WATER SENSITIVE PLANNING GUIDELINES
AT
RESIDENTIAL CLUSTER LEVEL

Resource Efficiency in Urban Water Management
Case study from Medinipur, WB

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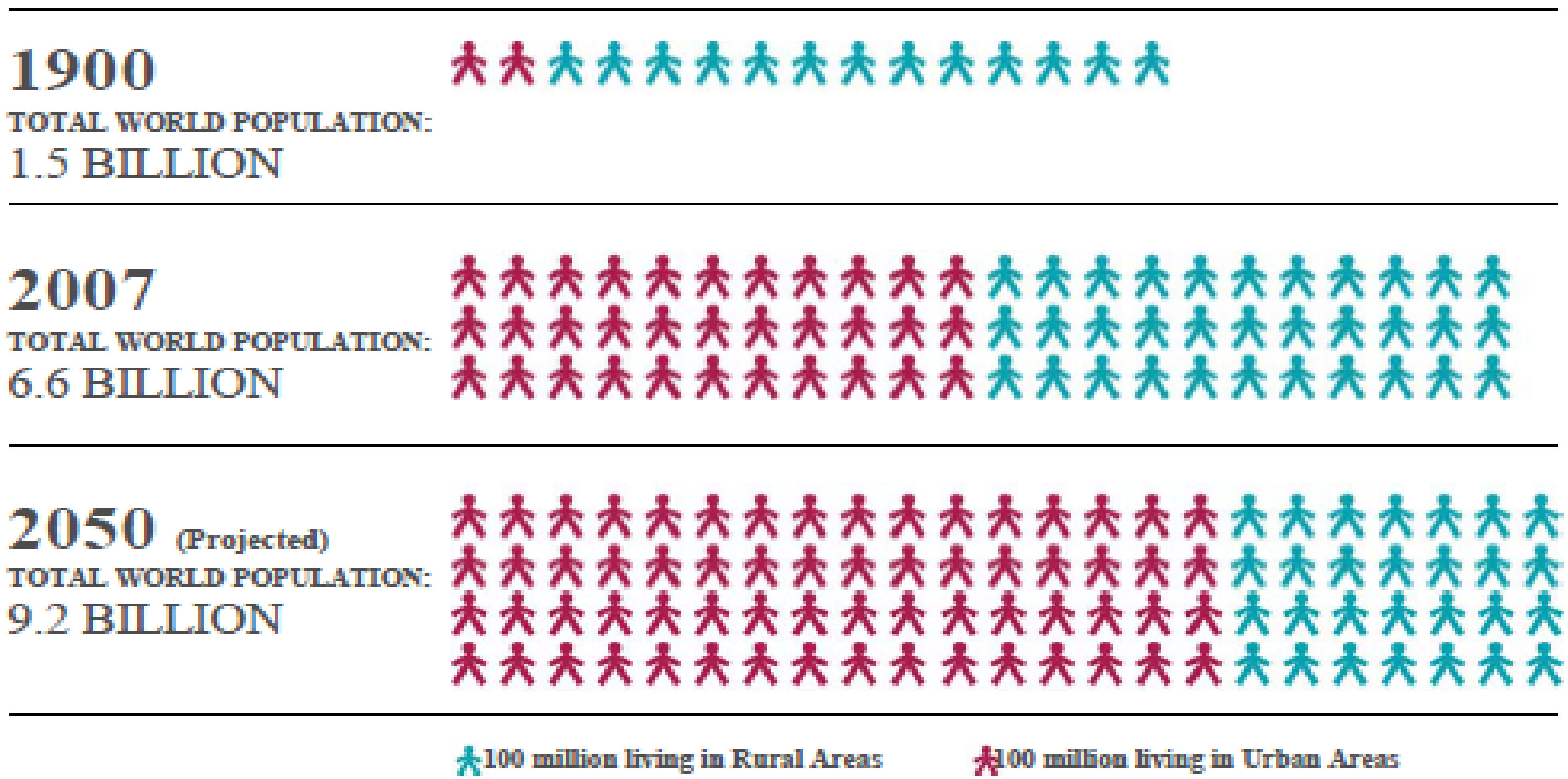
CSE Regional Workshop in " URBAN WATER MANAGEMENT", KMDA, June 20 , 2013

Total World Population

1900 - 2050

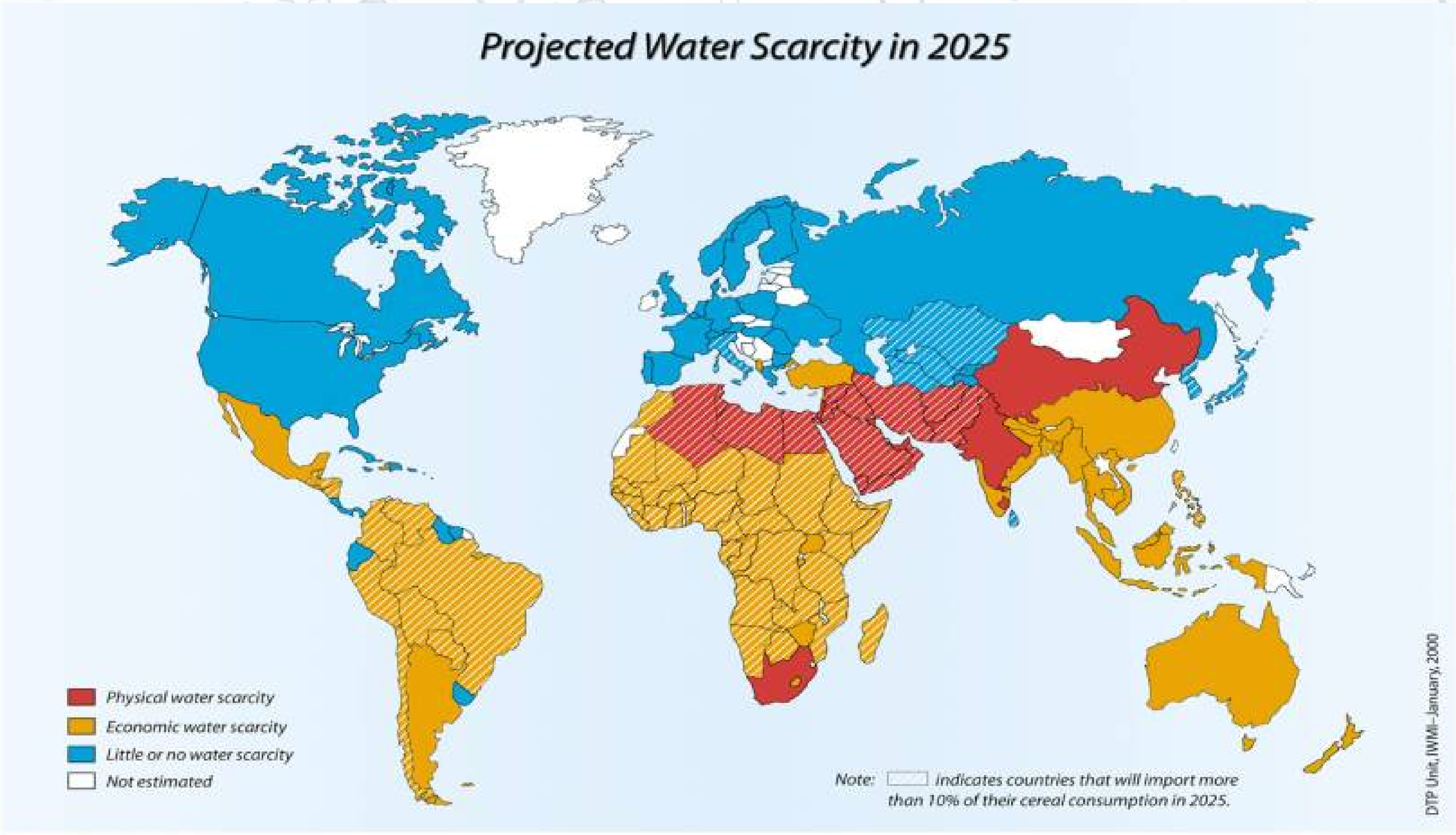


Mark Fletcher, (Nov. 2011) ,Water cities in Transition, International Conference, Amsterdam

Effect of Urbanisation

Mark Fletcher, (Nov. 2011) ,Water cities in Transition, International Conference, Amsterdam

