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Stormwater Management of Laksam in Water-Sustainable Urban Planning: A Blue-Green Infrastructure (BGI) Network Approach

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Abstract - *The study aims to illustrate how urban planning in Laksam Municipality, Bangladesh can be guided by a blue-green infrastructure (BGI) network approach by considering its major drainage basins, sub-basins, and watersheds, which combines blue, green, and grey elements to provide a water-sustainable urban form. The author uses a three-step approach: a spatial assessment to identify green and blue spaces, analyzing existing and potential BGI network locations to identify viable places for new blue-green corridors, and proposing a framework for a BGI network. The proposed network addresses the water dynamics and characteristics of Laksam Municipality's watersheds, offering flood control and stormwater management options. The paper also discusses the social, spatial, environment, financial, and governance benefits and challenges for implementing BGI networks in the existing context of a local urban institution in Bangladesh. The study highlights the need for a comprehensive approach to discourse urban environmental stresses in third world cities, addressing the challenges of population growth, climate change, and uncontrollably dense urban growth.*

***Key Words*: Blue-Green Infrastructure, drainage basin, sustainable, stormwater, watershed.**

1. INTRODUCTION

Urban areas are frequently dependent on water since it is essential to their growth and good operation. Other than for domestic use and trash disposal, water serves a variety of roles that can also include ecological ones. The pursuit of water-sustainable urban planning is essential to achieving the objectives of SDG 6 (clean water and sanitation), SDG 11 (sustainable cities and communities), and SDG 13 (climate action) where the agendas address the quality and sustainability of water resources, which are essential to human and environmental existence. In actuality, water is a factor in several SDGs, either directly or indirectly. Hence urban planning would be oriented on achieving water conservation in this process, ensuring that all bodies of water within the municipal territory receive natural flow to their destinations and retain acceptable quality across different purposes. Wherever blue-green infrastructures are intended to include natural processes allowing for the likelihood of water logging condition, ejection of contaminants etc., the water channels must be let to run through the municipality. In principle, rainwater and other surface water bodies should be regarded as resources that can be treated and used [1]. Therefore, cost-effective conscious development of a city's drainage system is a key component of water sustainable urban design. This involves integrating stormwater runoff and man-made drains through primary and secondary drains and natural streams. Moreover, the landscape will be designed with ecological consideration in mind so that impermeable land surfaces can be changed into permeable ones for groundwater infiltration [1]. Additionally, all of these will continue to work together as a cohesive system to prevent flooding of streets, homes, and other structures during severe storms without polluting the environment or upstream water bodies.

Both natural (blue and green) and man-made (grey) features can be seen in a municipality's landscape. Unplanned urbanization and excessive densification leave little room for interaction between blue, green, and grey elements, therefore natural features like water and green spaces as well as natural qualities like geology and terrain are given less importance in many cities [2]. As a result, a Blue-Green Infrastructure (BGI) network concept integrates hydrological and natural water management processes into systems where blue and green components appear to be superimposed. Furthermore, blue and green infrastructure combine the requirements of sustainable water and stormwater management with the requirements of urban design and urban life to strengthen urban ecosystems by introducing natural processes into artificial environments [3].

Consequently, such systems have favorable effects on how natural resources are used in cities (e.g., green values) besides on how users of these infrastructures feel and act (for example, social values) [3]. In actuality, a metropolitan area's drainage system is a necessary component of its good functioning system. Many ancient civilization towns had been destroyed because their proper drainage systems were not protected. In reality, the lack of an adequate drainage and transportation system negatively impacts urban living [4]. Accordingly, drainage systems, both natural and man-made, are crucial to urban life. The river, canals, and irrigation canals comprise the area's natural drainage system. Making priority setup in terms of its individual drainage importance for a suitable future drainage plan is vital if a municipality is to ensure water-sustainable urban approach.

In addition, the physical infrastructure in our cities is shockingly subpar, and many developments initiatives neglect or even completely disregard "blue and green" infrastructures. This is a result of our ignorance of the advantages of a sustainable city over the long term [1]. Likewise, when evaluating the ecosystems' natural processes, the service mechanisms are not taken into proper consideration. Thus, from the standpoint of our municipal infrastructures today, promoting blue and green infrastructures can help to make the water bodies visible rather than capturing and managing nature [1]. With this strategy, city dwellers would be allowed to rely on the region's water supplies.

Cities all across the world are reevaluating the traditional municipal water management system in light of these realities [5]. Many ideas and methods have therefore emerged in recent years to deal with urban stormwater with a variety of solutions, including low impact development and Sustainable Urban Drainage Systems in the UK [6], Green Stormwater Infrastructure in the USA [7], the Sponge City in China [8], and Water Sensitive Urban Design in Australia [9]. In light of these circumstances, the goal of this research is to find out how a Blue-Green Infrastructure (BGI) network approach might be used to direct the future urban development plan for Laksam Municipality that focuses on water sustainability.

