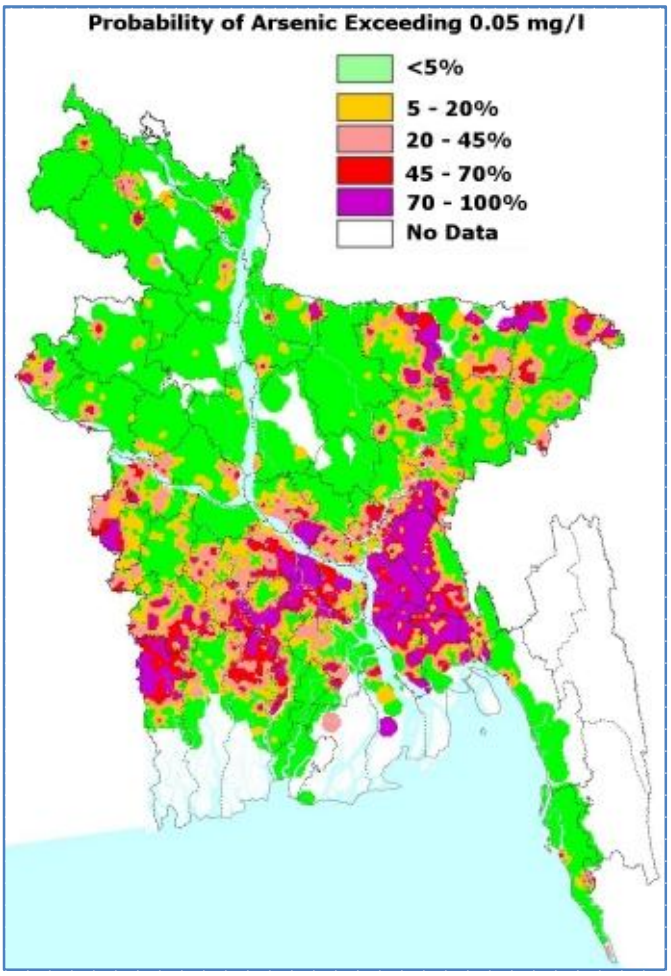
Urban Development Directorate (UDD)

Ministry of Housing and Public Works
82, Segunbagicha, Dhaka-1000.

Inception Report

Hydro-Geological Survey Under Preparation of Development For Mirsharai Upazila, Chittagong District: Risk Sensitive Landuse Plan (MUDP)



Submitted By

Center for Geoservices and Research

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Section-1: Introduction

Hydro-Geological Survey in broad sense is an immense stuff. For this project, the area Mirsharai Upazila is a small and Hydro-Geological Survey in this area is confined with few major parameters like safe drinking water source, its recharge source, its contaminants, quantities to be drawn, areal extension of aquifers etc. Bangladesh is mainly a flood plain land on which a huge number of rivers, channels and tributaries are going thru. The shallow aquifers are recharging by these rivers so there is a direct influence of rivers on the shallow aquifers. On the basis of the quality of surface water shallow aquifer's water quality varies but the deep aquifers remain constant in sense of safe drinking water. Salt water intrusion is a major barrier here for safe water as Bay of Bengal is very close to the project area. For the urbanization planning it is mandatory to ensure the water supply for domestic, industrial and agricultural purpose and so on. Safe water source need to be identified for drinking and other uses. The amount of water to be drawn for drinking as well as other use and its sustainable management is essential for the planning.

Bangladesh is very risk prone country for safe drinking water because shallow aquifers here are mostly contaminated by various poisonous elements like Arsenic, Iron, Chloride, Magnesium, Sulfates etc. Mirsharia Upazila of Chittagong district is bounded by Tripura state of India, Chhagalnaiya and Feni sadar upazials on the north, Sitakunda upazila and Bay of Bengal on the south, Fatikchari upazila on the east, Sonagazi and Companiganj (Noakhali) upazilas on the west. So the ground water in this area may contaminate by sea water as well as the water carried by the rivers and charas coming from the hilly area. Flash flood is another major concern because south-eastern side of the project area is hilly and in monsoon season the project area is in high risk of flash flood effects.

Urban Development Directorate (UDD) has planned to identify safe water source, proper water supply and surface water management including flash flood for the development plan of the project area. Regarding this UDD initiated a project, named 'Hydro-Geological Survey under Preparation of Development Plan for Mirsharai Upazila, Chittagong District: Risk Sensitive Landuse Plan (MUDP)' which will be surveyed in Sixteen unions under two municipalities. "Center for Geoservices and Research" has been entrusted to conduct this project work. This project work comprises of Hydro-geological, geophysical investigations and ground water modeling, water quality mapping, surface water

distribution and its management planning including flash flood. Finally, the investigation will provide a clear estimation of available water resources in the study area, their quality, and vulnerability to both physical exhaustion and chemical pollution. The groundwater model developed in this study will be useful in identifying areas suitable for groundwater development. It will be also useful in identifying vulnerable areas for groundwater contamination and declination, which will help decision makers to formulate policy to prevent further degradation of water resources.

