Frontiers in Hydrology

Assessment of Drainage Congestion at Sylhet City of Bangladesh and Development of Stormwater Drainage Masterplan Using GeoSWMM Model

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OUTLINE OF THE PRESENTATION

1. BACKGROUND OF THE STUDY
2. STUDY AREA
3. OBJECTIVES OF THE STUDY
4. METHODOLOGY
5. DATA COLLECTION
6. DATA ANALYSIS AND RESULT
7. CONCLUSION
8. LIMITATIONS AND RECOMMENDATIONS

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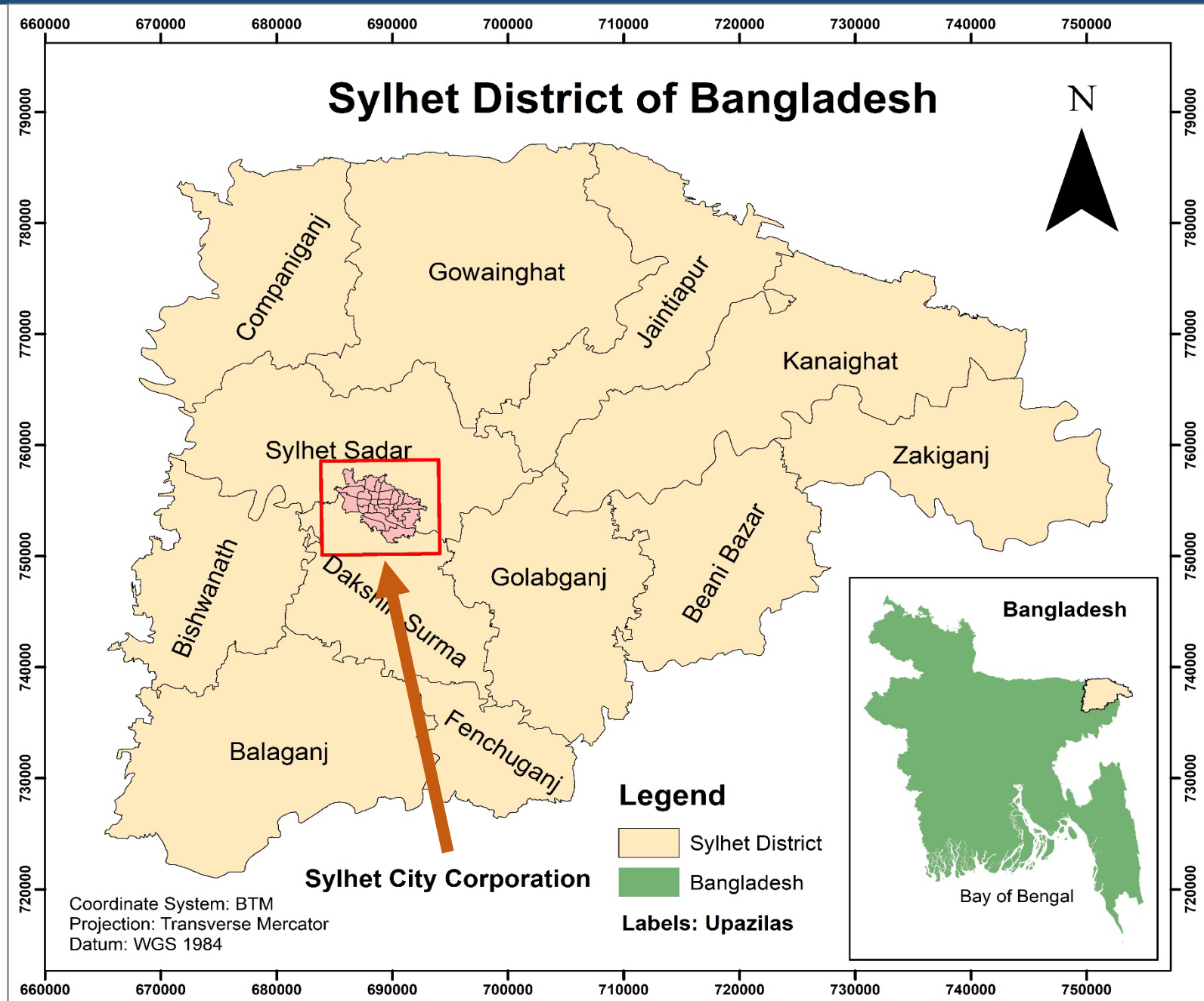
BACKGROUND OF THE STUDY

- Sylhet City is a metropolitan city in Sylhet district of northeastern Bangladesh
- Town is bordered by Surma River
- 23 canals flow through the area

- Major causes of drainage congestion
  - ➢ Heavy rainfall
  - ➢ Hilly catchments and steep terrain
  - ➢ Backwater effect of the Surma River
  - ➢ Unplanned Urbanization



BACKGROUND OF THE STUDY

Drainage Congestion in Londony Road Area at Ward No. 8 (Source: The Daily Sun; 17 June 2017)

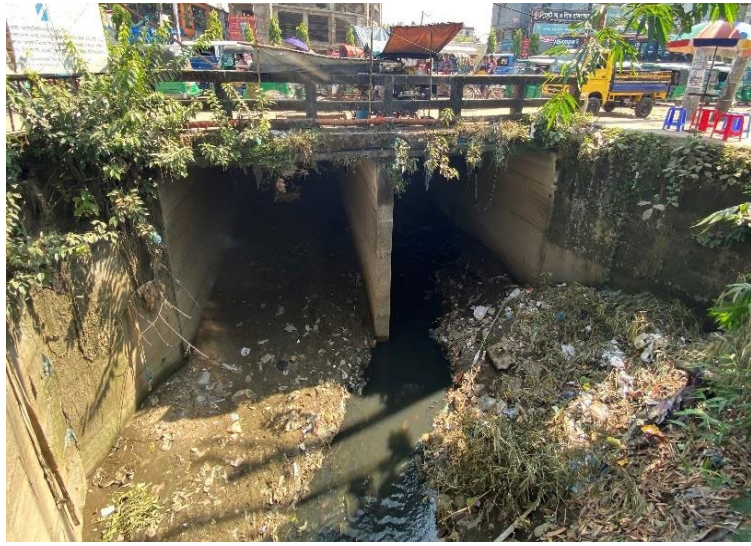
Congestion due to flash flood in Machimpur Area at Ward No. 15 (Source: The Daily Star; 20 July 2020)

BACKGROUND OF THE STUDY

Existing Drainage Condition at Different Locations in 2021

Upashahar chhara at Ward No.22

Upashahar chhara at Ward No.22



Upashahar chhara at Ward No. 23

Goali chhara and Surma River

Malni chhara and Surma River

Roadside gutter at Ward No. 14

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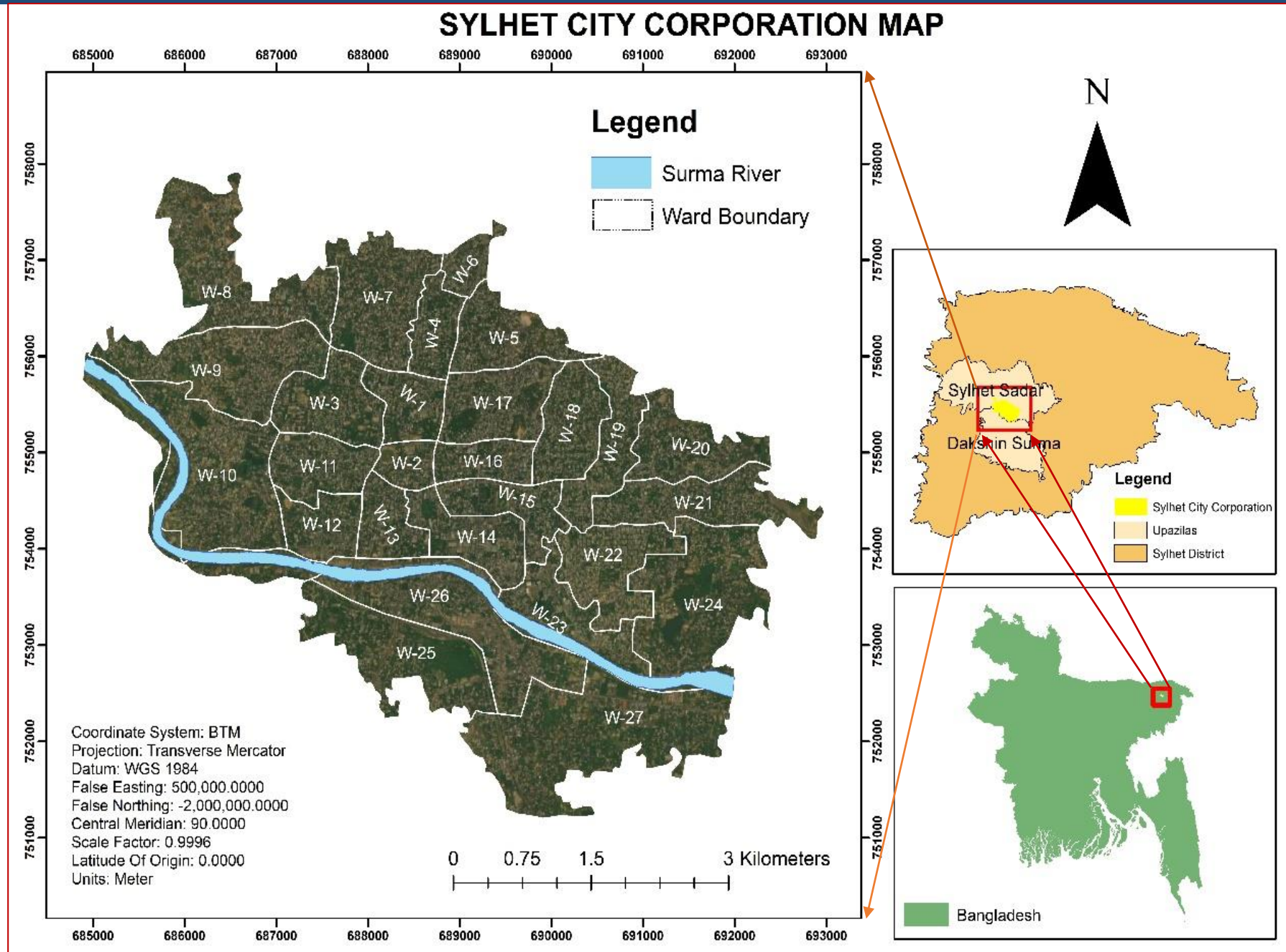
STUDY AREA

Sylhet City

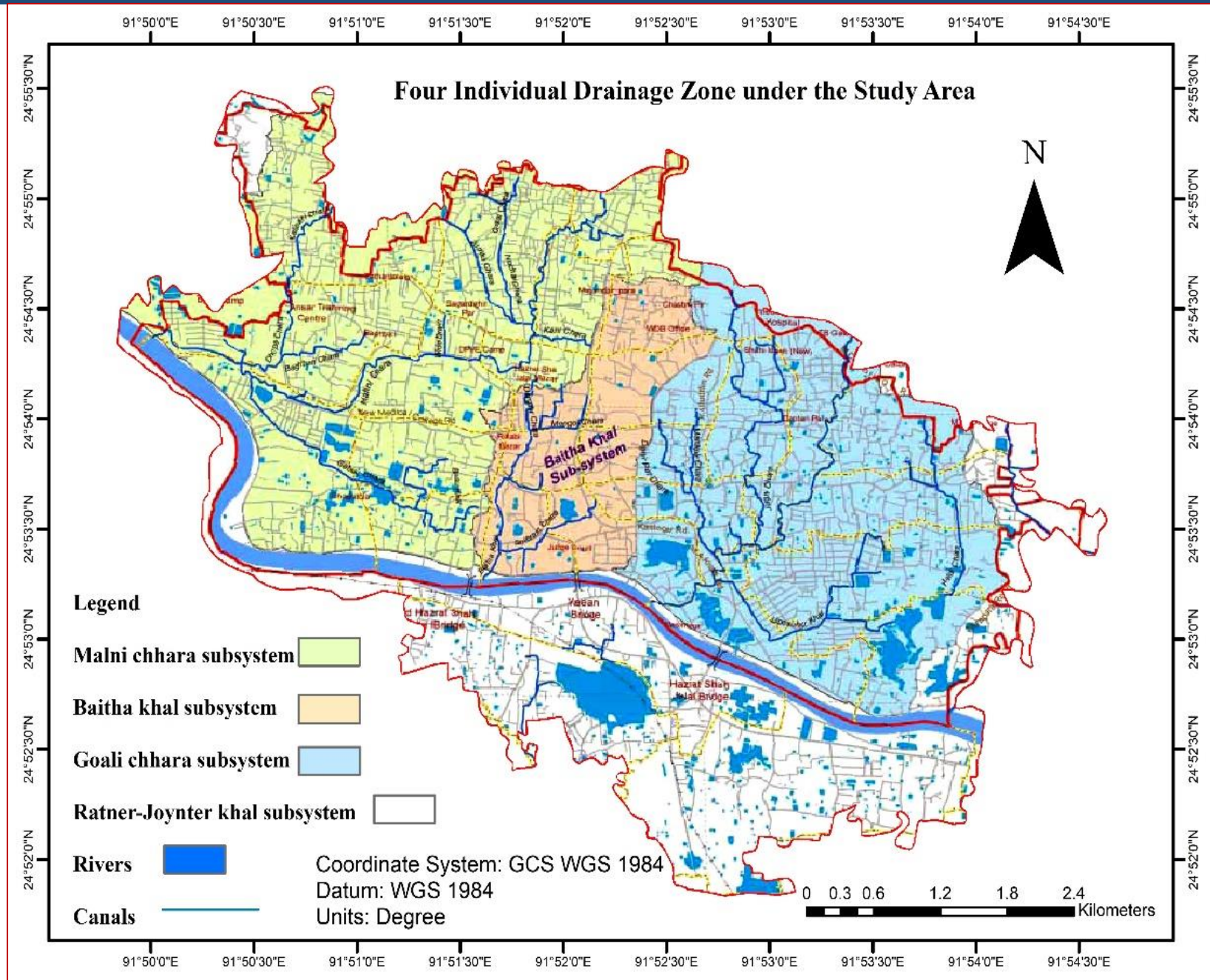
- Area = 26.5 sq. km.
- 7 metropolitan police stations and 27 wards
- Climate: Tropical Monsoon
- 23 canals, 450 km solid drains, 570 km non-solid drains and 51 culverts



