PLANNING PROPOSALS FOR SUSTAINABLE WATER SUPPLY FOR BHOPAL

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree
of
MASTER OF URBAN AND RURAL PLANNING

By
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CANDIDATE'S DECLARATION

I hereby declare that the work, which is presented in this dissertation entitled **"Planning Proposals for Sustainable Water Supply for Bhopal"** in partial fulfillment of the requirements for the award of degree of **Master of Urban and Rural Planning,** submitted in the **Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee,** is an authentic record of my own work carried out for a period of about one year from June 2003 to June 2004 under the supervision of **Prof. R. Shankar,** Prof. & Head, Department of Architecture and Planning, IIT-Roorkee, Roorkee.

The matter embodied in this dissertation has not been submitted by me for award of any other degree.

(Manish Kumar Verma)

CERTIFICATE

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

Date : 23 /06/ 2004

Place : Roorkee

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CONTENTS

Page No.

CHAPTER 3
STUDY AREA PROFILE

ABSTRACT

*Bhopal the capital of Madhya Pradesh is known as the **"City of Lakes"**. There are seven lakes in Bhopal. There was a time when water was in surplus in Bhopal and people thought that it would be available in abundance as free gift of nature now it become scarce commodity.*

The fast pace of urbanization (40% decadal growth), negligence of water resources of the city (Upper lake gets polluted due to lack of maintenance and garbage disposal), over exploitation of groundwater (ground water has gone down to 250 feet from 80-100 feet in last 3 years only), Contamination of ground water (area around Union Carbide factory), wastage of water in the past few years and less amount of rainfall (718 mm in past four years, although avg. annual precipitation is 1209 mm), now the situation became such that there are people who do not even get sufficient water to drink. The level of water of the lakes is decreasing at an alarming rate. People have to stand in long queues to get water.

Despite of this entire people are continuously wasting water and not caring about the circumstances. In this context, the dissertation shall aim "to workout planning proposals for sustainable water supply for Bhopal", simultaneously highlighting the issues of water scarcity in the Bhopal through the analysis of the reasons for this crisis. Further, it shall explore into the various measures & probabilities to mitigate the crisis in sustainable manner.

LIST OF MAPS

LIST OF TABLES

LIST OF FIGURES

LIST OF CHARTS

LIST OF ABBREVIATIONS

ASA	Arid and semi-arid
BHEL	Bharat Heavy Electrical Limited
BDA	Bhopal Development Authority
BDP	Bhopal Development Plan
CGWB	Central Ground Water Board
BMC	Bhopal Municipal Corporation
Dia	Diameter
DBT	Dry bulb temperature
ESR	Elevated Storage Reservoir
ft	Feet
GIS	Geographical Information System
GW	Ground water
HIG	High income group
IT	Information Technology
LIG	Low income group
MIG	Medium income group
m	Metre
mm	Millimetre
MGD	Million gallon per day
MLPD	Million litter per day
NIH	National Institute of Hydrology
NGO	Non Government Organisation
O & M	Operation and maintainance
OHT	Over head tank
PC	Personal computer
PHED	Public Health Engineering Department
RWH	Rain water harvesting
RWHS	Rain water harvesting system
sqm	Square metre
SOI	Survey of India
SOI-DPMS	Survey of India District Planning Map Series
ULB	Urban local body
VO	Voluntary Organisation.

Introduction

Topics covered in this chapter

- BACKGROUND
- NEED OF THE PROJECT
- IDENTIFICATION OF THE PROBLEMS
- AIMS AND OBJECTIVES
- SCOPE
- LIMITATIONS
- RESEARCH METHODOLOGY
- TOOLS AND TECHNIQUES

CHAPTER 1

1.1. BACKGROUND: It is said that the future wars would be fought for water - the lifeline of humanity (*Asit K. Biswas,* 1993). Water plays a crucial role in any country's welfare/economic development. It is a central feature and can be a source of energy, avenue of transportation, means of production and aesthetics. Water is a finite and limited resource, and thus its efficient and effective use of water resources is necessary for sustainable economic and social development. (Ritu Batra, 1990).

Fortunately 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 **32,87,590 km** & population is **1,027,015,247** (census 2001). Most of the Indian landmass is in the **semi-arid tropical belt** characterized by seasonal rainfall lasting over a period **3-4 months**. Water resources of India are enormous but they are unevenly distributed in space, time, and quantity. Due to lack of proper water resources planning and budgeting, famine in the vast tracts of the western and southern peninsula plateau region and flood in northern and eastern India ravage the lives of million of human and animal population. Famine, especially scarcity of drinking water, is causing havoc in Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Tamilnadu & few **Parts of Madhya Pradesh.**

Although India has indeed achieved significant strides in the water supply sector. However, in 1991, only about 82% of the urban households covering *85% of the urban population had access to safe drinking water.* Against the national average target of supply of **140 lpcd** of water, the per-capita consumption is too low and ranges from *165 lpcd in few larger towns to about 50 lpcd in smaller* towns (*Ashutosh Kumar Sahu,* 2001). In fact, the availability in the urban slums is around **27 lpcd**. The situation is critical in many large cities. For instance, in Chennai, the fourth largest city of the country, *only 2 million of the 3.7 million* residential consumers within the service area of the Water Supply and the Sewerage Board are estimated to be connected to the system. On an average, they receive a supply of about **36 lpcd** while the rest within the service area use the public taps which serve about **240 persons per tap**. In respect of Calcutta too, some three million are estimated to be living in Bastis and refugee settlements and about 2.5 million in urban blights which lack potable water.

1.2. NEED OF THE PROJECT: Water is an essential resource for **sustaining life and environment**. The available water resources are under pressure due to increased demand and time is not far when water, which we have always thought to be available in abundance and free gift of nature, will become a **scare commodity.** Conservation and preservation of water resource is urgently required to be done.

In Bhopal down the ages, people have developed a wide variety of techniques to harvest and conserve the water resources, which are simple efficient and cost effective. One of the best examples of water conservation is **Upper Lake** *(Constructed by Raja Bhoj)* it is manmade and follows the natural slopes, in which many natural streams (365 streams said) are converging and acts as a major source of water. Even today inspite of facing over exploitation and pollution the upper lake is the largest source of water supply in Bhopal. We should draw upon the wisdom of our ancient life sustaining system and through better planning and management, conserve our precious water resources.

Despite the advancements in the field of water supply, rapid population growth **{1062771(1991) – 14,37,354(2001)}** in Bhopal has outstripped the supply of this critical resource. As a result of the technique of flood irrigation in agriculture sector and the further requirement of the growth in agriculture production (by the use of chemical fertilizer and increased crop intensity) the irrigation demand has become competing and limiting factor vis-à-vis urban demand. **Kolar reservoir** water has been utilized to extent of not being left with transferable surplus. The ground water aquifers in Bhopal have been indiscriminately exploited with the help of deep pumping so that their yields are no longer to sustainable. The increase portion of hard surfaces *(impermeable surfaces)* in the city has been matched by proportionate increase in runoff and proportionate decrease in recharge. Simultaneously, insufficient supply forces individuals to meet their requirements through groundwater exploitation thereby driving down the water table still further. Furthermore, inability to dispose both solid and liquid wastes approximately is resulting in their disposal in fresh water bodies leading to the destruction of lakes and low laying areas as well as fresh water aquifers. Thus while urban growth trends are galloping the resource constraints is beginning to inhabit the quality life.

One of the biggest environmental challenges that Bhopal has to faces in the coming decades is that of balancing its increasing demand of water coupled with the diminishing availability of water. Increase in the population along with the rapid urbanization, industrialization and agriculture development, on one hand leading to an ever increasing demand of water and, *on the other hand, a decreased supply of fresh* *water, specially in the absence of effective mechanism to regulate the pollution.* The future scenario is one, characterized by over exploitation of water resources, decreased accessibility to clean water, and increased competition for the potential conflict over water resources.

Due to huge population there is already a lot of pressure on existing water supply. Not only due to rapid population growth but also due to raise in standard of living (*use of flush, air cooler, wash basin, shower, bath tub, car, bike, flower pot and small front garden*) is one of the major factors in demand.

In Bhopal natural water resources are already exploited to such extent that there is an urgent need to resort for other type of water resource. If we fail in doing so we can see the effects of population on the water resources in table below. After analyzing rain water potential in Bhopal one can easily say that rain in itself can fulfill the greater part of part of the demand. Rainwater is pure and little purification makes it of drinking water quality. At least we can use it for the non-drinking purposes because drinking water requirement is only about 25 lpcd.

In Bhopal good rainfall **(1209mm)** during the month **of mid June to September** and has good potential to meet the water requirement of the city, then why we are facing acute water shortage. It is only because of our sole dependency on groundwater resources and surface water resources. The problem is further aggravated when surface water sources are getting contaminated. Even the ground water source in not intact of pollution. Is rainwater free from pollution? The answer is not entirely, it may also contain bacteria as coming in contact with the atmosphere and contaminated. But only little purification makes it usable for drinking

Table 1.1. Bhopal: Capacity of Water Resources* (2001)

S.No	Source	Capacity (mgd) (Existing)	Capacity (mgd) (Supply)	Remark
1.	Upper lake	28	26	Major source
2.	Kolar Dam	34 (Designed capacity)	21	Largest source, 35 km away from main city.
3.	Hataikheda	1.5	1.5	Mini Source
4.	G. W & others	5**	5	Smaller sources
5.	Total	68.5	53.5 (51.0 mgd during scarcity)	

** the existing yield capacity of above reservoirs and lake are only true if normal rainfall takes place other wise it goes down drastically.*

*** 2.5 mgd during scarcity period.*

Source: Bhopal Development Plan 2005

Table 1.2. Requirement of water in Bhopal

Present requirement (2001 population 14,37,354)	@40 Gallon/day/person (180 lpcd), Total requirement 57.03 **mgd.**
Inadequacy	3.53 Mgd **(6.19%)** (Normal Period) 6.03 Mgd **(10.57%)** (Scarcity Period)
Requirement for 21.84 lakh population (2021)	@40 Gallon/day, Total requirement **86.75 mgd (38.29%)**
Potential existing	**68.5 mgd (Production 53.5 mgd.** During normal rainfall)
Source: Bhopal Development Plan 2005	

Note: Figure in bracket show the percentage inadequacy.

The above table revels that availability of water shall be critical factor for future growth of the Bhopal. As per the water resource potential in and around Bhopal, the urban area may not be able to support population beyond **20 lakh.** In view of this, it would be necessary to explore, new sources to meet the city growth beyond **22 lakh** *(Estimated population for 2021)* or so. So it is necessary now to think of planning proposals for the sustainable water supply for Bhopal.

1.3. IDENTIFICATION OF THE PROBLEMS:

Based on observation of the study area and literature survey, the specific problems of the Bhopal related to water could be listed as:

1. Contamination of ground water around Union Carbide factory, this pollution is due to leakage of chemical (1984-Bhopal gas tragedy) used in the factory and it is proven to be extremely harmful for health.
2. Acute shortage of water during summer, because of over dependency on surface water source.
3. In adequate water supply system form Kolar dam to Bhopal, since the water from which is supplied through a single pipeline, any hitch in supply, be it due to power failure or maintenance work, wrecks havoc on the city.
4. Supply of lake water without treatment during crisis period *(Hindustantimes.com – lake city in distress)*
5. Over exploitation of ground water over past three year, the ground water has gone down to 250 feet from 80-100 feet.
6. Duration of water supply is ¾ to 1.5 hours and once in a day.

7. Water supply at very low pressure so that people living at higher altitude get little water.
8. Excessive use of pump to suck the water from Municipal Water Supply line.
9. High degree of pollution at upper lake due to lack of maintenance and garbage disposal.

1.4. AIMS AND OBJECTIVES:

Aim:

Aim of this dissertation is "to workout planning proposals for sustainable water supply for Bhopal".

Objectives:

Keeping the aim in view, the following set of broad objectives has been framed for thesis project. They are:

1. To analyze the prevailing water supply shortage of Bhopal in the light of demand, existing water resources and supply systems.
2. To assess the potential of water resources available in the form of lakes and ground water reservoir in and around the Bhopal.
3. To assess the potential of rainwater harvesting including rooftop rainwater harvesting to supplement the conventional system.
4. To study the various traditional rainwater harvesting practices as well as modern technologies, if any, in terms of their appropriateness to diverse situation including the probability of recharge and reuse of wastewater.
5. To work out plan proposals incorporating strategies for most viable solution for meeting water supply problems.

1.5. SCOPE:

The scope of study includes assessment of the potential of water resources available in the form of lakes and ground water reservoir in and around the Bhopal not only for the drinking purpose but also for all other uses of the city. While the main purpose will be to deal with urban households primarily, the project attempts to cover other sectors of urban water consumption as well.

1.6. LIMITATIONS:

Though the problem of water shortage in urban area is much more severe and here is urgent need to go for alternate water resources, we can't avoid the need of it in rural and fringe areas. But due to the limitation on time and resources for undertaking necessary studies, the bulk of the studies will be confined within the Municipal boundary of Bhopal & the field survey will be limited to cover only the key planning aspects and bulk of the data & maps will be from reliable secondary official sources.

1.7. RESEARCH METHODOLOGY:

The research methodology is given in the form of flow chart on the next page.(page No. 7)

1.8. TOOLS AND TECHNIQUES:

1.8.1 SURVEY TOOLS AND TECHNIQUES:

TOOLS

I. Questionnaire

II. Interview of the people

TECHNIQUES

I. Pilot Survey

II. Stratified Sampling

1.8.2 ANALYTICAL TOOLS:

I. **AutoCAD 2000,** for Preparation And Analysis of Spatial Data In First Stage of Works.

II. **GIS 3.2,** For The Preparation And Analysis of Spatial Data In Final Stage of Work.

III. **Ms Excel 2000,** For Processing of Data.

RESEARCH METHODOLOGY:

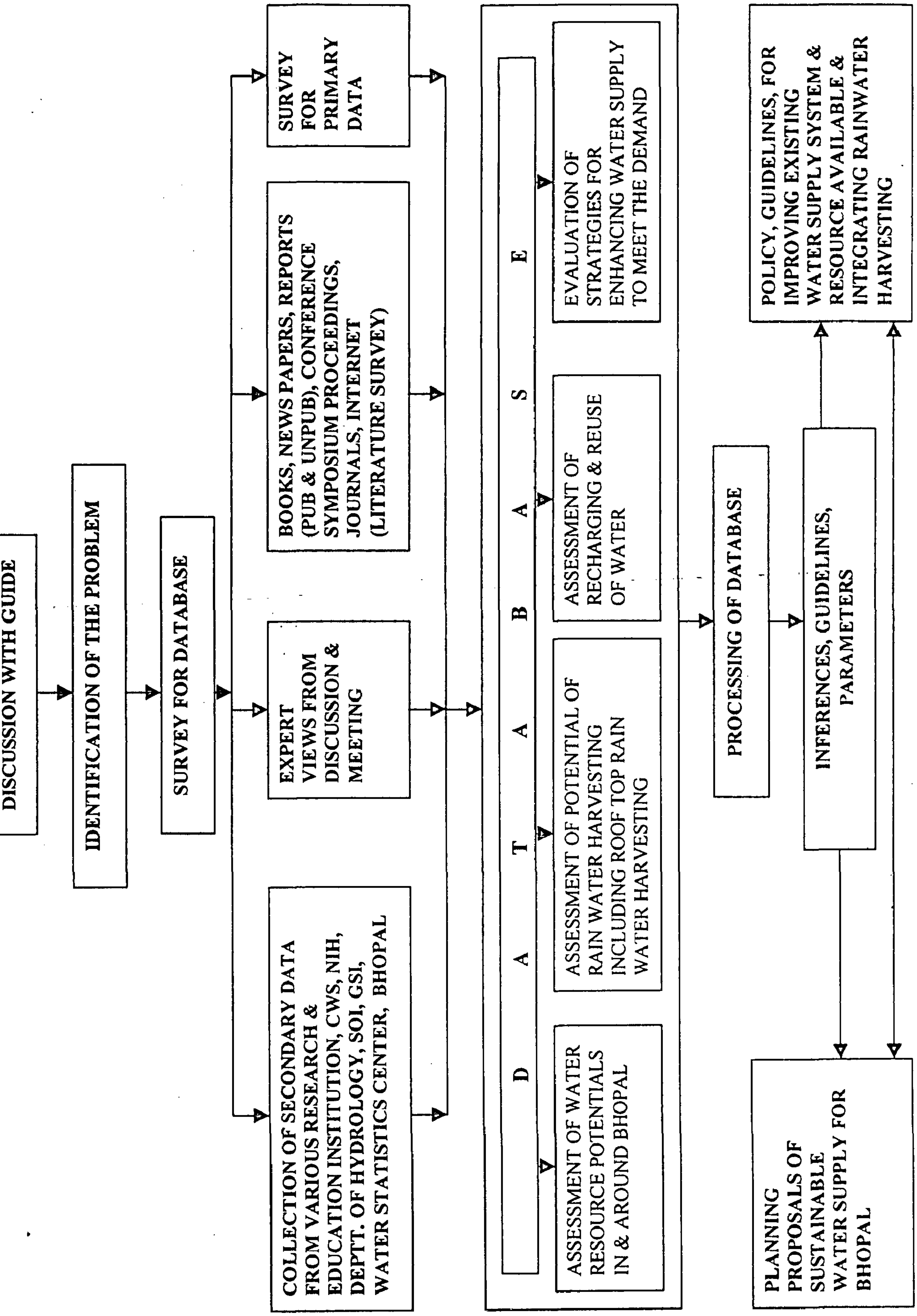

Chart 1.1

2.1. OVER ALL VIEW OF SUSTAINABLE WATER SUPPLY

2.1.1. INTRODUCTION: None of us denied with the fact that water is an essential resource for sustaining life and environment. We have always thought to be available in abundance and free gift of nature, but during the past few years (Only during the past 15 years ago) there has been increasing realization of the importance of water management in the continuing well being and development of the developing countries, especially those located in the **arid and semi-arid region**. More and more planners and decision makers have started to realize the critical importance of efficient water management for the sustainable development of their countries. *As sustainability is a new term in the planning process so there is no comprehensive literature written on & available in India.* There are separate studies carried out papers written on individual aspects of "Sustainable Water Supply" such as ***Water Resources Planning,*** *Water Resources Management,* ***Watershed Development,*** *Watershed Management,* ***Assessment of Climate Change,*** *Impact of Climate Change,* ***Assessment of Environmental Quality at Different Scales,*** *Pollutants and their Levels,* ***Migration of Pollutants,*** *Management of Aquatic Ecosystems,* ***Effluent – Ground water Interaction,*** *Effluent – Surface water Interaction,* ***Wastewater Treatment and Management,*** *Socio-Economic Aspects of Water Resources Development, Utilization and Conservation etc.* but in wholesome study of all these topics help me to get the complete solution for Sustainable Water Supply for Bhopal.

2.1.2. SUSTAINABLE WATER MANAGEMENT: What is Sustainable Water Management? The term uses two important concepts with respect to water, **sustainability** and **management**. In order to understand Sustainable Water Management, it is important to define these concepts.

A. SUSTAINABILITY

The **Bruntland Report** popularized the term ***sustainability for human and environmental development*** when it was published in 1987. In the report, *sustainable* activities were defined as ones where the needs of the present generation are met without compromising the needs of future generations.

What the Bruntland definition implies is an equitable distribution of the resource not only spatially between users in a given location, but temporally between users over time. The idea is to allocate the resource in such a way as for all, including the environment, to have an adequate share without making any one group worse off, both now and in the future.

To achieve sustainability, there must be a rethinking of what we consider a basic need. It is common in our society to say that we *need* a given resource, but how much of it do we really *need* to use? Also, how do we decide what the basic needs of our ecosystem and the organisms living within it are? Defining what constitutes a basic need is perhaps the greatest challenge to adopting sustainable practices in our daily lives, as interpretations of *need* vary widely from region to region, village to village and even from person to person (*V Suresh*, 2001).

B. MANAGEMENT

There has been a shift in recent years from the traditional 'top-down' approach to a more open management system where all levels have a say in the allocation and use of the resource. If properly done, this system ensures that the needs and concerns of those most affected by the use of the resource are addressed, without loosing sight of the wider issues touching the society as a whole.

Information is key to good management. Understanding the needs of the stakeholders, as well as the possibilities and limitations of the resource, is needed to manage it effectively. This requires sharing both indigenous and modern scientific knowledge, as well as establishing a dialogue between individuals and large institutions. With the right information, appropriate strategies can be formulated to deal with the realities of resource management, such as distribution, access, rights, etc.

2.1.2.1. DEFINING SUSTAINABLE WATER MANAGEMENT: *The purpose of Sustainable Water Management (SWM) is simply to manage our water resources while taking into account the needs of present and future users.*

However, SWM is much more than its name implies. It involves a whole new way of looking at how we use our precious water resources. The International Hydrological Programme, a UNESCO initiative, noted:

"It is recognised that water problems cannot be solved by quick technical solutions, solutions to water problems require the consideration of cultural, educational, communication and scientific aspects. Given the increasing political recognition of the importance of water, it is in the area of sustainable freshwater management that a

major contribution to avoid/solve water-related problems, including future conflicts, can be found."

Therefore, SWM attempts to deal with water in a holistic fashion, taking into account the various sectors affecting water use, including political, economic, social, technological and environmental considerations.

Since the **Mar del Plata Water Conference hosted by the UN in 1977**, SWM has been high on the international agenda. Later conferences and workshops have addressed the issue and have attempted to refine the concept as more and more research has been done in the area. The current understanding of SWM is based primarily upon the principles devised in Dublin during the International Conference on Water and the Environment (ICWE) in 1992, namely (*Asit K. Biswas*, 1993):

1. *Freshwater is a finite and valuable resource that is essential to sustain life, the environment and development.*
2. *The development and management of our water resources should be based on a participatory approach, involving users, planners and policy makers at all levels.*
3. *Women play a central role in the provision, management and safeguarding of water resources.*
4. *Water has an economic value and should therefore be seen as an economic good.*

These principles reflect the importance of water in our daily lives and the need for proper communication, gender equity, and economic and policy incentives to manage the resource properly.

2.1.2.2. SUSTAINABLE WATER MANAGEMENT IN INDIA: The statistics show an alarming trend for India: rapid population growth, urbanization and industrialization will lead to a greater demand for an increasingly smaller supply of water resources in the area. How will India avert the looming crisis? *The needs of India, and indeed the South Asian region to which it belongs, are unique. Nowhere else in the world does population growth and poverty play such a large role in affecting water resource issues.* To address the specific concerns of the region, the World Water Council formed **Regional Water Vision 2025 for South Asia**. A product of dialogue and debate between organizations from the region, the Vision 2025 reflects the current position of South Asia on the sustainable development of their water resources:

"Poverty in South Asia will be eradicated and living conditions of all people will be uplified to sustainable levels of comfort, health and well-being through co-ordinated and integrated development and management of water resources in the region." (*V Suresh*, 2001) This vision reflects the importance of providing for basic human needs to ensure that the livelihoods of all can be improved. In the case of South Asia, poverty and reduced access to safe water resources has limited the ability of the poor to improve their situation, which has only served to perpetuate the poverty cycle especially among rural population and women.

The South Asia Regional Water Vision 2025 *identified a number of common issues for water management in the region:*

- Welfare for the people and equitable distribution of resources
- Economic growth and development
- Sustainability and environmental aspects
- Policy and institutional aspects
- Increasing role of the market in water management

These issues affect both the region as a whole and the individual nations in varying degrees. For India, the two most important issues are how to balance the country's rapid economic growth with the need to ensure equitable distribution to all sectors, in particular the urban and rural drinking water supply.

2.1.2.3. FACTORS LIMITING THE ADOPTION OF SWM IN INDIA AND THE SOUTH ASIA REGION: A study conducted by the *U.S. Agency for International Development (USAID)* on water resource issues in South Asia described the three issues limiting sustainable management of water resources in the region, namely:

- Policy failures and institutional weaknesses, including cost recovery issues;
- Competition for water; and
- Health and environmental needs and effects

Policy Failures And Institutional Weaknesses

Inadequate policy and regulation, combined with a non-transparent and non-participatory process, is at the root of many of the water management problems alarming in the region. Until recently, water management projects have been the almost exclusive domain of government agencies. Government led and funded water development projects have seldom involved the private and volunteer sectors to ensure that the needs of the public are met. *Furthermore, full funding of the projects has resulted in low cost recovery and an unrealistic valuation of users' willingness to pay, leading to continued abuse of water resources.* No or little cooperation exists between the various agencies responsible for the management of water resources in different sectors such as environment, health and agriculture. The result is a planning process, which does not take into account the needs of these different interest groups and a lack of accountability on the part of any given agency. Many of the pollution control measures are based on "end of pipe" principles rather than a minimization/prevention approach. *Most of the current policies still encourage developing supplies of water resources rather than encouraging demand management*

- **Competition For Water**

It has been said that the next wars will be fought over water. Increasing competition for decreasing water resources will continue to pose a greater threat to national and international security. Already, conflicts have arisen between a numbers of South Asian countries and also between neighbouring states within these countries. But, competition for water occurs not only between neighbouring countries or states, but also between different user groups within a given watershed. *Already, the urban, agricultural and industrial demands for water are greater than the available supplies.*

The traditional approach to solving competition issues has been to develop further water supplies with the construction of dams, reservoirs or other engineered structures. However, even this is becoming difficult since the remaining water resources are no longer easily accessible and readily developed at reasonable costs. *Therefore, there is a need to optimize the use and distribution of the current supplies to meet the needs of all users. This would include implementing conservation measures such as reduced wastage and leakage, demand regulations, low-flow technologies, wastewater reclamation and reuse, etc.*

Inadequate data on water resource availability and use has hampered attempts to accurately determine water quantity and quality situation in South Asia. In addition, the lack of a standardized indicator has made it difficult to evaluate performance and to facilitate reporting and data collection. Improvements in both of these areas will assist managers in determining how best to allocate water resources among the different users.

