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Sustainable Natural Drainage System for Stormwater Management of Laksam Municipality: Transition towards Nature-based Solutions (NbS)

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Abstract

Sustainable Natural Drainage System (SNDS) is a solution that integrates time, place, and human values to address climate change related concerns like flooding and stormwater management in urban areas. In comparison, Nature-based Solutions (NbS) offer social, economic, and environmental benefits, replicating natural processes and providing community and ecological benefits. However, a well-designed urban drainage system is crucial for a comfortable urban life, and SNDS has enabled the evolution to a resilient and sustainable environment. Therefore, the study aims to demonstrate Laksam Municipality's transition from sustainable natural drainage system to Nature-based Solutions (NbS) in response to climate change adaptation. The paper provides a detailed procedure in three steps. It uses a Physical Feature Survey, GIS data, Rainfall Analysis, and a Multi-criteria-based Drainage Priority. The author considers factors like Structural Density, Land use, and Waterlogging areas to prioritize natural canals for drainage. Moreover, 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. By leveraging SNDS, Laksam Municipality can mitigate waterlogging and improve stormwater management, facilitating stormwater infiltration and passive treatment by mimicking natural drainage patterns. In addition, SNDS supports the creation of swales, maintenance surfaces, pollution prevention measures, filter trenches, and bioretention zones. Ultimately, this system enhances Laksam Municipality's resilience, adaptability, and socio-economic growth, correlating closely with NbS applications.

Keywords: waterlogging; nature-based solutions; natural drainage, stormwater; sustainable.

1.1 Introduction

In most urban areas of Bangladesh, the natural drainage system has been replaced by hard surfaces due to the fast pace of urban growth and the physical development that has accompanied it in recent years. Laksam Municipality is a prime example of this hard surface development. Therefore, the municipality's urban floods have been partially caused by the rate at which these hard surfaces are growing as well as climate change issues (Asare, 2021). However, the effect of the shrinking green and natural environment on the incidence of urban flooding has not received enough attention. Because of this, Laksam's flood mitigation plans continue to focus on building and desilting sewers as well as how effective solid waste management may lessen the frequency and severity of urban floods. Nevertheless, the country's urban floods, including those in the Laksam

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Municipality, have not been effectively handled or managed by flood mitigation techniques.

Present trends of urban land development activities, like filling low lands, encroachment of natural drainage, non-existence outfall etc. are major causes behind the waterlogging in Laksam Municipality (Master Plan, 2020). With the passage of time, the paved area of the city become large which causes minimum open space to infiltrating water naturally from various sources and thus drainage condition become worse at the same rate. Therefore, municipal drainage system of Laksam should be developed by proper utilization of existing natural channels like canals, water reservoirs like lakes, ponds, ditch and other low lands, as well as ultimate outfalls like Dakatia River etc. Both structural and non-structural measures are involved for municipal drainage system. To make a balance between demand and supply of drainage, municipality needs to take proper decisions for achieving sustainable natural drainage system considering standards and technical issues, which will minimize the drainage cost as well (LGD, 2018).

Sustainable natural drainage system can be used to transport (convey) surface water, slow down (attenuate) runoff before it enters watercourses, and allow water to percolate (infiltrate) into the ground or evaporate from surface water and transpire from vegetation, in addition to offering spaces for storing water in natural contours (WWF International, 2016). Additionally, Nature-based Solutions, or NbS, refers to the sustainable application and control of natural processes to socio-environmental issues. For example, disaster risk reduction, water security, and climate change adaptation and mitigation are among these issues. However, examples of Nature-based Solutions (NbS) to flood management and control include the restoration of upper watersheds, soil conservation measures, wetland restoration, infiltration measures, rainwater harvesting, detention basins, riparian vegetation restoration, natural drainage route restoration, barrier removal, green roofs, and coastal and reef restoration (WWF International, 2016). Hence, finding out how the Laksam Municipality's sustainable natural drainage system for stormwater management changes toward Nature-based Solutions (NbS) in response to its climate change adaptability is the aim of this study.

1.2 Literature Review

Using the natural characteristics of the ground to control water flow, natural drainage system is made to blend in with the surroundings. This system efficiently distributes extra water without the need for large-scale man-made buildings by utilizing the terrain, vegetation, and soil properties found in nature. Particularly for estates with plenty of land or those seeking little upkeep, natural drainage system is attractive due to its many advantages. However, Sustainable Natural Drainage System (SNDS) of a municipality incorporate a range of professionals and stakeholders. In order to address SNDS, Fryd et al. (2012) present a paradigm that integrates time, place, and human values. The framework is based on a number of models, such as the resource analysis model by Mitchell (1979), the land-use changes model by Agarwal et al. (2002), and the development framework for ecocity planning by Tjallingii (1996). The three main themes and features of these models - biophysical processes, spatial strategies, and adaptive strategies - are connected and deliberated. There are both quantitative and qualitative components to the biophysical processes. The local climate of a place affects the processes. Precipitation, runoff, evaporation, local soil types and conditions, and receiving water bodies such as rivers, lakes, ponds, and natural canals are some of the elements that make up biophysical processes. The actual physical orientation, layout, and design of cities and urban regions are all included in spatial strategies. To regulate the urban drainage system, a combination of ecological and technical frameworks is used. The adaptive methods pertain to the decision-making process and the variables that impact it, such as time, uncertainty, technology advancements, and the decision field. By using these tactics, SNDS may be robust and adjust to shifting circumstances of a municipality.

