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Session H2: Hydrology

Management of Storm Water Flooding in Metropolitan Cities of India

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आपो हि ष्ठा मयोभुव

Presented
by
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National Institute of Hydrology
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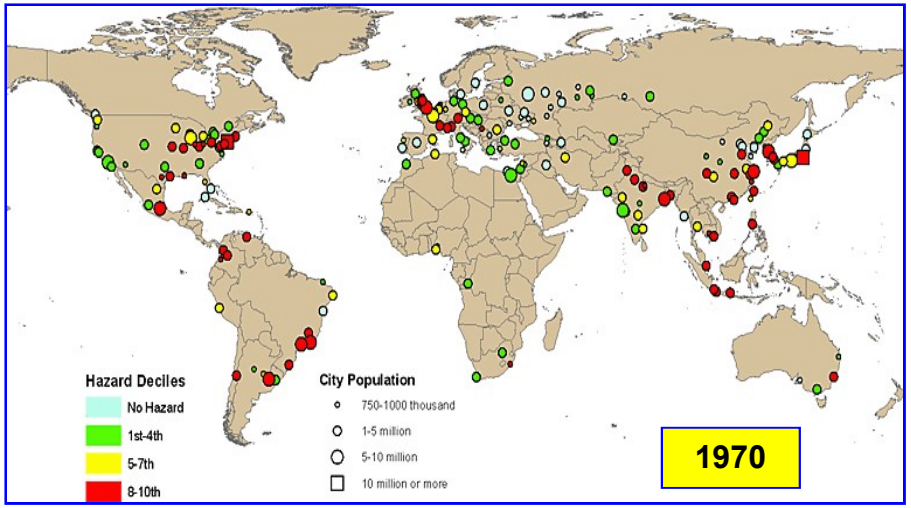
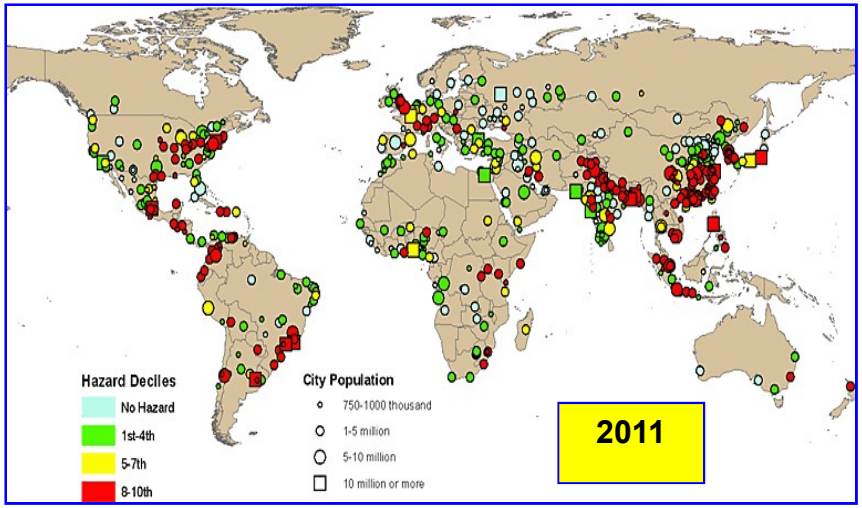
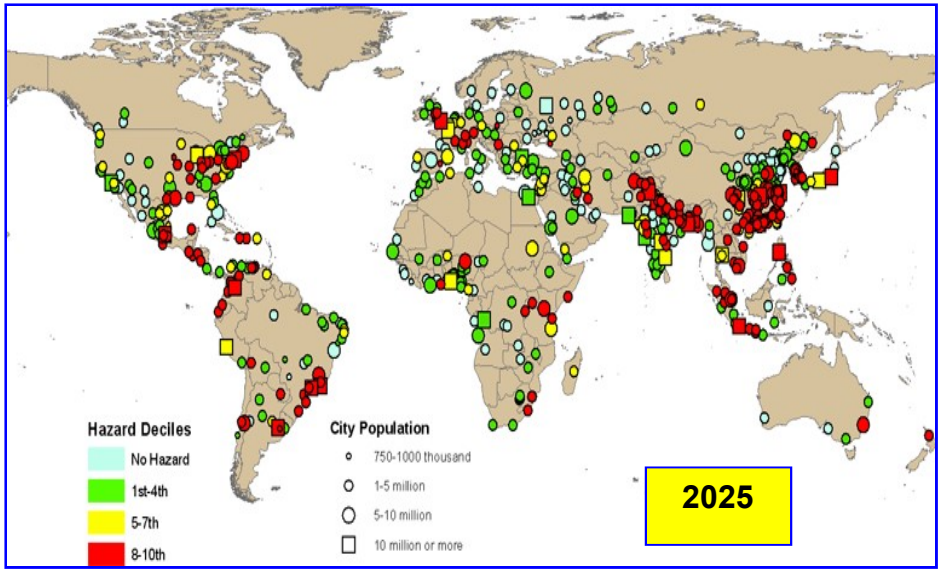
Global Potential Risk of Urban Flooding







Multiple & uncertain drivers of future change

- ✓ Extreme rainfall events
- ✓ Nutrient and pollutant loading
- ✓ Urbanisation effects
- ✓ Land use change
- ✓ Socio-economic trends

Transient shocks vs. Chronic stresses

Storm Water Runoff in urban areas

- No measurements on storm water Quantity and Quality
- Indirect estimation of quantity from Hydraulic structures or storm water drains
- No information on flood prone area (Depth, Duration and Area)

- No information on high resolution topography
- Mixing up of storm water, waste water and sewage water
- Natural filling up of water bodies, temple tanks, reservoirs

- Limited information on artificial groundwater recharge
- No information on storm water reuse/conservation
- No forecast on urban floods for Transport authorities/ Infrastructure developers/ Govt., and public sectors/other sectors

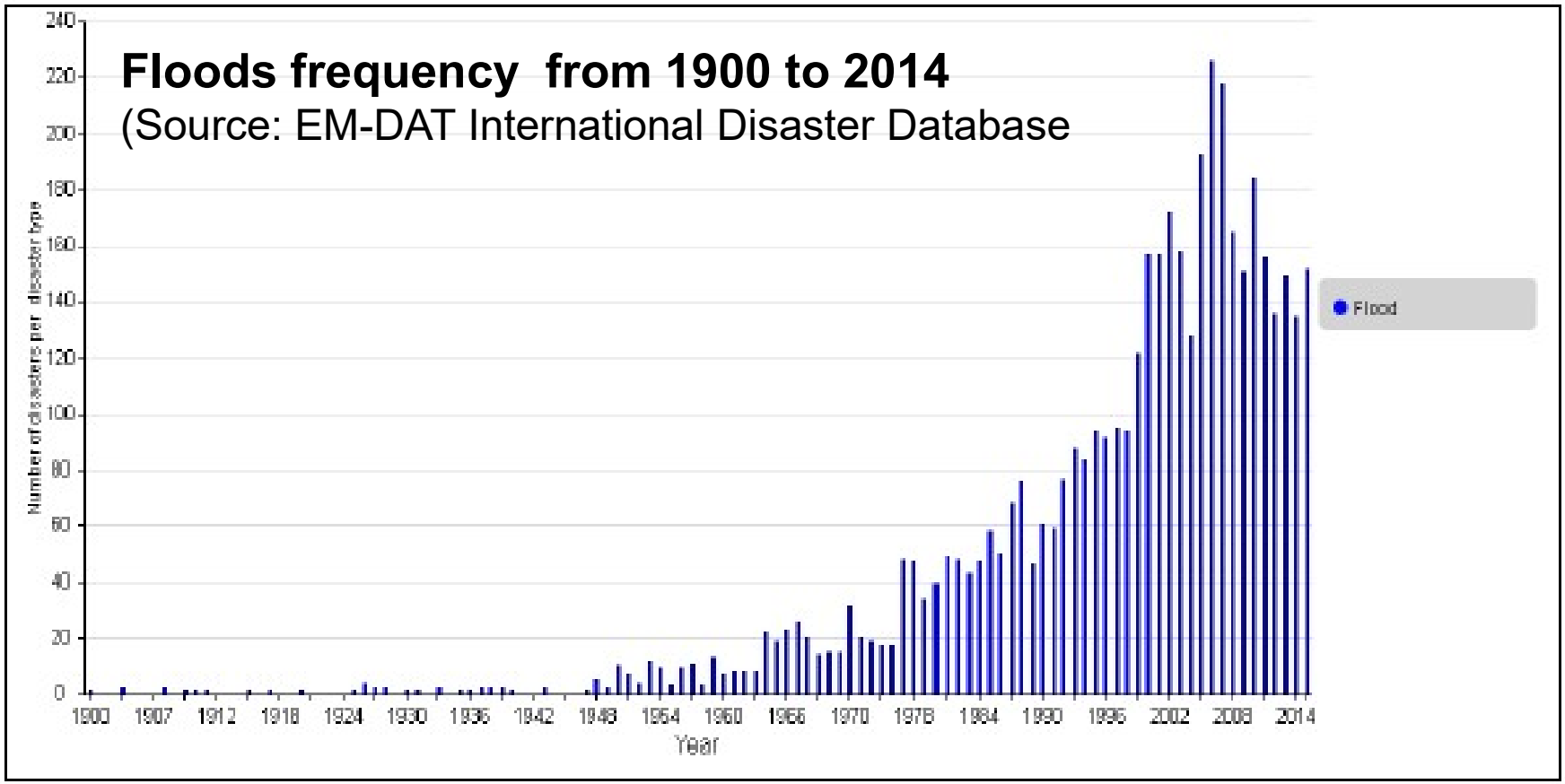
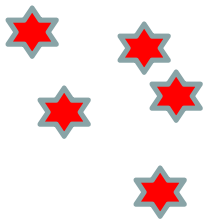


Fig.2 Floods Frequency from 1900 to 2014 (Source EM-DAT International Disaster Database)

Highest Daily Rainfall events (Observed)

Mumbai: 94.42 cm/day (26.07.2005)
36.62 cm/day (08.08.1997)
29.76 cm/day (30.08.2017)

Chennai: 33.78 cm/day (30.11.2015)
14.40 cm/day (Aug 2005)



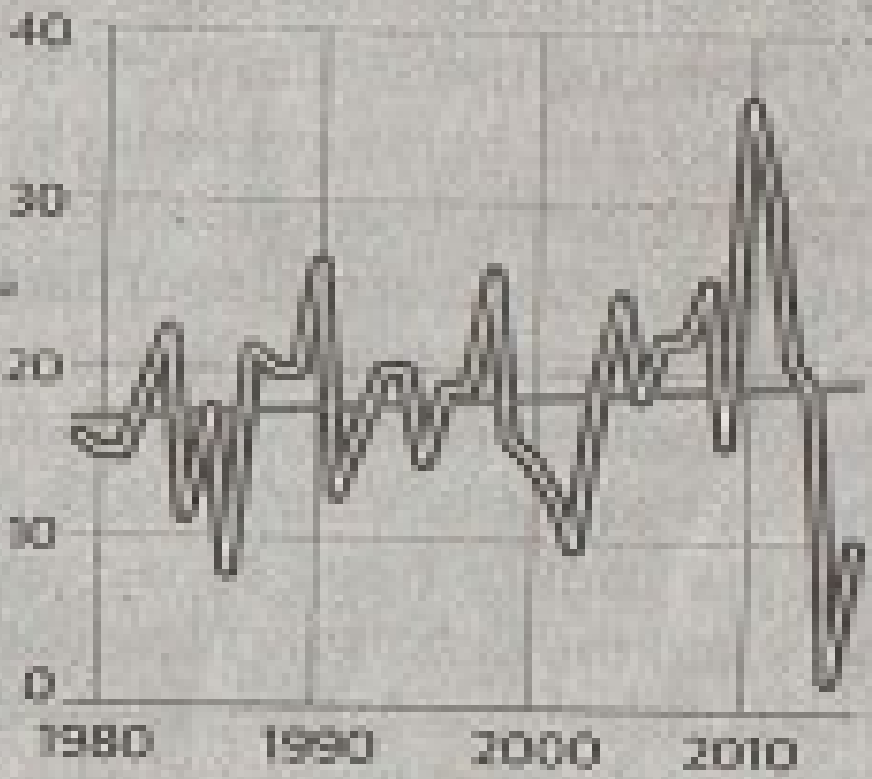
Hyderabad: 24.16 cm/day (24.08.2000)
16.71 cm/day (21.09.2016)

Bangalore: 16.6 cm/day (year 1890)
18.4 cm/day (14.8.2017)

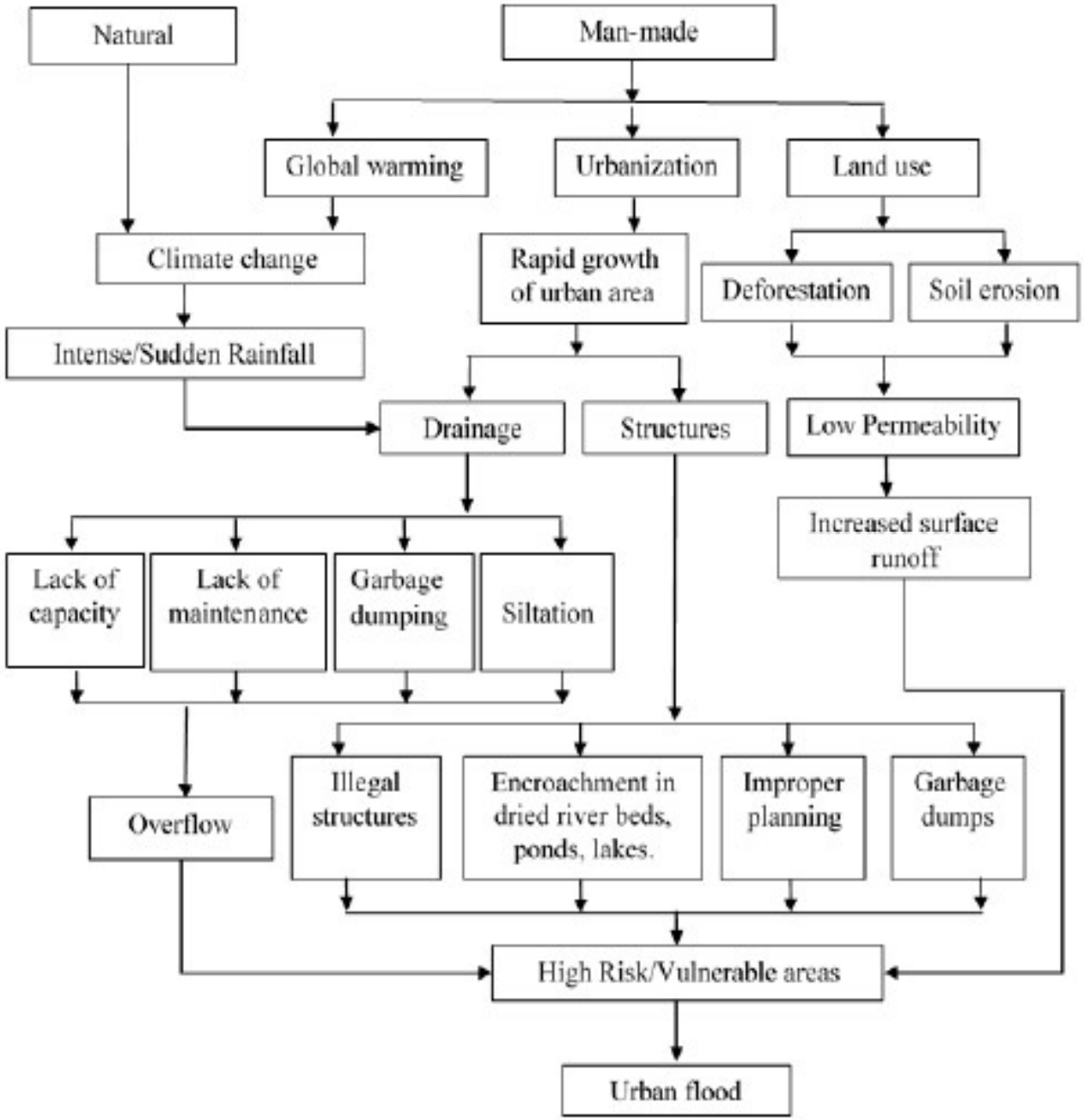
Amaravati: 20 cm/day (16.10.1969)
15 cm/day (01.11.1994)
13.76 cm/day (21.9.1997)

* The number of extreme rain days* in Mumbai peaked in 2010 and 2011 with 35 and 30 such days. Since then, there has been a trough (2 days in 2014)

Frequency of extreme-rain days*



Methodology



Why Storm Water Flood Modeling ?

