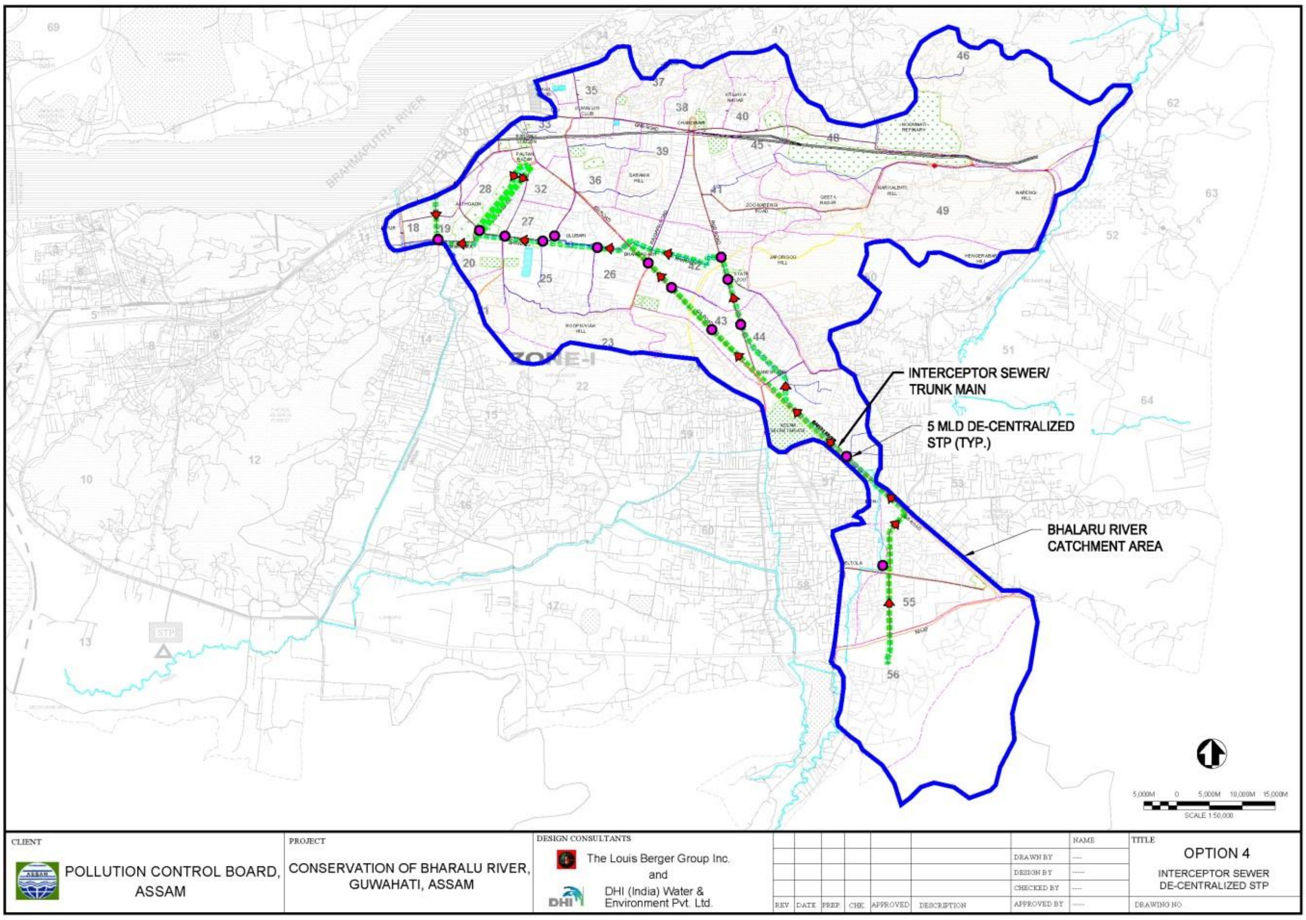
Pollution Control Board, Assam

Conservation of River Bharalu, Guwahati

Preparation of Detailed Project Report

Project Feasibility Report for Sewerage Schemes



Joint Venture of The Louis Berger Group, Inc.
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LIST OF KEY ABBREVIATIONS

AUWSSB	:	Assam Urban Water Supply and Sewerage Board
BOD	:	Biological Oxygen Demand
CDM	:	Clean Development Mechanism
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
CPHEEO	:	Central Public Health Environmental Engineering Organisation
CSP	:	City Sanitation Plan
CWC	:	Central Water Commission
DA	:	Drainage Area
DBO	:	Design, Build & Operate
DO	:	Dissolved Oxygen
DPR	:	Detailed Project Report
GIS	:	Geographical Information System
GJB	:	Guwahati Jal Board
GL	:	Ground Level
GMA	:	Guwahati Metropolitan Area
GMC	:	Guwahati Municipal Corporation
GMDA	:	Guwahati Metropolitan Development Authority
GoI	:	Government of India
ICT	:	Information and communications technology
IEC	:	Information, Education & Communication
JNNURM	:	Jawahar Lal Nehru National Urban Renewable Mission
LPD	:	Litres Per Day
MLD	:	Million Litres per Day
MoEF	:	Ministry of Environment and Forests, Govt. of India
MSW	:	Municipal Solid Waste
NGRBA	:	National Ganga River Basin Authority
NRCD	:	National River Conservation Directorate
NRCP	:	National River Conservation Plan
O&M	:	Operation and Maintenance
PCBA	:	Pollution Control Board, Assam
PFR	:	Project Feasibility Report
PHE	:	Public Health Engineering
PMU	:	Project Management Unit
PS	:	Pumping Station
RFD	:	River Front Development
SPS	:	Sewage Pumping Station
SS	:	Suspended Solids
STP	:	Sewerage Treatment Plant
SWM	:	Solid Waste Management
TSS	:	Total Suspended Solids
ULB	:	Urban Local Bodies

SALIENT FEATURES OF THE PROJECT

Background and Objective

Bharalu River is listed by the Central Pollution Control Board (CPCB) as one of 71 most polluted rivers in India. The Bharalu originates in the Meghalaya foothills and flows through the City of Guwahati's (Guwahati) densely populated industrial and commercial centre before draining into the south bank of Brahmaputra River (Brahmaputra). Guwahati is considered to be one of the fastest growing cities in India. Therefore, the Pollution Control Board of Assam (PCBA) has commissioned preparation of this Detailed Project Report (DPR) in accordance with the Ministry of Environment and Forests (MoEF), National River Conservation Directorate (NRCD) guidelines (NRCD, 2010) for the stretch of Bharalu that traverses Guwahati.

After flowing a few kilometres from its origin in the Khasi Hills, the Bharalu bifurcates into two rivulets: the Basistha River, which flows towards Deepor Beel, and the Bahini River, which in its downstream stretch is called the Bharalu while flowing through Guwahati and eventually draining into the Brahmaputra at Bharalumukh. The Bharalu catchment area in Guwahati has undergone rapid urbanization in recent years, resulting in unabated encroachment and discharge/dumping of solid and liquid wastes, thereby severely degrading the river system.

The NRCD had earlier prescribed specific guidelines for the preparation of the Project Feasibility Report (PFR) and DPR under the National River Conservation Plan. Subsequent developments including the formulation of the March 2001 resolution by the National River Conservation Authority, lead to the issuance of new guidelines for the preparation of the DPR under the consolidated National River Conservation Plan and the National Lake Conservation Plan. The overall objective of the DPR is formulating a comprehensive and integrated river restoration plan for the Bharalu in accordance with the 2010 NRCD guidelines.

Scope of Work

As per the NRCD (2010) guidelines, the DPR will be prepared in a three-stage process related to sewerage schemes, namely:

- City Sanitation Plan (CSP)
- Project Feasibility Report (PFR) for sewerage, which constitutes this report
- Detailed Project Report (DPR).

EXECUTIVE SUMMARY

The stretch of the Bharalu River that flows through the City of Guwahati suffers from severe environmental degradation and continues to impact the health/hygiene of the inhabitants in the surrounding area. The Pollution Control Board of Assam (PCBA) has therefore assigned its highest priority to restoring the Bharalu in accordance with the NRCD guidelines by adopting a series of integrated conservation measures. These measures will include among others: wastewater management; solid waste management; water resources management for hydraulic improvement of the river channel; provision of civil amenities along the river and around the area of influence; and formulation of an awareness program among the affected communities and stakeholders to refrain from activities that degrade the condition of the river in any manner. The conservation measures will be analysed and documented in a DPR in accordance with the NRCD guidelines. The DPR will thereafter serve as the primary guidance document for future river restoration measures.

The overall aim of the project is to revitalize the Bharalu within the context of the continued urbanization of Guwahati by restoring it to its natural state, while allowing the river system to continue to support flood management, landscape development and recreational activities. In its current degraded state, the Bharalu serves as an extended sewer canal running through the densest populated areas within Guwahati. The water quality of the river will be restored per NRCD guidelines by: restricting inflows of raw sewerage from residential/commercial establishments; limiting direct discharge from storm water drains along roads adjacent to the river; and preventing unabated dumping of solid waste by communities residing along the river. Measures will be adopted to augment inflow of clean water to improve river hydraulics and flood management controls, and to develop an integrated water resource management system to sustain optimum water levels required in the river during the dry winter months. The revitalization efforts will incorporate riverfront development to encourage public participation and ownership of the river. It is noted that this DPR is one of the several initiatives currently underway by the Government of Assam to improve the living conditions in Guwahati.

The DPR is being prepared by an experienced team of Indian and international professionals with a wide range of expertise in river restoration and wastewater management controls. In addition to collecting data and reviewing reports and documents of relevant programmes, consultations have been carried out with relevant Government agencies, municipalities, community members and other stakeholders. The DPR will also address diverse yet related issues such as environmental sustainability and dependency of local communities. As per NRCD Guidelines, following the city Sanitation Plan (CSP), The Project Feasibility Report (PFR) of the sewerage works has been prepared. The PFR contains analysis of options considered for immediate actions as well as for mid- and long-term work plan. The sewerage scheme to be taken up during the project as part of the first phase is designed for the Bharalu catchment areas (wards) directly discharging waste water to the river.

This PFR addresses the needs for providing an effective interception of sewage before it enters into the river, conveyance, treatment, and disposal system to safeguard the River and also to maintain normal ecological system of the river. A series of decentralised treatment plants have been proposed to be implemented.

1 ABOUT THE PROJECT AREA

The authority for preparation of the project is:

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1.1 Description of Project Area

The Bharalu originates in the hilly catchment of Meghalaya, and remains in a relatively natural state till it enters the densely inhabited areas of Guwahati incorporated within Assam's Kamrup Metro District. The Bharalu sub-basin is located along the south bank of the Brahmaputra. The sub-basin is located within the coordinates of 25°59' to 26°11' North and 91°43' to 91°51' East.

The degradation of the Bharalu starts around the Basistha hill immediately south of National Highway 37 (NH37) and worsens as it flows through the densely populated residential and commercial areas of Guwahati, crossing the NH37 and undergoing more intense degradation till it joins the Brahmaputra at Bharalumukh. The Bharalu carries a large portion of the city's municipal and other wastes and also serves as the natural drainage for storm water runoff (Figure 1-1). The major localities of the city that contribute to the degradation are Sixth Mile, G.S. Road, Zoo Road, Bhangagarh, Athgaon and Bharalumukh. The refinery waste water discharging from the Indian Oil Corporation Refinery at Noonmati drains directly into the Bharalu. The waste water from households, commercial/business establishments, and small to medium industries within the city flows directly into the Bharalu River through the system of mutually interconnected drains.

The degradation caused by domestic and commercial wastes poses a serious threat especially for the inhabitants of Guwahati and finally the downstream receptor, the Brahmaputra. Measures to address the entire urban stress on the river system require immediate intervention.

1.1.1 Brief History of the Town

Guwahati has been identified to be the legendary Pragjyotishpur, or the City of Eastern Light. The city has had a rich history and finds frequent mention in medieval historical sources and also in the epics Mahabharata, Ramayana and Raghuvansham of Kalidasa. In 640 AD, the famous Chinese traveller Yuen Chawan visited the city. The emergence of modern Guwahati started around 1826, and in 1890 the city was connected to the rest of India via a railway line. Guwahati experienced phenomenal growth after independence of the country following the establishment of major institutions of higher education like Guwahati University, Engineering College, and Medical College. The Guwahati Oil Refinery was established in 1961. In 1972, after the reorganization of the State of Assam, the capitol was shifted from Shillong to Dispur (Guwahati), whereby the city gained enough political importance. Since then, the city has grown enormously in terms of population and development of commercial activities.

1.1.2 Geographical Location

Guwahati is situated on the banks of Brahmaputra with its cardinal points being 26°11′0″N and 91°44′0″E. It is located towards the south-eastern side of Kamrup district, which is surrounded by the Nalbari district in the North, the Darrang and Marigaon districts in the East, the Meghalaya State in the south, and the Goalpara and Barpeta districts in the West (Figure 1-1).

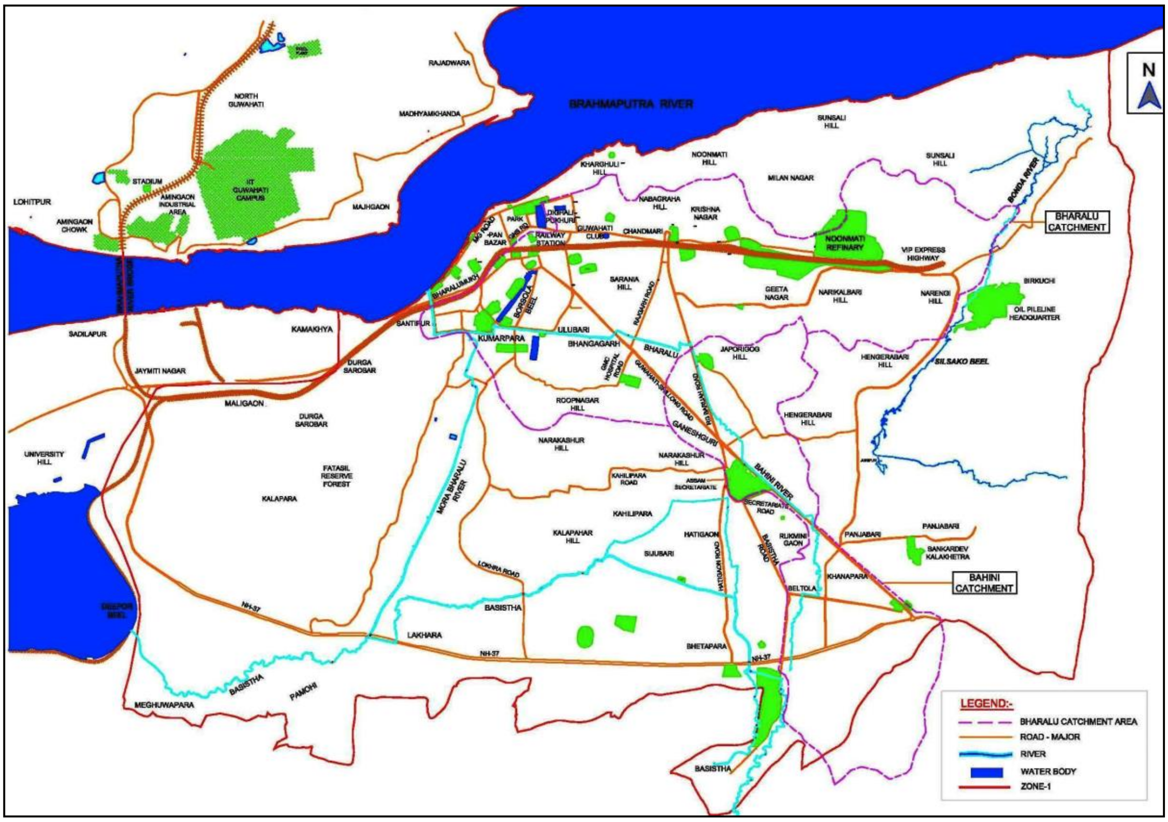


Figure 1-1: The Bharalu River System

The city is situated on an undulating plain with varying altitudes of 49 to 56 m above Mean Sea Level (MSL). The southern and eastern sides of the city are surrounded by hillocks. Apart from the hilly tracts, swamps, marshes, water bodies such as Deepor Beel, Silpukhuri, Dighali Pukhuri, Borsola Beel and Silsakoo Beel are also within the city.

Figure 1-2 shows the Zonal Map of Guwahati. Zone 1 is directly affected by the Bharalu. The DPR addresses river restoration measures for Bharalu within this zone.

1.1.3 Climate

The Bharalu sub-basin falls within the climatic Zone 1 which comprises northern and north-eastern India as well as adjoining parts of Nepal, Bhutan, Bangladesh and North Myanmar. In this zone, rainfall generally occurs in the monsoon months from June to September while the months from November to February are generally dry with occasional winter rains. In this basin, four meteorological conditions are mainly responsible for heavy rainfall and subsequent floods:

- Movement of a monsoon trough to the northeast from the Bay of Bengal to the sub-basin
- Shifts of the monsoon trough to the north from its normal position.
- Formation and movement of lowlands or land depressions over North-East India.
- Circulation of cyclonic upper air over North-East India.

The annual rainfall in Guwahati was on average 1,681 mm from 2008 to 2012 (Table 1-1). Of this amount, 63% of the rain fell during the monsoon months (June to September), 31% during the pre-monsoon months (March to May), 5% during the post-monsoon months (October to November), and 1% during winter (December to February). Hence, approximately 94% of total annual rainfall occurred during the wettest seven months (March to September).

Table 1-1: Monthly Rainfall (mm) in Guwahati from 2008 to 2012

Month	Year					Annual Mean	Percent of Annual Mean
	2008	2009	2010	2011	2012		
January	34	0		9	5	**10**	
February	10	2		23	8	**9**	
March	139	60	124	54	23	**80**	
April	159	112	370	101	382	**225**	
May	143	200	356	225	181	**221**	
June	354	190	483	88	396	**302**	
July	236	363	251	373	344	**313**	
August	281	287	234	204	310	**263**	
September	126	100	223	256	180	**177**	
October	116	119	76	0	58	**74**	
November	0	4	5	15	0	**5**	
December	2	4	1	1	5	**2**	
Annual Total	**1,600**	**1,440**	**2,122**	**1,350**	**1,892**	**1,681**	
June – Sept.	997	940	1,190	921	1,230	**1,056**	63%
Oct. – Nov.	116	123	81	16	58	**79**	5%
Dec. - Feb.	46	6	1	34	18	**21**	1%
Mar – May	441	372	850	380	587	**526**	31%

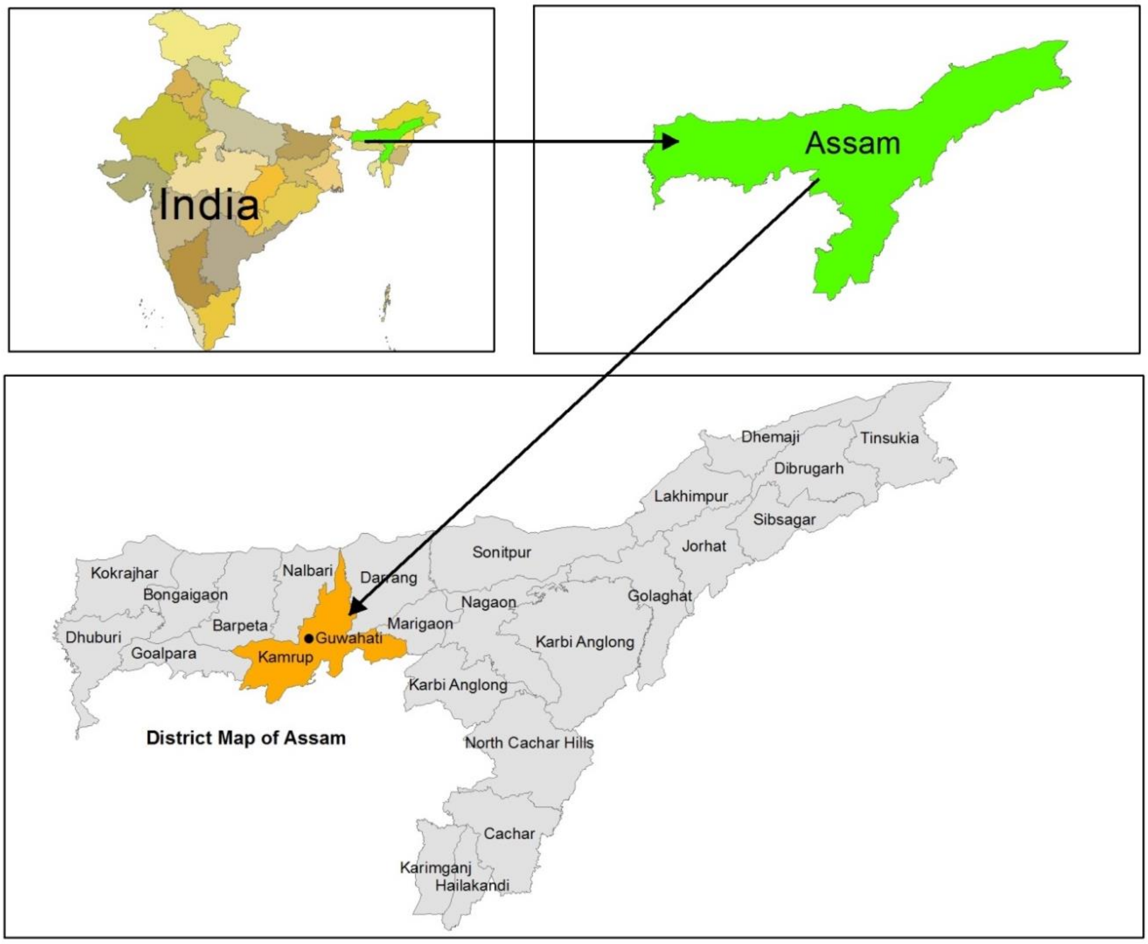


Figure 1-2: Districts of Assam

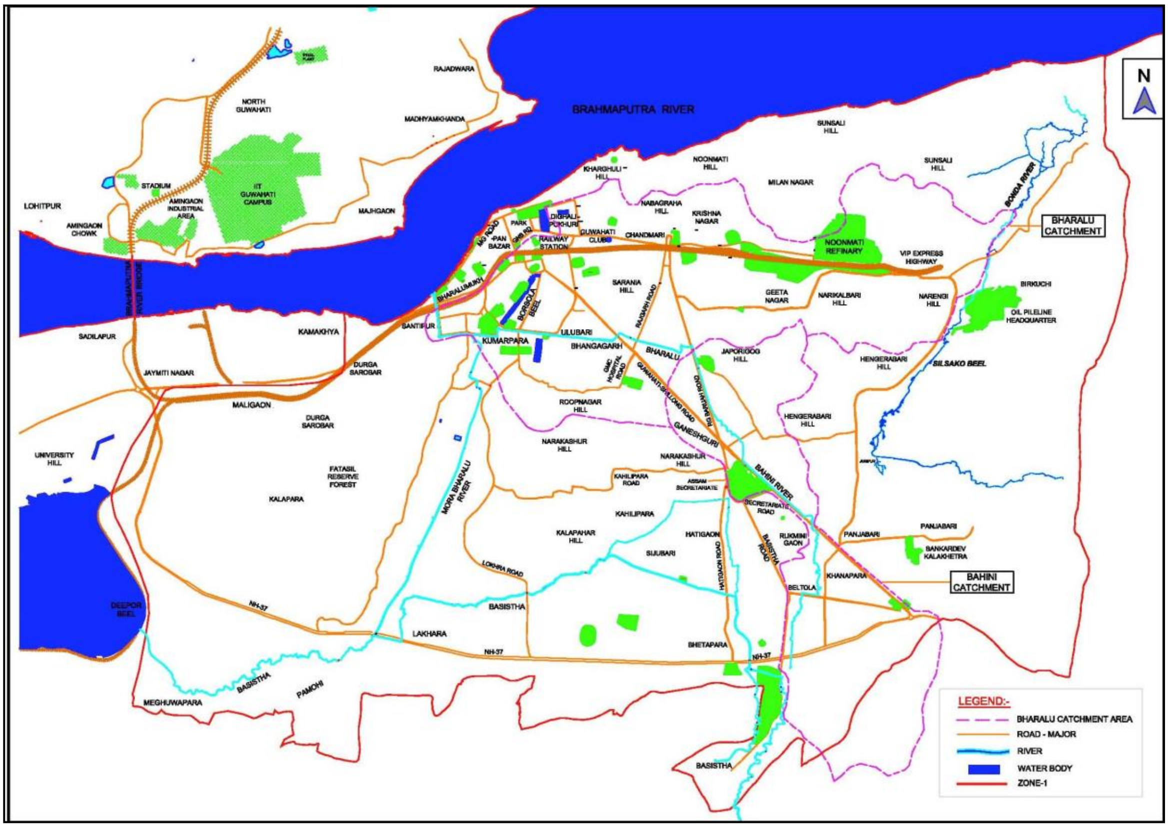


Figure 1-3: Bharalu Catchment Area in Guwahati Zone-1

1.1.4 Topography

The stretch of Bharalu and Bahini which traverses through the densest areas of Guwahati is approximately 16 km long (Table 1-2) with a catchment area that is almost equally divided between the hilly regions and the plains. Specifically, the hilly upstream section of the Bharalu has a catchment area of 60 km^2 (where it is known as Bahini), and a catchment area of 40 km^2 in its downstream stretch passing through Guwahati (Figure 1-3). The Bharalu is the main drainage channel of the Guwahati Municipality area. It discharges into the Brahmaputra at Bharalumukh.

Table 1-2: Description of the Course and Length of Bharalu, Bahini, Basistha, Morabharalu and Pamohi

River	Description of the Course of River	Length	Total Length
Bharalu	Split from Bahini at the Indian Oil Refinery drain to Bharalumukh where it drains into Brahmaputra River	7	16
Bahini	Split from Basishta to its downstream point at the Indian Oil Refinery drain where it is known as Bharalu	9	
Basistha	From its origin in Meghalaya Hills to confluence point with Dead Bharalu or Morabharalu	19	27
	After the confluence point with the Dead Bharalu or Morabharalu up to Deepor Beel	8	
Dead Bharalu (Morabharalu)	Between Bharalu and Basishta		13
Pamohi	Between Deepor Beel and Brahmaputra River		7

Covering an estimated area of 11 km^2 in the heart of Guwahati, the catchment area has seen rapid urbanization from economic and demographic developments. From Basistha Chariali, the Bharalu River runs for about 17 km till Bharalumukh with an average channel width of 5 to 9 m. The average water depth in the channel is 3 m, although it varies considerably as a result of different flow volumes and ever-increasing piles of garbage. Based on earlier estimates, the velocity of flow is 0.76 m/sec for the stretch between Basistha and R.G. Barua Road, and on average 1.2 m/sec for the rest of the course.

The study area is part of the Brahmaputra basin, with the Himalayan Mountain range in the North and East and the Naga-Patkai hill range in the South. The basin merges with the Indo-Gangetic plain in West. The Brahmaputra has a water depth of approximately 47 m in the Guwahati area. The width of its basin within Assam is 70 to 80 km. The slope of the river bed is very gentle, varying from 1:66000 to 1:99000. In some place, the elevation of the river bed lies below mean sea level (Dutta, Chaudhury and Dass, 1968). The drainage pattern of the Brahmaputra valley is an antecedent type. Lateral erosion as well as changes in fault lines due to earthquakes causes the river to change its course often.

