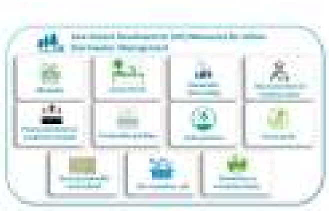
DRAFT FINAL REPORT

STORMWATER DRAINAGE AND FLOOD CONTROL MASTER PLAN








December 2025

PREPARATION OF CHATTOGRAM METROPOLITON MASTER PLAN

Prepared in Association with

datEx-Tiller-EGS JV

datEx DATA EXPERTS

Chattogram Development Authority
Ministry of Housing and Public Works
People's Republic of Bangladesh

PREPARATION OF CHATTOGRAM METROPOLITAN MASTER PLAN (PERIOD: 2025-2050)

Draft Final Report

Stormwater Drainage and Flood Control Master Plan

Date of Submission
December / 2025

Consultant: datEx Tiller EGS JV

TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	
1.1	Background	1-1
1.2	Rationale of SDFM and Study Area	1-1
1.3	Scopes of the Work Component 3	1-6
2.	FIELD VISIT, STAKEHOLDER CONSULTATION AND DATA COLLECTION	
2.1	Field Visit Report	2-1
2.2	Stakeholder Consultation Report	2-1
2.3	Previous Study Reports and Government Policies	2-2
2.4	Primary Data Collection	2-2
2.5	Secondary Data Collection	2-2
3.	EXISTING DRAINAGE CONDITION	
3.1	Physical Description	3-1
3.2	Description of Stormwater Drainage System in Chittagong	3-2
3.3	Poor Drainage Condition and The Causes	3-3
3.4	Division of Drainage Area/Basins	3-9
3.5	Previous Drainage Plans and On-going Works	3-15
4.	HYDROLOGICAL ANALYSIS	
4.1	Rainfall Data Analysis	4-1
4.2	Water Level Analysis	4-3
4.3	Hydrological Scenario Development	4-4
5.	MATHEMATICAL MODELLING STUDY	
5.1	General	5-1
5.2	DEM Preparation	5-1
5.3	Watershed Delineation	5-2
5.4	Model Setup with SOBEK	5-4
5.5	Urban Flood Inundation Pattern in Different Drainage Areas	5-12
5.6	Drainage Conditions of Major Water-logged Areas	5-17
5.7	Drainage Condition with Intervention (Khal Modification)	5-19
6.	OPTIONS FOR DRAINAGE AND FLOOD CONTROL	
6.1	General	6-1
6.2	Elements Comprising the Master Plan	6-1
6.3	Components Of Nature Based Solution/LID For IDP	6-5
7.	MASTER PLAN	7-1
7.1	Drainage Area-wise Measures of Traditional Elements and LID/ NBS	7-1
7.2	General Comments	7-15
7.3	Strategies for Stormwater, Drainage and Flood Improvement	7-16
7.4	Recommended Policy for Stormwater, Drainage and Flood Control	7-18

8. SUMMARY AND CONCLUSION 8-1

ANNEXURE-1: EXISTING DRAINAGE MAPS AND LIST OF EXISTING KHALS

ANNEXURE-2: FLOOD INUNDATION MAPS AND MODIFIED KHALS SECTION

ANNEXURE-3: INTEGRATED DRAINAGE PLAN (IDP) MAPS

CHAPTER ONE

INTRODUCTION

1. INTRODUCTION

1.1 Background

Chattogram Development Authority (CDA) is the authority under the Ministry of Housing and Public Works responsible for development control and promotion of Chattogram. For guided development, Chattogram Metropolitan Master Plan (CMMP) was prepared for the years 1995 to 2015 under which a Structure Plan and Urban Development Plan (1995-2008) were prepared in 1995 for the study area as shown in Figure 1-1. The other two components of that Master Plan were Long Term Development Strategies for Traffic and Transportation (Popularly known as Transportation Master Plan) and Storm Water, Drainage and Flood Control Master Plan (Popularly known as Drainage Master Plan). The final tier of CMMP, the Chattogram Detailed Area Plan was prepared for whole of CMMP area in 2008 under the project of CDA named 'Preparation of Detailed Area Plan for Chattogram Metropolitan Master Plan (CMMP) area within the framework of Chattogram Structure Plan (1995-2015) funded by CDA and GoB.

Since the Structure Plan's term has expired, CDA has taken the initiative to prepare a new set of plans comprising a Structure Plan, a Drainage Master Plan, a Transportation Master Plan, an Environmental Management Plan, and Action Area Plans to guide it between 2020 and 2050. The study area (CDA jurisdiction area) for this project is shown in Figure 1-2. The total area is about 1241 sq km. This report presents the Final Drainage Masterplan. The specific objective to prepare the Storm Drainage Master Plan is to develop a practical and cost-effective drainage improvement plan and a proper inventory of all drainage structures and assess their capacity existed within the study area. The study area has been outlined taking the total jurisdiction of CCC area (Patenga, Bandar, Halishahar, Pahartali, Double Mooring, Kotwali, Bakulia, Khulshi, Panchlaish, Chandgaon, Baizid Bostami) plus potential growth center of neighboring Thanas (Part of Hathazari, Raojan, Rangunia, Anowara, Boalkhali, Patiya, Sitakundu).

1.2 Rationale of the Stormwater Drainage and Flood Control Masterplan and Study Area

The drainage lines of core City of Chattogram include khals, secondary and tertiary drains. The drainage water goes to main khal through secondary and tertiary drains. The major khals of Chattogram are- Chaktai Khal, Rajakhali Khal, and Mohesh Khal. Both Chaktai and Rajakhali Khals are traversing through Chaktai commercial area and Mohesh khal is traversing through the Bandar and Halishahar area and all three terminate in the river Karnaphuli. Also, the drainage water of Agrabad commercial area falls in the river Karnaphuli through a primary R.C.C box drain. There are more than 50 sub khals situated in Chattogram city which are connected through these 3 main khals.

Chattogram Development Authority (CDA) is providing drainage service, and Chattogram Water Supply and Sewerage Authority (CWASA) is providing water supply and sewerage facilities for the core area of Chattogram city. In parallel with CDA, Chattogram City Corporation (CCC) is also responsible for maintaining drainage system and khals (mainly surface drainage which include tertiary drains within the city corporation boundary). CDA is mainly responsible for management of stormwater drainage within its jurisdiction.

As a fast-growing metropolitan city, Chattogram has not developed the drainage system in a planned way. Consequently, blocking of drainage and water logging occur frequently within the core city area. Due to rapid urbanization with unplanned construction, most of the storm water drainage have been encroached, filled up, diverted and caused obstruction to the smooth flow of water to the Outfall Rivers, creating severe water logging in the city every year. On top of that, erratic weather patterns, rising sea levels, onrush of water from hills, and poor drainage system aggravate the problem. CDA prepared a Masterplan in 1995 which expired in 2015 and CWASA prepared a drainage Masterplan in 2016 of the area as shown in Figure 1-1. Despite Masterplans prepared in 1995 and 2016 by CDA and CWASA, waterlogging has become more frequent and intense in recent years, especially in the core area of CDA. Moreover, the jurisdiction of CDA is significantly larger than the study area covered in 1995 CDA Masterplan and 2016 CWASA Masterplan, which is 260 sq km. Therefore, a review of the previous drainage masterplans, their implementation status and limitations need to be assessed to identify the causes of severe waterlogging. Moreover, the masterplans need to be updated to prepare a new drainage masterplan to improve the drainage condition of the city.

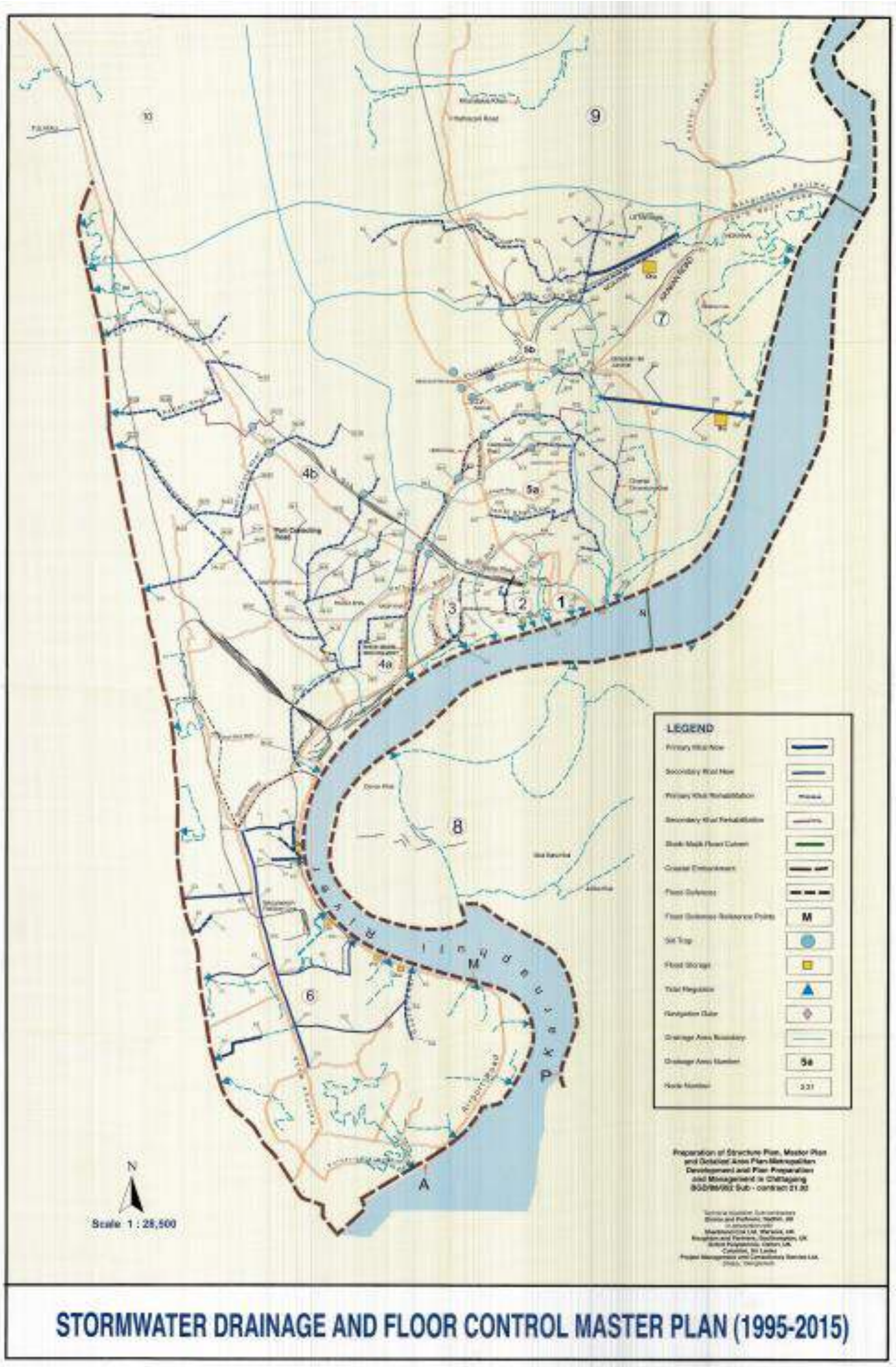


Figure 1-1 Study Area of 1995 CMPP

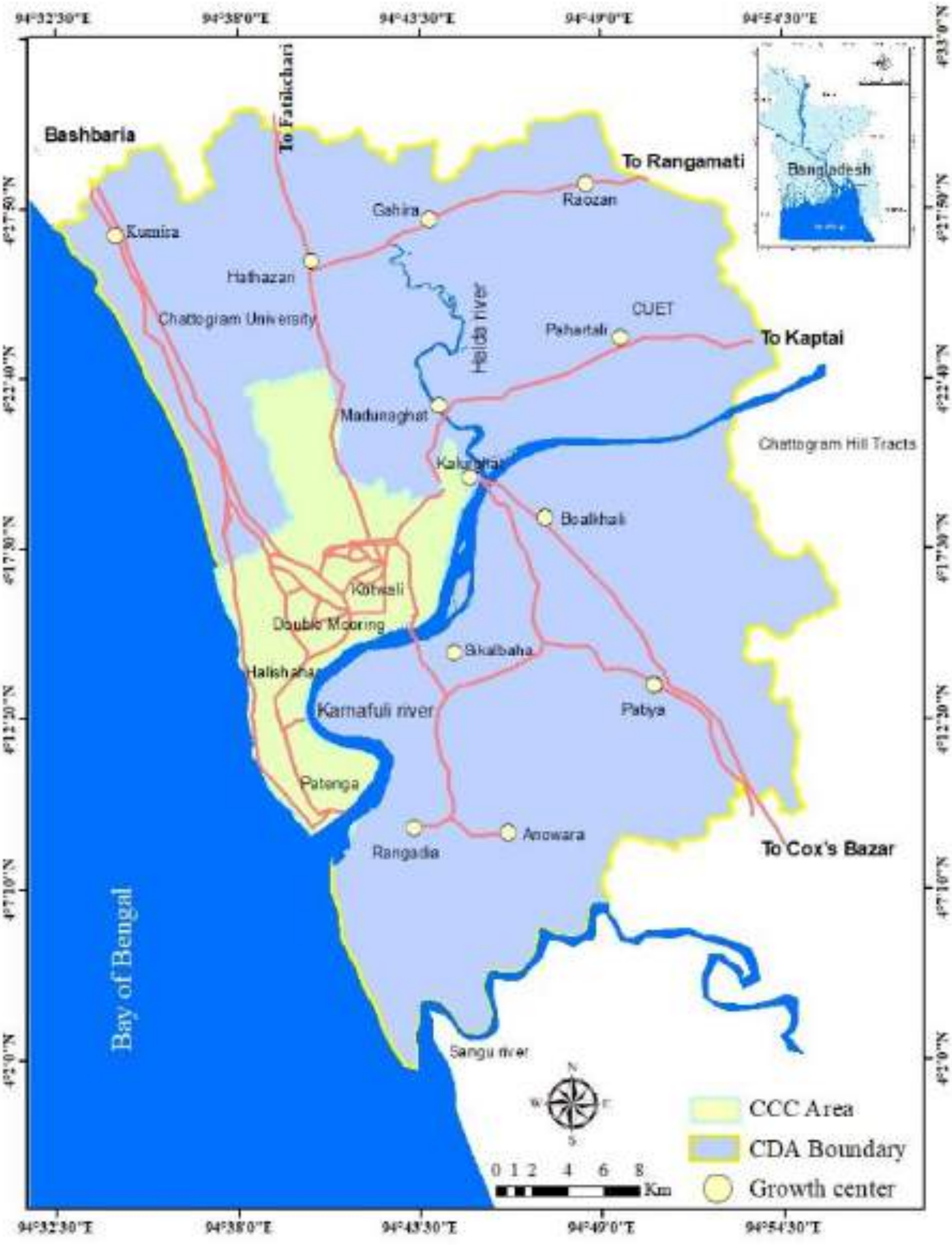


Figure 1-2 Study Area of Current CMPP

1.3 Scopes of the Work Component 3 – Preparation of Storm Water Drainage and Flood Control Master Plan

The purpose of this Component is to critically review the progress and problems of implementing the approved Storm Water Drainage and Flood Control Master Plan (1995-2015) under the CMMP and to prepare a new Storm Water Drainage and Flood Control Master Plan for the period 2020-2050.

The following activities will be required to ensure completion of this Component:

(i) Set the vision, aims and objectives for review;

(ii) Critically review the status and progress of implementing the approved Storm Water Drainage and Flood Control Master Plan (1995 – 2015) and Updated Drainage Master Plan prepared by CWASA in the light of current circumstances, consolidate and incorporation of completed and ongoing projects taken by different Authorities/ Agencies and identify assumptions to be carried forward into the CMMP Review;

(iii) Prepare and implement a Stakeholder Consultation Plan to considering the objective to develop stakeholder awareness and participation; CMMP should be reviewed and updated through extensive consultation with concerned municipality, general citizen, professional groups, and key policy makers. A series of consultation meetings, seminars, and information campaign should be organized;

(iv) Identify conceptual options for implementing Storm Water Drainage and Flood Control Master Plan and investment. Evaluate the conceptual options using a SWOT ('strengths, weaknesses, opportunities and threats') analysis and other evaluation methods, as appropriate;

(v) Prepare a preferred Regional Development Strategy and Plan for the period up to 2050 to include

- The water transport policies and proposals;
- The policies for flood control and drainage;
- Policies for preservation of Natural Water bodies and Waterfront
- Policies for water supply
- Policies for preservation of Halda river and Karnaphuli river
- The nature, scale and location of land areas to be conserved

(vi) Identification and developing flood management techniques

(vii) Define a phasing and implementation plan for developing and investing in the implementation of Storm Water Drainage and Flood Control Master Plan

(viii) Propose the preferred institutional arrangements, including the organizational and regulatory framework required to secure development and investment and the implications of Storm Water Drainage and Flood Control Master Plan

(ix) Developing mechanism for coordination among relevant agencies and departments involved in Storm Water Drainage and Flood Control Master Plan

(x) Identify the potential mechanisms and incentives required to optimize private sector investment in the implementation of the proposed Storm Water Drainage and Flood Control Master Plan;

(xi) Consolidate the above in the form of an updated and new CMMP including Storm Water Drainage and Flood Control Master Plan (2020-2050).

CHAPTER TWO

FIELD VISIT, STAKEHOLDER CONSULTATION AND DATA COLLECTION

2. Field Visit, Stakeholder Consultation and Data Collection

A number of field visits were conducted to physically inspect the physical conditions of the existing drainage networks including the khals, drains, drain/khal crossings (culverts, bridges), outlets and structures in the outlets at selected locations. Meetings with the Project officials and representatives of Chittagong City Corporation were also held to discuss various drainage issues including their perception on the degraded drainage condition of the city area. Consultants also explained their approach to the preparation of the Drainage Masterplan. In addition, questioner surveys were done for each wards of the study area. Furthermore, a number of survey works have been carried out under this project including all the data required for developing a drainage master plan. Moreover, various secondary data have also been collected.

2.1 Field Visit Report

A team of consultants comprising Deputy Team Leader Engr. Ullash and Engr. Shahadat and other team members visited the critical locations in regard to the city drainage conditions on May 18, 2024. The team also met with the Project Director (PD) Mr. Essa Ansary and other project officials. The field visit was conducted as part of the data collection process for the Chattogram Metropolitan Master Plan, specifically focusing on stormwater drainage and flood control. The visit aimed to gather precise geospatial data from various key locations within the metropolitan area to support the development of effective stormwater management and flood mitigation strategies. The team has visited several critical areas, including but not limited to Muradpur, Bahaddarhat, Chawkbazar, Andarkilla, and Halishahar Areas.

General Observations:

These areas are most water-logged prone areas in Chattogram City Corporation area. The water in the khals appears to be polluted. There is a significant accumulation of garbage and debris within the khals. This blockage prevents the smooth flow of water, exacerbating the problem of waterlogging and potentially leading to flooding during severe weather events. The khals are also experiencing siltation, where sediments settle and build up over time. This reduces the khals' capacity to carry stormwater, further increasing the risk of overflow and flooding. These observations underscore the need for comprehensive waste management, regular maintenance of infrastructure, and effective flood control measures to improve the stormwater drainage and overall environmental conditions in the area.

2.2 Stakeholder Consultation Report

The responses from the ward counselors highlight areas with both identified needs for new drains and those where no immediate need has been reported. Based on the questioner survey, the following insights have been identified which will be helpful for the proposed masterplan:

1. Prioritize Immediate Needs: South Pahartali, Panchlaish, West 16th Ward, North Patenga, West Madarbari, Alkoron, Enayet Bazar, East Baklia: These wards have identified urgent needs for new drains. Priority should be given to these areas for immediate planning and implementation.
2. Assess and Plan for Complex Areas: Firingee Bazar, Lalkhan Bazar, Saraipara: Further assessment is required to confirm specific drain needs and to ensure the effective integration of new drains into existing infrastructure.
3. Maintain Existing Infrastructure: West Baklia: Focus on maintaining and enhancing natural canals and existing drainage systems rather than constructing new drains.
4. Investigate Unspecified Areas: Pahartali, South Middle Halishahar: Further investigation is needed to identify any latent drainage issues or confirm if current systems are adequate.

5. Infrastructure Expansion: Alkoron: New drains are needed in various lanes, suggesting a comprehensive approach to expanding the drainage infrastructure in this ward.

2.3 Previous Study Reports and Government Policies and Acts

The relevant reports collected for review for the development of drainage and flood control master plan are provided in Table 3-1.

Table 3-1. List of selected reports

Sl. NO	Report/Acts	Organization
1	Stormwater, Drainage and Flood Control Master Plan (1995-2015)	Chattogram Development Authority (CDA)
2	Detailed Area Plan for CMMP (2008)	CDA
3	Water logging mitigation of Chattogram City	CDA
4	Drainage Master Plan (Draft 2016)	CWASA
5	Sanitation Master Plan (2017)	CWASA
7	Strategic Master plan (2015)	CPA
8	Bangladesh Environment Conservation Act (1995)	Ministry of Environment
9	National Water Policy (1999)	Ministry of Water resources
10	Reservoir Protection Act (2000)	Ministry of Environment
11	National Water Management Plan (2001)	Ministry of Water Resources
12	National Land Use Policy (2001)	Ministry of Land
13	Coastal Zone Policy (2005)	Ministry of Water Resources
14	National Water Act (2013)	Ministry of Water Resources
15	National Water Rules (2018)	Ministry of Water Resources
16	Bangladesh Delta Plan 2100 (2018)	Ministry of Planning
17	CDA Act (2018)	Ministry of Local Government

2.4 Primary Data Collection

Different Primary Feature Data have been collected and generated by the survey team under this study which will be used in this drainage study. For example, Ward Boundaries, Existing Road network, Existing khal and river network, water bodies, Bridge culvert locations, and Digital Elevation model data, khal bathymetry. These data will be helpful in setting up the drainage model using SOBEK model. Details on the data generation are available in the main survey report and the working report.

2.5 Secondary Data Collection

Besides primary feature data collection, several data have been collected from different secondary sources as well. For example, existing drainage network shapefile data has been collected from CWASA. In addition, a number of previous study reports have been collected from CDA and other sources. Soil map classification is also important datasets required for proper modeling of the drainage system of the study area which have been collected from SRDA. Moreover, the land cover pattern of the study area have been monitored through Google Earth and fine-resolution land cover maps produced by Environmental Systems Research Institute (ESRI).

The three hourly water level data (from 6:00 am – 6:00 pm) at two stations (SW120 and SW121) of the Halda river for the period 2000-2020 have been collected from BWDB. The hourly tide data at two locations (Sadarghat and Kalurghat) of Karnafuly river have been collected from Chattogram port Authority for the period of 2012-2022. The daily rainfall data for the period 1948-2014 and three hourly data for 2008-2022 of Patenga station have been collected from BMD. Moreover, temperature data has also been collected. The cross-section data of the Karnafuly and Halda rivers have been obtained from BWDB. These data will be used for developing the drainage and flood model. Moreover, a total of 850 cross sections of 36 khals located in Chattogram city have been obtained from CDA. Water logged areas for the Chattogram city area have been collected from the previous report and from ongoing Khal excavation project. All the data have been reported and used in the hydrologic and modeling analysis section.

CHAPTER THREE

EXISTING DRAINAGE CONDITION

3. EXISTING DRAINAGE CONDITION

3.1 Physical Description

The city of Chattogram, second largest in Bangladesh, lies on the north bank of the Karnaphuli River and the west bank of its tributary, the Halda. However, the study area of CDA also covers several Upazillas located to the east of the Karnaphuli River. Thus, the CDA area can broadly be divided into two large segments: i) the first segment encompasses the area to the north and west of the Karnaphuli river which includes the core of the city of about 15km upstream of the river mouth where the Karnaphuli meets the Bay of Bengal (Figure 3.1). The total area within this segment is 700 sq km (184 sq within CCC and 516 sq km within Upazillas). A north-south central range of hills extends into the urban zone from the North and gradually loses height as it nears the river. The core city covers an area of small hills and narrow valleys, bounded by the Karnaphuli to the South, the coastal plain to the West and the flood plain of the Halda to the East. ii) the second segment covers the area located to the south and east of the Karnaphuli river. The total area of this segment is 542 sq km. This part is generally flatter with some low-lying areas and some patches of hills located near the left bank of the Karnaphuli river. A north-south rage of hills runs along the eastern boundary of this part of the study area. Several important Upazillas and growth centers such as Boalkhali, Shikolbaha, Patiya Anwara is located in this segment. Moreover, the KAFCO and KEPZ is located here.

Chattogram experiences over 3000mm of mean annual rainfall, of which about 80% falls during the normal monsoon period. Before development of the city stormwater running off the hills could flood the low lying paddy fields and drain slowly via the natural khals into the main rivers. Urbanization has increased the run- off from the developed areas and has tended to obstruct the flow of water from the hills. Thus greater flows are imposed on the khals which could not pass the higher discharges even if the channels were in good condition. The blockage of the khals with garbage and encroachment and constriction by structures has aggravated the drainage condition. In addition discharge from the khals to the river or to the sea is, at times of high spring tides, slowed by the backwater effect of high water levels in the river because of the low elevation of the land and its small gradient. As a result of urbanization, ponding that used to take place in the ponds, paddy fields, open spaces and low-lying areas, now occurs in urban areas, with all the damage to buildings and inconvenience and discomfort to the population that may be expected from flooding. Areas flooded by rainfall are shown in Figure 3.2.

In Chattogram, drainage congestion occurs due to the following events occurring alone or in combination with each other:

- Fast-running storm water runoff from the hilly terrain
- Intrusion of river water through the open Khals
- Intrusion of river water through bank overtopping
- Cyclonic surge

The most common cause of drainage congestion in the monsoon season is fast-running storm water runoff from the hilly terrain. Intrusion of river water through the Khals occurs both in the monsoon and in the dry season. The other two events (numbering 3 and 4 from above) occur occasionally. The degree of drainage congestion increases when more than one event occurs together and it reaches to the maximum when all events occur together, although the probability of this is extremely low.

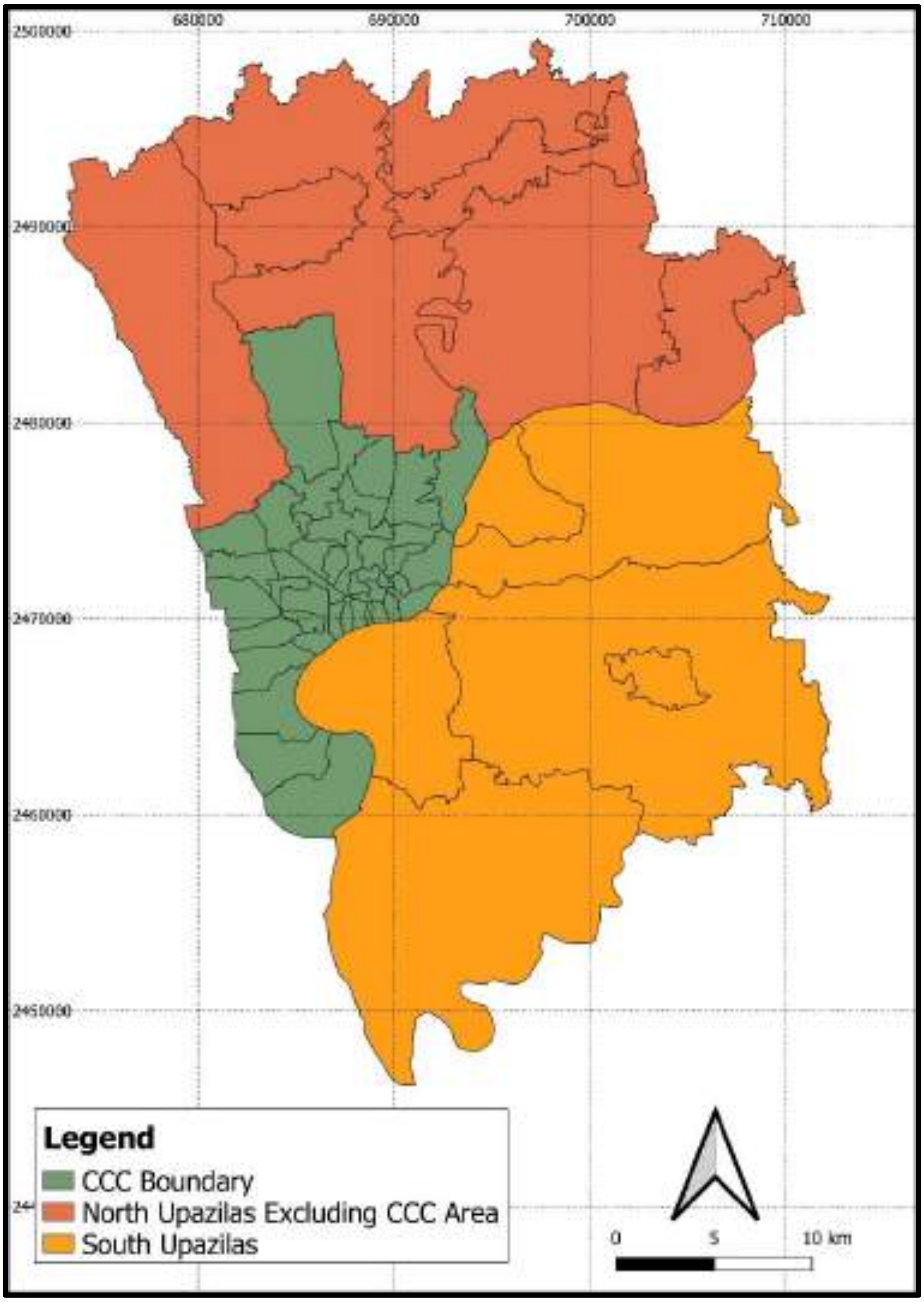


Figure 3.1 Jurisdiction of the Study Area

3.2 Description of Stormwater Drainage System in Chattogram

The drainage system in Chattogram is organized around three main elements: a) Primary system b) Secondary system and c) Tertiary system. Besides the primary, secondary and tertiary systems, both the Halda and Karnaphuli Rivers are very important for the drainage of Chattogram. The Karnaphuli River is tidal all the way from its mouth to Kaptai dam, approximately 70 km upstream. There are two tides a day in the Karnaphuli River, one tidal cycle lasting about 12.5 hours. This represents a big challenge for the drainage system, as the water level in the river is not stable, which means it effectively acts as one of the dominating parameters in design considerations, especially in coping with maximum peak and mean tidal levels in July and August. The Halda River, on the other hand, is also tidal about 45 km upstream of the confluence with the Karnaphuli. However, tidal influences in this river are less significant for the drainage system of Chattogram city.

3.2.1 Primary System

The primary khals are mainly based on natural channels which existed before the city was built. In hilly areas they have steep gradients giving good velocities of flow but when they reach the low lying plains flow becomes sluggish. In the central city area, development extends in many places right up to the edge of the channels thus preventing access for maintenance. In general, khals have not been planned in advance of building development, nor has land for khals been allocated alongside new road construction. On the plains in some rural areas, khals draining the hills behind have become high in relation to the surrounding ground due to the amount of silt carried down and deposited on the bed. The rural flood plains have no planned drainage channels, but these will become necessary as development proceeds.

3.2.2 Secondary Drainage Systems

Secondary Khals, which carry discharge from tertiary systems to the primary khals, are in some cases original natural drainage channels but very often are man-made channels constructed in connection with residential or industrial developments. Many of them suffer from problems similar to those of primary khals. They cannot pass the required flows because of inadequate cross-section, poor alignment or gradient. blockage by siltation, waste matter and encroachment and lack of adequate maintenance. In some areas, the man-made secondary channels have not been planned adequately to drain all future development and in these cases new or re-habilitated khals will be required. Some secondary khals in silt-free areas of the city area have been laid underground in the form of pipes or box culverts.

3.2.3 Tertiary Drainage Systems

Tertiary or roadside channels have been constructed over the years in a random manner, and designed only to suit the needs of the immediate area, without thought for future extensions of developed areas or their effect on the khals further downstream. In urban areas they are generally lined, and in congested streets many are as small as 0.3m square. They suffer from many of the inadequacies described above. In many cities the tertiary drainage systems consist of underground pipes but in Chattogram, where this system has been tried, the pipes have usually become choked and unworkable due to lack of maintenance. Most of the city's tertiary drains consist of channels. In several drainage areas a considerable amount of improvement to the tertiary system is required, but one of the most effective ways to improve tertiary drainage would be to provide efficient sanitation and refuse collection systems.

3.3 Poor Drainage Condition and The Causes

As described earlier, the drainage condition in Chattogram city is very poor and water logging due to moderate to intense rain has become a regular phenomenon. The torrential rains often put two-thirds of the areas in the port city under knee to waist-deep water. The 2016 CWASA mater plan identified a number areas within their study area severely affected by drainage congestions as shown in Figure 3.2a. Water-logged areas have also been identified from an ongoing project as shown in Figure 3.2b. The situation has further aggravated in recent times. The low-lying areas of Chattogram City gets inundated 2-4 times in every year in almost knee-deep water, including the Chawkbazar area, Bakalia area, Sholakhbahar area, Agrabad area, Halisahar area, Muradpur area, Barborak Intersection area, KB Aman Ali Road, DC Road (Chandgaon), East Nasirabad area, Dewanbazar area, etc. One of the largest business hubs in the country, Khatunganj-Chaktai, gets severely affected by the rain and tidal waters as more than 5,000 business establishments in the area were submerged and daily essential commodities inside the warehouses were damaged. This causes serious disruption to the lives of citizens, as well as to the port and business operations in the city. The water does not spare the more well-off neighborhoods either. The World Trade Center, the most important building in the Agrabad commercial area, had been surrounded by floodwater in 2023. The city's most elite residential area, the Chattogram Development Authority (CDA) housing estate, has come up near Agrabad. The heavy downpour also raises landslide concerns in the Lakhan Bazar area of the city.

The drainage condition of the city is getting worse every year with the development and expansion of the city. The reasons for this poor condition are well known and have been well identified in 1995 CDA and 2016 Drainage Masterplan. The issues to poor drainage condition can be classified as structural and non-structural as they are summarized below.

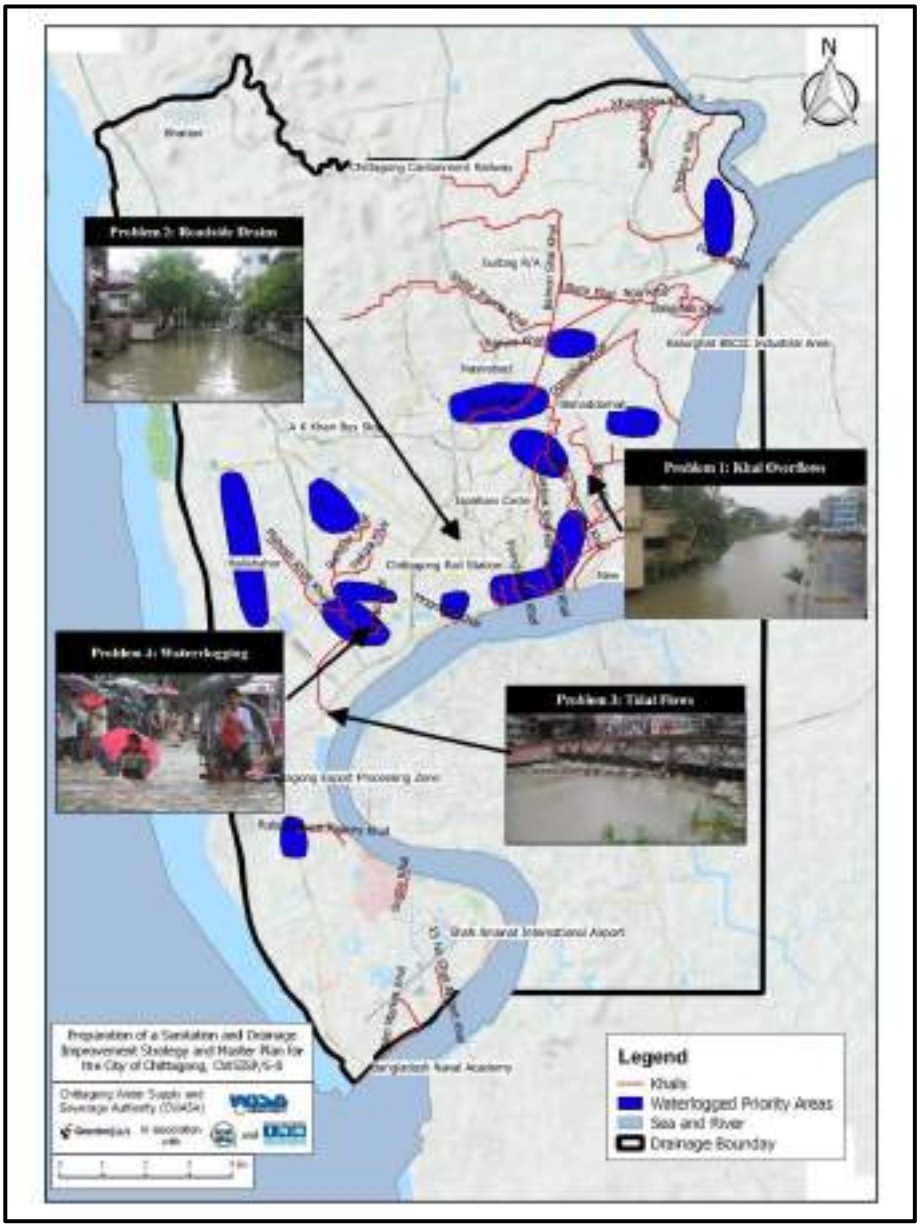


Figure 3.2a Areas of Severely Affected by Drainage Congestions as Identified in CWASA Master Plan 2016

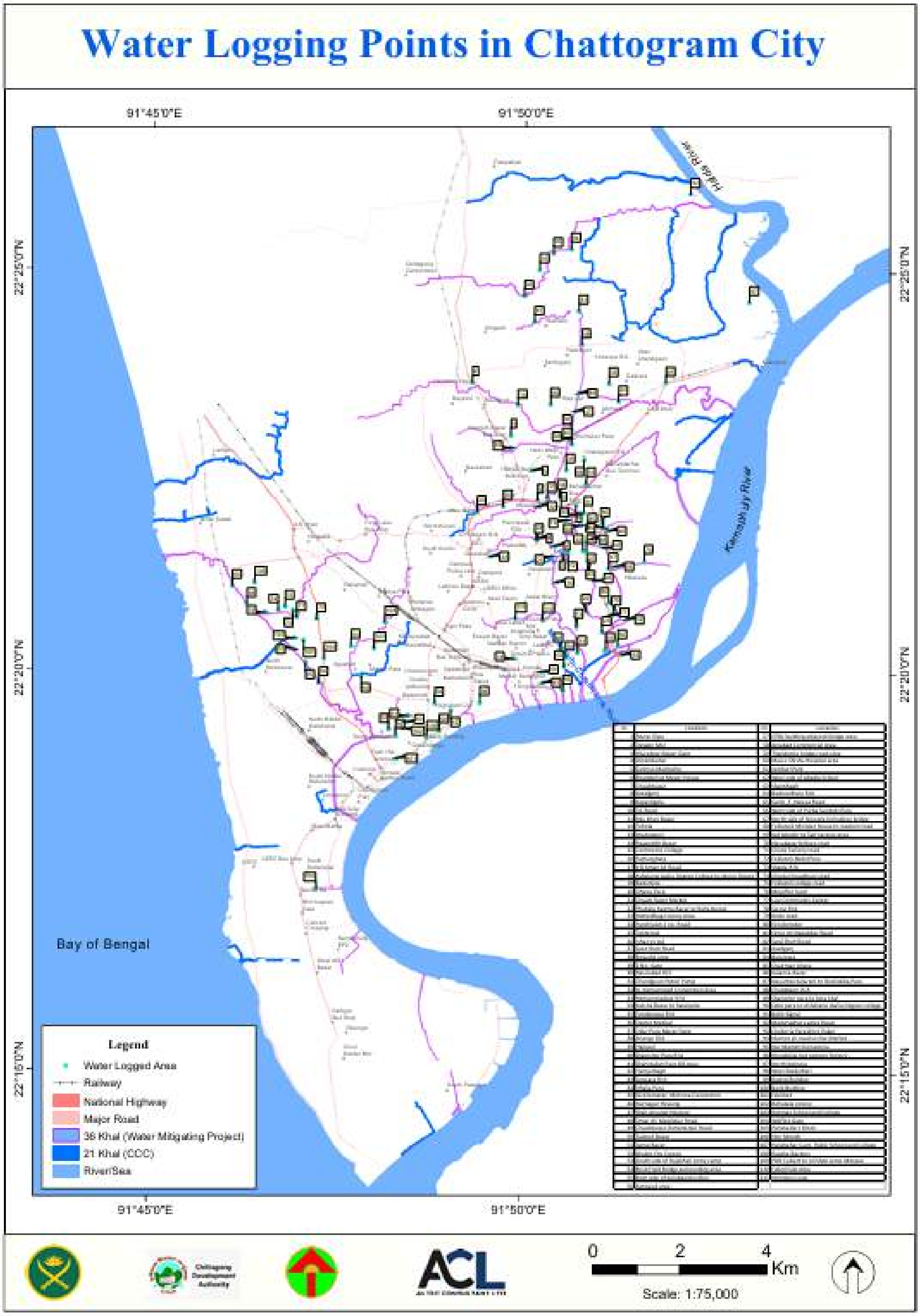


Figure 3.2b Areas of Severely Affected by Drainage Congestions as Identified in 36 Khal Excavation project 2024

3.3.1 Structural Issue

Filling Up of Channels by Solid Waste

This is probably the foremost reason for the aggravated drainage condition in the City apart from improper city development. Domestic and industrial solid wastes as well as liquid waste and sewage find their way into the land drainage channels in great quantities. This is due to the lack of a sewerage system within the city and also to the inefficacy of the solid waste collection system. The sewerage and solid waste (plastic bags in particular) bind together with the silt brought down from the hills to form a solid mass which the channel flow cannot move. Only improved collection of solid waste and sewage can remedy this situation where, at times of low flow, some of the khals are nothing more than open sewers. The resulting pollution of land and atmosphere must have an effect on the health of the population.

Siltation of Khals

Khals originating in eroding hilly areas carry a high silt load, a phenomenon that is seriously aggravated by the practice of hill cutting. When the flow reaches the foot of the hills the velocity is reduced and the larger-grained material is deposited on the bed of the khal. As the velocity of flow becomes still lower so the finer-grained material is deposited. Given the gentle gradients of the low-lying plains it is not possible to design khals having a self-cleansing velocity. Further, the nature of the material deposited makes it become hard such that even flood flows fail to remove most of it. Thus the cross-section of the khal is reduced and the channel cannot carry the run-off from a rainstorm wihout overflowing. Some silt traps have been constructed but these have tended to fill during one rainstorm: thus they become totally ineffective until the silt is removed. The sites of siltation problems change as hill-cutting operations are relocated. Unfortunately, access to existing traps for the purpose of silt removal is often difficult.

Structures over Khals

Khals are blocked in many places by construction carried out within and over the waterway and by pipes and cables laid across it. Many culverts and bridges are insufficiently wide or high to pass the required flow and, even where they are of adequate size, their effective area of opening has been reduced by services laid across them. Some domestic and other properties, both kutcha and pucca, have been extended and retaining walls have been built in the khals so that they now obstruct part of the waterway. Solids carried by the flow in the khal build up behind such obstructions and can cause considerable local flooding.

Lack of Control Gate at Primary Khal Outlets

Apart from some khals which discharge through sluices into the Bay of Bengal, most of the khals which discharge into the main rivers have no form of control gate at their mouth. In consequence, at times of high spring tides and when there is a cyclonic surge the tide flows up many of the khals for a considerable distance. Whilst spring tides do not in many places of themselves cause flooding, when high river levels coincide with rainstorms the discharge from khals is prevented from flowing into the river and the result is flooding of surrounding land. If the outlets of the khals were provided with tidal regulators, combined as necessary with storage ponds. flooding due to high water levels in the main rivers would be prevented and saline intrusion into the land, where tubewells for drinking water are sometimes sited, would be reduced. Flooding due to cyclonic surges would be prevented by tidal regulators in conjunction with riverside embankments.

3.3.2 Non-structural Issues

Chattogram drainage system is suffering from range of non-structural problems that are posing serious threat and challenge to the urban drainage that is resulting in annual water congestion, Khal overflows and localised flooding in important commercial and business districts. The non-structural drainage challenges are summarized below.

Lack of Regular O&M

Chattogram city's drainage suffers from poor operation and maintenance negligence on all its drainage infrastructure components. CCC has a continuing program of maintenance but it is not extensive enough to keep the primary khals in good condition. Many of them are half full of silt, debris and rubbish over considerable lengths so that their discharge capacity is much reduced. It is difficult for CCC to clean the total existing drainage system every year due to shortage of resources and budget. Moreover 3 km box culvert along the Sheik Mujieb Road is heavily silted up which needs an immediate attention for desilting to accommodate the flows that are routed. Chattogram City Corporation maintains the Khals and drains. As per 2015 CCC Drainage Masterplan Report, CCC spends about Tk. 500 lac to 700 lac per year to keep the Khals/drains clean. Moreover, 2,300 m RCC retaining wall was constructed at both sides of Mahesh Khali Khal at ward no. 24, 27 and 36 in financial year 2013-14 and 2014-15.

Lack of Inter-Agency Cooperation

Both CCC and CWASA are mandated for drainage management of the City. It appears that CCC is leading and overseeing the drainage related operation and maintenance. For an effective drainage system a close coordination along the organizations is required.

Uncontrolled Urban Development Plans

Rapid population growth and aggressive urbanization in the last three decades is seen in Chattogram City, which resulted in tremendous pressure on the land requirement which is already an issue in congested Chattogram City. Extensive upsurge in built-up has been witnessed due to development of residential and commercial areas through realtors. Often houses are built on low lying areas without required land improvements and drainage facilities causing local inundations. Although CDA has prepared a Detailed Area Plan (DAP), Chattogram is losing its flood lands, natural drainage reserves and paths, agricultural lands are paving their way to the housing developments and roads due to the lack of the enforcement of DAP. This unplanned development activities resulted in significant increase in impervious area, obstructed the natural drainage pattern, and reduced or in some cases completely eliminated the retention basins. Aggressive unplanned urbanization, increased pressure of population, disappearance of natural drains and construction of roads with no attached drains have significantly exacerbated the drainage system within Chattogram.

Building Codes and Land Restrictions

There is no stringent land and structural development policy with the existing Building Construction Rules-2008, Bangladesh National Building Code (BNBC), and Land Development for Private Housing Act, 2004 that can control the aggressive nature of private developer's lack of vision towards the implications of urbanization and reduced pervious areas on drainage and the frequent floods.

Deforestation and Hill Cutting

The practice of hill cutting is identified as the main source for siltation downstream in the city areas. Hence, dealing effectively with this practice will have very positive impacts on siltation. Source-control measures would certainly improve conditions, i.e. more stringent permission requirements, better aerial planning, provision of silt traps just downstream of the hill cutting zone, among others.

Lack of Right of Way
Reckless encroachers of the City's waterbodies such as Khals, lakes and rivers by land developers and the properties owners adjacent to the Khal, illegal structures and waste disposal have already affected the city life significantly. The natural drainage system for example Khals have lost their natural width and existence due to the illegal encroachments eventually reducing the flow carrying capacity thus resulting frequent waterlogging and Khal overflows within the urban parts of Chittagong.

Budget Constraints
Unlike the water supply and sanitation, drainage facilities have no means of collecting tariffs. At present CCC has a lump sum amount for annual operation and maintenance activity which is not adequate to meet the ailing issues within the drainage sector. There is a significant financial limitation for any extensive cleaning and modification works.

Improper Alignment of Utility Lines
The utility authorities in Chattogram have chosen their service line alignments under the culvert or bridges where there is a Khal crossing.

Encroachments
Within the core city the land owners have a common practice to extend their land area where there is a scope for it. Since the land enforcement system of local government land is not adequate enough, some land owners or the residents slowly encroach the land. Encroachments reduce the capacity and flow of the drainage system.

Lack of Public Awareness
At large, majority of the people living in both in urban and rural parts of Bangladesh are unaware about drainage except for the events of water logging. They are unaware of the fact that the majority of the waste they generate on daily basis is dumped in to the drainage system by themselves is a primary source for congested drainage system. Roadside storage of construction materials cause clogging of inlets very acutely.

Inadequate Solid Waste Management
The City lacks regular and efficient management of solid waste is resulting in the dumping of waste in to the Khals which is the primary cause for the blocking of drainage system. This continuous process triggered the blockage of inlets, drains, pipes and Khals which ultimately reduced the drainage capacity and resulting overflows and localised flooding. For lack of an efficient refuse collection system roadside channels are almost universally used as a dumping ground for domestic waste, even though the population can see that this action aggravates flooding.

Inadequate Staff Training and Equipment
For effective O&M of drainage system and the box culvert along the Sheikh Mujieb Road requires robust mechanical cleaning equipment. However, the current cleaning process adopted by CCC is predominantly a traditional manual process. Majority of the cleaning and maintenance staff are not well trained to meet the growing operational issues.

Lack of Effective Wastewater Management
Presently, there is no sewerage system in Chattogram. The population rely on septic tank sanitation system. There are uncountable illegal connections to the drainage system which are the

major sewage discharge contributors to the drainage system. It is often seen in Chattogram that sludge removed from the septic tanks is dumped in to the nearest Khal or drains. In many areas the roadside channels are also used as latrines and, further, they also receive general rubbish from the highway.

3.4 Division of Drainage Area/Basins

A Masterplan may often follow administrative divisions (e.g. ward, upazila, union) to prepare structural and implementation plans for other components. However, developing a storm drainage plan requires divisions to be selected based on physical and drainage characteristics known as drainage area/basins or catchments. Therefore, the CDA area has been divided into 17 drainage areas where the boundaries have been set *considering their physical and hydrological characteristics*. To develop a storm drainage master plan in the CDA area, all the drainage issues will be addressed and, all analysis and planning will be carried out in each individual drainage basin based on its characteristics. The drainage areas are shown in Figure 3.3. Out of the 17 areas, 12 (Basin No: 1-12) are located in the first segment located north-west of Karnaphuli. Basin 1 – 5 are mostly with the CCC boundary and 6 and 8 share both CCC and Upazaill jurisdictions and basins no. 7, 9 -12 are in Upazaillas. The rest 5 basins (Basin No: 13-17) in the second segment located to the south-east of Karnaphuli falls within Upazailla jurisdiction.

The physical attributes of each individual basin such as the total area, total khal, drain, and road lengths coverage of the waterbodies are provided in Table 3.1. There are 1,668 km length of Khals, 1,886 km of drains, 8,787 km of Roads, and 65.2 sq km of waterbodies in the study area. Furthermore, there are 27 no silt trap and 18 regulator in the study area. The table also shows drain density which is the ratio of length of drains to the road length water body percentage which is the ratio of waterbody area to the total drainage area within each drainage. Moreover, the list of the primary khals in each drainage area is provided in Annexure 1 (Table A1-1). And, the existing drainage condition maps are provided in Annexure 1, spanning Figures A1-1 to A1-17.

Drainage Area No. 1

This drainage area as shown in Figure A1-1 is located to the southern part of the CCC jurisdiction with the Karnaphuli river to the east and the sea to the west with an area of 28.23 sq km. This area houses the Chattogram airport, Ruby Cement Factory, BNS Isha Khan, EPZ and other important establishments. There are 8 primary khals of which 3 khals are draining into the Bay of Bengal and have sluice gates, while 5 are draining into the Karnaphuli River. There are no silt traps here. The drainage and waterbody density are 0.35 and 0.07 respectively. One of the drainage congested area is the surrounding of Ruby Cement Factory area.

Drainage Area No. 2

This drainage area as shown in Figure A1-2 is located to the north of Drainage Area 1 and is within the CCC jurisdiction with the sea to the west with an area of 46.92 sq km. One of the most severely drainage affected area Halishahar, part of Agrabad and Rampura are located here. This area also houses Lalkhan Bazar, Salimpur and Kattoli and other important establishments. There are 9 primary khals of which, 8 khals are draining into the Bay of Bengal while Mahesh khal which is the major channel draining a significant portion of the drainage area, falls into the Karnaphuli River. There is a sluice gate in each of these nine khals. There are a total of 7 silt traps within this Drainage area. The drainage and waterbody density are 0.7 and 0.03 respectively. The waterbody density has significantly been reduced due to rapid urbanization in this area.

Drainage Area No. 3

This drainage area, which is relatively a small area of 4.37 sq km, as shown in Figure A1-3, is located to the east of Drainage Area and lies within the CCC jurisdiction with the Karnaphuli River to the south. This area houses Sadarghat, Commerce College and Firingi Bazar, and all three locations are prone to drainage problem. There are 6 primary khals, all draining into the Karnaphuli River. There are 3 sluice gates in three khals. There is a silt trap within this drainage area. The drainage and waterbody density are 0.79 and 0.02 respectively. The waterbody density has significantly been reduced due to rapid urbanization in this area.

