Storm Water Flood Modeling in the Sub- basin of Chennai Corporation, Chennai, Tamilnadu, India

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जल संरक्षण वर्ष 2013 Water Conservation Year

जल बचायें - जीवन बचायें

Save Water - Save Life

Types of Flooding (Geographically):

Riverine flooding

It happens when extreme rainfall attacks in a river basin (Mississippi, 1993; Miller, 1997; Changman, 1998; Li and Guo et al., 1999; NVE, 2000; Meade, 2002).

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).

Coastal flooding

It takes place when heavy rainfall on inland encounters storm surges from the sea (Miller, 1997; Barry, 1997; Smith and Ward, 1998; Parker1, 2000; Pilarczyk and Nuoi, 2002).

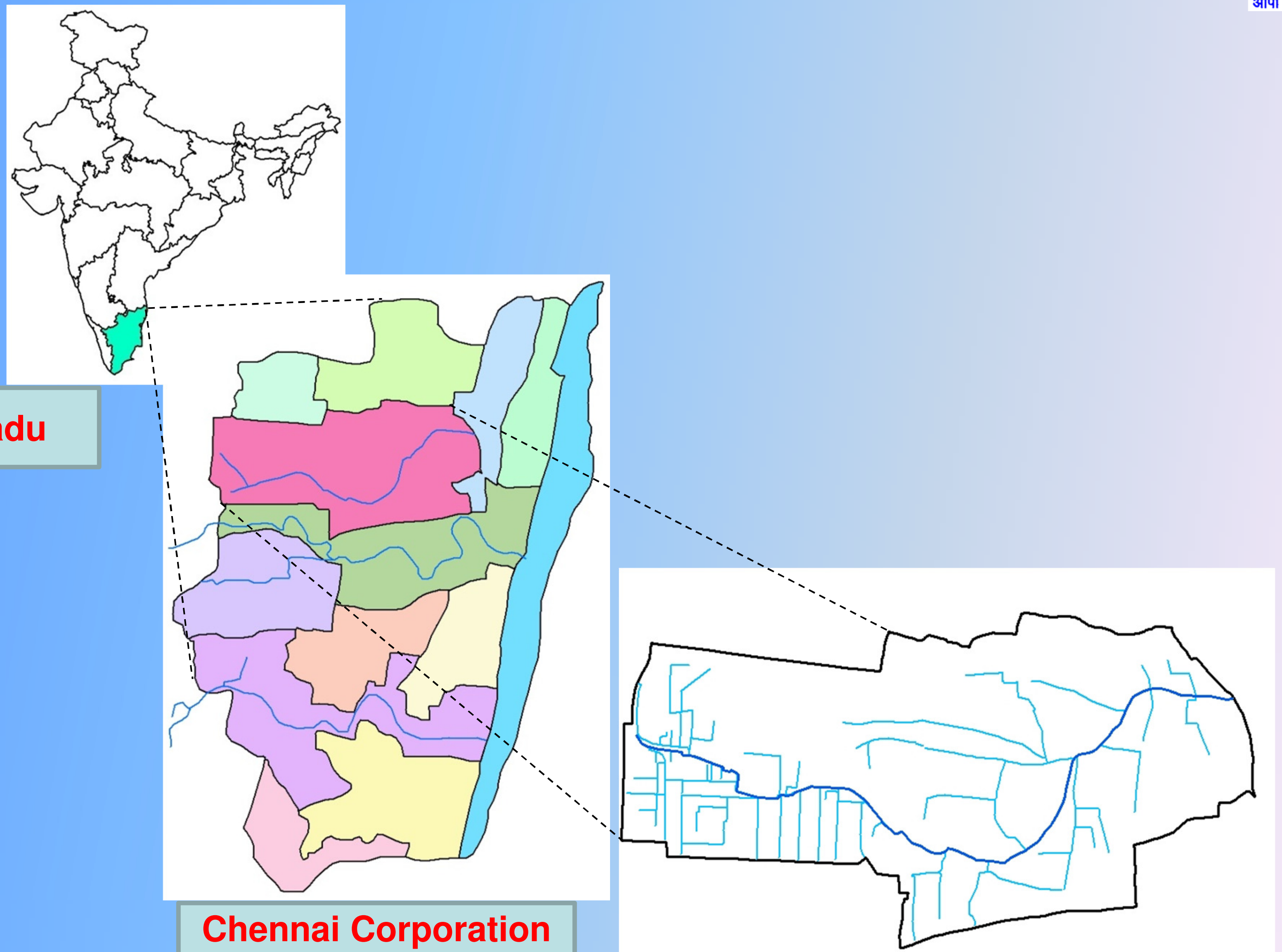
Definition of Urban Drainage Systems

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).

Why Urban Floods are increasing ?

- Increase in Flood peak and storm water network designs are old (Design limitations)
- Improper maintenance of storm water network (Carrying capacity)
- Impact of Boundary Conditions (Confluence points/backwater/tides)
- Changes in Landuse/cover (pervious to impervious)
- Increase in rainfall Intensity(Climate change/variability)
- Bridge designs across stream/drain
- Layout new roads/colonies/railway tracks/Metros/changes in topography/interconnection of drains etc

Project Location



Tamilnadu

Chennai Corporation with sub watersheds

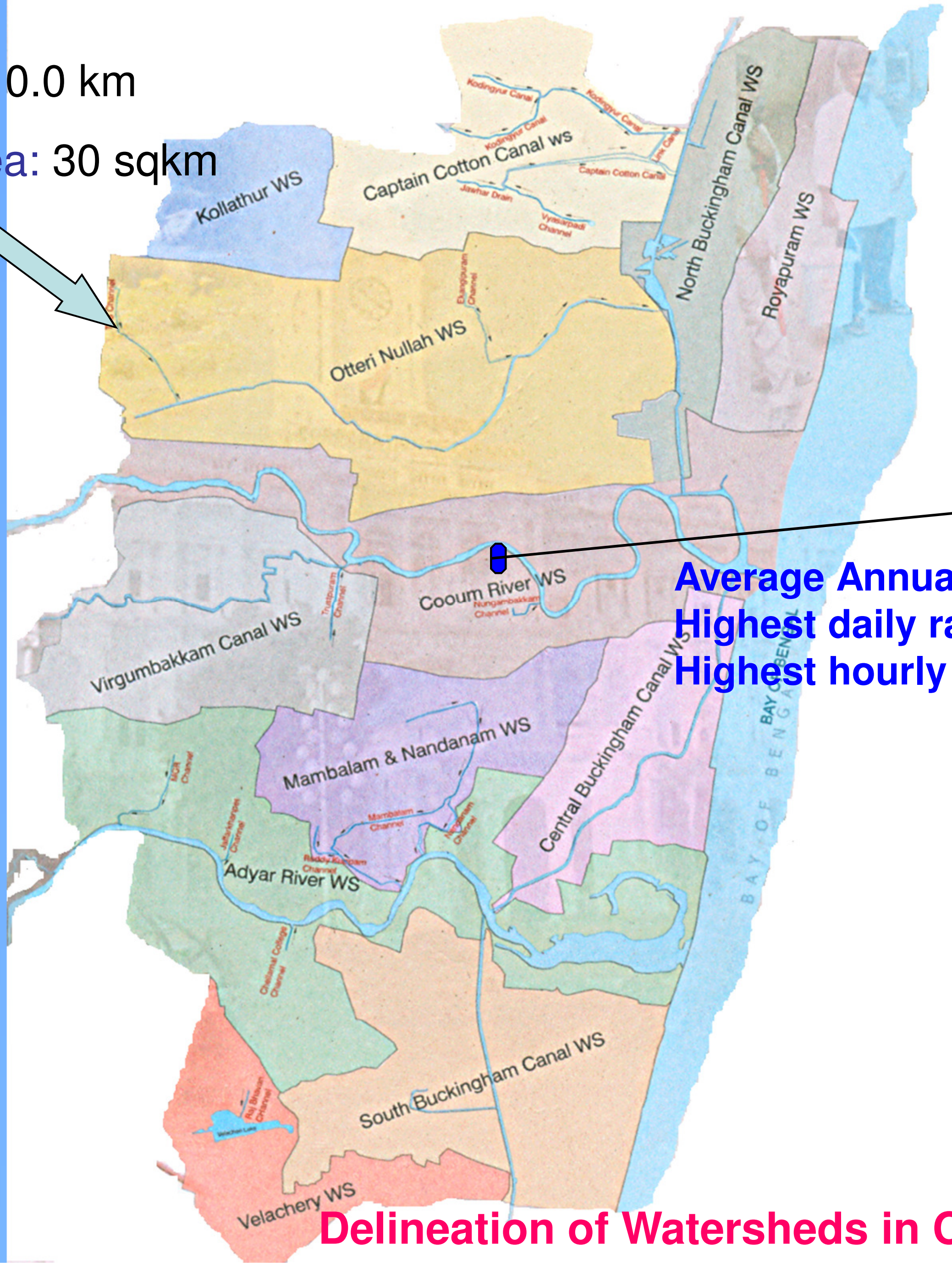
Otteri nullah sub basin

Otteri nullah watershed

Total Length: 10.0 km

Watershed area: 30 sqkm

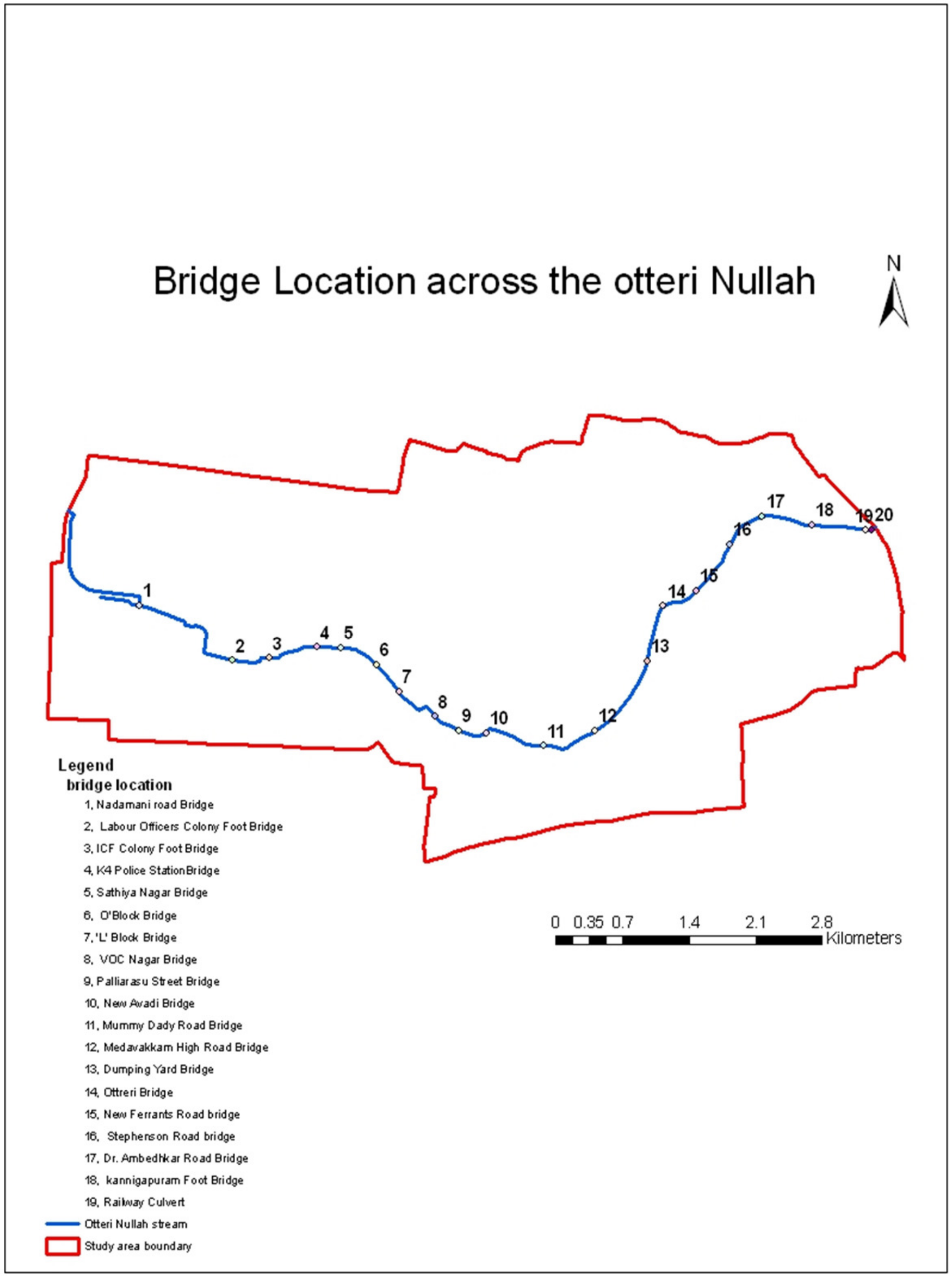
….Study Area

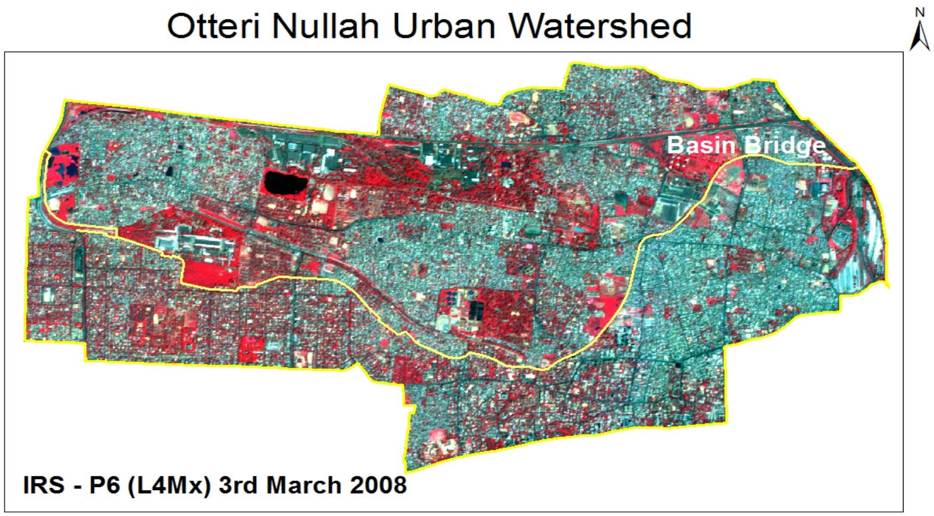


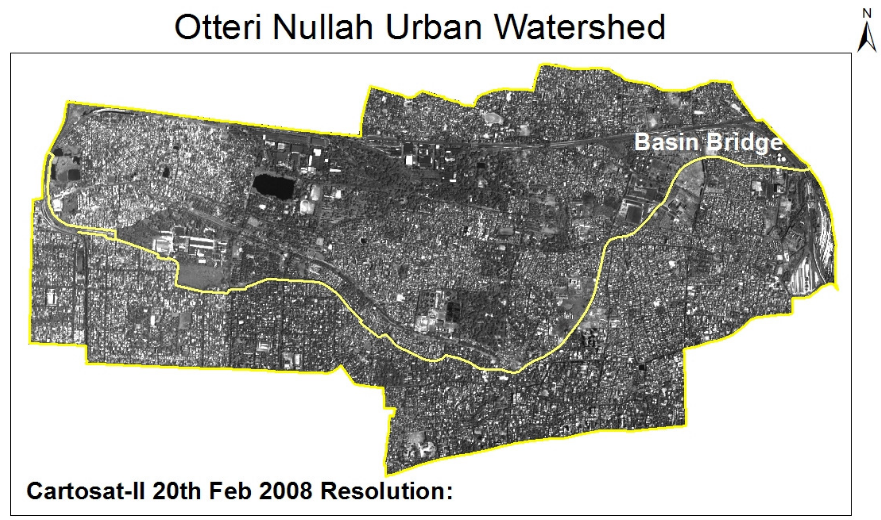
Nungambakkam Rain Gauge Station (IMD)

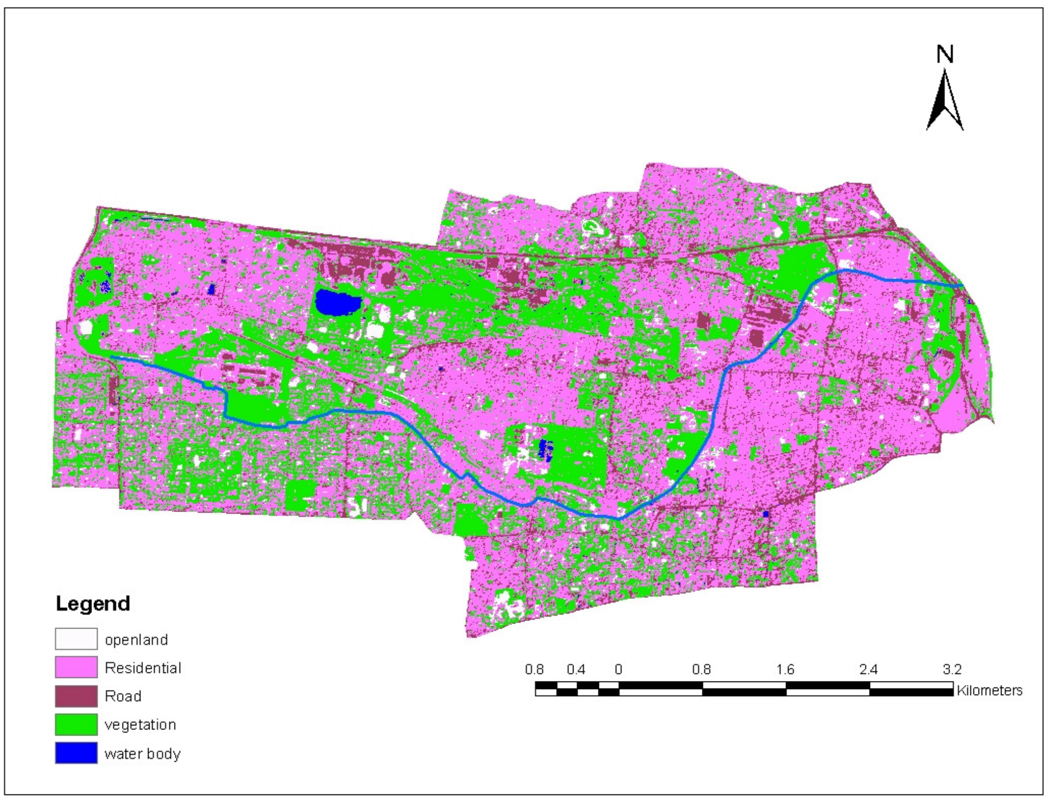
Average Annual Rainfall: 1300 mm
Highest daily rainfall 40 cm (2005)
Highest hourly rainfall 93.5 mm (1996)

Delineation of Watersheds in Chennai Corporation


Bridge Location across the otteri Nullah
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0 0.35 0.7 1.4 2.1 2.8
Kilometers
Legend
bridge location
1, Nadamani road Bridge
2, Labour Officers Colony Foot Bridge
3, ICF Colony Foot Bridge
4, K4 Police StationBridge
5, Sathiya Nagar Bridge
6, O'Block Bridge
7, 'L' Block Bridge
8, VOC Nagar Bridge
9, Palliarasu Street Bridge
10, New Avadi Bridge
11, Mummy Dady Road Bridge
12, Medavakkam High Road Bridge
13, Dumping Yard Bridge
14, Ottreri Bridge
15, New Ferrants Road bridge
16, Stephenson Road bridge
17, Dr. Ambedhkar Road Bridge
18, kannigapuram Foot Bridge
19, Railway Culvert
Otteri Nullah stream
Study area boundary







Water Body: 0.6%

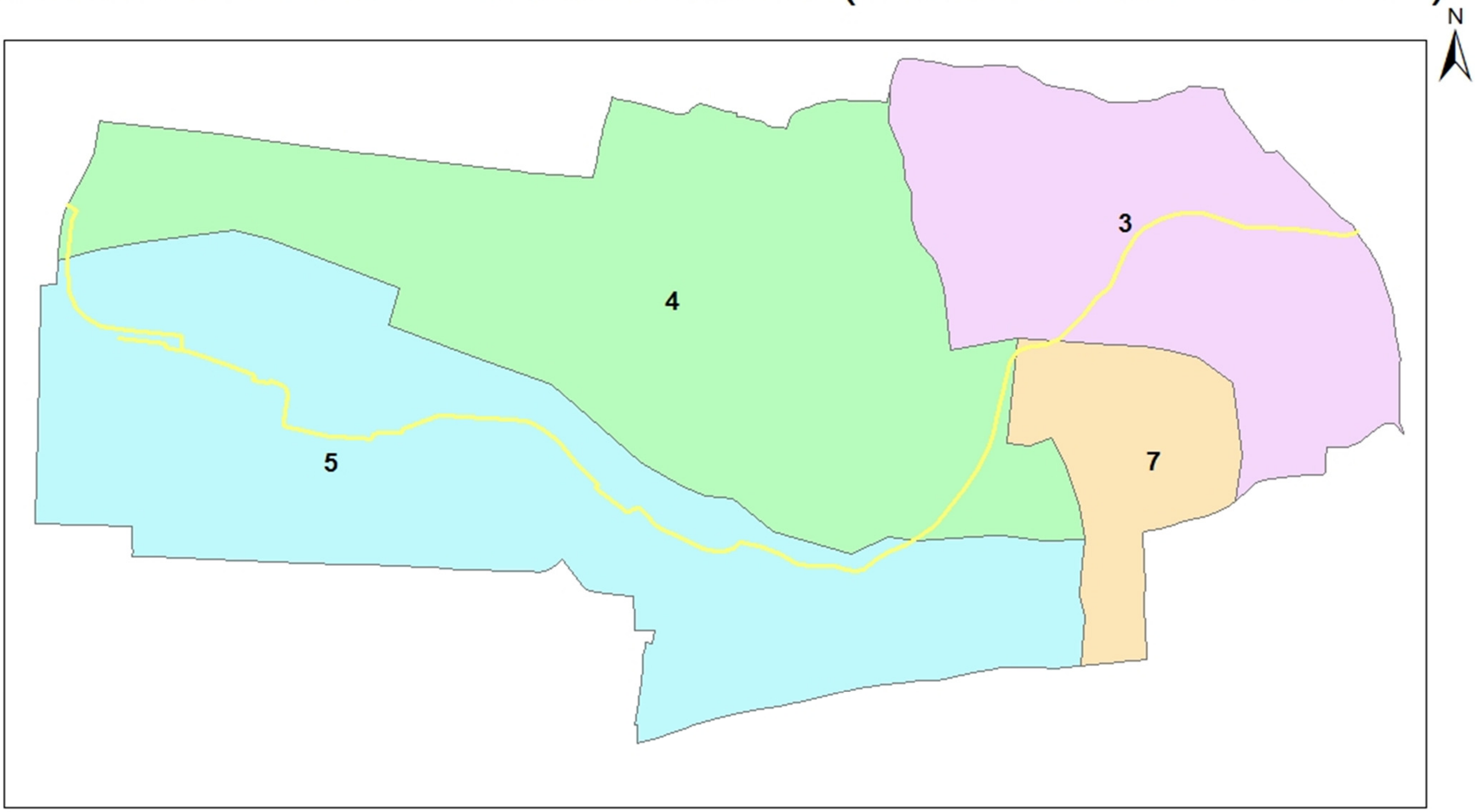
Vegetation: 28.9%

Roads: 10.9%

Open Land: 3.3%

Residential area: 56.3%

Otteri Nullah Urban Watershed (Administrative Zones)



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आपो हि ष्ठा मयोभुव

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.