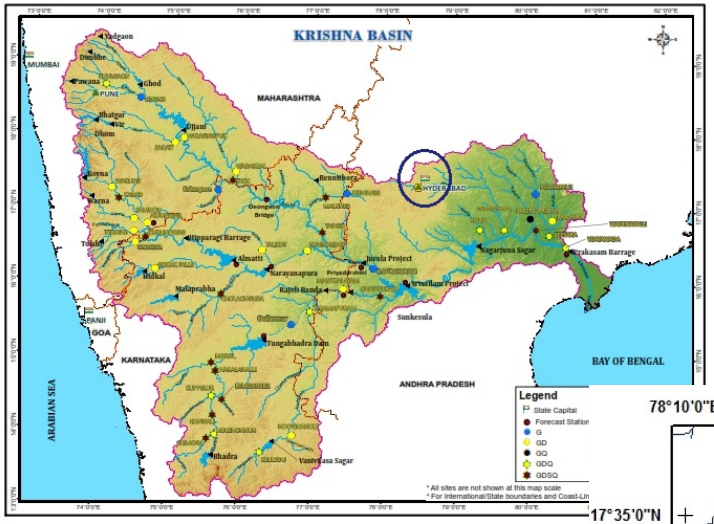
- To design effective storm water drains to avoid flooding or to identify flood prone areas in new urban areas
- To understand system inflow and outflow characteristics in new and existing urban areas
- To understand storm water network efficiencies in existing urban areas.
- To propose or incorporate various flood mitigation measures in existing urban areas

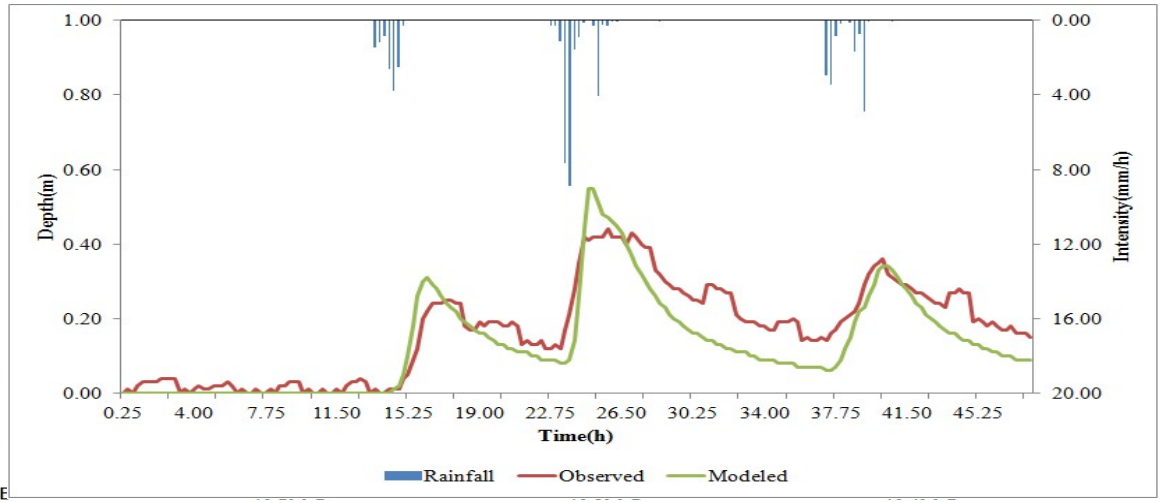
Developing city: Hyderabad

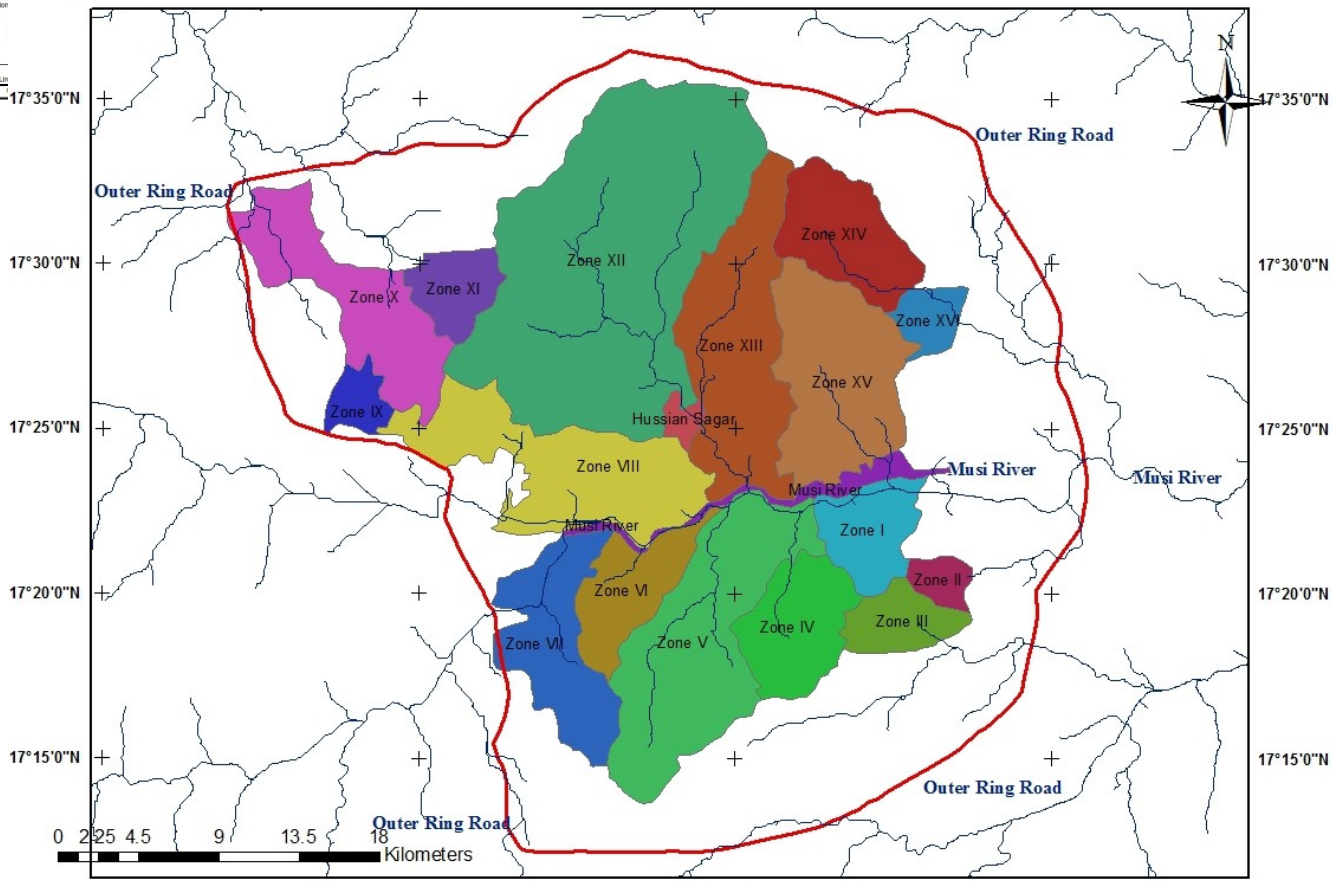
Upcoming city (Capital of A.P): Amaravathi

Fully Developed urban city: Chennai

Hyderabad

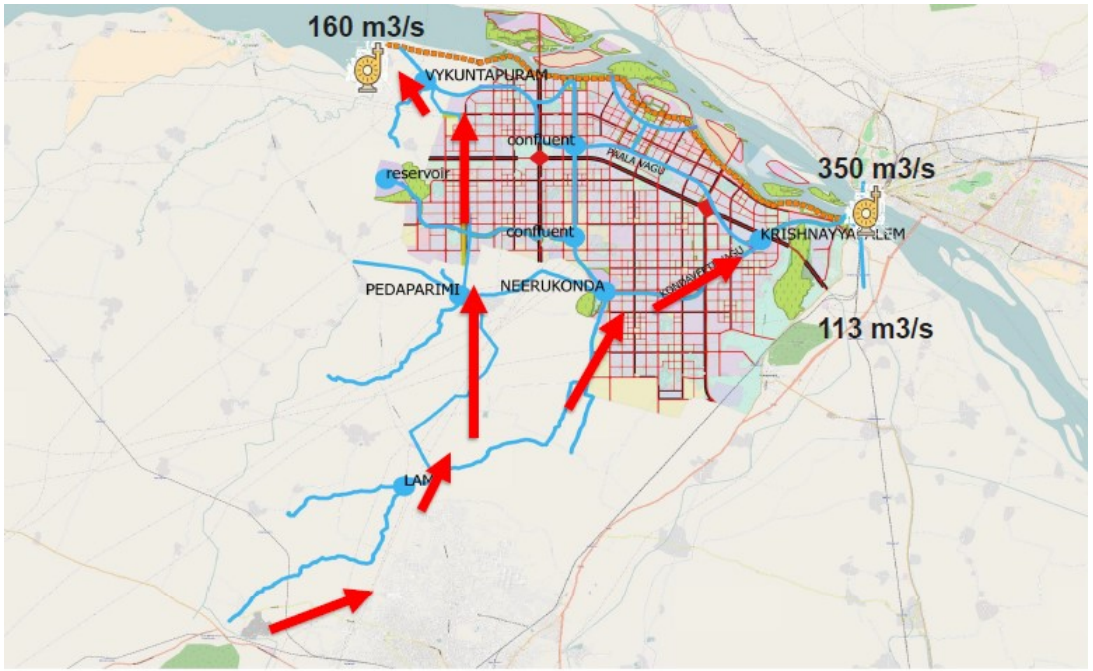

KRISHNA BASIN
MAHARASHTRA
KARNATAKA
ANDHRA PRADESH
BAY OF BENGAL
ARABIAN SEA
HYDERABAD
Legend


Depth(m)
Intensity(mm/h)
Time(h)
Rainfall
Observed
Modeled

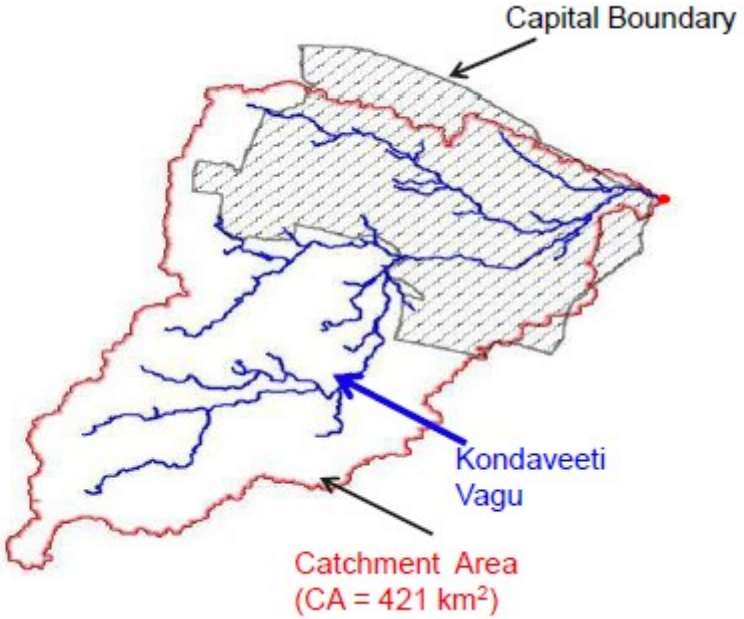

Outer Ring Road
Zone I
Zone II
Zone III
Zone IV
Zone V
Zone VI
Zone VII
Zone VIII
Zone IX
Zone X
Zone XI
Zone XII
Zone XIII
Zone XIV
Zone XV
Zone XVI
Hussian Sagar
Musi River
17°35'0"N
17°30'0"N
17°25'0"N
17°20'0"N
17°15'0"N
0 2.25 4.5 9 13.5 18
Kilometers

Objectives	Findings
Adequacy verification of existing storm water drainage network.	Existing storm water drainage work has been analysed using GIS & SWMM. Model results was calibrated with observed data and simulated with 2 & 5 year design storm. existing storm water drainage network of study basin not adequate even 2 year design storm.
To develop the outfall hydrograph and water surface profiles along the drains.	Model simulated with 2 & 5 year design storm and develop the outfall hydrographs and water surface profile along the drains to find-out flooding locations along drains.
Design of the alternative drainage net-work.	Existing storm water drainage work has been modified with hydraulic parameters (depth & width) and proposed the new drainage to taken care of the flood mitigation measures up-to 5 year design storm.

Amaravathi (on going)



- Proposed capital city boundary area - 217 km^2
- Area bounded with high contours/ridges
- HFL of Krishna river (RL 21.5 m) higher than KV (RL 17.5m) level
- Presently entire KV flood discharges through Undavalli outlet, u/s of Prakasam Barrage
- Gravity drainage impossible in the above scenario!!!
- With topographical-hydraulic constraints pumping is required

