WATER RESOURCE MANAGEMENT POLICY FOR SUSTAINABLE DEVELOPMENT OF AN URBAN AREA

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree

of

DOCTOR OF PHILOSOPHY

in

ARCHITECTURE AND PLANNING

by

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **WATER RESOURCE MANAGEMENT POLICY FOR SUSTAINABLE DEVELOPMENT OF AN URBAN AREA** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Hydrology of the Indian Institute of Technology Roorkee is an authentic record of my own work carried out during a period from January, 2004 to December, 2010 under the supervision of Dr. R. K. Jain, Associate Professor, Department of Architecture and Planning and Dr. Deepak Khare, Professor, Department of Water Resource Development and Management, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

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Tejwant Singh Brar.

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

Sustainable Urban Development refers to community and societal development that "meets the needs of the present without undermining the environment or social systems on which we depend". Sustainable development has become an important guide to many communities which have discovered that traditional approaches to planning and development are creating, rather than solving, societal and environmental problems. The concept also embodies the belief that the world has "finite resources" and, consequently, in order to continue improving the quality of life for future generations, societies must adopt coordinated approaches to planning and policy making which involves the individual and public on both local and international level. Water is key to sustainable development, crucial to its social, economic and environmental dimensions. Water is life, essential for human health. Water is an economic and social good, and should be allocated first to satisfy basic human needs. Water security is a key dimension to poverty reduction.

World population currently stands at 6 billion with 47% living in urban areas. Early in the next century, more than half of the **world's** population will be living in urban areas. It is estimated that by the year 2025, proportion will rise to 60%, comprising some 5 billion people. Rapid urban population **growth and** industrialization are putting severe strains on the water resources and environmental protection capabilities of many cities. Special attention needs to be **given to** the growing effects of urbanization on water demands and usage and to the critical role played by local and municipal authorities in managing the supply, use and **overall** treatment of water, particularly in developing countries for which special support is needed (Dorota Z. Haman, 2002)

Indian Scenario

India is one of the few countries in the world endowed with abundant land and water resources, it is the seventh largest country in the world and Asia's second largest country with an area of 3,287,590 km^2 (Compendium of Environment Statistics, 1997). Most of the Indian landmass is semi-arid tropical belt characterized by seasonal rainfall lasting over a period of three to four months i.e., June to September over a span of roughly 100 days (Meteorological Department, GOI). The water resources of India are enormous but they are unevenly distributed in space, time and quantity.

Average annual precipitation including snowfall over the country is 4000 billion cum. (BCM), in addition; it receives another 200 BCM from river flowing in from other countries. Average annual water resources in various river basins are estimated to be 1869 BCM of which the utilizable volume of water that has been estimated to be 1086 BCM including 690 BCM surface water and 396 BCM of ground water. Rest of water is lost either by evaporation or by flow into the sea (Compendium of Environment Statistics, 1997).

The population of India was 0.846 billion in 1991 and per capita availability of water in India was 2301 cum/year as against the per capita availability of water in World in 1991 was 9231 cum/year. But this is still more than the average per capita demand of 649 cum/year in India in 1991. Out of 100 countries India's position in per capita water availability is 42nd in 1991. Per capita Availability of water is further expected to be reduced to 1563 cum/year by 2010 (Compendium of Environment Statistics, 1997).

Need Of Study

The urban population in India is presently about 27.8% of the total population (Census of India, 2001) and is expected to reach 50% by 2050 at the present growth rate. This number would be 820 million by 2050 (Agrawal, C.S., Mittal, S., Goyal, H., 2000), which would further aggravate the currently strained water resources in the urban areas. With rapid urbanisation along with industrialisation there is a rapid increase in demand of water supply

but resources are limited. It has resulted in increase in wastewater and untreated sewage which constitutes 80% of the total quantity of water supplied for city. (Report of The National Commission On Urbanisation, 1988). Hence there is a need to evolve - "Water Resource Management Policy for Sustainable Urban Development."

There is a severe shortage of water supply in many parts of the country and in almost all the urban centers. Population pressures along with neglect of water resources while planning in urban areas has resulted result in –

- Growth of city in low lying areas,
- Depletion of ground water (due to excess discharge than recharge of ground water),
- Environmental degradation of water bodies due to disposal of untreated domestic sewage & industrial effluents.

With growing urban population no thought was given to about ever-increasing gap between supply and demand. In most of the urban areas only ground water is used to fill this gap. There is a steep fall in ground water levels in most of the urban areas as water discharge is higher than recharge. In our country in race for rapid industrialization there were no checks on wasteful technology and pollution of water resources and industry still continues to be the biggest polluter of water resources. This is also the case in Punjab inspite of having three rivers of Indus river basin and network of Canals the main source of Urban water supply is the ground water. This had lead to over exploitation of ground water mainly in the class-I towns of Punjab. There is heavy extraction of water in four highly urbanised districts of Punjab – Ludhiana, Jalandhar, Amritsar and Patiala. The ground water table in state is falling at the rate of 70 – 75 cms per year. The area where water depth has gone below 10m increased from 3% in 1973 to 46% 1994

Urban Water Cycle

The hydrologic cycle has been used to represent the continuous transport of water in the environment (Asano, 1998). The urban hydrologic cycle comprises water supply, wastewater disposal, and stormwater runoff systems, making up the total urban water system. However, the history and fragmentation of the water industry has meant that current research is dominated by detailed modelling of only sub-components of the total water system (Newall et al., 1998). Particularly, the interaction between the potable water supply–wastewater discharge network, and the rainfall–stormwater runoff network, is rarely considered. In order to provide a complete picture of the spatial and temporal pattern of water demand and stormwater and wastewater supply, the water balance approach must be adopted along with the nature of urban development. The conceptual model developed to represent the urban water balance, known as Aquacycle, is given in Eq. (1), also known as water balance model; arrows show the way in which water flows between the various surfaces and storages. The urban water cycle receives input both from precipitation and imported water, which together pass through the system and output in the form of evapotranspiration, stormwater, or wastewater. The state of the water stores is used to calculate the change in storage within the system.

$$P + I = E + R_s + R_w + \Delta S \qquad (1)$$

Study Area

Patiala City was founded in 1763 A.D. by Baba Ala Singh when he laid the foundation of "Qila Mubarak". The earlier development of the town spread around the Fort and mud wall (Kot) surrounded the town, this mud wall was demolished in 1878 AD but quite a number of gates still remain. The Moti Bagh Palace whose design is based on the "Shalimar Garden Lahore" with terraces fountains, Canals and Sheeshmahal is a combination of Mughal and Rajput Architecture. The Palace was built in 1880 A.D near Bir Moti Bagh on banks of "Patialwi Nadi".

Patiala city was built on high ground surrounded by low lying areas with number of small and large drains and other water bodies. To protect the city from ravages of annual floods a proper drainage network for the walled city was designed in 1870 A.D. with all the drains of the city culminating in "Ganda Nallah" / "Jackob Drain". The two defence bandh's against floods namely – first one forming outer edge of defence of the city and second on the Patialawi Nadi, were executed in 1889 A.D.

After independence Patiala is a seat of Divisional Administration with office of commissioner and other division and state level offices like Income Tax Commissioner, Excise and Taxation Commissioner, Head Quarters of PWD- B&R, and Punjab Public Service Commission D.C.W and National Institute of Sports. With the location of these Important Offices Patiala has developed into a forefront Service City. The city is also an important centre of trade and commerce and is famous for Gota, Kinari and Embroidery work. Patiala is also an important educational centre with a university, four Arts and Science Colleges, a Commerce College, Two Medical Colleges, a Engineering College, a State Education College, a College of Physical Education, Two Polytechnics, etc. All this has lead to the rapid

The Patiala planning area lies between latitudes 30°24'-10" North & 30°16'-10" North and longitudes 76°20'-30" East & 76°29'-40" East. The Patiala city is the division and district head quarter of Patiala division and district. It lies in the South Eastern part of state of Punjab. The city is surrounded by Bhakhra main line canal and model town drain on East, Patialwi nadi on the west and wild life Sanctuary - Bir Moti Bagh and protected forest Bir Kheri Gujjran on the South. Patiala Being a Division Headquaters, and a service city has grown rapidly after independence, its Population has increased from 53,000 in 1951 to about 4.0 lakh in 2001. Patiala being a multifunctional town has medium growth rate between 30% and 35%.

Demography

- Patiala is fourth largest, Class-I city of Punjab according to Population size. Population of Patiala Municipal Corporation is 3,60,663 persons in 2001 with decadal variation/growth of +35.63%.
- Population of rural areas of planning area is projected as 49,055 (approximately). The growth rate has been taken as +21.19% i.e. growth rate of rural population of Patiala tehsil in 1991.
- Taking rate of Projection for urban population (i.e. M.C. Population) as +35.63% and that of rural population as +19.0% from the growth rate of last decade. Total projected population of planning area is 7,22,000 for 2021 and 9,70,000 for 2031.

Objectives

- To identify the existing water supply system and study the water resource management policies in the study area
- To estimate the potential of all possible water resources in the study area.
- To prepare the water resource management plan of the study area
- To identify and prepare the most appropriate water resource management policy for sustainable urban development applicable for both developed as well as newly planned areas.

Methodology

- Water resources in an area can be divided into –Surface and Sub-Surface water resources. Both of these depend on – Climate, Geographical location, Topography, and Geology of the area. Thus water resources of an area have a regional character and their behavior can't be studied in isolation to evolve the water resource management policy of an urban area. Therefore the present water resource management in the study area is analyzed in detail and the existing water resources are studied. Unit Hydrograph is prepared with the catchments characteristics and rainfall data to access the surface water quantity. Ground water resources estimation is made using existing practices.

- For the database generation GIS has been used and to understand the impact of urbanization, landuse data in time series has been used.
- Assessment of water resource management policies in each urban settlement has been done using GIS and analytical models like SCS Dimensionless Hydrograph, Rational Method etc.
- Water resource management plan for Study region and generalizing it to evolve a Water Resource Management Policy for Sustainable Urban Development applicable for both developed as well as newly planned area.

Salient Findings Of Research

In order to provide a complete picture of the spatial and temporal pattern of water demand and stormwater and wastewater supply, the water balance approach will be adopted, i.e. the application of the principle of mass conservation to water (Grimmond et al., 1986), given in Equation – (1) . This will account for the movement of water in the land phase of the hydrological cycle for a given area of land and a selected time interval (McPherson, 1973).

The Urban planning process has been studied and found to be lacking in consideration for hydrology of the area. When ever the master plans are prepared there is found to be no studies undertaken regarding the water availability, supply and infrastructure requirements for the future. To overcome this lacuna in planning process the water balance approach has been adopted. Various tools such as ArcView GIS, ERADAS and Excel Spread sheet have been used in data preparation and analysis.

Data for Landuse and Contours has been collected from DTP Office and Existing landuse has been updated using Remote Sensing Imagery. While the data for Water resources from various sources has been collected in time series basis has been collected and analysed using Excel Spread sheet. Arithmetic Overlay models have been used to found land suitability with respect to drainage pattern of the planning area Using D.E.M. and Existing landuse map. Major findings of this Analysis are that with time due to lack of planning w.r.t. water resources, the development in Patiala has taken place in low-lying areas. As ground water has been used as the only source for water supply while other sources like canal water available in the area are being wasted, this has resulted in fall in ground water at an alarming rate of 0.25m. Due to lack of sewage treatment facilities in the city and disposal of untreated sewage in city drains has resulted in ground water pollution in 2029 hectares (i.e. 20.9% of total developed area) and total population affected by it, is 215218, i.e. 41.1% of total population.

Three different models for the horizon year of 2031 have been generated using GIS and Excel Spread sheet and have been compared.

- In the demand and supply model, the status quo is maintained and conventional technologies have been used for water resource management. This will result in need of 332 Tube wells, Trunk sewer of size between 0.70m – 1.80m. with a centralized sewage treatment plant with a capacity of 400 MLD and a drainage network for run off disposal with a size varying between 0.70m to 2.5m. This will result huge expenditure and over all depletion of ground water at 0.75 m per year.

- In the hybrid model Ground water supply is supplemented with canal water and use of rain water harvesting at both domestic and community level, for which Water Sensitive Urban Controls have been Proposed for each land use, but for sewage disposal conventional technology is adopted resulting in non depletion of ground water, Trunk sewer of size between 0.70 m – 1.80 m with a centralized sewage treatment plant with a capacity of 400 MLD and a drainage network for run off disposal with a size varying between 0.70 m to 1.2 m.

- In the Integrated Land and water resource management model, Ground water supply is supplemented with canal water and use of rain water harvesting at both domestic and community level, for which Water Sensitive Urban Controls have been proposed for each land use, and sewerage network for the city is proposed to be a combination of Centralized sewage disposal network in high density areas and decentralized sewage treatment plants in new and low density areas. The type of sewage network for an area has selected using arithmetic overlay analysis. This will result in over all rise in ground water in the area by 0.15 m – 0.25 m, Trunk sewer size is also reduced to 0.7 m – 1.2 m and a drainage network for run off disposal with a size varying between 0.70 m to 1.2 m.

By adopting surface water (Canal water – 269.2 MLD) for urban water supply, ground water recharging structures at sector level, the changes in the building bye laws to encourage rain water harvesting, and ground water recharging structures in low-lying area i.e. in drains and low-lying areas (with total effective recharge – 53.8 MLD), and Recycling of sewage/wastewater (total quantity – 246.9 MLD) for recreational and other uses (demand – 81.4 MLD) will not only reduce the rate of water consumption from 135 lpcd to less than 90 lpcd but will also result in reducing the demand of ground water to 39.4 MLD; Thus resulting in net rise in ground water level Therefore adopting a sincere effort to implement integrated water resource management plan can turn around the scenario, which at present looks grim.

Conclusions and Recommendations

Proposed residential development must be located above 252 m contour level. No land use other than recreational and open areas must be located in low lying areas i.e. below 250m contour level, at city level and recreational land use at suitable places in sectors must be proposed according to slope analysis of site to act as a catchment for the runoff generated in a sector. The water sensitive urban controls must be proposed for each land use

Circulation should be such as to consolidate the existing surface water resources. Existing water bodies must be preserved and the water bodies which have become redundant must be revived. Existing reserved forest must be preserved and a green belt around it must be created to have a buffer between forest and the developed areas.

Integrated Land and water resource management model must be adopted for sustainable water resource management in Patiala planning area. Water supply should be a designed to be a combination of ground water, canal water, rain water harvesting and waste water recycling. Groundwater recharging at neighbourhood level, sector level and city level must be adopted to recharge the groundwater and it will also help to reduce the runoff generated. Minimum pervious area for each building must be fixed to reduce the runoff generated. Water supply must be designed to exploit both surfaces as well as groundwater resources to avoid over exploitation of groundwater.

Sewerage network for the city must be a combination of Centralized sewage disposal network in high density areas and decentralized sewage treatment plants in new and low density areas and sewage must be treated before disposal to avoid contamination of ground water and drains. All industrial and commercial areas must have there own effluent treatment plants be made mandatory.

ACKNOWLEDGEMENTS

At very first instant, the author bows his head with reverence to Him who is omnipresent, omnipotent and omniscient and is the cause behind every effect.

It gives me immense pleasure to express my profound indebtedness, heartfelt gratitude and reverence to my supervisors Dr. R.K. Jain, Associate Professor, Department of Architecture and Planning, IIT Roorkee and Dr. Deepak Khare, Professor, Department of WRDM, IIT Roorkee, for their invaluable guidance, constant encouragement, moral support, and wholehearted co-operation during this research work in spite of their busy schedules. Their painstaking efforts in going through the manuscript and personal interest into the research work can not be described in words. I wish to express my gratitude to the respected families of my supervisors for their love and blessings during the research work.

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LIST OF ABBREVIATIONS

ACN	-	Average Curve Number
AFSD		Authorised Full Supply Discharge
AMO		Arithmetic Mean Overlay
BCM	:	Billion cubic metre
bgl	:	Below ground level
BIS	:	Bureau of Indian Standards
BOD	:	Biological / biochemical oxygen demand
CGWB	:	Central Groundwater Board
CN		Curve Number
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
CPHEEO	:	Central Public Health and Environmental Engineering Organisation
CRASH	:	Catchment Resources and Soil Hydrology
CTS	:	Central wastewater Treatment System
D.T.P.	:	District Town Planner
DEM	:	Digital elevation model
DO	:	Dissolved oxygen
DRH	:	Direct Runoff Hydrographs

DRRWH	:	Domestic Rooftop Rain Water Harvesting
DTS	:	Decentralised Waste Water Treatment System
e.g.	:	For example
EC	:	Electrical conductivity
ERDAS	:	Earth Resources Data Analysis System
et al.	:	And others
etc.	:	Etcetera
Fig.	:	Figure
GEC	:	Groundwater Estimation Committee
GeoTIFF	:	Geographic Tagged Image File Format
GIS	:	Geographical Information System
GOI	:	Government of India
GPS	:	Global Positioning System
HFL	:	Highest Flow Level
HSG	:	Hydrologic soil group
http	:	Hypertext transfer protocol
i.e.	:	That is
IIT	:	Indian Institute of Technology
ILWIS	:	Integrated Land and Water Information System

IMD	: India Meteorological Department
IRS	: Indian remote sensing satellite
ITPI	: Institute of Town Planners, India
IUWM	: Integrated urban water management
KM	: Kilo Meter
LISS	: Linear imaging self scanner
lpcd	: litres per capita per day
LULC	: Land use-land cover
MLD	: Million Litres Per Day
MoEF	: Ministry of Environment and Forest
MPN	: Most Probable Number
MSS	: Multi-spectral scanner
NMR	: Normal monsoon season rainfall
No.	: Number
OHSR	Over Head Service Reservoir
PDA	: Patiala Development Authority
pH	: Power of Hydrogen
PUDA	: Punjab Urban Development Authority
PWSSB	: Punjab Water Supply And Sewerage Board

RIF : Rainfall Infiltration Factor

SBC : Soil Bearing Capacity

SCS : Soil Conservation Service

SUH Synthetic Unit Hydrograph

SWARGEM : Small watershed Runoff Generation Model

TCPO : Town and Country Planning Organisation

TIN : Triangulated Irregular Network

UDPFI : Urban Development Plans Formulation & Implemantation

USA : United States Of America

WCED : World Commission on Environment and Development

WLF : Water Level Fluctuation

CHAPTER – 1

INTRODUCTION

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Sustainable Development refers to community and societal development that "meets the needs of the present without undermining the environment or social systems on which we depend". Sustainable development has become an important guide to many communities which have discovered that traditional approaches to planning and development are creating, rather than solving, societal and environmental problems. The concept also embodies the belief that the world has "finite resources" and, consequently, in order to continue improving the quality of life for future generations, societies must adopt coordinated approaches to planning and policy making which involves the individual and public on both local and international level. Water is a key to sustainable development, crucial to its social, economic and environmental dimensions. Water is life, essential for human health. Water is an economic and social good, and should be allocated first to satisfy basic human needs. Water security is a key dimension to poverty reduction.

1.1 URBAN WATER CYCLE

The hydrologic cycle has been used to represent the continuous transport of water in the environment (Asano, 1998). The urban hydrologic cycle comprises water supply, wastewater disposal, and stormwater runoff systems, making up the total urban water system. However, the history and fragmentation of the water industry has meant that current research is dominated by detailed modelling of only sub-components of the total water system (Newall et al., 1998). Particularly, the interaction between the potable water supply–wastewater discharge network, and the rainfall–stormwater runoff network, is rarely considered. In order to provide a complete picture of the spatial and temporal pattern of water demand and stormwater and wastewater supply, the water balance approach must be adopted along with the nature of urban development. The conceptual model developed to represent the urban water balance, known as Aquacycle, is given in Eq. (1.1), also known as water balance model; arrows show the way in which water flows between the various surfaces and storages. The urban water cycle receives input both from precipitation and imported water, which together pass through the system and output in the form of evapotranspiration, stormwater, or wastewater. The state of the water stores is used to calculate the change in storage within the system.

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Urbanization affects the Water Resources in following ways (Fig 1.1):

- *Water resources get overexploited:* These are over exploited when single source is exploited while others are neglected e.g. ground water is used while surface resources are neglected.
- *Water resources are polluted:* By disposing of untreated sewage in drains & other water resources resulting in Pollution of drains as well as ground water.
- *Water resources are eliminated / destroyed:* Water resources are destroyed by filling up of ponds, lakes & drains resulting in disruption of natural drainage pattern of city.
- *Natural calamities like flood, water logging:* These are caused by development in low-lying areas with poor drainage or the development resulting in destruction of existing natural drainage of site.

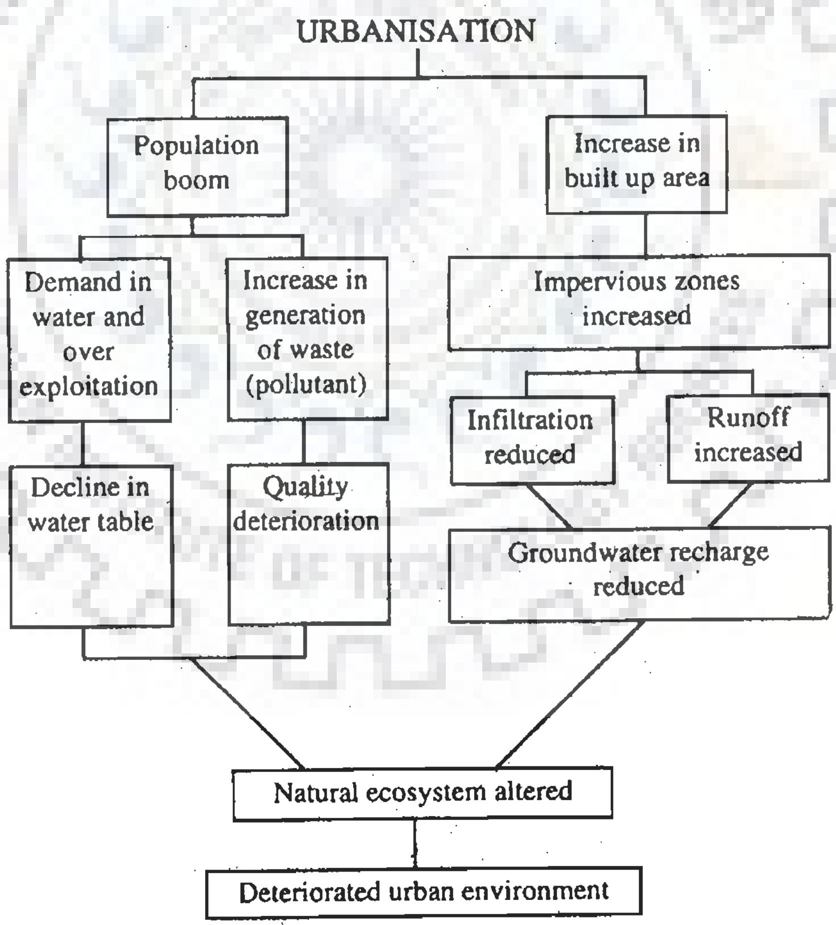

Fig 1.1: Impact of urbanization/ development on water resources.

Source : Groundwater in Urban Environment, John Chilton.

1.2 AVAILABILITY OF WATER

World population currently stands at 6 billion with 47% living in urban areas. Early in the next century, more than half of the world's population will be living in urban areas. It is estimated that by the year 2025, proportion will rise to 60%, comprising some 5 billion people. Rapid urban population growth and industrialization are putting severe strains on the water resources and environmental protection capabilities of many cities. Special attention needs to be given to the growing effects of urbanization on water demands and usage and to the critical role played by local and municipal authorities in managing the supply, use and overall treatment of water, particularly in developing countries for which special support is needed (Dorota Z. Haman, 2002).

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There is a severe shortage of water supply in many parts of the country and in almost all the urban centers. Population pressures along with neglect of water resources while planning in urban areas has resulted result in –

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1.5 OBJECTIVES

In view of the importance of the water resources management for an urban area following objectives are outlined:

- To identify the existing water supply system and study the water resource management policies in the study area
- To estimate the potential of all possible water resources in the study area, Patiala.
- To prepare the water resource management plan of the study area
- To identify and prepare the most appropriate water resource management policy for sustainable urban development applicable for both developed as well as newly planned areas.

1.6 SCOPE

The scope of the study is:

- Study the growth of Patiala Planning area with respect to existing water resources of the Patiala Planning Area under following parameters :
  - Number, Type and Capacity of resource.
  - Catchment area of resource
  - Low lying and relatively high area and thus, to evolve suitable strategy for urban planning and development of Patiala (Planning area).
- To study :
  - The demand and supply of water in Patiala planning area and also type of network and its capacity.
  - The sewerage network, its capacity, method of disposal, number of disposal points and quantity of sewage disposed.
  - The drainage network, its type and capacity
  - To evolve suitable strategy for water budgeting.
- To study the various mater plans (1971-1991) and revised 1985-2005) in light of :
  - The Planning process adopted with respect to water resources.
  - The proposed land use with respect to water resources in Patiala

1.7 LIMITATIONS

The present study has following limitations:

- The data collected from surveys and studies for the study – Water Resource Management Policy For Sustainable Development Of An Urban Area, in almost all the cases from the reliable secondary sources.
- Primary survey is done only for the drainage network, vegetation and open spaces. The studies and surveys for data collection and compilation from relevant sources is undertaken separately for each component.

1.8 METHODOLOGY

It refers to the systematic/ stage wise steps to achieve the goal of a research/study. The success or failure of a project largely depends upon the methodology that is followed. A proper methodology saves time and reflects clarity and understanding of the topic. The present study has been divided into five stages (Fig 1.2).

1. Definition of Scope and Formulation of objectives.
2. Literature study
3. Collection and analysis of data
4. Projections
5. Recommendations

1.8.1 Scope

Scope of a study is defined to remain focus on the identified problems of Urban Planning and Development with respect to water resources in Patiala and to define the area of study. The scope is defined by studying books, journals and previous studies. The basic aim of this stage is the formulation of objectives.

1.8.2 Literature Study

Literature search has been done to clarify the concepts, definitions, development of cities with respect to water resources, measures adopted to integrate water resource planning with urban planning and norms and standards for infrastructure. This entire literature search has been carried out through books, journals and previous studies. The basic aim of this stage is to form a theoretical framework to identify parameters to examine Urban Planning and Development strategies with respect to water resources.

1.8.3 Collection and Analysis of Data

Data has been identified to define Urban Planning and Development of city with respect to identified physical parameters. The collection of data has been done through various Primary and Secondary Sources. Various organisations/Offices like D.T.P Office etc. has been visited for collection of data. Critical areas and issues have been identified in this stage on basis of various parameters.

Water resources in an area can be divided into –Surface and Sub-Surface water resources. Both of these depend on – Climate, Geographical location, Topography, and Geology of the area. Thus water resources of an area have a regional character and their behavior can't be studied in isolation to evolve the water resource management policy of an urban area. Therefore water resource management in the study area is to be analyzed in detail and the existing water resources are to be studied using various types of synthetic Unit Hydrographs, prepared for different catchments, characteristics and rainfall data to access the surface water quantity. Ground water resources estimation is made using existing practices. For the database generation and analysis in time series GIS is to be used and to understand the impact of urbanization and different land uses on water resources in each urban settlement is to be done using GIS and analytical models like SCS Dimensionless Hydrograph, Rational Method etc.

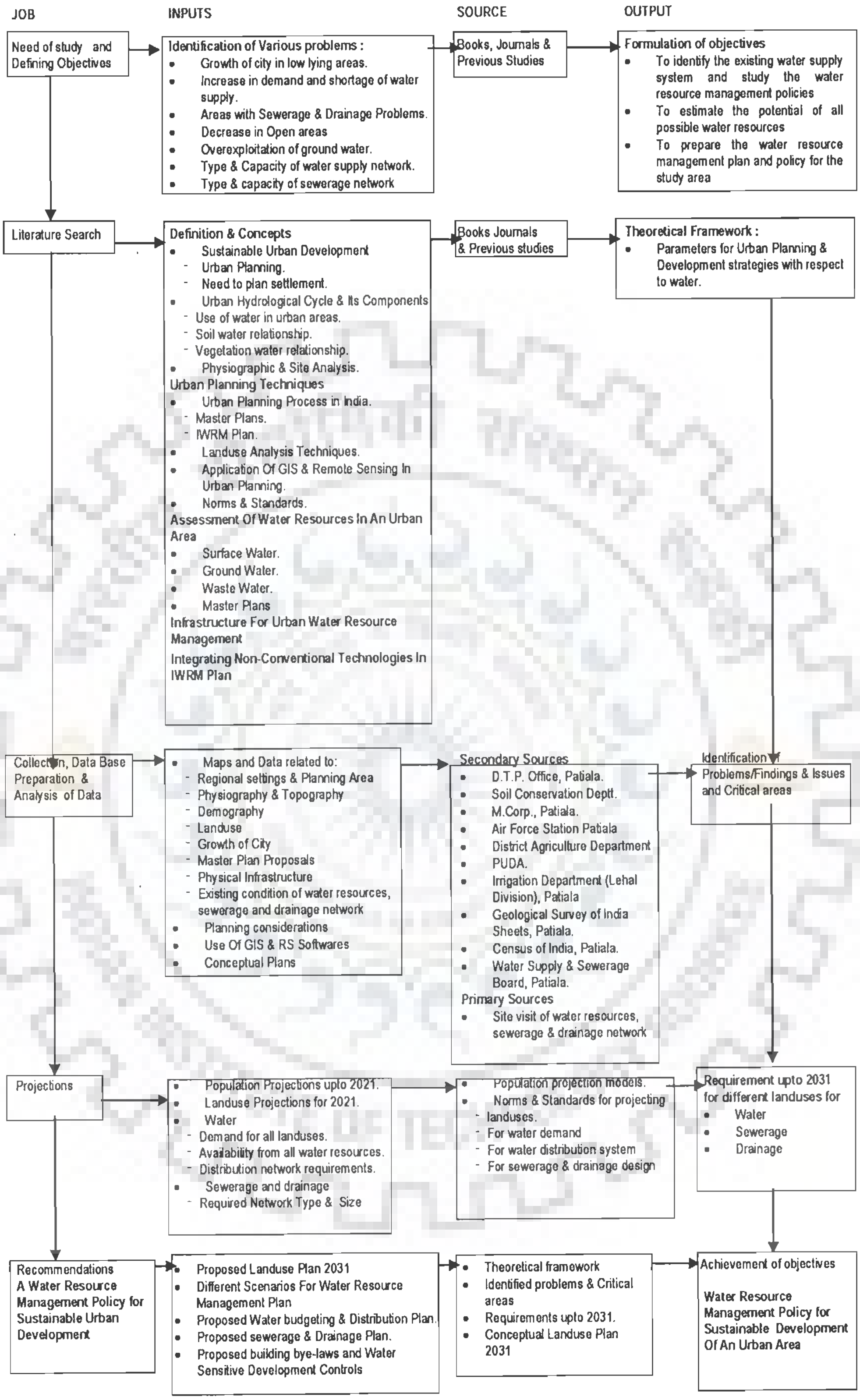
1.8.4 Projections

Projections have been done for population, land use, and infrastructure for year 2021. Projections have been done to formulate requirements of water supply and utility network for 2021.

1.8.5 Recommendations

This stage involves formulation of policy to achieve the objectives. This has been done by formulation of conceptual plan and land use, water distribution, sewerage and drainage details, building bye laws and water sensitive development controls.

Fig – 1.2: METHODOLOGY



CHAPTER – 2

LITERATURE REVIEW

CHAPTER – 2

LITERATURE REVIEW

Over the last two decades there has been process of rapid urbanisation in Punjab, this is especially true in class-I and II towns, which have increased both in number and size i.e. population. The growth of cities had lead to increase in pressure on land and natural resources (water vegetation, drainage pattern) in cities. This had lead to acute shortage of amenities i.e. water supply sanitation, and drainage problems in newly developed areas of these cities as no consideration as given to site Analysis (slope, drainage water resources, soil, climatic, etc. analysis). Hence to avoid these problems due to lack of integration of planning of natural resource availability, there is need to integrate site analysis as an integral part of comprehensive planning exercise along with the projections/ requirements of resources for the future.

To know the nature and magnitude of relationship between urban planning and development with water resources, retrospection is required to be done. For this purpose understanding of basic concepts and definitions related to urban planning and development, water resources, site analysis etc. is essential. It is necessary to understand the development of cities with respect to the resources of water available in that city. It is also necessary to understand the measures to be adopted at various stages of planning to integrate water resource planning as an integral part of urban planning and development. Hence a literature study is needed which is divided into following aspects:

(i) Definition & Concepts

- Sustainable development
- Urban Hydrological Cycle & Its Components
- Use of water in urban areas.

(ii) Urban Planning Techniques

- Urban Planning Process In India
- Landuse Analysis Techniques
- Application of GIS & Remote Sensing in Urban Planning
- Norms and Standards

(iii) Urban Water Resource Planning & Management

- Assessment Of Water Resources In An Urban Area.
- Infrastructure For Water Resource Management.
- Integrating Non-Conventional Technologies in Urban Water Resource Management Plan.
- Integrated Water Resource Management Plan.

2.1 DEFINITION & CONCEPTS

2.1.1. Sustainable development

The World Commission on Environment and Development defines sustainable development as "meeting the needs of current generations without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). This definition succinctly conveys a long-term future orientation (Smith, 1993), and acknowledges an ethical intergenerational obligation towards the satisfaction of human needs. Sustainable development implies a dynamic balance between maintenance (sustainability) and transformation (development) functions (Robinson et al., 1990) both directed towards human needs.

The WCED definition, however, provides an incomplete representation of the sustainability concept. Any characterization of sustainability forms, whether economic, social, or ecological (Goodland, 1994) reflects the dynamic nature of sustainability (consistent with evolving ecological, social and economic processes and conditions) (Niu et al., 1993); and acknowledges that sustainability will vary by context (Shearman, 1990), and will take many forms (i.e. a pluralistic model of sustainability) (Robinson et al., 1990). The concept should also consider aspirations, address the spatial dimension (i.e. not compromise the needs of one geographic area to meet the needs of another) (Niu et al., 1993), and include the needs of other species (Milbrath and Junker). Human, social and economic activities must operate within ecological limits (Sadler, 1990). Given this fundamental interdependence, natural capital should be maintained (Goodland, 1994), and we should strive for a symbiotic relationship with other species (Peacock, 1995).

Sustainable development is a process of achieving human development (widening or enlarging the range of peoples choices) (United Nations Development Programme, 1994) in an inclusive, connected, equitable, prudent, and secure manner. Inclusiveness implies human, ecological, social and economic interdependence. Equity suggests intra-generational, inter-generational, and inter-species fairness. Prudence connotes duties of care and prevention scientifically, technologically, and politically. Security demands safety from chronic threats and protection from harmful disruption (Khanna et al., 1991, 1999).

Sustainability initiatives will inevitably have normative ethical (e.g. redistributive) and socio-political objectives and repercussions (Sunderlin; Leith and O). For sustainability to be more than a noble set of needs and aspirations, sustainability objectives will need to be translated into operational criteria (Brooks, 1992). Obstacles to sustainability will need to be identified and sustainability instruments integrated into coherent strategies, with complete with defined roles for each stakeholder. In selecting and applying sustainability instruments, it is necessary to differentiate between material or quantitative growth and qualitative development (i.e. the realization of potential) (Goodland, 1994).

Planning for sustainable development needs to implicitly recognize that the economy is a sub-system of a finite regional ecosystem, and that while the indefinite growth of the economy is not possible, the qualitative development of non-growing systems is a distinct possibility. From a macroeconomic perspective, this would mean that the level of economy must be within the carrying-capacity of the region with limits on, and trade-offs between, population size and per capita resource use in the region.

Hence, planning for sustainable development involves exploratory search for resource use options, technology choices, system structural changes, and consumption patterns that result in continuously rising, or at least non-declining, equitable quality of life levels, and environmental status, while ensuring minimization of ecological loading exerted by the economic processes. Operationalization of such a scheme at the regional level entails identification of links between resource capacity, developmental activities, assimilative capacity, environmental status, economic progress, amenities and quality of life levels.

Lewis Mumford, who was critical of the rationalist approach, proposed the organic approach to planning. "Organic planning does not begin with a preconceived goal: it moves from need to need, from opportunity to opportunity, in a series of adaptations that are coherent and purposeful, so that they generate a complex final design" (Mumford, 1961). Planners of the organic approach emphasized the task of planners to "create order out of chaos ... adapt to changing conditions, and to act in a contingent manner".

2.1.2. Urban Hydrological Cycle & Its Components

Urban Hydrology is defined as the interdisciplinary science of water and its interrelationship with urban man (Jones, 1971), resulting in creation of large impervious areas, producing noticeable drainage problems, and urban hydrology was born out of the necessity to control these problems.

The hydrologic cycle has been used to represent the continuous transport of water in the environment (Asano, 1998). The urban hydrologic cycle comprises water supply, wastewater disposal, and stormwater runoff systems, making up the total urban water system. However, the history and fragmentation of the water industry has meant that current research is dominated by detailed modelling of only sub-components of the total water system (Newall et al., 1998). Particularly, the interaction between the potable water supply–wastewater discharge network, and the rainfall–stormwater runoff network, is rarely considered. In order to provide a complete picture of the spatial and temporal pattern of water demand and stormwater and wastewater supply, the water balance approach must be adopted along with the nature of urban development. The conceptual model developed to represent the urban water balance, known as Aquacycle, is given in Eq. (2.1) & Fig. 2.1, also known as water balance model; arrows show the way in which water flows between the various surfaces and storages. The urban water cycle receives input both from precipitation and imported water, which together pass through the system and output in the form of evapotranspiration, stormwater, or wastewater. The state of the water stores is used to calculate the change in storage within the system.

$$\mathbf{P + I = E + R_s + R_w + \Delta S} \qquad (2.1)$$

P = Precipitation; **I** = Imported Water

E = Evapotranspiration; $\mathbf{R_s}$ = Stormwater Runoff

$\mathbf{R_w}$ = Wastewater Discharge; $\mathbf{\Delta S}$ = Change In Storage

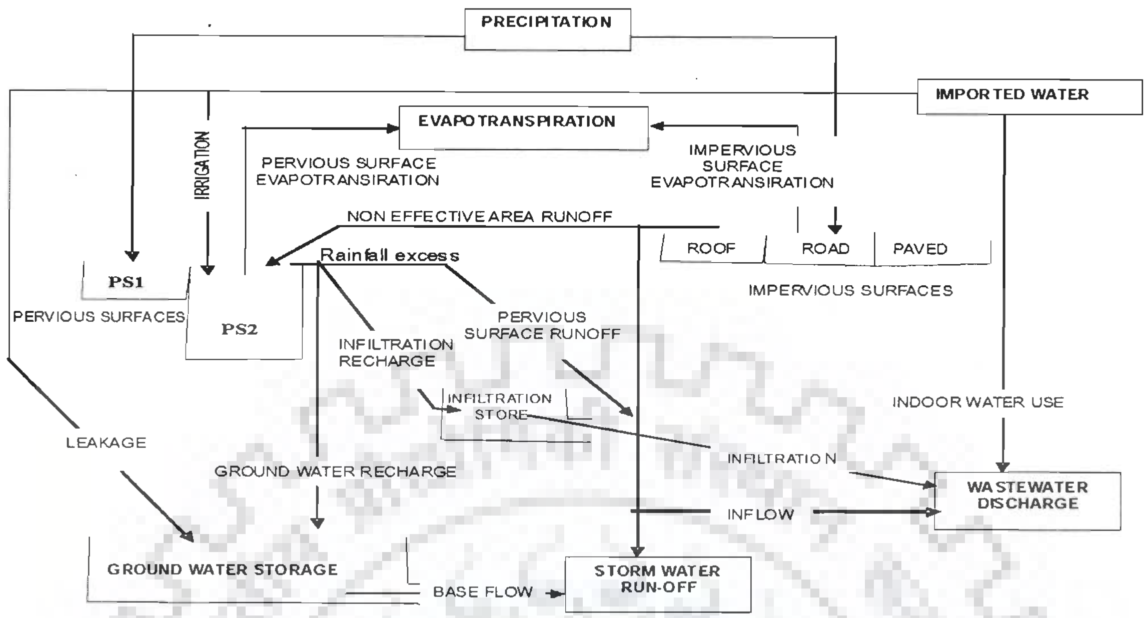


Fig. 2.1. Structure of the urban water cycle represented by Aquacycle.

Source : Modelling the urban water cycle, Mitchell, V.G., Mein, R.G., McMahon, T.A., (2001).

In thinking about sustainable development, one must view environmental capacity from a dynamic perspective and consider the time required for the restoration of the hydrological cycle. "Cycle capacity" refers to the time that nature needs revive the hydrological cycle. The use of groundwater should be considered from the point of view of cycle capacity. Rain seeps underground and over time becomes shallow stratum groundwater. Then, over a very long period of time, it becomes deep stratum groundwater. For sustainable use of groundwater, it is necessary to consider the storage capacity for groundwater over time. If this is neglected and groundwater is extracted too quickly, it will disappear within a short time.

2.2 URBAN PLANNING TECHNIQUES

Although Planning landuse is a complex process there are several major steps involved in it

- Stating landuse goals & Objectives.
- Surveying Optimal land suitability.
- Developing landuse design strategy.

- Preparing a final landuse plan.

Along with land use plan Socio-Economic planning must also be done. Land use plan is prepared by overlapping the potential Soil composition, land suitability & land value maps other factors like climate etc. must also be given due consideration when land use potential plan is integrated of combined with socio-economic variables to produce final alternative land uses. One of the important goal/objective while formulating a land use plan is to recognize the "thresholds of the site" i.e. resources especially water resources and avoid crossing them for process of planning land use while preparing Master plans (Fig. 2.2).

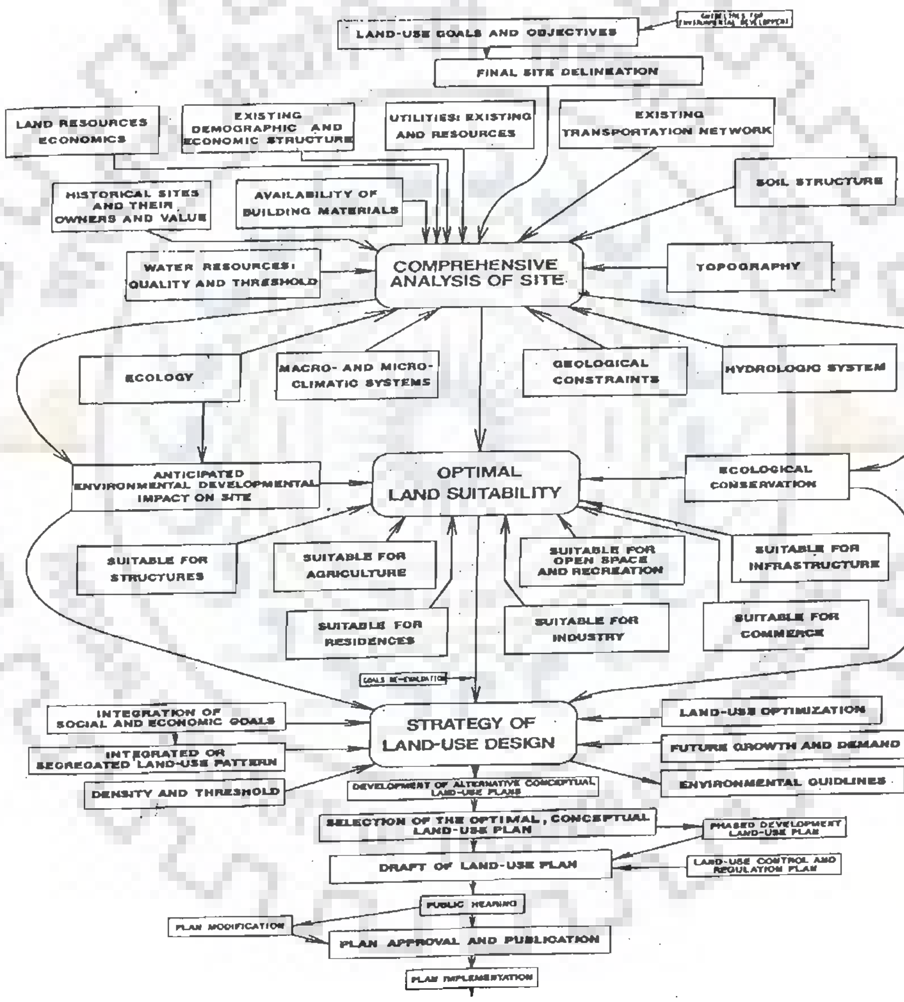


Fig. 2.2: Process of Landuse Planning

Source : Newtown Planning : Principles and Practice, Gideon Golany

2.2.1 Urban Land use Planning Process In India

Urban land use planning in India I governed under the framework provided by 74th Constitutional Amendment Act, 1992 and Urban Development Plans Formulation and Implementation (UDPFI) guidelines. 74th Constitutional Amendment Act, 1992 forms the basis for urban local governments, while UDPFI guidelines provide framework for the land use planning at different levels from regional to local level. The municipal government / local government has attained a special status at the third level after central and state level with urban planning and development as one of its major functions.

UDPFI guidelines for India has recommended urban land use planning process as a four tier structure which consists of – Perspective or Master plan, Development Plan, Annual plan and Action plans.

2.2.1.1 The Master plan

The master plan is a long term (20 – 25 years) written document supported by necessary maps providing the state government goals, policies, strategies and general programs of urban local authority regarding spatio-economic development of the settlement under its governance while other plans are conceived prepared and implemented according to the vision of the master plan. A Master plan gives the location and area of the various proposed land uses, the density of proposed development and the details of the development controls to achieve the proposed development. For the preparation of Master Plan, base plan 1: 10000 or large is used. The Master Plan is approved and adopted by the state and local authority for implementation with the help of development plans for each area and divided into different phases to be implemented over a period of 20 Years with appraisal of the development plans every 5 years and Master Plan modified accordingly.

2.1.1.2 Development Plan

Development plan prepared within the framework of the approved master plan is a medium term (5 year) comprehensive plan of spatio–economic development of the urban centre. The objective of a development plan is to provide further necessary details and intended actions in the perspective plan depending upon the economic and social needs and aspiration of the people, available resources and priorities. It contains implementation stratigies, agency wise schemes, projects, development promotion rules and resource mobilization plan. A development plan approved and adopted by the local authority for implementation with the help of schemes and projects and would be co-terminus with Five Year Plans of state governments / local bodies, which would provide opportunities to incorporate the needs and development aspirations of the people through the elected representatives. For this purpose base plan at 1: 4000 or larger along with trend of population growth are required.

2.1.1.3 Annual Plan

Annual plan is prepared to identify the new schemes / projects, which the authority will undertake for implementation during the year taking into account the physical and fiscal profomance of the preceding year, keeping in view the priorities, the policies and proporsals contained in the approved development plan. These plans also provide the resource requirements during the year and the sources of funding. It is thus an important document for resource mobilization as on its basis the plan funds will be allocated by the funding agencies. The base map up to the scale of 1: 2000 is sufficient for the preparation of annual plans.

2.1.1.4 Plans of Schemes / Projects

Plans of scheme / Projects are conceived within the framework of the Development Plan. These are working layouts, providing all necessary details for execution including finance, development, administration and management. These schemes / projects could be for any area or landuse development separately or in an integrated manner by any agency such as government, semi-government, private or even individuals or for any agency prepared by town planners, architects, engineers etc. The schemes / projects provide all the required planning, architectural, engineering financial and administrative details required for execution. These are prepared by respective agencies on a scale of 1:500 to 1: 1000 according to the requirements.

In Punjab the planning of utilities/physical infrastructure in urban areas is the responsibility of town and country planning department. The planning for the physical infrastructure is done while preparing the master plan of a city/ town. The preparation of master plan for a town is also included in "The Punjab regional and Town Planning and development act 1995" and is to be done by PUDA. After the 74th constitutional amendment 1992, Planning for a town has been given responsibility to the local bodies thus Municipal Councils, and Corporation can plan for their own land use and physical infrastructure (water supply and sanitation). Hence now, there is duplicacy of responsibilities for the planning provision and maintenance of water supply and sewerage under various development agencies these is a need to give the responsibility of planning provision and maintenance to a single agency.

2.2.2 Land use Analysis Techniques

2.2.2.1 Site Analysis

Site Analysis is defined as the process to critically evaluate the various physical components of site and its surroundings to exploit them to the full potential in the project. Major physical components/natural resource factors which are evaluated are:

i. Slope
ii. Water table
iii. Soil analysis
   - Porosity of soil
   - Soil Bearing Capacity (SBC)
iv. Depth of Bed rock
v. Vegetation
vi. Water bodies, like pond Lake Etc.
vii. Visual and aesthetic assets, such as water falls and historic buildings.

i) Slope analysis

Slope is ratio of horizontal distance to vertical distance.

- Slope Analysis is done to calculate the slope of the site, low lying area relative high points, foldable area and drainage pattern of the site.
- It is done by contour analysis of the site (Fig 2.3 & 2.4 and Table 2.1). At regional level contours of site are at 10-20m interval while at city level they are at 0.5 to lm interval.
- Slope less than 10% is suitable for construction of buildings, sewerage and drainage network of conventional design.
- For slope between 10% to 15% some grading may be necessary to prepare building sites. Sewerage, drainage and septic tank trench design should be adjusted to accommodate slope.

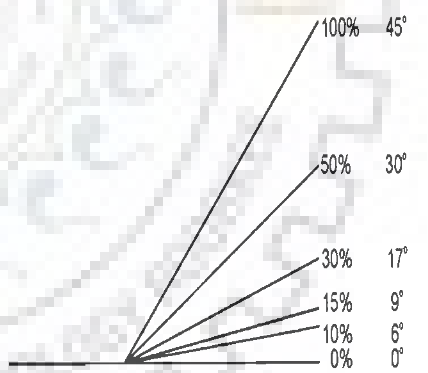


Fig 2.3: **SLOPE ANALYSIS**

- For slope greater than 15%, is hazardous for heavy equipment, considerable grading is necessary at building sites, requiring precaution against erosion and soil slumping. Extreme difficulty in laying sewerage, drainage and septic installation with use of grading and fill.
- Contour analysis along with flow in drains is required for delineating the favourable location of various land uses.
- Central contour i.e. watershed area is used to delineate various drainage zones of the area.

IMPORTANCE OF SLOPE ANALYSIS

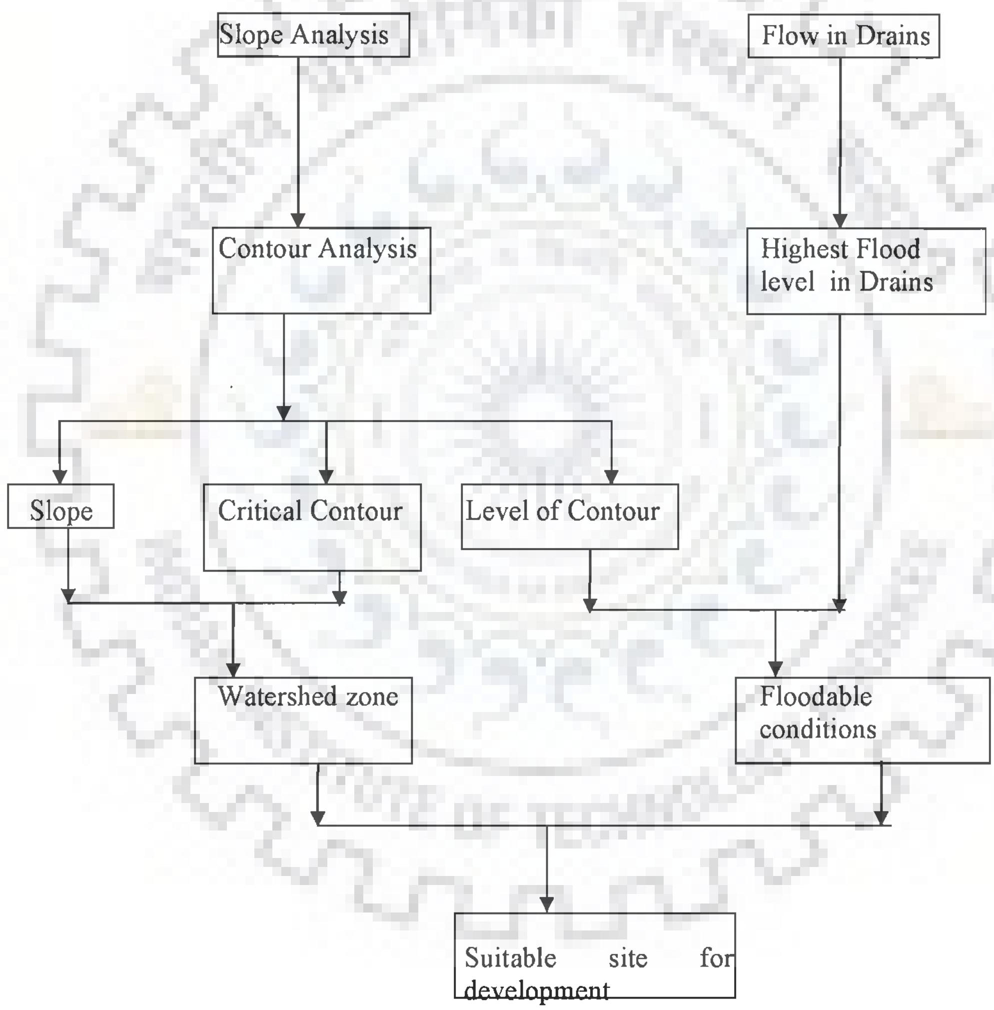


Fig 2.4: Importance of Slope Analysis in Urban Planning

Table 2.1: Criteria For Analysis Of Land use According To Topography And Drainage

S. No.	Landuse	Location
i)	Residential	2 m or above HFL of Drain
ii)	Commercial	2 m or above HFL of Drain
iii)	Industrial	2 m or above HFL of Drain
iv)	Public Semi Public	1 m or above HFL of Drain
v)	Transportation	0.5 to 1 m or above HFL of Drain
vi)	Recreation	0.5 m or above HFL of Drain

Source: Time Saver Standard for Residential Development, Joseph De Chiara (1985)

ii) Water table

It is the depth of ground water table.

- It is done to know which type of construction is suitable for the site and the areas where construction is not possible due to high water table.
- For water table greater than 3m conventionally designed basements, sewerage, drainage and septic system will not be flooded.
- For water table fluctuating between 1m to 3m building footings should be properly drained. Shallow foundations may be necessary. Sewerage drainage and septic systems require curtain drain and/ or use of fill material similar to existing soil.
- For permanently high water table i.e. wet lands there are sewerage limitation on development. Shallow foundations are required. Site preparation includes removal of organic material and replacement with clean fill. Elaborate drainage and fill necessary Sewerage and septic systems.

iii) Soil Analysis

It is done to calculate the type of foundation and infrastructure required in a particular soil type. It mainly has two components.

a) Porosity/ percolation rate of soil.

b) Soil bearing capacity of soil

a) Porosity/Percolation rate of Soil gives us the information about water retaining capacity of soil i.e. the rate at which water can flow through the soil.

It is necessary to adopt the type of design of building and infrastructure required for a particular soil type.

- If percolation rate is upto 8 min/ cm then conventional building design is adequate, standard sewerage, drainage and septic systems adequate in most cases. Special design needed where percolation exceeds 2 min/cm as it is too fast for adequate renovation.
- If percolation rate is between 8 min- 25 min/cm standard building design but larger leaching areas for disposal of sewerage, drainage and septic systems with standard or special trench design. Water mounding may occur because of slow percolation.
- For percolation rate more than 25min/cm standard building design severe limitations on drainage sewerage septic systems with extensive fill and or above ground system required.

b) **Soil Bearing Capacity**: It is the ability of soil to support the foundations. Soils with S.B.C. above 100 KN/m^2 are suitable to adequately support foundation while with soils below this mainly clays and wet land soil special measures are needed to prevent buildings from settling like raft or pile foundations.

iv) ***Depth of bed rock***

It is the depth at which the bed rock supporting the upper layers of soil is found. Its analysis is needed to adopt the type of foundation for building and type and method of laying infrastructure.

- For Depth of Bed rock greater than 3m conventional building design and sewerage, drainage and septic system design is adequate. Trench should be 1-2m below surface and at least 1.5m above bed rock.
- For Depth of Bed rock less than 3m sewerage, drainage and septic system trenches should be 1.5m above bed rock may be necessary for building sites. Foundations should rest on same material throughout.
- For numerous out crops above ground level then fill required for sewerage, drainage and septic system installation. Blasting required for building site preparation foundations should rest on gravel cushions to prevent uneven setting.

v) ***Vegetation***

Any vegetation like group of trees or any large tree must be protected and marked on site plan.

- Any protected forest, wet lands, wild life sanctuary must also be protected and must not be allowed to be exploited.
- Change in vegetation in an area over 15-20 years give information about change in water level and soil characteristics.

vi) Water bodies

If there are any existing water bodies like ponds, drains, lake etc they must not be disturbed or filled and exploited. They can be used for recreational purpose, also if filled it will disturb existing drainage pattern causing water logging back lash etc. There will also be problems like settlement of foundation etc.

vii) Visual assets

Visual assets of site like Ridge tops Valley bottoms vistas and views must be protected while planning a site and developed to exploit their maximum potential and developed as recreational open spaces.

viii) Aesthetic assets

There are historic buildings and assets like water falls etc. and must be protected and developed also as recreational areas.

2.2.2.2 Physiography Analysis

It includes:

i) Climatic Data

a) Seasons and their duration

b) Temperature

c) Precipitation (Rainfall)

d) Humidity (Relative and Absolute)

e) Wind (Direction and Speed)

f) Solar movements

ii) Location

iii) Mean height above sea level

i) Climatic data

a) **Seasons and their duration**

It is the number of seasons broadly a site has and with duration of each. This information is required to plan for the type of development suitable according to the seasonal variation of the area. There is a variation in demand of water with change in seasons.

b) **Temperature**

It is recorded as the mean maximum and minimum temperature for an area and gives us the information about the daily variation in day and night temperature and seasonal variation in temperature. This information helps us to plan and develop the type of building, design and material most suitable for particular area. There is also change in demand of water with change in temperature of a place.

c) **Precipitation**

It is of many types, Rainfall, snow, hail etc. It is calculated in millimetre information helps us to plan design and select material most suitable for the area. It also gives information about the type of development to be planned to maximize the exploitation of precipitation. There is increase or decrease in demand of water at a place from sources of water with the amount of precipitation.

d) **Relative humility**

It is the quantity of water vapours present in air by getting the information of R.H. we can calculate the days/ season with high R.H. and plan the development for comfort condition on those days. With change in relative humidity the demand of water also changes e.g. in rainy season when humidity is high the water demand is high.

e) **Wind (direction and speed)**

Information about Direction and speed of wind helps us in the orientation of buildings for maximum ventilation. If speed of wind is high the more evaporation takes place resulting in an increase in the demand of water.

f) **Solar movements**

They give information about the altitude, azimuthal and Zenith of sun at particular time of day in particular season and helps us to plan and design to exploit and avoid sun as per our requirements. The solar movement charts give us the information about the longitude and latitude of that place which inturn give us the information about the location and the seasons resulting in the demand of water of that place.

ii) Location

They give information about latitude and longitude of place. It gives us north of the site and helps us to prepare solar charts.

iii) Mean height above sea level

Mean height above sea level is important as there is variation in temperature at same latitude and longitude as we move above the sea level.

2.2.2.3 Soil Water Relationship

Soil and water are interrelated behaviour of surfaces water (i.e. run off generated) in an area depends largely on the type of soil in that area. The surface water loss (seepage) depends on the type of soil. For different types of soil it is (Table 2.2):

Table 2.2: Soil Water Relationship

S. No.	Type of Soil	Percentage
(i)	Sandy soil	70%
(ii)	Loamy soil	50%
(iii)	Clayey soil	15%
(iv)	Hard rock	2-5%

Source : Handbook of Civil Engineering, P.N. Khanna.

2.2.2.4 Vegetation Water Relationship

Vegetation and water are also interrelated. Vegetation protects soil from erosion and reduces the speed of surface water. It help absorbs water by soil thus augmenting groundwater in an area. Vegetation in an area also depends on the level and quality of groundwater. If groundwater level is low then vegetation usually is arid if it is high then evergreen trees are found.

2.2.3 GIS & Remote Sensing

Remote sensing is a tool to provide information on existing landuse and land cover and their updating and monitoring while GIS provides spatial data handling. Sattelite remote sensing can be used to provide accurate, unbiased and timely information about the urban areas. Masser (1998) emphasized that GIS must be seen as a special case of information as a whole. It is defined as "the information that identifies the geographic location and characteristics of natural features and boundaries on the earth". The definition makes distinction between two types of geographic information: location and attribute. Location is clearly important to make information geographic. However, location information without attribute information is of little inherent interest.

Remote sensing has brought miracle in the availability of the higher resolution imageries (Vyas et al., 2004)They are IRS-P6 Resourcesat imagery with 5.8 meter resolution, in multispectral mode, IRS P5 Cartosat imagery of 2.5 meter resolution with stereo capabilities and there are others like IKONOS and Quickbird with even higher resolution. Mahavir (2000) recommended spatial resolution of satellite images for various levels and scales of planning (Refer Table 2.3). High resolution images may be useful in working atscales varying from 1:500 to 1:2500 (i.e site planning, projects and schemes), relatively lower resolution images would be more useful for planning at scales varving from 1:25,000 to 1:50,000 or 1:100,000.

Table 2.3: Recommended Spatial Resolution Of Sattelite Images For Various Levels and Scales Of Planning

S. No.	Level	Scale(s)	Spatial Resolution Of Sattelite Imagery
1.	Regional Planning	1:50,000	72.5 m or lower resolution
		1:100,000	
		1:250,000	
		1:1000,000	
2.	Perspective Planning	1:50,000	36.2 m to 72.8 m resolution
		1:100,000	
		1:250,000	
3.	Development Planning	1:10,000	5.8 m resolution
		1:25,000	10 m resolution
		1:50,000	36.2 m resolution
4.	Annual Planning	1:5,000	5.8 m to 10 m resolution
		1:10,000	
		1:25,000	
5.	Project / Scheme / Site Planning	1:500	1 m to 5.8 m resolution
		1:1000	
		1:2,500	
		1:5,000	

Source :. Mahavir (2000)

2.2.3.1 Application of GIS & Remote Sensing in Urban Planning

Raghavswamy (2003) mentioned a variety of urban applications where satellite based remote sensing data are being applied. The important areas of applications are base mapping, urban sprawl / urban spatial growth trends, mapping and monitoring urban land uses, urban change detection and updation, urban utility and infrastructure planning, urban land use zoning, urban environment and impact / hazard assessment, urban hydrology, urban management models, census or urban population growth estimation, urban green belt or open spaces mapping. Donnay (1999) also highlighted the advantages of use of remote sensing information in urban planning

Urban remote sensing opens up enticing new prospects for comparing cities in terms of functional interrelationships and indicators of well being and integration of the study of spatial forms with an understanding of social, economic, cultural and political dimensions that led to their creation (Longley et al., 2001).

Mahavir (2003) emphasized the role of indicators for monitoring various aspects of human settlements. These ranges from socio-ecnomic, health, satisfaction level, and more physical indicators like ecological performance, physical growth and development and infrastructure. The available indicators vary in their scales of application (i.e. settlement level, sub-regional level, national level and global level).

2.2.3.2 Application of GIS & Remote Sensing in Hydrology

The use of Geographic information Systems (GIS) and remote sensing to facilitate the estimation of runoff from watershed and agricultural fields has gained increasing attention in recent years. This is mainly due to the fact that rainfall-runoff models include both spatial and geomorphologic variations (Melesse and Shih, 2002).

In India remote sensing and GIS has been used for the rainfall runoff modelling. Nayak and Jaiswal (2003) used LISS-II satellite image and GIS for the rainfall-runoff modeling of Bebas river in Madhya Pradesh and found good correlation between the measured and estimated runoff volume.

Pandey et al., (2003) used SCS Curve Number and GIS for Karso watershed (area about 2793ha) a part of Damodar Barakar catchment, situated in Hazaribagh district of Jharkhand State and found the estimated runoff to be close to the observed one (within ± 25%). Jaiswal et al., (2000) used Remote Sensing data and SCS Curve Number method to compute runoff for Ghaziabad district, Uttar Pradesh, India so as to provide a quick result for decision-makers. This method is less time consuming and also gives more and more reliable result as the imperviousness of the drainage area increases and the value of Runoff coefficient tends to approach unity. This method can be used effectively in the design of storm water drains and small control project.

Pandey and Sahu (2002), worked for generation of curve number using Remote Sensing and GIS for ungauged watersheds. Conventional methods of runoff measurement are not easy for inaccessible terrain. Remote Sensing technology can augment the conventional method to a great extent in rainfall-runoff studies. In the study they have used SCS Curve Number Method modified for Indian conditions for Remi watershed (area 210 km^2) which is located in the East Siang district of Arunachal Pradesh.

Adhikari, (2003) developed GIS-Remote Sensing compatible rainfall-surface runoff model for regional level planning. The model is compatible with both the GIS database and the Remote Sensing (RS). Interactive option is provided to the user for modifying the database; Algorithms have been used in the study to extract watershed features such as overland flow, cascade, channel network, confluence points ridges etc. for a given digital elevation data using Triangulated Irregular Network (TIN). The overland flow is modeled as one–dimensional sheet flow over cascades of overland "flow planes" contributing as lateral inflow to the channels flowing in the valley. The main input to the watershed is taken as the rainfall. The usage of the model for regional level planning is demonstrated for tasks such as determination of waterways for small bridges and culverts, design of spillways of small dams, construction of flood protection levees, agriculture, site planning for micro hydels etc.

Sarangi et al., (2004), used GIS tool in watershed hydrology. To assess runoff from the watershed GIS tool was used to assist in data base development which acted as input to a developed conceptual model (Small Watershed Runoff Generation Model, SWARGEM). The input to the model was in the form of data tables and digitized maps comprising of soil parameters, topological information and land use features of Banha watershed under Damodar Valley Corporation, Jharkhand, India. The model used 4-point pour-input technique to route surface flow from one grid to the other in an overlaid grid array of the Banha watershed. The output of the model generated event based Direct Runoff Hydrographs (DRH) for the watershed. The non-parametric statistical analysis(Wilcoxon's matched pair signed rank test) performed on the predicted value and observed runoff rate at the outlet of the watershed revealed that there is no significant difference between the observed and predicted values at 0.05 probability level.

Sukheswalla, (2003) used statistical model for estimating mean annual and monthly flows at ungauged locations for the USA. Marechal, (2004) developed Catchment Resources and Soil Hydrology (CRASH) model to rainfall-runoff modelling in ungauged catchments for England and Wales. He derived a regional set of model parameters from the calibration of CRASH in 32 catchments for England and Wales.

2.2.4 Norms and Standards

The basic objective of suggesting various norms and standards for urban development plans formulation is to provide a basis for taking decision. The suggested norms and standards are indicative and can be suitably modified depending upon the local conditions.

Norms and Standards for various landuses and urban infrastructure are formulated by various agencies to achive desirable quality of living environment consistent with needs of population. Various agencies like Town and Country Planning Organisation (TCPO), The Central Public Health and Environmental Engineering Organisation (CPHEEO), Institute of Town Planners, India (ITPI) have formulated these norms after undertaking various surveys with regard to requirements of an urban area. Various Other agencies like Bureau of Indian Standards (BIS) and committees and commissions formed from time to time have also formulated norms and standards for quality and quantity of water supply in an urban area.

2.2.4.1 Land use Structure

According to TCPO and UDPFI guidelines urban areas are dived into four types – Small towns, Medium Towns, Large cities and Metro Cities. Further more for planning purpose, various levels of infrastructure in the urban centre is divided into – Town level, District level, Sector level, and Neighbourhoods level infrastructure.

Norms and standards regarding land use structure for town, district, sector and neighbourhood have been given below in Table 2.4 to Table 2.7.

Table 2.4: Land use Structure For A Public Sector City Of Population > 1,00,000

S. No.	Uses	Percentage of developable area
(i)	Residential including area under flats, incidental open spaces, tot lots, pathways and access ways	40-45
(ii)	Roads and circulation network excluding pathways and access ways	22-24
(iii)	Public and Semi-Public facilities	14-11
(iv)	Organised and Recreational open spaces	19-16
(v)	Commercial, retail, wholesale and warehousing	3-2.75
(vi)	Service industries, small scale industries and miscellaneous uses	2-1.25
	Total	100

Source: Town and Country Planning Organisation, Report on Norms and Space Standards for Planning of Public Sector Towns

Table 2.5: Land use Structure For A District Population 35,000 – 40,000

S. No.	Uses	Percentage of developable area
(i)	Residential including area under flats, incidental open spaces, tot lots, pathways and access ways	50-55
(ii)	Roads and circulation network excluding pathways and access ways	22-19
(iii)	Public and Semi-Public facilities	12-14
(iv)	Organised and Recreational open spaces	12-9
(v)	Commercial, retail, wholesale and warehousing	2.5-2
(vi)	Service industries, small scale industries and miscellaneous uses	1.5-1
	Total	100

Source: Town and Country Planning Organisation, Report on Norms and Space Standards for Planning of Public Sector Towns.

Table 2.6: Land use Structure For A Sector Of Population 12,000

S. No.	Uses	Percentage Range
(i)	Residential including area under flats, incidental open spaces, tot lots, pathways and access ways	55-60
(ii)	Roads and streets excluding pathways and access ways	20-22
(iii)	Public and Semi-Public (schools)	13-10
(iv)	Organised open spaces (play fields and parks at sector level)	9-6
(v)	Shopping and community buildings	3-2
	Total	100

Source: Town and Country Planning Organisation, Report on Norms and Space Standards for Planning of Public Sector Towns

Table 2.7: Land use Structure For A Neighbourhood Of Population 4,000

S. No.	Uses	Percentage Range
(i)	Residential including area under flats, incidental open spaces, pathways and access ways	60-65
(ii)	Roads and streets excluding pathways and access ways	15-13
(iii)	Public and Semi-Public schools	12-10
(iv)	Organised open spaces (tot lots)	12-10
(v)	Shopping and community buildings	1-2
	Total	**100**

Source: TCPO, Report on Norms and Space Standards for Planning of Public Sector Towns

2.2.4.2 Urban Water Needs

Urban water needs can be divided into various sectors on the basis of the diverse kind of uses. The water demand of a city has two aspects:

- Domestic water demand,
- Water demand at city level

The following tables from Table 2.8 to Table 2.13 show various standards for water demand and sector wise and population wise breakup.

Table 2.8: Average Domestic Consumption In An Indian City

S. No.	USE	CONSUMPTION (LPCD)
(i)	Drinking	5
(ii)	Cooking	5
(iii)	Bathing	55
(iv)	Washing of cloths	20
(v)	Washing of utensils	10
(vi)	Washing and cleaning of houses and residences	10
(vii)	Flushing of latrines	30
	Total	**135**

Source: Bureau of Indian standards (IS: 1172-1971)

The city level demand varies according to the population size. On an average, the per capita demand for India cities may vary as shown in the following table. It must be noted that there is a big gap urban and rural demands. As urban demand is about 150 lpcd to 200 lpcd, rural demand is 70 to 100 lpcd. On an average of world's urban water demand is 150 lpcd or about 55 cum per year and average rural water consumption is only 50 lpcd or 18 cum per year.

Table 2.9 : Variation In Water Demand As Per City Size

S.No.	POPULATION SIZE	DEMAND (LPCD)
(i)	Less than 20,000	110
(ii)	20,000-50,000	110-150
(iii)	50,000-2,00,000	150-180
(iv)	2,00,000-5,00,000	180-210
(v)	5,00,000-10,00,000	210-240
(vi)	More than 10,00,000	240-270

Source: Bureau of Indian Standards.

Table 2.10: Breakup Of City Level Demand

S.No.	USE	DEMAND (LPCD)
(i)	Domestic	135
(ii)	Industrial	50
(iii)	Commercial	20
(iv)	Public	10
(v)	Waste and Theft	55
	Total	270

Source: Bureau of Indian Standards

Efforts should be made to reduce the water losses in transmission and distribution. The contingency provision of 15-20% is to be made, to account for the losses.

Table 2.11 : Water Supply As Per City Size And Land Use

S. No.	Aspect/ Landuse	Standard		
		Small town (<50,000)	Medium town (>50,000)	Large and Metro cities (>10 lakh)
		lpcd	lpcd	lpcd
a)	**Domestic**			
i)	Absolute Min.	70 lpcd	70-100 Upper Limit above 100,000	135 lpcd It can be reduced Up to 70 lpcd
ii)	Desirable	100 lpcd	135-150 lpcd	150-200 lpcd
		Upper limits for Metro cities		
b)	**Non-Domestic**			
i)	Institutional	Refer table 2.12		
ii)	Industrial	Refer table 2.11		
iii)	Fire Fighting	1% of total demand		
iv)	Public Purpose	10-15 lpcd	20-25 lpcd	30-35 lpcd

Source : Manual of water Supply, C.P.H.E.E.O. , Government of India

Table 2.12: Water Requirements For Various Land uses

S. No.	Land use	Requirements
(i)	Industrial	4.5×10^4 l/ha/day
(ii)	Circulation and Open Spaces	16.85×10^3 l/ha/day
(iii)	Utilities and Transportation	68×10^3 l/ha/day
(iv)	Commercial	0.68×10^3 l/ha/day
(v)	Industrial workers	1.49×10^3 l/day

Source: U.D.P.F.I., Practical Civil Engineers Handbook.

Table 2.13: Water Requirements For Institutional Buildings

S.No.	Institutions	Litres per head per day
(i)	Hospital (including laundry) a. No. of beds exceeding 100 b. No. of beds not exceeding 100	450 (per bed) 340 (per bed)
(ii)	Hotels	180 (per bed)
(iii)	Hostels	135
(iv)	Nurses home and medical quarters	135
(v)	Boarding schools/colleges	135
(vi)	Restaurants	70 (per seat)
(vii)	Airport and seaports	70
(viii)	Junction stations and intermediate stations Where mail or express stoppage (both railway and bus stations) is provided	70
(ix)	Terminal stations	45
(x)	Intermediate stations (excluding mail and express stops)	45 (could be reduced to25 where bathing facilities are not provided
(xi)	Day schools/colleges	45
(xii)	Offices	45
(xiii)	Factories	45 (could be reduced to 30 where no bathing rooms are required to be provided
(xiv)	Cinema, concert halls and theatres	15

Source: Manual on Water Supply, CPHEEO, Government of India.

There are also other components on which average consumption of water depends. These are mainly.

i) It is directly proportional to rainfall

- Irrigation demand decreases during wet months.
- Hot dry regions have high landscaping water demand thus there is an increase in per capita consumption.
- In high humidity and moderate temperature of coastal areas there is decrease in per capita consumption.

ii) It is also directly proportional to the standard of living of people.

iii) Availability of recycled water for different uses.

iv) Public awareness to conserve water.

v) Variation in income level and other economic criteria.

vi) Intensity of construction activity.

vii) Variation in consumption with concentration of water intensive industrial units, commercial, open areas and other land use.

2.2.4.3 Water Quality Standards

Quality of water supply to residents is also very important along with quantity the standards for quality are given in following tables (Table 2.14 & Table 2.15):

i) Categories of Water Quality

Central pollution control board (CPCB) has divided fresh water into 5 categories A,B,C,D and E.

A - Drinking water after disinfection

B - Outdoor bathing

C - Drinking after conventional treatment and disinfection

D - Propagation of wild life and fisheries.

E - Irrigation industrial cooling controlled waste disposal.

Table 2.14: Primary Water Quality Criteria

S. No.	Designated Best Use	Class of Water	Criteria
(i)	Drinking water source without Conventional treatment but after disinfection	A	1. Total Coliforms organisms MPN/ 100ml shall be 50 or less. 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand days 20^0C 2mg/l or less
(ii)	Outdoor bathing (organised)	B	1. Total coliforms organism MPN/ 100ml shall be 500 or less. 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more. 4. Biochemical Oxygen Demand 5 days 20^0C 3mg/l or less.
(iii)	Drinking Water source with conventional treatment Followed by disinfection	C	1. Total Coliforms organism MPN/ 100ml shall be 5000 or less. 2. pH between 6 and 9 3. Dissolved Oxygen 4mg/l or more. 4. Biochemical Oxygen Demand 5 days 20^0C 3mg/l or less.

(iv)	Propagation of Wild Life, Fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4mg/l or more. 3. Free Ammonia (as N) 1.2 mg/l or less.
(v)	Irrigation, Industrial cooling, Controlled Waste Disposal	E	1. pH between 6.0 to 8.5 2. Electrical Conductivity at 20^0C micro mhos/ cm Max 2250. 3. Sodium absorption Ratio Max 26. 4. Boron, Max 2mg/l

Source: Manual of Water Quality, Central Pollution Control Board (CPCB), Delhi.

Table 2.15: Water Quality Standards

S. No	Characteristics	A	B	C	D	E
1	Dissolved Oxygen mg/l (minimum)	6	5	4	4	-
2	Biological / Biochemical (BOD) oxygen demand mg/l (minimum)	2	3	3	-	-
3	Coliform bacteria	50	500	5000	-	-
4	pH	6.5-8.5	6.5-8.5	6-9	6.5-8.5	6.5-8.5
5	Free ammonia mg/l (maximum)	-	-	-	1.2	-
6	Electrical conductivity micromhos/cm (maximum)	-	-	-	-	2250
7	Sodium absorption ratio (maximum)	-	-	-	-	26
8	Boron mg/l (maximum)	-	-	-	-	2

Source : Manual of Water Quality, Central Pollution Control Board (CPCB), Delhi.

ii) Treatment of Water

Water from different sources usually contain certain impurities thus before it is supplied to consumers for domestic purposes it must be treated to desired standard (Table 2.16).