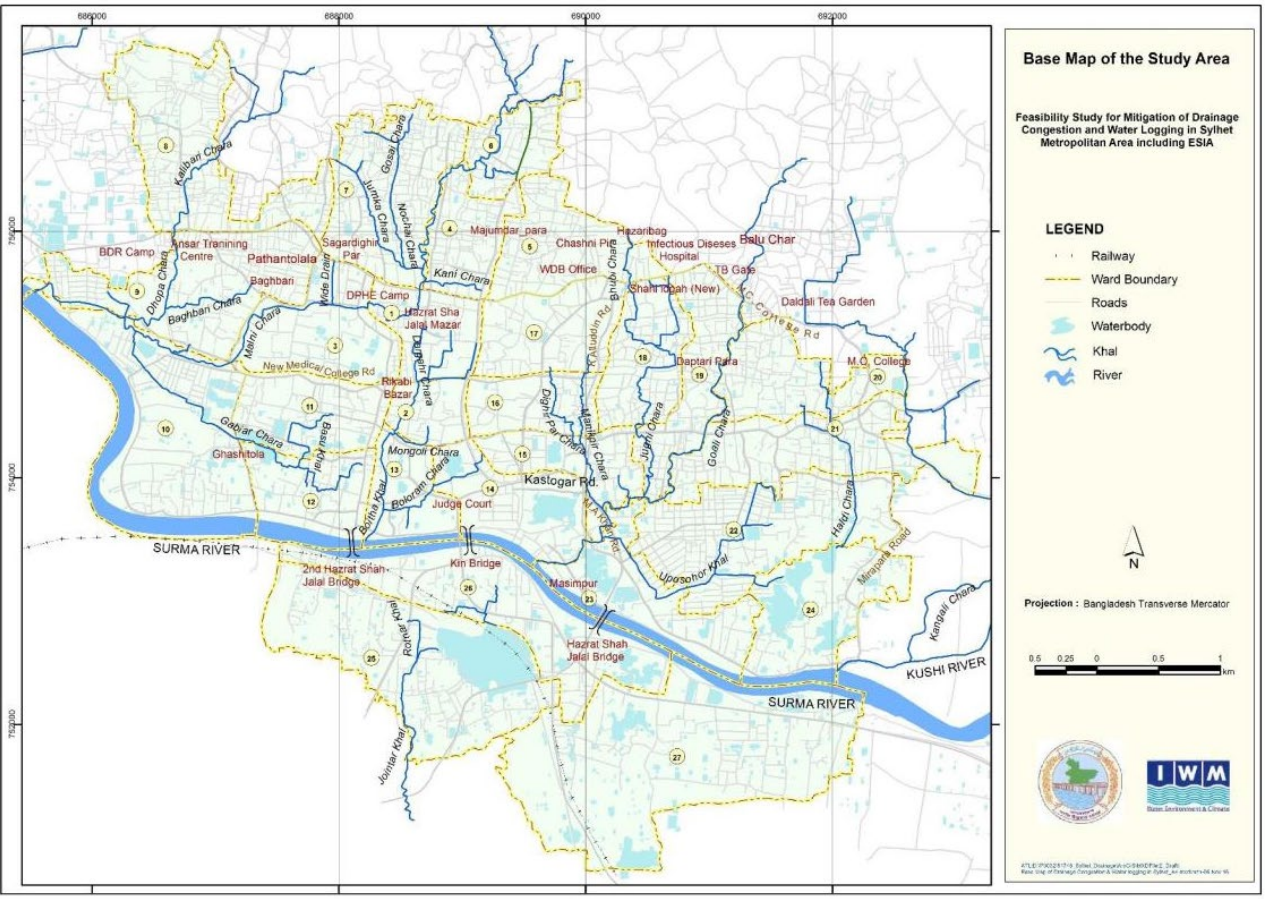
STUDY AREA

Sylhet City

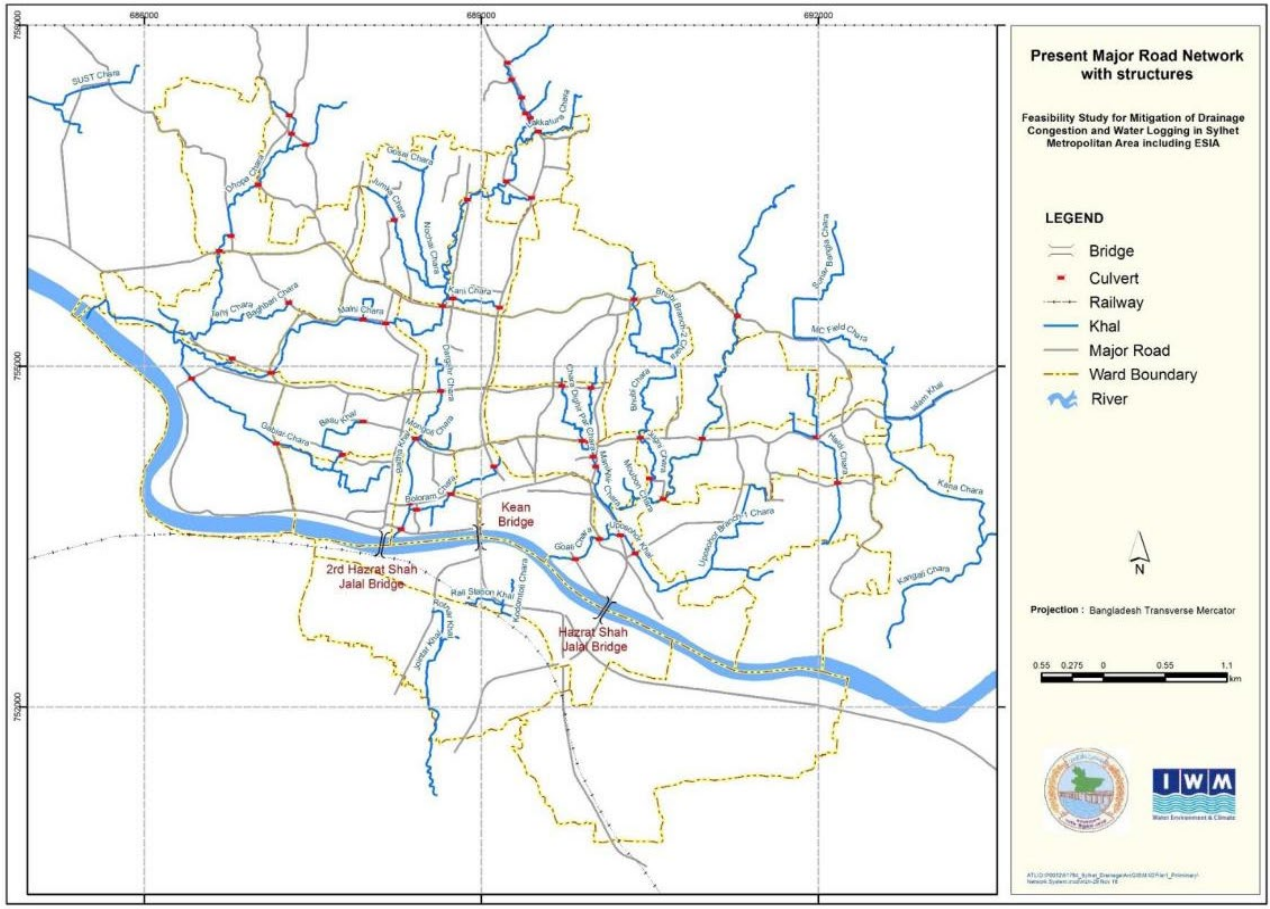
- 4 primary drainage sub-systems
- Extent for this study is Goali chhara sub-system



STUDY AREA

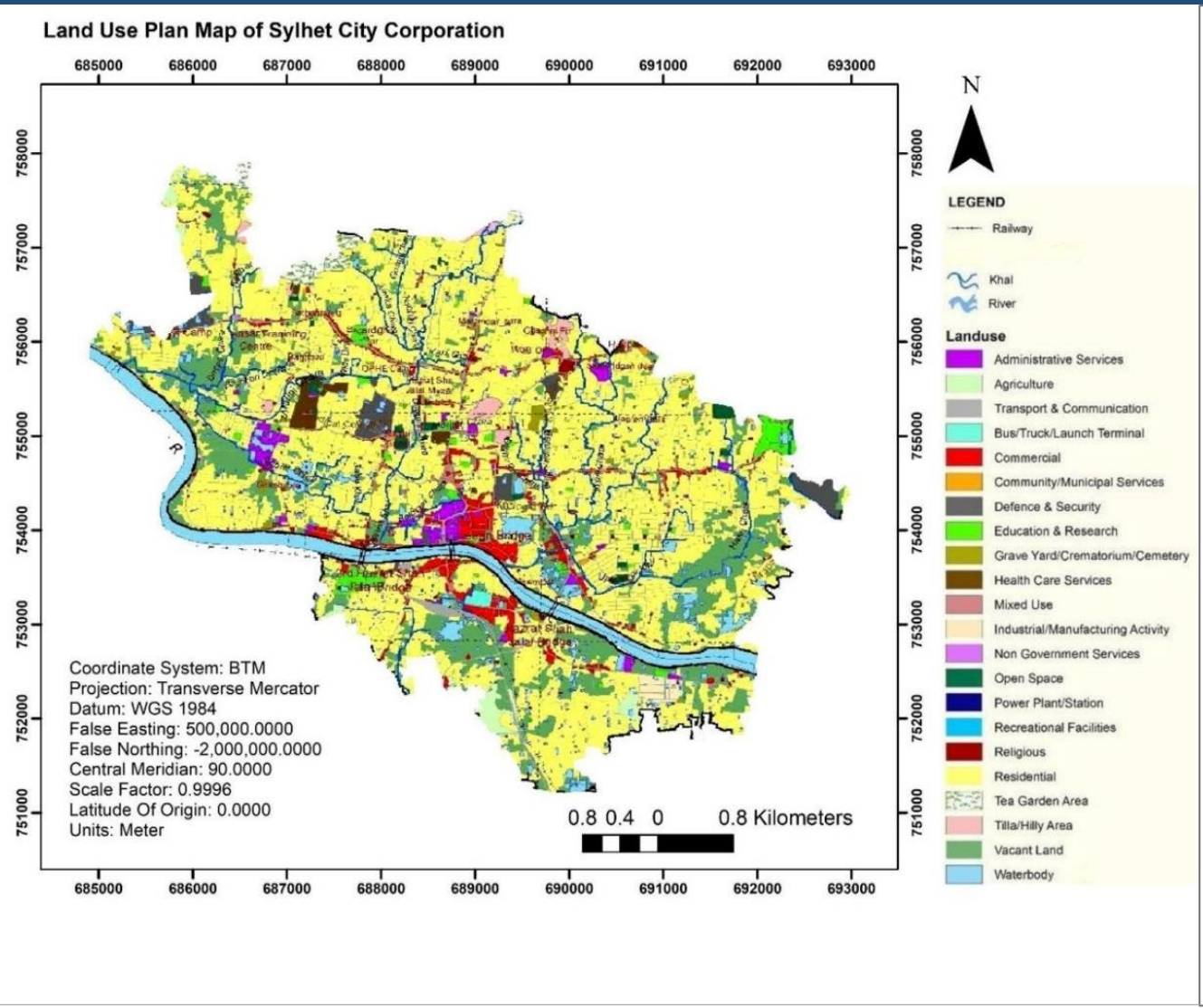


Canal Network and Waterbodies
(BWDB and IWM, 2017)

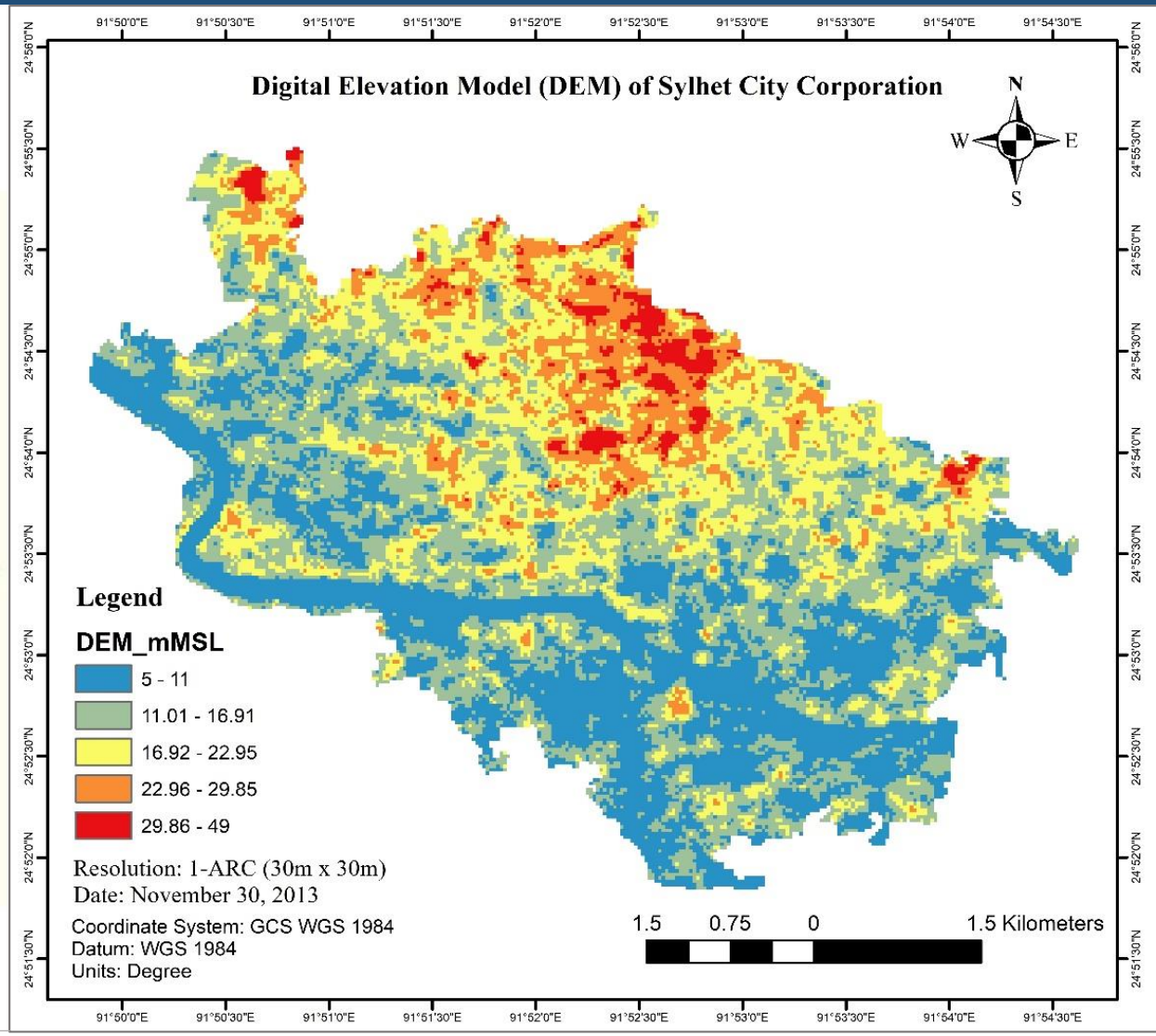


Present Major Road Network Map
(BWDB and IWM, 2017)

STUDY AREA



Existing Land Use Map (2010) *(UDD, 2010)*



DEM Map (Source: USGS)

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OBJECTIVES OF THE STUDY

I. To review existing drainage network and assess the drainage congestion problem in Sylhet City.

II. To estimate the hydrological parameters considering climate change effects.

III. To setup a GeoSWMM model for Goali chhara sub-system of Sylhet City.

IV. To simulate drainage scenarios for peak flood of the model area and estimate the requirements of drainage structures using model simulation method.

