Department of Environment

Final Report

Geospatial Technology based Water Quality Monitoring System for Bangladesh



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Geospatial Technology Based Water Quality Monitoring System for Bangladesh

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Abbreviations and Acronyms

BBS	Bangladesh Bureau of Statistics
BOD	Biochemical Oxygen Demand
BWDB	Bangladesh Water Development Board
DAE	Department of Agriculture Extension
PRA	Participatory Rural Appraisal
RRA	Rapid Rural Appraisal
PCM	Project Consultation Meeting
GPS	Geographic Positioning System
ETP	Effluent Treatment Plant
DoE	Department of Environment
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
E. Coli	Escherichia coli
EQR	Environmental Quality Standard
ECR	Environmental Conservation rules
GEMS	Global Environmental Monitoring System
GIS	Geographic Information System
GDP	Gross Domestic Product
GOB	Government of Bangladesh
ISO	International Organization for Standardization
ICT	Information and Communication Technology
IT	Information Technology
MIS	Management Information System
NTU	Nephelmetric Turbidity Units
NWRD	National Water Resource Database
pH	Power of Hydrogen
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WQ	Water Quality
WQM	Water Quality Monitoring
WQMS	Water Quality Monitoring System
WHO	World Health Organization
WQMS	Water Quality Monitoring System

Executive Summary

The main concern of this project is to develop a Geospatial Technology Based Water Quality Monitoring System (WQMS) for Bangladesh. The study has been conducted through assessment the existing monitoring system and water quality standard of DoE, collection of information/data and documents related to water quality standards in Bangladesh are available at DoE and other sources, identification and development of water pollution hotspot both from point and non-point sources, setting criteria to select the strategic location, incorporation of major issues in the new WQMS from the existing software of DoE anddevelopment of water quality sample collection protocol and guideline.

Water is an essential natural resource that demands wise and efficient management for conserving its optimum quality. This issue is crucial for major cities in Bangladesh due to rapid growth of industries across the country producing big volumes of industrial wastes with the provision of no ETP or inactive ETP. As the economy of Bangladesh is based on Agriculture, non-point agricultural pollution is a common scenario in the rivers of the country. The other sources of water pollution in the rivers are sediment pollution from earthwork or river bank erosion, pollution from urban runoff, use of pesticide and chemical fertilizer in the agricultural field (which contributes to water pollution during rainy season and flood), and dumping of solid as well as liquid waste into the river. It is evident from the field study that open water fisheries is increasing gradually that also contributes to water pollution. All these factors has urged The Department of Environment (DoE) to take an appropriate initiative for developing a water quality monitoring system.

The main components of the project are, i.) Identification and development of water pollution hotspot, ii.) Identification and selection of strategic location, iii.) standardization of water quality parameters, iv.) Designing of water quality data collection protocol and guidelines.

The overall approach of the study includes review of literature, information and maps, Hotspot Mapping, Selection of Strategic Location (SL) through developing criteria and field visit, as well as by exploring the existing water quality standard, proposing draft WQ standard, developing WQ sampling protocol andgeospatial technology based water quality monitoring system.

The water pollution hotspots have been identified based on the two major pollution sources, such as point source pollutants (industrial pollution) and non-point agricultural pollution, sediment pollution from river bank erosion, urban ruff off and others. The geospatial technique of Optimized Hotspot Analysis followed to identify the hotspots for point source pollutions. DoE has identified a number of 132 monitoring stations of river and inland surface waterbody without following standard system. Among these 132 monitoring stations 67 stations lie under the Study Rivers. Based on the water pollution hotspot, importance of the river, length and width of the river, use of river water for different purposes a total of 99 strategic location have been selected for the 30 study rivers.

In exercise of the powers conferred by section 20 of the Bangladesh Environment Conservation Act, 1995 (Act 1 of 1995), ECR, 1997 has been followed as guiding principles for water quality parameters and standards. The aspect of various uses of inland surface water has not got importance in the rules.Department of Fisheries (DoF) and Bangladesh Agricultural Development Corporation (BADC) also proposed some specific water quality parameters and standers for fisheries and irrigation purpose. All those national sources

havebeen reviewed to determine the water quality parameters and standards for different sectoral water use. Moreover, available secondary research papers/documents of different international organizations such as: Food and Agriculture Organization (FAO), European Union (EU), World Health Organization (WHO), Bureau of Indian Standard (BIS), Asian Development Bank (ADB), United States Environmental Protection Agency, Ministry of Environmental Protection of China and many others organizations of different countries has been reviewed. Finally a number of 21 physicochemical parameters have been proposed for different purposes (drinking, fisheries, agriculture and industrial use).

A surface water sample collection protocol and guideline has been developed under this study. It is essential to save the environment and ensure the safety of human health, hence it is also necessary to monitor the surface water quality on a regular basis. For this purpose surface water sample collection protocol and guidelines is developed following a standard and acceptable format. This guideline will ensure a consistent approach for field measurements and sampling techniques. This document will also provide information on how to collect water samples from the field to analyze different water quality parameters that can be measured in the field and by laboratory analysis.

To facilitate the whole system water quality monitoring network framework is developed based on GIS technology. The GIS& RS software (ArcMap 10.4, Erdas Imagine 14) are used to enhance the spatial data processing facility and presentation of output in map, table, and chart forms.The WQMS is developed so that a user can access tabular and spatial database and analyse the data in a user friendly and interactive manner.The WQMS software is developed with Microsoft SQL Server 2008 as the back end database and Visual Studio, HTML, CSS, JavaScript, jQuery and EsriMapObject plugin as the front end development tool.

To make the system user friendly the DoE officials have been trained on Web-based MIS and Mobile Application. This training included operation and maintenance of database and MIS. The process of data capture and display using Mobile Device have been demonstrated in this training.

It recommended that the water quality monitoring system of DoE should be modern technology based well organized and cost effective to cover maximum rivers. In some cases, DoE collects 3 samples from the same location (Middle & both bank side of river) which incur financial and temporal costs; DoE should collect one sample per location from the optimum polluted point. ECR’97 should be revised considering the standards of different organization working in Bangladesh (e.g. BADC, DPHE, FAO, WHO) as well as other neighboring organizations like Bureau of Indian Standards (BIS, ICMR), Malaysia and others. As manual system is complex to incorporate the regional office, the water quality monitoring system of DoE should be web-MIS based. They can introduce mobile-app for real-time test results entry. DoE should emphasize on pollution hotspot based and non-point pollution source based water quality monitoring which will be representative of the river. Finally it is recommended that, the standards for specific uses (Agriculture, Fisheries, and Drinking/consumption& Industrial Use) of river water should be incorporated in the revised ECR’1997.

1. Introduction

1.1 Background

Water is an essential natural resource that demands wise and efficient management for conserving its optimum quality. This issue is crucial for major cities in Bangladesh due to rapid growth of industries across the country producing big volumes of industrial wastes with the provision of no ETP or inactive ETP. As the economy of Bangladesh is based on Agriculture, non-point agricultural pollution is a common scenario in the rivers in this country. The wastes generated by other sources like dwelling units, slum dwellings, Hat-Bazar, vegetable markets and other sources are usually dumped into rivers or waterbodies and in some cases in barren land. As a result, the water quality of the major rivers especially the studied thirty (30) rivers(Balu, Bhairab, Brahmaputra, Buriganga, Dakatia, Dhaleshwari, Ganges, Gorai, Halda, Jamuna, Kaliganga, Kankshiali, Karnaphuli, Kirtankhola, Karatoya, Kushiara, Maodhumoti, Mathavanga, Meghna, Moyuri, Padma, Pashur, Rupsha, Shitalakhya, Sughandha, Surma, Teesta, Tetulia, Titas and Turag) including other rivers in Bangladesh are deteriorating rapidly due to pollution from industrial and municipal waste sources. The overall quality of river water turns alarming particularly during the dry season. In the rainy season the water pollutions happen mainly by urban flash flooding and it intensifies with other point and non-point pollution sources.

Apart from pollution, the other serious issue of concern is unabated encroachment of the rivers, inland khals, wetlands, and other waterbodies. Urban dwellers are all too familiar with such worsening situation of the rivers. Dark murky reeking water, the constant plying of vessels, dumping of industrial waste, encroachment of individuals and real estate companies are the other factors of river water pollution. The surface water quality in the river systems and other surface waterbodies e.g. khals and ponds have very low DO and high BOD, COD, E-coli, TDS, TSS, Turbidity, Salinity (mainly coastal rivers) contents which indicate discharge of untreated industrial effluents and domestic sewage.

The Department of Environment (DoE) needs adequate information about surface and ground water quality of different hotspots of river water pollution. It should be noted that, at present, DoE monitors river water quality without any adequate tool and database. Shortage of workforce, logistic support etc are the main reasons for smooth monitoring of water quality. Therefore, design of water quality data collection protocol and guidelines, data collection format, development of mobile application and hotspot mapping are important issues to address. Moreover, the DoE is committed to providing water quality data to Global Environmental Monitoring System (GEMS). In that case, providing representative data is a necessity that is dependent on design of sampling protocol, data collection format and guidelines, geo-spatial database and MIS and development of overall water quality monitoring system.

In this context, development of MIS and Internet Based Mobile Application are important initiatives of the DoE. In this context DoE engaed CEGIS for developing the web based water quality monitoring framework including the MIS and Mobile App. Hence the Department of Environment will use the framework and Mobile App as support tools for enforcing laws and regulations with enhanced efficiency. Moreover, the user-friendly geospatial database and water quality monitoring tools could be a milestone in establishing the e-Governance capacity of the DoE to contribute in the mandate of Digital Bangladesh.

1.2 Objectives

The overall objective is to develop a web-based water quality monitoring system and network for the whole of Bangladesh for monitoring of water quality for different sectoral use.

Specific objectives are:

- Assess the existing monitoring system and water quality standard;
- Develop a geospatial technology based and web-enabled water quality monitoring system;
- Develop draft/proposed water quality standard based on secondary literature and expert opinion;
- Develop capacity of the DoE personnel;
- Develop water sampling protocol and guidelines;
- Develop project portfolios for implementation of the sustainable water quality monitoring in Bangladesh.

1.3 Selected Important 30 Rivers under the Study

Bangladesh is the largest delta, having small and large 405 rivers (Source: *Bangladesher Nod-Nodi*, 2010), in the world. Three rivers (Padma, Meghna & Jamuna) has the largest basin are included in this study.

The other important rivers Ganges, Teesta, Meghna are also included. Depending on the non-point agricultural pollution sources some other rivers are also included like Rupsha, Moyuri, Halda and Karnaphuli. Due to extremely high industrial concentration, Dhaka and the surrounding areas are termed as water pollution hotspot. The major rivers in Dhaka, i.e. Buriganga, Dhaleshwari, Turag and Shitalakhya are studied in detail under this initiative. The other important rivers are selected as representative of the total rivers system of Bangladesh. The selected rivers are shown in **Table 1.1** and **Figure 1.1**.

Table 1.1: List of Study Rivers

Name of River			
SL		**SL**	
1	Teesta	16	Karatoya
2	Jamuna	17	Ganges
3	Brahmaputra	18	Gorai
4	Surma	19	Modhumoti
5	Kushiara	20	Mathavanga
6	Buriganga	21	Kankshiali
7	Turag	22	Bhairab
8	Shitalakhya	23	Rupsha
9	Dhaleshwari	24	Moyuri
10	Kaliganga	25	Pashur
11	Balu	26	Sughandha
12	Padma	27	Tetulia
13	Dakatia	28	Karnaphuli
14	Meghna	29	Halda
15	Titas	30	Kirtankhola

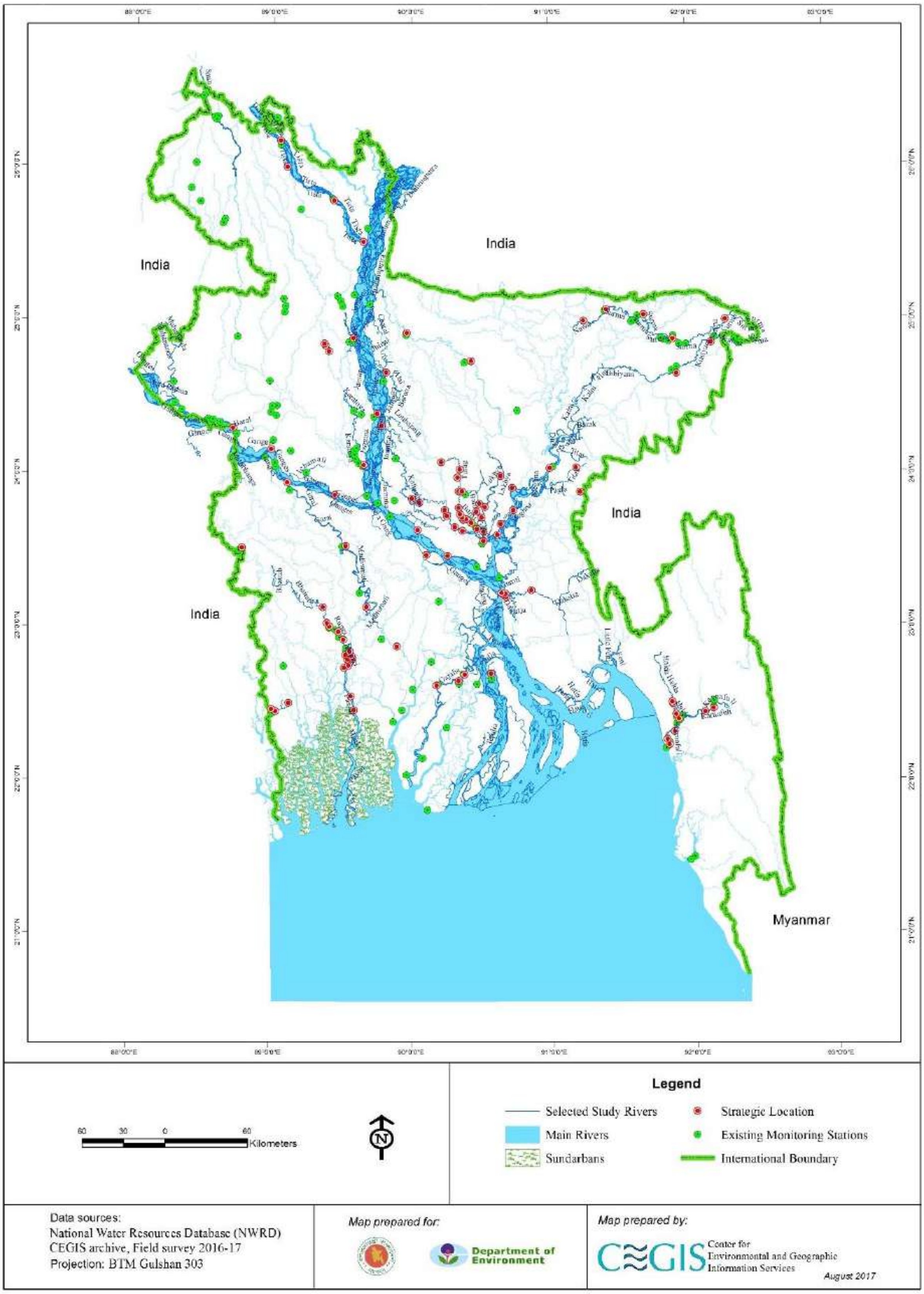


Figure 1.1: Study Rivers with Existing Monitoring Stations and Strategic Locations

1.4 Overall Approach

The project activities have been carried out following the designed overall approach and step by step methodologies which include review of Literature, information and maps, Hotspot Mapping, Selection of Strategic Location (SL) through developing criteria and field visit, as well as by exploring the existing water quality standard, proposing draft water quality (WQ) standard, developing WQ sampling protocol and geospatial technology based water quality monitoring (WQM) System.

Figure 1.2: Overall Approach of the Study

The detail methodological approach starts with conceptualization of the study and reviewing existing monitoring system (parameters, standards, & system). The overall approach also include identifying gaps in the existing monitoring system, reconnaissance field visit, pollution hotspot Mapping, identification of strategic location for water quality monitoring and validation of the strategic locations of water quality monitoring of Department of Environment (DoE).

Sample data collection protocol development, testing of water sample in lab and recasting and finalization of the monitoring network have also been discussed in this chapter.

The water quality monitoring network framework is developed based on GIS technology. The GIS& RS software (ArcMap 10.4, Erdas Imagine 14) are used to enhance the spatial data processing facility and presentation of output in map, table, and chart forms. The user interface provides directly the field based input data on water quality standard parameters and it is stored in the server. The DoE professional are now able to query, review, and analyse data to produce water quality status report. GIS layers of different data and information on rivers/drainage network, waterbodies, wetlands, industrial areas, and roads have been incorporated into the system.

In this development stage, mobile app (Android) is developed on android platform which is internet enable. To follow standard process of sample collection, a water quality sample collection protocol, and guideline is also developed and shared with DoE and other relevant agencies and/or professionals. After deployment of the database and WQMS into the DoE server a professional training on WQMS and Mobile App will be provided to DoE officials. The proposed WQMS has been validated in the validation workshop.

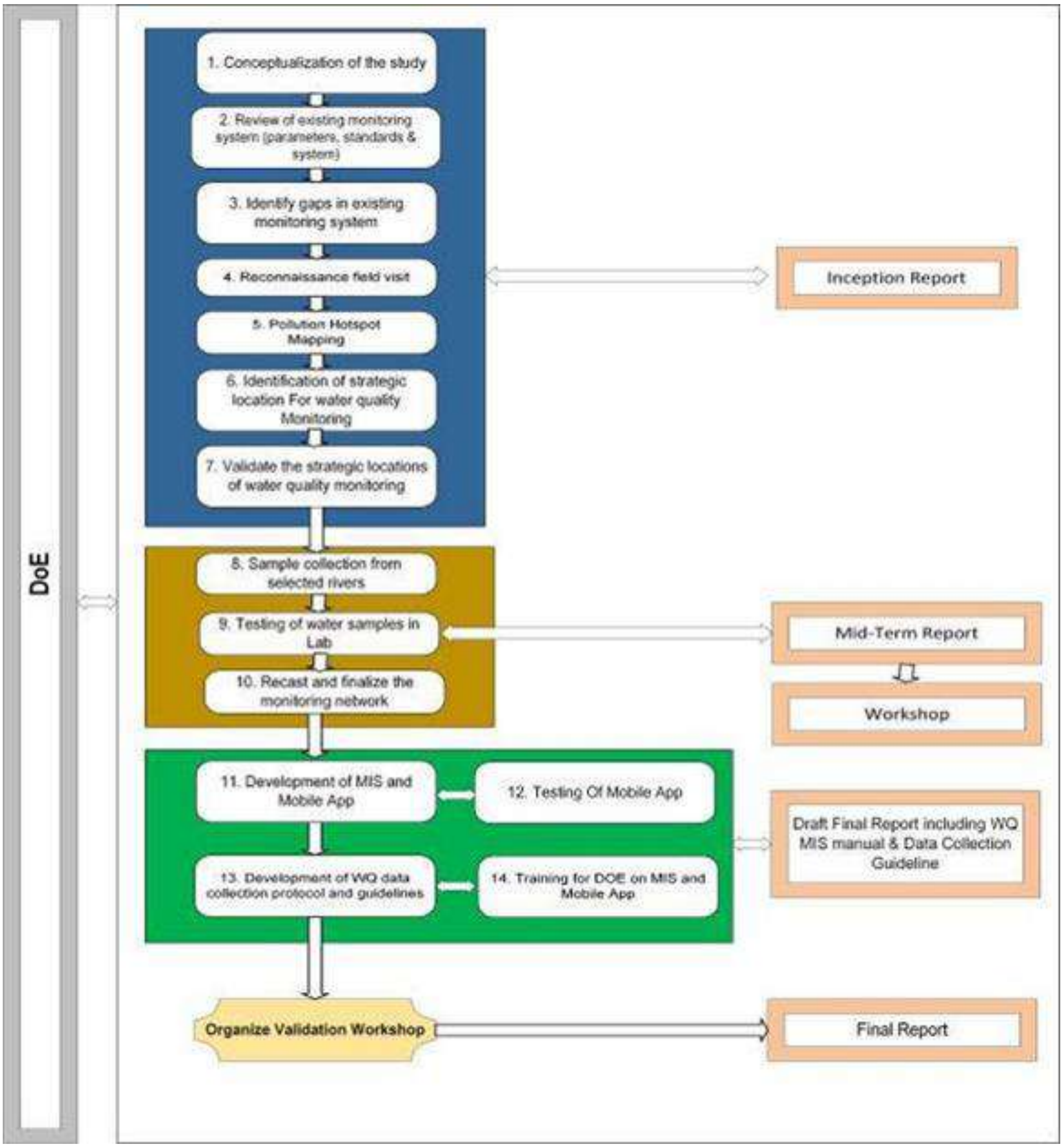


Figure 1.3: Detail Methodology of the Activities Conceptualization of the Study

1.5 Conceptualization of the Study

At the very beginning of the work, consultation meeting was organized with relevant officials of the DoE to understand the requirements and expectations of the client. The major issues that are discussed in the meeting includes (i) identification of existing water quality monitoring stations of DoE, (ii) collection of information/data and documents related to water quality standards in Bangladesh are available at DoE, (iii) setting criteria to select the strategic location, (iv) incorporation of major issues in the new WQMS from the existing software of DoE, and (v) Water Quality sample collection protocol and guideline.

1.6 Existing monitoring system

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is most usually used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact, and drinking water. This study is undertaken to assess the existing monitoring system and develop surface water monitoring specifically that of river water. The existing monitoring system of the DoE is reviewed and found that they cover a number of monitoring aspects which include selection of important rivers for monitoring, setting surface water quality monitoring stations, number of parameters have been tested to assess the quality of river water, point sources of pollutants & water quality monitoring, consideration of seasonal variations, sampling & measurement, and sample collection.

A number of 132 monitoring stations of river and inland surface waterbody have been selected all over Bangladesh by the DoE. From these 132 monitoring stations, 67 stations lie under the Study Rivers. The monitoring stations selected for a few locations are more than the representative samples. For example, at Tongi Rail Bridge area of Turag River they set four monitoring stations (Indo Washing Plant ltd., Tongi Rail Bridge, Hossain Dyeing and Azmeri Composite Ltd.). On the other hand, dense industrial concentration is seen at Zirabo area of Ashulia. But they did not set any monitoring stations there. Similar situations could be found in Port Road area of Narayanganj where no monitoring station is set by the department. So, there is a disparity of distribution of monitoring stations.

Moreover, Environmental Conservation Rules, 1997 contains standard of selected water quality parameters for some specific uses like: agriculture, fisheries, drinking, recreational etc. The parameters mentioned in the ECR,1997 for different uses are found inadequate compared to the standard of neighbouring countries (India, Malaysia) and international institutions (WHO, FAO, ICMR, BIS and other ones). In this stage, these parameters and their standards are also reviewed and selected parameters for different uses, such as Agriculture, Fisheries etc. The parameters and their standards will be reviewed and studied further including taking into account expert opinion. Finally, DoE lacks web-enable MIS that can include all divisional offices under the country-wide water quality monitoring system. Criteria followed by the DoE for selecting monitoring stations at present are the following:

- Down-stream of pollutant sources;
- Up-stream of pollutant sources;
- Close to industrial unit from where pollutant releases;
- Near outlet of urban swerege line;
- Area with special importance like Ahsan Manzil temple;

2. Identification of Strategic Location

2.1 Water Quality Monitoring Stations in Bangladesh

Different agencies in Bangladesh have their own monitoring stations based on the nature of works. In Bangladesh,rivers and streams are heterogeneous at different spatial scales. This heterogeneity may be attributed to a number of factors including anthropogenic input, local environmental factors, discharge of water, temporal variability, and surface water chemistry. Considering their important contribution of rivers to different uses like irrigation, fish culture, drinking and industrial cooling, it is imperative to have reliable information on water quality for effective and efficient management of river water. A few agencies also works on ground water monitoring and assessment. Considering all these factors, different organizations/ agencies have set their own monitoring stations like BWDB, DPHE, BMD, BADC, and others. The monitoring stations of different organizations are shows in **Figure 2.1** to **2.4**.

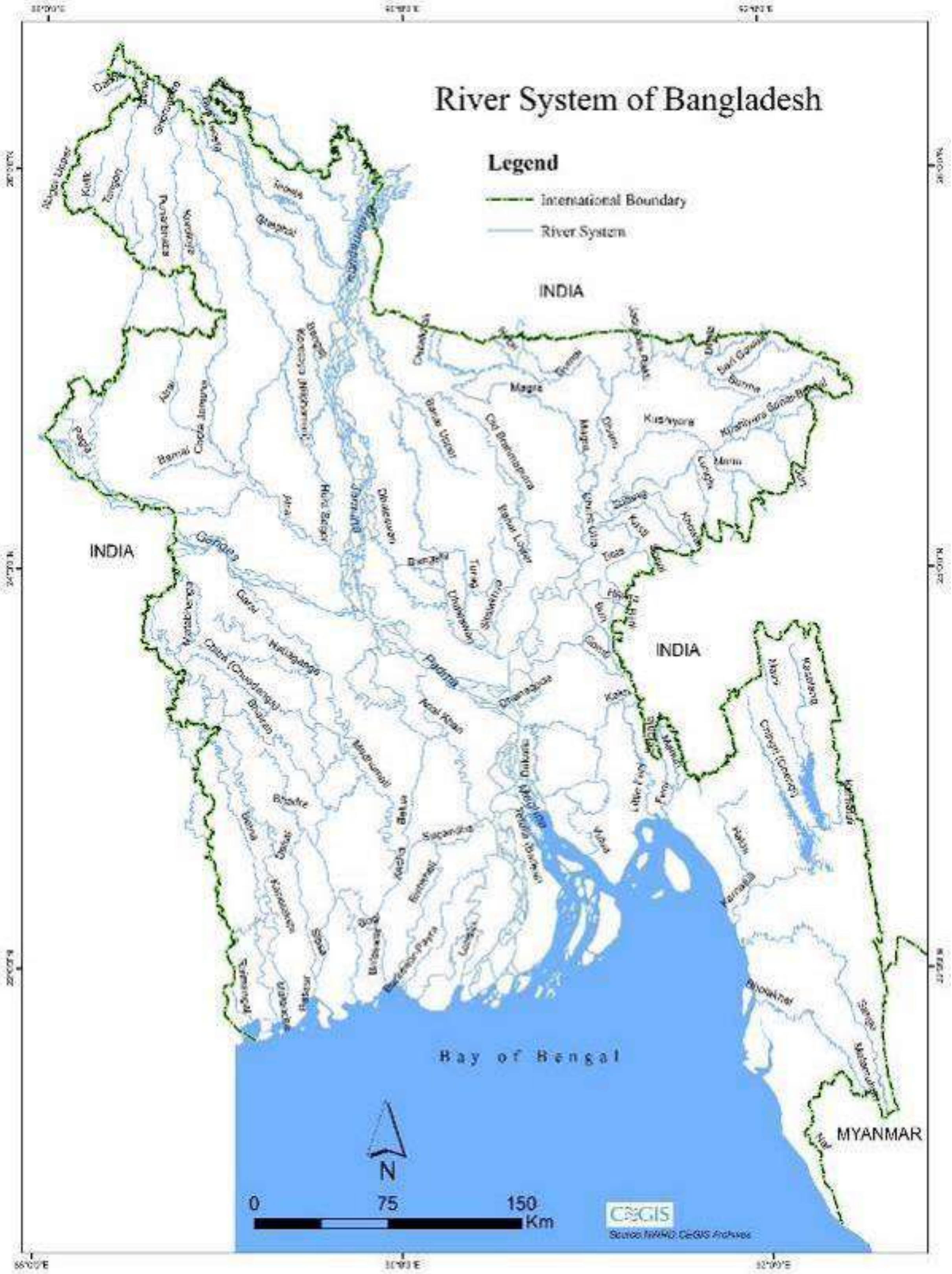


Figure 2.1: River System of Bangladesh

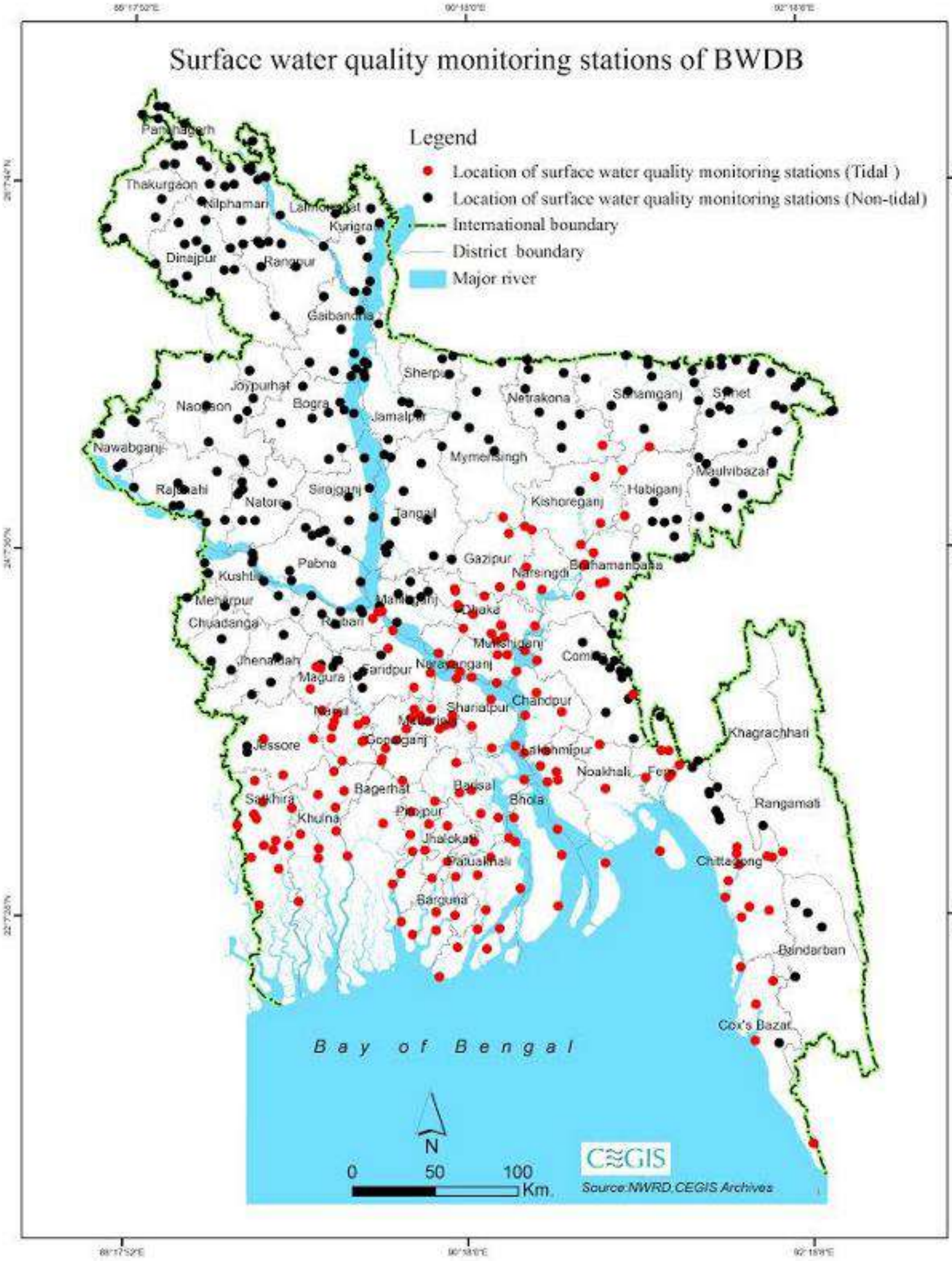


Figure 2.2: Surface water quality monitoring stations of BWDB

Figure 2.3: Ground water quality monitoring stations of BWDB

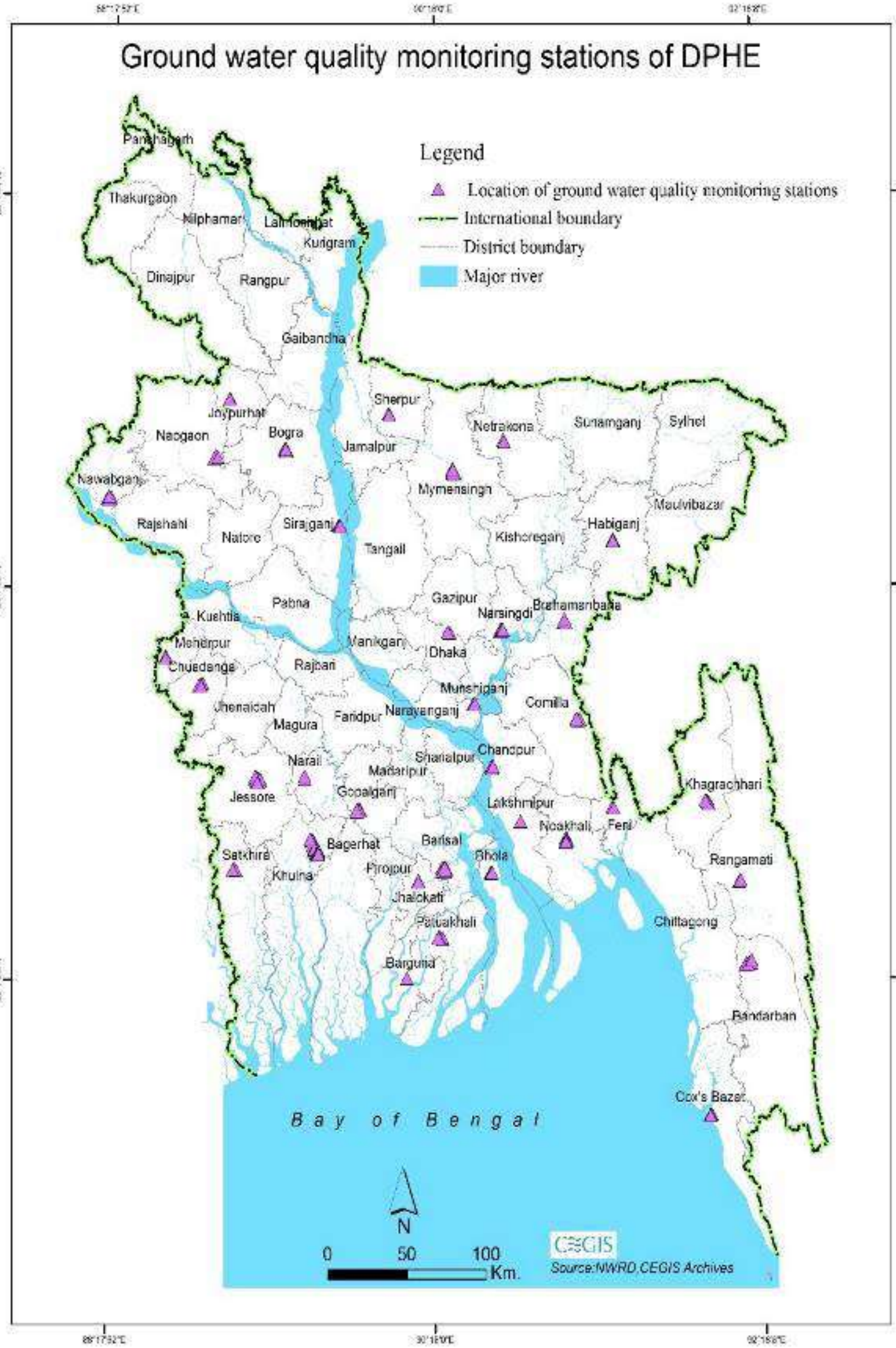


Figure 2.4: Ground water quality stations of DPHE

2.2 Existing Monitoring Stations of DoE

DoE used to collect water sample from existing 67 monitoring stations under the 27 selected rivers. Existing water quality monitoring stations of DoE under those 27 rivers are shown in the **Figure 2.5** and **Table 2.1a**:

Table 2.1a: Existing Water Quality Monitoring Stations of DoE for Selected 27 Rivers

Sl	River Name	Existing Monitoring stations
1	Buriganga	Mirpur Bridge, Hazaribagh, Kamrangir Char, Chandni Ghat, Sadar Ghat, Dholaikhal, Pagla, Bangladesh China Friendship Bridge
2	Shitalakhya	Narayanganj (Near ACI Factory), Demra Ghat, Ghorashal Fertilizer Factory
3	Turag	Fulpukuria Dyeing Ltd., Hossain Dyeing Ltd., Tongi Rail Bridge, Tongi Istema Field, Indigo Washing Plant Ltd.
4	Dhaleshwari	Muktarpur Ghat, Munshigonj, Horindhora-Hemayetpur
5	Brahmaputra	Mymensingh
6	Kaliganga	Veuta Ghat
7	Jamuna	Bahadurabad Ghat, Near Jamun Fertilizer Factory
8	Meghna	Bhairob Bazar, Meghna Ghat, Shahajalal Paper Mills
9	Padma	Mawa Ghat, Pakshi River (River Bank, Middle, Ishwardi), Baro Kuti (River Bank, Middle), Rajshahi
10	Karatoya	Fateh Ali Bridge, Dutta Bari Bridge, Matidali Bridge, S.P. Bridge
11	Karnaphuli	TSP Industry (Upstream), TSP Industry (Downstream), Karnaphuli Urea Fertilizer (Upstream), Karnaphuli Urea Fertilizer (Down Stream)
12	Halda	WASA intake Point (Upstream), WASA Intake Point (Down Stream), Maduna Ghat (River Bank, Middle)
13	Titas	Bakail Bridge, Brahmanbaria
14	Moyuri	Gallamari Bridge (Both River Bank, Middle)
15	Bhairab	Noapara Ghat (River Bank, Middle), Fultala Ghat (River Bank, Middle), Charerhat Ghat (River Bank, Middle)
16	Rupsha	Rupsha Ghat (Both River Bank, Middle), Labanchara Ghat (Both River Bank, Middle)
17	Mathavanga	Pipeghat, Darshana, Chuadanga; Pipeghat (200M Upstream), Darshana, Chuadanga; Pipeghat (200M Downstream), Darshana, Chuadanga
18	Pashur	Mongla Port (Both River Bank, Middle)
19	Kankshiali	Kaliganj (Both River Bank, Middle), Satkhira
20	Gorai	Kamarkhali Ghat (Both River Bank, Middle), Magura
21	Modhumoti	Mollarhat (Both River Bank, Middle); G.K Ghat (Both River Bank, Middle), Kushtia
22	Beel Dakatia	Khulna (Both River Bank, Middle)
23	Kirtankhola	Barisal Launch Ghat (River Bank, Middle)
24	Tetulia	Vedhoria Feri Ghat (River Bank, Middle)
25	Sugandha	Jhalkathi Launch Ghat (River Bank, Middle)
26	Surma	Shahjalal Bridge, Keen Bridge,Shak Ghat, Chattak, Kazir Bajar
27	Kushiara	Jokigonj B.S.F Ghat, Fenchuganj Fertilizer Industry

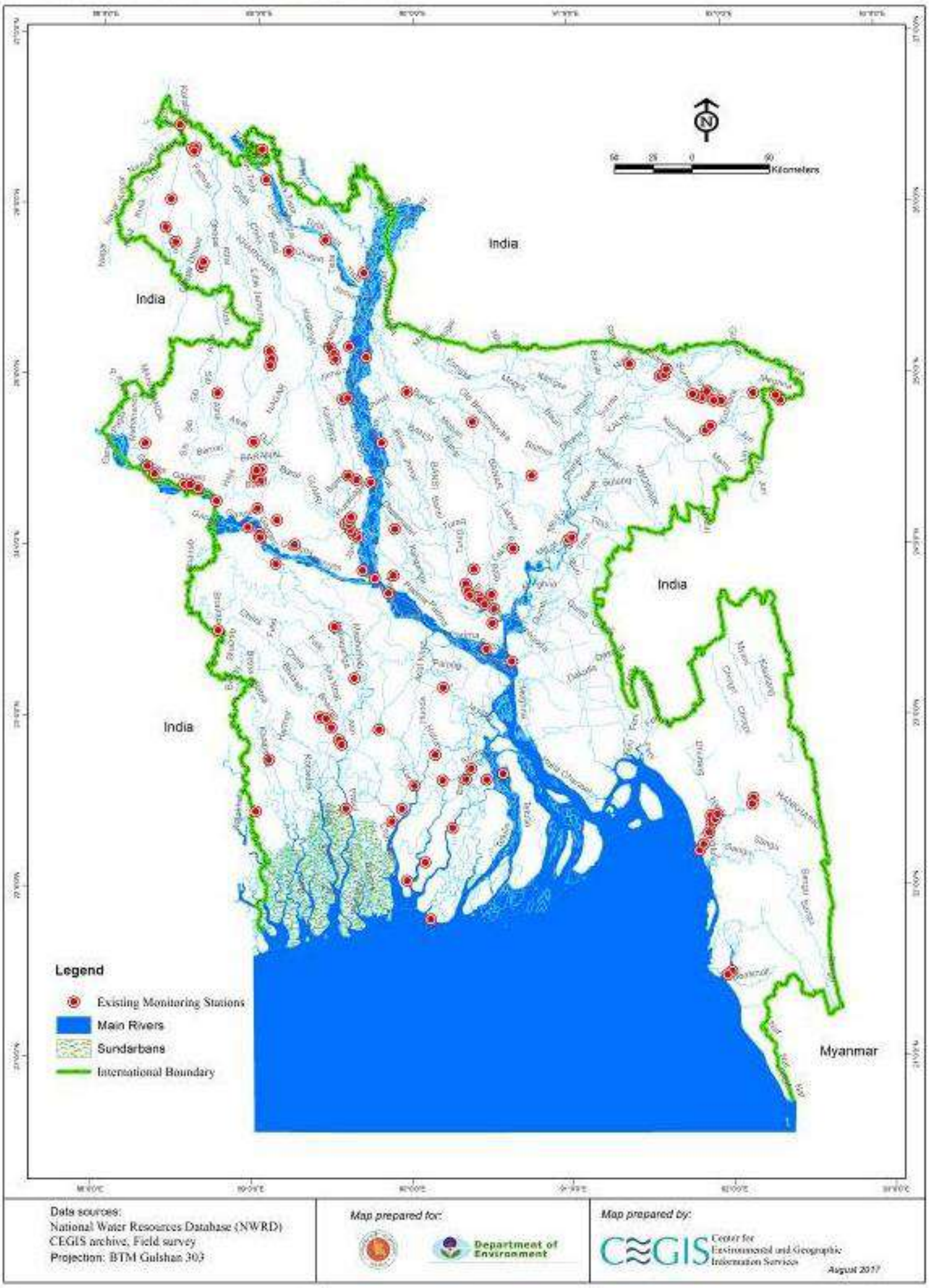


Figure 2.5: Existing Water Quality Monitoring Stations of DoE (27 Rivers)

2.3 Identification of Pollution Hotspot

The water pollution hotspots have been identified based on the two major pollution sources, such as point source pollutants (industrial pollution) and non-point agricultural pollution, sediment pollution from river bank erosion, urban ruff off and others. The geospatial technique of Optimized Hotspot Analysis followed to identify the hotspots for point source pollutions. Landsat Enhanced Thematic Mapper 8 Satellite images of July, August, September, and October were used to identify non-point water pollution sources (inundated areas during rainy season). SRTM DEM 30 meter is used to delineate watershed as catchment area of each river. Watersheds are delineated using SWAT Model in ArcGIS. These catchments helped delineating effective area of water pollution sources especially in non-point pollution source cases. Identifying non-point water pollution is very difficult, what so ever, the major non-point pollution sources in Bangladesh are:

- Excess fertilizers, herbicides, and insecticides from agricultural lands;
- Oil, grease, and toxic chemicals from urban runoff and energy production;
- Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks;
- Salt and acid from irrigation practices;
- Bacteria and nutrients from wastes and faulty septic systems
- Hydro modification (like Teesta Barrage);
- River and shoreline erosion (e.g. river bank erosion in Padma River);
- Land development by real estate developers;
- Solid waste disposal landfills (example: Hemayetpur, Fulbaria)

(Source: http://www.in.gov/idem/nps/2368.htm)

2.4 Develop Criteria for Pollution Hotspots

In general, a water pollution hotspot is an area where the concentration of a pollutant exceeds the standards. Pollution hotspots are characterized by both a high concentration, or loading of pollutants that enter adjacent waterbodies such as rivers, lakes, groundwater aquifers, and causing water pollution. Many of the proposed water quality strategic locations have become pollution hotspot over the years. The pollution hotspot assessment is useful in identifying areas with most serious pollution risks, thus allowing the decision-makers to target compliance efforts on the problem sites. The following criteria will be followed for developing water pollution hotspot.

- Populated areas around pollutant emitters such as old factories and waste storage sites are often toxic hotspots;
- Densely occurred phenomenon like population density, growth centres, tanneries and such phenomenon forming spatial clusters responsible for water pollution;
- Vector data were used in hotspot analysis and used to identify location of significance in respect to hotspot;
- Hotspot is the local association of water pollution phenomenon between observation and its neighbour;
- Hotspot requires data to be aggregated to some form of geographic unit (e.g. count of industries, grid cell of growth centres).

The pollution hotspot assessment is done to identify areas with most serious pollution risks, thus allowing the decision-makers to target compliance efforts on the problem sites. For every river separate maps have been prepared to identify pollution sources and point of water pollution.

2.5 Conceptual framework for identification of strategic location

Industrial processing unit or non-point agricultural and other pollution aspects are crucial which affect the water quality and should be taken into account when sampling sites are selected.A sampling site is the general area of a waterbody from which samples are to be taken and called Strategic Location. Selection of sampling sites requires consideration of the monitoring objectives and some knowledge of the geography of the water-course system, as well as of the uses of the water and of any discharges of wastes into it. Sampling sites can be marked on a map or an aerial photograph, but a final decision on the precise location of a sampling station can be made only after a field investigation. In this study, the proposed sampling stations are investigated during field visit and validated for GPS location, pollution sources, and pollution hotspot. The following examples illustrate how sampling sites have been chosen. The choices were made with respect to the delineated catchment area of each and every river under the study and are based on some of the monitoring objectives. The type of monitoring stations (strategic locations) have been chosen are described below:

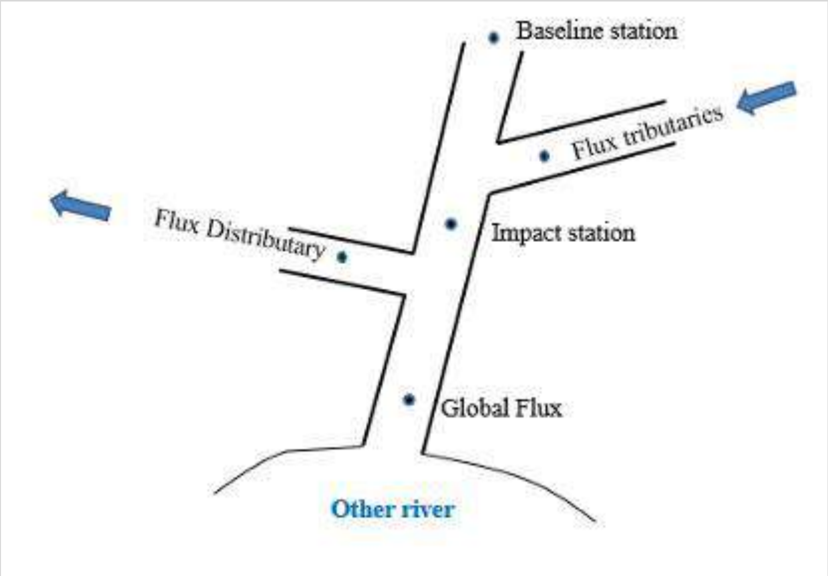


Figure 2.6: Types of Strategic Locations

Baseline Station (Strategic Location)

Type of Site: Baseline Station (Strategic Location)
Location: Upstream river stretches
Objectives: • To establish natural water quality conditions; • To provide a basis for comparison with stations having significant direct human impact (as represented by trend and global flux stations) • To test for the influence of long-range transport of contaminants and the effects of climatic change.

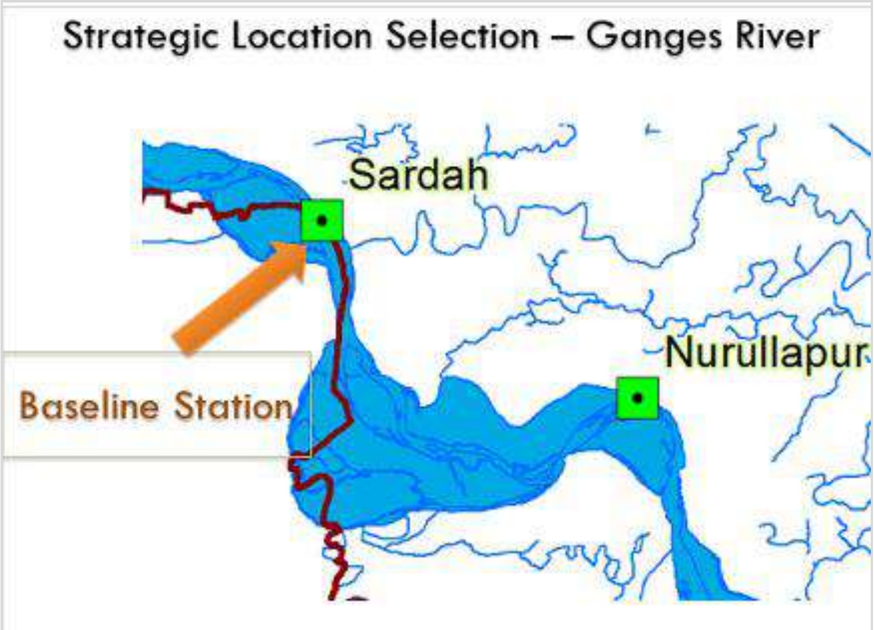


Figure 2.7: Baseline Monitoring Station of Ganges River.

Trend or Impact Station (Strategic Location)

Type of Site: Trend Station (Strategic Location)
Location: Major river basins
Objectives: • To assess for long-term changes in water quality • To provide a basis for statistical identification of the possible causes of measured conditions or identified trends

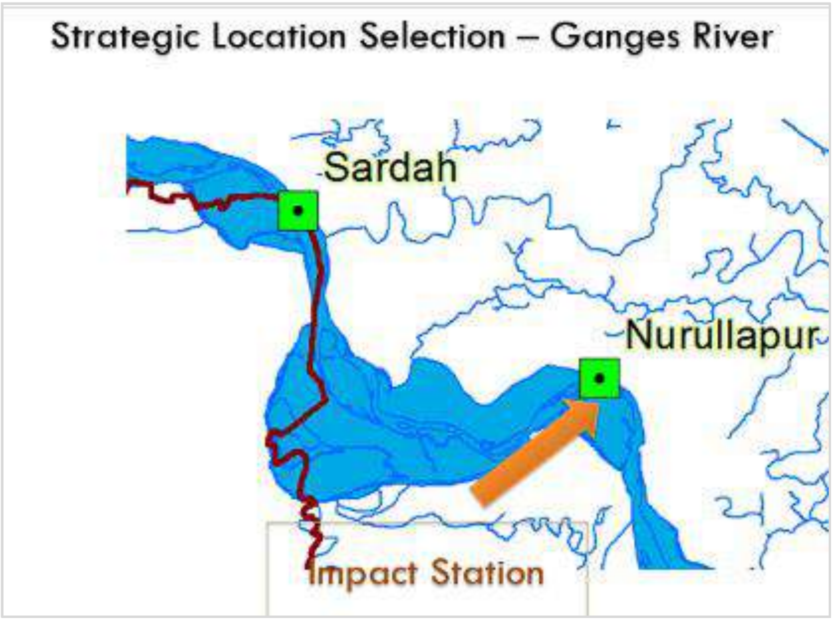


Figure 2.8: Trend/Impact Monitoring Station of Ganges River

Global Flux Station (Strategic Location)

Type of Site: Global Flux Station (Strategic Location)
Location: Mouth of a major river
Objectives: • To determine fluxes of critical pollutants from river basin to ocean or regional sea • Some trend stations on rivers also serve as global flux stations

Figure 2.9: Global Glux Station of Ganges River

Flux Tributary Station (Strategic Location)

Type of Site: Flux Tributary Station (Strategic Location)
Location: Mouth of the tributary of the main river (near to confluence)
Objectives: • To determine fluxes of critical pollutants from tributary that contributes to main river • Some trend stations on tributary also serve as global flux stations for that tributary

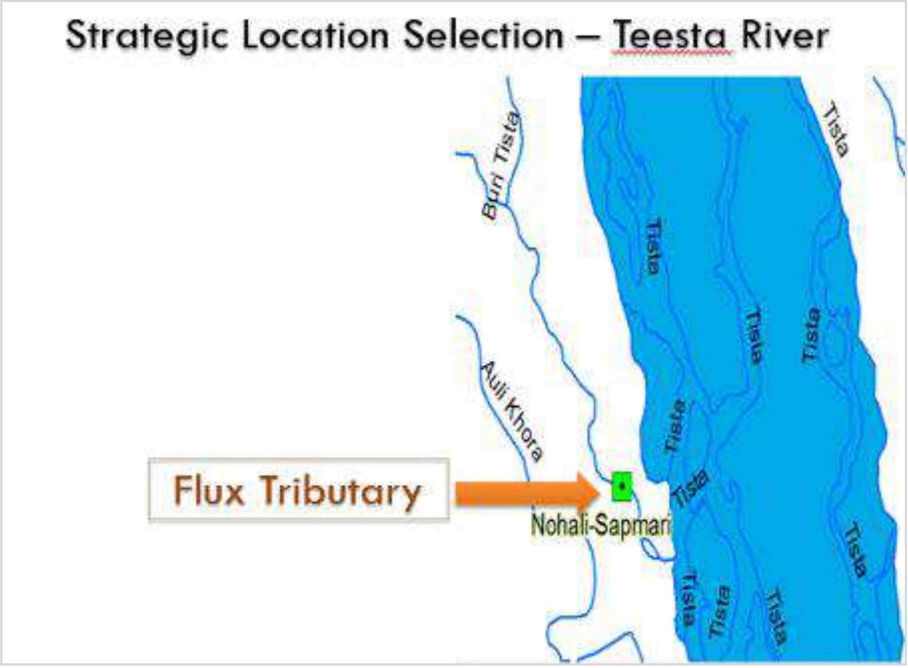


Figure 2.10: Flux Tributary Station in Teesta River

Flux Distributary Station (Strategic Location)

Type of Site: Flux Distributary Station (Strategic Location)
Location: Point of the tributary at which main river contribute discharge
Objectives: • To determine fluxes of critical pollutants from main river to tributary • To determine usability of the water for different purposes

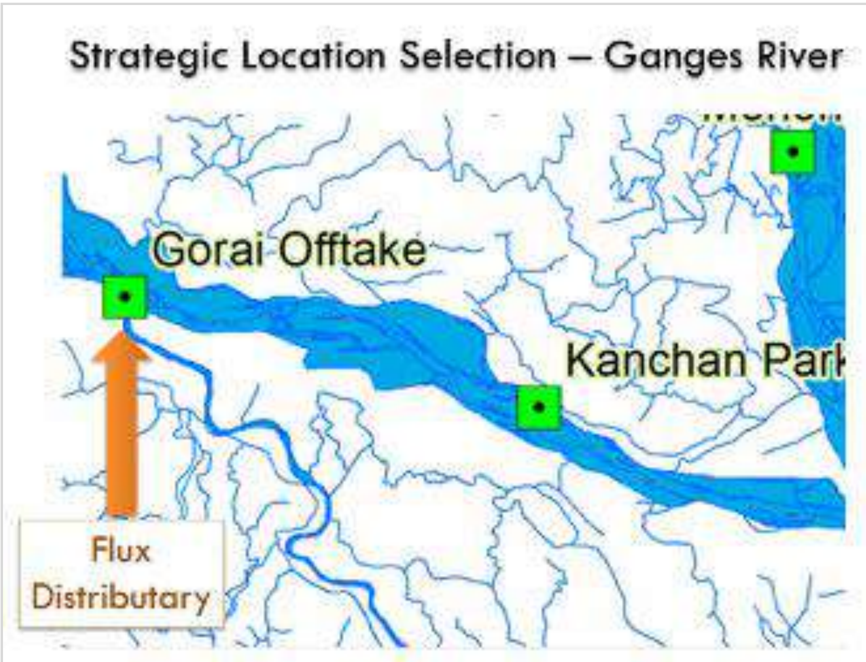


Figure 2.11: Flux Distributary Station in Ganges River

2.6 Identification of Strategic Locations

Identification of sample collection point is a major concern for monitoring water pollution. For this purpose the existing 67 locations have been assessed based on hotspot mapping and other criteria like upstream and downstream flow, purpose of water use, nearby ecological sensitive areas, river confluence and distributary and others. Then meteorological stations (BMD) as well as water level (WL) stations of BWDB are overlaid to identify the strategic locations. However, a set of criteria have been followed to identify the strategic locations which include the following:

- Location of the river with major environmental sensitive receptors (social forestry, community park, water bodies, nearby agricultural land and so on);
- Population density and habitat;
- Current use of river water e.g., drinking, agricultural, fish culture and other purposes;
- Pollution hotspots around the strategic locations;
- Industrial dense zone;
- Areas near to archaeological & historically significant sites;
- Drainage outfalls into the rivers;
- Rivers used as industrial effluent discharge outfalls;
- Areas with good transport/communication facilities;
- Physical characteristics of the area, such as tributary, distributary, and confluence of rivers.

2.7 Study Rivers with Existing Monitoring Stations and Strategic Locations

To identify strategic location, hotspot water pollution maps were prepared for the selected 30 rivers. The hotspot maps are prepared based on point and non-point pollution sources. From these maps the optimum polluted location of rivers as well as less polluted locations are identified. River confluences were considered while selecting strategic locations. Pollutants from surrounding areas met with the river water through the confluence point. Distributaries are also considered for selecting strategic locations, because water spreads to the surrounding areas by distributaries. Existing monitoring stations are also shown in the **Figure 2.12**. A total of 99 strategic locations have been proposed in the following **Table 2.1b**.

Tale 2.1b: Details of proposed water quality monitoring stations of DoE for selected 30 Rivers

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
1	Teesta (4)	1	Teesta Barrage	26°10'39.40"N	89° 3'1.10"E	Mouza: Doani Pittiphata Union: Goddimari Upazila: Hatibandha District: Lalmonirhat Division: Rangpur
		2	Nohali Shapmari	26° 0'18.0"N	89° 6'14.4"E	Mouza: Taluk Saulmari Union: Soulmari Upazila: Jaldhaka District: Nilphamari Division: Rangpur
		3	Teesta Bridge	25°47'17.50"N	89°26'18.70"E	Mouza: Tista Union: Gokunda Upazila:Lalmonirhat Sadar District: Lalmonirhat Division: Rangpur
		4	Horipur Kheya Ghat	25°31'6.00"N	89°39'4.50"E	Mouza: Ujan Bochagari Union: Chandipur Upazila: Sundarganj District: Gaibandha Division: Rangpur
2	Jamuna (5)	5	Sariakandi Kheya Ghat (Growin Bandh)	24°53'30.20"N	89°34'55.40"E	Mouza: Batia Union: Sariakandi Upazila: Sariakandi District: Bogra Division: Rajshahi
		6	Tarakandi	24°39'43.3"N	89°48'47.3"E	Mouza: Kulpal Union: Aona Upazila: Sarishabari District: Jamalpur Division: Dhaka
		7	Jamuna Eco Park	24°23'57.5"N	89°45'11.5"E	Union: Saidabad Upazila: Sirajganj Sadar District: Sirajganj Division: Rajshahi
		8	Kakua	24°19'6.7"N	89°47'41.5"E	Mouza: Kakua Union: Kakua Upazila: Tangail Sadar District: Tangail Division: Dhaka
		9	Mohonganj	24° 3'35.8"N	89°39'12.9"E	Union: Bera Paurashava Upazila: Bera District: Pabna Division: Rajshahi
3	Brahmaputra (2)	10	Jamalpur Bridge	24°55'30.76"N	89°57'56.37"E	Union: Char Pakshimari Upazila: Sherpur Sadar

<table>
<tr><th rowspan="2">SL no. of River</th><th rowspan="2">Name of River (no. of points)</th><th rowspan="2">SL ID</th><th rowspan="2">Strategic Location</th><th colspan="2">GPS Coordinates</th><th rowspan="2">Description</th></tr>
<tr><th>Latitude</th><th>Longitude</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td></td><td></td><td></td><td></td><td>District: Sherpur
Division: Dhaka</td></tr>
<tr><td>11</td><td>Rail Bridge</td><td>24°44'30.94"N</td><td>90°25'39.47"E</td><td>Union: Char Ishwardia
Upazila:Mymensingh Sadar
District: Mymensingh
Division: Dhaka</td></tr>
<tr><td rowspan="5">4</td><td rowspan="5">Surma
(5)</td><td>12</td><td>Jamalganj</td><td>25° 0'5.9"N</td><td>91°14'16.8"E</td><td>Mouza: Telia Jamalpur
Union: Jamalganj
Upazila: Jamalganj
District: Sunamganj
Division: Sylhet</td></tr>
<tr><td>13</td><td>Sunamganj Lunch Ghat</td><td>25° 4'23.6"N</td><td>91°23'37.5"E</td><td>Mouza: Tegharia (Part)
Union: Lakshmansree
Upazila: SunamganjSadar
District: Sunamganj
Division: Sylhet</td></tr>
<tr><td>14</td><td>Chatak Ferry Ghat</td><td>25° 2'2.3"N</td><td>91°40'20.3"E</td><td>Mouza:MandalibhogPaurashava: Chhatak
Upazila: Chhatak
District: Sunamganj
Division: Sylhet</td></tr>
<tr><td>15</td><td>Shahjalal Bridge</td><td>24°52'54.98"N</td><td>91°52'46.34"E</td><td>Ward: No-23
Upazila: Kotwali
District: Sylhet
Division: Sylhet</td></tr>
<tr><td>16</td><td>Kanaighat</td><td>25° 0'14.65"N</td><td>92°15'31.91"E</td><td>Mouza: Nandirai
Union: Kanaighat
Upazila: Kanaighat
District: Sylhet
Division: Sylhet</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">Kushiara
(2)</td><td>17</td><td>Bairagi Bazar</td><td>24°51'19.68"N</td><td>92° 9'21.11"E</td><td>Mouza; Saleshwarkuna
Union: Sheola
Upazila: Beani Bazar
District: Sylhet
Division: Sylhet</td></tr>
<tr><td>18</td><td>Fenchuganj Fertilizer Industry</td><td>24°39'15.73"N</td><td>91°54'17.80"E</td><td>Mouza: Baksipu
Union: Uttarbhag
Upazila: Rajnagar
District: Moulvibazar
Division: Sylhet</td></tr>
<tr><td rowspan="2">6</td><td rowspan="2">Buriganga
(7)</td><td>19</td><td>Mirpur Bridge</td><td>23°47'8.13"N</td><td>90°20'10.21"E</td><td>Ward no.: 09
Thana: Mirpur
District: Dhaka
Division: Dhaka</td></tr>
<tr><td>20</td><td>Boshila Bridge</td><td>23°44'35.26"N</td><td>90°20'42.67"E</td><td>Mouza: Washpur
Union: Sakta</td></tr>
</table>

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
						Thana: Keraniganj District: Dhaka Division: Dhaka
		21	Hazaribagh	23°43'18.18"N	90°21'34.42"E	Mouza: Brahmankita Union: Kalindi Upazila: Keraniganj District: Dhaka Division: Dhaka
		22	Sata Mosque Road (Kamrangir Char)	23°42'28.67"N	90°22'6.69"E	Mouza: Brahmankita Union: Kalindi Upazila: Keraniganj District: Dhaka Division: Dhaka
		23	Chandni Ghat	23°42'38.60"N	90°23'27.58"E	Mouza: Zinjira Union: Zinjira Upazila: Keraniganj District: Dhaka Division: Dhaka
		24	Bd-China Friendship Bridge	23°41'13.75"N	90°25'36.40"E	Mouza: Hasnabad (Nayatola) Union: Subhadya (part) Upazila: Keraniganj District: Dhaka Division: Dhaka
		25	Fatullah	23°38'52.68"N	90°28'0.93"E	Mouza: Dapa Idrakpur (Dapa) Union: Fatullah Upazila: Narayanganj Sadar District: Narayanganj Division: Dhaka
7	Turag (5)	26	Turag Bridge (Near Ashulia Bus Stop and Anon Text Group Industries)	23°53'32.28"	90°21'36.1"	Pourashava: Tongi Pourashava Upazila: Gazipur Sadar District: Gazipur Division: Dhaka
		27	Ashulia	23° 53' 30.12"	90° 20' 21.84"	Mouza: Chak Basaid Union: Ashulia Upazila: Savar District: Dhaka Division: Dhaka
		28	Kaliakair	24° 4' 57.72"	90° 12' 53.64"	Union: Sreefaltali Upazila: Kaliakair District: Gazipur Division: Dhaka
		29	Vawal	24° 2' 7.08"	90° 20' 48.84"	Mouza: Tekibari Union: Kayaltia

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
						Upazila: Gazipur Sadar District: Gazipur Division: Dhaka
		30	Nama Bazar (very near to Kashimpur High School)	23°59'1.64"N	90°19'43.71"E	Union: Kashimpur Upazila: Gazipur Sadar District: Gazipur Division: Dhaka
8	Shitalakhya (4)	31	Port Road	23° 37' 41.52"	90° 30' 58.68"	Paurashava: Kadam Rasul Upazila: Bandar District: Narayanganj Division: Dhaka
		32	Majhira (Demra Ghat)	23° 43' 17.04"	90° 30' 11.16"	Mouza: Taraba Union: Tarabo Upazila: Rupganj District: Narayanganj Division: Dhaka
		33	Murapara (Rupganj)	23° 47' 24.72"	90° 31' 31.44"	Union: Mura Para Upazila: Rupganj District: Narayanganj Division: Dhaka
		34	Ghorashal Fertilizer Industry	23° 47' 24.72"	90° 31' 31.44"	Mouza: Khanpur Union: Char Sindur Upazila: Palash District: Narsingdi Division: Dhaka
9	Dhaleshwari (6)	35	Mukterpur Bridge	23°34'9.91"N	90°30'43.22"E	Union: Panchasar Upazila: Munshiganj Sadar District: Munshiganj Division: Dhaka
		36	Patharghata (near Pathargatha Bazar (It Khola Road) and opposite of Dhaleswari Resort)	23°38'8.32"N	90°21'44.56"E	Mouza: Char Galgalia Union: Basail Upazila: Serajdikhan District: Munshiganj Division: Dhaka
		37	Ruhitpur (near BSCIC industrial areas)	23°39'40.31"N	90°18'34.56"E	Mouza: Sonakanda Union: Ruhitpur Upazila: Keraniganj District: Munshiganj Division: Dhaka
		38	Hazratpur (confluence of Kaliganga and Dhaleswari)	23°43'59.59"N	90°15'4.75"E	Union: Hazratpur Upazila: Keraniganj District: Dhaka Division: Dhaka
		39	Horindhora	23°46'19.73"N	90°14'15.21"E	Mouza: Hazratpur

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
			(south-western point of Hemayetpurt CETP)			Union: Hazratpur Upazila: Keraniganj District: Dhaka Division: Dhaka
		40	Uttar Mitora (near the Martinate River's Elementary High School)	23°49'3.80"N	90° 3'16.60"E	Mouza: Uttar Mitara Union: Betila Mitora Upazila: Manikganj Sadar District: Manikganj Division: Dhaka
10	Kaliganga (1)	41	Beutha Ghat	23°50'46.29"N	90° 0'7.59"E	Paurashava: Manikganj Upazila: Manikganj Sadar District: Manikganj Division: Dhaka
11	Balu (2)	42	Trimohini Bridge	23°45'36.57"N	90°27'46.05"E	Union: Demra (part) Thana: Sabujbagh District: Dhaka Division: Dhaka
		43	Jalshiri Abashon	23°48'46.02"N	90°29'4.33"E	Mouza: Naora Union: Kayet Para Upazila: Rupganj District: Narayanganj Division: Dhaka
12	Padma (4)	44	Barha Ghat	23°38'26.15"N	90° 2'35.86"E	Mouza: Dakshin Bahra Union: Nayabari Upazila: Dohar District: Dhaka Division: Dhaka
		45	Nort Beak Martin Island (near Chandrapara Trauler Ghat)	23°28'38.35"N	90° 6'22.24"E	Mouza: Karalkandi Union: Char Nasirpur Upazila: Sadarpur District: Faridpur Division: Dhaka
		46	Mawa Ghat	23°28'18.20"N	90°15'23.06"E	Point: Mawa Ghat Mouza: Mawa Union: Medini Mandal Upazila: Lohajang District: Munshiganj Division: Dhaka
		47	Puran Bazar	23°13'47.78"N	90°38'27.47"E	Pourashava: Chandpur Union: Medini Mandal Upazila: Chandpur Sadar District: Chandpur Division: Chittagong
13	Dakatia (4)	48	Pal Bazar Bridge	23°13'12.6"N	90°39'01.4"E	Paurashava: Chandpur Upazila: Chandpur Sadar District: Chandpur Division: Chittagong

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
		49	Dhali Ghat	23°12'12.4"N	90°40'22.2"E	Mouza: Bara Raghunathpur Union: Sakhua Upazila: Chandpur Sadar District: Chandpur Division: Chittagong
		50	Gazibari Road	23°13'30.1"N	90°40'09.3"E	Mouza: Gunrajdi Union: Tarpur Chandi Upazila: Chandpur Sadar District: Chandpur Division: Chittagong
		51	Hajiganj Bazar Bridge	23° 14' 48.81"N	90° 51' 10.33"E	Mouza: Randhanimura Union: Paschim Barkul Upazila: Hajigan District: Chandpur Division: Chittagong
14	Meghna (5)	52	Meghna Ghat Power Plant	23°36'29.70"N	90°36'49.30"E	Mouza: Char Ramjan Sonaullah Union: Pirijpur Upazila: Sonargaon District: Narayanganj Division: Dhaka
		53	Ananda Bazar	23°40'43.40"N	90°38'13.40"E	Mouza: Baradi Union: Baradi Upazila: Sonargaon District: Narayanganj Division: Dhaka
		54	Bishnandi	23°46'5.47"N	90°43'32.60"E	Mouza: Bishnandi Union: Bishnandi Upazila: Araihazar District: Narayanganj Division: Dhaka
		55	Narshingdi Launch Terminal	23°54'51.55"N	90°43'9.92"E	Paurashava: Narsingdi Upazila: Narsingdi Sadar District: Narsingdi Division: Dhaka
		56	Bhairab bazar	24° 2'36.15"N	90°59'23.14"E	Paurashava: Bhairab Upazila: Bhairab District: Kishoreganj Division: Dhaka
15	Titas (2)	57	Bakail Bridge	24° 2'42.61"N	91°10'39.21"E	Mouza: Sahbazpur Union: Shahbazpur Upazila: Sarail District: Brahmanbaria Division: Chittagong
		58	Titas Rail Bridge	23°52'43.49"N	91°12'0.03"E	Mouza: Akhaura Union: Akhaura

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
						Paurashava Upazila: Akhaura District: Brahmanbaria Division: Chittagong
16	Korotoa (3)	59	Dottobari Bridge	24°51'17.58"N	89°22'26.19"E	Mouza: Chilu Para Union: Shabgram Upazila: Bogra Sadar District: Bogra Division: Rajshahi
		60	Aziz Ahmed Taki Road	24°50'37.02"N	89°22'54.36"E	Mouza: Natai Para (Part-B) Union: Shabgram Upazila: Bogra Sadar District: Bogra Division: Rajshahi
		61	Sultanganj-Gabtoli Road	24°48'4.94"N	89°24'24.92"E	Mouza: Chanchaitara Union: Madla Upazila: Bogra Sadar District: Bogra Division: Rajshahi
17	Ganges (4)	62	Sardah	24° 21' 41.16"	88° 35' 52.95"	Union: Harian Upazila: Paba District: Rajshahi Division: Rajshahi
		63	Nurullapur	24˚10'5.7"N	88˚59'34.1"E	Mouza: Nurullapur Union: Ishwardi Upazila: Lalpur District: Natore Division: Rajshahi
		64	Gorai Off Take	23˚57'2.4" N	89˚06'39.1"E	Mouza: Mahanagar Union: HatashHoripur Upazila: KushtiaSadar District: Kushtia Division: Khulna
		65	Kanchan Park	23˚52'11.12"N	89˚27'6.16"E	Mouza: Nurullapur Union: Ishwardi Upazila: Lalpur District: Natore Division: Rajshahi
18	Gorai (1)	66	Kamarkhali Bridge	23° 32' 9.77"N	89° 31' 47.69"E	Mouza: Rajdharpur Union: Nakol Upazila: Sreepur District: Magura Division: Khulna
19	Modhumoti (2)	67	Dhalaitala	23° 8'19.78"N	89°40'40.66"E	Mouza: Kuraltala Union: Kotakul Upazila: lohagara

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
						District: Narail Division: Khulna
		68	Patgati-Nazimpur	22° 52' 52.2" N	89° 53' 44.08" E	Mouza: Patgati Union: Ptagati Upazila: Tungipara District: Gopalganj Division: Dhaka
20	Mathavanga (1)	69	Dorshona Railway Junction	23°31'25.28"N	88°47'20.30"E	Union: Damurhuda Upazila: Chuadanga District: Chuadanga Division: Khulna
21	Kankshiali (3)	70	Kaliganj Bazar Bridge	22°27'27.82"N	89° 2'1.84"E	Mouza: Kankshiali Union: Tarali Upazila: Kaliganj District: Satkhira Division: Khulna
		71	Boshontopur	22°28'23.34"N	89° 0'21.04"E	Mouza: BharaSimla Union: Tarali Upazila: Kaliganj District: Satkhira Division: Khulna
		72	Uzirpur, Gobindakathi	22°30'45.09"N	89° 7'38.64"E	Union: Champaphul Upazila: Kaliganj District: Satkhira Division: Khulna
22	Bhairab (4)	73	Bashundia Bazar	23° 8'14.76"N	89°22'8.90"E	Mouza: Aladipur Union: Basuari Upazila: Bagher Para District: Jessore Division: Khulna
		74	Noapara Ferry Ghat	23° 0'42.12"N	89°24'57.63"E	Mouza: Noapara Paurashava: Abhaynagar Upazila: Abhaynagar District: Jessore Division: Khulna
		75	Taltola, Noapara	23° 0'42.12"N	89°24'57.63"E	Mouza: Jafarpur Paurashava: Abhaynagar Upazila: Abhaynagar District: Jessore Division: Khulna
		76	Fultalah Ghat	22°58'38.76"N	89°28'41.29"E	Mouza: Dhulgram Union: Siddhipasha Upazila: Abhaynagar District: Jessore Division: Khulna

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
23	Rupsha (4)	77	Gilatala	22°55'39.44"N	89°30'53.23"E	Mouza: Nadan Pratap Union: Barakpur Upazila: Dighoalia District: Khulna Division: Khulna
		78	Charer Hat	22° 50' 52.34"N	89° 33' 37.02"E	Mouza: Sulpur Union: Aijganti Upazila: Rupsha District: Khulna Division: Khulna
		79	Kalibari Ghat	22° 49' 11.68"N	89° 34' 18.45"E	Mouza: Aijganti Union: Aijganti Upazila: Rupsha District: Khulna Division: Khulna
		80	RupshaGhat (Old)	22° 47' 18.25"N	89° 35' 13.55"E	Mouza: Jabusa Union: Naihati Upazila: Rupsha District: Khulna Division: Khulna
24	Moyuri (3)	81	Shashan Ghat	22° 47' 48.81"N	89° 32' 35.19"E	Mouza: Alutala Union: Jalma Upazila: Batiaghata District: Khulna Division: Khulna
		82	Buro Moulavir Darga	22°47'48.00"N	89°32'35.52"E	Mouza: Alutala Union: Jalma Upazila: Batiaghata District: Khulna Division: Khulna
		83	Dosh Gate	22°45'29.60"N	89°33'4.90"E	Mouza: Tentultala Union: Jalma Upazila: Batiaghata District: Khulna Division: Khulna
25	Pashur (3)	84	Kazibacha-Batiaghata Bypass	22°44'32.63"N	89°31'18.01"E	Mouza: Hatbaria Union: Batiaghata Upazila: Batiaghata District: Khulna Division: Khulna
		85	Rampal Power Plant	22°34'59.96"N	89°32'56.63"E	Mouza: SapmariKatakhali Union: Rajnagar Upazila: Rampal District: Bagerhat Division: Khulna
		86	Banishanta	22°27'59.39"N	89°35'25.31"E	Mouza: Banishanta Union: Banishanta

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
						Upazila: Dacope District: Khulna Division: Khulna
26	Sughandha (1)	87	Gab Khan Lunch Terminal	22°37'38.83"N	90°10'40.35"E	Mouza: Charkati Union: GabkhanDhansiri Upazila: JhalakhatiSadar District: Jhalakhati Division: Barisal
27	Kirtankhola (2)	88	Dopdopia Kheya Ghat	22° 39' 26.68"N	90° 20' 2.40"E	Mouza: Paschim Char DapdapiaUnion: Dapdapia Upazila: Nalchity District: Jhalakhati Division: Barisal
		89	Kauar Char Ferry Ghat	22° 41' 50.71"N	90° 22' 33.68"E	Mouza: Kaua Char Union: Char Kowa Upazila: Barisal Sadar District: Barisal Division: Barisal
28	Tetulia (1)	90	Vheduria Ferry Ghat	22° 42' 18.0"N	90° 33' 51.5"E	Mouza: Char Vheduria Union: Vheduria Upazila: Bhola Sadar District: Bhola Division: Barisal
29	Karnaphuli (6)	91	Chittagong Urea Fertilizer Factory Ltd (CUFL)	22˚14'19.6"N	91˚49'41.2"E	Mouza: Ragadia Union: Bairag Upazila: Karnaphuli District: Chittagong Division: Chittagong
		92	TSP Location	22˚16'32.4"N	91˚48'4.3"E	Ward No. 40 Upazila: Patenga District: Chittagong Division: Chittagong
		93	Shikalbaha Power Station	22˚19'17.2"N	91˚52'7.2"E	Mouza: Dwip Kalamoral Union: Sikalbaha Upazila: Karnaphuli District: Chittagong Division: Chittagong
		94	Kalurghat Bridge	22˚24'12.0"N	91˚53'31.9"E	Ward No-05 Upazila: Chandgaon District: Chittagong Division: Chittagong
		95	Mariam Nagar	22˚26'58.9"N	92˚4'43.5"E	Mouza: Katakhali Union: Dakshin Madarsha Upazila: Hathazari District: Chittagong Division: Chittagong

SL no. of River	Name of River (no. of points)	SL ID	Strategic Location	GPS Coordinates		Description
				Latitude	Longitude	
		96	Karnaphuli Paper Mills (KPM)	22˚28'17.9"N	92˚8'20.3"E	Mouza: Narangiri Union: Raikhali Upazila: Kaptai District: Rangamati Division: Chittagong
30	Halda (3)	97	Maduna Ghat	22˚26'0.6.0"N	91˚52'20.0"E	Mouza: Dakshin Madrasha Union: Dakhin Madarsha Upazila: Hathazari District: Chittagong Division: Chittagong
		98	Garduara Sluice Gate	22° 30' 7.62"N	91° 51' 5.61"E	Mouza: Garduara Union: Garduara Upazila: Hathazari District: Chittagong Division: Chittagong
		99	Halda Bridge	22˚30'53.6"N	91˚50'44.4"E	Mouza: Gahira Union: Gahira Upazila: Raozan District: Chittagong Division: Chittagong

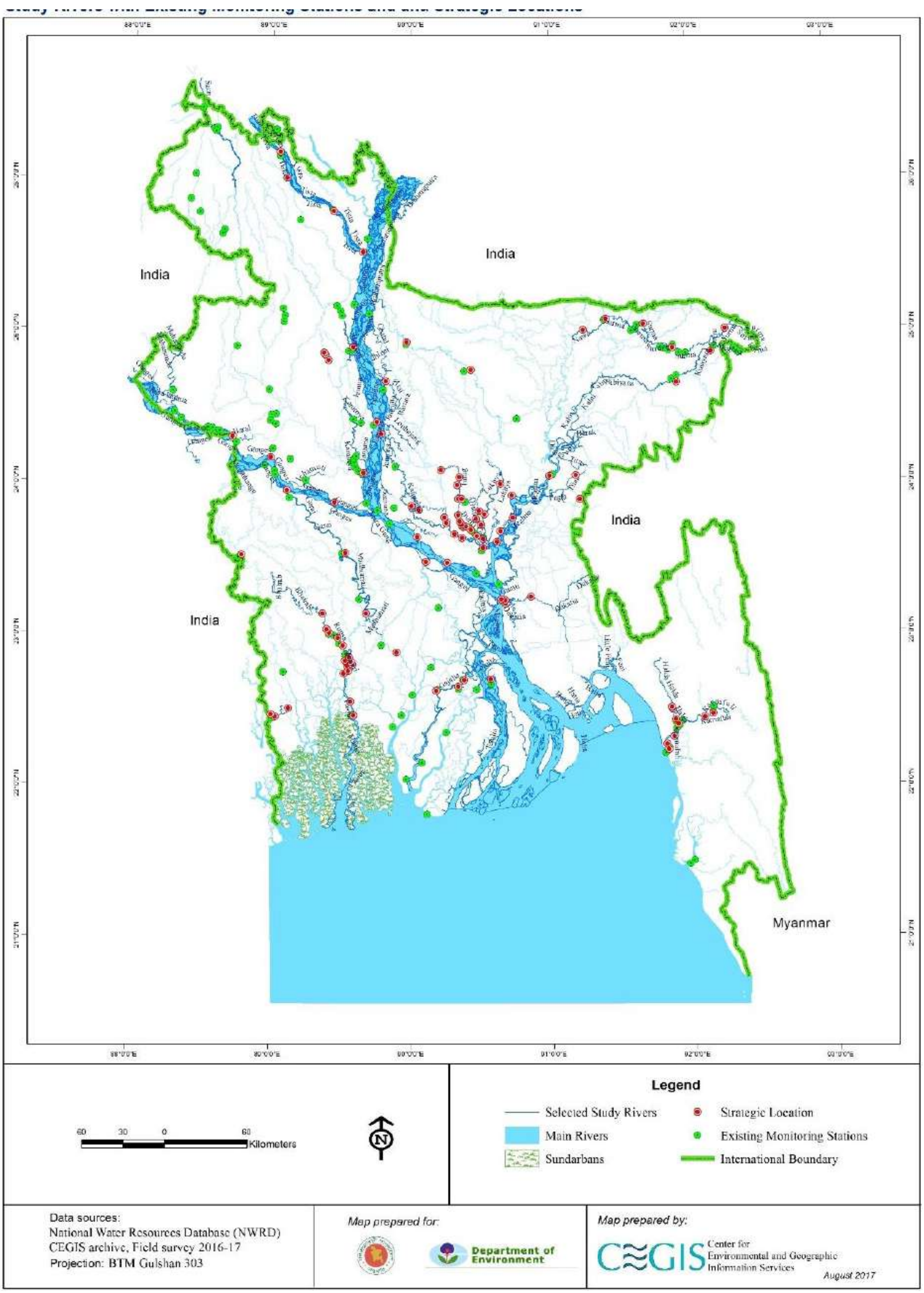


Figure 2.12: Study rivers with Existing Monitoring Stations and New Strategic Locations

2.8 Description of river wise Strategic Locations

A total of 99 strategic locations have been identified and selected for monitoring of water quality. The number of strategic locations per river are selected based on the importance of the river, pollution aspect, length, and width of the river. Digital Elevation Model (DEM) is one important parameter which have been used to select the strategic location. DEM shows the slope and flow direction which also used as possible dispersion of pollution from point and non-point sources to the river. Thus the DEM with strategic locations of each selected river has been presented in this chapter for clear understanding for the readers. The projection system of the all the maps shown here are in World Geodetic System (WGS) 1984. Descriptions of each location selected are given below:

2.8.1 Teesta River

Teesta is a trans-boundary river. Large volumes of water come from India and meet at Hatbandha of Lalmonirhat. Teesta barrage is an important hydro-modification structure constructed on this river. This barrage diverts water to the surrounding areas for irrigation. Non-point sources occur in Teesta River on the both sides from agricultural field. Total 4 locations have been selected as strategic locations for Teesta River (**Table 2.2**). The map of non-point water pollution sources and strategic locations in the Teesta River is in **Figure 2.13** and Digital Elevation of Teesta River has also shown in **Figure 2.14.**

Table 2.2: Strategic Location for Teesta River

River Name: Teesta				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Teesta Barrage	1	26°10'39.40"N	89° 3'1.10"E	Teesta Barrage is point is located at Goddimari Union of Hatibandha Thana.
Nohali Shapmari	2	26° 0'18.0"N	89° 6'14.4"E	Nohali is point is located at Saulmari Union of Jaldhaka Thana.
Teesta Bridge	3	25°47'17.50"N	89°26'18.70"E	Teesta Bridge point is located at Gokunda union of Lalmonirhat Sadar Thana.
Horipur Kheya Ghat	4	25°31'6.00"N	89°39'4.50"E	Horipur Kheya Ghat is located at Chandipur union of Sundarganj thana.