Table 2.16: Standards For Domestic Water Quality

S. No.	Classification of impurities	Impurity	Max. permissible limit in ppm or mg/litre
(i)	Physical	1. Colour (on cobalt scale)	15-25
		2. Turbidity (on silica scale)	5-10
		3. Temperature	10-15.6^0C
		4. Tastes and odours	Nil
(ii)	Biological	1. M.P.N. of caliform bacteria	Not more than 1 caliform colony per 100ml of water sample test
(iii)	Chemical	1. pH-value	6.6 to 8.0
		2. Total solids (suspended and dissolved)	500-100
		3. Hardness	75-115 (hardness expressed as $CaCo_3$ equivalent
		4. Barium	1.00
		5. Cadmium	0.01
		6. Chromium	0.05
		7. Selenium	0.05
		8. Arsenic	0.05
		9. Manganese	0.05
		10. Iron	0.30
		11. Lead	0.05 to 0.10
		12. Copper	1.04 to 3.00
		13. Zinc	15.00
		14. Silver	0.05
		15. Flouride	1.50
		16. Cyanide	0.2 to
		17. Phenolic substance	0.001(as phenol)
		18. Sulphate	250
		19. B.O.D.	Nil
		20. Nitrate (NO_3)	45
		21. Chloride	250
(iv)	Radiological	A emitters	1 μμ c/litre
		B emitters	10μμ c/litre

Source : Handbook of Civil Engineering, PN Khanna.

iii) Treatment Process

Treatment process directly depend on the types of impurities (Table 2.17)

Table 2.17: Treatment Process Different Type Of Impurities

S.No.	Impurity	Process of removal
(i)	Floating matters, leaves etc.	Screening
(ii)	Suspended impurities as silt clay etc.	Plan sedimentation
(iii)	Fine Suspended matter	Sedimentation with coagulation
(iv)	Micro Organisms and Colloidal matters	Filtration
(v)	Dissolved gases, taster and colours	Aeration and Chemical treatment
(vi)	Softening	Permutit method
(vii)	Pathogenic bacteria	Disinfection

Source : P.N. Khanna, Handbook of Civil Engineering.

The treatment plants should be located as near to town as possible and in case of ground water it must be installed along with tube well.

2.2.4.5 Design of Infrastructure

Design of Physical infrastructure includes the design of water supply sewerage and drainage networks of city (Details are in section 2.3.2.1).

2.3 URBAN WATER RESOURCE PLANNING & MANAGEMENT

Water resource planning and management in an urban area is a very complex subject. Water resource planning can broadly be divided into two broad categories – Demand and supply model, integrated resource planning model.

Demand and supply model also known as supply oriented model involves dividing the urban water demand into different components and dealing with them separately resulting in higher costs of infrastructure, increase in demand and more capacity for disposal of waste water. .

Integrated resource planning, is also known as least cost planning, is a process where the water utility determines the options at lowest cost, which will provide its customers with the water-services which they demand, rather than the water itself (Beecher, 1996; Dziegielewski, 1999; White and Howe, 1998). It recognizes that consumers do not necessarily want more water, they want the services such as clean hands, dishes and clothes and pleasing landscapes. There is scope for satisfying demand for these water-related services by improving the water use efficiency of products and landscapes. Using this frame-work one can provide quite different and more sustainable results than conventional supply-oriented methods. Supply methods lead to augmented storages, treatment, and reticulation systems to cater the increased demand, while integrated resource planning can results in supply options being recommended and a paradigm shift in the way services are delivered to consumers.

Integrated urban water management is based on the understanding of urban hydrological cycle, comprising of water supply, wastewater disposal, and stormwater runoff systems, making up the total urban water system in which all the components are interrelated. While in the conventional approaches i.e. demand and supply model, the research is dominated by detailed modelling of only sub-components of the total water system (Newall et al., 1998). Particularly, the interaction between the potable water supply–wastewater discharge network, and the rainfall–stormwater runoff network, is rarely considered. In order to provide a complete picture of the spatial and temporal pattern of water demand and stormwater and wastewater supply, the water balance approach must be adopted along with the nature of urban development.

2.3.1 Assessment of Water Resources in an Urban Area

Management of water resources requires an understanding of the nature and scope of the problem to be managed. This requires the detailed assessment of quantity and quality of water resources available in an urban area to access and identify the various demands, requirements and shortfalls. The demand for water resources can be accessed by identifying various uses and their water requirements using norms and standards while the availability of water resources can be identified by identifying the sources of water and their availability.

Broadly speaking the water resources in an urban area can be divided into three categories – Surface water (Precipitation, Canal water and Surface runoff), Ground water and Wastewater.

2.3.1.1 Surface Water

i) *Rainfall Runoff Analysis*

Surface water in an urban area can be broadly divided into Precipitation / rainfall, Surface runoff, Stream flow and Canal water. Rainfall is measured in terms of depth, in mm, and is measured by rain gauge. Surface runoff represents the output from the catchment in a given unit of time. Generally rational method, hydrographs and flood frequency studies are used to estimate flood peak.

Rational method is used to determine the peak value of runoff for a catchment to design storm water drainage in an urban area.

$$\mathbf{Q_p = CIA} \qquad \textbf{for time } \mathbf{t \geq t_c} \qquad (2.2)$$

$\mathbf{Q_p}$ = Peak discharge (m^3/s)

$\mathbf{I_{tc,P}}$ = The mean intensity of precipitation (mm/h) for a duration equal to time of concentration, $\mathbf{T_c}$ and the desired probability of exceedence P (i.e. return period T = 1/P)

A = Drainage Area in ha

C = Runoff Coefficient

{Kirpich, P.Z. (1940). Time of concentration of small agricultural watershed. Civil Engg., 10, 360p.}

Equation for time of concentration, T_c is given by Kirpich (1940)

$$\mathbf{T_c = 0.01947\, L^{0.77} S^{-0.385}} \qquad (2.3)$$

$\mathbf{T_c}$ = Time of concentration (min.)

L = Maximum length of travel of water (m)

S = Slope of catchment (m/m)

Rainfall intensity, i corresponding to t_c is given by

$$I_{Tc,P} = \frac{KT^x}{(T_c + a)^m} \qquad (2.4)$$

Where K, a, x and m are location constants.

Runoff Coefficient, **C** in Eq 2.2 represents the integrated effects of catchment losses and hence depends upon the nature of the surface, surface slope and rainfall intensity (Table 2.18).

Table 2.18: Value Of Coefficient C

Type of Area		Value Of C
A. Urban Area (P = 0.05 to 0.1)		
Lawns	Sandy soil, flat, 2%	0.05 - 0.10
	Sandy soil, Steep, 7%	0.15 - 0.20
	Heavy soil, average, 2.7%	0.18 – 0.22
Residential Areas:		
	Single Family Area	0.30 – 0.50
	Multi Family Area	0.60 – 0.75
Industrial Areas:		
	Light	0.50 – 0.80
	Heavy	0.60 – 0.90
Streets		0.70 – 0.95
A. Agriculture Area		
Flat:	Tight Clay: Cultivated	0.50
	Woodland	0.40
	Sandy Loam: Cultivated	0.20
	Woodland	0.10
Hilly:	Tight Clay: Cultivated	0.70
	Woodland	0.60
	Sandy Loam: Cultivated	0.40
	Woodland	0.30

Hydrograph, Plot of discharge against time, is used to study total surface runoff generated in a catchment. Depending on unit of time we have –

i) Annual Hydrograph,

ii) Monthly Hydrograph,

iii) Seasonal Hydrograph and

iv) Flood hydrograph.

In an attempt to arrive at a basis for comparison of hydrographs, a standardized method called unit hydrograph was proposed by Sherman (1932).The "unit hydrograph" is defined as the hydrograph resulting from a single unit of rainfall excess uniformly over a catchment at a constant rate during a specified period of time. Chow and Nash (1966) have presented techniques to derive unit hydrograph. Fig 2.5 (**Hydrograph Lazaro p24**). Since then it has became powerful tool employed by hydrologists and planners in determining watershed characteristics, precipitation effects on watershed and the influence of land use changes on discharge characteristics of the stream (Lazaro, 1979).

To develop unit hydrographs for a catchment, detailed information about the rainfall and resulting flood hydrograph are needed. However such information will only be available only for few gauged catchments but for other un-gauged catchments Synthetic-unit Hydrographs based on empirical correlations are used. The important Synthetic-unit Hydrographs (SUH) methods are –

i) Snyder Unit Hydrograph

ii) SCS Unit Hydrograph

iii) Clark instantaneous Hydrograph

- **Snyder's synthetic unit hydrograph (1938)**

Snyder considered the shape and area of the basin and gave the following empirical equations after analyzing a large number of hydrographs from drainage basins of area from 25 to 25000 km^2. The basin lag is given by –

$$t_p = 0.75\ C_t(LL_c) \qquad (2.5)$$

t_p is basin lag in hours

L is length of main stream of the catchment (km)

L_c is the distance from the outlet to the point on the stream nearest to the centroid of the watershed area (km)

C_t is the coefficient, which depends upon characteristics of the catchment. Its value ranges between 1.9 to 2.3.

The peak discharge per unit drainage area of standardized unit hydrograph is given by

$$Q_p = 2.75 C_p A/t_p \qquad (2.6)$$

Q_p is the peak discharge (m^3/s/km^2)

C_p is the coefficient varies from 0.5 to 0.7 and depends upon the retention and storage characteristics of the catchment. It is derived from gauged catchment in the same region.

A is watershed Area.

- **SCS Synthetic Unit Hydrograph**

SCS synthetic unit hydrograph is a dimensionless unit hydrograph which was developed by the US Soil Conservation Service (SCS), in which the discharge values (q) are expressed as a percentage of peak discharge value (Q_p) and time is given by ratio of time (t) to the time to peak (T_p) of the unit hydrograph. The time of recession as suggested by the SCS is approximated as $1.67T_p$; catchment lag (t_p) is estimated as $0.6T_c$ and the time to peak can be calculated using

$$T_p = \frac{D}{2} + t_p; \text{ where D is duration of rainfall.} \tag{2.7}$$

$$Q_p = \frac{5.36A}{T_p} \tag{2.8}$$

Synthetic unit hydrograph show variations of runoff with time and total runoff volume is found by integrating the direct runoff hydrograph obtained from this specific excess rainfall for that specific storm and should be equal to the estimated excess rainfall. The SCS curve number method (SCS-CN) can be applied to both gauged as well as un-gauged watershed.

$$I_a = 0.2S \tag{2.9}$$

I_a = Initial Abstraction

S = Potential maximum retention

$$S = \frac{25400}{CN} - 254 \tag{2.10}$$

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} = \text{Rainfall Excess} \tag{2.11}$$

P = Rainfall

In paved areas **S = 0** and **CN** = 100 and in an area where no surface runoff occurs S = ∞ and **CN** = 0. The average curve number can be obtained from standard tables for different combinations of land use and land cover, hydrologic soil group (HSG), treatment, and condition (Table 2.19, Table 2.20 and Table 2.21).

Table 2.19: Hydrologic Soil Group

Soil Group	Description
A	Lowest runoff potential
B	Moderately low runoff Potential
C	Moderately high runoff Potential
D	Highest runoff potential

Table 2.20: Curve Number for hydrologic cover complexes for watershed condition II and I = 0.2S

Land use Cover	Treatment	Hydrologic condition	Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight row	Poor	77	86	91	94
Row Crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	81	86
	Contoured	Good	65	75	82	86
	Contoured & Terraced	Poor	66	74	80	82
	Contoured & Terraced	Good	62	71	78	81
Small Grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Contoured & Terraced	Poor	61	72	79	82
	Contoured & Terraced	Good	59	70	78	81
Close seeded legumes	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Contoured & Terraced	Poor	63	73	80	83
	Contoured & Terraced	Good	51	67	76	80
Pasture Range		Poor	68	79	86	89
		Fair	48	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woodland		Poor	45	66	73	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		-	59	74	82	86
Roads, Dirt		-	72	82	87	89
Roads and Hard Surfaces		-	74	84	90	92

In SCS hydrograph the time on abscissa is the ratio of the period of rise, or time to peak (t/t_{peak}) and runoff rate on the ordinate are the ratios to the peak runoff rate (Q/Q_{ps}) (Table 2.21)

Table 2.21: Coordinates of SCS Dimensionless Unit Hydrograph

t/T_p	q/Q_p
0.00	0.00
0.25	0.12
0.50	0.43
0.75	0.83
1.00	1.00
1.25	0.88
1.50	0.66
1.75	0.45
2.00	0.32
2.25	0.22
2.50	0.15
2.75	0.11
3.00	0.08
3.25	0.05
3.50	0.04
3.75	0.03
4.00	0.02
4.25	0.01
4.50	0.01
4.75	0.01
5.00	0.00

Source: Mockus, 1957

As the area became urbanized there is an increase in impervious areas within the water shed, reducing its water storage capacity and thus large volume of rainfall excess is more readily available for runoff and hydrographs rise more abruptly attaining higher peaks due to reduced time of concentration, T_c causing flooding of low lying areas. (Lazaro, 1979). Snyder,s SUH gives fairly accurate results for large rural watersheds while SCS SUH is also equally good for small urbanized watersheds.

Table 2.22: Runoff Curve Numbers for Urban Area for watershed condition II and I = 0.2S

Cover Type and Hydrologic Condition	Average Percent Impervious Area	A	B	C	D
Open space (lawns, park, golf courses, cemeteries, etc)					
• Poor condition (grass cover <50%)		68	79	86	89
• Fair condition (grass cover 50% to 75%)		49	69	79	84
• Good condition (grass cover>75%)		39	61	74	80
Paved parking lots, roofs, driveways, etc (excluding right-of-way)		98	98	98	98
Streets and roads:					
• Paved: curbs and storm drains (excluding right-of-way)		98	98	98	98
		83	89	92	93
• Paved: open ditches (including right-of-way)		76	85	89	91
• Gravel(including right-of-way)		72	82	87	89
• Dirt (including right-of-way)					
Western desert urban areas:					
• Natural desert landscaping (pervious areas only)		63	77	85	88
• Artificial desert landscaping (impervious weed barrier, desert shrub with 1-to2 inch sand or gravel mulch and basin border		96	96	96	96
Urban districts:					
• Commercial and business	85	89	92	94	95
• Industrial	72	81	88	91	93
Residential districts by average lot size:					
• 1/8 acre or less (town houses)	65	77	85	90	92
• ¼ acre	38	61	75	83	87
• 1/3 acre	30	57	72	81	86
• ½ acre	25	54	70	80	85
• 1 acre	20	51	68	79	84
• 2 acre	12	46	65	77	82
Developing urban areas :					
Newly graded areas (pervious area only, no vegetation)		77	86	91	94

Notes: Values are for average runoff condition, and Ia = 0.2S.
The average percent impervious area shown was used to develop the composite RCNs
Other assumptions are: impervious area are directly connected to the drainage system, impervious areas have a RCN of 98, and pervious area considered equivalent to open space in good hydrologic condition

ii) *Canal Water and Seasonal Stream Water Availability*

Canal water is the water which is brought to an area from a reservoir to meet the needs of that area by a network of canals. Canal water is mainly meant for irrigation but as the urban areas increase in size the demand of water for different usages increase and so the need to import water from other areas arise and canals are used to bring water to meet these demands. Canal water is sanctioned for a particular area and for a use, and is regulated by authority usually irrigation department. The canal water sanctioned for an area is measured in cubic meters and its day to day record is kept.

Also due to a result of natural growth urban areas results in development of surrounding rural areas into urban land uses and thus the sanctioned canal water for these areas for irrigation is no longer used for being used for irrigation is available to be utilized for other urban water demands releasing pressure on other sources of water from over exploitation.

A seasonal stream is a flow channel which drains the runoff from a drainage basin. In addition to surface runoff, an exchange of stream water and underground water also takes place in the channel. Stream flow is measured in units of volume of water flowing through the cross-sectional area of the stream per unit of time. Hydrological measurements of streams are done at gauging stations. There are mainly two types of gauging stations manually operated (Staff gauges and wire gauges) and Automatic gauges. The record from these gauges is recorded on daily basis by the authorities usually the irrigation department.

The water from canals and seasonal streams is a good and clean source of water supply for an urban area if available.

2.3.1.2 Groundwater

Groundwater is an integral part of the hydrologic cycle. Water enters a groundwater system by infiltration of surface water through the ground surface to the saturated zone of the aquifer. A groundwater flow system consists of aquifer which are water-yielding strata and of confining beds which are geological units restricting flow of water. Water enters the flow system in recharge areas and moves through the aquifers and confining units, according to their hydraulic properties and the hydraulic gradient, to discharge areas (Heath, 1983). Aquifers are replenished from infiltration of rainfall through downward percolation of soil water past the plant root zone; seepage from streams, rivers, and lakes also contribute to groundwater recharge.

Groundwater has always been considered to be readily available source of water for urban water supply. However with an increase in demand, this resource is being overexploited in many areas resulting in permanent depletion of the aquifer system and associated environmental consequences such as land subsidence and water quality deterioration. However there is also decline in ground water quality due to pollution resulting from untreated effluents entering urban hydrological cycle. Thus there is a need to keep a check on the disposal of untreated effluents.

i) ***Ground Water Resource Estimation***

The ground water resource estimation of the entire country has been done broadly within the guidelines and recommendations of the Groundwater Estimation Committee, 1997 (GEC'97). In most of the states, the unit of assessment of groundwater resources has been the administrative units (Block/Tehsil/District). The groundwater recharge in the monsoon season and non-monsoon season has been estimated separately.

The two approaches adopted for estimation of rainfall recharge are – Water Level Fluctuation (WLF) method and Rainfall Infiltration Factor (RIF) Method.

In WLF method the change in storage has been computed by multiplying water level fluctuations between pre and post monsoon periods with the area of assessment and specific yield. The ground water resources (R) during monsoon season have been estimated as the sum of change in storage and gross draft which can be expressed as:

$$\mathbf{R = (h \times S_y \times A) + DG} \qquad (2.12)$$

h = Rise in water level in the monsoon season

A = Area for computation of recharge

S_y = Specific yield (Table 2.23)

DG = Gross ground water draft

Table 2.23: Specific Yield, S_y For Different Formation

Formation		Range of Specific Yield
Unconsolidated formations	Alluvium	0.04 to 0.20
Semi-consolidated formations	Sedimentary rocks	0.01 to 0.15
Consolidated formations	Crystallines and other hard rocks	0.002 to 0.04

The ground water recharge calculated from WLF method gives the recharge from rainfall and other sources during monsoon period. In order to segregate the rainfall recharge, contribution from the other sources such as recharge from recycled water from irrigation, seepage from canal, recharge from tanks and ponds and recharge from water conservation structures have been estimated separately based on the recommended norms as given in table 2.24. The rainfall recharge has been normalized for the normal monsoon season rainfall.

In RIF method the recharge (R_{rf}) from rainfall has been estimated as given as –

R_{rf} = **f X A X normal rainfall** (2.13)

f = Rainfall infilteration factor

A = Area

The same rainfall infilteration factor has been used for computation of recharge due to monsoon and non-monsoon rainfall. The norms adopted for computation of recharge from rainfall are given in Table 2.25.

Table 2.24: Estimation Of Recharge From Other Sources

Parameters		**Range of Parameters**
Canal seepage factor	Unlined canals	15 to 30 ham/day/million sq.m. of wetted area
	Lined canals	20% of above value for unlined canals
Return flow factor	Surface water Irrigation	0.10 – 0.50
	Ground water Irrigation	0.05 – 0.45
Seepage from water bodies	1.4 mm/day based on average area of water spread	

Table 2.25: Rainfall Infiltration Factor For Different Formation

Formation		**Range of Rainfall Infiltration Factor**
Unconsolidated formations	Alluvium	0.08 to 0.25
Semi-consolidated formations	Sedimentary rocks	0.03 to 0.14
Consolidated formations	Crystallines and other hard rocks	0.01 to 0.12

The total recharge in monsoon season is the sum of the normalized rainfall recharge and recharge from other sources. The recharge during non-monsoon season must be estimated by RIF method provided normal rainfall in the non-monsoon season is greater than 10% of the normal annual rainfall. If the rainfall is less than 10% of the normal annual rainfall then recharge due to rainfall is taken as zero.

2.3.1.3 Sewage Generated

Recycled sewerage must also be considered as a resource, as treated sewage and industrial effluents can be used to meet demand from many land uses like recreation, open spaces etc thus decreasing the demand for more water and also reducing the pressure on infrastructure. Quantity of sewage generated is normally calculated as 0.8 times the quantity of water supply and its total quantity depends on many factors like -

(i) Rate of water supply.

(ii) Population

(iii) Type of area served as residential, industrial or commercial.

i) ***Rate of water supply***

The quantity of sanitary sewerage produced is directly proportional to the rate consumption of water supply in a town.

- The consumption/Rate of water supply fluctuates seasonally and with in 24 hrs.

ii) ***Population***

With growth of population of a town the per capita consumption of water supply increases and thus increasing the sewerage produced (Table 2.26).

Table 2.26: Sewage Produced In Relation To Population Of City

S. No.	Population of the Town/city	Per capita demand of water (in litre/day)	Sewerage produced per capita (in litre/day)
(i)	**Upto 50,000**	135	115
(ii)	**50,000 to 2,00,000**	135-160	115
(iii)	**2,00,000 to 5,00,000**	160-180	135
(iv)	**5,00,000 to 10,00,000**	180-200	160
(v)	**More than 10,00,000**	200-225	180

Source : Water Supply and Sanitary Engineering, G.S. Birdie and J.S. Birdie

- The recommended values of water consumption and sewerage produced in India are given Table 2.26.
- There is a difference between water supplied and sewerage produced due to loss of water due to evaporation leakage, gardening industrial & commercial purposes etc. Thus quantity of sewerage produced is 70%-80% of water supplied.

iii) Type of Area Served

Quantity of Sewerage produced also depends on the area served for a residential area sewerage produced is directly proportional to water supplied; it is 0.8 times the water supplied, while in industrial it depends on the process adopted. Same is the case with other land uses.

2.3.2 INFRASTRUCTURE FOR WATER RESOURCE MANAGEMENT

Infrastructure for urban water management can be broadly divided into three main categories:

a. Water Supply network
b. Sewage Disposal Infrastructure
c. Drainage / Rainfall runoff network

The technologies available for each can be further divided into two categories:

a. Conventional technologies and
b. Non conventional Technologies

Conventional approach of urban water resource management, considers the water supply and disposal of waste water as two different things. Thus water is considered a commodity so total quantity of water required for an urban area is calculated and network is planned accordingly. While in case of non-conventional approach demand for different services is calculated separately and quantity and quality water required for it is calculated. Thus leading to saving in quantity of water and the network cost is also less.

In both conventional and non-conventional approaches for water supply in an urban area may not necessarily mean all together different technologies and sources of water supply but the concept of Integrated urban water management (IUWM) through the implementation of conservation and reuse strategies like rain water harvesting, recharge of ground water and recycling of sewage rather than centralization of treatment and supply of water.

IUWM requires the management of the urban water cycle in coordination with the hydrological water cycle which are significantly altered by urban landscapes and its correlation to increasing demand. Under natural conditions the water inputs at any point in the system are precipitation and overland flows; while the outputs are via surface flows, evapo-transpiration and groundwater recharge. The large volumes of piped water introduced with the change to an urban setting and the introduction of vast impervious areas strongly impact the water balance, increasing in-flows and dramatically altering the out-flow components (Barton, A.B., 2009). IUWM leads to decrease in per capita demand and saving of large quantity of water as well as the cost of infrastructure needed for water supply.

2.3.2.1 Conventional Urban Water Resource Management Technologies

In most of Indian urban areas the centralised conventional methods of water resource management are adopted in which water supply and waste water disposal are dealt separately.

i) *Water Supply Network*

Water supply is adopted with ground water as well as surface water i.e. canal water as the only sources. In most class I towns' water is supplied at the rate of 150 – 200 lpcd (Table 2.27). There is rarely any use of rain water harvesting, ground water recharge and waste water recycling at city level. There are few cases of experimental use of these technologies on experimental basis but not as policy at city level.

Table 2.27: Status Of Water Supply And Sewage Collection And Treatment In India

S. No.	Components	Metro cities	Class I including Metro cities	Class II Towns
1.	Number	23	299	345
2.	Total Population	709969724	13996636	22645614
3.	Total water supply	9047/KM^2	----------	3695/KM^2
4.	% Of population covered by water supply	90%	88%	88%
5.	Wastewater generation	9275 mld	16662 mld	1649 mld
6.	Average per capita water supply	241lpcd	183 lpcd	103 lpcd
7.	Volume of sewage collection	7471 mld	11938 mld	1090 mld
8.	% Of population covered	78%	70%	66%
9.	Sewage treatment plant facilities	16 cities	76 cities 4037 mld 32% of collection	17 cities 61.5 mld 6% of collection
10.	Economic value of sewage/annum	974 million	1828 million	160 million

Source; Decentralized sewage treatment system, CPCB (2001)

Conventional water supply system in an urban area has following components -

a. ***Distribution Systems***

Water mains, pumping stations and reservoirs combining to form any of the three distribution systems – gravity, pumping and dual system. The details are shown in Fig's 2.5, 2.6 & 2.7.

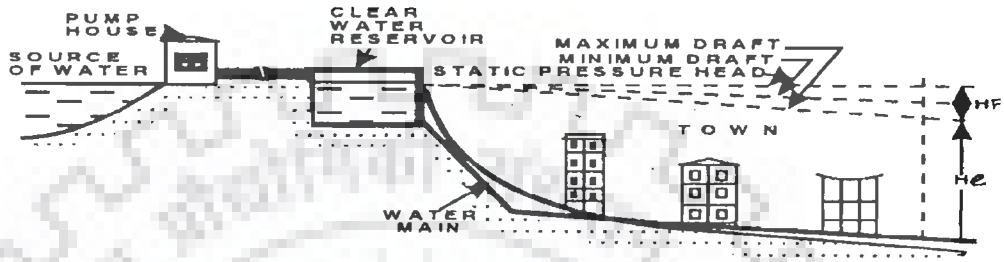


Fig 2.5: Gravity System

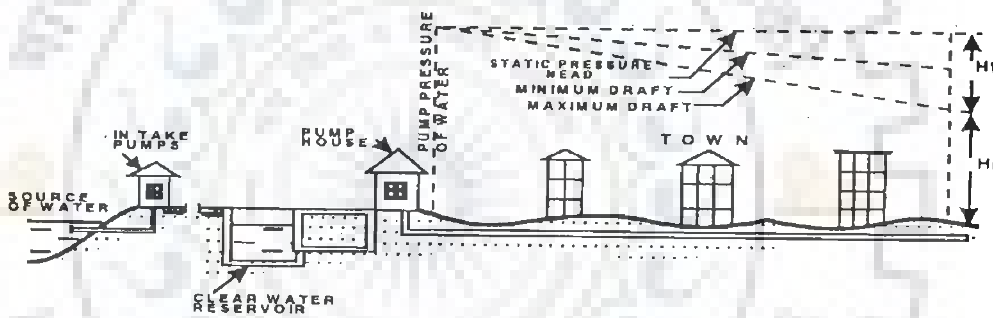


Fig 2.6: Pumping System

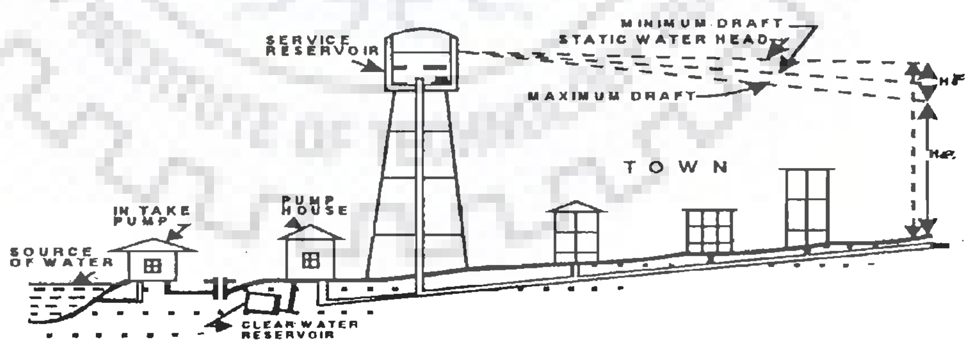


Fig 2.7: Dual System

b. ***Layout of Distribution Systems***

❖ ***Dead end or tree system***

- It is suitable for irregular developed towns or cities.
- Main starts form reservoir along the main road (Fig 2.8).
- Sub mains are connected to the mains in both the direction along the roads meeting main road.
- In streets lanes and other small roads which meet the roads carrying sub-mains branches and minor distribution are laid and connected to the sub mains. From these branches service connections are made to individual houses.
- The main advantages of this system are cheap in initial cost and easy determination of pipe diameters valves size etc.
- Main disadvantage of this system are formation of dead ends resulting in affecting a large area in case of repair and it can't meet fire demand.

❖ ***Grid Iron System***

- Convenient for towns having rectangular layout of roads.
- Main line is laid along the main road sub mains are taken in both the directions along other minor roads and streets and from these submains branches are taken out and inter connected (Fig 2.9).
- It has no dead ends, and is suitable for fire demand.
- More no. of valves and longer length of pipe required and it is costly.

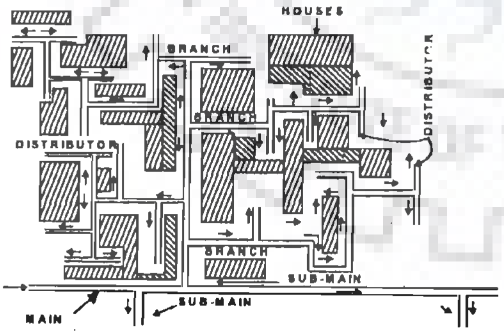


Fig 2.8: Dead end system

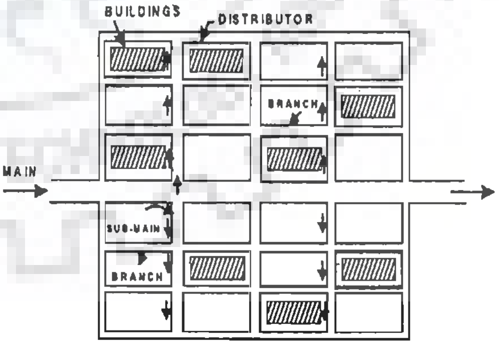


Fig 2.9: Grid iron system

❖ *Circular/Ring System*

- Water mains are laid all around the locality while branches, sub mains etc. are laid along inner roads and are inter connected (Fig 2.10).
- Design is easier, no dead ends and is suitable for fire demand.
- This system is used in only well planned localities and is some times used as looped feeder and is placed centrally around a high demand area with grid iron system.
- Costly due to more valves and longer pipe diameter.

❖ *Radial System*

- For this system water flows from centre towards periphery with reservoir at centre of the zone (Fig 2.11).
- The water lines are laid radically from the reservoir.
- This system gives quick and satisfactory water supply and also calculation of pipe sizes is very easy.

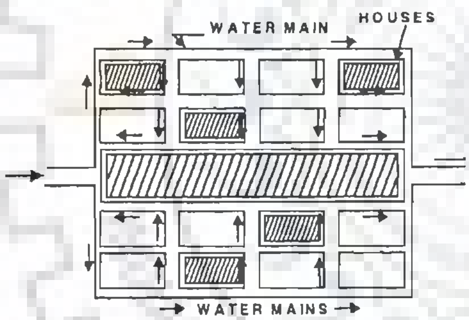


Fig 2.10: Ring system

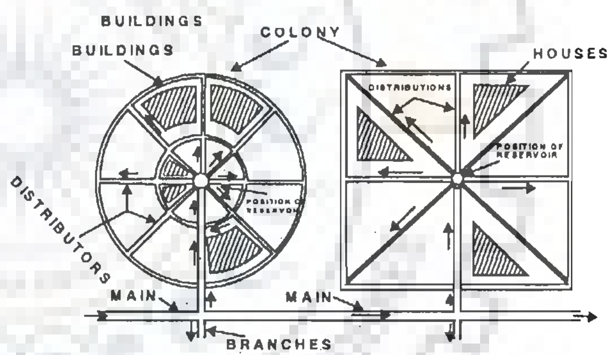


Fig 2.11: Radial system

❖ ***Major Considerations while designing distribution system***

- The main line should be designed to carry 3 times the overage demand of the city.
- The service pipes should be able to carry twice the average demand.
- The water demand at various points in the city should be noted.
- The lengths & sizes of each pipe should be clearly marked on the site plan along with hydrant, values, meters etc.
- The pressure drops at the end of each line should be calculated & marked.

- The minimum velocity in pipe should not be less than 0.6 m/sec and maximum velocity should not be more than 3 m/sec.
- Water supply system should be designed for at least 22 to 20 years.
  - Large diameter of pipe is required.
  - Large no. of valves is required in this system.
  - Causes inconvenience to consumer.
  - Separate system for fire fighting is laid.

ii) ***Sewerage & Drainage Network***

With Rapid urbanization along with industrialization there is a rapid increase in demand of water supply but resources are limited. It has resulted in increase in wastewater and untreated sewage which constitutes 80% of the total quantity of water supplied for city. (Report of The National Commission On Urbanisation, 1988). The sewerage disposal in an urban area (Fig 2.13) and the type of sewerage network system depends on:

a. Quantity of Sewerage

Factors affecting quantity sanitary sewerage in a city is:

- Rate of water supply.
- Population
- Type of area served as residential, industrial or commercial.

b. The sewerage systems are classifies as

- Combined system (Both sewage and rainfall runoff are handled by single network)
- Separate system (Sewage and rainfall runoff are handled by different networks)
- Partially Separate system

c. Hierarchy of sewerage system there are mainly 5 types of sewers.

- Laterals sewer
- Branch sewer
- Sub-main sewer
- Main sewer
- Trunk Sewer

d. Minimum Size of sewer

- It should not be less than 150mm but recommended size in 200mm.

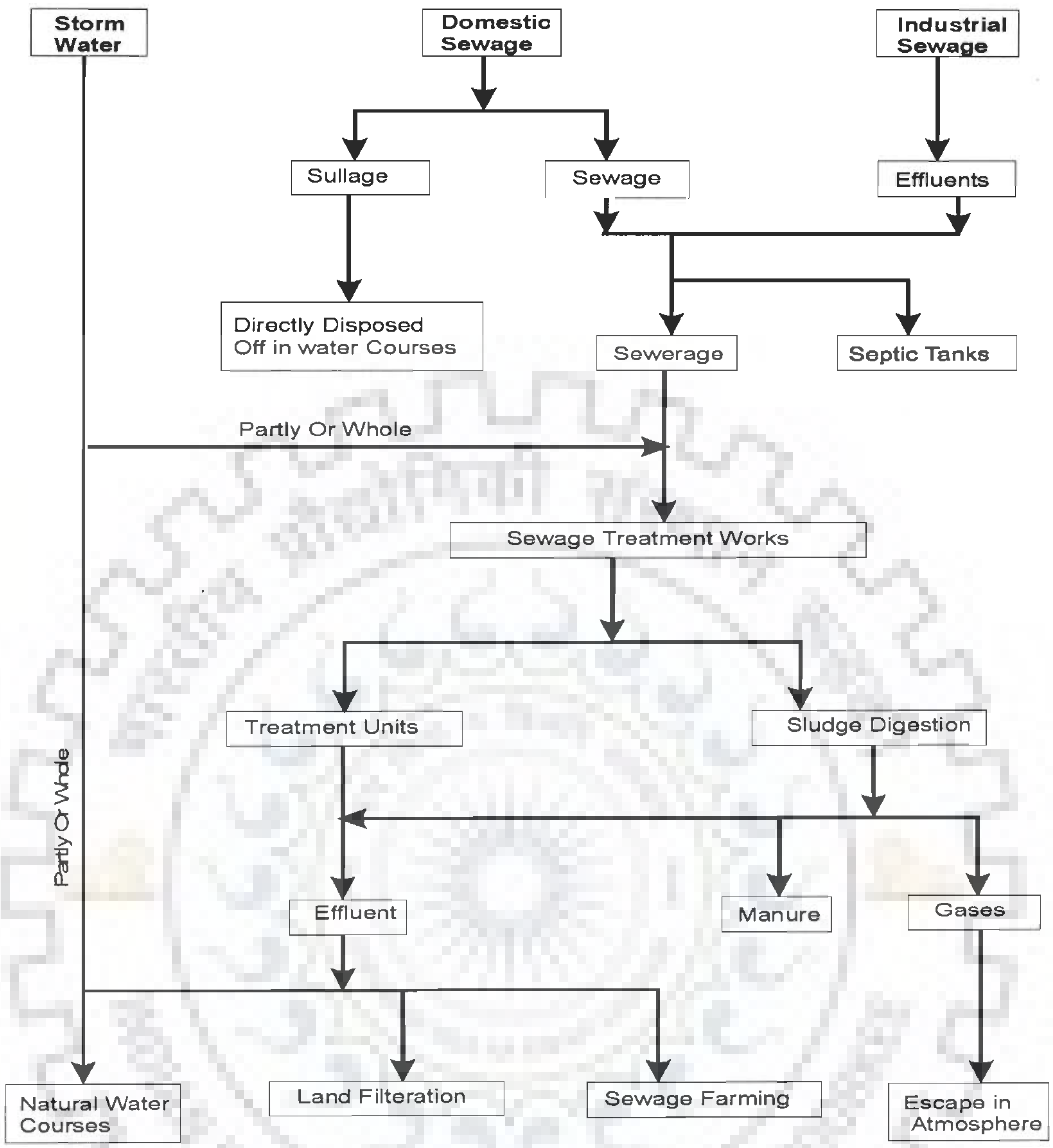


Fig. 2.12: Sewage Disposal in a City

Source: Need to adopt decentralized wastewater treatment system in urban areas, Brar,T.S. et. Al (2004)

e. Pattern of collection systems

The pattern of collection systems can be mainly divided into

- Perpendicular Pattern
- Interceptor pattern
- Radial pattern
- FAN pattern
- Zone pattern

❖ ***Perpendicular pattern***

Suitable for separate & partially separate system. Storm water sewers are laid perpendicular to natural courses to seek shortest possible path to them (Fig 2.13).

❖ ***Interceptor pattern***

This pattern is an improvement over the perpendicular pattern. In this pattern sewers are intercepted by a large size sewer, which is laid all along the water carrying sewage to a common point, where it can be disposed of with or without treatment. If the quantity of storm water is very large, overflows should be provided as shown in Fig. allowing the excessive sewage to spill over into natural water courses through outlets, which were existing before the interception (Fig 2.13).

❖ ***Radial Pattern***

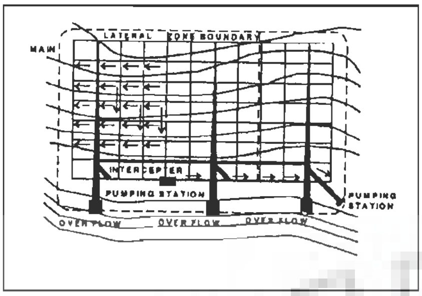
This type of pattern can be employed if the sewage is to be disposed of on land around the town. In this pattern large number of outlets are provided. The sewers are laid Radially outwards from the centre of the city therefore, this is called as radial pattern. In this pattern the suburbs can be served by relatively small and short lines of sewers which make it economical. The main disadvantage of this system being large number of disposal works (Fig 2.13).

❖ ***Fan Pattern***

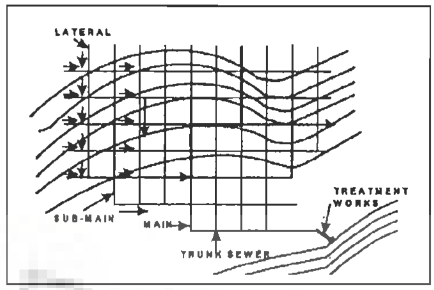
If the city is situated near the river, which is on one side of it only, the sewer can be laid in such a way that the whole sewage flows to a common point where one treatment plant is located. In this pattern number of converging main sewers are laid, which form a fan like shape, from which it derives its name, the only advantage of this system being single unit of treatment work. But the diameter of the sewer increases as the sewage moves, due to which the diameter of the main trunk is very large, increasing the over all cost of this pattern. The second drawback of this pattern is that if the outlying suburbs develop, it will increase the load on the treatment works, restricting the development (Fig 2.13).

❖ ***Zone Pattern***

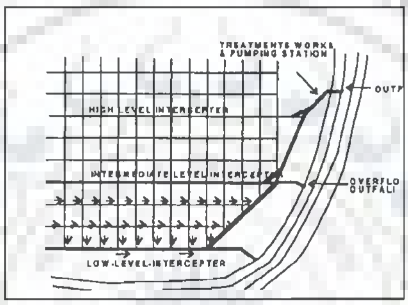
In the interceptor pattern only one single large size intercepting sewer is used to collect and convey the entire sewage, due to which it is over loaded. This over loading can be removed by providing more number of interceptors of each zone as shown in Fig. This type of pattern is most suited to sloppy areas as hills than flat areas (Fig 2.13).



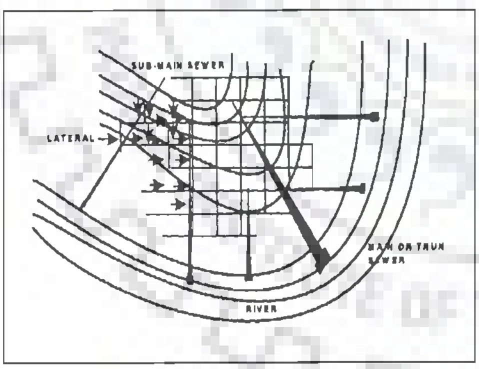
Interceptor Pattern



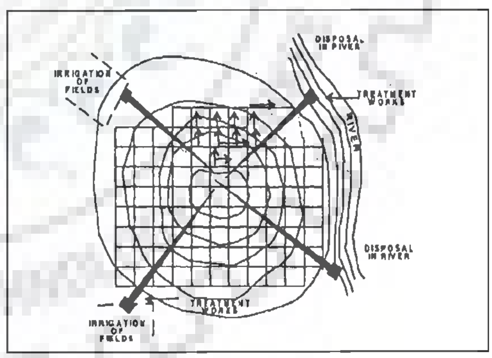
Interceptor Pattern



Fan Pattern



Perpendicular Pattern



Radial Pattern

Fig 2.13: Patterns of sewerage collection system

f. Methods of Disposal of sewage

This wastewater, untreated sewage, sullage and industrial effluents pass through the sewerage system and the disposal of untreated sewage by dilution and land treatment has resulted in many environmental problems such as the contamination and pollution of ground water, pollution of water bodies etc. To control problem of environmental degradation of urban areas Central wastewater Treatment System (CTS) plants were thought of as a solution along with a central sewerage network for the whole city. CTS plants are a combination of primary, like septic tanks, and secondary treatment methods, like activated sludge method, trickling filters. The common types of sewage treatment plants for small and medium towns are shown in Fig 2.14 and 2.15.

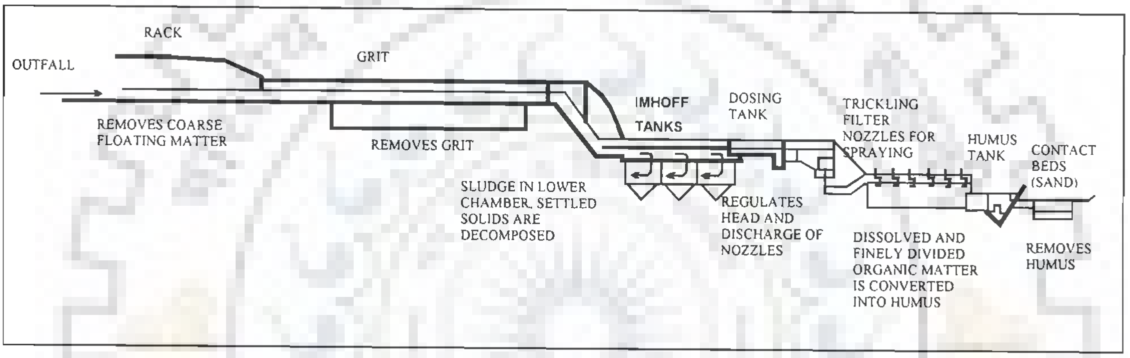


Fig 2.14: Sewarage Treatment Plant For Small Size Towns

Source: Water Supply And Sanitation Engineering, Birdie, G S, (1969)

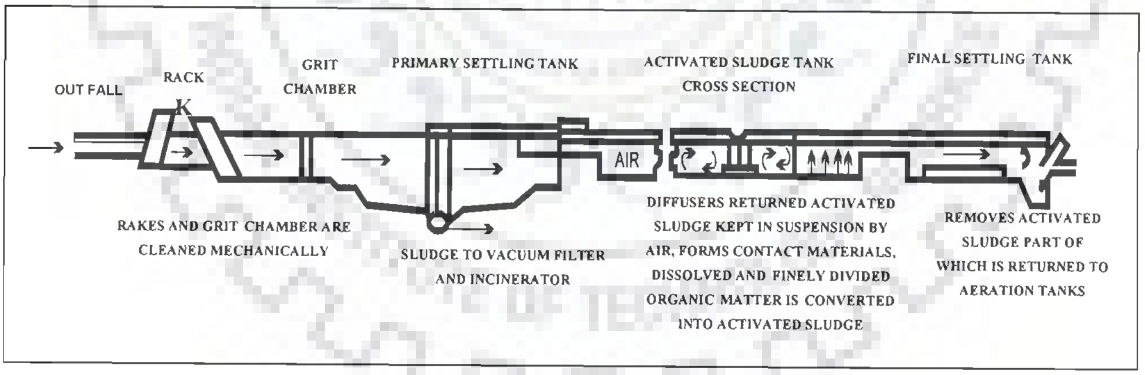


Fig 2.15: Sewarage Treatment Plant For Medium Size Towns

Source. Water Supply And Sanitation Engineering, Birdie, G S, (1969)

In CTS system sewage of whole city is collected at one terminal point of disposal and is treated in one of the conventional treatment plants before disposal as shown in Fig 2.14 and Fig 2.15). In conventional sewage treatment system about 80% of the cost is accounted for the collection of sewage and its conveyance to one terminal point in city is very high. It also requires lot of energy in pumping at intermediate and terminal points. In CTS volume of sewage becomes very large and distance of conveyance is very long as treatment plants are generally located outside the city. CTS aggravates the environmental problem as large volume of the wastewater of the entire city is discharged at one place. The size and components of sewage treatment system depend on the size of city and quantity of sewage produced. For small towns with a population less than 50,000 i.e. class III, IV, V and IV towns a combination of Imhoff tank and Trickling filter is used. For medium size towns with population between 50000 and one lakh Activated sludge method or trickling sand filter is used (Birdie.G S, 1969). The cost of installation of sewage treatment plant in this system is presently around 30 lakhs/MLD of Sewage. Area required for there installation is between 0.1 hectares for a town with a population of 15000 to to 6 hectares for a town with a population of one lakh (Jain,CP, 2003).

2.3.2.2 Non-Conventional Urban Water Resource Management Technologies..

The Rain water Harvesting, Ground water Recharging, Decentralized wastewater Treatment System, Recycling of waste water have also come to be known as non-conventional technologies. These traditional methods of water resource management can be adopted in the urban areas by little modifications according to the place and resources available to integrate it with available urban water resource management infrastructure. The available technologies can be divided broadly into – Surface water management techniques and Wastewater management techniques.

i) ***Surface Water Management Techniques***

Non- conventional surface water management techniques are two types – rain water harvesting structures and ground water recharging structures depending on the rainfall, and site conditions.

In the urban areas there is very little recharge to the sub-surface since most of the surface is either occupied by buildings or roads. Therefore, even if a part of the rainwater can be harvested, this may recharge the depleting ground water level and significantly contribute to the net availability of water for drinking and other purposes in the urban areas by rise in static water level (Shete.D.T. 2006), particularly in the deficient areas (CGWB 1999). Roof-water or rainwater harvesting techniques had traditionally been practiced by the urban communities in different parts of the country. Ranging from a purely domestic based system such as collection of falling water in containers or storage tanks to a community or even town level systems such as ponds, percolation tanks, dams or dykes had been in existence in many introduction of pipe water supply on the one hand and gradual replacement of the community by the Government and Municipalities for the management of water supply in the cities on the other, has led to the abandonment of the 'ancient wisdoms' (Agarwal, A. and Narain, S. 1997). The deepening urban water crisis has off late revived the interest on water harvesting structures.

Of all the techniques of rainwater harvesting, Domestic Rooftop Rain Water Harvesting (DRRWH) is very simple and inexpensive and can be adopted on a decentralised scale at the domestic level without much of additional investment. What are required are simply a catchment surface, an inflow conduit, a storage structure and a filtration system, if the collected water is to be used for drinking purposes (CGWB 2000). This method is particularly suitable for large buildings having the roof area of more than 1000 sqm with rain fall not less than 800mm. For a smaller building having the roof area up to 150 sqm water can be diverted from the rooftop to the hand pump through the pipe of 50 to 100 mm diameter for ground water recharging (IS 15797 : 2008, IS 15792 : 2008). Various studies on DRRWH, based on different types of roofing materials and storage systems have established that generally a loss up to 20% may take place due to evaporation and inefficiencies in collection processes, thus only 80% of rainfall can be harnessed through rooftop (Brar, T. S. et al, 2006).

❖ **Rain Water Harvesting And Ground Water Recharging Structures In Urban Environment**

- **Storage Tanks**

For harvesting the roof top rain water, the storage tanks may be used. These tanks may be constructed on the surface as well as under ground by utilising local material. The size of tank depends upon availability of runoff & water demand. After proper chlorination, the stored water may be used for drinking purpose.

- **Recharge pits**

Recharge pits are constructed for recharging the shallow aquifers. These are constructed 1 to 2 m. Wide and 2 to 3 m. Deep which are back filled with boulders, gravels & coarse sand. The size of filter material is generally taken as below:

- Coarse sand: 1.5 - 2 mm
- Gravels: 5 - 10 mm
- Boulders: 5 - 20 cm

The filter material should be filled in graded form. Boulders at the bottom, gravels in between & coarse sand at the top so that the silt content that will come with runoff will be deposited on the top of the coarse sand layer and can easily be removed. If clay layer encountered at shallow depth, it should be punctured with auger hole and that auger hole should be refilled with fine gravel of 3 to 6 mm size (Fig 2.16).

- **Trenches**

These are constructed when the permeable strata is available at shallow depths. Trench may be 0.5 to 1 m. Wide, 1 to 1.5 m. Deep and 10 to 20 m. Long depending upon availability of water. These are back filled with filter materials. In case of clay layer encountered at shallow depth, the number of auger holes may be constructed & back filled with fine gravels (Fig 2.16).

- **Abandoned dug wells**

Existing abandoned dug wells may be utilised as recharge structure after cleaning and desilting the same. For removing the silt contents, the runoff water should pass either through a desilting chamber or filter chamber (Fig 2.16).

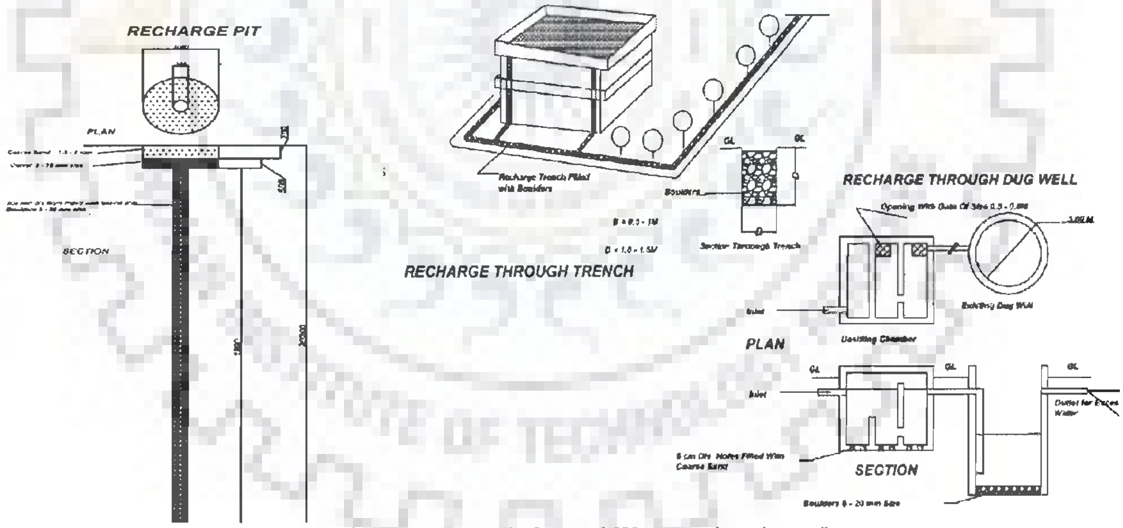


Fig 2.16: Rain Water harvesting Structures & Ground Water recharging – I

- **Abandoned hand pumps**

The existing abandoned hand pumps may be used for recharging the shallow / deep aquifers, if the availability of water is limited. Water should pass through filter media before diverting it into hand pumps (Fig 2.17).

- **Abandoned tube well**

Abandoned tubewell may be used for recharging the shallow / deep aquifers. These tube wells should be redeveloped before use as recharge structure. Water should pass through filter media before diverting it into recharge tube well (Fig 2.17).

- **Recharge wells**

Recharge wells of 100 to 300 mm. Diameter are generally constructed for recharging the deeper aquifers and roof top rain water is diverted to recharge well for recharge to ground water. The runoff water may be passed through filter media to avoid choking of recharge wells (Fig 2.17).

- **Vertical recharge shafts**

For recharging the shallow aquifers which are located below clayey surface at a depth of about 10 to 15 m, recharge shafts of 0.5 to 3 m. Diameter and 10 to 15 m. Deep are constructed depending upon availability of runoff. These are back filled with boulders, gravels & coarse sand. For lesser diameter shafts, the reverse / direct rotary rigs are used with larger diameter shafts. In upper portion of 1 or 2 m depth, the brick masonry work is carried out for the stability of the structure (Fig 2.17).

- **Shaft with recharge well**

If the aquifer is available at greater depth say 20 or 30 m, in that case a shallow shaft of 2 to 5 m diameter and 5 to 6 m deep may be constructed depending upon availability of runoff. Inside the shaft, a recharge well of 100 to 300 mm diameter is constructed for recharging the available water to deeper aquifer. At the bottom of the shaft a filter media is provided to avoid choking of the recharge well (Fig 2.17).

- **Lateral trench with bore wells**

For recharging the upper as well as deeper aquifers, lateral trench of 1.5 to 3 m. Wide & 10 to 30 m. long depending upon availability of water with one or more bore wells may be constructed. The lateral trench is back filled with boulders, gravels & coarse sand (Fig 2.17).

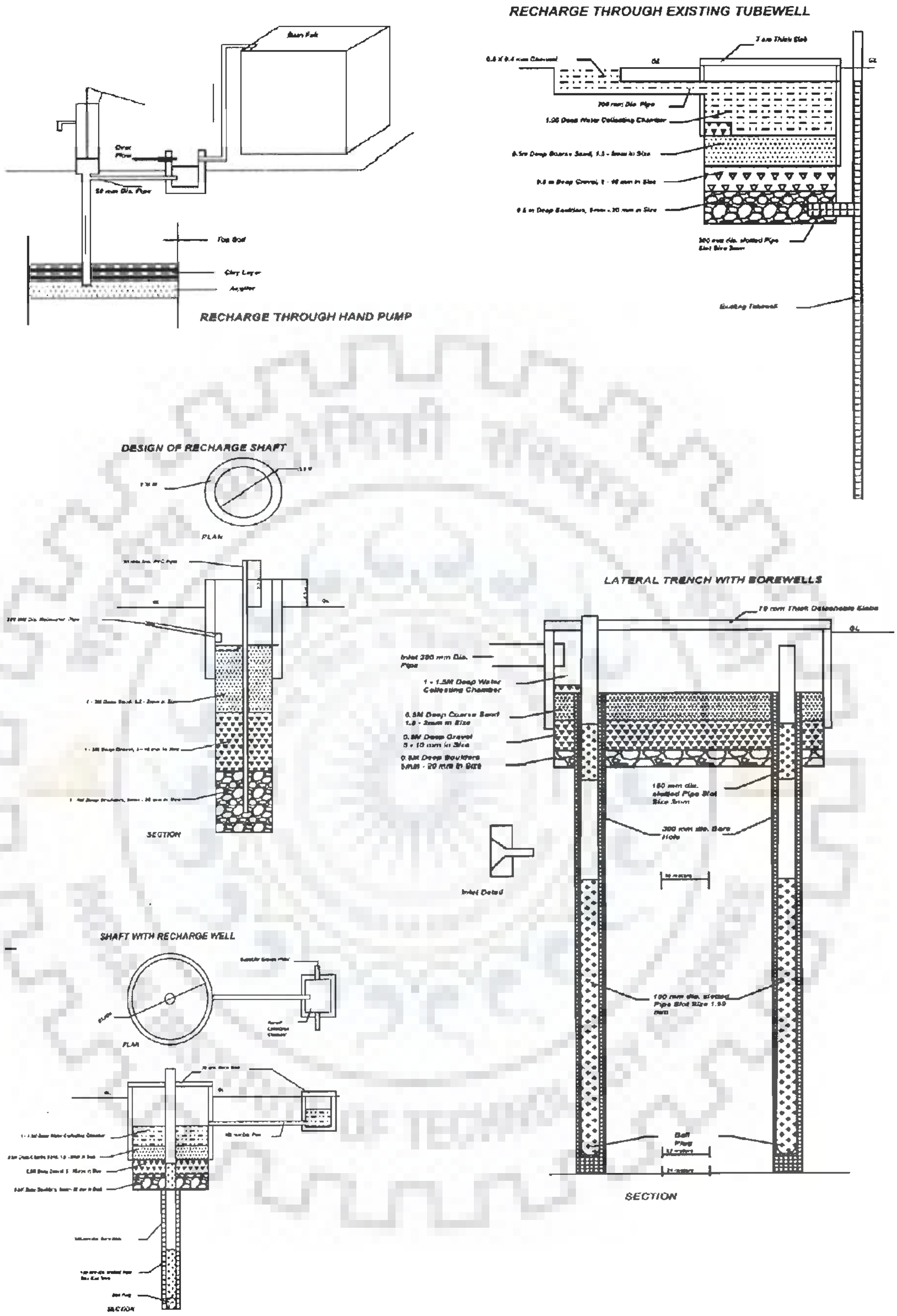


Fig 2.17: Rain Water harvesting Structures & Ground Water recharging – II

ii) *Waste Water Management Techniques*

By non-conventional waste water management techniques can be simply described as Decentralised Waste Water Treatment System (DTS) and recycling of waste water. DTS generally, not necessarily, mean the low-cost treatment system like Root zone Treatment, Stabilization ponds, Septic Tanks, Imhoff Tanks etc. wherein initial cost of such treatment system are low in comparison with conventional energy intensive treatment system (Table 2.28). However, sometimes even the hi-tech/ Conventional Sewage Treatment Plants may be adopted in DTS due to lack of sufficient area required for low-cost treatment system. Each Treatment Technology has got its advantages and disadvantages, and therefore a particular technology should be selected after taking all necessary considerations. It is the concept and approach of DTS, which is more important, i.e. treatment and disposal of sewage near the source, rather than cost or types of treatment technologies (Central Pollution Control Board, 2001).

Domestic wastewater management of a city consists of collection, treatment and disposal of sewage. In conventional sewage treatment system about 80% of the cost is accounted for the collection of sewage and its conveyance to one terminal point in city is very high. It also requires lot of energy in pumping at intermediate and terminal points. In CTS volume of sewage becomes very large and distance of conveyance is also very long, as treatment plants are generally located outside the city. CTS aggravates the environmental problem as large volume of the wastewater of the entire city is discharged at one place (CPCB, 2001).

In DTS, a balance between the advantages of large-scale treatment system in terms of economy of scale and individual responsibility for domestic wastewater treatment is achived by providing colony-wise/sector-wise treatment system. Responsibility of construction as well as operation and maintenance may be taken up collectively by the residential societies / builders / developers. Specific treatment technology can be selected as per the prevailing ground situation such as availability of land etc.

In a DTS, for a sector or zone combinations of these methods of sewage treatment is used and are designed according to the sewage load of the area. The most commonly used combination is anaerobic baffled tank (Baffled septic tank), anaerobic filter, root-zone treatment and anaerobic / duckweed pond. Minimum area required for this combination is 1.5 ha for an area with a population of 5000 persons, (Fig. 2.18) but if area available for STP is less than this in a developed area then a small conventional STP can also be installed in an area of 0,1ha.

Table 2.28: Methods of Decentralized Wastewater Treatment System (DTS)

S. No.	Methods of DTS	Treatment	Use of wastewater after treatment	Advantages	Disadvantages
1.	*Septic Tank*	Sedimentation sludge stabilization	Wastewater of settle able solids	Simple durable, little space as of being underground	Low treatment efficiency, effluent not odourless
2.	*Imhoff Tank*	Sedimentation sludge stabilization	Wastewater of settle able solids	Simple durable, less space as of being underground, odourless effluent	Less simple than septic tank, needs regular desludging
3.	*Root zone treatment system*	Aerobic facultative – anaerobic degradation of dissolved and fine suspended solids, pathogen removal	Suitable for domestic wastewater where settleable solids and most suspended solids already removed by pre-treatment	High treatment efficiency when properly constructed, pleasant landscaping possible, no wastewater above ground, no nuisance of odour	High space requirement, great knowledge and care required during construction, intensive maintenance and supervision during first 1-2 years
4.	*Baffled Septic Tank*	Anaerobic degradation of dissolved and fine suspended solids.	Suitable for pre-settled domestic wastewater of narrow COD/BOD ratio	Simple and durable, high treatment efficiency, less space as of being underground, hardly any blockage, relatively cheap in comparison to anaerobic filter	Less efficient with weak waste water, longer start up phase than anaerobic filter
5.	*Anaerobic Filter*	Anaerobic degradation of dissolved and fine suspended solids.	Suitable for pre-settled domestic wastewater of narrow COD/BOD ratio	Simple and fairly durable if well constructed, and waste water has been properly treated, high treatment efficiency, little permanent space required because of being underground	Costly in construction because of special material, blockage of filter possible, effluent smells slightly despite high treatment efficiency
6.	*Anaerobic pond*	Sedimentation, anaerobic degradation and sludge stabilization	Domestic and strong and medium water	Simple in construction, flexible in respect to degree of treatment, and little maintenance	Wastewater pond occupies open land, there is always some odour, can even be stinky, mosquitoes are difficult to control
7.	*Aerobic pond*	Aerobic degradation and Pathogen removal	Pre-treated domestic wastewater	Simple in construction, reliable in performance if properly dimensioned, high pathogen removal rate, can be used to create an almost natural environment, fish farming is possible when large in size and loaded low	Large space requirement, mosquitoes and odour become a nuisance if undersized, algae can raise effluent BOD
8.	*Duckweed pond*	Anaerobic except aerobic at the top, degradation of suspended and dissolved solids, nutrient removal	Sullage or pre-treated sewage	Simple in construction, revenue generation through pisciculture, suitable for rural and semi-rural area	Large space requirement, possibility of odour can not be ruled out, proper harvesting of duckweed is must

Source: Decentralized sewage treatment system, CPCB Delhi

In both CTS and DTS the cost of sewerage network at sector / neighborhood level is same as the size of network for collection system is same in both the cases. Difference is mainly in case of the city level trunk sewer which is used to convey the sewage to the centralized disposal plant. The size and length of the city level trunk sewer mainly depends on the type of size and area of the city, sewage generated and also the natural slope of the area. Its size varies from 30" diameter to 60" diameter from collection point to the disposal point and its rate per meter varies from Rs. 7 million/km for 30" diameter to Rs. 9 million/km for 60" diameter sewer while cost of STP in CTS is Rs 3million /MLD + land cost with an area of minimum 12 hectare for STP and 1.6 hectare for Sewage Disposal (PWSSB, 2001). Thus per person cost of CTS, excluding branch sewer is ranges between Rs. 900/- to Rs.1700/- per meter.

In the case of DTS there is large number of sewerage treatment plants located at sector / neighborhood level (Fig 2.18). Their number, type and size depend on the population of the area, density of the area, and availability of required area for the STP. High Density areas like walled city, CBD that have density above 350 ppha and which have very less open areas can be provided a STP for every 25000 persons, while for rest of the areas depending on the density and availability of area, STP is provided for every 5000 to 10000 persons. For details of the type of sewerage treatment plant suitable for different areas of city are given in Table 2.29, other than these, industrial and commercial areas must have their own effluent treatment plants as per CPCB guidelines. But DTS involves high initial investment at household level as two-pipe system for water supply must be installed with different pipes for

Table 2.29: Economic analysis of various types of Sewerage Treatment Plants

S.No.	Population	Density (ppha)	Type of STP	Area Required for STP (ha)	Total cost	Cost of Maintenance
1.	25000	450 - 500	Conventional	0.15	Rs. 127 lacs	Rs. 5.52 lacs
2.	10000	200-350	Anaerobic Baffled Reactor, RTS, Duckweed pond	2.5	Rs. 30 lacs	Rs. 1.00 lacs
3.	5000	100-200	Anaerobic Baffled Reactor, RTS, Duck weed pond	1.5	Rs. 30 lacs	Rs. 1.00 lacs
4.	House Hold	5 -8 Persons	Baffled Septic Tank & RTS	$10m^2$	Rs. 4000/-	Rs. 500/-

Source: 1. Decentralised Sewage Treatment Plants in Squatter Resettlement Colonies of Delhi, Er, C.P. Jain. (2003).

2. Design Manual for waste Stabilization Ponds in India, Duncan Mara domestic uses (like drinking, kitchen, bathing and wash basins) and flushing of toilets and gardening, where water after treatment can be used. Inspite of it proper care should be taken about disinfecting the water before it is used for flushing of toilets to avoid any infection (Jeppsen, 1995).

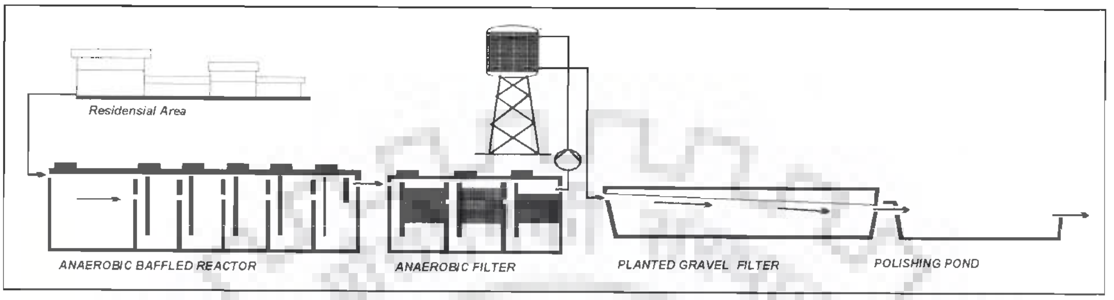


Fig. 2.18: Detail of a Decentralized waste water Treatment System

Source: Project description of DTS at Aravind Eye Hospital, Pondicheery, FEDINA and BORDA, (2003).

❖ **Savings in the cost of water supply due to recycling of wastewater**

In a CTS, the treated sewage is mainly used for urban irrigation or is disposed of in a natural water course after treatment. While in DTS domestic sewage can be divided into two parts:

- **At household level**, i.e. waste water generated from bathing, washing of clothes, utensils, and flushing of toilets which is around 90 lpcd after treatment can be recycled for gardening, washing of courtyards and in some cases if proper care is taken for disinfecting it, can also be used for flushing thus reducing the over all per capita water demand by around 40 lpcd (Report of the National Commission On Urbanisation, 1988 and UDPFI Guidelines, 1996), which is the water required for these activities, and bringing down the overall demand for water supply to 90 lpcd from 135 lpcd (Fig. 2.19)

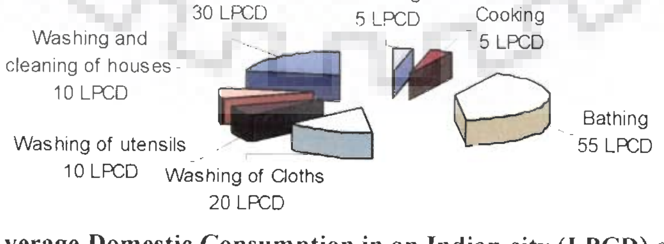


Fig. 2.19: Average Domestic Consumption in an Indian city (LPCD) at house hold Level

Source: Report of the National Commission On Urbanization (1988) and UDPFI Guidelines (1996)

- **At neighborhood level,** i.e. wastewater after treatment at sector level is recycled for landscaping and recreation and in turn resulting in the saving of water, which would have been used for these activities (Report of the National Commission On Urbanisation, 1988 and UDPFI Guidelines, 1996), thus reducing the over all demand at sector level by 40 lpcd and bringing down the overall demand for water supply to 230 lpcd from 270 lpcd at sector level (Fig. 2.20) and if we include in it the water saved by recycling at domestic level then over all demand is reduced to 185 lpcd which results in substantial saving in the cost of supplying fresh water to the residents of an urban area.

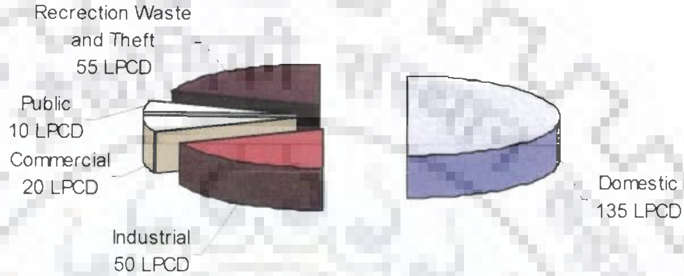


Fig. 2.20: Average Domestic Consumption in an Indian city (LPCD) at Neighbourhood Level

In a CTS, waste water after treatment is either used for irrigation or is disposed of in water courses. But in the case of small and medium towns due to shortage of power and machinery brake downs for almost half a year around sewage is discharged off without any treatment resulting in high organic and nutrient loads in the water bodies and hence spoiling there ecological balance and in this case sewage gets collected at one place also resulting in various other problems like high heavy metal content which if not removed at source becomes a problem later on in such high volumes of sewage.

In a DTS, as wastewater is treated generally near the source and is recycled by using the water after treatment for flushing of toilets, gardening and landscaping resulting in drastic reduction of pollution of natural water courses and pollution of ground water from seepage of untreated sewage and thus help to maintain an ecological balance. In case of non-conventional methods of DTS there is very less use of energy as all of them are gravity based systems and energy is generally required for pumping the treated wastewater for reuse thus they are unaffected by power failures resulting in more efficient disposal of wastewater (Brar, T. S. et al, 2005).

❖ **Standard For Polluted Waters**

If sewage to be discharged in sea or tidal river water the required standard for the polluted water are given in Table 2.30.

Table 2.30: Standard For Polluted Sea Or Tidal River Water

Class of water	Standard of Polluted Water	Use of Polluted Water
A.	(i) Full removal of floating and suspended solids (ii) M.P.N. of B-coil - 50/100ml (iii) D.O. 50% of saturation value	For fish life development recreation and shell fish culture.
B.	(i) Full removal of floating solids (ii) Minimum 10% removal of suspended solids (iii) D.O.50 % of saturation value (iv) M.P.N. of B-coil – 100/100ml	All other use except given in class A

Source :*Manual for Water Supply and Sanitation Standard, Central Pollution Control Board (CPCB).*

The polluted water has been categorized into four categories. The standards of the polluted water and their uses are given in Table 2.31.

Table 2.31: Standards For Polluted Waters

Class of water	Standard of Polluted Water	Use of Polluted Water
A.	B-coil <50/100 ml without filtration	For drinking purpose after chlorinating
B.	B-coil <100/100ml No. visible sewage	For recreation, bathing and shell fish culture or fish culture
C.	D.O.3 to 5 p.p.m and $CO_2 < 40$	For recreation, and fish culture etc.
D.	No odour, nuisance and unsightly suspended floating matters. D.O. should be present	For irrigation and rough industrial use etc

Source :*Manual for Water Supply and Sanitation Standard, Central Pollution Control Board*

2.3.3 Integrated Urban Water Resource Management Plan

IURM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems

The major flaw in the present planning process in India is that the water management is not conceived as its integral part (Fig 2.21), hence the proposed land use development is not according to the available water resources of the urban area and due this reason the necessary Water Sensitive Development Controls which include, reuse of rainwater, storm water and wastewater are never proposed in the Master Plan of an urban area. Thus the water

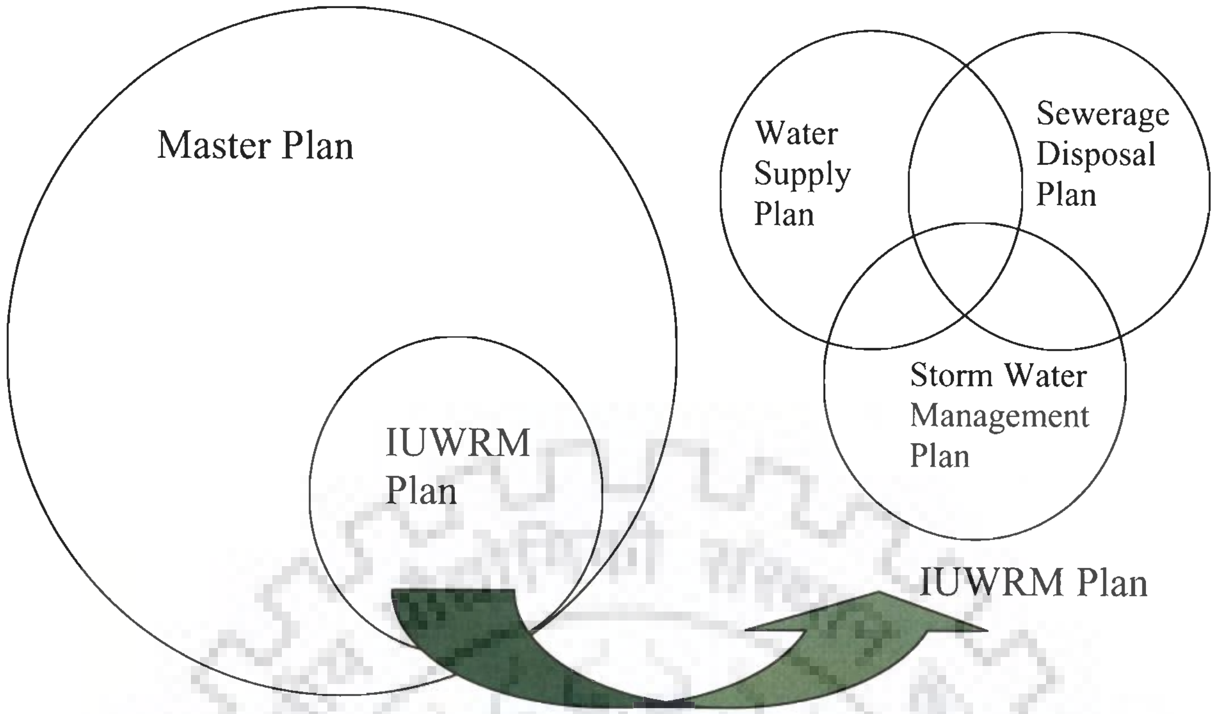


Fig 2.21: Integrated urban water resource management plan as part of master plan

supply is only considered as a service (Demand & Supply Model Approach) rather than the part of the plan, which results in the supply oriented model in which water demand resulting from urban development is met by importing large volumes of treated water, across large distances and at considerable cost, from neighboring catchments. At the same time similar volumes of storm water from roofs are discharged unused from urban developments via expensive storm water systems.

During recent years, decentralized and integrated water management has developed into a remarkable strategy for sustainable and safe urban infrastructure (Kim *et al.*, 2008). Decentralized approaches also offer increased opportunities for local stakeholder participation in planning and decision-making. Parkinson *et al.*, 2003 emphasized the importance of building the capacity of local organizations in all aspects of decentralized wastewater management. Alternative approaches include decentralized rainwater infiltration, on-site treatment and wastewater reuse. All of these techniques also influence the urban groundwater resource in terms of quality and quantity and need to be assessed in a common framework (Wolf *et al.*, 2006).

Present government approaches are not framed in a way that supports the development of decentralized systems in developing countries. Therefore there is a need to develop appropriate standards to be utilized for the design and construction of decentralized wastewater systems and also to promote realistic and acceptable standards for treatment where wastewater is reused. It also requires that these institutions develop capacities for monitoring and regulation and effective systems for enforcing appropriate policies.

CHAPTER – 3

STUDY AREA

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Patiala Known as the city of Lakes and Gardens is the forth largest urban centre of the state of Punjab is considered as study area in the present study. Over the years Patiala has seen a lot of changes from a princely state at the time of independence to become the capital of PEPSU till 1956 when it was merged with other areas to form the larger state of Punjab. It has grown from a town of less than 50000 at the time of independence to about 350000 in five decades. This unchecked growth without any vision and planning to conserve the environment has also put pressure on infrastructure and water resources available in the area leading to diminishing water bodies, gardens and deteriorating urban water availability and its quality.

This chapter give the over view of the Patiala planning area. The surveys and studies were undertaken for the identified components of the study to collect the relevant data for each from the identified sources. The data collected from surveys and studies in almost all the cases is from the reliable secondary sources. Primary survey is done only for the drainage network, vegetation and open spaces. The studies and surveys for data collection/ compilation from relevant sources is undertaken separately for each component.

