URBAN DEVELOPMENT DIRECTORATE (UDD)

Ministry of Housing and Public Works

Government of the People's Republic of Bangladesh

Mobilization Report
On
HYDRO-GEOLOGICAL SURVEY UNDER PREPARATION OF DEVELOPMENT PLAN FOR MIRSHARAI UPAZILA, CHITTAGONG DISTRICT: RISK SENSITIVE LANDUSE PLAN (MUDP)

Package No.: 5 (Five)

December, 2017

Submitted by

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Executive Summary

Water is the most important issue for any livelihood and industrial area as its use is for drinking, industrial and other purposes. Without water no civilization or urbanization plan can sustain. For drinking as well as other purpose water should be safe from all types of contaminates and other dissolved solids/elements. Although the country is very small but has got a vast population with a high rate of growth. In respect of the urbanization for the people and sustainable development, the country needs safe water, proper water management plan and proper maintenance of its source/aquifers.

The Government of the People's Republic of Bangladesh is committed to ensure safe water for all. Urban Development Directorate (UDD) had initiated a project named 'Hydro-Geological Survey under Preparation of Development Plan for Mirsharai Upazila, Chittagong District: Risk Sensitive Landuse Plan (MUDP)'. The aim of the project is to identify water aquifers, its extensions, the quantity as well as quality of water, its reservation, maintenance, surface water network development and proper management for sustainable development plan of urbanization by developing standard water model and maps integrating all hydro-geological database.

UDD entrusted to conduct the Hydro-Geological Survey 'Center for Geoservices and Research' a consultant firm. To execute the survey, the firm will conduct some investigation like monitoring well, Resistivity survey, water sampling and testing for its quality, testing of lithological characters form monitoring well, water levels with seasonal variations, depth and areal extension of the shallow and deep aquifers, contaminations (Arsenic, Chloride, Manganese, Iron etc) and salt water intrusions, effects of tidal action and surface water network study and its developments and finally the ground water model and water quality mapping.

The eastern part of the study area is hill tracks, which can be approximated as a no-flow boundary condition in the model. The southwestern side is the Bay of Bengal, which can be approximated as a constant head boundary with the compensated head for higher density of saline water. However, the northwestern and southeastern model boundaries are tricky and should be chosen wisely as they are not constrained by any true hydrologic boundary. To get the approximate boundary conditions for those two sides the Bengal Basin model of Michael and Voss (2008) will be used in this study. Either the head data from the Basin scale model

along those two boundaries will be extracted and used directly in the model in the current study or the local model for this study will be nested in the regional scale model and both will be simulated simultaneously.

The model will be transient, and will be verified against the seasonal water level data collected in this study. After developing the basecase scenario depicting the current groundwater situation in the study area a number of alternative management scenarios will be simulated. Current and future pumping scenarios will be assessed using the model and the best practice scenario will be selected.

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.

Contents

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.

Urban Development Directorate (UDD) has planned to identify safe water source and proper water supply 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 and geophysical investigations and ground water modeling, water quality mapping, surface water distribution and its management planning by using those data.

All the above mention investigations will be done according to TOR but for fulfillment of the Hydro-Geological Survey some additional investigations have to be conducted. Those are hydraulic properties and specific yield/storage of the aquifer surrounding the monitoring wells which will be conducted via slug test which is quick but very much effective. 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.

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, land development and urbanization policy, socio-economic research, human settlement planning and development for small, medium and large town and cities of Bangladesh and also giving plan to local development authorities on the basis of its research and activities.

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 and developing gender equality.

3. Location and Accessibility

Mirsharai Upazila (Chittagong District) area 482.88 sqkm (BBS)/509.80sqkm (GIS Data), 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 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. Mirsharai Thana was formed in 1901 and it was turned into an uapazila in 1983. Mirsharai Upazila consists of 2 Municipality, 16 Union and 113 Mouza.

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 Khoyachora, Baghbani, Napitachora, Sonaichora, Mithachora and Boyalia waterfalls. This area is located 192.2 km far from Dhaka and 4.5 hour bus journey. Anuone can travel by rail and it is 197 km of rail journey and it takes 4.5 hour from Dhaka. 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: Bangalapedia, 2012)