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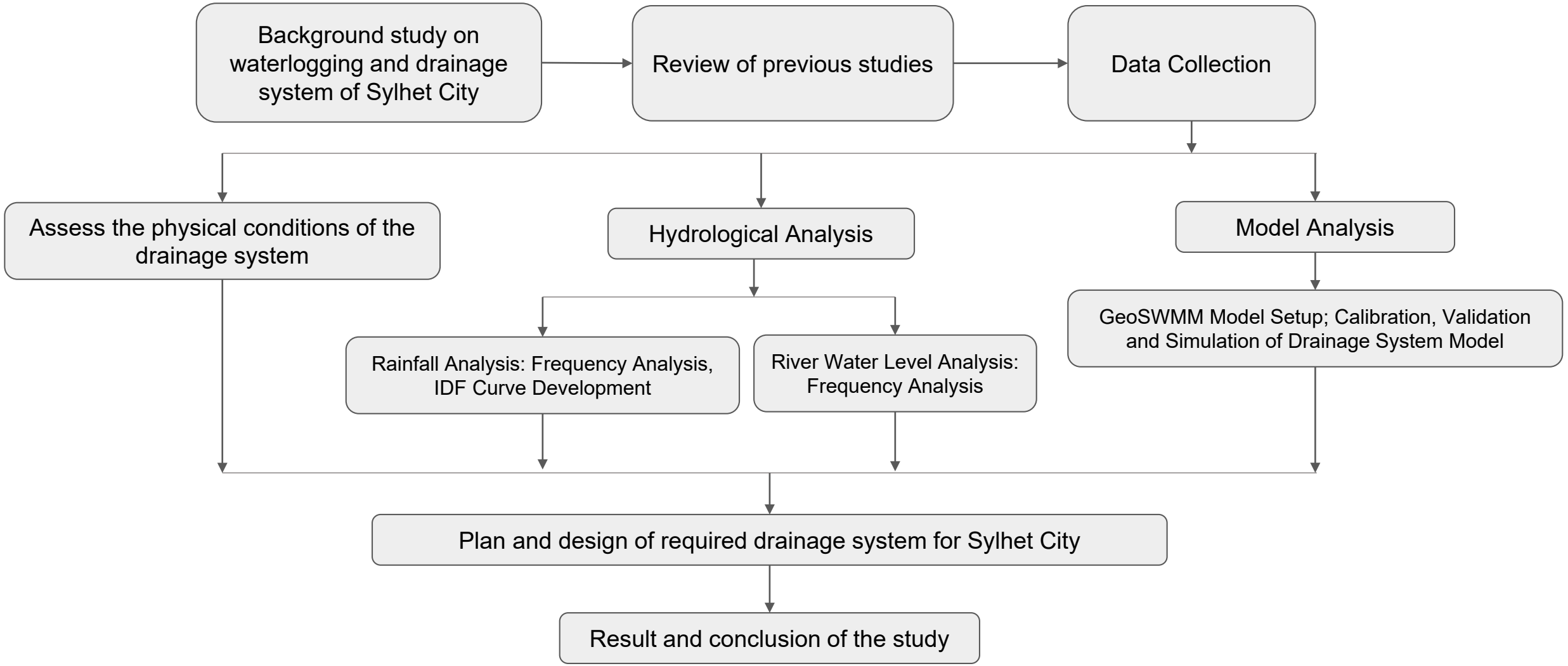
METHODOLOGY



Methodology Flowchart

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DATA COLLECTION

Summary of Data Collection

	Data Type	Data Source	ID	Period (Year)
Primary Data ←	Pictorial Images	Reconnaissance Survey and Field Visit		10 Oct – 12 Oct 2021
Secondary Data	Canal and Road Network	BWDB and IWM	-	2017
	Land Use Map	UDD	-	2010
	DEM (30m x 30m)	USGS	Entity ID: ASTGTMV 003N24E091	2013
	Rainfall Data	BWDB	Station: CL128	1980 – 2020
	Water Level Data	BWDB	Station: SW267	1980 – 2020

* BWDB = Bangladesh Water Development Board
IWM = Institute of Water Modelling
UDD = Urban Development Directorate
USGS = United States Geological Survey

DATA COLLECTION

Pictorial Images captured during field visit from 10 Oct – 12 Oct 2021

Malni chhara at Ward No. 08

Goali chhara at Ward No. 15

Silt trap in Lackatoorah Tea Estate

Roadside drain at Ward No. 08

Missing links at Ward No. 08

Proposed silt trap in Goabari

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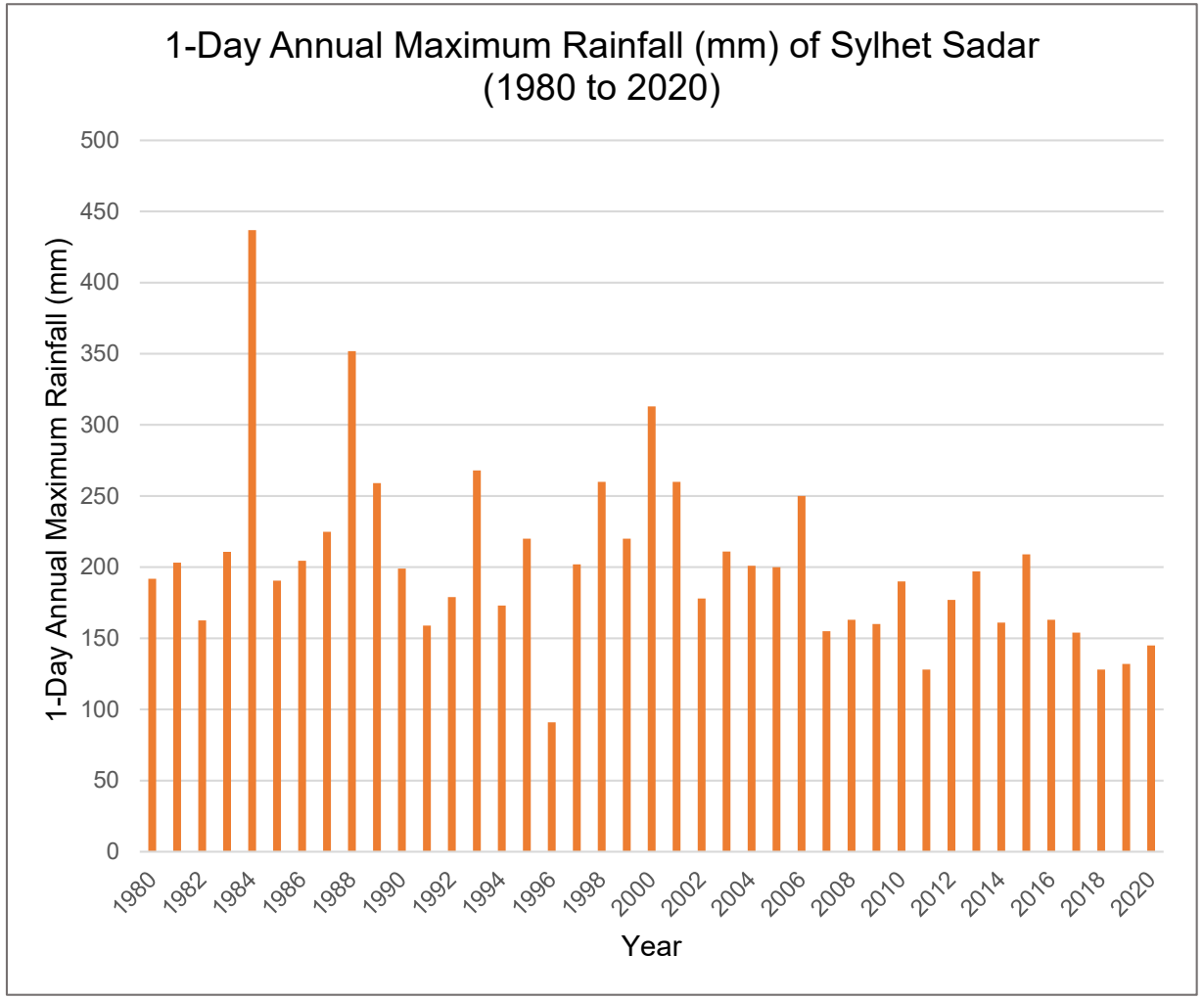
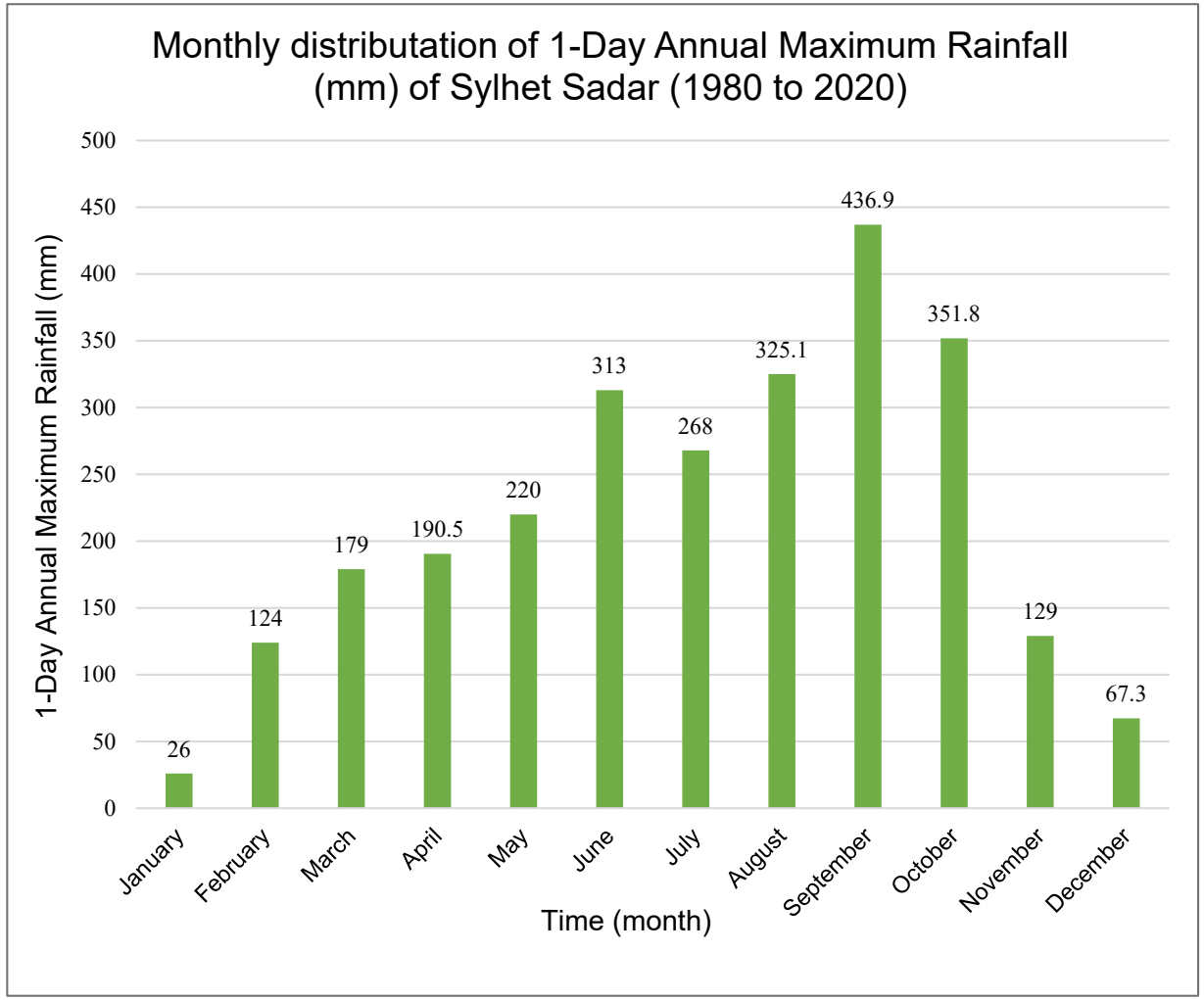
DATA ANALYSIS AND RESULT

