Water Management to Water Sensitive Planning- A contemporary approach for sustainable urban development

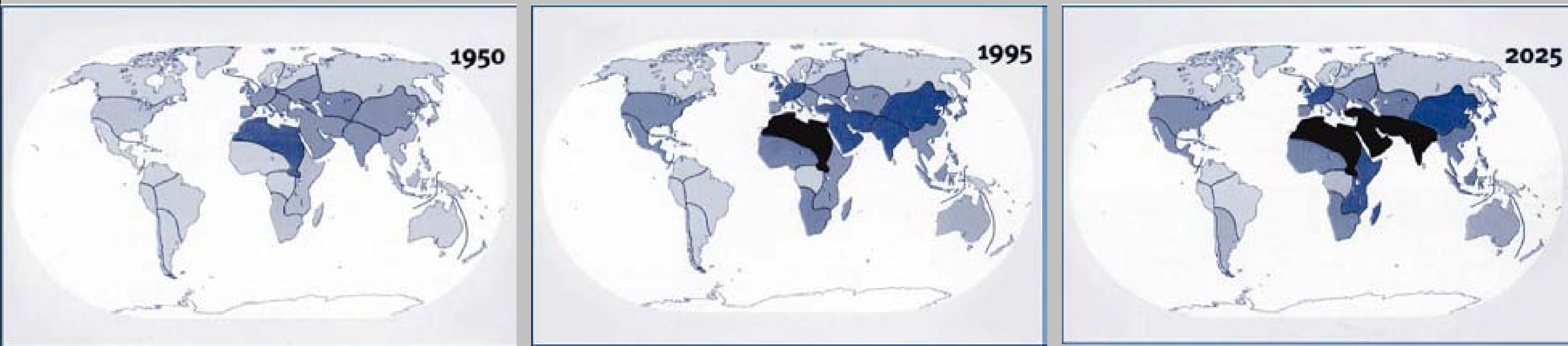
Dr. Somnath Sen, Architect Planner

Associate Professor,

Architecture & Planning,

IIT Kharagpur, INDIA

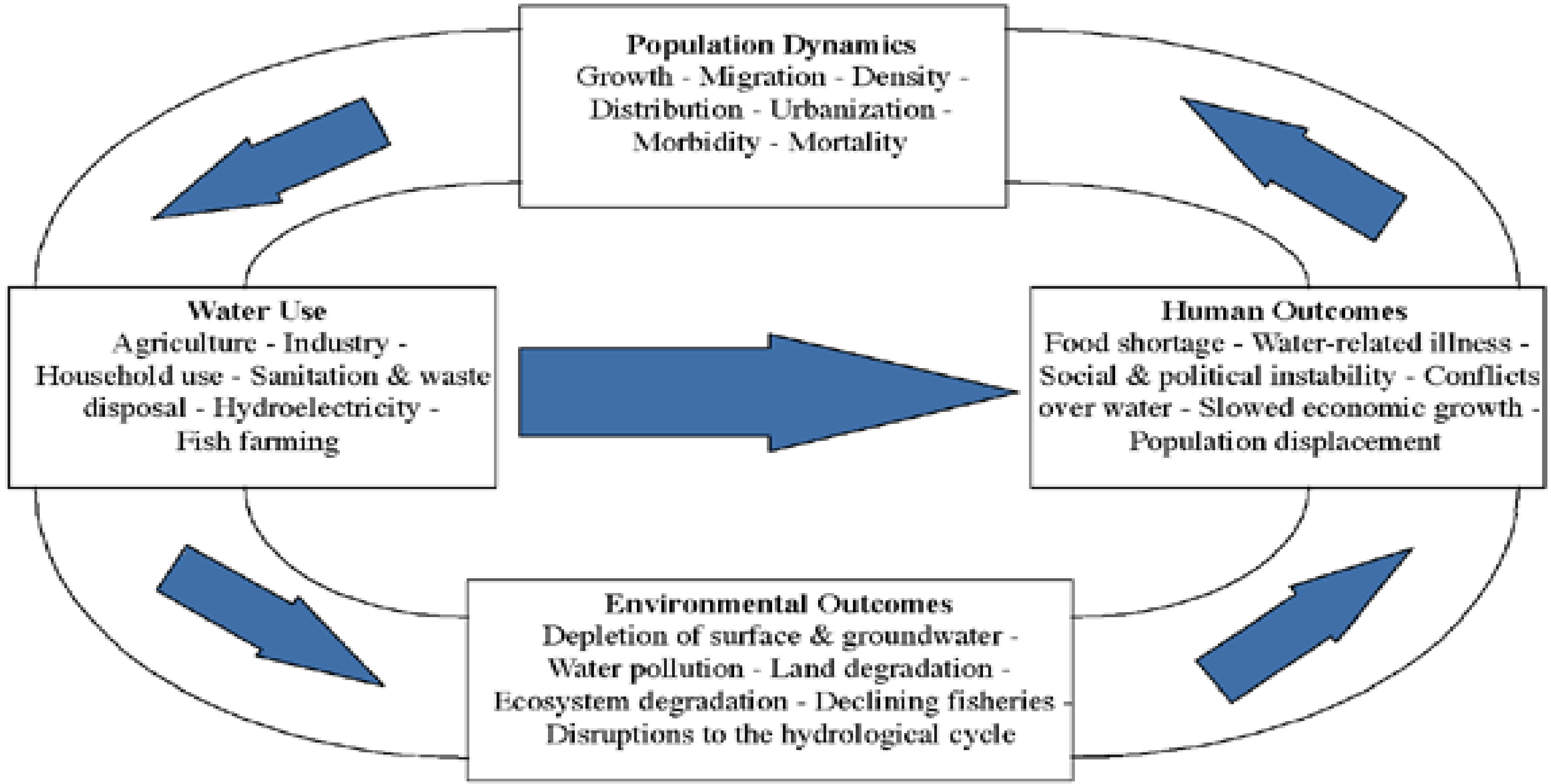
Global Water Availability



In 2020, 60% of the world population will be urban, a concentration that makes urban water infrastructure development an extremely urgent issue.

Source: UN World Water Development Report

Link between Population and Fresh Water



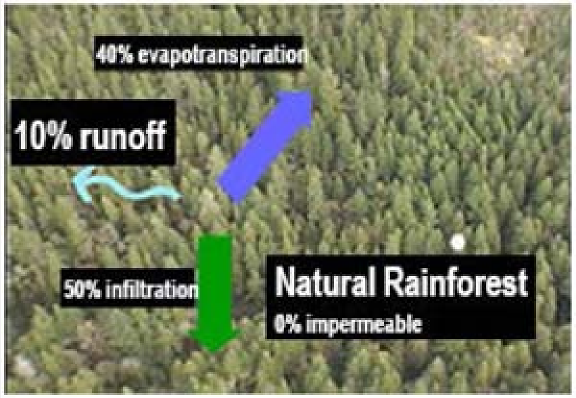
Source: IUCN et al. 1996 (199)

Changes to Natural water balances

Runoff volume increases in proportion to **impervious area** (hard, non-absorbent surfaces).

Land uses with extensive roof and paving areas create more runoff than land uses with extensive areas of absorbent soils and forest cover

Traditional ditch and pipe systems have been designed to remove runoff from impervious surfaces as quickly as possible and deliver it to receiving waters.



Natural Rainforest

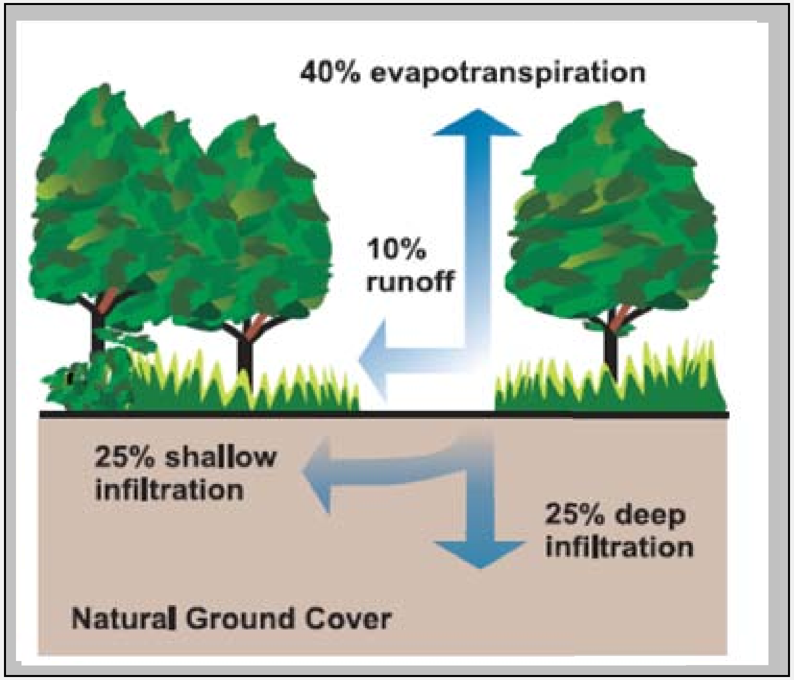
Single Family Development

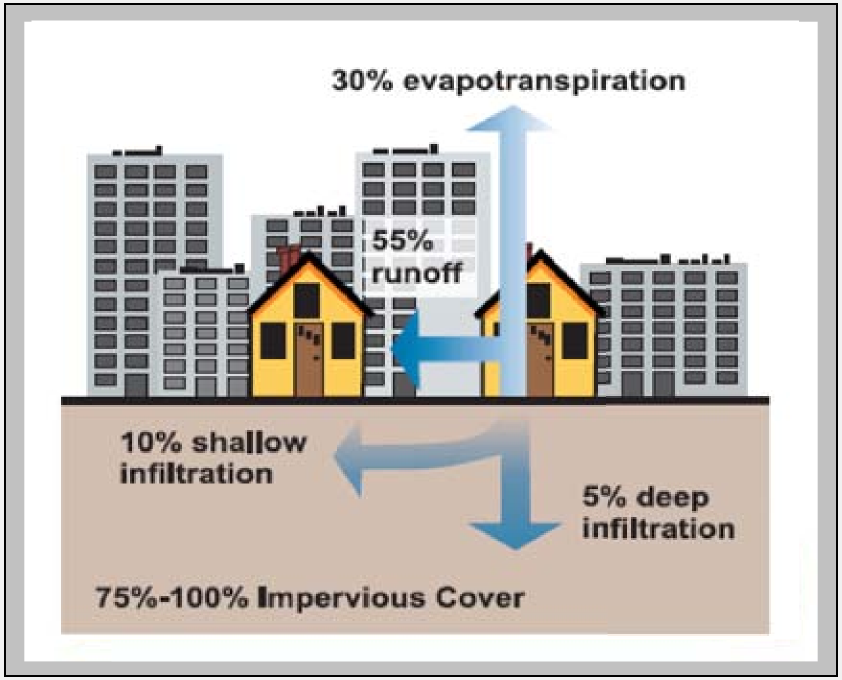

Flooding in the Urban Environment

Commercial Development

Effect of urbanization on storm runoff

Urbanization increases surface storm water runoff and modifies its quality.





- Population density
- Building density

- Modification of the land surface
- Impervious surfaces

Impervious surfaces and urbanization affect runoff characteristics in the metro Atlanta, Georgia area.

- **Hydrological Front**

  Drop in Ground water levels and loss in water quality.
- **Ecological Front**

  Erosion of land, loss of aquatic resources and vegetation.
- **Physical Front**

  Flooding, loss of property, loss of open space.
- **Climatology Front**

  Increased temperature, increased rainfall, decreased wind speed.
- **Socio-economic Front**

  Loss of health, loss of man-days and loss of employment.

THREATS OF URBAN SPRAWL

Urban development will not be halted for water considerations. Hence, there is an urgent need to manage urban development with minimal damage to groundwater resources.

Traditional water management techniques:

19th 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.**

WHAT HAS NOT BEEN RESEARCHED SO FAR ?

- 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.

- 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 water demand in local areas.

- What could be the appropriate technique for an effective flood control management in urban catchment under emergency situation.

Concept

Water sensitive urban design- WSUD

Urban design involves multi-disciplinary inputs including town planning, landscape architecture, building design, ecology and infrastructure engineering. WSUD has no scale constraints and is equally applicable from individual houses to whole catchments,

What is water sensitive urban design?

WSUD aims **to minimize the impact of urbanization on the natural water cycle** and its principles can be applied to the design of a single building or to a whole subdivision.

Why implement WSUD?

•Trying to more closely **match the pre-development storm water runoff regime** – both quantity and quality

•**Optimizing the use of rainwater** that falls on our urban areas

•**Reducing the amount of water we transport between catchments**, both in water supply import and wastewater export.

CURRENT RESEARCHES AROUND THE WORLD

In Australia –

Australia has adopted **Water sensitive urban design** (WSUD) in a holistic manner and is to establish a National Water Initiative that, among other aspects, will encourage water conservation in the cities including better use of storm water and recycled water.

In Israel –

Water sensitive urban planning is gradually being introduced into some localities in Israel in light of the results of research studies pointing to the loss of as much as 70 million cubic meters of water due to surface runoff in urban areas.

In U.S.A –

Water Sensitive Urban Design (WSUD) (also known as **Low Impact Development, LID in the USA)** recognizes the need to incorporate all aspects of water into urban development and planning from the earliest stages.

Planning and feasibility

Water-sensitive urban design concepts and technologies, if planned and implemented correctly, offer an opportunity for not only elements of the water cycle complementing the development, but the **development to complement the water cycle.**

In order to achieve the **best possible results of implementation**, the pre-planning and design phase must:

• identify the **land use capabilities and existing conditions** or constraints of the site
• consider the **intended design and function of the proposed development**
• identify the **likely impacts of the development on the existing environment**

• match these factors with the most appropriate water-sensitive urban design technologies designed **to achieve a sustainable balance between development and environment.**

Water-sensitive urban design techniques

- **Grassed or vegetated swales** – primary treatment and conveyance function; can provide secondary treatment benefits

- **Filtration trenches** – primary treatment and conveyance and detention options; can provide secondary treatment benefits

- **Bio-retention systems** – secondary treatment, conveyance, detention and retention functions (through infiltration); can provide tertiary treatment benefits

- **Wetlands** – tertiary treatment system, storage, detention, possible reuse options
- **Rainwater tanks** – using storm water as a resource – detention, retention, a substitute for drinking water in garden irrigation, car washing, toilet flushing, etc

- **Grey water reuse** – collect from households, primary treatment on site, reuse for external irrigation or internal toilet flushing options

- **Rain gardens, rooftop greening, urban forests** – provide natural vegetated features of aesthetic value and provide treatment function by filtering storm water

- **Porous pavements**
- Any combination of these and other techniques for the best possible outcome.

Indian Institute of Management, Kozhikode (IIM-K)

Area: 96 acres campus
Population :400 residents
Rainfall:
The average **daily water consumption** exceeds one lakh litres.The campus is dependant **entirely on stored rain water.**
Capital cost: 80 lakh rupees

Topography :It occupies 2steep hillocks. The topography is such that some portion of the runoff goes from the back of 2 hillocks, but a major portion of run-off gets down to the front Side. At the foot of the hillock, there is a huge pond of 1.5 acres dug only to catch rain water. It is fed by the slopes on which the buildings stand.

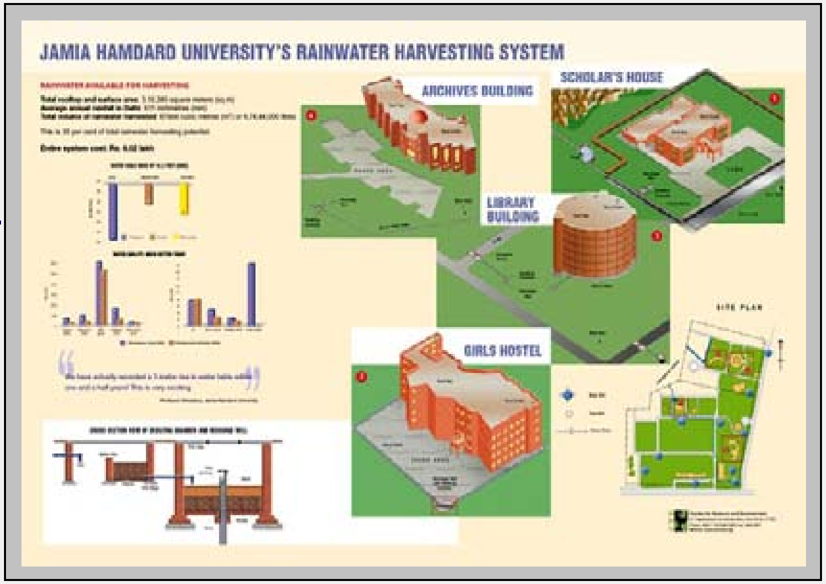
Water from the main pond is treated and pumped to an overhead tank at the hilltop using a massive pumpset. From here, it is distributed to the necessary domestic use, including drinking, at the institution and staff quarters.

The large pond that stores rainwater for the campus.(30 million litres capacity)

It is a model for other educational institutions and corporate houses

JAMIA HAMDARD UNIVERSITY, DELHI

Total rooftop and surface area: 3,15,380 sq. m
Average annual rainfall in Delhi : 611mm
Total volume of rainwater harvested: 67444 cu. m.
35 per cent of total rainwater harvesting potential



WATER SUPPLY SOURCE

The daily water requirement :6 lakh litres, extracted from 6 borewells.
The remaining requirement is met through private water tankers.