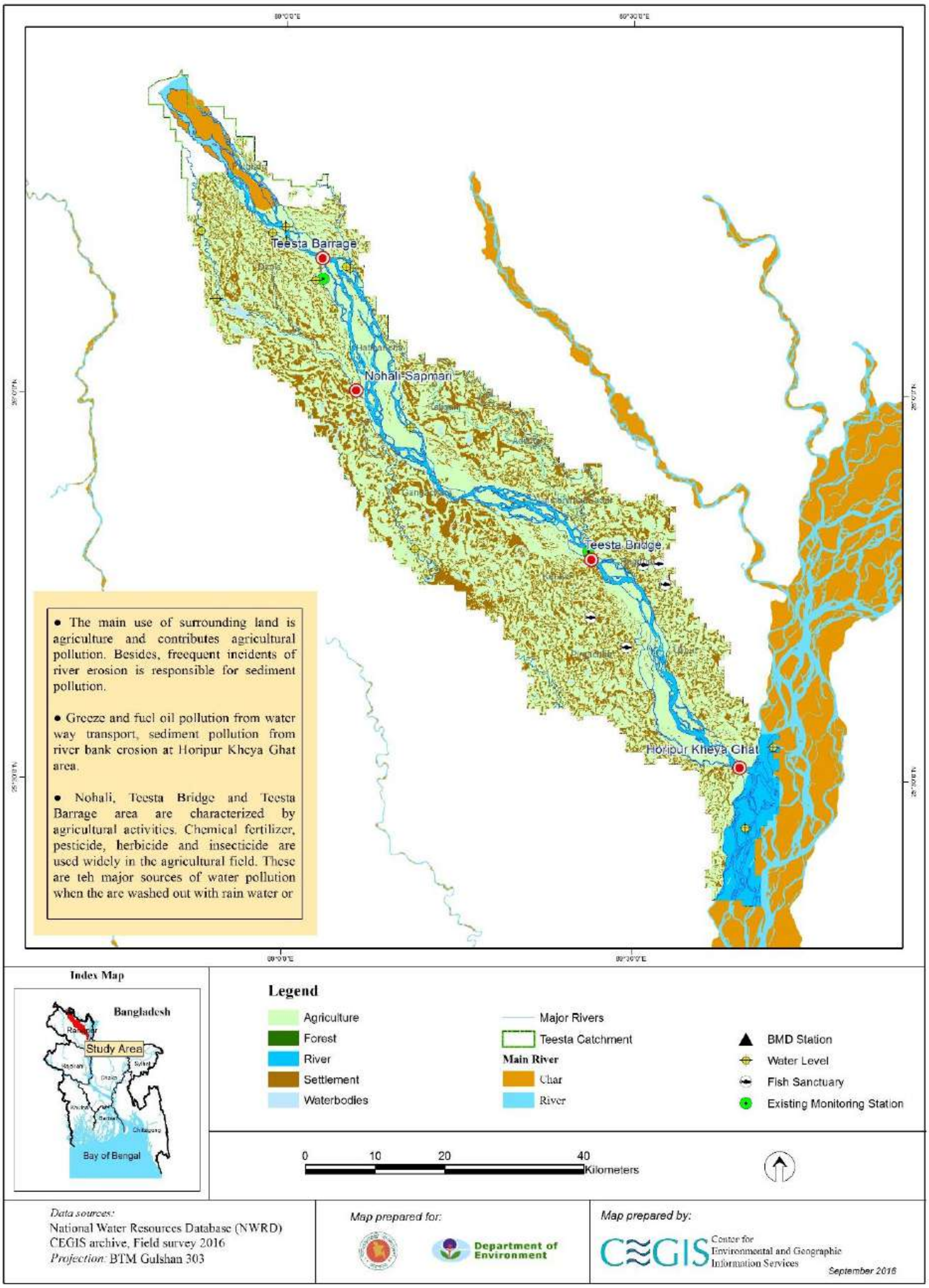


Figure 2.13: Non-Point Water Pollution Sources and Strategic Locations in Teesta River

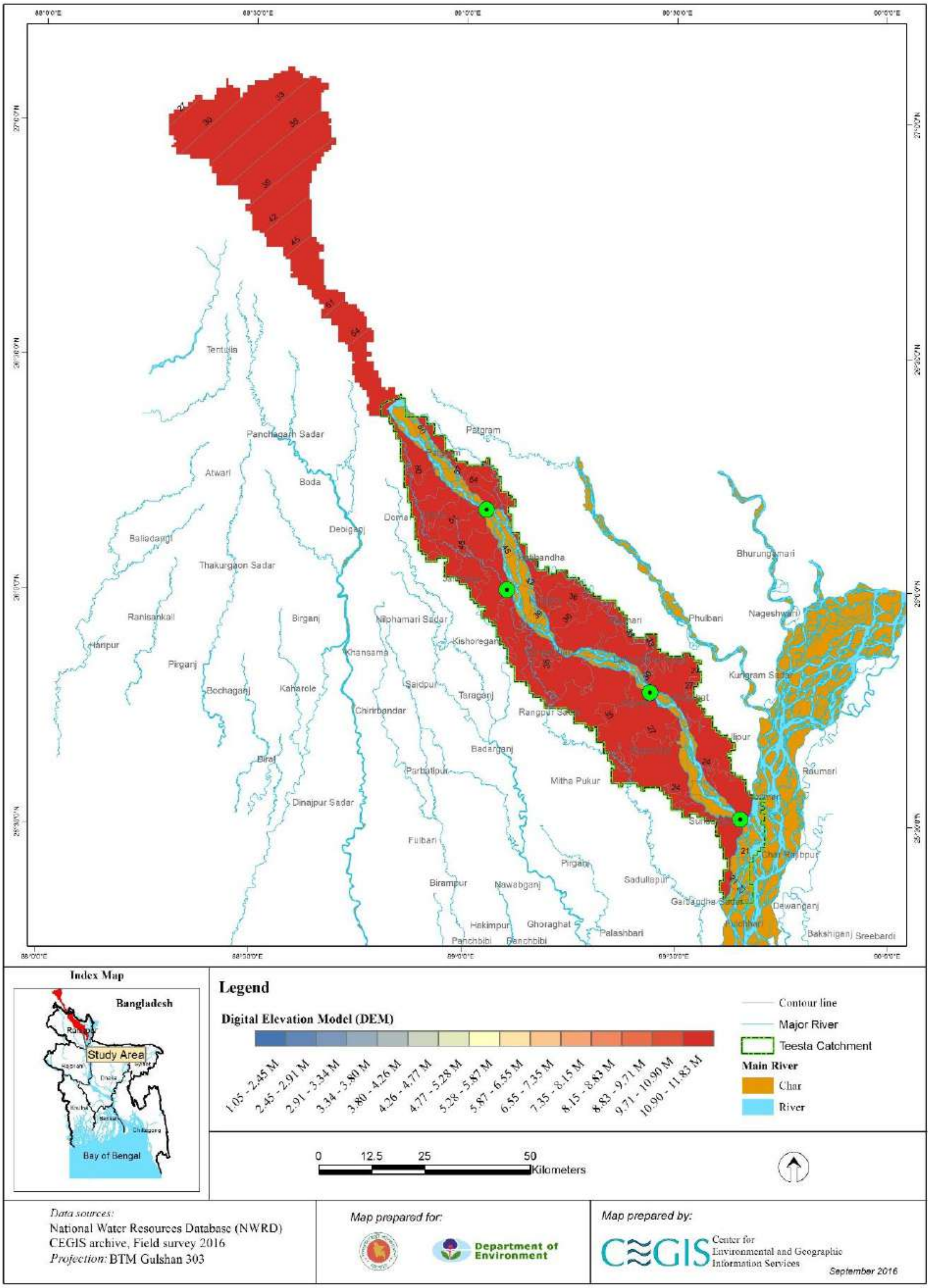


Figure 2.14: Digital Elevation Model (DEM) Map of Teesta River Catchment

2.8.2 Jamuna River

Both Industrial pollution and pollution form non-point sources occur in the Jamuna River. It is a wide and long river. Many small canals and rivers meet with Jamuna at different locations. During the rainy season, huge amounts of washed out water come to Jamuna River from the surrounding locations. Non-point sources occur in Jamuna River on both sides of the river from agricultural field. A total of 5 locations have been selected as strategic locations for Jamuna River (**Table 2.3**). The map of non-point water pollution sources and strategic locations in the Jamuna River is in **Figure 2.15** and Digital Elevation of Jamuna River has also shown in **Figure 2.16**.

Table 2.3: Strategic Location for Jamuna River

River Name: Jamuna				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Sariakandi Kheya Ghat (Growin Bandh)	5	24°53'30.20"N	89°34'55.40"E	Growin Bandh is located at Sariakandi union of Sariakandi Thana.
Tarakandi	6	24°39'43.3"N	89°48'47.3"E	Tarakandi location is situated at Aona union of Sarishabari Thana.
Jamuna Eco Park	7	24°23'57.5"N	89°45'11.5"E	Jamuna Eco Park is situated at Saidabad Union of Sirajganj Sadar Thana.
Kakua	8	24°19'6.7"N	89°47'41.5"E	Kakua is location is situated at Kakua Union of Tangail Sadar Thana.
Mohonganj	9	24° 3'35.8"N	89°39'12.9"E	Mohonganj is located at Bera Paurashava of Bera Thana.

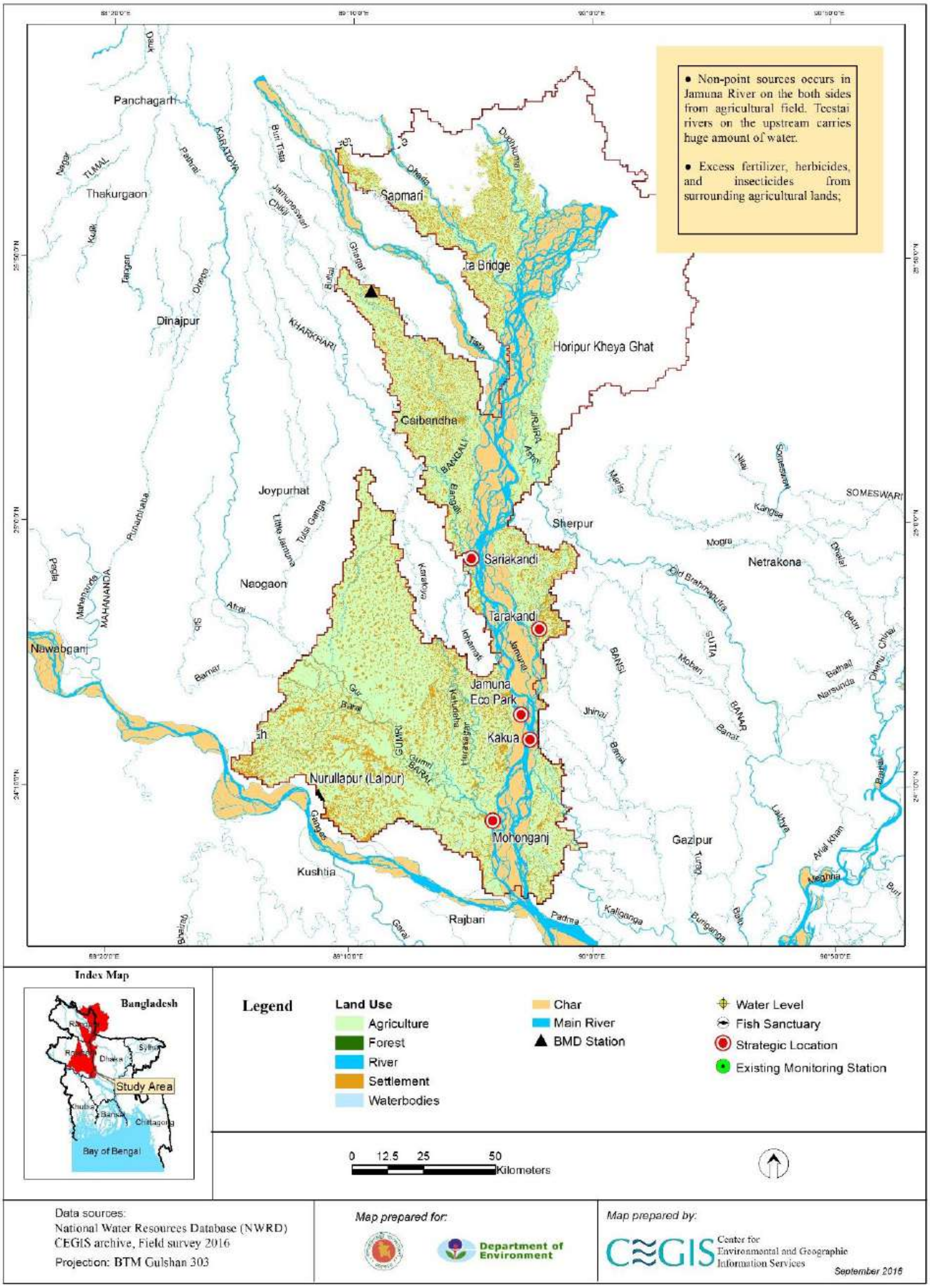


Figure 2.15: Non-Point Water Pollution Sources and Strategic Locations in the Jamuna River

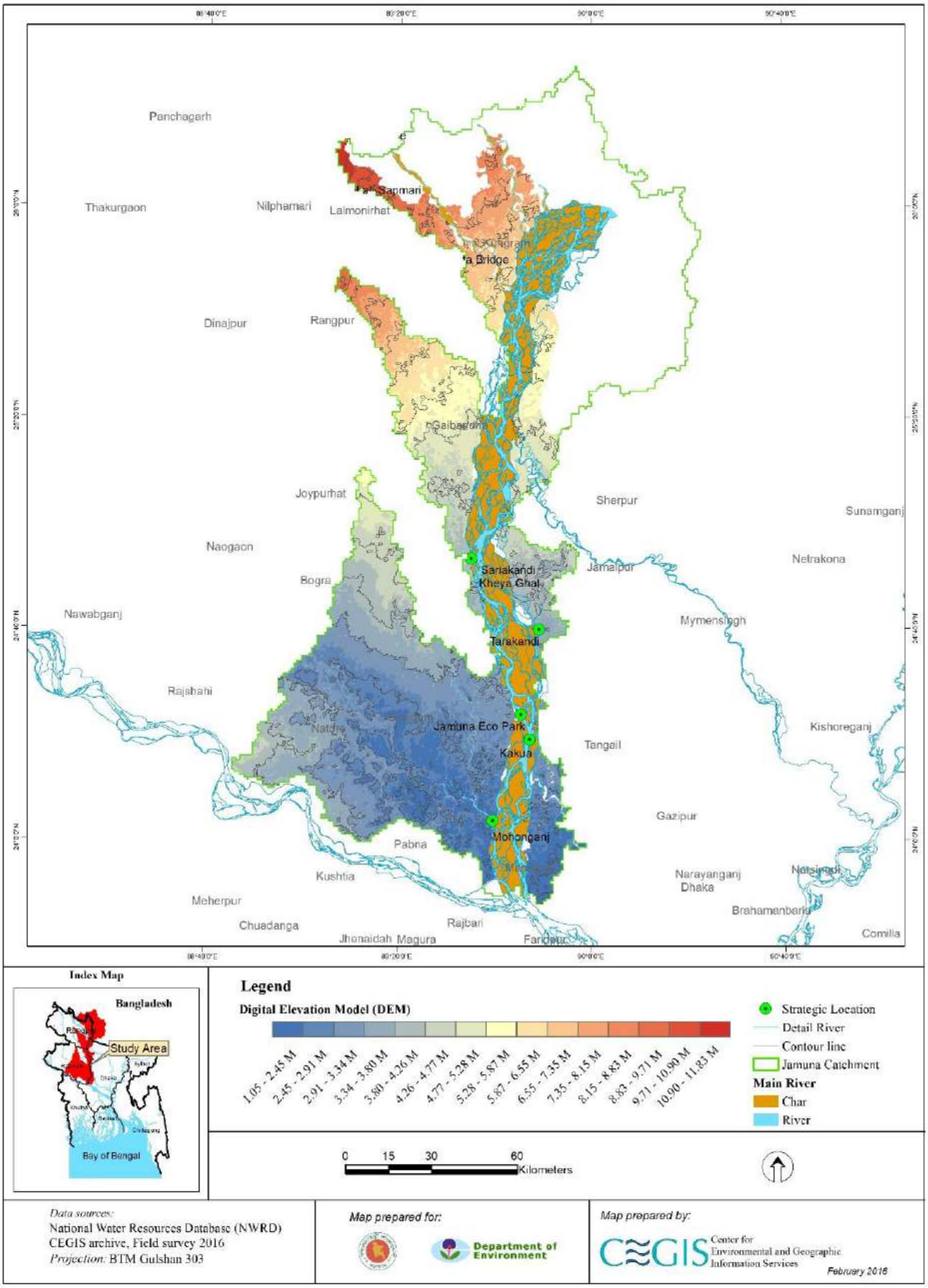


Figure 2.16: Digital Elevation Model (DEM) Map of Jamuna River Catchment

2.8.3 Brahmaputra River

Pollution from non-point sources occur in Brahmaputra River. Non-point pollution sources such as pesticides and chemical fertilizer used in agricultural field and they mix with river water during the rainy season. A total of 2 locations have been selected as strategic locations for Brahmaputra River (**Table 2.4**). The map of non-point water pollution sources and strategic locations in the Brahmaputra River is in **Figure 2.17** and Digital Elevation of Brahmaputra River has also shown in **Figure 2.18**.

Table 2.4: Strategic Location for Brahmaputra River

River Name: Brahmaputra				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Jamalpur Bridge	10	24°55'30.76"N	89°57'56.37"E	Jamalpur Bridge is located at Char Pakshimari union of Sherpur Sadar Thana.
Rail Bridge	11	24°44'30.94"N	90°25'39.47"E	Rail Bridge location is situated at Char Ishwardia union of Mymensingh Sadar Thana.

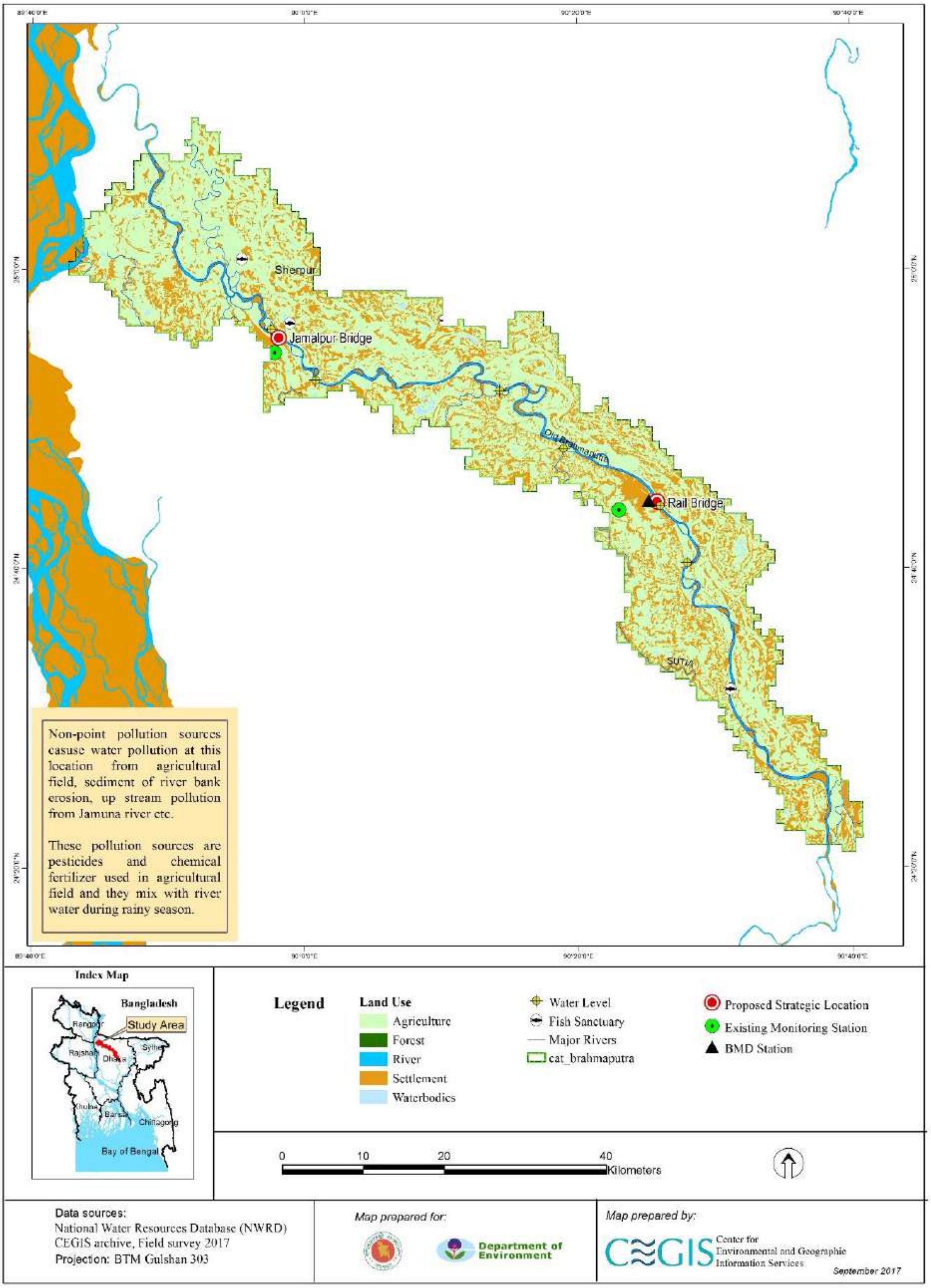


Figure 2.17: Non-Point Water Pollution Sources and Strategic Locations in the Brahmaputra River

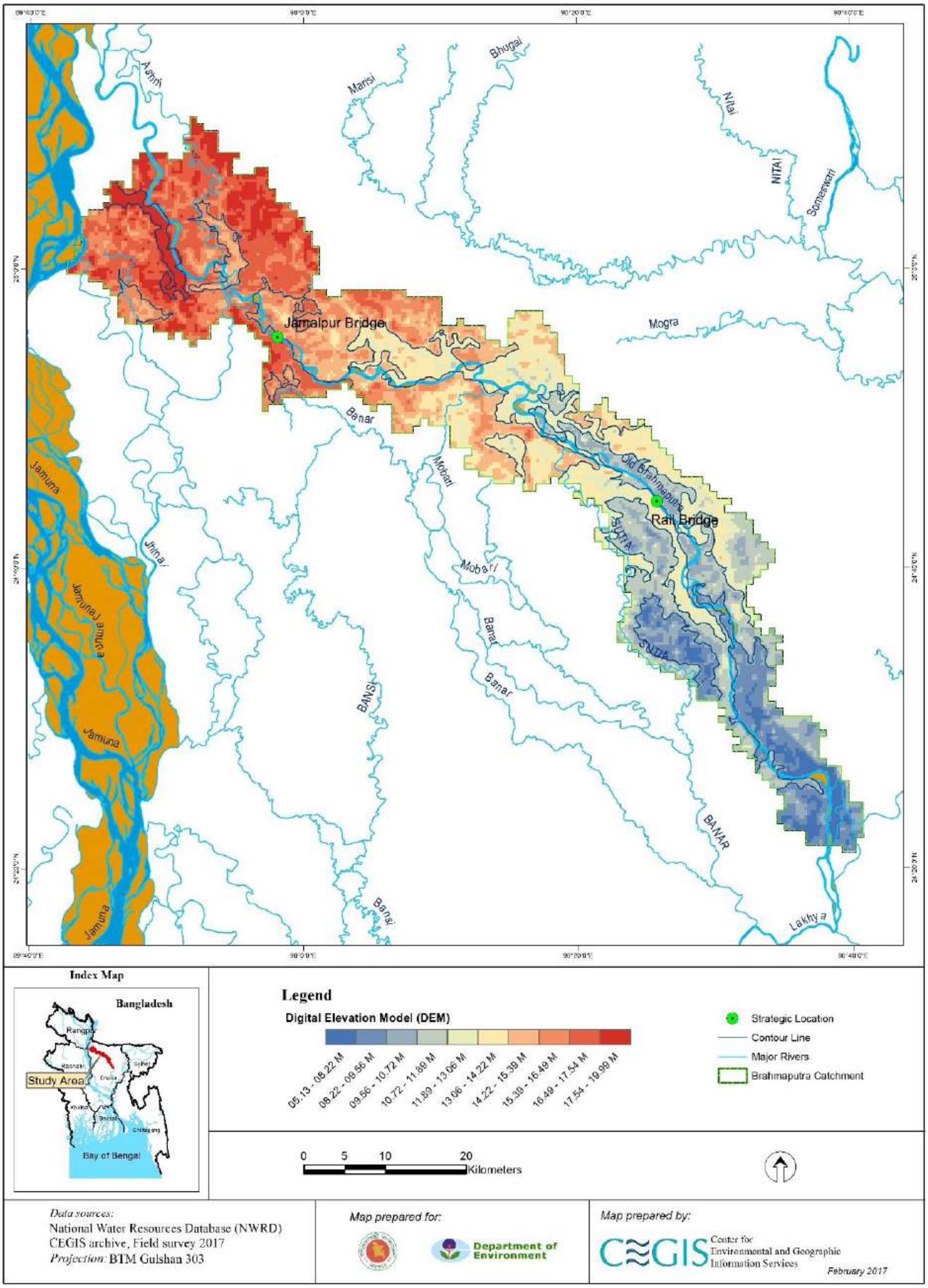


Figure 2.18: Digital Elevation Model (DEM) of Brahmaputra River Catchment

2.8.4 Surma River

Pollution form non-point sources occur in the Surma River. Non-point pollution sources such as pesticides and chemical fertilizer used in agricultural field and they mix with the river water during the rainy season. A total of 5 locations have been selected as strategic locations for the Surma River (**Table 2.5**). The map of non-point water pollution sources and strategic locations in the Surma River is in **Figure 2.19** and Digital Elevation of Surma River has also shown in **Figure 2.20**.

Table 2.5: Strategic Location for Surma River

River Name: Surma				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Jamalganj	12	25° 0'5.9"N	91°14'16.8"E	Jamalganj is located at Jamalganj union of Jamalganj Thana in Sunamganj.
Sunamganj Lunch Ghat	13	25° 4'23.6"N	91°23'37.5"E	Sunamganj Lunch Ghat is located at Lakshmanree union of Sunamganj Sadar Thana.
Chatak Ferry Ghat	14	25° 2'2.3"N	91°40'20.3"E	Chatak Ferry Ghat is situated at Chatak Paurashava of Chatak Thana.
Shahjalal Bridge	15	24°52'54.98"N	91°52'46.34"E	Shahjalal Bridge is situated at Ward No-23 of Kotwali Thana.
Kanaighat	16	25° 0'14.65"N	92°15'31.91"E	Kanaighatis situated at Kanaighat union of Kanaighat Thana.

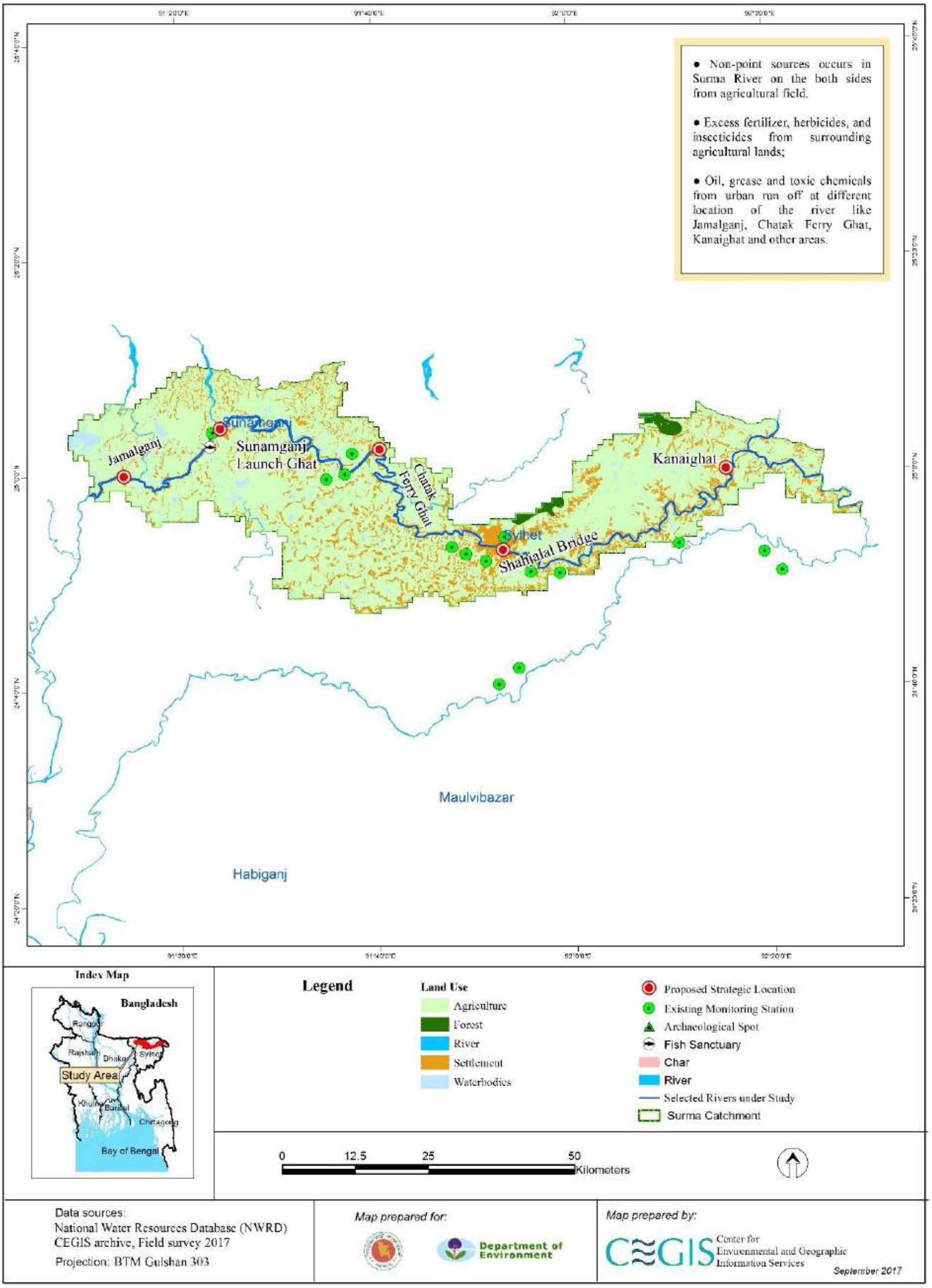


Figure 2.19: Non-Point Water Pollution Sources and Strategic Locations in the Surma River

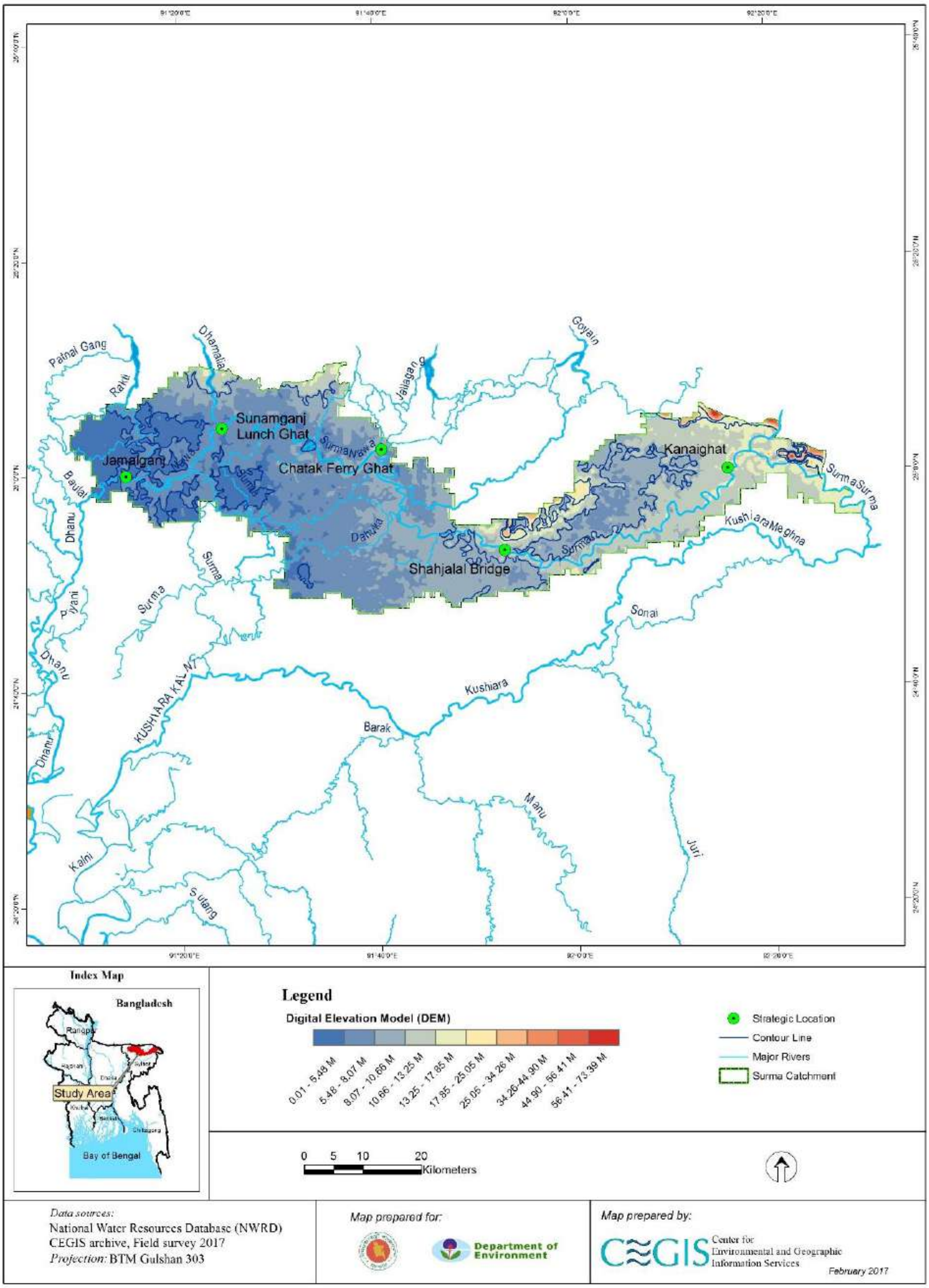


Figure 2.20: Digital Elevation Model (DEM) Map of Surma River Catchment

2.8.5 Kushiara

The Kushiara River is one of the Trans-boundary Rivers of Bangladesh. The total length of the Kushiara is about 161 km. The average width of the river is 250 m and in the rainy season the mean depth of the Kushiara reaches up to 10m (Ahmed, 2006). A total of 2 locations have been selected as strategic locations for Kushiara River (**Table 2.6**). The map of non-point water pollution sources and strategic locations in the Kushiara River is in **Figure 2.21** and Digital Elevation of Kushiara River has also shown in **Figure 2.22**.

Table 2.6: Strategic Location for Kushiara River

River Name: Kushiara				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Bairagi Bazar	17	24°51'19.68"N	92° 9'21.11"E	Bairagi Bazar is located at Sheola union of Beani Bazar Thana in Sylhet.
Fenchuganj Fertilizer Industry	18	24°39'15.73"N	91°54'17.80"E	Fenchuganj Fertilizer Industry is located at Uttarbhag union of Rajanagar Thana.

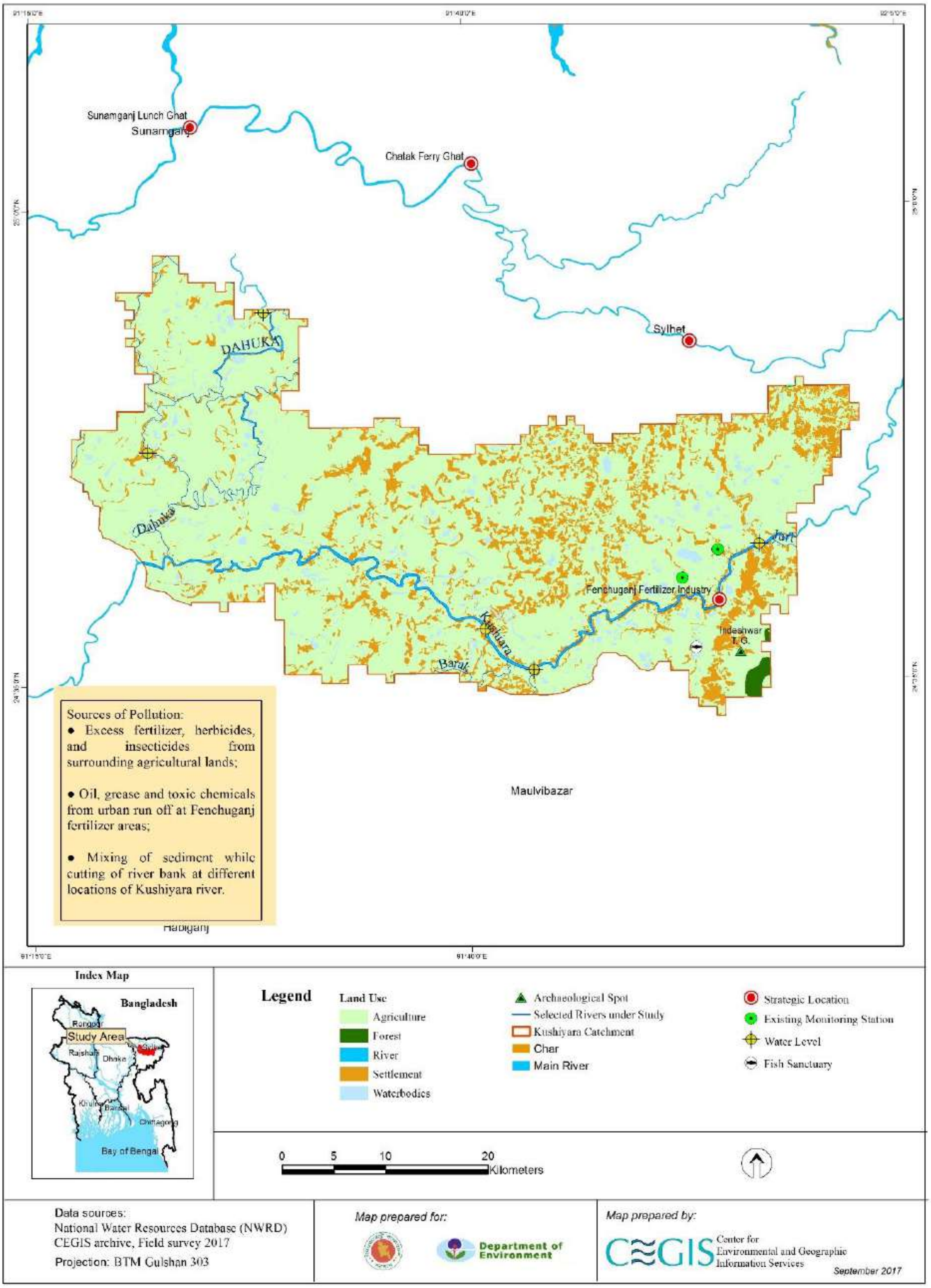


Figure 2.21: Non-Point Water Pollution Sources and Strategic Locationsin the Kushiara River

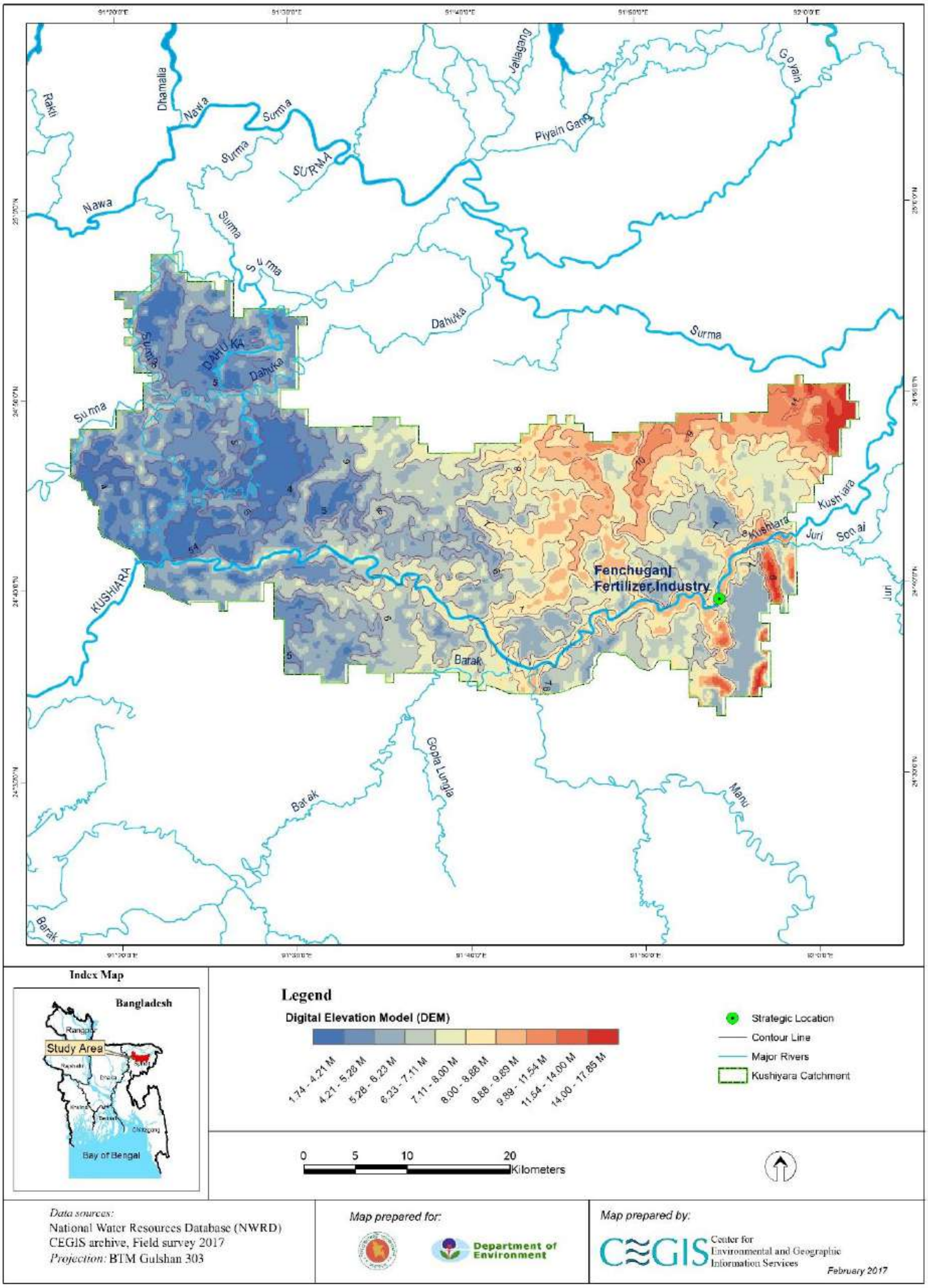


Figure 2.22: Digital Elevation Model (DEM) Map of Kushiara River Catchment

2.8.6 Buriganga River

The severe polluted water from the Turag River meets with the Buriganga at Mirpur Bridge. The north-western part of the location is mainly agricultural field including few waterbodies. The widespread waste dumping site of Dhaka City is located beside N.R. CNG Filling Station at Savar comprises all kinds waste like medical waste (Syrine, needle, saline bags, medicine bottles, drugs), kitchen garbage, solid waste from Kancha Bazar (plastic, brick, wood, metal and glass, ploythene shredded skin and leather, paper, food waste) and industrial wastes (field visit 2016). Agricultural runoff from the Amin Bazar area and surroundings also contribute to major water pollution of the Buriganga River. The Inland water vessel stations at Gabtoli also release burned oil, bilge water and other liquid waste to Buriganga River. The severe industrial pollution occurs in Buriganga at Hazaribagh (from tannery and other industries) and Chandni Ghat areas. The water of Buriganga finally mixes with the water of Dhaleshwari at Muktrpur (**Table 2.7**). The map of non-point water pollution sources and strategic locations in the Buriganga River is in **Figure 2.23** and Digital Elevation of Buriganga River has also shown in **Figure 2.24**.

Table 2.7: Strategic locations for Buriganga River

River Name: Buriganga				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Mirpur Bridge	19	23°47'8.13"N	90°20'10.21"E	This location is situated at ward no. 09 (near Gabtoli) in Mirpur Thana.
Boshila Bridge	20	23°44'35.26"N	90°20'42.67"E	Boshila bridge is a location which is in Sakta Union under Keraniganj thana.
Hazaribagh	21	23°43'18.18"N	90°21'34.42"E	Hazaribagh is located at Kalindi Union under Keraniganj Thana.
Sata Mosque Road	22	23°42'28.67"N	90°22'6.69"E	This location is situated at Kalindi in Kamrangir Char.
Chandni Ghat	23	23°42'38.60"N	90°23'27.58"E	Chandni Ghat is situated at Zinjira Union in Kamrangir Char Thana.
BD-China Friendship Bridge	24	23°41'13.75"N	90°25'36.40"E	Bd-China Friendship Bridge location is situated at Subhadya union in Keraniganj.
Fatullah	25	23°38'52.68"N	90°28'0.93"E	This location is situated at Fatullah Union in Narayanganj Sadar Thana.

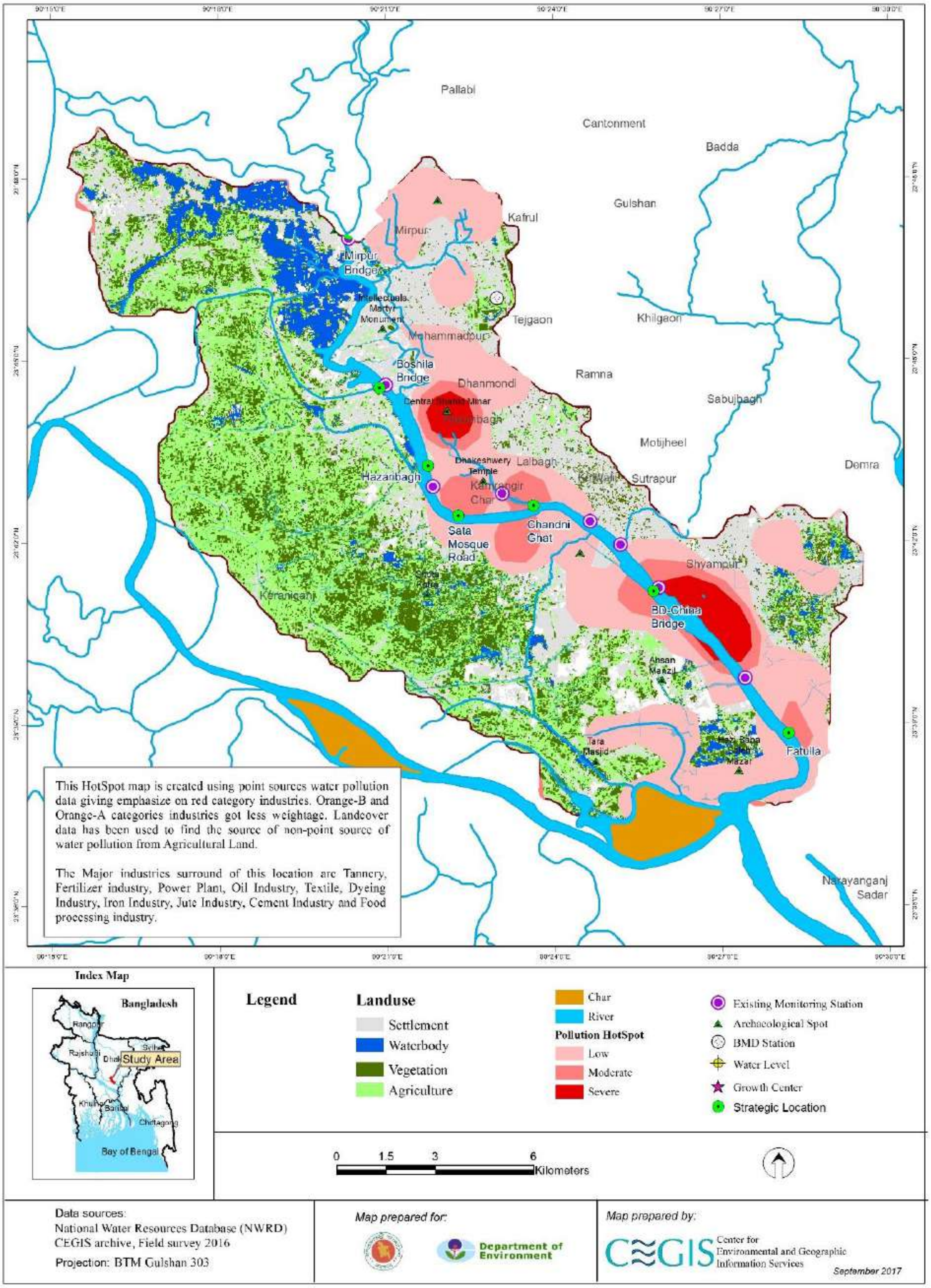


Figure 2.23: Water Pollution Hotspot and Strategic Locations in the Buriganga River

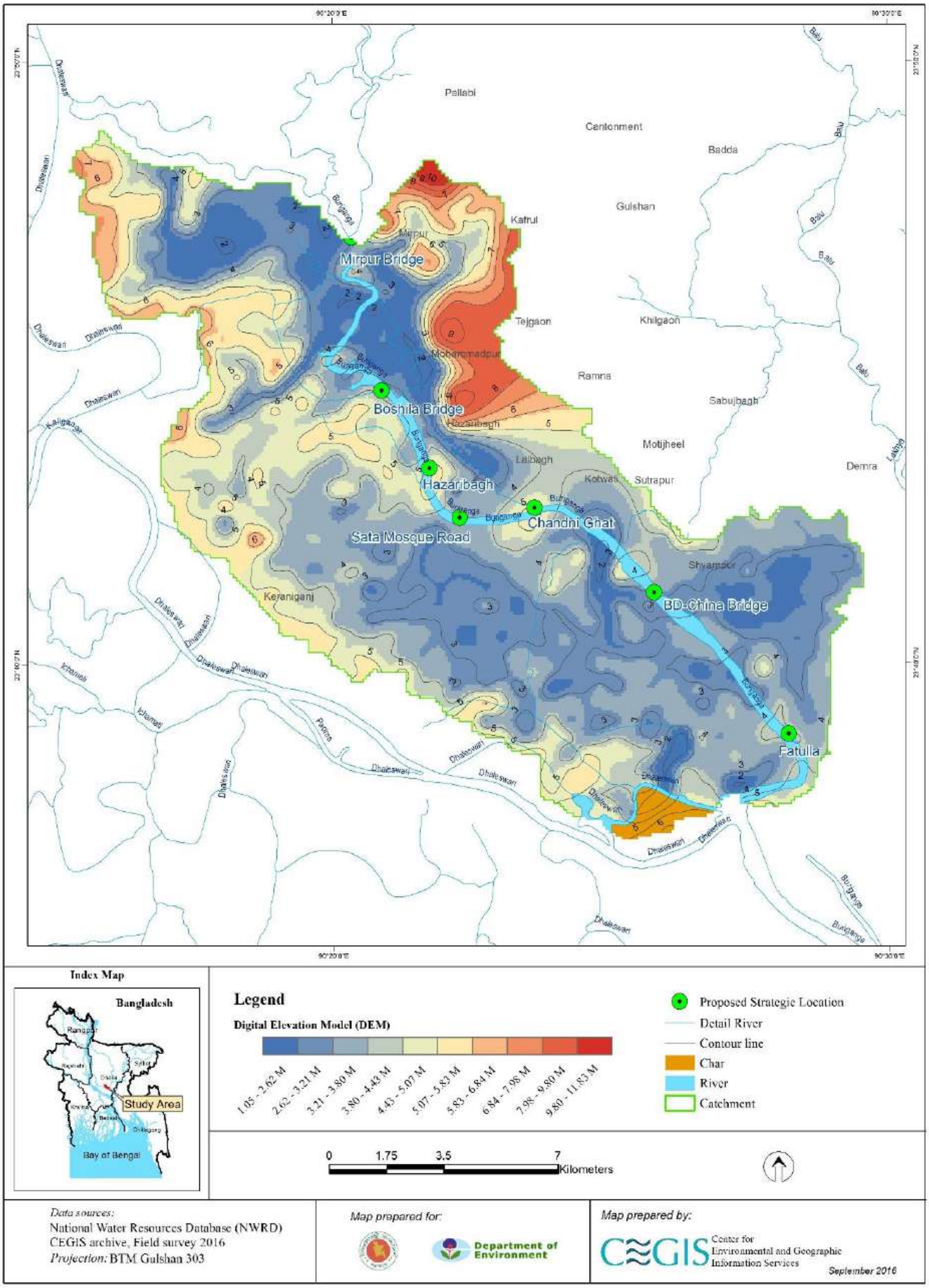


Figure 2.24: Digital Elevation Model (DEM) Map of Buriganga River Catchment

2.8.7 Turag River

The Turag River is connected with Bangshi in the north and Buriganga in the southern part. The industrial concentration has found in Ashulia and Zirani area. Total 5 locations have been selected as strategic locations for Turag River (**Table 2.8**). The map of non-point water pollution sources and strategic locations in the Turag River is in **Figure 2.25** and Digital Elevation of Turag River has also shown in **Figure 2.26**.

Table 2.8: Strategic Location for Turag River

River Name: Turag				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Turag Bridge	26	23°53'32.28"	90°21'36.1"	This location is in Tongi Pourashava near Ashulia Bus Stop and Anon Text Group Industries.
Ashulia	27	23° 53' 30.12"	90° 20' 21.84"	Ashulia point is located at Ashulia Bridge of Ashulia Union in Savar Thana.
Kaliakoir	28	24° 4' 57.72"	90° 12' 53.64"	Kaliakoir point is located at Sreefaltali Union of Kaliakoir Thana.
Vawal	29	24° 2' 7.08"	90° 20' 48.84"	Vawal point is located at Kayaltia Union of Gazipur Sadar Thana.
Nama Bazar	30	23°59'1.64"N	90°19'43.71"E	Nama Bazar is located at Kashimpur Union of Gazipur Sadar Thana. Kashimpur High School is very near to this location.

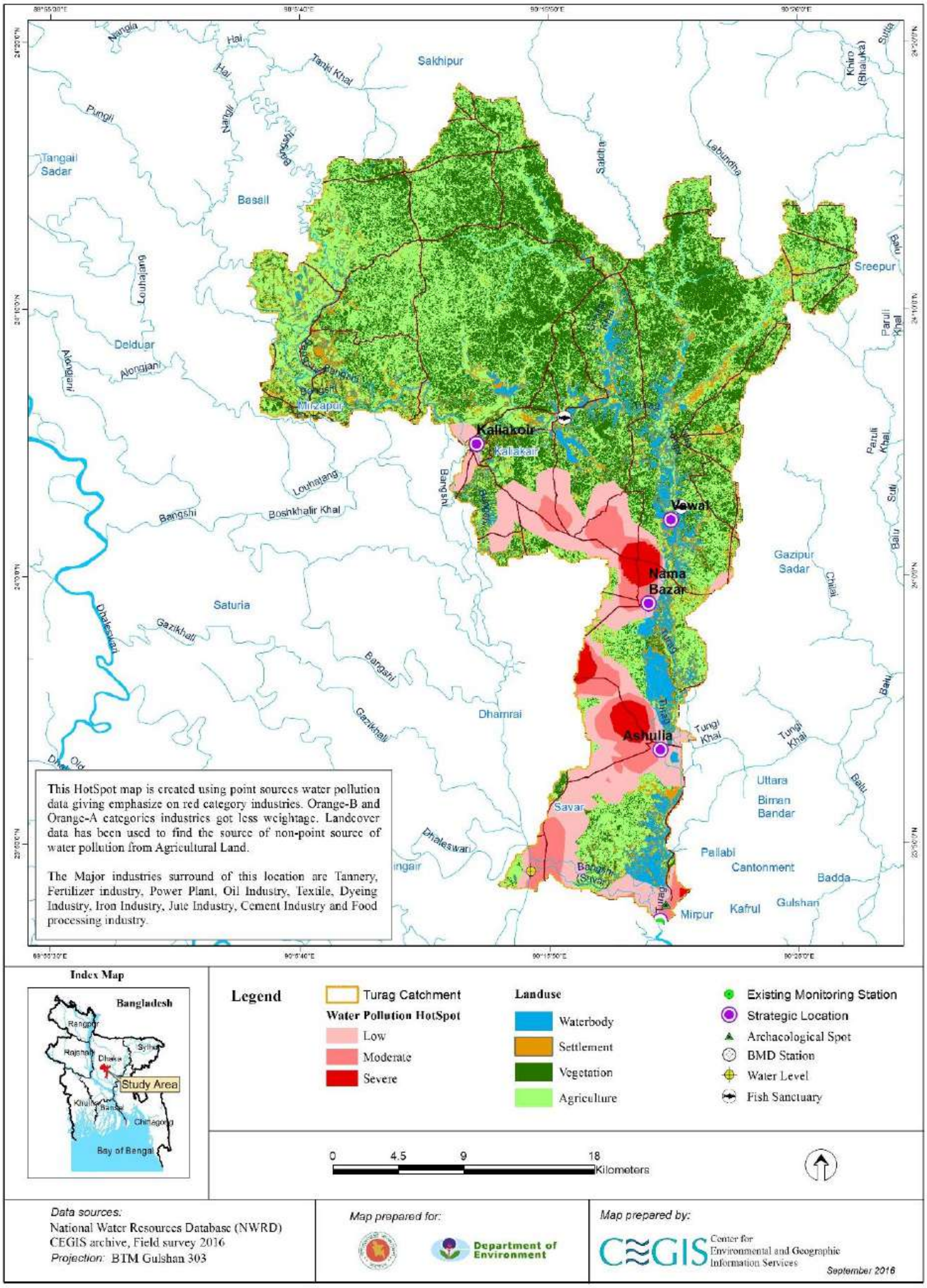


Figure 2.25: Water Pollution Hotspot and Strategic Locations in the Turag River

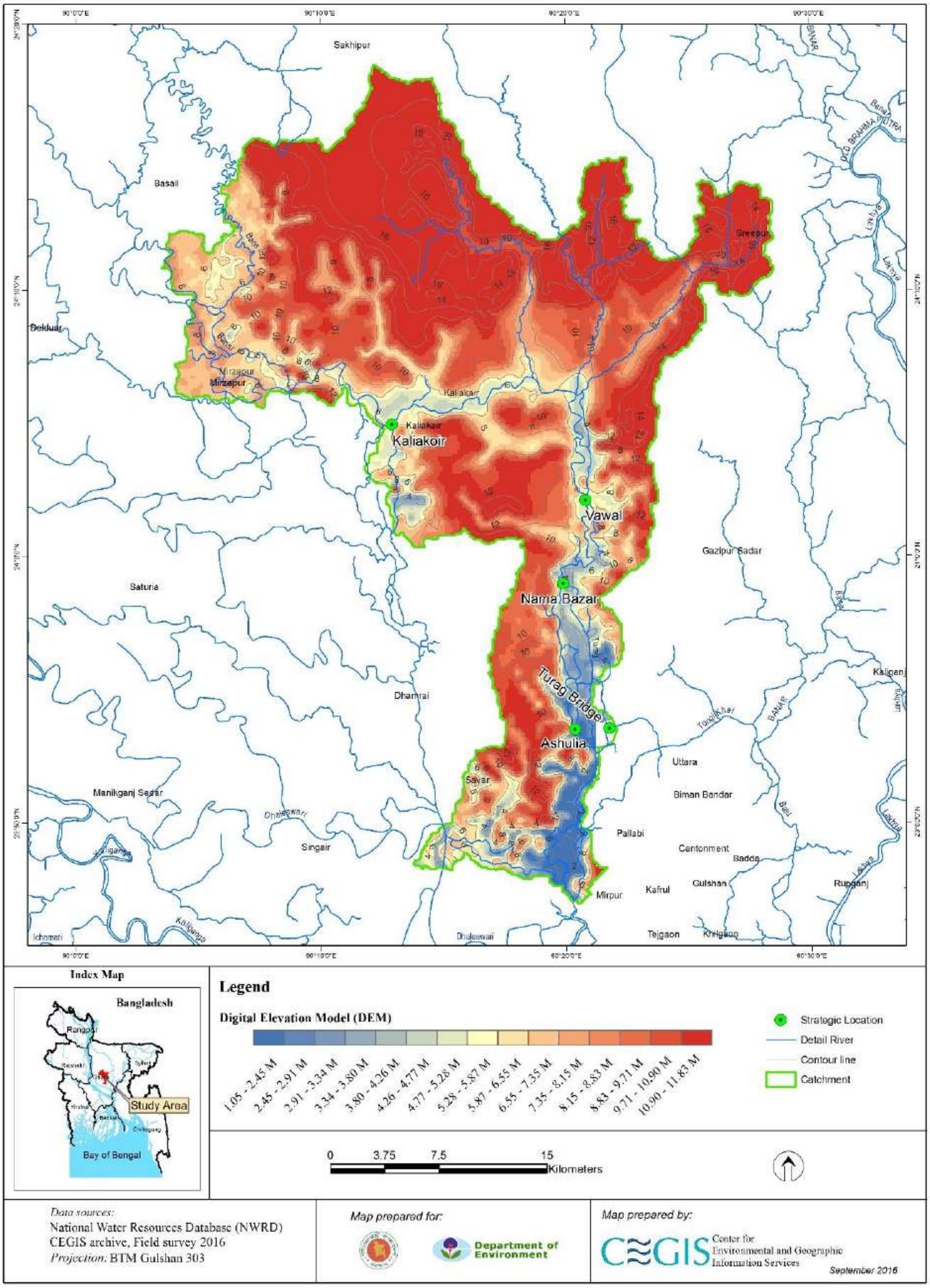


Figure 2.26: Digital Elevation Model (DEM) Map of Turag River Catchment

2.8.8 Shitalakhya River

The Shitalakhya is also a major polluted river in Dhaka region due to industrial pollution. Canal of Hajiganj area meets with Shitalakhya that carries industrial pollutants. The Balu River also joins with Shitalakhya at Demra ghat point. Few areas around Shitalakhya are also characterized by agricultural land. Comparatively more pollution occurs at Port-Road and Majhira areas. A total of 4 locations have been selected as strategic locations for the Shitalakhya River (**Table 2.9**). The map of non-point water pollution sources and strategic locations in the Shitalakhya River is in **Figure 2.27** and Digital Elevation of Shitalakhya River has also shown in **Figure 2.28**.

Tabel 2.9: Strategic Location for Shitalakhya River

River Name: Shitalakhya				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Port Road	31	23° 37' 41.52"	90° 30' 58.68"	This location is situated at Kadam Rasul Paurashava of Bandar Thana.
Majhira (Demra Ghat)	32	23° 43' 17.04"	90° 30' 11.16"	This location is situated at Tarabo Union in Rupganj Thana.
Murapara (Rupganj)	33	23° 47' 24.72"	90° 31' 31.44"	Murapara is located at Mura Para Union of Rupganj Thana.
Ghorashal Fertilizer	34	23° 47' 24.72"	90° 31' 31.44"	The point near Ghorashal Fertillizer located at Char Sindur Union of Palash Thana.

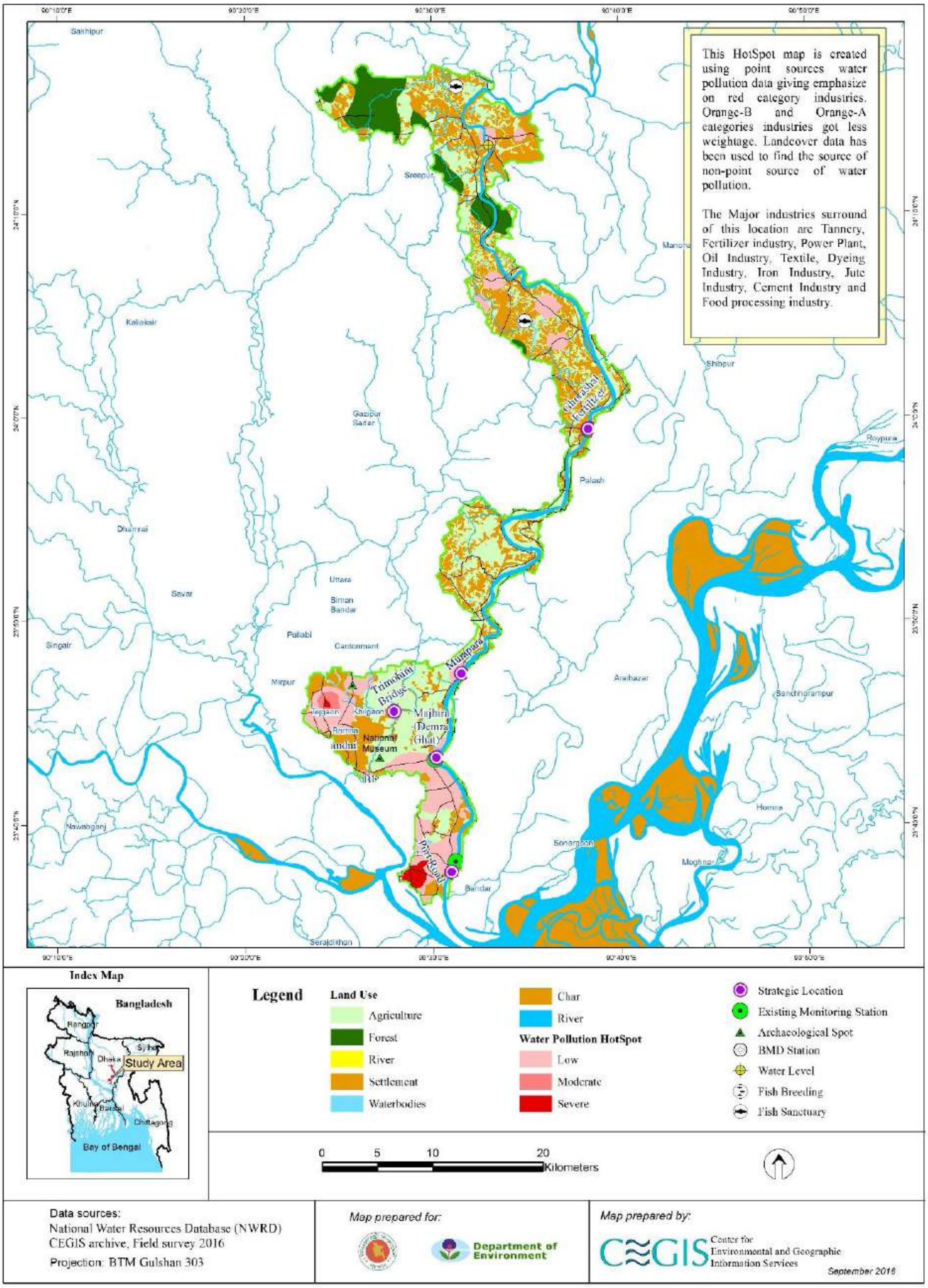


Figure 2.27: Water Pollution Hotspot and Strategic Locations in the Shitalakhya River

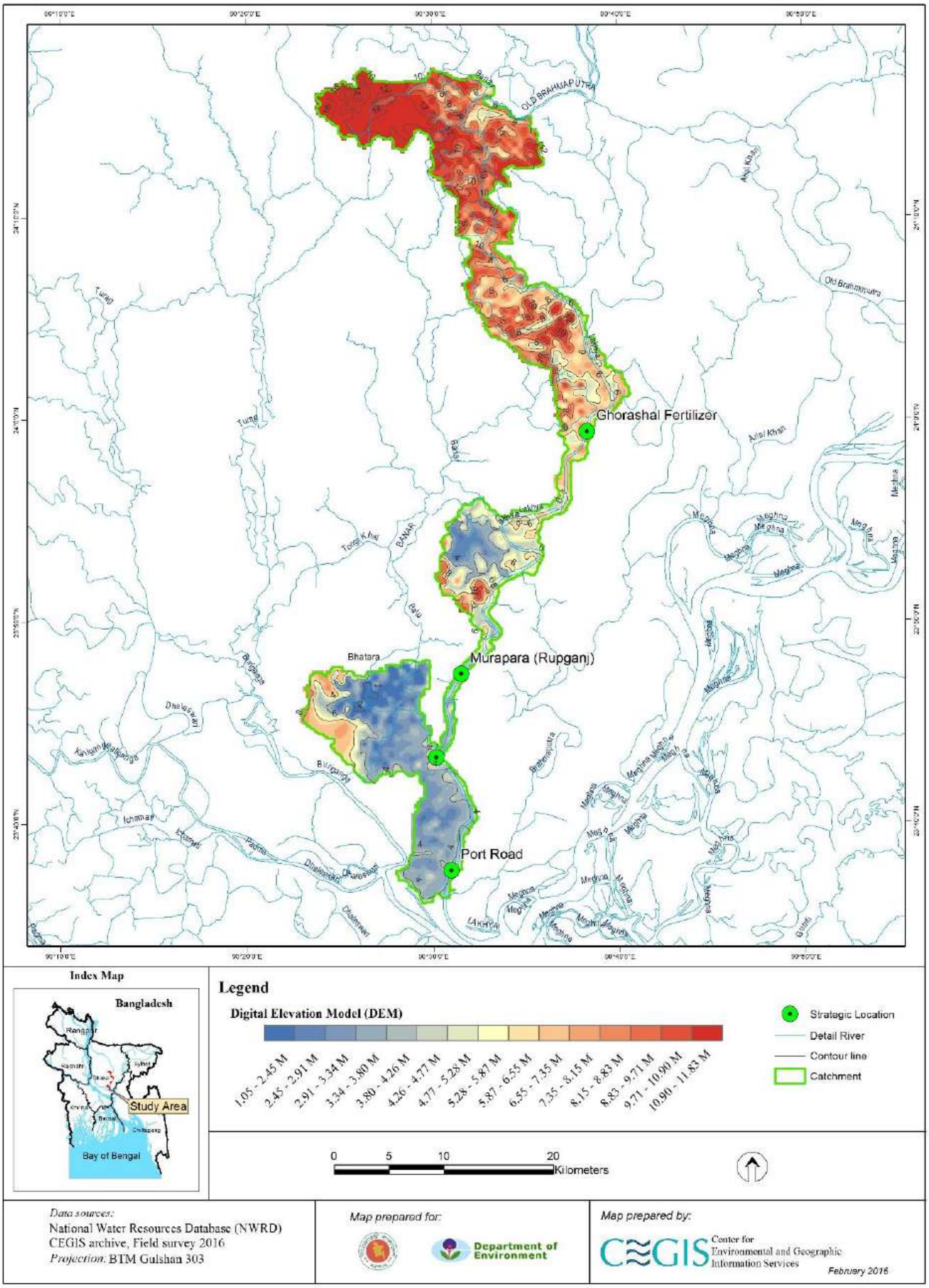


Figure 2.28: Digital Elevation Model (DEM) Map of Shitalakhya River Catchment

2.8.9 Dhaleshwari River

Comparatively less pollution occurs in the Dhaleshwari River. The water comes from the Bangshi River and meets with Dhaleshwari at Hazratpur. On both sides of the river, from Hazratpur to Patharghata, are mainly agricultural fields. Comparatively more pollution occurs at Patharghata area as water from Buriganga mixes with the Dhaleshwari water during tidal effects. Recent shiftment of tannery industries has turned Horindhora area into a water pollution hotspot. A total of 6 locations have been selected as strategic locations for the Dhaleshwari River (**Table 2.10**). The map of non-point water pollution sources and strategic locations in the Dhaleshwari River is in **Figure 2.29** and Digital Elevation of Dhaleshwari River has also shown in **Figure 2.30 (a) and (b).**

Tabel 2.10: Strategic Location for Dhaleshwari River

River Name: Dheleshwari				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Mukterpur Bridge	35	23°34'9.91"N	90°30'43.22"E	Mukterpur Bridge is located at Panchasar Union in Munshiganj Sadar Thana.
Patharghata	36	23°38'8.32"N	90°21'44.56"E	Patharghata is situated at Basail Union near Pathargatha Bazar (It Khola Road) and opposite of Dhaleswari Resort in Serajdikhan Thana.
Ruhitpur (BSCIC Ind.)	37	23°39'40.31"N	90°18'34.56"E	This point is located at Ruhitpur union near BSCIC industrial areas in Keraniganj Thana.
Hazratpur	38	23°43'59.59"N	90°15'4.75"E	This point is located at Hazratpur union (confluence of Kaliganga and Dhaleswari) near Alinagar in Keraniganj Thana.
Horindhora (CETP)	39	23°46'19.73"N	90°14'15.21"E	This monitoring station is located at the south-western point of Hemayetpurt CETP at Hazratpur Union of Keraniganj Thana.
Uttar Mitora	40	23°49'3.80"N	90° 3'16.60"E	This location is situated at Betila Mitara Union near the Martinate River's Elementary High School in Manikganj Sadar Thana.