Hydrological Analysis

Rainfall Analysis

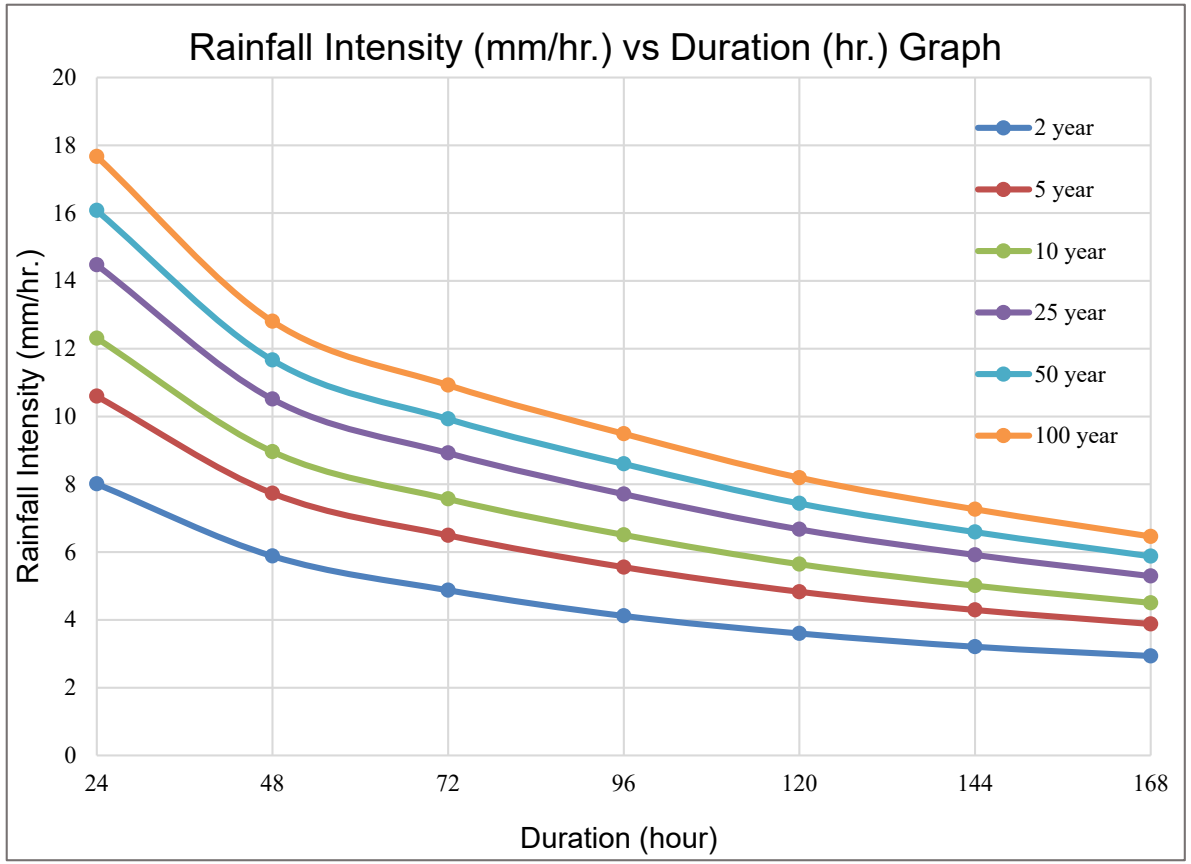




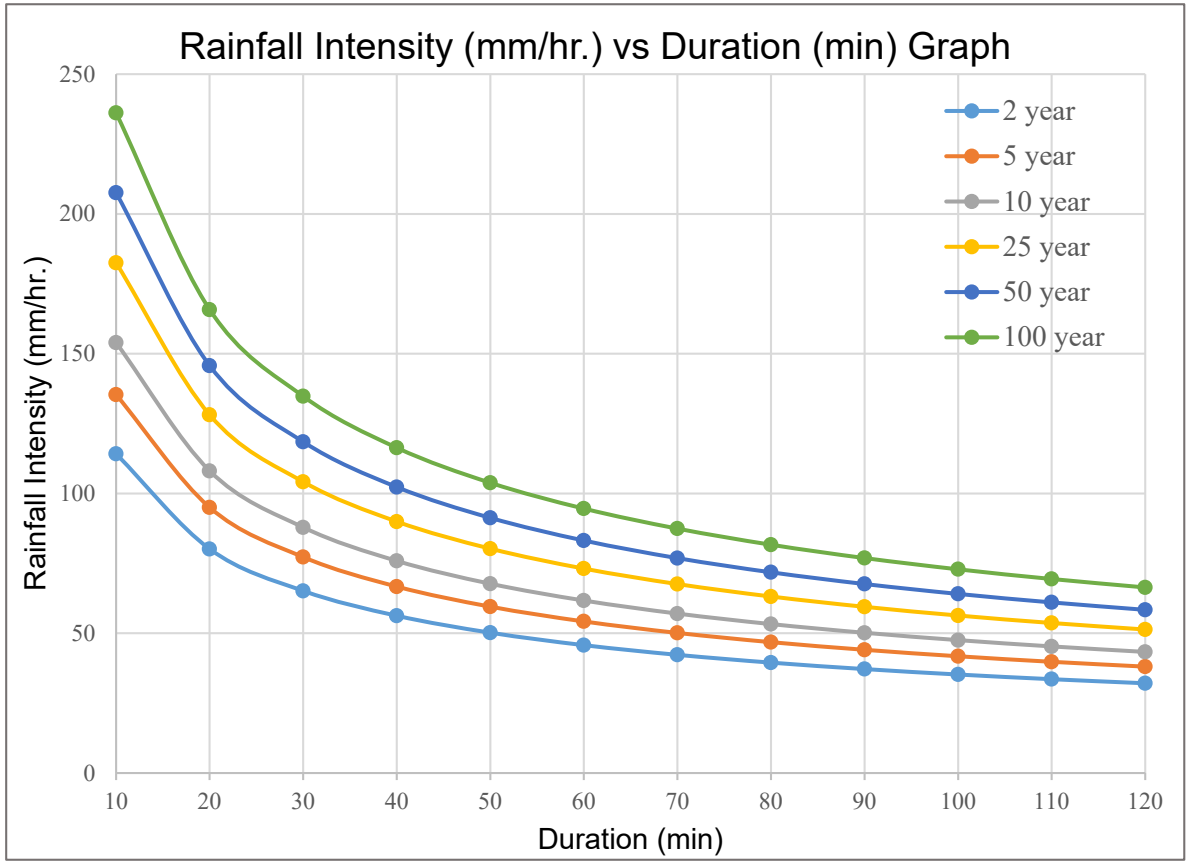
DATA ANALYSIS AND RESULT

Hydrological Analysis

Rainfall Analysis



IDF curve for long-duration rainfall at Sylhet Sadar

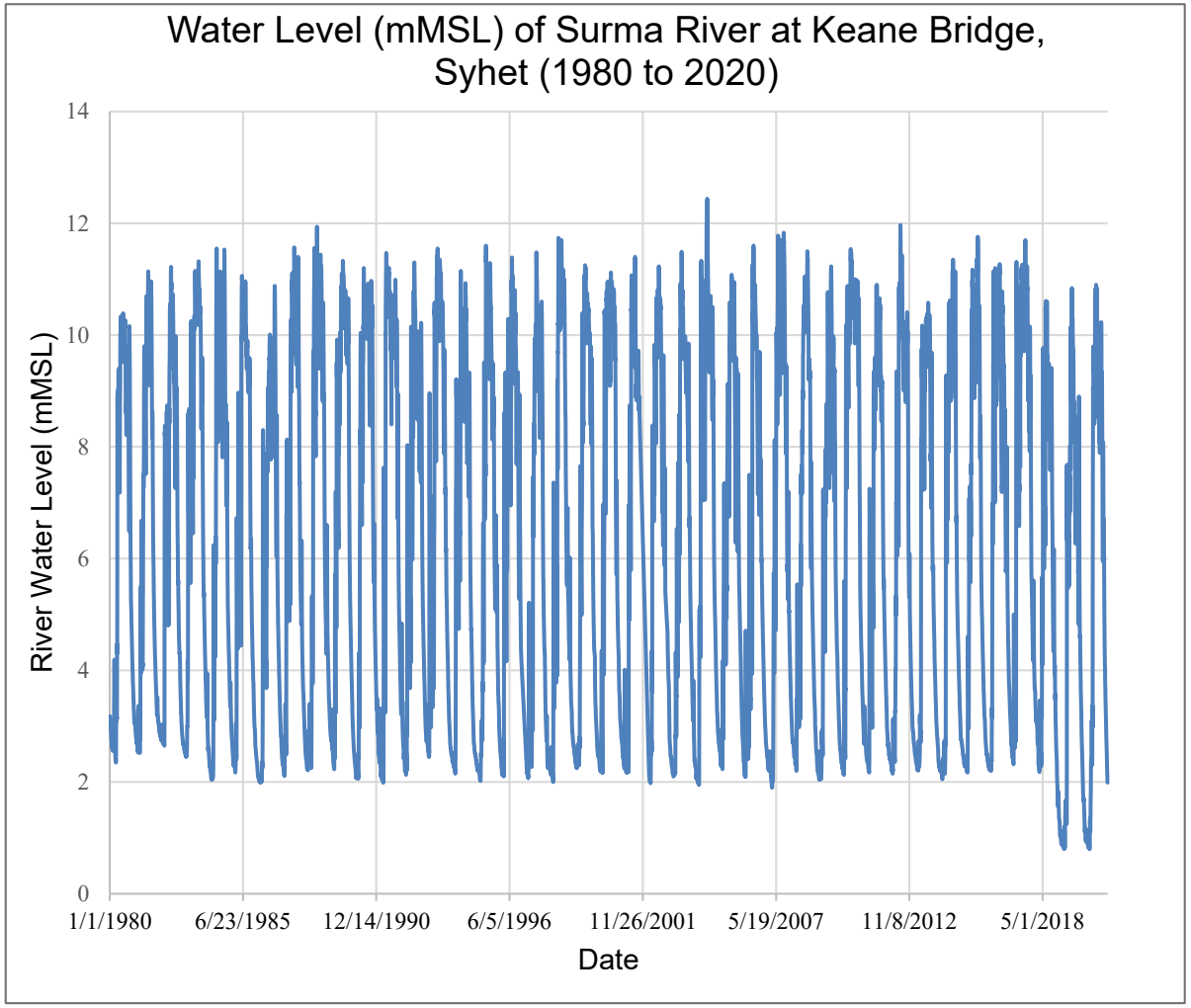


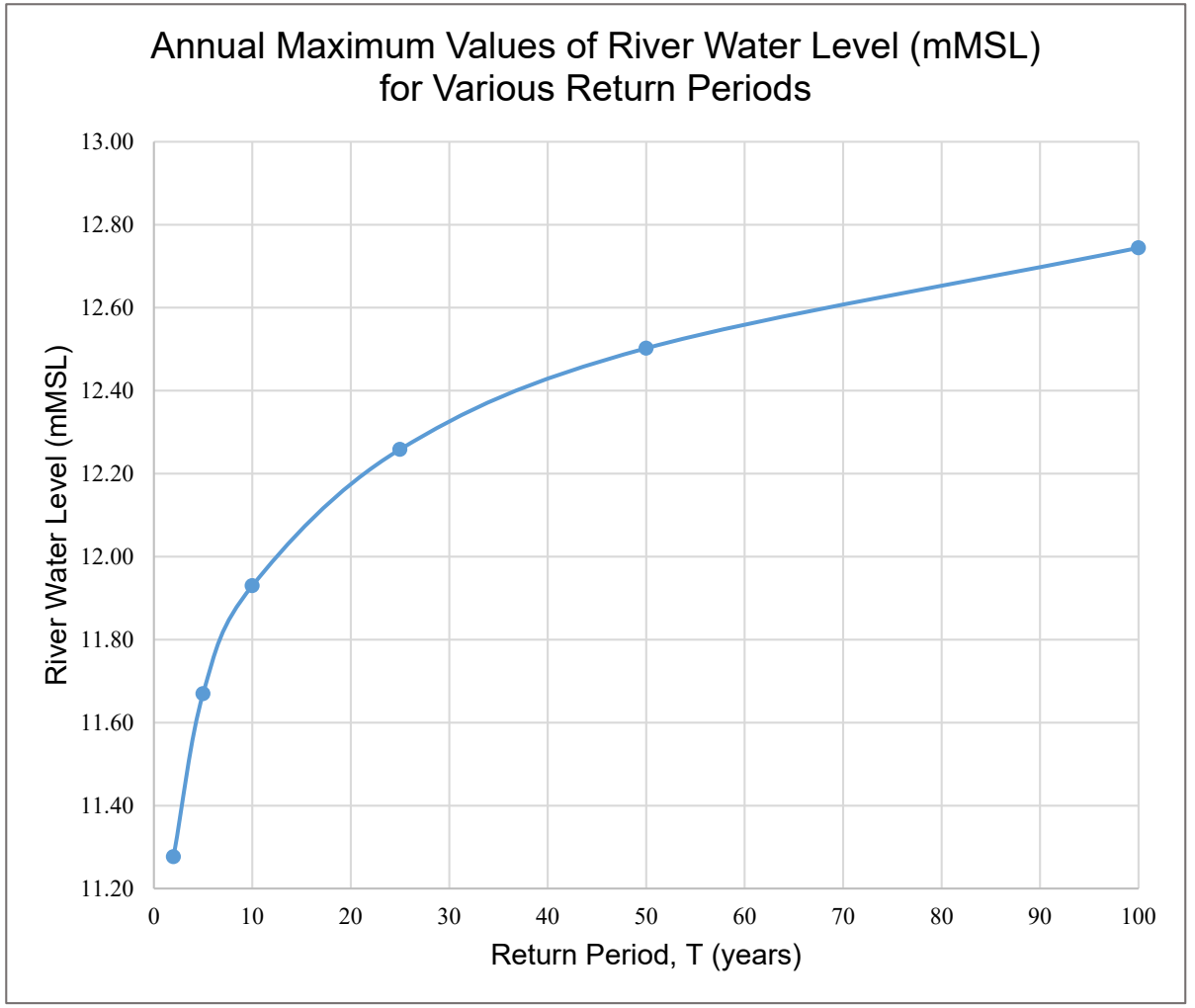
IDF Curve for short-duration rainfall at Sylhet Sadar