1.1 Purpose of Inception Report: Generally the Inception Report is the blueprint for the life of the project. The broad purpose of the Inception Report is to set out the Consultant's approach to the Project, focusing on the overall requirement of the project related to the proposed methodology, program of work and staffing requirements. The report deals with the objectives of the Project together with the activities that are planned in order to achieve those objectives. After signing the contract with UDD, surveys locations fixing on ground was done keeping in view of geological considerations as well as the logistics as a vital part of the survey works. Finalising the surveys locations would help in fine tuning the time schedule and project planning which is included in the report.

1.2 Physical Status of the Project Area: Contract signing was done on 19th December, 2017 and on 21st December, 2017 Center for Geoservices and Research has visited the project area for six days (6) to fix up the surveys locations and accessibilities, logistics available locally and the possible difficulties in the project area and expecting that the surveys will be started from mid January 2018. The team observed very poor access like tinny earthen roads; broken and depressed brick built and cobbled roads, water loggings etc. to the maximum surveys locations. But the satisfactory matter is the full cooperation of the local peoples.

Section-2: Project Overview

2.1 Objectives of Consultancy: As per the signed contract between Urban Development Directorate (UDD) and Center for Geoservices and Research, the consultancy works broadly includes:

a) To identify the surface water body and their management for sustainable management.
b) To identify the aquifer level of the region including its seasonal variation.
c) To identify the areas potential for drawing fresh ground water.
d) To develop a seasonal fluctuation model of regional ground water table.
e) To prepare a 3D model of individual aquifer with lateral extension
f) To develop a water quality map
g) Analysis of effects of Flash Flood over the project area and identify the zone of possible affected area. A guideline to mitigate these flash flood effects using provided design of drainage system
h) Analysis of Salt Water Intrusion in the ground water aquifer system and influence of Tidal Effects on ground water table
i) Finally, develop a hydro-geological model for the study area to know the ground water quality and aquifer extension.

2.2 Approach: Consultancy for Hydro-Geological Survey for UDD is the first time. The project has to be completed as per industry standard and within the time frame. There are various disciplines/services which are to be synchronized properly and save all sorts of man day loss, except for circumstances beyond control of the project team or UDD. The services should be kept in readiness and equipment/tools are maintained, checked from time to time to ensure proper collection of data. The future of the project totally depends on the quality of data acquired and their proper interpretation.

Help would be required from Urban Development Directorate (UDD) regarding secondary data collection from relevant government organization like Bangladesh Meteorological Department (BMD), Water Development Board (BWDB) and Department of Public Health Engineering (DPHE) which would be required at various phases of the survey period. Local resource as and when required, will be fully utilized for the smooth and faster completion of jobs.

Following steps are being taken to keep the time line intact:

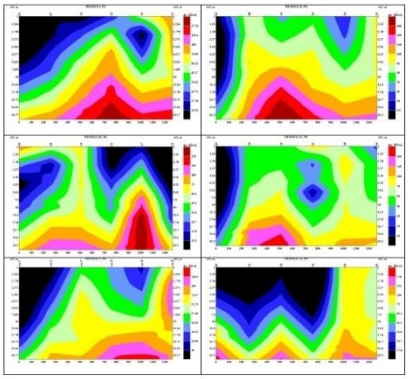
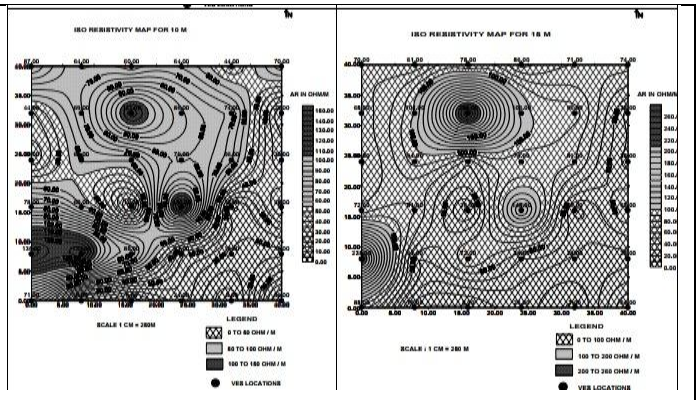
2.2.1 Establishment of Field Office: Center for Geoservices and Research has taken decision to hire an office cum residence for the Hydro-Geologists, Associated Geologists and officers in Mirsharai area from where it is easy to move all around the project area. For the field crews temporary tents will be prepared on survey location site for their accommodation.

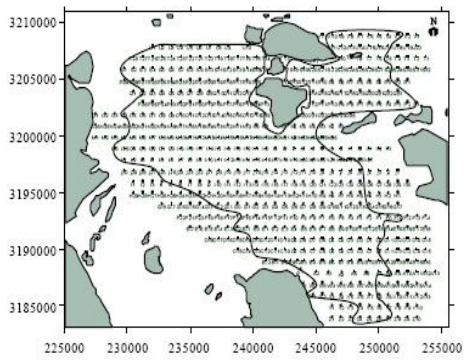
2.2.2 Mobilization of services: Drilling rig for monitoring wells and personnel have been identified locally in Mirsharai area. The resistivity survey equipments and other equipments will be mobilized form Dhaka to the field office in Mirsharai. Actual movement will take place by mid January, 2018. Once drilling of a particular monitoring well is over, the soil samples, collected water samples and resistivity data will be sent to Dhaka Office for further tests in the laboratory. Physical survey for flash flood and surface water body will be continued by the technical team and regular monitoring for the water level in the well will be continued up to the end of the project. Till date all are going on as per plan and mobilization will take place as scheduled.