1.1.5 Drainage Channels

After flowing a few kilometres, the original channel bifurcates into two rivulets. One rivulet known as the Basistha River flows towards Deepor Beel. The other rivulet (initially called Bahini and later Bharalu) passes though the city covering areas of Basistha cantonment, Beltola, Rukrninigaon, Mathura Nagar, Dispur, Hengrabari, and Ganeshguri, and then passes along the R.G. Baruah Road. This rivulet known as the Bharalu meets a major drain (carrying storm water and waste water run-off from the public sector; the Guwahati Refinery, owned by Indian Oil Corporation Limited; and domestic waste water from large areas in the eastern part of the city) near the Assam State Zoo and thereafter turns to the western direction, crosses the R.G. Barua Road and flows through a dense residential neighbourhood along Rajgarh Road. It then crosses the G.S. Road at Bhangagarh and flows towards Ulubari, Fatasil and Kumarpara prior to joining the Brahmaputra at Bharalumukh.

1.1.6 Administrative Divisions

District Administration

The District Administration is headed by the Deputy Commissioner. He also acts as the Collector in case of Revenue matters, as District Magistrate in case of maintenance of Law and Order and General Administration, as District Election Officer in case of conduct of Election and so on. The Deputy Commissioner is aided by a number of Officers such as the Additional Deputy Commissioner (ADC), Sub-divisional Officers, Extra Assistant Commissioners.

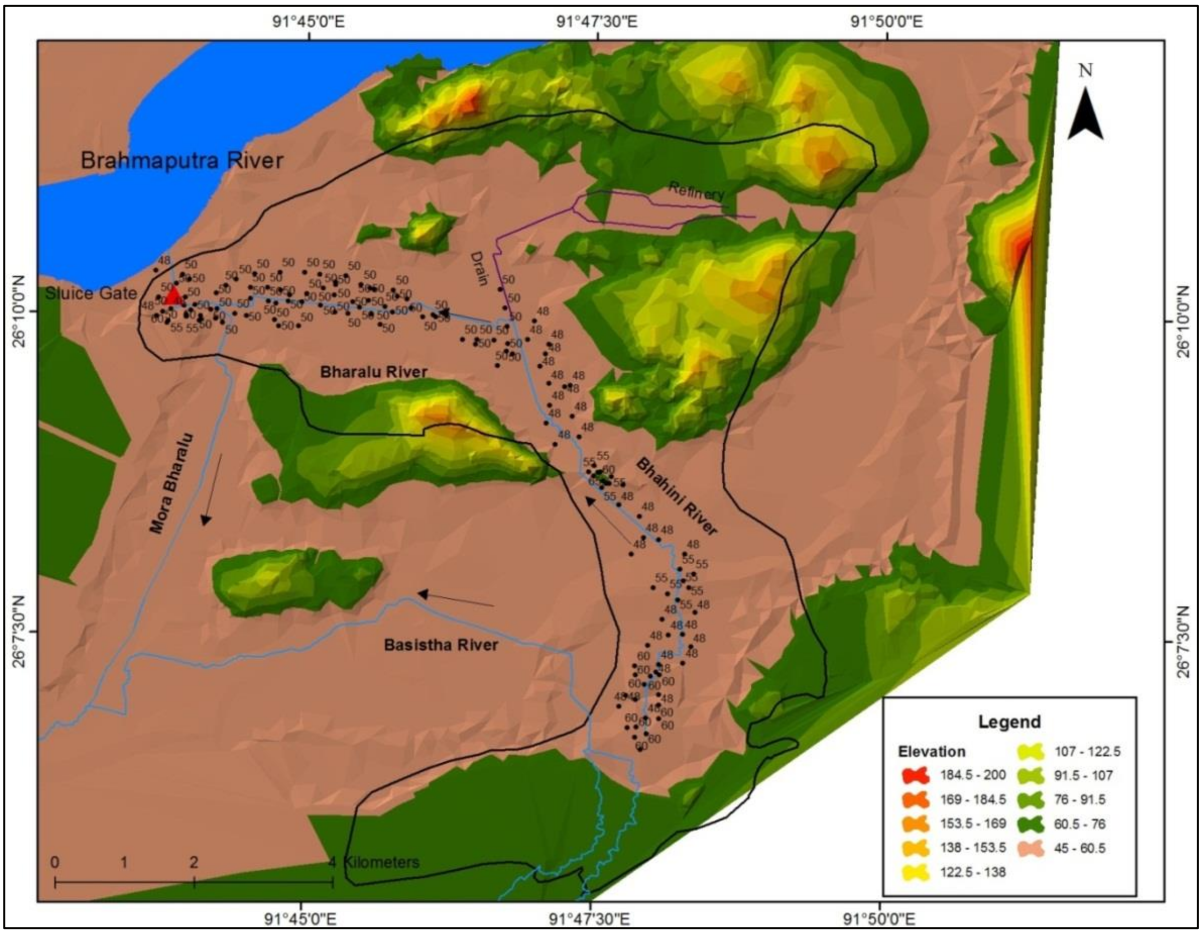


Figure 1-4: Elevations of the Bharalu River Catchment Area (in metres above MSL)

Revenue Administration has historically been the primary responsibility of the District Administration. This involves collection and fixing of land revenue, registration, mutation and overall management regarding land matters - private and public. Besides the Revenue Branch of the Deputy Commissioner's Office, which is looked after by the Additional Deputy Commissioner (Revenue), there are 6 outlying Revenue Circles in the district, supervised by Circle Officers. The Mouzadars under the Circle Officers are responsible for collecting land revenue (Khazna) from land owners (pattadars). All the Circle Officers are required to submit 'doul' (demand of revenue) to the DC, and after their approvals, Mouzadars are to collect revenue as per demand.

Apart from revenue matters, District Development has the important objective of the District Administration. As Head of the District Administration, the DC is responsible for all developmental activities in the district under various programmes such as Member of Parliament's Local Area Fund, Member of Legislative Assembly's fund, Untied Fund, Sub-divisional Plan Scheme Fund, Border Area Development Fund. For this work, the DC assigns the ADC (Development) the specific task of looking after and coordinating various developmental activities undertaken in various sectors. The ADC (Development) is aided by the Decentralised Planning Cell of the DC's office. All development departments in the district (such as Public Works Department, Irrigation, Health, Education) work in coordination. A District Development Committee headed by DC has been in place to ensure this coordination. Under the Government policy of rapid upliftment of rural population, a District Rural Development Agency (DRDA) is functioning in the district with the DC as the Chairman and one Project Director as its functional head. All schemes for Rural Development are implemented by this agency and are aided by the four Development Blocks situated in outlying rural areas of the district. These Development Blocks are supervised by Block Development Officers (BDOs).

Local Administration

For management and implementation of various developmental schemes, elected bodies are constituted at the level of corporation, municipality and town committees for urban areas and Panchayat bodies for rural areas. The Kamrup District has three urban local administration bodies as follows (with population as per 2001 Census):

1) Guwahati Municipal Corporation (GMC) = 8,09,895
2) North Guwahati Town Committee = 16,286
3) Narangi (OG) = 8,914

1.1.7 Commercial Aspects

Guwahati is the major hub of economic activity in the entire north-eastern region. The establishment of the Guwahati refinery in 1962 marked the beginning of industrialization in the city. The construction of the bridge over the Brahmaputra at Saraighat and the shifting of capitol from Shillong to Guwahati in 1972 had a tremendous economic impact on the city and turned Guwahati into one of the most important cities in the North-East India.

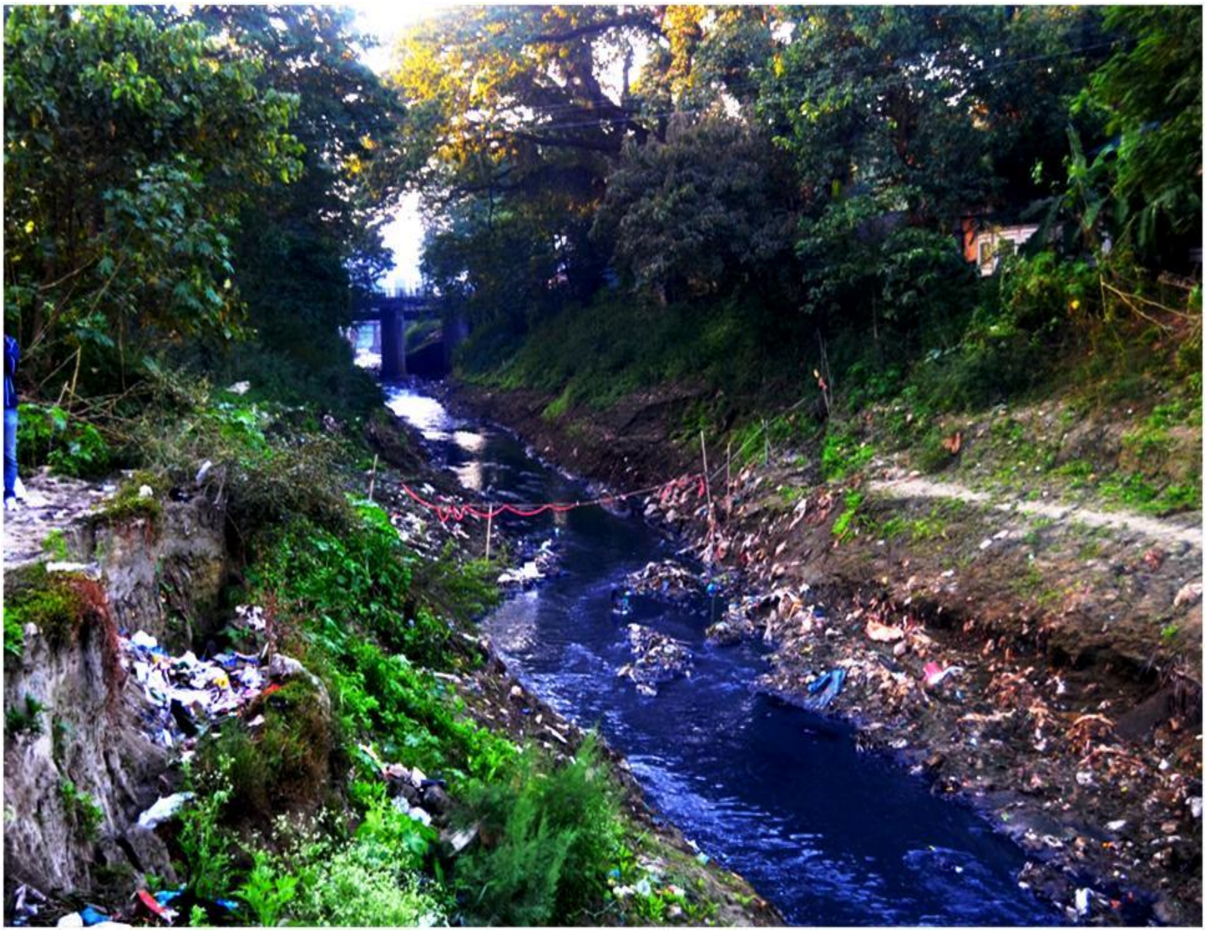


Figure 1-5: Bharalumukh; Outfall of the Bharalu River into the Brahmaputra River

1.1.8 Industrial Aspects

Assam has many natural and precious mineral resources. Its industrial history began during the pre-independence period. India's first oil well was drilled in Assam and the first oil refinery was built here as well. The introduction of tea cultivation during this period started a global export of finished tea, bringing an economic boom to Assam. The continuous process of economic and industrial development of the State was almost stopped after independence. At present, Assam is amongst the industrially underdeveloped States in the Country. The industrial scenario of the State is now confined within the growth of the employment-oriented SSI Sector, which comprises manufacturing and processing industries. Assam is still making efforts for gearing up industrial activities by harnessing the untapped resources available in the State through various growth-inducing factors and by removing infrastructure inadequacies in the power, communication and transport sectors.

Major industries in Assam currently include:

- Petroleum and refineries
- Tea industry
- Forest and wood industry
- Handloom and handicraft industries

1.1.9 Educational Activities

Guwahati is the centre of education in the north-eastern region, and education in Guwahati has always attracted people from different parts of the country. Guwahati has both privately run schools and Government-aided public schools. The schools are affiliated either with the Assam Council of Secondary and Higher Secondary Education, the Indian Council of Secondary Education and Certificate (ICSE/ISC), or the Central Board of Education (CBSE).

Prestigious institutes in Guwahati include the following:

- Indian Institute of Technology (IIT) Guwahati, an autonomous institute dedicated to the field of technical studies/science, as a renowned technical institute in India.
- Guwahati Medical College, the oldest medical institution under Guwahati University, recognised by the All India Medical Council.
- Assam Engineering College for Bachelor and Master Degrees of different engineering branches with a prestigious reputation.
- Assam Ayurvedic College for Ayurvedic Health Education, Assam Engineering Institute, Institute of Co-operative Management, Assam Institute of Management, Guwahati Institute of Management, and Indian Institute for Hotel Management are also renowned institutes.

1.1.10 Cultural Activities

Guwahati is known for its rich traditional and cultural heritage. It is the main centre of cultural activities in Assam. Tourists coming to Guwahati are drawn to the cultural heritage the city possesses. The colourful culture of Guwahati can be seen in its music and dance, art and craft forms, festivals, and food.

1.1.11 Religious Activities

Nestled in the Brahmaputra valley, Tantrik Shaktism, Shivaism, and later Vaishnavism flourished in this State. The Mohmmedan invasions brought Islam into the state. The famous Gurudwara at Dhubri established by the ninth Sikh Guru Teg Bahadur is held in high veneration by the Sikhs throughout the country.

With the advent of new faith and religion, many temples and monuments were built all over Assam. Most of these architectural grandeurs belong to the medieval period and represent the architectural style of the Koch, Kachari and Ahom royal courts. These temples and monuments, spread almost all over Assam, bear silent witness to a glorious past.

1.1.12 Socio-Economic Status

The Bharalu sub-basin consists of the Kamrup metro district of Assam in the plain portion and Ribhoi district of Meghalaya in the hilly catchment. The plain catchment of the sub-basin, which is covered by greater Guwahati City, is densely populated compared to the southern hilly portion of the catchment. The population statistics of the Bharalu sub-basin are shown in Table 1-3. Socio-economic indicators for the Kamrup district are presented in Table 1-4.

Table 1-3: Population Statistics of Bharalu Sub-basin

District	Type	Male	Female	Total
Kamrup Metropolitan	Urban	5,36,523	5,00,488	10,37,011
	Rural	1,11,062	1,05,865	2,16,927
	Total	**6,47,585**	**6,06,353**	**12,53,938**
Ribhoi	Rural	1,18,705	1,14,882	2,33,587
	Urban	13,826	11,427	25,253
	Total	**1,32,531**	**1,26,309**	**2,58,840**

Table 1-4: Block Level Information on Socio-economic Indicators of Kamrup District

S.No.	Indicators	Name of Development Block				Remarks
		Dimoria	Chandrapur	Rani	Bezera	
1	Percentage of villages having paved approach roads	60	65	63	N.A.	1. Data furnished for Rani Dev. Block as a whole. No segregated data is available for 26 villages under Kamrup Metro District. 2. No segregated data is available for 7 villages under North-Guwahati Rev. Circle of Bezera Dev. Block.
2	Percentage of land irrigated	2	47	11	N.A.	
3	Percentage of villages having safe source of drinking water	96	65	57	N.A.	
4	Percentage of villages having electricity	94	52	65	N.A.	
5	Percentage of literates	58	44	67	N.A.	
6	Percentage of villages having primary education facility	97	76	92	N.A.	
7	Percentage of villages having any healthcare facility	34	30	29	N.A.	
8	Percentage of main workers to total workers	78	77	74	N.A.	

1.1.13 Town Management

Multiple civic agencies operate in Guwahati with overlapping jurisdiction and similar service responsibilities as indicated in Table 1-5 below.

Table 1-5: Institutional Framework

Infrastructure	Planning and Design	Construction	Operation and Maintenance
Water Supply	PHE/AUWSSB/GMC	PHE/AUWSSB/GMC	PHE/AUWSSB/GMC
Sewerage	PHE/AUWSSB/GMC/ FCD	PHE/AUWSSB/GMC/ FCD	PHE/AUWSSB/GMC/ FCD
Drainage	PHE/AUWSSB/GMC/ FCD	PHE/AUWSSB/GMC/ FCD	PHE/AUWSSB/GMC/ FCD
Storm Water Drainage	GMDA/GMC/T&CP	GMDA/GMC	GMDA/GMC
Solid Waste Disposal	GMC	GMC	GMC
Municipal Roads (including flyover)	PWD/GMDA/GMC	PWD/GMDA/GMC	PWD/GMDA/GMC
Street Lighting	PWD/GMDA/T&CP	PWD/GMDA/GMC	PWD/GMDA/GMC
Town Planning	GMDA/T&CP	GMDA	GMDA

PHE - Public Health Engineering; PWD - Public Works Department; FCD - Flood Control Department; T&CP: Town and Country Planning

Overlapping jurisdiction by the civic agencies often results in duplicitous efforts as it creates confusion for the general consumer, who has to deal with a number of agencies often for very same service delivery. Wherever possible, the functioning of the agencies must be streamlined to bring it under one agency, which will not only help in improving service delivery but also bring about accountability.

1.1.14 Cost of Land in and around Guwahati

The land use pattern for Guwahati as per the Town and Country Planning Department of the State in 2001 is provided in Table 1-6:

Table 1-6: Land Use Pattern

Land Use	Percentage
Residential	25.1
Commercial	2.5
Industrial	5.2
Special Category Government	6.2
Recreational and Parks	5.4
Public and Semi-Public	9.4
Transport	12.9
Green Belt	15.4
Water Bodies, hills	17.7
Total	**100.0**

1.1.15 City Development Plan

The City Development Plan (CDP; July 2006) focuses on the GMDA jurisdiction, comprising the GMC area, North Guwahati Town Committee area, Amingaon and some revenue villages. The area is known as the Guwahati Metropolitan Area (GMA) and has a size of 264 km^2.

Guwahati is recognised as the most critical city in North-East India. The city has a well-developed connectivity with the rest of the country and acts as the gateway to the region. Hence, the development of the city is not only critical to the state of Assam but also to the entire north-eastern region. The population of the city will likely continue to grow rapidly.

Developing a vision for the city is central to the preparation of a CDP. A vision is a statement concerning what the city wishes to achieve within a given timeframe, and is often expressed in terms of clear expectations. It defines the potential of the city besides reflecting its unique attributes in terms of comparative and competitive advantages, values and preferences of the city's residents, relationship of the city to the state, national and global economies, and of course, the history and physical characteristics of the city. Preparation of a vision is a critical element in the JNNURM process. The comprehensive Master Plan for the GMA 2025 includes the following vision for the region:

> *"Guwahati is visualised to be one of the most admired state capitals of India with a unique image. To this end, Guwahati shall Promote and focus on balanced and sustainable economic and infrastructure growth that will enable the city to fulfill its role as the Gateway to the North-East India and South-East Asia"*

The primary goal of the CDP is the creation of quality infrastructure. This includes:

- Smooth drainage system free from clogging
- Municipal water supply and sewerage connection to 100% of all households
- Thorough solid waste management system for all types of wastes
- Integrated modern transportation
- System including traffic management and Mass Rapid Transit System.

1.2 Population within the Project Area

The State of Assam has consistently witnessed a steady growth in population. Assam accounts for more than 70% of the population of the North-East (Census 2001). The Kamrup District is one of the most densely populated regions in Assam.

Guwahati is a fast growing metropolis and the most important city of the region. The city with a population of 8.9 Lakhs (Census 2001) is by far the largest settlement, while Shillong and Imphal, with population sizes of only 2.7 and 2.5 lakhs, respectively, are the second and third largest cities in the north-eastern region. With a substantial increase in population in the last few decades, the city needs a well-structured development plan in its infrastructure to sustain its rapid growth.

The population of the GMA has grown almost 6.5 times between 1971 and 2001. The municipal limit of the city during the period increased from 44 km^2 in 1971 to 217 km^2 in 1991 (Tables 1-7 and 1-8; Figure 1-6).

Table 1-7: Population Growth in Guwahati vis-à-vis India, Assam and Kamrup

Name	1971	1991		2001	
	Population (in million)	Population (in million)	Average Decadal Growth Rate	Population (in million)	Average Decadal Growth Rate
India	548	846	24%	1,027	21%
Assam	14.6	22.4	24%	26.6	19%
Karup	1.2	2.0	29%	2.5	26%
GMA	0.29	0.65	48%	0.89	38%
GMCA	0.12	0.58	117%	0.81	39%

Table 1-8: Population Growth in Guwahati (1951 and 2001)

Year	Population in GMCA	Decadal Growth (%)	GMA excluding GMCA	Decadal Growth (%)	GMA	Decadal Growth (%)
1951	43,615		53,774		97,389	
1961	1,66,273	2.81	33,209	-0.38	1,99,482	1.05
1971	2,51,642	0.51	40,387	0.22	2,92,029	0.46
1991	5,84,342	1.32	61,827	0.53	6,46,169	1.21
2001	8,09,895	0.39	80,878	0.31	8,90,773	0.38
2011					9,68,549	0.09

1.2.1 Ward Wise Population

There are currently 74 wards identified on the ward map for the City of Guwahati (Figure 1-7), although the 2011 census data show population in only 64 wards. Wards 73 and 74 have been identified as future towns in North Guwahati. The Bharalu River flows through the central part of Guwahati where most of the population lives. The catchment area of the Bharalu includes 36 wards of the city of which 16 contribute to the Bahini River, while 20 contribute to the Refinery Ditch and the Bharalu.

The ward wise population data for all wards in the city are presented in Table 1-9. The wards within the Bharalu catchment area are highlighted.

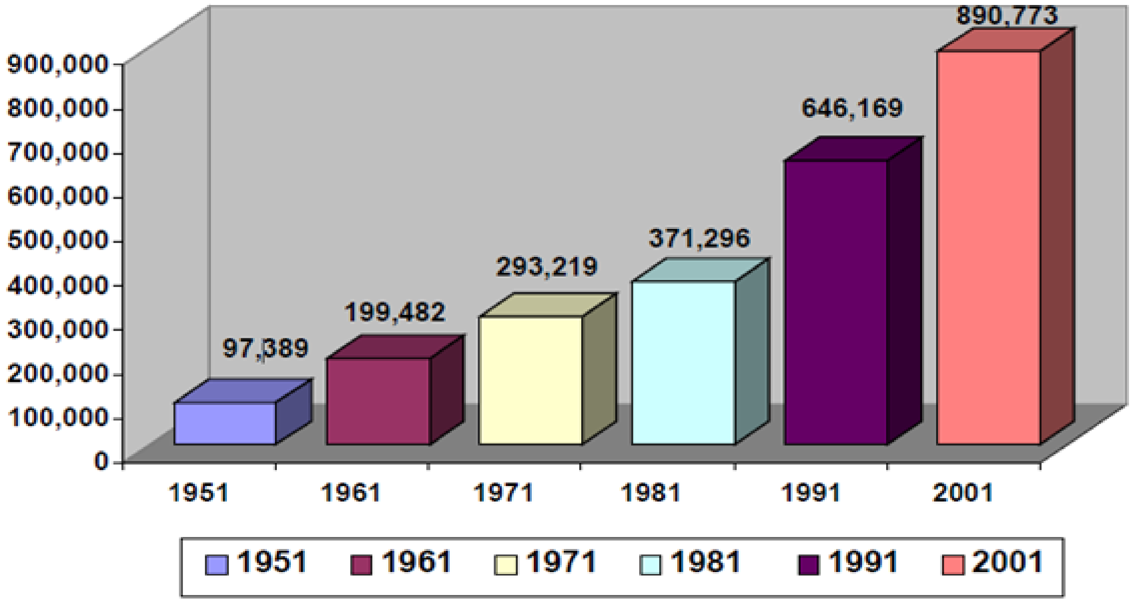


Figure 1-6: Population Growth of GMA (1951 to 2001)

Table 1-9: Ward wise population of Guwahati

Area	Ward	No. of Households	Total Population	Male	Female
North Guwahati	69	273	1,233	603	630
	70	576	2,665	1,303	1,362
	71	708	3,123	1,549	1,574
	72	737	3,307	1,633	1,674
GMC	01	3,598	16,692	8,547	8,145
	02	3,671	16,613	8,780	7,833
	03	2,609	11,106	5,666	5,440
	04	2,617	10,731	5,424	5,307
	05	3,076	12,526	6,357	6,169
	06	2,372	10,171	5,086	5,085
	07	4,647	20,366	10,368	9,998
	08	1,715	7,593	3,856	3,737
	09	1,580	6,746	3,164	3,582
	10	2,336	10,216	5,204	5,012
	11	4,251	18,514	9,508	9,006
	12	9,055	39,995	20,657	19,338
	13	6,663	29,041	14,985	14,056
	14	3,991	17,629	9,252	8,377
	15	4,704	19,228	9,843	9,385
	16	9,238	39,056	20,100	18,956
	17	5,359	21,292	11,083	10,209
	18	1,614	7,431	3,916	3,515
	19	3,049	14,957	7,825	7,132
	20	2,696	11,887	6,405	5,482
	21	1,807	7,718	4,171	3,547
	22	4,997	21,169	10,629	10,540
	23	2,601	10,837	5,604	5,233
	24	4,374	17,830	9,071	8,759
	25	5,170	20,707	10,771	9,936
	26	2,552	10,431	5,329	5,102
	27	2,719	12,008	6,172	5,836
	28	2,024	9,828	5,270	4,558
	29	1,196	6,988	3,754	3,234
	30	1,219	5,688	2,929	2,759

Area	Ward	No. of Households	Total Population	Male	Female
	31	1,753	7,387	4,100	3,287
	32	2,381	10,332	5,417	4,915
	33	1,919	8,368	4,455	3,913
	34	2,591	11,088	5,497	5,591
	35	2,738	11,012	5,527	5,485
	36	3,321	13,966	7,336	6,630
	37	3,924	15,854	8,224	7,630
	38	2,200	8,589	4,429	4,160
	39	2,874	11,574	5,690	5,884
	40	2,022	7,782	4,023	3,759
	41	5,365	21,514	11,008	10,506
	42	4,192	16,649	8,519	8,130
	43	2,214	9,295	4,757	4,538
	44	3,883	15,073	7,884	7,189
	45	3,066	12,537	6,597	5,940
	46	6,754	28,309	14,923	13,386
	47	2,510	9,772	5,147	4,625
	48	3,194	12,686	6,565	6,121
	49	7,113	30,124	15,540	14,584
	50	3,691	14,084	7,446	6,638
	51	7,550	30,057	15,417	14,640
	52	2,112	9,000	4,697	4,303
	53	5,982	14,890	7,812	7,078
	54	3,507	24,226	12,572	11,654
	55	6,337	13,670	7,070	6,600
	56	3,336	26,625	13,797	12,828
	57	8,165	13,359	6,859	6,500
	58	6,846	31,876	16,838	15,038
	59	6,761	25,709	13,335	12,374
	60	232,012	26,951	14,155	12,796
	Total		9,67,680	5,00,450	4,67,230

Note:
Highlighted wards are those contributing to the Bharalu catchment area

1.2.2 Slum Wise Population of the last 5 Decades

There are number of slums in Guwahati. It is understood that there are 26 slum pockets in the GMC area covering 1.6 lakh people. It is proposed that a comprehensive Slum Improvement Programme be undertaken. The programme must have the following components:

- Provision of shelter and other physical infrastructure at affordable prices so as to improve the sanitation and living conditions in the slums and other squatter settlements.
- Provision of adequate health care including family welfare, immunization, child health care, etc.
- Development of facilities for community development and recreation
- Program for basic education and training; and
- Ensuring maintenance and up-gradation of the existing housing stock of the poorer sections.