RAINWATER HARVESTING SYSTEM

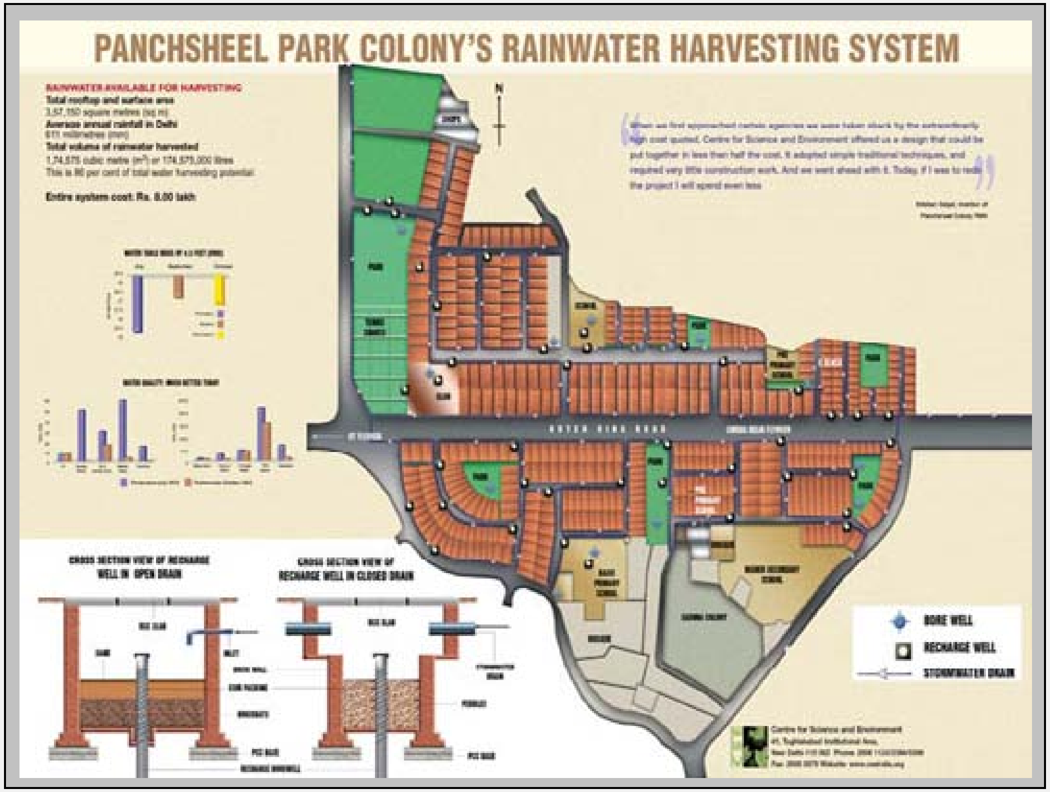
Rainwater from various catchments, such as rooftop, surface runoff from open areas and runoff from the Jahanpanah Reserve Forest are harvested. Rooftop rainwater harvesting at the library and hostel buildings **desilting chamber ->filtering chamber-> recharge well.**

SURFACE RUNOFF HARVESTING near library building and Jahanpanah Reserve Forest
Trenches or ponds->stormwater drain->desilting chamber->recharge wells

Total cost of implementation - Rs. 6.52 lakhs.
Impact -There was significant improvement in water table and quality of water. Within one year there was a rise in 3m.

PANCHSHEEL PARK COLONY, DELHI

Total rooftop and surface area
3,57,150 (sq m)
Average annual rainfall in Delhi
611 (mm)
Total volume of rainwater harvested: 1,74,575 cu.m
80 per cent of the total water harvesting potential.



WATER SUPPLY SOURCE

The water supply is mainly through six borewells.

Recharge wells measuring 1m x 1m x 2m are constructed in the stormwater drain for facilitating groundwater recharge. The quality of runoff, which passes through a 15m borewell installed inside the recharge well, is ensured through a filter bed of pebbles

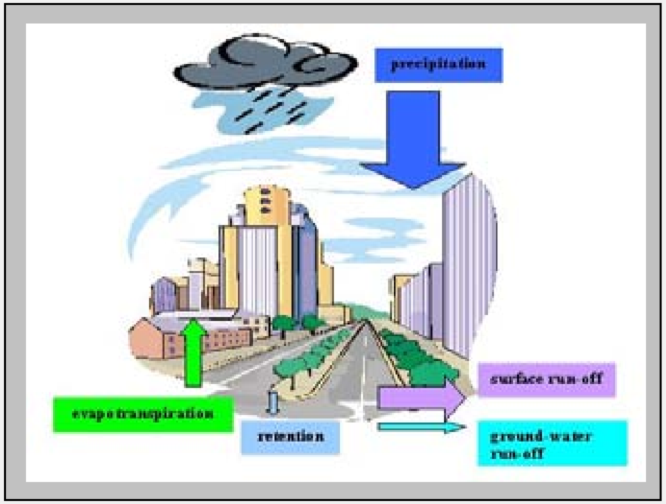
DR. SOMNATH SEN, ASSOCIATE PROFESSOR, DEPARTMENT OF ARCHITECTURE AND REGIONAL PLANNING, IIT KHARAGPUR

RUNOFF TOOLS

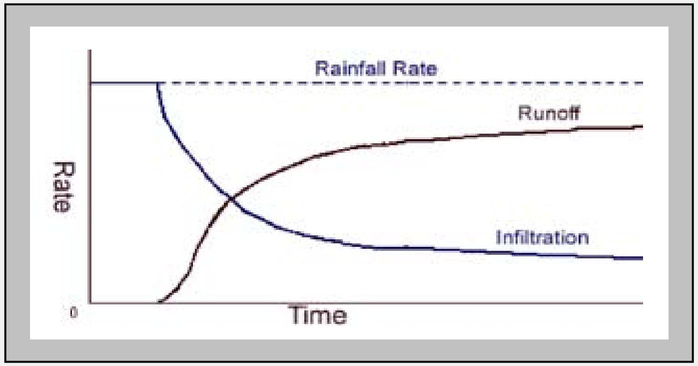
RAINFALL – RUNOFF = INFILTRATION

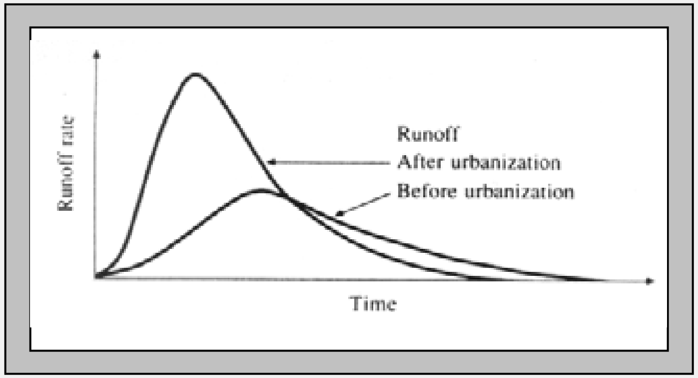
FACTORS AFFECTING RUNOFF:

Size, shape, topography, soils, surface culture, Runoff Hydrology, surface runoff process



Effect of urbanization on storm runoff





Water Sensitive Planning Guidelines for the City of Chennai

INDIA

Prof. Somnath Sen and P. Divya

Architecture & Planning, IIT Kharagpur,INDIA

2008

Urban water scenario – India

• India with 16% of the world's population has only 4% of the fresh water resources.
• Per capita availability of fresh water in India has dropped from 5,177 cubic meters in 1951 to 1,820 cubic meters in 2001.
• ***By 2020, about 50 per cent of India's population will be living in cities.***
This is going to put further pressure on the already strained centralized water supply systems of urban areas.

Per capita consumption in Indian cities

*According to a World Bank study, of the 27 Asian cities with populations of over 1,000,000, **Chennai and Delhi are ranked as the worst performing metropolitan cities in terms of hours of water availability per day**, while Mumbai is ranked as second worst performer and Calcutta fourth worst.*

WATER CONSUMPTION IN INDIAN CITIES

Town	Consumption litres per capita per day
Bangalore	140
Mumbai	260
Delhi	270
Chennai city	**90**
Pune	220

Study Area – Chennai

Demography

CITY area : 174 sq.km.
CMA area : 1178sq.km.

POPULATION
City- 43.43 lakhs
CMA- 75.22 lakhs
(census 2001)

Growth of Population in CMA, 1971-2001

Sl. No.		Population (in lakhs)				Annual Rate of growth (in percent)			Area	Density per
		1971	1981	1991	2001	1971-81	1981-91	1991-01	in Sq.km.	Hect.in 2001
1	Chennai City	26.42	32.85	38.43	**43.44**	2.2	1.58	1.23	176	**247**
2	Municipalities	4.84	8.14	11.84	**15.81**	5.24	3.8	2.91	240	**66**
3	Town Panchayats	1.11	1.64	2.71	**3.86**	4.43	4.94	3.62	156	**25**
4	Panchayat Unions	2.67	3.38	5.2	**7.31**	2.4	4.38	3.58	617	**12**
5	**CMA Total**	**35.04**	**46.01**	**58.18**	**70.41**	**2.76**	**2.37**	**1.93**	**1189**	**59**

NEED FOR THE STUDY

•Chennai, is the only metropolitan city **without a perennial source** of drinking water, is now in the grip of acute water scarcity.

•The **rapid growth of the Chennai city's population** and the development activities over the years has adversely affected the ground water regime.

•Even though Chennai gets an average rainfall of 1260 mm, the residents of Chennai allow the **rainwater to flow through the city roads** and join the Bay of Bengal. Thus the infiltration rate is very less.

•The emergence of the availability, quality, and sustainability of drinking water in Chennai is a serious concern for policy makers.

•Therefore there is a **need for sensitive planning of water** for effective management of this vital and scarce resource.

AIM:

To determine the feasibility of minimizing the adverse effects of urbanization on hydrological parameters through appropriate water sensitive planning, by integrating water supply, storm water and waste water management.

OBJECTIVES:

- To study and analyze the relationship between runoff, rainfall and imperviousness over different spaces.
- To explore the possibility of rain water harvesting in reducing the potable water demand in selected areas.
- To identify various technologies for minimizing the adverse effects of urban development on ground water quantity.

SCOPE:

- The principal scope of the study is to derive developmental guidelines so as to have little impact on urban hydrology.
- The scope of the study extends to only certain areas within the Chennai city.

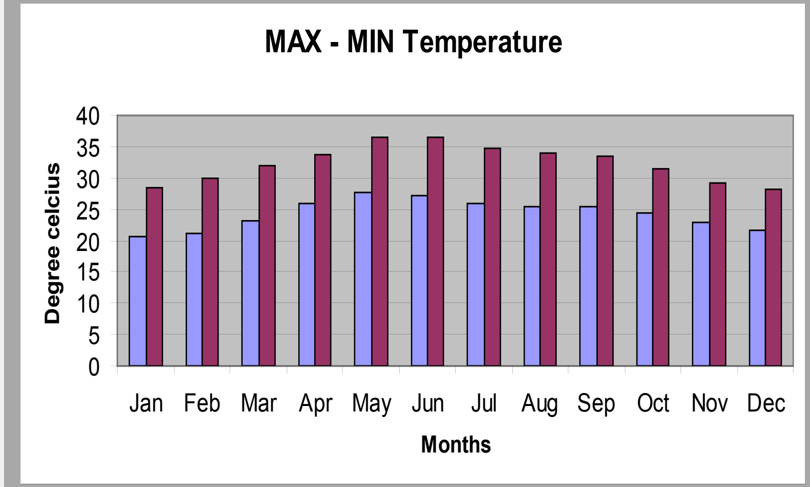
LIMITATIONS:

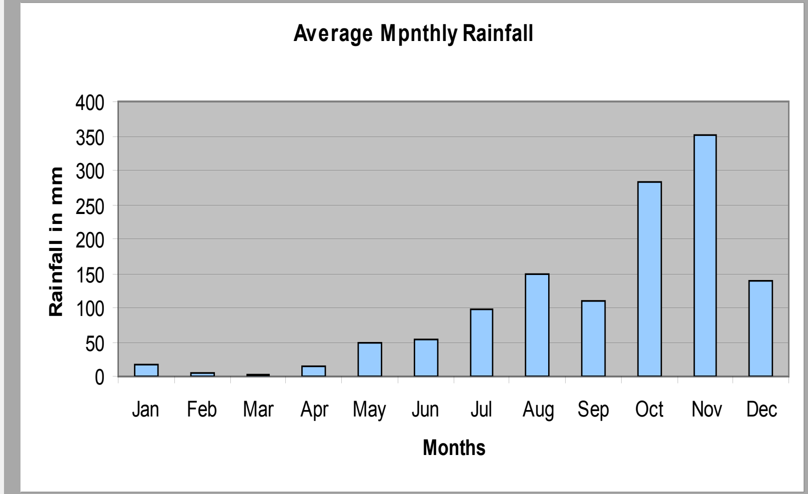
- The study would rely on the availability of primary and secondary data
- The work will be carried out in only selected wards of Chennai city area.
- The study will not attempt any detail design on water supply distribution system

CLIMATE

- Chennai **lies on the thermal equator** and is also coastal, which **prevents extreme variation** in seasonal temperature. For most of the year, the **weather is hot and humid.**

- The **average annual rainfall is about 1,260mm** (51 inches). The city gets most of its seasonal rainfall from the **north-east monsoon** winds, from mid-September to mid-December

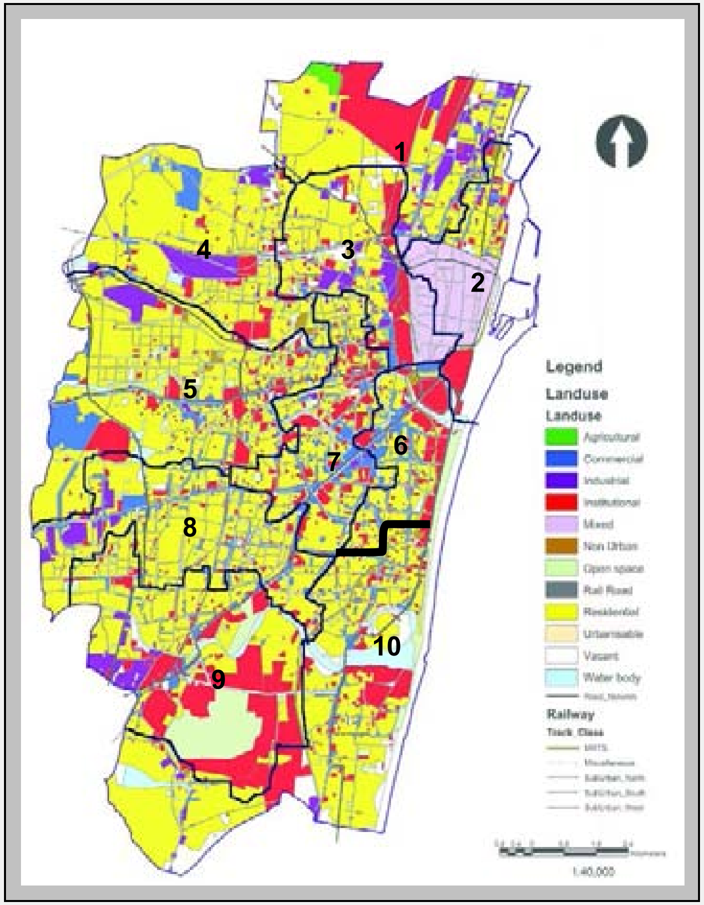




MAX -38–42 °C **MIN - 19–20 °C**

Avg. annual Rainfall = 1260 mm

Land use Map of Chennai City

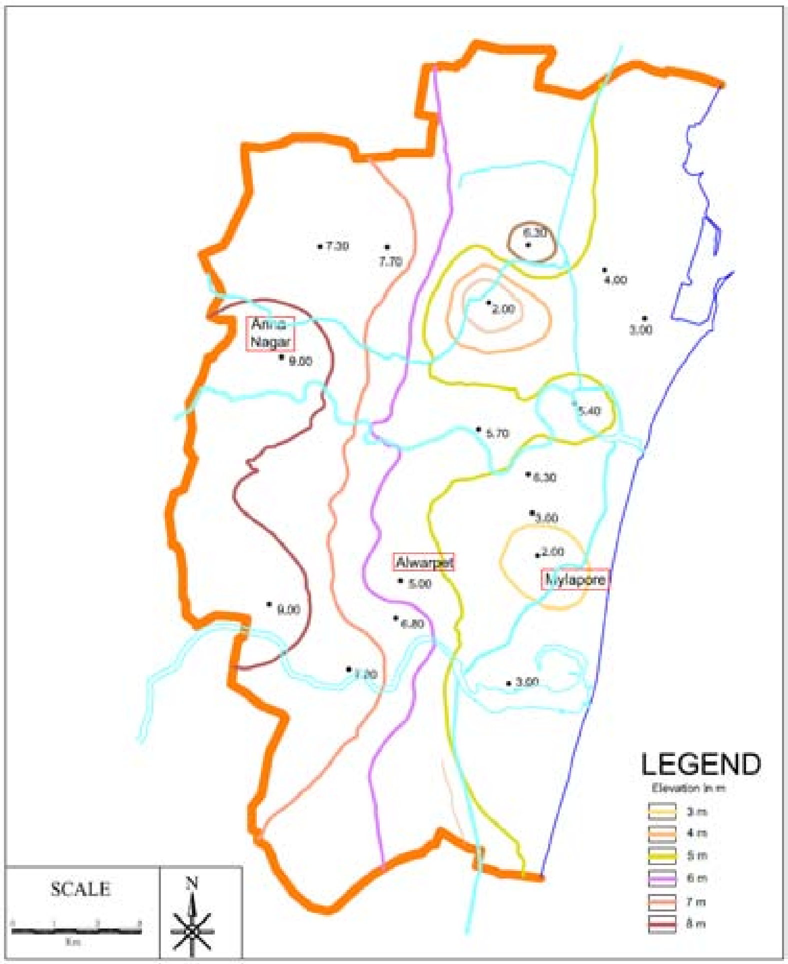


Source: CMDA, Chennai

Land Use	1991	2001
	%	%
Residential	48.57	52.94
Commercial	5.85	7.05
Industrial	6.66	5.07
Institutional	16.51	18.11
Open space and Recreational	14.55	2.07
Agricultural/Vacant	2.86	2.56
Non Urban		12.2

In Chennai City, residential use is predominant covering 52.94 % of the total area. The percentage of **open spaces and recreational areas has sharply declined from 14.55% in 1991 to nearly 2.07%** in 2001, which represents the threatening eco-system.

PHYSIOGRAPHY



Source: SGWSWB, Chennai

CITY CONTOUR MAP

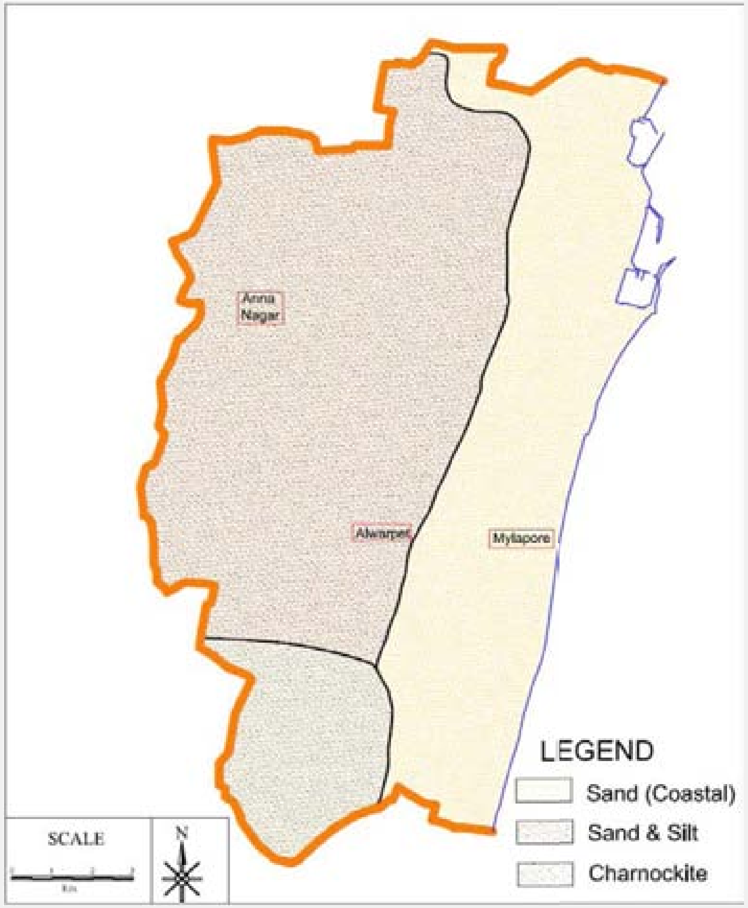
Major part of the city is having flat topography with very gentle slope towards east.