□ **Health And Environmental Needs And Effects**

Almost one half of the population in South Asia lacks access to potable water. There is obviously a need to over come water supply and sanitation deficiencies, as well as a need to prevent pollution and manage extreme events such as floods and droughts. Yet, past development projects have come at a price. Negative impacts of these include: increased prevalence of mosquitoes and other disease vectors, displacement and over-riding of property rights/ownership, water logging and salinization of agricultural land, intrusion of salt water into aquifers, destruction of wetlands and loss of biodiversity in riparian and coastal areas.

The poor success of past projects can be attributed to insufficient data on the links between health and water quality, as well as little or no public involvement in the decision-making process. In addition, the needs of the ecosystem to maintain its functions have often been omitted from water-balance budgets. The result has been projects that do not fully address the needs of the public or the environment.

2.1.2.4. STRATEGIES FOR SUSTAINABLE WATER SUPPLY FOR ALL: INDIAN EXPERIENCE

a. **Water Supply In India – Present Scenario:** Water plays a crucial role in any country's welfare/economic development. India has indeed achieved significant strides in the water supply sector. However, in 1991, only about 82% of the urban households covering 85% of the urban population had access to safe drinking water.

b. Financial Requirements For Water Supply: Water supply and sanitation is a state subject and funding of projects in this sector is essentially supported through the Plan provisions to the State governments. *Though the plan provisions for this sector steadily increased from 0.65 per cent of the total outlay in **the Second Five Year Plan (1956-61)** to 1.81 per cent in the **Seventh Five Year Plan (1985-90)**, this provision has been found to be highly inadequate.* As a result, in urban areas against the target of achieving 100 per cent coverage (which was subsequently scaled down to 90 per cent) with safe drinking water, during the **International Drinking Water and Sanitation Decade (1980-90)**, the coverage achieved in urban areas was only 85 per cent with safe drinking water.

The resources required to achieve *100* per cent coverage with safe drinking water are massive and call for recurring and non-recurring investments of very high magnitude. The Planning Commission has estimated additional investment needs for water supply for the period 1996 to 2001, to be about US$ 3000 million. About one-third of the urban population lives below the poverty line.

c. Factors Inhibiting Development Of Sustainable Water Supply Systems In India: There has been a substantial understanding on the need to improve the water supply position in the country. There are a number of factors that inhibit achieving this objective as discussed below:

I. Poor financial status of local bodies: Provision of water supply in cities and towns has remained the primary responsibility of the Urban Local Bodies (ULBs). The financial base of the ULBs over the last four decades has become increasingly fragile and the ULBs are finding it difficult to maintain even the existing lower level of water supply services or meet essential expenditure on staff out of the revenues that they are able to collect from tax sources. The failure on the part of the local bodies to collect adequate revenues from tax sources has made them increasingly dependent on the State governments Plan as well as non-Plan funds. The task of source development, maintenance of the distribution system and collection of water charges generally remained with the local bodies. However, while the *Plan funds of urban development are spent through a variety of State level agencies such as State or city level parastatal institutions like Water Supply and Sewerage Boards, Public Health Engineering Depts. etc*, the assets created are transferred to the local bodies for operation and maintenance without assuring them the consequent Plan assistance.

II. Unrelated links between cost, price and consumption: *In India, the pricing mechanism is rarely used to guide the decision of the consumer, as to how much to consume or to balance supply with demand.* The existing water (connection) charges and water tariffs are highly subsidised. Revisions of water charges and water tariff have remained indifferent to the inflation rate. Quite often, the State governments, being the guarantors of loans received from the financial institutions for implementation of water supply systems, come to the rescue of the state level agencies for repayment of loans and the water tariff structures intended to be revised remains untouched due to various socio-economic and political reasons. *The ratio between the water tariff and water* *charges collected and expenditure incurred on O & M in some of the States has been found to range between 30 per cent and 46 per cent.*

III. The continuance of poor staff strength for maintenance activities: *In pursuance of the statutory provisions, the responsibilities of the local bodies include identification of sources, generating of potable water from those sources, distribution of water, fixation of tariffs and charges, collection of revenue and operation and maintenance.* Studies reveal a substantial shortage in the staff strength of appropriate calibre to deal with the above complex issues. Poor cost recovery has been primarily attributed to irrational water charges, wastages and mismanagement. ***A 'National Policy towards Full Cost Recovery' in respect of water supply and sanitation sector was adopted in March 1993.*** However, full or realistic cost recovery still remains to be put in place in India. *A sense of public participation in terms of 'customer' rather than 'consumer' needs to prevail.* The water supply Authorities also need to be clearly informed that the citizens are not to pay for the inefficient management. A quick response system to the customer needs and problems coupled with an efficient metering system and transparent billing and collection would substantially improve the 'willingness to pay' of the public.

IV. Absence of regular maintenance and consequent higher operation and maintenance cost: The apathy of the ULBs towards the important issue of maintenances of water supply systems. For instance, to assist the local bodies, the Central Public Health Environmental Engineering Organisation (CPHEEO) of the Government of India has formulated a 'Manual on Water Supply and Treatment', which lays down guidelines as to how the systems should be maintained. The guidelines also lay emphasis on keeping a set of plans giving details of the layout and the production/distribution lines; establishing a systematic programme for daily operations including an operation schedule for machinery and equipment; keeping data and record on all equipment - their condition, when repaired and replaced; maintenance of records on the analysis on the waste collected at various points and listing safety measures that are necessary for proper maintenance of the system; etc. However, studies indicate that in most of the towns these are more often not followed. Water supply projects are capital intensive and require longer repayment period more so due to initial capital costs and recurring operation and maintenance costs. *Neglect of* *maintenance of assets created has led to decline in quality of services resulting in resistance from the users against any increase in tariff rates/user charges.*

V. Substantial losses and leakages: A considerable portion of the treated water is lost through leakages in the transmission and distribution system. Reduction in loss due to leakages through leak detection equipment has been found to be one of the most vital measures to minimise service cost and maximise service, but this aspect is still largely ignored. While there is considerable awareness about the need to reduce the same, there are no reliable estimates of the actual quantities lost. *This problem has a direct linkage to the revenue generation and sustainability of the entire water supply system.* Further, the awareness about use of conservation methods/equipments to ensure efficient use of water is generally lacking. Use of Flow Control Taps is still absent except in general services such as Railways etc. *Detailed investigations carried out by National Environmental Engineering Research Institute (NEERI) have revealed that about 17 to 44 per cent of the total flow in the distribution system is lost as unaccounted through leakages in main, communication and service pipes and leaking valves.* The major portion of leakage (about 82 per cent) occurs in the house service connection, through service pipes and taps. The remaining 18 per cent is due to leakages in pipelines. Water supply is unmetered in major parts of urban areas and also a significant proportion is supplied, particularly in low-income areas through stand posts resulting in unaccountable losses.

VI. High administrative and supervision charges burden on ULBs: The State level Water Supply and Sewerage Boards/PHEDs are generally responsible for *investigation, planning, designing and implementation of water supply projects on behalf of the ULBs.* Operation and maintenance is however the responsibility of the ULBs. The Administrative & Supervision charges of the Water Supply & Sewerage Boards are quite high and vary between 18 to 22 per cent. As the Administration and Supervision charges calculated are levied as a percentage of the total project cost, the officials of the implementing agencies do not have much consideration towards project cost/time over-runs.

VII. Lack of recycling initiatives: In India, water is essentially used as a one-time commodity. Often treated and un-treated water is used indiscriminately. There is substantial scope for segregated use of the water for appropriate uses and recycling of the waste water for further use for gardening, industries, street cleaning, fire fighting, agriculture etc. This also brings in another important consideration that the same quality of water use for drinking purposes need not be (miss) used for large number of other activities like flushing, washing besides other uses, and from that point of view, the possibilities of alternate water supply systems could also be kept in view for potable and un-potable water.

2.1.2.5. INITIATIVES IN INDIA TOWARDS ACHIEVING SUSTAINABLE WATER SUPPLY FOR ALL: The **Habitat II Conference** at Istanbul has given a clear vision on the essential requirements that needs to be adhered to, to achieve the goal of water for all. Recognising the need for an integrated approach to the provision of those environmental services and policies that are essential for human life, the 'Global Plan for Action: Strategies for implementation', urges the governments at the appropriate levels, in partnership with other interested parties, to ensure that clean water is available and accessible to all human settlements as soon as possible through, inter alia the adoption of improvement of technology, and ensure that environmental protection and conservation plans are designed and implemented to restore polluted water systems and rebuild damaged watersheds. It recognises that water resources management in human settlements presents an outstanding challenge for sustainable development which combines the challenge of securing for all the basic human need for a reliable supply of safe drinking water and meeting the competing demands of industry and agriculture, which are crucial to economic development and food security, without compromising the ability of future generations to meet their water needs.

Emphasising the need for a strong political commitment the Habitat Agenda stresses the need to pursue policies for water resources management that are guided by the broader consideration of economic, social and environmental sustainability of human settlements at large, rather than by sectoral considerations alone and establishment of strategies and criteria (biological, physical and chemical water quality) to preserve and restore aquatic ecosystems in a holistic manner, giving consideration to entire drainage basins and the living resources contained therein. It advocates for management of supply and demand for water in an effective manner that provides for the basic requirements of human settlements development, while paying due regard to the carrying capacity of natural ecosystems. More importantly, it suggests promotion of partnerships between the public and private sectors and between institutions at the national and local levels so as to improve the allocative efficiency of investments in water and sanitation and to increase operational efficiency. In regard to the institutional mechanisms, it impresses to implement the institutional and legal reforms necessary to remove unnecessary overlaps and redundancies in the functions and jurisdictions of multiple sectoral institutions and to ensure effective coordination among those institutions in the delivery and management of services. It advocates for the introduction of economic instruments and regulatory measures to reduce wastage of water and encourage recycling and reuse of wastewater and to develop strategies to reduce the demand for limited water resources by increasing efficiencies in the agricultural and industrial sectors. *It also emphasizes the need to involve women in decision-making process in regard to management of infrastructure systems at large.*

In recognition of such concerns in advance, a number of new initiatives have been taken in the last seven years for achieving sustainable water supply systems in India. The details are given below:

a. Registration Charges On Water Connections And Collection Of Advance Payments: In order to elicit the cooperation of the public in advance, it would be appropriate for the Development Authorities/Local Bodies to announce a registration scheme as being done in housing and telecommunications sector inviting applications from the public to register their names for new connections as and when the city authorities plan to implement water supply scheme. A non-refundable one time deposit can be collected from the house owners who are willing to get the house service connection from the proposed water supply scheme. This will enable the local authorities to gain part of the resources required against the capital cost or generate revolving funds even before the service is made available. *The Tirupur Municipality (Tamil Nadu) has tried this proposal successfully at Tirupur.* An amount of Rs 25 million from 10,000 house owners at the rate of Rs. 2000 per house and Rs 4,000 from commercial institutions has been collected. Part of this amount has been deposited with the Tamil Nadu Water Supply and Drainage Board - the state level-implementing agency, for executing the work of laying additional distribution system of 110 Kms in the town. Thus, about 37 per cent of the total project cost of Rs 135 million is to be met in this process from the users themselves. *In fact in about 261 water supply schemes* *funded by the Housing and Urban Development Corporation Ltd. (HUDCO)*, the need for advance registration charges have been put on as an important condition for extending loan assistance.

b. Metering Of Water Connection: The procedures of application of flat rates for un-metered connections defy the principles of allocative efficiency. Although, metering of water supplied to industrial and commercial premises have largely been accepted without much controversy, metering domestic water supply has been a subject of debate for a long time. Findings of a study carried out in *Uttar Pradesh revealed that the consumption of domestic water supply came down to less than 50 per cent when metering was resorted to.* In view of the fact that substantial percentage of the area does not have the facility of metering, flat rates are levied which are based on the location as well as the area of houses. In certain cases, even the size of the ferrule, which connects to the main water supply line, is taken as the parameter to decide the charges payable on flat rate monthly.

c. Realistic Pricing Policies: *The pricing policies should be on the principle of full cost recovery.* Water supply and Sanitation agencies including local bodies need to be given full autonomy for determination of tariff with the provision for automatic annual increase to cover the average incremental operation and maintenance costs, depreciation charges, debt services, etc. *Associations and involvement of local bodies and the resident population at large from the conception stage to implementation stage of the project and also in fixation of tariff will ensure sustainable operation of the service system.* The local bodies in general, adopt the rates that are prescribed for by the State as a whole as a minimum and they rarely exercise the power conferred on them to enhance such rates depending on the local conditions and requirements. A survey regarding the extent of cost recovery possible in water supply sector during 1990-95 revealed that many of the local bodies would not have been in a position to bear the additional burden of debt servicing and O&M costs unless the water charges were nearly doubled and collection performance improved they would have not been able to meet the O&M costs. *In India normally, local bodies revise water tariff once in five years.* As the quantum jump is considerable, consumers generally resist such revisions. The Govt of Andhra Pradesh has recently revised the water tariffs for house service connection from Rs 20 to a minimum of Rs 40/- per month. A 10 per cent increase in the water tariff every year should be resorted to which might have been well received by the consumers. This aspect has been well recognised in recent years. For instance, in the State of Kerala, the scheme of automatic annual water tariff revision to an extent of 15 per cent has been successfully implemented. Similar approaches are being implemented in a number of other states too.

In addition, the financial institutions in India are increasingly becoming assertive in emphasizing the need to appropriately fix/revise the tariff/charges as a pre-condition to gain access to institutional credit. For instance, in respect of the water supply scheme *in Jaipur, Orissa the Housing and Urban Development Corporation (HUDCO) had emphasized the need for immediate hike in tariff rates both in respect of domestic, commercial and industrial rates followed by an annual automatic increase of 10 per cent.* In addition a one-time connection charge of Rs. 4000 per connection was also insisted. Similarly, in respect of Kolhapur in Maharashtra, in addition to immediate hike of the tariffs ranging from 75 to 100 per cent depending on the type of use, an automatic increase of 10 per cent in the tariff every four years was insisted. This was in addition to levy of a minimum advance registration charge of Rs. 2000 per new domestic connection. *The above approaches have led to implementation of water supply systems becoming sustainable and profit making over a time horizon.* Nearly 261 water supply schemes with a project cost of Rs. 32.7 billion (US $ 886 million) and with loan component of Rs. 16.75 billion (US $453 million) funded by HUDCO have incorporated these requirements.

d. Conservation Through Rain Water Harvesting: Ground water is a valuable economic commodity and to avoid its depletion, measures to recharge the aquifers should be extensively practiced. In places where there is an acute scarcity of drinking water, there is an increasing need to adopt rainwater-harvesting methods to adequately recharge the acquirers. In the water-starved city of Chennai, people resorted to rain harvesting in a big way during the Northeast monsoon in 1993 following acute scarcity preceding the monsoon. The rainwater was collected in ground level sumps, which was subsequently used after filtering and boiling. A number of voluntary organisations took the case for wider adoption and today incorporation of *provisions for rain water harvesting and aquifer charging in the building plans in Chennai is mandatory for approval* as the Chennai Municipal Development Authority has incorporated a regulation for conservation of rain water in its building guidelines in the area of Chennai in view of the acute scarcity of water.

e. Private Sector Participation In Water Supply: It is believed in general that owing to the capital-intensive nature and with long gestation period, private sector would not be interested in urban infrastructure provision and it may not be desirable to allow full private sector monopolies in this crucial sector. Apprehension about the successful association of private sector in water supply sector may be misconceived as the supply of water would be a monopolistic proposition with demand being perpetual, a well managed private enterprise with appropriate tariff structure and effective collection mechanism could out market or marginalize the low income households unless internalised transparent subsidies are put in place. Varied forms of public private partnership in water supply provision are being practiced in many developing countries with ranging options from large scale trucking, formation of water corporation, water vending kiosks and door to door service, coin operated meters.

Recently many progressive cities are coming up with privatisation of water supply on a BOT, BOOT basis like Pune, Belgaum, Dewas, Bangalore, Tirupur etc. However the learning process is taking longer time due to initial steps needed to ensure prudency in selection, interests of people, accountability etc.

f. Unbundling Of Water Supply Systems: There exists a substantial scope for involvement of private sector in water supply provision through appropriately unbundling of the operations. The private sector could be involved effectively in the source development from where bulk transfer of treated water could be effectuated through a bulk water purchase agreement by the ULBs. While the distribution has to remain under the control of the public sector, the collection of tariffs/user charges could be effectively delegated to the private sector. *The private sector could be allocated a commensurate profit, which would encourage them to maintain appropriate metering and reach of water to the individual households.*

g. Participation Of Community Groups: It is being increasingly realised that the user participation, either as provider or for performance assessment can be critical to the effectiveness and efficiency of the smaller community level infrastructure services. In many of these, the provisions and operations at the local level can be better handled by the user or community groups. Some of the important initiatives taken in this context are given below:

Specific arrangements for involving user and community groups may be achieved by unbundling of the services in an effective manner. For example, depending on the technical considerations of scale economies, local distribution networks for water may be provided by the community groups and they may be supplied with bulk water by a water utility company. In such cases the entire provision and operation can be transferred to the SPVs formed of the user and community groups.

The City and Industrial Development Corporation (CIDCO), a public sector institution at New Bombay has had a very successful experience with privatisation efforts. The privatisation experience includes maintenance of sewerage pumps, and water pumps, meter reading and billing, maintenance of parks and gardens, collection of CIDCO's service charges and so on. CIDCO has given the responsibility of collection of its service charges to the Senior Citizens Club (an association of retired persons) to whom it pays 1 per cent as commission. If CIDCO was to collect the charges on its own it would have cost it three times more.

Another important initiative is to make available the cooperative societies, the bulk water supply by the local agencies and in turn the members of the Group Housing take care of the distribution of available water and collection of water charges.

A unique example of community participation in the field of water supply has been the experience of the Baroda Citizens Council (BCC), constituted in 1966 by the partnership of University of Baroda, Baroda Municipal Corporation, the American Friends Service Society and the Gujarat Federation of Mills and industries. Initially the BCC was involved in construction of family toilets, hand pumps, sanitation facilities and training of health and hygiene workers and training of women volunteers in hand pump maintenance. In this scheme the beneficiaries contributed upto 70 per cent of the capital costs. The remaining came from contributions from bilateral and other donors, routed through the BCC. Usually the contribution per family was in the range of Rs. 500 per family for the Mark III hand pump. These hand pumps and community drains are fully maintained by the community and money is collected from the users for procuring spare parts or for engaging mechanics. The BCC has moved on to find sustainable systems for financing the maintenance and upgradation of this infrastructure in the slums with the help of the Municipal Corporation and the UNICEF.

Another National Level Initiative for Sustainable Rural Water Supply taken by the Government is the establishment of the Rajiv Gandhi National Drinking Water Mission which was launched in August 1986 to accelerate the progress of drinking water supply in rural areas and to provide cost effective science and technology inputs to improve the programme implementation in active collaboration and cooperation with the states, local people and institutions. *The Mission's objective is to provide safe drinking water free from chemical and biological contamination as also ensure provision of 40 litres of safe drinking water per person per day (LPCD) in all areas for all human being and additional 30 LPCD in Desert Development Programme areas for drinking water requirement of cattle.* Habitations, which are not getting full supply of 40 LPCD, are treated as partially covered requiring augmentation facilities to bring them to the level of 40 LPCD.

The Mission's major activities include the improvements in the quality of drinking water through the sub Missions on Eradication of Guinea worm, Control of Fluorosis, Removal of excess Iron and Brackishness, Removal of Arsenic, Water Conservation and Recharge of Aquifers. In addition, other programmes on water quality surveillance, training of villagers and officers/staff involved in the programme, research and development, and information, education and communication for health awareness are being implemented in cooperation with the State/UT Governments, Panchayats and non-Governmental Organisations with special provisions for SCs and STs.

Another innovative initiative in Gujarat has been the organisation of **'Paani Panchayats'** (Water Courts). An NGO called **'Shelter for health awareness'** was asked to help in developing local users water committees to increase the per capita availability of water.

h. Role Of Financing Agencies In Institutionalizing Change: The financing institutions have been substantially successful in sensitizing the ULBs on the need to evolve and implement infrastructure systems, which are sustainable. In order to make the water supply schemes sustainable, while agreeing to extend financial assistance HUDCO emphasises on the provisioning of I) Principle of full cost recovery to be adopted, ii) Adequate subsidy to be provided in a transparent manner to meet the basic minimum requirement of the poor, iii) Efforts must be made for cost reduction by effective savings on manpower, energy consumption, reduction in leakages, improvement in billing and collection, etc., iv) Concerned agencies including the local bodies, be given full autonomy for determination of tariffs with the provision for automatic annual increase to cover costs, v)Tariff fixation should be based on average incremental cost including O&M cost depreciation charges, debt dues etc., vi)State level institutions should associate the local bodies and the community at large to instill better sense of participation, vii)As the chances of success of privatisation are greater in O&M, privatisation could be introduced for new installations initially, viii)Compulsory 100 per cent metering, ix)Elimination of Stand Post as far as possible and x)Operation of Escrow Account.

2.1.2.6. FUTURE AHEAD: Urban water supply services do not pay for themselves and the government doesn't have the financial capacity to continue subsidising them. Falling levels of government funding will result in deficiency in volumes as well as quality of services. Many users who currently receive free or highly subsidised services could infact afford to pay. *A National Committee (1997) suggests extensive private-public partnerships in the field of water supply particularly in areas relating to source development, treatment and bulk supply with private agency, retail distribution and pricing with public sector.* Differential treatment of water for different uses, micro level treatment to recycle water at the household level and metering of water supply to reduce leakage. It also suggests proper packaging of projects to reduce project cost and improve viability. The need for integrated water management through conservation and use of wastewater recycling, acquifer recharging and rainwater harvesting is also being increasingly emphasised.

India is indeed poised for substantial involvement of private sector in the field of water supply. In the emerging scenario of liberalisation there has already been a welcome trend in this direction in the fields of power and telecommunications. The realisation and recognition of the possibilities for unbundling of water supply operations has opened up a whole new world of opportunities for the private sector to involve itself profitably. The emerging concepts of bulk purchase agreements in water supply, even though relatively new in India, are gaining substantial attention in recent years. *A consensus is slowly emerging on the need for establishment* ***Urban Utilities Regulatory Board*** *on the lines of Telecom Regulatory Authorities, either at the city level or at the state level, which may look into the larger issues of equity aspects of pricing/supply/distribution, production cost and leakage reduction ensuring quality of service as well as involvement of private sector with special reference to urban utilities.*

It is hoped that very shortly many city water supply schemes would be managed collaboratively through Public- Private partnerships for mutual advantage.

Another significant area is to put people at centre stage and involve the community in regard to development of safe drinking water systems and create the proper environment for developing a attitude of **'willingness to pay'** through the Resident welfare Associations, Ward Committees, Councilors, city authorities etc. so that a deep sense of participation is ensured. Further, in the unbundling process in the water supply provision and management sector the community can be allocated certain physical roles

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2.2. RAINWATER HARVESTING

2.2.1. INTRODUCTION: Water is essential for life on the planet; water resources have been a decisive factor in the growth and development of human civilization in the history. India receives an average annual rainfall of around 1100mm., which is the highest in the world among countries of comparable size, and should be sufficient enough to satisfy its ever-increasing demand (*A. K. Sahu,* 2001). But the temporal and spatial distribution of rainfall throughout the country is so erratic that drought and floods occurs frequently and simultaneously. Also the alarming rate of population growth at 2.11 percent has led to increasing pressure on the basic life supporting system. The utilization of water resources in the country has increased over the years.

Rainwater Harvesting means catching and holding rain where it falls and using it. You can store it in tanks or you can use it to recharge groundwater.

Quality of rainwater is quite considerable even in drought prone areas. About 10 mm rainfall in a small farmer's lands of a hectare amounts to 1,00,000 litres. An effective rainfall or each 100mm. works out to a million liters, the quantity which is sufficient not only for drinking purposes but also for selective cropping *(A. K. Sahu,* 2001*)*. These good quantities of rainwater in low rainfall areas could effectively be stored for different purposes through harvesting. Collection of rain as it falls near a house of a small farm is known as catchment, while collection of runoff by minor structures is styled as harvesting.

There are various questions raise in ones mind when we talk of roof top RAINWATER harvesting like how much cost effective it is, how it can be done, what should be the surface finish of how we can store if? In this chapter I have tried to answer all these queries. To show the details I have taken a hypothetical case, but the same may hold good for any other places with the little modifications.