Water Scarcity, Demand and Usage

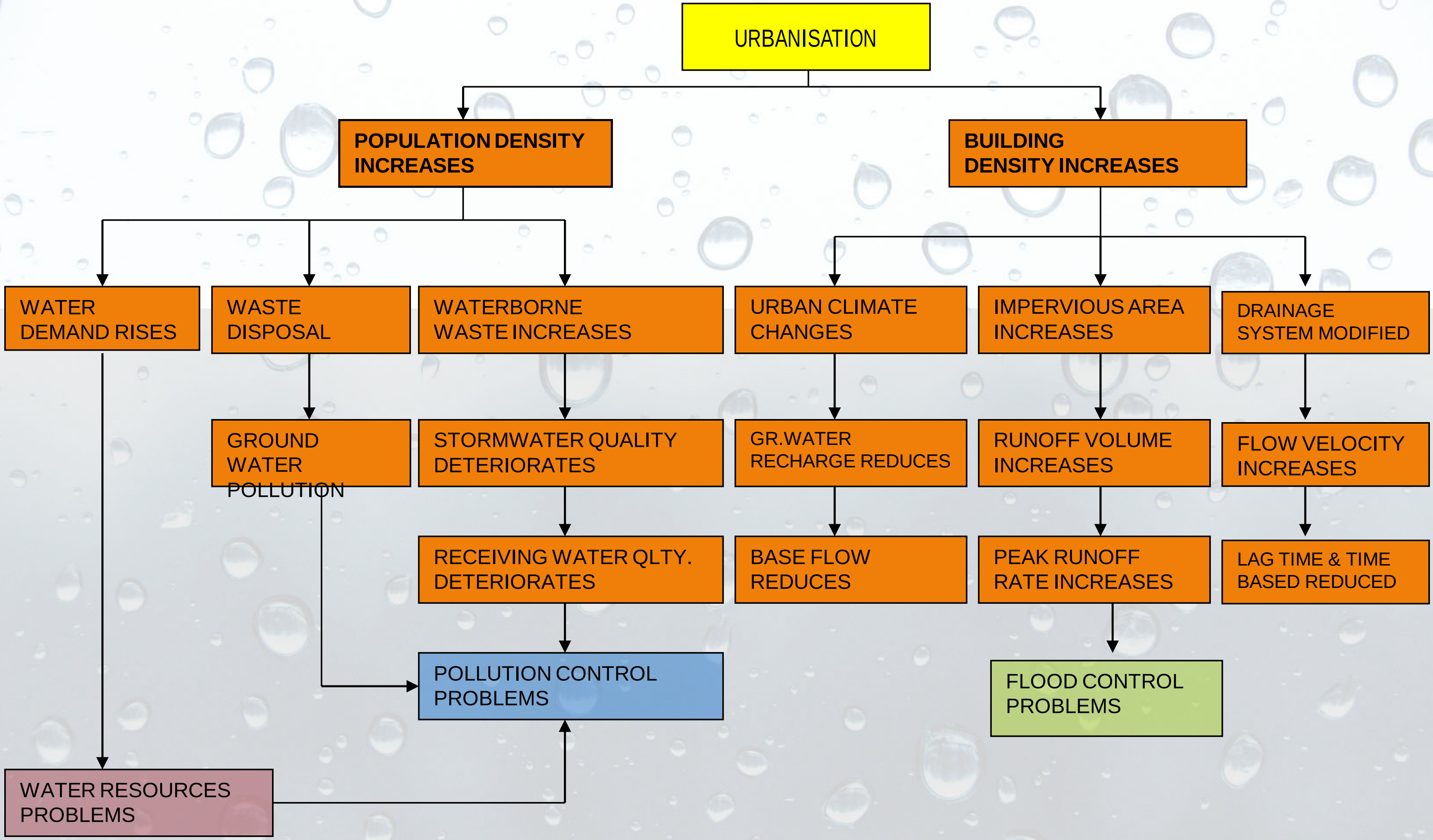


INTERNATIONAL WATER MANAGEMENT INSTITUTE

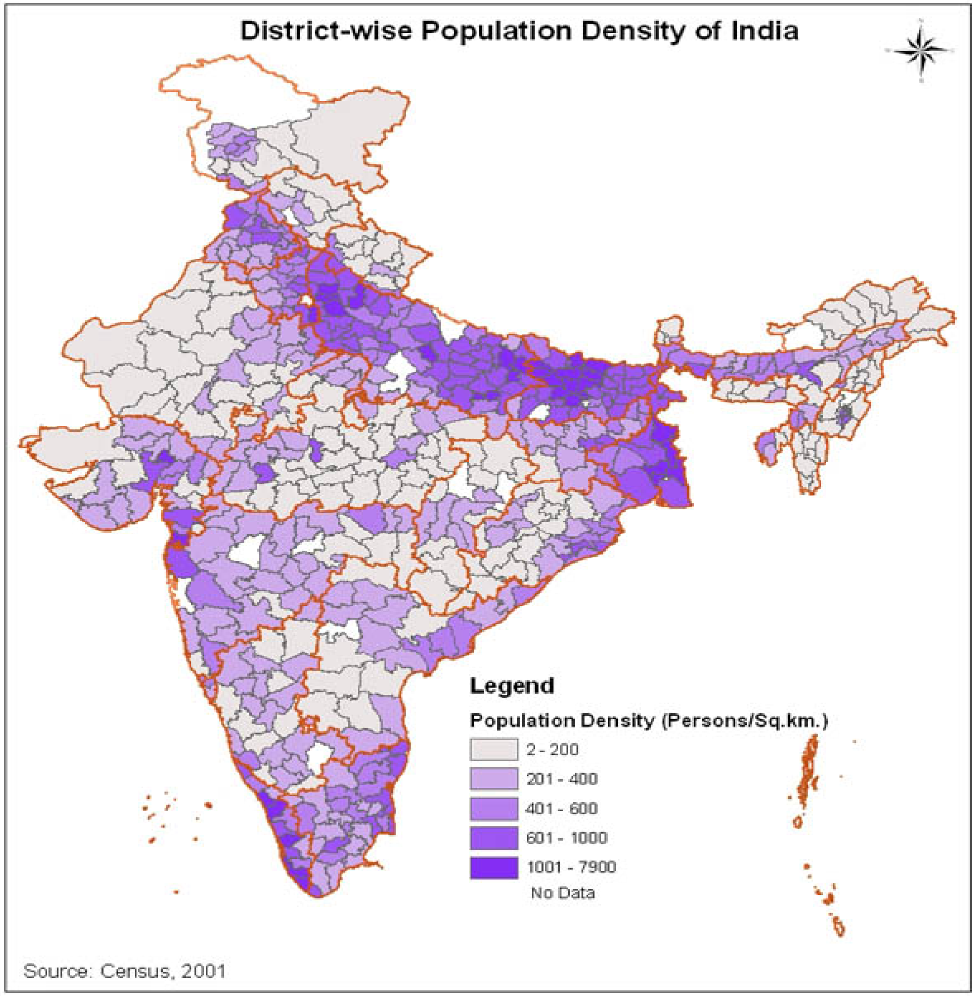
Prepared by IWMI as input for the World Water Vision, The Hague, March, 2000.

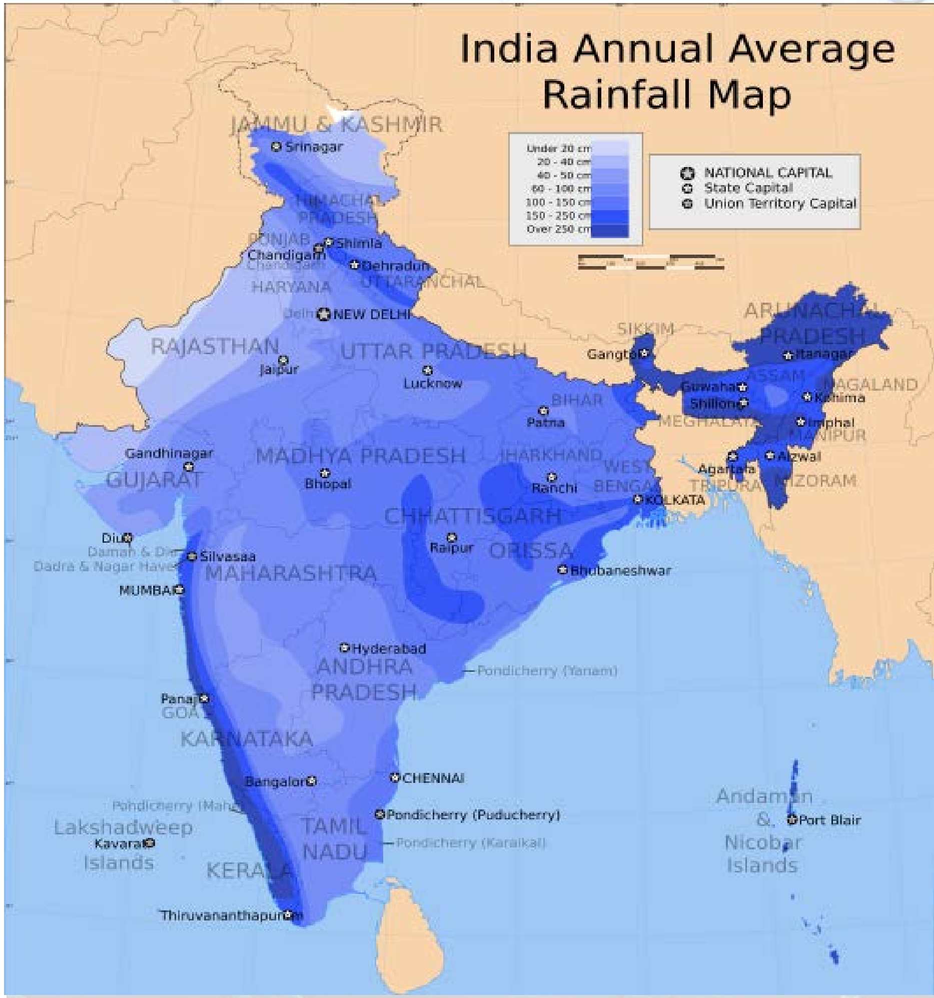
http://iwmi.org

Effect of Urbanisation on Water



Link between population density and availability of Freshwater



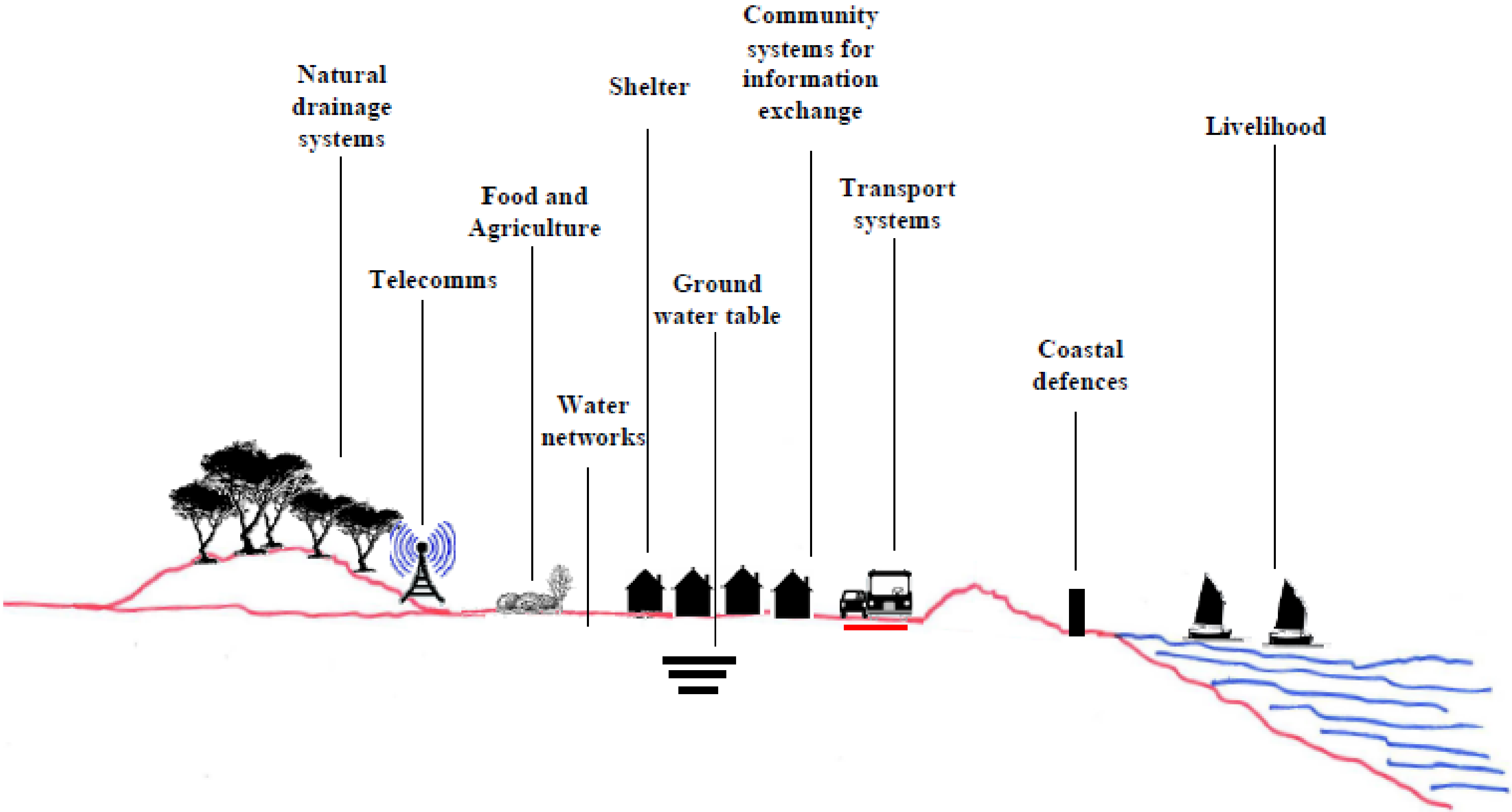


Densely populated portion of India receives heavy rainfall causing Urban Flooding

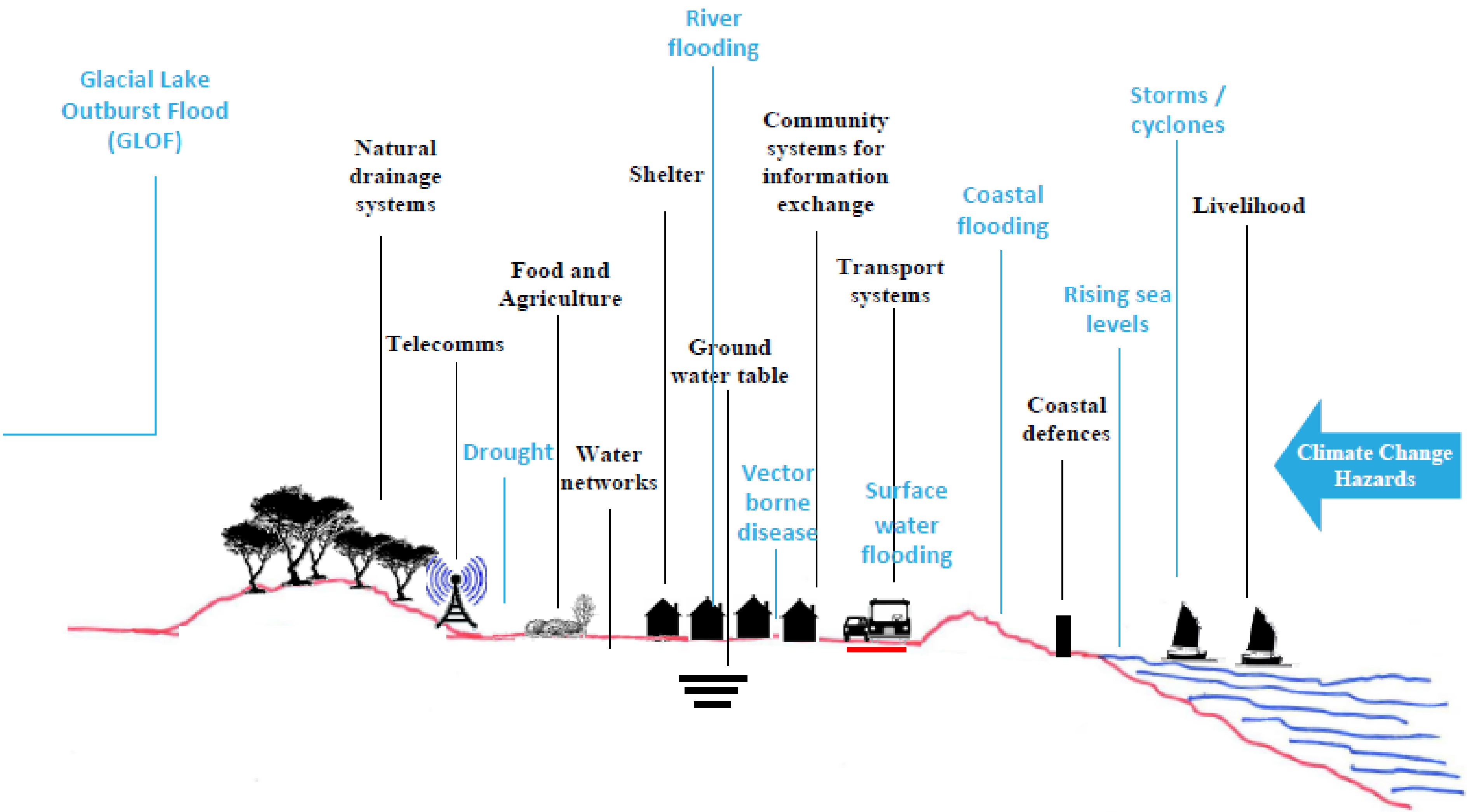
There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people—and the environment—suffer badly.