Drainage Area No. 4 and 5

These two drainage areas now possess the most complex drainage characteristics in Chattogram City and need to be discussed together. These two drainage areas are shown in Figure A1-4 and A1-5. Previously, the stormwater from the catchment of Chashama khal and surrounding used to flow into Mirza khal crossing the CDA Avenue. This water of from Mirza khal then again used to cross the CDA avenue and flow to the North and meet with Tripura and Uttara khal. Therefore, the catchments of Chashma and Mirza khals were a part of Drainage Area 5 only. On the other hand, Drainage Area 4 consisted of catchments of Hizra, Chaktai, Jamal Khan, Rajakhali and other connected khals draining to the Karnaphuli River. However, following the 1995 CDA Master Plan, a connection between Mirza khal and Chaktai khal was established by a 3 m lined drain laid along the south of CDA avenue. This connection allowed a part of the storm water from Chashma and Mirza khals to be transfered to Chaktai khal. Therefore, The catchments of Chashma and Mirza khals are now both parts of Drainage Area 4 and 5.

Recently, a channel is being constructed from the connection of Mirza and Chaktai Khals at Baraipara Bridge towards the east direction upto the Karnaphuli at Balirhat after crossing the highway N1 at Mohona Community center. The purpose of this connection is to divert some storm water from Mirza khal through this new channel to reduce the flooding of CDA avenue. It is expected that a good amount of storm water of the catchments of Chashma and Mirza khal will be drained out though the new channel and Chaktai khal. Therefore, Drainage Area 4 has been delineated including the catchments of Chashma, a part Mirza of Mirza Khal, Chaktai khal, the new channel and other khals Chaktai khal.

As shown in Figure A1-4, Drainage Area 4 is located to the north of Drainage Area 1 and Karnaphuli River is within the CCC jurisdiction with an area of 25.11 sq km. Two most severely drainage congested areas, Chawkbazar and Muradpur are located in this Drainage Zone. Other areas prone to drainage problem are South Bakalia and East Sholoshohor. Some major khals such as Chaktai, Chaktai Diversion, Mirza, Charma, Rajakhali Hizra, Bakalia and other khals are located in the area. Chakati, Chaktai Diversion and Rajakhali khals falls into the Karnaphuli River. The channel under construction is also under this area and falls into the Karfully River with a sluice gate at Balirhat. New sluice gets are also being constructed on other khal outlets draining into the Karnaphuli Rivers. There are a total of 12 silt traps within this Drainage area. The drainage and waterbody density are 0.84 and 0.023 respectively. The waterbody density has significantly been reduced due to rapid urbanization in this area.

As shown in Figure A1-5, Drainage Area 5, located to the north of Drainage Area 4 and east of Karnaphuli River is within the CCC jurisdiction with an area of 30.2 sq km. Two most drainage congested areas are Chandgaon, a low-lying area, and Anannya Housing Area this Drainage Zone. Some major khals such as part of Mirza khal, Tripura, Shitol Jhorna, Bamonshahi, Uttara, Noa and Domkhali khals are located in the area. Among them Noa and Domkhali khals fall into the Karnaphuli river and have sluice gates. There is no silt trap and the drainage and waterbody density are 0.68 and 0.05 respectively.

Drainage Area No. 6

This drainage area as shown in Figure A1-6 is located to the north of Drainage Area 5 and east of Halda River. This drainage area is within both CCC and Upazila jurisdictions with an area of 34.64 sq km. This area is relatively underdeveloped. The low lying areas within this drainage area are subjected to drainage congestions. Khondokia and Krishna are two major khals in this drainage area falling into the Halda River. The total length of khals is 60.7 km. There are a total of 2 silt traps within this Drainage area. The drainage and waterbody density are 0.21 and 0.056 respectively. The drainage density is relatively low due to low development in this area.

Drainage Area No. 7

This drainage area as shown in Figure A1-7 is located to the north of Drainage Area 2 with its western boundary along the Sandwip channel in sea. This drainage area is under Sitakunda Upazila jurisdictions with an area of 81.4 sq km. There are 11 khals draining into the sea. This catchment is hilly in nature and is relatively less prone to drainage congestion. Khondokia and Krishna are two major khals in this drainage area falling into the Halda River. The total length of khals is 60.7 km. There are a total of 2 silt traps within this Drainage area. The drainage and waterbody density are 0.12 and 0.022 respectively.

Drainage Area No. 8

This drainage area as shown in Figure A1-8 is located to the north of Drainage Area 6 and east of Halda River. A small part of this drainage area lies within CCC jurisdiction and the rest is within Hathazari Upazila with a total area of 77.97 sq km. This area is relatively underdeveloped with the developments centered on both sides of Highway N106. The part of the catchment located west of the highway is relatively hilly and the eastern part near the Halda river is relatively low in elevation. The low-lying areas within this drainage area are subjected to drainage congestion. The total length of khals is 130 km with 5 primary khals draining into Halda. There are no silt traps within this Drainage area or control structures at the outlets. However, the widths of these 5 khals near the outlets have been constricted significantly by constructing culverts at the road crossings. The drainage and waterbody density are 0.09 and 0.06 respectively. The drainage density is very low due to low development in this area.

Drainage Area No. 9

This drainage area as shown in Figure A1-9 is located to the north of Drainage Area 8 and east of Halda River. This drainage area lies within Hathazari Upazila with a total area of 79.3 sq km. This area has characteristics similar to Drainage Area 8. The total length of khals is 128.2 km. The storm water of this catchment is drained into the Halda river mainly through the primary khal named Boalia. There are no silt traps within this Drainage area or control structures at the outlets. The drainage and waterbody density are 0.05 and 0.04 respectively. The drainage density is very low due to low development in this area.

Drainage Area 10

Drainage Area 10 is located to the east of Halda River and north of Karnaphuli River. This drainage area covers 89.39 sq km and is within Raozan Upazilla. This catchment contains seven primary khals. Four of these khals, West Guzara, West Barighina, Maishkaram, Noapara Khal Khals drain into the Halda River, while the remaining khals, Pachkhain, Lamburhat and Ram Gatir Hat khlas discharge into the Karnafuli River. The total length of all khals is 167 km. All these khals also establish connections between the Halda and Karnaphuli rivers through the drainage area. The drainage and waterbody density are 0.03 and 0.07 respectively.

Drainage Area 11

Drainage Area 11 is located to the east of Drainage Area 10 and north of Karnaphuli River. This area is relatively high in elevation and less prone to drainage problem. This drainage area covers 44.93 sq km and is within Rangunia Upazilla. This catchment has relatively less number of khals with a total lenths of 36.8 km. Two primary khals are Kaukhali and Pomra khals draining into the Karnaphuli river. The drainage and waterbody density are 0.03 and 0.027 respectively.

Drainage Area 12

Drainage Area 12 is located to the north of Drainage Area 10 and east of Halda River. This catchment covers relatively a large area of 109 sq km and is within Raozan Upazilla and Raozan Municipality. This drainage area contains four primary khals, named Nadimpur, Sattar, Garduara and Dewan Ali Khals, all draining into the Halda River. The total length of all khals within the catchment is 178 km. The drainage and waterbody density are 0.01 and 0.06 respectively.

Drainage Area 13

Drainage Area 13, as shown in Figure A1-13 is bounded by the sea in the west and Sangu river in the south and has a drainage area of approximately 103.8 sq km. This catchment lies within Anowara Upazilla. It features about six major khals namely Parki Canal falling into the sea and Khurushkul, Daskhin Barunchara, Icchakhali and Murai Khals draining into the Sangu river. The total length of all khals within the catchment is 88 km. The drainage and waterbody density are 0.02 and 0.057 respectively.

Drainage Area 14

Drainage Area, as shown in Figure A1-14 located to the east of the Karnaphuli River and South of Drainage Area 13. and has a drainage area of approximately 167 sq km. This catchment lies within Patia and Karnaphuli Upazilla. Murai khal is one of the longest khals, originating from Karnaphuli and passing through drainage area 14 and 13 and finally meeting the Sangu river. There appears to be complex khal network around the Muraikhal at the center of this drainage area. The total length of all khals within the catchment is 273 km. The drainage and waterbody density are 0.04 and 0.057 respectively.

Drainage Area 15

Drainage Area 15, as shown in Figure A1-15 is located north of Drainage Area and falls withing the jurisdiction of Both Patia and Boalkhali Upazilla. This catchment covers approximately 152 sq km. Baremba, Boalkhali and Kharana are there major drainage channels with Baremba and Boalkhali channels connected to the Karnaphuli river. The total length of all khals within the catchment is 160 km. The drainage and waterbody density are 0.04 and 0.09 respectively.

Drainage Area 16

Drainage Area 16, as shown in Figure A1-16 located along the left bank of the Karnafuli River and to the north of Catchment 15 and is within Boalkhali Upazilla and Municipility. The total drainage area of this catchment is 54.43 sq km. The area is intersected by four major primary khals namely Charandip, Kalurghta and Shakpura all connected to the Karnaphuli river. The total length of all khals within the catchment is 82 km. The drainage density is almost negligible and waterbody density is 0.074 respectively.

Drainage Area 17

Drainage Area, as shown in Figure A1-17, is located to the south of the Karnaphuli river and east of Drainage Area 16. It covers 34.67 sq km area and is largely underdeveloped, with minimal built-up infrastructure. The catchment elevation is relatively high. Jaisthapura khal is the only primary khal draining into the Karnaphuli river from two secondary khals. The total length of all khals within the catchment is 26.8 km. The drainage density is 0.01 and waterbody density is less than 0.01.

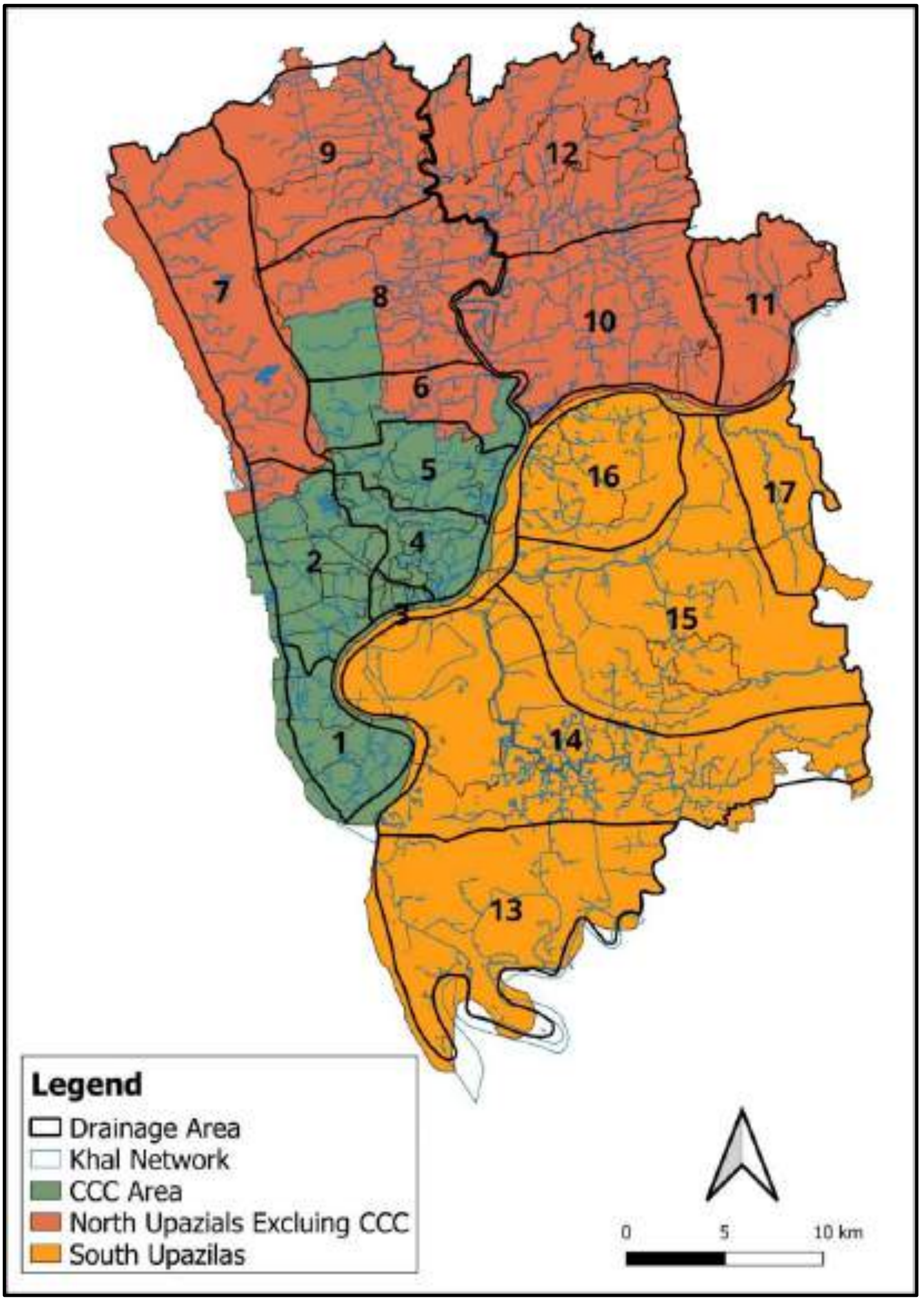


Figure 3.3: Division of Study Area in Drainage Area/Basin

Table 3.1: Summary of Atributes of Drainage Areas

Drainage Area No	Area (sq Km)	Total Khal Length (km)	Drain Length (km)	Road Length (km)	Waterbodies Area (sq km)	No of Silt Trap	No of Regulator	Drainage Density	Waterbodies Percentage
1	28.23	62.56	128.88	365.46	2.08	0	5	0.35	7.37
2	46.92	74.7	613	816	1.71	7	9	0.75	3.64
3	4.37	4.7	95.9	121.6	0.097	1	3	0.79	2.22
4	25.11	54.1	427	508	0.58	12	1	0.84	2.31
5	30.2	62.8	323.7	475.8	1.47	5	0	0.68	4.87
6	34.64	60.7	63.4	295.3	1.96	2	0	0.21	5.66
7	81.4	76.2	38.7	334.6	1.77	0	0	0.12	2.17
8	77.97	130.6	45	512.4	4.64	0	0	0.09	5.95
9	79.3	128.2	18.3	392.6	3.11	0	0	0.05	3.92
10	89.4	167	16.6	630.4	6.3	0	0	0.03	7.05
11	44.93	36.8	7.07	239.5	1.2	0	0	0.03	2.67
12	108.73	178	7.18	696.6	6.8	0	0	0.01	6.25
13	103.77	88.4	15.3	688	5.96	0	0	0.02	5.74
14	167.07	273.6	38.4	1021.4	9.6	0	0	0.04	5.75
15	152.1	160.7	44.5	1110	13.7	0	0	0.04	9.01
16	54.43	82.2	2.36	533.4	4.04	0	0	0.004	7.42
17	34.67	26.8	0.68	45.4	0.13	0	0	0.01	0.37
Total/ Average	1163	1668	1886	8787	65.2	27	18	0.24	4.85

3.5 Previous Drainage Plans and On-going Works

3.5.1 Previous Drainage Plans and Study Reports

There have been a number of studies and plans relating to the drainage system in Chattogram. These are summarized in **Table 3.2**.

Table 3.2: List of previous plans and reports reviewed

No.	Title	Prepared by
1	Chattogram Stormwater Drainage and Flood Control Master Plan, 1995	Binnie and Partners, Redhill, UK & Others
2	Chattogram Metropolitan Master Plan: Structure Plan, 1995	Binnie and Partners, Redhill, UK & Others
3	Detailed Area Plan, 2008	The Technical Management Committee and Inter-Ministerial Steering Committee
4	Master Plan for Water Supply and Wastewater Management of the Detailed Planned Area of Chattogram: Sewerage Master Plan, 2009	Korea International Cooperation Agency, Korea Water resources Corporation and Saman Corporation
5	Master Plan for Water Supply and Wastewater Management of the Detailed Planned Area of Chattogram: Water Supply Master Plan, 2009	Korea International Cooperation Agency, Korea Water resources Corporation and Saman Corporation
6	Development Project Proforma/Proposal for Construction of Regulators at the Outfall of Mohesh Khal and Kumar Khal to Eliminate Drainage Congestion and Prevent Saline Water	Bangladesh Water Development Board, Chattogram
7	CWASA Drainage and Sanitation Masterplan, 2016	Grontjmii, AQUA and IWM
8	Chattogram City: Drainage and Flood Control Project (Vol-I), 1972	Bangladesh National Consultants in association with Commonwealth Associates Inc. Jackson

The following is an appraisal of the most relevant aspects of 1995 CDA and 2016 CWASA plans. There is significant over-lapping between the plans. However, implementation of these plans is limited.

3.5.2 CDA Drainage Masterplan (1995) and and CWASA Drainage Materplan (2016)

The Drainage Master Plan from 1995, prepared under the sponsorship of the CDA and funded by the United Nations Development Programme (UNDP), is the most relevant document for the current project. A comprehensive study was performed, and recommendations were made for upto 2015. The CWASA Drainage Masterplan of 2016 followed this masterplan recommendations and mad additional recommendations.

The study covered an area of 260 km^2 including the City Corporation area in in both masterplans, the actual CWASA area and the projected urban area. 1995 master plan divided the city into ten drainage areas as shown in Figure 3.4, for which specific stormwater drainage improvements were proposed.

The CWASA Drainage Masterplan (2016) was prepared for the duration from 2016-2030. This plan reviewed the 1995 masterplan, conducted detailed study and made recommendations in addition to 1995 Masterplan recommendations as the implementation of the was very limited due to variety of reasons including budget and land acquisition until 2016. A comparison of both Masterplans is provided in Table 6. along with their implementation status.

The recommendations of both masterplans can be grouped as i) excavation/ reconstruction/desludging of the khals ii) Lining of the khals iii) construction of silt traps iv) construction of tertiary drains v) Construction of regulators at the outlets with pumping facilities and vi) construction of flood control embankments. The masterplans recommended additional measures such removal of illegal encroachment, realignment of service lines and culvert adjustment and widening. Moreover, some ancillary but important recommendations were made regarding pollution control of drains, strong regulation of hill cutting, land-acquisition and resettlement, planned land development, regular maintenance, flood preparedness.

As per 2016 CWASA masterplan review, the implementation of 1995 was limited to i) excavation of Chaktai khal diversion khal ii) construction of Sk. Mujib Road Box culvert and iii) Mirza-Chaktai Khal connecting khal/drain. Moreover, some additional initiatives were undertaken before 2016 to improve drainage condition i) Mohesh khal closure which was completed but did not improve the condition ii) purchase of excavators, pumps, construction of flood walls, construction of regulators, iii) rehabilitation of Hizra khal, iv) construction of drain along CDA avenue from Biplob Uddin to Chemon Ara Bridge v) Construction of Feeder Road along river bank from Shah Amanat Bridge to Kalurghat Bridge.

In last eight years, as per Table 3-3., most of the efforts in implementation is concentrated on construction of retaining walls and construction of regulators/sluice gates at outlets. Moreover, construction of some silt traps has also been initiated. However, in all places the regulators are being constructed by significantly constriction of the khal width (Figure 3.4), which would cause considerable delay in attenuation of inundation and quick blockage of khals by waste deposition. No pumping facilities has not been provided yet at these locations which may further deteriorate the drainage conditions of the catchments of these khals specially during construction.

Although both the Master Plans provided several good recommendations, suggestions on installation of trapping and removal of solid waste/garbage systems at intermediate locations and near outlets of khals is missing. Also, the under construction regulators also does not have any of such facilities in any khals. It will continue to pollute of the Karnaphuli river requiring huge expense in capital and maintenance dredging in the river and deteriorated river health. Provision of systems for trapping and removal of garbage is the next most important element to relieve the city from unbearable drainage conditions.

Table 3-3. 1995 CDA and 2016 CWASA Masterplan recommendations and their implementation status as per date

Drainage Area	1995 CDA Master Plan	2017 CWASA Drainage Master Plan	Ongoing and Current Status
No 1: Firingi Bazar	• No technical solution for drainage is needed • 50 m length Lining of three primary khals • A small tidal regulator will be built across the three khals • All the Pucca tertiary channels will be rehabilitated and all the kutcha tertiaries will be lined	• To install a regulator of two vents (size 1.5m * 1.8m) • 1360m^3 , 600 m^3 and 1,097 m^3 of desludging were suggested for Firingi Bazar Khal, Tekpara khal and Kalabagicha khal, respectively.	• Retaining walls of Firingi Bazar khal, Kolabagicha khal, and Tekpara khal have been completed. • Construction of Sluice gates are ongoing on Firingi Bazar, Tekpara and Kalabagicha khals.
No 2: Sadarghat	• The existing Sadarghat Khal will be re-built and the secondary khal will also be re-constructed. • Tertiary drains will be rehabilitated and local improvement will be made for Enayet Bazar, Nadankanan, and Jubilee road areas. • A tidal regulator will be provided at the mouth of the Sadarghat khal • 0.5 ha of flood storage will be provided nearby.	• To install a regulator of three vents (size 1.5m * 1.8m) at Sadarghat Khal1 • To install a regulator of two vents (size 1.5m * 1.8m) at Sadarghat khal2 • 3,702m^3 and 1,918m^3 of desludging were suggested for Sadarghat khal 1 and 2, respectively.	• Retaining walls of Sadarghat khals are completed. • Construction of Sluice gates are ongoing on both Sadarghat khals.
No 3: Agrabad C/A	• The khal alongside Dhaka Trunk Lane will be renovated and obstructions will be removed. • The drain along Dhaka Trunk Lane and running down to Strand Road will be reconstructed. • The drains being directed through two 3.5m wide channels under the railway bridge to the Karnaphuli. • A tidal regulator of 7m wide will be constructed. • A new secondary channel to drain Agrabad Commercial Area will be constructed and the existing Mughaltooli secondary drain will be extended upstream. • A flap gate will be provided at the mouth of the Namuna Bazar Khal • New Tertiaries will be provided and the existing tertiaries will be rehabilitated.	• To install a regulator of 4 vents (size 1.5m * 1.8m) at Mugoltoli Khal • 1,072m^3 of desludging was suggested for Mugoltuli Khal • Suggested 8 pumps each with 1 cusec capacity for Agrabad Area.	• Retaining wall of Mugoltoli khal is ongoing. • No construction of any sluice gate on Muholtuli khal has been observed.
No 4a: Nasir Khal	• Nasir khal will be widened and lined and the secondary khal will be re-profiled and lined. • Obstructions will be removed and sharp bends and junctions will be re-aligned. • Sheikh Mujib Culvert will be constructed. • Two silt traps will be built • All the Pucca tertiary channels will be	• 20,363m^3 of desludging was suggested for Nasir Khal • New slit trap was suggested at South of Railway line, Dewnahat on Nasir khal. • Cleaning of Sheik Mujib box Culvert.	• Retaining walls of Nasir khal have completed.

	rehabilitated and all the kutcha tertiaries will be lined		
No 4b: Moheskhali Khal	• All six primary khals will be rehabilitated. • Rampur khal will be re-profiled and two new rectangular lined secondaries will be constructed. • Pakija khal will be re-profiled and two new rectangular lined secondaries will be constructed. • Gainachara khal will be re-graded and the existing lining will be renovated. • Kattali khal will be re-profiled and lined. • Glaxo khal will be re-sectioned with stable side slopes • Mohesh khal will be re-profiled. Mohesh khal secondary will be lined to a new bed slope. Mohesh diversion khal will be re-sectioned to the required bed and side slopes. • Local improvements will be made • New tertiaries will be constructed and all the pucca tertiaries will be rehabilitated and kutcha tertiaries will be lined. • A tide regulator 21m wide will be built on the Mohesh khal.	• To install a regulator of 21 vents (size 1.5m * 1.8m) at Mohesh Khal • 4,721m^3 , 32,434m^3 and 91,818m^3 of desludging were suggested for Pakija khal, Rampur khal, Maheshkhali Khal. • New slit trap was suggested at Haji Amanat Ullah Rd, North Pahartali on Kattali Khal. • New slit trap were suggested at Jurana para road for Rampur Khal , at Muhuripara road on Pakija khal and at Hazi Ashraf Ali road on Gaina Chara khal. • Suggested 12 pumps each with 1 cusec capacity for Halishahar Area.	• Retaining walls of Mohesh khal, Rampur khal, Maheshkhali khal, Gaina Chara khal, Azob Bahar khal are ongoing. • Construction of sluice gate and installation of pump on Mohesh khal are ongoing.
No 5a: Chaktai Khal	• The Chaktai khal will have bed lowered between the Chatteswari and Jamal Khan khals, the side slopes re-profiled, high level abutment walls construted and the sloping sides of the khal lined with concrete. • At the mouth of the Chaktai a tide regulator 21m wide will be constructed. • The secondaries flowing into to west side of the chaktai khal (Badarpati, Jamal Khan and Chatteswari Khals) are to be rehabilitated. • The junctions between Chatteswari, Jamal Khan and Badarpati Khals and the chaktai khals will be re-aligned. • The link canal between Zahur Hawker Market and Badarpati Khal will also be improved. • All the pucca tertiaries will be rehabilitated and kutcha tertiaries will be lined.	• To install a regulator of 20 vents (size 1.5m * 1.8m) at Chaktai Khal • 3,963 m^3 , 107,812m^3 , and 3,112m^3 of desludging were suggested for Moriombibi khal, Chaktai khal and Razakhali khal to Chaktai khal respectively. • Suggested 9 pumps each with 1 cusec capacity for South Bakalia Area. • Suggested 8 pumps each with 0.5 cusec capacity for Chawk Bazar Area.	• Retaining walls of Chaktai khal, Chaktai Diversion khal, Jamalkhan khal are ongoing. • Retaining walls Morumbibi khal, Badarkhali khal have been completed. • Construction of sluice gate is ongoing on Morumbibi khal. • Construction of sluice gate and installation of pump house are ongoing on Chaktai khal.

No 5b: Mirza and Bakalia Khals	• The Hizra Khal and the Hizra secondary khal will be rehabilitated. • A new khal 554m long, the Mirza-Chaktai connector will be constructed from Mirza khal to the Chaktai with a culvert crossing beneath CDA Avenue. • The Chaktai Diversion South West or Bakalia Khal will be de-silted, re-graded and lined as necessary. • A new secondary tributaries of the Mirza-Noa connector and MCC1 will be constructed. • Local re-alognments and removal of obstructions will be carried out. • A tidal regulator 14m wide will be constructed at the downstream of the Rajakhali Khal • Nine silt traps will be constructed in the western paart of the area.	• To install a regulator of 12 vents (size 1.5m * 1.8m) at Rajakhal Khal main Branch • To install a regulator of 3 vents (size 1.5m * 1.8m) at Rajakhal Khal Branch2 • To install a regulator of 4 vents (size 1.5m * 1.8m) at Rajakhal Khal North Branch • 474m^3 , 5,180m^3 , 38,520m^3 and of 76,795m^3 desludging were suggested for Birza khal, Chaktai diversion, Razakhali Khal and Mirza khal respectively. • New slit traps were suggested at Fala Goli and Khal crossing with Mirzapul Road for Mirza khal • New slit trap was suggested at Meyhdi Bag Road on Hizra khal. • Suggested 5 pumps each with 1 cusec capacity for Muradpur Area. • Suggested 3 pumps each with 0.5 cusec capacity for East Bakalia Area.	• Retaining walls of Hizra khal, Mirza khal, are ongoing. • Retaining walls of Chosma khal and three branches of Rajakhal have been completed. • Construction of Sluice gates are ongoing on all branches of Rajakhal, and on Birza khal.
No 6: Bandar (Patenga)	• Seven new secondary drains will be provided, all being rectangular lined channels. Their widths will vary from 1.4 to 2.1m. • Safi contractor road drain, brickfield road drain, cable factory road drain, katgar road drain, swadagari road drain, Munshi road drain, CDA road drain. • Existing primary and secondary drains to be rehabilitated at the Zelepara khal, Dakshin Halishahar/Nacal Colony Khal, Munshi Khal and Gupta Khal. • New tertiary channels will be provided. • Existing tertiaries will be rehabilitated. • All khals will be provided with tidal regulator.	• To install a regulator of 4 vents (size 1.5m * 1.8m) at 15no Airport Khal • To install a regulator of 8 vents (size 1.5m * 1.8m) at Gupta Khal • To install a regulator of 4 vents (size 1.5m * 1.8m) at Nizam Khal • To install a regulator of 7 vents (size 1.5m * 1.8m) at Rubi Cement Khal • 13,215m^3 , 11,188m^3, 10,600m^3 and 8,409m^3 of desludging were suggested for Nizam Market Khal, 15 No Airport Khal, Gupta Khal and Rubi Cement Factory Khal, respectively. •	• Retaining walls of Gupta Khal, Rubi Cement Factory khal and 15 No Airport Khal have been completed. • No construction of any sluice gate has been observed for the khals in this area.
No 7: Sital Jharna Chara and Noa Khals	• A new trapezoidal unlined khal 2.73km in length will be excavated parallel to the Khwaja Road from the Chaktai Khal to the Karnaphuli River. • A storage pond of 9ha will be excavated and a tidal regulator will be built at the mouth of the khal. • Two rectangular lined secondary khals joining the main new khal will be constructed. • The Noa khal will be re-sectioned over a length of almost 4.5km.	• To install a regulator of 20 vents (size 1.5m * 1.8m) at Noa Khal • To install a regulator of 8 vents (size 1.5m * 1.8m) at Domkhali Khal • To install a regulator of 4 vents (size 1.5m * 1.8m) at Forest Khal • 64,708m^3 , 101,486m^3 , 32,485m^3 , 6,363m^3 , 8,736m^3 , and 190,951m^3 of desludging were suggested for Domkhali, Shitol Jhorna, Bamon Shahi, Tripura, Uttara and Noa Khal, respectively.	• Retaining walls of Noa khal. Domkhali khal, SHitol jhorna khal, Triupura khal are ongoing. • Retaining walls of Bamonshahi khal and Uttara khal have been completed. • Constructions of sluice gates are ongoing on Balirhat, Domkhali and Noa khals.

	• Five new secondaries will be built connecting Noa-khal. • A flood storage of 10ha will be constructed in paddy lands near by. • The Uttara khal will be re-profiled and re-sectioned and Three new secondary khals will be constructed. • The Sital Jharna Chara will be re-profiled and re-sectioned and a new secondary channel will be constructed. • A new khal, the Sital Jharna Diversion will be excavated as a trapeziadal sectionof 6m bed width and 1.31km long to the north side of the railway line. • Two silt traps are to be built. • all the pucca tertiaries will be rehabilitated and kutcha tertiaries will be lined and 9km of new secondaries will be built. • Total 170ha will be raised by an average of 0.56m near the downstream end of the Sital Jharna Chara Khal. • Tidal regulators will be built at the outlets of the Dhomkhali and Noa Khals and at the mouths of two smaller unnamed khals.	• New slit traps were suggested at Hata Zari Road on Shitol Jhorna khal, at Kalapur Road, Wazedia on Bamon Shahi Khal, at Behind Nazariria Primary School on Uttara Khal. •	
No 8: Left Bank	• Similar to Drainage Area No 6.	-	-
No 9:	• Similar to Drainage Area No 7.	• To install a regulator of 3 vents (size 1.5m * 1.8m) at Khandakar Khal • To install a regulator of 6 vents (size 1.5m * 1.8m) at Krishna Khal • 4,494m^3 , 2,530m^3 , 689m^3 , 29,593m^3 , 139,102m^3 , and 4,748m^3 of desludging were suggested for Baizza, Balu, Forest, Krishna, Khandakia and Kuaish Khal respectively. • New slit trap was suggested at Bayazid Bostami Road and Youth Development Road for Gate No 2 khal	• Retaining walls of Khandakia khal are ongoing. • No construction of any sluice gate has been observed for the khals in this area.
No 10: 10	• Similar to Drainage Area No 9.	-	-

Figure 3.4. Width Constriction at Khal Outlets by Regulators

CHAPTER FOUR

HYDROLOGICAL ANALYSIS

4. Hydrological Analysis

The collected rainfall and water level data to be used as input to model have been checked for data quality and consistency. These data have further been analysed to prepare design rainfall hyetograph and tidal cycle.

4.1 Rainfall Data Analysis

Rainfall Pattern in Chattogram

The daily rainfall distribution at Patenga Station (as shown in Figure 4.1a) demonstrates high variability, with distinct peaks corresponding to heavy rainfall events. Several days record exceptionally high values, indicating localized extreme events that are likely associated with intense monsoonal convection. This variability reflects the strong influence of synoptic-scale systems (e.g., depressions, cyclones) as well as localized convective storms. The average maximum daily rainfall across the 42-year period is 219.6 mm, with the highest recorded event reaching 511 mm (1983). Such intense, short-duration events contribute significantly to annual totals and increase risks of flash floods, urban inundation, and soil erosion.

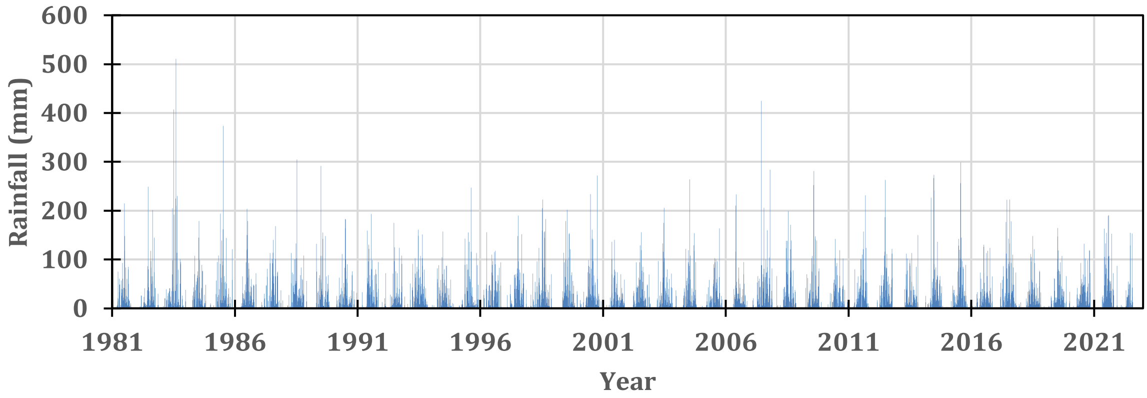


Figure 4.1a Daily Rainfall from 1981 to 2022 for Patenga Station

The annual total rainfall at Patenga station (as shown in Figure 4.1b) exhibits inter-annual fluctuations, with some years receiving substantially higher totals compared to the mean. The corresponding daily maximum rainfall values indicate that years with extreme daily rainfall events often coincide with higher annual totals. However, the data also suggests that even in years with moderate annual totals, isolated extreme daily events can still occur. The variability in annual rainfall, combined with spikes in daily maximum rainfall, points to an increasing risk of both seasonal flooding and isolated flash flood.

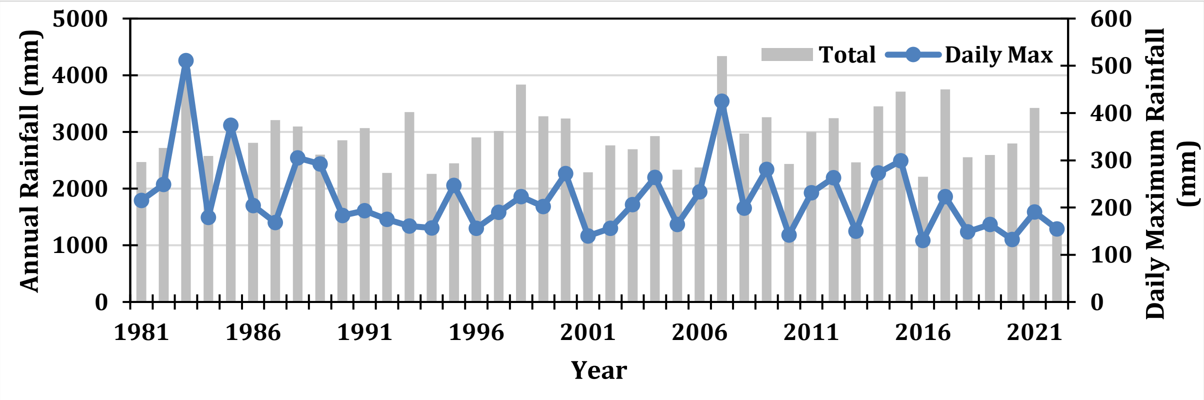


Figure 4.1b Annual total and annual daily maximum rainfall for Patenga Station

Estimation of Short Duration Rainfall

In urban area like Chattogram city high intensity short duration rainfalls are root cause for urban flooding, drainage issues and waterlogging. The mild land slope and tidal effect make the situation even worse. Being very close to the Bay of Bengal and for topography Chattogram can be highly prone to water logging for short-duration rainfall. This region Therefore, using daily data for frequency analysis and storm event selection will either underestimate or overestimate the peak value as well as the design of storm water drains. In this regard disintegration of daily rainfall data has been performed to get the hourly or sub-hourly data of met stations inside the study area using the daily rainfall. The short duration rainfall such as 5min, 10 min, 20min, 40 min 1 hour and 2-hour data can be calculated on the basis of an empirical formula deduced by Indian Meteorological Department (IMD)

The empirical formula provided by IMD is given by

$$P_t = P_{24} \sqrt[3]{\left(\frac{t}{24}\right)}$$

Pt: Required precipitation depth for duration t hour in mm.

P24: Daily precipitation in mm.

t: is the time in hours for which precipitation depth required in hours

IDF curve Generation

From the short duration rainfall data, the maximum rainfall (P) and the statistical variables (average and standard deviation) for each duration (05, 10, 20, 40, 60, 120, 360, 540, 720, 900, 1080, 1260, 1440 min) were calculated. Various duration of rainfalls like 05, 10, 20, 40, 60, 120, 360, 540, 720, 900, 1080, 1260, 1440 min were estimated from annual maximum 24 hours rainfall data for different return periods using Indian Meteorological empirical reduction formula. Gumbel extreme distribution was used to determine rainfall (PT) values and intensities (IT) for the region (Figure 4.2).

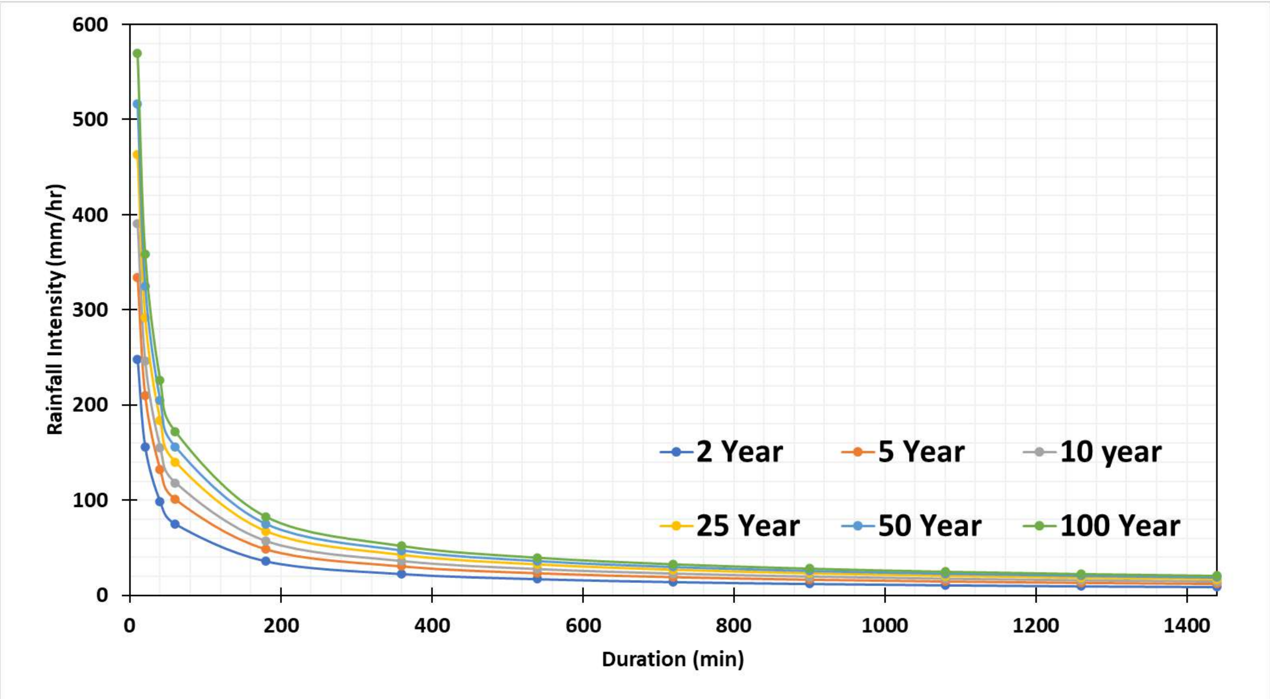


Figure 4.2 IDF curve for Patenga Station

Rainfall event generation

Rainfall event has been generated using alternating block methods. Alternating Block (AB) is a simple procedure of generating synthetic storm patterns (Chow et al. 1988) and is heavily dependent heavily dependent on Rainfall-Intensity-Duration-Frequency (RIDF) curves (Ghazimezade et al. 2011). RIDF curves are derived from statistical analysis of rainfall events, either on annual maxima series or partial duration series, over a period of time and used to capture important characteristics of point rainfall for shorter durations (Bougadis and Adamowski 2006). For this study rainfall of 10-year return period has been used to generate rainfall. Following charts shows rainfall of 6 hour and 12 hour durations.Maximum rainfall for these event are 113.9 mm and 115 mm respectively (Figure 4.3a and 3b). This event has been used to generate different scenario for model simulation.

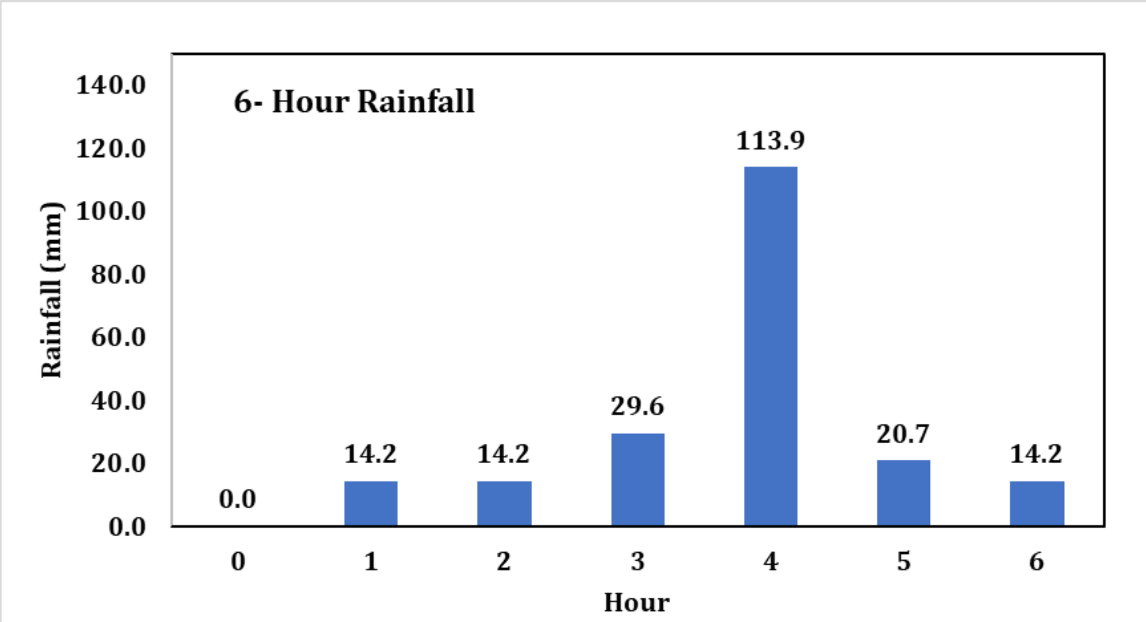


Figure 4.3a 6-Hour Rainfall event

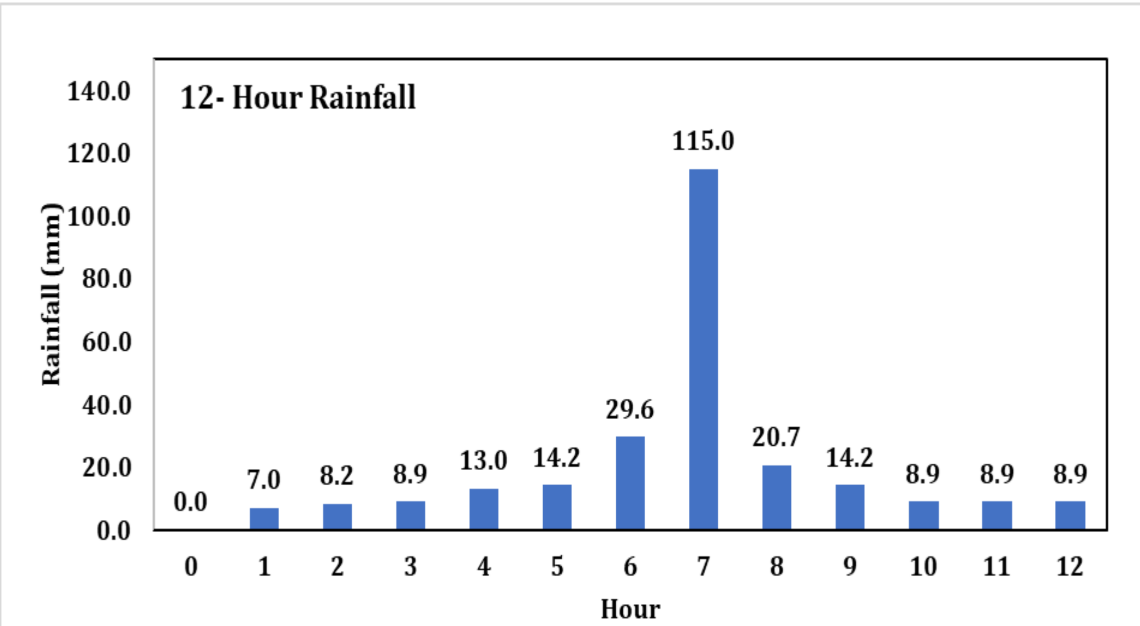


Figure 4.3b 12-Hour Rainfall event

4.2 Water Level Analysis

The water level at Patenga station consists of a time series (Figure 4.4a and 4b) which is derived from water level data received from Chittagong Port Authority, and it is based on an average month in the year 2020. Two water level boundaries are created for this model, one representing high water levels (Spring Tide) and one representing low water levels (Ebb tide). From the time series analysis, it has been found that the month of august have the highest water level thus the month of August has been chosen. Following figure show the water level of 2020 and august.

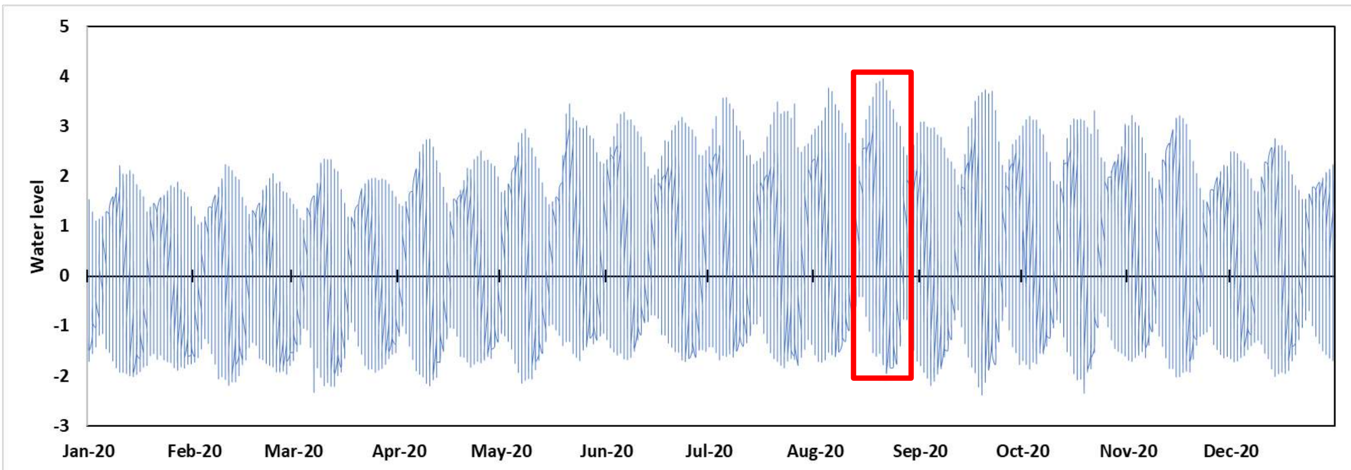


Figure 4.4a Water level for the year 2020 at Patenga Station

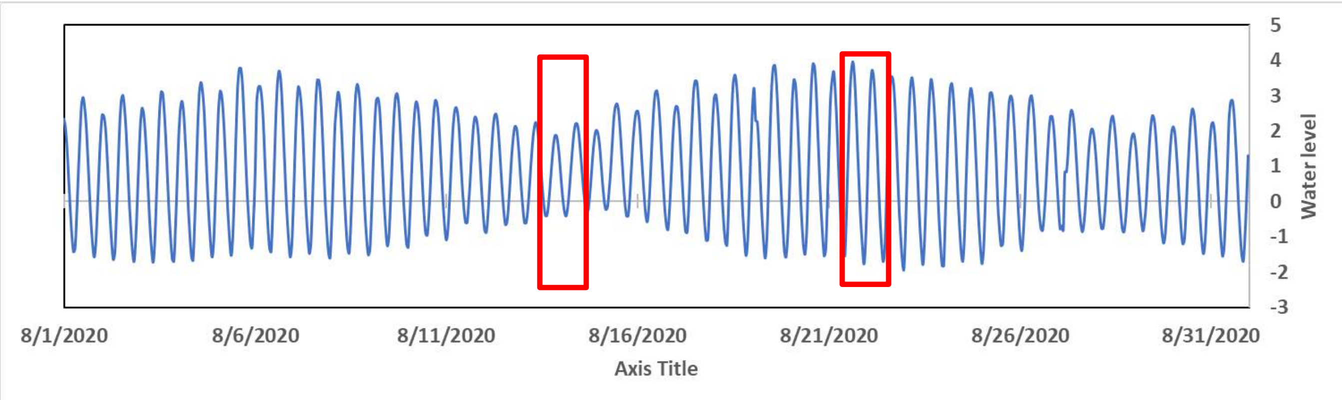
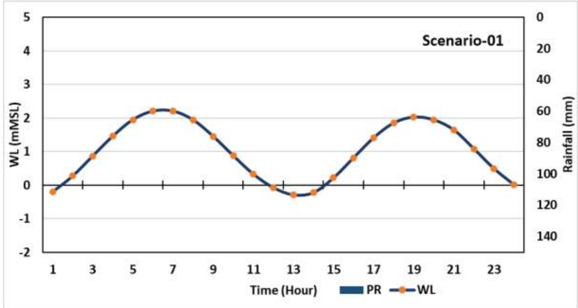


Figure 4.4b Water level in August 2020 at Patenga station

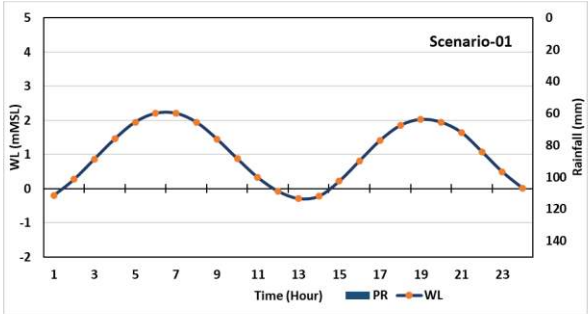
4.3 Hydrological Scenario Development

In order to get a comprehensive overview of flooding situation multiple scenarios were needed to be simulated. As the reivers and khals in Chittagong regions are highly influenced by tidal effect water logging occur not only due to heavy rainfall but also due to high tides. There is a regular tidal water ingress into Chattogram City due to some low-lying flat regions having little to no water level variations with the nearby tidal canals and the Karnaphuli River during high tide. Keeping that in mind combination of 6-hour rainfall and 12-hour rainfall with spring and ebb tides were simulated. Total 6 scenarios were finalized. They are as follows (Figure 4.5)-

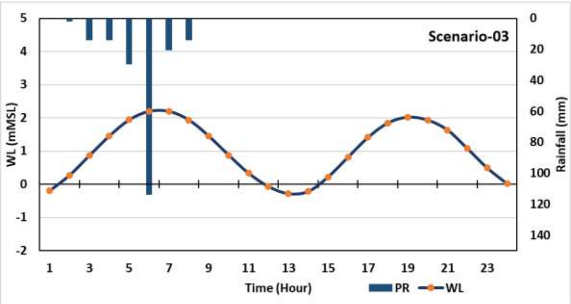
- **Scenario 01** – Ebb tides
- **Scenario 02** –Spring tides
- **Scenario 03** –Ebb tides + 6 Hour Rainfall
- **Scenario 04** –Spring tides + 6 Hour Rainfall
- **Scenario 05** – Ebb tides + 12 Hour Rainfall
- **Scenario 06** –Spring tides + 12 Hour Rainfall



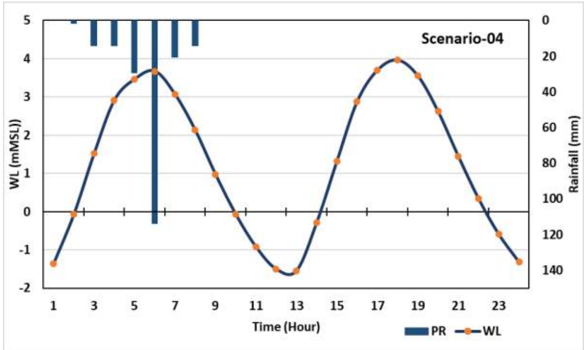
Scenario 01



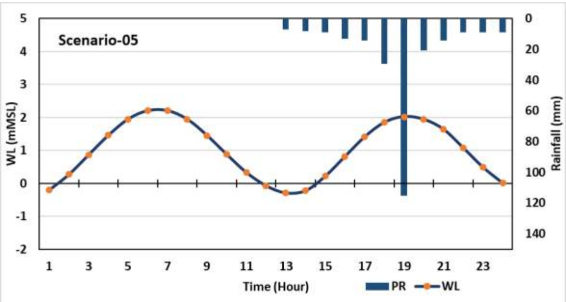
Scenario 02



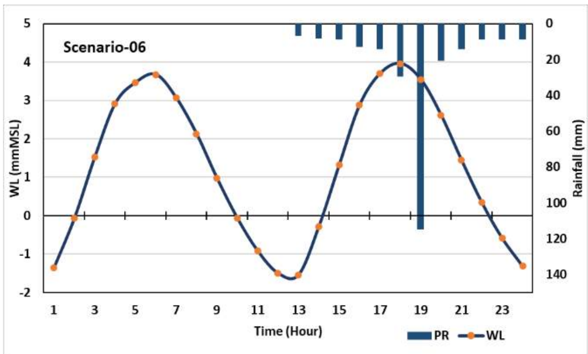
Scenario 03



Scenario 04



Scenario 05



Scenario 06

Figure 4.5 Developed scenarios for model simulation

CHAPTER FIVE

MATHEMATICAL MODELING STUDY

5. Mathematical Modeling Study

5.1 General

As a part of the modeling study input data were checked, quality controlled and made ready for model simulation. Input data preparation includes processing survey cross sections, DEM preparation, Rainfall data management and rainfall event data preparation. Then a skeleton model will be schematized following pre-processed shapefile for channel alignment. Once the 1D hydrodynamic model was ready then 1D hydrology sections were added and simulated. After calibration and validation of 1D hydrologic model a 2D grid was introduced to simulate 2D flood simulations. At the end output of the models were processed and mapped. Following Figure 5.1 shows the modeling steps.