The altitudes of land surface vary from 10m above **msl in the west to about 2m in the east.**

The Action Area Classification

Anna Nagar – 9m
Alwarpet – 5m
Mylapore- 3m

GEOLOGY



Source: SGWSWB, Chennai

Soil conditions :

City has been divided into three soil groups.

- Sandy soil
- Sand and Silt
- Charnockite

The Action Area Classification

Anna Nagar – Sand and silt
Alwarpet –Sand and silt
Mylapore – Sandy soil

SOURCES OF WATER SUPPLY

Sources

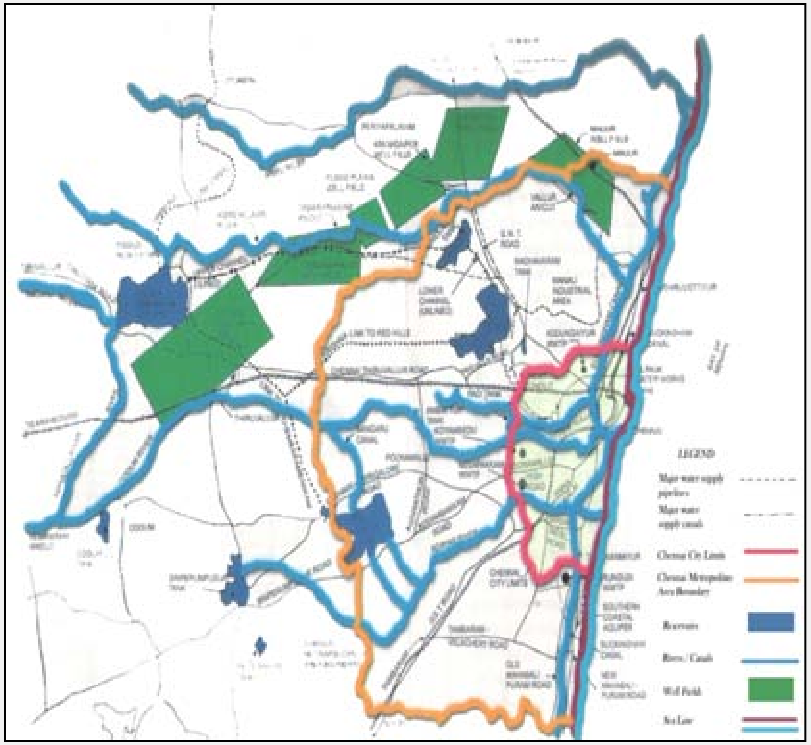
- **Surface water**
  - Poondi, Redhills, Cholavaram and Chembarambakkam , Porur Lake
- **Sub surface water**
  - Ground water from well fields, coastal aquifer and tube wells at individual premises.
- **Transported water**
  - Veeranam Lake(in Cudalore District of TN) Krishna River (in Andhra Pradesh)
  - Ground Water from various locations transported through tankers

Supply Levels

•The average water supply in Chennai city is **90 lpcd.**

•The current water supply from all the sources is of the order of **550 MLD.**

•However, during the summer season, in times of reduced storage, the supply levels would be as low as **300 MLD**



Source: Metro water, Chennai

DR. SOMNATH SEN, ASSOCIATE PROFESSOR, DEPARTMENT OF ARCHITECTURE AND REGIONAL PLANNING, IIT KHARAGPUR

Sources & Safe Yield

Sl. No.	Name of Source	Safe Yield
		in MLD
1	Poondi-Cholavaram – Red Hills Lake system (including diversion	445
	of flood flow from Araniar to Kosasthalaiyar;iyar	
2	Ground Water from Northern Well Field	100
3	Southern Coastal Aquifer	5
	Total	**550**

Major Source Augmentation Projects

Sl. No.	Name of the Scheme	Cost (Rs. Crores)	Quantity
			MLD
1	Chennai Water Supply Augmentation	720	180
	Project-I (Veeranam Lake as source)		
2	Chennai Water Supply Augmentation	124	20
	Project-II (Proposed)		
3	Sea Water Desalination Plant		100
	Total		300

Ground Water Scenario:

•Over exploitation of GW resources due to **increase in population, industries and less availability of surface water .**
•Water quality aspects due to poor industrial and municipal waste disposals, and salinity due to seawater intrusion.
•**Seawater intrusion** into coastal aquifer due to over exploitation of GW near coastal region

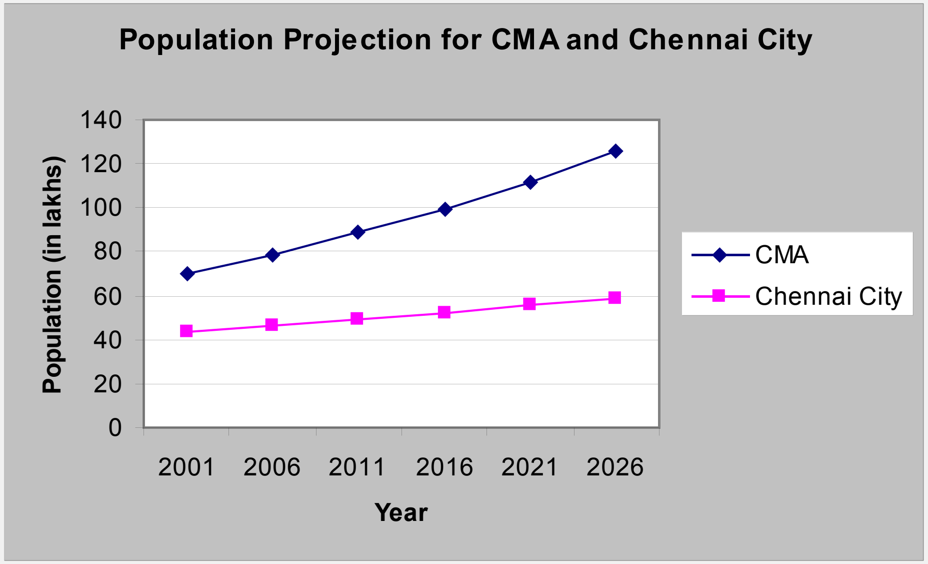
Why Chennai is Over Exploiting GW ?

Total Demand : 911.00 MLD
Total Supply : 550.00 MLD (surface water)
So nearly **50% of the demand is met through private wells and bore wells**, i.e. through Groundwater.

As a result of this unplanned large scale extraction of GW, the **water table in the city is depleting at an alarming rate and also causing serious quality problems**.

Population Projection :

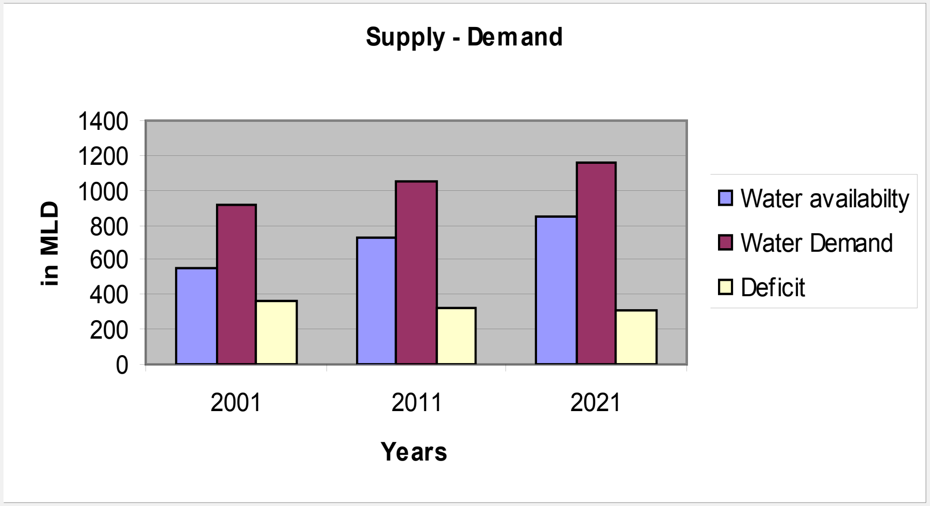
Sl. No.	Description	Actual	Projection (in lakhs)	Projection (in lakhs)
		2001	2011	2021
1	CMA	70.41	88.71	111.97
2	Chennai City	43.43	49.5	55.4



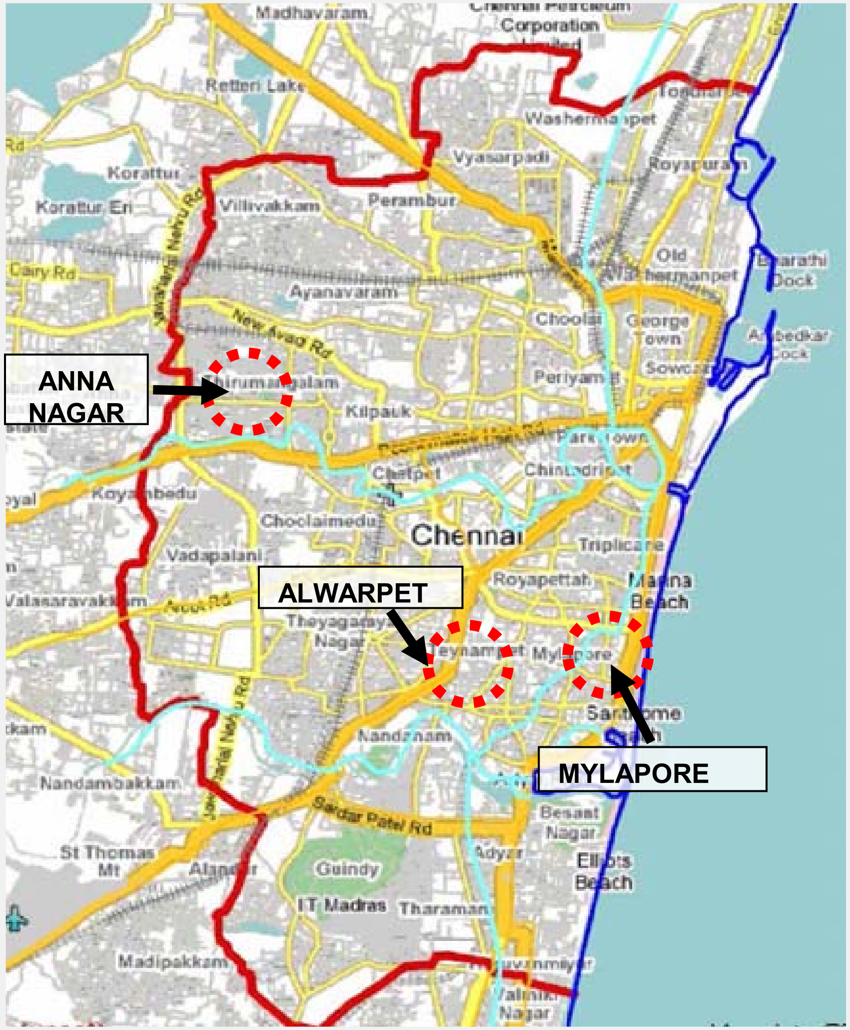
Source: CMDA, Chennai

Supply Demand analysis

Year	Population	Water availability	Water Demand	Deficit
	in lakhs	in MLD	in MLD	in MLD
2001	43.4	550	911	361
2011	49.5	730	1049	319
2021	55.4	850	1163	313



The projections indicate that the overall water demand for the city of Chennai for the year 2021 is of the order of 1163 MLD as against the full potential of the existing and presently ongoing source works totaling to 850 MLD, thus leaving a deficit of 313 MLD.



SELECTION OF PILOT AREAS FOR DETAILED STUDY

The selection of the pilot areas were based on the following criteria:

- Predominant land use/ land cover characteristic
- Plot size and coverage
- Ground water levels

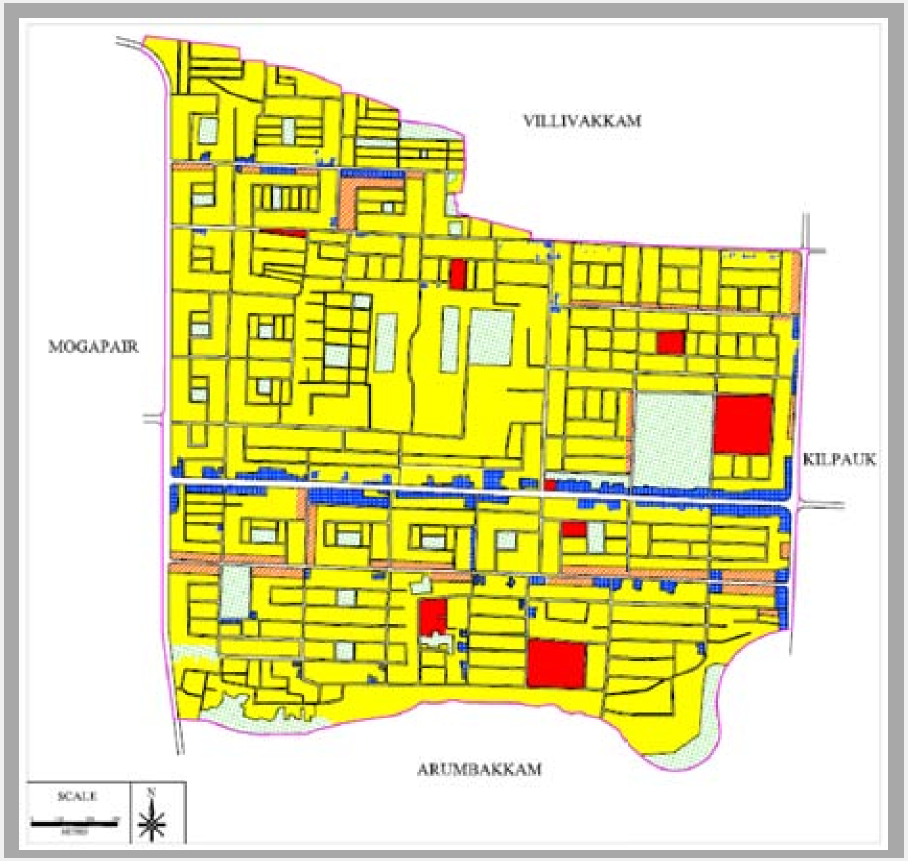
The selected pilot study areas are **Residential Area** of Anna Nagar in ward numbers 66 and 67 in Chennai.

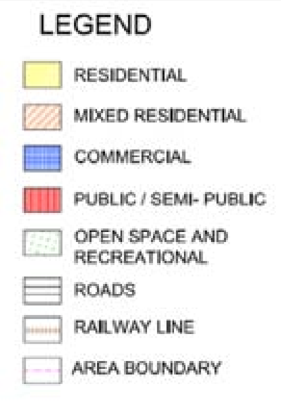
Commercial Area of Alwarpet in ward numbers 115 and 116 in Chennai.

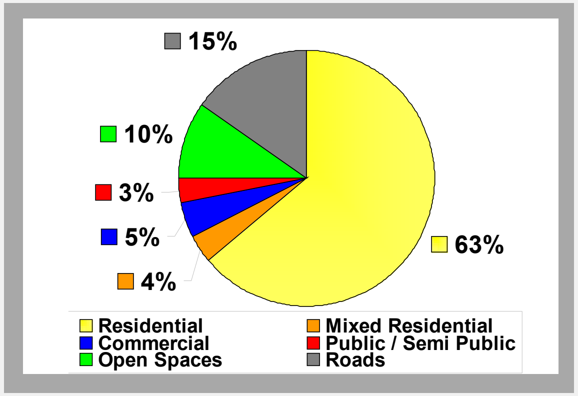
Institutional Area of Mylapore in ward numbers 146 and 147 in Chennai.

PRIMARY SURVEY ANALYSIS

LANDUSE PLAN – ANNA NAGAR - Residential Area







Total Area	3.36 sq.km.
Surface Sealing	74%
Population (2001)	74765
Density (pph)	223
Impervious / Pervious ratio	2.85
Roof / Pervious ratio	1.65
Average Plot size	2000 sq. ft.
Average Roof size	1200 sq.ft.
Average Household size	4.31
Average Water use	81 lpcd

Anna Nagar is a predominantly residential area with 63% of the area under residential use, located in the west of Chennai.