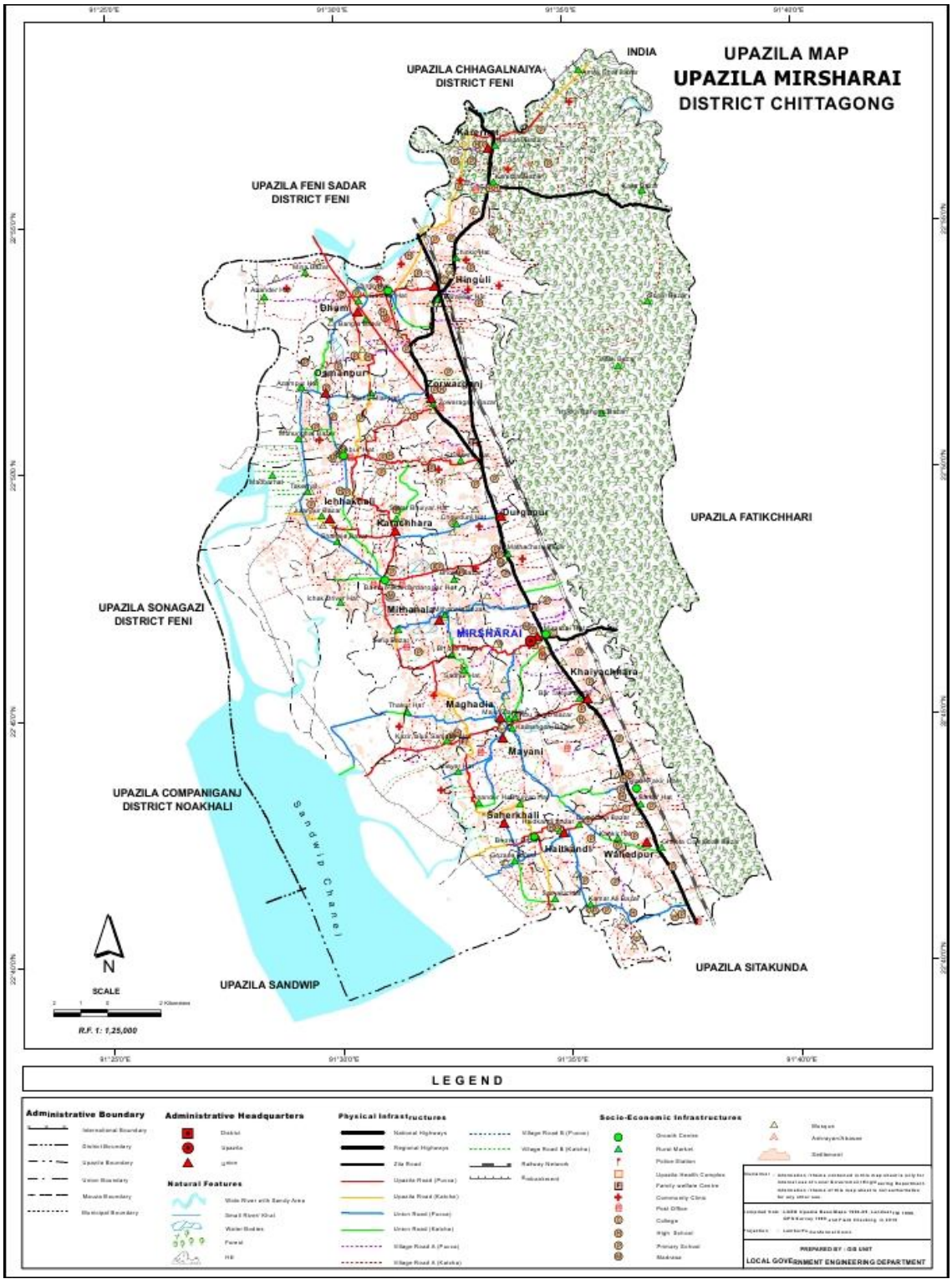

Figure-1: Map Showing Location and Accessibility (Source: LGED)

At Mirsharai Upazila main river is Feni; Sandwip Channel is notable; Cnal 30, most noted of which are Feni Nadi, Isakhali, Mahamaya, Domkhali, Hinguli, Molisaish, KoilaGovania 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- Name and Area of Sixteen Unions under Mirsharai Upazila.

Name of Union	Area (acre)	Population			Literacy rate (%)
		Male	Female	Total	
Ichhakhali	11341	12313	13238	25551	50.92
Wahedpur	4682	11969	12494	24463	56.04
Osmanpur	3326	6478	6965	13443	54.8
Karerhat	36582	15349	14628	29977	42.7
Katachhara	3446	10582	11600	22182	57.63
Khaiyachhara	1483	11849	12052	23901	48.41
Zorwarganj	5517	16302	15734	32036	45.74
Durgapur	3742	9950	9852	19802	54.7
Dhum	3310	7619	8079	15698	53.8
Maghadia	3677	10883	11649	22532	48.16
Mayani	4590	8642	9064	17706	53.59
Mithanala	5338	11402	12144	23546	57.72
Mirsharai	4360	13985	13299	27284	49.74
Saherkhali	5335	7769	8462	16231	53.25
Haitkandi	3271	9400	9572	18972	55.03
Hinguli	4562	12910	12597	25507	55.48

Source Bangladesh Population Census 2001, Bangladesh Bureau of Statistics.

4. Aim and Objectives

The main objective of the research is to carry out a Hydro-Geological Survey of 16 (Sixteen) unions including Ichhakhali, Wahedpur, Osmanpur, Karerhat, Katachhara, Khaiyachhara, Zorwarganj, Durgapur, Dhum, Maghadia, Mayani, Mithanala, Mirsharai, Saherkhali, Haitkandi, Hinguli under MUDP project area. The main objective will be achieved through accomplishment of the following sub-objectives:

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.

5. Methodology

5.1. Approach

The study area is located between the Chittagong hill tracts in the east and the Bay of Bengal in the west. The eastern part of the study area is hilly while the western part is coastal area. The central plain land is the most heavily populated area and most suitable for groundwater study.

Step 1: Delineation of aquifers and groundwater level in the study area

The first and foremost important work in any hydro-geological study is to identify and delineate the aquifers for the assessment of available groundwater and their quality. The central part of the study area comprises of a plain land and is the most suitable area for groundwater study. Based on the knowledge of aquifer architecture in the Bengal Basin, Bangladesh, it can be assumed that the aquifers in this area have a larger areal extent across the administrative boundary. The recharge and discharge area of these aquifers may located far beyond the administrative boundary. It is therefore highly important that the regional extent of the subsurface lithology in this region be identified at first. Department of Public Health Engineering has developed an aquifer database consisting of more than 3000 borehole logs covering for the whole Bangladesh (Figure-2). This dataset will be used for preliminary mapping of the regional extent of the aquifers. Afterwards, detail local investigation will be carried out in the study area for precise aquifer mapping and determination of hydraulic properties of the aquifers. Both the existing regional scale data and detail local scale data willbe used to prepare a 3D aquifer model, similar to what is shown in Figure-3.

