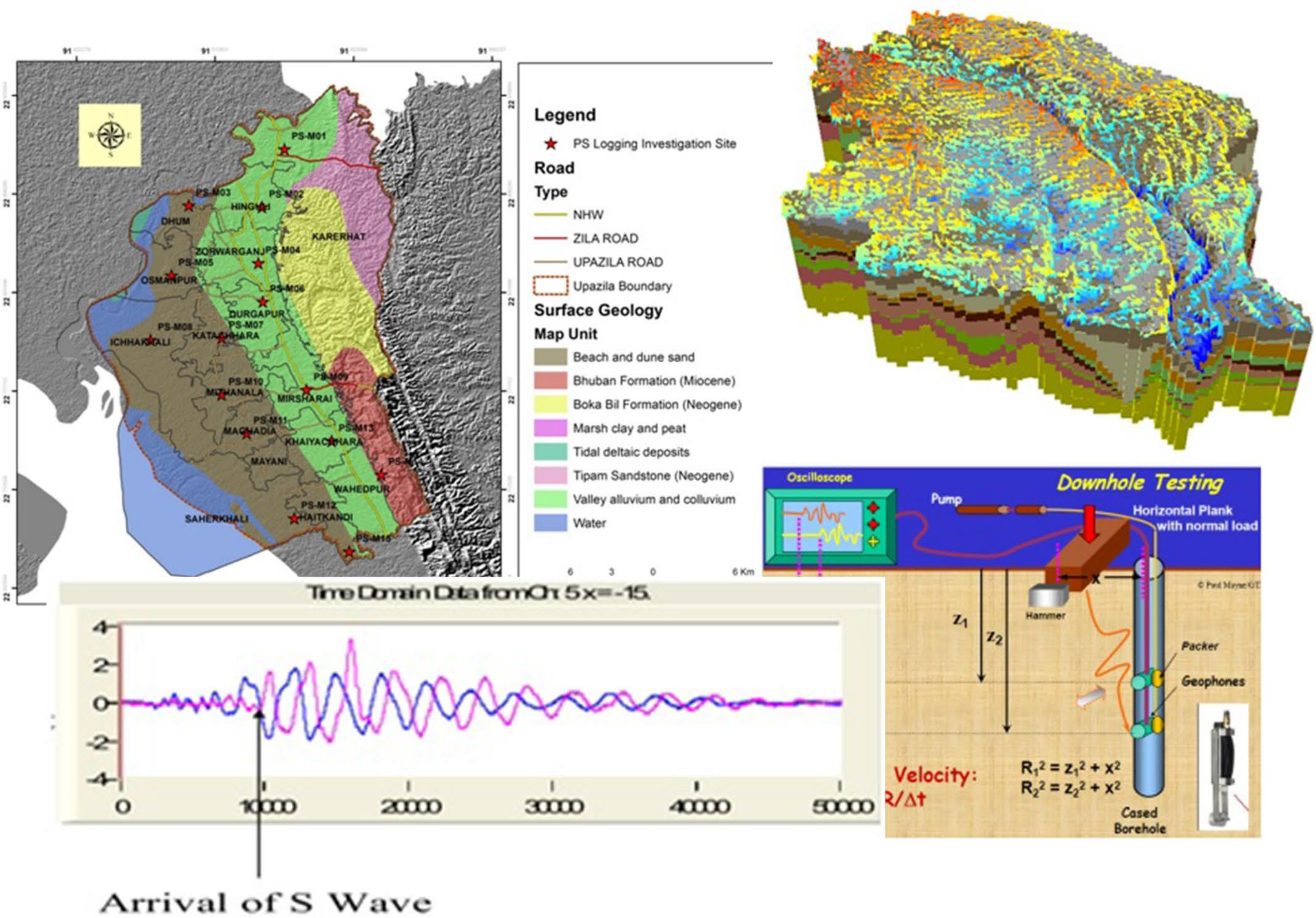
URBAN DEVELOPMENT DIRECTORATE (UDD)

Government of the People's Republic of Bangladesh

Inception 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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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. 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).

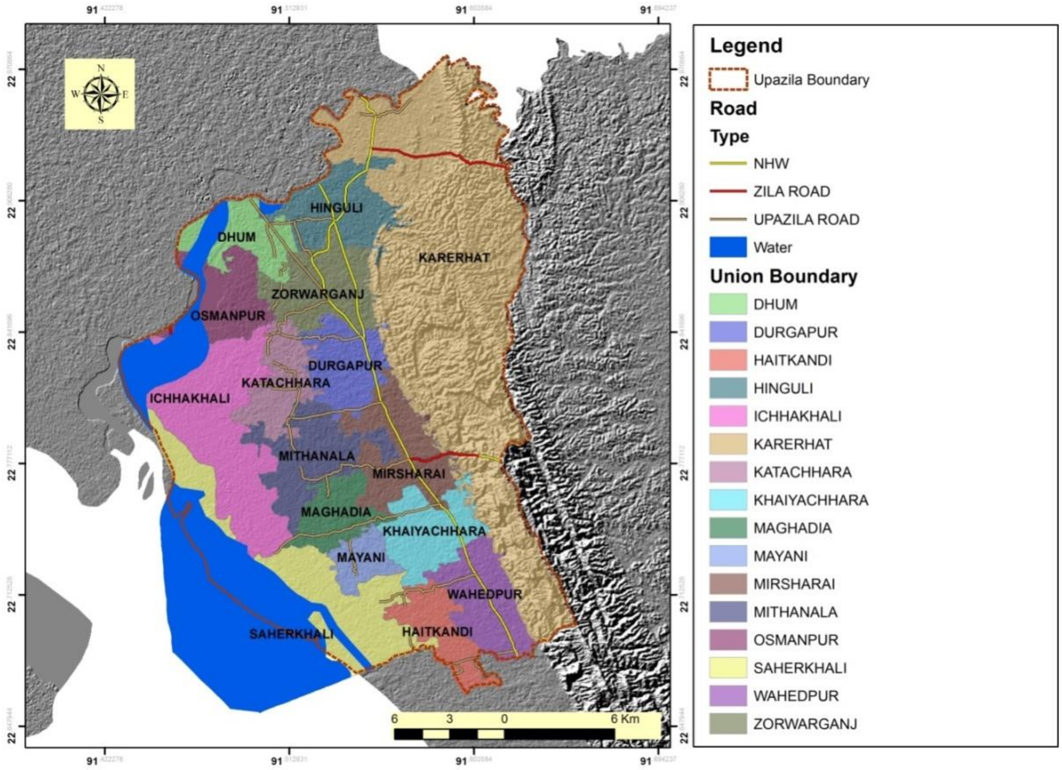


Figure 1.1 Location map of the project area

1.3. 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 0.2 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 potential index (LPI) 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.

2. METHODOLOGY

2.1. 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 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-

2.1.1. Geophysical Investigation

Field geophysical investigation is conducted to achieve the purpose of seismic risk and damage assessment. Seismic site characterization by analyzing seismic wave propagation velocity from acquired shallow seismic wave form data is the main objective. P-S logging, Multi Channel Analysis of Surface Wave (MASW) and Microtremor tools are involved in geophysical investigation.

General purposes of the geophysical survey:

- To estimate shear wave velocity and measure soil/rock properties (i.e. shear modulus, bulk modulus, compressibility, and Poisson's ratio)
- Engineering geological map development based on AVS30
- To Seismic site response study
- Risk Sensitive Building Height
- Characterization of strong motion sites
- Utilize this information for seismic hazard analysis

2.1.2. Geotechnical Investigation

Geotechnical investigations have become an essential component of every construction to ensure safety of human beings and materials. It includes a detailed investigation of the soil to determine the soil strength, composition, water content, and other important soil characteristics.

Geotechnical investigations are executed to acquire information regarding the physical characteristics of soil and rocks. The purpose of geotechnical investigations is to design earthworks and foundations for structures, and to execute earthwork repairs necessitated due to changes in the subsurface environment. A geotechnical examination includes surface and subsurface exploration, soil sampling, and laboratory analysis. Geotechnical investigations are also known as foundation analysis, soil analysis, soil testing, soil mechanics, and subsurface investigation. The samples are examined prior to the development of the location. Geotechnical investigations have acquired substantial importance in preventing human and material damage due to the earthquakes, foundation cracks, and other catastrophes.

Geotechnical investigations can be as simple as conducting only a visual assessment of the site or as detailed as a computer-aided study of the soil using laboratory tests.

General purposes of the geotechnical survey:

- Sub-surface lithological 3D model development
- Foundation layers delineation and developing engineering properties of the sub-soil
- Landslide vulnerable zones will be identified from the study
- Liquefaction susceptibility or Liquefaction potential index (LPI) map will be constructed from study data

Following investigations given in Table that will be conducted for the preparation of engineering geological maps for rural part of MUDP Project area:

Table : 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

2.2. Detail Procedures Of Survey/Testing

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-

2.2.1. 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 2.1 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.