Among the major concerns associated with climate change are flooding and stormwater management in urban areas. Diez et al. (2011) state that the requirement for suitable flood resilience systems is a result of the increased danger of severe flooding and damage in cities brought on by climate change. Therefore, in order to improve flood resilience in urban areas and handle water more efficiently, a Sustainable Natural Drainage System is required. "One, or a number of management structures and related procedures intended to drain surface runoff in a sustainable manner to primarily eradicate capacities in existing conventional drainage systems in an urban environment" is one way to describe it (Butler and Davies, 2000). By adding features that slow down runoff, the system mimic natural drainage and lessen the strain on conventional drainage systems. Before surface water runoff returns to the environment, it may be collected, stored, and cleaned appreciations to the SNDS. Because of its cheap implementation costs and environmental friendliness, this method is favored in cities with middle and lower-income economies.

Around the globe, signs of climate change are becoming more and more apparent. Its effects include, but are not limited to, increased occurrences of extreme weather events, altered rainfall patterns, and rising world average temperatures. Everywhere the world, the consequences of climate change have significantly altered the environment, livelihoods, and overall metropolitan landscape. Towns and cities are the locations most at risk from climate change. This highlights the urgent need to implement adaptation and mitigation strategies that might lessen these areas' susceptibility to climate change while enhancing their quality of life and the environment. Thus, Nature-Based Solutions (NbS) interventions and ecosystem-based strategies are required (Balica et al., 2012).

Nature-Based Solutions (NbS) are becoming more and more well-liked as a potential cost-effective and environmentally benign solution to mitigate the consequences of climate change in different corners on the earth. According to Curran and Hamilton (2020), it is defined as a range of environmental restoration strategies that improve environmental resilience while generating social and economic advantages for the local populations. As a result, NbS solutions can offer a variety of advantages, including social, economic, and environmental ones. These solutions are distinguished by their capacity to replicate and assist natural processes, their affordability in terms of both deployment and upkeep, and their capacity to provide both community and ecological advantages at the same time.

A comfortable urban life depends on good urban environment. A well-designed urban drainage system is one of the most important components of a respectable urban environment, along with all other urban services and facilities (LGD, 2018). Both the natural consequences and the everyday lives of citizens depend on it. If stormwater is not drained properly, it can cause waterlogging, inconvenience, damage to infrastructure and health hazard. The Laksam Municipality is very concerned about urban local flooding brought on by conventional drainage. Consequently, the use of SNDS to guide the city to NbS has enabled the municipality's transition to a resilient and sustainable environment, which will benefit Laksam Municipality in a variety of ways, including social, economic, and environmental as well.

1.3 Objective of the Study

The primary goal of the study is to illustrate how sustainable natural drainage system for stormwater management of Laksam Municipality transform towards Nature-based Solutions (NbS) in response to its climate change adaptation. Consequently, there are three objectives of this paper which are: identifying the Laksam Municipality's watershed characteristics to assess the effectiveness of the current natural drainage facilities and recognize future drainage needs; analyzing rainfall to offer recommendations for sustainable natural drainage systems and flood control-related improvements for all or a portion of an evolving watershed; and indicating a multi-criteria-based natural drainage priority to give the canals significance based on their drainage importance.

These can provide instructions on how to combine stormwater runoff and man-made drains through secondary and main drains, and then natural streams, in order to build the drainage system in the municipality in a cost-effective manner. Consequently, they will all continue to operate as a single, cohesive system to keep roads, homes, and other properties from flooding during strong storms without contaminating the waterbodies downstream in the Laksam Municipality. Therefore, maintaining the municipality's natural drainage system will offer cordial responses to a more robust climatic response. It will enhance urban floods and waterlogging risk management in a way that is more advantageous than conventional techniques and has the potential to provide several advantages, such as NbS.

2.1 The Study's Methodology

This paper has been written using a three-step procedure. The author began by outlining the drainage characteristics unique to the watersheds that empty into the Laksam Municipality. The assessment's basis was the Physical Feature Survey and pertinent GIS data and information acquired from a number of sources, including the Planning Section of Laksam Municipality, Development Design Consultants Ltd. (DDC), Bangladesh Meteorological Department, Soil Resource Development Institute (SRDI), etc. The subsequent drainage characteristics provide a summary of the site, topography, surface and stormwater flow directions, municipal parameters, existing natural drainage systems, and present and future land use conditions. The geographical evaluation uses data to assess the performance of the existing natural drainage system and forecast future natural drainage requirements. The next step is the Rainfall Analyses. In order to develop a reliable and cost-effective sustainable natural drainage system for stormwater management of Laksam Municipality, representative characteristics have been identified using rainfall pattern analysis. The resulting design storms are used to generate a hydraulic study of the stormwater drainage system and a model stormwater discharge. Moreover, in this phase runoff from each sub-basin has been determined using the U.S. Army Corps of Engineers' HEC-HMS hydrologic computer model. This model uses the Input Parameters, Basin Delineation and Model Parameters, to compute estimated peak flows from each sub-basin of the municipality. Peak flows from each sub-basin computes for the 10, 25, 50 and 100-year frequency events. In the final phase, the author has implied the natural drainage canals prominence according to their drainage value by indicating a multi-criteria-based drainage priority. The significance of natural canals for drainage is directly related to a few key criteria. To decide which canals should be prioritized, the author has considered a number of factors, including structural density, nearby current land use, the position of waterlogging areas, etc. Moreover, the nearby land use patterns of the Dakatia River and natural canals have been delineated by a 100-meter buffer for the river and a 20-meter buffer for the canals from the centerline, respectively. The larger buffer is essential for flood control, pollution filtration, and wildlife preservation, while the smaller buffer around canals is mainly to prevent bank erosion and facilitate maintenance (Song et al., 2025).