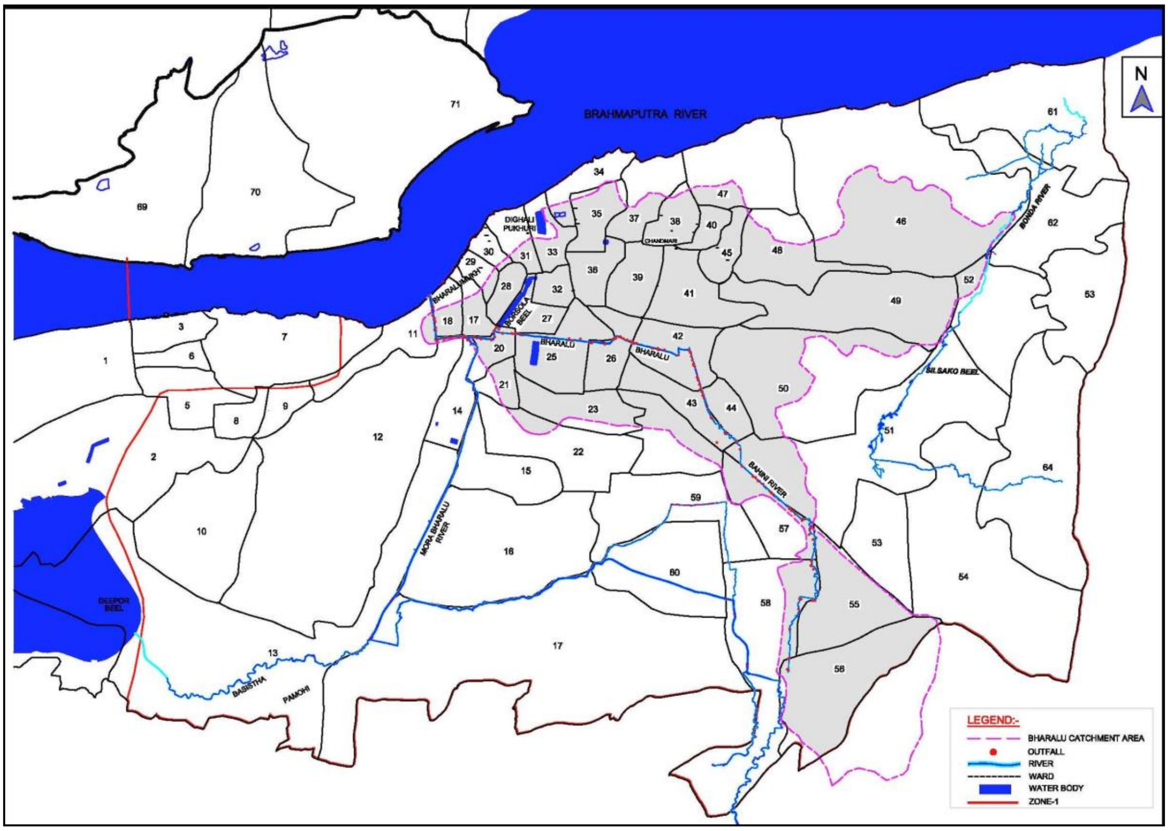


Figure 1-7: Wards of Guwahati

1.2.3 Population Projections as per the City Master Plan

Past population growth rates are presented in Table 1-8 above. Projections of future population growth for the GMA area were made for years 2014, 2029 and 2044 using the following methods:

- Geometrical Increase Method (Tables (1-10 and 1-11)
- Arithmetical Increase Method (Table 1-12)
- Incremental Increase Method (Tables 1-13 and 1-14)
- Graphical Method (Table 1-15).

Average values of all methods (Table 1-16) were considered for design purposes, as also suggested by CPHEEO. The geometrical increase method results selected for the design. It was observed that linear growth rate model results had higher fluctuations. Results based on the geometrical increase method are considered more accurate as populations tend to grow in geometric progression.

Table 1-10 Geometric Growth Rate Model: Geometric Growth Rates of Population in Guwahati

Year	GMA Population	Increment by Arithmetic Progression Method	Rate of Growth	Geometric Mean
1951	97,389			0.34
1961	1,99,482	1,02,093	105%	
1971	2,93,219	93,737	46%	
1981	3,50,979	58,950	121%	
1991	6,46,169	2,10,889	38%	
2001	8,90,773	2,44,604	9%	
2011	9,68,549	77,776	105%	

Notes:
Total population from 1951 to 2011 = 34,45,370. Average per decade = 4,92,196.
Projected Population = Population in 2011+'n' average increase per decade (Where, 'n' = no. of decade since 2011)

Table 1-11: Population Projection (up to year 2050) by the Geometrical Increase Method

Projection Year	Number of Decade 'n' (since 2011)	Geometric means	Total Projected Population
2020	0.9	0.34	12,89,022
2025	1.4	0.34	15,10,867
2030	1.9	0.34	17,70,892
2035	2.4	0.34	20,75,668
2040	2.9	0.34	24,32,898
2045	3.4	0.34	28,51,608
2050	3.9	0.34	33,42,379

Table 1-12: Population Projection (up to year 2050) - Arithmetic Progression

Projected Year	No of Decade, 'n' (since 2011)	Projected Population
2020	0.9	10,95,065
2025	1.4	11,63,649
2030	1.9	12,31,018
2035	2.4	12,97,170
2040	2.9	13,62,107
2045	3.4	13,62,107
2050	3.9	14,88,333

Table 1-13: Incremental Increase Method

Year	GMA Population	Increase X	Incremental Increase Y
1951	97,389		
1961	1,99,482	1,02,093	
1971	2,92,029	93,737	-9,564
1981	6,46,169	58,950	-33,597
1991	8,90,773	2,10,889	2,36,240
2001	9,68,549	2,44,604	-50,586
2011	97,389	77,776	-1,66,828
	Total from 1951 to 2011 =	**34,45,370**	**1,45,193**
	Average per decade =	**4,92,196**	**8,71,160**

Note: Projected population = Pn = Pr + nX + [n (n+1) Y/2]; Where, n = no. of decade since 2011; Pr = Population in 2011

Table 1-14: Population Projection (up to 2050) – Incremental Increase

Projected Year	No of Decade, 'n' (since 2011)	Projected Population
2020	0.9	10,99,223
2025	1.4	11,71,820
2030	1.9	12,44,416
2035	2.4	13,17,013
2040	2.9	13,89,610
2045	3.4	14,62,206
2050	3.9	15,34,803

Table 1-15: Population Projection (up to year 2050) - Graphical Method

Projected Year	Projected Population
2020	11,75,000
2025	13,75,000
2030	15,75,000
2035	24,90,000
2040	29,00,000
2045	29,58,735
2050	51,00,000

Table 1-16: Summary of Population Projection (years 2020 to 2050)

Year	Arithmetic Progression	Incremental Increase	Geometrical Progression	Graphical Projection
2020	10,99,223	10,95,065	12,89,022	11,75,000
2025	11,71,820	11,63,649	15,10,867	13,75,000
2030	12,44,416	12,31,018	17,70,892	15,75,000
2035	13,17,013	12,97,170	20,75,668	24,90,000
2040	13,89,610	13,62,107	24,32,898	29,00,000
2045	14,62,206	13,62,107	28,51,608	29,58,735
2050	15,34,803	14,88,333	33,42,379	51,00,000

Note:_ The geometrical increase method was selected for design.

Table 1-17: Basic Population Data for Wards within the Bharalu Catchment Area

Ward No	Population in 2001	Area in km^2	Rate of Growth per Year (%)
11	12,331	1.463	1.295
14	21,125	1.036	1.295
17	10,924	14.684	4.995
18	7,394	0.575	0.257
20	11,858	0.548	0.257
21	6,572	0.545	0.257
22	15,740	2.834	4.995
23	11,029	1.467	0.257
24	15,963	1.886	4.995
25	18,425	1.826	0.257
26	10,705	1.082	0.257
27	10,725	0.749	0.257
28	9,832	0.514	0.257
29	8,465	0.391	0.257
32	10,245	0.478	0.257
33	10,531	0.877	0.257
35	11,968	1.019	1.295
36	14,986	0.91	1.295
37	14,546	1.48	1.295
38	8,123	0.869	1.295
39	13,257	1.134	1.295
40	3,420	0.517	1.295
41	20,360	1.891	1.295
42	12,181	1.567	1.295
43	5,400	1.166	1.295
44	15,117	0.631	1.295
45	15,642	0.706	1.295
46	23,455	11.17	2.509
47	7,799	3.04	1.295
48	11,622	3.218	1.295
49	26,314	4.463	1.295
50	10,933	6.118	1.295
51	25,989	7.922	8.398
52	6,490	3,212	8.398
52	8,608	2.15	8.398
55	11,785	2.486	4.995
56	19,683	3.855	4.995
57	16,143	1.685	4.995
58	22,741	5.489	4.995

Table 1-18: Projected Population within the Bharalu Catchment Area

Ward No.	Population by Year		
	2020	2035	2050
11	13,480	17,760	8,133
14	23,093	30,426	8,447
17	18,679	29,476	62,704
18	6,803	8,040	22,662
20	10,911	12,894	13,142
21	6,047	7,146	10,756
22	26,914	42,471	7,648
23	10,148	11,993	6,225
24	27,295	43,073	8,084
25	16,953	20,035	11,308
26	9,850	11,640	9,158
27	9,868	11,662	12,135
28	9,047	10,691	16,678
32	9,427	11,140	17,529
33	9,690	11,451	11,786
35	13,083	17,238	25,215
36	16,382	21,584	14,077
37	15,901	20,951	22,828
38	8,880	11,700	18,987
39	14,492	19,094	59,011
40	3,739	4,926	14,800
41	22,257	29,325	19,213
42	13,316	17,544	45,623
43	5,903	7,778	21,330
44	16,525	21,773	1,81,978
45	17,099	22,529	54,490
46	30,386	43,464	90,151
47	8,525	11,233	1,46,675
48	12,705	16,739	48,074
49	28,765	37,900	93,634
50	11,951	15,747	46,980
51	59,180	1,00,196	1,12,100
52	14,779	25,021	90,412
53	19,601	33,187	94,780
54	34,947	59,168	7,716
55	20,151	31,799	16,030
56	33,656	53,111	12,176
57	27,603	43,559	20,016
58	38,885	61,362	1,07,575
Total	**6,96,916**	**10,06,826**	**15,90,266**

1.3 Status of Water Supply

1.3.1 Actual Water Supply from Different Sources

Broadly, the existing water supply system in Guwahati City consists of several schemes covering different parts of the city. Treatment Plants at Panbazar, both operated by GMC and PHE, along with AUWS&SB operated Zoo Road treatment plant and the GMC-operated treatment plant at Satpukhuri supply water to the central region. 35% of the city is covered by piped water supply (Master Plan 2025). The potable water generation capacity in Guwahati is 98 million litres per day (MLD). At present, about 73.5 MLD of potable water is produced in Guwahati by the GMC; out of this, 72 MLD is drawn from the Brahmaputra to eight water treatment plants. There were 14 GMC deep tube wells, out of which just 7 are functioning. These tube wells were supposed to generate 3 MLD of water; instead, the total water production from these tube wells is about 1.5 MLD.

The produced water is insufficient for the current demand of 132 MLD. Therefore, aside from water produced by the GMC, approximately 65% of the residents extract potable water from the ground with hand pumps, tube wells and wells in the GMA (Carrying Capacity Based Urban

Development Regulations, Guwahati, 2011). The projected demand for the city by year 2025 is estimated to be 425 MLD.

As only one third of the population of the whole city is served by piped water supply systems (that too with frequent complaints of inadequacy of water supply), the majority of the population is dependent on their individual water sources such as shallow tube wells or dug wells. Most of these sources are heavily contaminated. A few inhabitants can afford tapping water from deeper subsurface layers which are generally free from bacteriological contamination. However, water from those layers may contain elevated iron concentrations and other impurities. Even many of those houses having piped water supply connections have tube wells or dug wells as stand-by sources due to the unreliability of the piped water supply system.

The major industries (including the IOC's oil refinery, The Railways, Airport and Defence establishment) in Guwahati collect, treat, and supply their own water; water is obtained mainly from the Brahmaputra River. The Master Plan proposes that in the future all industries would have to manage water collection, treatment, and supply on their own without help with the Municipal Corporation.

1.3.2 Proposal for Augmentation of Water Supply System

The present JNNURM policy requires a water supply system to provide water supply reliability around the clock, with a planning target of 2040. Considering the ultimate water supply demand and numbers of floating barge intake systems required to provide this capacity, three water treatment facilities have been considered.

Only one water supply project worth Rs. 280 crores (90% funding from the Centre) has been sanctioned for financial support under the JNNURM water supply sector. Another project is currently planned for the West Guwahati region. Water supply improvements for South Central Guwahati and North Guwahati are to be covered by water supply schemes by JICA finding.

1.4 Status of Existing Waste Water Disposal Works

Presently there is no organized sewerage system in Guwahati City. Untreated or semi-treated sewage are discharged to the storm water drains due to lack of a proper sewerage and sanitation system in the city. There is one STP in Guwahati located at the northern end of Borsola Beel which discharges to the Bharalu. The SPT serves the area to the north-east of AK Azard Road. The plant was developed by the GMAC and is reported to have a capacity of 1.5 MLD. Detailed information about the specifics of the plant was not obtained prior to the preparation of this report, but it is assumed that it was installed as part of the development in the area, and is not adequate to handle any additional wastewater discharge and/or is operation in a fashion to remove all of the wastewater contribution to the Borsola Beel.

In the older part of Guwahati un-treated sewage and sullage is discharged into storm water drains causing unhygienic conditions for the city dwellers and also a grave risk to health of sanitation workers. Newer houses in relatively better planned and organized colonies have septic tanks but most of them lack soak pits. Partially treated effluent is usually discharged into open road drains which flow into the natural drainage channels that pass through the city. In view of existing status of environment of Guwahati without any engineered sewage system and treatment facilities, it is extremely important to plan and implement a scientific system of underground sewerage and sewage treatment to save the population from a calamity in the near future. Further, in accordance with the norms of the Government of India, a city like Guwahati with a population over 7.5 lakhs, falls under the obligation of having adequate facilities of sewerage and sewage treatment in the city.

1.4.1 Existing Works

The primary development of Guwahati is carried out by two main agencies, namely the GMC and the GMDA. These two agencies operate under the Guwahati Development Department (GDD), Government of Assam. It is important to understand the domain and responsibilities of such government organizations to better appreciate the issue of ownership and operation of infrastructure facilities.

At present, the institutional arrangements to deal with sewerage issues are inefficient and rest with a number of agencies. While the GMC is responsible for water supply only for a part of the city, its primarily responsibility is managing the solid waste, along with maintenance of storm drains and cleaning of septic tanks. GMDA is responsible for planning and carrying out some of the major developmental works to be undertaken in the city in future. As stated above, the area covered under GMDA includes a total area of 264 km^2, including the 216 km^2 large GMC area. The Kamrup District water supply data (per Census 2011) are presented in Table 2-1.

Table 1-19: Kamrup Water Supply Data, Census 2011

Main source of drinking water	Availability of Drinking Water Source	Total number of households	Electricity			
			Available		Not available	
			Latrine available	Latrine not available	Latrine available	Latrine not available
All Sources	Total number of households	41,707	6,994	2,112	10,338	22,263
All Sources	Within premises	24,138	5,386	1,231	5,804	11,717
All Sources	Near premises	9,123	963	486	2,627	5,047
All Sources	Away	8,446	645	395	1,907	5,499
Tap water from treated source	Total number of households	1,263	648	95	241	279
Tap water from treated source	Within premises	506	359	29	62	56
Tap water from treated source	Near premises	415	192	20	100	103
Tap water from treated source	Away	342	97	46	79	120
Tap water from un-treated source	Total number of households	534	132	25	229	148
Tap water from un-treated source	Within premises	239	66	10	105	58
Tap water from un-treated source	Near premises	206	48	5	93	60
Tap water from un-treated source	Away	89	18	10	31	30
Covered well	Total number of households	497	144	24	135	194
Covered well	Within premises	245	107	13	66	59
Covered well	Near premises	171	26	9	37	99
Covered well	Away	81	11	2	32	36
Un-Covered well	Total number of households	19,046	1,494	570	4,850	12,132
Un-Covered well	Within premises	13,978	1,262	385	3,529	8,802
Un-Covered well	Near premises	3,265	137	108	903	2,117
Un-Covered well	Away	1,803	95	77	418	1,213
Hand pump	Total number of households	15,797	4201	1248	3,541	6,807
Hand pump	Within premises	8,856	3,520	778	2,017	2,541
Hand pump	Near premises	3,344	455	299	793	1,797
Hand pump	Away	3,597	226	171	731	2,469

Main source of drinking water	Availability of Drinking Water Source	Total number of households	Electricity			
			Available		Not available	
			Latrine available	Latrine not available	Latrine available	Latrine not available
Tube well/Borehole	Total number of households	425	85	21	47	272
Tube well/Borehole	Within premises	314	72	16	25	201
Tube well/Borehole	Near premises	47	13	2	9	23
Tube well/Borehole	Away	64	-	3	13	48
All Others	Total number of households	4,145	290	129	1,295	2,431
All Others	Within premises	-	-	-	-	-
All Others	Near premises	1,675	92	43	692	848
All Others	Away	2,470	198	86	603	1,583

Source: 2011 Census Sheet DDWH3811TT-1800 XLS

The following observations apply to the about existing sewerage and sanitation facilities in Guwahati:

- Service delivery for sanitation in Guwahati does not match the requirements of the city and also the stipulated service level benchmarks (SLBs) by the Ministry of Urban Development, Government of India. Further, the presence of multiple agencies with similar duties might have compounded the problem of service delivery.
-
- Guwahati Metropolitan Water Supply and Sewerage Board or the “Jal Board” (also under GDD) has been established with the responsibility of creation of the assets and operation and maintenance of the water supply and sewerage components for the city. Septage management, once implemented, is expected to be handled in the future by the GMC. Decentralised waste water treatment systems, if implemented, may also be handled by either the Corporation or the Jal Board.
-
- In the older parts of Guwahati untreated sewage and sullage discharged directly into storm water drains causes a severe health risks for the citizens. Newer houses in more planned and organised colonies have septic tanks but most lack soak pits. The partially treated effluent is usually discharged into open road drains which flow into the natural drainage channels that pass through the city. This results in unhygienic conditions of the surrounding areas as well as pollution of ground and surface water sources. This also poses even greater health risks as ground water is also extracted for using as potable water in some areas pending the commissioning of the ongoing water supply systems. The two main causes of concern from the sanitation and health perspective are the untreated or partially treated effluent stream from septic tanks (if not being soaked into a soak pit) and the septage being emptied from the septic tanks.

1.4.2 Works under Execution

The works described in Section 2.2.3 has been approved by the State Level Appraisal Committees. However, suitable funding options are still being explored by the concerned agencies to implement the proposed work.

1.4.3 Works Sanctioned

The DPR for the Sewerage Network of Guwahati prepared by GMDA (2012) is based on the available survey data projected on topographical contour maps. The proposed sewerage system is divided into three distinct sewerage zones characterized by an independent collection, conveyance, treatment, and disposal system (Figure 2-1).

The complete new network system will provide house or service connections to the public municipal sewer. The trunk main routes in each zone have been reported to be marked along the side/ centre (as applicable) of existing roads along natural slopes with due consideration to crossings of existing drainage courses, railway lines, storm water drains, etc. The zoning of the sewerage system and natural valleys will result in minimal depth of cutting for laying of sewers (which has been restricted to 8 m). Intermediate sewage pumping stations and lift sewage pumping stations have been considered, as necessary.

The treatment processes have been selected based on technical and economic feasibility and suggestions from the funding agency (JICA) and the approving authority.

Table 1-20: Components of the Sewerage Network of Guwahati

SN	Main Components	Sub Components
1	Collection and conveyance system	Trunk, main, branch/lateral sewer line, manhole chambers, vent shaft, etc.
2	Sewage pumping stations	Terminal sewage pumping stations and lift stations, wet well, drywell, pumps, motors, rising main and accessories, electrical transformer and substation
3	Sewage treatment plants	Screen chambers, distribution chambers, grit chambers, chlorination tanks, gas holders, facultative aerated lagoons and sludge drying bed, electrical transformer and substation
4	Treated sewage disposal	Sump and pump house, pumps and fixture, gravity/forced main
5	Site development and building infrastructure	Site grading, roads boundary wall, administration building and essential staff quarters and area lighting
6	Laboratory	Lab building and testing equipment as prescribed in PHE manuals.

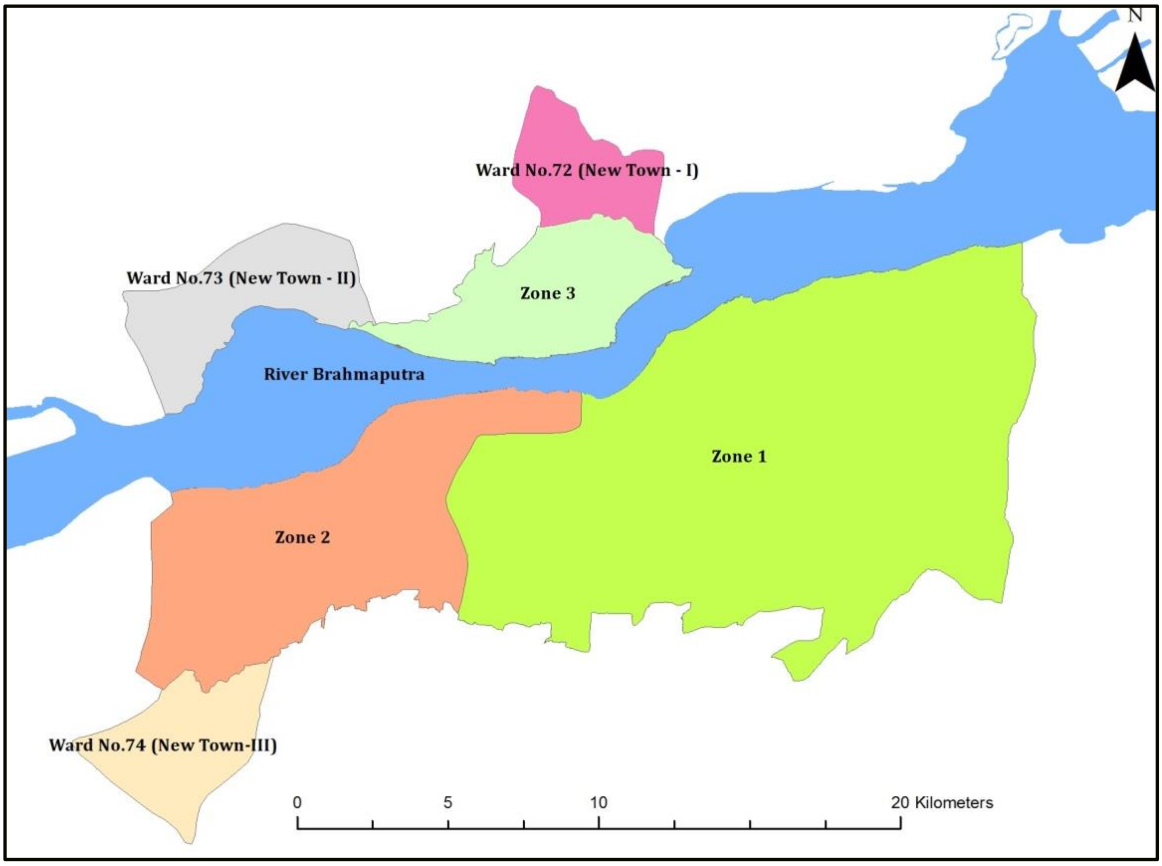


Figure 1-8: Proposed Sewerage Zone for Guwahati

Relevant elements of this proposal are as follows:

- The treated sewage discharge will be disposed to the Brahmaputra from the respective Sewerage Treatment Plants (STPs) through pumping mains (for Zone 1) and through gravity mains (for Zones 2 and 3). Alternatively, the treated waste water will be used for watering agricultural fields or for horticulture. Solids generated through the waste water treatment process are proposed to be transported to a landfill or used as fertilizer on agricultural fields after being sufficiently dried at the STPs.

-
- The sewerage system will significantly improve the overall environmental condition and reduce the risk of contagious diseases.
-
- Of particular note for this report is the recognition of low-lying pockets (or very low density populations in the city), which have not been covered under the proposed sewer network. It may be proposed to provide on-site treatment options or septage collection facilities for these areas. This in turn suggests due consideration of a septage management and decentralized waste water treatment options as an integral part of the solution for Guwahati, which may be restricted to such low-lying areas while all other areas are being covered by centralized sewerage system for their hydraulic amenability.

1.4.4 Total Waste Water Generation

Quantification of the industrial waste reaching the Bharalu has not yet been taken up, as per the concerned officials, as baseline information is presently not available.

Based on an inquiry during the reconnaissance survey, the average quantity of water used in the toilets is considered as 30 litres per capita per day (lpcd) at present. This is in line with Green Building Brain (Canada) and Government of New South Wales which also suggests that blackwater (sewage) percentage as 25-30% of total waste water generated.

At present, the city of Guwahati does not have an integrated sewerage system except for select residential areas such as the Railway Colonies, the Oil Refinery colonies and residential areas under defence establishments which have their own sewerage and treatment facilities. The only collection and treatment process followed is use of septic tanks. Therefore, much of the waste water generated in the city is being disposed of into rivers without treatment (Tables 2-2 and 2-3).

Table 1-21: Waste Water Generation in Guwahati

Total Households in the City	Total Wastewater Generated in the City (m^3)	Total Households Connected to Septic Tanks	Total Wastewater Collected in the Septic Tanks (m^3)
2,30,769[1]	1,03,932[2]	1,38,427[3]	17,442[4]

Notes: 1 As per Census data 2011
2 Assumption being 80% of 135 lpcd water supplied to 9,62,334 people
3 As per secondary data obtained from GMC
4 Assuming average household size of 4.2 (as per Census 2011) and 30 lpcd of wastewater

Table 1-22: Calculation of per Capita Sewage Generation

Description	Demand (lpcd)
Net per capita water demand for South Guwahati (proposed in Water Supply Project)	135
Add 10% for ICI demand1 @ 10%	13.5
Add ground water infiltration @ 5%	6.75
Sub Total	**155**
Considering 80% for sewage generation	124
USE	**125**

Notes:
1. As the Guwahati is a fast growing city and Industrial, Commercial and Institutional (ICI) activities are taking place at a rapid pace in some areas of the city, so a 10% provision has been used for ICI demand over the per capita demand of water supply for the whole population. This will eventually cover the need of ICI demand for the city as a whole taking care of unevenness of ICI demand distribution. This also accounts for the floating population which will be working in the ICI facilities.
2. Per capita sewage generation is considered as 125 lpcd for GMDA area.
3. The catchment area of the Bharalu includes 36 wards of the city and a projected 2035 population of approximately 870,000. The equivalent waste water generation from the projected population is shown in Table 2-5 below

The GMDA has prepared a DPR for the development of a sanitary sewage collection and treatment system for an area identified as Zone 1 of South Guwahati for 48 wards and a projected 2035 population of approximately 1.5 million people.