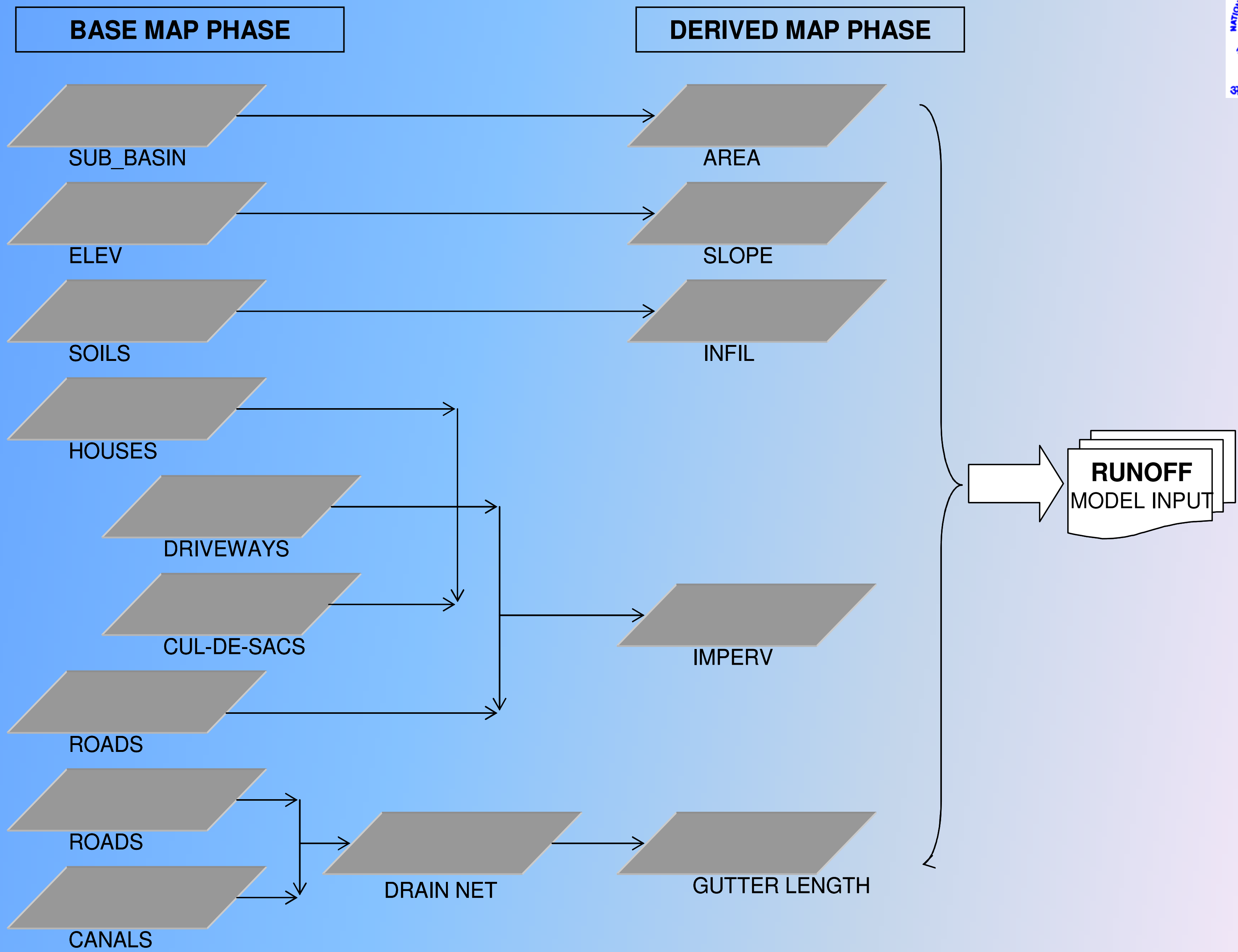
4. Dissemination of results of the project through workshops/ brain storming sessions/awareness programs with the help of NGO's/Govt., departments/Academic Institutions in the study area and elsewhere.

Popular Storm Water Model Software Packages

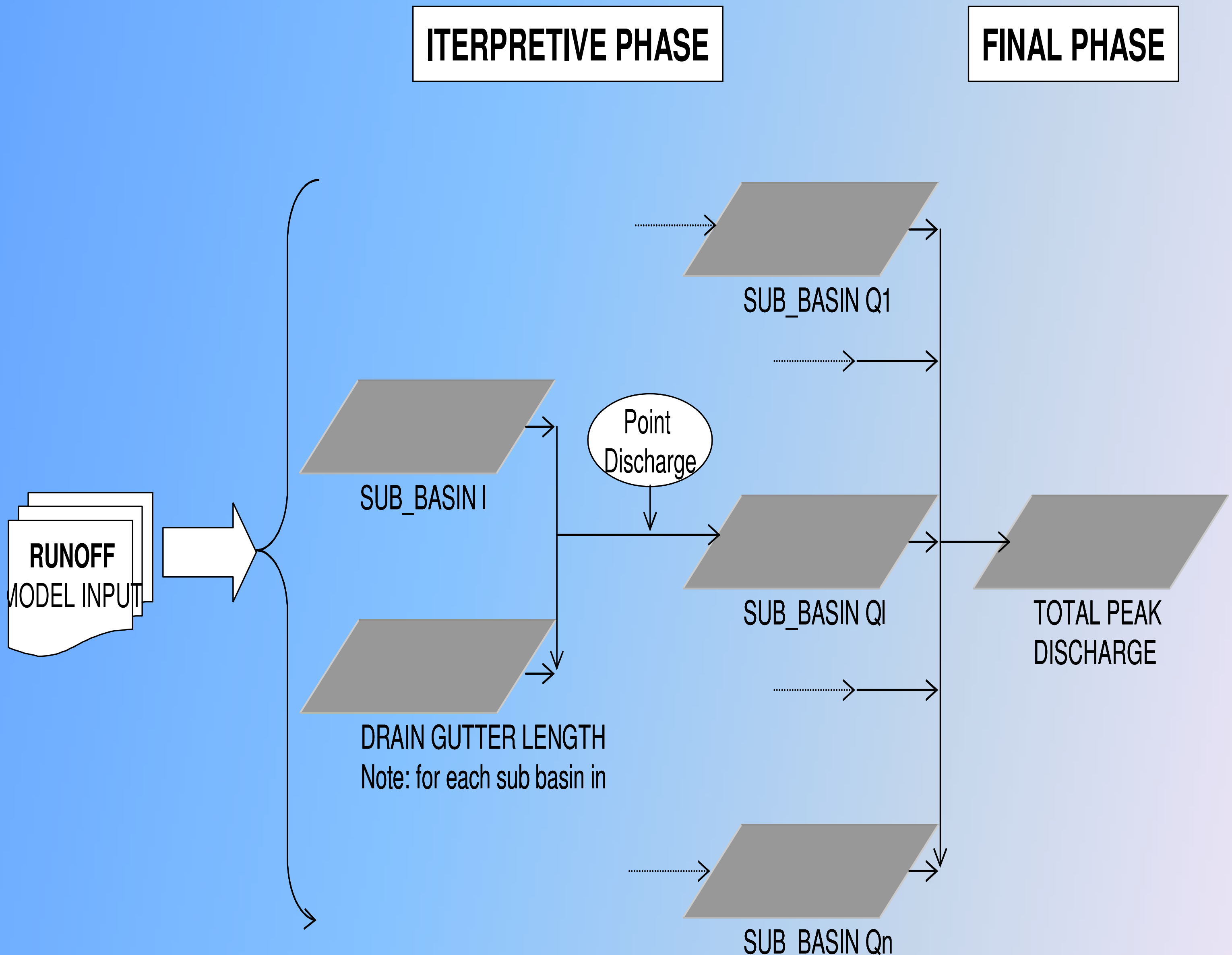
- US EPA
- DHI
- Bentley
- Wallingford
- **XPSWMM** XP Software Inc.

XP 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.