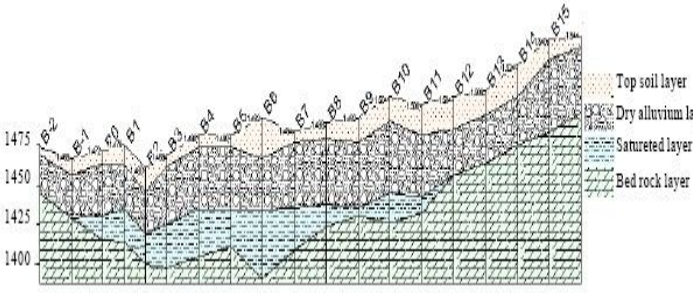
2.2.3 Drilling Monitoring Well: Reverse circulation conventional drilling method will be used for the drilling the monitoring wells. Sampling interval will be every 10 feet and preserved for the grain size analysis. Water sample will also be collected after finishing the well drilling and pipe installation for chemical analysis like $P^{H,}$ Electrical conductivity (EC), EH, Arsenic and Biochemical Oxygen Demand (BOD) in field and elemental analysis in laboratory. Water level will be measured every two days interval with water level meter by the maintenance personnel of the team. Total five (5) monitoring will be drilled and locations were selected by the technical team in the project area.

Figure-1: Drilling Procedure of Monitoring well.

2.2.4 Resistivity Survey (Vertical Electrical Sounding): Twenty (20) nos. of Vertical Electrical Sounding will be done. All the VES needs a straight open space of about 500 meter. The sites were selected by the technical team during field visit. The survey will measure the electric resistivity/conductivity of the subsurface layer types containing water, salt water, no water etc. Here are some samples of expected output from VES in Figure-2.

	
Expected Pseudosection for the VES	Expected isoresistivity depth contour

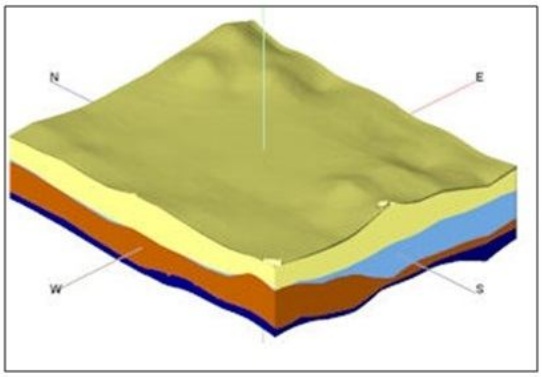


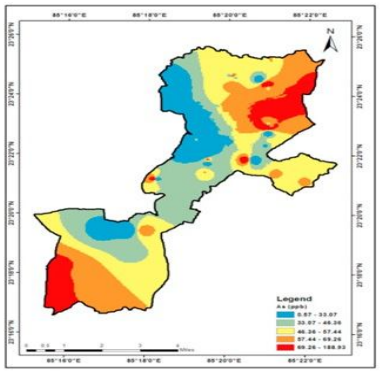


Expected aquifer boundary map	Expected Geoelectric Profile

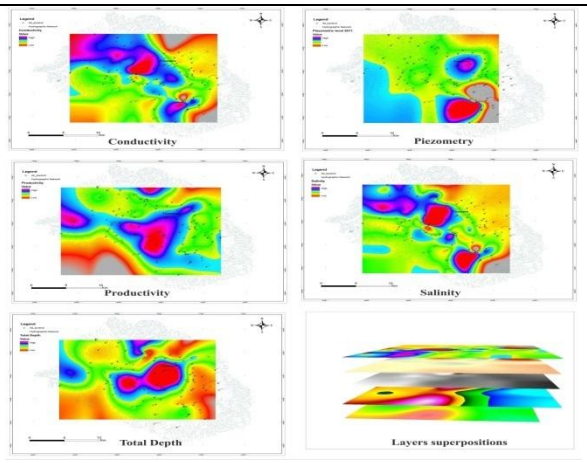
Figure-2: Sample outcome from VES.

2.2.5 Modeling and Submission of Report: After collecting the entire field data a interim report will be submitted including field data sheet. A ground water model will be run and the water quality mapping, flash flood mapping will be done sequentially. After the successful completion of the models, maps etc. draft final report will be submitted. Finally after review of the draft final report a final report will be submitted and this report will comment and suggest the most viable way for the planning management of the project and the concern authority will take initiative for future urbanization policy and sustainable development plan. Here are some samples of outcome from the survey in Figure-1.

