Government of the People's Republic of Bangladesh
Ministry of Housing and Public Works
Urban Development Directorate

Mymensingh Strategic Development Plan Project, 2011-2031

Guidelines for Flood Risk Assessment and Stormwater Drainage Plan

Final Report

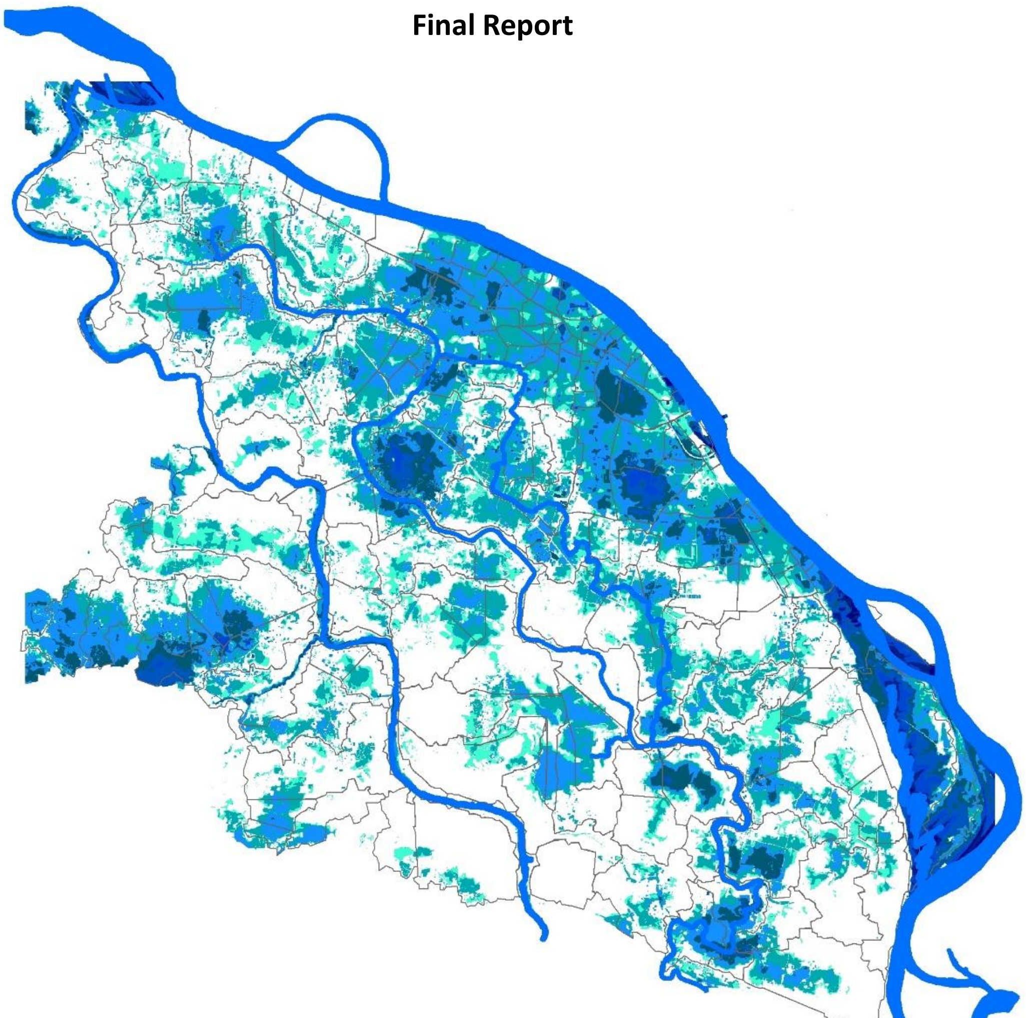

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TABLE OF CONTENTS

CHAPTER		Content	Page No
ACKNOWLEDGEMENT			i
TABLE OF CONTENTS			ii
LIST OF FIGURES			iii
LIST OF TABLES			iv
CHAPTER : 1		**INTRODUCTION**	1
	1.1	Approach to the Drainage Plan	1
	1.2	Relevance to National Water Management Plan 2001	2
	1.3	Principles of Stormwater Drainage Plan	3
	1.4	Steps in Preparing the Drainage Plan	3
	1.5	Methodologies and Data	5
CHAPTER : 2		**HYDROLOGICAL ANALYSIS**	6
	2.1	Daily Rainfall Data of Mymensingh	6
	2.2	Calculation of Short Term Rainfall Intensity	6
	2.3.1	Return Period and Freeboard	6
	2.3.4	Rainfall Intensity Analysis	10
	2.4.1	Peak Runoff	11
	2.4.2	Modified Rational Method	11
	2.5	Estimation of Waste Water	14
	2.5.1	Distribution of Wastewater	14
CHAPTER : 3		**NUMERICAL MODELING**	16
	3.1	Model Boundary and Schematization	16
	3.2	Integration with GIS	17
	3.3	Input and Output	17
	3.4	Calibration and Validation	18
CHAPTER : 4		**SIMULATION OF BASELINE CONDITION**	19
CHAPTER : 5		**RECOMMENDATIONS**	24

LIST OF FIGURES

Figure	Contant	Page No
Figure : 1.1	Drainage catchment boundaries.	04
Figure : 2.1	Illustration of Parameters of Time of Concentration.	07
Figure : 4.1	Inundation for the design condition 5-day 1:5 year rainfall.	19
Figure : 4.2	Observed inundated areas.	20
Figure : 4.3	Ecological linkages and flow directions.	21
Figure : 4.4	Structure plan.	22
Figure : 4.5	Urban area drainage.	23

LIST OF TABLES

Tables	Contant	Page No
Table : 2.1	Summary of Data used in the Hydrological Analysis.	06
Table : 2.2	Return Period of Rainfall and Freeboard.	06
Table : 2.3	Return Period of Rainfall and Freeboard.	08
Table : 2.4	Constant values for IDF curves.	10
Table : 2.5	Short Duration Rainfall Data for Dhaka.	10
Table : 2.6	Short Duration Rainfall Data for Mymensingh.	11
Table : 2.7	Storage Coefficients.	12
Table : 2.8	Runoff Coefficients.	13
Table : 2.9	Estimated Waste Water Generated in Mymensingh Pourashava.	14
Table : 2.10	Projected Peak Wastewater Generation in Mymensingh Pourashava.	15

CHAPTER 1
INTRODUCTION

1.1 Approach to the Drainage Plan

Mymensingh is located on the bank of the Brahmaputra river, but the urban areas are not usually affected by regular flooding except the extreme events such as the floods of 1988. An extensive network of internal channels and water bodies is linked to the external river system to which the stormwater and urban wastewater drain. The planned area has two parts- the built up urban areas, and the presently rural areas which will be developed under the plan in future. The urban areas are regularly affected by internal stormwater flooding primarily due to inadequate drainage infrastructure, and deficiency in maintenance and management of the drainage system.

Growth of urban areas in Bangladesh has profound influence on the performance of urban drainage systems. Experiences in other major urban areas show that several factors determine the effectiveness and efficiency of the system. The following points were considered during preparation of the guidelines and indicative drainage plan.

