URBAN DEVELOPMENT DIRECTORATE (UDD)

Ministry of Housing and Public Works
Government of the People's Republic of Bangladesh

Mobilization Report
On
HYDRO-GEOLOGICAL SURVEYS AND STUDIES UNDER PREPARATION OF DEVELOPMENT PLAN FOR MEHERPUR ZILLA

Package No.: 6 (Six)

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Submitted by

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Executive Summary

Ensuring access to safe and affordable drinking water for all by 2030 is one of the sustainable development goals. Freshwater scarcity affects 40% of the world population. In many areas the situation is worsening largely because of lack of management of the available freshwater resources. Groundwater is the most important source of water in Bangladesh both for drinking and irrigation purpose. Freshwater resources management in coastal areas is even more important than mainland areas because of the limited availability of freshwater in such areas and its high vulnerability to natural and anthropogenic contamination as well as over-abstraction. 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) has initiated a project named 'Preparation Development Plan for Meherpur Zilla Project'. Under this project a Hydrogeological Surveys and Studies in 3 upazilas belonging to the district an area of approximately 734.00 sq. km. (*source: Bangladesh National Portal*) will be carried out. The aim of the survey is to identify water aquifers, its extensions, the quantity as well as quality of water, its reservation, maintenance and proper management for sustainable development of the proposed Zilla.

UDD entrusted to conduct the Hydro-Geological Surveys and Studies 'Center for Geoservices and Research' a consultant firm. To execute the survey, the firm will conduct a number of hydrogeological investigations including installation of nested monitoring wells in each upazila to monitor temporal variation in both groundwater quality and water level for a period of more than a year, assess the aquifer characteristics as well as well yield, vertical Electrical Resistivity Tomography (ERT) to delineate the aquifer system, slug test for hydraulic conductivity of the aquifers and field testing of water quality, water sampling and laboratory analysis for its quality, testing of lithological characters from monitoring wells, and developments of a groundwater model to assess various current and future water abstraction scenarios.

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.

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1. Introduction

Any development work requires water. Assessment of the availability of water and its quality is a prerequisite in any development work. This is even more important in the coastal area because of the limited availability of fresh water and their high contamination risk. It is highly appreciated that the Government of Bangladesh included hydrogeological surveys and studies in the Meherpur Sadar, Mujibnagar, and Gagni Upazilas of Meherpur Zilla. 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.

Urban Development Directorate (UDD) has planned to identify safe water sources and proper water supply for the development plan of the project area. Regarding this UDD initiated a hydro-geological surveys and studies project, named 'Preparation of Development Plan for Meherpur Zilla Project" (Figure 1), an area of approximately 734.00 sq. km. which includes 20 unions and 2 pourashava (*source: Bangladesh National Portal.)* "Center for Geoservices and Research" has been entrusted to conduct this project work. This project comprises of Hydrogeological and Geophysical investigations, groundwater modeling, draught analysis, and water quality mapping.

2. Client: About Urban Development Directorate (UDD)

Urban Development Directorate (UDD) was established through a government order on 17th July 1965. This directorate is working under the Ministry of Housing and Public Works. Since its inception, UDD is contributing to 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.

The 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.