Procedure for GIS to SWMM



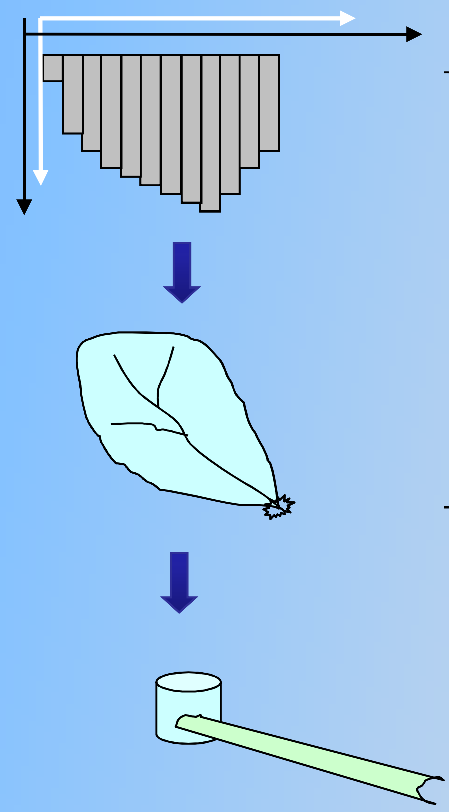
Procedure for GIS to SWMM

Process of Storm to Sewer network

Storm

Catchment

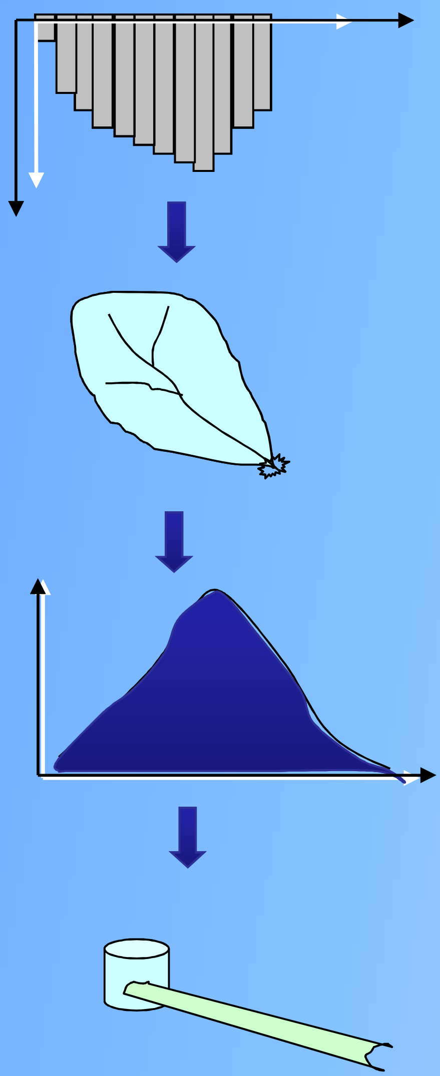
Sewer



Hydrological model

Hydraulic model

Modeling of Storm Sewer System



Rainfall

Losses model

Effective rainfall

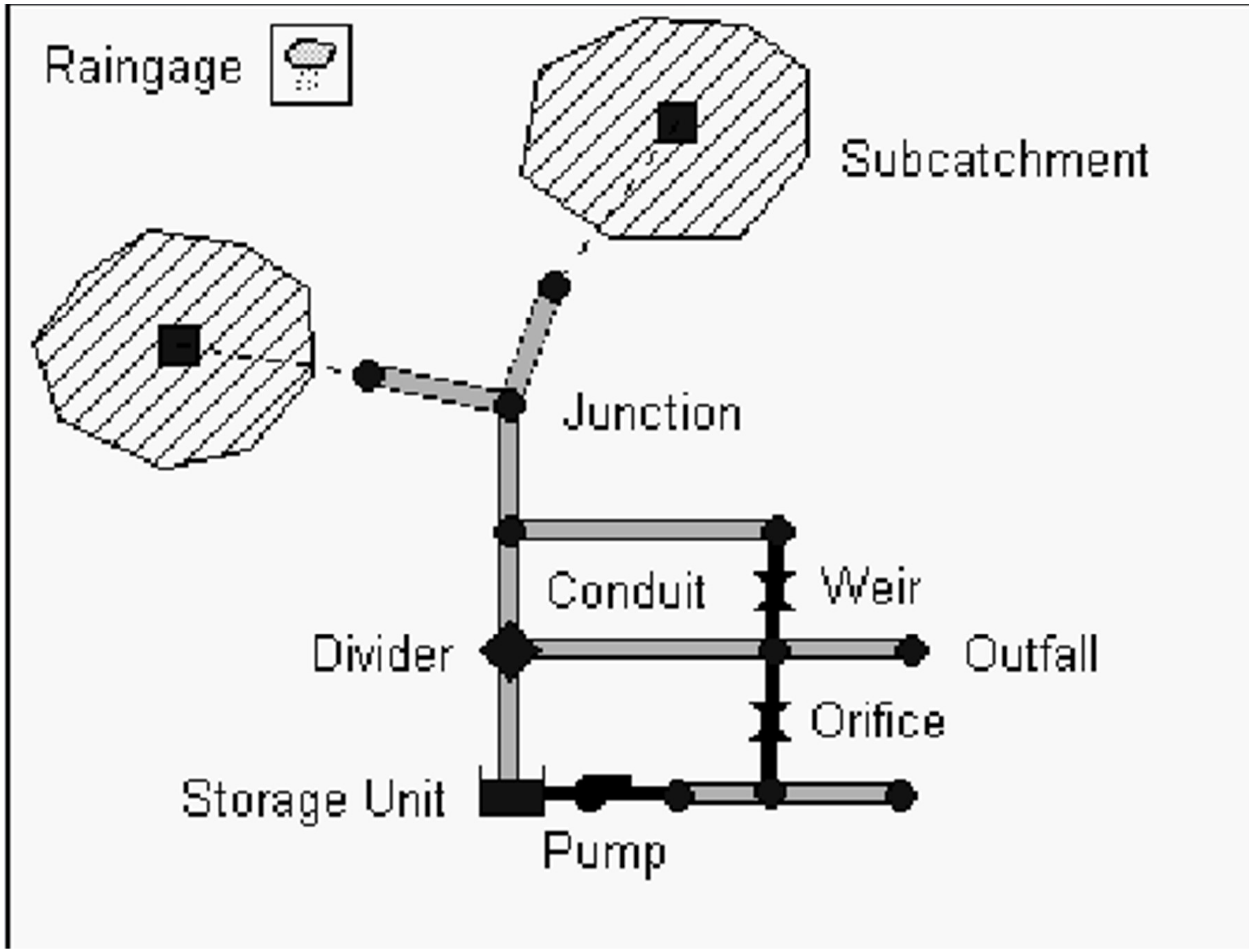
unit hydrograph

Inflow hydrograph of the inlet

Non-steady flow hydraulics numerical solutions

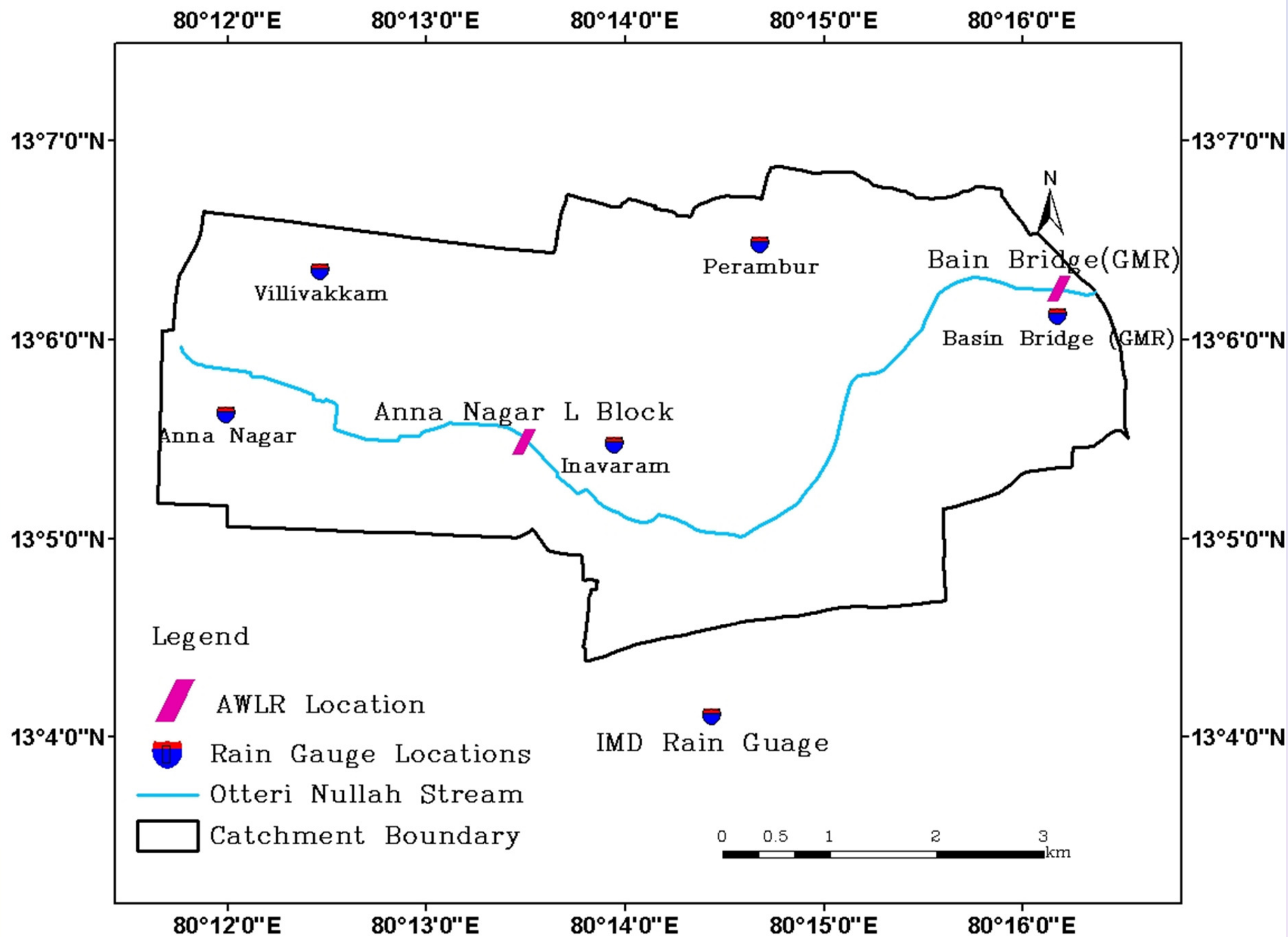
Outflow hydrograph of sewer system

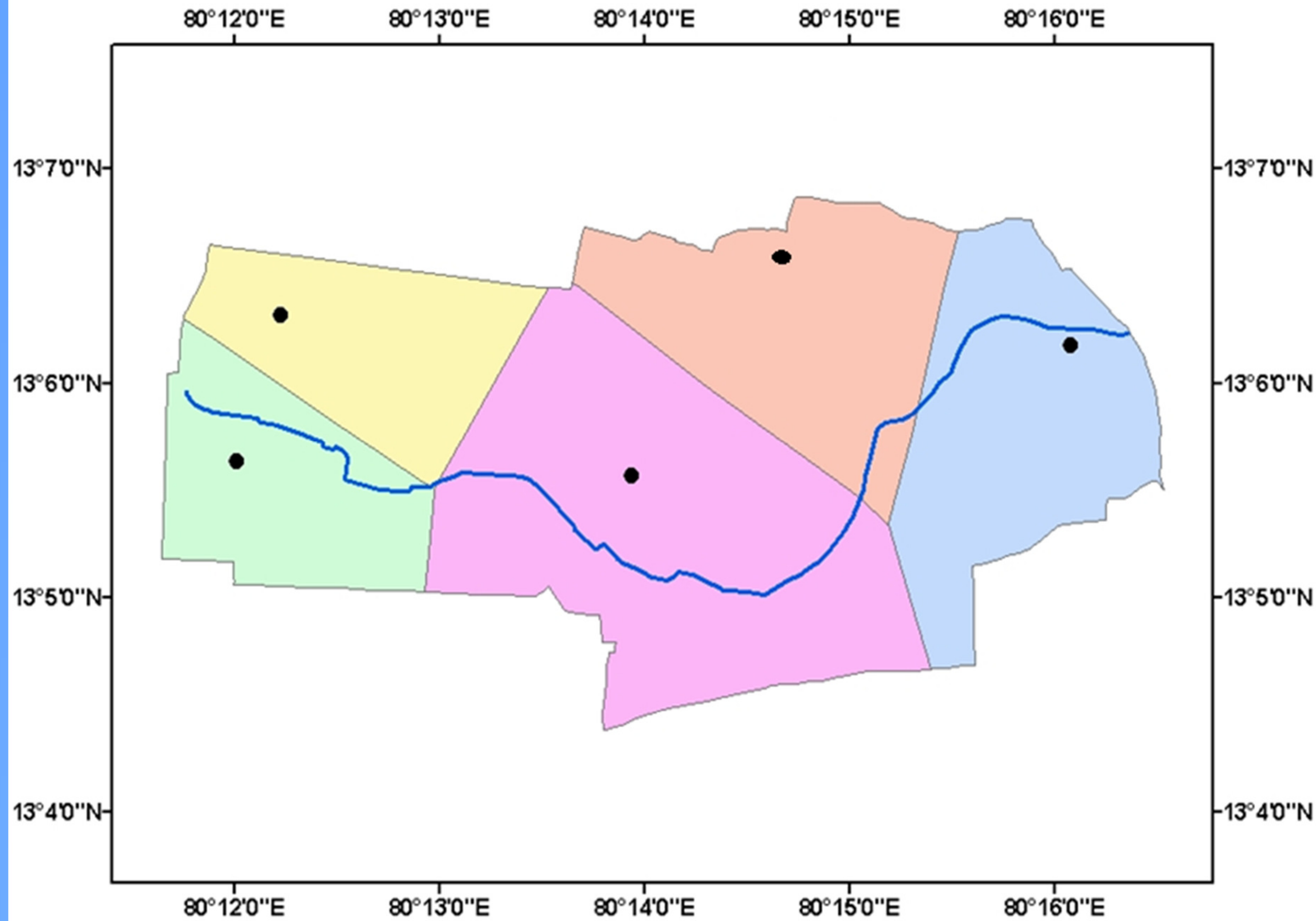
SWMM Model Structure



CONTRIBUTION IN PROJECT

Monitoring Network of Rain gauges and Water levels recorders





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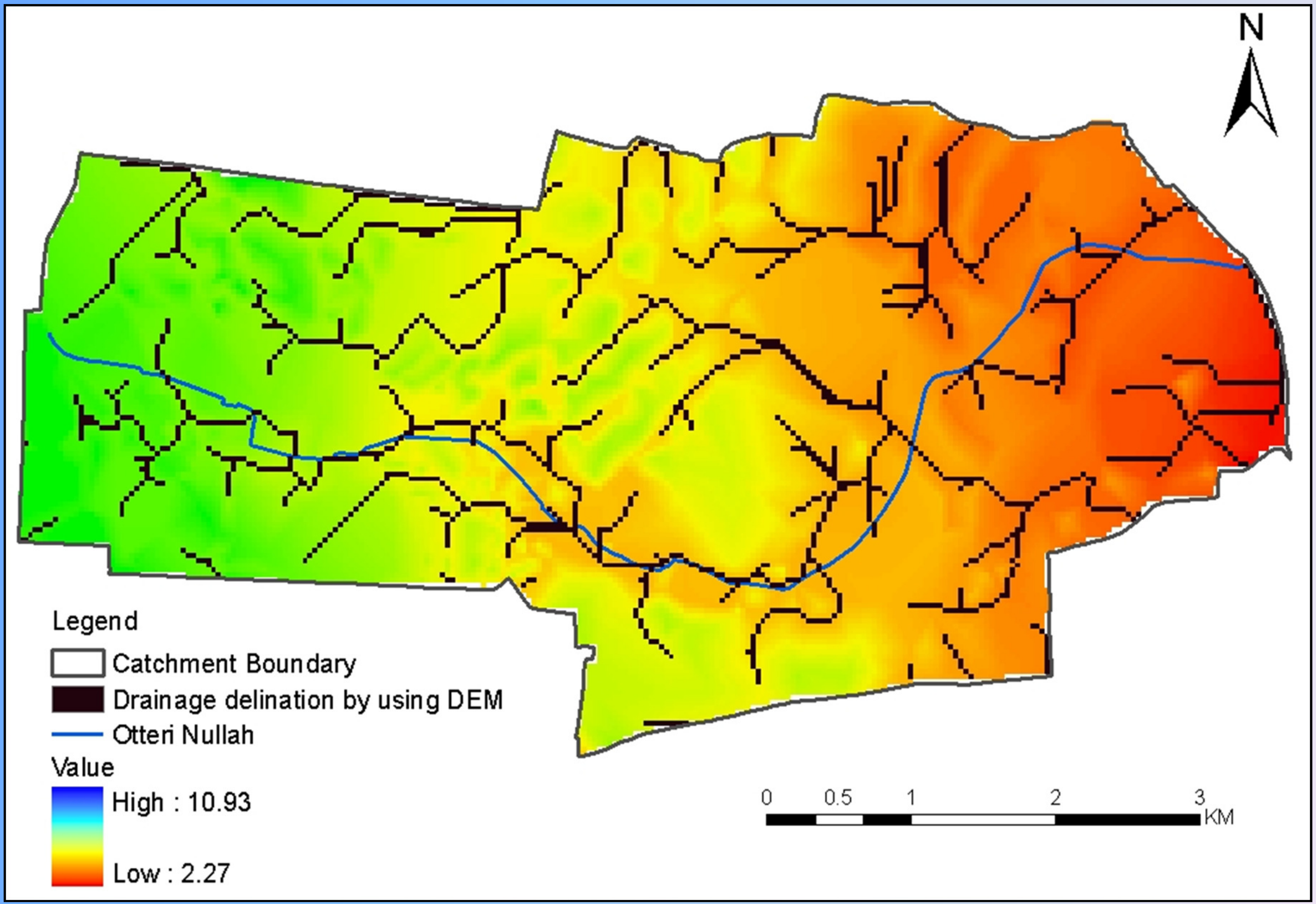
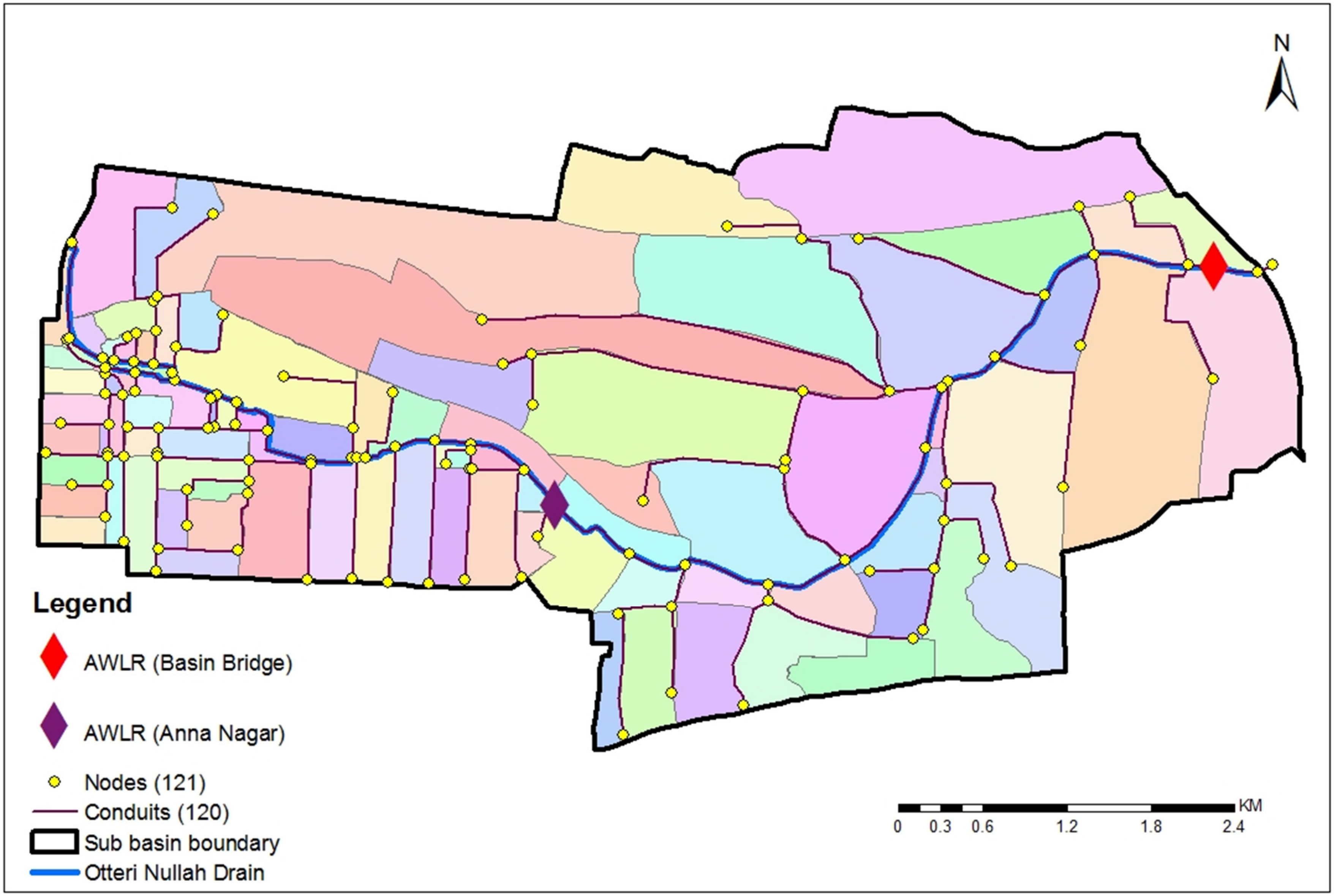
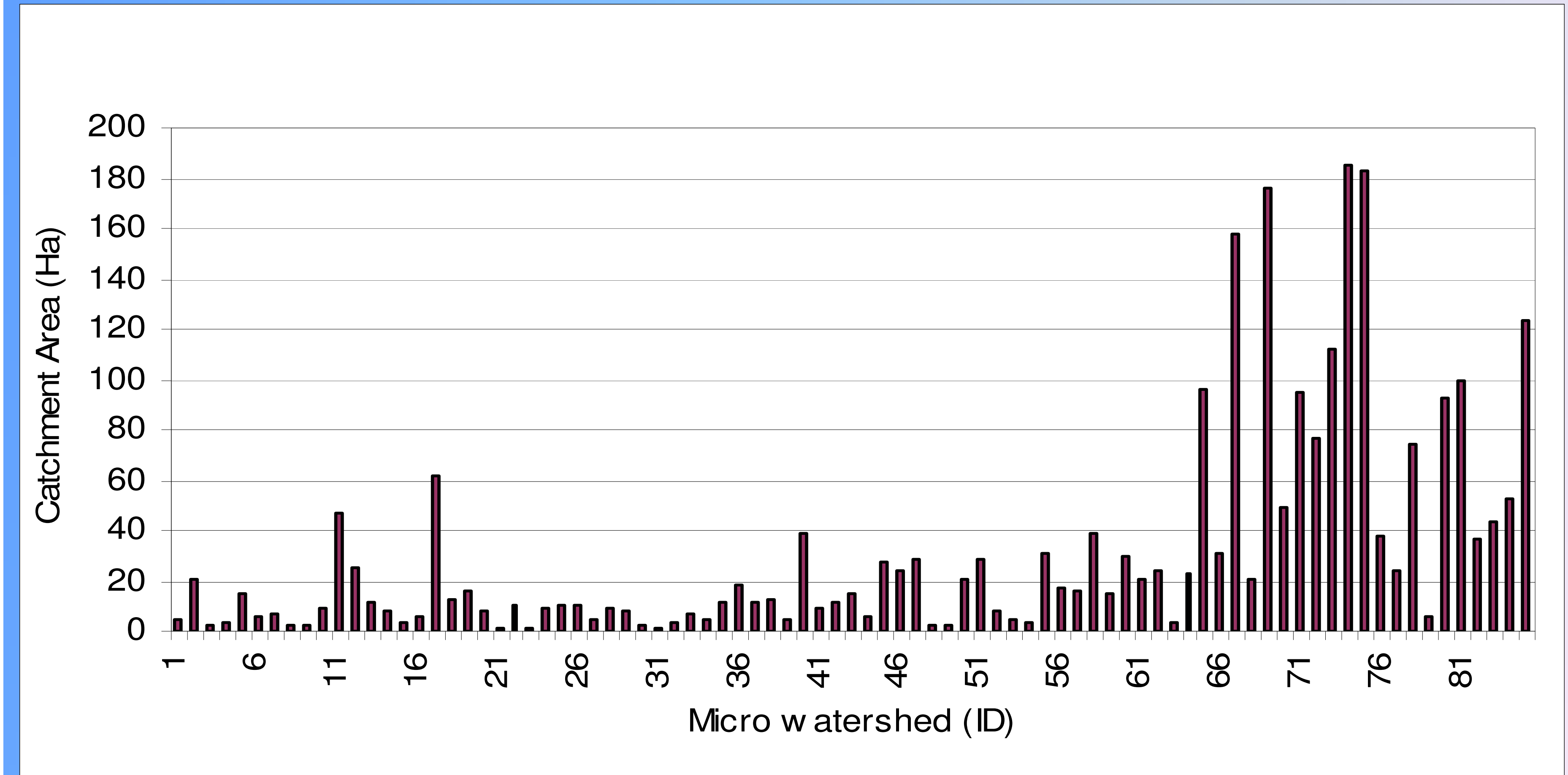
Digital Elevation Model (SOI Toposheet Bench Marks+ DGPS Survey Points+SRTM Data)



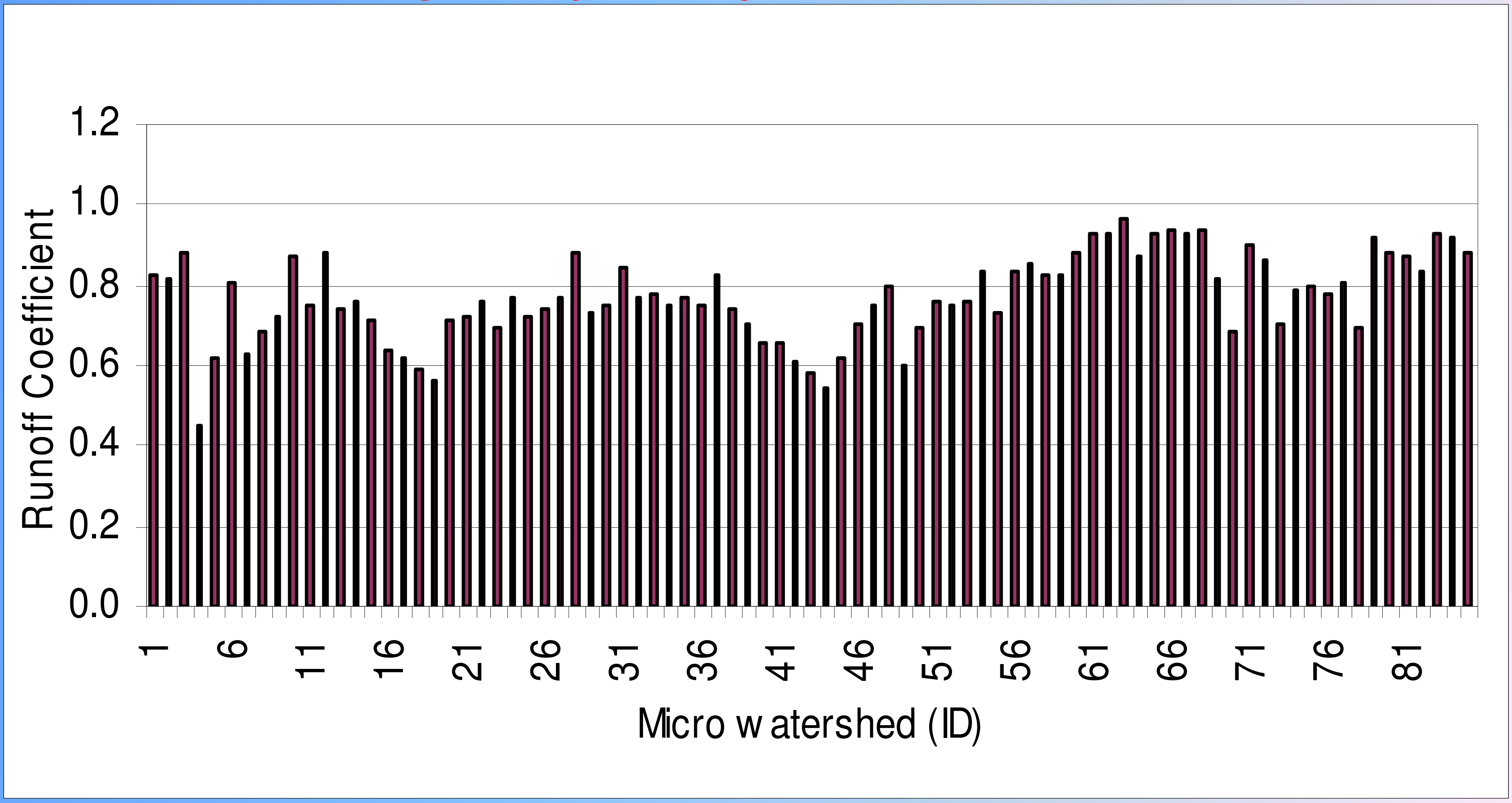
Descritization of study area into micro watersheds(86), nodes (121) and links (120)