Ground water level – 180’ to 200’

Supply Duration - 2 to 3 hours on daily basis

Alternative sources -Metro water tankers, Metro water storage points

Water scarcity period – April, May

Capacity

•Average OHT size – 3000 litres (ranging from 500 litres to 8000 litres)

•Average sump size – 6000 litres (ranging from 1000 litres to 10000 litres)

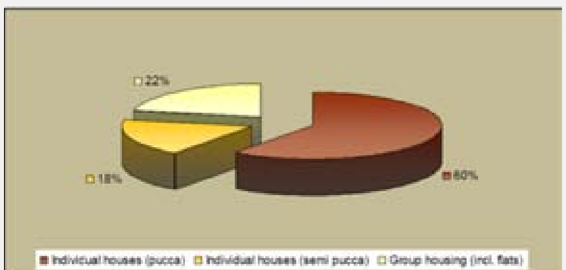


Fig no: 5.1 Housing types

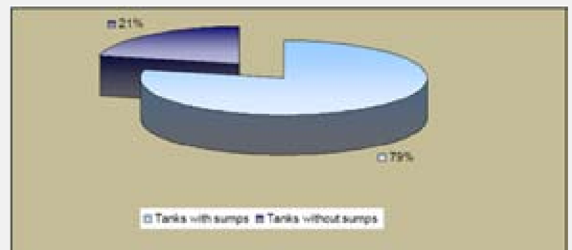


Fig no: 5.3 Types of water storage tanks

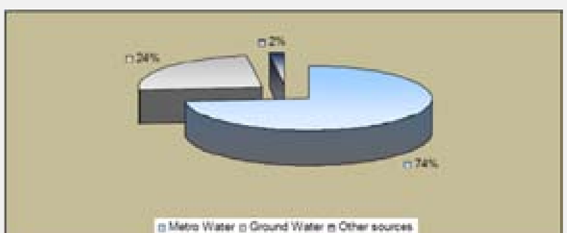


Fig no: 5.2 Sources of water

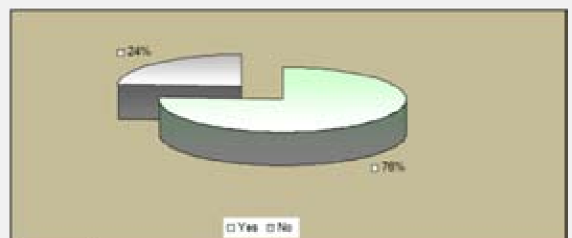
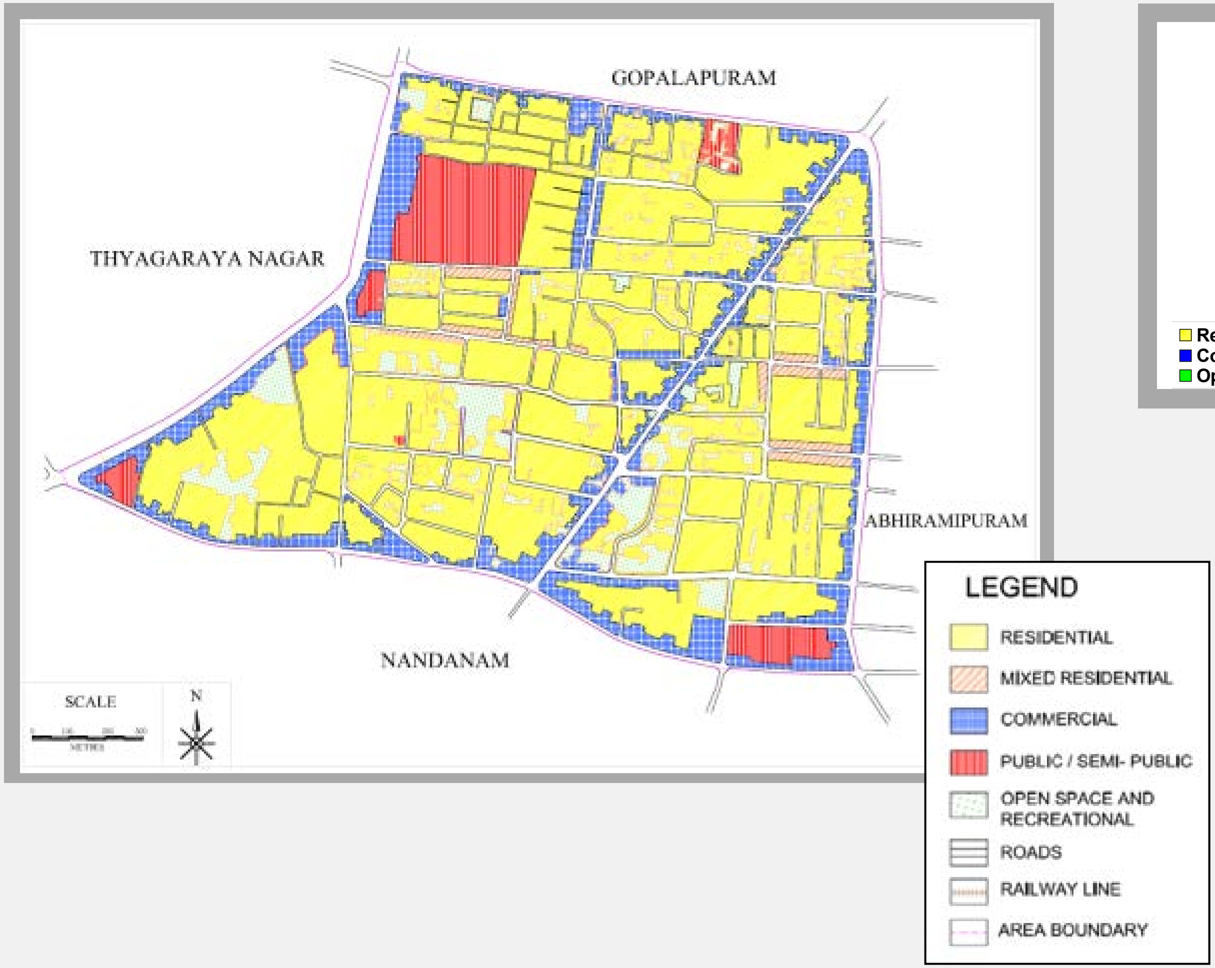
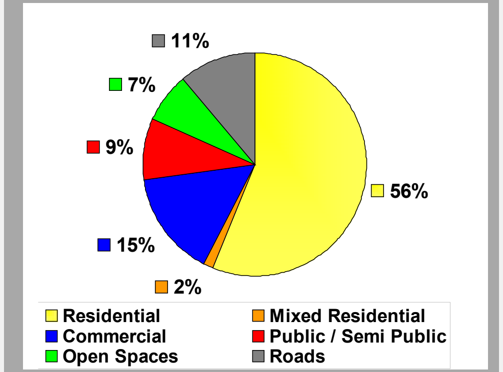


Fig no: 5.4 Willingness to reuse waste water

LANDUSE PLAN – ALWARPET –Commercial area





Total Area	1.97 sq.km.
Population (2001)	43639
Density (pph)	221
Surface Sealing	85%
Impervious / Pervious ratio	4.95
Roof / Pervious ratio	2.71
For Commercial Office spaces	
Average Plot size	12000 sq. ft.
Average Roof size	7000 sq.ft.
Average Water use	36 lpcd

DR. SOMNATH SEN, ASSOCIATE PROFESSOR, DEPARTMENT OF ARCHITECTURE AND REGIONAL PLANNING, IIT KHARAGPUR

Alwarpet is located in central Chennai and it mostly comprises of commercial establishments which mostly includes office complexes. It has 15% of the area under commercial use.

Ground water level – 170' to 180'

Supply Duration - 2 to 3 hours on daily basis

Alternative sources -Metro water tankers

Water scarcity period – April, May

Capacity

•Average OHT size – 20000 litres (ranging from 15000 litres to 25000 litres)

•Average sump size – 25000 litres (ranging from 20000 litres to 30000 litres)

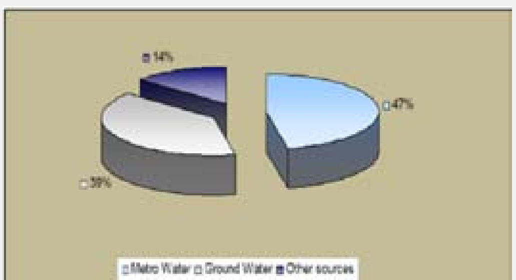


Fig no: 5.6 Sources of water

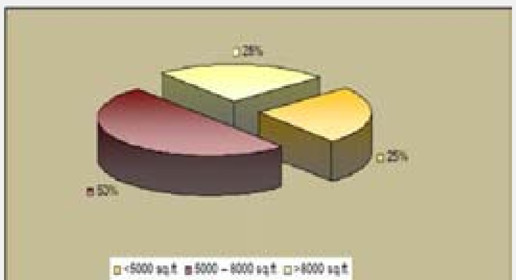


Fig no: 5.5 Office Types

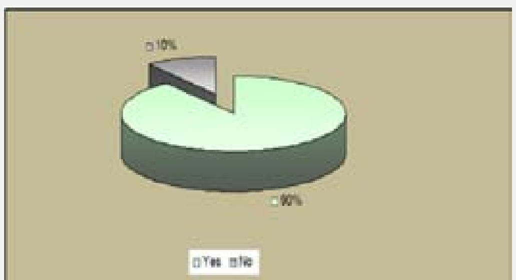
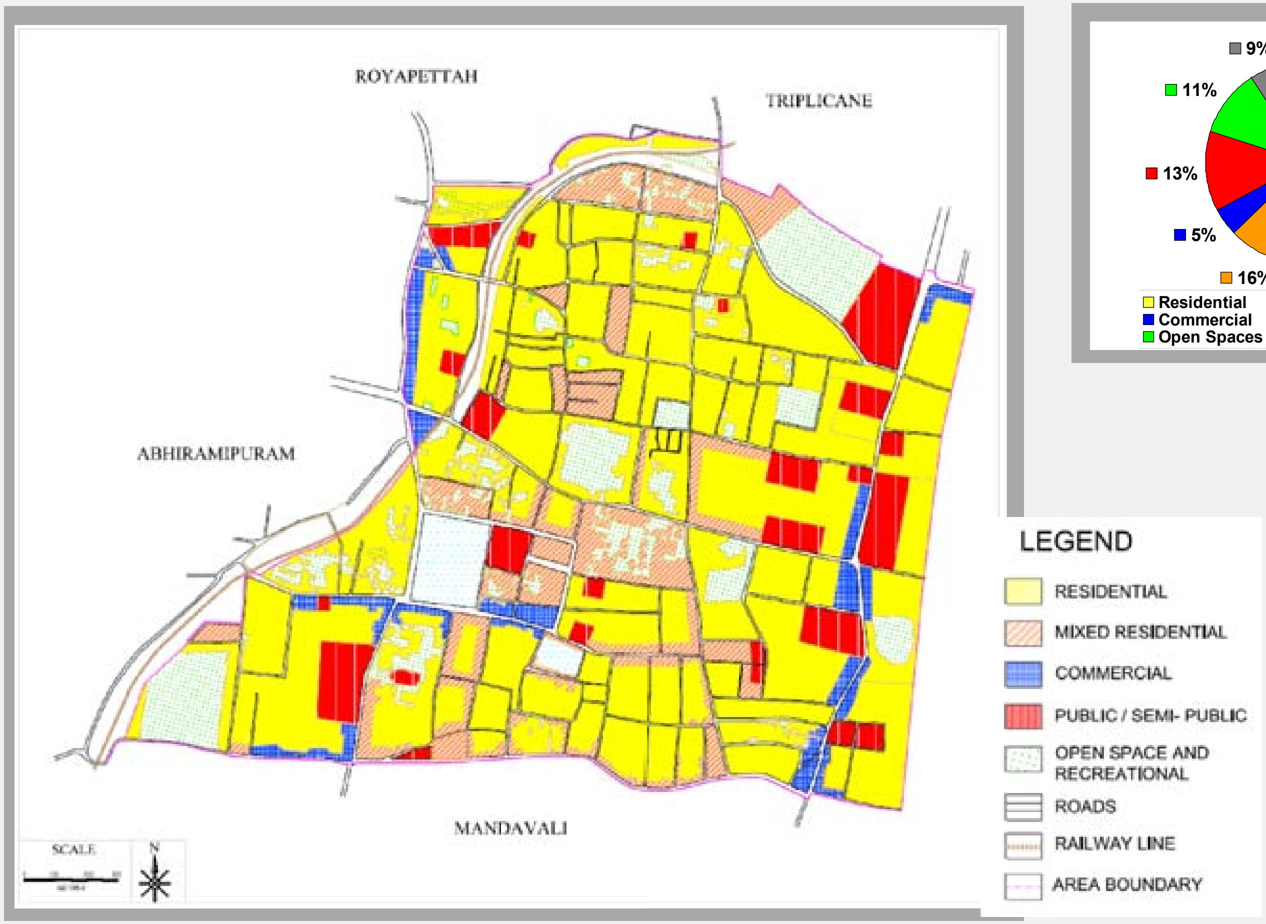
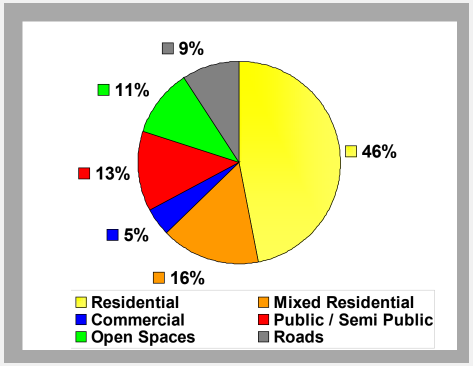


Fig no: 5.7 Willingness to reuse waste water

LANDUSE PLAN – MYLAPORE – Institutional area





Total Area	2.86 sq.km.
Population (2001)	91310
Density (pph)	320
Surface Sealing	70%
Impervious / Pervious ratio	2.32
Roof / Pervious ratio	1.31
For Institutional spaces	
Average Plot size	100000 sq. ft.
Average Roof size	40000 sq.ft.
Average Water use	32 lpcd

Mylapore is located a few kilometres to the south of Chennai city. It is one of the oldest parts of the city and home of temples and educational institutions.

Ground water level – 180’ to 200’

Supply Duration - 2 to 3 hours on daily basis

Alternative sources -Metro water tankers

Water scarcity period – March, April, May

Capacity

- **Average OHT size** – 15000litres (ranging from 6000 litres to 25000 litres)
- **Average sump size** – 30000 litres (ranging from 20000 litres to 40000 litres)

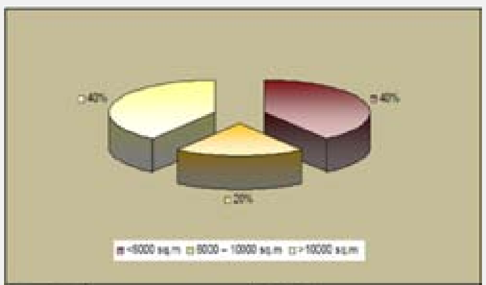


Fig no: 5.8 School types

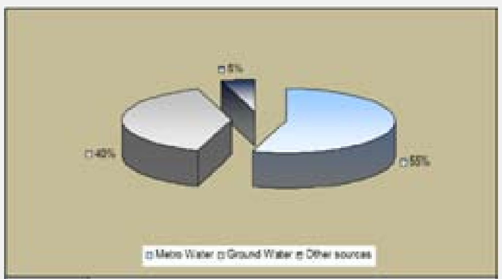


Fig no: 5.9 Sources of water

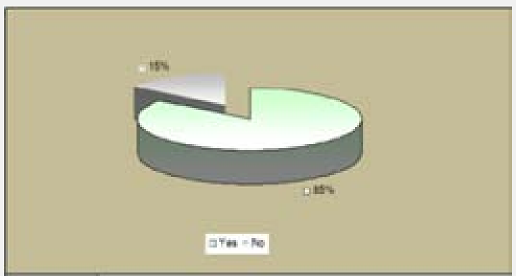


Fig no: 5.10 Willingness to reuse waste water

Water Tariffs:

Category	Water charges /Month
	(including sewerage charge)
Residential Premises	Rs.50 - per month per dwelling unit
Commercial	Rs.400 - 650 per month
Institutional	Rs.400 per month

Mobile Water Tankers	
Residential Premises	Rs.670 per load of 10000 litres
Commercial	Rs.850 per load of 10000 litres
Institutional	Rs.850 per load of 10000 litres

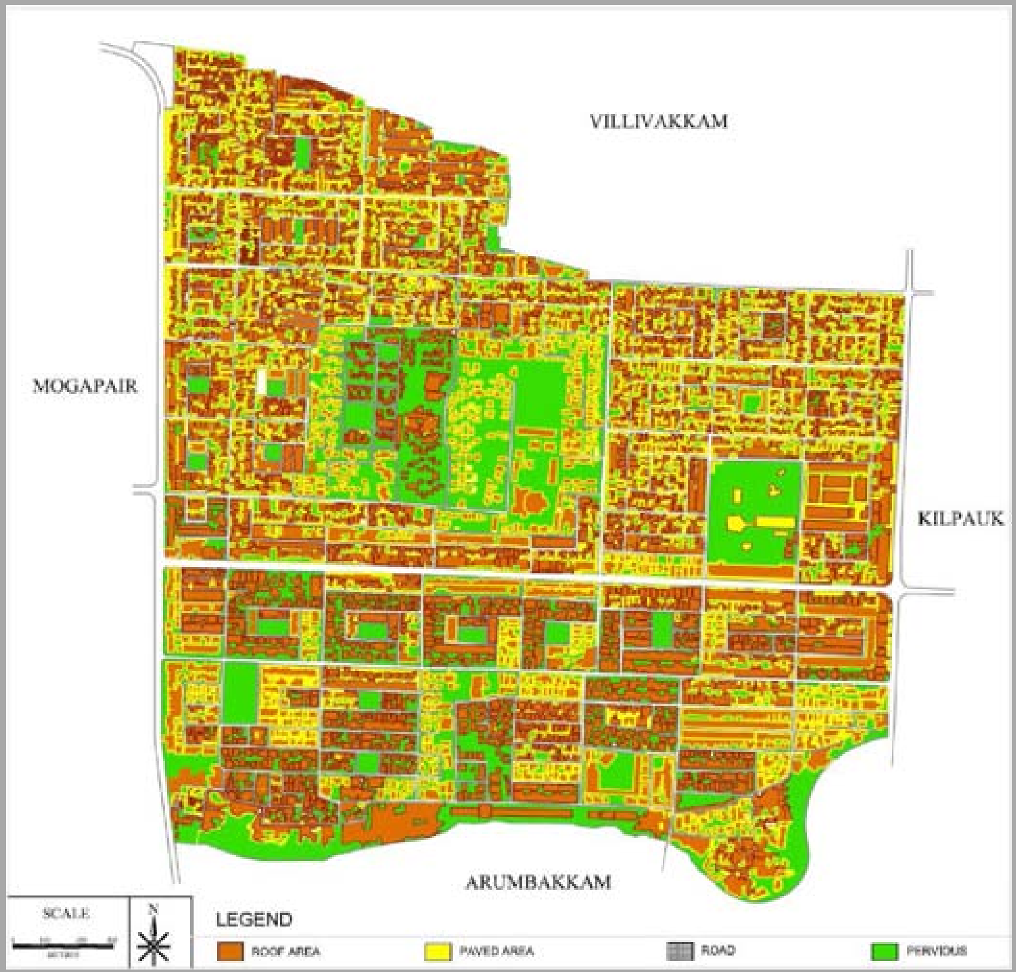
LAND COVER ANALYSIS

The selected study areas were divided into two zones –
- Impervious zone – consisting of roof areas, paved areas and roads.
- Pervious zone – consisting of open spaces and water bodies.