DATA ANALYSIS AND RESULT

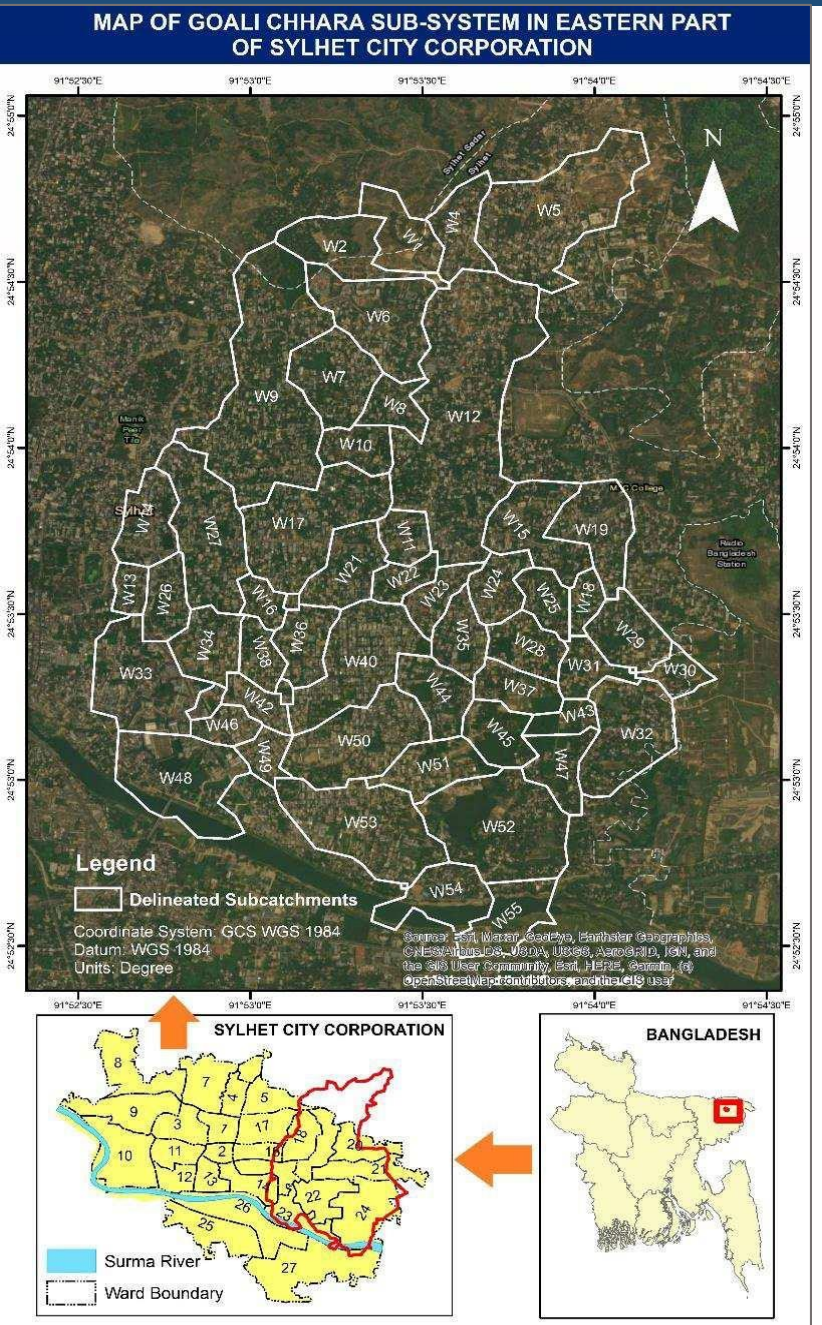
Hydrological Analysis

River Water Level Analysis



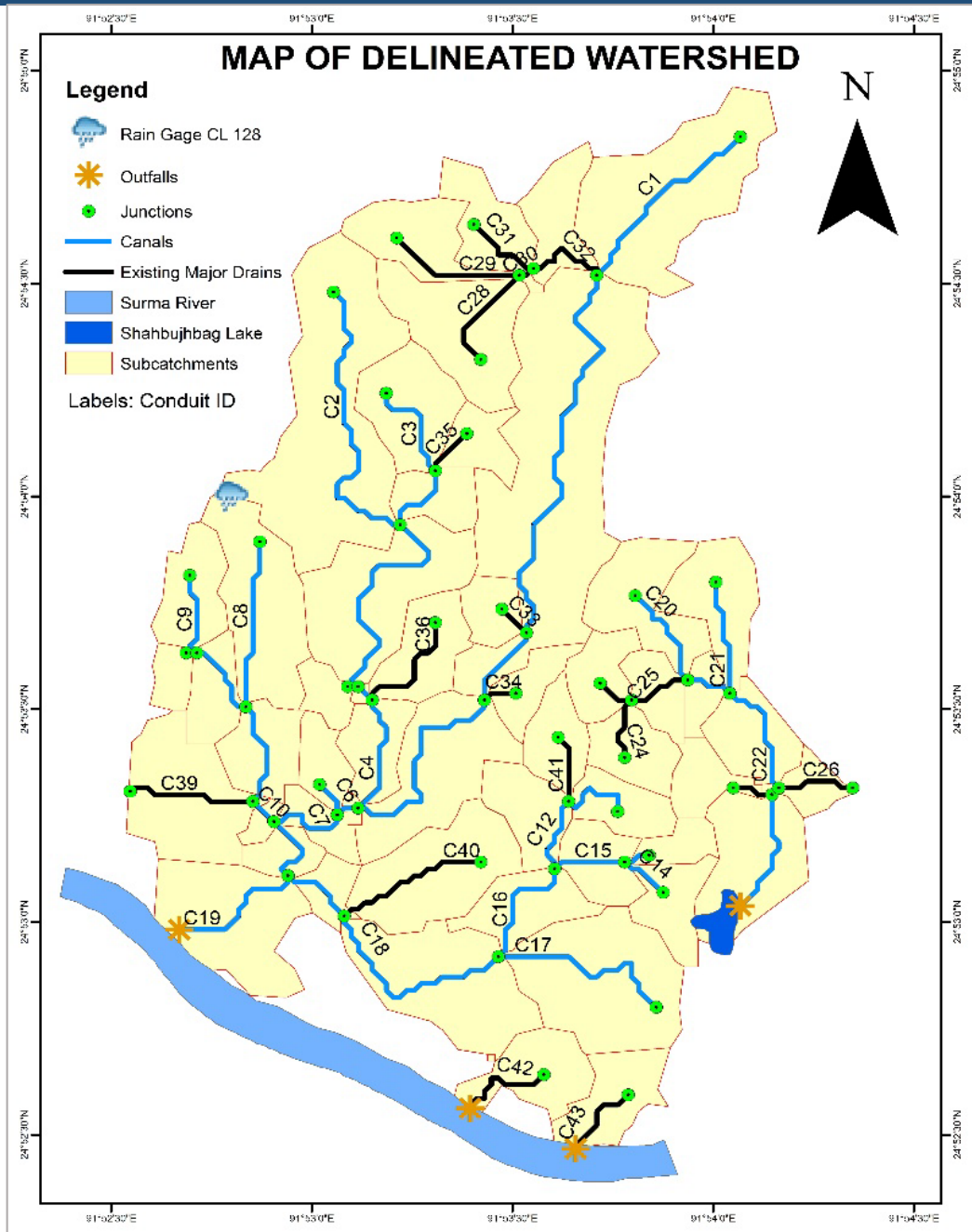


DATA ANALYSIS AND RESULT



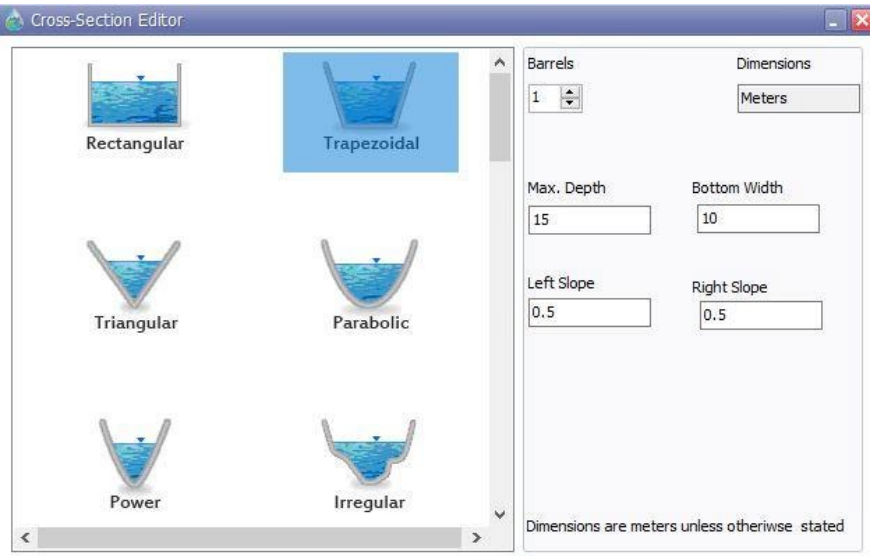
Model Setup for Goali Chhara Sub-system

- Total area of subcatchments is 9.77 sq. km.
- Delineated into 55 subcatchments
- Avg. slope of subcatchments is 6.33%
- Design rainfall depth of 2hr-5year return period has been used

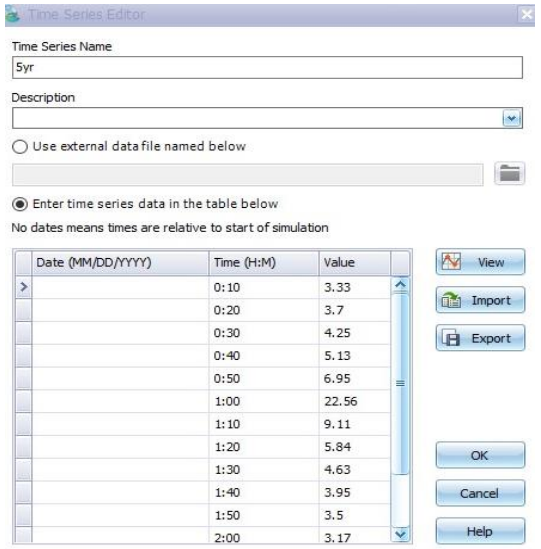


DATA ANALYSIS AND RESULT

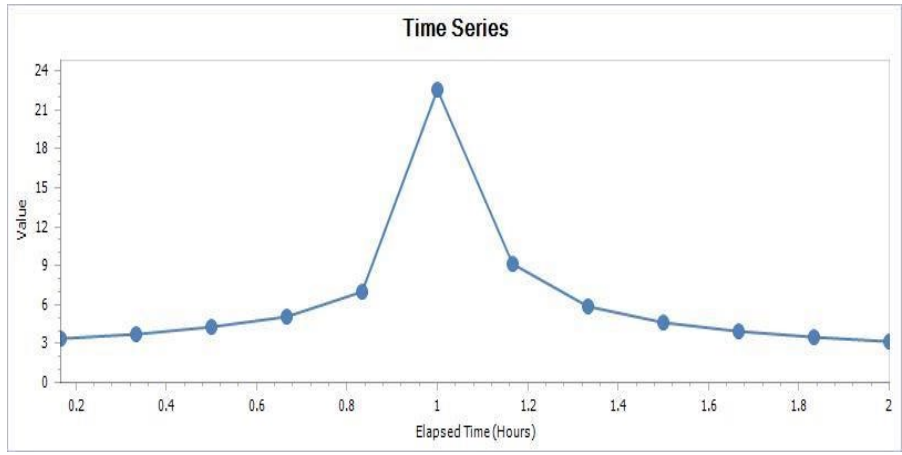
Model Input



Conduit Cross-section

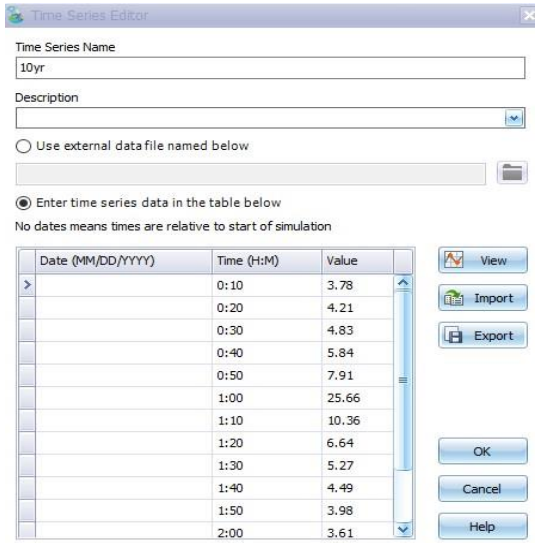


Setting Time Series, T=5-yr

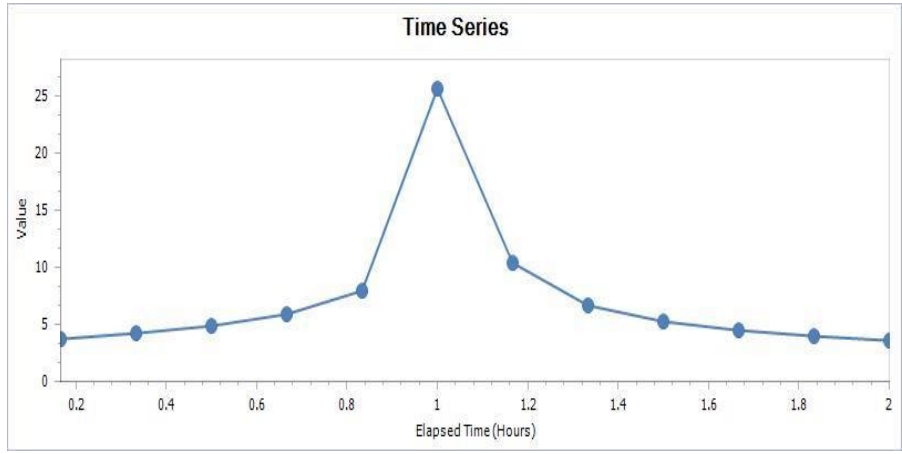


Rainfall Hydrograph, T=5-yr

Setting Rain Gage Information



Setting Time Series, T=10-yr



Rainfall Hydrograph, T=10-yr

DATA ANALYSIS AND RESULT

Link	Type	Max Flow CMS	Day of Max Flow	Hour of Max Flow	Max Velocity m/s	Max/Full Flow	Max Full Depth
C1	CONDUIT	5.35	0	1:35	1.54	0	0.03
C10	CONDUIT	3.13	0	0:52	2.13	1	1
C11	CONDUIT	15.17	0	1:23	1.69	0.01	0.06
C12	CONDUIT	2.74	0	1:12	2.13	0.01	0.06
C13	CONDUIT	0.82	0	1:22	0.09	0.01	0.06
C14	CONDUIT	0.51	0	1:11	0.15	1	1
C15	CONDUIT	4	0	1:11	1.94	0.02	0.08
C16	CONDUIT	0.29	0	0:45	0.11	1	1
C17	CONDUIT	1.66	0	0:54	1.46	1	1
C18	CONDUIT	4.31	0	2:28	0.25	0.73	0.7
C19	CONDUIT	19	0	2:39	0.25	0.24	0.44
C2	CONDUIT	17.25	0	1:14	2.69	0.01	0.05
C20	CONDUIT	4.93	0	1:15	1.09	0	0.03
C21	CONDUIT	3.99	0	1:13	1.47	0	0.02
C22	CONDUIT	9.71	0	1:18	2.19	0.75	0.83
C23	CONDUIT	2.84	0	1:11	2.28	0.22	0.31
C24	CONDUIT	0.01	0	0:21	0.05	1	1
C25	CONDUIT	0.1	0	0:17	0.65	1	1
C26	CONDUIT	0.72	0	1:25	0.14	0.18	0.26
C27	CONDUIT	0.32	0	0:35	1.04	1	1
C28	CONDUIT	3.68	0	1:26	0.2	0.24	0.33
C29	CONDUIT	4.59	0	1:14	1.5	0.23	0.3
C3	CONDUIT	1.21	0	0:56	1.12	1	1
C30	CONDUIT	6.08	0	1:27	0.16	0.27	0.36
C31	CONDUIT	3.97	0	1:11	2.85	0.03	0.09
C32	CONDUIT	6.9	0	1:52	0.17	0.19	0.3
C33	CONDUIT	0.8	0	1:02	2.04	1	1
C34	CONDUIT	0.27	0	0:53	0.1	1	1
C35	CONDUIT	1.14	0	1:25	0.12	0.28	0.36
C36	CONDUIT	0.34	0	0:25	1.06	1	1
C37	CONDUIT	1.1	0	1:15	0.11	0.31	0.4
C38	CONDUIT	1.18	0	1:11	2.1	0.07	0.14
C39	CONDUIT	7.44	0	1:13	1.43	0.05	0.12
C4	CONDUIT	9.12	0	1:08	1.76	1	1
C40	CONDUIT	0.22	0	0:21	0.68	1	1
C41	CONDUIT	3.18	0	1:11	1.97	0.33	0.42
C42	CONDUIT	1.74	0	1:25	0.17	0.16	0.24
C43	CONDUIT	3.51	0	1:11	1.81	0.03	0.08
C5	CONDUIT	14.44	0	1:39	0.2	0.19	0.38
C6	CONDUIT	2.19	0	1:11	1.3	0	0.01
C7	CONDUIT	11.46	0	1:19	1.93	1	1
C8	CONDUIT	7.8	0	1:13	1.75	0	0.03
C9	CONDUIT	3.81	0	1:13	1.76	0	0.02