Assumptions:

Average annual rainfall: ***1200 mm.*** *(Avg. annual rainfall of Bhopal 1209 mm)*

Plot size: ***200 sq.m.***

Ground coverage: ***50%***

Average family size: ***5***

Use zone: ***residential***

Rooftop area: ***100 sq.m.***

Total rainwater collected in a year: ***120 cum.***

Considering losses made due to:

*Evaporation + first wash + shifting due to wind + pits in gutters = **25%***

*Hence net water available for harvesting from = 90 **cum / year***

*Per capita requirement of water for domestic use: **135 Ipcd or 50 cum. per year***

*Per capita availability rainwater: 90/5 = 18 **cum.** per year. Hence it is fulfilling about 36% of water need in a family. It is, when only rooftop area is considered.*

It is obvious from the above figures that rainwater from the rooftop alone is sufficient to fulfill more than one third of the need of the household. It shall be possible to use this rainwater for various domestic purposes. Generally the quality of rainwater is good enough but due to its contact with atmosphere it is advisable to do some treatment for pathogenic bacteria and coliform.

2.2.2. CATCHMENT: The catchment of a water harvesting system is the surface, which receives rainfall directly and contributes the water to the system. The catchment is either from a roof, compound of a house, or from a small field area. The catchment is done in house basement, separate tanks or well like structures known as Kunds. It would be better to follow these practices for meeting the requirements of households, cattle, schools, gardens and small farms. Rainwater catchment is the most economical means of using rainwater by villagers and farmers.

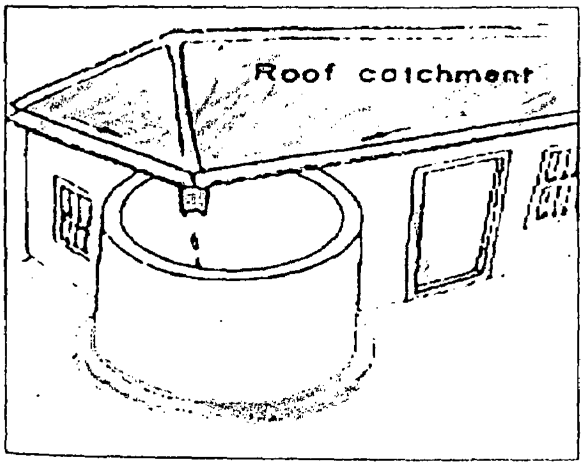


Figure 2.2.1 Roof catchment

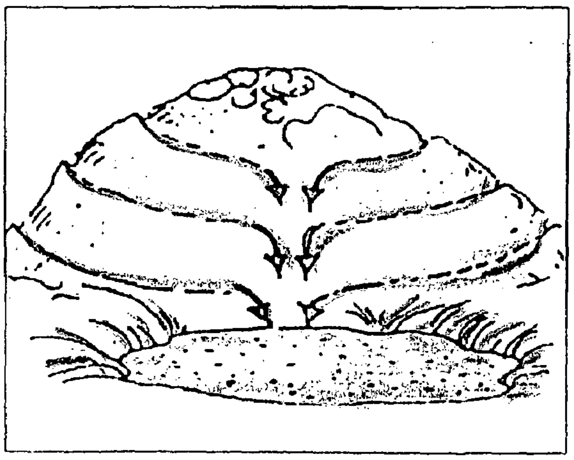


Figure 2.2.2 Hill catchment

2.2.3. HARVESTING: Rainwater is possible in areas with as little as 50 –80 mm average annual rainfall. This seems to be lowest limit, but during a year with only 24 mm of rain, water harvesting in Israel still yielded a usable runoff *(A.K. Shahu, 2001).*

Water harvesting is to be planned depending upon the topography, soil, rainfall, and other meteorological parameters. Water harvesting system, once installed, will provide water without motivating power in contrast to ground water exploitation structures. A few of the water harvesting practices are:

- Historical large step wells across streamlets
- Collection of runoff water into ditches
- Harvesting in cisterns from hillsides
- Graded & rolled areas with drains for harvesting
- Large step tanks with storage cells (Sudan)
- Paved tanks with mud & flat stones (Botswana)
- Lime-sealant-surfaces for harvesting open areas
- Covering soil with plastic, butyl rubber & metal foil increases runoff for harvesting.

2.2.4. HARVESTING STRUCTURES: Farm ponds are the common structures in rainwater harvesting. These are very important in utilizing rainwater for drinking as well as irrigation purposes. There are various types of structures with different designs and dimensions. They are constructed mostly, at proper sites with good storage, along stream courses or in low-lying areas. The best dimensions are 10 –30 m lengths, 5 -20 m width and 2 m depth. This practice proves best because;

- Water is harvested & velocity is reduced
- Low-cost of construction & maintenance
- No scouring action

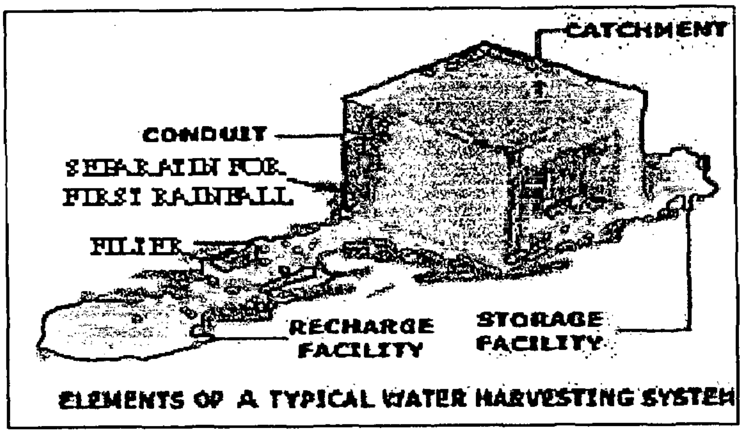
2.2.5. TYPES AND METHODS OF RAINWATER HARVESTING:

2.2.5.1 ROOF TOP RAINWATER HARVESTING FOR DRINKING WATER:

Roof water harvesting is common in areas having high rainfall intensity well distributed the year. There are many methods available for harvesting rainwater. The method is site-specific. Following steps are commonly followed in roof top rainwater harvesting system

a. Collection of rainwater, b. Separation of first rain flush, c. Filtration of rainwater, d. Storage of rainwater, e. Recharge of groundwater, f. Distribution of water.

Before supplying for human consumption the raw water from the pond should be filtered through a sand filter and kept in a PVC tank connected to a hand pump for withdrawal. In spite of certain limitations rainwater harvesting will be beneficial for providing drinking water to human beings as well as cattle in areas lacking alternative sources.



ELEMENTS OF A TYPICAL WATER HARVESTING SYSTEM

Figure 2.2.3 Elements of roof top rainwater harvesting system.

METHODS OF ROOF TOP RAINWATER HARVESTING

a. Recharge Pit Method: This method is suitable for building having roof area upto 1000 sq.ft. This small roof can recharge 1.0 lakhs of rainwater. The shape of pits is of any type it can be circular, square and rectangular

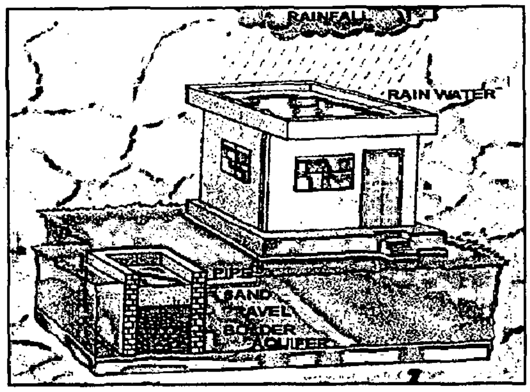


Figure 2.2.4 Recharge assembly for pit with rooftop runoff.

b. Recharge Trench Method: This method is suitable for building having roof area 2000 - 3000 sq.ft and open space around the building surrounded by boundary wall. Trench is made along the boundary wall upto depth of 3-5 ft.

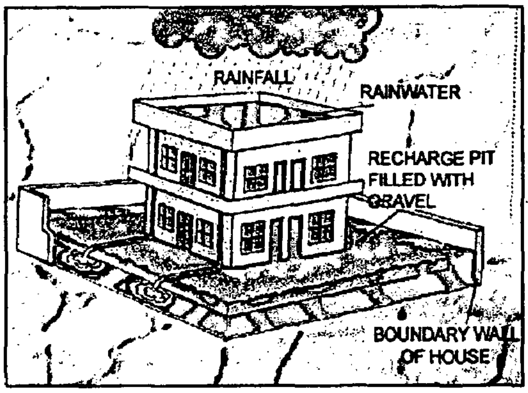


Figure 2.2.5 Recharge assembly for trench with rooftop runoff.

c. Recharge Well Method: This method is suitable for recharging well inside or outside the house, this is also very use full to recharge dry well. By this method we simultaneously recharge aquifer as well as well.

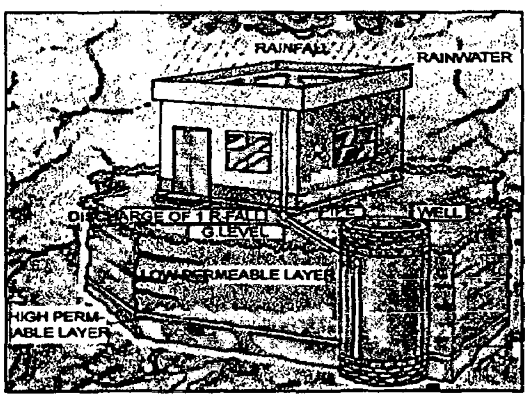


Figure 2.2.6 Recharge assembly for dug well with rooftop runoff.

d. Recharge Tube Well Method: This method is suitable for building having roof area 1500 - 2500 sq.ft. Here deep aquifer is recharge with help of the help of tubewell in and around the houses.

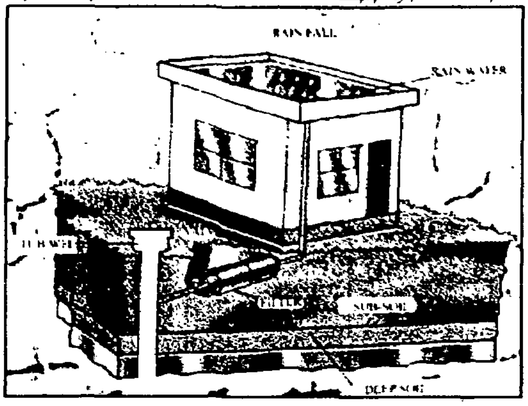


Figure 2.2.7 Recharge assembly for deep aquifer with roof top runoff.

e. Recharge Tube Well Method For Large Building: This method is suitable for govt., pvt. & ind. building whose roof collects lakhs of liter of RW, though this process in expensive but for public interest this should be adopted.

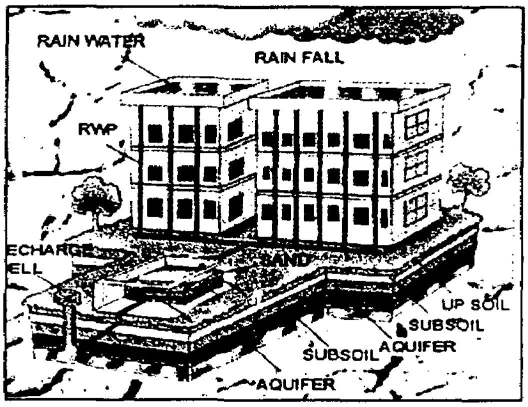


Figure 2.2.8 Recharge assembly for tube well with roof top runoff.

f. Recharge Shaft Method: This method is suitable for area where alluvial soil is available and ground water available at shallow depth. Dia. of shaft is 2 – 6 ft. and its dept can be 30 – 50 ft.

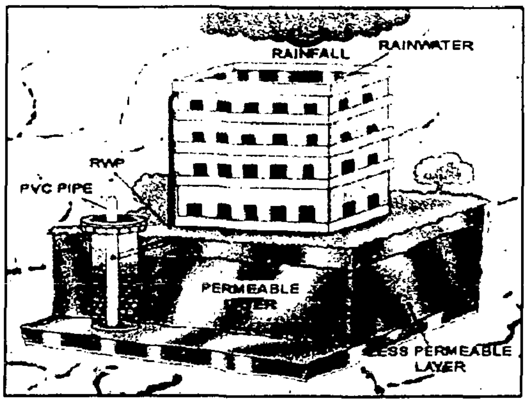


Figure 2.2.9 Recharge assembly for shaft with rooftop runoff.

g. Recharge Ditch Method: This method is suitable in urban area having alluvial soil and where thick layer impermeable soil is available, through which it is difficult to across rainwater to deep aquifer. Size of the ditch depends upon runoff intensity of concerned area.

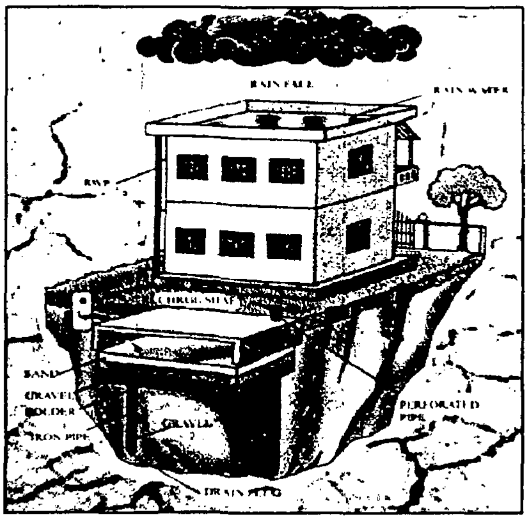


Figure 2.2.10 Recharge assembly for ditch with rooftop runoff.

2.2.5.2 RAINWATER HARVESTING BY GROUND CATCHMENT AND MICRO-CATCHMENTS: This method can be used to supply water for crops, wild life and livestock as well as for domestic use.

2.2.5.3 RAINWATER HARVESTING BY LAND TREATMENT (forestation etc): The conservation of moisture particularly in arid and semiarid regions is of most importance. In such areas infiltration capacity of the soil is reduced through different land treatments, which can be served for agricultural purpose in drought prone areas.

2.2.5.4 RAINWATER HARVESTING BY PERCOLATION TANKS, INJECTION WELLS AND SUBSURFACE DAMS: In areas of declining trend of ground water the artificial recharge of ground water is of great importance in water harvesting. GW recharge involves augmenting the natural movement surface water into underground formations by some method of construction by spreading of water or by artificially changing natural conditions.

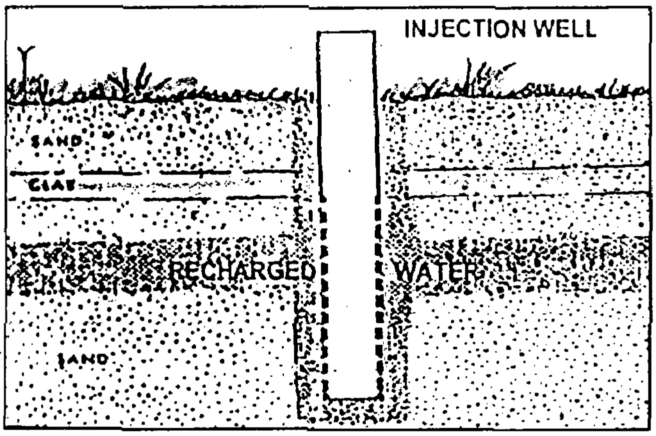


Figure 2.2.11 Water harvesting by injection well.

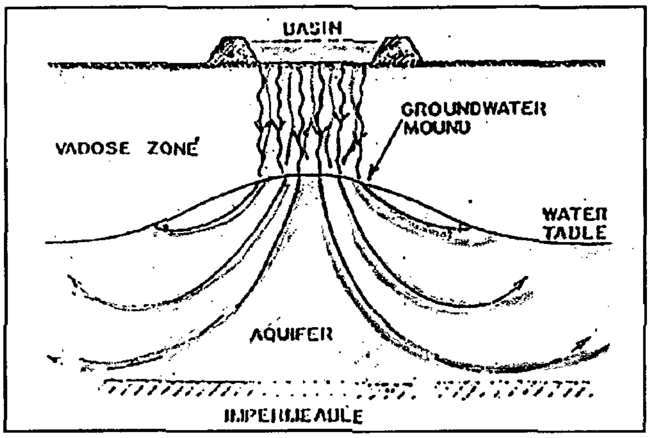


Figure 2.2.12 Water harvesting by percolation tank.

2.2.5.5 RAINWATER HARVESTING BY MECHANICAL MEASURES: Such practices as contour farming and strip cropping are effective in water holding capacity. Level terracing is a good water harvesting practice where the slopes are gentle enough so that the water can spread where a relatively large area.

2.2.5.6 RAINWATER HARVESTING BY MULCH AND FARMING PRACTICES: Various type of fanning practices is there for rainwater harvesting.

a. Contour farming b. Strip fanning

2.2.5.7 WATER HARVESTING BY ENGINEERING PRACTICES: The important types of water harvesting practices are;

a. Silt Traps: Silt traps are build of stones across the beds of interminated streams. The size of silt trap structure varies enormously. In order to assess the adequacy of silt traps one must consider two aspects: first it's cost; and seconds its effectiveness in harvesting runoff.

b. Check Dams: Check dams of varying design are constructed for the purpose of stabilizing the erosion and harvesting runoff water from large catchments, even under arid conditions. Check dams are made of locally available materials like brush, poles, and woven wire, loose rock and planks or slabs. Temporary check dams constructed across the bed of a channel have two uses: (1) to collect enough soil and water to ensure the eventual growth of protective vegetation and (2) to check channel erosion until sufficient stabilizing vegetation can be established.

The life of temporary check dams depends on the quality of the materials and efficiency of construction, but under the ordinary conditions, they should last from 3 to 8 years. The following are the check dams normally used in small catchments.

- Woven-wire darns
- Brush dams
- Loose rock darns
- Plank or slab dams

c. Bunds and Terraces: Bunding is the most effective and widely practiced field measures for water harvesting. It is the placing of small earthen dams across local streams to collect the rainwater. The reservoirs so formed are called tanks. Tanks are usually shallow and the stored water covers a large area means a relatively large evaporation. Bench terracing is one of the most popular water-harvesting device on sloping and undulating lands. The water either stored in the soil of the cultivated land or sometimes artificial storage facilities are provided. Most contour terraces are located on slopes of less than 25 percent.

The following types of terraces normally adopted are

- Level bench terrace
- Inwardly sloping bench terraces
- Outwardly sloping bench terraces

2.2.6. ELEMENTS OR ROOF TOP RAINWATER HARVESTING: The basic elements/functional parameters of any rooftop RWH are as follows:

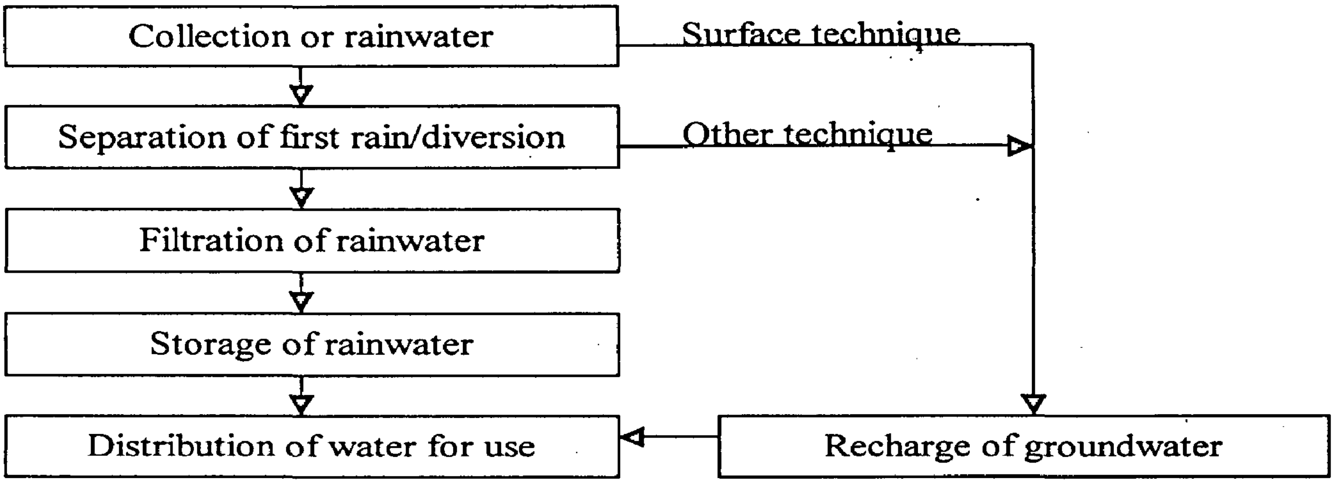


Chart 2.2.1 Elements of roof top rainwater harvesting

2.2.6.1 COLLECTION OF RAINWATER: Catchment is the first thing the rainwater comes in contact with. Hence it is the first thing where one should pay attention very first. The quality and quantity of harvested rainwater depend very much on the type and surface finish of the roof, its size, slope and maintenance etc. sloping roofs have the maximum potential of harvesting rainwater, next comes the flat roofs. Surface finish of the roof is also important. It should not be of any harmful material. Even thatch roof can be used for rainwater harvesting, the only thing is that the water will have some color and odour, which can be avoided by putting the plastic sheet on the roof. (*Source: www.Rainwaterharvesting.org)*

Table 2.2.1 Runoff coefficients for various catchment surfaces

Type of Catchment	**Coefficients**
Roof Catchments	
-Tiles	0.8- 0.9
- Corrugated metal sheets	0.7- 0.9
Ground surface coverings	
- Concrete	0.6- 0.8
- Brick pavement	0.5- 0.6
Untreated ground catchments	
- Soil on slopes less than 10 per cent	0.0 - 0.3
- Rocky natural catchments	0.2 - 0.5
Untreated ground catchments	
- Soil on slopes less than 10 per cent	1.0 - 0.3
- Rocky natural catchments	0.2 - 0.5

Source: www.Rainwaterharvesting.org

2.2.6.2 SEPARATION OF FIRST RAIN/DIVERSION: A first flush device is used to ensures that runoff from the first spell of rain is flushed out and does not enter the system. This needs to be done since the first spell of rain carries a relatively larger amount of pollutants from the air and catchment surface.

The water from the rooftops can be directed towards an opening by providing mild Run slopes. This opening connected with a PVC pipe will enable the water to flow down to a tank or a well. If there are many rainwater pipes then they may be joined at some suitable point and the total rainwater can be then directed to the filter section.

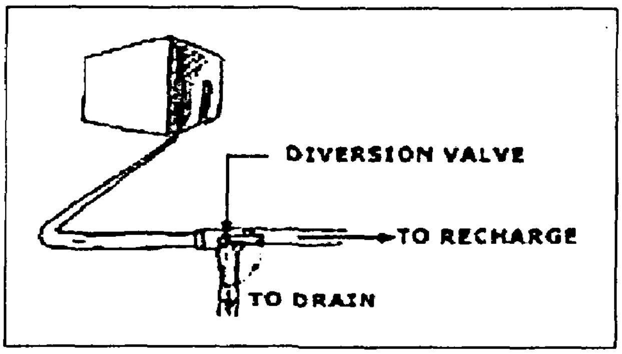


Figure 2.2.13 Separation of first rain/diversion.

2.2.6.3 FILTRATION OF RAINWATER: Rainwater collected from the rooftops will have lot of impurities in them. It has to be filtered to clear the filth. For this a filtering tank should be made. The collected water should be passed through this filtering tank before being stored. This will enable to harvest good quality freshwater for usage. Various types of filters arc available in the market ranging from Rs.300 to Rs.2400.

Common types of filter used for to filter rainwater are

a. Charcoal water filter
b. Sand filters
c. Devas filters

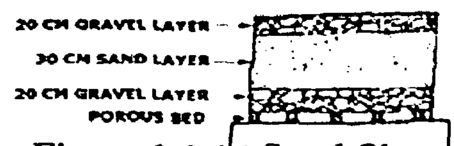


Figure 2.2.14 Sand filters

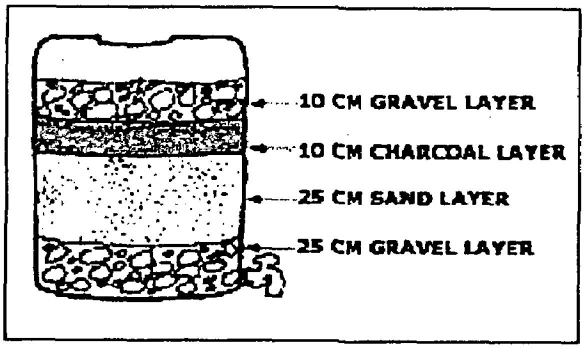


Figure 2.2.15 Charcoal water filters

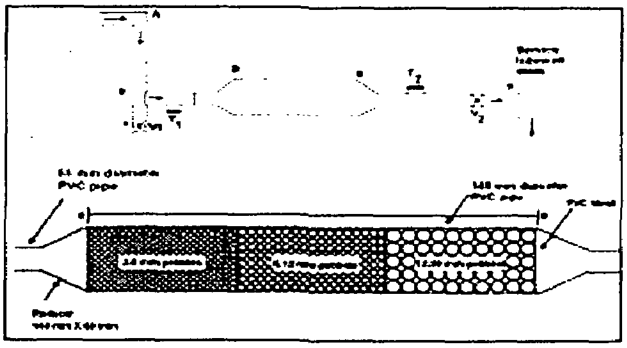


Figure 2.2.16 Devas water filters

2.2.6.4 STORAGE OF RAINWATER: After filtering, storage of the rainwater is required. This storage may be of two types. **First type** consists the storage above the ground level and second type consists the underground storage, which is called recharge of ground water. In the first method the quality of water is likely to deteriorate with time and demand proper treatment for that(C. S Agrawal, Dr. Satyendra Mittal, Himani Goyal, 2000). While in the second type the water remain fresh forever and readily available for use. In the second method the advantage is that it may occupy less space depending on the technique used for recharge. The disadvantage is that withdrawing water needs more energy.