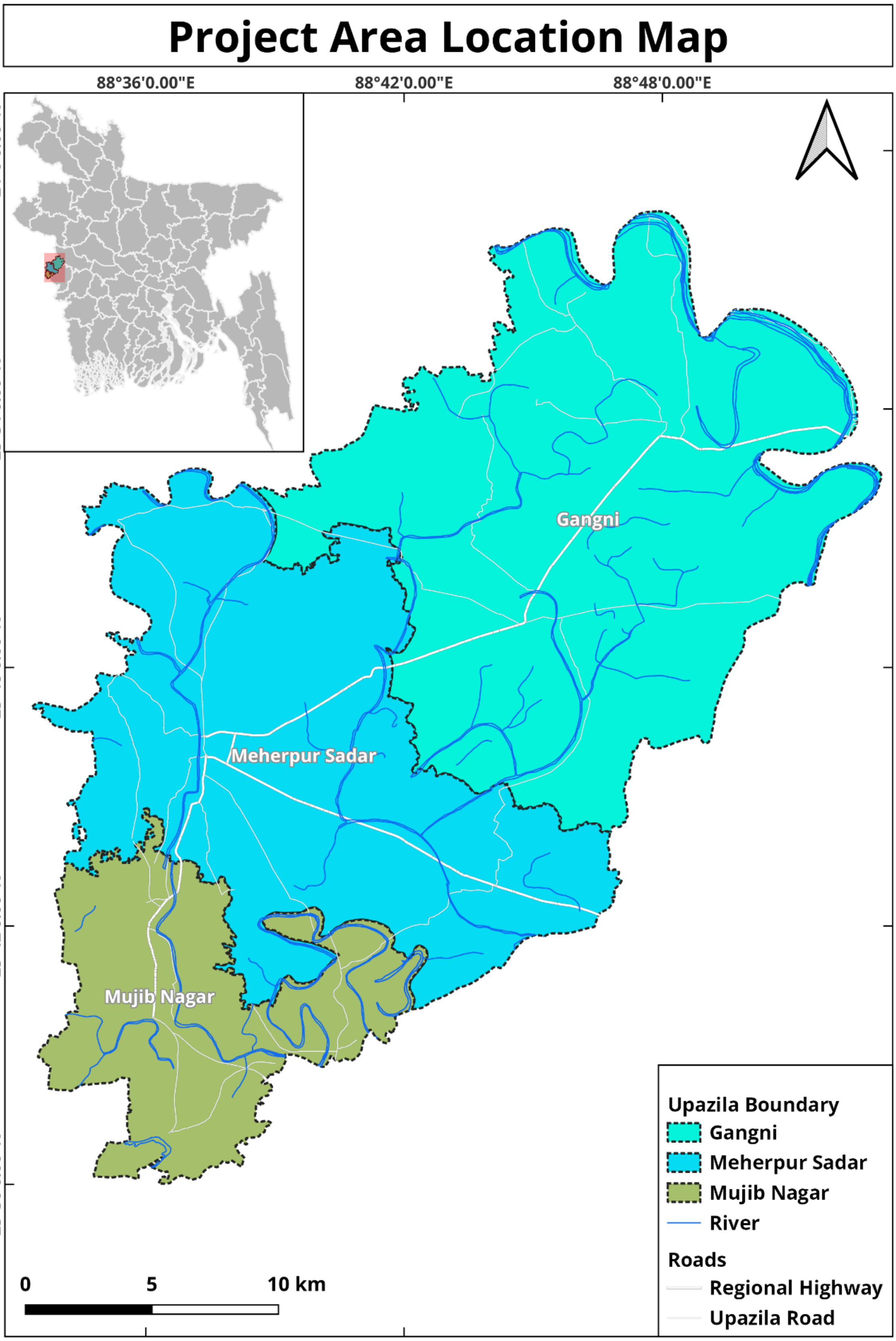


Figure 1 Map Showing Location and Accessibility

3. Location and Accessibility

The project area is in Meherpur District including Meherpur Sadar, Mujibnagar and Gangni Upazilas. The project area is bounded by It is bordered by the Indian state of West Bengal to the west, and by the Bangladeshi districts of Kushtia and Chuadanga to the east. (Figure-1). The major rivers flowing through the project area are Bhairab River, Kazla River, Chewtia River, Mathavanga River. The study area is located between 22º36´N and 24º00´N latitude and between 88º33´E and 88º56´E longitude. The 3 upazilas in the study area include 20 unions, 2 pourashava and a total population of 6,55,392 (*source: Bangladesh National Portal)* (Table 1).

Table 1 Name and Area of three Upazilas under Meherpur District.

District	Upazila	Total Area (km^2)	No of Unions	No. of Municipality	Male Population	Female Population	Total Population
Meherpur	Meherpur Sadar	275.15	7	1	1,27,300	1,29,342	2,56,642
	Mujibnagar	112.86	4	-	49,084	50,059	99,143
	Gangni	344.47	9	1	1,48,250	1,37,919	2,99,607
Total	**3 Upazilas**	**734.00**	**20**	**2**	**3,24,634**	**3,17,320**	**6,55,392**

Source: Bangladesh National Portal.

4. Aim and Objectives

The Government of the people's Republic of Bangladesh has allocated public funds for the cost of "preparation of Development Plan for 3 Meherpur Zilla" and assign Urban Development Directorate (UDD) to execute this project. Now UDD is inviting consulting firms to provide the services: "Hydro-geological Surveys and Studies". The consulting firm shall prepare the aquifer level of the region including seasonal variation, the potential area of groundwater recharge, the areas potential for drawing fresh water, the areas of interruption including probable change in hydrological cycle due to human intervention and climate change, suggest the remedial measures to make the hydrological system of the region sustainable, Draught model and development of an interactive groundwater model for future planning and impact assessment and Groundwater budget etc.

(i) To identify the aquifer level of the region including its seasonal variation
(ii) To identify the potential area of groundwater recharge
(iii) To identify the areas potential for drawing fresh water
(iv) To identify the areas of interruption including probable change in the hydrological cycle due to human intervention and climate change
(v) To suggest remedial measures to make the hydrological system of the region sustainable
(vi) Draught model development
(vii) Finally, development of an interactive groundwater model for future planning
(viii) Groundwater budget.

5. Methodology

5.1 Approach

Bangladesh is a developing country having the multi-sector development, industrialization and urbanization. As the development running forward, the need for water is also following the trends. The per capita water demand for urban area is 6-10 times more than rural area as well as the growing industry needs huge volume of water. The main source of the required water is groundwater and surface water serves partial needs which come from rivers, khals, ponds, rain etc. So it is needed to access the water availability and quality of water of an area prior to develop. The Government of Bangladesh has decided to introduce sustainable development plan for Meherpur Zilla. Prior to prepare landuse plan it is very essential to access surface and subsurface hydro-geological conditions and its relation with the development plan.

Step 1: To define the groundwater level and aquifer system in the project area

The most important work in any hydrogeological study is to identify the aquifer system for the assessment of available water storage and quality of Groundwater, how much water to be drawn per year, water level variations and longevity of the aquifer. As the study area is mostly deltaic deposits, the availability of fresh water is very important. Delineation of aquifers in the study area can be done by direct methods of subsurface data collection. Direct method includes drilling boreholes at multiple locations and collections of lithological data for laboratory analysis to determine hydraulic properties of the aquifers and locate the recharge and discharge area of the aquifer system which may situated far beyond the project area. Department of Public Health Engineering has developed an aquifer database consisting of more than 3000 borehole logs covering for the whole Bangladesh (Source: DPHE) (Figure-2). This dataset will be used for preliminary mapping of the regional extent of the aquifers, then detailed local investigation will be carried out in the study area for exact aquifer mapping and determination of hydraulic properties of the aquifers. The regional and local firsthand data will be used to prepare a 3D aquifer model, like shown in Figure-3.