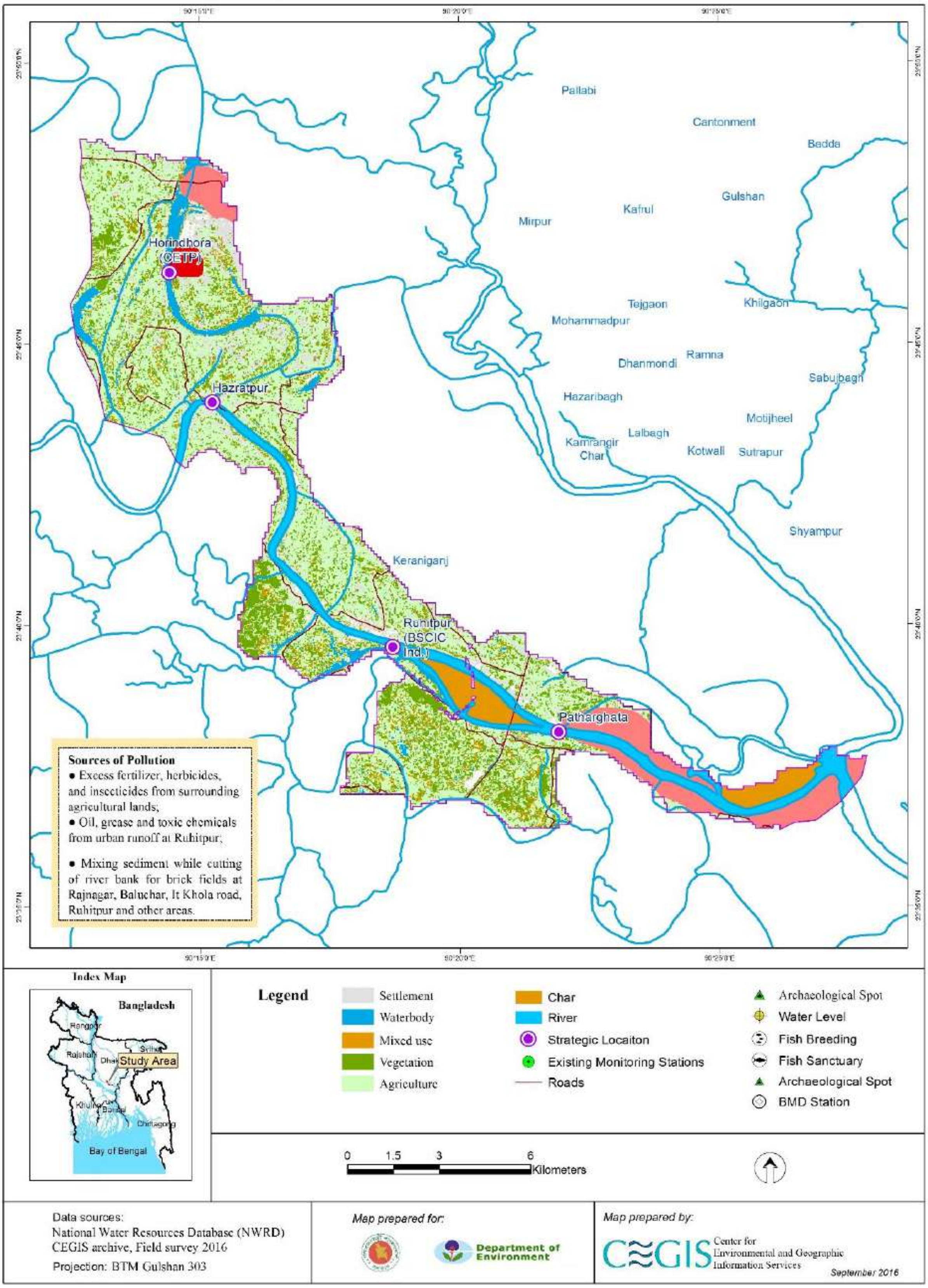


Figure 2.29: Water pollution hotspot and strategic locations in the Dhaleshwari River

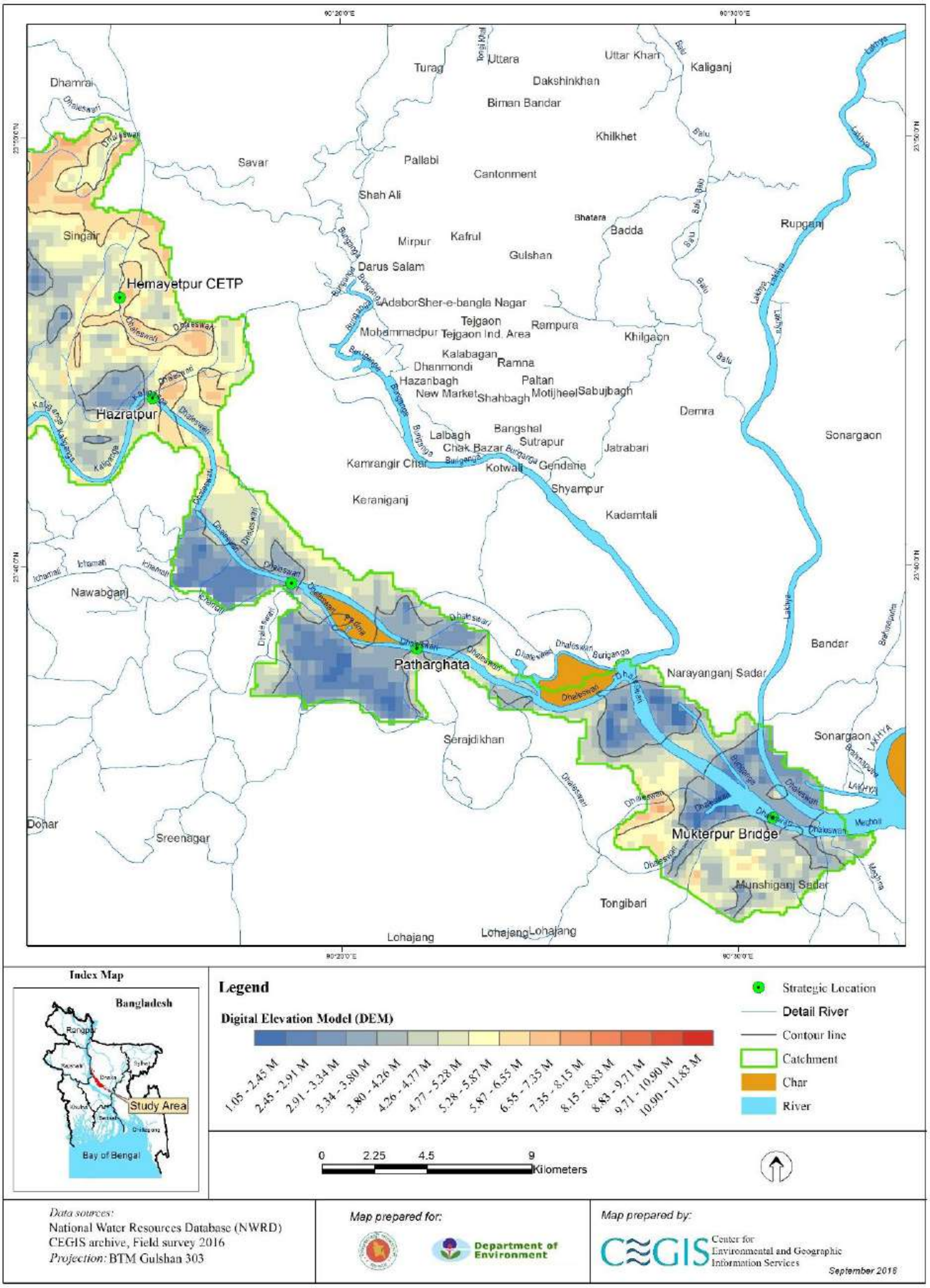


Figure 2.30 (a): Digital Elevation Model (DEM) Map of Dhaleshwari River Catchment

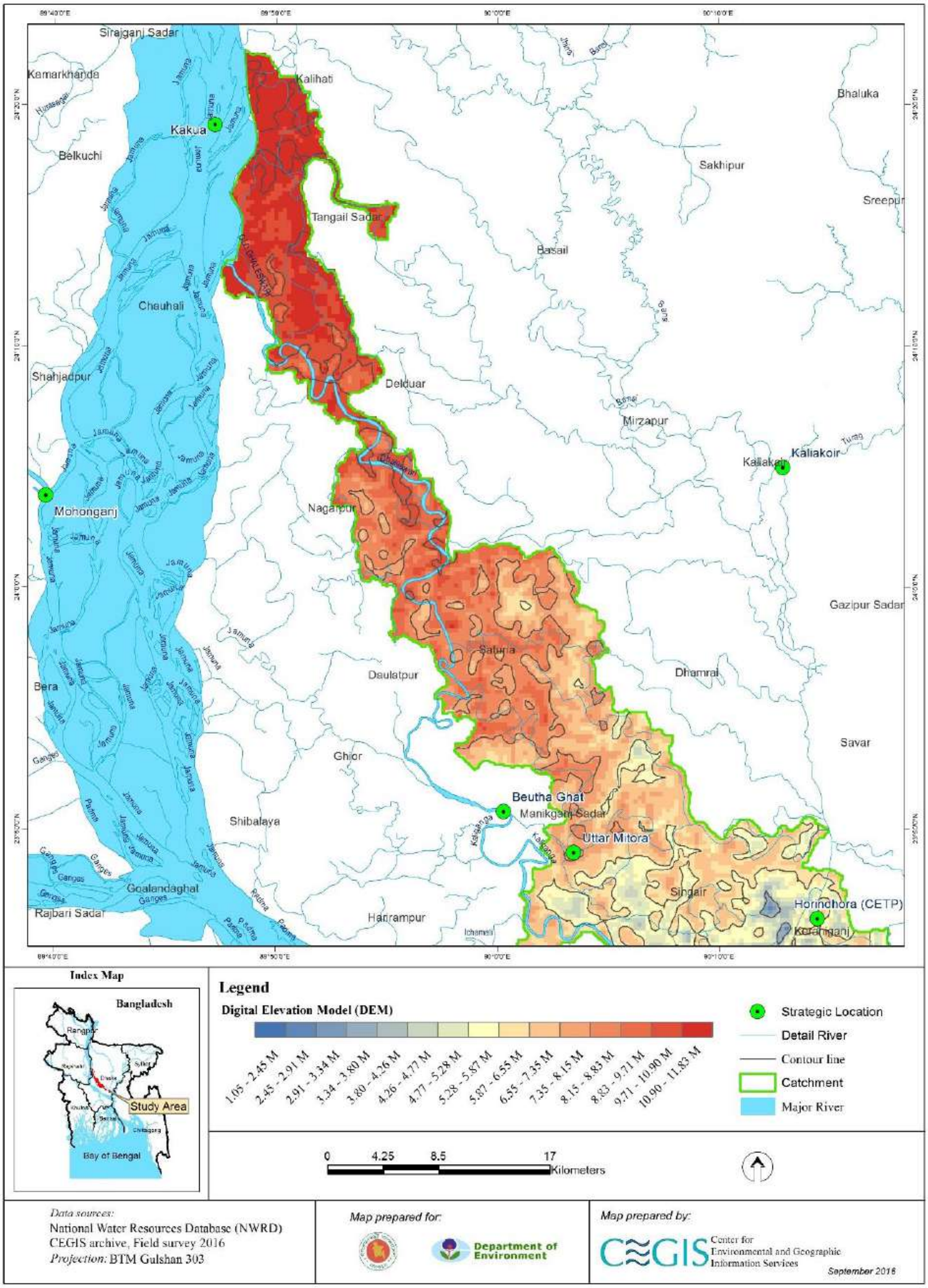


Figure 2.30 (b): Digital Elevation Model (DEM) Map of Dhaleshwari River Catchment (1)

2.8.10 Kaliganga

The Kaliganga River flows by Manikganj district. For monitoring of water quality, one location has been selected as strategic locations for Kaliganga River (**Table 2.11**). The map of non-point water pollution sources and strategic locations in the Kaliganga River is in **Figure 2.31** and Digital Elevation of Kaliganga River has also shown in **Figure 2.32**.

Table 2.11: Strategic Location for Kaliganga River

River Name: Kaliganga				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Beutha Ghat	41	23°50'46.29"N	90° 0'7.59"E	Beutha Ghat is located at Manikganj Paurashava in Manikganj Sadar Thana.

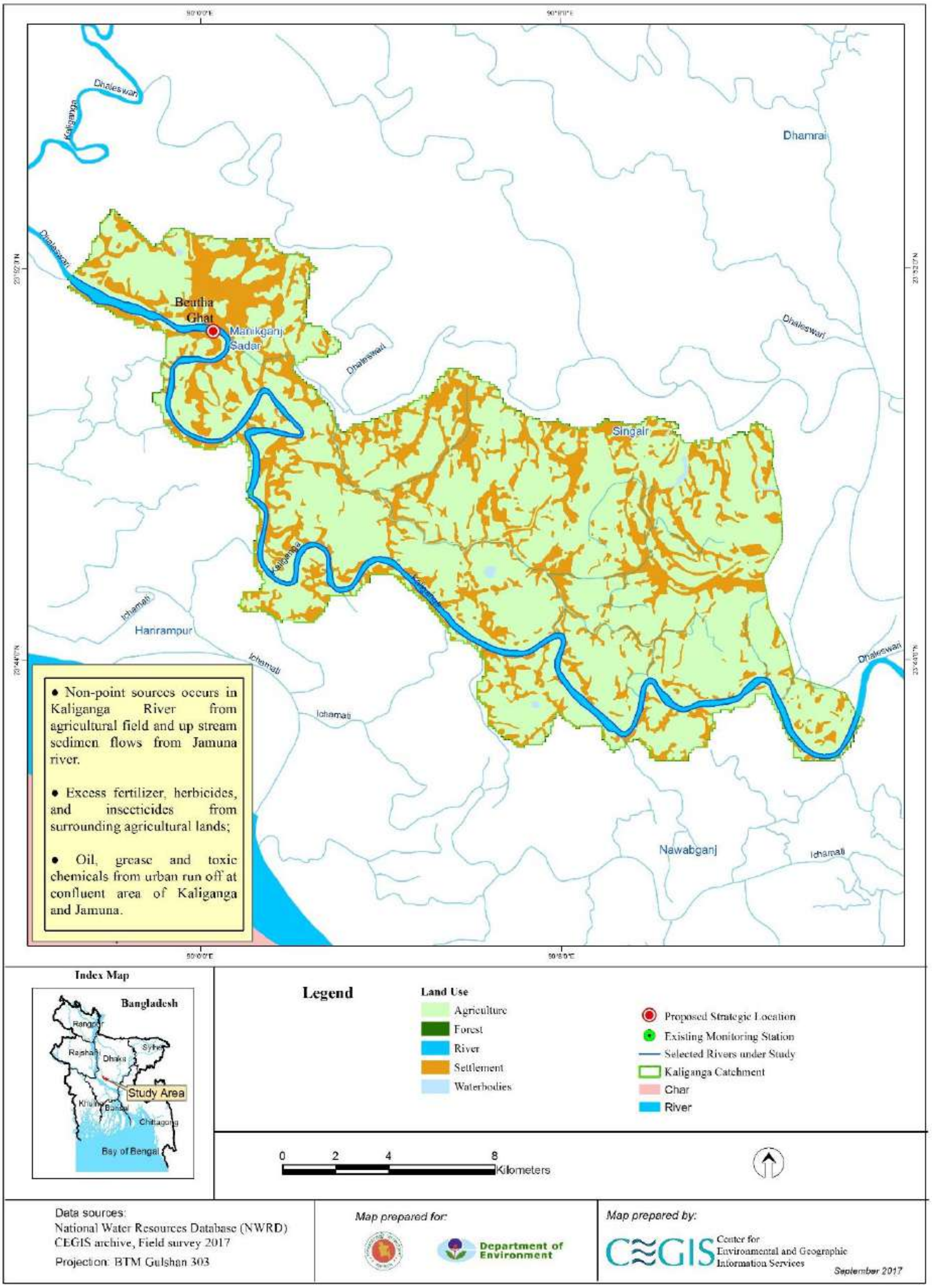


Figure 2.31: Non-Point Water Pollution Sources and Strategic Locations in the Kaliganga River

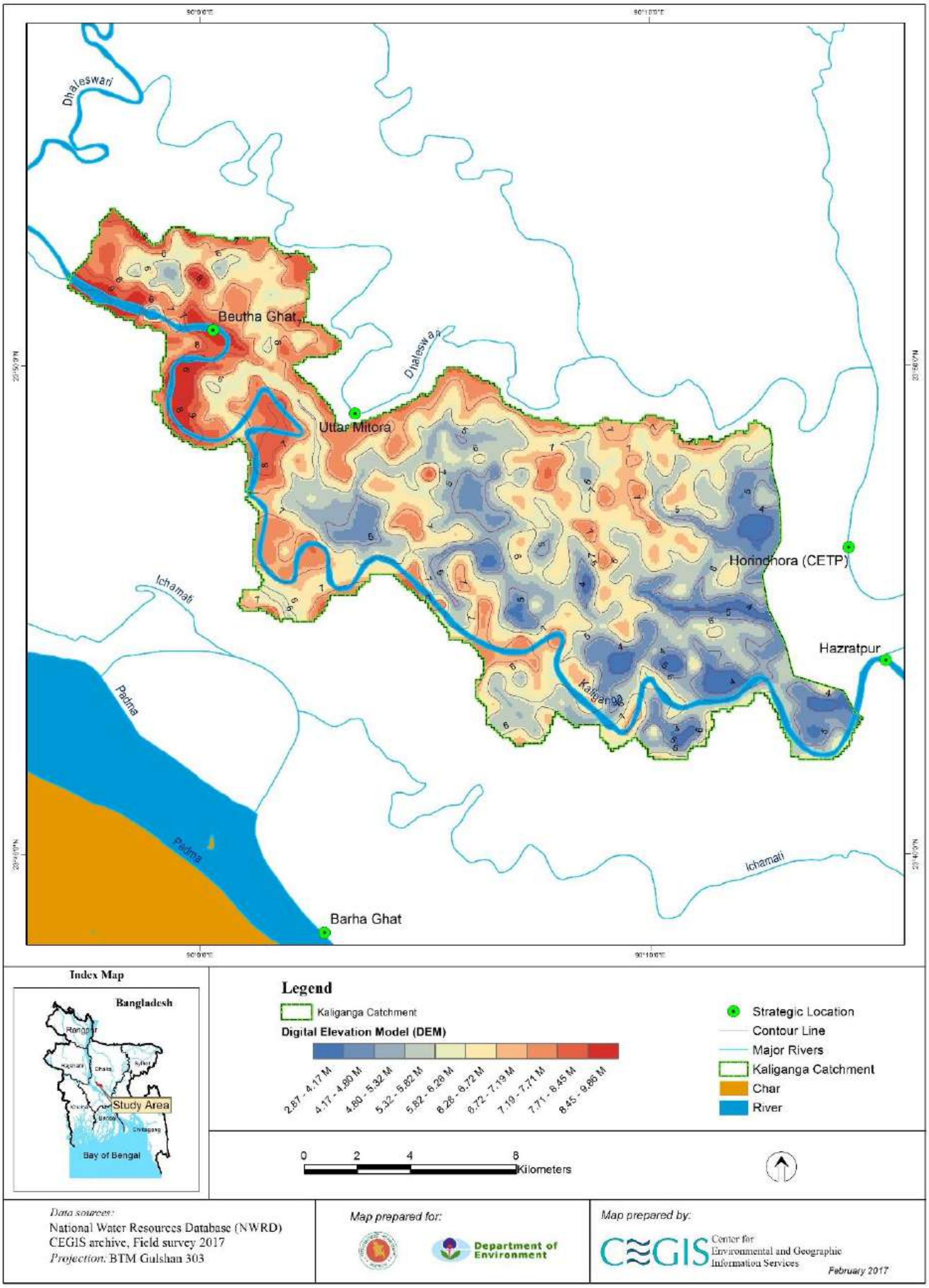


Figure 2.32: Digital Elevation Model (DEM) Map of Kaliganga River Catchment

2.8.11 Balu River

The Balu River runs mainly through the extensive swamps of Beel Belai and located east of Dhaka, joining the Shitalakhya near Demra. It has a narrow connection through the Suti Nadi near Kapasia with the Shitalakhya, and also by way of the Tongi Khal with the Turag; there is also a link with the Shitalakhya near Kaliganj. Although it carries floodwater from the Shitalakhya and the Turag during the flood season, the Balu is of importance mainly for local drainage and access by small boats. [Sifatul Quader Chowdhury]. A total of 2locations have been selected as strategic locations for the Dhaleshwari River (**Table 2.12**). The map of non-point water pollution sources and strategic locations in the Balu River is in **Figure 2.33** and Digital Elevation of Balu River has also shown in **Figure 2.34**.

Table 2.12: Strategic Location for Balu River

River Name: Balu				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Trimohini Bridge	42	23°45'36.57"N	90°27'46.05"E	Trimohini Bridge is located at Demra (part) in Sabujbagh Thana.
Jalshiri Abashon	43	23°48'46.02"N	90°29'4.33"E	Jalshiri Abashon is located at Kayet Para in Rupganj Thana.

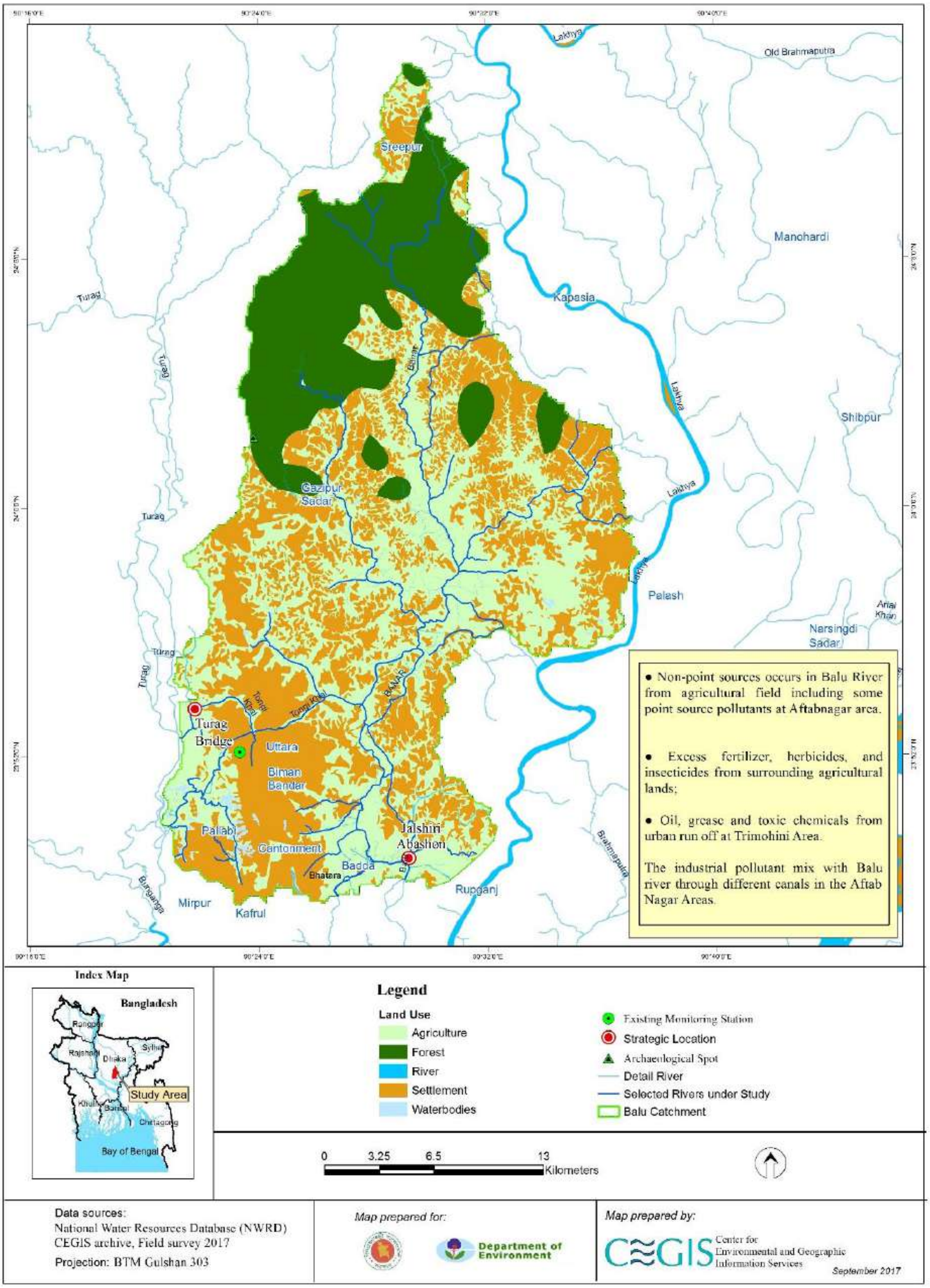


Figure 2.33: Non-Point Water Pollution Sources and Strategic Locationsin the Balu River

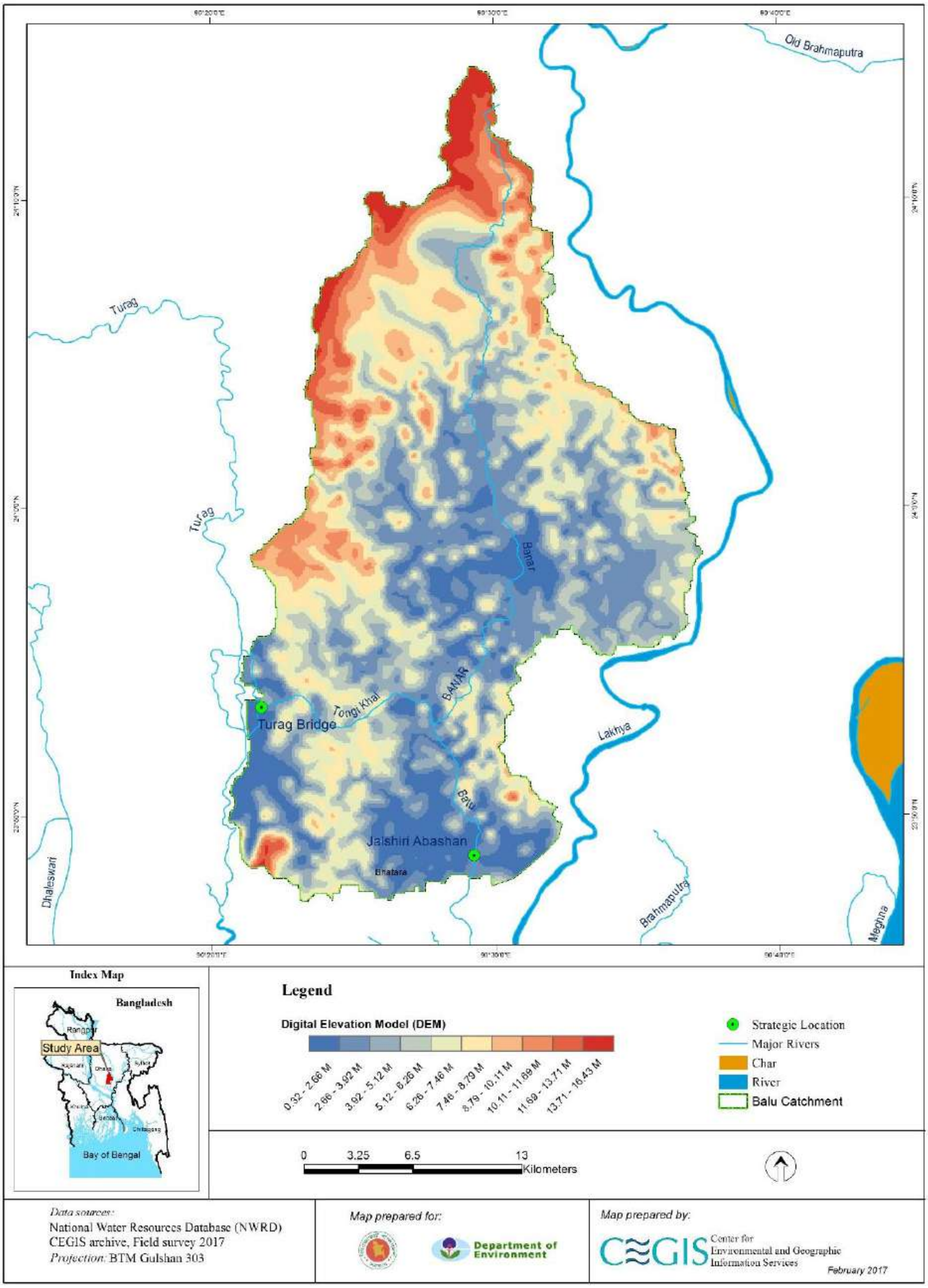


Figure 2.34: Digital Elevation Model (DEM) Map of Balu River Catchment

2.8.12 Padma River

Both industrial pollution and pollution from non-point sources occur in the Padma River. Many industries are located on the banks of Padma at Shilakotha area. The distributary Dakatia plays a key role carrying water to Chandpur area. Agricultural pollution occurs through a number of confluences as well as runoff water from agricultural land. A total of 4 locations have been selected as strategic locations for Padma River (**Table 2.13**). The map of non-point water pollution sources and strategic locations in the Padma River is in **Figure 2.35** and Digital Elevation of Padma River has also shown in **Figure 2.36**.

Table 2.13: Strategic Location for Padma River

River Name: Padma				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Barha Ghat	44	23°38'26.15"N	90° 2'35.86"E	Barha Ghat is located at Nayabari union of Dohar Thana.
Nort Beak Martin Island	45	23°28'38.35"N	90° 6'22.24"E	Nort Beak Martin Island is located near Chandrapara Trauler Ghat at Char Nasirpur Union of Sadarpur Thana.
Mawa Ghat	46	23°28'18.20"N	90°15'23.06"E	Mawa Ghat is located at Medini Mandal of Lohajang Thana.
Puran Bazar	47	23°13'47.78"N	90°38'27.47"E	Puran Bazar at Chandpur Pourashava in Chandpur Sadar Thana.

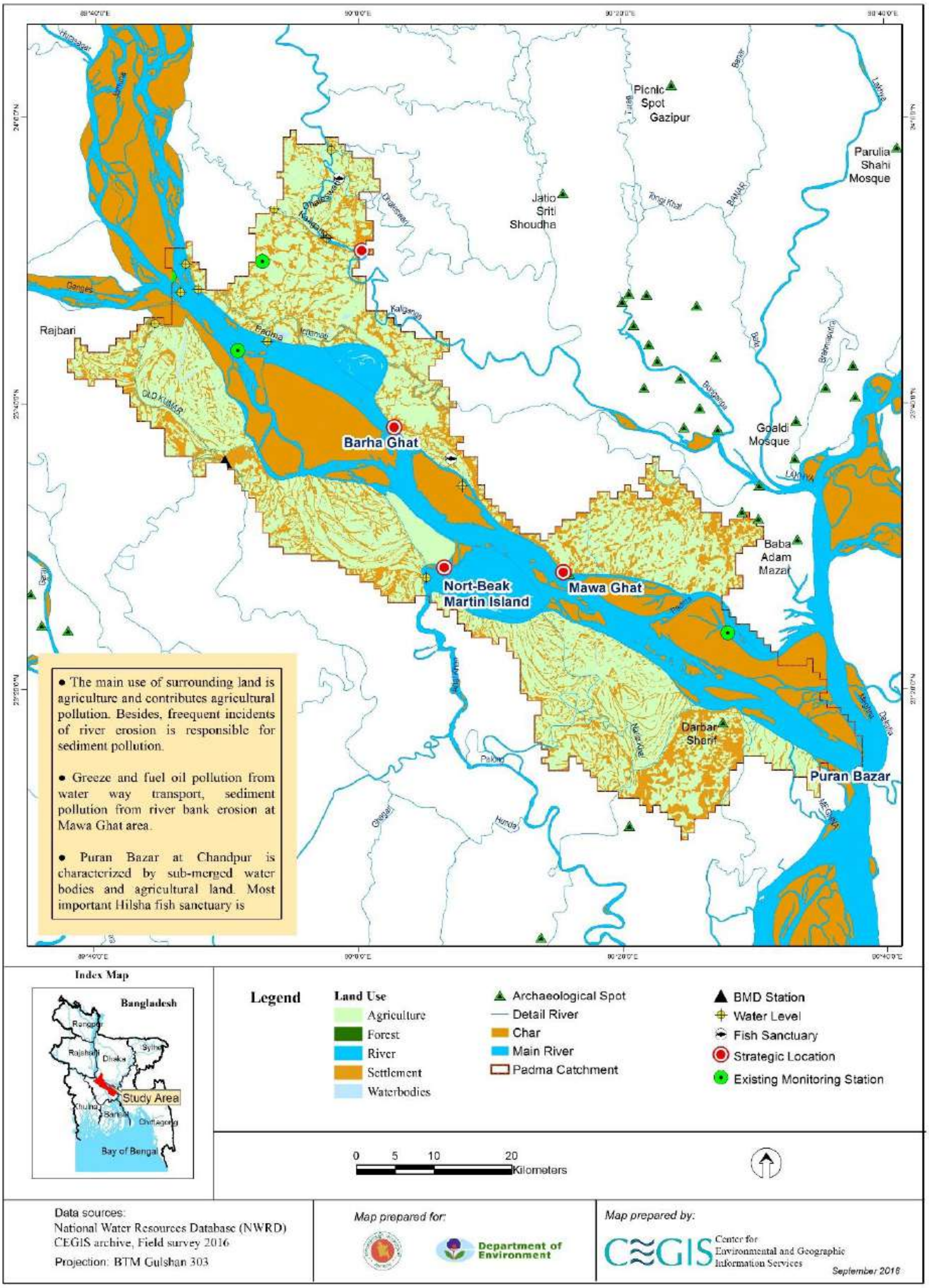


Figure 2.35: Non-Point Water Pollution Sources and Strategic Locations in the Padma River

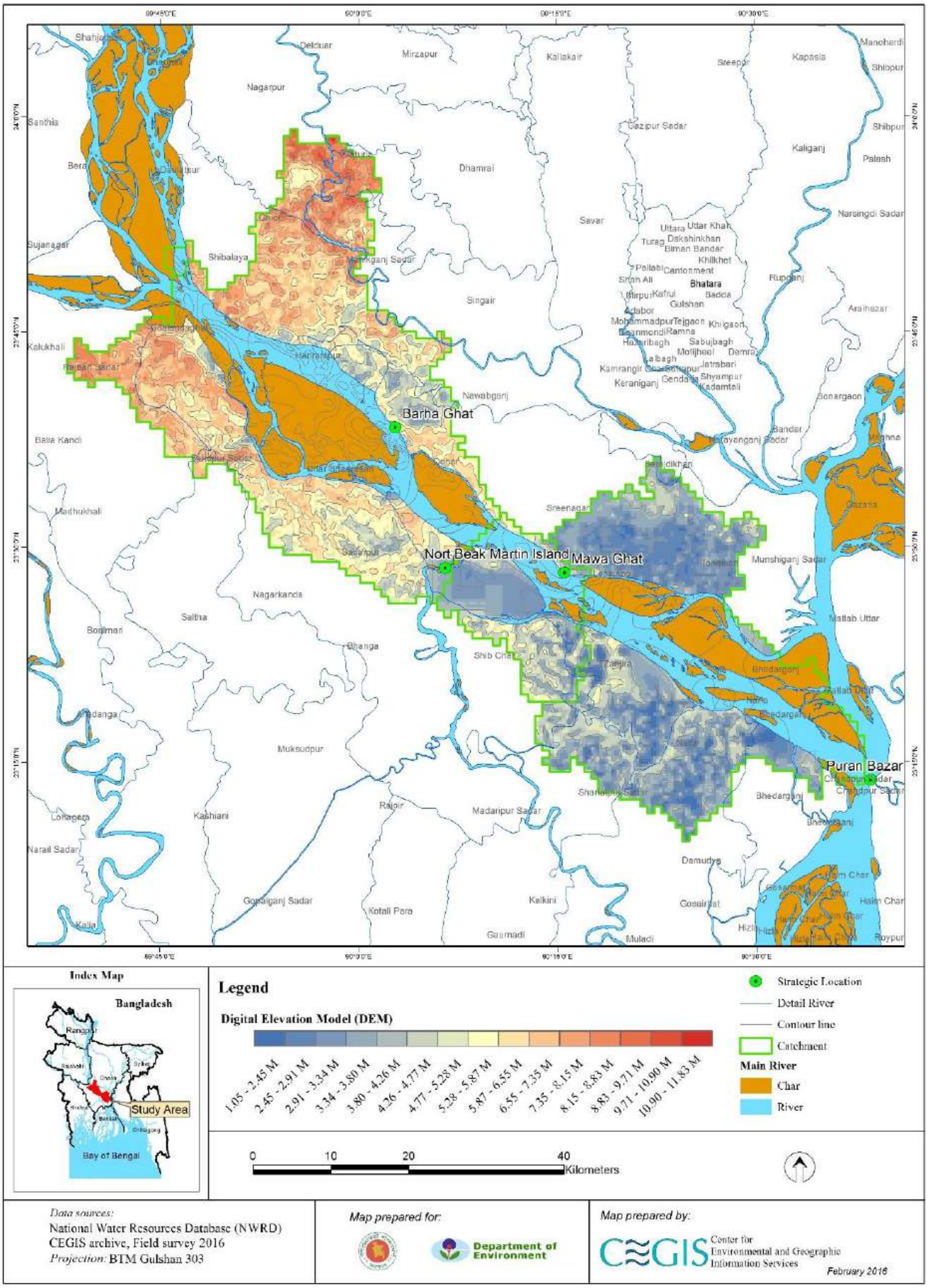


Figure 2.36: Digital Elevation Model (DEM) Map of Padma River Catchment Area

2.8.13 Dakatia River

The Dakatia River is one of the trans-boundary rivers of Bangladesh. It is a tributary of the Meghna. The main source of flow of this river was the Kakrai, but the Little Feni cuts back and captured its upper portion. The Dakatia now has its source in Chauddagram Khal, which connects it with the Little Feni. The Dakatia sends out a channel southward, which forms the Noakhali Khal. The main channel meanders westward to Shekherhat, from where the old course goes south to join the Meghna at Raipur, and the new and stronger channel passes through Chandpur Khal to join the Meghna west of Chandpur town. Total length of the Dakatia is about 207 km. Tidal currents feed the Dakatia through the Meghna for three-fourths of the year. [Masud Hasan Chowdhury]. A total of 4 locations have been selected as strategic locations for DakatiaRiver (**Table 2.14**). The map of non-point water pollution sources and strategic locations in the Dakatia River is in **Figure 2.37** and Digital Elevation of Dakatia River has also shown in **Figure 2.38**.

Table 2.14: Strategic Location for Dakatia River

River Name: Dakatia				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Pal Bazar Bridge	48	23°13'12.6"N	90°39'01.4"E	Pal Bazar Bridge is located at Chandpur Paurashava of Chandpur Sadar Thana.
Dhali Ghat, Dakatia	49	23°12'12.4"N	90°40'22.2"E	Dhali Ghat is located at Sakhua union of Chandpur Sadar Thana.
Gazibari Road	50	23°13'30.1"N	90°40'09.3"E	Gazibari Road is located at Tarpur Chandi union of Chandpur Sadar Thana.
Hajiganj Bazar Bridge	51	23° 14' 48.81"N	90° 51' 10.33"E	Hajiganj Bazar Bridge is located at Paschim Barkul union of Chandpur Sadar Thana.

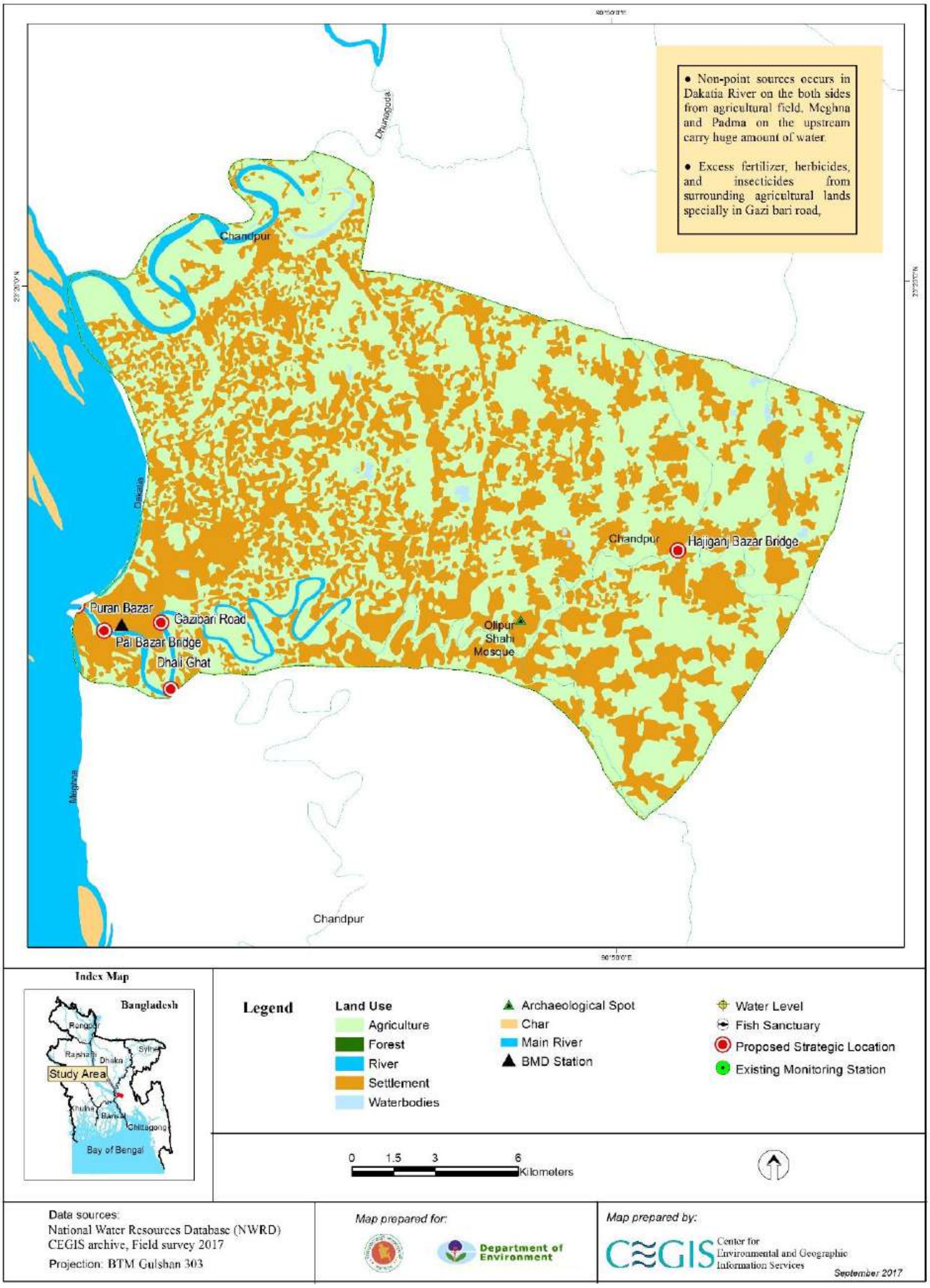


Figure 2.37: Non-Point Water Pollution Sources and Strategic Locations in the Dakatia River

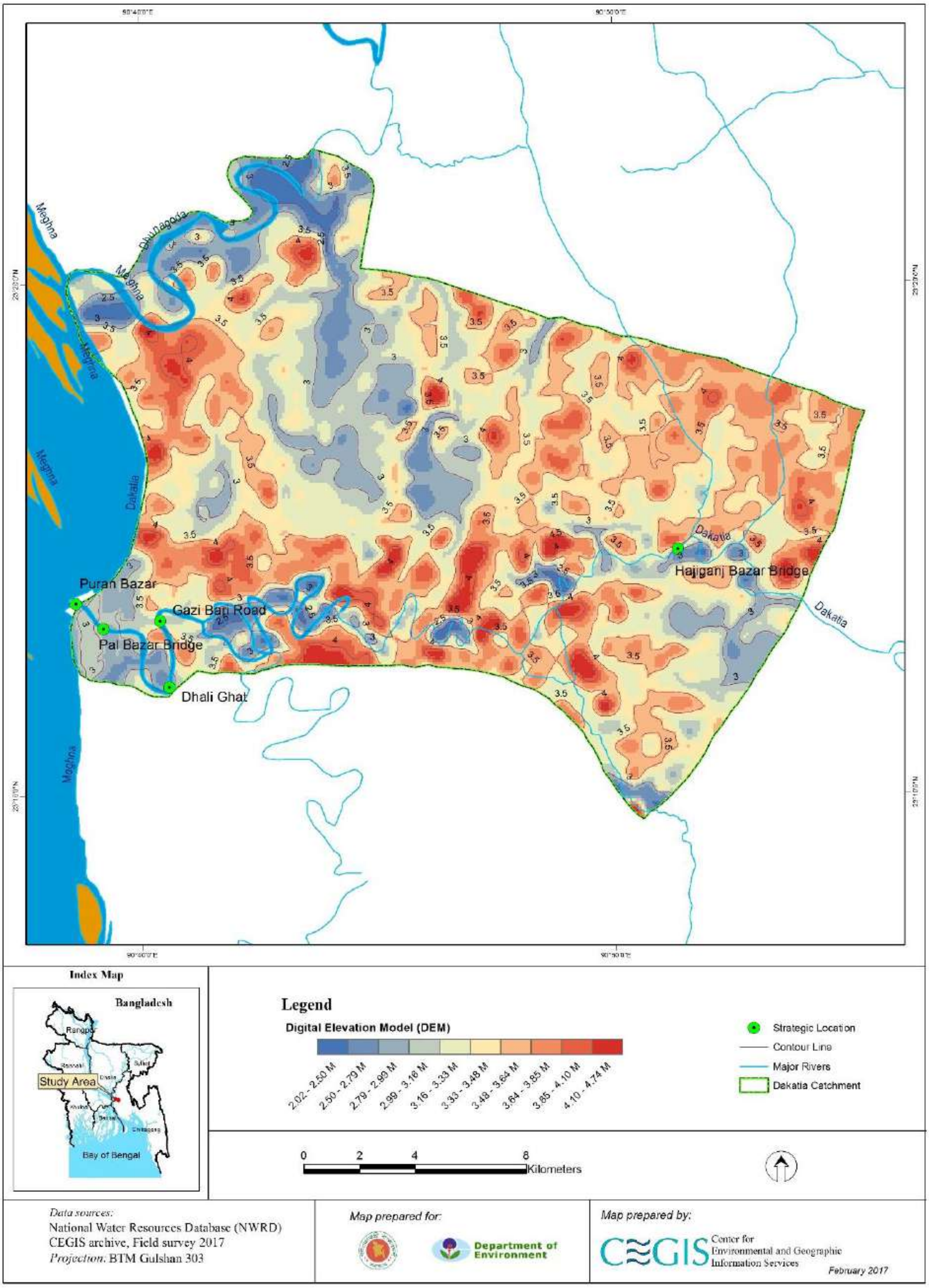


Figure 2.38: Digital Elevation Model (DEM) Map of Dakatia River Catchment Area

2.8.14 Meghna River

Both industrial pollution and pollution from non-point sources are found in the Meghna River. Many industries are located on the banks of Meghan like Meghna Ghat Power Plant, Summit Power Plant, salt industries, dyeing industries and other ones. Agricultural pollution occurs through a number of confluences as well as runoff water from agricultural land. A total of 5 locations have been selected as strategic locations for the MeghnaRiver (**Table 2.15**). The map of non-point water pollution sources and strategic locations in the Dakatia River is in **Figure 2.39** and Digital Elevation of Dakatia River has also shown in **Figure 2.40**.

Tabel 2.15: Strategic Location for Meghna River

River Name: Meghna				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Meghna Ghat Power Plant	52	23°36'29.70"N	90°36'49.30"E	Meghna Ghat power plant is located near Meghna Bridge at Pirijpur union of Sonargaon Thana.
Ananda Bazar	53	23°40'43.40"N	90°38'13.40"E	Ananda Bazar is located at Baradi Union in Sonargaon Thana.
Bishnandi	54	23°46'5.47"N	90°43'32.60"E	Bishnandi is located at Bishnandi Union of Araihazar Thana.
Narshingdi Launch Terminal	55	23°54'51.55"N	90°43'9.92"E	Narshingdi Launch Terminal is located in Narshingdi Pourashava in Narshingdi Sadar Thana.
Bhairab bazar	56	24° 2'36.15"N	90°59'23.14"E	Bhairabbazar is located at Bhairab bazar Pourashava in Bhairab Thana.

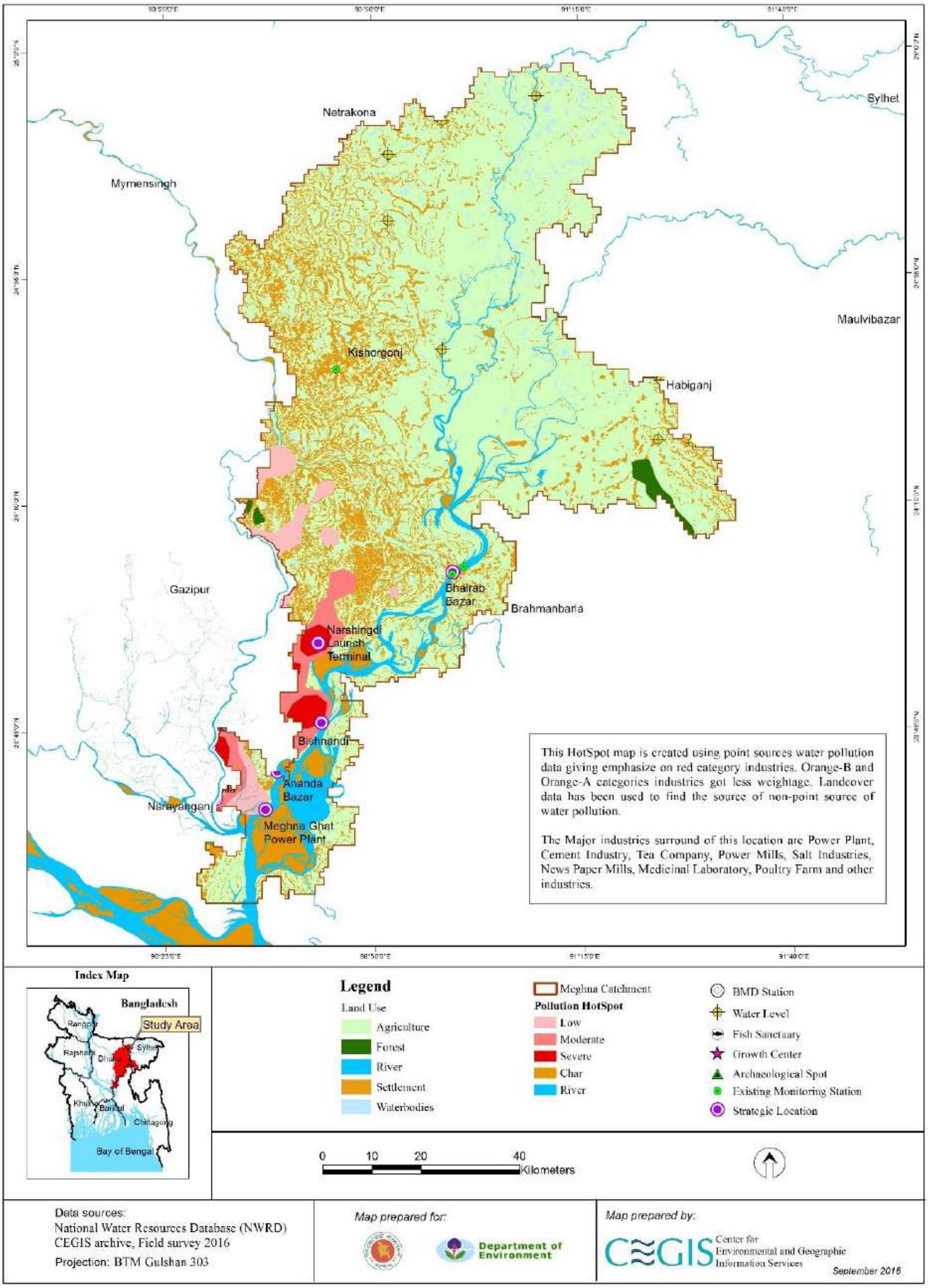


Figure 2.39: Water Pollution Hotspot and Strategic Locations in the Meghna River

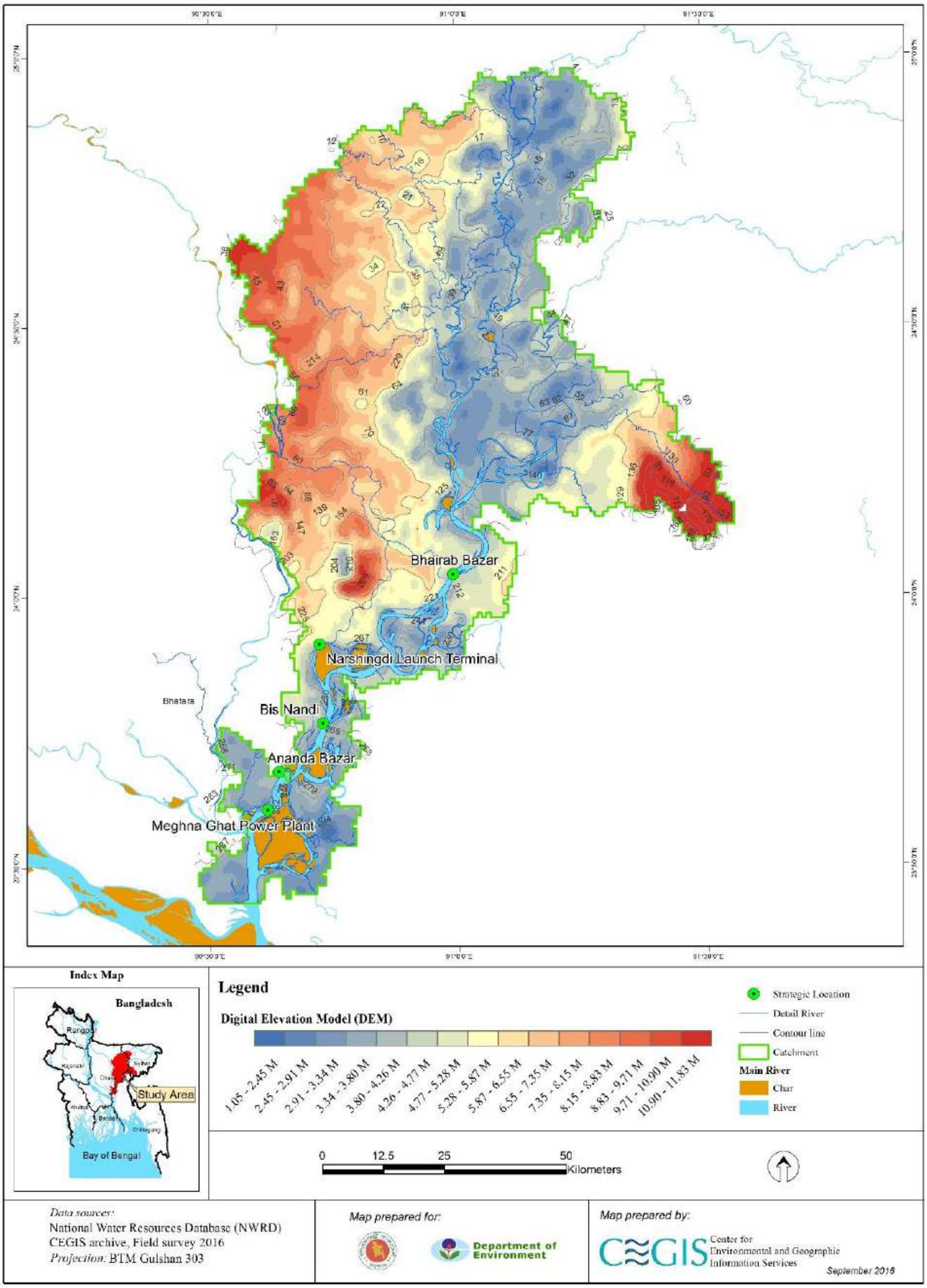


Figure 2.40: Digital Elevation Model (DEM) Map of Meghna River Catchment

2.8.15 Titas River

The Titas River is the main branch of the Meghna River. Titas started its journey from the Meghna River from the chatalpar area of Brahmanbaria district and at the Lalpur of Nabinagar upazila it fell again in the Meghna River. The distance from Lalpur to Chatalpal is only 16 miles, but the length of the Titas River is 150 miles. A total of 2 locations have been selected as strategic locations for the Titas River (**Table 2.16**). The map of non-point water pollution sources and strategic locations in the Titas River is in **Figure 2.41** and Digital Elevation of Titas River has also shown in **Figure 2.42**.

Table 2.16: Strategic Location for Titas River

River Name: Titas				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Bakail Bridge (Titas)	57	24° 2'42.61"N	91°10'39.21"E	Bakail Bridge is located at Shahbazpur union of Sarail Thana in Brahmanbaria district.
Titas Rail Bridge	58	23°52'43.49"N	91°12'0.03"E	Titas Rail Bridge is located at Akhaura Paurashava of Akhaura Thana in Brahmanbaria district.

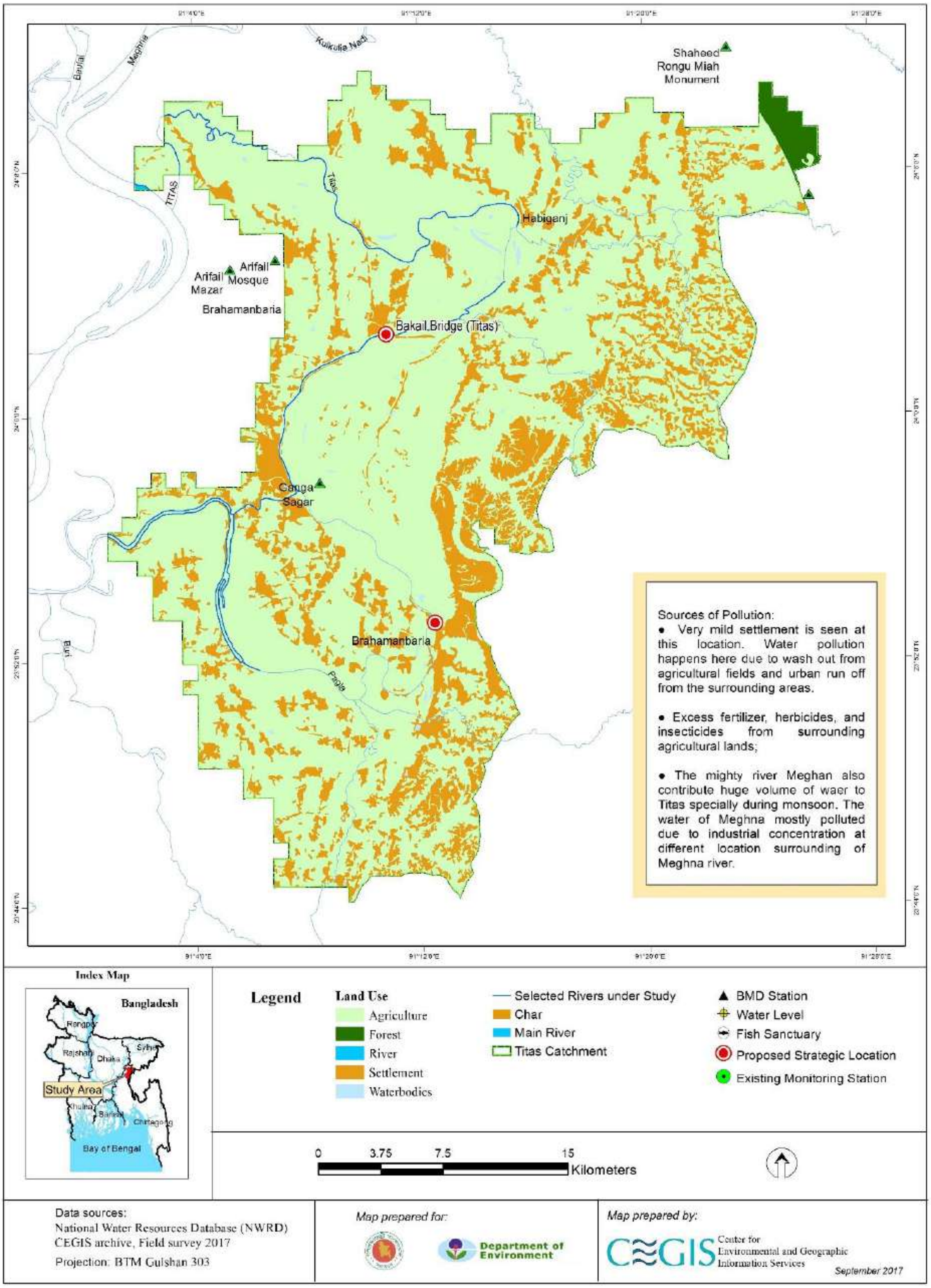


Figure 2.41: Non-Point Water Pollution Sources and Strategic Locations in the Titas River

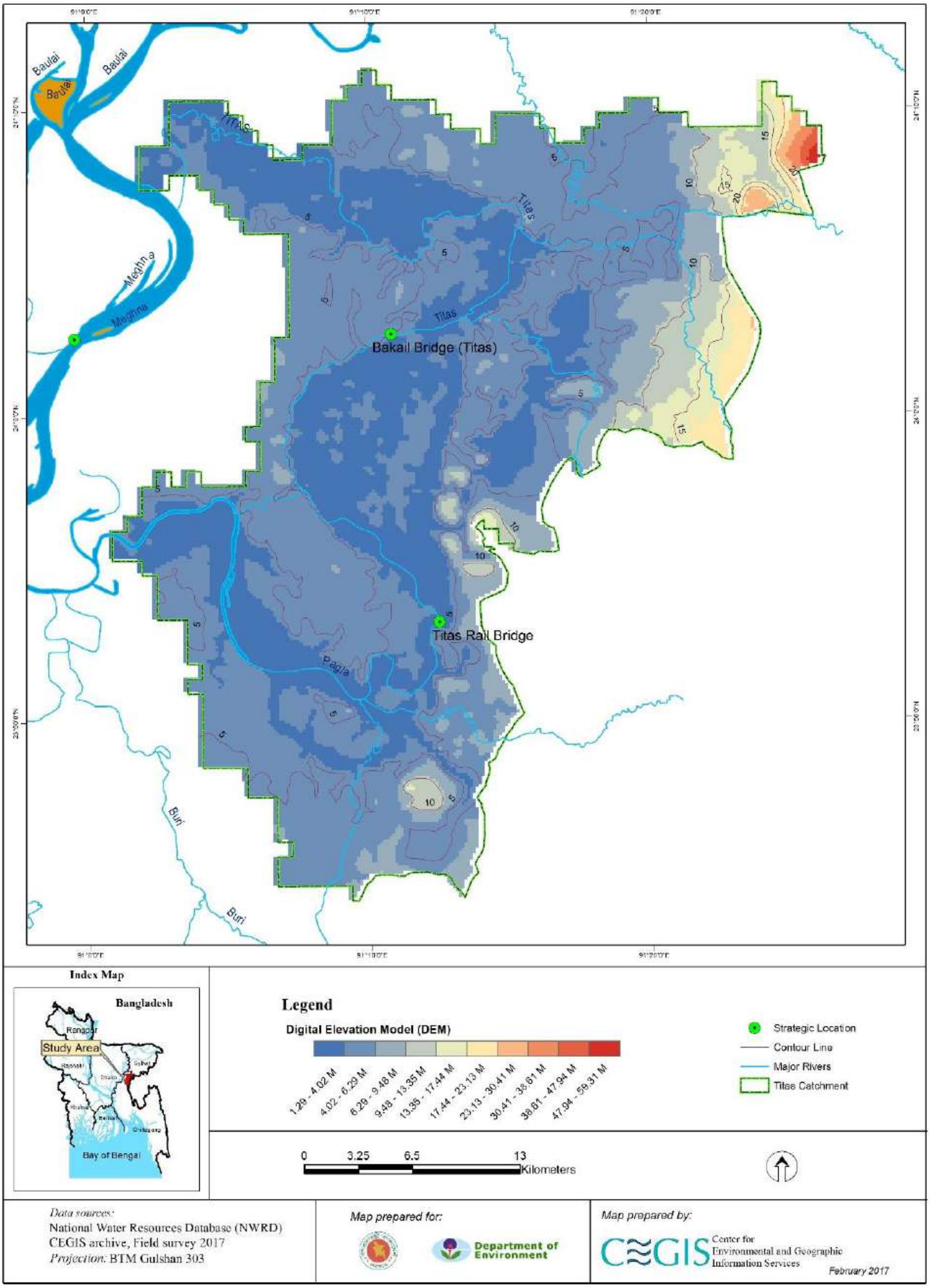


Figure 2.42: Digital Elevation Model (DEM) Map of Titas River Catchment

2.8.16 Karatoya River

The Karatoya River, a small stream in Rajshahi Division of Bangladesh, was once a large and sacred river. A channel of it currently flows by the ancient ruins of Mahasthangarh (or Pundranagara, ancient capital of Pundravardhana) in Bogra District. . A total of 3 locations have been selected as strategic locations for Karatoya River (**Table 2.17**). The map of non-point water pollution sources and strategic locations in the Karatoya River is in **Figure 2.43** and Digital Elevation of Karatoya River has also shown in **Figure 2.44**.

Table 2.17: Strategic Location for Karatoya River

River Name: Karatoya				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Dottobari Bridge	59	24°51'17.58"N	89°22'26.19"E	Dottobari Bridge is located at Shabgram union of Bogra Sadar Thana.
Aziz Ahmed Taki Road	60	24°50'37.02"N	89°22'54.36"E	Aziz Ahmed Taki Road is located at Shabgram union of Bogra Sadar Thana.
Sultanganj-Gabtoli Road	61	24°48'4.94"N	89°24'24.92"E	Sultanaganj Gabtoli Road is located at Madla union of Bogra Sadar Thana.

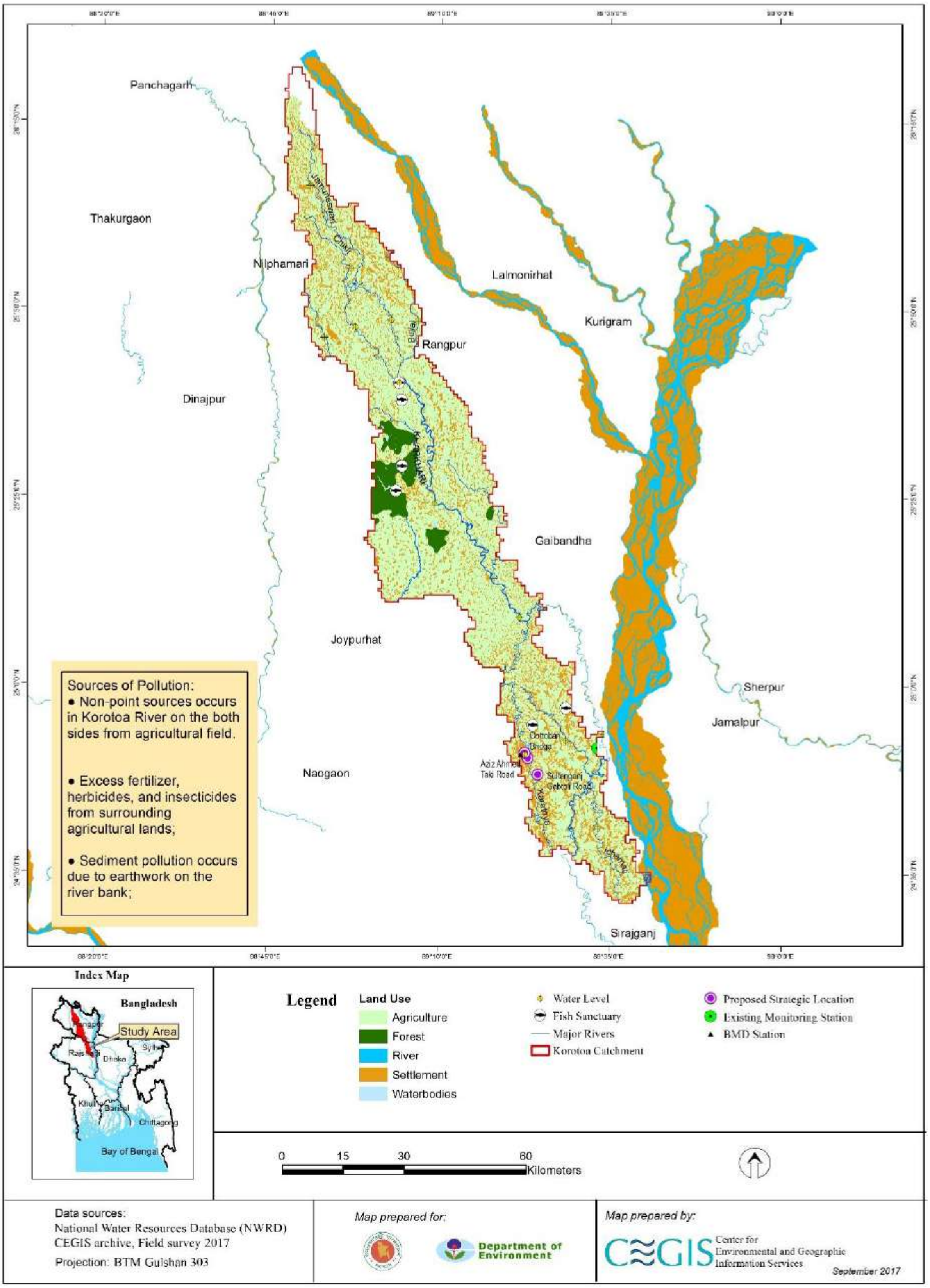


Figure 2.43: Non-Point Water Pollution Sources and Strategic Locations in the Karatoya River

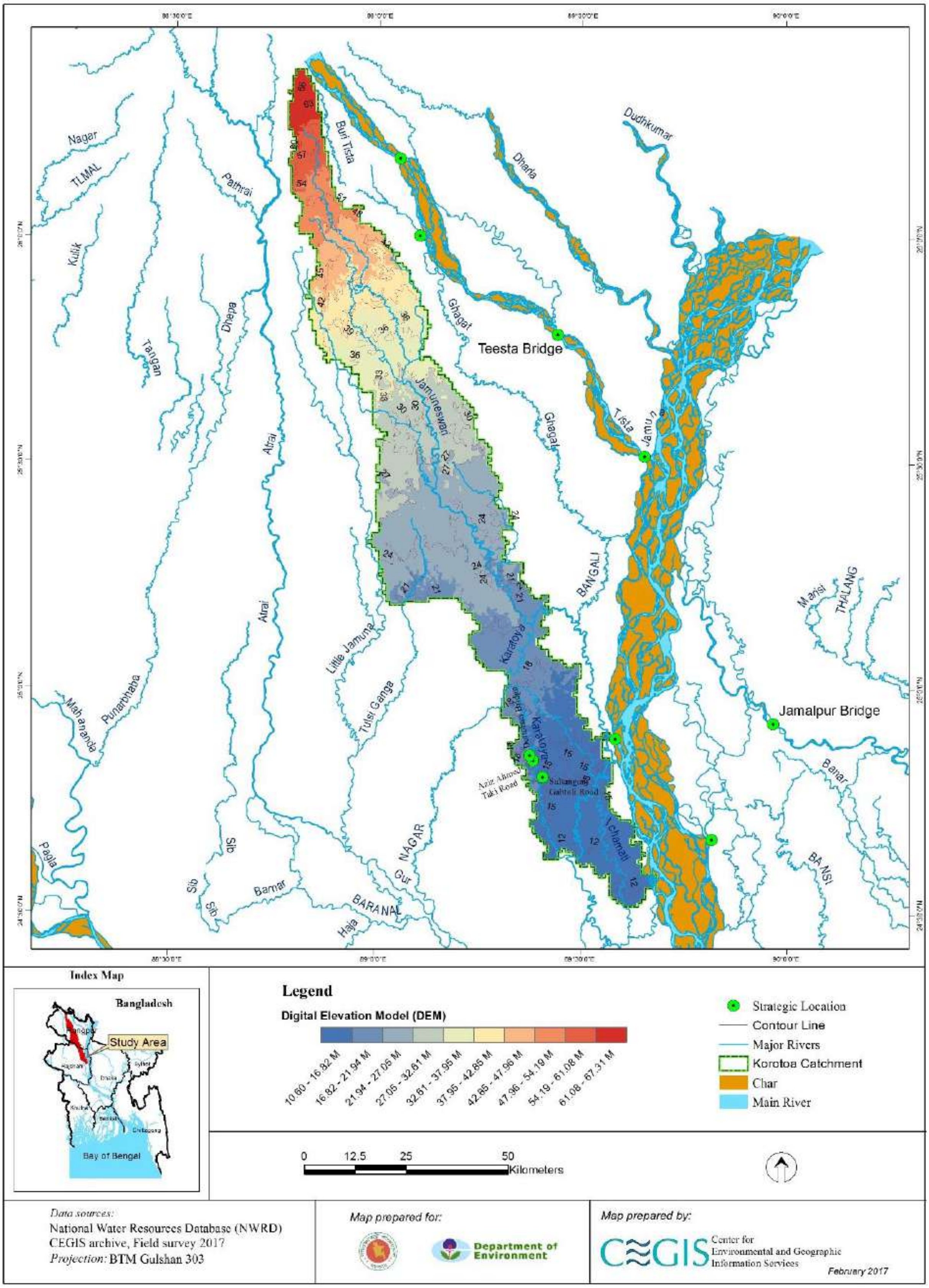


Figure 2.44: Digital Elevation Model (DEM) Map of Karatoya River Catchment

2.8.17 Ganges River

No major industrial pollution was seen in the Ganges River. It is a trans-boundary river. During the rainy season huge amounts of water flows down from India. The stations proposed at Sardah Rajshahi will help monitoring the water quality coming from India. Non-point sources of pollution occur in the Ganges River on both sides from agricultural field. Gorai offtake carries huge amount of water and spread out over the large areas in Kushtia area. A total of 4 locations have been selected as strategic locations for the Ganges River (**Table 2.18**). The map of non-point water pollution sources and strategic locations in the Ganges River is in **Figure 2.45** and Digital Elevation of Ganges River has also shown in **Figure 2.46**.

Table 2.18: Strategic Location for Ganges River

River Name: Ganges				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Sardah	62	24° 21' 41.16"	88° 35' 52.95"	Sardah point is located at Harian union of Paba Thana.
Nurullapur	63	24˚10'5.7"N	88˚59'34.1"E	Nurullapur is located at Ishwardi union of Lalpur Thana.
Gorai Off Take	64	23˚57'2.4" N	89˚06'39.1"E	Gorai Off Take is located at Hatash Haripur union of Kushtia Sadar Thana.
Kanchan Park	65	23° 52' 11.12"N	89° 27' 6.16"E	Kanchan park is located at Ishwardi union of Lalpur Thana.

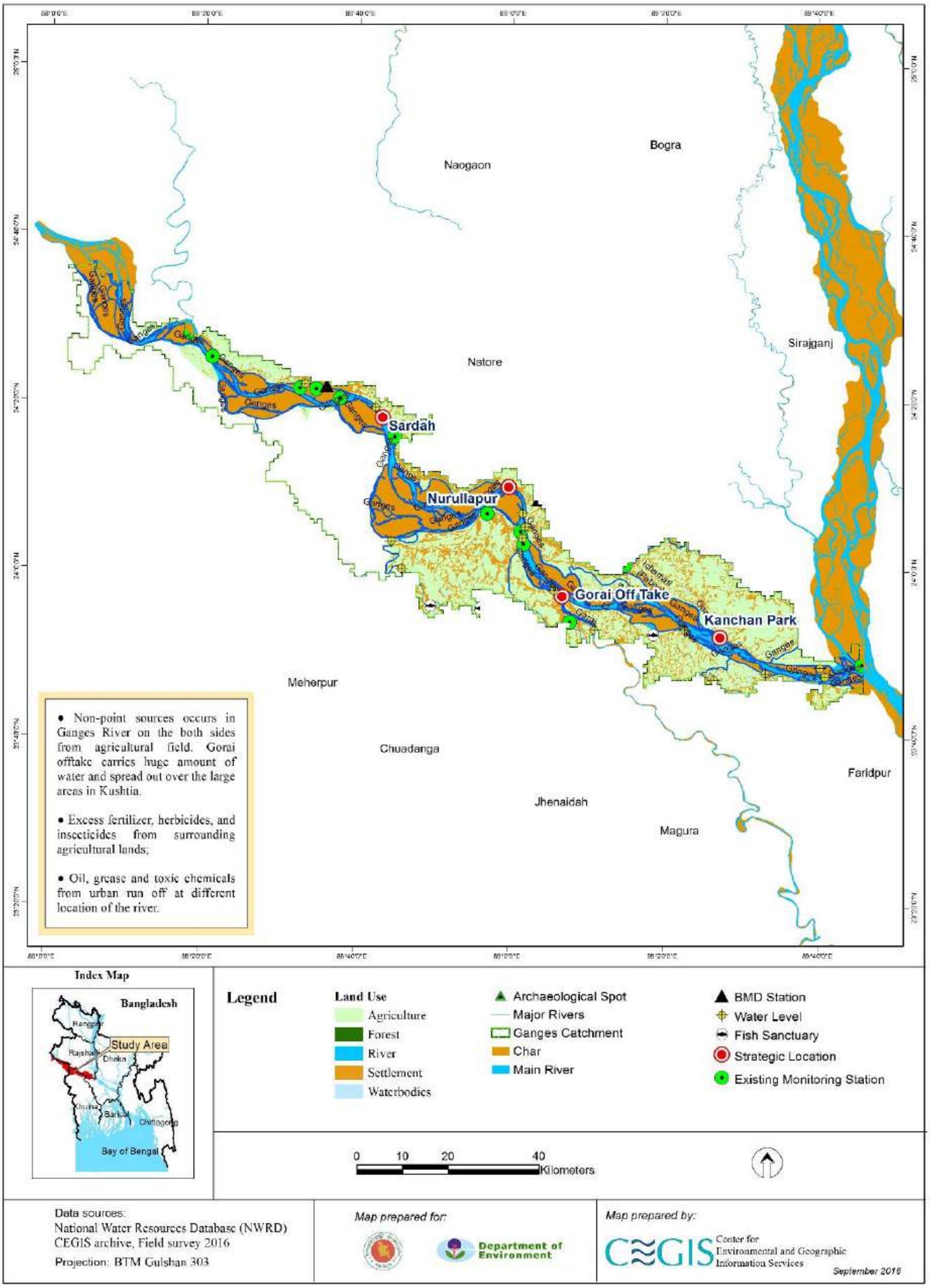


Figure 2.45: Non-Point Water Pollution Sources and Strategic Locations in the Ganges River

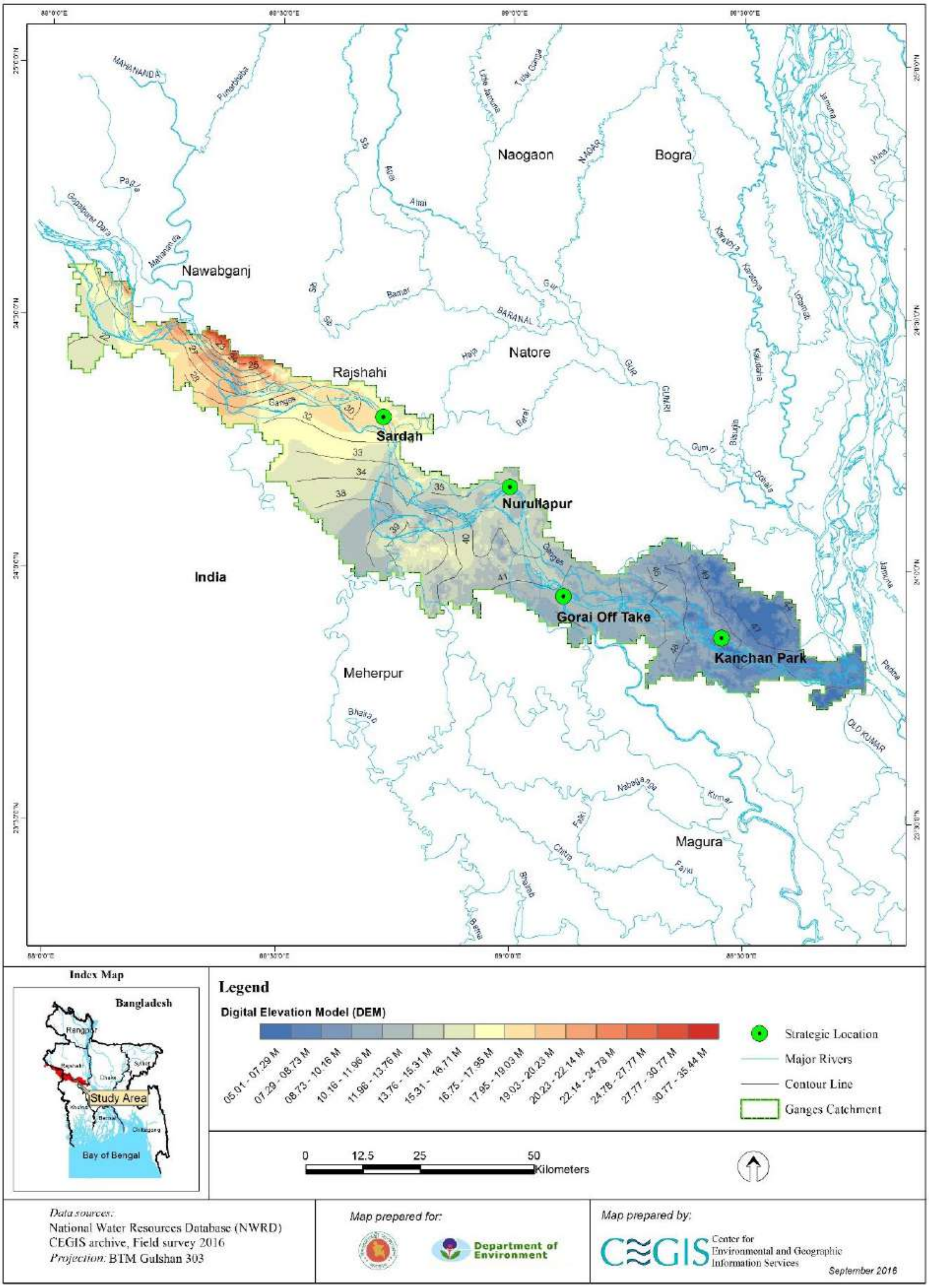


Figure 2.46: Digital Elevation Model (DEM) Map of Ganges River Catchment Area

2.8.18 Gorai River

The **Gorai River**, a distributary of the Ganges, is an important artery for Bangladesh, used for navigation, fisheries, agriculture and domestic purposes. The fresh water flow of the river is also important for the ecology. Total 1 (one) location for the Gorai has been selected as strategic locations. (**Table 2.19**). The map of non-point water pollution sources and strategic locations in the Gorai River is in **Figure 2.47** and Digital Elevation of Gorai River has also shown in **Figure 2.48**.

Tabel 2.19: Strategic Location for Gorai River

River Name: Gorai River				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Kamarkhali Bridge	66	23° 32' 9.77"N	89° 31' 47.69"E	Kamarkhali Bridge is located at Nakol union of Sreepur thana in Magura.

