URBAN DEVELOPMENT DIRECTORATE (UDD)

Ministry of Housing and Public Works

Government of the People's Republic of Bangladesh

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

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Submitted by

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1 Introduction

Any development work requires water. Therefore, assessing the availability and quality of water is crucial for any development work. This is particularly important in coastal areas, where fresh water is scarce and at high risk of contamination. It is highly appreciated that the Government of Bangladesh included hydrogeological surveys and studies in the Meherpur Sadar, Mujibnagar, and Gangni Upazilas. 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.

The Urban Development Directorate (UDD) has planned to identify safe water sources and establish an appropriate water supply system for the development of the project area. Regarding this UDD initiated a Hydrogeological surveys and studies project, named 'Preparation of Development Plan for Meherpur Zilla" (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, draught modeling, groundwater modeling, and water quality mapping.

All the abovementioned investigations will be done according to TOR but for fulfillment of the Hydrogeological Survey some additional investigations must be conducted. Those are Electrical Resistivity Tomography (ERT) surveys, using the electrical resistivity method, to delineate the aquifer architecture. The specific yield/storage of the aquifer surrounding the monitoring wells which will be conducted via slug test which is quick but very effective.

1.1 Purpose of the Inception Report:

Generally, an inception report is the blueprint of a project. The broad purpose of the Inception Report is to set out the Consultant's approach to completion of a Project, focusing on overall requirements, equipment, and manpower as well as work schedule in relation to the proposed methodology. 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, a preliminary field survey was carried out to select locations on the ground for carrying out various field activities according to the TOR. Factors considered during site selection in the field include geological conditions, accessibility, and logistics. Selection of field sites helps in fine tuning the time schedule and project planning; this report outlines the details of proposed work plans and the field site selected during the preliminary field survey.

1.2 Physical Status of the Project Area:

The contract for this project between UDD and CGR was signed on December 04, 2024. Following the signing, a team from the Center for Geoservices and Research completed a five-day field trip from 8th December to 12th December 2024. The team visited the project area to assess site accessibility, logistics available locally and the possible difficulties in the project area. Among the 3 upazilas, all have good accessibility (Figure 1).