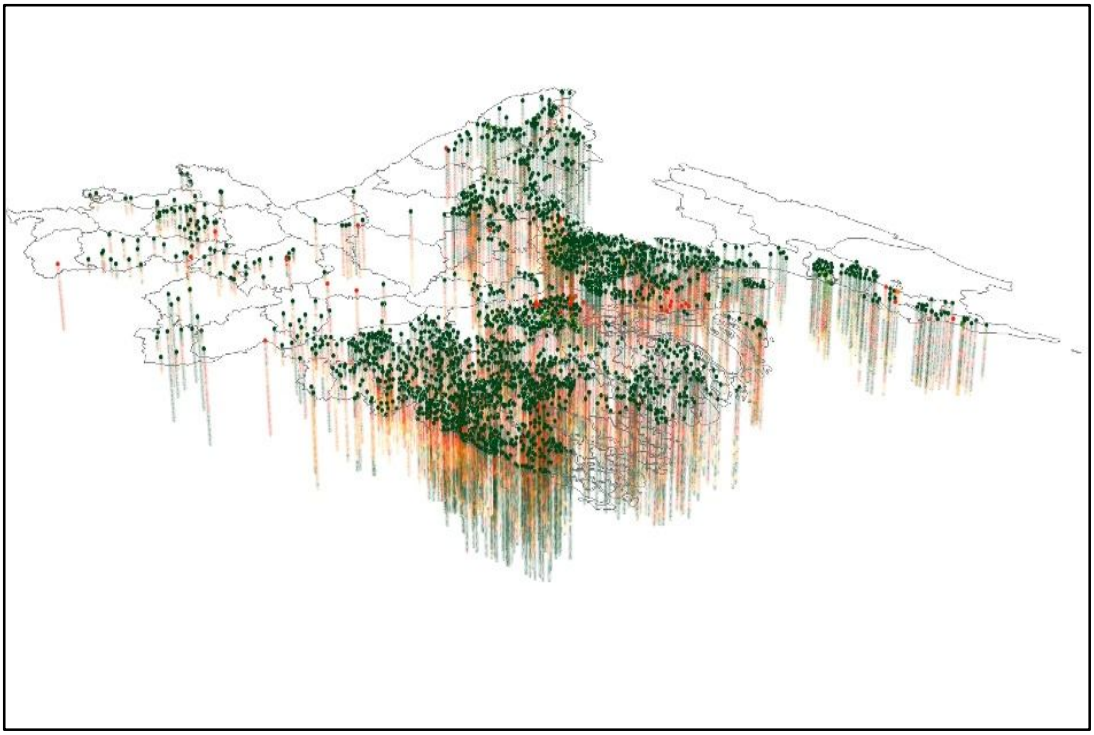

Figure-2: Showing the 3D distribution of existing borehole logs of DPHE distributed all over Bangladesh.

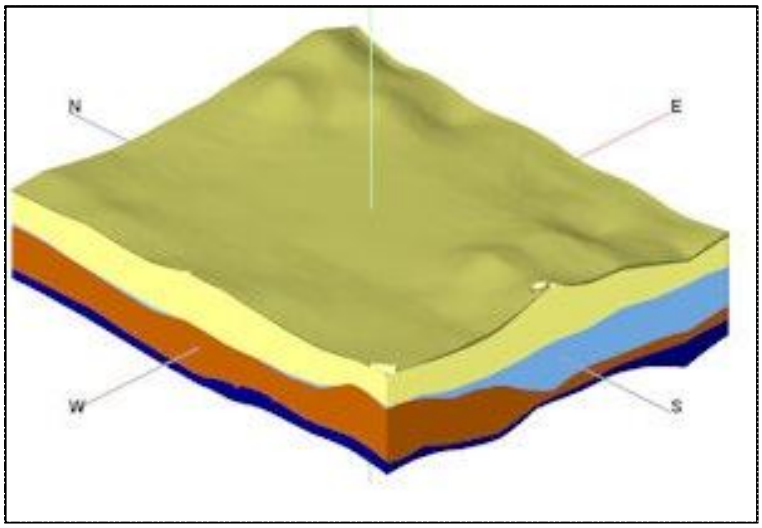

Figure-3: 3D model of ground water aquifer.

Seasonal fluctuation of groundwater level provides important insights on the seasonal recharge and water availability. For accurate estimation of available groundwater resource volume long term groundwater level observation data is important. Bangladesh Water Development Board has three groundwater monitoring stations in the study area collected

data since 1970. These data will be collected and used for assessment of seasonal variability in groundwater level and to identify long term trend, if any. Additional groundwater level data that will be collected during this study will be used for quality checking and increasing the areal coverage for seasonal water level map. Three separate groundwater level maps will be prepared; a) groundwater level in wet season, b) groundwater level in dry season, and c) long term trend in groundwater level.