-- World Water Council

Water Related Impact



Climate Related Impact



The Urban Water related Crisis

- Dynamic use of Water in Urban Centers.
- Gap between supply and demand.
- Supply infrastructure not in pace with increasing consumption.
- Heavy Exploitation of ground water and surface resources.
- Incapability of U.L.B. to respond to challenges.

19^{th} CENTURY SOLUTIONS TO URBAN WATER MANAGEMENT

WATER SUPPLY	STORMWATER	SEWAGE
➢ Large scale water supply from a few large sources	➢ Collect it all and discharge to receiving waters. ➢ Engineer water courses and drains	➢ Collect it all and discharge after some treatment to receiving waters i.e. based on dilution

i.e. “BIG PIPES IN – BIG PIPES OUT”

Towards a new approach – Sustainable water management

Characteristics of 'old' and 'emerging' paradigms of urban water systems:

The Old Paradigm	The Emerging Paradigm
Storm water is a nuisance..	**Storm water is a resource.**
Demand is a matter of quantity.	**Demand is multi-faceted.**
One use. Water follows one-way path from supply, to a single use, to treatment and disposal to the environment.	**Reuse and reclamation**. Water can be used multiple times, by cascading from higher to lower quality needs, and reclamation treatment for return to the supply side of infrastructure.
Gray infrastructure.	**Green infrastructure**.
Bigger/centralized is better	**Small/decentralized is possible**
Limit complexity and employ standard solutions.	**Allow diverse solutions.**
Integration by accident.	**Physical and institutional integration by design.**

Trends and Emerging Issues

Municipal water use has been on rise due to increase in urbanisation.

Growing trend towards water demand management measures aimed at

- Increasing system **efficiency** at utility level, e.g.
  - Reduction in systems losses
- Increasing end-use **efficiency**, e.g.
  - Domestic water **efficiency** measures, Public education
- Promoting locally & unused available resources, e.g.
  - Rainwater Harvesting, Greywater reuse
- Promoting substitution of resource use, e.g.
  - Waterless toilets, Greywater reuse
- Using economic instruments to promote **efficient** use of water
  - Flexible water tariffs

(adapted from White & Fane, 2001)

What has not been looked into, so far?

- To what extent rainwater available in an area could be effectively utilised with appropriate technology and environmental safeguard so as to partially meet the domestic as well as non-domestic water demand in local areas.

- To what extent storm water could be appropriately utilised for an effective flood control management under emergency situations.

- To what extent ground water resources should be utilised so as not to exceed the recharging possibilities, and also to avoid the detrimental environmental consequences of overexploitation of ground water.

- To what extent the waste water , in absence of sewerage system, could be properly managed for non-domestic purposes, so that the untreated water do not pose serious health concerns.

- How Urban Development might be planned and executed in a manner so as to lower the hydrological impact of urbanisation and present opportunities for improved water management.

What is Water Sensitive Urban Design ?

- Optimising the use of rain that falls on the city catchment
- Reducing the storm water runoff and manage flooding
- Prevent flash flood related damage
- Reducing the amount of potable water demand for the city
- Incorporating water related social and ecological objectives into our design (Mouritz, M. 2000)

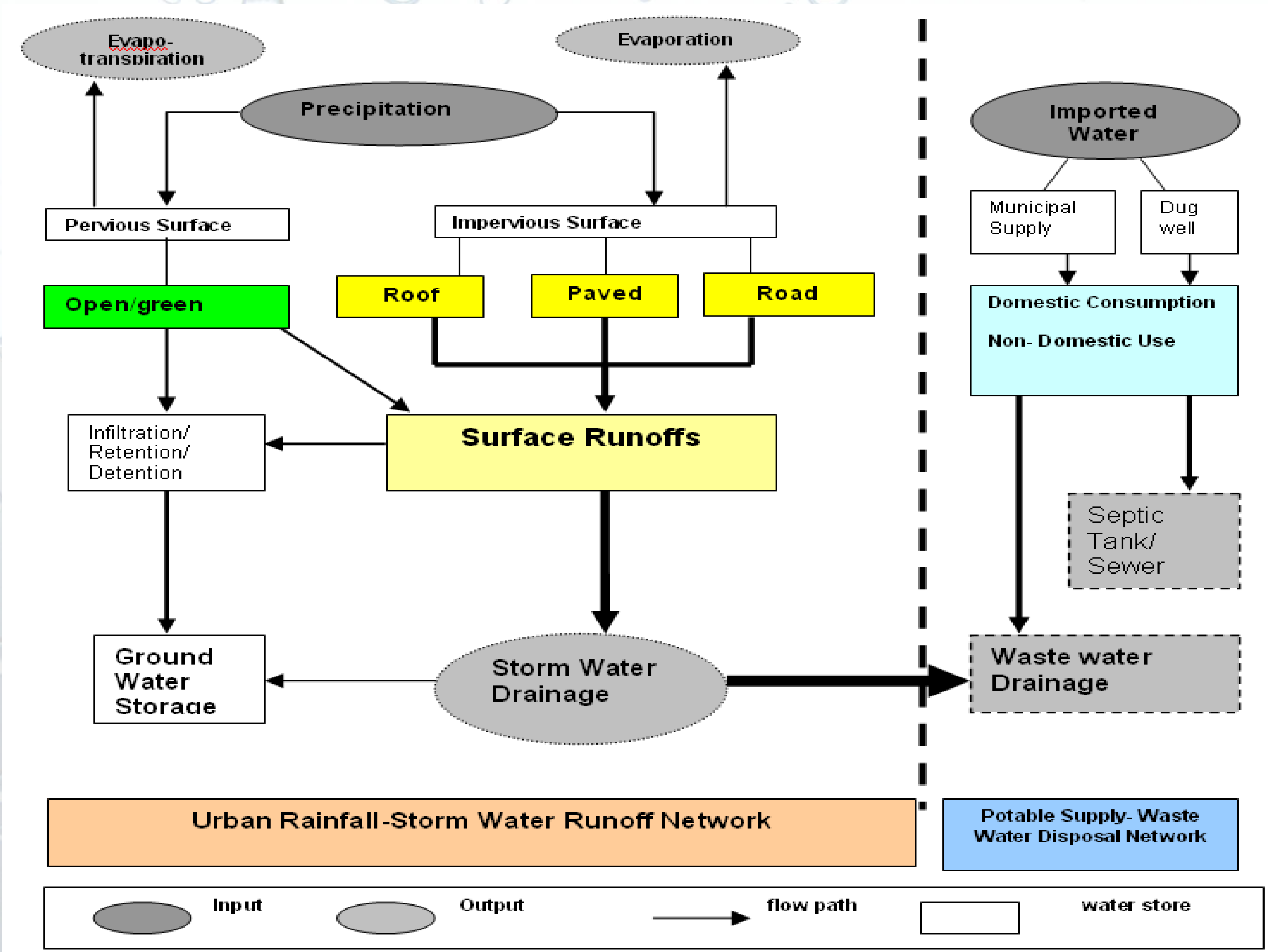
WSUD Elements

•**Conveyance Control**, to detain the large events of rainfall at neighbourhood level.
•**Discharge Control**, for conveying the extreme rainfall events at the watershed level.
•**Source Control**, to retain the small frequent rainfall events at the individual lot level.

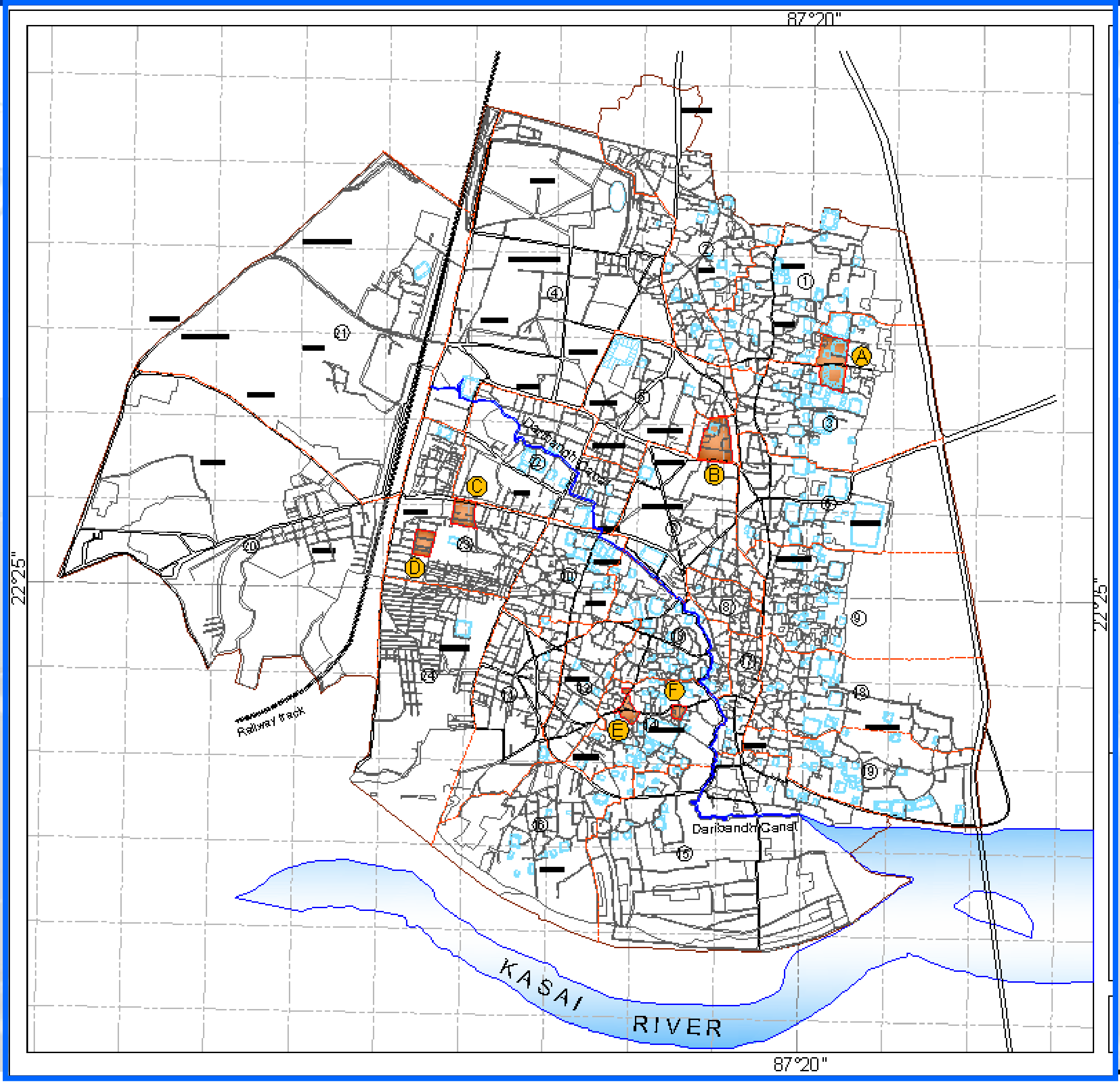
Research Objective

- To identify the physical factors which affect mostly the surface runoff in small towns
- To study the water use patterns in domestic sector in terms of quantity and spatial pattern
- To analyse the factors affecting rainwater harvesting in urban areas
- To develop a relationship amongst Annual Surface Runoff, Precipitation and Factors of Imperviousness at residential cluster levels
- To make a sensitivity analysis on various developmental options for control of runoff while designing for future site planning exercises on three issues.
  - ***Imperviousness control and its implication on residential site planning***
  - ***Effectiveness of rainwater tanks to substitute non-potable water requirement under different rainfall conditions***
  - ***Performance of roadside drains to mitigate extreme cloudburst***