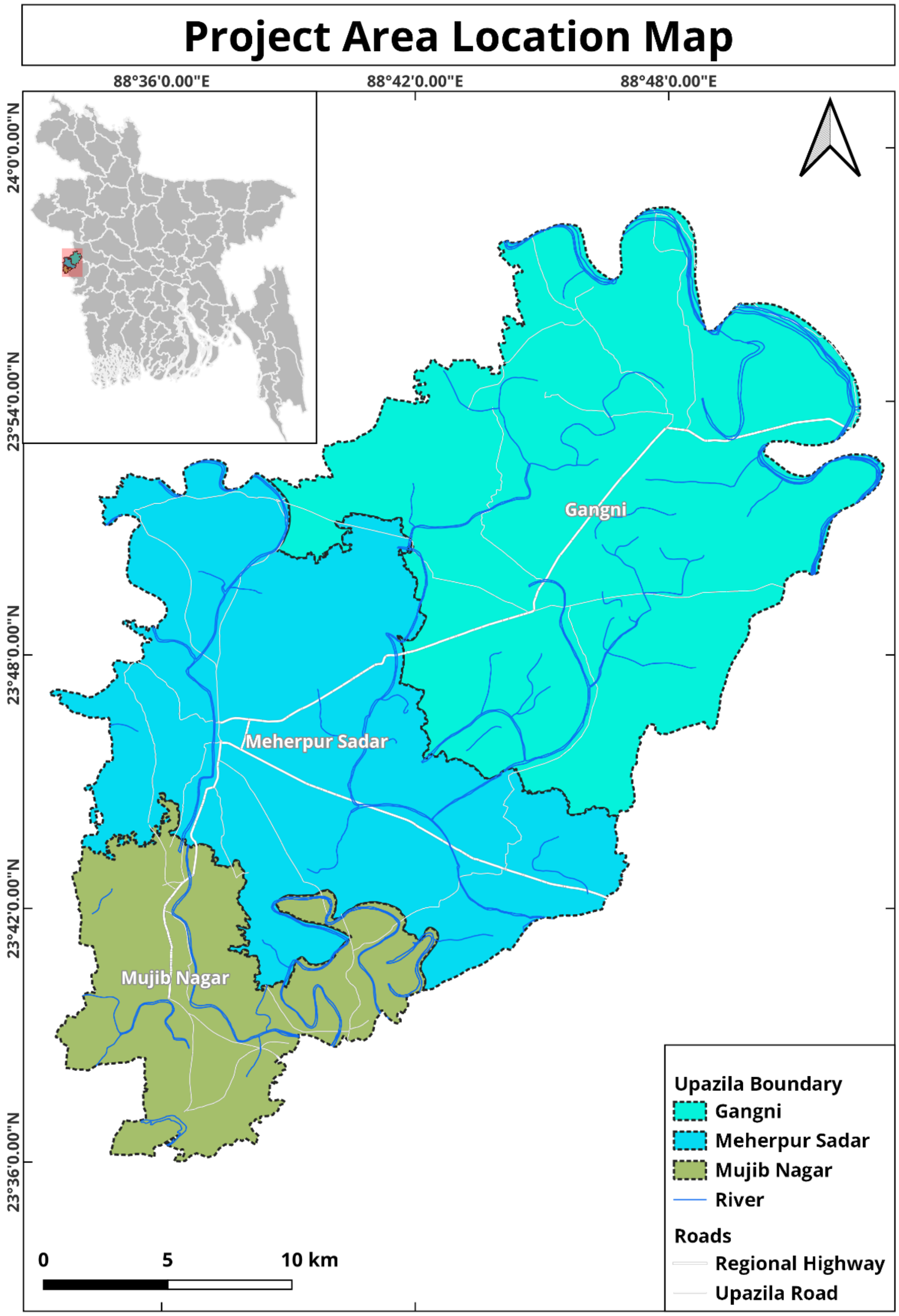


Figure 1 Location Map of the Project area (Source: BBS and LGED)

2 Project Overview

2.1 Objectives of Consultancy:

As per the signed contract between Urban Development Directorate (UDD) and Center for Geoservices and Research (CGR), the consultancy works broadly include:

a) To identify the groundwater (aquifer) level of the region including its seasonal variation.
b) To identify the potential area of groundwater recharge.
c) To identify the areas potential for drawing fresh ground water.
d) To identify the areas of interruption including probable change in the hydrological cycle due to human intervention and climate change.
e) To suggest remedial measures to make the hydrological system of the region sustainable.
f) Draught model development
g) Finally, development of an interactive groundwater model for future planning.

2.2 Approach:

Project objectives in the TOR can be grouped into two major objectives-

1) **Field survey and laboratory analysis:** This is essential to determine the aquifer system and their physical, chemical and biological characteristics. Physical characteristics include groundwater level and their spatial-temporal variation, aquifer properties pertaining to groundwater flow and their spatial variation, properties pertaining to groundwater yielding capacity of the aquifer (recharge, aquifer extent, thickness, and aquifer boundaries), and the distribution of surface water bodies and their water quality in the study area. Chemical characteristics include the quality of groundwater in the study area and their spatial and seasonal variations. The most important chemical contaminants in the study area are arsenic and salinity. The only potential biological contaminant in the study area is likely to be the presence of fecal contaminant in the very shallow depth (10-20 m depth).
2) **Assessment of groundwater potential and threats:** This is the second but most important part of the study that will be initiated after the completion of the field survey and laboratory analysis. Completion of this part would require synthetization of all the field and laboratory data and development of a series of groundwater

models. Hydrogeological understanding gained from the field survey and laboratory data analysis will guide the hydrogeologist in developing several alternative conceptual models of the study area, each of these conceptual models will be tested using the 3D groundwater flow code MODFLOW, SUTRA, and SEAWAT. Model output for each of the conceptual systems will be verified against the field data and the model for which the model data would match the observations will be the basis for further analysis of groundwater management scenarios and aquifer risk analysis. A series of variable density cross-sectional models will be developed to quantify the groundwater-surface water interaction in the study area.

An interim report will be submitted after the completion of the field survey, laboratory analysis, and synthetization of field and laboratory data. The report should include all the results from the field and laboratory analysis as well as hydrogeological interpretation of the study area. It will also include the conceptual models developed by a hydrogeologist.

Groundwater modeling will begin after the submission of the interim report. Details of the modeling results focusing on the freshwater availability, its vulnerability, and management options will be included in the draft final report. The final report will be submitted after incorporating the comments and concerns of UDD on the draft final report.

The project must be completed as per industry standards 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.

3 Methodology:

The complete survey operation for Hydro-Geological Survey must be planned in such a manner that all the tests/studies are 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.

3.1 Establishment of Field Office:

Center for Geoservices and Research has been hired an office cum residence for the Hydrogeologists, Associated Geologists and officers in Meherpur Sadar area from where it is easy to move all around the project area. For the field crew temporary tents will be prepared on the survey location site for their accommodation.

3.2 Mobilization of services:

Drilling rigs for monitoring wells and personnel have been identified locally in each upazila in the project area. The resistivity survey equipment and other equipment will be mobilized from Dhaka to the field office in Meherpur Sadar. The actual movement will be taking place 10^{th} January 2024. Drilling and installation of monitoring wells and other hydrogeological surveys will begin from the second week of January 2024. 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. Both automatic and manual monitoring for the water level in the monitoring wells will be continued for one year from the completion of the monitoring wells. Till date all are going on as per plan and mobilization will take place as scheduled.

3.3 Selection of Survey Location:

Survey locations were selected first based on 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 landowners or head of specific organization. All the locations are verified finally, and permission is also obtained from the landowners or head of the organizations.

