Climate Change Adaptation of Laksam Municipality: A Planning Framework for Sustainable Urban Stormwater Management (SUSM)

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ABSTRACT

Laksam Municipality in Bangladesh, a floodplain area, is vulnerable to the effects of climate change, including seasonal floods due to excessive rainfall and rising water levels. A Sustainable Urban Stormwater Management (SUSM) planning framework is crucial for climate change adaptation in municipalities, focusing on environmental and social benefits alongside traditional drainage concerns, ensuring inclusive urban stormwater management. The study aims to create a comprehensive, practical framework for sustainable stormwater solutions in the municipality to mitigate climate change risks and improve urban resilience. The author used a three-step process to write this paper: identifying the watershed characteristics and assessing the existing storm drainage system, rainfall patterns analysis, and drainage priority setting based on multiple factors for the city's drainage network and flood-prone area management. Factors like physical feature surveys, GIS data, land use and structural density, drainage basins and sub-basins, drainage outfalls, potential flood-prone areas, and stakeholder consultation are considered for community participation. However, the implementation of sustainable stormwater management approach in third-world urban context is challenging due to socio-cultural dynamics and slow development. Understanding the capabilities, trade-offs, and synergies of the existing storm drainage system is essential to overcoming these challenges. Non-regulatory interventions like education and participatory planning can help raise awareness about SUSM's benefits. The research concludes by emphasizing the necessity of implementing a thorough approach to the SUSM framework in order to improve water quality, build a sustainable urban environment, and increase Laksam Municipality's resistance to floods.

Keywords: climate change, drainage network, municipality, stormwater, sustainable.

INTRODUCTION

Bangladesh ranks seventh on the 2021 World Climate Risk Index [1], highly vulnerable to climate change due to its flat topography and flat terrain. Climate-induced natural disasters, such as tropical cyclones, floods, droughts, and sea-level rise, exacerbate socioeconomic stress and hinder human well-being. Besides, a floodplain region in Bangladesh, Laksam Municipality is vulnerable to the consequences of climate change, such as seasonal floods brought on by high rainfall and rising water levels. Despite being a global pioneer in climate adaptation, Bangladesh is working to build resilience and adapt to climate change impacts. However, the rapid rate of urban expansion and the physical development that has followed it in recent years have caused hard surfaces to supplant the natural drainage system

in Laksam Municipality. Consequently, the rate of growth of these hard surfaces and the effects of climate change have contributed to the municipality's urban floods [2]. Nevertheless, there hasn't been enough focus on how the loss of green space and the natural environment affects the frequency of urban floods. Thus, the construction and desilting of sewers and the potential for efficient solid waste management to reduce the frequency and intensity of urban floods remain central to Laksam's flood mitigation strategies. Yet, flood mitigation measures have not been able to adequately control or manage the nation's urban floods, including those in the Laksam Municipality. Therefore, Sustainable Urban Stormwater Management (SUSM) planning framework, which prioritizes social and environmental advantages in addition to conventional drainage issues, is essential for municipalities adapting to climate change and ensuring inclusive urban stormwater management.

Sustainable stormwater management in urban areas presents several challenges, necessitating innovative approaches [3]. Traditional methods, such as retrofitting sites with green infrastructure, are less effective in areas with impervious pavement. Traditional engineering solutions in stormwater collection systems are outdated due to non-point source pollution, flooding, and poor waterway conditions. To achieve sustainable objectives, traditional engineering approaches must be altered [4]. As urban water resources face increasing pressures, the need for sustainable stormwater management in various contexts is pressing, necessitating effective and efficient stormwater management.

Waterlogging in Laksam Municipality is primarily due to urban land development trends, such as filling low lands, encroaching on natural drainage, and lack of outfalls. As the city's paved area grows, less open space allows water from various sources to infiltrate, worsening the drainage situation. To address this, Laksam's municipal drainage system should use both structural and non-structural methods, balance supply and demand, and create a sustainable urban drainage system while considering technical standards and reducing costs [5]. Therefore, the purpose of this study is to explore how sustainable urban stormwater management might be used as a strategy for climate adaptation in Laksam Municipality.

LITERATURE REVIEW

The effects of climate change are becoming increasingly noticeable on a global scale. Rising global average temperatures, changed rainfall patterns, and a rise in the frequency of extreme weather events are just a few of its effects. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate attributed directly or indirectly to human activity that modifies the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods" [6]. As a result, the phenomenon has both natural and man-made causes. The effects of climate change have profoundly changed the ecology, livelihoods, and general urban landscape everywhere in the world. The area's most vulnerable to climate change are towns and cities. This emphasizes the pressing need to put adaptation and mitigation plans into place that might improve the environment and the quality of life in these regions while reducing their vulnerability to climate change.

A healthy urban environment is essential to a comfortable urban living. Significant changes in the hydrology and environment of cities have resulted from the continual growth of impermeable areas brought on by highdensity construction, fast urbanization as well as climate change in recent years [7]. Urban stormwater management (USM) faces significant issues as a result of these changes, which include decreased stormwater infiltration, increased stormwater runoff, decreased groundwater recharge, and ongoing escalation of non-point source pollution [8]. Along with all other urban services and amenities, a well-designed urban drainage system is one of the most crucial elements of a respectable urban environment [5]. It is essential to citizens' daily lives as well as the natural implications. Improper drainage of stormwater can result in waterlogging, inconvenience, infrastructure damage, and health risks. In light of these difficulties, conventional technical approaches to USM are becoming more widely acknowledged as inappropriate due to their lack of environmental sustainability. An alternative adaptive strategy for reducing the long-term effects of urbanization and climate change, such as increased frequency of extreme weather events like heatwaves, droughts, and floods, as well as other threats to people and the environment, is green infrastructure-based sustainable urban stormwater management (SUSM) [9]. Thus, to attain best management practices, a comprehensive and integrated SUSM framework is required.

Sustainable urban drainage systems (SUDS), stormwater best management practices (BMPs), green infrastructure (GI), low impact development (LID), and water sensitive urban design (WSUD) are some of the SUSM concepts that have surfaced in industrialized nations in recent decades [10]. Although the scope and context of these ideas varies, they usually seek to reduce the adverse effects of excessive urban stormwater and try to restore natural hydrological processes through the use of wetlands, rain gardens, permeable pavements, green roofs, and other techniques. According to scholarly and applied research, these SUSM strategies can have positive social, economic, and environmental effects [11]. Additional benefits of SUSM include improved public health, recreational value, ecological conservation, and the aesthetic appeal of constructed spaces [10]. To help decision makers identify the main functions, operational performances, and extended advantages of various aspects, a thorough evaluation framework for SUSM must be established. A trustworthy and appropriate comprehensive evaluation procedure and methods can also expedite the assessment process and significantly cut down on the time and expense involved in decision-making. Developed nations can provide valuable insights and experience that can aid other regions in developing more scientific SUSM strategies [10]. Therefore, urban local flooding caused by conventional drainage is a major concern for the Laksam Municipality. The municipality's transition to a resilient and sustainable environment has thus been made possible by the implementation of SUSM, and Laksam Municipality would be benefited from this in a number of ways, including social, economic, and environmental ones.

Objective Of the Study

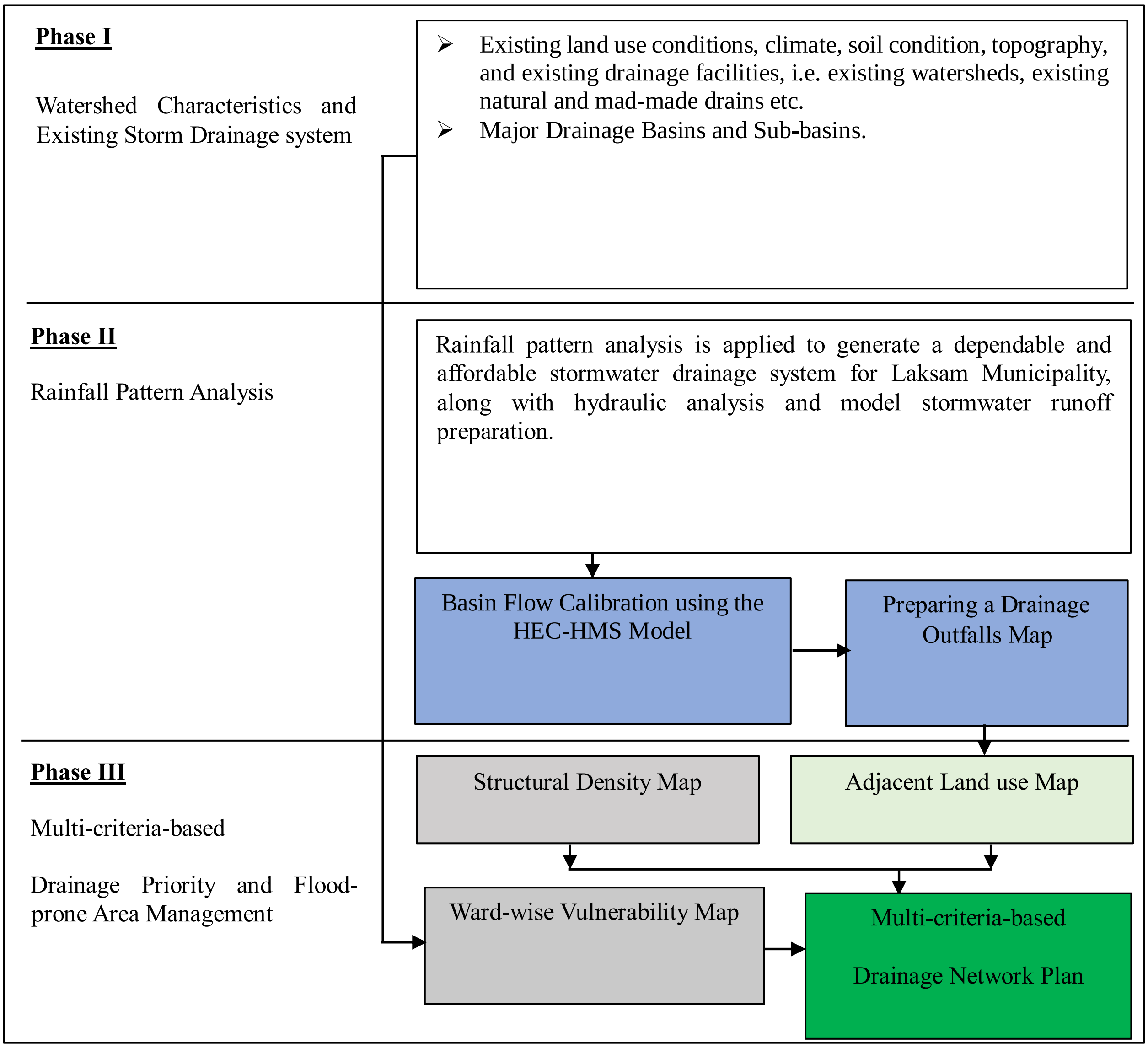
The study's main objective is to provide a thorough, workable framework for the Laksam municipality's sustainable stormwater solutions in order to reduce the hazards associated with climate change and enhance urban resilience. In order to determine the effectiveness of the current drainage facilities and identify future drainage needs, this paper aims to: identify the watershed characteristics of the Laksam Municipality and evaluate the storm drainage system; analyze rainfall in order to provide recommendations for sustainable urban drainage systems and flood control related improvements for all or a portion of an evolving watershed; and indicate a drainage priority setting based on multiple factors for the city's drainage network and flood-prone area management.