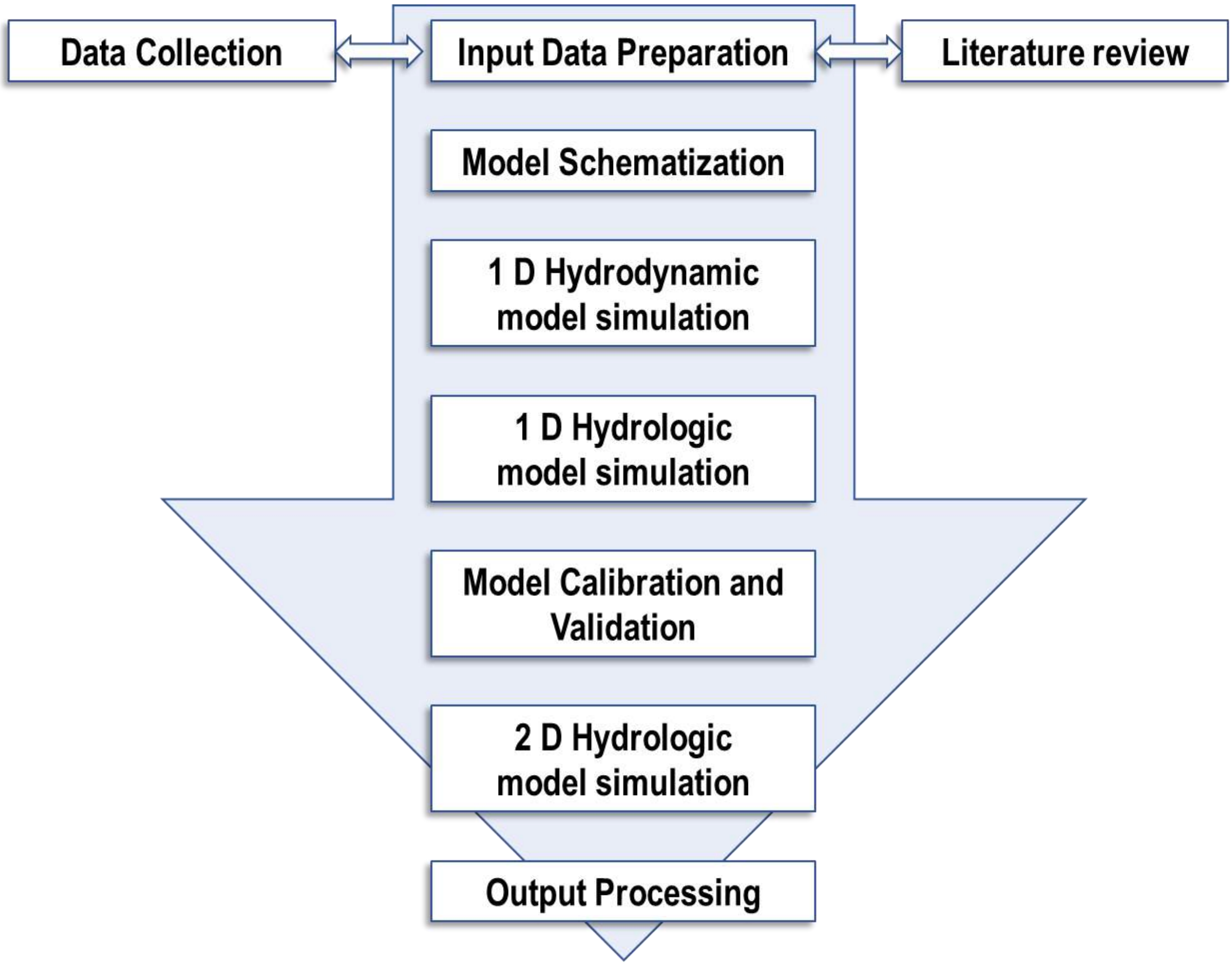


Figure 5.1: Methodological framework of the Modeling Study

5.2 DEM preparation

The DEM is based on point elevation data found from field surveys under this study. The point elevations were first transformed in raster using ArcGIS environment. Then the raster was resampled into 10 m resolution afterwards it was converted in ASCII format. As Sobek requires elevation information in ASCII format.

5.3 Watershed delineation

Sub watersheds of each drainage area have been identified based on existing urban drainage system. Basin boundary and sub watershed borders determined using roads, land use maps, topographic map, building blocks, direction of flow in canals and land survey. The use of distributed type model, which means that a study area can be subdivided into any number of irregular sub catchments to best capture the effect that spatial variability in topography, drainage pathways, land cover, and soil characteristics have on runoff generation. An idealized sub catchment can be conceptualized as a rectangular surface that has a uniform slope and a width that drains to a single outlet channel. Each sub catchment can be further divided into three subareas: an impervious area with depression (detention) storage, an impervious area without depression storage and a pervious area with depression storage. Only the later area allows for rainfall losses due to infiltration into the soil. In the urbanized catchment there are channelized elements (gutters and swales) that conduct runoff to the site's outlet. The partitioning of the study area into individual sub catchments depends not only on the spatial variability in land features but also on the location of the channelized elements. The sub catchment boundaries were determined by aggregating together sub-areas whose potential overland flow paths share a common direction and drain to the same collection channel.

Total 207 sub catchments have been identified using a combination of automatic and manual process. As some of the sub catchments is dominated by urban area the natural watershed has been modified using existing road layers and other infrastructures. Following figure 5.2 shows sub watershed maps of the study area.

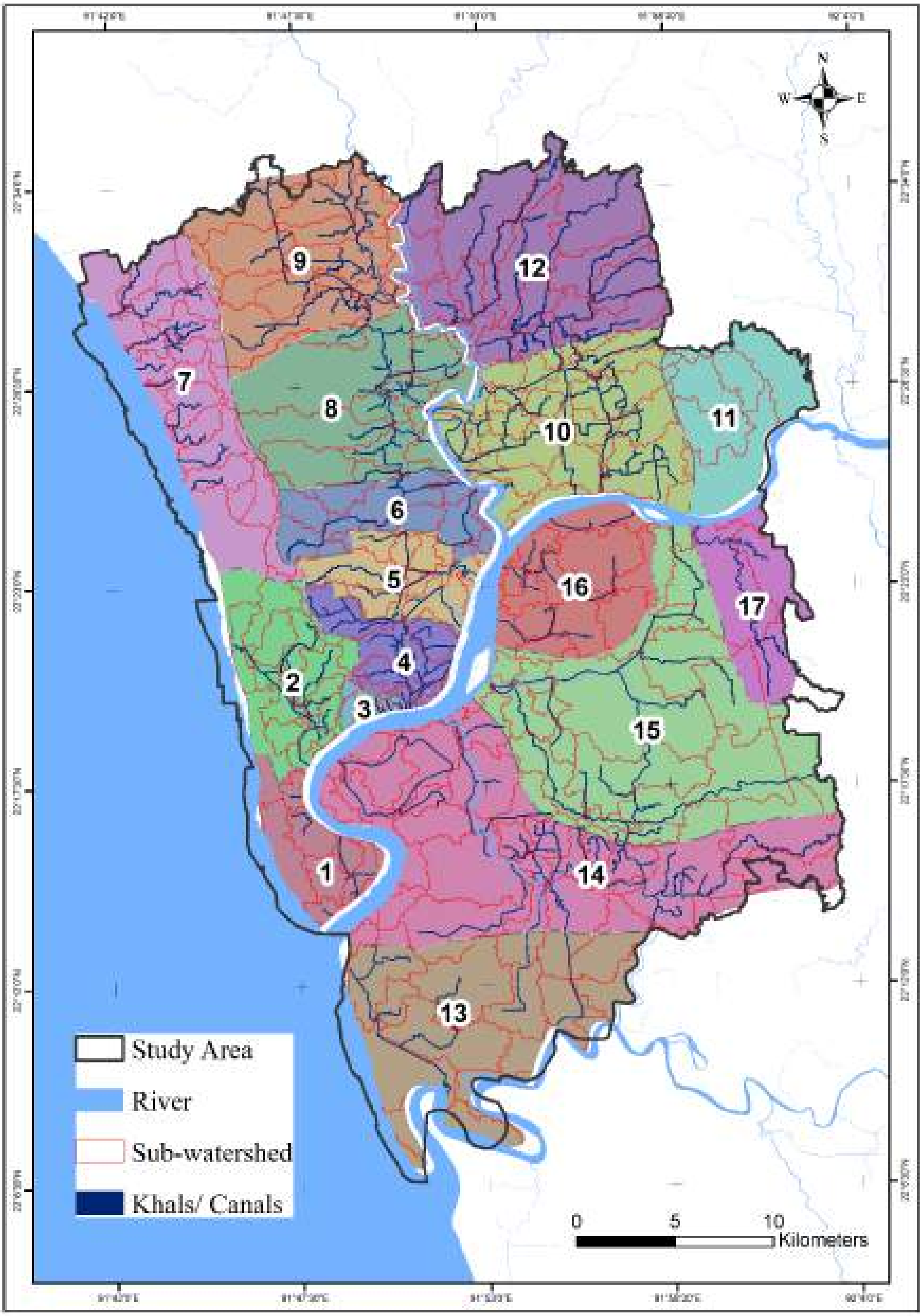


Figure 5.2: Delineated watershed for the study area

5.4 Model setup with SOBEK

The SOBEK modelling suite models water flows and processes in almost any system. The modelling suite includes a combined rainfall-runoff, hydrodynamic (1D/2D), and water quality model designed for river, urban and rural management. The program can employ several model choices to model different the physical process of runoff. Hydrodynamic modelling is based on the St Venant equation. SOBEK is used for flood forecasting, optimizing drainage systems, controlling irrigation systems, designing sewer overflow, river morphology, salt intrusion and surface water quality.

When compared to more widely applied 1D modelling, the main feature of the combined 1D-2D approach is bringing the model behavior closer to the real physical behaviour. Thus, on one side simulating the flow in river/channel with extensive details within the 1D system, while on the other side simulating the overland flow with extensive details within the 2D system. In general, the combined one-two dimensional integrated model offers wide range of modelling options. It is easy to combine an urban drainage model to simulate the street flow, and flow over, for example, parks and parking places (Bishop and Catalano). Further, the combined 1D-2D modelling is capable of modelling problems related to flood hazard and risk mapping (Frank, et al.,). Considering all aspects and data availability the urban flood simulation was performed using SOBEK.

5.4.1 Model schematization

The first step of model schematization was to identify the channels, khals and other flow routing channel from the collected shapefile from secondary source. Once the channels were finalized flow direction and topology errors were corrected. Then using the schematization module of SOBEK khals and river systems were developed. Then when preliminary schematization was done cross sections for each channel were added using location point. Similarly, boundary condition points were added at the beginning of each channel. 145 no of boundary nodes, 633 cross-sections and 207 watersheds were schematized (Figure 5.3).

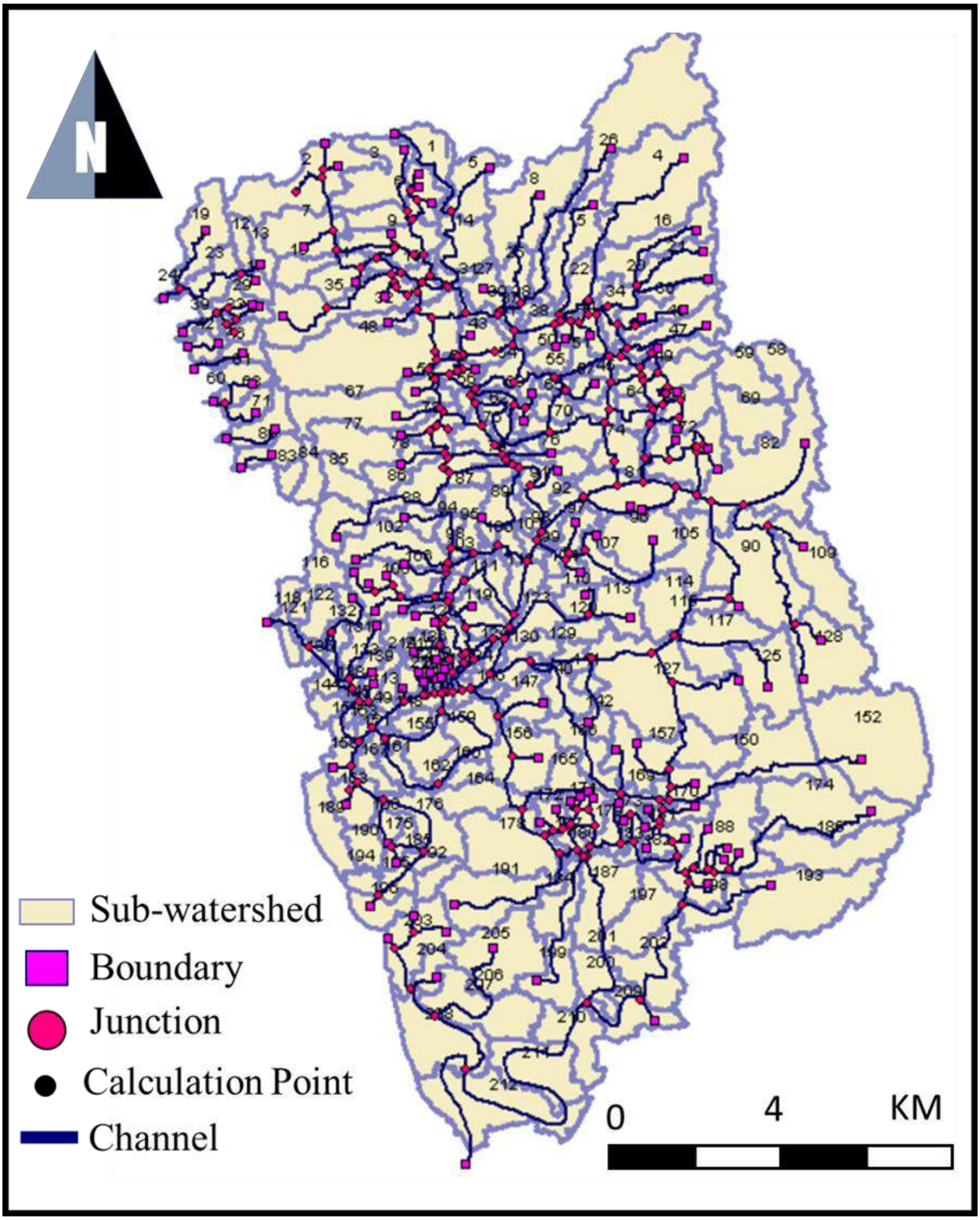


Figure 5.3 : Model Schematization

5.4.2 Model Calibration and validation

Model simulation has been performed for 15 hours using rainfall event of rainfall and tidal water level of hydrologic Scenario 3 as described in hydrological analysis. Water is routed through the channel network using the Variable Storage method. For estimating runoff, the SCS curve number method has been used. Simulation was run for hourly interval with calculation points 250m apart from each other.

Model output validation was performed using observed water logging area. In recent years water logged area was collected and super imposed with inundation layers. In most of the cases the water-logged area coincides with the flood inundated area. Following Figure 5.4 shows the comparison between observed and simulated waterlogging area.

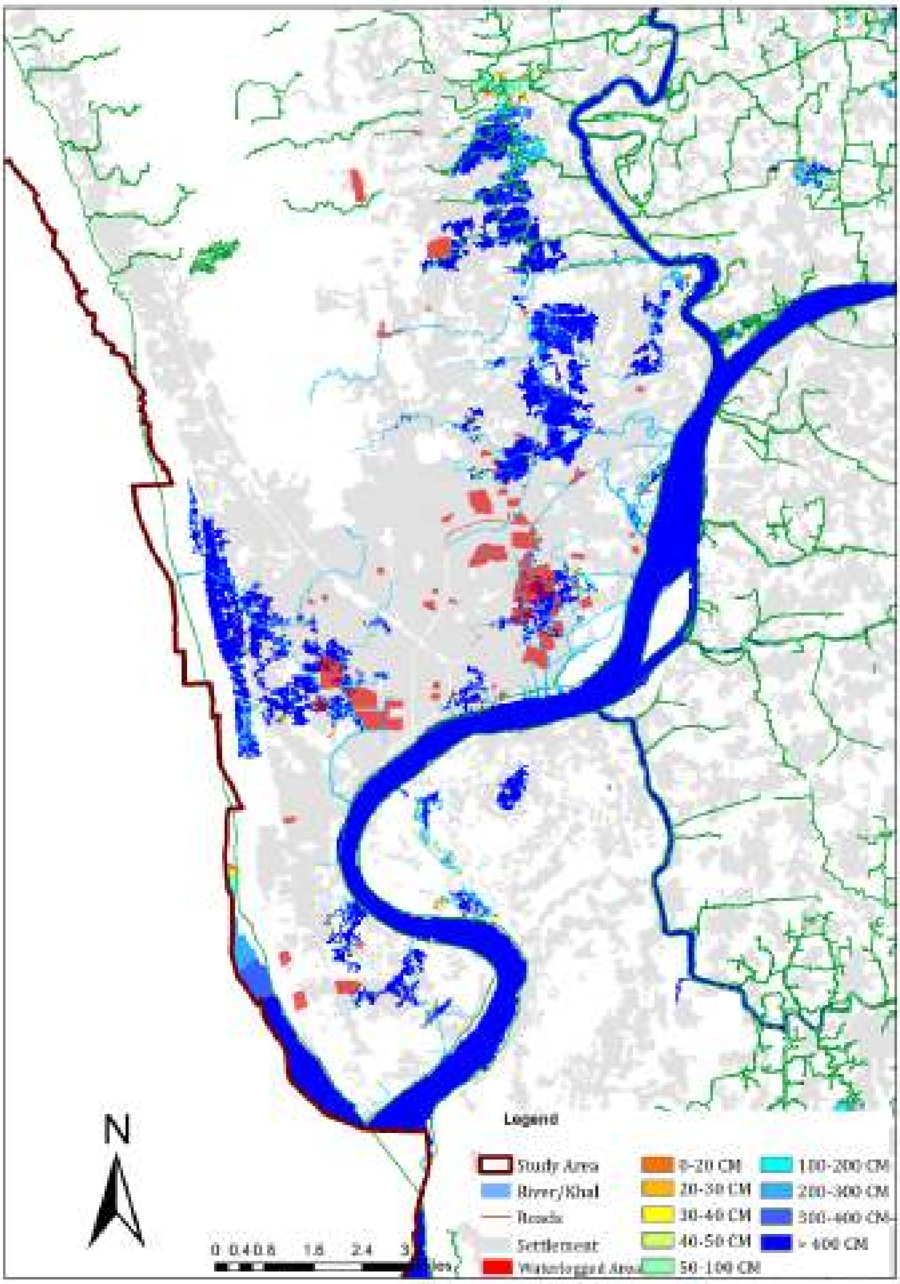


Figure 5.4: Comparison between observed and simulated waterlogging area

5.4.3 Model Simulation of Different Hydrologic Scenarios

For the existing drainage network based on survey data, the drainage model has been simulated for the scenarios selected in the Hydrologic analysis chapter. Figures below shows flood inundation extents and flood depths. Overall inundation depths vary from 0.1 m to 1 m, but the mapping representation shows maximum flood 0.4 (40 cm). Flooding due to only tidal effects are represented in Figure (5.5). In low tide scenario no flooding has been found in urban area but during high tides some area near the Karnafuli river get inundated. On the left of Karnafuli some area near Dangar Char Naval area, Moulovi para and Ichanagar has been found to affected by tidal flooding.

For the ebb tide scenarios namely scenario 03 and scenario 04 the inundation was observed to be increased substantially from scenario 01. Thus, the flooding exhibited in the figure 5.5a and 5.5b are mostly due to heavy storm water runoff. The flooding depth in CDA area for 6-hr rainfall and 24-hr rainfall are shown in Figure 5.5c and 5.5d. Flooding occurred mostly from Gupta Khal, Maheshkhali Khal, Goyna Chara Khal, Rampur Khal, Nasir Khal, Chaktai khal, Birja Khal, Chaktai diversion Sheetol jharna khal, Noa and Uttara khal in the city area. Flooding cluster can also be observed on the both sides of halda river.During high tides when the rain fall is also high generated runoff cannot flow to the adjacent river rather due to tidal effect it flows backward. Thus, when heavy rainfall coincides with high tides the probability of waterlogging increased.

Similar to the ebb tide two scenarios have been simulated for spring tides. The inundation extent and depth increase in those two scenarios. Figure 5.5e and 5.5f shows flood inundation for scenario 04 and scenario 06. Similar to the previous scenarios all khals mention in the earlier section flooded the urban areas. Scenario 06 shows the maximum flooding extent. In further design analysis, Scenario 06 has been used.

Figure 5.5a: Flood inundation due to ebb tide (Scenario 01)

Figure 5.5b: Flood inundation due to spring tide (Scenario 02)

Figure 5.5c: Flood inundation depth for scenario 03 (Ebb tide and 6-hr Rainfall)

Figure 5.5d: Flood inundation for scenario 04 (Spring tide and 6-hr Rainfall)

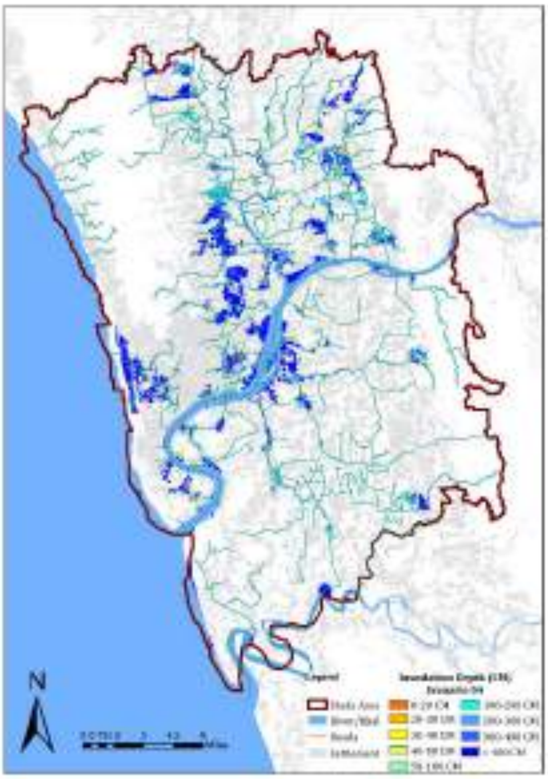


Figure 5.5e: Flood inundation for scenario 05 (Ebb tide and 12-hr Rainfall)

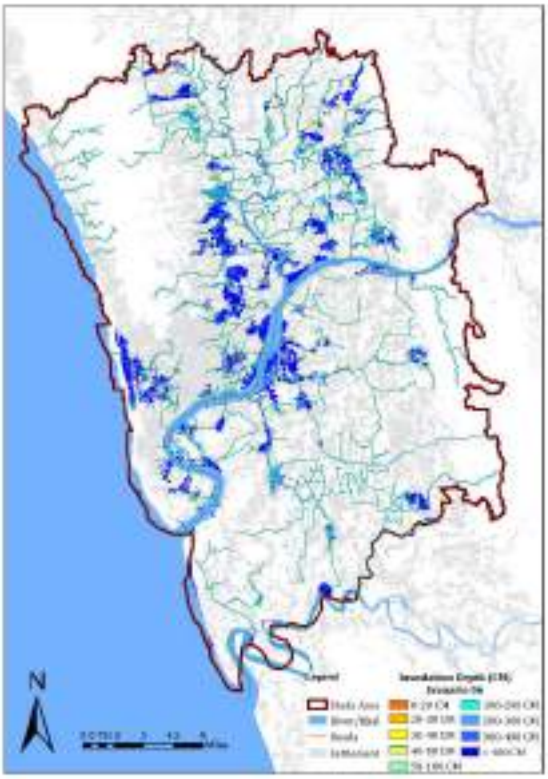


Figure 5.5f: Flood inundation for Scenario 06 (Spring tide and 12-hr Rainfall)

5.5 Urban Flood Inundation Pattern in Different Drainage Areas

Waterlogging generally brings a shallower inundation depth and slower flow velocity than floods but causes severe disruptions of regular city life, including traffic paralysis, infrastructure damage, health, and environmental problems, in Bangladesh. Due Insufficient drainage infrastructure accompanied by tidal effect the port city more often than not gets inundated during monsoon. Some low-lying flat areas in Chattogram City have small or no water level differences with the adjacent tidal canals and Karnaphuli River during high tide, resulting in a tidal water entrance into the city on a regular basis. This study, thus identify the inundation due to a combination of 12-hr rainfall and spring tidal (Scenario 6) as shown in Annexure – 2 spanning Figures A2-1 to A2-17.

Drainage Area 01

Drainage area 01, covering approximately 2700 hectares, experiences significant water management challenges. The elevation of this area ranges from 2 to 7.6 meters above mean sea level, with an average elevation of 4 meters. It features 7 notables primary khals with a total length of 9322 meters, supplemented by 62 kilometers of secondary khals. Additionally, the area comprises about 208 hectares of waterbodies, 365 kilometers of roads, and only 128 kilometers of available drains. Major khals such as Noyarhat Khal, Ruby Cement Factory Khal, Gupta Khal, and 15 No Ghat Airport Khal discharge into the Karnafuli River, while the remaining khals outfall into the Bay of Bengal. These khals are significantly influenced by tidal effects, leading to severe waterlogging issues when heavy rainfall coincides with high tides. Preliminary simulation results indicate that about 32% of the drainage area becomes inundated under extreme conditions, highlighting the critical issue of drainage congestion. Most of the flooding occur due to the over flow Gupta khal and Ruby cement factory khal. This confluence of rainfall and tidal effects exacerbates waterlogging, disrupting daily life and posing risks to infrastructure and public health, emphasizing the urgent need for improved drainage solutions and effective water management strategies.

Drainage Area 02

The total drainage area in this watershed is approximately 4692.3 hectares, which includes 170.8 hectares of wetland and 613 kilometers of drainage infrastructure. There are 13 prominent primary khals circulating within the drainage area, including notable ones such as Mohesh Khal, Nasir Khal, Gaina Chara Khal, Rampur Khal, and Azob Bahar Khal. These primary khals are complemented by secondary khals, totaling 74 kilometers in length. Most khals drain into the Bay of Bengal, while others drain into the Karnafuli River and nearby khals. Waterlogged areas are predominantly due to the overflow of Maheshkhali, Gaynachhara, and Rampur Khals. Gayna Chhara Khal runs through varied terrain with sudden elevation drops similar to the Chosma system, contributing to Maheshkhali Khal. The confluence of these channels, especially where Gayna Chhara Khal meets Maheshkhali Khal, results in significant waterlogging. In the Mahesh Khal system, areas where Goynachara Khal and Rampur Khal meet Mahesh Khal are heavily inundated during the monsoon season. The discharge curve indicates that most flooding occurs from Mahesh Khal. The Flood inundation in the drainage area, according to the preliminary output of the model simulation about 17% of the lands get inundated during monsoon due to high intensity short duration rainfall.

Drainage Area 03

Drainage area 03 encompasses approximately 450 hectares, featuring 6 primary khals totaling 4.6 kilometers and 4.7 kilometers of secondary khals. This area has a minimal waterbody coverage of 9.74 hectares. All khals in this region discharge into the Karnafuli River. The mean elevation is about 5 meters above mean sea level (MSL), with some areas having elevations below MSL. Inundation during heavy rainfall and high tide primarily results from the overflow of Moghultuli Khal and Sadarghat Khals. Initial model simulation results indicate that only 14% of the area experiences inundation during the monsoon season. The combination of heavy rainfall and high tide exacerbates flooding, particularly due to the limited capacity of Moghultuli Khal and Sadarghat Khals to handle the excess water, highlighting the need for improved drainage infrastructure and management to mitigate waterlogging in this region.

Drainage Area 04

Drainage area 04 is one of the most critical areas severely affected by urban flooding each year. Chaktai Khal drains a significant volume of runoff quickly after heavy rainfall due to its very steep slope. This area encompasses 2511 hectares, with only 58.6 hectares of wetland. Despite having comparatively better drainage coverage, it is still inadequate to minimize the impact of urban floods. Preliminary simulation results indicate that flooding occurs due to the overflow of Birza Khal, Chaktai Diversion Khal, and Bakolia Khal. The upstream section of Chasma Khal, which collects surface runoff from the Foy's Lake area, consists of low hilly terrain with a steep slope. The elevation changes dramatically from 10-12 meters to 3-5 meters over a short horizontal distance where Mirza Khal meets Chasma Khal at Muradpur. Beyond this sudden drop, the terrain flattens out significantly, creating a natural funnel for surface runoff during heavy rainfall events. When heavy rainfall occurs, surface runoff from higher elevations rapidly moves downslope due to gravity. The steep slope accelerates the flow, causing a significant volume of water to converge where the higher elevation meets the lower elevation. At this convergence point, the terrain flattens out, causing a bottleneck effect. The kinetic energy of the fast-moving water from the higher elevation is dissipated as it encounters the flatter terrain, leading to a rapid accumulation of water. This process is exacerbated by accumulated debris and waste materials obstructing the natural flow of water, reducing the effective capacity of the drainage channels. These blockades can cause localized flooding and increase water levels upstream of the blockage. Insufficient or poorly designed drainage systems fail to handle the sudden influx of water, leading to overflows and inundation of the surrounding areas.

Drainage Area 05

Noa khal, Domkhali khal, Mirza khal, Tripura khal, Uttara khal, Shitol Jharna khal, Bamon shahi khal etc khals encircled Drainage area 05. Total 30 km of primary khals along with 62 km of secondary khals can be identified in this area. With an area of 3020 ha this drainage area has around 150 ha of wetlands and 320 km of drain. As per the initial results of the simulation approximately 22 % of the area gets inundated during monsoon. Similar to drainage area 04, Chosma khal drains huge volume of water within a short period of time near Muradpur area then majority of the flow diverts towards the drain area 05 and a partial flow diverts towards drainage area 04. There are some low-lying areas, not very densely populated, mostly these areas get inundated. Inundation occurs mainly from Noa khal, Mirza khal and Bamon shahi khal.

Drainage Area 06

The drainage area 06 spans 346 hectares, including 196 hectares of waterbody and 63 km of stormwater drains, with some regions below mean sea level that are prone to inundation during the monsoon season. Preliminary model simulations have highlighted significant flooding issues, particularly clustered near the Halda River, affecting about 14% of the area. This suggests that the proximity to the river and the elevation of the land contribute to the flooding. Despite having a substantial network of stormwater drains, their effectiveness in handling heavy rainfall may need reassessment. Implementing improved flood management strategies and increasing community awareness about flood risks and preparedness can help mitigate the impact of flooding and enhance resilience in the area.

Drainage Area 07

One of the largest drainage areas within the CDA encompasses 8,140 hectares, with most of its khals oriented toward the Bay of Bengal and draining into the Sandwip channel. This extensive drainage network includes approximately 35 km of primary channels and around 76 km of secondary khals. Remarkably, this area experiences comparatively minimal urban flood inundation. Preliminary simulation results indicate that less than one percent of the land is affected by flooding, highlighting the area's effective drainage system and resilience against urban flood events.

Drainage Area 08

Drainage Area 08, a predominantly suburban region, encompasses a total area of 7,797 hectares, of which 646 hectares are covered by water bodies. This area is characterized by the presence of five significant khals, or natural drainage channels, that direct water flow into the Halda River. During the monsoon season, approximately 16% of the land within this drainage area experiences inundation. This flooding is influenced by the interplay between the khals and the river, which collectively manage the runoff and water levels in the region.

Drainage Area 09

Drainage Area 09 consists of a mix of open lowland and developing urban regions. The total area is approximately 7,390 hectares, with 311 hectares covered by water bodies. The drainage area has moderate to low coverage of drainage infrastructure. Simulation results indicate that the low-lying areas between suburban regions are primarily subjected to flooding. Only 8% of the area is inundated during heavy rainfall and high tide scenarios.

Drainage Area 10

Drainage Area 10 notably contains seven primary khals, most of which drain into the Halda River, while the remaining khals discharge into the Karnafuli River. This drainage area covers 8,939 hectares, including 628 hectares of water bodies. Every year during the monsoon season, the area near Noapara gets inundated due to the overflow of the Noapara Khal. According to the initial simulation results, 23% of the area is inundated during heavy rainfall and high tide events.

Drainage Area 11

The drainage area consists of relatively high land and moderate water bodies. It spans 4,493 hectares, of which 119 hectares are water bodies. This area is minimally affected by urban flooding due to its higher elevation and limited water coverage.

Drainage Area 12

One of the largest drainage areas spans 10,873 hectares, with approximately 680 hectares covered by water bodies. This area features four notables primary khals and 178 kilometers of secondary khals. Additionally, it has about 7.18 kilometers of stormwater drainage infrastructure. According to the initial model output, around 10% of the area becomes inundated, particularly near Ghorio, Raozan, and Dabua Raozan, during heavy rainfall and high tide events.

Drainage Area 13

Drainage Area 13 encompasses approximately 10,377 hectares, including 600 hectares of water bodies. It features about six major khals and 88 kilometers of secondary khals, with most of the khals discharging into the Sangu River. According to the initial simulation results, only 4% of the area gets inundated during the monsoon season.

Drainage Area 14

Drainage Area 14 spans approximately 16,707 hectares, with 958 hectares classified as water bodies. This region is characterized by three majors primary khals, or natural drainage channels, and has comparatively fewer stormwater drainage infrustructures than other areas, primarily due to its relatively undeveloped status in terms of urbanization and human habitation. According to modeling results, around 14% of the area experiences inundation during periods of intense monsoon rains combined with high tides. Specific locations such as Dangar Char and Maulvi Bazar are prone to flooding from the overflow of the Karnafuli Channel, while areas like Daulatpur, Kaigram, and Sikdarpara face inundation due to the overflow of Murari Khal. This pattern of flooding underscores the region's susceptibility to seasonal weather events and the challenges associated with managing water flow and land use in less developed areas.

Drainage Area 15

Drainage Area 15 covers approximately 15,216 hectares, of which 1,639 hectares are designated as water bodies. This area features three primary khals extending over 30 kilometers, complemented by an additional 160 kilometers of secondary channels. The stormwater drainage infrastructure in this area is similar to that of Drainage Area 14, reflecting its ongoing development in managing water flow. Preliminary simulation results indicate that about 8.4% of the area becomes inundated during heavy rainfall and high tides. The region's most severely affected by flooding are situated along both banks of the Boalkhali Khal. This flooding is indicative of the challenges faced in balancing water management and infrastructure development within the drainage area.

Drainage Area 16

Drainage Area 16, located along the banks of the Karnafuli River, spans 5,443 hectares and includes 404 hectares of water bodies. This region is notably underdeveloped, characterized by extensive open fields and minimal stormwater drainage infrastructure, with only 3 kilometers of drainage channels present. The area is intersected by four major primary khals and 82 kilometers of secondary khals. Initial simulation results indicate that during the monsoon season, three distinct clusters of inundated areas can be identified. These clusters are primarily situated along the banks of Shakpura Khal and Charndip Khal. The inundation mapping reveals that approximately 9.5% of the area is affected by flooding, highlighting the region's vulnerability to seasonal water management challenges.

Drainage Area 17

Drainage Area 17 covers 3,467 hectares and is largely underdeveloped, with minimal built-up infrastructure. It features a relatively low percentage of water bodies. According to simulation results, less than 1% of the area experiences inundation during the monsoon season or heavy rainfall.

5.6 Drainage Conditions of Major Water-logged Areas

From the modelling study major water-logged area have been identified within the study area. Among these, most of the areas within the CCC area can be characterized as dense urban are varying from 70% -100% urban coverage. Areas outside the CCC have combination of urban area and crop land and other land uses. water-logging issues in the urbanized area may be exacerbated by factors such as insufficient drainage infrastructure, impermeable surfaces, and encroachment into natural watercourses. The combination of these factors can lead to recurrent flooding, particularly during monsoon seasons or extreme weather events, impacting both residents and local businesses. Table 5.1 and Figure 5.6 below outline identified major water-logged areas in the study area.

Table 5.1 List of Water-logged Areas

Drainage area	Waterlogged area name	Area (Ha)	Location	Type of LULC	Contributing Khals
1	D	1566.2	Patenga	70% Urban area	Gupta khal, Ruby cement Factory khal, 15 no, ghat airport khal,
2	A	1114.0	Halishahar Housing, Noyabazar, Agrabad, Monsurabad	97% Urban area	Gaina Chhara KhalMohesh Khal, Rampur Khal, Maheshkhali Khal
3	V	93.0	Madarbari firingi bazar.	96 % Urban area	Parbati para khal
4	B	307.3	Muradpur, Sholoknahar	100 % Urban area	Domkhali Khal, Mirza Khal, Cjaktai Khal, Kakolia khal, Chosma Khal
	C	259.6	Bakalia	96 % Urban area	Jamal khan Khal, Chaktai khal, Chaktai Diversion, Bakolia khal, Birza khal
5	B	73.5	Muradpur, Sholoknahar	98 % Urban area	Domkhali Khal, Mirza Khal, Chaktai Khal, Kakolia khal, Chosma Khal

Drainage area	Waterlogged area name	Area (Ha)	Location	Type of LULC	Contributing Khals
	E	617.2	Hasem Nagar, Chandrima, Kamrabad, Dalipara, Miahnagar	62 % Urban area, 30% Crop land	Noa Khal, Mirza khal, Tripura Khal, Uttara khal etc
6	E	241.6	Hasem Nagar, Chandrima, Kamrabad, Dalipara, Miahnagar	15% Urban area, 83% Crop land	Noa Khal, Mirza khal, Tripura Khal, Uttara khal etc
	F	140.7	Shikdar Para, Bara Dighir par, Nehalpur.	32 % Urban area, 66% Crop land	Bamonshahi khal, Khandokia khal, Shitol jharna khal
8	F	1130.5	Shikdar Para, Bara Dighir par, Nehal pur.	23 % Urban area, 73% Crop land	Bamonshahi khal, Khandokia khal, Shitol jharna khal
	G	307.7	Mekhal, Mehedi Para	23 % Urban area, 74% Crop land	Mekhol road khal
9	H	712.4	Mohammadpur, Rudrapur,	15 % Urban area, 83% Crop land	Zilani bazar khal, Balukhali road khal
10	J	893.3	East Gujara, Bhumardara	6% Urban area, 80% Crop land	Bhumardara khal
	K	471.7	Kharandwip, Quepara,	2% Urban area, 94 % Crop land	Kharandwip khal
	L	824.2	Noapara, Potiapara,	24 % Urban area, 65% Crop land	Noapara khal
	M	213.0	Panchkhain, Mazi para	10 % Urban area, 78% Crop land	Noapara khal
	T	194.7	Purba Ukir Char	23 % Urban area, 71% Crop land	Barigona khal
12	J	272.7	East gujara, Bhumardara	2 % Urban area, 94% Crop land	Bhumardara khal
	N	842.5	Jalil Nagar	24% Urban area, 52% Crop land	Jalinagar khal
	O	649.9	Lelangara	15 % Urban area, 75% Crop land	Lelangara khal
	S	154.5	Gohira	3 % Urban area, 94% Crop land	Gohira khal
14	I	1379.1	Moulvi para, Dangar Char, Julda	47% Urban area, 50% Crop land	Karnafully canal
	P	303.1	Panchariya, Lakhera, Mohammadnagar	30% Urban area, 55 % Crop land	Boalkhali khal
	Q	1231.3	Kalpul, Sikderpara, Kaigram, Daulatpur.	50% Urban area, 30% Crop land	Murai khal
	R	234.1	Ashata	24% Urban area, 73% Crop land	Ashata khal
15	P	1572.1	Panchariya, Lakhera, Mohammadnagar	36 % Urban area, 44 % Crop land	Boalkhali Canal
	U	204.3	Moitala, ratanpur,	8 % Urban area, 90% Crop land	Ratanpur khal
16	P	328.1	Panchariya, Lakhera, Mohammadnagar	55% Urban area, 27 % Crop land	Boalkhali Canal

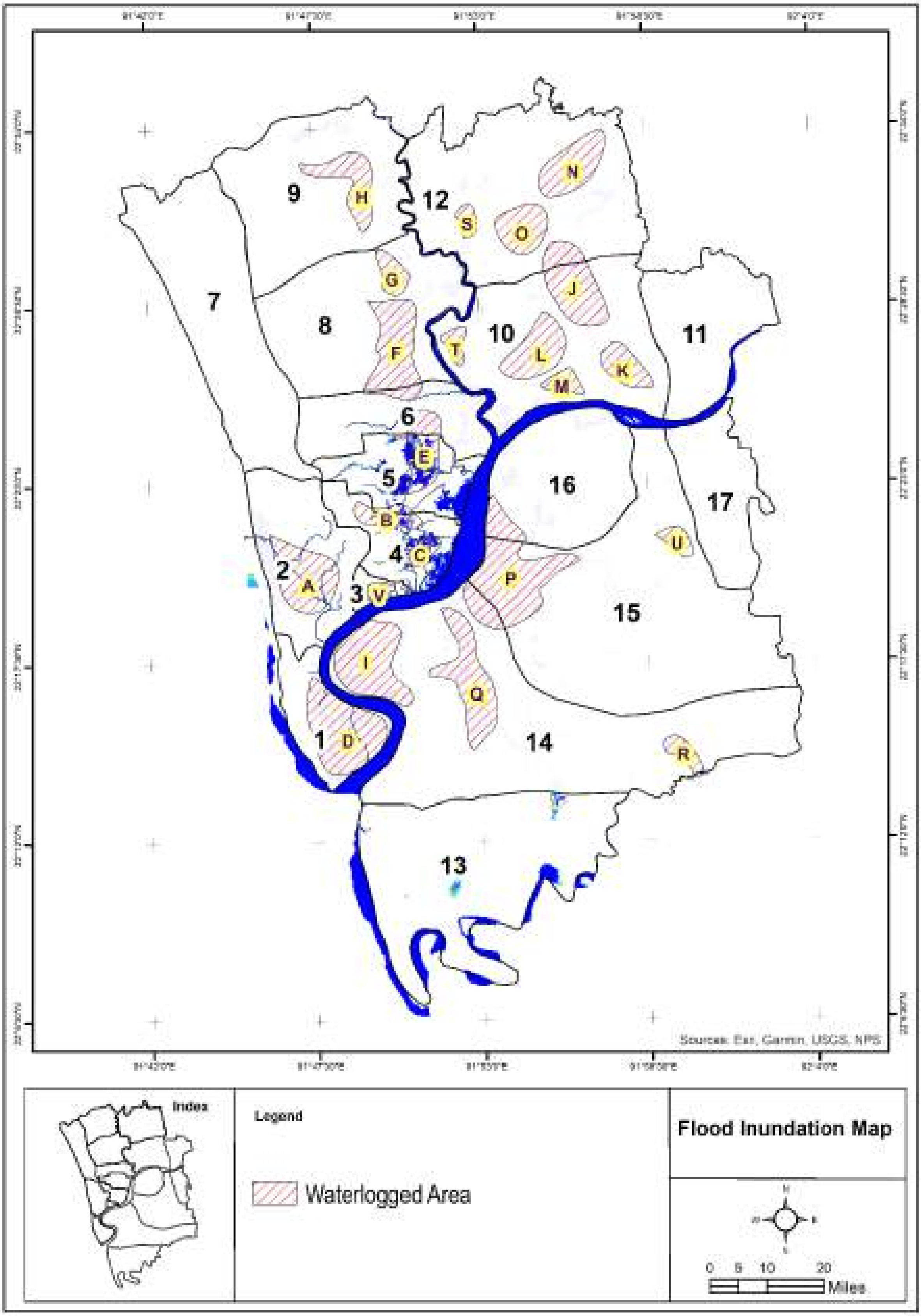


Figure 5.6: Water logged areas from the model simulation

5. 7 Drainage Condition with Intervention

5.7.1 Khal Enlargement

From the modeling exercise it has been found that some of prominent khals overflow during monsoon due to heavy rainfall accompanied by tidal effect. Khals namely Guptakhal, Maheshkhali Khal, Rampur khal, Chaktai khal, Chaktai diversion, Bamonshahi khal, Shitol jharna khal, Uttara khal, Mirja khal, Krishna khal and Noa khal. In most of the cases it has been found that the khals corss sections are not adequate to accommodate the runoff generated during heavy rainfall. This study thus suggested average cross section for each of the khal system to accommodate the runoff and mitigate flood in most of the area in CDA. The existing bed and proposed bed level of different khals are shown in Figure A2-18.

Using the proposed Khal sections a separate model scenario has also been simulated to observe the effectiveness of the proposed sections of the khals. Figure 5.7 shows the improve condition of the for the intervention. The proposed drainage can improve the current scenario of flooding.

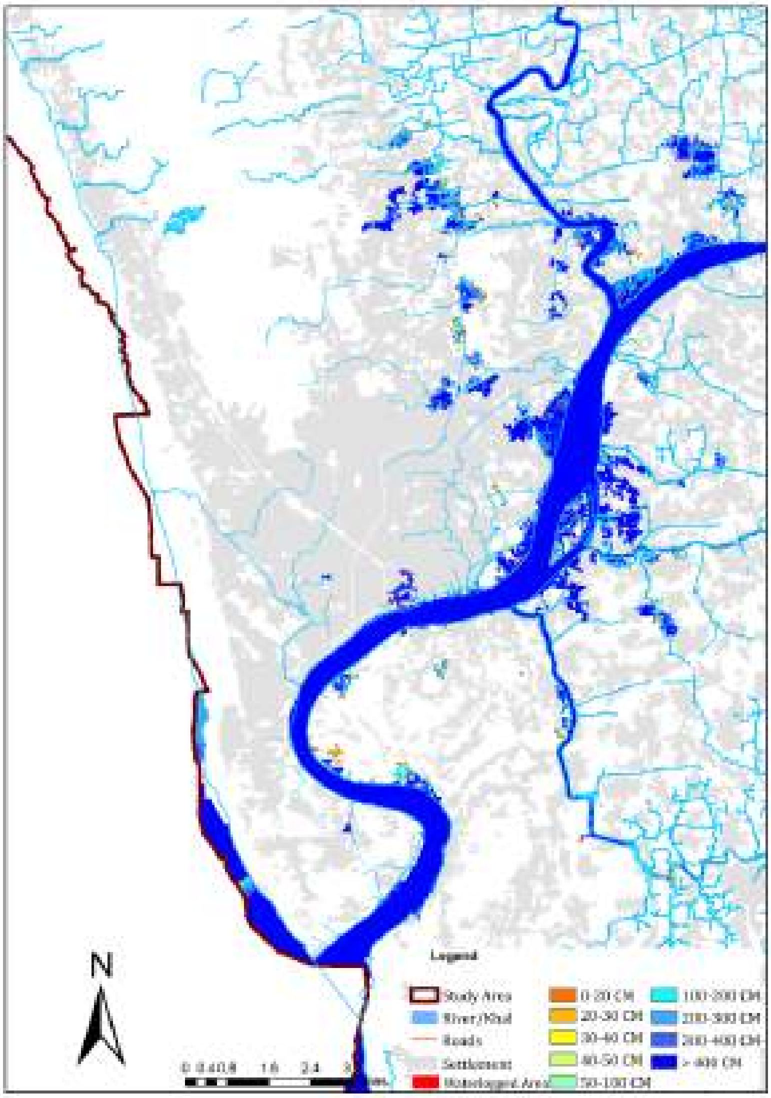


Figure 5.7: Improved flood condition for the CCC Area

5.7.2 Provision of New Khal/ Drain for Muradpur Area

1995 Mater Plan suggested to construct a new khal from Baraipara to Balirhat to improve the drainage condition of Muradpur area. However, this construction has not been completed yet. Therefore, a model simulation has been performed incorporating the new khal of 2.75 km. This inclusion can reduce the drainage condition to some extent as compared to the existing condition as shown in Figure 5.8a and b. There is a connection between Mirza khal and Chaktai khal on the southside of CDA Avenue using a 3 m wide khal. However, during the field visit it was observed that, another drain might be useful along the northside of CDA avenue connecting Mirza and Chaktai khal. A model simulation incorporating this drain of 9 m width shows that it can also reduce the drainage congestions of Muradpur Area (Figure 5.8c).