3.4 Drilling of Monitoring Wells:

Since the groundwater quality in the study area varies with depth, monitoring wells at multiple depth intervals is essential. A total of 21 monitoring wells will be installed in seven locations (one set of 3 wells in each location), (Figure 2). At each location a *well cluster of three wells (one at around 300 m depth, one at around 125 m depth and the other at around 30 m depth, each well will be within 5-10 ft from the other) will be installed. The location of these monitoring wells will be decided based on the locations of existing monitoring wells, if any, local variation in aquifer/groundwater quality, and site logistics. After successful completion of drilling, short screen (10-20 ft) 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.

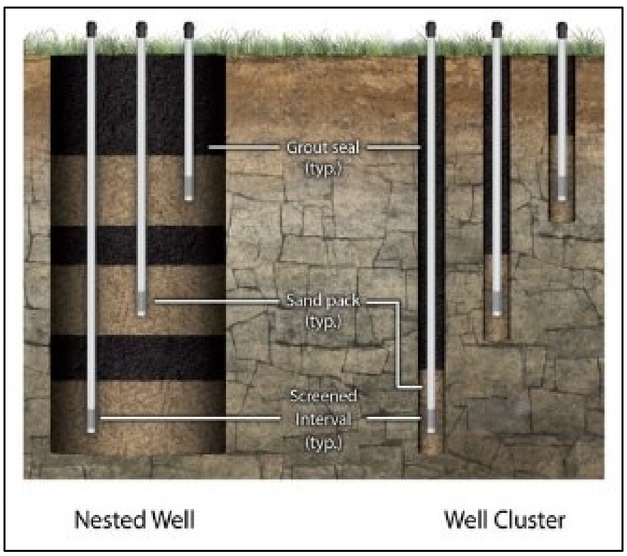


Figure 2 Well Cluster (Vertical and Surface view)

* **Well Cluster:** 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.

Reverse circulation conventional drilling method (Figure 3) will be used for the drilling the monitoring wells. The sampling interval will be every 10 feet and preserved for the grain size analysis. Water samples will also be collected after finishing the well drilling and pipe installation for chemical analysis like $P^{H,}$ Electrical conductivity (EC), and Arsenic, in field and elemental analysis in laboratory. Water levels will be measured automatically in hourly intervals in the deep well using automatic data loggers for a period of one year. In the shallow wells water levels will be measured bi-weekly using a water level meter for a period of one year.

Figure 3 Drilling Procedure of Monitoring well (Source: CGR)

3.5 Lithological Logging:

A well site Geologist will be present during drilling, and he will be responsible for logging samples in standard format, collected every 10 feet interval. He will log the lithology into the log sheet provided by the 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 the surrounding area will be restored and drilling equipment will be released for the next location.

3.6 Resistivity Survey (Vertical Electrical Sounding):

Boreholes provide direct information about the subsurface. However, drilling boreholes is expensive and their density in an area is usually low resulting in 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 4). These 6 points will be distributed in between these nested wells.

Figure 4 Resistivity Survey Setup (Source: CGR)

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 resistivity of the subsurface formations. VES is 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.

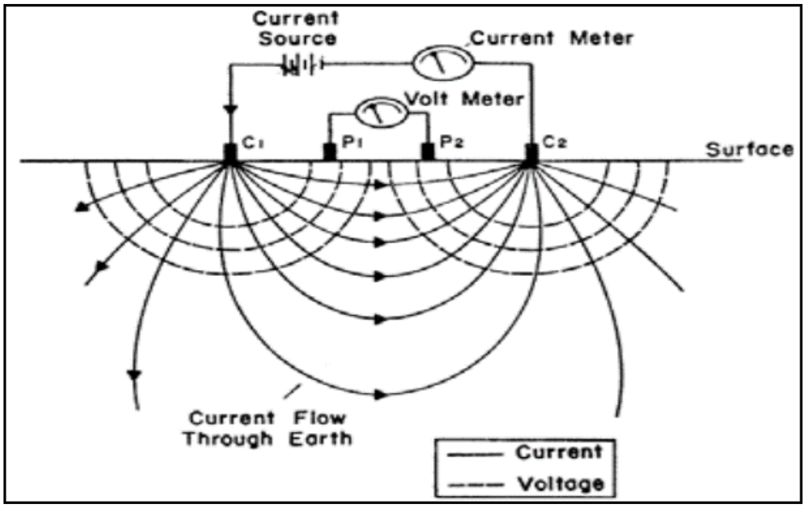


Figure 5 Basic Concept of Resistivity Measurement. [Source: Abstracted from Benson et al. (1988)]. Note: C1 and C2, P1 and P2 refer to the current and voltage/potential electrodes respectively.

According to the following formula which is based on Ohm's Law: $k\,(\Delta V/I)=\rho$ ……….. eq 1

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, depends 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 6.