- Diminished stormwater detention areas and natural water bodies: aggravates urban flooding.
- Empoldering the urban area and installing pumped drainage: often a challenging and expensive venture; inefficient performance often causes urban flooding, e.g. the pumped drainage system in Dhaka.
- Inclusion of domestic wastewater in storm sewers: an almost unavoidable phenomenon.
- Box culverts: act as sediment traps rather than drainage conduits because of their inefficient cross-sections at low flows, and due to the present solid waste management practices in urban catchments.
- Deferred maintenance and inadequate O&M financing: cause deterioration in the efficiency of the drainage system.
- Uncoordinated governance and unclear institutional arrangement: cause the lack in inter-agency coordination, unclear roles and responsibilities, and delay in effective decision-making.

With these considerations, this report provides an overall assessment of floods risks, and an indicative plan for stormwater drainage for Mymensingh municipality and its surrounding areas.

1.2 Relevance to National Water Management Plan 2001

The National Water Management Plan (NWMP) projects rapid urbanization in Bangladesh with 40% of people (73 million) living in the towns and major cities by 2025, and 60% (136 million) by 2050. The plan is presented in three phases: short-term (2000-05), medium-term (2006-10), and long-term (2011-25). A major focus of the plan is on urban and rural water supply and sanitation, and urban flood protection and storm drainage. The flood protection and stormwater drainage options in the plan are directed at towns (large and small) in the medium- to long-term, and include adequate stormwater drainage as an integral component in municipal infrastructure, with a preference for gravity systems wherever possible. Such systems are often inadequate or overlooked in the planning process. The NWMP projects that all towns and cities will have an appropriate level of flood protection and about 70% of towns and each city will be equipped with storm drainage. Two programs in the NWMP directly address flood protection and stormwater drainage: (i) TR 007 Large and small town flood protection – All large and small towns protected from 1:100 year floods, and (ii) TR 008 Large and small town stormwater drainage – Stormwater drainage installed in all large and small towns.

The NWMP states that stormwater drainage is an increasing problem in urban areas, since the construction of buildings and paved areas are increasing storm runoff. At the same time, land development activities have caused filling in and encroachment on natural drainage channels and water bodies. The NWMP also states that no urban areas in Bangladesh have adequate storm drainage at present. The relevant programs in the NWMP therefore provide resources for a nationwide installation/upgrading and maintenance of stormwater drainage facilities in large and small towns. These facilities are likely to be gravity systems which will be cost-effective, but will require regular adequate maintenance.

The NWMP estimates that 35% of urban populations in Bangladesh are living in poverty. At present, 134 towns (26% of the total) have some form of stormwater drainage facilities, but most are either inadequate or in poor condition with little or no regular maintenance. Natural drainage channels, concrete open drains and underground sewers are frequently blocked due to poor management of municipal solid waste and indiscriminate dumping practices. Also, many stormwater drainage systems need considerable upgrading to accommodate future growth in the large and small towns. The relevant programs in the NWMP consist of upgrading of the existing stormwater drainage facilities and installation of new facilities in 388 large and small towns. Final option selection will depend on local conditions and requirements in each town, including:

(a) gravity or pumped systems;
(b) open or covered drainage networks; and
(c) need to set aside low lying areas for stormwater retention to reduce peak flows.

Many of the urban areas are projected to grow significantly over the next 25 years. Therefore, improved and extended stormwater drainage systems will be required. Any urban planning activity should consider the needs and views of the poor, and encourage their active participation in basic maintenance of the drainage networks.

1.3 Principles of Stormwater Drainage Plan

This report presents an indicative drainage plan in accordance with the principles set forth in the NWMP, and based on the practical experiences in other growing urban areas. The final detailed drainage layout plan should be prepared based on the following principles:

1. Detention-based gravity drainage; temporary pumping only during extreme floods.
2. Separate systems for stormwater and domestic wastewater drainage.
3. Operation and Maintenance embedded in the activities of the local government; adequate funds in the annual budget.

Detention-based gravity drainage

The basic principle for the drainage layout plan would be detention-based gravity flow, which would follow the natural slope of the terrain. Temporary pumping may be provided only during extreme floods.

Separate Systems for Storm Water and Domestic Waste Water Drainage

The stormwater and domestic wastewater (black water) systems should be separated. Provisions should be kept in the plan for future wastewater treatment facilities.

Operation and Maintenance

Operation and Maintenance should be embedded in the activities of the local government. Adequate funds should be allocated in the annual budget of the concerned local government institution for drainage improvement and maintenance.

1.4 Steps in Preparing the Drainage Plan

The following steps should be followed in preparing the detailed drainage plan:

1. Identification of the boundary of the planned area: identify built areas and land use characteristics, future development areas, and planned developments in different areas.
2. Identification of water bodies and drainage network (natural and constructed).
3. Identify ground elevations for future development in different area.
4. Design stormwater drainage system (sewer network, detention areas, drainage management structures: sluice gates, regulators, embankments, temporary pumping, etc.).

The indicative drainage plan was prepared following the steps stated below:

1. Preparation of Land Elevation Contours

Contours at 0.25 m interval has been generated for the MSDP Project area by using 4-band multispectral Stereo image. Contours show that the highest and lowest land elevations are 16.127 m and 9.07323 m, respectively.

2. Preparation of Digital Elevation Model from Contours

DEM for the whole of project area has been prepared from the contours. DEM suggests that the natural slope of the town is from the north to the south. The northern part of the Brahmaputra river falls within the active channel of the river Brahmaputra, which is comparatively fragile.

Step 14

3. Identification of Catchments

First, the outfall locations of the drainage network were identified from the DEM. Then the drainage channels were back-tracked and tentative catchments were delineated following the natural levee and roads, which were considered as the boundaries of the catchments. Figure 1.1 shows the drainage catchment boundaries.