- The sewerage system will be designed as follows: STP for the intermediate design period (i.e., for 2035) and a sewer network for the ultimate design year of 2050.
- The sewerage system for the Bharalu catchment area will be taken up after the water supply system is implemented in these wards.

The waste water collection system has been considered a "Separate System". For the waste water collection system design, the parameters and guidelines of CPHEEO "Manual on Sewerage and Sewage Treatment" second edition were adopted. The sewerage system will be designed for the peak flow for year 2050. The projected population considered for the water supply system was adopted for the sewerage system.

Table 1-23: for Total Waste Water Generation for Bharalu Catchment Area

River	Population			Sewage Contribution (lpcd)	Sewage Generation in MLD		
	2020	2035	2050		2020	2035	2050
Bahini	3,97,166	6,08,842	11,80,661	125	44	58	137
Bharalu	2,75,644	3,97,984	4,09,605	125	25	33	38
Total	**6,96,916**	**10,06,826**	**15,90,266**		**69**	**91**	**175**

1.5 Status of Pollution of River

1.5.1 Number and Details of Drainage Channels

As stated in Section 1.3, the Bharalu is the master drainage channel of the GMC area which is highly commercialized and industrialized and drains into the Brahmaputra at Bharalumukh (Figure 2-2). From Basistha Chariali, the Bharalu flows up to Bharalumukh for about 16 km with an average width of 5 to 9 m. The water depth varies with flow and due to other reasons, but is on average 3 m. The peak discharge of the Bharalu is about 35 m^3/s.

The Bharalu is the primary drainage course for most of the eastern and southern part of Guwahati. Bharalu has several storm outfalls which drain into it. The Bharalu catchment area is covered by the G.N. Bordoloi Road in the North from Chandmari to Bharalu, R.G. Baruah Road in the East including the Chandmari flyover, G.S. Road in the South & South West from Dispur to Ulubari and L.P.B. Road up to Sabipool and the road along the Bharalu River, reaching Kumarpara Pachali.

Municipal wards covered by this area are mainly Wards 18, 19, 20, 27 to 36 and 38 to 44. The topography is fairly flat with very little natural slope. The remaining parts are covered with some hillocks and pockets of low lands. The basin covers very densely populated areas of Guwahati. To regulate the flow of the river, a sluice gate has been constructed by the State Water Resources Department at Bharalumukh to prevent reverse flows from the Brahmaputra during high floods. However, during the dry season, the flow is very low, the primary source being urban drainage (sewage).

Several obstructions have been identified in the Bharalu between R.G. Baruah Road Bridge Crossing and Bharalumukh. For example, at R.G. Baruah Road crossing, projection of the lower slab of the road bridge together with crossings of service pipelines have obstructed the flow through the drainage course and reduced its carrying capacity. Moreover, a large number of temporary wooden foot bridges along with a number of old existing bridges (both made of wood/timber and concrete) at various locations along the Bharalu have obstructed normal flow of water during peak hours due to lower deck level and thereby have reduced the travel time of storm water through the drain considerably.

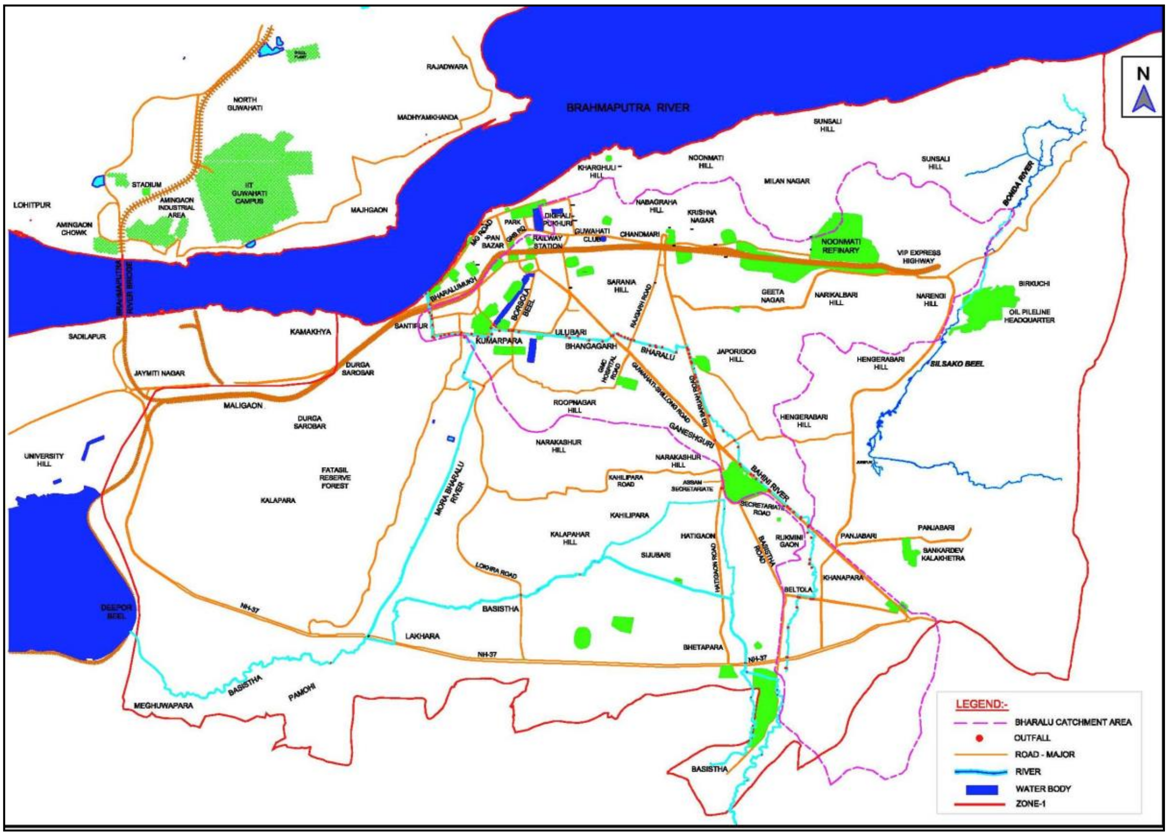


Figure 1-9: Known Outfall locations along Bharalu

At various locations, these obstructions have led to water overflowing into the adjoining areas. A number of shops and commercial establishments have encroached on the waterway of the drain at Fatasil area. The width of the Bharalu ranges from approximately 10 to 18 m. Its width increases to 36 m at the outfall point.

Water from the Brahmaputra backflows into the Bharalu when high flood levels (HFL) primarily during the monsoon season exceed the full supply level (FSL) of the Bharalu. In order to limit the flooding in the adjacent areas due to such backflow, a sluice gate has been provided near the outfall of the Bharalu and excess water is pumped to its downstream end.

There are several prominent secondary drains which serve the Bharalu catchment area:

- Pub-Sarania – Rajgarh Area Secondary Drain: This is major secondary covered drain carrying storm water from parts of Chandmari, carrying storm water from Krishna Nagar and from the foothill of Sarania Hill on the eastern side. The drain is divided into two parts; one towards Nabin Nagar-Anil Nagar underground drain and the other reaching Lachit Nagar underground drain. The total length of this drain is 3700 m.
- Lachit Nagar Area Storm Drain (Lachit Nagar Road to Bharalu Drainage Channel via B.T. College Road): It is a combination of a pipe conduit (N.P.-3 Hume Pipe) and a concrete box drain. This underground drain carries storm water from all of Lachit Nagar and the southern part of the Sarania Hill catchment area through drains meeting it at different locations. This drain starts at the Lachit Nagar G.S. Road junction and terminates at the Bharalu River through B.T. College Road. The approximate length of the drain is 1 km.
- Railway Open Drain (from Voltas Point near Sadin Office to B.Baruah over bridge): This is an open concrete drain that was constructed in 2004. It carries storm water from parts of Nabagraha Hill, Chandmari, Krishna Nagar and Silpukhuri area. It flows through the railway culvert below the B. Baruah over-bridge and passes through Hedayatpur and ultimately outfalls at Borosila Beel through Solapara. The total length of the drain is about 1.3 km.
- Underground drain from Ambari via parts of G.N.B. Road to Railway open drain at Ambari: This drain carries storm runoff from Lamb Road area, Ambari and parts of Uzan Bazar Area. This drain originates at the Lamb Road area, then meets the railway culvert below B. Baruah over-bridge, and finally outfalls at Borosila Beel.
- R.G. Baruah Road Drain (From Zoo Narengi Tiniali to Bharalu Drain): This is an open concrete drain. The origin point of this drain is at Zoo Narengi Tiniali; the outfall is at the Bharalu. This is one of the major open secondary drains collecting storm/ waste water from the Guwahati Refinery, Noonmati and Bamunimaidan area through drains running along the railway line at Bamunimaidan, the Bhaskar Nagar area and ultimately meeting it at Zoo Narengi Tiniali. Water from Narikal Basti and Ambikagiri Nagar also contributes to this drain. Some of the runoff from the Rajgarh and Chandmari areas is also contributing to this drain. This drain meets the Bharalu at Jonali, the confluence between the Bharalu and the Bahini Rivers. The total length of the drain is about 1 km.
- Chandmari - Bharalu Secondary Drain (through Bhaskar Nagar, Rajgarh, Nabin Nagar, Anil Nagar): This drain was constructed by the T&CP Department and carries water from parts of the Chandmari area, Bhaskar Nagar, Rajgarh, Nabin Nagar, part from Pub-Sarania and Anil Nagar. The total length of this drain is almost 5 km.
- Underground drain along the boundary of Nabin Nagar and Anil Nagar to Bharalu (through Anil Nagar): This drain carries storm runoff from the Anil Nagar area. Part of drain flows towards the Chandmari - Bharalu Secondary drain; the remaining part of the drain flows towards the Bharalu primary drain. The total length of the drain is 1.4 km.

Extended stretches of several drains are clogged with silt and garbage. Storm runoff from adjoining hills and the runoff carries huge loads of silt and vegetation, which ultimately get deposited within the drains, severely restricting flow. The outfalls in the Borosila Beel have been reduced significantly due to encroachment and garbage dumping, reducing the storage capacity of the lake.

Several of the manholes have been paved over by a layer of bitumen during road construction. Some of the existing manholes were found to be damaged or broken. Sometimes, manhole openings are inadequate for manual cleaning.

The major reasons of ineffectiveness of drains are therefore as follows:

- Deposition of garbage and solid waste that reduce the carrying capacity of the drain
- HFL of the drain is higher than the surrounding area causing backflow.
- Obstruction of flow at the outfall point due to silt deposition.
- Obstruction in flow due to construction of low level cross structures on the drain.
- Non-functioning of installed equipment due to lack of maintenance.

1.5.2 Waste Water Flow Carried by Drains

Presently there is no sewerage system in Guwahati City. Untreated or semi-treated sewage is disposed of into the storm water drains due to lack of proper sewerage and sanitation systems in the city. Details are presented in Section 2.2.1. Available bathing and waste water drainage facilities in Kamrup District are listed in Table 2-6.

Table 1-24: Available Bathing and Waste Water Drainage Facilities in Kamrup District of Assam

Type	Total number of Households	Number of Households having bathing facility within the premises			Waste Water outlet connected to		
		Yes		No			
		Bathroom	Enclosure without Roof		Closed drainage	Open drainage	No drainage
Total	32,490	18,429	4,105	9,956	4,619	9,976	17,895
Rural	11,739	2,507	1,310	7,922	260	979	10,500
Urban	20,751	15,922	2,795	2,034	4,359	8,997	7,395

1.5.3 Measurement of Flows in Drains along with Copies of Test Report

There are multiple sources of pollution to the Bharalu. The sources have been observed (e.g., solid waste), and in some cases documented through the collection of field data (e.g., sewage drain data). Some sources (e.g., the local refinery) have been identified anecdotally and warrant further investigation. Identified sources include the following:

- *Raw domestic sewage:* Raw domestic sewage drains are directly connected to the storm water drainage system. The direct sewage discharges contribute heavy organic loads which affect water quality and include bacteria, viruses, and other pollutants harmful to human and ecological health.

- *Municipal solid waste (MSW):* MSW (i.e., garbage) is routinely dumped in the city streets and along the banks of the Bharalu River. Nearly everywhere along the river banks, MSW is strewn about in thin, non-contiguous layers, but in many location, thicker, contiguous fills exist on the River banks and lie in contact with the flowing water. In many cases, metal, wood, and food wastes appear to be scavenged by local populations, dogs, and other animals, and the resulting mixture is dominated by plastic wastes. As these wastes slowly degrade, they release toxic pollution to the water.

- *Storm water:* Storm water is directly discharged to the Bharalu River via the surface drainage system, and also as overland surface runoff. In both cases, this storm water carries solids and pollution from the city streets into the river. In addition to domestic sewage, this runoff likely includes particulates from combustion of diesel fuel and other petroleum fuels, pollution from MSW, oils and greases from pavement areas, abraded asphalt particulates, animal wastes, agricultural waste products, and other pollution sources.

- *Industrial pollution:* Industrial pollution sources may include the refinery, automotive maintenance areas, fuelling stations, and other industries in the catchment area. Any pollution from these sources may be directly discharged to the drainage system, may flow overland, or may infiltrate groundwater which ultimately discharges to the Bharalu.

- *Atmospheric deposition:* The air quality in Guwahati is affected by sources such as the combustion of petrochemicals for transportation, energy, and industrial purpose and regional air quality pollution. Particulates which contain toxic combustion by-products and heavy metals such as mercury settle and dissolve into the city's waterways.

Figure 1-10: Solid Waste Collected at Sluice Gate

Due to the density of the residential population, the most significant source of pollution to the Bharalu River appears to be the direct discharge of domestic sewage. Given the prevalence and magnitude of the problem, MSW dumping may also be a significant source. It is likely that the pollution loads from storm water, industry, and atmospheric deposition are less significant, but there has been little study done to confirm this assertion.

As an example of the level of pollution from domestic sewage sources, Table 1-25 provides data from studies conducted in 2011.

Table 1-25: Level of Pollution from Domestic Waste

Source (Drain Near)	Date of Collection	Time of Collection	pH	Chemical Parameter (in mg/l)			Bacteriological Parameter (MPN/1000ml) (Faecal Coliform)
				COD	BOD	TSS	
Ganeshguri Chariali	8/8/2011	9.00am	7.0	56	20	38	1,500
	8/8/2011	12.10am	7.1	48	22	36	1,500
	8/8/2011	4.10pm	7.0	80	25	34	1,500
Japorigog near Bihu Field	8/8/2011	9.15am	6.9	168	46	36	730
	8/8/2011	12.30am	7.1	160	44	36	1,500
	8/8/2011	4.30pm	7.0	168	48	30	4,300
Solapara Road, Paltanbazar	8/8/2011	9.35am	6.5	312	92	142	2,400
	8/8/2011	1.15pm	6.5	288	72	54	6,400
	8/8/2011	5.15pm	6.5	352	96	26	7,500
Ambikagiri Nagar	8/8/2011	9.50am	7.2	80	49	172	1,500

	8/8/2011	1.45pm	7.0	128	68	106	1,500
	8/8/2011	5.30pm	7.3	144	90	72	1,500

Source: Detailed Project Report – Guwahati Sewerage Project Zone 1, 2013

Copies of test reports for detailed water quality measurements taken at different specific drain locations and at various locations along the Bharalu are included in Appendix A to this report.

The NRCD Guidelines for River Water Quality Standards are based on Water Quality Standards for rivers from the Central Pollution Control Board's classification of designated best use criteria of rivers for bathing as indicated in Table 2-7 below:

Table 1-26: Guidelines for River Water Quality Standards

Parameter	Standards
pH	6.5 to 8.5
BOD	3 mg/l or less
DO	5 mg/l or more
Fecal Coliform Desirable Maximum Permissible	500 MPN/100 ml 2,500 MPN/100 ml

The levels from the 2011 study show that the raw domestic sewage discharges exceed these standards and guidelines in nearly all locations and at all times.

1.5.4 Waste Water Characteristics of Different Drains

Wastewater characteristics from different drains discharging to the Bharalu are included in Section 2.3.6 below.

1.5.5 Details of Measurement of Waste Water Characteristics along with Copies of Test Reports

In order to adequately evaluate the quality of the water being discharged to the Bharalu for the drains identified above, as well as the effect of the discharges on the river, a water quality sampling programme was initiated in December 2013. Under direct supervision of the PCBA, water quality samples were acquired from eight (8) locations (Figure 2-4) by. Environmental Research & Evaluation Centre (EREC), located in Rupnagar, Guwahati. EREC is a certified laboratory to collect and analyse water quality samples. At each location, three (3) water quality samples were collected during 2 to 4 December 2013. The locations sampled included:

- At Bharalumukh
- 200 m Downstream of Borsola Beel
- At Borosola Beel
- At Roopnagar Bridge
- In Bharalu downstream of the IOC Refinery drain
- At the drain from Indian Oil Corporation Refinery Site
- At Bahini before the IOC Refinery drain
- At NH37

The samples have been analysed for pH, BOD, COD, TSS, TDS, temperature, and faecal coliform. Sampling protocols and laboratory results of the additional water quality samples collected on December 2-4, 2013 are included in Appendix B.

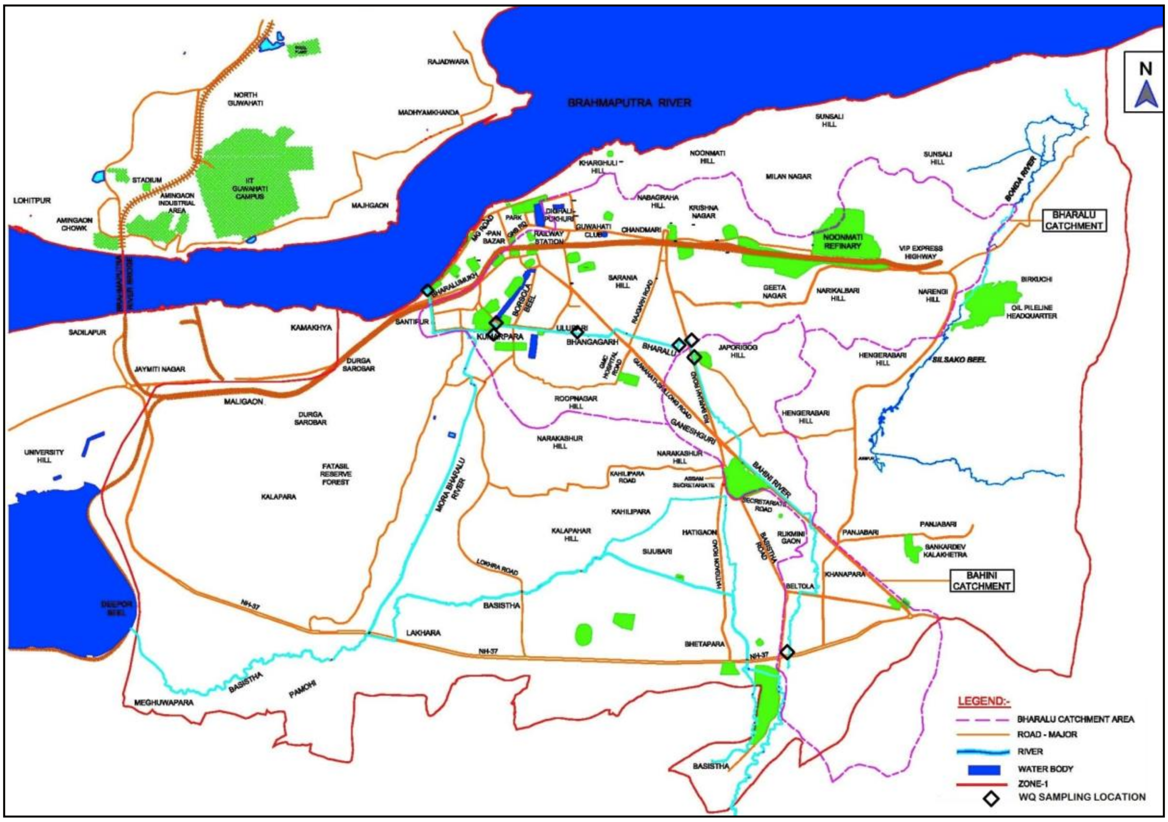


Figure 1-11: 2013 Water Quality Sampling Locations

1.5.6 Water Quality of the River U/S, D/S and at Outfall of Drain discharging into River

Water quality of the river has been measured u/s, d/s and at outfall of drains discharging into river. The actual water quality data can be found in Appendix A.

1.5.7 Measurement of the Quality of River Water along with copies of Test Report

Details on water samples collected can be found in section 1.5.5. The actual water quality data can be found in Appendix A.

Based on the collected water samples in Bharalu and analysed as part of the present project it is found:

- pH, BOD and DO levels do not meet the limits in NRCD guide (see section 1.5.9); and
- Fecal coliform levels at most locations inside the town do not meet the limits in NRCD guide (see section 1.5.9).

The water quality data obtained in the present project shows that Bharalu is highly polluted within Guwahati and does not adhere to the NRCD rules.

1.5.8 Methodology followed for Flow Measurement and Quality Characteristics

The methodology adopted by the laboratory for flow measurement and quality characteristics is presented in Appendix B.

1.5.9 Water Quality Standards of River Water Quality

NRCD specify the following limits for water quality for rivers if used for bathing (or if it should be suitable for bathing):

Table 1-27: Water Quality Standards per NRCD[1]

Parameter	Unit	Limits
pH	---	From 6.5 to 8.5
BOD	mg/l	< 3
DO	mg/l	> 5
Fecal coliforms	MPN/100ml	Desirable – 500 Permissible – 2,500

For propagation of wild life and fisheries the following extra or stricter limits apply:

- DO > 4 mg/l; and
- Free ammonia (as N) < 1.2 mg/l.

1.5.10 Justification of the Project for Pollution abatement of the River

As stated in Section 1.3.2, CPCB identified the Bharalu among the most polluted rivers in India. The documented pollution levels in the Bharalu exceed the NRCD (2010) guidelines for water

1 Water Quality Standards as listed in Tables 2.3 and 4.5 of 2010 NRCD Guidelines as classification of Designated Best Use criteria of rivers for bathing

quality for bathing[2] listed as biological oxygen demand (BOD) <3 milligrams per litre (mg/l), dissolved oxygen (DO) >5 mg/l, and maximum permissible faecal coliform of 2,500 Most Probable Number (MPN). These high values justify the selection of Guwahati for restoration of the Bharalu river system. Furthermore, there has been a strong and collective demand from various stakeholders including inhabitants of Guwahati to restore the Bharalu to its natural state.

With the emergence of SLBs being mandated by the Ministry of Urban Development, Government of India, several Indian cities are now either taking or in the process of initiating necessary steps to clean up their existing drainage courses. Such drainage courses are mostly nallah, small stream or river, or usually natural drainage courses which have been polluted to an extent where restoration is of paramount interest to maintain normal flow in the river and have acceptable water quality.

One such stretch of river has now been identified as that of Bharalu in Guwahati. Guwahati does not yet have any organized sewerage system in place. Raw or partially treated sewage finds its way through existing small drains and drainage courses into the Bharalu from the adjoining areas. The older section of the city has either make-shift and/or temporary courses to channelise their liquid waste to nearby streams which ultimately drain into the river. Newer sections of the city have better organised development and the housing enclaves have septic tanks, however for the most part the tank overflow is bypassed and eventually makes it to the river in the one or other way.

In absence of any solid waste management scheme, littering and throwing of trash in the river are two persistent problems which adversely affect the health of the river. Biodegradable portion of this solid waste is decayed in open places directly affecting Bharalu's water quality or adversely affecting areas located along the river bank. Non-biodegradable portions of the solid waste either lingers in the same place for a while or is carried by the river to the downstream control structure, where clogging creates its own problem. Remnants of bio-degradation and the inorganic waste in the river limit the carrying capacity of the river which can be directly correlated to water logging problem experienced during monsoon. Patches of river bank are sometimes occupied by unorganised shanties and small temporary or semi-permanent houses and give rise to the problem of open defecation in the river itself or its adjoining areas. The river is also treated as a place for disposing of solid waste from these households.

Clogging of the river course by solid waste and debris deposition also becomes a cause of concern in as it decreases the carrying capacity of the river to drain its catchment efficiently during the monsoon or following a major downpour. This causes water logging problem in the riverside areas causing unhygienic conditions for the inhabitants and affecting public health.

Several long stretches of river were found to be not defined from an engineering standpoint and have loose earthen embankments. At stretches solid waste dumping could be witnessed on these embankments during site survey accompanied with embankment erosion. Absence of adequate and appropriate vegetative cover can be concluded to be chief causes of such bank erosion which also affects flow in the river and clog its waterway.

The river also has to convey partially treated industrial effluents from a few large and small industrial units in its catchment. Though these units are required to be regulated by installing their respective waste water management systems, sometimes it is not maintained properly to avoid river pollution. The direction taken by the PCBA to restore the Bharalu is aimed at achieving the following important objectives that would benefit the stakeholders and maintain an acceptable environmental condition in and around the river is as follows:

- All households in Bharalu's delineated catchment to have individual toilets on their premises with adequate water supply and ensure that the relevant population have access to toilets in the form of community toilets.
- All major public places have an adequate number of public toilets in fully serviceable condition.
- The quality of river water is improved.

2 NRCD (2010) Chapter 3, Selection of City for Pollution Abatement Project and Preparation of City Sanitation Plan.

- All the waste water generated in the influence area is collected and conveyed through an appropriate sewer network to treatment facilities, treated to acceptable quality levels and then disposed of or reused.
- All households as well as non-residential users have access either to a door-to-door collection of garbage or to a municipal collection facility within easy walking distance.
- All the solid waste generated in the households is segregated, collected, transported and either processed for reuse or disposed of in a sanitary landfill.
- The entire sanitation system as visualized above is socially, environmentally and economically sustainable and effectively managed by a capable team in the municipality, maintaining adequate standards of safety for the workers.

It is acknowledged that complete realization of the above vision would be achieved in a phased manner, over a stipulated period of time. This is the goal that this CSP and its related action plans. The guiding principles for the realization of the requirements of this project and hence the defined goals as articulated above are as follows:

- Equality
- Sustainability – environmental and economical
- Transparency
- Local adaptability
- Improved public health conditions
- Inclusive growth

The development of the implementation strategy entails detailed planning; initiatives supported by incentives, guidance system / sound financial systems; innovations; context specific solutions, prioritization; supportive context; and ownership and leadership. The prime responsibility of implementation of the CSP rests with the Assam Pollution Control Board (APCB), however, it is imperative that the APCB shall engineer and institutionalize the collaborative efforts of all stakeholders involved to help achieve the defined goals as part of the implementation strategy. The implementation strategy is based on detailed analysis of the situation in the major sectors of sanitation namely: (a) sewerage; (b) access to sanitation – toilets; (c) storm water (d) solid waste, (e) water logging, and (f) erosion.