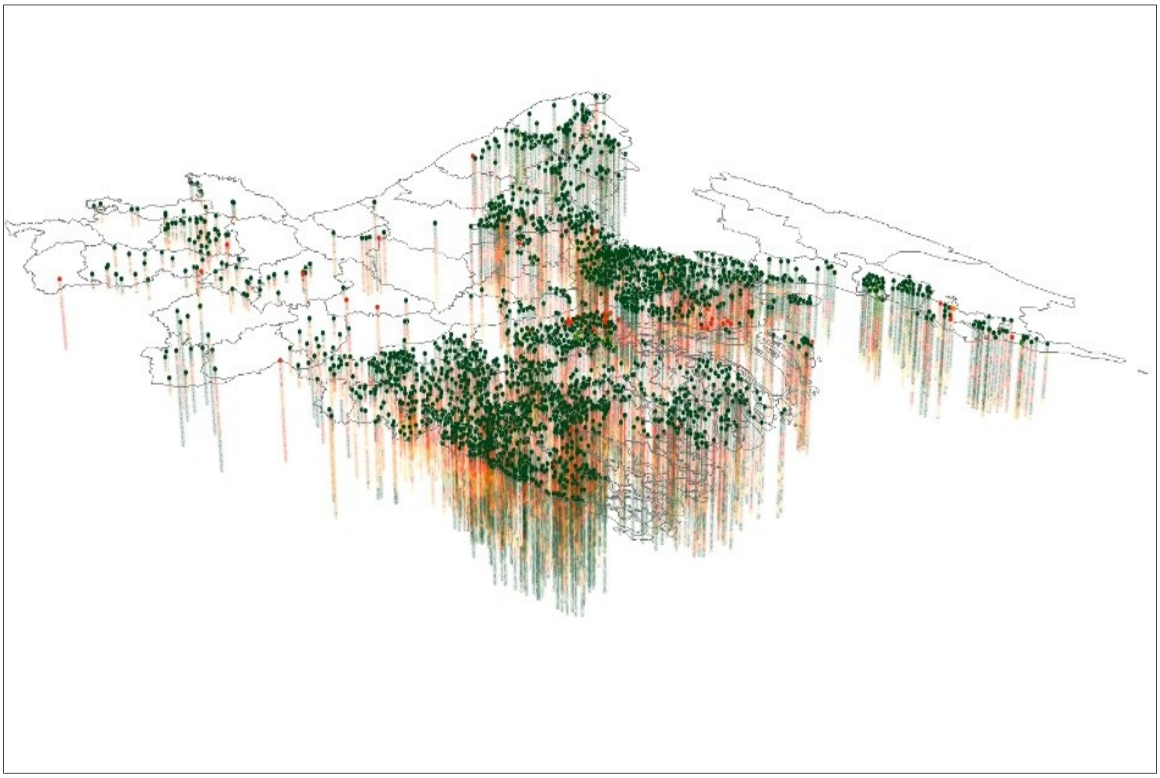


Figure 2 Showing the 3D distribution of existing borehole logs of DPHE distributed all over Bangladesh.

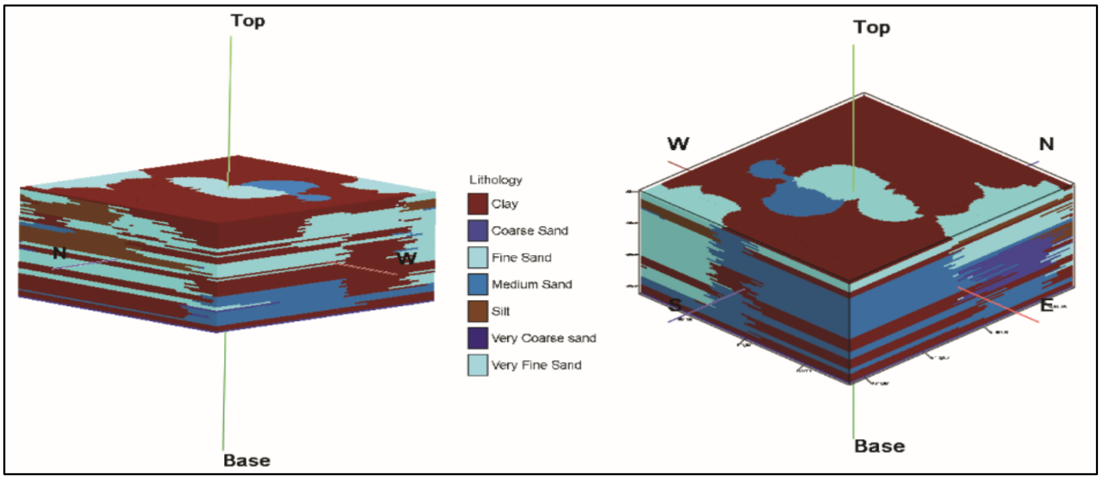


Figure 3 3D model of ground water aquifer.

To estimate the actual available groundwater resource volume, long time groundwater level observation data is important. 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 types of groundwater level maps will be prepared, groundwater level in wet season, groundwater level in dry season, and regional trend in groundwater level using secondhand data if available.

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 field data water quality map will be prepared, one for each water quality parameter such as Electrical Conductivity or Chloride, Arsenic etc. Local-scale groundwater quality maps will be produced for the study area, Example maps for arsenic and Electrical Conductivity are shown in Figure-4.