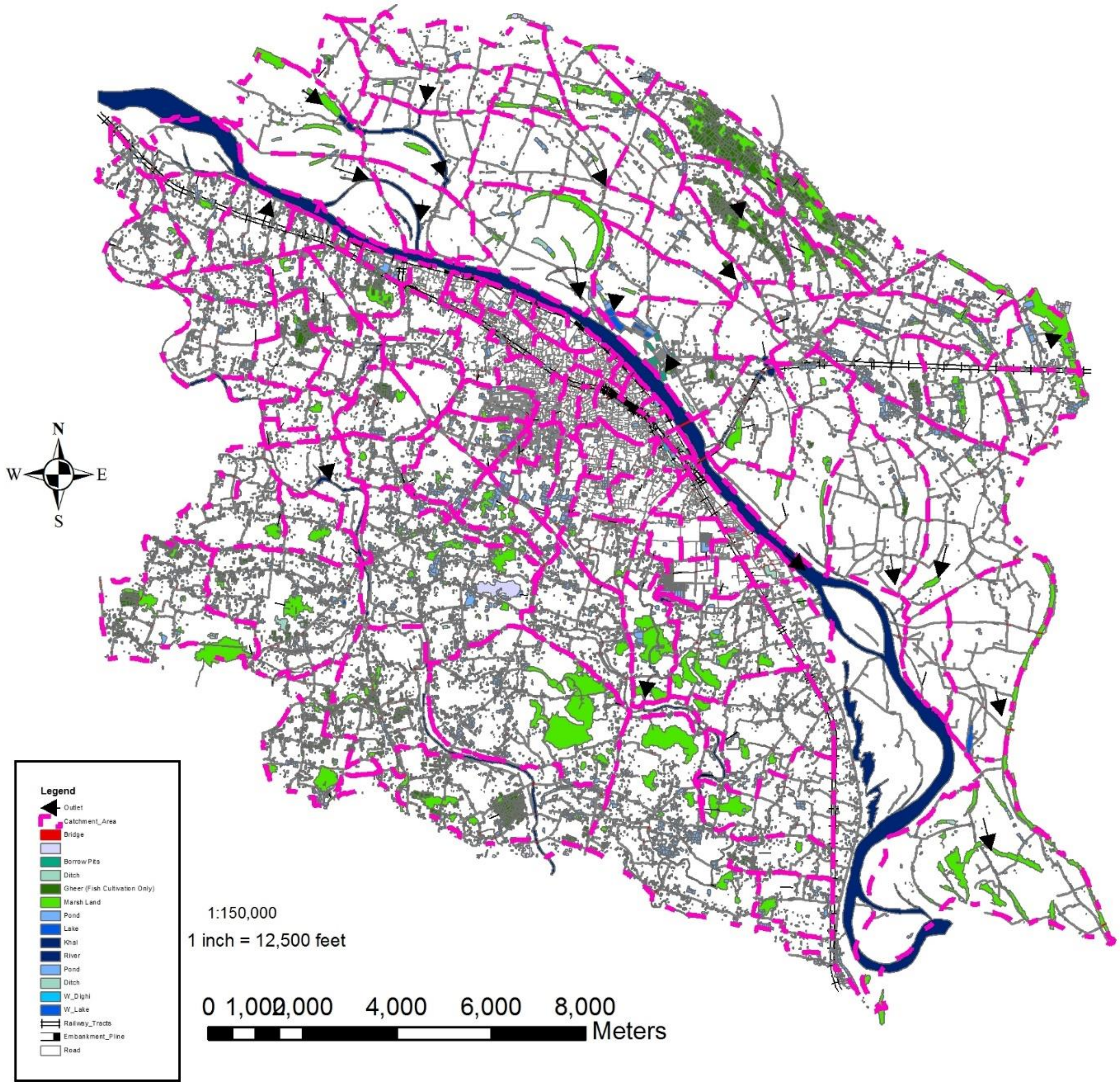

Figure 1.1: Drainage catchment boundaries.

4. Field Verification of Identified Catchments

After identifying the tentative catchments of the project area, the probable outlets were identified in the field, the flow directions in the drainage network were back-tracked, and the catchments of the drainage network were finalized. During field verification some missing outlets were identified, and the catchments were modified thereby.

1.5 Methodologies and Data

An outline of the methodologies followed and data used in preparation of the indicative plan is given below.

1. Flood Risk Assessment:
   1. External (river) flooding: topographic data and DEM, inundation maps.
   2. Internal (stormwater) drainage/flooding: identify sub-catchments, assign runoff coefficients based on future land use characteristics, projected design rainfall considering climate change trend, estimate catchment runoff and sewer discharge.

3. Hydrological Analysis:
   Water level and rainfall at different frequencies: tidal water level data, daily rainfall data.

4. Design of storm water drainage system components: storm sewer network, detention areas, water control structures, etc. - IDF curves and construct design rainfall: hourly rainfall data.

5. Performance evaluation of the proposed system: numerical model PC SWMM, topographic data and DEM, assessment of storm runoff quality based on improved solid waste management.

CHAPTER 2
HYDROLOGICAL ANALYSIS

2.1 Daily Rainfall Data of Mymensingh

Daily rainfall data of Mymensingh for 50 (fifty) years ranging from 1962 to 2012 have been collected from Bangladesh Meteorological Department (BMD).

2.2 Calculation of Short Term Rainfall Intensity

Since there are no short duration rainfall records for Mymensingh, short duration rainfall data for Dhaka have been used for Mymensingh. The Gumbel distribution for estimating probability of occurrences was used to develop the frequency analysis of rainfall intensities of Mymensingh for 2-year, 5-year, 10-year and 25-year recurrence intervals. Detailed calculations are presented below.

Table 2.1: Summary of Data used in the Hydrological Analysis.

No of years of Long-term for Dhaka	50
Dhaka Long-term Average (Average 1) mm	141.34
No of years of data of Mymensingh	50
Dhaka Long-term Average (Average 2) mm	153.92
Mymensingh town mean to Dhaka mean ratio (Ratio 2)	1.09

1. Preparation of Rainfall Intensity-Duration-Frequency Curve

2.3.1 Return Period and Freeboard

Open drains are usually designed to flow full when carrying the design flow with an allowance for freeboard. Freeboard is used as a safety factor. Drains and culverts are designed to flow full with the additional capacity available when the flow depth is just below the top of the drain. The design flow is the peak runoff resulting from design storm rainfall and waste water on the catchments. The Return Periods of rainfall and freeboard for the design of size of different types of drains in Mymensingh Pourashava are given in Table 2.2.

Table 2.2: Return Period of Rainfall and Freeboard.

Drain Type	Return Period	Freeboard
Tertiary	5 years	100mm
Secondary	5 years	150mm
Primary	5 years	200mm

1. Time of Concentration

Entry Time

It is the time taken for runoff from the farthest point in the contributing area to flow over the ground and into the drain. Entry time has been calculated by the following Kirpich Equation.

$$Te = 0.019621\ L^{0.77} / S^{0.385} \qquad (2.1)$$

where, L = Maximum Length of overland flow, and S = Average ground slope.

Travel Time

It is the time taken for runoff to flow through the drain. It is calculated by dividing the length of the drain by the water velocity.

$$Tt = L/V \qquad (2.2)$$

where, L = Length of Drain (m), and V = Design Velocity (m/s).

Time of Concentration

It is the sum of entry time and travel time.

$$Tc = Te + L/V \qquad (2.3)$$

where, Tc = Time of Concentration (minutes).

Figure 2.1 shows these parameters.

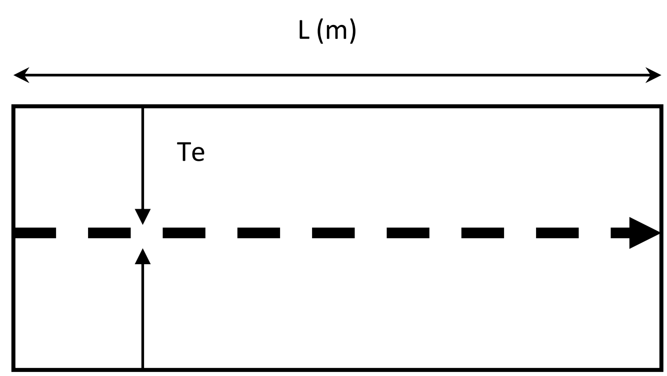

Figure 2.1: Illustration of Parameters of Time of Concentration.

2. Design Rainfall

Conversion Factor

Data for individual storm events are scarce and inadequate for design, but relatively long term daily rainfall records are available for most areas. Rainfall data for durations less than one day is however available only for Dhaka. It is therefore practical to assume that the relationship observed between the Dhaka daily rainfall and the Dhaka rainfall of durations less than one day has the same relationship for the rainfalls in the other project towns. A procedure to estimate rainfall for durations less than one day for other locations can then be proposed.

Project town rainfall data are generally available for a shorter period (years) than the Dhaka rainfall data available. It is therefore necessary to calculate the adjustment of the Dhaka long term mean annual maximum daily rainfall corresponding to period of records of project towns. The ratio between the project town annual maximum daily rainfall and the Dhaka annual maximum rainfall data is then calculated.