Model Output

Link Flow Summary

T = 5 year

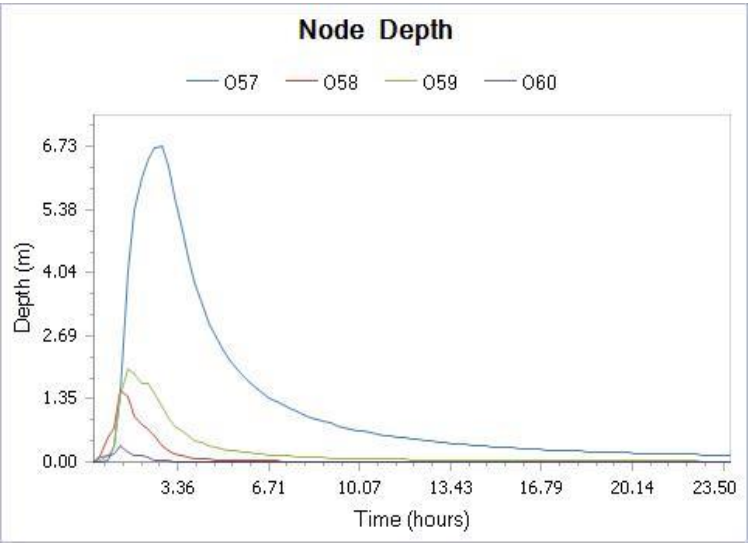
T = 10 year

* T = Time period

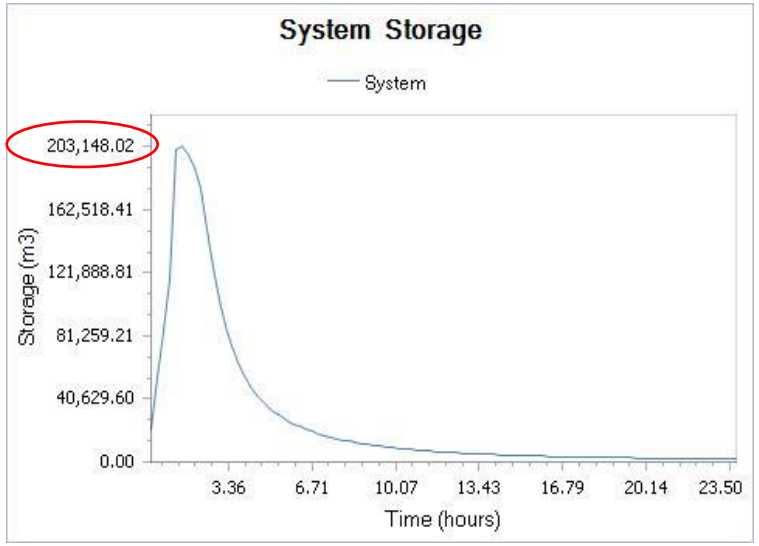
Link	Type	Max Flow CMS	Day of Max Flow	Hour of Max Flow	Max Velocity m/s	Max/Full Flow	Max Full Depth
C1	CONDUIT	6.21	0	1:25	1.62	0	0.03
C10	CONDUIT	3.13	0	0:46	2.2	1	1
C11	CONDUIT	15.87	0	1:14	1.73	0.01	0.06
C12	CONDUIT	3.14	0	1:12	2.23	0.01	0.06
C13	CONDUIT	0.96	0	1:18	0.1	0.01	0.07
C14	CONDUIT	0.51	0	1:08	0.15	1	1
C15	CONDUIT	4.56	0	1:11	2.03	0.02	0.09
C16	CONDUIT	0.29	0	0:42	0.11	1	1
C17	CONDUIT	1.66	0	0:47	1.51	1	1
C18	CONDUIT	4.6	0	2:29	0.25	0.78	0.72
C19	CONDUIT	19.79	0	2:43	0.26	0.25	0.45
C2	CONDUIT	19.93	0	1:14	2.85	0.01	0.05
C20	CONDUIT	5.67	0	1:15	1.16	0	0.04
C21	CONDUIT	4.58	0	1:12	1.54	0	0.02
C22	CONDUIT	11.31	0	1:18	2.28	0.88	0.91
C23	CONDUIT	3.26	0	1:11	2.38	0.25	0.35
C24	CONDUIT	0.01	0	0:20	0.05	1	1
C25	CONDUIT	0.1	0	0:16	0.65	1	1
C26	CONDUIT	0.83	0	1:25	0.15	0.2	0.29
C27	CONDUIT	0.32	0	0:30	1.06	1	1
C28	CONDUIT	4.33	0	1:25	0.21	0.29	0.37
C29	CONDUIT	5.26	0	1:13	1.56	0.26	0.33
C3	CONDUIT	1.21	0	0:52	1.16	1	1
C30	CONDUIT	7.06	0	1:27	0.16	0.31	0.4
C31	CONDUIT	4.54	0	1:11	2.99	0.04	0.1
C32	CONDUIT	8.05	0	1:49	0.18	0.23	0.33
C33	CONDUIT	0.8	0	1:01	2.04	1	1
C34	CONDUIT	0.27	0	0:48	0.1	1	1
C35	CONDUIT	1.32	0	1:25	0.13	0.32	0.4
C36	CONDUIT	0.34	0	0:23	1.07	1	1
C37	CONDUIT	1.29	0	1:15	0.12	0.37	0.45
C38	CONDUIT	1.36	0	1:11	2.21	0.08	0.16
C39	CONDUIT	8.58	0	1:13	1.51	0.06	0.13
C4	CONDUIT	9.12	0	1:06	1.81	1	1
C40	CONDUIT	0.22	0	0:20	0.68	1	1
C41	CONDUIT	3.64	0	1:11	2.04	0.38	0.47
C42	CONDUIT	2.05	0	1:25	0.17	0.19	0.27
C43	CONDUIT	4.03	0	1:11	1.9	0.03	0.09
C5	CONDUIT	15.31	0	1:38	0.2	0.2	0.4
C6	CONDUIT	2.51	0	1:11	1.37	0	0.01
C7	CONDUIT	11.46	0	1:12	1.93	1	1
C8	CONDUIT	8.97	0	1:13	1.84	0	0.04
C9	CONDUIT	4.39	0	1:13	1.86	0	0.02

DATA ANALYSIS AND RESULT

Model Output



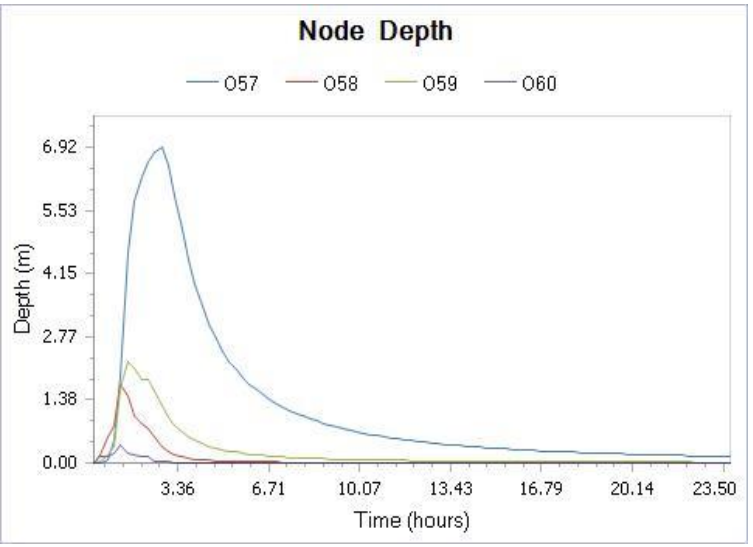
Outfall Depth vs Time (T = 5-year)



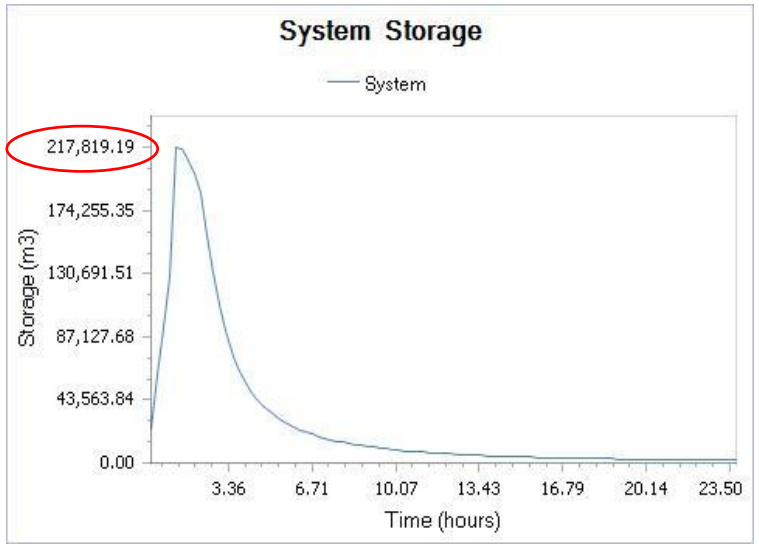
System Storage vs Time (T = 5-year)

Node	Hours Flooded	Maximum Rate CMS	Time of Max Occurrence days hr:min	Total Flood Volume 10^6 ltr	Maximum Ponded Volume 1000 m3
J4	0.95	4.480	0 01:10	4.054	0.000
J5	0.63	16.035	0 01:12	15.611	0.000
J7	0.94	3.848	0 01:39	8.655	0.000
J10	1.10	11.251	0 01:13	12.419	0.000
J14	2.69	9.922	0 01:11	22.973	0.000
J16	0.51	1.243	0 01:10	0.885	0.000
J17	0.97	6.282	0 01:10	5.733	0.000
J18	0.33	5.502	0 01:10	3.163	0.000
J29	0.36	1.197	0 01:10	0.725	0.000
J31	1.81	1.941	0 01:10	2.605	0.000
J35	1.96	4.083	0 01:10	6.449	0.000
J43	2.16	7.930	0 01:10	14.911	0.000
J47	2.56	3.129	0 01:10	6.316	0.000
J48	2.38	5.155	0 01:10	10.500	0.000
J50	1.50	1.630	0 01:10	1.851	0.000

Node Flooding (T = 5-year)



Outfall Depth vs Time (T = 10-year)



System Storage vs Time (T = 10-year)

Node	Hours Flooded	Maximum Rate CMS	Time of Max Occurrence days hr:min	Total Flood Volume 10^6 ltr	Maximum Ponded Volume 1000 m3
J4	1.16	5.286	0 01:10	5.229	0.000
J5	0.80	19.898	0 01:12	20.608	0.000
J7	1.34	4.840	0 01:38	12.798	0.000
J10	1.33	13.481	0 01:12	16.011	0.000
J14	2.73	11.428	0 01:11	26.369	0.000
J16	0.66	1.487	0 01:10	1.153	0.000
J17	1.22	7.405	0 01:10	7.389	0.000
J18	0.37	6.810	0 01:10	4.256	0.000
J29	0.40	1.484	0 01:10	0.975	0.000
J31	1.87	2.258	0 01:10	3.216	0.000
J35	1.99	4.702	0 01:10	7.679	0.000
J43	2.17	9.071	0 01:10	17.208	0.000
J47	2.57	3.568	0 01:10	7.203	0.000
J48	2.40	5.917	0 01:10	12.056	0.000
J50	1.73	1.911	0 01:10	2.362	0.000

Node Flooding (T = 10-year)

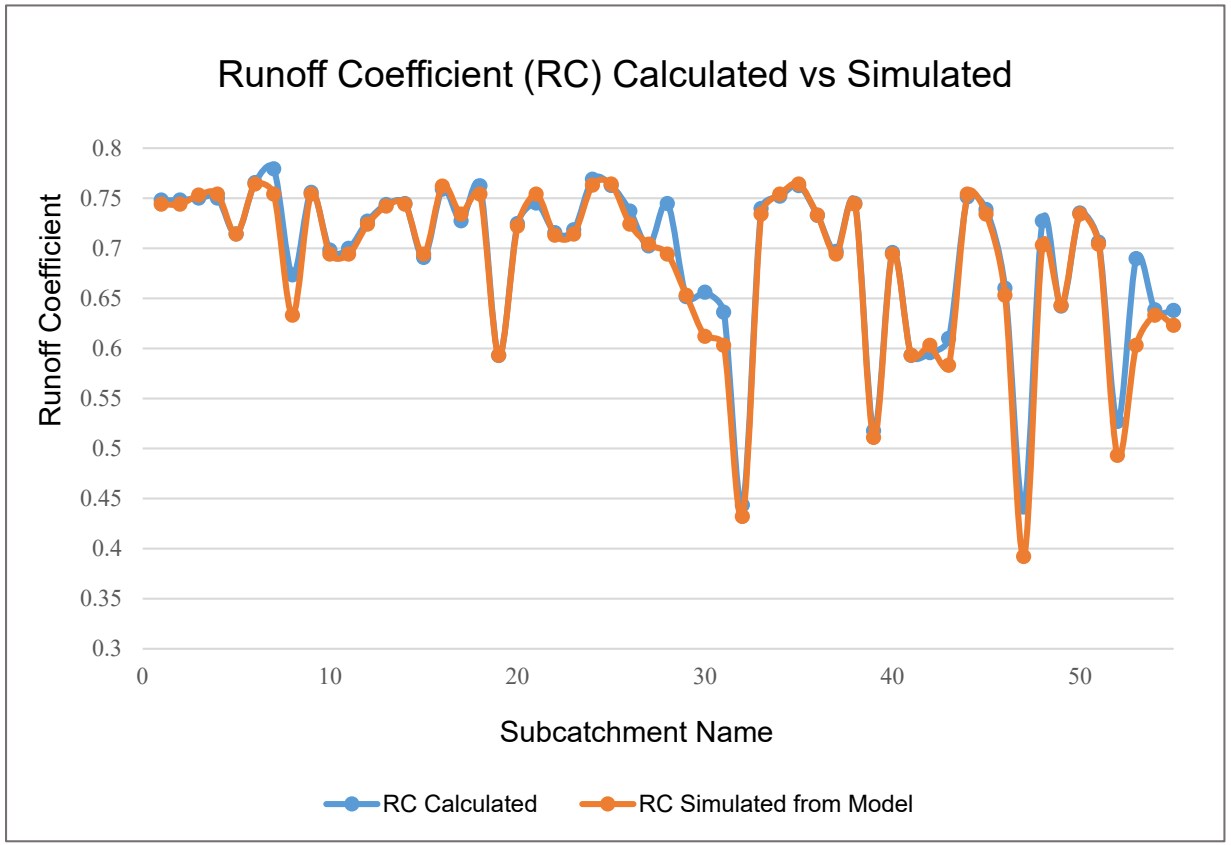
DATA ANALYSIS AND RESULT

Calibration of GeoSWMM Model

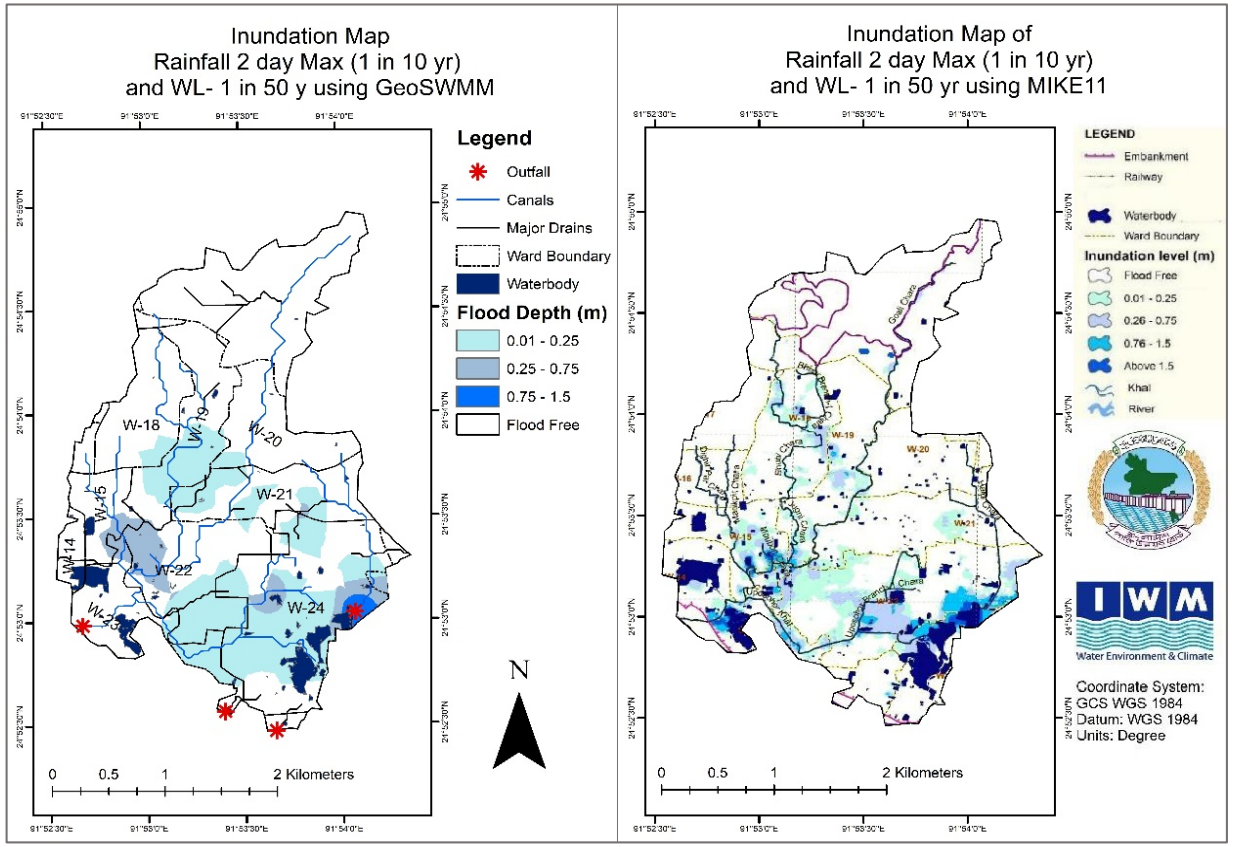
- Model was calibrated comparing with runoff coefficients obtained from the model simulation with the estimated values