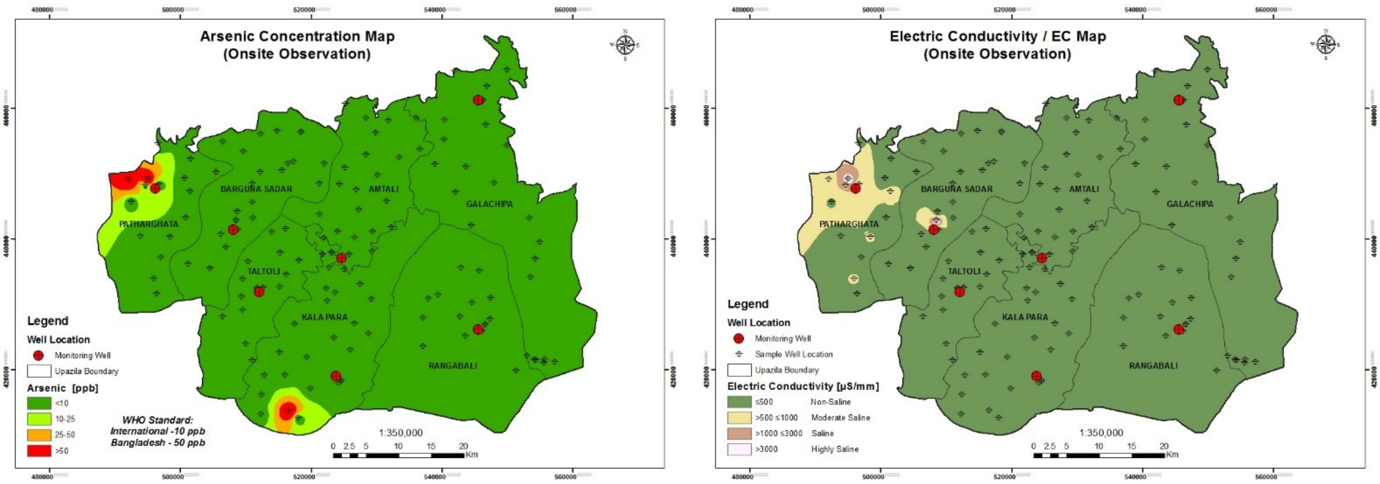


Figure 4 Example map for water quality by means of Arsenic and Electrical Conductivity

Table 2 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 various pumping/abstraction 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 be assessed based on the variations in groundwater and river water level as well as the variation in EC.

5.1. Detailed work Methodology.

5.1.1 Delineation of aquifers and determination of their hydraulic properties

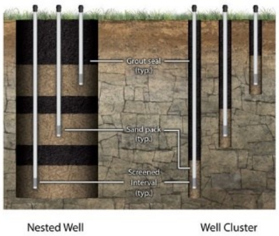
Both direct and indirect methods of subsurface data collection will be employed for the delineation of aquifers in the study area. Direct investigation includes drilling boreholes at multiple locations and collections of lithological data for laboratory analysis to determine hydraulic properties of the aquifers. The direct method provides precise information of the subsurface; however, they provide only point information and are expensive. Surface geophysical investigations 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.

5.1.2 Monitoring Well

A total of 7 (Seven) monitoring wells clusters (each cluster contains 3 wells in different depths), will be drilled i.e. total 21 nos. of monitoring wells. Locally available direct 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 intervals throughout the study period to assess the spatial and temporal changes in water quality.

Note: Clustered well: A cluster of wells where tubes or pipes are constructed in separate (5-10 feet surface distance to each other), individual boreholes that are drilled and completed at different depths.



A

B

Vertical (fig: A) and surface (fig: B) position of clustered wells

Figure 5 Drilling setup direct circulation method.

5.1.3 Electrical Resistivity Survey

Boreholes provide direct information about the subsurface. However, drilling of boreholes is expensive and their density in an area is usually low resulting in a spare point data about the subsurface geology. Interpolation of these sparse data for mapping subsurface geology/aquifers can be erroneous since usually there are data gaps over a large area between each borehole. Geophysical methods can be very useful in minimizing the data gap. In this study Electrical Resistivity Tomography (ERT) will be conducted in a total of 15 locations, (Figure-6). These 15 will be distributed between these nested wells.

In electrical resistivity surveys, electrical currents are 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. A typical setup for resistivity survey is shown in Figure-7.

Figure 7 Typical ERT setup.

5.1.4 Determination of hydraulic properties of the aquifer

Accurate assessments of hydraulic properties of aquifers are essential for developing an acceptable groundwater model. Both laboratory (**grain size analysis**) and in-situ (**slug test**) methods will be employed to determine the hydraulic properties of the aquifers.

a. Grain Size Analysis: 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.

b. Slug Test: As the project area is very widely spread. 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 the 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 data logger (Figure 8). 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 well. In addition, slug tests will be carried out throughout the project area in existing hand tube wells.

Figure 8 Automatic data logger

A slug test is a controlled field experiment, performed by hydrogeologist to estimate the hydraulic properties of aquifers and aquitards, in which the water level in a control well is caused to change suddenly (rise or fall) and the subsequent water-level response (displacement or change from static) is measured through time in the control well and one or more surrounding observation wells (Figure 9). Slug tests are frequently designated as rising-head or falling-head tests to describe water-level recovery in the control well following test initiation. Other terms sometimes used instead of slug test include bail down test, slug-in test and slug-out test.

Figure 9 Field slug test

The goal of a slug test, as in any aquifer test, is to estimate hydraulic properties of an aquifer system such as hydraulic conductivity.