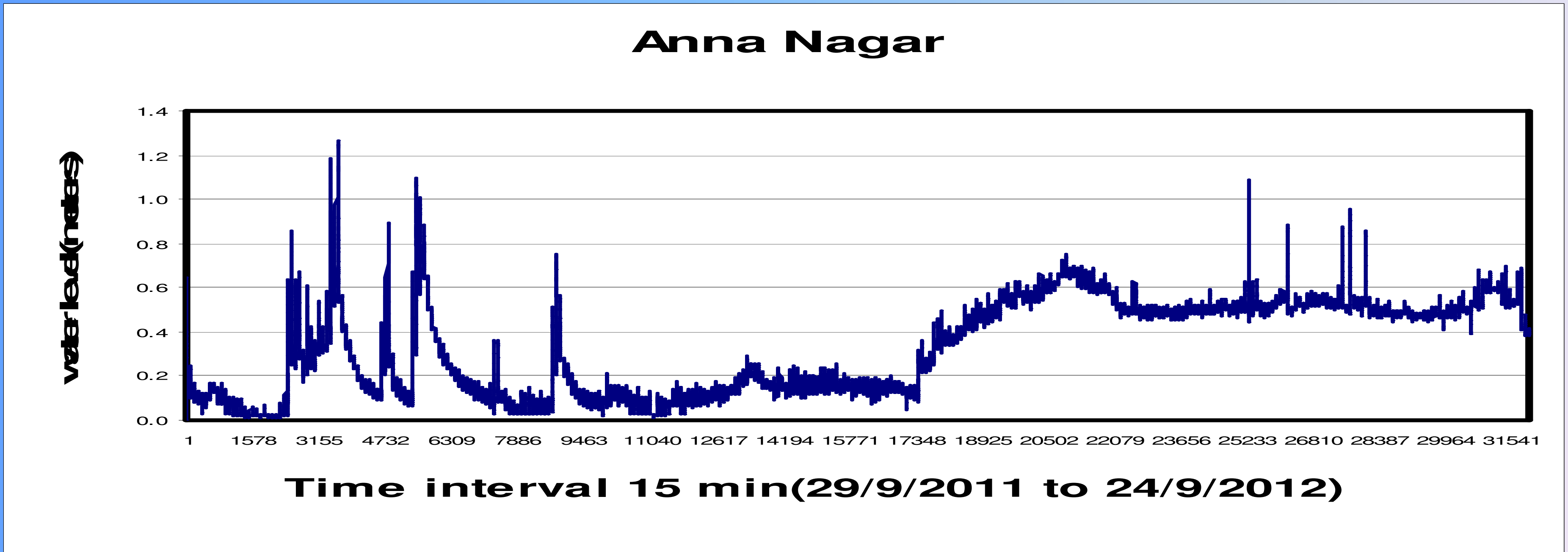


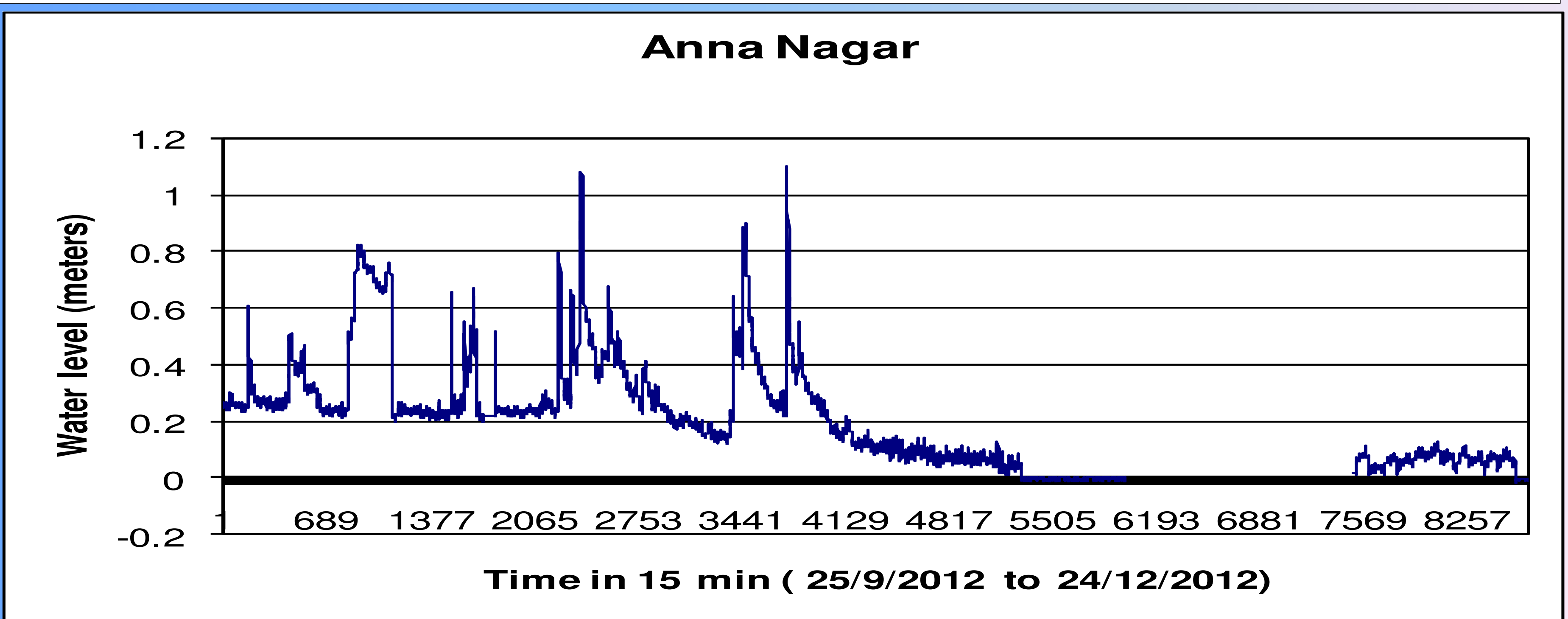


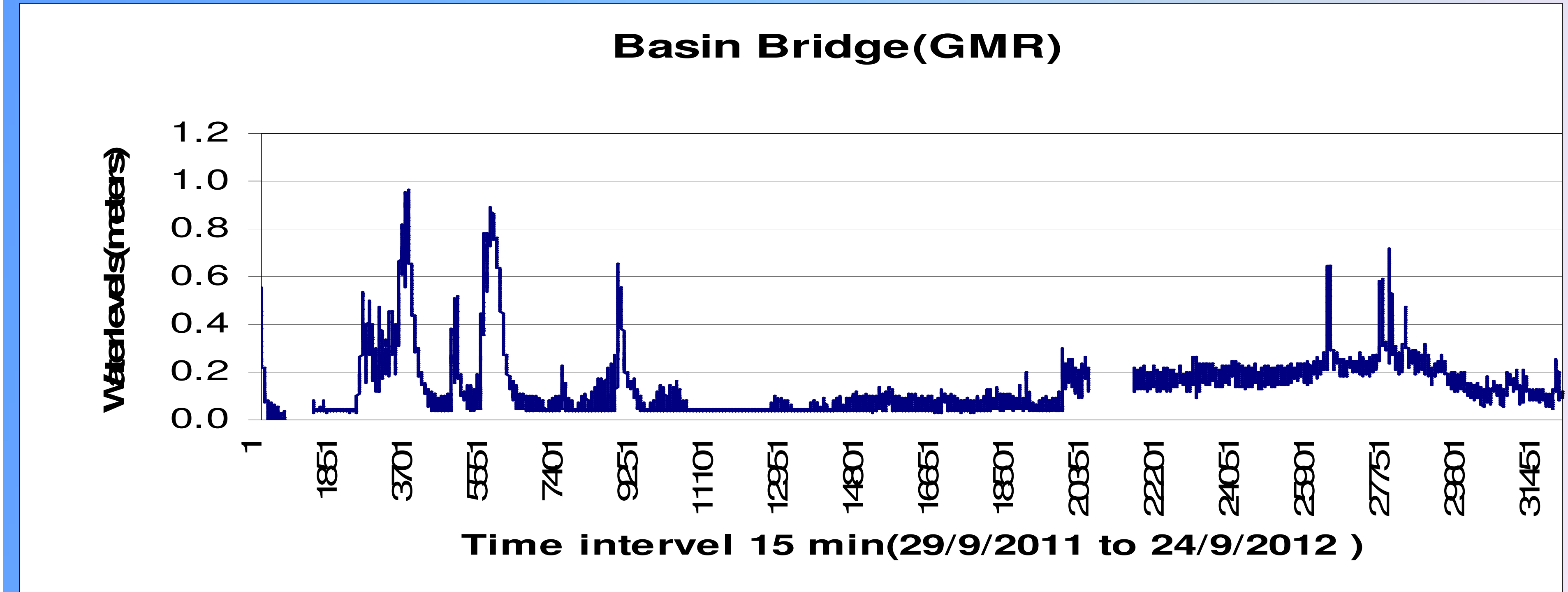
Variations in Micro Watershed areas

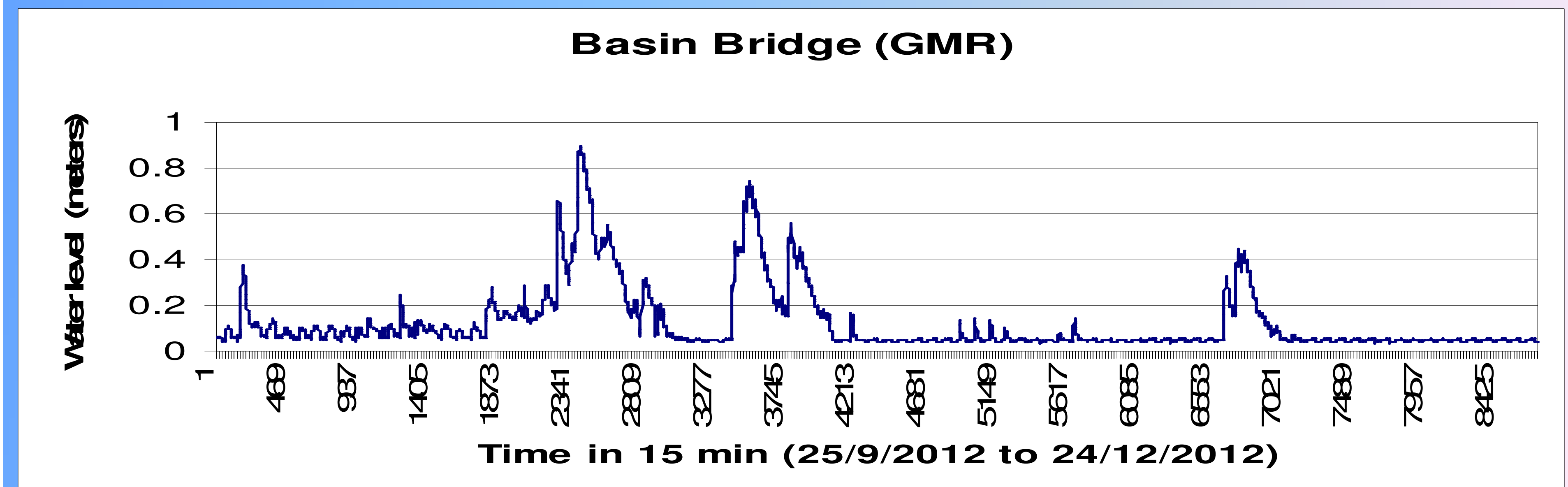
Runoff coefficient against 2 yr return period rainfall in each Micro watershed

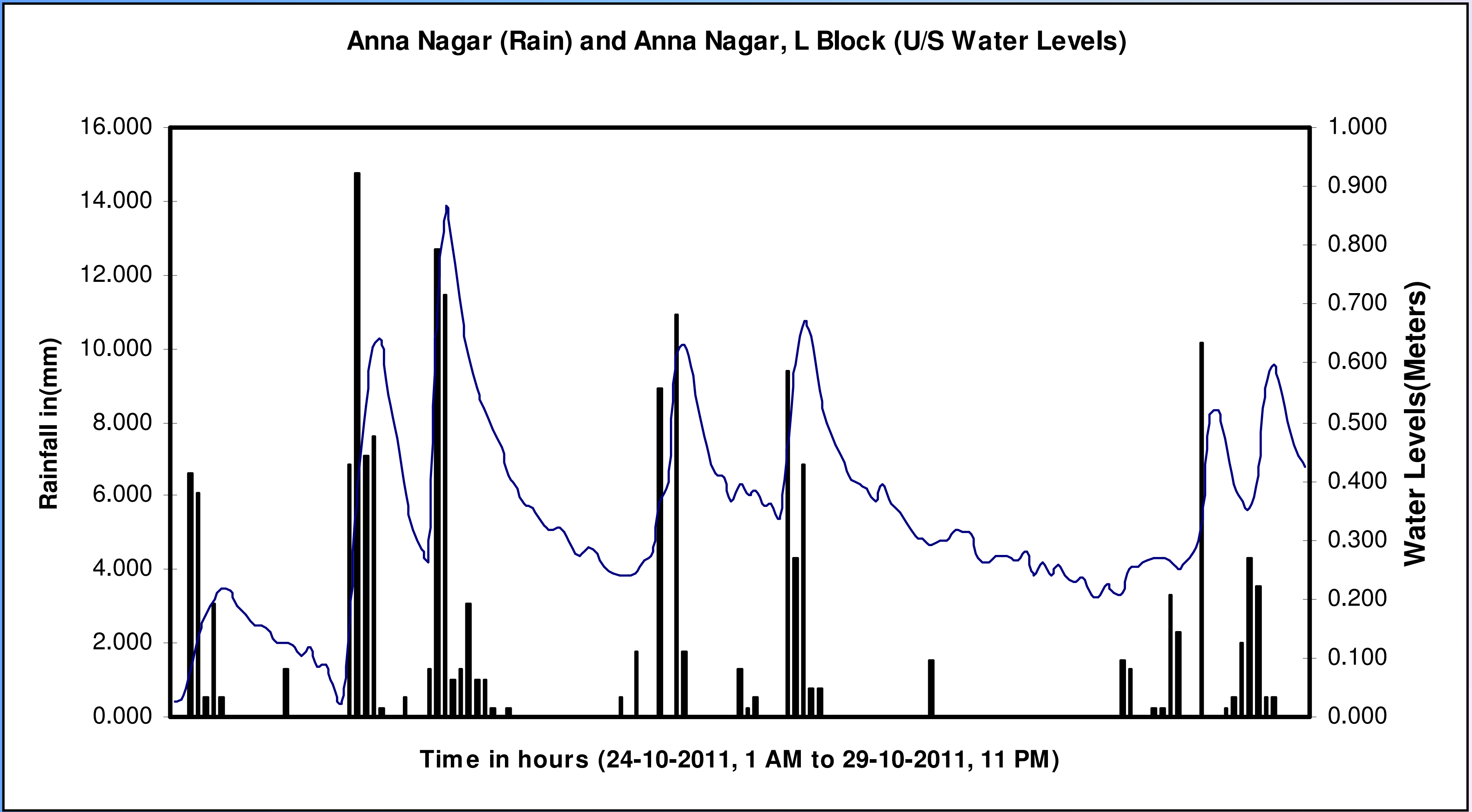



Anna Nagar
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1 1578 3155 4732 6309 7886 9463 11040 12617 14194 15771 17348 18925 20502 22079 23656 25233 26810 28387 29964 31541
Time interval 15 min(29/9/2011 to 24/9/2012)

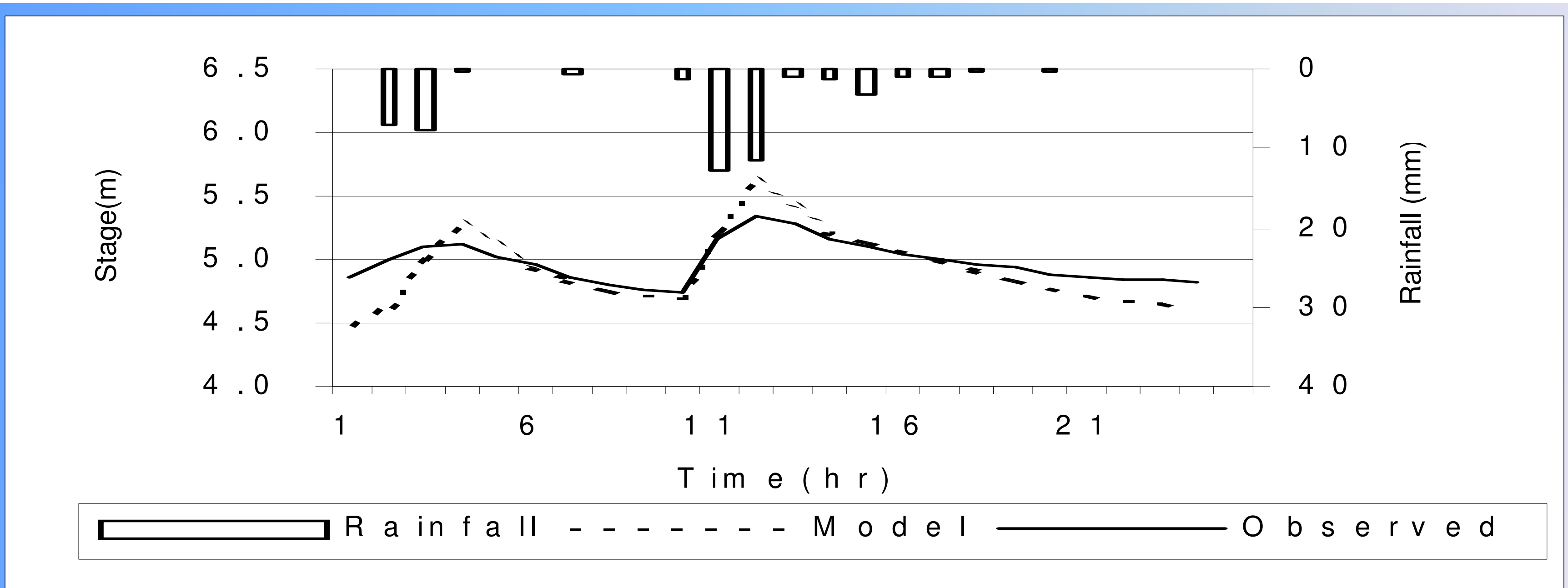

Anna Nagar
Water level (meters)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
1 689 1377 2065 2753 3441 4129 4817 5505 6193 6881 7569 8257
Time in 15 min (25/9/2012 to 24/12/2012)


Basin Bridge(GMR)
Water levels(meters)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
1851
3701
5551
7401
9251
11101
12951
14801
16651
18501
20351
22201
24051
25901
27751
29601
31451
Time intervel 15 min(29/9/2011 to 24/9/2012)

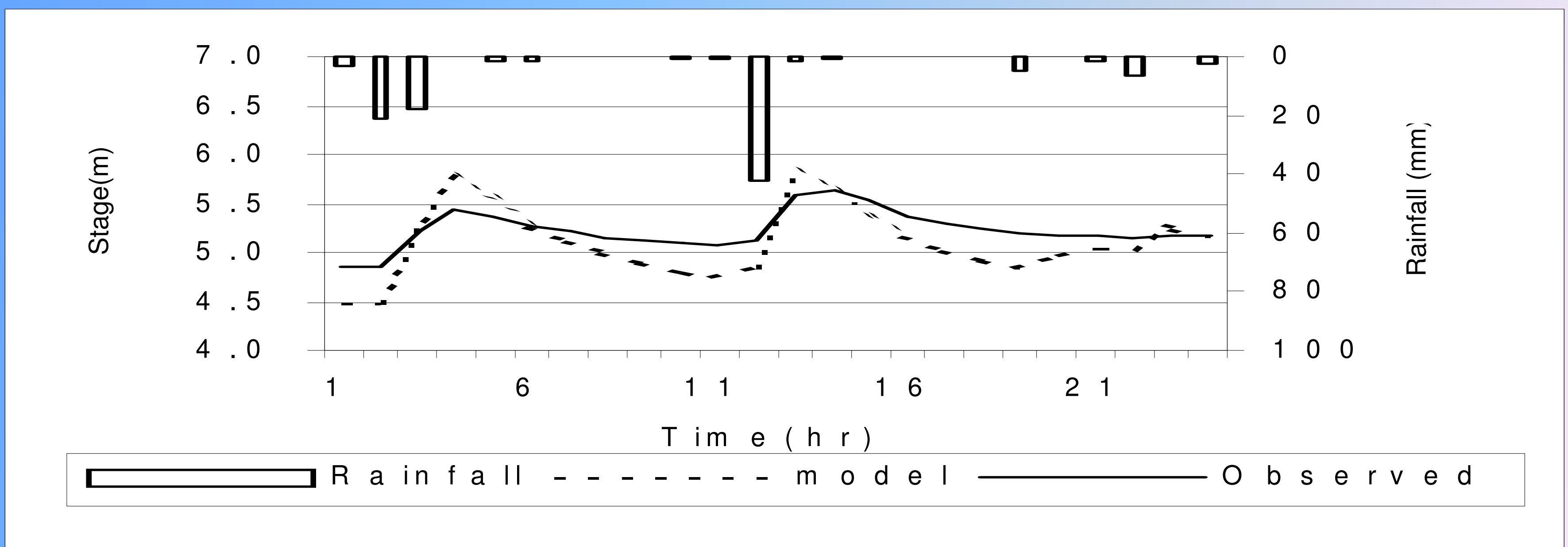

Basin Bridge (GMR)
Water level (meters)
1
0.8
0.6
0.4
0.2
0
1
469
937
1405
1873
2341
2809
3277
3745
4213
4681
5149
5617
6085
6553
7021
7489
7957
8425
Time in 15 min (25/9/2012 to 24/12/2012)



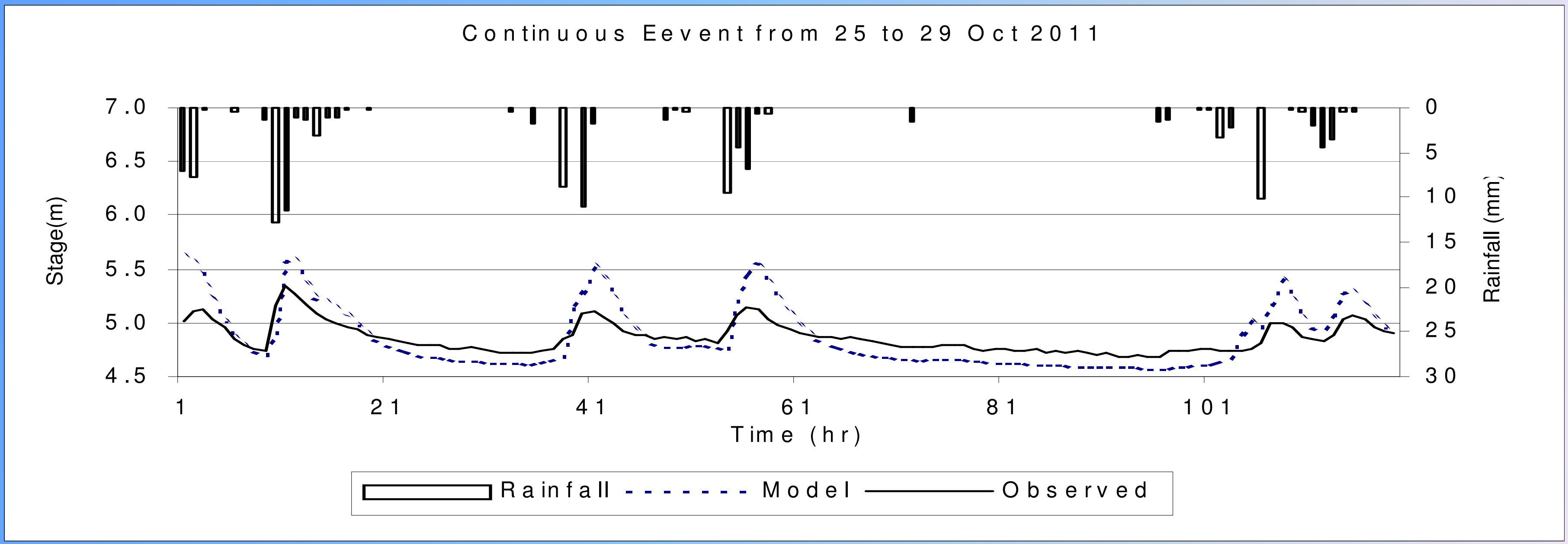
Comparison between hourly rainfall and water level data in the study area.