The procedure to calculate the conversion factor is :

1. The Dhaka long term mean annual maximum daily rainfall is 141.967mm = **Average 1.**
2. Obtain annual maximum daily rainfall data from the rain gauge nearest to nearest to project town and calculate the mean annual maximum daily rainfall for period of record, to give **Average 2**
3. From the mean annual maximum daily rainfalls measured at Dhaka, calculate the mean annual maximum daily rainfall of Dhaka for the same period of record in (b) above, to give **Average 3**. Note that years with missing data in the project towns must also be excluded from the calculation of the Dhaka average.
4. Calculate the ratio (Ratio1) between Dhaka long term mean annual maximum daily rainfall to Dhaka shorter period rainfall, i.e. **Ratio1 = Average 1/Average 3**
5. Calculate the rain ratio (Ratio 2) between the project town mean annual maximum daily rainfall and corresponding period Dhaka mean annual rainfall i.e. **Ratio2 = Average 2/Average 3**
6. The adjustment factor is thus Ratio 1 multiplied by Ratio 2 i.e. **Conversion Factor = Ratio 1 * Ratio 2.**

Table 2.3: Annual Maximum Daily Rainfall Data (mm) for Dhaka and Mymensingh.

Year	Dhaka	Mymensingh
1962	116	132
1963	189	166
1964	114	198
1965	177	114
1966	257	100
1967	125	103
1968	145	194
1969	86	134
1970	152	102
1971	251	508

1972	231	117
1973	168	105
1974	143	141
1975	163	17
1976	100	200
1977	128	167
1978	108	175
1979	91	78
1980	81	120
1981	146	146
1982	133	144
1983	151	192
1984	69	165
1985	176	75
1986	138	202
1987	135	171
1988	118	261
1989	118	165
1990	94	125
1991	123	314
1992	90	116
1993	140	181
1994	74	70
1995	83	119
1996	150	156
1997	121	138
1998	122	197
1999	141	96
2000	158	117
2001	71	116
2002	88	162
2003	93	100
2004	341	229
2005	128	157
2006	185	134
2007	152	152
2008	190	135

2009	333	154
2010	87	167
2011	94	169
2012	62	13

2.3.4 Rainfall Intensity Analysis

The rainfall data for Dhaka has been analyzed using the Gumbel Analysis method and the derived return period rainfalls for a range of storm durations are presented in Table 3.3. Note the values have been adjusted to take in account the frequency of maximum daily rainfalls occurring during the period of observation and the long term average values. For use in a specific project area, the rainfall intensity values must be multiplied by the rainfall conversion factor.

Short duration rainfall data are not available for Mymensingh Pourashava area. The daily (24 hours) rainfall records are available for the period from 1962-2012. To generate short duration rainfall data, the following approach has been adopted. Based on the ratio of 24 hours rainfall, the short duration rainfall for Mymensingh Pourashava has been converted from the short duration record for Dhaka City.

The Rainfall Intensity Duration Frequency (IDF) curves for a 12-hour storm with 2-year and 5-year recurrence intervals for Mymensingh Pourashava have been developed by using the following equation.

$$i = a / (T^b + c) \qquad (2.4)$$

where, i = Rainfall Intensity (mm/hour), T = Duration (hour), and a, b, c = Constant

Table 2.4: Constant values for IDF curves.

Return Period (Years)	a	b	c
5	152.8	0.95	1.12

Since there are no short duration rainfall records for Mymensingh, short duration rainfall for Dhaka has been used for Mymensingh also. The Gumbel distribution for estimating probability of occurrences was used to develop the frequency analysis of rainfall intensities of Mymensingh for 2-year, 5-year, 10-year and 25-year recurrence intervals. Detailed calculations are presented below.

Table 2.5: Short Duration Rainfall Data for Dhaka.

Return Period (Years)	T (hrs)	0.25	0.5	1	2	3	6	12
2	i	92.40	78.60	56.20	36.70	27.00	15.40	9.40
5	i	109.70	95.70	71.40	50.10	39.00	23.00	14.10
10	i	121.10	107.00	81.40	58.90	46.90	28.00	17.30
25	i	135.60	121.30	94.10	70.10	56.90	34.30	21.20
50	i	146.30	132.00	103.50	75.40	64.30	39.00	24.10

Table 2.6: Short Duration Rainfall Data for Mymensingh.

Conversion Factor = 1.09

Return Period (Years)	T (min)	15	30	60	120	180	360	720
2	i	100.72	85.67	61.26	40.00	29.43	16.79	10.25
5	i	119.57	104.31	77.83	54.61	42.51	25.07	15.37
10	i	132.00	116.63	88.73	64.20	51.12	30.52	18.86
25	i	147.80	132.22	102.57	76.41	62.02	37.39	23.11
50	i	159.47	143.88	112.82	82.19	70.09	42.51	26.27

Spatial Reduction Factor

Especially for thunderstorm type rainfalls the area experiencing intense rainfalls is frequently very localized and this is usually taken into account using a spatial reduction factor. However, no research has been undertaken in Bangladesh to evaluate spatial reduction factors. Research by Dharabd Bhattacharya in 1975 on 42 storms in North India showed that for 1 day rainfalls the difference between spatial rainfall and point rainfalls for areas up to 25 km^2 was less than 1%. It is therefore recommended that point rainfalls only be used to calculate urban storm runoff.

1. Determination of Drainage Capacity

2.4.1 Peak Runoff

The Modified Rational design method presented in this report is for areas less than 60ha. For larger areas a hydrograph routing method should be used so that the attenuating effects of channel storage is included in the design. Failure to include this storage will result in over design of the drains.

The Rational Method was derived by considering the effect of a uniform intensity rainfall of a long duration on a catchment. The runoff rate starts at zero and reaches a maximum value when flow from the most remote part of the catchment reaches the outlet. The flow would then remain constant. The time for the flow to reach the peak value is called the time of concentration. The designed rainfall intensity is selected from a set of standard rainfall intensity duration curves by selecting the rainfall intensity for duration equal to the time of concentration. There is a rainfall intensity duration curve for each return period.

2.4.2 Modified Rational Method

The Modified Rational method calculates the peak runoff using the following formula:

$$Q_P = C_S C_R IA/360 \qquad (2.5)$$

where, Q_P = peak runoff (m3/sec), C_S = storage coefficient, C_R = runoff coefficient, I = rainfall intensity (mm/hr), A = area (hectares).

Storage Coefficient (C_S)

Due to the very flat topography in many parts of Bangladesh, runoff is significantly slower than that would occur in many other countries. Rain first ponds on the ground and then runs off. To take this effect a storage coefficient is used. The value of the coefficient is based on the average ground slope and the nature of the ground surface. Coefficient of Storage is a factor to allow for the reduction in peak runoff due to the storage effects on the overland flows.

Table 2.7: Storage Coefficients.

Type of Area	**Coefficient corresponding to ground slope**		
	<1:1000	**<1:500**	**>1:500**
Paved areas – roads and markets	0.8	0.9	1.0
Densely built up areas	0.8	0.9	1.0
Central areas mixed commercial and housing	0.7	0.8	1.0
Residential areas with detached houses	0.7	0.8	0.9
Walled areas and gardens	0.6	0.7	0.8
Large permeable areas (e.g. dry paddy)	0.5	0.6	0.8
Paddy fields (flooded)	0.3	0.4	0.5

A storage coefficient is evaluated for each contributing area. The use of an average coefficient value for all drains is not correct. Use of an average coefficient will lead to under-sizing of drains in relatively impermeable and steeper areas and the over-sizing of drains in the more rural and flatter areas.