Figure 2.2 Main Component of the Freedom Data PC

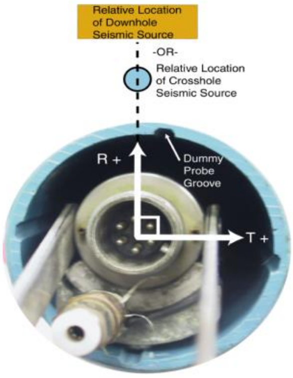


Figure 2.3 Receiver Orientation in Sinco casing

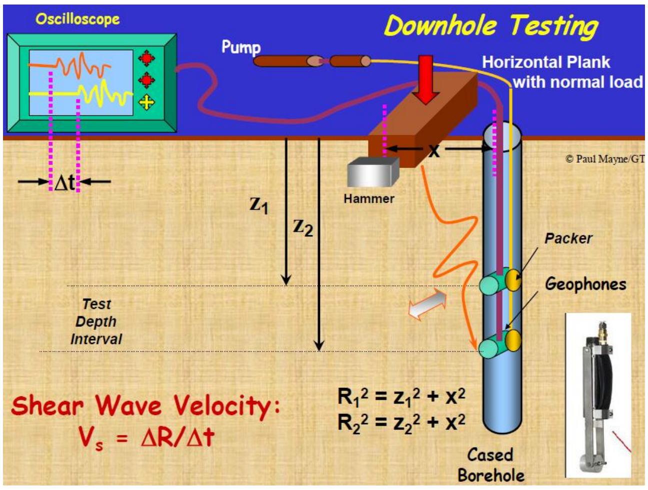


Figure 2.4 Calculation of Shear Wave Velocity by Down hole Seismic, where R_1=Distance between source to top geophone and R_2=Distance between source to bottom geophone

Figure 2.5 To set the wooden plank and sand bag 3.0 meters from a borehole

Figure 2.6 To attach the trigger to a hammer.

Figure 2.7 To connect the air pump with a battery.

Figure 2.8 To connect the computer with cables which are connected to the geophone.

Figure 2.9 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 2.10 Hit the wooden plank in 3 directions which are on the left, right and vertical directions.

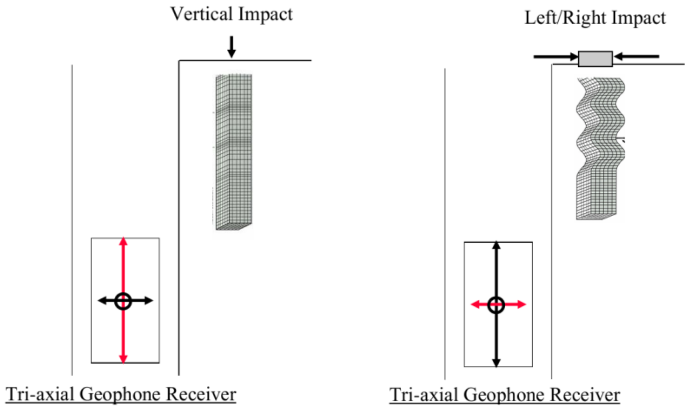


Figure 2.11 Triaxial geophone behavior.

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.

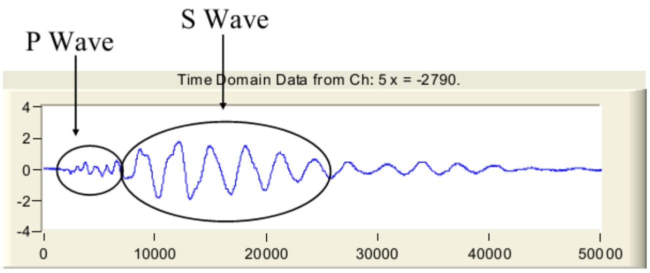


Figure 2.12 P wave and S wave in the Computer Window

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.

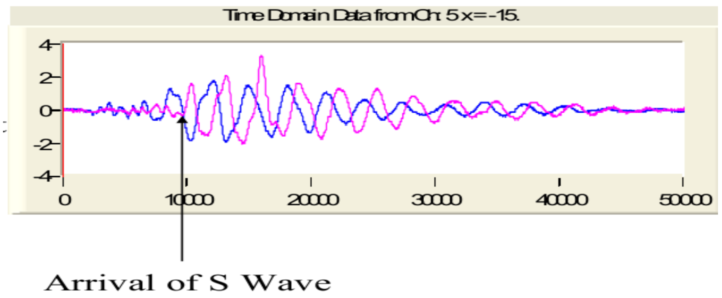


Figure 2.13 Arrival of S wave

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, *ρ*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 2.14 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.

2.2.2. 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 2.15. 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 2.16).

From field observation, the data in space-time domain (for instance, the left plot in Figure 3.19) 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.

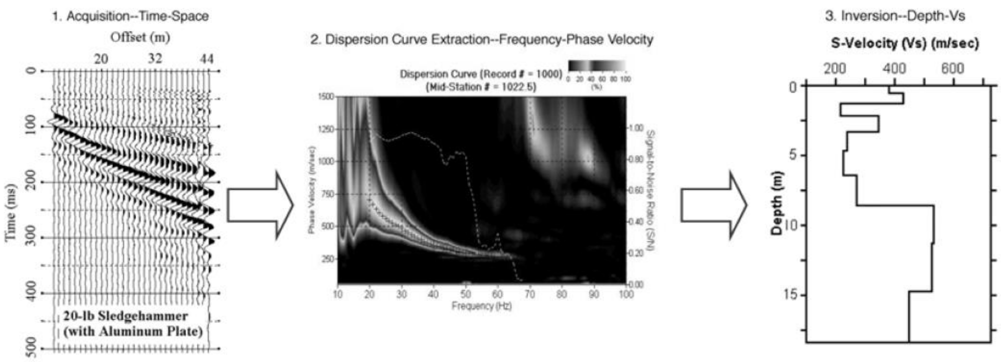


Figure 2.15 MASW data processing (Park et al., 1999)

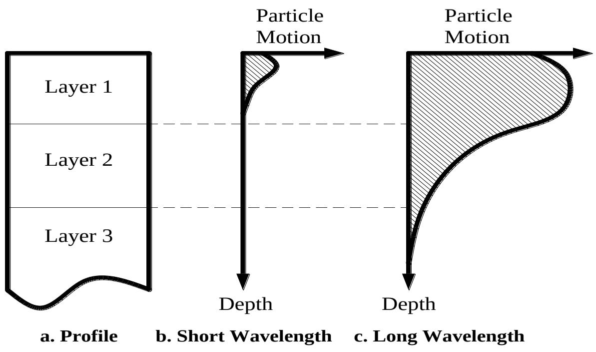


Figure 2.16 Rayleigh wave dispersion in layer media (Rix, 1988)

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.

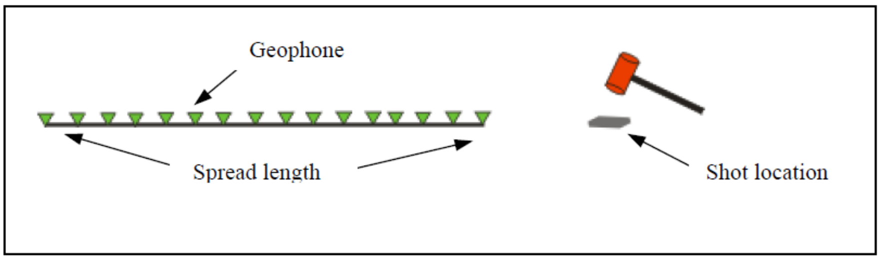
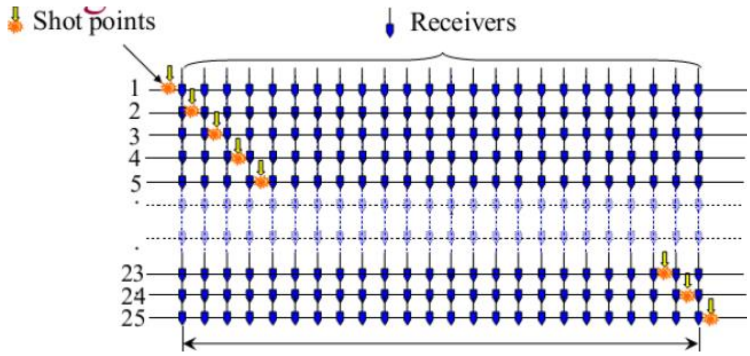


Figure 2.17 Schematic of linear active source spread configuration

During our field work we used 12 channels with 3m interval, 1.5 m source (sledge hammer) offset, 1 ms sample interval, 2 seconds record length and auto trigger option. Natural frequency of Geophone is 10 Hz. And the active source spread configuration for the station 20 was like below:



Survey Line Length

(Number of Sources= Number of Receivers + 1)

Figure 2.18 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.

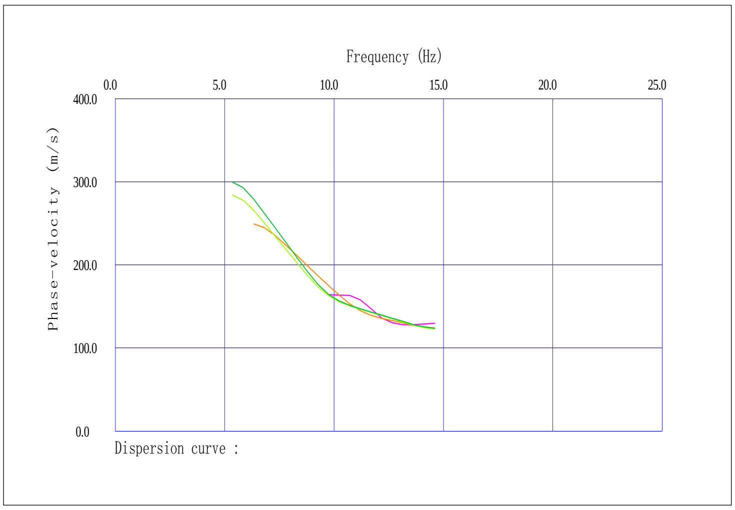


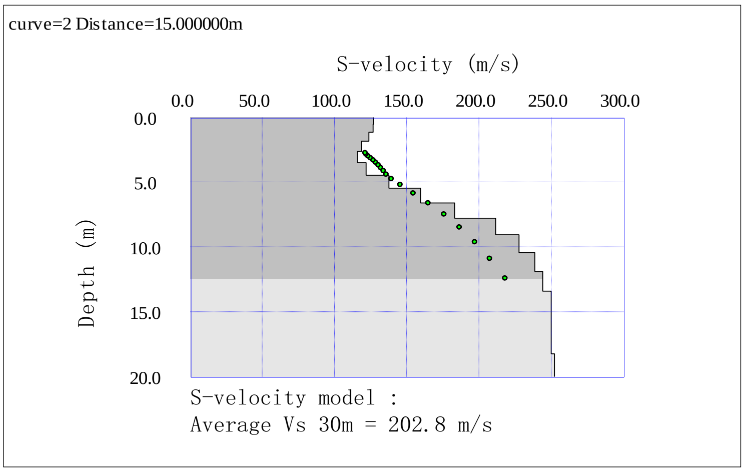
Figure 2.19 Dispersion Curve

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. 2.20.