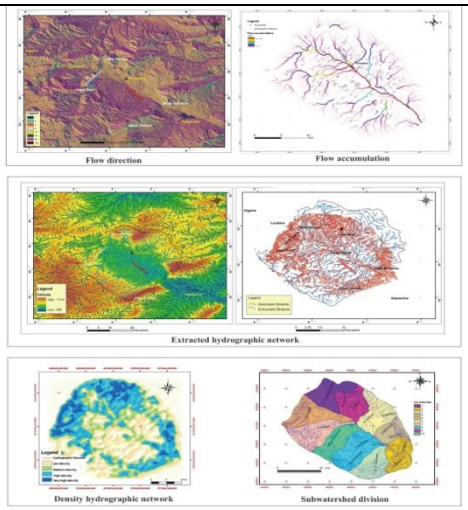




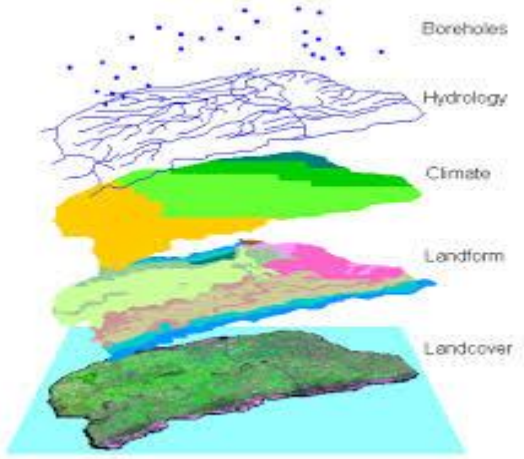
Expected Ground water model	Expected water quality map



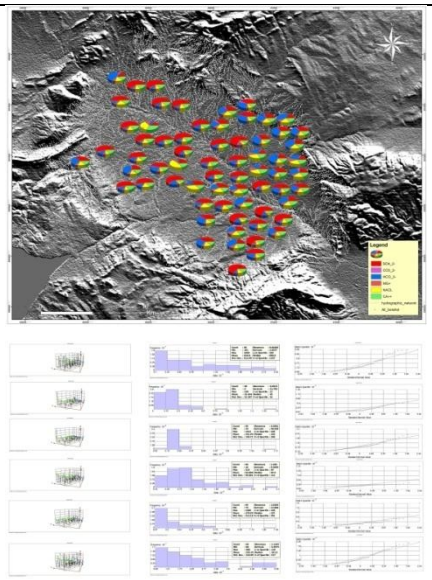
Expected conductivity with depth model



Expected Drainage network and flash flood model



Expected intigrated hydro-geological model



Expected water quality model

Figure-3: Samples of expected outcome models.

2.3 Methodology: The complete survey operation for Hydro-Geological Survey has to be planned in such a manner that all the tests/studies is done perfectly and in the shortest possible time. Quality of data acquisition is important for getting appropriate output from the hydro-geological survey. Following steps would be taken to ensure the proper and accurate data for analysis and reporting.

2.3.1 Selection of Survey Location: Survey locations were selected first on the basis of Geological, Geomorphological units. Later on, the locations were verified by physical observation and shifted a bit on the basis of local access and available space for the investigation as well as the

permission of the land owners. All the locations are verified finally and permission is also obtained from the land owners.

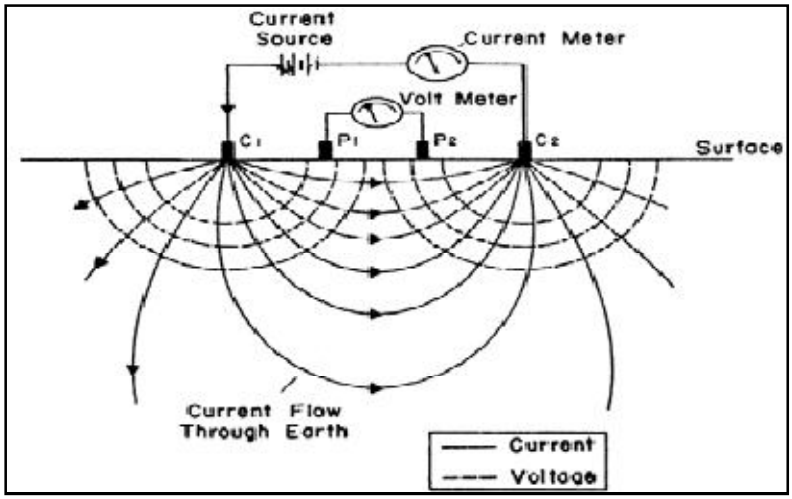
2.3.2 Drilling of Monitoring Wells: Five (5) numbers of monitoring wells will be drilling up to 250 meter depth. On the basis of deep aquifer available in the particular well a short screen will be installed for monitoring the water level for long time. The monitoring well will be prepared with 2 inches diameter PVC pipes and screens. Drilling operation will be conducted 24 hours and 12X12 hours shifts. Cow dung and water will be mixed and used as drilling mud.

2.3.3 Geological Logging: A well site Geologist will be present during drilling and he will be responsible for logging the samples in standard format, collected every 10 feet interval. He will log the lithology in the log sheet provided by consultancy firm and preserve the samples for further laboratory test i.e. Grain size analysis. After finishing drilling the hole will be preserved for water level monitoring and surrounding area will be restorated and drilling equipment will be released for next location.