3.1 DELINEATION OF STUDY AREA

3.1.1 Brief History of Patiala

Patiala City was founded in 1763 A.D. by Baba Ala Singh when he laid the foundation of "Qila Mubarak". The earlier development of the town Spread around the Fort and mud wall (Kot) surrounded the town this mud wall was demolished in 1878 AD but quite number of gates still remain. The Moti Bagh Palace whose design is based on the "Shalimar Garden Lahore" with terraces fountains, Canals and Sheeshmahal is a combination of Mughal and Rajput Architecture. The Palace was built is 1880 A.D Near Bir Moti Bagh on banks of Patialwi Nadi.

Patiala city was built on high ground surrounded by low lying areas with number of small and large drains and other water bodies. To protect the city from ravages of annual floods a proper drainage network for the walled city was designed in 1870 A.D. with all the drains of the city culminating in Ganda Nallah (Jacob Drain). The two defence bandh's against floods namely – first one forming outer edge of defence of the city and second on the Patialawi Nadi, were executed in 1889 A.D.

After independence Patiala City continued to be the capital of the eight princely states amalgamated as "PEPSU" with merger of PEPSU with PUNJAB in 1956 Patiala lost its traditional capital function. Since then Patiala is a seat of Divisional Administration with office of commissioner and other division and state level offices like Income Tax Commissioner, Excise and Taxation Commissioner, Head Quarters of PWD- B&R, and Punjab Public Service Commission D.C.W and national Institute of Sports. With the location of these Important Offices Patiala has developed into a forefront Service City. The city is also an important centre of trade and commerce and is famous for Gota, Kinari and Embroidery work. Patiala is also an important educational centre with one University, four Arts and Science Colleges, One Commerce College, Two Medical Colleges, One Engineering College, One Education College, One College of Physical Education, Two Polytechnics, etc. All this has lead to the rapid growth of Patiala especially after independence, i.e. from a town with a population of 53,000 in 1951 to a city with population of 0.40 million in 2001. Patiala being a multifunctional town has medium growth rate of 30% to 35%.

3.1.2 Location

The Patiala planning area lies between latitudes 30°24'-10" North & 30°16'-10" North and longitudes 76°20'-30" East & 76°29'-40" East. The Patiala city is the division and district head quarter of Patiala division and district. It lies in the South Eastern part of state of Punjab (Fig. 3.1). The city is surrounded by Bhakhra main line canal and model town drain on East, Patialwi nadi on the west and wild life Sanctuary - Bir Moti Bagh and protected forest Bir Kheri Gujjran on the South.

This study has been limited to the planning area delineated for the Patiala Master Plan 2011 – 2031. Patiala Planning area (Fig 3.1) consists of Patiala municipal area, Patiala cantonement. Urban Estate Phase –I, II & III, Punjabi University, Sanaur and villages, Sidhuwal, Rauni, Pasiana, Sher Majra, Kheri Gujjaran, Sulhar, Nurpurkheri. Seona, Hasanpur, Janowal, Mallu Majra, Ghalauri, Dalanpur, Ganaur, Dilwal, Chaura Nurkherian, Jalalpur, Nasirpur, Philauli, Shekhupura Shamspur, Mehmudpur, Rawas, Kherajattan.

3.1.3 Linkages

- It is the fourth largest city of Punjab and well connected by rail and road transport.
- It is connected to Chandigarh (State capital) by Chandigarh -Bathinda NH –61 and to other major cities by state high ways and major district roads.
- It lies on Ambala-Bathinda railway line between Rajpura and Nabha.

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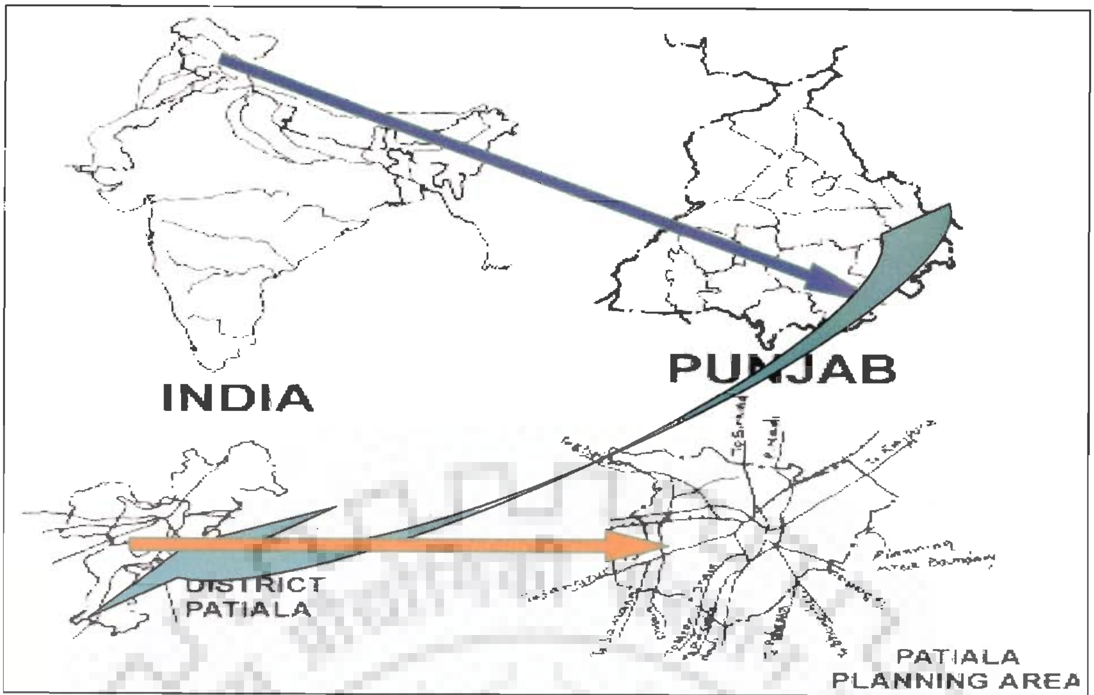


Fig 3.1: Location of Planning Area

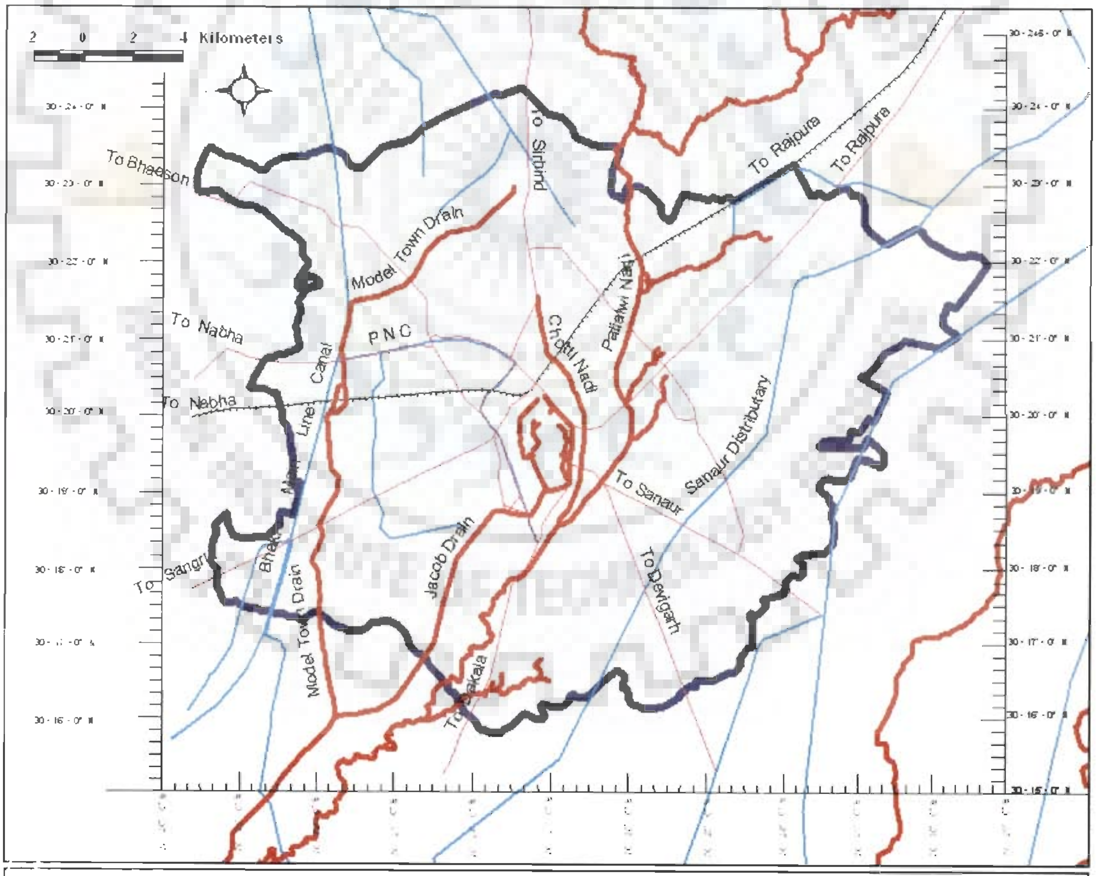


Fig 3.2: Patiala Planning Area

3.2 CLIMATE

The climate of Patiala district can be classified as tropical steppe, Semi-arid and hot which is mainly dry with very hot summer and cold winter except during monsoon. There are four seasons in a year. The hot weather season starts from mid March to last week of the June followed by the south west monsoon which lasts upto September. The transition period from September to October forms the post monsoon season. The winter season starts late in November and remains upto first week of March. The climate parameters of the study area are given in Table 3.1The mean minimum and maximum temperature in the area ranges from 7.1o C to 40.4o C during January and May or June respectively (Fig 3.3).

The normal monsoon and annual rainfall of the district is 547 mm and 677 mm , respectively which is unevenly distributed over the area 29 days. The south west monsoon, sets in from last week of June and withdraws in end of September, contributing about 81% of annual rainfall. July and August are the wettest months. Rest 19% rainfall is received during non-monsoon period in the wake of western disturbances and thunderstorms. Generally rainfall in the district increases from southwest to northeast The monthly average rainfall of the study area is shown in Fig 3.4.

The wind direction during most part of the year is, West to North – West from 330° to 360°. While in months of April, May and October wind direction is, East and North - East direction from 30° to 70°(Fig 3.5).

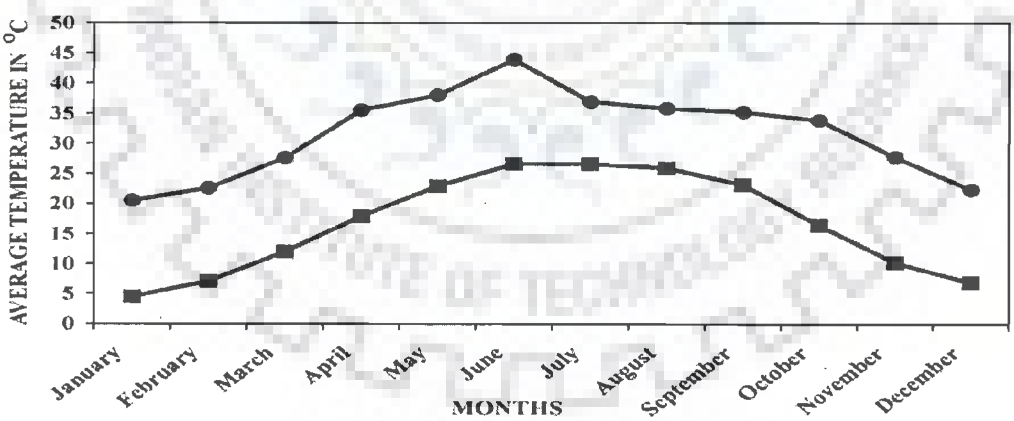


Fig 3.3: Average Temperature in Patiala

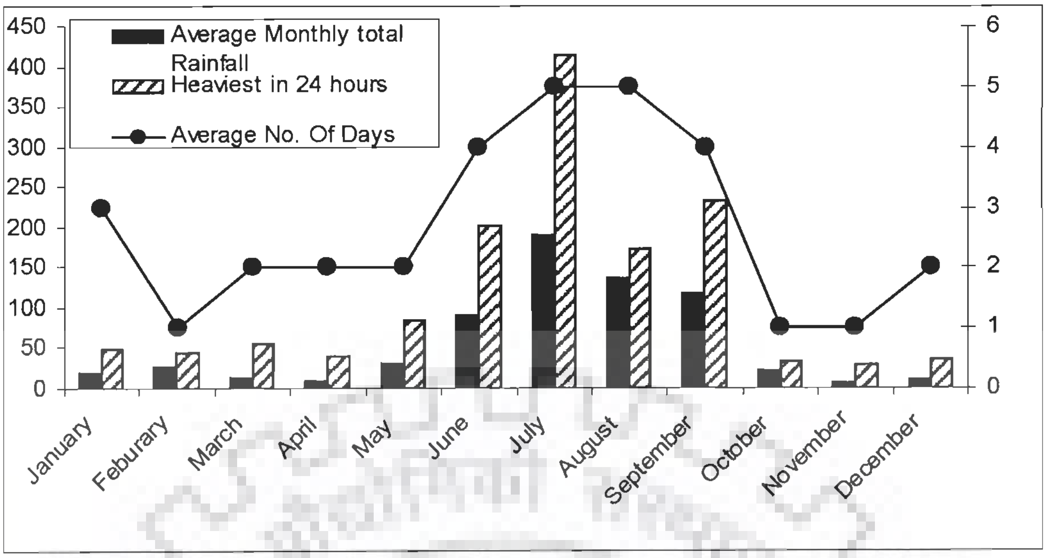


Fig 3.4: Average rainfall in Patiala

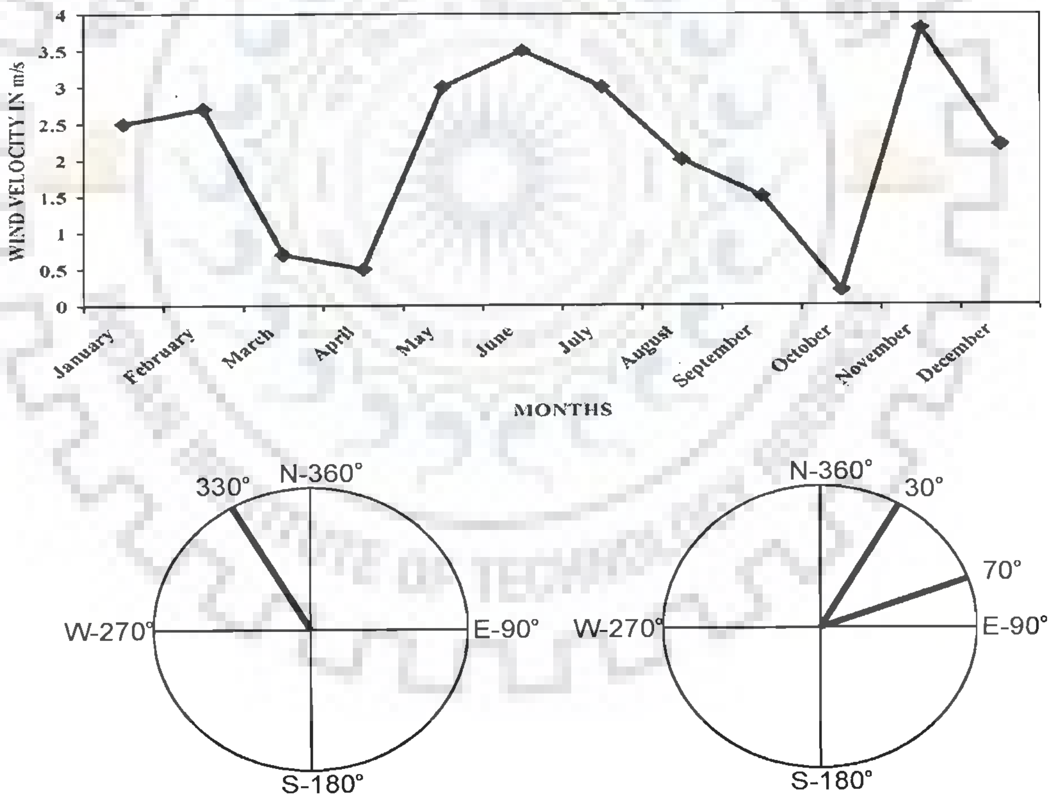


Fig 3.5: Average wind velocity and direction in Patiala

Table 3.1: Detailed Chart Of Climate Data Of Patiala

S. No.	Month	Pressure in N/m^2		Temperature in ^{0}C					R.H. %	Rainfall in MM						Max. Surface wind DDD/KTS
				Avg. Max.	Avg. Min.	EXT. MAX.		EXT. MIN		Avg. No. Of Days	Monthly total (MM)	Heaviest in 24 hours	Heaviest in month	Lowest in months		
i)	Jan.	1	994.1	20.5		28.4	2/88		86	3	20.5	49.6688	54	0.284	26/80	270/32
		2	992.8		4.5			-1.3	48							
ii)	Feb.	1	991.9	22.6		32.8	28/80		81	1	27.2	45.1579	89.9	0.185	13/88	270/30
		2	989.7		7.1			-0.5	46							
iii)	March	1	989.1	27.6		37.3	25/77		73	2	13.2	56.1583	10.1	0.277	11/88	270/43
		2	986.4		12.0			23	43							
iv)	April	1	984.4	35.5		45.5	28/79		48	2	9.3	40.1583	99.1	1.880	30/83	070/34
		2	981.9		17.9			8.5	26							
v)	May	1	980.2	38.0		48.5	4/77		38	2	30.0	33.4287	121.5	1.684	19/88	040/56
		2	972.9		22.9			12.8	20							
vi)	June	1	975.9	43.9		47.8	26.84		47	4	91.0	201.430	426.8	5.780	16/82	330/60
		2	972.9		26.6			18.8	27							
vii)	July	1	976.0	36.9		45.1	8/78		71	5	191.6	414.2229	504.9	0.280	26/80	360/50
		2	973.3		26.6			19.3	52							
viii)	August	1	977.6	35.8		43.0	9/79		76	5	137.4	172.866	280.2	9.777	14/81	350/45
		2	975.6		25.9			21.0	62							
ix)	Sept.	1	982.8	35.2		40.3	4/76		71	4	117.8	232.248	308.1	1.881	22/82	330/60
		2	980.3		23.1			17.2	51							
x)	Oct.	1	988.6	33.8		38.4	2/79		57	1	22.9	33.68	35.0	1.888	15/86	030/42
		2	985.7		16.4			8.6	39							
xi)	Nov.	1	992.4	27.7		35.4	1/80		75	1	6.5	27.835	47.6	1.888	7/79	340/35
		2	989.9		10.2			3.5	45							
xii)	Dec.	1	994.1	22.3		28.1	11/77		85	2	10.4	35.659	41.2	1.888	22/80	230/28
		2	992.1		6.9			-1.0	53							

Source: Airforce Station Patiala

3.3 DEMOGRAPHY

Patiala is fourth largest, Class-I city of Punjab according to Population size. Urban population of Patiala planning area was 3,51,929 persons in 2001 with a decadal variation / growth of +47.64% while rural population was 49,055 persons with a decadal growth of +34.50%. If we compare this with the growth rate of earlier decades the this growth rate is too fast but one thing must be taken in to account that planning area of Patiala has been increased only in 2001 leading to inclusion of a totally new urban area of Sanaur in the planning area with a population of 17935 if we take this into account then growth rate is around 36% for urban population. Similarly with rural population 9 new villages have been included into the planning area and if we take this into account then growth rate comes out to be 20% which is according to the previous trends. Thus growth rates of 36% for urban population and 20% for rural population can be assumed for future projections. Total projected population of planning area is 537900 for 2011, 722000 for 2021 and 970000 for 2031(refer Table 3.2).

Table 3.2: Decadal Change In Distribution Of Population In Patiala Planning Area.

S. No.	Year	Urban Population	Decadal change in Urban Population	Rural Population	Decadal change in rural Population	Total Population	Decadal change in total Population
(i)	1971	1,50,486	+20.16%	19,183	+17.31%	1,69,669	
(ii)	1981	2,05,141	+36.32%	23,060	+20.21%	2,28,201	+34.50%
(iii)	1991	2,38,368	+16.20%	27,328	+18.5%	2,65,696	+16.43%
(iv)	2001	3,51,929	+47.64%	49,055	+79.50%	4,00,984	+50.92%
(v)	2011	4,79,000*	+36.00%	58900*	+20.0%	5,37,900*	+34.15%
(vi)	2021	6,51,000*	+36.00%	71,000*	+20.0%	7,22,000*	+34.23%
(vii)	2031	8,85,000*	+36.00%	85,000*	+20.0%	9,70,000*	+34.23%

* Projected population

Source: Census of India, 1971, 1981, 1991 & 2001

Patiala also has a cantonment with a Brigade stationed there. Total area of cantonment is 750 ha and population is 25,000 (according to information provided by Garrison Engineer's Office).

3.4 GEOMORPHOLOGY AND SOIL TYPES

The district area is occupied by Indo-Gangetic alluvial plain and consists of three types of region viz. the Upland plain, the Cho-infested Foothill Plain and the Floodplain of the Ghaggar river. The elevation of land ranges from 240 to 278 m. Patiala Planning area lies in flood plain Ghaggar river and the elevation of land ranges from 244m to 256m.

Due to arid climate, the soils are light coloured. Tropical arid brown soils exist in the major parts of the planning area. Here soils are deficient in nitrogen, phosphorus and potassium. Soil type in planning area can be divided in to two types – sandy loam and clayey loam. The impermeability factor for sandy loam is 0.3 while for clayey loam is 0.5. Bearing capacity of Sandy loam soil is 245 KN/m^2 and for clayey loam soil is 180 KN/m^2 both these soils have percolation rate less than 8 min/cm and bed rock is 200m below ground level hence soil conditions are suitable for conventional design of buildings and infrastructure.

3.5 VEGETATION

As Patiala lies in the Malwa belt of Punjab so, the main vegetation found in this area is arid in nature. Trees mainly consisting of Sheesham Kikar Palms (Khajur), dhak, Jand, Kareer etc along the roads and forests (Table 3.3). There are also large numbers of orchards of, mangoes guava, litchi, pears, oranges etc. in planning area.

Table 3.3: Type of Vegetation Found In Planning Area

S No.	Name	Type of vegetation
i)	Along road sides canal bank, distributries and railway lines.	Sheesham, Kikar, Jand, Kareer, Eucalyptus etc.
ii)	City Parks - Baradari - Rose Garden	Ornamental trees and grasses and shubs
iii)	Play fields - N.I.S., Stadium, - D.C.W. ground etc.	Truff and Eucalyptus along, the boundary wall
iv)	Forests - Bir Moti Bagh - Bir Kheri Gujjar	Kikar Jand Sheesham, Eucalptus and others and also grasses like
v)	Mash lands	Kikar, Sheesham and grasses

Source : Office of District Town Planning Officer, Town and Country Planning Department, Patiala.

In planning area, there is also marshy land between and adjoining low lying areas of the Badi and Chotti Nadi. The vegetation found in this marshy land is Kikar and Sheesham trees and wild grasses like – Nara, anjan, Khawi, dab, Plawal, Kana and Babbar are also found in these marshy lowlying areas.

3.6 WATER RESOURCES

3.6.1 Surface Water

There are four Seasonal Streams in the planning area – Patialwi Nadi, Chotti Nadi, Jacob Drain, and Model town drain. The detailed discharge data of the different streams is not available except for monsoon months from July to September. All these drains are gauged by Punjab irrigation and drainage department. Except Patialwi Nadi all other drains have their catchment limited to the planning area itself so these get the flow when it rains in planning area thus there flow is only between 1.4m^3/s to 4.5m^3/s. While Patialwi Nadi which has a large catchment area in Patiala and Fatehgarh Sahib districts so its discharge varies between 56.6m^3/s to 226.6m^3/s from July to September (monsoon season) (Details are given in Chapter 5).

3.6.2 Ground Water Scenario

The planning area is occupied by Indo-Gangetic alluvial plain of Quaternary age, and falls in Ghaggar basin. The ground water occurs in alluvium formations comprising fine to coarse sand, which forms the potential aquifers. In the shallow aquifer (up to 50m) ground water occurs under unconfined/water table conditions, where as in deeper aquifer, semi-confined/confined conditions exist. The traditional dug wells tapping the shallow aquifer are not in use and most of them have been abandoned, however, this aquifer is being tapped through hand pumps and shallow tube wells, which are widely used for domestic purposes. The tube wells constructed by the municipal corporation and other agencies have been constructed tapping deeper aquifer down to 100m.

The depth to water level ranges from 26.99 to 34.28 m below ground level during pre monsoon period and 23.28 to 31.62 m below ground level during post monsoon period. The seasonal fluctuation varies from 2.03 to 3.66 m in the area. The long-term water levels trend indicates average fall of 0.70 m/year (Irrigation Department, Punjab).

The total ground water resource potential in the Patiala block has been assessed as per GEC-97. The stage of ground water development is 188%.The net ground water resource of Patiala block have been estimated to be 180.91 MCM and the gross ground water draft of the block is 340.45 MCM leaving behind a shortfall of (-)161.89 MCM. The stage of ground water development in the block is 188% hence ground water is over exploited and therefore Patiala block has been declared as black block by Central Ground Water Board (CGWB) where measures are needed to be undertaken to recharge the ground water and stop the over exploitation.

CGWB has give following recommendation in its annual report for Patiala

- It is necessary to notify the entire district for registration of all ground water abstraction structures and for the construction of any tube well, prior permission should be sought from the Central Ground Water Authority.
- Mass awareness program should be organized to educate the people regarding consequences of mining of ground water and need for its effective/economic use. Public awareness program should be arranged to make the people and industry aware about the menace of ground water pollution and dwindling ground water resources in the towns.
- More canals should be laid for irrigation so that stress on ground water can be reduced. Cropping pattern in the area should be changed by growing low water consuming crops instead of paddy. Improved irrigation practices should be followed in order to reduce burden on irrigation water.

3.7 SOCIO – ECONOMIC CONDITIONS

Patiala has a fast growing economy which is responsible for increasing urbanization in the city. The town is a multifunctional town. The literacy rate of the Patiala City is 78% which is a fairly high literacy rate as compared to the literacy rate of the previous decade i.e. in 1991 the literacy rate was 69% and in 1981 the literacy rate was 40.86% and in 1971 the rate was more 31.51%. This shows there is a tremendous increase in literacy rate of Patiala city.

There are a total of 35 social institutions in the city which caters to the needs of the people there are libraries, old age homes, etc. which are catering to the needs of the people. There has been an increase in the social institutions of the city. There were about 24 social institutions in 2001 and now there are 35 social institutions which show lately there has been an increase in the social infrastructure of the city.

The Patiala city is rich in its heritage and culture. There are small scale units which manufactures coloured cards (naalas), importance to the city. But earlier there was not much emphasis on this profession but lately there has been many steps taken to enhance this activity. There is one Gurudwara Dukh Niwaran Sahib and one Kali Devi Temple which attracts a lot of people from different parts of the region. There is adequate infrastructure at these places to cater the needs of the people visiting these places.

The city of Patiala has a rich cultural background. The city has a great demand for the cultural activities; the manufacturing of coloured cards (naalas), Punjabi juttis, parandi which are exported all over the world. Now steps have been taken to boost the heritage of the city. Recently, there have been heritage festivals being celebrated in the city which also helps to boost the heritage of Punjab.

3.8 ENVIRONMENTAL CONDITIONS

Patiala is a very clean city, with very less pollution. But he main problem in Patiala, is of water pollution. Patiala is surrounded by Bhakhra mian line on the west and Patialwi Nadi on east. There are four main seasonal drains are – Chhoti Nadi, Patialwi Nadi, Model Town Drain and Jacob Drain. These drains carry sewage of the whole Patiala city which creates problem of water pollution. There is no sewage treatment plant in Patiala. Sewage is directly discharged into these drains without any treatment. Quality of ground water is Patiala is being affected by the disposal of untreated industrial waste water and sanitary disposal the drains.

The air pollution in Patiala is mainly due to heavy volume of traffic. The increase in number of vehicles is creating more problems in the city. This is alarming at some junctions / roads. Noise pollution is only due to marriage palaces on Bhadson road and due to vehicles on high traffic volume roads like Twakli Mod, around bus stand etc.

Solid waste disposal site of Patiala city lies on S-E side i.e. on Sanaur road. The whole garbage from the city is disposed on this site. Total garbage generated in the Patiala city is 180 tonnes per capita per day. It is collected by the Municipal Corporation's trolleys from the whole city and finally dumped on this site. Open dumping is done and no other method is employed which can reduce foul smell and land pollution created by it. Other disposal sites are near Tripuri town, Yadwinder Basti etc. In addition to foul smell in vicinity of 200 to 300 m it is also causing pollution of ground water due to leaching.

3.9 PLANNING PROCESS IN PATIALA

Though historians have tried to trace the origin of Patiala (as far as the name is concerned) to Rig Vedic literature yet the town as it stands today was founded by Baba Ala Singh with the construction of the Qila Mubarak in the year 1763. The planning and development of the city can be divided into five main stages

- Period of evolutionary development (1763 – 1862)
- Period of moderate growth (1862 – 1948)
- Period of being capital of PEPSU (1948 – 1956)
- Period of being divisional headquarter in greater Punjab (1956 – 1966)
- Period of being divisional headquarter in Punjab (1966 – till date)

3.9.1 Period of evolutionary development (1763 – 1862)

During this period Patiala made a slow progress. The development of Patiala was determined by the political success of the rulers. Baba Ala Singh who did and desired a lot of growth of Patiala died on August 22, 1765. Maharaja Amar Singh completed the construction of brick fort (Quila Mubarak) during his regime i.e. 1765-1781. A large number of people migrated to Patiala from Saifabad after having captured it by the Patiala forces.

Patiala made a slow progress during the regime of Maharaja Sahib Singh (1781-1813) due to unfavourable economic political situations.

The growth of Patiala also remained slow during the rule of Maharaja Karam Singh (1813-1845). Some new buildings were added in Quila Mubarak, after 1823. Mata Kali Mandir and Kanwar Sahib's haveli were constructed during this period. Maharaja Narinder Singh (1845-1862) did a better work for the development of Patiala as compared to his predecessors. The Moti Bagh was designed on the pattern of Shalimar gardens of buildings like Diwan Khana, Shahi Samadhan, Gurudwara Moti Bagh and few temples were also constructed. The ten gates and ramparts were also built during this period's i.e. 1845-1862.

Thus, during 1765-1862, the growth remained slow and the town was confined within the wall. Quila Mubarak emerged as the nucleus of the town. The commercial area flourished along the Quila Mubarak. Residential area mainly developed in the northern and northern eastern sides of Quila Mubarak. The southern and western parts of the Patiala remained vacant due to big depressions known as Tobas. It seems these depressions of different sizes were carved out to use earth for the construction of Brick fort and Mud wall.

The Town has grown around a brick fort (Quila Mubarak). In the early period of development, the fort acted as a nucleus of development and some shops were developed in the periphery of the Quila. The Town expanded in all directions with the increase of population.

Ten gates on all major roads were constructed. The development of the residential area has taken place within the walled city in this period. The shape of town was also more compact and more influenced by defense. The streets were narrow and zigzag. All the major roads radiate out from the Quila. The layout of the town indicates that streets were only used for pedestrian purposes and vehicular traffic restricted to only major arteries. The function of the town was residential and commercial development took place around the fort.

3.9.2 Period of moderate growth (1862 – 1948)

The growth of Patiala can be termed as moderate during 1862-1948. The rules of Patiala established strong ties with the British who emerged as the most powerful force after their victory over Punjab in 1849.

During the regime of Maharaja Mohinder Singh (1862-1876) Mohinder College, Mohinder Sarai, Moti Bagh Palace and Dargah of Baba Rode Shah were built. Roads were constructed in different parts of Patiala town and some narrow streets were widened. The Mall road was constructed during 1862-1876. Patiala was connected with Rajpura town through metalled road in 1875, while steps were taken to link Patiala with Nabha. The drainage system consisting of a net work of open drains was laid out in 1870. The railway line connecting Patiala with Rajpura was opened on Nov. 1, 1884. The railway line was extended up to Bathinda. The construction of various metalled roads and railway line increased importance of Patiala and also enhanced its growth.

Patiala became an important medical centre of the region with the establishment of Rajindra Hospital (1883) and Mata Kaushyla Hospital (1888). After the heavy floods of 1887 and 1888, two defence bandhs were constructed to protect Patiala from floods. A state workshop was established, Rajindra palace in Barandari Gardens (1884); Leela Bhawan and Guest house (1885).

During 1876-1900. Patiala expanded in North west region. Maharaja Bhupindra Singh (1900-1938) did a commendable work for the development of urban amenities in Patiala. The establishment of Municipal committee in 1904 was a remarkable step in this direction.

The overhead water tank called 'A-Tank' or Minto Tank was constructed in 1910, to supply water in areas located near the Quila Mubarak. In 1918, another water tank known as 'B-Tank' was constructed to supply water to Rajindra Hospital and Barandari Gardens.

In year 1920 Maharaja of Patiala Invited Patrick Geddes to make a developmental plan for Patiala. In 1922 he submitted his report titled, "Town Planning at Patiala State and City: A Report to H. H. the Maharaja of Patiala" giving guidelines and stratigies to be adopted to improve urban environment of city.

The supply of electricity was extended to other parts of town in three stages i.e. 1919, 1921 and 1926. Polo ground outside Sunami Gate and a cricket stadium in Barandari were developed. To provide more recreation facilities, Malwas Cinema (1941), Phul Cinema (1943) and Capital Cinema along were constructed along the Mall road. The famous Gurudwara Dukhniwaran was built up in 1941.The Yadvindra Public school was established on the pattern of Aitchenson College of Nobles at Lahore. The Army headquarters, soldier's club, power house and fire brigade were the other important additions to Patiala during 1938-1948. Patiala city largely expanded beyond the walled area during the period spanning from 1862 to 1948. Northern and western sides of Patiala emerged as favorably accessible areas for further physical expansion. The town started growing beyond the walled area only after the construction of old Moti Bagh Area. The function of town started changing from being a largely residential. It began to grow as an important administrative, industrial, commercial and recreational centre.

3.9.3 Period of being capital of PEPSU (1948 – 1956)

A spectacular development took place during a small period of eight yrs (1948-1956) as Patiala became capital headquarter of Patiala and eastern Punjab states (PEPSU). The PEPSU government constructed new schools and strengthened facilities at Patiala. The Lehal area was selected for establishment of University. Thapar institute for engineering and technology was opened in 1956. Industrial Training centre was established in 1956. The central state library came up in 1956. Patiala after getting status of capital headquarter developed at very fast pace and establishment of number of educational institutions which provided other nucleus of development. Patiala grew in the northern and western part due to favourable geographical conditions. The arterial roads influenced the pattern of development due to their better accessibility. The other factors which influenced the pattern of growth during this were location of Bhakra mail line canal and forest Bir Moti Bagh.

Rajindra Hospital capacity of beds was increased Ayurvedic College was setup in Patiala. Shifting of Rajindra Hospital resulted in establishment of many chemist and druggist shops, fruits shop etc in the area. All these establishments collectively boosted the growth of Patiala city. On the commercial front new retail markets were developed in Tipuri area and near Railway crossing No. 22. Patiala made rapid progress in the industrial sector during the period extending from 1948-1956. The factory area was developed in 1954. The establishment of power house also boosted the industrial development.

With the establishment of a large number of educational institutions, medical institutions, many new residential colonies came up in Paitala from 1948 to 1956. The new residential colonies like Bhupindra nagar, Ajit Nagar, Model Town, Sant nagar sprang up. Many residential areas were added to Lehal which later merged with Patiala city. The establishment of military cantonment on Sangrur road was another important addition to Patiala city.

The PEPSU government made tremendous efforts for the development of Patiala, establishment of Patiala as an important educational, medical and industrial area was there. There is lack of segregation between residential commercial, industrial and other areas. The layout of different areas has great contrast. The planned areas have provision of amenities such as water supply, sewerage system, street lights, open spaces whereas most of unplanned areas lack this.

Patiala after getting status of capital headquarter developed at very fast pace and establishment of number of educational institutions provided other nucleus of development. Patiala grew in the northern and western part due to favourable geographical conditions.

3.9.4 Period of being divisional headquarter in greater Punjab (1956 – 1966)

The growth of Patiala can be termed as remarkably high during the period 1956-1966 after the merger of PEPSU into Punjab state due to state reorganization commission. Patiala became a tehsil, a district and a divisional headquarter. Many state level offices like PSEB, PPSC, PWD, Income Tax Commissioner's office, etc were retained in Patiala. Thus, Patiala remained an important administrative centre of Punjab. Patiala city witnessed many new additions of educational institutions in this period. Khalsa college was founded in 1960. Punjabi university was established on April 30, 1962. M.M. Modi College came up in 1966. NIS came up in old Moti Bagh area. The establishment of various educational institutions acted as a catalyst factor in promoting growth of Patiala.

3.9.5 TOWN PLANNING STAGE (1966 – till date)

In 1966 after reorganization of Punjab lead to formation of Punjab, Haryana and Himachal Pradesh as three different states and Patiala retained the status of divisional headquarters. The first master plan for Patiala city from 1971 – 1991 was the first town planning exercise undertaken by the government to control the haphazard development of the city. Underground sewerage system was planed in 1972. Three cinema houses namely Harbans, A.C and Ellora cam eup to strengthen Recreational facilities in Patiala city. New residential colonies were developed to accommodate fast increased population i.e. Hira Nagar, Punjabi Bagh, Bishan Nagar, Charan Bagh, Pratap Nagar, Officers colony, SST Nagar, Mathura colony etc. The arterial roads influenced the pattern of development due to their better accessibility. The other factors which influenced the pattern of growth during this were location of manmade features such as Bhakra main line, Bir Moti Bagh.

The first Master plan was revised in 1985 and second master plan from 1985 - 2005 was prepared with extended planning area to include the urban estates and other areas which have come up in the outskirts of city. During this period many new areas of Ranjit nagar, Century Enclave, focal point and many new developments on Sanuur road, Bhadson road Sirhind road took place. After establishment of Punjab Urban Development Authority (PUDA) in 1995 the uban estates were transferred under its jurisdiction. Urban estate phase-III , Urban estate Baran, Phulkian Enclave, Mini secretariat, new courts complex were undertaken by PUDA. Several projects for transportation including widening of roads, construction of grade separators, construction of south bye-pass were also were also undertaken to improve the traffic management in the city. Network of water supply and sewerage were also laid out in much new area. This has lead to increase in the number of tube wells in the city as ground water is being used as the only source of water supply. Also the networks of open drains were covered in many parts of the walled city but still lot needs to be done in case of disposal of sewage and effluents from industry as there are no sewage treatment plants in the city except in the urban estates which was constructed only in 2006.

Municipal corporation was established in 1997 and the Patiala development Authority was formed in 2003 and with this planning area was again extended to include surrounding areas including municipal committee of Sanaur and it was decided to prepare a new master plan from 2010 – 2030 and for the mean time the second master plan was extended till 2010 but with increased planning area.

3.10 CONCLUDING REMARKS

This chapter gives us the overview of the Patiala – Location, surroundings, climate, physiographic, socio-economic and environmental aspects and a broad picture of the issues involved in its development. For the purpose of this study the urbanisation of Patiala can be divided into three major categories

- 1947 to 1971 A.D. – After Independence upto the preparation of first master plan in 1971 A.D.
- 1971 to 1985 A.D. – First master plan duration before revised plan was prepared in 1985.
- 1985 to 2010 A.D. – Revised master plan 1985 – 2010 duration

And all the analysis of the land use development - proposed projects and undertaken during the duration of each plan phase, will be analysed in relation to the water resources in the planning area.

CHAPTER – 4

DATABASE PREPARATION

CHAPTER-4
DATABASE PREPARATION

To evolve a sustainable urban water resource management policy involves the analysis of the effect of urbanization on the water resources i.e. how the growth of the urban area has affected the quantity and quality of water resources. The urban growth and development policies affect the natural hydrology of an area resulting in decreased ground water recharge and increased surface runoff, to meet the increasing demand of water in the urban area involve exploitation of water resources in the area and importing large quantities of water in the area from other areas to meet the shortfall in demand. Urbanisation also brings changes to the vegetation of the area due to deforestation, change in land use from rural in urban and development of low-lying, marsh lands and water bodies into developed areas without taking into consideration the high environmental costs. The unregulated urbanisation without proper infrastructure for disposal of sewage results in contamination of water resources in the area having an adverse affect on total water availability for various uses.

In an urban area there are many agencies involved in formulation and implementation of various planning and development policies and regulations so to undertake the study and development of an urban area the data needs to be collected from various agencies and a database needs to be prepared in a common format to be utilised in analysis be prepared. It is a process which involves identification of various components of the study and the agencies involved with each component before hand to avoid duplication of data and it will also save time as well.

This chapter deals the identification of components of the study, the agencies and departments involved with each component, selection of methodology for the study and the software to be used in preparation of data base.

4.1 COMPONENTS OF THE STUDY

The components of study can be broadly divided into two categories – Land use data and water resource management data. Land use data of the planning area is needed to study the growth of city, change in land use and location of various land uses with respect to water resources in the planning area and various sources of land use data are – land use maps (District Town Planner, Town and country planning department, Punjab), Remote sensing imagery (National Remote Sensing Center, Hyderabad) , Google earth images and maps from various other agencies involved in land use planning and development such as Municipal Corporation, Punjab Urban Development Authority (PUDA), Patiala Development Authority (PDA), Improvement Trust, Cantonment Board etc. Water resource management data is needed to study the available water supply infrastructure in the area, quantity and quality of water resources in the area, how the changes in land use have affected the availability of water resources in the area, which of the sources are being exploited and which are being under utilised and the ones which need urgent intervention to save them from becoming extinct. The agencies involved in the water resource management are – Municipal Corporation, Punjab Urban Development Authority (PUDA), Patiala Development Authority (PDA), Improvement Trust, Punjab water supply and sewerage board (PWSSB), Puhlic Health and environment (PHE), Punjab Pollution control Board, Punjab Irrigation and Drainage Department, Central Ground Water Board (CGWB), Cantonment Board and various other private and government bodies with their independent water supply and sewage disposal network etc. The water resource data can be divided into three main categories on basis of their availability – Surface water, Ground water and water in canals and their distributaries sanctioned for the planning area.

4.2 DATA AND SOFTWARE USED

While creating the database for the study, it is broadly divided into spatial and non-spatial data. The data involving land and information directly related to the land like maps and information related to it is classified as spatial data and the data which gives us information regarding the quantity, quality and quantum of the a components such as population, water etc is known as non-spatial data. These two data sets are to be combined together with necessary inputs from each in different models for analysis to see the effect on water resources in area with the change in each parameter and policy. The data collected for the study is from different reliable secondary sources and no primary survey is conducted except to verify the ground truth of various land uses for the remote sensing imagery. The data used for study from various sources is given in Table 4.1.

In this research ERDAS Imagine 8.6 is used for image processing, while ArcViewGIS_3.2a. is used for database creation in GIS environment and related analysis, MSExcel spread sheet is used for analysis of non-spatial data and MSOffice is used for report writing and presentation of research work.

Table 4.1: Data Acquired for Study

S. No.	Data	Type	Source	Units/Scale
1.	Remote Sensing imagery of Patiala	Spatial	IRS P6, NRSA, Hyderabad.	Resolution: 5.4m
2.	Land use map of Patiala - 1951	Spatial	DTP Office Patiala	1:15000
3.	Land use map of Patiala - 1971	Spatial	DTP Office Patiala	1:15000
4.	Master Plan – 1971 to 1991	Spatial	DTP Office Patiala	1:15000
5.	Land use map of Patiala - 1985	Spatial	DTP Office Patiala	1:15000
6.	Master Plan – 1985 to 2005	Spatial	DTP Office Patiala	1:15000
7.	Land use map of Patiala - 2005	Spatial	DTP Office Patiala	1:15000
8.	Google Earth Image of Patiala - 2010	Spatial	Google Earth 5.0.11733.9347	-
9.	Contour Map of Patiala	Spatial	DTP Office Patiala	1:15000
10.	Topo Sheet No. 53B/7	Spatial	Survey Of India	1: 50000
11.	Topo Sheet No. 53B	Spatial	Survey Of India	1: 250000
12.	Ward Map Of Municipal Corporation, Patiala	Spatial	Municipal corporation, Patiala	1:15000
13.	Water Supply and Sewerage Zones of, Patiala	Spatial	Punjab water Supply Sewerage Board, Patiala	1:50000
14.	Ground Water Quality in Patiala	Non Spatial	Punjab pollution Control Board, Patiala	
15.	Surface Water Quality in Patiala	Non Spatial	Punjab pollution Control Board, Patiala	
16.	Demographic Data of Patiala	Non Spatial	Census Of India, New Delhi	
17.	Building Bye Laws Of Municipal corporation Patiala	Non Spatial	Municipal corporation, Patiala	
18.	Building Bye Laws Of Patiala Development Authority	Non Spatial	Patiala Development Authority, Patiala	
19.	Building Bye Laws Of Improvement Trust, Patiala	Non Spatial	Improvement Trust, Patiala	
20.	Vegetation In Patiala	Spatial	Forest department, Patiala	
21.	Flow in Canal Distributaries and Drains	Non Spatial	Irrigation & Drainage Department Punjab	
22.	Climatic Data for Patiala	Non Spatial	Indian Metrological Department, Air force Station Patiala	
23.	History Of Patiala	Non Spatial	Archives Of Patiala.	

4.4 DATA BASE PREPARATION

Database preparation involves following steps:-

- Geo-referencing of Imagery and Maps.
- Classification of Imagery to identify various land uses.
- Preparation of Base map
- Preparation of different layers in GIS environment and attaching data to them.
- Primary and secondary analysis in GIS environment using various tools and models.

4.4.1 Geo-Referencing Of Imagery and Maps

Remote sensing image of Patiala (Fig 4.1) which has been used in this research is an IRS P6 . The different parameters of the image used are given in Table 4.2

Table 4.2: Parameters of Image Used

S.No.	Parameters of Image	Value of each Parameter
(i)	PRODUCT	1
(ii)	Product number	060104300501
(iii)	Satellite ID	P6
(iv)	Sensor	L-4
(v)	Path-Row	202-039
(vi)	Date, Time and Scene Id	08-MAR-05 05:45:18L4X ST00B234F
(vii)	Product Code	STPC0026J
(viii)	Orbit Number	7219
(ix)	Image Layout	BIL
(x)	Number Of Bands	3
(xi)	Bands Present in Product	2 3 4
(xii)	Bands in this volume	2 3 4
(xiii)	File Header	540
(xiv)	Line Header (Prefix Bytes)	32
(xv)	Line Trailer(Suffix Bytes)	0
(xvi)	Scan Lines	5276
(xvii)	Pixels	4937
(xviii)	Bytes Per Pixel	1
(xix)	Image Record Length(Bytes)	4969
(xx)	No of Volume	1/1

The False colour composite (FCC) of the image is prepared by using Earth Resources Data Analysis System (ERDAS) IMAGINE 8.6. The satellite image is Geo-referenced with a Universal Transverse Mercator (UTM) projection, using the World Geodetic System of year 1984 (WGS-84) datum using ERDAS Imagine 8.6 along with the maps of Patiala planning area (Fig 4. 3) and survey of India Topo Sheet 53-B/7 (Fig 4.4). The details of the projection system are given below:

- PROJCS["WGS_1984_UTM_Zone_43N",

- GEOGCS["GCS_Everest_India_Nepal",
- DATUM["D_Everest_India_Nepal",
- SPHEROID["Everest_Definition_1962",6377301.243,300.8017255]],
- PRIMEM["Jakarta",106.8077194444444],
- UNIT["Degree",0.0174532925199433]],
- PROJECTION["Transverse_Mercator"],
- PARAMETER["False_Easting",500000.0],
- PARAMETER["False_Northing",0.0],
- PARAMETER["Central_Meridian",75.0],
- PARAMETER["Scale_Factor",0.9996],
- PARAMETER["Latitude_Of_Origin",0.0],
- UNIT["Meter",1.0]]

4.4.2 Classification of Imagery to identify various land uses

The False colour composite (FCC) of the image is classified using Earth Resources Data Analysis System (ERDAS) IMAGINE 8.6. A combination of unsupervised and supervised classification methods has been used in identifying the different land use and land cover (LULC) classes. First, the image have been classified for LULC classes of forest, agriculture, settlements, water bodies and other (barren land and dry river/ stream bed) by supervised classification method. Again, the same imageries have been classified by unsupervised classification method for fifteen numbers of land use classes and subsequently, these classes have been reduced to four by manually merging them with visual interpretation with simultaneous comparison with already classified imageries by supervised method Fig 4.2). The recognized patches have been verified using spatial database information and high resolution real world images of recent years from Google Earth Launch Programme (www.earth.google.com and www.wikimapia.org) (Fig 4.6). Intended LULC classes are also based on the information acquired and observed during the field visits.

4.4.3 Preparation of Base map

Base map of Patiala is prepared by digitising the geo-referenced planning area map and satellite image of Patiala in GIS environment using ARC View 3.2a software. The base map includes planning area boundary, road network, water bodies, drains, canals, forests, agricultural land and existing land use of the Planning area. All these features are prepared in different layers and the non-spatial data is attached to each layer using data base tables for

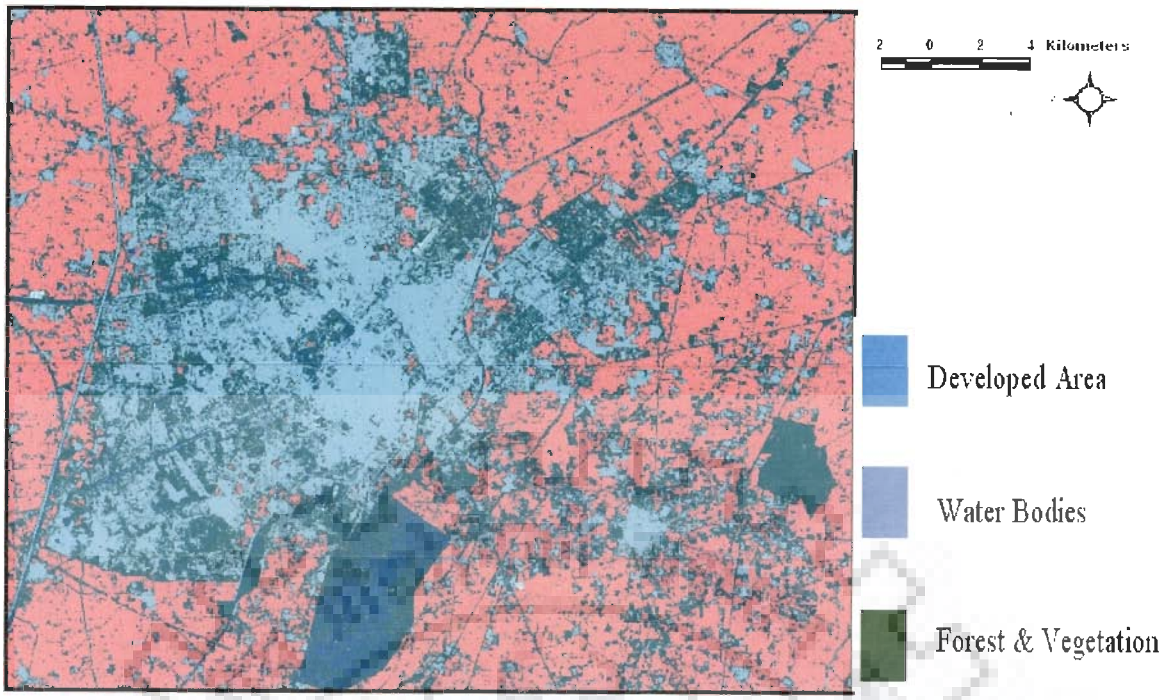


Fig 4.1: IRS Image of Patiala Planning Area

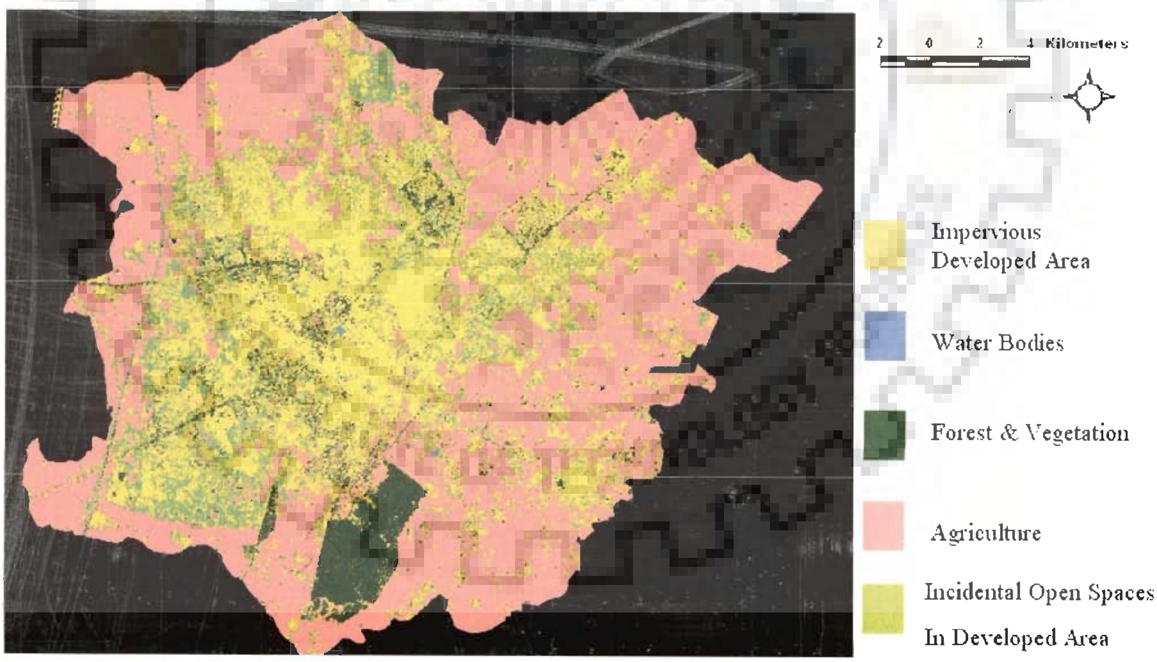


Fig 4.2: Classified Image of Patiala Planning Area

Fig 4.3: Existing Land use Map of Patiala – 2005

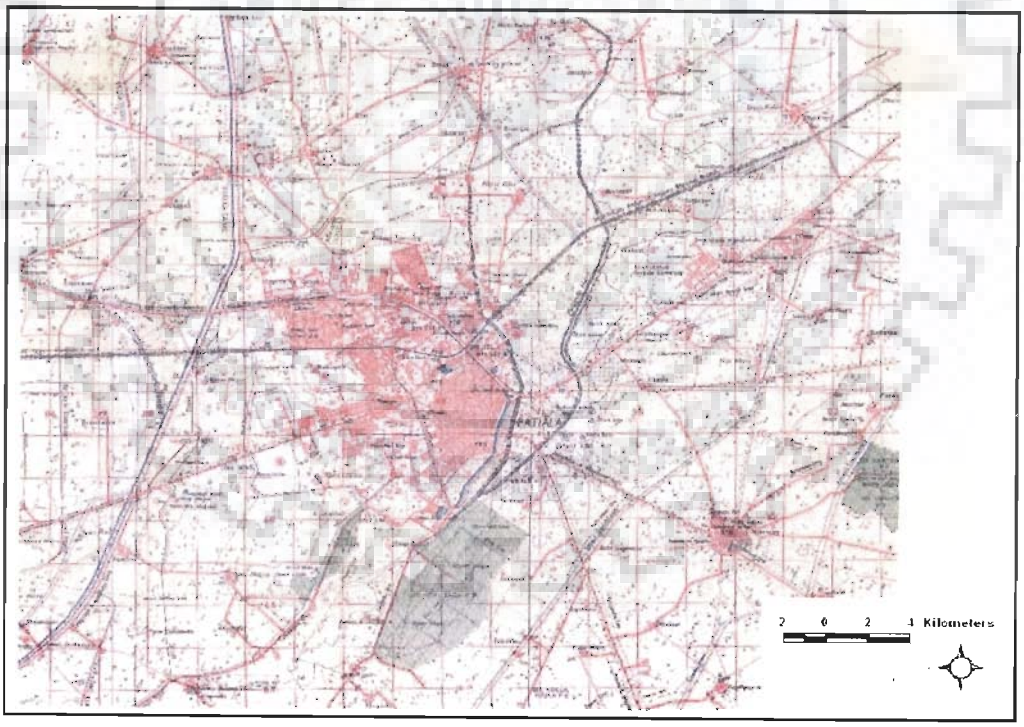


Fig 4.4: Topo Sheet 53-B/7

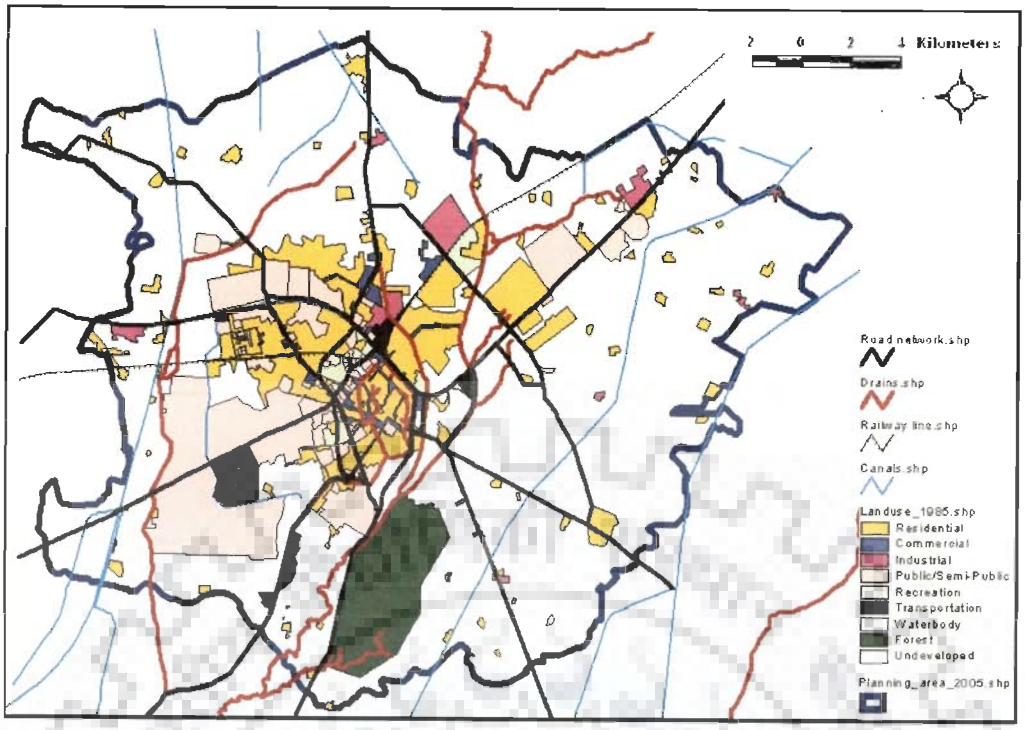


Fig 4.5: Base Map with Land use of 2005

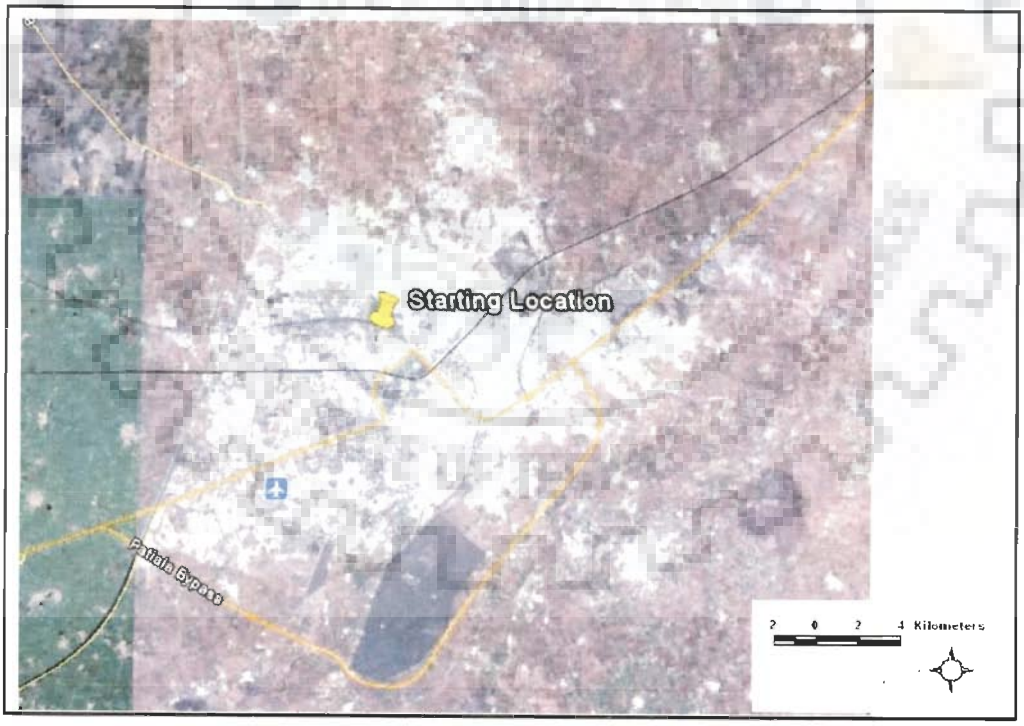


Fig 4.6: Google Earth Image of Patiala – 2010

analysis. This map (Fig 4.5) is then used as the base for preparation of other maps so the accuracy during digitisation and field verification of various land uses is of utmost importance and changes are incorporated and land use updated wherever there is a change.

4.4.4 Preparation of different layers in GIS environment and attaching data to them

To study the effect of urbanisation on water resources in Patiala different maps are prepared. These maps are divided into primary maps and secondary maps. Primary maps give the information regarding the topography, growth of city, size of city, growth pattern of city, circulation, water bodies, open areas, location of different land uses etc. The spatial data information for each layer is calculated by using area calculation tools of ARCVIEW 3.2a. While non spatial data of each feature is attached in each layer table which is used to for analysis using various methods like buffering, intersection, union, and running of various models with arithmetic overlay and weighted overlay etc. The maps which are an output of these various operations are known as secondary maps.

The primary maps of this research are:

- Location map of Patiala
- Classified satellite image of Patiala
- Base map of Patiala Planning Area.
- Land use map of 1971.
- Land use map of 1985.
- Land use map of 2005.
- Land use map of 2010.
- Growth of developed area in Patiala from 1951 – 2010.
- Master Plan of Patiala 1971 – 1991.
- Master Plan of Patiala 1985 – 2005.
- Contour map of Patiala.
- Census ward map of Patiala.
- Water supply map of Patiala.
- Sewerage network map of Patiala.
- Drainage network map of Patiala.
- Rainfall runoff zones in Patiala.
- Recommended land use map for Patiala according to water resources.

The Secondary maps in this research are:

- Extent of ground water pollution map

- DEM of Patiala
- Flood map of Patiala
- Flood analysis of 1971 Land use.
- Flood analysis of 1985 Land use
- Flood analysis of 2010 Land use
- Flood analysis of 1971 – 1985 Master Plan
- Flood analysis of 1985 – 2005 Master Plan

4.4.5 Primary and secondary analysis in GIS environment using various tools and models

Analysis in this research is divided in to two categories spatial analysis and quantitative analysis. Spatial analysis is done in GIS environment using ARC VIEW 3.2a and ERDAS Imagine 8.6. The methods used for analysis include buffering – to see the extent of ground water pollution from disposal of untreated sewage in the drains, creating DEM from contours – to analyse the location of various land uses, intersection and union of different layers and running of weighted arithmetic overlay model for flood analysis of land use during various periods and type sewerage network suitability for an area (Fig 4.7).

While quantitative analysis is done using Microsoft Office EXCEL 2003 with spatial inputs from various thematic layers generated in ARC VIEW 3.2a and data from other secondary sources like census of India, Punjab pollution control board, Punjab water supply and sewerage board, Punjab irrigation department, Punjab drainage department, Municipal corporation, Improvement trust, Patiala Development Authority, District Planning officer, Town and country planning department, Punjab. The Microsoft Office EXCEL 2003 is used to calculate quantities of various element of research like: Population, Area under different land uses, Water Demand, Density of development, Generation of Sewage, Increase in Surface runoff with change in land use, and to generate different scenarios if different policies for development are adopted. To present the various results which are generated in Microsoft Office EXCEL 2003 charts, pie diagrams and line diagrams are generated.

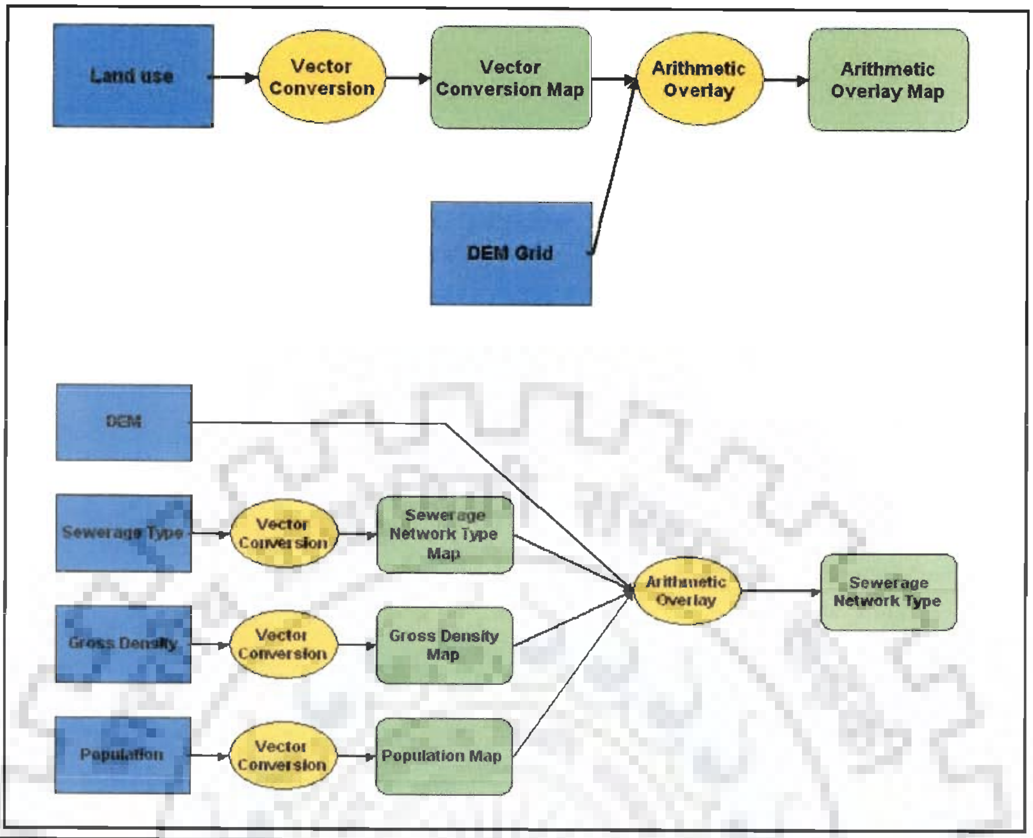


Fig 4.7: Arithmetic Overlay models used for flood analysis & sewerage network suitability map for Patiala.

4.5. CONCLUDING REMARKS

The accuracy of data base prepared is the most important thing in a research to achieve the accurate results. For this purpose the different components of the study and the agencies and departments involved in water resource management from which this data is available are identified. The data collected from each agency is then reviewed, corrected and converted wherever necessary in a common platform to be used in the study. Then the data base has been prepared using ERDAS Imagine 8.6, ARC View 3.2a and Micro soft Office EXCEL 2003.

CHAPTER – 5

URBANIZATION OF PATIALA AND ITS IMPACT ON WATER RESOURCES

CHAPTER-5

URBANIZATION OF PATIALA AND ITS IMPACT ON WATER RESOURCES

Urbanization can describe a specific condition at a set time, i.e. the proportion of total population or area in cities or towns, or the term can describe the increase of this proportion over time. So the term urbanization can represent the level of urban relative to overall population, or it can represent the rate at which the urban proportion is increasing. Uncontrolled urbanization can lead to severe pressure on physical infrastructure leading to deterioration of urban environment, so there is a need to have a sustainable urban planning.

This chapter give the over view of urbanization of Patiala planning area and the impact of this uncontrolled and environmentally insensitive urbanization on water resources. The urbanization of Patiala can be broadly divided into three phases –

- Pre town planning Stage till 1971
- First master plan Phase from 1971 – 1985.
- Revised Master Plan Phase from 1985 – 2005.

and the urbanization of Patiala is studied for each phase with respect to water resources in the Patiala planning area.

5.1 URBANIZATION OF PATIALA

5.1.1 Urbanization and Changes in Topography of Patiala Planning Area.

In India census of India has defined Urban area as a settlement with more than 5,000 population or any notified area or cantonment etc. with more than 75% population engaged in non-agricultural activities and it has administration such as Municipal Council, notified area committee, Municipal Corporation, Cantonment Board and Nagar Panchayat. Density of an urban area must be more than or equal to 400 persons / Km^2. Patiala planning area consists of two towns i.e. Patiala municipal corporation & its out growths and Sanaur municipal committee, census towns – Shekhpura and Rurki Kasba, cantonment board and 52 villages. (For details refer Annexure – I). Patiala Municipal committee was formed in 1904 and elevated to Municipal Corporation in 1997 has grown from a town confined within walled city with an area of around 320 hectares, with a population of about 50000 in 1951 to a city with a developed area of more than 10000 hectares and a population of approximately 4.5 lakhs by 2010 (Table 5.1). But the population of the planning area is not distributed uniformly; about 20% of the population (70181 persons) is confined within walled city in an area of 316 hectares which is less than 10% of the total developed area of the city and with gross density of the walled city is more than 200 persons per hectare. The average residential size in walled city is less than 100 m^2 (Fig 5.1).

Table 5.1: Decadal Change In Distribution Of Population In Patiala Planning Area.

S. No.	Year	Urban Population	Decadal change in Urban Population	Rural Population	Decadal change in rural Population	Total Population	Decadal change in total Population
(i)	1971	1,50,486	+20.16%	19,183	+17.31%	1,69,669	
(ii)	1981	2,05,141	+36.32%	23,060	+20.21%	2,28,201	+34.50%
(iii)	1991	2,38,368	+16.20%	27,328	+18.5%	2,65,696	+16.43%
(iv)	2001	3,51,929	+47.64%	49,055	+79.50%	4,00,984	+50.92%
(v)	2011	4,79,000*	+36.00%	58900*	+20.0%	5,37,900*	+34.15%
(vi)	2021	6,51,000*	+36.00%	71,000*	+20.0%	7,22,000*	+34.23%
(vii)	2031	8,85,000*	+36.00%	85,000*	+20.0%	9,70,000*	+34.23%

* Projected population
Source : Census of India, 1971, 1981,1991 & 2001

The land use of Patiala also has a cantonment and many state and central government offices so the public semi-public land use has a very large share in the total developed land use so the component of cantonment along with other government offices has been analysed under government land use other than public semi-public land use.

5.1.2 Topography Of Planning Area

The Patiala planning area lies between latitudes 30°24'-10" North & 30°16'-10" North and longitudes 76°20'-30" East & 76°29'-40" East. It is confined between Bhakra main line canal on west side, Raipur on the east, Village Baran in the north and Bir moti bagh in the south. The catchment of planning area is divided between four major drains – Chotti nadi, Model town drain, Jacob drain (all three are local in character) and Patialwi Nadi (It is a regional drain and a tributary of river Ghaggar and meets Ghagar at Rattanheri).

The slope of planning area is from North to South. The highest elevation point in Patiala is 256m – Patiala fort, and lowest point is near the junction of two drains Patialwi nadi and chotti nadi in village Shermajra. Highest flow level (HFL) of Patialwi nadi during monsoons is 250m so this has affected the urbanisation pattern of Patiala in a big way. HFL of patialwi nadi divides the topography of Patiala planning area into three broad categories developed areas below 250 m (Low lying areas inundated during the monsoons), developed area between 250 m – 252 m (Areas with drainage problems like sewage back lash and water logging) and developed area above 252 m the areas suitable for development and for detailed classification of land suitability for various land uses are given in Table 2.1, chapter 2.

Hence the chronological analysis of urbanization with respect to topography of Patiala needs to be studied on basis of this division.

This is done by using model builder tool of ArcView 3.2a and making an arithmetic mean overlay (AMO) model with digital elevation model (DEM) & land use as its two major components. The TIN is prepared from contour map (Fig 5.2) of the Patiala planning area and then DEM grid (Fig 5.3) is prepared from it which is then broadly classified into 3 categories (Fig 5.4), while land use map is converted into grid by converting it into a raster grid and an AMO model (Fig 5.5) is run in GIS environment to find the topographic suitability of each land use (Fig 5.6).

From independence till date two master plans have been prepared while the third master plan preparation is going on. The first master plan was prepared for a period of 1971 – 1991 but was revised in 1985 and prepared for a period of 1985 – 2005. On basis of these master plans the development of Patiala can be divided in to five parts (Fig 5.7) –

- Before 1951
- From 1951 – 1971.
- From 1971 – 1985 (first master plan phase)
- From 1985 – 2005 (Second master plan phase)
- From 2005 – 2010 i.e. till date (third master plan phase)

5.1.3 Location Of Developed Area With Respect To Topography Before 1951

Before 1951 city developed around Qila Mubarak, which was built on raised ground / highest point (256 m above sea level) in the area on the bank of Patialwi Nadi. There were a large number of small and large drains around the city constituting a natural drainage network. To protect the city from ravages of flood a proper drainage network for walled city was designed in 1870 A.D. with all the drains culminating in the "Ganda Nallah". All major drains around the city were also consolidated and two defence bundhs against flood were also executed in 1889 A.D. first on the Chotti Nadi and second on the Patialwi Nadi. During the period, all the development was on the high grounds with good drainage (Table 5.2 & Fig 5.7 & Fig 5.8).