Runoff Coefficient (C_R)

A runoff coefficient is used in the Modified Rational method, as not all of the rainfall falling on the ground flows off into the drains. Some water infiltrates into the ground and some go into storage in ponds or tanks. The runoff coefficient represents the ratio between the volumes of rainfall. In Bangladesh taking into account the fact that at the time of intense rainfalls in the Monsoon period the ground is normally saturated, the following coefficients should be used:

Table 2.8: Runoff Coefficients.

Type of area	Coefficient
Paved areas – roads and markets	0.9
Areas of paddy (flooded)	0.8
Densely built up areas	0.7
Central areas mixed commercial and housing	0.6
Residential areas with detached houses	0.4
Walled areas and gardens	0.3
Large permeable areas (e.g. dry paddy)	0.3

Rainfall Intensity (I)

Rainfall Intensity is the amount of rainfall falling in a unit time period. Conventionally this is quoted in millimeters per hour (mm/hr). The Rainfall Intensity will reduce in magnitude as the time of concentration increases.

Contributing Area (A)

The Contributing Area is the total catchments area upstream of a drain that can contribute flow. This includes the total area contributing flows to upstream drains. Contributing / Catchment Area is the area of ground surface that can drain to a length of drain. For any one drain, this also includes area draining into upstream drains. The contributing area is measured in hectares.

2. Estimation of Water Demand

The socio-economic condition and income status of the domestic consumer are the governing key factors to estimate the unit water demand of the population. Water consumption will gradually increase for high-income groups when their consciousness about Public Health is focused and addressed properly. The Per Capita Water Demand is the annual average water consumption of one person daily. The annual water demand divided by 365 will give the average day demand. Thus the average daily demands over a year, means the annual average daily demand.

The total quantity of water required by the community can be computed by using the following formula:

$$D_f = P_f * R \qquad (2.7)$$

where,

Q_f = Quantity of water required per day

P_f = Projected population estimated for the design period

R = Rate of water consumption per day

The Unit of Per Capita water demand is usually expressed in liters per capita per day (lpcd). Water consumption is not constant throughout the year, during dry months water demand is more than that during the winter. Therefore, an allowance of at least 20% is kept for such seasonal variation. The population figures of 2001 were collected from the census of 2001 and the population projections were carried out for the year 2010 to 2030. Domestic water demand in ML/day is computed by assuming average per capita water consumption @ 115 lpcd (WHO, 1987).

2.5 Estimation of Waste Water

Approximately one-third of the water of domestic consumption is used for flushing toilets, one-third for personal use via wash basin, bath and shower and one-third for food preparation and drinking, laundry and other cleaning activities. Relatively small percentage of the supplied water is used for drinking.

The general theory to calculate waste water is

$$G' = n\,G \qquad (2.8)$$

Where,

G = Water consumption per person (liter/person/day),

G ' = Waste water generated per person (liter/person/day) and

n = Return factor in %.

= 70%

Table 2.9: Estimated Waste Water Generated in Mymensingh Pourashava.

Year	***Population***	***Water Demand (ml/ day)***	**Waste Water (ml/day)**
2001	227204	26.13	18.29
2011	258040	29.80	20.86
2016	276479	32.05	22.43
2021	296236	34.48	24.13
2031	340087	39.89	27.92

2.5.1 Distribution of Wastewater

The first peak generally occurs in the morning. The second peak occurs in the early evening. A third peak can be also distinguished sometimes. In general, the peak flow is about 16% of the total flow of the whole day. Hence, the peak waste water discharge has been considered as the 16% of the total waste water generated per day. Now, the peak waste water in m3/sec/sq.km for Mymensingh Pourashava might be calculated as follows:

Peak Waste Water in m3/sec/sq.km = Waste Water (ML/day)*0.16*1000000 / (Poura Area in sq.km*3600*1000) (2.9)

According to Equation 2.9, peak waste water generation for Mymensingh Pourashava has been shown in Table 2.10.

Table 2.10: Projected Peak Wastewater Generation in Mymensingh Pourashava.

Year	***Population***	***Water demand (ml/day)***	***Waste Water (ml/day)***	***Peak waste water (m3/sec/sq.km)***
2001		26.13	18.29	0.0374
2011		29.80	20.86	0.0427
2016		32.05	22.43	0.0459
2021		34.48	24.13	0.0493
2031		39.89	27.92	0.0571

Population and associated peak waste water generation of Mymensingh Pourashava has been considered 10, 15 and 20 years for design of tertiary, secondary and primary drains respectively. Under this consideration, peak waste water generation m3/sec/sq.km will be 0.0459, 0.0493 and 0.0571 for design of tertiary, secondary and primary drains, respectively.

CHAPTER 3
NUMERICAL MODELING

3.1 Model Boundary and Schematization

Three steps have been taken for implementation of this model:

1. Preprocessing
2. SWMM model
3. Post processing

ArcGIS 10.1 software has been used in preprocessing and post processing step. That process has been discussed in section 3.3. PC SWMM 2D has been used to run this model. The friendly usable PC SWMM software is more comfortable and easier than EPA SWMM because this software is directly connected to the GIS software. However, the study area has been characterized by river network surrounded by the area, drainage network in urban part and overland flow in rural part. For that reason, The SWMM model has been combined with three different analysis such as Hydrological, hydraulics and hydrodynamic analysis. This analysis has been done by PC SWMM software.

For hydrological analysis, overland flow and sheet flow have been derived by DEM data. From the field survey, the Hydraulics information has been collected. On the other hand, by using PC SWMM software, the river cross section data has been derived from 10m DEM data of the study area. The rational formula and Manning equation have been used to run this model. Long term and short term rainfall frequency data has been used. 5 days 5 year rainfall frequency has been used for design condition to calculate both peak discharge and water volume which was ponded in ponding area for long time period. The 5day rainfall distribution has been followed by the report of Hallcrow. This distribution has described both hourly distribution and daily distribution. For hourly distribution, the peak intensity value has been considered to measure peak discharge. The 5 days rainfall has been considered to find out the volume of water which has been trapped by the ponded area.

The contour line and flow path has been followed to identify and calculate the ponded area. For extreme event 1 day 100 year and 50 year rain fall frequency has been used to calculate the peak discharge of this area. In a simulation option, Horton law has been used for infiltration model. Dry antecedent condition has been applied from start of simulation. Also for routing, dynamic wave method has been used where Hazen-Williams equation has been applied. The ponded area has been allowed. The boundary condition of river data has been derived from gage station. For boundary condition in Bhamaputra river and Shutia river, average stage value on the month of July data has been taken. Outfall of the river, the fixed stage has been taken.

3.2 Integration with GIS

In preprocessing step, the AarcGIS 10.1 software has been used to -

1. Digitizing the existing drainage network of pourashava area along with the indication of flow direction
2. Building the attribute table and data base which has been collected from field survey
3. Create the flow accumulation, flow direction and natural flow path by 10m DEM data
4. Delineate the subcatchment area
5. Classification of land use of the area to calculate the percentage of pervious and impervious area for every subcatchment .
6. Soil map has been merged to the land use data to find out infiltration characteristics of every subcatchment area.