1.1 Literature Review

A network of "blue and green" infrastructures was first developed in Sao Paolo, Brazil, as part of planning efforts to discourse flood hazards. BGI is a relatively new term compared to its predecessors, most notably GI [10] thorough review of the literature on blue, natural, ecological, and green infrastructure from 1986 to 2015 [11] revealed a change in emphasis from green, or natural infrastructure to BGI. The latter adopts a more comprehensive strategy, integrating numerous ecosystem kinds and the ecosystem services that go along with them. The "land use view" is being replaced by more flexible ecosystem service-based solutions [12] that do not merely include green and blue components and procedures. Permeable pavements, bio swales, retention basins, and artificial wetlands all need to be considered as a whole.

There have been a number of researches on BGI, but most of these focus on its benefits [13]. Although the concept of BGI is widely accepted in countries like the Netherlands and Sweden, there are still no theoretical analyses of how it might influence planning practice. BGI is a theoretical departure from conventional water management methods that emphasizes the natural environment [14] in order to provide "resilient and adaptive measures to deal with flooding by imitating pre-development hydrology (for instance, methods of custody and retention)" [15]. In contrast, urban "grey" infrastructure is less stressed because to this technique [16]. As a result, BGI planning is very different from traditional planning, which in the past has placed an undue emphasis on 'hard' physical infrastructures like roads, sewage and drainage systems, and utility lines [17]. Incorporating blue and green infrastructure among current land uses, where sealed or paved surfaces can be effectively eliminated, is necessary for a successful BGI, according to the experience of the Malmo City Council [18], which calls for a careful balance between hard and soft aspects. In relation to the study, BGI planning should focus on attracting more polycentric growth and multiple densities throughout the area in order to achieve a "symbiotic" contact between the city and its region [19]. The overall objective is to have a more harmonious blend of blue, green, and grey components, with "the barrier between natural and technical networks eliminated" [19].

The delineation of BGI used in the present study is that of Ghofrani, who defined it as "an interconnected network of natural and designed landscape components, including water bodies and green and open spaces, which provide multiple functions, comprising flood control, water storage for irrigation and industry use, and wetland areas for wildlife habitat or water purification, among many others" [20]. This more contemporary approach to BGI diverges from earlier engineering discourses that were inspired by the idea of green infrastructure, which was mostly employed to control water in urban contexts. A variety of names and ellipses were used to denote different features, designs, and purposes, or occasionally features that were quite similar to one another [21]. Studies have used a variety of abbreviations and titles for water management since the 1980s [22]. The concept of water sensitive urban design (WSUD), which lays a heavy emphasis on "blue" aspects (such as rainfall and flood) to characterize infrastructure [5], is more closely aligned to the approach to BGI taken in the later time [21]. In accordance with Liao et al., 2017, BGI is a type of "green infrastructure" [23] that involves of a network of landscape systems which are deliberately constructed and maintained to provide ecosystem services related to stormwater by integrating natural and man-made materials.

However, stormwater runoff reduction is the basis for the first BGI component combination. Specially, the elements of protection and retention when it rains heavily, detention components can store water and discharge it gradually into the sewer system. Instead of requiring a sewage connection, retention components can store water and allow it to gently seep into the ground. As storage retention mechanisms, natural storage basins with low infiltration capacities and constant water levels are engaged. Saturation preservation works directly permeate water without containing it [24]. Besides according to Hansen et al., 2019, the initial step in creating a BGI network is to carry out a systematic "spatial assessment" of the urban morphology to find all blue and green spaces at the "city-wide" [25] that could be strategically organized in the future to fulfill various

functions of Laksam Municipality. The requirement for "connectivity" between the blue and green lanes is emphasized in the second phase by considering its watersheds, major drainage basins, as well as sub-basins. The two are combined in the final step to formulate a multi-scale solution that accounts for both water dynamics and the urban structure of the Municipality.

1.2 Objective of the Study

The primary goal of the study is to illustrate how urban planning of Laksam Municipality, Bangladesh can be steered by a blue-green infrastructure (BGI) network approach that combines blue, green, and grey elements together to provide a water sustainable urban form of the city. Therefore, there are three objectives of this paper which are: identifying possible development sites to overcome obstacles as well as the kinds of solutions required for water management in various urban densities of the city; examining both current and prospective blue and green network locations; and suggesting a BGI system to ensure a planned network offering a variety of alternatives for flood control and stormwater management, depending on the magnitude and location. These can offer guidance on how to consider planned development of the drainage system in the municipality in a cost-effective way, to integrate stormwater runoff and man-made drains through secondary and primary drains and natural streams. As a result, all of these will maintain function as an integrated system to prevent inundation of roads, houses and properties during heavy storms without environmental contamination of downstream water bodies of Laksam Municipality.