Before 1951 total developed area of Patiala was 819 ha. (Table 5.2) and 678 ha (80.8%), mainly core/walled city and cantonment, has developed on a high ground with good drainage. This had maintained a balance between behaviour of water, and development of the

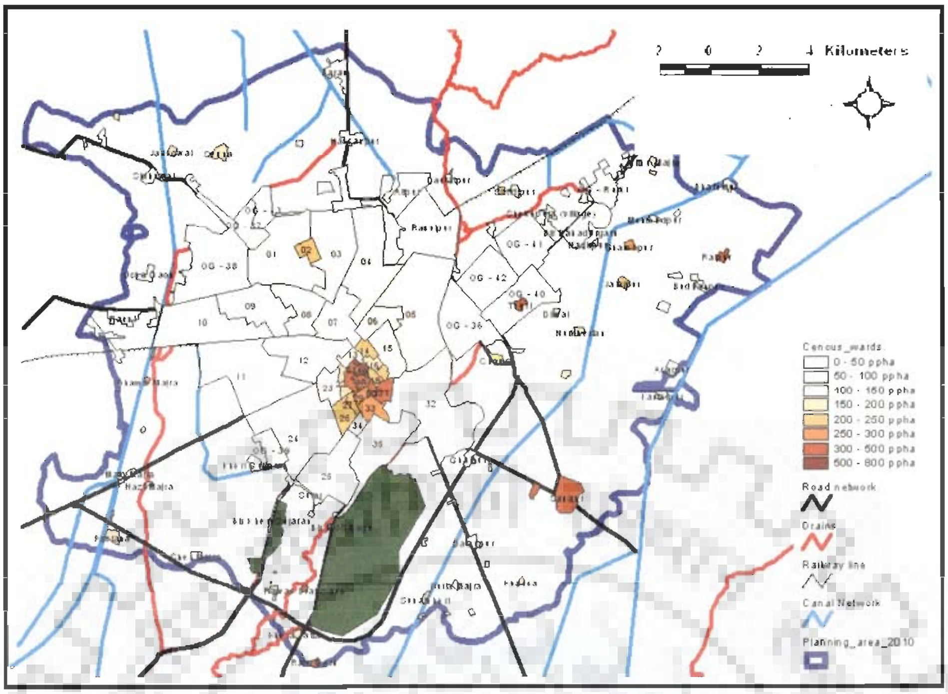


Fig 5.1: Population density map - 2001

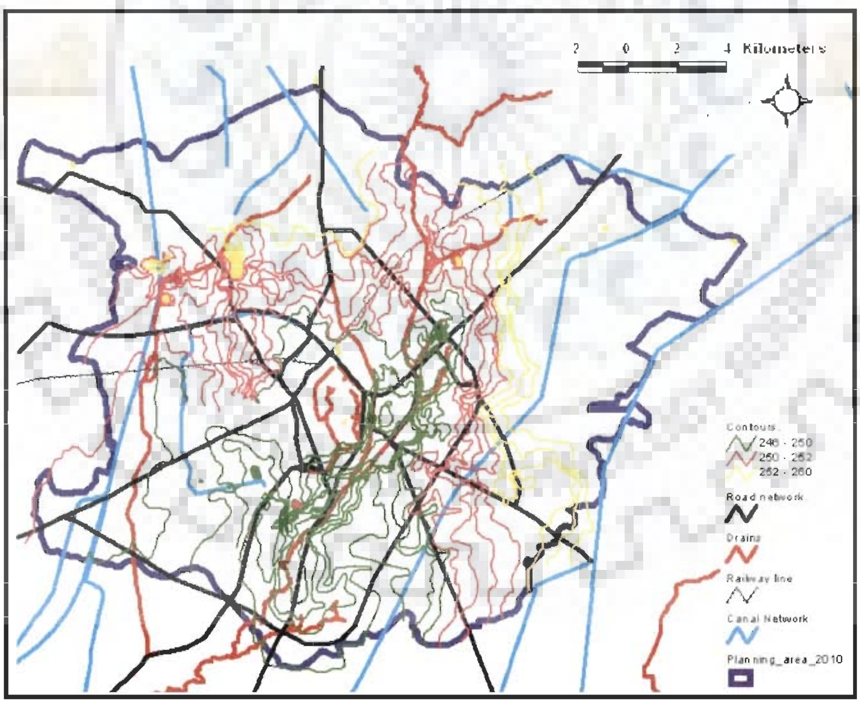


Fig 5.2: Contour map of Patiala

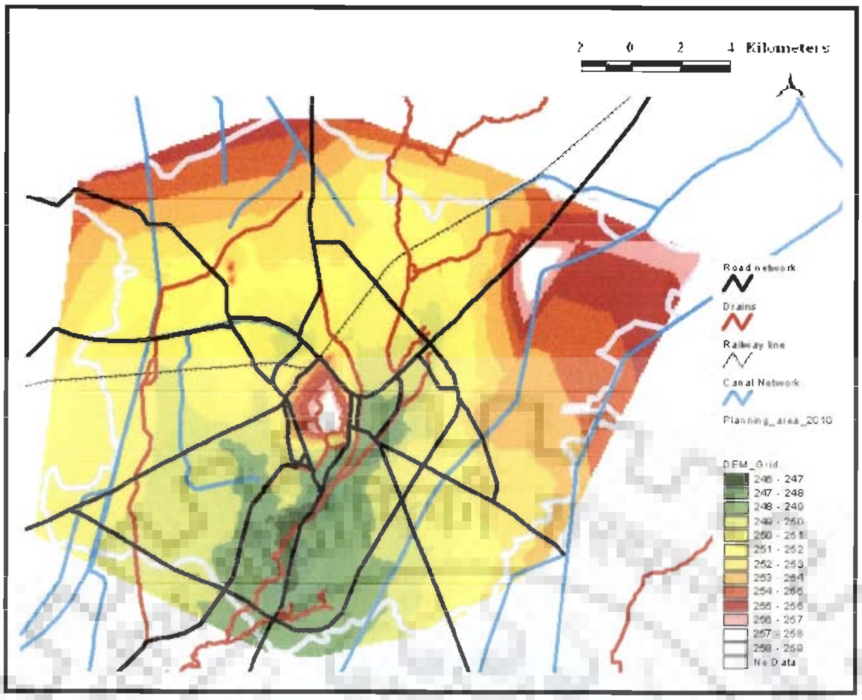


Fig 5.3: DEM of Patiala

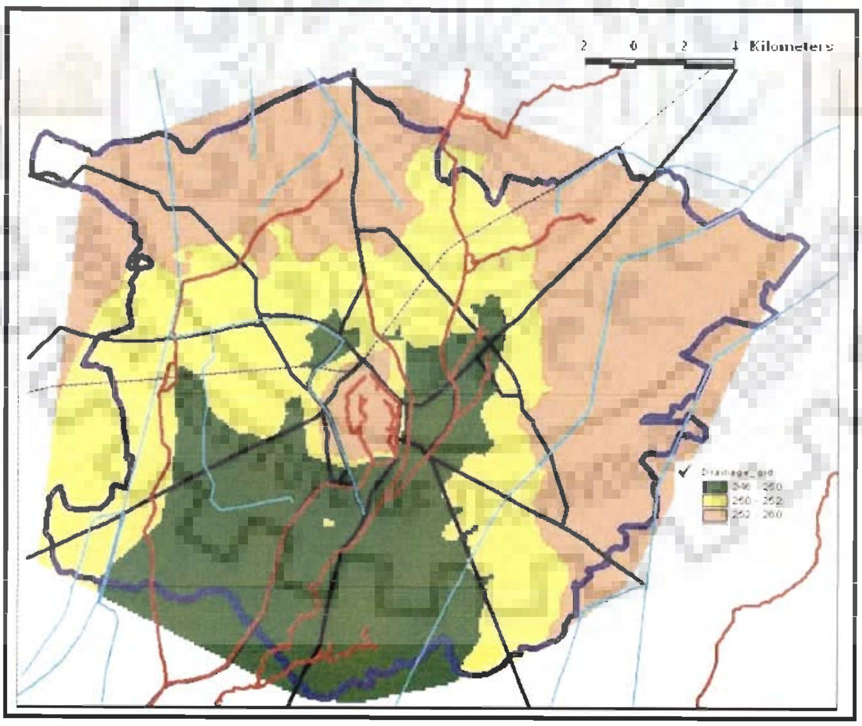


Fig 5.4: Topography of Patiala planning area in relation to HFL of Patialwi Nadi

city. The low lying area acted as barrier and helped in absorption of storm water drained from developed areas. The natural drainage pattern around the city helped to drain the storm water from the developed areas. Besides low lying areas were used as recreational open spaces and also as water bodies which helped to recharge the ground water, thus percentage of recreational open spaces was high as compared to other land use.

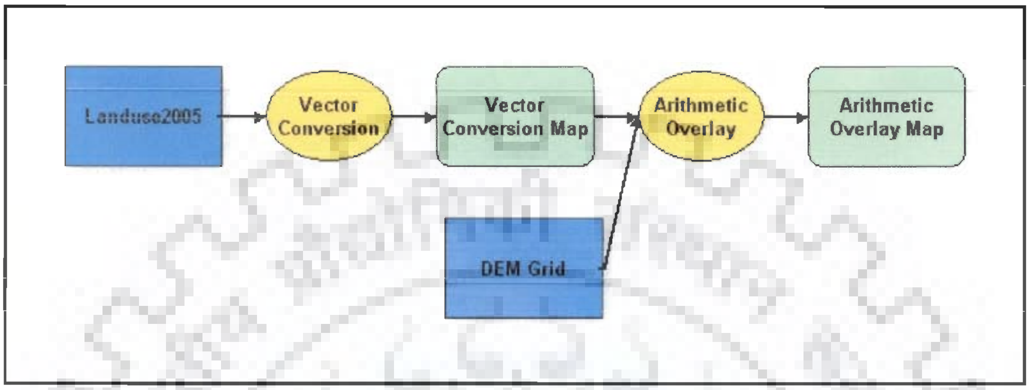


Fig 5.5: Arithmetic overlay model (AOM) for topographic suitability of land use

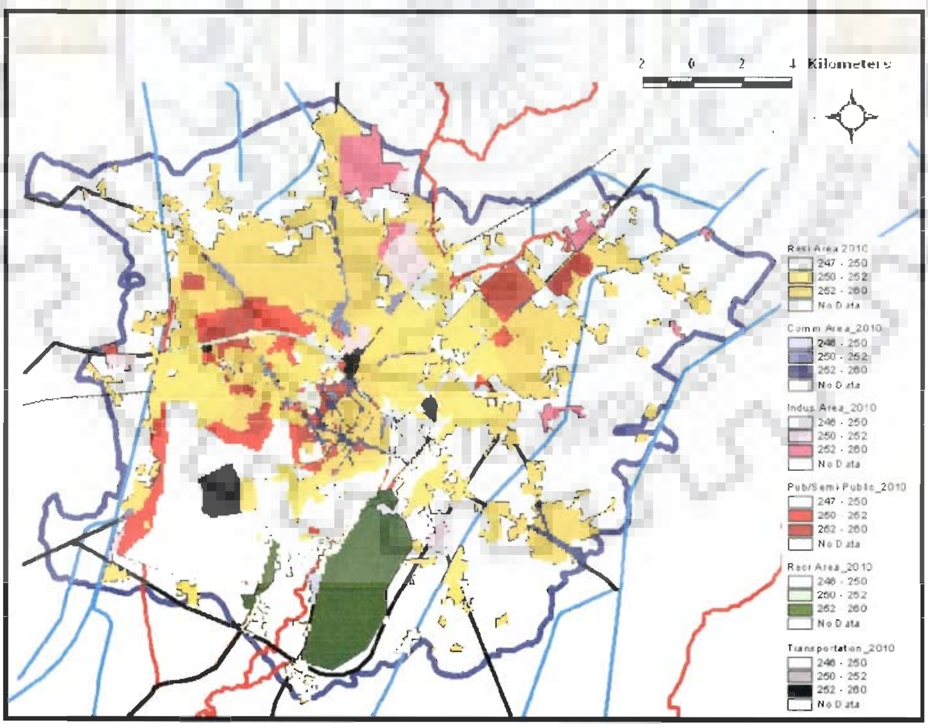


Fig 5.6: Location of Land Use According To Topography and Drainage in Patiala – 2010

Table 5.2: Urbanization In Patiala

S.No.	Year	Total develop-ed area (ha)	Developed area located on high ground with good drainage (252 m contour level or above)		Developed area located on relatively high ground with drainage problem		Low - lying developed area with poor drainage		Remarks
			Area in ha	%	Area in ha	%	Area in ha	%	
(i)	Before 1951	819	678	82.8%	141	17.2%	-	-	Development was mainly around Qila Mubarak and other high grounds. High percentage of development according to water.
(ii)	1951-71	1577	1083	68.7%	494	31.3%	-	-	Development outside the core but on relatively high grounds. No drainage problem except in areas where roads and Railway line act as barrier.
(iii)	1971-85	2574	1672	65.0	732	28.4	170	6.6	Development outside the core on relatively high grounds and in low lying areas. Drainage problems in low lying areas and pollution of ground water from discharge of sewerage in drains.
(iv)	1985-2005	4312	2467	57.2	1625	37.7	220	5.1	Development outside the core on relatively high grounds and in low lying areas. Drainage problems in low lying areas and pollution of ground water from discharge of sewerage in drains.
(v)	2005-2010	9688	6568	67.8	2209	22.8	911	9.4	Development outside the core on high grounds and in adjoining low lying areas. Drainage problems in low lying areas and pollution of ground water from discharge of sewerage in drains.

Source : Office of District Town Planning Officer, Town and Country Planning Department, Patiala

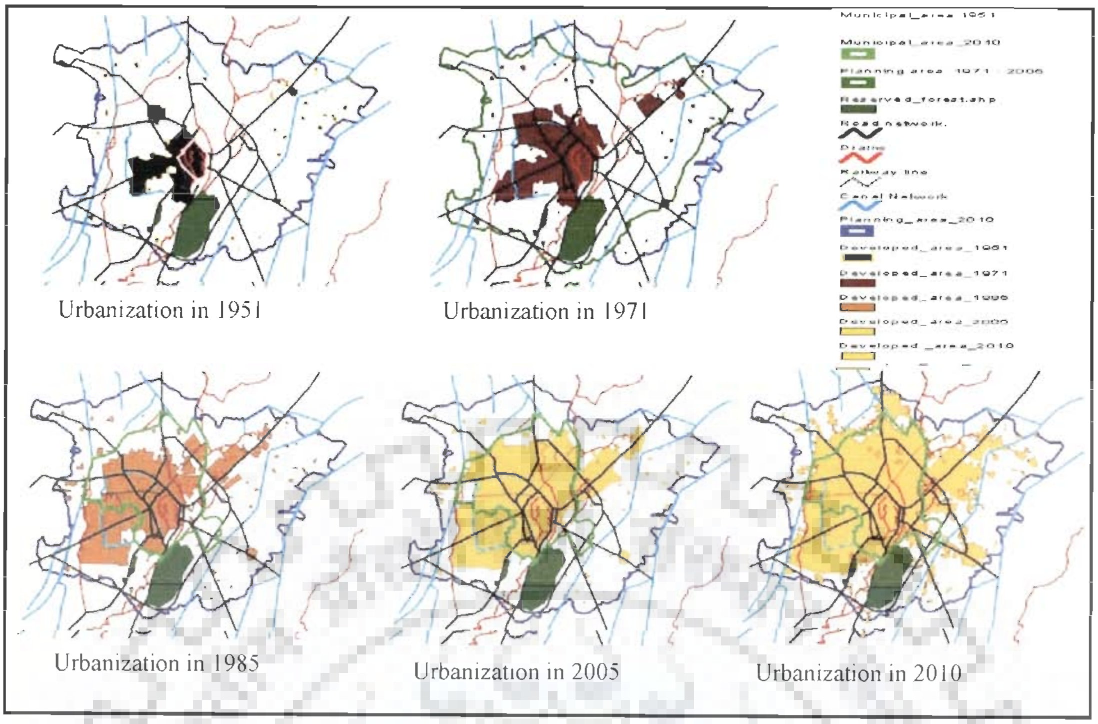


Fig 5.7: Urbanization of Patiala 1951 – 2010

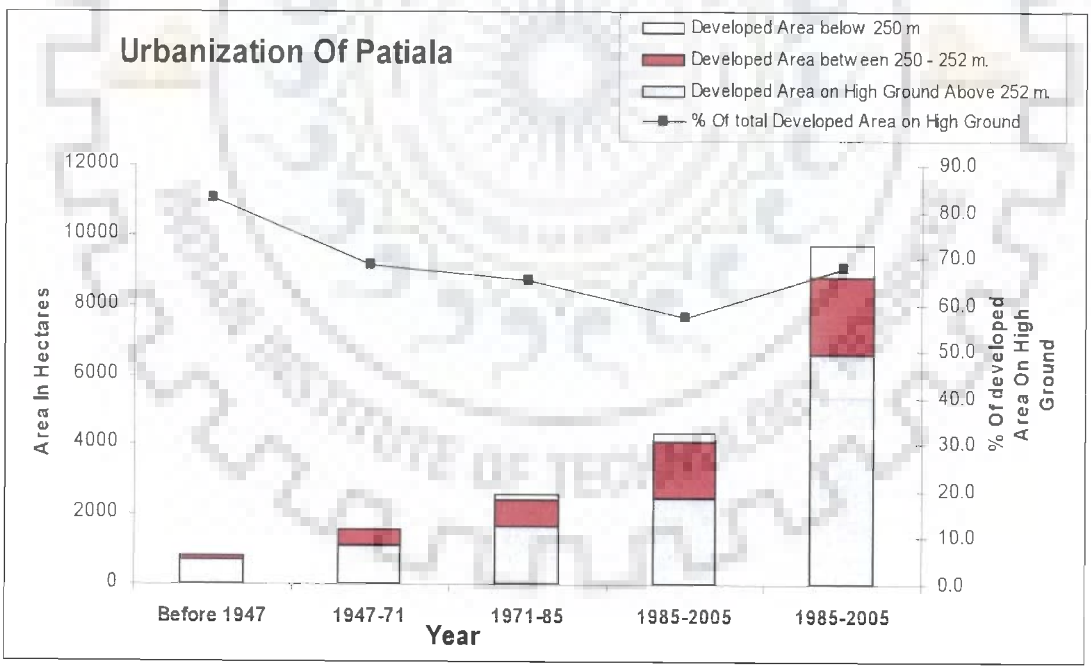


Fig 5.8: Urbanization of Patiala

5.1.4 Location Of Developed Area With Respect To Topography Between 1951 – 1971

During this period / phase new townships were developed outside the core like Tripuri Township, Model Town, Punjabi Bagh, Hira Nagar etc. The newly developed areas in this phase were on relatively high ground but with drainage problems caused by the lack of planning considerations as roads, railway lines and distributaries acted as barrier against natural drainage of few of these areas. Total developed area during this phase was 1577 ha and 1083 ha (68.7%) has developed on high ground with good drainage (Table 5.2& Table 5.3 and Fig 5.9 & Fig 5.10).

During this period several large projects were also under taken like – Punjabi University, Thapar College, Medical College, State College of Education, etc. All these projects were also located at the sites which have good drainage. During this phase no planning was done at city level thus there was no integrated plan for development of city. This resulted in faulty location of various projects without giving any thought to the natural drainage pattern of the area. This created various problems like drainage of storm water and reduction in area under water bodies (Ponds etc.).

Table 5.3 : Land use Pattern Of Patiala Planning Area -1971

S. No.	Landuse	Area	% of total developed area	Area & Location of Landuse according to topography & drainage					
				High ground with good drainage (252m contour level or above)	% of total landuse	Relatively high ground with drainage problem (between 252m to 250m contour level)	% of total landuse	Low lying area with poor drainage (Below 252m contour level)	% of total landuse
		ha.	%	ha.	%	ha.	%	ha.	%
i)	Residential	684	43.37	395	57.75	287	41.96	2	0.29
ii)	Commercial	24	1.52	22	91.67	2	8.33	-	-
iii)	Industrial	29	1.84	29	100.00	-	-	-	-
iv)	Public/ Semi Public facilities	320	20.29	269	84.06	51	15.94	-	-
v)	Transportation	125	7.93	119	95.20	6	4.80	-	-
vi)	Recreation	209	13.25	200	95.69	9	4.31	-	-
vii)	Govt. Land use	186	11.80	49	26.34	137	73.66	-	-
	Total dev. land	**1577**	**100**	**1083**	**68.67**	**492**	**31.20**	**2**	**0.13**
viii)	Vacant/ Unutilized urban land	833	-	123		367	-	343	-
	Total urbanised	**2410**	-	**1206**	**50.04**	**857**	**35.56**	**345**	**14.4**
ix)	Forest	687	-	-	-	-	-	-	-
x)	Water bodies	25	-	-	-	-	-	-	-
xi)	Vacant Land	602	-	-	-	-	-	-	-
xii)	Fallow land coverage	2535	-	-	-	-	-	-	-
xiii)	Cropped area	8639	-	-	-	-	-	-	-
xiv)	Not available for cultivation	1393	-	-	-	-	-	-	-
	Total Rural	**13881**	-	-	-	-	-	-	-
	Total Planning Area	**16291**	-	-	-	-	-	-	-

Source : Office of District Town Planner, Town and Country Planning Department, Patiala

Bhakra Canal and its Distributries were built during this phase to supply water for irrigation to open areas of city like Baradari, Agriculture and Husbandry farms and rural areas. The distributries built in planning area were – Patiala Navigational Channel (P.NC Minor and Motibagh Minor), Sanaur Distributry and Baran Distributry.

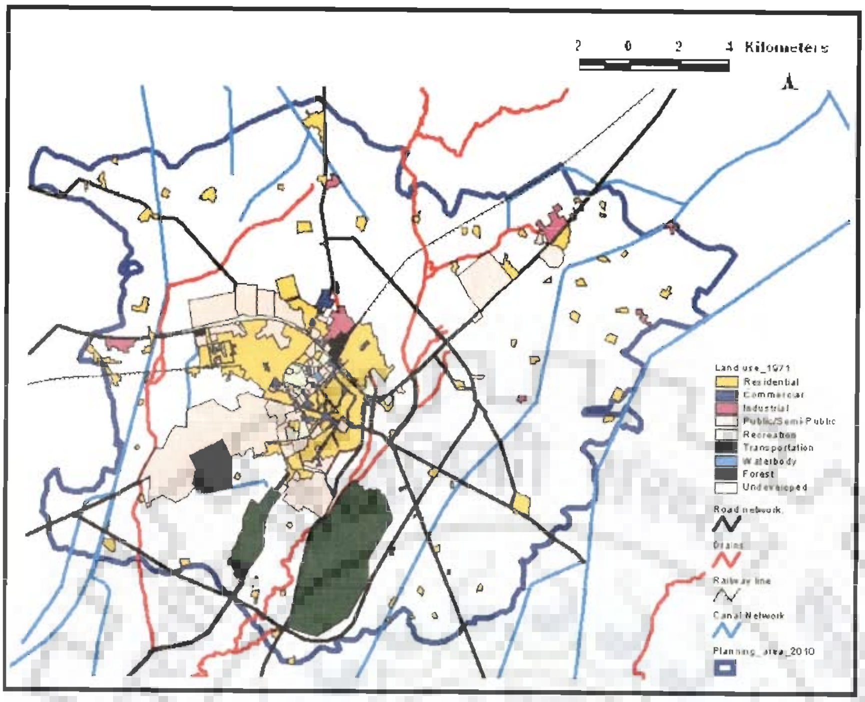


Fig 5.9: Existing Land Use - 1971

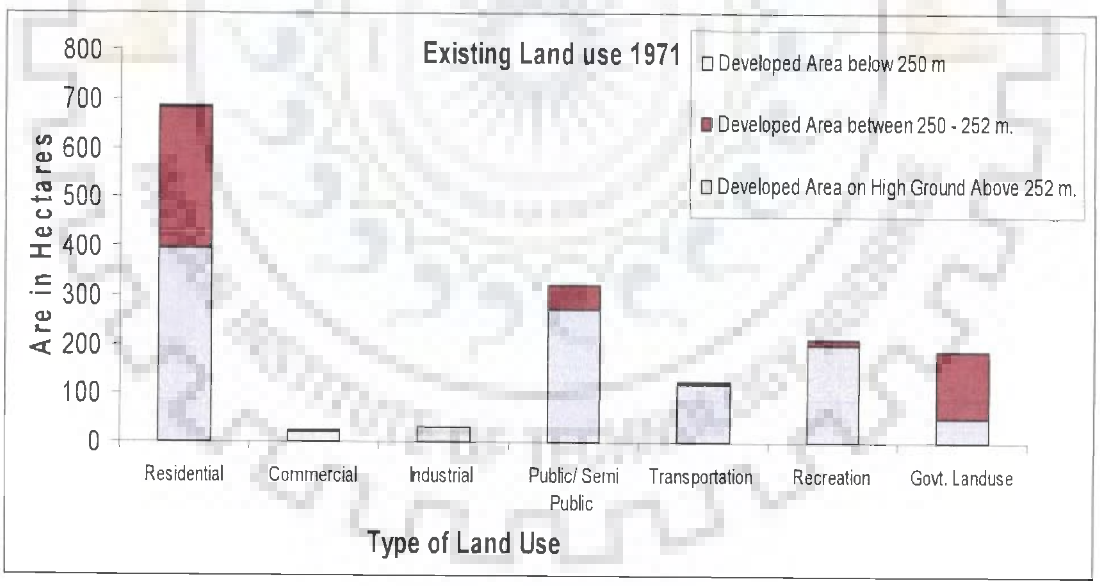


Fig 5.10: Topographic Analysis of Existing Land Use – 1971

In this phase major development was in residential and public and semi-public land use, residential land use was 684 ha (43%) and public-semi public facilities land use was 320 ha (20.3%) (Table 5.3).

5.1.5 Location Of Developed Area With Respect To Topography Between 1971 – 1985

During this phase first effort for planned development was done. First master plan for a period of 1971-1991 was prepared and for this purpose planning area was marked. The Master plan prepared to integrate various land uses but while preparing master plan no consideration was given to natural drainage pattern of the planning area. Low lying areas between and around two Nadi's were marked for residential, commercial, transportation and public-semi public landuses, thus disturbing the natural drainage of the area (Fig 5.11, Fig 5.12 & Table 5.4).

Bye pass was proposed through reserved forests – Bir Moti Bagh and Bir Kheri Gujjar. Major part of Bir Kheri Gujjar reserved forest was proposed for Govt. landuse. New sectors which were proposed but their detailed plans were not prepared. During this phase enforcement was also not done properly for planning and development of new areas which were not developed resulting in intensification of existing developed areas and development of surrounding low lying areas between Chotti Nadi and walled city and in village Rasulpur between two Nadi's (Table 5.5, Fig 5.13 & Fig 5.14).

Table 5.4 : Master Plan Proposal For Patiala-1971-1991

S. No.	Land use	Area	% of developed area	Area and Location of landuse according to drainage and topography					
				Developed area located on high ground with good drainage (252 m contour level or above)	% of total landuse	Relatively high ground with drainage problem (between 252m & 250m contour level)	% of total landuse	Low lying area with poor drainage (less than 250 m contour level)	% of total landuse
		ha.	%	ha.	%	ha.	%	ha.	%
i.	Residential	1935	25.78	402	20.78	1487	76.85	46	2.37
ii.	Commercial	136	1.81	54	39.71	68	50.00	15	10.29
iii.	Industrial	304	4.05	304	100.00	-	-	-	-
iv.	Public-Semi Public	758	10.10	269	35.49	478	24.70	11	39.81
v.	Transportation	1147	15.28	180	15.69	949	82.73	18	1.58
vi.	Recreation	806	10.74	400	49.63	390	48.39	16	1.9
vii.	Government	2422	32.24	2015	83.20	167	6.90	240	9.90
viii.	Total developed land	7508	100.00	3624	48.27	3539	48.47	345	3.26
ix.	Forest	134							
x.	Rural & others land use	8661							
xi.	Total Planning	16291							

Source : Office of District Town Planning Officer, Town and Country Planning Department, Patiala

This haphazard development disturbed natural drainage pattern of the planning area which resulted in problem like storm water drainage, backlash of sewerage and water logging in monsoon season. No integrated planning effort was carried out, only piece meal approach was adopted in what ever little effort was done for planned development like – T.P. Schemes, development schemes, D.C.W. Workshop, Urban Estate–I, Most of these developments were

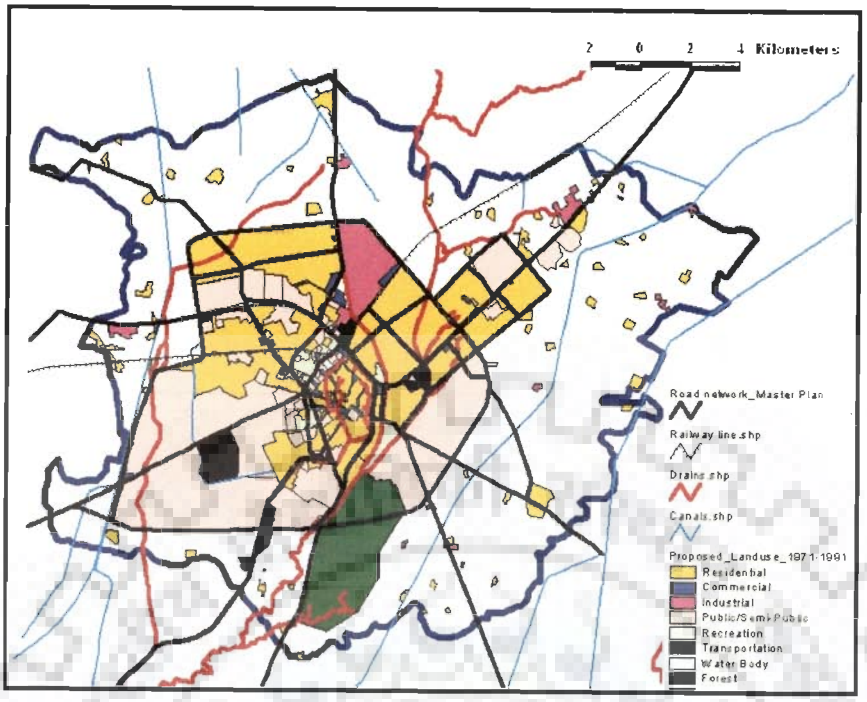


Fig 5.11: Master Plan 1971 – 1991

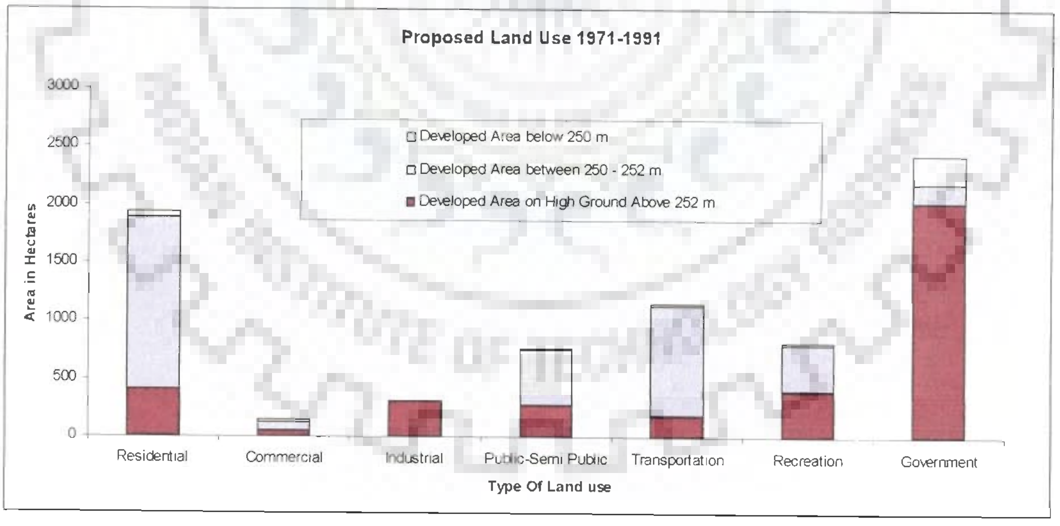


Fig 5.12: Topographic Analysis of Proposed Master Plan Land Use – 1971 - 1911

not according to master plan. Also no thought was given in these developments to the existing drainage pattern of the site. With a decrease in low-lying areas and natural drains and over all decrease in percentage of recreational open spaces also affected the ground water recharge of the area.

Table 5.5 : Land use Pattern Of Patiala Planning Area - 1985

S. No.	Land use	Area (ha)	Increase in Area	% of total developed area	Area and Location of Landuse according to topography and drainage					
					High ground with good drainage (252m contour level or above)	% of total landuse	Relatively high ground with drainage problem (250m to 252m contour level)	% of total landuse	Low lying area with poor drainage (Below to 250 m contour level)	% of total landuse
		ha.	Ha.	%	ha.	%	ha.	%	ha.	%
i)	Residential	980	296	38.07	434	44.29	394	40.20	152	15.51
ii)	Commercial	47	23	1.83	23	48.94	24	51.06	-	-
iii)	Industrial	89	60	3.46	38	42.70	51	57.30	-	-
iv)	Public/ Semi Public facilities	350	30	13.60	269	76.86	81	23.14	-	-
v)	Transportation	143	18	5.56	119	83.22	6	4.20	18	12.58
vi)	Recreation	209	-	8.12	200	95.69	9	4.31	-	-
vii)	Govt. Land use	756	570	29.39	589	77.91	167	22.09	-	-
	Total developed land	**2574**	**997**	**100**	**1672**	**64.96**	**732**	**28.44**	**170**	**6.60**
viii)	Vacant/ Unutilized urban land	323	-	-	24	-	124	-	175	-
	Total urbanised	**2897**	**487**	**16.81**	**1696**	**58.54**	**856**	**29.55**	**345**	**11.91**
ix)	Forest	687	-	-	-	-	-	-	-	-
x)	Water bodies	25	-	-	-	-	-	-	-	-
xi)	Vacant Land	387	-	-	-	-	-	-	-	-
xii)	Fallow land coverage	2135	-	-	-	-	-	-	-	-
xiii)	Cropped area	9036	-	-	-	-	-	-	-	-
xiv)	Not available for cultivation	1437	-	-	-	-	-	-	-	-
	Total Rural	**13707**	-	-	-	-	-	-	-	-
	Total Planning Area	**16291**	-	-	-	-	-	-	-	-

Source : Office of District Town Planner, Town and Country Planning Department, Patiala

During this phase sewerage system for whole city was planned and laid. But in this case also no effort was done to combine the sewerage disposal of the whole city. Sewage for different areas was disposed off at different points in the two Nadi's that too in most cases even without primary treatment several institutions like Thapar College, Military Cantonment, Milk Plant, D.C.W. have their own sewage disposal system but they too dispose their sewage in the drains.

Hence in this phase, piece meal approach to planning without any consideration to natural drainage and topography has resulted in various problems like – flash flood and sewage backlash etc.

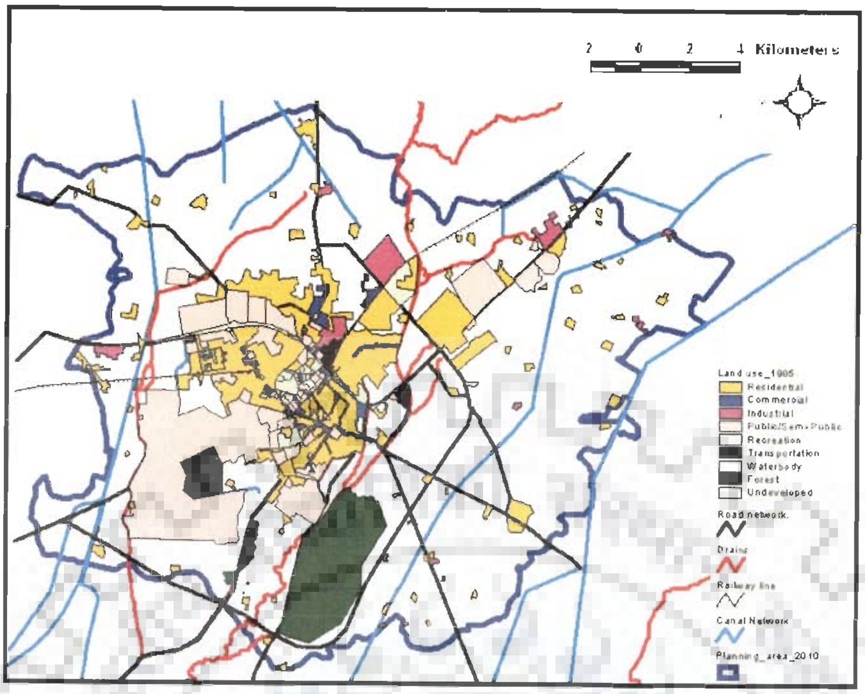


Fig 5.13: Existing Land Use 1985

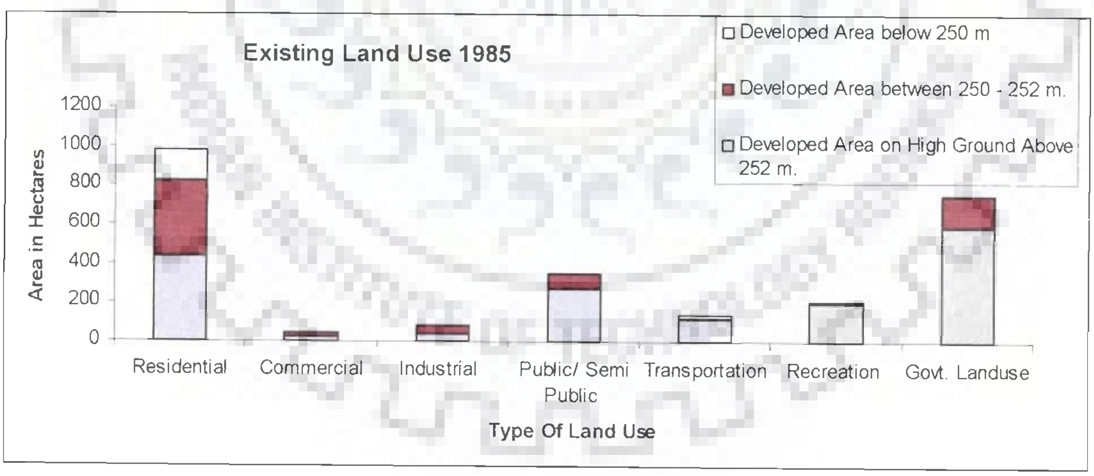


Fig 5.14: Topographic Analysis of Existing Land Use – 1985

5.1.6 Location Of Developed Area With Respect To Topography Between 1985 – 2005

During this phase old master plan was revised for a period of 1985-2005. In this plan again no consideration was given to the existing natural drainage pattern – Residential sectors were proposed without giving any consideration to the natural drainage. Passing through them and their detailed land use plans were never prepared (Table 5.6, Fig 5.15 & Fig 5.16). In the low lying areas between two Nadi's (drains) commercial and transportation land use was proposed. Bye pass was again proposed to pass along the Bir Moti Bagh protected forest. Bir Kheri Gujjar, protected forest was marked for Govt. land use. Sector planning was again proposed for new areas and controlled areas were marked but detailed plans were never prepared. The areas which were developed up to 1985 were incorporated as such while preparing this plan.

During this phase there is an enormous increase in total developed area. It increased from 2080 ha to 3916 ha with an increase of 1836 ha (88.3%) during this phase but main increase was in residential area which increase from 908 ha in 1985 to 2034 ha in 2005, an increase of 1126 (124%)–Industrial area which increased from 89 ha in 1985 to 267 ha in 2001 an increase of 178 h (200%) – Area under transportation increased from 143 ha in 1985 to 477 ha in 2005 an increase of 334 ha (233%) the over all the percentage of transportation landuse to developed area increased from 6.8% in 1985 to 72% in 2005 (Table 5.7).

Table 5.6 : Master Plan Proposals For Patiala-1985-2005

S. No	Landuse	Area	% of developed area	Area and Location of landuse according to drainage and topography					
				Developed area located on high ground with good drainage (252 m contour level or above)	% of total landuse	Developed area located on medium high ground with drainage problem	% of total landuse	Low lying developed area with poor drainage	% of total landuse
		ha.	%	ha.	%	ha.	%	ha.	%
i.	Residential	3097	31.62	522	16.85	2390	71.17	185	5.98
ii.	Commercial	164	1.67	54	32.93	96	58.54	14	8.53
iii.	Industrial	733	7.48	682	93.04	51	6.96	-	-
iv.	Public-Semi Public	596	6.08	269	45.13	316	53.02	11	1.85
v.	Transportation	1008	10.30	180	17.85	810	80.35	18	1.80
vi.	Recreation	1447	14.77	418	28.89	1013	70.01	16	1.10
vii.	Government	2750	28.08	2343	85.20	306	11.13	101	8.67
viii.	Total developed land	9795	100.00	4458	45.51	4982	45.78	345	8.71
ix.	Forest	577							
x.	Rural & others land use	5979							
xi.	Total Planning Area	16291							

Source : Office of District Town Planning Officer, Town and Country Planning Department, Patiala

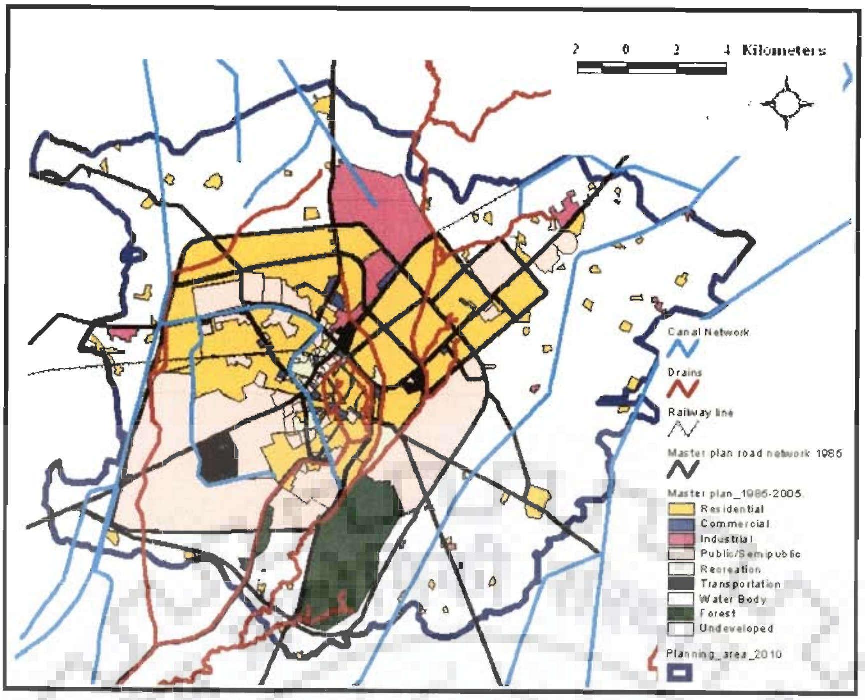


Fig 5.15: Proposed Land Use 1985 – 2005

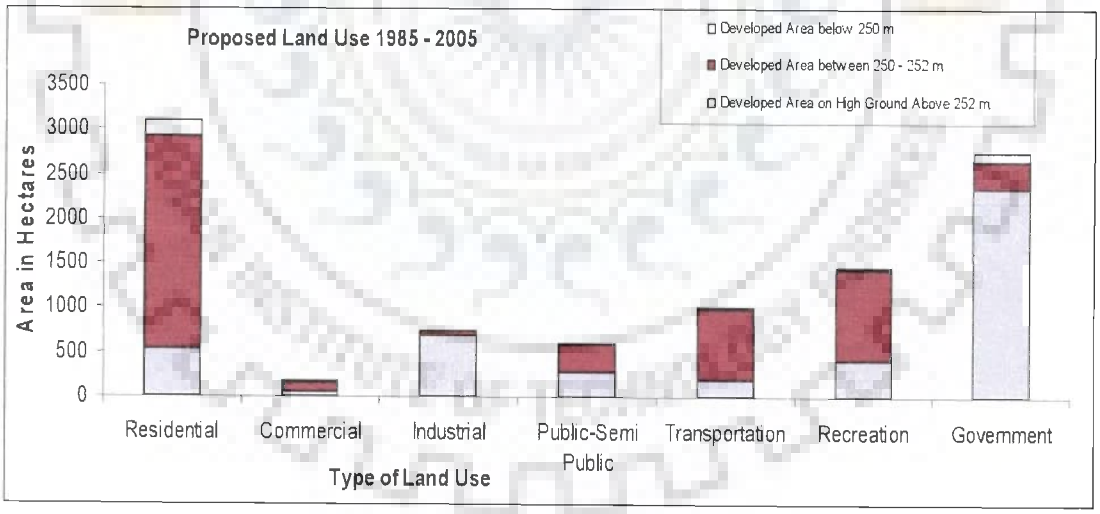


Fig 5.16: Topographic Analysis of Proposed Master Plan Land Use 1985 – 2005

During this phase also enforcement was not done properly and no new areas were developed except Urban Estate Phase II and III. This resulted in development of unplanned new areas and haphazard development. Development also took place in the low lying areas in vicinity of developed areas and along the major roads resulting in an increased pressure on existing physical infrastructure (water supply and sewerage network) (Table No. 5.7,Fig 5.17 & Fig 5.18).

Due to lack of planned development there is a phenomenal decrease in percentage of recreational open spaces from 10.1% in 1985 to 6.9% in 2005 and percentage of developed area in low lying areas increased from 1.25% in 1985 to 1.9% in 2005 (Table No. 5.7). The haphazard development disturbed the natural drainage pattern of the planning area which storm water drainage, backlash of sewage, water logging in Monsoon season. Decrease in low lying areas water bodies and natural drains had also affected recharge of ground water.

Decrease in percentage of open spaces and destruction of natural drainage pattern of Patiala Planning area resulted in Flash floods in 1992 and 1995 after a record rains on a single day i.e. 3rd September 1995. After this period some efforts were made to clean and protect the existing drainage system but no systematic efforts was done to revive the old drainage pattern of the planning area.

Table 5.7: Land use Pattern Of Patiala Planning Area – 2005

S. No.	Land use	Area (ha)	Increase in Area	% of total developed area	Area and Location of Landuse according to topography and drainage					
					High ground with good drainage (252m contour level or above)	% of total landuse	Relatively high ground with drainage problem (250m to 252m contour level)	% of total landuse	Low lying area with poor drainage (Below to 250 m contour level)	% of total landuse
		ha.	Ha.	%	ha.	%	ha.	%	ha.	%
i)	Residential	1626	646	37.7	631	38.81	793	48.77	202	12.42
ii)	Commercial	104	57	2.4	47	45.19	57	54.81	-	-
iii)	Industrial	267	178	6.2	164	61.42	103	38.58	-	-
iv)	Public/ Semi Public facilities	415	65	9.6	364	87.71	51	12.29	-	-
v)	Transportation	477	334	11.1	210	44.03	249	52.20	18	3.77
vi)	Recreation	271	62	6.3	262	96.68	9	3.32	-	-
vii)	Govt. Land use	1152	396	26.7	789	68.49	363	31.51	-	-
	Total developed land	**4312**	**1738**	**100**	**2467**	**57.21**	**1625**	**37.69**	**220**	**5.1**
viii)	Vacant/ Unutilized urban land	1439	1116	-	588	-	726	-	125	-
	Total urbanised	**5751**	**2854**	**49.62**	**3055**	**53.12**	**2351**	**40.88**	**345**	**6.00**
ix)	Forest	677	-	-	-	-	-	-	-	-
x)	Water bodies	22	-3	-	-	-	-	-	-	-
xi)	Vacant Land	43	-344	-	-	-	-	-	-	-
xii)	Fallow land coverage	267	-1975	-	-	-	-	-	-	-
xiii)	Cropped area	8410	-626	-	-	-	-	-	-	-
xiv)	Not available for cultivation	1121	104	-	-	-	-	-	-	-
	Total Rural	**10540**	**-3167**	-	-	-	-	-	-	-
	Total Planning Area	**16291**		-	-	-	-	-	-	-

Source : Office of District Town Planner, Town and Country Planning Department, Patiala

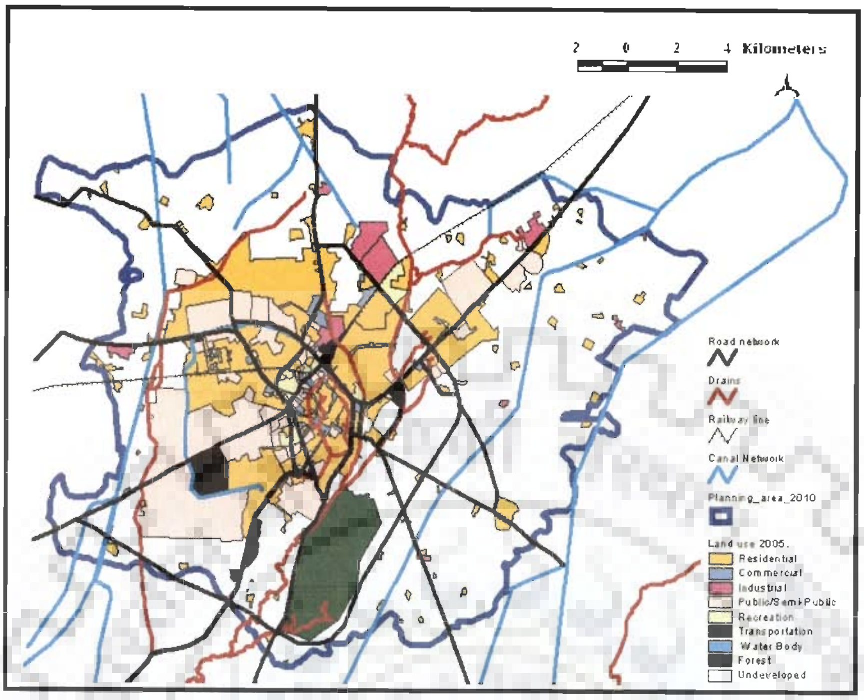


Fig 5.17: Existing land use – 2005

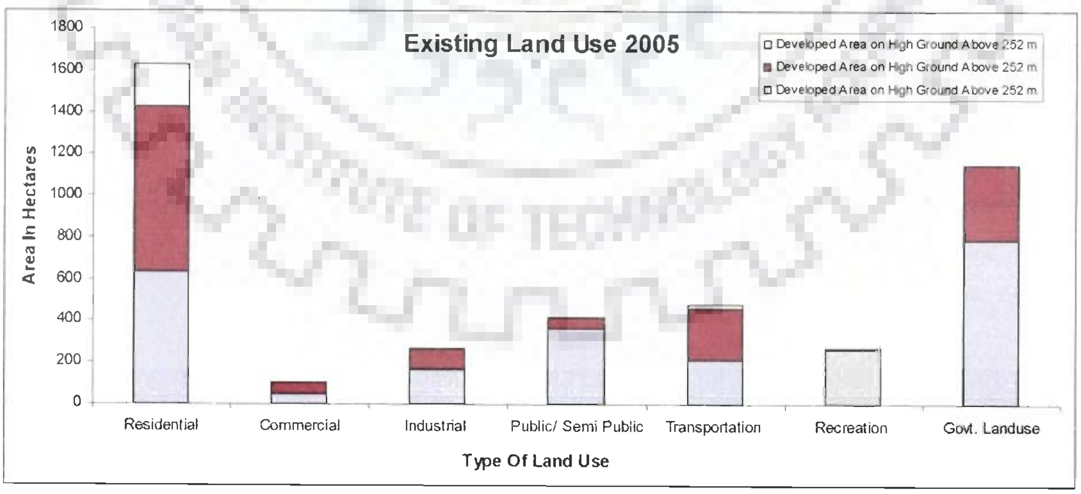


Fig 5.18: Topographic analysis of existing land use – 2005

The network of distributries – P.N.C. minor and Moti Bagh minor used to supply water for irrigation of open spaces in the city has completely became redundant due to lack of maintenance. This has resulted in pressure on ground water for irrigation purposes.

Due to lack of integration of Sewerage network in city the sewerage of the whole city is still disposal off in drains with primary treatment only thus, polluting the ground water. Lack of any policy on the water resource planning has resulted in increase pressure on ground water which is going down at an enormous rate of 0.75 m per year.

5.1.7 Location Of Developed Area With Respect To Topography Between 2005 – 2010

During this phase second master plan from 1985 – 2005 was extended till the preparation of new master plan by Patiala Development Authority (PDA) for a period of 2005 – 2025. For this purpose the planning area was extended to include Sanaur and adjoining villages in the south and village Baran was included in the north.

During this extended phase many new project have come up – Mini Secretariat, Phulkian enclave, fly over at 21 number railway crossing, four laning of Patiala – Sirhind road till Baran, and Patiala – Sangrur till Bhakra Canal. In the low lying areas between two nadi's (drains) new bus stand is coming up. Sangrur bye pass has been built with its alignment along the Bir Moti Bagh protected forest. Sector planning which was proposed for new areas in the second master plan and controlled areas were marked but their detailed plans were never prepared. The areas which were developed up to 2005 have been incorporated as such while preparing the new plan.

New areas which were developed during this phase were mainly in the north of the planning area along Sirhind road and in the south on Sanaur road along new bye pass. Under the Integrated Township Scheme of Patiala Development Authority, a modern residential colony and an I.T. Park are being developed at Baran on the Sirhind Road. Sewerage Treatment Plant was constructed at Urban Estate, Patiala.

During this phase there is an enormous increase in total developed area. It increased from 4312 ha to 9658 ha with an increase of 5346 ha (123.9%) during this phase but main increase was in residential area which increase from 1626 ha in 2005 to 5351 ha in 2010, an increase of 3725 (229.1%)–Industrial area which increased from 267 ha in 2005 to 495 ha in2010 an increase of 228 ha (85.4%) – Area under transportation increased from 477 ha in

2005 to 798 ha in 2010 an increase of 321 ha (67.3%) the over all the percentage of transportation land use to developed area decreased from 11.1% in 2005 to 8.2% in 2010 (Table 5.8, Fig 5.19 & 5.20).

Table 5.8: Land use Pattern Of Patiala Planning Area – 2010

S. No.	Land Use	Area In Hectares	% of total Developed Land	Area And Location Of Land Use According to Topography and Drainage					
				Developed Area on High Ground Above 252 m.	% Of Land Use	Developed Area on High Ground Above 252 m.	% Of Land Use	Developed Area on High Ground Above 252 m.	% Of Land Use
1	Residential	5351	55.2	3459	64.6	1252	23.4	640	12.0
2	Commercial	371	3.8	248	66.8	114	30.7	9	2.4
3	Industrial	495	5.1	327	66.1	103	20.8	65	13.1
4	Public/ Semi Public	520	5.4	455	87.5	65	12.5	0	0.0
5	Transportation	798	8.2	310	38.8	301	37.7	187	23.4
6	Recreation	311	3.2	280	90.0	11	3.5	10	3.2
7	Govt. Landuse	1842	19.0	1489	80.8	363	19.7	0	0.0
8	Total Developed Land	9688	100.0	6568	67.8	2209	22.8	911	9.4
9	Vacant / unutilized urban land	500							
10	Total Urbanized Area	10188							
12	Forest	805							
13	Water Bodies	22							
14	Vacant Land	43							
15	Fallow Land	300							
16	Cropped Area	7651							
17	Not Available for Cultivation	987							
19	Total Planning	19996							

Source : Office of District Town Planner, Town and Country Planning Department, Patiala

There is a five times increase in residential land use due to involvement of private players in the land development and also the inclusion of Sanaur in the planning area which is primarily a residential town. During this phase also enforcement was not done properly and no new areas were developed except Baran Urban Estate IT Park developed by Omaxe and promoted by PDA. This resulted in development of unplanned new areas and haphazard development. Development also took place in the low lying areas in vicinity of developed areas and along the major roads resulting in an increased pressure on existing physical infrastructure (water supply and sewerage network).

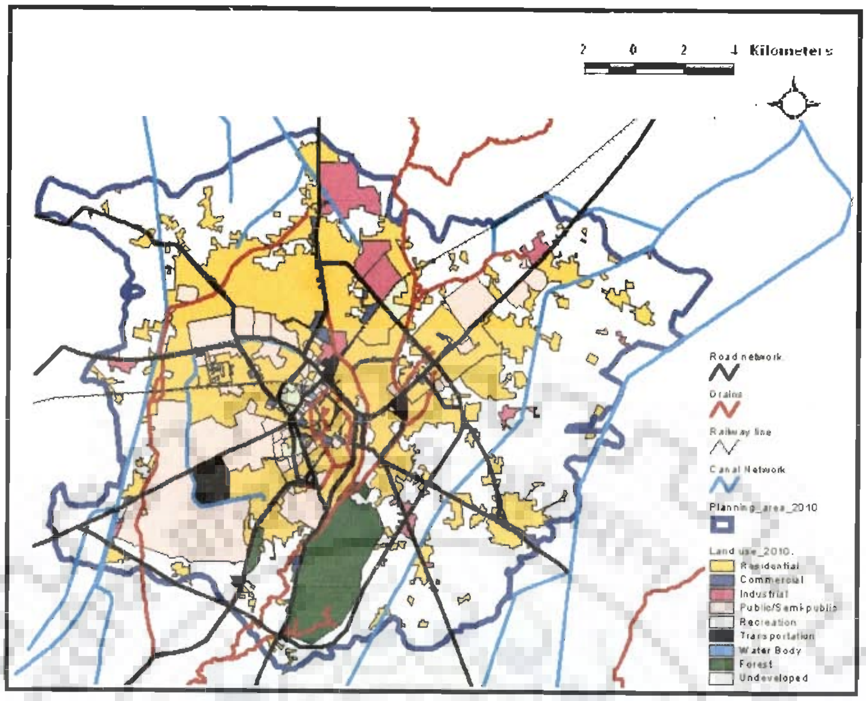


Fig 5.19: Existing Land Use – 2010

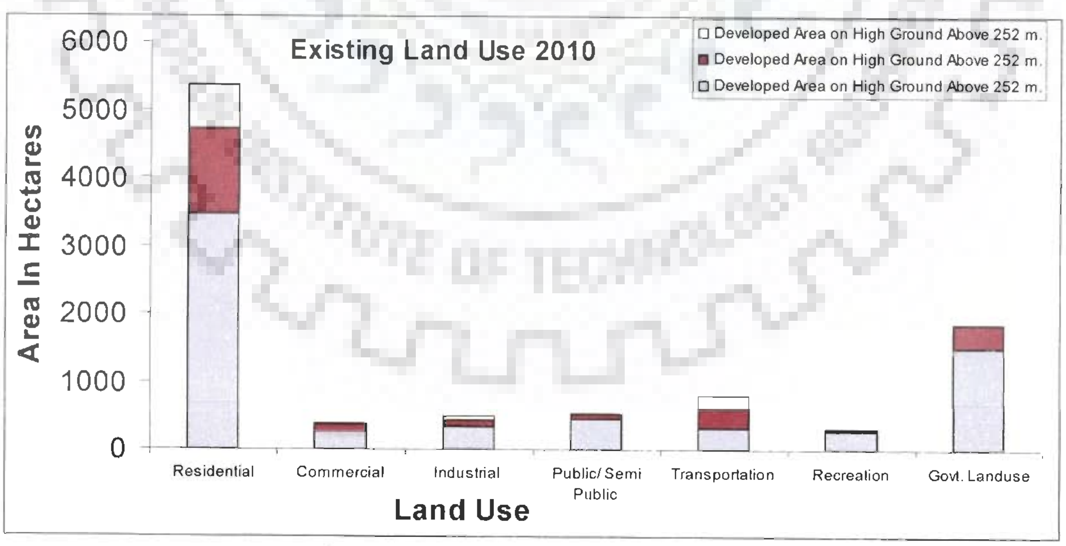


Fig 5.20: Topographic Analysis of Existing land use – 2010

Due to lack of planned development there is a phenomenal decrease in percentage of recreational open spaces from 6.3% in 2005 to 3.2% in 2010 and percentage of developed area in low lying areas increased from 6.0% in 2005 to 9.4% in 2010 (Table No. 5.8). The haphazard development disturbed the natural drainage pattern of the planning area which storm water drainage, backlash of sewage, water logging in Monsoon season. Decrease in low lying areas water bodies and natural drains had also affected recharge of ground water. The marsh land between two nadi's near Bir moti bagh has been allocated for disposal of solid waste by land fill. This has tremendously reduced the water retention capability of the area and this has resulted in flooding in up stream low lying areas between two nadi's. This decrease in percentage of open spaces and destruction of natural drainage pattern of Patiala Planning area resulted in Flash floods in last week of September 2010. After this period some efforts were made to clean and protect the existing drainage system but no systematic efforts was done to revive the old drainage pattern of the planning area.

The network of distributries – P.N.C. minor and Moti Bagh minor used to supply water for irrigation of open spaces in the city has completely became redundant due to lack of maintenance. This has resulted in pressure on ground water for irrigation purposes. The effort has been made to rejuvenate Rajindra lake by using water from PNC minor but the project was abandoned in mid stage.

Due to lack of integration of Sewerage network in city the sewerage of the whole city is still disposal off in drains with primary treatment only thus, polluting the ground water. Lack of any policy on the water resource planning has resulted in increase pressure on ground water which is going down at an enormous rate of 0.75 m per year.

5.1.8 Analysis Of Various Projects According To Topography And Drainage

After Independence development projects undertaken in Patiala by various agencies can be divided in to three categories (Table 5.9 and Fig 5.21) :

- Government Agencies
- Municipal Corporation (T.P. Schemes)
- Improvement Trust (Development Schemes)

- Total developed area by these projects is 2035 ha (21.0%) of the total developed area in Patiala in 2010.

- Area developed by state government under various projects is 1196 ha i.e. (12.4%) of total developed area. Out of total area developed by state government 533 ha (44.6%) is on high ground with drainage.
- Area developed by municipal corporation under various T.P. Schemes is 724 ha i.e. (7.5%) of total area developed. Out of total area developed by municipal corporation 155 ha (21.4%) is on high ground with drainage.
- Area developed by improvement trust under various development schemes is 118 ha i.e. (1.9%) of total area developed. Out of total area developed by improvement trust 14 ha (11.9%) is on high ground with drainage.
- Out of total developed by various agencies 702 ha (34.4%) is on high ground with good drainage.
- Out of total land developed by various agencies 882 ha (43.3%) is on high ground with drainage problem.
- While 455 ha (22.3%) is in low lying areas with poor drainage
- The problem of planned development in low lying areas was seen in a period between 1971-1985 due to lack of planned development in new areas.

Details regarding the location of all the projects is given in Annexure – I.

Table 5.9: Area Developed By Various Agencies

S. No.	Development Agency	Total developed area of various projects (ha)	Developed area located on high ground with good drainage (252 m contour level or above)		Developed area located on medium high ground with drainage problem (Between 252m to 250m contour level)		Low lying developed area with poor drainage (Below 250m Contour Level)	
			Area	% of total developed area	Area	% of total developed area	Area	% of total developed area
			ha	%	ha	%	ha	%
i)	State Government	1196	533	44.6	497	41.6	166	13.9
ii)	Municipal Corporation	724	155	21.4	381	52.6	188	26.0
iii)	Improvement Trust	118	14	11.9	3	3.4	101	85.6
	Total	2038	702	34.4	882	43.3	452	22.3

Source : Office of District Town Planning Officer, Town and Country Planning Department, Patiala

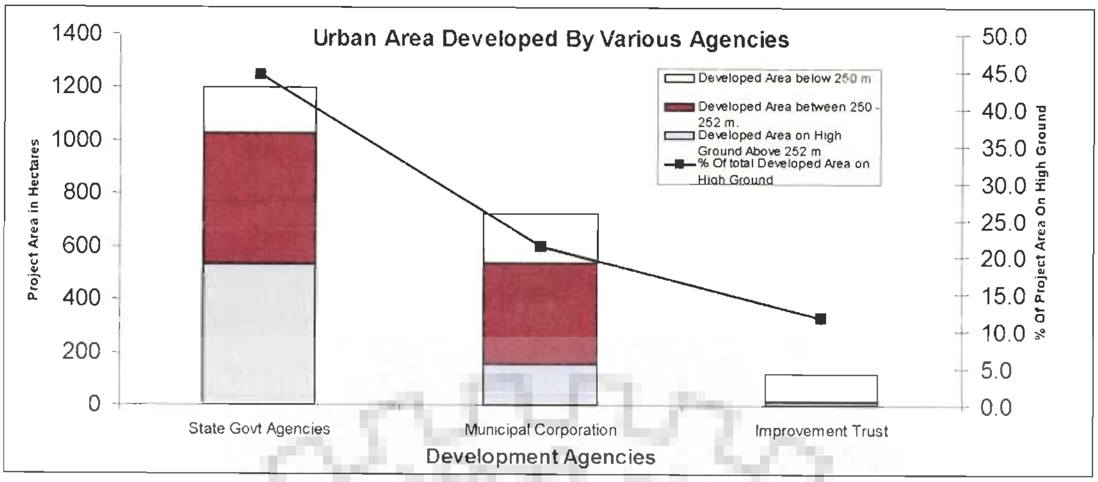


Fig 5.21: Urban Area Developed by various Development Agencies in Patiala Planning Area

5.2 WATER SUPPLY, SANITATION AND DRAINAGE IN PATIALA

5.2.1 Growth Of Water Supply and Sewerage Network in Patiala

❖ **Before 1951**

Before 1951 city developed around Quila Mubrak and within walled city on the Banks of Patialwi Nadi. The Patiala city was confined during this period mainly within walled city, with its adjoining areas, like-cantonment, Moti Bagh Palace, Jail and Tafajalpura.

During this period the water supply network has been divided into four zones with in the walled city and its adjoining areas. This area has public water supply network with four OHSR's and 12 tubewells. Moti Bagh, Cantonment and Central Jail have their own water supply network. While rest of the areas like Tafajalpura have no public water supply network and source of water supply was mainly handpumps and wells. In this phase 799 ha (i.e. 87.6% of area) was under public water supply and 92.0% of population has been supplied with public water supply (Table 5.10 & Fig 5.22).

During this phase sewerage network was present mainly in walled and its adjoining areas. The network during this phase mainly consisted of open drains lined with bricks. In this phase 774 ha. (i.e. 94.5% of the total developed area) was under public sewerage network while. 92% of population has been under public sewerage network. During this phase sewage of city was disposed off in Gandha Nalah without any treatment while land treatment was used to dispose off sewage in central jail and cantonment (Table 5.11 & Fig 5.22).

❖ **Between 1951 – 1971**

During this phase several new town ships were developed outside the walled city like Tripuri Township. Model town, Punjabi Bagh, Lehal, Hira Bagh, etc.. These townships mainly have public water supply. During this phase several large projects like –Thapar College, Punjabi University. Medical College and Expansion of Cantonment etc. have came up. All these institutions have their own water supply network. In this phase there were 9 OHSR's and 21 tube wells of Municipal Committee. In this phase 1483 ha (i.e. 94.0% of area) was under public water supply network while 79.7% of population has been supplied with public water supply (Table 5.10 & Fig 5.22).

During this phase sewerage network with open drains was present in walled city and in institutional areas like Thapar College. Punjabi University etc. with their own sewage disposal system (i.e. land treatment) in this phase 1075 ha (i.e. 68.2% of the total developed area) was under public sewerage network while 59.8% of population has been under public sewerage network (Table 5.11 & Fig 5.22).

Table 5.10: Growth of Water Supply Network In Patiala.

S. No.	Year	Total Developed Area	Area under Water Supply Network						Total Population	Population with Public Water Supply	
			Area under Municipal Water Supply		Area under institutional water supply		Total area under public water supply network				
			Area	% of total dev. area	Area	% of dev. area	Area	% of dev. area		Net population	% of total population
			ha	%	ha	%	ha	%			%
i.	Before 1951	819	262	32.0	537	65.6	799	97.6	50000*	46,000*	92.0
ii.	1951 to 1971	1577	615	39.0	868	55.0	1483	94.0	1,50,486	1,20,000	79.7
iii.	1971 to 1985	2574	639	27.9	1582	58.4	2221	85.3	2,38,000*	2,00,000	84.1
iv.	1985 to 2001	4312	1373	31.8	1619	37.5	2992	69.3	400984	331975	82.7
v	2001 to 2010	9688	4407.4	45.5	2621.6	27.1	7029	72.6	524000*	45000*	85.9

*Projected/approximate population

❖ **Between 1971 – 1985**

During this phase development took place mainly around walled city. Area between two Nadi's (i.e. colonies like Gurbax Colony, Gurunanak Nagar) and intensification of old areas took place. Several new institutional, residential and development project like-D.C.W., Urban Estate Expansion of Cantonment, Truck Stand, and Seva Singh Thikri Nagar etc. have also came up.

In this phase there were 9 OHSRs and 24 tubewells of municipal committee in this phase 2221ha (i.e. 86.3% of total development area) was under public water supply network while 84.1% of population has been supplied with public water supply (Table 5.10 & Fig 5.22).

During this phase underground sewerage network for new townships like Model town, Tripuri etc. along with the walled city and adjoining areas by Water Supply and Sewerage Board (WSSB). Sewage was disposed of in drains after primary treatment. The new institutional and residential area like D.C.W. Urban Estate etc. which came up during this phase also have their own underground sewerage network with their own disposal. In this phase 2107 ha (i.e. 81.9 of total developed area) was under public sewerage network while 75.6% of population has been under public sewerage network (Table 5.11 & Fig 5.22).

Table 5.11: Growth of Sewerage network in Patiala

S. No.	Year	Total developed area	Area under sewerage network						Total population	Population with sewerage network	
			Area under M.C. Network	% of dev. area	Area with indepen-dent network	% of dev. area	Total area under public sewerage network	% of dev. area		Net population	% of total population
		ha	Ha	%	ha	%	ha	%			%
i.	Before 1951	819	262	32.0	512	62.5	774	94.5	50000*	46,000*	92.0
ii.	1951 to 1971	1577	262	16.6	813	51.6	1075	68.2	1,50,486	90000*	59.8
iii.	1971 to 1985	2574	623	24.2	1484	57.7	2107	81.9	2,38,000*	1,80,000	75.6
iv.	1985 to 2001	4312	1016	23.6	1597	37.0	2613	60.6	400984	271530	67.7
v.	2001 to 2010	9688	2950.9	30.5	2896.3	29.9	5837.2	60.3	524000	300000	57.25

**Projected/approximate population*

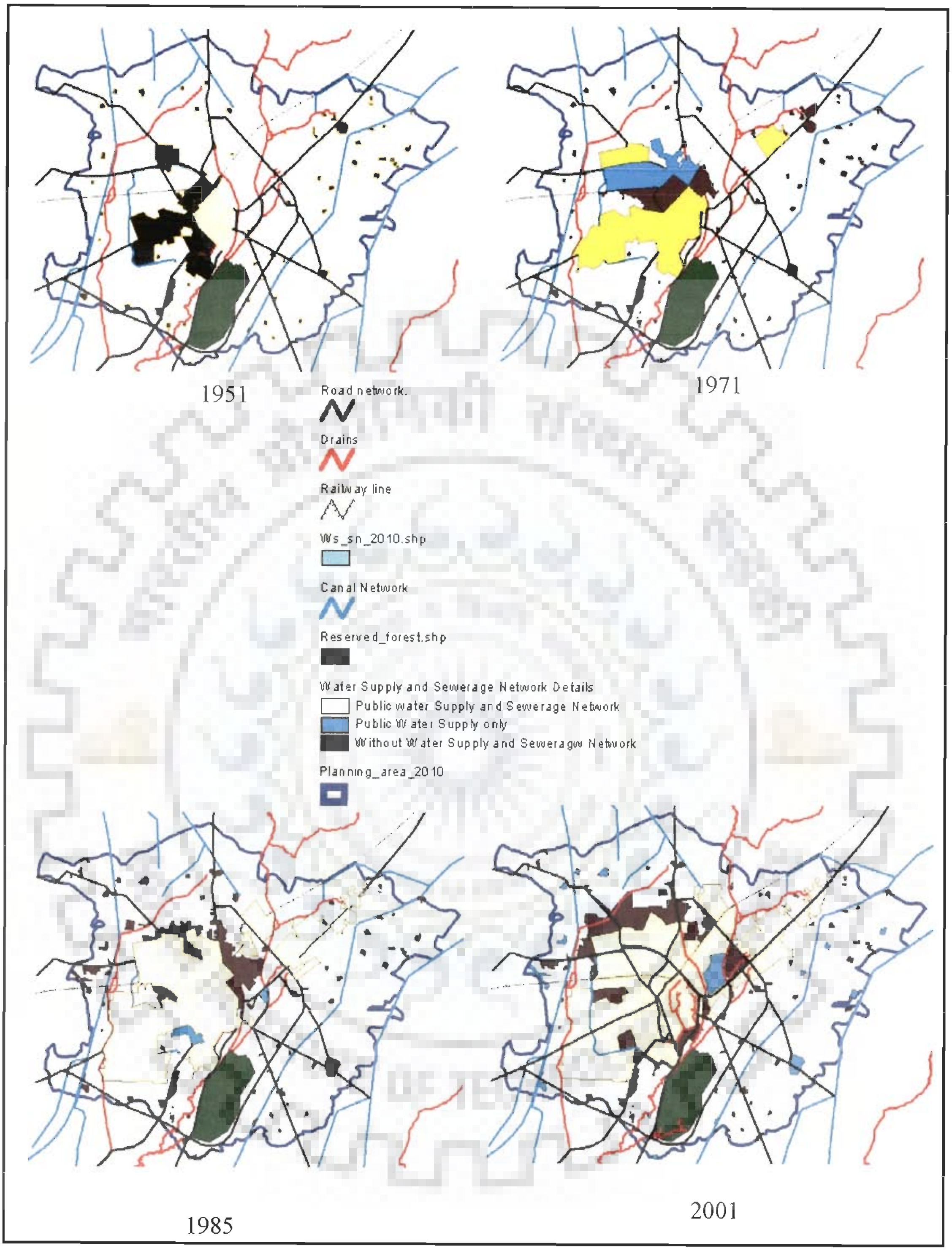


Fig 5.22: Growth of Water Supply and Sewerage Network in Patiala

❖ **Between 1985-2005 (Revised Master Plan Phase)**

During this phase several new developmental projects like focal point expansion of urban estate etc. camp up. Development during this phase took place between Sirhind road byepass – Bhadurgarh Road and also mainly between two nadis and near Cantonment.

In this phase there are 9 OHSR's and 49 tube wells of Municipal Corporation. In this phase 2992 ha (i.e. 69.4% of total developed area) was under public water supply network while 80.4% of population has been supplied with public water supply (Table 5.10 & Fig 5.22)

During this phase underground sewerage network was laid for Gurbax Colony and other areas between two Nadi's and their surroundings with disposal after primary treatment in drains. The new institutional and residential area like Urban Estate Plan III Focal Point etc. which have came up during this phase also have their own underground sewerage network with their own disposal in this phase 2613 ha (i.e. 60.6% of total developed area) was under public sewerage network while 69.3% of population has been under public sewerage network (Table 5.11 & Fig 5.22).

❖ **From 2005 till date (Extended Master Plan Phase)**

During this phase the Sanaur municipality was included along with many villages in the planning area. Several new developmental projects like Baran SEZ, developed by Omaxe and promoted by PDA came up. Development during this phase took place between Sirhind road, Bhadurgarh Road and Bhadson Road in the north and also between two nadis and near Cantonment.

In this phase there are 9 OHSR's and the number of tube wells has increased from 49 to110 in Municipal Corporation. In this phase 7029 ha (i.e. 72.6% of total developed area) was under public water supply network while 85.9% of population has been supplied with public water supply (Table 5.10 & Fig 5.22)

During this phase underground sewerage network was laid for Anand Nagar Officers Colony and for areas between two Nadi's and their surroundings with disposal after primary treatment in drains. The new institutional and residential area like Baran Urban Estate SEZ etc. which have came up during this phase also have their own underground sewerage network with their own disposal. During this phase 58372ha (i.e. 60.3% of total developed area) is under public sewerage network while 57.25% of population has been under sewerage net work coverage.During this phase Central Sewerage Treatment plant has been proposed at Bir Kheri Gujjar in Zone-C, while sewerage treatment plant has been constructed for urban estates (Table 5.11 & Fig 5.22).

5.2.2 Water Supply in Patiala (Demand and Network)

Water Supply in Patiala can be broadly divided into three categories –

- ❖ Public Water Supply
- ❖ Institutional independent water supply
- ❖ Private water supply

❖ **Public Water Supply**

This is the water supplied by a Local government or authority under whose jurisdiction the area falls. In Patiala planning area there are many local government and authorities – Municipal Corporation Patiala, Municipal Committee Sanaur, Nagar Panchayat Kasba Rurki, Patiala Development Authority (Urban estates phase I, II, III and Urban estate Baran) and Public Health Engineering (PHE) department under whose jurisdiction whole of rural area falls. Municipal Corporation of Patiala has divided the city in sixteen zones with zone no. 10, 12 and 13 having partial supply while other zones are fully covered (Fig 5.24).

The demand for each zone is calculated on basis of population and land use character of each zone from 2001 census and again for 2010 by projecting the population of each zone. Public water supply for entire Patiala Municipal Corporation Area has been divided into sixteen zones (Fig. 5.24) and Sanaur municipal area and urban estates into separate zones. The Baran SEZ is another separate zone under development. There are 19 villages also in the planning area which have a net work of public water supply. The demand for water supply has been calculated separately for rural and urban areas based on population and land use pattern of that area. As urban population of the planning area was more than 2 lakhs so the water demand has been calculated as 250 lpcd taking into account both losses and theft and for rural areas demand has been calculated as 150 lpcd (Table 2.9 & Table 2.11, Chapter 2) and peak water demand is taken as 1.5 times the average demand. But all the projections have been done according to average demand and the peak demand is used for designing the supply network.

Table 5.12: Water Supply in Patiala in 2001

S. No.	Zone	Area of zone	Population	Total Average demand	Total peak demand	Tube wells	Maximum Available Supply	OHSR's No.	OHSR's Capacity	Maximum Supply (Supply +OHSR)	Remarks
		Ha		MLD	MLD		MLD		MLD	MLD	
i)	Urban Areas with Public Water Supply	4408	328191	80.3	119	52	56.16	11	0.58	56.7	Total supply is less than demand.
ii)	Urban Areas with Independent Institutional Water Supply	2621	6500*	12.6	19	41	44.3	22	1.1	45.4	Total capacity is more than demand
iii)	Urban Areas without Public Water Supply	1612	13161*	16.7	2.5	-	-	-	-	-	No Water Supply is Available. Private Tube wells are used for supply
iv)	Cantonment	1500	20000*	13.6	13.6	15	15.0	16	0.64	15.6	Total capacity is more than demand
v)	Rural Areas with Public Water Supply	575	28224*	4.2	6.3	19	20.5	19	0.9	21.4	Total supply is surplus
vi)	Rural Areas without Public Water Supply	620	12166*	8.1	12.7	-	-	-	-	-	No Water Supply is Available. Private Tube wells are used for supply
vii)	Circulation (Area under roads)	441	-	5.0	7.4	-		-	-	-	No supply is available
viii)	Fire fighting	-	-	2.0	2.0	-		-	-	0.20 (10% of OHSR capacity)	Supply is less
ix)	Water bodies with water changed every day (Gurudwara Dukhniwaran Sahib & Moti Bagh Sarovar)	1.125	-	25.0	25.0	-		-	-	25.00	Supply is less
	Total	9725	395081	167.5	202.0	117	125.3	68	3.28	153.7	

Source : Water Supply and Sewerage Board, Patiala Municipal Corporation Patiala

*Approx. Population of area

Table 5.13: Water Supply in Patiala in 2010

S. No.	Zone	Area of zone	Population	Total Average demand	Total peak demand	Tube wells	Maximum Available Supply	OHSR's No.	OHSR's Capacity	Maximum Supply (Supply +OHSR)	Remarks
		Ha		MLD	MLD		MLD		MLD	MLD	
i)	Urban Areas with Public Water Supply	4408	415970	114.3	171.5	116	112..8	11	0.6	113.4	Total supply is less than demand.
ii)	Urban Areas with Independent Institutional Water Supply	2621	6500*	25.3	38	41	40.0.	22	1.16	41.2	Total capacity is more than demand
iii)	Urban Areas without Public Water Supply	1612	43170	10.0	15.0	-	-	-	-	-	No Water Supply is Available. Private Tube wells are used for supply
iv)	Cantonment	1500	20000*	13.6	13.6	15	15.0	16	0.6	15.6	Total capacity is more than demand
v)	Rural Areas with Public Water Supply	575	35000	5.2	7.8	19	18.5	19	0.9	19.4	Total supply is surplus
vi)	Rural Areas without Public Water Supply	620	15000	8.7	13.1	-	-	-	-	-	No Water Supply is Available. Private Tube wells are used for supply
vii)	Circulation (Area under roads)	441	-	5.0	7.4	-		-	-	-	No supply is available
viii)	Fire fighting	-	-	2.0	2.0	-		-	-	0.20 (10% of OHSR capacity)	Supply is less
ix)	Water bodies with water changed every day (Gurudwara Dukhniwaran Sahib & Moti Bagh Sarovar)	1.125	-	25.0	25.0	-		-	-	25.00	Supply is less
	Total	9968	500000	209.1	291.0	191	194.4	68	3.28	197.7	

Source : Water Supply and Sewerage Board, Patiala, Municipal Corporation Patiala

*Approx. Population of area

Source of Water Supply in Patiala is Ground Water which is chlorinated before being supplied water is supplied in each area for 5 hours daily. The Distribution System of water supply in Patiala is dual system with tube well (45 HP each) and Over Head Supply Reservoir's (OHSR's) while layout of water supply network in Patiala is a combination of ring and radial networks and mains of all tube wells are inter connected.