Step 2: Mapping groundwater quality in the study area

After identifying and delineating the aquifer framework, the next important job is to assess the quality of the water. Based on existing data a number of regional background water quality map will be prepared, one for each water quality parameters such as Electrical Conductivity or Chloride, Arsenic, Manganese, Iron etc. These maps will be updated based on data collected during this study. Finally, based on all data collected during this study local-scale groundwater quality maps will be produced for the study area, an example map for arsenic is shown in Figure-4.

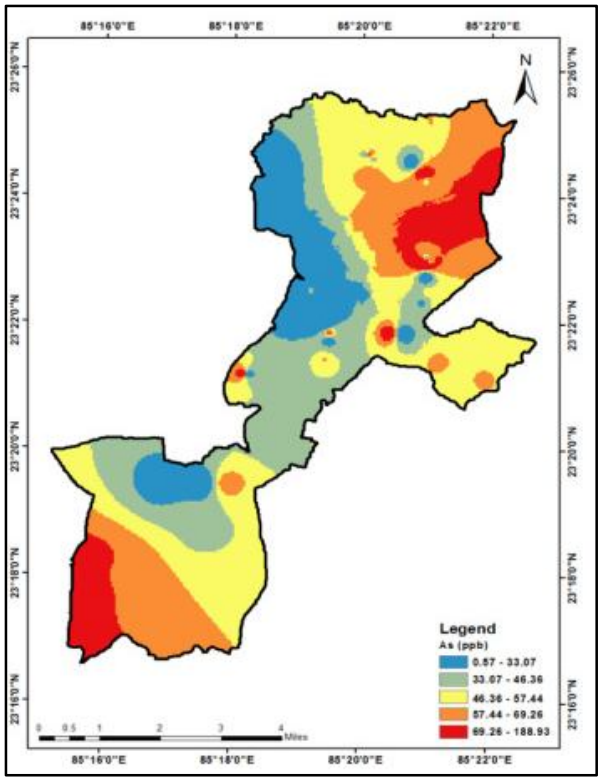

Figure-4: Example map for water quality.

Table Methods and instruments used for different chemical constituents

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)

Step 3: Assessment of the availability of potable groundwater in the study area and their sustainability

After the delineation of aquifers and the water quality mapping a 3D groundwater model will be developed to assess the available fresh groundwater resources in the study area and to analyze the impacts of different pumping scenarios on both water quality and quantity.

Step 4: Surface water body Identification and their sustainable management

Flowing and stagnant surface water bodies are to be identified and the flow of flowing water channel/river will be observed in dry as well as monsoon season. The recharge ability of the shallow aquifer by these water bodies will also be assessed. The water quality test of these water bodies is very prominent task.

5.2. Detail work Methodology

1. Delineation of aquifers and determination of their hydraulic properties

Both direct and indirect methods of subsurface data collection will be employed for the delineation of aquifers in the study area. Direct investigation includes drilling boreholes at multiple locations and collections of lithological data for laboratory analysis to determine hydraulic properties of the aquifers. Direct method provides precise information of the subsurface; however, they provide only point information and are expensive. Surface geophysical investigation such as electrical resistivity survey is very useful in providing continuous subsurface information over a wide area and is highly useful when used in combination with direct borehole data. Details of these methods are discussed in subsequent sections.

1.1 Monitoring Well

A total of 5 (five) boreholes, each 250 m deep, will be drilled at multiple locations distributed throughout the study area. Locally available reverse circulation drilling methods will be used (Figure-5). During drilling a geologist will be present at the drill site and will record lithological variability with depth at an interval of 10 feet. Lithological samples will be collected for laboratory analysis for all aquifer and aquitard intervals encountered during drilling.

After successful completion of drilling, short screen monitoring wells will be installed in these boreholes for groundwater level monitoring and water quality sampling. Water samples will be at regular interval throughout the study period to assess the spatial and temporal changes in water quality.

Figure-5: Drilling setup reverse circulation method.

1.2 Electrical Resistivity Survey

In electrical resistivity survey, electrical currents are in introduced in the subsurface using two current electrodes and the voltage returns from the subsurface is measured using two potential electrodes. The recorded voltage is a function of the subsurface lithology and water quality and thus it is used in deducing the subsurface lithology as well as water quality. This study will conduct vertical electrical sounding (VES) at 20 (twenty) locations distributed throughout the study area including five at the location of the boreholes. Borehole data will play an essential role in converting the resistivity data into subsurface lithology. A typical setup for resistivity survey is shown in Figure-6.

Figure-6: Typical VES setup

1.3 Determination of hydraulic properties of the aquifer

Accurate assessments of hydraulic properties of aquifers are essential for developing an acceptable groundwater model. Both laboratory and in-situ methods will be employed to determine the hydraulic properties of the aquifers. Sediment samples collected during the drilling will be brought to lab for grain size analysis. Grain size data can be converted into hydraulic conductivity values using different empirical formulas. However, the bulk of the high density hydraulic conductivity data will be collected in the field using slug test. Slug test is a field method where a slug (usually a rod) is inserted in a well below the water table, which causes an instantaneous rise of water level in the well. Dissipation of the water level in the well is then recorded, usually; by an automatic water level logger (Figure -7).The temporal rate of this water level declination provides information on the hydraulic conductivity and specific yield/storage of the aquifer surrounding the well. This is a quick but accurate method of estimating hydraulic conductivity in any small diameter tube wells. In addition to the 5 monitoring wells that will be installed under this study, slug test will be carried out in at least 100 locations in the existing hand tube wells throughout the study area.