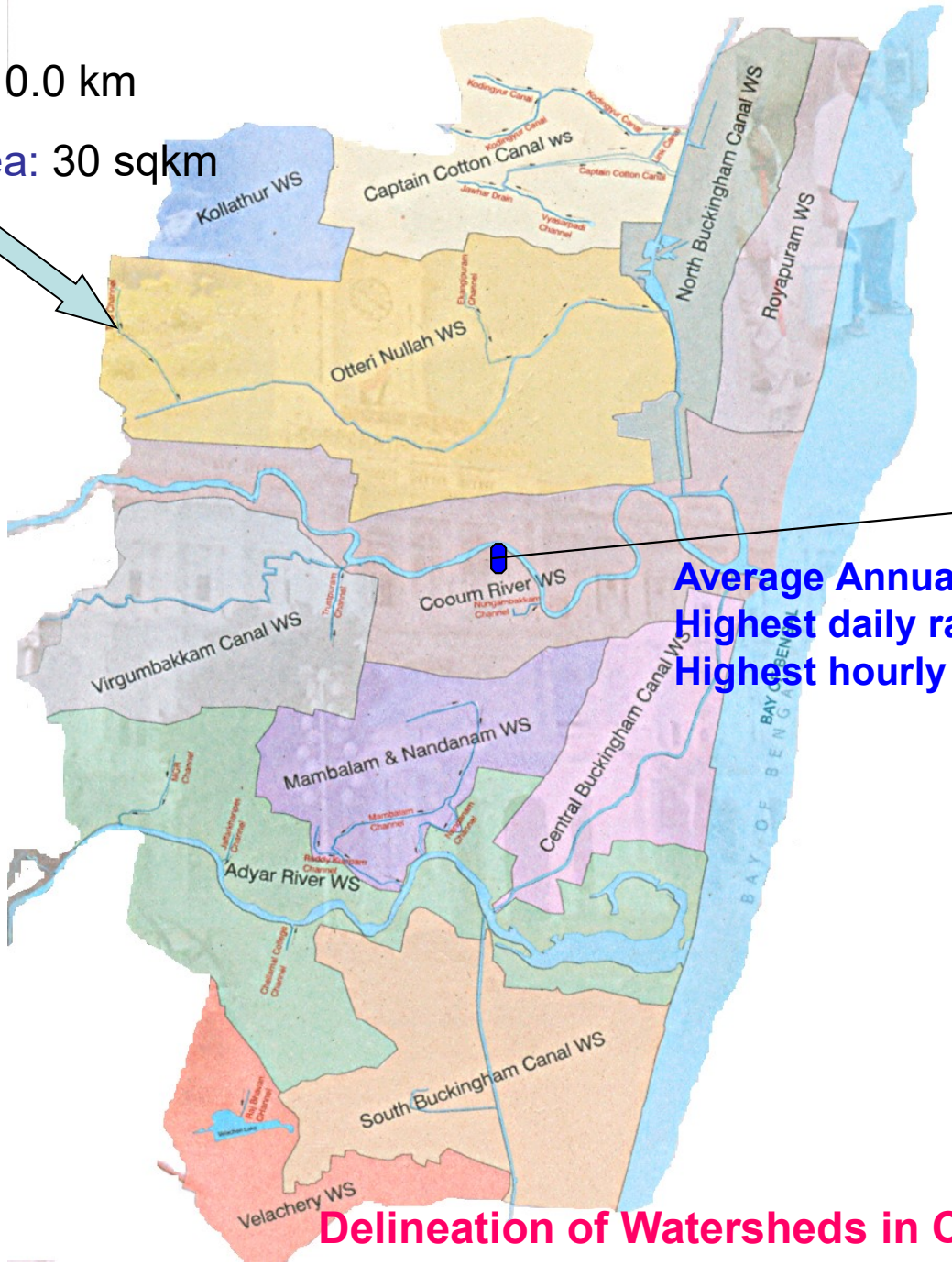


Case Study: Chennai

Otteri nullah watershed

Total Length: 10.0 km

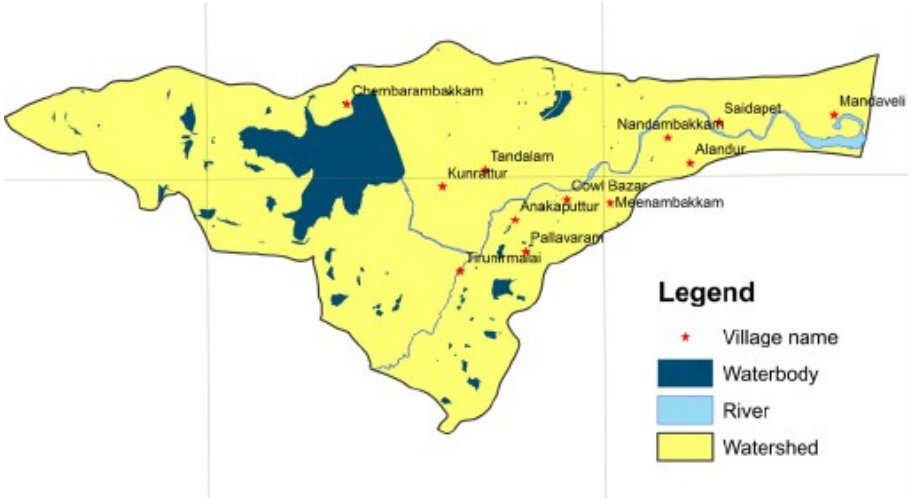
Watershed area: 30 sqkm



Nungambakkam Rain Gauge Station (IMD)

Average Annual Rainfall: 1300 mm
Highest daily rainfall 34/40 cm (2005)
Highest hourly rainfall 93.5 mm (1996)

Delineation of Watersheds in Chennai Corporation



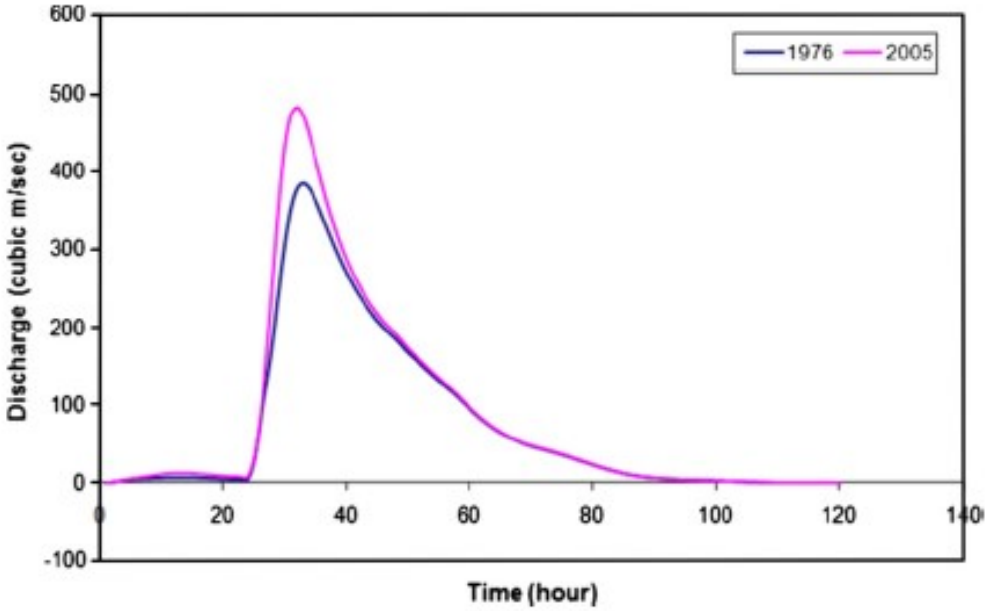


Fig. 7. Runoff hydrograph before and after urbanization for the return period of 100 years.

Land use changes.

Sl. no.	Land use	Area in sq km		% Change
		1976	2005	
1	Agricultural land	71.79	44.03	−39
2	Barren land	65.46	83.50	+28
3	Built-up area	70.30	107.64	+53
4	Canal	0.15	0.07	+53
5	Forest	9.73	10.62	+9
6	Plantation	11.38	4.12	−64
7	River	3.99	3.41	−15
8	Scrub land	32.26	17.69	+45
9	Tanks	34.69	28.67	−17
	Total	299.75	299.75	

Urban flooding

- It is triggered when surface runoff exceeds the capacity of drainage systems, which happens when heavy rainfall pours on sewers with the limited capacity, or even medium rainfall falls on poorly planned or operated drainage systems (Kamal and Rabbi, 1998; Arambepola, 2002).

Definition of Urban Drainage Systems

- Urban drainage systems are defined as physical facilities that collect, store, convey, and treat runoff in urban areas. These facilities normally include detention and retention facilities, streets, storm sewers, inlets, open channels, and special structures such as inlets, manholes, and energy dissipaters" (ASCE and WEF, 1992).

Popular Storm Water Model Software Packages

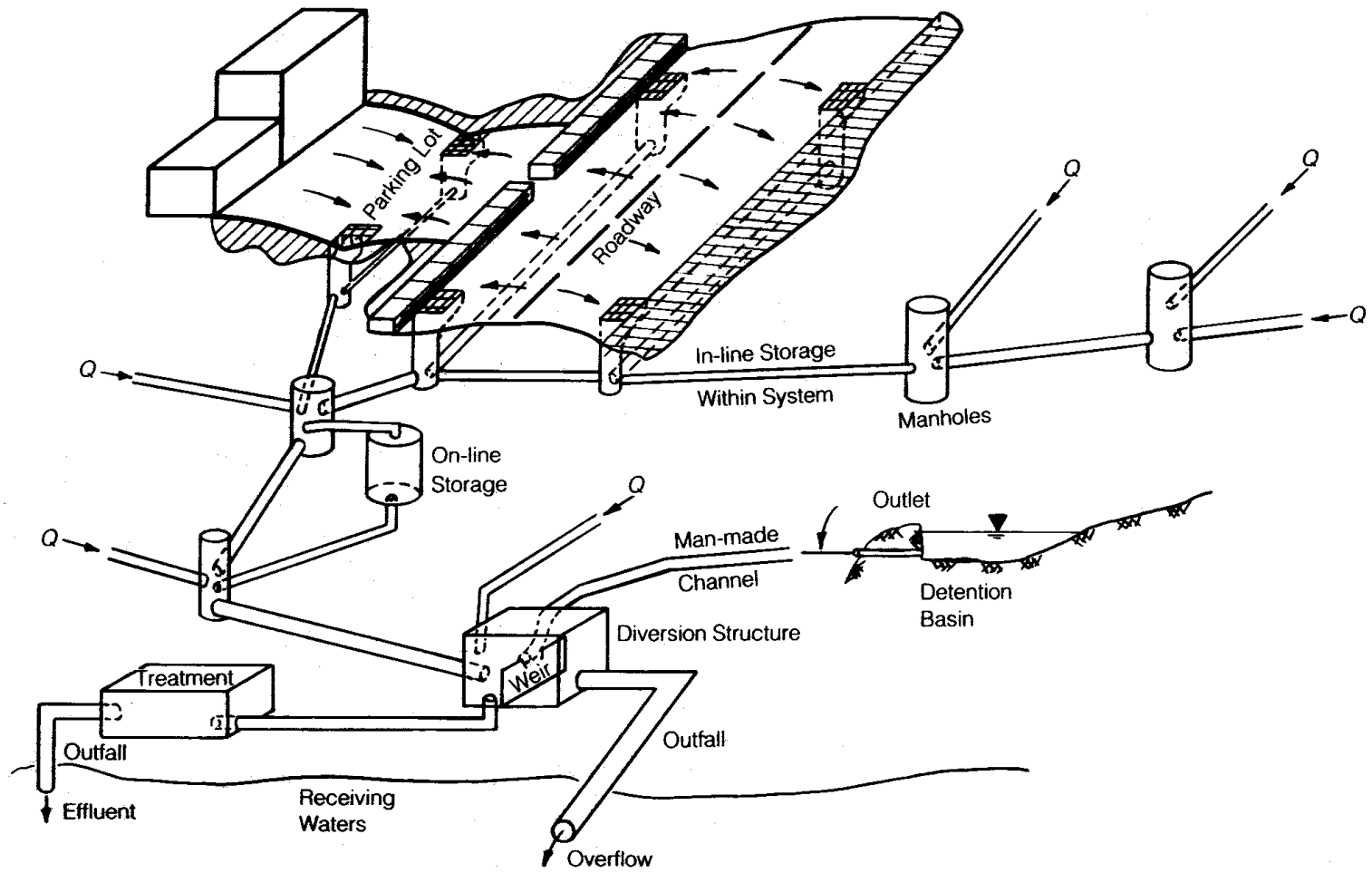
- US EPA (SWMM)
- DHI (MIKE URBAN)
- Bentley (Storm net)
- Wallingford
- **XPSWMM** XP Software Inc.

SELECTED MODEL

XP SWMM/EPA SWMM
(Stormwater and Wastewater Management Model)

XPSWMM used to develop link-node and spatially distributed models that are used for the analysis, design and simulation of storm and waste water system. It also models flow and pollutant in natural system including rivers, lakes, and floodplains with groundwater interaction.

What is SWMM?



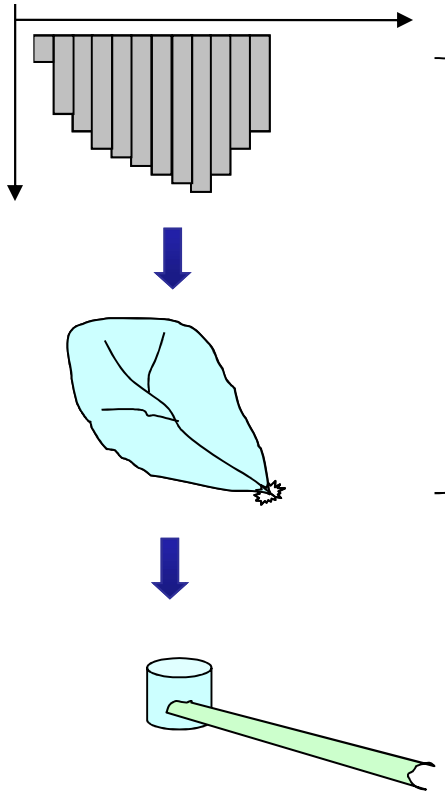
SWMM is a distributed dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas.

Process of Storm to Sewer network

Storm

Catchment

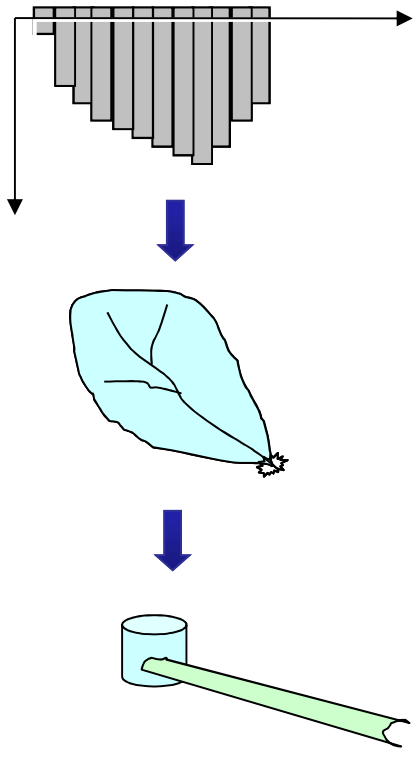
Sewer



Hydrological model

Hydraulic model

Design of Storm sewer system

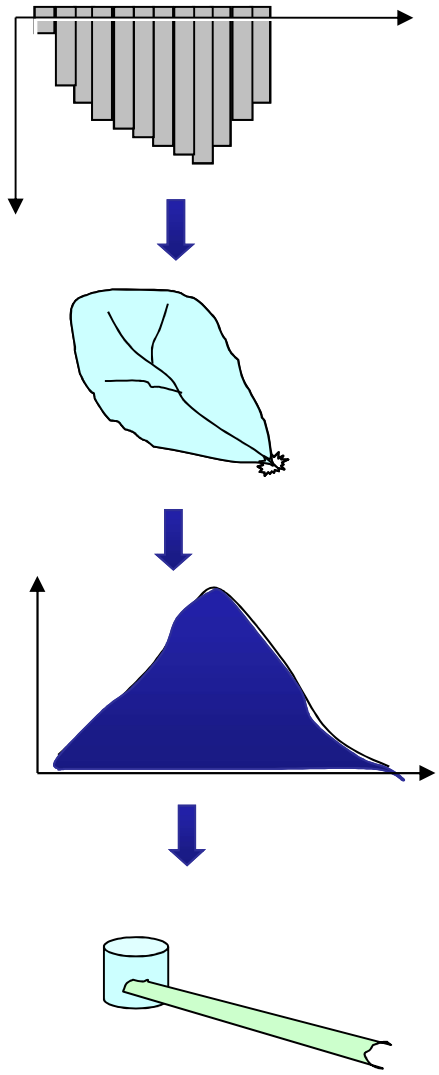


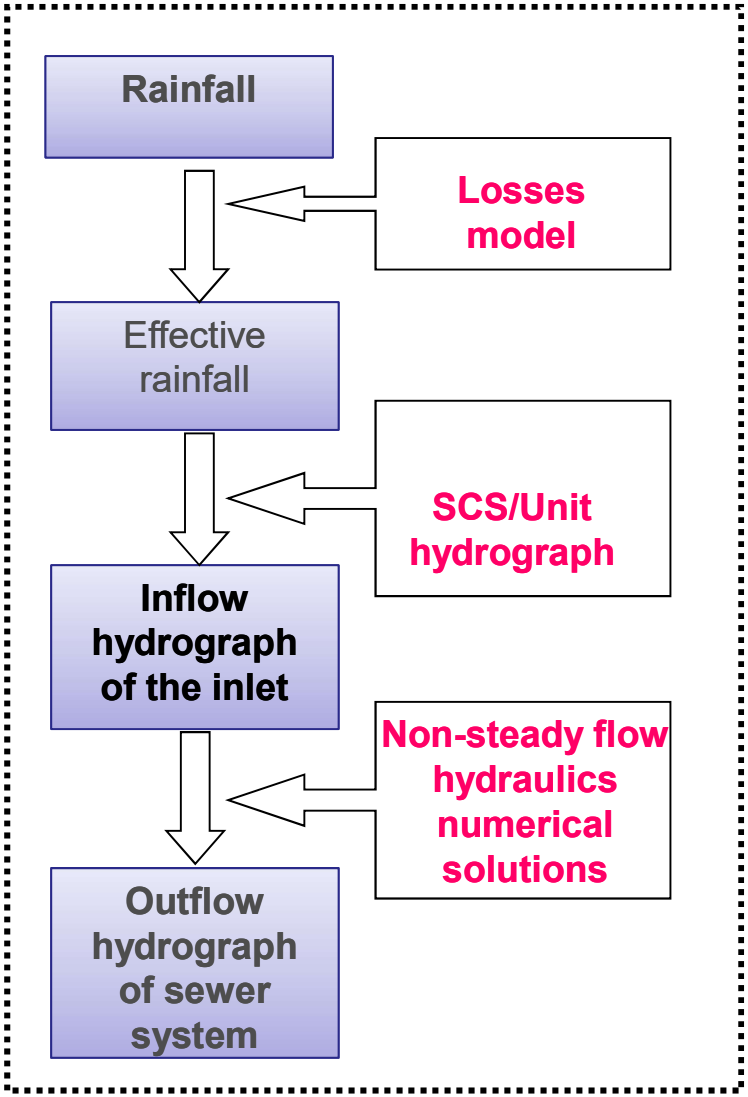
Design storms are routinely used for designing storm sewer system.