The hierarchy of network is:

- Mains 250mm to 200mm

- Sub main 150mm to 100mm

- Branch 100mm to 75mm
- Distribution 75mm to 50mm

For the purpose of public water supply with in planning area there were 52 tube wells in urban areas and 19 tube wells in rural areas (Table 5.12) in 2001 and this has increased to 116 tube wells in urban areas in 2010 (Table 5.13) but there is no increase in number of tube wells in rural area. The ground water level which was at 20m in 2001 has fallen to 27m in 2010 this has resulted in reduction in the yield of tub wells by as much as 20%.

- Flow of tube wells = 0.068 m^3/s in 2001 to 0.054m^3/s in 2010
- Hours of supply = 5hrs.
- No. of OHSRS = 14 out which only 11 are in working condition
- The analysis of water supply has been done in (Annexure – II to calculate demand and Supply in planning area).
- From Table No. 5.12, Table 5.13, Fig 5.23, Fig 5.24 &Fig 5.25 major observation are :
  - Only 73.2% of the urban area is under public water supply.
  - Total public water supply demand in Patiala has increased from 80.3 MLD to 114.3MLD in 2010.
  - Total capacity of tube wells has increased from 56.7 MLD in 2001 to 113.4 MLD for 5 hr. daily supply.
  - Total numbers of OHSR in working condition 11 and their capacity = 0.58MID
  - Out growths of Zone no. 10, 12 & 13 does not have any municipal water supply.
  - Only 19 villages have an access to public water supply which is about 48.1% of the total developed rural area. While 70% of the population have access to public water supply.

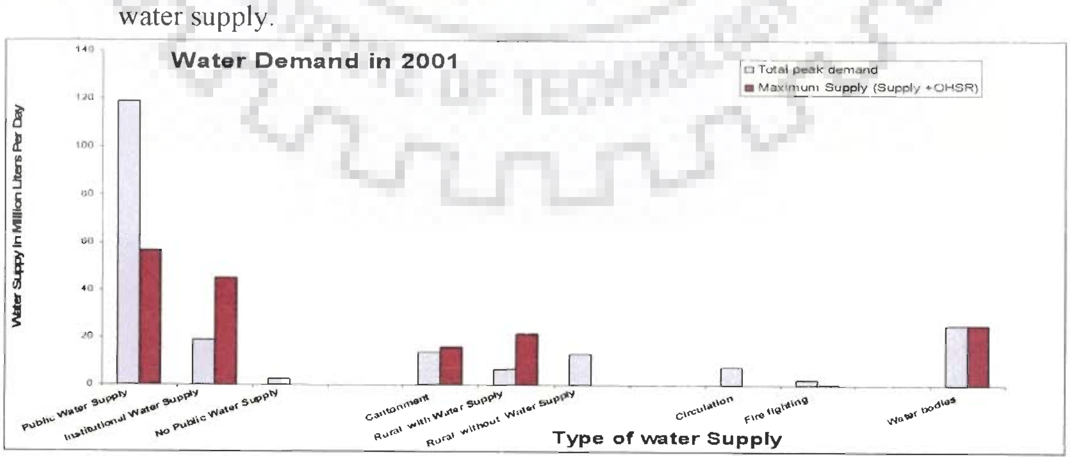


Fig 5.23: Water Demand in 2001

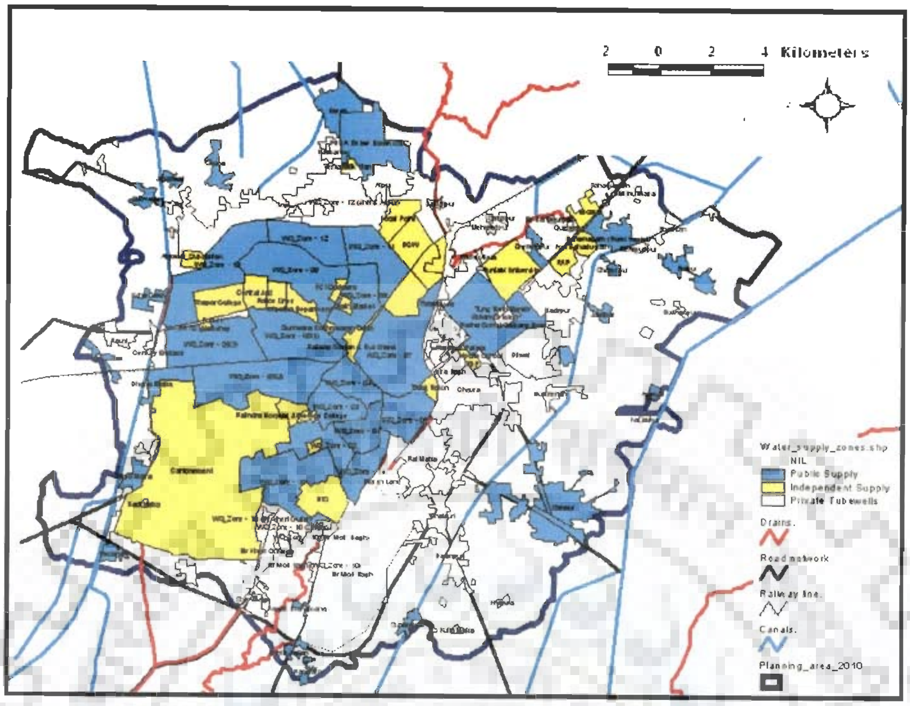


Fig 5.24 Type of Water Supply in Patiala

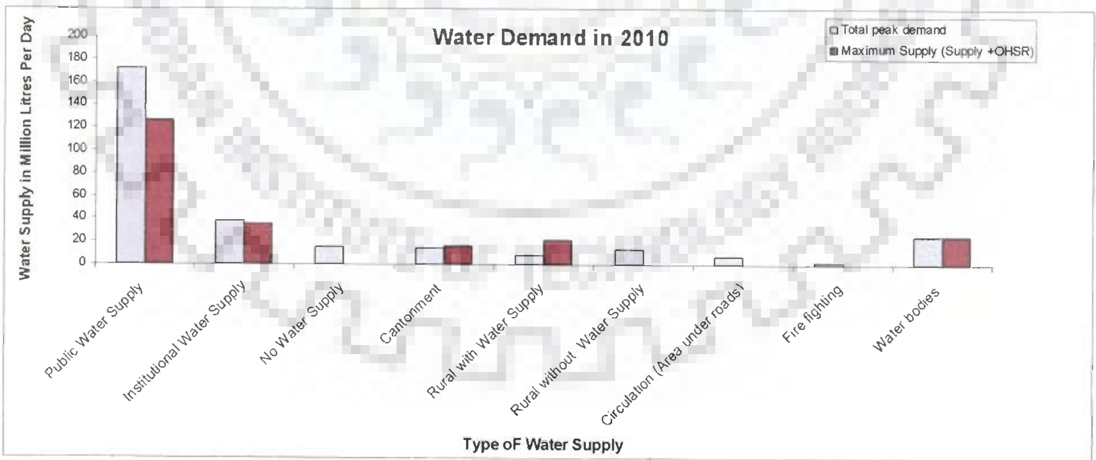


Fig 5.25 Water Demand in 2010

❖ **Independent Institutional Water Supply**

This is the water supplied with in the institutions which have a network of water supply independent of the public water supply network. For Institutional water supply there are 41 tube wells and 22 OHSR's. There is a 24 hr water supply in these institutions. The water supply capacity is in surplus to the peak demand of 19 MLD (Table 5.12, Table 5.13, Fig 5.23, Fig 5.24, Fig 5.25 and Annexure - II).

❖ **Cantonment**

There is a cantonment in Patiala planning with an area of 1500ha and the water supply data has been provided by the office of Garrison Engineer, Patiala For cantonment water supply there are 15 tube wells and 16 OHSR's. There is a 24 hr water supply in this cantonment area. The water supply capacity is in surplus to the peak demand of 13.6 MLD. (Table 5.12, Table 5.13, Fig 5.23, Fig 5.24, Fig 5.25 and Annexure - II).

❖ **Private Water Supply**

These are the areas which don't have access to public water supply and have water supply with own hand pump or tube well. These areas are the newly developed areas in water supply zones 10, 12 and 13 in the Patiala Municipal Corporation of the planning area and the out growths across the Patialwi nadi on sanaur road. There are also more than 30 villages without access to public water supply (Table 5.12, 5.13, Fig 5.23, 5.24, 5.25 & Annexure - II).

5.2.3 Sewerage network and Disposal Patiala

Sewerage network in Patiala can be divided into three broad categories:

- ❖ Municipal Network
- ❖ Independent disposal
- ❖ No sewerage network

❖ **Municipal Network**

Only Patiala Municipal Corporation has the sewerage network within the planning area. The type of sewerage disposal system in Patiala is partially separate system with no separate storm water drainage in Municipal Corporation area except for Thapar College, D.C.W., and Railway Colony. Sewerage network in Patiala is not continuous. It has been divided into six zones with eight temporary disposal works which dispose of the sewage in drains and seepage from drains is polluting the ground water (Fig 5.29). The details of municipal disposal works are given in Table 5.14, Table 5.15, Table 5.16, Fig 5.26, Fig 5.27, and Fig 5.28)

Table 5.14: Sewerage Disposal Works of Municipal Corporation in Patiala

S. No.	Name	Drain in which disposal is zone
i)	Model Town Disposal works	Connected to next zone
ii)	Bhoot Nath Mandir Disposal works	Jacob drain (Ganda Nalah)
iii)	Tripuri Disposal works	Connected to Yadwindra Nagar Disposal works
iv)	Yadwindra Nagar Disposal works	Chotti Nadi
v)	Guru Nanak Nagar Disposal works	Chotti Nadi
vi)	Mathura Colony Disposal works	Chotti Nadi
vii)	Rai Majra Disposal works	Chotti Nadi
viii)	Moti Bagh Disposal works	Patialwi Nadi

Source: Punjab Water Supply and Sewerage Board, Patiala

Table 5.15: Urban Areas with Municipal Sewerage Network – 2001

S.No.	Name Of Area	Land Use	Area in Hectares	Population in 2001
i)	Central Jail	Public/Semi-Public (Govt)	55.5	0
ii)	Irrigation Department	Public/Semi-Public (Govt)	45.9	0
iii)	Police Lines	Public/Semi-Public (Govt)	38.2	0
iv)	Zone_A	CBD	400.4	75436
v)	Zone_B (Tripuri)	Residential + Comm.	307.8	39993
vi)	Zone_B (Yadwindra Colony)	Resi + Industrial	198.0	18916
vii)	Zone_C	Residential	1261.2	70565
viii)	Zone_D	Residential	380.3	42261
ix)	Zone_E	Residential	168.9	3741
x)	Zone_F	Residential + Trans.	107.6	15658
Total			**2963.8**	**266570**

Table 5.16: Urban Areas with Municipal Sewerage Network – 2010

S.No.	Name Of Area	Land Use	Area in Hectares	Popupation in 2010 (approx.)
(i)	Central Jail	Public/Semi-Public (Govt)	55.5	
(ii)	Irrigation Department	Public/Semi-Public (Govt)	45.9	
(iii)	Police Lines	Public/Semi-Public (Govt)	38.2	
(iv)	Zone_A	CBD	400.4	75436
(v)	Zone_B (Anand Nagar)	Residential	94.7	9000
(vi)	Zone_B (Indra Colony)	Residential	166.0	10000
(vii)	Zone_B (Tripuri)	Residential + Comm.	307.8	42000
(viii)	Zone_B (Yadwindra Colony)	Resi + Industrial	198.0	19000
(ix)	Zone_C	Residential	1261.2	100000
(x)	Zone_D	Residential	380.3	50000
(xi)	Zone_E	Residential	168.9	4000
(xii)	Zone_F	Residential + Trans.	107.6	14000
Total			**3224.5**	**323436**

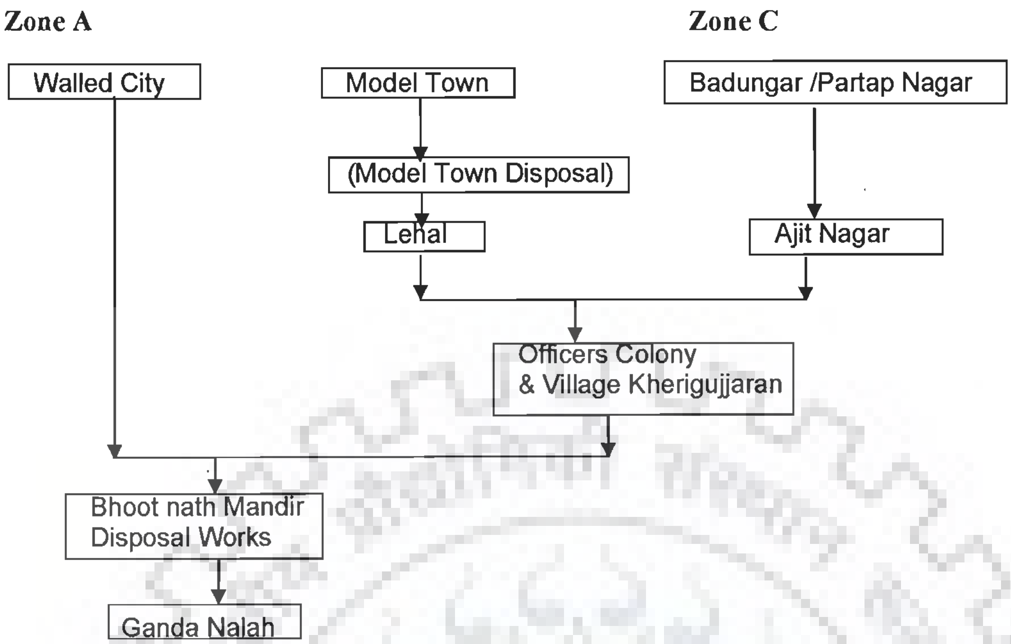


Fig 5.26 Present sewerage disposal network in Patiala for zone A & C.

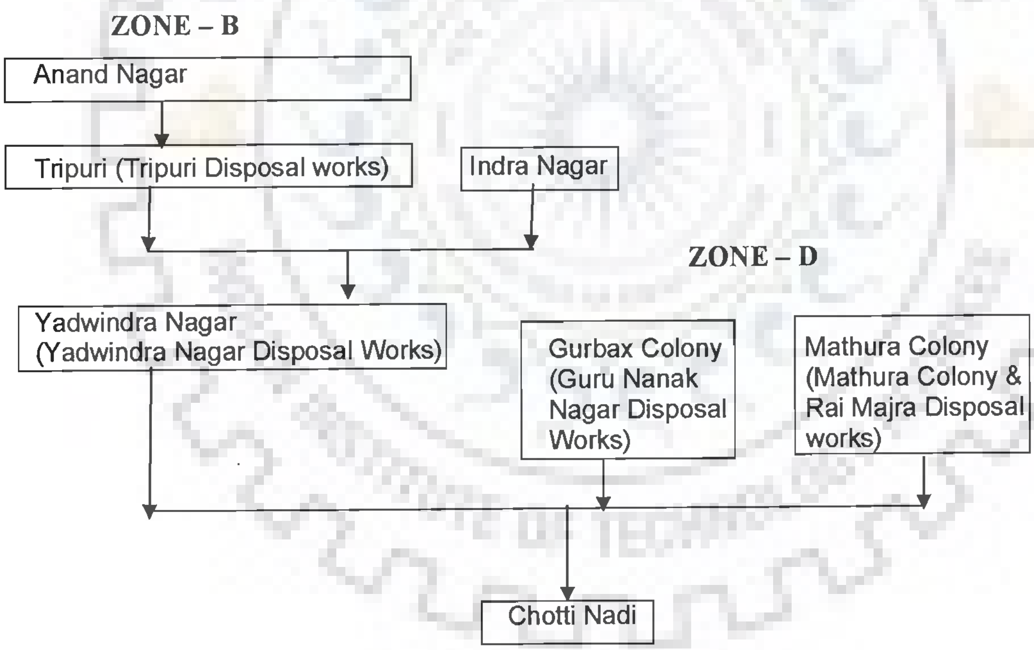


Fig 5.27: Present sewerage system in Patiala for zone B and zone D

Sewerage system in zone E has two disposal works one at Mathura colony and second one at Rai majra and zone F has its disposal works near Bir Moti bagh near junction of Patialwi nadi and Chotti Nadi (Fig 5.28).

❖ Independent Sewerage network and disposal

Within Patiala planning area there are institution which have there own independent sewerage network and disposal which is not connected to city sewer and disposal works. These areas dispose off the sewage after treatment on site by land treatment or dispose it off in a drain after primary or secondary treatment. The details are given in Table 5.17 annexure – III.

Table 5.17: Urban Areas with Independent Sewerage Disposal

S.No.	Name Of Area	Land Use	Population	Area in Hectares	Method of Disposal	Point Of Disposal
(i)	NIS	Public/Semi-Public	0	119.6	Aerobic Pond	On Site
(ii)	Escorts	Industrial	0	45.6	Active Sludge Treatment	Philauli Drain
(iii)	PAP	Public/Semi-Public (Govt)	0	38.0	Aerobic Pond	On Site
(iv)	Fort Bahadurgarh	Public/Semi-Public (Govt)	0	33.5	Aerobic Pond	On Site
(v)	ITBP	Public/Semi-Public (Govt)	0	17.6	Aerobic Pond	On Site
(vi)	Verka Milk Plant	Industrial	0	12.1	Active Sludge Treatment	On Site
(vii)	Focal Point	Industrial	0	72.1	Active Sludge Treatment	Patialwi Nadi
(viii)	Thapar College	Public/Semi-Public	0	105.8	Active Sludge Treatment	On Site
(ix)	DCW	Industrial	0	92.1	Primary Treatment	Patialwi Nadi
(x)	DCW	Residential	878	30.1	Primary Treatment	Patialwi Nadi
(xi)	DCW	Residential	5750	84.8	Primary Treatment	Patialwi Nadi
(xii)	DCW	Recreation	0	50.0	Primary Treatment	Patialwi Nadi
(xiii)	Punjabi University	Public/Semi-Public	0	141.0	Active Sludge Treatment	Philauli Drain
(xiv)	Cantonment	Public/Semi-Public (Govt)	20000*	1452.6	CST	Jacob & Model Town Drains
(xv)	Ablowal Sub-station	Public/Semi-Public	0	28.0	Aerobic Pond	On Site
(xvi)	Ubban Estates	Residential	11145	310.2	Active Sludge Treatment	Land Treatment Chaura Village
(xvii)	PUDA Estate Baran (SEZ)	Industrial	0	229.8	Active Sludge Treatment	Land Treatment Baran Village
(xviii)	Railway Station	Transportation	0	33.5	Primary Treatment	Chotti Nadi
Total			17773	2896.3	Aerobic Pond	On Site

❖ Areas Without Sewerage Network

All the villages in planning area and some parts within each zone which are without sewerage network the details are in Table 5.18, Fig 5.28 and Annexure – III.

Table 5.18: Sewerage Network in Patiala Planning Area – 2010

S.No.	Sewerage Network	Area in Hectares	% Of Developed Area	Population	% of total population
(i)	Area with Municipal Sewerage Network	3224.5	37.4	324000	72.2
(ii)	Urban Area without Sewerage Network	2495.9	29.0	100000	22.3
(iii)	Urban Area Independent Sewerage Network	2896.3	33.6	25000	5.6
(iv)	**Total Urban**	**8616.7**	100.0	**449000**	**100**
(v)	Rural Area Without Sewerage network	1195.2	100.0	45000	100
(vi)	Area Without Sewerage Network	3691.1	37.6	145000	29.4

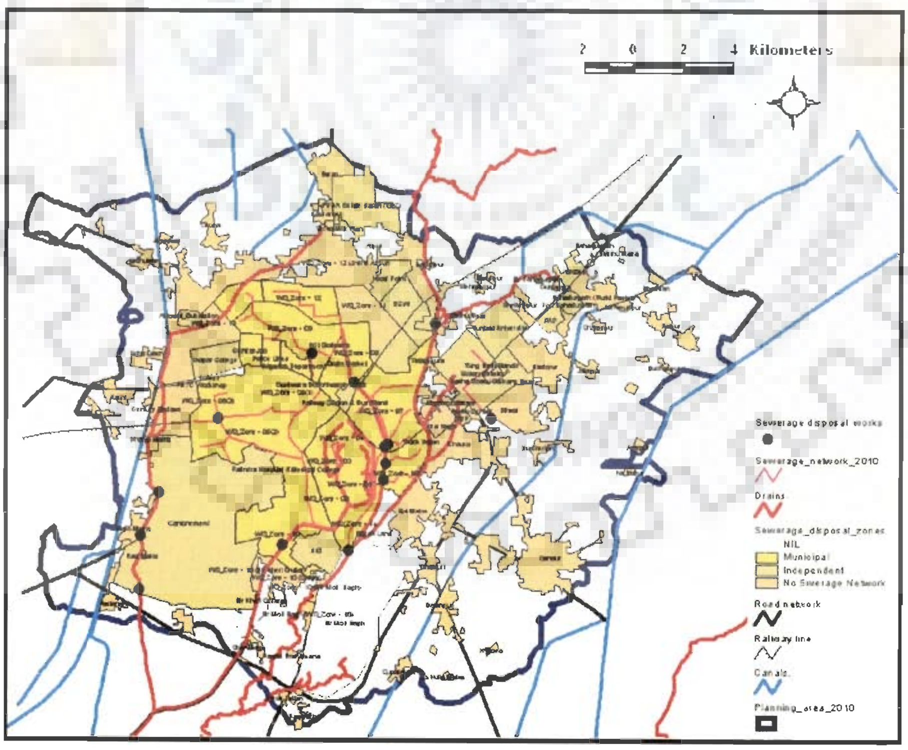


Fig 5.28: Type of Sewerage Network in Patiala

5.2.4 Drainage network in Patiala

Drainage pattern of the Patiala city is divided into fourteen catchment zones (Fig 5.30) on the basis of contour analysis, presence of drains, canals and highways which act as a barrier.

The drains present in the planning area are:

- Patialwi Nadi
  - Philauli Drain
  - Tafajal Pura drain
  - Hirabagh drain
  - Bir Moti Bagh drain
- Chotti Nadi
- Model Town Drain
- Jacob Drain / Ganda Nalah

Canals and Distributries present in Patiala Planning area are:

- Bakhra Main Line Canal
- P.N.C. (Patiala Navigational Channel)
  - Moti Bagh Minor
  - Baradari Minor
- Baran Distributory
  - Baran Minor-I
  - Baran Minor-II
  - Siona Minor
- Sanur Distributary
  - Sanaur Distributory
  - Bahadurgarh Minor

Patiala receives most of its rainfall in monsoon months so separate drainage system of sewerage network is most suitable system. But at present Patiala has partially separate system with most of the areas without any type of storm water run off drains and storm water runoff is carried of by surface drainage to the drainage outlet of their catchment zones.

Areas in Patiala with drainage network are - (Table 5.19)

- Walled city
- Thapar College
- DCW

- Punjabi University
- Urban Estates

Table 5.19: The Areas with Drainage Network In Patiala

S.No.	Name of the Zone	Type of Drainage	Point of Disposal
(i)	Catchment zone A (Walled city)	Open drains	Jacob Drain (Ganda Nalah)
(ii)	Thapar College	Under ground separate network	Model Town drain near Ablowal
(iii)	D.C.W.	Under ground separate network	Patialwi Nadi
(iv)	Punjabi University	Under ground separate network	Philauli Drain
(v)	Urban Estates	Under ground separate network	Patialwi Nadi

Source : Punjab Water Supply and Sewerage, Patiala

5.3 AVAILABLE WATER RESOURCES IN PATIALA

In Patiala planning area water resources can be divided into – surface water, runoff generated from rainfall, ground water and waste water generated. As demand has been calculated on daily basis so the total availability of water resources has been converted into daily availability in Million Liters Per Day (MLD).

5.3.1 Surface water

5.3.1.1 Flow in Drains

There are four main and many minor drains merging in these drains. Main drains are:

- **Patialwi Nadi :** Maximum discharge is in monsoon season. It varies between 56.6m^3/sec (2000 cusecs/day) to 226.6 m^3/sec (8000 cusecs/day) from July to September with a maximum single day discharge 230m^3/sec (8000 cusecs/day). Maximum discharge in a monsoon season in nadi was in 1995, with a total discharge of 69,724 cusecs, with maximum discharge on 1st September,1995 of 228.7m^3/sec (8070 cusecs/day). Maximum discharge capacity of nadi is 340 m^3/sec (12000 cusecs/day) below danger mark. All this water is going waste as this water is not used for any purpose like rainwater harvesting etc. It is only used for disposal of sewerage and drainage of D.C.W., urban estate etc (Table 5.20).

- ***Model Town Drain:*** This drain has very less discharge. It starts near Hassanpur and meets Ganda Nallah outside the planning area Its discharge varies between 2.84 to 4.25 m^3/sec (100 to 150 cusecs/day) between July to September. This water is also wasted and not used for any useful purpose (Table 5.20).

- **Chotti Nadi :** It starts from Sirhind road and merge into Patialwi Nadi near Bir Moti Bagh its maximum discharge is in monsoon season and varies between 1.41m^3/sec (50 cusec/day) to 2.83 m^3/sec (100 cusecs/day) from July to September but normally it is being used for discharge of daily sewerage of the area in it. This discharge of sewerage is polluting the drain and also Patialwi Nadi (Table 5.20).

Table 5.20: Flow of Various Drains

S.No	Drain	Year								
		1988			1995			2010		
		Days of flow	Av. Flow	Max. flow in a day	Days of flow	Av. Flow	Max. flow in a day	Days of flow	Av. Flow	Max. flow in a day
			m^3/s	m^3/s		m^3/s	m^3/s		m^3/s	m^3/s
i)	**Patialwi Nadi**									
	July	24	61.9 (2183 cusecs)	180.0 (6340 cusecs)	2	18.5 (652 cusecs)	24.9 (878 cusecs)	12	61.7 (2176 cusecs)	211.8 (7472 cusecs)
	August	25	36.6 (1290 cusecs)	126.8 (4477 cusecs)	6	45.1 (1591 cusecs)	147.9 (5220 cusecs)	19	30.1 (1061 cusecs)	130.9 (4620 cusecs)
	September	7	111.1 (3920 cusecs)	131.5 (4642 cusecs)	9	142.7 (5037 cusecs)	228.7 (8070 cusecs)	11	108.7 (3837 cusecs)	140.7 (4966 cusecs)
ii)	**Model Town Drain**									
	July	2	2.4 (83 cusecs)	2.6 (9.2 cusecs)	-	-	-	4	4.1 (144 cusecs)	17.6 (621 cusecs)
	August	1	2.6 (90 cusecs)	2.6 (90 cusecs)	1	2.6 (92 cusecs)	2.6 (92 cusecs)	3	2.3 (81 cusecs)	4.1 (145 cusecs)
	September	2	4.5 (160 cusecs)	6.3 (223 cusecs)	1	5.9 (208 cusecs)	5.9 (208 cusecs)	3	1.1 (39 cusecs)	2.1 (74 cusecs)
iii)	**Chotti Nadi**	7	2.3 (1493 cusecs)	4.0 (3106 cusecs)	3	1.8 (64 cusecs)	3.4 (120 cusecs)	10	2.8 (77cuse cs)	4.2 (148 cusecs)
iv)	**Jacob Drain (Ganda Nalah)**	7	2.6 (92 cusecs)	4.1 (145 cusecs)	3	2.8 (99 cusecs)	5.1 (180cus ecs)	10	2.3 (81 cusecs)	3.1 (109 cusecs)

Source : Irrigation Department, XEN East, Patiala, Punjab

- **Jacob Drain (Ganda Nalah)** : *It* is the drain which passes through the old city and acts as its drainage network. Its maximum drainage discharge is in monsoon season. It varies between 1.42 to 2.83m^3/sec (50 to 100 cusecs/day) between July to September (Refer Table No. 5.2). In this drain all the sewerage after primary treatment is also discharged daily at Bhoot Nath disposal works, near village Kheri Gujjaran, seepage of untreated sewage from Ganda Nalah is polluting ground water (Table 5.20).

5.3.1.2 Rainfall Runoff

Patiala receives major chunk of its rainfall in monsoons while small amount in winters. Total average rainfall in Patiala is 800 mm with maximum of 650 mm in monsoon season this water is not conserved in any form to be used latter or to recharge ground water etc. resulting in wastage of this precious resource (Table 3.1 and Fig 3.4).

5.3.1.3 Water Bodies

Two main lakes Rajendra lake and Moti Bagh lake. Rajendra lake has been renovated now but Moti Bagh lake is lying vacant. There are large number of ponds, Marshy, lowlying area between two Nadi's and other lowlying areas. These water bodies are being encroached and developed logging etc. resulting in problems like water logging, sewerage backlash etc.

5.3.2 Ground Water

Present ground water situation is very critical is nature. The ground water is the only source presently used in Patiala for various purposes. The demand of water has increased from 202.0 MLD (million litres per day) in 2001 to 291.0 MLD in 2010 for Patiala planning area. The ground water level has receded from 20 min 2001 to 27 m in 2010. The ground water table is receding at an annual rate of 0.75 m per year. This is alarming and would recede with increasing urban population. Due to this alarming decrease in ground water level in Patiala, it has been declared as one of the eight blocks where ground water is being over exploited.

5.3.3 Canal Water

There are three distributes of Bhakra main line & Nirwana Branch in planning area.

5.3.3.1 Patiala Navigational Channel (P.N.C.)

It is sub divided into two more distributes namely Baradari minor and Moti Bagh Minor Total average allocated discharge of the distributary is 30 cusecs per day. 0.51m^3/sec (18 cusecs/day) for Baradari minor and 0.34m^3/sec (12 cusecs day) discharge for Moti Bagh minor. But due to lack of repair and development of the areas served by these distributaries the present discharge in Baradari minor is only 0.20m^3/sec (7-8 cusecs/day) and 0.14 m^3/sec 5-6 cusecs/day discharge in Moti Bagh mind with total discharge between 0.34 (12-15 cusecs/day) all of which is getting wasted. (Table 5.21)

Table 5.21: Flow in Canal Distributaries

S. No.	Surface Water Sources	Maximum flow (Authorised full supply discharge)	Existing flow capacities	Days of Supply Per Week	Days of Supply in planning area	Total Supply available per day according to A.F.S.D.
		m^3/sec	m^3/sec.			MLD
(i)	**P.N.C.**	0.85 (30 cusecs)	0.34	7	7	73.41
(a)	Moti Bagh Minor	0.34(12 Cusecs)	0.14	-	7	29.35
(b)	Baradari Minor	0.51(18 Cusecs)	0.20	7	7	44.06
(ii)	**Baran Distributary**	1.13 (50 cusecs)	1.13	7	-	97.87
(a)	Baran Minor-I	0.74 (26 cusecs)	0.74	-	4	36.53
(b)	Baran Minor-II	0.27 (12 cusecs)	0.27	-	7	23.43
(c)	Siona Minor	0.50(12 Cusecs)	0.50	-	2	12.34
(iii)	**Sanaur Distributary**	1.13(50 cusecs)	1.13	7	-	97.87
(a)	Bahadurgarh minor	0.34 (15 cusecs)	0.34	-	6	25.12
(b)	Sanaur Mainline	0.79 (35 cusecs)	0.79	-	4	39.00
	Total					**269.15**

Source : Irrigation Department, Punjab

5.3.3.2 Baran Distributary

Its tail end is in the North part of planning area and part of it which lie in industrial estate and D.C.W. workshop has been dismantelled. Its allocated average discharge is 1.13m^3/sec (50 cusecs/day) and within the planning area water from it is used for agriculture in villages Alipur, Daulatpur, Hassanpur and Siona (Table 5.21)

5.3.3.3 Sanaur Distributary :

Large portion of Sanaur distributary lies in Patiala planning area. Its allocated average daily discharge is 1.13m^3/sec (50 cusecs/day). In planning area its water is used for agricultural purposes in Village-Dalanpur, Sanaur, Chaura, Nurkherian, Dilwal, Jalalpur, Shamspur, Nasirpur, Mehmudpur Raipur, Kasba Rurki, Suniarheri, Ramgarh, Rain Majra.

Total canal water available in planning area is 270MLD out of which 73.4 MLD of water from PNC is being wasted by not being used for any thing as the area under its irrigation has been urbanised and this water is not used for urban water supply. Rest of the water 196.3 MLD is being used for irrigation and is available for future urban water supply in planning area so there is a need to include this resource while planning for the Patiala planning area (Table 5.21).

5.3.4 Waste water Generated

Total quantity of sewage produced in Patiala has increased from 107.6 MLD in 2001 to 133.3 MLD in 2010. While only 71.0% of developed urban area is under sewerage network with total population of 77.8%. Quantity of sewage produced will increase to 212.0 MLD in 2031(Table). This water which is also an important resource is not being utilized for any activity but is being disposed of in drains, in planning area without any treatment. This has polluted the ground water in the areas around these drains. There is a need to adopt the measures to recycle and reuse this water for other activities this will in turn reduce the water demand by as much as 20% (Table 5.21).

5.4 IMPACT OF URBANIZATION ON WATER RESOURCES

Urbanization of Patiala without any consideration to existing topography (conturs), drainage and available water resources has affected the both quantity and quality of water resources in the Patiala planning area as ground water level is receding at an alarming rate of 0.75 m per year, ground water is getting polluted by discharge of untreated sewage in the drains, and flooding of low-lying areas during monsoons.

5.4.1 Impact On Water Resource Quantity and Quality

Urbanization has affected the water resources in adverse ways, over exploitation of ground water as the only source of water supply in the planning area which had led to the fall of ground water level at an alarming rate of 0.75 m per year. The canal water sanctioned for the area has been neglected and not used for water supply. The discharge of untreated sewage in the drains has lead to the pollution of ground water in the vicinity of drains up to the distance of 250 m from the drains. Lack of drainage network in the city has led to the flooding of low-lying areas. The ground water recharging and harvesting has not been considered as an option to control the drainage problems and to compensate for the reduction in ground water recharging due increase in impervious areas due to urbanization. The low-lying areas in Patiala planning area has not been conserved but projects have been planned and developed in these areas.

5.4.1.1 Impact on Quantity of Water

With increase in urbanization there is an increase in impervious area leading to the decrease in ground water recharge. This can be calculated by using rainfall infiltration method factor method developed by GEC – 97.

Table 5.22. Change in ground water recharge potential with urbanisation

S.No.	Year	Impervious Area (ha)	Pervious Area (ha)	Total G.W.Recharge ($1 X 10^{10}$ litres)	G.W.Recharge Potential per Day(MLD)
1	1951	1176.7	18818.3	2.8	77.3
2	1971	2551.0	17444.0	2.6	71.6
3	1985	3383.8	16611.2	2.5	68.2
4	2001	4814.3	15180.7	2.3	62.3
5	2010	6418.3	13576.7	2.0	55.8

From 1951 with increase in impervious areas there is a reduction in ground water recharge potential from 77.3 MLD in 1951to 55.8 MLD in 2010 (Table 5.22). The development of low-lying areas between Patialwi nadi and Chotti nadi had drastically reduced the area which earlier acted as a rain water harvesting area with an area of over 265 hectares with a capacity of over 10.6 MCM. This has been reduced to less than 45 hectares in 2010 and this area has been diverted for solid waste disposal.

5.4.1.2 Impact on Quality of Water

The ground water is the only source of water supply in the Patiala planning area. Quality of ground water is Patiala is being affected by the disposal of untreated industrial waste water and sanitary disposal in drains. Extent of water pollution has been known by considering. pH and value of coli-form bacteria for which the samples around drains have been taken by the Punjab Pollution Control Boards and Punjab State Sample Testing Laboratory. For quality of ground water affected by untreated sewage disposal in drains in Patiala details are in Table 5.23, Table 5.24 & Fig 5.29.

Table 5.23: Extent Of Water Pollution

S.No.	Distance From drains	pH	Coli form Bacteria
(i)	Upto 50 m	4.5 – 5.5	200 – 300
(ii)	50 – 250 m	5.5 – 6.5	130 – 200
(iii)	250 – 500 m	6.5 – 7.5	50 –130

Source : Punjab Pollution Control Board, Patiala (2000)
Punjab State Sample Testing Laboratory, Chandigarh (2000).

Table 5.24: Effect of Ground Water Pollution

S. No.	Zone/ Area with ground water pollution	Area of zone	Density of zone	Population effected
(i)	Zone-1	106	198	21000
(ii)	Zone-2	40	225	9000
(iii)	Zone-3	120	167	20000
(iv)	Zone-4	115	191	22000
(v)	Zone-6	147	50	4000
(vi)	Zone-7	380	242	50000
(vii)	Zone-8	76	127	9600
(viii)	Zone-10	100	70	5950
(ix)	Zone-13	25	28	700
(x)	Zone-14	107	130	14000
(xi)	Jhill & Hasanpur	305	134	40870
(xii)	D.C.W.	96	29	2784
(xiii)	Ablowal	90	14	1260
(xiv)	Mahindra Colony	93	25	2325
(xv)	Suhlar	81	23	4991
(xvi)	Hira Nagar	41	140	5740
(xvii)	Ghlauri	46	11	506
(xviii)	NIS	61	8	488
	Total	**2029**		**215214**

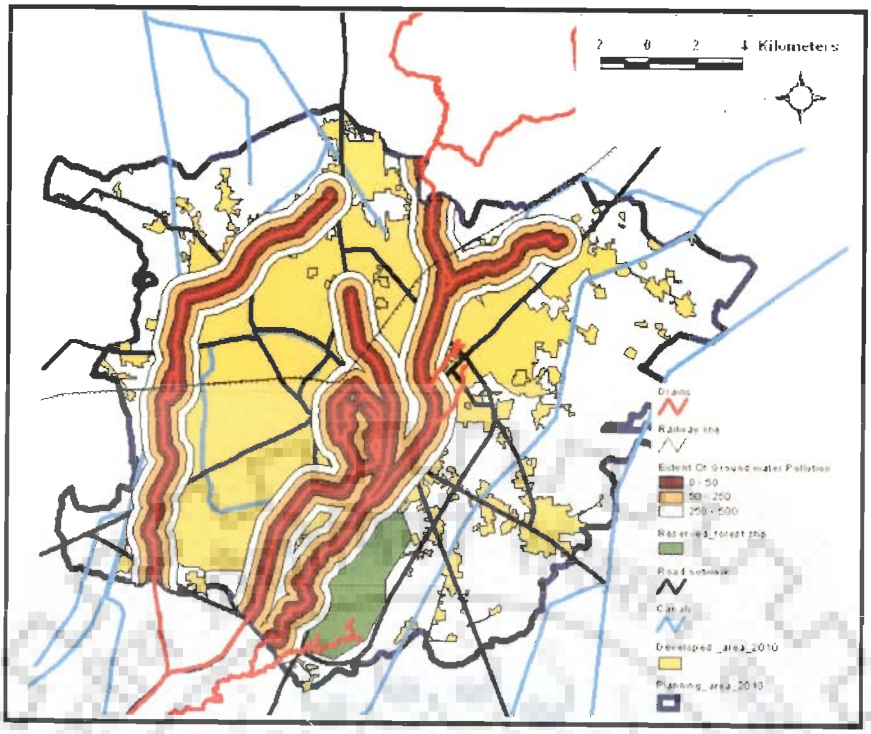


Fig 5.29: Ground Water Pollution Caused By Disposal of Untreated Sewage in Drains

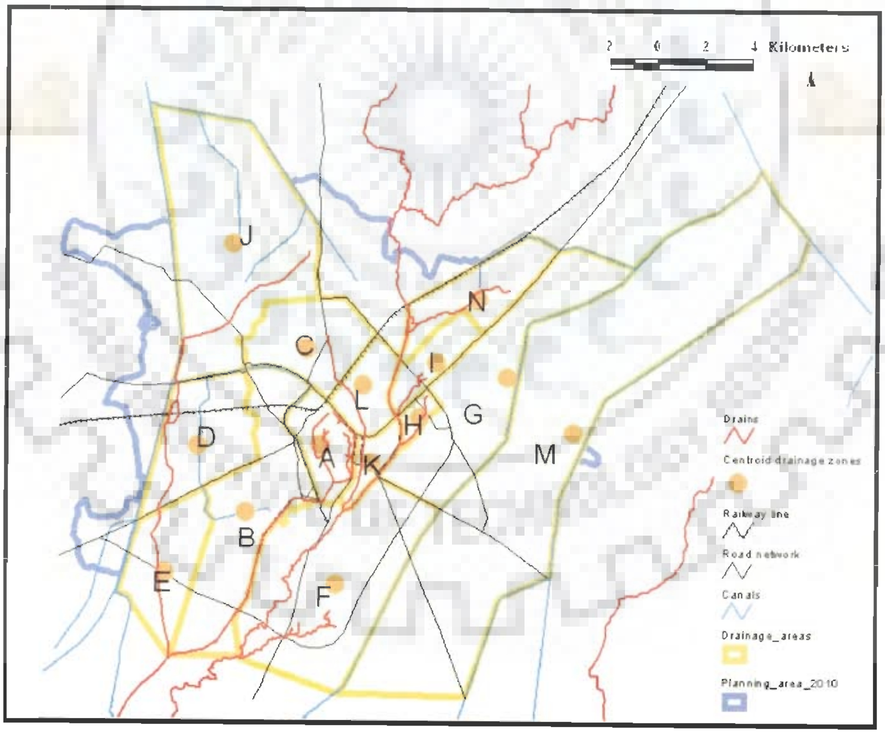


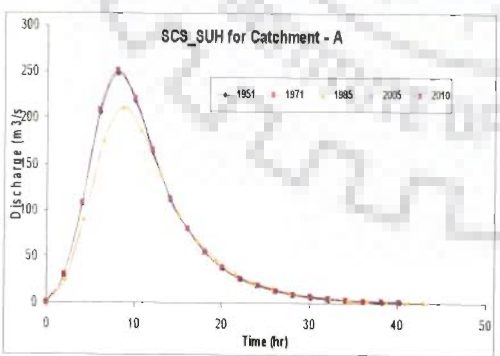
Fig 5.30: Drainage Catchments in Patiala Planning Area

The acidity of water and coli form bacterial content in under ground water near drains is more as compared to standards and goes on decreasing with increasing distance from the drain. The samples reach neutrality in third band i.e. from 250 m to 500 m (Table 5.23). The source of water pollution is disposal of untreated domestic and industrial wastes in water bodies which disturb the quality of water and makes it unsafe for human consumption and unfit to be used for vegetation. The water supply zone affected by water pollution are 1, 2, 3, 4, 6,7, 8, 10 and other areas like Jhill, Ablowal, Suhlar, Hira Nagar etc. Zone no. 6, 7 & 8 are 100% affected while other wards are partially affected (Fig 5.29).

Total area affected by ground water pollution from Seepage of Sewage disposal in drains is 2029 hectares (i.e. 20.9% of total developed area) and total population affected by it is 215218 (i.e. 41.1% of total population) (Table 5.24).

5.4.2 Impact On Surface Water Runoff and Drainage

The Patiala planning area can be divided into 14 catchments on basis of the topography, drainage pattern, location of distributaries, and highways. In some cases the catchment extends beyond the planning area (Fig 5.30). With increase in developed area in each catchment there is an increase in surface runoff. To analyse this increase for each catchment SCS unit hydrograph has been used to generate in chronological order. The storm with the duration, D of six hours, a return period, T of ten years has been taken and the intensity, i of such storm for Patiala have been calculated as 20.0 mm/hr. From SCS unit hydrograph analysis of each catchment it is clear that with urbanization of each catchment there is a rapid increase in surface runoff and time to peak has also decreased causing flooding in low lying areas (Fig 5.31 to Fig 5.33 and Annexure – IV).



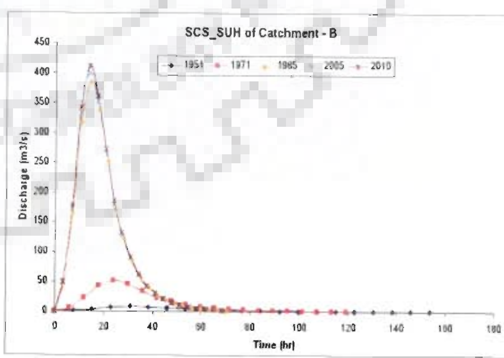


Fig 5.31: SCS – SUH for Catchment A & B

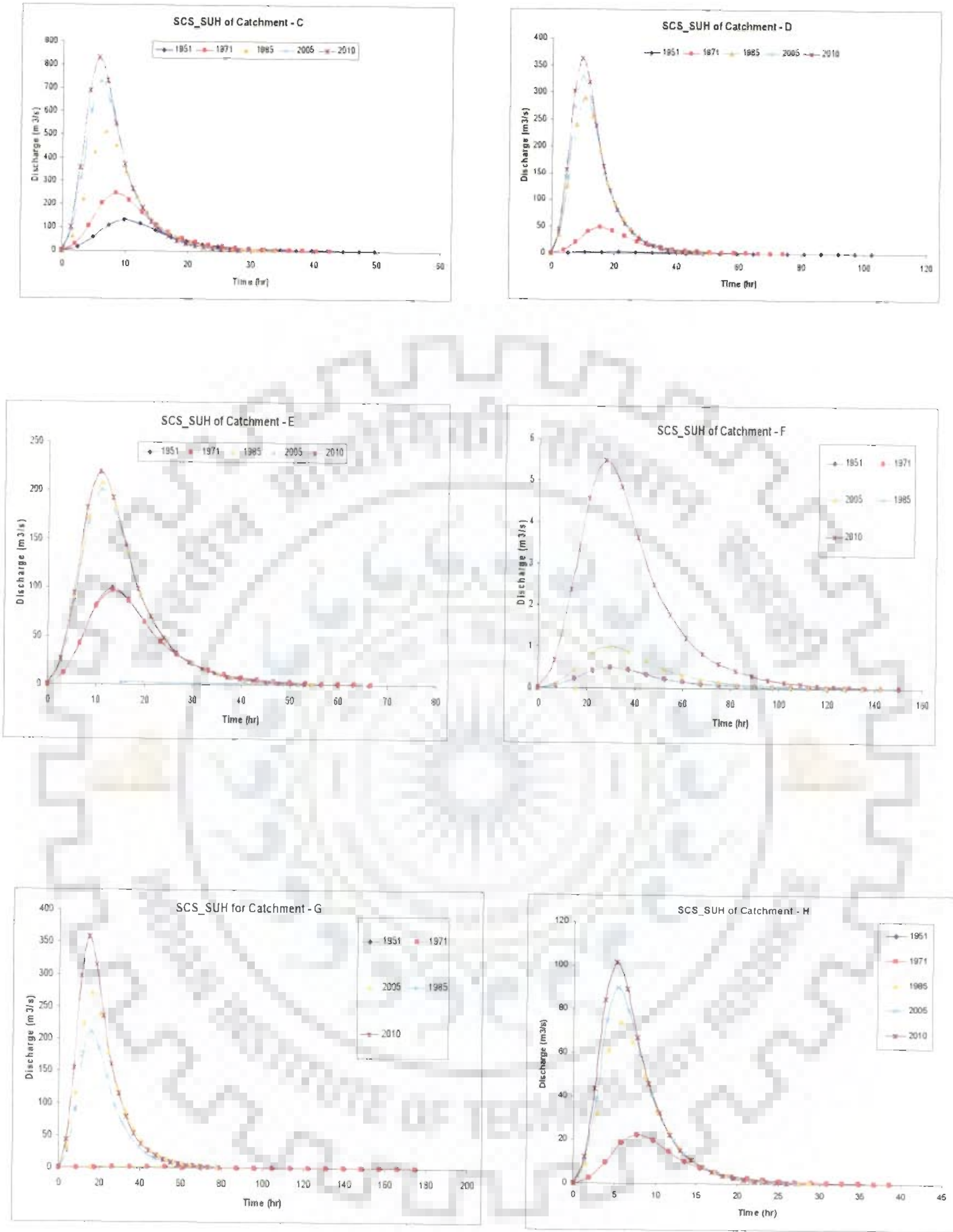


Fig 5.32: SCS – SUH for Catchment C, D, E, F, G & H

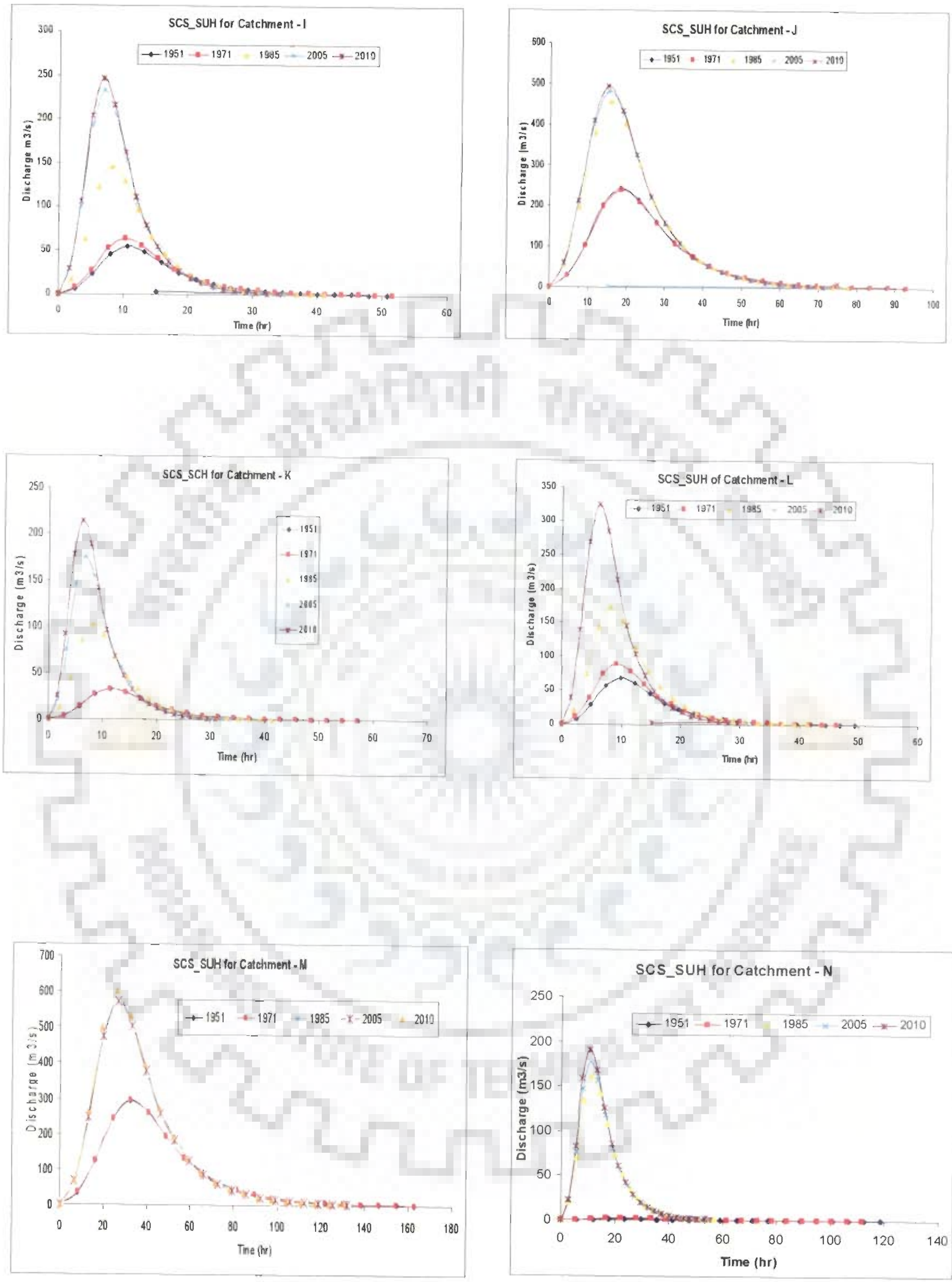


Fig 5.33: SCS – SUH for Catchment I, J, K, L, M & N.

5.5 IMAGES OF PATIALA PLANNING AREA

5.5.1 Topography of Patiala

Fig 5.34: Low lying area at the junction of Patialwi Nadi and Chotti Nadi

Fig 5.35: Low lying area between Patialwi Nadi and Chotti Nadi being used as Landfill

Fig 5.36: Old Flood Gate Of Patialwi Nadi

5.5.2 Sewage Disposal Works

Fig 5.37: Tripuri Disposal works

Fig 5.38: Rajpura Clony & Gurbax Colony Disposal works

Fig 5.39: Yadwindra Nagar Disposal Works

Fig 5.40: Raimajra Disposal Works

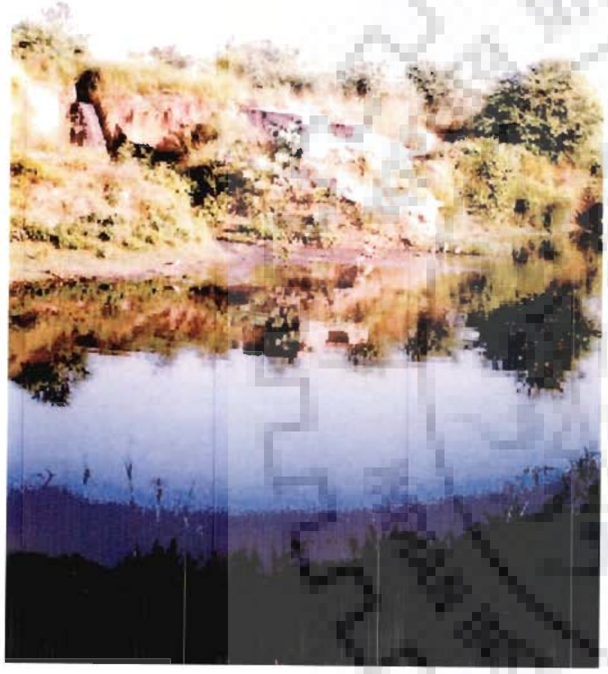


Fig 5.41: DCW Disposal Works Drains

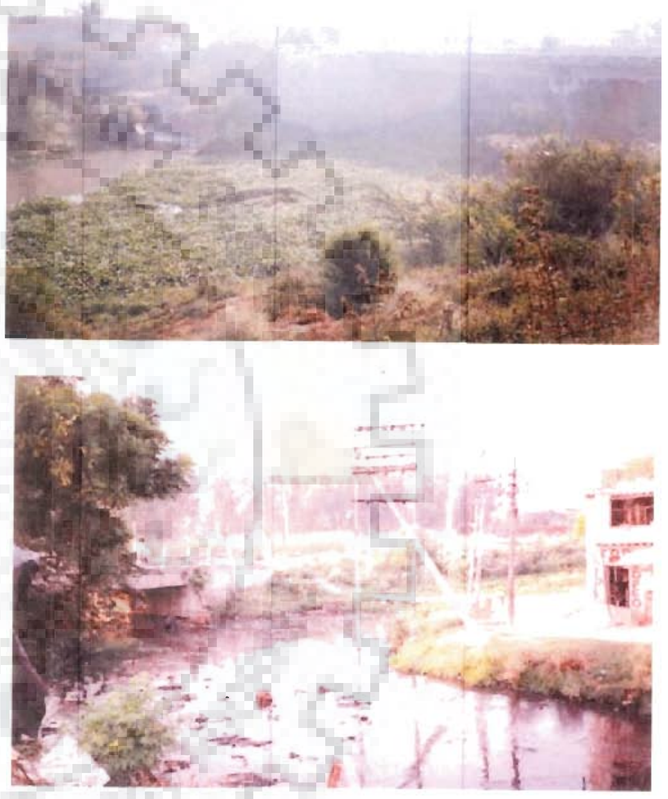


Fig 5.42: Other Smaller Disposal Works Along

5.5.3 Development In Low-lying Area

Fig 5.43: Development In Low Lying Areas Between Patialwi Nadi And Chotti Nadi

5.5.4 Tube wells Used For Water Supply

Fig 5.44: Tube Wells In Patiala For Water Supply

5.5.5 Flooding in Low-lying Areas

Fig 5.45: Flooding In Low-lying Areas

Fig 5.45: Rain Water Harvesting Structures Installed On Experimental Basis under State Of Neglect and Have Become Redundant

5.5.6 Drains In Patiala Planning Area

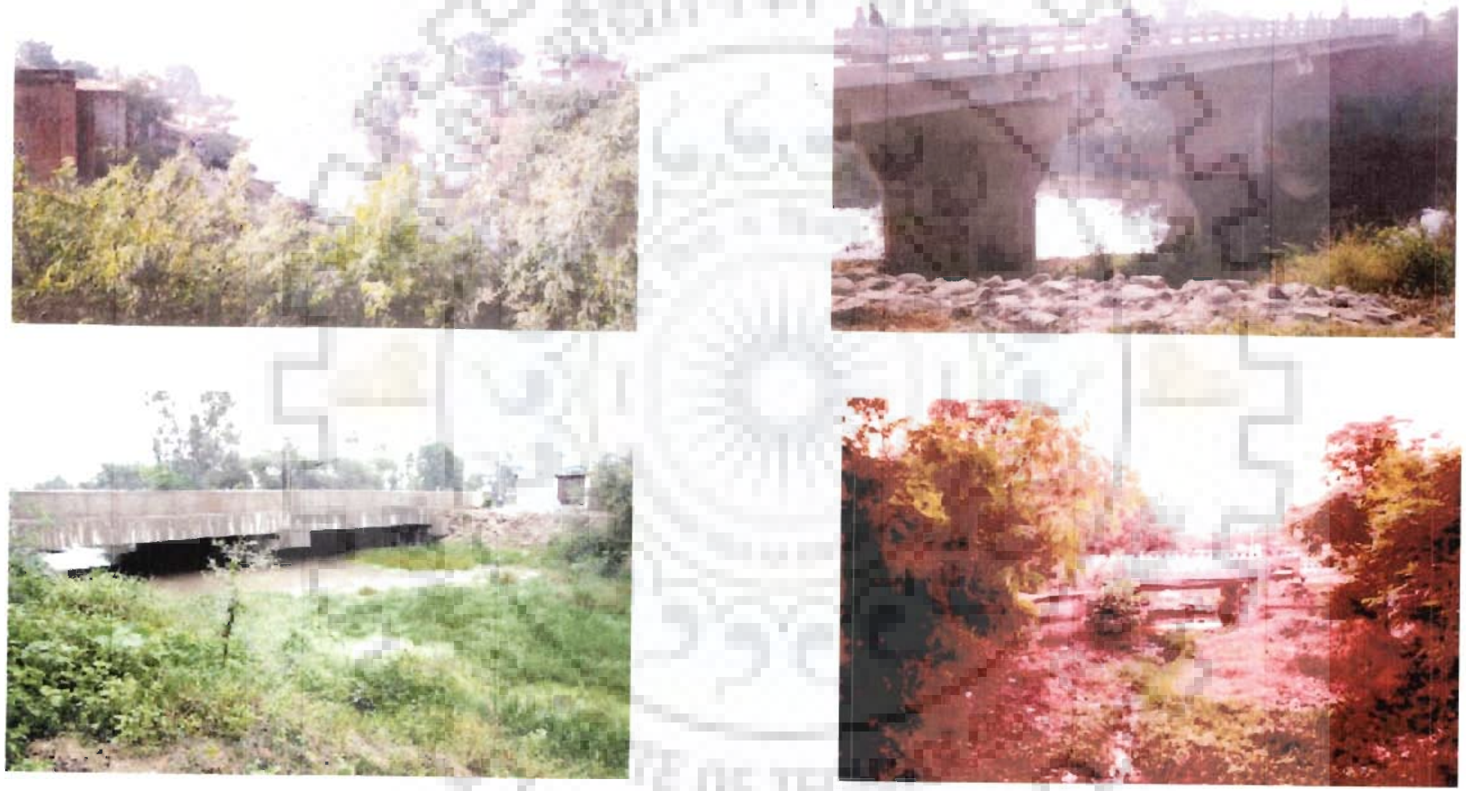


Fig 5.46: Drains In Patiala, 1. Chotti Nadi, 2. Patialwi Nadi, 3. Model Town Drain, 4. Jacob Drain /

5.5.7 Drains In Walled City

5.5.8 Distributaries In Planning Area

Fig 5.48 Sanaur Distriburary

Fig 5.49: P.N.C. Distributary

5.6 CONCLUDING REMARKS

In Patiala the urbanization has adversely affected the water resources availability, their quality, and the infrastructure is highly strained. Due to lack of policy of integrating water resource management in the master plan preparation there is no coherent development and land uses are proposed and development has taken place without giving any consideration to the topography and drainage resulting in water logging etc.

CHAPTER – 6

SUSTAINABLE URBAN WATER RESOURCE MANAGEMENT POLICY FOR PATIALA

CHAPTER – 6

SUSTAINABLE URBAN WATER RESOURCE MANAGEMENT POLICY FOR PATIALA

Sustainable urban water resource management policy is evolved by integrating land use planning with the water resource management. It involves quantification of – demand of water for different land uses, availability of water in planning area, topographic analysis of the planning area to find suitable location for different land uses. There is a need to evolve effective controls and mechanisms for implementing the sustainable water resource management policy.

This chapter gives the different processes involved in formulation of the sustainable water resource management policy –

- Projections and requirements
- Different scenarios are generated to see the effects of changes in policy.
- Formulation of Sustainable water resource management plan for Patiala.

6.1. PROJECTIONS AND REQUIREMENTS

6.1.1. Population

Population of Patiala planning area is 4,00,984 persons in 2001 (Table 6.1) with decadal variation/growth of +50.92%. This extra ordinary rate of growth in the planning area population from around 35% (Table No. 5.1) to 50% is due to the increase in planning area to include surrounding villages and Sanaur town in the planning area, so the decadal growth rate for projection of urban population is taken as 36% and for rural areas as 20% for projecting the population for 2021 and 2031

Table 6.1: Decadal Change In Distribution Of Population In Patiala Planning Area.

S. No.	Year	Urban Population	Decadal change in Urban Population	Rural Population	Decadal change in rural Population	Total Population	Decadal change in total Population
(i)	2001	3,51,929	+47.64%	49,055	+79.50%	4,00,984	+50.92%
(ii)	2011	4,79,000*	+36.00%	58900*	+20.0%	5,37,900*	+34.15%
(iii)	2021	6,51,000*	+36.00%	71,000*	+20.0%	7,22,000*	+34.23%
(iv)	2031	8,85,000*	+36.00%	85,000*	+20.0%	9,70,000*	+34.23%

* Projected population

Source : Census of India, 2001

6.1.2. LAND USE

According to Master Plan 1985-2005 gross density of 160 persons per hectare and residential density of 250 ppha has been proposed for Patiala, but at present the residential density of Patiala in 2010 is 100 ppha which is far less than the residential density of 250 ppha in 2005, this is due to an unprecedented growth of new residential areas in planning area in last five years which has increased from 1626 ha in 2005 to 5351ha in 2010 with a growth rate of 229%. The percentage of residential land use in planning are has increased from 52% in 2005 to 68.2% in 2010. Hence it is quite right to assume that at first the growth is going to take place at first in these newly developed areas before spreading to some other areas and percentage of residential area is not going to be between 55.0% to 60. So for projecting the area for residential land use in 2031 residential density is assumed as 160 ppha.

Total projected residential area in year 2031 is 6100 ha,

Assuming residential area as 50% of total developed area (Table 2.4, Chapter – 2)

Total developed area in 2031 = 12200 ha

The developed area in planning area also includes government land use (cantonment and other govt. offices) is kept at 2750ha as in Master plan 1985 - 2005 and is added to projected land use. Thus, total developed land in 2031 is about 15000ha (The details of land use break up for 2031 are given in Table 6.2).

Table 6.2 : Proposed Land Use -2031

S.No.		Master Plan 1985-2001			Existing Landuse 2010			Projected Landuse 2031		
	Landuse	Master Plan 2001 Area	Inc. Govt. Landuse	Without Govt.	Existing Landuse 2010 area	Inc. Govt. Landuse	Without Govt. Landuse	Prop. landuse 2031 area	Inc. Govt. Landuse	Without Govt. Land-use
		ha	%	%	ha.	%	%	ha.	%	%
i)	Residential	3097	31.6	44.0	5351	55.2	68.2	6125	40.9	50.0
ii)	Commercial	164	1.7	2.3	371	3.8	4.7	490	3.3	4.0
iii)	Industrial	733	7.5	10.4	495	5.1	6.3	980	6.5	8.0
iv)	Public Semi Public	596	6.1	8.5	520	5.4	6.6	735	4.9	6.0
v)	Transportation	1008	10.2	14.3	798	8.2	10.2	1715	11.4	14.0
vi)	Recreation	1447	14.7	20.5	311	3.2	4.0	2205	14.7	18.0
vii)	Govt.	2750	28.2	-	1842	19.0	-	2750	18.3	-
viii)	**Total dev.**	**9795**	**100**	**100**	**9688**	**100.0**	**100**	**15000**	**100**	**100**
ix)	Forest	517			805			805		
x)	Rural & other	5954			9479			4166		
xi)	Water bodies	25			22			25		
	Total planning area				**19996**			**19996**		

Source : Draft Master Plan 1985-2001, DTP Office, Town and Country Planning Department, Punjab

The population which can be adjusted in the newly developed urban areas with density less than 130 ppha is about 4.0 lakhs, which is almost equal to the projected increase in urban population. So there is a need to develop infrastructure in the newly developed areas and to formulate policies with regard to water resource management before it's too late.

6.1.3. Water Resource Infrastructure

6.1.3.1 Water Supply

Peak Water demand in Patiala planning area is expected to reach 477.8 MLD by year 2031 @ of 250 lpcd which is an increase of 186 MLD for details refer Table 6.3

Table 6.3 : Water Supply in Patiala in 2031

S. No.	Zone	Area of zone	Population	Total Average demand	Total peak demand
		Ha		MLD	MLD
i)	Urban Areas with Public Water Supply	5400	885000	221.3	332.0
ii)	Urban Areas with Independent Institutional Water Supply	2621	6500*	25.3	38.0
iii)	Cantonment	1500	20000*	13.6	13.6
iv)	Rural Areas with Public Water Supply	700	85000	21.3	32.0
v)	Recreation	2205	-	55.8	37.2
vi)	Water bodies with water changed every day (Gurudwara Dukhniwaran Sahib & Moti Bagh Sarovar)	1.125	-	25.0	25.0
	Total		**500000**	**362.3**	**477.8**

Source : Water Supply and Sewerage Board, Patiala, Municipal Corporation Patiala
*Approx. Population of area

6.1.3.2 Sewerage Network

Total Sewage generated in Patiala planning area will be 332.5 MLD which is 80% of the water demand for all uses except recreation and water bodies and water available after treatment of sewage for reuse will be 249 MLD which is 75% of sewage generated

6.1.3.3 Drainage Network

The surface run off generated can be calculated by rational formula ($Q_p = CIA$) for all land uses. In Patiala planning area, only walled city has a density more than 200 ppha and an average plot size less than 100m^2 so it can be assumed that other than area under recreational land use whole of the walled city is impervious in character. All other areas have density less than 100 ppha so while calculating run off for these areas the maximum impervious area per house according to bye laws (usually 20% of the area of residential neighbourhood) can also be included in recreation land use of the neighbourhood sector (10% of the area of residential neighbourhood) so effectively 30% of the area of a residential neighbourhood sector is pervious. Pervious area for different land uses is – Commercial and industrial land use pervious are is 30% of the land use, for government land use pervious area is 40% , for public

Semi-public land use pervious area is 35% and for transportation also pervious area is 35%. The rain fall intensity i, for a storm of 6 hour duration with a return period of 10 years is 20 mm /hr for Patiala. The total runoff for all land uses in 2031 will be 355m^3/s (Table 6.3)

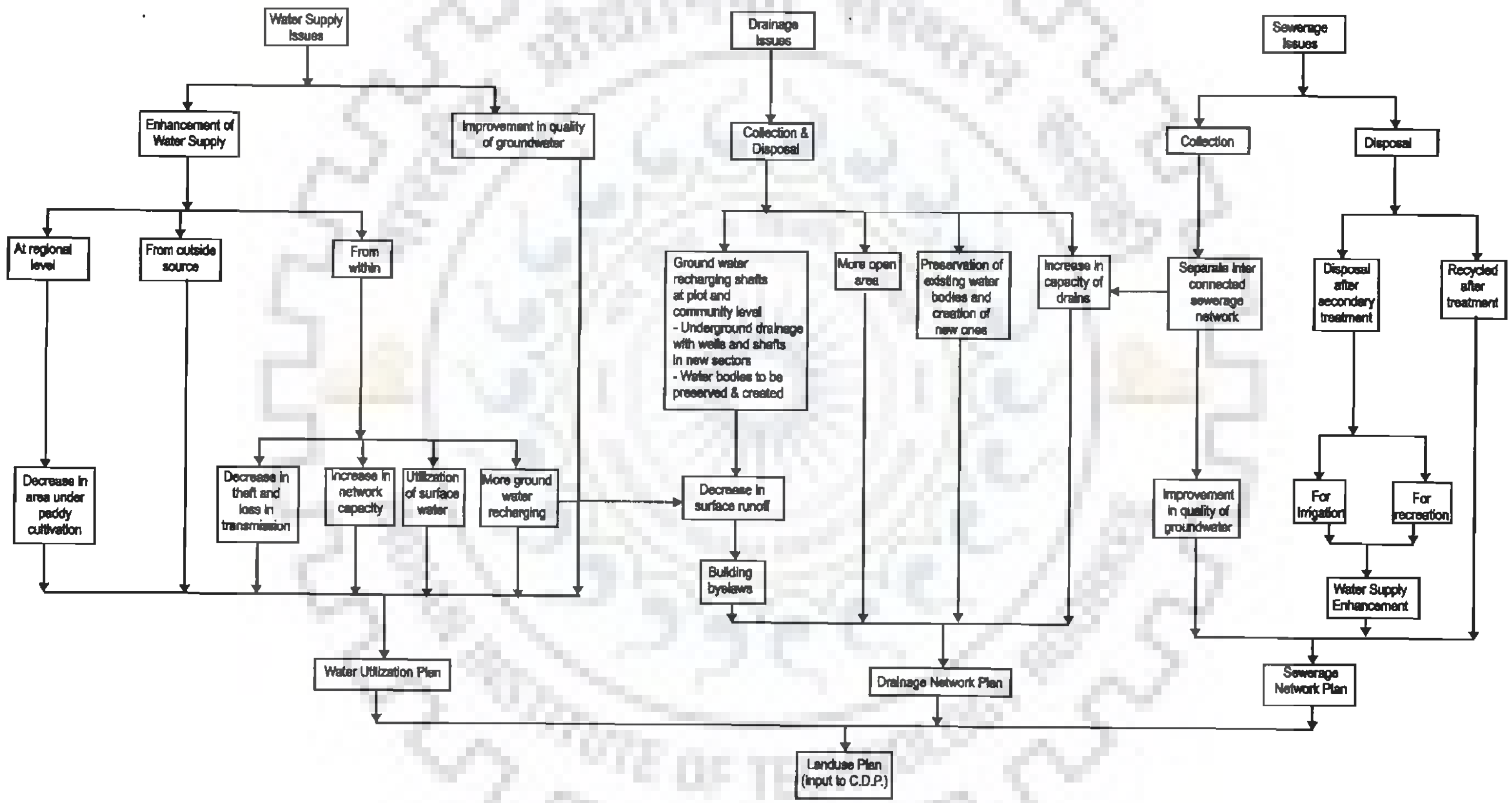
Table 6.4: Run Off Generated For Different Land Uses – 2031

S.No.	Land Use	Area ha	Pervious		Impervious		Total Runoff m^3/s
			Area ha	Runoff m^3/s	Area ha	Runoff m^3/s	
(i)	Walled City	350	9	0.01	341	16.1	16.1
(ii)	Residential	5750	1725	0.96	4025	190.1	191.0
(iii)	Commercial	490	147	0.08	343	16.2	16.3
(iv)	Industrial	980	294	0.16	686	32.4	32.6
(v)	Public Semi Public	735	257.25	0.14	477.75	11.9	12.1
(vi)	Transportation	1715	600.25	0.33	1114.75	52.6	53.0
(vii)	Recreation	2205	2205	1.23	0	0.0	1.2
(viii)	Govt.	2750	1100	0.61	1650	32.1	32.7
	Total	**14975**	**6337.5**	**3.52**	**8637.5**	**351.4**	**355.0**

6.2. PLANNING CONSIDERATIONS

- Water resource Management plan must be part of the master plan (Fig 6.1)
- Proposed residential areas must be located above 252 m contour level.
- Only Recreational and other open areas must be located in low lying areas i.e. below 250m contour level, at city level and at suitable places in sectors according to slope analysis of site to act as a catchment for the runoff generated in a sector.
- Circulation should be such as to consolidate the existing surface water resources.
- Existing water bodies must be preserved.
- Existing reserved forest must be preserved.
- Proper sewerage network for the city must be designed and interconnected with sewerage treatment plant before disposal to avoid contamination of ground water and drains.
- Groundwater recharging at neighbourhood level, sector level and city level must be adopted to recharge the groundwater and it will also help to reduce the runoff generated. Minimum pervious area for each building must be fixed to reduce the runoff generated.
- Water supply must be designed to exploit both surfaces as well as groundwater resources to avoid over exploitation of groundwater.

Fig 6.1:CONCEPTUAL PLAN FOR WATER RESOURCE DEVELOPMENT IN A CITY



- Public-Semi Public areas must be located in areas with good drainage and with maximum pervious area to reduce surface runoff and also provided with groundwater recharging well.
- Present drains and natural drainage system of Patiala city must be preserved and their capacity must be increased to take the increase in runoff generated by the development of new areas.

6.3. APPROACHES FOR URBAN WATER RESOURCE MANAGEMENT

There can be different approaches to water resource management in an urban area, by adopting different combinations of available technologies to manage available water resources in an area. These can broadly be divided into three categories –

- ❖ Demand and supply model
- ❖ Hybrid Model
- ❖ Integrated resource planning model

6.3.1. Demand and Supply Model

This model involves a centralized approach to water supply, sewage disposal and management of surface runoff is adopted (Table 6.5 & Fig 6.4).

- For water supply ground water is continued to be used.
- For sewage disposal centralized sewerage network along with waste water treatment plant is adopted.
- Separate drainage network for disposal of storm water runoff.

Table 6.5: Demand Of Different Components for Demand and Supply Model

S. No.	Year	Ground water recharge Potential MLD	Water Demand MLD	Sewage Generated MLD	Runoff Generated MLD
(i)	1951	96.4	24.5	19.6	5.9 + 59 = 64.9
(ii)	1971	89.4	37.6	30.1	21.5 + 59 = 80.5
(iii)	1985	85.1	55.6	44.5	35.8 + 59 = 94.8
(iv)	2001	77.8	167.5	134	53.1 + 59 = 112.1
(v)	2010	69.6	209.1	167.8	92.3 + 59 = 151.3
(vi)	2031	62.1	362.3	289.8	140.1 + 59 = 199.1

- If ground water is continued to be used for water supply then by year 2031 ground water level would recede at an yearly rate of more than 0.75 m then ground water level will recede to 42 m resulting in reduction in discharge from 0.06 m^3/s to 0.044 m^3/s i.e. reduction of 20%. So the number of tube wells needed to meet the demand with a five hour daily supply is 332 tube wells.