Figure-7: Automatic data logger

1.4 Preparation of a 3D model of aquifer architecture

Based on existing borehole logs, the 5 borehole logs from this study, and the lithologic information deduced from geophysical survey a detail but simplified three dimensional map of the aquifer architecture will be prepared using aquifer mapping software 'Rockware'. A separate geostatistical analysis will be performed to determine the uncertainty in the data as well as to assess the heterogeneity in the subsurface lithology. A good understanding of the aquifer heterogeneity is crucial for a valid model.Hydraulic conductivity data collected in this study will be assigned to each of the aquifer aquitard layer in this 3D model and then this model will be used in the groundwater model that will be developed in the final stage of the study.

2. Delineation of groundwater level in the study area

Detail delineation of groundwater level and their seasonal variability is a crucial step in hydro-geological study. In the beginning of the study a detail groundwater level map for each of the wet and dry season will be prepared based on extensive groundwater level survey in existing hand tube wells throughout the study area. An electrical groundwater level meter will be used in measuring groundwater level (Figure-8). Seasonal variability in groundwater level will be determined based on groundwater level monitoring in the five monitoring wells that will be installed during this study. Besides, long term data from existing monitoring stations of Bangladesh Water Development Board will be used for determination of long term trend in groundwater level, if any.

Besides groundwater level monitoring, data on existing pumping, another information crucial for modeling, will be collected during field survey. Together with the seasonal groundwater table fluctuation data existing pumping will provide estimation on the seasonal groundwater

recharge, which is an essential parameter for groundwater modeling. Moreover, areas with depleting groundwater will be readily identified from the groundwater level maps.

Figure-8: Groundwater Level meter

3. Groundwater quality mapping

A detail map of groundwater quality will be prepared in this study based on both field and laboratory methods. Some water quality parameters such as *electrical conductivity (EC), pH, Eh, and BOD* will be measured in situ using hand held instrument (Figure-9). In the lab both major ions and trace elements will be analyzed. Emphasis will be on *arsenic (As), manganese (Mn), Nitrate, Chloride, Iron and other trace elements.* Detail water quality map of each of these parameters will be prepared. Further, seasonal changes in water quality will be monitored in the monitoring wells. Moreover, should there be any potential sources of water pollution and contamination; it will be readily identified in the water quality map, which will be verified in the field.

Figure-9: In field water quality measurement instrument

4. Groundwater modeling

A detail 3D groundwater model will be developed in this study to assess available groundwater resources, their quality, and management. The USGS flow code MODFLOW will be employed in the aquifer modeling. The 3D lithological model that will be developed in this study will provide the basic aquifer framework for the model. The model top will be a recharge boundary. Recharge will be estimated based on long term rainfall data available from Bangladesh Meteorological Department (BMD) as well as the seasonal water table fluctuation. The eastern part of the study area is hill tracks, which can be approximated as a no-flow boundary condition in the model. The southwestern side is the Bay of Bengal, which can be approximated as a constant head boundary with the compensated head for higher density of saline water. However, the northwestern and southeastern model boundaries are tricky and should be chosen wisely as they are not constrained by any true hydrologic boundary. To get the approximate boundary conditions for those two sides the Bengal Basin model of Michael and Voss (2008)[1] will be used in this study. Either the head data from the Basin scale model along those two boundaries will be extracted and used directly in the model in the current study or the local model for this study will be nested in the regional scale model and both will be simulated simultaneously.

The model will be transient, and will be verified against the seasonal water level data collected in this study. After developing the basecase scenario depicting the current groundwater situation in the study area a number of alternative management scenarios will be simulated. Current and future pumping scenarios will be assessed using the model and the best practice scenario will be selected.

Extensive sensitivity analysis will be carried out in the modeling exercise to address the uncertainty and gap in the data. Should sea water intrusion be important in the southwestern boundary of the area, variable density modeling will be considered using wither USGS flow code SUTRA or SeaWAT.

[1]Michael, H. A. & Voss, C. I. Evaluation of the sustainability of deep groundwater as an arsenic-safe resource in the Bengal Basin. Proc. Natl. Acad. Sci. U. S. A. 105, 8531–6 (2008).

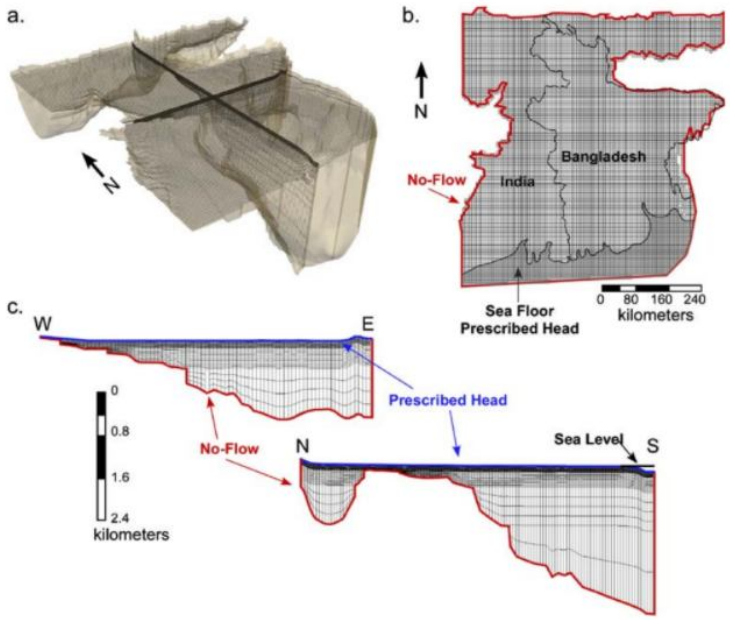

Figure-10: Bengal Basin groundwater flow model of Michael and Voss (2008, 2009[2]).