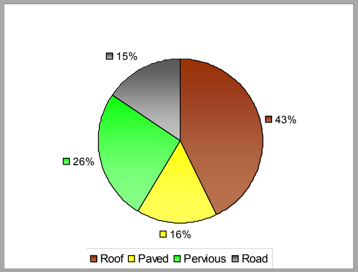
Land Cover characteristics of the Study areas

Location	Area	% Road	% Roof	% Paved	% Pervious	Surface sealing	Imp/Perv	Roof /Perv
	in sq.km					(Roof+Paved+Road)	Ratio	Ratio
AnnaNagar (R)	3.36	15.4	42.7	15.8	26.0	74.0	2.85	1.65
Alwarpet (C)	1.97	11.3	45.6	26.3	16.8	83.2	4.95	2.71
Mylapore (I)	2.86	9.2	39.4	21.3	30.1	69.9	2.32	1.31

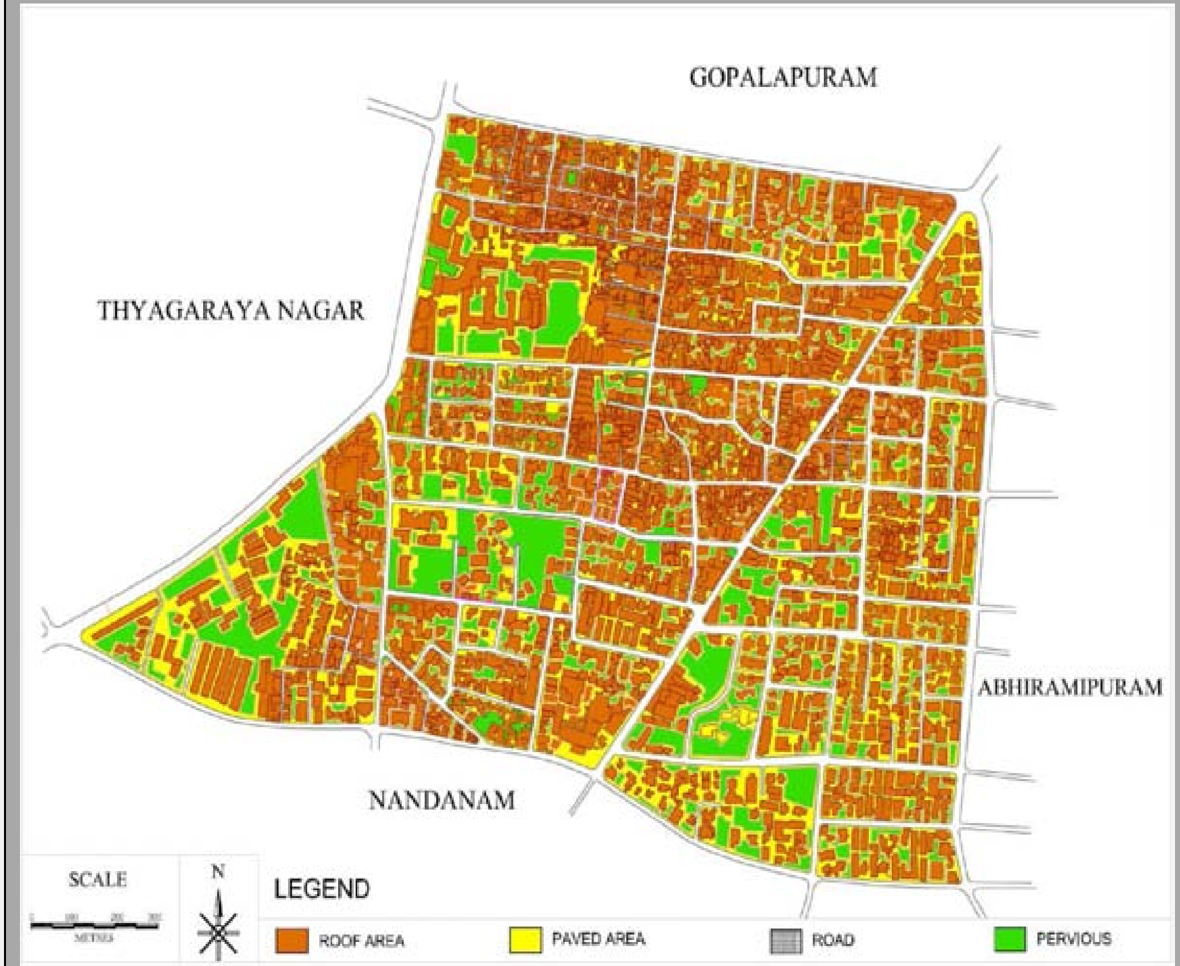
The amount of **imperviousness or the surface sealing is highest in a commercial area** and it is much lesser in a residential area and least in an institutional area. This corresponds directly to the changes in percentages of built up area and perviousness in the three study areas.



Total Area	3.36 sq.km.
Surface Sealing	74%
Impervious / Pervious ratio	2.85
Roof / Pervious ratio	1.65
Average Plot size	2000 sq. Ft.
Average Roof size	1200 sq.ft.
Average Household size	4.31
Average Water use	81 lpcd

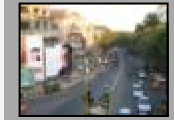


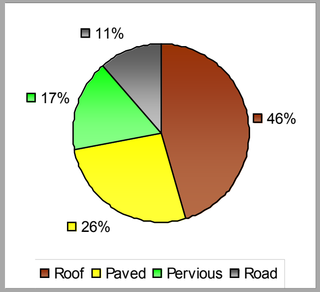
Land Cover Characteristics of Anna Nagar – Residential Area in Chennai

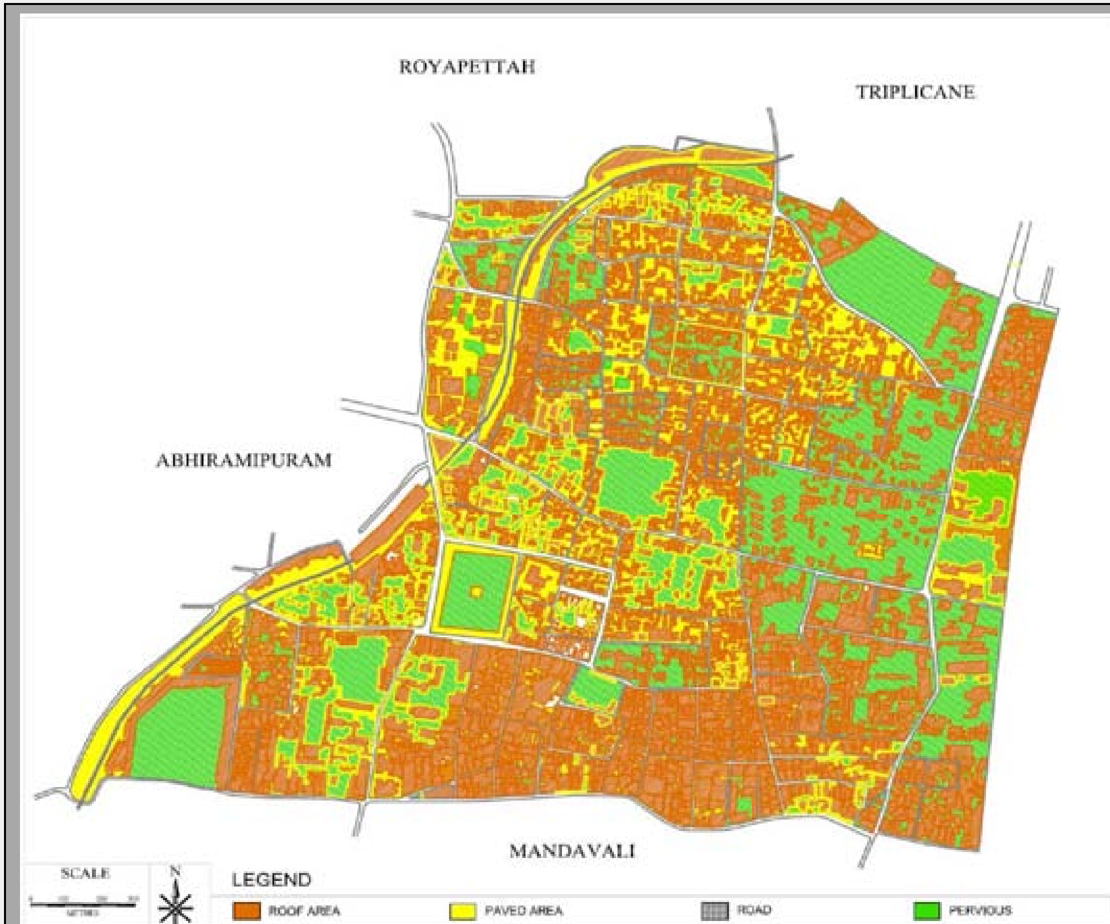


Land Cover Characteristics of Alwarpet – Commercial Area in Chennai

Total Area	1.97 sq.km.
Surface Sealing	85%
Impervious / Pervious ratio	4.95
Roof / Pervious ratio	2.71
For Commercial Office spaces	
Average Plot size	12000 sq. ft.
Average Roof size	7000 sq.ft.
Average Water use	36 lpcd

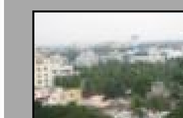


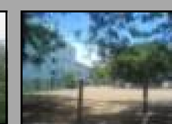


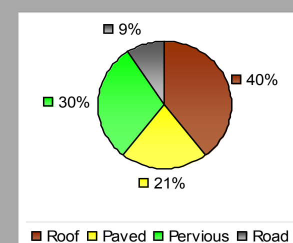


Land Cover Map of Mylapore – Institutional Area in Chennai

Total Area	2.86 sq.km.
Surface Sealing	70%
Impervious / Pervious ratio	2.32
Roof / Pervious ratio	1.31
For Institutional spaces	
Average Plot size	100000 sq. ft.
Average Roof size	40000 sq.ft.
Average Water use	32 lpcd

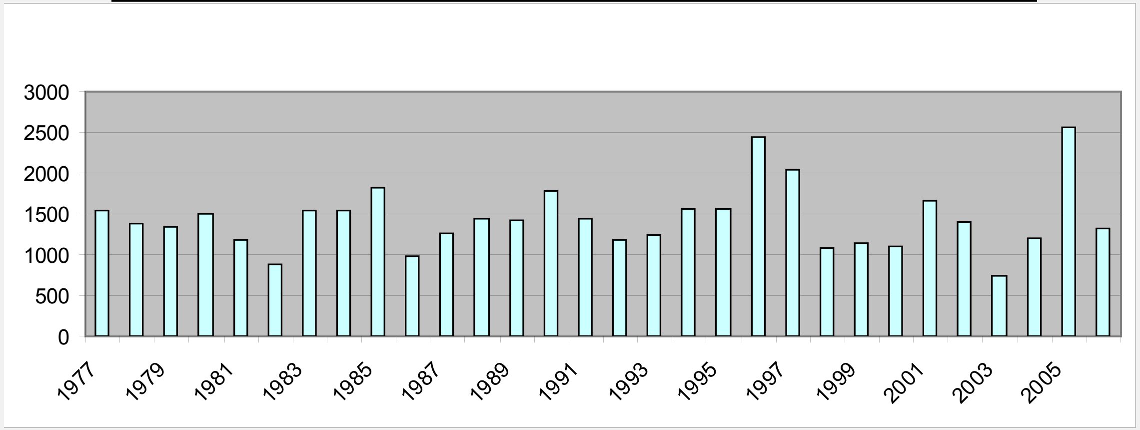






RAINFALL ANALYSIS

Annual rainfall variation in Chennai city for a period of 30 years



Source: Indian Meteorological department, Chennai

Classification of Annual Rainfall

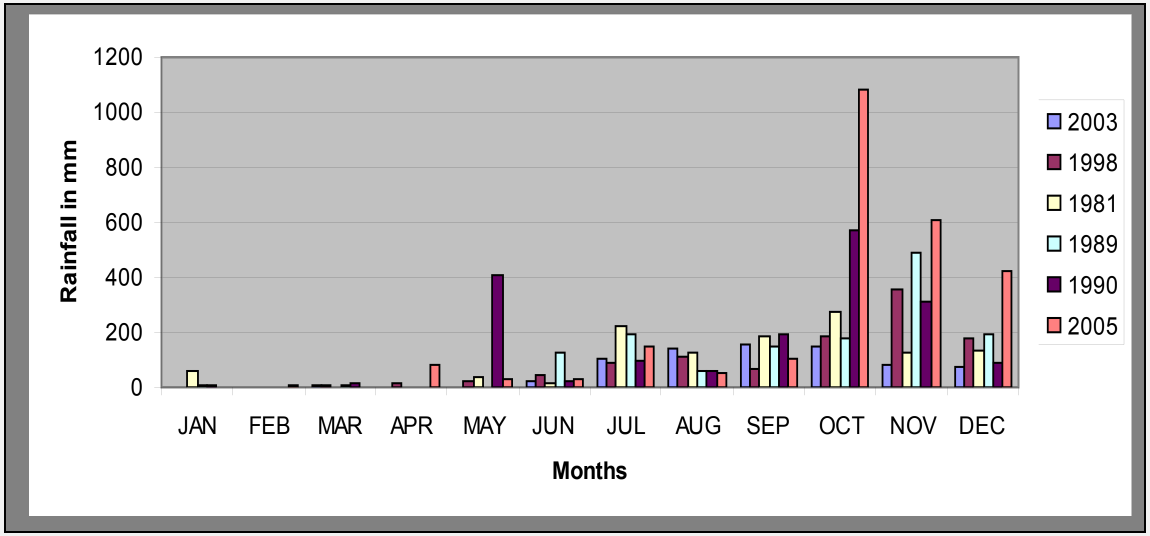
Classification	Dry	Below Normal	Normal	Above Normal	Wet	Very Wet
Range in mm	Below 800	800 - 1200	1200	1200 - 1600	1600 - 2000	Above 2000
Selected year	2003	1998	1981	1989	1990	2005
Annual Rainfall in mm	738.1	1077.7	1182.1	1413.2	1776.3	2565.8

These six rain years selected are used in calculating the runoff for the study areas.

Rainfall Characteristics for the selected rain years

	Dry	Below Normal	Normal	Above Normal	Wet	Very Wet
Selected year	**2003**	**1998**	**1981**	**1989**	**1990**	**2005**
Annual Rainfall (in mm)	738.1	1077.7	1182.1	1413.2	1776.3	2565.8
No. of Rainy Days	41	61	65	59	69	66
Heaviest Rainfall in 24 hrs	Sept	Dec	July	Dec	May	Oct
Value (in mm)	105.1	102.3	105.8	131.2	147.2	272.5

Average monthly rainfall for the six selected rain years



In a period of 30 years, the **annual rainfall varies from 738 mm to 2566 mm** with an average annual rainfall of 1260 mm. It is also observed that the peak rainfall occurs between October to December.

RUNOFF ANALYSIS

Customized CN values for the study areas

	% Impervious area			CN for urban area (a)	Customised
	(f)	(1-f)	CNp	f (98)+ (1-f) CNp	CN value
Alwarpet	0.84	0.16	74	94.16	90.93
Mylapore	0.7	0.3	61	86.9	79.13
Anna Nagar	0.74	0.26	74	91.76	87.14

Soil Groups and CN values for the study areas

Location	Area in sq.km	Surface sealing (Roof+Paved+Road)	Imp/Perv Ratio	Roof /Perv Ratio	Soil Group	CN value
Anna Nagar (R)	3.36	74.0	2.85	1.65	C	87.14
Alwarpet (C)	1.97	83.2	4.95	2.71	C	90.93
Mylapore (I)	2.86	69.9	2.32	1.31	B	79.13

SCS Curve Number Method

The SCS curve number method is a simple, widely used and efficient method for determining the approximate amount of runoff from a rainfall event in a particular area.

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad (1)$$

$$S = \frac{1000}{CN} - 10 \quad \text{(in inches)}$$

$$S = \frac{25400}{CN} - 254 \quad \text{(in mm)}$$

$$I_a = 0.2\,S \qquad (2)$$

Typical values for the SCS Curve Number CN as a function of **soil type, land use and degree of saturation.**

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)} \qquad (3)$$

where,
Q = runoff (in mm)
P = rainfall (in mm)
S = potential maximum retention after runoff begins (in mm)
Ia = initial abstractions

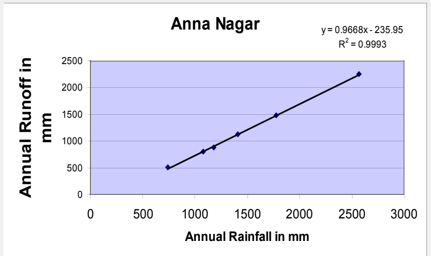
Runoff Analysis of the study areas for different rain years

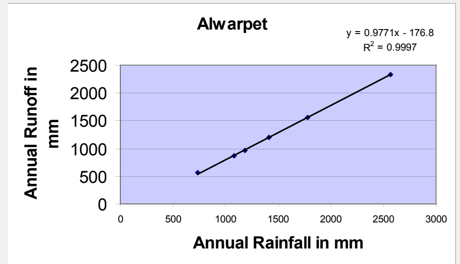
Classification	Year	Annual Rainfall (in mm)	Mylapore Runoff (in mm)	%	Anna Nagar Runoff (in mm)	%	Alwarpet Runoff (in mm)	%
Dry	2003	738.1	389.6	52.8	502.7	68.1	562.8	76.2
Below Normal	1998	1077.7	663.2	61.5	796.9	73.9	867.4	80.5
Normal	1981	1182.1	733.3	62.0	886.3	75.0	964.7	81.6
Above Normal	1989	1413.2	979.2	69.3	1130.8	80.0	1205.6	85.3
Wet	1990	1776.3	1317.6	74.2	1475.5	83.1	1554.0	87.5
Very Wet	2005	2565.8	2087.2	81.3	2254.3	87.9	2337.1	91.1

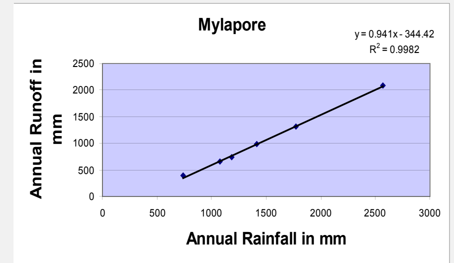
•The **runoff from a commercial area is more than that of the residential and institutional area** only due to the variations in percentage of Imperviousness.