These can offer guidance on how to integrate stormwater runoff and artificial drains via secondary and main drains, followed by natural streams, to construct the municipality's drainage system economically. In order to prevent roads, houses, and other properties from flooding during severe storms without contaminating the waterbodies downstream in the Laksam Municipality, they will all continue to function as a single, integrated system. As a result, preserving the municipal sustainable stormwater drainage infrastructure will provide friendly reactions to a stronger climate response. It has the potential to offer multiple benefits, including sustainable urban stormwater management (SUSM), and will improve urban floods and waterlogging risk management in a manner that is more beneficial than traditional approaches.

The Study's Methodology

This paper has been written using a three-step process. The author started by determining the features of the watershed and evaluating the Laksam Municipality's existing storm drainage system. The physical feature survey and relevant GIS data and information obtained from various sources, such as the Bangladesh Meteorological Department, Development Design Consultants Ltd. (DDC), the Planning Section of Laksam Municipality, the Soil Resource Development Institute (SRDI), etc., served as the basis for the assessment. The site, topography, surface and stormwater flow directions, municipal parameters, present drainage systems, and current and prospective land use circumstances are summarized in the drainage characteristics that follow. The geographical evaluation forecasts future drainage needs and evaluates the effectiveness of the current stormwater drainage system using data. The investigation of rainfall patterns comes next. Using rainfall pattern analysis, representative features have been initiated in order to create a sustainable urban drainage system that is both dependable and reasonably priced for the management of stormwater in the Laksam Municipality. A model stormwater discharge and a hydraulic assessment of the stormwater drainage system are formed using the resulting design storms. Additionally, the HEC-HMS hydrologic computer model developed by the U.S. Army Corps of Engineers has been used to calculate runoff from each sub-basin in this phase. This model calculates the expected peak flows from each municipality sub-basin using the Input Parameters, Basin Delineation, and Model Parameters. Each sub-basin's peak flows are calculated for occurrences with frequencies of 10, 25, 50, and 100 years. Multi-criteria-based priority setting for the municipality's drainage network and flood-prone area management is hinted at in the final phase. The author has considered a variety of elements, such as the location of waterlogging regions, adjacent present land use, and structure density, while determining the drainage network's priority setting in the city. Furthermore, a 100-meter buffer for the Dakatia River and a 20-meter buffer for the canals from the centerline, respectively, have been established to define the adjacent land use patterns of the river and natural canals. Furthermore, urbanization modifies natural hydrologic and water quality response of the watershed. Therefore, based on the vulnerability and risk assessment of the flood prone areas, the author illustrates a flood-prone area management procedure as well to reduce the exposure to floods of the municipality. The three-step planning framework used to illustrate the present study's methodology is showed in Figure 1 below.

Figure 1: A planning framework of the proposed three-step Methodology



Sustainable Urban Stormwater Management (Susm) Of Laksam Municipality

Rising temperatures, intense rains, and tropical cyclones are predicted to significantly impact Laksam Municipality's urban core, leading to increased rainfall, river floods, and extreme heat. Flash flooding is expected during the monsoon season, affecting fisheries, water supplies, drainage, waterlogging, urban transportation infrastructure, community health, and energy supply. The deterioration of infrastructure and environment, including waterbodies, water supplies, and biodiversity, increases the population's susceptibility to these effects. The rise in temperature will also affect bituminous roads, increasing the need for water. The destruction of temporary dwelling constructions and disruption of infrastructure, such as road communication, will further strain low-income households. Sustainable Urban Stormwater Management (SUSM) is crucial for climate change adaptation in Laksam Municipality, identifying remedial measures for waterlogging, stormwater quality, and flood risk management, and guiding new land development.

First Phase: Watershed Characteristics and Existing Storm Drainage System

The existing land use, topography, major drainage basins and sub-basins of Laksam Municipality, soil and climatic conditions, and existing drainage infrastructure are all displayed using data in the first phase.

Existing Land use

With nine wards and 1,02,562 inhabitants altogether, the Laksam Municipality is 19.63 square kilometres (4851.31 acres) in size [12]. Due to the dominance of agriculture, the municipality is not flawless. The city has

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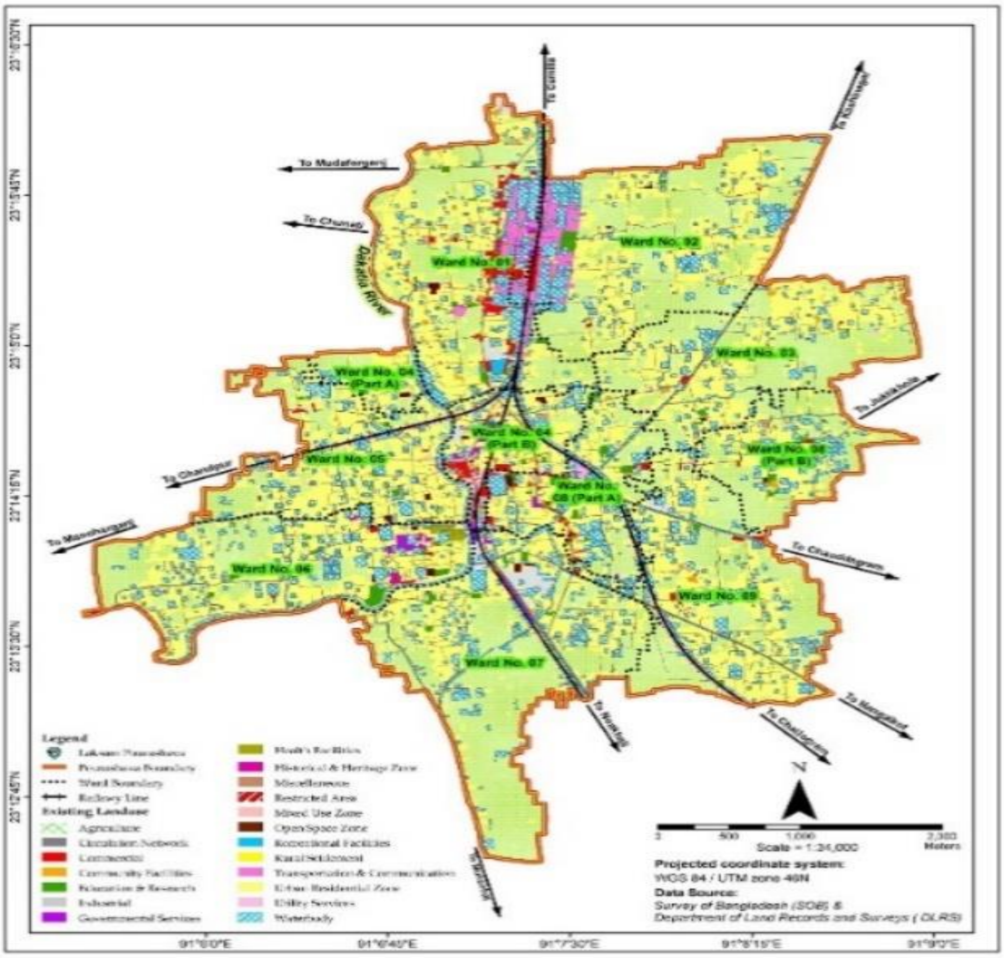
been known as a railway junction since the early nineteenth century. At now, however, its water body occupies 710.29 acres (Table 1), which represents 14.64% of its total land use [12]. The current municipal land utilization is shown in Figure 2.

Figure 2: Existing Land use of the Laksam Municipality



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

Table 1: Existing Land use of the Laksam Municipality

Land use	Area (Acre)	%
Agricultural Zone	1654.78	34.11
Circulation Network	176.76	3.64
Commercial Zone	57.39	1.18
Community Facilities	23.48	0.48
Education & Research Zone	45.50	0.94
Government Office	17.63	0.36
Health Services	9.81	0.20
Historical & Heritage Site	1.50	0.03
Industrial Zone	43.32	0.89
Miscellaneous	15.40	0.32
Mixed Use Zone	21.24	0.44
Open Space	12.09	0.25
Recreational Facilities	3.41	0.07
Residential Zone	1936.22	39.91
Restricted Area	0.81	0.02

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Transportation Facilities	117.59	2.42
Utility Services	4.09	0.08
Waterbody	710.29	14.64
Total	**4851.31**	**100.00**

Source: Physical Feature Survey, 2019 (Master Plan, 2020).

Hydrology

By using the knowledge gained from the past, the Municipality hopes to get ready for the future. The city has previously experienced floods. Significant floods have occurred in the municipality several times, most notably in 1988, 1992, and 1998 [12]. The area is often affected by a number of small floods throughout the years, which can sometimes affect both smaller and larger portions of the Municipality's low-lying districts. From north to southwest, the Dakatia River traverses the western part of the city. Table 2 illustrates the Laksam Municipality's hydrology.