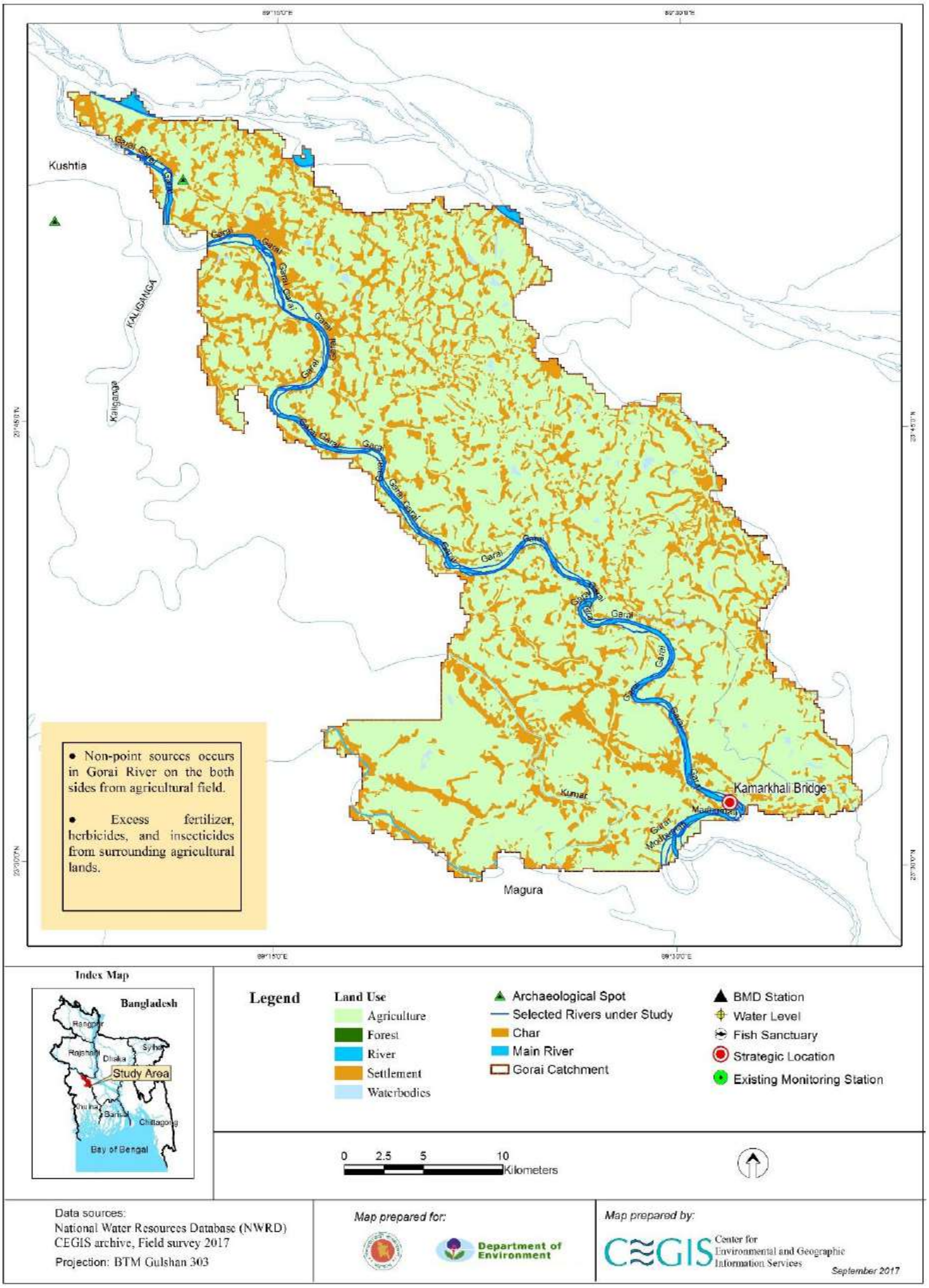


Figure 2.47: Non-Point Water Pollution Sources and Strategic Locations in the Gorai River

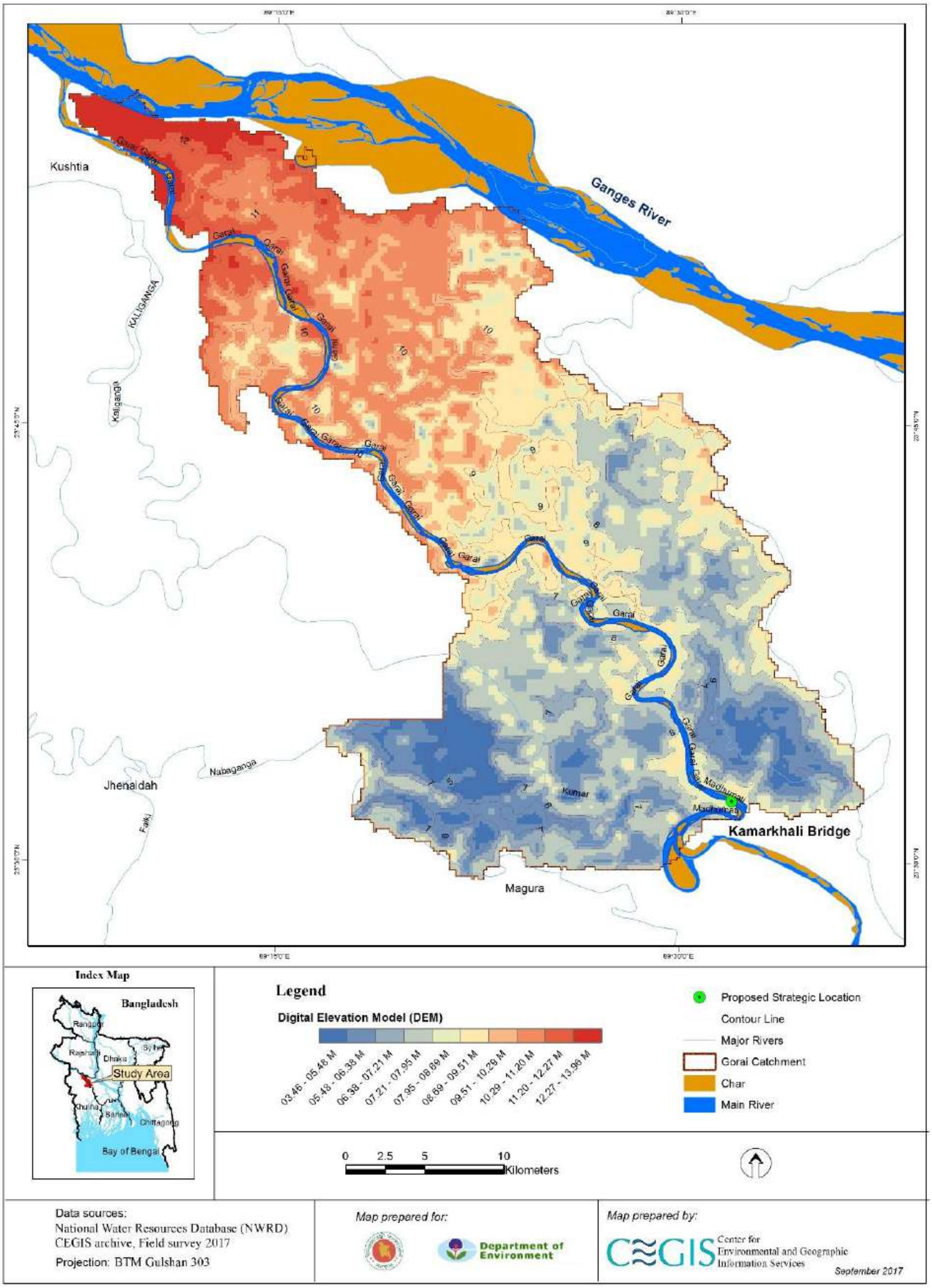


Figure 2.48: Digital Elevation Model (DEM) Map of Gorai River Catchment

2.8.19 Modhumoti River

The **Modhumati River**, distributary of the upper Padma River (Ganges River), flowing through southwestern Bangladesh. It leaves the Padma just north of Kushtia and flows 190 miles (306 km) southeast before turning south across the swampy Sundarbans region to empty into the Bay of Bengal. In its upper course it is called the Gorai; in its lower course it is known as the Baleswar; and its estuary mouth, which is some 9 miles (14 km) wide, is called the Haringhata. Total 2 (two) locations for the Modhumoti have been selected as strategic locations. (**Table 2.20**). The map of non-point water pollution sources and strategic locations in the Modhumoti River is in **Figure 2.49** and Digital Elevation of Modhumoti River has also shown in **Figure 2.50**.

Tabel 2.20: Strategic Location for Modhumoti River

River Name: Modhumoti River				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Dhalaitala	67	23° 8'19.78"N	89°40'40.66"E	Dhalaitala point is located at Kotakul union of lohagara thana in Narail.
Patgati-Nazimpur	68	22° 52' 52.2" N	89° 53' 44.08" E	Patgati - Nazimpur point is located at Ptagati Union of Tungipara Thana.

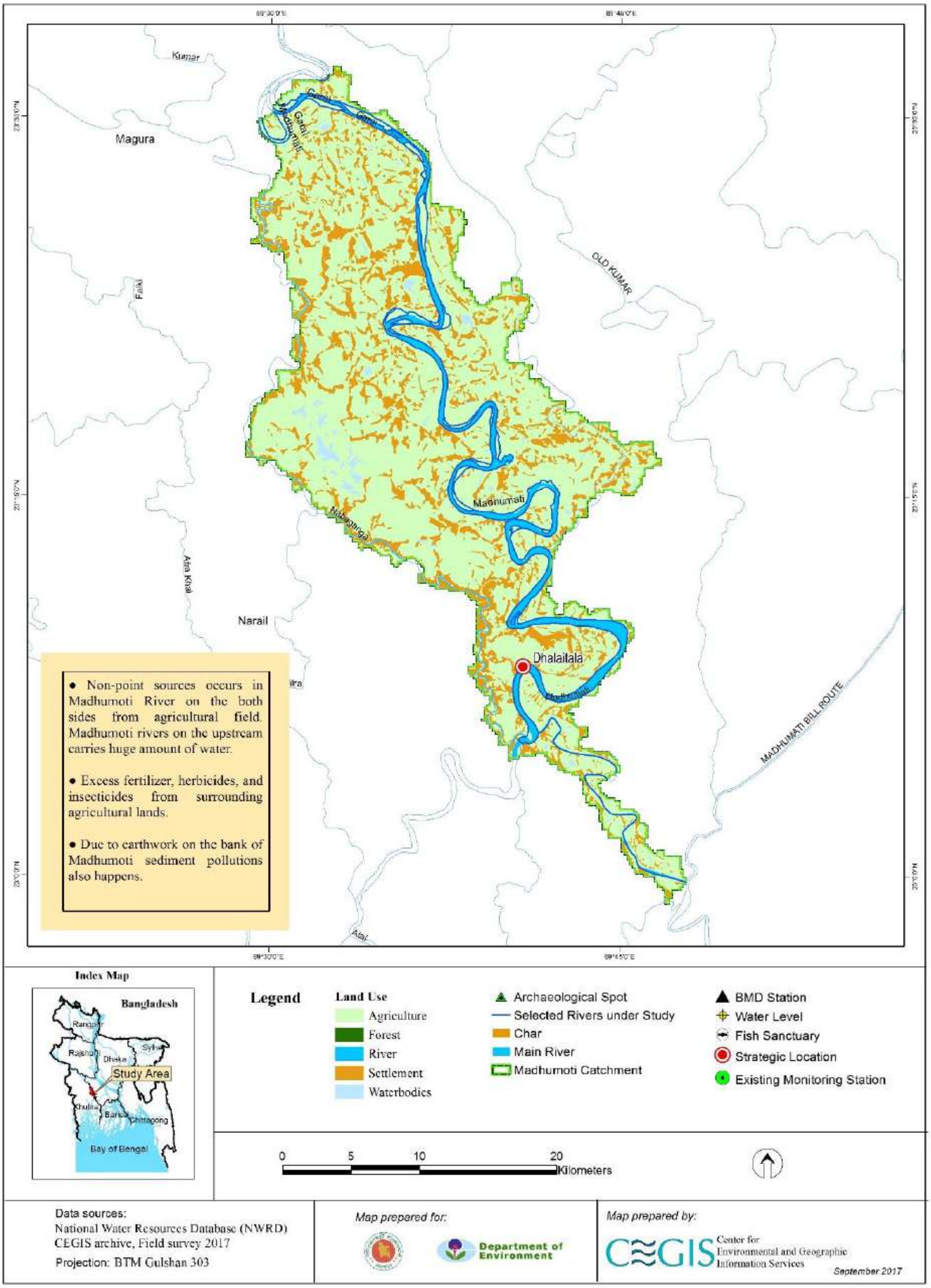


Figure 2.49: Non-point water pollution sources and Strategic Locations in Modhumoti River

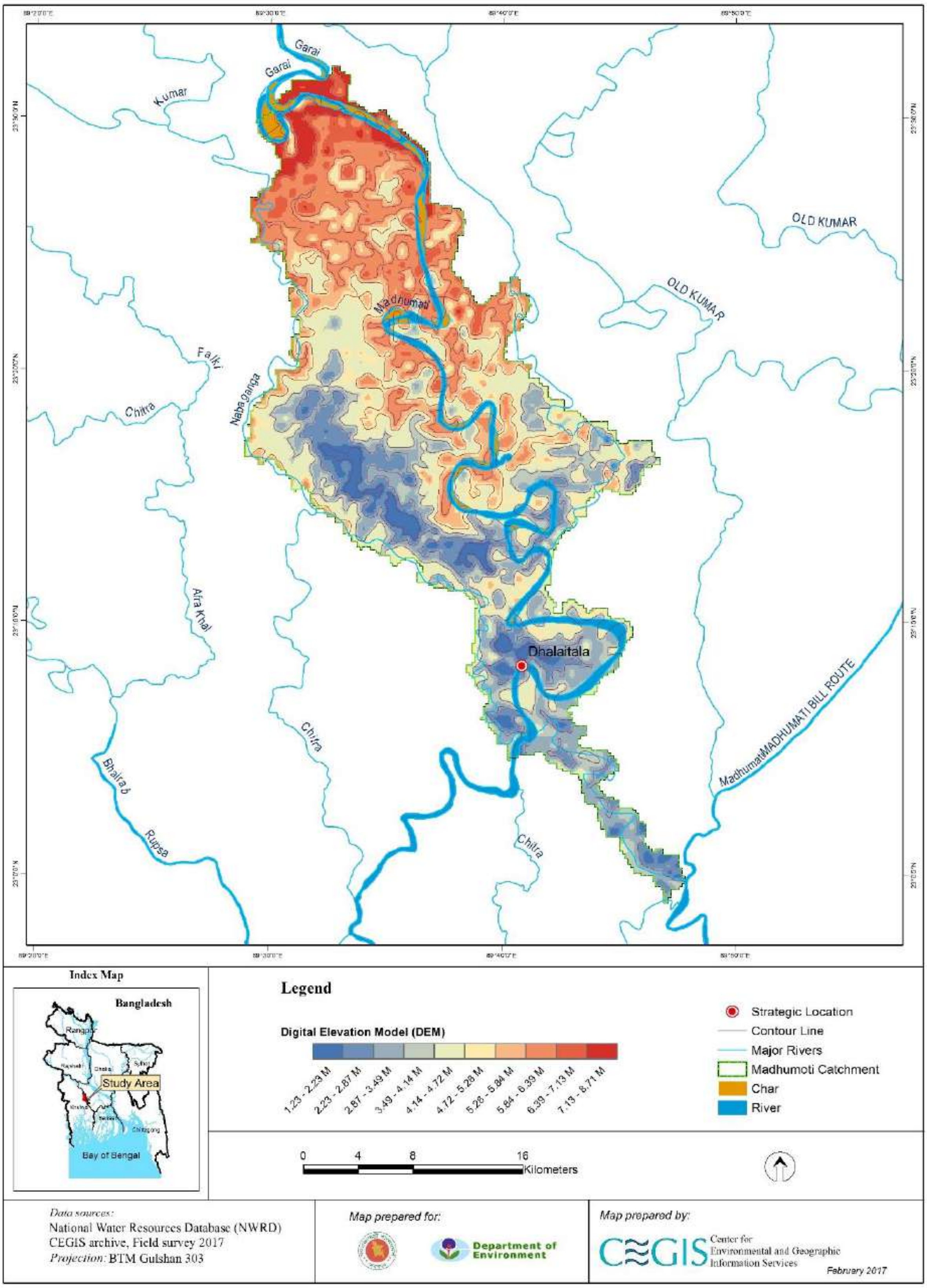


Figure 2.50: Digital Elevation Model (DEM) Map of Modhumoti River Catchment

2.8.20 Mathavanga River

The Mathavanga river, flows first in a south-east direction as far as Hatboalia, where it divides and one branch, which is subsequently known as the Kumar or Pangasi, proceeds in the same direction. One location for Mathavanga has been selected as strategic locations (**Table 2.21**). The map of non-point water pollution sources and strategic locations in the Mathavanga River is in **Figure 2.51** and Digital Elevation of Mathavanga River has also shown in **Figure 2.52**.

Tabel 2.21: Strategic Location for Mathavanga River

River Name: Mathavanga River				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Dorshona Railway Junction	69	23°31'25.28"N	88°47'20.30"E	Kamarkhali Bridge is located at Darshana Paurashava of Damurhuda thana in Chuadanga.

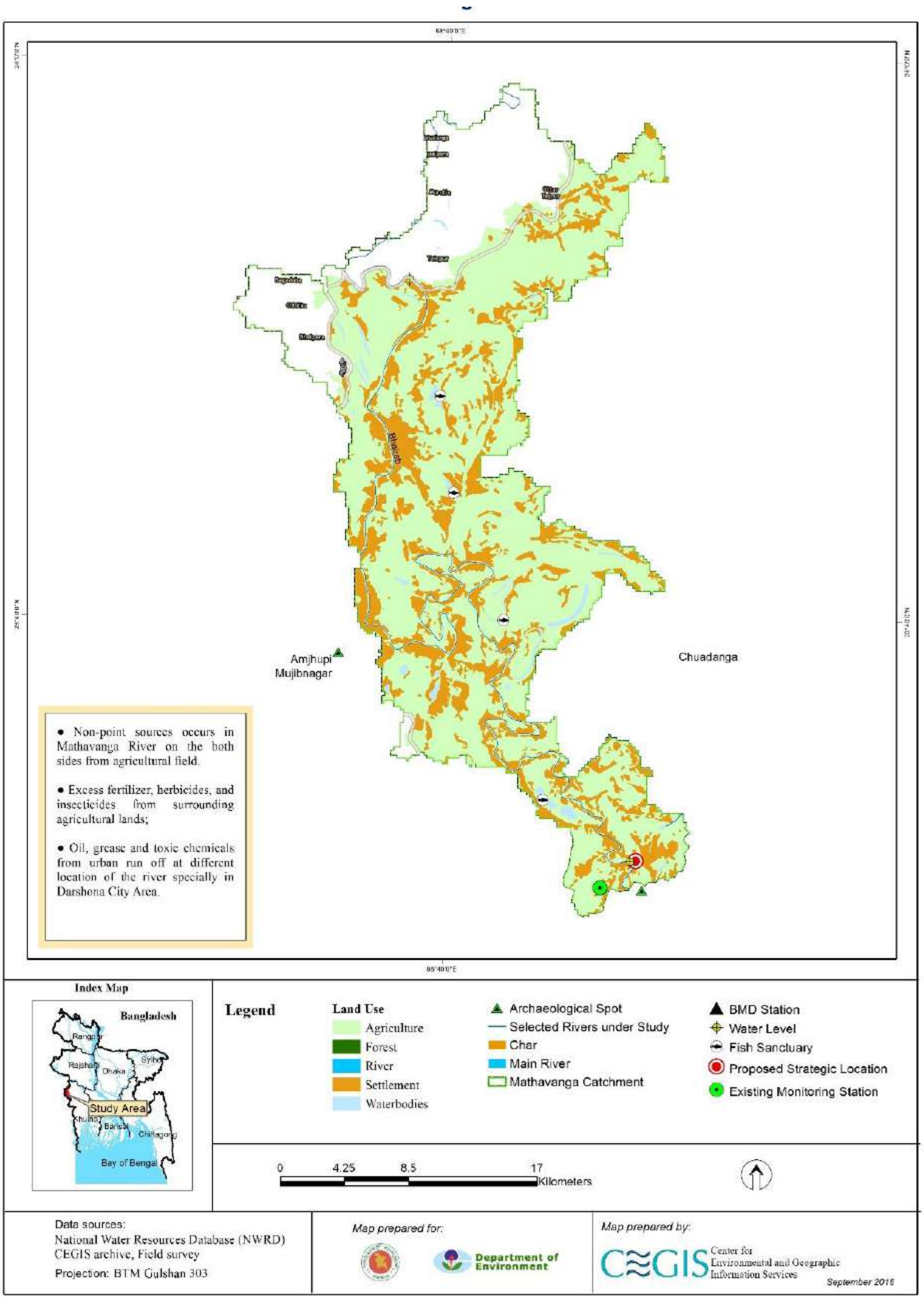


Figure 2.51: Non-Point Water Pollution Sources and Strategic Locations in the Mathavanga River

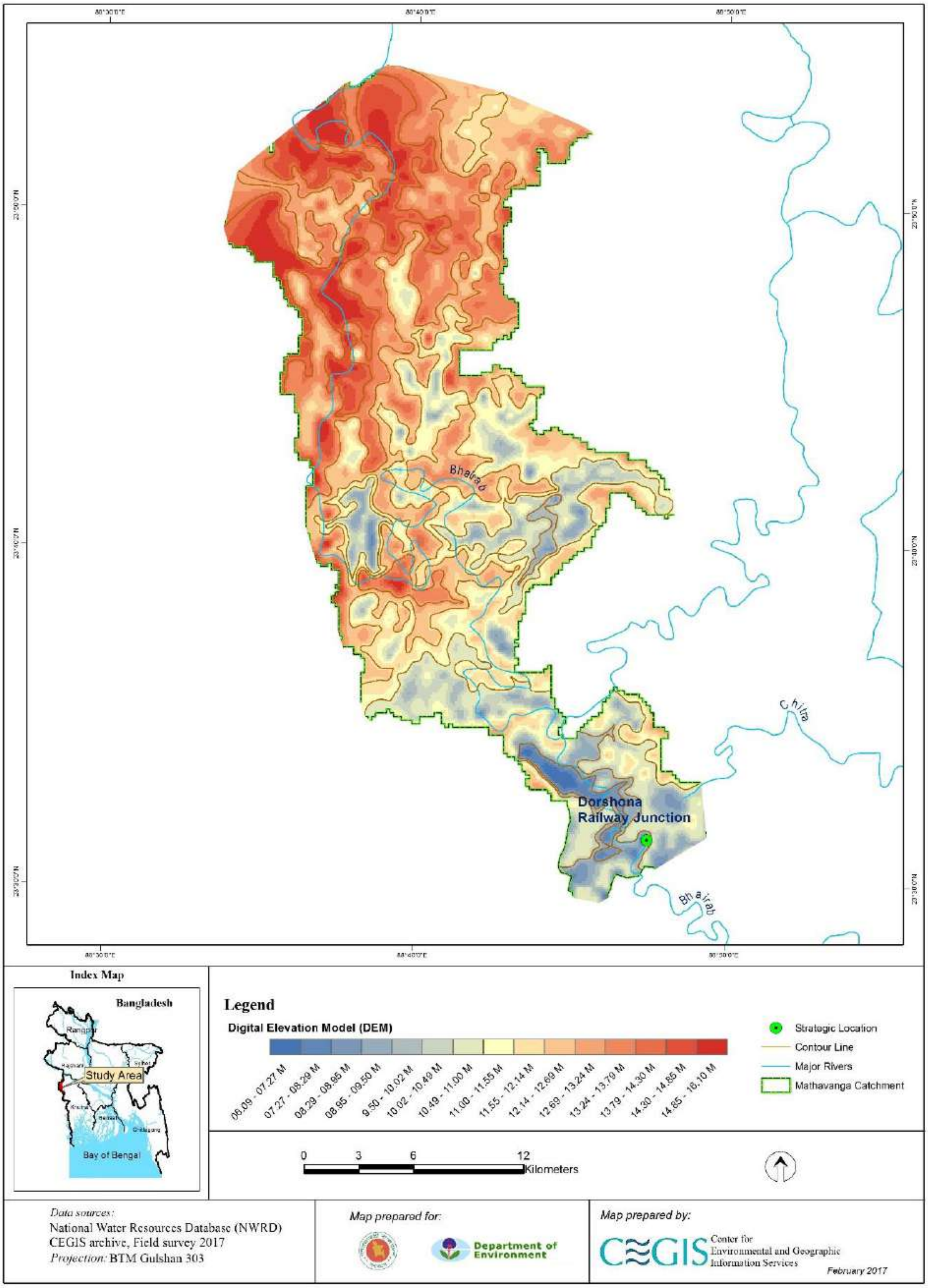


Figure 2.52: Digital Elevation Model (DEM) Map of Mathavanga River Catchment

2.8.21 Kankshiali River

The Kankshiali River is a distributary and is located in Khulna District, Bangladesh. The estimate terrain elevation of the river is above sea level is 10 metres. A total of 3 locations for the Kankshiali River have been selected as strategic locations (**Table 2.22**). The map of non-point water pollution sources and strategic locations in the Kankshiali River is in **Figure 2.53** and Digital Elevation of Kankshiali River has also shown in **Figure 2.54**.

Table 2.22: Strategic Location for Kankshiali River

River Name: Kankshiali River				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Kaliganj Bazar Bridge	70	22°27'27.82"N	89° 2'1.84"E	Kaliganj Bazar Bridge is located at Tarali union of Kaliganj thana in Stakhira.
Boshontopur	71	22°28'23.34"N	89° 0'21.04"E	Kaliganj Bazar Bridge is located at Barha Simla union of Kaliganj thana in Stakhira.
Uzirpur, Gobindakathi	72	22°30'45.09"N	89° 7'38.64"E	Uzirpur, Gobindakathi is located at Champaphul union of Kaliganj thana in Stakhira.

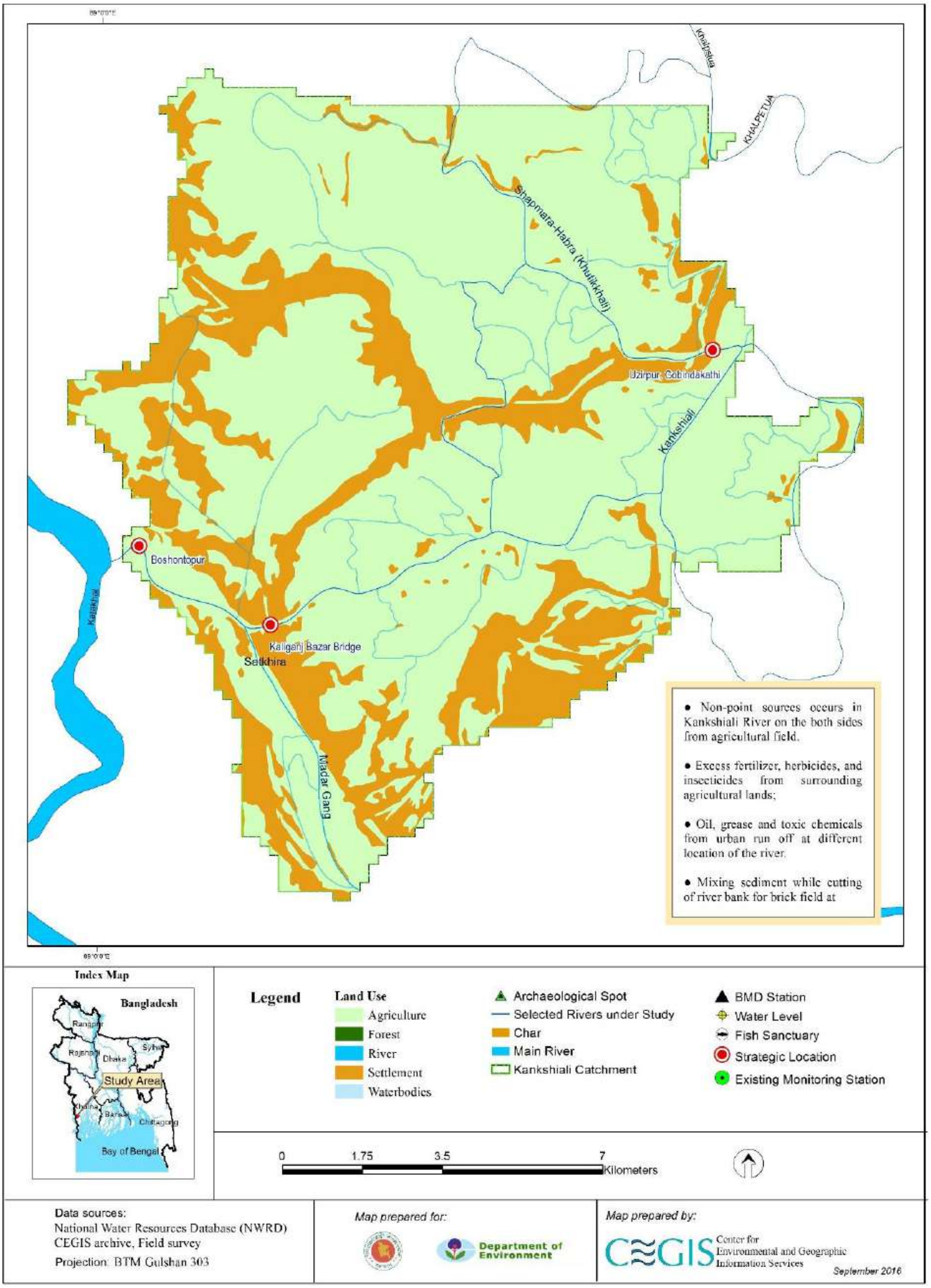


Figure 2.53: Non point water pollution sources and Strategic Location in Kankshiali River

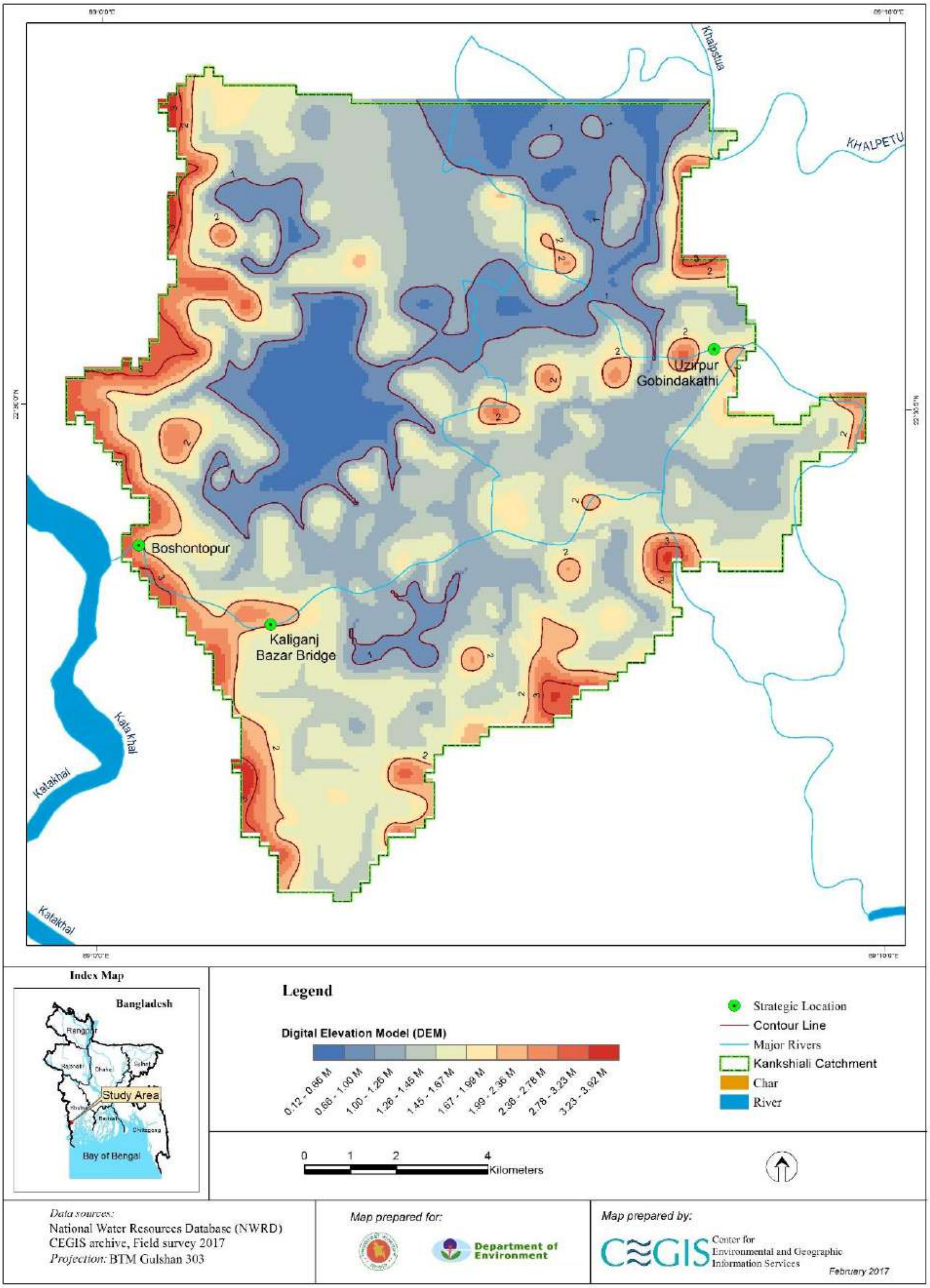


Figure 2.54: Digital Elevation Model (DEM) Map of Kankshiali River Catchment

2.8.22 Bhairab River

The **Bhairab River,** an important river in the moribund delta area. It has two main branches, the Ichamati(Khulna-Ichamati) and the Kobadak. Part of the Khulna-Ichamati is in India and partly it is in SatkhiraDistrict of Bangladesh, and so it forms the boundary between the two countries. Khulna and Jessore towns stand on the bank of this river. In the past, the Bhairab greatly influenced development of settlements and cultures in these two towns. The Hindus regard it as sacred. Meherpur, Chuadanga, Barobazar, Kotchandpur, Chaugachha, Jessore, Daulatpur, Bagerhat and Khulna are some of the important places located on the banks of the Bhairab. A total of four (4) locations for the Bhairab have been selected as strategic locations. (**Table 2.23**). The map of non-point water pollution sources and strategic locations in the Bhairab River is in **Figure 2.55** and Digital Elevation of Bhairab River has also shown in **Figure 2.56**.

Table 2.23: Strategic Location for Bhairab River

River Name: Bhairab River				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Bashundia Bazar	73	23° 8'14.76"N	89°22'8.90"E	Bashundia Bazar point is located at Basuari union of Bagher Para Thana.
Noapara Ferry Ghat	74	23° 0'42.12"N	89°24'57.63"E	Noapara Ferry Ghat point is located at Abhaynagar Paurashava of Abhaynagar Thana.
Taltola, Noapara	75	23° 0'42.12"N	89°24'57.63"E	Taltola point is located at Abhaynagar Paurashava of Abhaynagar Thana.
Fultala Ghat	76	22°58'38.76"N	89°28'41.29"E	Fultala Ghat point is located at Siddhipasha Union of Abhaynagar Thana.

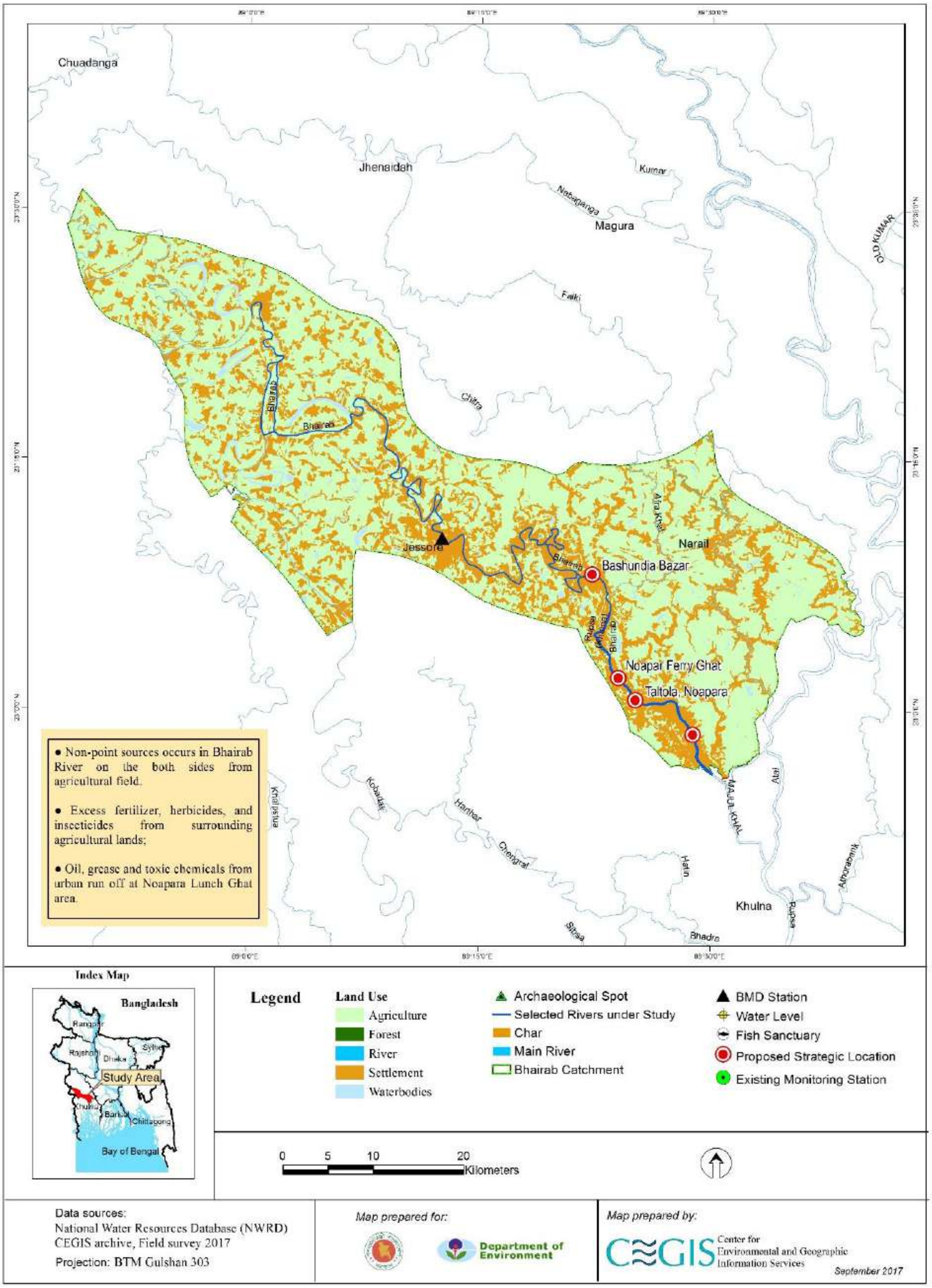


Figure 2.55: Non-Point Water Pollution Sources and Strategic Locations in Bhairab River

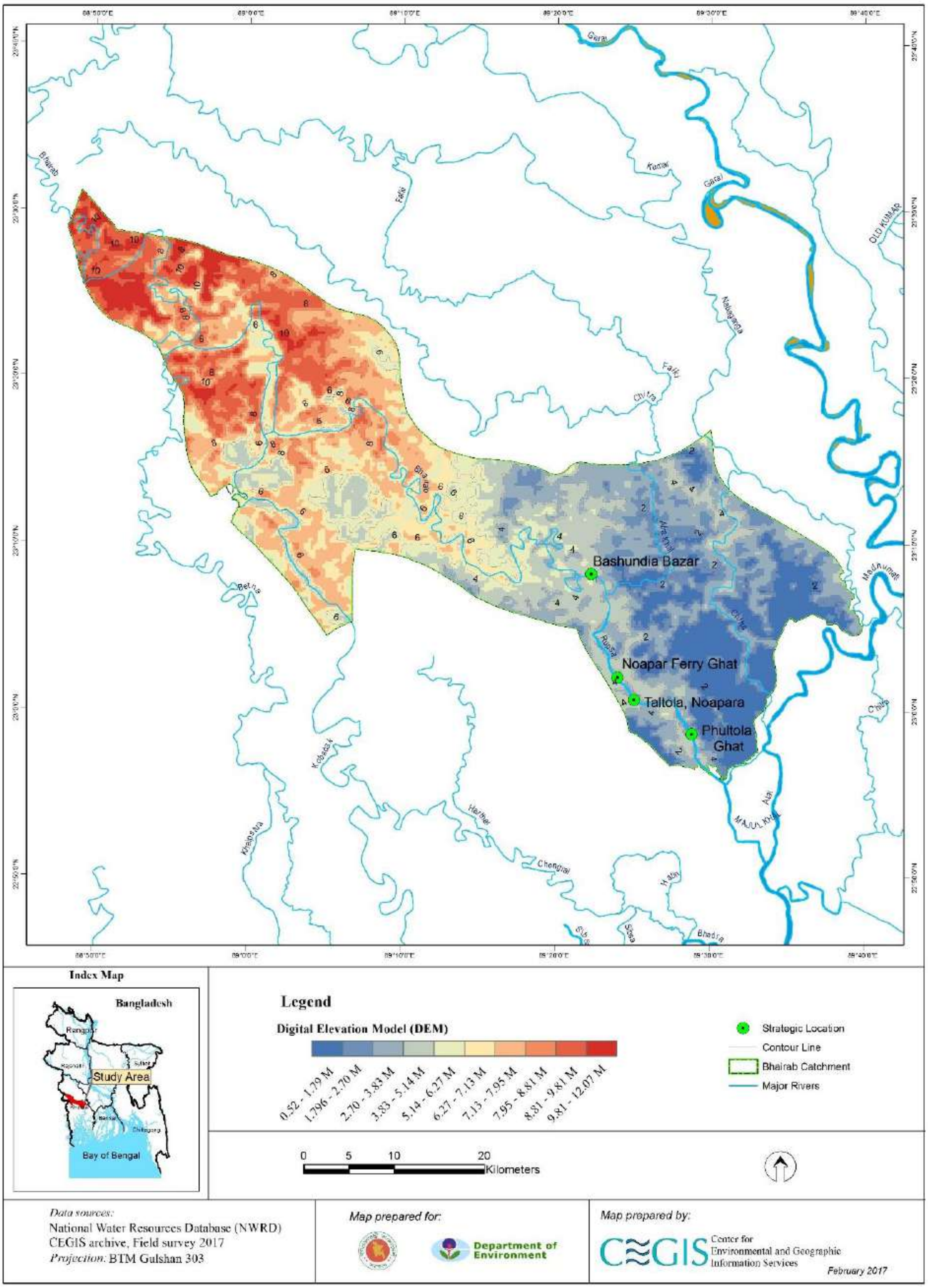


Figure 2.56: Digital Elevation Model (DEM) Map of Bhairab River Catchment

2.8.23 Rupsha River

The Rupsha is an important river of Bangladesh that flows by the port city Khulna and falls to the Bay of Bengal through Pashur river at Mongla channel. Many salt industries are built on the bank of the Rupsha River. Besides this, other industries also contribute to water pollution. A total of 4 locations for Rupsha have been selected as strategic locations (**Table 2.24**). The map of non-point water pollution sources and strategic locations in the Rupsha River is in **Figure 2.57** and Digital Elevation of Rupsha River has also shown in **Figure 2.58**.

Tabel 2.24: Strategic Location for Rupsha River

River Name: Rupsha River				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Gilatala	77	22°55'39.44"N	89°30'53.23"E	Gilatala point is located at Barakpur union of Digohalia Thana.
Charer Hat	78	22° 50' 52.34"N	89° 33' 37.02"E	Charer Hat point is located at Aijganti Union of Rupsha Thana.
Kalibari Ghat	79	22° 49' 11.68"N	89° 34' 18.45"E	Kalibari Ghat point is located at Aijganti Union of Rupsha Thana.
Rupsha Ghat (Old)	80	22° 47' 18.25"N	89° 35' 13.55"E	Rupsha Ghat (Old) point is located at Naihati Union of Rupsha Thana.

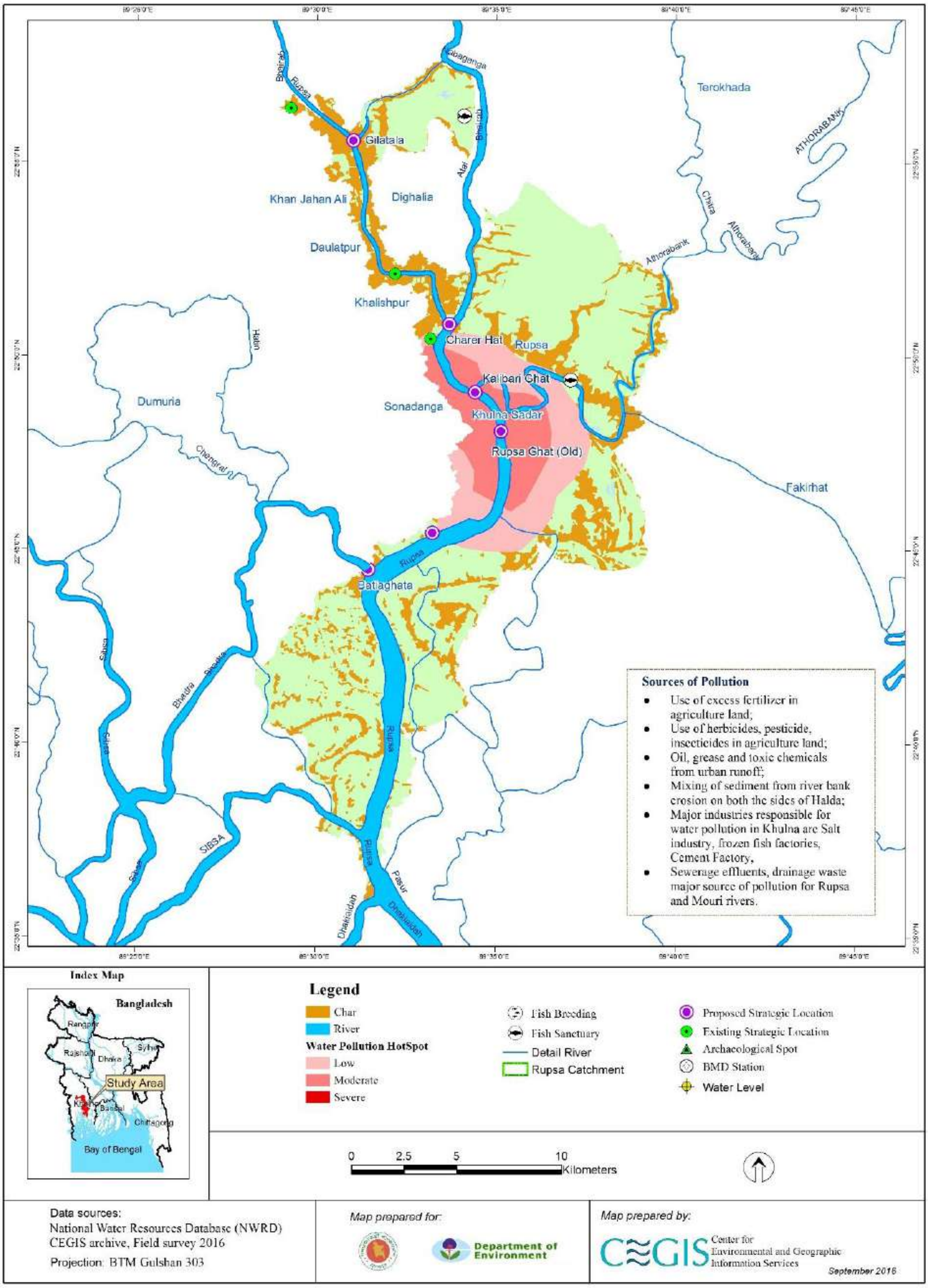


Figure 2.57: Water Pollution Hotspot and Strategic Locations in Rupsha River

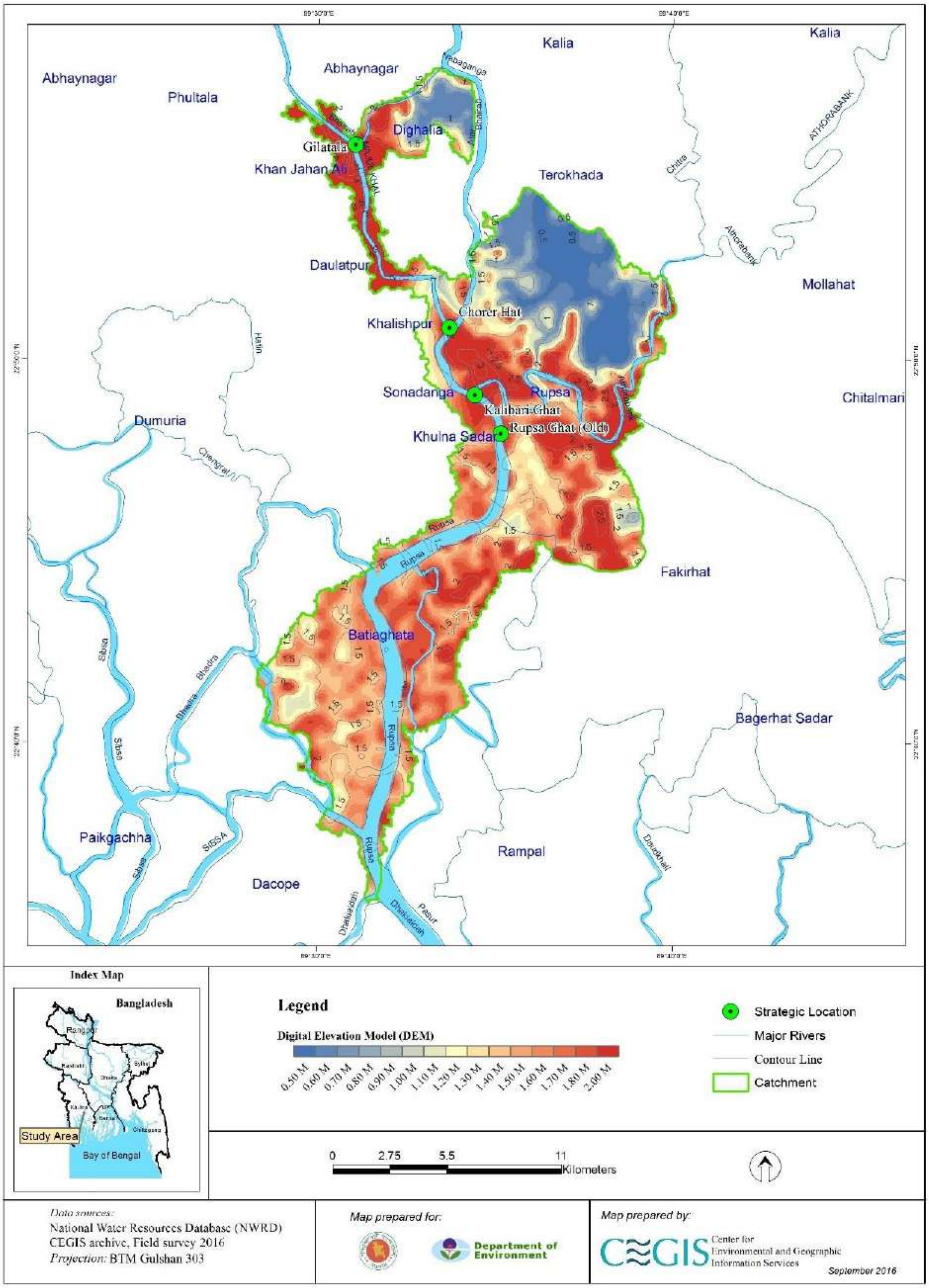


Figure 2.58: Digital Elevation Model (DEM) Map of Rupsha River Catchment

2.8.24 Moyuri River

The Moyuri is a very important river for Khulna City. Moyuri River confluence at Dosh Gate area in Batiaghata with Rupsha contributing polluted water. Pollution occurs at the Moyuri River mainly due to agricultural activities and drain out water from Khulna city. A total of 3 locations for Moyuri have been selected as strategic locations (**Table 2.25**). The map of non-point water pollution sources and strategic locations in the Moyuri River is in **Figure 2.59** and Digital Elevation of Moyuri River has also shown in **Figure 2.60**.

Tabel 2.25: Strategic Location for Moyuri River

River Name: Moyuri River				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Shashan Ghat	81	22° 47' 48.81"N	89° 32' 35.19"E	Shashan Ghat point is located at Jalma union of Batiaghata Thana.
Buro Moulavir Darga	82	22°47'48.00"N	89°32'35.52"E	Buro Moulavir Darga point is located at Jalma Union of Batiaghata Thana.
Dosh Gate	83	22°45'29.60"N	89°33'4.90"E	Dosh Gate is point is located at Jalma Union in Batiaghata thana.

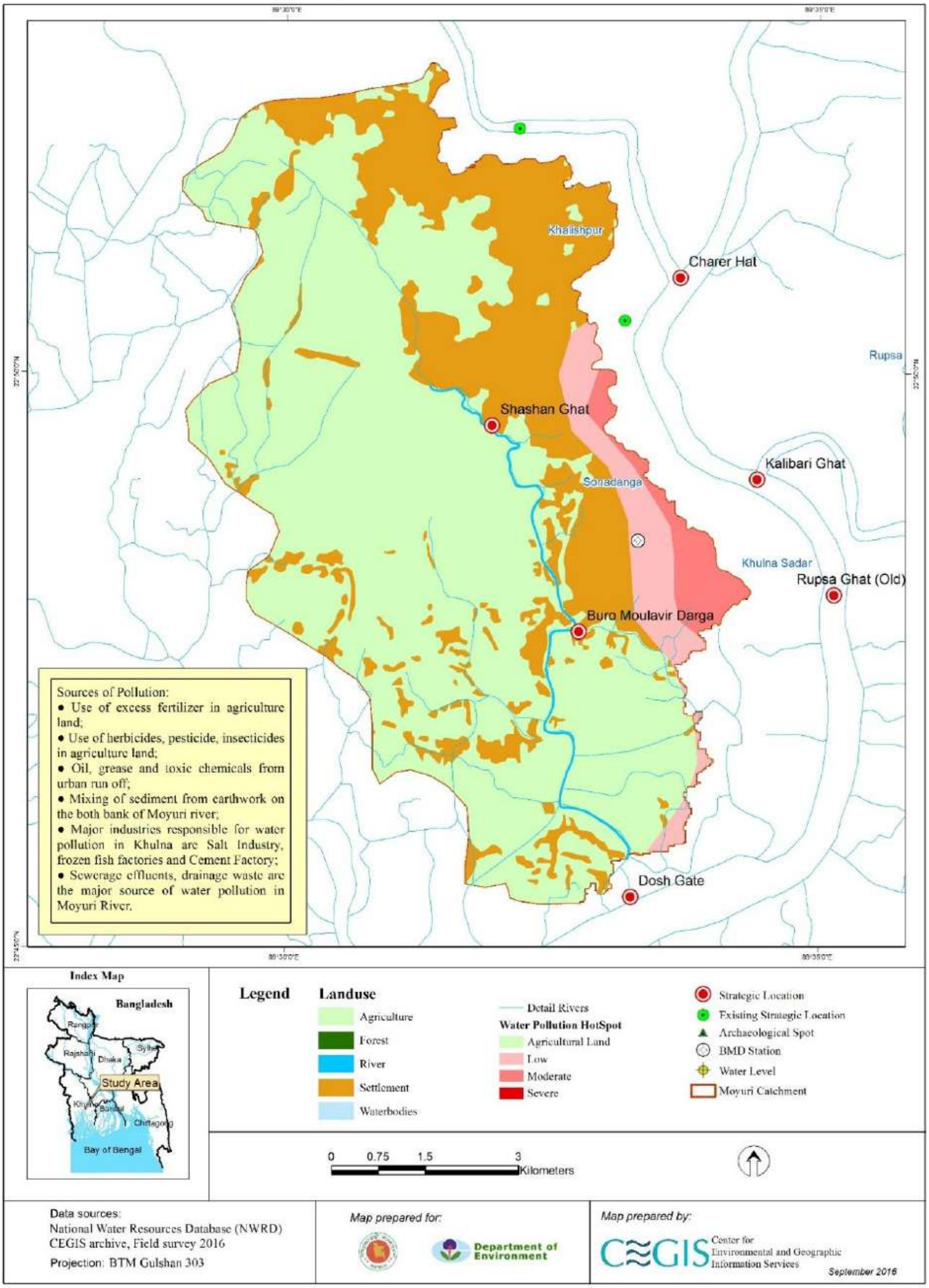


Figure 2.59: Water pollution Hotspot Map and Strategic Locations in Moyuri River

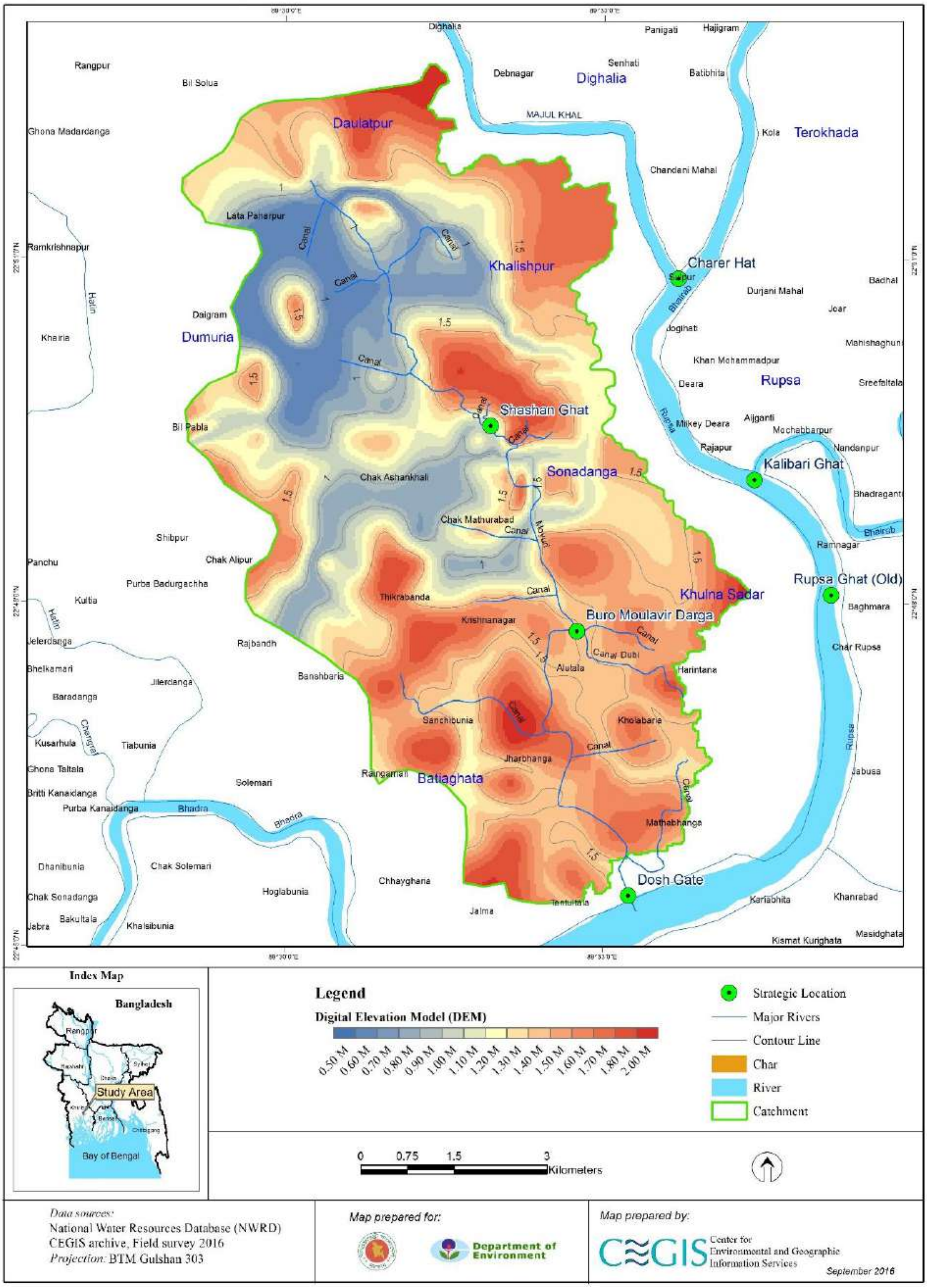


Figure 2.60: Digital Elevation Model (DEM) Map of Moyuri River Catchment Area

2.8.25 Pashur River

The Pashur River is a river in southwestern Bangladesh and a distributary of the Ganges. It continues as the Rupsha River at the point of Kazibacha river confluents. All its distributaries are tidal. It meets the Shibsa River within the Sundarbans, and near to the sea the river becomes the Kunga River. It is the deepest river in Bangladesh. A total of 3 locations for Pashur have been selected as strategic locations (**Table 2.26**). The map of non-point water pollution sources and strategic locations in the Pashur River is in **Figure 2.61** and Digital Elevation of Pashur River has also shown in **Figure 2.62**.

Table 2.26: Strategic Location for Pashur River

River Name: Pashur				
Strategic Location	SL ID	GPS Location		Description
		Latitude	Longitude	
Kazibacha-Batiaghata Bypass	84	22°44'32.63"N	89°31'18.01"E	Kazibacha-Batiaghata Bypass point is located at Batiaghata union of Batiaghata Thana.
Rampal Power Plant	85	22°34'59.96"N	89°32'56.63"E	Rampal Power Plant Location is situated at Rajnagar union in Rampal Thana.
Banishanta	86	22°27'59.39"N	89°35'25.31"E	Banishanta point is located at Banishanta union of Dacope Thana.

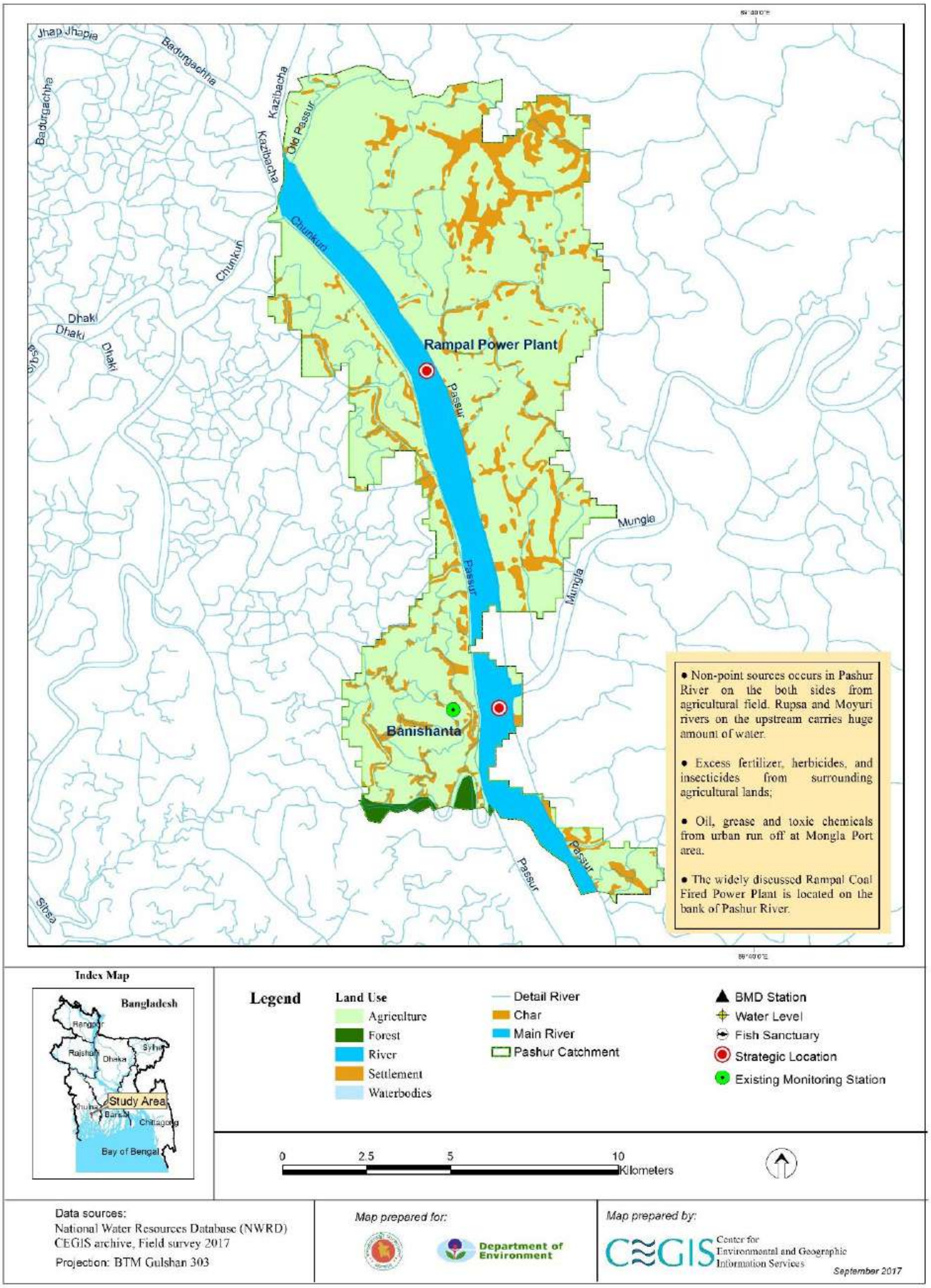


Figure 2.61: Non-Point Water Pollution Sources and Strategic Locationsin Pashur River

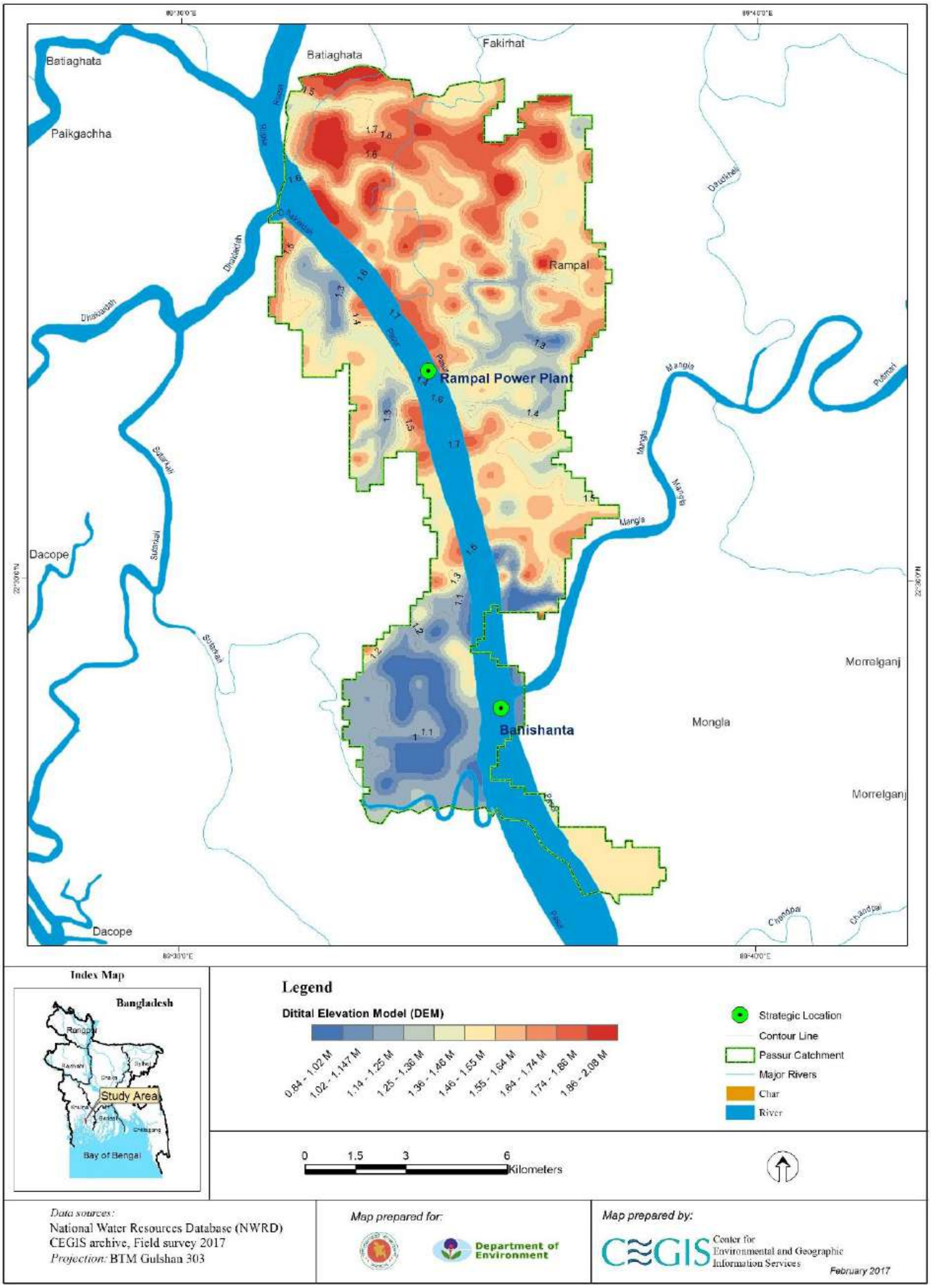


Figure 2.62: Digital Elevation Model (DEM) of Pashur River Catchment

2.8.26 Sughandha River

The Sughandha river is a beautiful river of Bangladesh. It the Sughandha is a coastal river under Jhalakathi district of Bangladesh. The length of this river is 30km, the width is 1000m and the depth is 10m. It flows eastern near Shayestabd and falls into the Bay of Bengal after meeting with the Megna river at Sahbazpur in Bhola. A total of 1 (one) location for Sughandha has been selected as strategic locations (**Table 2.27**). The map of non-point water pollution sources and strategic locations in the Sughandha River is in **Figure 2.63** and Digital Elevation of Sughandha River has also shown in **Figure 2.64**.

Table 2.27: Strategic Location for Sughandha River

River Name: Sughandha				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Gab Khan Lunch Terminal	87	22°37'38.83"N	90°10'40.35"E	Gab Khan Lunch Terminal is located at Gabkhan Dhansiri union of Jhalokati Sadar Thana in Jhalokati.

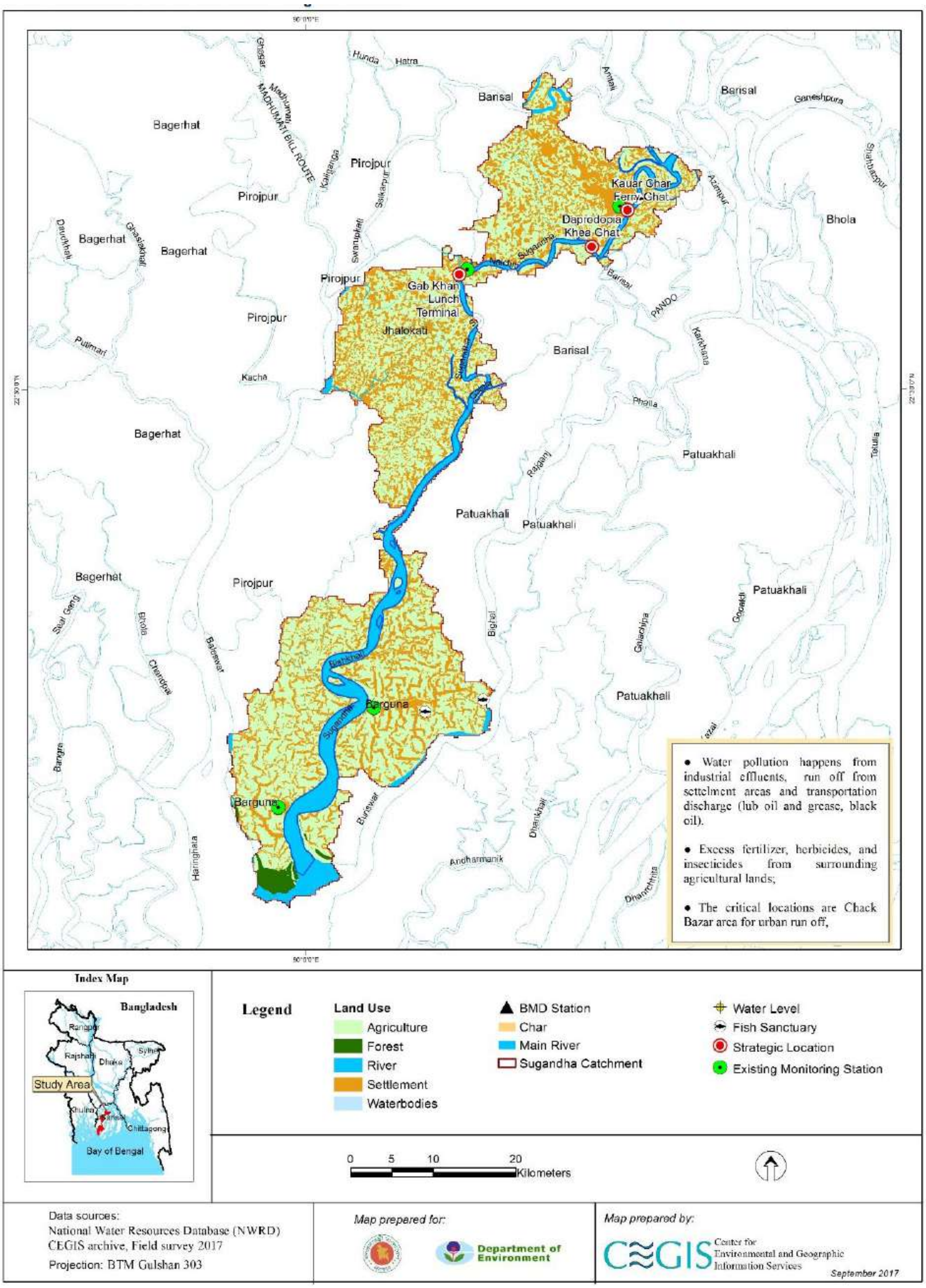


Figure 2.63: Non-point water pollution sources and strategic locations in theSughandha River

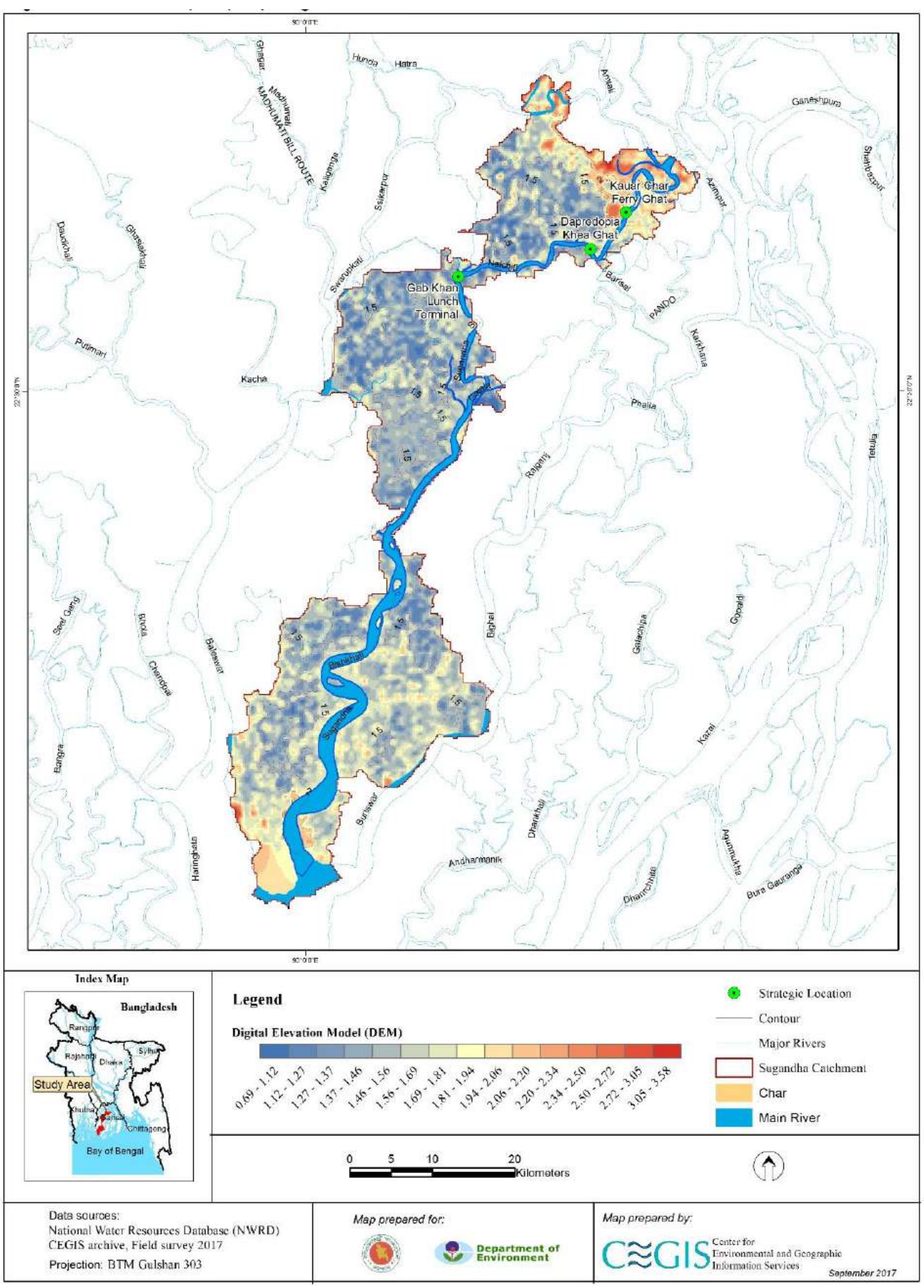


Figure 2.64: Digital Elevation Model (DEM) of Sughandha River Catchment

2.8.27 Kirtankhola River

Kirtankhola is a river that starts from Sayeshtabad in Barisal district and ends into the Gajalia near Gabkhan khal (canal). The total length of the river is about 160 kilometres (99 mi). Kirtankhola rivers take the name Sughandha at Jhalokathi and continues with this name till Barisal. A total of 2 (two) locations for Kirtankhola have been selected as strategic locations (**Table 2.28**).The map of non-point water pollution sources and strategic locations in the Kirtankhola River is in **Figure 2.65** and Digital Elevation of Kirtankhola River has also shown in **Figure 2.66**.

Table 2.28: Strategic Location for Kirtankhola River

River Name: Kirtankhola				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Dopdopia Kheya Ghat	88	22° 39' 26.68"N	90° 20' 2.40"E	Dapdopia Khea Ghat point is located at Dapdapia union of Nalchity Thana in Jhalokati.
Kauar Char Ferry Ghat	89	22° 41' 50.71"N	90° 22' 33.68"E	Kauar Char Ferry Ghat Location is situated at Char Kowa union of Barisal Sadar Thana.