A design storm is a hypothetical storm with specific duration *D* and return period *T.*

The information of design storms is conveniently presented in the form of depth-duration-frequency (DDF) curves or intensity-duration-frequency (IDF) curves.

Modeling of Storm Sewer System





Project Objectives:

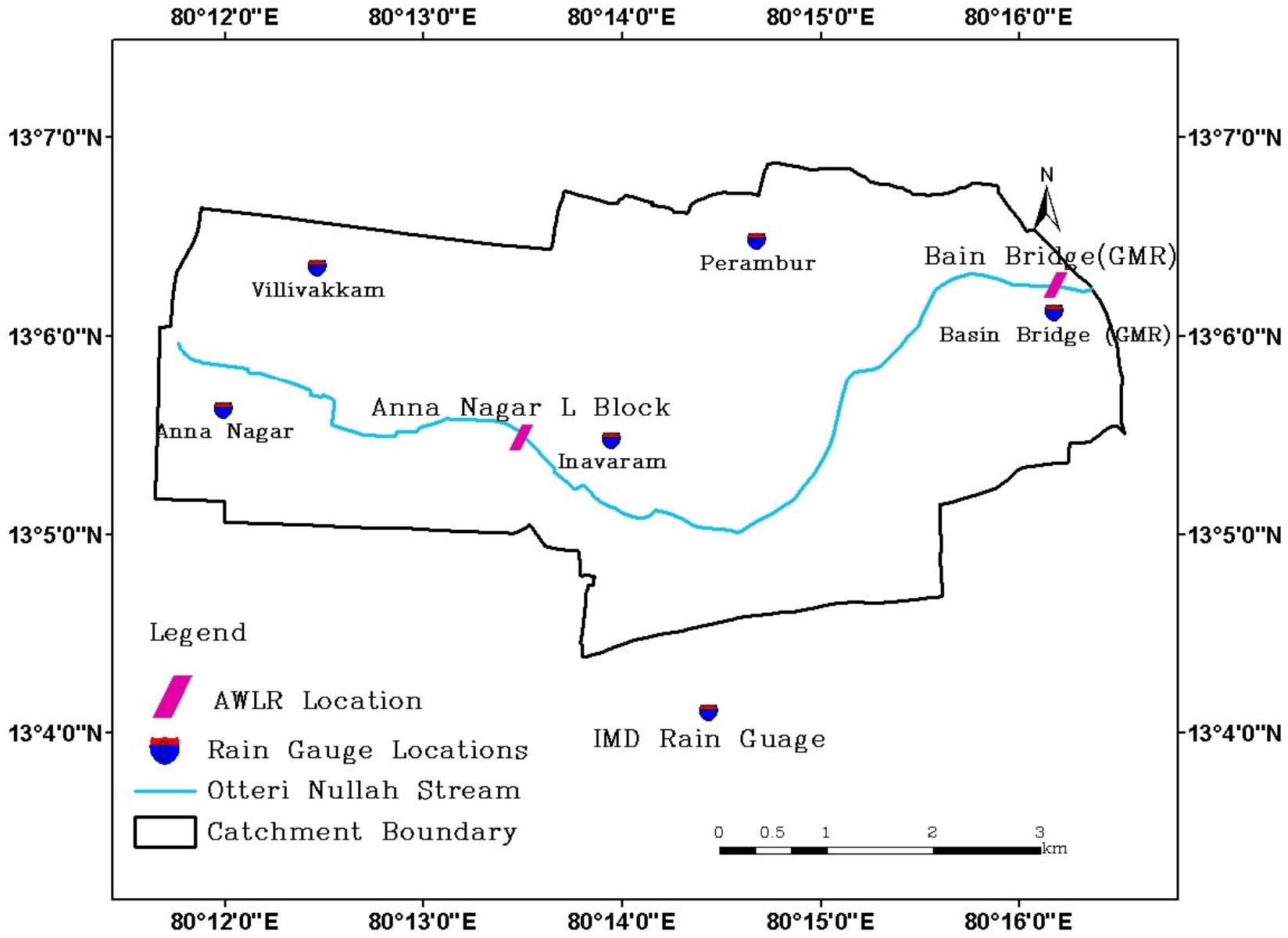
1. Evaluation of existing storm water drainage network efficiency in the study area

2. To find out the inflow-outflow hydrograph at various outlets and the water surface profile along the storm water drains.

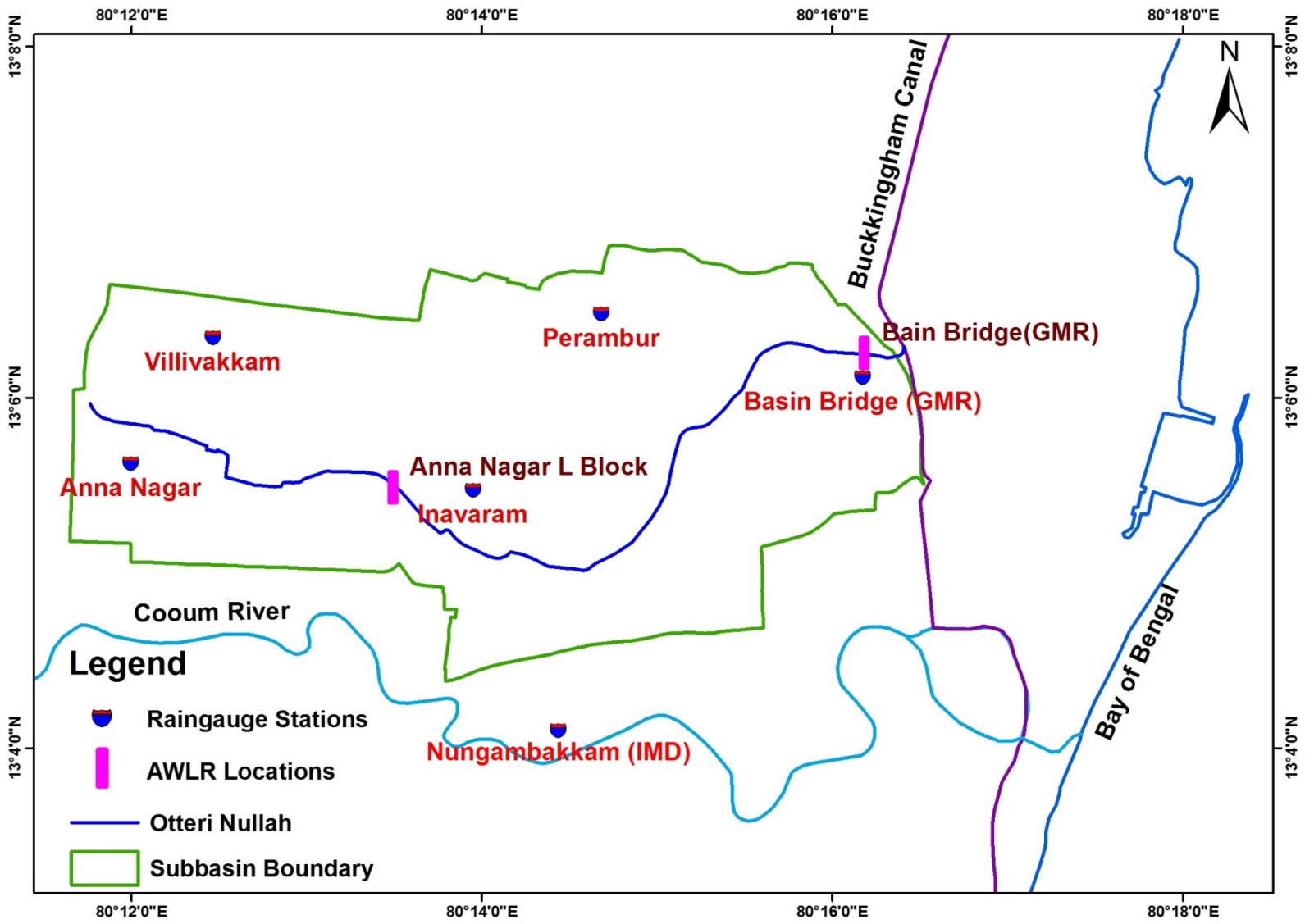
3. Feasibility of improvement of the existing storm water drainage network or to propose additional network to mitigate urban storm water flooding in the study area.

4. Dissemination of results of the project through workshops/ brain storming sessions/awareness programs with the help of NGO's/Govt., departments/Academic Institutions in the study area and elsewhere.

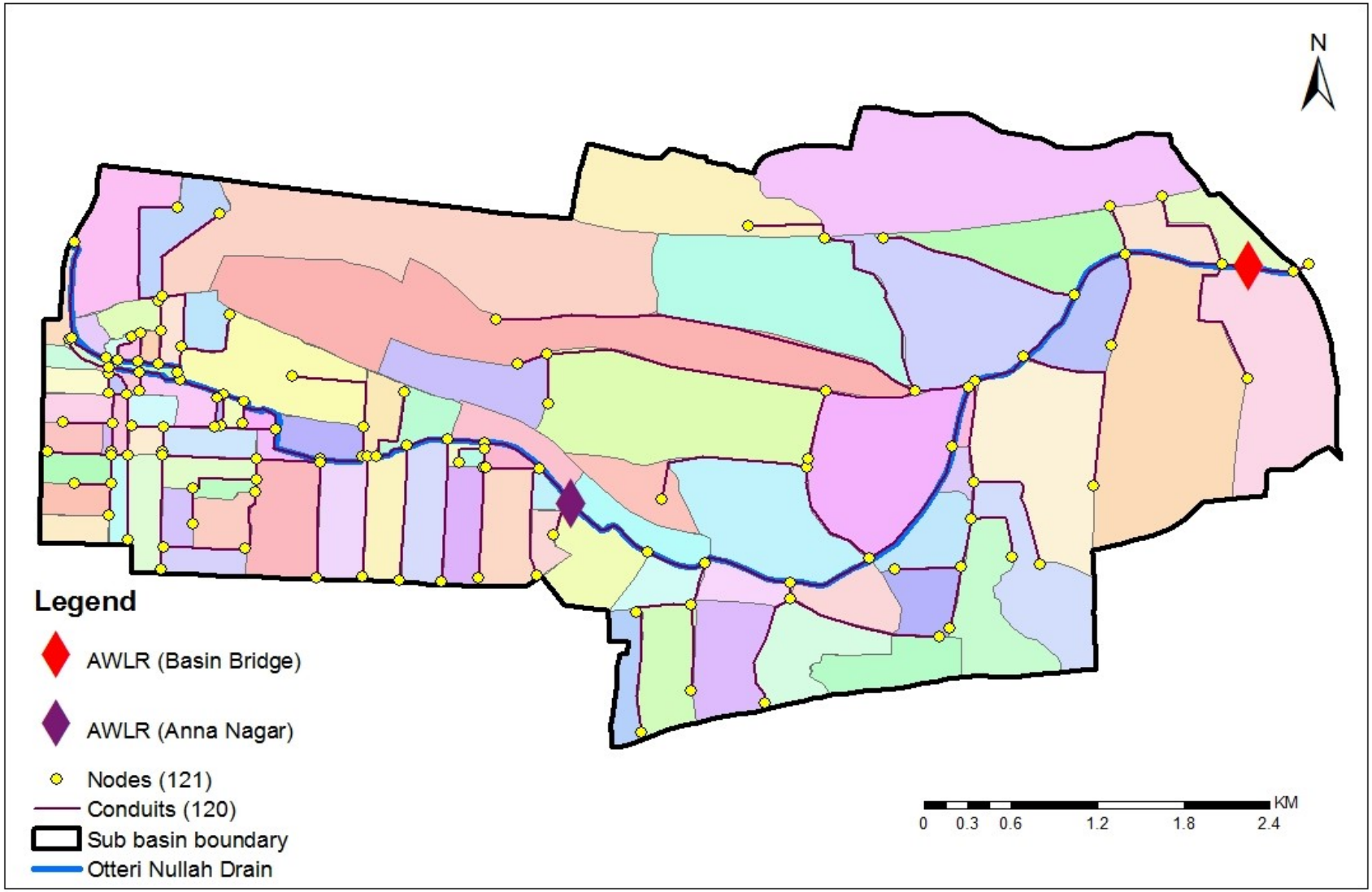
Instrumentation in Project Location: Monitoring Network of Rain gauge and Water level Recorders

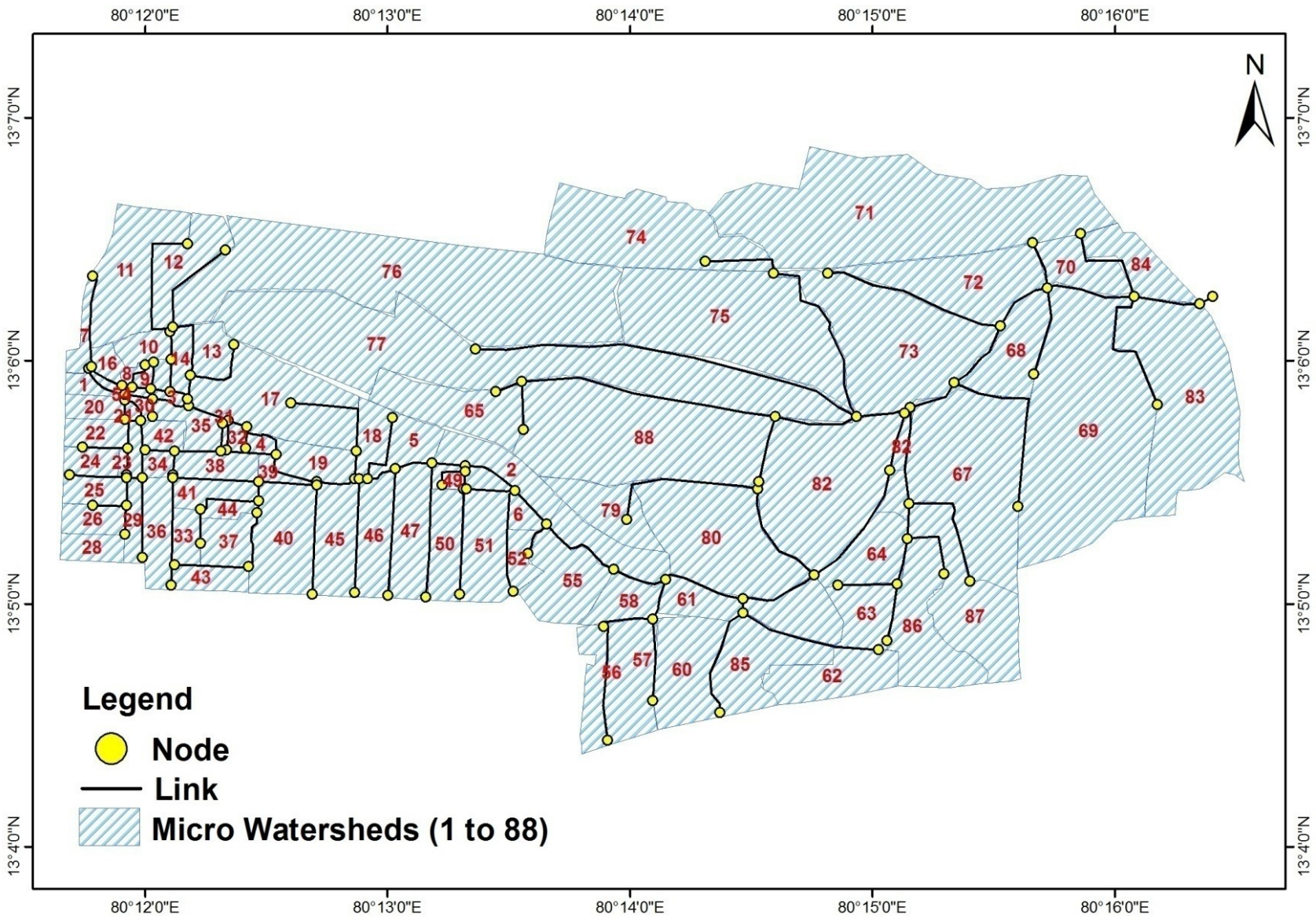


Application of Model (XP-SWMM)