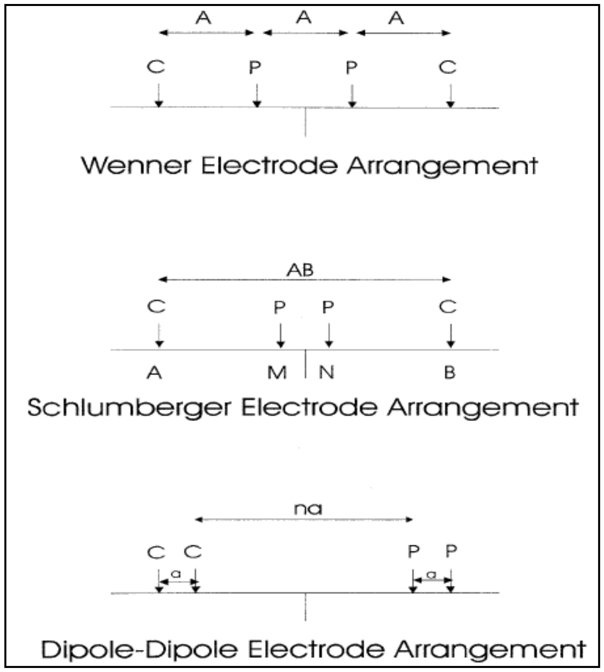


Figure 6 Standard Electrode Geometries. Source: Abstracted from ASTM D6431-99 (2005)

The Wenner array is mainly used for resistivity imaging/profiling and the Schlumberger array provides better results 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 7 shows the proportion of current flowing beneath a given depth Z as the ratio 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). Portion of current penetrating below a depth Z for a current electrode separation AB Proportion of current flowing below depth Z. For Wenner Configuration the expected depth of penetration is about one third of the array length (AB/3).

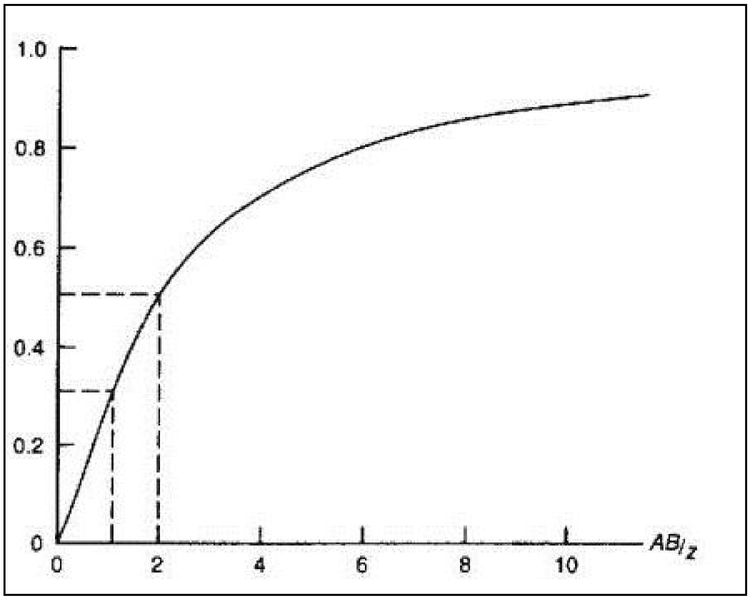


Figure 7 Fraction of current penetrating below a depth Z for a current electrode separation AB Proportion of current flowing below depth Z (Source: Telford, Second Edition)

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

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	0-50^0 C
Dimensions	(W) 206 X (H) 281 X (D) 200 mm
Weight	Approx. 7.5 Kg (Including Battery)

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.

3.7 Slug Test:

Since pump tests are very expensive, they are usually carried out at only a few locations, providing very sparse data on the aquifer properties. A cheap alternative to pump test is slug test. For high density coverage of hydraulic conductivity data slug tests will be performed in a large number of wells throughout the study area. 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 8). The temporal rate of this water level declines 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 to the 21 monitoring wells that will be installed under this study, slug tests will be carried out in at least 60 locations in the existing hand tube wells throughout the study area.

Figure 8 Automatic data logger (Source: CGR)

A slug test is a controlled field experiment, performed by groundwater hydrologists 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. 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 9 Field slag test (Source: CGR)