1.3 The Study's Methodology

A three-step process has been used to write this paper. To begin with, the author has conducted a methodical "Spatial Assessment" of the urban morphology of Laksam Municipality in order to identify all green and blue spaces on a "city-wide" scale, as well as recognize potential development sites. The Physical Feature Survey and relevant GIS data and information gathered from several organizations namely Planning Section of Laksam Municipality, Development Design Consultants Ltd. (DDC), Bangladesh Meteorological Department, Soil Resource Development Institute (SRDI) etc. to serve as the basis for the assessment. This section describes the drainage features which are specific to the watersheds that drain into the Municipality. The location, municipal parameters, topography, surface as well as stormwater flow directions, existing drainage facilities, and current and prospective land use circumstances are summarized in the subsequent drainage characteristics. Data is used in the spatial evaluation to determine future drainage needs and analyze how well the current drainage infrastructure are performing. "Analyzing Existing and Potential Blue and Green Network Locations" is the next step. This phase's purpose is to identify viable places for new blue-green corridors that would integrate the current water network with prospective sites for stormwater infrastructure. These corridors would function as a mechanism to drain stormwater runoff during periods of high rainfall. The rainfall pattern analyzes to identify representative characteristics appropriate for the design of a cost-effective and reliable stormwater drainage system for the Laksam Municipality. The resulting design storms use to prepare model stormwater runoff and perform hydraulic analysis of the stormwater drainage system of the city. In the third phase, "Proposing a Framework for a Blue-Green Network," the author has combined all of the findings from the first two processes to create a framework for a BGI network that addresses the water dynamics and characteristics of the Laksam Municipality's watersheds. Based on a two-pronged approach of mitigation and preservation, this phase offers recommendations for drainage and flood control related improvements for all or part of a growing watershed. It is preferable to preserve current drainage features and related floodplains in areas where development has not yet taken place in a way that maintains natural flow routes, ecological advantages, and natural floodplains. Moreover, mitigation of the effects of urbanization by enhancements that stabilize or restore stream canals, contain higher runoff volumes, and improve conveyance may be necessary for both historic and future development. The author has proposed a BGI network framework as the final step.

2. Water-Sustainable Urban Planning of Laksam

Considering crucial instruments to recognize remedial drainage congestion, stormwater quality, and flood risk management for construction, as well as to guide new land development to be consistent with regional drainage and flood control needs, the BGI network approach has significant planning implications in achieving a water sustainable urban form for Laksam Municipality. Therefore, the method accurately pinpoints flaws in the drainage system and offers a roadmap for the planned growth of the city.

1.1 First Step: Spatial Assessment

A total population of 1,02,562 in 9 Wards, the Municipality has a land area of 19.63 sq. km (4851.31 acres) [4]. Because of the dominance of agriculture, the municipality is not ideal. The city is well known as a Railway Junction from the beginning of the 19th century. Its current water body, however, measures 710.29 acres (14.64%) [4]. Additionally, the primary drainage basins inside the municipality are defined by the railway-originated boundary line and the major drainage routings that already exist within. Every drainage path, along with the watersheds that they are connected to, is natural. These natural basins are designated as Zone-1, which faces Cumilla; Zone-2, which faces Chandpur and Manoharganj; Zone-3, which faces Noakhali

and Chattogram; and Zone-4, which faces Kashinagar. Four major drainage basins (Figure-1) are highlighted because they include areas that directly discharge into the main streams and eventually run via all of the city's canals and finally into the Dakatia River (Figure-2). Tables 1 and 2, respectively, list the names and areas of the main basins as well as the length and direction of flow of natural canals and river.

Table -1: 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)	2140.29	8.66
Total	**4851.31**	**19.63**

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

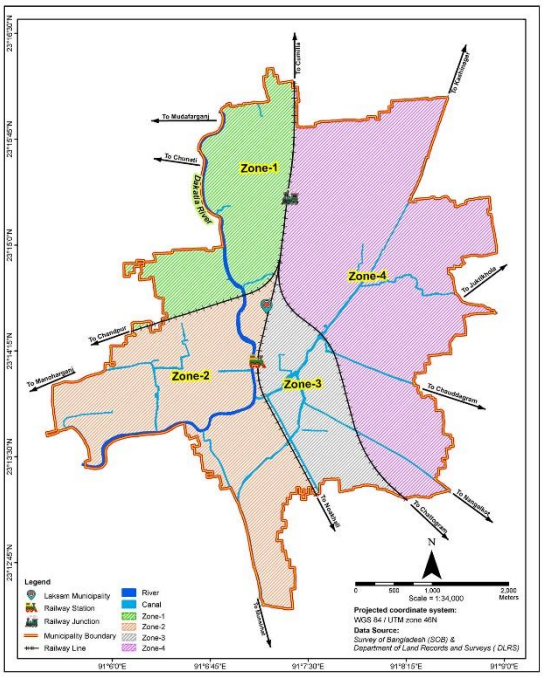

Figure-1: Major Drainage Basins of Laksam Municipality.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