2.3.4 Resistivity Survey (Vertical Electrical Sounding): Twenty (20) of Vertical Electrical Sounding will be performed in the project area of Mirsharai Upazila, Chittagong District. All the survey locations are visited and selected physically. So far space needed for resistivity survey is enough but accessibility is limited because of worst condition of roads and some water logged area. In the field session water logged area will be dry hopefully.

Procedure: The resistivity of a material is defined as the resistance in ohms between the opposite faces of a unit body of the material. The SI unit of resistivity is ohm-meter. A series of measurements of resistivity are made by increasing the electrode spacing in successive steps about a fixed point. This method of vertical exploration is known as the expanding electrode method, “Resistivity sounding” or “Depth probing” or vertical electrical sounding (VES). The apparent resistivity values obtained with increasing values of electrode separation are used to estimate the thickness and resistivities of the subsurface formations. VES mainly employed in groundwater exploration to determine the disposition of the aquifers.

Electrical resistivity methods rely on measuring subsurface variations of electrical current flow which is exhibited by an increase or decrease in electrical potential (voltage) between two electrodes. It is commonly used to map lateral and vertical changes in subsurface material.



Note: C1 and C2, P1 and P2 refer to the current and voltage/potential electrodes respectively.

Figure-4: Basic Concept of Resistivity Measurement. [Source: Abstracted from Benson et al. (1988)]

According to the following formula which is based on Ohm's Law: $k(\Delta V/I)=\rho$ eq1

Where ρ = Electrical resistivity

ΔV = Potential difference (voltage)

I = Applied current

k = Geometric factor

There are several standard combinations of electrode geometries which have been developed. The value of the geometric factor, k would depend on the particular electrode geometry used.

ASTM D6431-99 (2005) indicates that the most common electrode geometries used in engineering, environmental and ground-water studies are the Wenner, Schlumberger and dipole-dipole arrays. These arrays are shown in Figure-4.

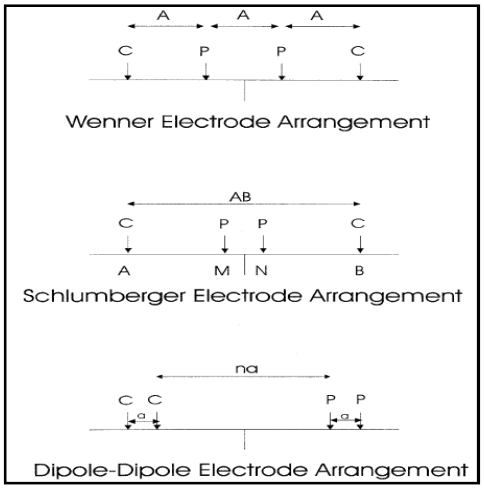


Figure-5: Standard Electrode Geometries.Source: Abstracted from ASTM D6431-99 (2005)

Wenner array mainly used for resistivity imaging/profiling and Schlumberger array provide better result in Vertical Electrical Sounding (VES). Dipole-Dipole array is used when survey line is very large with a view to getting greater depth of penetration. In this survey Wenner electrode configuration has been used.

The geometric factor (k) for Wenner array of equation1 is

$K = 2\pi a$

Where, 'a' is spacing between two electrodes.

Hence the equation become

$\rho = 2\pi a \times \Delta V/I$

Depth of Penetration: In homogeneous ground the depth of current penetration increases as the separation of the current electrodes is increased. Figure 3 shows the proportion of current flowing beneath a given depth Z as the ratios of electrode separation L to depth Z increases. When L=Z about 30% of the current flows below Z and when L=2Z about 50% of the current flows below Z. The current electrode separation must be chosen so that the ground is energized to the required depth, and should be at least equal to this depth (Figure-10).Fraction of current penetrating below a depth Z for a current electrode separation AB Proportion of current flowing below depth Z. For Wenner Configuration expected depth of penetration is about one third of the array length (AB/3).

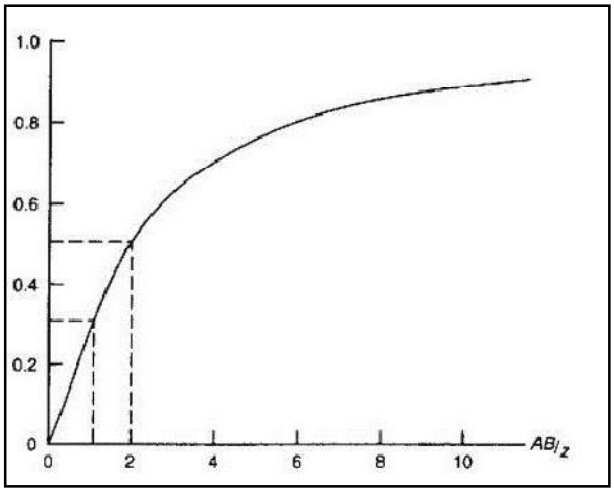


Figure-6: Fraction of current penetrating below a depth Z for a current electrode separation AB

Proportion of current flowing below depth Z (Source: Telford, Second Edition)