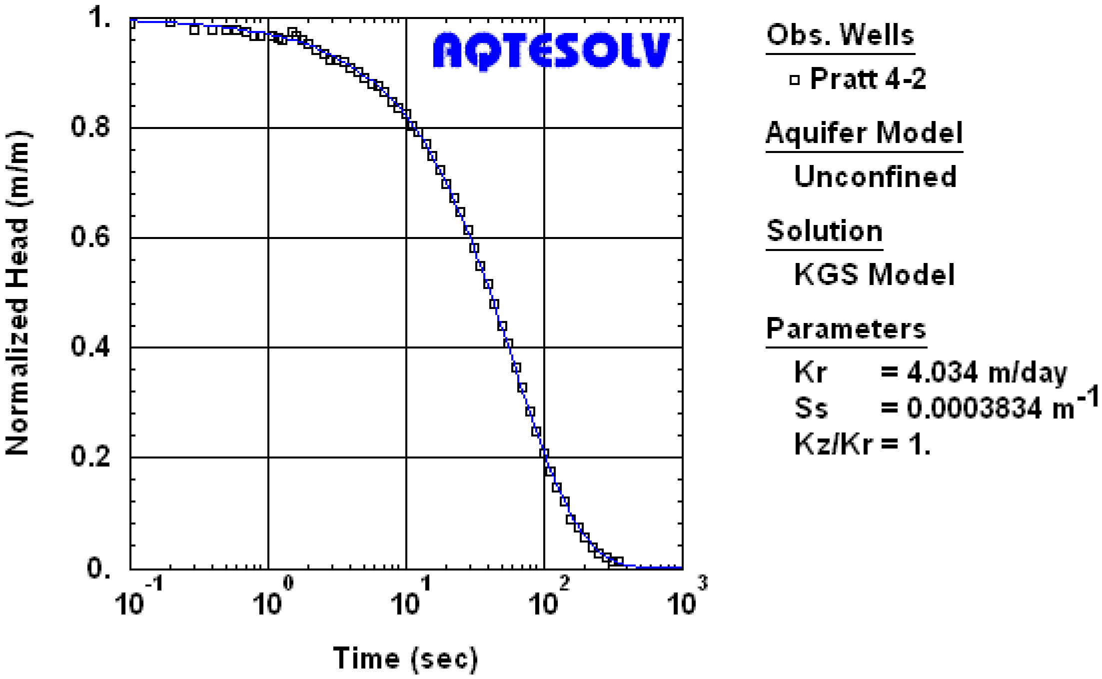


Figure 10 Estimation of aquifer properties from time-displacement data collected during an overdamped slug.

Typically, aquifer properties are estimated from a slug test by fitting mathematical models (type curves) to displacement data through a procedure known as curve matching (Figure 10).

5.1.5 Preparation of a 3D model of aquifer architecture

Based on existing borehole logs, the 21 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.

5.1.6 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 detailed groundwater level map for each of the wet and dry seasons will be prepared based on extensive groundwater level survey in existing hand tube wells throughout the study area. An automatic electrical data logger will install 21 monitoring wells to measure continuous groundwater level (Figure 8). Seasonal variability in groundwater level will be determined based on groundwater level monitoring in the 21 monitoring wells that will be installed during this study. If there is available any existing monitoring station from other organizations, that data will be collected and used for ground water level mapping.

Besides groundwater level monitoring, data on existing pumping, another piece of information crucial for modeling, will be collected during field surveys. 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 11).

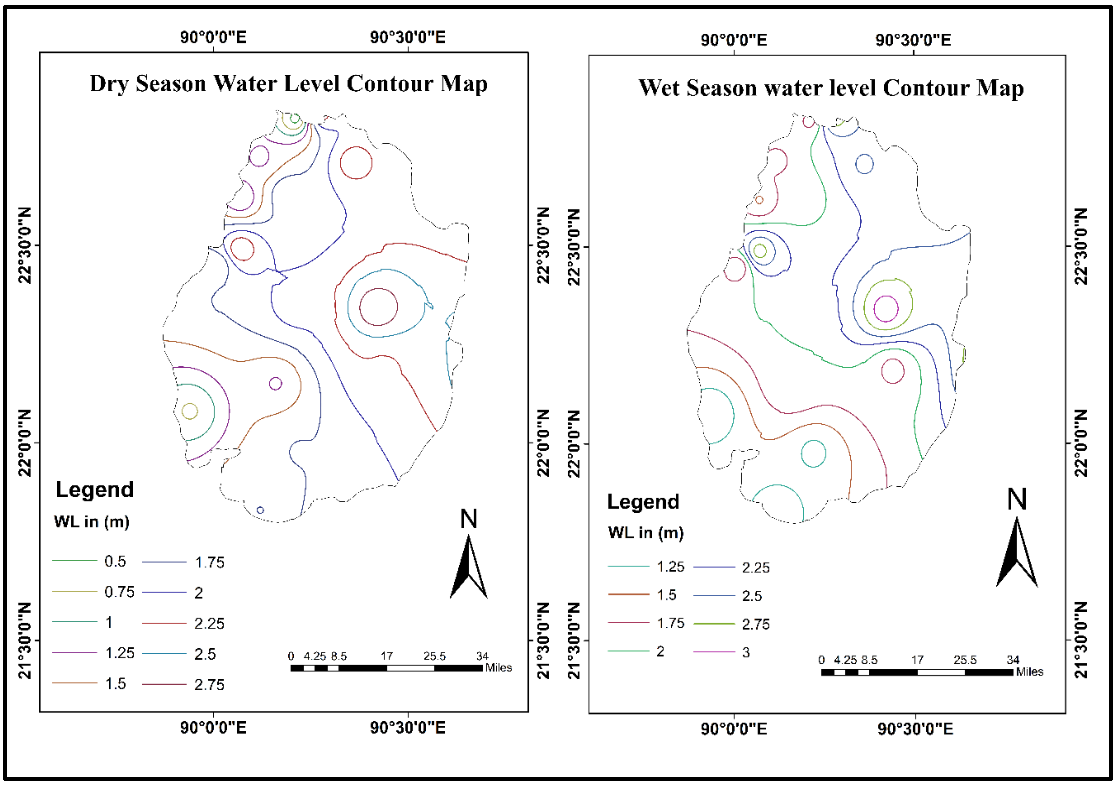


Figure 11 Example Ground water level map Dry and wet Season.

5.1.7 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, and TDS* will be measured in situ using hand held instruments (Figure 12, 13). 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*. A detailed 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 12 In field water quality measurement instrument.

Figure 13 Checking water quality in field.