There are various options available fort the construction of these tanks with respect to the shape, size and the material of construction.

Shape: Cylindrical, rectangular and square.

Material of construction: Reinforced cement concrete, (RCC), ferrocement, masonry, plastic (polyethylene) or metal (galvanised iron) sheets are commonly used.
Capacity/size: The capacity of storage tank depends on the following factors:

1. Average annual rainfall
I. The length of dry season
2. Number of rainy days
3. Number of users per tank
4. Type of the catchment or roof type
5. Maintenance
6. Space available for storage
7. Water requirement

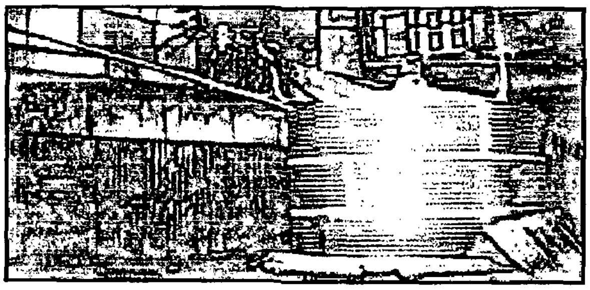


Figure 2.2.17 A storage tank made of galvanised iron sheets

One major aspect of storing water in tank for a long period is the quality. One can put sodium hypo chloride of potassium permanganate into the water so that the bacteria can be checked from time to time. One more thing I would like to mention here that rainwater lacks the necessary minerals, which are generally in the groundwater. Monthly application of chlorine or bleaching powder is considered to be sufficient to check the bacterial growth. (*Source: www.Rainwaterharvesting.org)*

2.2.6.5 RECHARGE OF GROUNDWATER: Recharging of groundwater through rooftop rainwater harvesting is an important feature. It is suitable in condition where there is no space to store the rainwater like existing and densely built up areas of the town and cities and where groundwater table is very low or quality of groundwater is not good. It is also good in places where seawater intrusion is a problem (*Journal of*

Indian Building Congress). Cities like Chennai, Vishakhapattanam etc. are the main example of such cities.

2.2.6.6 DISTRIBUTION OF WATER: Distribution of collected rainwater is the utilisation of rainwater, is also very important thing. At the household level various uses may need the rainwater. Some of them are following.

- For drinking and cooking purposes after proper treatment
- Flushing of sewers and drains
- Washing of utensils and cloths
- Washing of cars etc.
- Gardening / watering purposes
- Recharging the ground water
- Terrace gardening
- Used for cooler and air conditioner
- Construction of buildings

2.2.7. QUALITY ASPECT: Rainwater is the purest form of water available on the earth. It gets contaminated during the contact with atmosphere. But in areas where pollution is not so much, rainwater can be directly put into use for the domestic use including for drinking purpose also. But the place, where pollution is more it needs careful analysis and treatment for the use of drinking. Various types of filters come in the market to purify the water, which can be used for the same. After filtering water must be chlorinated or some chemical should be done to remove pathogenic bacteria if any. To ensure the purity rooftop finish should not be of any harmful material or painted with any such kind of material. It is better to have the rooftop of cement concrete or GI or AC sheets etc. if the GI sheet is very old and rusty it should be painted on top with any harmless paint. Even thatch roof can be able to work as rainwater catchment, the only thing is to cover it with any polythene sheet or plastic sheet.

2.2.8. RECHARGING TECHNIQUES:

Aquifers: Aquifers may be scientifically defined as a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells, bore wells etc.

and costly systems with low capital efficiency ensuring that power and authority stays with the bureaucracy and the community remains bonded to it;

- The fostering of greater dependence on the state itself for even small matters like maintenance of existing systems and the powers that government agencies have acquired through existing water and land resources laws which provide complete control over these resources, leading to large scale misuse,
- State promotion of individual beneficiary-oriented schemes and the accompanying decline of active community participation in the maintenance of traditional systems;
- Commercialisation of agriculture and the large scale cultivation of cash crops alien to local micro-climates, which work well for a short time but with serious problems emerging over the long term;
- Expectations of quick individual returns, resulting in a general decline in community cooperation;
- Changes in distribution and concentration of ownership of land and community resources in fewer hands;
- Emergence of state-sponsored institutions which were largely land-centered in their perspective as compared to traditional water harvesting systems which viewed land in relation to water and thus had a water-centred perspective;
- Unchanged state investment patterns which were developed during the colonial regime and neglected small water harvesting irrigation systems; and,
- Inability of government agencies to take a holistic view of water as a product of larger environmental management.

Modem attempts to restore traditional systems must reckon with the causes for their decline. They must also be based on a clear understanding of whether the conditions for their restoration are present today or not. If the 'community' supporting the traditional system no longer exists, it would be futile trying to build the structure first. Initial efforts would have to be made on building up the 'community' once again. Further more, social contradictions in some systems developed to the point that they collapsed. These contradictions will have to be carefully considered.

2.3.7 CONCLUSION:

Traditional water harvesting systems definitely have relevance in areas where water scarcity is acute or where groundwater is either brackish or too deep to obtain cheaply. However, in some areas, a supplementary source may well be necessary.

Indian Building Congress). Cities like Chennai, Vishakhapattanam etc. are the main example of such cities.

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Aquifers: Aquifers may be scientifically defined as a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells, bore wells etc.

Artificial recharge: It is a process of augmenting aquifer to underground water table by artificial infiltration of rainwater and the surface runoff.

The purpose of artificial recharge is:

- To arrest groundwater declines and improves ground water levels and availability.
- Beneficiate water quality in aquifers.
- Arrest seawater ingress.
- Conserve surface water run-off during monsoon.
- Enhance availability of ground water at the specific place and time.
- Reduce power consumption.
- Conserve urban wastewater.
- Arrest urban flooding during monsoon period.

The rainwater harvesting techniques need to be differentiated based on the final outcome or the product generate from such efforts. One, the most commonly being used is to directly store rainwater in appropriate closed tanks or containers, which can be utilised in time to come. These tanks have no connection with the subterranean ground water resource. The other one is utilising the rainwater to directly or indirectly recharge the ground water and the water so recharges becomes the part of common pool ground water reservoir. The movement and subsequent utilisation of the rainwater harvested in the ground water reservoir which becomes integral part of ground water regime is controlled by the characteristics and behaviour of aquifers wherein the rainwater harvested has been recharged (A. K. Sahu, 2001).

Three types of techniques are there:

- Direct surface technique
- Direct subsurface technique
- Indirect or induced technique

2.2.8.1 DIRECT SURFACE TECHNIQUE:

a. Flooding: Recommended for the places where the shallow aquifers continue to show deep ground water levels even in post monsoon period.

b. Stream Augmentation: The natural drainage can be modified with a view to increase the infiltration by increasing the streambed area and detaining stream flow.

c. Ditch And Furrow System: This technique can be used over gentle slopes. In this technique shallow, flat-bottomed and closely spaced ditches or furrows, provide larger contact area for ground water recharge from perennial streams or canals.

d. Basin or Percolation Tank: Most prevalent in India to recharge ground water both in alluvial as well as in hard rock terrain. The surface runoff from steep slopes and streams is checked by constructing "Gabion" structures, check dams, weirs, gullies plugs etc. Percolation tanks are more feasible in mountain fronts occupied by talus scree deposits.

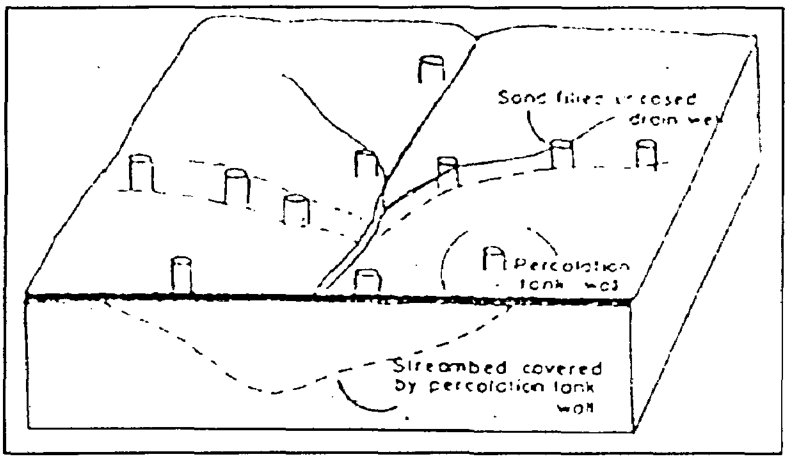

Figure 2.2.18 Front view of percolation tank

2.2.8.2 DIRECT SUBSURFACE TECHNIQUES: In this technique the structure is below the ground and directly recharges the ground water.

a. Subsurface Dykes or Dams: The promising sites for construction of such structures are narrow valleys underlying by impermeable rocks at shallow depth. Subsurface dykes or dams or bandharas with impervious material viz. clay, bitumen, tarlet or polythene sheets, arrests subsurface lateral flow of ground water.

b. Injection Well / Recharge Well: This method is used to replenish semi-confined aquifers at deeper levels, by pumping in treated surface water. These wells can be used as pumping wells during summers.

c. Recharge Pits and Shafts: These are the most efficient and cost effective structures to recharge the shallow aquifers directly. It can be suitable in areas where source of water is perennial in the form of base flow or springs. It can be dug manually at low cost.

d. Dug Well Recharge: In areas where water levels have declined considerably, most of the dug wells remain dry and non-operational. Such dug wells can be utilised for ground water recharge.

e. Roof Top Rainwater Harvesting: This method can be widely used in major towns where, high building density provides large roof top area for collection of rainwater. The source of water for recharge is the rooftop rainwater.

2.2.8.3 INDIRECT OR INDUCED TECHNIQUE: This method involves excessive pumping from shallow aquifers those hydraulically connected with surface water, to induce recharge to ground water reservoir. Cone of depression is also important in this method.

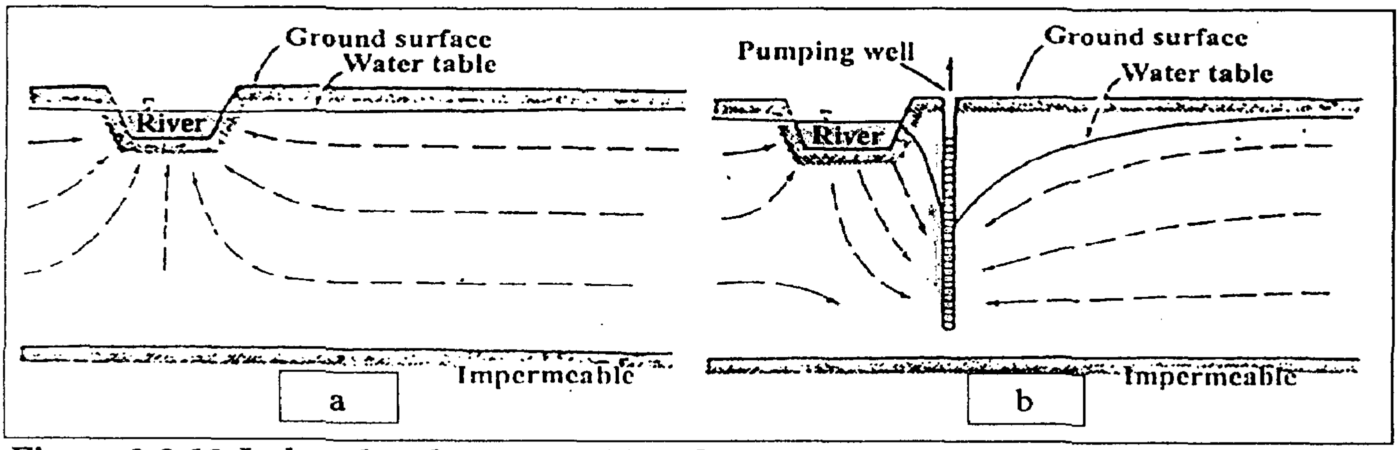

Figure 2.2.19 Induced recharge resulting from a well pumping near river. (a) Natural flow pattern (b) Flow pattern with pumping well.

2.2.9 ADVANTAGES OF ARTIFICIAL RECHARGE:

Following are the advantages of artificial recharge:

a. Enhanced sustainability of water supply projects and structures.

b. Improved well yields and reduced pumping lifts and costs.

c. Improved water supply.

d. Conservation of water lost to run off and evaporation

c. Enhanced well yield in areas where there is overdraft of ground water.

f. Arrest decline in ground water table.

g. Improved quality of ground water through dilution, especially fluoride, nitrate and salinity.

2.2.10 TECHNIQUES RELEVANT TO URBAN AREAS:

- **Recharging through Defunct Open wells, Borewells & Hand pumps:** Due to severe depletion of ground water level, many open wells, bore wells and hand pumps are getting dried. Instead of discharging these wells, they can be converted into useful recharge wells. Roof water and runoff water can be diverted into these wells after filling the wells with pebbles and river sand. There should be an effective arrangement for desilting before diverting the water into these wells.

- **Rainwater Harvesting through Ponds:** Rainwater collected from terrace of row house buildings may be lead into the nearby ponds (with previous top layer) through pipelines for recharging the ground water aquifers. Runoff water can also be diverted into this pond after proper desilting arrangements. A production well can be constructed nearby to tap the water recharged.

- **Rainwater harvesting through Ditch and Furrow system:** This type of Ditch system can be designed to suit the topographic and geological conditions that exist at a potential artificial recharge site. This system is particularly advantageous where recharge water contains high loads of suspended sediments.

- **Storm run off collection and recharge:** The run off water generated during monsoon within an area can be well utilized for ground water recharging by diverting it into suitable designed recharge structures in Public parks, Play grounds, Stadiums, Airports, Railway stations, Bus stations, Temple tanks, Artificial Ponds, Huge dug wells etc.

- **Artificial Recharge through Storm water Drains:** Storm water drains should be designed in such a way that two separate segments are made so as to accommodate water coming from houses and water coming from the roads. The segment on the side of the road should be covered with perforated slab and should have percolation pit at regular intervals of depth 20 to 50 ft. depending on the soil condition.

- **For Agriculture Lands, Farms etc:** .It is advisable to have numerous percolation pits (pits with deep bore) in Agriculture lands for gradual percolation and recharging of aquifer. Construction of small bunds on slope area slows down the run off water and helps easy percolation. . Runoff water can be diverted into a large well through a Baby well and Filtering tank to avoid silt depositing in the well.

- **Reclamation of Sewage water:** Huge quantities of sewage water generated from the domestic segment can be separated and reclaimed through Soil Aquifer Treatment (SAT). This treated water can be used for recharging dry rivers and for irrigation purposes.
- **Construction of Bandharas on the Riverbeds:** Bandharas are nothing but concrete walls or impermeable soil, built across the river but below the riverbed at regular intervals. This will act as underground reservoirs and recharge the Surrounding area.

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2.3. TRADITIONAL PRACTICES OF RAINWATER HARVESTING IN INDIA

2.3.1 INTRODUCTION: In earlier times the state took care of the water supply to large extent by development and maintenance of several ingenious and indigenous ways of storing rain and floodwaters. The concentration of rainfall in the monsoon season and the variation in extent of precipitation over space compelled the storage of rainwater in order to spread the resource availability into the lean season. It was the "dhrama" of the ruler to support and execute water storage structures. Urban planning took into consideration natural catchments and focused on enhancing the water harvesting systems. The tank system was so well developed in many watersheds of Karnataka that it was estimated that hardly any runoff water escaped from the catchment. Settlements like Mandu, Jodhpur, Coimbatore were based around their water tanks and their associated catchments. The city of Jodhpur was built around the catchments of 35 tanks and Coimbatore around 24 tanks (Ashish Banarjee & Manu Bhatnagar, 2000).

During Harappan period there was very good system of water management as could be seen in latest excavation at Dholvira in Kutch.

The traditional structures varied from State to State and even from different regions of India (*Sunita Narain,* 2003). In hilly and high rain fall areas, general practice is rooftop collection and storage by constructing dug cum embankment type of water storage structures on foothills to arrest flow from the springs and streams. In Rajasthan, traditional water harvesting systems are Tankas (underground tanks), Khadins (embankment in plain areas), which are utilised for collection of surface runoff from the micro-catchment.

2.3.2 HILL AND MOUNTAIN REGION:

I. Garhwal region (Western Himalayas): Diversion channels leading directly to agricultural fields. About 40 percent of the heavy rainfall is lost as runoff in the Garhwal region. As a result irrigation depends on diversion channels called guhls, which are full during the monsoon but whose discharge gets sharply reduced during the winter.

Figure 2.3.1 Photograph showing Guhls of Garhwal region.

II. Ladakh (Trans-Himalayan Region):

Occasionally, the channels first lead into a storage structure so that water can be used in the subsequent dry period, too (e.g. zings of Ladakh). The entire cultivated area of Ladakh, which stands out like an oasis in cold, rocky desert, depends on assured irrigation from the waters of melting snow through long, winding streams from the upper mountain reaches. Snow and glaciers melt slowly throughout the day and water is available for irrigation in the later evening. This water is collected in tanks, locally called Zings, and used the next day.

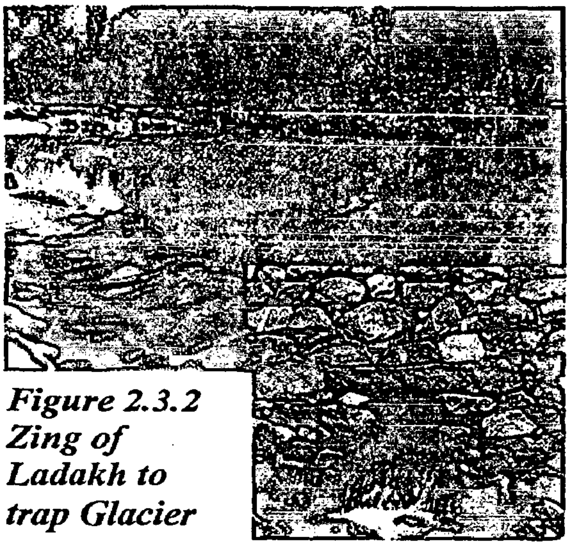

Figure 2.3.2 Zing of Ladakh to trap Glacier

III. Zabo system of cultivation (Nagaland):

It is a combination of forestry, agriculture and animal care with a well-founded conservation base, soil erosion control, water resources development and protection of environment.

Figure 2.3.3 Zabo system in Kikruma village in Nagaland.

IV. Qanat:

Quanta's or underground canals that tap an alluvial fan on mountain slopes and carry it over large distances, were one of the most ingenious of ancient hydro-technical inventions. They originated in Armenia around 1000 B. C. and were found in India since 300 B. C.

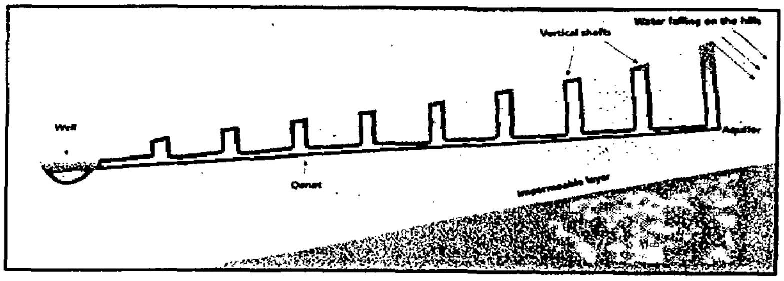

Figure 2.3.4 Qanat, transferring water by gravity

V. NORTHEAST (Meghalaya): In the Meghalaya, spring water is often carried over long distances with the help of bamboo poles, which is 200 year old About 18-20 liters of water enters the bamboo pipe system, gets transported over hundreds of metres, and finally reduces to 20-80 drops per minute at the site of the plant.

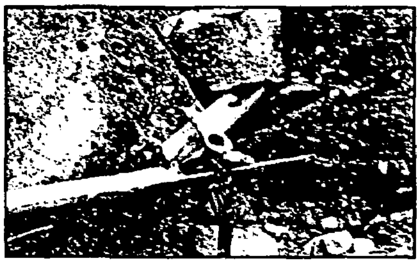

Figure 2.3.5 Bamboo Drip irrigation system of Meghalaya,

VI. Aizwal (Capital of Mizoram)

Rooftop Rainwater harvesting widespread in Aizwal. Many households in Aizwal have tanks made of tin or concrete, situated on the ground or underground to store rainwater.

Figure 2.3.6 RWHS in Aizwal

2.3.3 ARID AND SEMI- ARID REGION (Rajasthan & Gujarat):

I. Rain fed storage structures which provided water for a command area downstream (e.g. tanks).

II. Stream or river fed storage structures, sometimes built in a series, with overflow from one becoming runoff for the subsequent one (e.g. system tanks of Tamil Nadu, bandharas of Maharashtra, keres of Karnataka).

III. Rain fed storage structures, which allow runoff to stand over and moisten the fertile soil-bed of the storage structure itself, which is later used for growing crops (e.g. khadins of the Jaisalmer district and johads of the Alwar in Rajasthan).

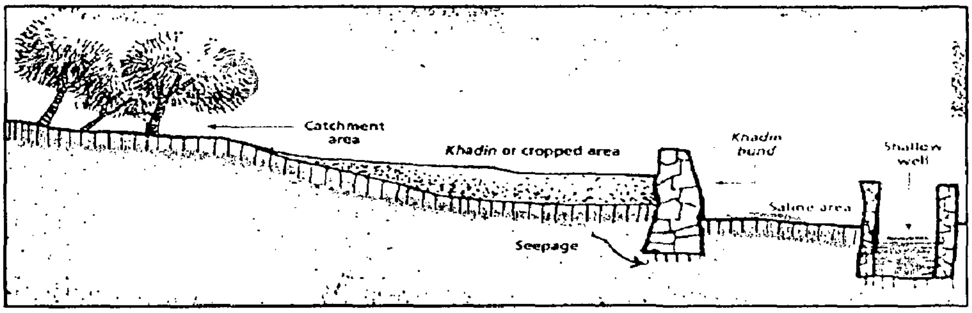

Figure 2.3.7 Khadin system of Rajasthan

IV. Groundwater harvesting structures like wells and stepwells were built to tap groundwater aquifers (e.g. bavdis of Rajasthan).

V. Groundwater harvesting structures like wells and stepwells were invariably built wherever they were possible, especially below storage structures like tanks to collect clean seepage for use as drinking water (e.g. several such structures can he found in the forts of Chittor and Rantharnbhore). Step wells are unique form of underground wells found in Rajasthan and Gujarat. A long stepped corridor leading down five to six stores to the well at the far end is an essential feature of a stepwell.

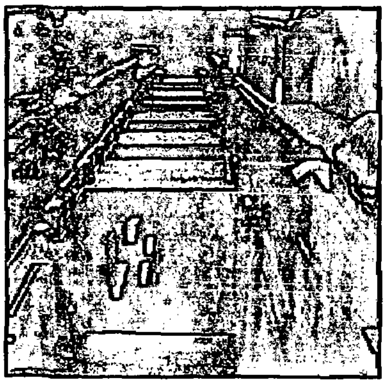

Figure 2.3.8 Step well of Gujarat

VI. Rainwater harvesting from rooftops (e.g. tankas of Pali). Rainwater harvesting using artificially created catchments, which drain water into an artificial well just about any land, can be used to create such a water harvesting structure (e.g. kunds of Rajasthan). Kunds are roughly 6 m deep and 2 m broad. The sides of the pits are plastered with lime and ash. (*Anil Agrawal,2003)*

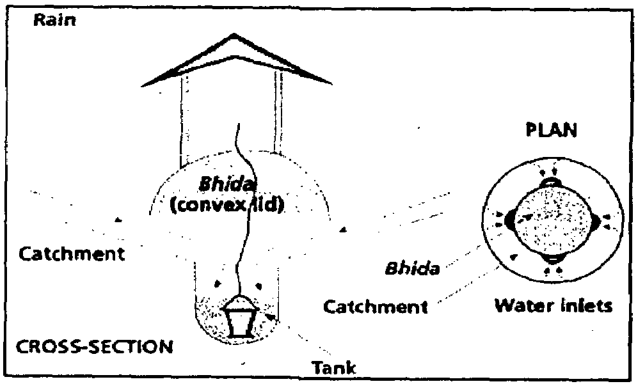

Figure 2.3.9 Cross section of kund in Rajasthan

VII. Special rainwater harvesting structures which help to keep sweet rainwater from mixing with saline groundwater and, thus, providing a layer of potable water. Virdas were the principal means of water harvesting by the nomadic Maldharis of Gujarat. Virdas are shallow wells dug in low depressions called jheels (tanks). These are usually connected to a trough with a channel. A fence is put to prevent animals from destroying these troughs. Virdas collect enough rainwater to ensure the availability of fresh water throughout the year. The water can be utilised from 20 days to four months depending upon the use.