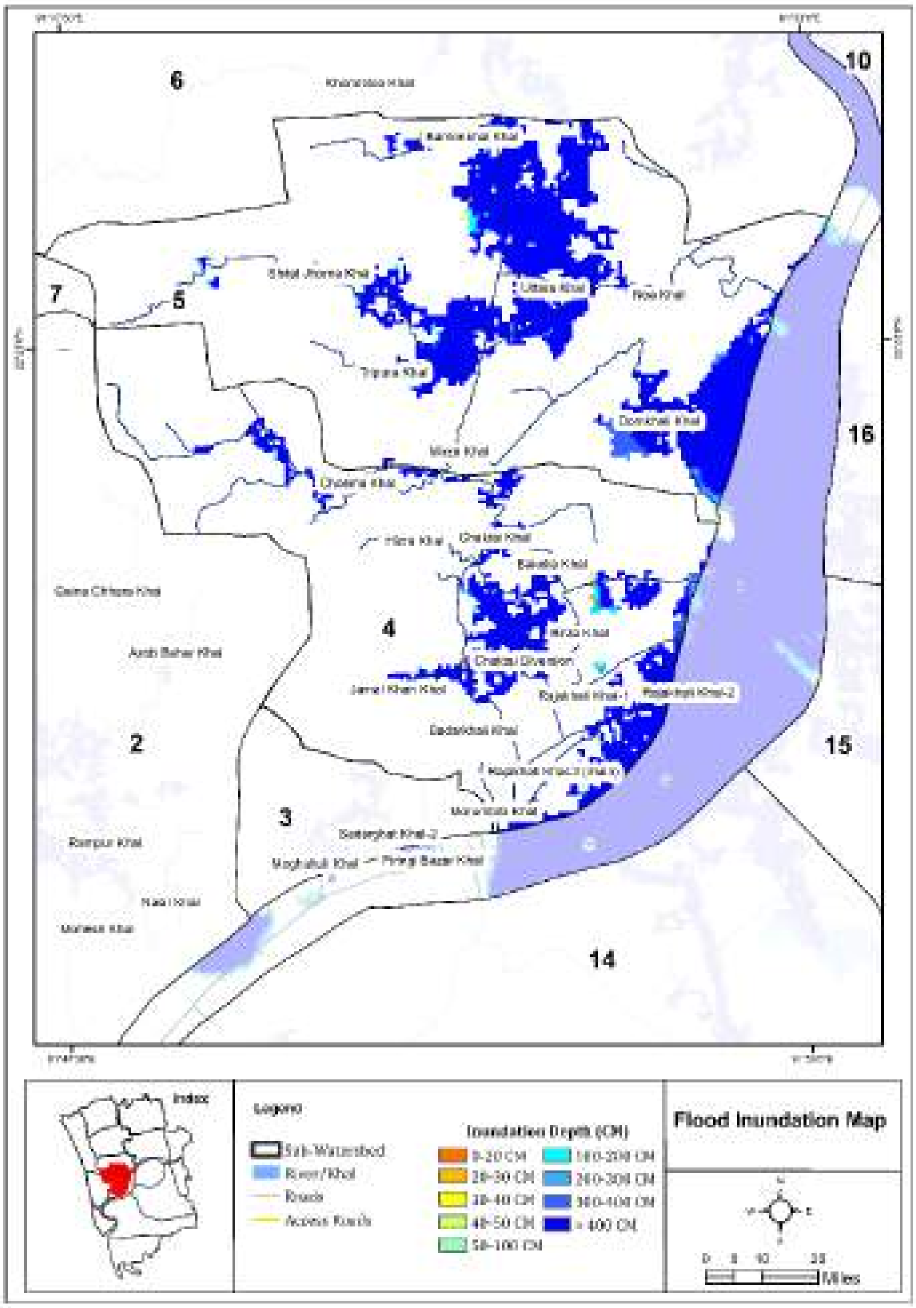


Figure 5.8a: Existing Flooding Condition of Muradpur-Bahaddarhat Area

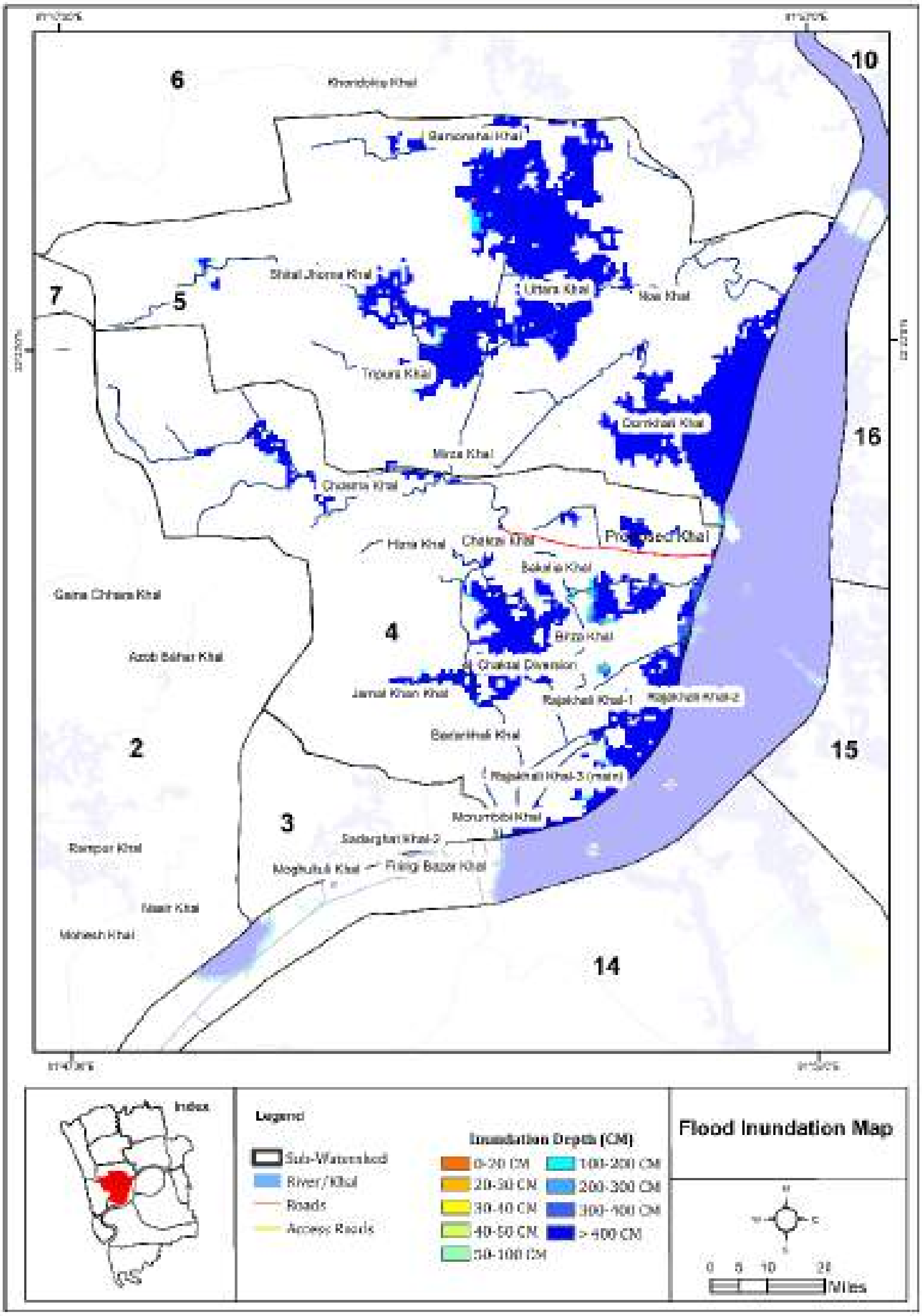


Figure 5.8b: Flooding Condition of Muradpur-Bahaddarhat Area after implementation of Broipara – Balirhat Khal

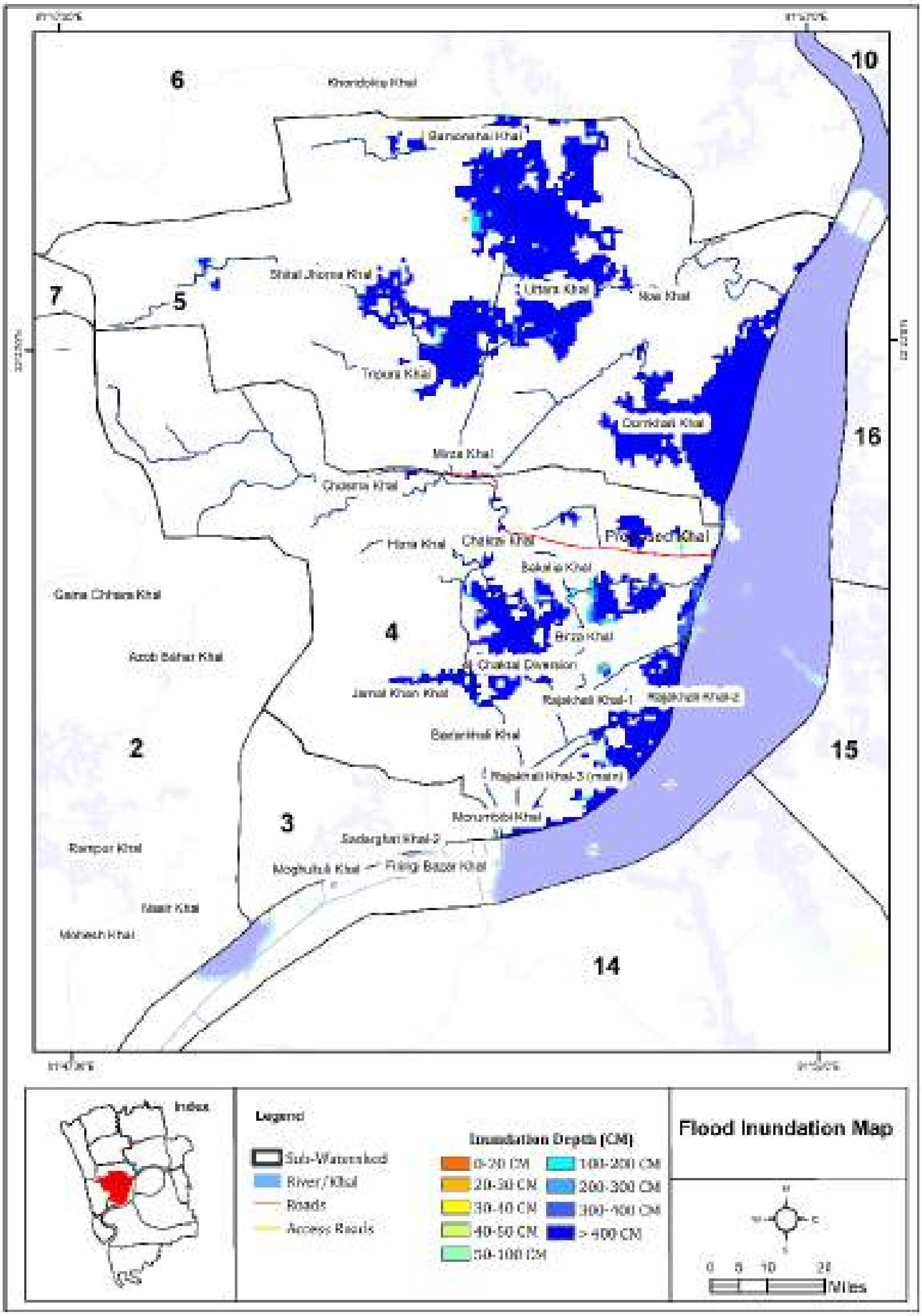


Figure 5.8c: Flooding Condition of Muradpur-Bahaddarhat Area after implementation of Boroipara – Balirhat Khal and a new khal on the North side of the Road

CHAPTER SIX

OPTIONS FOR DRAINAGE AND FLOOD CONTROL

6. Options for Drainage and Flood Control

6.1 General

Various options will be examined in the process of arriving at the Master Plan following the CDA drainage Master Plan (1995-2015) and CWASA Drainage Mater Plan (2016-2030). Moreover, the Low Impact Development Measures as suggested in National Adaptation Plan (2023-2050). These options can be classified as:

(a) options which are generally applicable throughout the Study Area. Examples of these are the relative merits of channels or pipes for drainage construction or the level of storm return period to design for;
(b) options which are applicable within a specific drainage area. These will typically concern alternative drainage routes, widening existing drains or providing relief drains or providing storage rather than pumping.

6.2 ELEMENTS COMPRISING THE MASTER PLAN

The Master Plan will comprise a number of solutions applied as appropriate. Some of these solutions are to be applied universally, while others may be appropriate in some locations only.

Regular Maintenance

The drainage system within Chattogram is particularly prone to siltation and blockage. These effects are accentuated by:
(a) high sand loads in the system due to hill cutting;
(b) the practice of solid waste disposal into khals and their use as open sewers.
and
(e) the flat. tidal nature of many khals, resulting in extensive deposition at the break of slope between the hills and the flat coastal strip and at the limit of tidal influence, where velocities pass through zero at each turn of the tide.
Although difficult to quantify, regular maintenance or rehabilitation of the drainage system will reduce the frequency and extent of flooding. Without maintenance, the efficiency of any drainage improvements constructed will be quickly reduced. This maintenance will be most effective if combined with continuing development of the city's solid waste disposal and sanitation programs in order to limit the amount of rubbish and human waste entering the drainage system.

Provision of Mechanical Trash Screen and Removal System

A **Mechanical Trash Screen and Removal System** is an automated setup designed to filter and remove debris from water flow in drainage systems, rivers, and wastewater treatment plants. The system typically consists of a series of screens that trap floating and submerged trash, preventing it from entering downstream areas. These screens are often accompanied by mechanical rakes or conveyors that continuously remove the collected debris, ensuring that the screens do not become clogged, and that water flow remains unobstructed. However, no trash screen and removal system are present in khals of the City. It is important to install such systems at intermediate locations as well as at the outlets before the sluice gates and must be considered a firm component of the drainage Master Plan.

Silt Traps

Maintenance commitments would be reduced if garbage loads and silt loads in the drainage system could be significantly reduced. A number of silt traps have been constructed, mainly in the northern parts of the city, to reduce the impact of hill cutting. The project team inspected some of these silt traps. Most are of small volume and have been constructed to the dimensions of the available land. The small volume of the existing traps means that they are rapidly filled at the start of the monsoon season.

There is evidence of filling of traps in two days. Despite the difficulty in correct siting of silt traps due to the moving hill cutting operations, and the large land areas required for an effective trap, silt traps must be considered a firm component of the drainage Master Plan. One option is the combined operation of silt traps with flood storage and detention ponds. The large volume of flood ponds and resultant low velocities within them promotes siltation, which would in general create a maintenance commitment to the pond. If such storage can be sited to act also as a silt trap, maintenance may be concentrated at such sites.

Local Drainage Improvements

There are numerous local blockages throughout the existing drainage network. Some of these were located during previous studies, and further examples have been found by the project team. Examples of such blockages, and possible improvements, include:

(a) poor design of channel bends and culvert entrance and exits, resulting in hydraulic inefficiency and hence excessive loss of hydraulic head and siltation. Redesign of such details is required:

(b) Low bridge soffits, or narrow bridge waterway, resulting in orifice or surcharged flow at the structure, and resulting high hydraulic head losses. Raising or widening of bridges is required.

(c) pipes for services crossing channels are situated below bridge soffits or channel bank crest level, reducing the cross-sectional area of flow and collecting debris that further reduces the flow area. Raising of pipes is required.

(d) reduction of channel cross-section due to encroachment by adjacent properties. Local channel widening to obtain a uniform section is required

(e) crossings over roadside channels to adjacent properties, these have an impact similar to that of the larger structures described above.

Tertiary Drains and Micro-drains

Tertiary drainage and micro-drains convey run-off from adjacent properties into the more major khals. Typical examples are the roadside drains found in many colony areas and in commercial areas of the city center. Most areas in the city center appear to have such drains. Observation by the study team indicates many are in poor condition with standing water, suggesting downstream obstructions. Many also appear small for the high intensities of rain that fall in the monsoon season.

Similar systems exist in the more modern colony developments, such as the Agrabad area. Again, condition and lack of capacity appear to be the cause of some flooding problems in such areas.

The provision of adequate tertiary and micro-drain systems offers two benefits:

(a) Efficient drainage of frequent, low return period rainstorm events can be achieved, reducing frequency of flooding.

(b) Flooding will still occur during larger rainstorm events, unless and until the capacity of primary and secondary khals is increased. However, more efficient tertiary and micro-drainage will reduce in duration of flooding.

New or Enlarged Khals

The provision of new or enlarged khals will be required in some areas. They are also well defined, self-contained projects. However, there are potential problems in their implementation in Chattogram:

a) Larger or duplicated khals will result in lower flow velocities in all but the design flood. In flat, inter-tidal areas, this will result in rapid siltation of the new khals. Examples of this can be seen in parts of the Chaktai reprofiling.

b) They will require land purchase and resettlement of residents.

c) In some areas, the land may be too low-lying to achieve a solution against high tide levels by gravity drainage alone.

Adding lining to the khals will only increase by capacity of small channels. In wide sections dominated by the bed, siltation will quickly increase bed friction to a figure close to the original value. However, lining can facilitate de-silting.

Raising Land Levels

Low-lying land can be raised with imported fill to facilitate gravity drainage. This approach has the advantage that it can allow complete design of the drainage system to eliminate all flooding. It is already carried out on a small scale for most development in the rural fringes of Chattogram, where housing is built on a fill platform above the surrounding land, but the level is generally only raised sufficiently to enable drainage into the surrounding land. This elevation is likely to become insufficient for drainage as the surrounding areas themselves become developed.

However, the approach has major disadvantages:

(a) It can best be carried out on a large scale where there is little existing development. Any existing inhabitants and industry would have to be resited to prevent creation of low-lying "islands" within the filled area. Such low areas would carry an increased risk of flooding and could only be protected by their own flood pond and, probably, a small flood pumping station, Existing development within Chattogram being generally in piecemeal form is likely to prevent large scale filling.

(b) Large quantities of material would be required to fill such a development area with upto two metres of fill would be required in areas adjacent to the coast or the river. Material won by dredging from the adjacent river or sea bed is likely to be silty and require significant consolidation time before construction is started. Dredging operations to extract large volumes of material may require expensive overseas plant. The sand hills to the north of Chattogram could provide fill, and because of its extraction could create new development sites. However, the logistics of transportation and the time required to fill a large development site would need to be carefully assessed, as would the impacts on the environment and on transportation systems.

Flood Storage

Flood storage can be provided in a limited number of locations:

(a) downstream of new development areas, in order to attenuate the peak run- off and to limit downstream flows to the capacities of the existing khals;

(b) between low-lying areas and the river or sea, so as to collect run-off when the drainage system is tide locked and hold it until gravity drainage can be resumed.

Flood storage has the disadvantage of requiring relatively large area of land. Acquiring a site at the required location in the older, more densely populated areas of Chattogram may be difficult. However, no such problem exists in future development areas, and the excavation of the pond will produce additional fill for land raising.

Pumping

Where ground levels are close to normal river or tide levels, the only option to eliminate regular flooding is to construct flood pumping stations behind embankments. These have major disadvantages:

Flood pumping stations are extremely expensive to build and operate because of the very high discharges involved. There is a commitment to continuing operations and maintenance.

They would only be operated a few times in each monsoon season. It is difficult to ensure reliable operation of pumps that operate only occasionally and, in order to minimise the risk of pump malfunction at a critical moment, regular and frequent maintenance and testing must be carried out.

In areas that have not been developed we believe that very low-lying land should remain undevloped or should be developed by using landfill. The economics of pumping and landfill need to be assessed.

Tidal and River Flood Defences

The land drainage alternatives described above can be combined with coastal defences against cyclonic, tidal and river flooding. The coastal defense will be the embankment already being constructed with tidal regulators at the mouths of the khals. The river defenses can consist of embankments, with or without a road on the crest, sheet pile walls or concrete walls, the choice to be made according to the amount of space available and the type of development existing on the river bank. Tidal regulators can be provided at the mouths of the khals.

6.3 Components of Nature Based Solution/LID

Nature-Based Solutions (NBS) and Low Impact Development (LID) are innovative approaches to stormwater management that leverage natural processes to reduce the impact of urbanization on water systems. In the context of storm drainage, NBS and LID focus on integrating natural elements like vegetation, soil, and permeable surfaces into urban landscapes to manage rainwater at its source. Rather than relying solely on traditional engineered systems like concrete drains and pipes, these approaches aim to reduce runoff, enhance water infiltration, and promote natural water cycles. Techniques such as green roofs, bioswales, rain gardens, and permeable pavements are commonly used in LID to capture and filter stormwater, reducing the risk of flooding and improving water quality. By mimicking natural hydrological processes, NBS and LID not only provide effective stormwater management but also enhance urban resilience, support biodiversity, and create healthier, more livable communities.

Constructed Wetland Basin/Storm Pond:

Constructed wetlands/Storm Pond are generally artificial ponds designed to filter water through physical and biological processes. They offer a natural method for treating and removing pollutants from stormwater, ensuring cleaner water enters our khals rivers, and oceans as well as reducing peak runoff volume. Any existing shallow or deep ponds can also be designed as a Storm Pond. In wet ponds, ponds are required to be designed such a way that they remain empty up to certain level before and after heavy rainfall events. In dry pond they are designed to remain dry before heavy rainfall events.

Rain Garden/ Bio-retention System

Raingardens, also known as bioretention systems, are constructed garden beds crafted to filter stormwater runoff originating from nearby areas or stormwater pipes. These gardens leverage soil, plants, and microbes to naturally treat stormwater, effectively fulfilling their dual role of filtration and biological treatment.

Raingardens vary in size from 1 to over 100 square meters, typically constituting 1-2% of the catchment area, depending on collected water volume. They are usually installed after the upstream catchment is 95% developed because poorly managed construction sites create sediment and clog the raingarden. A sediment pond or swale is a good temporary solution to manage sediment during construction.

Bioswales

Bioswales are depressed channels designed to gather and move stormwater. They may have grass lining or more abundant vegetation and landscaping. In urban areas, swales may be used as an alternative to:

- conventional street nature strips

- centre median strips of roads
- run-off collection points in car park areas

In rural areas with enough space and slope, swales may be used with the sealing of rural roads to reduce negative impacts from increased stormwater run-off.

Rainwater Harvesting

Rooftops are commonly used to collect rainwater for storage and later use. Observing the annual growth rate of urban expansion, it is estimated that approximately 50% of the drainage area will be covered by urban structures. As per the guidelines in *Managing Urban Stormwater: Soils and Construction – Volume 1* (EPA NSW), it is recommended that 15% of the rooftop area be allocated for rainwater harvesting. Implementing this measure could help reduce surface runoff across the area. In the existing scenario, rainwater harvesting plans are primarily identified for the rooftops of government-authorized buildings and educational institutions.

Storage Pond

Existing ponds—whether shallow or deep—can be repurposed as functional storage ponds. As per *UN-Habitat's Stormwater Management Manual* (2008), each storage pond in an urban setting should have a minimum surface area of 2,000 m² to effectively control flood and stormwater. In this study area, ponds exceeding this threshold have been identified and proposed for such use.

As per the *Indicative Guidelines for Restoration of Water Bodies* by the Central Pollution Control Board (CPCB), it is recommended that 1% to 5% of the total drainage area be allocated for water bodies such as ditches and ponds. For the study area, maintaining a minimum wetland coverage of 3% is proposed, with efforts to preserve existing water bodies wherever legally feasible. Within these reserved waterbodies, specific areas are designated as storage ponds, covering approximately 1% of the total drainage area according to the *UN-Habitat*'s guidelines, to further reduce stormwater runoff volume.

Conservation of Open Spaces

According to the guidelines outlined in *Rain Gardens: Managing Water Sustainably in the Garden* by Andy T. Bruns and Sue C. Barton, it is recommended that 20% of the total drainage area be designated as open spaces.

CHAPTER SEVEN

MASTER PLAN

7. MASTER PLAN

7.1 Drainage Area-wise Measures of Traditional Elements and LID/ NBS

Drainage Area No.1

Drainage Area 1, located in Patenga, spans approximately 2,700 hectares with 70 percent urban area, 8 percent water bodies, and 22 percent other land uses. It faces significant drainage congestion, with about 32 percent of the area inundated during extreme rainfall and high tide conditions due to tidal backflow through major khals like Gupta Khal and Ruby Cement Factory Khal. The area currently has five existing regulators, with two additional regulators proposed on Ruby Cement Factory Khal and Gupta Khal. Several new khals have been proposed, following the alignment of former khals, totaling 9.66 kilometers, which may require excavation and reclamation. Five major khals—CEPZ Khal, Ruby Cement Factory Khal, Noyerhat Khal, Gupta Khal, and Nizam Market Khal—have been designated for routine maintenance, covering approximately 9.53 kilometers. The extent of these khals is shown in Figure A3-1.

6 mechanical trash traps are proposed along major khals and upstream of silt traps. Their locations are illustrated in Figure A3-1. Three silt traps are proposed along Saikat Khal, Nizam Market Khal, and Gupta Khal. Each is recommended to be integrated with a flood storage and detention pond. A total of 6.74 kilometers of secondary drains are proposed to improve drainage connectivity and reduce localized flooding. Their locations are shown in Figure A3-1. Flood pumping stations are also recommended in areas where gravity drainage is insufficient, such as CEPZ Khal, Gupta Khal, Ruby Cement Factory Khal, and Nizam Market Khal, though their feasibility should be carefully assessed.

Approximately 411.6 acres of open space have been proposed, against a requirement of 1,395.15 acres. Only 6.26 acres of government buildings and public institutions have been considered for rainwater harvesting, far below the required 523.18 acres. Existing ponds totaling around 189.91 acres are designated as storage ponds and totaling 207.7 acres as water retention area, exceeding the required 69.76 acres. The locations of rainwater harvesting zones, open spaces, storage ponds, and water retention area are shown in Figure A3-1, with detailed low impact development calculations provided in Table 7-1 to Table 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.2

Drainage Area 2, covering approximately 4,692.3 hectares, includes Halishahar Housing, Noyabazar, Agrabad, and Monsurabad, with 97% urban land use and 170.8 hectares of wetland. The drainage system includes 13 major primary khals—such as Mohesh Khal, Nasir Khal, Gaina Chhara Khal, Rampur Khal, and Azob Bahar Khal—supported by 74 km of secondary khals and 613 km of drainage infrastructure. Most khals discharge into the Bay of Bengal or the Karnaphuli River. Waterlogging is mainly due to overflow from Maheshkhali, Gaynachhara, and Rampur Khals, particularly at low-lying confluences.

The area currently has 1 existing regulator, and 8 additional regulators are proposed at khals including Uttar Kattali Khal, Ananda Bazar Khal, Maheshkhali Khal, Fakirpara Khal, and Salimpur Khal. Six mechanical trash screens are proposed at Mohesh Khal, Rampur Khal, Maheshkhali Khal, Selimpur Khal, and Fakirpara Khal. In addition, 6 silt traps are proposed at khals including Maheshkhali Khal, Salimpur Khal, Fakirpara Khal, and Mohesh Khal to improve sediment management. These proposals, along with

0.78 km of secondary drains, 11.44 km of new khal alignment, and maintenance of 14.67 km of existing khals, are detailed in Table 7.5 and illustrated in Figure A3-2.

Regarding open spaces, 1,118.93 acres have been proposed in this drainage area, but this is not sufficient, as 2,318.83 acres are required for effective stormwater management—this gap should be addressed in future development. A similar inadequacy is evident in the rainwater harvesting plan, which currently includes only 8.82 acres of rooftop area from government buildings and public institutions, whereas the requirement is 869.56 acres. Additionally, the area contains numerous ponds, with around 163.82 acres proposed to be utilized as storage ponds and 62.35 acres as water retention area, while the area requires 115.94 acres—thus meeting the requirement for storage ponds but not sufficient for water retention area. The locations of the proposed open spaces, rainwater harvesting areas, storage ponds, and water retention area are shown in Figure A3-2, and the corresponding proposed LID measures are presented in Table 7-1 to Table 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.3

Drainage Area 3 covers approximately 450 hectares and includes 6 primary khals with a total length of 4.6 km, supplemented by 4.7 km of secondary khals. The area has minimal waterbody coverage of about 9.74 hectares and a mean elevation of around 5 meters above mean sea level, with some pockets lying below MSL. All khals in this area drain into the Karnaphuli River. Inundation during monsoon mainly results from overflow of Moghultuli Khal and Sadarghat Khal.

Currently, no regulators exist in the area, and 2 new regulators are proposed, one of which is planned along Sadarghat Khal. Additionally, 2 silt traps are proposed at Sadarghat Khal and Tekpara Khal to improve sediment control. Four mechanical trash screens are also proposed at Sadarghat Khal, Firingi Khal, Tekpara Khal, and Kalabagicha Khal to manage floating debris and protect infrastructure. These proposed interventions are summarized in Table 7-5 and illustrated in Figure A3-3. Furthermore, 3.70 km of new khal alignment is proposed to improve connectivity. No secondary drains have been proposed for this area, as drainage infrastructure is already well developed.

In terms of Low Impact Development (LID) measures, 31.05 acres of open space have been proposed, while 215.97 acres are required—indicating a considerable shortfall to be addressed in future land development. Rainwater harvesting is currently planned only for 1.11 acres of rooftop area from government buildings and institutions, whereas 80.99 acres are required as per guidelines. The area includes 18.95 acres of existing pond space designated for storage ponds, which surpasses the required 10.80 acres and but no designated area for water retention was suggested. The locations of rainwater harvesting areas, open spaces, storage ponds, and water retention area are shown in Figure A3-3, and the detailed LID components are provided in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.4

Drainage Area 4 spans approximately 2,511 hectares and is one of the most flood-prone zones due to its steep terrain and rapid runoff. The area includes only 58.6 hectares of wetlands and is drained by major khals such as Chaktai, Chaktai Diversion, Birza, Bakolia, Jamal Khan, Mirza, and Rajakhali Khals. Although drainage infrastructure is relatively better here, the rapid surface runoff from upper slopes (notably from the Foy's Lake area) overwhelms the flatter downstream terrain. Elevation drops from 10–12 meters to 3–5 meters across short distances, causing bottleneck effects at locations like where Mirza Khal meets Chasma Khal in Muradpur. This leads to severe flooding during intense rain events, further exacerbated by sediment accumulation and debris blockage.

No regulators are proposed in this area, as key outfalls are already managed. However, 3 silt traps are proposed at Jamal Khan Khal, Rajakhali Khal, and Chaktai Khal to improve sediment control. Additionally, 8 mechanical trash screens are proposed at Chaktai, Rajakhali, and Jamal Khan Khals to manage debris and maintain flow capacity. Routine maintenance is proposed for key segments of Chaktai Khal, with the total length of khals to be maintained estimated at 3.18 km. No secondary drains have been proposed for this area, as the existing drainage layout is considered adequate. Furthermore, 6.45 km of new khal alignment is proposed to improve flow conveyance across the drainage network, as detailed in Table 7-5 and shown in Figure A3-4.

As part of LID measures, 357 acres of open space have been proposed, whereas 1,240.96 acres are required for effective stormwater infiltration and detention. Only 11 acres of rooftop area from government buildings and public institutions have been included in the rainwater harvesting plan, compared to the required 465.36 acres. Additionally, 35.52 acres of existing pond area are designated to serve as storage ponds and 29.31 acres are proposed as water retention area. The proposed LID elements—including open spaces, rainwater harvesting areas, storage ponds, and water retention area are depicted in Figure A3-4 and summarized in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.5

Drainage Area 5 spans approximately 3,020 hectares and includes major khals such as Noa Khal, Domkhali Khal, Mirza Khal, Tripura Khal, Uttara Khal, Shitol Jharna Khal, and Bamon Shahi Khal. The area includes about 150 hectares of wetlands and 320 km of drainage infrastructure. With a total of 30 km of primary khals and 62 km of secondary khals, the system is well-connected. Drainage Area 5 is characterized by low-lying, less densely populated zones where inundation primarily occurs due to overflow from Noa Khal, Mirza Khal, and Bamon Shahi Khal. Significant volumes of water flow from Chosma Khal through Muradpur, with major runoff directed toward this area and partially into Drainage Area 4.

There is currently no existing regulator in the area, and 3 new regulators are proposed, including one specifically at Noa Khal. Three silt traps are proposed to enhance sediment control, notably at Tripura Khal and Uttara Khal. Additionally, 4 mechanical trash screens are planned along Tripura Khal, Uttara Khal, Domkhali Khal, and Noa Khal to manage floating debris. No secondary drains have been proposed, as the area already has adequate coverage. A total of 9.93 km of new khal alignments are proposed to improve flow, and 2.66 km of existing khal stretches are designated for routine maintenance. All proposed components are detailed in Table 7-5 and mapped in Figure A3-5.

As part of the LID measures, 622.33 acres of open space have been identified, which is below the required 1,492.51 acres for adequate infiltration and water management. Rainwater harvesting is currently planned for only 2.75 acres of rooftop area from government and institutional buildings, while 559.69 acres are needed. However, the area includes 148.44 acres of pond area suitable for conversion into storage ponds, exceeding the required 74.63 acres but only 45.36 acres for water retention area.

The proposed open space, rainwater harvesting zones, storage ponds, and water retention area are shown in Figure A3-5, with detailed LID measures summarized in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.6

Drainage Area 6 consists of two distinct sub-regions. The first encompasses Hasem Nagar, Chandrima, Kamrabad, Dalipara, and Miah Nagar, characterized by 15% urban and 83% crop land—reflecting a predominantly rural setting transitioning into a semi-urban landscape. The second sub-area includes Shikdar Para and Bara Dighir Par in Nehalpur, with 32% urban and 66% crop land, also indicating a developing mixed-use profile. Drainage Area 6 covers approximately 346 hectares and includes 196 hectares of water bodies and 63 km of stormwater drains. The area lies near the Halda River, with several low-lying regions below mean sea level that are prone to inundation during the monsoon season. Waterlogging issues remain prominent, particularly due to the area's proximity to the river and unfavorable topographic conditions.

To improve discharge management, 3 regulators have been proposed, including specific installations along Khondokia Khal and Krishna Khal. 4 silt traps are also proposed, including one at Krishna Khal to enhance sediment capture. Mechanical trash screens are planned along Khondokia Khal and Krishna Khal to control solid waste and prevent blockages. To support better stormwater management, 20.14 km of secondary drains have been proposed in this area. A total of 2.49 km of new khal alignments are proposed, along with 7.64 km of khals designated for maintenance to ensure effective flow. All proposed elements are summarized in Table 7-5 and illustrated in Figure A3-6.

For LID measuring perspective, 996 acres of open space have been proposed, while 1,711.94 acres are required, indicating a shortfall that may need to be addressed in future land development. Rainwater harvesting is currently allocated for only 2.12 acres of government rooftops, far below the 641.98 acres required as per guidelines. However, the area contains 92.18 acres of ponds identified for conversion into storage ponds, exceeding the required 85.60 acres and offering potential for effective water retention in 43.94 acres. These LID components including rainwater harvesting zones, open spaces, storage ponds, and water retention area are mapped in Figure A3-6 and detailed in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.7

Drainage Area 7 spans approximately 8,140 hectares and is one of the largest within the CDA. It includes around 35 km of primary khals and 76 km of secondary khals, with most outfalls directed toward the Bay of Bengal and the Sandwip Channel.

To support flow regulation, 5 regulators have been proposed at key khals including Sonaichari, Madan Hat, Ichamoti Bridge, Bhatiari, and Dhamair khals. Additionally, 7 silt traps are proposed to enhance sediment control along Kumira, Joramtal, Madan Hat, Ichamoti Bridge, and Dhamair khals. No mechanical trash screens have been proposed for this area. About 6.45 km of new khal alignments and 63.96 km of secondary drains are also recommended to further improve drainage infrastructure. All proposed elements are outlined in Table 7-5, and their spatial layout is presented in Figure A3-7.

In terms of LID, 773.44 acres of open space have been proposed, which is below the required 4,022.87 acres. Rainwater harvesting is planned for only 5.26 acres of rooftop area, while 1,508.58 acres are needed based on guidelines. For storage ponds, the area includes 114.70 acres of ponds short of the 201.14 acres required but no area designated for water retention. These LID measures, including open spaces, rainwater harvesting zones, storage ponds, and water retention area, are illustrated in Figure A3-7 and detailed in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.8

Drainage Area 8, a predominantly suburban region, covers 7,797 hectares, including 646 hectares of water bodies. The area is served by 5 major natural drainage channels that discharge into the Halda River. During the monsoon season, approximately 16% of the area becomes inundated due to the interaction between khal flows and the river level.

To support drainage improvement, 6 regulators are proposed at locations including South Madarsha Khal and Garduara Khal. Additionally, 7 silt traps are proposed along South Madarsha Khal, Garduara Khal, Porapali Khal, Boalia Khal, and Madari Khal. No mechanical trash screens have been proposed in this drainage area. A total of 51.4 km of secondary drains are also proposed to strengthen the surface water drainage network. All proposed elements are summarized in Table 7-5 and illustrated in Figure A3-8.

For LID measures, 1,235.22 acres of open space have been identified, while 3,853.85 acres are required, resulting in a significant shortfall. The rainwater harvesting plan includes 19.45 acres of rooftop area from government buildings and public institutions, whereas the requirement is 1,445.19 acres. In terms of sotage ponds, 222.50 acres of ponds have been identified, exceeding the required 192.69 acres, whereas 28.81 acres proposed for water retention area. The proposed LID components are shown in Figure A3-8 and detailed in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.9

Drainage Area 9 consists of a mix of open lowland and emerging urban zones, covering 7,390 hectares, of which 311 hectares are water bodies. This area has limited drainage infrastructure, and the low-lying lands between developed zones are prone to flooding. Approximately 8% of the area is inundated during monsoon events under high rainfall and tidal conditions.

To support sediment control, 6 silt traps are proposed, particularly at Mora Khal and Chhibatali Khal. No regulators or mechanical trash screens are proposed for this area. However, 43.03 km of secondary drains are proposed to improve drainage conveyance. All proposed elements are detailed in Table 7-4 and shown in Figure A3-9.

In terms of LID implementation, only 0.2 acres of open space currently exist, whereas 3,919.09 acres are required—indicating a critical deficit. Similarly, only 2.31 acres of rooftop area from public buildings are considered for rainwater harvesting, while 1,469.66 acres are needed per guideline. For storage ponds, 258.91 acres of existing ponds have been identified, exceeding the required 195.95 acres and 25.24 acres proposed for water retention area. The locations of the proposed open space, rainwater harvesting zones, storage ponds, and water retention area are provided in Figure A3-9 and detailed in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.10

Drainage Area 10 spans 8,939 hectares, including 628 hectares of water bodies. It comprises 7 primary khals, most of which discharge into the Halda River, with the rest flowing into the Karnaphuli River. Annual flooding is common, particularly near Noapara, due to overflow from the Noapara Khal. The drainage coverage is moderate and requires targeted improvements to mitigate waterlogging and support runoff management.

To improve flow control, 4 regulators are proposed at West Barighina, Maishkaram, and Noapara khals. Additionally, 7 silt traps are planned at West Barighina, Maishkaram, West Guzara, and Ram Gatir Hat khals to enhance sediment management. No mechanical trash screens are proposed in this area. Around 25.29 kilometers of secondary drains and 7.27 kilometers of new khal alignments are proposed to expand the drainage system. All proposed components are listed in Table 7-5.

Regarding Low Impact Development (LID), only 5.6 acres of open space currently exist compared to the required 4,417.74 acres. Rainwater harvesting capacity from government buildings is just 6.76 acres, falling short of the required 1,656.65 acres. On a positive note, 391.42 acres of pond area are available and can be utilized as storage ponds, exceeding the 220.89-acre requirement though 19.96 acres proposed for water retention area. The proposed open space, rooftop harvesting zones, storage ponds, and water retention area are shown in Figure A3-10, with LID calculations detailed in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.11

Drainage Area 11 spans 4,493 hectares and features relatively high land with 119 hectares of water bodies. Due to its higher elevation and limited water coverage, the area experiences minimal urban flooding and generally supports natural drainage.

To improve discharge control, 4 regulators are proposed at Pomra and Kaukhali khals. Additionally, 3 silt traps are proposed, including one specifically at Pomra Khal. No mechanical trash screens are planned for this drainage area. A total of 22.75 kilometers of secondary drains and 4.82 kilometers of new khal alignments are proposed to enhance connectivity and improve flow distribution. These components are detailed in Table 7-5.

In terms of LID, only 0.71 acres of open space currently exist, while 2,220.98 acres are required. Rainwater harvesting is also inadequate, with just 0.21 acres available from public institutions, far below the 832.87-acre requirement. Pond storage is slightly under the threshold, with 76.14 acres available against a need for 111.05 acres but no area proposed for water retention. The proposed open space, rooftop harvesting areas, storage ponds, and water retention area are shown in Figure A3-11, with detailed LID breakdowns presented in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.12

Drainage Area 12 spans 10,873 hectares, including approximately 680 hectares of water bodies. The area comprises 4 major khals and 178 kilometers of secondary khals, supported by about 7.18 kilometers of stormwater drainage infrastructure. The area experiences around 10% inundation during monsoon, particularly near Ghorio, Raozan, and Dabua Raozan, due to overflow and low-lying topography.

To improve discharge control, 5 regulators have been proposed at Nadimpur, Sattar, Garduara, and Dewan Ali khals. Additionally, 9 silt traps are proposed, including at Nadimpur, Sattar, Garduara, and Dewan Ali. No mechanical trash screens are suggested for this area. About 48.18 kilometers of secondary drains and 7.96 kilometers of new khal alignments are proposed to address existing drainage limitations. These interventions are summarized in Table 7-5.

As for LID, the area has 5.01 acres of open space available, whereas 5,373.55 acres are required. Rainwater harvesting capacity is only 1.18 acres from public institutions, against a 2,015.08-acre requirement. On a positive note, 369.30 acres of pond area are available, exceeding the 268.68-acre guideline for storage but no available area could be proposed for water retention. The proposed open space, rainwater harvesting zones, storage ponds, and water retention area are detailed in Figure A3-12, and the corresponding LID measures are listed in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.13

Drainage Area 13 spans approximately 10,377 hectares, with 600 hectares of water bodies. It comprises 6 major khals and 88 kilometers of secondary khals, most of which discharge into the Sangu River. The region experiences relatively low flood vulnerability, with only 4% of the area affected during the monsoon.

To improve drainage regulation, 7 regulators are proposed at Parki, Khurushkul, South Barunchara, Icchakhali, and Murai khals. Additionally, 4 silt traps are planned, including at Parki, Icchakhali, and Murai. No mechanical trash screens are suggested for this area. The drainage enhancement plan also includes 114.23 kilometers of proposed secondary drains and 2.62 kilometers of new khal alignment, as listed in Table 7-5.

In terms of LID, only 0.67 acres of rooftop area is available for rainwater harvesting, while 1,923.16 acres are needed. Open space provision is also inadequate, with 698.55 acres currently available against the required 5,128.42 acres. However, the area has 345.03 acres of pond area, which exceeds the 256.42-acre requirement for storage ponds and 114.07 acres for water retention area. The locations of rainwater harvesting zones, open spaces, storage ponds, and water retention area are illustrated in Figure A3-13, with LID measures detailed in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.14

Drainage Area 14 spans 16,707 hectares, with 958 hectares of water bodies. The area contains 3 major primary khals and a comparatively low density of stormwater drainage infrastructure due to underdevelopment. About 14% of the land experiences inundation during intense monsoon rains and high tides. Flooding is primarily caused by the overflow of the Karnafuli Channel in locations like Dangar Char and Maulvi Bazar, and Murari Khal in areas such as Daulatpur, Kaigram, and Sikdarpara.

To enhance flow control, 3 regulators are proposed at Karnafuli and Murai khals. 5 silt traps are also planned, particularly at Karnafuli, Murai, and Kurangigiri khals. No mechanical trash screens are suggested. As per Table 7-5, the plan includes 46.21 km of proposed secondary drains and 4.17 km of new khal alignments.

Regarding LID provisions, only 6.78 acres of rooftop area are currently allocated for rainwater harvesting, while the required area is 3,096.29 acres. Open space availability is severely limited, with 16.61 acres available against a requirement of 8,256.77 acres. The area contains 528.11 acres of ponds, meeting the 412.84-acre requirement for storage ponds though there was no possible area for proposed water retention necessity. The locations of proposed LID components are shown in Figure A3-14, with detailed measures listed in Tables 7-1 to 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.15

Drainage Area 15 spans approximately 15,216 hectares, including Pancharia, Lakhera, Mohammadnagar (36 percent urban, 44 percent crop) and Moitala, Ratanpur (8 percent urban, 90 percent crop), with 1,639 hectares of water bodies. The area is served by a network of primary and secondary khals, but about 8.4 percent of the area becomes inundated during heavy rainfall and high tides, especially near Boalkhali Khal. At present, there are no existing regulators in this drainage area. To improve flow control, two regulators have been proposed with outfalls to the Karnaphuli River, and their planned locations are shown in Figure A3-15. Additionally, six silt traps are proposed to enhance sediment management and maintain khal functionality. With respect to Low Impact Development, only 2.11 acres of rooftop area from public institutions are currently allocated for rainwater harvesting, whereas the standard requirement is 2,820.15 acres—indicating a significant gap. Similarly, open space provision is critically low at 2.52 acres compared to the required 7,520.39 acres needed for effective stormwater retention and infiltration. These deficits highlight the importance of incorporating private sector engagement and long term planning policies to scale up LID interventions. On a positive note, the drainage area includes 862.63 acres of ponds, exceeding the recommended 376.02 acres, but no area was proposed for water retention. The proposed rainwater harvesting zones, open spaces, storage ponds, and water retention area are shown in Figure A3-15, and detailed LID strategies are provided in Table 7-1 – 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.16

Drainage Area 16 spans 5,443 hectares, including Pancharia, Lakhera, and Mohammadnagar with 55 percent urban and 27 percent crop land, and contains 404 hectares of water bodies. The area is underdeveloped with only 3 kilometers of drainage infrastructure, making it highly prone to flooding, with 9.5 percent of the area inundated during the monsoon season, particularly along Shakpura and Charndip Khals. At present, there are no existing regulators in this drainage area. To improve flow control, four regulators have been proposed with outfalls to the Karnaphuli River, and their planned locations are shown in Figure A3-16. Additionally, three silt traps are proposed to enhance sediment management and maintain khal functionality. With regard to Low Impact Development strategies, only 2.05 acres of rooftop area from public institutions have been identified for rainwater harvesting, compared to a required 1,008.74 acres—indicating a significant implementation gap. Open space provision is critically low, with only 0.89 acres available against the required 2,689.99 acres for effective stormwater absorption and runoff regulation. These deficits underscore the need for policy-driven planning and inclusion of private development in LID programs. In terms of storage ponds, approximately 185.25 acres of pond area have been identified, which exceeds the 134.50 acres requirement and contributes positively to flood mitigation But there was no available area potential for water retention. The proposed locations for rainwater harvesting areas, open spaces, storage ponds, and water retention area are presented in Figure A3-16, with detailed LID measures outlined in Table 7-1 – 7-4. Dimensions of the silt traps are provided in Table 7-6.

Drainage Area No.17

Drainage Area consist of almost all of hilly area and there is very little developments. At present, there are no existing regulators in this drainage area. To improve flow control, one regulator has been proposed on Jaishthapura Khal, and its planned locations are shown in Figure A3-17. Additionally, 2 silt traps are proposed to enhance sediment management and maintain khal functionality in terms of Low Impact Development, only 0.10 acres of rooftop area from government buildings are identified for rainwater harvesting, while the recommended requirement is 642.53 acres, reflecting a major gap. Open space availability is also minimal, with only 1.91 acres proposed against a requirement of 1,713.43 acres, necessitating significant attention in future land use planning. Furthermore, the area includes just 12.52 acres of pond coverage, which is far below the 85.67 acres requirement. There was no low lying potential area that could be designated for water retention. These shortfalls across all LID components highlight the need for comprehensive planning and policy support to strengthen climate resilience and water management capacity in this zone. Proposed interventions are mapped in Figure A3-17, with detailed calculations and strategies provided in Table 7-1 – 7-4. Dimensions of the silt traps are provided in Table 7-6.

Table 7-1: Proposed LID Measures for Rainwater Harvesting

Drainage Area No.	Total Drainage Area (acres)	Existing Roof Area for Rainwater Harvesting (acres)	Future Ext. of Roof Area (50%) (acres)	Area Required for Rainwater Harvesting as per Guideline (15%) (acres)
1	6976	6.3	3488	524
2	11594	8.8	5798	870
3	1078	1.1	540	81
4	6205	11.0	3102	465
5	7463	2.8	3731	560
6	8560	2.1	4280	642
7	20114	5.3	10058	1509
8	19270	19.5	9635	1445
9	19595	2.3	9798	1470
10	22088	6.8	11044	1657
11	11105	0.2	5552	833
12	26867	1.2	13434	2015
13	25642	0.7	12821	1923
14	41284	6.8	20642	3096
15	37600	2.1	18800	2820
16	13450	2.1	6725	1008
17	8567	0.1	4284	642
Total	2,87,462	79.0	1,43,731	21,560

Table 7-2: LID Measures Considering Existing Storage Pond

Drainage Area No.	Total Drainage Area (acres)	Existing Pond Area (acres)	Suggested Pond Area as per guideline (3%) (acres)	Area Required for Storage Ponds as per guideline (1%) (acres)
1	6976	190	209	70
2	11594	134	348	116
3	1078	19	32	11
4	6205	36	186	62
5	7463	148	224	75
6	8560	92	257	86
7	20114	115	603	201
8	19270	223	578	193
9	19595	259	588	196
10	22088	391	663	221
11	11105	76	333	111
12	26867	369	806	269
13	25642	345	769	256
14	41284	528	1239	413
15	37600	863	1128	376
16	13450	185	404	135
17	8567	13	257	86
Total	2,87,462	3986	8624	2875

Table 7-3: Proposed LID Measures for Open Space

Drainage Area No.	Total Drainage Area (acres)	Designated Existing Open Space (acres)	Open Area Required as per Guideline (20%) (acres)
1	6976	412	1395
2	11594	1119	2319
3	1078	31	216
4	6205	357	1241
5	7463	622	1493
6	8560	996	1712
7	20114	773	4023
8	19270	1235	3854
9	19595	0.2	3919
10	22088	6	4418
11	11105	1	2221
12	26867	5	5374
13	25642	699	5128
14	41284	17	8257
15	37600	3	7520
16	13450	1	2690
17	8567	2	1713
Total	2,87,462	6278	57492

Table 7-4: Proposed LID Measures for Water Retention Area

Drainage Area No.	Total Drainage Area (acres)	Location of the Designated Water Retention Area	Designated Water Retention Area (acres)	Total Water Retention Area (acres)	Suggested Area as per guideline (1%) (acres)
1	6976	GEM Officers' Colony	30.0	208	70.0
		Dhumpara	48.0		
		Behind Airport	121.0		
		Near Padma Oil Company	8.0		
2	11594	Near Abdullah Convention	9.0	62	116.0
		Halishohor Rail Station	24.0		
		CGD Railway Hospital	2.0		
		Near Budha Gazi Masjid, Halishohor	17.0		
		Near Nou Camp Sports Arena	11.0		
3	1080	-	-	0	10.80
4	6205	Beside Ahmadia Karimia Madrasa	22.0	29	62.0
		Ehsan City School & College	3.2		
		Beside Brother's Cricket Academy	1.3		
		Beside Notun Bridge Riverside Road, Chaktai	3.4		
5	7463	Evercare Hospital	25.2	45.3	74.6
		Behind Bangladesh Convention Hall	25		
		Near Chattogram Intl. Medical College	3.1		
6	8560	Near Baraka Incubator Hatchery	33.8	43.9	85.6
		Near South Burischor Alamia Govt. School	10.1		
7	20114	-	-	0	201.0
8	19270	Beside Helal Chowdhury Para Masjid	18.5	28.8	192.7
		Boalia Chara	3.1		
		Near Sikdar Para Masjid	7.2		
9	19595	Near Balu Shah Gate	16.3	25.2	196.0
		Near Zaforabad Govt. Primary School	9.5		
10	22088	Beside Urkirchor Madrasa	9.4	18.4	221.0
		Purbo Urkirchor	9.0		
11	11105	-	-	0	111.0
12	26868	-	-	0	268.7
13	25642	Parki Beach	58.6	114.0	256.4
		Saad Musa Agro Project	10.6		
		Char Juidandi near Khurush Khal	13.3		
		Char Juidandi Nurani Madrasa	31.6		
14	41284	-	-	0	412.8
15	37602	-	-	0	376.0

16	13450	-	-	0	134.5
17	8567	-	-	0	85.7
Total	2,87,462			576.8	2,875.0

Table 7-5: Elements Comprising the Master Plan

Drainage Area No.	Number of Proposed Silt Traps	Number of Proposed Regulators	Number of Mechanical Trash Screens	Length of Proposed Secondary Drains (km)	Length of Proposed Khals (km)	Length of Khals Proposed for Maintenance/Re-excavation (km)
1	3	2	6	6.7	9.7	9.5
2	7	8	6	0.8	11.4	14.7
3	2	2	4	0	3.7	0
4	3	0	8	0	6.5	3.2
5	3	3	4	0	9.9	2.7
6	3	3	3	20.1	2.5	7.6
7	6	5	0	64.0	24.0	0
8	7	6	0	51.4	2.9	0
9	6	0	0	43.0	10.2	0
10	7	4	0	25.3	7.3	0
11	3	4	0	22.8	4.8	0
12	9	5	0	48.2	8.0	0
13	4	7	0	114.2	2.6	0
14	4	3	0	46.2	4.2	0
15	5	2	0	57.1	2.1	0
16	3	4	0	25.3	3.8	0
17	2	1	0	3.4	0	0
Total	80	59	31	528.5	111.3	37.7

Table 7-6: Approximate Dimensions of the Proposed Silt Traps

Drainage Area No.	Silt Trap No.	Corresponding Khal Name	Silt Trap Size
1	1	Saikat Khal	45m x 45m
	2	Nizam Market Khal	30m x 30m
	3	Gupta Khal	60m x 60m
2	1	Fakirpara Khal	20m x 20m
	2	Salimpur Khal	30m x 30m
	3	Kalir Chara Khal	55m x 55m
	4	Uttor Kattali Khal-2	45m x 45m
	5	Maheshkhali Khal	75m x 75m
	6	Rampur Khal	80m x 80m
	7	Mohesh Khal	80m x 80m
3	1	Sadarghat Khal-2	20m x 20m
	2	Tekpara Khal	20m x 20m
4	1	Jamal Khan Khal	65m x 65m
	2	Rajakhali Khal	35m x 35m
	3	Birza Khal	30m x 30m
	4	Chaktai Khal	50m x 50m
5	1	Shital Jhorna Khal	70m x 70m

	2	Bamon Shahi Khal	65m x 65m
	3	Uttara Khal	50m x 50m
6	1	Khondokia Khal (Cantonment)	55m x 55m
	2	Khondokia Khal	40m x 40m
	3	Krishna Khal	50m x 50m
7	1	Kumira Khal	70m x 70m
	2	Kumira Khal Branch	80m x 80m
	3	Joramtal Khal	80m x 80m
	4	Madanhat Khal	60m x 60m
	5	Ichamoti Bridge Khal	50m x 50m
	6	Dhamair Khal	60m x 60m
8	1	Khal near Chittagong University	80m x 80m
	2	Khal near Fatehabad Railway Station	70m x 70m
	3	Garduara Khal	70m x 70m
	4	Porapali Khal	70m x 70m
	5	Boalia Chara Khal	70m x 70m
	6	Khagira Chara Khal	80m x 80m
	7	South Madrasa Khal	80m x 80m
9	1	Khal near Mansurabad Masjid	80m x 80m
	2	Khal near Balukhali Primary School	55m x 55m
	3	Chhibatali Khal	80m x 80m
	4	Mora Khal	50m x 50m
	5	Boalia Khal	80m x 80m
	6	Mulaparla Khal	80m x 80m
10	1	West Guzara Khal	70m x 70m
	2	West Guzara Khal Branch	65m x 65m
	3	West Barighina Khal	35m x 35m
	4	Maishkaram Khal	80m x 80m
	5	Pachkhain Khal	60m x 60m
	6	Lamburhat Khal	80m x 80m
	7	Ram Gati Hat Khal	55m x 55m
11	1	Pomra Khal Branch-1	40m x 40m
	2	Pomra Khal Branch-2	65m x 65m
	3	Pomra Khal	80m x 80m
12	1	Nadimpur Khal	35m x 35m
	2	Sattar Khal	40m x 40m
	3	Garduara Khal Branch-1	40m x 40m
	4	Garduara Khal Branch-2	65m x 65m
	5	Garduara Khal	80m x 80m
	6	Dewan Ali Khal Branch-1	65m x 65m
	7	Dewan Ali Khal Branch-2	75m x 75m
	8	Dewan Ali Khal Branch-3	70m x 70m
	9	Dewan Ali Khal	75m x 75m
13	1	Murai Khal	65m x 65m
	2	Icchakhali Khal	50m x 50m
	3	Dakshin Baruchara Khal	80m x 80m

	4	Parki Khal	55m x 55m
14	1	Karnafuli Khal	75m x 75m
	2	Char Patharghata Khal	55m x 55m
	3	Murai Khal	80m x 80m
	4	Kurangigiri Khal	45m x 45m
15	1	Boalkhali Khal	75m x 75m
	2	Baremba Khal	80m x 80m
	3	Boalkhali Khal-2	75m x 75m
	4	Boalkhali Khal-3	70m x 70m
	5	Kharana Khal	75m x 75m
16	1	Shakpura Khal	75m x 75m
	2	Kalurghat Khal Branch	70m x 70m
	3	Kalurghat Khal	75m x 75m
17	1	Jaishthapura Khal Branch	70m x 70m
	2	Jaishthapura Khal	80m x 80m

7.2 General Comments

Applicable to the Entire Study Area

- The Master Plan serves as a guideline only. For implementation in any specific area, a comprehensive 1D-2D simulation-based study and detailed design of all components are required for each individual drainage basin.
- For localized drainage interventions targeting waterlogged hotspots, measures should consider the entire catchment area of the khals/rivers connected to the hotspot.
- Demarcation of all existing khals is required, and lining of the khals with necessary walkways is recommended.
- Cleaning and excavation of all drains and khals are recommended.
- The width of sluice gates must not be smaller than that of the existing khal.
- Ensure that all sluice gates are functioning properly.
- It is strongly recommended to integrate each silt trap with a flood storage and detention pond to improve sediment control and overall system performance.
- A detailed study should be conducted to determine the most suitable locations for the installations of silt traps.
- There are low-lying areas within the DAP-proposed residential zones, a portion of which is flood-prone due to lower elevation as illustrated in Figure A3-18. Raised land levels should be considered in the drainage master plan as a flood mitigation measure. However, land raising is not a substitute for drainage and should only be applied in areas that cannot be drained without pumping during high tides and elevated river levels.
- Flood pumping stations should be considered only in areas where ground levels are close to river or tide levels and gravity drainage is not feasible, ensuring regular testing and maintenance.
- Increase the manpower of the City Corporation’s drainage unit, and implement a capacity-building training program.
- Establish a high-level coordination team.
- Monitor drainage conditions (e.g., blockages, water levels, flow rates) using sensor-based smart devices.
- Develop community-led solid waste management programs in collaboration with local authorities.
- Increase the frequency of drain cleaning and maintenance, especially before the monsoon season.
- Enforce the Detailed Area Plan (DAP) to prevent further encroachment on wetlands and floodplains as per the Master Plan.
- Establish new retention ponds in low-lying areas.
- Promote sustainable urban drainage systems (SuDS), including permeable pavements and rainwater harvesting initiatives.
- Preserve open spaces in accordance with guidelines.
- Introduce nature-based solutions, such as urban wetlands and bio-retention basins, to enhance water absorption capacity.
- Develop GIS-based hydrological models to predict and manage high-risk flood zones.
- Develop a comprehensive GIS-based dataset.