5.1.8 Draught Modeling

GIS based draught analysis, and modeling will be developed in this study area with the help of satellite images (Landsat_8 OLI/TIRS), remote sensing, standardized precipitation index, Multiple criteria decision analysis and hydro meteorological data.

5.1.9 Groundwater modeling

A detailed 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) 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.

In case of sea water intrusion being important in the southern boundary of the area, variable density modeling will be considered using wither USGS flow code SUTRA or SeaWAT.

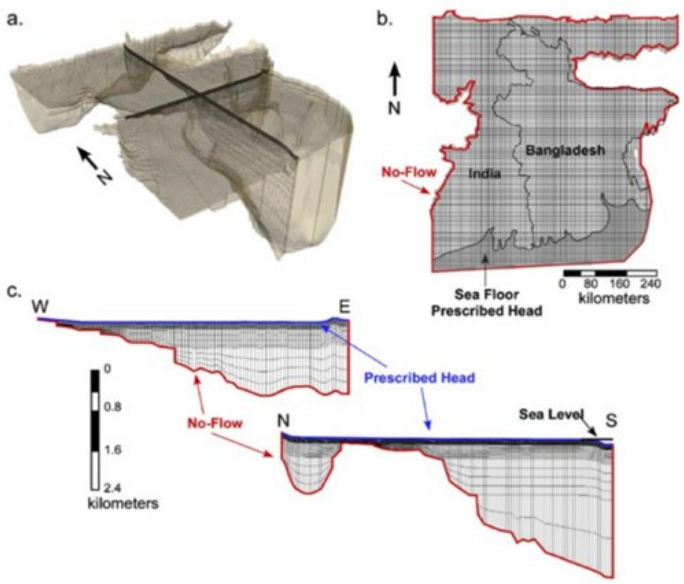


Figure 6 Bengal Basin groundwater flow model of Michael and Voss (2008, 2009[1]).

5.1.10 Surface water bodies identification

In the primary stage the surface water bodies will be identified using the physical survey conducted by another team assigned by Urban Development Directorate (UDD). Tidal flood history and Digital Elevation Map (DEM) will be used for zoning the tidal flood prone area which will be delivered by UDD as well. Our team will then conduct direct observation of

[1]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).

those water bodies. The direct observation will be both in dry and monsoon period to mark the variations of water level as well as the surrounding aspects.

5.1.11 Training and Workshop

On-the-job training will be provided in the 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.

6. Project Personnel and Team Composition

Professional Staff					Total Staff-month input		
Name of Staff	**Firm/Organization**	**Area of Expertise**	**Position Assigned**	**Task Assigned**	**Home**	**Field**	**Total**
Md. Fuad Hasan M.S in Geology, University of Dhaka.	Center for Geoservices and Research	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.	**1**	**2**	**3**
Dr. Mahfuzur Rahman Khan Ph.D in Hydro-Geology, Department of Geological Sciences, University of Delaware, USA.	Center for Geoservices and Research	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.	**2**	**1**	**3**
Md. Delwaruzzaman M.S in Geology, University of Dhaka.	Center for Geoservices and Research	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.	**3**	**3**	**6**
Md. Pavel Khan	Center for Geoservices	Geotechnical survey, Hydro-	Associate	**Tasks:** Hydro-geological data processing,	**3**	**3**	**6**

Professional Staff					Total Staff-month input		
Name of Staff	**Firm/Organization**	**Area of Expertise**	**Position Assigned**	**Task Assigned**	**Home**	**Field**	**Total**
M.S in Geology, King Fahd University of Petroleum and Minerals, Saudi Arabia. M.S in Geology, University of Dhaka.	and Research	geological data collection and processing, Borehole logging, GIS mapping and analyses, database management.	Geologist	GIS mapping and analyses, database management, help to Hydro-geologist to interpretation, modeling and reporting. His task will be at Head office.			
				Total			**18**

7. Project Office

Client

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Consultant

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Center for Geoservices and Research

Tel : +8801745787457
E-mail : fuad3014@gmail.com/fuad@cgrbd.com
Web : https://cgr.com.bd/

8. Work Plan Time Schedule and Deliverables

The work is intensive, will be completed within eighteen months (18) time. Field activities will be finished by Five (5) months and the monitoring activities of monitoring well will be continued through dry and monsoon season.

We have a plan to mobilize from the first week of December 2024, presuming that the parties can start the works by the time, according to notification in **53.1 of ToR** of **Section 2. Proposal Data Sheet** (Page 25-28) after completing all the formalities. The tasks and individual work are graphically represented in the following page-26.

In the first phase of the study all monitoring wells installation, electrical resistivity survey, groundwater level mapping, field test of water quality, sample collection for laboratory test of water and sediments, and slug test will be carried out. In the second phase all the laboratory analysis will be completed, all the field and laboratory data will be analyzed and compiled. The last phase of the study will include draught modeling and groundwater modeling to come up with the best management practice that will ensure the supply and protect the quality of potable water in the study area.

Table 3 Monitoring Well Locations

Nest No.	District	Upazila	Lat	Long
Clusterd Well-1	Meherpur	Mujibnagar	23.6682050	88.6182135
Clusterd Well-2		Meherpur Sadar	23.7742445	88.6340245
Clusterd Well-3			23.8152581	88.6262600
Clusterd Well-4			23.7228176	88.7336138
Clusterd Well-5		Gangni	23.8114222	88.7314160
Clusterd Well-6			23.8613449	88.7769227
Clusterd Well-7			23.8981255	88.8346004