5. Surface water bodies identification, Flash Flood and its Management

In the primary stage the surface water bodies will be identified using the physical survey data conducted by another team assigned by Urban Development Directorate (UDD). Our team will then conduct direct observation of those water bodies, collect samples for laboratory tests. The direct observation will be both in dry and monsoon period to mark the variations of water level as well as the surrounding aspects. 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

6. Training and Workshop

On job training will be provided in field and finally after completion of final report submission a workshop will be arranged in UDD to make understand client about working methods and interpretation.

[2]Michael, H. A. & Voss, C. I. Controls on groundwater flow in the Bengal Basin of India and Bangladesh: regional modeling analysis. Hydrogeol. J. 17, 1561–1577 (2009).

Table 02: Monitoring wells and Resistivity Survey will be carried-out in MUDP Project Area

Name of Union	Name of investigations	
	Monitoring well *(upto 250m)*	Resistivity Survey *(300m profile)*
Ichhakhali, Wahedpur, Osmanpur, Karerhat, Katachhara, Khaiyachhara, Zorwarganj, Durgapur, Dhum, Maghadia, Mayani, Mithanala, Mirsharai, Saherkhali, Haitkandi, Hinguli	05	15

6. Grain size analysis of 100 numbers of samples from 5 numbers of monitoring wells will be conducted in Laboratory.
7. Field water level measurement and Slug test, P^H, EC etc.
8. Geophysical data (Resistivity survey) analysis for 20 numbers of Resistivity Survey.
9. Water quality test and major Anaion, Cation, Trace elements, TDS in Laboratory.
10. Organizing of workshop and seminar to present the research findings to different professionals.
11. Report writing.

6. Project Personnel and Team Composition

Professional Staff			
Name of Staff	**Area of Expertise**	**Position Assigned**	**Task Assigned**
Md. Fuad Hasan M.S in Geology, University of Dhaka.	Geotechnical, Hydro-geological, Geophysical, Borehole logging, Resistivity, Project Planning, Project Monitoring, Reporting, Data Processing and Interpretation, GIS mapping and analyses, Presentation.	Hydro-Geologist	**Tasks:** Project Planning and Monitoring, Monitoring Well Establishment, Resistivity Survey, data analysis and interpretation, Report writing, Presentation.
Dr. Mahfuz R Khan PhD in Hydro-Geology, University of Delaware, USA.	Hydrological and Hydro-geological Survey, Hydro-geological data processing and interpretation, Ground water modeling, Pump test, Slug test, Water quality mapping, Aquifer contamination characterization, GIS mapping and analyses, Presentation.	Hydro-Geologist	**Tasks:** Hydrological and Hydro-geological data analyses and interpretation, water quality mapping, ground water modeling, aquifer delineation, Reporting.
Md. Saddam Hossain M.S in Geology, University of Dhaka.	Geotechnical survey, Hydro-geological data collection and processing, GIS mapping, Resistivity survey data collection and processing, Ground water modeling.	Associate Geologist	**Tasks:** Hydro-geological data collection and processing, drilling sampling, water sampling, resistivity data collection.
Md. Delwaruzzaman M.S in Geology, University of Dhaka.	Hydro-geological data collection and processing, GIS mapping, Resistivity survey data collection and processing, Ground water modeling.	Associate Geologist	**Tasks:** Hydro-geological data collection and processing, drilling sampling, water sampling, resistivity data collection.

Md. Badrul Alam M.S in Geology, University of Dhaka.	Geotechnical survey, Hydro-geological data collection and processing, Borehole logging, GIS mapping and analyses, database management.	Associate Geologist	**Tasks:** Hydro-geological data processing, GIS mapping and analyses, database management, help to Hydro-geologist to interpretation, modeling and reporting. His task will be at Head office.
M.I.M Fuad M.S in Geology, University of Dhaka.	Hydro-geological data collection and processing, Resistivity survey data collection and processing, Borehole logging and sampling	Associate Geologist	**Tasks:** Hydro-geological data processing, help to Hydro-geologist to interpretation, modeling and reporting. His task will be at Head office.

7. Project Office

Client

Director
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Office Address: 82, Segunbagica, Dhaka - 1000.

Attention : Ahmed Akhtaruzzaman
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Consultant

Center for Geoservices and Research
Office Address: Flat # GCA (Gr. Floor), House # 409, Road # 06, Mirpur DOHS, Dhaka-1216

Attention : Md.Fuad Hasan
Proprietor,
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E-mail :fuad3014@gmail.com/fuad@cgrbd.com

8. Work Plan Time Schedule and Deliverables

Within the outcomes of Hydro-geological survey under Preparation of Development Plan for Mirsharai Upazial, Chittagong District: Risk Sensitive Landuse Plan (MUDP), risk reduction is a potential thematic area that comprise of reducing risk for urban & rural populations through surface and ground water, improved awareness of toxic elements in drinking water that targeted the specifically extreme poor. Considering the contaminated threat of the populated urban and rural areas of the project, UDD will have to be taken many initiatives for preparedness of the Project area. So Hydro-geological investigations are essential tools for safe drinking water assessment in this project area. The Hydro-geological investigations include monitoring well, resistivity survey, and water quality determination. The laboratory tests, such as major cataion, anaion, trace elements analysis and water quality tests. Finally the risk sensitive ground water model, water quality mapping and aquifer recharge area map will be prepared.