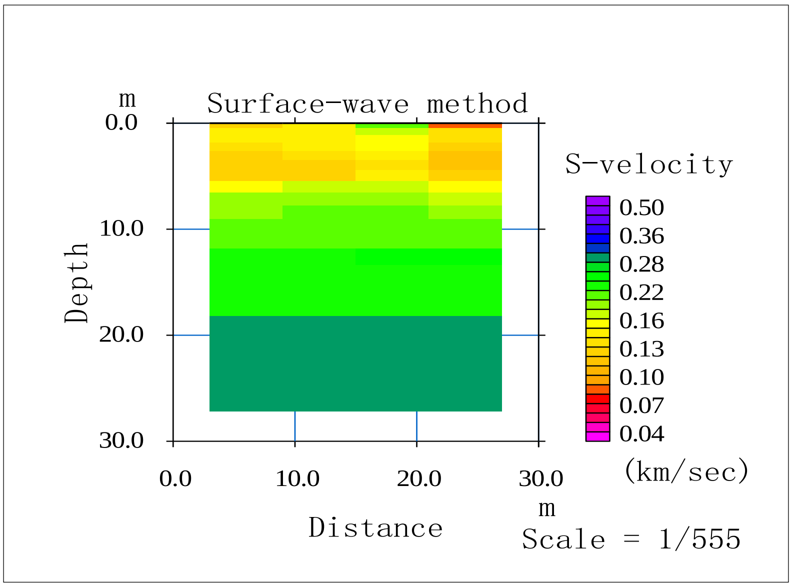


Figure 2.20 One dimensional Velocity Structure and 2 D velocity Model

Figure 2.21 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 2.22).

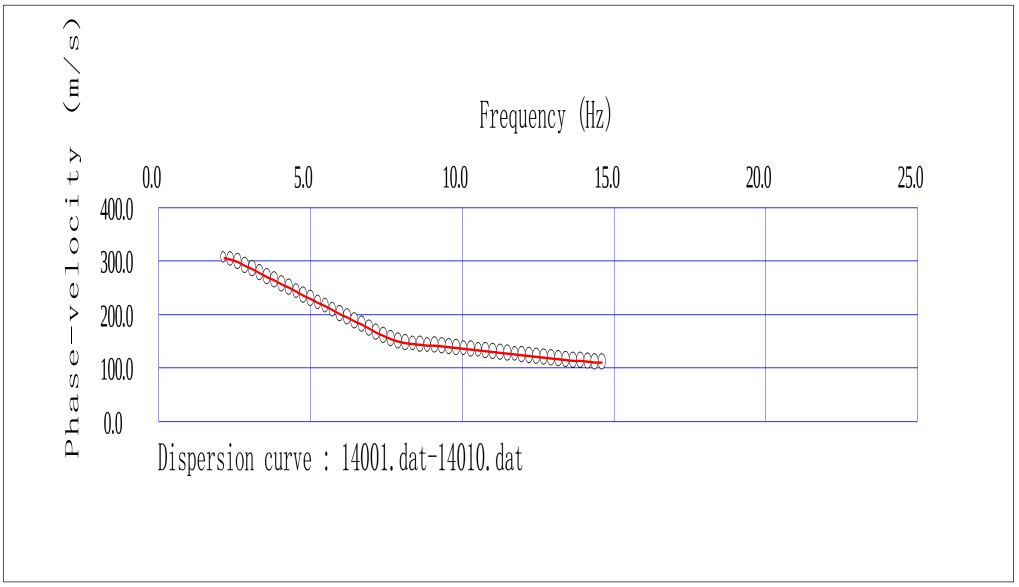


Figure 2.21 Dispersion Curve for Passive MASW

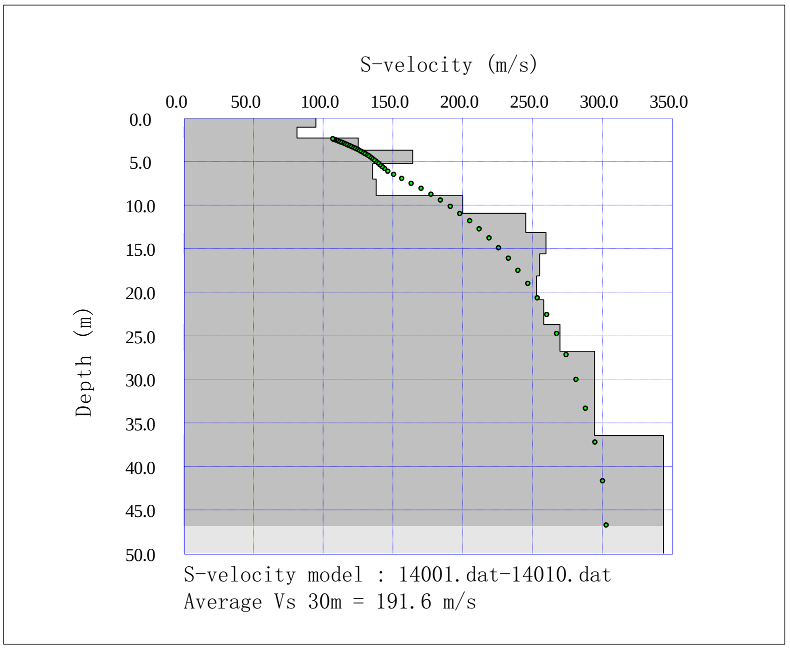


Figure 2.22 One dimensional velocity structure for Passive MASW

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 $\sum$Hi= 30

Vi= S wave velocity of the I th layer

2.2.3. 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

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

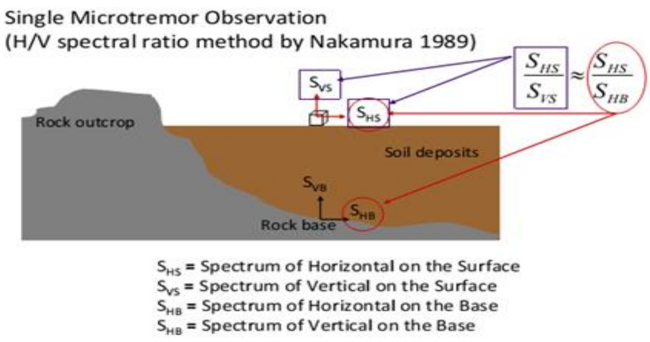


Figure 2.23 Fundamental of Single Microtremor observation

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 2.24 Field data acquisition of Single microtremor

2.2.4. 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.

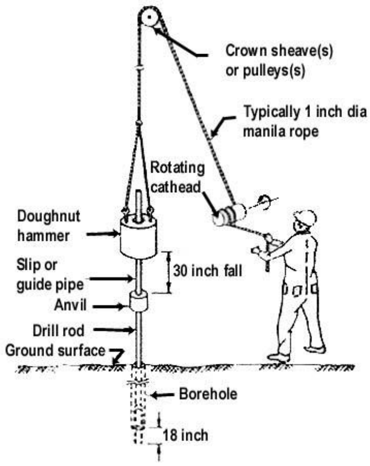


Figure 2.25 The SPT sampler in place in the boring with hammer, rope and cathead (Adapted from Kovacs, et al., 1981)

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.

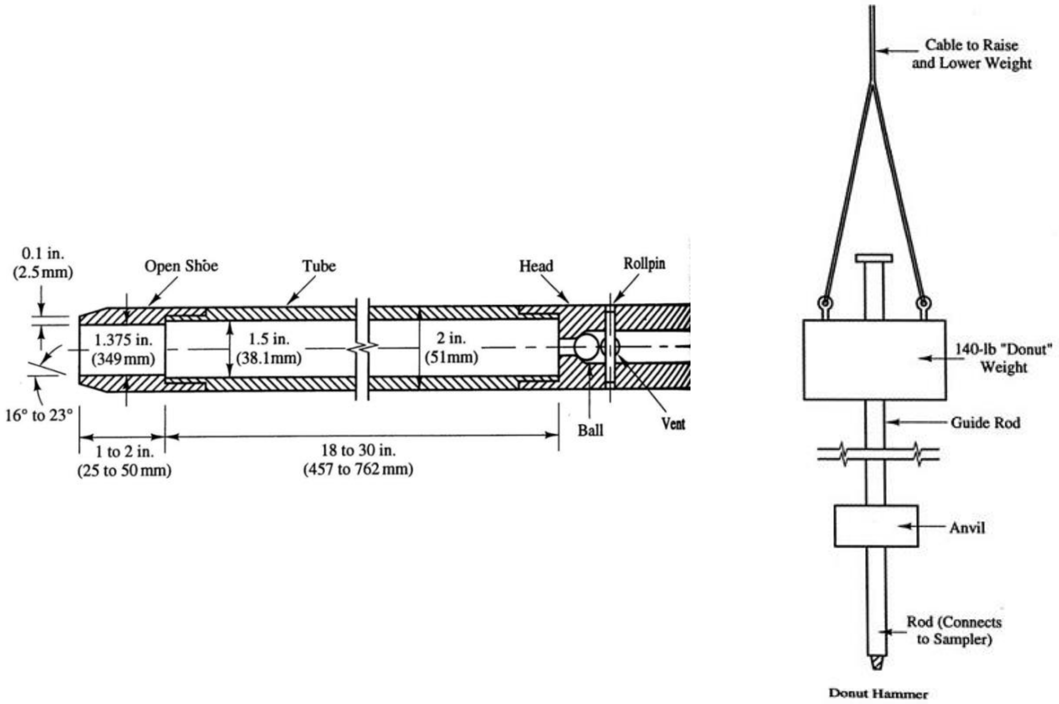


Figure 2.26 SPT Sampler and Donut Hammer

2.2.5. 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), 152 Hydrometer, Sedimentation cylinder, Control cylinder, Thermometer, Beaker,Timing device.