To maintain safe and hygienic environmental conditions in the Bharalu catchment, it is mandatory to have a properly planned sanitation and municipal solid waste management system implemented. Such basic infrastructure facilities are essential for restoring such an important river in an important commercial centre like Guwahati. A few other environmental plans and development reports prepared earlier have also suggested immediate provision of properly organised and managed sanitation facilities.

2 SEWERAGE WORK

2.1 Status of Water Supply

2.1.1 Actual Water Supply from Different Sources

Broadly, the existing water supply system in Guwahati City consists of several schemes covering different parts of the city. Treatment Plants at Panbazar, both operated by GMC and PHED, along with AUWS&SB operated Zoo Road treatment plant and the GMC-operated treatment plant at Satpukhuri supply water to the central region. 35% of the city is covered by piped water supply (Master Plan 2025). The potable water generation capacity in Guwahati is 98 million litres per day (MLD). At present, about 73.5 MLD of potable water is produced in Guwahati by the GMC; out of this, 72 MLD is drawn from the Brahmaputra to eight water treatment plants. There were 14 GMC deep tube wells, out of which just 7 are functioning. These tube wells were supposed to generate 3 MLD of water; instead, the total water production from these tube wells is about 1.5 MLD.

The produced water is insufficient for the current demand of 132 MLD. Therefore, aside from water produced by the GMC, approximately 65% of the residents extract potable water from the ground with hand pumps, tube wells and wells in the GMA (Carrying Capacity Based Urban Development Regulations, Guwahati, 2011). The projected demand for the city by year 2025 is estimated to be 425 MLD.

As only one third of the population of the whole city is served by piped water supply systems (that too with frequent complaints of inadequacy of water supply), the majority of the population is dependent on their individual water sources such as shallow tube wells or dug wells. Most of these sources are heavily contaminated. A few inhabitants can afford tapping water from deeper subsurface layers which are generally free from bacteriological contamination. However, water from those layers may contain elevated iron concentrations and other impurities. Even many of those houses having piped water supply connections have tube wells or dug wells as stand-by sources due to the unreliability of the piped water supply system.

The major industries (including the IOC's oil refinery, The Railways, Airport and Defence establishment) in Guwahati collect, treat, and supply their own water; water is obtained mainly from the Brahmaputra River. The Master Plan proposes that in the future all industries would have to manage water collection, treatment, and supply on their own without help with the Municipal Corporation.

2.1.2 Proposal for Augmentation of Water Supply System

The present JNNURM policy requires a water supply system to provide water supply reliability around the clock, with a planning target of 2040. Considering the ultimate water supply demand and numbers of floating barge intake systems required to provide this capacity, three water treatment facilities have been considered.

Only one water supply project worth Rs. 280 crores (90% funding from the Centre) has been sanctioned for financial support under the JNNURM water supply sector. Another project is currently planned for the West Guwahati region. Water supply improvements for South Central Guwahati and North Guwahati are to be covered by water supply schemes by JICA finding.

2.2 Status of Existing Waste Water Disposal Works

Presently there is no organized sewerage system in Guwahati City. Untreated or semi-treated sewage are discharged to the storm water drains due to lack of a proper sewerage and sanitation system in the city. There is one STP in Guwahati located at the northern end of Borsola Beel which discharges to the Bharalu. The SPT serves the area to the north-east of AK Azard Road. The plant was developed by the GMAC and is reported to have a capacity of 1.5 MLD. Detailed information about the specifics of the plant was not obtained prior to the preparation of this report, but it is assumed that it was installed as part of the development in the area, and is not adequate to handle any additional wastewater discharge and/or is operation in a fashion to remove all of the wastewater contribution to the Borsola Beel.

In the older part of Guwahati un-treated sewage and sullage is discharged into storm water drains causing unhygienic conditions for the city dwellers and also a grave risk to health of sanitation workers. Newer houses in relatively better planned and organized colonies have septic tanks but most of them lack soak pits. Partially treated effluent is usually discharged into open road drains which flow into the natural drainage channels that pass through the city. In view of existing status of environment of Guwahati without any engineered sewage system and treatment facilities, it is extremely important to plan and implement a scientific system of underground sewerage and sewage treatment to save the population from a calamity in the near future. Further, in accordance with the norms of the Government of India, a city like Guwahati with a population over 7.5 lakhs, falls under the obligation of having adequate facilities of sewerage and sewage treatment in the city.

2.2.1 Existing Works

The primary development of Guwahati is carried out by two main agencies, namely the GMC and the GMDA. These two agencies operate under the Guwahati Development Department (GDD), Government of Assam. It is important to understand the domain and responsibilities of such government organizations to better appreciate the issue of ownership and operation of infrastructure facilities.

At present, the institutional arrangements to deal with sewerage issues are inefficient and rest with a number of agencies. While the GMC is responsible for water supply only for a part of the city, its primarily responsibility is managing the solid waste, along with maintenance of storm drains and cleaning of septic tanks. GMDA is responsible for planning and carrying out some of the major developmental works to be undertaken in the city in future. As stated above, the area covered under GMDA includes a total area of 264 km^2, including the 216 km^2 large GMC area. The Kamrup District water supply data (per Census 2011) are presented in Table 2-1.

Table 2-1: Kamrup Water Supply Data, Census 2011

Main source of drinking water	Availability of Drinking Water Source	Total number of households	Electricity			
			Available		Not available	
			Latrine available	Latrine not available	Latrine available	Latrine not available
All Sources	Total number of households	41,707	6,994	2,112	10,338	22,263
All Sources	Within premises	24,138	5,386	1,231	5,804	11,717
All Sources	Near premises	9,123	963	486	2,627	5,047
All Sources	Away	8,446	645	395	1,907	5,499
Tap water from treated source	Total number of households	1,263	648	95	241	279
Tap water from treated source	Within premises	506	359	29	62	56
Tap water from treated source	Near premises	415	192	20	100	103
Tap water from treated source	Away	342	97	46	79	120
Tap water from un-treated source	Total number of households	534	132	25	229	148
Tap water from un-treated source	Within premises	239	66	10	105	58
Tap water from un-treated source	Near premises	206	48	5	93	60

Main source of drinking water	Availability of Drinking Water Source	Total number of households	Electricity			
			Available		Not available	
			Latrine available	Latrine not available	Latrine available	Latrine not available
Tap water from un-treated source	Away	89	18	10	31	30
Covered well	Total number of households	497	144	24	135	194
Covered well	Within premises	245	107	13	66	59
Covered well	Near premises	171	26	9	37	99
Covered well	Away	81	11	2	32	36
Un-Covered well	Total number of households	19,046	1,494	570	4,850	12,132
Un-Covered well	Within premises	13,978	1,262	385	3,529	8,802
Un-Covered well	Near premises	3,265	137	108	903	2,117
Un-Covered well	Away	1,803	95	77	418	1,213
Hand pump	Total number of households	15,797	4201	1248	3,541	6,807
Hand pump	Within premises	8,856	3,520	778	2,017	2,541
Hand pump	Near premises	3,344	455	299	793	1,797
Hand pump	Away	3,597	226	171	731	2,469
Tube well/Borehole	Total number of households	425	85	21	47	272
Tube well/Borehole	Within premises	314	72	16	25	201
Tube well/Borehole	Near premises	47	13	2	9	23
Tube well/Borehole	Away	64	-	3	13	48
All Others	Total number of households	4,145	290	129	1,295	2,431
All Others	Within premises	-	-	-	-	-
All Others	Near premises	1,675	92	43	692	848
All Others	Away	2,470	198	86	603	1,583

Source: 2011 Census Sheet DDWH3811TT-1800 XLS

The following observations apply to the about existing sewerage and sanitation facilities in Guwahati:

- Service delivery for sanitation in Guwahati does not match the requirements of the city and also the stipulated service level benchmarks (SLBs) by the Ministry of Urban Development, Government of India. Further, the presence of multiple agencies with similar duties might have compounded the problem of service delivery.

- Guwahati Metropolitan Water Supply and Sewerage Board or the “Jal Board” (also under GDD) has been established with the responsibility of creation of the assets and operation and maintenance of the water supply and sewerage components for the city. Septage management, once implemented, is expected to be handled in the future by the Guwahati Municipal Corporation. Decentralised waste water treatment systems, if implemented, may also be handled by either the Corporation or the Jal Board.

- In the older parts of Guwahati untreated sewage and sullage discharged directly into storm water drains causes a severe health risks for the citizens. Newer houses in more planned and organised colonies have septic tanks but most lack soak pits. The partially treated effluent is usually discharged into open road drains which flow into the natural drainage channels that pass through the city. This results in unhygienic conditions of the surrounding areas as well as pollution of ground and surface water sources. This also poses even greater health risks as ground water is also extracted for using as potable water in some areas pending the commissioning of the ongoing water supply systems. The two main causes of concern from the sanitation and health perspective are the untreated or partially treated effluent stream from septic tanks (if not being soaked into a soak pit) and the septage being emptied from the septic tanks.

2.2.2 Works under Execution

The works described in Section 2.2.3 has been approved by the State Level Appraisal Committees. However, suitable funding options are still being explored by the concerned agencies to implement the proposed work.

2.2.3 Works Sanctioned

The DPR for the Sewerage Network of Guwahati prepared by GMDA (2012) is based on the available survey data projected on topographical contour maps. The proposed sewerage system is divided into three distinct sewerage zones characterized by an independent collection, conveyance, treatment, and disposal system (Figure 2-1).

The complete new network system will provide house or service connections to the public municipal sewer. The trunk main routes in each zone have been reported to be marked along the side/ centre (as applicable) of existing roads along natural slopes with due consideration to crossings of existing drainage courses, railway lines, storm water drains, etc. The zoning of the sewerage system and natural valleys will result in minimal depth of cutting for laying of sewers (which has been restricted to 8 m). Intermediate sewage pumping stations and lift sewage pumping stations have been considered, as necessary.

The treatment processes have been selected based on technical and economic feasibility and suggestions from the funding agency (JICA) and the approving authority.

Table 2-2: Components of the Sewerage Network of Guwahati

SN	Main Components	Sub Components
1	Collection and conveyance system	Trunk, main, branch/lateral sewer line, manhole chambers, vent shaft, etc.
2	Sewage pumping stations	Terminal sewage pumping stations and lift stations, wet well, drywell, pumps, motors, rising main and accessories, electrical transformer and substation
3	Sewage treatment plants	Screen chambers, distribution chambers, grit chambers, chlorination tanks, gas holders, facultative aerated lagoons and sludge drying bed, electrical transformer and substation
4	Treated sewage disposal	Sump and pump house, pumps and fixture, gravity/forced main
5	Site development and building infrastructure	Site grading, roads boundary wall, administration building and essential staff quarters and area lighting
6	Laboratory	Lab building and testing equipment as prescribed in PHE manuals.

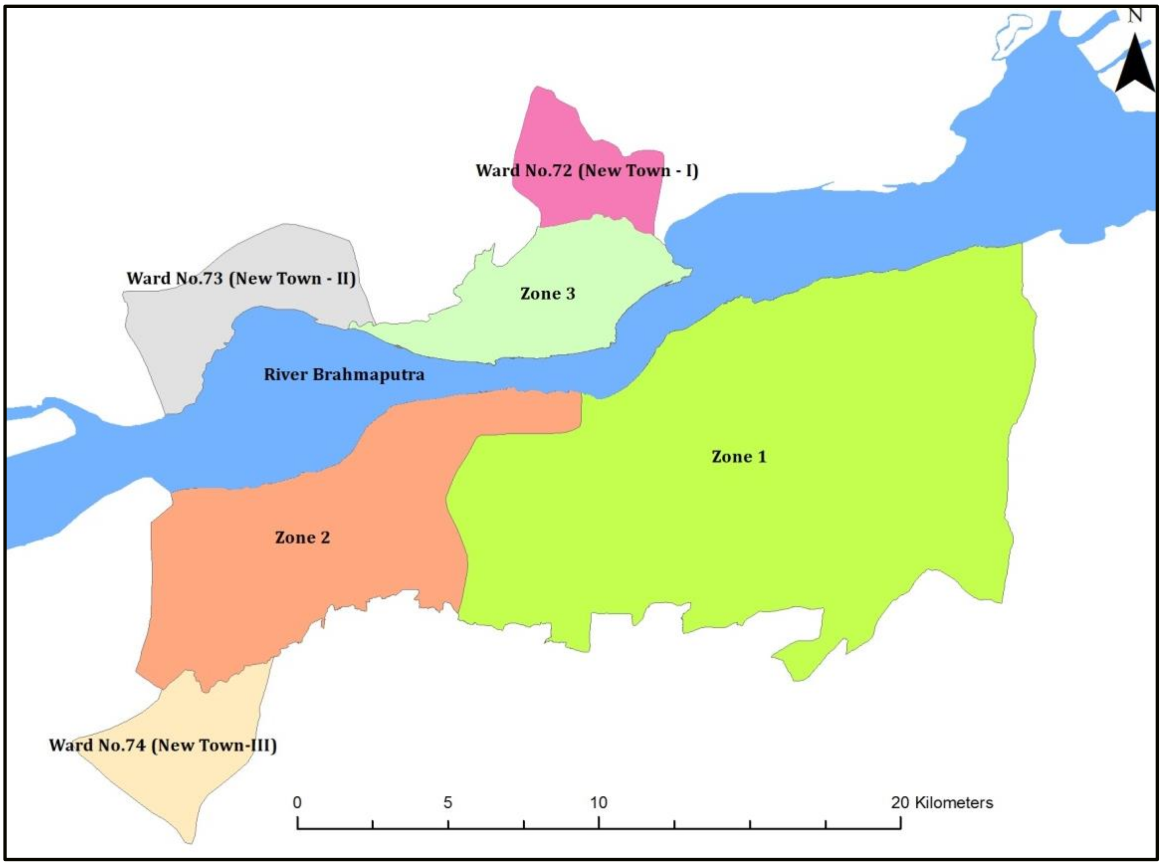


Figure 2-1: Proposed Sewerage Zone for Guwahati

Relevant elements of this proposal are as follows:

- The treated sewage discharge will be disposed to the Brahmaputra from the respective Sewerage Treatment Plants (STPs) through pumping mains (for Zone 1) and through gravity mains (for Zones 2 and 3). Alternatively, the treated waste water will be used for watering agricultural fields or for horticulture. Solids generated through the waste water treatment process are proposed to be transported to a landfill or used as fertilizer on agricultural fields after being sufficiently dried at the STPs.

- The sewerage system will significantly improve the overall environmental condition and reduce the risk of contagious diseases.

- Of particular note for this report is the recognition of low-lying pockets (or very low density populations in the city), which have not been covered under the proposed sewer network. It may be proposed to provide on-site treatment options or septage collection facilities for these areas. This in turn suggests due consideration of a septage management and decentralized waste water treatment options as an integral part of the solution for Guwahati, which may be restricted to such low-lying areas while all other areas are being covered by centralized sewerage system for their hydraulic amenability.

2.3 Drainage Areas

The stretch of Bharalu and Bahini which traverses through the densest areas of Guwahati is approximately 16 km long (Table 2-3) with a catchment area that is almost equally divided between the hilly regions and the plains. Specifically, the hilly upstream section of the Bharalu has a catchment area of 60 km^2 (where it is known as Bahini), and a catchment area of 40 km^2 in its downstream stretch passing through Guwahati. The Bharalu is the main drainage channel of the Guwahati Municipality area. It discharges into the Brahmaputra at Bharalumukh.

Table 2-3: Description of the Course and Length of Bharalu, Bahini, Basistha, Morabharalu and Pamohi

River / tributary name	from	to	length (km)
Basistha	Basistha temple	Deepor Bill	27.00
Bahini	Meghalaya hills	Nautan bazaar (at closed sluice gate)	8.00
Bahini	Nautan bazaar (at closed sluice gate)	Jonali Bridge	8.70
Bharalu	Jonali bridge	Bharalu Mukh at Brahmaputra	7.00
Dead Bharalu	Bharalu Sluice gate (Shantipur)	Near ISBT (confluence of Basitha & dead Bharalu)	6.50
Pamohi	Deepor Beel	Brahmaputra (near Garigaon)	7.00

Covering an estimated area of 11 km^2 in the heart of Guwahati, the catchment area has seen rapid urbanization from economic and demographic developments. From Basistha Chariali, the Bharalu River runs for about 17 km till Bharalumukh with an average channel width of 5 to 9 m. The average water depth in the channel is 3 m, although it varies considerably as a result of different flow volumes and ever-increasing piles of garbage. Based on earlier estimates, the velocity of flow is 0.76 m/sec for the stretch between Basistha and R.G. Barua Road, and on average 1.2 m/sec for the rest of the course.

The study area is part of the Brahmaputra basin, with the Himalayan Mountain range in the North and East and the Naga-Patkai hill range in the South. The basin merges with the Indo-Gangetic plain in West. The Brahmaputra has a water depth of approximately 47 m in the Guwahati area. The width of its basin within Assam is 70 to 80 km. The slope of the river bed is very gentle, varying from 1:66000 to 1:99000. In some place, the elevation of the river bed lies below mean sea level (Dutta, Chaudhury and Dass, 1968). The drainage pattern of the Brahmaputra valley is an antecedent type. Lateral erosion as well as changes in fault lines due to earthquakes causes the river to change its course often.

2.4 Population Projections of Each District in Design Years

The Bharalu River flows through the central part of Guwahati where most of the population lives. The catchment area of the Bharalu includes 36 wards of the city of which 16 contribute to the Bahini River, while 20 contribute to the Refinery Ditch and the Bharalu.

The ward wise population data for all wards in the city are presented in Tables 2-4 and 2-5. The wards within the Bharalu catchment area and Bahini catchment area are presented.

Table 2-4 Ward Wise Population in Bharalu Catchment

Bhalaru River			
Ward No.	**Population**		
	2020	**2035**	**2050**
11	13,480	17,760	8,133
14	23,093	30,426	8,447

17	18,679	29,476	62,704
18	6,803	8,040	22,662
20	10,911	12,894	13,142
21	6,047	7,146	10,756
22	26,914	42,471	7,648
23	10,148	11,993	6,225
25	16,953	20,035	11,308
26	9,850	11,640	9,158
27	9,868	11,662	12,135
28	9,047	10,691	16,678
32	9,427	11,140	17,529
33	9,690	11,451	11,786
35	13,083	17,238	25,215
36	16,382	21,584	14,077
37	15,901	20,951	22,828
38	8,880	11,700	18,987
39	14,492	19,094	59,011
40	3,739	4,926	14,800
41	22,257	29,325	19,213
Total	**2,75,644**	**3,61,643**	**3,92,442**

Table 2-5 Ward wise population in Bahini Catchment

Bahini River			
Ward No.	**Population**		
	2020	2035	2050
24	27,295	43,073	8,084
42	13,316	17,544	45,623
43	5,903	7,778	21,330
44	16,525	21,773	1,81,978
45	17,099	22,529	54,490
46	30,386	43,464	90,151
47	8,525	11,233	1,46,675
48	12,705	16,739	48,074
49	28,765	37,900	93,634
50	11,951	15,747	46,980
51	59,180	1,00,196	1,12,100
52	14,779	25,021	90,412
53	14,779	25,021	90,412
54	19,601	33,187	94,780
55	34,947	59,168	7,716
56	20,151	31,799	16,030
57	33,656	53,111	12,176

58	27,603	43,559	20,016
Total	**3,97,166**	**6,08,842**	**11,80,661**

2.5 Projected Waste Water Flows in each District in Design years

At present, the city of Guwahati does not have an integrated sewerage system except for select residential areas such as the Railway Colonies, the Oil Refinery colonies and residential areas under defence establishments which have their own sewerage and treatment facilities. The only collection and treatment process followed is use of septic tanks. Therefore, much of the waste water generated in the city is being disposed of into rivers without treatment (Tables 2-6 and 2-7).

Sewage generated is considered as 80% of the water supplied for residential area and 70% of Non-Residential demand. This figure is used for estimation of sewage flow. The Domestic sewage generation is considered as 135 LPCD at the consumer end up to the year 2040 for the permanent residential area and 45 LPCD for the migrating population. (ii) Industrial, commercial and institutional demand (ICI demand).

No major industrial unit in the designated sewerage zones is considered. Hence contribution from major industry is not considered for the analysis and design of the sewerage system. Some small scale industries, institutions and hotels are located in the project area. An allowance of 10% over and above the drinking water demand is considered while estimating wastewater from such areas. This number also accounts for the marginal population which enters the catchment are on a daily basis.

Estimate of flow in sanitary sewer may include certain flows due to infiltration of ground water through joints. The quantity will depend upon workmanship in laying the sewers and level of ground water table. Since sewers are designed for peak discharges, allowance for ground water infiltration for the worst condition in the area has been taken as an additional 5% of the estimated sewage flow.

The waste water collection system has been considered a "Separate System". For the waste water collection system design, the parameters and guidelines of CPHEEO "Manual on Sewerage and Sewage Treatment" second edition were adopted. The sewerage system will be designed for the peak flow for year 2050. The projected population considered for the water supply system was adopted for the sewerage system.

Since the City of Guwahati currently has a DPR for the complete sewer separation within the city, an option for the Bhalaru River restoration is to prioritize the sewer system in the catchment area, and build a sewage treatment plant which can be expanded for future flows.

Table 2-6: Calculation of per Capita Sewage Generation

Description	Demand (lpcd)
Net per capita water demand for South Guwahati (proposed in Water Supply Project)	135
Add 10% for ICI demand @ 10%	13.5
Add ground water infiltration @ 5%	6.75
Sub Total	**155**
Considering 80% for sewage generation	124
USE	**125**

Notes:
4. As the Guwahati is a fast growing city and Industrial, Commercial and Institutional (ICI) activities are taking place at a rapid pace in some areas of the city, so a 10% provision has been used for ICI demand over the per capita demand of water supply for the whole population. This will eventually cover the need of ICI demand for the city as a whole taking care of unevenness of ICI demand distribution. This also accounts for the floating population which will be working in the ICI facilities.
5. Per capita sewage generation is considered as 125 lpcd for GMDA area.
6. The catchment area of the Bharalu includes 36 wards of the city and a projected 2035 population of approximately 870,000. The equivalent waste water generation from the projected population is shown in Table 2-5 below

The Bhalaru catchment area has projected 2035 population of approximately 1.0 million people.

- The sewerage system will be designed as follows: STP for the intermediate design period (i.e., for 2035) and a sewer network for the ultimate design year of 2050.
- The sewerage system for the Bharalu catchment area will be taken up after the water supply system is implemented in these wards.

Table 2-7: Projection for Total Waste Water Generation for Bharalu Catchment Area

River	Population			Sewage Contribution (lpcd)	Sewage Generation in MLD		
	2020	2035	2050		2020	2035	2050
Bahini	3,97,166	6,08,842	11,80,661	125	44	58	137
Bharalu	2,75,644	3,97,984	4,09,605	125	25	33	38
Total	**6,96,916**	**10,06,826**	**15,90,266**		**69**	**91**	**175**

2.5.1.1 Length of Sewer Lines and Capacity of SPS, STPs in each District

The wastewater generated within the sewerage zone will be collected by means of trunk mains/sub mains. The trunk mains and laterals will preferably be laid along the side / center the road and has been routed based on the topographical data. Provision has been kept for separate connection for each household. Of course house connection will be made agency under a separate project. Trunk mains have been designed to carry cumulative flows i.e. the flow from the respective contributory areas as well as the flow contribution from the upstream and sub-trunk mains joining them. A properly designed trunk main sewer would carry the optimum discharge to transport solids such that the deposits are kept to a minimum. For this, it is desired to achieve self-cleaning velocity at least once a day during peak flows and also cater to expected fluctuation in discharge. Provision of Flushing arrangement is kept on lines where velocity is less than 0.6m/sec (minimum self cleaning velocity). Adequate number of concrete manholes will be kept in the sewer pipes @ 30m interval for diameter of pipe below 500mm and @50m interval for pipe size 500mm and above. The sewerage system network has been so planned as to minimize the number of pumping/lifting station.

2.6 Sewage Collection and Treatment Options

As part of the restoration of the Bharalu, four (4) options for the removal of raw sewage from polluting the river were considered and are discussed below.

- Option 1, will consist of full separation of the domestic waste in a separate sanitary sewer collection system and will convey the collected waste to a 95 STP central sewage treatment plant. This option is consistent with the DPR developed by the GMAC for the collection and treatment of sewage for the South Central and Eastern portion of Guwahati, as identified as Zone 1, in Figure 2-2, with the exception that only the areas contributing to the Bharalu are considered for this plan.
- Option 2 is contains the same principals as Options 1 and includes the installation of a separate sewer system. But rather than conveying the collected waste to a central STP, multiple de-centralized STPs would be located throughout the city, along the river, and possibly over the river, as availability of government owned land along the river is scarce. If a maximum 5 MLD decentralized STP is considered and is the largest decentralized facility that can be constructed at multiple locations, nineteen (19) decentralized plants will be required to treat the 95 MLD estimated for the population projection in the Bharalu catchment area for 2035, Figure 2-3.
- Option 3 includes the collection of the existing sewage and storm water drains in interceptor pipes which would run parallel to the length of Bahini/Bharalu on both the north and south sides as well as along the Refinery Ditch. Intercepted flows would be conveyed to the proposed 95 MLD STP which would be located on government owned land near the Deepor Beel. The interceptor system would be sized to collect and convey the full capacity of a separated system, but would not be able to convey storm water drainage during wet weather,

which would overflow into the Bharalu. This is a less desirable option as during the wet weather the combined sewage overflow could potentially add diluted sewage to the river, Figure 2-4.

- Option 4 proposes to intercept the sewage and storm drainage in interceptor sewers along the river but this flow would be treated at numerous decentralized STPs located throughout the city as indicated in Option 2. If a maximum 5 MLD decentralized STP is considered and is the largest decentralized facility which could be constructed at multiple locations, nineteen (19) decentralized plants will be required to treat the 95 MLD estimated for the population projection in the Bharalu catchment area for 2035, Figure 2-5.