Eastern part of the study area comprises with very hard and compact older sequence (Tipam sandstone, Bhuban and Boka Bil formation) and are hilly land thus this part of the study area in not suitable for groundwater assessment. The top layer of the central part of the area is comprised with valley alluvial and colluviums and Beach and dune sand. The valley alluvium and colluvium is mostly composed of silts and finer particles therefore the aquifer of the area may be confined by silts and clay on top. To understand the confined aquifer condition of the area 2 monitoring well will be constructed at this part of the area. Aquifer of the area where the top layer (Western Part) is comprised with Beach and dune sand may be unconfined at top by sand particles. Therefore 2 monitoring well will be constructed at this part of the area for understanding the unconfined aquifer condition. The most western part of the study area is bounded by ocean thus there is a possibility of saline water intrusion at western part of the area. So to understand the salinity intrusion; one monitoring well will be constructed at the western part of the project area.

8.1. Monitoring Well Locations

Union Name	Survey Location Id	Tentative Coordinates	
		Latitude	Longitude
Hinguli	MW-1	22.89296	91.54902
Ichhakhali	MW-2	22.82140	91.48606
Mirsharai	MW-3	22.78972	91.55391
Saherkhali	MW-4	22.72626	91.49458
Haitkandi	MW-5	22.70858	91.57176

Use coordinate system of the data source-GCS: WGS 1984

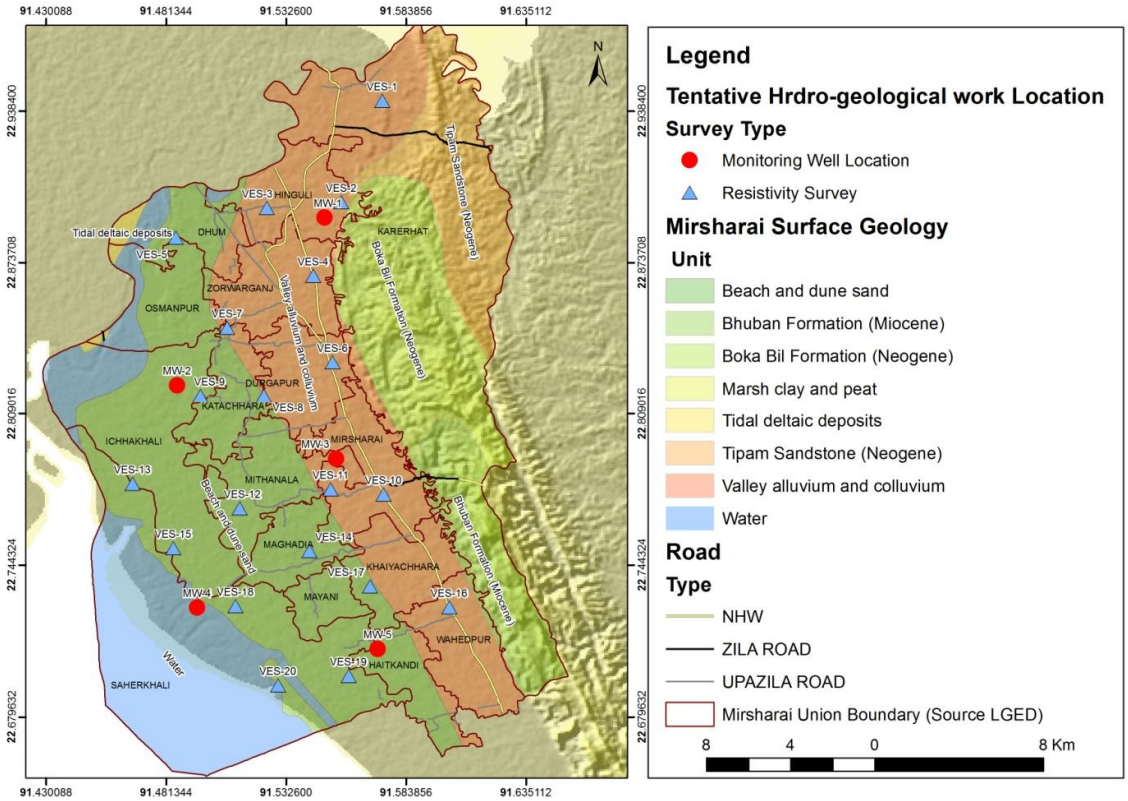


Figure-1:- Tentative site location for Monitoring Well (MW) and Resistivity (VES).