Table 2: Hydrology of the Laksam Municipality

Type	No.	Total length (km)	Covered area (acre)	Average depth (m)
River	01	7.10	47.37	9.00
Pond	1168	-	467.32	1.70
Ditch	342	-	95.91	1.20
Natural canal	17	25.75	94.66	3.70
Irrigation canal	05	1.70	2.36	2.20
Beel	01	-	2.67	0.32

Source: Physical Feature Survey, 2019 (Master Plan, 2020).

Climate

The climate of Laksam Municipality is moderate, with short winters and long, dry, and rainy summers. Northern winds from the Himalaya/Meghalaya Range and moist marine air masses from the Bay of Bengal both affect the climate. With a maximum monthly precipitation of 2500mm and an average annual rainfall of 2000mm, precipitation mostly accumulates during the summer and monsoon seasons. The backwater conditions of the Meghna and Gomati Rivers cause high water in the south section of the Dakatia River. Waterway flow is decreased in the summer due to increased irrigation and a lack of precipitation. Only two rainfall episodes occur per year; July and August see no discernible precipitation. The average monthly temperature is between 12°C to 36°C, and high weather frequently evaporate potential runoff. Table 3 displays the average rainfall and temperature for Laksam Municipality.

Month	Rainfall (mm)	Average Rainy Day (No.)	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)	Wind Speed (m/s)
January	7.5	02	25.4	12.1	77	1.16
February	28.8	03	27.7	15.2	75	1.58
March	66.2	04	31.0	19.7	77	2.81
April	153.9	09	34.2	22.8	81	4.30
May	329.6	14	36.2	24.2	82	4.36
June	329.8	15	32.6	25.3	86	4.64
July	415.5	17	30.9	25.4	87	4.73
August	316.0	16	31.3	25.4	86	4.10
September	226.6	12	31.6	25.2	86	2.69
October	141.6	06	31.4	23.4	84	1.44
November	41.6	03	29.6	18.7	80	0.89
December	8.6	01	26.6	13.3	79	0.88

Source: Bangladesh Meteorological Department, 2019.

Existing Watersheds

The three features – the pond, ditch, and beel – help to partially prevent flooding in the area by retaining rainfall during the monsoon. The Laksam Municipality is surrounded by watershed regions (Figure 3). Nonetheless, Table 4 shows that the city's watersheds cover 565.90 acres in total.

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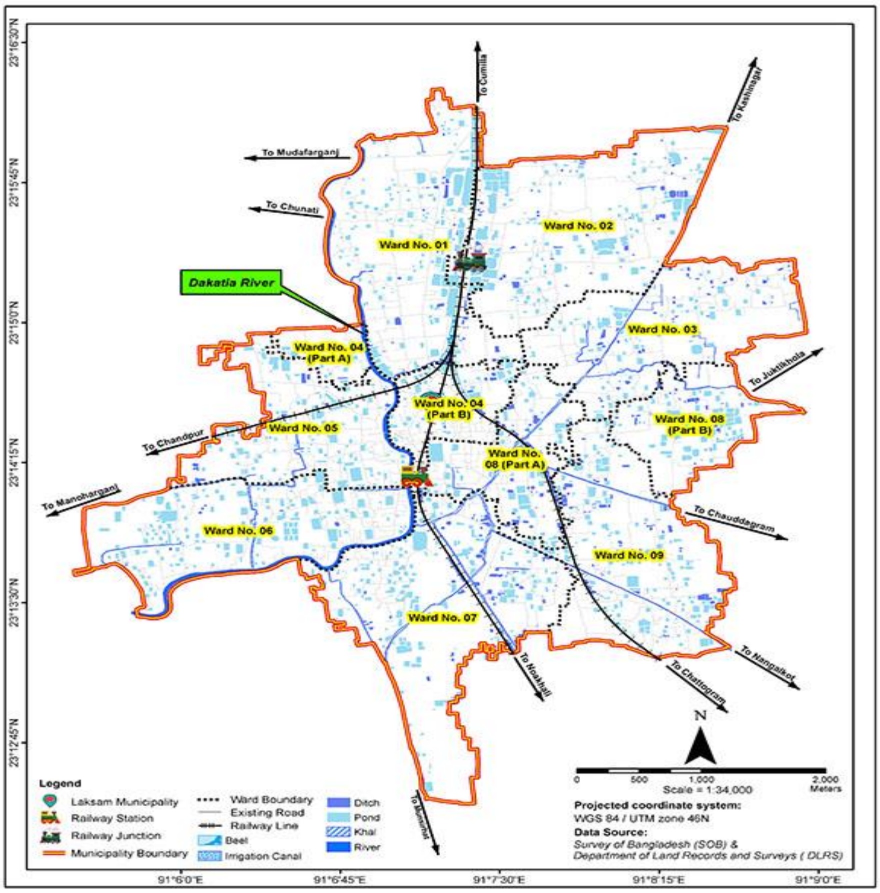
Figure 3: Watersheds of Laksam Municipality



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

Table 4: Watersheds Areas

Zone	Ward No.	Area in acre		
		Pond	**Ditch**	**Beel**
Zone 1	01	65.98	4.48	2.67
	02	3.21	4.11	0.00
	04	6.51	3.44	0.00
	05	12.95	1.80	0.00
Zone 2	01	0.00	5.23	0.00
	04	7.01	6.13	0.00
	05	27.47	1.89	0.00
	06	61.86	1.02	0.00
	07	38.14	3.86	0.00
Zone 3	04	3.97	4.74	0.00
	07	18.35	9.46	0.00
	08	24.66	3.43	0.00
	09	4.44	3.58	0.00
Zone 4	01	4.01	2.08	0.00
	02	71.62	10.15	0.00
	03	28.34	6.81	0.00
	04	9.13	2.07	0.00
	08	34.40	10.20	0.00
	09	45.27	11.43	0.00
Total		**467.32**	**95.91**	**2.67**

Source: Physical Feature Survey, 2019 (Master Plan, 2020).

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Existing Man-made Drain

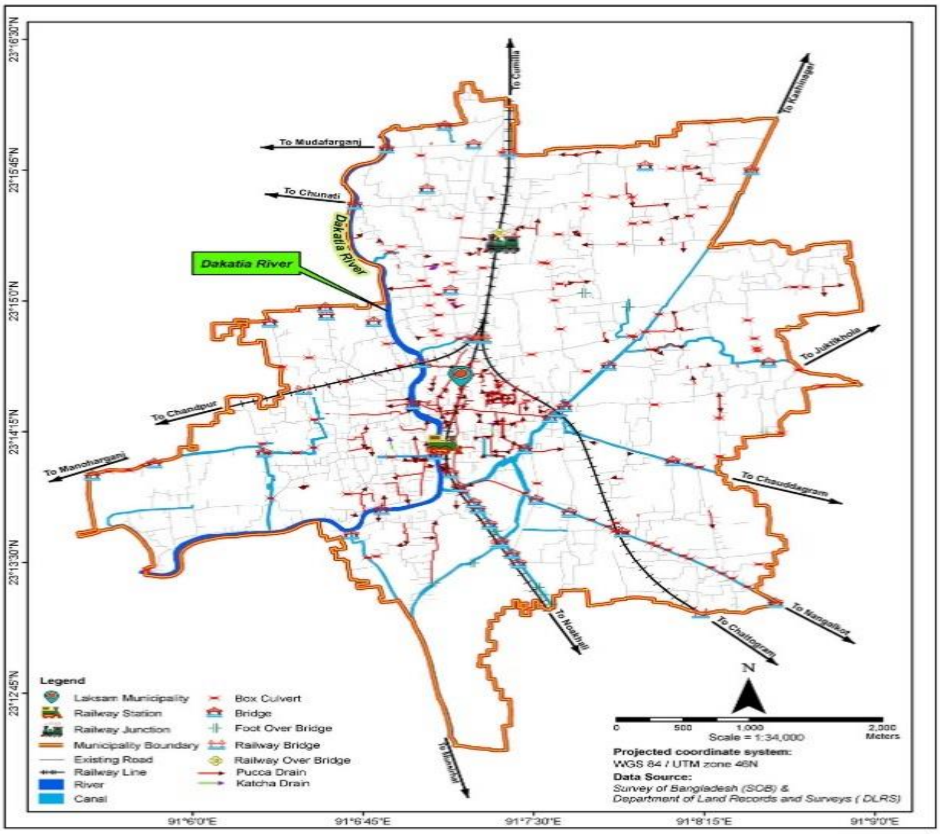
Natural open canals drain the Municipality's stormwater runoff via the watersheds. The majority of runoff from populated regions, particularly in the centre, covers open drains. After passing via various drains, runoff eventually empties into the Dakatia River and the surrounding lowlands and canals (Figure 4). The present municipal storm drainage system configurations with man-made drains are displayed in Table 5.

Table 5: Man-made Drains

Zone	Man-made Drain (meter)	No. of Bridge	No. of Culvert
Zone 1	2143.84	14	23
Zone 2	10228.63	12	16
Zone 3	9599.70	20	10
Zone 4	5562.59	13	56
Total	**27534.76**	**59**	**105**

Source: Physical Feature Survey, 2019 (Master Plan, 2020).

Figure 4: Existing Man-made Drains



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

Major Basins in Laksam Municipality

The primary drainage basins are delineated by the boundary line established by the railway and the primary drainage channels that are already within the municipality. Both the drainage channels and the watersheds they link to are naturally occurring. The zones that face Cumilla, Chandpur and Manoharganj, Noakhali and Chattogram, and Kashinagar are designated as Zone 1, Zone 2, Zone 3, and Zone 4, respectively. Because they include areas that instantly discharge into the main streams, progressively pass through all of the city's canals, and finally empty into the Dakatia River (Figure 5), four important drainage basins are emphasized (Figure 6). Tables 6 and 7, respectively, include the length and direction of the natural rivers and canals as well as the names and locations of the major basins.