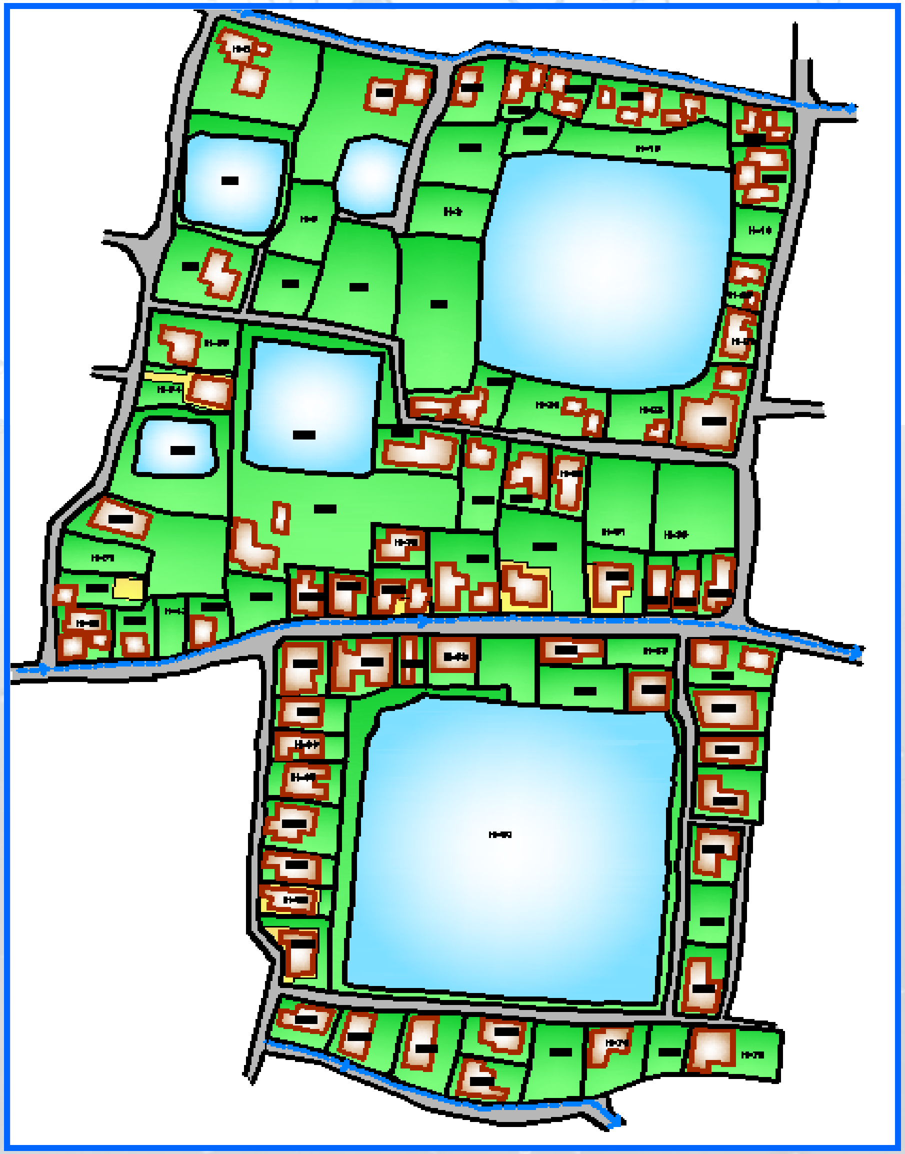
Typical Urban Water Cycle in Indian small and medium Towns



Selected Areas for detail Investigation in Medinipur Town



Site A : Habibpur



Total No of Plots	:	87
Total No. of Buildings	:	64
Total Area	:	4.31 Ha
Surface Sealing	:	25%
Imp/Per. Ratio	:	0.34
Roof/Per Ratio	:	0.17
Avg. Plot Size	:	440 sq. m.
Avg. Roof Size	:	87 sq. m.
Avg. H.Hold Size	:	4.27

Site B : Kamarara

Total No of Plots	:	73
Total No. of Buildings	:	57
Total Area	:	2.93 Ha
Surface Sealing	:	40%
Imp/Per. Ratio	:	0.67
Roof/Per Ratio	:	0.32
Avg. Plot Size	:	330 sq. m.
Avg. Roof Size	:	100 sq. m.
Avg. H.Hold Size	:	6.02

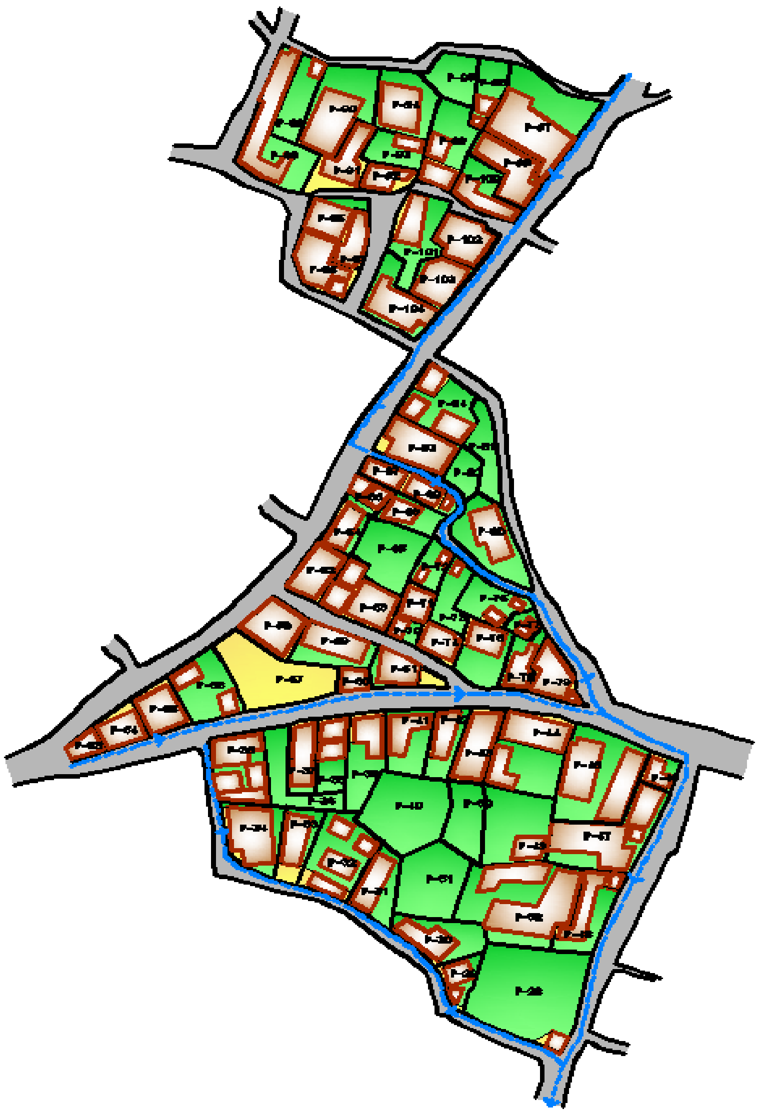
Site C : Mitra Compound

Total No of Plots	:	46
Total No. of Buildings	:	44
Total Area	:	1.94 Ha
Surface Sealing	:	84%
Imp/Per. Ratio	:	5.15
Roof/Per Ratio	:	1.67
Avg. Plot Size	:	300 sq. m.
Avg. Roof Size	:	120 sq. m.
Avg. H.Hold Size	:	4.5

Site D : Bidhannagar

Total No of Plots	:	39
Total No. of Buildings	:	37
Total Area	:	1.41 Ha
Surface Sealing	:	82%
Imp/Per. Ratio	:	4.59
Roof/Per Ratio	:	1.52
Avg. Plot Size	:	260 sq. m.
Avg. Roof Size	:	103 sq. m.
Avg. H.Hold Size	:	4.5

Site E : Patnabazar



Total No of Plots	:	77
Total No. of Buildings	:	70
Total Area	:	1.83 Ha
Surface Sealing	:	62%
Imp/Per. Ratio	:	1.65
Roof/Per Ratio	:	0.72
Avg. Plot Size	:	180 sq. m.
Avg. Roof Size	:	70 sq. m.
Avg. H.Hold Size	:	5.47

Site F : Boxibazar

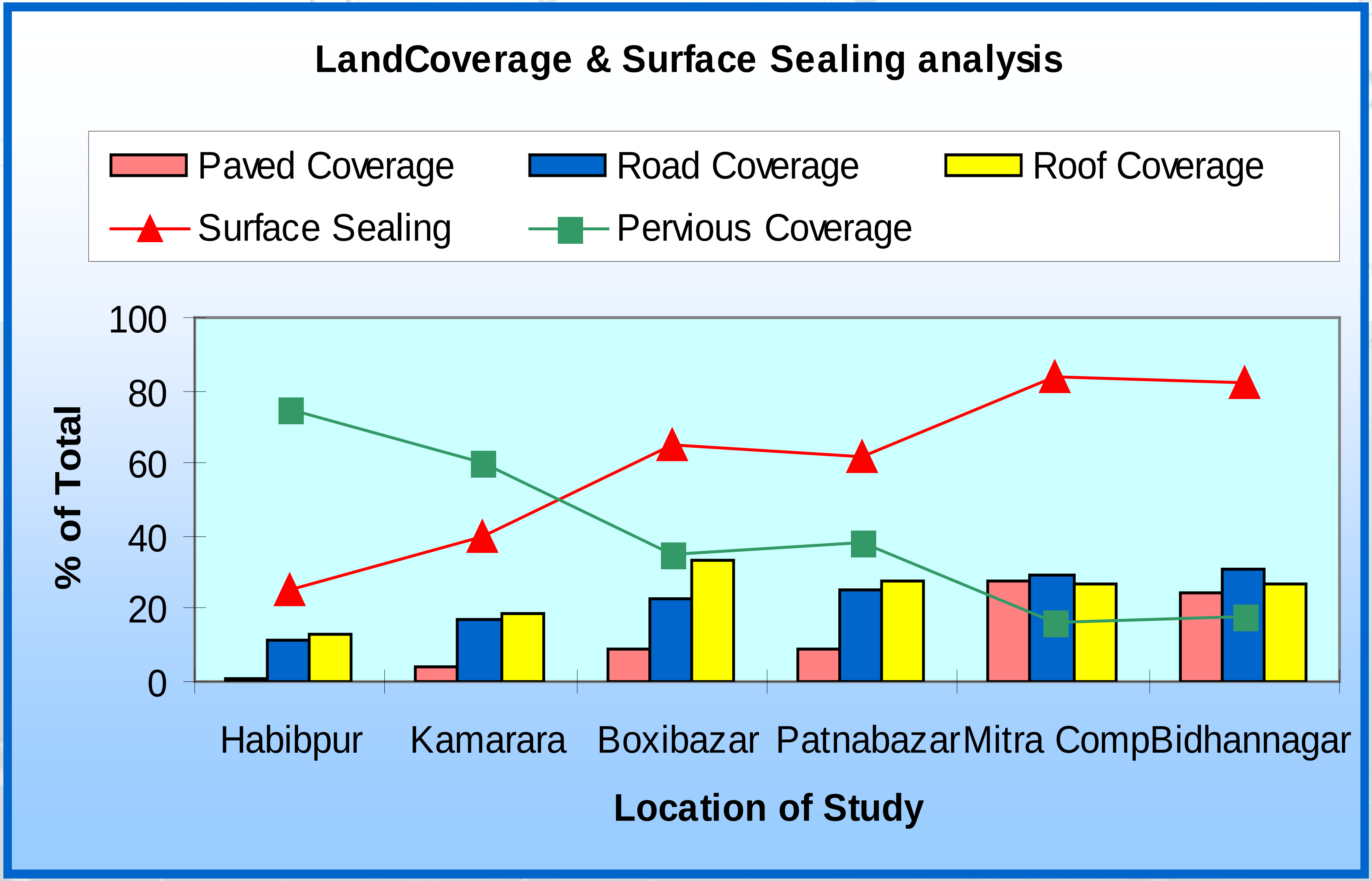
Total No of Plots	:	27
Total No. of Buildings	:	24
Total Area	:	0.56 Ha
Surface Sealing	:	65%
Imp/Per. Ratio	:	1.87
Roof/Per Ratio	:	0.94
Avg. Plot Size	:	160 sq. m.
Avg. Roof Size	:	77 sq. m.
Avg. H.Hold Size	:	7.46