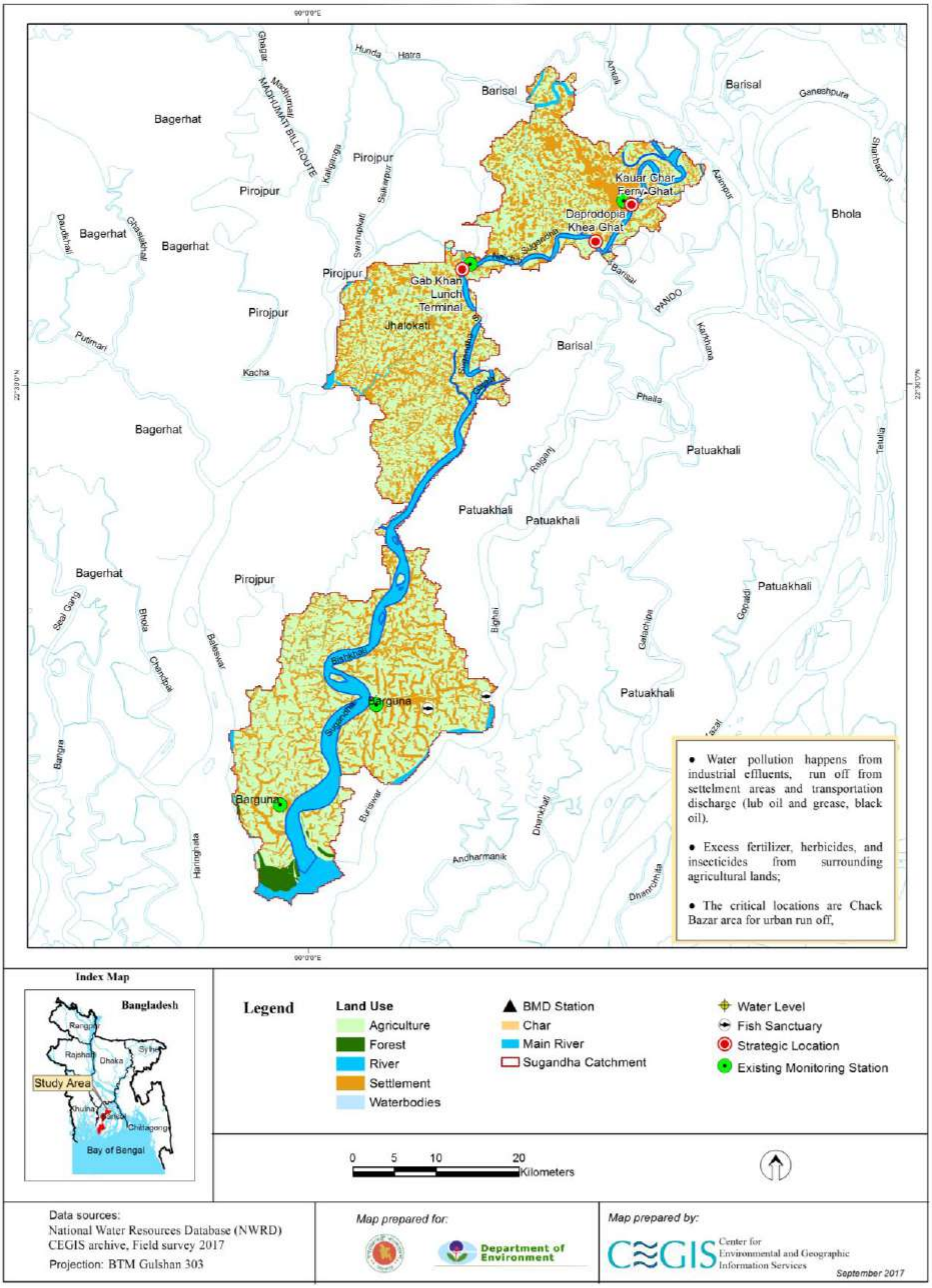


Figure 2.65: Non-point water pollution sources and strategic locations in the Kirtankhola River

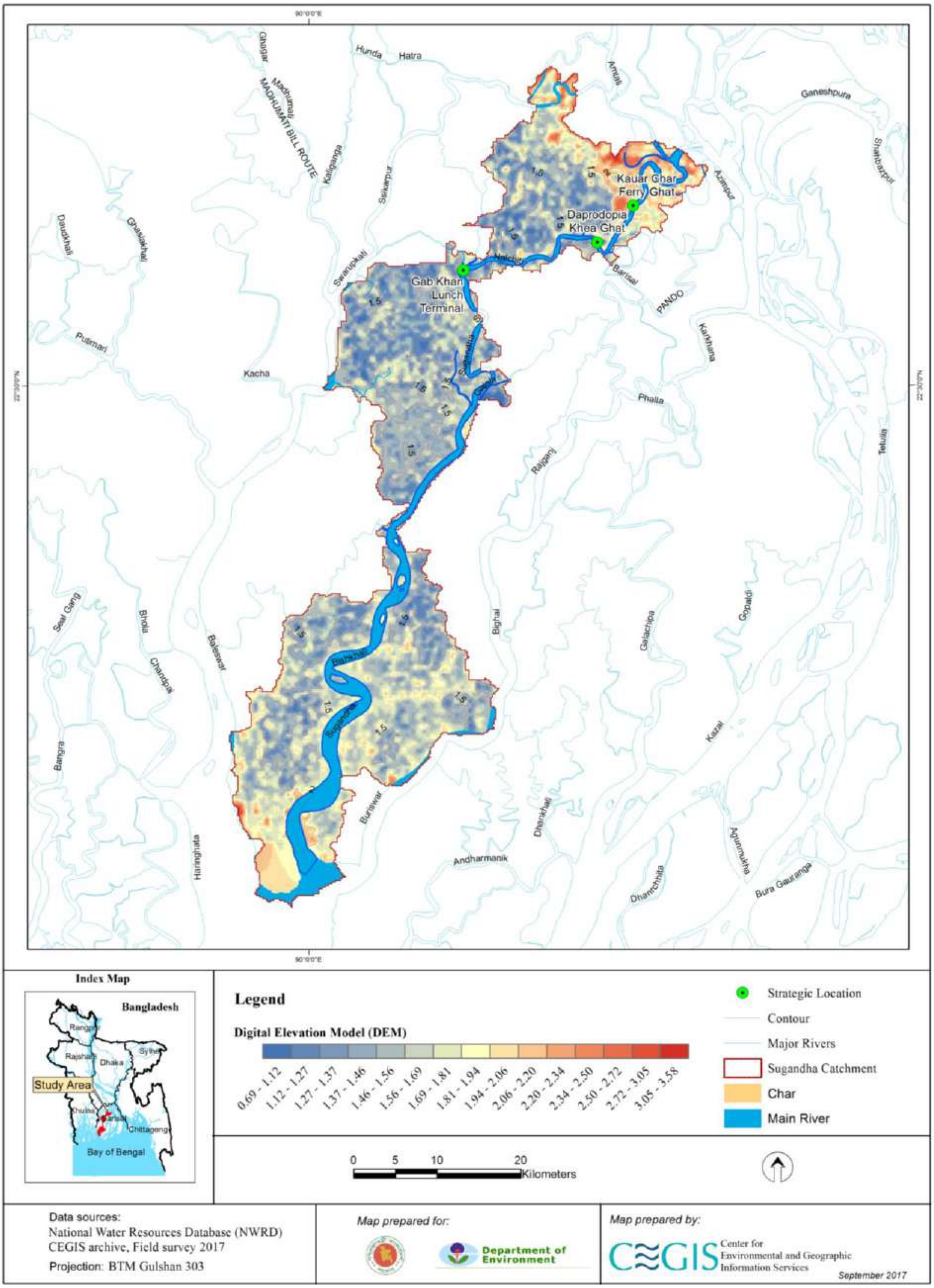


Figure 2.66: Digital Elevation Model (DEM) of Kirtankhola River Catchment

2.8.28 Tetulia River

The Tetulia River, called Ilsha for part of its length, is located in Bhola district. It is one of the larger coastal rivers of the Ganges-Padma system, and a major flow of the Meghna River. Runoff from agricultural field and residues of water transports cause water pollution in this risver. Oil spill pollution also happens here from waer way vehicles at Veduriya Ferry Ghat. Natural fishing ground, agricultural use, and water way transportation key three aspect of water use in this location Tetulia River. The only important location Veduriya Ferry Ghat has been selected as the strategic location (**Table 2.29**). The map of non-point water pollution sources and strategic locations in the Tetulia River is in **Figure 2.67** and Digital Elevation of Tetulia River has also shown in **Figure 2.68**.

Table 2.29: Strategic Location for Tetulia River

River Name: Tetulia				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Vheduria Ferry Ghat	90	22° 42' 18.0"N	90° 33' 51.5"E	Vheduria ferry ghatpoint is located at Vheduria union of Bhola SadarThana.

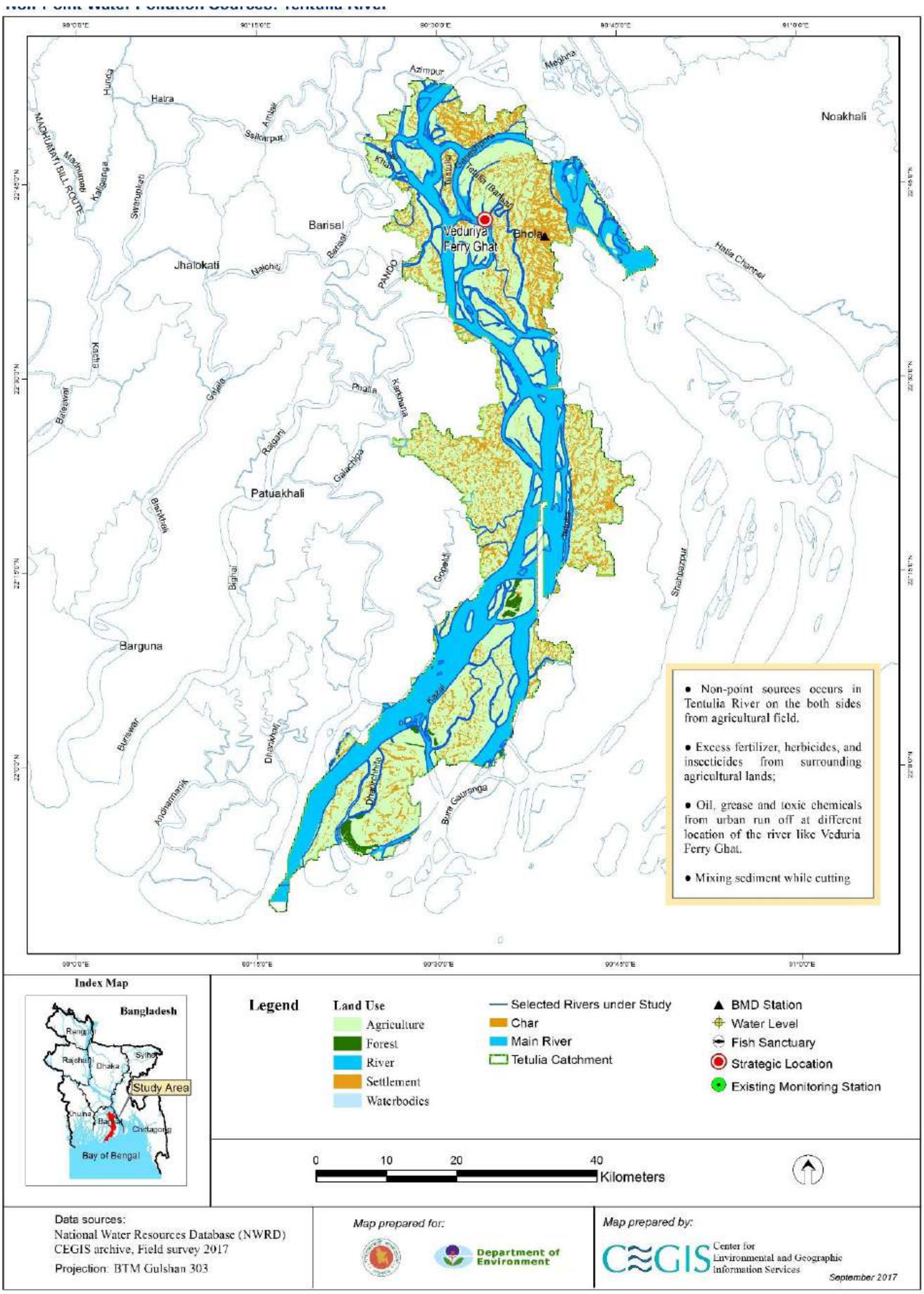


Figure 2.67: Non-point water pollution sources and strategic locations in the Tetulia River

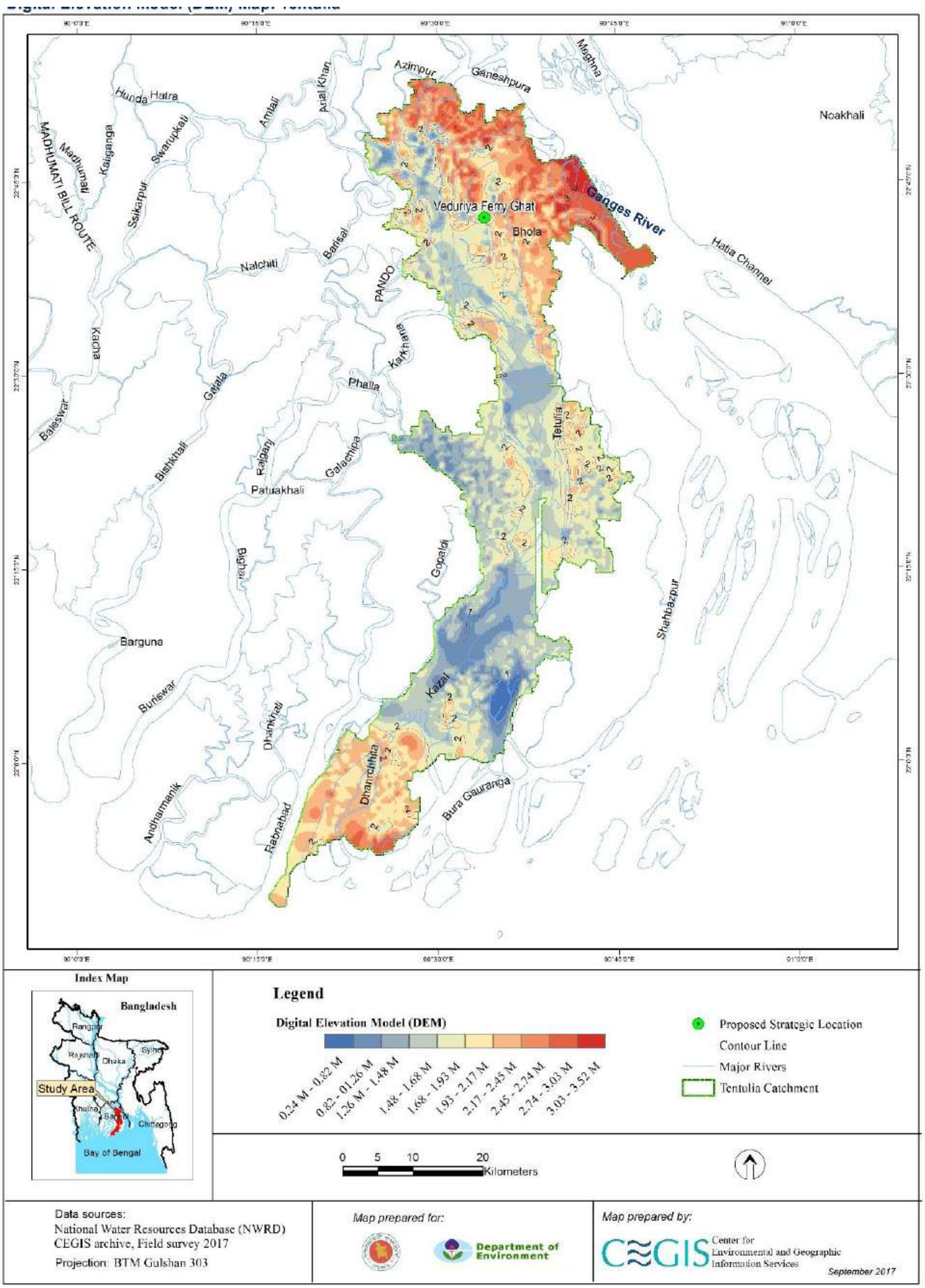


Figure 2.68: Digital Elevation Model (DEM) of Tetulia River Catchment

2.8.29 Karnaphuli River

Karnaphuli is a very important river for Chittagong. Many industries are situated on the northern bank of the river. Two large industries, namely CUFL and TSP, are located on the southern bank of the river. Many salt industries, dyeing industries, washing plants, and power plants are also located near the bank of the river. Kaptai Lake is connected with this river. Karnaphuli Paper Mills and a few tea gardens are located near the Kaptai Lake. Total 6 locations for Karnaphuli have been selected as strategic locations (**Table 2.30**). The map of non-point water pollution sources and strategic locations in the Karnaphuli River is in **Figure 2.69** and Digital Elevation of Karnaphuli River has also shown **in Figure 2.70**.

Table 2.30: Strategic Location for Karnaphuli River

River Name: Karnaphuli				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
CUFL	91	22˚14'19.6"N	91˚49'41.2"E	CUFL point is located at Bairag union of Karnaphuli Thana.
TSP Location	92	22˚16'32.4"N	91˚48'4.3"E	TSP Location is situated at Ward No. 40 in Patenga Thana.
Shikalbaha Power Station	93	22˚19'17.2"N	91˚52'7.2"E	Shikalbaha Power Station point is located at Sikalbaha union of Karnaphuli Thana.
Kalurghat Bridge	94	22˚24'12.0"N	91˚53'31.9"E	Kalurghat Bridge point is located at Ward no-05 of Chandgaon Thana.
Mariam Nagar	95	22˚26'58.9"N	92˚4'43.5"E	Mariam Nagar point is located at Dakshin Madarsha union in Hathazari Thana.
Karnaphuli Paper Mills (KPM)	96	22˚28'17.9"N	92˚8'20.3"E	Karnaphuli Paper Mills (KPM) point is located near the Kapti Lake at Raikhali union of Kaptai Thana.

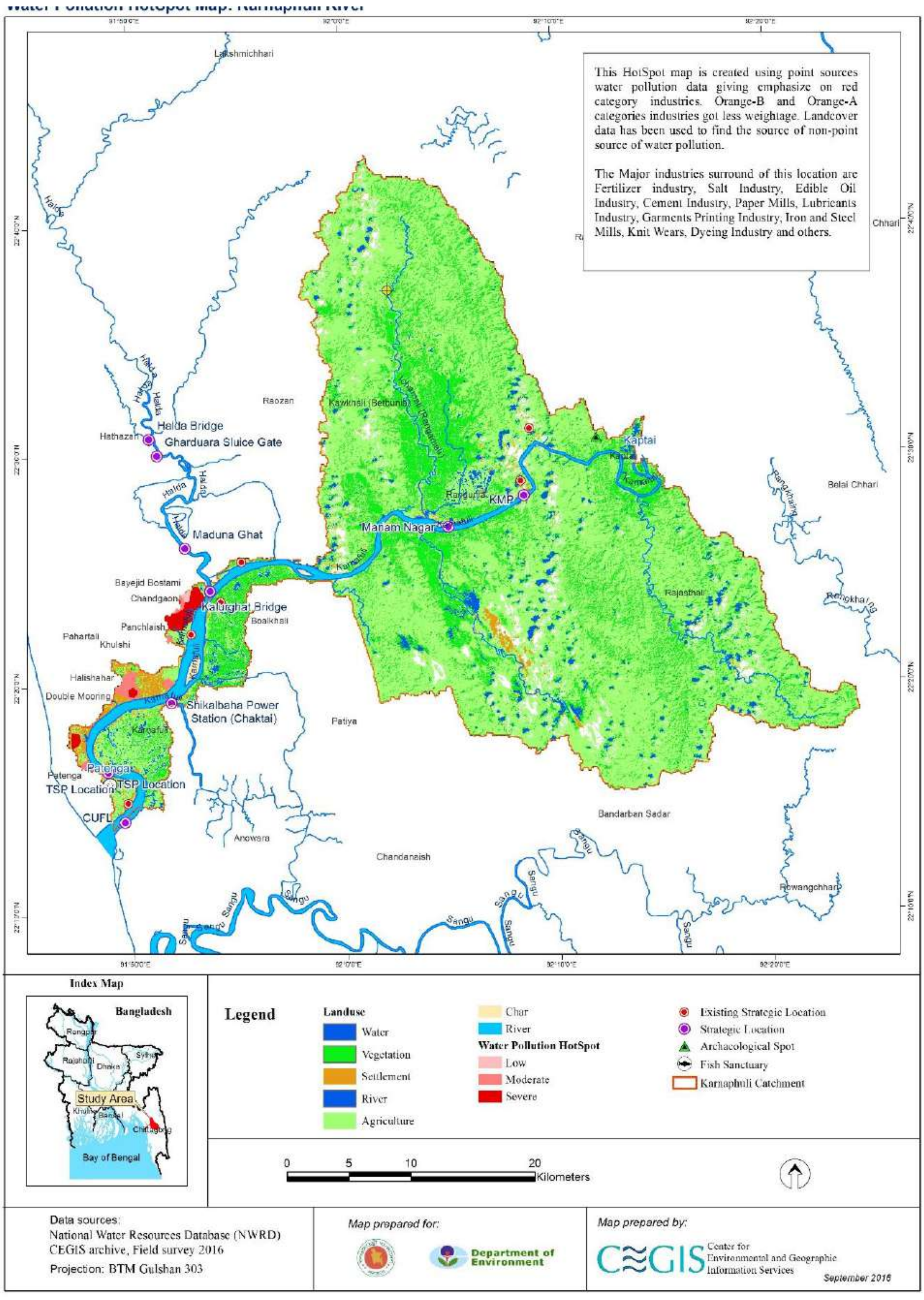


Figure 2.69: Water Pollution Hotspot and Strategic Locations in Karnaphuli River

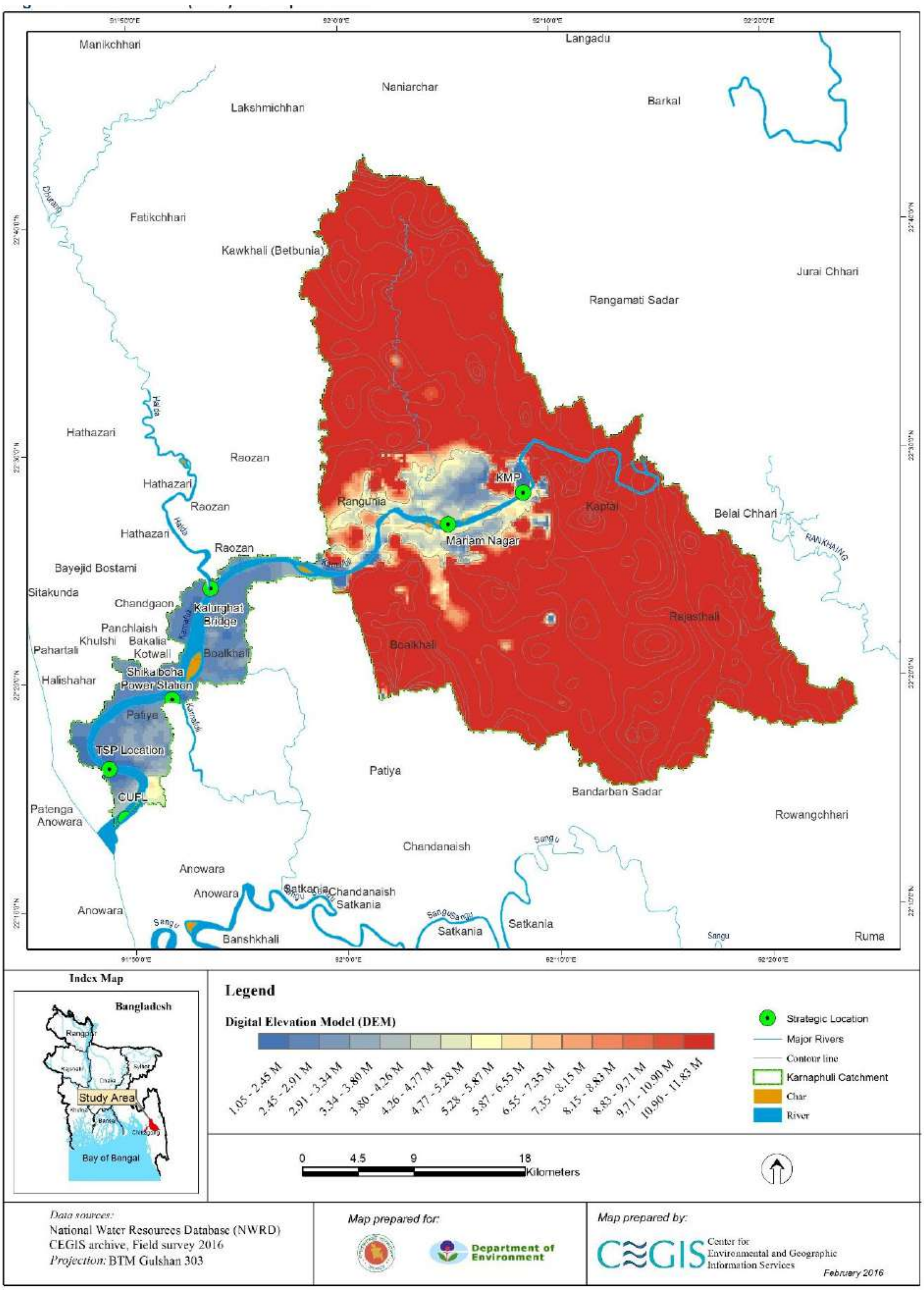


Figure 2.70: Digital Elevation Model (DEM) of Karnaphuli River Catchment

2.8.30 Halda River

Halda is the only breeding ground for Carp Fishes. A large number of fisher communities lead their livelihood based on the river. Pollution occurs mainly due to agricultural runoff. A total of 3 locations for Halda have been selected as strategic locations (**Table 2.31**). The map of non-point water pollution sources and strategic locations in the Halda River is in **Figure 2.71** and Digital Elevation of Halda River has also shown in **Figure 2.72**.

Table 2.31: Strategic Location for Halda River

River Name: Halda				
Strategic Location	**SL ID**	**GPS Location**		**Description**
		Latitude	**Longitude**	
Maduna Ghat	97	22˚26'0.6.0"N	91˚52'20.0"E	Maduna Ghat point is located at Dakhin Madarsha Union of Hathazari Thana.
Garduara Sluice Gate	98	22° 30' 7.62"N	91° 51' 5.61"E	Garduara Sluice gate is located at Garduara union of Hathazari thana.
Halda Bridge	99	22˚30'53.6"N	91˚50'44.4"E	Halda Bridge point is located at Gahira union of Raozan thana.

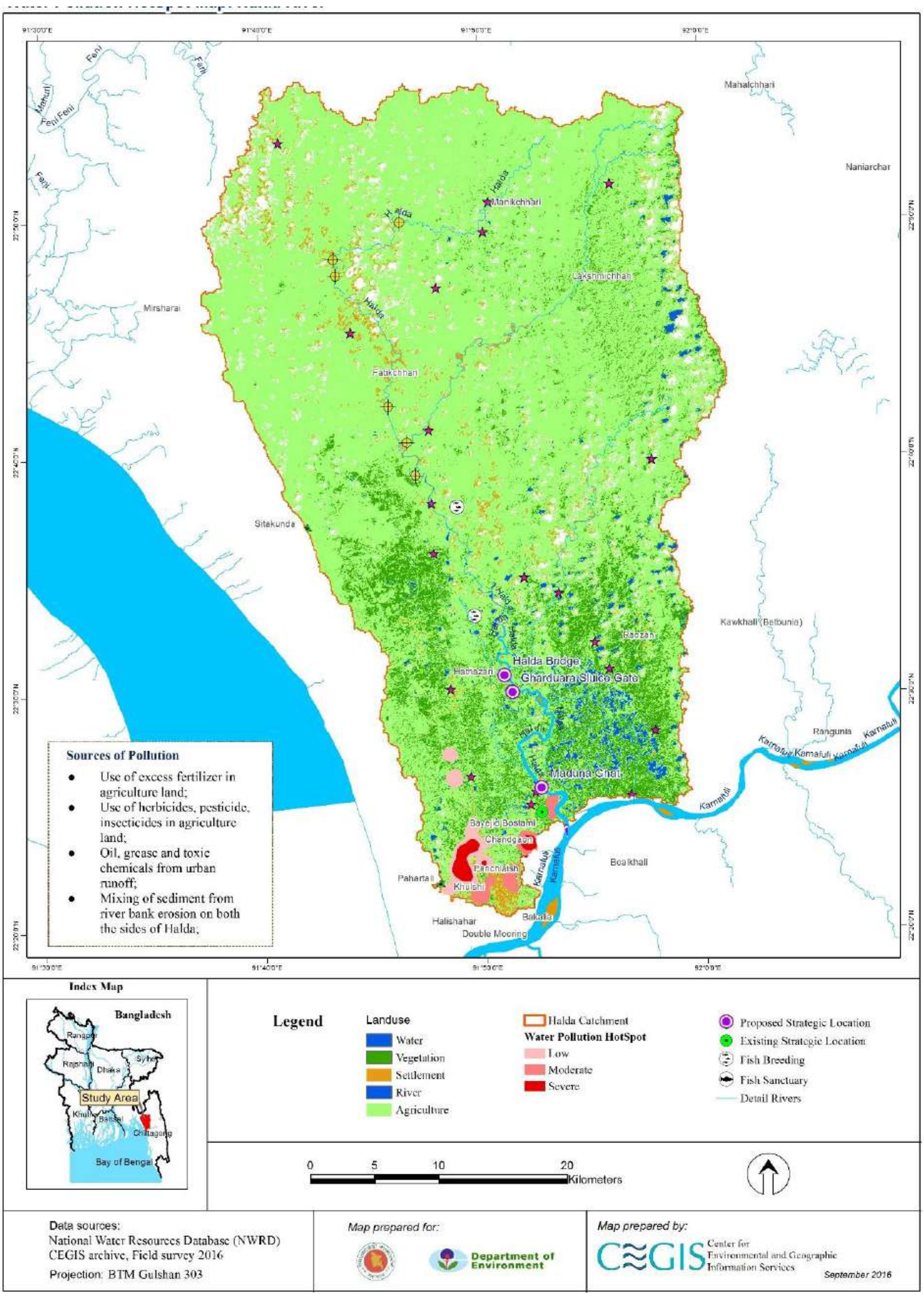


Figure 2.71: Water Pollution Hotspot and Strategic Locations in Halda River

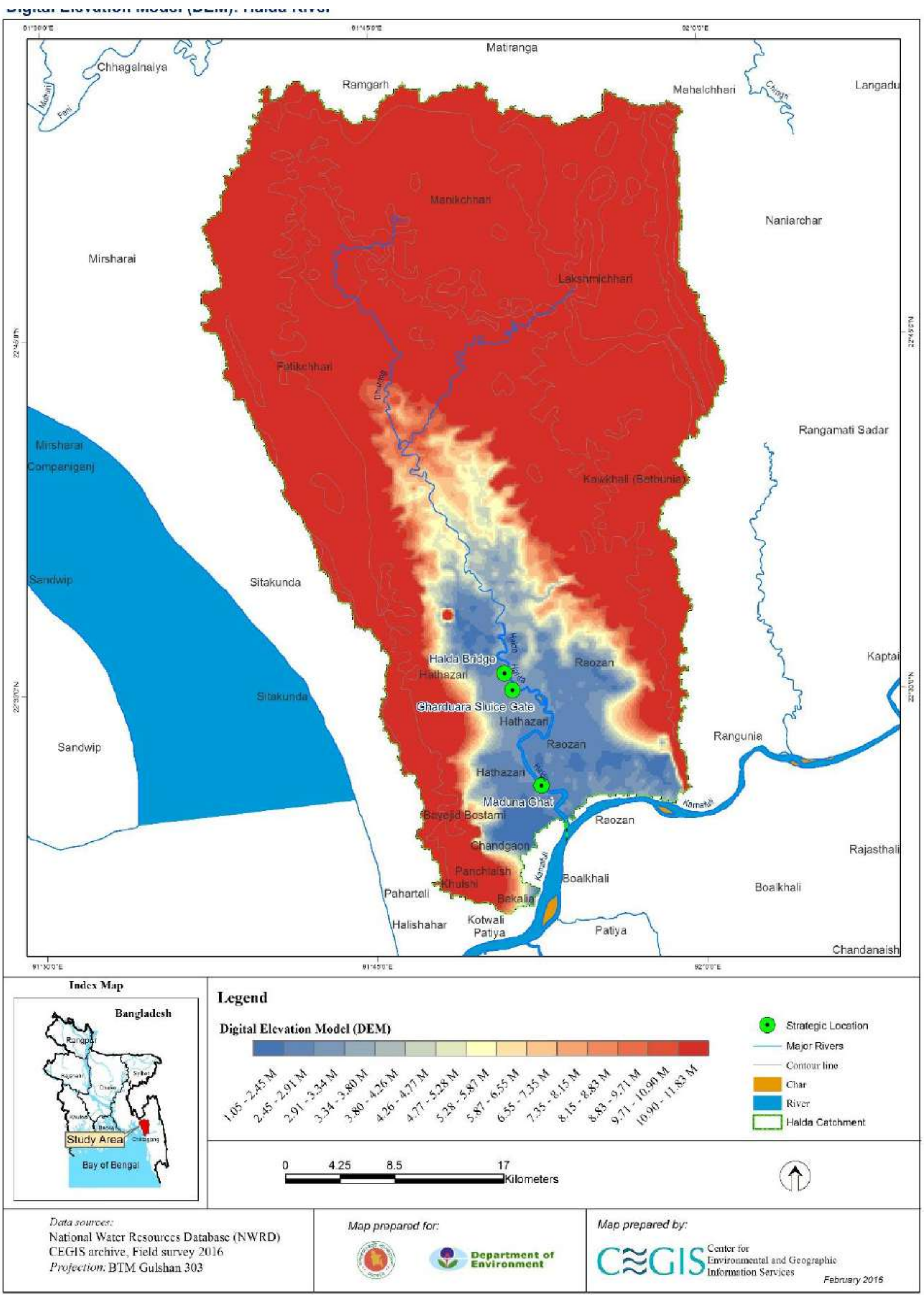


Figure 2.72: Digital Elevation Model (DEM) Map of Halda River Catchment

2.9 Validation of Selected Strategic Location

Strategic locations of selected thirty (30) rivers have been selected and validated based on field visit data and information. Accessibility issues have been considered as an important aspect for collecting water sample. So, detail road network has been analysed during field visit. Besides, ways of water sample collection (collection from bridge, collected by boat or manual) are also assessed. The detail description of validation process of each and every Strategic Locations is described below:

2.9.1 Selection of Strategic Location

River Name: Teesta

1. Teesta Barrage	Teesta barrage point is an important strategic location in many aspects. Teesta barrage diverts water to Khalisha Chapani, Nilphamari Delta Canal, Kishoregonj and other surrounding areas mainly for irrigation purposes. The river water that comes from India via Teesta needs to be monitored and assessed for different uses. BWDB set six water level stations near this location. This location would be suitable for setting water quality monitoring stations in respect to agricultural use only.
Geographic Location	Mouza: Doani Pittiphata, Union: Goddimari, Thana: Hatibandha, District: Lalmonirhat Division: Rangpur
GPS Location: Lat: 26˚10'39.40"N Long: 89˚3'1.10"E	
2. Nohali-Shapmari	At Nohali point Buri Teesta meets with Teesta carrying large amounts of Agricultural pollutants. This tributary mainly carries fresh water which is suitable for fish culture. Besides this a water level stations is located near this location. This is a major source of freshwater to be used for agriculture. From the agricultural point of view, this location is suitable for setting up water quality monitoring stations.
Geographic Location	Mouza: Taluk Saulmari, Union:Saulmari, Thana: Jaldhaka, District: Nilphamari, Division: Rangpur

GPS Location Lat: 26° 0' 18.0"N Long: 89° 6' 14.4"E	
3. Teesta Bridge	A branch of Teesta River flows from Mohipur Ghat and flows over a large agricultural field and meets again with Teesta main stream at Teesta Bridge. This water carries agricultural pollutants. 6 Fish breeding grounds are located near this point which is most important in respect to fish culture and natural breeding of fishes. This location would be suitable for setting water quality monitoring stations in respect to agricultural use and fish culture.
Geographic Location	Mouza: Tista, Union: Gokunda, Thana: Lalmonirhat Sadar, District: Lalmonirhat, Division: Rangpur
GPS Location Lat: 25˚47'17.50"N Long: 89˚26'18.70"E	
4. Horipur Kheya Ghat	At north side of Horipur Ghat there is a large agricultural field. Agricultural pollutants mix with the mainstream of teesta river water at this point. A water level station of BWDB is located here.This is a major source of fresh water and can be used for irrigation and fish culture. In agricultural point of view this location would be suitable for setting water quality monitoring stations.
Geographic Location	Mouza: Ujan Bochagari, Union: Chandipur, Thana: Sundarganj, District: Gaibandha, Division: Rangpur

GPS Location Lat: 25˚31'6.00"N Long: 89˚39'4.50"E	

River Name: Jamuna

5. Sariakandi Kheya Ghat (Growin Bandh)	Bangali river flows on the western side of this location. Agricultural pollutants mix with Jamuna water at this location. An important fish sanctuary is located at this location. Sand is extracted from Jamuna River at this location. This location is also important for tourist place. Bangladesh Water Development Board also set their 3 water level stations near this location. This location is suitable for setting up monitoring stations in respect to fisheries and agricultural use of river water.
Geographic Location	Mouza: Batia, Union: Sariakandi, Thana: Sariakandi, District: Bogra. Division: Rajshahi
GPS Location Lat: 24˚53'30.20"N Long: 89˚34'55.40"E	
6. Tarakandi	Jamuna Fertilizer Company Ltd (JFCL) is located at this point. River water is used in the fertilizer factory. Pollutants mix with the river water from the factory. This location is important to set up water quality monitoring station for Industrial use point of view.
Geographic Location	Mouza: Kulpal, Union: Aona, Thana: Sarishabari, District: Jamalpur, Division: Dhaka

<table>
<tr><td>GPS Location

Lat: 24˚39'43.3"N
Long: 89˚48'47.3"E</td><td></td></tr>
<tr><td>7. Jamuna Eco Park</td><td>Jamuna river distributes fresh water to its distributaries Banshi river and this is the off take of Banshi river. This is a major pollution source of river erosion and agricultural pollutants. Jamuna Eco Park developed on the bank of the Jamuna river and near this location. The water that flows through Elenga is heavily used by Agricultural land in Kuiz Bari and Elenga area. This location is suitable for monitoring water to assess the water quality for Agricultural use.</td></tr>
<tr><td>Purpose of Monitoring</td><td>Agriculture</td></tr>
<tr><td>Geographic Location</td><td>Union: Saidabad, Thana: Sirajganj Sadar, District: Sirajganj, Division: Rajshahi</td></tr>
<tr><td>GPS Location

Lat: 24˚23'57.5"N
Long: 89˚45'11.5"E</td><td></td></tr>
<tr><td>8. Kakua</td><td>At east side of Kakua there is a large agricultural field. Agricultural pollutants mix with the mainstream of Jamuna river water at this point. This is a major source of fresh water and can be used for irrigation and fish culture. In agricultural point of view, this location would be suitable for setting up water quality monitoring stations.</td></tr>
<tr><td>Purpose of Monitoring</td><td>Agriculture</td></tr>
<tr><td>Geographic Location</td><td>Mouza: Kakua, Union: Kakua, Thana: Tangail Sadar, District: Tangail, Division: Dhaka</td></tr>
</table>

GPS Location Lat: 24˚19'6.7"N Long: 89˚47'41.5"E	
9. Mohonganj	Different aspects like dolphin habitat, surrounding broad agricultural field. A number of water level stations of BWDB and monitoring stations of DoE have made this point significant. The tributary Hurasagor of Jamuna River confluents at this location. Pollutants come from agricultural field and Baghabari power plant and mixes with river water surrounding this location. This location is suitable for setting monitoring station to assess water quality usable for Fisheries and Agriculture.
Geographic Location	Union: Bera Paurashava, Thana: Bera, District: Pabna, Division: Rajshahi
GPS Location: Lat: 24˚3'35.8"N Long: 89˚39'12.9"E	

River Name: Brahmaputra

10. Jamalpur Bridge	The major uses of water are for irrigation and domestic purposes. Non-point pollution sources casuse water pollution at this location. These pollution sources are pesticides and chemical fertilizers used in agricultural field and these mix with river water during rainy season.
Geographic Location	Mouza: Char Pakshimari, Union: Char Pakshimari, Thana: Sherpur Sadar, District: Sherpur, Division: Dhaka
GPS Location Lat: 24°55'30.76"N Long : 89°57'56.37"E	
11. Rail Bridge	Water mainly used for agricultural and domestic purposes. Pesticides use in the agricultural field and surface run-off from nearby settlements are the two main pollution sources.
Geographic Location	Char Ishwardia, Char Ishwardia, Mymensingh Sadar, Mymensingh
GPS Location: Lat: 24°44'30.94"N Long: 90°25'39.47"E	

River Name: Surma and Kushiara

12. Jamalganj	Water pollution happens at this locaiton from pesticide and chemical fertilizer usage in agricultural fields. Agriculture and Fisheries are the two major fields of water uses.
Geographic Location	Mouza: Telia Jamalpur, Union: Jamalganj, Thana: Jamalganj, District: Sunamganj, Division: Sylhet
GPS Location Lat: 25° 0' 5.9"N Long: 91° 14' 16.8"E	
13. Sunamganj Lunch Ghat	The sources of pollution at this point are non-point sources, such as agricultural land and surface run off from settlement areas. Due to freequent movement of water vehicles, grease and oil spill happens at this point. This water is used in agricultural field and settlement areas.
Geographic Location	Mouza: Tegharia (Part), Union: Lakshmansree, Thana: Sunamganj Sadar, District: Sunamganj, Division: Sylhet
GPS Location: Lat: 25˚ 4' 23.6"N Long: 91˚ 23' 37.5"E	
14. Chatak Ferry Ghat	Water pollution sources in this location are agricultural run off, industries basically Cement Factory, water way transportaion (oil and grease) and urban run off. The major uses of water are for agriculture, industrial purpose (Cement Factory), Transportation and domestic purposes.
Geographic Location	Mouza: Mandalibhog, Union: Chhatak Paurashava, Thana: Chhatak, District: Sunamganj, Division: Sylhet

GPS Location: Lat: 25° 2' 2.3"N Long: 91° 40' 20.3"E	
15. Shahjalal Bridge	Pollutants from surface run-off of settlement areas and oil spill from water way vehicles. Water is used for domestic as well as Municipal areas basically for domestic purposes.
Geographic Location	Union: Ward No-23, Thana: Kotwali, District: Sylhet, Division: Sylhet
GPS Location: Lat: 24°52'54.98"N Long: 91°52'46.34"E	
16. Kanaighat	Low concentration of settlements are found at this location. But the surrounding areas are characterized by intense agricultural practice. As pesticide & chemical fertilizer used in agriculture field and fish farms water pollutes from these sources. Water used mainly in agricultural land for irrigation.
Geographic Location	Mouza: Nandirai, Union: Kanaighat, Thana: Kanaighat, District: Sylhet, Division: Sylhet
GPS Location Lat: 25° 0'14.65"N Long: 92°15'31.91"E	

17. Bairagi Bazar	Low concentration of settlements are found at this location. But the surrounding areas are characterized by intense agricultural practice. Pesticide, Chemical fertilizer use for agriculture mix with river water. In addition, sediment pollution occurs during earth work in Brick Fields.
Geographic Location	Mouza; Saleshwar kuna, Union: Sheola, Thana: Beani Bazar, District: Sylhet, Division: Sylhet
GPS Location: Lat: 24°51'19.68"N Long: 92° 9'21.11"E	
18. Fenchuganj Fertilizer Industry	Low concentration of settlements are found at this location. But the surrounding areas are characterized by intense agricultural practice. Pesticide, Chemical fertilizer use for agriculture mix with river water. The large Fenchuganj Fertilizer Industry is located at this location.
Geographic Location	Mouza: Baksipu, Union: Uttarbag, Thana: Rajanagar, District: Moulvibazar, Division: Sylhet
GPS Location Lat.: 24°39'15.73"N Long: 91°54'17.80"E	

River Name: Buriganga River

19. Mirpur Bridge	The Mirpur Bridge is surrounded by large waterbodies, dense settlement, and a many red and orange-B categories of industries within the catchment of Buriganga River. The north-western part of the location is mainly agricultural field including a few waterbodies. The parsed waste dumping site of Dhaka City located beside N.R. CNG Filling Station at Savar comprises all kinds of wastes (medical, solid waste from Dhaka city and chemicals used in agricultural field). Two major cement factories stand on both sides of the river.
Geographic Location	Union: Ward No-09, Thana: Mirpur, District: Dhaka, Division: Dhaka
GPS Location: Lat: 23°47'8.13"N Long: 90°20'10.21"E	
20. Bosila Bridge	Wide agricultural field and waterbodies are seen at the western side of this location. The pollutants from commercial fish farms (specifically Pangash) and agricultural land flow and mix with Buriganga river. A large power plant is situated at the right side of Bosila bridge. Polluted water from the industry is released into the river. Fixing strategic location at this point will help assessing water quality before entering into industrial zone of Hazaribagh.
Geographic Location	Mouza: Washpur, Union: Sakta, Thana: Keraniganj, District: Dhaka, Division: Dhaka
GPS Location Lat: 23°44'35.26"N Long: 90°20'42.67"E	

<table>
<tr><td>21. Hazaribagh</td><td>Hazaribagh is a critical area as major industrial concentration is seen at this location. The major portions of industries located here are of red categories, the rest fall under the orange-B and orange-A catagories. About eleven effluent discharge outlets of industrial wastages including sewerage outlets are found at this location. Major pollution sources at this location are tannery and dying factories.</td></tr>
<tr><td>Geographic Location</td><td>Mouza: Brahmankita, Union: Kalindi, Thana: Keraniganj, District: Dhaka, Division: Dhaka</td></tr>
<tr><td>GPS Location:

Lat: 23°43'18.18"N
Long: 90°21'34.42"E</td><td></td></tr>
<tr><td>22. Sata Mosque Road</td><td>Sata Mosque is situated near the industrial zone at Kamrangirchar area. Many industries concentrate at this location. At least 10 effluents outlet are found in this area.</td></tr>
<tr><td>Geographic Location</td><td>Mouza: Brahmankita, Union: Kalindi, Thana: Keraniganj, District: Dhaka, Division: Dhaka</td></tr>
<tr><td>GPS Location

Lat: 23°42'28.67"N
Long: 90°22'6.69"E</td><td></td></tr>
<tr><td>23. Chandni Ghat</td><td>A channel through Hazaribagh, Hasannagar and Lalbagh area meets with Buriganga at Chandnighat location. Effluents from Hazaribagh industries mix with Buriganga river at this location. Four effluent outlets were found here. The industries of major portion located here are of red categories.</td></tr>
<tr><td>Geographic Location</td><td>Mouza: Zinjira, Union: Zinjira, Thana: Keraniganj, District: Dhaka, Division: Dhaka</td></tr>
</table>

GPS Location: Lat: 23°42'38.60"N Long: 90°23'27.58"E	
24. BD-China Friendship Bridge	Bangladesh-China Friendship Bridge is located in the industrial concentrated areas. The major portions of the industries located here are of red categories. A number of effluent outlets for industrial wastage discharge are found at this location.
Geographic Location	Mouza: Hasnabad (Nayatola), Union: Subhadya (part), Thana: Keraniganj, District: Dhaka, Division: Dhaka
GPS Location: Lat: 23°41'13.75"N Long: 90°25'36.40"E	
25. Fatullah	Both the sides of the Buriganga river at this location are characterized by settlements and agricultural land. This is the end point of Buriganga and the other part of Buriganga confluents with Dhaleswari and named Buriganga before meeting with Shitalakhya. Major sources of water pollution at this location are agriculture, industry, and commercial fish farming, like Pangas Farm, at Sata Mosque road.
Geographic Location	Mouza: Dapa Idrakpur (Dapa), Union: Fatullah, Thana: Narayanganj Sadar, District: Narayanganj, Division: Dhaka

GPS Location: Lat: 23°38'52.68"N Long: 90°28'0.93"E	

River Name: Turag

26. Turag Bridge	The severe polluted water from industries via various channels and outlets meets with Turag water at Turag Bridge point. The northern part of the location is mainly agricultural field including a few waterbodies having fish culture. Agricultural runoff from Bhadam, Bhakral, Jamaldia, KakilSataish areas contribute to major water pollution in Turag River at this location. The industries located surrounding this location are mainly readymade garments industry (Fashion industries, spinning, dying, textile, and knit composite) and steel mills. A large polluting industries of sweater and yearn dying is located at close distance to the location.
Geographic Location	Union: Tongi Paurashava, Thana: Gazipur Sadar, District: Gazipur, Division: Dhaka
GPS Location Lat: 23°53' 32.28" Long: 90°21' 36.1"	
27. Ashulia	The northern and southern parts of this location are agricultural field and waterbodies. Fish culture is found during rainy season when the quality of water is comparatively good. Water pollution happens here due to agricultural practice and industrial effluent discharge. The industries located at Ashulia are fashion industries, spinning mills, dying, textile mills, knit composite and steel mills. A large power plant is also located at Ashulia.

Geographic Location	Mouza: Chak Basaid, Union: Ashulia, Thana: Savar, District: Dhaka, Division: Dhaka
GPS Location Lat: 23° 53' 30.12" Long: 90° 20' 21.84"	
28. Kaliakoir	Bangshi river starts at this location in Kaliakoir. This is also a river oxbow has made this location important for fish culture specifically for carp fishes. The surrounding land is used mainly for agricultural practices which is the principal source of water pollution also. Bangladesh water development board has set their water level stations at this location.
Geographic Location	Mouza: Kaliakair, Union: Sreefaltali, Thana: Kaliakair, District: Gazipur, Division: Dhaka
GPS Location Lat: 24° 4' 57.72" Long: 90° 12' 53.64"	
29. Bhawal	The fish sanctuary Alua *beel* is located in Bhawal. This area is surrounded by waterbodies and broad agricultural fields. Pollutants from agricultural land mix with Turag water at the surrounding areas of this location. Branches of the Turag confluent with main Turag at Bhawal. All the aspects have made this location important as a strategic point. This location is suitable for monitoring water quality in respect to fisheries and agriculture.
Geographic Location	Mouza: Tekibari, Union: Kayaltia, Thana: Gazipur Sadar, District: Gazipur, Division: Dhaka

GPS Location Lat: 24° 2' 7.08" Long: 90° 20' 48.84"	
30. Nama Bazar	Nama Bazar is located at Kashimpur union of Gazipur Sadar Upazila. Kashimpur High School is very close to this location. Both industrial pollution and agricultural pollution happens here.
Geographic Location	Mouza: Kasimpur, Union: Kashimpur, Thana: Gazipur Sadar, District: Gazipur, Division: Dhaka
GPS Location: Lat: 23°59'1.64"N Long: 90°19'43.71"E	

River Name: Shitalakhya

31. Port Road	A canal from Hajiganj area meets with Shitalakhya carrying industrial pollutants. Many industries are concentrated around this location. Industries located at this area are fibre glass, screen printing, washing plants, pharmaceuticals, knit wears, garments.
Geographic Location	Union: Kadam Rasul Paurashava, Thana: Bandar, District: Narayanganj, Division: Dhaka
GPS Location Lat: 23° 37' 41.52" Long: 90° 30' 58.68"	
32. Majhira (Demra Ghat)	The Demra Ghat point is located at Shitalakhya where Balu joins with Shitalakhya. Heavy industrial effluents are discharged into Shitalakhya rivers at Demra Ghat point. The surroundings of the location are built up area and industrial concentrations. The industries found here are rerolling steel mills, textile mills, dyeing industries, plastic and polymers, fibre glass, jute mills and others.
Geographic Location	Mouza: Taraba, Union: Tarabo, Thana: Rupganj, District: Narayanganj, Division: Dhaka
GPS Location Lat: 23° 43' 17.04" Long: 90° 30' 11.16"	
33. Murapara (Rupganj)	This location is characterized by agricultural agglomeration, fish culture, and inland waterbodies. Industrial concentration and discharge of industrial pollutants are the major aspect of water pollution here. The

	industries found at this location are cement, textile, fabrics, knit composite, sweater factories, salt industries, paper mills, concrete mills, and dyeing industries BWDB also set their water level stations at this location.
Geographic Location	Mouza: Mangalkhali, Union: Mura Para, Thana: Rupganj, District: Narayanganj, Division: Dhaka
GPS Location Lat: 23° 47' 24.72" Long: 90° 31' 31.44"	
34. Ghorashal Fertilizer Industry	This location is selected as baseline station. Ghorashal Fertilizer Industry is located near this point.
Geographic Location	Mouza: Khanpur, Union: Char Sindur, Thana: Palash, District: Narsingdi, Division: Dhaka
GPS Location Lat: 23° 47' 24.72" Long: 90° 31' 31.44"	

River Name: Dhaleswari

35. Mukterpur Bridge	This is the confluence of river Buriganga and Dhaleswari and renamed as Buriganga at this location. Wide agricultural land, high concentration of brick fields and establishment of cement factories are the main characters of this area. Due to high discharge, water quality is better in comparison to other parts of the river.
Geographic Location	Mouza: Paschim Moktarpur, Union: Panchasar, Thana: Munshiganj Sadar, District: Munshiganj, Division: Dhaka
GPS Location Lat: 23°34'9.91"N Long: 90°30'43.22"E	
36. Patharghata	The surrounding location of Patharghata is mainly agricultural field. Few industries flourished near this location. Runoff from agricultural field and industrial effluent are the major pollution sources of the river Dhaleswari at this point.
Geographic Location	Mouza: Char Galgalia, Union: Basail, Thana: Serajdikhan, District: Munshiganj, Division: Dhaka
GPS Location Lat:23°38'8.32"N Long: 90°21'44.56"E	
37. Ruhitpur (BSCIC Ind.)	The surrounding location of Ruhitpur is mainly agricultural field. Few industries flourished near this location. BSCIC Industrial belt is also located near this point. Runoff from agricultural field and industrial effluents are the major pollution sources of the river Dhaleswari at this point.

Purpose of Monitoring	Agriculture
Geographic Location	Mouza: Sonakanda, Union: Ruhitpur, Thana: Keraniganj, District: Dhaka, Division: Dhaka
GPS Location: Lat: 23°39'40.31"N Long: 90°18'34.56"E	
38. Hazratpur	Extensive agricultural practices are seen at Hazratpur area. The water carried by Dhaleswari is sweet and suitable to be used for irrigation. The water pollution source at Hazratpur is mainly non-point agricultural practice. The river oxbow at this location is important for fish culture.
Geographic Location	Mouza: Hazratpur, Union: Hazratpur, Thana: Keraniganj, District: Dhaka, Division: Dhaka
GPS Location: Lat: 23°43'59.59"N Long: 90°15'4.75"E	
39. Horindhora (CETP)	This location is selected to specifically monitor the pollution caused by tannery industry. The industries shifted from Hazaribagh to Hemayet are located near this location in Tannaery Shilpa Nagori at Hemayetpur in Savar. The Central Effluent Treatment Plant (CETP) is also located at this location shown in the below picture.
Geographic Location	Mouza: Char Narayanpur, Union: Hazratpur, Thana: Keraniganj, District: Dhaka, Division: Dhaka

GPS Location Lat: 23°46'19.73"N Long: 90°14'15.21"E	
40. Uttor Mitora	The river water of Dhaleswari is comparatively better at this location. No industrial pollution has been found in this area. Slight sediment pollution happens here due to river bank erosion. This location is considered as baseline station.
Geographic Location	Mouza: Uttar Mitara, Union: Betila Mitara, Thana: Manikganj Sadar, District: Manikganj, Division: Dhaka
GPS Location Lat: 23°49'3.80"N Long: 90° 3'16.60"E	

River Name: Kaliganga

41. Beutha Ghat	Water use at this locaiton is mainly for irrigation and domestic pourposes. The area is highly concentrated with agricultural practices. Pollutions are coming from non-point sources such as pesticide & chemical fertilizer used in agriculture fields and settlements. This strategic location would be suitable for monitoring of river water in respect to agriculture and fisheries point of view.
Geographic Location	Union: Manikganj Paurashava, Thana: Manikganj Sadar, District: Manikganj, Division: Dhaka
GPS Location: Lat: 23°50'46.29"N Long: 90° 0'7.59"E	

River Name: Balu

42. Trimohini Bridge	There is no major use due to severe pollution from industries around this location. But people frequently use this location for water transport ways. Swerage effluent from Dhaka city through Balu canal and surrounding industrial effluents are responsible for water pollution in this location.
Geographic Location	Union: Demra (part), Thana: Sabujbagh, District: Dhaka, Division: Dhaka
GPS Location Lat: 23°45'36.57"N Long: 90°27'46.05"E	
43. Jalshiri Abashon	No major use due to severe pollution due to pollution. But people frequently use this location for water transport ways. Swerage effluent from Dhaka city through Balu canal, surrounding industrial effluents
Geographic Location	Mouza: Naora, Union: Kayet Para, Thana: Rupganj, District: Narayanganj, Division: Dhaka

GPS Location: Lat: 23°48'46.02"N Long: 90°29'4.33"E	

Name of River: Padma River

44. Barha Ghat	The distributary Ilishmari river carry's water from Padma river to the horizon of agricultural land in Dohar area. Few red category industries are situated on both the banks of Ilishmari river. Industrial effluents and pollutants from Padma river are major concerns for irrigation. Near the Ilishmari river an important fish sanctuary is located. All these factors are considered while selecting Shilakotha as the strategic location considering agriculture and fisheries.
Geographic Location	Mouza: Dakshin Bahra, Union: Nayabari, Thana: Dohar, District: Dhaka, Division: Dhaka
GPS Location: Lat: 23°38'26.15"N Long: 90° 2'35.86"E	
45. Nort Beak Martin Island	Nort Beak Martin is situated on a confluence of Padma and Arialkhan river. The main use of surrounding land is agriculture and contributes agricultural pollution. There are three fish sanctuaries located in this area. Bangladesh Water Development Board (BWDB) set a water level station near this location. This location would be suitable for monitoring water quality in respect to Agriculture.
Geographic Location	Mouza: Karalkandi, Union: Char Nasirpur, Thana: Sadarpur, District: Faridpur, Division: Dhaka

GPS Location Lat: 23°28'38.35"N Long: 90° 6'22.24"E	
46. Mawa Ghat	Mawa ghat is an important junction for waterways. On the eastern side of this location intensive agricultural practices are found. The main pollution source for Padma river is agricultural fields. Bangladesh water development board set their water level stations at this location. From the agricultural point of view, this location has been set for water quality monitoring stations.
Geographic Location	Mouza: Mawa, Union: Medini Mandal, Thana: Lohajang, District: Munshiganj, Division: Dhaka
GPS Location Lat: 23°28'18.20"N Long: 90°15'23.06"E	
47. Puran Bazar	Puran Bazar is situated on a confluence of Padma and Dakatia river. This area is characterized by submerged waterbodies and agricultural land. Agricultural pollutants flows in via Dakatia River and finally mix with Padma water. The most important Hilsha fish sanctuary is located in this area. Such aspects are considered while selecting this location as strategic point from the point of view of fisheries.
Geographic Location	Union: Chandpur Paurashava, Thana: Chandpur Sadar, District: Chandpur, Division: Chittagong

GPS Location: Lat: 23°13'47.78"N Long: 90°38'27.47"E	

Name of River: Dakatia River

48. Pal bazar Bridge	The Palbazar bridge locatin is surrounded by dense settlements and busy growth center. Everyday a large number of urban runoff is discharged in the river directly from this point. The municipal sewerage line is 500 meters upstream, through this sewerage line the total effluents are directly discharged in the river. Also transportation of wholesale goods are unloaded at the *kheya ghat*.
Geographic Location	Union: Chandpur Paurashava, Thana: Chandpur Sadar, District: Chandpur, Division: Chittagong
GPS Location: Lat: 23°13'12.6"N Long:90°39'01.4"E	
49. Dhali Ghat, Dakatia	The Dhalighat is an important strategic location, as it has some dockyards around the point. In these yards launch and pontoons are repaired and recolored. So the chances of oil spillage, residue from welding and colour mixes in the river. Also there are 5 brickfields upstream to the point, which makes the point more prone to pollution.
Geographic Location	Mouza: Bara Raghunathpur, Union: Sakhua, Thana: Chandpur Sadar, District: Chandpur, Division: Chittagong

GPS Location Lat: 23°12'12.4"N Long:90°40'22.2"E	
50. Gazibari Road	This strategic location is situated besides Chandpur 150MW combined cycle power plant. Mostly cooling water from the power plant and urban runoff from surroundings is discharged near this location. Downstream from this point, water is collected for municipality supply of Chandpur. Thus, this point stands as a special strategic location
Geographic Location	Mouza: Gunrajdi, Union: Tarpur Chandi, Thana: Chandpur Sadar, District: Chandpur, Division: Chittagong
GPS Location: Lat: 23°13'30.1"N Long:90°40'09.3"E	
51. Hajiganj Bazar Bridge	The water of this river is used for domestic as well as irrigation purposes. Discharge of urban runoff, solid and liquid waste from growth center and use of Pesticides for agricultural runoff are mainly responsible for water pollution at Hajiganj Bazar Bridge areas.
Geographic Location	Mouza: Randhanimura, Union: Paschim Barkul, Thana: Hajiganj, District: Chandpur, Division: Chittagong
GPS Location: Lat: 23° 14' 48.81"N Long: 90° 51' 10.33"E	

River Name: Meghna

52. Meghna Ghat Power Plant	Meghna Ghat power plant is located near Meghna Bridge at Pirganj union of Sonargaon Thana. This is a global flux station for Meghna river. Moreover, a significant number of polluting industries are located in this region.
Geographic Location	Mouza: Char Ramjan Sonaullah, Union: Pirijpur, Thana: Sonargaon, District: Narayanganj, Division: Dhaka
GPS Location: Lat: 23°36'29.70"N Long: 90°36'49.30"E	
53. Ananda Bazar	Ananda Bazar is located at Baradi Union in Sonargaon Thana. A tributary is located at this location. This location is suitable as an flux tributary strategic location.
Geographic Location	Mouza: Baradi, Union: Baradi, Thana: Sonargaon, District: Narayanganj, Division: Dhaka
GPS Location: Lat: 23°40'43.40"N Long: 90°38'13.40"E	
54. Bishnandi	A few tributaries meet at this location with the main stream of Meghna river. Bishnandi is located at Bishnandi Union of Araihazar Thana. Very mild settlement and human intervention are seen at in this locality. Pollutants from agricultural field also contribute through a few canals.
Geographic Location	Mouza: Bishnandi, Union: Bishnandi, Thana: Araihazar, District: Narayanganj, Division: Dhaka

GPS Location: Lat: 23°46'5.47"N Long: 90°43'32.60"E	
55. Narshingdi Launch Terminal	Narshingdi Launch Terminal is located in Narshingdi Pourashava in Narshingdi Sadar Thana. This is also flux tributary monitoring station. Industrial pollutants mix with Meghan water at this location. The water is seen blakish here.
Geographic Location	Union: Narsingdi Paurashava, Thana: Narsingdi Sadar, District: Narsingdi, Division: Dhaka
GPS Location: Lat: 23°54'51.55"N Long: 90°43'9.92"E	
56. Bhairabbazar	Bhairabbazar is located at Bhairab bazar Pourashava in Bhairab Thana. This a baseline station for this river. Pollutants get mixed with this water from urban run off, agricultural field via a few canals.
Geographic Location	Union: Bhairab Paurashava, Thana: Bhairab, District: Kishoreganj, Division: Dhaka
GPS Location: Lat: 24° 2'36.15"N Long: 90°59'23.14"E	

River Name: Titas

57. Bakail Bridge (Titas)	Agricultural practices are seen near this strategic location. Pollutants are coming from non-point sources, such as pesticides used in the agricultural fields and brickfields. This location would be suitable for setting monitoring stations in respect to agricultural and industrial point of view.
Geographic Location	Mouza: Sahbazpur, Union: Shahbazpur, Thana: Sarail, District: Brahmanbaria, Division: Chittagong
GPS Location: Lat: 24° 2'42.61"N Long: 91°10'39.21"E	
58. Titas Rail Bridge	The surrounding area of this strategic location is characterized by dense agricultural practices. Pollutants are coming from non-point sources, such as pesticides used in the agricultural fields. This location would be suitable for setting monitoring stations in respect to fisheries and agricultural point of view.
Geographic Location	Mouza: Akhaura, Union: Akhaura Paurashava, Thana: Akhaura, District: Brahmanbaria, Division: Chittagong
GPS Location: Lat: 23°52'43.49"N Long: 91°12'0.03"E	

River Name: Karatoya

59. Dottobari	Dense settlement is seen near this strategic location. Pollutants are coming from the municipal area and the pesticides used in the agricultural field. Agricultural practices are also seen near this location. This location would be suitable for setting monitoring stations in respect to agricultural and industrial point of view.
Geographic Location	Mouza: Chilu Para, Union: Shabgram, Thana: Bogra Sadar, District: Bogra, Division: Rajshahi
GPS Location: Lat: 24°51'17.58"N Long : 89°22'26.19"E	
60. Aziz Ahmed Taki Road	The water from Karatoya river is used for domestic purposes, municipal purposes as well as for irrigation purposes.Moderate to mild concentration of settlement is found in this location. Sewage effluent also get mixed with the river water here. In addition agricultural runoff causes water pollution.
Geographic Location	Mouza: Natai Para (Part-B), Union: Shabgram, Thana: Bogra Sadar, District: Bogra, Division: Rajshahi
GPS Location: Lat: 24°50'37.02"N Long: 89°22'54.36"E	
61. Sultanganj-Gabtoli Road	The surrounding area of this strategic location is characterized by agricultural fields and several brickfields. Pollutants are coming from non-point sources, such as pesticides used in the agricultural field.

	Some pollutants also come from brickfields. This location would be suitable for setting monitoring stations in respect to industrial and agricultural point of view.
Geographic Location	Mouza: Chanchaitara, Union: Madla, Thana: Bogra Sadar, District: Bogra, Division: Rajshahi
GPS Location: Lat: 24°48'4.94"N Long: 89°24'24.92"E	

River Name: Ganges

62. Sardah	Sardah is located in Rajshahi district. This location is surrounded by broad agricultural fields. Water pollution happens at this location due to agricultural pollutants.
Purpose of Monitoring	Agriculture
Geographic Location	Union: Harian, Thana: Paba, District: Rajshahi, Division: Rajshahi
GPS Location Lat: 24° 21' 41.16" Long: 88° 35' 52.95"	
63. Nurullapur	Nurullapur is located at Natore district. The surrounding area is heavily characterized by agricultural practices. Pollution of river water happens mainly due to agricultural practices.
Geographic Location	Mouza: Nurullapur, Union: Ishwardi, Thana: Lalpur, District: Natore, Division: Rajshahi

GPS Location Lat: 24˚10'5.7"N Long: 88˚59'34.1"E	
64. Gorai Off Take	Gorai Off Take is located at Talbaria, Muradpur in Kushtia which contributes water to Gorai river from Ganges. The surrounding area is heavily characterized by agricultural practices and fish culture. Pollution of river water happens mainly due to agricultural practices. Sand is extracted from river in this location. Bangladesh Water Development Board (BWDB) also set their water level stations at this location.
Geographic Location	Mouza: Mahanagar, Union: Hatas Haripur, Thana: Kushtia Sadar, District: Kushtia, Division: Khulna
GPS Location Lat: 23˚57'2.4" N Long: 89˚06'39.1"E	
65. Kanchan Park	Kanchan Park is located at Sujanagar of Pabna district. The surrounding area is heavily characterized by agricultural practices. Pollution of river water happens mainly due to agricultural practices. Sand is extracted from the river near this location. This location is suitable for setting water quality monitoring stations in respect to agricultural use only.
Geographic Location	Mouza: Nurullapur, Union: Ishwardi, Thana: Lalpur, District: Natore, Division: Rajshahi

GPS Location Lat: 23° 52' 11.12"N Long: 89° 27' 6.16"E	

River Name: Gorai

66. Kamarkhali Bridge	This location is used as trensportation way. People use water from this river for irrigation as well as bathing purposes. The surrounding area is heavily characterized by agricultural practices. Pollution of river water happens mainly due to agricultural practices.
Geographic Location	Mouza: Rajdharpur, Union: Nakol, Thana: Sreepur, District: Magura, Division: Khulna
GPS Location: Lat: 23° 32' 9.77"N Long: 89° 31' 47.69"E	

River Name: Modhumoti

67. Dhalaitala	The area is highly concentrated with agricultural practices. Pollutions are coming from non-point sources such as pesticide & chemical fertilizer used in agriculture field. This strategic location would be suitable for monitoring of river water in respect to agriculture and fisheries point of view.
Geographic Location	Mouza: Kuraltala, Union: Kotakul, Thana: Lohagara, District: Narail, Division: Khulna
GPS Location Lat: 23° 8'19.78"N Long: 89°40'40.66"E	
68. Patgati - Nazimpur	Water is used for Irrigation and fisheries purposes. In the Brickfields at Patgati, river water is also used. Agricultural runoff are mainly responsible for water pollution here. Beside this, sediment pollution occurs during earth work of Brick preparation.
Geographic Location	Mouza: Patgati, Union: Patgati, Thana: Tungipara, District: Gopalganj, Division: Dhaka
GPS Location: Lat: 22° 52' 52.2" N Long: 89° 53' 44.08" E	

River Name: Mathavanga

69. Dorshona Railway Junction	The surrounding area is heavily characterized by agricultural practices. Pollution of river water happens mainly due to agricultural practices. This location is used as transportation way. People use water from this river for irrigation as well as bathing purposes.
Geographic Location	Union: Darshana Paurashava, Thana: Damurhuda, District: Chuadanga, Division: Khulna
GPS Location Lat: 23°31'25.28"N Long: 88°47'20.30"E	

River Name: Kankshiali

70. Kaliganj Bazar Bridge	The main use of water at the surrounding area of Kaliganj Bazar Bridge is water way transport, brakish water fishing culture and domestic use. Runoff from shrimp farms and settlement areas are the polutant sources.
Geographic Location	Mouza: Kakshiali, Union: Tarali, Thana: Kaliganj, District: Satkhira, Division: Khulna
GPS Location: Lat: 22°27'27.82"N Long: 89° 2'1.84"E	
71. Boshontopur	People make use of water for shrimp culture and agricultural purpose. As this river is in the saline zone, other brakish water fishing is found here

	by the poor people. Some people collect shrimp fry, specially the women collect shrimp fry to lead their families. Pesticide and chemical fertilizer used in agricultural fields mix with the water of Kankshialy river. The other pollutants are fish feed waste that comes from the surrounding shrimp enclosures.
Geographic Location	Mouza: Kamdebpur, Union: Bhara Simla, Thana: Kaliganj, District: Satkhira, Division: Khulna
GPS Location Lat: 22°28'23.34"N Long: 89° 0'21.04"E	
72. Uzirpur, Gobindakathi	People make open water fishing, use water for shrimp farming as well as for brickfields. Surface run off from Hat-bazar (market places), agriculture field and fish feed waste from Shrimp farms. Sediment pollution also happens here from the brickfields.
Geographic Location	Mouza: Uzirpur, Union: Champaphul, Thana: Kaliganj, District: Satkhira, Division: Khulna
GPS Location Lat: 22°30'45.09"N Long: 89° 7'38.64"E	

River Name: Bhairab

73. Bashundia Bazar	The area is highly concentrated with agriculture practices. People use river water for domestic purposes and agricultural fields. Pollutants are coming here from different sources such as hat-bazar and agriculture fields.
Geographic Location	Mouza: Aladipur, Union: Basuari, Thana: Bagher Para, District: Jessore, Division: Khulna
GPS Location Lat: 23° 8'14.76"N Long: 89°22'8.90"E	
74. Noapara Ferry Ghat	Water of Bhairab at this point is used mainly for water way transport facilities. Pollution happens due to surface run off and industrial effluents. From the ferry ghat grease and lubricant oil pollution happens at this location.
Geographic Location	Mouza: Noapara, Union: Abhaynagar Paurashava, Thana: Abhaynagar, District: Jessore, Division: Khulna
GPS Location: Lat: 23° 0'42.12"N Long: 89°24'57.63"E	
75. Taltola, Noapara	Water of Bhairab at this point is used mainly for water way transport facilities. Pollution happens due to surface run off and industrial effluents. This location is gradually becoming industrial and getting risk of industrial pollution.
Geographic Location	Mouza: Jafarpur, Union: Abhaynagar Paurashava, Thana: Abhaynagar, District: Jessore, Division: Khulna

GPS Location: Lat: 23° 0'42.12"N Long: 89°24'57.63"E	
76. Fultala Ghat	There is no specific use of river water at this point. This river is used as inland navigational route from Khulna to Fultala, Noapara and other surrounding areas. Pollutants come from surface run off at hat-bazar, fallow land, brickfields and settlement areas.
Geographic Location	Mouza: Dhulgram, Union: Siddhipasha, Thana: Abhaynagar, District: Jessore, Division: Khulna
GPS Location: Lat: 22°58'38.76"N Long: 89°28'41.29"E	

River Name: Rupsha

77. Gilatala	Gilatola is comparatively a low lying area surrounded by agricultural land and shrimp farms. Pollutants are mainly coming here from agricultural land. At this location the river Moyuri is also connected with the Modhumoti and undergoes diurnal tidal effect.
Geographic Location	Mouza: Nadan Pratap, Union: Barakpur, Thana: Dighalia, District: Khulna, Division: Khulna
GPS Location: Lat: 22°55'39.44"N Long: 89°30'53.23"E	
78. Charer Hat	Charer hat is a comparatively low lying area located in Rupsa. Pollutants are coming from non-point sources, such as agricultural land. Canals connected with this river contain fresh water round the year used as fish culture and irrigation.
Geographic Location	Mouza: Sulpur, Union: Aijganti, Thana: Rupsa, District: Khulna, Division: Khulna
GPS Location: Lat: 22° 50' 52.34"N Long: 89° 33' 37.02"E	
79. Kalibari Ghat	Runoff from agricultural land on both sides of old Rupsa river is the major cause of water pollution at this location. In addition, pollutants are also coming from other sources like shrimp farms, fish farms etc. Few industries

	are also found near this location especially frozen fish and fish processing industries.
Geographic Location	Mouza: Aijganti, Union: Aijganti, Thana: Rupsa, District: Khulna, Division: Khulna
GPS Location: Lat: 22° 49' 11.68"N Long: 89° 34' 18.45"E	
80. Rupsa Ghat (Old)	Rupsha ghat region is a comparatively low lying area. Pollutants come from non-point sources, such as- agricultural land, shrimp, or fish farms etc. Many industries are found at this location. This is a strategic location and would be suitable for monitoring river water for fisheries, agriculture and industrial use.
Geographic Location	Mouza: Jabusa, Union: Naihati, Thana: Rupsa, District: Khulna, Division: Khulna
GPS Location: Lat: 22° 47' 18.25"N Long: 89° 35' 13.55"E	

River Name: Moyuri

81. Shashan Ghat	Bulk garbage is being disposed from Boyra area into Moyuri river in Shashanghat area. Sewerage disposal are the major pollution source for Moyuri river in this area. Moyuri river carries fresh water round the year.
Geographic Location	Mouza: Alutala, Union: Jalma, Thana: Batiaghata, District: Khulna, Division: Khulna
GPS Location: Lat: 22° 47' 48.81"N Long: 89° 32' 35.19"E	
82. Buro Moulavir Darga	Moyuri river caries fresh water from surrounding areas and supplies to Rupsa. Land on both sides of the Moyuri river is used for agriculture and the river carries agricultural pollutant loaded runoff. There is a river oxbow band near the selected location which is suitable for fish culture specifically carp fishes.
Geographic Location	Mouza: Alutala, Union: Jalma, Thana: Batiaghata, District: Khulna, Division: Khulna
GPS Location: Lat: 22° 47' 48.00"N Long: 89° 32' 35.52"E	
83. Dosh Gate	Moyuri river confluent at this location with Rupsha contributing fresh water. Daosh gate is located in Labonchora where agriculture is practiced widely. Moyuri river is mainly polluted by agricultural runoff, sewerage effluents, and industrial pollutants of whole Khulna City.
Geographic Location	Mouza: Tentultala, Union: Jalma, Thana: Batiaghata, District: Khulna, Division: Khulna

GPS Location: Lat: 22° 45' 29.60"N Long: 89° 33' 4.90"E	

River Name: Pashur

84. Kazibacha-Batiaghata Bypass	Local people use this water for open water fishing, shrimp farming as well as for brickfields. As a result, there is surface run off from agriculture field and fish feed waste from Shrimp farms. Sediment pollution is also happens here from the brick fields.
Geographic Location	Mouza: Hatbaria, Union: Batiaghata, Thana: Batiaghata, District: Khulna, Division: Khulna
GPS Location: Lat: 22°44'32.63"N Long: 89°31'18.01"E	
85. Rampal Power Plant	The strategic location Rampal Power Plant is situated at Rampal Upazila of Bagerhat District in Khulna, Bangladesh. River water will be used in the power plant. The Rampal Power Plant would draw 219,600 cubic metres of water every day from the Poshur River, and discharge treated waste water back into that river causing pollutants to be introduced into the water supply to the detriment of the mangroves, the marine animals living there and nearby population. This location would be suitable for setting monitoring stations in respect to industrial point of view.
Geographic Location	Mouza: Sapmari Katakhali, Union: Rajnagar, Thana: Rampal, District: Bagerhat, Division: Khulna

GPS Location: Lat: 22°34'59.96"N Long: 89°32'56.63"E	
86. Banishanta	The river Mongla confluents at this location. Mongla river carries industrial pollutants and contributes to Pashur river. Mongla port is situated at the eastern side of Pashur river. This location would be suitable for setting monitoring stations in respect to fisheries and industrial point of view.
Geographic Location	Mouza: Banishanta, Union: Banishanta, Thana: Dacope, District: Khulna, Division: Khulna
GPS Location: Lat: 22°27'59.39"N Long: 89°35'25.31"E	

River Name: Sughandha

87. Gab Khan Launch Terminal	This point is situated in Jhalakhatidistrict. This is a transportation place which discharges transport related pollutants. On the opposite side of the point, there are agricultural fields, from which pesticide induced agricultural runoff mix with the river. Jhalakhati sewerage discharge comes from the north of the point.
Geographic Location	Mouza: Charkati, Union: Gabkhan Dhansiri, Thana: Jhalokati Sadar, District: Jhalokati, Division: Barisal
GPS Location: Lat: 22°37'38.83"N Long:90°10'40.35"E	

Name of River: Kirtankhola River

88. Dopdopia Kheya Ghat	Dapdapia kheya ghat is located at the southwest side of Barishal town. This kheya ghat is a junction for transportation and there is a bazar surrounding this area. Adjacent to the kheya ghat, there is a cement factory. On the south and eastern side of the point, there is vast agricultural land. From there large amounts of agricultural runoff is discharged into the river.
Geographic Location	Mouza: Paschim Char Dapdapia, Union: Dapdapia, Thana: Nalchity, District: Jhalokati, Division: Barisal
GPS Location: Lat: 22° 39' 26.68"N Long: 90° 20' 2.40"E	

89. Kauar Char Ferry Ghat	Kirtankhola is a river that starts from Sayeshtabad in Barisal district and ends into the Gajalia near Gabkhan khal. The total length of the river is about 160 kilometres. The Kauarchar Ferry ghat is the one of the busiest water transportation junction of this river. Everyday a huge number of inter district water transport docks here. Oil spillage and residue of urban runoff is the key point to select this strategic location.
Geographic Location	Mouza: Kaua Char, Union: Char Kowa, Thana: Barisal Sadar (kotwali), District: Barisal, Division: Barisal
GPS Location: Lat:22°41'50.71"N Long: 90° 22' 33.68"E	

Name of River: Tetulia River

90. Veduriya Ferry Ghat	This is a river confluent. Barishal-Bhola highway ends at this location. The surrounding land is characterized by agricultural practices. Runoff from agricultural field and residues of water transports cause water pollution. Oil spill pollution also happens here from waer way vehicles. Natural fishing ground, agricultural use and water way transportation key three aspect of water use in this locaiton.
Geographic Location	Mouza: Char Vheduria, Union: Vheduria, Thana: Bhola Sadar, District: Bhola, Division: Barisal
GPS Location: Lat.: 22° 42' 18.0"N Long: 90° 33' 51.5"E	

River Name: Karnaphuli

91. Chittagong Urea Fertilizer Factory Ltd (CUFL)	CUFL point is located near Anowara, Chittagong. Large industries concentrate such as Di-Ammonium Phosphate Fertilizer, Chittagong Urea Fertilizer Factory Ltd (CUFL) and Karnaphuli Fertilizer Company Ltd located at this point. River water uses in the fertilizer factory. Pollutant comes to the river from the factory. From the point of view of industrial use of water, this location is important to set water quality monitoring station..
Geographic Location	Mouza: Ragadia, Union: Bairag, Thana: Karnafuli, District: Chittagong, Division: Chittagong
GPS Location: Lat: 22˚14'19.6"N Long: 91˚49'41.2"E	
92. TSP Location	TSP point is located near Patenga road. Large industries concentrate at this location. Bangladesh Metrological Department set their monitoring station at this location. Pollutants are coming from point sources. This location is important to set water quality monitoring station for Industrial use point of view.
Geographic Location	Union: Ward No-40, Thana: Patenga, District: Chittagong, Division: Chittagong,
GPS Location: Lat: 22˚16'32.4"N Long: 91˚48'4.3"E	

93. Shikalbaha Power Station	The distributaries Murari Khal carrier's water from Karnaphuli to the horizon of agricultural land in Shikalbaha area. Few red category industries are also situated on the bank of Karnaphuli river such as Shikalbaha Power Station and Western Marine Shipyard at this location. Industrial effluents and pollutants from Karnaphuli river are the major concern for irrigation here. All of these factors are considered while selecting Shikalbaha as the strategic location considering agriculture and fisheries.
Geographic Location	Mouza: Dwip Kalamoral, Union: Sikalbaha, Thana: Karnafuli, District: Chittagong, Division: Chittagong
GPS Location: Lat: 22˚19'17.2"N Long: 91˚52'7.2"E	
94. Kalurghat Bridge	The river Halda confluents at this location with Karnaphuli river and both the rivers have diurnal effects. Halda river carries agricultural pollutants and contributes to Karnaphuli mainstream. Halda is a natural breeding ground for fisheries. This location would be suitable for setting monitoring stations in respect to fisheries and agriculture.
Geographic Location	Union: Ward No-05, Thana: Chandgaon, District+Division: Chittagong
GPS Location: Lat: 22˚24'12.0"N Long: 91˚53'31.9"E	

95. Mariam Nagar	The area is highly concentrated with agricultural practices. Pollutions are coming from non-point sources such as pesticide & chemical fertilizer used in agriculture field. Some of the pollutant come from brickfields. Two water level station of BWDB is located near this point. From many aspects, this is a strategic location for water quality monitoring for agriculture and fisheries use.
Geographic Location	Mouza: Katakhali, Union: Mariamnagar, Thana: Rangunia, District: Chittagong, Division: Chittagong
GPS Location: Lat: 22˚26'58.9"N Long: 92˚4'43.5"E	
96. Karnaphuli Paper Mills (KPM)	A large area is used for tea gardening near this location. The Karnaphuli Paper Mill is located here. The distributaries of Karnaphuli carries polluted water to nearby large agricultural lands. This river is a natural fish breeding ground and fish culture.
Geographic Location	Mouza: Narangiri, Union: Raikhali, Thana: Kaptai, District: Rangamati, Division: Chittagong
GPS Location: Lat: 22˚28'17.9"N Long: 92˚8'20.3"E	

River Name: Halda

97. Maduna Ghat	Maduna Ghat is a very important location for the supply of drinking water, agricultural practices and fish culture. Maduna Water Treatment Plant is constructed near the strategic location for the supply of drinking water in Chittagong city. Pollutants are coming from non-point sources, such as brickfields and agricultural land. This strategic location is selected as the baseline point for monitoring water quality.
Geographic Location	Mouza: Dakshin Madrasha, Union: Dakshin Madarsha, Thana: Hathazari, District: Chittagong, Division: Chittagong
GPS Location: Lat: 22˚26'0.60"N Long: 91˚52'20.0"E	
98. Garduara Sluice Gate	This is the most important natural fish breeding ground. Here river water is also used for irrigation purposes.Pollutants are coming from non-point sources, such as brickfields and agricultural land.
Geographic Location	Mouza: Garduara, Union: Garduara, Thana: Hathazari, District: Chittagong, Division: Chittagong
GPS Location: Lat: 22° 30' 7.62"N Long: 91° 51' 5.61"E	

99. Halda Bridge	Two Canals (Sattar Khal and Boalia Khal) meet at Halda Bridge point and carry agricultural pollutants from the surrounding area. This point is a very important location for natural fish breeding ground. Also, the local people use river water for bathing and domestic use near the strategic location. This strategic location would be suitable for monitoring of river water in respect to fisheries, agriculture, and domestic use.
Geographic Location	Mouza: Gahira, Union: Gahira, Thana: Raozan, District: Chittagong, Division: Chittagong
GPS Location: Lat: 22˚30'53.6"N Long: 91˚50'44.4"E	

3. Standardization of Water Quality Parameters

3.1 Review of Existing Water Quality Parameters

Standard water quality parameters proposed by different organization of different countries has been collected and reviewed to finalize important parameters and their standard values for drinking, fisheries, agricultural/irrigation and industrial water usage.