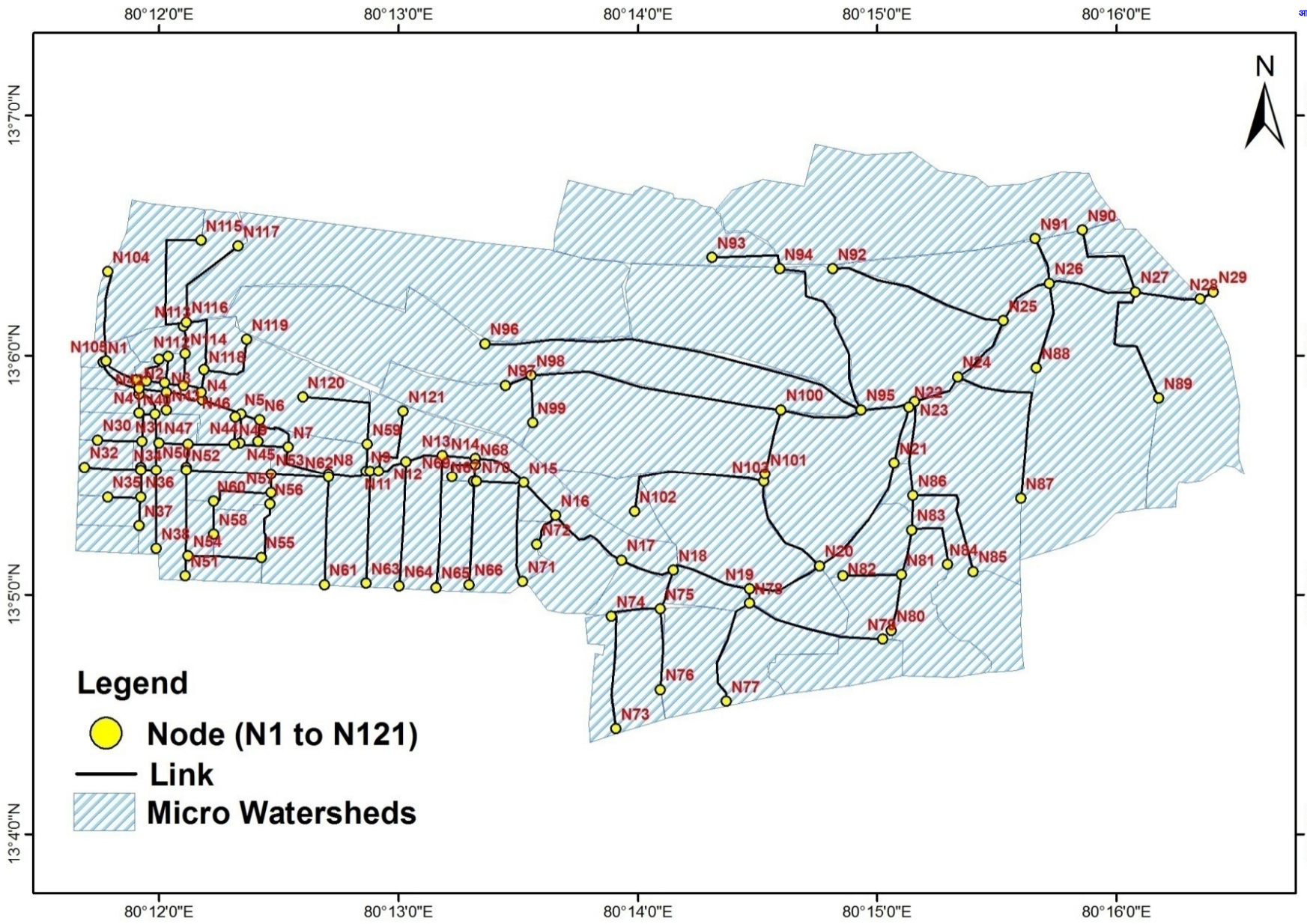

80°12'0"E
80°14'0"E
80°16'0"E
80°18'0"E
13°8'0"N
13°6'0"N
13°4'0"N
N
Buckkinggham Canal
Villivakkam
Perambur
Bain Bridge(GMR)
Basin Bridge (GMR)
Anna Nagar
Anna Nagar L Block
Inavaram
Coum River
Nungambakkam (IMD)
Bay of Bengal
Legend
Raingauge Stations
AWLR Locations
Otteri Nullah
Subbasin Boundary

Schematization of Project Area: Micro watersheds(86), Node (121) and Links (120)

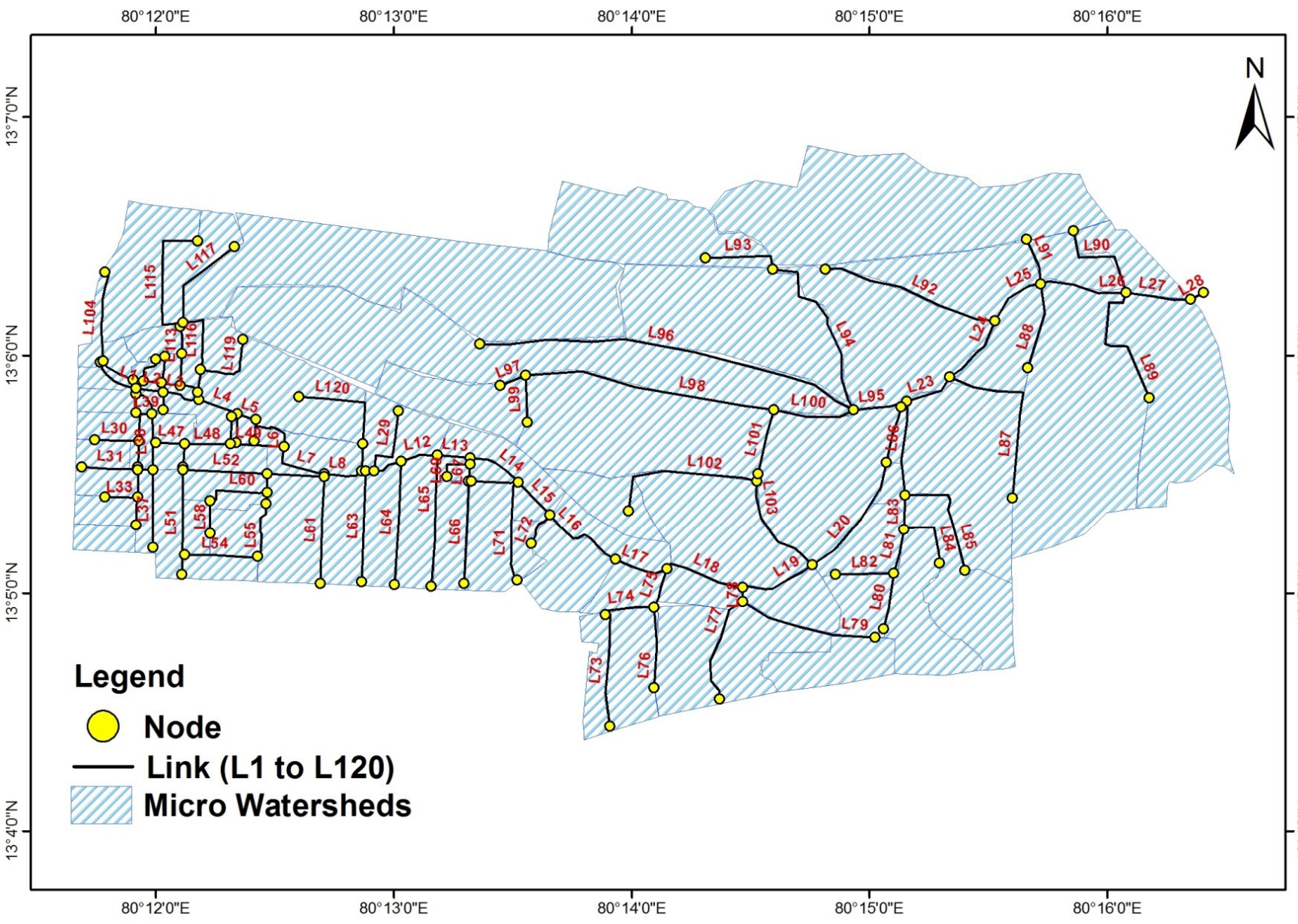




Delineated micro watersheds of the study area in XP-SWMM

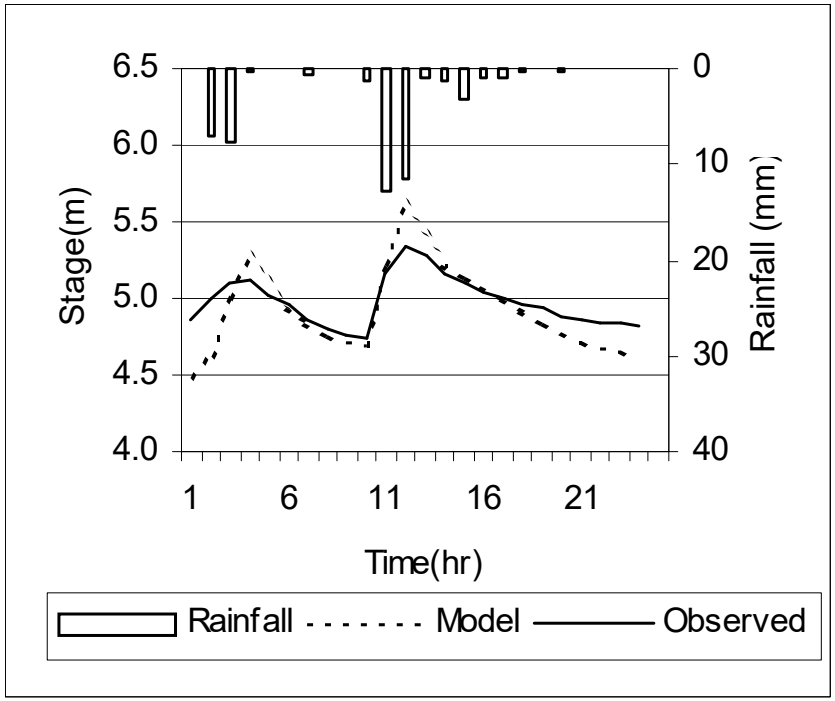


Connectivity of micro watersheds with nodes in XP-SWMM

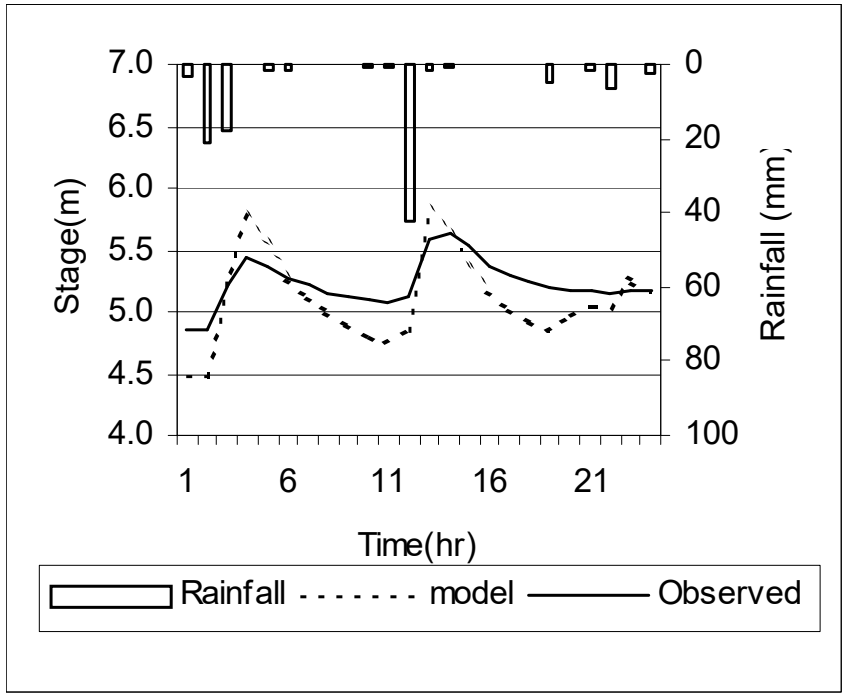


Details of links considered in the XP-SWMM

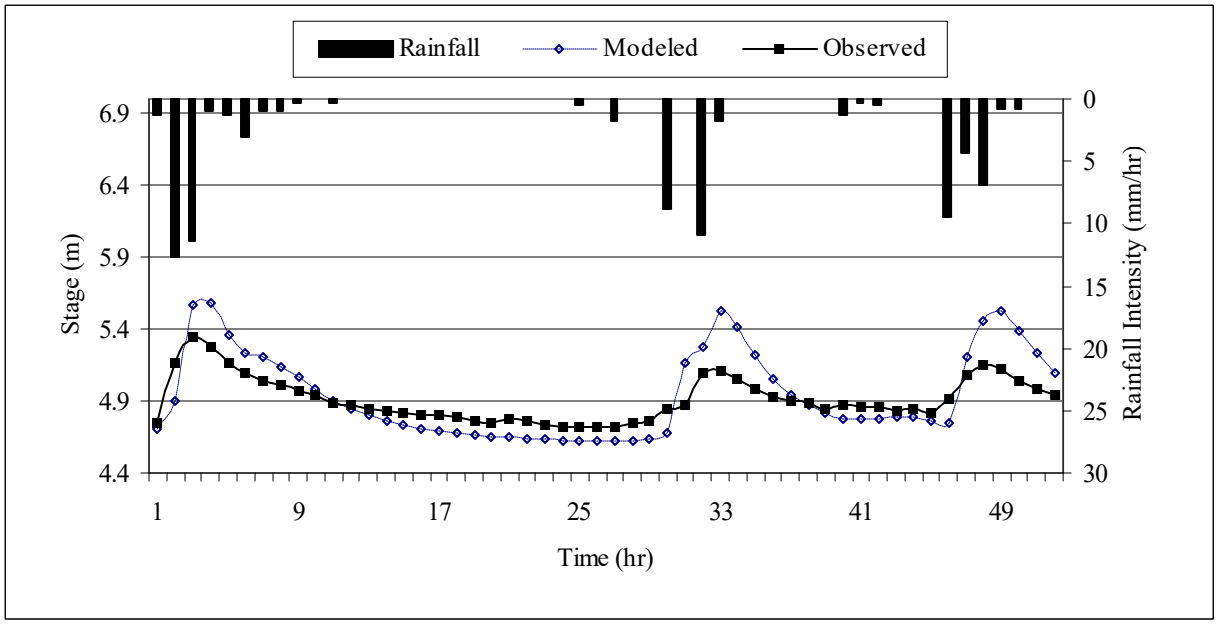
Model Testing



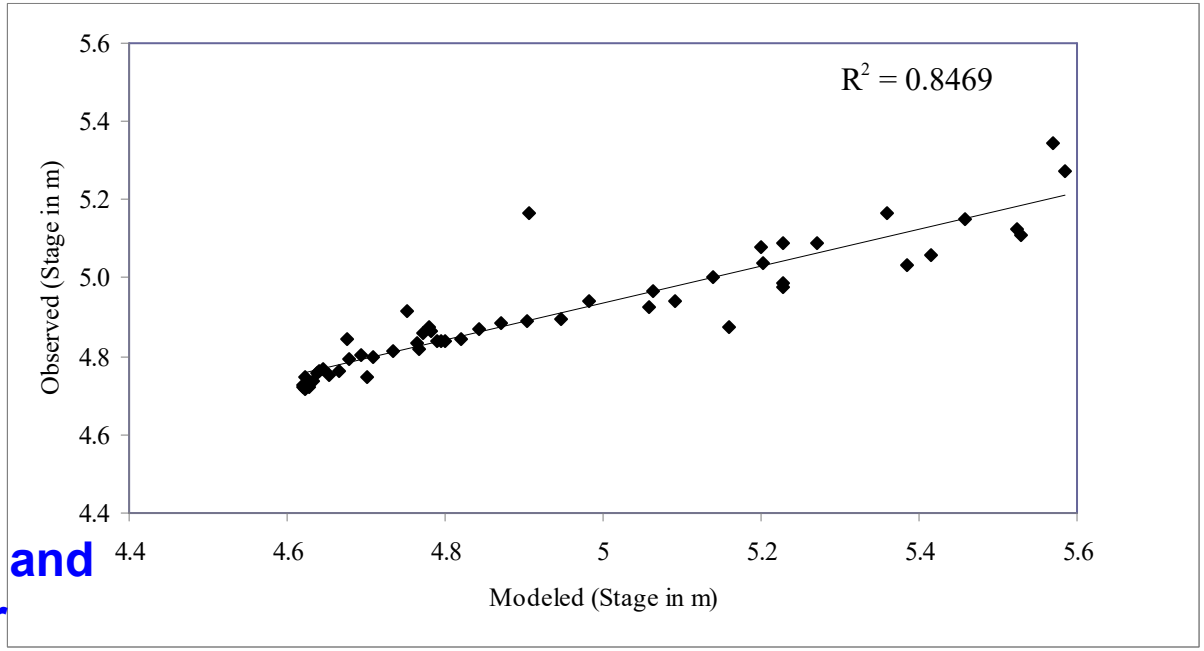
Comparison between observed and modeled stage at Anna Nagar (25th Oct. 2011)