Transmitter	
Output Voltage	400 V pp (Constant current)
Output Current	1, 2, 5,10,20, 50,100,200 mA (Constant current)
Operating Voltage	12 VDC
Receiver	
Input Impedance	1 M-ohm
Measurement Potential	±0.6 V ±6 V (Auto Range)
Resolution	20 micro V
S/N Ratio	90 dB (With 50/60 Hz.)
No of Stacking	1, 2, 4, 16, 64
Time of One Measurement	
Cycle	3.5 sec
Data memory	
Max No. of Files	128
Max No. of Data	2000
Max No. of Data Files	110
Interface	*RS-232C*
Power	DC 12 V Internal Rechargeable Battery,
	External 12 V Battery applicable
Operation Temperature Range	$0\text{-}50^{0}$ C
Dimensions	(W) 206 X (H) 281 X (D) 200 mm

Weight	Approx. 7.5 Kg (Including Battery)

Table-1: Standard specifications for McOHM resistivity meter (Model-2115)

Interpretation Techniques of Data: When electrical resistivity measurements are conducted in the field, the values obtained are referred to as the apparent resistivity. These apparent resistivity values must be inverted in order to determine the true resistivity. The process of inversion entails comparing plots of apparent resistivity versus depth with master or theoretical curves. This process not only determines the true resistivity, but it also gives an estimate of the respective layer thickness. For the case studies outlined later, the inversion process was conducted using the computer program RES2DINV.The final model obtained through software is taken to be the layered geo-electric image of the subsurface.

2.3.5 Samples collection for Laboratory Tests: From the drilling of monitoring wells samples from every 10 feet interval will be collected and preserved for grain size analysis. After completion of monitoring wells water samples from the monitoring wells as well as from the surface water body will be collected for elemental analysis in laboratory. Furthermore, local tube wells and community well's Water will be tested at field for Arsenic (Ar) using arsenic testing kits.

Serial no.	Chemical constituents	Methods and Instruments
1	Sodium (Na^{+})	Flame photometer (Jenway PFP-7) Wavelength 769 nm
2	Potassium (K^{+})	Flame photometer (Jenway PFP-7) Wavelength 589 nm
3	Calcium ($Ca^{2+)}$	Atomic absorption spectrometer (GBC Sens AA)
4	Magnesium (Mg^{2+})	Atomic absorption spectrometer (GBC Sens AA)
5	Iron (Fe^{2+})	Atomic absorption spectrometer (GBC Sens AA)
6	Manganese (Mn^{2+})	Atomic absorption spectrometer (GBC Sens AA)
7	Bicarbonate (HCO_3^{-})	Titration method (Standard H_2SO_4 for HCO_3^{-})
8	Chloride (Cl^{-})	Titration method (Standard $AgNO_3$ for Cl^{-})
9	Nitrate (NO_3^{-})	UV visible spectro-photometer (T60 PG) Wavelength 410nm
10	Sulphate (SO_4^{2+})	UV visible spectro-photometer (T60 PG) Wavelength 410nm
11	Arsenic (Ar)	Atomic absorption spectrometer (GBC Sens AA)

Table-2: Methods and instruments used for elemental analysis.

2.3.6 Site Restoration: For monitoring well drilling, the site will be dug and after finish the drilling restoration works will be done by consultant's responsibility.

2.3.7 Reporting: Inception report which forms the basic structure of this whole program of exploration will be the starting material. With the progress of drilling monitoring wells, resistivity survey and acquisition of new data several base maps and sections are to be made and updated. On the basis of the data acquired and lab tests results, some models and interpretation will be performed. Just after finishing the field activities an interim report will be prepared using the raw data collected from the field. Later on draft final and final reports will be prepared.

2.3.8 Key Elements of the Project: Urban Development Directorate (UDD) is going to perform Hydro-Geological Survey for the first time to associate the outcomes with the Development plan. So it will be the milestone to formulate the policy of future urbanization and development plan. The key elements of the project are:

a. ***Resource:*** Center for Geoservices and Research has experience expertise team for the Hydro-Geological Survey who will take great care of the project and achieve the Mirsharai Upazila development plan project success. Here is the list of resources to be used in the field survey.

Sl. No.	Items	Quantity	Pictures
1	Resistivity Profiling and Imaging Equipment	1 set	
2	Geotechnical drilling Rigs (Manual and Rotary)	7 set	
3	Water level Meter	4 Nos.	

4	Water Flow meter	1 Nos.	
5	PH Meter	1 Nos.	
6	Water Thermometer	2 Nos.	
7	Electric Conductivity (EC) meter	1 Nos.	
8	Automatic Data Logger	1 Nos.	
9	Hand GPS	5 Nos.	
10	Ground water modeling software (MODFLOW, SUTRA, SeaWAT), Rockware.		
11	Work Station, Plotter, Printer, Scanner, Latop,Tab and Android Phone	10 os .	

b. ***Right equipments:*** The consultancy firm selected the right equipments for the survey works by analyzing the target outcome and the real field conditions for the successful completion of the project.

c. ***Project Execution:*** The consultancy firm will ensure smooth supply system and continuous monitoring of the operation so that the date lines are maintained.

d. ***Training:*** Center for Geoservices and Research is committed to provide "on job" training for the UDD's personnel.