• For the different rain years the corresponding runoff in the commercial area varies from 76% to 91% and that in the residential area varies from 68% to 88% and the runoff in the institutional area varies from 52% to 81%

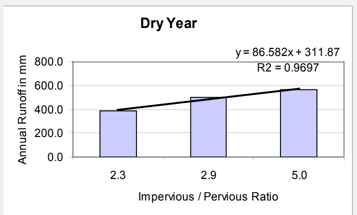
Relationship between Annual rainfall and annual runoff for all three study areas

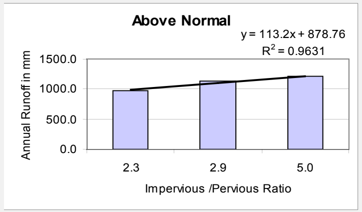


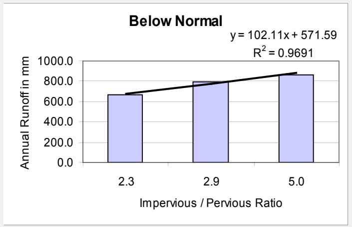


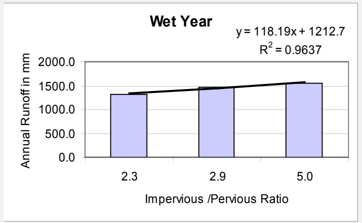


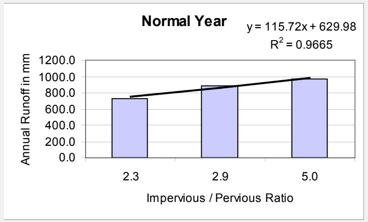
Relationship between Annual runoff and impervious/pervious ratio for different rain years

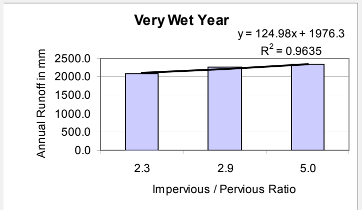




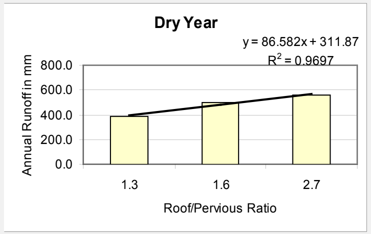


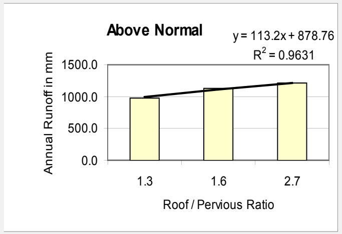


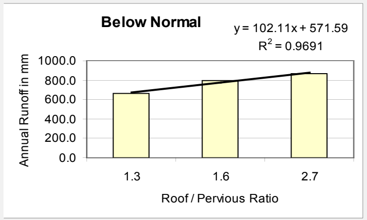


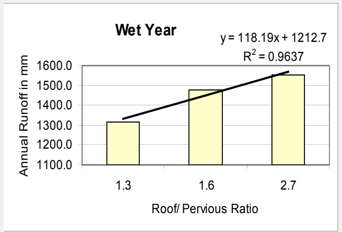


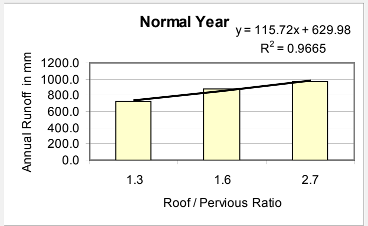
Relationship between Annual runoff and roof / pervious ratio for different rain years

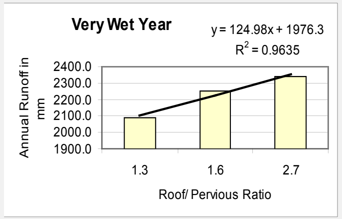












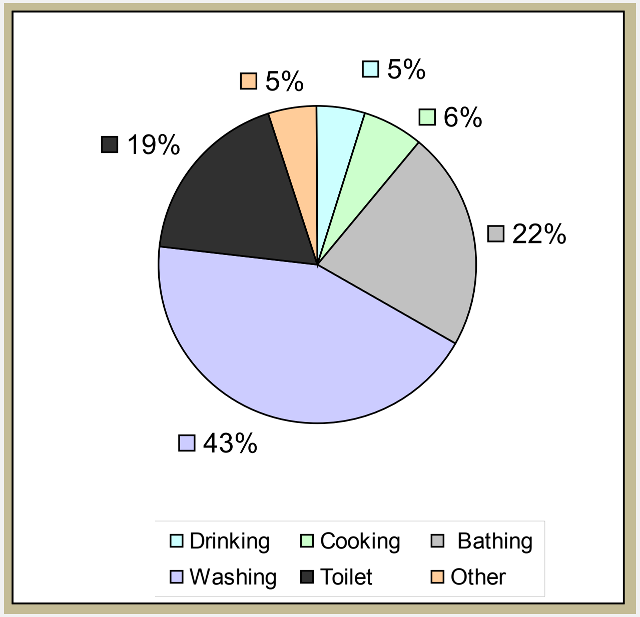
WATER USE ANALYSIS

Per capita consumption in the three pilot study areas

Water consumption pattern – household

Per capita consumption based on reported use (in lpcd)

Water Use	Lpcd	%
Drinking	4	4.9
Cooking	5	6.2
Bathing	18	22.3
Washing	35	43.2
Toilet	15	18.5
Other uses	4	4.9
Total Use	**81**	**100**

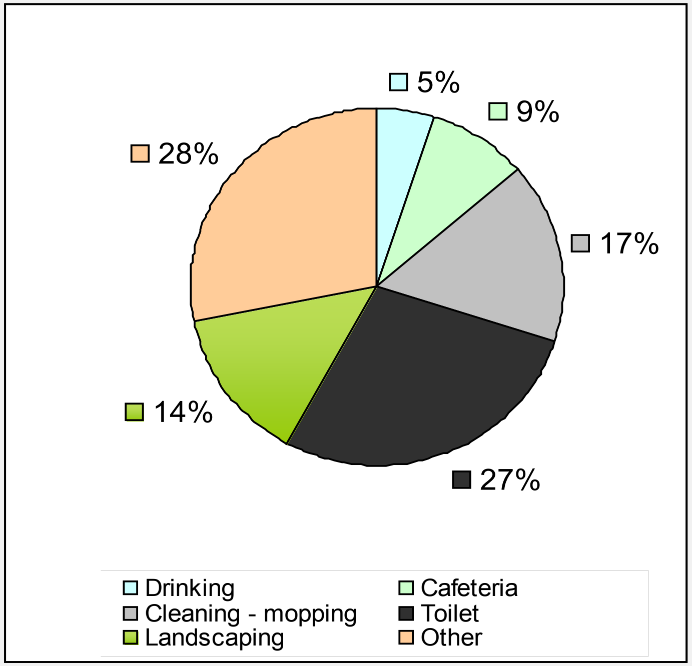


The average water use is 81 lpcd in residential use of which about 60% of the water consumed comes out as grey water from a household.

Water consumption pattern – Commercial Office complex

Per capita consumption based on reported use (in lpcd)

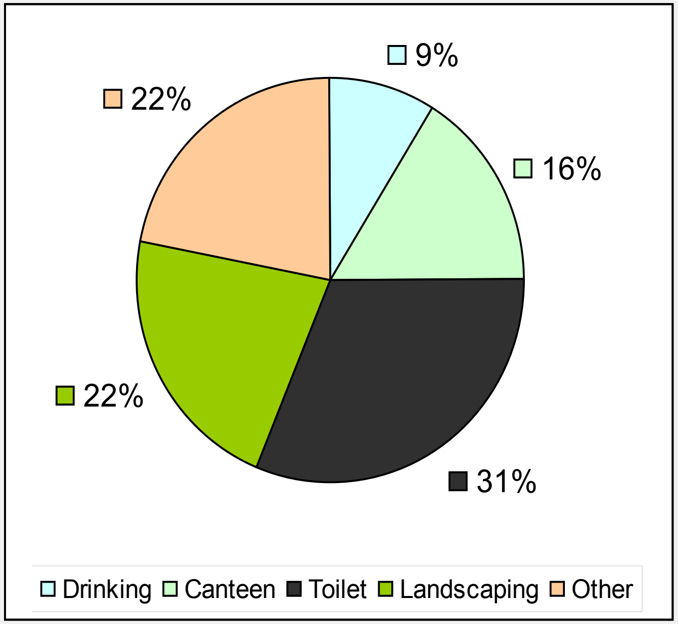
Water Use	Lpcd	%
Drinking	2	5
Cafeteria	3	8.5
Cleaning - mopping	6	16.5
Toilet	10	28
Landscaping	5	14
Other uses	10	28
Total Use	**36**	**100**



Water consumption pattern – Institutional area

Per capita consumption based on reported use (in lpcd)

Water Use	Lpcd	%
Drinking	3	9
Canteen	5	16
Toilet	10	31
Landscaping	7	22
Other Uses	7	22
Total Use	**32**	**100**



From the analysis on water consumption pattern it is observed that about **70% to 80% of the water supplied is used for non-potable purposes.**

On an average around **60% of the total water consumed comes out as grey water** from a site which has the potential to be recycled. This indicates the potential of replacing main water with other sources in order reduce the potable water consumption

WATER DEMAND ANALYSIS

Existing water supply levels to the study areas

Location	Population 2001	Metro Water (in MLD)	Ground Water (in MLD)	Total (in MLD)	lpcd
Anna Nagar	74765	4.39	1.7	6.1	81
Alwarpet	43639	2.25	2.55	4.8	110
Mylapore	91310	4.51	3.69	8.2	90

Supply demand analysis for the study areas

Location	Population 2001	Supply in MLD	Population 2021	Demand in MLD	Deficit in MLD
Anna Nagar	74765	6.1	95467	14.3	8.2
Alwarpet	43639	4.8	54741	8.2	3.4
Mylapore	91310	8.2	114539	17.2	9.0

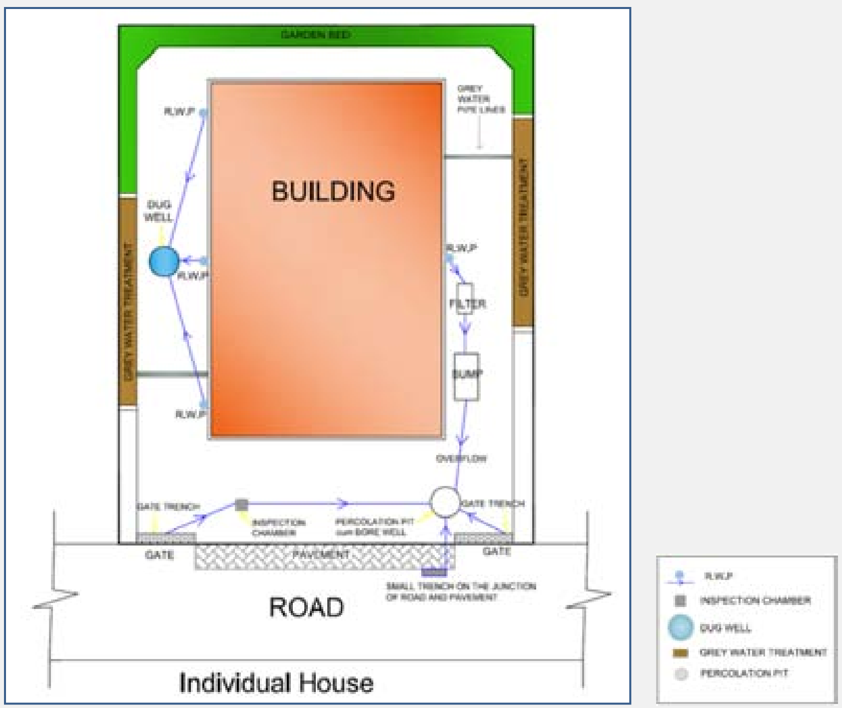
It is observed from the water demand analysis that the **present supply will not be sufficient to meet the future demand.**

Design Proposal - PLOT LEVEL

At individual building allotment or plot level the **Water sensitive techniques can be incorporated as a source control measure.** The various techniques include **Rainwater tanks, infiltration trenches including percolation pits and recharge wells, permeable pavements, grey water recycling systems including vegetation filter strips and planter beds.**

Conceptual proposal for integrated water management systems

RESIDENTIAL - INDIVIDUAL HOUSE



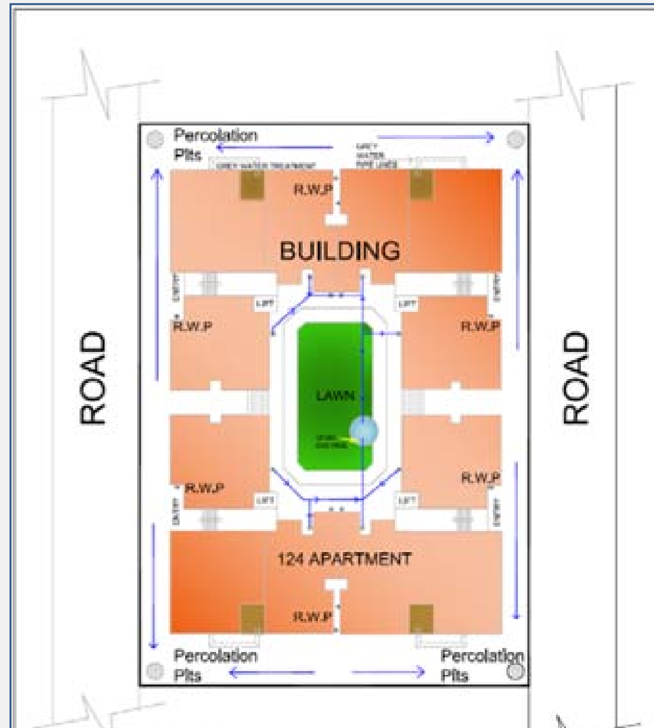
Sl.no.	Residential area	units	
1	The Average rainfall in mm	1260	mm
2	Building Type	Individu al	House
3	Roof top area	130	Sq.m
4	Avg Household size	4	
5	Actual requirement	160	@40 lpcd
6	Quantity collected @ 60% efficiency	98280	lts
7	Actual requirement per day	160	lts
8	Actual requirement per year	58400	lts
9	Investment for RWH	6000	Rs.
10	Cost of Rain water saved	9828	Rs.
11	**Cost recovery period**	**0.6**	**years**

DR. SOMNATH SEN, ASSOCIATE PROFESSOR, DEPARTMENT OF ARCHITECTURE AND REGIONAL PLANNING, IIT KHARAGPUR

RESIDENTIAL - APARTMENTS

8 Apartment complex

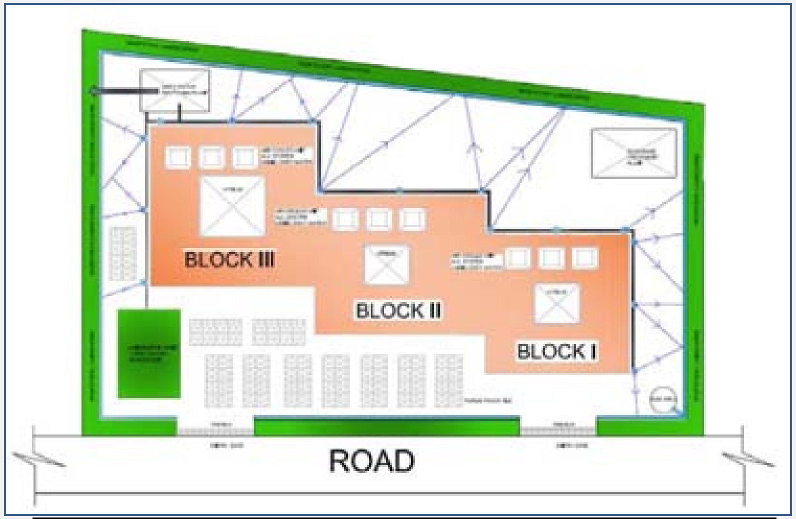
Sl.no.	Residential area	units	
1	The Average rainfall in mm	1260	mm
2	Building Type	Apartment	
3	Roof top area	350	sqm
4	Avg. number of users	32	
5	Actual requirement	1280	@40 lpcd
6	Quantity collected @ 60% efficiency	264600	lts
7	Actual requirement per day	1280	lts
8	Actual requirement per year	467200	lts
9	Investment for RWH	50000	Rs.
10	Cost of Rain water saved	26460	Rs.
11	**Cost recovery period**	**1.8**	**years**



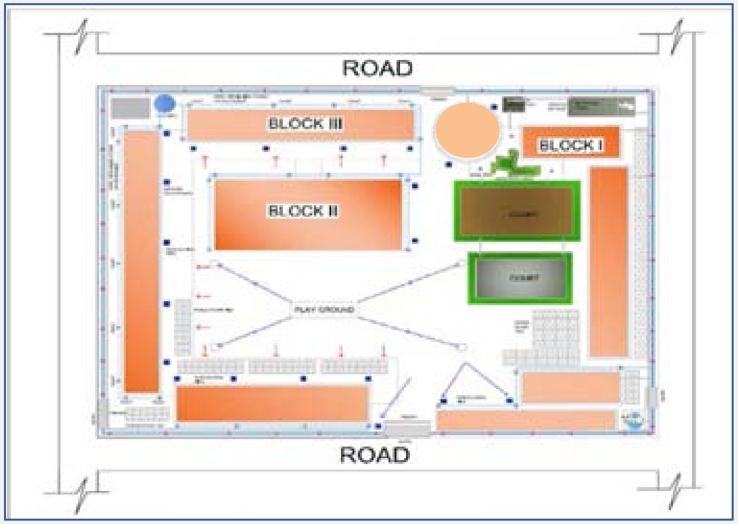
124 Apartment complex

DR. SOMNATH SEN, ASSOCIATE PROFESSOR, DEPARTMENT OF ARCHITECTURE AND REGIONAL PLANNING, IIT KHARAGPUR

COMMERCIAL – COMPLEX



INSTITUTIONAL – CAMPUS LEVEL



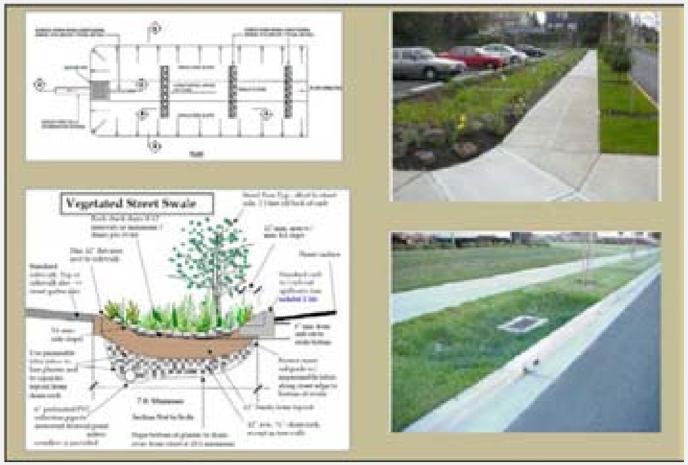
Sl.no.	Commercial Office complex	units	
1	The Average rainfall in mm	1260	mm
2	Building Type	Office Complex	
3	Roof top area	700	sqm
4	Avg. number of users	100	
5	Actual requirement	1000	@ 10 lpcd
6	Quantity collected @ 60% efficiency	529200	lts
7	Actual requirement per day	1000	lts
8	Actual requirement per year	365000	lts
9	Investment for RWH	80000	Rs.
10	Cost of Rain water saved	52920	rs.
11	Cost recovery period	1.51	years

Sl.no.	Educational area	units	
1	The Average rainfall in mm	1260	mm
2	Building Type	Educational campus	
3	Roof top area	3500	sqm
4	Number of person	1000	
5	Actual requirement	10000	@10 lpcd
6	Quantity collected @ 60% efficiency	2646000	lts
7	Actual requirement per day	10000	lts
8	Actual requirement per year	3650000	lts
9	Investment for RWH	200000	Rs.
10	Cost of Rain water saved	264600	Rs.
11	**Cost recovery period**	**0.75**	**years**

Design Proposal - STREET LEVEL

Water sensitive measures **maximize passive storm water treatment opportunities, reduce reliance upon traditional costly water treatment systems and reduce long-term maintenance costs.**

Therefore at the street level various water sensitive treatments like vegetated swales, infiltration devices and porous paving materials can be integrated in the design depending on the local conditions so that it minimizes runoff and maximises recharge.