Thus, ensuring sustainable natural drainage system of Laksam Municipality will provide amicable retorts to more resilient climate response. It will improve risk management of flooding as well as waterlogging in urban area in a manner that yields more benefit than traditional methods and have the capabilities of offering myriad benefits like Nature-based Solutions (NbS).

3.1 Sustainable Natural Drainage System (SNDS) in Laksam

The Laksam Municipality, covering 19.63 square kilometers and home to 102,562 residents, is predominantly agricultural and historically a railway junction. The area faces challenges due to climate change, including rising temperatures, increased rainfall, and severe tropical storms, which exacerbate flooding, drainage issues, and urban infrastructure problems. These climatic extremes threaten local fisheries, water supplies, and the health of communities, particularly affecting low-income households through disrupted housing and livelihoods. Sustainable Natural Drainage Systems (SNDS) are proposed for stormwater management to address waterlogging and flood risks, aiming to integrate climate change adaptation with new land development strategies.

3.2 First Phase: Watershed Characteristics of Laksam Municipality

The first phase utilizes data to show the topography, major drainage basins and sub-basins of Laksam Municipality, climatic conditions, and current drainage facilities.

3.2.1 Climate and Hydrology

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 an average yearly rainfall of 2000 mm and a maximum monthly precipitation of 2500 mm, precipitation is mostly deposited during the summer and monsoon seasons (Haider & Akter, 2024). Additionally, there have been other notable floods in the municipality, especially in 1988, 1992, and 1998 (Master Plan, 2020). The area is regularly affected by a number of small floods over 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 01 shows the Laksam Municipality's hydrology.

Table 01: 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).

3.2.2 Major Drainage Basins

The boundary line that was created by the railway and the main drainage routes those are already present inside the municipality define the main drainage basins. Each drainage channel is natural, as are the watersheds to which it connects. The Cumilla-facing zone, the Chandpur and Manoharganj-facing zone, the Noakhali and Chattogram-facing zone, and Kashinagar -facing zone are known as Zone 1, Zone 2, Zone 3 and Zone 4, accordingly. Four significant drainage basins are highlighted (Figure 01), because they comprise regions that immediately discharge into the main streams, gradually go through all of the city's canals, and ultimately empty into the Dakatia River. The names and locations of the major basins is listed in table 02.

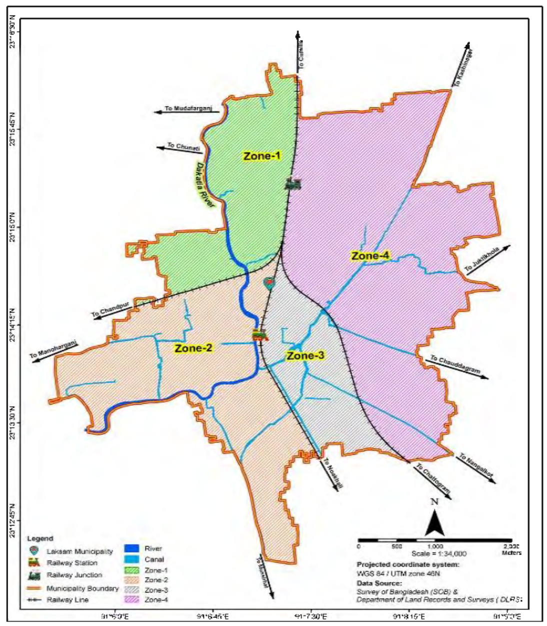


Figure 01: Major Drainage Basins of Laksam Municipality.
Source: Author, 2025, based on Master Plan, 2020.

Table 02: 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).

3.2.3 Existing Watersheds

There are watershed zones (Figure 02) all around the Laksam Municipality. By holding onto rainfall during the monsoon, the three features - the pond, ditch, and beel help to partially avoid floods in the region. However, the total size of the city's watersheds is 565.90 acres (Table 03).

Table 03: 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).

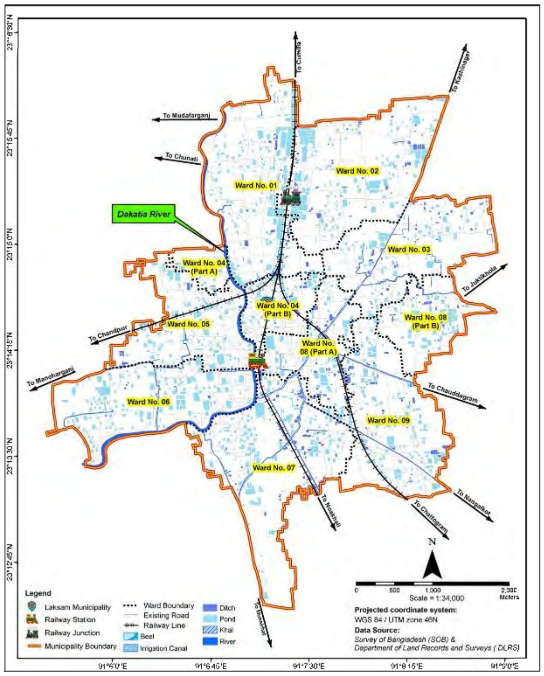


Figure 02: Watersheds of Laksam Municipality.
Source: Author, 2025, based on Master Plan, 2020.