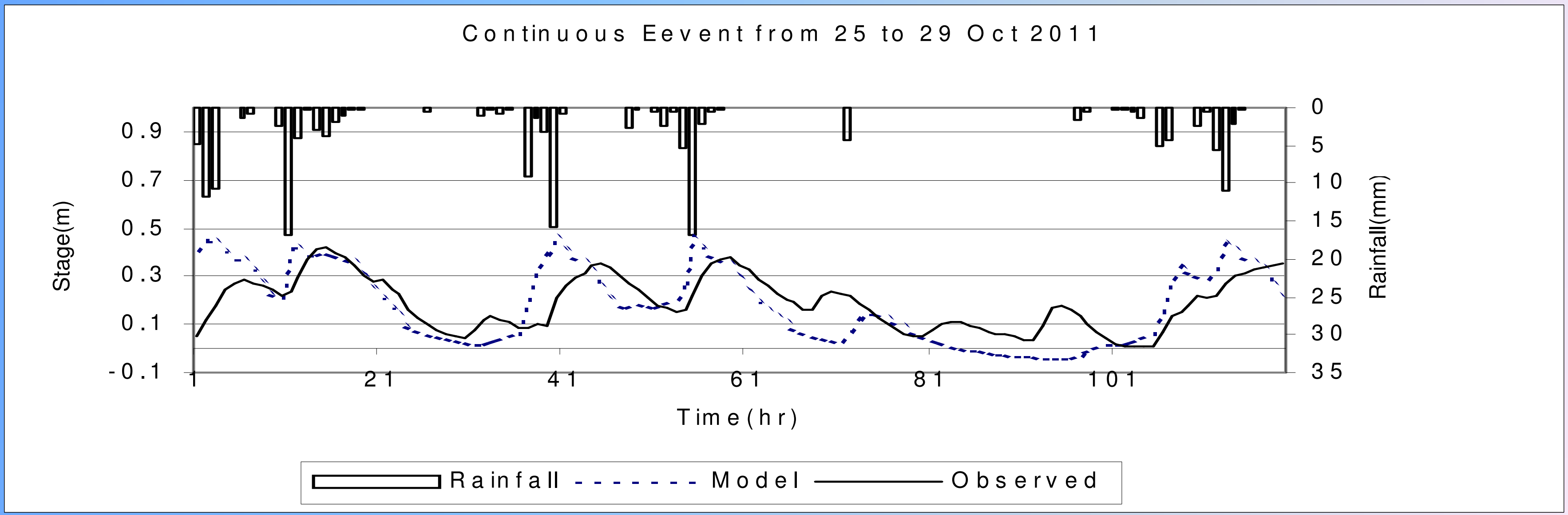
Comparison between observed and modeled stage at Anna Nagar (25th Oct. 2011)



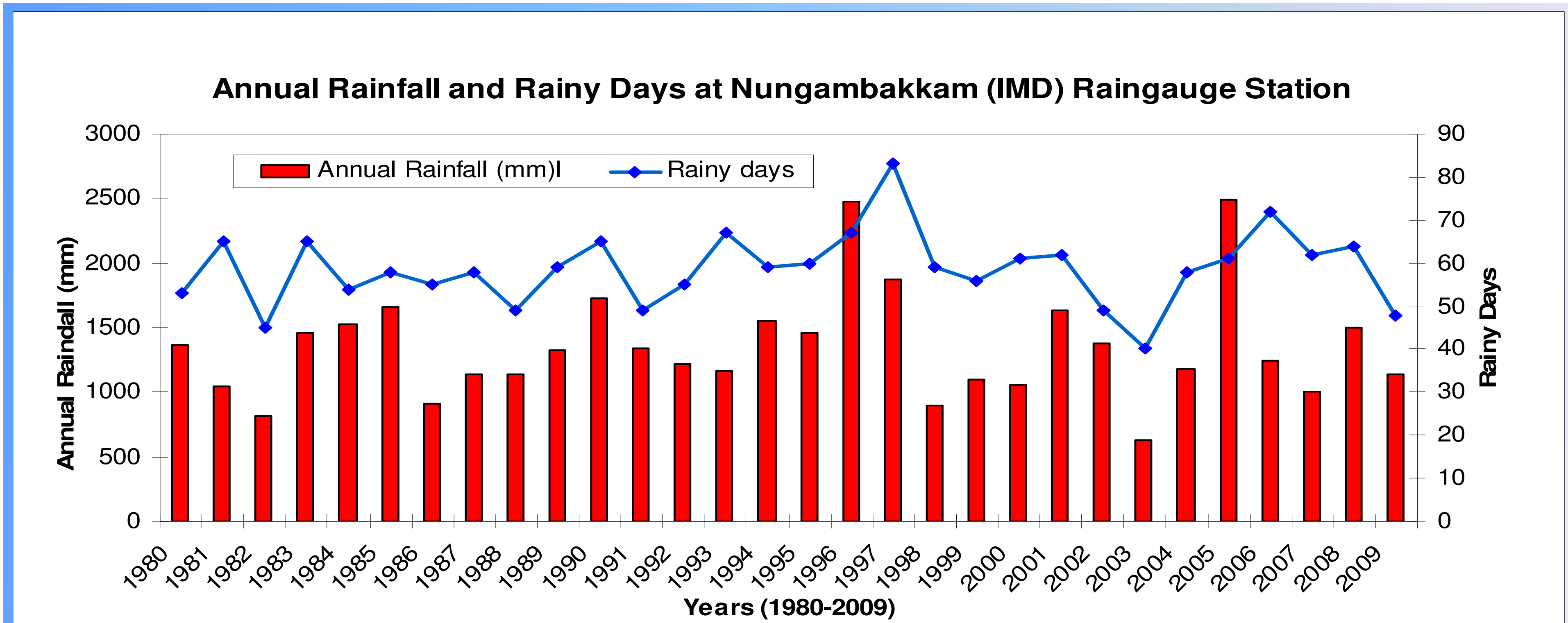
Comparison between observed and modeled stage at Anna Nagar (4th Nov. 2011)



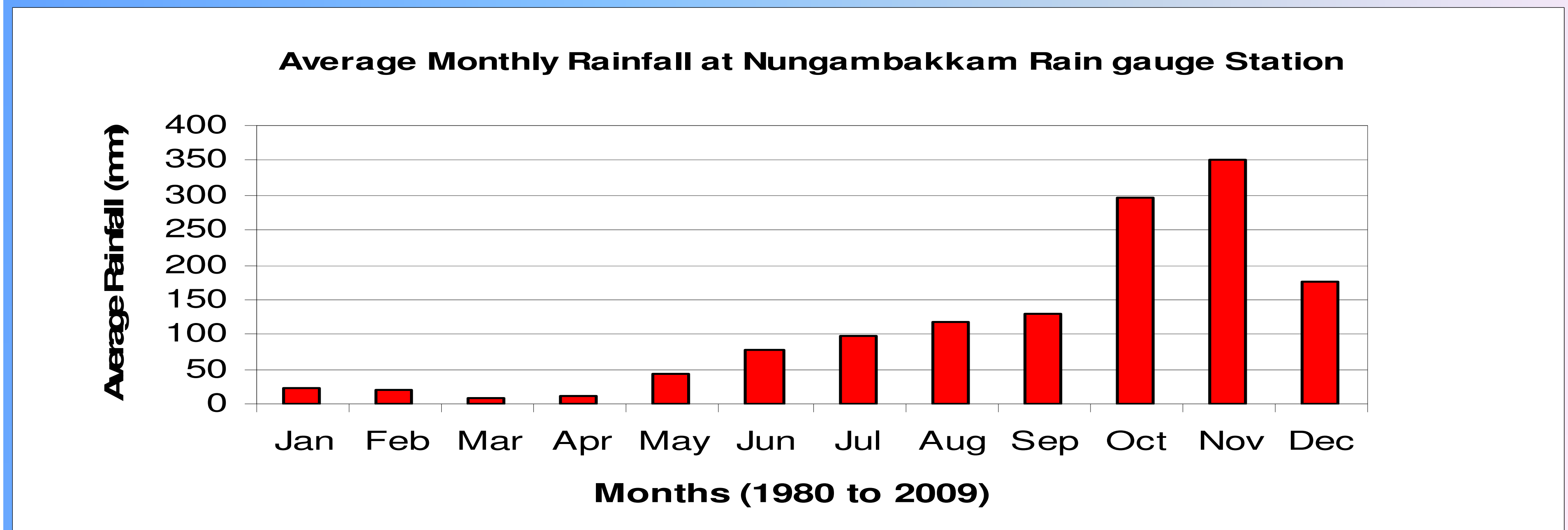
Comparison between observed and simulated water levels at Anna Nagar



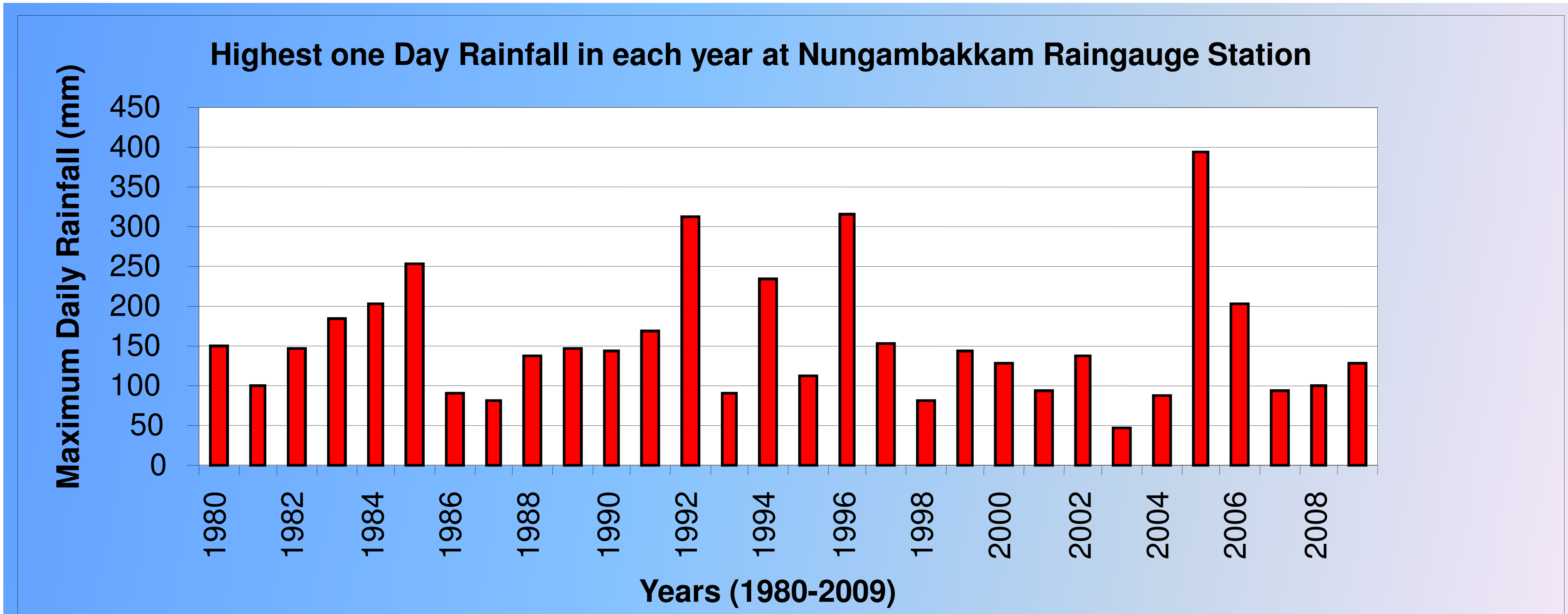
Comparison between observed and simulated water levels at Basin Bridge

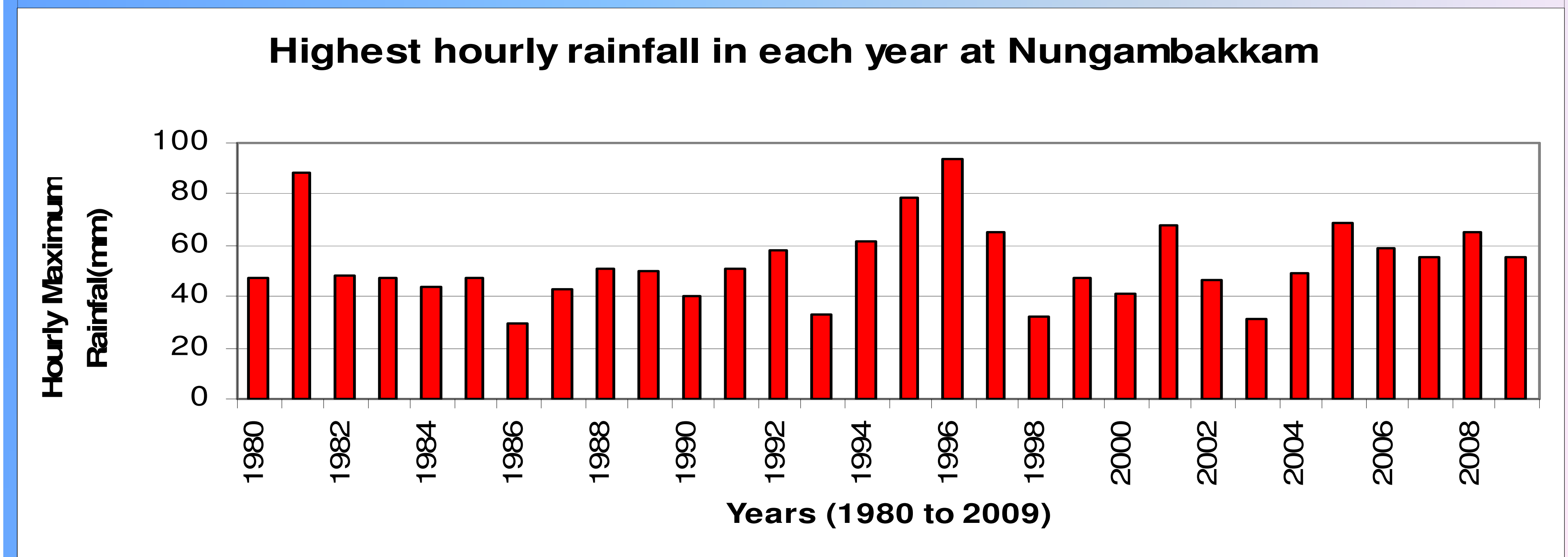


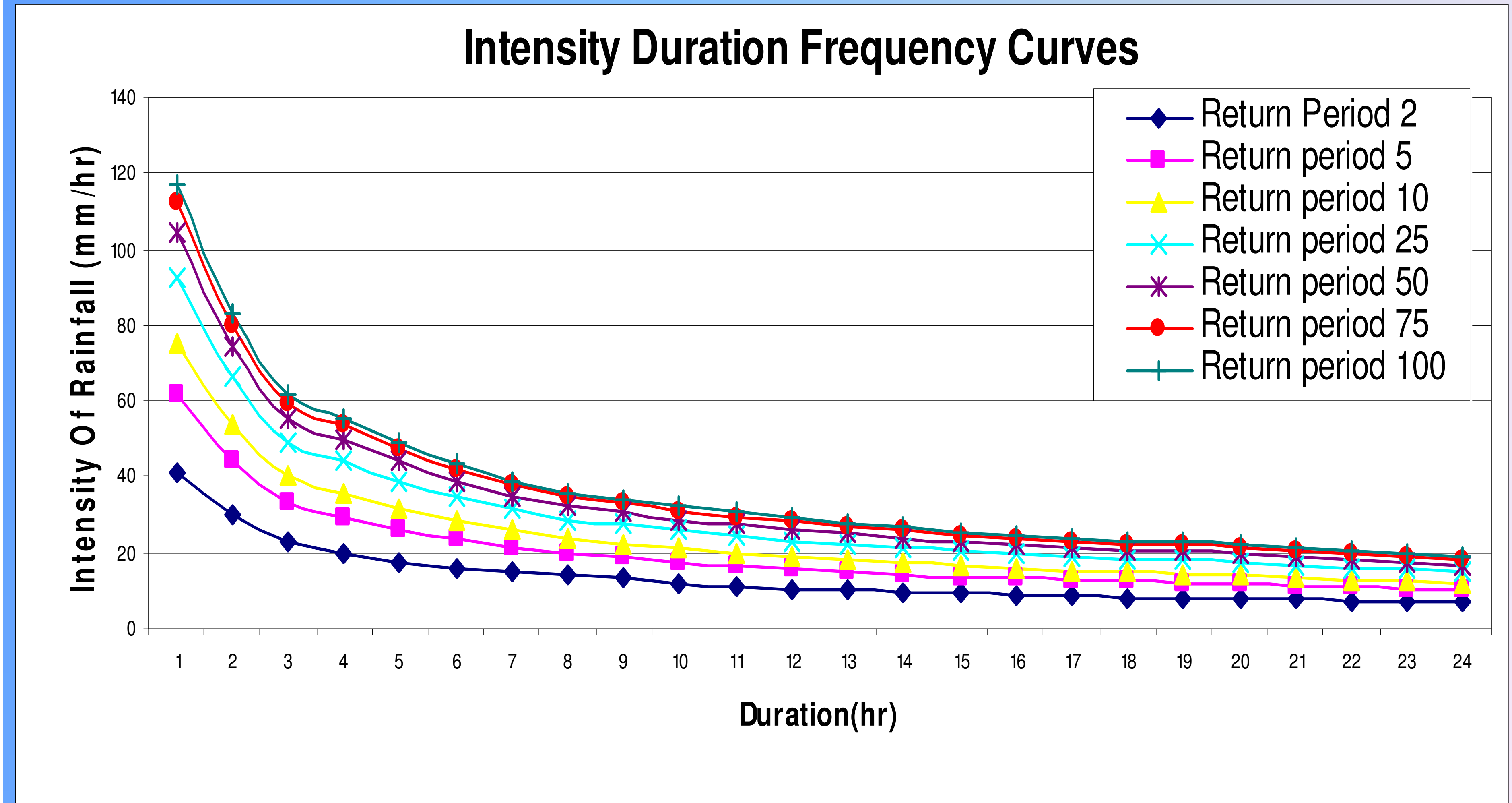
Annual Rainfall and Rainy Days at Nungambakkam (IMD) Raingauge Station
Annual Rainfall (mm)I
Rainy days
Annual Raindall (mm)
Rainy Days
3000
2500
2000
1500
1000
500
0
90
80
70
60
50
40
30
20
10
0
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
Years (1980-2009)



Average Monthly Rainfall at Nungambakkam Rain gauge Station
Average Rainfall (mm)
400
350
300
250
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months (1980 to 2009)