Summary of urban catchments

Cluster Location	Total Plots	Total Bldgs.	Area in Hect	% of Blt.up	Imper/Per Ratio	Roof/Perv Ratio
Habibpur	87	64	4.31	15.57	0.34	0.17
Kamarara	73	57	2.93	27.73	0.67	0.32
Boxibazr.	27	24	0.56	54.84	1.87	0.94
Patnabazr.	77	70	1.83	49.29	1.65	0.72
MitraComp	46	44	1.94	77.08	5.15	1.67
Bidhanagr.	39	37	1.41	74.14	4.59	1.52

Source : primary survey, September, 2003

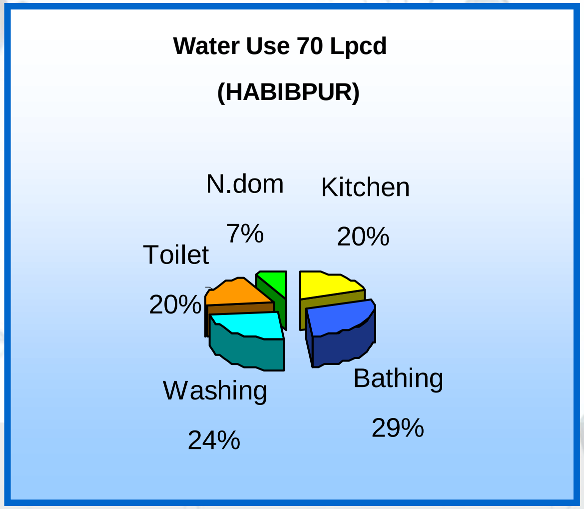
Analysis at Catchment Front

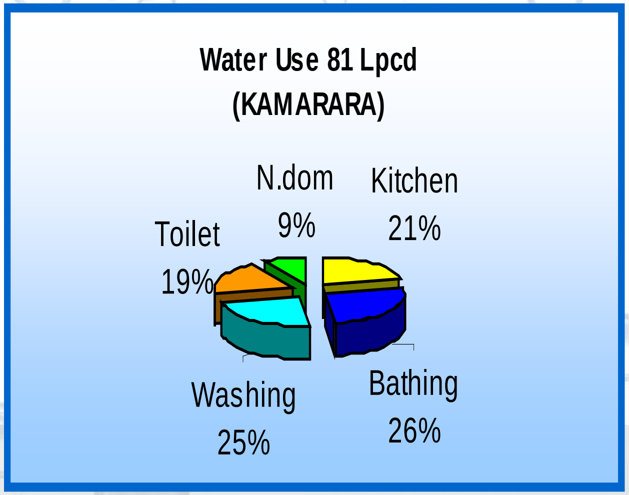


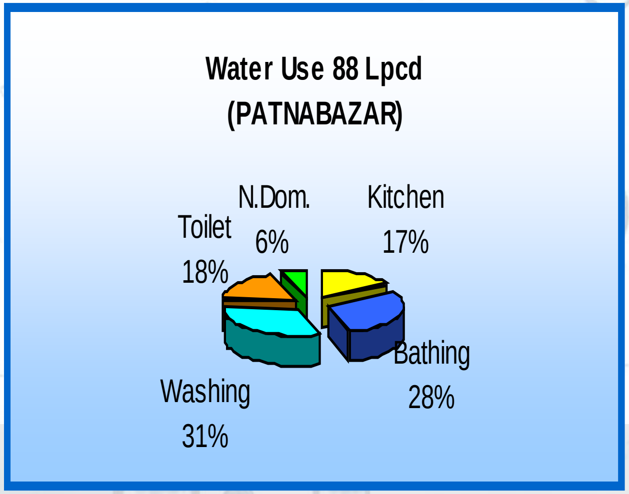
Summary on Water Use pattern

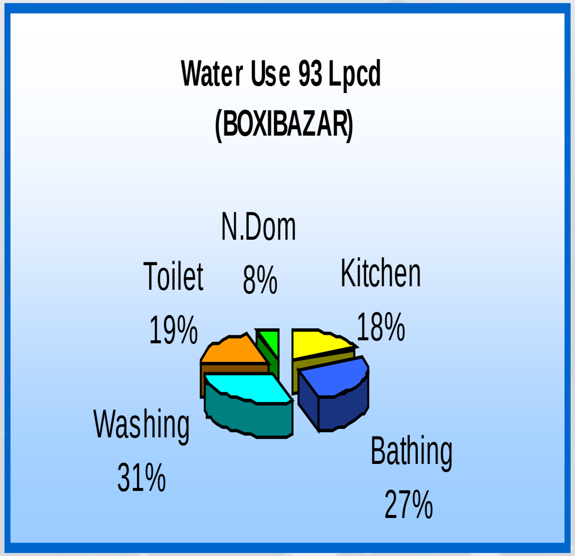
Location of Study	Total Number of Buildings	Number of Household surveyed	Average Household Size	Average Water Use Lit./cap./day	Kitchen and Bathing Use Lit./cap/day	Toilet,Wash And other Lit./cap/day
Habibpur	64	49	4.27	**70**	34	36
Kamarara	57	50	6.02	**81**	39	42
Boxibazar	24	24	7.46	**93**	42	51
Patnabazar	70	70	5.47	**88**	40	48
Mitra Compound	44	44	4.5	**121**	60	61
Bidhan Nagar	37	37	4.5	**112**	54	58

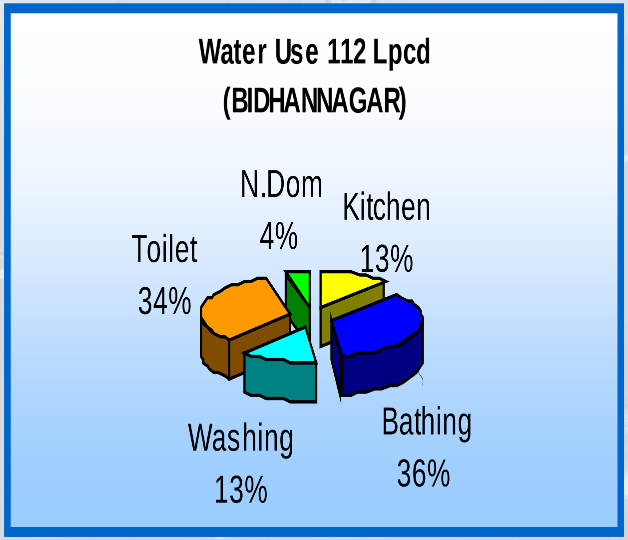
Analysis on the Water Use pattern

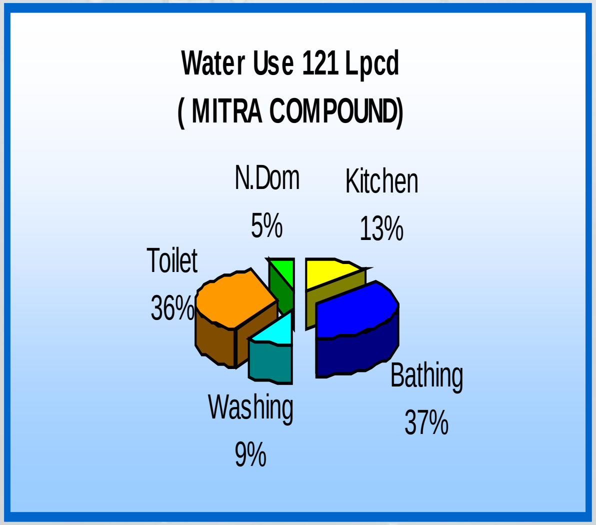




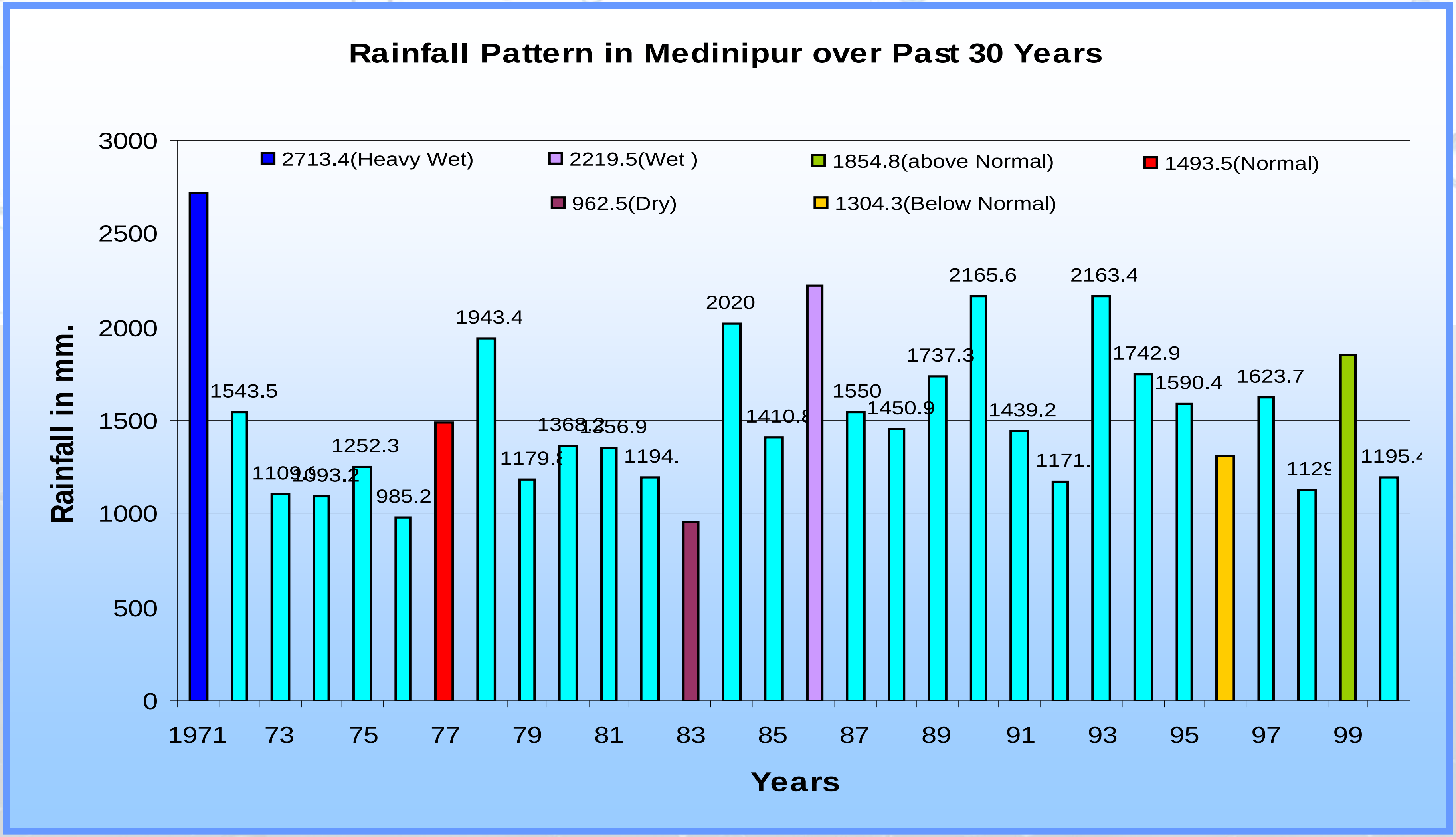








Annual Rainfall variations



Source: Meteorological Register, Soil Service Station , Medinipur, WB.

Classification of Annual Rainfall

Years of Record – 1971-2000, Highest-2713.4 mm.,Lowest-962.5 mm.