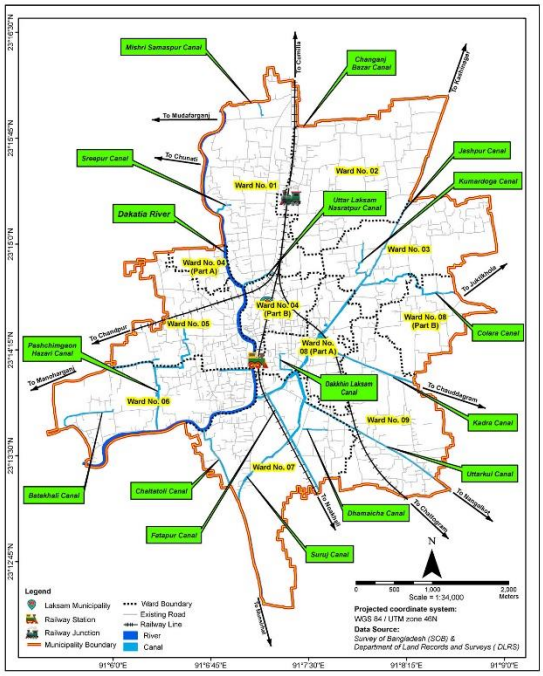

Figure-2: River and Canals in Laksam Municipality.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

Table-2: 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
Zone-3: Towards Noakhali and Chattogram (Z3)	Dakkhin Laksam Canal	0.62	North to South
	Dhamaicha Canal	0.33	East to West
	Uttarkul Canal	0.77	Southeast

	(part)		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).

2.1.1 Existing Watersheds

Watershed regions (Figure-3) are scattered throughout the Laksam Municipality. The three features – the pond, ditch, and beel contribute to partially prevent flooding in the area by retaining rainwater during the monsoon. However, in the city, 542.62 acres of land make up the watersheds of total area.

Table -3: Watersheds Areas.

Zone	Ward No.	Area in acre		
		Pond	Ditch	Beel
Zone 1	01	65.98	4.48	2.67
	02	3.21	0.11	0.00
	04	6.51	0.44	0.00
	05	12.95	1.80	0.00
Zone 2	01	0.00	0.68	0.00
	04	7.01	0.13	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	0.74	0.00
	07	18.35	9.46	0.00
	08	24.66	3.43	0.00
	09	4.44	0.58	0.00
Zone 4	01	4.01	2.08	0.00
	02	72.88	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		**468.58**	**71.37**	**2.67**

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

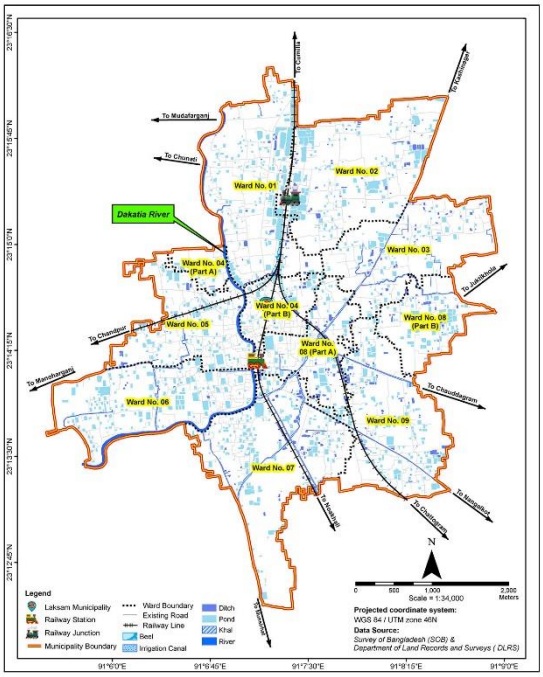

Figure-3: Watersheds of Laksam Municipality.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040)

2.1.2 Existing Man-made Drain

Stormwater runoff of the Municipality is drained by natural open canals throughout the watersheds. Most of the runoff from the urbanized areas, especially the central part, covers open drain. Runoff transports through those drains and discharges into the nearby low-lands and canals, at last in Dakatia River (Figure-4). Existing municipal storm drainage system configures with man-made drain is presented in the Table-4.

Table-4: 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).

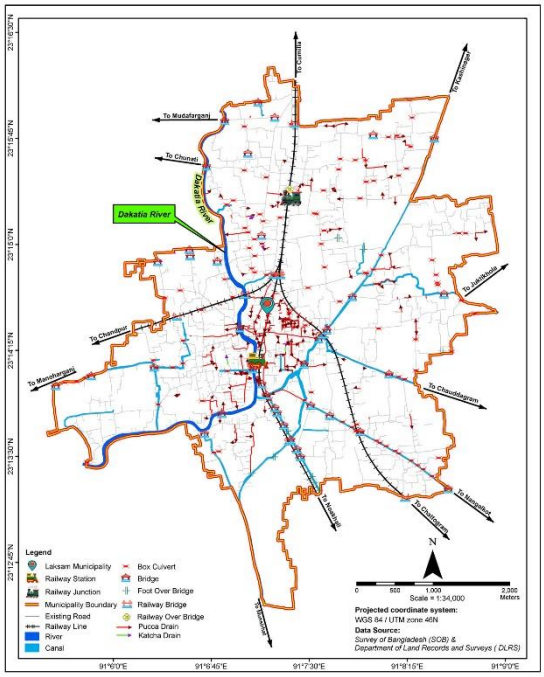

Figure-4: Existing Man-made Drains.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