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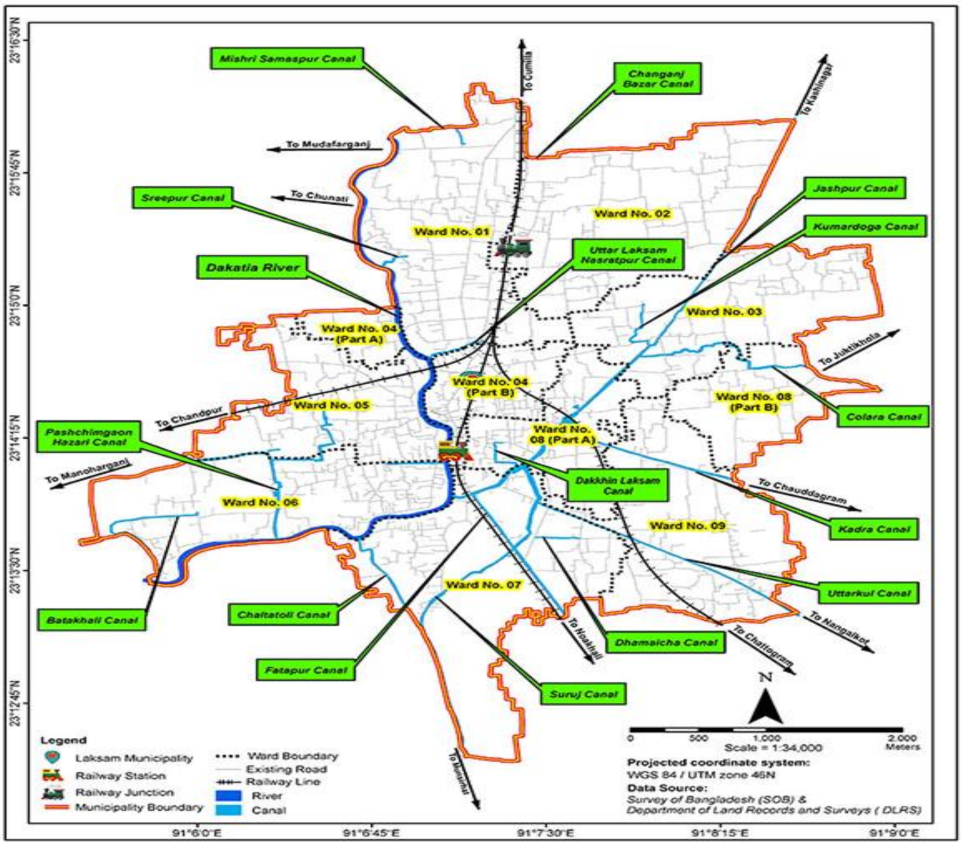
Table 6: Natural Canals and River in the Major Drainage Basins (Length in Km.)

Major Drainage Basin	**Name of the Natural Canal and River**	**Length**	**Flow Direction**
Zone-1: Towards Cumilla (Z1)	Dakatia River (part)	3.10	North to South
	Mishri Samaspur Canal	0.77	East to West
	Sreepur Canal	0.24	East to west
	Uttar Laksam Nasratpur Canal	0.46	East to West
Zone-2: Towards Chandpur and Manoharganj (Z2)	Dakatia River (part)	4.00	East to West
	Zila Parishad Canal	0.43	West to East
	Batakhali Canal	1.49	North to South
	Pashchimgaon Hazari Canal	3.50	North to South
	Suruj Canal	2.51	Southwest to Northeast
	Chaltatoli Canal	1.10	South to North
	Dakkhin Laksam Canal	0.62	North to South
Zone-3: Towards Noakhali and Chattogram (Z3)	Dhamaicha Canal	0.33	East to West
	Uttarkul Canal (part)	0.77	Southeast to Northwest
	Kadra Canal (part)	0.25	South to North
Zone-4: Towards Kashinagar (Z4)	Uttarkul Canal (part)	1.60	Southeast to Northwest
	Kadra Canal (part)	1.40	East to Northwest
	Colara Canal	2.21	East to West
	Kumardoga Canal	0.62	North to South
	Jashpur Canal	2.79	Northeast to Southwest
	Changanz Bazar Canal	0.17	East to West
	Fatahpur Canal	4.49	South to North

Source: Physical Feature Survey, 2019 (Master Plan, 2020).

Figure 5: River and Canals in Laksam Municipality



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

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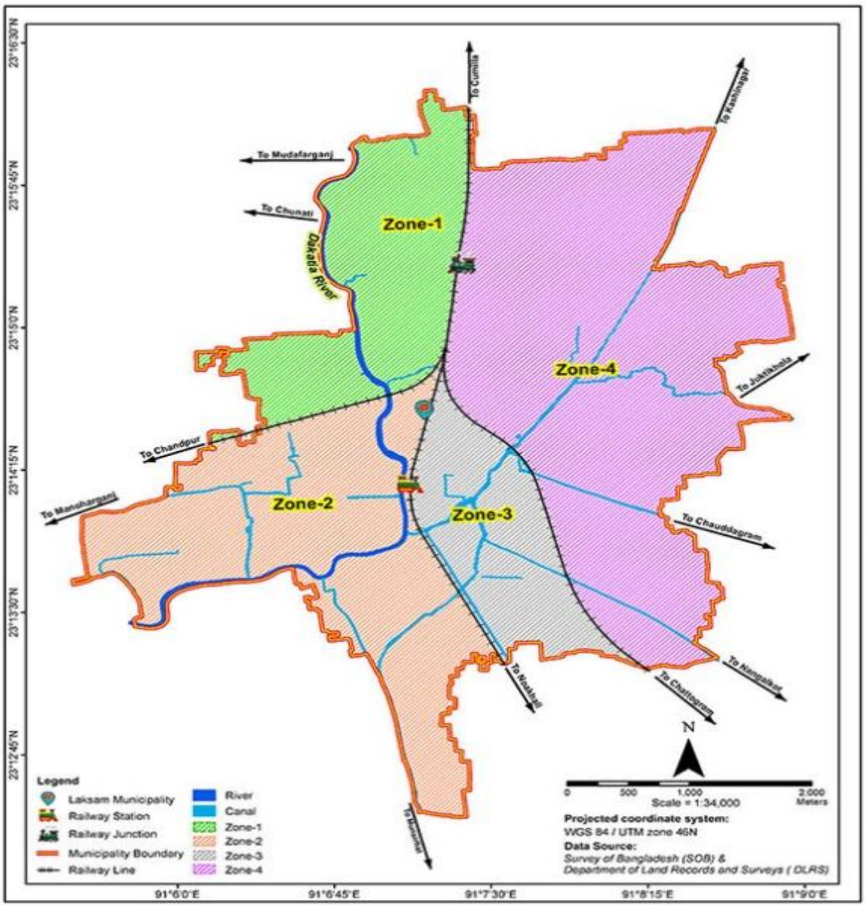
Table 7: Major Drainage Basins in Laksam Municipality

Name of Major Drainage Basins	**Covered Area (acre)**	**Covered Area (sq.km)**
Zone-1 Towards Cumilla (Z1)	802.56	3.25
Zone-2 Towards Chandpur and Manoharganj (Z2)	1361.77	5.51
Zone-3 Towards Noakhali and Chattogram (Z3)	546.68	2.21
Zone-4 Towards Kashinagar (Z4)	2140.30	8.66
Total	**4851.31**	**19.63**

Source: Physical Feature Survey, 2019 (Master Plan, 2020).

Figure 6: Major Drainage Basins of Laksam Municipality



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

Sub-basins in Laksam Municipality

The sub-basin region is the watershed where runoff is thought to go to a single discharge point. It is considered a region. The four zones of the Laksam Municipality have twenty-one sub-basin areas (Table 8). To improve the demonstrating analysis and make it simpler to find any drainage problems and improvements, each major basin was then split up into smaller basins. Numerous sub-basins, particularly in the Z2 and Z3, are smaller than 20 acres due to the presence of river and railway crossings. For sub-basins larger than 20 acres, Z2 is classified as a Beel. Since the amount of impervious surface areas has a significant impact on runoff rates and volumes and the quantity of impervious surfaces is mostly a consequence of zoning intensity, defining sub-basins with largely consistent land uses enables more meaningful runoff. A single storm drain outfall should be the primary destination for all of the sub-basin's flow. The canal often receives a large number of sometimes murky discharges from sub-basins next to larger streams. Nonetheless, it is frequently assumed that sub-basins that empty into drainage channels do so at a single outfall into the river. The locations of such sub-basins are depicted in Figure 7.

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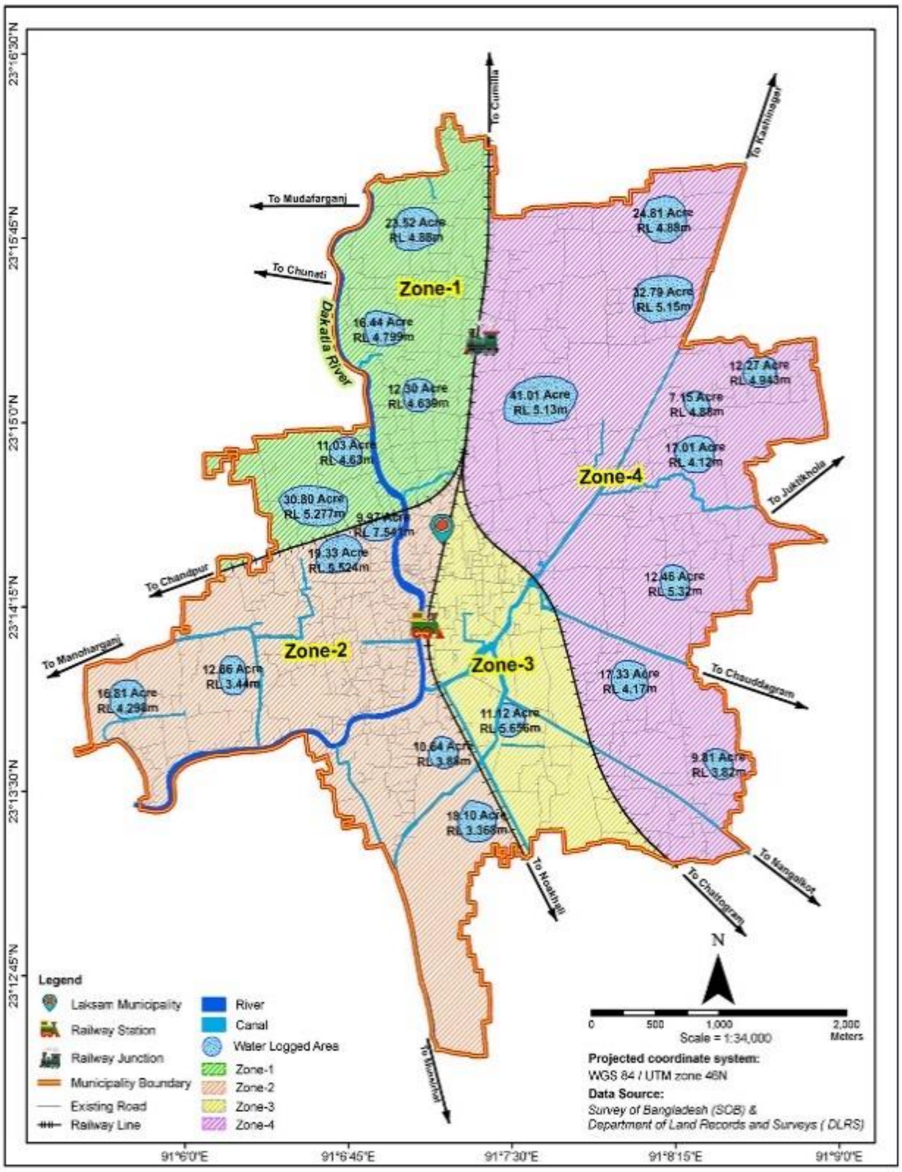
Table 8: Sub-basins according to covered Area and Zone