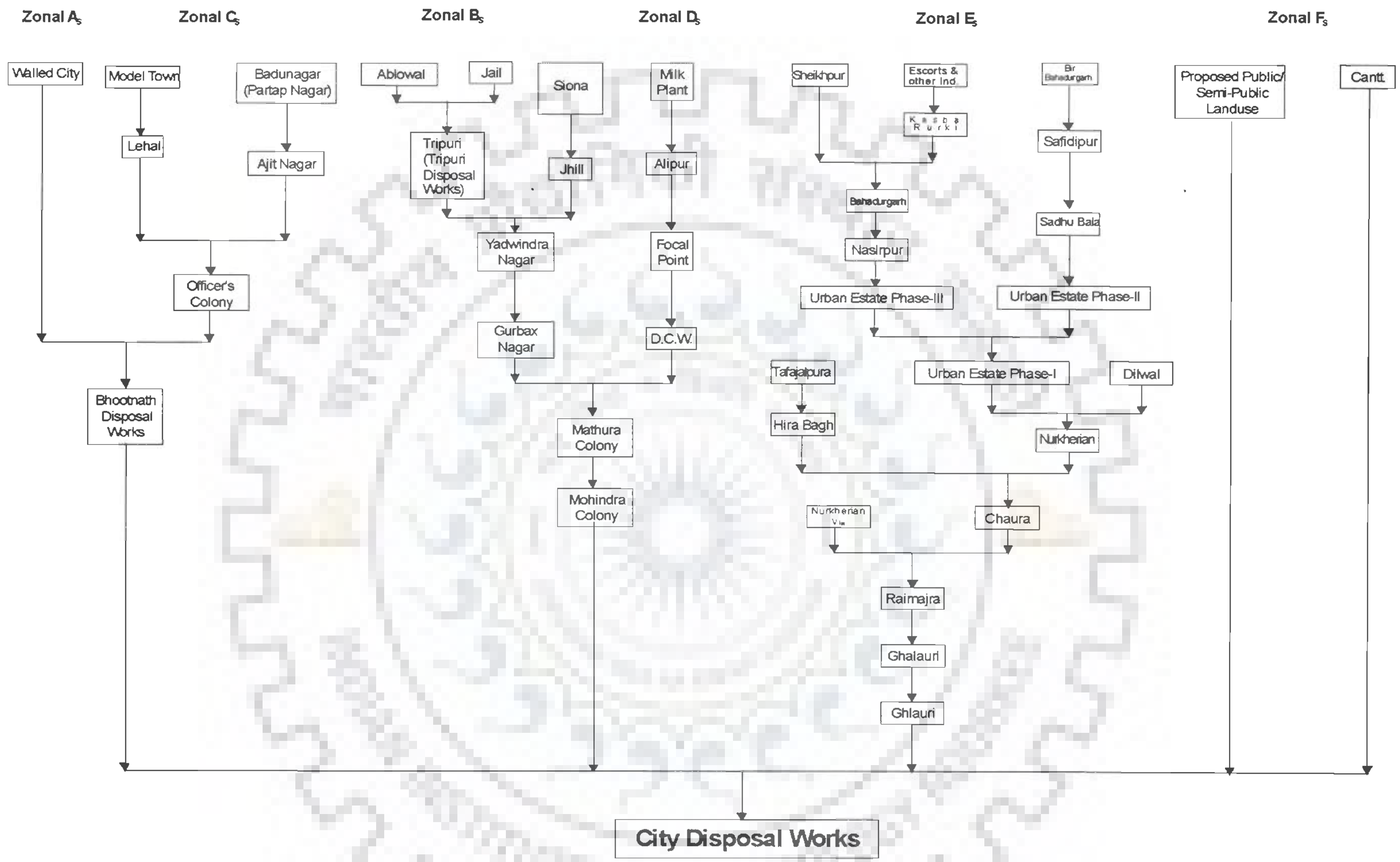


Fig 6.2: Proposed Sewerage Network, Patiala -2031

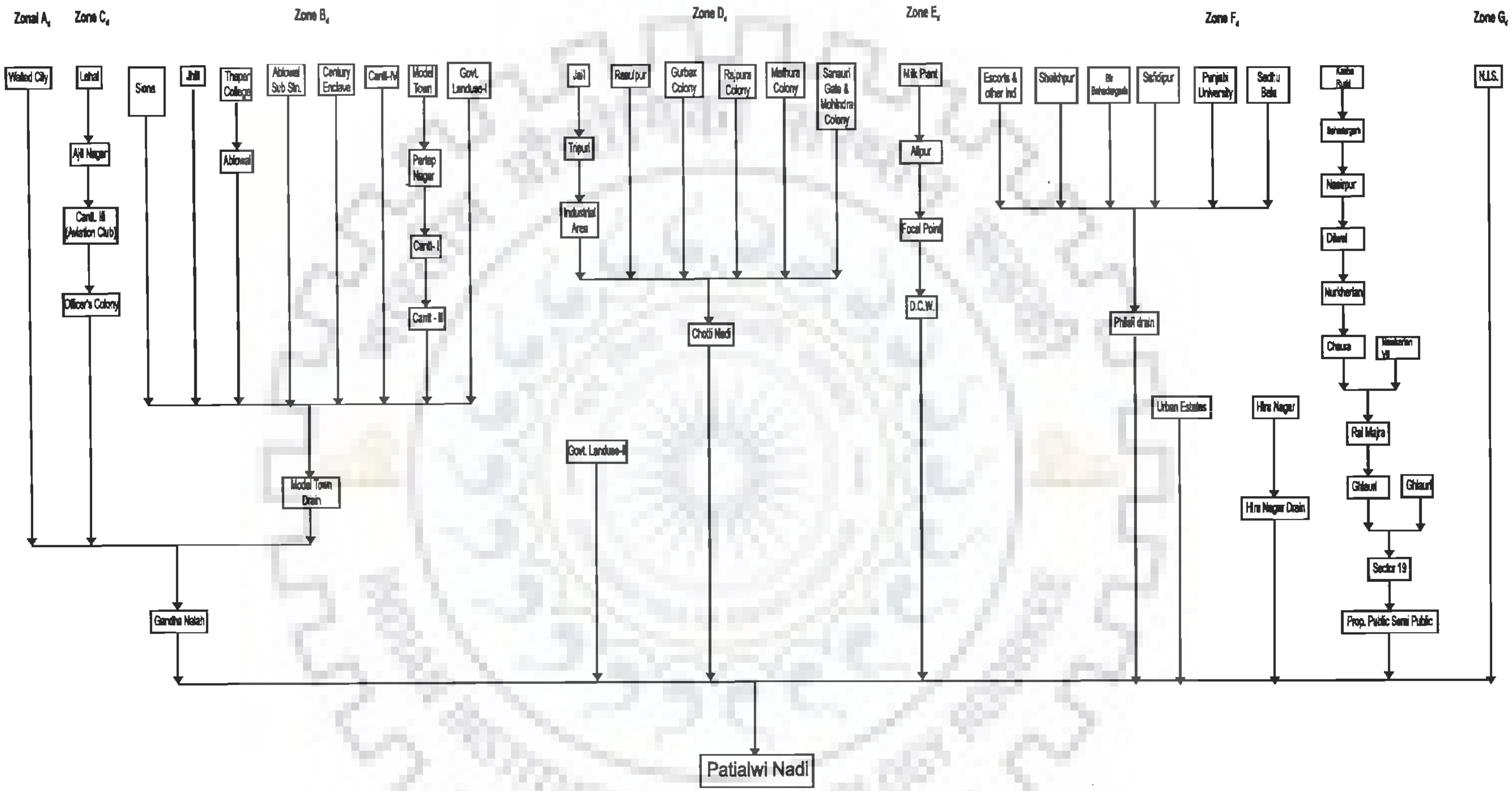


Fig 6.3:Proposed Drainage Network, Patiala -2031

the demand with a five hour daily supply is 332 tube wells.

- Proposed sewerage system in Patiala is underground separate and concrete. and is divided into seven zones.
- Proposed sewerage network is proposed to be interconnected (Fig 6.2, Table 6.6) and disposal of sewage into different drains is proposed to be stopped to avoid pollution is drains and of ground water.
- Combined disposal of sewage is proposed in village Sher majra. After secondary treatment sewage is proposed to be disposed off for irrigation.
- Size of trunk sewer is between 30" to 72". Recommended sizes of sewerage network are given in Table 6.7.
- Sanaur will have its own STP and an independent sewerage network as it is not economically feasible to join it with Patiala sewerage disposal works.

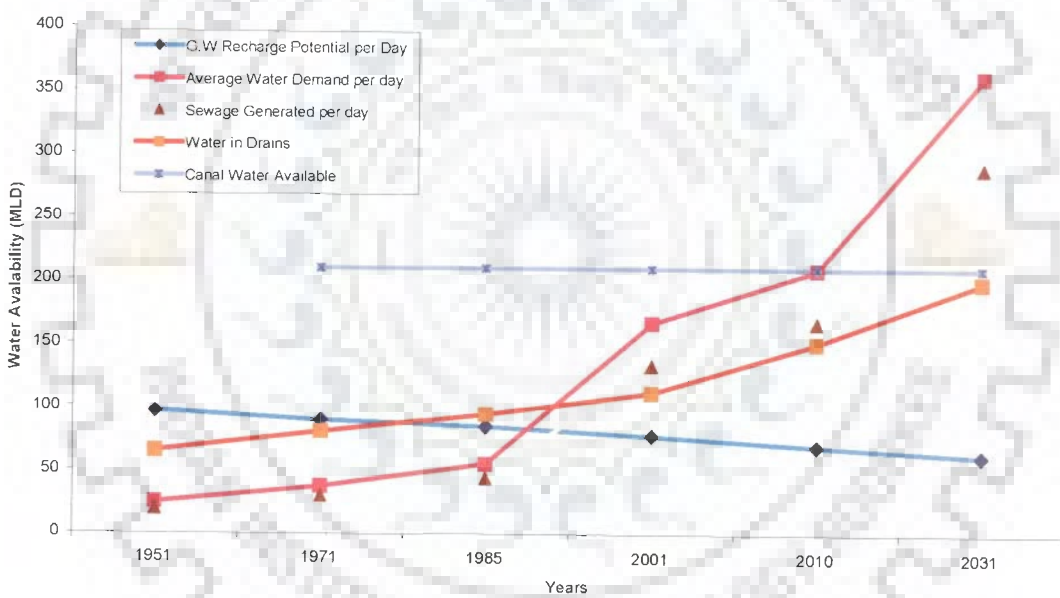


Fig 6.4: Water Resources Available In Planning Area - 2031

- Separate drainage system for the city has been planned (Fig 6.3, Table 6.7) along with the sewerage system and surface runoff is disposed off from each zone to the nearest drain.
- The size of pipe is between 72" to 200" at disposal point in each zone

Table 6.6: PROPOSED SEWERAGE NETWORK FOR PATIALA –2031

S. No.	Zone	Area		Quantity of Sewerage Produced		Type of Sewerage System	Method of Sewerage Disposal	Point of Sewerage Disposal	Recommended size
		Total Area	Developed Area	For a Zone	Cumulative				
		ha	ha	MLD	MLD				m
i.	A_S walled city	223	223	26.44	26.44	Separate	Sec. Treat.	Sher Majra	1.070 ϕ (42")
ii.	C_S1.1 Model Town	144	144	3.55	3.55	Separate	Sec. Treat.	Sher Majra	0.762ϕ (30")
iii.	C_S 1.2 Lehal	187	187	4.15	7.70	Separate	Sec. Treat.	Sher Majra	0.914ϕ (36")
iv.	C_S 2.1 Badungar	105	105	3.60	3.60	Separate	Sec. Treat.	Sher Majra	0.762ϕ (30")
v.	C_S 2.2 Ajit Nagar	117	117	1.89	5.49	Separate	Sec. Treat.	Sher Majra	0.914ϕ(36")
vi.	C_S 3 Officer's Colony & Kheri Gujjar	237	237	5.84	19.03	Separate	Sec. Treat.	Sher Majra	1.016ϕ (40")
vii.	F_S-1 N.I.S.	95	95	0.14	0.14	Separate	Sec. Treat.	Sher Majra	0.254ϕ (10")
viii.	Cumulative Flow at Kheri Gujjar				143.82	Separate	Sec. Treat.	Sher Majra	2.286ϕ (90")
ix.	B_S.1 Milk Plant	6	6	0.41	0.41	Separate	Sec. Treat.	Land Disposal	0.305ϕ (12")
x.	B_S.2.1 Alipur	512	512	27.12	27.12	Separate	Sec. Treat.	Sher Majra	1.219ϕ(48")
xi.	B_S 2.2 Focal Point	76	76	4.33	31.45	Separate	Sec. Treat.	Sher Majra	1.219ϕ (48 »)
xii.	B_S 2.3 DCW	193	193	3.86	35.31	Separate	Sec. Treat.	Sher Majra	1.524ϕ (60")
xiii.	B_S.1 Thapar College	63	63	0.62	0.62	Separate	Sec. Treat.	Land Disposal	0.508ϕ (20")
xiv.	B_S.2.1 Ablowal	212	212	5.22	5.22	Separate	Sec. Treat.	Sher Majra	0.610ϕ (24")
xv.	B_S.3.1 Siona	500	500	12.33	12.33	Separate	Sec. Treat.	Sher Majra	0.762 ϕ (30")
xvi.	B_S 3.2 Jhill	452	452	11.15	23.48	Separate	Sec. Treat.	Sher Majra	1.070 ϕ (42")
xvii.	B_S 2.2 Jail	82	82	0.64	5.86	Separate	Sec. Treat.	Sher Majra	0.762 ϕ (30")
xviii.	B_S4.1 Tripuri	366	366	10.83	40.17	Separate	Sec. Treat.	Sher Majra	1.372 ϕ(54")
xix.	D_S.4.2 Yadwindra Colony	351	351	8.65	48.82	Separate	Sec. Treat.	Sher Majra	1.524ϕ (60")
xx.	D_S 4.3 Gurbax Colony	347	347	11.00	59.82	Separate	Sec. Treat.	Sher Majra	1.778ϕ (70%)
xxi.	E_S 4.4 Mathura Colony (Total zone D+B)	237	237	3.08	98.21	Separate	Sec. Treat.	Sher Majra	2.130ϕ (84")
xxii.	Escorts & Other. Industries	120	120	4.97	4.97	Separate	Sec. Treat.	Sher Majra	0.610 ϕ(24")
xxiii.	Kasba rurki	120	120	4.42	9.39	Separate	Sec. Treat.	Sher Majra	0.762ϕ(30")
xxiv.	Sheikhupur	90	90	3.33	3.33	Separate	Sec. Treat.	Sher Majra	0.457ϕ(18")
xxv.	Bahadurgarh	110	110	1.93	14.65	Separate	Sec. Treat.	Land Disposal	0.914ϕ(36")
xxvi.	Nasirpur	45	45	1.66	16.31	Separate	Sec. Treat.	Sher Majra	0.914ϕ(36")
xxvii.	Urban Estate III	30	30	1.11	17.42	Separate	Sec. Treat.	Sher Majra	0.914ϕ(36")
xxviii.	Bir bahadurgarh	90	90	3.33	3.33	Separate	Sec. Treat.	Sher Majra	0.457ϕ(18")
xxix.	Safidipur	88	88	3.18	6.51	Separate	Sec. Treat.	Sher Majra	0.533ϕ(21")
xxx.	Sadhubela	55	55	0.69	7.20	Separate	Sec. Treat.	Sher Majra	0.610ϕ(24")
xxxi.	Tafajalpura	70	70	1.10	8.30	Separate	Sec. Treat.	Sher Majra	0.762ϕ(30")
xxxii.	Nasirpur Farm	56	56	1.79	10.09	Separate	Sec. Treat.	Land Disposal	0.762ϕ (30")
xxxiii.	Urban Estate-I	31	31	1.11	28.62	Separate	Sec. Treat.	Sher Majra	1.143ϕ (45")
xxxiv.	Dilwal	110	110	4.14	4.14	Separate	Sec. Treat.	Sher Majra	0.457ϕ(18")
xxxv.	Nurkherian	90	90	3.33	36.09	Separate	Sec. Treat.	Sher Majra	1.320ϕ(52")
xxxvi.	Hirabagh	41	41	1.38	1.38	Separate	Sec. Treat.	Sher Majra	0.250ϕ (10")
xxxvii.	Chaura	100	100	3.59	41.06	Separate	Sec. Treat.	Sher Majra	1.422ϕ(56")
xxxviii.	Nurkherian vill	95	95	3.33	3.33	Separate	Sec. Treat.	Sher Majra	0.457ϕ(18")
xxxix.	Raimajra	140	140	5.29	49.63	Separate	Sec. Treat.	Land Disposal	1.524ϕ(60")
xl.	Ghlauri	115	115	4.14	53.77	Separate	Sec. Treat.	Sher Majra	1.828ϕ(72")
xli.	Ghlauri	137	137	4.97	58.74	Separate	Sec. Treat.	Sher Majra	1.828ϕ(72")
xlii.	Cantt	1152	1152	3.68	5.68	Separate	Sec. Treat.	Sher Majra	0.600ϕ (24")
xliii.	Proposed Public & Semi-Public Landuse between cantt & bye-pas	1432	1432	2.43	6.11	Separate	Sec. Treat.	Sher Majra	0.600ϕ (24")
xliv.	Total Sewerage disposal at disposal site				203.66	Separate	Sec. Treat.	Sher Majra	4.267ϕ(168")

Table 6.7: REQUIRED DRAINAGE NETWORK IN PATIALA – 2031

S. No.	Catchment / Drainage Zone	Area of Catchment	Recreation & Undeveloped area	Point of Disposal for Catchment	Water course for Disposal	Flow of Storm (Q) Cumulative $Q_n = CAI/360 + Q_{n-1}$	Recommended size
		ha	ha			m^3/s	m (l/d)
i.	Ad	223	9	Ganda Nalah	Ganda Nalah	10.16	5x2
ii.	Siona	382	38	Siona	Model Town Drain	16.46	3.510 ϕ (138")
iii.	B_d 2.1Jhill	452	45	Jhill	Model Town Drain	19.47	3.810 ϕ (150")
iv.	Ablowal sst	145	24	Ablowal sst	Model Town Drain	8.11	2.438 ϕ (96")
v.	B_d 4.1 Thapar College	63	41	Ablowal	Model Town Drain	0.78	0.760 ϕ (30")
vi.	B_d 4.2 Ablowal	212	22	Ablowal	Model Town Drain	9.87	2.743 ϕ (108")
vii.	B_d 5.1 Century Enclave	63	6	Century Enclave	Model Town Drain	2.73	1.524 ϕ (60")
viii.	B_d 6.1 Model Town	81	43	Haji Majra	Model Town Drain	1.61	1.143 ϕ (45")
ix.	B_d 6.2 Partap Nagar	105	10	Haji Majra	Model Town Drain	5.40	2.286 ϕ (90")
x.	B_d 6.3 Cantt-I	232	153	Haji Majra	Model Town Drain	7.49	2.591ϕ (102")
xi.	B_d 6.4 Cantt-II	239	179	Haji Majra	Model Town Drain	9.65	0.914ϕ (36")
xii.	B_d 7.1 Cantt-IV	430	322	Haji Majra	Model Town Drain	3.89	1.823 ϕ (72")
xiii.	B_d 8.1 proposed Govt. landuse –II	-	-	Vill. Rawas	Model Town Drain	3.61	1.680 ϕ (66")
xiv.	B_d 9.1 Proposed Govt. landuse-III	-	-	Vill. Khera Jattan	Model Town Drain	4.31	1.830 ϕ (72")
xv.	C_d 1.1 Lehal	187	45	Kheri Gujjar	Ganda Nalah	5.38	2.134 ϕ (84")
xvi.	C_d 1.2 Ajit Nagar & Bank Colony	117	48	Kheri Gujjar	Ganda Nalah	8.14	2.438 ϕ (96")
xvii.	C_d 1.3 Cantt-III	251	189	Kheri Gujjar	Ganda Nalah	10.40	2.743 ϕ (108")
xviii.	C_d 1.4 Officer's Colony	237	24	Kheri Gujjar	Ganda Nalah	20.59	3.962 ϕ (156")
xix.	D_d 1.1 Jail	82	33	Yadwindra Colony	Choti Nadi	1.14	0.914 ϕ (36")
xx.	D_d 1.2 Tripuri	448	65	Yadwindra Colony	Choti Nadi	19.59	3.810 ϕ (150")
xxi.	D_d 1.3 Industrial Area & Grain Market	65	5	Yadwindra Colony	Choti Nadi	22.66	4.064 ϕ (160")
xxii.	D_d 2.1 Rasulpur	286	30	Yadwindra Colony	Choti Nadi	12.26	3.048 ϕ (120")
xxiii.	D_d 3.1 Rajpura Colony	121	19	Guru Nanak Nagar Disposal	Choti Nadi	4.83	1.219 ϕ (48")
xxiv.	D_d 4.1 Gurbax Colony	226	6	Yadwindra Colony	Choti Nadi	10.38	2.134 ϕ (84")
xxv.	D_d 5.1 Mathura Colony	144	61	Mathura Colony	Choti Nadi	4.28	1.830 ϕ (72")
xxvi.	D_d 6.1 Sanauri gate & Mahindra Colony	93	27	Mohindra Colony	Choti Nadi	2.63	1.371ϕ (54")
xxvii.	E_d1.1 Milk Plant	6	2	D.C.W.	Patialwi Nadi	0.12	0.457 ϕ (18")
xxviii.	E_d1.2 Alipur	512	56	D.C.W.	Patialwi Nadi	17.36	3.660 ϕ (44")
xxix.	E_d1.3 Focal Point	76	10	D.C.W	Patialwi Nadi	19.12	3.180 ϕ (150")
xxx.	E_d1.4 D.C.W.	193	53	D.C.W	Patialwi Nadi	23.21	4.120 ϕ (162")
xxxi.	Escorts & Ind. Area	120	18	Mithu Majra	Philauli Drain	5.02	1.905 ϕ (75")
xxxii.	Bir bahadurgarh	90	9	Bir bahadurgarh	Philauli Drain	3.93	1.830 ϕ (72")
xxxiii.	Safidipur	88	9	Safidipur	Philauli Drain	3.83	1.830 ϕ (72")
xxxiv.	Sheikhupur	90	9	Sheikhupur	Philauli Drain	3.93	1.830 ϕ (72")
xxxv.	Punjabi Univ.	88	54	Punjabi University	Philauli Drain	1.63	1.220 ϕ (48")
xxxvi.	Sadhubela	55	36	Sadhubela	Philauli Drain	0.88	0.813 ϕ (32")
xxxvii.	Kasba rurki	120	12	Khera Jattan	Patialwi Nadi	5.23	1.905 ϕ (75")
xxxviii.	Bahadurgarh	110	58	Khera Jattan	Patialwi Nadi	6.55	2.280 ϕ (90")
xxxix.	Nasirpur	45	5	Hira Bagh	Patialwi Nadi	8.49	2.54 ϕ (100")
xl.	F_d7.4 Urban Estate	117	29	Hira Bagh	Patialwi Nadi	4.66	1.830ϕ (72")
xli.	F_d7.5 Hira Bagh	41	6	Hira Bagh	Hira Bagh Drain	1.72	1.140ϕ (45")
xlii.	Tafajalpura	70	40	Tajapal Pura	Tafajal pura Drain	1.36	1.020ϕ (40")
xliii.	Dilwal	110	11	Khera Jattan	Patialwi Nadi	13.39	3.100ϕ (120")
xliv.	Nurkherian	90	9	Khera Jattan	Patialwi Nadi	17.32	3.520ϕ (138")
xlv.	Chaura	100	10	Khera Jattan	Patialwi Nadi	21.68	3.960ϕ (156")
xlvi.	Nurkherian vill	95	10	Khera Jattan	Patialwi Nadi	4.13	1.720ϕ (66")
xlvii.	Raimajra	140	15	Khera Jattan	Patialwi Nadi	31.88	4.880ϕ (192")
xlviii.	Ghlauri	115	12	Khera Jattan	Patialwi Nadi	36.88	5.180 ϕ (204")
xlix.	Ghlauri	137	15	Khera Jattan	Patialwi Nadi	45.26	5.790 ϕ (222")
l.	Ghalauri	203	180	Khera Jattan	Patialwi Nadi	2.45	1.37 ϕ (54")
li.	Proposed Public & Semi-Public Landuse between cantt & bye-pas	798	400	Khera Jattan	Patialwi Nadi	55.22	6.400 ϕ (252")
lii.	G_d1.1 N.I.S.	95	57	N.I.S.	Patialwi Nadi	1.37	1.067 ϕ (42")

6.3.2. Hybrid Model

This model involves an integrated approach to water supply and management of surface runoff, while centralized approach is adopted for sewage disposal there by treating fresh water and waste water as different entities.

- For water supply ground water is supplemented by available canal water.
- The rainwater is used to meet the demand of water for non-consumable activities like – car washing, gardening, flushing of toilets resulting in reduction in demand by as much as 40 lpcd during monsoons resulting in over all reduction of 10 lpcd for the whole year and it can also be used for ground water recharging.
- For sewage disposal centralized sewerage network along with waste water treatment plant is adopted.
- Separate drainage network combined with rain water harvesting structures will augment ground water and will also result in reduction of runoff by as much as 80% in new development and by making it mandatory to install ground water recharging structures in old areas for all land uses other than residential will result in reduction of run off by 40% - 50% in these areas. Hence over all there is reduction in runoff generation by 60%

The use of canal water for water supply in combination with ground water recharging will reduce the pressure on receding ground water level. The use of canal water for water supply will reduce the average ground water demand from 362.3 MLD to 93.1 MLD (Table 6.10 & Fig 6.5).

There is a need to fix the percentage of pervious area in each plot to reduce the run off and to augment recharge. The ground water recharging structures suitable for a residential development of 150 hectares are given in Table No. 6.8 & 6.9. There is also a need to push for adoption of ground water recharging structures in high density development along with new areas. If 5% of the already developed areas are adopting ground water recharging every year then by 2031 there will be 80% reduction in ruoff generation for Patiala. This can be done by adopting a policy of giving subsidy for installation of ground water recharging structures, reduction in water supply and sewerage charges for consumers who have recharging structure installed in their residences. If there is a reduction of 80% in run off generated then total runoff generated will come down to 71 m^3/s from 355 m^3/s and ground water recharging potential of Patiala planning area will increase to 94.4 MLD i.e. to 1951 level and 1 MLD more than Ground water demand.

Table 6.8: TYPE OF GROUND WATER RECHARGING STRUCTURES SUITABLE FOR RESIDENTIAL DEVELOPMENT (150HA)

S. No.	Area of Plots	Size of Plots	No. of plots (approx.)	% area of sector	Total area under one category (Approx.)	Coverage	Runoff with 100% metalled Plot Area		Maximum unmattled area available after circulation (50% of ncovered)		Run off with maximum unmattled in a plot		Decrease in runoff	Size & type of ground/water recharging structure
							For single plot	For all plots	Plot	Sector	For a Single plot	For all plots		
	m^2			%	ha				m^2	ha	m^3/s	m^3/s	%	mmϕ
(i)	418m^2 (1 Kanal 500 sq.yards)	15.24x27.43m (50'-0"x90'-0")	350	20%	16.4	50%	$2.1x10^{-3}$	0.74	104.5	3.7	$1.6x10^{-3}$	0.57	23%	300 mmϕ well with shaft
(ii)	334.44m^2 (16 marls 400 sq. yards)	13.72x24.38m (45'-0"x80'-0")	450	20%	16.4	60%	$1.7x10^{-3}$	0.77	66.9	3.0	$1.4x10^{-3}$	0.62	17.6%	300 mmϕ well with shaft
(iii)	292.64 m^2 (14 marls, 350 sq. yards)	10.97x26.67m (36'-0"x87-6")	400	15%	12.3	60.75%	$1.5x10^{-3}$	0.60	57.4	2.3	$1.2x10^{-3}$	0.48	20%	300 mmϕ well with shaft
(iv)	250.83 m^2 (12 marls, 300 sq. yards)	10.97x22.86m (36'-0"x75'-0")	300	10%	8.2	62%	$1.3x10^{-3}$	0.40	47.7	1.4	$1.0x10^{-3}$	0.3	23%	300 mmϕ well with shaft
(v)	209.03 m^2 (10 marla, 250 sq. yards	9.14x22.86m (30'-0"x75'-0")	350	10%	8.2	65%	$1.1x10^{-3}$	0.37	36.6	1.3	$8.8x10^{-4}$	0.31	27%	300 mmϕ well with shaft
(vi)	167.22 m^2 (8 marlas, 200 sq. yards	9.14x18.29m (30'-0"x60'-0")	250	10%	4.1	65%	$8.4x10^{-4}$	0.21	29.3	0.7	$7.1x10^{-4}$	0.18	16%	300 mmϕ well
(vii)	125.41 m^2 (6 marla 150 sq. yards	8.23x15.24m (27'-0"x50'-0")	300	5%	4.1	70%	$6.2x10^{-4}$	0.19	18.8	0.6	$5.4x10^{-4}$	0.16	13%	300 mmϕ well
(viii)	83.61 m^2 (4 marla, 100 sq. yards)	6.10x13.72 (20'-0"x45'-0")	450	5%	4.1	75%	$4.2x10^{-4}$	0.19	10.5	0.5	$3.7x10^{-4}$	0.17	12%	300 mmϕ well
(ix)	E.W.S. (38 m^2)		750	10%	8.2	35%	$5.5x10^{-4}$	0.41	35.5	2.7	$3.9x10^{-4}$	0.29	29%	Trench with borewells 1.5 to 3 m wide
	Total		**3600**		**8.2**		-	**3.88**	-	16.2	-	**3.08**	**21%**	

Table 6.9: Ground Water Recharging Structures Suitable For Residential Neighbourhood of 150 Hectare

S. No.	Landuse	% of landuse	Area	Maximum pervious area available		Run off with maximum pervious area	Remarks
				% of pervious area	Area		
		%	ha	%	ha	m^3/s	
(i)	Residential	55%	82	-	16.2	3.08	300 mm dia shaft per house and trenches in EWS housing
(ii)	Commercial	3%	5	35%	1.75	0.17	10 wells*/ trenches**
(iii)	Public-Semi Public	12%	18	35%	6.30	0.62	30 wells*
(iv)	Circulation	20%	30	35%	10.50	1.03	50 wells*/ trenches**
(v)	Recreational	10%	15	100%	15.00	0.08	5 wells*/ trenches**
	Total	100%	150			4.98	95 wells*/trenches**

* 4 m dia 6 m deep recharging wells with 300 mm dia shafts.
** 1.5 to 3 m wide trenches with borewells

Table 6.10: Demand Of Different Components for Hybrid model

S. No.	Year	Ground water recharge Potential MLD	Water Demand MLD	Water Available in Canals MLD	Ground Water Demand MLD	Sewage Generated MLD	Runoff Generated MLD
(i)	1951	96.4	24.5	269.2.	24.5	19.6	5.9 + 59 = 64.9
(ii)	1971	89.4	37.6	269.2	37.6	30.0	21.5 + 59 = 80.5
(iii)	1985	85.1	55.6	269.2	55.6	44.4	35.8 + 59 = 94.8
(iv)	2001	77.8	167.0	269.2	167.0	133.6	53.1 + 59 = 112.1
(v)	2010	69.6	209.1	269.2	209.1	167.3	92.3 + 59 = 151.3
(vi)	2031	94.4	362.3	269.2	93.1	289.8	28.1 + 59 = 87.1

The details of sewerage network for 2031 are same as in the demand and supply model. In this model by using canal water for water supply the demand for ground water is reduced to 93.1 MLD which is less than the ground water recharge but the main concern in this model is the increasing quantity of sewage from 167.3 MLD to 289. 8. MLD. The details of drainage network after are given in Table No. 6.11

Table 6.11: REQUIRED DRAINAGE NETWORK IN PATIALA – 2031 (WITH GROUND WATER HARVESTING)

S. No.	Catchment / Drainage Zone	Area of Catchment	Recreation & Undeveloped area	Point of Disposal for Catchment	Water course for Disposal	Cumulative flow with ground water recharging 20 % of Q_s	Recommended size
		ha	Ha			m^3/s	m (l/d)
i.	Ad	223	9	Ganda Nalah	Ganda Nalah	2.03	1.220 φ (48")*
ii.	Sìona	382	38	Sector II	Model Town Drain	3.29	1.530 φ (60")
iii.	B_d 2.1Jhill	452	45	Jhill	Model Town Drain	3.89	1.676 φ (66)
iv.	Ablowal sst	145	24	Proposed Sector –I	Model Town Drain	1.62	1.43 φ (45")
v.	B_d 4.1 Thapar College	63	41	Ablowal	Model Town Drain	0.16	10.400 φ (15")
vi.	B_d 4.2 Ablowal	212	22	Ablowal	Model Town Drain	1.97	1.220 φ (48")"
vii.	B_d 5.1 Century Enclave	63	6	Century Enclave	Model Town Drain	0.55	0.760 φ (30")*
viii.	B_d 6.1 Model Town	81	43	Haji Majra	Model Town Drain	0.32	0.508 φ (20")
ix.	B_d 6.2 Partap Nagar	105	10	Haji Majra	Model Town Drain	1.08	0.915 φ (35")
x.	B_d 6.3 Cantt-I	232	153	Haji Majra	Model Town Drain	1.50	1.067 φ (42")
xi.	B_d 6.4 Cantt-II	239	179	Haji Majra	Model Town Drain	1.93	1.371 φ (54")*
xii.	B_d 7.1 Cantt-IV	430	322	Haji Majra	Model Town Drain	0.78	0.762 φ (30")*
xiii.	B_d 8.1 proposed Govt. landuse – II	289	144	Vill. Rawas	Model Town Drain	0.72	0.762 φ (30")
xiv.	B_d 9.1 Proposed Govt. landuse-III	345	172	Vill. Khera Jattan	Model Town Drain	0.86	0.915 φ (36")
xv.	C_d 1.1 Lehal	187	45	Kheri Gujjar	Ganda Nalah	1.08	0.915φ (36")
xvi.	C_d 1.2 Ajit Nagar & Bank Colony	117	48	Kheri Gujjar	Ganda Nalah	1.63	1.220 φ (48")
xvii.	C_d 1.3 Cantt-III	251	189	Kheri Gujjar	Ganda Nalah	2.08	1.220φ (48")
xviii.	C_d 1.4 Officer's Colony	237	24	Kheri Gujjar	Ganda Nalah	4.12	1.830 φ (72")
xix.	D_d 1.1 Jail	82	33	Yadwindra Colony	Choti Nadi	0.23	0.457φ (18")
xx.	D_d 1.2 Tripuri	448	65	Yadwindra Colony	Choti Nadi	3.92	1.830 φ (72")
xxi.	D_d 1.3 Industrial Area & Grain Market	65	5	Yadwindra Colony	Choti Nadi	4.53	1.830 φ (72")
xxii.	D_d 2.1 Rasulpur	286	30	Yadwindra Colony	Choti Nadi	2.45	1.371 φ (54")
xxiii.	D_d 3.1 Rajpura Colony	121	19	Guru Nanak Nagar Disposal	Choti Nadi	0.97	0.762 φ (36")
xxiv.	D_d 4.1 Gurbax Colony	226	6	Yadwindra Colony	Choti Nadi	2.08	1.220 φ (48")
xxv.	D_d 5.1 Mathura Colony	144	61	Mathura Colony	Choti Nadi	0.86	0.915 φ (36")
xxvi.	D_d 6.1 Sanauri gate & Mahindra Colony	93	27	Mohindra Colony	Choti Nadi	0.53	0.762 φ (30")
xxvii.	E_d1.1 Milk Plant	6	2	D.C.W.	Patialwi Nadi	0.02	0.400 φ (15")
xxviii.	E_d1.2 Alipur	512	56	D.C.W.	Patialwi Nadi	3.47	1.830 φ (72")
xxix.	E_d1.3 Focal Point	76	10	D.C.W	Patialwi Nadi	3.82	1.830 φ (72")
xxx.	E_d1.4 D.C.W.	193	53	D.C.W	Patialwi Nadi	4.64	1.830φ (72")
xxxi.	Escorts & Ind. Area	120	18	Proposed Sector –9	Philauli Drain	1.01	0.915 φ (36")
xxxii.	Bir bahadurgarh	90	9	Proposed Sector –7	Philauli Drain	0.79	0.760 φ (30")
xxxiii.	Safidipur	88	9	Proposed Sector –6	Philauli Drain	0.77	0.760 φ (30")
xxxiv.	Sheikhupur	90	9	Proposed Sector –8	Philauli Drain	0.79	0.760φ (30")
xxxv.	Punjabi Univ.	88	54	Punjabi University	Philauli Drain	0.33	0.610 φ (24")
xxxvi.	Sadhubela	55	36	Proposed Sector –5	Philauli Drain	0.18	0.457 φ (18")
xxxvii.	Kasba rurki	120	12	Khera Jattan	Patialwi Nadi	1.05	0.915 φ (36")
xxxviii.	Bahadurgarh	110	58	Khera Jattan	Patialwi Nadi	1.31	1.067 φ (42")
xxxix.	Nasirpur	45	5	Hira Bagh	Patialwi Nadi	1.70	1.220 φ (48")
xl.	F_d7.4 Urban Estate	117	29	Hira Bagh	Patialwi Nadi	0.93	0.910φ (36")
xli.	F_d7.5 Hira Bagh	41	6	Hira Bagh	Hira Bagh Drain	0.34	0.600φ (24")
xlii.	Tafajalpura	70	40	Tajapal Pura	Tafajal pura Drain	0.27	0.457φ (18")
xliii.	Dilwal	110	11	Khera Jattan	Patialwi Nadi	2.68	1.370φ (54")
xliv.	Nurkherian	90	9	Khera Jattan	Patialwi Nadi	3.46	1.600φ (63")
xlv.	Chaura	100	10	Khera Jattan	Patialwi Nadi	4.34	1.830φ (72")
xlvi.	Nurkherian vill	95	10	Khera Jattan	Patialwi Nadi	0.83	6.813φ (32")
xlvii.	Raimajra	140	15	Khera Jattan	Patialwi Nadi	6.38	2.140φ (84")
xlviii.	Ghlauri	115	12	Khera Jattan	Patialwi Nadi	7.38	2.300φ (96")
xlix.	Ghlauri	137	15	Khera Jattan	Patialwi Nadi	9.05	2.560φ (100")
l.	Ghalauri	203	180	Khera Jattan	Patialwi Nadi	0.49	0.600φ (24")
li.	Proposed Public & Semi Public Landuse	798	400	Khera Jattan	Patialwi Nadi	11.04	2.800φ(108")
lii.	G_d1.1 N.I.S.	95	57	N.I.S.	Patialwi Nadi	0.27	0.45φ (18")

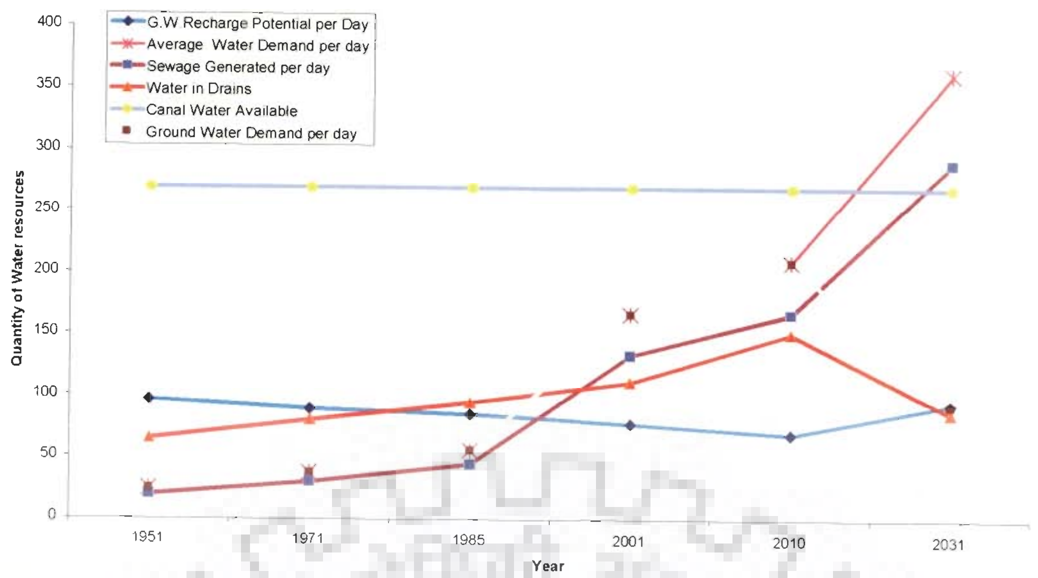


Fig 6.5: Water Resources of Planning Area

6.3.3. Integrated resource planning model

This model involves integrating water resource management with land use planning. This model is based on the understanding of urban hydrological cycle comprising of water supply, wastewater disposal, and storm water runoff systems, making up the total urban water system in which all the components are interrelated and the supply of water for each land use and component is based on the quality of water required for that component. In this model a complete picture of the spatial and temporal pattern of water demand, storm water runoff and wastewater disposal, is provided by adopting the water balance approach along with the nature of urban development.

- The topographic survey of the planning area must be done to identify the areas suitable for water harvesting and ground water recharging at city level.
- For water supply ground water is supplemented by available canal water and water demand is also reduced by adopting waste water recycling at domestic level.
- The waste water recycling after treatment is to be used to meet the demand of water for non-consumable activities like – car washing, gardening, flushing of toilets resulting in reduction in demand by as much as 40 lpcd, and it will also result in decrease in sewage generated at the domestic level
- For sewage disposal decentralised waste water treatment (DTS) is to be adopted at neighbour hood level where ever feasible and to be made compulsory for industry to have DTS installed in their premises before giving

them no objection certificate. This will result in reduction of quantity of sewage to be disposed off.

- Separate drainage network combined with rain water harvesting structures will augment ground water and will also result in reduction of runoff by as much as 80% in new development and by making it mandatory to install ground water recharging structures in old areas for all land uses other than residential will result in reduction of run off by 40% - 50% in these areas. Hence over all there is reduction in runoff generation by 60%

The areas below the HFL of Patialwi nadi, i.e. 250 m are to be reserved only for recreation and public-semi-public land use. The suitable site for rain water harvesting at city level in this zone is the area where Chotti nadi meets Patialwi nadi and is confined on the third side by Sanaur road. The reservoir, in an area of 265 hectares, is proposed to be built here by building flood gates near the point where Patialwi nadi cross Dakala Road, will increase the ground water recharge by 29.0 MLD.

By adopting recycling of waste water at domestic level as well as neighbour hood level will reduce the domestic demand to 90 lpcd from 135 lpcd and neighbourhood demand to 210 lpcd from 250 lpcd. The areas where decentralized sewage treatment system can be adopted are found out by using overlay analysis (Fig 6.6). The criteria adopted for over lay analysis are – The areas above HFL of Patialwi nadi, the areas without sewerage network, the areas with gross density less than or equal to 160 ppha, areas with population less than 12000 (neighborhood population, Table 2.6 Chapter - 2). The proposed sewerage network suitable for each areas – DTS or CTS are shown in Fig 6.6 and details in Table 6.11.

The use of canal water for water supply in combination with ground water recharging will reduce the pressure on receding ground water level. The use of canal water for water supply will reduce the average ground water demand from 308.6 MLD to 39.4 MLD (Table 6.12 & Fig 6.7).

The percentage of pervious area and type of rain water harvesting structure for each development must be fixed along with coverage and setback details in building bye laws to reduce the run off and to augment recharge. The ground water recharging structures suitable for a residential development of 150 hectares are given in Table No. 6.7 & 6.8. There is also a need to push for adoption of ground water recharging structures in high density development along with new areas. If 5% of the already developed areas are adopting ground water recharging every year then by 2031 there will be 80% reduction in runoff generation for Patiala. This can be done by adopting a policy of giving subsidy for installation of ground water recharging structures, reduction in water supply and sewerage charges for consumers who have recharging structure installed in their residences. If there is a reduction of 80% in run off generated then total runoff generated will come down to 71 m^3/s from 355 m^3/s and ground water recharging potential of Patiala planning area will increase to 123.4 MLD i.e. to 1951 level and this will be further augmented by creating a water body at junction of two drains.

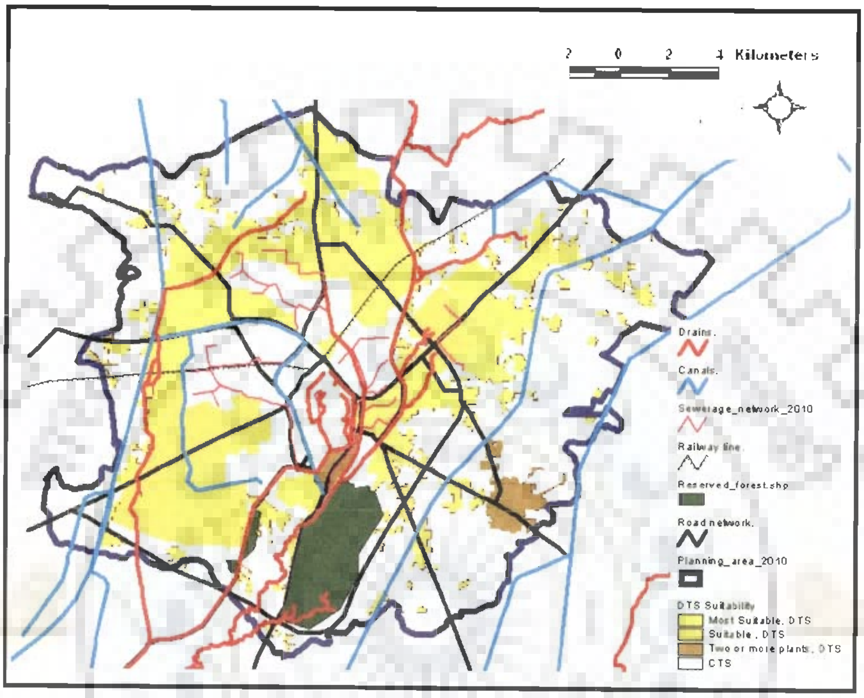


Fig 6.6: Proposed Sewerage network in planning area

Table 6.12: Demand Of Different Components for integrated resource planning model

S. No.	Year	Ground water recharge Potential MLD	Water Demand MLD	Water Available in Canals MLD	Ground Water Demand MLD	Sewage Generated MLD	Runoff Generated MLD
(i)	1951	96.4	24.5	269.2	24.5	19.6	5.9 + 59 = 64.9
(ii)	1971	89.4	37.6	269.2	37.6	30.0	21.5 + 59 = 80.5
(iii)	1985	85.1	55.6	269.2	55.6	44.4	35.8 + 59 = 94.8
(iv)	2001	77.8	167.0	269.2	167.0	133.6	53.1 + 59 = 112.1
(v)	2010	69.6	209.1	269.2	209.1	167.3	92.3 + 59 = 151.3
(vi)	2031	123.4	308.6	269.2	39.4	246.9	28.1 + 59 = 87.1

Table 6.13: PROPOSED SEWERAGE NETWORK FOR PATIALA – 2031 (Integrated Resource Planning Model)

S. No.	Zone	Area		Quantity of Sewerage Produced		Type of Sewerage System	Method of Sewerage Disposal	Point of Sewerage Disposal	Recommended size
		Total Area	Developed Area	For a Zone	Cumulative				
		ha	ha	MLD	MLD				m
xlv.	A_S walled city	223	223	26.44	26.44	Separate	Sec. Treat.	Sher Majra	1.070 ϕ (42")
xlvi.	C_S1.1 Model Town	144	144	3.55	3.55	Separate	Sec. Treat.	Sher Majra	0.762ϕ (30")
xlvii.	C_S 1.2 Lehal	187	187	4.15	7.70	Separate	Sec. Treat.	Sher Majra	0.914ϕ (36")
xlviii.	C_S 2.1 Badungar	105	105	3.60	3.60	Separate	Sec. Treat.	Sher Majra	0.762ϕ (30")
xlix.	C_S 2.2 Ajit Nagar	117	117	1.89	5.49	Separate	Sec. Treat.	Sher Majra	0.914ϕ(36")
l.	C_S 3 Officer's Colony & Kheri Gujjar	237	237	5.84	19.03	Separate	Sec. Treat.	Sher Majra	1.016ϕ (40")
li.	F_S-1 N.I.S.	95	95	0.14	0.14	Separate	Sec. Treat.	Sher Majra	0.254ϕ (10")
lii.	Cumulative Flow at Kheri Gujjar				143.82	Separate	Sec. Treat.	Sher Majra	2.286ϕ (90")
liii.	B_S 1 Milk Plant	6	6	0.41	0.41	Separate	Sec. Treat.	Land Disposal	0.305ϕ (12")
liv.	B_S.2.1 Alipur	512	512	27.12	27.12	Separate	Sec. Treat.	Sher Majra	1.219ϕ(48")
lv.	B_S 2.2 Focal Point	76	76	4.33	31.45	Separate	Sec. Treat.	Sher Majra	1.219ϕ (48 »)
lvi.	B_S 2.3 DCW	193	193	3.86	35.31	Separate	Sec. Treat.	Sher Majra	1.524ϕ (60")
lvii.	B_s.1 Thapar College	63	63	0.62	0.62	Separate	Sec. Treat.	Land Disposal	0.508ϕ (20")
lviii.	B_S.2.1 Ablowal	212	212	5.22	5.22	Separate	Sec. Treat.	Sher Majra	0.610ϕ (24")
lix.	B_S.3.1 Siona	500	500	12.33	12.33	Separate	Sec. Treat.	Sher Majra	0.762 ϕ (30")
lx.	B_S 3.2 Jhill	452	452	11.15	23.48	Separate	Sec. Treat.	Sher Majra	1.070 ϕ (42")
lxi.	B_S 2.2 Jail	82	82	0.64	5.86	Separate	Sec. Treat.	Sher Majra	0.762 ϕ (30")
lxii.	B_S4.1 Tripuri	366	366	10.83	40.17	Separate	Sec. Treat.	Sher Majra	1.372 ϕ(54")
lxiii.	D_S.4.2 Yadwindra Colony	351	351	8.65	48.82	Separate	Sec. Treat.	Sher Majra	1.524ϕ (60")
lxiv.	D_S 4.3 Gurbax Colony	347	347	11.00	59.82	Separate	Sec. Treat.	Sher Majra	1.778ϕ (70%)
lxv.	E_S 4.4 Mathura Colony (Total zone D+B)	237	237	3.08	98.21	Separate	Sec. Treat.	Sher Majra	2.130ϕ (84")
lxvi.	Escorts & Other. Industries	120	120	4.97	4.97	Separate	DTS	DTS	0.610ϕ (24")
lxvii.	Kasba rurki	120	120	4.42	9.39	Separate	DTS	DTS	0.610ϕ (24")
lxviii.	Sheikhupur	90	90	3.33	3.33	Separate	DTS	DTS	0.610ϕ (24")
lxix.	Bahadurgarh	110	110	1.93	14.65	Separate	DTS	DTS	0.610ϕ (24")
lxx.	Nasirpur	45	45	1.66	16.31	Separate	DTS	DTS	0.610ϕ (24")
lxxi.	Urban Estate III	30	30	1.11	17.42	Separate	DTS	DTS	0.610ϕ (24")
lxxii.	Bir bahadurgarh	90	90	3.33	3.33	Separate	DTS	DTS	0.610ϕ (24")
lxxiii.	Safidipur	88	88	3.18	6.51	Separate	DTS	DTS	0.610ϕ (24")
lxxiv.	Sadhubela	55	55	0.69	7.20	Separate	DTS	DTS	0.610ϕ(24")
lxxv.	Tafajalpura	70	70	1.10	8.30	Separate	DTS	DTS	0.610ϕ (24")
lxxvi.	Nasirpur Farm	56	56	1.79	10.09	Separate	DTS	DTS	0.610ϕ (24")
lxxvii.	Urban Estate-I	31	31	1.11	28.62	Separate	DTS	DTS	0.610ϕ (24")
lxxviii.	Dilwal	110	110	4.14	4.14	Separate	DTS	DTS	0.610ϕ (24")
lxxix.	Nurkherian	90	90	3.33	36.09	Separate	DTS	DTS	0.610ϕ (24")
lxxx.	Hirabagh	41	41	1.38	1.38	Separate	DTS	DTS	0.610ϕ (24")
lxxxi.	Chaura	100	100	3.59	41.06	Separate	DTS	DTS	0.610ϕ (24")
lxxxii.	Nurkherian vill	95	95	3.33	3.33	Separate	DTS	DTS	0.610ϕ (24")
lxxxiii.	Raimajra	140	140	5.29	49.63	Separate	DTS	DTS	0.610ϕ(24")
lxxxiv.	Ghlauri	115	115	4.14	53.77	Separate	DTS	DTS	0.610ϕ (24")
lxxxv.	Ghlauri	137	137	4.97	58.74	Separate	DTS	DTS	0.610ϕ (24")
lxxxvi.	Cantt	1152	1152	3.68	5.68	Separate	DTS	DTS	0.610ϕ (24")
lxxxvii.	Proposed Public & Semi-Public Landuse between cantt & bye-pas	1432	1432	2.43	6.11	Separate	DTS	DTS	0.610ϕ (24")
lxxxviii.	Total Sewerage disposal at disposal site				203.66	Separate	DTS	DTS	0.610ϕ(24")

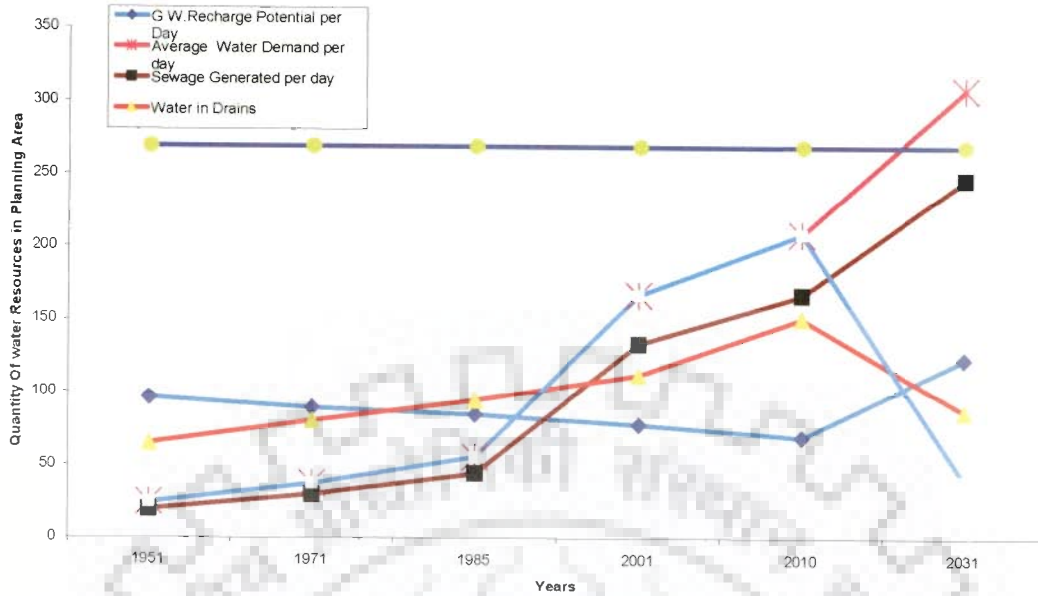


Fig 6.7: Water Resource Availability in Integrated Planning Model - 2031

If all the proposed development come up with wastewater recycling units along with rain water harvesting structures and the existing development is encouraged to adopt these methods at the rate of 5% per year then by the end of the plan Patiala will become a sustainable urban centre and ground water level will rise annually by 0.15 to 0.25m/Year.

6.4. CONCLUDING REMARKS

From the three models compared in section 6.3 it is clear that integrated resource planning model is most suitable for sustainable water resource management in Patiala, so there is a need to adopt this model in master plan rather than demand and supply model under which water resource infrastructure has been designed till date.

CHAPTER – 7

CONCLUSION AND RECOMMENDATIONS

CHAPTER – 7

CONCLUSION AND RECOMMENDATIONS

The present research have been undertaken to evolve a sustainable water resource management policy for Patiala planning area. It involved the study of urbanization of Patiala, critical analysis of land use planning efforts in Patiala, growth of water resource infrastructure in the planning area and how it has affected the availability and quality of water resources in the planning area. It has been done by studying the growth of Patiala with respect to the topography and drainage of Patiala. For this purpose the GIS based modelling has been done to analyse the existing and proposed land use of the planning area.

7.1 CONCLUSIONS OF THE STUDY

The study has been divided into three stages

- ❖ Chronological land use analysis of existing as well as proposed land use of two master plans and various projects with respect to the topography, drainage and contour analysis
- ❖ Growth of public water resource infrastructure – water supply, sewerage and drainage network in the planning area and how it has affected the quantity and quality of water resources available in the planning area.
- ❖ To see the effect of different water resource management models on water resources in planning area for the duration of next master plan 2011 – 2031.

7.1.1 Analysis of land use

The analysis of location of land use has been done in chronological order in five parts

- Before 1951 (First Census after independence)
- From 1951 – 1971 (First master plan was prepared)
- From 1971 – 1985 (First master plan phase)
- From 1985 – 2005 (Second master plan phase)
- From 2005 – 2010 (extended master plan phase)

Drainage and topographic analysis of planning area is done by dividing the topography of planning area into three categories – low-lying areas (below HFL of Patialwi nadi), areas with drainage problems (between 250 m – 252 m), and high ground areas with out any drainage problems. The analysis is done by using arithmetic overlay model in Arc View 3.2a GIS software for each land use for each phase

In 1951 Patiala was a town with a developed area of 819 ha with 678 ha (82.8%) on high ground with good drainage and no development in low lying areas. This has changed dramatically over the years, now Patiala has a developed area of 9688 ha with 6588 ha (68.7%) on high ground with good drainage and also 911 ha (9.4%) in low lying areas. This has lead to problem of flooding in low lying areas during monsoons and this has also reduced the area which had earlier acted as buffer to save the town from flooding and also helped in recharging the ground water.

7.1.2 Growth of water resources infrastructure in planning area

In 1951 the area under public water supply was divided in to four zones with 97.6% of the total developed area of Patiala with 92% of population covered with public water supply. The ground water was used for water supply with 12 tube wells and 4 OHSR's. The round water has till date remained the only source of water supply in Patiala. The number of tube wells has increased to over 191 with 68 OHSR's in 2010 with only 72.6% area and 85.9% covered under public water supply. In planning area the ground water level is receeding at an alarming rate of 0.75m / year.

In 1951 the area under public sewerage net work was limited to the walled city and its adjacent areas with an area of 774 ha (94.5%) of the total developed area with 92.0% population covered with public sewerage network and the sewage was disposed off in Jacob drain. The area under sewerage network has increased to 5837.2 ha (60.3%) of the total developed area with 57.5% population covered with public sewerage network and the untreated sewage is disposed off in Jacob drain, Patialwi Nadi, Chotti nadi and model town drain. The discharge of untreated sewage in drains have affected the quality of ground water in 2029 ha (20.9%) with 41.1% population getting affected.

7.1.3 Water resource management models for master plan 2011 - 2031

Three different models for the horizon year of 2031 have been generated using GIS and Excel Spread sheet and have been compared.

- In the demand and supply model if the status quo is maintained and conventional technologies have been used for water resource management. This will result in need of 332 Tube wells, Trunk sewer of size between 0.70m – 1.80m. with a centralized sewage treatment plant with a capacity of 400 MLD and a drainage network for run off disposal with a size varying between 0.70m to 2.5m. This will result huge expenditure and over all depletion of ground water at 0.75 m per year.

between 0.70m to 2.5m. This will result huge expenditure and over all depletion of ground water at 0.75 m per year.

- In the hybrid model ground water supply is supplemented with canal water and use of rain water harvesting at both domestic and community level, for which 'Water Sensitive Urban Controls' have been proposed for each land use, but for sewage disposal conventional technology is adopted resulting in non depletion of ground water, Trunk sewer of size between 0.70 m–1.80 m with a centralized sewage treatment plant with a capacity of 400 MLD and a drainage network for run off disposal with a size varying between 0.70 m to 1.2 m.
- In the Integrated Land and water resource management model, ground water supply is supplemented with canal water, use of rain water harvesting at both domestic and community level and waste water recycling of waste water, for which Water Sensitive Urban Controls have been proposed for each land use, and sewerage network for the city is proposed to be a combination of Centralized sewage disposal network in high density areas and decentralized sewage treatment plants in new and low density areas. The type of sewage network for an area has selected using arithmetic overlay analysis. This will result in average rise in ground water table in the area by 0.15 m–0.25 m, Trunk sewer size is also reduced to 0.7 m – 1.2 m and a drainage network for run off disposal with a size varying between 0.70 m to 1.2 m.

7.2 RECOMMENDATIONS

7.2.1 For The Patiala Planning Area

7.2.1.1 Planning considerations

- Proposed residential areas must be located above 252 m contour level.
- No land use other than recreational and open areas must be located in low lying areas i.e. below 250m contour level, at city level and recreational land use at suitable places in sectors must be proposed according to slope analysis of site to act as a catchment for the runoff generated in a sector.
- Circulation should be such as to consolidate the existing surface water resources.

- Existing water bodies must be preserved and the water bodies which have become redundant must be revived.
- Existing reserved forest must be preserved and a green belt around it must be created to have a buffer between forest and the developed areas.
- Integrated land and water resource management model must be adopted for sustainable water resource management in Patiala planning area.
- Water supply should be a designed to be a combination of ground water, canal water, rain water harvesting and waste water recycling.
- Groundwater recharging at neighbourhood level, sector level and city level must be adopted to recharge the groundwater and it will also help to reduce the runoff generated.
- Minimum pervious area for each building must be fixed to reduce the runoff generated. Water supply must be designed to exploit both surfaces as well as groundwater resources to avoid over exploitation of groundwater.
- Sewerage network for the city must be a combination of centralized sewage disposal network in high density areas and decentralized sewage treatment plants in new and low density areas and sewage must be treated before disposal to avoid contamination of ground water and drains.

7.2.1.2 Land use proposals and other policy interventions

- The existing water bodies in the Patiala planning area must be conserved. The reservoir at the junction of Patialwi nadi and Chotti nadi must be created by building a flood gates across the Patialwi nadi near bir moti bagh (Fig 7.1).
- The buffer zone must be created around the forests to preserve the forests.
- The green belt must be created around the bye pass and other radial and sector level roads with rain water harvesting and recharging structures.
- The water sensitive urban controls must be proposed for each land use (Table 7.1).
- Ground water recharging and waste water recycling must be made compulsory for all new development and must be encouraged for the already developed areas by giving incentives like reduced rates for water supply and sewerage to the persons adopting them in their properties
- Areas between Cantonment and bye pass and also sanaur distributary and bye pass must be reserved for public /semi – public land use.

- Area beyond Sanaur distributary must be freezed for development till low density areas get developed
- All other land uses must be located on high ground with good drainage on 252 m contour or beyond.
- The proposed sewerage network must be a combination of CTS – zone A, B C and D are interconnected with STP at Sher majra in the south of planning area. existing and DTS for the low density areas and new development (Fig 7.2)
- All industrial and commercial areas must have there own effluent treatment plants be made mandatory.

Table 7.1: Ground Water Recharging Structures Suitable For Various Land uses

S. No.	Landuse	% of landuse	Minimum pervious area	Remarks
		%	% of pervious area	
(i)	· Residential	55%	20%	300 mm dia shaft per house and trenches in EWS housing
(ii)	Commercial	3%	35%	10 wells*/ trenches**
(iii)	Public-Semi Public	12%	35%	30 wells*
(iv)	Circulation	20%	35%	50 wells*/ trenches**
(v)	Recreational	10%	100%	5 wells*/ trenches**

7.2.2 For Any Other Urban Area

- Integrated water resource management plan be made part of plan making process
- Topographic and drainage analysis of any area must be done to identify areas suitable for development. The ecologically sensitive areas, water bodies etc be preserved.
- Water Sensitive urban development controls be developed for the area and be made mandatory for any development
- Integrated land and water resource management model must be adopted for sustainable water resource management

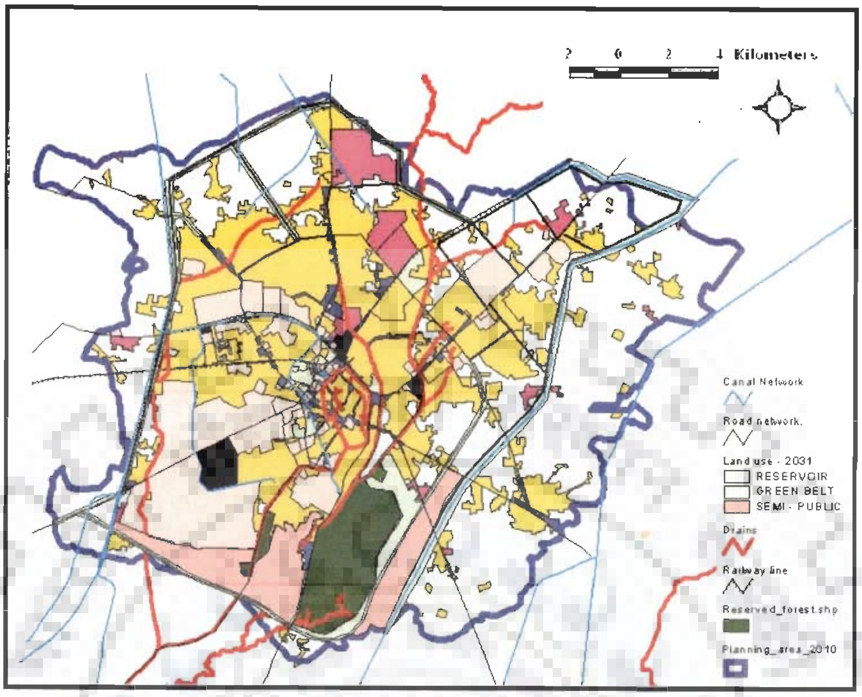


Fig 7.1: Land Use Proposals For Master Plan 2011 – 2031

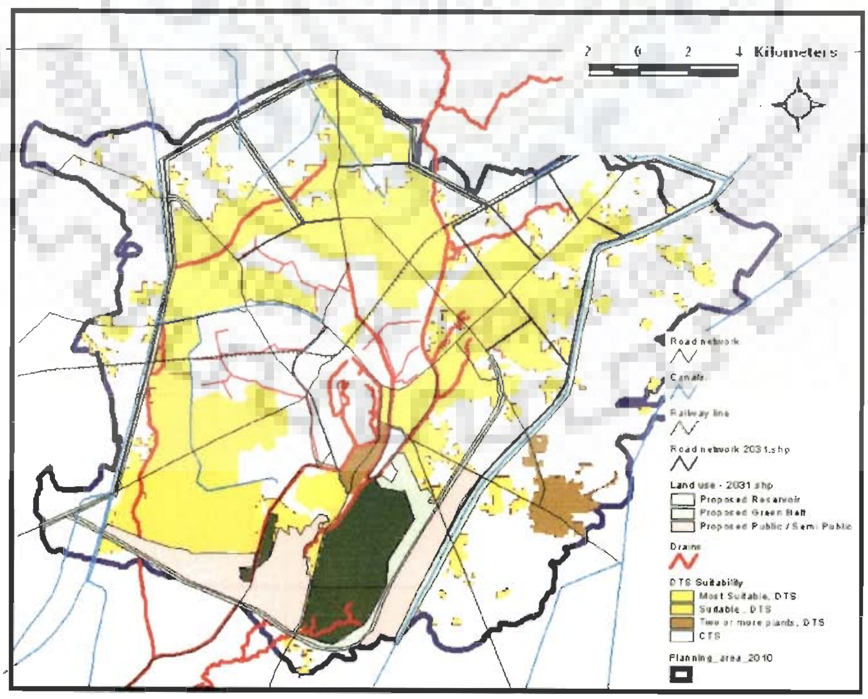


Fig 7.2: Sewerage Disposal Proposals For Master Plan 2011 – 2031

BIBLIOGRAPHY

BIBLIOGRAPHY

- "**www.cgwaindia.com/suo/rain-waterharvesting.htm.**" (2001), Internet Site on Rainwater Harvesting Structures in Urban Environment.
- **Adhikari C.**, (2003) A GIS-Remote Sensing compatible rainfall-runoff model for regional level planning, Map India,.
- **Agrawal, A., Narain, S. and Khurana, I.** (2001), 'Making Water Everybody's Business', *Centre for Science and Environment, New Delhi.*
- **Agrawal, C.S., Mittal, S., Goyal H.**, (2000), 'Rainwater harvesting – An appropriate technology for rural water supply', *In proceedings of International Seminar on Rural Water Supply, Roorkee.*
- **Agrawal, S. K.** (2006), 'Faith-based Ethnic communities: Process of Inclusion or Exclusion?'. Paper presented in the World Planning Congress, Mexico City.
- **Agrawal, S. K. and Martin, G.** (2004), 'A Case for Culturally Responsive Urban Design'. Ontario Planning Journal, Vol. 19 No. 5 pp 5-7.
- **Ahmad, S., Khan, I. H. and Parida, B. P.** (2001), 'Performance of stochastic approaches for forecasting river water quality'. Water Research, Volume 35, Issue 18 (12), pp 4261-4266.
- **Arnold, Whittick** (1974), 'Encyclopedia of Urban Planning', *McGraw Hill, New York.*
- **Asano, T.**, (1998). The role of reclaimed municipal wastewater in sustainable water resources management. In: Proceedings of the 6th Recycled Water Seminar, Sydney, Australia, 3–4 November. Australian Water and Wastewater Association Incorporated, pp. 7–13.
- **Barton, A.B.**,(2009). "Advancing IUWM through an understanding of the urban water balance". Australian Commonwealth Scientific and Research Organization(CSIRO).
- **Bashir, B. and Mimi, Z. (2005)** Synthetic Unit Hydrograph Development for Wadi Al Fara Catchment. Water International, Published for International Water Resources Association (IWRA), Published by Taylor & Francis, 30(3): 272-377.
- **Batty, Michael** (1976), 'Urban Modelling', *Cambridge University Press, Cambridge.*
- **Bhardwaj, R.K.** (1974), 'Urban Development in India', *National, Delhi.*

- **Bhatnagar, Manu** (March 2000), 'Planning For Sustainable Water Resource Base', *ITPI Journal, Vol. 17, No. 4 (178), ITPI, New Delhi.*
- **Bhatnagar, Manu and Rohilla, Suresh K.** (1995), 'Water Augmentation Plan For Delhi : A Proposal For Urban and Regional Water Harvesting', *S.D.R. Vol. 2, No. 6, Nov.-Dec., 1995, New Delhi.*
- **Birdie, G.S. and Birdie, J.S.** (1998), 'Water Supply and Sanitary Engineering', *Dhanpat Rai Publishing Company (P) Ltd., New Delhi.*
- **Boparai, Swaran S.**, (1983), 'Inaugural address of an ICSSR North Western Regional Centre Seminar on Urbanization and Urban Development in Punjab' *Organized by Guru Ramdass Post – Graduate (GRPG) School of Planning, Guru Nanak Dev University, Amritsar*
- **Bose, Ashish** (1973), 'Studies in Indian Urbanization (1901-1971)', *Tata McGraw Hill Publishing Co. Ltd., New Delhi.*
- **Bose, Ashish** (1970), 'Urbanization in India : An Inventory of Source Material', *Academic Books Limited, New Delhi.*
- **Bracken, Ian** (1981), 'Urban Planning Methods : Research and Policy Analysis', *Methuen, London.*
- **Branch, Melville C.** (1970), 'Urban Planning Theory', *Dowden Huchinson and Ross, Stroudsburg, Pennsylvania.*
- **Brar, T.S., Khare, D. and Jain, R.K.** (2004), 'Need to adopt decentralized wastewater treatment system in urban areas', *In Proceedings of Seminar on Challenges and Priorities in Urban and Regional Planning Organized by Guru Ramdass School of Planning, Guru Nanak Dev University, Amritsar.*
- **Brooks, H.**, (1992). The concept of sustainable development and environmentally sound technology. In: Environmentally Sound Technology for Sustainable Development. Advanced Technology Assessment System, Issue #7, United Nations, New York, pp. 19–25.
- **Caminos, Horacio and Gdethert, Reinhard** (1977), 'Urbanization Primer', *The MIT Press, Massachusetts.*
- **Census of India** (1981), 'Census Atlas Series – 17, Punjab Part XII', *Registrar General and Census Commissioner, Chandigarh.*

- **Census of India** (1981), 'District Census Handbook, Patiala Series – 17, Punjab Part XIII A&B', *Registrar General and Census Commissioner, Chandigarh.*
- **Census of India** (1991), 'District Census Handbook, Patiala. Series – 20, Punjab Part – XII A&B', *Registrar General and Census Commissioner, Chandigarh.*
- **Census of India** (1991), 'Town Directory, (Patiala) Punjab. Series – 20 Punjab, Part IX-A' *Registrar General and Census Commissioner, Chandigarh.*
- **Central Board Survey Team** (1989), 'Status of Water Quality of Some Rivers of India Monitored Under Global Environmental Monitoring Systems', *Central Pollution Control Board, New Delhi.*
- **Central Board Survey Team** (1989), 'Status of Water Supply and Waste Water Collection, Treatment and Disposal in Class-I Cities – 1988', *Central Pollution Control Board, New Delhi.*
- **Central Ground Water Board** (1998), 'Guide to Artificial Recharge to Groundwater', *Central Ground Water Board, New Delhi.*
- **Central Pollution Control Board** (1990), 'Water Quality Monitoring : The Indian Experience', *Central Pollution Control Board*, New Delhi.
- **Central Public Health and Environmental Engineering Organisation** (1987), 'Manual of Sewerage and Sewage Treatment', *Ministry of Urban Development, New Delhi.*
- **Central Public Health and Environmental Engineering Organisation** (1991), 'Manual on Water Supply and Treatment', *Ministry of Urban Development, New Delhi.*
- **Centre For Research Documentation and Training, Institute of Town Planner India** (Aug. 1996), 'Urban Development Plans Formulation and Implementation (UDPFI) Guidelines', *Ministry of Urban and Employment, Government of India, New Delhi.*
- **Chiara, Joseph De** (1985), 'Time Saver Standard for Residential Development', *McGraw Hill Company, New York.*
- **Chilton, John** (1997), 'Groundwater in Urban Environment', *International Association of Hydrologists, Rotterdam.* **Compendium of Environment Statistics** (1997), *prepared by Central Statistical Organisation, Department of Statistics and Ministry of Planning and Programme Implementation, Government of India, New Delhi.*
- **Choguill, C.L.** (1996), 'Ten Steps to Sustainable Infrastructure'. *Habitat International.*

Vol. 20, No. 3, pp. 389-404.

- **Choguill, C.L.,** (1994), 'Cricis, Chaos, Crunch? Planning For Urban Growth In The Developing World'. Urban Studies, Vol. 31 No. 6, pp 935-945.
- **Decentralized Sewage Treatment System** (2001), *Central Pollution Control Board, New Delhi.*
- **Dorota Z. Haman and Donald A. Brown**, (2002) '*Water and Sustainable Urban Development*', AE248, Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Institute of Food and Agricultural Sciences, University of Florida.
- **Duncan Mara,** 'Design Manual for waste Stabilization Ponds in India', *National River Conservation Directorate, Ministry of Environment and Forests, Government of India, New Delhi.*
- **Economic Advisor to Government of Punjab** (1978), 'Statistical Abstract of Punjab', *Economic and Statistical Organisation, Chandigarh.*
- **Economic Advisor to Government of Punjab** (1995), 'Statistical Abstract of Punjab', *Economic and Statistical Organisation.*
- **Fair, Gordan Maskew; Geyer, John Charles and Okun, Daniel Alexander** (1971), *Elements of Water Supply and Waste Water Disposal.*
- **GHK International and Operation Research Group** (2001), 'Delhi Urban Environment and Infrastructure Improvement Project (DUEIIP) – Delhi 21', *Ministry of Environment and Forests, Government of India and the Planning Department, Government of National Capital Territory of Delhi.*
- **Gibbs, Jack P.** (1961), 'Urban Research Methods', *D. Van Nostrand Company, New York.*
- **Gibson, J.E.** (1977), 'Designing the New City : A Systematic Approach', *John Wiley, New York.*
- **Golany, Gideon** (1976), 'New Town Planning : Principles and Practice', *John Wiley & Sons, New York.*
- **Golany, Gideon** (1978), 'International Urban Growth Policies', *John Wiley & Sons, New York.*
- **Goodland, R.,** (1994). Environmental sustainability and the power sector. Impact

Assessment 12, pp. 275–304.

- **Government of Punjab** (1972), 'Chandigarh Code', *Chandigarh Administration, Law Department, Chandigarh.*
- **Grimmond, C.S.B., Oke, T.R.,** (1986). Urban water balance 2. Results from a suburb of Vancouver, British Columbia. Water Resources Research 22 (10), 1404–1412.
- **Gupta, N.L.** (1995), 'Urban Water Supply', *Rawat Publications, Jaipur.*
- **Gurbachan Singh** (1983), 'Integrated Development of Citie and Towns in Punjab', Proceedings of an ICSSR North Western Regional Centre Seminar on Urbanization and Urban Development in Punjab Organised by GRPG School of Planning, Guru Nanak Dev University, Amritsar.
- **Harjinder Singh** (1985). "Patterns and Trends of Urbanization in Punjab-1951-81," in S.N. Mishra (ed.), Urbanization and Urban Development in Punjab, G.N.D. University, Amritsar. Ch-3
- **HELD, I., EISWITH, M., WOLF L., & HÖTZL, H.** (2004), 'Leaky sewers as a source for groundwater recharge and quality changes. - XXXIII. IAH & 7. ALHSUD Congress October 11-15, 2004, Zacatecas, Mexico.
- **Helliwell, P.R.** (1981), 'Urban Storm Drainage', *Pentech Press, London.*
- http://www.fao.org/NR/WATER/AQUASTAT/regions/lac/index3.stm. Retrieved 2009-09-14.
- **Ishaq, Achi M., and Amir Ali Khan.** (1997). "Recharge of Aquifers with Reclaimed Wastewater: A Case for Saudi Arabia," The Arabian Journal for Science and Engineering, AJSE, Volume 22, Number 1C, June 1997, pp. 133-141.
- **Jain, C.P.** (2003), 'Decentralised Sewage Treatment Plants in Squatter Resettlement Colonies of Delhi', *Journal of Indian Water Works Association.*
- **Jain, S. and Jain, R. K.** (2005), 'Evaluation of High Resolution Satellite Data (IKONOS) for Urban Database Development'. Journal of Institute of Town Planners, India (ITPI), vol. 2, no. 3, pp. 42-46.
- **Jain, S., Sur, U. and Sokhi, B. S.** (2005), 'Slum Identification using High Resolution Satellite Data'. GIM International, vol. 19, no. 9, pp. 60-63
- **Jain, S., Sur, U. and Sokhi, B. S.** (2005), 'Vulnerability identification of low-income settlements'. GIS@development, vol. 9, no. 10, pp. 26-28.