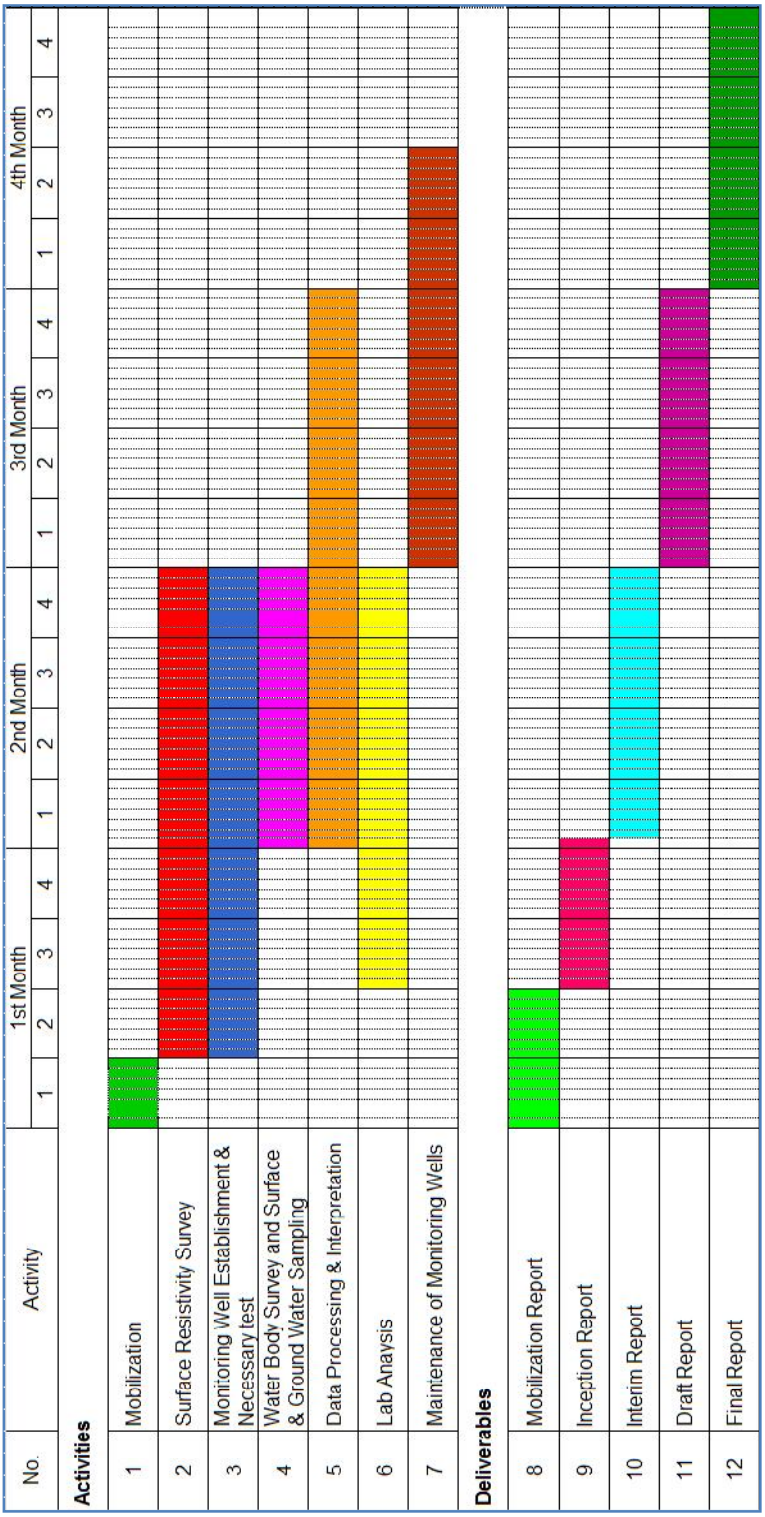
8.2. Resistivity Survey (VES) Locations

Union Name	Number of Test/Survey	Survey Location Id	Tentative Coordinates	
			Latitude	Longitude
Karerhat	1	VES-1	22.94273	91.57366
Hinguli	2	VES-2	22.89947	91.55612
		VES-3	22.89706	91.52427
Dhum	1	VES-5	22.88427	91.48550
Zorwarganj	1	VES-4	22.86804	91.54417
Osmanpur	-	-	-	-
Durgapur	1	VES-6	22.83116	91.55238
Katachhara	2	VES-7	22.84584	91.50734
		VES-8	22.81687	91.52311
Ichhakhali	3	VES-9	22.81680	91.49598
		VES-13	22.77897	91.46696
		VES-15	22.75153	91.48439
Mirsharai	2	VES-10	22.77438	91.57423
		VES-11	22.77658	91.55154
Mithanala	1	VES-12	22.76838	91.51278
Saherkhali	3	VES-18	22.72686	91.51099
		VES-19	22.69706	91.55936
		VES-20	22.69314	91.52918
Maghadia	1	VES-14	22.75030	91.54250
Khaiyachhara	1	VES-17	22.73524	91.56847
Mayani	-	-	-	-
Wahedpur	1	VES-16	22.72628	91.60224
Haitkandi	-	-	-	-

Use coordinate system of the data source-GCS: WGS 1984

Time schedule of activities with milestones (project duration 4 months)

The component-wise major activities are shown below:



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

Serial no.	**Deliveries**	**Submitted date**
1	Mobilization Report	21/12/2017
2	Inception Report	26/12/2017
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

9. Resource Allocation

Resources to be used in field data collections, data processing and interpretation are given in following Table-

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 Nos.	

10. Limitation and Mitigation Approach

In the field condition there may come some limitations and adverse conditions. We are to be alert to mitigate those adverse conditions. The main limitations are listed below:

1. Inaccessible site because of unavailable road network and hilly area.
2. Non co-operation of local people about the selected locations for field investigations.
3. Unavailability of secondary data on demand basis.

The mitigation approach should be like:

1. Hire local transport and labors where there is no accessible roads/hills.
2. By managing local government representative non co-operative problems can be solved.
3. If secondary data is needed to improve final outcome Urban Development Directorate (UDD) can issue letter to collect secondary data from concern authorities.

11. 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 starting phase of the project and verify the tentative locations of investigation 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 water 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