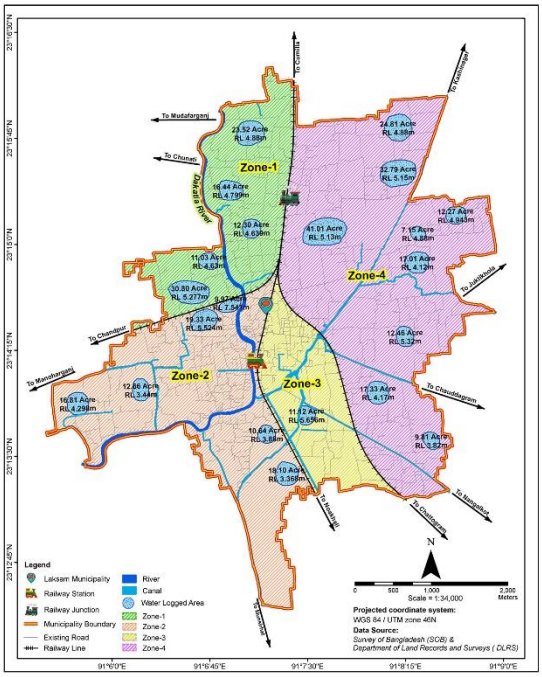

Figure-5: Location of Sub-basins.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

2.2 Second Step: Analyzing Existing and Potential Blue and Green Network Locations

To analyze existing as well as potential blue and green network locations, each major basin has further delineated into sub-basins. Sub-basin area is the watershed within which runoff assumes to flow to a single discharge point. It considers as an area. In the Laksam Municipality, 21 sub-basin areas identify in its 4 zones (Table-5). Locations of those sub-basins are shown in the Figure-5.

Table-5: 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	0	04	02
Z3	01	0	0	01
Z4	09	03	03	03
Total	**21**	**04**	**09**	**08**

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

2.2.1 Runoff Analysis

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

2.2.2 Flow Calibration

Using collected flow monitoring data from four locations distributed across the Municipality, an effort was made to Calibrate Model Flows to measure values. The graphs below show how the measured peak flows compare to the uncalibrated HEC-HMS model. A perfect calibration would show the highest value (peak) between two observation points equal to the observed Peak Flow. A tabular description on each figure summarizes the results by basin. The HEC-HMS model in the Basin underestimated the greater peak flows but matched well for the lesser rain events. Here are the specifics.

2.2.3 Basin Flow Calibration

When calibrating data values linked to rainfall, stormwater, washing, and bathing water, the HEC-HMS Model provides guidance and influences the flow of data from upper to lower order in accordance with the contour line (land level). Once more, the parameter that displays the average value is the

time factor. In order to execute the model, the minimal consideration for flow analysis is -1 if there isn't any significant congestion in the area.

Here, Bulk Rainfall + Space + Flow Canal + Time Duration = Negative or Positive change needed. Moreover, negative average value means no drainage congestion available in the basin except some borrow-pit where rainwater stands for a certain time that is not the congestion.

Zone 1: Towards Cumilla (Z1).

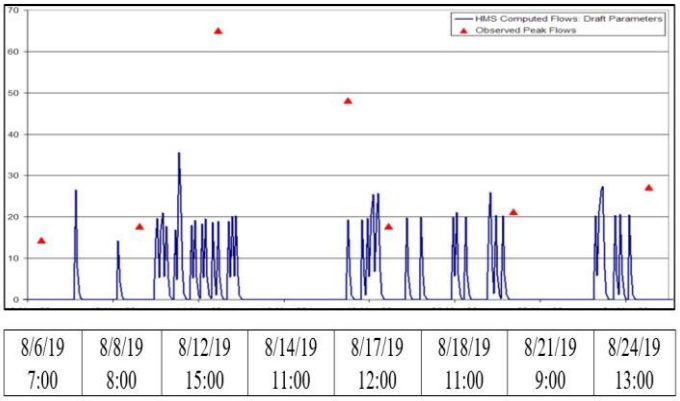

Figure-6: Z1 Basin Flow Calibration.
Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

Table-6: Basin/Dancer Outfall, Zone 1.

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.

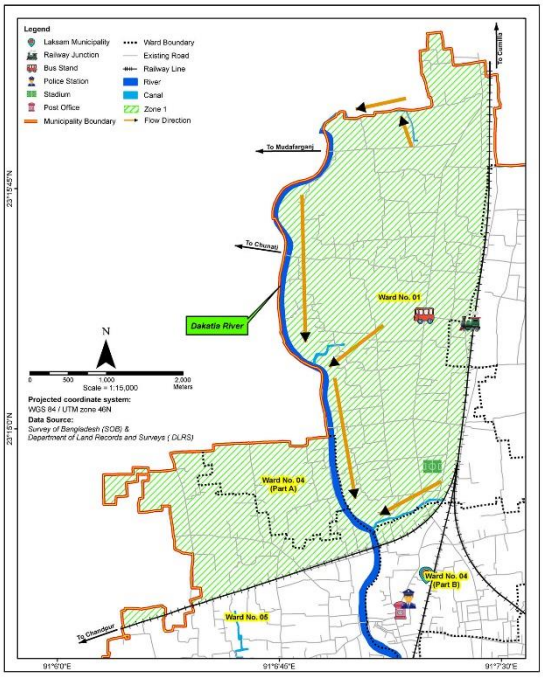

Figure-7: Flow Direction of Zone 1.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

Zone 2: Towards Chandpur and Manoharganj (Z2).