2.2.6. 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.

2.2.7. 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.

2.2.8. 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.

2.2.9. 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.

2.2.10. 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.

2.2.11. 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)

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

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):

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

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

2.3. Expected Outcome

The ultimate target is to develop the risk-informed and environment friendly physical plan. These outcomes shall further guide to develop the design of the infrastructures addressing their risk reduction aspects. Form the study the following information can be deliverables

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 0.2 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.

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.

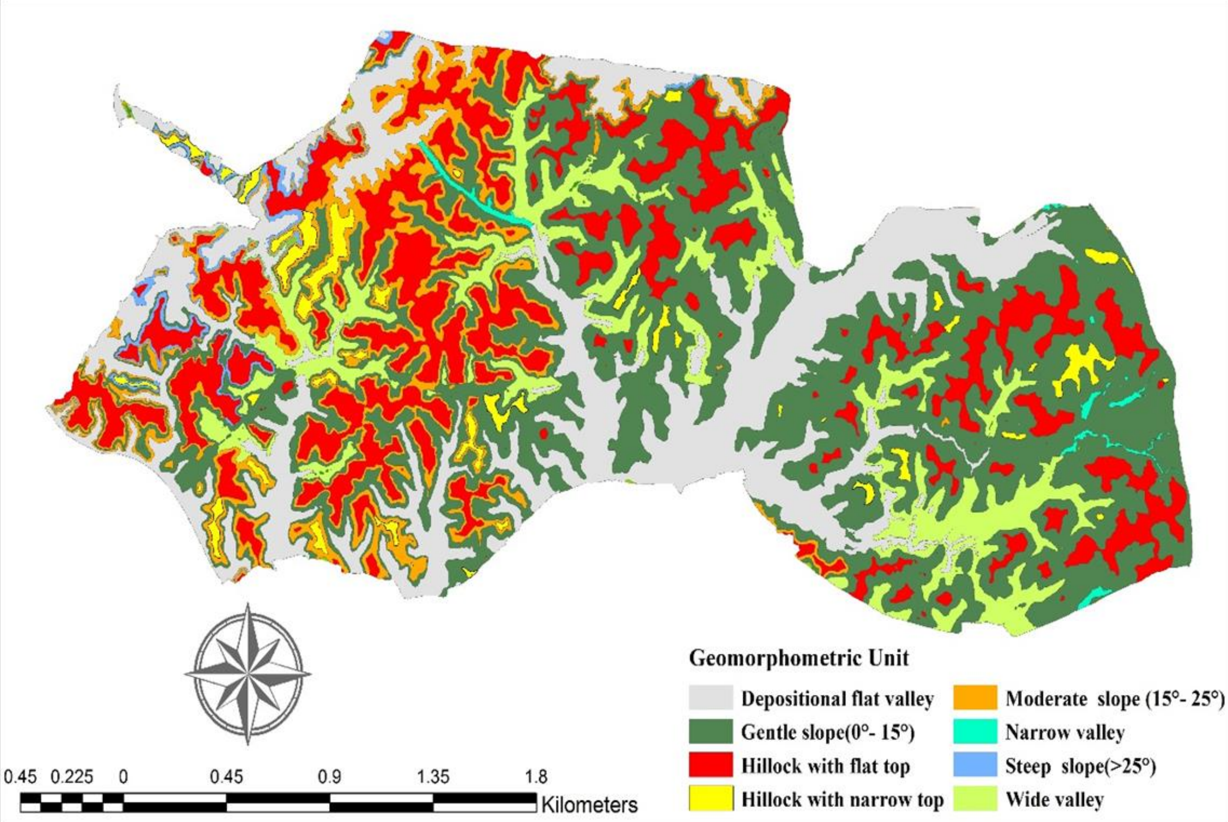


Figure 2.27 Geomorphological map

b) Subsurface 3D model of different layers through Geotechnical 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 illustrate the sub-soil condition and behavior if over-burden pressure and dynamic load are given in a specific site.

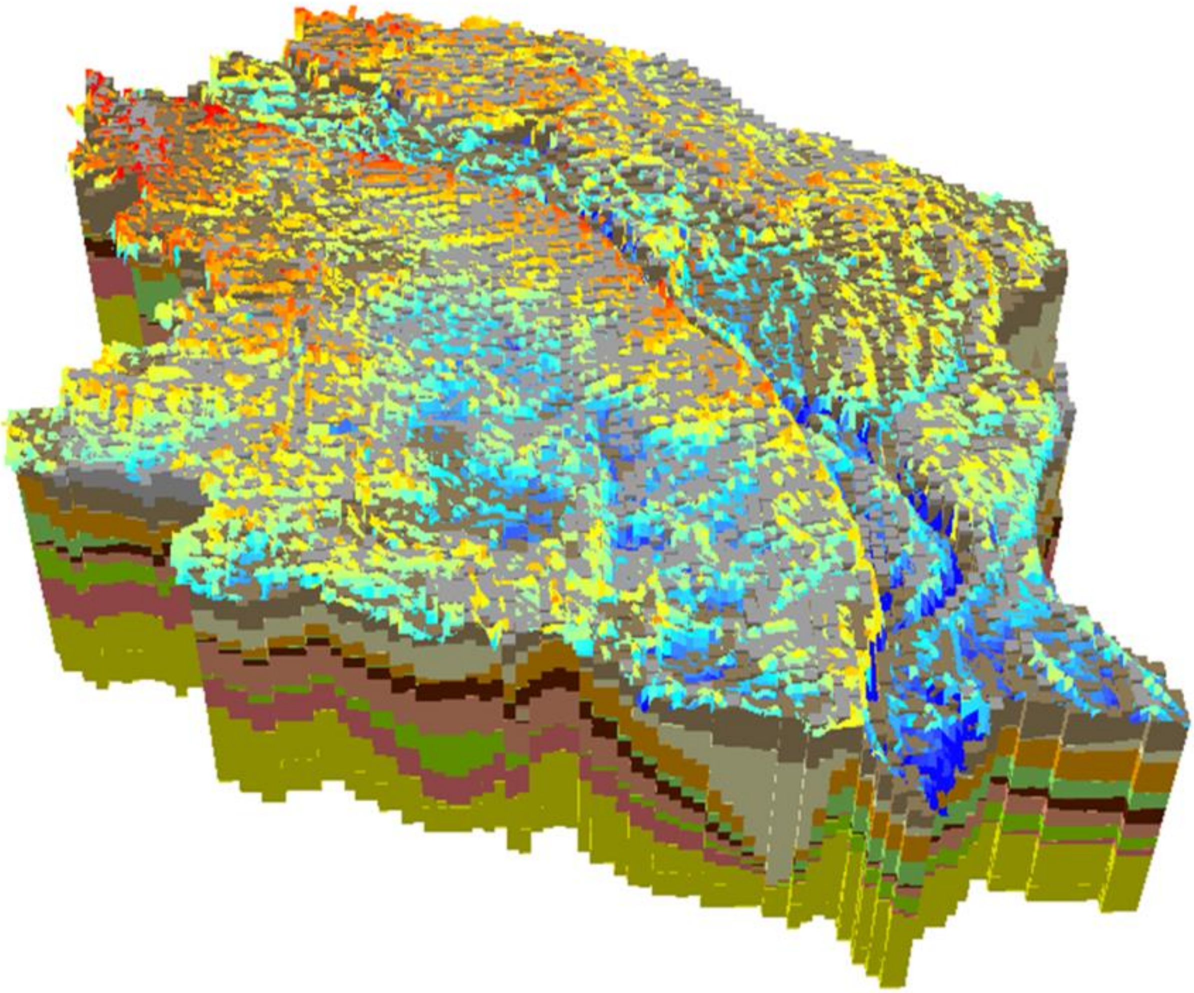


Figure 2.28 Subsurface Lithological 3D Model

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.