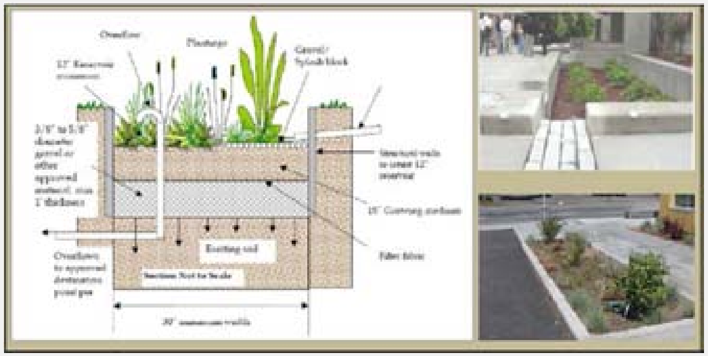


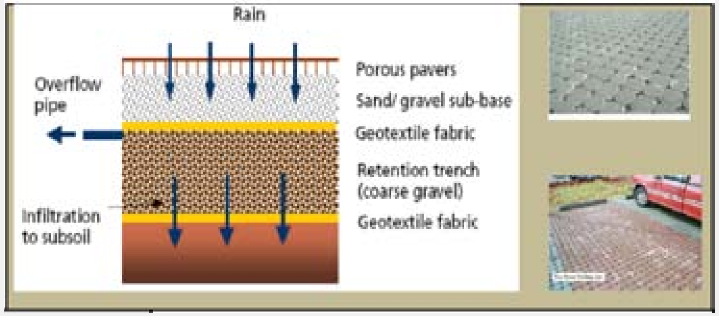
Vegetated Swales

Swales are formed, vegetated depressions that are used for the conveyance of storm water runoff from impervious areas.

Infiltration planter

Infiltration planters are structural landscaped reservoirs used to collect, filter, and infiltrate storm water runoff, allowing pollutants to settle and filter out as the water percolates through the planter soil and infiltrates into the ground.





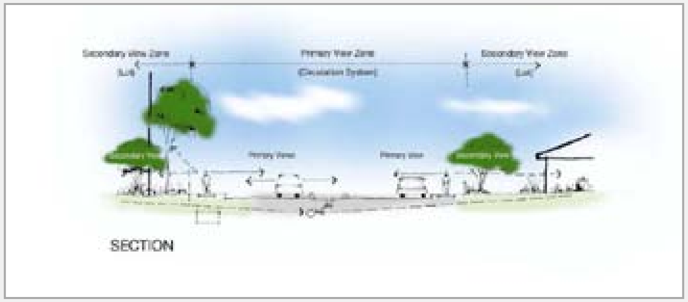
Permeable Pavement

Permeable pavements, which are an alternative to typical impermeable pavements, allow runoff to percolate through hard surfaces to an underlying granular sub-base reservoir for temporary storage

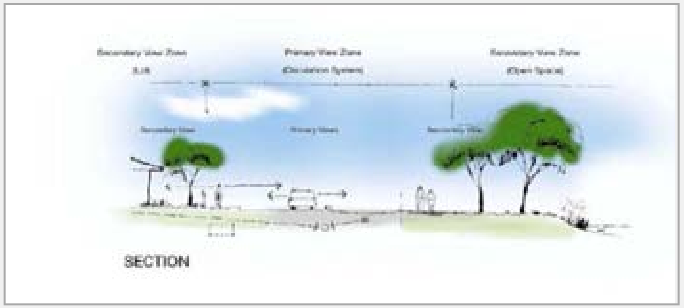
Street recharges

These include percolation pits which are placed at the point where the road level is lowest. Percolation pits may be dug in the pedestrian pavement area on either sides of the road. The rainwater tending to stagnate in the street will flow into these percolation pits and enrich the water table in that street.

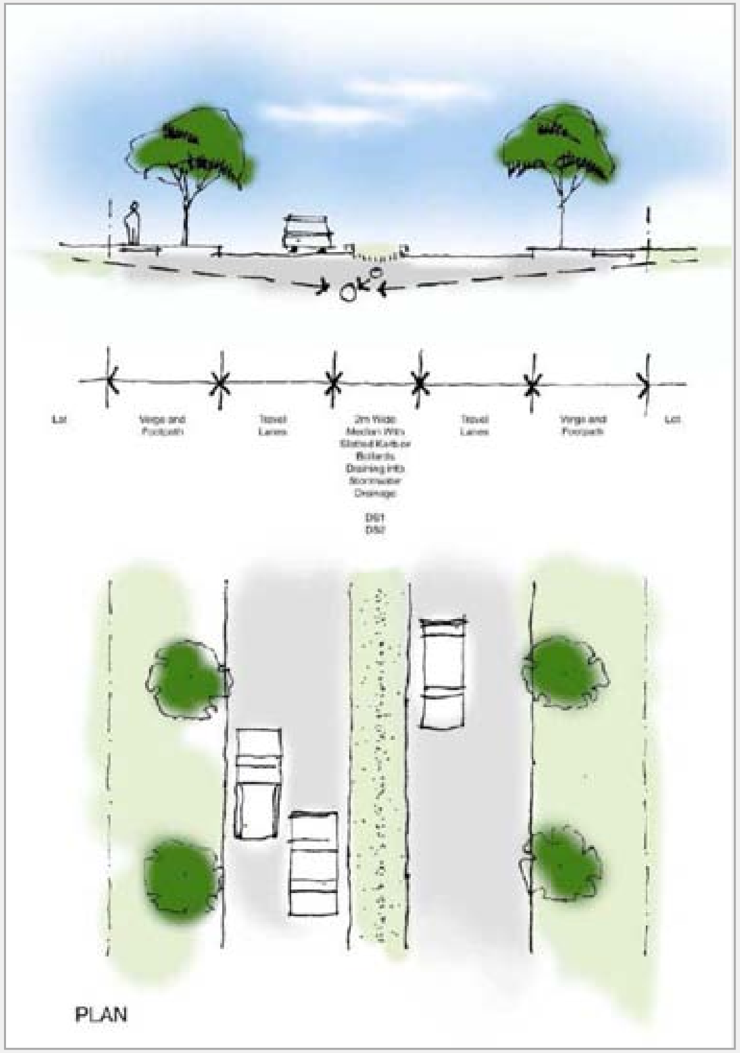
STREET WITH DEVELOPMENT ON BOTH SIDE



STREET WITH DEVELOPMENT ON ONE SIDE

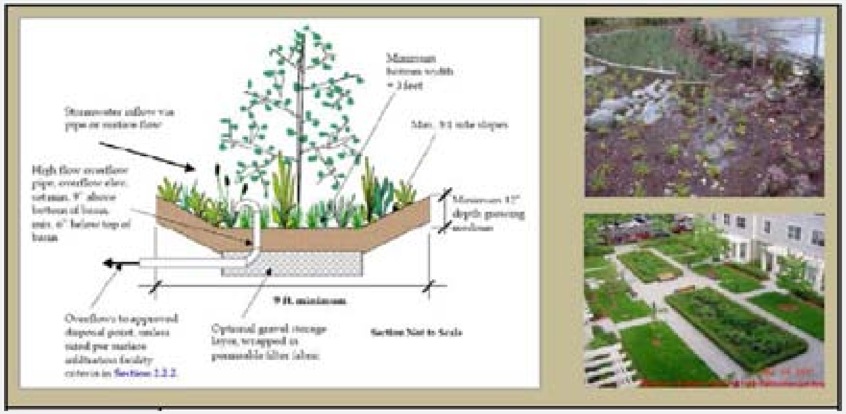


STREET WITH 2M WIDE MEDIAN



DR. SOMNATH SEN, ASSOCIATE PROFESSOR, DEPARTMENT OF ARCHITECTURE AND REGIONAL PLANNING, IIT KHARAGPUR

Design Proposal -COMMUNITY LEVEL



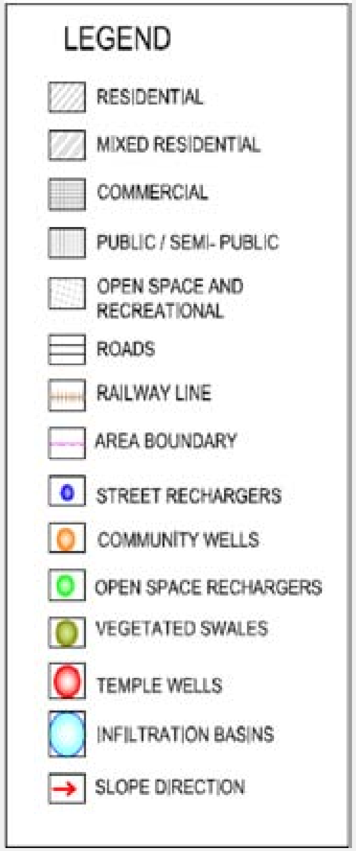
Vegetated infiltration basin

Vegetated infiltration basins are shallow landscaped depressions used to collect and hold storm water runoff, allowing pollutants to settle and filter out as the water infiltrates into the ground.

Infiltration / Retention basins

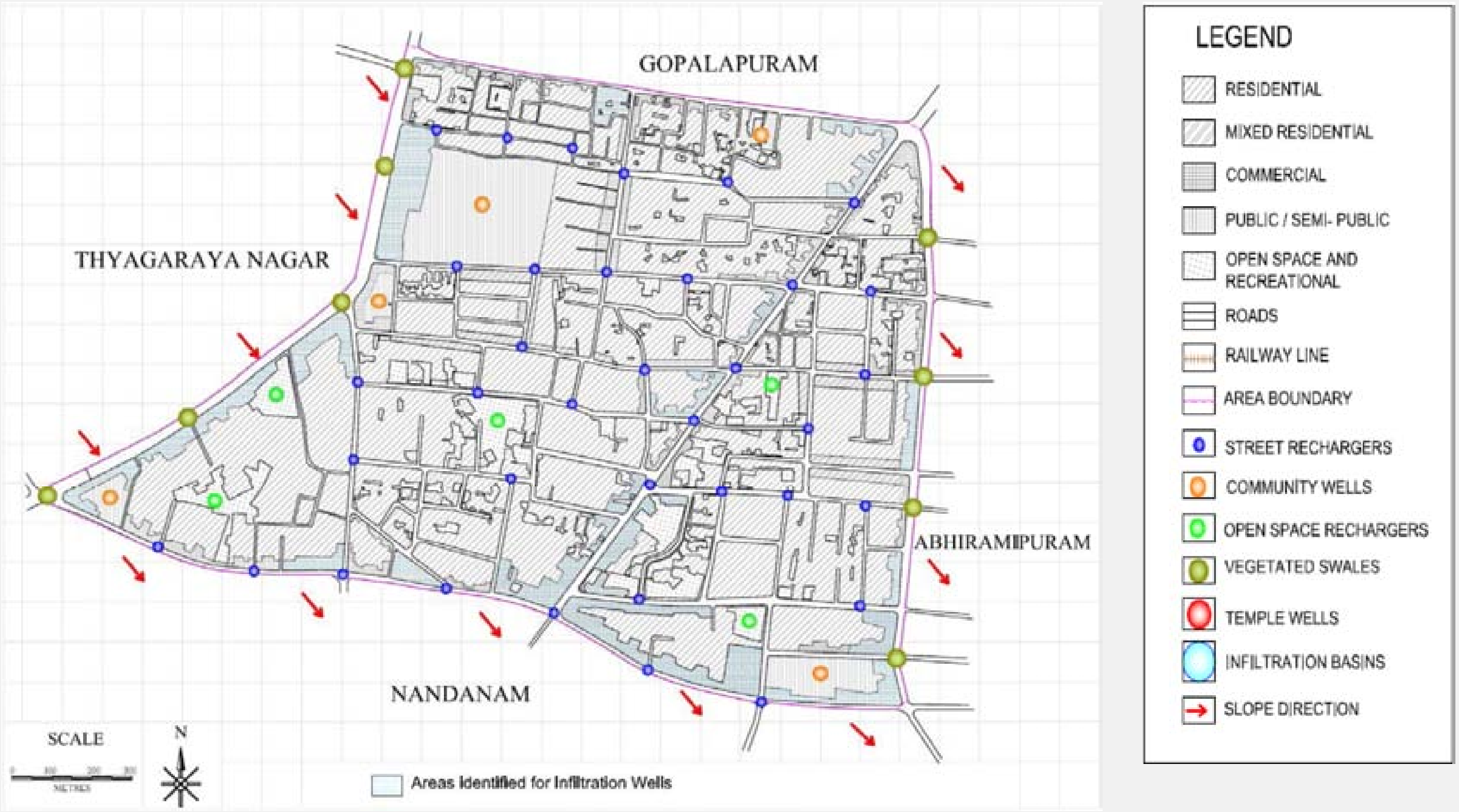
Infiltration basins are either sited in natural or excavated open areas, designed to temporarily hold storm water runoff prior to infiltrating through the basin floor.

PROPOSALS FOR THE PILOT STUDY AREAS



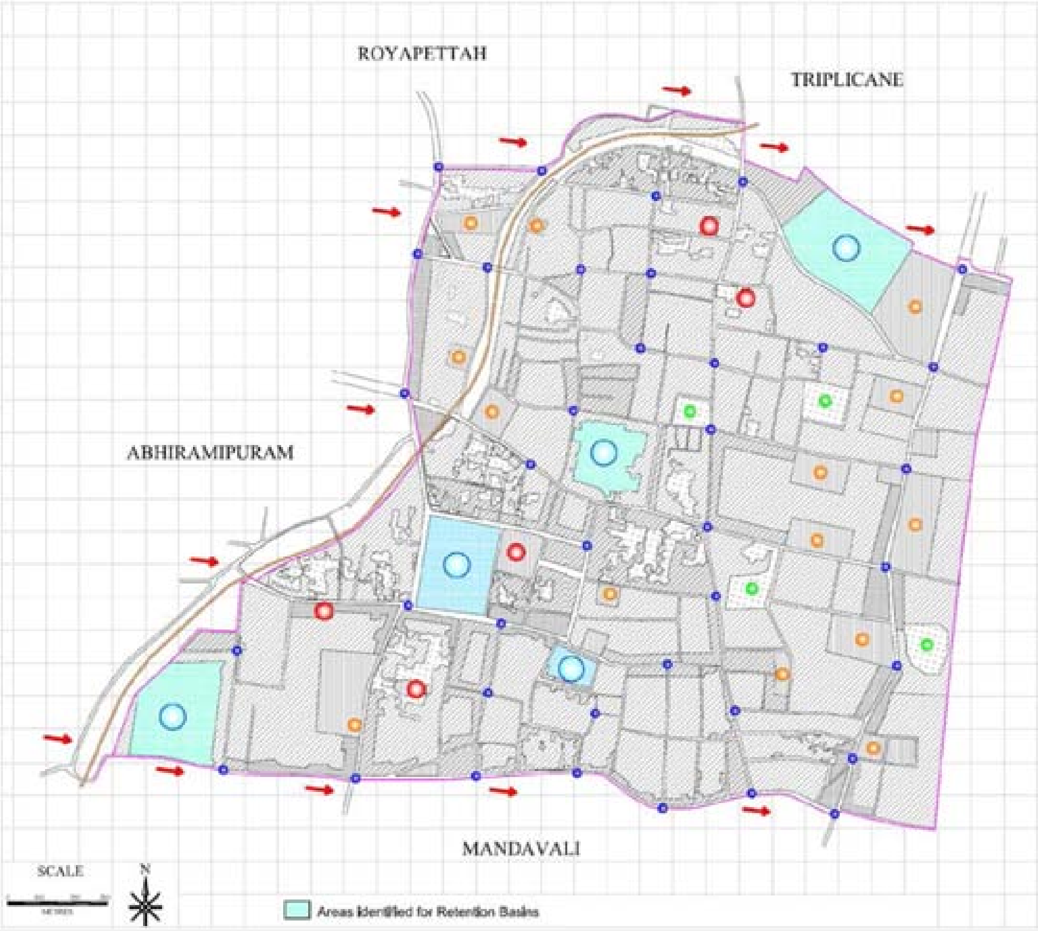
Rain water Harvesting System with focus on Collection wells- Anna Nagar – Residential Area

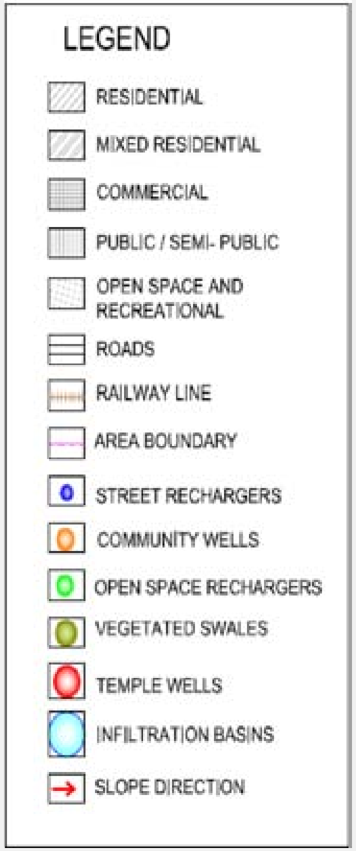
PROPOSALS FOR THE PILOT STUDY AREAS



Rain water Harvesting System with focus on Infiltration wells - Alwarpet – Commercial Area in Chennai

PROPOSALS FOR THE PILOT STUDY AREAS





Rain water harvesting system with focus on Retention Basins- Mylapore – Institutional Area in Chennai

Components of urban planning which should be considered in connection with their effect on runoff and infiltration are identified

1) The proportion of impervious versus pervious land cover in common building Patterns

Policy -1: Future buildings should have low ground coverage with vertical development to reduce building footprints.

2) The distribution of open (pervious) spaces over the area

Policy -2: Introduce green spaces for more infiltration of runoff.

3) Sub-division of the area into small `micro' catchments.

Policy -3: Encourage on site infiltration.

