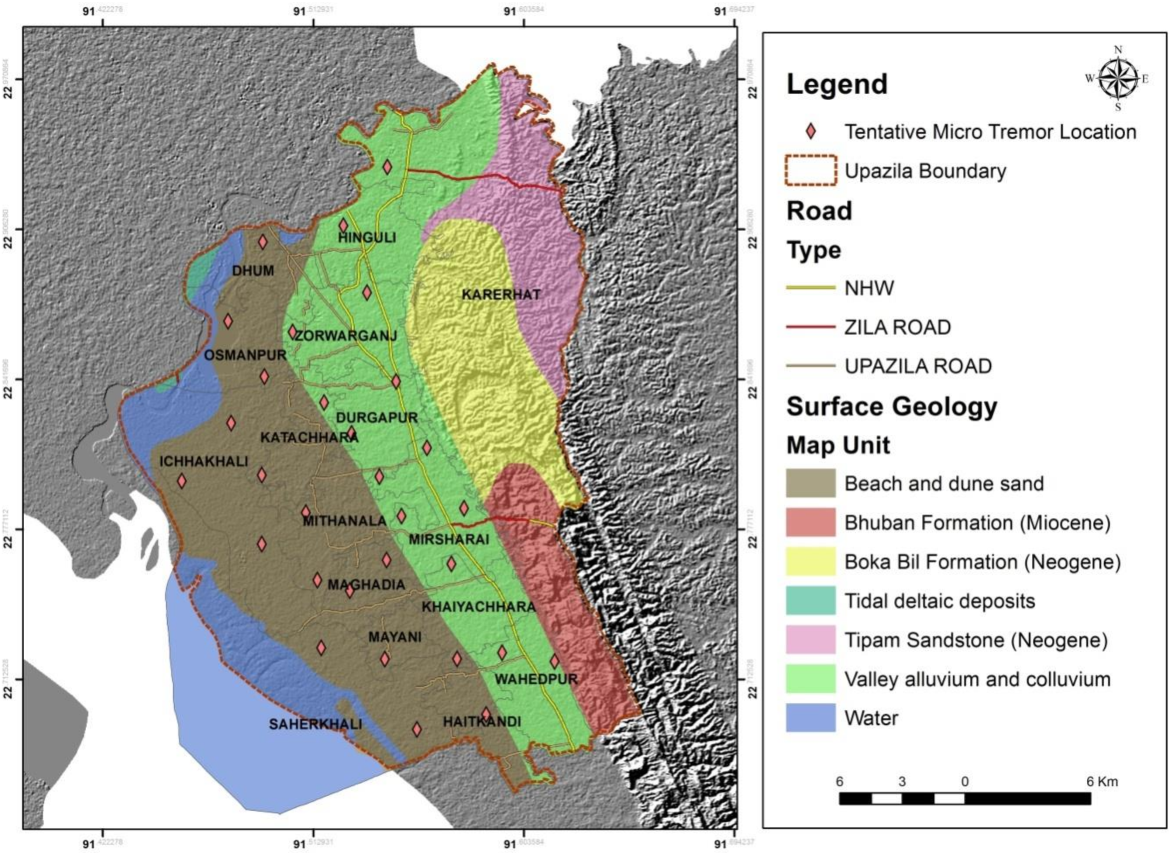

Figure6. 4 Tentative sites location for single microtremor survey

6.1. Time Schedule

No.	Activity	1st Month				2nd Month				3rd Month				4th Month				5th Month				6th Month			
		1	2	3	4	1	2	3	4	1	2	3	4		2	3	4		2	3	4	1	2	3	4
Activities																									
1	Site Selection for Geotechnical & Geophysical Works including Mobilization and demobilization																								
2	Conducting boring : SPT and Sample collection																								
3	Conducting Geophysical Test: Downhole seismic (PS logging), MASW & Microtremor																								
4	Lab Test and Analysis																								
5	Data Processing & Interpretation																								
6	Secondary data Collection																								
Deliverables																									
7	Mobilization Report																								
8	Inception Report																								
9	Review Report																								
10	Geo-technical & Geophysical test Report																								
11	Draft Report																								
12	Final Report																								

6.2. Deliveries

The following reports will be submitted to the UDD on or before the following dates:

Serial no.	Deliveries	Submitted date
1	Mobilization Report	24/12/2017
2	Inception Report	28/12/2017
3	Report on review of (i) Morphotectonic and neotectonic studies of Bangladesh and its surrounding areas, (ii) Geodynamic model of Bangladesh, (iii) Updating fault model, (iv) Report on geophysical and geotechnical investigations and engineering geological mapping (v) Land use interpretation of such reviews	15/02/2018
4	Geotechnical and Geophysical test Report	15/04/2018
5	Draft report on Data relating to Geo-technical and Geo-physical Survey including Laboratory test results including seismic hazard assessment and its interpretation	15/05/2018
6	Final Report on seismic hazard assessment and its interpretation	10/06/2018

7. RESOURCE ALLOCATION

Geophysical Test		
SL No.	**Name of Test/Survey**	**Test Category**
1	PS Logging	Down-hole Seismic Test (DS)
		Cross-hole Seismic Test (CS)
2	Multi-channel Analysis of Surface Wave	Active
3	Small Scale Microtremor Measurement (SSMM)	Passive
4	Microtremor Survey	Single Array
		MT Array
5	Electrical Resistivity Survey	Vertical Electrical Sounding (VES)
		2D Resistivity (Electrical Tomography)
		Spontaneous Potential (SP)

Geotechnical Test	
SL No.	**Name of Test/Survey**
In-Situ (Field)	
1	Standard Penetration Test (SPT)
2	Field Permeability Test
3	Field Van Shear Test
4	Pressure Meter Test
5	Field Density Test
Laboratory Test	
1	Water Content Determination
2	Organic Matter Determination
3	Density (Unit Weight) Determination
4	Specific Gravity of Soil Particles Determination
5	Relative Density Determination
6.	Grain Size Analysis
7	Atterberg Limits
8	Moisture-Density Relation(Compaction) Test
9	Permeability (Hydraulic Conductivity) Test
10	Consolidation Test
11	Unconfined Compression Strength(UCS) Test
12	Direct Shear Test
13	Tri-axial Compression Test (UU)

INSTRUMENT LISTS

Geophysical Equipment's

1.		Down-hole/Cross-hole Seismic Logger OLSON INSTRUMENTS, U.S.A.
2.		Multi-channel Analysis of Surface Wave (MASW) Survey Instrument. EXPLORATION SEISMOGRAPH PASI MOD. ANTEO
3.		4 pole Resistivity Meter OYO JAPAN
4.		MicrotremorSurvey Instrument Japan

Geotechnical Equipment's

1		Two sets of Standard Penetration Test Boring Rig
2		ELE International Triaxial Instrument
3		One Dimensional Consolidation Test Instrument ELE International
4		Direct Shear Test Instrument ELE International

5		Oven
6		Sieve shaker
7		Hydrometer

8. LIMITATION AND MITIGATION APPROACH

The project "Geological Study and Seismic Hazard Assessment" will contribute to develop a sustainable development plan for Mirsharai Upazila in Bangladesh. However, the project is quite challenging. The entrusted Consultant, EGS, of UDD, for this project, who has to accomplish the assigned task with limited time period. Accessibility of the project area is quite difficult, due to inadequate road network and hilly area as well as support of the local people is very important for accomplishing this project. Another limitation of the project is the availability and accessibility of secondary data.So we have to engage a team having a number of technicians, geologist and specialists; and we will do that accordingly. UDD will provide sufficient support regarding the secondary data issue. Thus the project will be much costlier than expected initially.

9. CONCLUSION

An intensive Geological and Geomorphological, Geotechnical, and Geophysical survey will be carried out for site characterization and sustainable development plan at Mirsharai Upazila, Chittagong of Bangladesh. From geotechnical and geological data base would give a clear idea about the geo-hazard status of particular landscape where newly urban developing activities or any other mega infrastructure project is going on and these mentioned investigation also gives an idea about the vulnerability of existing build up the infrastructure of a particular area. Based on these results, proper management techniques as well as other necessary adaptation process could be addressed before or after the development activities in the studied area. On the other hand, if the infrastructures are built according to this risk informed physical land-use plan, the long-term maintenance cost will be reduced and the developed structure will withstand against the potential natural hazards.