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

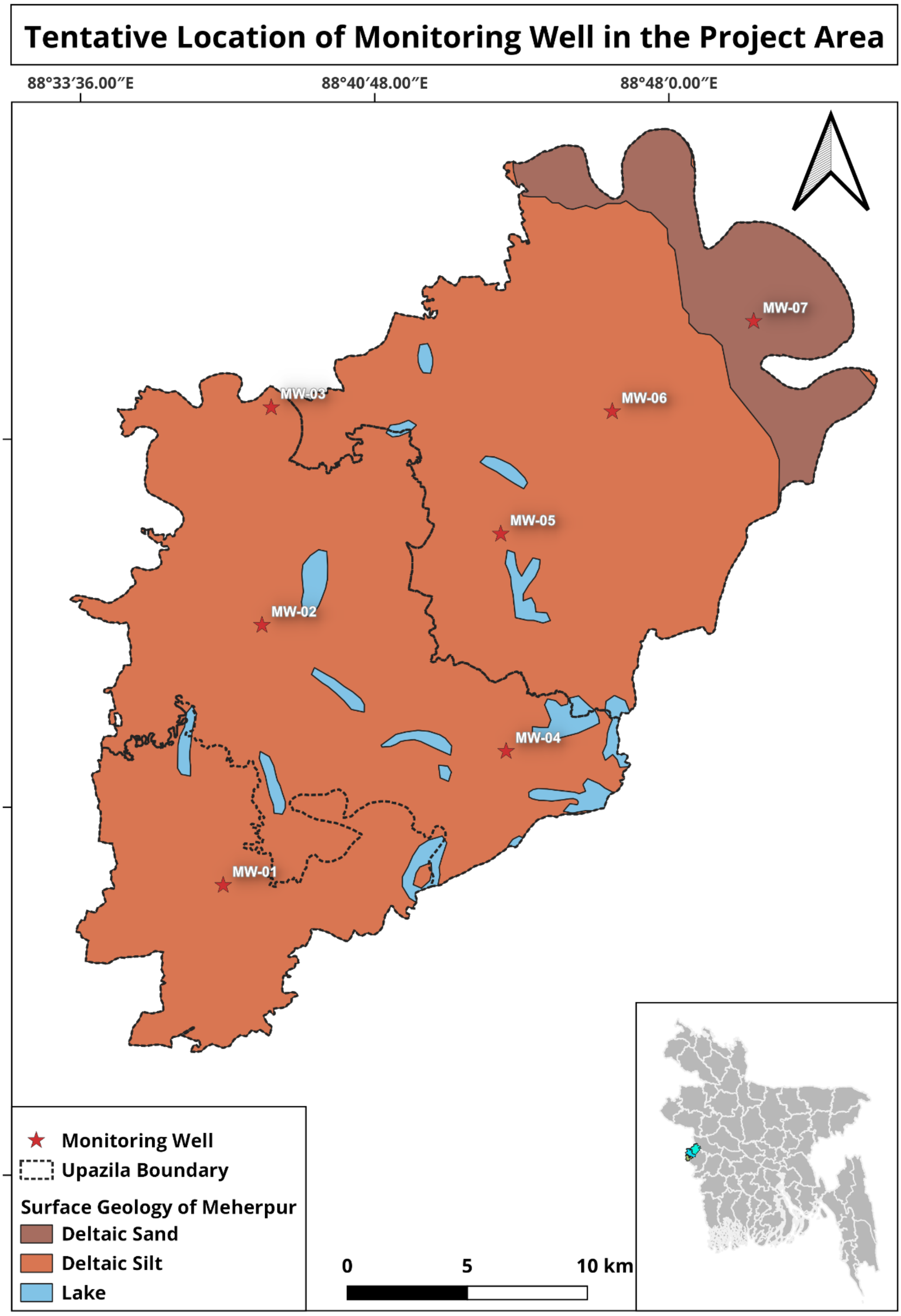


Figure 7 Tentative site location for Monitoring Well (MW) and Resistivity (VES).

Table 4 Resistivity Survey (ERT) Locations

VES No	District	Thana	Latitude	Longitude
ERT_1	Meherpur	Mujibnagar	23.709192	88.610437
ERT_2			23.632328	88.608547
ERT_3			23.679925	88.678750
ERT_4		Meherpur Sadar	23.779930	88.573950
ERT_5			23.839616	88.612999
ERT_7			23.746032	88.686194
ERT_8			23.715255	88.776730
ERT_6		Gangni	23.825234	88.682740
ERT_9			23.833839	88.758360
ERT_10			23.781947	88.740598
ERT_11			23.784475	88.804593
ERT_12			23.850144	88.835890
ERT_13			23.897269	88.801637
ERT_14			23.936034	88.768265
ERT_15			23.890410	88.720635