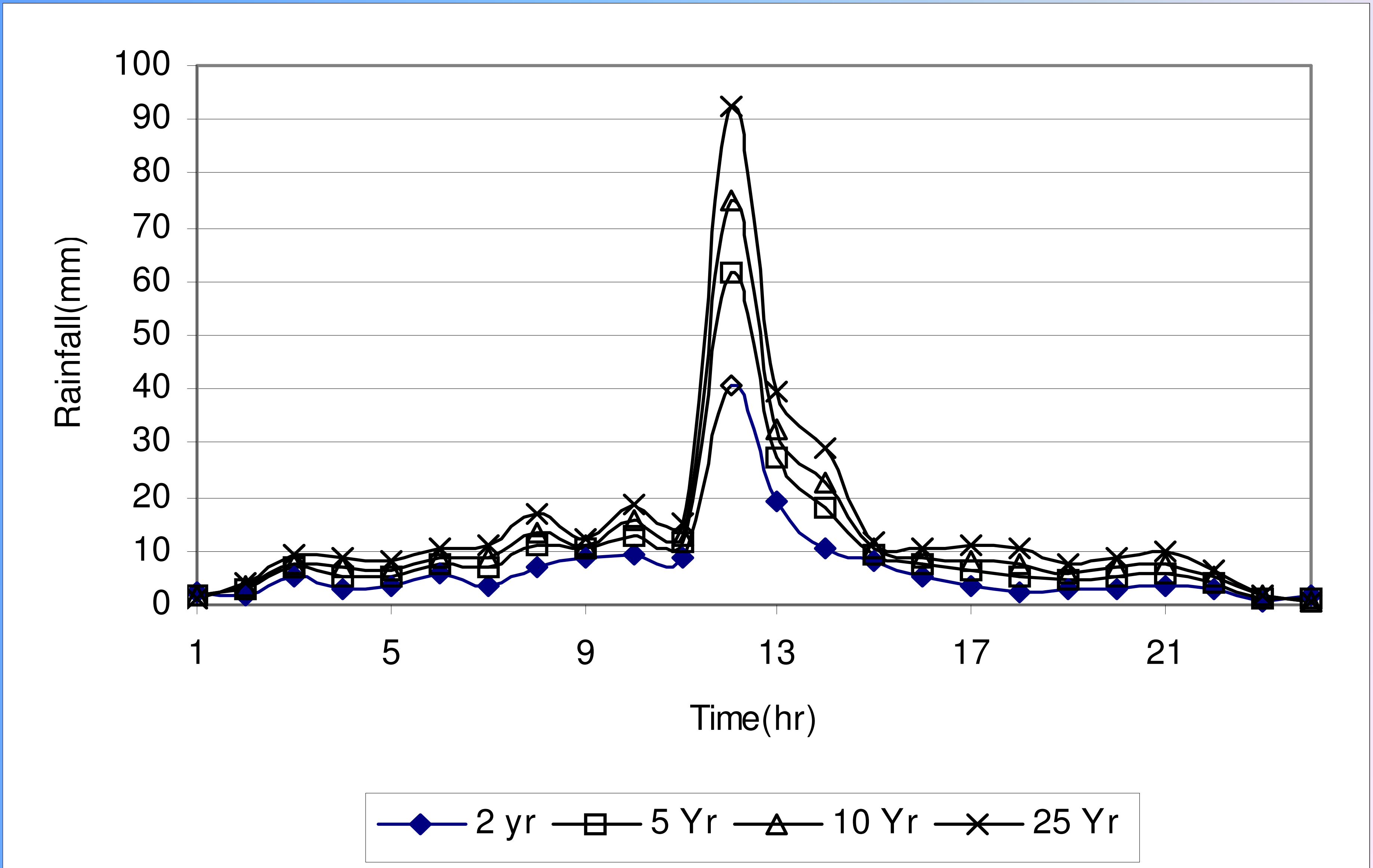

Highest one Day Rainfall in each year at Nungambakkam Raingauge Station
Maximum Daily Rainfall (mm)
450
400
350
300
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Years (1980-2009)

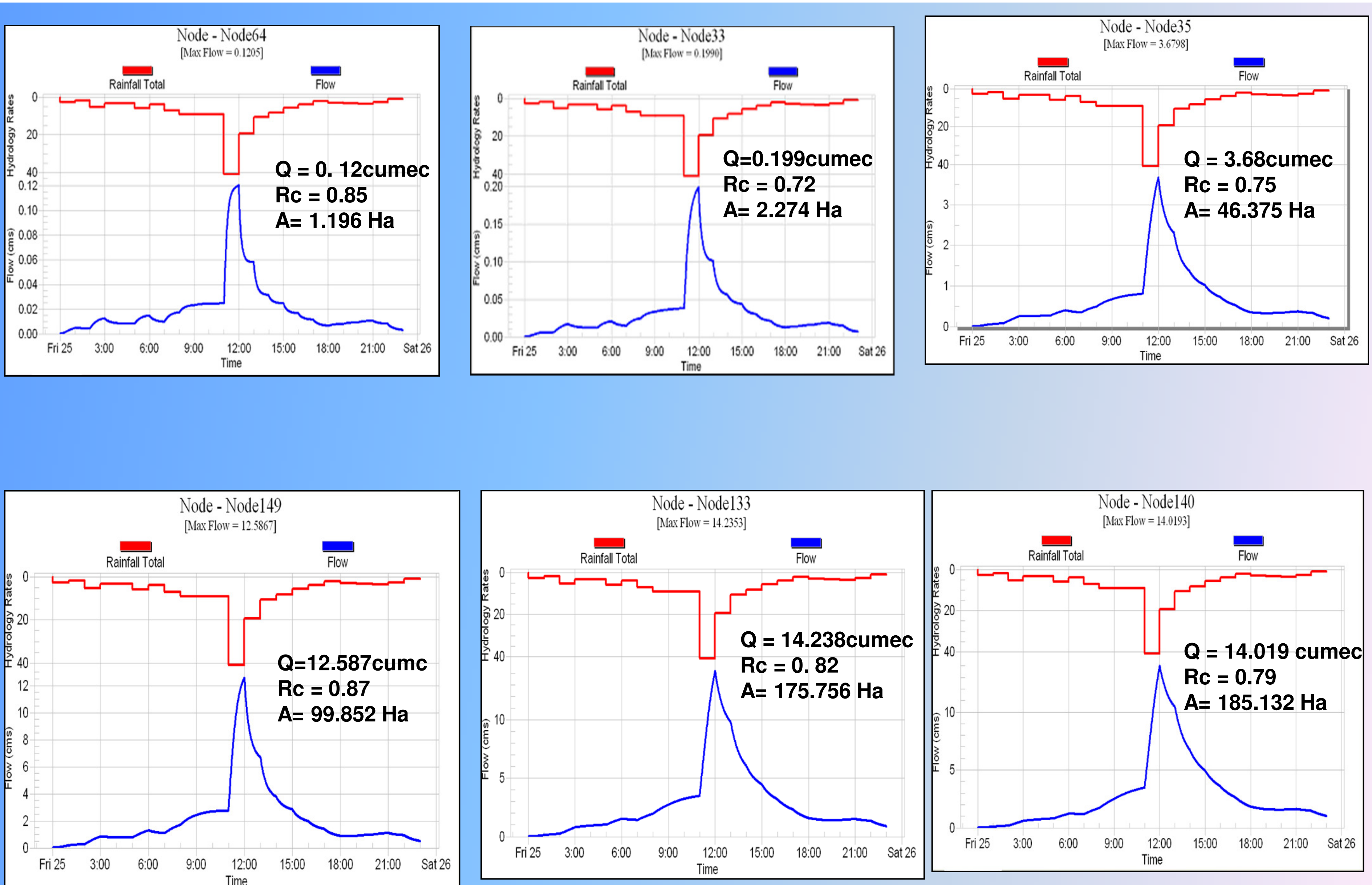

Highest hourly rainfall in each year at Nungambakkam
Hourly Maximum Rainfall(mm)
100
80
60
40
20
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Years (1980 to 2009)



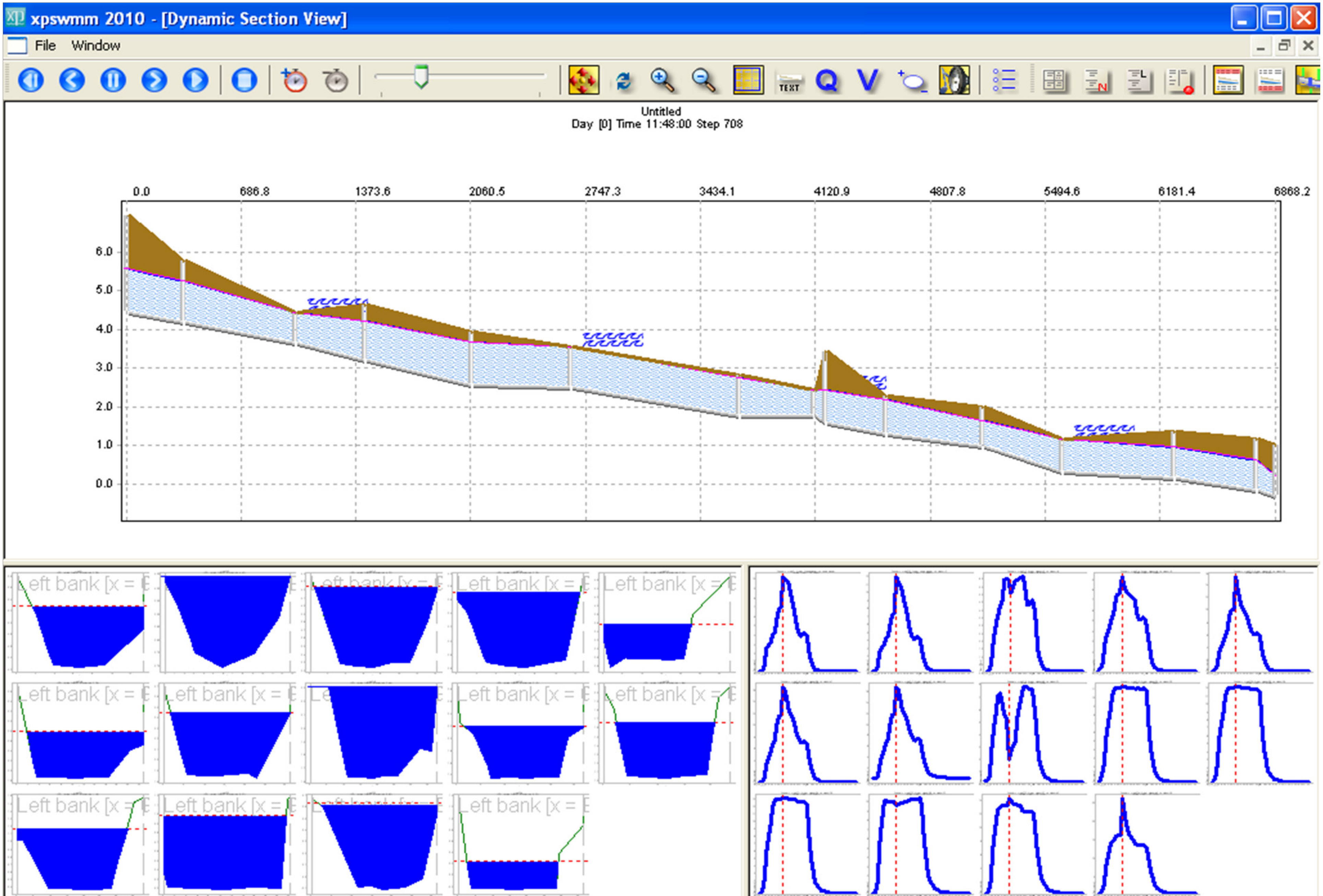
IDF curves for Chennai city at Nugambakkam (1980 to 2009)

24 hr Design Storms for various Return Periods

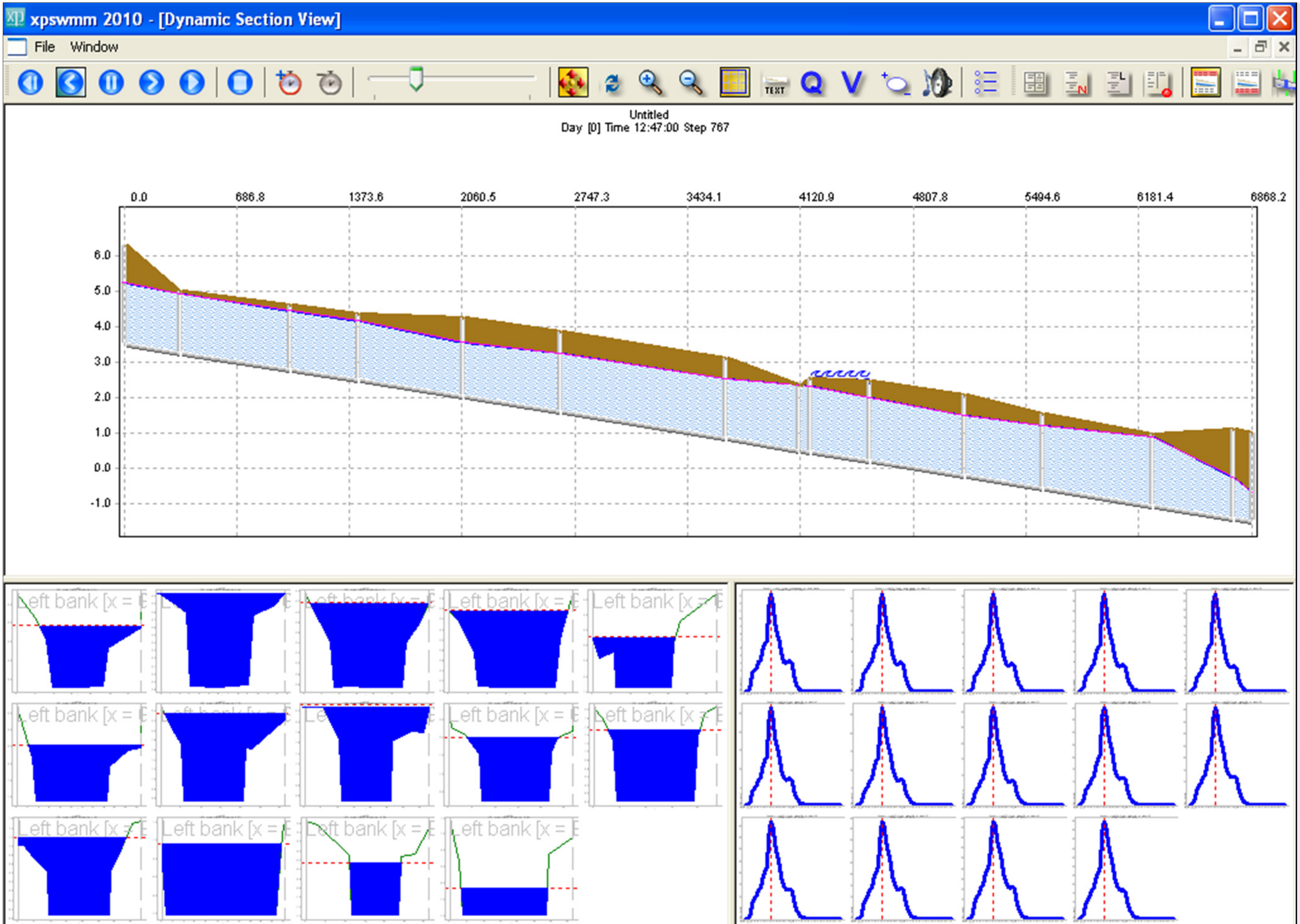




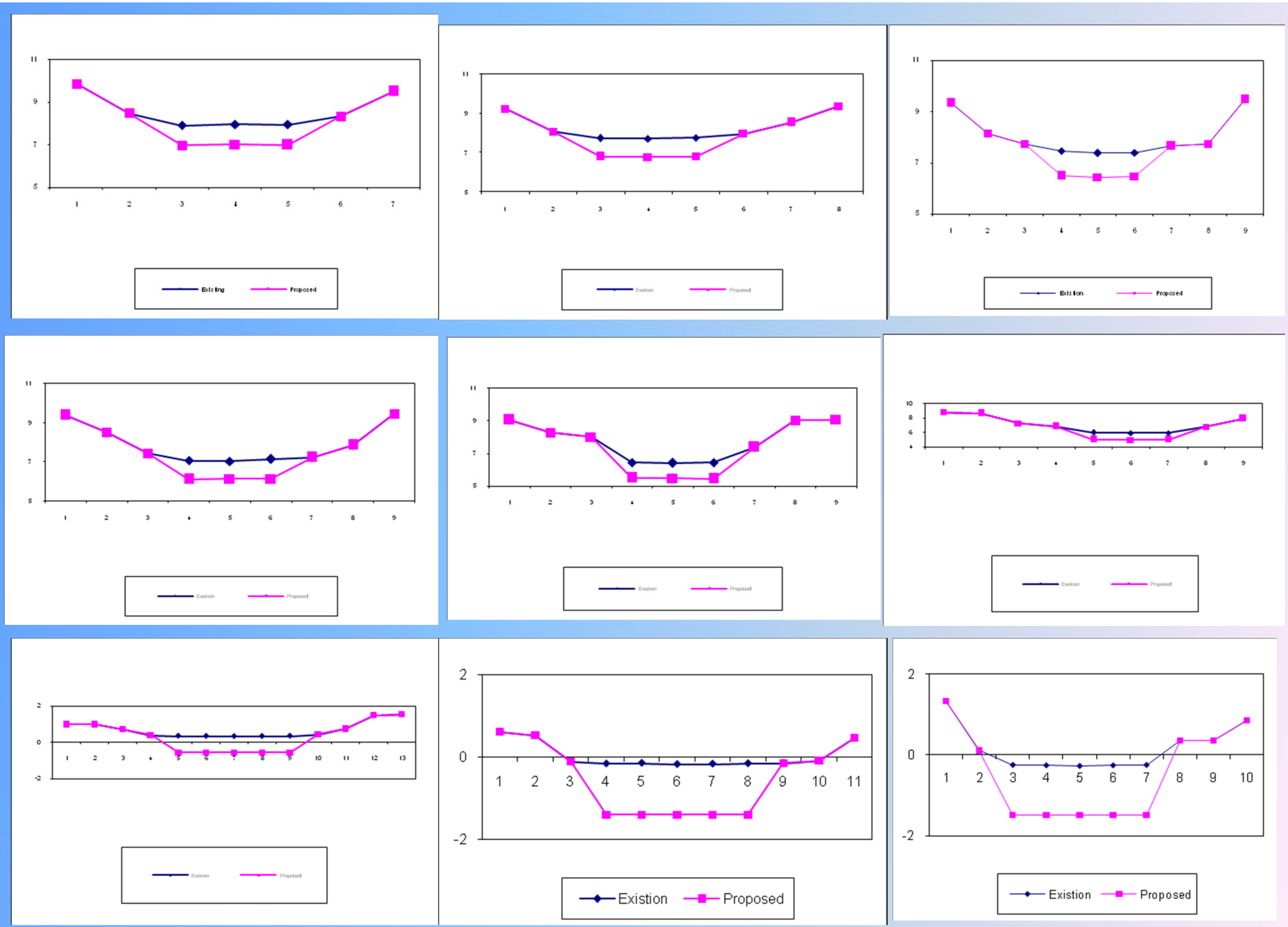
Runoff hydrographs of different micro watersheds against 2 year 24-Hr design storm



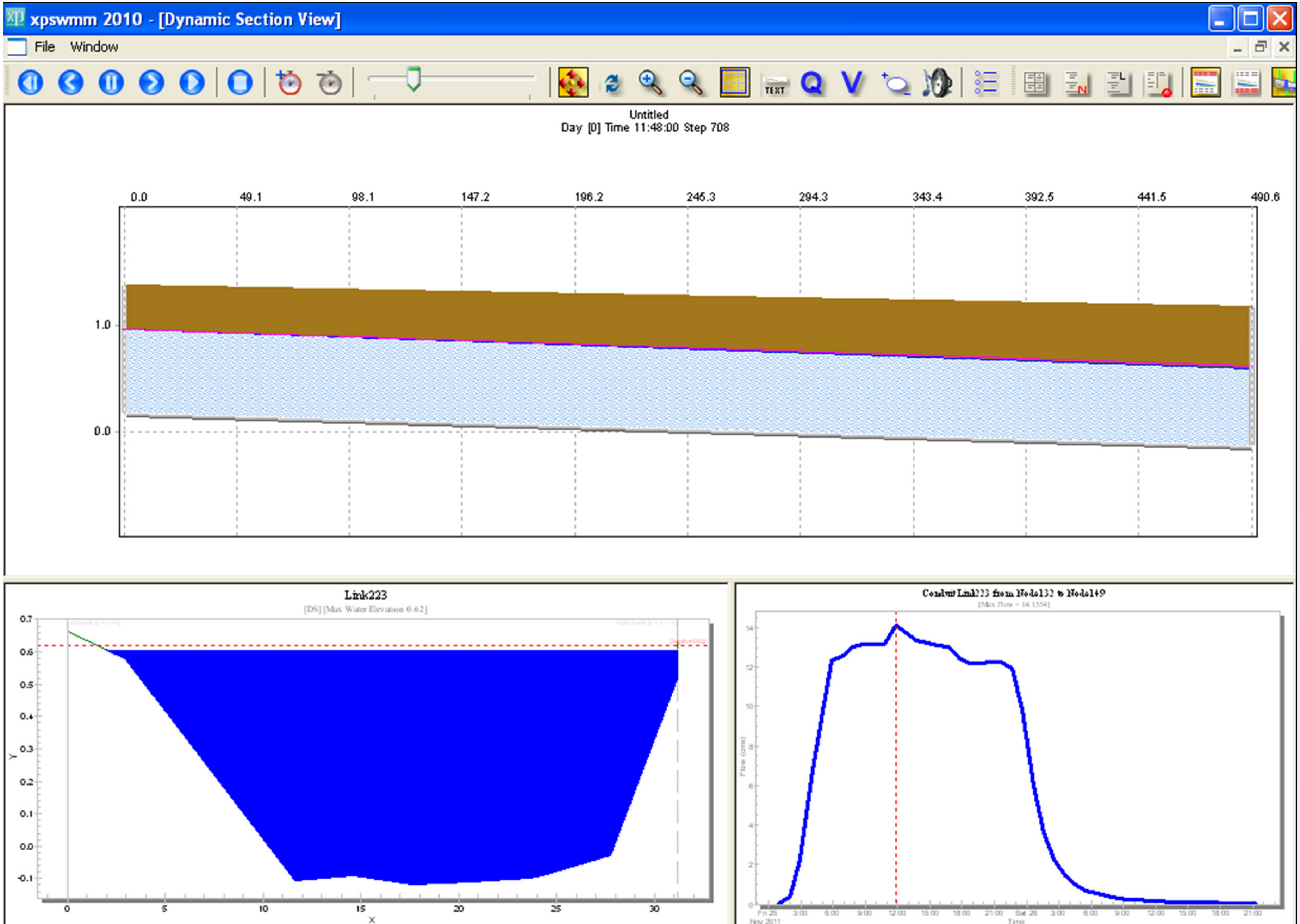
Water surface profile against 2 year return period 24hr design storm (existing L/P)