In Bangladesh, Environmental standards promulgated under the Environment Conservation Rules 1997 are prescribed for varying water sources, ambient air, noise, odour, industrial effluent and emission discharges, vehicular emission and others with the main aim of limiting the volume and concentrations of pollution discharged into the environment. A number of surrogate pollution parameters like Dissolve Oxygen, Biochemical Oxygen Demand, or Chemical Oxygen Demand; Total Suspended Solids are specified in terms of concentration and/or total allowable quality discharged in case of waste water and solid waste. Additionally specific parameters are specified such as phenol, cyanide, copper, zinc, chromium, various types of particulate, sulphur dioxide, nitrogen oxides, volatile organic compounds, and other substances (MSP. GOB, 2010).

In exercise of the powers conferred by section 20 of the Bangladesh Environment Conservation Act, 1995 (Act 1 of 1995), ECR, 1997 has been followed as guiding principles for water quality parameters and standards. The aspect of various uses of inland surface water has not got importance in the rules. Classification of water use, parameters, and standards for inland surface water were developed based on best practices. These classes are: a. Sources of drinking water for supply only after disinfecting; b. Water usable for recreational activities; c. Sources of drinking water for supply only after conventional treatment; d. Water usable by fisheries; e. Water usable by various process and cooling industries; f. Water usable by irrigation. BOD, pH, DO and Total Coliform are prescribed as important water quality parameters along with their standards. In addition, parameters are suggested for pisiculture (Amonia as Nitrogen) and irrigation (EC and Sodium) with standards (Schedule-3. GoB, 1997).

Department of Fisheries (DoF) and Bangladesh Agricultural Development Corporation (BADC) also proposed some specific water quality parameters and standers for fisheries and irrigation purpose. All those national sources have been reviewed to determine the water quality parameters and standards for different sectoral water use. Moreover, available secondary research papers/documents of different international organizations such as: Food and Agriculture Organization (FAO), European Union (EU), World Health Organization (WHO), Bureau of Indian Standard (BIS), Asian Development Bank (ADB),United States Environmental Protection Agency, Ministry of Environmental Protection of China and many others organizations of different countries has been reviewed.

3.2 Selection of Water Quality Parameters

Based on national and international research it has found that the important water quality parameters are DO, pH, TDS, TSS, BOD, COD, Temperature, Faecal coliform, EC, Total Hardness, Arsenic, Lead, Iron etc. Results of different research show that for public health, chlorides up to 250 mg/l are not harmful but values greater than this are indication of organic pollution (Nahar, 2000). Free oxygen (O2) or DO is needed for respiration. DO levels below

1 ppm do not support fish; levels of 5 to 6 ppm are usually required for most of the fish population. The average value of DO levels (6.5 mg/l) indicates the average quality of river water (APHA, 1995).

However, the important parameters that are selected primarily for drinking, fisheries, agricultural/irrigation and industrial water use are given in Table 3.1 and described in following sub-section.

Table 3.1: Major water quality parameters for drinking, agricultural, fisheries, and industrial uses

Drinking Water		**Water use of Fisheries**	
1	DO	1	Dissolved Oxygen (DO)
2	pH	2	pH
3	Faecal Coliform	3	Temperature
4	Electrical Conductivity (EC)	4	Total dissolved Solid (TDS)
5	Total Suspended Solid (TSS)	5	Biological Oxygen Demand (BOD)
6	Arsenic	6	Chemical Oxygen Demand (COD)
8	Total Hardness	7	Electrical Conductivity (EC)
9	Biological Oxygen Demand (BOD)	8	Hydrogen Sulphide (H_2S)
10	Chemical Oxygen Demand (COD)	9	Ammonia
11	Total Coliform	10	Carbon Dioxide
12	Lead	11	Total Hardness
13	Iron	12	Lead
14	Calcium	13	Iron
15	Chloride	14	Turbidity
16	Sulphate		
17	Nitrate		
18	Turbidity		
Water use for Agriculture/Irrigation		**Water use for Industries**	
1	pH	1	Temperature
2	Electric Conductivity (EC)	2	Dissolved Oxygen (DO)
3	Total Dissolved Solids (TDS)	3	pH
5	Salinity	4	Total dissolved Solid (TDS)
6	Arsenic	5	Total Hardness
7	Ammonia	6	Sulphate
8	Iron	7	Calcium
9	Zinc	8	Chloride
10	Chloride	9	Iron
11	Sulphate	10	Total Coliform
12	Nitrate		
13	Boron		

3.2.1 Dissolved Oxygen (DO)

Oxygen is the single most important gas for most aquatic organisms; free oxygen or DO is needed for respiration. The DO levels below 1 ppm will not support fish; levels of 5 to 6 ppm are usually required for most of the fish population. The average value of DO levels (6.5mg/l) indicates the average quality of river water (APHA, 2005). DO values in our study varied between 0.5 to 1.5 ppm in dry season and 0.1 to 1.1 ppm in wet season. The average value of DO is 1.01 ppm in dry season and 0.45 ppm in wet season where as the standard value is about 6.5 ppm. So comparison between average value and standard value of DO is highly deviated so that it represents the lower quality of river water for fish life and other aquatic life.

Agriculture: The permissible level of DO is 5 or more (GoB, 1997);

Industrial Use: Study reveals that clean water usually contains dissolved oxygen 4 to 6 mg/l which is suitable for most of the industrial uses to avoid metallic corrosion.

Fisheries: The permissible limit (mg/l) of DO for fisheries is 5-6 (www.fish-farming.net, 2015), 4> (FAO), 5-12 (articles.extension.org), 4-5 (www.thefishsite.com).

Drinking: 6 (GOB, 1997), 5 (BIS), 5 (ICMR), 5 to 7 (Malaysia).

Table 3.2: Standards for Dissolved Oxygen (DO) as per different sources

Parameters	Organization	Standards (mg/l)
Dissolve Oxygen	Environmental Conservation Rules, 1997	5 or more
	www.fish-farming.net, 2015	5-6
	www.thefishsite.com	4-5
	Bureau of Indian Standard, 1997	5
	Indian Council of Medical Research	5
	Malaysia	5-7
Recommented Standard: Recommended Dissolved Oxygen (mg/l) for **drinking** 5-6, **fisheries** 4-6, **agriculture**>5 and for **industrial cooling water** 5 mg/l.		

3.2.2 pH

pH describes the acidity or alkalinity of water and represents the balance between hydrogen ions (H+) and hydroxide ions (OH^-) in water. The value for pH is expressed on a scale ranging from 0 to 14. Solutions with more H+ than OH^- ions have a pH value lower than 7 and are said to be acidic. Solutions with pH values higher than 7 have more OH^- than H+ ions and are said to be basic, or alkaline. If the pH value is 7, the solution is said to be neutral (an equal number of H+ and OH^- ions) and is neither acidic nor alkaline. It is important to note that the pH scale is logarithmic. For example, water with a pH of 5 has ten times the number of H+ ions than water with a pH of 6 and is ten times more acidic. The recommended values found from different national and international sources that work on water quality are as follows:

Agriculture: The permissible limit of pH for irrigation 6.0 −8.4 (Ayers and Westcot, 1985), 6.5 −8.5 (FAO, 1992), 6.0–8.5 (ADB, 1994) or 6.0 – 9.0 (GOB, 1997).

Industrial Use: Low pH increases corrosion of concrete, pH 7.0 is required for most industries, pH 2.7- 7.2 advised for carbonated beverage industry (BIS, 1991).

Fisheries: Direct Impact for fisheries is below pH 6.5, species experience slow growth. When the value of pH is 4 or below and pH 11 or above, most species die. Low pH reduces the amount of dissolved inorganic phosphorous and carbon dioxide available for phytoplankton photosynthesis.

Drinking: Recommended standards for drinking water is 6.5 to 8.5 mg/l (BIS, India). The standard range of pH for drinking water is 6.5-8.5 (Beyond this range pH affects mucous membrane; bitter taste; corrosion and also affects aquatic life BIS, 1991). The other standards for pH are 6.5-8.5 (ICMR, 2012), <8 mg/l.

Table 3.3: Standards for pH as per different sources

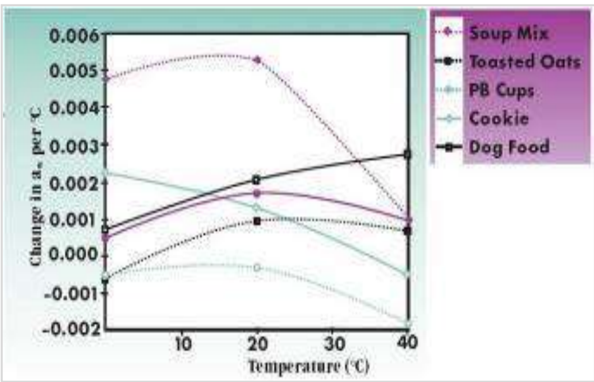
Parameters	Organization	Standards
pH	Bureau of Indian Standard (BIS)	6.5 to 8.5
	Indian Council for Medical Research (ICMR)	6.5 to 8.5
	World Health Organization (WHO)	<8
	Malaysia	6.5 to 9
	Food and Agriculture Organization (FAO)	6.5 −8.5
	Asian Development Bank (ADB)	6.0–8.5
	(Ayers and Westcot, 1985)	6.0 −8.4
Recommented Standard: Recommended pHstandards for **drinking, fisheries, irrigation or industrial cooling** water is 6.5 to 8.5 mg/l.		

3.2.3 Temperature

Temperature may be the single most important factor affecting the welfare of fish. Fish are cold-blooded organisms and assume approximately the same temperature as their surroundings. The temperature of the water affects the activity, behavior, feeding, growth, and reproduction of all fishes. The cooler the water the more soluble the gas, but that does not mean that ice covered pounds are not subject to low dissolved oxygen levels.

Normally, ice cover does not impede photosynthesis. Fish consume less oxygen at colder temperatures, greatly reducing the overall oxygen demand. But under extended ice cover, other gases (carbon dioxide, hydrogen sulfide, methane, etc.) can build up to dangerously high levels and the concentration of dissolved oxygen can become lower. Mechanical aeration is probably the most reliable way of preventing an ice build-up by keeping large areas of the pond free of ice (*www.fish-farming.net, 2015*). The fluctuation in river water temperature usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream (Ahipathy, 1995). The suitable temperature range of water for irrigation is 20–30ºC (GoB, 1997). Temperature also determines the amount of dissolved gases (oxygen, carbon dioxide, nitrogen, etc.) in the water. 25-32ºC is better for Carp, Tilapia fishes. (*www.fish-farming.net, 2015*). Respiration rates, feeding, metabolism, growth, behavior, reproduction and rates of detoxification and bioaccumulation Dissolved oxygen level in water such as the solubility of oxygen, and the rate of oxidation of organic matter (World Bank, 1999).

Annual cycles may be the result of regular rainfall patterns and seasonal temperature changes, among others. The seasonal growth and decay of vegetation will also give rise to cyclical changes in the composition of the water, and rates of self-purification and nitrification are strongly temperature-dependent. There may be daily cycles of natural origin, particularly those caused by photosynthesis and affecting DO and pH.



Source: aqualab.com, 2016

Industrial, agricultural, and domestic activities may cause cyclical changes due to cycles of discharge and abstraction (WMO, 2013). Selection of variables for the assessment of water quality in relation to some key industrial usage, such as industrial cooling, heating, pulp and paper mills, ice factory and steel & Iron mill (Chapman (Ed.), 1996).

European Union, 2001 carried out a study on “Reference Document on the application of Best Available Techniques to Industrial Cooling Systems” and suggested water temperature of 15°C for industrial cooling. According to their study water is the secondary cooling medium and is mostly re-circulated. Evaporating water transfers the heat to the air. Air is the cooling medium in which the heat is transferred to the environment and evaporation is the main cooling principle.

In fact, no recommended temperature is required for heating system in the industrial process. Water gains recommended temperature in the process of boiling. Aqua Lab, 2016 carried out an experiment, “The Temperature Dependence of Water Activity in Foods” suggest keeping water temperature 0-25°C.

Study and experiment carried out on recommended water temperatures by various agencies/department, as discussed above, recommends the following temperature.

Table 3.4: Standards for Temperature as per different sources

Parameters	Organization	Standards (degree centigrade)
Temperature	Bangladesh Environmental Conservation Rules, 1997	20-30
	www.fish-farming.net	25-32
	Food and Agriculture Organization (FAO)	20-30
	www.articles.extension.org	24-34
	www.thefishsite.com	25-32
Recommented Standard: Recommended temperature for fisheriesis 20 to 34°C, for industrial cooling system 15°C and water temperature for food related industries 0-25°C.		

3.2.4 Faecal Coliform

To put it briefly, the organisms (coliform bacteria) are good indicators of the potential contamination of a water source. Coliform bacteria have been used to evaluate the general quality of water. Faecal coliforms are the coliform bacteria that originate specifically from humans, beavers (Apec water, 2016). Faecal coliforms, on the other hand, are more specific because they refer to the coliforms that live in the intestinal track of humans and many other animals.

Water borne diseases are the major cause of morbidity and mortality in developing countries like Bangladesh, where disease outbreaks occur due to unsafe drinking water, inadequate sanitation, and poor hygienic practices. Among 50 diseases prevalent in Bangladesh, 40 of them including diarrhoea, dysentery, typhoid, parasitic worm infection etc. are related to the contaminated food and water. Different strains of E.coli are responsible for a variety of diseases including diarrhea, dysentery, hemolytic uremia syndrome (kidney failure), bladder infections, septicaemia, pneumonia, meningitis, etc. All the water sources were found to be contaminated with total coliform, faecal coliform, Escherichia coli, Klebsiella spp., Salmonella spp., Shigella spp., Vibrio cholera, Aeromonas spp. and Fungi Mrityunjay, *et al.* (2011). This study recommends testing of water for E-Coli, Faecal Coliform, or Total Coliform within 24 hours of sample collection. WHO, 2011 guideline suggests, E.-Coli must not be detectable in any 100 millilitre (ml) sample. Field observation reveals that people use river water for drinking, cooking, and other household purposes in river bank areas of Rupsha, Bhairab, Halda including Buriganga (field visit on August, 2016). In that respect, Faecal Coliform should be considered as an important parameter for drinking of river water. The standards suggested by various organizations/countries are mentioned in the table below. Faecal Coliform is recommended to be monitored specifically when water is to be used as drinking and the recommended value is 50 or less (colonies/100 ml).

Table 3.5: Standard for Total Coliform as per different sources

Parameters	ECR'97	BIS	ICMR	WHO	Malaysia
Total Coliform	50 or less	-	-	-	100 or less

3.2.5 Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers) or wastewater, making COD a useful measure of water quality. It is expressed in milligrams per litre (mg/L), which indicates the mass of oxygen consumed per litre of solution (*www.rmagreen.com*).

The measure of COD determines the quantities of organic matter found in water. This makes COD useful as an indicator of organic pollution in surface water (King *et al*., 2003 and Faith, 2006). COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances (Sawyer *et al*., 2003). The higher amount of organic compounds in water which demands higher COD and as a result the lower quality of water for fish and other aquatic life. In Bangladesh the major source of water pollution is industrial discharge and COD value remain high in the area of discharge outlet. As per the standard of BIS (Bureau of Indian Standard), the COD is 250 mg/l, where as ECR, 1997 recommends COD only for drinking.

Chemical Oxygen Demand (COD) is a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. It representspotential “consumption” of oxygen within the receiving water. The standard of Chemical Oxygen Demand is 20-60mg/l *http://www.undeerc.org/watman/FMRiver/PPTV/factsheets.asp*). It is essential to monitor the Chemical Oxygen Demand (COD) for assessing suitability of river water for fish culture and recommended standards is 20-60 mg/l.

3.2.6 Electrical Conductivity (EC)

Its value depends on the concentration and degree of dissociation of the ions as well as the temperature and migration velocity of the ion in the electric filed. The electrical conductivity measures the concentration of ions in water. The concentration of ions depends on the environment, movement, and sources water. Specific conductance of most natural water generally ranges from about 50 to 1500 µS/cm.

Electrical Conductivity depends on water temperature: the higher the temperature, the higher the electrical conductivity would be. The electrical conductivity of water increases by 2-3% for an increase of 1 degree Celsius of water temperature. Electrical Conductivity is a good indicator of the total salinity (ECR, 1997). The electrical conductivity values can be measured in low quality water (e.g. water rich with Sodium, Boron, and Fluorides) as well as in high quality irrigation water (e.g. adequately fertilized water with appropriate nutrient concentration and ratios).

The recommended threshold values of Electrical Conductivity are 0.70 dS/m (FAO, 1992), 0.75 dS/m (ADB, 1994) or 4 dS/m (GOB, 1997).

These parameters can be used for the purpose of drinking, agriculture, fisheries, as well as industrial use maintaining standard of 0.70 to 1 dSm^{-1}.

3.2.7 Biochemical Oxygen Demand (BOD)

If source water contains a large amount of BOD, microbial growth will be enhanced especially at high temperatures. With this microbial growth and the corresponding degradation of organic matter, oxygen will be consumed. This can lead to the depletion of oxygen in the river and its associated effects on fish including death.

BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. Usually, unpolluted natural water has BOD of 5 mg/l or less. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff.

The recommended threshold values of BOD are 10 mgl^{-1} (ADB, 1994), 5 mgl^{-1} (ICMR) and 10 mgl^{-1} (ECR, 1997). The permissible value of BOD is suggested as 5-10 mgl^{-1} for fisheries and aquatic life.

3.2.8 Total Dissolved Solids (TDS)

Total dissolved solids comprise inorganic salts and small amounts of organic matter. The common dissolved mineral salts are claimed to affect the taste, hardness, corrosion, and encrustation. Dissolved inorganic substances may exert adverse effects on aquatic animals and plants, and may cause irrigation problems. Total Dissolve Solids (TDS) refers to the sum of all the components dissolved in water. In natural water dissolved solids are composed of mainly Na^+, K^+, Ca^{2+}, Mg^{2+}, and Cl^-, $SO4^{2-}$, $PO4^{3-}$, H_4SiO4^{2-}, and HCO^{3-}. Water that contains too much dissolve matter is not suitable for common uses.

Low TDS value is required in most industries. High TDS leads to corrosion (BIS, 1991). The threshold limit of TDS as per different state/organization are:

Table 3.6: Standard for Total Dissolved Solids (TDS) as per different sources

1	2	3	4	5	6
Parameters	ECR'97	BIS	ICMR	WHO	Malaysia
TDS	1000	500	500	1000	500 to 1000

The permissible value of TDS is suggested as 500-1000 mgl^{-1} for agriculture, fisheries (including aquatic life) and industrial use.

3.2.9 Total Suspended Solids (TSS)

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

The more particles suspended in a sample of water, the more difficult it is for light to travel through it and the higher the water's turbidity, or murkiness. Although the suspended particles that reduce clarity can include organic particles (microbes, algae and plant particles, and animal detritus) as well as inorganic particles (silt and clay particles), turbidity in the river is usually a measure of the inorganic particles that account for most of the total suspended solids (TSS).

Once satisfactorily established, the correlation can be used to estimate TSS from more frequently made turbidity measurements, saving time and effort. Because turbidity readings are somewhat dependent on the particles size, shape and color. Particles above a certain size (anything larger than silt) are not measured by a bench turbidity meter (they settle out before the reading is taken), but contribute substantially to the TSS value (DoE, 2014. The Water Quality Report).

The recommended threshold values of Total Suspended Solids (TSS) of ECR, 1997 are 150 and 200 mg/l for inland surface water and irrigated land, respectively. Most people considerwater with a TSS concentration less than 20 mg/l to be clear. Water with TSS levels between 40 and 80 mg/l tends to appear cloudy, while water with concentrations over 150 mg/lusually appears dirty. The nature of the particles that comprise the suspended solids may cause these numberstovary(www.michigan.gov/documents/deq/wb-npdes-Total Suspended Solids_247238_7.pdf).

The permissible value of TSS is suggested as 20 to 40 mg/l for drinking as well as for other human consumption.

3.2.10 Arsenic

Arsenic is one of the most toxic elements that can be found naturally on earth in small concentrations. It occurs in soil and minerals and it may enter air, water and land through wind-blown dust and water run-off (www.lenntech). An increase in pH may increase the concentration of dissolved arsenic in water (Slooff et al., 1990). Humans may be exposed to arsenic through food, water and air. (www.lenntech). People are exposed to inorganic arsenic through drinking contaminated water, using contaminated water in food preparation and irrigation of food crops, industrial processes, eating contaminated food and smoking tobacco. (www.who.int). Levels of arsenic in food are fairly low, as it is not added due to its toxicity. But levels of arsenic in fish and seafood may be high, because fish absorb arsenic from the water they live in. Luckily this is mainly the fairly harmless organic form of arsenic, but fish that contain significant amounts of inorganic arsenic may be a danger to human health. Plants absorb arsenic fairly easily, so that high-ranking concentrations may be present in food. (www.lenntech). In 2001, IPCS states that long-term exposure to arsenic in drinking-water is causally related to increased risks of cancer in the skin, lungs, bladder and kidney, as well as other skin changes such as hyperkeratosis and pigmentation changes.

Table 3.7: Standards for Arsenic as per different sources

Parameter	Organization	Standards
Arsenic (As)	Environmental Conservation Rule (ECR), 1997	0.05 mg/l
	World Health Organization (WHO)	0.01 mg/l
	European Union (EU)	0.01 mg/l
	Indian Standard Institution (ISI)	0.05 mg/l
	Indian Council of Medical Research (ICMR)	0.05 mg/l
	United States Environmental Protection Agency	0.01 mg/l
	Ministry of Environmental Protection of China	0.05 mg/l
	Food and Agriculture Organization (FAO)	0.1 mg/l
Recommended Standard: Recommended arsenic (As) standards for drinking water 0.05 mg/l and irrigation water 0.1 mg/l.		

3.2.11 Calcium

Calcium is the most important and abundant element for the human body and an adequate intake is essential for normal growth and health. The maximum daily requirement is of the order of 1 - 2 grams and comes especially from dairy products. There is some evidence to show that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary constituent of which is calcium, so that the presence of the element in a water supply is beneficial to health. (www.who.int/water_sanitation_health)

Inadequate intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Most of these disorders have treatments but no cures. However, excess calcium intake is directed primarily to those who are prone to milk alkali syndrome (the simultaneous presence of hypercalcaemia, metabolic alkalosis and renal insufficiency). Calcium can interact with iron, zinc, magnesium and phosphorus within the intestine. (World Health Organization, 2009)

Table 3.8: Standards for Calcium as per different sources

Parameter	Organization	Standards
Calcium	Environmental Conservation Rule (ECR), 1997	75 mg/l
	World Health Organization (WHO)	75 mg/l
	Indian Standard Institution (ISI)	75 mg/l
	Indian Council of Medical Research (ICMR)	200 mg/l
Recommended Standard: Recommended calcium standards for drinking water is 75 mg/l and for industrial water 20-250 mg/l.		

3.2.12 Lead

Lead (Pb) comes from deposition of exhaust from vehicles in the atmosphere, batteries, waste from lead ore mines, lead smelters and sewage discharge. Lead is present in tap water to some extent as a result of its dissolution from natural sources, but primarily from household plumbing systems in which the pipes, solder, fittings or service connections to homes contain lead. The amount of lead dissolved from the plumbing system depends on several factors, including the presence of chloride and dissolved oxygen, pH, temperature, water softness and standing time of the water, soft, acidic water being the most plumbosolvent. (WHO, 2011)

Both children and adults are vulnerable to the effects of lead. Exposure to lead can have a wide range of effects on a child's development and behavior. Blood lead levels less than 10 micrograms per deciliter (µg/dL) are associated with increased behavioral effects, delayed puberty, and decreases in hearing, cognitive performance, and postnatal growth or height. Some of these health effects are found even at low blood lead levels less than 5 µg/dL, including lower IQ scores, decreased academic achievement, and increases in both behavioural problems and attention related behaviours. There is a wide range of lead associated behavioural effects in the area of attention. Attention deficit hyperactivity disorder (ADHD) is one example on the more severe end of the spectrum. (www.niehs.nih.gov)

Lead exposure has been linked to a number of health effects in adults. As a general rule, the more lead you have in your body, the more likely it is you will have health problems. High blood lead levels greater than 15 µg/dL are associated with cardiovascular effects, nerve disorders, decreased kidney function, and fertility problems, including delayed conception and adverse effects on sperm and semen, such as lower sperm counts and motility. Blood lead levels below10 µg/dL are associated with decreased kidney function and increases in blood pressure, hypertension, and incidence of essential tremor, a degenerative disorder of the central nervous system whose most recognizable feature is a tremor of the arms or hands during voluntary movements, such as eating and writing. There is also evidence showing that adults who have low levels of exposure to lead less than 5 µg/dL may have decreased kidney function. (www.niehs.nih.gov)

The toxicity of lead increased at lower pH level, low alkalinity and low solubility in hard water which has effects on fish. Chronic lead toxicity in fish leads to nervous damage which can be determined by the blackening of the fins (Dojlido and Best, 1993). Acute toxicity, on the other hand causes gill damage and suffocation (Svobodova et al., 1993).

Table 3.9: Standards for Lead as per different sources

Parameter	Organization	Standards
Lead	Environmental Conservation Rule (ECR), 1997	0.05 mg/l
	World Health Organization (WHO)	0.01 mg/l
	European Union (EU)	0.01 mg/l
	Indian Standard Institution (ISI)	0.10 mg/l
	Indian Council of Medical Research (ICMR)	0.05 mg/l
	United States Environmental Protection Agency	0.015 mg/l
	Ministry of Environmental Protection of China	0.01 mg/l
Recommended Standard: Recommended lead standards for drinking water is 0.01 mg/l, fisheries and industrial water is <0.02 ppm		

3.2.13 Chloride

Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl). Natural levels in rivers and other fresh waters are usually in the range 15-35 mg/l Cl. In fresh waters the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride therefore; a high concentration of chloride may indicate pollution of water by a sewage effluent. (Environmental Protection Agency, 2011)

A normal adult human body contains approximately 81.7 g chloride. On the basis of a total obligatory loss of chloride of approximately 530 mg/day, a dietary intake for adults of 9 mg of chloride per kg of body weight has been recommended (equivalent to slightly more than 1g of table salt per person per day). For children up to 18 years of age, a daily dietary intake of 45 mg of chloride should be sufficient. (WHO, 2003)

Too little chloride in the body can occur when your body loses a lot of fluids. This may be due to excessive sweating, vomiting, or diarrhea. Too much chloride from salted foods can: increase blood pressure; cause a build-up of fluid in people with congestive heart failure, cirrhosis, or kidney disease. (www.nytimes)

Table 3.10: Standards for Chloride as per different sources

Parameters	Organization	Standards
Chloride	Environmental Conservation Rule (ECR), 1997	150-600 mg/l
	World Health Organization (WHO)	200 mg/l
	Indian Standard Institution (ISI)	250 mg/l
	Indian Council of Medical Research (ICMR)	1000 mg/l
Recommended Standard: Recommended chloride standards for drinking water is 250 mg/l, irrigation water is 600 mg/l and industrial water use is 25-250 mg/l		

3.2.14 Sodium

Sodium salts are always present in natural waters including drinking water. It is also an essential dietary requirement and the normal intake is as common salt (sodium chloride) in food. Sodium is abundant constituent of rocks and soils.

Daily consumption of sodium may amount to 5 grams or more. Sodium salts are generally highly soluble in water and are leached from the terrestrial environment to groundwater and surface water. Most water supplies contain less than 20 mg of sodium per liter, but in some countries levels can exceed 250 mg/liter (Sodium chlorides and conductivity in drinking water. Copenhagen, WHO Regional Office for Europe, 1979. EURO Reports and Studies No.2).

Although it is generally agreed that sodium is essential to human life, there is no agreement on the minimum daily requirement. However, it has been estimated that a total daily intake of 120–400 mg will meet the daily needs of growing infants and young children, and 500 mg those of adults (National Research Council. Recommended dietary allowances, 10th ed. Washington, DC, National Academy Press, 1989.). In case of agricultural and irrigation purpose about 20-40mg/l sodium is considered as very good intensity (Guidelines for Evaluation of Quality of Irrigation Water,BIS (IS: 10500: 1991)).

Table 3.11: Standards for Sodium as per different sources

Parameter	Organization	Standards
Sodium (Na)	Environmental Conservation Rule (ECR),1997	200 mg/l
	World Health Organization (WHO),1979	200 mg/l
	Indian Standard Institution (ISI)	250 mg/l
	Indian Council of Medical Research (ICMR)	500 mg/l
	United States Water Sample Survey	402 mg/l
	Canadian Drinking Water Quality, 1996	200 mg/l
Recommended Standard: Recommended sodium standards for drinking water is 200 mg/l.		

3.2.15 Nitrate

Nitrogen is abundant on earth, making up about 80% of our air as N_2 gas. Most plants cannot use it in this form. However, blue-green algae and legumes have the ability to convert N_2 gas into nitrate (NO_3-), which can be used by plants. Plants use nitrate to build protein, and animals that eat plants also use organic nitrogen to build protein. When plants and animals die or excrete waste, this nitrogen is released into the environment as NH_4+ (ammonium). This ammonium is eventually oxidized by bacteria into nitrite (NO_2-) and then into nitrate. In this form it is relatively common in freshwater aquatic ecosystems. Nitrate thus enters streams from natural sources like decomposing plants and animal waste as well as human sources like sewage or fertilizer.

Natural levels of nitrate are usually less than 1 mg/l. Concentrations over 10 mg/lwill have an effect on the freshwater aquatic environment. 10 mg/lis also the maximum concentration allowed in human drinking water by the U.S. Public Health Service. For a sensitive fish such as salmon the recommended concentration is 0.06 mg/l (Environmental Protection Agency 2001).

Table 3.12: Standards for Nitrate as per different sources

Parameter	Organization	Standards
Nitrate (NH_3)	Environmental Conservation Rule (ECR),1997	10 mg/l
	World Health Organization (WHO),1979	50 mg/l
	European Union (EU)	50 mg/l
	Drinking Water Standards of BIS (IS: 10500: 1991)	45 mg/l
	United States Water Sample Survey	10 mg/l
	Canadian Drinking Water Quality, 1996	10 mg/l
	Ministry of Environmental Protection of China	10 mg/l
Recommended Standard: Recommended nitrate standards for drinking water is 10 mg/l, irrigation water <5 mg/l and industrial cooling water is 15-30 mg/l.		

3.2.16 Turbidity

Turbidity in water is found because of suspended solids and colloidal matter. It may be due to eroded soil caused by dredging or due to the growth of micro-organisms. High turbidity makes filtration expensive. If sewage solids are present, pathogens may be encased in the particles and escape the action of chlorine during disinfection. High turbidity in water adversely affects its flora and fauna and makes the water unsuitable for drinking and other uses (www.mdpi.com/journal/water).

The US EPA and Greece recommend a level lower than 2 NTU only for directly consumed crops and unrestricted irrigation and Spain recommends a level lower than 10 NTU for vegetables. The MOE sets the standards at under 2 NTU for food crops, and under 5 NTU for processed food crops. Most countries that do not have a standard for turbidity have a standard for suspended solids instead (Vinten *et.al.,* 1983).

A high level of turbidity can affect the performance of the irrigation facility, and can lower the hydraulic conductivity of the soil and in turn pollute the soil surface through surface flow. Therefore, the standard for turbidity can be set up based on the turbidity's influence on the irrigation facility performance, or vegetables which are vulnerable to germ infection (Ragusa *et.al.,* 1994).

Table 3.13: Standards for Turbidity as per different sources

Parameter	Organization	Standards
Turbidity [NTU]	Environmental Conservation Rule (ECR),1997	10
	World Health Organization (WHO),1979	<1
	European Union (EU)	5
	Indian Standard Institution (ISI)	10
	Indian Council of Medical Research (ICMR)	10
	Central Pollution Control Board (CPCB)	10
	United States Water Sample Survey	10
	Canadian Drinking Water Quality, 1996	10
	Primary Water Quality Criteria (Aquaculture). Environment (Protection) Rules, 1986	30
Recommended Standard: Recommended turbidity standards for drinking is 10 NTU.		

3.2.17 Boron

Boron is a naturally occurring trace element. Used in cleaning compounds and in alloys. Although excessive amounts of boron can cause nervous problems, the element is not considered a problem in drinking water. It has been identified as a danger to crops when present in irrigation water at the 1-2 mg/l concentration range. Boron present in seawater is around 5 mg/l. The Surface Water and Drinking Water Regulations specify limits.

Table 3.14: Standards for Boron as per different sources

Parameter	Organization	Standards
Boron	Environmental Conservation Rule (ECR),1997	1 mg/l
	World Health Organization (WHO),1979	2.4 mg/l
	European Union (EU)	1 mg/l
	Ministry of Environmental Protection of China	1 mg/l
	Canadian Drinking Water Quality, 1996	1 mg/l
	United States Environmental Protection Agency	1 mg/l
	Food and Agriculture Organization	0.7 mg/l
Recommended Standard: Recommended boron standards for drinking water is 1 mg/l and for irrigation water is <0.5 mg/l.		

3.2.18 Sulphate

Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. They get into water due to erosion of rocks and soil, biochemical oxidation of sulphur and its compounds, atmospheric precipitation, biochemical decomposition of plant and animal proteins (in aerobic conditions) and from industrial sewage. Especially high content of sulphates can be present in sewage form chemical industry.

In surface waters concentration of sulphates usually vary between 250-500 mg/l. In ground waters the concentration is higher and very often exceeds 700 mg/l (http://www.pg.gda.pl/chem/Dydaktyka/Analityczna/WQC/wqc_p2.pdf). Sulphates are one of the least toxic anions and large quantities would have to be ingested in order to health disorders to occur (especially diarrhoea type symptoms). The presence of sulphate in drinking water can result in noticeable bitter taste.

Table 3.15: Standards for Sulphate as per different sources

Parameter	Organization	Standards
Sulphate	Environmental Conservation Rule (ECR),1997	400 mg/l
	Indian Council of Medical Research (ICMR)	400 mg/l
	Central Pollution Control Board (CPCB)	400 mg/l
	Drinking Water Standards of BIS (IS: 10500: 1991)	200 mg/l
	Indian Standard Institution (ISI)	150 mg/l
	Canadian Drinking Water Quality, 1996	75 mg/l
	Bangladesh Agricultural Development Corporation (BADC)	1000 mg/l
Recommended Standard: Recommended sulphate standards for drinking water is <400 mg/l, irrigation water 1000 mg/l and industrial water 25-250 mg/l .		

3.2.19 Ammonia

Ammonia is generally present in natural waters, though in very small amounts, as a result of microbiological activity which causes the reduction of nitrogen-containing compounds. Ammonia in surface waters can be of organic origin, the by product of decomposition of plant and animal matter, or of inorganic origin, formed due to chemical or biochemical reduction of nitrate and nitrite. Ammonia is an indicator of pollution originating from soil (the excessive use of ammonia rich fertilizers), atmosphere and sewage (K. Lipkowaska *et.al.,* 1998).

Ammonia NH_3 is a very unstable compound and easily undergoes nitrification. Ammonia is present in all natural waters. Ground water and clean surface waters contain about 0.1 mg/dm^3; marine water - few mg/dm^3 and the concentration increases with depth. The highest concentration of ammonia is observed in waters near crude oil beds, and can be as high as 100 mg/dm^3 (W.F. McCoy and B.H. Olson, 1986).

Drinking water, according to hygienic rules, should not contain ammonia of organic origin. From the viewpoint of human health, although it is a nutrient required for life, excess of ammonia is marked because it can accumulate in the organism and cause alteration in metabolism or increase body pH and the consequent possible presence of pathogenic micro-organisms (http://www.aaawatertesting.com/nitrogen.htm#EPA).

Ammonia is toxic for aquatic organisms. The ammonia tolerances for fishery waters are narrow and have been considered and reported on by the European Inland Fisheries Advisory Commission. Research has shown that it is the un-ionized species of ammonia which is most harmful for freshwater aquatic life, in particular.

Table 3.16: Standards for Ammonia as per different sources.

Parameter	Organization	Standards
Ammonia	Environmental Conservation Rule (ECR),1997	0.5 mg/l
	Environmental Protection Agency (EPA), 2001	0.02mg/l
	Drinking Water Standards of BIS (IS: 10500: 1991)	0.5 mg/l
	Indian Standard Institution (ISI)	0.5 mg/l
	Surface Water Regulations, (1989)	0.2-1.5 mg/l
Recommended Standard: Recommended ammonia standards for drinking water is 0.5 mg/l and for aquaculture <0.0125 ppm.		

3.2.20 Total Hardness

Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. Total Hardnessis taken to comprise the results of direct measurement of calcium and magnesium concentrations expressed as mg/l CaCO3. The following types of water hardness are under consideration (K. Lipkowaska *et.al.,* 1998):

- Total (temporary) hardness - total amount of calcium and magnesium ions responsible for water hardness
- Carbonate hardness - amount of calcium and magnesium hydrocarbons; disappears while boiling - precipitation of insoluble sediment

The effect of hardness mainly consists in causing soap scum and water spots, scaling in swamp coolers, cooling towers, boilers and pipes.

The following is one of several such arbitrary classifications of waters by hardness:

Water type	Hardness Values (mg/l)
Soft	50 mg/l
Moderately Soft	51-100 mg/l
Slightly Hard	101 - 150 mg/l
Moderately Hard	151-250 mg/l
Hard	251-350 mg/l
Excessively Hard	<350 mg/l

The widespread abundance of metals in rock formations leads often to very considerable hardness levels in surface and ground waters. Hard waters are satisfactory for human consumption as soft waters. Health studies in several countries in recent years indicate that mortality rates from heart diseases are lower in areas with hard water (http://www.pg.gda.pl/chem/Dydaktyka/Analityczna/WQC/wqc_p2.pdf).

Table 3.17: Standards for Total Hardness as per different sources

Parameter	Organization	Standards
Total Hardness	Environmental Conservation Rule (ECR),1997	200-500 mg/l
	Drinking Water Standards of BIS (IS: 10500: 1991)	300-600 mg/l
	Indian Standard Institution (ISI)	300 mg/l
	World Health Organization (WHO),1979	500 mg/l
	Indian Council of Medical Research (ICMR)	600 mg/l
	Central Pollution Control Board (CPCB)	600 mg/l
Recommended Standard: Recommended standards for drinking and industrial cooling water is 300 mg/l and for fisheries >100 mg/l		

3.2.21 Salinity

Salinity relates to the amount of salt in the water, where the salt can be in many different forms (salt used in food is sodium chloride). Typically waters can contain two or more of the following salts:

- sodium
- potassium

- calcium
- magnesium
- chloride
- sulphate
- bicarbonate
- carbonate
- nitrate

There are two main methods of defining the concentration of salt in water:

- Total Dissolved Solids (TDS) - measured by evaporating water to dryness and weighing the solid residue;
- Electrical Conductivity (EC) - measured by passing an electric current through the water and measuring how readily the current it flows. (www.sahealth.sa.gov.au)

The total concentration of all ions in the water is its salinity. Freshwater fish exhibit a range in salinity tolerance. Many commercially important species (e.g., channel catfish, Ictalurus punctatus; largemouth bass, Micropterus salmoides; tilapia, Tilapia sp.) survive and grow well in slightly salty water. After they smelt, salmon and trout can tolerate salt water. Salinity not only affects osmoregulation it also influences the concentration of un-ionized ammonia. During the planning stage of an aquaculture operation, salinity should be measured and the water's appropriateness determined.(www.fisheries.tamu.edu)

3.3 Proposed New Water Quality Standards from Existing Standards

Different water quality parameters for drinking, fisheries, agriculture/irrigation and industrial use have been reviewed from available secondary sources. Based on the existing standards new standards have been proposed which is given below (**Table 3.18 to Table 3.21**).

Table 3.18: Summary of reviewed different water quality standards and suggested standards for drinking

Parameters	ECR, 1997	WHO	FAO	ADB	EU (drrajivdesaimd.com)	USEPA	ISI	USA (drrajivdesaimd.com)	China (drrajivdesaimd.com)	Bureau of Indian Standards (BIS) (wqaa.gov.in)	Malaysia	ICMR	Recoommended Standard
DO	6 or above	6 or more	-	-	-	-	-	-	-	5	5-7	-	5-6
pH	6.5-8.5	6.5- 8.5	-	-	-	6.5- 8.5	6.5- 8.5	-	-	6.5- 8.5	6.5- 9	-	6.5-8.5
EC	-	-	0.70 ds/m	0.75 ds/m	-	-	-	-	-	-	-	-	0.70-1.0 ds/m
BOD	2 mg/l or less	2 mg/l or less	-	10 mg/l	-	-	-	-	-	-	-	5 mg/l	2 mg/l or less
COD	4 mg/l	-	-	-	-	-	-	-	-	-	-	-	4 mg/l
Arsenic	0.05 mg/l	0.01 mg/l	-	-	0.01 mg/l	0.05 mg/l	0.05 mg/l	0.01 mg/l	0.05 mg/l	0.05 mg/l	-	-	0.05 mg/l
Total Hardness	200-500 mg/l	500 mg/l	-	-	-	-	300 mg/l	-	-	300-600 mg/l	-	600 mg/l	300 mg/l
Calcium	75 mg/l	75 mg/l	-	-	-	-	75 mg/l	-	-	75 mg/l	-	-	75 mg/l
Lead	0.05 mg/l	0.01 mg/l	-	-	0.01 mg/l	-	0.10 mg/l	0.015 mg/l	0.01 mg/l	0.05 mg/l	-	-	0.01 mg/l
Iron	0.3-1 mg/l	0.1 mg/l	-	-	-	-	0.3 mg/l	-	-	0.3 mg/l	-	-	0.3-1 mg/l
TDS	1000 mg/l	500 mg/l	-	-	-	-	-	-	-	500 mg/l	1000 mg/l	-	500 mg/l
TSS	-	-	-	-	-	-	-	-	-	-	-	-	20-40 mg/l
Chloride	150-600 mg/l	200 mg/l	-	-	-	250 mg/l	250 mg/l	-	-	250 mg/l	-	-	250 mg/l
Total Coliform	50 or less (No./100ml)	50 (No./100ml	-	-	-	-	-	-	-	-	100 (No./100ml	-	50 or less (No./100 ml)

Parameters	ECR, 1997	WHO	FAO	ADB	EU (drrajivdesaimd.com)	USEPA	ISI	USA (drrajivdesaimd.com)	China (drrajivdesaimd.com)	Bureau of Indian Standards (BIS) (wqaa.gov.in)	Malaysia	ICMR	Recoommended Standard
Fecal Coliform	0 (No./100ml)	-	-	-	-	-	-	-	-	-	-	-	0 (No./100 ml)
Boron	1 mg/l	2.4 mg/l	0.7 mg/l	-	1 mg/l	1 mg/l	-	-	1 mg/l	-	-	-	1 mg/l
Ammonia	0.5 mg/l	-	-	-	-	-	0.5 mg/l	-	-	0.5 mg/l	-	-	0.5 mg/l
Sulphate	400 mg/l	-	-	-	-	-	150 mg/l	-	-	200 mg/l	-	400 mg/l	<400 mg/l
Nitrate	10 mg/l	50 mg/l	-	-	50 mg/l	-	45 mg/l	10 mg/l (as N)	10 mg/l (as N)	45 mg/l	-	100 mg/l	10 mg/l
Sodium	200 mg/l	200 mg/l	-	-	-	-	200 mg/l	402 mg/l	-	-	-	500 mg/l	200 mg/l
Turbidity	10 NTU	< 1NTU	-	-	5 NTU	30 NTU	10 NTU	10 NTU	-	5-10 NTU	-	10 NTU	10 NTU

Table 3.19: Summary of reviewed different water quality standards and suggested standards for fisheries and aquaculture

Parameters	ECR, 1997	Department of Fisheries, Bangladesh	www.fish-farming.net, 2015	www.thefishsite.com	Department of Animal Sciences, Purdue University (www.articles.extension.org)	Aquaculture Center, University of Massachusetts Dartmouth (www.fisheries.tamu.edu)	www.sciencefairwater.com	Proposed Standard
DO	5 ppm or More	>5 ppm	5-6 ppm	4-5 ppm	5 ppm or More	>4-5 ppm	-	4-6 ppm
pH	6.5-8.5	6.5-8.5	-	-	6.5-9.0	6.0-9.0	-	6.5-8.5
BOD	6 or less mg/l	-	-	-	-	-	-	3-5 mg/l
COD	-	-	-	-	-	-	-	20-30 mg/l
EC	-	-	-	-	-	-	-	0.70-1.0 ds/m
TDS	450-2000 mg/l	<400 mg/l	-	-	-	-	-	500-1000 mg/l
Temperature	20-34 °C	-	25-32 °C	25-32 °C	75-90 °F (warmwater species)	-	-	20-34°C
Carbon Dioxide	-	<60	-	-	-	<10 ppm	-	10-50 ppm
Ammonia	-	<0.0125 (Salmonids); <3.0 (Warm-water fish)	-	-	<0.02 ppm	-	-	<0.0125 ppm
Salinity	-	<0.5 to 1 mg/l	-	-	-	<0.5- 1.0 ppt (for freshwater fish)	-	<0.5- 1.0 ppt
Lead	-	-	-	-	0.03 ppm	-	-	<0.02 ppm
Iron	-	<0.15 mg/l	-	-	0.0 to 0.15 ppm	<0.5 ppm	-	<0.1 ppm
Hardness, Total (as $CaCO_3$)	-	>100	-	-	10 to 400 ppm	>50 ppm	-	>100
Turbidity	-	-	-	-	-	-	<500	<500

Table 3.20: Summary of reviewed different water quality standards and suggested standards for agriculture/irrigation

Parameters	ECR, 1997	BADC	Environmental Studies Board, 1973, NAS, Washington (wqaa.gov.in)	FAO (www.who.int)	www.eagri.tnau.ac.in	Proposed Standard
pH	6.5-8.5	6.5-8.5	-	-	-	6.5-8.5
BOD	10 or less	-	-	-	-	< 10
DO	5 or more	-	-	-	-	> 5
Arsenic	-	0.1 ppm	0.1 mg/l	0.1 mg/l	-	0.1 mg/l
EC	2250 µmhoms/cm	2250 µmhoms/cm	-	-	0-2.5 dS m-1	2250 µmhoms/cm
TDS	-	2000 mg/l	-	-	-	500-1000
Iron	-	1-5 mg/l	5 mg/l	-	-	< 5 mg/l
Zinc	-	5 mg/l	2 mg/l	2 mg/l	-	2 mg/l
Total Coliform	1000 or less	-	-	-	-	1000 or less
Nitrate	-	-	-	-	< 5	< 5
Ammonia	-	-	-	-	-	-
Boron	-	0.1 ppm	0.5-1.0 mg/l	-	< 1 mg/l	< 0.5 mg/l
Chloride	-	600 mg/l	-	-	4-12 mg/l	-
Sulphate	-	1000 mg/l	-	-	< 4 mg/l	-
Temperature	-	20-30 oC	-	-	-	20-30 oC

Table 3.21: Summary of reviewed different water quality standards and suggested standards for industrial water use

Parameters	ECR, 1997	Bureau of Indian Standards (BIS) (wqaa.gov.in)	Proposed Standard
DO	5 mg/l or more	-	5 mg/l
pH	6.5-8.5	6.5-8.2	6.5-8.5
BOD	10 mg/l or less	-	10 mg/l
COD	-	-	20-30 mg/l
Total Coliform	5000 or less	-	3000
TDS	-	50-3000 mg/l	500-2000 mg/l
Temperature	-	-	20-30^{o} C
Lead	-	-	<0.02 ppm
Iron	-	0.1-2.0 mg/l	< 2 mg/l
Chloride	-	25-200 mg/l	25-250 mg/l
Calcium	-	20-500 mg/l	20-500 mg/l
Sulphate	-	25-250 mg/l	25-250 mg/l
Nitrate	-	15-30 mg/l	15-30 mg/l

3.4 Consultation with experts and Finalization of parameters with standards

The preliminary selected parameters and their standard values are shared with DoE and other relevant experts for finalizing the water quality standards for Bangladesh in drinking, fisheries, agricultural/irrigation and industrial water use.

References

http://www.lenntech.com/who-eu-water-standards.htm

http://www.lenntech.com/periodic/elements/as.htm#ixzz4e1gHRvr0

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3482709/

http://www.who.int/mediacentre/factsheets/fs372/en/

http://aquaculture.asia/files/PMNQ%20WQ%20standard%202.pdf

http://drrajivdesaimd.com/2014/03/07/drinking-water/

http://www.who.int/water_sanitation_health/publications/publication_9789241563550/en/index.html

https://www.niehs.nih.gov/health/materials/lead_and_your_health_508.pdf

http://www.nytimes.com/health/guides/nutrition/chloride-in-diet/overview.html

http://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/protecting+public+health/water+quality/salinity+and+drinking+water

http://www.articles.extension.org/sites/default/files/w/3/32/A_Fish_Farmer's_Guide_to_Understanding_Water_Quality.pdf

http://www.fisheries.tamu.edu/files/2013/09/NRAC-Publication-No.-170-An-Introduction-to-Water-Chemistry-in-Freshwater-Aquaculture.pdf

http://wqaa.gov.in/WriteReadData/UserFiles/Documents/WaterQualityStandards.pdf

http://www.eagri.tnau.ac.in/eagri50/SSAC122/lec27.pdf

http://www.who.int/water_sanitation_health/resourcesquality/wpcchap2.pdf

http://www.pg.gda.pl/chem/Dydaktyka/Analityczna/WQC/wqc_p2.pdf

http://www.sciencefairwater.com/physical-water-quality-parameters/water-turbidity/water-turbidity-effects-on-fish/

World Health Organization, (2009). Calcium and magnesium in drinking-water: public health significance. Geneva: World Health Organization. (http://apps.who.int/iris/bitstream/10665/43836/1/9789241563550_eng.pdf?ua=1)

WHO, (2011). Lead in Drinking-water, Background document for development of WHO Guidelines for Drinking-water. Geneva: World Health Organization. (http://www.lenntech.com/periodic/elements/pb.htm)

Dojlido, J., and G. A. Best. 1993. Chemistry of Water and Water Pollution. West Sussex: Ellis Horwood Limited.

Svobodová, Z., R. L., J. Máchová, and B. Vykusová. 1993. Water Quality and Fish Health. EIFAC Technical Paper no. 54. Rome: FAO.

Environmental Protection Agency. (2011). PARAMETERS OF WATER QUALITY: Interpretation and Standards. Ireland: Environmental Protection Agency.

IPCS (2001) *Arsenic and arsenic compounds.* Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 224).

Slooff W et al., eds. (1990) *Integrated criteria document arsenic*. Bilthoven, National Institute of Public Health and Environmental Protection (Report No. 710401004).

Vinten, A.J.A.; Minelgrin, U.; Yaron, B. The effect of suspended solids in wastewater on soil hydraulic conductivity: II. Vertical distribution of suspended solids. Soil Sci. Soc. Am. J. 1983, 47, 408–412.

Ragusa, S.R.; de Zoysa, D.S.; Rengasamy, P. The effect of microorganisms, salinity and turbidity on hydraulic conductivity of irrigation channel soil. Irrig. Sci. 1994, 15, 159–166.

www.mdpi.com/journal/water

K. Lipkowaska – Grabowska, E. Faron – Lewandowska "Pracownia chemiczna. Analiza wody iścieków", Warszawa 1998

W.F. McCoy, B.H. Olson "Relationship among turbidity, particle counts and bacteriological quality within water distribution lines", 1986

http://www.aaawatertesting.com/nitrogen.htm#EPA

4. Water Quality Sampling Protocol

4.1 Introduction

Water is undoubtedly needed for every living creature of the earth. On the other hand, the quality of water is also a vital issue which influences human and environmental health. Compared to ground water, surface water quality needs major concern as it is easily contaminated and directly used for drinking and domestic purposes, irrigation and aquatic life including fisheries. Surface water is a vast network of branching rivers, estuaries, wetlands, lakes, bays, etc. and each waterbody can contain different levels of pollution. Although it is difficult to measure water quality but monitoring the quality of surface water will help us to recognize and prevent contamination problems.

4.2 Necessity of WQ data collection protocol and guidelines

Surface water quality of Bangladesh is affected by human activities, rise of urbanization, industrial production, climate change and other factors. The discharge of raw sewage, partially treated and untreated industrial waste, as well as oil spills are mainly deteriorating the quality of the rivers and waterbodies in the major cities. However, there are a number of water resources management plans and policies in this country but due to the lack of proper implementation of these, both the quality and quantity of surface water have reached a very critical situation which does not allow the direct use of it. The poisonous waters of these rivers have not only been killing all its aquatic life but also been posing health hazards to the people (J. N. Halder, 2015). Therefore, to save the environment and ensure the safety of human health, it is necessary to monitor the surface water quality on a regular basis. These days, different government and non govt. organizations are working to improve the quality of water through various projects but still there is no standard guidelines for collecting water sample from the field. Even at times researchers are not aware that for the different sample collection processes the result of the analysis could vary for a specific location.

Thus, to collect surface water sample following a standard and acceptable format it is essential to promote a consistent approach for field measurements and sampling techniques. This document will provide information on how to collect water samples from the field to analyse different water quality parameters that can be measured in the field and by laboratory analysis. The information includes how water samples are collected correctly, methods for in situ parameters analysis and how to store, preserve and transport samples to enable effective analysis by a laboratory testing.

4.3 Objective of the Protocols and Guidelines

The purpose of the guideline is to assist the user in planning and implementing the sampling survey with proper arrangement. This document discusses the equipment, technique, and steps that are required and considered for in-house preparation for field level data collection during surface water sampling programs.

The objectives are:

- To get structured instruction for collection of water sample from field;
- To assure the quality of water sample for reliable data;

- To develop a standard sampling procedure and guidelines for Bangladesh;

4.4 User of the Water Sample Collection Protocols and Guideline

The standard water sample collection protocols and guideline is developed specially for the personal use of the Department of Environment (DoE). While the structured method for water-quality sampling and data collection could be used by public and private sectors, including local agencies, research institute, academia and other educational institutions; professional consultants; environmental advocacy groups and volunteer organizations; and scientists and interested parties throughout the international community.

4.5 Sampling frequency

CEGIS has identified 99 strategic water sample collection locations of 30 rivers all over the country which has been already described in chapter two. Those strategic locations should be considered for collecting water samples. Considering the purpose of research, water sample could be collected several times from one source. However, to monitor the surface water quality it is necessary to collect water sample in different periods for different purposes. The following (**Tables 4.1 to 4.3**) described the appropriate month-date-time for monitoring surface water quality for drinking, agricultural/irrigation, fisheries and industrial use over the year.

Table 4.1: Schedule for monitoring of surface water quality for drinking purpose

For Fisheries Purpose			
Month		**Date**	**Time**
Pre monsoon period	April	15th Apr	08:00 am to 10:00 am
	June	15th Jun	08:00 am to 10:00 am
Monsoon period	August	15th Aug	08:00 am to 10:00 am
	October	15th Oct	08:00 am to 10:00 am
Post monsoon period	December	15th Dec	08:00 am to 10:00 am
	February	15th Feb	08:00 am to 10:00 am

Table 4.2: Schedule for monitoring of surface water quality for agricultural purpose

For Agricultural Purpose		
Month	**Date**	**Time**
February: Post monsoon period, Robi season	15th Feb	10:00 am to 11:00 am
June: Pre monsoon period, Kharif-I season	15th Jun	10:00 am to 11:00 am
October: Monsoon period, Kharif-II season	15th Oct	10:00 am to 11:00 am

Table 4.3: Schedule for monitoring of surface water quality for fisheries purpose

For Fisheries Purpose			
Month		**Date**	**Time**
Pre monsoon period	April	15th Apr	08:00 am to 10:00 am
	June	15th Jun	08:00 am to 10:00 am
Monsoon period	August	15th Aug	08:00 am to 10:00 am
	October	15th Oct	08:00 am to 10:00 am
Post monsoon period	December	15th Dec	08:00 am to 10:00 am
	February	15th Feb	08:00 am to 10:00 am

General instruction to be followed for field data collection

i. To avoid errors, it is recommended to calibrate all meters (DO, pH, EC, and temperature) at the beginning of each day (unless overnight travel is required). The meters should minimally be calibrated once a week. Perform a drift check at the end of each day (or on return to office if overnight sampling).

ii. Avoid cross contamination of samples. Always use new certified clean bottles for chemical samples and sterilized bottles for bacteriological samples. It is recommended that samples be placed in colorless plastic zip type bags to avoid cross contamination in the cooler. In case the sampling containers need to be re-used, it is necessary to clean them in a proper way following recommended steps given below (Department of Water, 2009):

   - rinse the equipment well in tap water
   - clean with De-Con 90 (a phosphate free detergent)
   - rinse well with tap water
   - rinse three times with de-ionized water
   - allow to dry.

iii. Both acidified and no-acidified bottles are required for collection of different water quality parameter samples. The size of the bottle would depend on the number of parameters to be tested.

iv. Efficient and experienced person should be engaged for quality field sample collection. Professional with the educational background on B.Sc. from water resource engineering/chemistry/environmental science/any trained person who have at least six months of field experience could be engaged as field data enumerator.

v. The field teams must be equipped with sterilized (both acidified and non-acidified) bottles, in situ test kit/equipment, Esky or portable refrigerator, digital camera, GPS, field data sheet, field maps and others (pencil, pen, eraser, clip board, bag, sample labels). Required financial and other logistic supports should be provided to the members of the field team.

vi. Safety equipment such as communication equipment, safety glasses, powerless hand gloves, mask, proper footwear, life jacket or flotation devices, survival gear, umbrella, raincoat and first-aid kits should be provided to the field team. All this should be suitably located, readily available and routinely checked before and during the field survey.

vii. The field team must be trained for the potential hazards and safety procedures relevant to their work.

viii. Contact with the zonal laboratories of DPHE and/or any others before the field data collection. It is necessary to submit samples in laboratory within suitable time for maintaining the quality of water sample.

ix. Record all time in a 24 hour (military) clock format.

x. Write all dates inmm/dd/yy or mm/dd/yyyy format. (For example, March 2, 2017 would be 03/02/17 or 03/02/2017.)

xi. Use GPS to confirm location at site. Record latitude and longitude in decimal degrees.

xii. Field team should use a field data collection check list at every water sample station to keep all important records during field.

xiii. Use the standardized station ID naming protocol for all surface water samples. Each sample collection bottle must be labelled with unique sampleidentification number. It is better to use Geocode for every single sample bottle.A format for labeling water quality sample bottles is given bellow (Form 4.1).

Form 4.1: Water sample collection bottle labelling form.

Sample ID: ………………………………
Date: ……………………………………..
Time: ……………………………………..
River name: ……………………………..
Exact location: ………………………….
District: …………………………………..
Upazila: ………………………………….
Union: ……………………………………
Mouza: …………………………………..
Sample type: ……………………………
Water temperature: …………………….
Water level: ……………………………..
Stream flow: …………………………….
Weather condition: ………………….....

4.6 Sampling procedure of different parameters during field survey

Sample collection procedure is not the same for all water quality parameters. Even some parameters need to be tested in the field which is called in situ measurement and most of the parameters are analysed in laboratory. (Department of mines and energy, Darwin, 2009)

The detail surface water sampling procedure for both field measured and laboratory analyzed parameters are described below from **Table 4.4** to **Table 4.17**:

- **Field measured parameters**

Table 4.4: Sampling procedures for electrical conductivity (EC)

Collection technique using hand-held meter – *in situ* field measurement
• Meter should be kept in gentle motion through the water column while a reading is being taken. Allow several minutes for the meter to stabilise. • Ideally, measurements should be made about 10 cm below the water surface (and then about 10

cm above the sediment surface); however, this is not always possible in shallow waterbodies. A mid water column reading will be sufficient in these cases.	
Sample collection technique for laboratory analysis at 25°C	
Sample requirements	Unfiltered sample
Volume	125 mL
Container	Plastic* Bottle cap must have a teflon liner Use new pre-cleaned bottles
Collection technique	Direct collection into sample bottle or transfer into a sample bottle from collection vessel. Ensure sample bottle is pre-rinsed three times with sample water (3 × 20 mL) before final collection.
Treatment to assist preservation	Refrigerate at 1–4°C, do not freeze
Filling technique	Excessive turbulence should be avoided to minimize presence of air bubbles in the sample. Fill container completely to the top to exclude air. The sample must be free of air bubbles and capped tightly.
Maximum sample holding time and storage conditions	Analyze within 24 hours for samples of low conductivity, i.e. below 20 µS/cm. Other samples can be held for one month if sample is kept refrigerated at 1–4°C and stored in an airtight container.
Units of measurement	µS/cm (or mS/cm).
Comments	It is preferable to perform this test in the field.

**Plastic sample bottles should not be made from low-density polyethylene (LDPE) as these tend to leak. Appropriate sample container plastics are high-density polyethylene (HDPE), polypropylene, polycarbonate or a fluoropolymer (e.g. teflon).*

Table 4.5: Sampling procedures fordissolved oxygen (DO)

Collection technique using hand-held meter – in situ field measurement	
• Meter should be kept in gentle motion through the water column while a reading is being taken. • Excessive turbulence should be avoided to minimize presence of air bubbles in the water, near the measurement cell. • Allow several minutes for the meter to stabilize. • Ideally measurements should be made about 10 cm below the water surface (and then about 10 cm above the sediment surface); however, this is not always possible in shallow waterbodies. A mid water column reading will be sufficient in these cases.	
Units of measurement	mg/L (dissolved oxygen concentration) or % (saturation)
Comments	This test must be done in the field.

Table 4.6: Sampling procedures forpH

Collection technique using hand-held meter – *in situ* field measurement
• Meter should be kept in gentle motion through the water column while a reading is being taken. • Allow several minutes for the meter to stabilize. • Ideally, measurements should be made about 10 cm below the water surface (and then about 10 cm above the sediment surface); however, this is not always possible in shallow waterbodies. A mid water column reading will be sufficient in these cases.

Sample collection technique for laboratory analysis	
Sample requirements	Unfiltered sample
Volume	125 mL
Container	Plastic* Bottle cap must have a teflon liner Use new pre-cleaned bottles
Collection technique	Direct collection into sample bottle or transfer into a sample bottle from collection vessel. Ensure sample bottle is pre-rinsed three times with sample water (3 × 20 mL) before final collection.
Treatment to assist preservation	Refrigerate at 1–4°C, do not freeze
Filling technique	Excessive turbulence should be avoided to minimize presence of air bubbles near the measurement cell or in the sample. Fill container completely to the top to exclude air. The sample must be free of air bubbles. Cap tightly.
Maximum sample holding time and storage conditions	Analyze directly as soon as possible after sample is collected and preferably in the field, but within 6 hours if the sample is refrigerated at 1–4°C, do not freeze sample.
Units of measurement	Standard pH units
Comments	It is preferable to perform this test in the field, in situ.

Table 4.7: Sampling procedures forsalinity

Collection technique using hand-held meter – *in situ* field measurement	
• Meter should be kept in gentle motion through the water column while a reading is being taken. • Allow several minutes for the meter to stabilise. • Ideally, measurements should be made about 10 cm below the water surface (and then about 10 cm above the sediment surface); however, this is not always possible in shallow water bodies. A mid water column reading will be sufficient in these cases.	
Sample collection technique for laboratory analysis	
Sample requirements	Unfiltered sample
Volume	200 mL
Container	Plastic* Bottle cap must have a teflon liner Use new pre-cleaned bottles
Collection technique	Direct collection into sample bottle or transfer into a sample bottle from collection vessel. Ensure sample bottle is pre-rinsed three times with sample water (3 × 20 mL) before final collection.
Treatment to assist preservation	Refrigerate at 1–4°C, do not freeze
Filling technique	Excessive turbulence should be avoided to minimize presence of air bubbles near the measurement cell or in the sample. Fill container completely to the top to exclude air. The sample must be free of air bubbles. Cap tightly.
Maximum sample holding time and storage conditions	Analyze directly as soon as possible after sample is collected, but within 24 hours if the sample is refrigerated at 1–4°C, do not freeze.
Units of measurement	Parts per thousand (‰)
Comments	It is preferable to perform this test in the field.

Table 4.8: Sampling procedures fortemperature

Collection technique using hand-held meter – in situ field measurement	
• Meter should be kept in gentle motion through the water column while a reading is being taken. • Allow several minutes for the meter to stabilise. • Ideally, measurements should be made about 10 cm below the water surface (for surface measurements).	
Units of measurement	Degrees Celsius (°C)
Comments	This test must be performed in the field.

Table 4.9: Sampling procedures forturbidity

Collection technique using hand-held meter – *in situ* field measurement	
• Meter should be kept in gentle motion through the water column while a reading is being taken. • Allow several minutes for the reading to stabilise. • Measurements using probes must be made at least 1 m below the water surface and deeper in clear waters to ensure that there is no influence from ambient light.	
Sample collection technique for laboratory analysis	
Sample requirements	Unfiltered sample
Volume	250 mL
Container	Plastic* or glass Use new pre-cleaned bottles
Collection technique	Direct collection into sample bottle or transfer into a sample bottle from collection vessel. Ensure sample bottle is pre-rinsed three times with sample water (3 × 20 mL) before final collection. It is important not to increase the turbidity of the water while collecting a sample, so do not disturb the bottom or the aquatic plants.
Treatment to assist preservation	Store container in dark Refrigerate at 1–4°C, do not freeze
Filling technique	Excessive turbulence should be avoided to minimize presence of air bubbles in the water. Fill to just below shoulder of the bottle.
Maximum sample holding time and storage conditions	Analyze directly as soon as possible after sample is collected and preferably in the field (only if you have an accurate probe, measuring accurately), but within 24 hours if the sample is refrigerated at 1–4°C. Keep cold but do not freeze.
Units of measurement	NTU (nephelometric turbidity units)
Comments	Freezing must be avoided, as irreversible changes in turbidity will occur if the sample is frozen.

- **Laboratory analyzed parameters**

Table 4.10: Sampling procedures for total suspended solids

Sample collection technique for laboratory analysis	
Sample requirements	Unfiltered sample
Volume	1 L
Container	Plastic* Use new pre-cleaned bottles
Collection technique	Direct collection into sample bottle or transfer into a sample bottle from collection vessel. Ensure sample bottle is pre-rinsed three times with sample water (3 × 20 mL) before final collection. It is important not to increase the turbidity of the water while collecting a sample, so do not disturb the bottom or the aquatic plants.
Treatment to assist preservation	Refrigerate at 1–4°C, do not freeze
Filling technique	Excessive turbulence should be avoided to minimize presence of air bubbles in the water. Fill to the shoulder of bottle.
Maximum sample holding time and storage conditions	Analyze directly as soon as possible after sample is collected, but within 24 hours if the sample is refrigerated at 1–4°C. Do not hold samples longer than 7 days. Keep cold but do not freeze. Alternative holding time is 3 days at 4°C.
Units of measurement	mg/L (mg total suspended solids/L)
Comments	Take care not disturb bottom sediments or plants during collection.

Table 4.11: Sampling procedures for total oxidised nitrogen (NOx-N), [Nitrate (NO_3^-) + Nitrite (NO_2^-)]

Sample collection technique for laboratory analysis	
Sample requirements	Filtered sample*
Volume	125 mL
Container	Plastic** Use new pre-cleaned bottles
Collection technique	The sample can be collected in a clean sample container prior to filtration. Filtered sample is placed into a different sample bottle, after rinsing. Ensure sample bottle is pre-rinsed three times with filtered sample water (3 × 20 mL) before final collection.
Filtration technique	Filter the sample through 0.45 µm pore diameter cellulose acetate (membrane) filter***.
Treatment to assist preservation	Refrigerate at 1–4°C or freeze and store in the dark
Filling technique	Fill to just below shoulder of the bottle.
Maximum sample holding time and storage conditions	Analyze within 24 hours if sample is kept refrigerated at 1–4°C. Analyze within 30 days if kept frozen below -20°C. Alternative holding time is 1–3 days at 4°C.
Units of measurement	mg/L (mg oxidised nitrogen as nitrogen/L)

Comments	• If determining nitrite species, the sample may be refrigerated (< 4°C) upon collection and analyzed as soon as possible thereafter. If the sample is frozen, the analysis must occur within 2 days of collection. • Samples for determining NOx-N, NH4-N /NH3-N, soluble reactive phosphorus and dissolved organic nitrogen can be collected in the same 250 mL container.

**Samples should be filtered as soon as possible after sample collection, preferably on site. Filter paper should be washed with sample first prior to filtration. Do not re-use filter paper.*

***Plastic sample bottles should not be made from low-density polyethylene (LDPE) as these tend to leak. Appropriate sample container plastics are high-density polyethylene (HDPE), polypropylene, polycarbonate or a fluoropolymer (e.g. teflon).*

****Optional: If the sample has high particulate matter content then it may be necessary to pre-filter using a glass fibre filter paper (GFC 1.2 µm).*

Table 4.12: Sampling procedures for nitrogen as ammonia/ammonium (NH_3-N/NH_4-N)

Sample collection technique for laboratory analysis	
Sample requirements	Filtered sample*
Volume	125 mL
Container	Plastic** or glass Use new pre-cleaned bottles
Collection technique	• The sample can be collected in a clean sample container prior to filtration. • Filtered sample is placed into a different sample bottle, after rinsing. • Ensure sample bottle is pre-rinsed three times with filtered sample water (3 × 20 mL) before final collection.
Filtration technique	Filter the sample through 0.45 µm pore diameter cellulose acetate (membrane) filter***.
Treatment to assist preservation	Refrigerate at 1–4°C or freeze and store in the dark
Filling technique	Fill to just below shoulder of the bottle.
Maximum sample holding time and storage conditions	• Analyze within 24 hours if sample is filtered and kept refrigerated at1–4°C • Analyze within 30 days if filtered and kept frozen below -20°C. • Alternative holding time is 1–3 days at 4°C.
Units of measurement	mg/L (mg N/L)
Comments	• Store in an area free from contamination as ammonia vapour may permeate the walls of HDPE. • Samples for determining NH4-N /NH3-N, NOx-N, soluble reactive phosphorus and dissolved organic nitrogen can be collected in the same 250 mL container.

**Samples should be filtered as soon as possible after sample collection, preferably on site. Filter paper should be washed with sample first prior to filtration. Do not re-use filter paper.*

***Plastic sample bottles should not be made from low-density polyethylene (LDPE) as these tend to leak. Appropriate sample container plastics are high-density polyethylene (HDPE), polypropylene, polycarbonate or a fluoropolymer (e.g. teflon).*

****Optional: If the sample has high particulate matter content then it may be necessary to pre-filter using a glass fibre filter paper (GFC 1.2 µm).*

Table 4.13: Sampling procedures for biochemical oxygen demand (BOD)

Sample collection technique for laboratory analysis	
Sample requirements	Unfiltered sample
Volume	1 L
Container	Plastic* or glass – brown (amber) ** Use new pre-cleaned bottles only
Collection technique	• Do not pre-rinse container with sample. • Direct collection into sample bottle or transfer into a sample bottle from collection vessel. • Keep samples at or below 4°C during compositing. Limit compositing period to 24 hrs after sample collection.
Treatment to assist preservation	Refrigerate at 1–4°C and store in the dark Do not freeze.
Filling technique	Do not pre-rinse container with sample. Fill container completely to the top to exclude air. The sample must be free of air bubbles.
Maximum sample holding time and storage conditions	Analyze directly as soon as possible after sample is collected, but within 24 hours if the sample is refrigerated at 1–4°C in the dark. Do not freeze.
Units of measurement	mg/L
Comments	• Need a separate sample container for BOD. • Sample must be free of air bubbles. • Dark (or amber) glass bottles are preferable for samples that are low in BOD (<5 mg L-1).

**Plastic sample bottles should not be made from low-density polyethylene (LDPE) as these tend to leak.*

**Appropriate sample container plastics are high-density polyethylene (HDPE), polypropylene, polycarbonate or a fluoropolymer (e.g. teflon).*

***Amber glass bottles are preferable for samples that are low in BOD (< 5 mg L^{-1}).*

Table 4.14: Sampling procedures for heavy metals [arsenic (As), boron (B), calcium (Ca), sodium (Na), lead (Pb),]

Sample collection technique for laboratory analysis	
Sample requirements	Filtered sample*
Volume	250 mL, unless speciation of As (total, trivalent, pentavalent) and/or Cr (total, trivalent) is required, in which case 500 mL is required.
Container	Plastic** Bottle cap must have a teflon liner Use new pre-cleaned acid rinsed bottles
Collection technique	Decant from collection vessel and filter immediately. Filtered sample is placed directly in sample bottle.
Filtration technique	Filter sample through 0.45 µm pore diameter cellulose acetate (membrane) filter***.
Treatment to assist preservation	After filtration, add 10% nitric acid (concentrated HNO3) to pH <2**** (if bottle from laboratory does NOT already have 2 mL present in pre-prepared bottles). Do not pre-rinse these sample bottles. Refrigerate at 1–4°C or freeze.

Sample collection technique for laboratory analysis	
Filling technique	If the sample bottles contain acid do not pre rinse them, otherwise, prerinse bottle with filtered sample three times, then add filtered sample and add acid preservative. Fill to the shoulder of bottle.
Maximum sample holding time and storage conditions	• 1 month if at 1–4°C, and pH < 2 • 6 months if frozen
Units of measurement	mg/L or µg/L (mg metal/L or µg metal/L)
Comments	• Samples for total metal concentrations are not filtered. • Generally, all metals/metalloids can be analyzed from the same sample bottle, except for when the special Hg analysis or speciation analysis is required. • **Safety note:** Use the appropriate personal protective equipment (e.g. safety glasses and gloves) when filling the sample bottles for dissolved metal analysis. Avoid contact or accidental splashing with the concentrated nitric acid preservative present in the bottles. Concentrated nitric acid is corrosive and care should be taken to avoid any eye or skin contact, or inhalation of fumes. If eyes or skin are exposed to the acid, wash thoroughly and with copious amounts of water and seek medical attention without any delay.

**Samples should be filtered as soon as possible after sample collection, preferably on site. Filter paper should be washed with sample first prior to filtration. Do not re-use filter paper.*

***Plastic sample bottles should not be made from low density polyethylene (LDPE) as these tend to leak. Appropriate sample container plastics are high-density polyethylene (HDPE), polypropylene, polycarbonate or fluoropolymer (e.g. nalgene, teflon (polytetrafluoroethylene, PTFE)). NMI now use 125 mL nalgene bottles for heavy metals, as the previously used HDPE bottles were found to leach trace quantities of Zn over time.*

****Optional FOR SOLUBLE METALS ANALYSIS ONLY: If the sample has high particulate matter content then it may be necessary to pre-filter using a glass fibre filter paper (GFC 1.2 µm).*

*****For the analysis of Li, K, and Na in samples, acidification is not required. These metals in solution are stable for 1 month without acidification (but acidification allows analysis of other metals).*

Table 4.15: Sampling procedures for total water hardness (as $CaCO_3$)

Sample collection technique for laboratory analysis	
Sample requirements	Unfiltered sample
Volume	125 mL
Container	Plastic** Bottle cap must have a teflon liner Use new pre-cleaned acid rinsed bottles
Collection technique	Decant from collection vessel, ensuring sample bottle is pre-rinsed three times with sample water (3 × 20 mL) before final collection.
Filling technique	Pre-rinse bottle with sample water three times, then add sample water. Fill to the shoulder of bottle.
Maximum sample holding time and storage conditions	7 days
Units of measurement	mg/L (mg $CaCO_3$/L)

**Plastic sample bottles should not be made from low-density polyethylene (LDPE) as these tend to leak.*

Appropriate sample container plastics are high-density polyethylene (HDPE), polypropylene, polycarbonate or fluoropolymer (e.g. nalgene, teflon).

Table 4.16: Sampling procedures for Chloride (Cl^-)

Sample collection technique for laboratory analysis	
Sample requirements	Filtered sample*
Volume	500 mL
Container	• Plastic** or glass • Use new pre-cleaned bottles • If necessary, bottles should be washed in phosphate-free detergent and rinsed three times with tap water and three times with deionised water.
Collection technique	• The sample can be collected in a clean sample container prior to filtration. • Filtered sample is placed into a sample bottle, after rinsing. • Ensure sample bottle is pre-rinsed three times with filtered sample water (3 × 20 mL) before final collection.
Filtration technique	Filter sample through 0.45 µm pore diameter cellulose acetate (membrane) filter***
Treatment to assist preservation	Refrigerate at 1–4°C or freeze.
Filling technique	Fill to below shoulder of bottle if freezing.
Maximum sample holding time and storage conditions	Analyze within 1 month if sample is kept refrigerated at 1–4°C.
Units of measurement	mg/L (mg Cl/L)

**Samples should be filtered as soon as possible after sample collection, preferably on site. Filter paper should be washed with sample first prior to filtration. Do not re-use filter paper.*

***Plastic sample bottles should not be made from low-density polyethylene (LDPE) as these tend to leak.*

Appropriate sample container plastics are high-density polyethylene (HDPE), polypropylene, polycarbonate or a fluoropolymer (e.g. teflon).

****Optional: If the sample contains a lot of particulate matter then it may be necessary to pre-filter sample using a glass fibre (GF/C) filter paper (GFC 1.2 µm).*

Table 4.17: Sampling procedures for microbiological analysis (faecal coliforms or thermotolerant coliforms)

Sample collection technique for laboratory analysis	
Sample requirements	Unfiltered sample
Volume	100 mL
Container	Sterilised plastic* or glass** Use new pre-cleaned sterilised bottles If necessary, bottles should be washed in phosphate-free detergent and rinsed three times with tap water and three times with deionised water, prior to sterilisation.
Collection technique	• Keep sterilised sample bottle closed until it is ready to be filled • Carefully remove container cap & do not contaminate inner surface of bottle and cap • Do not rinse sample container with sample • Direct collection into sample bottle or transfer into a sample bottle

Sample collection technique for laboratory analysis	
	from collection vessel • Replace cap immediately
Treatment to assist preservation	Store in the dark. Refrigerate at 1–4°C. Do not freeze.
Filling technique	Fill to below shoulder of bottle to facilitate mixing by shaking. If composite samples are prepared, care must be taken to ensure that the samples remain homogeneous during transfer.
Maximum sample holding time and storage conditions	Immediate analysis is preferable. Analyze within 24 hours if sample is kept refrigerated at 1–4°C.
Units of measurement	Coliform density is reported as counts per 100 mL water sample.

** Sterilisation by autoclaving is preferable. Sterilise glass containers for no less than 1 hour at a temperature of 170°C, and plastic containers at 121°C for no less than 15 minutes. For plastic bottles, loosen caps before autoclaving to prevent distortion.*

*** Plastic sample bottles should not be made from low-density polyethylene (LDPE) as these tend to leak. Appropriate sample container plastics are high-density polyethylene (HDPE), polypropylene, polycarbonate or a fluoropolymer (e.g. teflon).*

References

Department of mines and energy, Darwin. (2009). *AA7-025 Surface Water Sampling Methodology.* Retrieved from http://www.nt.gov.au/d/Minerals_Energy/Content/File/Forms_Guidelines/AA7-025%20Surface%20Water%20Sampling%20Methodology.docx.

Department of Water. (2009). *Surface water sampling methods and analysis — technical appendices.* Perth Western Australia: Department of Water, Government of Western Australia.

J. N. Halder, M. N. (2015). Water Pollution and its Impact on the Human. *Journal of environment and human, Volume 2*, 36-46.

U.S. Geological Survey. (2006). *National Field Manual for the Collection of Water-Quality Data, Book 9: Handbooks for Water-Resources Investigations.* Reston, VA: U.S. Geological Survey, TWRI.