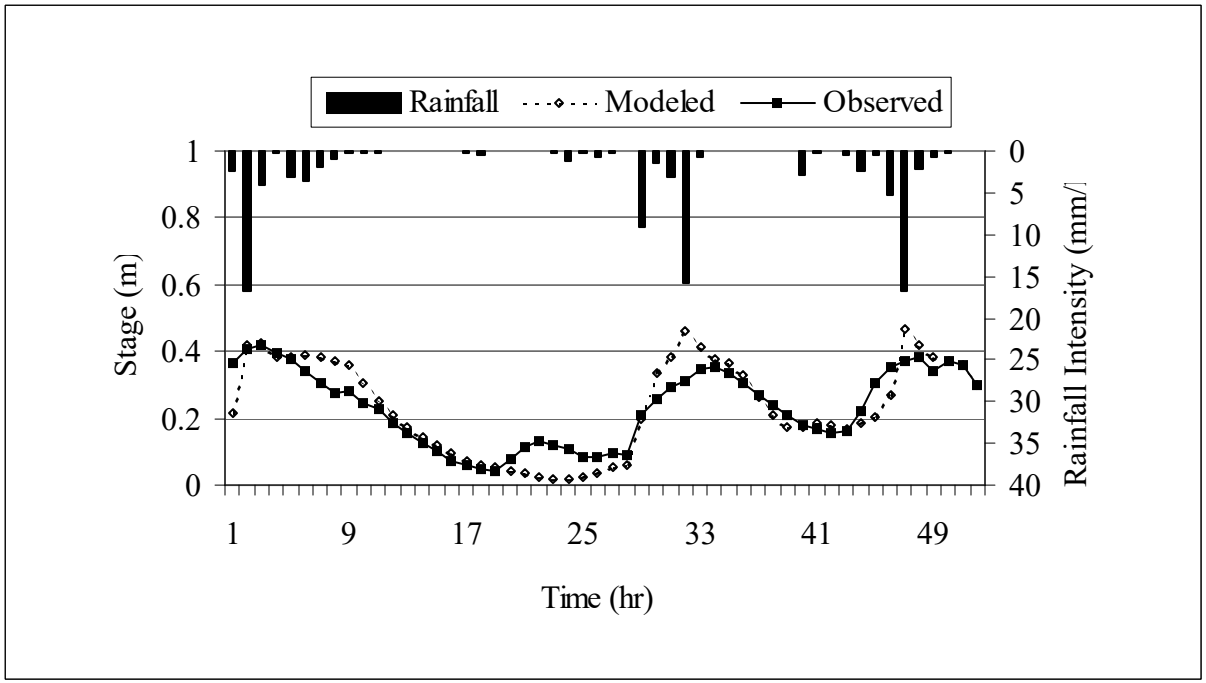
Comparison between observed and modeled stage at Anna Nagar (4th Nov. 2011)



Comparison between observed and simulated stage at Anna Nagar (25-10-2011, 9.00 to 27-10-2011, 12.00 hrs)

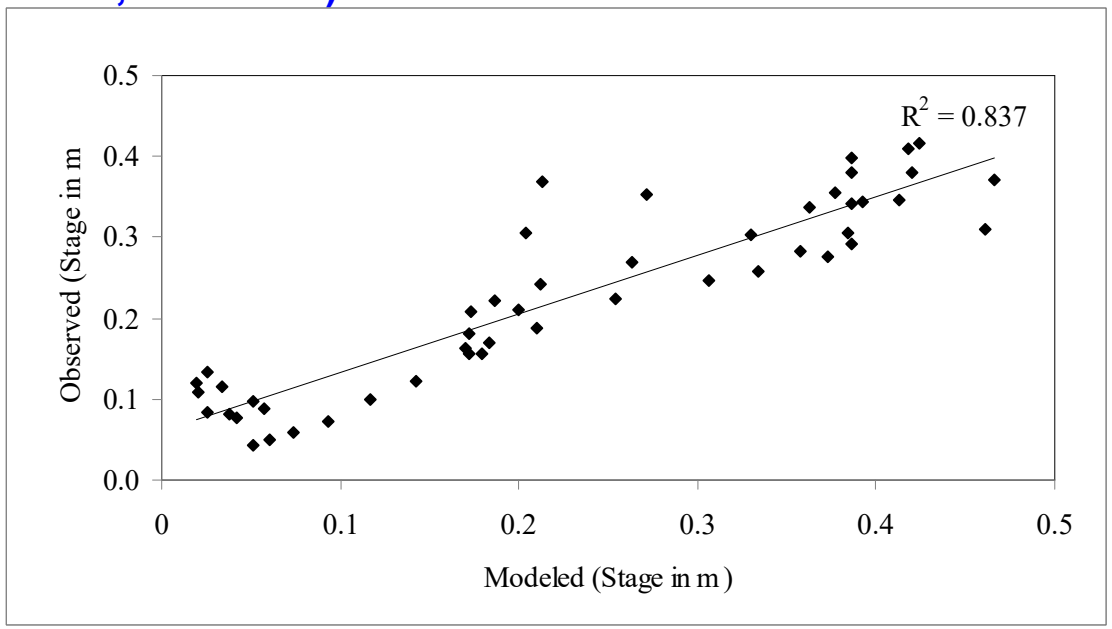


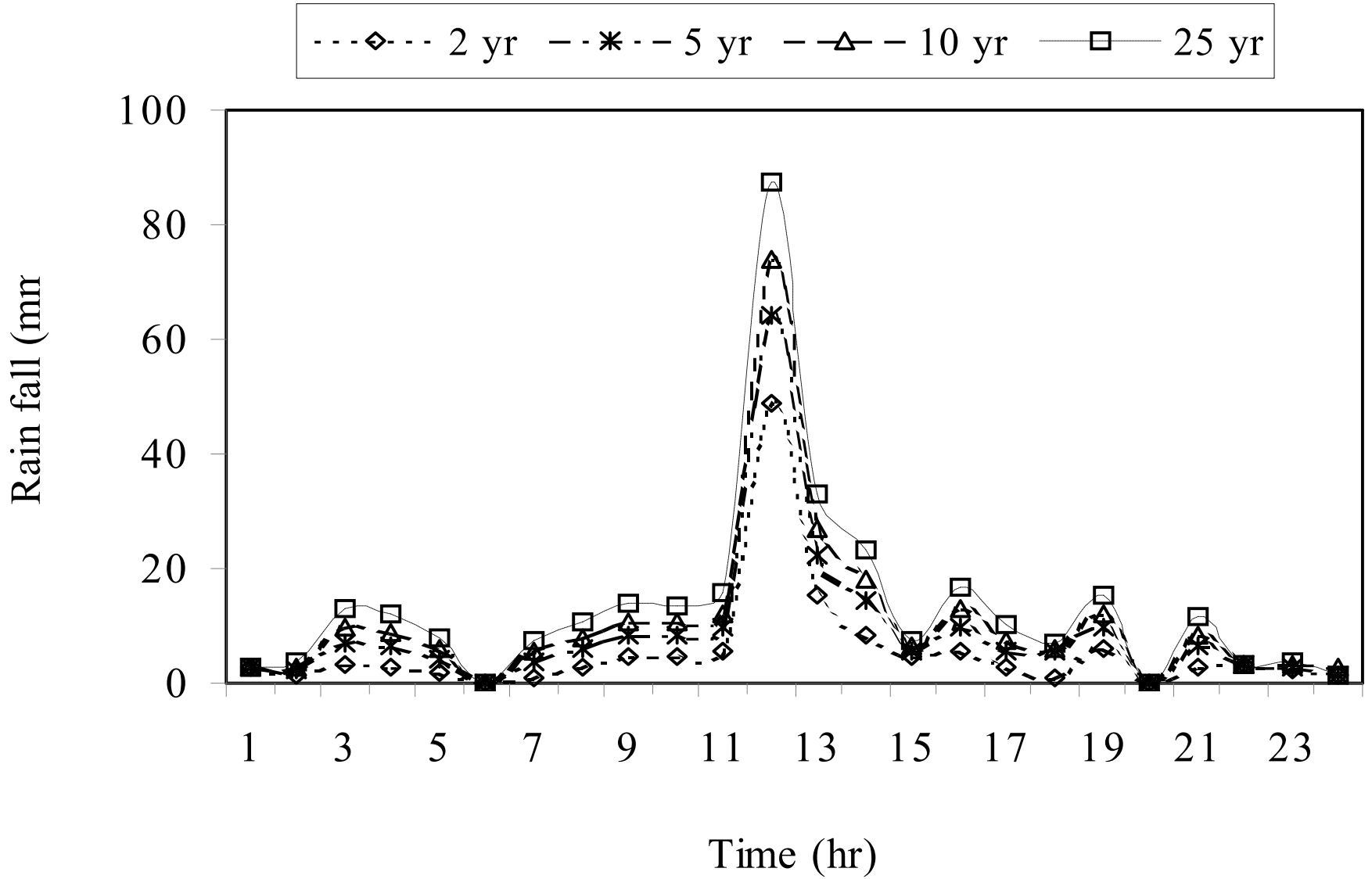
Correlation between observed and simulated stage at Anna Nagar



Comparison between observed and simulated stage at Basin Bridge (25-10-2011, 9.00 to 27-10-2011, 12.00 hrs)

Correlation between observed and simulated stage at Basin Bridge

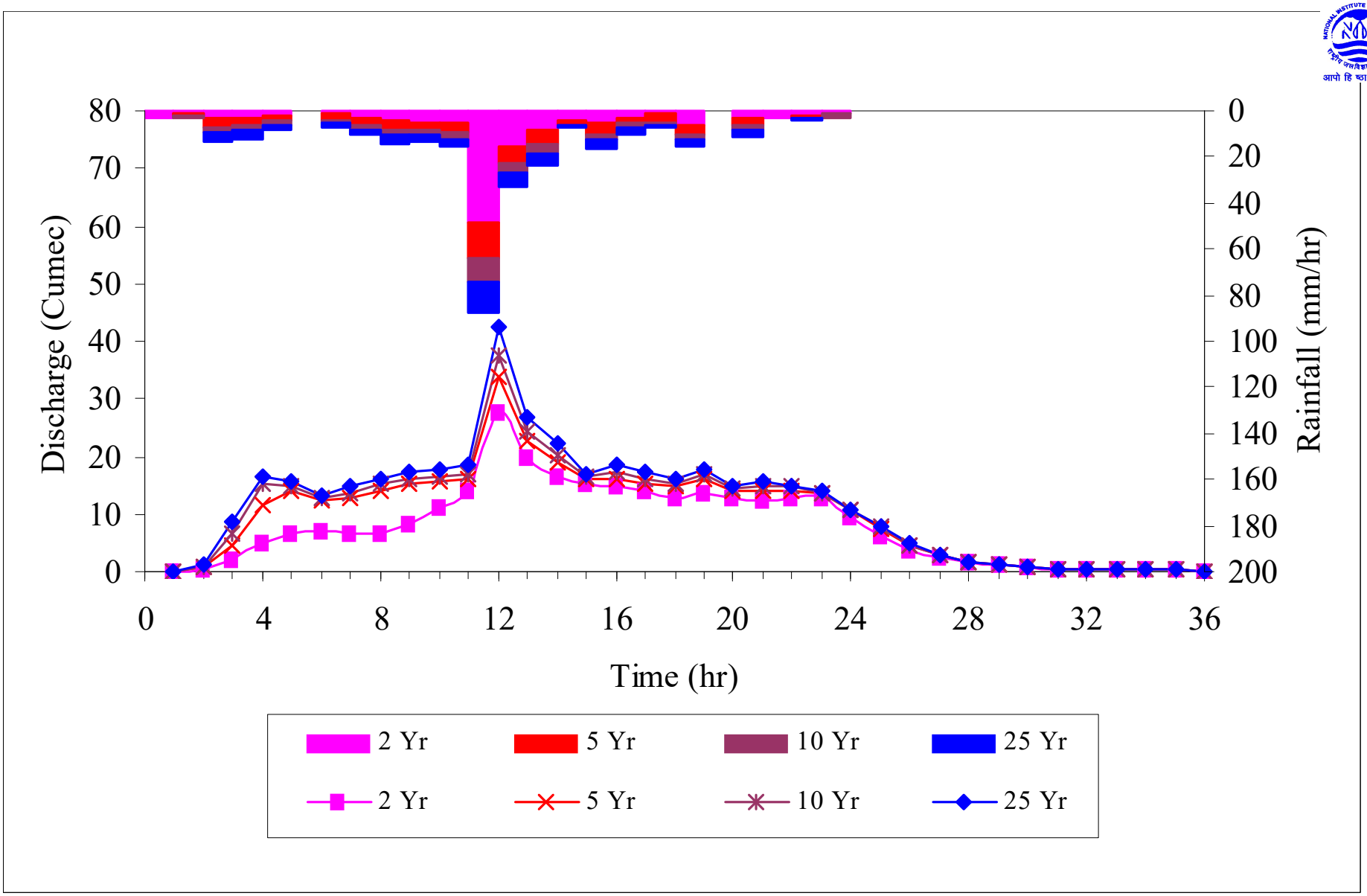




24 hr Design Storms for various Return Periods

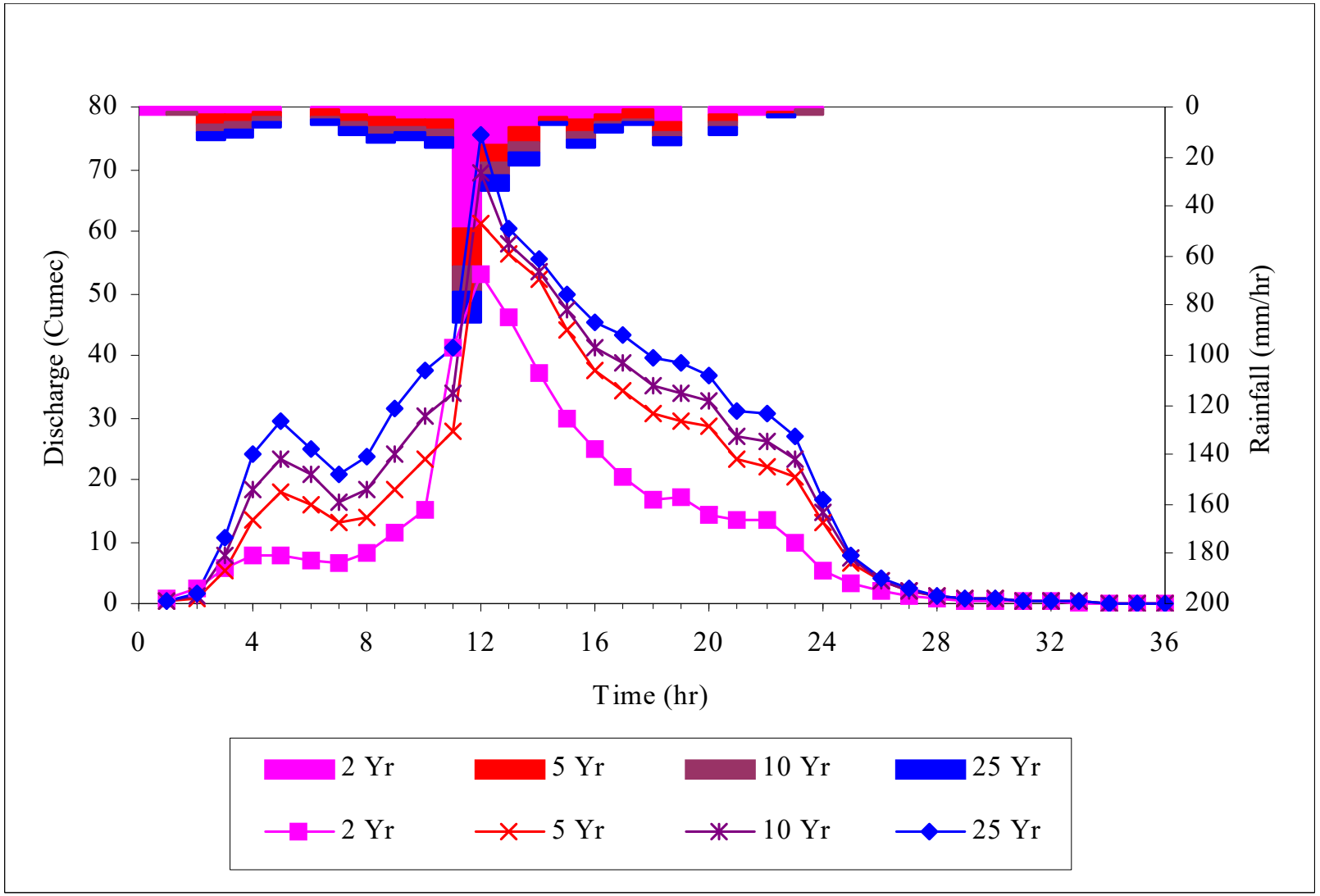
Details of water balance, flood peaks with existing and proposed longitudinal profile of Otteri Nullah against various return period of design storm