* **Jaiswal I., Murali R. M. and Panchal V.K.**,(2000) Estimation of Runoff through Remote Sensing, Map India.
* **Jat, Mahesh K., Khare, D., and Garg, P. K.**, (2009), Urbanisation and its impact on groundwater: A remote sensing and GIS based assessment approach, The Environmentalist, Volume 29, Issue 1, 17-32.
* **Jeppesen, B.** (1996), 'Domestic greywater reuse: Australia's challenge for the future', *Desalination – Elsvier Science B.V.*
* **Jones, D. E., Jr**. (1971). "Where is Urban Hydrology Practice Today?" Proc. American Society Of Civil Engineering, Hydrology Division, 97(HY2): 257-264.
* **Joong cho-Gi, Nam Kim Y., Ran Lim, B., Lee, S., (2008).** Effect of admixture and churning methods on solidification of fly ash from sewage sludge incinerator. Journal of Korea society of waste management, 13, 93-99.
* **Junker, K.**, (1994). Understanding the rhetorical nature of science in the implementation of Agenda 21. The Environmental Professional 16 4, pp. 349–355.
* **Kasperson, Roger E. and Kasperson, Jean X.** (1987), 'Water Reuse and the Cities', *Academic Publishers, Jaipur*.
* **Khanna, P., Kulkarni, V.S., Dutt, P.S., Pande, J.S., Joshi, V. and Aggarwal, A.L.**, 1991. An approach to carrying capacity based developmental planning process. Journal of IAEM 18 1&2, pp. 12–19.
* **Khanna, P.N.** (1997), 'Indian Practical Civil Engineers Handbook', *Engineer's Publishers, New Delhi.*
* **Kim, I.S., B.S. Oh, and H.W. Hyun.** (2008), Moving Desalination Forward. Proceedings of the Singapore International Water Week Water Convention. Singapore, June25–26, 2008.
* **Krueckeberg, Donald A. and Silvers, Arthur L.** (1974), 'Urban Planning Analysis : Methods and Models', *John Wiley & Sons, New York.*
* **Lazaro, T. R.** (1979), 'Urban Hydrology A multi disciplinary Perspective', Ann Arbor Science Publishing Science, Michigan, pp 24 – 27.
* **Leith, B.**, 1995. The social cost of sustainability. Alternatives 21 1, pp. 18–24. Abstract-GEOBASE.
* **Longley, P. A., Michael, J. B. and Donnany, J.** (2001) Remote Sensing and Urban

Analysis: A Research Arenda. In Longley, P. A., Michael, J. B. and Donnany, J. (eds.) Remote Sensing and Urban Analysis, Taylor and Francis Publication, London, pp. 243-258.

- **Mahavir** (2003), Geo-Information for Assesing Growth, Development and Ecological Performance of Cities. Spatio-Economic Development Record, Vol. 10, no. 3, pp 18-21.
- **Marechal D**. (2004), A Soil based approach to Rainfall-Runoff Modeling in Ungauged Catchments for England and Wales, Ph. D. Thesis, Cranfield University.
- **Masser I**. (1988), Governments and Geographic Information. Taylor and Francis Publication, London, pp 121.
- **McPherson, M.B.** (1973). Need for metropolitan water balance inventories. Journal of the Hydraulics Division ASCE Proceedings 99 (10), 1837–1848.
- **Melesse A.M. and Shih S.F**. (2002), Spatially Distributed Storm Runoff Depth estimation using Landsat Images and GIS.
- **Memoirs of The Indian Meteorological Department Vol. Xxi, Part iii** (1961), *Government of India Press.*
- **Milbrath, L.W.** (1989), Envisioning a Sustainable Society, State University of New York Press, Albany.
- **Mitchell, V.G., Mein, R.G., McMahon, T.A.** (2001), 'Modelling the urban water cycle', Environmental Modelling & Software 16. pp. 615 – 629.
- **Mumford, L.** (1961), The City in History, Harcourt Brace, New York.
- **Municipal Corporation Amritsar** (1997), 'The Punjab Municipal Corporation and Municipal Council/Nagar Panchayat Building Bye-Laws', *Ministry of Local Bodies of Punjab.*
- **Municipal Corporation of Patiala** (2001), 'Functioning of Water Supply and Sewerage Branch', *Municipal Corporation of Patiala, Ministry of Local Bodies of Punjab.*
- **Murthy, J.V.S.** (1998), 'Water Shed/Management', *New Age International (P) Limited Publishers, New Delhi.*
- Nayak, T.R. and Jaiswal R.K., Rainfall-Runoff Modelling using Satellite Data and GIS for Bebas River in Madhya Pradesh, IE (I) Journal Vol. 84, May 2003.
- **Newall, B., Cameron, I., Lant, P., von Meunch, E., Olsson, G.,** (1998). Modelling sustainable urban water systems. In: Proceedings of the 11th IWSA-ASPAC Regional

Conference, 1–5 November, Sydney, Australian Water and Wastewater Association Incorporated, pp.550–556.

- **Niu, W., Lu, J.J. and Khan, A.A.**, (1993). Spatial systems approach to sustainable development: a conceptual framework. Environmental Management 17 2, pp. 179–186. Abstract-EMBASE
- **Ojha, C.S.P. and Shrivastava, R.** (1997), 'Identification of Linearity in Biofilm Processes and its Operational Utility'. Biotech. and Bioengrg., March.
- **Ojha, C.S.P. and Shrivastava, R.** (1998), 'A Rational Approach for Design of In-series Biofilm Reactors'. Wat. Res., 32(3), pp 741-746.
- **O'Riordon, T.**, (1988). The politics of sustainability. In: Turner, R.K., Editor, , 1988. Sustainable Environmental Management, Belham Press, London, pp. 29–50.
- **P. Khanna, P. Ram Babu and M. Suju George**, (1999). Carrying-capacity as a basis for sustainable development: A case study of National Capital Region in India Progress in Planning, Volume 52, Issue 2 , August 1999, Pages 101-163
- **Pandey A. and Sahu A.K.**,(2002) Generation of curve number using Remote Sensing and Geographic Information System, Map Asia.
- **Pandey A., Chowdary V.M., Mal B.C. and Dabral P.P.**(2003), Estimation of runoff for Agricultural Watershed using SCS Curve Number and Geographic Information System, Map India.
- **Pandya, U. H. and Shete, D. T.** (2006), 'Efficacy of Rainwater Harvesting Structure in Vallabhipur Village in Vallabhipur Taluka of Bhavnagar District. National Seminar on Rainwater Harvesting and Water Management'. Nagpur 11-12 Nov, pp 282 – 287.
- **Parida, B. P., Moalafh, D.B., and Kenabatho, P.K.** (2006), 'Forecasting runoff coefficients using ANN for water resources management: The case of Notwane catchment in Eastern Botswana'. Physics and Chemistry of the Earth 31: 928–934.
- **Parkinson, J., & Tayler, K.** (2003). "Decentralized wastewater management in peri-urban areas in low-income countries". Environment and Urbanization, 75-90.
- **Paul, Subir** (2002), 'Water Harvesting In Delhi : Need for Sincere Actions', *Spatio-Economic Development Record, Vol. 9, No. 1, January-February, New Delhi.*
- **Peacock, K.A.**, 1995. Sustainability as symbiosis. Alternatives 21 4, pp. 16–22.

- **Prasijka, D. W.** (1985), 'Current Trends in Water Supply Planning : Issues, Concepts and Risks', *Van Nostrand Reinhold Company, New York.*
- **Proceeding of Water Resource Management in 21st Century** (1996), 'Compendium of Environment Statistics', *General of Water Works Association, New Delhi.*
- **Project description of DTS at Aravind Eye Hospital, Pondicheery, FEDINA and BORDA,** (2003). In Workshop on Decentralized Wastewater Treatment Systems organized by *Auroville Center for Scientific Research (CSR), Auroville.*
- **Punjab Urban Development Authority (PUDA)** (1998), 'Building Bye-Laws - PUDA', *Ministry of Urban Development, Punjab.*
- **Punjab Urban Development Authority (PUDA)** (1998), 'Norms for New Sector Development', *Ministry of Urban Development, Punjab.*
- **Ramegowda, K.S.** (1977), 'Urban and Regional Planning', *Prasaranga University of Mysore, Mysore.*
- **Ranjan, A. and Pandit, K.** (2005), 'Issues and Challenges In Urban Transport Management'. The Journal of The Indian Institute of Architects, volume 70 No. 1 pp 14-17.
- **Report of the National Commission On Urbanisation** (1988), *Government of India, New Delhi.*
- **Robinson, J., Francis, G., Legge, R. and Lerner,** S., (1990). Defining a sustainable society. Alternatives 12 2, pp. 36–46.

- **Robinson, J., Francis, G., Legge, R. and Lerner, S.**, (1990). Defining a sustainable society. Alternatives 12 2, pp. 36–46.

- **Sadler, B.**, 1990. Sustainable development and water resource management. Alternatives 17 3, pp. 14–19.
- **Santosh Pingale, Deepak Khare, H. C. Sharma & Mahesh K Jat** (2009) "Design of Water Harvesting Structure based on Supply and Demand of Water in a Hilly Watershed". Journal of Environmental Research and Development, Vol. 3, No. 3, 645-653.
- **Sarangi A., Rao N.H., Brownes S. M. and Singh A.K.**, Use of GIS tool in Watershed Hydrology and Irrigation Water Management, Map India, 2004.

- **Sasse, L.** (1998), 'Decentralised Wastewater Treatment in Developing Countries' , *SIITRAT, New Delhi.*
- **Sekhon, B.S.** (1999), 'Planning Policy For Technical Degradation in Punjab', *48^{th} National Town and Country Planners Congress, Jaipur, I.T.P.I, New Delhi.*
- Shearman, R., 1990. The meaning and ethics of sustainability. Environmental Management 14 1, pp. 1–8. Abstract-GEOBASE | Abstract-EMBASE
- **Sikka, V.M.** (1995), 'Groundwater Resources of Delhi State : An Overview', *S.D.R. Vol. 2, No. 6, Nov.-Dec., 1995, New Delhi.*
- **Smith, L.G.,** 1993. Impact Assessment and Sustainable Resource Management, Longman Scientific and Technical, Essex.
- **Status of Water Supply and Waste Water Collection, Treatment and Disposal in Class-I Cities – 1988** (1989), *Central Pollution Control Board, New Delhi.*
- **Sukheswalla Z. R**.,(2003), A Statistical model for estimating mean annual and mean monthly flows at ungauged locations. Master of Science Thesis, Texas A&M University.
- **Sundaram, K.V.** (1977), 'Urban and Regional Planning in India', *Vikas Publishing House Pvt. Ltd., New Delhi.*
- **Sunderlin, W.D**., (1995). Managerialism and the conceptual limits of sustainable development. Society and Natural Resources 8 4, pp. 481–492. Abstract-GEOBASE.
- **Swamee, P.K., Mishra, G.C., and Chahar, B.R**. (2000), 'Design of minimum seepage loss canal sections, J. Irrig. and Drain. Engrg., ASCE, vol. 126(1), pp. 28-32.
- **Swamee, P.K., Mishra, G.C., and Chahar, B.R**. (2002), 'Design of minimumwater-loss canal sections'. JOURNAL OF HYDRAULIC RESEARCH, VOL. 40, NO. 2 pp 215-220.
- **Taylor, F. Noel** (1927), 'The Main Drainage of Towns', *Charles Griffin and Company, London.*
- **Tebbutt, T. H.Y.,** (1983), 'Principles of Water Quality Control', *Pergamon Press, Oxford.*
- **Town and Country Planning Dept.** (1973), 'Draft Master Plan – Patiala – 1971-1991', *Ministry of Urban Development-Punjab.*
- **Town and Country Planning Dept.** (1988), 'Draft Master Plan – Patiala – 1985-2001', *Ministry of Urban Development-Punjab.*

- **Town and Country Planning Organisation** (1965), 'Report on Norms and Space Standard for Planning of Public Sector Towns', *Ministry of Urban Development, New Delhi.*
- **Town and Country Planning Organisation** (1965), 'TCPO Norms for Industrial Townships', *Ministry of Urban Development, New Delhi.* **Raj Bala**, (1985), 'Trends in Urbanization in India 1901 – 81', *Rawat Publications, Jaipur.*
- **United Nations Development Programme**, (1994). Human Development Report 1994, UNDP, New York.
- **Urban Development Plans Formulation and Implementation (UDPFI) Guidelines,** (1996), 'Centre For Research Documentation and Training, Institute of Town Planner India', *Ministry of Urban and Employment, Government of India, New Delhi.*
- **Wegelin, E. A.** (1990), 'New approaches in urban services delivery: A comparison of emerging experience in selected Asian countries'. Cities, Volume 7, Issue 3 (08), pp 244-258.
- **Wegelin, E. A. and Borgman, K. M.,** (1995), 'Options for municipal interventions in urban poverty alleviation'. Environment and Urbanization, Vol. 7, No. 2, October, pp 131-151.
- **Wolf, L., Held, I., Eiswirth, M. and Hötzl, H.** (2004), 'Impact of leaky sewers on groundwater quality'. Acta hydrochim. Hydrobiol. Vol. **32** (4-5), pp 361-373.
- **Wolf, L., Morris, B and Burn, S.**, (2006), "Urban water resources toolbox: Integrating groundwater into urban water management". Report of EC Project EVK1-CT-2002-00110. IWA Publishing, London.
- **World Commission on Environment and Development**, 1987. Our Common Future, Oxford University Press, Oxford.

ANNEXURES

ANNEXURE – I

DETAILS OF VARIOUS PROJECTS IN PATIALA PLANNING AREA

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Table 1: Location of Project According to Topography and Drainage Developed By Various Government Agencies

S. No.	Name of Project	Area (ha)	Year of execution	Implementing Agency	Location	Remarks
(i)	Tripuri township	35	1950	PEPSU Township Development Board	Behind	Location on relatively high ground but drainage problem due to jail road and distributry.
(ii)	Govt. Medical College	10	1953	Government of Punjab	Sangrur	Location on relatively high ground with good drainage
(iii)	Ayurvedic Hospital	5	1953	Government of Punjab	Sohlar Road	Located on relatively high contour with good drainage
(iv)	Model Town	27	1955	PEPSU Township Development Board	Near Patiala Cantonment station	Located on relatively high contour with good drainage
(v)	T.I.E.T.	63	1956	Thapar Group	Bhadson Road	Located on relatively high ground with minor drainage problem due to distributry
(vi)	PEPSU Bhakra Colony	11	1956	PEPSU Township Development Board	Nabha Road	Located on relatively high ground with good drainage
(vii)	State College of Education	12	1956	Government of Punjab	Punjabi Bagh	Location on relatively high ground with drainage problem due to Railway line and distributry
(viii)	Physical College of Education	5	1956	Government of Punjab	Punjabi Bagh	Location on relatively high ground with drainage problem due to Railway line and distributry
(ix)	Multipurpose Senior Secondary School	7	1960	Government of Punjab	Passey Road	Location on relatively high ground with drainage problem due to Railway line and distributry
(x)	Punjabi University	88	1962	Government of Punjab	Rajpura Road	Located on relatively high ground with good drainage.
(xi)	P.S.E.B. Colony-I	14	1963	Punjab State Electricity Board	Model town	Located on high ground with problem due to distributry and Railway line.
(xii)	P.S.E.B. SHED	7	1968	Punjab State Electricity Board	Badungar	Located on relatively high ground with no drainage problem.
(xiii)	F.C.I.	20	1968	Food Corporation of India	Sirhind Road and Sirhind Bye Pass	Located on relatively high ground with no drainage problem
(xiv)	Godowns Grain Market	6	1968	Government of Punjab	Sirhind Road	No drainage problem
(xv)	P.R.T.C. Workshops	14 (6+8)	1968	Government of Punjab	Nabha road and Rajpura road	Located on relatively high ground with drainage
(xvi)	Urban Estate Phase-I	100	1970	Urban Estates Development Board	Rajpura Road	Located on relatively high ground with good drainage
(xvii)	Urban Estate Phase-II	166	1980	Urban Estate Development Board	Rajpura Road	Poor drainage due to neglecting natural drainage of site while planning. The seasonal drain which was part of site was eliminated .

(xviii)	P.S.E.B. Colony-II	10	1978	Punjab State Electricity Board	Badungar	No drainage problem
(xix)	P.S.E.B. Colony-III	5	1988	Punjab State Electricity Board	Badungar	No drainage problem
(xx)	National Institute of Sports	56	1950	Ministry of Sports G.O.I.	Dakala Road	No drainage problem
(xxi)	Milk plant	6	1980	Government of Punjab	Sirhind Road	Drainage problem due to Sirhind road and bye pass.
(xxii)	Urban Estate Phase-III	44	1992	Punjab Urban Development Authority	Rajpura Road	No drainage problem
(xxiii)	Railway Colony	50	1980	Ministry of Railways G.O.I.	Sirhind Bye pass	No drainage problem
(xxiv)	D.C.W. workshop and Colony	84	1980	Ministry of Railways G.O.I.	Sirhind Bye pass	Drainage problem due to Sirhind bye pass and Railway line.
(xxv)	Rajpura Power House Colony	24	1958	Government of PEPSU	Rajpura Road	No drainage problem
(xxvi)	Divisional Secretariat & Phulkian Enclave	25	1998	Government of Punjab	Jail Road	Drainage problem due to distributry
(xxvii)	Focal Point	72	1996	PSIDC	Sirhind Bye pass	No drainage problem
(xxviii)	PDA SEZ, Baran	230	2006	Patiala Development Authority (PDA)	Sirhind Road, Baran	No drainage problem
(xxix)	**Total**	**1196**				

Source : Office of District Town Planning Officer, Town and Country Planning Department, Patiala

Table 2: Location of Development Schemes According To Topography

S. No.	Name of Development Scheme	Area (ha)	Year	Location	Remarks
i)	Chotti Baradari	8	1977	Mall Road	No drainage problem
ii)	Bachittar Singh Trust	3	1992	Bhupindra Road	Bhupindra Road act as barrier
iii)	Sai market	1	1975	Lower mall	No drainage problem
iv)	Guru Tegh Bahadur Market	3	1975	Gurudwara Dukhniwaran Sahib	No drainage problem
v)	Truck Stand	21	1976	Rajpura Road	Low lying area poor drainage
vi)	Seva Singh Thikri Nagar Scheme	80	1976	Rajpura Road	Low lying area poor drainage
vii)	Kaur Singh Ji Di Haveli	2	2006	Lower mall	No drainage problem
	Total area	**118**			

Source : Office of District Town Planning Officer, Town and Country Planning Department, Patiala

Table 3: Location of Town Planning Schemes According To Topography					
S. No.	**Name of Scheme**	**Area (ha)**	**Date of Sanction/ approval**	**Location**	**Remarks**
i)	No.1	36	04.06.76	Ragho Majra	No drainage problem
ii)	2A part-I	45	03.04.74	Power House Colony	No drainage problem
iii)	2A Part-II	41	28.01.75	Preet Nagar	No drainage problem
iv)	3	96	23.06.76	Lehal	Drainage problem due to distributry (PNC minor and Sirhind Road.
v)	4A	22	31.03.76	Punjabi Bagh	Drainage problem due to distributry (P.N.C. Minor) and Railway line.
vi)	4B	40	22.03.79	Sewak Colony	Drainage problem due to Bhupindra Road and Railway line.
vii)	4D	24	18.12.76	Civil Lines	Drainage problem due to Bhupindra Road
viii)	4E	41	10.12.75	Ranjit Bagh & Green Lehal	Drainage problem due to relatively low lying area and distributry
ix)	4F	10.2	24.11.84	Civil Lines	Drainage problem due to Bhupindra Road,
x)	5A	67	29.08.82	Mehar Singh Colony	On drainage problem due to location on relatively high ground.
xi)	5B	76	03.10.83	Harinder Nagar	Drainage problem due to Sirhind Road.
xii)	5C	13	10.07.84	Rasulpur	No drainage problem
xiii)	6 Part-I	45	26.01.75	Vijay Colony	Low lying area with very poor drainage.
xiv)	10 A	23	23.03.88	Gobind Nagar	Problem in drainage due to railway line.
xv)	9A	60	10.08.88	Hira Nagar	Problem due to railway line & Bhupindra road.
xvi)	9B	16	23.03.99	Khalsa Colony	On a relatively high ground
xvii)	10	23	14.06.78	Bachittar Nagar	On a relatively high ground with problem due to Railway line.
xviii)	12A	7	13.08.72	Partap Nagar	Problem due to Railway line and distributry (Moti Bagh/ minor)
xix)	13	6	11.06.76	Friends Colony	Problem due to Railway line and distributry P.N.C. Minor.
xx)	14	25	06.03.84	Bank Colony	Located on relatively high ground.
xxi)	15	8	18.03.76	New Lal Bagh	No drainage problem.
xxii)	16	14	04.11.77	Guru Nanak Nagar	No drainage problem
xxiii)	17	3	25.05.86	Ajit Nagar	Problem due to Bhupindra Road.
xxiv)	18 Part-I	24	24.04.81	Mohindra Colony	Low lying area with poor drainage.
xxv)	18 Part-II	22	03.07.77	Kesar Colony	Low tying area with poor drainage.
xxvi)	28	9	10-05.90	Narula Colony	No drainage problem.
xxvii)	S. Joginder K. W/o Preetam	2	28.08.74	Lower Mall	No drainage problem
xxviii	Karam Singh	3	04.10.68	Lower Mall	No drainage problem
xxix)	Nihal Bagh	2	06-06-73	Baradari	No drainage problem
xxx)	Housing Society	2	10-06-75	Rajpura Road	No drainage problem
xxxi)	D.L.F.	9	12-07-76	Sirhind Road	Drainage problem due to Sirhind road and P.N.C. minor distributry.
xxxii)	Rani Indira Kumari	2	06.08.68	Rai Majra	Low lying area with poor drainage.
xxxiii	Leela Bhawan	5	09.09.75	Bhupindra Road	Drainage problem due to Bhupindra road
xxxiv)	Mahesh Inder Singh	2	04-10-68	Mall Road/ Baradari	No drainage problem
	Total	**724**			

Source : Office of District Town Planning Officer, Town and Country Planning Department, Patiala

Attributes of Water_supply_zones shp

ANNEXURE - II

	Rural Areas With Public Water Supply											Rural Areas With Public Water Supply						
S. No.	Area_Chara	Name_Of_Ar	Area in Hectares	Ws_type	Wsup_type	Tubewells_2010	Available Supply	Tubewells _2001		Land_Use	Landuse	Popu_2001	Density	Water Demand 2001	Peak Demand 2001	Popu_2010	Water Demand 2010	Peak Demand 2010
	Forest	Bir Kheri Gujaran	50 6	NIL	0	0		0		Forest	8	0	0					
	Forest	Bir Moti Bagh	753.9	NIL	0	0		0		Forest	8	0	0					
1	Rural	Asarpur	9.6	PHE	1	1	1.08	1	1.08	Residential	1	1126	117 37	168900	253350	1400	210000	315000
2	Rural	Baran	93.6	PHE	1	1	1.08	1	1.08	Residential	1	2671	28.54	400650	600975	3200	480000	720000
3	Rural	Dhamo Majra	62.2	PHE	1	1	1.08	1	1 08	Residential	1	1287	20.69	193050	289575	1550	232500	348750
4	Rural	Jalalpur	18.3	PHE	1	1	1.08	1	1.08	Residential	1	1346	73.38	201900	302850	1650	247500	371250
5	Rural	Jassowal	14.8	PHE	1	1	1.08	1	1.08	Residential	1	1162	78.61	174300	261450	1400	210000	315000
6	Rural	Khera Jattan	17 3	PHE	1	1	1.08	1	1.08	Residential	1	833	48.21	124950	187425	1000	150000	225000
7	Rural	Malo Majra	35 8	PHE	1	1	1.08	1	1.08	Residential	1	318	8.87	47700	71550	400	60000	90000
8	Rural	Nurkherian	16.7	PHE	1	1	1.08	1	1.08	Residential	1	1536	91.78	230400	345600	1850	277500	416250
9	Rural	Pasiana	23.8	PHE	1	1	1.08	1	1.08	Residential	1	2404	100 92	360600	540900	2900	435000	652500
10	Rural	Raipur	62 7	PHE	1	1	1.08	1	1.08	Residential	1	2335	37.23	350250	525375	2800	420000	630000
11	Rural	Ramgarh	13.5	PHE	1	1	1 08	1	1.08	Residential	1	1072	79.43	160800	241200	1300	195000	292500
12	Rural	Rauni	25 7	PHE	1	1	1.08	1	1.08	Residential	1	1369	53 25	205350	308025	1650	247500	371250
13	Rural	Rawas Brahamana	8.7	PHE	1	1	1.08	1	1.08	Residential	1	723	83.32	108450	162675	900	135000	202500
14	Rural	Seuna	43.1	PHE	1	1	1.08	1	1.08	Residential	1	2456	57	368400	552600	3000	450000	675000
15	Rural	Shamspur	12 7	PHE	1	1	1.08	1	1.08	Residential	1	1584	125	237600	356400	1900	285000	427500
16	Rural	Sheikhupur	33.4	PHE	1	1	1.08	1	1 08	Residential	1	2532	75 78	379800	569700	3050	457500	686250
17	Rural	Sidhuwal	30.5	PHE	1	1	1.08	1	1.08	Residential	1	1357	44.54	203550	305325	1650	247500	371250
18	Rural	Sunainheri	20.4	PHE	1	1	1 08	1	1.08	Residential	1	1064	52 14	159600	239400	1300	195000	292500
19	Rural	Ucha Gaon	32.3	PHE	1	1	1.08	1	1.08	Residential	1	1049	32 47	157350	236025	1300	195000	292500
			575.1			**19**	**20.52**	**19**	**20.52**			**28224**		**4233600**	**6350400**	**34200**	**5130000**	**7695000**

	Rural Areas Without Public Water Supply								Rural Areas Without Public Water Supply							
S No.	Area_Chara	Name_Of_Ar	Area in Hectares	Ws_type	Wsup_type	Tubewells_2010	Available Supply	Tubewells _2001	Land_Use	Landuse	Popu_2001	Density	Water Demand 2001	Peak Demand 2001	Popu_2010	Water Demand 2010	Peak Demand 2010
20	Rural	Bhathlan	17.8	Private	3	0		0	Residential	1	337	18.9	50550	75825	400	60000	90000
21	Rural	Bir Bahadurgarh	3.6	Private	3	0		0	Residential	1	397	110 58	59550	89325	500	75000	112500
22	Rural	Budhanpur	7 1	Private	3	0		0	Residential	1	83	11.7	12450	18675	100	15000	22500
23	Rural	Budhanpur	4.4	Private	3	0		0	Residential	1	29	6.54	4350	6525	50	7500	11250
24	Rural	Dalanpur	58.3	Private	3	0		0	Residential	1	126	2 16	18900	28350	150	22500	33750
25	Rural	Daulatpur	5.4	Private	3	0		0	Residential	1	360	66.37	54000	81000	450	67500	101250
26	Rural	Dilwal	141.1	Private	3	0		0	Residential	1	625	4.43	93750	140625	750	112500	168750
27	Rural	Ghalauri	1.5	Private	3	0		0	Residential	1	17	11.35	2550	3825	20	3000	4500
28	Rural	Ghalauri	6.5	Private	3	0		0	Residential	1	23	3.54	3450	5175	30	4500	6750
29	Rural	Ghalauri	33 1	Private	3	0		0	Residential	1	314	9.5	47100	70650	400	60000	90000
30	Rural	Ghalauri	12 2	Private	3	0		0	Residential	1	26	2.14	3900	5850	30	4500	6750
31	Rural	Hassanpur	2 7	Private	3	0		0	Residential	1	999	0	149850	224775	1200	180000	270000
32	Rural	Hassanpur	5.8	Private	3	0		0	Residential	1	195	33.4	29250	43875	250	37500	56250
33	Rural	Hassanpur	27.6	Private	3	0		0	Residential	1	0	0	0	0	0	0	0
34	Rural	Hazi Majra	3.3	Private	3	0		0	Residential	1	179	54.08	26850	40275	220	33000	49500
35	Rural	Jassowal	2 3	Private	3	0		0	Residential	1	24	10.47	3600	5400	30	4500	6750
36	Rural	Kartarpur	5 2	Private	3	0		0	Residential	1	576	109.86	86400	129600	700	105000	157500
37	Rural	Khansa	6 7	Private	3	0		0	Residential	1	684	101.68	102600	153900	820	123000	184500
38	Rural	Kulla Majra	5.2	Private	3	0		0	Residential	1	115	21.97	17250	25875	140	21000	31500
39	Rural	Kulla Majra	1.2	Private	3	0		0	Residential	1	18	15.56	2700	4050	20	3000	4500
40	Rural	Kulla Majra	3.7	Private	3	0		0	Residential	1	98	26.25	14700	22050	120	18000	27000
41	Rural	Malo Majra	14.5	Private	3	0		0	Residential	1	188	12.96	28200	42300	230	34500	51750
42	Rural	Mehmadpur	7.1	Private	3	0		0	Residential	1	699	98 59	104850	157275	840	126000	189000
43	Rural	Mithu Majra	2 7	Private	3	0		0	Residential	1	336	124.77	50400	75600	400	60000	90000
44	Rural	Mithu Majra	1 3	Private	3	0		0	Residential	1	265	209.32	39750	59625	320	48000	72000
45	Rural	Rauni	10 7	Private	3	0		0	Residential	1	585	54.9	87750	131625	700	105000	157500
46	Rural	Safidipur	6.5	Private	3	0		0	Residential	1	613	94.51	91950	137925	740	111000	166500
47	Rural	Sher Majra	23 7	Private	3	0		0	Residential	1	951	40 11	142650	213975	1150	172500	258750
48	Rural	Sher Majra	25.3	Private	3	0		0	Residential	1	706	27 91	105900	158850	850	127500	191250
49	Rural	Sidhuwal	6.6	Private	3	0		0	Residential	1	151	23.03	22650	33975	200	30000	45000
50	Rural	Sidhuwal	1.5	Private	3	0		0	Residential	1	8	5.26	1200	1800	10	1500	2250
51	Rural	Sunainheri	1.9	Private	3	0		0	Residential	1	35	18.04	5250	7875	40	6000	9000
52	Rural	Malo Majra	5.8	Private	3	0		0	Commercial	2	0	0	3972.56	5958.84	0	3972.56	5958.84
53	Rural	Bhathlan (Brick Kiln)	6 7	Private	3	0		0	Industrial	3	0	0	299790	449685	0	300000	450000
54	Rural	Budhanpur	8 2	Private	3	0		0	Industrial	3	0	0	370665	555997 5	0	370665	555997.5
55	Rural	Dalanpur	2.4	Private	3	0		0	Industrial	3	0	0	109035	163552.5	0	109035	163552 5
56	Rural	Dalanpur	4.7	Private	3	0		0	Industrial	3	0	0	209340	314010	0	209340	314010
57	Rural	Ghalauri	51.6	Private	3	0		0	Industrial	3	0	0	2321820	3482730	0	2321820	3482730
58	Rural	Ghalauri	5.1	Private	3	0		0	Industrial	3	0	0	227610	341415	0	227610	341415
59	Rural	Khansa	1.3	Private	3	0		0	Industrial	3	0	0	59220	88830	0	59220	88830
60	Rural	Nurkherian	28.7	Private	3	0		0	Industrial	3	0	0	1292805	1939207 5	0	1292850	1939275
61	Rural	Pasiana	11 6	Private	3	0		0	Industrial	3	2404	0	1554945	2332417.5	2900	1554945	2332417 5
62	Rural	Rauni	26.5	Private	3	0		0	Industrial	3	0	0	520830	781245	0	520830	781245
63	Rural	Rauni	10.9	Private	3	0		0	Public/Semi-Pub	4	0	0	7443.96	11165.94	0	7450	11175
			620.1								**12166**		**8441776.52**	**12662664.78**	**14760**	**8756737.56**	**13135106.34**
													12675376 52	**19013064.78**	**48960**		

ANNEXURE - II

	Urban Areas With Public Water Supply													Urban Areas With Public Water Supply						
S_No	Area_Chara	Name_Of_Ar	Area in Hectares	Ws_type	Wsup_type	Tubewells_2010	Available Supply		Tubewells _2001			Land_Use	Landuse	Popu_2001	Density	Water Demand 2001	Peak Demand 2001	Popu_2010	Water Demand 2010	Peak Demand 2010
1	Urban	Bahadurgarh (Rurki Kasba)	84 7	Municipal	1	2	2.16		0	0		Residential	1	8170	96.48	2042500	3063750	10000	2500000	3750000
2	Urban	Sanaur	71 0	Municipal	1	3	3.24		2	2 16		Residential	1	921	12 96	230250	345375	5000	1250000	1875000
3	Urban	Sanaur	58 7	Municipal	1	0	0		0	0		Residential	1	8507	144 99	2126750	3190125	10000	2500000	3750000
4	Urban	Sanaur	36 5	Municipal	1	0	0		0	0		Residential	1	0	0	0	0	200	50000	75000
5	Urban	Sanaur	11 2	Municipal	1	0	0		0	0		Residential	1	329	29 34	82250	123375		0	0
6	Urban	Sanaur	113.7	Municipal	1	0	0		0	0		Residential	1	8178	71.93	2044500	3066750	10000	2500000	3750000
7	Urban	WS_Zone - 01	106 0	Municipal	1	10	10.8		5	5.4		Residential	1	20396	192 35	5099000	7648500	20396	5099000	7648500
8	Urban	WS_Zone - 02	137 8	Municipal	1	8	8 64		6	6 48		Residential	1	17336	125.8	4334000	6501000	17336	4334000	6501000
9	Urban	WS_Zone - 03	120.0	Municipal	1	7	7 56		4	4 32		Residential	1	19982	166.48	4995500	7493250	19982	4995500	7493250
10	Urban	WS_Zone - 04	115 0	Municipal	1	6	6 48		4	4 32		Residential	1	22056	191.71	5514000	8271000	22056	5514000	8271000
11	Urban	WS_Zone - 05(1)	264.4	Municipal	1	7	7 56		3	3 24		Residential	1	10903	41 24	2725750	4088625	20000	5000000	7500000
12	Urban	WS_Zone - 05(2)	367.6	Municipal	1	11	11 88		4	4 32		Residential	1	25719	69 97	6429750	9644625	35000	8750000	13125000
13	Urban	WS_Zone - 05(3)	280 0	Municipal	1	6	6 48		2	2 16		Residential	1	16483	58.88	4120750	6181125	20000	5000000	7500000
14	Urban	WS_Zone - 06	147 6	Municipal	1	5	5.4		2	2 16		Residential	1	3741	25.35	935250	1402875	4000	1000000	1500000
15	Urban	WS_Zone - 07	380 3	Municipal	1	10	10.8		4	4 32		Residential	1	42261	111 13	10565250	15847875	50000	12500000	18750000
16	Urban	WS_Zone - 08	177.7	Municipal	1	4	4 32		2	2 16		Residential	1	18916	106 46	4729000	7093500	19000	4750000	7125000
17	Urban	WS_Zone - 09	293.4	Municipal	1	10	10 8		5	5.4		Residential	1	39993	136 29	9998250	14997375	42000	10500000	15750000
18	Urban	WS_Zone - 10	297 3	Municipal	1	7	7 56		3	3 24		Residential	1	13730	46 18	3432500	5148750	30000	7500000	11250000
19	Urban	WS_Zone - 11	185 3	Municipal	1	2	2 16		0	0		Residential	1	9458	51.05	2364500	3546750	11000	2750000	4125000
20	Urban	WS_Zone - 12	166 0	Municipal	1	2	2 16		0	0		Residential	1	5487	33 06	1371750	2057625	10000	2500000	3750000
21	Urban	WS_Zone - 13	302 8	Municipal	1	5	5.4		0	0		Residential	1	5689	18.79	1422250	2133375	12000	3000000	4500000
22	Urban	WS_Zone - 14	107 6	Municipal	1	5	5 4		0	0		Residential	1	15658	145 54	3914500	5871750	14000	3500000	5250000
23	Urban	WS_Zone - 10 (Suhlar)	55.1	Private	3	0	0		0	0		Residential	1	0	0	0	0	1000	250000	375000
24	Urban	WS_Zone - 12 (Jhill & Alipur)	279 1	Private	3	0	0		0	0		Residential	1	289	1.04	72250	108375	8000	2000000	3000000
25	Urban	WS_Zone - 13	251.6	Private	3	0	0		0	0		Residential	1	2844	0	711000	1066500	7000	1750000	2625000
26	Urban	Bahadurgarh	4 6	Municipal	1	0	0		0	0		Commercial	2	0	0	3159 28	4738.92		3159.28	4738 92
27	Urban	Sanaur	29.6	Municipal	1	0	0		0	0		Commercial	2	0	0	20139 56	30209.34		20139.56	30209.34
28	Urban	Sanaur	8.6	Municipal	1	0	0		0	0		Commercial	2	0	0	5842 56	8763.84		5842 56	8763 84
29	Urban	Ubban Estates	310 2	Independent	1	4	4.32		4	4 32		Residential	1	11145	35 93	2786250	4179375	18000	4500000	6750000
30	Urban	PDA Estate Baran (SEZ)	229.8	Independent	1	2	2 16		2	2.16		Industrial	3	0	0	10341945	15512917.5		10341945	15512917 5
			4993.3			**116**	125.28		**62**	56 16				**328191**		**79290641.4**	**118935962.1**	**416970**	**114363686.4**	**171645379.6**
										0 58				334819						

ANNEXURE - II

	Urban Areas With Public Institutional Water Supply													Urban Areas With Public Institutional Water Supply						
S No	Area_Chara	Name_Of_Ar	Area in Hectares	Ws_type	Wsup_type	Tubewells_2010	Available Supply		Tubewells _2001			Land_Use	Landuse	Popu_2001	Density	Water Demand 2001	Peak Demand 2001	Popu_2010	Demand 2010	Peak Demand 2010
1	Urban	DCW	30 1	Independent	2	1	1 08		1	1 08		Residential	1	878	29 16	219500	329250	900	225000	337500
2	Urban	DCW	84 8	Independent	2	1	1 08		1	1 08		Residential	1	5750	67 85	1437500	2156250	5750	1437500	2156250
3	Urban	FCI Godowns	14 4	Independent	2	1	1 08		1	1 08		Commercial	2	0	0	9766.84	14650.26		9766 84	14650 26
4	Urban	Grain Market	13 8	Independent	2	1	1 08		1	1 08		Commercial	2	0	0	9367	14050 5		9367	14050 5
5	Urban	DCW	92 1	Independent	2	1	1 08		1	1 08		Industrial	3	0	0	4143645	6215467 5		4143645	6215467 5
6	Urban	Escorts	45 6	Independent	2	2	2 16		2	2 16		Industrial	3	0	0	2050245	3075367 5		2050245	3075367 5
7	Urban	Focal Point	72 1	Independent	2	2	2 16		2	2 16		Industrial	3	0	0	3242610	4863915		3242610	4863915
8	Urban	Verka Milk Plant	12 1	Independent	2	2	2 16		2	2 16		Industrial	3	0	0	544005	816007.5		544005	816007 5
9	Urban	Ablowal_Substation	28 0	Independent	2	1	1 08		1	1 08		Public/Semi-Pub	4	0	0	19054.96	28582.44		19054 96	28582 44
10	Urban	Cantonement	12 2	Independent	2	1	1 08		1	1 08		Public/Semi-Pub	4	0	0	0	0		8293.96	12440 94
11	Urban	Cantonement	1452 6	Independent	2	13	14 04		10	10.8		Public/Semi-Pub	4	20000	13 77	5987787 04	8981680.56		987787 04	1481680 56
12	Urban	Cantonement	12 4	Independent	2	1	1.08		1	1 08		Public/Semi-Pub	4	0	0	0	0		8424.52	12636 78
13	Urban	Central Jail	55 5	'Independent	2	2	2 16		1	1 08		Public/Semi-Pub	4	0	0	37767 88	56651 82		37767 88	56651 82
14	Urban	Fort Bahadurgarh	33 5	Independent	2	1	1 08		1	1 08		Public/Semi-Pub	4	0	0	22778.64	34167.96		22778.64	34167 96
15	Urban	Gurdwara Dukhniwaran Sahib	6.6	Independent	2	2	2 16		2	2 16		Public/Semi-Pub	4	0	0	4468 28	6702 42		4468.28	6702 42
16	Urban	Irrigation Department	46.0	Independent	2	2	2 16		2	2 16		Public/Semi-Pub	4	0	0	31252 8	46879.2		31252.8	46879.2
17	Urban	ITBP	17.6	Independent	2	1	1.08		1	1 08		Public/Semi-Pub	4	0	0	11952 36	17928 54		11952.36	17928.54
18	Urban	NIS	119.6	Independent	2	5	5.4		5	5 4		Public/Semi-Pub	4	0	0	81300.12	121950 18		81300.12	121950.18
19	Urban	PAP	38 0	Independent	2	1	1 08		1	1 08		Public/Semi-Pub	4	0	0	25871 28	38806 92		25871.28	38806.92
20	Urban	Police Lines	38 2	Independent	2	1	1 08		1	1.08		Public/Semi-Pub	4	0	0	25973 96	38960.94		25973 96	38960 94
21	Urban	Punjabi University	141 0	Independent	2	3	3 24		3	3.24		Public/Semi-Pub	4	0	0	95909.24	143863.86		95909 24	143863 86
22	Urban	Rajindra Hospital & Medical College	34 4	Independent	2	4	4 32		3	3 24		Public/Semi-Pub	4	0	0	23384.52	35076 78		23384.52	35076 78
23	Urban	Thapar College	105.8	Independent	2	3	3 24		3	3 24		Public/Semi-Pub	4	0	0	71969 16	107953 74		71969 16	107953 74
24	Urban	DCW	50 0	Independent	2	1	1 08		1	1 08		Recreation	5	0	0	841876.55	1262814.825		841876 55	1262814 825
25	Urban	PRTC Work Shop	1 2	Independent	2	1	1.08		1	1.08		Transportation	6	0	0	809.2	1213 8		809.2	1213.8
26	Urban	PRTC Workshop	6 1	Independent	2	1	1.08		1	1 08		Transportation	6	0	0	4121 48	6182 22		4121 48	6182 22
27	Urban	Railway Station & Bus Stand	36 8	Independent	2	2	2 16		2	2 16		Transportation	6	0	0	25027 4	37541.1		25027 4	37541.1
28	Urban	Truck Union	21 3	Independent	2	1	1 08		1	1 08		Transportation	6	0	0	14508 48	21762.72		14508.48	21762 72
			2621.6			**43**	**46.44**		**41**	**44.28**						**18982452.19**	**28473678.29**		**14004670.67**	**21007006.01**

ANNEAURE - II

Urban Areas With Private Water Supply

S No.	Area_Chara	Name_Of_Ar	Area in Hectares	Ws_type	Wsup_type	Tubewells_2010	Available Supply	Tubewells_2001	Land_Use	Landuse	Popu_2001	Density	Water Demand 2001	Peak Demand 2001	Popu_2010	Water Demand 2010	Peak Demand 2010	Water Demand 2001 DTS
1	Urban	Nasirpur	46.2	Private	3	0		0	Undeveloped	0	0	0	0	0	1000		0	0
2	Urban		6 4	Private	3	0		0	Residential	1	0	0	0	0			0	0
3	Urban	Alipur	102 5	Private	3	0		0	Residential	1	426	4 16	106500	159750	4000	1000000	1500000	89460
4	Urban	Bahadurgarh	2 6	Private	3	0		0	Residential	1	9	3.42	2250	3375	20	5000	7500	1890
5	Urban	Century Enclave	32 8	Private	3	0		0	Residential	1	0	0	0	0	4000	1000000	1500000	0
6	Urban	Chaura	218 6	Private	3	0		0	Residential	1	2263	10.35	565750	848625	5000	1250000	1875000	475230
7	Urban	Hira Bagh	29 3	Private	3	0		0	Residential	1	2411	82 27	602750	904125	5000	1250000	1875000	506310
8	Urban	Mehmudpur	10.8	Private	3	0		0	Residential	1	405	37 48	101250	151875	500	125000	187500	85050
9	Urban	Nasirpur	18 9	Private	3	0		0	Residential	1	72	3 81	18000	27000	100	25000	37500	15120
10	Urban	Nasirpur	142 6	Private	3	0		0	Residential	1	0	0	0	0	2000	500000	750000	0
11	Urban	Nasirpur	6.6	Private	3	0		0	Residential	1	201	30 68	50250	75375	0	0	0	42210
12	Urban	Rai Majra	146 3	Private	3	0		0	Residential	1	106	0 72	26500	39750	1000	250000	375000	22260
13	Urban	Sadhu Bela	5.6	Private	3	0		0	Residential	1	38	6.83	9500	14250	50	12500	18750	7980
14	Urban	Sadhu Bela	1 4	Private	3	0		0	Residential	1	0	0	0	0	0	0	0	0
15	Urban	Tafajalpura	5.4	Private	3	0		0	Residential	1	269	50	67250	100875	1000	250000	375000	56490
16	Urban	Tafajalpura	18.3	Private	3	0		0	Residential	1	0	0	0	0	2000	500000	750000	0
17	Urban	Tafajalpura	99 9	Private	3	0		0	Residential	1	0	0	0	0	0	0	0	0
18	Urban	WS_Zone - 10 (Bir Kheri Gujjar)	36 5	Private	3	0		0	Residential	1	0	0	0	0	500	125000	187500	0
19	Urban	WS_Zone - 10 (Bir Moti Bagh)	17.0	Private	3	0		0	Residential	1	44	2 58	11000	16500		0	0	9240
20	Urban	WS_Zone - 10 (Suhlar)	55 1	Private	3	0		0	Residential	1	0	0	0	0	1000	250000	375000	0
21	Urban	WS_Zone - 12 (Jhill & Alipur)	279.1	Private	3	0		0	Residential	1	289	1.04	72250	108375	8000	2000000	3000000	60690
22	Urban	WS_Zone - 13	251 6	Private	3	0		0	Residential	1	0	0	0	0	8000	2000000	3000000	0
23	Urban		0 2	Private	3	0		0	Commercial	2	0	0	150.96	226.44		150 96	226.44	150 96
24	Urban		2.9	Private	3	0		0	Commercial	2	0	0	1957.72	2936.58		1957.72	2936.58	1957 72
25	Urban	Bir Moti Bagh (WS_Zone - 10)	18 8	Private	3	0		0	Commercial	2	0	0	12758 84	19138.26		12758.84	19138 26	12758 84
26	Urban	Hira Bagh	14.1	Private	3	0		0	Commercial	2	0	0	9575.08	14362.62		9575.08	14362.62	9575 08
27	Urban	Petrol Pump	0 5	Private	3	0		0	Commercial	2	0	0	331 84	497 76		331 84	497 76	331 84
28	Urban	Apollo School	8.5	Private	3	1		0	Public/Semi-Pub	4	0	0	5756 2	8634 3		5756 2	8634.3	5756 2
29	Urban	Gurdwara	0.6	Private	3	0		0	Public/Semi-Pub	4	0	0	400.52	600.78		400.52	600.78	400 52
30	Urban	Gurdwara	5 6	Private	3	0		0	Public/Semi-Pub	4	0	0	3777 4	5666.1		3777 4	5666 1	3777.4
31	Urban	Hira Bagh	3 3	Private	3	0		0	Public/Semi-Pub	4	0	0	2237 2	3355 8		2237 2	3355.8	2237 2
32	Urban	Marriage Palace	1 4	Private	3	0		0	Public/Semi-Pub	4	0	0	954 04	1431 06		954 04	1431 06	954 04
33	Urban	Radha Soami Satsang Beas	18 0	Private	3	2		1	Public/Semi-Pub	4	0	0	12251.56	18377.34		12251 56	18377 34	12251 56
34	Urban	Tung Nath Mandir	4 6	Private	3	0		0	Public/Semi-Pub	4	0	0	3134 8	4702 2		3134 8	4702.2	3134 8
35	Urban	Forest	21.1	Private	3	0		0	Forest	8	0	0	0	0			0	0
			1612.0			**374**		**237**			**13161**		**1686536.16**	**2529804.24**	**43170**	**10696786.16**	**15893679.24**	
															466790			

ANNEXURE - III

Urban Areas with Municipal Sewerage Network

S.No	Hectares	Area	Perimeter	Area_Chare	Name_Of_Ar	Land_Use	Landuse	Popu_2001	Gross_Dens	Popu_2010	Ws_type	Wsup_type	Method_Of_Disposal	Point_Of_Disposal	Sew_Networ	SNet_Type	Density	Popu_134 ppha	Pop in 2010 Approx	Popu can be adjusted	Area_Not_R	Net_Resi	Density	Houses_01	Plot_Size
1	55.541	0.555	3.098	Urban	Central Jail	Public/Semi-Publi	4	0	0	0	Municipal	1	Aerobic Pond	Tripuri Disp	Independe	2					0	55.54	0	0	0
2	45.96	0.46	3.399	Urban	Irrigation Departm	Public/Semi-Publi	4	0	0	0	Municipal	1	Aerobic Pond	Tripuri Disp	Independe	2					0	45.96	0	0	0
3	38.197	0.382	2.581	Urban	Police Lines	Public/Semi-Publi	4	0	0	0	Municipal	1	Aerobic Pond	Tripuri Disp	Independe	2					0	38.2	0	0	0
4	400.352	4.004	8.749	Urban	Zone_A	CBD	1	75436	188.42	0	Municipal	1	CST	Bhoot Nath	Municipal	1	188.4242		75436		291	109.35	689.86	13097	83.49
5	94.671	0.947	4.046	Urban	Zone_B (Anand N	Residential	1	2845	30.05	0	Municipal	1	CST	Tripuri Disp	Municipal	1	30.05144	12307	9000	9462	39	65.17	43.66	494	1319.23
6	165.992	1.66	5.956	Urban	Zone_B (Indra Co	Residential	1	5487	33.06	0	Municipal	1	CST	Yadwindra	Private	0	33.05581	21579	10000	16092	37.2	149.39	36.73	953	1567.58
7	307.798	3.078	9.008	Urban	Zone_B (Tripuri)	Residential + Com	1	39993	129.93	0	Municipal	1	CST	Tripuri Disp	Municipal	1	129.9326	40014	42000		107.2	231.4	172.83	6943	333.29
8	198.02	1.98	6.803	Urban	Zone_B (Yadwind	Resi + Industrial	1	18916	95.53	0	Municipal	1	CST	Yadwindra	Municipal	1	95.5257	25743	19000		144.7	73.12	258.7	3284	222.66
9	1261.163	12.612	26.209	Urban	Zone_C	Residential	1	70565	55.95	0	Municipal	1	CST	Bhoot Nath	Municipal	1	55.95232	163951	100000	93386	610.3	863.51	82.42	12251	704.85
10	380.299	3.803	9.929	Urban	Zone_D	Residential	1	42261	111.13	0	Municipal	1	CST	Rajpura Co	Municipal	1	111.1257	49439	50000	7178	124.7	293.6	143.94	7337	400.16
11	168.915	1.689	6.027	Urban	Zone_E	Residential	1	3741	22.15	0	Municipal	1	CST	Rajpura Co	Municipal	1	22.14723	21959	4000		143	51.41	72.77	649	792.14
12	107.587	1.076	5.739	Urban	Zone_F	Residential + Tran	1	15658	145.54	0	Municipal	1	CST	Rai Majra D	Private	0	145.538	13986	14000		21.5	96.79	161.77	2718	356.11
13	2950.916	·						253757										348978	299436	126118					
14	3224.496							274902											323436						
																				388639					

ANNEXURE - III

Urban Areas Without Sewerage Network

S.No	Hectares	Area	Perimeter	Area_Chare	Name_Of_Ar	Land_Use	Landuse	Popu_2001	Gross_Dens	Popu_2010	Ws_type	Wsup_type	Method_Of_Disposal	Point_Of_Disposal	Sew_Networ	SNet_Type	Density	Popu_134 ppha	Pop in 2010 Approx	Popu can be adjusted	Area_Not_R	Net_Resi	Density	Houses_01	Plot_Size
1	18.763	0.188	2.579	Urban	Zone_F (Bir Mot	Commercial	2	0	0	0	Private	3	Septic Tanks	NIL	Private	0		0	0		0	25.71	53.25	0	0
2	17.023	0.17	2.761	Urban	Zone_F (Bir Mot	Residential	1	44	2.58	0	Private	3	Septic Tanks	NIL	Private	0		0	0		0	10.66	54.88	0	0
3	55.121	0.551	6.432	Urban	Zone_C (Suhlari)	Residential	1	0	0	0	Private	3	Septic Tanks	NIL	Private	0		7166	1000	7166	0	2.42	0	0	0
4	128.922	1.289	4.792	Urban	Zone_C (Century)	Residential	1	604	4.69	0	Private	3	Septic Tanks	NIL	Private	0		16760	4000	15156	0	1.5	11.33	0	0
5	36.543	0.365	6.181	Urban	Zone_C (Bir Kher	Residential	1	0	0	0	Private	3	Septic Tanks	NIL	Private	0		0	500	0	0	7.1	11.69	0	0
6	185.277	1.853	8.79	Urban	Zone_B (Rasulpu	Residential	1	9458	51.05	0	Private	3	Septic Tanks	NIL	Private	0		24086	11000	14628	0	4.43	6.55	0	0
7	279.149	2.791	13.627	Urban	Zone_B (Jhill & A	Residential	1	289	1.04	0	Private	3	Septic Tanks	NIL	Private	0		36289	8000	36000	0	8.24	0	0	0
8	251.644	2.516	18.836	Urban	Zone_B (Bhadson	Residential	1	0	0	0	Private	3	Septic Tanks	NIL	Private	0		32714	8000	32714	0	2.69	124.91	0	0
9	102.491	1.025	8.273	Urban	Zone_B (Alipur)	Residential	1	426	4.16	0	Private	3	Septic Tanks	NIL	Private	0		13324	4000	12898	0	1.27	208.66	0	0
10	208.095	2.081	7.817	Urban	Zone_B (Ablowal)	Residential	1	2844	13.67	0	Private	3	Septic Tanks	NIL	Private	0		27052	7000	24208	0	3.59	110.58	0	0
11	4.61	0.046	0.96	Urban	Tung Nath Mande	Public/Semi-Publi	4	0	0	0	Private	3	Septic Tanks	NIL	Private	0		0	0	0	0	2.69	0	0	0
12	118.873	1.189	19.462	Urban	Tafajalpura	Residential	1	269	2.26	0	Private	3	Septic Tanks	NIL	Private	0		15453	3000	15184	0	6.56	23.02	0	0
13	21.966	0.22	5.23	Urban	Sheikhupur	Residential	1	2532	115.27	0	Private	3	Septic Tanks	NIL	Private	0		2856	2600	324	0	1.52	5.26	0	0
14	71.039	0.71	7.185	Urban	Sanaur	Residential	1	921	12.96	0	Private	3	Septic Tanks	NIL	Private	0		9235	5000	8314	0	2.29	10.48	0	0
15	258.324	2.583	18.514	Urban	Sanaur	Residential	1	17014	65.87	0	Private	3	Septic Tanks	NIL	Private	0		33582	20000	16568	0	6.66	0	0	0
16	5.567	0.056	1.259	Urban	Sadhu Bela	Residential	1	38	6.83	0	Private	3	Septic Tanks	NIL	Private	0		724	100	686	0	23.82	100.92	0	0
17	1.427	0.014	0.514	Urban	Sadhu Bela	Residential	1	0	0	0	Private	3	Septic Tanks	NIL	Private	0		186	0	186	0	23.71	40.11	0	0
18	146.281	1.463	8.383	Urban	Rai Majra	Residential	1	106	0.72	0	Private	3	Septic Tanks	NIL	Private	0		19017	1000	18911	0	14.78	78.62	0	0
19	18.017	0.18	2.21	Urban	Radha Soami Sat	Public/Semi-Publi	4	0	0	0	Private	3	Septic Tanks	NIL	Private	0		0	0	0	0	30.47	44.54	0	0
20	18.878	0.189	2.622	Urban	Nasirpur	Residential	1	116	6.14	0	Private	3	Septic Tanks	NIL	Private	0		2454	1000	2338	0	43.09	57	0	0
21	152.039	1.52	8.559	Urban	Nasirpur	Residential	1	0	0	0	Private	3	Septic Tanks	NIL	Private	0		19765	1000	19765	0	5.23	21.99	0	0
22	10.806	0.108	1.35	Urban	Mehmudpur	Residential	1	405	37.48	0	Private	3	Septic Tanks	NIL	Private	0		1405	500	1000	0	1.16	15.52	0	0
23	60.455	0.605	5.786	Urban	Hira Nagar	Residential	1	2411	39.88	0	Private	3	Septic Tanks	NIL	Private	0		7859	5000	5448	0	20.41	52.13	0	0
24	5.555	0.056	1.508	Urban	Gurdwara	Public/Semi-Publi	4	0	0	0	Private	3	Septic Tanks	NIL	Private	0		0	0	0	0	1.32	0	0	0
25	218.581	2.186	15.058	Urban	Chaura	Residential	1	2263	10.35	0	Private	3	Septic Tanks	NIL	Private	0		28416	5000	26153	0	6.73	101.63	0	0
26	2.632	0.026	0.676	Urban	Bahadurgarh	Residential	1	9	3.42	0	Private	3	Septic Tanks	NIL	Private	0		342	50	333	0	3.73	26.27	0	0
27	89.324	0.893	7.986	Urban	Bahadurgarh	Residential	1	8170	91.46	0	Private	3	Septic Tanks	NIL	Private	0		11612	10000	3442	14.2	63.94	14.4	160	3996.25
28	8.465	0.085	1.518	Urban	Apollo School	Public/Semi-Publi	4	0	0	0	Private	3	Septic Tanks	NIL	Private	0		0	0	0	0	16.73	91.81	0	0
	2495.867							47919										310296	97750	262421					
																			421186						

ANNEXURE - III

Urban Areas with Independent Sewerage Disposal

S.No.	Hectares	Area	Perimeter	Area_Chare	Name_Of_Ar	Land_Use	Landuse	Popu_2001	Gross_Dens	Popu_2010	Ws_type	Wsup_type	Method_Of_Disposal	Point_Of_Disposal	Sew_Networ	SNet_Type	Density	Popu_134 ppha	Pop in 2010 Approx	Popu can be adjusted	Area_Not_R	Net_Resi	Density	Houses_01	Plot_Size
1	119.559	1.196	4.9	Urban	NIS	Public/Semi-Publi	4	0	0	0	Independent	2	Aerobic Pond	On Site	Independe	2			0		0	119.56	0	0	0
2	45.561	0.456	6.394	Urban	Escorts	Industrial	3	0	0	0	Independent	2	Active Sludge T	Philauli Dr	Independe	2			0		0	45.56	0	0	0
3	38.046	0.38	2.691	Urban	PAP	Public/Semi-Publi	4	0	0	0	Independent	2	Aerobic Pond	On Site	Independe	2			0		0	38.05	0	0	0
4	33.498	0.335	2.173	Urban	Fort Bahadurgarh	Public/Semi-Publi	4	0	0	0	Independent	2	Aerobic Pond	On Site	Independe	2			0		0	33.5	0	0	0
5	17.577	0.176	2.021	Urban	ITBP	Public/Semi-Publi	4	0	0	0	Independent	2	Aerobic Pond	On Site	Independe	2			0		0	17.58	0	0	0
6	12.089	0.121	1.803	Urban	Verka Milk Plant	Industrial	3	0	0	0	Independent	2	Active Sludge T	On Site	Independe	2			0		0	12.09	0	0	0
7	72.058	0.721	3.912	Urban	Focal Point	Industrial	3	0	0	0	Independent	2	Active Sludge T	Patialwi Na	Independe	2			0		0	72.06	0	0	0
8	105.837	1.058	4.271	Urban	Thapar College	Public/Semi-Publi	4	0	0	0	Independent	2	Active Sludge T	On Site	Independe	2			0		0	105.84	0	0	0
9	92.081	0.921	4.009	Urban	DCW	Industrial	3	0	0	0	Independent	2	Primary Treatm	Patialwi Na	Independe	2			0		0	92.08	0	0	0
10	30.113	0.301	3.17	Urban	DCW	Residential	1	878	29.16	0	Independent	2	Primary Treatm	Patialwi Na	Independe	2			878		0.62	27.01	32.51	152	1776.97
11	84.75	0.847	3.881	Urban	DCW	Residential	1	5750	67.85	0	Independent	2	Primary Treatm	Patialwi Na	Independe	2			5750		17	76.25	75.41	998	764.03
12	49.963	0.5	4.131	Urban	DCW	Recreation	5	0	0	0	Independent	2	Primary Treatm	Patialwi Na	Independe	2			0		0	49.96	0	0	0
13	141.043	1.41	4.772	Urban	Punjabi University	Public/Semi-Publi	4	0	0	0	Independent	2	Active Sludge T	Philauli Dr	Independe	2			0		0	141.04	0	0	0
14	1452.628	14.526	22.89	Urban	Cantonement	Public/Semi-Publi	4	20000	13.77	0	Independent	2	CST	Jacob & M	Independe	2			20000		0	1452.63	13.77	3472	0
15	28.022	0.28	2.055	Urban	Ablowal_Substati	Public/Semi-Publi	4	0	0	0	Independent	2	Aerobic Pond	On Site	Independe	2			0		0	28.02	0	0	0
16	310.204	3.102	11.168	Urban	Ubban Estates	Residential	1	11145	35.93	0	PUDA	2	Active Sludge T	Land Treat	PUDA	1			18000		212	129.1	86.33	1935	667.18
17	229.821	2.298	8.766	Urban	PUDA Estate Bar	Industrial	3	0	0	0	PUDA	2	Active Sludge T	Land Treat	PUDA	1			0		0	229.82	0	0	0
18	33.482	0.335	4.593	Urban	Railway Station	Transportation	6	0	0	0	Independent	2	Primary Treatm	Chotti Nadi	Independe	2			0		0	33.48	0	0	0
19	2896.332							17773											24628						
20	5847.248							271530											324064						

ANNEXURE - III

Rural Areas Without any Sewerage Network

S.No	Hectares	Area	Perimeter	Area_Chara	Name_Of_Ar	Land_Use	Landuse	Popu_2001	Gross_Dens	Popu_2010	Ws_type	Wsup_type	Method_Of_Disposal	Point_Of_Disposal	Sew_Networ	SNet_Type	Density	Popu_134ppha	Pop in 2010 Approx	Popu can be adjusted	Area_Not_R	Net Resi	Density	Houses_01	Plot_Size
1	25.71	0.257	4.989	Rural	Rauni	Residential	1	1369	0	0	Private	3				0			1643		0	28.73	0	0	0
2	10.656	0.107	2.225	Rural	Rauni	Residential	1	585	0	0	Private	3				0			702		0	18.34	73.39	0	0
3	2.423	0.024	0.76	Rural	Dalanpur	Industrial	3	0	0	0	Private	3				0			0		0	62.72	37.23	0	0
4	1.498	0.015	0.558	Rural	Ghalaun	Residential	1	17	0	0	Private	3				0			20		0	12.67	125.02	0	0
5	7.097	0.071	1.038	Rural	Budhanpur	Residential	1	83	0	0	Private	3				0			100		0	17.83	18.9	0	0
6	4.434	0.044	0.982	Rural	Budhanpur	Residential	1	29	0	0	Private	3				0			35		0	13.5	79.41	0	0
7	8.237	0.082	1.872	Rural	Budhanpur	Industrial	3	0	0	0	Private	3				0			0		0	26.54	0	0	0
8	2.693	0.027	0.729	Rural	Mithu Majra	Residential	1	336	0	0	Private	3				0			403		0	32.3	32.48	0	0
9	1.266	0.013	0.483	Rural	Mithu Majra	Residential	1	265	0	0	Private	3				0			318		0	5.24	109.92	0	0
10	3.59	0.036	0.727	Rural	Bir Bahadurgarh	Residential	1	397	0	0	Private	3				0			476		0	9.59	117.41	0	0
11	2.691	0.027	0.656	Rural	Hassanpur	Residential	1	0	0	0	Private	3				0			0		0	7.09	98.58	0	0
12	6.556	0.066	1.408	Rural	Sidhuwal	Residential	1	151	0	0	Private	3				0			181		0	6.49	94.45	0	0
13	1.521	0.015	0.79	Rural	Sidhuwal	Residential	1	8	0	0	Private	3				0			10		0	5.42	66.42	0	0
14	2.292	0.023	0.634	Rural	Jassowal	Residential	1	24	0	0	Private	3				0			29		0.5	2.33	3.86	2	11650
15	6.662	0.067	1.566	Rural	Bhathian (Brick K	Industrial	3	0	0	0	Private	3				0			0		0	8.46	0	0	0
16	23.821	0.238	2.587	Rural	Pasiana	Residential	1	2404	0	0	Private	3				0			2885		0	5.84	33.39	0	0
17	23.712	0.237	3.253	Rural	Sher Majra	Residential	1	951	0	0	Private	3				0			1141		0	4.61	0	0	0
18	14.782	0.148	2.606	Rural	Jassowal	Residential	1	1162	0	0	Private	3				0			1394		0	18.02	0	0	0
19	30.465	0.305	3.723	Rural	Sidhuwal	Residential	1	1357	0	0	Private	3				0			1628		0	3.31	54.08	0	0
20	43.085	0.431	5.191	Rural	Seuna	Residential	1	2456	0	0	Private	3				0			2947		0.6	4.97	7.65	7	7100
21	5.234	0.052	0.988	Rural	Kulla Majra	Residential	1	115	0	0	Private	3				0			138		0	5.55	0	0	0
22	1.157	0.012	0.462	Rural	Kulla Majra	Residential	1	18	0	0	Private	3				0			22		0	4.65	0	0	0
23	20.406	0.204	3.013	Rural	Sunainhen	Residential	1	1064	0	0	Private	3				0			1277		0	93.6	28.54	0	0
24	1.316	0.013	0.494	Rural	Khansa	Industrial	3	0	0	0	Private	3				0			0		0	5.84	0	0	0
25	6.727	0.067	1.214	Rural	Khansa	Residential	1	684	0	0	Private	3				0			821		0	35.84	8.87	0	0
26	3.733	0.037	0.826	Rural	Kulla Majra	Residential	1	98	0	0	Private	3				0			118		0	14.5	12.97	0	0
27	16.735	0.167	1.765	Rural	Nurkherian	Residential	1	1536	0	0	Private	3				0			1843		0	62.2	20.69	0	0
28	28.729	0.287	4.62	Rural	Nurkherian	Industrial	3	0	0	0	Private	3				0			0		0	10.95	0	0	0
29	18.343	0.183	2.457	Rural	Jalalpur	Residential	1	1346	0	0	Private	3				0			1615		0	11.57	0	0	0
30	62.722	0.627	7.607	Rural	Raipur	Residential	1	2335	0	0	Private	3				0			2802		0	8.68	83.29	0	0
31	12.672	0.127	2.263	Rural	Shamspur	Residential	1	1584	0	0	Private	3				0			1901		0	25.29	27.92	0	0
32	17.829	0.178	3.242	Rural	Bhathian	Residential	1	337	0	0	Private	3				0			404		0	18.76	0	0	0
33	13.497	0.135	3.258	Rural	Ramgarh	Residential	1	1072	0	0	Private	3				0			1286		1.1	15.32	2.87	8	19150
34	26.541	0.265	2.758	Rural	Rauni	Industrial	3	0	0	0	Private	3				0			0		0	17.28	48.21	0	0
35	32.302	0.323	3.861	Rural	Ucha Gaon	Residential	1	1049	0	0	Private	3				0			1259		0	51.6	0	0	0
36	5.243	0.052	0.924	Rural	Kartarpur	Residential	1	576	0	0	Private	3				0			691		0	6.5	3.54	0	0
37	9.594	0.096	1.249	Rural	Asarpur	Residential	1	1126	0	0	Private	3				0			1351		0	5.06	0	0	0
38	7.09	0.071	1.772	Rural	Mehmadpur	Residential	1	699	0	0	Private	3				0			839		0	33.07	9.5	0	0
39	6.486	0.065	1.133	Rural	Safidpur	Residential	1	613	0	0	Private	3				0			736		43.7	196.68	11.51	393	5004.58
40	5.424	0.054	1.275	Rural	Daulatpur	Residential	1	360	0	0	Private	3				0			432		0	27.55	0	0	0
41	5.838	0.058	1.334	Rural	Hassanpur	Residential	1	195	0	0	Private	3				0			234		3	1.23	0	0	
42	3.31	0.033	0.747	Rural	Hazi Majra	Residential	1	179	0	0	Private	3				0			215		3.8	16.98	4.24	20	8490
43	4.652	0.047	0.974	Rural	Dalanpur	Industrial	3	0	0	0	Private	3				0			0		2.2	9.71	41.71	70	1387.14
44	93.601	0.936	5.434	Rural	Baran	Residential	1	2671	0	0	Private	3				0			3205		0	141.06	4.43	0	0
45	5.842	0.058	1.336	Rural	Malo Majra	Commercial	2	0	0	0	Private	3				0			0		0	58.34	2.16	0	0
46	35.84	0.358	3.31	Rural	Malo Majra	Residential	1	318	0	0	Private	3				0			382		0	12.16	2.14	0	0
47	14.502	0.145	3.958	Rural	Malo Majra	Residential	1	188	0	0	Private	3				0			226		0	1.94	18.04	0	0
48	62.197	0.622	5.543	Rural	Zone_C (Dhamo I	Residential	1	1287	0	0	Private	3				0			1544		7.3	32.84	0	0	
49	10.947	0.109	1.606	Rural	Rauni	Public/Semi-Publi	4	0	0	0	Private	3				0			0		11	49.62	0	0	
50	11.574	0.116	2.166	Rural	Pasiana	Industrial	3	0	0	0	Private	3				0			0		29.3	130.68	0.81	18	72600
51	8.677	0.087	2.257	Rural	Rawas Brahamar	Residential	1	723	0	0	Private	3				0			868		59.5	144.28	65.55	1642	878.68
52	25.294	0.253	6.9	Rural	Sher Majra	Residential	1	706	0	0	Private	3				0			847		50.3	226.44	0	0	
53	17.279	0.173	3.507	Rural	Khera Jattan	Residential	1	833	0	0	Private	3				0			1000		55.8	251.25	1.15	50	50250
54	51.596	0.516	5.524	Rural	Ghalaun	Industrial	3	0	0	0	Private	3				0			0		20.8	81.69	5.21	74	11039.19
55	6.499	0.065	1.211	Rural	Ghalaun	Residential	1	23	0	0	Private	3				0			28		51.6	177.29	16.04	494	3588.87
56	5.058	0.051	0.991	Rural	Ghalauri	Industrial	3	0	0	0	Private	3				0			0		31.5	35.06	68.77	419	836.75
57	33.068	0.331	5.207	Rural	Ghalaun	Residential	1	314	0	0	Private	3				0			377		23.8	106.97	2.51	47	22759.57
58	27.55	0.275	3.489	Rural	Hassanpur	Residential	1	0	0	0	Private	3				0			0		30.4	136.84	0	0	
59	141.064	1.411	6.658	Rural	Dhiwal	Residential	1	625	0	0	Private	3				0			750		13.6	75.72	0	1418	0
60	58.338	0.583	6.891	Rural	Dalanpur	Residential	1	126	0	0	Private	3				0			151		64.6	194.32	0	0	
61	12.158	0.122	2.638	Rural	Ghalaun	Residential	1	26	0	0	Private	3				0			31		0	33.41	75.79	0	0
62	1.94	0.019	0.576	Rural	Sunainhen	Residential	1	35	0	0	Private	3				0			42		4.4	19.77	128.07	440	449.32
63	33.413	0	0.015	Rural	Sheikhupur	Residential	1	2532	0	0	Private	3				0			3038		92.3	36.62	16.49	105	3487.62
	1196.208							36987											44384						

9811.902

ANNEXURE - IV

Table1 : CALCULATIONS FOR CATCHMENT (A) USING SCS METHOD, YEAR 1951

	Type Of soil	Total Dev. Area (KM^2)	Pervious	% Of Total Area	CN(p)	Impervious	% Of Total Area	CN (Im)	WCN	L	WCN	Y(Slope)	tL	tp(per)=(D/2+tL)	Qp	Potential Maximum Retention, S	Initial Abstraction, I	Excess Rainfall	
A	Sandy Loam, A	5.44356	1.61476	29.66	39	3.8288	70.34	98	80.50	3610	80.50	0.002	5.053376	8.053	3.623	61.534	12.3068	68.5	A
B	Sandy Loam, A	19.39638	16.05048	82.75	32	3.3459	17.25	61	37.00	9130	37.00	0.003	27.73147	30.731	3.383	432.439	86.4879	2.4	B
C	Sandy Loam, A	9.48578	8.63328	91.01	58	0.8525	8.99	54	57.64	3170	57.64	0.003	6.941748	9.942	5.114	186.662	37.3325	25.4	C
D	Sandy Loam, A	11.63922	10.92022	93.82	32	0.719	6.18	54	33.36	4860	33.36	0.003	18.62124	21.621	2.885	507.413	101.4826	0.7	D
E	Sandy Loam, A	9.49981	9.37961	98.73	58	0.1202	1.27	54	57.95	5220	57.95	0.003	10.26531	13.265	3.839	184.314	36.8627	25.8	E
F	Sandy Loam, A	28.03928	27.05528	96.49	30	0.984	3.51	51	30.74	7020	30.74	0.003	27.08563	30.086	4.995	572.367	114.4733	0.1	F
G	Sandy Loam, A	20.42382	19.87602	97.32	32	0.5478	2.68	51	32.51	9270	32.51	0.003	32.02636	35.026	3.125	527.307	105.4615	0.4	G
H	Silt Loam, B	1.24031	1.24031	100.00	58	0	0.00	68	58.00	1980	58.00	0.003	4.720769	7.721	0.861	183.931	36.7862	25.9	H
I	Silt Loam, B	4.20418	4.20418	100.00	58	0	0.00	68	58.00	3640	58.00	0.003	7.683546	10.684	2.109	183.931	36.7862	25.9	I
J	Sandy Loam, A	32.4252	32.113	99.04	58	0.3122	0.96	51	57.93	8730	57.93	0.003	15.49641	18.496	9.396	184.441	36.8881	25.8	J
K	Silt Loam, B	2.65092	2.62502	99.02	58	0.0259	0.98	68	58.10	3200	58.10	0.002	8.467882	11.468	1.239	183.195	36.6389	26.1	K
L	Silt Loam, B	4.752	4.6482	97.82	58	0.1038	2.18	68	58.22	3190	58.22	0.003	6.875709	9.876	2.579	182.288	36.4576	26.3	L
M	Sandy Loam, A	68.70675	67.93965	98.88	58	0.7671	1.12	68	58.11	19710	58.11	0.003	29.59413	32.594	11.299	183.090	36.6179	26.1	M
N	Silt Loam, B	8.03305	7.87295	98.01	32	0.1601	1.99	68	32.72	5410	32.72	0.003	20.68516	23.685	1.818	522.343	104.4687	0.4	N
		225.94026	**214.17296**	**94.79**		**11.7673**	**5.21**												

Table 2: Dimensionless Unit Hydrograph, Year 1951 – 1

			Drainage_Area_A			Drainage_Area_B			Drainage_Area_C			Drainage_Area_D		
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	8.22	2.01	29.78	0.288	7.683	0.974	3.048	2.486	15.587	0.084	5.405	0.242
5.	0.50	0.43	29.46	4.03	106.72	1.032	15.366	3.491	10.922	4.971	55.855	0.301	10.811	0.868
6.	0.75	0.83	56.86	6.04	205.99	1.992	23.048	6.739	21.082	7.457	107.813	0.581	16.216	1.676
7.	1.00	1.00	68.50	8.05	248.18	2.400	30.731	8.119	25.400	9.942	129.896	0.700	21.621	2.020
8.	1.25	0.88	60.28	10.07	218.39	2.112	38.414	7.145	22.352	12.428	114.308	0.616	27.026	1.777
9.	1.50	0.66	45.21	12.08	163.80	1.584	46.097	5.359	16.764	14.913	85.731	0.462	32.432	1.333
10.	1.75	0.45	30.83	14.09	111.68	1.080	53.779	3.654	11.430	17.399	58.453	0.315	37.837	0.909
11.	2.00	0.32	21.92	16.11	79.42	0.768	61.462	2.598	8.128	19.884	41.567	0.224	43.242	0.646
12.	2.25	0.22	15.07	18.12	54.60	0.528	69.145	1.786	5.588	22.370	28.577	0.154	48.647	0.444
13.	2.50	0.15	10.28	20.13	37.23	0.360	76.828	1.218	3.810	24.855	19.484	0.105	54.053	0.303
14.	2.75	0.11	7.19	22.15	26.06	0.252	84.510	0.853	2.667	27.341	13.639	0.074	59.458	0.212
15.	3.00	0.08	5.14	24.16	18.61	0.180	92.193	0.609	1.905	29.826	9.742	0.053	64.863	0.151
16.	3.25	0.05	3.63	26.17	13.15	0.127	99.876	0.430	1.346	32.312	6.884	0.037	70.268	0.107
17.	3.50	0.04	2.47	28.19	8.93	0.086	107.559	0.292	0.914	34.797	4.676	0.025	75.674	0.073
18.	3.75	0.03	1.78	30.20	6.45	0.062	115.241	0.211	0.660	37.283	3.377	0.018	81.079	0.053
19.	4.00	0.02	1.23	32.21	4.47	0.043	122.924	0.146	0.457	39.768	2.338	0.013	86.484	0.036
20.	4.25	0.01	0.82	34.23	2.98	0.029	130.607	0.097	0.305	42.254	1.559	0.008	91.889	0.024
21.	4.50	0.01	0.62	36.24	2.23	0.022	138.290	0.073	0.229	44.739	1.169	0.006	97.295	0.018
22.	4.75	0.01	0.41	38.25	1.49	0.014	145.972	0.049	0.152	47.225	0.779	0.004	102.700	0.012
23.	5.00	0.00	0.27	40.27	0.99	0.010	153.655	0.032	0.102	49.710	0.520	0.003	108.105	0.008