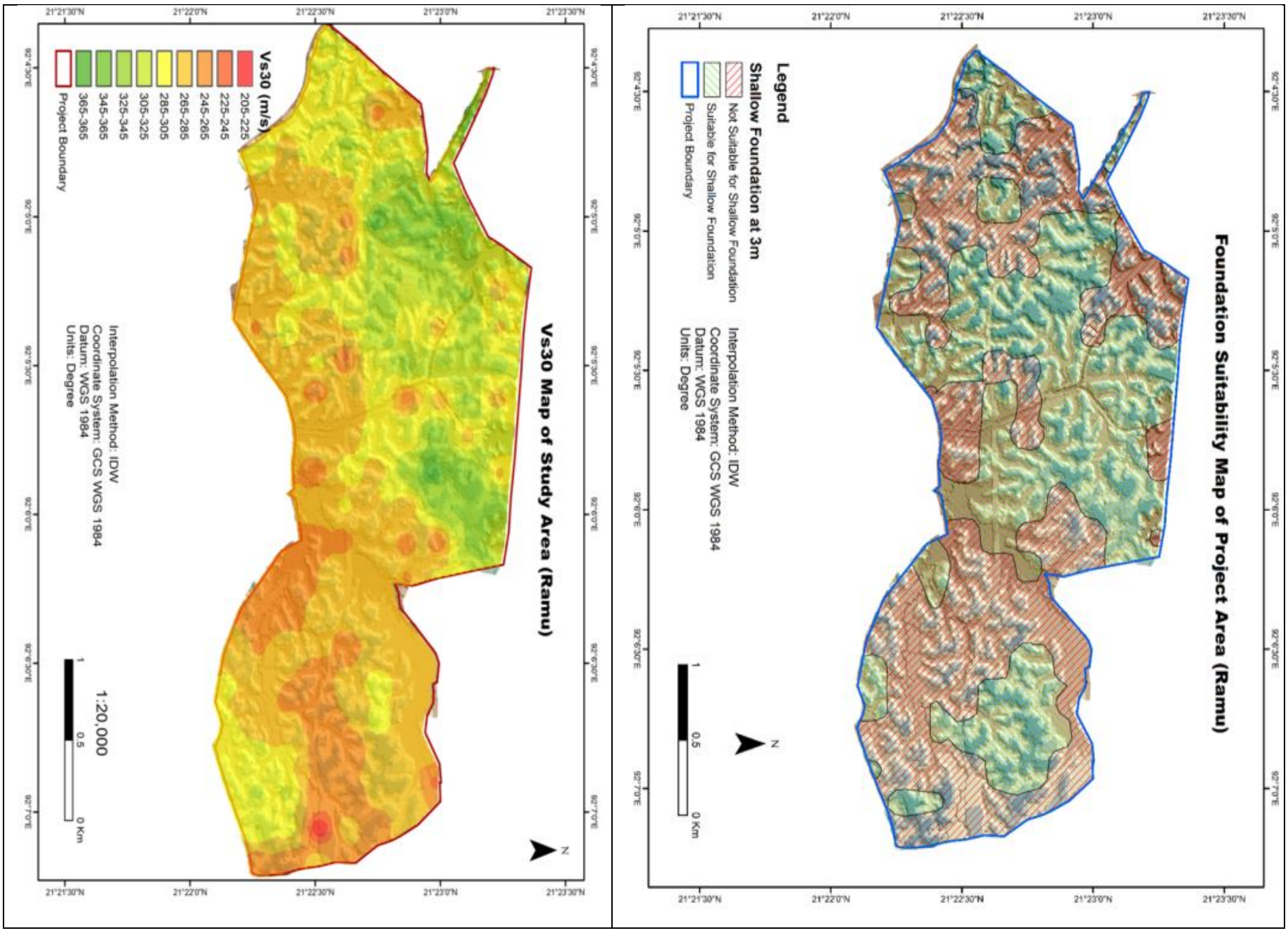


Figure 2.29 Engineering geological mapping based on AVS30 and Foundation Suitability map

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.

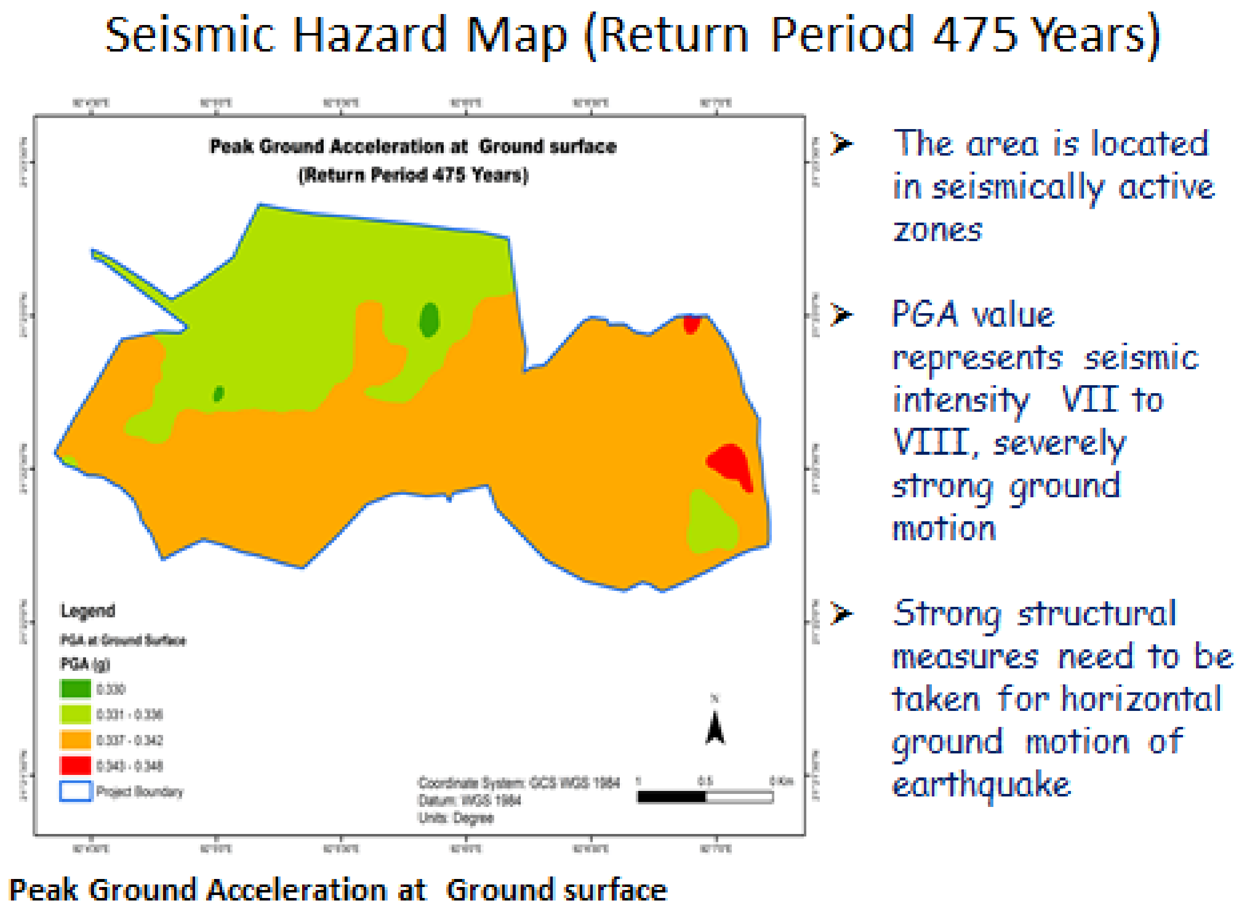


Figure 2.30 Seismic Hazard Map (Return Period 475 Years)

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.

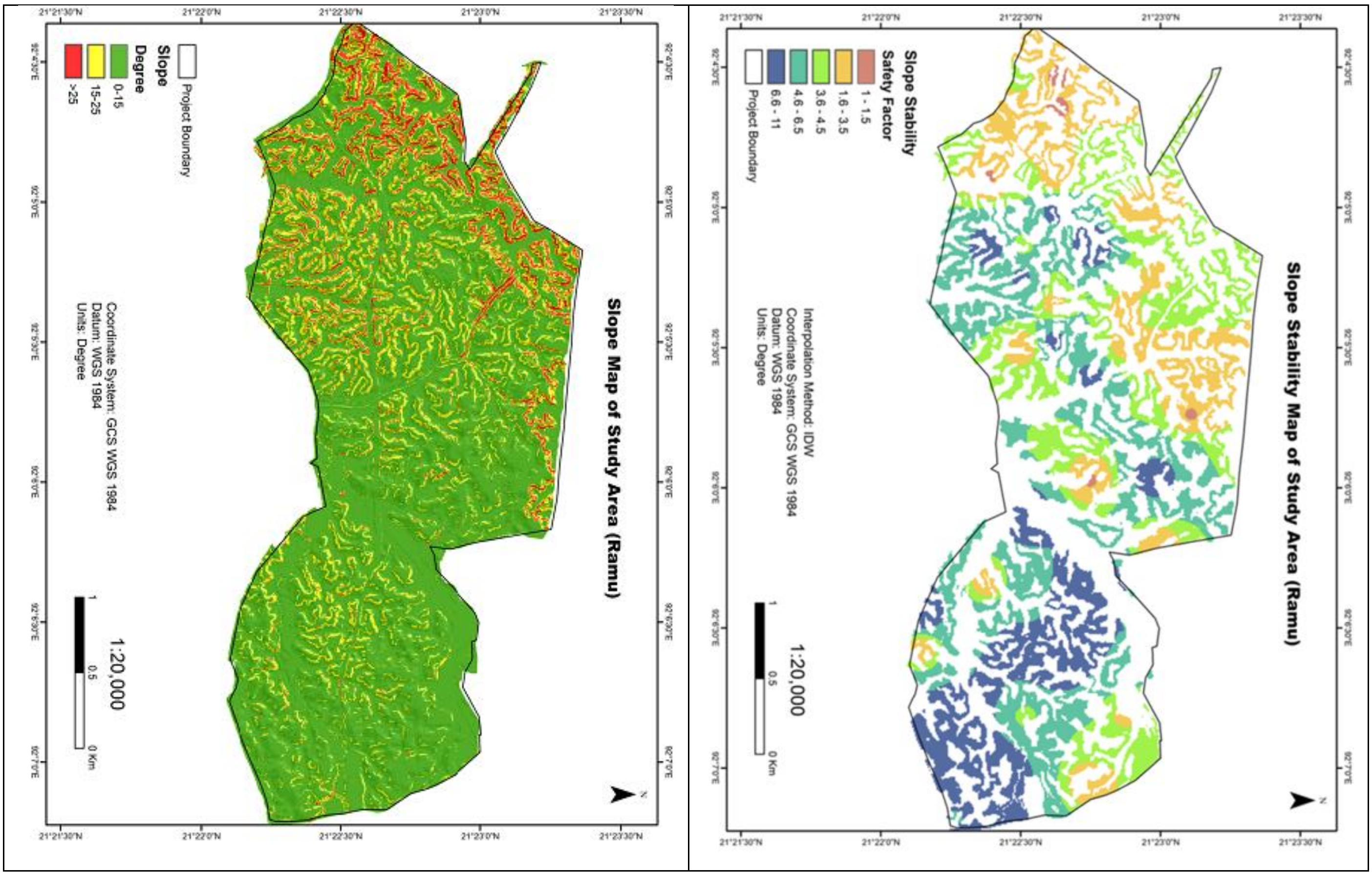


Figure 2.31 DEM based Slope Map and Slope Stability map

3. 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.