Validation of GeoSWMM Model

- Total inundated area in GeoSWMM model simulation is 2.15 km^2
- Total inundated area in BWDB-IWM study is 1.9 km^2



Comparison of Runoff Coefficients between calculated and simulated from the model



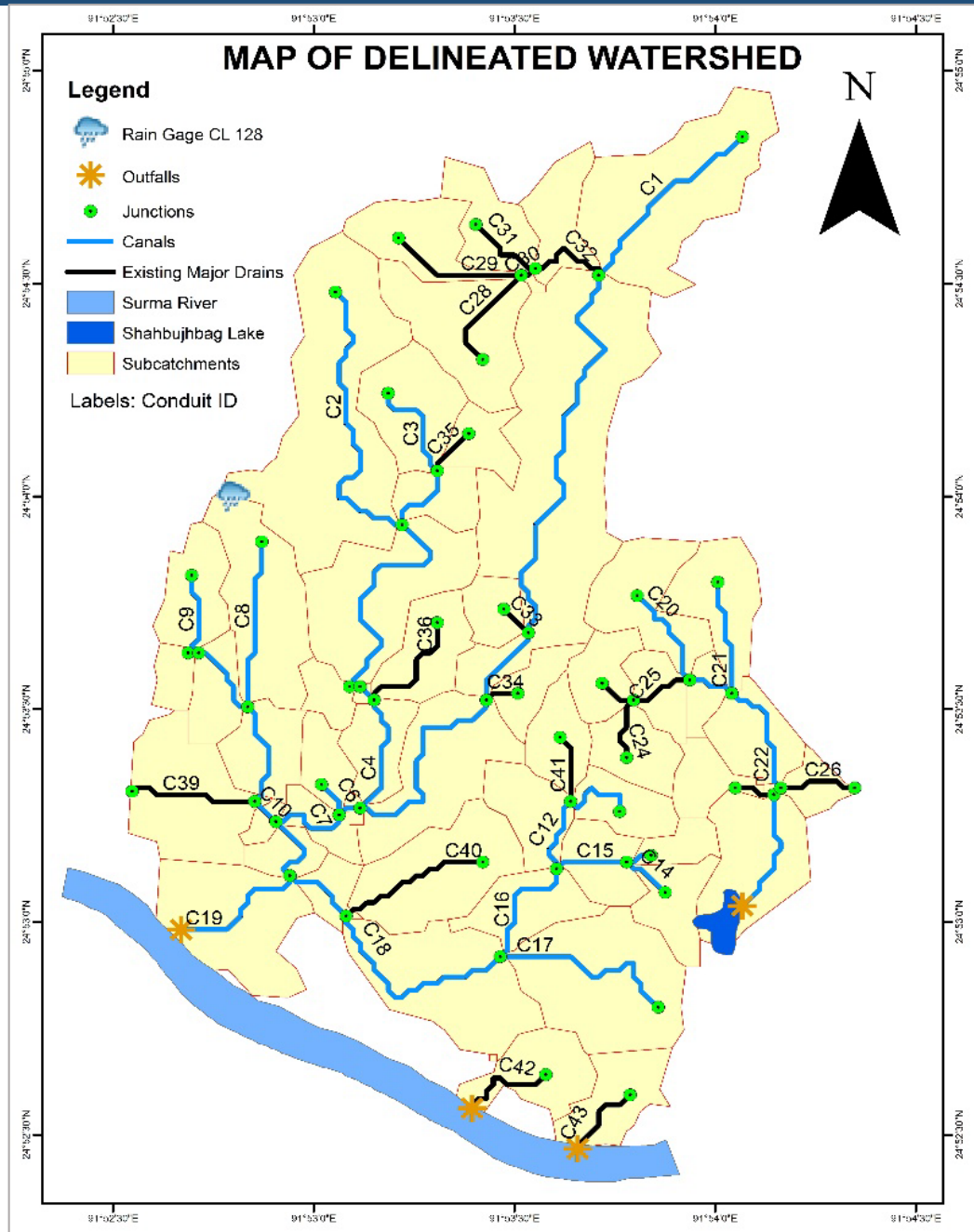
Inundation Map of Goali chhara Sub-system simulated in GeoSWMM model and BWDB-IWM study

DATA ANALYSIS AND RESULT

Conduit ID	Peak Flow, Q (cumec) T = 5-yr	Peak Flow, Q (cumec) T = 10-yr	Area, A (sq. m.) T = 5-yr	Area, A (sq. m.) T = 10-yr	Conduit Shape
C1	5.35	6.21	6.6875	7.7625	Trapezoidal
C10	3.13	3.13	3.9125	3.9125	Trapezoidal
C11	15.17	15.87	18.9625	19.8375	Trapezoidal
C12	2.74	3.14	3.425	3.925	Trapezoidal
C13	0.82	0.96	1.025	1.2	Trapezoidal
C14	0.51	0.51	0.6375	0.6375	Trapezoidal
C15	4	4.56	5	5.7	Trapezoidal
C16	0.29	0.29	0.3625	0.3625	Trapezoidal
C17	1.66	1.66	2.075	2.075	Trapezoidal
C18	4.31	4.6	5.3875	5.75	Trapezoidal
C19	19	19.79	23.75	24.7375	Trapezoidal
C2	17.25	19.93	21.5625	24.9125	Trapezoidal
C20	4.93	5.67	6.1625	7.0875	Trapezoidal
C21	3.99	4.58	4.9875	5.725	Trapezoidal
C22	9.71	11.31	12.1375	14.1375	Trapezoidal
C23	2.84	3.26	3.55	4.075	Rectangular
C24	0.01	0.01	0.0125	0.0125	Rectangular
C25	0.1	0.1	0.125	0.125	Rectangular
C26	0.72	0.83	0.9	1.0375	Rectangular
C27	0.32	0.32	0.4	0.4	Rectangular
C28	3.68	4.33	4.6	5.4125	Rectangular
C29	4.59	5.26	5.7375	6.575	Rectangular

Determination of Conduit Cross-section

- Using Continuity equation, Q=A x V
- V = 0.8 m/s (non-silting, non-scouring velocity)

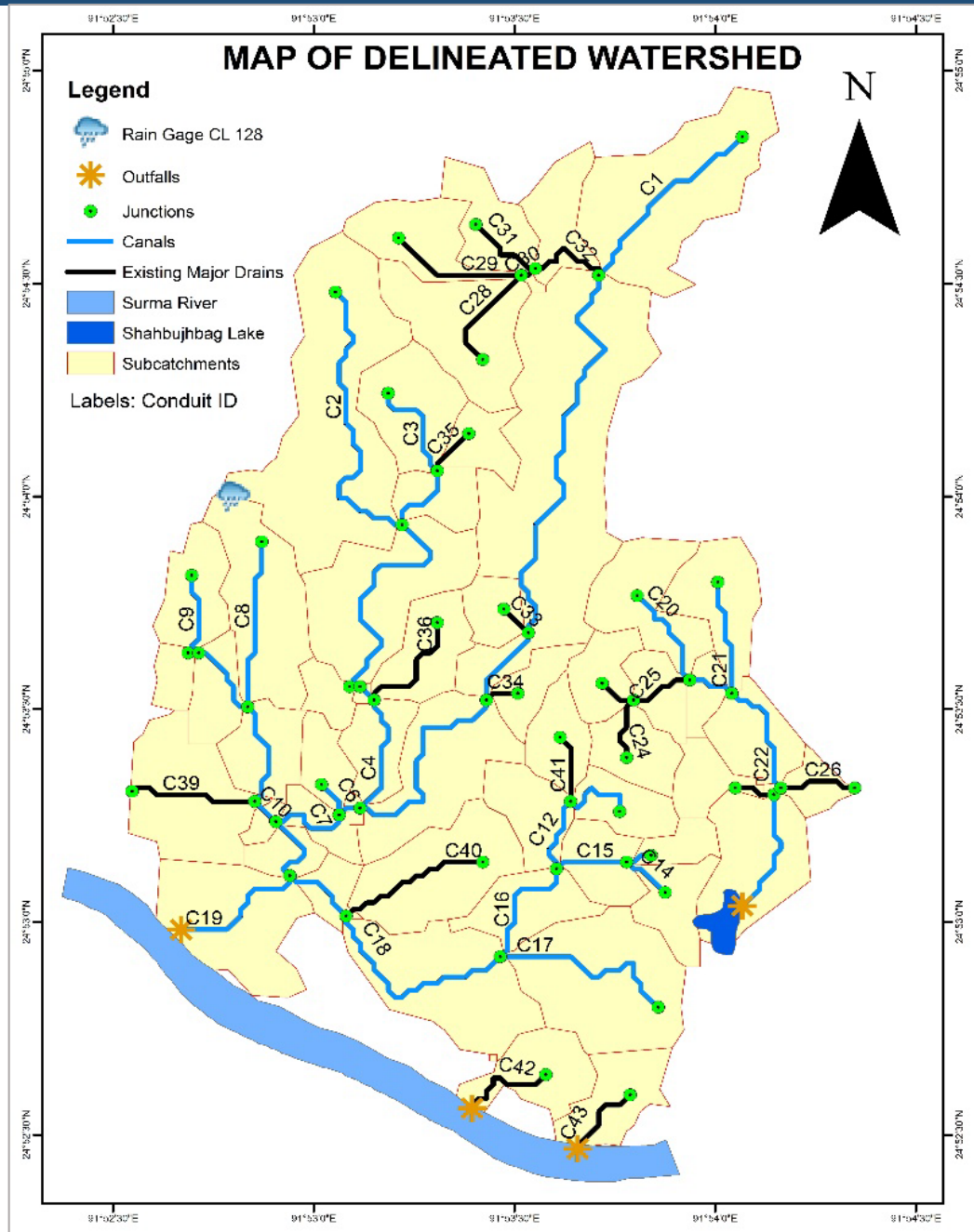


DATA ANALYSIS AND RESULT

Conduit ID	Peak Flow, Q (cumec) T = 5-yr	Peak Flow, Q (cumec) T = 10-yr	Area, A (sq. m.) T = 5-yr	Area, A (sq. m.) T = 10-yr	Conduit Shape
C3	1.21	1.21	1.5125	1.5125	Trapezoidal
C30	6.08	7.06	7.6	8.825	Rectangular
C31	3.97	4.54	4.9625	5.675	Rectangular
C32	6.9	8.05	8.625	10.0625	Rectangular
C33	0.8	0.8	1	1	Rectangular
C34	0.27	0.27	0.3375	0.3375	Rectangular
C35	1.14	1.32	1.425	1.65	Rectangular
C36	0.34	0.34	0.425	0.425	Rectangular
C37	1.1	1.29	1.375	1.6125	Rectangular
C38	1.18	1.36	1.475	1.7	Rectangular
C39	7.44	8.58	9.3	10.725	Rectangular
C4	9.12	9.12	11.4	11.4	Trapezoidal
C40	0.22	0.22	0.275	0.275	Rectangular
C41	3.18	3.64	3.975	4.55	Rectangular
C42	1.74	2.05	2.175	2.5625	Rectangular
C43	3.51	4.03	4.3875	5.0375	Rectangular
C5	14.44	15.31	18.05	19.1375	Trapezoidal
C6	2.19	2.51	2.7375	3.1375	Trapezoidal
C7	11.46	11.46	14.325	14.325	Trapezoidal
C8	7.8	8.97	9.75	11.2125	Trapezoidal
C9	3.81	4.39	4.7625	5.4875	Trapezoidal

Determination of Conduit Cross-section

- Using Continuity equation, Q=A x V
- V = 0.8 m/s (non-silting, non-scouring velocity)

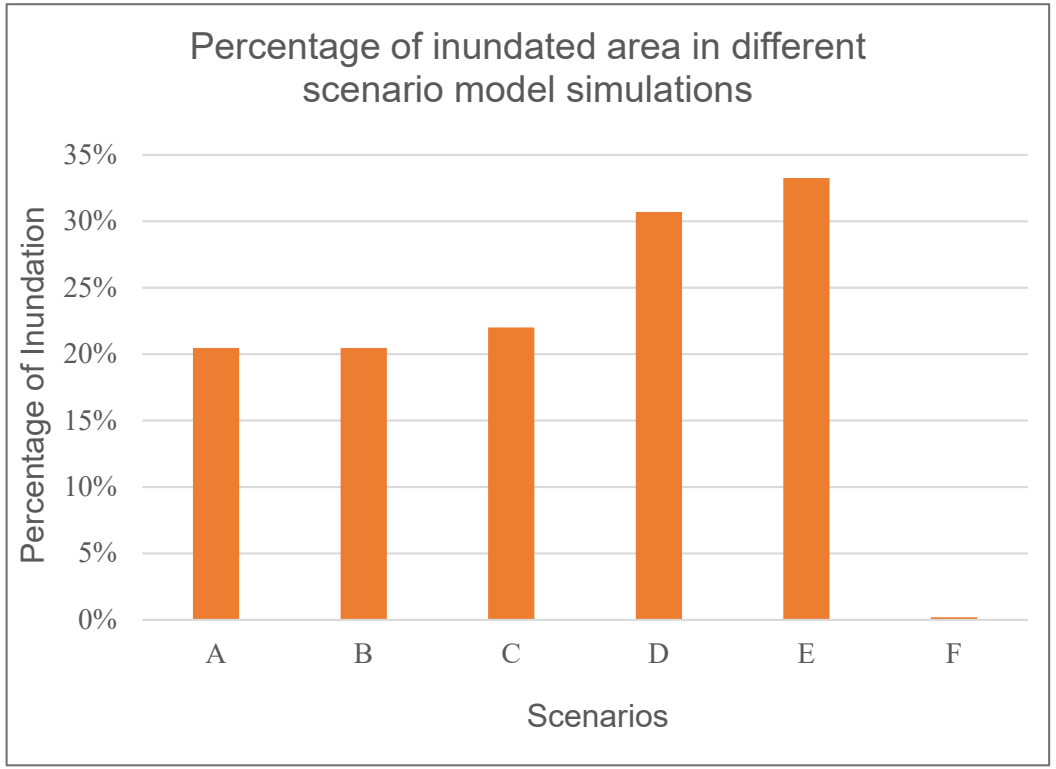


DATA ANALYSIS AND RESULT

Model Simulation for Different Hydrological and Climate Change Scenarios (Goali Chhara Sub-system)