24 hr design storm return period	Peak (m^3/s)		System Inflow (m^3)		System Outflow (m^3)		± % Error	
	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
2	27.57	53.00	$2.7463*10^6$	$2.7463*10^6$	$2.7429*10^6$	$2.7538*10^6$	0.065	-0.323
5	33.80	61.40	$4.6879*10^6$	$4.6879*10^6$	$4.6817*10^6$	$4.6931*10^6$	0.065	-0.110
10	37.58	69.31	$5.9395*10^6$	$5.9395*10^6$	$5.9345*10^6$	$5.9411*10^6$	0.031	-0.050
25	42.37	75.60	$7.6090*10^6$	$7.6091*10^6$	$7.6056*10^6$	$7.6092*10^6$	0.005	-0.001

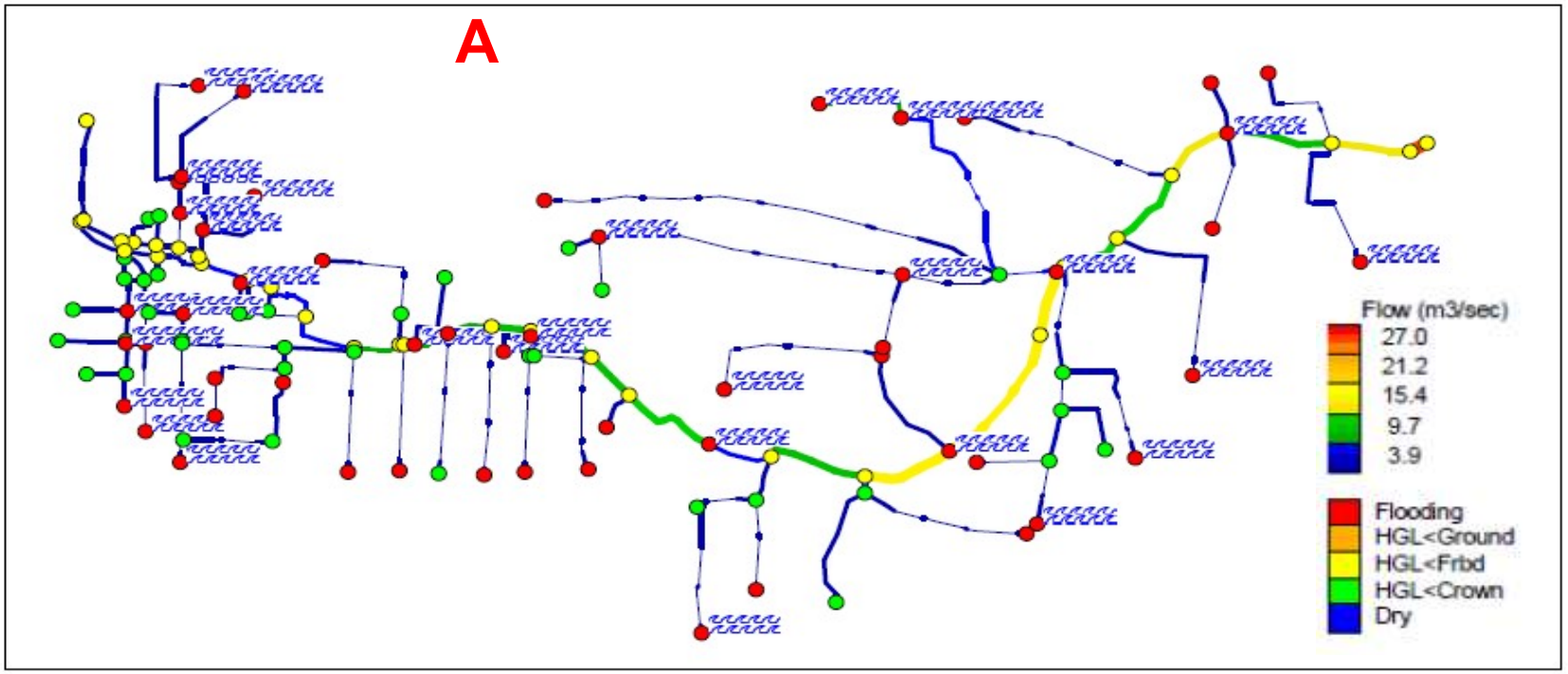


24hr design hyetographs and its corresponding hydrographs at sub basin outfall with existing longitudinal Profile

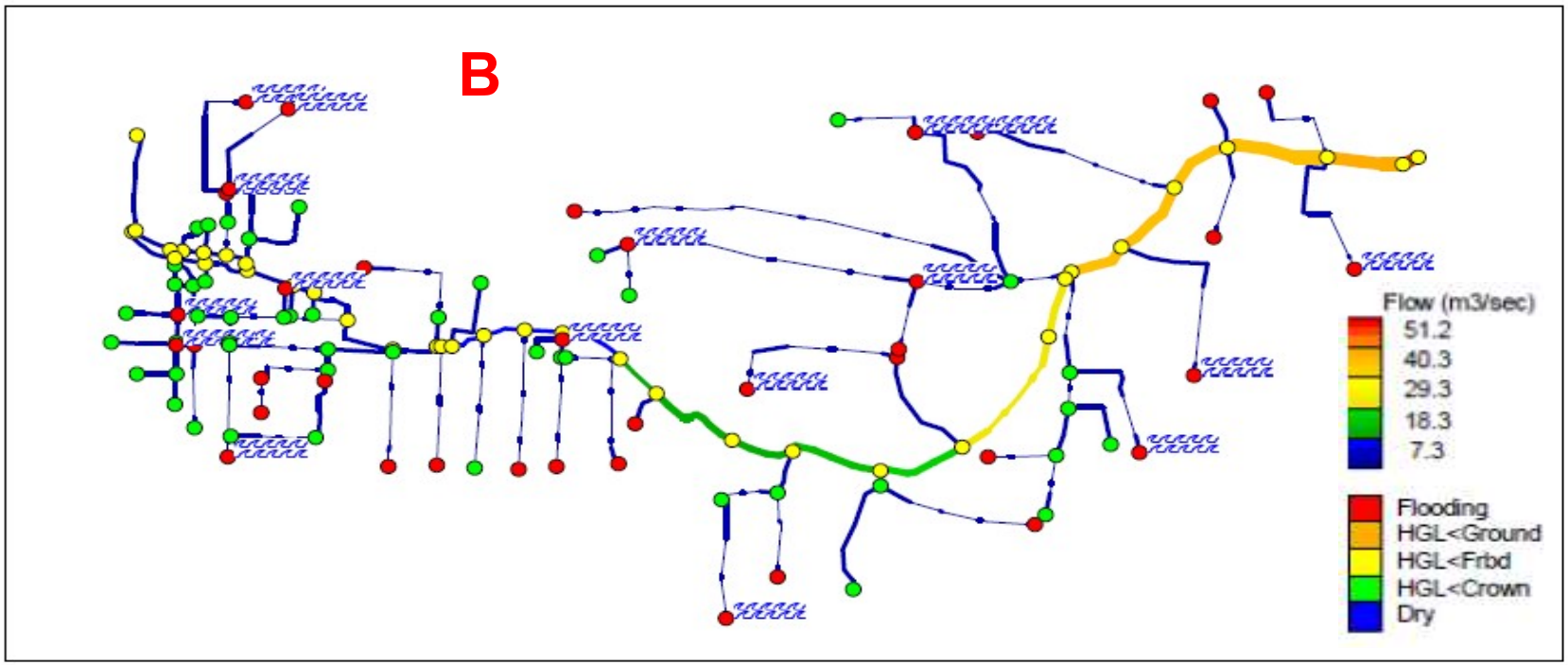
Flood Mitigation Measures



24hr design hyetographs and its corresponding hydrographs at sub basin outfall with proposed longitudinal profile.

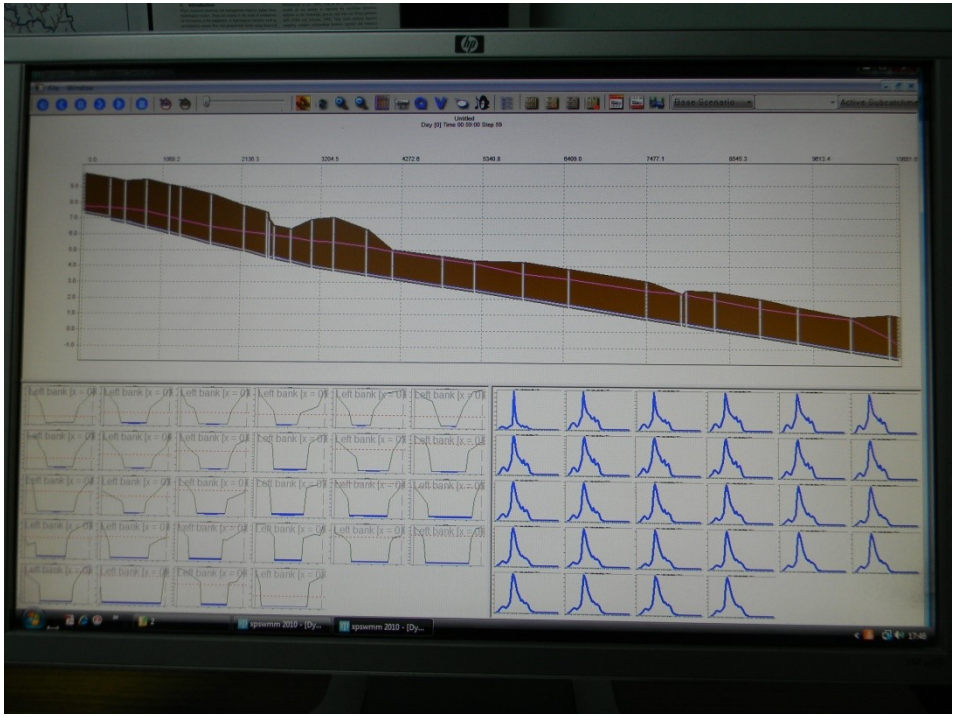


A. Plan view of flooding nodes in the study area for 2 yrs return period design storm with existing L/P



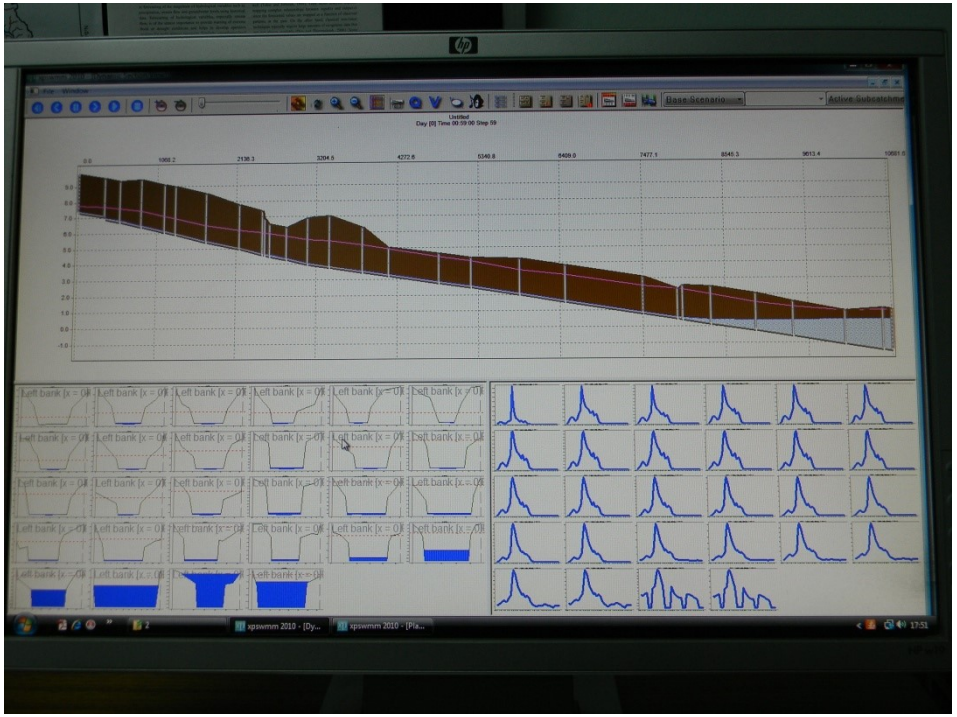
B. Proposed L/P

Water surface profile in the OND with 2-yr return period 24 hrs design storm with/with out boundary conditions