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.

85 Nos. of 30 m soils exploratory boring of 100 mm diameter will be conducted by mechanical percussion wash boring method at the locations according to the work plan. As 30 m boring is so complicated and time consuming moreover it will be done continuously to the end the boring, we decide to send two or three sets of team who will work in 8 hrs. In this manner the estimated time for boring execution 3- shifts will considered for mobilization, assemble and disassemble of the equipment, site cleanup and backfill the bore holes to their pre-existing condition. During boring work, geophysical survey will also be carried out during the same field work period. So a separate team will be make involved to conduct this geophysical survey respectively, fifteen (15) PS Logging, twenty (20) MASW, and thirty (30) Microtremor (single array). Considering all these works and conditions a work plan is submitted to the client as shown in the table below:

SL No	Types of Survey	No. of Test	Starting Date	Finishing Date	Remarks
1	Site Selection		21/12/2017	26/12/2017	
2	Standard Penetration Test	85	19/01/2018	20/02/2018	Two or three SPT will be done per day
3	Borehole preparation for PS Logging Test	15	29/01/2018	15/02/2018	
4	PS Logging	15	10/02/2018	27/02/2018	At least two PS Logging will be done per day
5	MASW	20	06/02/2018	12/02/2018	At least three MASW will be done per day
6	Microtremor (Single)	30	06/02/2018	15/02/2018	At least three Microtremor (single) will be done per day

3.1. Site Selection Activities

Our team has visited to entire Mirsharai Upazila from 21st December, 2017 to 26th December, 2017 for suitable site selection. To accomplish this project eighty five (85) no. borehole sites have been selected for SPT test. Beside this, geophysical investigations sites are also selected such as fifteen (15) Downhole seismic, Twenty (20) MASW, thirty (30) single Microtemor respectively. All investigated points (i.e. Borehole, Downhole seismic, MASW and Microtemor) have been selected by considering Surface geologic unit, union boundaries, accessibility and well distribution.

Geotechnical and Geophysical investigations' sites selection








Geotechnical and Geophysical investigations' sites selection

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	14	1	3	4
2	Wahedpur	19.37	4	1	1	2
3	Osmanpur	17.77	5	1		3
4	Karerhat	25.27/130	5	1	1	2
5	Katachhara	14.1	4	1	2	2
6	Khaiyachhara	17.76	4	1	1	1
7	Zorwarganj	21.01	4	1	1	2
8	Durgapur	16.59	3	1	1	2
9	Dhum	16.71	2	1	1	
10	Maghadia	12.27	6	1	1	1
11	Mayani	7.67	5			2
12	Mithanala	21.68	3	1	1	1
13	Mirsharai	22.45	10	1	2	2
14	Saherkhali	25.55/57.08	7	1	2	2
15	Haitkandi	13.13	3	1	1	1
16	Hinguli	20.14	6	1	2	3
17	**Total area**	**459.00**	**85**	**15**	**20**	**30**

Standard Penetration Test (SPT) Locations

BH_ID	Union Name	Number of BH in Each Union	Latitude	Longitude
BH-M01	Karerhat	5	22.942860	91.542070
BH-M02			22.935760	91.558390
BH-M03			22.924630	91.573790
BH-M04			22.962630	91.582600
BH-M05			22.933480	91.566450
BH-M06	Hinguli	6	22.915570	91.540312
BH-M07			22.897790	91.543600
BH-M08			22.893160	91.529400
BH-M09			22.887470	91.554890
BH-M10			22.900370	91.520560
BH-M11			22.879500	91.531861
BH-M12	Dhum	2	22.898770	91.495730
BH-M13			22.882040	91.510530
BH-M14	Zorwarganj	4	22.861027	91.541257
BH-M15			22.859357	91.517412
BH-M16			22.878152	91.549317
BH-M17			22.844480	91.554580
BH-M18	Osmanpur	5	22.881955	91.480864
BH-M19			22.842960	91.476640
BH-M20			22.853736	91.499971
BH-M21			22.872450	91.496410
BH-M22			22.852950	91.484320
BH-M23	Durgapur	3	22.815110	91.540820
BH-M24			22.830401	91.559832
BH-M25			22.835690	91.544190
BH-M26	Katachhara	4	22.837873	91.517807
BH-M27			22.811930	91.517300
BH-M28			22.799670	91.513710
BH-M29			22.812968	91.494089
BH-M30	Ichhakhali	14	22.762365	91.500529
BH-M31			22.752624	91.504095
BH-M32			22.800810	91.489639
BH-M33			22.834310	91.454730
BH-M34			22.734210	91.502110
BH-M35			22.826650	91.483520
BH-M36			22.792330	91.464520
BH-M37			22.752050	91.517220
BH-M38			22.762310	91.466640
BH-M39			22.778740	91.471530
BH-M40			22.810600	91.470700
BH-M41			22.822170	91.451290
BH-M42			22.829219	91.502083
BH-M43			22.746920	91.485370
BH-M44	Mirsharai	10	22.819160	91.567710
BH-M45			22.804550	91.572620
BH-M46			22.803540	91.560390
BH-M47			22.786310	91.582440
BH-M48			22.779420	91.595750
BH-M49			22.788560	91.550940
BH-M50			22.777930	91.572750
BH-M51			22.793450	91.568980
BH-M52			22.772000	91.575070
BH-M53			22.781040	91.562650
BH-M54	Mithanala	3	22.788641	91.506424
BH-M55			22.774710	91.517090

BH-M56			22.784000	91.532620
BH-M57	Maghadia	6	22.737610	91.562350
BH-M58			22.758420	91.562760
BH-M59			22.761810	91.529500
BH-M60			22.749420	91.533530
BH-M61			22.765650	91.557500
BH-M62			22.737870	91.533290
BH-M63	Saherkhali	7	22.685740	91.585550
BH-M64			22.720860	91.516030
BH-M65			22.711020	91.530490
BH-M66			22.696470	91.548760
BH-M67			22.762310	91.466640
BH-M68			22.711000	91.564900
BH-M69			22.693690	91.564690
BH-M70	Khaiyachhara	4	22.768660	91.566040
BH-M71			22.762449	91.610257
BH-M72			22.744420	91.589260
BH-M73			22.770992	91.601457
BH-M74	Mayani	5	22.754240	91.577700
BH-M75			22.729820	91.579090
BH-M76			22.717450	91.545700
BH-M77			22.732640	91.542260
BH-M78			22.745690	91.556500
BH-M79	Wahedpur	4	22.699102	91.622789
BH-M80			22.727814	91.603446
BH-M81			22.722355	91.621741
BH-M82			22.709230	91.605770
BH-M83	Haitkandi	3	22.683040	91.621830
BH-M84			22.671930	91.600630
BH-M85			22.712090	91.578900