In post processing step,

1. Flood depth data derived by the swmm model has been used to create the water surface elevation
2. Flood area has been created by minus water surface elevation data with DEM data
3. Different thematic information derived by SWMM model has been shown in Map

3.3 Input and Output

In a SWMM model,

1. To add the Gis shape file such as catchment and subcatchment boundary, flow path, drainage network, DEM , soil, river and land use which has before been done in arcgis
2. To add the junction point and outfall point on the drainage network
3. Digitizing the drainage network, river network and overland flow path.
4. To connect the every subcatchment area with those junction point where the water of subcatchment area first reach
5. To Input the junction attribute of urban drainage network. Such as rim and invert elevation data which has been collected from field survey.
6. Input the attribute of conduit in urban drainage network. Such as width, height
7. For open channel of these conduits, the cross section has been used. The cross section has been derived from DEM data. The height and width collected by the field survey have to be used in the main channel of these conduits. The roughness value has been used in these conduits.
8. For The overland flow and river network of the area, the cross section has been used and which is also derived by DEM data. The deriving cross section has been input into the every section of the river and over land flow. The height value of the river data has been input to the junction point.
9. The invert and rim elevation data has also been extracted from DEM data.

10. To add the subcatchment attribute such as land use data, manning’s number, infiltration value.
11. Add the rainfall data and dry weather flow in every junction of urban catchment area
12. To select the simulation start and end time of the model
13. To add the boundary condition of the river and out fall point.
14. To Run the simulation and check and solve the error if it has been found
15. Flooded node, peak discharge, flooded volume, total inflow, runoff coefficient and surface runoff etc data have been obtained from this model. Later these data has been used in post processing step(arc gis) to prepare the flooded map.

3.4 Calibration and Validation

The following steps were followed:

1. Collection of Rainfall data from Meteorological stations.
2. Water level, velocity and flow data from known point on the canal systems.
3. Comparison of observed data with model simulations
4. Goodness of fit of the model
5. Improve model performance during calibration
6. Verification of model with another event.

CHAPTER 4
SIMULATION OF BASELINE CONDITION

Step 14

The calibrated and validated PC SWMM model was used to simulate the baseline condition. Figure 4.1 shows the inundation for the design condition with 5-day 1:5 year rainfall. [Plz insert table of flood depth]

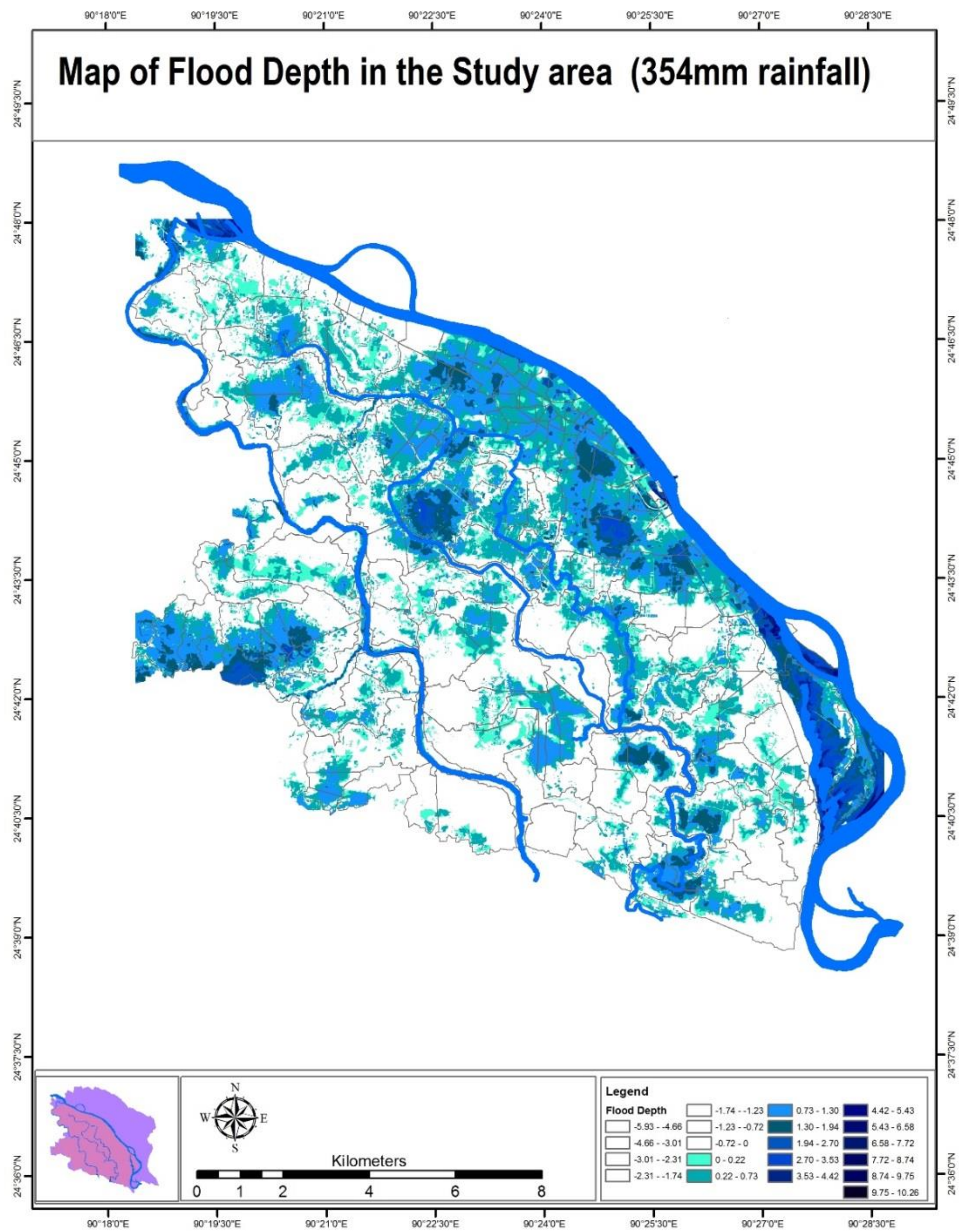

Figure 4.1: Inundation for the design condition 5-day 1:5 year rainfall.

Step 14

The simulated inundation areas matched reasonably with the observed inundated areas shown in Figure 4.2. [Plz insert table]