Institutional and Policy Reforms

- Implement strict regulations against dumping waste into canals and drains.
- Enforce strict legal actions against illegal encroachments on natural drainage systems.
- Establish a unified Stormwater Management Authority to streamline responsibilities among various agencies.
- Strengthen legal frameworks to regulate land development in drainage zones.
- Conduct public awareness campaigns to educate citizens on the importance of protecting drainage infrastructure.
- Policies should be formulated to promote rainwater harvesting in private buildings and institutions, and to ensure the inclusion of open spaces in future land development and expansion plans.

Applicable for Core City Area

- Most of the khals in the core areas fall under the 36 khals included in the CDA's dredging project for excavation and are therefore shown as existing khals. Additionally, a few other khals outside this list are proposed for maintenance to ensure proper drainage in the surrounding areas.
- It is recommended that the maintenance frequency of khals be determined based on available supporting infrastructure. Khals equipped with outfall regulators, silt traps, and mechanical trash removal systems may be maintained every five years, while those lacking these facilities should undergo more frequent maintenance, preferably every two to three years.
- Mechanical trash removal systems should be maintained according to their scale and placement. Units installed in major khals should undergo annual servicing, while smaller systems may be maintained every two to three years.
- The core city areas already possess a well-established drainage network; therefore, only a limited number of secondary drains are proposed to enhance overall drainage capacity where needed.

Applicable for Areas Outside the Core City

- The khals outside the core city areas are not currently included in the khal maintenance, and mechanical trash removal systems have not been proposed for these areas. However, if required in the future, excavation of khals should be carried out to restore their natural drainage capacity.
- The areas outside the core city lack a well-established existing drainage network; therefore, a number of secondary drains are proposed to improve drainage capacity and support future development and expansion.
- New drains should be designed based on further detailed studies, incorporating 1D-2D simulation models.
- Plinth levels for buildings in these areas should be determined and regulated by the CDA (Chattogram Development Authority).

7.3 Strategies for Stormwater, Drainage and Flood Improvement

Chattogram Metropolitan Area faces increasing challenges from waterlogging, urban flooding, and inadequate drainage due to rapid urbanization, topographic variation, encroachment on canals, and climate change. To address these issues sustainably, a combination of structural and non-structural strategies is essential. The following strategies aim to enhance flood resilience, ensure effective stormwater management, and protect urban ecosystems.

1. Integrated Urban Water Management (IUWM)

A coordinated water management approach should be adopted by integrating drainage, water supply, and wastewater systems. IUWM promotes efficient use of water resources and encourages inter-agency collaboration among CDA, CWASA, CCC, and WASA for a holistic and climate-resilient urban water system in Chattogram.

2. Restoration and Protection of Natural Drainage Systems

Reviving and protecting canals, rivers, and natural flow paths is critical. Encroachment removal, re-excavation, and embankment stabilization will restore flow capacity. Maintaining buffer zones along water bodies will also reduce flood risk and improve ecological balance.

3. Green Infrastructure and Low Impact Development (LID)

Incorporating nature-based solutions such as green roofs, rain gardens, and permeable surfaces reduces runoff and enhances groundwater recharge. These decentralized interventions also improve urban aesthetics and air quality while lowering the burden on centralized drainage infrastructure.

4. Expansion and Maintenance of Urban Drainage Network

An upgraded drainage network based on hydrological data is essential to accommodate increased runoff. Regular maintenance and pre-monsoon cleaning of drains and culverts will prevent blockages and reduce urban waterlogging.

5. Flood Zoning and Land Use Regulation

Flood-prone zones should be identified and mapped. Development restrictions and zoning regulations in these areas will prevent further vulnerability. Integrating flood risk into land use planning ensures long-term urban safety and climate resilience.

6. Urban Retention and Detention Basins

Constructing stormwater detention and retention basins allows temporary storage of excess rainwater, reducing peak flow and downstream flooding. These multi-functional facilities can also serve as urban green spaces and recharge groundwater.

7. Early Warning System and Real-Time Monitoring

Installing real-time monitoring systems, such as rain gauges and water level sensors, enables proactive flood management. A centralized early warning system will improve disaster preparedness and help evacuate residents from flood-prone areas in time.

8. Community Participation and Awareness

Involving communities in local drainage maintenance and awareness campaigns promotes responsible behavior. Community-led monitoring, waste management, and participation in canal protection can enhance the effectiveness of stormwater management at the neighborhood level.

9. Institutional Strengthening and Coordination

A multi-agency taskforce or committee should be established to ensure coordination between CDA, CWASA, CCC, BWDB, and DoE. Institutional strengthening through training and resource allocation will improve flood response and long-term planning.

10. Climate Resilience and Adaptive Infrastructure
All flood control structures must consider future climate scenarios, including increased rainfall and sea level rise. Adaptive infrastructure ensures long-term functionality and aligns with national strategies like the Delta Plan 2100 and the Bangladesh Climate Change Strategy and Action Plan.

7.4 Recommended Policy for Stormwater, Drainage and Flood Control

SDF-1 : Canal and Water Body Protection Policy
Legally protect canals and natural drains by establishing buffer zones and prohibiting encroachment. Conduct regular surveys and enforce land use controls to restore and maintain Chattogram's critical drainage and flood pathways.

SDF-2: Green Infrastructure Mandate
Require all new high-rise developments to include rainwater harvesting, green roofs, and permeable surfaces. Incentivize sustainable construction practices through tax rebates or FAR bonuses to reduce runoff and increase infiltration.

SDF-3: Urban Flood Zoning Policy
Use flood hazard mapping to classify risk zones and restrict development in vulnerable areas. Enforce resilient construction standards in moderate-risk zones to reduce future flood damage and improve urban safety.

SDF-4: Stormwater Impact Assessment Policy
Mandate storm water impact assessments for all large-scale developments. Ensure on-site runoff storage and delayed discharge systems are implemented to minimize stress on the public drainage system.

SDF-5: Drainage Infrastructure Maintenance Policy
Establish mandatory pre-monsoon and routine cleaning schedules for all major urban drains. Assign clear responsibilities to CCC or CWASA and allocate dedicated maintenance funds annually to ensure system efficiency.

SDF-6: Institutional Coordination Framework Policy
Create a formal coordination platform involving CDA, CWASA, CCC, BWDB, and DoE. Ensure regular joint planning, data sharing, and implementation monitoring to reduce overlap and improve project effectiveness.

SDF-7: Urban Groundwater Recharge Policy for Chattogram
All urban development in Chattogram Metropolitan Area shall incorporate measures to promote natural and artificial groundwater recharge through rainwater harvesting, permeable surfaces, and preservation of water retention zone, ensuring sustainable aquifer management and long-term water security for the city.

CHAPTER EIGHT

CONCLUSION

8. SUMMARY AND CONCLUSION

The purpose of this Component is to critically review the progress and problems of implementing the approved Storm Water Drainage and Flood Control Master Plan (1995-2015) under the CMMP and to prepare a new Storm Water Drainage and Flood Control Master Plan for the period 2020-2041. The progress of this stduy has been outlined in this working report. Following conclusion can be drawn from this report.

i. The study area under this Master Plan covers a geographic area of about 1241 sq km compared to the area of the 1995 Master Plan, which is 260 sq km. Moreover, the validity of 1995 Master plan expired in 2015. Therefore, a new Master Plan needs to be prepared with a validity until 2041.

ii. The urban growth rate of Chittagong is significantly higher than Dhaka's growth in last 20 years, however, the implementation of drainage plan is relatively limited causing severe drainage problem specially in the core city area.

iii. To address the persistent drainage problems of the core city and considering the future expansion of the urbanization, a number of scope of this study has been set and proper methodology has been formulated including field visit and stakeholder consultation, review of previous studies and government policies, primary and secondary data collection, review of existing drainage condition, hydrologic analysis, formulation of different drainage options, hydrodynamic and flood modelling with existing and proposed drainage options, preparation of drainage and flood control strategies, preparation of phase wise implementation and investment plan, prepare institutional and mechanism for coordination and finally prepare the consolidated Storm Water Drainage and Flood Control Master Plan (2020-2041) for Chittagong Metropolitan under Chittagong Development Authority (CDA).

iv. Several field visits were conducted to physically inspect the physical conditions of the existing drainage networks at critical locations including Andarkilla, Chawkbazar, Halishohor, Muradpur, and Bahaddarhat. The field visits provided a grim picture of city's drainage system of drains and khals accumulated with garbage, encroachment and narrowing of khals, siltation of khals and silt traps, very narrow outlet sluices, poor water quality of channels posing serios health concerns.

v. A stakeholder consultation, in the form of questionnaire survey, was conducted with the Ward Councillors of 41 wards. The responses from 18 ward counsellors highlight areas with both identified needs for new drains and those where no immediate need has been reported. Futher stakeholder consultation will be carried out with the representatives of Upazilla and Paurashavas.

vi. Seventeen reports on relevant previous studies and government policies and acts have been collected for review including the CDA Drainage Master Plan (1995-2015), CWASA Drainage Master Plan (2016 (2030) etc. Secondary data have been collected in the form of drainage network from CWASA, soi map form SRDA, land cover pattern from google earth, fine-resolution land cover maps from ESRI, water level data and river cross sections from BWDB, rainfall and temperature data BMD, cross sections of khals from CDA and information on water-logged area from reports.

vii. A detailed survey work was undertaken to collect primary data which includes bathymetry survey of khals and topographic survey of the whole study area. Different Primary Feature Data have been generated such as Ward Boundaries, Existing Road network, Existing khal and river network, water bodies, Bridge culvert locations, and Digital Elevation model.

viii. In Chittagong, drainage congestion occurs due to the following hydrologic events occurring alone or in combination with each other: a) Fast-running storm water runoff from the hilly terrain b) Intrusion of river water through the open Khals iii) Intrusion of river water through bank overtopping iv) Cyclonic surge.

ix. The drainage system in Chittagong is organized around three main elements: a) Primary system b) Secondary system and c) Tertiary system. Besides the primary, secondary and tertiary systems, both the Halda and Karnaphuli Rivers are very important for the drainage of Chittagong. The primary khals are mainly based on natural channels which existed before the city was built. Secondary Khals, which carry discharge from tertiary systems to the primary khals, are in some cases original natural drainage channels but very often are man-made channels constructed in connection with residential or industrial developments. Tertiary or roadside channels have been constructed over the years in a random manner, and designed only to suit the needs of the immediate area, without thought for future extensions of developed areas or their effect on the khals further downstream.

x. The neighbourhoods in Chittagong city that are severely affected by storm drainage are Chawkbazar area, Bakalia area, Sholakhbahar area, Agrabad area, Halisahar area, Muradpur area, Barborak Intersection area, KB Aman Ali Road, DC Road (Chandgaon), East Nasirabad area, Dewanbazar area, Khatunganj-Chaktai, Agrabad etc.

xi. The reasons behind the severe drainage in the city have been identified as filling up of channel by solid waste, siltation of khals, constriction of khals by structures such as bridge or culvers and illegal encroachments, lack of control gates at outlets. Other issues as identified are lack of operation and maintenance, lack of inter-agency cooperation, uncontrolled urban development palns, deforestation and hill-cutting, budget constraint, lack of public awareness, inadequate solid waste managementt etc.

xii. In order to prepare the new Drainage Master Plan (2021-2040), the CDA area has been divided into 17 drainage areas where the boundaries have been set considering their physical and hydrological characteristics. all the drainage issues will be addressed and, all analysis and planning will be carried out in each individual drainage basin based on its characteristics.

xiii. Drainage area no 1 – 5 are within core city and CCC jurisdiction and has relatively high drain density ranging from 0.35 to 84 meaning higher tertiary drains. Drainage Area No. 6 shares both CCC and Upazilla jurisdiction with a drain density of 0.21. Other drainage areas are mostly in rural and low lying areas and under Upazila jurisdiction has limited tertiary drains.

xiv. All the drainage areas, there exists significant length of khals, which generally be adequate to drain storm water in ideal condition during low tide. However, due to the poor conditions the khals as stated earlier hinders the drainage. Low lying areas also suffer from prolonged drainage congestions.

xv. CDA Drainage Master Plan (1995-2015) and CWASA Drainage Mater Plan (2016-2030) provided a number of suggestion based in each of their drainage areas. The recommendations of both masterplans can be grouped as a) excavation/reconstruction/desludging of the khals b) Lining of the khals c) construction of silt traps d) construction of tertiary drains e) Construction of regulators at the outlets with pumping facilities and f) construction of flood control embankments. The masterplans recommended additional measures such removal of illegal encroachment, realignment of service lines and culvert adjustment and widening. Moreover, some ancillary but important recommendations were made regarding pollution control of drains, strong regulation of hill cutting, land-acquisition and resettlement, planned land development, regular maintenance, flood preparedness. As per 2016 CWASA masterplan review, the implementation of 1995 was limited

xvi. In last eight years, most of the efforts in implementation is concentrated on construction of retaining walls and construction of regulators/sluice gates at outlets. Moreover, construction of some silt traps has also been initiated. However, in all places the regulators are being constructed by significantly constriction of the khal width. Although both the Master Plans provided several good recommendations, suggestions on installation of trapping and removal of solid waste/garbage systems at intermediate locations and near outlets of khals is missing.

xvii. Hydrologic analysis of rainfall and water level data have been performed and rainfall hyetograph of different duration for 10-year return period have been generated. Six hydrologic scenarios have been formulated for model input: a) Scenario 01 – Ebb tides b) Scenario 02 –Spring tides, c) Scenario 03 –Ebb tides + 6 Hour Rainfall d) Scenario 04 –Spring tides + 6 Hour Rainfall e) Scenario 05 – Ebb tides + 12 Hour Rainfall f) Scenario 06 –Spring tides + 12 Hour Rainfall

xviii. Mathematical models have been set up for all 17 Drainage areas and preliminary simulations have been performed. Based on the simulation results, Scenario-f has been selected for further detailed analysis. Preliminary simulations have been performed and areas subjected to drainage congestions have been identified under existing drainage conditions. Moreover, further model simulations have also been performed incorporating the suggested interventions in previous masterplans.

xix. Possible drainage interventions for general considerations have been identified such as Regular Maintenance, Provision for Mechanical Trash Screen and Removal System, Provision for Silt Trap, Local Drainage Improvements (channel bends, culvert entrance exit, low bridge soffits, narrow waterway, encroachment etc), provision for tertiary drains, New or Enlarged Khals, Raising Land Levels, Flood Storage. Moreover, Nature Based Solutions/ Low Impact Development Initiatives such as rainwater harvesting, storage ponds, open spaces, etc are also considered.

xx. The proposed master plan includes a total of 79 silt traps, 65 regulators, and 34 mechanical trash screens across the 17 drainage areas under CDA jurisdiction. These components are recommended to improve sediment removal, regulate outfalls, and prevent solid waste from obstructing drainage.

xxi. To support stormwater management, approximately 587.2 km of secondary drains and 104.4 km of new khal alignments have been proposed. Additionally, 40.7 km of existing khals are recommended for maintenance to restore conveyance capacity in the system.

xxii. Raised land levels is also considered as a flood mitigation option in low-lying areas within DAP-proposed residential zones; however, this should not replace drainage and should be applied only where pumping is essential due to high tides and elevated river levels.

xxiii. The available surface areas for low impact development (LID) interventions across all drainage areas are estimated to be 82.02 acres for rooftop rainwater harvesting, 5,205.0 acres for pond storage, 576.8 acres of water retention area and 7,033.2 acres of open spaces. However, as per design guidelines, the required areas are 24,427.2 acres in total—869.6 acres for rooftop harvesting, 1,606.9 acres for ponds, 2875 acres for water retention area and 43,127.1 acres for open space—indicating major gaps in existing LID capacity.

xxiv. Appropriate policies should be formulated to promote rainwater harvesting in private institutions and residential buildings in order to meet the required capacity. The currently allocated areas for open space within the study area are inadequate for effective stormwater management. Therefore, it is recommended that provisions for additional open spaces and water retention through storage ponds be incorporated into future land development and urban expansion plans.