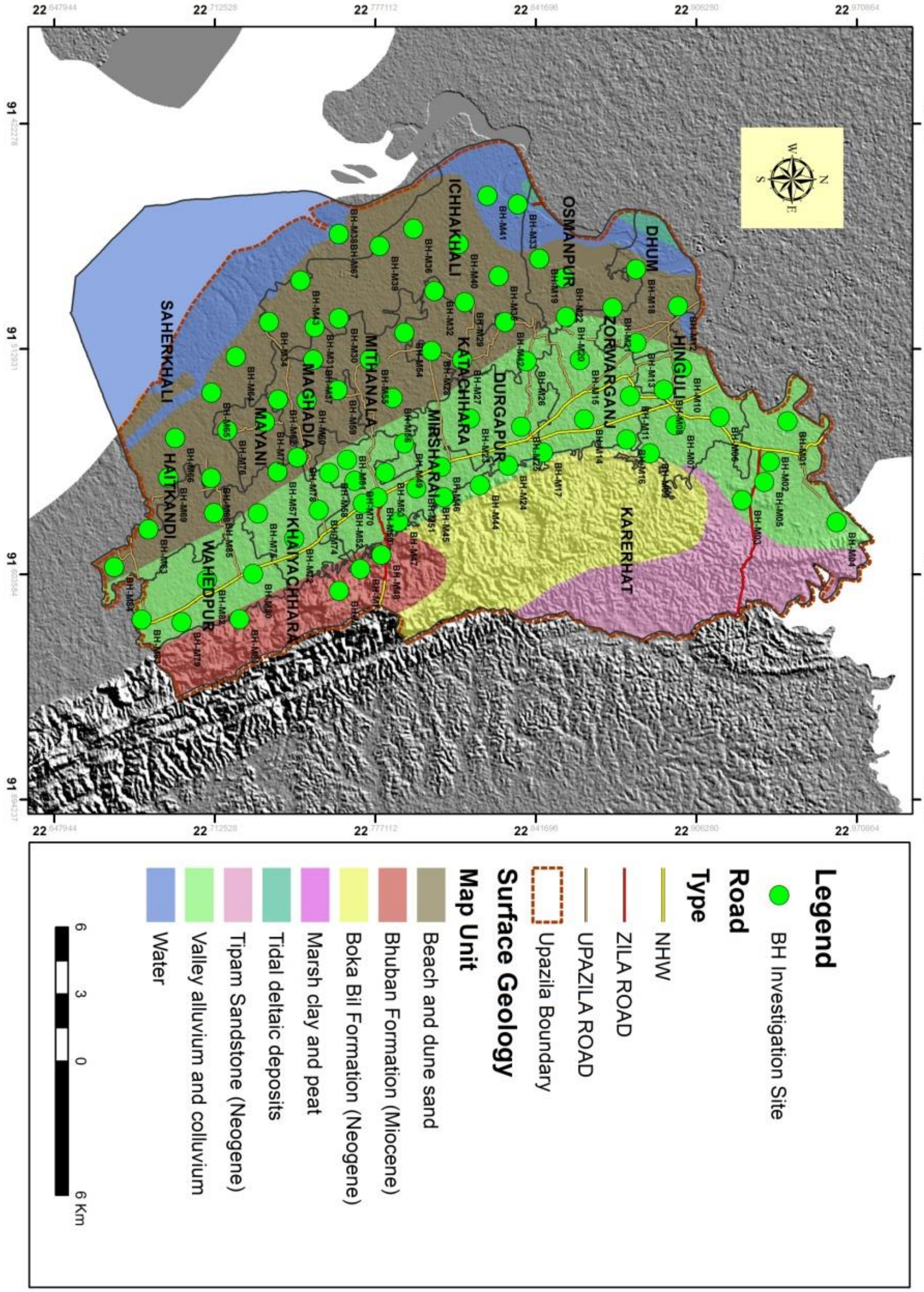


Figure 3.1 Borehole location for SPT test

MASW Survey Locations

MASW ID	Union_Name	Num. of Investigation Each Union	Latitude	Longitude
MASW-M01	Karerhat	1	22.947710	91.568720
MASW-M02	Hinguli	2	22.899470	91.556120
MASW-M03			22.895610	91.520730
MASW-M04	Dhum	1	22.880310	91.512050
MASW-M05	Zorwarganj	1	22.873480	91.539310
MASW-M06	Durgapur	1	22.817609	91.554702
MASW-M07	Katachhara	2	22.845840	91.507340
MASW-M08			22.821742	91.513339
MASW-M09	Ichhakhali	3	22.784200	91.470000
MASW-M10			22.750940	91.487560
MASW-M11			22.826650	91.483520
MASW-M12	Mirsharai	2	22.778550	91.586460
MASW-M13			22.788560	91.550940
MASW-M14	Mithanala	1	22.771220	91.529683
MASW-M15	Maghadia	1	22.749893	91.552942
MASW-M16	Saherkhali	2	22.699710	91.544640
MASW-M17			22.733950	91.503290
MASW-M18	Khaiyachhara	1	22.728780	91.573000
MASW-M19	Wahedpur	1	22.703799	91.612780
MASW-M20	Haitkandi	1	22.708140	91.568470

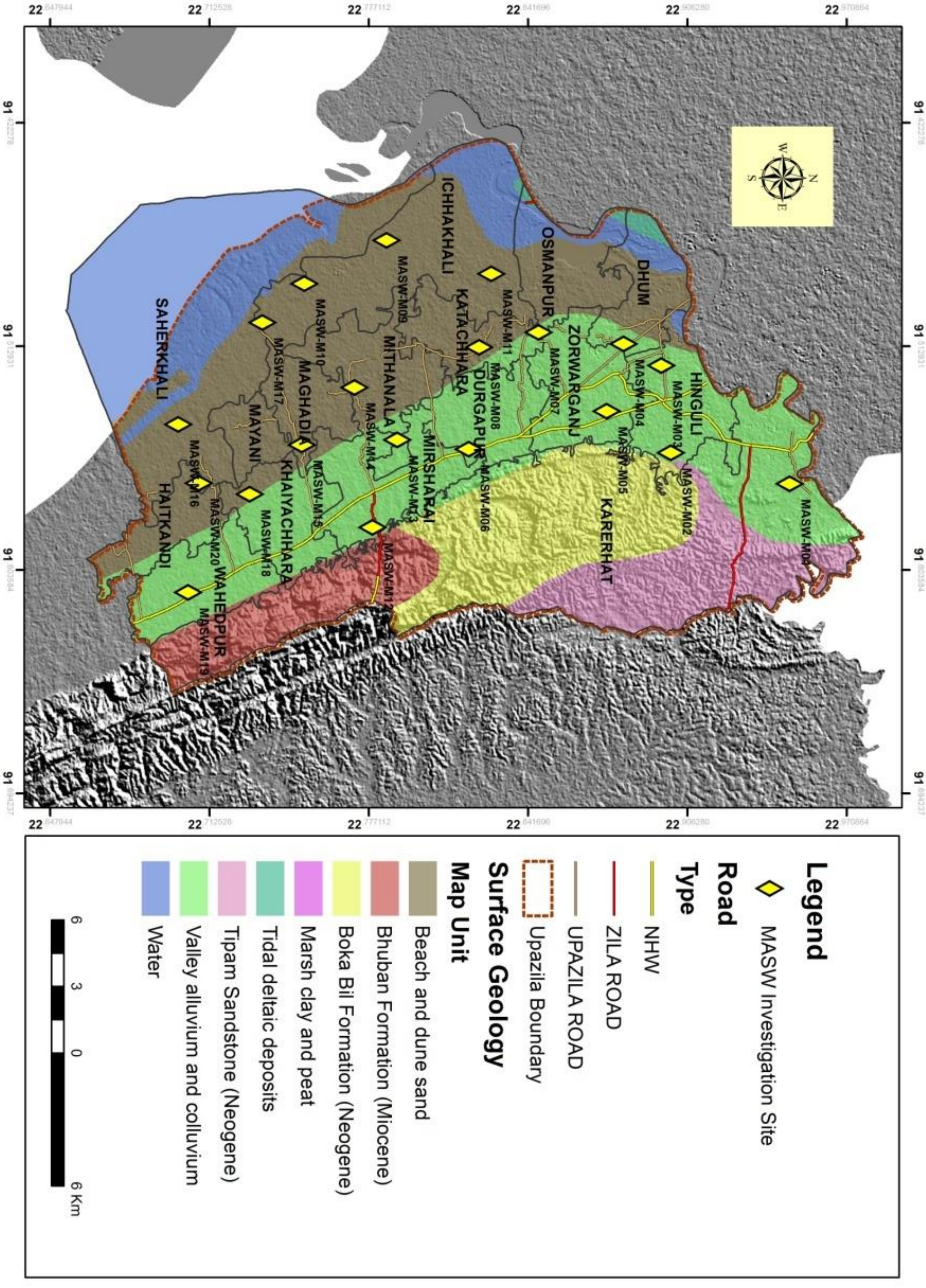


Figure 3.2 Location for MASW survey

PS Logging Test Locations

PS_ID	Union_Name	Test No. Each Union	Latitude	Longitude
PS-M01	Karerhat	1	22.935760	91.558390
PS-M02	Hinguli	1	22.897790	91.543600
PS-M03	Dhum	1	22.898770	91.495730
PS-M04	Zorwarganj	1	22.861027	91.541257
PS-M05	Osmanpur	1	22.852950	91.484320
PS-M06	Durgapur	1	22.835690	91.544190
PS-M07	Katachhara	1	22.811930	91.517300
PS-M08	Ichhakhali	1	22.810600	91.470700
PS-M09	Mirsharai	1	22.777930	91.572750
PS-M10	Mithanala	1	22.774710	91.517090
PS-M11	Maghadia	1	22.749420	91.533530
PS-M12	Saherkhali	1	22.693690	91.564690
PS-M13	Khaiyachhara	1	22.744420	91.589260
PS-M14	Wahedpur	1	22.722355	91.621741
PS-M15	Haitkandi	1	22.671930	91.600630