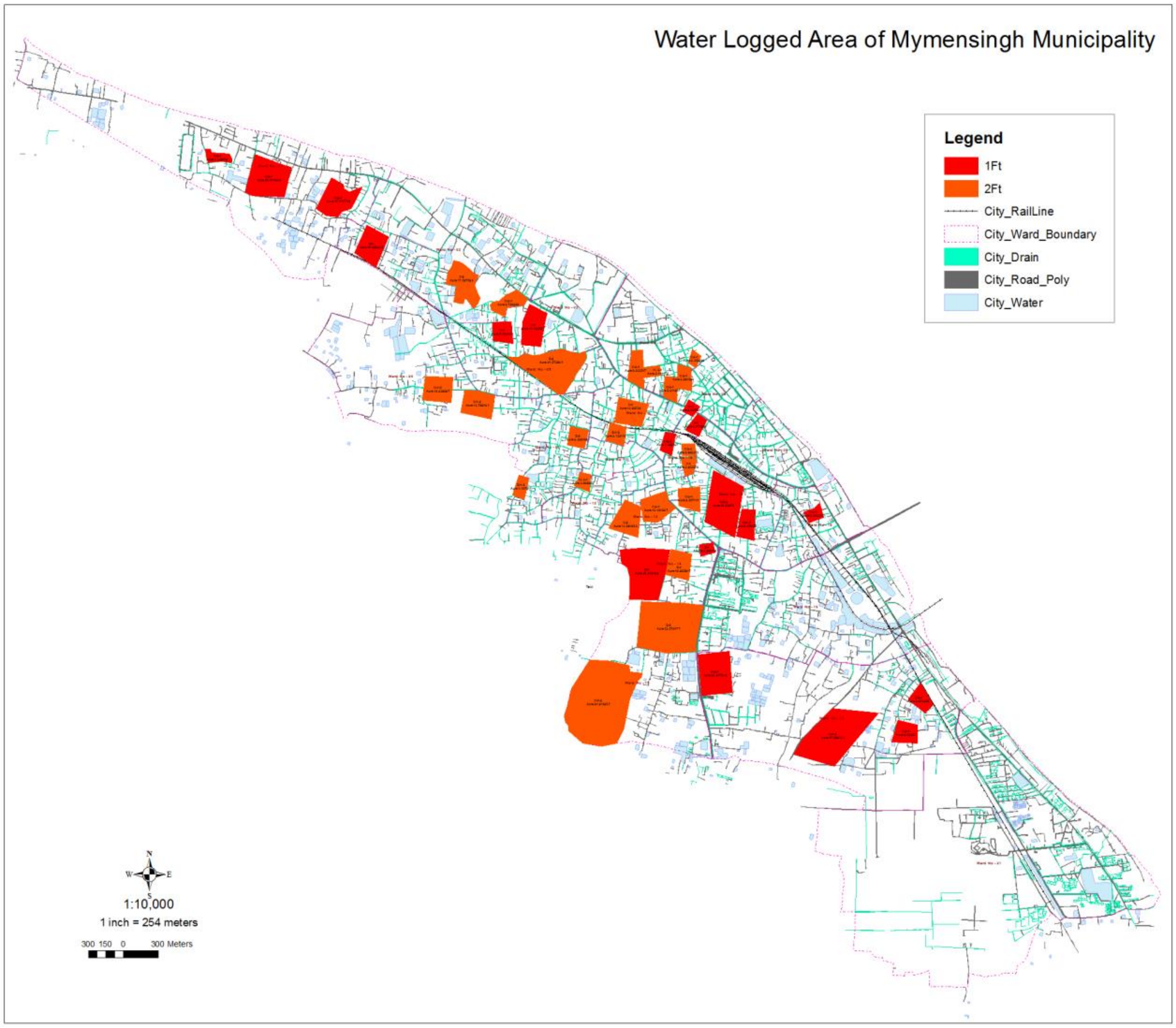

Figure 4.2: Observed inundated areas.

The MSDP interventions should consider these inundation scenarios, and integrate with the ecological linkages (shown in Figure 4.3), structure plan (shown in Figure 4.4) and urban drainage plan (shown in Figure 4.5).

[Plz insert table]

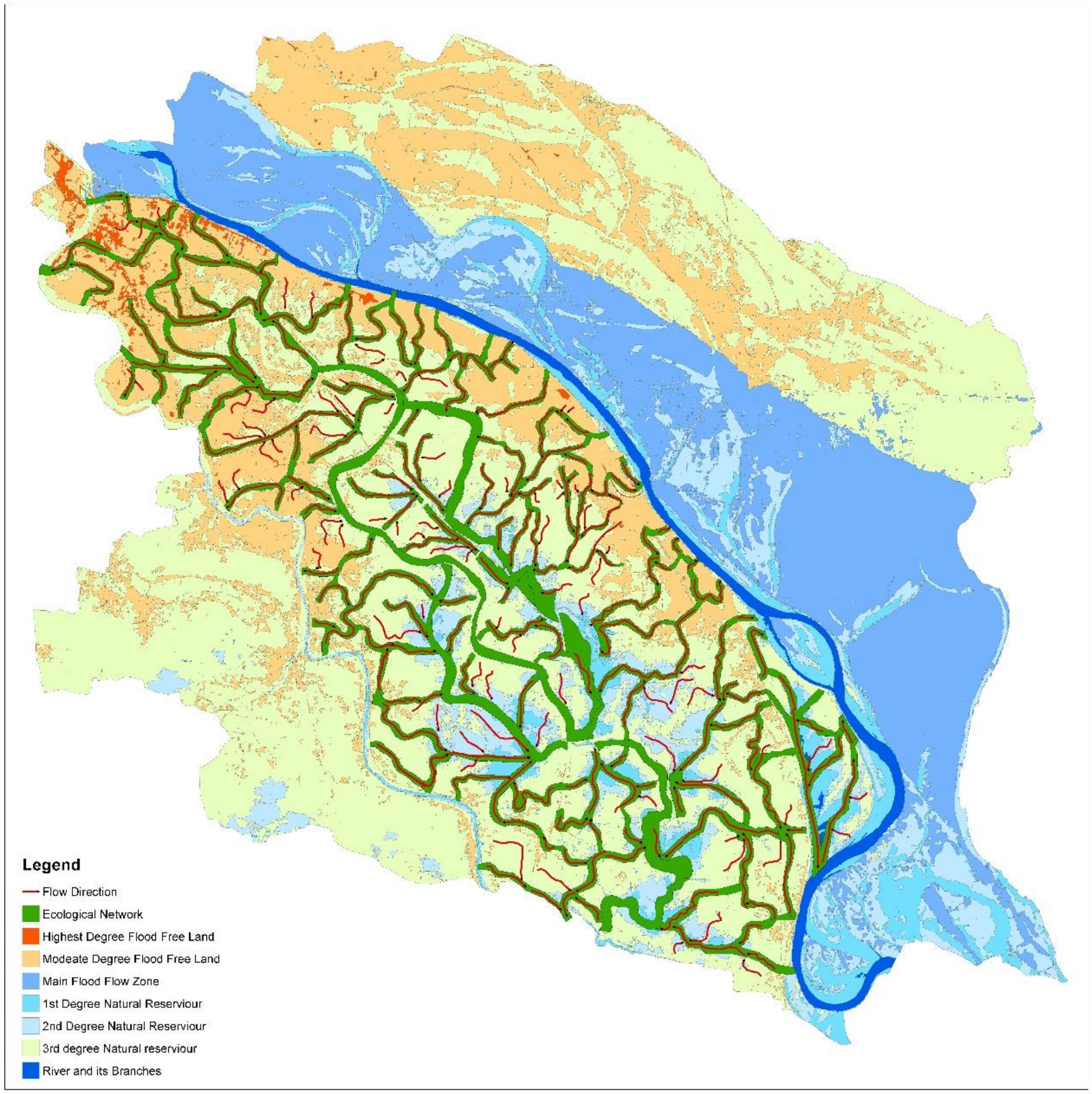

Figure 4.3: Ecological linkages and flow directions.