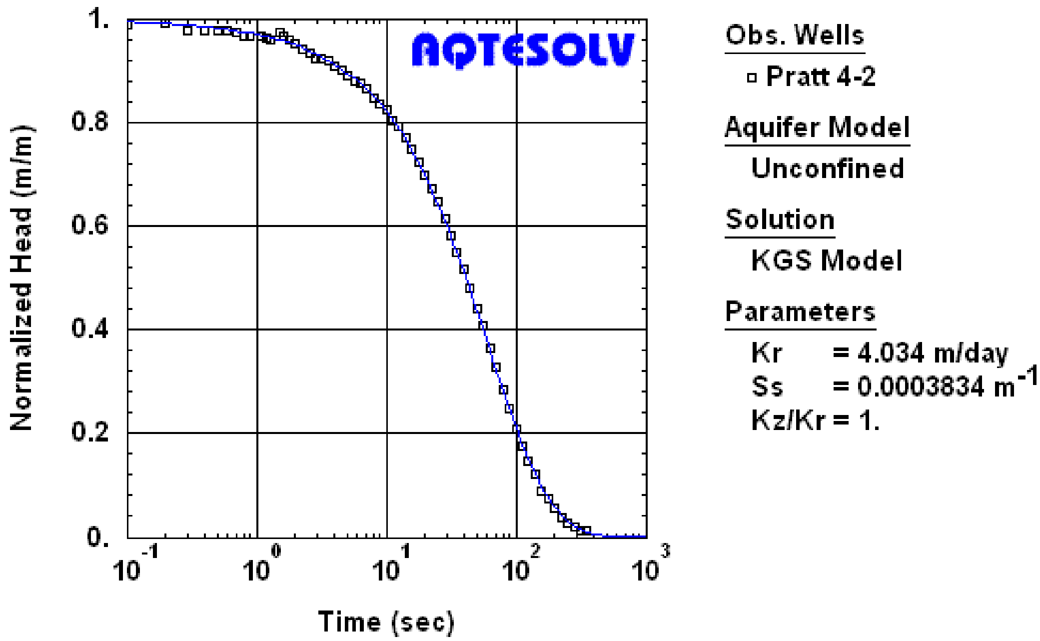


Figure 10 Estimation of aquifer properties from time-displacement data collected during an overdamped slug.

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).

3.8 Sediment and Water Quality 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 the completion of monitoring wells water samples from the monitoring wells as well as from the surface water body will be collected for a number of elemental analyses in laboratory, list of the chemical parameters are given in Table-2. Furthermore, local tube wells and community well's water will be tested at field for Arsenic (Ar), EC, and P^H using field kits and mobile testers.

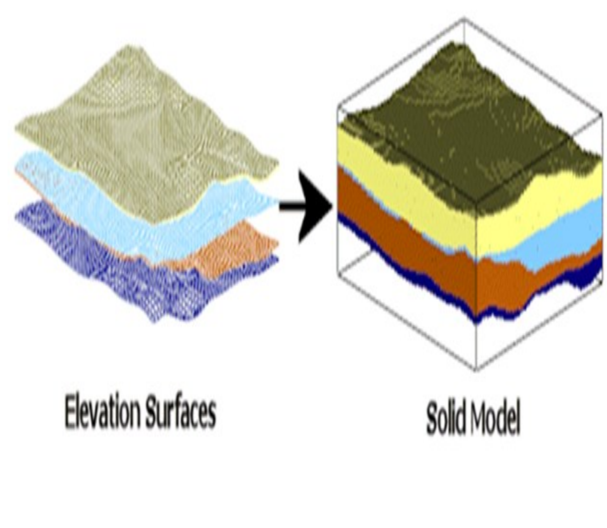
Table 2 Methods and instruments used for elemental analysis.

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	Atomic absorption spectrometer (GBC Sens AA)

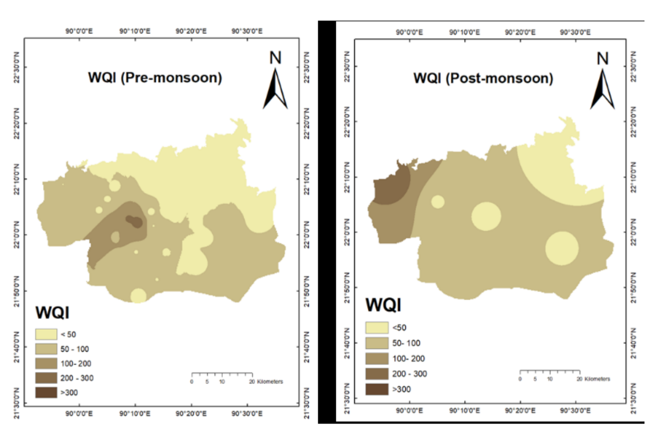
	(Mg^{2+})	
5	Iron (Fe^{2+})	Atomic absorption spectrometer (GBC Sens AA)
6	Manganese (Mn^{2+})	Atomic absorption spectrometer (GBC Sens AA)
7	Bicarbonate (HCO_3^-)	Titration method (Standard H_2SO_4 for HCO_3^-)
8	Chloride (Cl^-)	Titration method (Standard $AgNO_3$ for Cl^-)
9	Nitrate (NO_3^-)	UV visible 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)

3.9 Modeling

After collecting the entire field data an interim report will be submitted including a field data sheet. Ground water modeling will be done sequentially. After the successful completion of the models, maps etc., the final draft report will be submitted. Finally, after reviewing 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 the outcome from the survey in Figure 11.