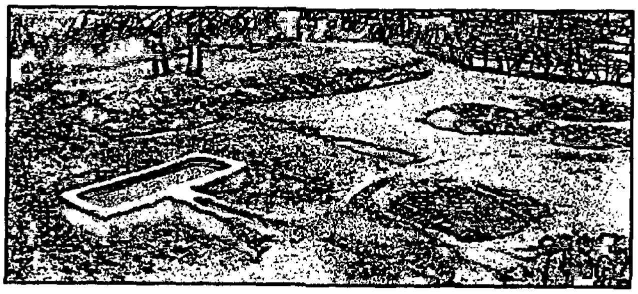

Figure 2.3.10 Water harvesting thorough Virdas Kutch.

VIII. Horizontal wells similar to the Qantas of the Middle East to harvest seepage down hill slopes (e.g. surangams of Kerala).

2.3.4 PLAINS AND FLOOD PLAINS:

I. In the flood plains of major rivers, people built inundation channels which allowed floodwater to be diverted to agricultural lands (e.g. flood irrigation system of west Bengal).

II. In specific types of soil and cropping regions, people also store rainwater in the agricultural fields by bunding them (e.g. haveli system of Madhya Pradesh).

III. Dugwells.

2.3.5 COASTAL AREAS:

I. Regulatory systems to control ingress of saline river waters, especially during coastal tides, and thus maintain crop productivity in the coastal plains (e.g. khazana lands of Goa).

II. Dugwells.

2.3.6 CAUSES FOR DECLINE OF TRADITIONAL SYSTEM:

People want 'modern' systems because nobody likes to walk long distances to fetch water from a well or a tank if this facility is available by turning a tap at home. Similarly irrigation water available from a sluice or by switching on a pumpset is considered more desirable. Only when modem systems fall -taps go dry, dams silt up - people think of traditional systems.

Some of the facts responsible for the decline of traditional systems are:

- Growth in population and water demand, which could not be met through traditional technologies and systems; and at the same time, availability of modern and more convenient water supply through centralised storage systems like reservoirs and canals because of the official emphasis on them led not only to a halt in the expansion of traditional systems but also to disuse and consequent deterioration of the existing ones.
- The centralised modem systems were initially installed in good faith to provide the people with more convenient and abundant supply. But, over the years, the government machinery has developed an open bias in flavour of these large complex

and costly systems with low capital efficiency ensuring that power and authority stays with the bureaucracy and the community remains bonded to it;

- The fostering of greater dependence on the state itself for even small matters like maintenance of existing systems and the powers that government agencies have acquired through existing water and land resources laws which provide complete control over these resources, leading to large scale misuse,
- State promotion of individual beneficiary-oriented schemes and the accompanying decline of active community participation in the maintenance of traditional systems;
- Commercialisation of agriculture and the large scale cultivation of cash crops alien to local micro-climates, which work well for a short time but with serious problems emerging over the long term;
- Expectations of quick individual returns, resulting in a general decline in community cooperation;
- Changes in distribution and concentration of ownership of land and community resources in fewer hands;
- Emergence of state-sponsored institutions which were largely land-centered in their perspective as compared to traditional water harvesting systems which viewed land in relation to water and thus had a water-centred perspective;
- Unchanged state investment patterns which were developed during the colonial regime and neglected small water harvesting irrigation systems; and,
- Inability of government agencies to take a holistic view of water as a product of larger environmental management.

Modem attempts to restore traditional systems must reckon with the causes for their decline. They must also be based on a clear understanding of whether the conditions for their restoration are present today or not. If the 'community' supporting the traditional system no longer exists, it would be futile trying to build the structure first. Initial efforts would have to be made on building up the 'community' once again. Further more, social contradictions in some systems developed to the point that they collapsed. These contradictions will have to be carefully considered.

2.3.7 CONCLUSION:

Traditional water harvesting systems definitely have relevance in areas where water scarcity is acute or where groundwater is either brackish or too deep to obtain cheaply. However, in some areas, a supplementary source may well be necessary.

Traditionally, in these areas people have developed cultural practices, which encourage judicious use of water, but now these practices are dying. Water conservation education should be encouraged across the country.

It is clear that the issues involved in the revival of traditional systems are intricate and interlinked these systems are location specific and management-intensive. Planning for their revival must be based on the needs and capacities of the people so as to ensure their Sustainability.

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2.4. CONTEMPORARY PRACTICES OF RWH IN INDIA & ABROAD

2.4.1 CENTRAL GROUND WATER BOARD:

NCT of Delhi

- Artificial recharge through 4 check dams in JNU and IIT created storage of 4,600 to 22,180 cubic metre and water levels in the wells recorded rise of 0.8 to 9.9 m and area of 75 hectare benefited.

- Rooftop Rainwater Harvesting and recharge through two injection wells in IIT campus-Rise of 0.5 m in water levels.

- On the President's estate, recharging of ground water began recently using water, which would otherwise flow into drains.

Punjab

- Rooftop Rainwater harvesting to recharge ground water through injection well in one of the CSIO buildings. Rise of 2m in water level was observed.

- In Amritsar, water flowing out of golden temple Sarovar is to be used for recharging ground water.

2.4.2 STATE GOVERNMENTS:

Madhya Pradesh

- District Administration in Dewas made roof top Rainwater Harvesting mandatory for all houses having tubewells and banned tubewell drilling -Improved soil moisture and recharged first aquifer.

Tamil Nadu

- Chennai Metro Water Board has made roof top Rainwater Harvesting mandatory under the city's building regulations. The decision has led to a rise in ground water levels.
- Central Public Works Department has employed rainwater harvesting techniques in Rajaji Bhawan in Chennai.

Andhra Pradesh

- Andhra Pradesh government has made it mandatory to have rainwater harvesting structures in all new constructions in urban areas and for leaving sufficient open area forground water recharge.
- Percolation tanks and checks dams constructed chronically drought affected Rayalseema region helped in drought proofing.

Himachal pradesh

- In Himachal Pradesh the state government has made it compulsory for any new buildings in Shimla to have rainwater harvesting.

2.4.3 NON-GOVERNMENT ORGANIZATION:

Gujarat

- Rooftop Rainwater Harvesting and recharging of wells as a movement in Gujarat by the *Saurashtra Lok Manch* Trust in Mandlikpur village of Rajkot district prevented drying up of wells.

- *Agakhan Rural Support Programme* in Junagadh and Surendranagar districts of Saurashtra harvested rainwater by check dams and percolation ponds involving beneficiary fanners optimum utilisation of harvested rainwater achieved.

- *Vivekanand Research and Training Institute* in Kutch, Bhavnagar, and Amreli districts constructed Rainwater Harvesting structures, helped in improving water quality and controlling the decline in water level.

Rajasthan

- *Tarun Bharat Sangh* has taken up desilting and deepening of village ponds and built water harvesting structures and johads with villager's participation in more than 750 villages. The dried up streams have become perennial.

- In Jodhpur district, *Gramin Vigyan Vikas Samiti* motivated the resident of 25 villages

- and built 2000 storage tanks (tankas). Each house has a tanka (a water collection structure) lined with lime and alum to keep the water fresh for four to five months.

- *Prayathna Sansthan,* Solavata village constructed roof water harvesting tanks firstly on school buildings to provide safe drinking water to children. Remarkably, the attendance in these schools went up. Tanks such constructed have an average capacity of 30,000 liters and being used by village community also.

Central Ground Water Board, New Delhi has selected 3 major buildings in India for rooftop Rain Water Harvesting. These buildings are National Institute of Hydrology Roorkee., Brahamputra Board headquarter Guwahati and C.G.W.B. head office in Faridabad.

2.4.4 THE INITIATIVES ABROAD: Water harvesting - collecting natural precipitation from prepared watersheds -has the potential to provide the only source of water in some areas of the World and economical water source in many others. Water harvesting techniques were used in the Middle East as early as 3000 years back.

- **Runoff farming in the Negev**

The Negev desert of Israel, maintained a thriving agriculture in the desert using runoff farming, at least four to five thousand years back. The farming, is diverting runoff from precipitation events to from bigger area to small-cultivated area.

- **Water harvesting on public lands: southeastern Arizona**

Twenty water harvesting systems for livestock watering have been constructed on natural resource lands of the Safford district of the Arizona. Precipitation in the area ranges from 150 to 405 mm. the water harvesting systems installed have included catchments of nonreinforced, 0.8 mm butyl rubber; fiberglass asphalt and mopped with ½ gal clay asphalt emulsion.

- **Water harvesting in Hawaii**

In Hawaii, to alleviate the water shortage problem, over 300 water storage systems, often combined with catchment facilities, have been installed during the past 15 years. Often water harvesting is competitive with other forms of water supply. Since over 300 water systems have been installed and the frequency of installation continues to be about one per month, this attests to their successful use and indicates that water harvesting systems should be very carefully considered where alternative means of obtaining water supplies are limited.

- **Rainwater catchment and storage -Jamaica**

In Jamaica, studies showed supplies were plentiful over much of the area but depth to water was as great as 610 metre. This difficulty leads to consideration of water harvesting catchments and storage facilities to attain the water supply. Storage tank of 10,000 gallon was constructed of metal lined with PVC bag, was built at Cross Keys, Manchester. These are as good at individual household.

- **Japan**

Tokyo is short of water once, every few years. Almost 60% of Tokyo's ground is covered with asphalt and concrete. In Sumida City office provision for roof top rainwater harvesting is made, having the capacity of 1000 cum. This water is used mainly for flushing toilets in the buildings. In Ryogoku Kokugikan, Tokyo's famous sumo wrestling arena one of the biggest facilities to harvest rainwater has been installed. It has 8400 sqm roof area drains 1000 Cum. water into storage tank. About 70 percent of the facilities including the air conditioning system and toilets, use rainwater collected from its roof.

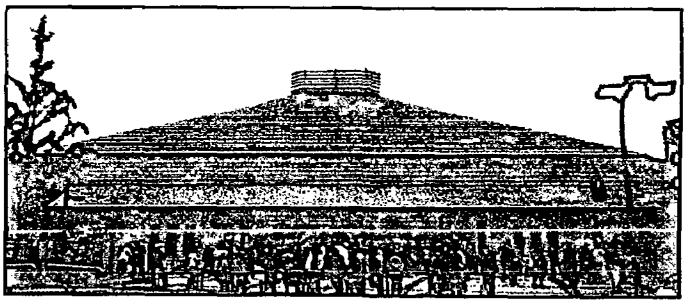

Figure 2.4.1 Tokyo's famous sumo wrestling arena

- **China**

The Chinese have captured rainwater for over 1000 years but the efficiency is too low. *Rainwater catchment and utilization* (RWCU) were set up aimed at supplying water for drinking and courtyard irrigation. Roof top rain water harvesting, highways, threshing yards and also from seepage controlled fields are some common methods practiced in China for rainwater harvesting

(Source: Anil Agrawal, Sunita Narain, Indira Khurana, 2003)

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2.5. RAINWATER HARVESTING AT VARIOUS LEVEL OF URBAN PLANNING

2.5.1 INTRODUCTION: So far planning no due consideration has been given to this critical issue of resource management inspite of the growing unsustainability of the resource base and the limitations being thus imposed upon urban growth. Urban expansions and the rampant construction activity in the past have had negative impact on the water systems as the site development had ignored the local hydrological considerations. *Planners aim at systematic colonization of the hinterland and leave resource planning to water departments and central water authorities, working on a strictly engineering approach, to deliver water and the constraints in this regard have not come in the way of planning for projected population.*

The level of planning that is covered in a city will decide the approach of planners. These can be broadly discussed under following levels of urban planning.

- HOUSEHOLD LEVEL
- CLUSTER LEVEL
- NEIGHBOURHOOD LEVEL
- SECTOR LEVEL
- CITY LEVEL

2.5.2 HOUSEHOLD LEVEL: At the household level various techniques of rainwater harvesting can be adopted. Various catchments in the house are rooftop, courtyard and open spaces. Rooftop rainwater may provide the rainwater of drinking quality. But the other open spaces also provide the water, which can be used for the purposes other than drinking like gardening, recharging etc, various techniques have been already discussed.

Rainwater harvesting techniques at household level shall differ according to type of housing and location of the house means it is either in densely built up area or in newly well planned area. Let us consider the type of household and possible harvesting measures.

- **Plotted development:**

In the newly developed area roof top rainwater harvesting and its storage in tank is possible. Open spaces can also be harvested and the collected rainwater can be put into use for recharging and other purposes. In plotted development one can individually install the rainwater harvesting structure.

In plotted development setbacks play an important role, as they are integral part of the open spaces that receive considerable amount of rainfall. Hence the surface treatment of the open spaces and the diversion of the rainwater are also important. This water can be diverted to recharge the ground water through various measures.

- **II Row houses:**

Row houses need special attention for the provision as they are having comparatively less roof area and these houses are occupied by the lower income groups of the society. Hence it shall not be feasible to construct individual rainwater harvesting structure. Another point is that roofs of the houses are joined side by side and buildings are having only front and rear setbacks. It would be a better proposition to group some houses and provide a common rainwater harvesting structure.

- **III. Semidetached houses:**

Semidetached houses common roof area can be used, hence reducing the cost of rainwater harvesting. A common storage tank and recharge pit can be made on plots. In the same way runoff from the ground can be stored in underground tanks and used for gardening etc.

2.5.3 CLUSTER LEVEL: In the group housing most of the services in the building are shared by the inhabitants. The whole building complex is in one unit of construction. Here management of water supply and other things are done by a group of society, same way runoff from the ground can be stored in underground tanks and used for gardening etc.

Hence rainwater harvesting adopted for such buildings will be different from plotted houses or any other type of housing.

Rooftop area is common hence the system adopted here will he very economical to individuals. But if it is multistoried building then per capita rainwater harvested will be less. In this type of housing the entire roof area can be divided into appropriate sections and each section having its own rainwater storage tank, and that water is supplied to that particular group for their use. That group will be responsible for the maintenance and management of the structure. Similarly recharge well can be made for group of households.

Open areas of the housing complex can have underground rainwater storage tank, water of which can be used for several purposes e.g. washing of floors, gardening, car washing etc.

2.5.4 NEIGHBOURHOOD LEVEL: Cluster is the next level of urban planning. It is very important to see what is the size of the cluster and how many houses are there. This will decide the level of facility they can sustain. Generally a cluster contains a tot-lot, nursery school, park, retail shop, club, sport center, temple roads and residences. I have already said the rainwater harvesting measure at the household level. *Cluster level rainwater harvesting will involve the community participation, and government intervention.*

At the cluster road catchment can divert its water to side storm water drain which should ultimately lead to any recharge structure. Similarly parks may have the recharge structure and storage tank, and park's water needs should be fulfilled from its own water resources as far as possible. *Actually when we talk of using one own resource; we talk of self-sustainability.* It can be achieved only through proper ecological balance means whatsoever we take from nature we should give it back. Rainwater harvesting at any level is to maintain this water cycle at that level.

When we talk of any project at community level, social and cultural aspects becomes very important to consider. "Even though a society may be local or remote, it is subjected to internal differentiation, stratification, and unequal social and gender relations. Many a time, development efforts may reproduce the status quo and the existing internal inequity. In implementing water-harvesting programs it is essential to look at the issue of equity. Does the program has bridge the gap between the better half and the disadvantaged or does it, as an unintended consequence, escalate the divide?"

Dr. Ujjawal Pradhan from Ford Foundation stressed the need to pay attention to promotion of local self-governance and local control for multiple uses of water.

At the neighbourhood level 3 or 4 clusters are grouped together to form a neighbourhood. At the neighbourhood level we can extend the provision of the clusters but on the larger level. At the neighbourhood level rainwater collected from the public places can be used for fire fighting after the filtration. Excess water should be used for ground water recharge and this water can be used to fill the ponds etc. in neighbourhood parks. This pond can be used for fishing and aquaculture etc. Storm water drain should be separate from the sewer line and storm water should be used for recharge of groundwater and other purposes.

2.5.5 SECTOR LEVEL: Sector level is very important from the geological point of view. Generally the lithology, soil condition and groundwater level varies at this level. Hence on the basis on proper survey and information of the hydrological features we can specifically recommend the type and method or rainwater harvesting and recharge techniques.

At the sector there are various land uses, on the basis of which we can further categorize the various rules and regulation related to rainwater harvesting. Like for commercial use the measures and byelaws will be different that the residential use. In the same way institutional and public buildings may have the common provisions.

Roads, parks and other public open spaces can be used for rainwater harvesting. At this level government and public participation is must. The following general methods can also be adopted using the site condition.

RWH structure: Structures like recharging shafts, recharge trenches are suitable for garden parks. Small check dams are suitable for areas in the ridges.

Open ground: Remove the topsoil to a depth of 30 cm to 60 cm and place with river sand to allow for slow percolation of the rainwater into the soil.

Paved surfaces: Dig 120 cm deep square percolation pits measuring 60 cm each along its length and breadth, fill with small pebbles of river sand and cover with perforated concrete slabs. This is useful on footpaths and paved surfaces of various institutional and government buildings premises.

Outlets: Connect wastewater outlets from the bathroom to pits, instead of to the drainage pipes.

Storm water drains: Cover the drains existing within the premises and construct small boundary walls around them to a height of 30 to 60 cm to ensure that rainwater rushes into the drains and the water stagnates over the ground until it seeps into the soil. In community schemes larger areas of catchment are used for collection of rainwater runoff in large size underground tanks, fenced reservoirs or by diverting it to large lakes. Treated land, protected hill slopes, protected farm areas or runoff collection from watershed management projects, can be used but the water will need treatment before human consumption. Filtration and chlorination are generally enough for this purpose.

2.5.6 CITY LEVEL: The runoff water generated in monsoons within an area can be well utillised for ground water recharging by diverting it into suitably designed recharge structures in public parks, play grounds, stadiums, airports, railway stations, temple tanks etc.

Storm water drains should be designed in such a way that two separate segments are made so as to accommodate water coming from house and water coming from the rocks. The segment on the side of the road should be covered with perforated slabs and should have percolation pits of depth 20 to 50 ft. depending on the soil condition at regular intervals.

Huge quantities of sewage waters generated from the domestic segment can be separated and reclaimed through soil aquifer treatment (SAT). This treated water can be used for recharging dry rivers for irrigation purpose.

There are various factors, which should be taken care while planning for new cities like there should be enough for afforestation and green areas, which can work as natural infiltration areas for rainwater. The planners must lake care of natural drainage pattern of the site and preserve the catchment and water shed areas. Every effort should be made to check the runoff water. The whole city can have the network of canals and ponds and reservoirs. Existing ponds and tanks must be preserved.

The cities like Bhopal are having the advantage of high gradient can have the system of water supply, which work on gravity. Runoff water collected on the high catchment areas can reach the low-lying areas. And the series of this kind of supply will necessitate, the supply of the highest areas to be fed by other means. This supply will be through gravity and no power or very little power will be required to supply the low-lying area.

Several seasonal streams become activated during monsoons providing the outlet to floodwater as well as local runoff. This water should be stored on the channel itself. The water can be detained through construction of appropriately located regulators. Deepening and widening wherever possible can enhance the storage capacity of channels.

As all storm water cannot be stored on channel, possibilities exist for off-channel storage. It is useful device for storing water for lean season. In the same way we can store storm water in lakes and depressions.

Deepening and cleaning of lakes & tanks, construction of new lakes & tanks, percolation pits, cleaning of dug wells, etc. are some important measures to adopt.

2.6. CASE STUDY-1

TRADITIONAL WATER MANAGEMENT IN JODHPUR: A Case Study

2.6.1. INTRODUCTION: Jodhpur is the second largest city of Rajasthan, and ancient capital of the Marwar clan of the Rajputs. The old capital of the Marwar was shifted from Mandore to Jodhpur for several reasons, one of which was shortage of water. Located on the slopes of a rocky hill, the city of Jodhpur has been dependent on rain and groundwater for essential Water supplies. The whole plateau serves as the water catchment for 50 functional surface water bodies like nadis, talabs, tanks and lakes, and indirectly for about 154 ground water bodies like wells, baoris, and jhalaras. The city of Jodhpur is an excellent example of how an extraordinary water management system has been destroyed in a desert city through unthinking processes of modernization and urbanization.

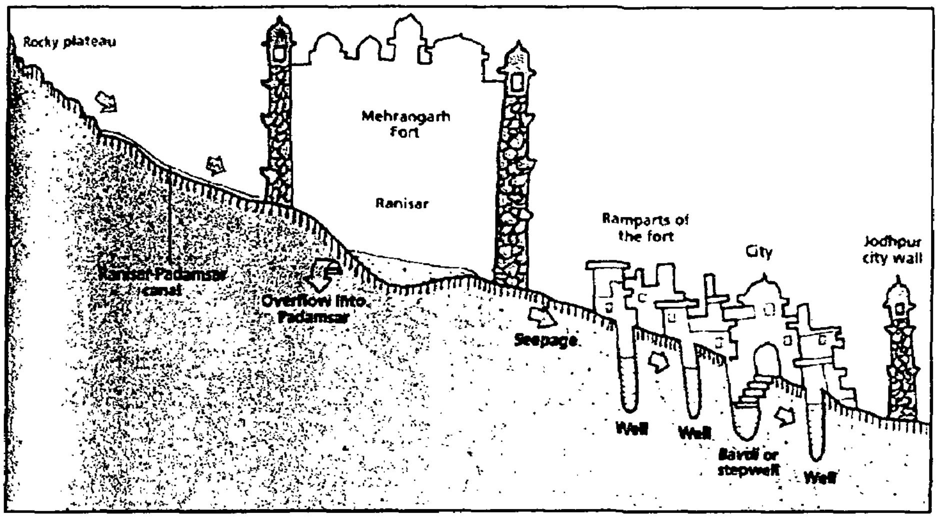

Figure 2.6.1 Jodhpur once ingeniously captured the runoff from the rocky plateau and also the seepage through wells and stepwells

2.6.2 WATER SUPPLY: The present water requirement of Jodhpur, with an estimated population of 0.9 million in 1991, is 27 mgd. This is largely met by surface reservoirs but with an increasing dependence on groundwater. Of the 27 mgd requirement, 22.4 mgd is being currently supplied. Surface water reservoirs account for 55-60 percent of the water supply. The major reservoirs, Jawai and Kemavas, in addition to supplying water to Jodhpur, also serve the needs of Pali and Rohit towns as well as the villages of Pali and Jodhpur districts. Only 30 percent of water released from Jawai, and 50 percent released from Kemavas goes to Jodhpur. During poor monsoon years, the available water is not sufficient to meet the demands of Jodhpur and all other settlements.

Dependence on groundwater has 'increased because of the increasing shortage of surface Water. During the last few years, groundwater has been the only available source for Jodhpur from January to the next monsoon. Aquifers in and around Jodhpur are not abundant therefore can't meet the requirements of the city. The water table has already reached 45 m. below ground level.

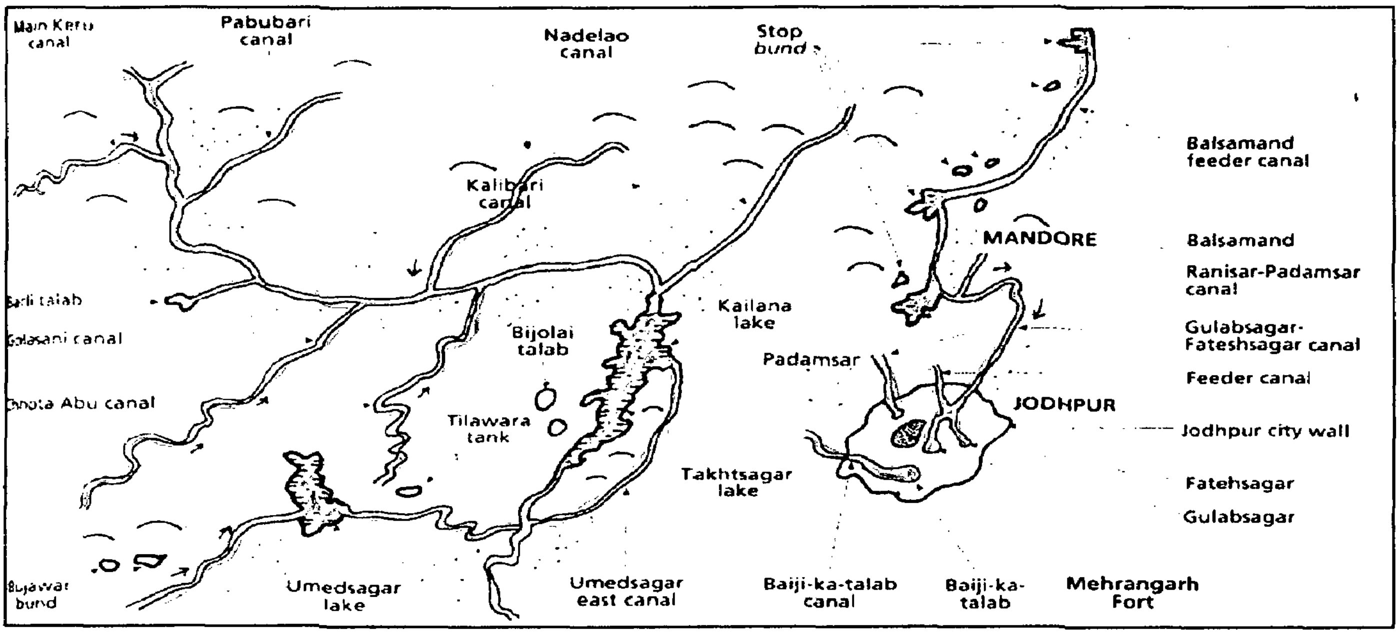

Figure 2.6.2 The map shows some of the key canals and reservoirs that used to supply water to Jodhpur *(A great impetus to water supply schemes of Jodhpur was given during the reign of Mahraja Jaswant Singh ji (1872-95), when Kailana lake was constructed in a famine year. Ranisar bunds were raised, and long canals were constructed to feed the city tanks.)*

2.6.3 WATER SELLERS: Since 1980-81, water has turned into a saleable commodity in Jodhpur. Although prior to 1980-81, water was being sold for functions and constructions only, but now it is sold for marriages, social functions and domestic use as well. Normally it is sold for Rs. 10/- for one tractor although there have been times when it was sold at the rate ofRs 35/- per tractor.