ANNEX - 1

EXISTING DRAINAGE MAPS AND LIST OF EXISTING KHALS

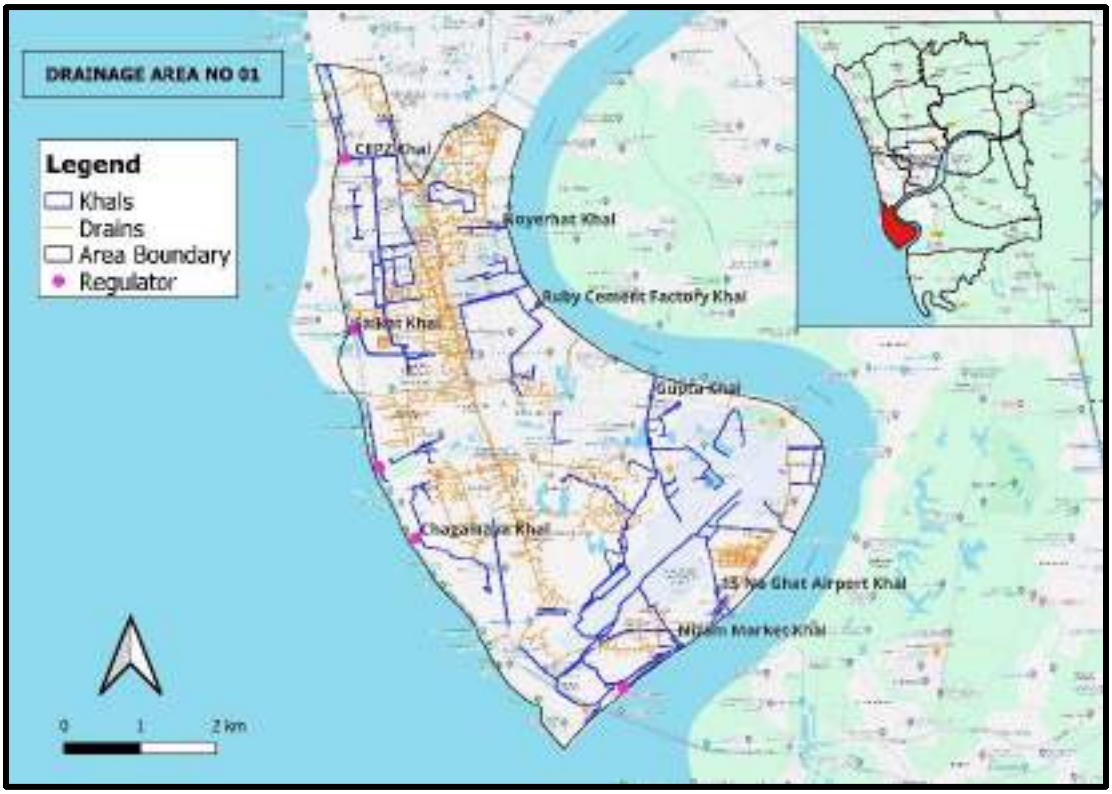


Figure A1-1 Drainage Area No. 01

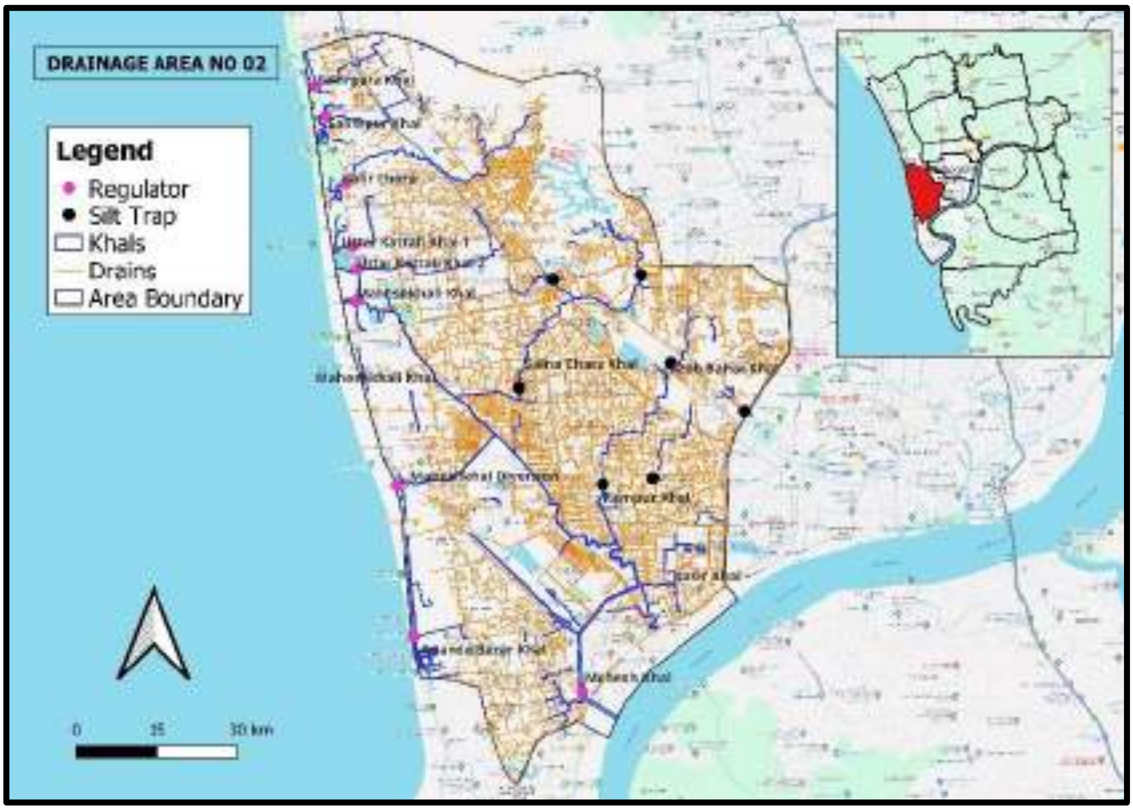


Figure A1-2 Drainage Area No. 02

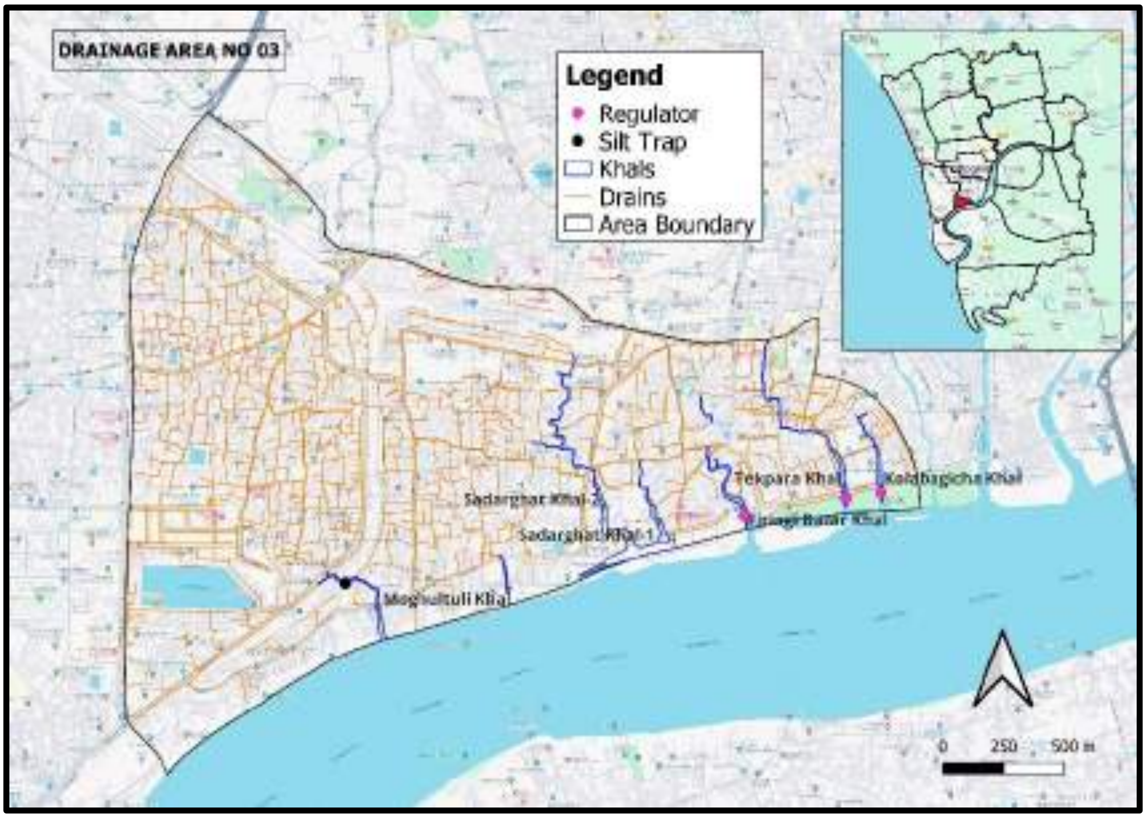


Figure A1-3 Drainage Area No. 03

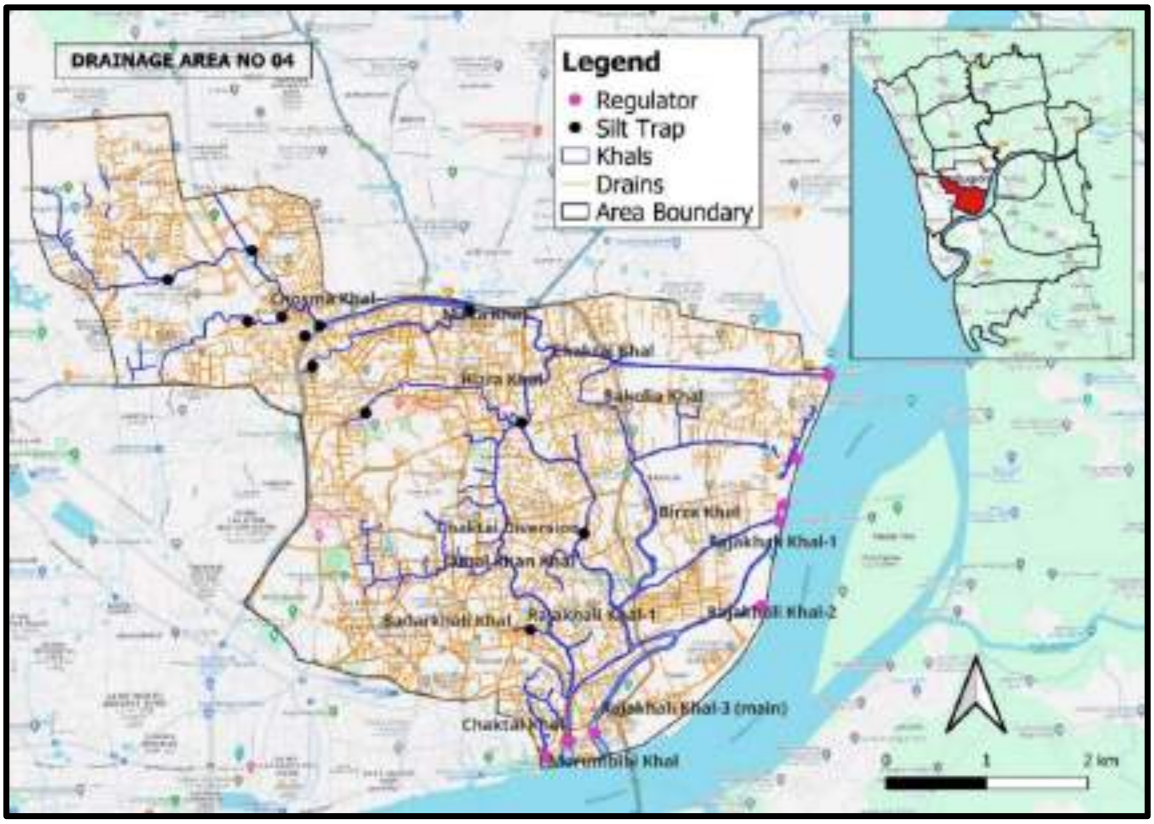


Figure A1-4 Drainage Area No. 04

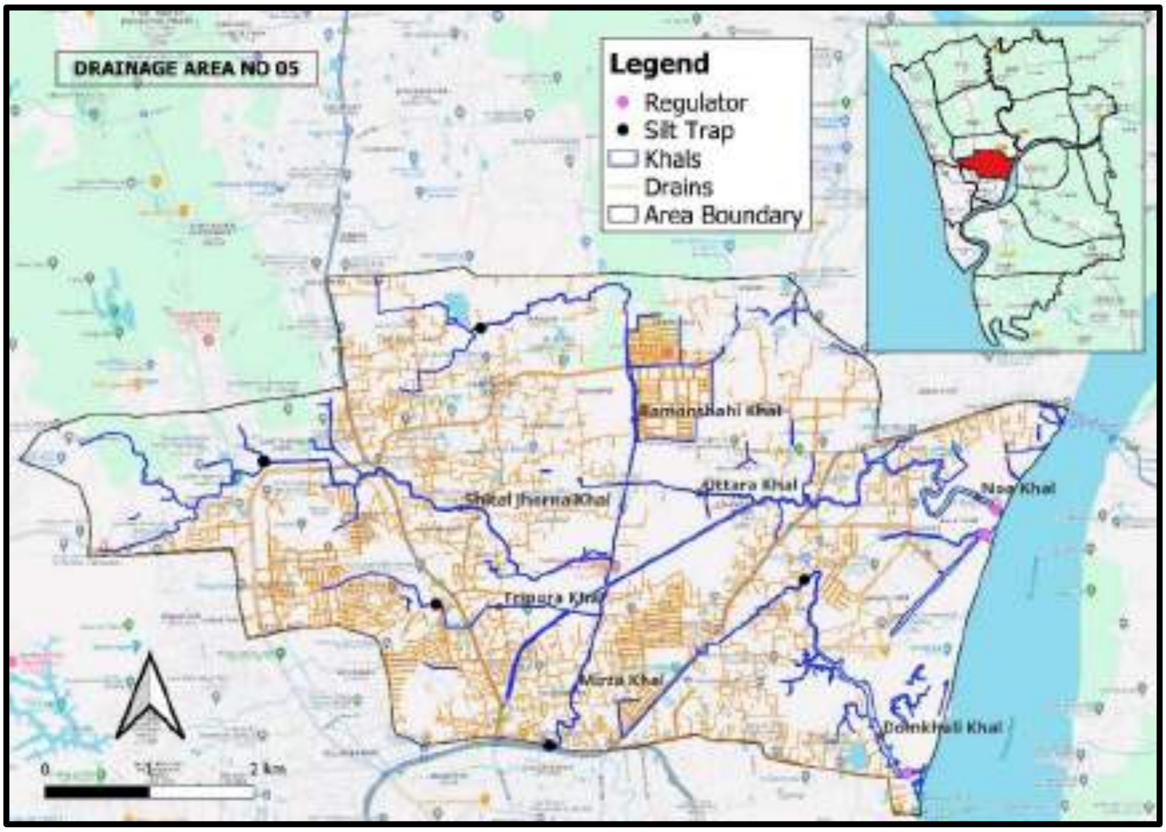


Figure A1-5 Drainage Area No. 05

Figure A1-6 Drainage Area No. 06

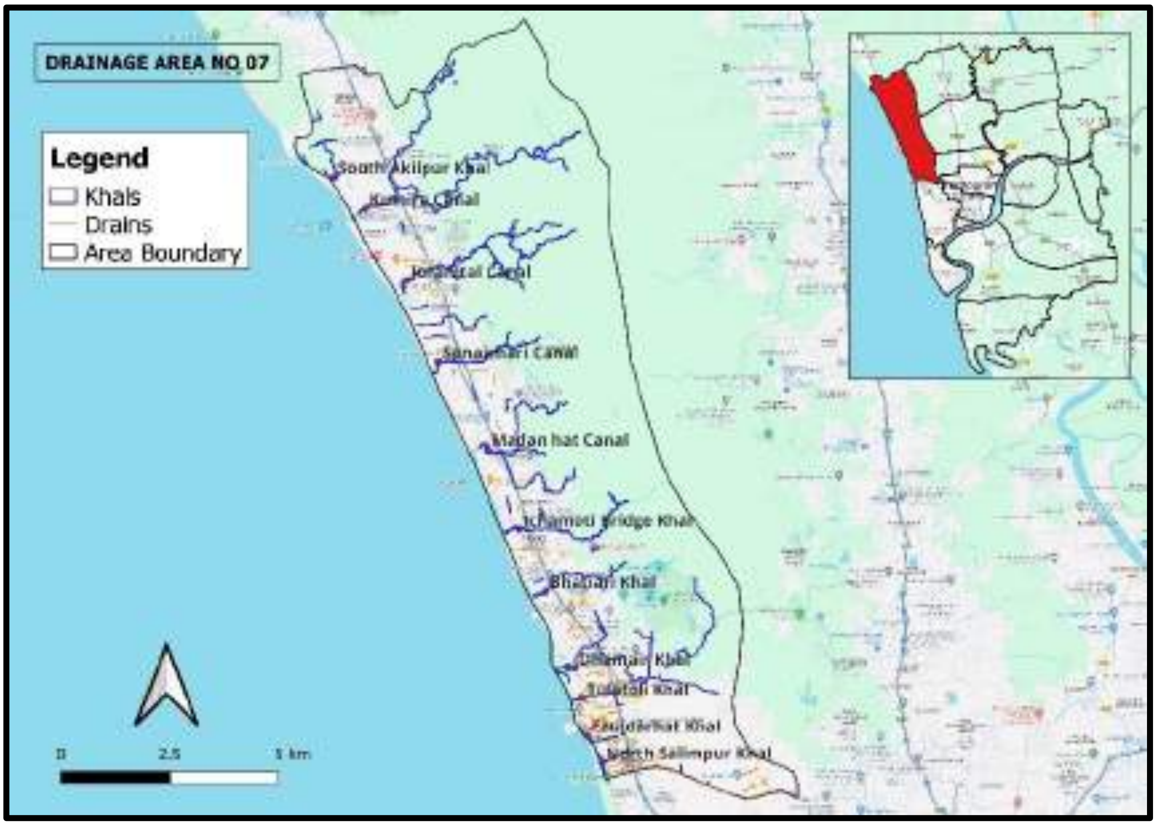


Figure A1-7 Drainage Area No. 07

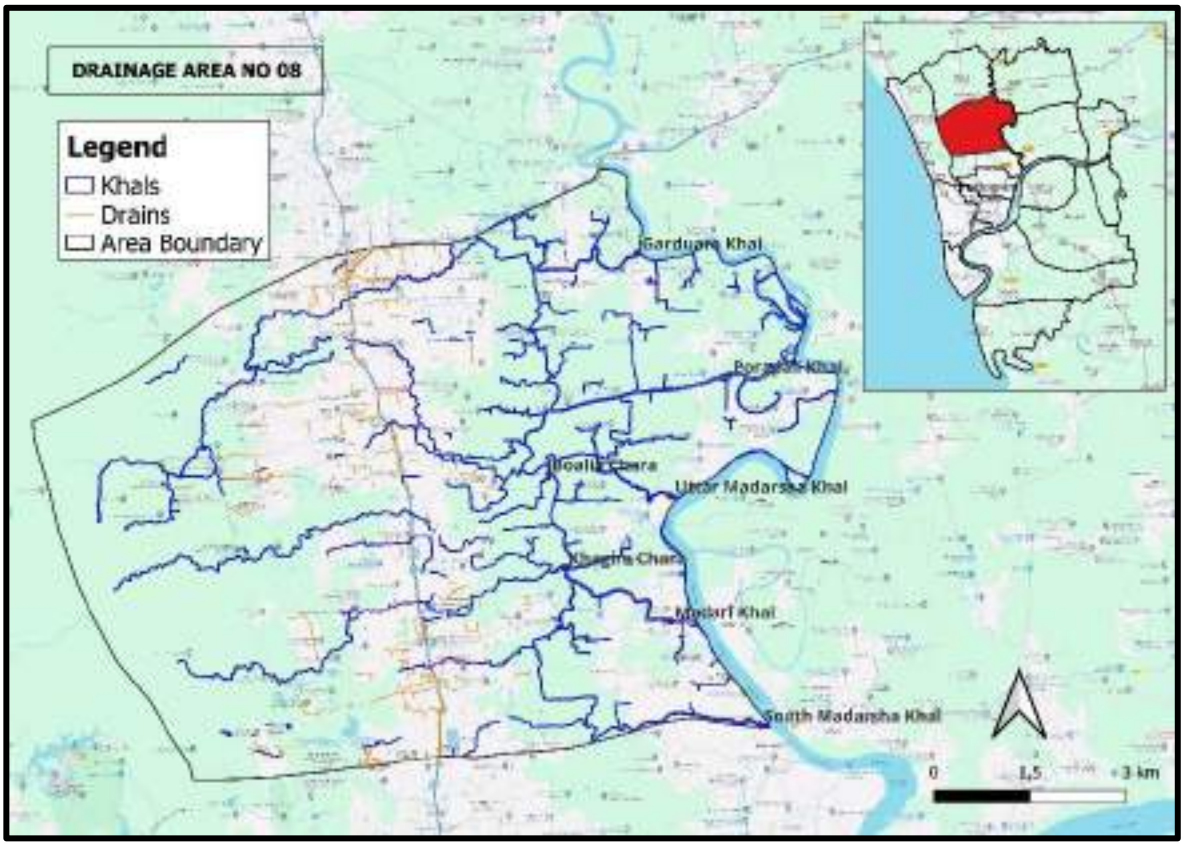


Figure A1-8 Drainage Area No. 08

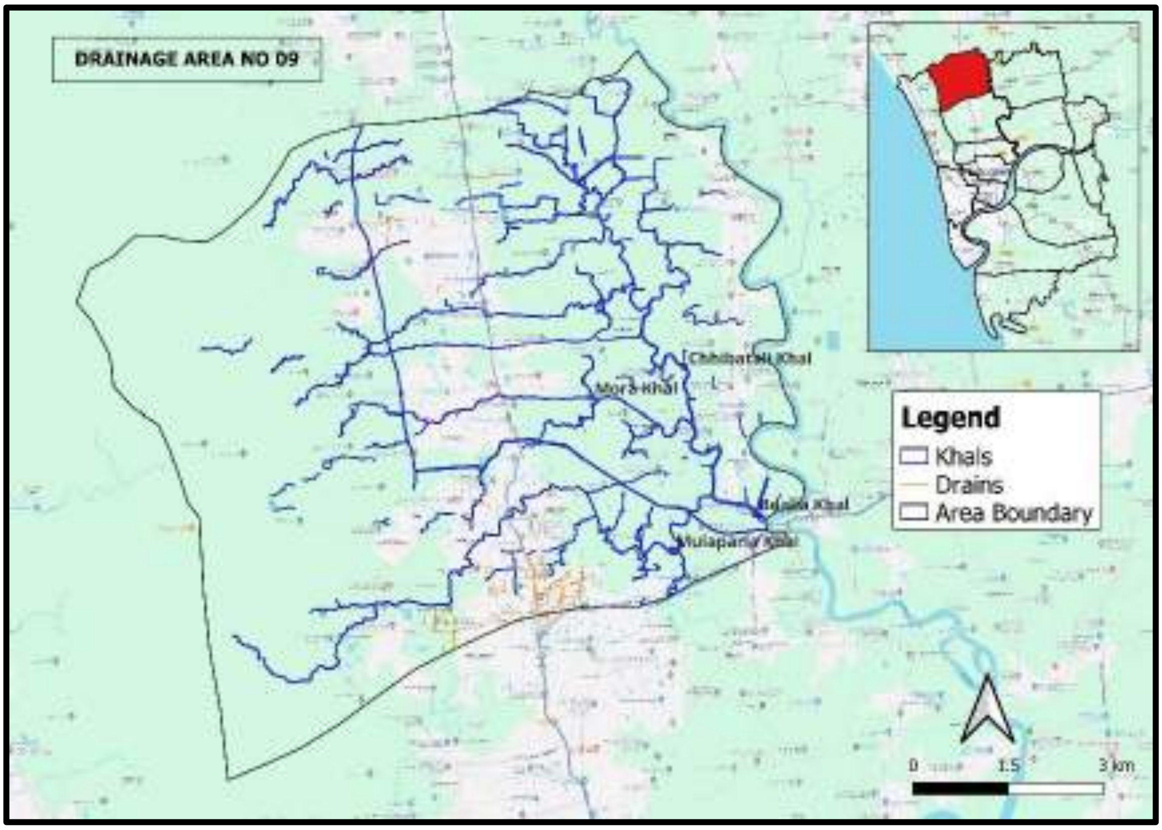


Figure A1-9 Drainage Area No. 09

Figure A1-10 Drainage Area No. 10

Figure A1-11 Drainage Area No. 11

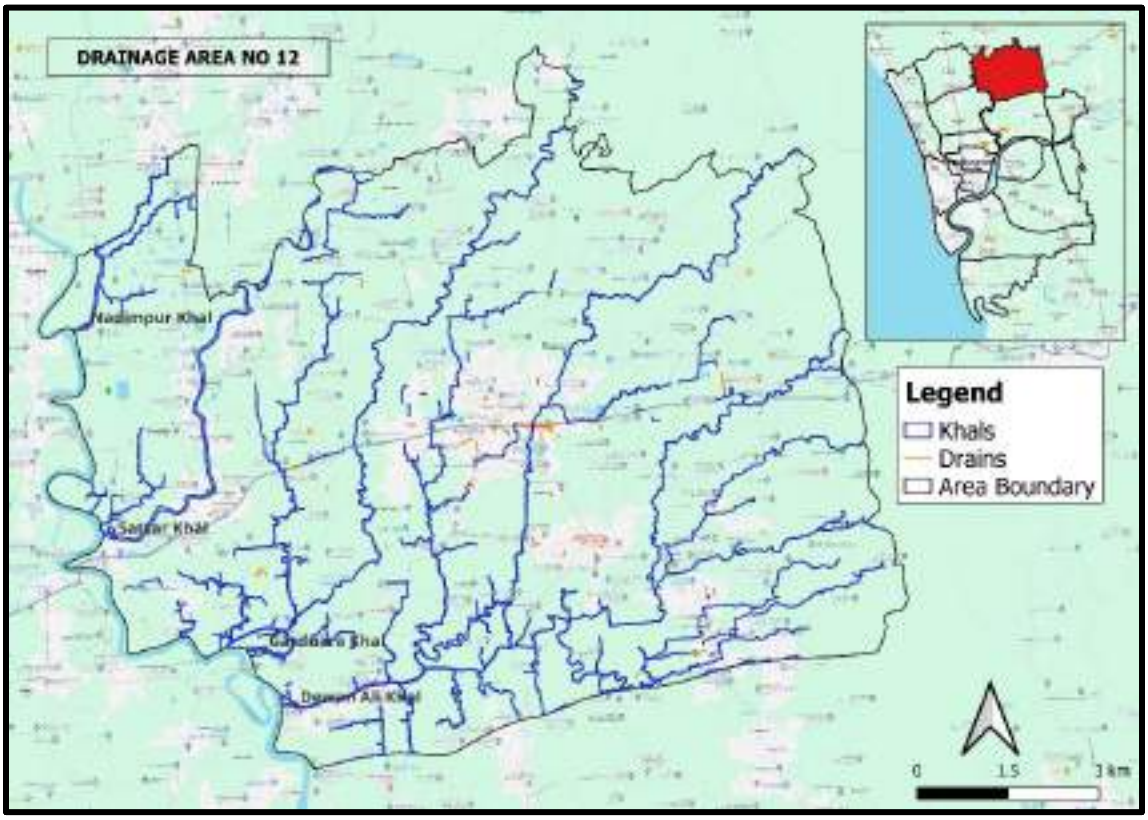


Figure A1-12 Drainage Area No. 12

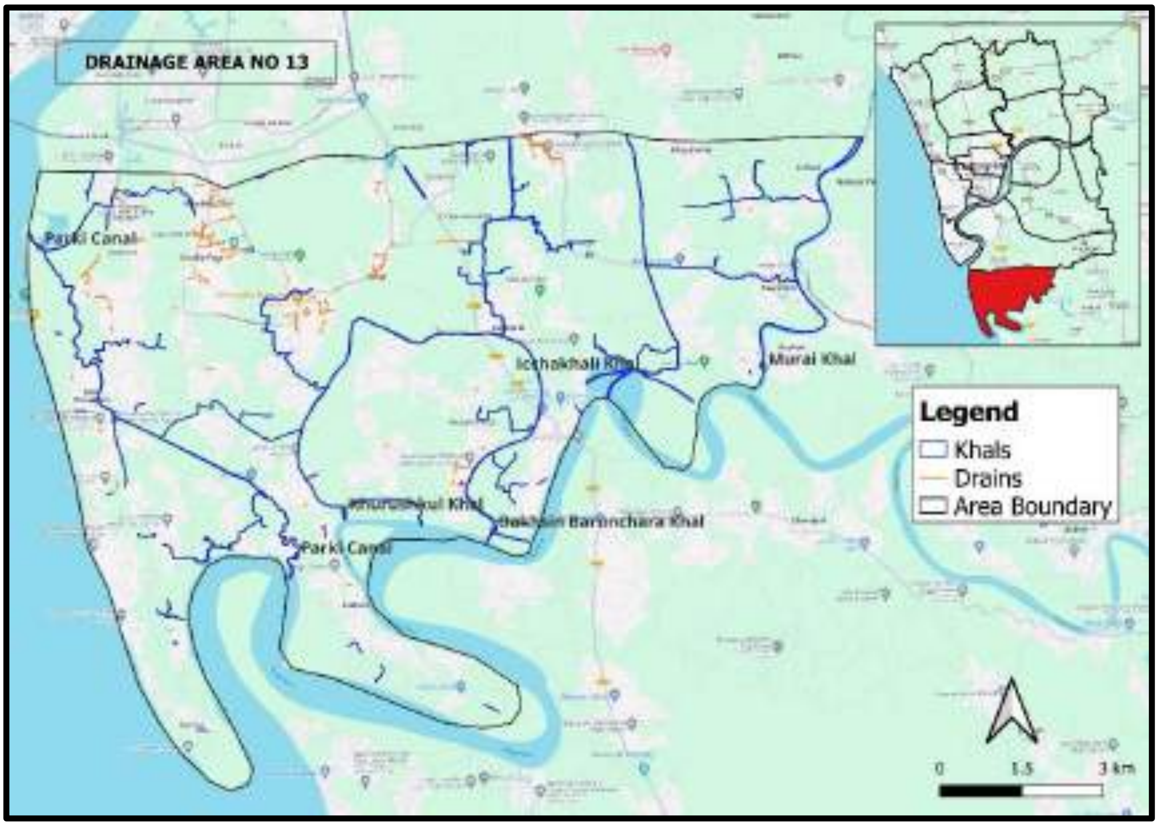


Figure A1-13 Drainage Area No. 13

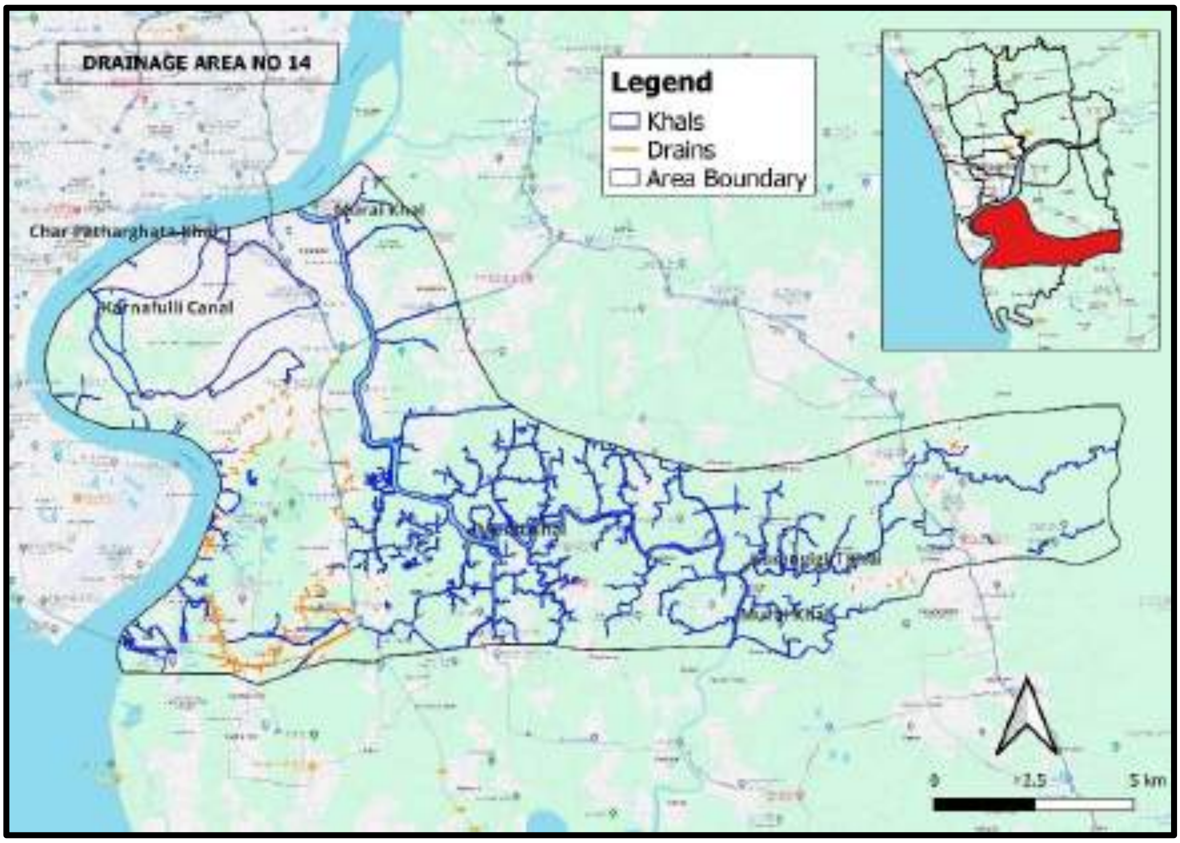


Figure A1-14 Drainage Area No. 14

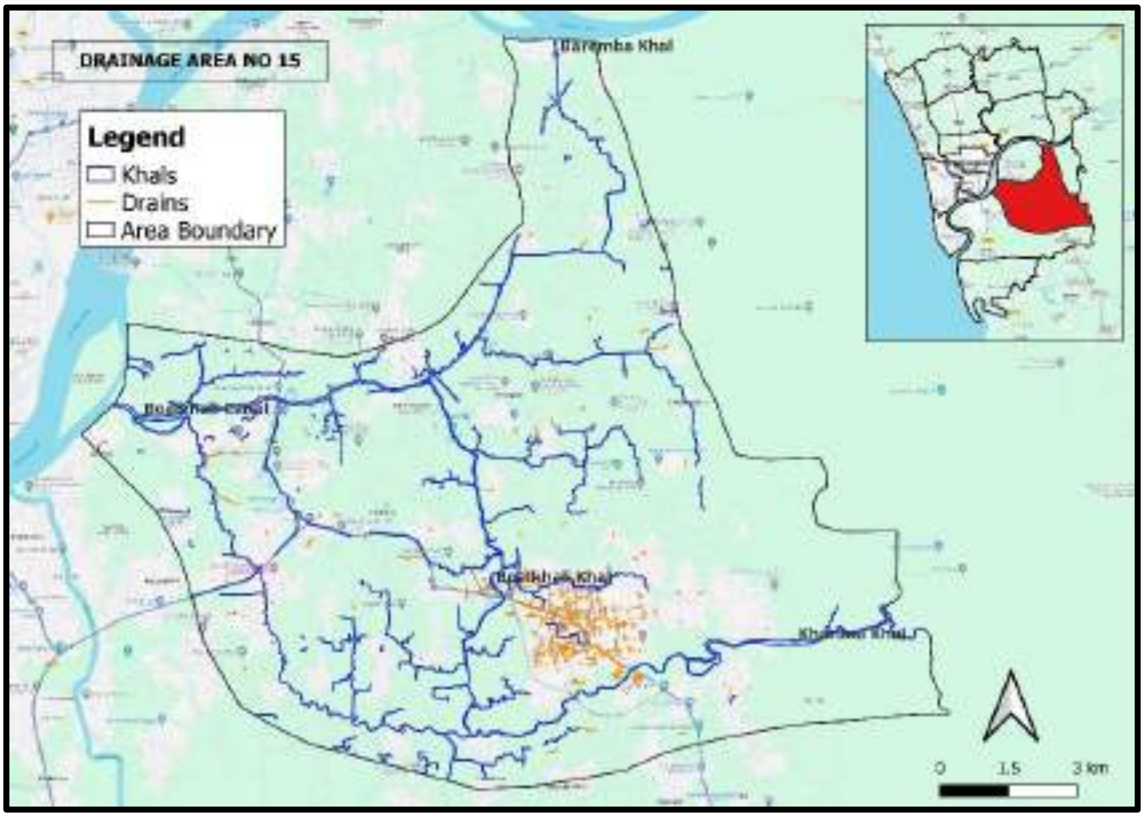


Figure A1-15 Drainage Area No. 15

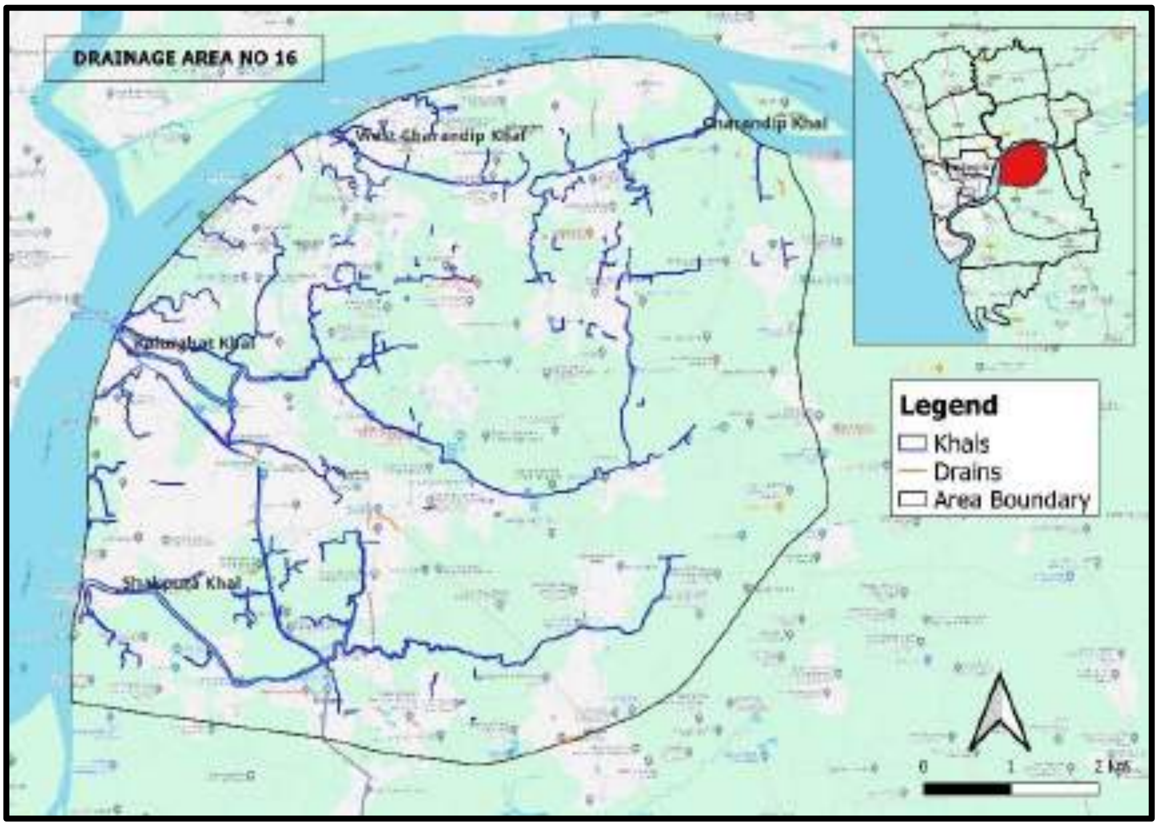


Figure A1-16 Drainage Area No. 16

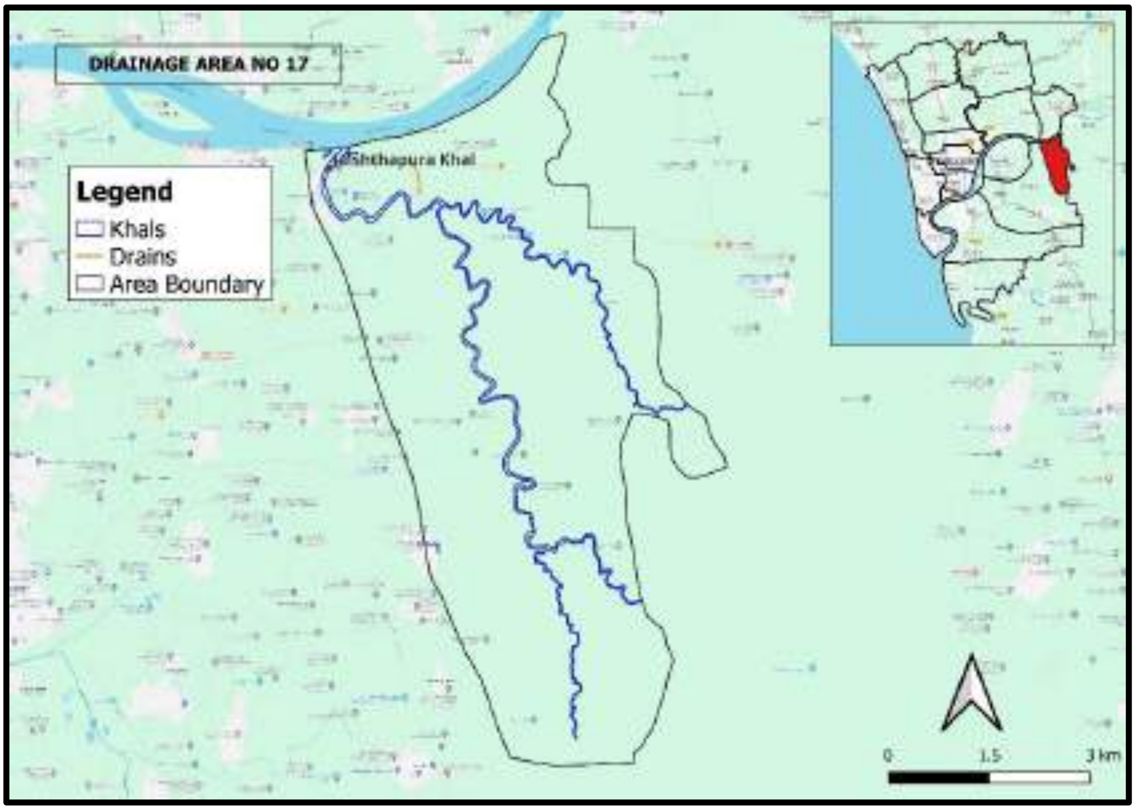


Figure A1-17 Drainage Area No. 17

Table A1-1 List of Primary Khals in CDA Study Area

Drainage Area No	Sl No	Primary Khal Name	Outfall	Primary Khal Length (m)
1	1	Noyerhat Khal	Karnaphuli	678
	2	Ruby Cement Factory Khal	Karnaphuli	1300
	3	Gupta Khal	Karnaphuli	2152
	4	15 No Ghat Airport Khal	Karnaphuli	1204
	5	CEPZ Khal	Bay of Bengal	955
	6	Saikat Khal	Bay of Bengal	970
	7	Chagalnaya Khal	Bay of Bengal	2063
	8	Nizam Market Khal	Karnaphuli	1023
2	1	Fakirpara Khal	Bay of Bengal	1640
	2	Salimpur Khal	Bay of Bengal	3071
	3	Kalir Chara	Bay of Bengal	4654
	4	Uttar kattali Khal-1	Bay of Bengal	1515
	5	Uttar Kattali Khal-2	Bay of Bengal	3576
	6	Maheshkhali Khal	Bay of Bengal	4535
	7	Maheshkhali Diversion	Bay of Bengal	1814
	8	Anada Bazar Khal	Bay of Bengal	1236
	9	Mohesh Khal	Karnaphuli	6789
	10	Nasir Khal	Mohesh khal	1777

Drainage Area No	Sl No	Primary Khal Name	Outfall	Primary Khal Length (m)
	11	Gaina Chara Khal	Mohesh khal	6324
	12	Rampur Khal	Mohesh khal	2974
	13	Azob Bahar Khal	Rampur Khal	1926
3	1	Moghultuli Khal	Karnaphuli	824
	2	Sadarghat Khal-1	Karnaphuli	393
	3	Sadarghat Khal-2	Karnaphuli	1210
	4	Tekpara Khal	Karnaphuli	622
	5	Kolabagachia Khal	Karnaphuli	514
	6	Firingi Bazar Khal	Karnaphuli	1134
4	1	Badarkhali Khal	Chaktai Khal	870
	2	Mirza Khal	Shital Jhorna Khal	3,646
	3	Morumbibi Khal	Karnaphuli River	1,009
	4	Jamal Khan Khal	Chaktai Khal	2,365
	5	Chaktai Khal	Karnaphuli River	5,989
	6	Chaktai Diversion	Rajakhali Khal	2,633
	7	Rajakhali Khal-3 (main)	Karnaphuli River	1,776
	8	Rajakhali Khal-2	Karnaphuli River	1,892
	9	Rajakhali Khal-1	Karnaphuli River	3,246
	10	Bakolia Khal	Rajakhali Khal	2,221
	11	Hizra Khal	Chaktai Khal	2,478
	12	Mirza Khal	Shital Jhorna Khal	821
	13	Chosma Khal	Mirza Khal	1,640
	14	Birza Khal	Rajakhali Khal	3,001
5	1	Noa Khal	Karnaphuli River	5,916
	2	Domkhali Khal	Karnaphuli River	5,387
	3	Mirza Khal	Shital Jhorna Khal	3,646
	4	Tripura Khal	Mirza Khal	3,087
	5	Uttara Khal	Bamonshai Khal	1,325
	6	Shital Jhorna Khal	Rajakhali Khal	6,801
	7	Bamonshai Khal	Shital Jhorna Khal	4,830
6	1	Krishna Khal	Halda	4,310
	2	Khondokia Khal	Halda	9,586
7	1	South Akilpur Khal	Sandwip Channel	1,206
	2	Kumira Canal	Sandwip Channel	9,280
	3	Joramtal Canal	Sandwip Channel	4,245
	4	Sonaichari Canal	Sandwip Channel	4,416
	5	Madanghat Canal	Sandwip Channel	2,171
	6	Ichamoti Bridge Khal	Sandwip Channel	3,849
	7	Bhatiari Khal	Sandwip Channel	3,130
	8	Dhamair Khal	Sandwip Channel	4,153
	9	Tulatoli Khal	Sandwip Channel	1,445
	10	Faujdarhat Khal	Sandwip Channel	1,105
	11	North Salimpur Khal	Sandwip Channel	860

Drainage Area No	Sl No	Primary Khal Name	Outfall	Primary Khal Length (m)
8	1	Garduara Khal	Halda	3,430
	2	Porapali Khal	Halda	3,994
	3	Uttar Madarsha Khal	Halda	1,920
	4	Madari Khal	Halda	2,725
	5	South Madarsha Khal	Halda	3,530
9	1	Boalia Khal	Halda	3,661
10	1	West Guzara Khal	Halda	8,233
	2	West Barighina Khal	Halda	6,573
	3	Maishkaram Khal	Halda	5,565
	4	Noapara Khal	Halda	1,945
	5	Pachkhain Khal	Karnaphuli	7,180
	6	Lamburhat Khal	Karnaphuli	5,680
	7	Ram Gatir Hat Khal	Karnaphuli	2,142
11	1	Kaukhali Khal	Karnaphuli	2,160
	2	Pomra Khal	Karnaphuli	5,880
12	1	Nadimpur Khal	Halda	3,333
	2	Sattar Khal	Halda	10,615
	3	Garduara Khal	Halda	14,900
	4	Dewan Ali Khal	Halda	9,520
13	1	Parki Canaal	Bay of Bengal	5,425
	2	Parki Canal	Sangu	4,705
	3	Khurushkul Khal	Sangu	6,081
	4	Daskhin Barunchara Khal	Sangu	7,854
	5	Icchakhali Khal	Sangu	5,967
	6	Murai Khal	Sangu	6,870
14	1	Murai Khal	Karnaphuli	22,765
	2	Cha Patharghata Khal	Karnaphuli	4,090
	3	Karnafuli Canal	Karnaphuli	5,031
15	1	Baremba Khal	Karnaphuli	6,066
	2	Boalkhali Khal	Karnaphuli	16,606
	3	Kharana kHal	Boalkhali Khal	8,175
16	1	Charndip Khal	Karnaphuli	4,093
	2	West Charandip Khal	Karnaphuli	3,050
	3	Kalurghat Khal	Karnaphuli	7,844
	4	Shakpura Khal	Karnaphuli	9,500
17	1	Jaishthapura Khal	Karnaphuli	14,605