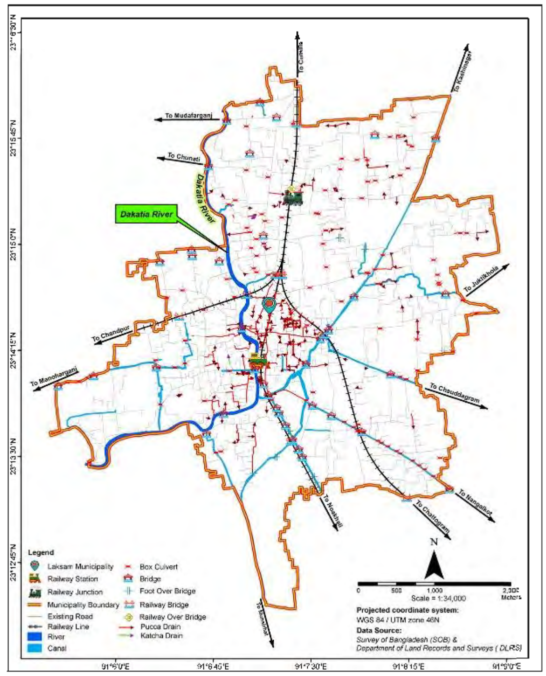


Figure 03: Existing Man-made Drains.
Source: Author, 2025, based on Master Plan, 2020).

3.2.4 Current Man-made Drain

Stormwater runoff of the Municipality is drained by natural open canals through the watersheds. Most of the runoff from the built-up areas, especially the central part, covers open drain. Runoff conveyances through those drains and discharges into the nearby low-lands and canals, finally in Dakatia River (Figure 03). Table 04 shows the configurations of the current municipal storm drainage system with man-made drains.

Table 04: 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).

3.2.5 Sub-basins in Laksam Municipality

The watershed where runoff is assumed to flow to a single discharge point is known as the sub-basin area. There are twenty-one sub-basin regions in the four zones of the Laksam Municipality. Each large basin was then divided into smaller basins to better the demonstrating analysis and make it easier to identify any drainage issues and enhancements. Because of the existence of river and railway bridges, several sub-basins, especially in the Z2 and Z3, are less than 20 acres. Z2 is designated as a Beel for sub-basins greater than 20 acres. Figure 04 shows the locations of those sub-basins.

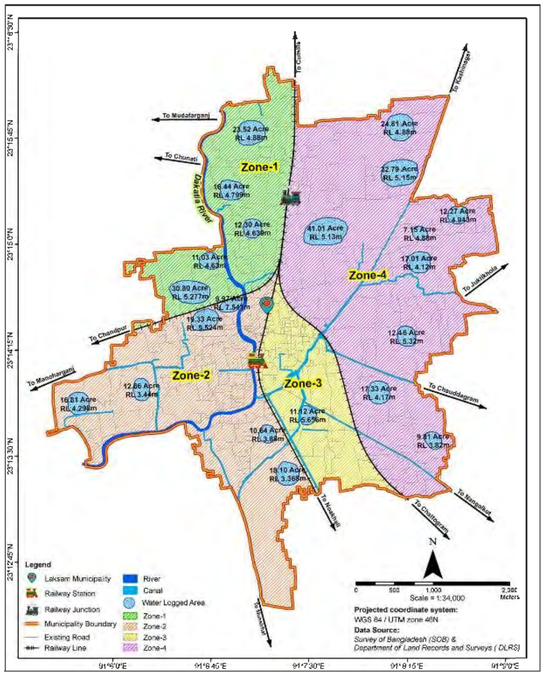


Figure 04: Location of Sub-basins.
Source: Author, 2025, based on Master Plan, 2020.

3.3 Second Phase: Rainfall Analyses

In the second phase of the present study, rainfall pattern analysis is used to design a useful and consistent stormwater drainage arrangement for Laksam Municipality, formulating typical stormwater runoff and screening hydraulic analysis.

3.3.1 Analyzing Runoff

Runoff from each sub-basin is calculated using the U.S. Army Corps of Engineers' hydrologic computer model, HEC-HMS. This model uses the input parameters, basin delineation, and model parameters to determine the expected peak flows from each sub-basin. Every sub-basin's peak flows are computed for frequency occurrences that happen 10, 25, 50, and 100 years apart.

3.3.2 Calibration of Flow

An attempt was undertaken to calibrate model flows to measure values using flow monitoring data that was gathered from four places spread around the municipality. The recorded peak flows and the uncalibrated HEC-HMS model are contrasted in the graphs (Figures 05-07) below. The greatest value (peak) between two observation locations would match the measured Peak Flow in a flawless calibration. Each picture includes a tabular (Tables 05-08) explanation that breaks out the data by basin. In the basin, the HEC-HMS model performed well for the smaller rain events but understated the larger peak flows. The details are as follows.

3.3.2.1 Calibration of Basin Flow

The HEC-HMS Model provides direction and affects the data flow from higher to lower order in accordance with the contour line (land level) while calibrating data values associated with rainfall, stormwater, washing, and bathing water. Moreover, the time factor is the parameter that shows the average value. If there is not any major congestion in the area, the least consideration for flow analysis in order to run the model is -1.

Here, Bulk Rainfall + Space + Flow Canal + Time Duration = Negative or Positive change needed. Furthermore, a negative average value indicates that there is no drainage congestion in the basin, with the exception of a borrow pit where rainfall collects for a while and does not cause congestion.

Zone 01: Towards Cumilla (Z1).