Number of Observations-30,

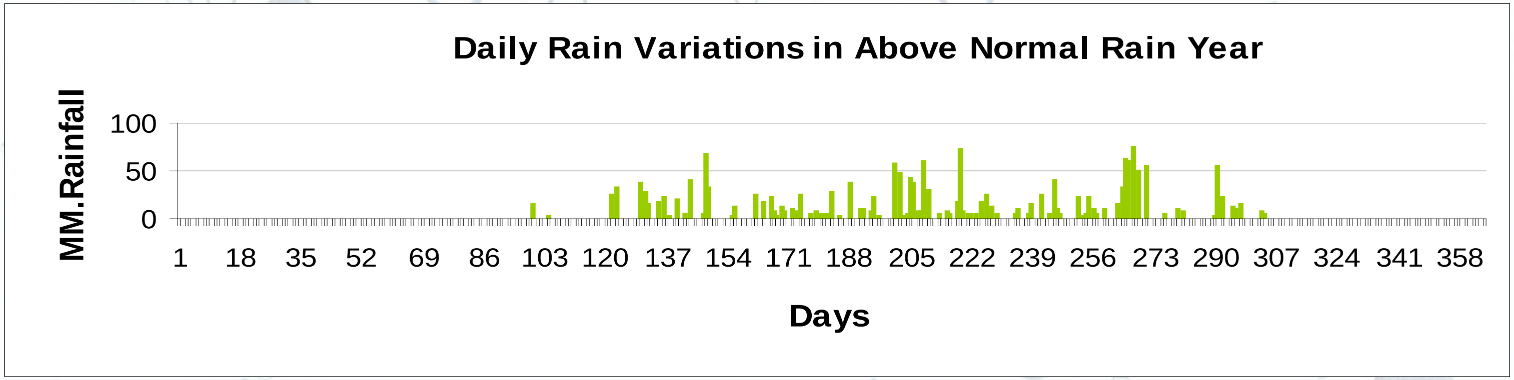
Mean Rainfall-1532mm.,Std.Dev. – 420.83

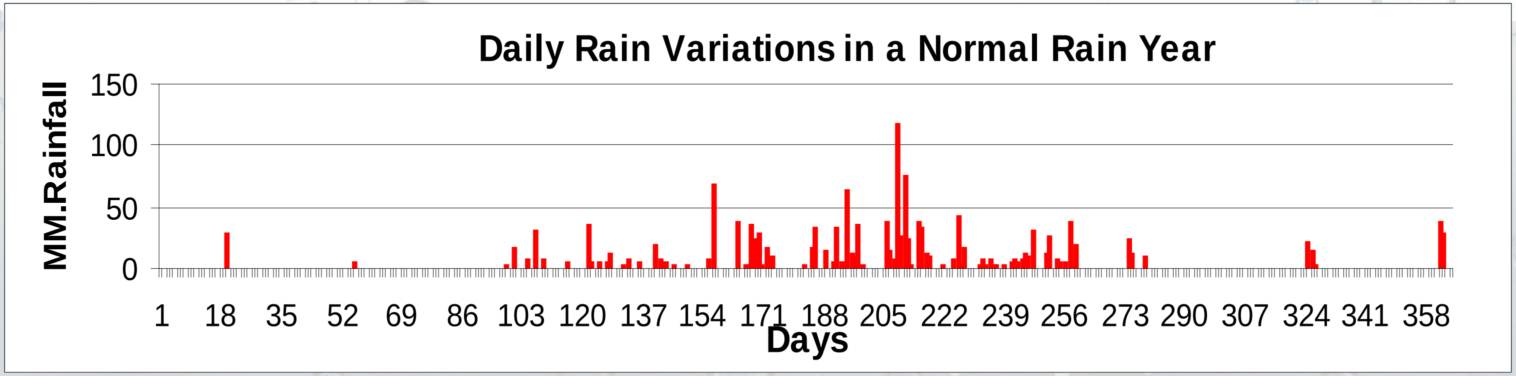
Classific-ation	Dry Year	Below Normal	Normal Year	Above Normal	Wet Year	Very Wet Yr.
Range in mm.	Below 1000	1000 to1500	Near 1500	1500 to 2000	2000 to 2500	2500 above
Selected RainYear	**1983**	**1996**	**1977**	**1999**	**1986**	**1971**
Value in mm.	**962.5**	**1304.3**	**1493.5**	**1854.8**	**2219.5**	**2713.4**

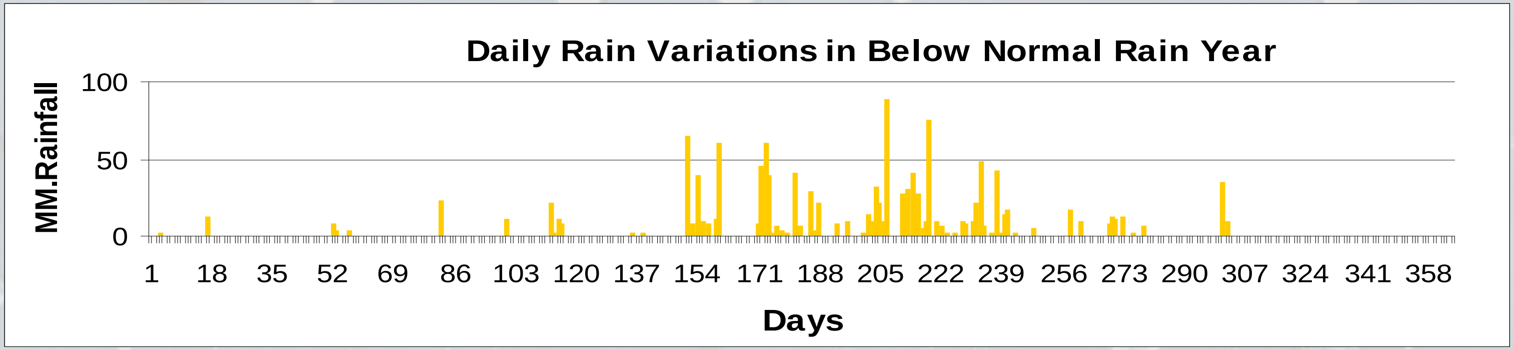
Rainfall Spectrum analysis

Inferred Parameters	Very Wet	Wet Year	Above Normal	**Normal**	Below Normal	Dry Year
Annual Rainfall	2713.4 mm.	2219.5 mm.	1854.8 mm.	**1493.5 mm.**	1304.3 mm.	962.5 mm.
No.of Rainy Days	84	97	95	**77**	65	70
Tier-A 2.5-25 mm.	54 (65%)	53 (54%)	76 (80%)	**55 (72%)**	47 (72%)	61 (87%)
Tier-B 25-55 mm.	15 (18%)	40 (42%)	18 (19%)	**18 (23%)**	13 (20%)	8 (11%)
Tier-C 55-115 mm	11 (13%)	3 (3%)	1 (1%)	**3 (4%)**	5 (8%)	1 (2%)
Tier-D 115 above	4 (4%)	1 (1%)	0 (0%)	**1 (1%)**	0 (0%)	0 (0%)

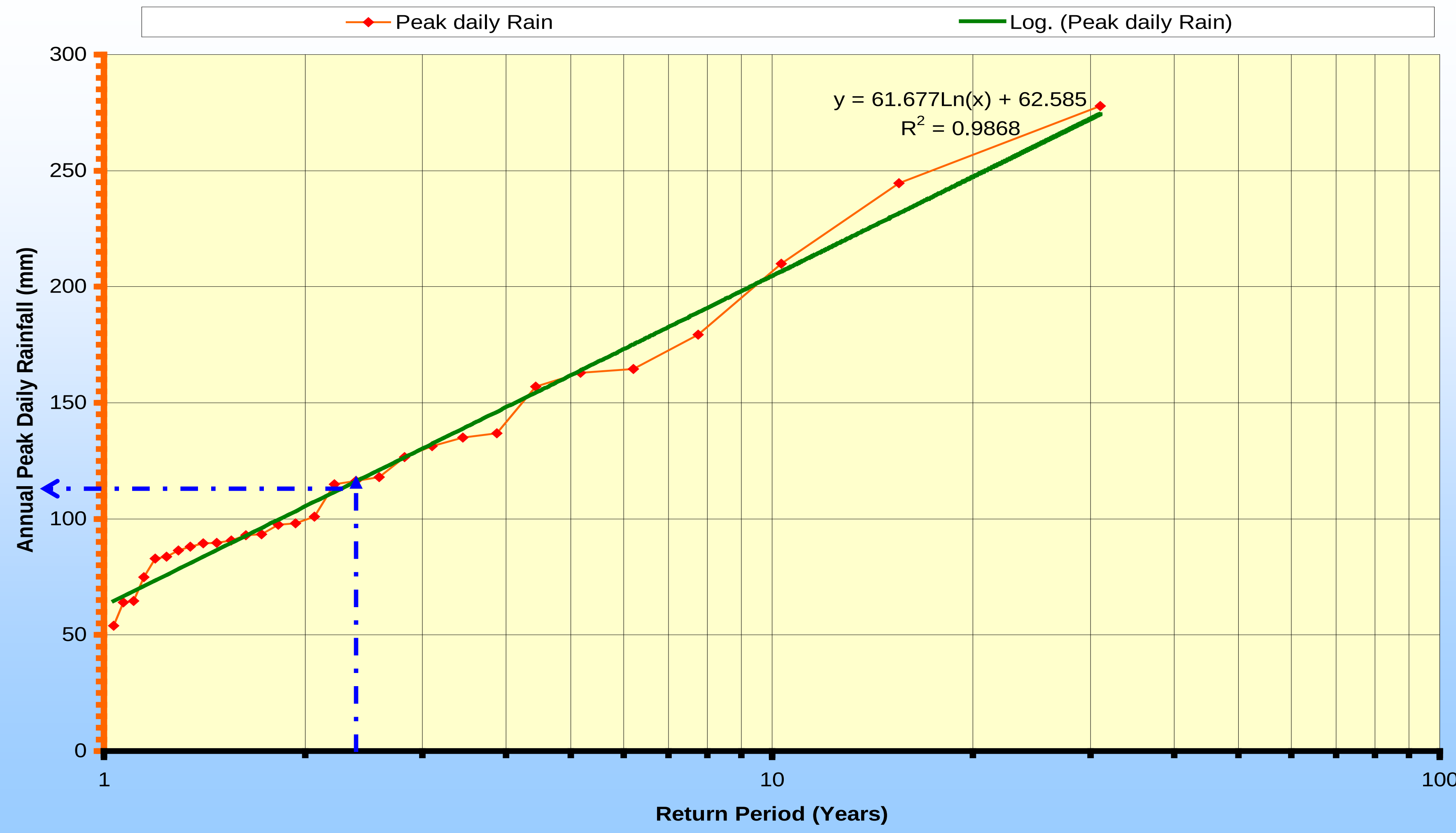
Daily Rainfall Variations







Computing Maxima Daily Rainfall



Key Parameters of runoff management

- Values of Impervious/pervious area ratio (R-1) of the cluster were considered to represent various surface sealing (*applicable for plots having buildings, paving and approach roads)*

- Values of Roof/Pervious area ratio (R-2) of the cluster were considered to represent the built coverage, (*applicable for large plots having only buildings with no approach road or paving)*

Estimating Surface Runoff Volume

SCS Curve number technique (USDA,1972)

$$Q_d = (P - 0.2\,S)^2 / (P + 0.8S) \text{ and } S = 254(100/CN - 1)$$

Where Q_d *= runoff depth in mm.*

P *= daily rainfall in mm.*

S *= Potential maximum retention and initial abstraction consisting of interception, depression storage and infiltration*

- And the value of CN is obtained from TR-20 and TR-55 tables depending on the following properties of the catchment basin

- Land use- here in this case all residential

- Soil Type- Group C for slow infiltration rate (ave.1-5 m./hr.)

- Hydrologic Condition- good, fully developed & water table below 2.5 m.

- Antecedent Moisture Condition- AMC-II due to average soil moisture

SCS Curve no. method generally had a lower % of Std. deviation in errors, Zarriello,1998

Customized Curve Numbers for six study areas in Medinipur

Cover Descrption	Curve Numbers for hydrologic Soil Group			
Average percent Impervious area	(1-f)	CN for Urban Area	CN_p for soil group C	Customised Curve No.
Habibpur (25% or 0.25)	0.75	80	74	**75.5**
Kamarara (40% or 0.40)	0.60	83	74	**77.6**
Boxibazar (65% or 0.65)	0.35	92	74	**85.7**
Patnabazar (62% or 0.62)	0.38	90	74	**83.9**
MitraCompnd (84% or 0.84)	0.16	95	74	**91.6**
Bidhan-nagar(82% or 0.82)	0.18	94	74	**90.4**

Source: (NRCS, Technical Release 55, Urban hydrology of small watersheds, Second Ed. June, 1986)

Annual runoff vs. Annual Rainfall Analysis

For every 20% increase in annual rainfall the average runoff increases by about 30% over its previous value.

Annual Runoff vs. Impervious/Pervious area Ratio analysis

There exists a linear relationship between the annual runoff and the various Impervious/Pervious area ratios measured in all the residential clusters under the study area.

Annual Runoff vs. Roof /Pervious Area Ratio analysis

There exists a linear relationship even between annual runoff and Roof/Pervious Area ratio in all the residential clusters of the study area.