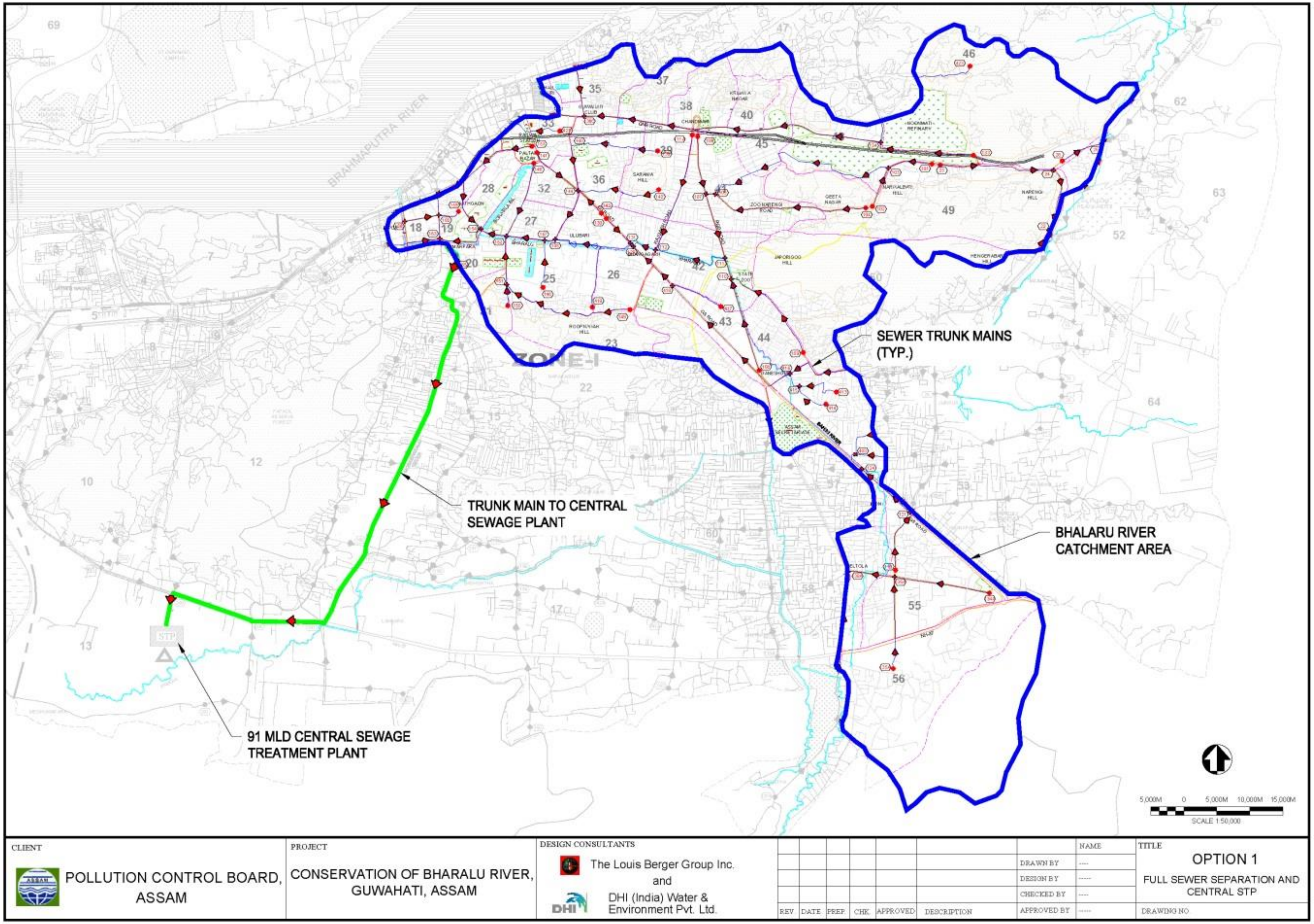


Figure 2-2 Sewerage Network Option 1

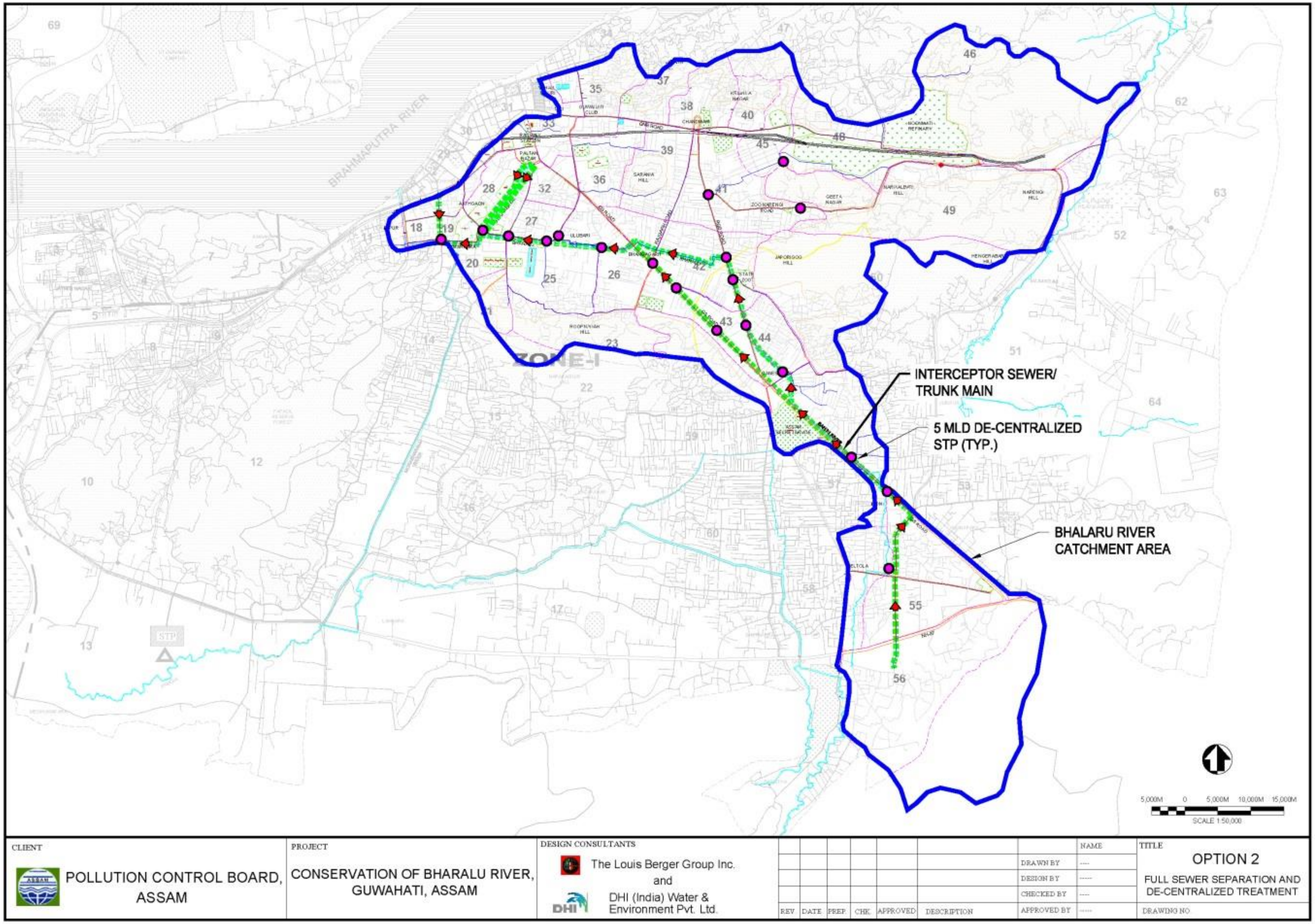


Figure 2-3 Sewerage Network Option 2

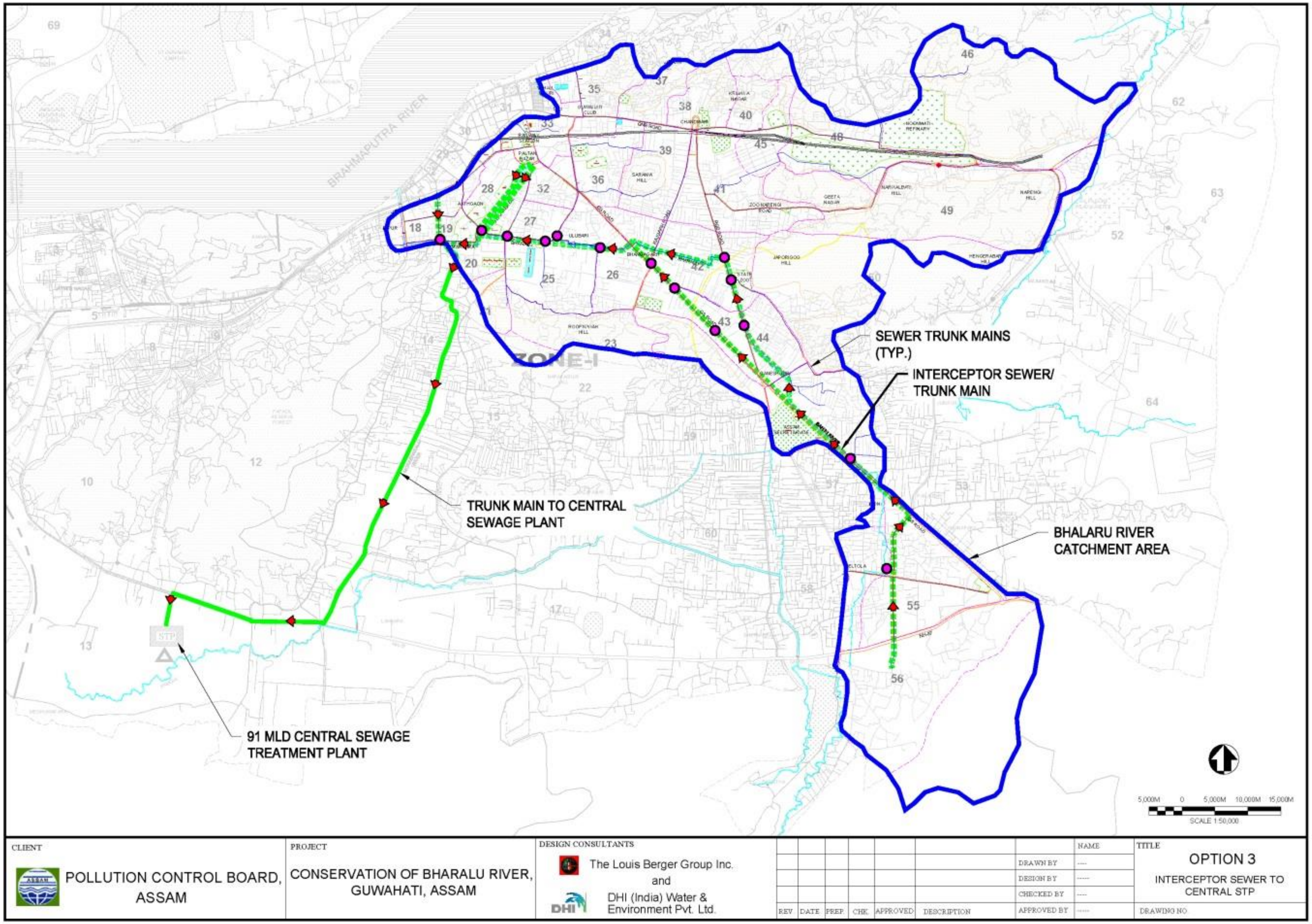


Figure 2-4 Sewerage Network Option 3

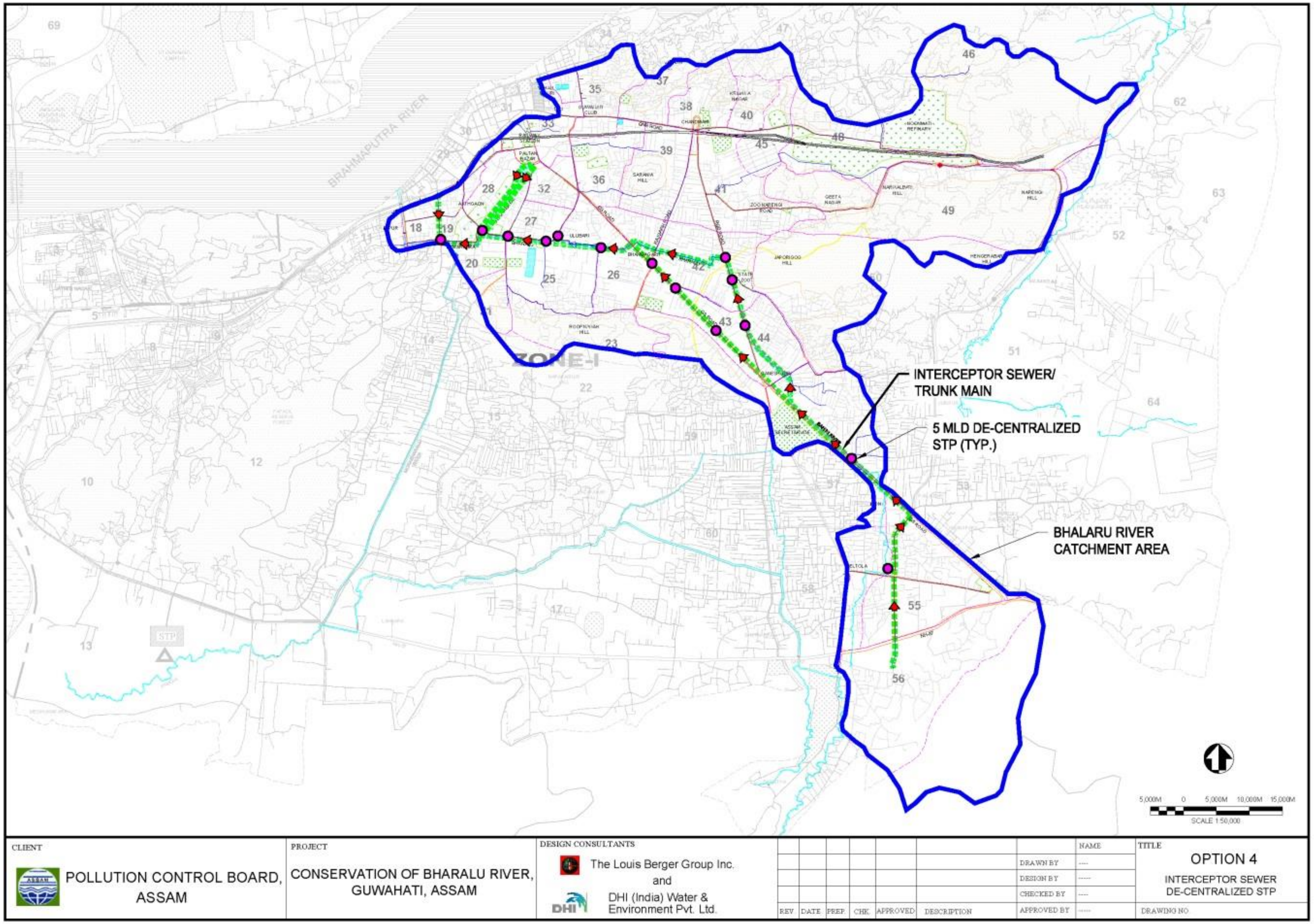


Figure 2-5 Sewerage Network Option 4

The length of sewer lines for the decentralized option is broken down into two options. The first category is the length of sewer line required to completely separate all of the storm drains and sewer drains in the Bharalu catchment area into a separated system. A summary of the lengths of sewer lines is presented in Table 2.6.

Table 2-6: Length of Sewer Lines for Separated System – Option 2

Sewer System	Length (m)
Trunk Mains	43240
Laterals	92099
Pumping Mains	3677

The second Option is to only install the trunk mains along the banks of the river which would capture the combined sewage and storm drainage in intercept it from the roadside drainage channels and convey it to the de-centralized sewage treatment plants. A summary of the lengths of sewer lines is presented in Table 2.7.

Table 2-7 Length of Sewer Lines for Combined Interceptor System – Option 4

Sewer System	Length (m)
Trunk Mains	28640
Pumping Mains	2400

In addition to the Trunk mains, lateral sewers and pumping mains, 20 lift stations will be required to lift the sewage from the interceptors and discharge it into the de-centralized STPs.

2.6.1.1 Availability of Land for various Components in each District

The availability of government owned land within the Bharalu catchment area is limited. The location of the de-centralized STPs proposed for this feasibility report is over the Bharalu River, Refinery Ditch, and Bahini River. It is anticipated that each de-centralized STP will have a capacity of 5 MLD. Based on the projection of wastewater generated through 2035, 18 STPs would be required to meet the demands of the Bharalu catchment area. Each STP is estimated to require approximately 800 square meters of land area.

Due to the scarcity of available government owned land in the urbanized wards of the City of Guwahati, it is proposed to site the 5 MLD STPs over the rivers. This will require the bridging of the rivers and provision of access to the sites from the adjoining roads.

The 5 MLD STP can be describe as follows:

The suggested 5 MLD de-centralized STP is proposed to be a Submerged Aerated Fixed Film process containing the following process equipment:

Influent pump station equipped with two submersible pumps, pump pedestals, control box, alarm system that would be installed on site casted concrete tank 100 m3.

The hydraulic load for this size treatment plant will be 10 m3/min. The duplex influent pump station will be sized to handle 3 time average daily flow rates up to 30 m3/min. The 100 m3 pump well will level out the hydraulic load, thus in normal operation only one pump would be required and the second would be provided for back-up and alternating operation.

Pre-treatment Screening would be accomplished with a fine mesh screen and combined sand, fat and grease trap in one single Chamber. The screening unit would be sized to handle up to 18 m3/min. The pre-treatment would remove sand, fat and grease simultaneously as following:

- The sand is transported to a waste bin container by screw conveyer.
- The grease is scraped off into a small container.
- The screening material is washed and compressed and end up into a waste bin container.

The sand, fat and grease trap will be constructed locally in concrete tanks.

Equilization tanks (2 × 500 m3) - In order to make the biologically treatment work efficiently, the key factor is loading the bioreactor with a constant flow. Two 500 m3 equalization tanks will ensure the hydraulic load to the bioreactors is constant during the day.

The biological treatment zone will consists of an aerated filter media, where the microorganism grows. The microorganisms perform the degradation of the organic load in the influent sewage water to the required treatment level. The biological cleaning process is performed by natural and indigenous bacteria only, without adding any other microorganisms. In order the system perform fully, needs about 3 – 6 weeks from the beginning of wastewater loading into it, which allows the bacteria are fully established and acclimated on the filter media. Each individual bioreactor cleaning unit is a self-contained system comprises an active aerated cleaning section. The bioreactor units will be installed in an onsite built concrete tank for this specific system. In addition, air blowers and diffusers will be incorporated into the biological treatment process.

The biological sludge will be removed by three drum filters with 20 μm filter elements. The sludge cake will be deposited onto a conveyor and discharge into a waste bin. The reject water from the drum filters (150 m3/day) will be discharged into a sludge pit decanting tank. In the tank, the suspended solids level will be increase to about 2%. The overflow water from sludge pit will be piped into the inlet pump well. The sludge pit will require dewatered from the bottom by a dewatering machine. The machine will run continuously.

Disinfection system – An Ultraviolet (UV) medium pressure UV system complete with UV sensor will be provided. Painted steel control panel. UV dose 400J/m2 at end of lamp life. System fitted with 6 UV lamps WTL2000. UV system features:

- Pressure drop at 208m3/hr: 3cm H2O
- Maximum active power: 19300W
- Maximum apparent power: 20470VA
- UV transmittance: T10mm = 60%
- Required UV dose: 400 J/m2
- Total average power consumption over 9,000 hrs: 14390W

The UV Technology Advantages:

- To control all types of microorganisms, including those which are chlorine-resistant, withoutusing any chemicals.
- Improves disinfection efficacy
- Reduces environmental, health and safety risks
- Eliminates formation of disinfection by-products

The treated effluent will be discharge back into the Bharalu River at each STP location.

2.7 Septage Management Plan

As per EPA's definition (EPA 1999), "septage" can be defined as a combination of liquid and solid materials that is pumped out from a septic tank, cesspool, or other primary treatment source. The scum accumulates on the surface of this aggregate and the sludge settles to the bottom, which comprises about 20 to 50% of the total septic tank volume when pumped. A septic tank can usually retain 60 to 70% of the solids, oil, and grease passing through the system.

As given in a policy paper by CSE (CSE, 2011), as per the Centre Pollution Control Board (CPCB) study, out of 38.254 billion litre of sewage generated in India on a daily basis, the treatment facilities are available for 30% of this volume, i.e. 11.787 billion litres per day. Indiscriminate disposal of domestic wastewater is the main reason for degradation of water quality in urban areas, having direct negative impacts on health, economy, and environment, and the town of Guwahati is not any exception. Major part of urban India is yet to be connected to the municipal sewer system (e.g. Guwahati) and the people are mainly dependent on the conventional individual septic tanks. As per US AID (USAID, 2010), an estimated 29% of the entire population of India uses septic tanks.

A comprehensive program for septage management aimed at regulating periodic septic tank cleaning, septage transport, its treatment, reuse, and disposal are fast becoming important for cities wherever centralized systems for sewage collection, transport and treatment are not yet available. This is specially the case in part of Guwahati city and particularly the project area, i.e. catchment of Bharalu river. One such program will serve to improve city sanitation while reducing the prevalence of waterborne diseases. In order to be effective, such programs should take into account existing practice of septic tank with regard to its usage, design, and construction. Implementation of a septage transportation and treatment program is something that the ULB or other organizations will be tasked with.

De-sludging septic tanks when 1/3rd of the tank is filled with settled solids has been advised by the Advisory Note on Septage Management, 2013. Adopting this, the right approach and practice should be to remove only the septage from the septic tank and not the entire sewage and septage volume.

Therefore, taking a de-sludging interval of 2-3 years (as per CPHEEO guidelines) for the existing septic tanks (adopting an average capacity of 12 m^3), the septage volume that would have to be de-sludged is 1/3rd of the total volume. This means that 4 m^3 is required to be de-sludged from every tank once every 2 or 3 years.

From a technical standpoint, periodical de-sludging also helps in reducing pollution levels in the effluent, which would otherwise culminate into natural water bodies untreated. But, a little amount of sludge should be left in the tank to maintain a reasonable concentration of necessary microorganisms responsible for anaerobic digestion of the septage being stored in the tank.

Based on the population, number of households in the city, the de-sludging interval and the number of working days in a year, it can be estimated that the septage quantity that can be collected in the Bharalu catchment area is approximately 230 m^3 per day. It has been learn that presently Guwahati Municipal Corporation maintains 2 nos. 3,000 liter capacity vacuum trucks for de-sludging of septage from households. These trucks are at the most able to make 4 to 5 trips per day. Therefore, a total amount of about 24 m^3 of septage can be collected with this present resource.

2.8 Details of Centralized Option

The Guwahati Metropolitan Development Authority (GMDA) has prepared a DPR for the development of a sanitary sewage collection and treatment system for an area identified as Zone-1 of the City Guwahati for 48 Wards and a projected 2035 population of approximately 1.5 million people.

In a DPR prepared by GMDA the proposed sewerage system for Zone-1 consists of a conventional system with the following elements:

- Collection system with sewers (trunk mains, branch and laterals) and sewer appurtenances
- Conveyance system (pumping stations and rising/gravity main)
- 187 MLD capacity STP
- Final locations of the treatment plants
- The treated effluent can be discharged to the water body.
- Proposed STP located downstream to the intake point for water supply.
- Proposed STP located at an approximate elevation of 50 m (MLW) which is above the recorded High Flood Level.

The treatment processes have been selected based on raw sewage quality, techno-economic feasibility and suggestion from the funding agency (JICA) and approving authority. It has been decided to consider Activated Sludge Process for the STP. The treated sewage discharge will be disposed to the Basistha. Hence, the STPs have been designed in such a way as to meet the discharge standards (BOD: 20mg/l) set by the regulatory body for inland water discharge/ State Pollution Control Board. Alternatively, the treated waste water will be used for watering agricultural fields / horticulture. Solids generated through the waste water are proposed to be transported to a landfill, and partly used as agricultural fertilizer after being dried to a 50–60% moisture content at the STP.

As described in the previous chapter, two of the options considered include the construction of a central STP. As a result of the previous efforts completed by the City, alternative locations for the central STP have not been considered, rather it is proposed that a phased approach to the City's DPR be implement by which the Bharalu catchment area be prioritized such that the collection and treatment of the sewage entering the Bharalu and Bahini rivers will be accomplished first.

As described in Chapter 2.3.1 above, the Bharalu catchment area has projected 2035 population of approximately 1.0 million people.

- The sewerage system will be designed as follows: STP for the intermediate design period (i.e., for 2035) and a sewer network for the ultimate design year of 2050.
- The sewerage system for the Bharalu catchment area will be taken up after the water supply system is implemented in these wards.

Table 2-8: Projection for Total Waste Water Generation for Bharalu Catchment Area

River	Population			Sewage Contribution (lpcd)	Sewage Generation in MLD		
	2020	2035	2050		2020	2035	2050
Bahini	3,97,166	6,08,842	11,80,661	125	44	58	137
Bharalu	2,75,644	3,97,984	4,09,605	125	25	33	38
Total	**6,96,916**	**10,06,826**	**15,90,266**		**69**	**91**	**175**

2.8.1 Capacity of STP

As part of the restoration of the Bharalu, four (4) options for the removal of raw sewage from polluting the river were considered. Option 1, will consist of full separation of the domestic waste in a separate sanitary sewer collection system and will convey the collected waste to a 91 MLD STP central sewage treatment plant. This option is consistent with the DPR developed by the GMAC for the collection and treatment of sewage for the South Central and Eastern portion of Guwahati, as identified as Zone 1, in Figure 2-2, with the exception that only the areas contributing to the Bharalu are considered for this plan. The length of sewage collection system for this option is summarized as follows:

Table 2-9: Length of Sewer Lines for Separated System – Option 1

Sewer System	Length (m)
Trunk Mains	51,755
Laterals	92,099
Pumping Mains	3,677

The alternative option considered as Option 3 is to only install the trunk mains along the banks of the river which would capture the combined sewage and storm drainage in intercept it from the roadside drainage channels and convey it to the centralized STP. A summary of the lengths of sewer lines is presented in Table 2.7.

Table 2-6: Length of Sewer Lines for Combined Interceptor System – Option 3

Sewer System	Length (m)
Trunk Mains	39,145
Pumping Mains	2,400

In addition to the Trunk mains, lateral sewers and pumping mains, 20 lift stations will be required to lift the sewage from the interceptors and discharge it into the de-centralized STPs.

2.8.2 Land Available for Various Components

The proposed STP for Zone 1 will be located on government owned land in Boragaon, on the bank of Basistha near Garchuk. The the land area required for the STP is estimated to be 170 bighas (Note: 1 bigha = 1,337.8 m^2). Approximately 100 bighas will be required for the initial phase of construction to support the 91 MLD STP, if phase construction is proposed.

2.8.3 O&M Cost of Proposed Works

Operation and Maintenance of the centralized STPs, will require expertise in wastewater treatment plant operations. The O&M costs have been derived based on the GMAD DPR for the City of Guwahati sewer system. The costs presented in the table below include the O&M of the STP, pumping/lift stations, the sewage network, and staff (both technical and administrative) , electricity, chemicals and sludge screening and disposal.

Table 2-11 – O&M Costs for Central 91 MLD STP

SI No.	Item	Annual Cost (₹ in Crores)
1	Staff	5.00
2	Operational Costs	13.00
3	Annual Repair and Maintenance	2.00
	Net Total Annual O&M Costs	**20.00**

2.8.3.1 Life Cycle Cost of Proposed Works

Cost is the prime consideration in the selection of the treatment method. It should include the cost of installation, capitalized cost of maintenance and operation taking into account interest charges and period of amortization. An alternative will be to consider the annual cost covering amortization and interest charges for the loan obtained for the installation together with the annual operating and maintenance costs.