2.6.4 WATER DURING DROUGHT: During drought periods, the local sources have usually played a very important role. In 1985, the water crisis had reached such a stage that the government was at one time thinking of evacuating the city. But local sources like Tapi bavdi, which were cleaned up, supplied 0.25 mgd of water and saved inhabitants living within a radius of 5 Km from the bavdi. An effort to revive the local sources is, therefore, urgently needed.

2.6.5 VARIOUS RAINWATER HARVESTING STRUCTURES IN JODHPUR: We can divide these structures into two main categories.

2.6.5.1 SURFACE WATER BODIES: The survival of surface water bodies of Jodhpur depends essentially on the survival of its magnificent water catchment the Chonka-Daijar plateau. Each water body was provided with an extensive catchment. watercourses and canals to trap the precious rainwater.

Nadis: The local name given to a village pond used for storing water from an adjoining natural catchment during the rainy season was an ancient system for harnessing rainwater. Most villages had their own nadi, and the site was selected on the basis of available natural catchment its water yield potential. It serves the need of water for two months after the rains.

Talabs: A talab is a popular word used locally for water reservoirs situated in valleys and natural depressions. These talabs have been the main source of water for the human and animal population until recently. Today only Ranisar and Padmsar are safe talabs and still used for drinking and other purposes by the local population.

Tanks: In contrast to talabs, especially those of more recent origin, tanks were constructed in situ with massive masonry walls on four sides and an almost impermeable floor as a standard pattern. Tanks were invariably provided with an efficient system of canals to bring rainwater from the catchment areas on the outskirts of the city. An exclusive catchment area and a system of canals thus supported each tank. Out of five tanks in Jodhpur, Fatehsagar is the oldest one built in 1780.

Lakes: Jodhpur has five large reservoirs located on the outskirts of the city in a more or less in natural setting. The oldest is Baliamand, built in 1126 AD. The total five lakes in the city can hold about 700 million cubic feet of water at a given time, which can

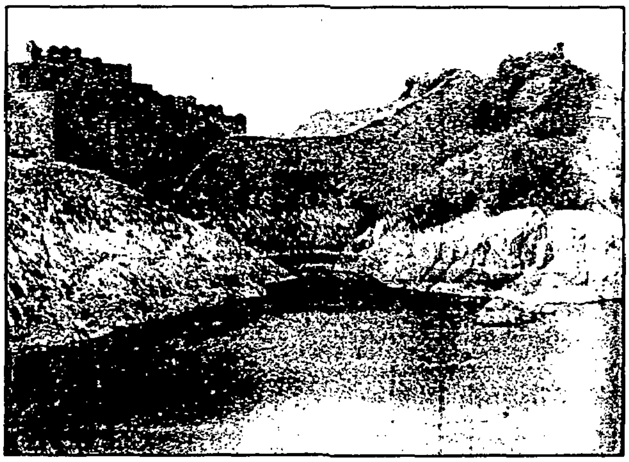

Figure 2.6.3 The Ranisar lake of Jodhpur, situated inside the Meharangarh fort, was reserved for the use of the nobility. Its water is still used for drinking. The window in the center of the picture is the port through which the overflow from the lake goes into

the Padmsar.

support 0.8 million people for eight months. Due to poor state of catchments and canals which carry rainwater to them, these lakes do not get adequate water, even during normal rain years.

Canals: Jodhpur's canal system consists of numerous watercourses, channels and aqueducts to carry rainwater to the city's various nadis and talabs. It is perhaps these canals which led to the construction of large number or nadis and talabs around Jodhpur before tanks came into existence.

Jodhpur is perhaps the only city in the country where an all-out effort was made to conserve every drop of rainwater. To achieve this, every catchment and hillock was drained by canals. Not only each lakes, tanks and talabs have efficient canal system, there were interconnections between lakes and between lakes and tanks to distribute to distribute water to all parts of the city. The city also had underground canals, which seem to have escaped the attention of most experts.

2.6.5.2 GROUND WATER BODIES: A large number of-wells, baoris and jhalaras constitute the major groundwater bodies of Jodhpur. These water bodies were built with the sole purpose of ensuring easy and regular water supply to the neighboring areas. They neither have any catchment of their own nor are they connected with any watercourse. However, each one collects the subterranean seepage of a talab or lake located upstream. Their size, shapes, depths, designs, layouts and locations vary a great deal. Minimum space has been used in the construction to save money, time and energy. Wells were dug essentially to enhance drinking water supply while baoris and jhalaras were meant for washing and bathing, a situation which exists to date.

2.6.6 CONCLUSION: The above case study reveals the fact that the city, even in desert can survive through better water management practices. The city of Jodhpur is situated in desert area of Rajasthan and is supporting the population of millions only due to the better water management practices and subtle utilization of rainwater through rainwater harvesting. *The study also establishes the fact that rainwater harvesting (rainwater harvesting at city level as well as roof-top rain water harvesting) is used for sustainable water supply of a city.* It is the combined effort of the government and people, which brings the prosperity. There are many such practices in India and abroad that need to be studied and incorporated in the planning and management. We have already discussed the various technologies and practices, which are or were in practice. Jodhpur is the one example of such tradition. This study shows that Jodhpur had taken the advantage of natural slopes and drainage patterns to harvest its rainwater, but the current response from people and government has nearly ruined the city and created acute shortage of water. The encroachment upon natural drainage network has badly affected the traditional water storage structures. Hence there is an urgent need to revive such practices and adopt rainwater harvesting in town planning before it is too late to realize the situation.

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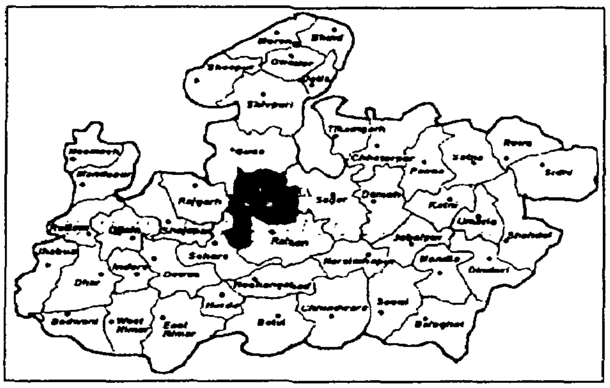
Source: Anil Agrawal, Sunita Narain, 2003, ***Dying Wisdom,*** Center for Science and Environment, New Delhi.

2.7 CASE STUDY-2

UNCONVENTIONAL METHOD (TUBE & DUG WELL) OF RECHARGING AQUIFER: A Case Study of VIDISHA

2.7.1 INTRODUCTION: Vidisha district is next to Bhopal as we move towards north. It is well linked by road and links of all-important districts of MP. It is situated on the Delhi-Bhopal railway link.



Map 2.7.1 Map of MP showing the location of Vidisha & Bhopal.

2.7.2 URBANISATION: After Bhopal it is the next in the urbanization process in M.P., due to its location and near to state capital.

2.7.3 SHORTAGE OF WATER: Due to inadequate rainfall in this region since 1998 whole area facing the acute shortage of water for domestic, industrial and agriculture purpose.

2.7.4 SOURCES OF WATER:

a. **Ground water** (Measure share of water supply is meet by it.)
b. **Surface water** (River- Betwa – which is dry during summer)

2.7.5 ARTIFICIAL RECHARGING OF AQUIFER: The increasing use of ground water for municipal supply, industrial demand and irrigation has emphasized the needs to replenish ground water resources by artificial recharge. Although conventional techniques offer a rich choice of prospecting methods, most of these applications cannot be pursued to the desired extent. In most of cases they turn out to be too time consuming and costly. Therefore it is advisable to use all available techniques with respect to their potential.

2.7.6 UNCONVENTIONAL METHOD OF RECHARGING AQUIFER: Use of this method will lead to an increase of success rates. So this method is used in Vidisha in the association with SATI.

2.7.7 STUDY AREA: The study area is **SATI** (Samrat Ashok Technological Institute) Vidisha district, M.P. Geographical area of study area is 1sq.km at SATI, Vidisha premises.

2.7.8 MATERIAL AND METHODOLOGY ADOPTED FOR SITE SELECTION FOR GROUND WATER RECHARGING: The study has been carried out by using mainly dowsing method along with the hydrogeomorphological maps derived from satellite data. For Dowsing, coconut and copper rods were used. The results derived from dowsing were correlated with the information derived from satellite data.

The steps are as follows:

i) Remote sensing technique

ii) Dowsing and

iii) Geophysical technique

2.7.9 SUCCESSFUL STORY: On the request of SATI, Vidisha, the study was undertaken for recharging of the area. The area experienced acute shortage of drinking water during summer season. About **32 Tube** wells were drilled in the premises. Most of them were dried during summer season. Detailed observation of wells yield (*before implementation of structures*) was carried out. 4 tube wells were recharged by selecting sites during April-May, 2002. Recharge Shaft method was selected for artificial groundwater recharge and applied in the area. 25 Recharge shafts were constructed around the each selected tube wells at low-lying areas so that maximum surface water reaches to the shafts. The shafts were drilled penetrating the total soil column through auger drilling till the weathered basalt (Kopra). Average depth of shafts is 12 feet to 15 feet. Diameter has been g kept 12 inches. Drilled shafts were filled with cobbles and pebbles. The top portion was covered with coconut fibers to prevent from soil entrance. One dug well was also recharged in SATI premises by constructing pits where 6-7 pits around the well

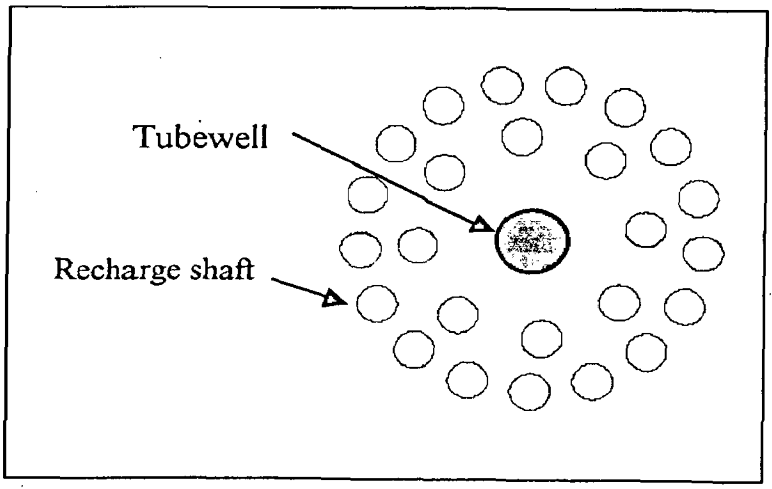


Figure 2.7.1 25 recharge shaft are constructed around a selected tube well.

were drilled having 4 feet depth, and 4 feet diameter uses auger drilling till Kopra is found. **The same method was applied in various places on the demand of private persons also apart from SATI premises.**

2.7.10 RESULTS: It has been found that the surface water during rainy season got percolated just after rain which was accumulated for long duration about 3 to 4 days in the SATI premises before construction of these structures. It shows speedy recharge of wells and increase in the yield. Before construction of structures, the tube wells get started drying in the month of January and dried after the month of April but after implementation they survived till the month of April and even working. *The study reveals that the shaft and pit method for recharging the wells is very appropriate in hard rock areas.*

2.7.11 CONCLUSION AND RECOMMENDATION: On the basis of the above study, it can be summarized that the dowsing plays an important role in selection of artificial recharge site as an efficient management of groundwater. When it is used in association with remote sensing and geophysical methods, it gives the best results. It has been found that dowsing can be used for locating site for recharging sites, confirming the lineaments derived from the satellite data.

Finally it is suggested that Dowsing method for groundwater recharge should not be ignored and should be given proper recognition considering its application in the service of human kind and efforts should be given to know the science behind it.

This method should be applied in all low yielding government wells first to make aware the people so that they also use this technique. Municipal and Panchayati Raj institutions should be trained in this method.

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Source: National Seminar on Ground Water Conservation and Recharging in M.P. 2003, **Unicef Bhopal**

2. 8. USEFUL INFERENCES & GUIDELINES FROM LITERATURE SURVEY

2.8.1 INFERENCES:

2.8.1.1 INFERENCES RELATED TO WATER SUPPLY:

1. Water supply schemes in metropolitan cities of India are venerable to not only natural calamities like flood and earthquake etc. but also to terrorist attacks.
2. WHO norms for water supply in a city is 250 liters per capita, most of the Indian city are far behind to meet this standard.
3. Constantly open tap lower water pressure contributing to high calcium deposit.
4. For a healthy living, a supply of 90 liters of water per capita per day shall be the most optimum considering the average demands for various purposes *(Journal of Indian Building Congress).*
5. As per an estimate, 70% of the water available in most of the Indian cities is chemically or biologically infected (*Anil Agrawal, Sunita Narain,* 2003).
6. Accordingly to world Bank Estimates, the average water supply in large Indian cities is only 5-6 hours a day. Which compares very poorly with other major cities of Asia (Journal of Indian Building Congress).
7. A considerable portion of treated water is lost through leakages in transmission and system. Water lost in distribution is 20-40% of total flow, so we are getting 20-40% less water as claimed by water supply agencies.
8. The cost recovery as water bill from consumers is very poor, ranging from 30-46 percent, in most of the state due to unrealistic water tariffs & improper billing Massive investment much more than what the government can commit is required to develop water resources (*V Suresh*, 2001).
9. Metering system reduce the wastage of water, a study carried out in Uttar Pradesh revealed that the consumption of domestic water supply came down to less than 50 per cent when metering was resorted (*V Suresh*, 2001).
10. In India normally, local bodies revise water tariff once in five years (*V Suresh*, 2001).
11. Using a combination of physical and biological filters, drinking water can be made safe (*Journal of Indian Building Congress).*

2.8.1.2 INFERENCES RELATED TO RAINWATER HARVESTING:

1. Encroachment natural drainage network has badly affected the traditional water harvesting system.
2. A city can even sustain in desert through better water management practices and subtle utilization of rainwater through rainwater harvesting. For example Jodhpur *(details given in Chapter 2-Case Study-1)*
3. Unconventional method gives immediate response with respect to conventional method and it is also flexible and used anywhere at local level as well as at city level. *(details given in Chapter 2-Case Study-2)*
4. The key to harnessing and harvesting the maximum quantum of water available from rain is to delay the flow of water towards the sea or into atmosphere.
5. Per capita availability of rainwater is higher than the per capita need and it is about 9 times greater than replenishable ground water (for Indian average rainfall).
6. It is very interesting to see that per capita availability of rainwater is high in those areas where per capita availability of ground water is very low. For example Bhopal *(details given in Chapter 4)*
7. Unfortunately the phenomenon of constructing and developing water bodies came to a vital halt around 1897-98, when public water supply system was first introduced. (*Anil Agrawal, Sunita Narain,* 2003)
8. Ancient surface water bodies not only represent an excellent feat of architectural and engineering design but also a high degree of community sharing and social moral and religious values built around a desire for "water for all" in the society.
9. The potential of RWH differs according to development type and topography of the area and landuse pattern.
10. The study reveals that the shaft and pit method for recharging the wells is very appropriate in hard rock areas. *(details given in Chapter 2)*
11. The sloping site can be effectively utilized as rainwater harvesting at city and regional level. *(details given in Chapter 2)*
12. The study also establishes the fact that rainwater harvesting (rainwater harvesting at city level as well as roof-top rain water harvesting) is used for sustainable water supply of a city
13. Traditional methods of water conservation have been neglected.
14. Urban waterbodies are today no more than dumping grounds in India. They are not only heavily polluted but also uncared for maintenance. (*Anil Agrawal*2003)

15. Rain is an incredibly important resource. It is essential to city planning and to mitigate water shortages, control floods and disasters (*V Suresh*, 2001).
16. Cluster, sector & city level rainwater harvesting will involve the community participation, and government intervention.
17. New technology neglect the traditional RWH .practices (for example The city of Aizal depends heavily on rainfall to meet its drinking water requirement but the government continues to give higher priority to piped water supply)
18. Chennai leads the country in urban water harvesting.
19. Many countries provide subsidies to people to install RWH system (e.g. Japan).
20. Water harvesting system, once installed, will provide water without motivating power in contrast to ground water exploitation structures.
21. The catchments areas of RWH are generally of three types – hard surfaces like roofs and rocks that generate 100 percent runoff, semi-hard surfaces like roads and house premises that allow 50 percent runoff, and loose catchment area in the countryside that permit only 25 per cent runoff.
22. To augment water supply, various options such as on-channel storage, off-channel storage, floodplain reservoirs, quarries, historical waterbodies, check dams, paleochannels, lakes, village ponds, rooftop water harvesting and economic sewage recycling techniques were considered. (*Anil Agrawal, Sunita Narain,* 2003)
23. The primary advantage of collecting and storing rainwater in urban area is not only producing additional water but also controlling storm runoff and preventing urban floods as a result. (*Anil Agrawal, Sunita Narain,* 2003)
24. In many countries their governments are planning water conservation policies for promoting rainwater utilization and restricting groundwater use. (e.g. Japanese, Singapore etc.)
25. IT has al lot to offer for optimizing the results of water harvesting implementation.
26. RWH makes use of the natural water cycle in a sustainable way. By bringing water closer to the users, it minimizes the amount of energy needed to transport it.
27. Monte-Carlo simulations of RWHS allow us to make optimum use of an important source of water available to communities living in ASA regions. (*Agrawal,,* 2003)
28. On the whole, it has been established in Singapore that the utilization of urban catchments is a reality that can be highly efficient is the system is well planned, maintained and monitored.
29. It is important to study traditional systems(A scientific analysis of traditional water harvesting structure around Ramtek township in Maharashtra revealed how a whole

system for capturing water, based on local topography and soil type had been developed)

30. Traditional technologies, ideal for the time in which they were devised, can be augmented by modern science. For example, runoff from catchments can be increased. Recharging efforts can be made more efficient. In fact, traditional technologies can also be used to deal with the present day water quality problems that we face like fluoride and arsenic in groundwater. Modern science can also be used to explain how groundwater recharge, through the construction of traditional water harvesting system, has revived rivers.
31. Using GIS, it is possible to identify potential water harvesting and storage sites. The structure ideal for the region can be selected. Using computer and software it is possible to optimize the size of the water structure being built, taking into account the rainfall, catchment area and water demand. Past data can be used to predict trends. Computerized databases, available on the internet, offer a mine of information. (*Journal of Indian Building Congress*).
32. The technologies of RWH being highly location-specific based on physiographic, environmental technical and socioeconomic conditions, an appropriate technology developed for a particular region cannot simply be replicated in other areas, and this is where remote sensing play vital role.
33. In contrast to many advantages of RWHS is its unreliability, since its depends on meager and erratic rainfalls, particularly in ASA region (*Anil Agrawal, Sunita Narain,* 2003).

2.8.1.3 INFERENCES RELATED TO WATER MANAGEMENT/OTHER:

1. Factors inhibiting development of sustainable water supply systems in India (*V Suresh*, 2001).
   - *Lack of recycling initiatives*
   - *Unrelated links between cost, price and consumption*
   - *The continuance of poor staff strength for maintenance activities*
   - *Absence of regular maintenance and consequent higher operation and maintenance cost*
   - *Substantial losses and leakages*
   - *Lack of recycling initiatives*
   - High administrative and supervision charges burden on ulbs

2. A major role played HUDCO in sustainable development in water sector and discusses the various emerging alternatives for water sector financing. HUDCO also outlines the pertinent issue emerging towards the same, with particular emphasis on the need to increase the investment and reforms for providing both quantity and quality of water.
3. Majority of our large cities have virtually exhausted or depleted all their proximate water supply sources through overexploitation (overuse, misuse, temporary underused and / or misconceived decision), and are now dependent on rivers, reservoir and or groundwater sources situated as 50/80/100 km away. As a consequence, the water supply situations in the respective rural neighbourhoods become critical, and for the demanding urban center, more uneconomical(due to transport of water over long distances and) undependable and so necessarily needing heavy subsidies on its overall cost (www.rainwaterharvesting.org).
4. Urban Water Management is a special case of water resources management applied for cities i.e., areas with a very high level of human interference with natural processes.
5. Chemical composition and physical properties of many different types of water in urban area are substantially different than water in rural areas At present, there is no appreciable involvement of the private sector.
6. *Drainage is the key issue in solving the water supply problem.*
7. Even more than development issue, management issues are critical. Considerably more satisfaction and benefits can be obtained from the present system, in managed efficiently.
8. Jaisalmer in the heart of the Thar Desert. Annual rainfall 100mm, in the 1987 drought, the government's piped water supply ran dry. But there was enough water for people who stuck to their harvesting structure. But Cherrapunji, a village in the Northeast. Annual rainfall is 15000mm. Officially recorded as a village that suffers water shortage during summer (*Anil Agrawal, Sunita Narain,* 2003).
9. Providing citizens with access to potable water and sanitation services in an efficient and sustainable manner is one of the biggest challenges facing the central state and local governments.
10. In near future drinking water will be the most important use of water.
11. Catching the water when it is on the land and controlling it by organizational skill is the crux of water planning/water management.

12. Water resource management is largely exploitative rather than conservationist.
13. Traditional wisdom need not be sacrosanct (free from attack) but the experience from local inhabitant can provide valuable lesson for designing and sustaining water development programmes.
14. Professional societies can act as multi disciplinary agencies for national and regional debate, analysis and framing of local plans on water related matters by utilizing their infrastructure, professional expertise, library, publications and documentation services.
15. It is imperative that conservation, recycle, reuse of precious water and proper treatment of waste water must be given serious attention for sustainability of built environment for our high populated country.
16. There is no regulatory authority for the water sector, which would make private project more bankable.
17. Water resources management in human settlements presents an outstanding challenge for sustainable development which combines the challenge of securing for all the basic human need for a reliable supply of safe drinking water and meeting the competing demands of industry and agriculture, which are crucial to economic development and food security, without compromising the ability of future generations to meet their water needs.
18. Local bodies would not have been in a position to bear the additional burden of debt servicing and O&M costs unless the water charges were nearly doubled and collection performance improved they would have not been able to meet the O&M costs (*Journal of Indian Building Congress*).
19. India is indeed poised for substantial involvement of private sector in the field of water supply and very shortly many city water supply schemes would be managed collaboratively through Public- Private partnerships for mutual advantage.
20. Urban areas face peculiar water problems the world over. Urban citizen has to deal with water scarcity on one hand flooded street on the other.
21. Control of water pollution required great inter departmental coordination.
22. Planners aim at systematic colonization of the hinterland and leave resource planning to water departments and central water authorities, working on a strictly engineering approach, to deliver water and the constraints in this regard have not come in the way of planning for projected population.

2.8.2 GUIDELINES:

2.8.2.1 GUIDELINES FOR WATER SUPPLY:

1. Quality monitoring in a drinking water supply schemes is undertaken at all three levels, viz, the source, the treatment plant and the distribution system.
2. Within the present water supply and demand scenario measures must be taken to both to enhance supply and to control demand.
3. Metering system should employed to every connection.
4. Registration charges on water connections and collection of advance payments just like road tax (the revenue collected from road tax is such a huge amount that only 10% of it, utilized for O&M and transportation system) in India.
5. The pricing policies should be on the principle of full cost recovery.
6. Water supply and Sanitation agencies including local bodies need to be given full autonomy for determination of tariff with the provision for automatic annual increase to cover the average incremental operation and maintenance costs, depreciation charges, debt services, etc

2.8.2.2 GUIDELINES FOR RAINWATER HARVESTING:

1. Proper investigation of site is done before application of new (unconventional) techniques.
2. Steps involved in ground water recharge and site selection followed by implementation of suitable and cheaper indigenous recharge structure.
3. We have to be open minded to accept the new technology in addition to conventional method or recharging the aquifer
4. Unfortunately the phenomenon of constructing and developing water bodies came to a vital halt around 1897-98, when public water supply system was first introduced, its very bad sign for development of a community so it should be revived.
5. Traditional methods of harnessing surface water with combination of new technology may provide some alternatives to meet the demand problem.
6. Pavement should be perforated as far as possible and it should be avoided in open space.
7. Technical assistant should be given for bore drilling and suitable subsidies should be given on equipments related to Rainwater Harvesting
8. Use of gray water in flushing in different bigger institutions and organizations.