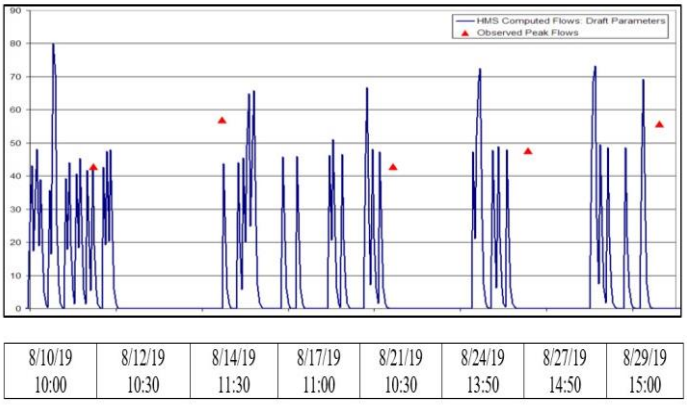

Figure-8: Z2 Basin Flow Calibration.
Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

Table-7: Basin/Dancer Outfall, Zone 2.

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.

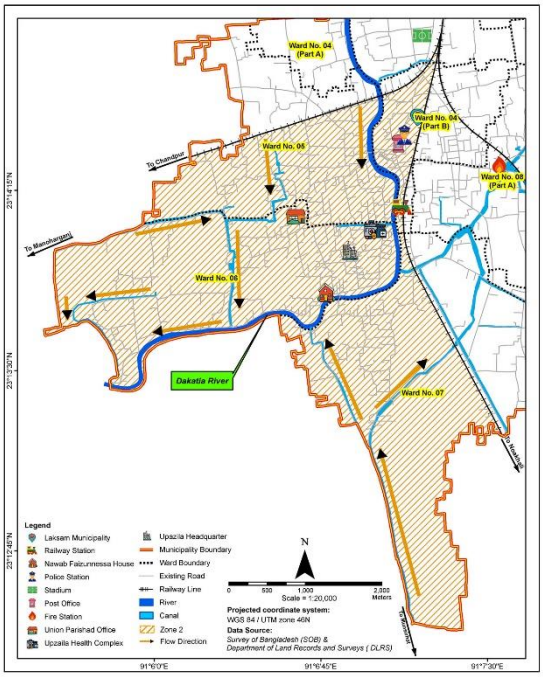

Figure-9: Flow Direction of Zone 2.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

However, it has observed that for Zones 3 and 4, the values of measured flow, uncalibrated HEC-HMS flows, and the percentage of flow change required are nearly same. As a result, there has been no separate display of the Z4 Basin Flow Calibration.

Zone 3: Towards Noakhali and Chattogram (Z3).

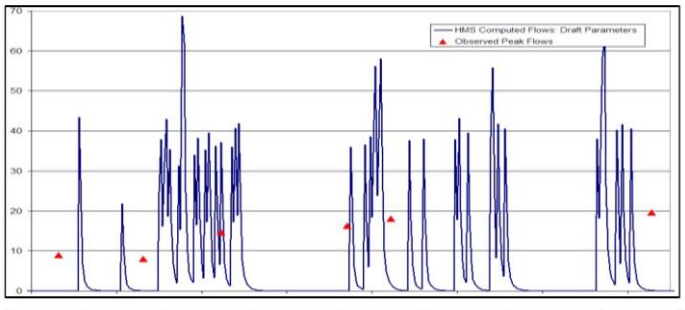

Figure-10: Z3 Basin Flow Calibration.
Source: DDC, 2020 & Master Plan, 2020, based on Physical Feature Survey, 2019.

Table-8: Basin/Dancer Outfall, Zone 3.

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

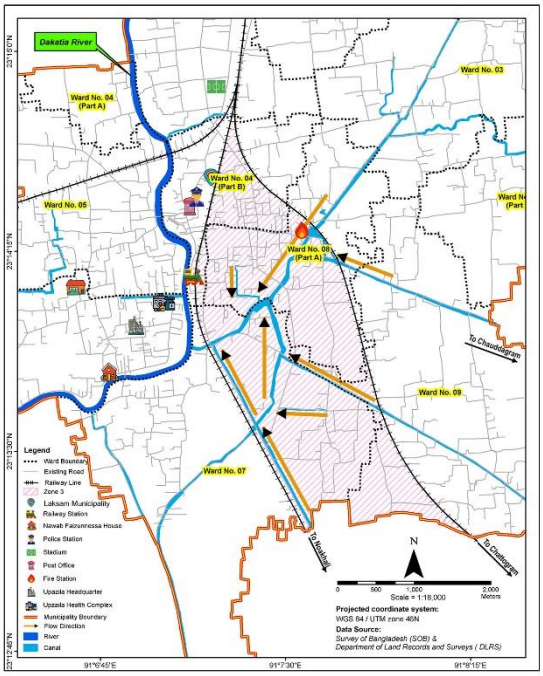

Figure-11: Flow Direction of Zone 3.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

Table-9: Basin/Dancer Outfall, Zone 4.