Modelling relationship: Rain, Runoff and Land cover Parameters

Relationship were best fitted using the following form of multivariate linear regression equation **RO= a + b*P + c* R1 + d* R2**

where **RO** = Annual Runoff in mm.

P = Annual Rainfall in mm.

R1 = Impervious/Pervious Area ratio of cluster including roads

R2 = Roof/Pervious area Ratio of the cluster containing plots

And **a, b, c, d** are the constants of linear regression

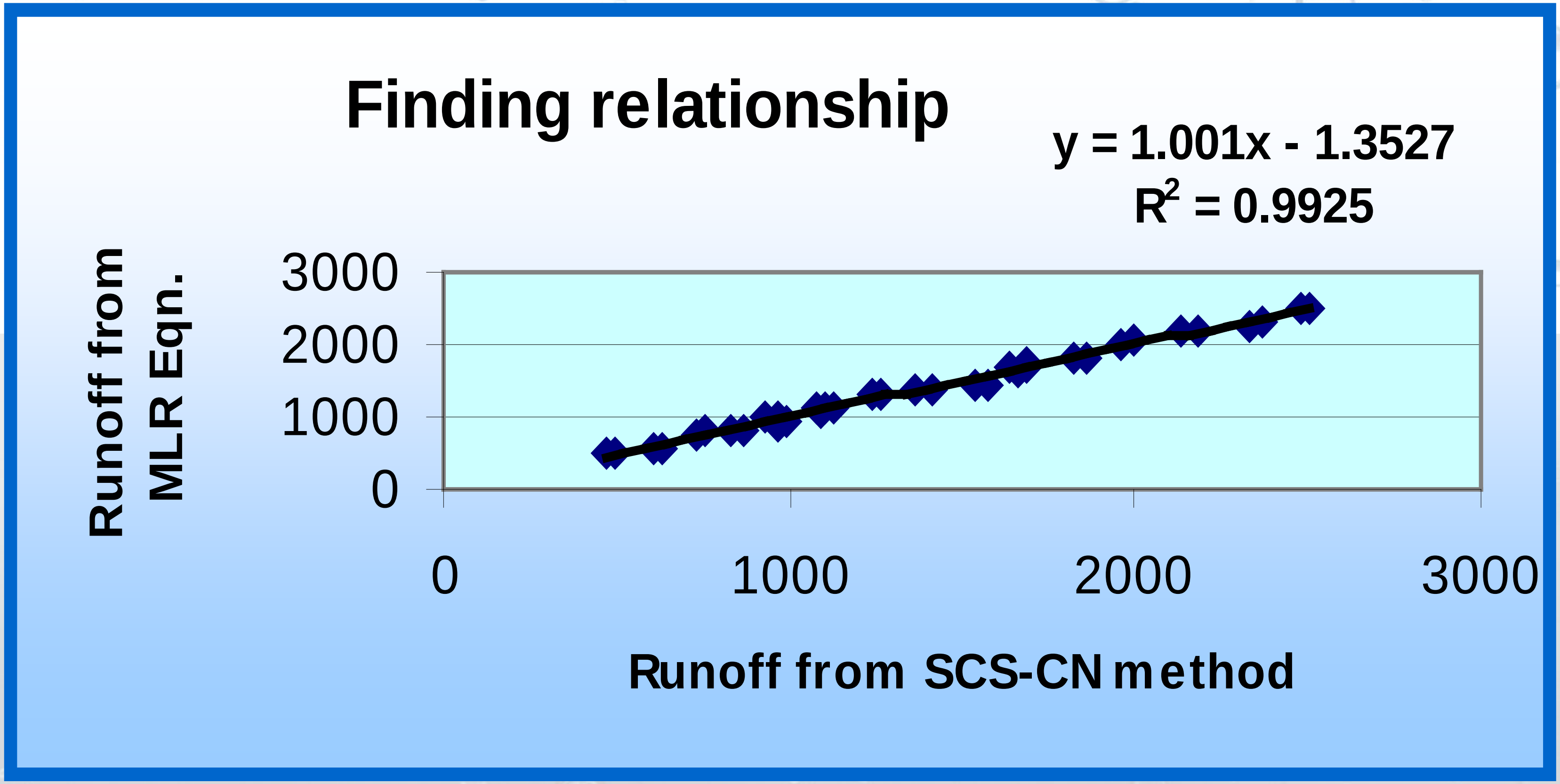
Using the method of curve fitting the above constants were found to be

a = (-) 492.88 , b = 0.97 , c = 70.00, and d = 5.63

Hence the MLR equation could be expressed as

RO = (-) 492.88 + 0.97 * P + 70* R1 + 5.63* R2

Co-relation between SCS eqn. runoff and runoff from MLR equation



MLR equation gave a good fit where R^2 and F values are highly significant

Sensitivity Analysis on Development Options

Alternative developmental scenario for land use distribution and its implication in controlling imperviousness using a C Program

Where RO= 0.5 P, P = 1500 mm., R1 & R2 are varying and Site area=5 hect

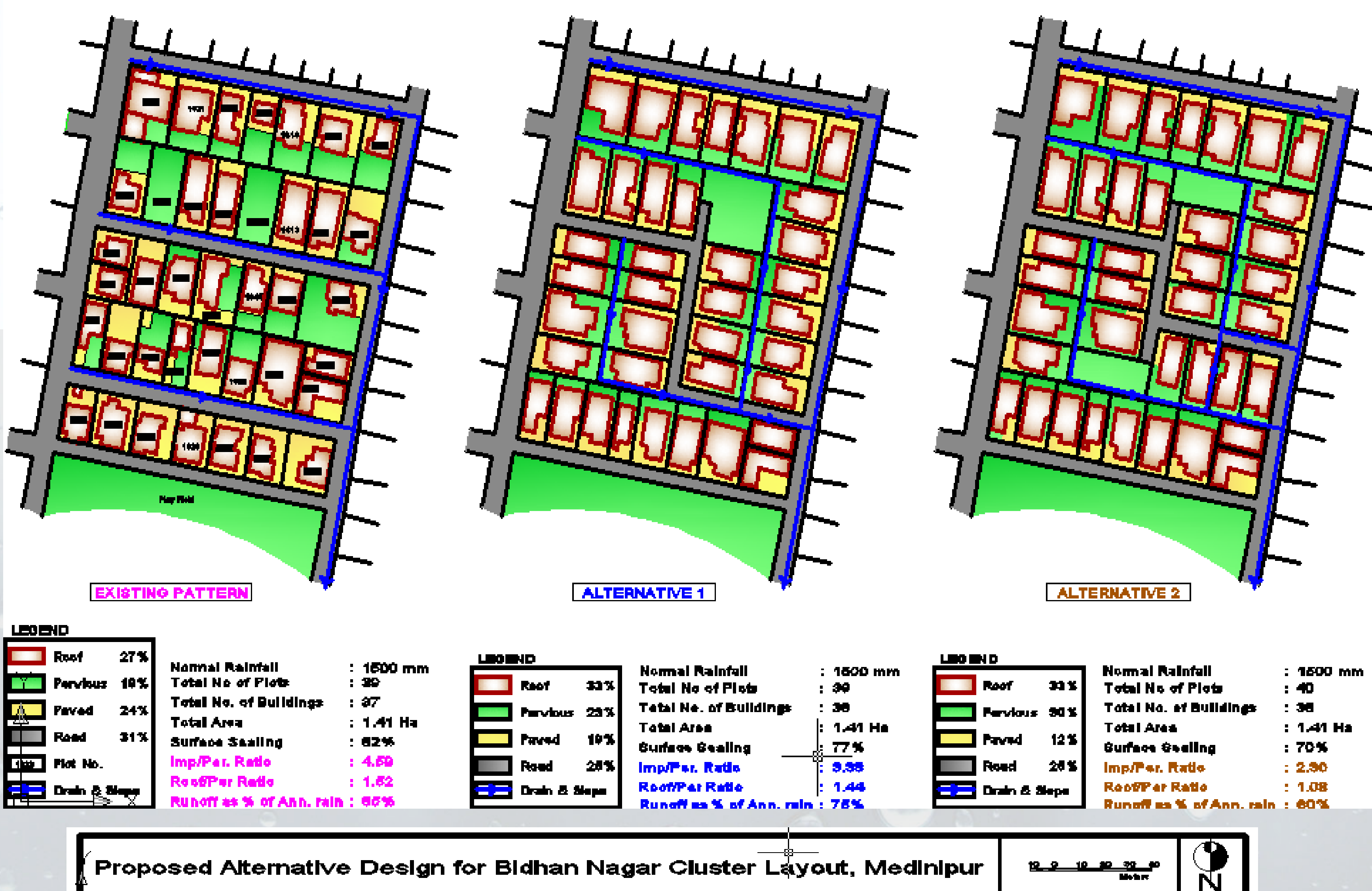
Options for plotted development assuming I.T.P.I Standard

Alternative -1

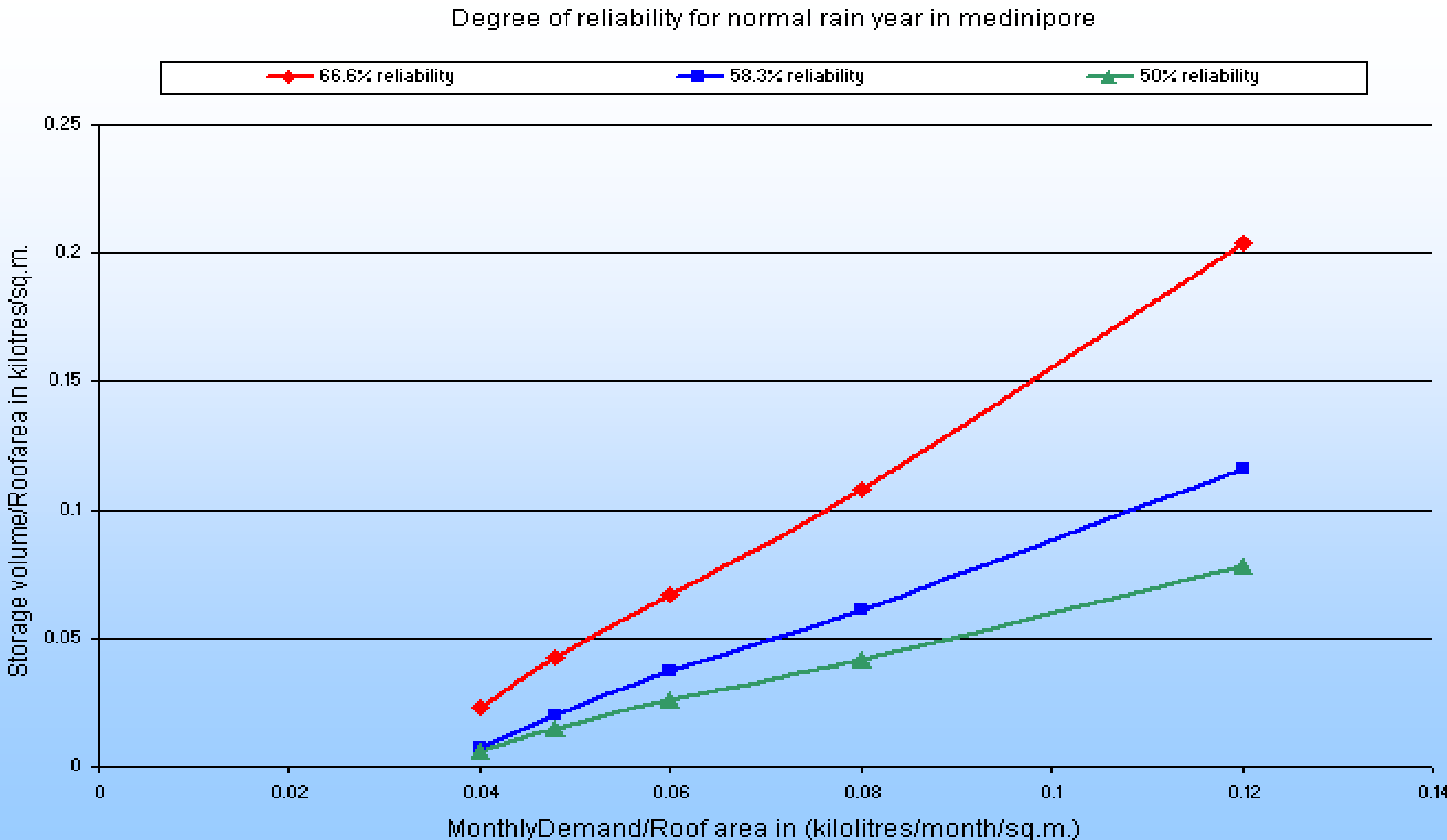
Assumptions as per I.T.P.I source	Gross Site Area Hectares	Roof/ Perv. Area ratio (R2)	Impervious/ Perv. Area ratio (R1)	Net Plot Area percentage	Roof Area percentage	Paved Area percentage	Pervious Area percentage
Road Area as 14% of total area	5.0	2.5	3.35	76	32.5	30.5	13.0
	5.0	3.0	3.39	76	38.4	24.8	12.8
	5.0	3.5	3.43	76	44.0	19.4	12.6
CommonOpenSpace as 10% of total area	5.0	4.0	3.47	76	49.5	14.1	12.4
	5.0	4.5	3.51	76	54.8	9.0	12.2
	5.0	5.0	3.55	76	59.9	4.1	12.0