5. Water Quality Data Analysis

5.1 Background

Water is essential for the existence of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities. Water in the natural environment contains many dissolved substances and non-dissolved particulate matter. Dissolved salts and minerals are necessary components of good quality water as they help to maintain the health and vitality of the organisms that rely on this ecosystem service (Stark et al., 2000). Water can also contain substances that are harmful to life like metals such as mercury, lead and cadmium, as well as pesticides, organic toxins and radioactive contaminants. Water from natural sources almost always contains living organisms that are integral components of the biogeochemical cycles in aquatic ecosystems. However, some of these, particularly bacteria, fungi, and viruses, can be harmful to humans if present in water used for drinking.

Water quality is variable in both time and space and requires routine monitoring to detect spatial patterns and changes over time. Monitoring of water quantity can be undertaken, to a certain degree, with a minimal amount of human intervention, once a monitoring station has been set up. In contrast, water quality is usually determined by analyzing samples of water collected from the selected monitoring stations at regular intervals. DoE has been monitoring surface and ground water quality since 1973 and DoE is currently monitoring water quality of 27 rivers of the country at monthly interval. However, most of the monitoring stations are selected long ago from where the pollution scenario has been changed. Therefore, under this study about 59 strategic locations are selected considering the existing stations from 13 important rivers of the country. Some of the strategic locations were identified as pollution hotspots. Descriptions of the strategic locations are given in Chapter 2.

5.2 Water Quality Parameters

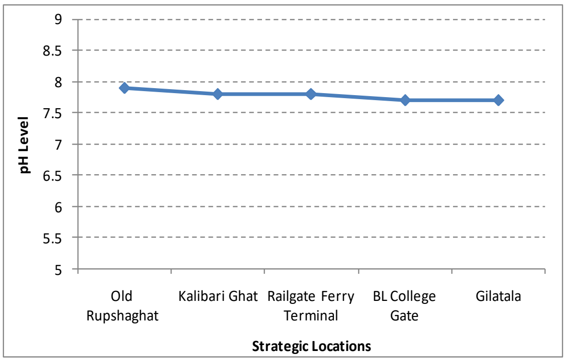
Water quality of a system is neither its static condition, nor can be explained by the measurement of only one parameter. There are a range of chemical, physical, and biological components that affect water quality. However, a comprehensive range of physico-chemical parameters like temperature, Electric Conductivity (EC), Dissolved Oxygen (DO), pH, Turbidity, Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) were measured from the selected strategic locations of the selected rivers. Results of the river water quality parameters are compared with the Environmental Quality Standard (EQS) for different uses set in the Environmental Conservation Rules, 1997.

5.3 Water Quality of the Selected Rivers

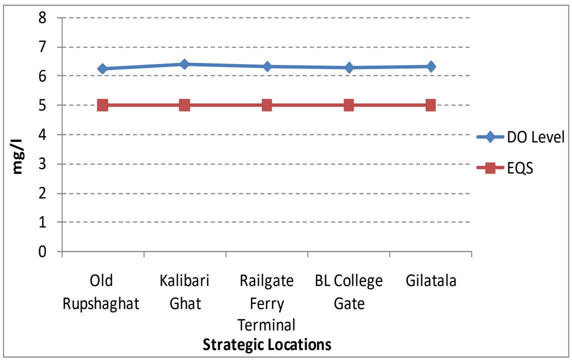
5.3.1 Rupsha River

The Rupsha River is a river in southwestern Bangladesh and a distributary of the Ganges. To monitor the water quality of Rupsha river samples were collected from five different strategic locations viz Old Rupsha ghat, Kalibari ghat, Railgate ferry terminal, BL College Gate and Gilatala along the river. There is no pollution hotspot identified in Rupsha river. The samples were collected on 26 November 2016.

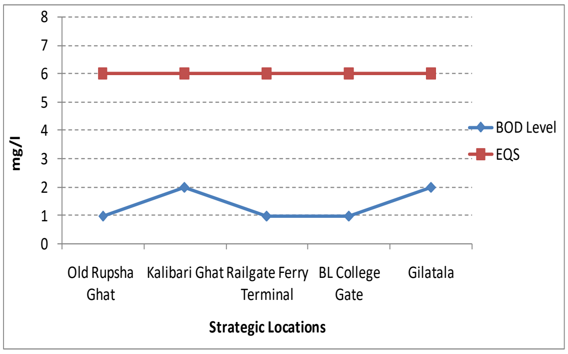
From the analysis, it is observed that pH level of the Rupsha river water varied between 7.7-7.9 while standard pH range for inland surface water is 6.5-8.5. Dissolved Oxygen (DO) of the river water was also above the Environmental Quality Standard (EQS) for fisheries (<5 mg/l). In 2014, DO level of the Rupsha ghat varied between 5.1-6.7 (DoE, 2015). The maximum and minimum BOD level was 2 mg/l and 1 mg/l respectively which were within the EQS of fisheries. COD values at all locations except Kalibari ghat were below the EQS for drinking water (4 mg/l). Chloride concentration of the river water was also within the EQS (<600 mg/l) at all locations. TDS of the river is far below the EQS (2100 mg/l).



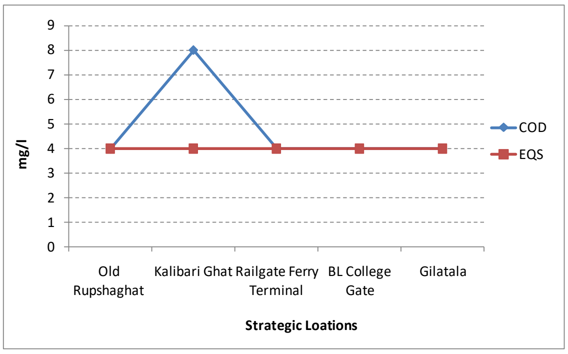
a. pH



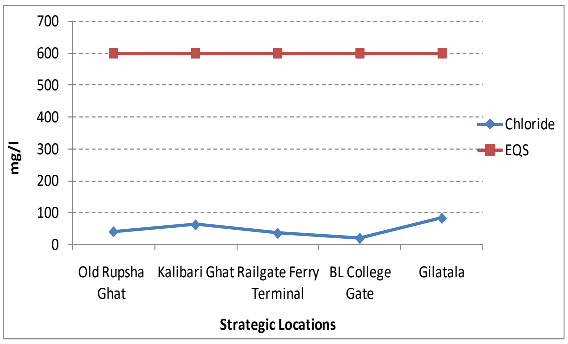
b. DO



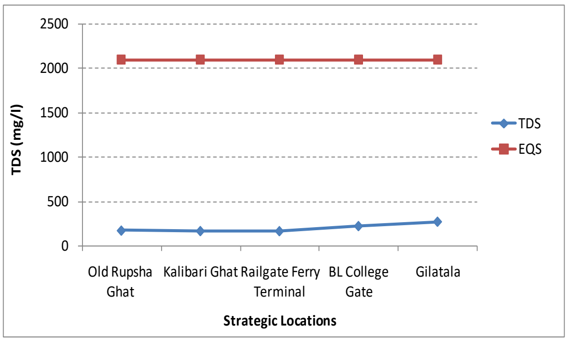
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.1: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Rupsha River

Electrical conductivity (EC) of the river water also varied between 342 μS/cm to 570 μS/cm while the standard for treated wastewater is 1200 μS/cm. From the analysis it is also observed that both TSS and turbidity values were beyond the acceptable limits at all locations. TSS values varied from 12 to 26 mg/l which is beyond the standard TSS (10 mg/l) for drinking water. The minimum and maximum turbidity level of the river water was 27.7 NTU to 80 NTU which is 8 times higher the EQS (10 NTU) for drinking water. The prime reason may be carrying huge silt throughout the year. However, the lead, nitrate and sulfate concentration are within the EQS for drinking water.

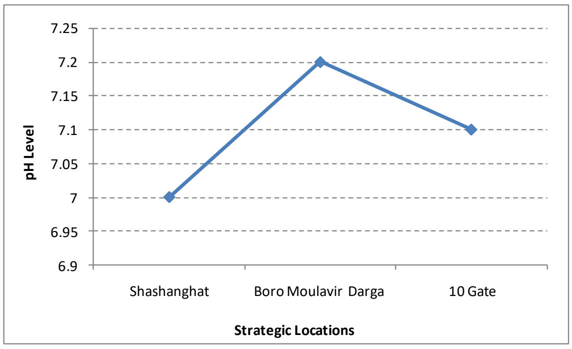
Table 5.1: Value of other water quality parameters at selected locations of the Rupsha River

Sampling Locations	Temperature (ºC)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Fecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulfate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Rupsha Ghat Old	24.8	0.62	0.002	48	350	242	310	0.003	0.87	51	5	12	46.7
Kalibari Ghat	25	0.7	0.002	24	350	320	310	0.009	0.93	29	4	15	27.7
Railgate Ferry Terminal	24.9	0.64	0.001	0.59	342	336	295	<LOQ	1.7	63	6	21	37.2
BL College Gate	24.9	0.69	0.002	43	448	280	340	0.017	0.68	45	7	19	63.1
Gilatala	24.8	0.82	0.003	69	570	404	350	0.004	2.15	73	7	26	80
Bangladesh standard for drinking water	20-30	0.5	0.05	75	1200	0	200-500	0.05	10	200	400	10	10

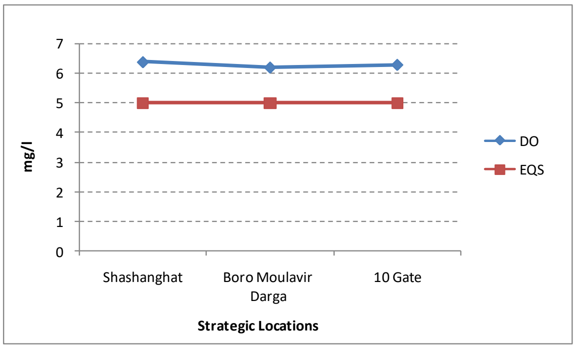
5.3.2 Moyuri River

The Moyuri river, which used to be very important for Khulna city but now is frequently cited as a dead river. Moyuri river is important from numerous points of view like irrigation purposes, carrying storm water, discharging municipal sewer. But due to human interruption the natural flow of the river is totally retarded and the river is completely converted into a feeder channel. For monitoring water quality of the Moyuri river, water samples were collected from three different strategic locations of the river: Shashanghat, Boro Moulavir Darga and 10 Valve Sluice Gate. None of these locations are pollution hotspot. The samples were collected on 26 November 2016.

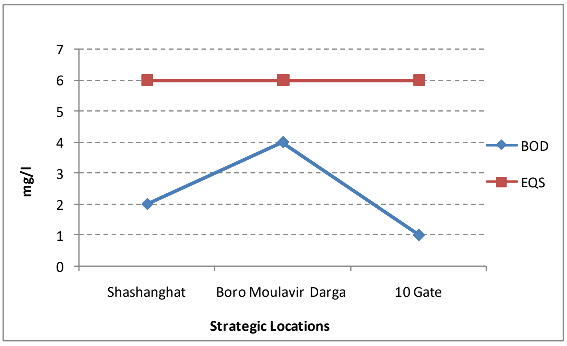
Analysis result revealed that pH level of theMoyuri River water varied from 7-7.2 which is within the EQS limit. In 2014, pH level also varied from 7.53 to 8.0. DO content of Moyuri river waterwas above the EQS (≥5 mg/l) for fisheries. But in 2012 and 2013 DO levels were below the EQS and from March to May, no dissolved oxygen was found (DoE, 2013 and DoE, 2014). BOD level of the Moyuri river water varied from 1to 4 mg/l while EQS for fisheries is ≤6 mg/l (Figure 5.2c.) but in 2013, BOD level varied from 10 to 36 mg/l. COD concentration of the Moyuri River was very high in one location but equal to the EQS in remaining two locations.



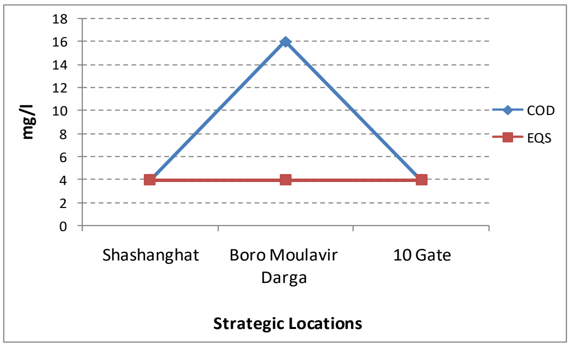
a. pH



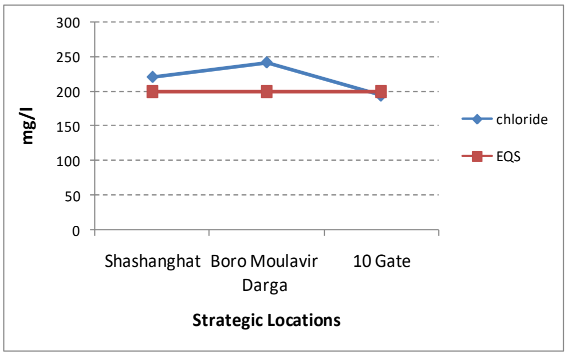
b. DO



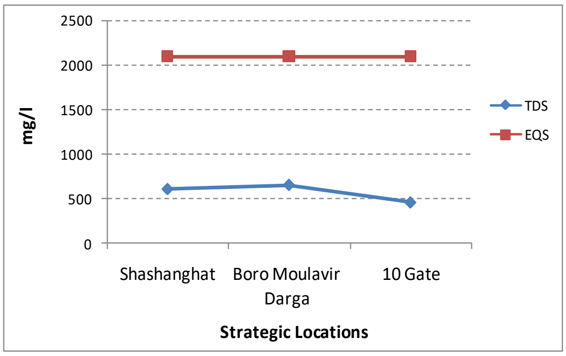
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.2 : Graphical presentation of pH, DO, BOD, COD, Chloride and TDS of Moyuri River

Chlorides occur in natural waters in widely varying concentrations and rivers and groundwater usually have a considerable amount of chloride. However, Chloride concentration of theMoyuri River is above the EQS (200 mg/l) in two locations: Shashan ghat (221 mg/l) and Boro Moulavir Darga (242 mg/l). TDS of the river is also within the EQS at all locations.

Table 5.2: Value of water quality parameters at selected locations of the Moyuri River

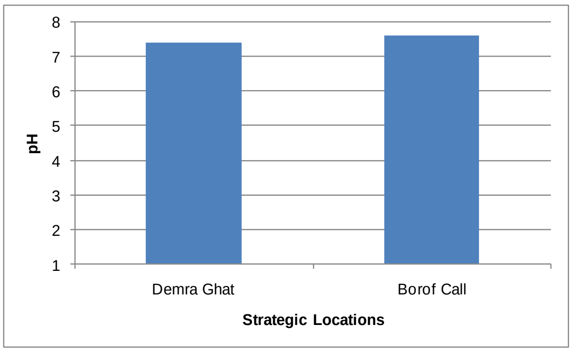
Sampling locations	Temperature (ºC)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	Coliform (Faecal) N/100ml	EC (µS/cm)	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Shashanghat	24.8	0.86	0.003	147	380	1232	540	0.014	0.64	162	10	31	6.5
Boro Moulavir Darga	24.9	0.78	0.002	165	182	1320	475	0.01	0.39	178	3	25	2.9
10 Valve Sluice Gate	24.7	0.61	0.001	138	240	930	425	0.004	3.11	129	15	20	16.3
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

Ammonia concentration in the Moyuri River is above the Bangladesh standard for drinking water. TSS values of the Moyuri River at all points were very high. It varied from 20 to 31 NTU while TSS for drinking water is 10 NTU. Turbidity level at 10 valve sluice gate point is above the EQS.

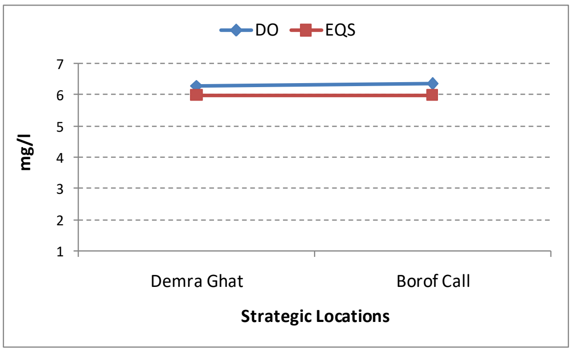
5.3.3 Shitalakhya River

The river Shitalakhya is one of the most prominent rivers in the flood plain region of Bangladesh. It is located in Narayanganj City, the second most vital industrial zone of the country. Various types of industrial units have been established on the bank of the Shitalakhya River; most of these industries directly or indirectly discharge huge quantities of wastes and effluents into the river without any treatment and also municipal and domestic sewage sludges from Narayanganj urban area, and find their way untreated into this river. Moreover, the river is the route of the communication with Chandpur, Chittagong port for cargo transportation. Besides these, the people live on and around the Shitalakhya River have been utilizing its water for their household washing, bathing and other necessary works.

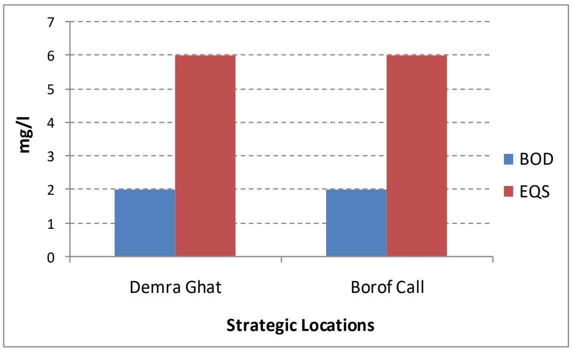
For monitoring water quality of the Sitalakhya River, four strategic locations are identified along the river: Port Road (Borof Call), Demra Ghat, Murapara (Rupganj) and location near the Ghorashal fertilizer factory. However, under this study, water samples were collected from two strategic locations which are more polluted viz: Demra ghat and Port Road (Near ICE Miil Factory). The samples are collected on 28 November 2016.



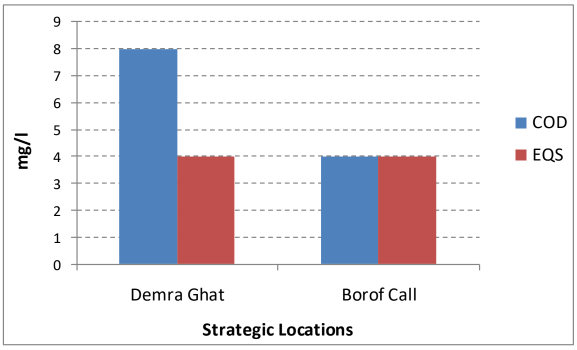
a. pH



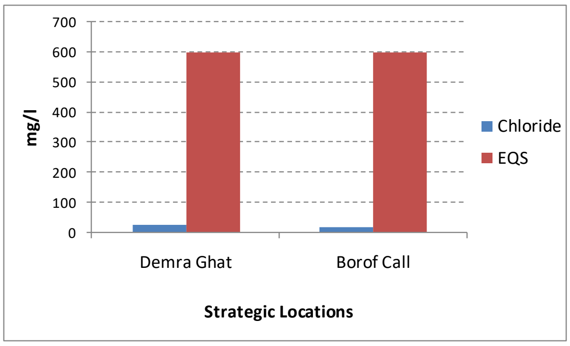
b. DO



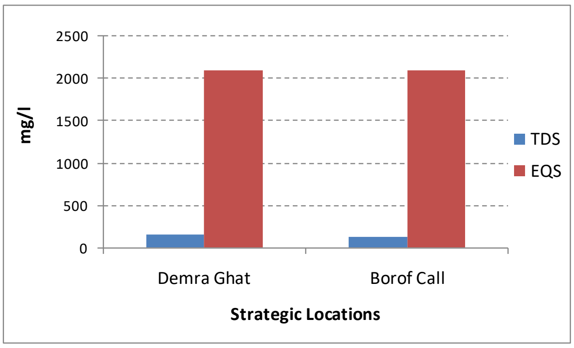
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.3: Graphical presentation of pH, DO, BOD, COD, Chloride and TDS of Shitalakhya River

From the result of the analysis, it is observed that pH value of the river was within the EQS (6.5-8.5) for inland surface water. Both DO and BOD values were found within the EQS (DO>6 and BOD <6) for Source of drinking water for supply after conventional treatment. Chloride concentration of the river was 17 and 25 mg/l at Port Road (Borof call) and Demra ghat locations respectively. However, DoE has an existing water quality monitoring station near the ACI salt factory. In 2014, the maximum chloride level was about 180 mg/l which is also with the EQS (150-600 mg/l) for drinking water. Maximum observed TDS of the Sitalakhya River was 153 mg/l which is far below than the EQS (2100 mg/l).

Table 5.3: Value of other water quality parameters at selected locations of the Shitalakhya River

Sampling locations	Temperature (oC)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	Coliform (Faecal) N/100ml	EC (µS/cm)	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulfate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Demra Ghat	24.9	0.81	0.003	14.74	316	317	138	0.006	11.82	19	28	18	25.1
Port Road (Borof Call)	25.2	0.87	0.002	12.05	208	292	155	0.002	4.52	16	33	11	26
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

Ammonia concentration at both of the measured locations were above the EQS for drinking water (<0.5 mg/l) usually an indication of bacterial, sewage, and animal waste pollution (Parliamentary Standing Committee on Ministry of Environment & Forests, 2010). Calcium, EC, hardness, lead, sodium and sulfate concentration was within the Bangladesh standard for drinking water. But concentration at Demra ghat is above the EQS (<10 mg/l) for drinking water and TSS and turbidity concentration at both of the locations were above the EQS (TSS<10 mg/l and turbidity <10 NTU) for drinking water.

5.3.4 Buriganga River

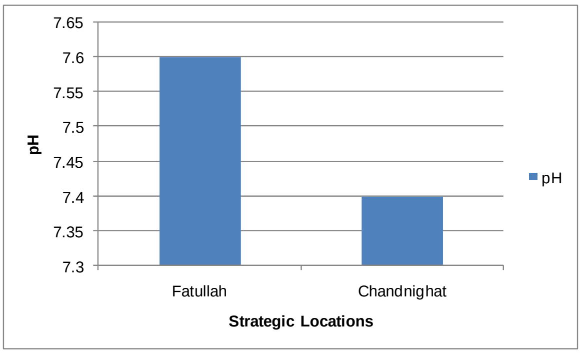
The Buriganga River is a tide-influenced river passing through southwest periphery of Dhaka City. Its average width and depth are 400m and 10m respectively. This river is only 27 km long. The Buriganga is of great economic importance to Dhaka. It provides river connection by launch and country boats. However, the Buriganga River is afflicted by the detrimental problem of pollution. The chemical waste of mills and factories, household waste, medical waste, sewage, dead animals, plastics, and oil are some of the Buriganga's pollutants. The city of Dhaka discharges about 4,500 tons of solid waste every day and most of it is released into the Buriganga. According to the Department of Environment, 21,600 cubic metres (5.7 million US gallons) of toxic waste are released into the river by the tanneries every day.

For monitoring the water quality of the Buriganga River, seven strategic locations are identified along the river: Mirpur Bridge, Boshila Bridge, Hazaribagh, Chandnighat, Sata Mosque Road, BD-China Friendship Bridge and Fatullah. However, under this study, water samples were collected from two strategic locations which are more polluted viz: Chandnighat and Fatullah. The samples were collected on 8 November 2016.

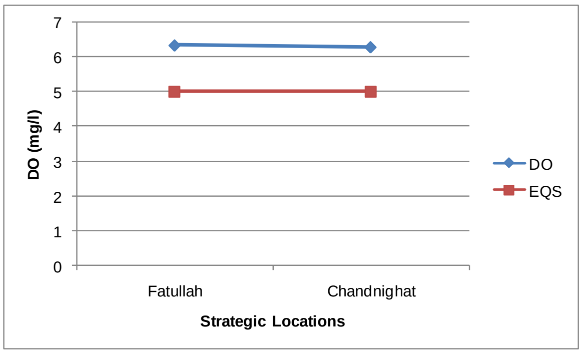
From the analysis, it is observed that the concentration of pH in Buriganga river water varied from 7.4 to 7.6 while standard pH range for inland surface water is 6.5-8.5. Dissolved Oxygen (DO) concentration of the river water was above than the Environmental Quality Standard (<5 mg/l). In 2014, the maximum DO (5.48mg/l) was found at Mirpur Bridge in August and the minimum (0.0 mg/l) was at Sadar Ghat in January (DOE, 2015).

The maximum and minimum concentration of BOD was 3 mg/l and 1 mg/l respectively which are within the EQS of fisheries.

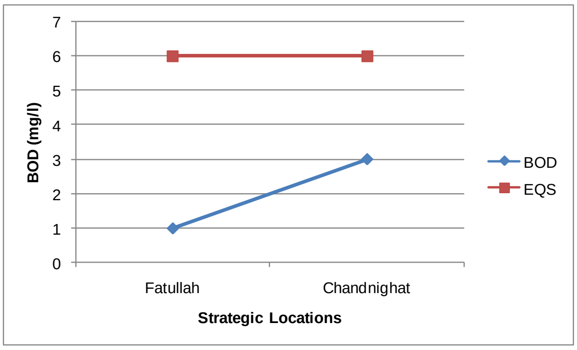
COD concentration in Chandnighat was above the EQS for drinking water (4 mg/l). Chloride concentration of the river water was also within the EQS (<600 mg/l) at all locations. TDS of the river is far below the EQS (2100 mg/l).



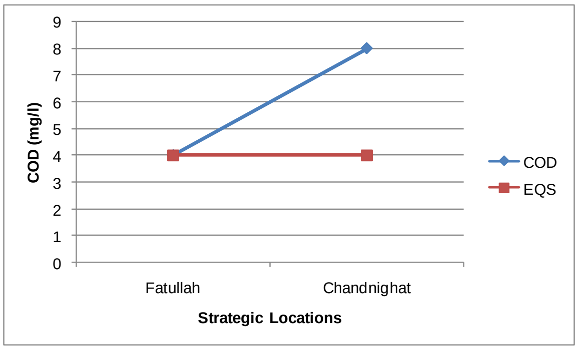
a. pH



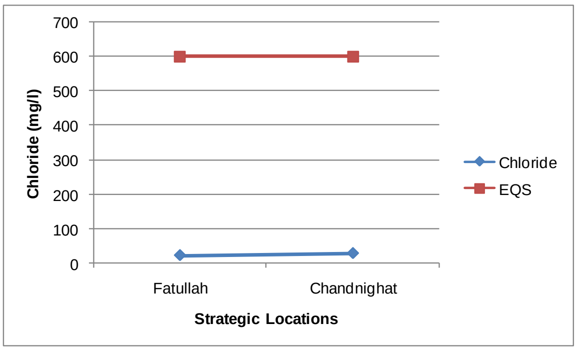
b. DO



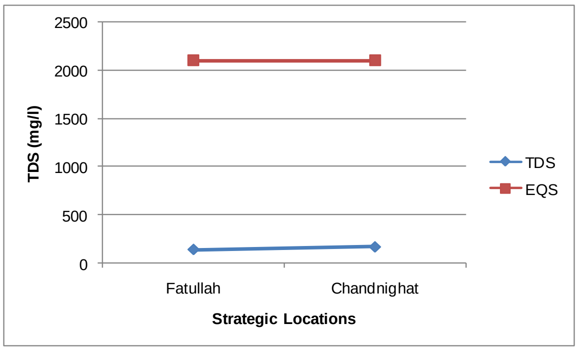
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.4: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Buriganga River

Electrical conductivity (EC) of the river water also varied from 292 µS/cm to 354 µS/cm while the standard for treated wastewater is 1200 µS/cm. From the analysis it is also observed that TSS value was above the acceptable limits at all locations. TSS values varied from 14 to 15 mg/l which is beyond the standard TSS (10 mg/l) for drinking water. The minimum and maximumturbidity level of the river water was 8.5 NTU to 10.3 NTU while the EQS (10 NTU) for drinking water.

Table 5.4: Value of other water quality parameters at selected locations of the Buriganga River

Strategic Location	Parameter												
	Temperature (ºC)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Fatullah	21.1	0.85	0.002	11.1	292	382	155	<LOQ	17.6	15	16	15	8.5
Chandnighat	24.9	0.69	0.002	12.21	354	290	135	<LOQ	35.1	16	35	14	10.3
Bangladesh standard for drinking water	20-30	0.5	0.05	75	-	2100	200-500	0.05	10	200	400	10	10

5.3.5 Turag River

The Turag River is the upper tributary of the Buriganga, a major river in Bangladesh. It originates from the Bangshi River, the latter an important tributary of the Dhaleshwari River, flows through Gazipur and joins the Buriganga at Mirpur in Dhaka District. Both organic and inorganic waste effluents that are discharged into the Turag River water are adversely interacting with the river system and deteriorating the water quality of the river. For this reason, the water causes the adverse effect of surrounding land and aquatic ecosystem as well as subsequent impact on the livelihood of the local community (Meghla *et al.*, 2013; Rahman *et al.,* 2012).

The Turag River has been declared as as ecologically critical area (ECA) by the Department of Environment. Study on Turag River water quality that was carried out at different points in time by the Department of Environment (DoE, 2001). But the various industries beside the Turag River are continuously discharging their effluents and waste water into the Turag River and seriously polluting the river water.

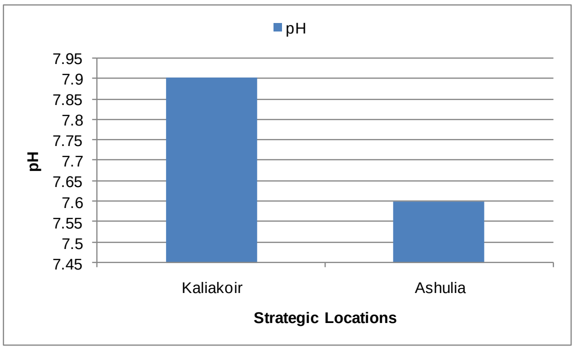
The major pollution sources of Turag River water are various consumer goods industries (soap and detergent), garments industries, pharmaceuticals industries, dyeing industries, aluminum industries, battery manufacturing, match industries, ink manufacturing industries, textile, paint, iron industries, pulp and paper factories, chemical factories, frozen food factories and steel workshop etc. (Rahman *et al.,* 2012). During the Bishwa Ijtema, Muslim pilgrims coming from all over the world stay at the riverside for days. Unfortunately, there is no proper accommodation and adequate sanitation system at the site of the Bishwa Ijtema. As a result, human waste and garbage generated at the time of Ijtema is disposed into the river. This also pollutes the river heavily.

For monitoring the water quality of Turag River, five strategic locations are identified along the river: Turag Bridge, Ashulia, Nama Bazar, Vawal and Kaliakoir. However, under this study, water samples were collected from two strategic locations which are more polluted viz: Kaliakoir and Ashulia. The samples are collected on 7-8 November 2016.

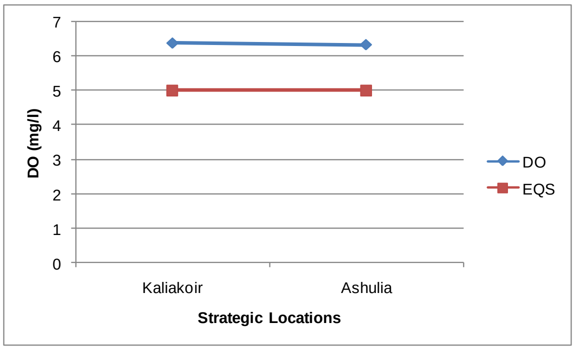
From the analysis, it is revealed that concentration of pH level of the Turag River water varied between 7.6-7.9 while standard pH range for inland surface water is 6.5-8.5. In 2014, concentration of pH level of Turag varied between 7.01 to 7.4. Maximum value of pH was in March and minimum pH 7.01 was found in July respectively. Concentration of Dissolved Oxygen (DO) in river water was above the Environmental Quality Standard (<5 mg/l). DO concentration of Turag River was very low during the dry season of 2014 and it varied from 0 to 4.5 (DoE, 2015).

The concentration of BOD in Turag river water was beyond the (EQS ≤6 mg/L) for all locations. In 2014, concentration of BOD varied between 2 to 154 mg/l. Maximum Concentration of BOD was found in March at Aztneri Composite Ltd and the minimum in August at South Side Tongi Rail Bridge (DoE, 2015).

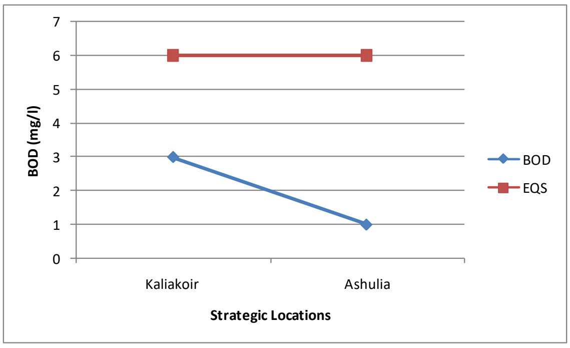
The maximum and minimum concentration of COD level was 8.0 mg/l and 4.0 mg/l respectively which were within the EQS for drinking water (4 mg/l). Chloride concentration of the river water was also within the EQS (<600 mg/l) at all locations. TDS of the river is far below the EQS (2100 mg/l).



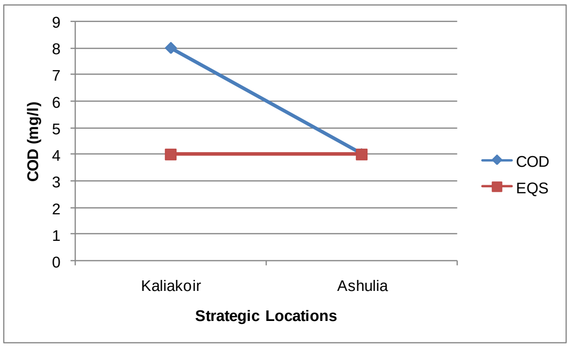
a. pH



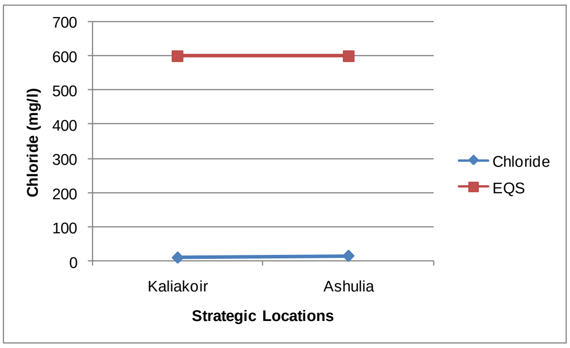
b. DO



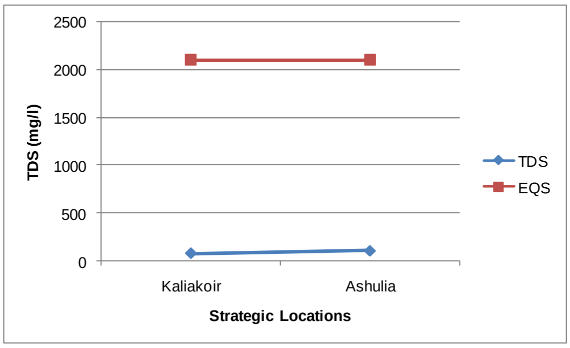
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.5: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Turag River

Electrical conductivity (EC) of the river water also varied from 171 µS/cm to 221 µS/cm while the standard for treated wastewater is 1200 µS/cm. From the analysis it is also observed that TSS values of the selected strategic locations varied from 10 mg/l to 12 mg/l where the standard TSS (10 mg/l) for drinking water. The minimum and maximum turbidity level of the river water was 8.10 NTU to 65.7 NTU which is 6.5 times higher the EQS (10 NTU) for drinking water.

Table 5.5: Value of other water quality parameters at selected locations of the Turag River

Strategic Location	Parameter												
	Temperature (°C)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Kaliakoir	25.1	0.92	0.003	10.91	171	400	125	<LOQ	0.68	13	24	10	65.7
Ashulia	25	0.74	0.002	16.05	221	418	130	0.006	7.14	20	5	12	8.1
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

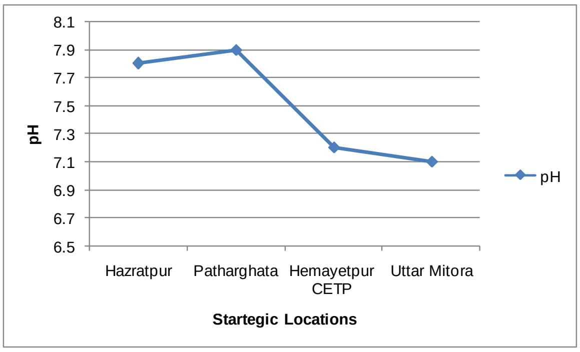
5.3.6 Dhaleshwari River

The Dhaleshwari River is a distributaries of the Jamuna, takes off in the northwestern part of Tangail district. It is a meandering river which has two branches. The main stream flows north of Manikganj and joins the other branch, the Kaliganga, south of Manikganj. The Kaliganga again joins with the Dhaleshwari. Total length of the river is about 160 km.

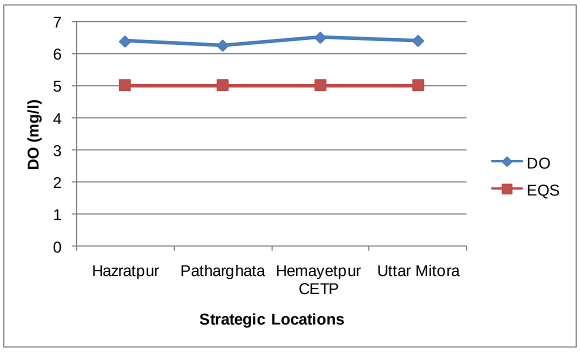
For monitoring water the quality of Dhaleshwari River, six strategic locations are identified along the river: Mukterpur Bridge, Patharghata, Ruhitpur, Hazratpur, Hemayetpur CETP (Horindhora) and Uttar Mitora. However, under this study, water samples were collected from four strategic locations which are more polluted viz: Patharghata, Hazratpur, Hemayetpur CETP (Horindhora) and Uttar Mitora. The samples are collected on 08 December 2016 and 30 January 2017 respectively.

From the analysis, it is revealed that concentration of pH level of the Dhaleshwari River water varied between 7.1-7.9 while standard pH range for inland surface water is 6.5-8.5. In 2014, concentration of pH level of Dhaleshwari varied from 6.91 to 7.72. Concentration of Dissolved Oxygen (DO) in river water was above the Environmental Quality Standard (<5 mg/l). DO concentration of Dhaleshwari River was very low during dry season of 2014 and it varied 0 to 4.5 (DOE, 2015). BOD concentration in DhaleshwariRiver varied from 1.0-36 mg/l while EQS for fisheries is ≤6 mg/L. In 2014, concentration of BOD varied between 0.0 to 17.8 mg/L (DOE, 2015).

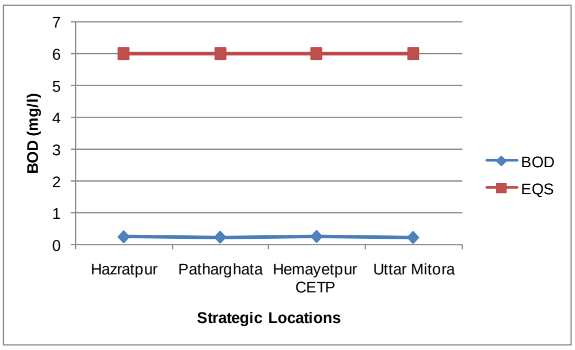
The maximum and minimum concentration of COD level was 4 mg/l and 128 mg/l respectively which were within the EQS for drinking water (4 mg/l). Chloride concentration of the river water was also within the EQS (<600 mg/l) at all locations. TDS of the river is far below the EQS (2100 mg/l).



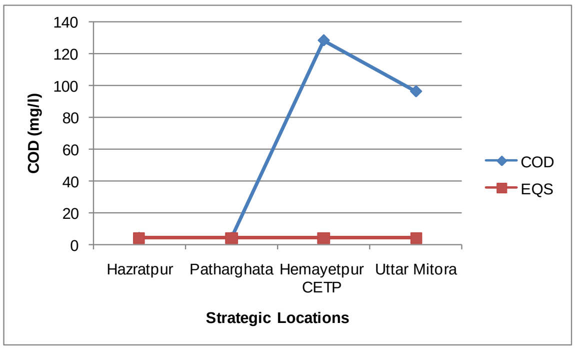
a. pH



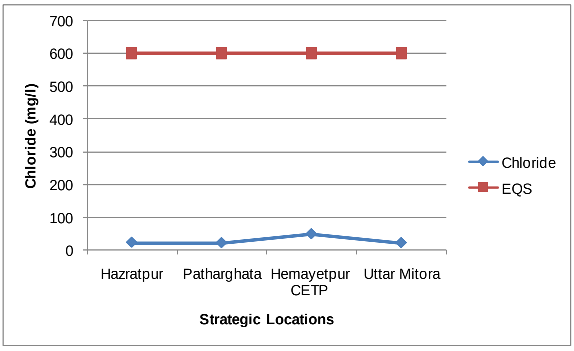
b. DO



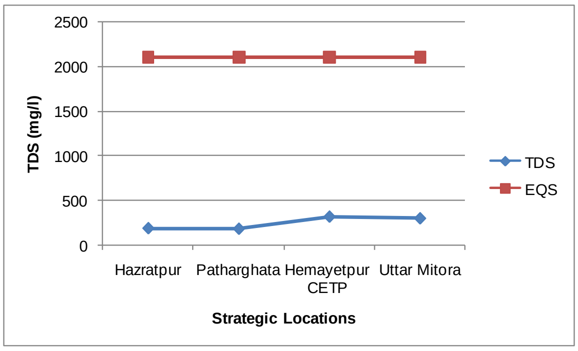
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.6: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Dhaleshwari River

Electrical conductivity (EC) value varied from 367 µS/cm to 642 µS/cm while EC standard for treated wastewater is 1200 µS/cm. From the analysis it is also observed that both TSS and turbidity values were beyond the acceptable limits at all locations. TSS values varied from 4.0 to 8.0 mg/l which is beyond the standard TSS (10 mg/l) for drinking water. The minimum and maximum turbidity level of the river water was 2.48 NTU to 8.30 NTU which is lower than the EQS (10 NTU) for drinking water.

Table 5.6: Value of other water quality parameters at selected locations of the Dhaleshwari River

Strategic Location	Parameter												
	Temperature (°C)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Fecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulfate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Hazratpur	26	0.73	0.004	20	367	72	715	0.026	2.76	24	100	4	8.3
Patharghata	26.1	0.59	0.005	36	369	60	710	0.01	1.79	38	9	4	4.4
Hemayetpur CETP	24.8	2.2	0.007	70	642	780	360	0.008	10.86	109	72	8	4.71
Uttar Mitora	25.1	1.3	0.007	43	592	860	475	0.007	0.97	57	1	7	2.48
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

5.3.7 Meghna River

The Meghna is an important river in Bangladesh and one of the three that forms the Ganges Delta, the largest on the earth ended up the Bay of Bengal. Both industrial pollution and pollution from non-point sources occurs in Meghna River. Many industries are located on the bank of Meghnalike Meghna Ghat Power Plant, Summit Power Plant, salt industries, and dyeing industries and other ones. Agricultural pollution occurs through a number of confluences as well as runoff water from agricultural land.

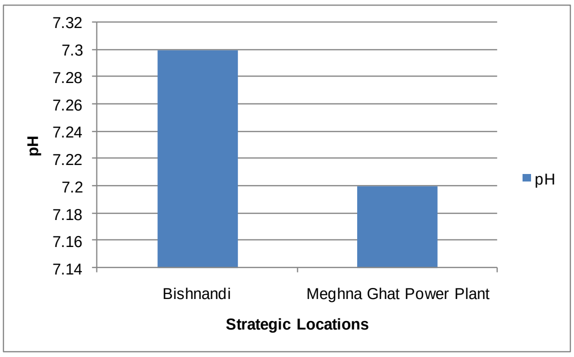
For monitoring the water quality of Meghna River, five strategic locations are identified along the river: Meghna Ghat Power Plant, Ananda Bazar, Bishnandi, Narshingdi Launch Terminal and Bhairab Bazar. However, under this study, water samples were collected from two strategic locations which are more polluted viz: Bishnandi and Meghna Ghat Power Plant. The samples were collected on 01 January 2017.

From the analysis it is observed that, concentration of pH in the selected strategic locations of the Meghna River varied between 7.2-7.3 while standard pH range for inland surface water is 6.5-8.5. In 2014, concentration of pH varied from 6.92 to 9.56. High pH (9.56) in June at SPM may indicate untreated waste disposal by the SPM.

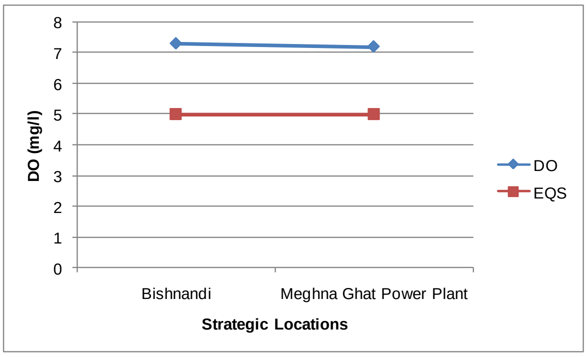
Concentration of Dissolved Oxygen (DO) in river water varied from 6.5 to 7.6 mg/l which are often below the EQS (≥5 mg/l) for fisheries. In 2014, DO concentration of the selected strategic locations of the Meghna River varied between 1.0 to 6.7 mg/l.

BOD concentration of the river water varied from 3.0 to 4.0 mg/l while the EQS (≤6 mg/l) for fisheries. In 2014, maximum and minimum concentration of BOD was 17 mg/l in June and 2.3 mg/l in December at Bhairab Bazar (DOE, 2015). COD level of the river was above the EQS for drinking water (4 mg/l). TDS concentration varied from 52.0 to 102 mg/l. TDS of Meghna river was very low in 2014 and ranged from 27.6 to 138 mg/1 (DoE, 2015).

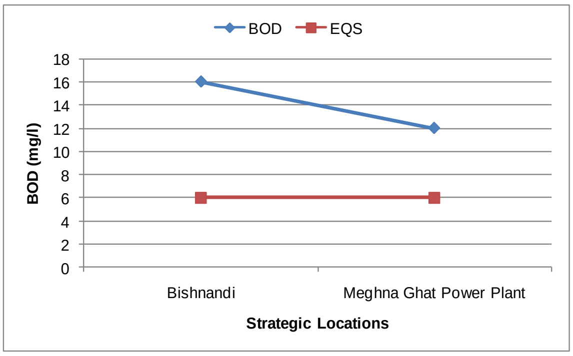
Chloride concentration at all the sampling locations was within the EQS (600mg/l) for wastewater after treatment from industrial units.The maximum Chloride (16.0mg/l) was found at Bishnandi and the minimum (12.0 mg/l) was at Meghna Ghat Power Plant.In 2014, Chloride concentration varied from 3.5 to77.7mg/l.



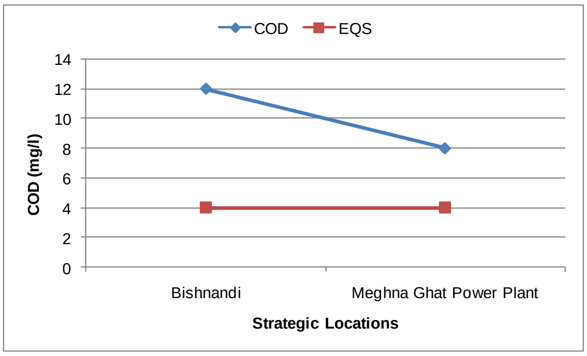
a. pH



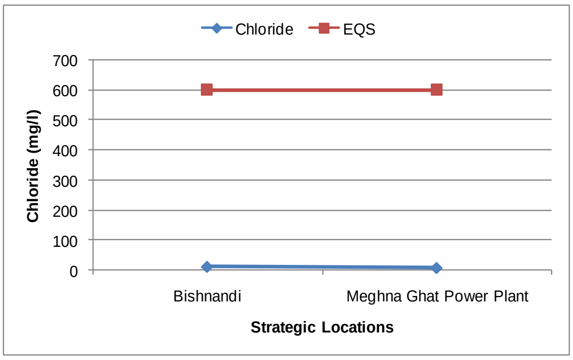
b. DO



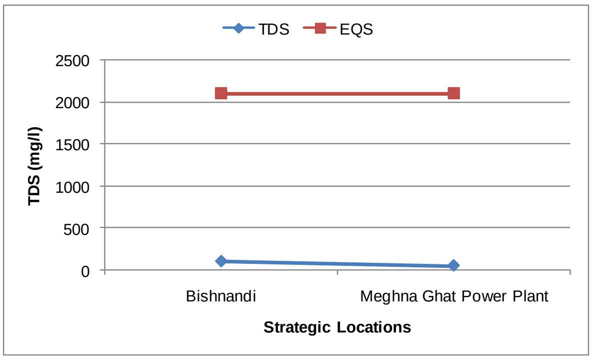
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.7: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Meghna River

Electrical conductivity (EC) value varied between 103 µS/cm to 215 µS/cm while EQS for treated wastewater is 1200 µS/cm. From the analysis it is also observed that turbidity value were beyond the acceptable limits at all locations. TSS values varied from 7.0-12.0 mg/l. In Meghna Ghat Power Plant point, TSS value is beyond the standard TSS (10 mg/l) for drinking water and in Bishnandi it is above the standard TSS (10 mg/l) for drinking water.

Table 5.7: Value of other water quality parameters at selected locations of the Meghna River

Strategic Location	Parameter												
	Temperature (°C)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Bishnandi	22	0.61	0.004	11	215	96	270	0.001	3.62	14	15	12	4.7
Meghna Ghat Power Plant	22.4	0.74	0.002	26	103	118	255	0.002	2.98	27	2	7	3.2
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

5.3.8 Padma River

The Padma is a major river in Bangladesh. It is the main distributary of the Ganges, flowing generally southeast for 120 kilometres (75 mi) to its confluence with the Meghna River near the Bay of Bengal. Both industrial pollution and pollution from non-point sources occur in the Padma River. Many industries are located on the bank of Padma at Shilakotha area.

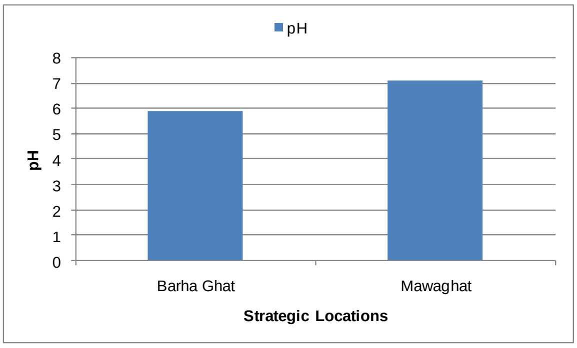
For monitoring water quality of the Padma River, four strategic locations are identified along the river: Puran Bazar, Mawa Ghat, Nort Beak Martin Island and Barha Ghat. However, under this study, water samples were collected from two strategic locations which are more polluted viz: Mawa Ghat and Barha Ghat. The samples are collected on 11 November 2016 and 30 January respectively.

From the analysis it is observed that, concentration of pH in the selected strategic locations of the Padma River varied from 5.90 to 7.10 while standard pH range for inland surface water is 6.5-8.5. In 2014, concentration of pH varied from 5.3 to 8.6 (DoE, 2015).

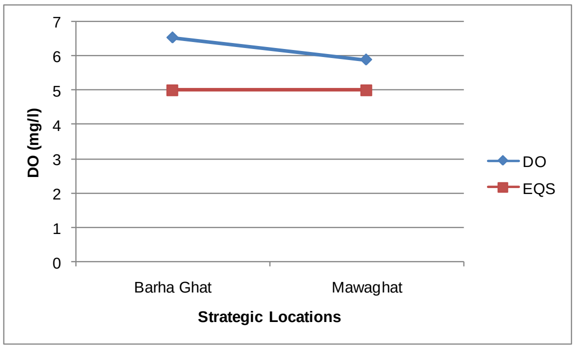
Dissolved Oxygen (DO) concentration in river water varied from 5.88 to 6.53 mg/l which are often above the EQS (≥5 mg/l) for fisheries. In 2014, DO concentration of the selected strategic locations of the Padma River varied between 1.0 to 6.7 mg/l (DOE 2015).

BOD concentration is within the EQS (≤6 mg/l) for fisheries in Mawa Ghat point but in Barha Ghat BOD concentration exceeds the standard value. In 2014, maximum BOD was found 2.9mg/l in January and that of the minimum was 0.8mg/lin May (DOE, 2015). COD level of the river was within the EQS (200 mg/l) for wastewater from industrial units round the year. TDS concentration varied from 128 to 145 mg/l. In 2014, TDS of Padma River varied from 110 to 270 mg/l (DoE, 2015).

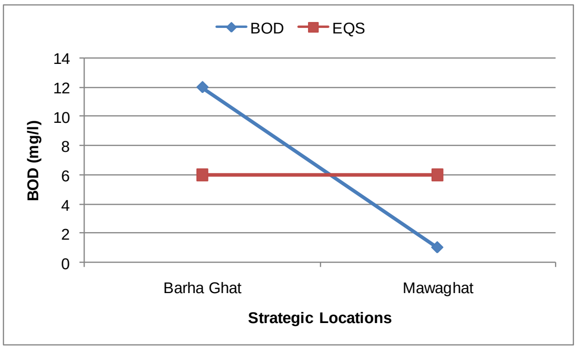
Chloride concentration at all the sampling locations was within the EQS(600mg/l)for waste water after treatment from industrial units. In 2014, maximum and minimum chloride concentration of Padma river water was 40mg/l in January and 20mg/l in December (DoE, 2015).



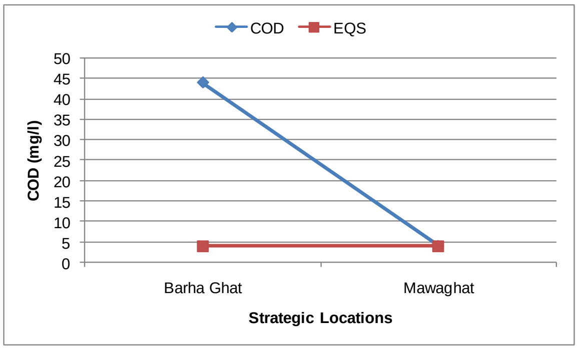
a. pH



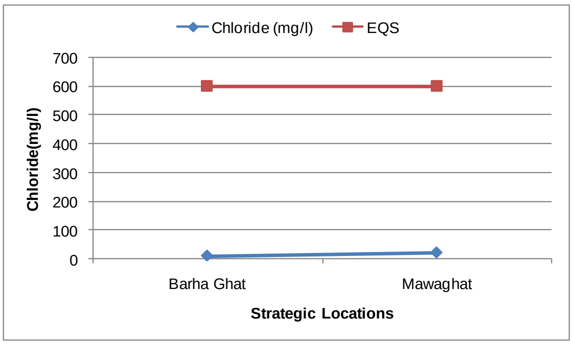
b. DO



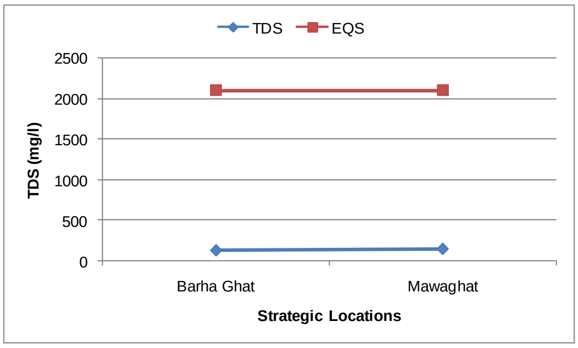
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.8: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Padma River

The maximum and the minimum concentration of EC value in the selected strategic locations of the Padma River is 216 μS/cm and 300 μS/cm respectively, while EQS is 1200 μS/cm for treated waste water from industrial units. In 2014, EC varied between 214 μmhos/cm and 561μmhos/cm. From the analysis it is also observed that both TSS values were within the acceptable limits at all locations. TSS values varied from 5 to 10 mg/l where the standard TSS (10 mg/l) for drinking water. The minimum and maximum turbidity level of the river water was 2.1 NTU to 12 NTU while the EQS (10 NTU) for drinking water.

Table 5.8: Value of other water quality parameters at selected locations of the Padma River

Strategic Location	Parameter												
	Temperature (°C)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Barha Ghat	25.2	0.51	0.001	17	216	640	20	0.006	0.51	22	11	5	12
Mawaghat	24.7	0.59	0.001	39	300	282	325	0.007	20.36	41	61	10	2.1
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

5.3.9 Ganges River

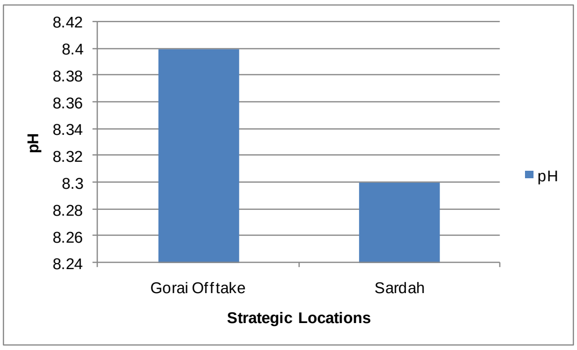
The Ganges River is a major trans-boundary river which originated in the glacier of Himalaya. The Ganges River runs a long distance on the Indo-Gangetic plain in India and enters Bangladesh at Shibganj of Chapi-Nababganj district. Rajshahi is one of the major Cities in north-west Bangladesh, which is situated on the bank of the Ganges River.

For monitoring water quality of the Ganges River, four strategic locations are identified along the river: Kanchan Park, Gorai Offtake, Nurullapur and Sardah. However, under this study, water samples were collected from two strategic locations which are more polluted viz: Sardah and Gorai Offtake. The samples were collected on 14 to 15 January, 2016. Gorai offtake carries huge amount of water and spread out over the large areas in Kushtia area.

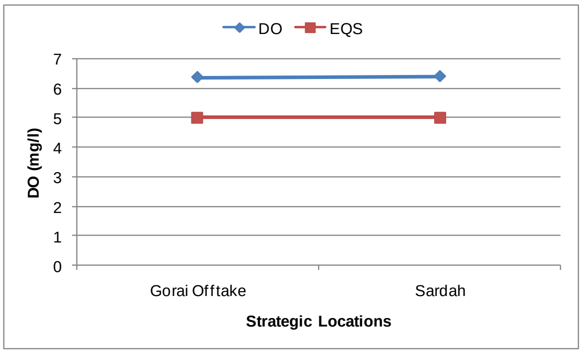
From the analysis it is revealed that, concentration of pH in the selected strategic locations of the Ganges River varied between 8.3-8.4 while standard pH range for inland surface water is 6.5-8.5. Concentration of Dissolved Oxygen (DO) in river water varied from 6.37 to 6.40 mg/l which are often above the EQS (≥5 mg/l) for fisheries. BOD concentration of the river water varied from 36 to 42 mg/l while the EQS (≤6 mg/l) for fisheries.

COD level of the river was below the EQS (200 mg/l) for wastewater from industrial units round the year. TDS concentration varied from 139 to 140 mg/l.

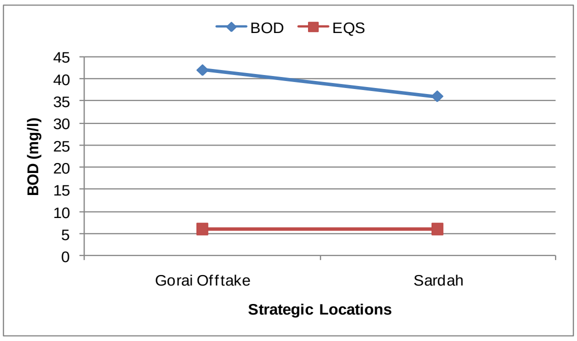
Chloride concentrations at all the sampling locations were within the EQS (600mg/l) for wastewater after treatment from industrial units.The maximum Chloride (19.0mg/l) was found at Sardah and the minimum (18 mg/l)was at Gorai Offtake.



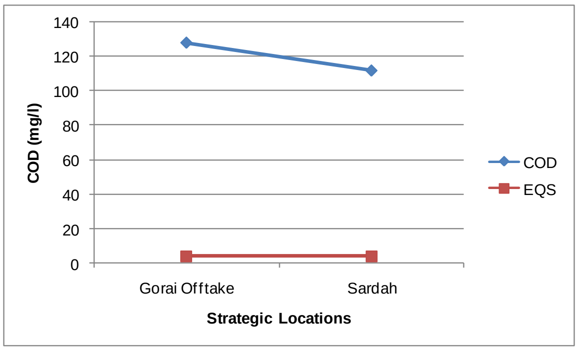
a. pH



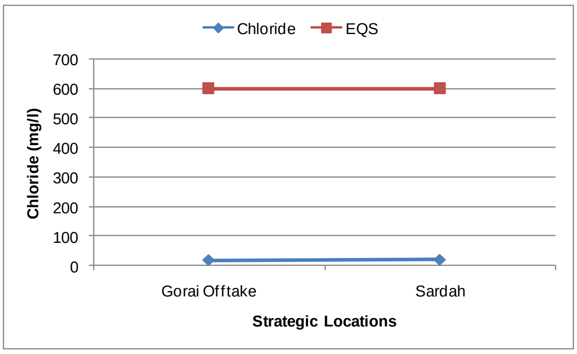
b. DO



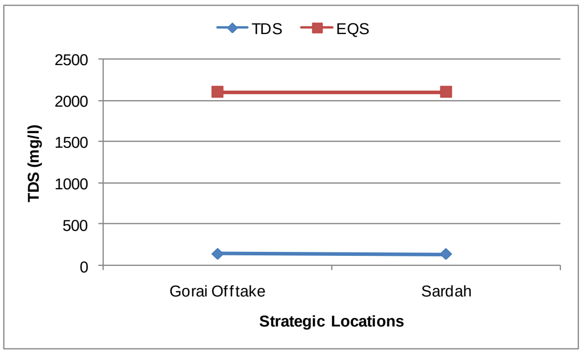
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.9: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Ganges River

Electrical conductivity (EC) value was found 275 μS/cm while standard for treated wastewater is 1200 μS/cm. From the analysis it is also observed that TSS values varied from 11 to 13 mg/l which is above the standard TSS (10 mg/l) for drinking water. The minimum and maximum turbidity level of the river water was 11.6 NTU to 42.7 NTU which is 4 times higher the EQS (10 NTU) for drinking water.

Table 5.9: Value of other water quality parameters at selected locations of the Ganges River

Strategic Location	Parameter												
	Temperature (°C)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Gorai Offtake	25	0.43	0.003	19	275	102	463	0.003	2.51	21	7	11	11.6
Sardah	24.9	0.61	0.003	39	275	192	685	0.004	2.1	47	8	13	42.7
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

5.3.10 Karnaphuli River

Karnaphuli River, the largest and most important river in Chittagong and the Chittagong hill tracts, originates in the Lushai hills in Mizoram State of India. It travels through 180 km of mountainous wilderness making a narrow loop at Rangamati and then follows a zigzag course before it forms two other prominent loops, the Dhuliachhari and the Kaptai.

Karnaphuli is a very important river for Chittagong. Many industries are situated on the northern bank of the river. Large industries like CUFL and TSP Industry are located on the southern bank of the river.

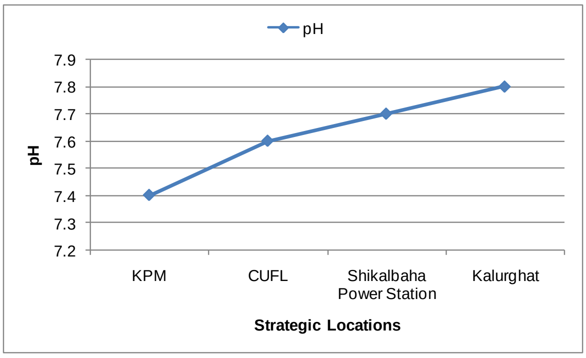
For monitoring the water quality of the Karnaphuli River, six strategic locations are identified along the river: CUFL, TSP Location, Shikalbaha Power Station, Kalurghat Bridge, Mariam Nagar and Karnaphuli Paper Mills (KPM). However, under this study, water samples were collected from four strategic locations which are more polluted viz: CUFL, Shikalbaha Power Station, Kalurghat Bridge and Karnaphuli Paper Mills (KPM). The samples were collected from 7 to 8 December 2016.

From the analysis it is observed that, concentration of pH in the selected strategic locations of the Karnaphuli River varied between 7.4-7.8 while standard pH range for inland surface water is 6.5-8.5. In 2014, concentrations of pH varied from 7.27 to 8.05 (DoE, 2015).

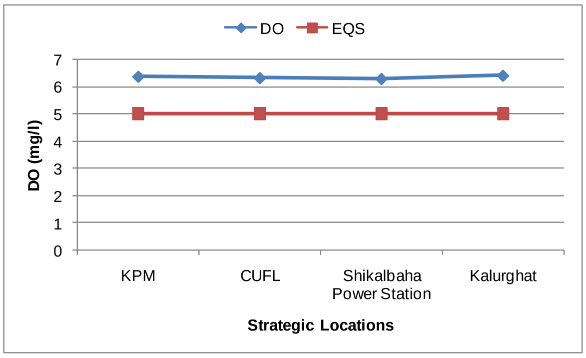
Dissolved Oxygen (DO) concentration in river water varied from 6.28-6.40 mg/l which are often above the EQS (≥5 mg/l) for fisheries. In 2014, DO concentration of the existing strategic locations of the Karnaphuli River varied between 4.5 to 5.7 mg/l (DoE 2015).

BOD concentration is varied from 1.0 to 7.0 mg/l which are often above the EQS (≤6 mg/l) for fisheries at all locations. In 2014, maximum BOD concentration varied between 4.5 to 5.7 mg/l (DOE 2015). COD value of the river varied from 4.0 to 24. In 2014, COD value of the river varied from 9.0 to 144.5, while EQS for wastewater after treatment from industrial units is 200 mg/l. Level of SS at different points of Karnaphuli River was within the EQS (150 mg/l). SS values varied from 15-34 mg/l in 2014 (DOE, 2015).

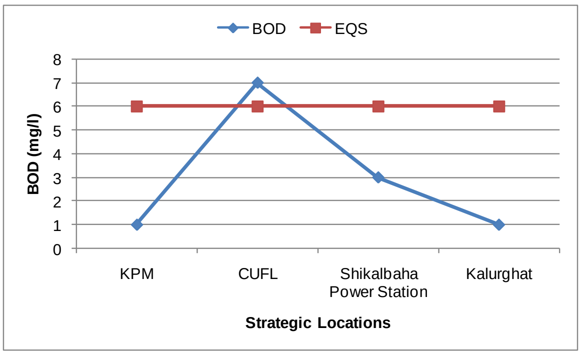
Chloride concentration at all the sampling locations varied from 10 to 7200, while the EQS (600mg/l) for waste water after treatment from industrial units. In 2014, chloride concentration of Karnaphuli river water was higher, especially at KUFL upstream and downstream which varied from 302 mg/l to 12500.5 mg/l (DoE, 2015).



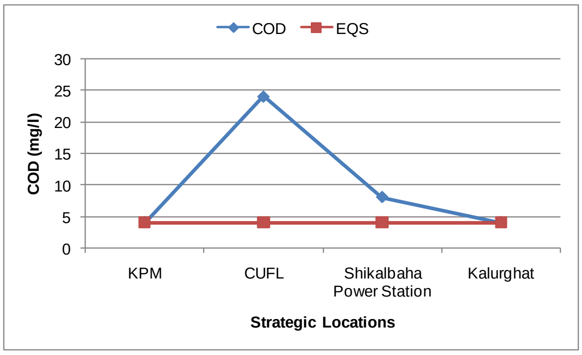
a. pH



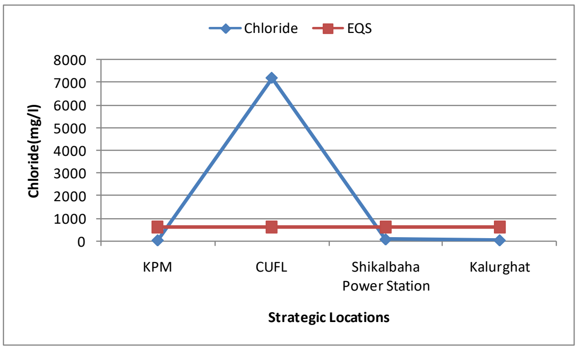
b. DO



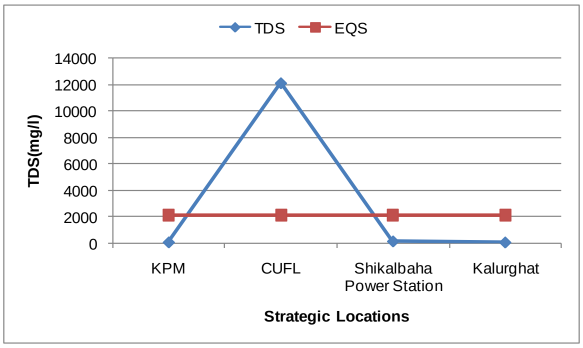
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.10: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Karnaphuli River

Table 5.10: Value of other water quality parameters at selected locations of the Karnaphuli River

Strategic Location	Parameter												
	Temperature (ºC)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) /100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
KPM	24.2	0.58	0.001	32	115	412	185	0.023	2	38	4	15	4
CUFL	24.1	0.87	0.001	196	42260	680	5800	0.002	1.95	1277	960	34	143
Shikalbaha Power Station	24.4	0.72	0.001	90	258	310	195	0.079	2.05	107	5	30	117
Kalurghat	24.2	0.55	0.001	21	103	230	155	0.005	2.68	29	3	17	12
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

5.3.11 Halda River

Halda River is one of the major rivers in the South-East region of Bangladesh. The 98 km long river has a very turbulent tributary, the Dhurung River, which joins at Sundarpore about 48.25 km downstream. The river is navigable by big boats 29 km into it (up to Nazirhat) and by small boats 16-24 km further (up to Narayanhat).

The Halda River is the one and the only natural carp breeding ground in Bangladesh from where fertilized carp fish's (*Catla catla, Labeo rohita, Labeo calbasu* and *Cirrhinus mrigala*) eggs are collected by local fisherman and egg collectors during April to June almost every year from time immemorial. The collected eggs are hatched in the artificial mud-made scoop on the riverbank to produce carp fries. The fries are supplied from here to different regions of the country for aquaculture.

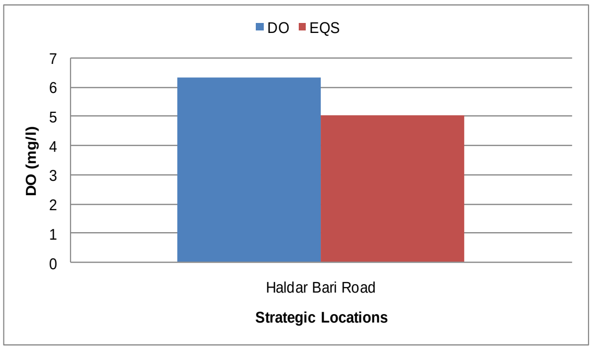
For monitoring the water quality of the Halda River, three strategic locations are identified along the river: Maduna Ghat, Gharduara Sluice Gate, Haldar Bari Road. However, under this study, water sample was collected from one strategic location viz: Haldar Bari Road. The sample was collected on 7 December 2016.

The concentration of pH in the selected strategic location of the Halda River is 7.7 while standard pH range for inland surface water is 6.5-8.5. In 2014, concentration of pH was varied from 7.0 to 7.51(DOE, 2015).

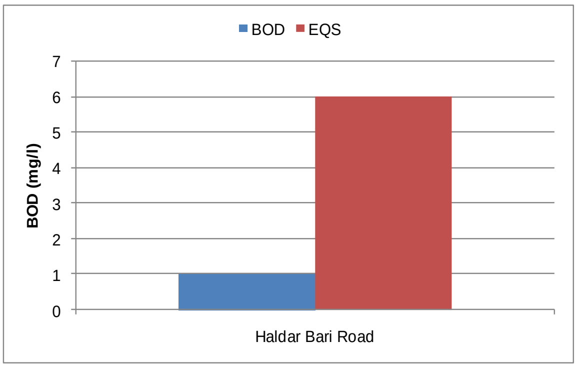
Dissolved Oxygen (DO) concentration in Halda River is 6.32 mg/l which are often above the EQS (≥5 mg/l) for fisheries. In 2014, DO concentration of the selected/existing strategic locations of the Halda River varied from 5.0 to 5.7 mg/l (DoE 2015).

BOD concentration is within the EQS (≤6 mg/l) for fisheries at all locations. In 2013, BOD concentration varied between 0.2 to 0.8 mg/l (DOE 2015). COD concentrations of the selected locations were within EQS for wastewater after treatment from industrial units is 200 mg/l.

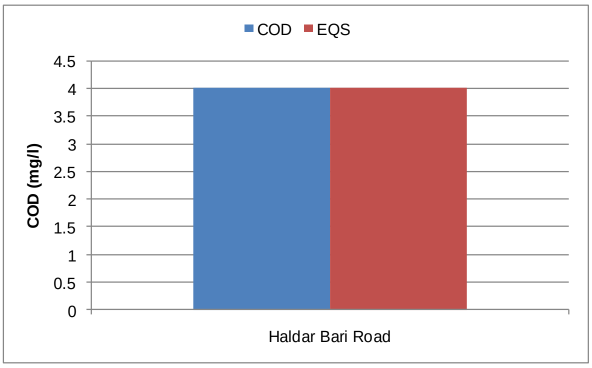
a. pH



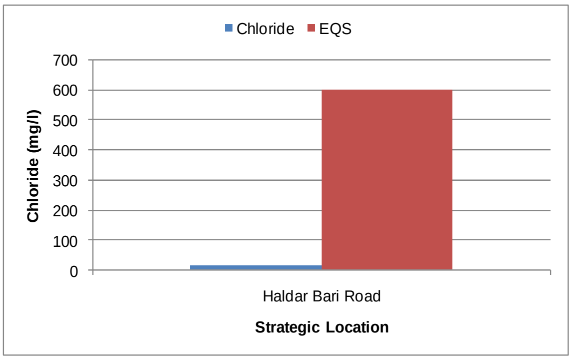
b. DO



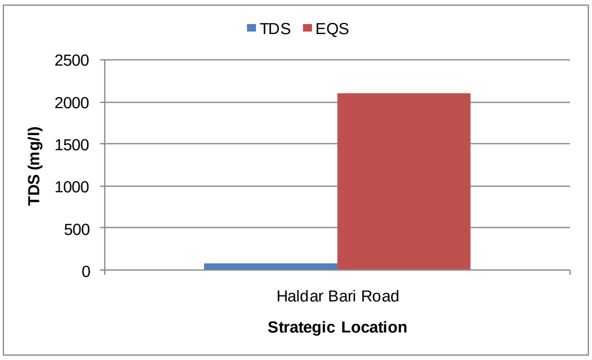
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.11: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Halda River River

Suspended Solid value of the selected strategic locations of the Halda River is 28 mg/l which is above the standard TSS (10 mg/l) for drinking water.

Chloride concentration of the selected sampling locations was well below the EQS (600mg/l) for wastewater after treatment from industrial units. In 2014, chloride concentration of Halda River varied from 7 mg/l to 909 mg/l (DOE, 2015).

Table 5.11: Value of other water quality parameters at selected locations of the Halda River

Strategic Location	Parameter												
	Temperature (°C)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Haldar Bari Road	24.5	0.49	0.001	48	149	460	150	0.002	3.08	48	2	28	55
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

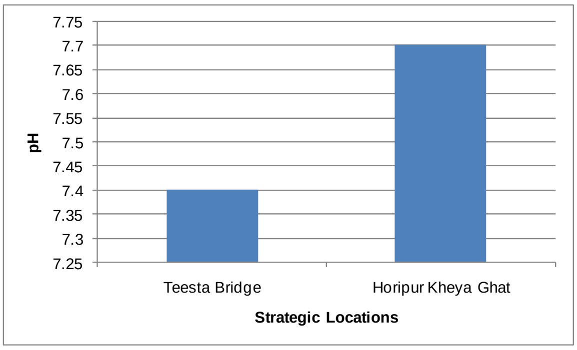
5.3.12 Teesta River

The Teesta River originates in the Himalayas and flows through the Indian States of Sikkim and West Bengal before entering Bangladesh, where it flows into the Brahmaputra. Flowing through the length of Sikkim, the Teesta River is considered to be the lifeline of the state. The Teesta valley in Sikkim is rich in biodiversity, and the river provides livelihoods for the residents along its entire length of 393 km (245 miles).

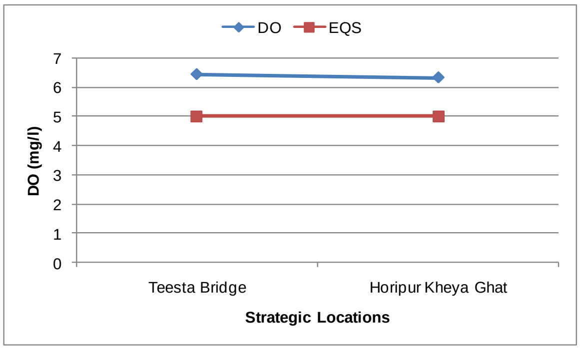
The Teesta River has become a contested battleground between the government and the indigenous Lepcha and Bhutia communities in Sikkim, India. The government of India hopes to dam the last free-flowing 13 kms (8 miles) of the Teesta River for hydropower. Already over 71 kms (44 miles) of the river – which flows through earthquake-prone, ecologically and geologically fragile terrain – is either in reservoirs or diverted through tunnels for hydropower generation. These dams pose a threat to the river communities and the rich biodiversity of the region. Studies of potential projects along the Teesta River lack the rigorous environmental and social assessments necessary and fail to properly address potential long-term cumulative impacts the dams will have.

For monitoring water quality of Teesta River, four strategic locations are identified along the river: Horipur Kheya Ghat, Teesta Bridge, Shapmari (Nohali) and Teesta Barrage. However, under this study, water samples were collected from two strategic locations viz: Teesta Bridge and Horipur Kheya Ghat. The samples are collected from 18 December 2016.

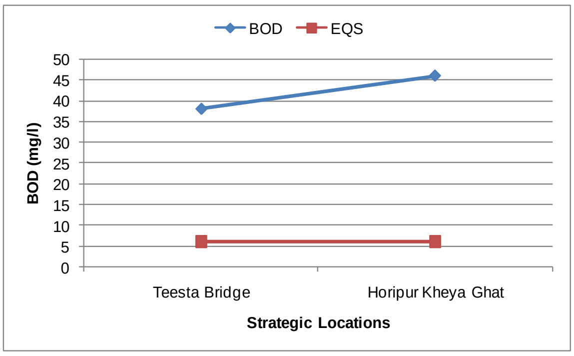
From the analysis it is observed that, concentration of pH in the selected strategic locations of the TeestaRiver varied between 7.4-7.7 while standard pH range for inland surface water is 6.5-8.5. Dissolved Oxygen (DO) concentration in river water varied from 6.31-6.42 mg/l which are often above the EQS (≥5 mg/l) for fisheries. BOD concentration is varied from 38.0 to 46.0 mg/l which are often above the EQS (≤6 mg/l) for fisheries at all locations. COD value of the river varied from 104 to 132 while EQS for wastewater after treatment from industrial units is 200 mg/l. Level of TSS at different points of Teesta River was within the EQS (10 mg/l) for drinking water. Chloride concentration at all the sampling locations was varied from 10 to 12, while the EQS (600mg/l) for waste water after treatment from industrial units.