Section-3: Work Done During Inception Phase

Contract signing between "Urban Development Directorate (UDD)" and "Center for Geoservices and Research" was done on 19th December, 2017. Field visits were made from 21st December to 26th December, 2017 and the locations are identified on ground and had permission of the land owners.

3.1 Fixing locations of Proposed Monitoring Wells and VES on Ground: Total five (5) numbers of monitoring wells and twenty (20) numbers of Vertical Electrical Sounding (VES) locations were fixed on ground. The verified coordinates of the monitoring well locations and associated maps are below in table-3 and Figure-5.

Union Name	Survey Location Id	Tentative Coordinates	
		Latitude	Longitude
Hinguli	MW-1	22.88738	91.55460
Ichhakhali	MW-2	22.82665	91.48352
Mirsharai	MW-3	22.78856	91.55094
Saherkhali	MW-4	22.73395	91.50329
Haitkandi	MW-5	22.70814	91.56847

Table-3: Verified Monitoring well locations.

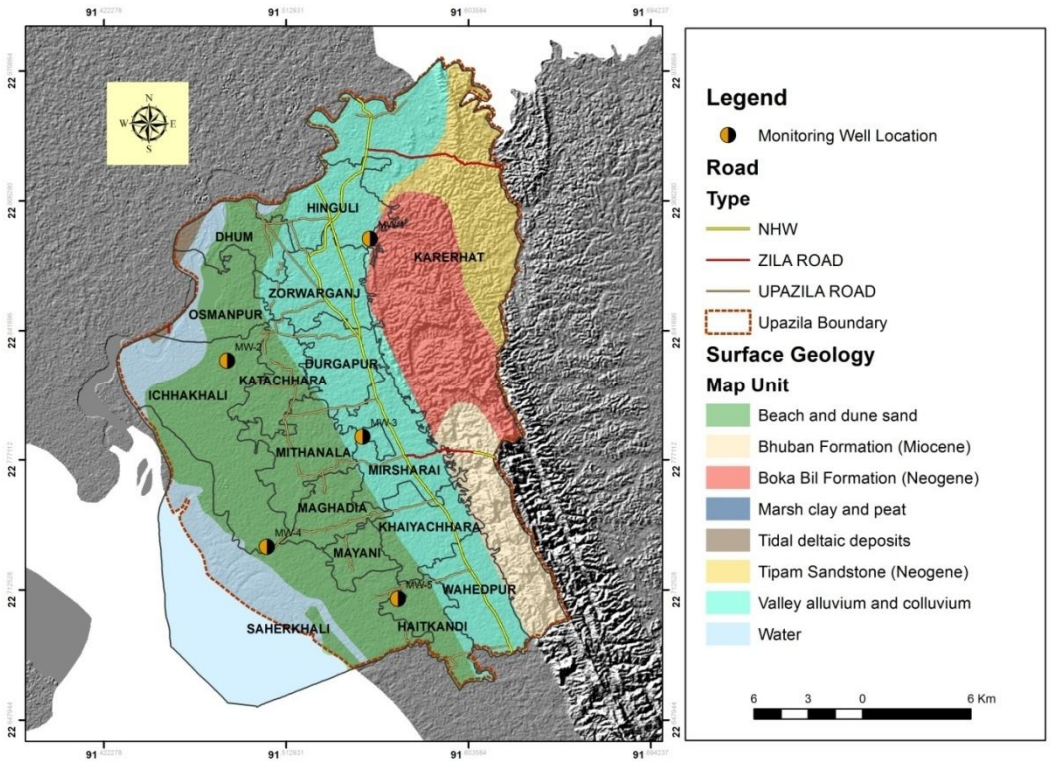


Figure-7: Verified Monitoring well locations in map.

VES locations and associated maps are shown in table-4 and Figure-8.

The VES locations were verified on ground and are given in table-7 and Figure-6**Union Name**	**Number of Test/Survey**	**Survey Location Id**	**Tentative Coordinates**	
			Latitude	**Longitude**
Karerhat	1	VES-1	22.94771	91.56872
Hinguli	2	VES-2	22.89947	91.55612
		VES-3	22.89561	91.52073
Dhum	1	VES-5	22.88031	91.51205
Zorwarganj	1	VES-4	22.87348	91.53931
Osmanpur	-	-	-	-
Durgapur	1	VES-6	22.83569	91.54419
Katachhara	2	VES-7	22.84584	91.50734
		VES-8	22.81165	91.52259
Ichhakhali	3	VES-9	22.81680	91.49598
		VES-13	22.78420	91.47000
		VES-15	22.75094	91.48756
Mirsharai	2	VES-10	22.77855	91.58646
		VES-11	22.78707	91.55951
Mithanala	1	VES-12	22.77164	91.51875
Saherkhali	3	VES-18	22.73459	91.50903
		VES-19	22.70364	91.56542
		VES-20	22.69971	91.54464
Maghadia	1	VES-14	22.74695	91.54285
Khaiyachhara	1	VES-17	22.72878	91.57300
Mayani	-	-	-	-
Wahedpur	1	VES-16	22.73029	91.59596
Haitkandi	-	-	-	-

Table-4: Verified VES locations.