Table 3: Dimensionless Unit Hydrograph, Year 1951 – 2

			Drainage_Area_E			Drainage_Area_F			Drainage_Area_G			Drainage_Area_H		
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	3.096	3.316	11.886	0.012	7.522	0.060	0.048	8.757	0.150	3.108	1.930	2.676
5.	0.50	0.43	11.094	6.633	42.590	0.043	15.043	0.215	0.172	17.513	0.538	11.137	3.861	9.589
6.	0.75	0.83	21.414	9.949	82.208	0.083	22.565	0.415	0.332	26.270	1.038	21.497	5.791	18.509
7.	1.00	1.00	25.800	13.265	99.046	0.100	30.086	0.500	0.400	35.026	1.250	25.900	7.721	22.300
8.	1.25	0.88	22.704	16.581	87.161	0.088	37.608	0.440	0.352	43.783	1.100	22.792	9.651	19.624
9.	1.50	0.66	17.028	19.898	65.370	0.066	45.129	0.330	0.264	52.539	0.825	17.094	11.582	14.718
10.	1.75	0.45	11.610	23.214	44.571	0.045	52.651	0.225	0.180	61.296	0.563	11.655	13.512	10.035
11.	2.00	0.32	8.256	26.530	31.695	0.032	60.172	0.160	0.128	70.052	0.400	8.288	15.442	7.136
12.	2.25	0.22	5.676	29.846	21.790	0.022	67.694	0.110	0.088	78.809	0.275	5.698	17.372	4.906
13.	2.50	0.15	3.870	33.163	14.857	0.015	75.215	0.075	0.060	87.565	0.188	3.885	19.303	3.345
14.	2.75	0.11	2.709	36.479	10.400	0.011	82.737	0.052	0.042	96.322	0.131	2.720	21.233	2.341
15.	3.00	0.08	1.935	39.795	7.428	0.008	90.258	0.037	0.030	105.078	0.094	1.943	23.163	1.672
16.	3.25	0.05	1.367	43.111	5.249	0.005	97.780	0.026	0.021	113.835	0.066	1.373	25.093	1.182
17.	3.50	0.04	0.929	46.428	3.566	0.004	105.301	0.018	0.014	122.591	0.045	0.932	27.024	0.803
18.	3.75	0.03	0.671	49.744	2.575	0.003	112.823	0.013	0.010	131.348	0.033	0.673	28.954	0.580
19.	4.00	0.02	0.464	53.060	1.783	0.002	120.344	0.009	0.007	140.104	0.023	0.466	30.884	0.401
20.	4.25	0.01	0.310	56.376	1.189	0.001	127.866	0.006	0.005	148.861	0.015	0.311	32.814	0.268
21.	4.50	0.01	0.232	59.693	0.891	0.001	135.387	0.004	0.004	157.617	0.011	0.233	34.745	0.201
22.	4.75	0.01	0.155	63.009	0.594	0.001	142.909	0.003	0.002	166.374	0.008	0.155	36.675	0.134
23.	5.00	0.00	0.103	66.325	0.396	0.000	150.430	0.002	0.002	175.130	0.005	0.104	38.605	0.089

Table 4: Dimensionless Unit Hydrograph, Year 1951 – 3

			Drainage_Area_I			Drainage_Area_J			Drainage_Area_K			Drainage_Area_L		
1.														
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	3.108	2.671	6.555	3.096	4.624	29.090	3.132	2.867	3.881	3.156	2.469	8.139
5.	0.50	0.43	11.137	5.342	23.488	11.094	9.248	104.239	11.223	5.734	13.905	11.309	4.938	29.166
6.	0.75	0.83	21.497	8.013	45.337	21.414	13.872	201.206	21.663	8.601	26.840	21.829	7.407	56.297
7.	1.00	1.00	25.900	10.684	54.623	25.800	18.496	242.417	26.100	11.468	32.338	26.300	9.876	67.828
8.	1.25	0.88	22.792	13.355	48.068	22.704	23.120	213.327	22.968	14.335	28.457	23.144	12.345	59.688
9.	1.50	0.66	17.094	16.026	36.051	17.028	27.744	159.995	17.226	17.202	21.343	17.358	14.814	44.766
10.	1.75	0.45	11.655	18.697	24.580	11.610	32.368	109.088	11.745	20.069	14.552	11.835	17.283	30.522
11.	2.00	0.32	8.288	21.368	17.479	8.256	36.992	77.573	8.352	22.936	10.348	8.416	19.752	21.705
12.	2.25	0.22	5.698	24.039	12.017	5.676	41.616	53.332	5.742	25.803	7.114	5.786	22.221	14.922
13.	2.50	0.15	3.885	26.710	8.193	3.870	46.240	36.363	3.915	28.670	4.851	3.945	24.690	10.174
14.	2.75	0.11	2.720	29.381	5.735	2.709	50.864	25.454	2.741	31.537	3.395	2.762	27.159	7.122
15.	3.00	0.08	1.943	32.052	4.097	1.935	55.488	18.181	1.958	34.404	2.425	1.973	29.628	5.087
16.	3.25	0.05	1.373	34.723	2.895	1.367	60.112	12.848	1.383	37.271	1.714	1.394	32.097	3.595
17.	3.50	0.04	0.932	37.394	1.966	0.929	64.736	8.727	0.940	40.138	1.164	0.947	34.566	2.442
18.	3.75	0.03	0.673	40.065	1.420	0.671	69.360	6.303	0.679	43.005	0.841	0.684	37.035	1.764
19.	4.00	0.02	0.466	42.736	0.983	0.464	73.984	4.364	0.470	45.872	0.582	0.473	39.504	1.221
20.	4.25	0.01	0.311	45.407	0.655	0.310	78.608	2.909	0.313	48.739	0.388	0.316	41.973	0.814
21.	4.50	0.01	0.233	48.078	0.492	0.232	83.232	2.182	0.235	51.606	0.291	0.237	44.442	0.610
22.	4.75	0.01	0.155	50.749	0.328	0.155	87.856	1.455	0.157	54.473	0.194	0.158	46.911	0.407
23.	5.00	0.00	0.448	15.155	3.331	0.103	92.480	0.970	0.104	57.340	0.129	0.105	49.380	0.271

Table 5: Dimensionless Unit Hydrograph, Year 1951 – 4

			Drainage_Area_M			Drainage_Area_N		
1.								
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0
4.	0.25	0.12	3.132	8.149	35.388	0.048	5.921	0.087
5.	0.50	0.43	11.223	16.297	126.809	0.172	11.843	0.313
6.	0.75	0.83	21.663	24.446	244.770	0.332	17.764	0.604
7.	1.00	1.00	26.100	32.594	294.904	0.400	23.685	0.727
8.	1.25	0.88	22.968	40.743	259.515	0.352	29.606	0.640
9.	1.50	0.66	17.226	48.891	194.637	0.264	35.528	0.480
10.	1.75	0.45	11.745	57.040	132.707	0.180	41.449	0.327
11.	2.00	0.32	8.352	65.188	94.369	0.128	47.370	0.233
12.	2.25	0.22	5.742	73.337	64.879	0.088	53.291	0.160
13.	2.50	0.15	3.915	81.485	44.236	0.060	59.213	0.109
14.	2.75	0.11	2.741	89.634	30.965	0.042	65.134	0.076
15.	3.00	0.08	1.958	97.782	22.118	0.030	71.055	0.055
16.	3.25	0.05	1.383	105.931	15.630	0.021	76.976	0.039
17.	3.50	0.04	0.940	114.079	10.617	0.014	82.898	0.026
18.	3.75	0.03	0.679	122.228	7.668	0.010	88.819	0.019
19.	4.00	0.02	0.470	130.376	5.308	0.007	94.740	0.013
20.	4.25	0.01	0.313	138.525	3.539	0.005	100.661	0.009
21.	4.50	0.01	0.235	146.673	2.654	0.004	106.583	0.007
22.	4.75	0.01	0.157	154.822	1.769	0.002	112.504	0.004
23.	5.00	0.00	0.104	162.970	1.180	0.002	118.425	0.003

Table 6: CALCULATIONS FOR CATCHMENT (A) USING SCS METHOD, YEAR 1971

	Type Of soil	Total Dev. Area (KM^2)	Pervious	% Of Total Area	CN(p)	Impervious	% Of Total Area	CN (Im)	WCN	L	WCN	Y(Slope)	tL	tp(per) =(D/2+tL)	Qp	Potential Maximum Retention, S	Initial Abstraction, I	Excess Rainfall	
A	Sandy Loam, A	5.44356	1.60216	29.43	39	3.8414	70.57	98	80.6350	3610	80.6350	0.002	5.031611	8.032	3.633	61.0	12.20	68.8	A
B	Sandy Loam, A	19.39638	12.70068	65.48	32	6.6957	34.52	77	47.5342	9130	47.5342	0.003	20.90416	23.904	4.349	280.4	56.07	11.9	B
C	Sandy Loam, A	9.48578	6.81968	71.89	58	2.6661	28.11	89	66.7129	3170	66.7129	0.003	5.501819	8.502	5.980	126.7	25.35	40.5	C
D	Sandy Loam, A	11.63922	7.61522	65.43	32	4.024	34.57	77	47.5577	4860	47.5577	0.003	12.61542	15.615	3.995	280.1	56.02	11.9	D
E	Sandy Loam, A	9.49981	8.75061	92.11	58	0.7492	7.89	54	57.6845	5220	57.6845	0.003	10.33416	13.334	3.819	186.3	37.27	25.4	E
F	Sandy Loam, A	28.03928	27.05528	96.49	30	0.984	3.51	51	30.7370	7020	30.7370	0.003	27.08563	30.086	4.995	572.4	114.47	0.1	F
G	Sandy Loam, A	20.42382	19.77872	96.84	32	0.6451	3.16	51	32.6001	9270	32.6001	0.003	31.93832	34.938	3.133	525.1	105.03	0.4	G
H	Silt Loam, B	1.24031	1.24031	100.00	58	0	0.00	68	58.0000	1980	58.0000	0.003	4.720769	7.721	0.861	183.9	36.79	25.9	H
I	Silt Loam, B	4.20418	3.37378	80.25	58	0.8304	19.75	68	59.9752	3640	59.9752	0.003	7.309031	10.309	2.186	169.5	33.90	29.0	I
J	Sandy Loam, A	32.4252	30.9045	95.31	58	1.5207	4.69	51	57.6717	8730	57.6717	0.003	15.59879	18.599	9.345	186.4	37.28	25.4	J
K	Silt Loam, B	2.65092	2.56772	96.86	58	0.0832	3.14	68	58.3139	3200	58.3139	0.002	8.421778	11.422	1.244	181.6	36.31	26.4	K
L	Silt Loam, B	4.752	2.8449	59.87	58	1.9071	40.13	68	62.0133	3190	62.0133	0.003	6.244354	9.244	2.755	155.6	31.12	32.3	L
M	Sandy Loam, A	68.70675	67.79165	98.67	58	0.9151	1.33	68	58.1332	19710	58.1332	0.003	29.57803	32.578	11.304	182.9	36.59	26.1	M
N	Silt Loam, B	8.03305	7.38505	91.93	32	0.648	8.07	68	34.9040	5410	34.9040	0.003	19.38172	22.382	1.924	473.7	94.74	1.3	N
		225.94026	**200.43026**	**88.71**		**25.51**	**11.29**												

Table 7: Dimensionless Unit Hydrograph, Year 1971 – 1

			Drainage_Area_A			Drainage_Area_B			Drainage_Area_C			Drainage_Area_D		
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	8.280	2.008	30.081	1.428	5.976	6.210	4.920	2.126	29.422	1.428	3.904	5.705
5.	0.50	0.43	29.670	4.016	107.791	5.117	11.952	22.254	17.630	4.251	105.427	5.117	7.808	20.442
6.	0.75	0.83	57.270	6.024	208.062	9.877	17.928	42.955	34.030	6.377	203.499	9.877	11.711	39.459
7.	1.00	1.00	69.000	8.032	250.677	11.900	23.904	51.753	41.000	8.502	245.180	11.900	15.615	47.541
8.	1.25	0.88	60.720	10.040	220.596	10.472	29.880	45.543	36.080	10.628	215.758	10.472	19.519	41.836
9.	1.50	0.66	45.540	12.048	165.447	7.854	35.856	34.157	27.060	12.753	161.819	7.854	23.423	31.377
10.	1.75	0.45	31.050	14.056	112.805	5.355	41.832	23.289	18.450	14.879	110.331	5.355	27.326	21.393
11.	2.00	0.32	22.080	16.064	80.217	3.808	47.808	16.561	13.120	17.004	78.458	3.808	31.230	15.213
12.	2.25	0.22	15.180	18.072	55.149	2.618	53.784	11.386	9.020	19.130	53.940	2.618	35.134	10.459
13.	2.50	0.15	10.350	20.080	37.602	1.785	59.760	7.763	6.150	21.255	36.777	1.785	39.038	7.131
14.	2.75	0.11	7.245	22.088	26.321	1.250	65.736	5.434	4.305	23.381	25.744	1.250	42.941	4.992
15.	3.00	0.08	5.175	24.096	18.801	0.893	71.712	3.881	3.075	25.506	18.389	0.893	46.845	3.566
16.	3.25	0.05	3.657	26.104	13.286	0.631	77.688	2.743	2.173	27.632	12.995	0.631	50.749	2.520
17.	3.50	0.04	2.484	28.112	9.024	0.428	83.664	1.863	1.476	29.757	8.826	0.428	54.653	1.711
18.	3.75	0.03	1.794	30.120	6.518	0.309	89.640	1.346	1.066	31.883	6.375	0.309	58.556	1.236
19.	4.00	0.02	1.242	32.128	4.512	0.214	95.616	0.932	0.738	34.008	4.413	0.214	62.460	0.856
20.	4.25	0.01	0.828	34.136	3.008	0.143	101.592	0.621	0.492	36.134	2.942	0.143	66.364	0.570
21.	4.50	0.01	0.621	36.144	2.256	0.107	107.568	0.466	0.369	38.259	2.207	0.107	70.268	0.428
22.	4.75	0.01	0.414	38.152	1.504	0.071	113.544	0.311	0.246	40.385	1.471	0.071	74.171	0.285
23.	5.00	0.00	0.276	40.160	1.003	0.048	119.520	0.207	0.164	42.510	0.981	0.048	78.075	0.190

Table 8: Dimensionless Unit Hydrograph, Year 1971 – 2

1.			Drainage_Area_E			Drainage_Area_F			Drainage_Area_G			Drainage_Area_H		
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	3.048	3.334	11.640	0.012	7.522	0.060	0.048	8.735	0.150	3.108	1.930	2.676
5.	0.50	0.43	10.922	6.667	41.711	0.043	15.043	0.215	0.172	17.469	0.539	11.137	3.861	9.589
6.	0.75	0.83	21.082	10.001	80.512	0.083	22.565	0.415	0.332	26.204	1.040	21.497	5.791	18.509
7.	1.00	1.00	25.400	13.334	97.003	0.100	30.086	0.500	0.400	34.938	1.253	25.900	7.721	22.300
8.	1.25	0.88	22.352	16.668	85.362	0.088	37.608	0.440	0.352	43.673	1.103	22.792	9.651	19.624
9.	1.50	0.66	16.764	20.001	64.022	0.066	45.129	0.330	0.264	52.407	0.827	17.094	11.582	14.718
10.	1.75	0.45	11.430	23.335	43.651	0.045	52.651	0.225	0.180	61.142	0.564	11.655	13.512	10.035
11	2.00	0.32	8.128	26.668	31.041	0.032	60.172	0.160	0.128	69.876	0.401	8.288	15.442	7.136
12.	2.25	0.22	5.588	30.002	21.341	0.022	67.694	0.110	0.088	78.611	0.276	5.698	17.372	4.906
13.	2.50	0.15	3.810	33.335	14.550	0.015	75.215	0.075	0.060	87.345	0.188	3.885	19.303	3.345
14.	2.75	0.11	2.667	36.669	10.185	0.011	82.737	0.052	0.042	96.080	0.132	2.720	21.233	2.341
15.	3.00	0.08	1.905	40.002	7.275	0.008	90.258	0.037	0.030	104.814	0.094	1.943	23.163	1.672
16.	3.25	0.05	1.346	43.336	5.141	0.005	97.780	0.026	0.021	113.549	0.066	1.373	25.093	1.182
17.	3.50	0.04	0.914	46.669	3.492	0.004	105.301	0.018	0.014	122.283	0.045	0.932	27.024	0.803
18.	3.75	0.03	0.660	50.003	2.522	0.003	112.823	0.013	0.010	131.018	0.033	0.673	28.954	0.580
19.	4.00	0.02	0.457	53.336	1.746	0.002	120.344	0.009	0.007	139.752	0.023	0.466	30.884	0.401
20.	4.25	0.01	0.305	56.670	1.164	0.001	127.866	0.006	0.005	148.487	0.015	0.311	32.814	0.268
21.	4.50	0.01	0.229	60.003	0.873	0.001	135.387	0.004	0.004	157.221	0.011	0.233	34.745	0.201
22.	4.75	0.01	0.152	63.337	0.582	0.001	142.909	0.003	0.002	165.956	0.008	0.155	36.675	0.134
23.	5.00	0.00	0.102	66.670	0.388	0.000	150.430	0.002	0.002	174.690	0.005	0.104	38.605	0.089

Table 9: Dimensionless Unit Hydrograph, Year 1971 – 3

			Drainage_Area_I			Drainage_Area_J			Drainage_Area_K			Drainage_Area_L		
1.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
2.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
3.	0.25	0.12	3.480	2.577	7.607	3.048	4.650	28.484	3.168	2.8555	3.940992	3.876	2.311	10.678
4.	0.50	0.43	12.470	5.155	27.259	10.922	9.300	102.066	11.352	5.711	14.12189	13.889	4.622	38.264
5.	0.75	0.83	24.070	7.732	52.617	21.082	13.949	197.011	21.912	8.5665	27.25853	26.809	6.933	73.859
6.	1.00	1.00	29.000	10.309	63.394	25.400	18.599	237.363	26.4	11.422	32.8416	32.300	9.244	88.987
7.	1.25	0.88	25.520	12.886	55.787	22.352	23.249	208.879	23.232	14.2775	28.90061	28.424	11.555	78.308
8.	1.50	0.66	19.140	15.464	41.840	16.764	27.899	156.660	17.424	17.133	21.67546	21.318	13.866	58.731
9.	1.75	0.45	13.050	18.041	28.527	11.430	32.548	106.813	11.88	19.9885	14.77872	14.535	16.177	40.044
10.	2.00	0.32	9.280	20.618	20.286	8.128	37.198	75.956	8.448	22.844	10.50931	10.336	18.488	28.476
11.	2.25	0.22	6.380	23.195	13.947	5.588	41.848	52.220	5.808	25.6995	7.225152	7.106	20.799	19.577
12.	2.50	0.15	4.350	25.773	9.509	3.810	46.498	35.604	3.96	28.555	4.92624	4.845	23.110	13.348
13.	2.75	0.11	3.045	28.350	6.656	2.667	51.147	24.923	2.772	31.4105	3.448368	3.392	25.421	9.344
14.	3.00	0.08	2.175	30.927	4.755	1.905	55.797	17.802	1.98	34.266	2.46312	2.423	27.732	6.674
15.	3.25	0.05	1.537	33.504	3.360	1.346	60.447	12.580	1.3992	37.1215	1.740605	1.712	30.043	4.716
16.	3.50	0.04	1.044	36.082	2.282	0.914	65.097	8.545	0.9504	39.977	1.182298	1.163	32.354	3.204
17.	3.75	0.03	0.754	38.659	1.648	0.660	69.746	6.171	0.6864	42.8325	0.853882	0.840	34.665	2.314
18.	4.00	0.02	0.522	41.236	1.141	0.457	74.396	4.273	0.4752	45.688	0.591149	0.581	36.976	1.602
19.	4.25	0.01	0.348	43.813	0.761	0.305	79.046	2.848	0.3168	48.5435	0.394099	0.388	39.287	1.068
20.	4.50	0.01	0.261	46.391	0.571	0.229	83.696	2.136	0.2376	51.399	0.295574	0.291	41.598	0.801
21.	4.75	0.01	0.174	48.968	0.380	0.152	88.345	1.424	0.1584	54.2545	0.19705	0.194	43.909	0.534
22.	5.00	0.00	0.116	51.545	0.254	0.102	92.995	0.949	0.1056	57.11	0.131366	0.129	46.220	0.356

Table 10: Dimensionless Unit Hydrograph, Year 1971 – 4

			Drainage_Area_M			Drainage_Area_N		
1.								
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0
4.	0.25	0.12	3.132	8.145	35.404	0.156	5.582	0.300
5.	0.50	0.43	11.223	16.289	126.865	0.559	11.164	1.076
6.	0.75	0.83	21.663	24.434	244.879	1.079	16.746	2.076
7.	1.00	1.00	26.100	32.578	295.034	1.300	22.328	2.501
8.	1.25	0.88	22.968	40.723	259.630	1.144	27.910	2.201
9.	1.50	0.66	17.226	48.867	194.723	0.858	33.492	1.651
10.	1.75	0.45	11.745	57.012	132.765	0.585	39.074	1.126
11.	2.00	0.32	8.352	65.156	94.411	0.416	44.656	0.800
12.	2.25	0.22	5.742	73.301	64.908	0.286	50.238	0.550
13.	2.50	0.15	3.915	81.445	44.255	0.195	55.820	0.375
14.	2.75	0.11	2.741	89.590	30.979	0.137	61.402	0.263
15.	3.00	0.08	1.958	97.734	22.128	0.098	66.984	0.188
16.	3.25	0.05	1.383	105.879	15.637	0.069	72.566	0.133
17.	3.50	0.04	0.940	114.023	10.621	0.047	78.148	0.090
18.	3.75	0.03	0.679	122.168	7.671	0.034	83.730	0.065
19.	4.00	0.02	0.470	130.312	5.311	0.023	89.312	0.045
20.	4.25	0.01	0.313	138.457	3.540	0.016	94.894	0.030
21.	4.50	0.01	0.235	146.601	2.655	0.012	100.476	0.023
22.	4.75	0.01	0.157	154.746	1.770	0.008	106.058	0.015
23.	5.00	0.00	0.104	162.890	1.180	0.005	111.640	0.010

Table 11: CALCULATIONS FOR CATCHMENT (A) USING SCS METHOD, YEAR 1985

	Type Of soil	Total Dev. Area (KM^2)	Pervious	% Of Total Area	CN(p)	Impervious	% Of Total Area	CN (Im)	WCN	L	WCN	Y(Slope)	tL	tp(per) =(D/2+tL)	Qp	Potential Maximum Retention, S	Initial Abstraction, I	Excess Rainfall I	
A	Sandy Loam, A	5.44356	1.52966	28.10	39	3.9139	71.90	92	77.1068	3610	77.1068	0.002	5.605	8.605	3.391	72.741	14.548	62.4	A
B	Sandy Loam, A	19.39638	10.44198	53.83	68	8.9544	46.17	77	72.1549	9130	72.1549	0.003	11.078	14.078	7.385	94.547	18.909	52.2	B
C	Sandy Loam, A	9.48578	4.06568	42.86	68	5.4201	57.14	89	79.9992	3170	79.9992	0.003	3.777	6.777	7.502	61.253	12.251	68.7	C
D	Sandy Loam, A	11.63922	9.61522	82.61	68	2.024	17.39	77	69.5651	4860	69.5651	0.003	7.179	10.179	6.129	107.188	21.438	47.2	D
E	Sandy Loam, A	9.49981	9.35691	98.50	68	0.1429	1.50	77	68.1354	5220	68.1354	0.003	7.897	10.897	4.673	114.578	22.916	44.5	E
F	Sandy Loam, A	28.03928	27.05528	96.49	30	0.984	3.51	54	30.8422	7020	30.8422	0.003	26.996	29.996	5.010	549.365	109.873	0.2	F
G	Sandy Loam, A	20.42382	18.56102	90.88	67	1.8628	9.12	54	65.8143	9270	65.8143	0.003	13.290	16.290	6.720	127.259	25.452	40.3	G
H	Silt Loam, B	1.24031	1.23141	99.28	78	0.0089	0.72	68	77.9282	1980	77.9282	0.003	2.762	5.762	1.154	69.392	13.878	64.2	H
I	Silt Loam, B	4.20418	2.00908	47.79	78	2.1951	52.21	68	72.7788	3640	72.7788	0.003	5.217	8.217	2.742	91.637	18.327	53.5	I
J	Sandy Loam, A	32.4252	30.2549	93.31	67	2.1703	6.69	54	66.1299	8730	66.1299	0.003	12.563	15.563	11.167	125.483	25.097	40.9	J
K	Silt Loam, B	2.65092	1.98372	74.83	78	0.6672	25.17	70	75.9865	3200	75.9865	0.002	5.261	8.261	1.720	77.426	15.485	60.0	K
L	Silt Loam, B	4.752	1.4046	29.56	78	3.3474	70.44	70	72.3646	3190	72.3646	0.003	4.749	7.749	3.287	93.563	18.713	52.7	L
M	Sandy Loam, A	68.70675	67.39815	98.10	67	1.3086	1.90	51	66.6953	19710	66.6953	0.003	23.747	26.747	13.769	122.342	24.468	41.9	M
N	Silt Loam, B	8.03305	7.19505	89.57	67	0.838	10.43	68	67.1043	5410	67.1043	0.003	8.351	11.351	3.793	120.103	24.021	42.6	N
		225.94026	**192.10266**	**85.02**		**33.8376**	**14.98**												

Table 12: Dimensionless Unit Hydrograph, Year 1985 – 1

			Drainage_Area_A			Drainage_Area_B			Drainage_Area_C			Drainage_Area_D		
1.														
2.	t/tp	Q/qp .	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	7.488	2.15125	25.392	6.26	3.52	46.26	8.244	1.694	61.846	5.664	2.54475	34.715
5.	0.50	0.43	26.832	4.3025	90.987	22.45	7.04	165.76	29.541	3.389	221.617	20.296	5.0895	124.394
6.	0.75	0.83	51.792	6.45375	175.627	43.33	10.56	319.96	57.021	5.083	427.772	39.176	7.63425	240.110
7.	1.00	1.00	62.4	8.605	211.598	52.20	14.08	385.50	68.700	6.777	515.387	47.2	10.179	289.289
8.	1.25	0.88	54.912	10.75625	186.207	45.94	17.60	339.24	60.456	8.471	453.541	41.536	12.72375	254.574
9.	1.50	0.66	41.184	12.9075	139.655	34.45	21.12	254.43	45.342	10.166	340.156	31.152	15.2685	190.931
10.	1.75	0.45	28.08	15.05875	95.219	23.49	24.64	173.47	30.915	11.860	231.924	21.24	17.81325	130.180
11.	2.00	0.32	19.968	17.21	67.711	16.70	28.16	123.36	21.984	13.554	164.924	15.104	20.358	92.572
12.	2.25	0.22	13.728	19.36125	46.552	11.48	31.68	84.81	15.114	15.248	113.385	10.384	22.90275	63.644
13.	2.50	0.15	9.36	21.5125	31.740	7.83	35.20	57.82	10.305	16.943	77.308	7.08	25.4475	43.393
14.	2.75	0.11	6.552	23.66375	22.218	5.48	38.71	40.48	7.214	18.637	54.116	4.956	27.99225	30.375
15.	3.00	0.08	4.68	25.815	15.870	3.92	42.23	28.91	5.153	20.331	38.654	3.54	30.537	21.697
16.	3.25	0.05	3.3072	27.96625	11.215	2.77	45.75	20.43	3.641	22.025	27.316	2.5016	33.08175	15.332
17.	3.50	0.04	2.2464	30.1175	7.618	1.88	49.27	13.88	2.473	23.720	18.554	1.6992	35.6265	10.414
18.	3.75	0.03	1.6224	32.26875	5.502	1.36	52.79	10.02	1.786	25.414	13.400	1.2272	38.17125	7.522
19.	4.00	0.02	1.1232	34.42	3.809	0.94	56.31	6.94	1.237	27.108	9.277	0.8496	40.716	5.207
20.	4.25	0.01	0.7488	36.57125	2.539	0.63	59.83	4.63	0.824	28.802	6.185	0.5664	43.26075	3.471
21.	4.50	0.01	0.5616	38.7225	1.904	0.47	63.35	3.47	0.618	30.497	4.638	0.4248	45.8055	2.604
22.	4.75	0.01	0.3744	40.87375	1.270	0.31	66.87	2.31	0.412	32.191	3.092	0.2832	48.35025	1.736
23.	5.00	0.00	0.2496	43.025	0.846	0.21	70.39	1.54	0.275	33.885	2.062	0.1888	50.895	1.157

Table 13: Dimensionless Unit Hydrograph, Year 1985 – 2

1.			Drainage_Area_E			Drainage_Area_F			Drainage_Area_G			Drainage_Area_H		
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	5.34	2.724	24.954	0.024	7.499	0.12024	4.836	4.0725	32.498	7.704	1.4405	8.890416
5.	0.50	0.43	19.135	5.449	89.418	0.086	14.998	0.43086	17.329	8.145	116.451	27.606	2.881	31.85732
6.	0.75	0.83	36.935	8.173	172.597	0.166	22.497	0.83166	33.449	12.2175	224.777	53.286	4.3215	61.49204
7.	1.00	1.00	44.5	10.897	207.949	0.2	29.996	1.002	40.3	16.29	270.816	64.2	5.762	74.0868
8.	1.25	0.88	39.16	13.621	182.995	0.176	37.495	0.88176	35.464	20.3625	238.318	56.496	7.2025	65.19638
9.	1.50	0.66	29.37	16.346	137.246	0.132	44.994	0.66132	26.598	24.435	178.739	42.372	8.643	48.89729
10.	1.75	0.45	20.025	19.070	93.577	0.09	52.493	0.4509	18.135	28.5075	121.867	28.89	10.0835	33.33906
11.	2.00	0.32	14.24	21.794	66.544	0.064	59.992	0.32064	12.896	32.58	86.661	20.544	11.524	23.70778
12.	2.25	0.22	9.79	24.518	45.749	0.044	67.491	0.22044	8.866	36.6525	59.580	14.124	12.9645	16.2991
13.	2.50	0.15	6.675	27.243	31.192	0.03	74.99	0.1503	6.045	40.725	40.622	9.63	14.405	11.11302
14.	2.75	0.11	4.6725	29.967	21.835	0.021	82.489	0.10521	4.2315	44.7975	28.436	6.741	15.8455	7.779114
15.	3.00	0.08	3.3375	32.691	15.596	0.015	89.988	0.07515	3.0225	48.87	20.311	4.815	17.286	5.55651
16.	3.25	0.05	2.3585	35.415	11.021	0.0106	97.487	0.053106	2.1359	52.9425	14.353	3.4026	18.7265	3.9266
17.	3.50	0.04	1.602	38.140	7.486	0.0072	104.986	0.036072	1.4508	57.015	9.749	2.3112	20.167	2.667125
18.	3.75	0.03	1.157	40.864	5.407	0.0052	112.485	0.026052	1.0478	61.0875	7.041	1.6692	21.6075	1.926257
19.	4.00	0.02	0.801	43.588	3.743	0.0036	119.984	0.018036	0.7254	65.16	4.875	1.1556	23.048	1.333562
20	4.25	0.01	0.534	46.312	2.495	0.0024	127.483	0.012024	0.4836	69.2325	3.250	0.7704	24.4885	0.889042
21.	4.50	0.01	0.4005	49.037	1.872	0.0018	134.982	0.009018	0.3627	73.305	2.437	0.5778	25.929	0.666781
22.	4.75	0.01	0.267	51.761	1.248	0.0012	142.481	0.006012	0.2418	77.3775	1.625	0.3852	27.3695	0.444521
23.	5.00	0.00	0.178	54.485	0.832	0.0008	15.535	0.004008	0.1612	15.265	1.083	0.468	28.81	0.540072

Table 14: Dimensionless Unit Hydrograph, Year 1985 – 3

t/tp	Q/qp
0.00	0.00
0.25	0.12
0.50	0.43
0.75	0.83
1.00	1.00
1.25	0.88
1.50	0.66
1.75	0.45
2.00	0.32
2.25	0.22
2.50	0.15
2.75	0.11
3.00	0.08
3.25	0.05
3.50	0.04
3.75	0.03
4.00	0.02
4.25	0.01
4.50	0.01
4.75	0.01
5.00	0.00

Drainage_Area_I		
Q'/qp	t	Q
0	0	0
6.420	2.054	17.604
23.005	4.109	63.080
44.405	6.163	121.759
53.500	8.217	146.697
47.080	10.271	129.093
35.310	12.326	96.820
24.075	14.380	66.014
17.120	16.434	46.943
11.770	18.488	32.273
8.025	20.543	22.005
5.618	22.597	15.403
4.013	24.651	11.002
2.836	26.705	7.775
1.926	28.760	5.281
1.391	30.814	3.814
0.963	32.868	2.641
0.642	34.922	1.760
0.482	36.977	1.320
0.321	39.031	0.880
0.214	41.085	0.587

Drainage_Area_J		
Q'/qp	t	Q
0	0	0
4.908	3.891	54.808
17.587	7.782	196.394
33.947	11.672	379.086
40.900	15.563	456.730
35.992	19.454	401.923
26.994	23.345	301.442
18.405	27.235	205.529
13.088	31.126	146.154
8.998	35.017	100.481
6.135	38.908	68.510
4.295	42.798	47.957
3.068	46.689	34.255
2.168	50.580	24.207
1.472	54.471	16.442
1.063	58.361	11.875
0.736	62.252	8.221
0.491	66.143	5.481
0.368	70.034	4.111
0.245	73.924	2.740
0.164	77.815	1.827

Drainage_Area_K		
Q'/qp	t	Q
0	0	0
7	2.0653	12.3840
26	4.1305	44.3760
50	6.1958	85.6560
60	8.2610	103.2000
53	10.3263	90.8160
40	12.3915	68.1120
27	14.4568	46.4400
19	16.5220	33.0240
13	18.5873	22.7040
9	20.6525	15.4800
6	22.7178	10.8360
5	24.7830	7.7400
3	26.8483	5.4696
2	28.9135	3.7152
2	30.9788	2.6832
1	33.0440	1.8576
1	35.1093	1.2384
1	37.1745	0.9288
0	39.2398	0.6192
0	41.3050	0.4128

Drainage_Area_L		
Q'/qp	t	Q
0	0	0
6.324	2.065	20.787
22.661	4.131	74.487
43.741	6.196	143.777
52.700	8.261	173.225
46.376	10.326	152.438
34.782	12.392	114.328
23.715	14.457	77.951
16.864	16.522	55.432
11.594	18.587	38.109
7.905	20.653	25.984
5.534	22.718	18.189
3.953	24.783	12.992
2.793	26.848	9.181
1.897	28.914	6.236
1.370	30.979	4.504
0.949	33.044	3.118
0.632	35.109	2.079
0.474	37.175	1.559
0.316	39.240	1.039
0.211	41.305	0.693

Table 15: Dimensionless Unit Hydrograph, Year 1985 – 4

t/tp	Q/qp
0.00	0.00
0.25	0.12
0.50	0.43
0.75	0.83
1.00	1.00
1.25	0.88
1.50	0.66
1.75	0.45
2.00	0.32
2.25	0.22
2.50	0.15
2.75	0.11
3.00	0.08
3.25	0.05
3.50	0.04
3.75	0.03
4.00	0.02
4.25	0.01
4.50	0.01
4.75	0.01
5.00	0.00

Drainage_Area_M		
Q'/qp	t	Q
0	0	0
5.028	6.687	69.231
18.017	13.374	248.076
34.777	20.060	478.845
41.900	26.747	576.921
36.872	33.434	507.691
27.654	40.121	380.768
18.855	46.807	259.614
13.408	53.494	184.615
9.218	60.181	126.923
6.285	66.868	86.538
4.400	73.554	60.577
3.143	80.241	43.269
2.221	86.928	30.577
1.508	93.615	20.769
1.089	100.301	15.000
0.754	106.988	10.385
0.503	113.675	6.923
0.377	120.362	5.192
0.251	127.048	3.462
0.168	133.735	2.308

Drainage_Area_N		
Q'/qp	t	Q
0	0	0
5.112	2.838	19.390
18.318	5.676	69.480
35.358	8.513	134.113
42.600	11.351	161.582
37.488	14.189	142.192
28.116	17.027	106.644
19.170	19.864	72.712
13.632	22.702	51.706
9.372	25.540	35.548
6.390	28.378	24.237
4.473	31.215	16.966
3.195	34.053	12.119
2.258	36.891	8.564
1.534	39.729	5.817
1.108	42.566	4.201
0.767	45.404	2.908
0.511	48.242	1.939
0.383	51.080	1.454
0.256	53.917	0.969
0.170	56.755	0.646

Table 16: CALCULATIONS FOR CATCHMENT (A) USING SCS METHOD, YEAR 2005

	Type Of Soil	Total Dev. Area (KM^2)	Pervious	% Of Total Area	CN(p)	Impervious	% Of Total Area	CN (Im)	WCN	L	WCN	Y(Slope)	tL	tp(per) =(D/2+ tL)	Qp	Potential Maximum Retention, S	Initial Abstraction, I	Excess Rainfall	
A	Sandy Loam, A	5.44356	1.16156	21.34	39	4.282	78.66	92	80.6907	3610	80.6907	0.002	5.022738	8.023	3.637	60.782	12.1564	69.0	A
B	Sandy Loam, A	19.39638	8.29398	42.76	68	11.1024	57.24	77	73.1516	9130	73.1516	0.003	10.77445	13.774	7.548	93.224	18.6449	52.8	B
C	Sandy Loam, A	9.48578	1.83958	19.39	68	7.6462	80.61	92	87.3457	3170	87.3457	0.003	2.94165	5.942	8.557	36.799	7.3597	84.9	C
D	Sandy Loam, A	11.63922	6.02282	51.75	68	5.6164	48.25	77	72.3429	4860	72.3429	0.003	6.654504	9.655	6.462	97.106	19.4212	51.2	D
E	Sandy Loam, A	9.49981	9.35691	98.50	68	0.1429	1.50	77	68.1354	5220	68.1354	0.003	7.897365	10.897	4.673	118.787	23.7574	43.1	E
F	Sandy Loam, A	28.03928	26.78878	95.54	30	1.2505	4.46	54	31.0704	7020	31.0704	0.003	26.80375	29.804	5.043	563.499	112.6999	0.1	F
G	Sandy Loam, A	20.42382	19.22742	94.14	67	1.1964	5.86	77	67.5858	9270	67.5858	0.003	12.6863	15.686	6.979	121.819	24.3637	42.1	G
H	Silt Loam, B	1.24031	0.46431	37.43	78	0.776	62.57	85	82.3796	1980	82.3796	0.003	2.401931	5.402	1.231	54.329	10.8658	72.9	H
I	Silt Loam, B	4.20418	1.77278	42.17	78	2.4314	57.83	85	82.0483	3640	82.0483	0.003	3.95202	6.952	3.241	55.574	11.1147	72.1	I
J	Sandy Loam, A	32.4252	27.3258	84.27	67	5.0994	15.73	70	67.4718	8730	67.4718	0.003	12.12804	15.128	11.489	122.454	24.4907	41.9	J
K	Silt Loam, B	2.65092	1.02002	38.48	78	1.6309	61.52	92	86.6131	3200	86.6131	0.002	3.729919	6.730	2.111	39.258	7.8516	83.1	K
L	Silt Loam, B	4.752	0	0.00	78	4.752	100.00	85	85.0000	3190	85.0000	0.003	3.218603	6.219	4.096	44.824	8.9647	79.1	L
M	Sandy Loam, A	68.70675	67.39815	98.10	67	1.3086	1.90	77	67.1905	19710	67.1905	0.003	23.43973	26.440	13.929	124.030	24.8060	41.3	M
N	Silt Loam, B	8.03305	7.12485	88.69	67	0.9082	11.31	85	69.0350	5410	69.0350	0.003	7.933853	10.934	3.938	113.929	22.7858	44.8	N
		225.94026	**177.79696**	**78.69**		**48.1433**	**21.31**												

Table 17: Dimensionless Unit Hydrograph, Year 2005 – 1

			Drainage_Area_A			Drainage_Area_B			Drainage_Area_C			Drainage_Area_D		
1.														
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	8.280	2.006	30.114	6.360	3.444	48.005	10.2	1.486	87.281	6.120	2.414	39.547
5.	0.50	0.43	29.670	4.012	107.910	22.790	6.887	172.019	36.55	2.971	312.758	21.930	4.828	141.712
6.	0.75	0.83	57.270	6.017	208.291	43.990	10.331	332.037	70.55	4.457	603.696	42.330	7.241	273.536
7.	1.00	1.00	69.000	8.023	250.953	53.000	13.774	400.044	85	5.942	727.345	51.000	9.655	329.562
8.	1.25	0.88	60.720	10.029	220.839	46.640	17.218	352.039	74.8	7.428	640.064	44.880	12.069	290.015
9.	1.50	0.66	45.540	12.035	165.629	34.980	20.661	264.029	56.1	8.913	480.048	33.660	14.483	217.511
10.	1.75	0.45	31.050	14.040	112.929	23.850	24.105	180.020	38.25	10.399	327.305	22.950	16.896	148.303
11.	2.00	0.32	22.080	16.046	80.305	16.960	27.548	128.014	27.2	11.884	232.750	16.320	19.310	105.460
12.	2.25	0.22	15.180	18.052	55.210	11.660	30.992	88.010	18.7	13.370	160.016	11.220	21.724	72.504
13.	2.50	0.15	10.350	20.058	37.643	7.950	34.435	60.007	12.75	14.855	109.102	7.650	24.138	49.434
14.	2.75	0.11	7.245	22.063	26.350	5.565	37.879	42.005	8.925	16.341	76.371	5.355	26.551	34.604
15.	3.00	0.08	5.175	24.069	18.821	3.975	41.322	30.003	6.375	17.826	54.551	3.825	28.965	24.717
16.	3.25	0.05	3.657	26.075	13.301	2.809	44.766	21.202	4.505	19.312	38.549	2.703	31.379	17.467
17.	3.50	0.04	2.484	28.081	9.034	1.908	48.209	14.402	3.06	20.797	26.184	1.836	33.793	11.864
18.	3.75	0.03	1.794	30.086	6.525	1.378	51.653	10.401	2.21	22.283	18.911	1.326	36.206	8.569
19.	4.00	0.02	1.242	32.092	4.517	0.954	55.096	7.201	1.53	23.768	13.092	0.918	38.620	5.932
20.	4.25	0.01	0.828	34.098	3.011	0.636	58.540	4.801	1.02	25.254	8.728	0.612	41.034	3.955
21.	4.50	0.01	0.621	36.104	2.259	0.477	61.983	3.600	0.765	26.739	6.546	0.459	43.448	2.966
22.	4.75	0.01	0.414	38.109	1.506	0.318	65.427	2.400	0.51	28.225	4.364	0.306	45.861	1.977
23.	5.00	0.00	0.276	40.115	1.004	0.212	68.870	1.600	0.34	29.710	2.909	0.464	48.275	2.998

Table 18: Dimensionless Unit Hydrograph, Year 2005 – 2

			Drainage_Area_E			Drainage_Area_F			Drainage_Area_G			Drainage_Area_H		
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	.Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0.000	0.000	0.000	0	0	0	0	0	0
4.	0.25	0.12	5.160	2.724	24.113	0.012	7.451	0.061	5.040	3.922	25.417	8.760	1.351	10.784
5.	0.50	0.43	18.490	5.449	86.404	0.043	14.902	0.217	18.060	7.843	91.077	31.390	2.701	38.641
6.	0.75	0.83	35.690	8.173	166.779	0.083	22.353	0.419	34.860	11.765	175.799	60.590	4.052	74.586
7.	1.00	1.00	43.000	10.897	200.939	0.100	29.804	0.504	42.000	15.686	211.806	73.000	5.402	89.863
8.	1.25	0.88	37.840	13.621	176.826	0.088	37.255	0.444	36.960	19.608	186.389	64.240	6.753	79.079
9.	1.50	0.66	28.380	16.346	132.620	0.066	44.706	0.333	27.720	23.529	139.792	48.180	8.103	59.310
10.	1.75	0.45	19.350	19.070	90.423	0.045	52.157	0.227	18.900	27.451	95.313	32.850	9.454	40.438
11.	2.00	0.32	13.760	21.794	64.300	0.032	59.608	0.161	13.440	31.372	67.778	23.360	10.804	28.756
12.	2.25	0.22	9.460	24.518	44.207	0.022	67.059	0.111	9.240	35.294	46.597	16.060	12.155	19.770
13.	2.50	0.15	6.450	27.243	30.141	0.015	74.510	0.076	6.300	39.215	31.771	10.950	13.505	13.479
14.	2.75	0.11	4.515	29.967	21.099	0.011	81.961	0.053	4.410	43.137	22.240	7.665	14.856	9.436
15.	3.00	0.08	3.225	32.691	15.070	0.008	89.412	0.038	3.150	47.058	15.885	5.475	16.206	6.740
16.	3.25	0.05	2.279	35.415	10.650	0.005	96.863	0.027	2.226	50.980	11.226	3.869	17.557	4.763
17.	3.50	0.04	1.548	38.140	7.234	0.004	104.314	0.018	1.512	54.901	7.625	2.628	18.907	3.235
18.	3.75	0.03	1.118	40.864	5.224	0.003	111.765	0.013	1.092	58.823	5.507	1.898	20.258	2.336
19.	4.00	0.02	0.774	43.588	3.617	0.002	119.216	0.009	0.756	62.744	3.813	1.314	21.608	1.618
20.	4.25	0.01	0.516	46.312	2.411	0.001	126.667	0.006	0.504	66.666	2.542	0.876	22.959	1.078
21.	4.50	0.01	0.387	49.037	1.808	0.001	134.118	0.005	0.378	70.587	1.906	0.657	24.309	0.809
22.	4.75	0.01	0.258	51.761	1.206	0.001	141.569	0.003	0.252	74.509	1.271	0.438	25.660	0.539
23.	5.00	0.00	0.172	15.155	2.889	0.000	149.020	0.002	0.456	78.430	2.300	0.292	27.010	0.359

Table 19: Dimensionless Unit Hydrograph, Year 2005 – 3

			Drainage_Area_I			Drainage_Area_J			Drainage_Area_K			Drainage_Area_L		
1.														
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	8.640	1.738	28.002	5.040	3.782	57.905	9.972	1.683	21.051	9.480	1.555	38.830
5.	0.50	0.43	30.960	3.476	100.341	18.060	7.564	207.491	35.733	3.365	75.432	33.970	3.110	139.141
6.	0.75	0.83	59.760	5.214	193.682	34.860	11.346	400.507	68.973	5.048	145.602	65.570	4.664	268.575
7.	1.00	1.00	72.000	6.952	233.352	42.000	15.128	482.538	83.100	6.730	175.424	79.000	6.219	323.584
8.	1.25	0.88	63.360	8.690	205.350	36.960	18.910	424.633	73.128	8.413	154.373	69.520	7.774	284.754
9.	1.50	0.66	47.520	10.428	154.012	27.720	22.692	318.475	54.846	10.095	115.780	52.140	9.329	213.565
10.	1.75	0.45	32.400	12.166	105.008	18.900	26.474	217.142	37.395	11.778	78.941	35.550	10.883	145.613
11.	2.00	0.32	23.040	13.904	74.673	13.440	30.256	154.412	26.592	13.460	56.136	25.280	12.438	103.547
12.	2.25	0.22	15.840	15.642	51.337	9.240	34.038	106.158	18.282	15.143	38.593	17.380	13.993	71.188
13.	2.50	0.15	10.800	17.380	35.003	6.300	37.820	72.381	12.465	16.825	26.314	11.850	15.548	48.538
14.	2.75	0.11	7.560	19.118	24.502	4.410	41.602	50.666	8.726	18.508	18.420	8.295	17.102	33.976
15.	3.00	0.08	5.400	20.856	17.501	3.150	45.384	36.190	6.233	20.190	13.157	5.925	18.657	24.269
16.	3.25	0.05	3.816	22.594	12.368	2.226	49.166	25.575	4.404	21.873	9.297	4.187	20.212	17.150
17.	3.50	0.04	2.592	24.332	8.401	1.512	52.948	17.371	2.992	23.555	6.315	2.844	21.767	11.649
18.	3.75	0.03	1.872	26.070	6.067	1.092	56.730	12.546	2.161	25.238	4.561	2.054	23.321	8.413
19.	4.00	0.02	1.296	27.808	4.200	0.756	60.512	8.686	1.496	26.920	3.158	1.422	24.876	5.825
20.	4.25	0.01	0.864	29.546	2.800	0.504	64.294	5.790	0.997	28.603	2.105	0.948	26.431	3.883
21.	4.50	0.01	0.648	31.284	2.100	0.378	68.076	4.343	0.748	30.285	1.579	0.711	27.986	2.912
22.	4.75	0.01	0.432	33.022	1.400	0.252	71.858	2.895	0.499	31.968	1.053	0.474	29.540	1.942
23.	5.00	0.00	0.288	34.760	0.933	0.168	15.240	1.930	0.332	33.650	0.702	0.316	31.095	1.294

Table 20: Dimensionless Unit Hydrograph, Year 2005 – 4

			Drainage_Area_M			Drainage_Area_N		
1.								
2.	t/tp	Q/qp	Q'/qp	t	Q	Q'/qp	t	Q
3.	0.00	0.00	0	0	0	0	0	0
4.	0.25	0.12	4.920	6.610	68.531	5.400	2.734	21.265
5.	0.50	0.43	17.630	13.220	245.568	19.350	5.467	76.200
6.	0.75	0.83	34.030	19.830	474.004	37.350	8.201	147.084
7.	1.00	1.00	41.000	26.440	571.089	45.000	10.934	177.210
8.	1.25	0.88	36.080	33.050	502.558	39.600	13.668	155.945
9.	1.50	0.66	27.060	39.660	376.919	29.700	16.401	116.959
10.	1.75	0.45	18.450	46.270	256.990	20.250	19.135	79.745
11.	2.00	0.32	13.120	52.880	182.748	14.400	21.868	56.707
12.	2.25	0.22	9.020	59.490	125.640	9.900	24.602	38.986
13.	2.50	0.15	6.150	66.100	85.663	6.750	27.335	26.582
14.	2.75	0.11	4.305	72.710	59.964	4.725	30.069	18.607
15.	3.00	0.08	3.075	79.320	42.832	3.375	32.802	13.291
16.	3.25	0.05	2.173	85.930	30.268	2.385	35.536	9.392
17.	3.50	0.04	1.476	92.540	20.559	1.620	38.269	6.380
18.	3.75	0.03	1.066	99.150	14.848	1.170	41.003	4.607
19.	4.00	0.02	0.738	105.760	10.280	0.810	43.736	3.190
20.	4.25	0.01	0.492	112.370	6.853	0.540	46.470	2.127
21.	4.50	0.01	0.369	118.980	5.140	0.405	49.203	1.595
22.	4.75	0.01	0.246	125.590	3.427	0.270	51.937	1.063
23.	5.00	0.00	0.164	132.200	2.284	0.180	54.670	0.709

Table 21: CALCULATIONS FOR CATCHMENT (A) USING SCS METHOD, YEAR 2010

	Type Of Soil	Total Dev. Area (KM^2)	Pervious	% Of Total Area	CN(p)	Impervious	% Of Total Area	CN (Im)	WCN	L	WCN	Y(Slope)	tL	tp=(D/2+tL)	Qp	Potential Maximum Retention, S	Initial Abstraction, I	Excess Rainfall		Rainfall Excess
A	Sandy Loam, A	5.44356	1.1585	21.28	39	4.28506	78.72	92	80.7205	3610	80.7205	0.002	5.017997	8.018	3.639	60.666	12.1332	69.0	A	69.0
B	Sandy Loam, A	19.43008	7.43708	38.28	68	11.993	61.72	77	73.5551	9130	73.5551	0.003	10.65303	13.653	7.628	91.319	18.2638	53.6	B	53.6
C	Sandy Loam, A	9.48578	0.71338	7.52	68	8.7724	92.48	92	90.1951	3170	90.1951	0.003	2.630301	5.630	9.030	27.612	5.5224	92.2	C	92.2
D	Sandy Loam, A	11.63922	3.94132	33.86	68	7.6979	66.14	77	73.9524	4860	73.9524	0.003	6.361148	9.361	6.664	89.464	17.8929	54.4	D	54.4
E	Sandy Loam, A	9.49981	7.89391	83.10	68	1.6059	16.90	77	69.5214	5220	69.5214	0.003	7.610162	10.610	4.799	111.355	22.2710	45.7	E	45.7
F	Sandy Loam, A	28.03928	23.14768	82.55	30	4.8916	17.45	54	34.1869	7020	34.1869	0.003	24.3816	27.382	5.489	488.974	97.7948	1.0	F	1.0
G	Sandy Loam, A	20.42382	12.89092	63.12	67	7.5329	36.88	77	70.6883	9270	70.6883	0.003	11.67373	14.674	7.460	105.324	21.0648	47.9	G	47.9
H	Silt Loam, B	1.24031	0.00031	0.02	78	1.24	99.98	85	84.9983	1980	84.9983	0.003	2.197828	5.198	1.279	44.830	8.9659	79.1	H	79.1
I	Silt Loam, B	4.20418	1.15318	27.43	78	3.051	72.57	85	83.0799	3640	83.0799	0.003	3.819733	6.820	3.304	51.730	10.3459	74.5	I	74.5
J	Sandy Loam, A	32.4252	22.8043	70.33	67	9.6209	29.67	70	67.8901	8730	67.8901	0.003	11.99453	14.995	11.591	120.134	24.0268	42.6	J	42.6
K	Silt Loam, B	2.65092	0.26152	9.87	78	2.3894	90.13	92	90.6189	3200	90.6189	0.002	3.189156	6.189	2.296	26.295	5.2590	93.3	K	93.3
L	Silt Loam, B	4.752	0	0.00	78	4.752	100.00	85	85.0000	3190	85.0000	0.003	3.218603	6.219	4.096	44.824	8.9647	79.1	L	79.1
M	Sandy Loam, A	68.70675	63.05095	91.77	67	5.6558	8.23	77	67.8232	19710	67.8232	0.003	23.05111	26.051	14.136	120.503	24.1006	42.5	M	42.5
N	Silt Loam, B	8.03305	6.54375	81.46	67	1.4893	18.54	85	70.3371	5410	70.3371	0.003	7.660323	10.660	4.039	107.118	21.4236	47.2	N	47.2
		225.97396	**150.9968**	**66.82**		**74.97716**	**33.18**													

Table 22:Dimensionless Unit Hydrograph, Year 2010 – 1

			Drainage_Area_A			Drainage_Area_B			Drainage_Area_C			Drainage_Area_D		
1.														
2.	t/tp	Q/qp	Q'/q	t	Q	Q'/q	t	Q	Q'/q	t	Q	Q'/q	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	8.28	2.005	30.131	6.48	3.413	49.429	11.04	1.408	99.691	6.53	2.340	43.503
5.	0.50	0.43	29.67	4.009	107.969	23.22	6.827	177.122	39.56	2.815	357.227	23.39	4.681	155.884
6.	0.75	0.83	57.27	6.014	208.406	44.82	10.240	341.887	76.36	4.223	689.531	45.15	7.021	300.893
7.	1.00	1.00	69	8.018	251.091	54	13.653	411.912	92	5.630	830.760	54.40	9.361	362.522
8.	1.25	0.88	60.72	10.023	220.960	47.52	17.066	362.483	80.96	7.038	731.069	47.87	11.701	319.019
9.	1.50	0.66	45.54	12.027	165.720	35.64	20.480	271.862	60.72	8.445	548.302	35.90	14.042	239.264
10.	1.75	0.45	31.05	14.032	112.991	24.3	23.893	185.360	41.4	9.853	373.842	24.48	16.382	163.135
11.	2.00	0.32	22.08	16.036	80.349	17.28	27.306	131.812	29.44	11.260	265.843	17.41	18.722	116.007
12.	2.25	0.22	15.18	18.041	55.240	11.88	30.719	90.621	20.24	12.668	182.767	11.97	21.062	79.755
13.	2.50	0.15	10.35	20.045	37.664	8.1	34.133	61.787	13.8	14.075	124.614	8.16	23.403	54.378
14.	2.75	0.11	7.245	22.050	26.365	5.67	37.546	43.251	9.66	15.483	87.230	5.71	25.743	38.065
15.	3.00	0.08	5.175	24.054	18.832	4.05	40.959	30.893	6.9	16.890	62.307	4.08	28.083	27.189
16.	3.25	0.05	3.657	26.059	13.308	2.862	44.372	21.831	4.876	18.298	44.030	2.88	30.423	19.214
17.	3.50	0.04	2.484	28.063	9.039	1.944	47.786	14.829	3.312	19.705	29.907	1.96	32.764	13.051
18.	3.75	0.03	1.794	30.068	6.528	1.404	51.199	10.710	2.392	21.113	21.600	1.41	35.104	9.426
19.	4.00	0.02	1.242	32.072	4.520	0.972	54.612	7.414	1.656	22.520	14.954	0.98	37.444	6.525
20.	4.25	0.01	0.828	34.077	3.013	0.648	58.025	4.943	1.104	23.928	9.969	0.65	39.784	4.350
21.	4.50	0.01	0.621	36.081	2.260	0.486	61.439	3.707	0.828	25.335	7.477	0.49	42.125	3.263
22.	4.75	0.01	0.414	38.086	1.507	0.324	64.852	2.471	0.552	26.743	4.985	0.33	44.465	2.175
23.	5.00	0.00	0.468	40.090	1.703	0.216	68.265	1.648	0.476	28.150	4.298	0.22	46.805	1.450

Table 23: Dimensionless Unit Hydrograph, Year 2010 – 2

			Drainage_Area_E			Drainage_Area_F			Drainage_Area_G			Drainage_Area_H		
1.														
2.	t/tp	Q/qp	Q'/q	t	Q	Q'/q	t	Q	Q'/q	t	Q	Q'/q	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	5.484	2.653	26.318	0.120	6.832	0.659	5.748	3.669	42.880	9.492	1.300	12.140
5.	0.50	0.43	19.651	5.305	94.305	0.430	13.664	2.360	20.597	7.337	153.654	34.013	2.599	43.503
6.	0.75	0.83	37.931	7.958	182.031	0.830	20.496	4.556	39.757	11.006	296.587	65.653	3.899	83.970
7.	1.00	1.00	45.7	10.610	219.314	1.000	27.328	5.489	47.9	14.674	357.334	79.100	5.198	101.169
8.	1.25	0.88	40.216	13.263	192.997	0.880	34.160	4.830	42.152	18.343	314.454	69.608	6.498	89.029
9.	1.50	0.66	30.162	15.915	144.747	0.660	40.992	3.623	31.614	22.011	235.840	52.206	7.797	66.771
10.	1.75	0.45	20.565	18.568	98.691	0.450	47.824	2.470	21.555	25.680	160.800	35.595	9.097	45.526
11.	2.00	0.32	14.624	21.220	70.181	0.320	54.656	1.756	15.328	29.348	114.347	25.312	10.396	32.374
12.	2.25	0.22	10.054	23.873	48.249	0.220	61.488	1.208	10.538	33.017	78.613	17.402	11.696	22.257
13.	2.50	0.15	6.855	26.525	32.897	0.150	68.320	0.823	7.185	36.685	53.600	11.865	12.995	15.175
14.	2.75	0.11	4.7985	29.178	23.028	0.105	75.152	0.576	5.0295	40.354	37.520	8.306	14.295	10.623
15.	3.00	0.08	3.4275	31.830	16.449	0.075	81.984	0.412	3.5925	44.022	26.800	5.933	15.594	7.588
16.	3.25	0.05	2.4221	34.483	11.624	0.053	88.816	0.291	2.5387	47.691	18.939	4.192	16.894	5.362
17.	3.50	0.04	1.6452	37.135	7.895	0.036	95.648	0.198	1.7244	51.359	12.864	2.848	18.193	3.642
18.	3.75	0.03	1.1882	39.788	5.702	0.026	102.480	0.143	1.2454	55.028	9.291	2.057	19.493	2.630
19.	4.00	0.02	0.8226	42.440	3.948	0.018	109.312	0.099	0.8622	58.696	6.432	1.424	20.792	1.821
20.	4.25	0.01	0.5484	45.093	2.632	0.012	116.144	0.066	0.5748	62.365	4.288	0.949	22.092	1.214
21.	4.50	0.01	0.4113	47.745	1.974	0.009	122.976	0.049	0.4311	66.033	3.216	0.712	23.391	0.911
22.	4.75	0.01	0.2742	50.398	1.316	0.006	129.808	0.033	0.2874	69.702	2.144	0.475	24.691	0.607
23.	5.00	0.00	0.1828	53.050	0.877	0.004	136.640	0.022	0.1916	73.370	1.429	0.3164	25.990	0.405

Table 24: Dimensionless Unit Hydrograph, Year 2010 – 3

			Drainage_Area_I			Drainage_Area_J			Drainage_Area_K			Drainage_Area_L		
1.														
2.	t/tp	Q/qp	Q'/q	t	Q	Q'/q	t	Q	Q'/q	t	Q	Q'/q	t	Q
3.	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0
4.	0.25	0.12	8.94	1.705	29.53776	5.112	3.74875	59.25319	11.196	1.54725	25.70602	9.492	1.55475	38.87923
5.	0.50	0.43	32.035	3.41	105.8436	18.318	7.4975	212.3239	40.119	3.0945	92.11322	34.013	3.1095	139.3172
6.	0.75	0.83	61.835	5.115	204.3028	35.358	11.24625	409.8346	77.439	4.64175	177.7999	65.653	4.66425	268.9147
7.	1.00	1.00	74.5	6.82	246.148	42.6	14.995	493.7766	93.3	6.189	214.2168	79.1	6.219	323.9936
8.	1.25	0.88	65.56	8.525	216.6102	37.488	18.74375	434.5234	82.104	7.73625	188.5108	69.608	7.77375	285.1144
9.	1.50	0.66	49.17	10.23	162.4577	28.116	22.4925	325.8926	61.578	9.2835	141.3831	52.206	9.3285	213.8358
10.	1.75	0.45	33.525	11.935	110.7666	19.17	26.24125	222.1995	41.985	10.83075	96.39756	35.595	10.88325	145.7971
11.	2.00	0.32	23.84	13.64	78.76736	13.632	29.99	158.0085	29.856	12.378	68.54938	25.312	12.438	103.678
12.	2.25	0.22	16.39	15.345	54.15256	9.372	33.73875	108.6309	20.526	13.92525	47.1277	17.402	13.99275	71.27859
13.	2.50	0.15	11.175	17.05	36.9222	6.39	37.4875	74.06649	13.995	15.4725	32.13252	11.865	15.5475	48.59904
14.	2.75	0.11	7.8225	18.755	25.84554	4.473	41.23625	51.84654	9.7965	17.01975	22.49276	8.3055	17.10225	34.01933
15.	3.00	0.08	5.5875	20.46	18.4611	3.195	44.985	37.03325	6.9975	18.567	16.06626	5.9325	18.657	24.29952
16.	3.25	0.05	3.9485	22.165	13.04584	2.2578	48.73375	26.17016	4.9449	20.11425	11.35349	4.1923	20.21175	17.17166
17.	3.50	0.04	2.682	23.87	8.861328	1.5336	52.4825	17.77596	3.3588	21.6615	7.711805	2.8476	21.7665	11.66377
18.	3.75	0.03	1.937	25.575	6.399848	1.1076	56.23125	12.83819	2.4258	23.20875	5.569637	2.0566	23.32125	8.423834
19.	4.00	0.02	1.341	27.28	4.430664	0.7668	59.98	8.887979	1.6794	24.756	3.855902	1.4238	24.876	5.831885
20.	4.25	0.01	0.894	28.985	2.953776	0.5112	63.72875	5.925319	1.1196	26.30325	2.570602	0.9492	26.43075	3.887923
21.	4.50	0.01	0.6705	30.69	2.215332	0.3834	67.4775	4.443989	0.8397	27.8505	1.927951	0.7119	27.9855	2.915942
22.	4.75	0.01	0.447	32.395	1.476888	0.2556	71.22625	2.96266	0.5598	29.39775	1.285301	0.4746	29.54025	1.943962
23.	5.00	0.00	0.298	34.1	0.984592	0.1704	74.975	9.71706	0.3732	30.945	0.856867	0.3164	15.065	2.674846

Table 25: Dimensionless Unit Hydrograph, Year 2010 – 4

			Drainage_Area_M			Drainage_Area_N		
1.								
2.	t/tp	Q/qp	Q'/q	t	Q	Q'/q	t	Q
3.	0.00	0.00	0	0	0	0	0	0
4.	0.25	0.12	5.1	6.51275	72.0936	5.664	2.665	22.8769
5.	0.50	0.43	18.275	13.0255	258.3354	20.296	5.33	81.97554
6.	0.75	0.83	35.275	19.53825	498.6474	39.176	7.995	158.2319
7.	1.00	1.00	42.5	26.051	600.78	47.2	10.66	190.6408
8.	1.25	0.88	37.4	32.56375	528.6864	41.536	13.325	167.7639
9.	1.50	0.66	28.05	39.0765	396.5148	31.152	15.99	125.8229
10.	1.75	0.45	19.125	45.58925	270.351	21.24	18.655	85.78836
11.	2.00	0.32	13.6	52.102	192.2496	15.104	21.32	61.00506
12.	2.25	0.22	9.35	58.61475	132.1716	10.384	23.985	41.94098
13.	2.50	0.15	6.375	65.1275	90.117	7.08	26.65	28.59612
14.	2.75	0.11	4.4625	71.64025	63.0819	4.956	29.315	20.01728
15.	3.00	0.08	3.1875	78.153	45.0585	3.54	31.98	14.29806
16.	3.25	0.05	2.2525	84.66575	31.84134	2.5016	34.645	10.10396
17.	3.50	0.04	1.53	91.1785	21.62808	1.6992	37.31	6.863069
18.	3.75	0.03	1.105	97.69125	15.62028	1.2272	39.975	4.956661
19.	4.00	0.02	0.765	104.204	10.81404	0.8496	42.64	3.431534
20.	4.25	0.01	0.51	110.7168	7.20936	0.5664	45.305	2.28769
21.	4.50	0.01	0.3825	117.2295	5.40702	0.4248	47.97	1.715767
22.	4.75	0.01	0.255	123.7423	3.60468	0.2832	50.635	1.143845
23.	5.00	0.00	0.456	130.255	6.446016	0.46	53.3	1.85794

ANNEXURE - V

LEVEL	NAME	TRU	No_HH	TOT_P
TOWN	Sanaur (M Cl)	Urban	3159	17935
WARD	Sanaur (M Cl) - Ward No.1	Urban	267	1487
WARD	Sanaur (M Cl) - Ward No.2	Urban	244	1437
WARD	Sanaur (M Cl) - Ward No.3	Urban	258	1552
WARD	Sanaur (M Cl) - Ward No.4	Urban	224	1385
WARD	Sanaur (M Cl) - Ward No.5	Urban	208	1224
WARD	Sanaur (M Cl) - Ward No.6	Urban	242	1291
WARD	Sanaur (M Cl) - Ward No.7	Urban	217	1291
WARD	Sanaur (M Cl) - Ward No.8	Urban	246	1346
WARD	Sanaur (M Cl) - Ward No.9	Urban	202	1139
WARD	Sanaur (M Cl) - Ward No.10	Urban	266	1397
WARD	Sanaur (M Cl) - Ward No.11	Urban	366	1941
WARD	Sanaur (M Cl) - Ward No.12	Urban	217	1334
WARD	Sanaur (M Cl) - Ward No.13	Urban	202	1111
				17935

TOWN	Patiala (M Corp+OG)	Urban	64214	323884
TOWN	Patiala (M Corp.)	Urban	59794	303151
WARD	Patiala (M Corp.) - Ward No.1	Urban	5408	28232
WARD	Patiala (M Corp.) - Ward No.2	Urban	1160	6274
WARD	Patiala (M Corp.) - Ward No.3	Urban	2174	10974
WARD	Patiala (M Corp.) - Ward No.4	Urban	5569	28374
WARD	Patiala (M Corp.) - Ward No.5	Urban	8636	41932
WARD	Patiala (M Corp.) - Ward No.6	Urban	1591	7924
WARD	Patiala (M Corp.) - Ward No.7	Urban	558	3103
WARD	Patiala (M Corp.) - Ward No.8	Urban	1507	7800
WARD	Patiala (M Corp.) - Ward No.9	Urban	2513	11647
WARD	Patiala (M Corp.) - Ward No.10	Urban	1057	4836
WARD	Patiala (M Corp.) - Ward No.11	Urban	3562	17587
WARD	Patiala (M Corp.) - Ward No.12	Urban	1749	8132
WARD	Patiala (M Corp.) - Ward No.13	Urban	557	2724
WARD	Patiala (M Corp.) - Ward No.14	Urban	776	4170
WARD	Patiala (M Corp.) - Ward No.15	Urban	1727	8424
WARD	Patiala (M Corp.) - Ward No.16	Urban	469	2434
WARD	Patiala (M Corp.) - Ward No.17	Urban	327	1710
WARD	Patiala (M Corp.) - Ward No.18	Urban	433	2189
WARD	Patiala (M Corp.) - Ward No.19	Urban	1076	5607
WARD	Patiala (M Corp.) - Ward No.20	Urban	806	4122
WARD	Patiala (M Corp.) - Ward No.21	Urban	632	3222
WARD	Patiala (M Corp.) - Ward No.22	Urban	506	2599
WARD	Patiala (M Corp.) - Ward No.23	Urban	914	4747
WARD	Patiala (M Corp.) - Ward No.24	Urban	3531	18522
WARD	Patiala (M Corp.) - Ward No.25	Urban	1049	5404
WARD	Patiala (M Corp.) - Ward No.26	Urban	1595	8075
WARD	Patiala (M Corp.) - Ward No.27	Urban	359	2064
WARD	Patiala (M Corp.) - Ward No.28	Urban	873	4301
WARD	Patiala (M Corp.) - Ward No.29	Urban	500	2972
WARD	Patiala (M Corp.) - Ward No.30	Urban	814	4213
WARD	Patiala (M Corp.) - Ward No.31	Urban	1428	7493
WARD	Patiala (M Corp.) - Ward No.32	Urban	677	3847
WARD	Patiala (M Corp.) - Ward No.33	Urban	1533	8120
WARD	Patiala (M Corp.) - Ward No.34	Urban	285	1483
WARD	Patiala (M Corp.) - Ward No.35	Urban	3443	17894
WARD	Hira Bagh Colony (OG) - Ward No.36	Urban	475	2411
WARD	Ranjit Nagar Extension - I (OG) - Ward No.37	Urban	307	1423
WARD	Grid Colony PSEB on Bhadson Road (OG) - W	Urban	488	2403
WARD	Kheri Gujran (OG) - Ward No.39	Urban	317	1417
WARD	Urban Estate - I (OG) - Ward No.40	Urban	1180	5107
WARD	Punjabi University (OG) - Ward No.41	Urban	393	2322
WARD	Urban Estate - II (OG) - Ward No.42	Urban	829	3504
WARD	Ranjit Nagar Extension - II (OG) - Ward No.43	Urban	431	2146
				323884

TOWN	Shekhpura (CT)	Urban	376	1931
WARD	Shekhpura (CT) - Ward No.1	Urban	376	1931
TOWN	Rurki Kasba (CT)	Urban	1807	8179
WARD	Rurki Kasba (CT) - Ward No.1	Urban	1807	8179
				10110

Rural	74	426
Rural	176	351
Rural	430	2671
Rural	55	337
Rural	70	397
Rural	110	544
Rural	9	44
Rural	112	637
Rural	17	112
Rural	405	2263
Rural	29	126
Rural	70	360
Rural	116	625
Rural	224	1287
Rural	27	184
Rural	98	432
Rural	37	179
Rural	195	999
Rural	216	1346
Rural	217	1186
Rural	276	1325
Rural	141	833
Rural	246	1440
Rural	91	506
Rural	219	1338
Rural	71	405
Rural	157	976
Rural	98	601
Rural	23	116
Rural	254	1536
Rural	407	2404
Rural	404	2335
Rural	164	1072
Rural	161	878
Rural	186	1111
Rural	396	1954
Rural	124	723
Rural	464	2534
Rural	114	613
Rural	187	1099
Rural	431	2456
Rural	95	601
Rural	199	1325
Rural	300	1657
Rural	276	1515
Rural	288	1584
Rural	300	1612

Total Urban Population In Planning Area	351929
Total Rural Population Pf Planning Area	49055
Total Population Of Planning Area	400984

PUBLICATIONS FROM THE THESIS

PUBLICATIONS FROM THE THESIS

List of Papers in Refereed Journals and Books

1. Brar, T.S., Jain, R.K. and Khare, D., 'Use Of Non-Conventional Technologies For Sustainable Urban Water Resource Management: Case Study Patiala', Raja IA, (ed.) Environmentally Sustainable Development, ESDev-2005, COMSATS Institute of Information Technology, Pakistan, 2005., Pages 1149 – 1158, ISBN 969 8779 07 8.
2. Brar, T.S., Jain, R.K. and Khare, D., 'Role Of Non-Conventional Technologies For Sustainable Urban Water Resource Management: Case Study Patiala', Recent Advances in Water Resources Development & Management, Edited by Khare, D., Mishra, S. K., Tripathi, S. K., Chauhan, G. and Sharma, N., Allied Publishers, Delhi, 2005. Page 965 – 979. ISBN: 81-7764-9299 (VOL. I & II).
3. Brar, T.S., Jain, R.K. and Khare, D., 'Decentralized Wastewater Treatment System: Technological and Economic viability for small and medium towns', Journal of Indian Association of Environmental Management, NEERI, Nagpur, Vol 32 No. 3, 2005. Page 171 – 180. ISSN 0970-8480
4. Biswas, R., Brar, T.S., Jain, R.K. and Khare, D., 'Water Supply In New Regional Growth Centre : Case Study', Journal of Indian Buildings Congress, New Delhi, Vol. 14 No. 1, 2007. Pages 180 – 186.
5. Brar, T.S., Jain, R.K. and Khare, D., 'Integrating Solar and green Architecture for a residential building in hot arid climate', Journal of Indian Buildings Congress, New Delhi, Vol. 13 No. 3, 2006. Pages 43 – 48.
6. Brar, T.S., Jain, R.K. and Khare, D., 'Strategies for Water Resource management in Urban Areas: Case Study Patiala', Journal of Indian Buildings Congress, New Delhi, Vol. 12 No. 1, 2005. Pages 215 – 226.

List of Papers in Proceedings of National and international conferences

7. Brar, T.S., Jain, R.K. and Khare, D., 'Water Resource Management Plan For Patiala', International conference on Water Resources Engineering & Management (ICWREM), Civil Engineering Department , University of Engineering & Technology Lahore, Pakistan, March 07 – 08, 2011.
8. Brar, T.S., Jain, R.K. and Khare, D., 'Decentralized Wastewater Treatment System For Restoring Streams And Ground Water Quality In An Urban Area', International Conference on Sustainable Water Resource Management and Treatment Technologies', Nagpur, India, January, 19 – 22, 2011.

9. Brar, T.S., Jain, R.K. and Khare, D., 'Sustainable Urban Water Resource Management Policy in Patiala', XII International Rainwater and Urban Design Conference 2007, Melborne, Australia, August 21- 23, 2005.
10. Brar, T.S., Jain, R.K. and Khare, D., 'Innovative Policy Interventions to Increase Domestic Rainwater Harvesting in Urban Areas', XII International Rainwater Catchment systems Conference 2005, New Delhi, India, November 15-18, 2005.
11. Brar, T.S., Jain, R.K. and Khare, D., 'Plan For Sustainable Urban Water resource Management: Case Study Patiala', IWA Watershed & River Basin Management Specialist Group Conference, Calgary, Alberta, Canada, September 13-15, 2005.
12. Brar, T.S., Jain, R.K. and Khare, D., 'Public Participation and Innovative Techniques for Water Management in Urban Areas', In the Proceedings of 53rd National town and Country Planners Congress, Indore, 2004. Pages 247 – 253.
13. Brar, T.S., Jain, R.K. and Khare, D., 'Decentralized Wastewater treatment System For Sustainable Urban Planning', 7th International Conference On Humane Habitat, Rizvi College Of Architecture, Mumbai, 2005.
14. Yadav, S.R., Brar, T.S., Jain, R.K. and Khare, D., 'Rain Water Harvesting and Ground Water Recharge for Sustainable Development of Urban Areas', In the Proceedings of National Conference on Sustainable Management of Water Resources, CAET, Junagadh Agriculture University, Junagadh, 2005. Pages 170 – 176.
15. Brar, T.S., Jain, R.K. and Khare, D., 'Water resource management plan for patiala – 2021', National Seminar on sustainable Urban Settlements: Issues and strategies', Department of Sociology, Guru Nanak Dev University, Amritsar, March, 2005.
16. Brar, T.S., Jain, R.K. and Khare, D., 'Changes In Building Bye-Laws For Domestic Rain Water Harvesting', Planning and Construction of Buildings in Modern India, The Institution of Engineers (India), Roorkee Local Centre, IIT Roorkee, Roorkee, 2004.
17. Brar, T.S., Khare, D. and Jain, R.K., 'Need to adopt decentralized wastewater treatment system in urban areas', In Proceedings of Seminar on Challenges and Priorities in Urban and Regional Planning Organized by Guru Ramdass School of Planning, Guru Nanak Dev University, Amritsar, 2004.