I.T.P.I – Institute of Town Planners, India

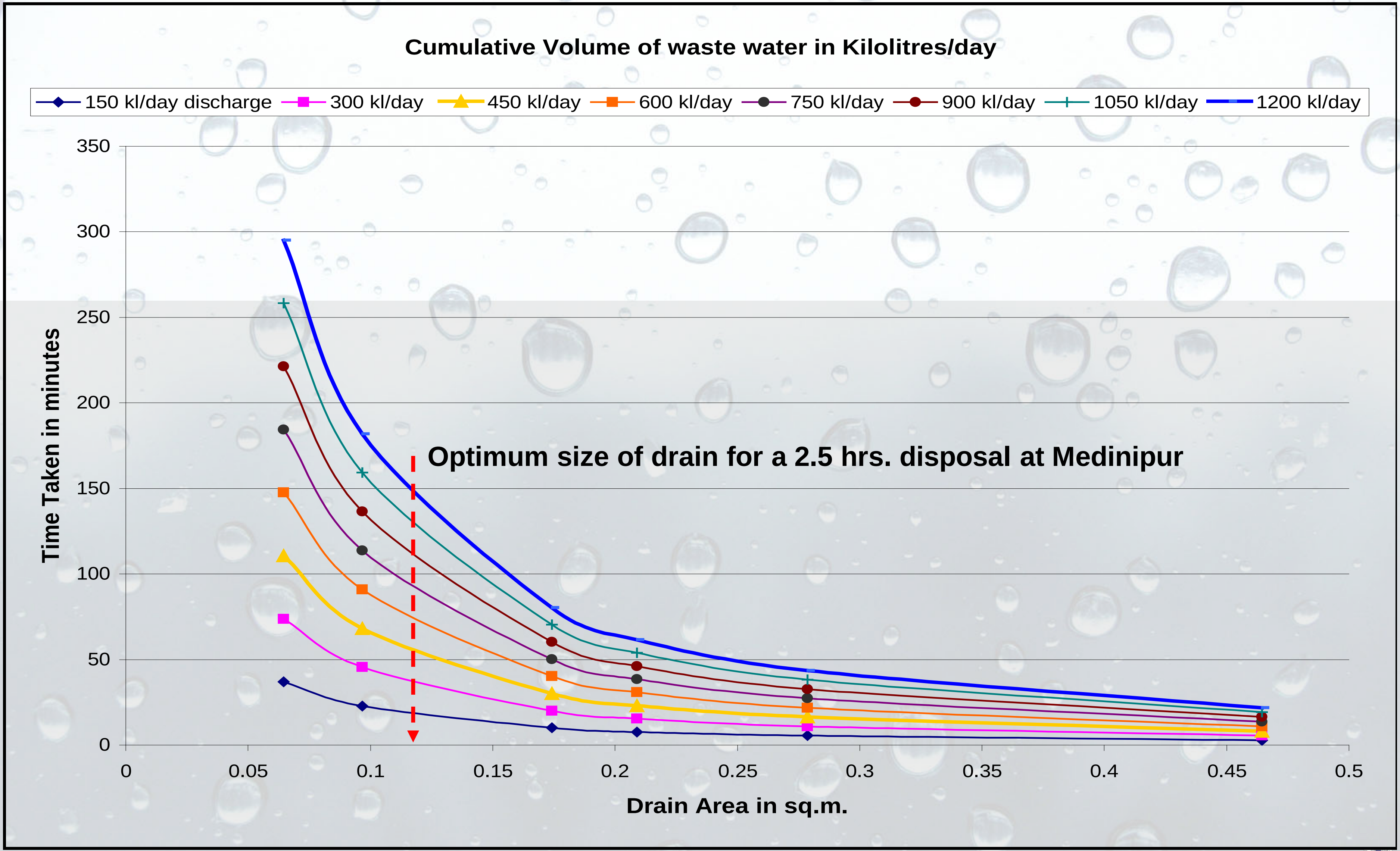
Benefits of Low impact development



Reliability of Rainwater tank for water substitution



Performance of road side drains in Medinipur



Principal Recommendations

- Builders, Architects, Planners and Engineers should adopt suitable measures for impervious control so as to minimize storm runoff and maximize re-use of rainwater in Medinipur and its vicinity for **developing any land of 5 hectares** or below for residential plotting.

- The State Governments should suitably modify the existing building byelaws incorporating all water sensitive measures mandatory for all public establishments and properties such as schools, colleges, hospitals, offices, terminal buildings having a **roof area of about 1000 m^2 or more** in all urban areas of West Bengal.

- **Rainwater collected from roofs and stored in tanks** is found to be an excellent water source for all non-consumptive domestic uses especially during the dry periods in Medinipur area with an average annual rainfall of 1500 mm.

Principal Recommendations

- All **plots in the range of 150-300 m^2 should have at least 15 % of total land devoted under open pervious coverage** with absorbent landscaping with a **maximum of 55% of roof coverage** to achieve a Roof/Pervious ratio of 3.5 for capturing the entire tier-A events of rainfall in Medinipur town.

- All new building plans with a roof area of 50-100 m^2 or more **must provide for a minimum 4.5- 6.0 kilolitres of rainwater storage tank in their premises** in Medinipur Municipal town and its vicinity. This stored water could be used for all emergency **purposes such as gardening, car washing, fire fighting etc.**

- **Introduce a system of development incentives** either in terms of increased Floor Area Ratio (F.A.R) or a **rebate on property tax** for implementing rainwater harvesting system in a permanent manner. This encourages vertical expansion over horizontal expansion.

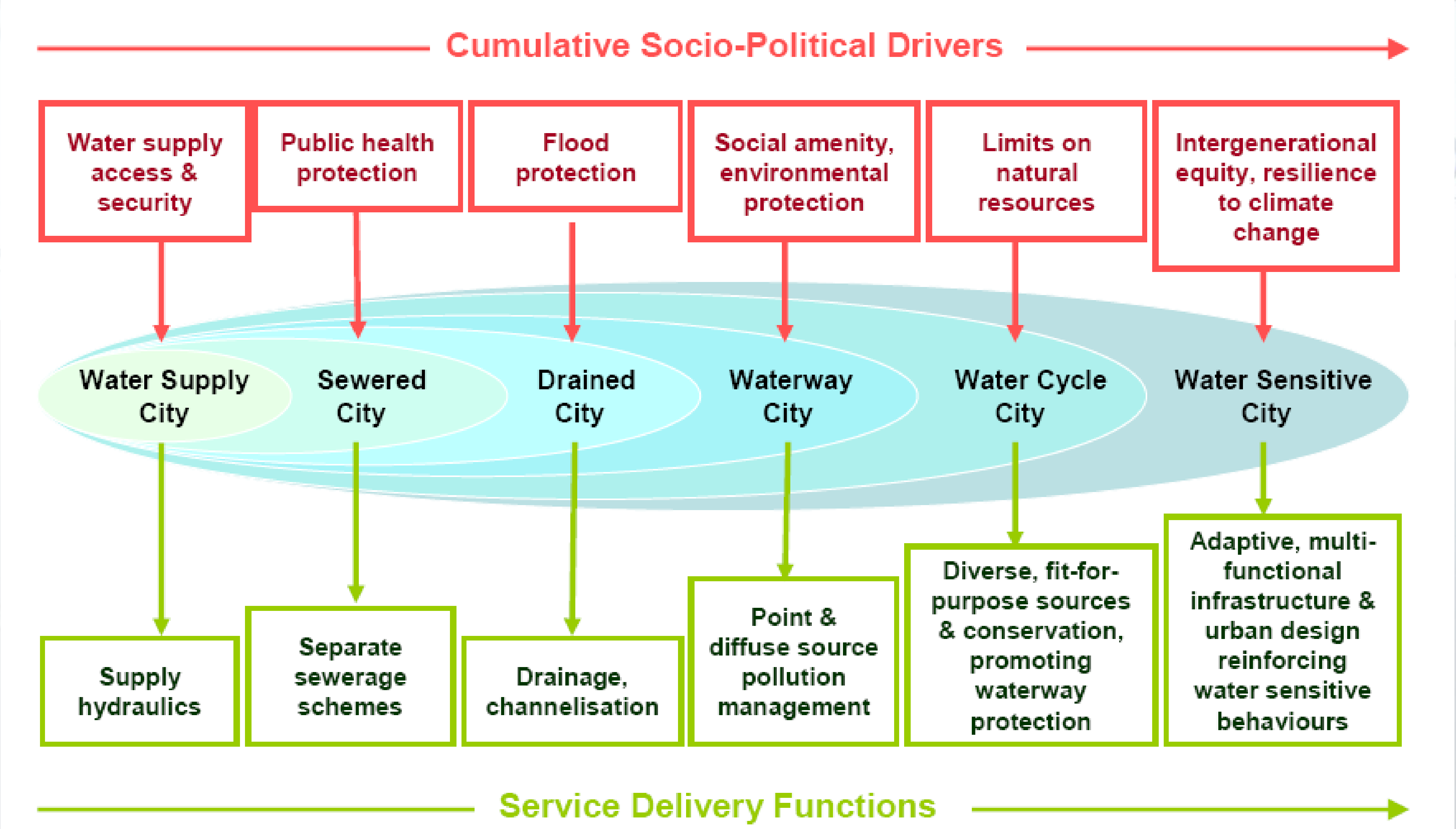
Principal Recommendations

- **All types of paving or impervious surfaces should be controlled right at the planning stage in the site level** through a number of water sensitive design practices such as:-
a) reducing road coverage; b) limiting the amount of surface parking ; c) introducing porous pavements; d) reducing parking standards etc;

- **Planning for flood control**, to discharge the peak runoff during sudden cloudburst, should consider various combinations of drain sizes and finishes for variety of plotted development by using **software program to be developed by the local bodies.**

- A separate **"WATER SENSITIVE UNIT" has to be formed** consisting of representatives drawn from various cross sections of society, as the case may be, **within all local bodies**. This unit should be vested with the control and regulation of all water bodies, including rivers, canals, ponds/tanks and groundwater in urban areas.

Urban Water Management Transitions framework



Source: Wong and Brown,11th International Conference on Urban Drainage, Edinburgh, Scotland, UK, 2008

Major Emerging issues

1. Should WSUD measures be specified that are appropriate at the house, neighbourhood, and sub-catchment levels?

2. Is a ‘ star rating’ system be appropriate for assessing such development ?

3. What is the best way to provide scenarios for implementing WSUD at different levels?

4. What mechanisms are required to ensure effective installation and maintenance?

5. Is it possible to link the model planning provisions with financial incentives?

Future Scope of Research

- Reuse potential of urban storm water.
- Design strategies for sullage and waste water network specially to avoid contamination.
- Urban drainage system under sustainable city concept.
- Decision support system for rain water management.
- Economic and environmental benefits of source control strategies in urban water cycle management.

Rating of Catchments

No.	Criteria's for consideration	SET -A	SET-B	SET -C
1	Peak Daily Rainfall	< 80 mm.	80-120mm.	> 120 mm.
2	Ground Water Table	< 6.0 m.	6.0 – 9.0 m.	> 9.0 m.
3	Average Slope of Terrain	<1:100	1:100-200	>1:400
4	Soil Condn. (hydrology grp.)	A	B	C
5	Water Consumption pattern	<100 lpcd	100-250	>250 lpcd
6	Density of Dwelling Unit	<80 du/ac.	80-125	>125du/ac.
7	Ground Coverage	45%	55%	65%
8	Impervious/ Pervious ratio	2.5	3.0	3.0
9	Roof/ Pervious ratio	1.5	2.2	2.5
10	Ave. Size of Drain	<0.15 sq.m.	0.15 – 0.2	>0.25 sq.m.

Water Sensitive Planners Motto

- ***"Catch Water, Where-ever It Falls"***
- ***"Control Imperviousness,"------ Where-ever You Can"***

THANK YOU