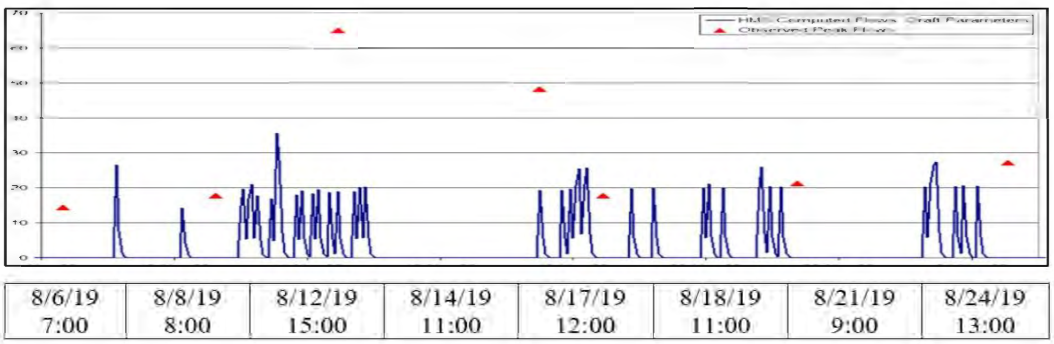


Figure 05: Z1 Basin Flow Calibration.

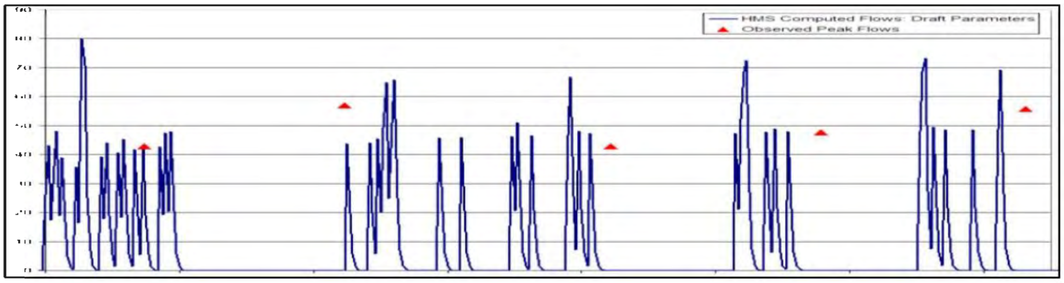
Source: Master Plan, 2020.

Table 05: 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: Master Plan, 2020.

Zone 02: Towards Chandpur and Manoharganj (Z2).



8/10/19 10:00	8/12/19 10:30	8/14/19 11:30	8/17/19 11:00	8/21/19 10:30	8/24/19 13:50	8/27/19 14:50	8/29/19 15:00

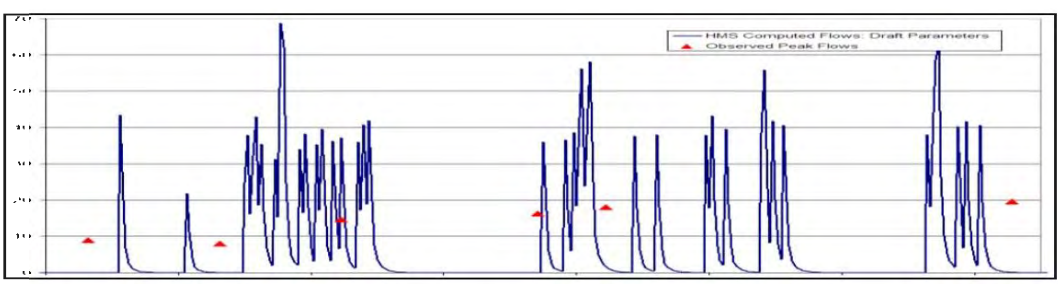
Figure 06: Z2 Basin Flow Calibration.
Source: Master Plan, 2020.

Table 06: 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: Master Plan, 2020.

Zone 03: Towards Noakhali and Chattogram (Z3).



8/7/19 11:30	8/9/19 11:00	8/15/19 10:30	8/19/19 13:50	8/22/19 14:50	8/23/19 12:00	8/25/19 10:30	8/26/19 11:00

Figure 07: Z3 Basin Flow Calibration.
Source: Master Plan, 2020.

Table 07: Basin/Dancer Outfall, Zone 03.

Time	Measured Flow	Uncalibrated HEC-HMS 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%