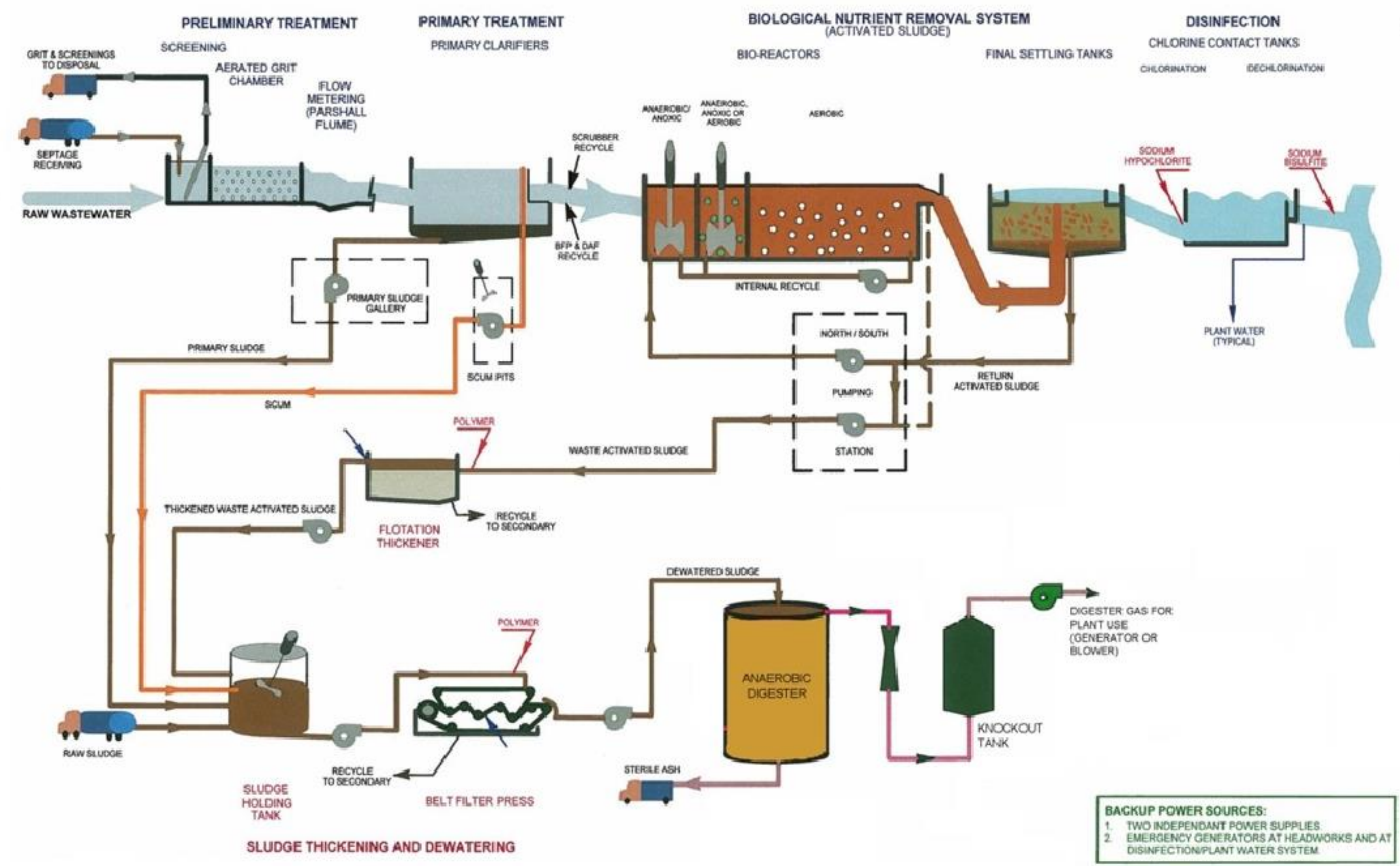
Proposed Sewage Treatment Technology

The GMAD DPR investigated the pros and cons of treatment processes and its suitability to the conditions of the Guwahati city the suitable treatment option is found to be UASB followed by Final Polishing Unit (Facultative Aerated Lagoon). The major difference between two processes is only in respect of the land requirement and the use of process energy. Keeping in view, the availability of land or its constraints it is recommended to adopt UASB. An Extended Aeration and Activated Sludge process will require more electrical power to run and also higher maintenance cost as compared to UASB, hence it was not recommended. A typical wastewater treatment plant process diagram is included in Figure 2-7.

Effluent BOD5 shall be 20 mg/l and effluent solid content shall be 30 mg/l to meet the State Population Control Board norms for discharge of treated effluent into inland surface water. The raw municipal sewage flow coming to the plant will first be screened and grit will be removed in the same way as for conventional plants. The flow is then taken to a distributing inlet chamber from which several vertical pipes take the flow down the Up-flow Anaerobic Sludge Blanket (UASB) reactor of 4.5 to 5 m depth (for BOD values around 200-300 mg/1) and release it uniformly in the lower part of the reactor allowing it to rise at a desired velocity up to the outlet which is at the upper part of the periphery of the unit.

In the UASB process, sewage will be passed through the anaerobic reactor in an up flow mode, with a hydraulic retention time (HRT) of only about 8-10 hours at average flow. No prior sedimentation is required. The anaerobic unit does not need to be filled with any stones or other media; the upflowing sewage itself forms millions of small “granules” or particles of sludge which are held in suspension and provide a large surface area on which organic matter can attach and undergo biodegradation. A high solid retention time (SRT) of 30-50 or more days occurs within the unit. No mixers or aerators are required, thus conserving energy and giving very low operating costs. The gas produced can be collected and used if desired. Anaerobic systems function satisfactorily when temperatures inside the reactors are above 180-200C. Thus, in most parts of India, cold temperature are not a problem.

Excess sludge will be removed from time to time through a separate pipe and sent to simple sand bed for drying. The nutrients, nitrogen and phosphorus are not removed but are in fact conserved in the process and, to that extent, make irrigational use of the effluent more valuable.



POLLUTION CONTROL BOARD, ASSAM	The Louis Berger Group Inc. and DHI (India) Water & Environment Pvt. Ltd.	CONSERVATION OF BHARALU RIVER, GUWAHATI, ASSAM	2013

Various treatment processes are individually described below:

Screening: Screens shall be used to remove the material which would otherwise damage equipment, interfere with the satisfactory operation of treatment units or equipment. The screens of thickness 10 mm and spaced 25 mm c/c shall be mechanically cleaned and shall be erected almost vertically. Such bar screens have openings 25% in excess of the cross section of the sewage channel.

Grit Removal: Grit Chambers are provided for the removal of sand, ash and clinkers, egg shells and many inert materials organic in nature. Removal of grit also reduces the frequency of cleaning of settling tanks. The grit chamber is designed for peak flows and the flow velocity is maintained constant within the range of flow. The quality and quantity of grit varies from sewage to sewage. These factors are very useful in proper design of grit collecting, elevating and washing mechanisms. Hydraulic control device e.g. Parshall flume shall be provided at the end of the channel to keep the velocity relatively constant over expected flow fluctuations.

UASB Reactor: The Up-flow Anaerobic Sludge Blanket Reactor maintains a high concentration of biomass through formation of highly settle able microbial aggregates. The wastewater flows upwards through a layer of sludge. At the top of reactor phase separation between gas-solid-liquid takes place. Any biomass leaving the reaction zone is directly re-circulated from the settling zone. The process is suitable for both soluble wastes and those containing particulate matter.

Gas collection and Gas Holders: Sludge gas is normally composed of about 60 to 70% methane and 25 to 35% carbon dioxide by volume, with smaller quantities of other gases like hydrogen sulphide, hydrogen, nitrogen and oxygen. The combustible constituent in the gas is primarily the methane. Sludge gas should be collected under positive pressure to prevent its mixing with air and causing explosion. A gas dome above the digester roof should be used for gas take off. The velocity in sludge gas piping should not exceed 3.5 mps to prevent carry over of the condensate from the condensation traps and avoid high pressure loss and damage to meters or flame traps and other appurtenances of the system. Where the gas is to be used as domestic fuel or for power generation, additional equipment like compressor, H2S Scrubber may have to be used. The primary purpose of a gas holder is to adjust the difference in the rate of gas production and consumption as well as to maintain uniform pressure at the burner. When gas holders are used for storage of gas for utilization, a storage capacity of at least 25% of the total daily gas production should be provided.

Aerated Lagoons: Aerated lagoons are generally provided in the form of simple concrete/brick lined earthen basin with inlet at one end and outlet at other to enable the wastewater to flow through while aeration is usually provided by mechanical means to stabilise the organic matter. Facultative aerated lagoons are those in which some solids may leave with the effluent stream and some settle down in the lagoon since aeration power input is just enough for oxygenation and not for keeping all solids in suspension.

Sludge Drying Beds: The dewatering of digested sludge is usually accomplished on sludge drying beds which can reduce the moisture content to below 70%. Dried sludge can be used for soil conditioning. Where digested sludge is deposited on well drained bed of sand and gravel, the dissolved gases tend to buoy up and float the solids leaving a clear liquid at the bottom which drains through sand rapidly. The major portion of the liquid drains off in a few hours after which the drying commences by evaporation. The sludge cake shrinks producing cracks which accelerates evaporation from the sludge surface. Sludge is generally spread to a thickness of 15-30 cm over the sand which is kept about 20 cm deep and supported on a gravel bed about 30 cm deep, through which is laid an open-jointed earthen pipe 15 cm in diameter spaced about 3 m apart and sloping at a gradient of 1 in 150 towards the filtrate sump. The drying time averages about 1-2 weeks in warmer climates and 3-6 or even more in unfavorable ones.

Surface Aeration: Surface Aerators are used for transferring oxygen in preference to diffused aeration system. Some of the advantages of using surface aerators are higher oxygen transfer capacity, absence of air piping, air filters and simplicity of operations / maintenance. Surface Aerator consist of large diameters impeller plates revolving on vertical shafts at the surface of liquid. A Hydraulic jump is created by the impellers at the surface causing air entrainment in the sewage and also inducing mixing. The speed of rotation is usually 70 - 100 rpm for geared motor system.

Discharge of Treated Effluent - Effluent received from the sewage treatment plants have the characteristics of suspended solids 30 ppm and BOD of 20 ppm. These concentrations confirm to prescribed standards for the disposal of treated effluent into inland surface waters / rivers. The treated effluent is therefore recommended to be finally disposed of to the Brahmaputra near the bridge connecting North and South Guwahati. Treated effluent should be disinfected vie either chlorination of Ultra-violet disinfection systems. Chlorine is proved to be economical and effective for treating wastewaters.

- To remove effectively odor causing compounds.
- Chlorine residues that remain in wastewater effluent can prolong the disinfection even after treatment.

- Chlorine residues that remain in wastewater effluent can prolong the disinfection even after treatment.
- May require de-chlorination to protect the receiving waters.

The estimated capital costs for the centralized options are presented in the table 2-12. below.

Table 2-12 Full Sewer Separation and Centralized 91 MLD STP – Option 1

S.No.	Item	Qty	Unit	Rate (Rs.)	Amount (Rs.)
1	**Separated Sewer System**		m		
	Trunk Mains	51,755	m	1,550	80,220,250
	Laterals	92,099	m	9,300	856,520,700
2	Pumping Mains	3,677	m	6,200	22,798,478
3	Pumping Stations	5	Each	10,735,308	53,676,540
4	Utility Relocations	47,951	m	7,625	365,628,917
5	Sewage Treatment Plant	91	MLD	13,200,000	1,201,200,000
7	Contingiencies			5%	258,000,000
8	Grand TOTAL			Aprox	**271 crore**

In addition, O&M cost of about 125 Crore Rs. will be required for the STP as well as the sewer network. Therefore the total cost of the centralized option is about 396 Crore Rs.

2.9 Decentralized Option

The decentralized option is shown in Figure 2-5.

The main consideration behind this option is to allow treated effluent discharge into Bharalu to sustain flora, fauna and life. The sewerage scheme to be taken up during the project as part of the first phase is designed for the Bharalu catchment areas (wards) directly discharging waste water to the river. This addresses the needs for providing an effective interception of sewage before it enters into the river, conveyance, treatment, and disposal system to safeguard the River and also to maintain normal ecological system of the river. A series of decentralised treatment plants have been proposed to be implemented. This option will be constructed as a first phase of the Guwahati Sewerage Master Plan and therefore, is designed for waste water generation of 2020 only (70 MLD). 14 sets of modular decentralized STPs will be installed along the Bharalu river.

Figure 2-6 shows the interceptor arrangements at the waste water outfalls.

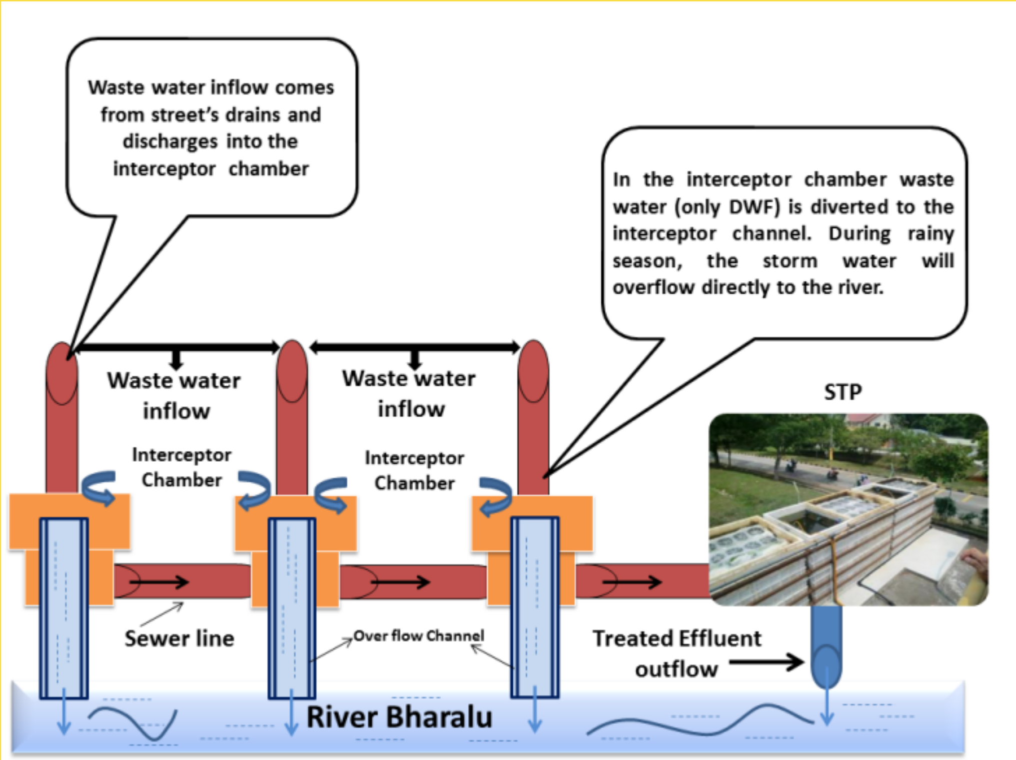


Figure 2-6 Interceptor and overflow arrangements

As shown in Figure 1.9 total outfalls in Bharalu from Bahini at Nutan bazaar to Bharaumukh are given in Table 2-13. Three minor outfalls will be combined into one structure to provide inflow to one set of interceptor chamber. Therefore, a total of 42 such chamber arrangements will be made along the Bharau river.

Table 2-13 Number of Outfalls and proposed interceptor chambers

Type	Left Bank	Right Bank	Total
Major (with gate)	3	15	18
Minor	31	47	78
Total			96
Proposed interceptors combined overflow structures	11	31	42

Figure 2-7 shows a typical modular STP for a decentralized arrangement.

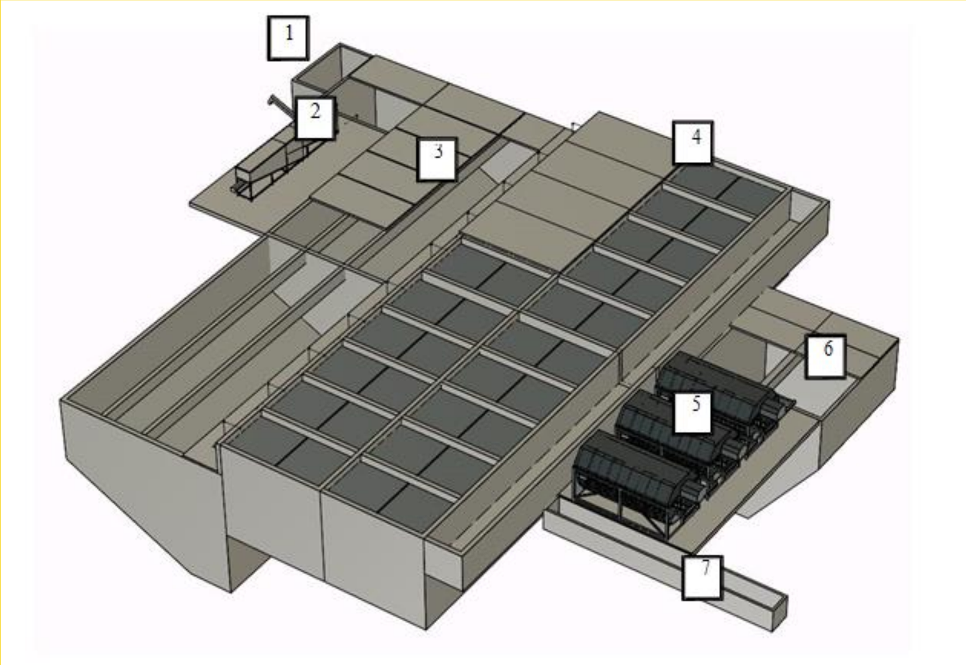


Figure 2-7 Typical Modular structure of a decentralized STP (bio-reactor type)

In the above figure the various components are arranged as follows:

1. Inlet Pump Well
2. Pre-treatment : Sand, Grease, Fat, Oil trap
3. Buffer Tanks
4. Bio Reactors
5. Removal of Bio Sludge
6. Sludge Dewatering
7. Tertiary Treatment : UV and / or Chlorination for disinfection.

An estimated of cost of the Decentralized STP option is given Table 2-14 and for the interceptor structure the estimated cost is given in Table 2-15.

Table 2-14 Estimate d cost of Decentralized STP option

S.No.	Item	Qty	Unit	Rate (Rs.)	Amount (Rs.)
1	14 sets of 5 MLD decentralized STPS including installation, all inclusive	70	MLD	2,37,30,000	166,11,00,000
2	O& M cost for 5 years @ Rs. 4000/MLD/day, with escalation adjusted factor	1	LS		13,55,06,250
	Grand Total				179,66,06,250
				Approx	**180 Crore**

Table 2-14 Estimated cost of Interceptor Structures for the Decentralized STP option

S.No.	Item	Qty	Unit	Rate (Rs.)	Amount (Rs.)
1	Intercepting Chamber	42	No	750,000	3,15,00,000
2	Interceptor	32	km	500,000	1,60,00,000
3	Repair of outfall drains	96	No	400,000	3,84,00,000
4	Other civil works, gates	1	LS	1,00,00,000	1,00,00,000
5	Sub total				9,59,00,000
6	Contingencies			5%	47,95,000
	TOTAL				10,06,95,000

2	O& M cost for 5 years @ 2% of capital cost per year with escalation adjustment factor	1	LS		1,51,04,250
	Grand Total				11,57,99,250
				Approx	**11.60 Crore**

Total of STP and the interceptor structures is estimated to be about 191.60 Crore Rs.

2.10 Operation and Maintenance

Operation and Maintenance of the de-centralized STPs, will require expertise in wastewater treatment plant operations. The operation of 14 de-centralized STPs will require a staff of maintenance personnel and equipment such as pick-up truck, sludge removal equipment, by-pass pumps, vacuum trucks, etc. In addition, for the interceptor sewer option, Option 4, a septage management plan will need to be implemented to remove the setpage from the household septic tanks. This can be taken up by individual households with motivational support form PCBA/GMC. This will not require any additional costs, as costs of awareness and education will be included in a separate component of the DPR.

3 OPTION ADOPTED

3.1 Cost Comparison

	Centralised Option (cot in Crore Rs.)	Decentralised Option (Cost in Crore Rs.)
STP and sewerage network including O&M	396.00	
STPs and interceptor structures including O&M		191.60

3.2 Impact of the Proposed Works on the Health of the River

In addition to the costs, the centralised option has the disadvantage that the treated effluent will not be discharged back to the Bharalu river, therefore, the river will more or less run dry in the dry season making the condition worse that at present.

The effect of raw and treated sewage discharged from street in river can have a significant localised impact on the river environment. It can be disturb the water health means BOD will be increase. Potential impacts of sewage on human health and aesthetic issues in the vicinity of popular bathing ghats.

Biochemical Oxygen Demand - when human waste, Commercial waste and is discharged into the river, bacteria feed on the organic matter within the sewage. As the organic substances are decomposed by the bacteria, dissolved oxygen in the water is consumed. If large quantities of waste are discharged into the water the bacteria's biochemical oxygen demand (BOD) can seriously deplete dissolved oxygen levels in the water.

The reduction in dissolved oxygen levels can have serious consequences for fish and other flora and fauna, which depend upon oxygen for survival. High levels of BOD resulting from waste discharge are a particular problem in low flushing areas where water circulates only slowly. However, it should be noted that there are many other significant sources of high BOD including decaying plants and animal wastes.

Nutrient Enrichment - human waste discharges contain phosphorus and nitrogen in varying quantities. Phosphorous and nitrogen are nutrients which are essential for plant growth. However, when present in the water in excessive quantities these nutrients can trigger algal 'blooms' which reduce light penetration through the water column. Populations of submerged aquatic vegetation or macrophytes which rely on light transmission for survival can be seriously affected by such blooms. As the algae die, the process of decomposition also increases BOD in a similar way to that of sewage decomposition.

It used to be said that "the solution to pollution is dilution." When small amounts of sewage are discharged into a flowing body of water, a natural process of stream self-purification occurs. However, densely populated communities generate such large quantities of sewage that dilution alone does not prevent pollution. Instead of discharging sewage directly into a nearby body of water, it's better to let it pass through a combination of physical, biological, and chemical processes that remove some or most of the pollutants. This takes place in sewage treatment plants.

Sewage treatment plants neutralize and deactivate the chemicals found in the sewage water. They work by relying on the bacteria that is found in our colons, which eat away the nitrates, phosphates and organic matter that is found in sewage. These plants can be expensive to build and operate for many governments, but there are cheaper alternative which rely on nature to do most of the work. This is done by rebuilding or restoring wetlands, because the plants and bacteria found in the wetlands will do the same thing that bacteria in standard sewage treatment plants do. This helps the environment in two ways: restoring river, wetlands and treating human waste water before it pollutes the natural waterways.

There is limited possibility of water augmentation, which will be addressed in detailed in the DPOR.

3.3 Recommendation

As discussed in Chapter 2 above and section 3.1 and 3.2, the decentralized option of providing 14 numbers of 5 MLD modular STPs is recommended. The existing waste waterfalls will be directed to a number of combined interceptor chambers to trap the Dry Weather Flow (DWF) and transport via interceptors along the sides of the river to the nearest STP. By this arrangement, storm water will be allowed to overflow to the river.

4 INSTITUTIONAL ARRANGEMENTS

4.1 Existing Institutional Framework

To develop an institutional mechanism, it is very essential to identify and understand the mandate of various key agencies associated with the project. As discussed earlier in Section 1.1.13, the primary development agenda of Guwahati is carried out by two main agencies: the GMC and the Guwahati Metropolitan Development Authority (GMDA). The area covered under GMDA is 264 km^2 (i.e., the GMC area of 216 km^2 and an additional 48 km^2).

Multiple civic agencies operate in Guwahati with overlapping jurisdiction and similar service responsibilities often results in duplicitous efforts as depicted in Table 4-1). It creates confusion for the general consumer, who has to deal with a number of agencies often for very same service delivery. Wherever possible, the functioning of the agencies must be streamlined to bring it under one agency, which will not only help in improving service delivery but also bring about accountability. For example, the planning and design for drainage could be entrusted to the PHE department and the construction could be with the PWD. It is imperative that the various agencies must be brought under the GMC, where the GMC should have the overall responsibility of providing infrastructure services in Guwahati and while utilizing the services of other agencies on an as-needed basis.

Table 4-1: Institutional Framework

Infrastructure	Planning and Design	Construction	Operation and Maintenance
Water Supply	PHE/AUWSSB/GMC	PHE/AUWSSB/GMC	PHE/AUWSSB/GMC
Sewerage	PHE/AUWSSB/GMC/ FCD	PHE/AUWSSB/GMC/ FCD	PHE/AUWSSB/GMC/ FCD
Drainage	PHE/AUWSSB/GMC/ FCD	PHE/AUWSSB/GMC/ FCD	PHE/AUWSSB/GMC/ FCD
Storm Water Drainage	GMDA/GMC/T&CP	GMDA/GMC	GMDA/GMC
Solid Waste Disposal	GMC	GMC	GMC
Municipal Roads (including flyover)	PWD/GMDA/GMC	PWD/GMDA/GMC	PWD/GMDA/GMC
Street Lighting	PWD/GMDA/T&CP	PWD/GMDA/GMC	PWD/GMDA/GMC
Town Planning	GMDA/T&CP	GMDA	GMDA

Notes: PHE - Public Health Engineering
PWD - Public Works Department
FCD - Flood Control Department
T&CP: Town and Country Planning

As discussed in Section 1.4.4, GMDA has prepared a DPR for the development of a sanitary sewage collection and treatment system for an area identified as Zone 1 of South Guwahati for 48 wards and a projected 2035 population of approximately 1.5 million people.

- The sewerage system will be designed as follows: STP for the intermediate design period (i.e., for 2035) and a sewer network for the ultimate design year of 2050.
- The sewerage system for the Bharalu catchment area will be taken up after the water supply system is implemented in these wards.

The waste water collection system has been considered a "Separate System". For the waste water collection system design, the parameters and guidelines of CPHEEO "Manual on Sewerage and Sewage Treatment" second edition were adopted. The sewerage system will be designed for the peak flow for year 2050. The projected population considered for the water supply system was adopted for the sewerage system.

Many times there is an overlap in the roles of several bodies with the result that the efficiency with which the function should be performed suffers. The state Government needs to resolve such overlaps. The role of each institution involved needs to be very clearly specified. As the Bharalu River flows through diverse landscape, catering to various needs, multiple agencies can be having different roles in its management. That is why, an umbrella organization with core overall responsibility coordinating with all such bodies listed below will be necessary to avoid overlap or any conflict of interest.

- Pollution Control Board of Assam
- Guwahati Municipal Corporation (GMC)
- Guwahati Municipal Development Agency (GMDA)Board
- Public Health Engineering Department, Assam
- Town and Country Planning Department, Assam
- Water Resources Department, Assam

The institutions that are involved in the conservation programme of the Bharau River and the wards on its bank suffer from certain weaknesses that need to be overcome. Major among them are:

- Lack of adequate and trained manpower
- Lack of sufficient technical knowledge and awareness
- Lack of decision making capacity
- Lack of tools and utilities
- Lack of coordination between concerned departments
- Absence of an established institutional mechanism

It is expected that with the formation of a dedicated agency with adequate devolution of power, most of the above shortcomings can be addressed.