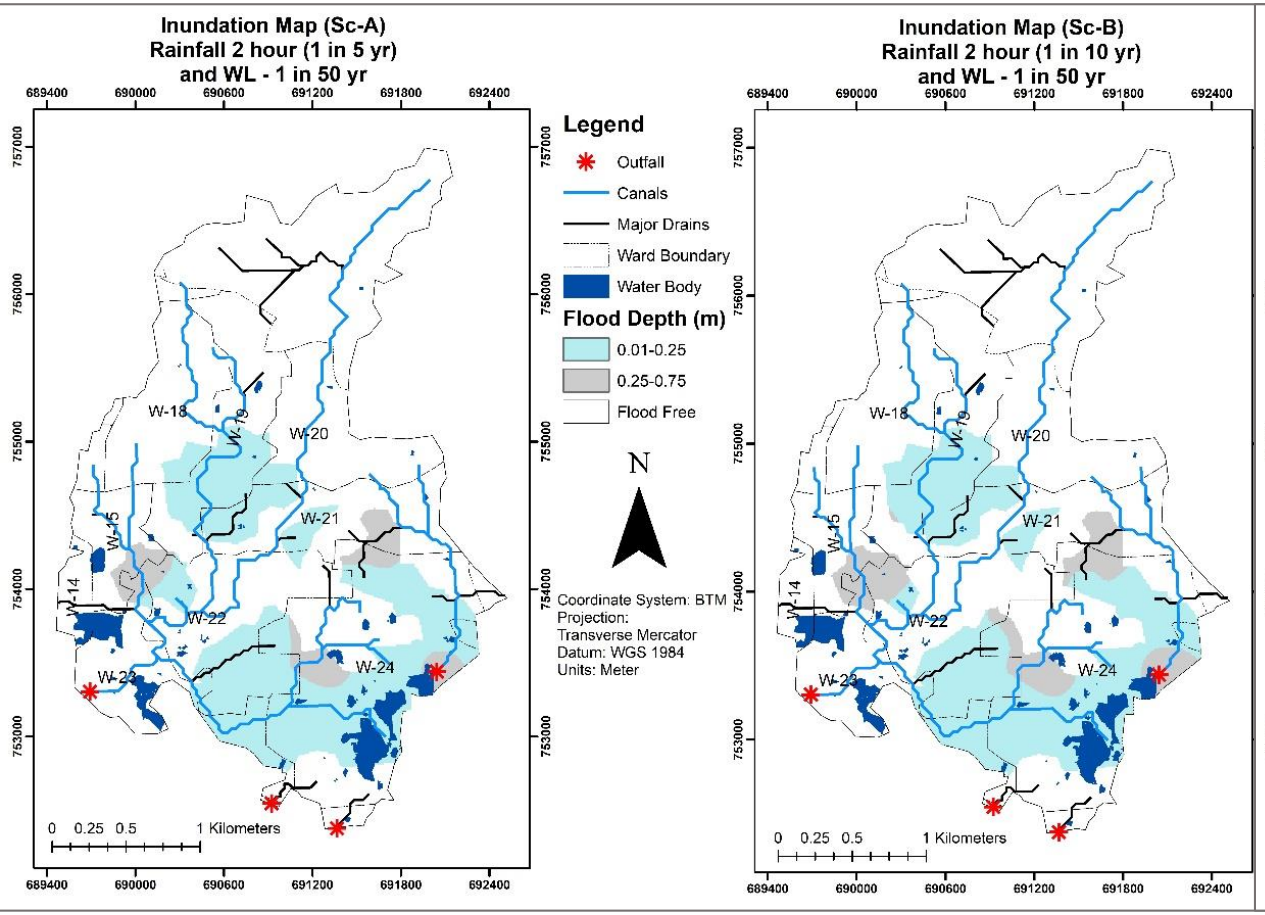
- 11% and 20% increase of rainfall intensity during monsoon for Sylhet in 2030 and 2050 from base year 2016 *(BWDB and IWM, 2017)*

Scenario ID	Scenario Description
Sc-A	Rainfall: 2-hour, return period T = 5 year
Sc-B	Rainfall: 2-hour, return period T = 10 year
Sc-C	Rainfall: 2-day, return period T = 10 year
Sc-D	Sc-C + climate change impact in 2030
Sc-E	Sc-C + climate change impact in 2050
Sc-F	Re-sectioning of drainage channels and drains using design conduit cross-section for return period, T = 10-year



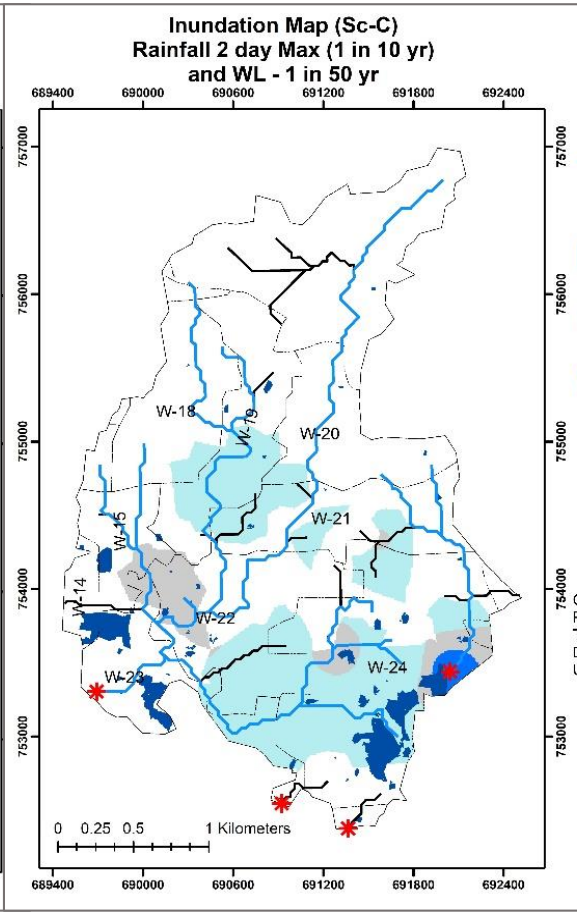
DATA ANALYSIS AND RESULT

Flood Inundation Map for Different Hydrological and Climate Change Scenarios

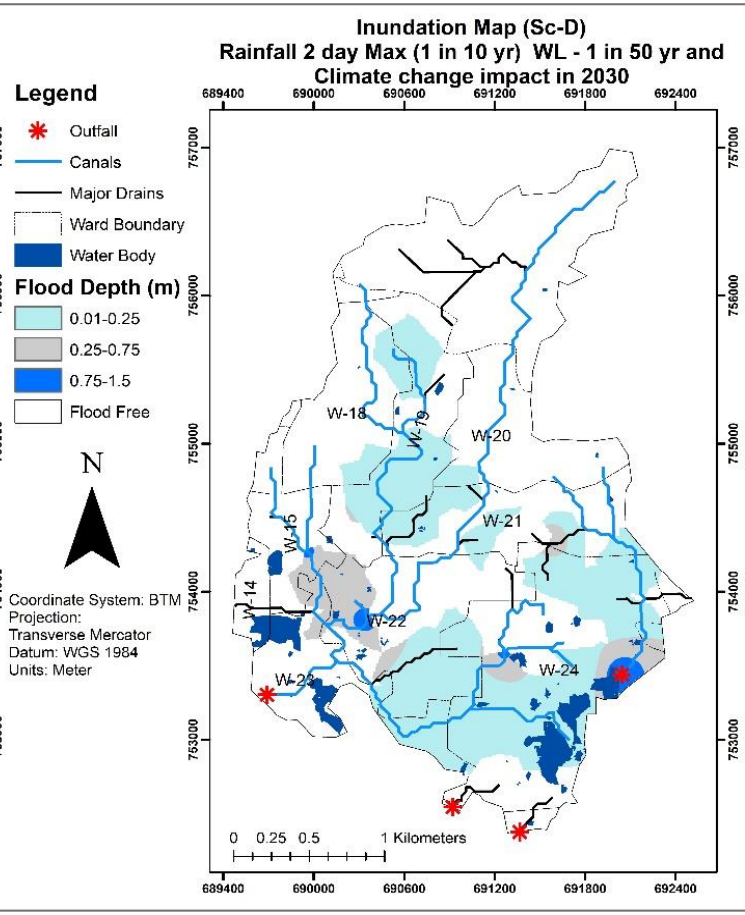


Sc-A

Sc-B



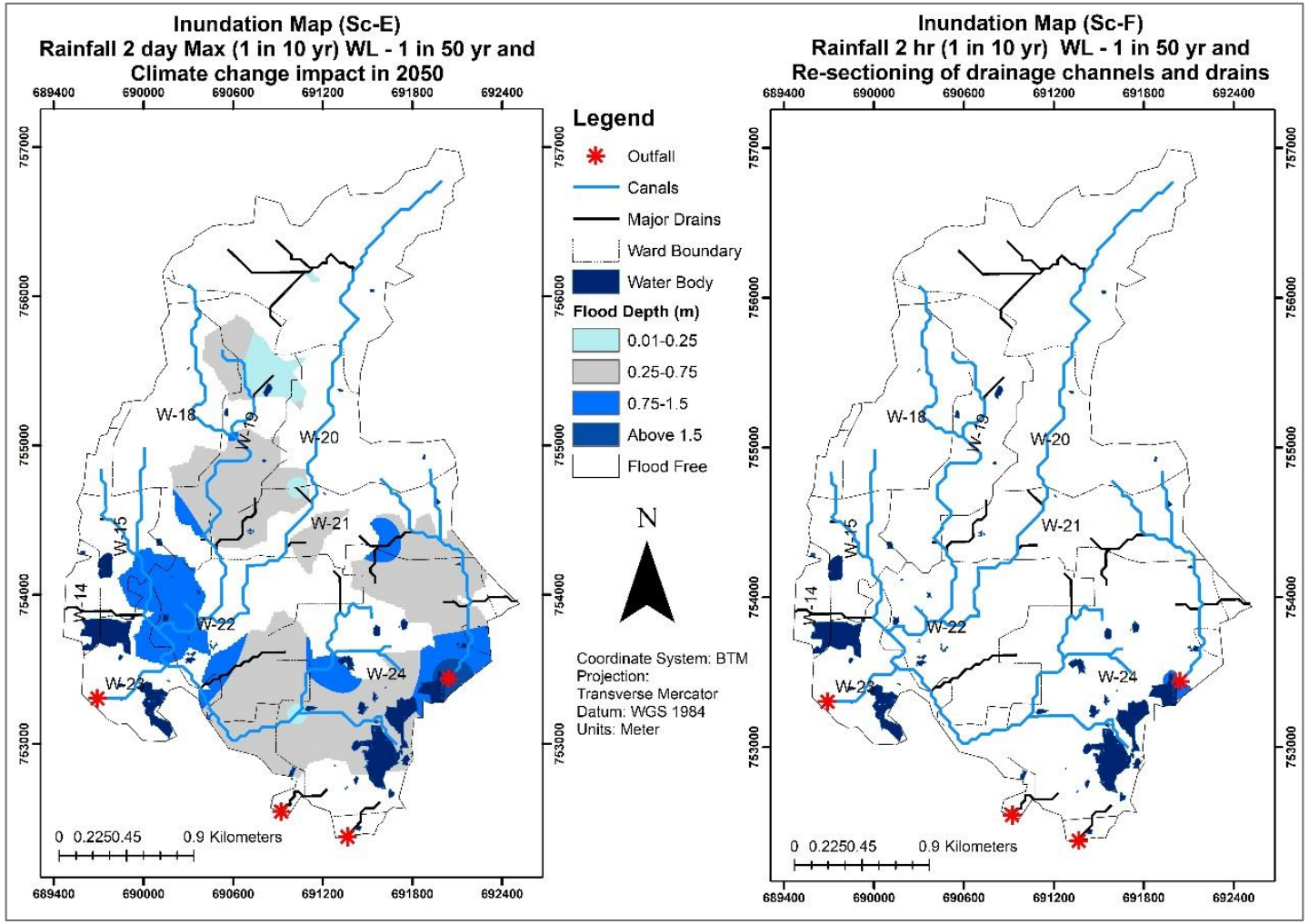
Sc-C



Sc-D

DATA ANALYSIS AND RESULT

Flood Inundation Map for Different Hydrological and Climate Change Scenarios



Sc-E

Sc-F

OUTLINE OF THE PRESENTATION

1. BACKGROUND OF THE STUDY
2. STUDY AREA
3. OBJECTIVES OF THE STUDY
4. METHODOLOGY
5. DATA COLLECTION
6. DATA ANALYSIS AND RESULT
7. CONCLUSION
8. LIMITATIONS AND RECOMMENDATIONS

CONCLUSION

1. The drainage system of Sylhet City is inadequate because the existing size of roadside drains, gutters, and canals is incapable of discharging moderate storm runoff during heavy rainfall and causes congestion.

2. Out of four sub-systems, Malni chhara and Goali chhara sub-systems are responsible for inundation due to inadequate drainage system, lack of maintenance of drainage system, garbage dumping in the drains and canals, and illegal encroachment of drainage canals.

3. The Surma River is the main outfall point of the drainage system of Sylhet City and backwater effect of the Surma River is observed at the outlet O57 of Goali chhara which meets Surma River, and no control structures are found.

4. Using model simulation method for Goali-chhara sub-system, suitable mitigation measures have been identified which include construction of drainage regulator at the outlet of Goali chhara, re-construction and re-sectioning of inadequate canals, roadside drains and gutters.

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LIMITATIONS AND RECOMMENDATIONS

Limitations

- In this study ASTER DEM (30m x 30m) coarse resolution is used. Using DEM measured from surveyed field data may increase the accuracy of work.
- No existing specific pipe drain layout has been found to conduct this study.
- Calibration was done using estimated runoff coefficients value due to unavailability of field observed data.

Recommendations

- The same study can be conducted using the updated data and covering the limitations.
- Only the Goali chhara sub-system of the eastern part of Sylhet City has been modeled using GeoSWMM. The entire Sylhet City area can be modeled using the updated data to have a more precise outcome.

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THANK YOU

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