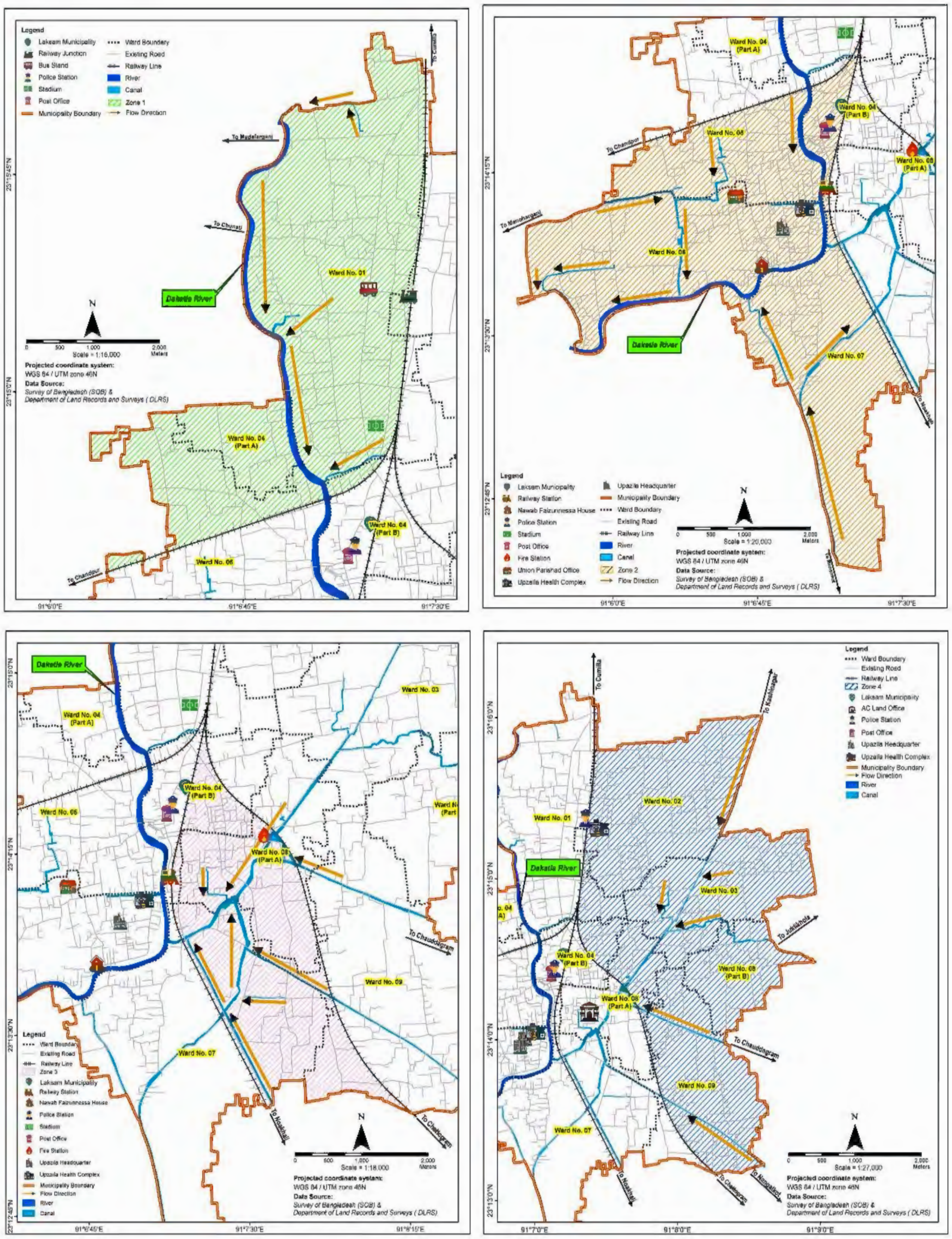
Source: Master Plan, 2020.

Table 08: 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: Master Plan, 2020.

The measured flow, uncalibrated HEC-HMS flows, and the percentage of flow change needed for Zones 03 and 04 have been shown to be almost identical. Consequently, the Z4 Basin Flow Calibration has not been shown separately. Additionally, based on the flow calibration of those four basins, maps (Figures 08–11) illustrating the flow direction in each zone have been formed.



Figures 08-11: Flow Direction of 04 Zones.
Source: Author, 2025, based on Master Plan, 2020.

3.3.3 Drainage Outfalls System

Without human assistance, the Laksam Municipality's natural canals were formed by following the natural slope of the earth to drain surface runoff from various parts of the city. The flow changes from high to low lying areas. All of the city's man-made drains flow into natural canals and the Dakatia River. While some canals are connected to other canals and ultimately flow into the river, others plunge straight into the river. The Pashchimgaon Hazari canal is cut off from the Dakatia River due to road encroachment, and the only canals without an outfall point are the Dhamaicha and Changanj Bazar canals. Therefore, an outfall system in the city's drainage network often focuses on a watershed tributary to a significant waterway, such a river. Following runoff analysis, flow calibration, and basin flow calibration, three outfalls have been found in the municipality (Figure 12). Two of them are in Zone-02 for both smooth surface water and stormwater runoff, while one is in Zone-01.

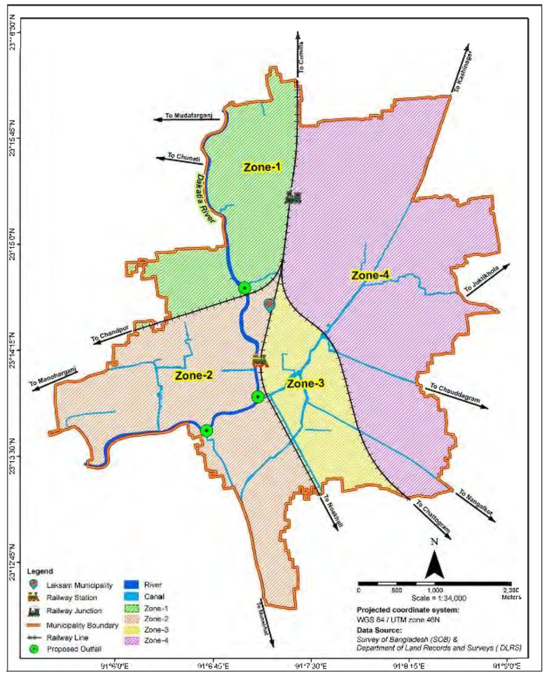


Figure 12: Drainage Outfalls of Laksam Municipality.

Source: Author, 2025, based on Master Plan, 2020.