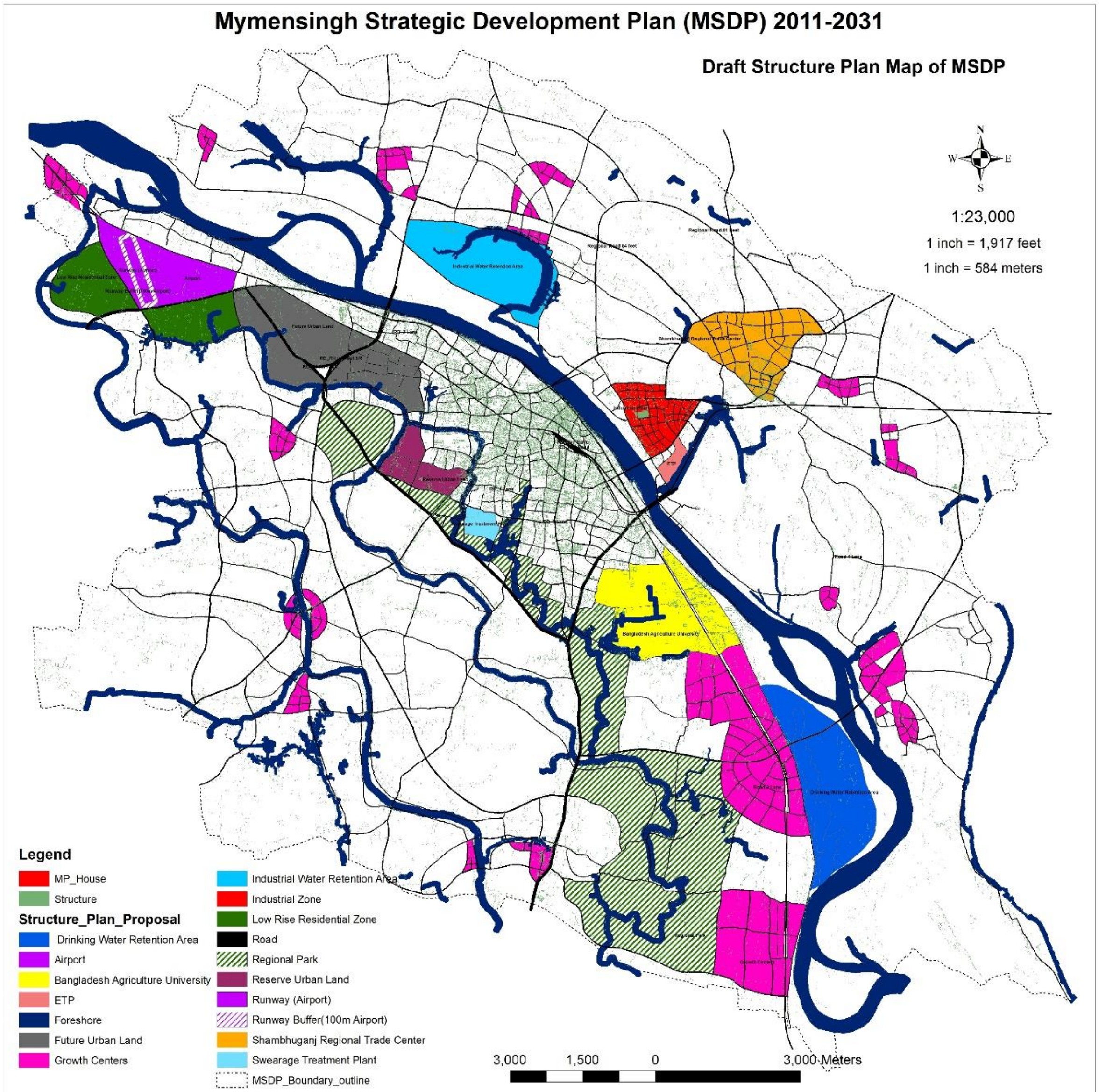

Figure 4.4: Structure plan.

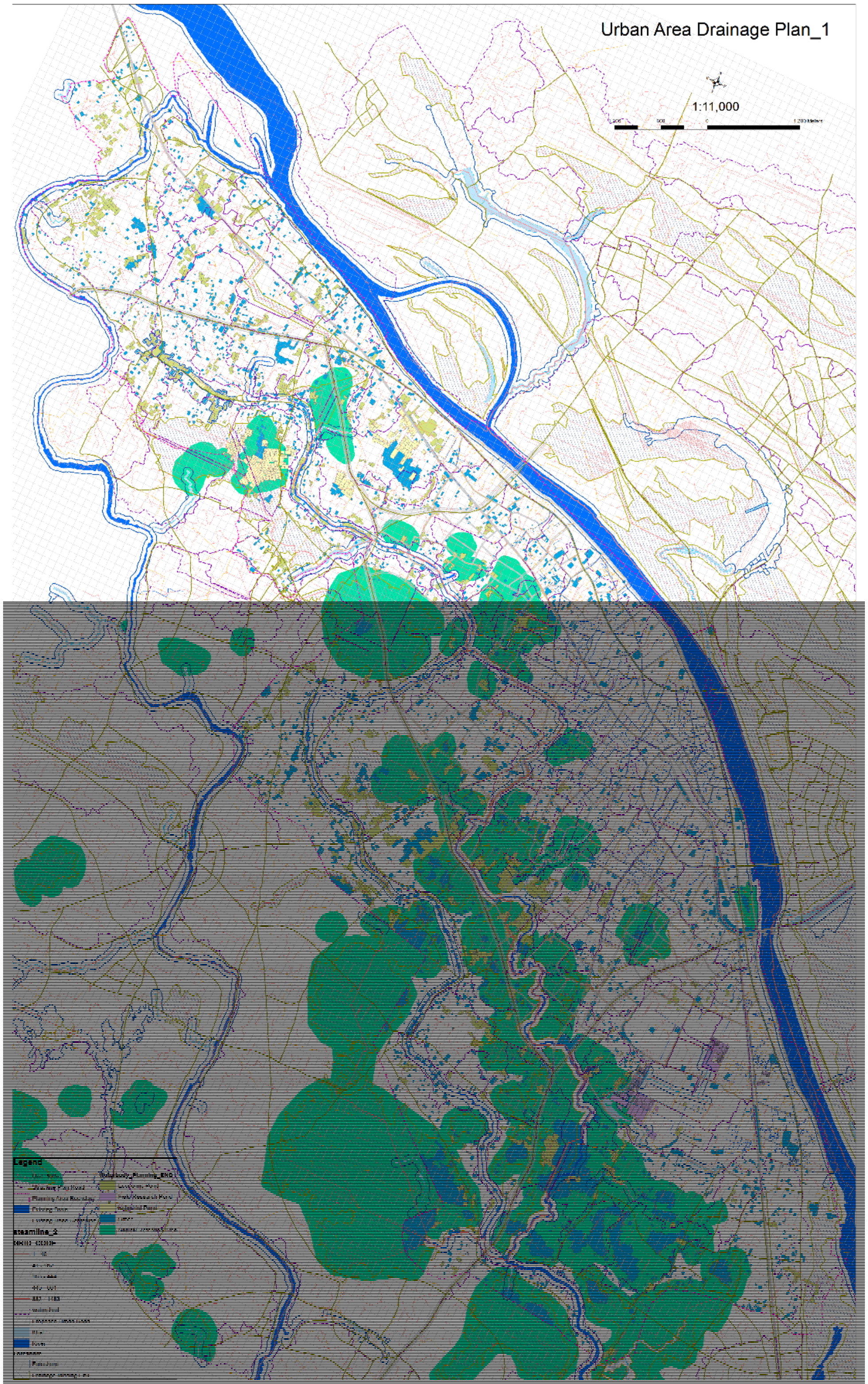

Figure 4.5: Urban area drainage.

CHAPTER 5
Recommendations

The following recommendations are made based on the drainage analysis.

1. Improve the drainage system to alleviate water logging in areas identified in the study.
2. Build and protect detention areas and flood buffer zones. Develop a contingency plan to allow limited flooding in designated areas in case of extreme rainfall events.
3. Integrate the drainage plan with other cross-cutting plans such as the structure plan, ecological sustenance plan, etc.
4. Prepare a plan for stormwater management and institutional arrangement involving key stakeholders, service providers and decision makers.
5. Prepare a plan for priority activities and financing,