9. We have to adopt water sensitive planning so that rainwater is used adequately and the runoff from impervious areas, such as car parks, roads and footpaths can be infiltrated into the aquifer after ascertaining its quality.
10. The cities will subsidies residents and companies planning to install rainwater utilization systems.
11. The city will install rainwater utilization system in all its new facilities.
12. With proper management, including improved water quality monitoring system, urban storm runoff can be successfully collected and stored as raw water that can be transferred to an impounding reservoir to augment the storage volume.

2.8.2.3 GUIDELINES FOR WATER MANAGEMENT/OTHER:

1. Water resource management should be largely conservationist rather than exploitative.
2. With increase in urbanisation and depleting water resources, there is a need to optimize water supply and wastewater disposal in a planned manner.
3. Registration of all borewells / pumps sets used for domestic as well as commercial purpose for exploiting ground water.
4. A levy should be imposed on it based on the purpose and withdrawal capacity.
5. Storm water drainage network should be compatible for encouraging ground water recharge.
6. Privatisation of water supply authorities helps us lot to improve water system its operation and maintainace.
7. Dual distributions system for the cities wherein separate supply lines would be furnishes potable water for drinking, cooking, bathing and laundry, while used water would be furnished for non-potable proposes.
8. Introduction of economic instruments and regulatory measures should introduced to reduce wastage of water and encourage recycling and reuse of wastewater and to develop strategies to reduce the demand for limited water resources by increasing efficiencies in the agricultural and industrial sectors.
9. *Emphasis should be given to involve women participation in decision-making process in regard to management of infrastructure systems at large.*
10. There must be legislation for controlling ground water extraction.

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Study Area Profile

Topics covered in this chapter

- INTRODUCTION
- HISTORY OF BHOPAL
- REGIONAL SETTINGS
- LOCATION
- LINKAGES
- ENVIRONS
- ECOLOGICAL PARAMETERS
- TOPOGRAPHY
- NATURAL DRAINAGE
- SOIL
- HYDROLOGY
- MINERALS & ROCKS
- CLIMATES
- DEMOGRAPHIC PROFILE
- MUNICIPAL LIMIT OF BHOPAL
- SOCIO-ECONOMIC PROFILE
- LANDUSE PATTERN
- POWER SUPPLY

CHAPTER 3

3.1. INTRODUCTION: In this chapter, I try to develop a holistic understanding of the town under study. Historical events and administrative compulsions of rulers often set the axis of development. Physical characteristics of land and their concurrence with water bodies set constraints and preferences for the local population these factors often lie at the root of the development as it occurs today.

3.2. A PEEP INTO THE HISTORY OF BHOPAL: Bhopal is one of those historic cities, which has enjoyed the splendor of a capital and has suffered the attack and destruction of feudal wars. The present city stands on the site of a ruined town of "Pramaras", the origin of which is lost in obscurity.

It is said, that this picturesque site was selected by **Raja Bhoj,** the Paramara ruler of Dhar, sometime in 1010-1015 AD. He is also credited with the creation of the **Upper lake,** by construction of an earthen dam along the southeastern side of the lake. At the time of Raja Bhoj, this lake constituted a part of larger water spread extending right up to Bhojpur. The industrial town of Mandideep was then only an island.

After the death of Aurangazeb, **Dost Mohammed Khan**, a chief of his army, established himself at Berasia the capital of a much larger territory. Between 1720 to 1726, Dost Mohammed Khan fortified the city of Bhopal with huge stonewalls and constructed the Fatehgarh Fort.

A pact was executed with the 'Company Government' in 1818 during the regime of **Nazar Muhammed Khan.** The city continued to flourish during the successive regime of **benevolent Begums.**

Quedesia Begum started construction of **Jama Masjid** over the ruins of Subha Mandal in 1828 and also built shops around the Masjid and developed a road from Jummerati to Ibrahimpura: A small unit or water works was also built.

Jehangir Mohammed Khan, built the first extension of Bhopal beyond Pul Pukhta know as Jehangirabad. **Begum Shahjahan** (1880-1901) was responsible for the second planned extension of Shahajahanabad with **Taj-ul-Masjid, Taj Mahal,** shopping center and residential areas etc. The most significant achievements during the period were linking of Bhopal with Itarsi and Jhansi with the narrow gauge railway line. **Sultan Jehan Begum** who ruled from 1901 also added another extension known as Ahemabad Palace area situated on the northwest hills over looking the lake, to provide accommodation for the royal family and officers of the State.

In 1956, Bhopal was selected as the Capital of the newly formed state of Madhya Pradesh. To accommodate the employees arriving from different cities, a new township "Tatya Tope Nagar" was established on the northeastern hills beyond "Shamla hills". At about the same time the Industrial township of **BHEL** was also established.

3.3. CHRONOLOGY OF PHYSICAL GROWTH:

I. 1010 AD

Creation of **upper lake** and founding the city by **Raja Bhoj.**

II. 1151 AD

Construction of **Sabha-Mandal** (Temple) by **Rani Salinti** wife of the grandson of Raja Bhoj in an area of 100 acres (approx.)

III. 1151 AD to 1184 AD

Raging feudal wars from 1151 to 1184 destroyed the Sabha Mandal

IV. 1722 AD

Fortification of the Town and construction of the fort by Dost Mohammed Khan, founder of Bhopal State. Bhopal becomes a **'Walled City'** the area of about 125 acres, so enclosed, is still known as **Shahri Khan.**

V. 1795. AD

Construction of lower **lake** by Chatte Khan.

VI. 1808 AD

Immigration of trading communities (Mahajans, Sahukars and Boros) to the city, which was mostly inhabited by soldiers. The city sprawls beyond its walls Area -200 acres (approx.)

VII. 1838 AD

Qudsia Begum began the construction of Jama Masjid over the ruins of Sabha Mandal

VIII. 1838 AD

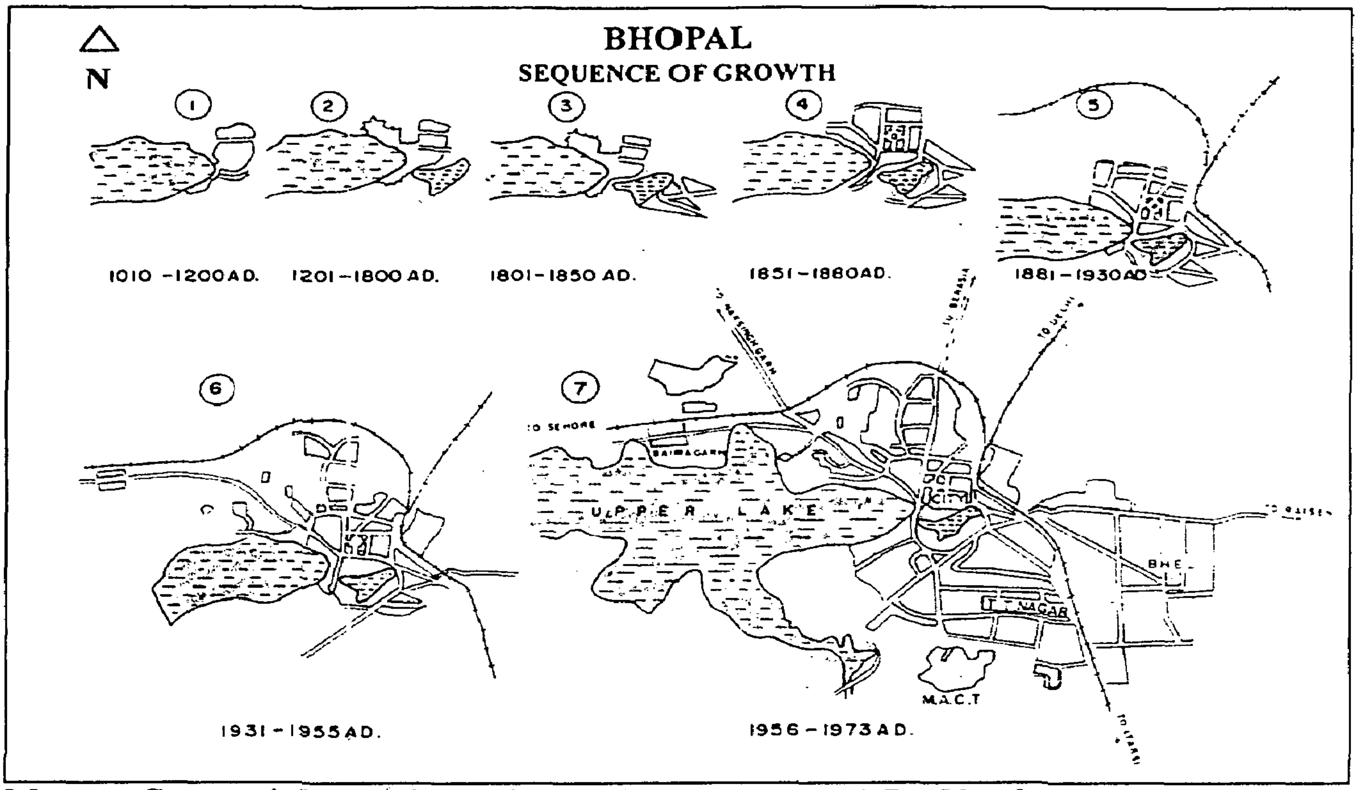
Development of Military cantonment "Jehangirabad" and shifting of army to the new site from the heart of the city. Area 300 acres (approx.)

IX. 1856 AD

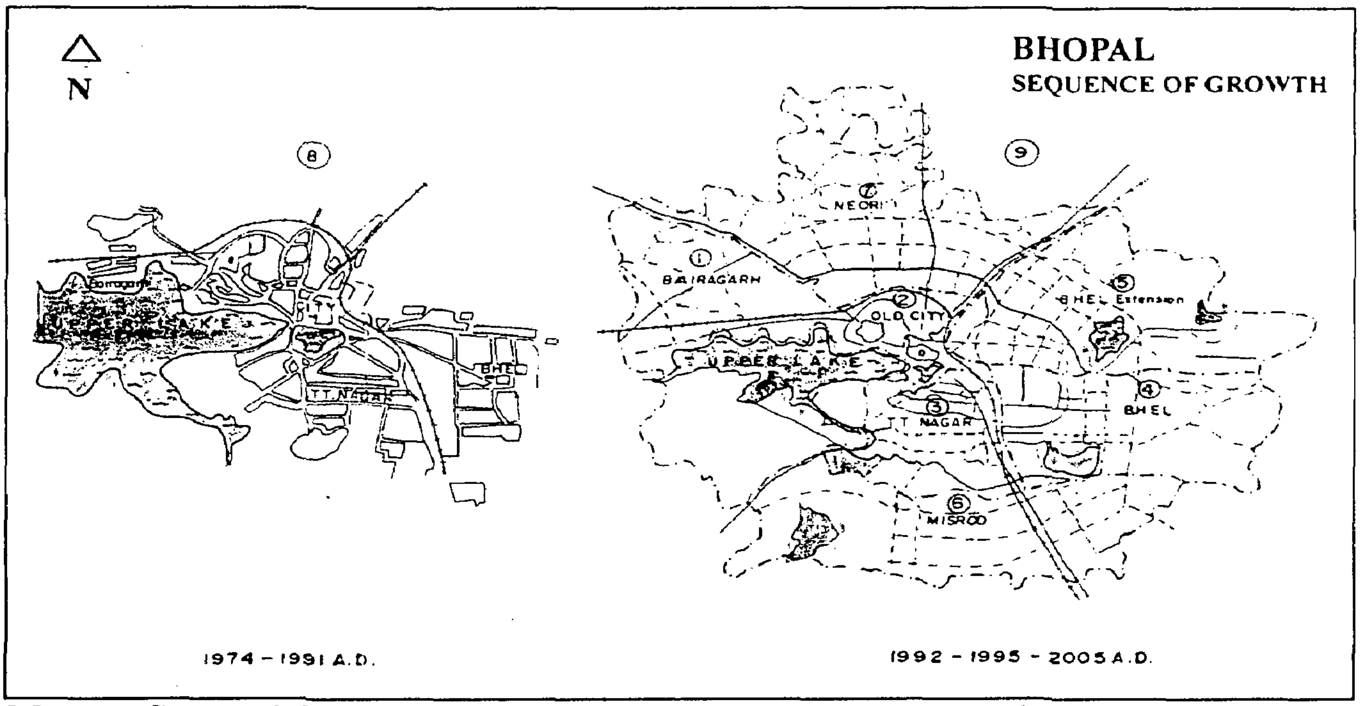
Construction of Central Mosque with shopping square. Population -37,539 Area -600 acres

X. 1910 AD

Construction of rail, road and power station. Development of new panned localities Shahjahanbad, Tajul Masjid, and Ahmedabad. Population -77,023, Area -4544 acres.



Map 3.1 Sequential growth of Bhopal city 1010-1973 A.D. (Vandna Tiwari, 2001)



Map 3.2 Sequential growth of Bhopal city 1974-2005 A.D. (Vandna Tiwari, 2001)

XI. 1933 to 1938 AD

Developments in trade and commerce, first textile mill and some other factories were set up. Mandi was started and Hamidia Road was constructed. Population -61,087, Area -7353.6 acres

XII. 1945 to 1955 AD

Demolition of city walls and gates occupying central part of the city. Population - 75,228, Area -7353.6 acres

XIII. 1950-to 1959 AD

Bhopal again assumed the status of the state capital of Madhya Pradesh, after the merger of Bhopal State in Indian Union (1949). Bhopal was selected for the location of Heavy Electrical Industries. Population -2,06,121, Area -22,116.48 acres

XIV. 1957 to 1960 AD

An overall plan was prepared. At the same time B.H.E.L. factory and township was also established on the plateau plains to the east of the city.

XV. 1960 to 1974 AD

The total impact of the above was not realized in Development Plan that was prepared and published. First phase of development was in progress.

XVI. 1974 to 1994 AD

The city increased in size with a developed area of 7851 hectares and population up to 10.65 lakhs. Master plan was published in 1975. The growth was now being directed by it.

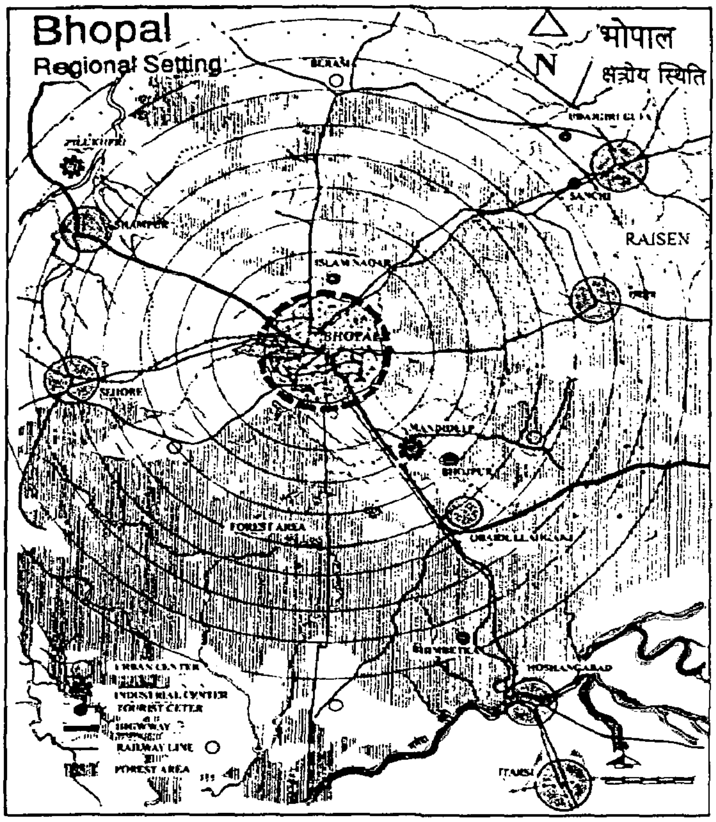
XVII. 1994 to 2000 AD

New Development plan was published in 1995 for a period of 1995-2005. The city's population is projected to grow upto 25 lakhs upto 2005. As against, existing five sub cities, (Main city, BHEL. BHEL SERVICE township, T.T. Nagar and Bairagarh), the development plan envisaged two additional sub-cities, namely Neori in the north and Misrod in the south to accommodate around 10 lakh additional population and further direct the growth of the city.

3.4. REGIONAL SETTINGS: The district of Bhopal is the most urbanized district of the state. The district is in the shape of an elongated strip with its major axis lying in the North South direction. The average width of the strip is 25 Km and the length is 94Km.

Bhopal City is surrounded by small and large towns like Sehore, Shyampur, Kuravor, Narsinghgarh, Mandideep, Obaidullaganj, Raisen, Sanchi, Vidisha and innumerable small villages. These settlements, depend on Bhopal for a large number of facilities like health and hospital services, educational facilities especially at higher secondary and college level, specialized shopping requirements for automobile parts, construction equipment, and building components like sanitary and hardware fittings, fabrication and machining requirements, etc.

Small and large villages depend on the City for their economic activity, trade and commerce and infrastructure. On the other hand, the city depends on the input that it receives from these areas in terms of flow of funds and food products. This dependence and interaction is further reinforced and encouraged by a network of roads and transport systems.



Map 3.3 Bhopal regional setting (BDP - 2005)

3.5. LOCATION: The city of Bhopal situated on **77°22' E** longitude **23°16' N** latitude on hard pink-red sandstone of **Vindhyan region** and is at an Average altitude of **551.12**m above mean sea level.

3.6. LINKAGES:

Rail: *linked directly with Delhi, Madras, Bombay, Indore, and Jabalpur.*

Road: National Highway **No. 12** passed through, the city linking the city with Agra - Bombay Road (N.H.3) at Biora. The city is linked via N.H.12 to Jabalpur, Indore and Nagpur.

Air: linked via air service to Delhi, Bombay, Indore, Gwalior, Raipur and Jabalpur.

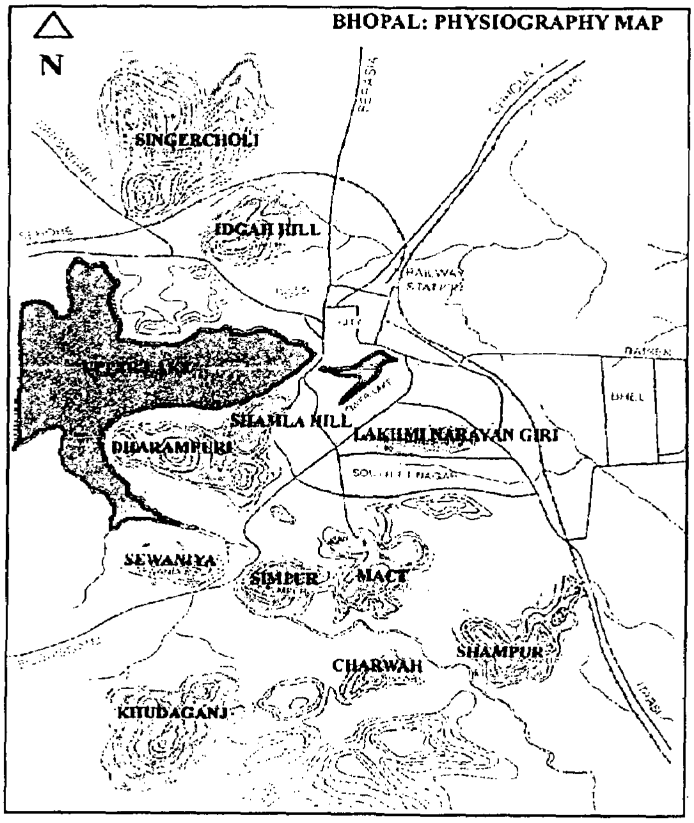
Bhopal is well connected to neighboring towns and other cities of the state. Good linkages directly increase in-migration. Road networks, especially, increase economic interaction and interdependence. Their direct impact is seen in the property market as many well to do villagers by plots and properties in the city with a view to provide opportunities to the future generations.

Bhopal being located in the central position it is directly connected to almost all the major cities in India through railways. This encourages the location of regional offices of various organizations and increases immigration.

3.7. ENVIRONS: Bhopal is surrounded by forests and relatively poor agricultural land. Very few large villages are situated within a radius of 15 to 20 km. From Bhopal. The city gets its supply of agricultural produces and vegetables from primary collection centers in the vicinity like Sehore, Ashta, Shyampur, Berasia, Bilkisganj, Obedullaganj and Sultanpur. The city is ringed by Mandi towns all around between a distance of 40-60 km. on all sides major being Sehore, Ashta, Berasia, Vidisha, Raisen and Obaidullanganj. The Development plan for 1975-95 desired to preserve the good agriculture land as far as possible. Thus, a series of small dams came up. The catchments and command areas of these dams further blocked land and provided an axis towards south to the growing city.

3.8. ECOLOGICAL PARAMETERS: The main objective of ecological study is to identify the natural forces that governed the direction of growth.

3.9. TOPOGRAPHY: The city is situated on a hilly terrain, which slopes towards north and southeast hillocks of different altitude along the Southwest & Northwest portion of the city. These hillocks form a continuous belt from Singarcholi in the northwest to the Vindhyachal ranges to the South. The remarkable topography of the city provides enchanting and panoramic views of the city and of natural beauty. Large portions of the city areas and new township are separated by hillocks and lakes, which act as barrier in social and cultural integration of the city.

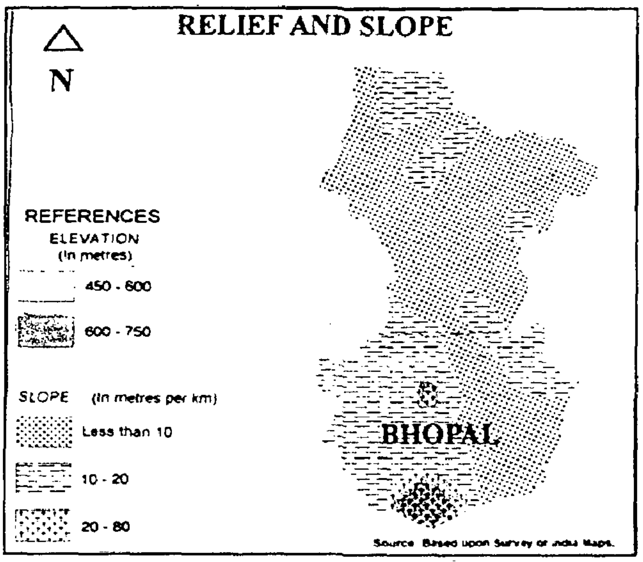


Map 3.4 Map showing the important hillocks of Bhopal (BDP - 2005)

The present city stands segregated distinctly in three parts. The capital project area is separated form the old core by two lakes upper and lower, BHEL Township is separated from the old core and Capital Project area both, by the broad gauge railway line. Thus, we see that topography affected the growth and influenced the direction of development.

The city was initially situated on the northeast edge of upper lake. Its initial axis of growth was northwest -southeast along the edge of lower lake. Then, with the strengthening and reinforcement of the Kamla Park bridge -post formation of the state Capital, the growth took a North East -South West direction. Capital project caused the growth to flow between Arera Hills and Char Imli hills. The emergence of Kolar road naturally funneled this growth between the hills of MACT and Shahpura.

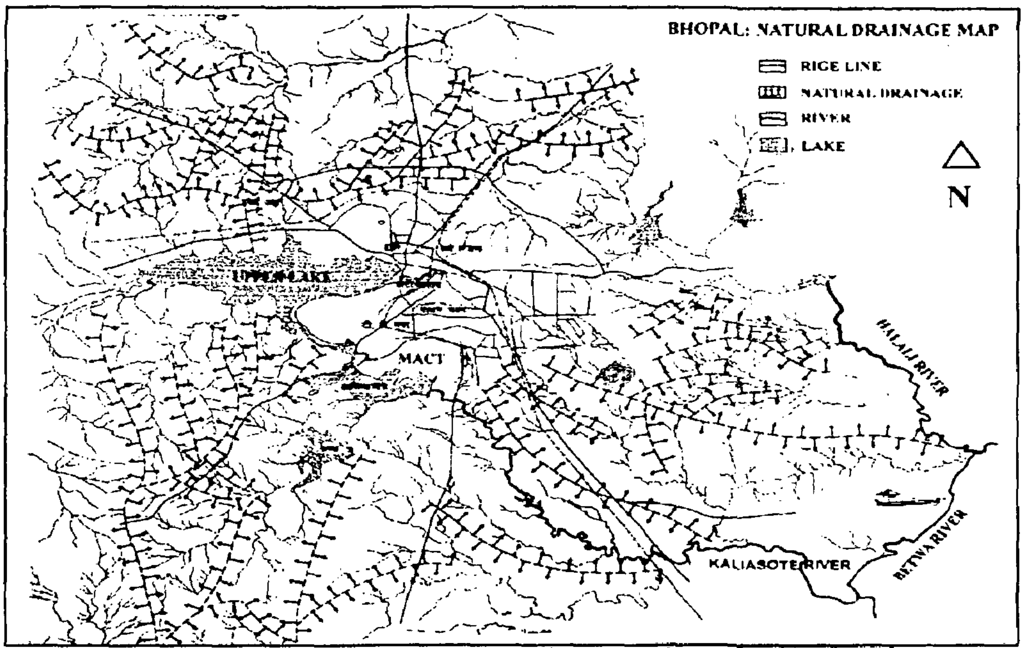
Thus, we see that the topography of the city has a major impact on its direction of growth. The entire Western face of the north south axis remains blocked by Upper Lake and its catchment areas. The two successive master plans tried to preserve this great water body. However, this land resource is now opening-up and being covered with low-density housing.