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.

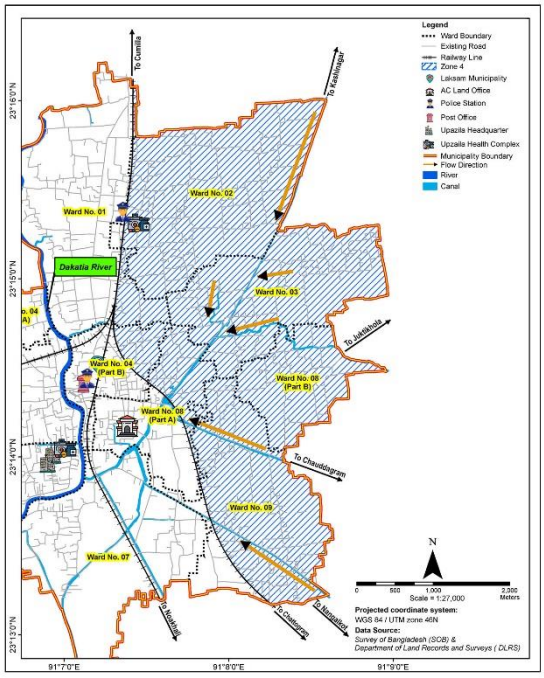

Figure-12: Flow Direction of Zone 4.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

3. Final Step: Proposing a Framework for a Blue Green Infrastructure (BGI) Network

The author has demonstrated one method of organizing a BGI network with a specific focus on a planned system that offers a range of options for flood control and stormwater management, addressing the realities of ongoing neglect to the municipality's blue and green elements as well as future risks from climate change and uncontrollably dense urban growth. This is just one of the many possible ways to implement a BGI network in an urban setting. Consequently, the author has provided strategies for the Laksam Municipality that will enable various stakeholders to follow a conceptual and structural framework for the municipality's future development. Hence, Major Drainage Network Plan, Minor Drainage Network Plan and Outfall System are all included in the framework and combinedly these would create morphological patterns which are more consistent with the topography of the current terrain and can also accommodate water and individuals in harmony.

3.1 Drainage Network and Outfall System

The Laksam Municipality's natural canals are created naturally, following the ground's natural slope to drain surface runoff from different areas of the city without the need for human intervention. From high to low lying locations, the flow shifts. All of the city's artificial drains empties into the Dakatia River and natural canals. Some canals fall directly into the river, while others are connected to other canals and eventually end up in the river. The Dhamaicha and Changanj Bazar canals are the only ones that have no outfall point, and the Pashchimgaon Hazari canal is disconnected from the Dakatia River because of road encroachment. Thus, in the city's drainage network, an outfall system usually concentrates on a watershed tributary to a large waterway, such as a river. In the municipality, three outfalls have been identified (Figure-13), one of which is in Zone 1 and two of which are in Zone 2 for both smooth runoff of surface water and stormwater.

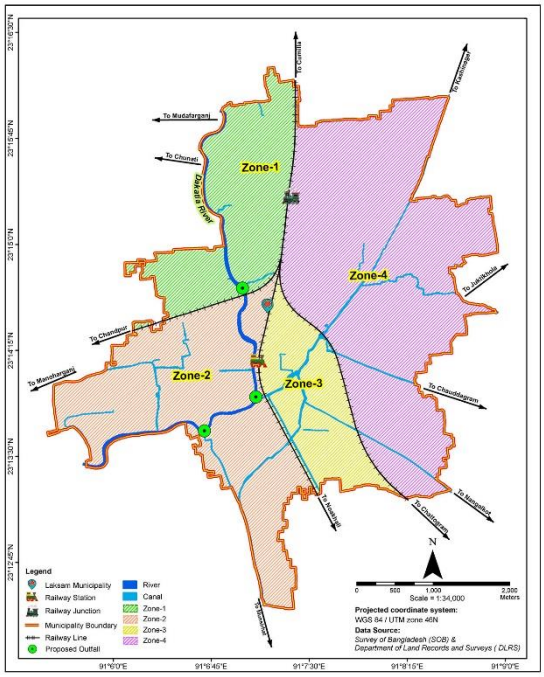

Figure-13: Drainage Outfalls of Laksam Municipality.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

3.2 Plan for Major Drainage Network

Laksam Municipality's well-planned primary drainage network (Figure-14) 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.