Expected Ground water model



Expected water quality map

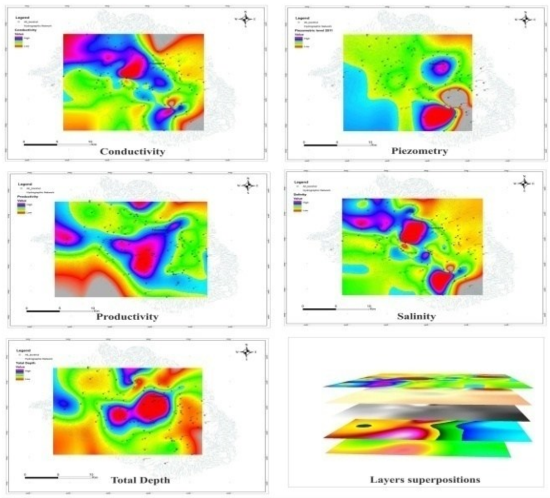
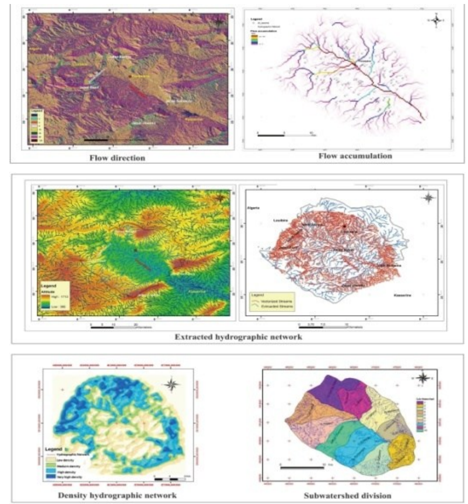
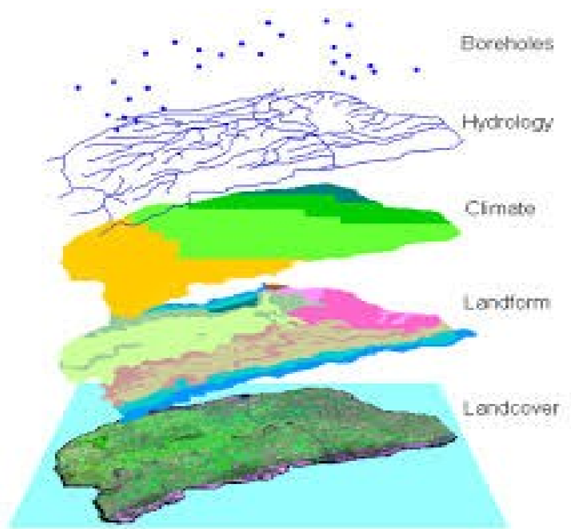
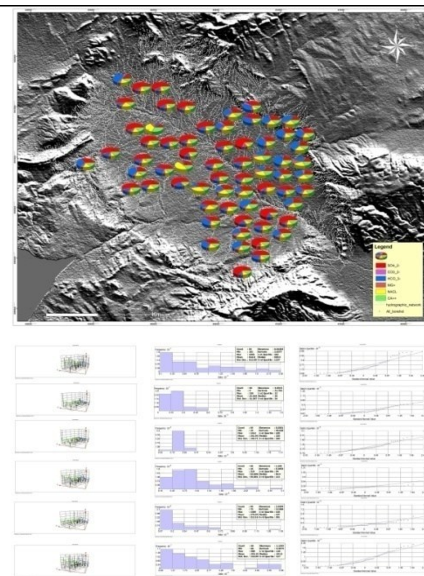
	
Expected conductivity with depth model	Expected Drainage network and draught model
	
Expected intigrated hydro-geological model	Expected water quality model

Figure 11 Samples of expected outcome models (Source: CGR)

3.10 Site Restoration:

For monitoring well drilling, the site will be dug and after finishing the drilling restoration works will be done by consultant's responsibility.

3.11 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.

3.12 Key Elements of the Project:

Urban Development Directorate (UDD) is going to perform Hydrogeological Survey 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 an experience expertise team for the Hydro-Geological Survey who will take great care of the project and achieve the project goals. Here is the list of resources to be used in the field survey.

Table 3 Resource Person of the firm

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.	Hydro-Geologist	**Tasks:** Project Planning and Monitoring, Monitoring Well Establishment, Resistivity Survey, data analysis and interpretation, Report writing, Presentation.
Dr. Mahfuzur 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	Hydro-Geologist	**Tasks:** Hydrological and Hydro-geological data analyses and interpretation, water quality mapping, ground water modeling, aquifer delineation, Reporting.

Name of Staff	Area of Expertise	Position Assigned	Task Assigned
	contamination characterization, GIS		
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. Pavel Khan M.S in Geology, King Fahd University of Petroleum and Minerals, Saudi Arabia. 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.

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

Table 4 List of equipment

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.	

12	Submersible Pump	1 Nos.	

c. ***Project Execution:*** The consultancy firm will ensure a 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 providing "on job" training for the UDD's personnel.

4 Work Done During Inception Phase

After signing the contract on 4th December 2024, a 5 days long field trip was completed by a team from the Center for Geoservices and Research between 8th to 12th December 2024. During the field trip locations for resistivity survey and monitoring well installation were selected and permission was taken from the landowner or the head of the organization for carrying out these activities.

4.1 Fixing locations of Proposed Monitoring Wells and ERT on Ground:

Total Twenty-One (21) numbers of monitoring wells in 7 locations and Fifteen (15) numbers of Electrical Resistivity Tomography (ERT) locations were fixed on ground. The verified coordinates of the monitoring well (Well Cluster) locations and associated maps are below in Table-5 and Figure 12 and midpoint of ERT coordinates, and location map are in table 6 and Figure 13.