Zone	No. of Sub-basin	Range of Area (acre)		
		10 to 20	5 to 10	2 to 5
Z1	05	01	02	02
Z2	06		04	02
Z3	01			01
Z4	09	03	03	03
Total	**21**	**04**	**09**	**08**

Source: Physical Feature Survey, 2019 (Master Plan, 2020).

Figure 7: Location of Sub-basins



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

Second Phase: Rainfall Pattern Analysis

In order to illustrate a planning framework for sustainable stormwater management system for Laksam Municipality, the second part of the present study uses rainfall pattern analysis to formulate typical stormwater runoff and screening hydraulic analysis.

Analyzing Runoff

The hydrologic computer model, HEC-HMS, developed by the U.S. Army Corps of Engineers, is used to calculate runoff from each sub-basin. The predicted peak flows from each sub-basin are calculated using the model parameters, basin delineation, and input parameters. Peak flows in each sub-basin are calculated for frequency events that occur 10, 25, 50, and 100 years apart.

Calibration of Flow

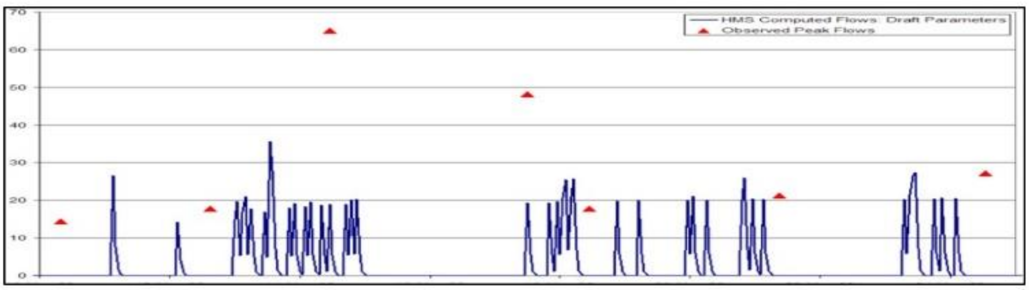
Using flow monitoring data collected from four locations around the town, an effort was made to calibrate model flows to measure values. The figures (Figures 8-10) below compare the uncalibrated HEC-HMS model with the reported peak flows. In a perfect calibration, the recorded Peak Flow would coincide with the highest value (peak) between two observation points. Every image has a tabular explanation that separates the data by basin (Tables 9-12). The HEC-HMS model underestimated the greater peak flows in the basin but did well for the smaller rain events. Here are the specifics.

Calibration of Basin Flow

When calibrating data values related to rainfall, stormwater, washing, and bathing water, the HEC-HMS Model gives guidance and influences the data flow from higher to lower order in accordance with the contour line (land level). Furthermore, the parameter that displays the average value is the time factor. The minimum flow analysis consideration needed to run the model is -1 if there isn't any significant congestion in the vicinity.

Here, the necessary change is either positive or negative: Bulk Rainfall + Space + Flow Canal + Time Duration. Additionally, except for a borrow pit where rainwater pools for a period without causing congestion, a negative average value means that there is no drainage congestion in the basin.

Figure 8: Z1 Basin Flow Calibration towards Cumilla



8/6/19 7:00	8/8/19 8:00	8/12/19 15:00	8/14/19 11:00	8/17/19 12:00	8/18/19 11:00	8/21/19 9:00	8/24/19 13:00

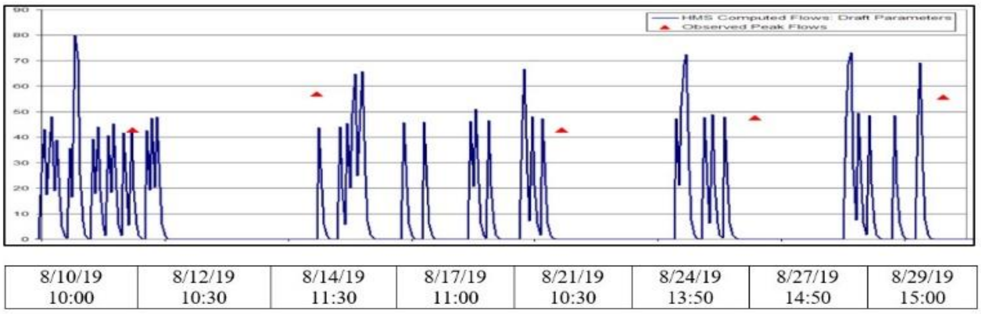
Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

Table 9: Basin/Dancer Outfall, Zone 01

Time	Measured Flow	Uncalibrated HEC-HMS Flows	% Flow Change Needed
8/6/19 7:00	10.4	13	2
8/8/19 8:00	14.4	14	3
8/12/19 15:00	17.7	26	-47
8/14/19 11:00	65.1	36	45
8/17/19 12:00	48.1	21	56
8/18/19 11:00	17.7	25	-41
8/20/19 9:00	21.2	26	23
8/21/19 13:00	27.1	27	0
			Average = 5%

Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

Figure 9: Z2 Basin Flow Calibration towards Chandpur and Manoharganj



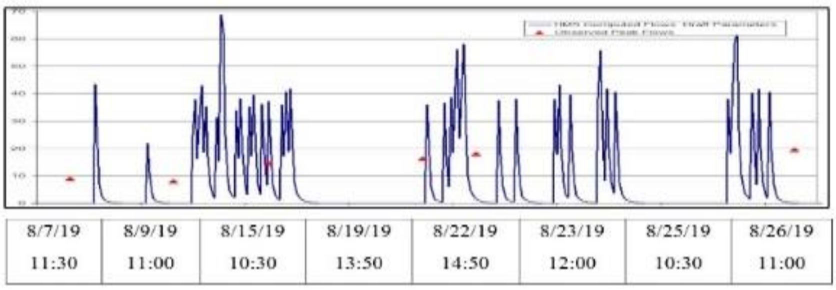
Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

Table 10: Basin/Dancer Outfall, Zone 02

Time	Measured Flow	Uncalibrated HEC-HMS Flows	% Flow Change Needed
8/10/19 10:00	29.9	33	-22
8/11/19 10:30	38.4	42	10
8/13/19 11:30	42.8	80	-87
8/16/19 11:00	57.0	48	16
8/21/19 10:30	42.8	48	-12
8/24/19 13:50	47.7	72	-51
8/27/19 14:50	55.7	73	-31
8/29/19 15:00	53.2	46	-11
			Average = -24

Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

Figure 10: Z3 Basin Flow Calibration towards Noakhali and Chattogram



Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

Table 11: Basin/Dancer Outfall, Zone 03

Time	Measured Flow	Uncalibrated HECHMS Flows	% Flow Change Needed
8/7/19 11:30	9.34	1	67
8/9/19 11:00	8.40	4	88
8/15/19 10:30	15.70	8	14
8/19/19 13:50	16.40	8	70
8/22/19 14:50	17.10	60	31
8/23/19 12.00	16.50	55	42
8/25/19 10.30	19.20	65	63
8/26/19 11.00	20.40	9	60
			Average = 54%

Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

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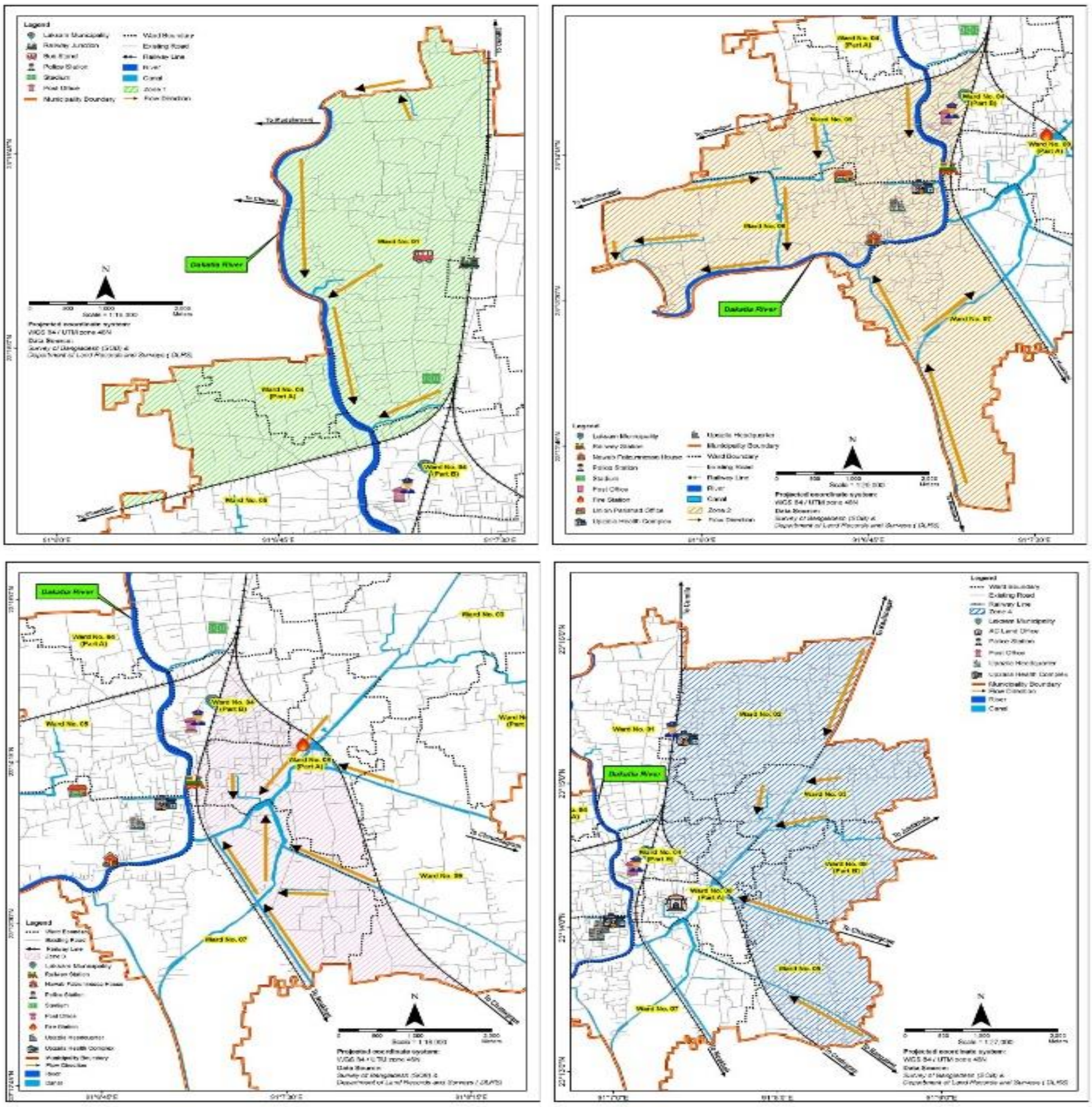
Table 12: Basin/Dancer Outfall, Zone 04

Time	Measured Flow	Uncalibrated HEC-HMS Flows	% Flow Change Needed
8/7/19 11:00	9.34	2	65
8/9/19 11:20	8.40	4	80
8/15/19 10:20	15.70	7	15
8/19/19 13:30	16.40	9	68
8/22/19 15:00	17.10	61	30
8/23/19 12.30	16.50	56	40
8/25/19 10.00	19.20	63	61
8/26/19 11.30	20.40	9	58
			Average = 52%

Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

It has been demonstrated that the measured flow, uncalibrated HEC-HMS flows, and the percentage of flow change required for Zones 03 and 04 are almost the same. The Z4 Basin Flow Calibration has not been displayed individually as a result. Furthermore, Figures 11–14 showing the flow direction in each zone have been created based on the flow calibration of those four basins.

Figures 11-14: Flow Direction of 04 Zones



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

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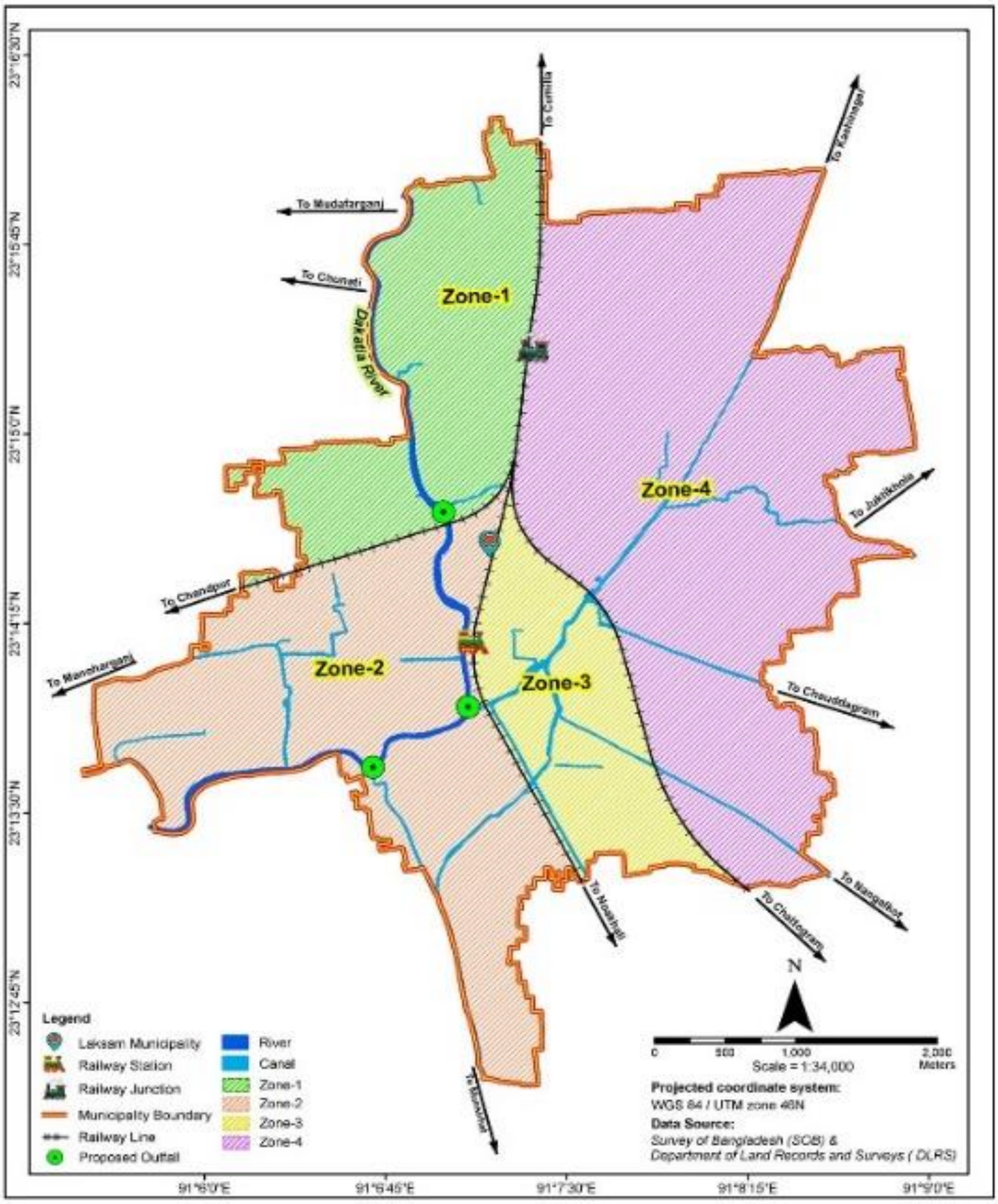
Drainage Outfalls System

Figure 15: Drainage Outfalls of Laksam Municipality



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

Drain surface runoff from different areas of the city, the Laksam Municipality created its natural canals by following the earth's natural slope without the aid of humans. Highlying regions give way to low-lying ones. Every man-made drain in the city empties into the Dakatia River and natural canals. Some canals plunge directly into the river, while others are connected to other canals and eventually flow into it. Due to road encroachment, the Pashchimgaon Hazari canal is disconnected from the Dakatia River; the Dhamaicha and Changanj Bazar canals are the only canals lacking an outfall point. As a result, a watershed tributary to a major waterway, such a river, is frequently the focus of an outfall system in the city's drainage network. Three outfalls have been identified in the municipality as a result of runoff study, flow calibration, and basin flow calibration (Figure 15). One is in Zone-01, while the other two are in Zone-02 for stormwater runoff and smooth surface water

Final Phase: Multi-Criteria-Based Drainage Priority and Flood-Prone Area Management

The drainage network's priority setting in the Laksam Municipality has been established by considering the nearby land use patterns of the river and natural canals, structure density, and flood-prone areas.

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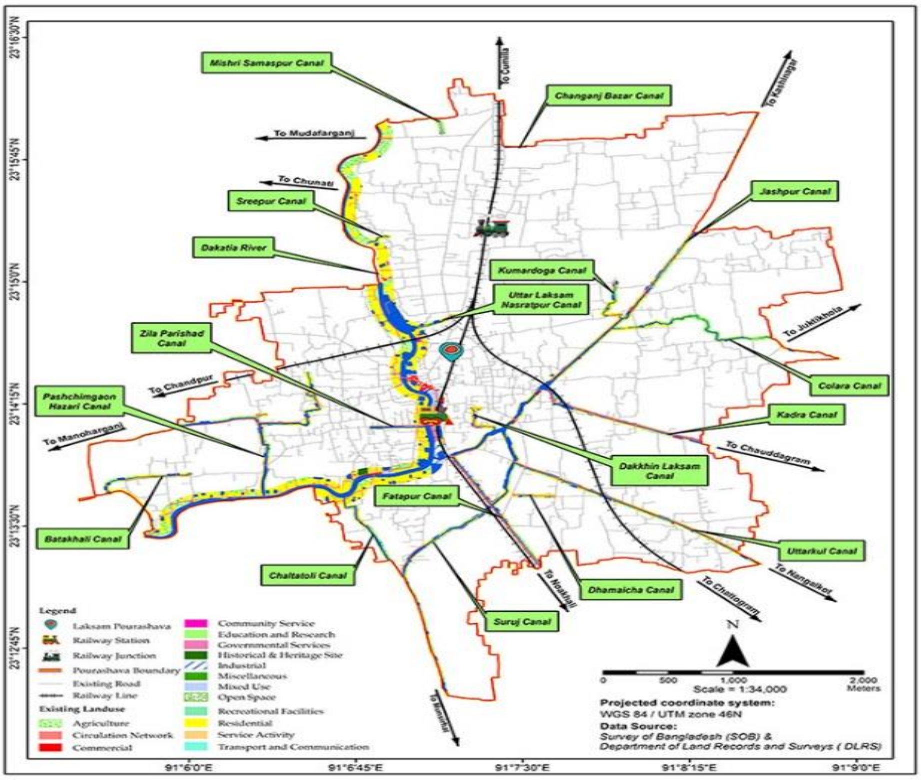
Adjacent Land use

Figure 16: Land use category of 20-meter buffer for Canals and 100-meter buffer for River



Source: Author. 2025. based on Laksam Pourashava Master Plan (2020-2040).