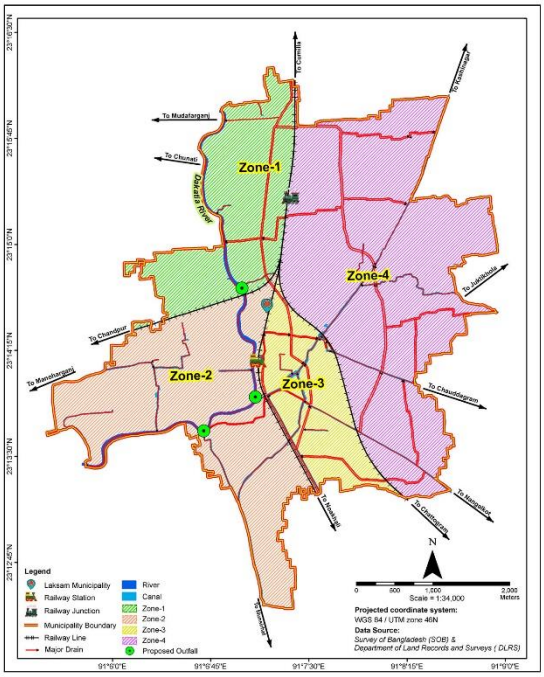

Figure-14: Major Drainage Network Plan.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

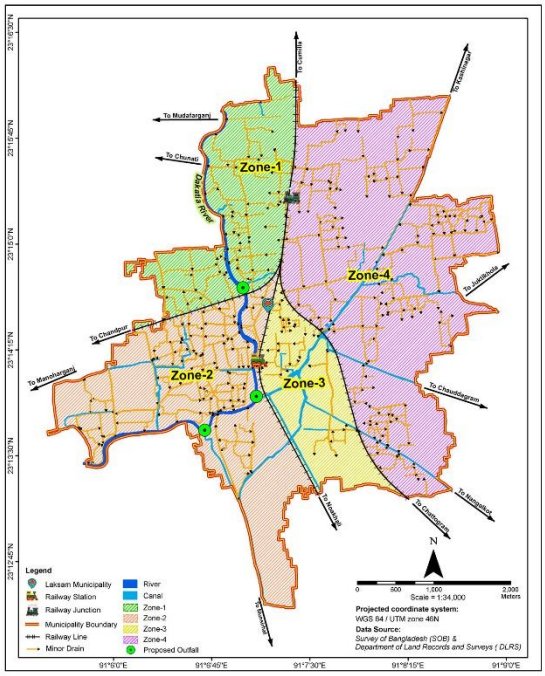

Figure-15: Minor Drainage Network Plan.
Source: Author, 2024, based on Laksam Pourashava Master Plan (2020-2040).

3.3 Plan for Minor Drainage Network

The minor drainage network plan includes conveyances such as grass swales, streets and gutters, storm drains and roadside ditches, storm drain pipes, on-site detention, and runoff reduction (e.g., minimized directly connected impervious areas). It also comprises conveyance and storage-based water quality facilities. Therefore, the initial drainage system (Figure-15) for Laksam Municipality has properly planned and designed to reduce complaints from the community related to localize flooding and drainage nuisance conditions. Moreover, a well-organized preliminary drainage (218.27 Km) arrangement of the city would provide for convenient drainage, reduces costs of streets and minimizes disruptions to the function of urban areas during runoff events.

For the area served by man-made drain, the original storm has defined to have a return frequency of once every 2 to 10 years. Furthermore, during the minor drainage network plan, it has been focused that the drainage system would drain a tributary not larger than 20 acres, as the runoff from that area would be in excess of the typical capacity of those features within a street section. In addition, the initial system exists with or without storm drains. Besides, storm drains are needed when the other parts of the initial system no longer have capacity for additional runoff. However, a good major drainage system coupled with wise layout of streets can often significantly reduce the need for storm drains.

4. CONCLUSIONS

A metropolitan area's drainage network is an essential component of its well-functioning system. Besides, without an adequate transportation and drainage arrangement, urban life suffers. An integral aspect of urban living is the drainage network, both natural and man-made. The rivers, canals, and irrigation canals that comprise a municipality's natural drainage network. Hence, setting priorities based on each individual's drainage value is crucial for creating an appropriate, long-term, water-sustainable urban plan.

In order to develop a water-sustainable urban form for Laksam Municipality, a framework for designing and executing the BGI network has been provided in this study. The municipality's planned network, which offers a variety of options for stormwater management and flood control, is addressed by the proposed BGI network. This network considers the risks associated with uncontrolled urban

growth and climate change, as well as the ongoing neglect of the city's green and blue elements. The benefits of adopting a BGI network within the current framework of a local urban organization in Bangladesh have also been conferred in the article, including social, geographical, environmental, financial, and governance aspects.

However, the implementation of a Blue Green Infrastructure (BGI) network in third-world urban contexts requires careful consideration due to the socio-cultural dynamics and slow pace of development. To overcome challenges, a better understanding of the synergies, trade-offs, and capacity of existing blue and green spaces are needed. Non-regulatory interventions, such as education, are needed to raise awareness about BGI's benefits in personal and public life. Additionally, participatory planning and creative flood management experiments can also help avoid top-down, technology-heavy, and large-scale infrastructural solutions.

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