Table 5 Verified Monitoring well (Well Cluster) locations.

Monotoring Well No	District	Upazila	Latitude	Longitude
MW-01		Mujib Nagar	23.668205	88.618213
MW-02		Mujib Nagar	23.620828	88.606308
MW-03		Meherpur Sadar	23.815262	88.626262
MW-04	Meherpur	Meherpur Sadar	23.722818	88.733614
MW-05		Gangni	23.811422	88.731416
MW-06		Gangni	23.835775	88.794261
MW-07		Gangni	23.898125	88.8346

Table 6 Verified ERT midpoint locations.

ERT No	District	Thana	Latitude	Longitude
ERT-1	Meherpur	Mujib Nagar	23.709192	88.610437
ERT-2		Mujib Nagar	23.632328	88.608547
ERT-3		Mujib Nagar	23.679925	88.67875
ERT-4		Meherpur Sadar	23.77993	88.57395
ERT-5		Meherpur Sadar	23.839616	88.612999
ERT-6		Gangni	23.825234	88.68274
ERT-7		Meherpur Sadar	23.746032	88.686194
ERT-8		Meherpur Sadar	23.715255	88.77673
ERT-9		Gangni	23.833839	88.75836
ERT-10		Gangn	23.781947	88.740598
ERT-11		Gangni	23.784475	88.804593
ERT-12		Gangni	23.833839	88.75836
ERT-13		Gangni	23.897269	88.801637
ERT-14		Gangni	23.936034	88.768265
ERT-15		Gangni	23.89041	88.720635

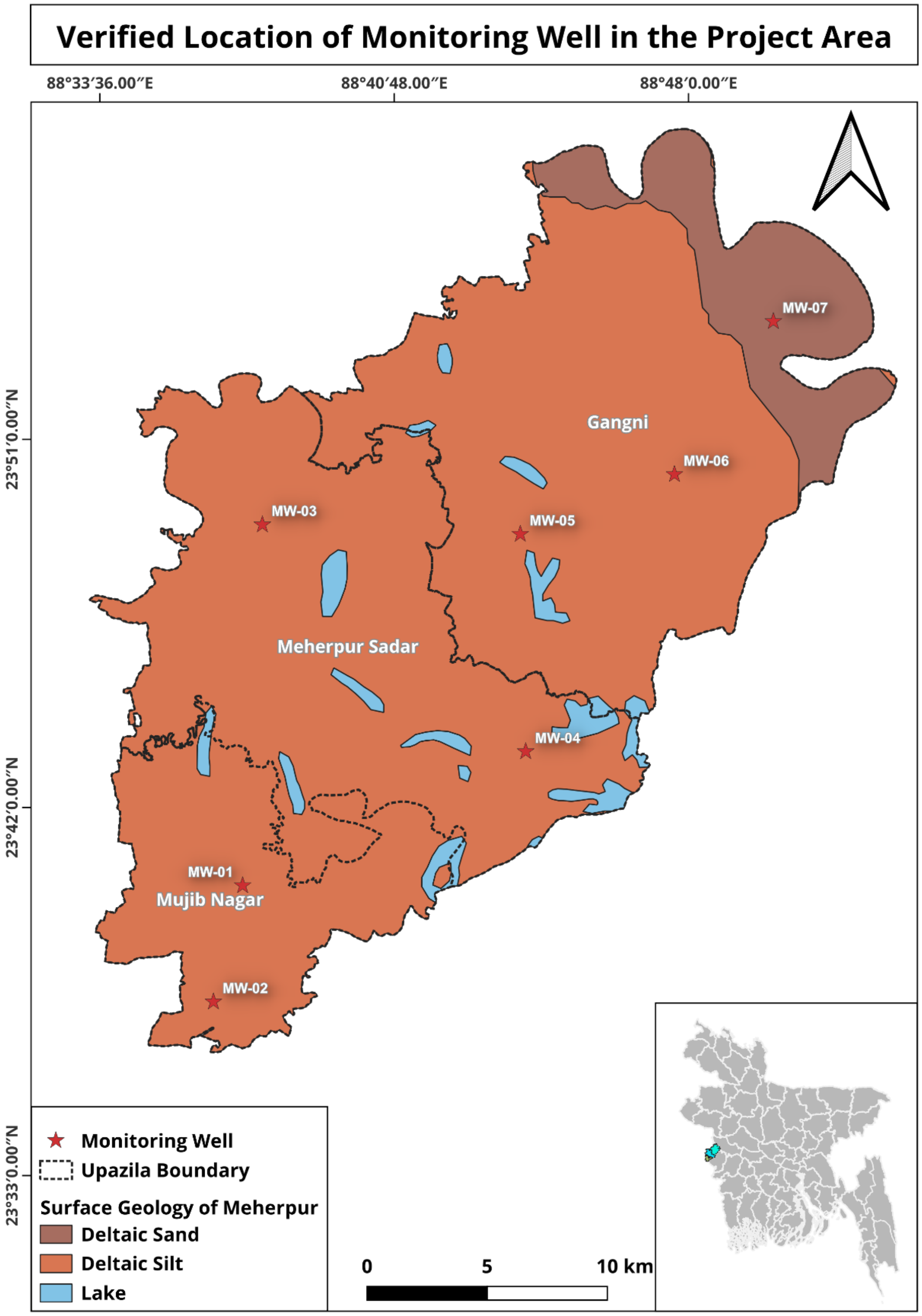


Figure 12 Verified Monitoring well and VES locations in map (Source: BBS, LGED and CGR)