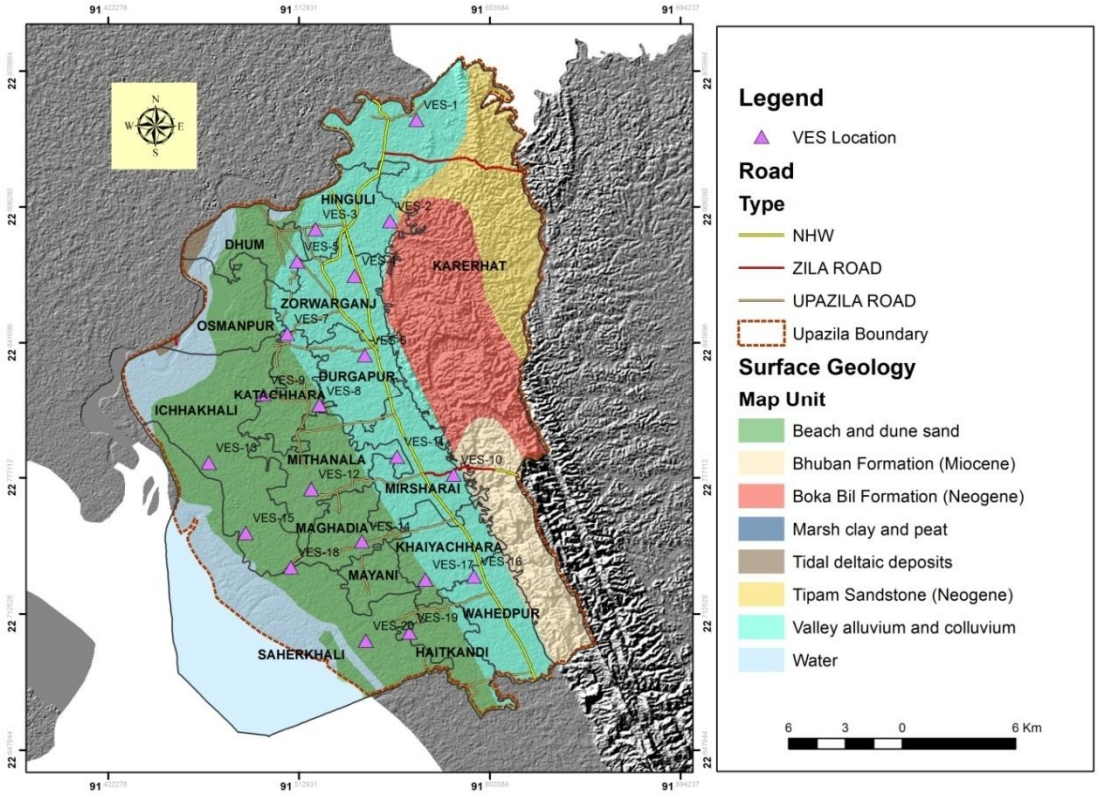


Figure-8: Verified VES locations in map.

3.2 Photographs of fixing survey locations on Ground: The program of fixing the survey locations on ground was done from 21st December to 26th December, 2017. A lot of difficulties were face during the period but it was overcome due to full cooperation of local people. Some photographs of this session is given below-

3.3 Deliverable with time frame:

The following reports will be submitted within the time frame to UDD-

Serial no.	Deliveries	Submitted date
1	Mobilization Report	24/12/2017
2	Inception Report	28/12/2017
3	Interim Report on review of (i) Monitoring well logs and water level data, (ii) Resistivity Survey raw data and interpreted data and aquifer depths and extension , (iii) Water quality test data , (iv) Maps based on field data.	25/02/2018
4	Draft report on Data relating to Monitoring wells, Geo-physical Survey including Laboratory test results including ground water modeling, water quality maps, surface and ground water levels with seasonal variation, salt water intrusion, flash flood and tidal effects, ground water contamination and its interpretation	29/03/2018
5	Final Report on ground and surface water modeling with seasonal variation of water levels, contaminants i.e. arsenic, salt water intrusions, tidal effects, sustainable use plan of ground water, water quality zonation and mapping and its interpretation.	30/04/2018

Section-4: Conclusion

To serve the purpose of Hydro-Geological Survey, the consultant firm 'Center for Geoservices and Research' will mobilize their team and equipments in the 2nd week of January, 2018 with due concern of Urban Development Directorate (UDD). Afterward, main investigation will be conducted to collect the necessary field data sequentially laboratory tests will be performed and finally develop a Hydro-Geological model.

The final outcome of this study will consist of

1. Detail 3D map of aquifer framework
2. Detail map of water table and their seasonal variability
3. Detail map of water quality
4. A 3D groundwater flow model.
5. Analysis report of flash flood and its mitigation management model.
6. All the information will be managed in GIS database as well as map.

The proposed hydro-geological investigation will provide a clear estimation of available water resources in the study area, their quality, and vulnerability to both physical exhaustion and chemical pollution. The groundwater model developed in this study will be useful in identifying areas suitable for groundwater development. It will be also useful in identifying vulnerable areas for groundwater contamination and declination, which will help decision makers to formulate policy to prevent further degradation of water resources. All the data and model output will be converted into easily understandable maps and figures for the decision makers and non-Hydro-Geologists.