4) Incorporation into the urban fabric of facilities designed to intercept, detain and infiltrate water from precipitation.

Policy 4: Incorporate infiltration facilities at all levels of planning – from an individual lot to a large urban area.

5) Pervious paving materials

Policy – 5: Reduction of imperviousness even in hard surfaces.

Based on the components of urban planning, the recommendations for new developments are given at two levels

At the Land Use Planning Level

- Impervious control
- Building Compact Communities
- Distribution of open (pervious) spaces over the area
- Sub-division of the area into small `micro' catchments

At the Site Design Level

There are a number of site design practices that can reduce impervious coverage for a wide range of land uses, which includes:

- Reducing building footprints
- Reducing road coverage
- Limiting the Amount of Surface Parking
- Use of Porous paving materials

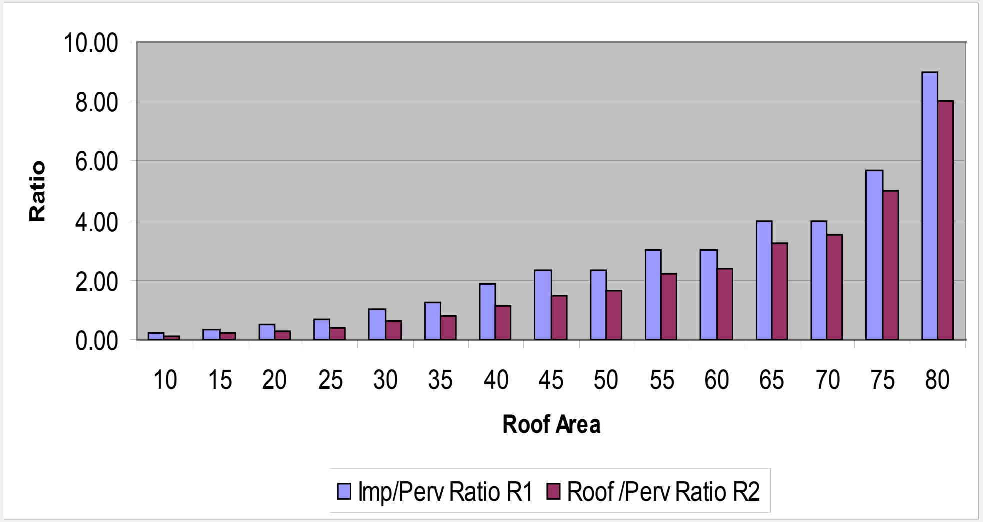
DR. SOMNATH SEN, ASSOCIATE PROFESSOR, DEPARTMENT OF ARCHITECTURE AND REGIONAL PLANNING, IIT KHARAGPUR

Impervious Control

Development control rules For CMA

	Residential	Commercial	Institutional
Min. Plot Extent (in sq.m)	90	110	1000
Max Plot coverage (%)	65	65	
Max FSI	1.5	1.5	1.5

Proportion of pervious cover versus impervious cover



Proportions of impervious versus pervious land cover in common building patterns.

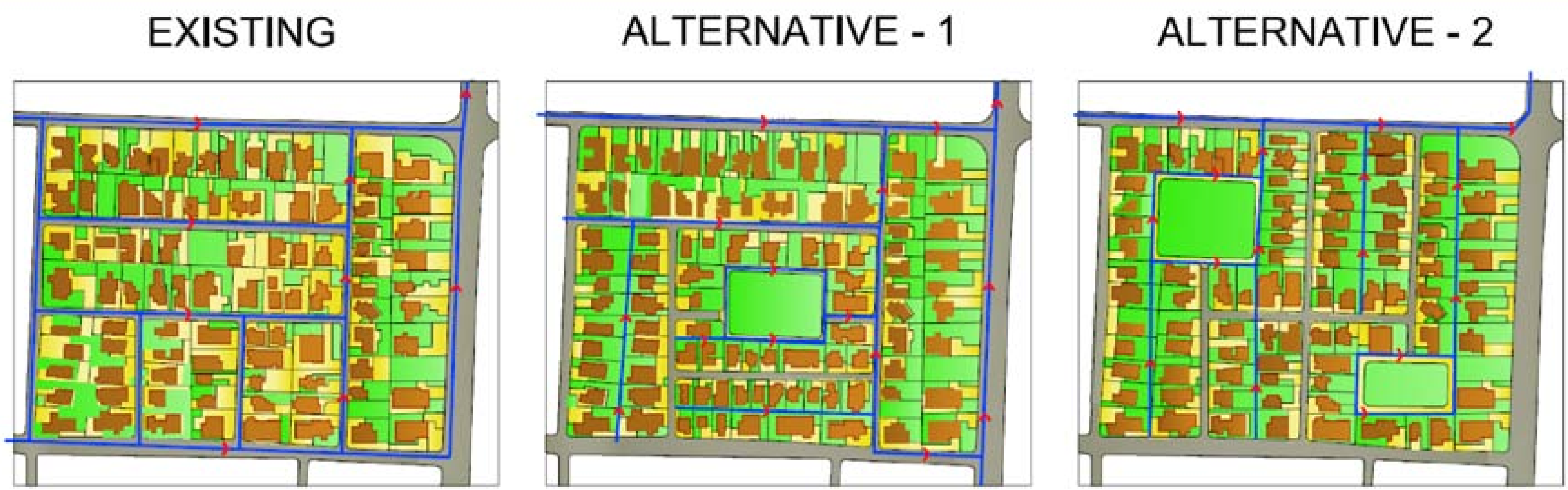
Roof Area	Paved Area	Pervious Area	Imp/Perv Ratio	Roof /Perv Ratio	Surface Sealing	Runoff	Runoff %
%	%	%	R1	R2		in mm	
10	10	80	0.25	0.13	20	689.32	57.44
15	10	75	0.33	0.20	25	695.58	57.96
20	15	65	0.54	0.31	35	710.54	59.21
25	15	60	0.67	0.42	40	720.13	60.01
30	20	50	1.00	0.60	50	744.50	62.04
35	20	45	1.22	0.78	55	761.05	63.42
40	25	35	1.86	1.14	65	807.55	67.30
45	25	30	2.33	1.50	70	842.90	70.24
50	20	30	2.33	1.67	70	843.84	70.32
55	20	25	3.00	2.20	75	893.51	74.46
60	15	25	3.00	2.40	75	894.63	74.55
65	15	20	4.00	3.25	80	969.42	80.78
70	10	20	4.00	3.50	80	970.83	80.90
75	10	15	5.67	5.00	85	1095.94	91.33
80	10	10	9.00	8.00	90	1346.16	112.18

The **impervious/ pervious ratio should range from 2.3 to 3** for all the plots in the future and the corresponding built up area will range from 45% to 60% in order to minimize the runoff.

Distribution of pervious spaces over the area and Building Compact Communities

RESIDENTIAL LAYOUT MODEL

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



	Roof Area	Paved Area	Pervious Area	Road Area	Surface sealing	Imp /Perv	Roof /Perv	Runoff (Ro)
	%	%	%	%	(Roof+Paved+Road)	Ratio	Ratio	
Existing	21.07	29.45	25.14	24.34	74.86	2.98	0.84	75%
Alternative-1	20.34	18.12	37.4	24.14	62.6	1.67	0.54	68%
Alternative-2	19.94	16.38	41.37	22.3	58.63	1.42	0.48	66%

- ROOF AREA - PAVED AREA - PERVIOUS AREA - ROAD - DRAIN AND SLOPE

Roof size determination for rain water harvesting

NON –POTABLE WATER DEMAND FOR RESIDENTIAL

Avg. household size	4.31
Per capita requirement (in litres)	40
(for non- potable use)	
No. of days applicable	365
Total Demand (in litres)	62926

NON- POTABLE WATER DEMAND – COMMERCIAL AREA

Average no. of users	100
Per capita requirement (in litres) (for non- potable use)	10
No. of days applicable	365
Total Demand (in litres)	365000

NON POTABLE WATER DEMAND FOR INSTITUTIONAL AREA

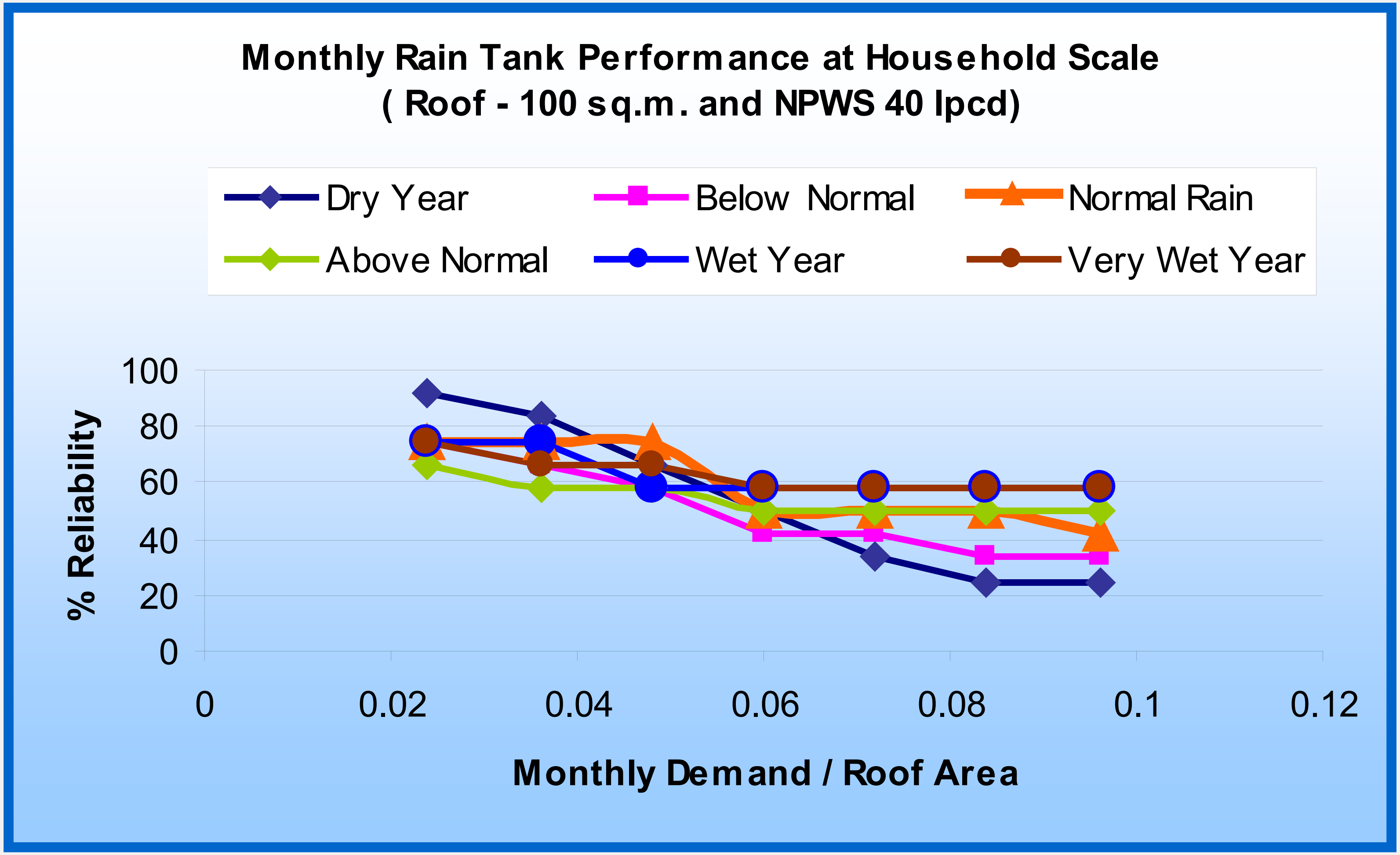
Average no. of users	1000
Per capita requirement (in litres) (for non- potable use)	10
No. of days applicable	365
Total Demand (in litres)	3650000

Roof size determination for rain water harvesting

Roof top area in sq.m	Rainfall in mm					
	DRY	BELOW NORMAL	NORMAL	ABOVE NORMAL	WET	VERY WET
	738.1	1077.7	1182.1	1413.2	1776.3	2565.8
	Volume of Rainwater in cu.m					Goa
20	11.8096	17.2432	18.9136	22.6112	28.4208	41.0528
30	17.7144	25.8648	28.3704	33.9168	42.6312	61.5792
40	23.6192	34.4864	37.8272	45.2224	56.8416	82.1056
50	29.524	43.108	47.284	56.528	71.052	102.632
60	35.4288	51.7296	56.7408	67.8336	85.2624	123.1584
70	41.3336	60.3512	66.1976	79.1392	99.4728	143.6848
80	47.2384	68.9728	75.6544	90.4448	113.6832	164.2112
90	53.1432	77.5944	85.1112	101.7504	127.8936	184.7376
100	59.048	86.216	94.568	113.056	142.104	205.264
150	88.572	129.324	141.852	169.584	213.156	307.896
200	118.096	172.432	189.136	226.112	284.208	410.528
250	147.62	215.54	236.42	282.64	355.26	513.16
300	177.144	258.648	283.704	339.168	426.312	615.792
400	236.192	344.864	378.272	452.224	568.416	821.056
500	295.24	431.08	472.84	565.28	710.52	1026.32
1000	590.48	862.16	945.68	1130.56	1421.04	2052.64
2000	1180.96	1724.32	1891.36	2261.12	2842.08	4105.28
3000	1771.44	2586.48	2837.04	3391.68	4263.12	6157.92
4000	2361.92	3448.64	3782.72	4522.24	5684.16	8210.56
5000	2952.4	4310.8	4728.4	5652.8	7105.2	10263.2

All new buildings with roof areas **more than 80sq.m for residential, 400sq.m for commercial and 3000sq.m for institutional** must provide rainwater harvesting structures in order to get approval of the building plans by the corresponding authorities.

Reliability of Rain water tank for water substitution



POLICY RECOMMENDATIONS:

Guidelines for the future developments

•All new future development in urban areas should **follow the guidelines of water sensitive planning** to incorporate the water resource issues early in the land use planning process.

•Due consideration should be given to the **characteristics of the site to be developed** which includes parameters like rainfall, soil conditions, water table, impervious / pervious ratio.

•Wherever possible, **rainwater should be captured on site**, before it flows and becomes polluted; special attention should be paid to using individual plots as micro catchments.

•The **impervious/ pervious ratio should range from 2.3 to 3** for all the plots in the future and the corresponding **built up area will range from 45% to 60%** in order to maintain as much as possible the pre-urban development levels.

•All new buildings with **roof areas more than 80sq.m for residential, 400sq.m for commercial and 3000sq.m for institutional** must provide rainwater harvesting structures in order to get approval of the building plans by the corresponding authorities.

DR. SOMNATH SEN, ASSOCIATE PROFESSOR, DEPARTMENT OF ARCHITECTURE AND REGIONAL PLANNING, IIT KHARAGPUR

- In case of ordinary buildings (ground-plus-one residential buildings), the grey water should be used for groundwater recharge after a simple organic filtration. In case of multi-storyed apartments, commercial office complexes and educational institutions and other public buildings, **grey water should be recycled and used for non-potable purposes** like toilet flushing and gardening.

- At the **street level various water sensitive treatments** like vegetated swales, infiltration devices and porous paving materials can be integrated in the design depending on the local conditions so that it **minimizes runoff and maximizes recharge**.

- At the **community level** the open spaces like parks and playgrounds, temple tanks, can act as **recharge structures in order to mitigate urban flooding**.

- Policy changes in the building bye-laws has to be made to limit the extent of paved area in a plot and introduce a system of **development incentives in terms of increased Floor Area Ratio (FAR) or a rebate on property tax** for installing rainwater harvesting systems. This will encourage vertical expansion rather than horizontal expansion

- **Water metering and appropriate tariff structures** should be introduced that allows a progressive rate of incentives for effective use of rainwater harvesting systems and treated waste water for non-potable use thereby reducing the potable water demand.

Climate Resilient Neighborhood

Klimakvarter will transform Østerbro to the greenest urban district in Copenhagen and the first climate adapted city area in Denmark.

Source:-www.sustainia.me

Scope for further study

- "Water Sensitive Urban Planning" is a relatively new approach that addresses a series of simple control measures such as land cover control, rainwater retention control, conveyance control of storm water through infiltration and ultimately discharge controls through proper drainage systems for a sustainable catchment development right from residential cluster level.
- Spatial decision support system for urban water management.
- Re-use potential of stormwater for recharging groundwater in urban areas.
- Modelling infiltration through various forms of absorbent landscaping in urban areas.
- Design strategies for sullage and waste water network
- Efficiency modelling in water sensitive street design.
- Modelling social acceptability for use of rainwater for non-consumptive purpose at household level in urban areas.
- Economic & environmental benefits of source control strategies in Urban Water Cycle management.

REFERENCES:

BOOKS

AGARWAL, A., NARAIN, S. and SEN, S. (1997) Eds. *Dying Wisdom: State of India's Environment,* Centre for Science & Environment, New Delhi

AGARWAL, A., NARAIN, S. and KHURANA, I. (2001) Eds., *Making Water Everybody's Business*, Centre for Science & Environment, New Delhi

CHENNAI METROPOLITAN DEVELOPMENT AUTHORITY, (2007), *Second Master Plan for Chennai metropolitan area -2026*, Chennai

MOTT MAC DONALD, (1995), *Madras metro flood relief/ storm water drainage master plan study*, Cambridge, UK

ROBERT L. FRANCE, (2002), *Handbook of Water Sensitive Planning and Design,* Harvard University, Cambridge, Massachusetts, USA

PUBLISHED PAPERS:

GUMBO,B., (2000), *Mass balancing as a tool for assessing integrated urban water management,* Department of Civil Engineering, University of Zimbabwe.

NIEMCZYNOWICZ . J, (1999), *Urban hydrology and water management –present and future challenges,* Department of Water Resources Engineering, University of Lund, Sweden

PAULEIT,S.,DUHME,F., (2000), *Assessing the environmental performance of land cover types for urban planning*, In: Journal of landscape and Urban planning

THESIS BOOKS:

RAJESH, G., (2002), *Planning guidelines for Rainwater Harvesting in residential areas of Chennai,* Department of Architecture and Regional Planning, IIT- Kharagpur.
SABHERWAL , P., (2006), *Planning for water supply management, Nagpur* , Department of Architecture and Regional Planning, IIT- Kharagpur.
SEN , S., (2005), *Water sensitive urban development- Planning provisions at residential cluster level, Medinipur, West Bengal,* Department of Architecture and Regional Planning, IITKharagpur.

WEBSITES:

www.wsud.org
www.wsud.melbournewater.com.au/
www.urbanwater.info
www.environment.nsw.gov.au/
www.technion.ac.il/technion/civil/
www.lid-stormwater.net/

THANK YOU