The canals' neighboring land use pattern has been thought to be delineated by a 20-meter buffer from the centerline. The nearby current land use features are represented by the 20-meter buffer on both sides of the land use (Figure 16). There are now about fifteen contiguous land use types. All of the land uses fall into two main land use categories: constructed area and non-built area. Built-up areas have more surface runoff than non-built-up areas due to their lower imperviousness. Non-built-up land uses include agricultural double and triple crops, open areas, waterbodies, and vacant land. Soil water perviousness is higher in non-built-up regions than in built-up areas. As a result, the percentage of constructed land adjacent to canals indicates its impermeability and increases the amount of runoff on the canals during the monsoon season; without these, the built-up area is more severely affected by waterlogging because of an inadequate drainage system, so the percentage of adjacent undeveloped land is an important factor in determining the priority of the drainage network. Table 13 shows the land use category for the 20-meter canal buffer and the 100-meter river buffer.

Table 13: Percentage of built land use for 20-meter buffer for Canals and 100-meter for River

Sl. No.	**Canal and River**	**Adjacent Land use Build-up Area (%)**	**Adjacent Land use Non-Buildup Area (%)**
1.	Batakhali Canal	60	40
2.	Chaltatoil Canal	86	14
3.	Colara Canal	33	67
4.	Dakkhin Laksam Canal	75	25
5.	Dhamaicha Canal	85	15
6.	Fatapur Canal	70	30
7.	Hazari Canal	58	42
8.	Jashpur Canal	46	54
9.	Kadra Canal	55	45
10.	Kumardoga Canal	75	25
11.	Mishri Samaspur Canal	40	60

12.	Sreepur Canal	60	40
13.	Suruj Canal	65	35
14.	Uttar Laksam Nasratpur Canal	65	35
15.	Uttarkul Canal	74	26
16.	Zila Parishad Canal	81	19
17.	Changanj Bazar Canal	18	82
18.	Dakatia River	64	36

Source: Based on the Land use Survey, 2019 (Master Plan, 2020).

Structural Density

The structural density of the entire municipality is not consistent. The density is high in several parts of the Municipality. The drainage network is vulnerable in places with a high density of structures. Canal watersheds with a high structural density are susceptible to drainage problems. In order to address drainage issues, focus has been given to canals with a high structural density area. Figure 17 shows the structural density of the Municipality, with red denoting higher densities and blue sections reflecting low densities.

Weighted Overlay

The output of each criterion is reclassified into a ranking of 1 to 10 (index value) in order to determine the stormwater drainage priority based on several criteria. Nearby land uses with a high percentage of developed area are given higher index values. A higher structural density is correlated with a better ranking value. In the same manner, canals with a higher index value are those that are closer to waterlogging regions, whilst those that are farther away have a lower index value. A weighted overlay has been calculated using ArcGIS software, considering every criterion. Nearby land use has been given the highest weight since it is the most important factor to be considered. The neighboring land utilization has been given more weight than the structure density and distance of the waterlogging area.

Here, **Weighted Index (WI)** = Adjacent Land use*0.60 + Structure Density*0.20 + Distance of waterlogging*0.20

Figure 17: Structural Density

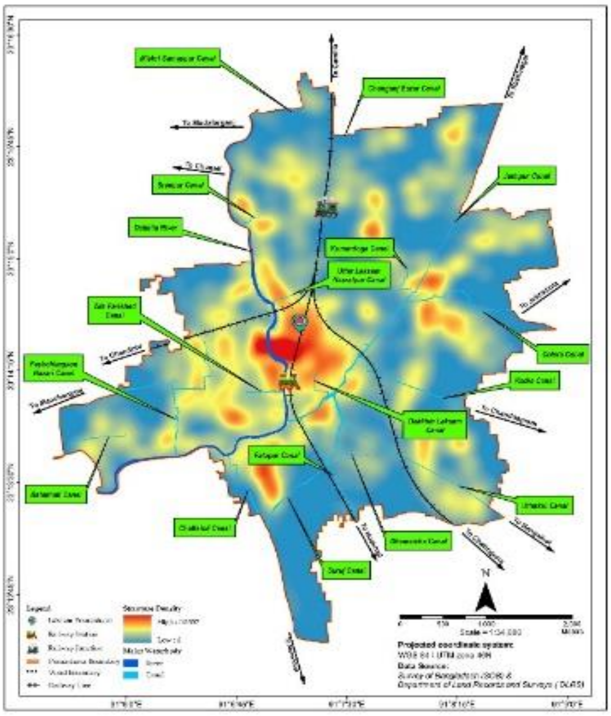
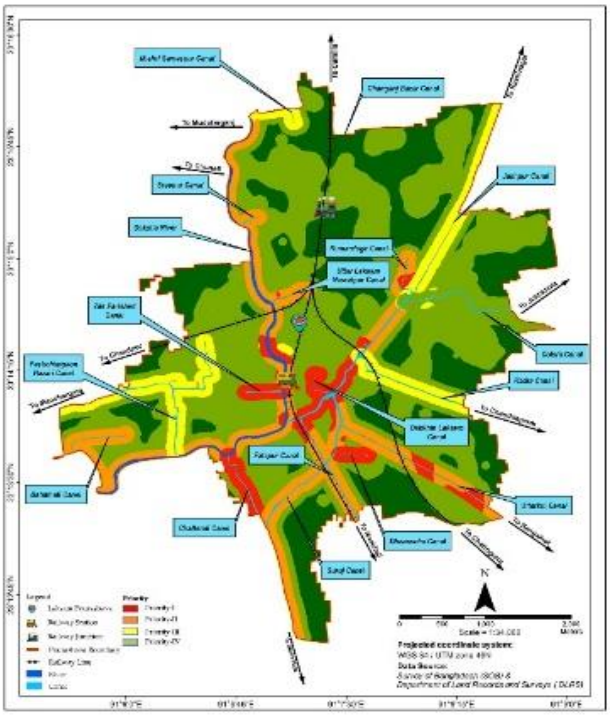


Figure 18: Multi-criteria-based Priority



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

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Flood-prone Area Management

Due to flood-prone area management of the municipality, a Ward-wise Vulnerability Map (Figure 19) has been prepared conducting environmental survey considering existing land use conditions, climate, soil condition, topography, existing drainage facilities as well as focus group discussions among the local stakeholders.

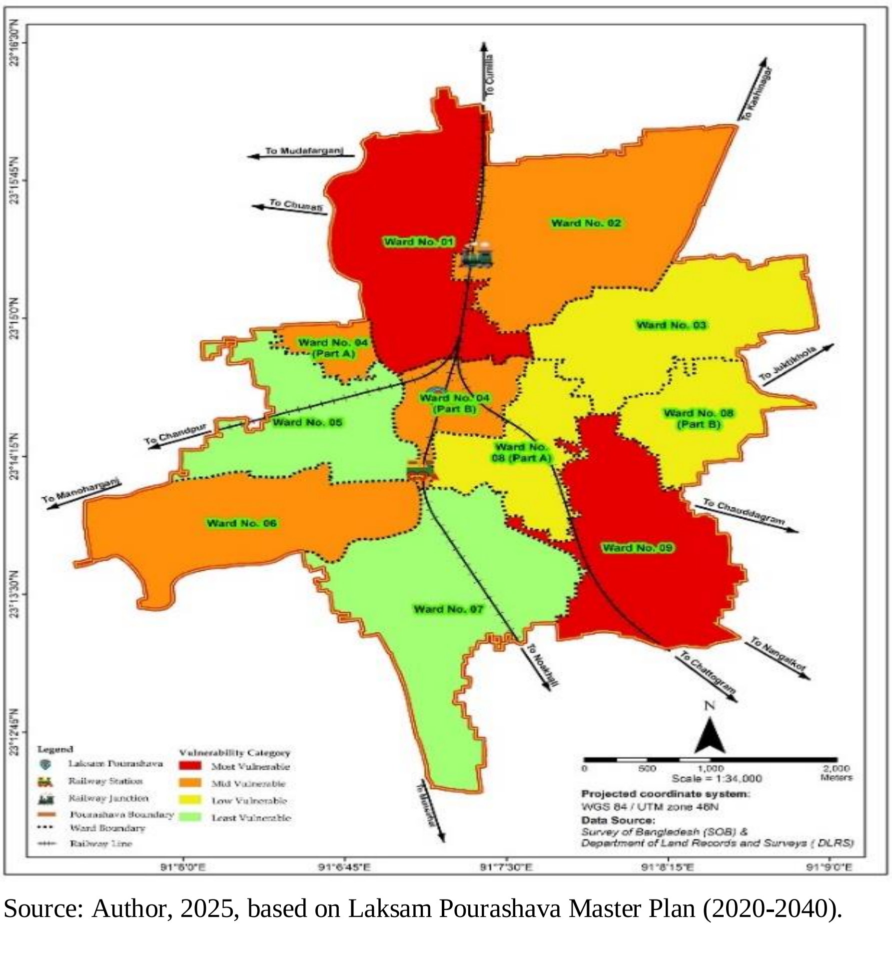
After vulnerability calculation, most vulnerability has found in the Ward No. 1 and 9 (main causes are Flash water, Flood and Waterlogging). Second highest vulnerable (Mid vulnerable) is Ward No. 2, 4 and 6 (main cause is Water scarcity problem). Third highest vulnerable (Low vulnerable) is Ward No. 3 and 8. And least vulnerability founds in Ward No. 5 and 7. Those Wards are more exposed to waterlogging problems. The Laksam Municipality's ward-by-ward vulnerability is displayed in Table 14.

Table 14: Ward-wise vulnerability

SL No.	Ward No.	Cause of Vulnerability	Status
1.	Ward No. 1	Flash water and water logging	Most vulnerable
2.	Ward No. 2	Water scarcity problem	Mid vulnerable
3.	Ward No. 3	Flash water and water logging	Low vulnerable
4.	Ward No. 4	Water scarcity problem	Mid vulnerable
5.	Ward No. 5	Least vulnerable	Least vulnerable
6.	Ward No. 6	Water scarcity problem	Mid vulnerable
7.	Ward No. 7	Least vulnerable	Least vulnerable
8	Ward No. 8	Flash water and water logging	Low vulnerable
9.	Ward No. 9	Flood and water logging	Most vulnerable

Source: Based on the Environmental Survey & Focus Group Discussions, 2020.