4.2 Project management Unit

For the implementation of the project, a Project Management Unit (PMU) will be established under PCBA, which will take care of funds related to the project and manage the planning and implementation of the project. PMU will ensure a clear allocation of funds for the management of the activities related to the project and will orient the internal organization towards an integrated functioning of the project. Such board form of management will ensure a clear cut budget and allocation of expenditures, allows better management of tasks and integrated planning, execution and maintenance of the project. PMU will also coordinate with all the departments connected with the project and the general stakeholders. PMU will be supported by a Project Management Consultant (PMC) during the project implementation period. Capacity building needs of PMU include, but not limited to the following:

- Administrative: Administrative capacity building would focus on strengthening of administrative functioning of the project and also to ensure accountability and transparency.
- Legal: Legal capacity building initiative would include adherence to all regulations pertaining to river water pollution.
- Project management: For the Successful project management, manpower skills would be enhanced through sufficient and relevant training, and sufficient physical and financial resources would be generated during the course of the project to deal with all the aspects mentioned above in all the phases of the project.
- Human resources: Human resources are increasingly recognized as a key asset of any successful and visionary project plan. Poorly trained human resources leads to poor performance and functioning of the project and will lead to ill management and poor quality in performance. Human Resources Development will deal with appropriate skill development in the organizations involved in the planning, design and management of the project. The main activities are listed below

4.3 Training needs Assessment

Human resources and related training needs are different for different fields. For example, for a sewerage system, there is the necessity of identifying the manpower training needs in managing the sewerage plants, power stations, in monitoring water quality and maintenance of equipment. Skilled manpower is needed, particularly for maintenance of developed works, equipment and manning of the sewerage and pumping stations. For the handling of various instruments, special training is needed as good handling of the machine increases their lifespan; moreover, regular wear and tear of the machinery can be rectified and repaired by the project manpower if they are trained appropriately. This will go a long way in reducing unnecessary overhead costs.

Presently, different organizations viz. PHED, AUWS&SB, GMDA and GMC are responsible in different areas of Guwahati city for the issues related to Sewerage. Though most of the employees of the existing organizations are qualified by education required for the O & M of the Sewerage system, they are not trained to handle and properly operate and maintain, the latest equipment of drain cleaning. They are not aware of preventive maintenance, resulting in reoccurrence of flooding in same place during monsoon. Training on Concept of separate sewerage system and its merits and demerits is required.

Recruitment of trained engineering personnel for management of sewerage works is an important issue confronting the organizations in Assam. Special efforts to impart in-service training or continuing professional education should go along with employment of such personnel. In view of the rapidly changing pace of technology, engineers need to get updated periodically about newly incorporated instruments and technologies through training and workshops. Enhancement of knowledge, both operational and theoretical will help in running such services smoothly.

Training employees at different levels is recognized as an essential aspect in any public utility agency. However, training cannot end with just one course. To be effective, it has to be a continuous process. In Guwahati, due to lack of sufficient training of field staff, maintenance personnel and engineers, public utility systems like the GMC do not function satisfactorily. It is therefore necessary to provide intensive training to the operation staff which may include:

- Dealing with public and stakeholders
- Importance of proper and efficient sewerage
- Importance of proper and efficient sewerage system
- Advanced training of handling instruments and other accessories required for maintenance work
- Training on maintenance of instruments and works
- Emergency restoration work after flooding and choking of drains
- Efficiency in record keeping
- Other

The outcome of the training will include

- Increased efficiency with advanced knowledge
- Organizational uplifting including economics
- Improvement in quality of Sewerage system;
- Improved public relations; and
- Improved public health conditions due to superior quality and efficient maintenance by trained O & M staff

The following training needs have been identified for the operational staff

- Basic principle of Sewerage, catchment areas, runoff etc.
- Basic Knowledge in the working of Sewerage cleaning equipment's.
- Reasons of blockage of drains
- Reasons of Flooding & Flood mitigation methods
- Preventive maintenance of electrical and mechanical equipment
- Attending to minor repairs, major repairs – procedure to be followed
- Log books – maintenance & upkeep of records
- Importance of keeping good health and hygiene
- Management crises in the operation & Maintenance

Local agencies are capable for providing technical training for operational staff. Some of them are:

- Industrial Institute of Technology, Guwahati – This organization can conduct training for field staff
- Government Engineering College, Guwahati conduct can short term courses for Sewerage
- Institution of Engineers (India), Guwahati Center, can also conduct training course for O & M for field staff

- The Indian Institute of Technology, Guwahati
- State Resource Centre, Department of Public Health and Engineering, Guwahati
- Staff College

These Institutions, which have an interest in the subject, may be asked to develop training modules required for specific needs of the project. They should be involved on a long-term basis so that they develop expertise in all the aspects of this programme. They should be involved in various aspects and activities of the programme.

4.4 Training Programmes

Code	Training module	Organisations	Staff
T-1	Concepts and advances in river restoration and conservation	PCBA, GMC, GMDA, MOEF	Senior administrative officials
T-2	Effluent monitoring & management (enforcement)	PCBA, PHED	Senior technical and managerial staff
T-3	Operation and maintenance of STPs, Pumps	PCBA, GMC, GMDA, PHED	Technical operational staff
T-4	Maintenance of sewerage network including structures	PCBA, GMC, GMDA	Technical operational staff
T-4	River monitoring and operation of water augmentation structures	WRD, PCBA	Technical staff
T-5	Maintenance of river front works	PCBA, private sector	Managerial and maintenance staff
T-6	Public awareness and educational programmes	PCBA, GMC, GMDA, NOGs, civil society members	All levels
T-7	Project Management	PCBA, GMDA, GMC	Administrative and managerial officials
T-8	Exposure, knowledge enhancement	PCBA, GMC, GMDA	Attending national & international seminars & conferences

5 ENVIRONMENTAL IMPACT ASSESSMENT

5.1 Environmental Impact Assessment

The major works which are expected to have an appreciable level of environmental impacts are construction and operation of sewage collection network, pumping stations, and sewage treatment plant. The various types of impacts at different levels of implementation of the scheme (during construction and operation) are mentioned here. Some mitigation measures have also been suggested. Minor impacts during the design phase of the scheme have been neglected.

Air Quality

This section presents an assessment of air quality impacts associated with the construction and operation of the proposed STP activity at Kekarai, Thiruvarur, Tamil Nadu. Major sources of air pollution have been identified namely construction dust emission and road traffic emissions. The sources of air pollutants at the different phases of the development are categorized as follows:

- Construction Phase: Construction works include site clearance, site formation, STP units & administration building works. The major temporary air pollution is dust generated as a result of these construction works. Cutting and welding operation, loading-unloading, operation is mainly responsible for the release of SPM, SO2, NOx, etc. However the overall impact may be rated as direct, short-term, adverse, and reversible.
- Operational Phase: The primary emission sources during the operations phase would include compressor and pumping station operations, vehicular traffic, carbon dioxide and a small quantity of Hydrogen sulphide may be produced in Aerobic Tank.

Noise Quality

The noise quality around the proposed site area is under the permissible limit.

- Construction Phase: The construction of the proposed sewage treatment plant may generate noise during the constructional phase due to activities of loading unloading, material handling and machine operation equipment & vehicular movement. Impact of noise level may be categorized as direct, short-term, adverse, reversible and of low to moderate magnitude.
- Operational Phase: The main sources of noise during the operations phase would include compressor and pumping station, producing wells (including occasional flaring), and vehicle traffic. The noise levels from the pumping stations may between 64 - 86 dBA or between 58 - 75 dBA at about 1 mile (1.6 kilometers) from the station. Other noise pollution during operation would be generated by other mechanical equipment, and sludge dewatering units.

Odour Problems

- Operation Phase - Inlet chamber, grit channels, screening and grit handling, aeration tanks, and sludge holding and dewatering units are the main sources of odor at the Sewage treatment plant.

Water Quality

- • Construction Phase - The construction of the proposed sewage treatment plants, Water augmentation activities will facilitate improvement of water quality in and around the Bharalu River and the Ground water Conditions by avoiding the unhygienic disposal of the raw sewage in the vicinity.
- • Operational Phase: There will not be any adverse impact on the ground water quality since the treated effluent will be within the standards prescribed by the Assam Government. The contaminated discharge will be highly reduced in the River and over a period of time the restoration of natural process, like self-cleaning of the river will enhance.

Solid Waste

The most obvious environmental damage caused by solid wastes is aesthetic, the ugliness of street litter and degradation of the urban environment and beauty of the city. More serious, however, and often unrecognized, is the transfer of pollution to water, ground water. Air pollution can be caused from the inefficient burning of wastes, either in open air, or in plants that lack effective treatment facilities from the gaseous effluents.

Solid Waste Management involves various activities like storage, collection, transportation, disposal etc. These activities even if properly controlled and with proper precautionary measures adopted, may have adverse impact on land, water and air environment, human and environmental health, aesthetics and quality of life. The Environmental Impact Assessment may help in assessing the potential adverse effects of these activities and in formulation of precautions which could prevent these effects from taking place.

- Construction Phase - Solid waste generated during site preparation and construction work would include cut vegetation and typical construction waste (e.g. wasted concrete, steel, wooden scaffolding and forms, bags, waste earth materials, etc.). This waste would negatively impact the site and surrounding environment if not properly managed and disposed of at an approved dumpsite.
- Operation Phase – Grit, screenings and the sludge generated from the treatment plant will be the major source of solid waste generation.

Most development activities are expected to have a beneficial effect on human health by increasing the resources available for food, education, employment, water supply, sanitation and health services. Proper management of solid waste should have minimum effects on environment and health impacts.

5.1.1 Cultural and Socio-Economic Impacts

The construction of proposed Sewer network and sewage treatment plant is a mark beneficial socio-economic aspect since it leads to safe and hygienic disposal of the treated effluent.

- It enhances the existing environment as the untreated raw sewage disposal will be ceased.
- Also, the project will provide employment to the people during the constructional and operational phase hence creating a positive impact due to this project.

5.1.2 Sewerage Network

Construction Phase Impacts

Most of the construction phase potential impacts will be temporary, in the nature of inconveniences to the citizens using the same space for their day-to-day activities, and will eventually withdraw once the construction phase is over. Despite this, the construction stage impacts as identified below need to be addressed and mitigated. Identified types of impact and their tentative mitiagtion are given as below, which will be be further reviewed and elaborated in the DPR stage.

- *Erosion Prevention* – Excavations for laying seweage collection network needs to be scheduled in such a way that large volume of soil should not remain stacked at site for considerable time especially during the monsoon.
- *Prevention of dust nuisance* – Fugitive dust generation from exposed construction surfaces during dry/windy periods is to be suppressed by light spraying of water or by other suitable means.
- *Disposal of spoil* – Major quantity of excavated soil and road crust will be used to fill-up the excavations after pipelines are laid.
- *Emission and noise from plying vehicles and noise from construction activities* – All construction vehicles are to be properly maintained and should have valid *'Pollution Under*

Control Certificate'. Noisy construction activities should be carried out only during normal working hours and local residents are to be advised in advance of any unusual or unavoidable noise.

- *Relocation of utility services* – Some inconveniences to public, such as temporary dislocation of civic amenities like water supply, drainage and sewerage, electricity, telephone and cable TV connection may be caused for relocation and/or replacement of these facilities.
- *Prevention of dust and noise during material handling operation* – Dust and noise producing activities such as stone crushing, bitumen and cement batching plant etc. are to be located downwind and away from habitation settlement wherever practicable.
- *Prevention of soil, ground and/or surface water contamination* – Silt after dewatering is to be immediately disposed in approved disposal site.
- *Prevention of waterlogging/ flooding* – Dewatering during trenching and water testing of new lines are to be regulated in a manner so that it does not lead to waterlogging of the nearby areas.
- *Road safety and traffic management during construction* – Since many roads in the project area are not wide enough, there may be some traffic congestion during the construction phase. In the narrow sections of road, construction activities may cause traffic disruption. A traffic management plan has to be prepared and approved by the ULB.
- *Prevention of accidents and damage to property* – All necessary precautions has to be taken to prevent accidents and/or damage to property. Unforeseen accidents could result in personal injury and/or damage to private or public property.
- *Health and safety of work force* – All occupational and health and safety requirements for work force has to be adhered to. Facilities of periodic health check up of workers must be available free of cost.
- *Environmental health and safety at construction camp sites and construction work sites* – Camps/ work sites are to be located so that they do not interfere with the existing drainage system. Camps/ work sites should have a suitable drainage outlet, if required.
- *Prevention of impacts on places of cultural importance* – Routing of sewers should avoid places of cultural importance including shrines, temples, maazars, mosques etc. to the extent feasible. Safe access to these places has to be maintained.
- *Social impacts* – Since it is not be feasible to provide complete sewerage coverage in all the areas under the project, it might result in some discontent from public residing in the areas which will not be covered by the project. Consultation with elected representatives, public relations and awareness building exercises including information disclosure through several known means has to be carried out by the project to address this issue.

Operational Phase Impacts

During the operational phase the environmental impacts are expected to be mostly positive. Provision of complete sewerage system under this project would minimize wastewater stagnation and waterborne disease propagation in the service area and ensure better sanitation practices. This is expected to lead to abatement of nuisance and public health hazard in the service areas, for instance, improved sanitary conditions is expected to result in reduction in incidence of parasitic infections, hepatitis and various gastrointestinal diseases including cholera and typhoid which occurs either through direct contact with fecal material or contamination of water supply and food.

Other potential adverse impacts during the operational phase are identified, along with their mitigation measures, as follows :

- Due to lack of control there may be discharge of hazardous industrial effluents from existing industries. Regulatory activities being carried out by the Assam Pollution Control Board (APCB), such as strict enforcement of treatment regulations of existing industrial discharge and regular monitoring activities carried out by the APCB would ensure that untreated or inadequately treated effluent from any industry is not discharged into the proposed sewer system.
- There is a potential health hazard to workers engaged in sewer maintenance works. These workers are likely to be exposed to toxic gases and hazardous materials present in the

sewage and are likely to contract communicable diseases from exposure to pathogens present in the sewage.

- There can be some stretches where there will be difficulty in achieving self cleansing velocity during operational stage. To minimize the siltation problem, the operating agency should undertake continual and routine maintenance of the system.
- Lack of proper operation and maintenance of the system could cause overflow of sewage, which would be a nuisance and health hazard to public.

5.2 Pumping Stations

In general, potential adverse environmental impacts from this sub-component are likely to arise from: (a) augmentation/renovation of existing pumps (if any); (b) civil construction of new pumping stations; (c) disposal of silt, soil and debris due to the construction of inlet and outlet channels and other civil works of the pump houses; and (d) safety, security and occupational hazards during construction and operation phases.

5.2.1 Construction Phase Impacts

Construction activities will inflict short-term minor adverse impacts on soil, surface water, air, noise, ecology of the area and quality of life values of nearby habitants and work force. In order to mitigate these impacts, construction phase activities related to earth work has to be scheduled in the dry season so that chances of flooding, inundation, waterlogging and surface erosion become minimal. Exposed construction sites has to be adequately covered to reduce erosion, surface runoff, air pollution, and construction spoils has to be suitably disposed of.

5.2.2 Operation Phase Impacts

Overall operation phase impact is expected to be positive as the proposed pumps have been designed to transmit DWF to next pumping station or STP and will significantly reduce the inadequacy of sanitation facility in the service area. Siltation of the pump houses is a potential impact, which may be mitigated by adequate operation and maintenance of the pumps with regular desiltation.

5.3 Sewage Treatment Plant

5.3.1 Design Phase Impacts

The proposed STP is exepcted to be located in relatively low land. Adequate drainage provisions has to be made in the design of the STPs to avoid flooding during incidence of rain. In addition, the following features have to be built into the STP designs, for both new STPs and the STP upgrades, in order to minimize adverse impacts on the environment :

- Provision of adequate capacity in the canals to receive the expected treated water discharge,
- Proper choice of specification of the pump(s) from the point of view of design capacity and operation at low noise level,
- Proper design of the pump house so as to contain noise within the pump house,
- Provision of a peripheral green belt, and
- Provision of 15-20% open space within the complex to improve scenic quality of the STP area.

5.3.2 Construction Phase Impacts

There may be minor air pollution from dust generation during construction of new STP. Excavations during the construction phase may produce surplus earth and spoil material and these are to be disposed in the designated areas. In order to mitigate these impacts, the following measures are to be adopted :

- Provision of fencing around the construction site with GI sheets all around to prevent encroachment and to ensure community safety,
- Use of construction machineries to the extent practicable so as to limit deployment of labourers and avoid accident,
- Provision of safety training to the construction laborers and ensuring the the provision and use of adequate protection gears for their safety,
- Storage of excavated earth separately for future use in greenbelt development and landscaping,
- Step cutting of earth or timber/metal shoring to be provided during deep excavation to protect against earth sliding,
- Settlement of construction wastewater carrying suspended solids like earth, cement and sand in a brickwork basin; decanted water may then be let into public drains,
- Avoidance of night time work; if at all needed, safety provisions and proper lighting arrangements are to be provided, and no noise generating construction activity is to be undertaken,
- Storage of all construction materials within the fenced area and absolutely not on public thoroughfare,
- Dispose of all construction debris and wastes in the low lying areas, and
- Spraying of water to prevent dust generation as and when required.

5.3.3 Operation Phase Impacts

Noise due to operation of the pumps and moving systems is be confined to the plants. The noise level of the equipment should meet the standard from occupational health point of view (with 85 dBA at a distance of 1.5m from the source). The discharge flow quantity from the STPs has been accommodated in the designed capacity of the receiving canals. Therefore over bank flooding of the canals due to increased discharge is not expected.

During the operation stage, continuous attention has to be paid for maintenance of the environmental improvement brought about by implementation of the sub-components. The STP site should remain all the time neat and clean i.e. with the highest order of house keeping. Adequate operation of the outlet pump(s) is to be ensured so that there is no overflow of untreated or partially treated wastewater from the STP. In case of failure of the pump(s) or prolonged power cut alternative arrangement of power has to be made.

Noise from the operation of the outlet pumps and other moving parts is not expected to add significantly to the ambient noise level if appropriate maintenance of the pumps and regular checking are carried out. Each individual operator may use ear plugs for which provisions will be made.

Special provisions of fresh water must be made to treat operators affected by accidental spillage from chlorinator plant. Sewage water should not be touched by the operators. Adequate soap and detergent are to be kept for washing of hands.

STP may cause bad odour principally by the release of H_2S formed by limited anaerobic reduction of sulphate by sulphate reducing bacteria. Recommended design loading should not be exceeded and sulphate (SO_4) concentration in the raw wastewater should not be allowed to exceed 300 mg/litre so that only odourless HS is produced instead of H_2S by the reduction process if at all formed. ‘No smoking’ signboard will be prominently displayed and carriage of match box or lighter should be prohibited to prevent fire hazard in case bio-gas (methane) is generated.

5.4 Concluding Remarks

The proposed activity will not result in any significant negative impact to Environment. Instead, various beneficial impacts have been envisaged. The proposed measures will give a positive impact in all sectors/segments and will help to improve the river water quality to a great extent.

6 COST ESTIMATES AND RESOURCE REQUIREMENT

6.1 Abstract of Cost Estimates for Each Component of Works

The abstract of costs for the selected sewerage schemes are given below in Tables 6-1 and 6-2.

Table 6-1 Estimate d cost of Decentralized STP option

S.No.	Item	Qty	Unit	Rate (Rs.)	Amount (Rs.)
1	14 sets of 5 MLD decentralized STPS including installation, all inclusive	70	MLD	2,37,30,000	166,11,00,000
2	O& M cost for 5 years @ Rs. 4000/MLD/day, with escalation adjusted factor	1	LS		13,55,06,250
	Grand Total				179,66,06,250
				Approx	**180 Crore**

Table 6-2 Estimated cost of Interceptor Structures for the Decentralized STP option

S.No.	Item	Qty	Unit	Rate (Rs.)	Amount (Rs.)
1	Intercepting Chamber	42	No	750,000	3,15,00,000
2	Interceptor	32	km	500,000	1,60,00,000
3	Repair of outfall drains	96	No	400,000	3,84,00,000
4	Other civil works, gates	1	LS	1,00,00,000	1,00,00,000
5	Sub total				9,59,00,000
6	Contingencies			5%	47,95,000
	TOTAL				10,06,95,000
2	O& M cost for 5 years @ 2% of capital cost per year with escalation adjustment factor	1	LS		1,51,04,250
	Grand Total				11,57,99,250
				Approx	**11.60 Crore**

Total of STP and the interceptor structures is estimated to be about 191.60 Crore Rs.

6.2 Possible Resources

It is expected that the Central Government will provide the major part of the estimated cost through MOEF/NRCD.

6.3 Phasing

The proposed sewerage works are considered as the immediate term or first phase works aimed at conserving the Bharalu river in a period of 3 years (2014-2017). The full sewerage works for the city of Guwahati will be implemented under the Guwahati Sewerage Master Plan Project in the long term by 2020-2015.

7 MAPS

List of Maps created for this PFR are summarized in Table 8-1.

Table 7-1: List of Maps for Bharalu PFR

S. No.	Maps	Description
1	India	State of India, with Assam highlighted as the project location.
2	Assam	District map of Assam; it includes the Kamrup district depicting the Bharalu River Catchment Area in the City of Guwahati
3	River Basin	It includes Bharalu river Basin
4	Bharalu Catchment Area	It includes Bharalu river Basin and Bahini river Basin
5	Outfall Location	It includes all the Sewerage outfall into the Bharalu river
6	Contour Map	It includes contour of Zone 1
7	Road Map	It includes Road in Zone -1
8	Ward Map	It includes ward of Bharalu Basin
9	Water Quality Sampling Location	It includes location of Water quality sampling on Bharalu.

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Appendix A
Water Quality Data (Source: PCBA, 2013)

Table 1. Water Quality of Bharalu at Bharalumukh before confluence with Brahmaputra River (During the period from 2004 to 2008)

Parameters	Month & Year of collection				
	April, 04	April, 05	April, 06	April, 07	April, 08
a. Physical Parameters:					
pH	6.9	6.5	7.3	6.8	7.7
Turbidity (NTU)	7	24.0	23.0	24	34.8
Conductance (µmho/cm)	556	660	648	638	773
b. Organic Parameters:					
DO (mg/L)	0.5	0.7	nil	0.4	nil
COD (mg/L)	49.73	240	148.9	91.5	59.2
BOD (mg/L)	18.5	43	52	19	16
c. Major Mineral Parameters:					
Chloride as Cl (mg/L)	42	44	56	60	124
PO_4 as P (mg/L)	3.48	1.5	2.41	1	10
Sulphate as SO_4 (mg/L)	25.4	27.25	19.87	48.7	16.7
d. Other Inorganic parameters:					
T. ALKALINITY (mg/L)	188	300	288	160	240
T. Hard ness as $CaCO_3$ (mg/L)	118	208	172	160	228
Calcium as $CaCO_3$ (mg/L)	76	108	140	114	120
Magnesium as $CaCO_3$ (mg/L)	42	100	32	46	108
NITRATE-N (mg/L)	0.11	0.04	0.029	0.1	0.1
Total Dissolved Solid (TDS) (mg/L)	368	498	430	486	580
Total Fixed Solid (TFS) (mg/L)	148	404	242	236	112
Total Suspended Solid (TSS) (mg/L)	15	63	28	40	54
Sodium (mg/L)	37	24	62	33.7	44.7
Potassium (mg/L)	10.2	12.8	17	9.4	13.2
Fluoride (mg/L)	0.01	0.09	0.27	0.51	0.59
e. Trace Metals:					
Zinc as Zn (µg/L)	199	2100	2500	319	141.2
Copper as Cu (µg/L)	BDL	BDL	BDL	50	21
Lead as Pb (µg/L)	BDL	BDL	BDL	10	10
Cadmium as Cd (µg/L)	BDL	BDL	BDL	BDL	3
Nickel as Ni (µg/L)	BDL	BDL	BDL	BDL	14.6
Chromium as Cr (T) (µg/L)	BDL	BDL	BDL	50	50
Arsenic as As (µg/L)	BDL	0.02	BDL	1	BDL
Mercury as Hg (µg/L)	BDL	BDL	BDL	BDL	BDL
Total Iron (µg/L)	380	300	480	400	2
f. Bacteriological Parameters:					
Total Coliform (MPN/100ml)	240000	240000	21000	730	2100
Faecal Coliform (MPN/100ml)	240000	240000	21000	730	2100

BDL : BELOW DETECTABLE LIMIT

Table 2. Water Quality of Bharalu at Bharalumukh before confluence with Brahmaputra River (During the period from 2009 to 2013)

Parameters	Month & Year of collection				
	April, 09	April, 10	April, 11	April, 12	April, 13
a. Physical Parameters:					
pH	6.9	7.4	6.8	6.8	6.8
Turbidity (NTU)	7.2	6.9	21	18.2	19.4
Conductance (µmho/cm)	533	697	734	799	836
b. Organic Parameters:					
DO (mg/L)	Nil	Nil	Nil	0.5	Nil
COD (mg/L)	56.4	54.4	160	81.2	85.7
BOD (mg/L)	6.5	30	32	15	48
c. Major Mineral Parameters:					
Chloride as Cl (mg/L)	92	36	14	156	68
PO_4 as P (mg/L)	9.3	10	3.1	10	14.2
Sulphate as SO_4 (mg/L)	52.6	29.4	11.8	23.2	5.6
d. Other Inorganic parameters:					
T. ALKALINITY (mg/L)	204	82	540	260	252
T. Hard ness as $CaCO_3$ (mg/L)	224	92	56	156	150
Calcium as $CaCO_3$ (mg/L)	168	60	38	104	110
Magnesium as $CaCO_3$ (mg/L)	56	32	18	52	40
NITRATE-N (mg/L)	0.10	0.73	0.38	2.4	3.4
Total Dissolved Solid (TDS) (mg/L)	393	432	448	562	548
Total Fixed Solid (TFS) (mg/L)	102	112	206	128	115
Total Suspended Solid (TSS) (mg/L)	38	28	37	33	38
Sodium (mg/L)	4.5	31.7	41	22.8	50.5
Potassium (mg/L)	2	10.1	3.1	6.4	18.4
Fluoride (mg/L)	0.68	0.71	0.56	0.49	0.52
e. Trace Metals:					
Zinc as Zn (µg/L)	144	232	101	142	130
Copper as Cu (µg/L)	10	105	80	61	9
Lead as Pb (µg/L)	BDL	285	10	10	13
Cadmium as Cd (µg/L)	3	2	2	3	4
Nickel as Ni (µg/L)	5.9	45	20	20	BDL
Chromium as Cr (T) (µg/L)	3	46	42	33	57
Arsenic as As (µg/L)	BDL	1.13	1.4	2.2	2.2
Mercury as Hg (µg/L)	BDL	BDL	BDL	BDL	BDL
Total Iron (µg/L)	80	80	320	120	730
f. Bacteriological Parameters:					
Total Coliform (MPN/100ml)	2100	1500	2000	2300	21000
Faecal Coliform (MPN/100ml)	730	720	Nil	910	2000

BDL : BELOW DETECTABLE LIMIT

Appendix B

EREC Environmental Laboratory Surface Water Analytical Result