3.4 Final Phase: Multi-criteria-based Drainage Priority

Following the major and minor drainage network plans, the prominence of the natural drainage canals has been inferred based on their drainage value in the final phase by designating a drainage priority based on multi-criteria.

3.4.1 Major and Minor Drainage Network Plan

The Laksam Municipality has developed a primary drainage network (Figure 13) spanning 80.59 km to mitigate severe flooding and protect properties, life, and enhance stream efficiency. The design is supported by hydraulic analysis and floodplain identification aimed at reducing flood risk. A benefit-cost analysis highlights not only the financial savings from reduced flood damage but also intangible benefits, including improved water quality, public safety, aesthetics, and recreational opportunities that promote psychological well-being. Additionally, the minor drainage system (Figure 14) includes various features such as grass swales, gutters, and storm drains to address local flooding concerns, with a total length of 218.27 km. This system is designed for effective drainage, minimizing maintenance costs and disruptions during storm events, and allows flexibility in storm drain use based on the capacity of the initial drainage components.

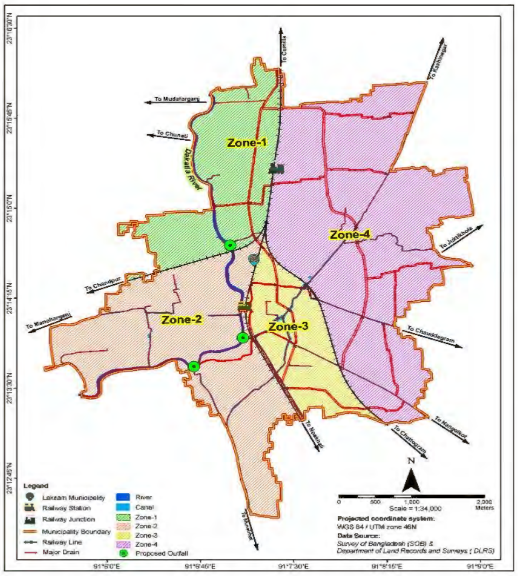


Figure 13: Major Drainage Network Plan.
Source: Author, 2025, based on Master Plan, 2020.

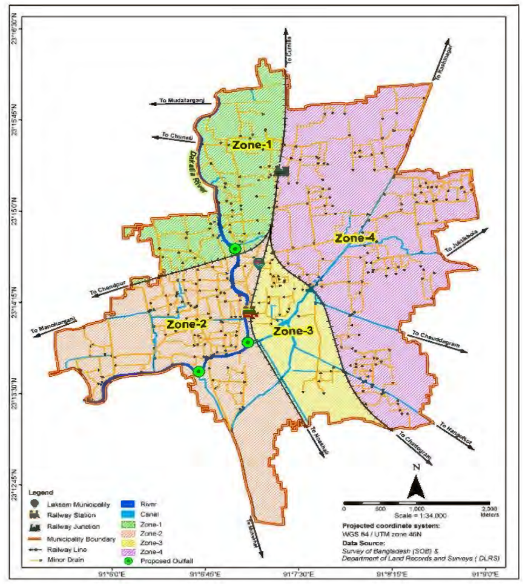


Figure 14: Minor Drainage Network Plan.
Source: Author, 2025, based on Master Plan, 2020.

3.4.2 Drainage Priority based on Multi-criteria

Prioritizing the canals according to their drainage significance is crucial. The importance of the canals' natural drainage is closely related to a few key characteristics. When deciding which canals and rivers should be prioritized, structural density, nearby current land use, the placement of water logging areas, etc., are important considerations.

3.4.2.1 Adjacent Land use

A 20-meter buffer from the centerline has been considered for demarcating the adjacent land use pattern of the canals. This adjacent 20-meter buffer on both side land use (Figure 15) represents the adjacent existing land use characteristics. Nearly fifteen contiguous land use classifications

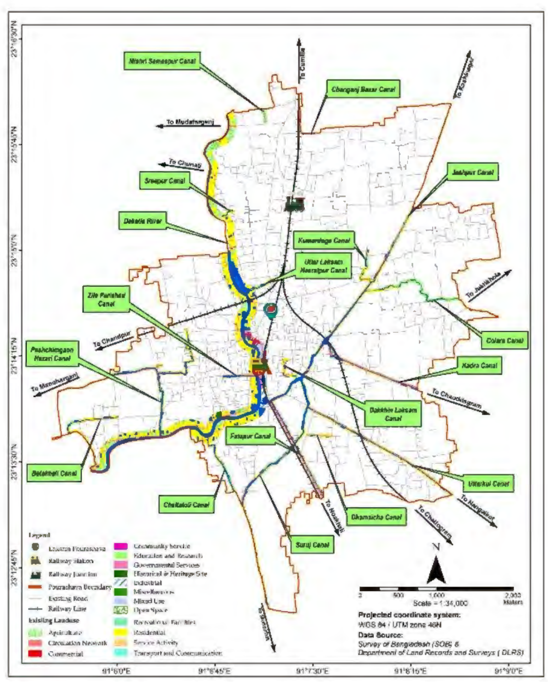


Figure 15: Land use category of 100-meter buffer for River and 20-meter buffer for Canals.
Source: Author, 2025, based on Master Plan, 2020.

now exist. Built area and non-built area are the two basic land use categories into which all of those land uses fall. Because of their lower imperviousness, built-up regions have more surface runoff than non-built-up areas. Waterbodies, open spaces, unoccupied ground, and agricultural double and triple crops are all considered non-built-up land uses. Compared to built-up areas, non-built-up areas have higher soil water perviousness. Therefore, the proportion of constructed land next to canals indicates how impermeable it is, and it also raises the amount of runoff on the canals during the monsoon season. Without these, the built-up region is more severely affected by waterlogging due to an inadequate drainage system. The percentage of adjacent undeveloped land is therefore a crucial factor in establishing the drainage network's priority. Table 09 displays the land use category for the 100-meter river buffer and the 20-meter canal buffer.