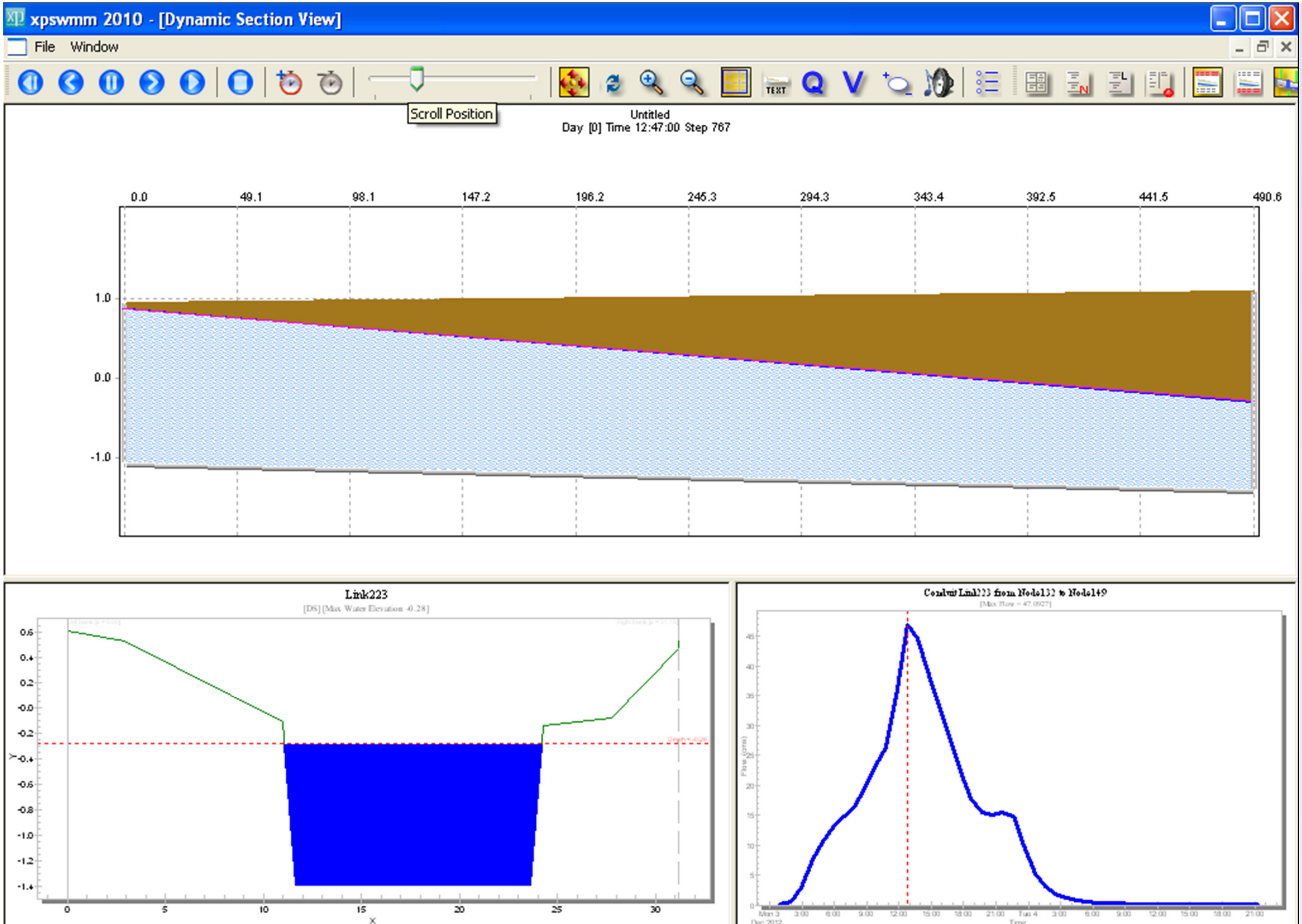
Water surface profile against 2 year return period 24hr design storm (proposed L/P)



Existing and Proposed C/S of Otteri Nuallah Drain



Water surface profile against 2 year return period 24hr design storm existing L/P at outlet)

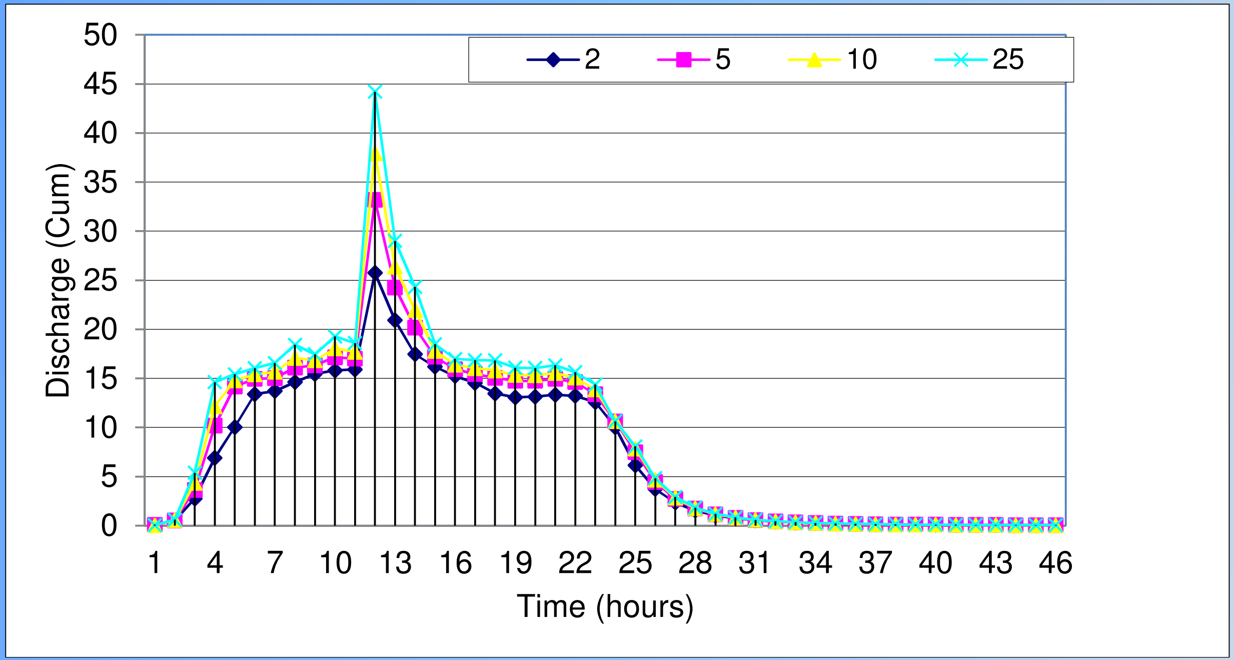


Water surface profile against 2 year return period 24hr design storm (proposed L/P at outlet)

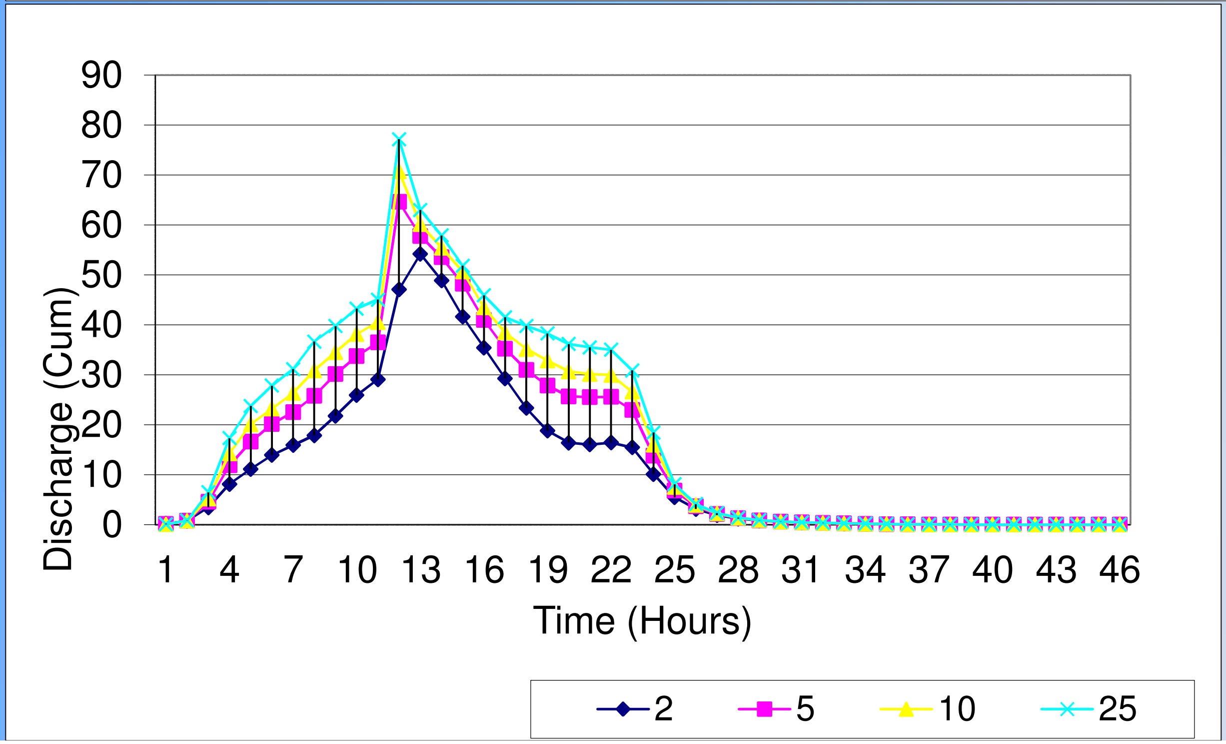
±

Flood peak at outfall, system inflow and out flow volume and percentage of error of existing and proposed L/P profile

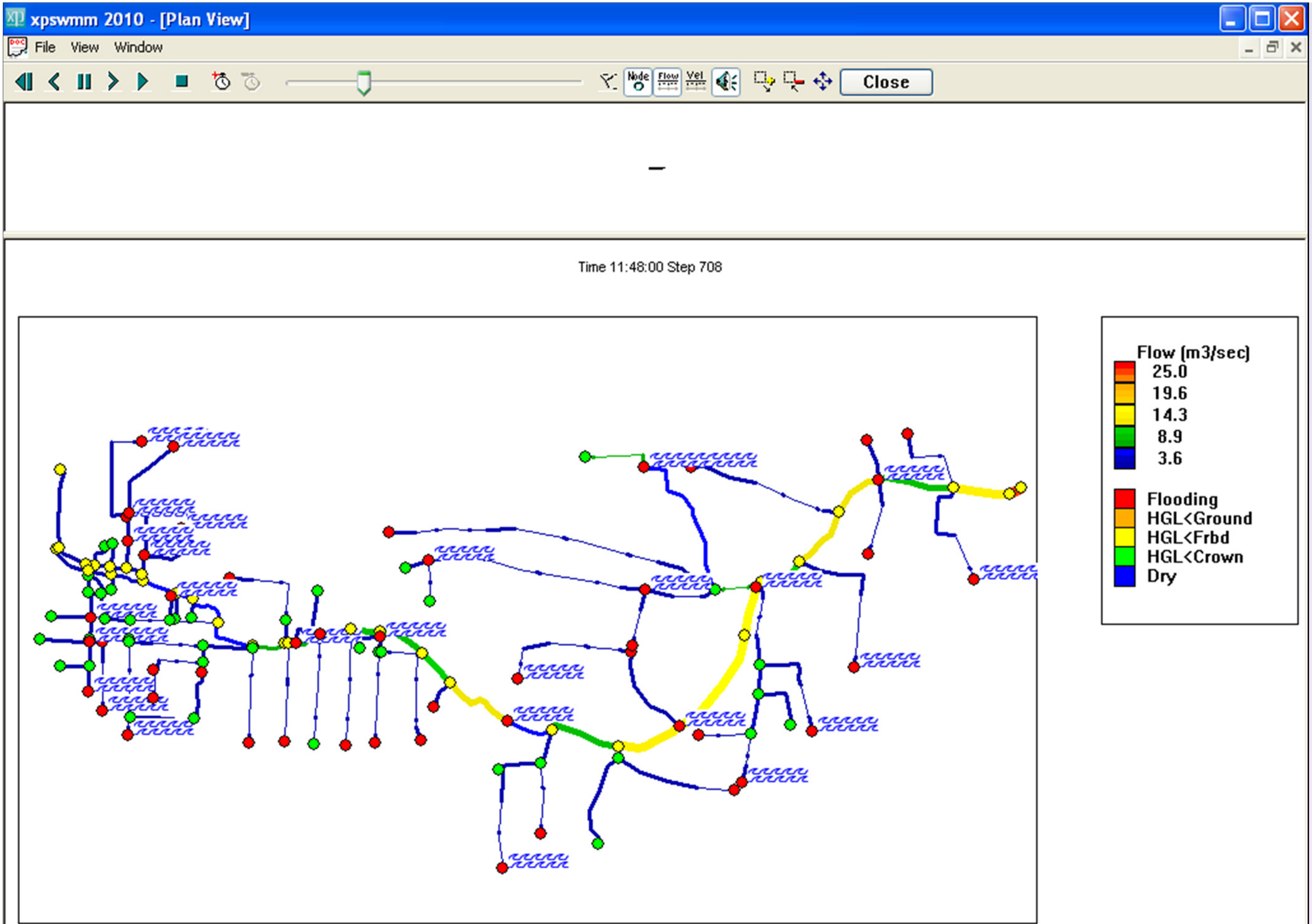
Return Period	Peak (m^3/s) at Outfall		System Inflow(m^3)		System Outflow(m^3)		%Error	
	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed
2	25.63	54.43	$3.5357*10^6$	$3.5353*10^6$	$3.5307*10^6$	$3.5364*10^6$	0.142	-0.030
5	33.08	64.82	$5.4912*10^6$	$5.4906*10^6$	$5.4874*10^6$	$5.4911*10^6$	0.069	-0.009
10	37.84	70.89	$6.7995*10^6$	$6.7990*10^6$	$6.7970*10^6$	$6.7986*10^6$	0.036	0.006
25	44.14	77.13	$8.5402*10^6$	$8.5395*10^6$	$8.5389*10^6$	$8.5377*10^6$	0.015	0.002



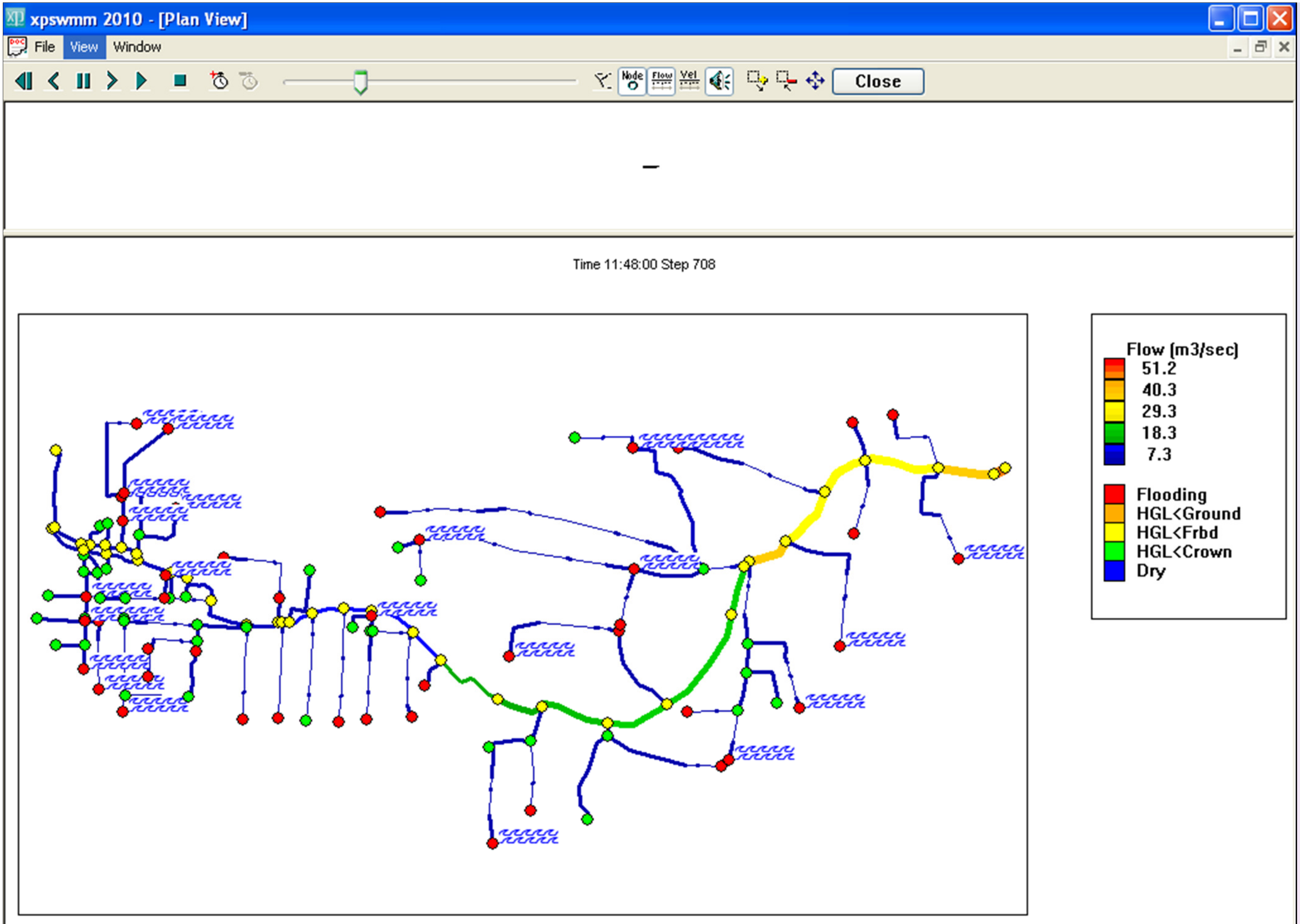
Hydrograph at Outfall with Existing L/P



Hydrograph at Outfall with Prposed L/P



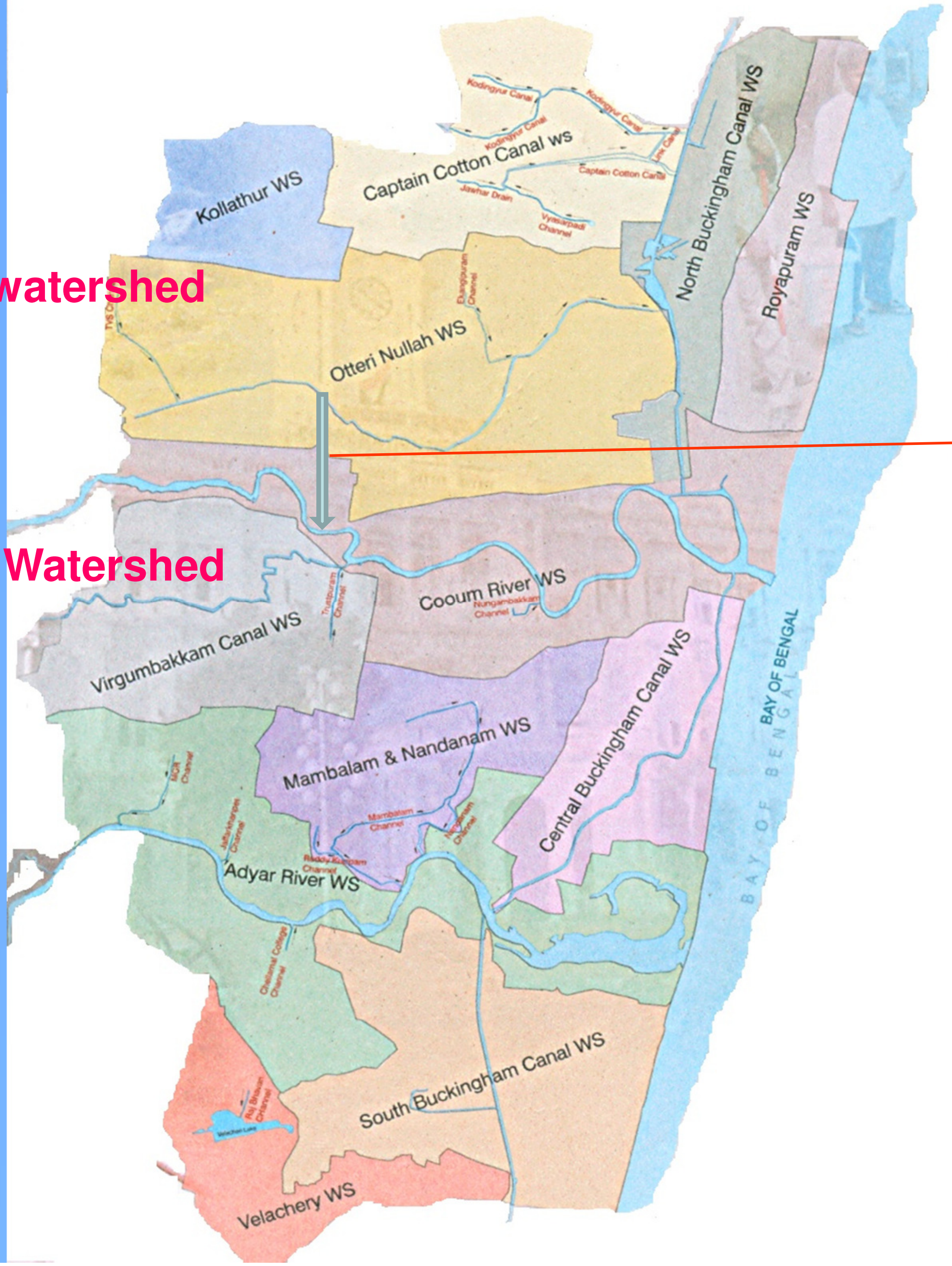
2 year return period flooding at nodes with existing L/P