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

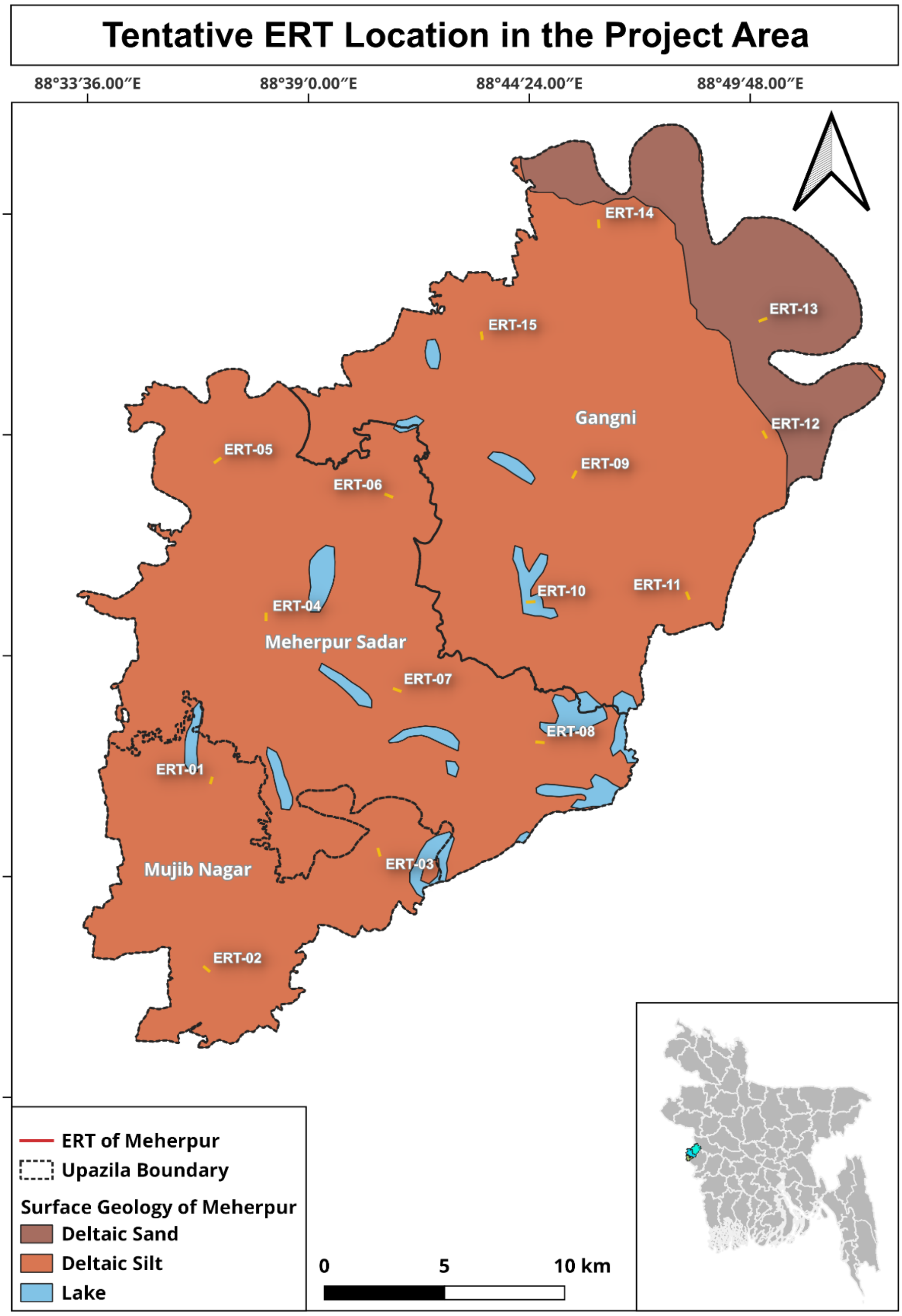


Figure 8 Tentative ERT location in the project area

Time schedule of activities with milestones (project duration 18 months)

The component-wise major activities are shown below:

No.	Activity	Activities by Months																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Activities																			
1	Site Selection for Monitoring well and ERT.																		
1	Monitoring Well Establishment & Necessary test																		
2	Electrical Resistivity Tomography																		
3	Monitoring Well and Existing well Water Sampling and Slug Test.																		
4	Lab Test for Water Quality and Hydrography for major Rivers and RTK Survey																		
5	Data Processing and Interpretation																		
Deliverables																			
6	Mobilization Report																		
7	Inception Report																		
8	Report on Establishment of Monitoring Well																		
9	Report on Literature based coastal morphodynamics study and sea level change																		
10	Report on Wet seasonal data collection, analysis and interpretation along with spatial distribution (GIS Shape file)																		
11	Report on Dry seasonal data collection, analysis and interpretation along with spatial distribution (GIS Shape file)																		
12	Report on Groundwater Scenario of the whole Hydrological Year along with identification of potential Area of Groundwater Recharge and Drawing; and Surface water and Groundwater Interfacing Model including GIS shape file and Thematic Map																		
13	Final Report Containing Recommendation on Sustainable Hydrological System, Human Intervention and Climate Change of the Project Area and Posting the Report on Website and 3D visualization subsurface model made by fiberglass																		

Table 5 The following reports will be submitted to the UDD on or before the following dates:

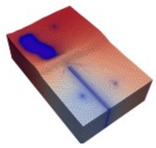
Serial no.	**Deliveries**	**Submitted date**
1	Mobilization Report	22/12/2024
2	Inception Report	29/12/2024
3	Report on Establishment of Monitoring Well	23/02/2025
4	Report on Dry seasonal data collection, analysis and interpretation along with spatial distribution (GIS Shape file)	24/06/2024
5	Report on Wet seasonal data collection, analysis and interpretation along with spatial distribution (GIS Shape file)	22/12/2025
6	Report on Groundwater Scenario of the whole Hydrological Year along with identification of potential Area of Groundwater Recharge and Drawing; and Surface water and Groundwater Interfacing Model including GIS shape file and Thematic Map	21/04/2026
7	Final Report Containing Recommendation on Sustainable Hydrological System, Human Intervention and Climate Change of the Project Area and Posting the Report on Website	23/05/2026

9. Resource Allocation

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

Table 6 List of equipments

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	Workstation, Plotter, Printer, Scanner, Latop, Tab and Android Phone	10 Nos.	
12	Submersible Pump	1 Nos.	

10. Limitation and Mitigation Approach

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

1. Non-co-operation of local people about the selected locations for field investigations.
2. Unavailability of secondary data on demand basis.

The mitigation approach should be like:

1. Hire local transport and labors where there are no accessible roads/rivers.
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 equipment in the starting phase of the project and verify the tentative locations of investigation with due concern of Urban Development Directorate (UDD). Afterward, the 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. Detailed 3D map of aquifer framework
2. Detail map of water table and their seasonal variability
3. Detail map of water quality
4. Draught model
5. A 3D groundwater flow model
6. A recharge area map
7. 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 policies 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-hydrogeologists.