Table 09: 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: Physical Feature Survey, 2019 (Master Plan, 2020).

3.4.2.2 Structural Density

The whole Municipality does not have a uniform structural density. In certain areas of the Municipality, the density is high. In areas with high structure density, the drainage network is susceptible. High structural density canal watersheds are vulnerable to

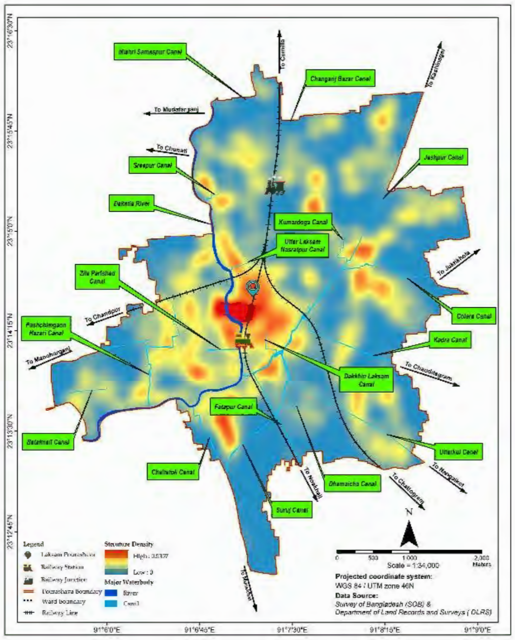


Figure 16: Structural Density in Laksam Municipality.
Source: Author, 2025, based on Master Plan, 2020.

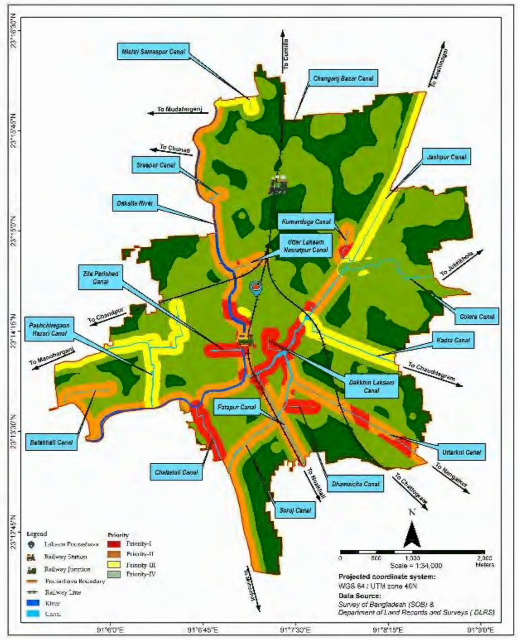


Figure 17: Multi-criteria-based Priority of Canals in Laksam Municipality.
Source: Author, 2025, based on Master Plan, 2020.

drainage issues. Therefore, canals with a high structural density area have been given priority for fixing drainage difficulties. The Municipality's structural density is depicted in Figure 16, with blue representing low-density areas and red signifying higher densities.

3.4.2.3 Weighted Overlay

Finally, to calculate the multi-criteria-based priority list of the canals all criteria output re-classifies into 1 to 10 ranked (index value). Higher index values are assigned to nearby land uses with a high proportion of developed area. A higher-ranking value corresponds to a higher structural density. Similarly, canals that are closest to waterlogging regions have a higher index value, while those that are farther away receive a lower index value.

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

ArcGIS software has computed a weighted overlay based on all the criteria. Since nearby land use is the most significant criterion to be taken into consideration, it has been assigned the highest weight. The waterlogging area's structure density and distance have been given less weight than the nearby land usage. Consequently, the Figure 17 is multi-criteria-based output where priority has been given on their drainage importance. Red colour represents the highest priority and blue colour denotes the lowest priority. As a result, the multi-criteria-based canal priority for Laksam Municipality is as follows:

Priority-I	Priority-II	Priority-III	Priority-IV
Zila Parishad Canal	Fatapur Canal (Part)	Hazari Canal	Colara Canal
Dhamaicha Canal	Uttar Laksam Nasratpur Canal	Jashpur Canal	Changanj Bazar Canal
Chaltatoil Canal	Suruj Canal	Kadra Canal	
Dakkhin Laksam Canal	Batakhali Canal	Mishri Samaspur Canal	
Fatapur Canal (Part)	Uttarkul Canal		
	Kumardoga Canal		
	Sreepur Canal		

4.1 Conclusion

Laksam Municipality in Bangladesh faces challenges from extreme weather, with moderate summers and cold winters, complicating stormwater management. The area's 17 natural canals and a river provide drainage solutions, prompting a study focused on adapting these systems towards Nature-based Solutions (NbS) for better climate resilience. The study prioritizes canals near waterlogging hotspots and emphasizes a sustainable natural drainage system (SNDS) that enhances stormwater infiltration and treatment, while supporting socio-economic growth. However, challenges such as socio-cultural dynamics and the slow evolution of urban systems necessitate careful consideration of collaborations, capacity, and trade-offs. Educational initiatives and innovative flooding control experiments are recommended to enhance the effectiveness of SNDS in the region.

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