2 year return period flooding at nodes with proposed L/P

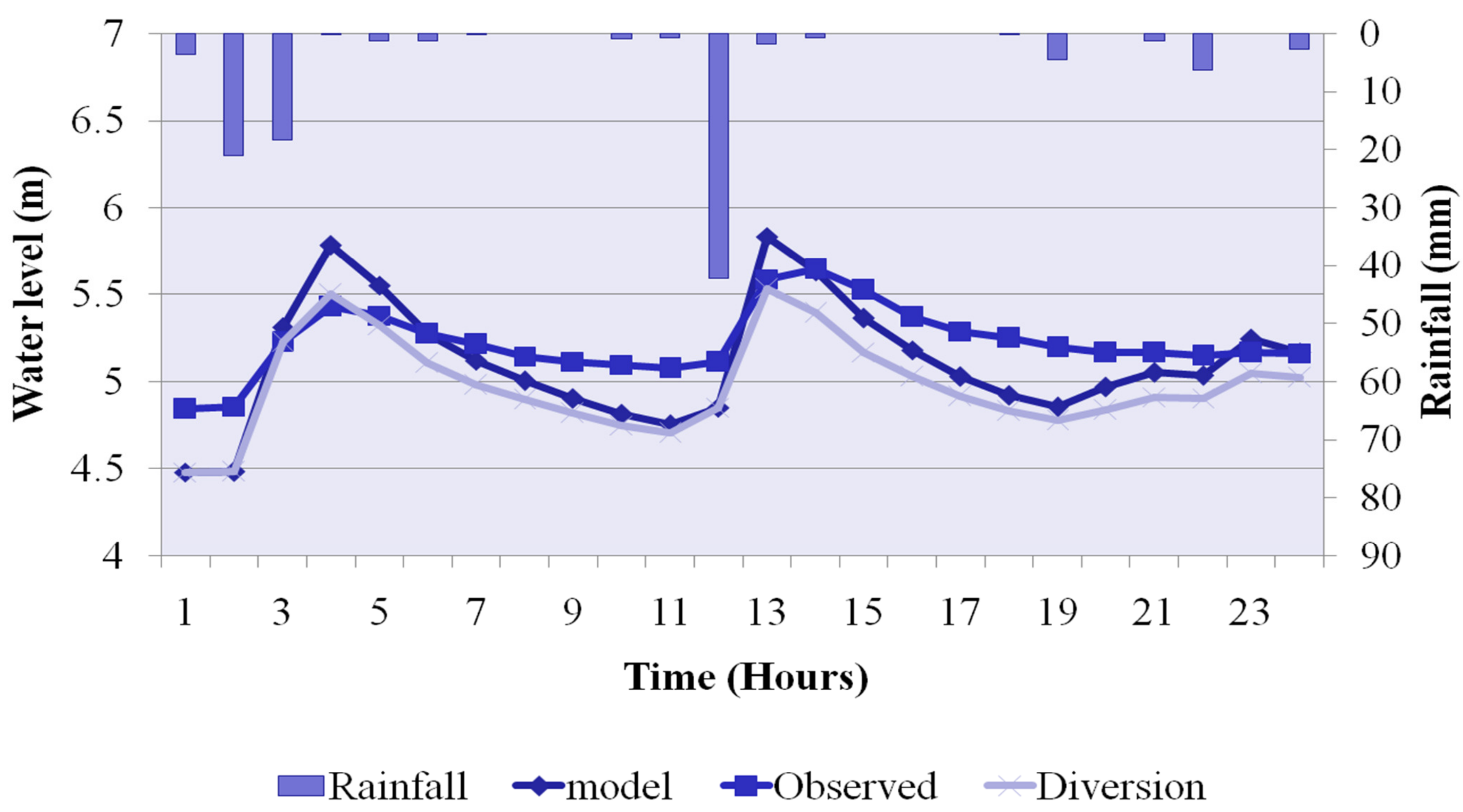
Otteri nullah watershed

Cooum River Watershed

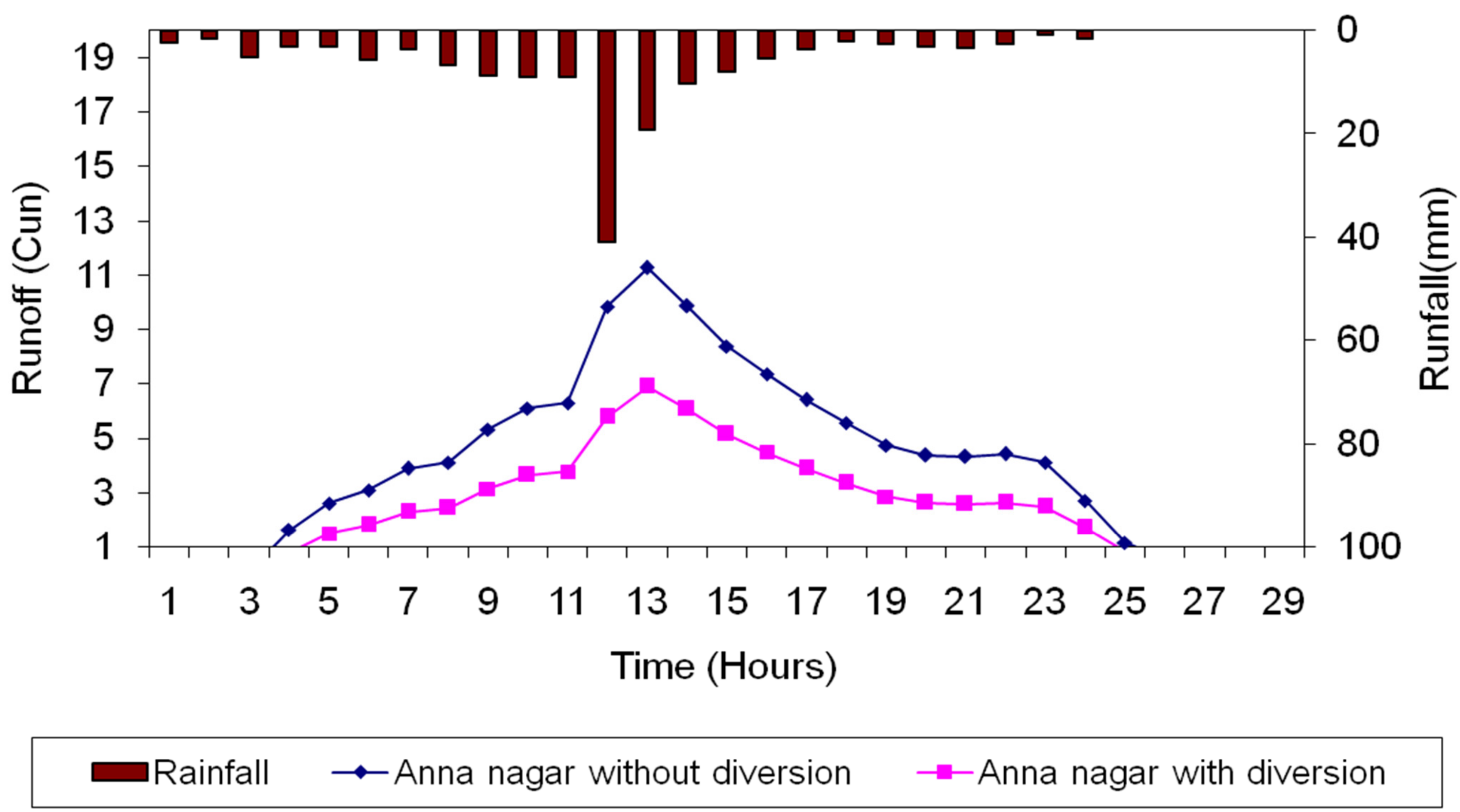


Proposed Diversion

Impact of Proposed Diversion on Water Level



Impact of Proposed Diversion on Runoff Peak
(24 hrs strorm with two years return period)



Existing Stormwater drainage conditions in the study area


NMF


A TRAINING COURSE
ON
URBAN HYDROLOGY
UNDER HYDROLOGY PROJECT -II (PDS)
4th - 6th OCTOBER 2010
AT
SG & SWRDC, CHENNAI
ORGANISED BY
NATIO INSTITUTE OF HY OGY
DELTA GIONAL CENTRE, NADA


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.
V. RAVI KUMAR
Dr. Y.R.SATYAJI RAO

CONCLUSIONS

- Thirty years hourly rainfall data of Nungambakkam raingauge station has been collected from IMD and IDF curves have been developed.

- The existing drainage system without any blockage is verified with 2, 5, 10 and 25 years return period storm and found that the existing storm water drainage network in the basin is inadequate even to dispose 2 years return period design storm runoff.

- Proposed longitudinal profile of Otteri Nuallh drain by PWD, Chennai is incorporated in the model and verified. It was found that drainage system is adequate only two years return period storm runoff and rest of return period storms are causing flooding.

- The hydrographs at outfall of the sub basin has been developed for various return period design storms and this information is very useful for best management practices (BMP).

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NATIONAL INSTITUTE OF HYDROLOGY
Thank you

Flow Routing Algorithms in SWMM5

- Steady Flow
  - simple hydrograph translation
  - applicable only to branched networks
- Kinematic Wave
  - gravity force balanced by friction force
  - attenuated & delayed outflow due to channel storage
  - applicable only to branched networks

$$S_f = S - \frac{\partial y}{\partial x} - \frac{V}{g}\frac{\partial V}{\partial x} - \frac{1}{g}\frac{\partial V}{\partial t}$$

Friction slope | *Bed slope* | *Water Surface slope* | *Convection term* | *Accleration term*

Kinematic wave

Diffusion wave

Full dynamic wave

Dynamic Wave

- solves full St. Venant eqns.
- accounts for channel storage, backwater effects, pressurized flow, and reverse flow
- applicable to any network layout
- requires smaller time step

Flow Routing Algorithms in SWMM5

- Steady Flow Routing
  - Sums instantaneous sub-catchment runoff for all sub-catchments upstream of the selected channel
- Kinematic Wave
  - Uniform, unsteady flow
  - No backwater, no surcharge, tree branch systems only
- Dynamic Wave
  - Non-uniform, unsteady flow
  - Backwater, surcharge, looped or parallel sewers, street routing of flooded sewer manholes

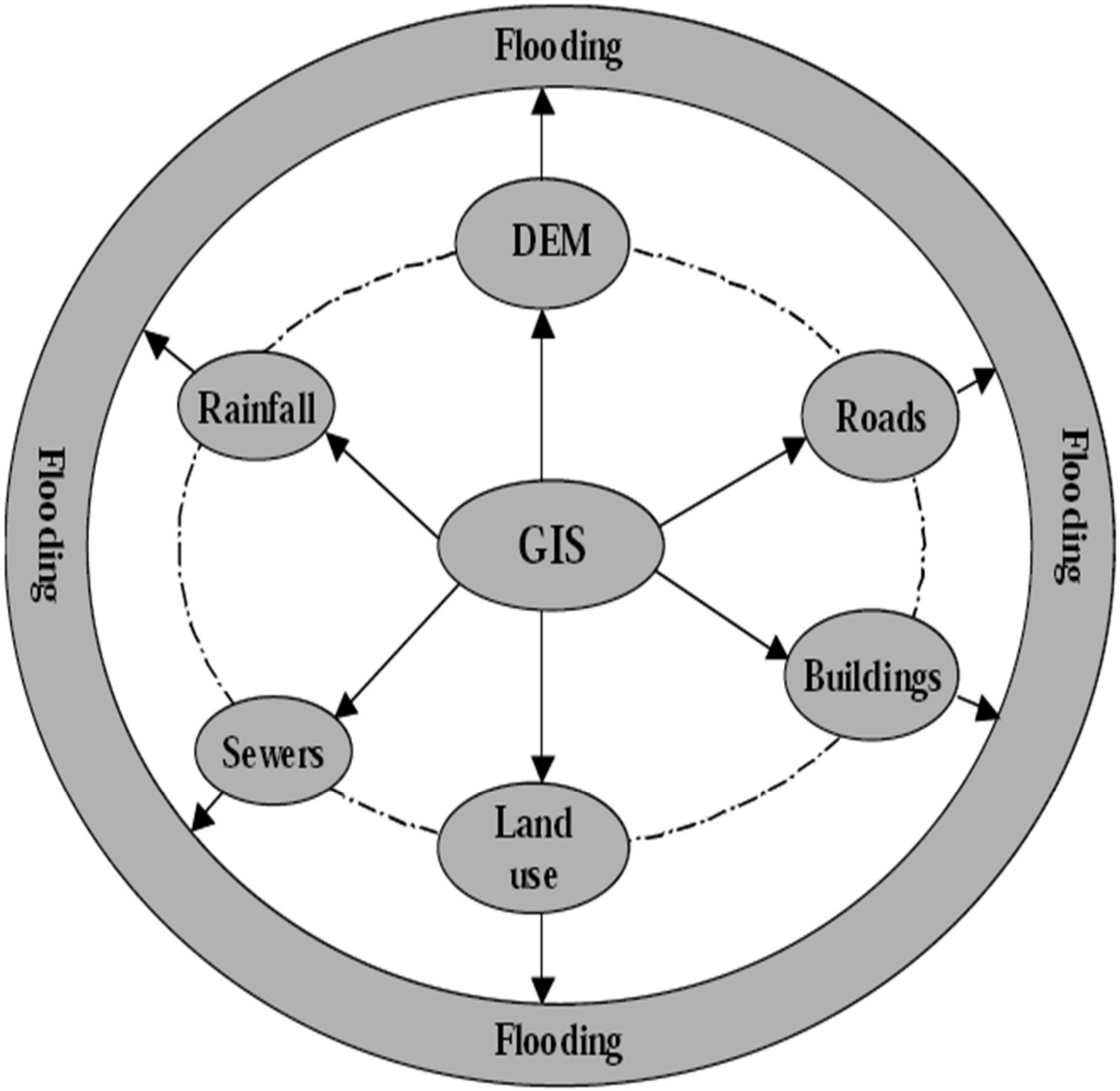
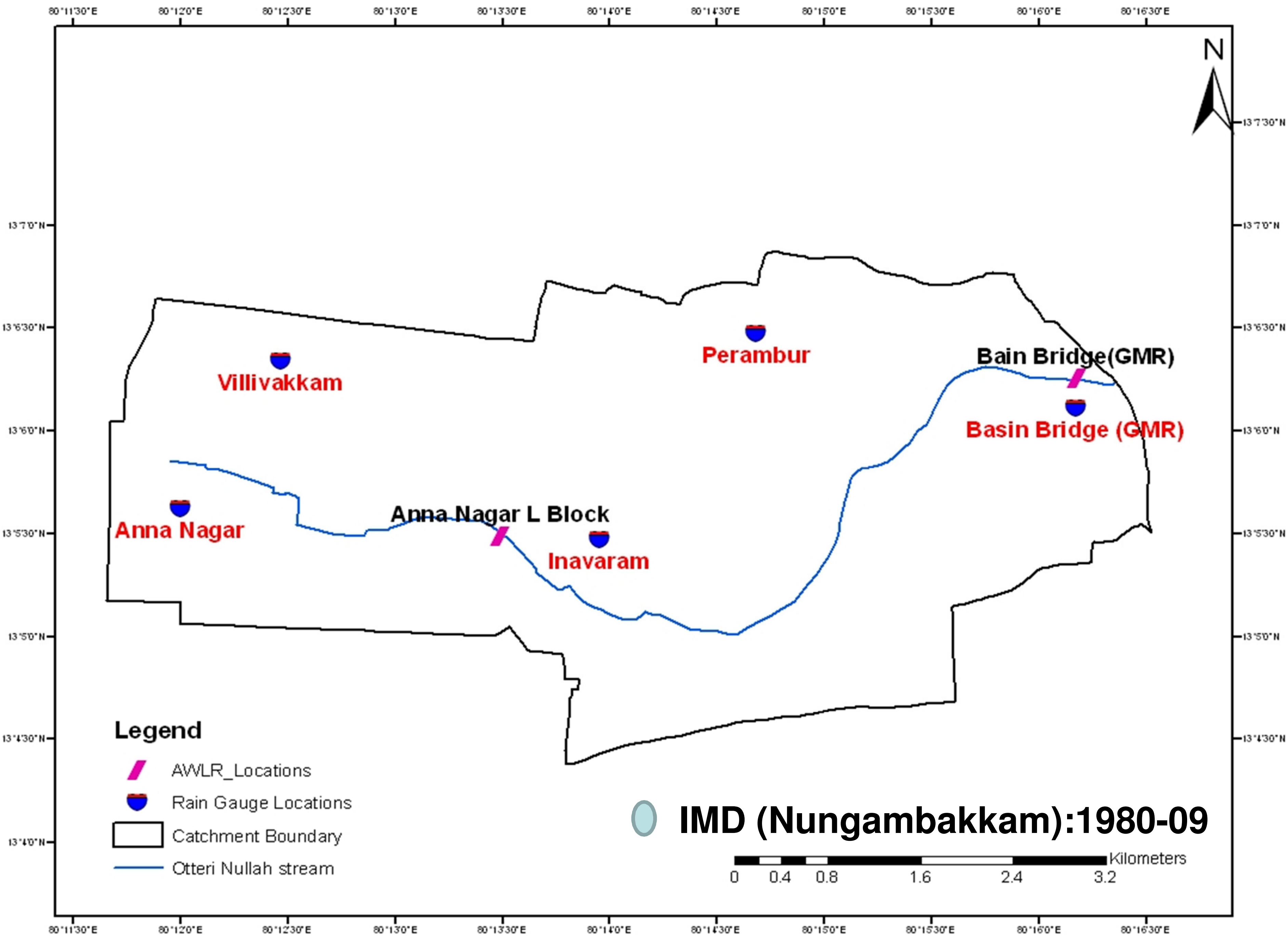


Figure 4.4 GIS based applications in flooding analysis


N
Perambur
Villivakkam
Bain Bridge(GMR)
Basin Bridge (GMR)
Anna Nagar L Block
Anna Nagar
Inavaram
Legend
AWLR_Locations
Rain Gauge Locations
Catchment Boundary
Otteri Nullah stream
IMD (Nungambakkam):1980-09
0 0.4 0.8 1.6 2.4 3.2 Kilometers