Water Surface Profile

Plan View



Water Surface Profile

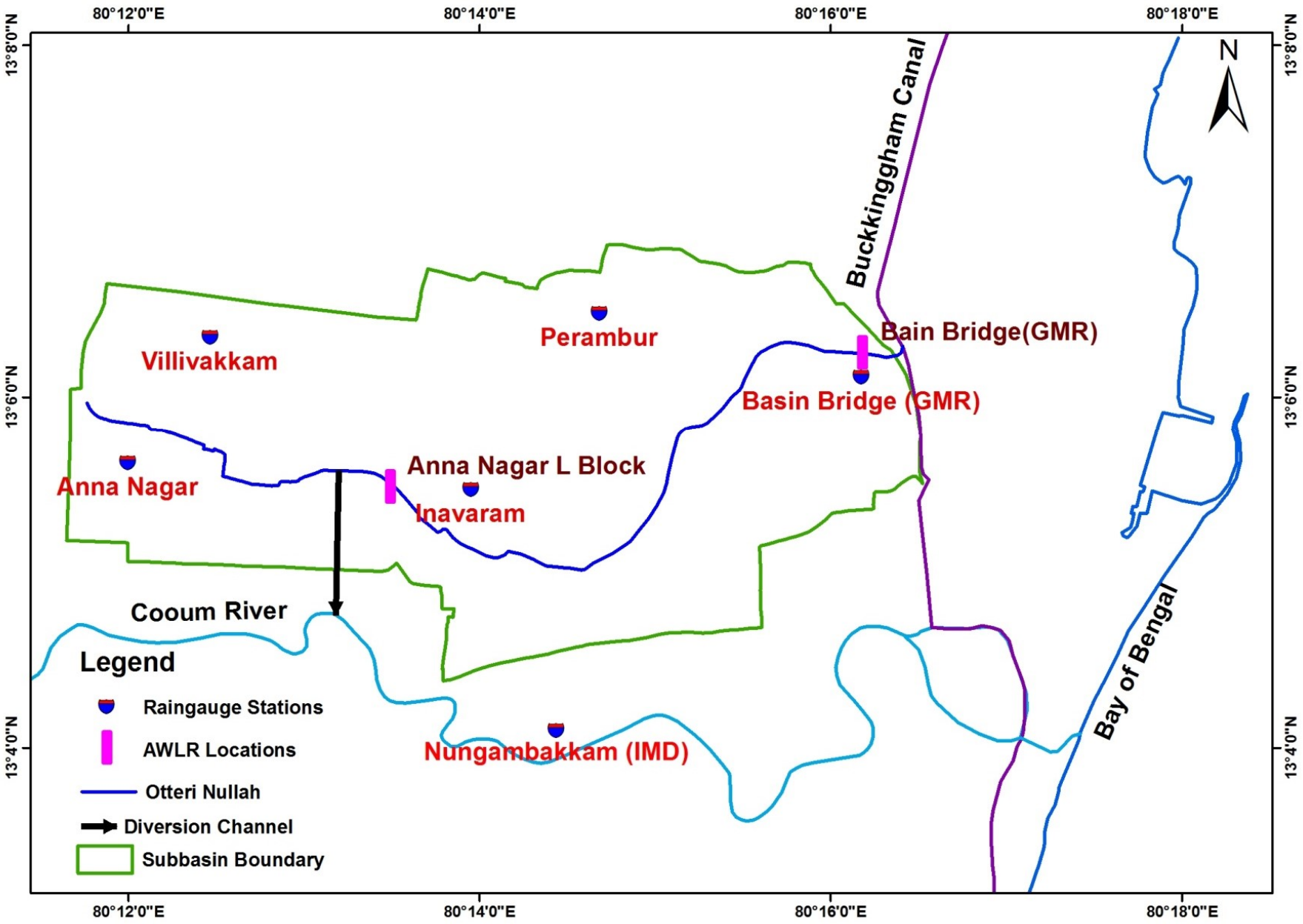
Plan View

Impact of Flood Mitigation Measures at Node Points

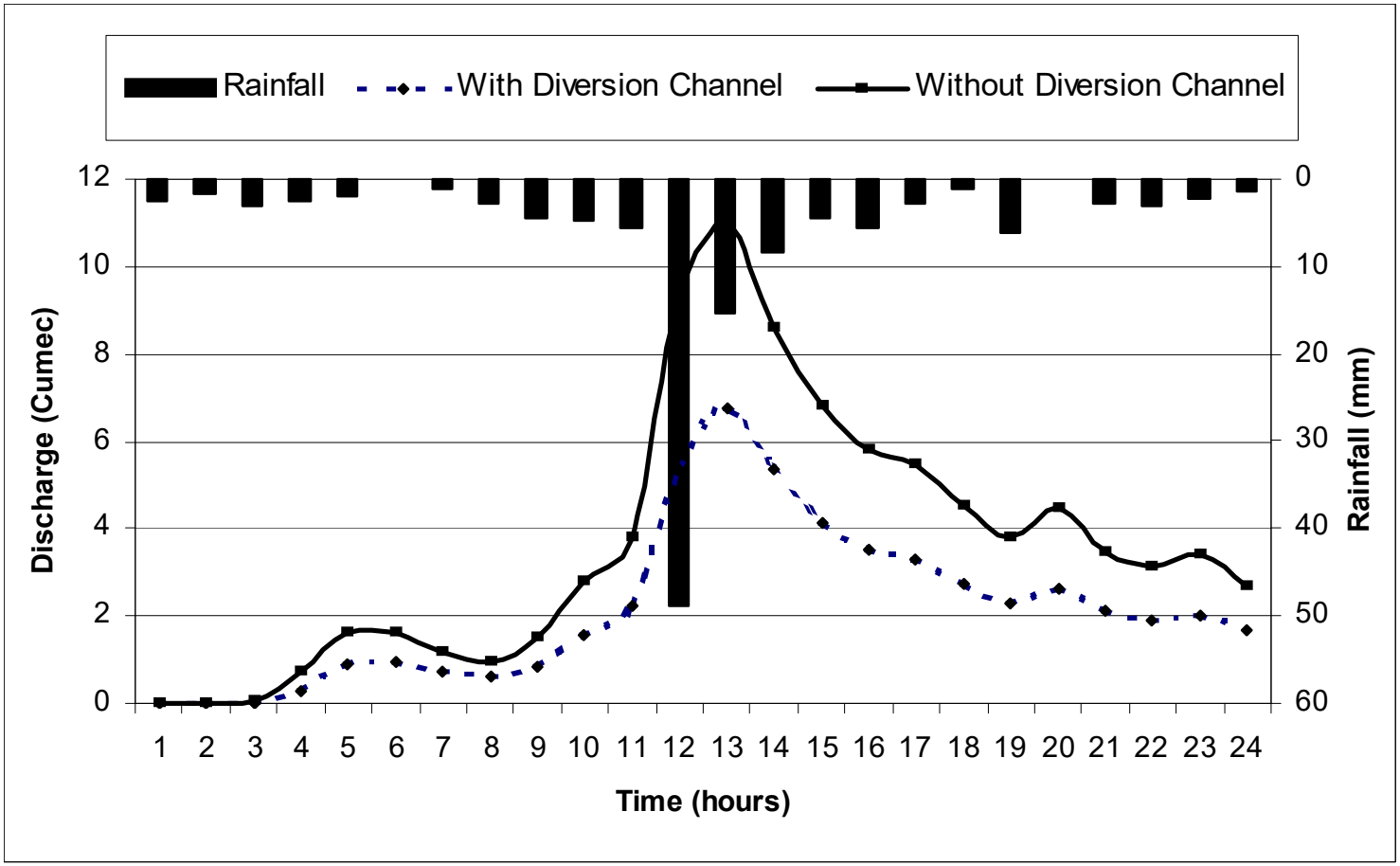
Total SWD Nodes (92)		
24-hrs storm Return period	FN Existing L/P	FN Proposed L/P
2 Yr	**64**	**54**
5 Yr	**68**	**58**
25 Yr	**71**	**61**
100 Yr	71	71

Total OND Nodes (29)		
24-hrs storm Return period	FN Existing L/P	FN Proposed L/P
2 Yr	**5**	**1**
5 Yr	**6**	**4**
25 Yr	**6**	**4**
100 Yr	6	6

Location of proposed diversion channel by PWD in the study area



Two years return period of hyetograph and corresponding hydrograph at Anna Nagar with and without diversion channel



Existing Stormwater drainage conditions in the study area

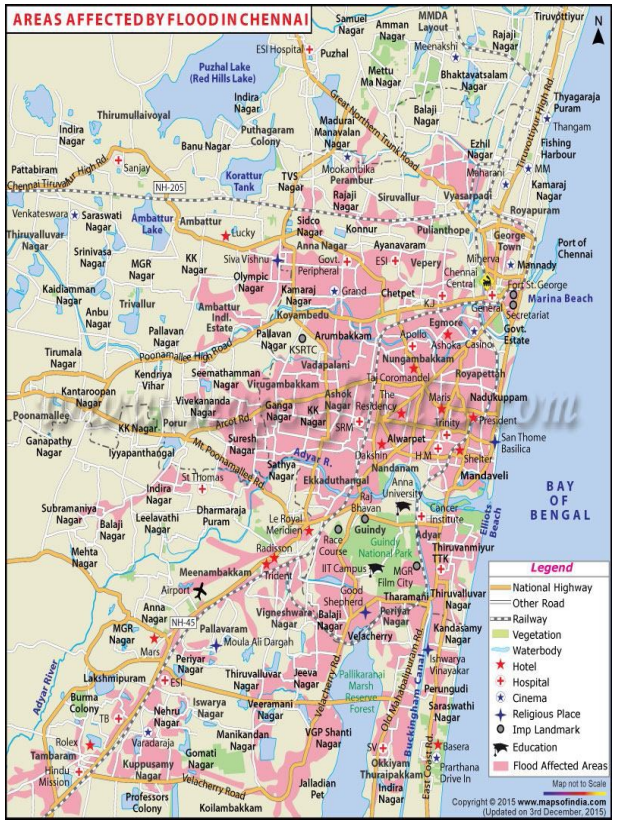

A TRAINING COURSE
ON
URBAN HYDROLOGY
UNDER HYDROLOGY PROJECT -II (PDS)
4th - 6th OCTOBER 2010
AT
SG & SWRDC, CHENNAI
ORGANISED BY


TRAINING WORKSHOP
on
STORM WATER MANAGEMENT IN URBAN AREAS
Under Hydrology Project - II (PDS)
September 21-23, 2011
Organised by
Deltaic Regional Centre
National Institute of Hydrology
Kakinada, Andhra Pradesh.

Objectives	Conclusions
Evaluation of existing storm water drainage network efficiency in the study area	The present storm drainage network is not sufficient even for two year return period rainfall except ON drain.
To find out the inflow-outflow hydrograph at various outlets and the water surface profile along the storm water drains.	Inflow/out flow Hydrographs and water surface profiles were developed at all nodes in the project area after testing of the XP-SWMM model. Flood hydrographs have been developed at basin out let with tide and without tide for 2,5, 10 and 25 years return period rainfall.
Feasibility of improvement of the existing storm water drainage network or to propose additional network to mitigate urban storm water flooding in the study area.	Proposed change in longitudinal profile of ON Drain is capable to drain five year return period rainfall. Proposed diversion of flood water from ON Drain to Coovam river reduces 38% of flood water in ON watershed above Anna Nagar. Both proposals are implementing by PWD in the field.
Dissemination of results of the project through workshops/ brain storming	One inception workshop at Chennai, three training workshops at Chennai

Integrated macro flood (Catchment) and micro flood (Sub basins) studies in urban areas yet to be initiated to address the urban flooding issues in many cities of India

Chennai City Urban Flood Real Scenario (2015)



IMPACT OF CLIMATE CHANGE ON URBAN FLOODING WITH SPECIAL EMPHASIS ON CHENNAI CITY

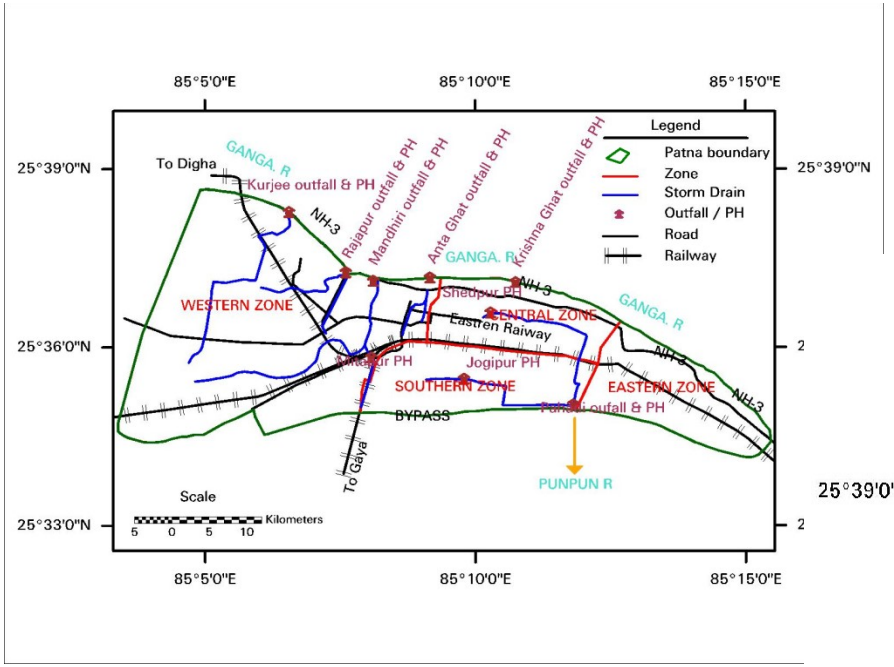
Acknowledgements:

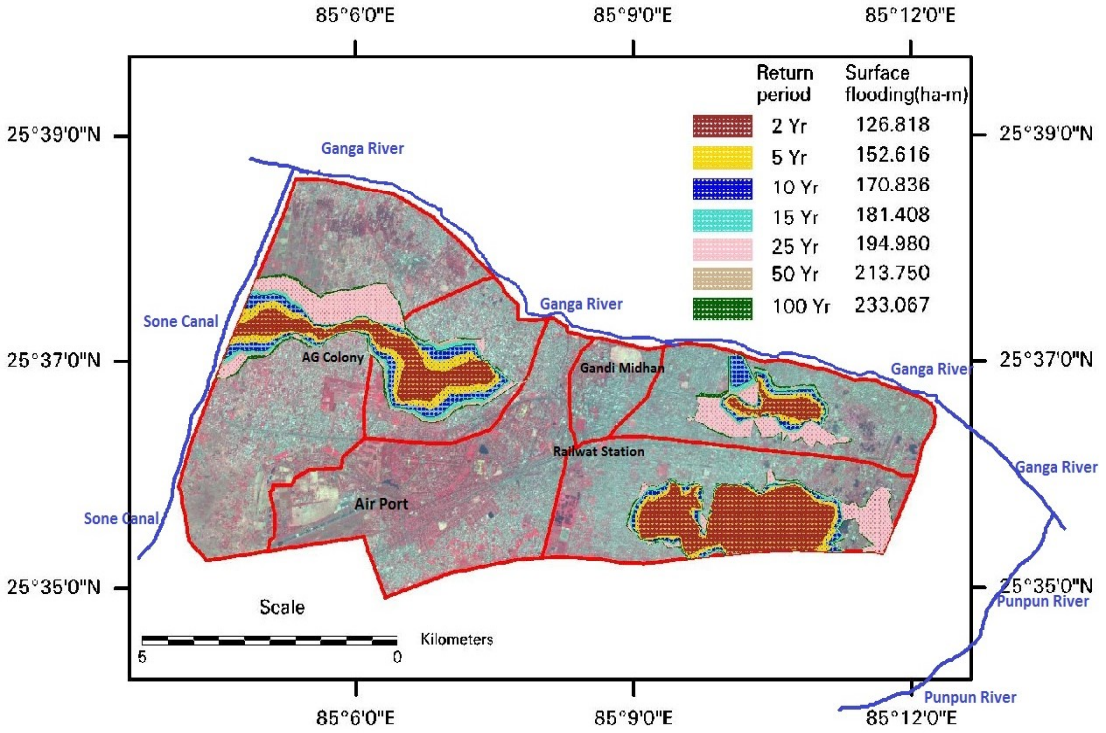
Funded by Hydrology Project –II as PDS, Govt., of India

Govt., of Tamilnadu, PWD and Chennai Corporation

Thank you..

Patna town


85°5'0"E
85°10'0"E
85°15'0"E
25°39'0"N
25°36'0"N
25°33'0"N
To Digha
GANGA. R
Kurjee outfall & PH
Rajapur outfall & PH
Mandhiri outfall & PH
Anta Ghat outfall & PH
Krishna Ghat outfall & PH
NH-3
Legend
Patna boundary
Zone
Storm Drain
Outfall / PH
Road
Railway
WESTERN ZONE
CENTRAL ZONE
Eastren Raiway
Sheikpur PH
Jogipur PH
SOUTHERN ZONE
EASTERN ZONE
BYPASS
To Gaya
PUNPUN R
Scale
Kilometers
5 0 5 10


85°6'0"E
85°9'0"E
85°12'0"E
25°39'0"N
25°37'0"N
25°35'0"N
Return period
Surface flooding(ha-m)
2 Yr 126.818
5 Yr 152.616
10 Yr 170.836
15 Yr 181.408
25 Yr 194.980
50 Yr 213.750
100 Yr 233.067
Ganga River
Sone Canal
AG Colony
Gandi Midhan
Railwat Station
Air Port
Punpun River
Scale
Kilometers
5 0