ANNEX - 2

FLOOD INUNDATION MAPS ANDS MODIFIED KHALS SECTION

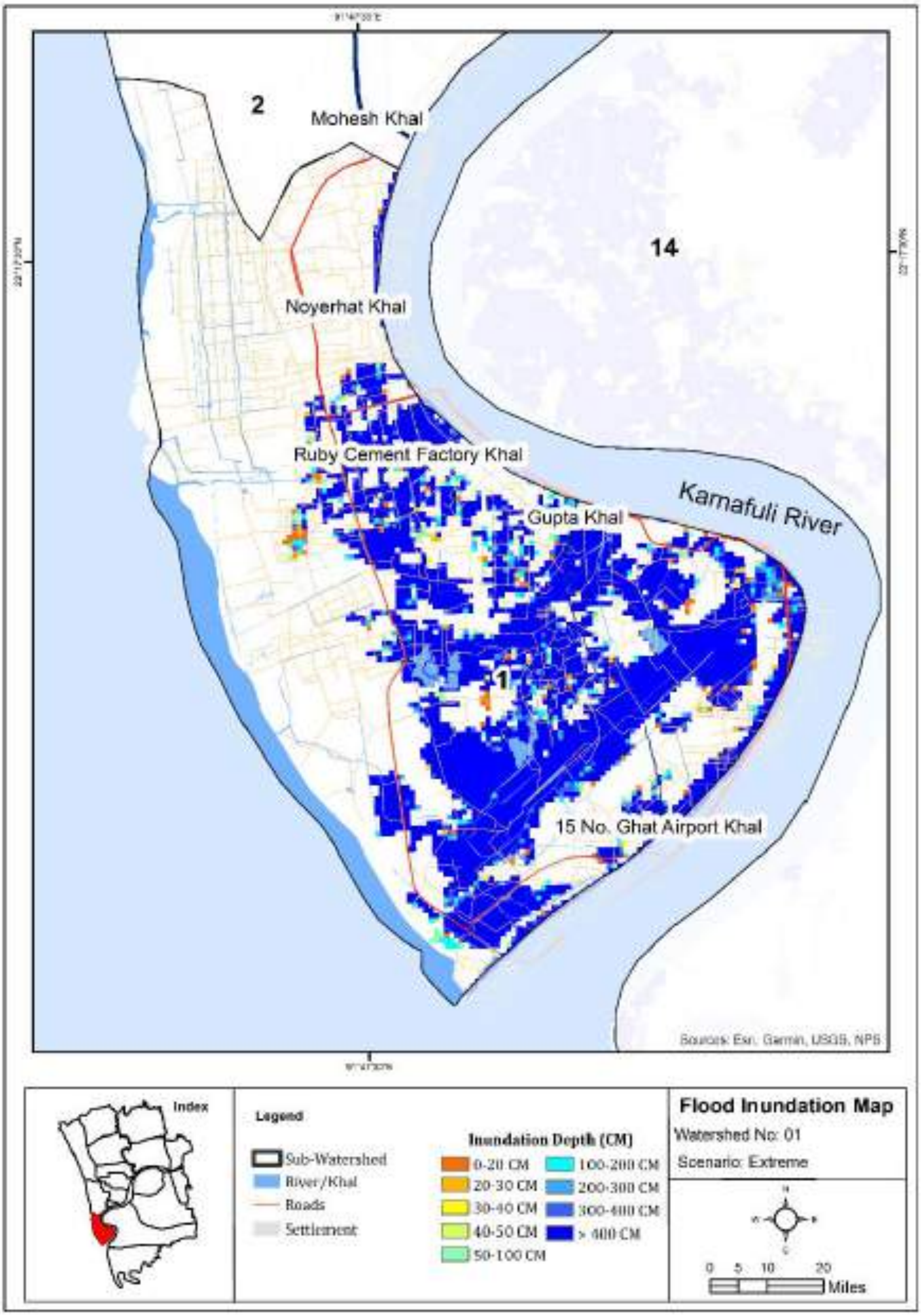


Figure A2-1: Flood inundation area for drainage area 01

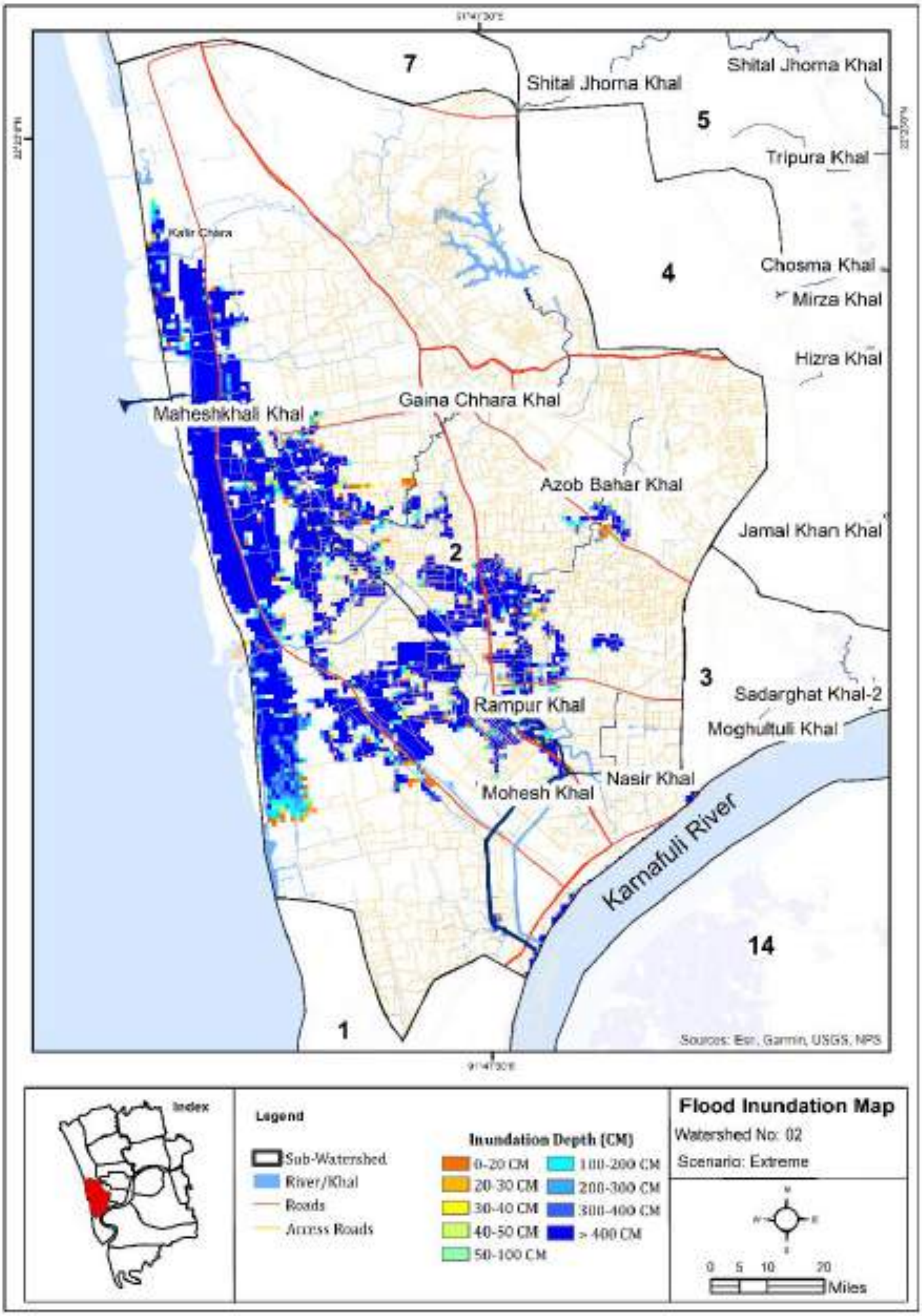


Figure A2-2: Flood inundation area for drainage area 02

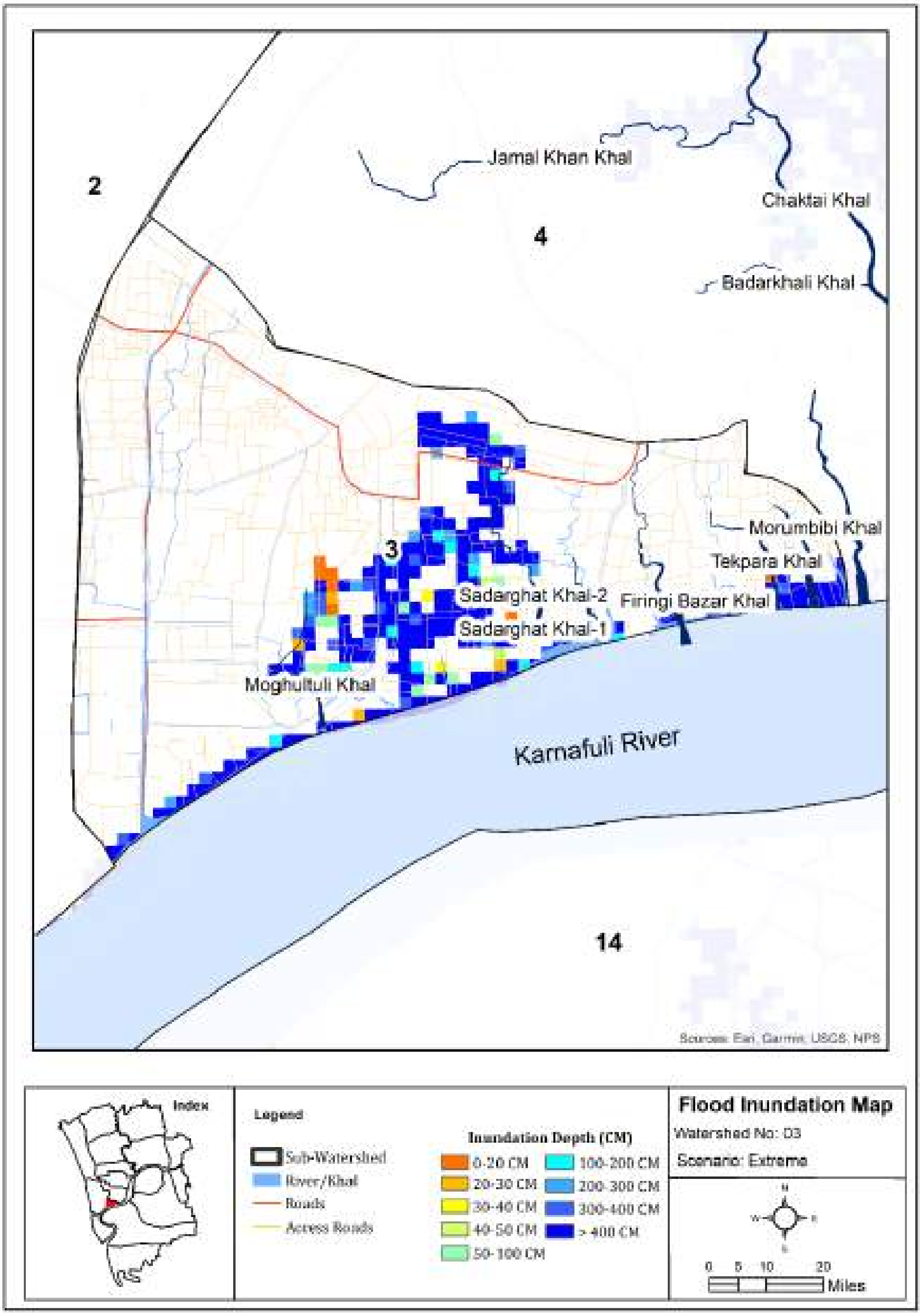


Figure A2-3: Flood inundation area for drainage area 03

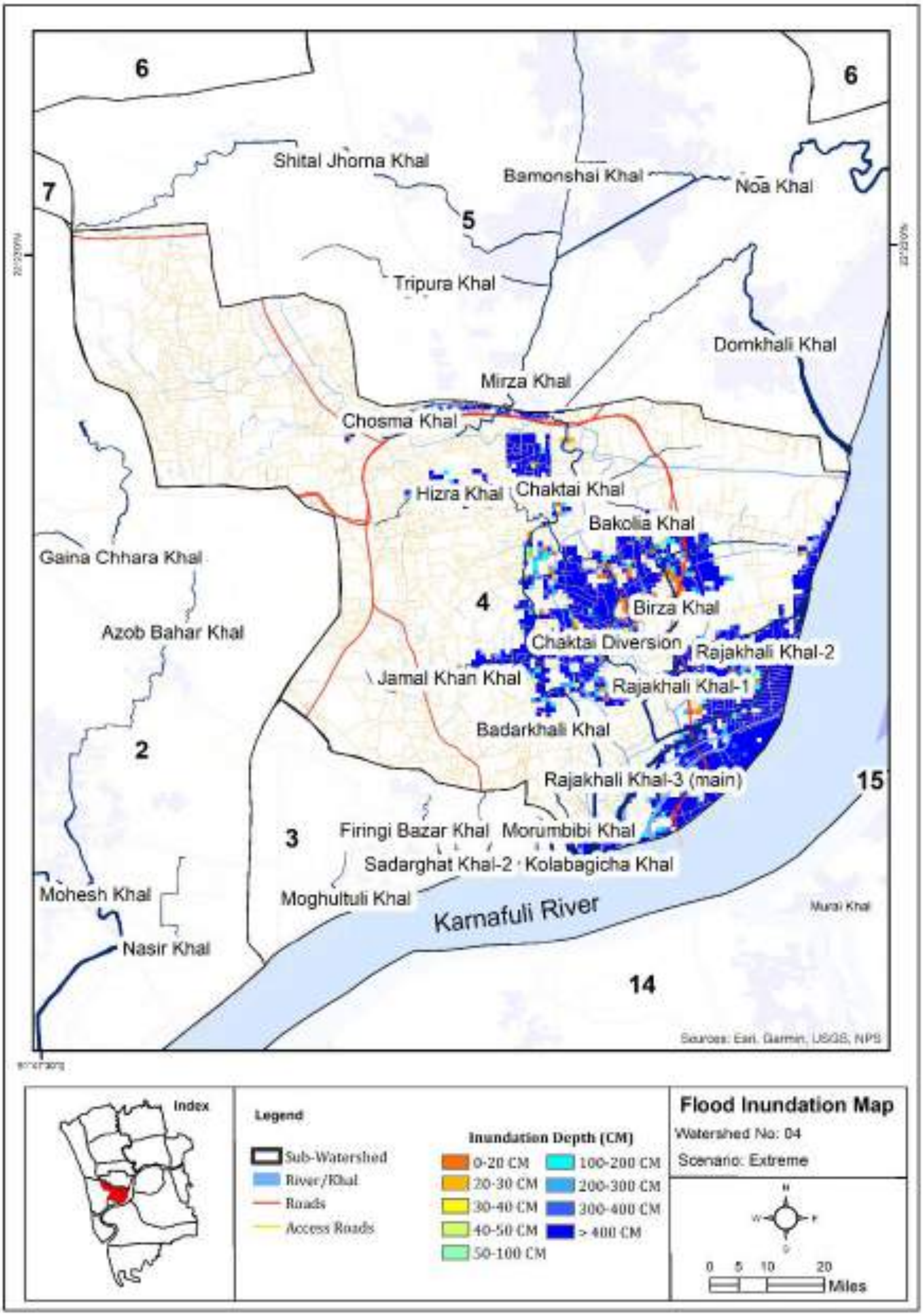


Figure A2-4: Flood inundation area for drainage area 04

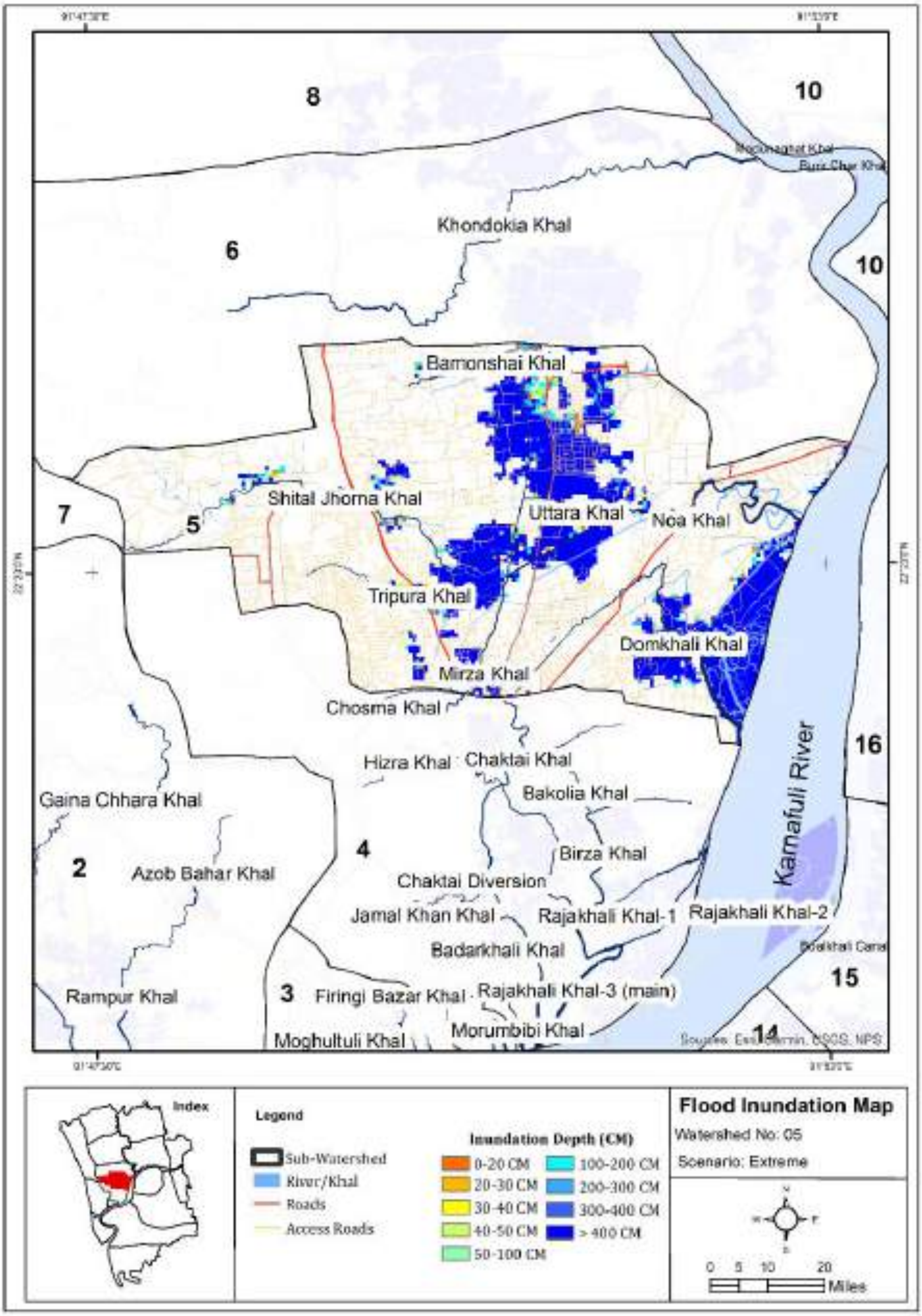


Figure A2-5: Flood inundation area for drainage area 05

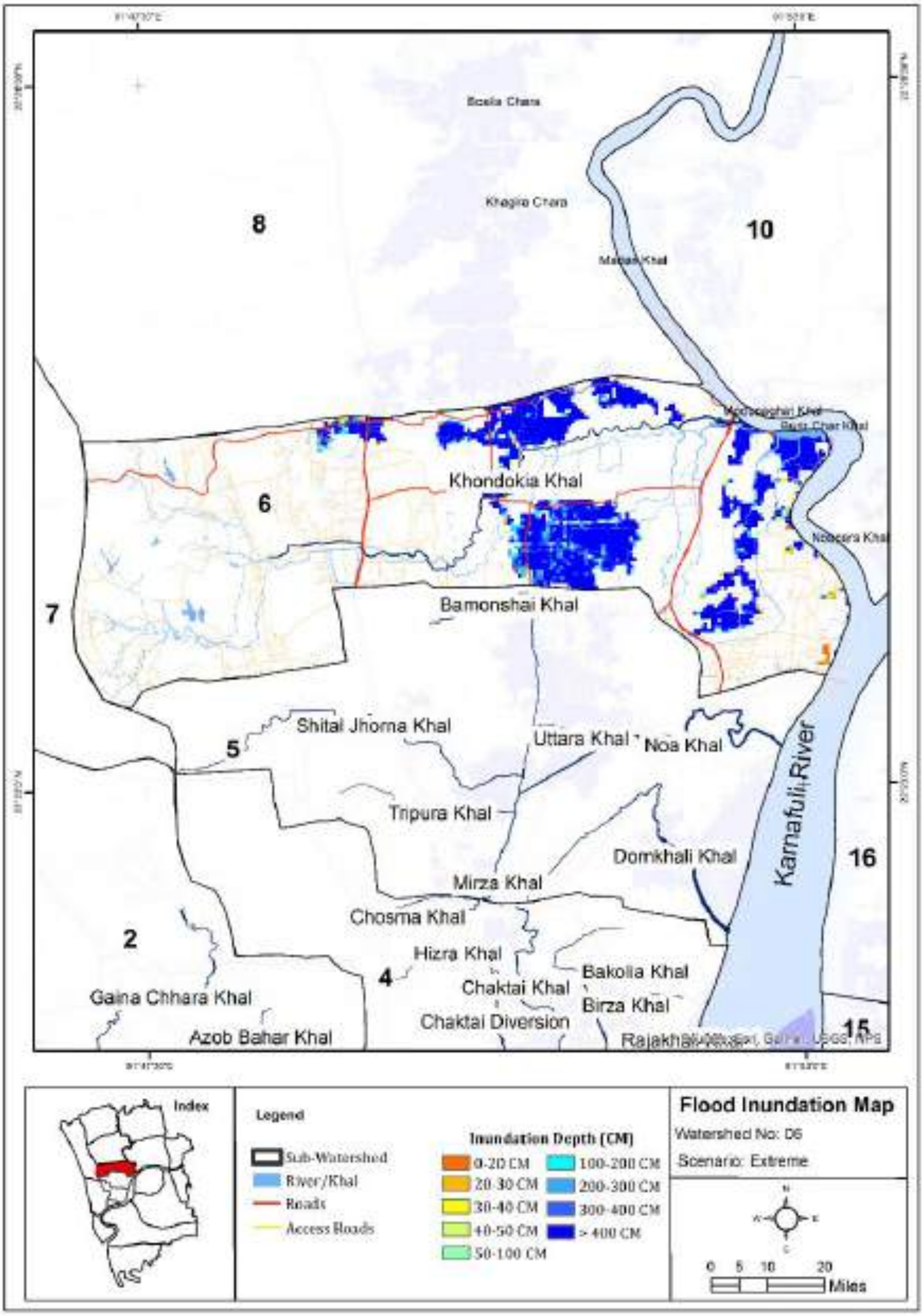


Figure A2-6: Flood inundation area for drainage area 06

Figure A2-7: Flood inundation area for drainage area 07

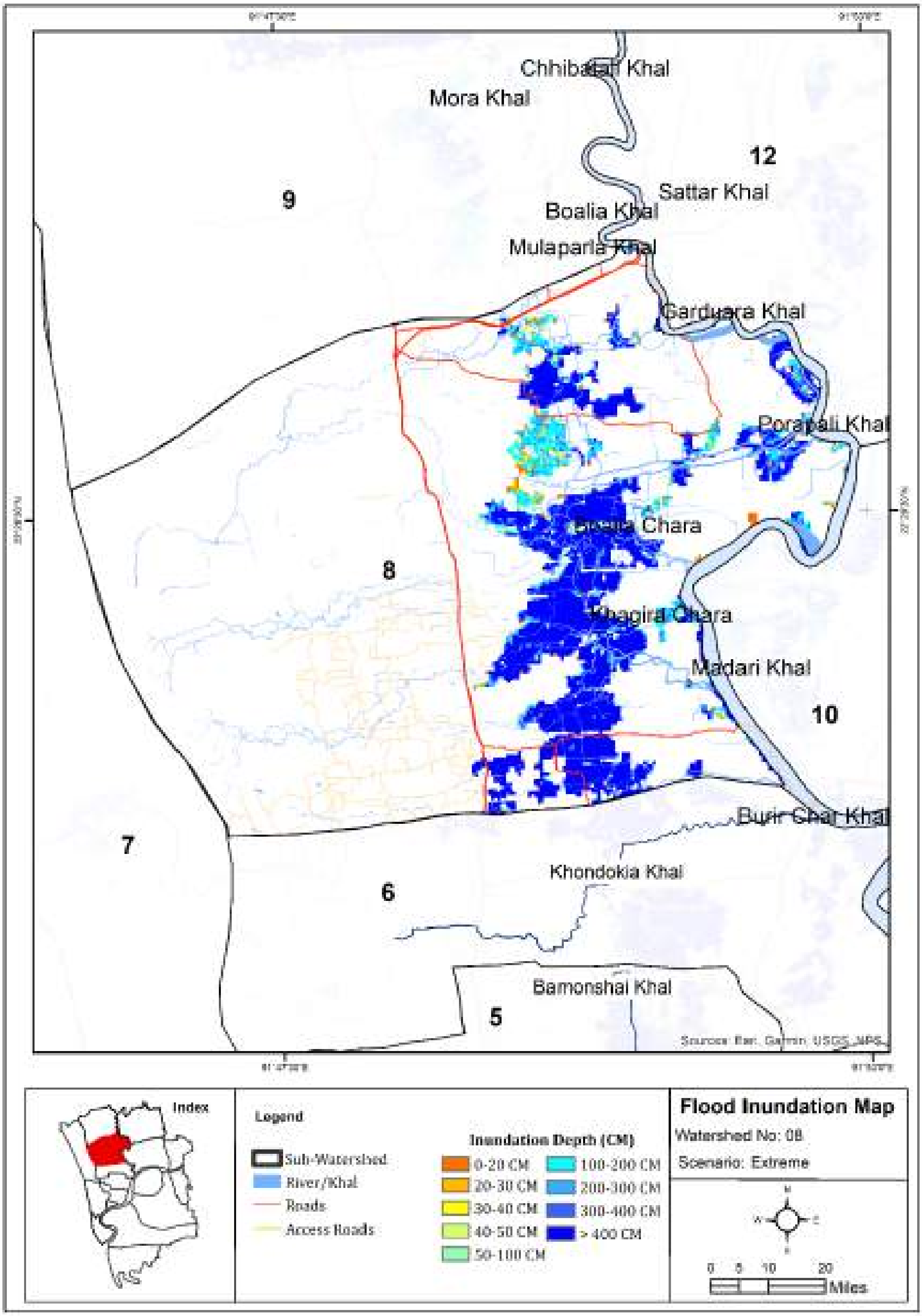


Figure A2-8: Flood inundation area for drainage area 08

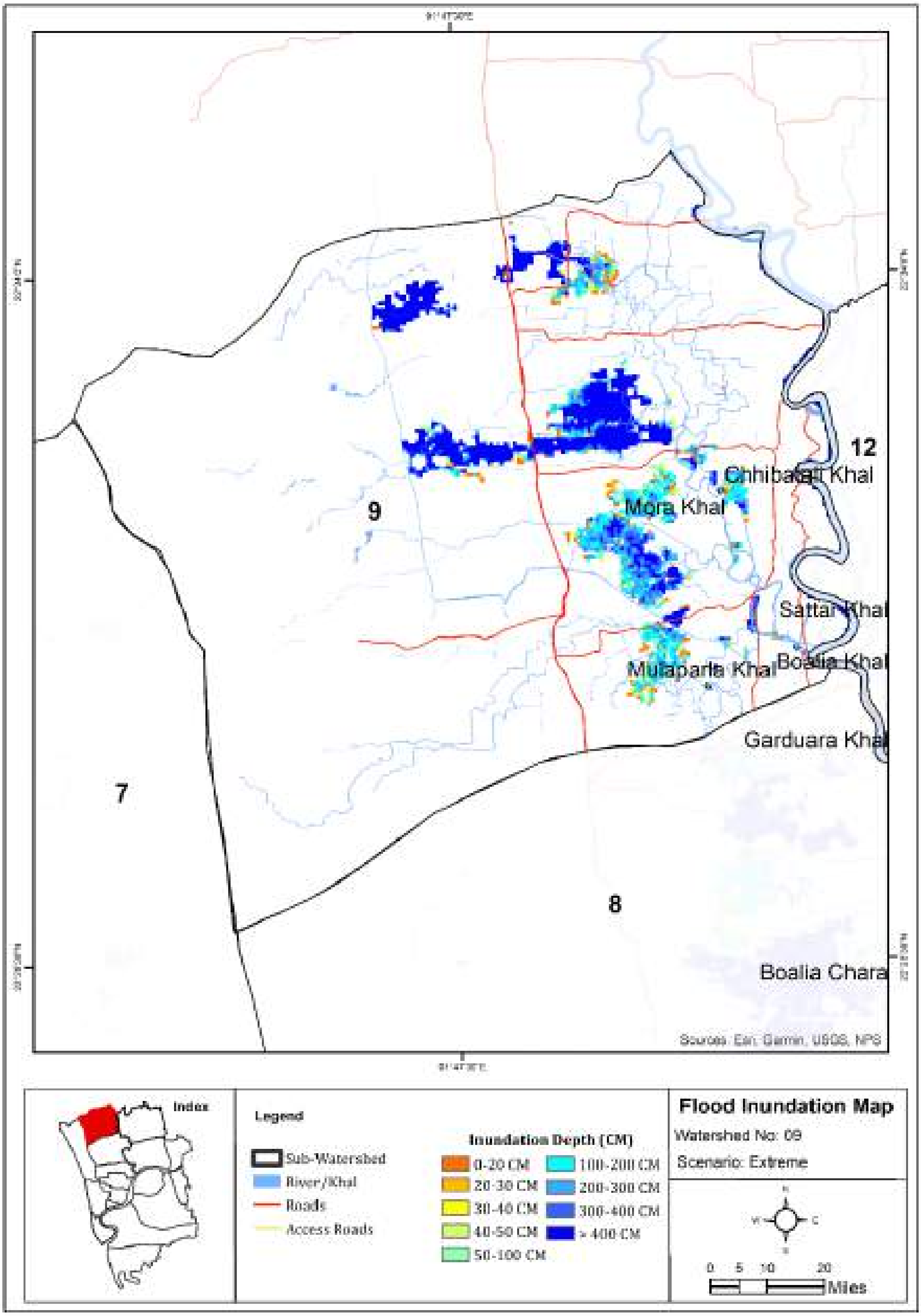


Figure A2-9: Flood inundation area for drainage area 09

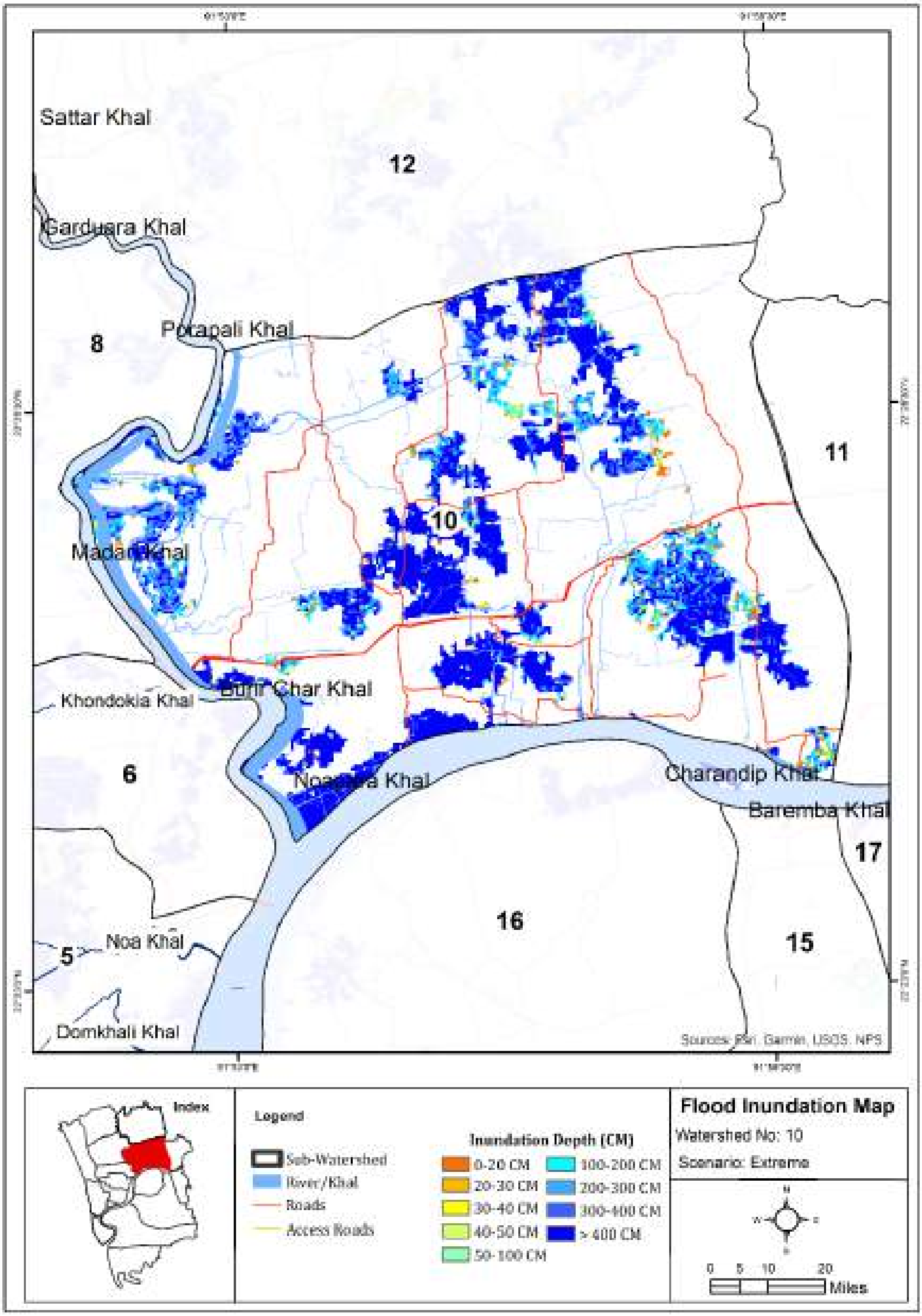


Figure A2-10: Flood inundation area for drainage area 10

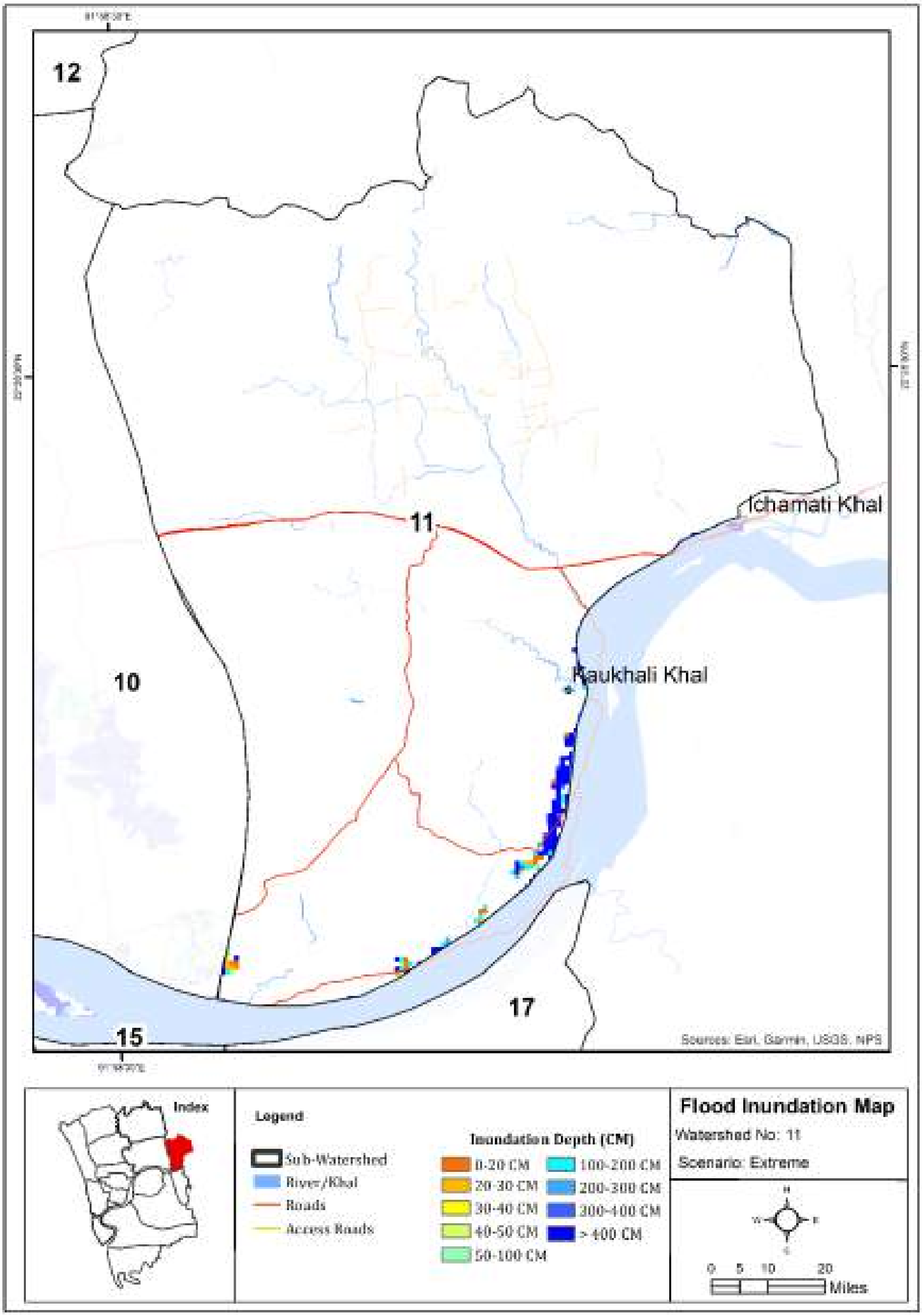


Figure A2-11 : Flood inundation area for drainage area 11

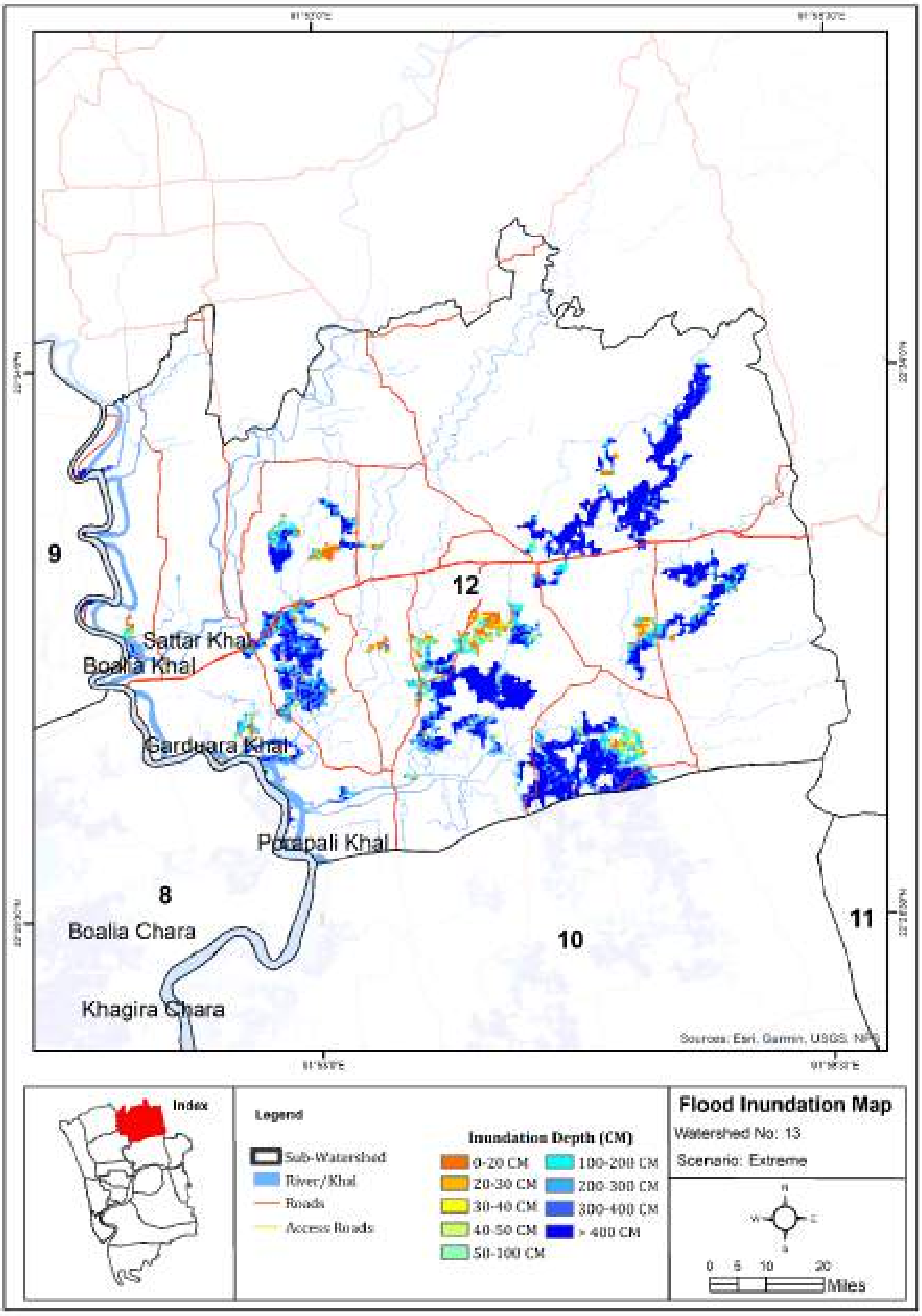


Figure A2-12: Flood inundation area for drainage area 12

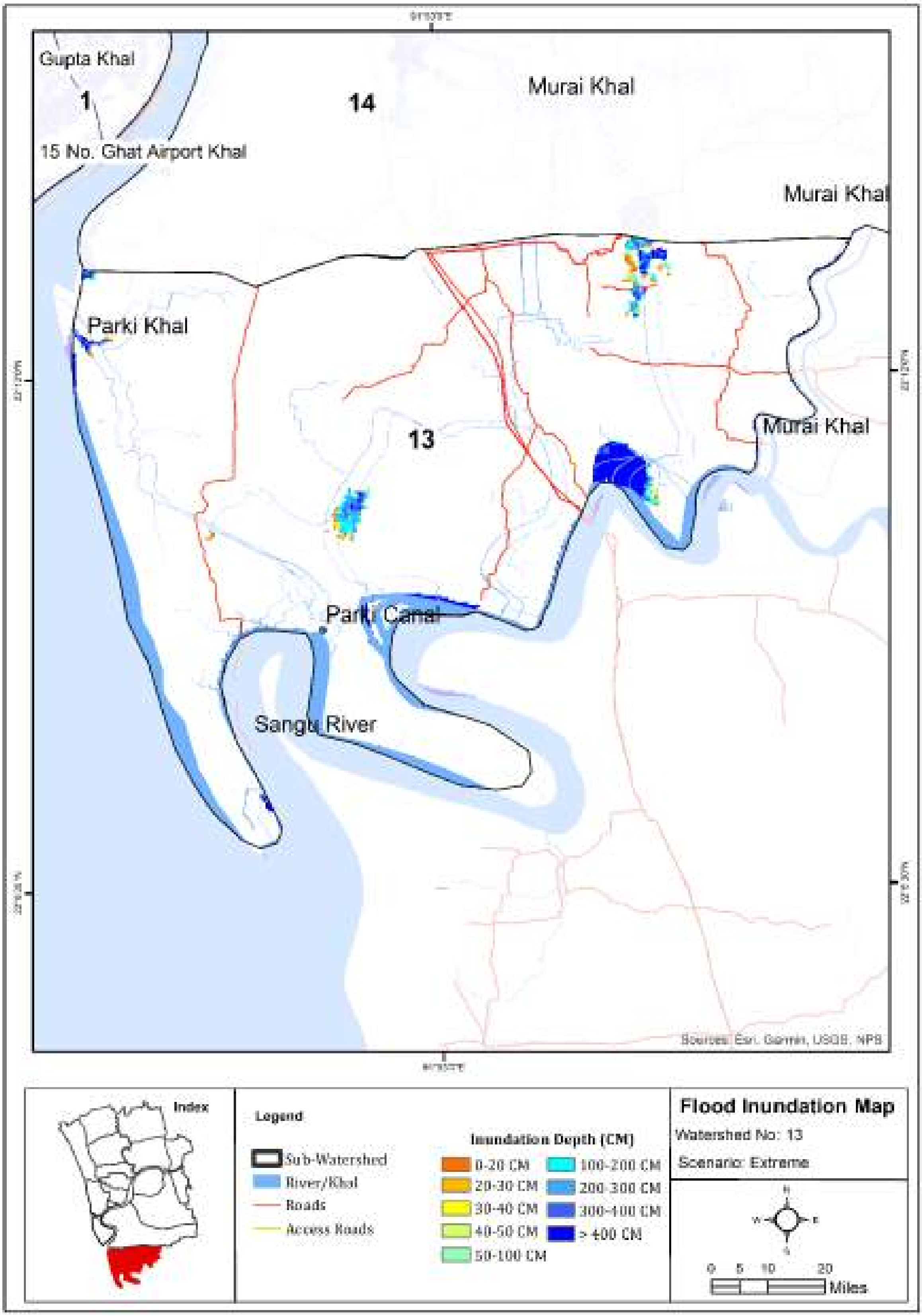


Figure A2-13: Flood inundation area for drainage area 13

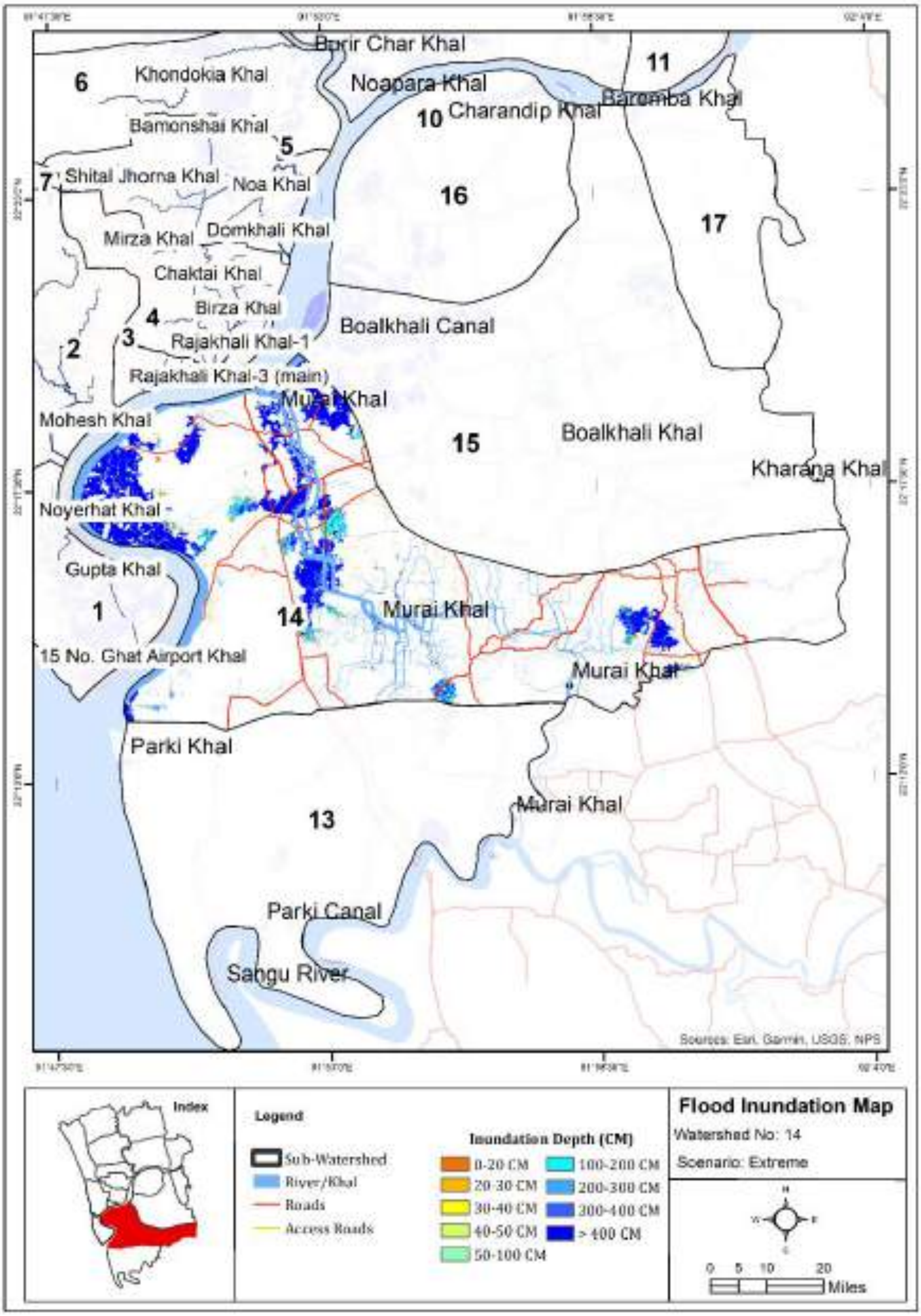


Figure A2-14: Flood inundation area for drainage area 14

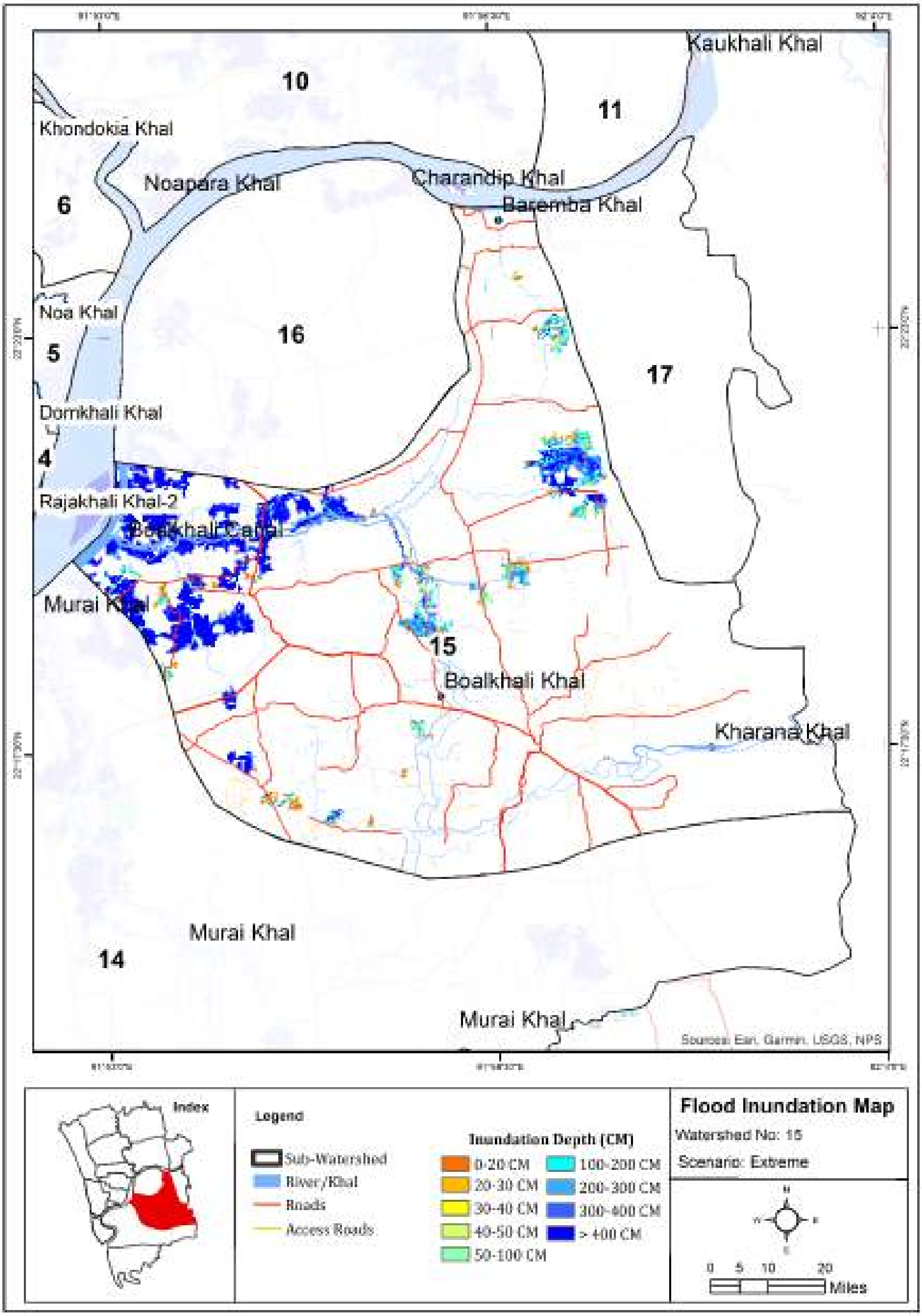


Figure A2-15: Flood inundation area for drainage area 15

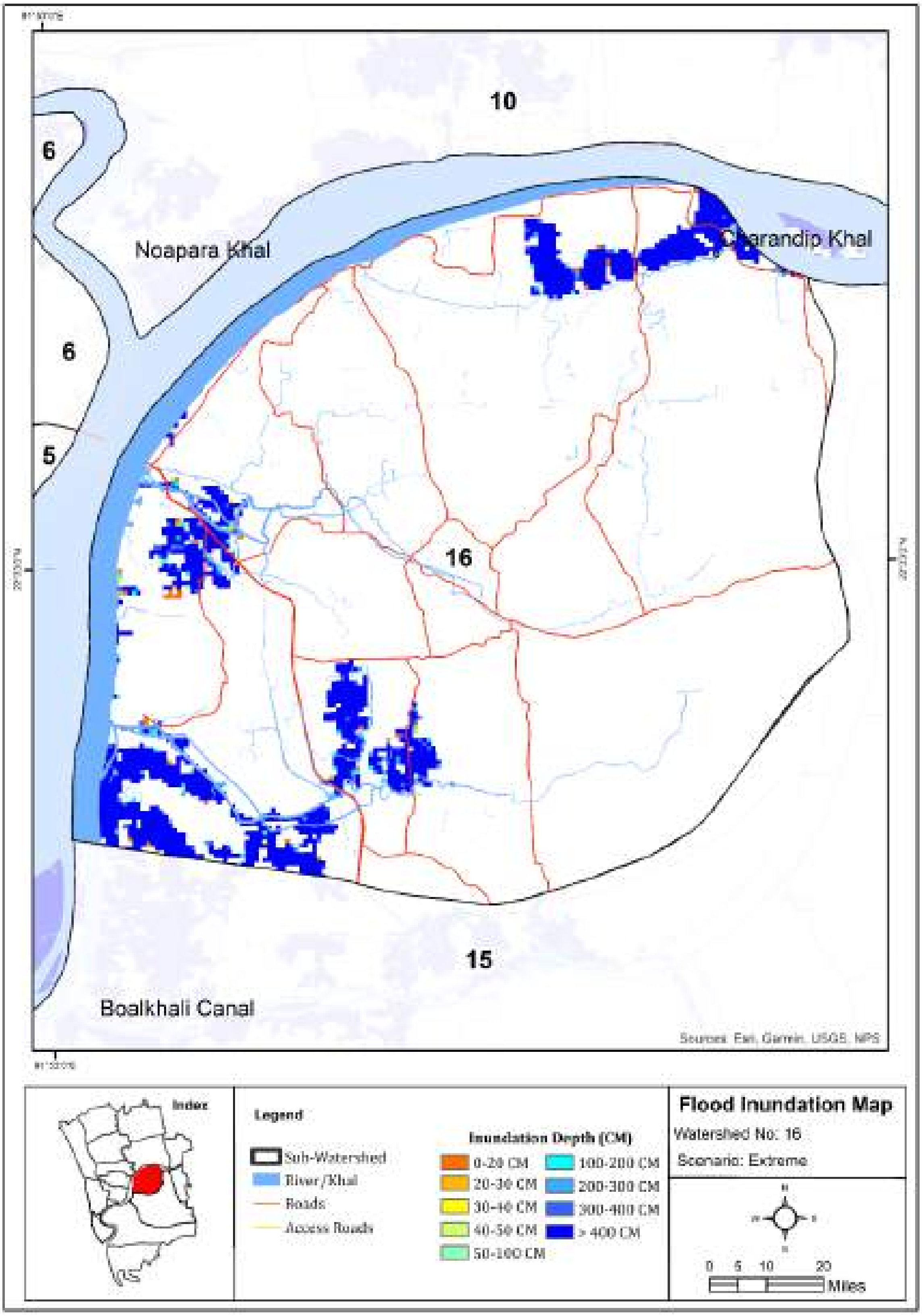


Figure A2-16: Flood inundation area for drainage area 16

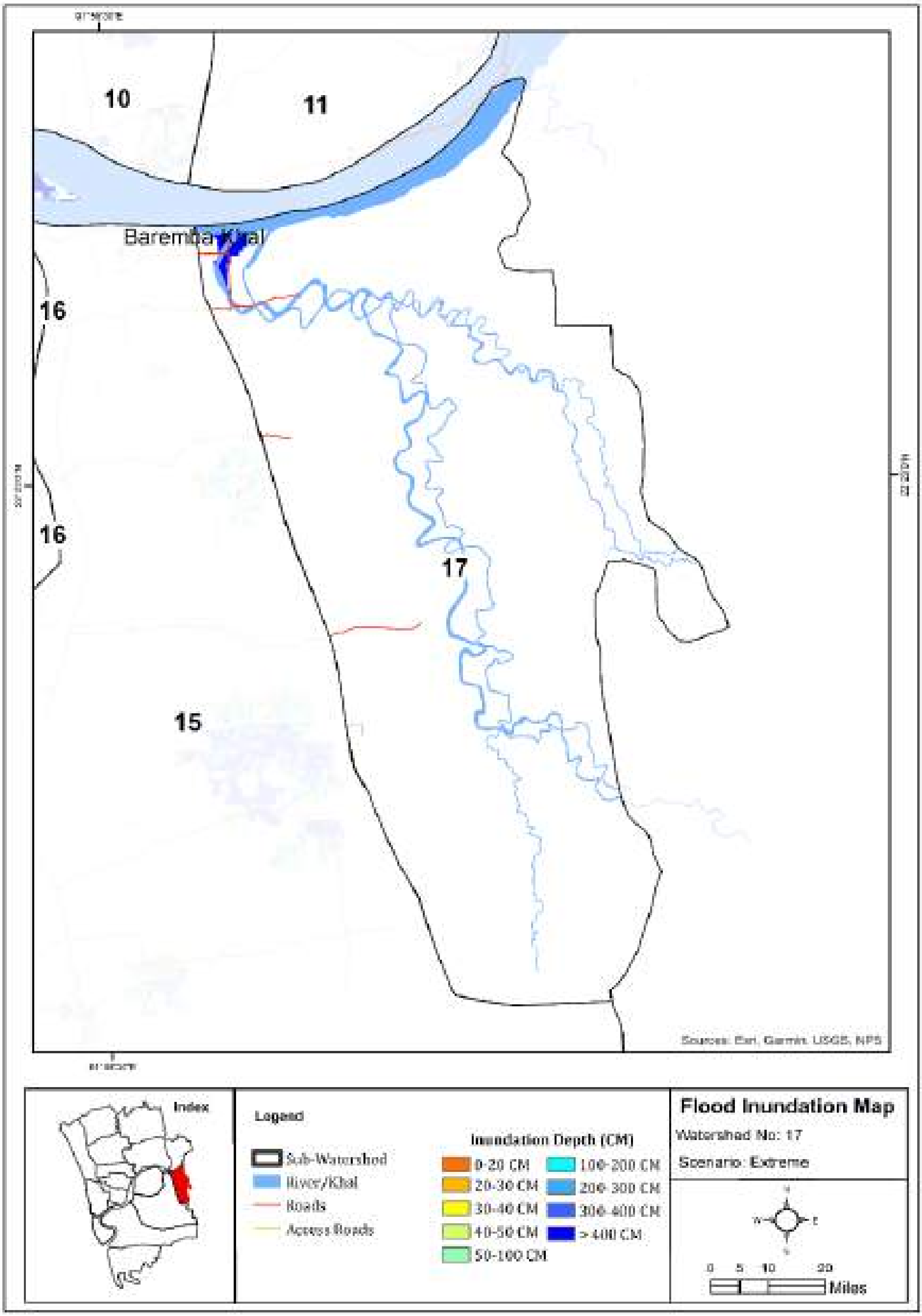


Figure A2-17: Flood inundation area for drainage area 17

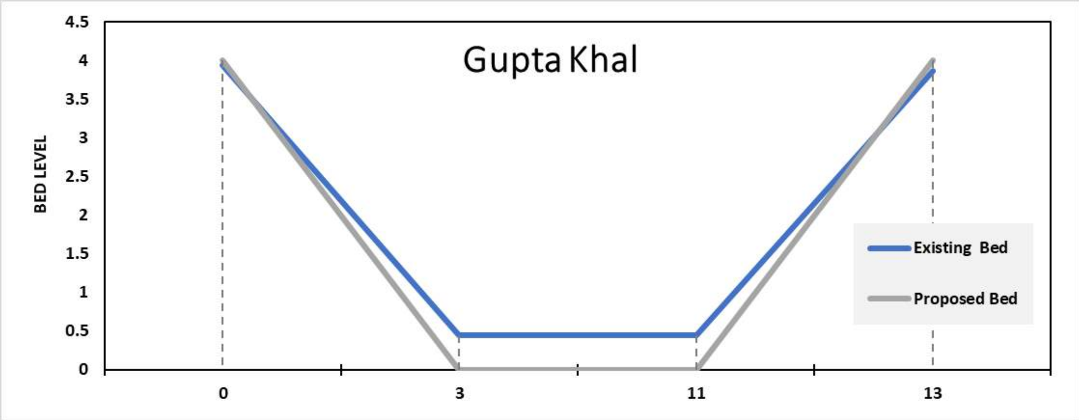


Figure A2-18a: Cross sections of Gupta khal

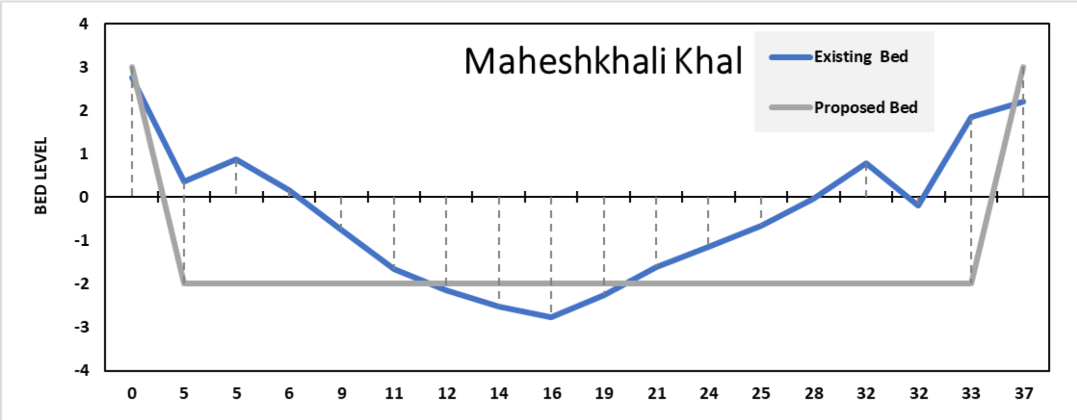


Figure A2-18b: Cross section of Mahesh khal

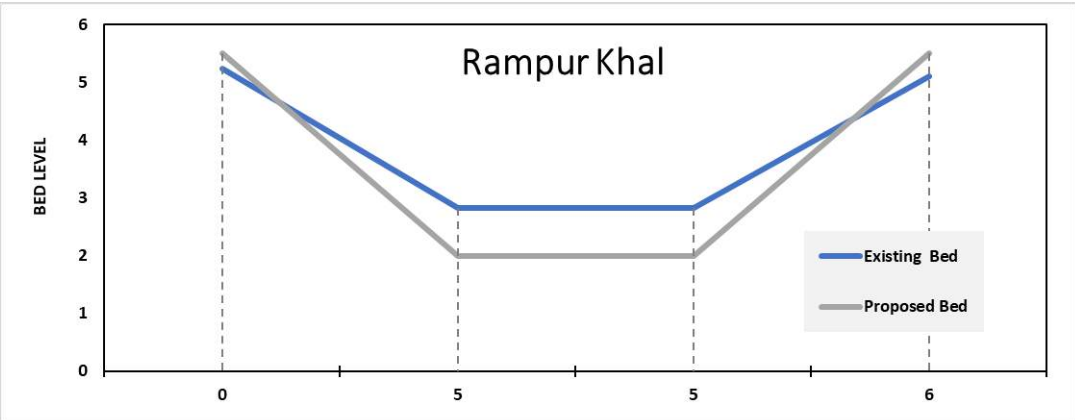


Figure A2-18c: Cross section of Rampur khal

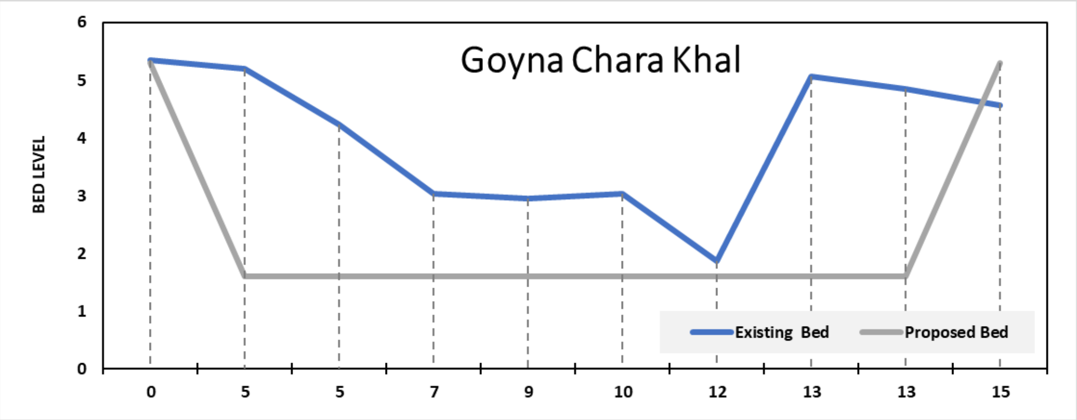


Figure A2-18d: Cross section of Goyna chara khal

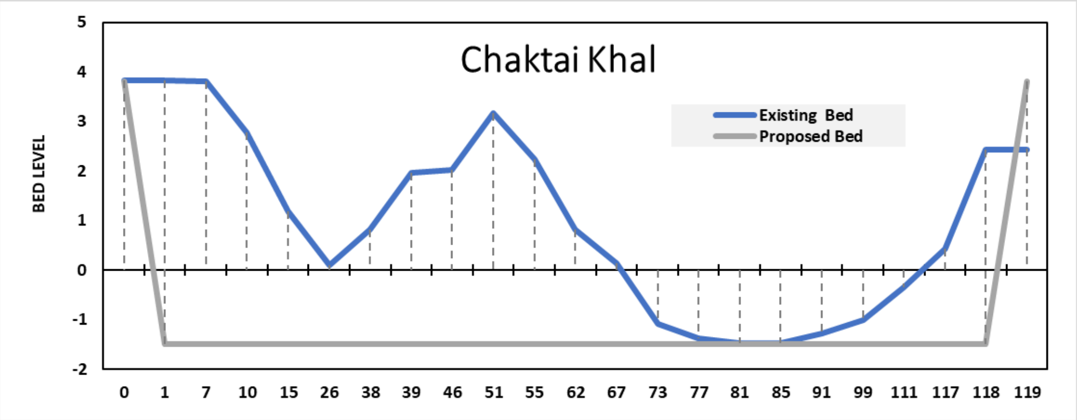


Figure A2-18e: Cross section of Chaktai khal

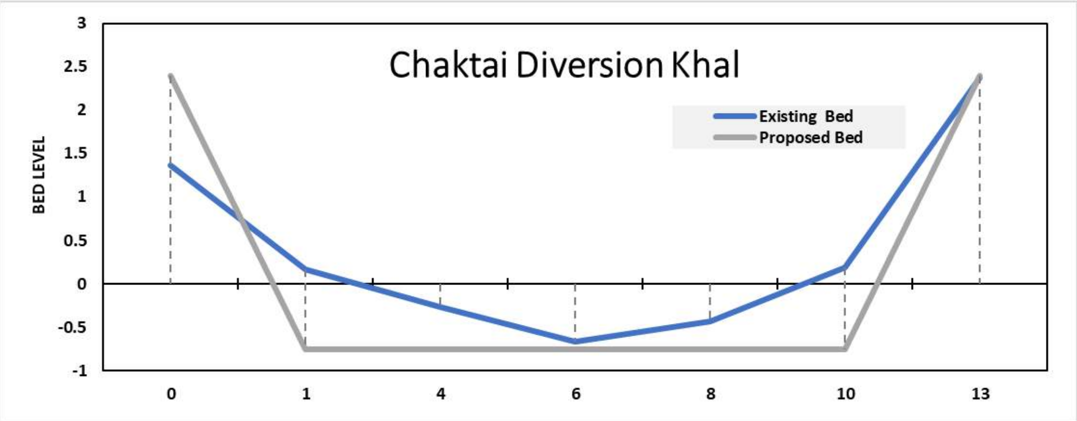


Figure A2-18f: Cross section of Chaktai Diversion khal

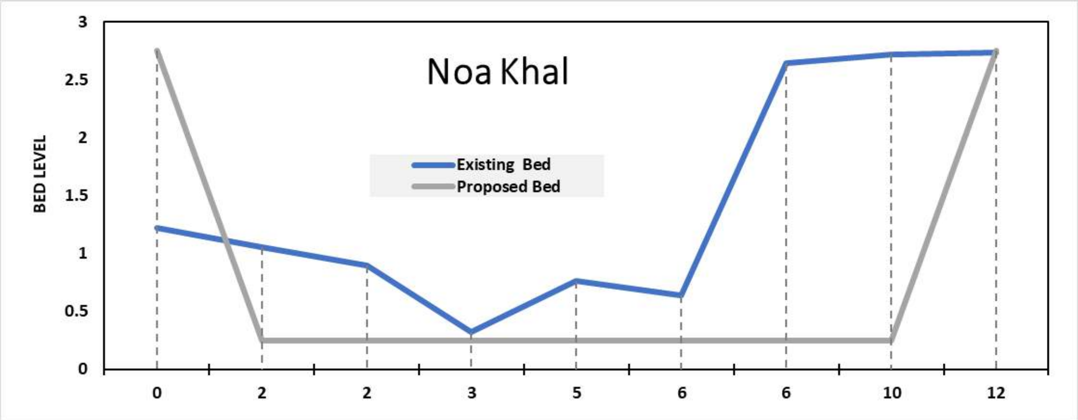


Figure A2-18g: Cross section of Noa khal