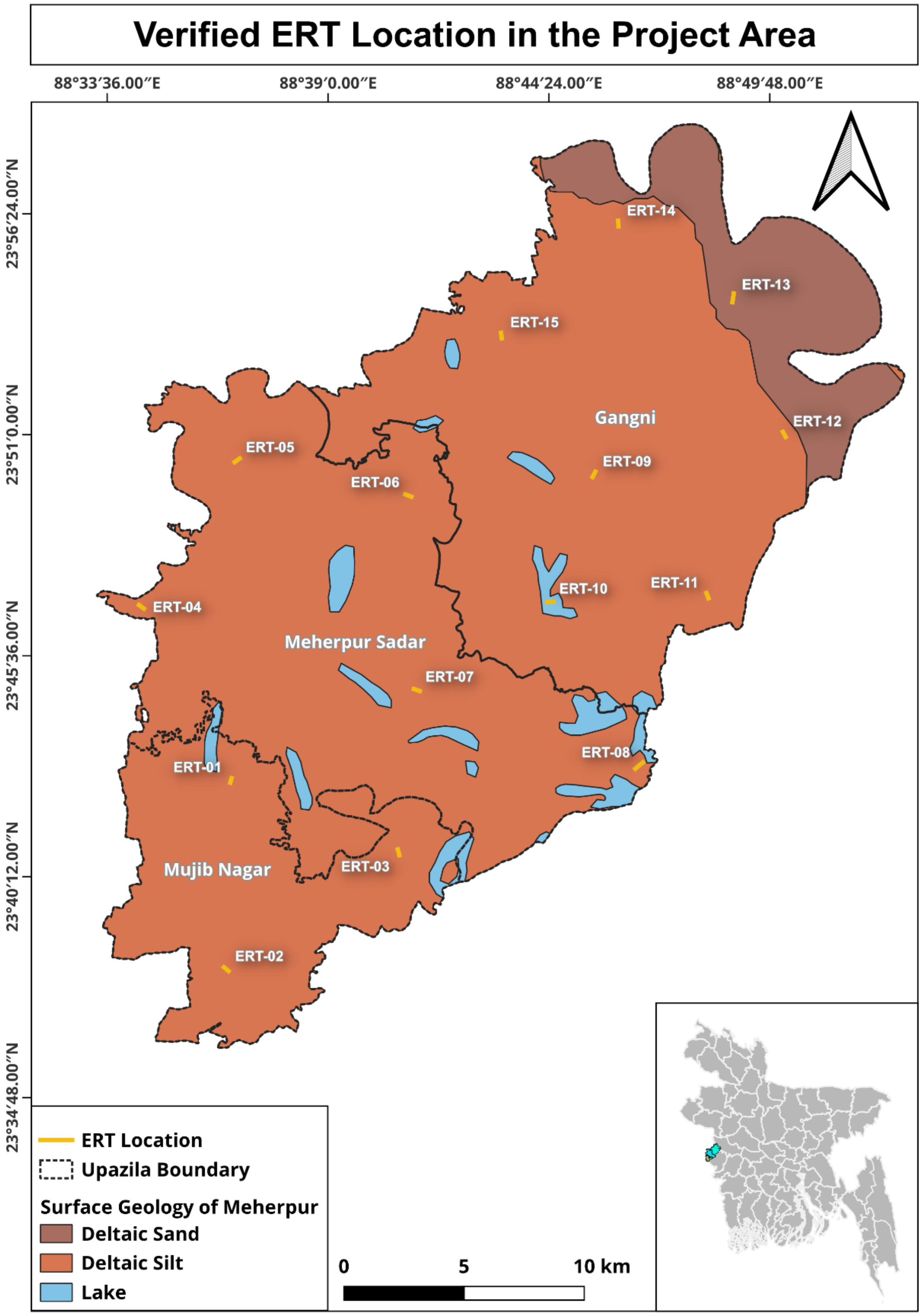


Figure 13 Verified location of VES in the project area (Source: BBS, LGED and CGR)

4.2 Photographs of fixing survey locations on Ground:

The program of fixing the survey locations on ground was done from 8th December to 12th December 2024. A lot of difficulties were faced during the period, but they were overcome due to the full cooperation of local people. Some photographs of this session are given below-

4.3 Deliverable with time frame:

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

Table 7 Deliverables with time frame

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 Wet seasonal data collection, analysis and interpretation along with spatial distribution (GIS Shape file)	24/06/2024
5	Report on Dry 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

5 Conclusion

To serve the purpose of Hydrogeological 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. Detail 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. 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.