Figure 19: Vulnerability according to the Ward



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

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Drainage Network Plan

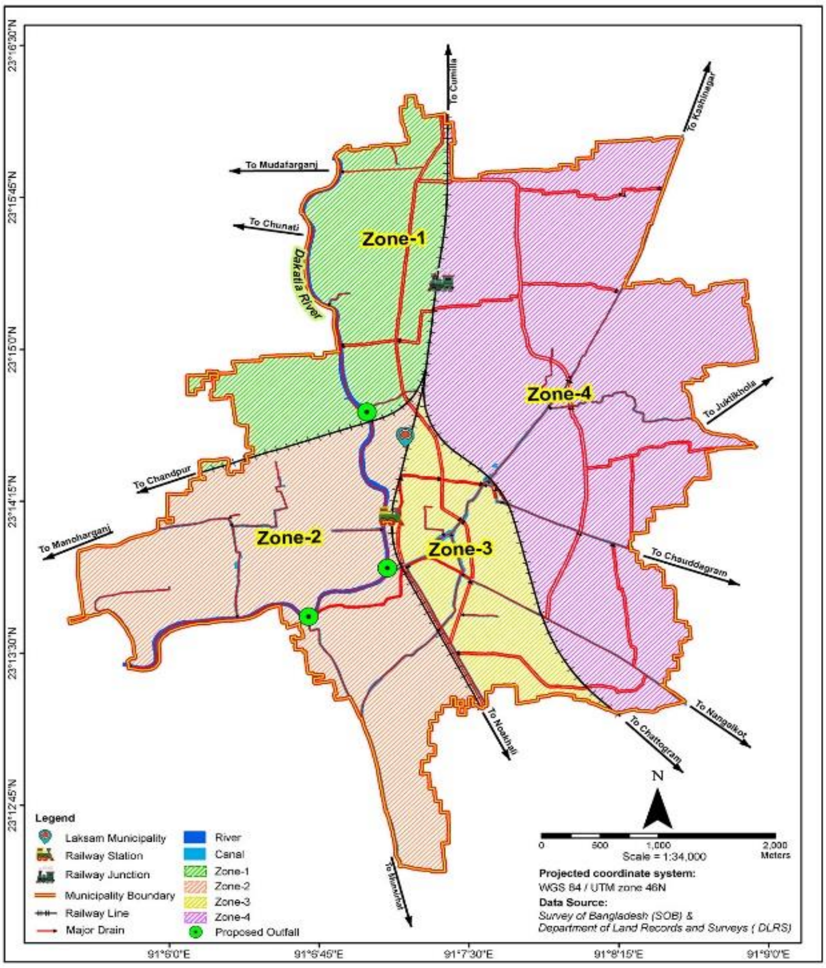
The Laksam Municipality's drainage network design encompasses both major and minor drainage plans, as indicated below:

Major Drainage Network Plan

The Municipality's well-planned primary drainage network (Figure 20) would protect the urban area from significant property damage, injury and loss of life from flooding. Hydrologic analyses provide the basis of this network (80.59 Km) design. The study generally focuses on the main stem of the stream, identifying a floodplain to mitigate the flood hazard, as well as to improve the safety and function of the stream.

In addition, a benefit-cost analysis has performed for reaching where structures have identified in the 30-year floodplain to assist in the alternative selection process. The benefit has mainly measured in reduced flood damages to present structures as a result of recognized improvements, though it is important to likewise identify other intangible (or at least difficult to valuate) benefits consistent improved water quality, removal of street flooding, public safety, aesthetics and recreation (either active recreation such as organized sports and individual exercise, or passive recreation which may simply entail being in the open space). Time spent in an urban open space for recreation offers the healthful benefit of an aesthetic and psychological reprieve from the urban environment of Laksam Municipality.

Figure 20: Major Drainage Network Plan



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

Minor Drainage Network Plan

Grass swales, roadways, gutters, roadside ditches, storm drains, storm drain pipes, on-site detention, and runoff reduction (e.g., reduced directly linked impermeable surfaces) are all included in the minor drainage network

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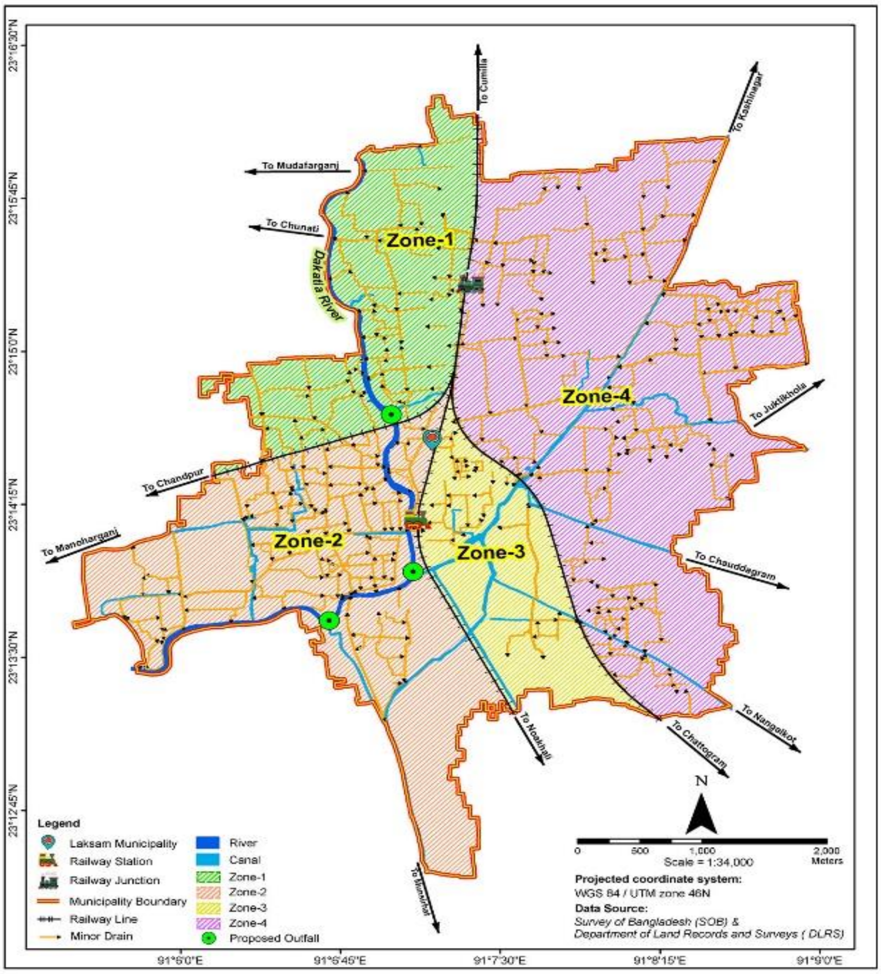
design. It also includes water quality facilities based on storage and transportation. As a result, the Laksam Municipality's minor drainage system (Figure 21) has thoughtfully planned to lessen community concerns about localized floods and drainage issues. Additionally, a well-planned preliminary drainage system (218.27 km) for the city would facilitate easy drainage, lower roadway maintenance costs, and limit disturbances to urban areas' ability to operate during stormwater runoff events.

The initial storm has been characterized as occurring once every two to ten years in the region that the manmade drain serves. Additionally, the drainage system would drain a tributary that is no greater than 20 acres, according to the minor drainage network design, because the runoff from that region would exceed the normal capacity of those features within a street segment. Furthermore, the first method may be used with or without storm drains. Furthermore, storm drains are required when the original system's other components are unable to handle more runoff. However, the demand for storm drains may frequently be greatly decreased by combining a competent primary drainage system with a well-planned street layout.

Figure 21: Minor Drainage Network Plan



Source: Author, 2025, based on Laksam Pourashava Master Plan (2020-2040).

CONCLUSION

Laksam Municipality in Bangladesh faces extreme weather conditions, with moderate summers and cold winters. Despite these challenges, the municipality has 17 natural canals and a river as its main source of stormwater drainage. A planning framework for Sustainable Urban Stormwater Management (SUSM) can efficiently solve municipal drainage problems. However, proper decisions must be made to balance demand and supply, minimizing costs. Hence, in order to reduce the hazards associated with climate change and enhance urban resilience, the present study intends to provide a thorough, workable framework for sustainable stormwater solutions in the municipality. This paper was written using a three-step method that involved identifying the watershed's characteristics, assessing the current storm drainage system, examining rainfall trends, and determining drainage priorities based on various factors for the city's drainage network and flood-prone region management. A number of factors are also taken into consideration including assessments of physical features, GIS data, land use and structure density, drainage basins and sub-basins, drainage outfalls, possible flood-prone locations, and stakeholder consultation. In light of the perpendicular distance between waterlogging hot spot regions and river/canal networks, the study gives priority to natural canals that are closer to these places. Thus, it can be determined that by putting in place a sustainable drainage system in accordance with the multi-criteriabased priority network throughout the integrated drainage system construction, the Laksam Municipality will enhance stormwater management and eradicate waterlogging. By simulating natural drainage patterns, this system promotes stormwater infiltration, attenuation, and passive treatment. It may also be used to dig filter trenches, maintain surfaces, avoid pollution, make swales, and establish bioretention areas. Moreover, a SUSM may increase the resilience, adaptability, and sustainability of Laksam Municipality in addition to promoting socio-economic growth.

However, socio-cultural complexities and slow growth make it difficult to execute a sustainable stormwater management system in a third-world urban setting. Overcoming these obstacles requires an understanding of the current storm drainage system's capabilities, trade-offs, and synergies. Raising awareness of the advantages of SUSM can be facilitated by non-regulatory measures like education and participatory planning. In conclusion, by implementing a full SUSM framework, Laksam Municipality would enhance its resilience to floods, improve the quality of its water, and provide a more sustainable and livable urban environment.

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