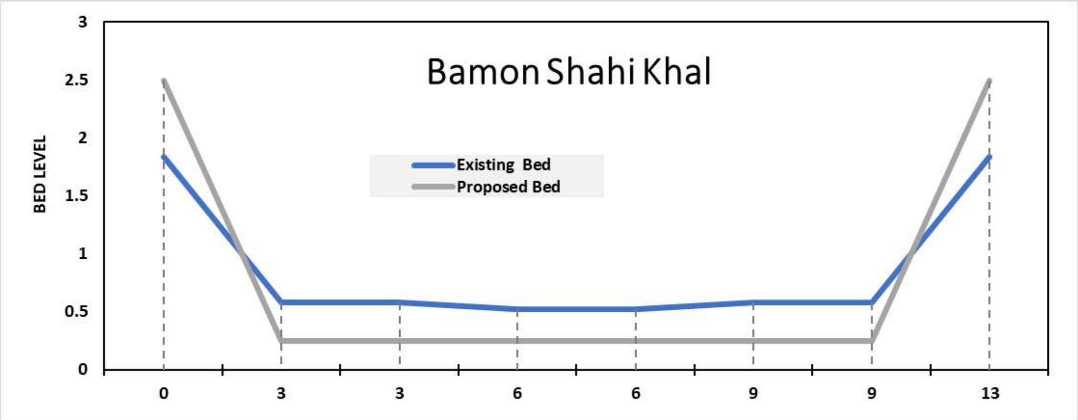


Figure A2-18h: Cross section of Bamon Shahi khal

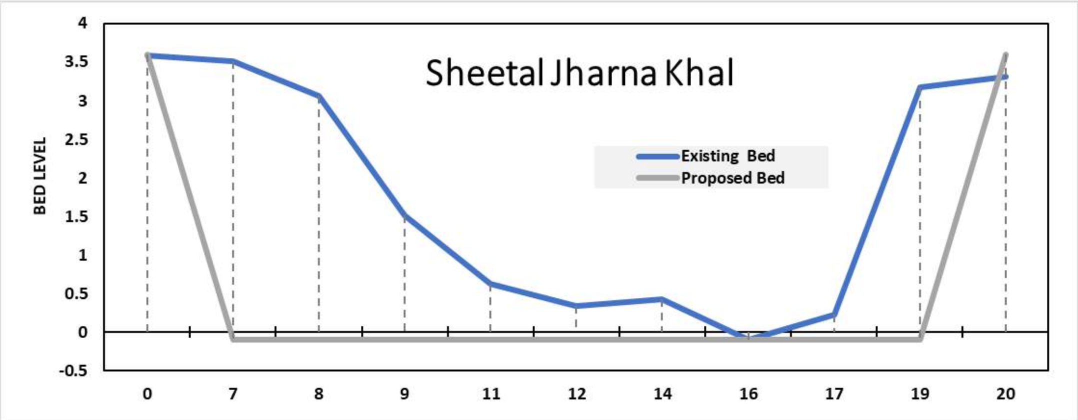


Figure A2-18i: cross section of Sheetal Jharna

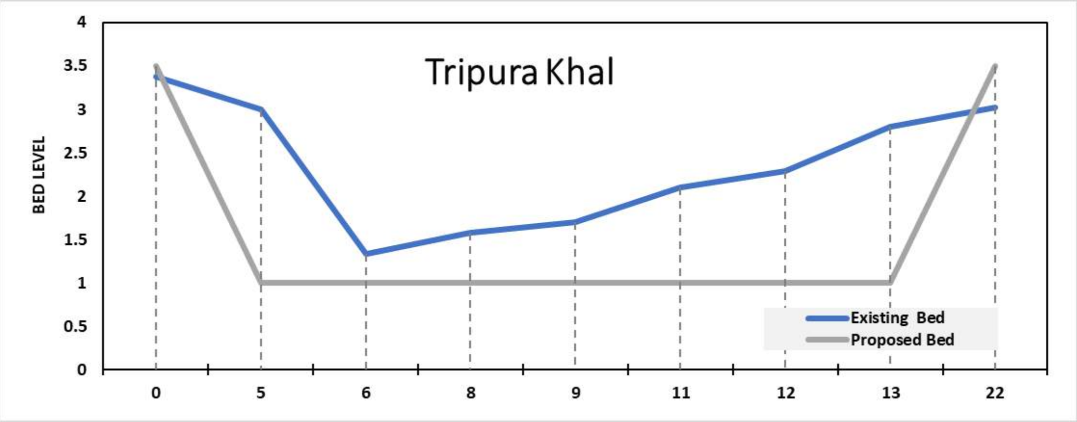


Figure A2-18j: cross section of Tripura Khal

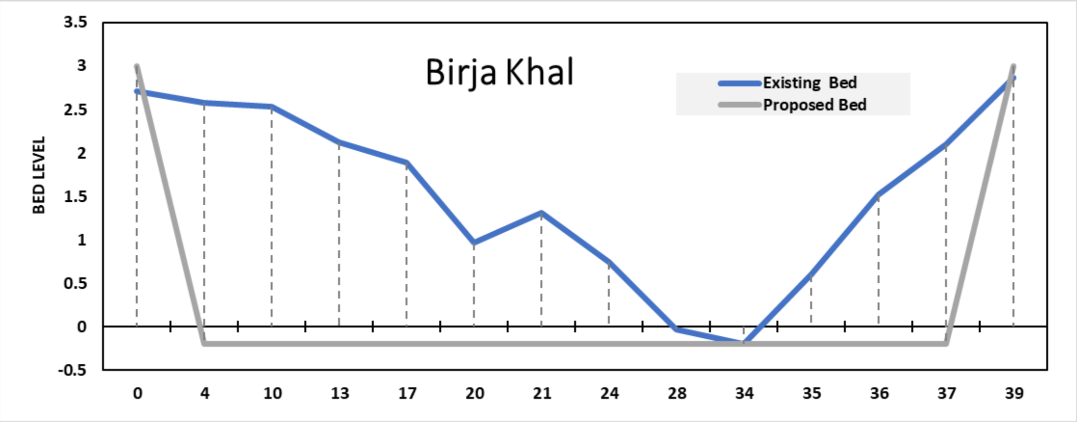


Figure A2-18k: Cross section of Birja khal

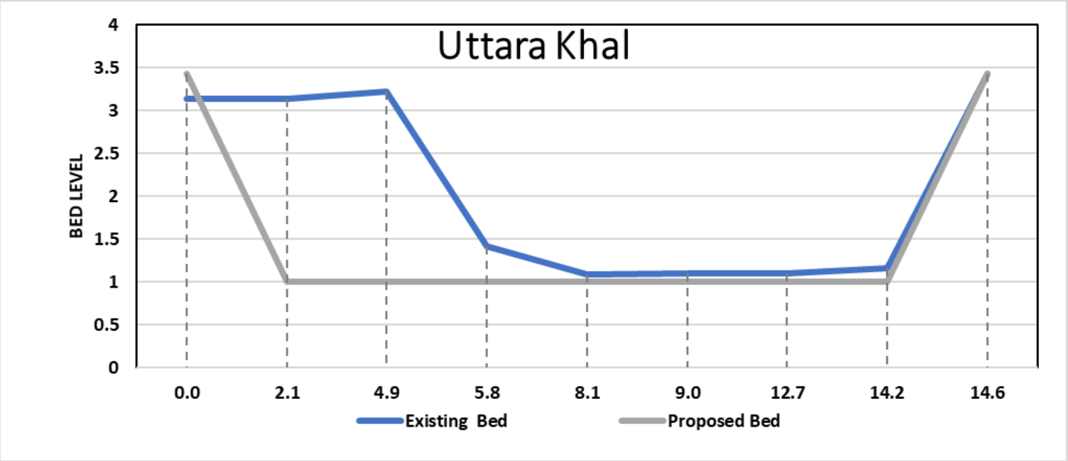


Figure A2-18l: Cross section of Uttara

ANNEX - 3

INTEGRATED DRAINAGE PLAN (IDP) MAPS

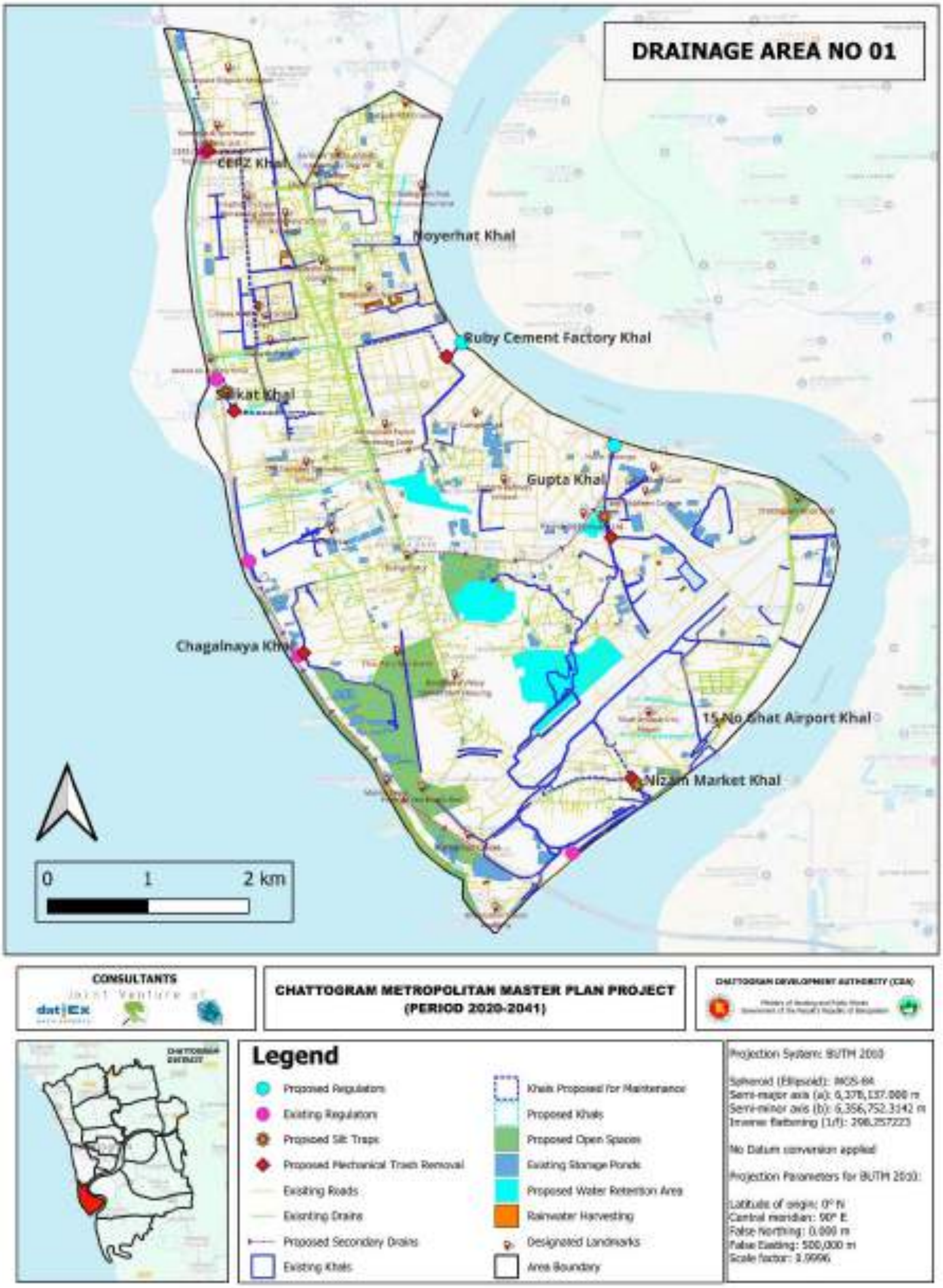


Figure A3-1 Integrated Drainage Plan (IDP) of Drainage Area 01

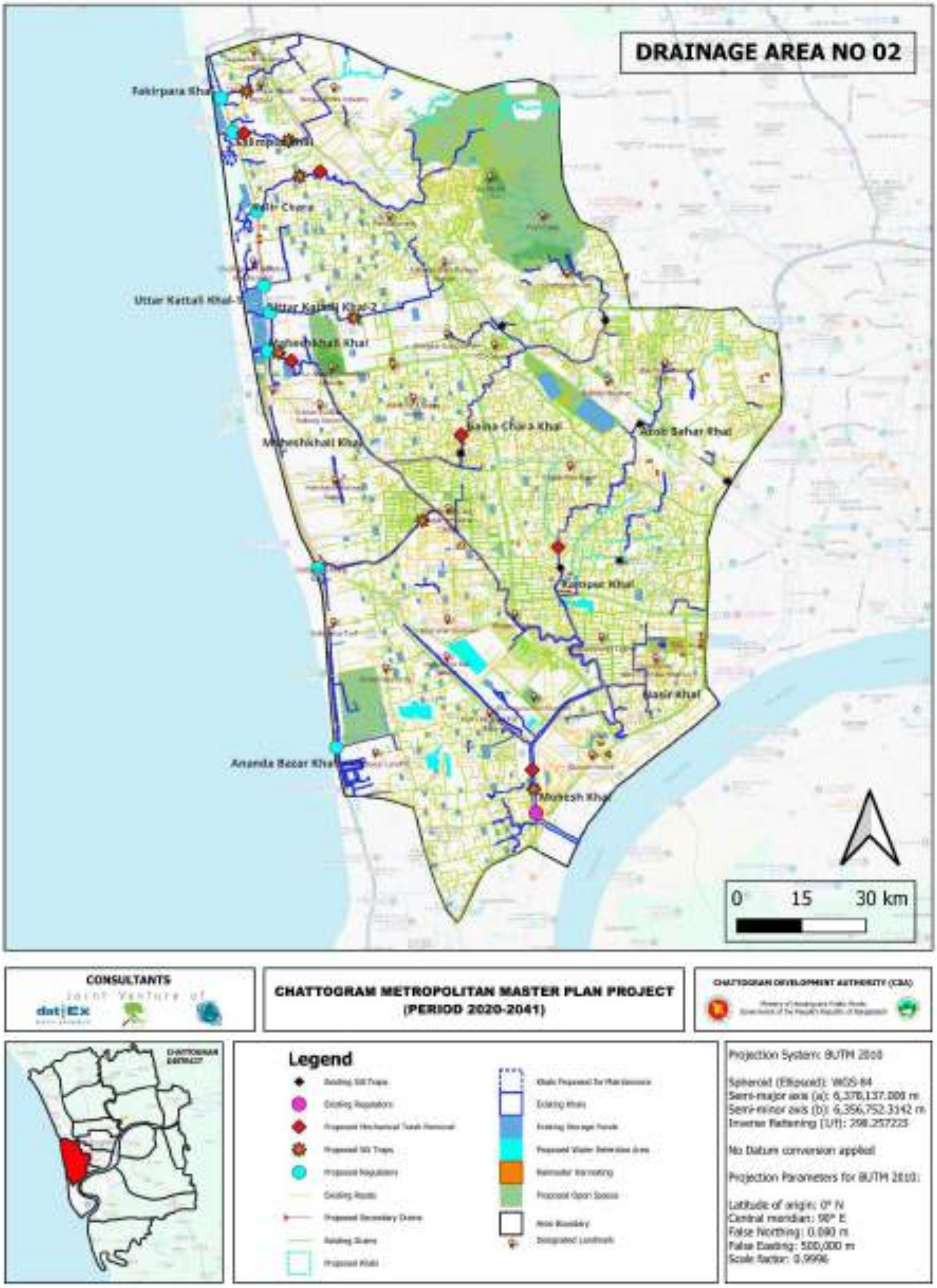


Figure A3-2 Integrated Drainage Plan (IDP) of Drainage Area 02

Figure A3-3 Integrated Drainage Plan (IDP) of Drainage Area 03

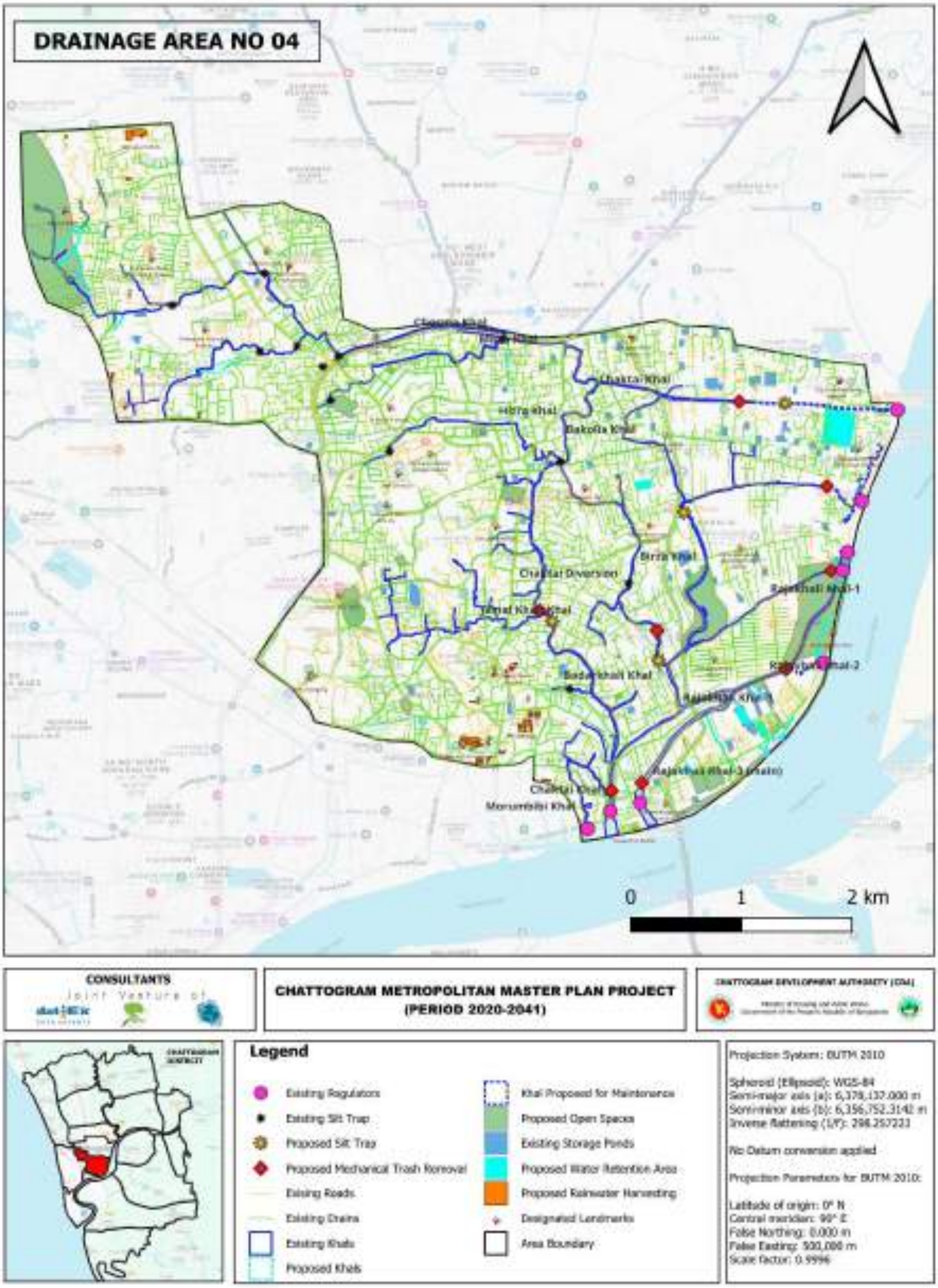


Figure A3-4 Integrated Drainage Plan (IDP) of Drainage Area 04

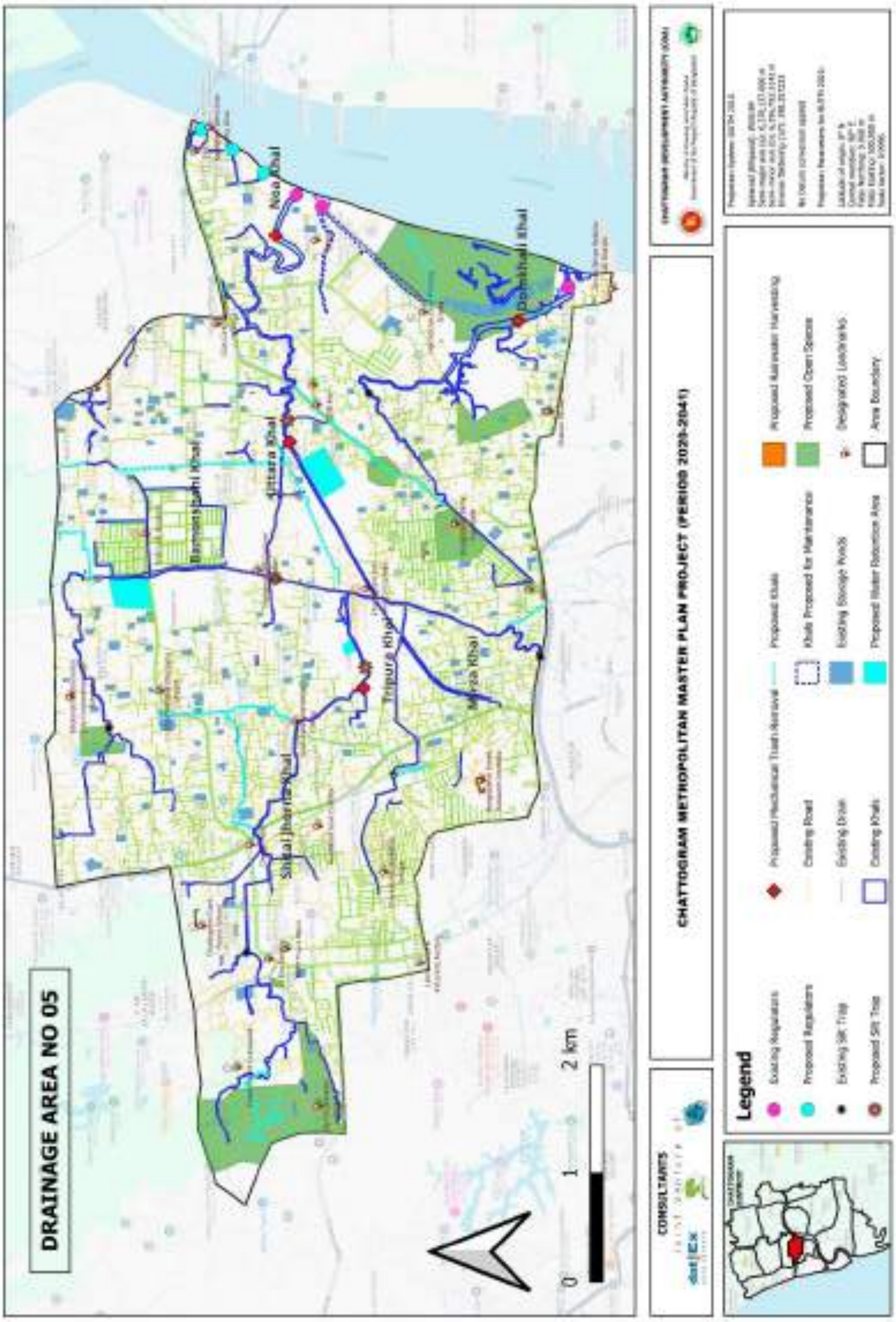


Figure A3-5 Integrated Drainage Plan (IDP) of Drainage Area 05

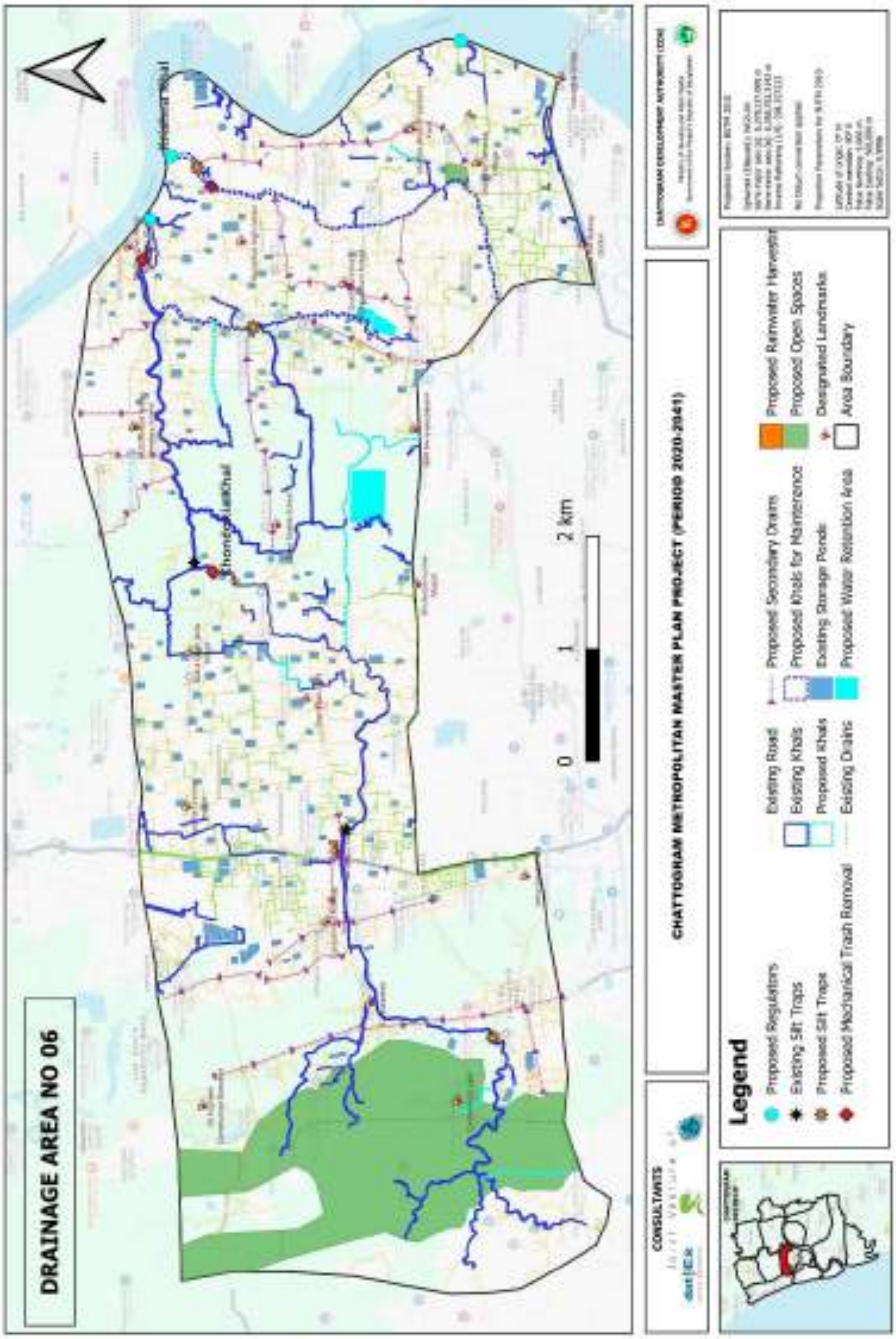


Figure A3-6 Integrated Drainage Plan (IDP) of Drainage Area 06

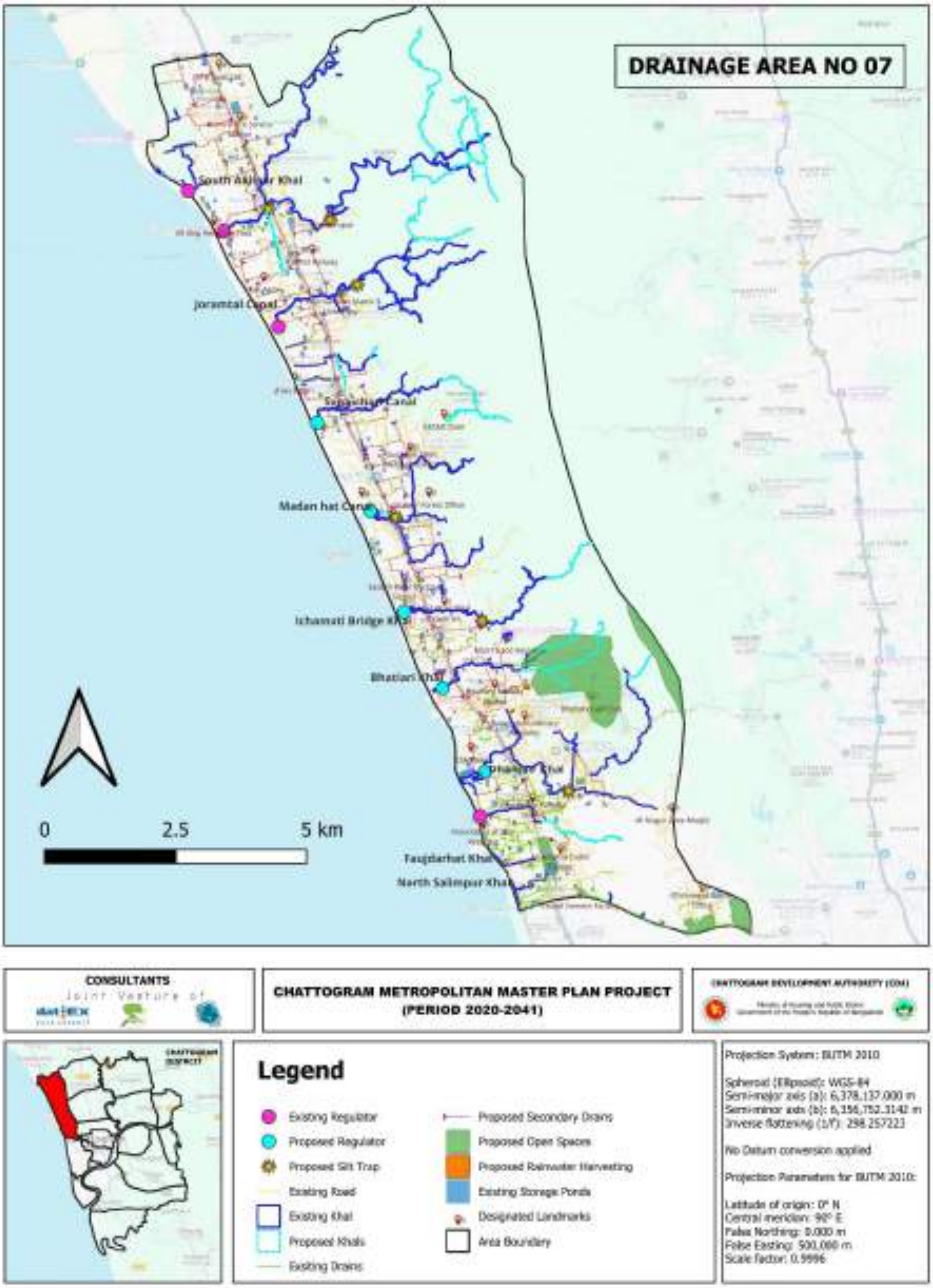


Figure A3-7 Integrated Drainage Plan (IDP) of Drainage Area 07

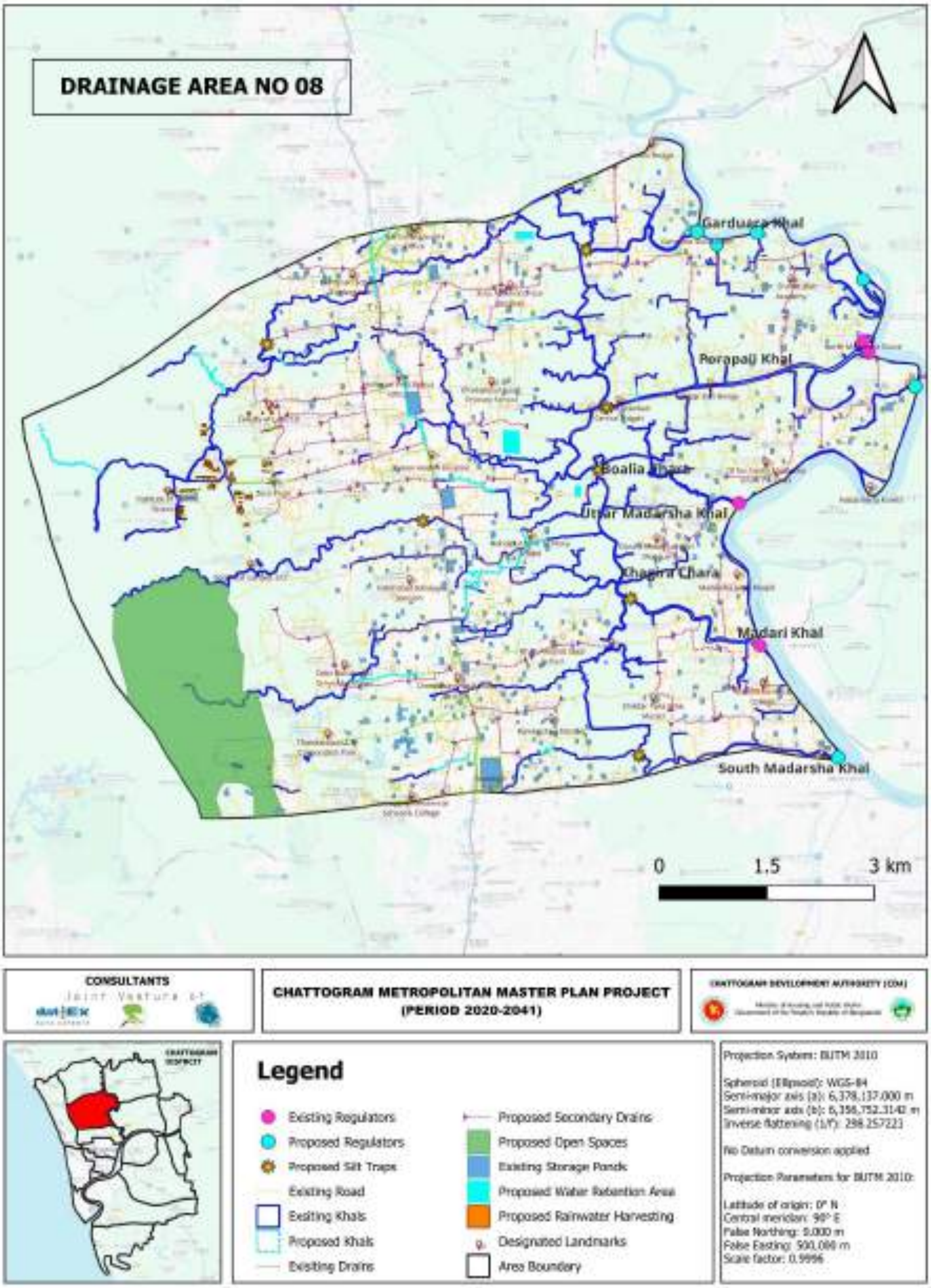


Figure A3-8 Integrated Drainage Plan (IDP) of Drainage Area 08

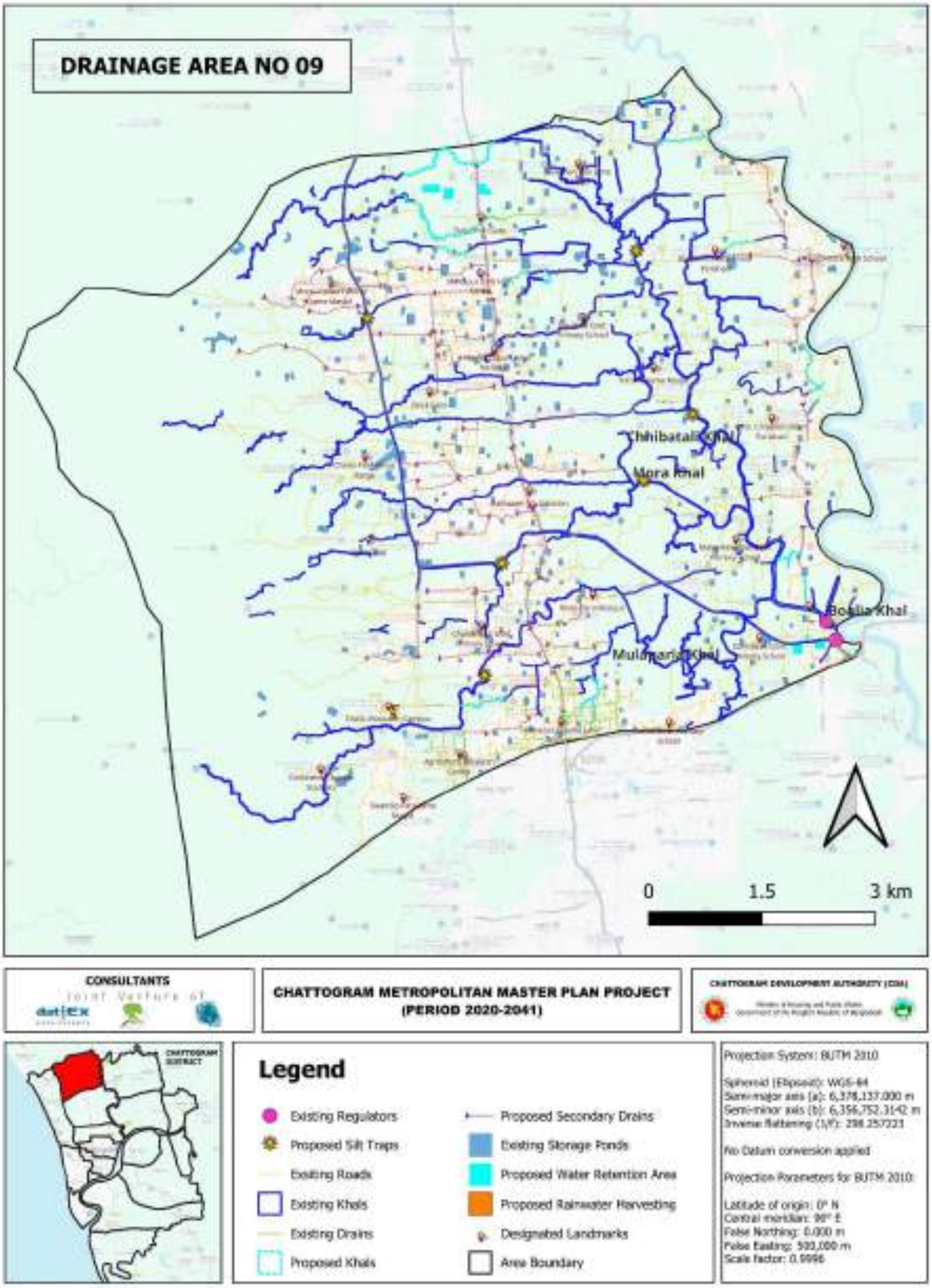


Figure A3-9 Integrated Drainage Plan (IDP) of Drainage Area 09

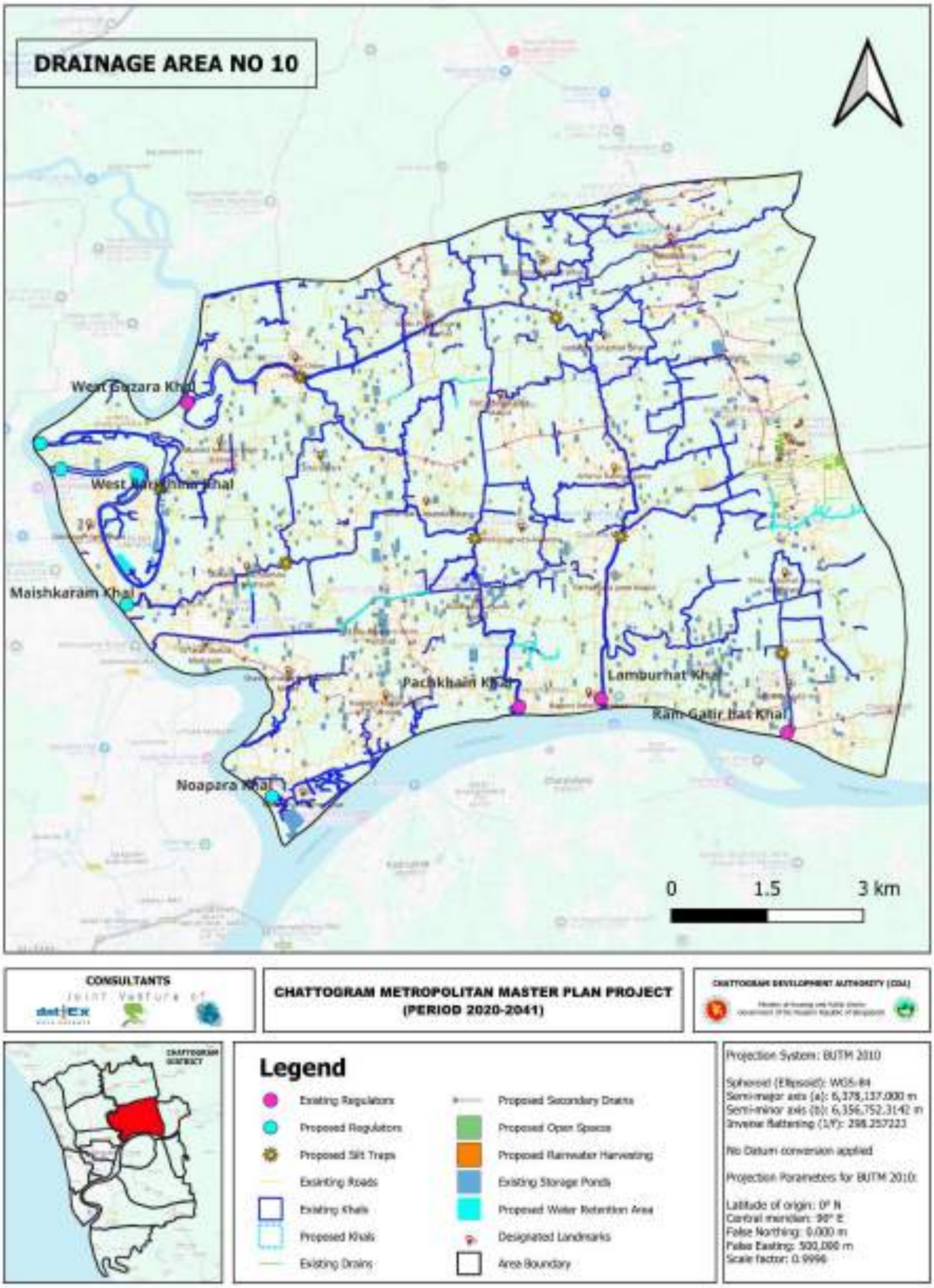


Figure A3-10 Integrated Drainage Plan (IDP) of Drainage Area 10

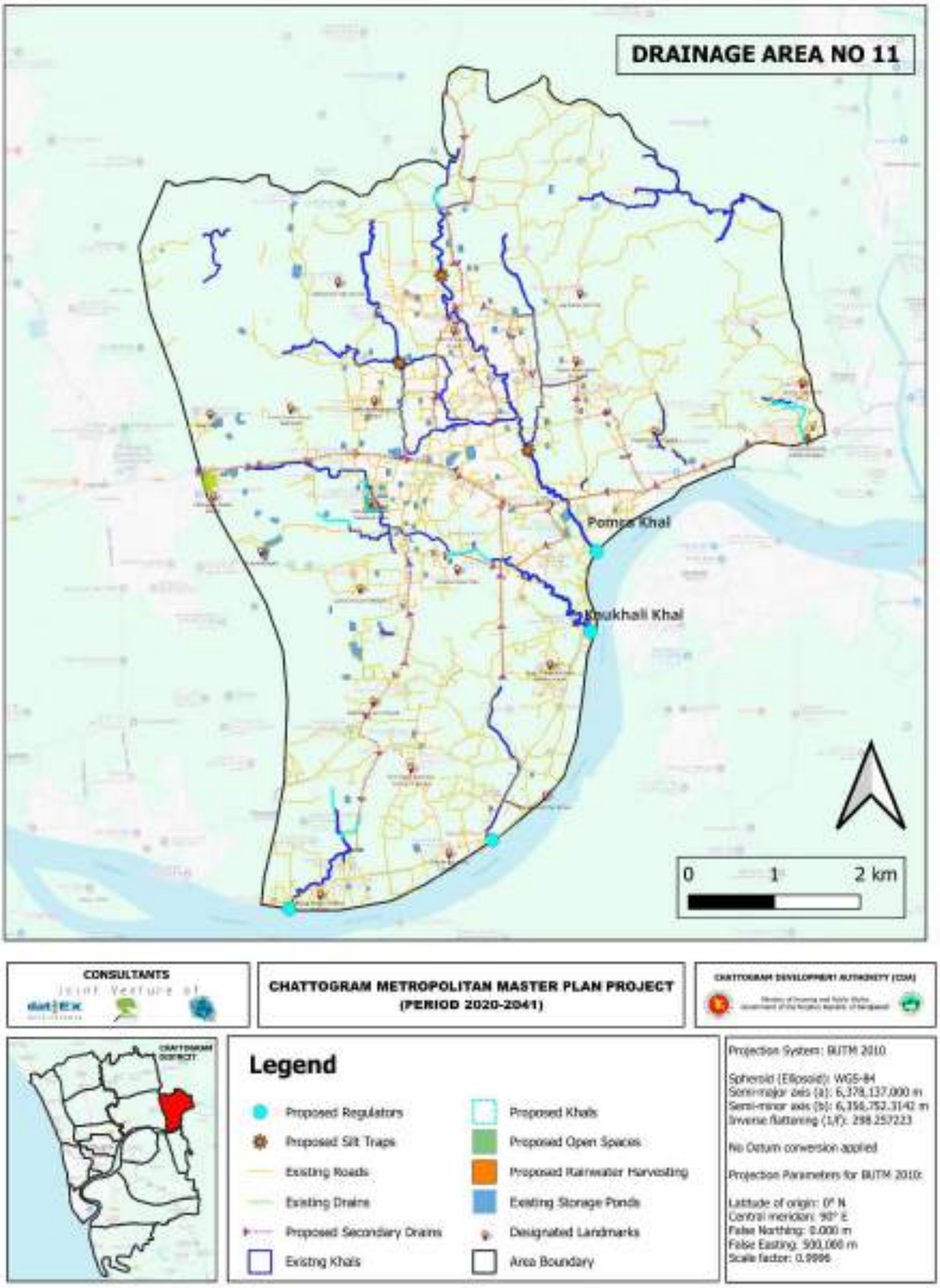


Figure A3-11 Integrated Drainage Plan (IDP) of Drainage Area 11

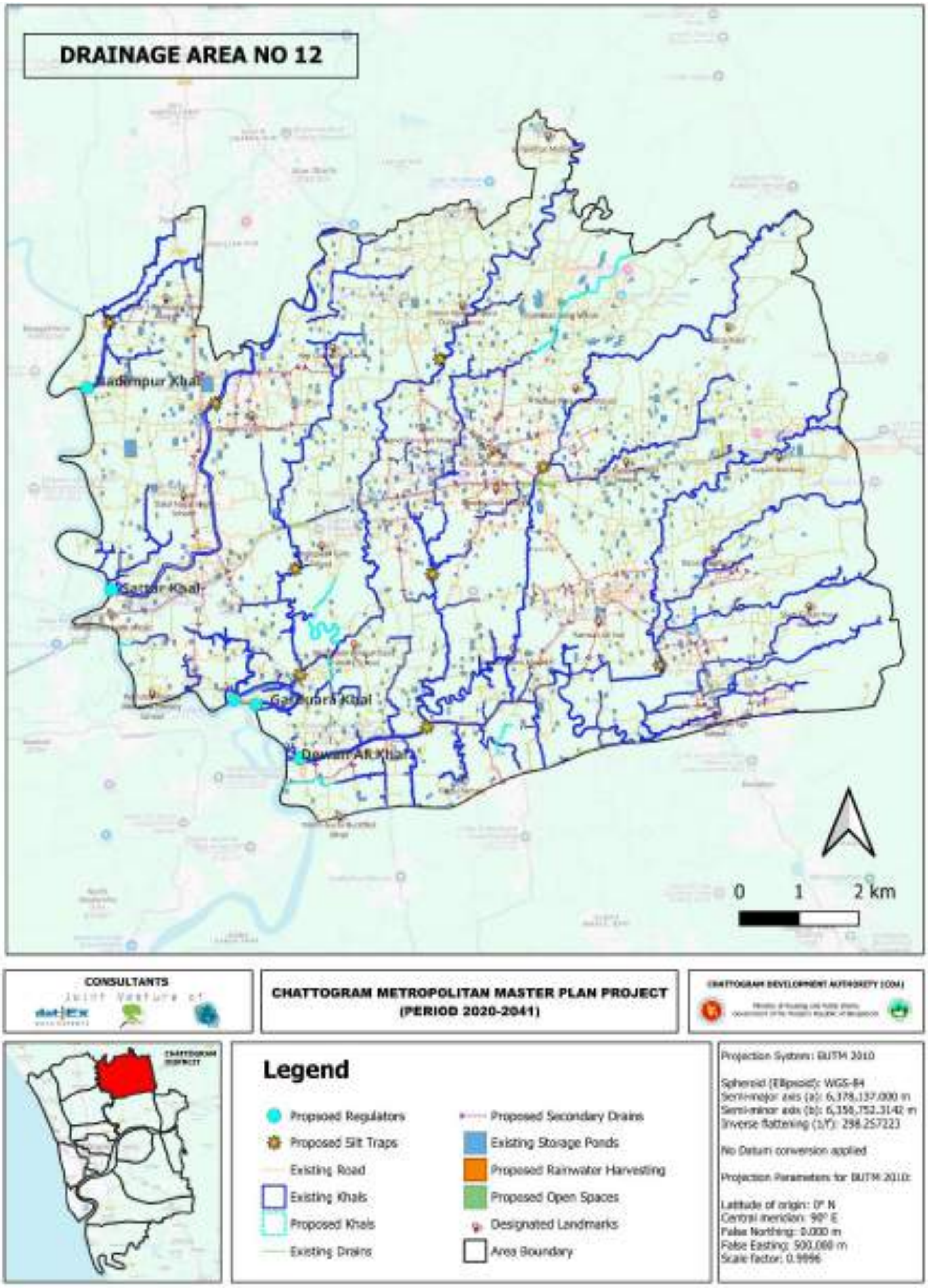


Figure A3-12 Integrated Drainage Plan (IDP) of Drainage Area 12

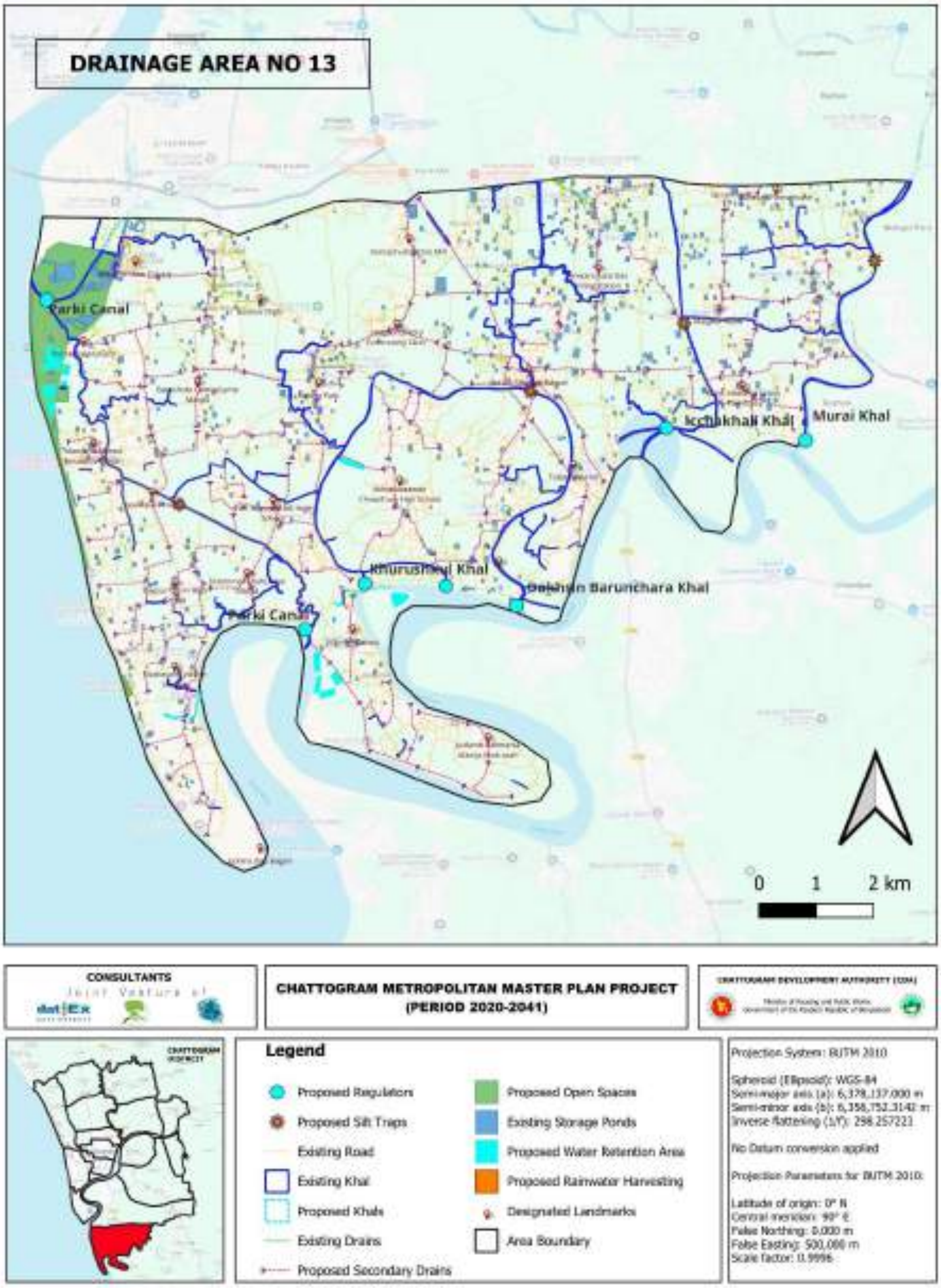


Figure A3-13 Integrated Drainage Plan (IDP) of Drainage Area 13

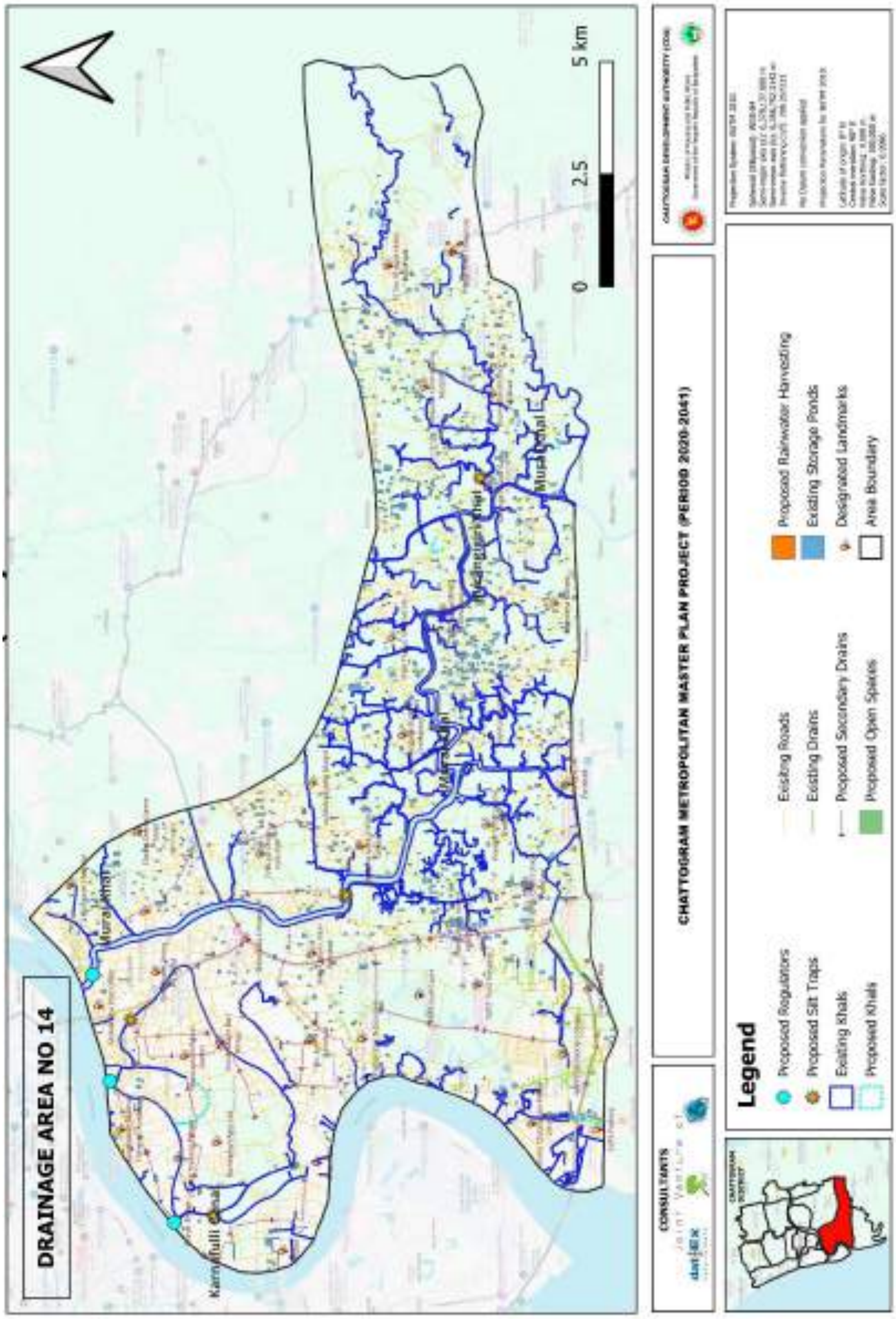


Figure A3-14 Integrated Drainage Plan (IDP) of Drainage Area 14

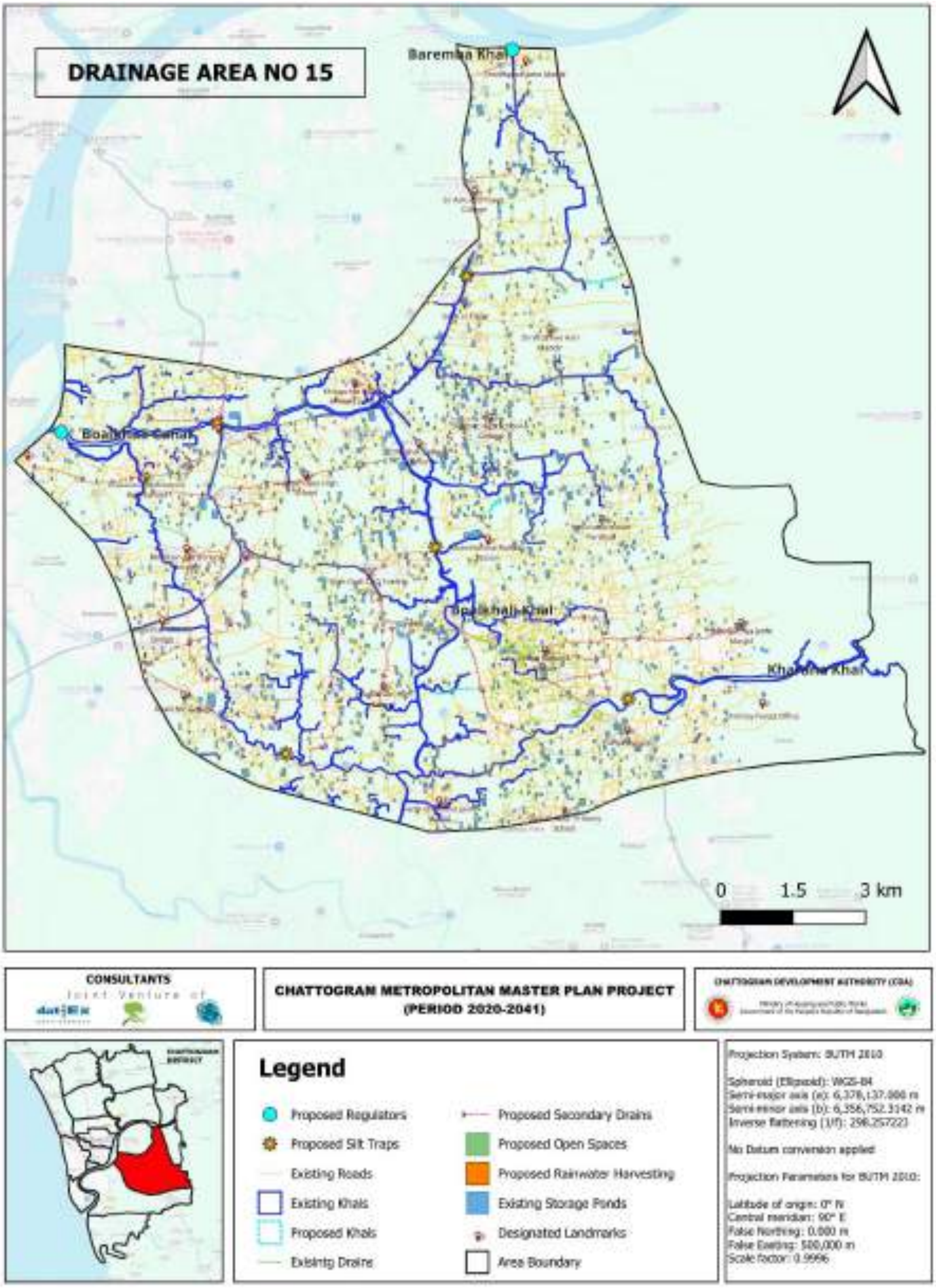


Figure A3-15 Integrated Drainage Plan (IDP) of Drainage Area 15

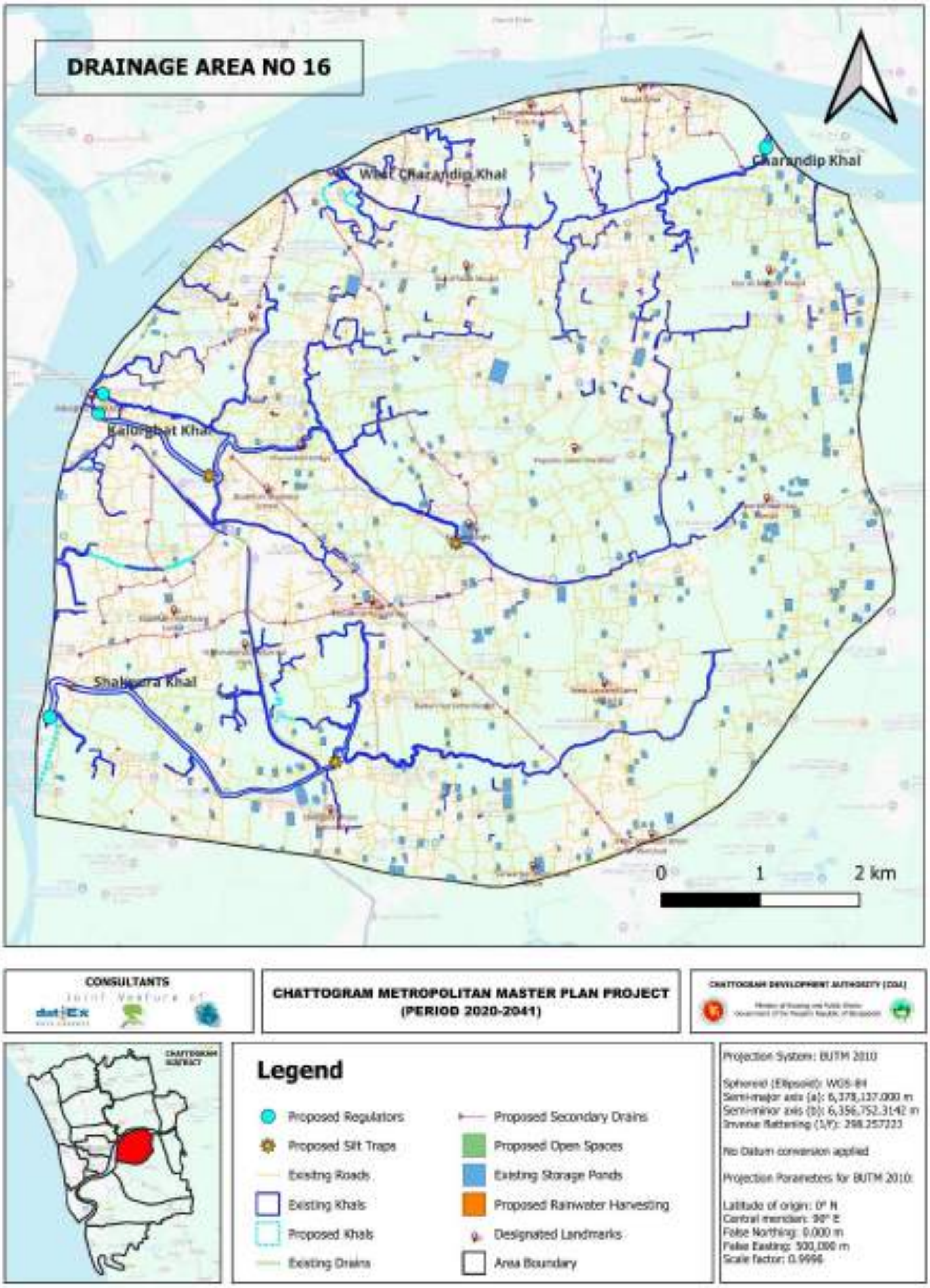


Figure A3-16 Integrated Drainage Plan (IDP) of Drainage Area 16

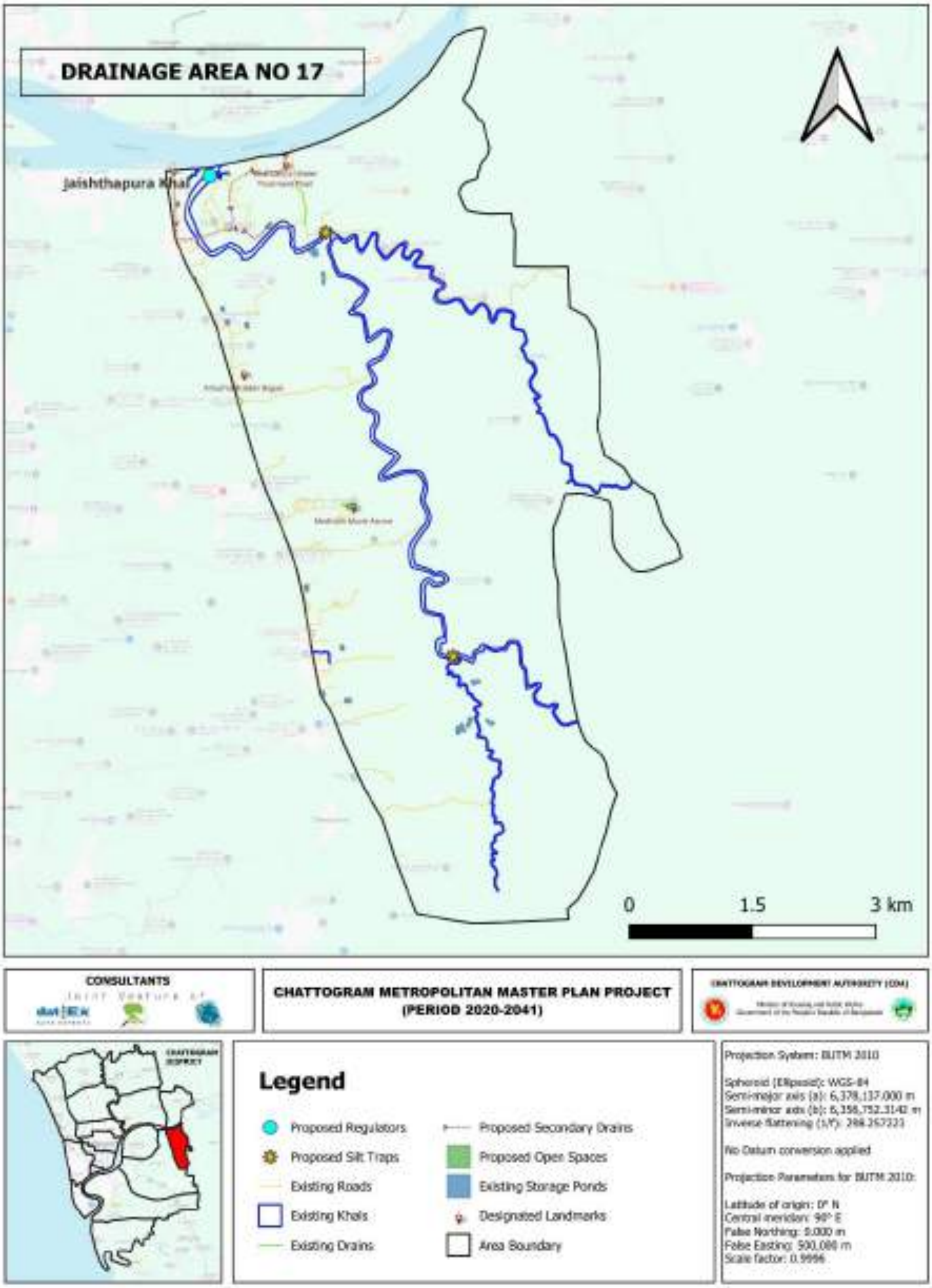


Figure A3-17 Integrated Drainage Plan (IDP) of Drainage Area 17

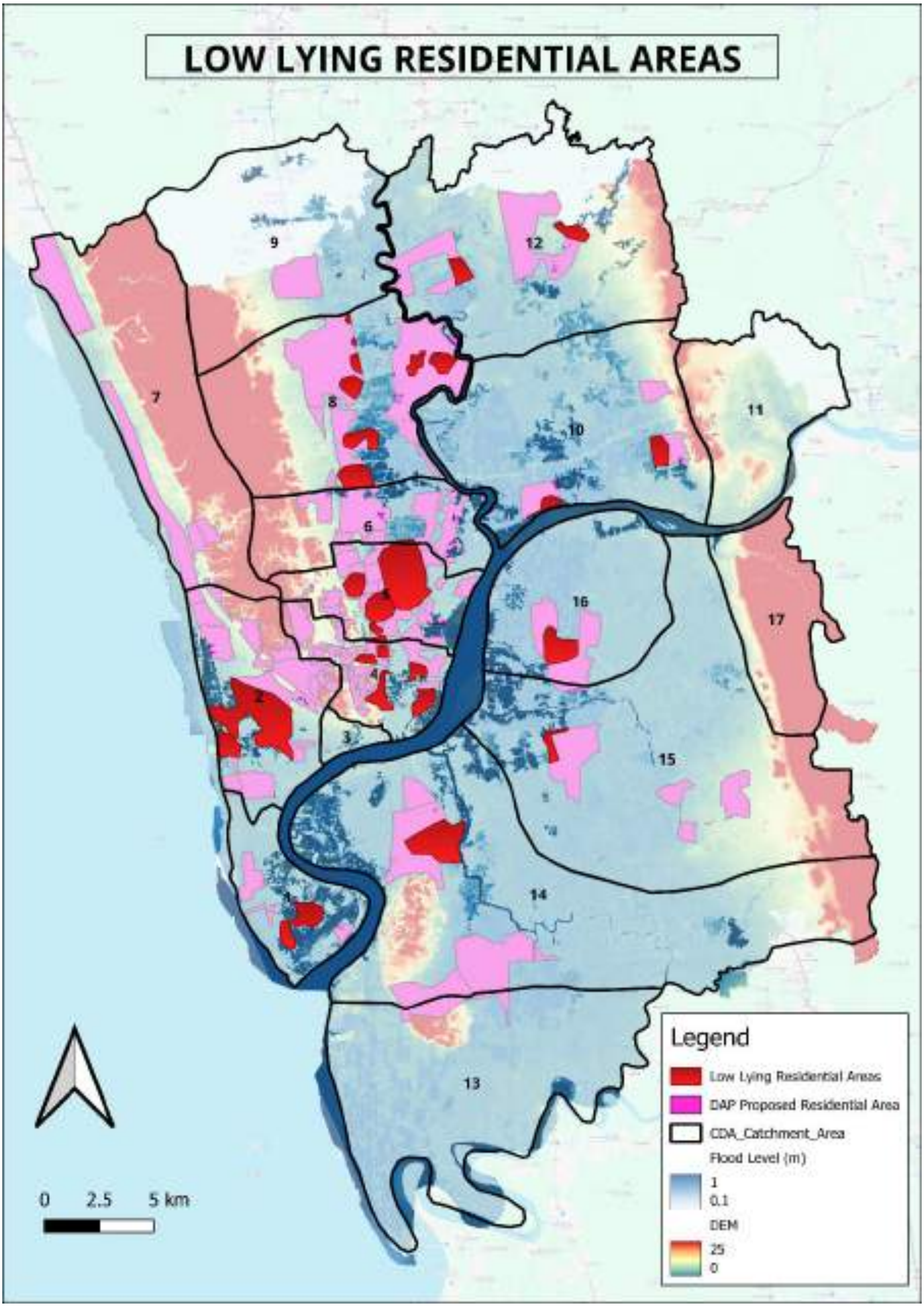


Figure A3-18 Low-lying Residential Areas