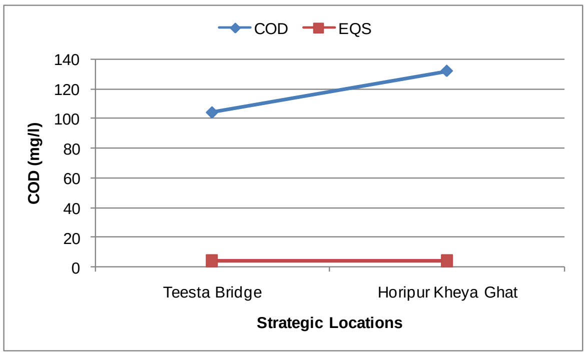
a. pH



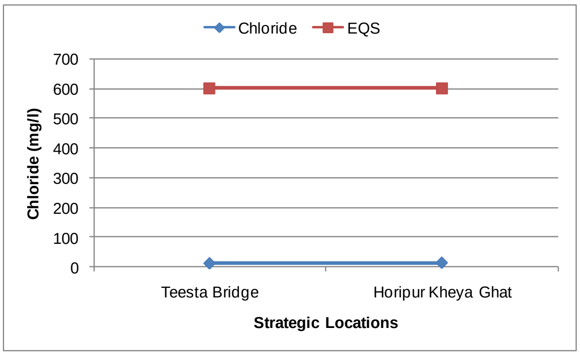
b. DO



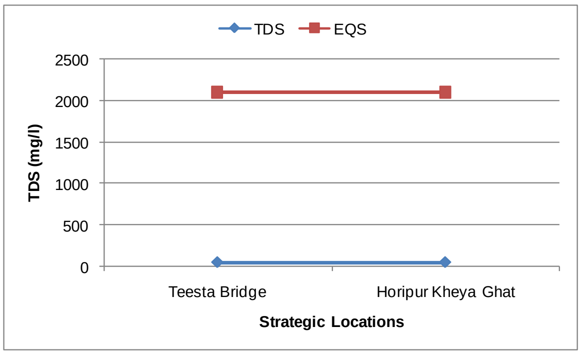
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.12: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Teesta River River

Table 5.12: Value of other water quality parameters at selected locations of the Teesta River

Strategic Location	Parameter												
	Temperature (oC)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Teesta Bridge	25	0.47	0.002	12	98.2	132	638	0.002	3.23	14	3	9	9.8
Horipur Kheya Ghat	25	0.52	0.002	10	94	210	615	0.003	1.03	13	3	18	21.4
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

5.3.13 Jamuna River

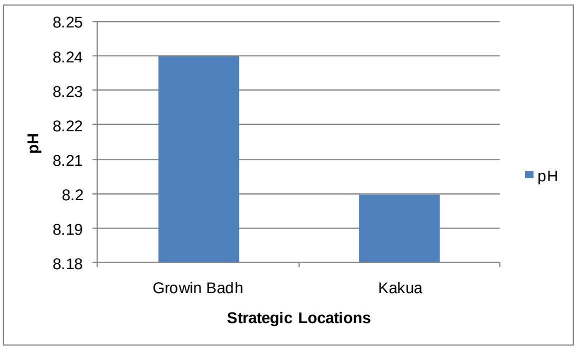
The Jamuna River is one of the three main rivers of Bangladesh. It is the main distributary channel of the Brahmaputra River as it flows from India to Bangladesh. The Jamuna flows south and joins the Padma River, near Goalundo Ghat, before meeting the Meghna River near Chandpur. It then flows into the Bay of Bengal as the Meghna River. The Brahmaputra-Jamuna is a classic example of a braided river and is highly susceptible to channel migration and avulsion.

For monitoring the water quality of the Jamuna River, five strategic locations are identified along the river: Mohonganj, Kakua, Jamuna Eco Park, Tarakandi and Growin Bandh. However, under this study, water sample were collected from two strategic locations viz: Kakua and Growin Bandh. The samples were collected between 09-21 December 2016.

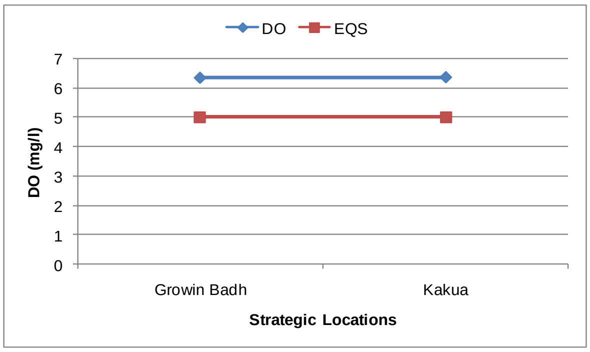
The concentration of pH in the selected strategic locations of the Jamuna River is 8.2-8.24 while standard pH range for inland surface water is 6.5-8.5. In 2014, concentration of pH was varied from 7.88 – 7.93 (DoE, 2015).

Dissolved Oxygen (DO) concentration in Jamuna River is 6.35 mg/l - 6.37 mg/l which are often above the EQS (≥5 mg/l) for fisheries. In 2014, DO concentration of the selected/existing strategic locations of the Jamuna River varied from 8.45 to 8.5 mg/l (DoE 2015).

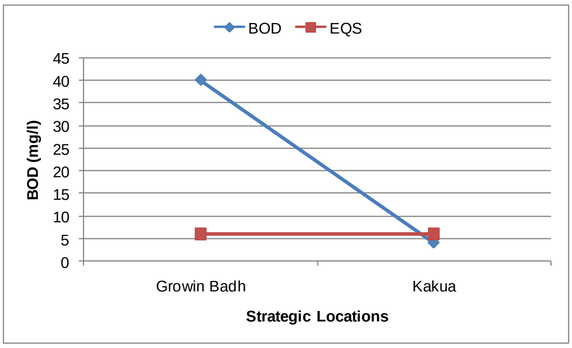
BOD concentration is within the EQS (≤6 mg/l) for fisheries at all locations except in Growin Bandh where the BOD concentration is 40 mg/l. In 2013, BOD concentration varied between 5.3 to 9.0 mg/l (DOE 2015). COD concentration of the selected locations is within EQS for wastewater after treatment from industrial units is 200 mg/l.



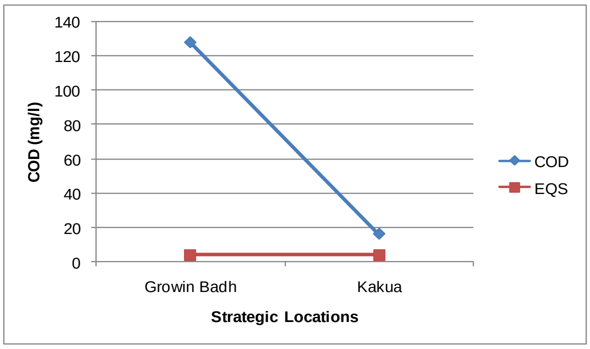
a. pH



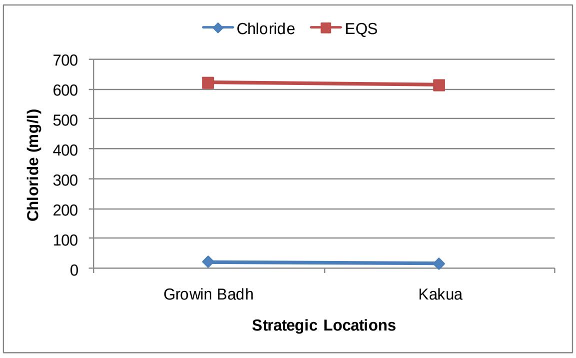
b. DO



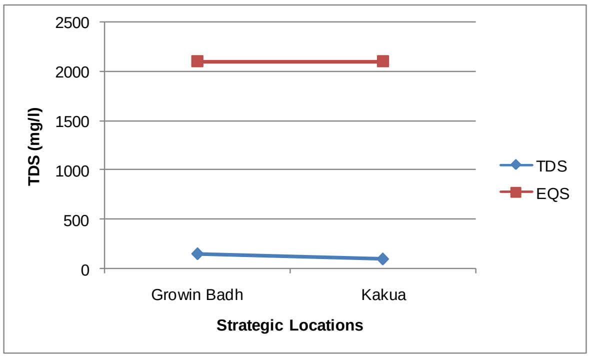
c. BOD



d. COD



e. Chloride



f. TDS

Figure 5.13: Graphical presentation of pH, DO, BOD, COD, EC and TDS of Jamuna River

Suspended Solid value of the selected strategic locations of the Jamuna River varied from 10 to 12 mg/l respectively while the standard TSS (10 mg/l) for drinking water.

Chloride concentration of the selected sampling locations was well below the EQS (600mg/l) for wastewater after treatment from industrial units. In 2014, chloride concentration of Jamuna River varied from 1.1 mg/l to 6.0 mg/l (DoE, 2015).

Table 5.13: Value of other water quality parameters at selected locations of the Jamuna River

Strategic Location	Parameter												
	Temperature (°C)	Ammonia (mg/l)	Arsenic (mg/l)	Calcium (mg/l)	EC (µS/cm)	Coliform (Faecal) N/100ml	Hardness (mg/l)	Lead (mg/l)	Nitrogen (Nitrate) (mg/l)	Sodium (mg/l)	Sulphate (mg/l)	TSS (mg/l)	Turbidity (NTU)
Growin Badh	24.9	0.44	0.003	12	312	308	590	0.001	1.62	16	2	10	1.85
Kakua	25	0.39	0.002	19	214	240	533	0.001	0.81	31	12	12	8.9
Bangladesh standard for drinking water	20-30	0.5	0.05	75	0	2100	200-500	0.05	10	200	400	10	10

References

Stark, J.R., Hanson, P.E., Goldstein, R.M., Fallon, J.D., Fong, A.L., Lee, K.E., Kroening, S.E., and Andrews, W.J. 2000. "Water Quality in the Upper Mississippi River Basin, Minnesota, Wisconsin, South Dakota, Iowa, and North Dakota, 1995-98." United States Geological Survey, Circular 1211. http://pubs.usgs.gov/circ/circ1211/pdf/circular1211.pdf

DoE, 2013, River Water Quality Report 2012, Department of Environment, Ministry of Environment and Forests, Government of the People's Republic of Bangladesh

DoE, 2014, River Water Quality Report 2013, Department of Environment, Ministry of Environment and Forests, Government of the People's Republic of Bangladesh

DoE, 2015, River Water Quality Report 2014, Department of Environment, Ministry of Environment and Forests, Government of the People's Republic of Bangladesh

Parliamentary Standing Committee on Ministry of Environment & Forests, 2010, Pollution Abatement Strategies for Rivers and Wetlands in and Around Dhaka City, Government of the People's Republic of Bangladesh and United Nations Development Programme available at http://ext.bd.undp.org/CCED/bgdp/BGDP%20Materials/Review%20Documents/Pollution%20abatement%20strategies%20for%20river%20and%20wetland.pdf accessed on 28th May, 2017

1. *http://en.banglapedia.org/index.php?title=Buriganga_River*
2. *https://en.wikipedia.org/wiki/Buriganga_River*
3. DoE, 2015, River Water Quality Report 2014, Department of Environment, Ministry of Environment and Forests, Government of the People's Republic of Bangladesh
4. https://en.wikipedia.org/wiki/Turag_River
5. Rahman, A. K. M. L.; Islam, M.; Hossain, M. Z. and Ahsan, M. A. 2012. Study of the seasonal variations in Turag river water quality parameters. *African Journal of Pure and Applied Chemistry,* 6(**10**)**:** 144-148.
6. Mobin, M.N.; Islam, M.S.; Mia, M.Y. and Bakali, B. 2014. Analysis of Physicochemical Properties of the Turag River Water, Tongi, Gazipur in Bangladesh. ***J**. Environ. Sci. & Natural Resources,* 7(1): 27 – 33.
7. Meghla, N. T.; Islam, M. S.; Ali, M. A.; Suravi and Sultana, N. 2013. Assessment of Physicochemical Properties of Water from the Turag River in Dhaka City, Bangladesh. *International Journal of Current Microbiology Applied Science,* 2(5):110-122.
8. https://en.wikipedia.org/wiki/Dhaleshwari_River
9. http://www.haldariver.org/about%20halda.html
10. https://www.internationalrivers.org/campaigns/teesta-river

6. Water Quality Monitoring System

6.1 Introduction

Presently DoE is performing surface water quality monitoring in maintainging general process and standard monitoring system is absent there.CEGIS developed a standard surface water (river) quality monitoring system including MIS and Mobile Application (Android Platform) and shared with DoE and other relevant professionals. GIS and Remote Sensing technologies are used for analysing spatial data and information. Proposed strategic locations are identified and validated with extensive field works. Finally the strategic locations were validated by the Department of Environment (DoE). These strategic locations are incorporated in the MIS and Mobile Applications. The other aspects of water quality monitoring like physicochemical parameters, purpose of monitoring, report generation, map view, water pollution hotspot etc. are also incorporated in the MIS and Mobile Application. An updated data collection form has been included in the system which has 4 (four) parts namely: Data Entry, Data Explorer, Reports and Map Browser.

The WQMS will enable to:

- Data Entry;
- Data Explorer;
- Reports;
- Map Browser;
- Gallery;
- Options;

6.2 Overview of the WQMS

6.2.1 Design of web-enable water quality database

Design and development of database is another major task. The different steps of the database design activity for this study are briefly described and given below:

6.2.2 Designing of Water Quality Monitoring System (e.g. Architecture)

Depending on the requirement identified in the needs assessment, a logical model or framework of WQMS is developed. The WQMS has been designed and developed using four layers:

- User Interface (Web-based and Android Mobile Application)
- Web Server
- Map Server and Data analysis
- Database

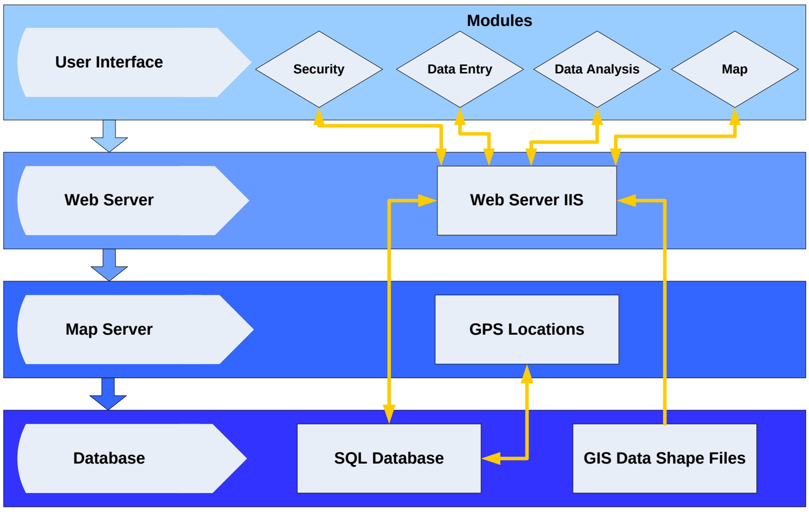


Figure 6.1: System Architecture of WCMS

6.3 Modules of the Software

The WQMS is developed so that a user can access tabular and spatial database and analyze the data in a user friendly and interactive manner. The software will be installed on a web server without installing any specialized GIS software like Arcinfo, ArcGIS etc. The WQMS software is developed with Microsoft SQL Server 2008 as the back end database and Visual Studio, HTML, CSS, JavaScript, jQuery and EsriMapObject plugin as the front end development tool. The client's Computer need not to have Visual Studio or EsriMapObject plugin installed.

The WQMS has the following main features:

Main Features	Sub-Features
1. Home	
2. Organize Data	a. Data entry (by Importing existing data and direct entry) b. Data explorer (Tabular)
3. Reports	a. Routine monitoring b. Non-routine monitoring
4. Map Browser	a. Strategic locations b. Existing monitoring stations c. Water pollution hotspot
5. Gallery	
6. Options	d. Parameter Category e. Parameters f. Rivers g. Strategic Locations
7. Administration	a. Users b. Groups c. Roles

In the following subsections, each of the above features are described in details.

6.3.1 Home

On the Dashboard menu, it contains a simple photo slide show of water quality monitoring information like purpose of monitoring (drinking water, agricultural use, fisheries use, industrial cooling), type of parameters to be tested , sources of water, name of strategic locations and other. The dashboard also shows a base map that includes Bangladesh map, major rivers, districts, profile of strategic locations and dynamic chart report.

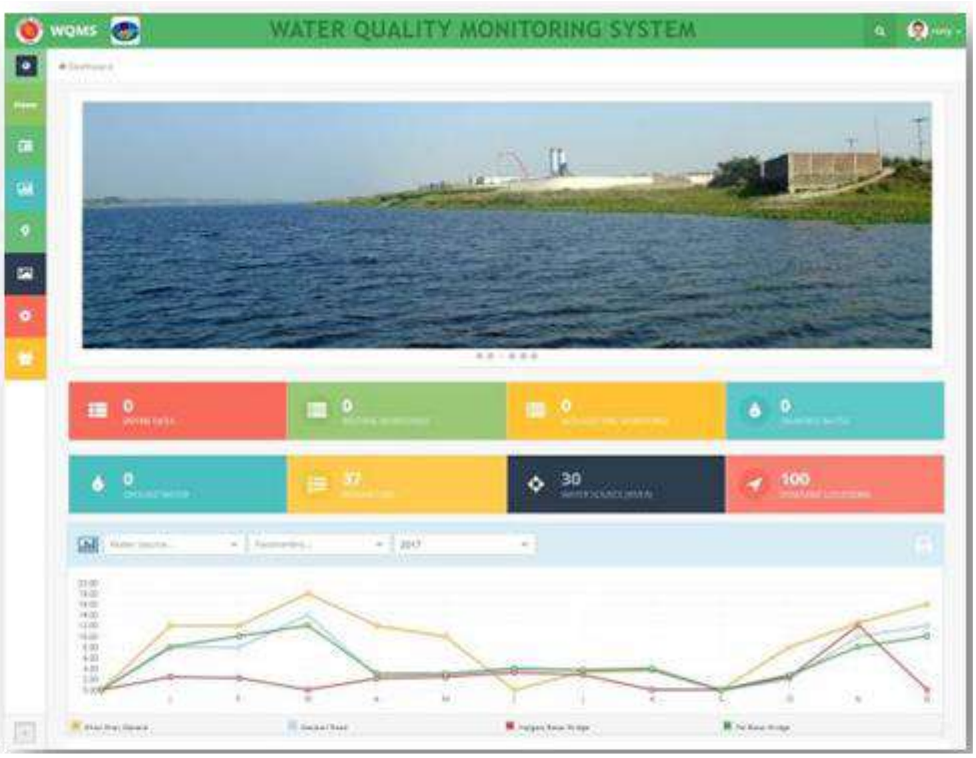


Figure 6.2: Home

6.3.2 Organize Data

This is the main component of the WQMS. It has Data Entry and Data Explorer modules. Data Entry module includes another three sub modules namely Import Data and Entry Data. User can entry raw data in the data entry form and also import bulk data from MS Excel sheet.

In Organize Data Main Menu, there are two Sub-Menus:

a. Data Entry
b. Data Explorer

a. Data Entry

Survey data will be stored in MS SQL Server database. A user-friendly data entry form is incorporated into WQMS for the entry of the surveyed data. The data entry form is the designed physical layout of the data collection form.

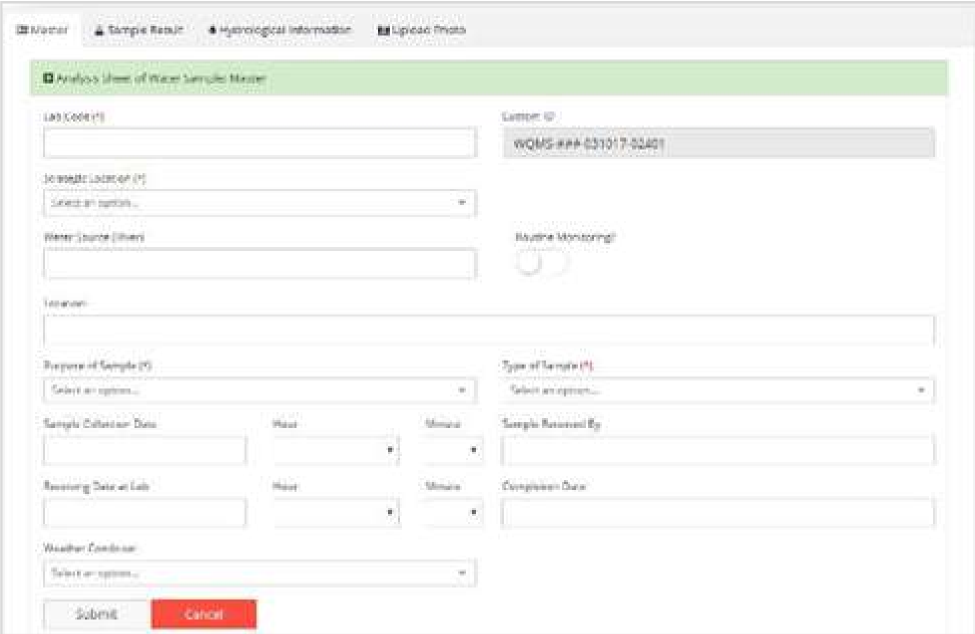


Figure 6.3: Data Entry form for master part

Custom ID is an auto generated field. When a strategic location is selected from the dropdown menu, then all the relevant information of the strategic location will be shown automatically. In addition, other relevant dependant parameters, ie Purpose of Monitoring, Purpose of Sample, and Type of Sample will be generated automatically in the field.In the next step, data entry personnel will have to select and put appropriate information, and then click on Submit button to save the data. If the information is not necessary for future use, then it can be cancelled by simply clicking the Cancel button.

Test result of water quality parameters will be recorded following the below format. This form will be solely used during water quality test in-situ.

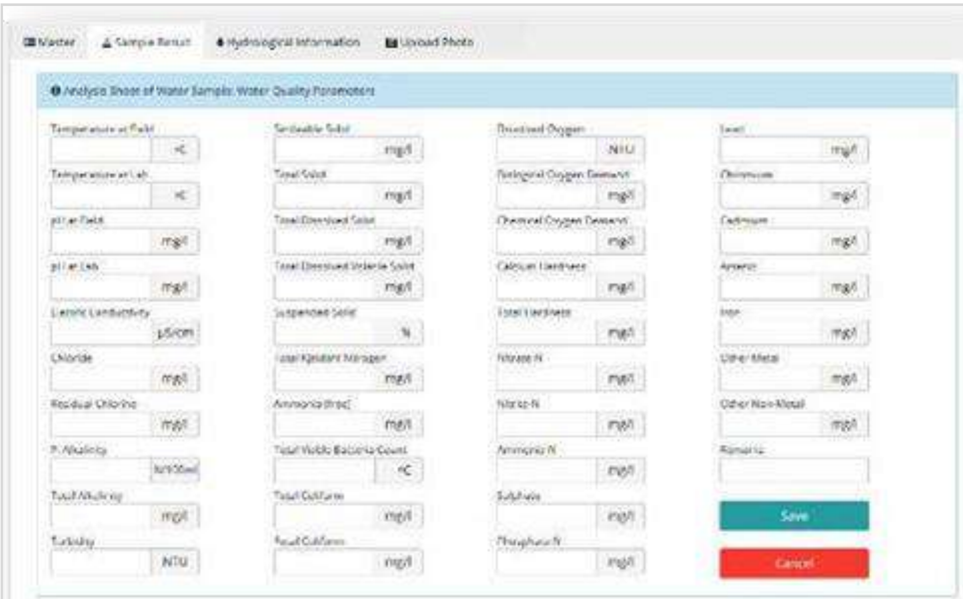


Figure 6.4: Data Entry form for in-situ water quality test result part

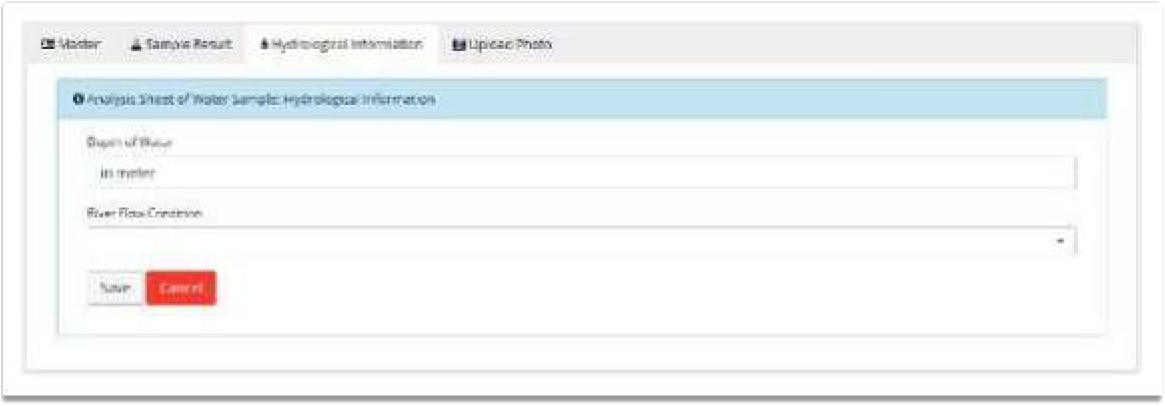


Figure 6.5: The hydrological information of strategic location

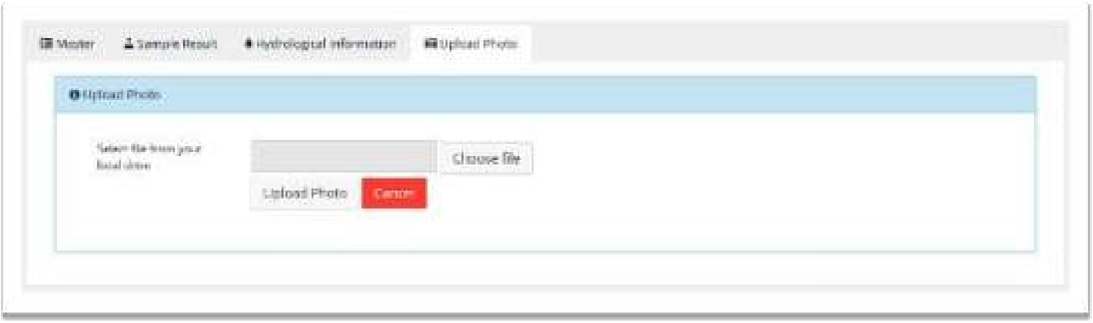


Figure 6.6: Upload photo of strategic location

This implementation will work only from SQL Server 2008 and updated versions. The input for the bulk import would be either **.xls** file or an **.xlsx** file. The records from, the input file, will be as per the importing table schema. So the values will be inserted or updated without any issue in the same order and with the same data type. If some records are already present, the records will be updated otherwise inserted.

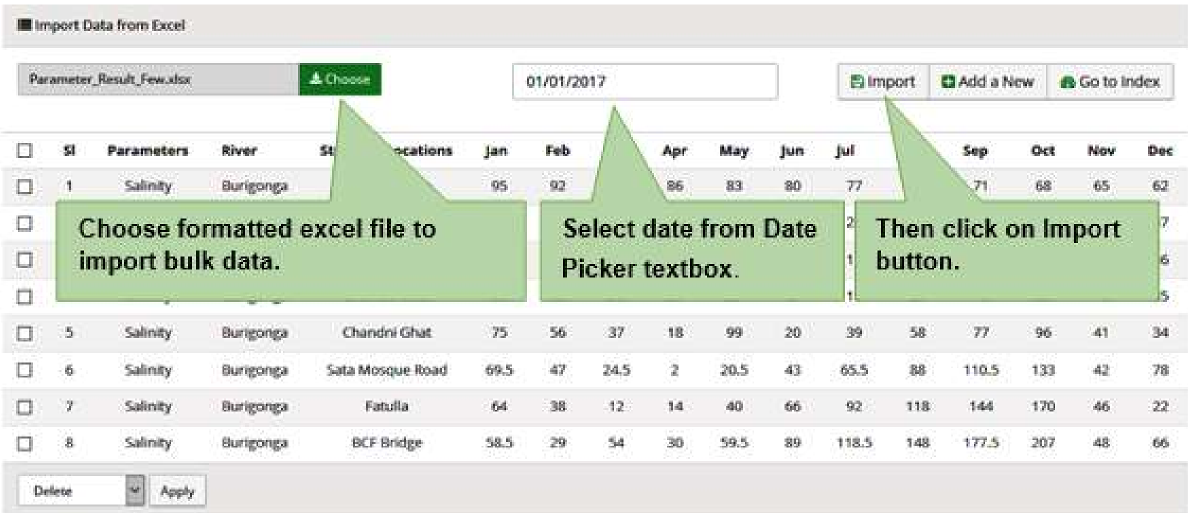


Figure 6.7: Importing water WQ test data (bulk) from spreed sheet (*.xls or *.xlsx)

b. *Data Explorer*

The data explorer module helps usersto easily retrieve data from the database. It has three components namely a. Tabular, b. Spatial, c. Time Series. Most of the information can be retrieved from the database using these queries. This query is flexible enough to retrieve information from the WQMS database in any arrangement, but the limitation is that the user must have a preliminary knowledge of the database query system and privileges.

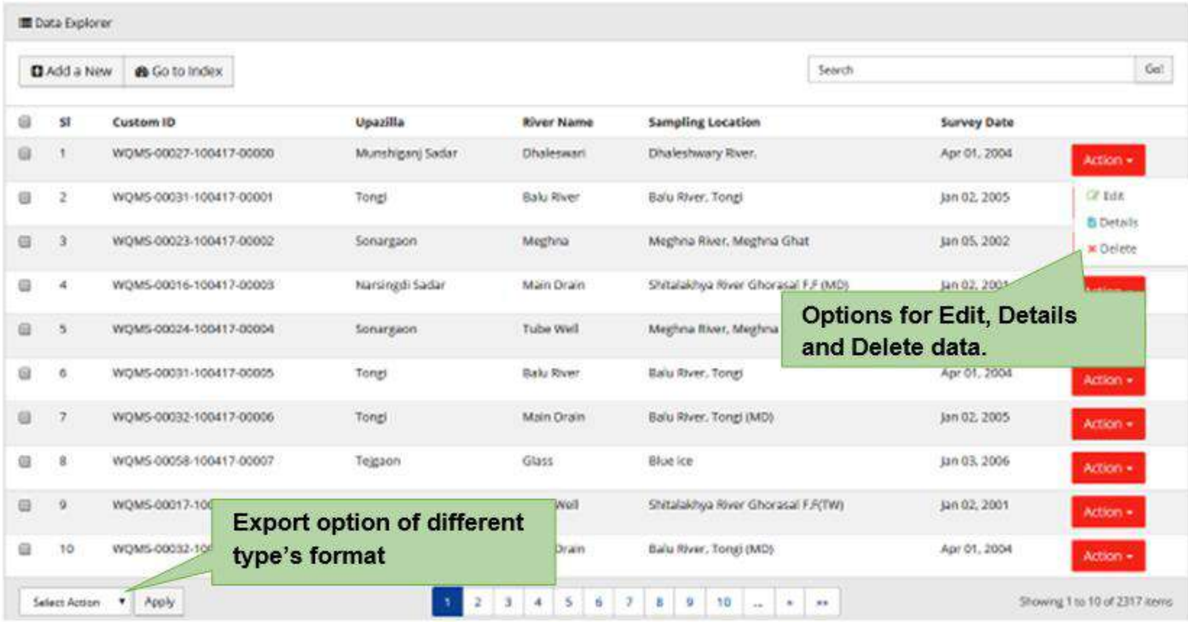


Figure 6.8: Data Explorer (demo data)

The data explorer enables the users to explore data in the following tabular format.

For retrieved data using any of the above method, the user can export these data into excel, PDF and Word format for further analysis.

6.3.3 Report Module (Pre-defined report module and graph report)

Analysis of data is a process of inspecting and reporting in tabular and graphical data with the goal of discovering useful information regarding water quality and usage of water for different purposes. Data analysis has multiple facets and approaches, encompassing diverse techniques to generate different water quality related reports.

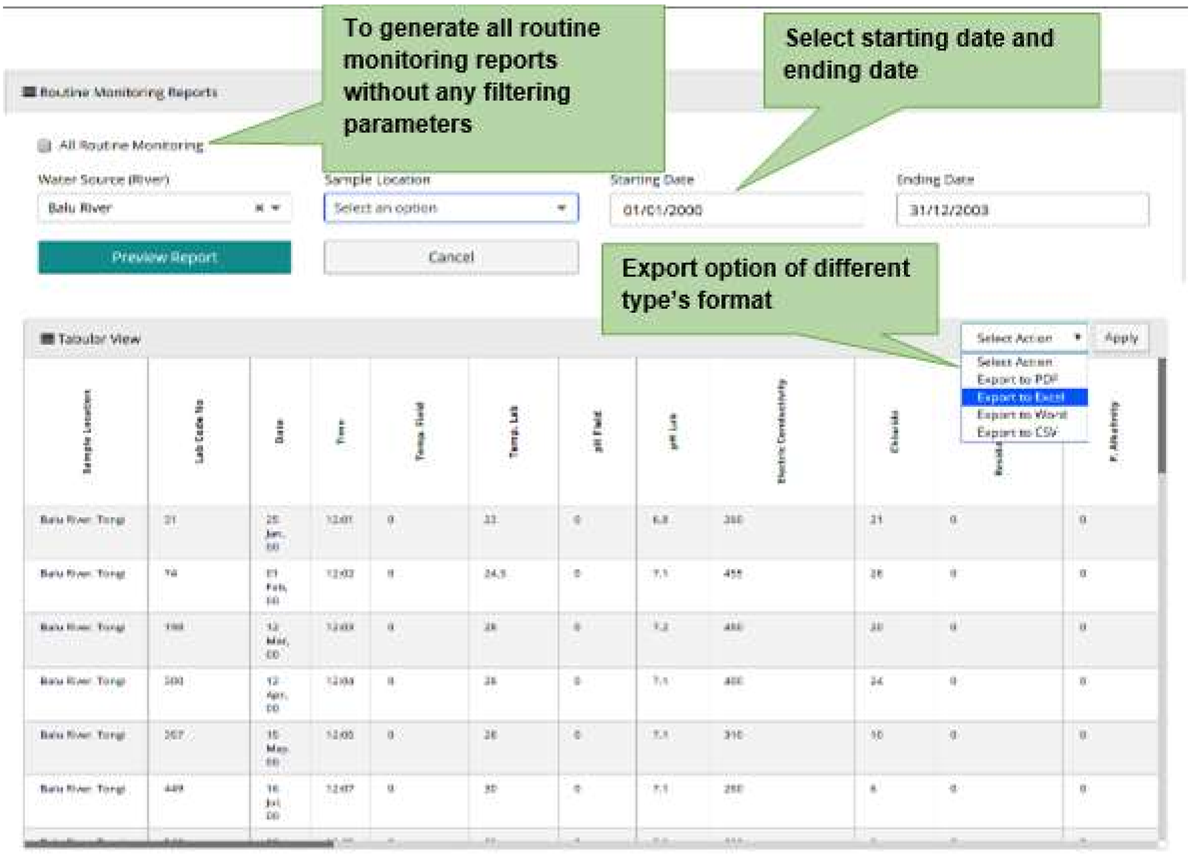


Figure 6.9: Routine Monitoring Report

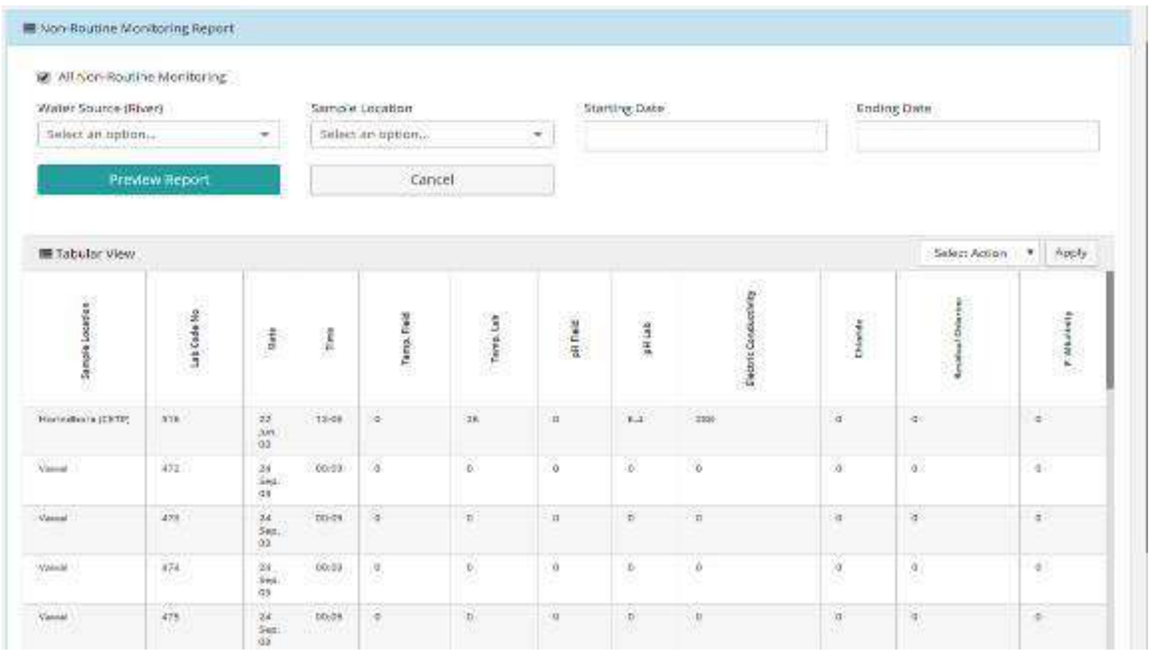


Figure 6.10: Non-Routine Monitoring Report

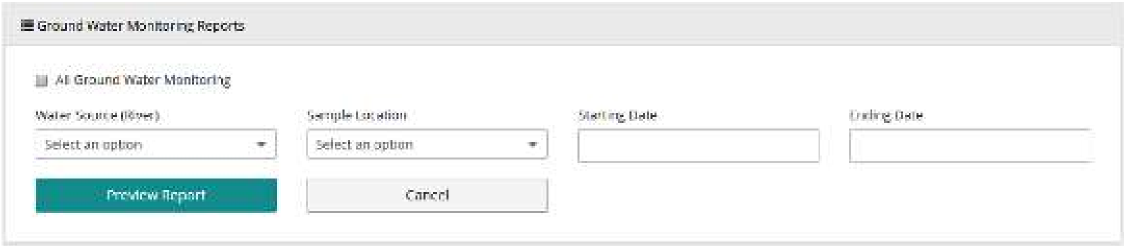


Figure 6.11: Ground Water Monitoring Report Filtering Parameters

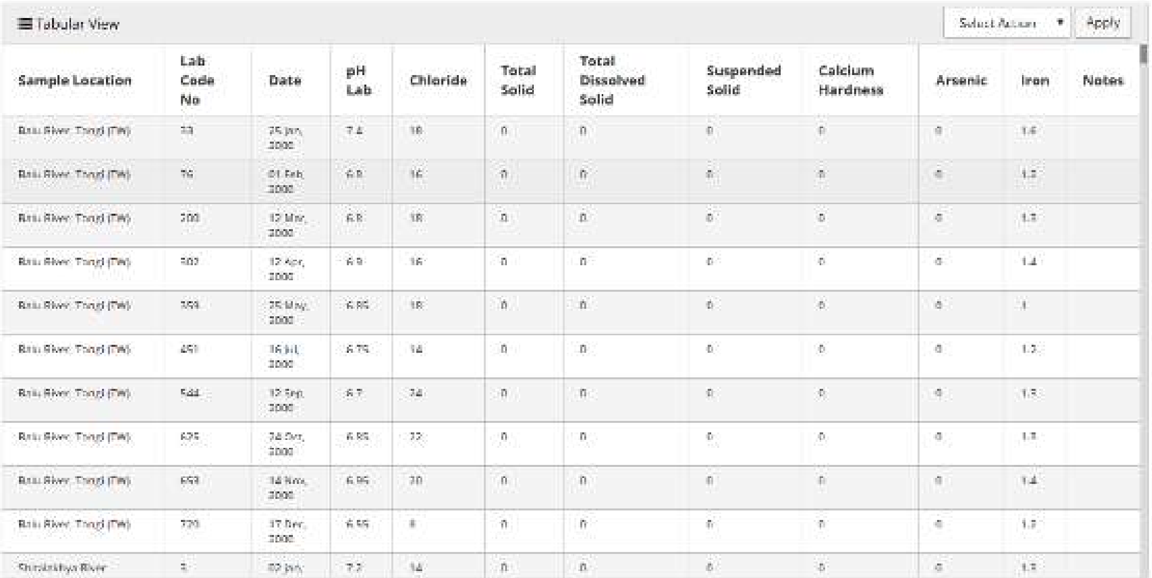


Figure 6.12: Ground Water Monitoring Report

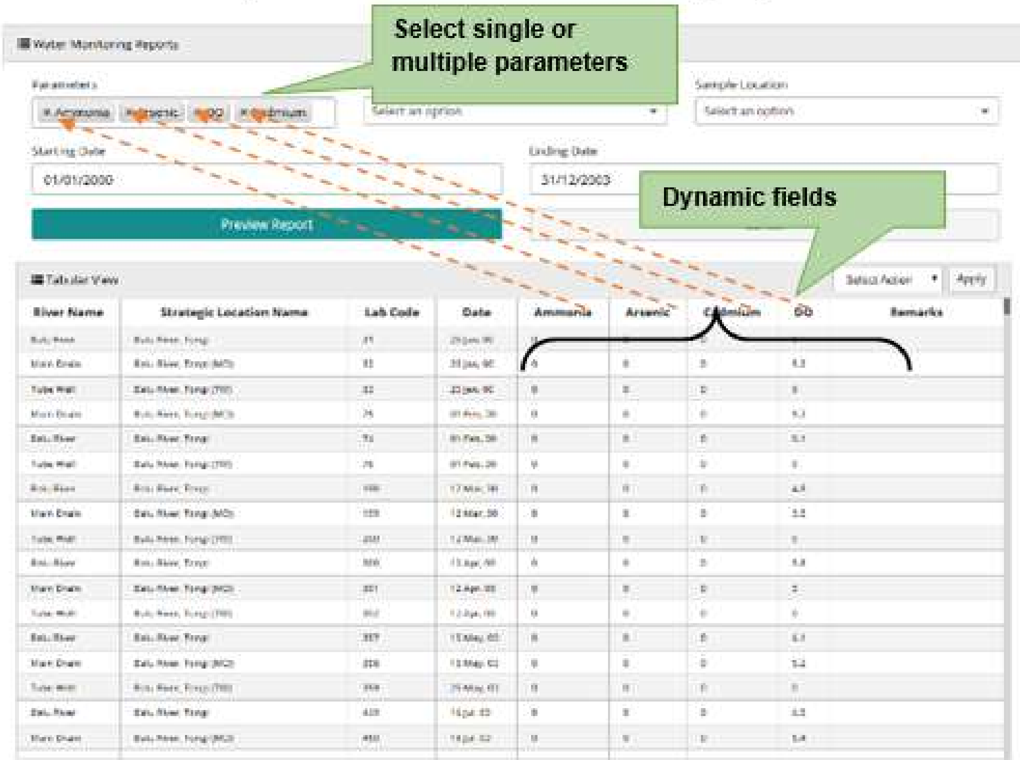


Figure 6.13: Individual Monitoring Report

6.3.4 Map Browser

The Map browser tool will be developed to facilitate users to use pre-processed maps stored in the database. With this feature of the software, the user can view, browse, print and zoom into the ESRI map plugin. The tool has a generic map View area where the user can view different data layers from the data layer tree. The viewed map can be exported to an image file or PDF format to use in other documents. The Map browser supports the GIS ESRI shape file (.shp) format.

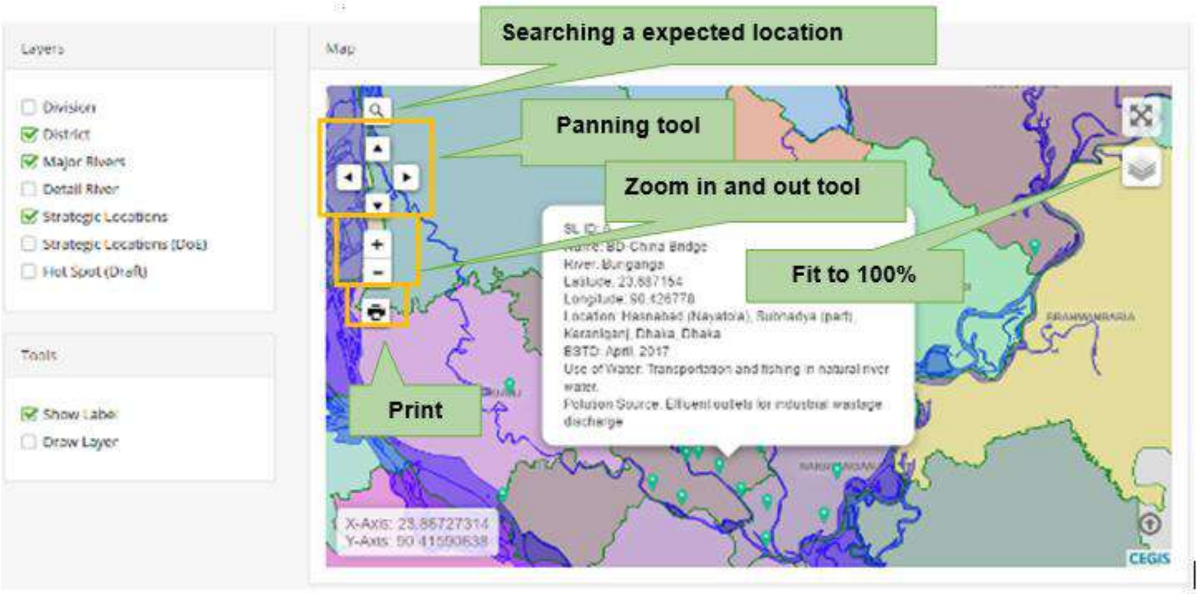


Figure 6.14: Strategic Locations

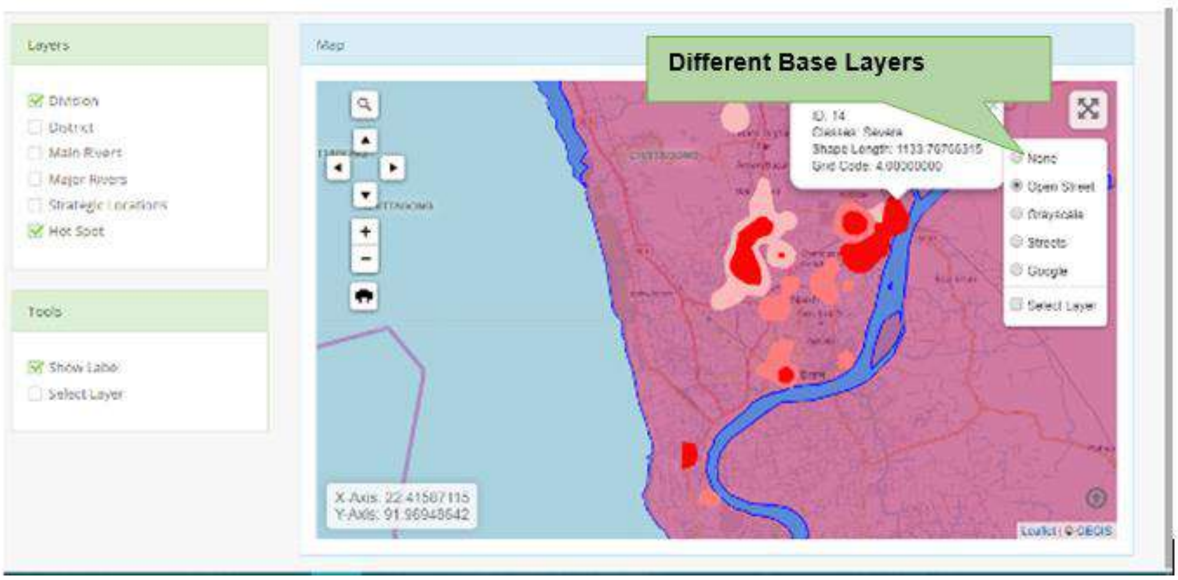


Figure 6.15: Hot Spot

6.3.5 Gallery

This gallery will be enriched with important photographs regarding water pollution hotspot, usage of river water, sample collection etc.

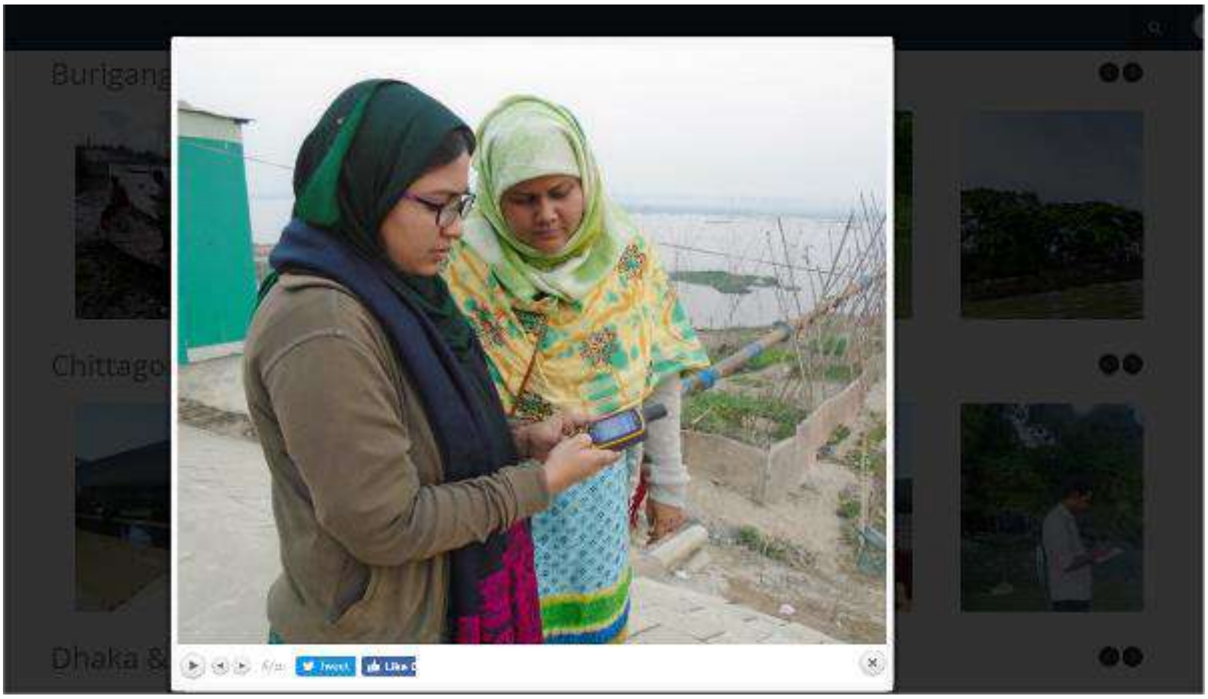


Figure 6.16: Gallery 1

Figure 6.17: Gallery 2

6.3.6 Options for New Entry

This is the most important part of the software for setting new strategic location, new parameters, as well as incorporating new rivers in the system.

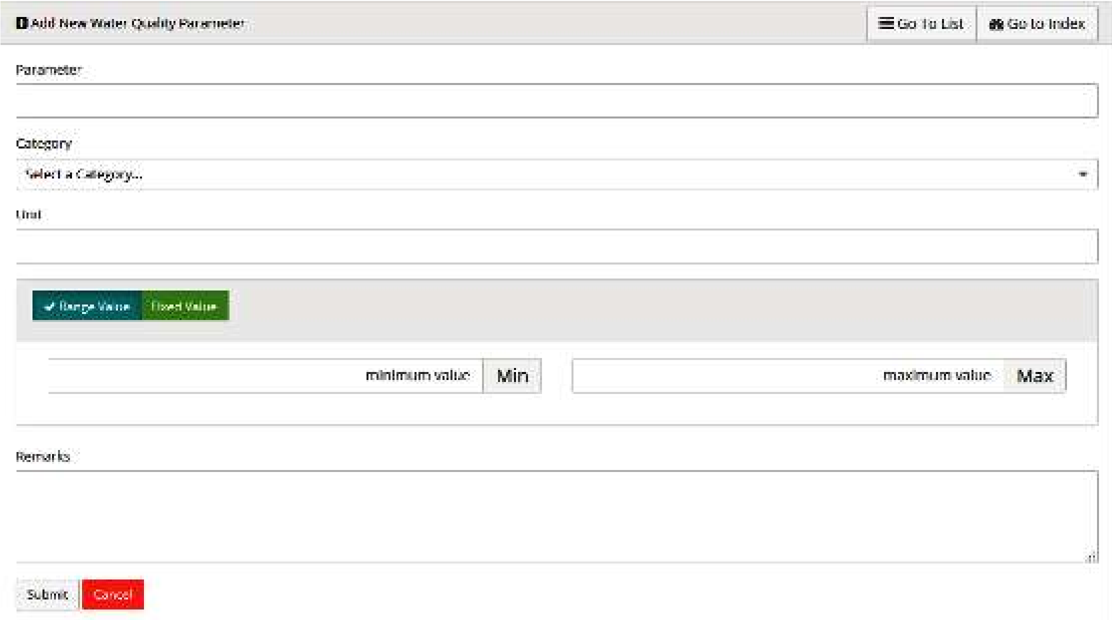
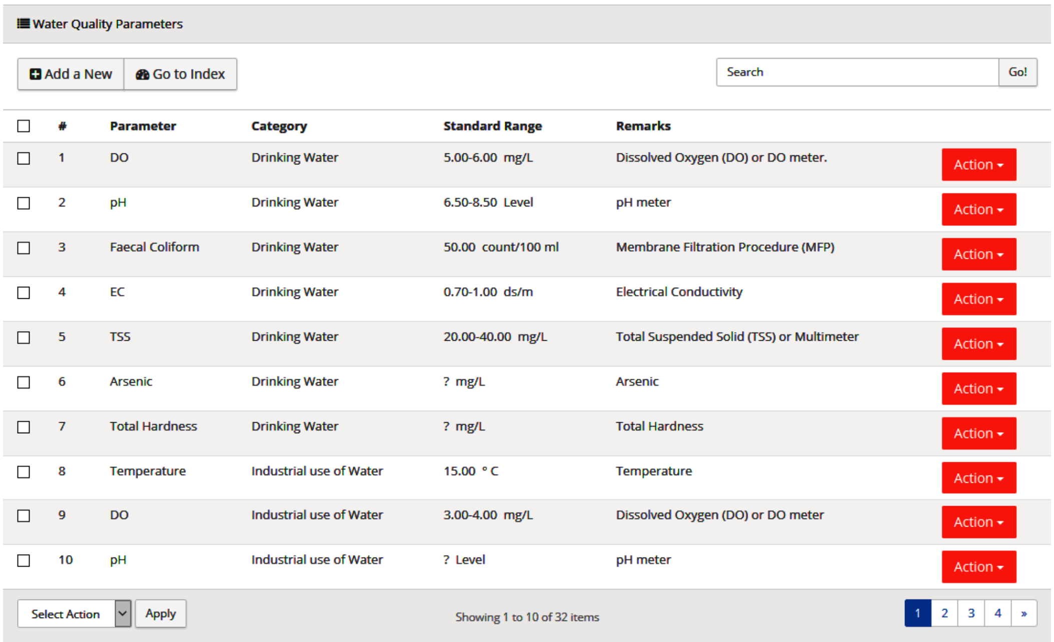


Figure 6.18: Add New Water Quality Parameter



#	Parameter	Category	Standard Range	Remarks	
1	DO	Drinking Water	5.00-6.00 mg/L	Dissolved Oxygen (DO) or DO meter.	Action
2	pH	Drinking Water	6.50-8.50 Level	pH meter	Action
3	Faecal Coliform	Drinking Water	50.00 count/100 ml	Membrane Filtration Procedure (MFP)	Action
4	EC	Drinking Water	0.70-1.00 ds/m	Electrical Conductivity	Action
5	TSS	Drinking Water	20.00-40.00 mg/L	Total Suspended Solid (TSS) or Multimeter	Action
6	Arsenic	Drinking Water	? mg/L	Arsenic	Action
7	Total Hardness	Drinking Water	? mg/L	Total Hardness	Action
8	Temperature	Industrial use of Water	15.00 ° C	Temperature	Action
9	DO	Industrial use of Water	3.00-4.00 mg/L	Dissolved Oxygen (DO) or DO meter	Action
10	pH	Industrial use of Water	? Level	pH meter	Action

Figure 6.19: List of Water Quality Parameters

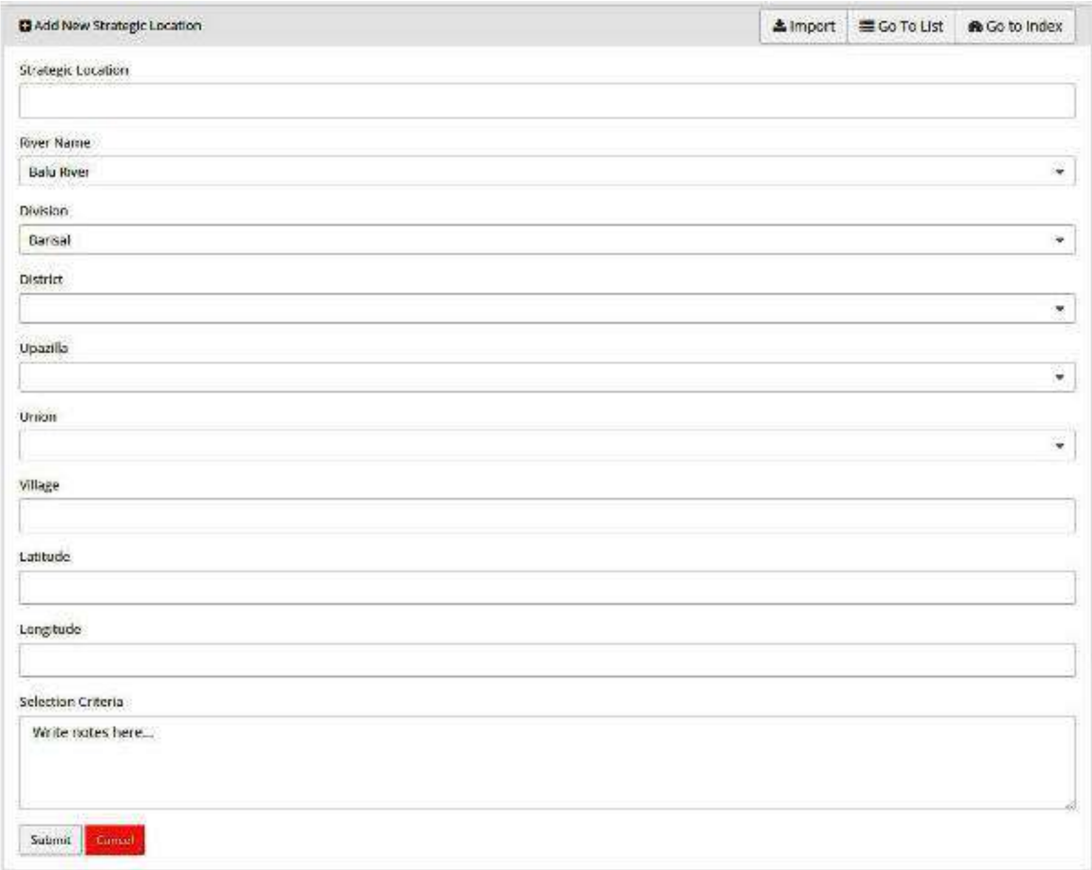
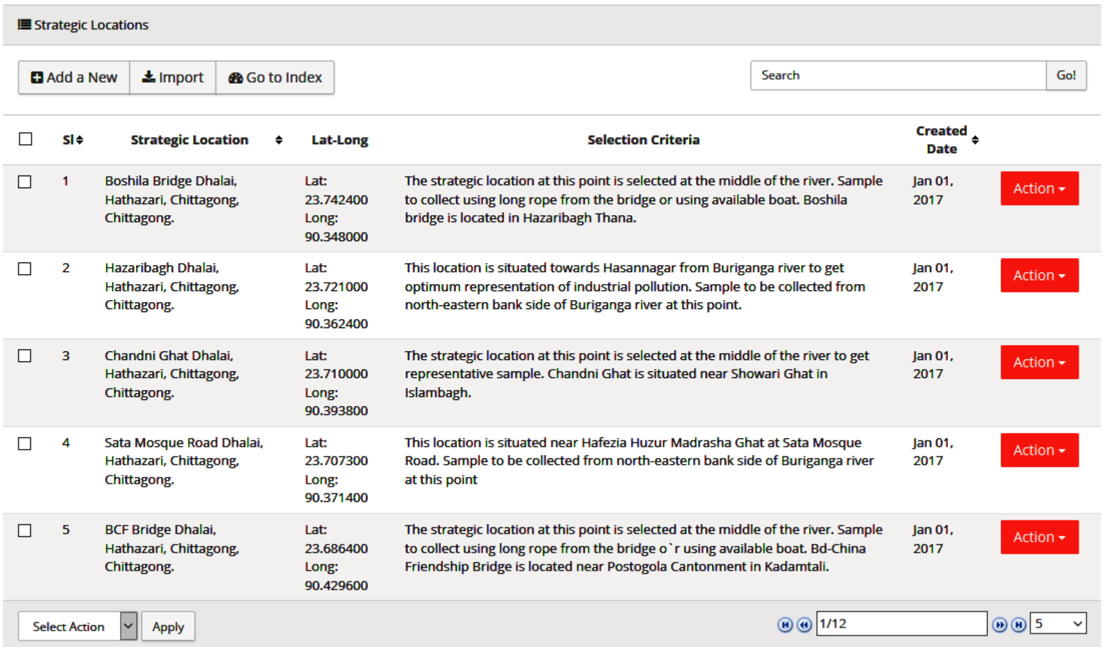


Figure 6.20: Add new Strategic Location



	Sl	Strategic Location	Lat-Long	Selection Criteria	Created Date	
☐	1	Boshila Bridge Dhalai, Hathazari, Chittagong, Chittagong.	Lat: 23.742400 Long: 90.348000	The strategic location at this point is selected at the middle of the river. Sample to collect using long rope from the bridge or using available boat. Boshila bridge is located in Hazaribagh Thana.	Jan 01, 2017	Action
☐	2	Hazaribagh Dhalai, Hathazari, Chittagong, Chittagong.	Lat: 23.721000 Long: 90.362400	This location is situated towards Hasannagar from Buriganga river to get optimum representation of industrial pollution. Sample to be collected from north-eastern bank side of Buriganga river at this point.	Jan 01, 2017	Action
☐	3	Chandni Ghat Dhalai, Hathazari, Chittagong, Chittagong.	Lat: 23.710000 Long: 90.393800	The strategic location at this point is selected at the middle of the river to get representative sample. Chandni Ghat is situated near Showari Ghat in Islambagh.	Jan 01, 2017	Action
☐	4	Sata Mosque Road Dhalai, Hathazari, Chittagong, Chittagong.	Lat: 23.707300 Long: 90.371400	This location is situated near Hafezia Huzur Madrasha Ghat at Sata Mosque Road. Sample to be collected from north-eastern bank side of Buriganga river at this point	Jan 01, 2017	Action
☐	5	BCF Bridge Dhalai, Hathazari, Chittagong, Chittagong.	Lat: 23.686400 Long: 90.429600	The strategic location at this point is selected at the middle of the river. Sample to collect using long rope from the bridge o`r using available boat. Bd-China Friendship Bridge is located near Postogola Cantonment in Kadamtali.	Jan 01, 2017	Action

Figure 6.21: List of Strategic Locations

6.3.7 Administrative Module

This module for WQMS has the simple function to add/remove User, Group, and Roles in the Administration Menu. The Administration Menu has 3 basic elements: Users, Groups, and Roles link. This module provides a settings for user privileges to change which elements will be accessed or denied.

a. Users

To add new user or view existing user, click on Users link under Administrative menu.

Figure 6.22: Add a new user

b. Groups

As an administrator, designated person can use groups to create and manage new group. New user will be assigned to selected groups. The android app has defalult (created) designated groups with assigned its permission.

c. Roles

As an administrator, you can use roles to create and manage new roles. New groups will be assigned to selected roles.

6.4 Organization and database development

Comprehensive and well-organized database is being developed in consultation with DoE considering their existing data. The databases have the tentative major data groups, which are (i) Water quality attribute data, (ii) Basic GIS data (rivers, roads etc.) (iii) Google map and (iv) Other data (photographs, documents, reports etc.). The database development activity includes (i) organization of field data, (ii) Organization of secondary data, and (iii) Integration of all types of data into a database system, and (iv) database development.

6.5 Production of Geo-spatial Data

From the processed field data, a geo-spatial/ GIS data layer has been produced. In the data collection forms,the provision for geo-spatial or GPS locations has been kept. These processed data can be shown on the map module.

6.6 Mobile App for using the WQMS

The water quality monitoring system (WQMS) has been developed for sustainable monitoring of water quality in Bangladesh. The system will also help to faciliated in South Asia. The DoE officials and staff will be able to access the WQMS software through the internet/ intranet or an android app depending on their access authorization. The user will also be able to access the software using his/her mobile phone prior with internet options or using developed android app. The user interfaces and input/output formats have been designed and developed in consultation with officials of the DoE. The major steps followed to develop the system are System design, Database design, Interface design, and System development.The detail about the Mobile App has been given in Chapter 7.

7. WQMS Android App

7.1 Concept of Android

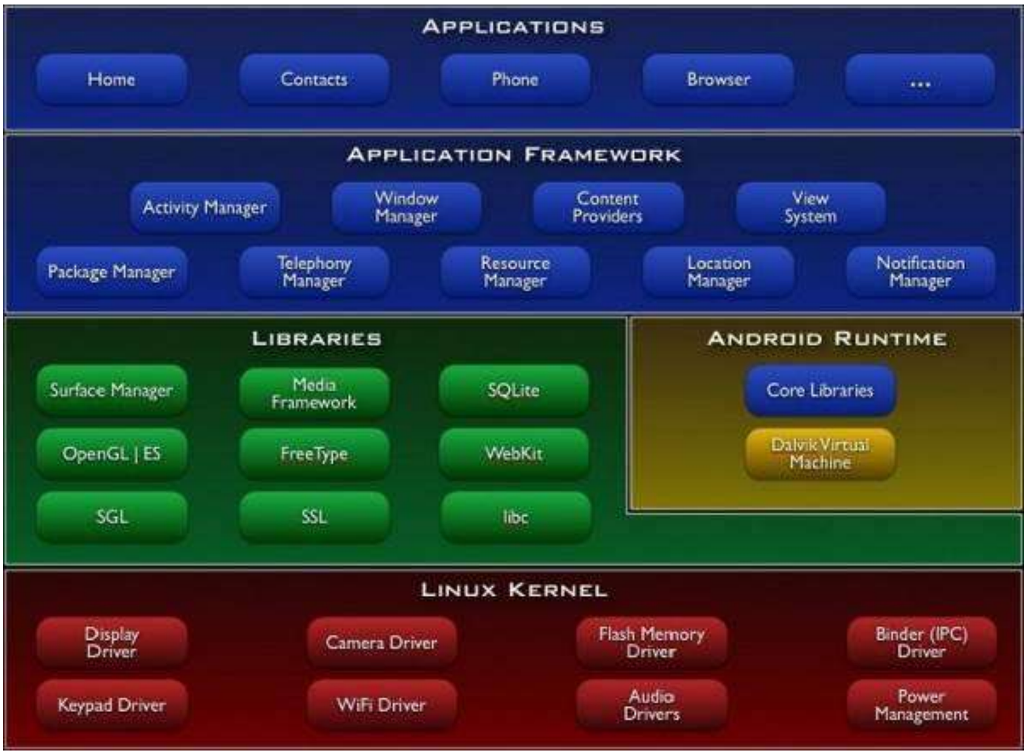
Android is basically an operating system for smartphones. But currently we find Android integrated into Cell Phone, PDAs, touch pads or televisions, even cars (trip computer) or netbooks. The OS was created by the start-up of the same name, which is owned by Google since 2005.

7.2 Specifications

This operating system is based on version 2.6 of Linux, so it has a monolithic system kernel, what means that all system functions and drivers are grouped into one block of code.

Android consists of five layers:

- The Linux kernel 2.6-which includes useful drivers that allow for example Wi-Fi or Bluetooth.
- The library written in C and C + + that provide higher level functionality such as an HTML engine, or a database (SQLite).
- A runtime environment for applications based on a virtual machine, made for inefficient machines such as telephones. The aim is to translate JAVA in machine language understood by Android.
- A JAVA framework allows applications to run on the virtual machine to organize and cooperate.
- The user applications written in Java (Web browser, contact manager etc.)



7.3 Current Version

Today Android is in its 7th version, Android 7.1.2. Each version is designed to gradually correct the lack of APIs, to enhance the user interface and add functionality. The latest version adds such things as support in HTML5 in the browser, it allows multi touch or it brings new Contact API, which defines a database for contact management.

On October 19, 2016, Google released Android 7.1.1 as a developer preview for the Nexus 5X, Nexus 6P and the Pixel C. A second preview became available on November 22, 2016, before the final version was released to the public on December 5, 2016.

Android Oreo is the 8th major release of the Android operating system. It was first released as a developer preview on March 21, 2017, with factory images for current Nexus and Pixel devices. The final developer preview was released on July 24, 2017, with the stable version released in August 2017.

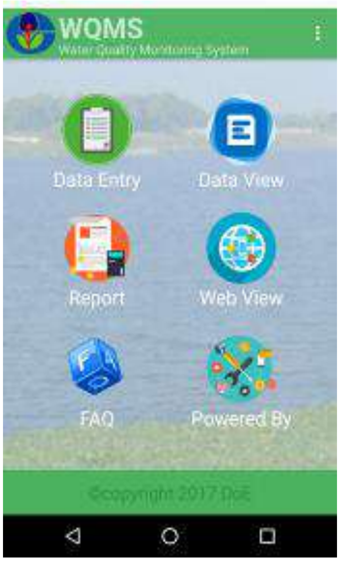
7.4 Development of WQMS App

The water quality monitoring system (WQMS) Android App has been developed for sustainable monitoring of water quality in Bangladesh. The system will also help to faciliated in South Asia. The DoE officials and staff will be able to access the WQMS app through the internet or a smart phone depending on their access authorization. The user interfaces, input/output formats have been designed and developed in consultation with officials of the DoE. The major steps followed to develop the system are System design, Database design, Interface design, and System development.

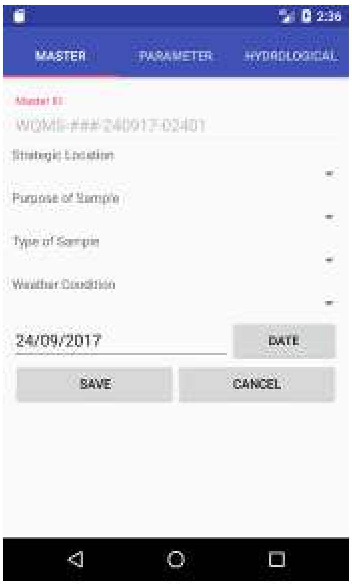
7.5 Designed Apps Screen Shot

App in the menu

Log in screen



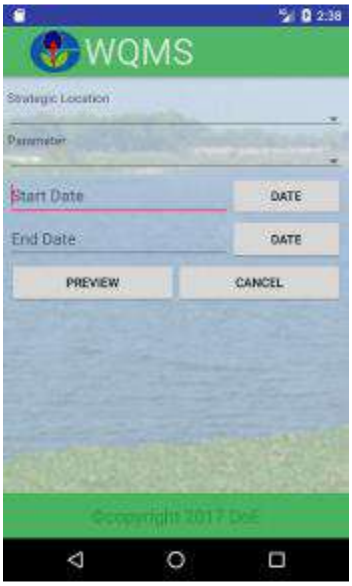
Home screen



Master data input screen

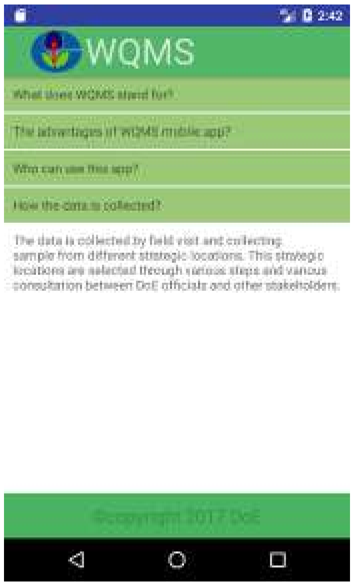
In-situ result input screen

Hydrological input screen



Report view screen

Upload Image



FAQ screen

7.6 Advantages of this Android app

- This Android app can be easily installed
- No need to give personal information when installing
- Relatively few data entry needed
- Since Android is an open source mobile operating system, this app can run on any Android-based mobile operating system
- Data entry from the field can be uploaded and photos of those places can be uploaded as well
- The information can be updated at any time, as the app is dynamic and easy to use

8. Technology Transfer

8.1 Technology Used

The technology used for the development of the WQMS is Microsoft .NET framework 4.5, Entity framework 6.0 and ASP Map technology for GIS support. The ASP Map technology is very useful for low cost and stable solutions. The following technologies have been used to develop the components of the MIST:

- Programming Language: C#
- Framework: Microsoft .NET MVC framework 5.0
- Web components: ASP.NET 4.5, Web API
- Database: Microsoft SQL Server 2008/2012
- Map service: ASP Map v 4.8.3

8.2 Main input and output for the system

To monitor the water quality data under different river locations of Bangladesh using the intended Water Quality Monitoring System (WQMS), a number of data layers are required as described below.

- General Information on water quality: spatial, attribute, timer view.
- Water quality data view
- Generated Report
- Tabular/ Graphical Report.

8.3 Deployment of Database and WQMS

Comprehensive and well-organized database is being developed in consultation with DoE considering their existing data. The databases have the major data groups, which are (i) Water quality attribute data, (ii) Basic GIS data (rivers, roads etc.) (iii) Google map and (iv) Other data (photographs, documents, reports etc.). The database development activity includes (i) Organization of field data, (ii) Organization of secondary data, and (iii) Integration of all types of data into a database system, and (iv) Database development.

From the processed field data, a geo-spatial/ GIS data layer is produced. In the data collection forms provision for geo-spatial or GPS locations have been kept. These processed data is shown on module of the map.

The database will be deployed to DoE computer system and server. Map server and GIS component will be installed into the computer system of DoE. The whole system will be well tested before starting the main business of water quality monitoring.

8.4 Capacity Building of DoE Officials

A training program will be organized on Web-based MIS and Mobile Application for DoE officers. This training will include operation and maintenance of database and MIS. The process of data capture and display using Mobile Device will be demonstrated in this training.

9. Findings and Recommendations

9.1 Summary of the Findings

- The existing WQ monitoring stations of DoE lacks supporting database, like GPS Coordinate, station profile, sources of pollution, pollution hotspot etc.;
- In some cases, DoE collects 3 samples from the same location (Middle & both bank side of river) which incur more financial and temporal costs;
- As per the standards of other organizations (e.g. WHO, BIS, BADC & others) the number of parameters in ECR'97 for different use are very limited. In some cases important parameters are not considered. The standard limits of different parameters also vary largely with others standards and the standard require revision;
- DoE collects and analyses water samples by regional offices and compiles manually in excel sheet;
- Existing monitoring system of DoE emphasizes industry based pollution monitoring rather than pollution hotspot based and non-point pollution sources based water quality monitoring;
- Presently the existing WQ monitoring system of DoE does not include Web-MIS based decision support system;
- DoE does not collect sample from all rivers (total rivers 405, sources: Bangladesher Nod-Nodi, BWDB);
- The water quality parameters and standards of ECR'97 does not include specific use (Agriculture, Fisheries, Drinking and Industrial Use) of river water for all parameters;
- Human resources of DoE is very limited and it is quite difficult for them to cover all the rivers;

9.2 Recommendations

- DoE WQ Monitoring system should be modern technology based well organized and cost effective to cover maximum rivers ;
- In some cases, DoE collects 3 samples from the same location (Middle & both bank side of river) which incur financial and temporal costs; DoE should collect one sample per location from the optimum polluted point;
- ECR'97 should be revised considering the standards of different organization working in Bangladesh (e.g. BADC, DPHE, FAO, WHO) as well as other neighbouring organizations like Bureau of Indian Standards (BIS, ICMR), Malaysia and others;
- The water quality monitoring system of DoE should be web-MIS based. They can introduce mobile-app for real-time test results entry. This mobile app will help snapping pollution incident as well as sampling locations;
- DoE should emphasize on pollution hotspot based and non-point pollution source based water quality monitoring;
- Standards for specific uses (Agriculture, Fisheries, Drinking/consuption& Industrial Use) of river water should be incorporated in the revised ECR'1997.

DoE should increase their human and other resources to cover maximum rivers;

9.3 Project Port-folio Development

9.3.1 Project Port-Folio 1

Strategic Thematic Area	Improve Surface Water Quality	
Development Area	Water Resources	Priority: Very High
Project Title	Development of Integrated Water Quality Data Storage Center	
Location	Dhaka	
Key Objectives	1. Designing automated system of river water quality monitoring; 2. Integration of water quality data into the server; 3. Develop water sampling protocol and guidelines;	
Description	There are many agencies (e.g. BWDB, DPHE, BADC, DoE, BUET and others) in Bangladesh that are engaged in monitoring water quality. These individual initiatives have been contributing in improving the surface water quality. All these efforts needed to be incorporated under a specific body. DoE can take this initiative to develop an integrated water quality data storage center.	
Lead Implementing Agency	Department of Environment (DoE)	
Supporting Implementing Agency	BWDB, DPHE, BADC, DoE, BUET, SRDI, IRRI, BRRI and other agency.	
Cost in BDT	-	

9.3.2 Project Port-Folio 2

Strategic Thematic Area	Improve Surface Water Quality	
Development Area	Water Resources	Priority: Very High
Project Title	Water Quality Monitoring System for all Rivers in Bangladesh	
Location		
Key Objectives	1. Assess the existing monitoring system of surface water (rivers); 2. Identify water pollution hotspots and monitoring stations for all rivers in Bangladesh; 3. Incorporate the rivers for monitoring within the existing monitoring system;	
Description	The rivers of Bangladesh are very dynamic. They continuously change their courses. Some of the rivers flow over the urban areas having dense industrial concentration. The other rivers run over the horizon of agricultural field. Thus the rivers of Bangladesh have been polluted by point as well as non-point sources of pollution. As ground water depletion rate is very high and has become a common scenario, surface water use can be promoted in this context. For this purpose different use based water quality monitoring is important for all the rivers of Bangladesh.	
Lead Implementing Agency	Department of Environment (DoE)	
Supporting Implementing Agency	BWDB, DPHE, BADC, DoE, BUET, SRDI, IRRI, BRRI and other agencies.	
Cost in BDT	-	

9.3.3 Project Port-Folio 3

Strategic Thematic Area	Improve Surface Water Quality	
Development Area	Water Resources	Priority: Very High
Project Title	Automated system of Surface Water Quality Monitoring of Bangladesh.	
Location		
Key Objectives		
Description	This automated system of surface water quality monitoring system can evaluate alternative sensors, transmission technologies, and use of GIS and Remote Sensing Software in order to implement an automated water quality monitoring system for the rivers in Bangladesh. This device will need to be installed at important monitoring stations which will subsequently test water quality on a regular basis and transmit test results to the central unit.	
Lead Implementing Agency	Department of Environment (DoE).	
Supporting Implementing Agency	BWDB, DPHE, BADC, DoE, BUET, SRDI, IRRI, BRRI and other agencies.	
Cost in BDT	-	

Appendix I: Water Quality Data Collection Form

Department of Environment

Section A: General/Locational Information

A1. Sample ID: **A2. Name of the River:**

A3. Location of Water Sample Collection:

Location Name (Mouza/village)	Union	Upazila	District

4. GPS Location: **Latitude** **Longitude**

Section B: Water Sample Related Information

B1. Description of Sample Bottle and Parameters

a. Sample collection with acidified bottles			
Parameter	**Put tic**	**Parameter**	**Put tic**
1. Arsenic		4. Boron	
2. Calcium		5. Lead	
3. Sodium			
Sample collection with non-Acidified bottles			
1. Dissolved Oxygen		9. Total Hardness	
2. Biochemical Oxygen Demand		10. Chemical Oxygen Demand	
3. Fecal Coliform		11. Total Suspended Solids	
4. Electrical Conductivity		12. Hydrogen Sulphide	
5. Total Dissolved Solids		13. Ammonia (NH_3, N),	
6. Temperature		14. Nitrate (NO_3),	
7. pH			
8. Salinity			
In-situ testing of sample			
1. Temperature		5. Dissolved Oxygen	
2. Electrical Conductivity		6. Salinity	
3. Total Dissolved Solids			
4. pH			

B2. Date and Time of Sample Collection:			
Date		Time	

B3. Date of Sample Transferring to Lab:

B4. Description of Sample Collector	**B5. Data Form Checked by**
• Name: • Signature: • Date:	• Name: • Signature: • Date:

B6. Hydrological Information:

Depth of water	River Flow condition (Flowing/Stagnant/Other)

Appendix II: Team Members

Engr. Md. Waji Ullah	Water Resources Advisor
Malik Fida Abdullah Khan	Climate Change Expert
Md. Motaleb Hossain Sarker	Team Leader, Environmental Expert
Nur Mohammad	Urban Planner & GIS Specialist
Mohammad Mukteruzzaman	Fisheries Specialist
Md. Abdur Rashid	Agriculture Specialist
Anushila Mazumder	Water Quality Specialist
H. M. Nurul Islam	Environmental Specialist
Laila Sanjida	GIS and Remote Sensing Specialist
Foez Ahmed	Junior Geologist
Md. Anisur Rahman	Software Development Specialist
A.T.M. Saidul Karim	Programmer
Abu Maleh Nooruddin Haider	Programmer
Dewan Mohammad Ariful Islam	Junior Geologist
Rakshanda Mobin	Field Researcher
Mashuda Parvin	Field Researcher