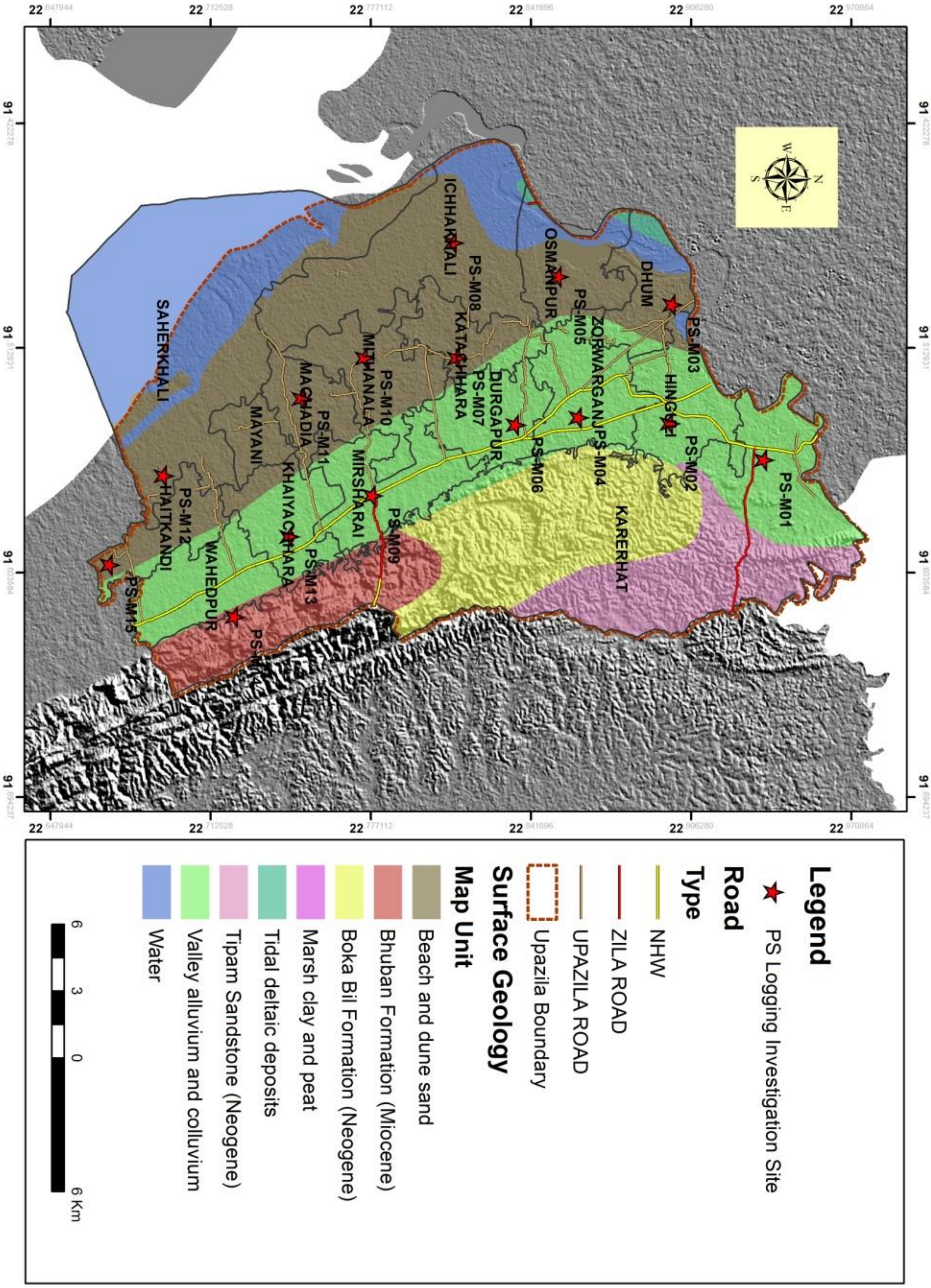


Figure 3.3 Location for PS Logging test

Single Microtremor survey Locations

Micro-Tremor ID	Union	Num. of Test Each Union	Latitude	Longitude
MT-M01	Karerhat	2	22.938246	91.544377
MT-M02			22.958477	91.581216
MT-M03	Hinguli	3	22.918338	91.542619
MT-M04			22.886086	91.550737
MT-M05			22.878116	91.527708
MT-M06	Zorwarganj	2	22.854743	91.518335
MT-M07			22.847248	91.549966
MT-M08	Osmanpur	3	22.884723	91.485017
MT-M09			22.841576	91.483100
MT-M10			22.870604	91.494103
MT-M11	Durgapur	2	22.813264	91.538052
MT-M12			22.830401	91.556141
MT-M13	Katachhara	2	22.839257	91.524728
MT-M14			22.799670	91.513710
MT-M15	Ichhakhali	4	22.767902	91.498222
MT-M16			22.807270	91.491946
MT-M17			22.795098	91.469595
MT-M18			22.829219	91.502083
MT-M19	Mirsharai	2	22.802156	91.541473
MT-M20			22.793450	91.568980
MT-M21	Mithanala	1	22.784000	91.532620
MT-M22	Maghadia	1	22.738071	91.552661
MT-M23	Saherkhali	2	22.680665	91.592932
MT-M24			22.738393	91.513723
MT-M25	Khaiyachhara	1	22.768660	91.566040
MT-M26	Mayani	2	22.751933	91.570779
MT-M27			22.717911	91.540625
MT-M28	Wahedpur	2	22.693565	91.623712
MT-M29			22.732428	91.609444
MT-M30	Haitkandi	1	22.715320	91.586744

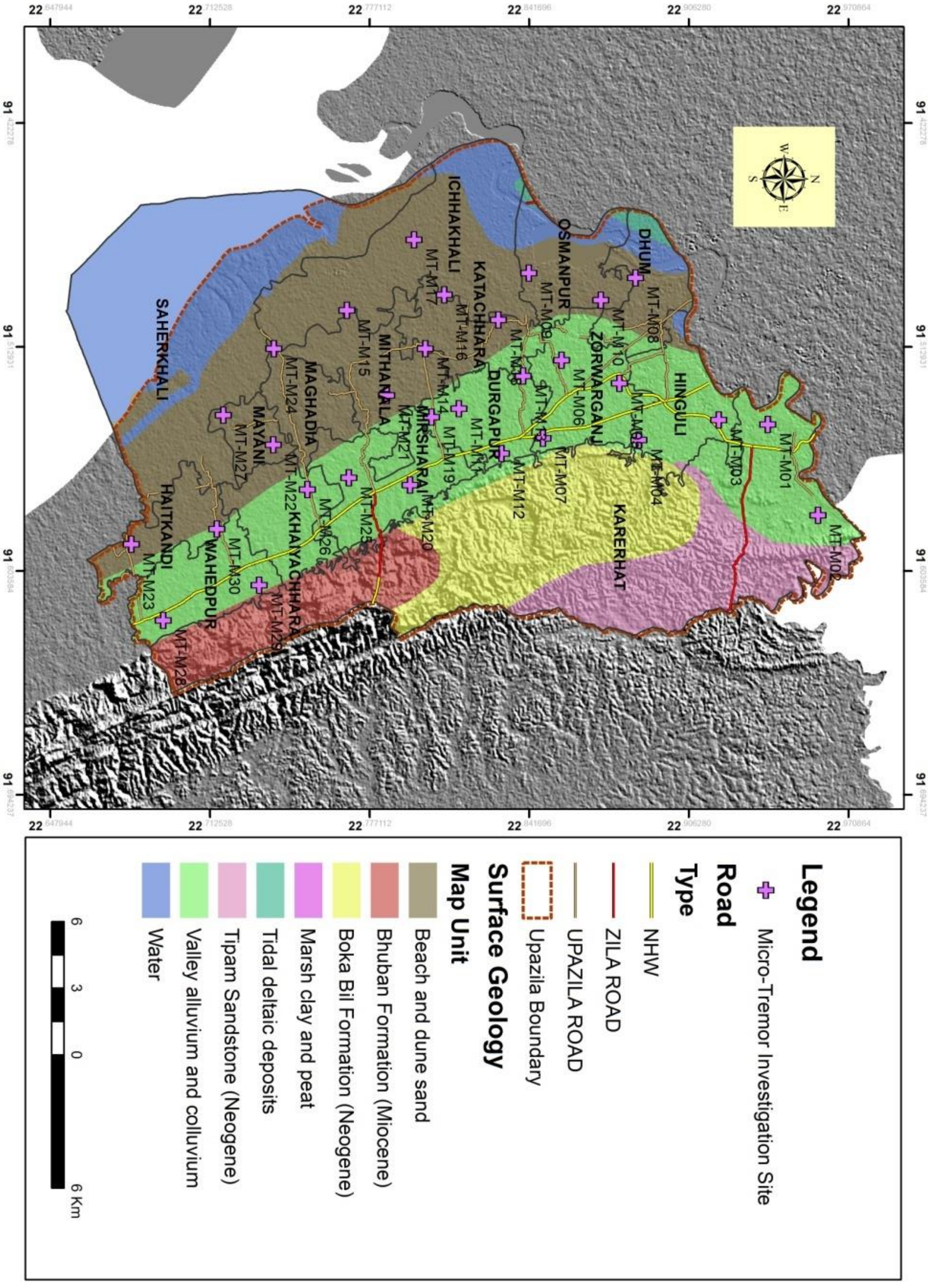


Figure 3.4 Location for single Microtremor survey

3.2. Schedule of Fieldwork

The survey category wise schedule has been given in the table below:

SL No	Types of Survey	No. of Test	Starting Date	Ending Date	Remarks
1	Site Selection		21/12/2017	26/12/2017	
2	Standard Penetration Test	85	19/01/2018	20/02/2018	Two or three SPT will be done per day
3	Borehole preparation for PS Logging Test	15	29/01/2018	15/02/2018	
4	PS Logging	15	10/02/2018	17/02/2018	At least two PS Logging will be done per day
5	MASW	20	06/02/2018	12/02/2018	At least three MASW will be done per day
6	Microtremor(Single)	30	06/02/2018	15/02/2018	At least three Microtremor(single) will be done per day

3.3. 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

4. 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)

5. CONCLUSION

Earthquakes are related to faulting and tectonic instability of an area. The overall tectonics of Bangladesh and adjoining region is conducive for the frequent and recurring earthquakes. The geo tectonic setting of the country is very active seismically. These are Himalayan Arc, Shillong Plateau and Dauki fault system in the North, Burmese arc and acrretionary wedges in the East, Naga-Disang-Haflong thrust zone in the Northeast. Threatened earthquake disaster inside Bangladesh may be expected from these active seismic zones outside the national boundary.

Seismically, Bangladesh is divided into three zones i.e. less risk zone (zone 1), moderate risk zone (zone2) and highly risk zone (zone3). Mirsharai Upazila at Chittagong district of Bangladesh is situated in zone 2. Besides these, this area is located between Arakan Megathrust and Sagaing fault. So, Mirsharai is moderately vulnerable to earthquake. To propitiate the risk of earthquake some initiatives have been taken by the concerned authorities. One of the projects works named "Geological Study And Seismic Hazard Assessment Under Preparation of Development Plan for Mirsharai Upazila, Chittagong District: Risk Sensitive Landuse Plan (MUDP)" which has been initiated by Urban Development Directorate.

In this project work, both the geophysical and geotechnical investigations will be conducted. The duration of the project is six months (19th December, 2017 to 18th June, 2018). In geotechnical survey 85 numbers of SPT boring (up to 30m) will be surveyed in the field and the soil samples collected from the field will be tested in the laboratory. And in geophysical Survey, fifteen (15) PS Logging, twenty (20) MASW, and thirty (30) Microtremor (single array) will be investigated by using some sophisticated instruments. Finally, by using these geotechnical and geophysical data, geological study and seismic hazard assessment will be prepared.