Map 3.5 Physiography map of Bhopal
(SOI-District Planning Map Series)

3.10. NATURAL DRAINAGE:

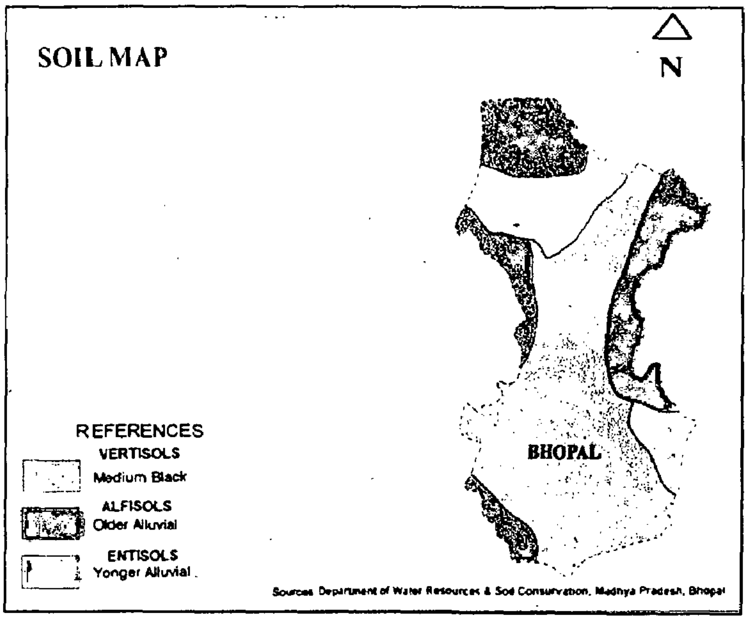
The natural drainage of the city is by three main steams, which are, joined by Nallahs and Rivulets. On the northeastern side drainage is provided by the **River Halali** and on the South-



Map 3.6 Natural drainage map of Bhopal. (BDP - 2005)

Eastern side by **River Kaliasot** which was ultimately joins the **River Betwa.** On the South-Western side the drainage is provided by **the Kolar river** which is a tributary of Narmada. The city has 7 lakes, two of which are very large in size. The upper lake, created by Raja Bhoj covers an area of 16 sq. km. And the Hathaikheda Reservoir, recently constructed covers an area of approximately 10 sq. km.

3.11. SOIL: The soil stratum around the city creates a great dilemma for the planners. Commonsense dictates that we should build on stable soils and avoid fertile and cultivable soils. However, the hard build able soil strata lies to the west of north-south axis, which forms the catchment area of the upper lake.



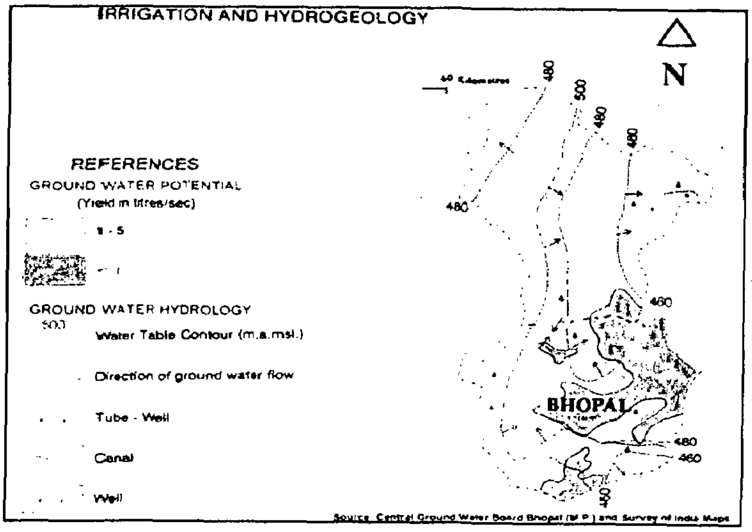
Map 3.7 Map showing the types of soil present in Bhopal. (SOI-DPMS)

The old city area is characterized by Red sand stone strata of Malwa Plateau. The top portions of various hillocks and the slopes have red soil mixed with boulders. As we move down the slopes of hills, Black cotton soil in depths of 1 to 2 1/2 meters is observed on the North, north-eastern, South and south-eastern directions. Valley portions in Capital Project area also contain black cotton soil to depths of 1 to 2 meters. Comparatively better agricultural land is situated on the northern and northeastern side, than on Berasia road. *The choice in planning was to sacrifice some cultivable land or to sacrifice the catchment area of the lake.* Fortunately, the planners made the right choice as hindsight has proved that cultivable land around the city is in any case lost to urban land uses due to rising land values.

Thus, preservation of catchment areas was and should continue to remain a major planning objective.

3.12. HYDROLOGY:

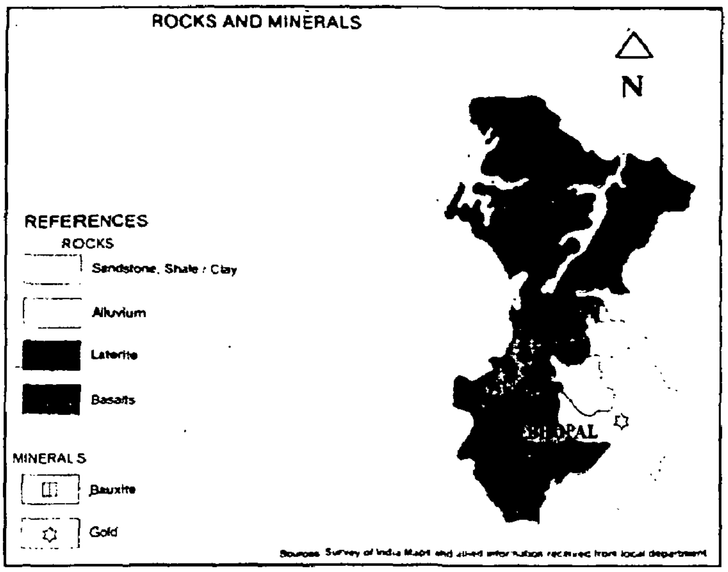
One third of Bhopal fall under the low ground water potential as shown in the map. Direction of ground water flow towards north and south.



Map 3.8 Map showing the ground water potential in Bhopal. (SOI-DPM)

3.13 MINERALS & ROCKS:

The Bhopal city is richly endowed with natural resources like rocks and minerals. The spatial position is shown in the map.



Map 3.9 Map showing the rocks and minerals in Bhopal. (SOI-DPMS)

3.14. CLIMATES:

(Source: free.weather.com)

3.14.1 Temperature:

Max 40°C May

Min 6°C December

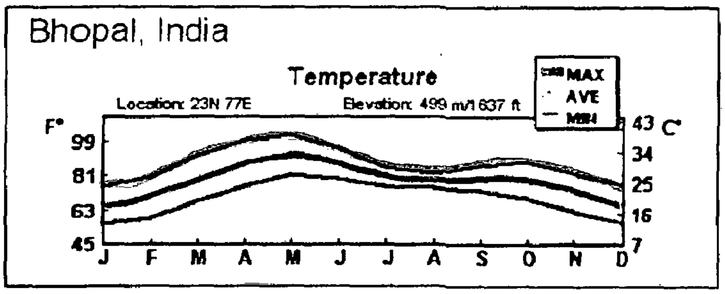


Chart 3.1 Monthly mean temperature (DBT) of Bhopal.

3.14.2 Humidity:

Max 85% August.

Min 37% April

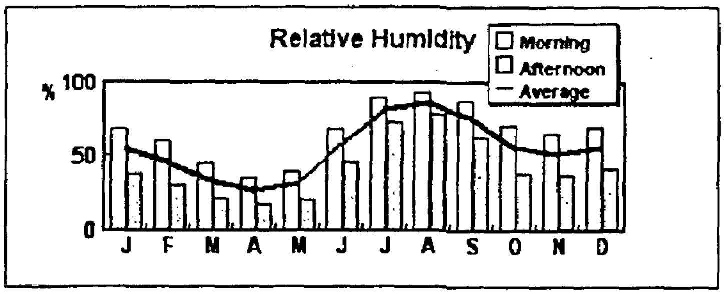


Chart 3.2 Monthly mean relative humidity of Bhopal.

3.14.3 Wind Speed:

Max 22 kmph. June

Min 9.5 kmph Dec.

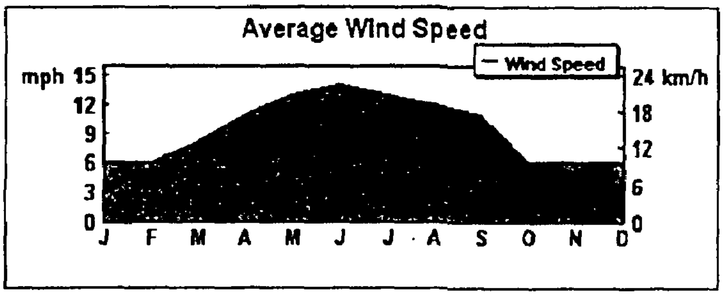


Chart 3.3 Monthly average wind speed of Bhopal

3.14.4 Rainfall:

Max - 429mm July

Min - 03mm February

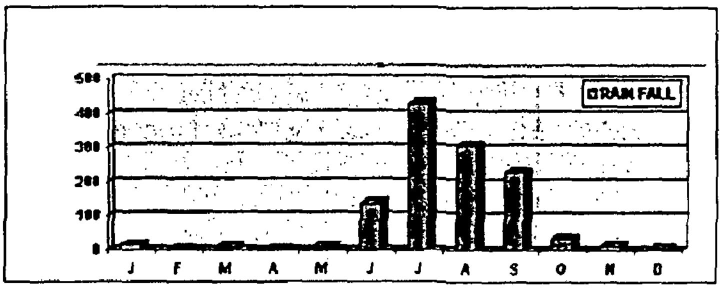


Chart 3.4 Monthly average rain fall Bhopal (**Annual Rainfall – 1209 mm**)

3.15 DEMOGRAPHIC PROFILE: The district of Bhopal is the most urbanized district of the state, 80.53% of its population is urban. The city of Bhopal has witnessed fluctuating trends in population growth. The population that was **37,529** in **1858** steadily increased to **77,023** in **1901**, due to the establishment of rail links with other major cities. During **1901-1911** the city witnessed a decrease of **27%** after being overrun by a sever epidemic. Between **1921-31**, a further decrease of **24%** occurred after which the health situation improved and the city witnessed steady growth up to **1951**. In **1948** a large number of Sindhi refugees displaced during the partition were settled in Bairagarh. In 1956 the state capital was established in Bhopal and concurrently the B.H.E.L. plant was setup. These two factors resulted in a registered a growth of **77%** due to increased industrialization, downstream industries of BHEL improved means of communications.

This sudden increase in population could not be absorbed by the city efficiently. All the urban services were badly strained and consequently number of slums and Jhuggi settlement sprang up. Total slum population 1,26,346 which is 8.81% of total urban population. The picturesque beauty of Bhopal was spoiled by large number of such settlements causing deterioration of environmental condition.

Table 3.1 -Decadal population growth

Year	*Bhopal Urban Area Population (lakhs)*	*Percentage Decade Variation*
1901	*0.77*	-
1911	*0.56*	-27.27
1921	*0.45*	-19.64
1931	*0.61*	35.56
1941	*0.75*	22.95
1951	*1.02*	36.00
1961	*2.23*	118.63
1971	*3.85*	72.65
1981	*6.71*	74.29
1991	*10.63*	58.42
2001	14.37	35.18
2011	18.11*	26.03
2021	21.85*	20.65

Source: Census of India 2001, Madhya Pradesh.

Note: For year 2005, 25 lakhs population has projected by T CP Bhopal.

*Projected population has been based upon the Arithmetic Increase Method, because it is most appropriate method in case of Bhopal population projection, when I compared its result with other two method Geometric projection and Exponential method. See Table 3.2, 3.3. & 3.4 for details. The average growth rate of total population in Bhopal is 37.79 during 1901-2001.

3.15.1 POPULATION PROJECTION: The population figures has Projected by using three methods.

Table 3.2 Arithmetic Increase Method

S.No.	Year	Population
1.	2001	14,37,354
2.	2011	18,11,046*
3.	2021	21,84,738*

Table 3.3 Geometrical Increase Method

S.No.	Year	Population
1.	2001	14,37,354
2.	2011	19,42,337*
3.	2021	26,24,725*

Table 3.4 Incremental/exponential Increase Method

S.No.	Year	Population
1.	2001	14,37,354
2.	2011	19,41,965*
3.	2021	26,23,728*

3.15.2 POPULATION GROWTH TRENDS: From 1901-51 the population of the city is fluctuating and its population is near about 1.0 lakh, but after getting the statutes of capital city of M.P, city growing at rapid rate upto 1961. After that growth rate has again slowed down, but still city still growing at the average decadal rate of 37.79%.

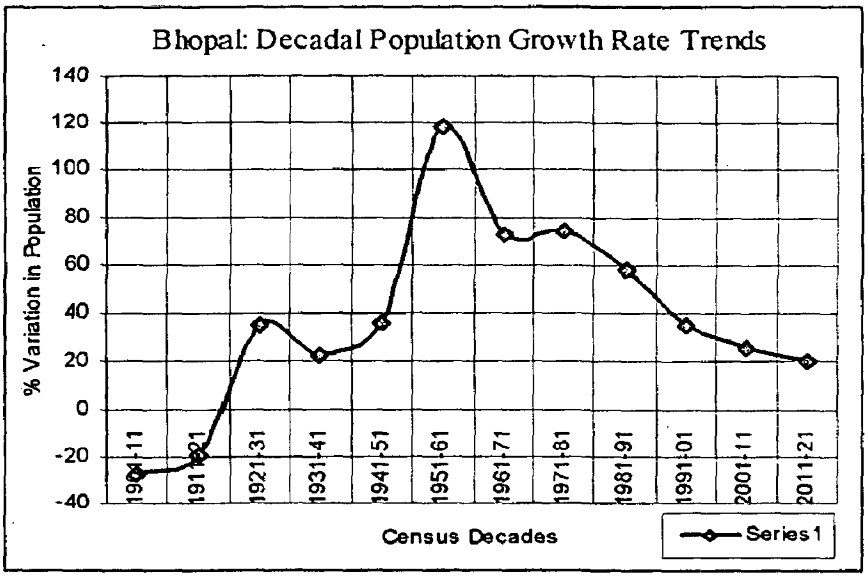


Chart 3.5 Bhopal decadal population growth rage trends.

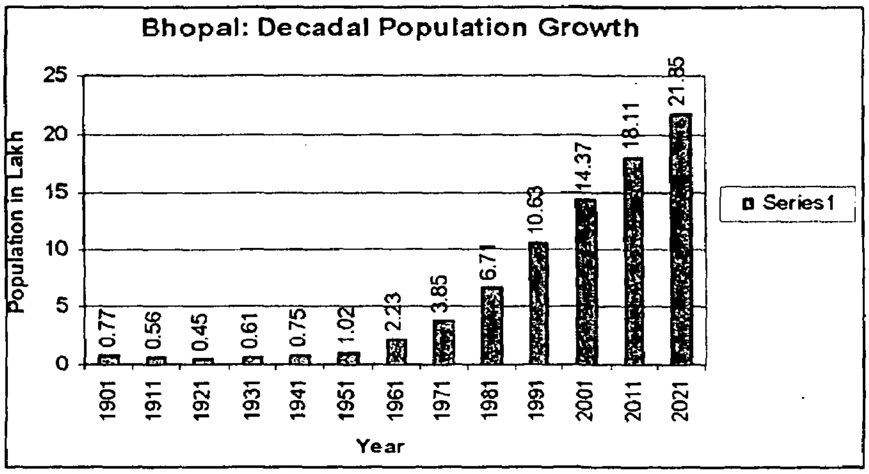
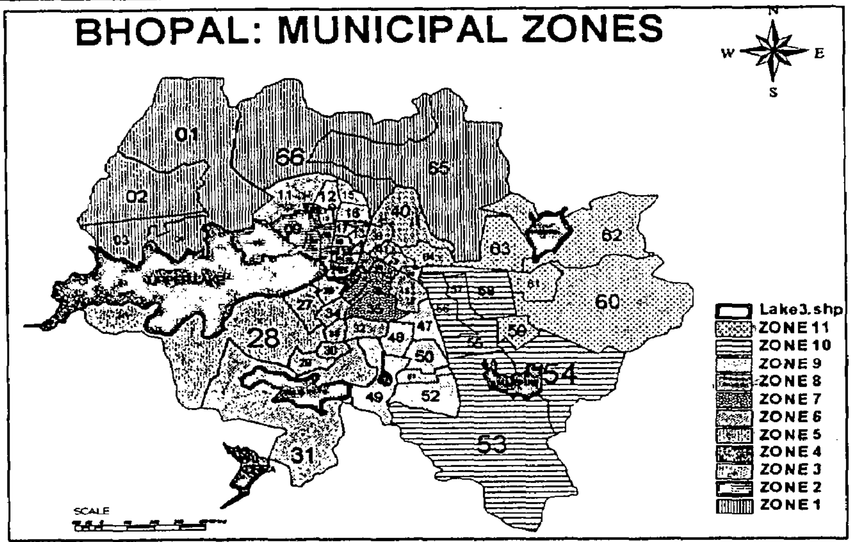


Chart 3.6 Bhopal decadal population growth trends.

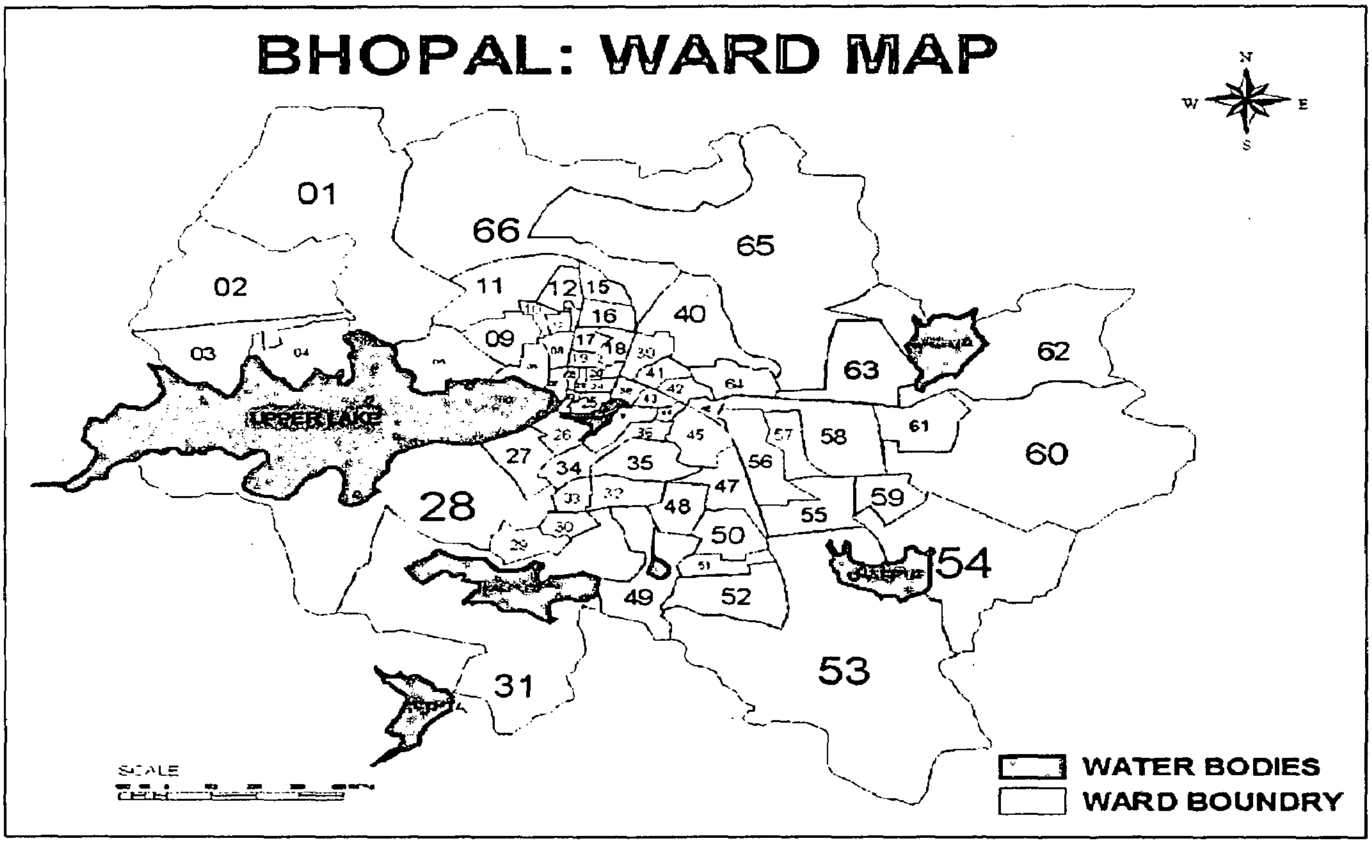
3.16 MUNICIPAL LIMIT OF BHOPAL: At present total area under Bhopal municipal limit is 285 Sq. Kms. Bhopal has been divided into 11 zones and each zones consist of 6 wards. The main objective of this division is to smoothen the service provide by municipality. There was 56 wards till 1983, which were later converted 66 wards. Each Zone having a zonal office of BMC.



Map 3.10 City map showing the 11 different zones of Bhopal.

Table 3.5 Distribution of ward in each Zone.

Zone	Ward Number	Zone	Ward Number	Zone	Ward Number
1	1, 2, 3, 4, 65, 66	5	23, 24, 25, 26, 27, 28	9	47, 48, 49, 50, 51, 52
2	5, 6, 7, 8, 9, 10,	6	29, 30, 31, 32, 33, 34	10	53, 54, 55, 56, 57, 58
3	11, 12, 13, 14, 15, 16	7	35, 36, 37, 38, 43, 44	11	59, 60, 61, 62, 63, 64
4	17, 18, 19, 20, 21, 22	8	39, 40, 41, 42, 45, 46		



Map 3.11 City map showing the total 66 different wards of Bhopal. (BMC)

Table 3.6 –Ward wise population of Bhopal

WARD WISE POPULATION OF BHOPAL 2001					
S.NO.	NAME OF WARD	POPULATION	S.NO.	NAME OF WARD	POPULATION
1	MAHATMA GANDHI	32459	34	JWAHAR LAL NEHRU	12352
2	C.T.O	17691	35	PADIT MADAN MOHAN MALVIYA	25519
3	HEMU KALANI	16519	36	RAVINDRANATH TAGORE	18496
4	SADHU WASWANI	24085	37	JAHANGIRA BAD	17195
5	KHO-E-FIZA	17127	38	BARKHDI MILL	16670
6	NOOR MAHAL	16125	39	CHAND BARH	17916
7	MALI PURA	13554	40	KAPRA MIL	25481
8	BAGH MUNSHI HUSSAIN	16747	41	BAGH UMRAO DULHA	29302
9	IDGAH HILLS	23326	42	AISH BAGH	35091
10	BABOO JAGJIWAN	15478	43	MAHARANI LAXMI BAI	14471
11	GUFA MANDIR	36466	44	JINSI	13601
12	GEETANJALI	20721	45	MAIDA MILL	17996
13	SHAHJAHAN BAD	20741	46	NETAJI SUBHASH CHNDRA	24810
14	CONGRES NEHRU	18928	47	MAHARANA PRATAP	15365
15	MOTILAL NEHRU	20979	48	RAVI SHANKAR	19859
16	J.P.NAGAR	13695	49	DR. RAJENDRA PRASAD	28692
17	IBRAHIM GANJ	22980	50	INDIRA GANDHI	24036
18	RAM MANDIR	12326	51	SHAH PURA	23621
19	MANGAL WARA	12116	52	ASHA NIKE	42035
20	LAL BAHADUR SHASTRI	12915	53	BARKATULLAH	33737
21	MAHAVEER WARD	12603	54	BARKHERA PATHANI	32608
22	JAIN MANDIR	10270	55	SAKET SHAKTI	14341
23	MOTI MASJID	17976	56	KASTURBA	18751
24	ISLAM PURA	12129	57	ANNA NAGAR	11821
25	BHOI PURA	16572	58	BARKHERA BHEL	13133
26	RANI KAMLA PATI	14433	59	GOVIND PURA	13935
27	VIVEKANAND	20065	60	PIPLANI	23424
28	AMBEDKAR	23395	61	GUATAM BUDH	12424
29	TULSI	25260	62	SONA GIRI	36779
30	PANCHSHEEL	15264	63	INDRA PURI	45235
31	MAULANA AZAD	35577	64	GRU NANAK	37621
32	SHIVAJI	17507	65	RAJEEV	35922
33	T.T.NAGAR STADIUM	11220	66	NABI BAGH	67866
TOTAL POPULATION					1,437,354

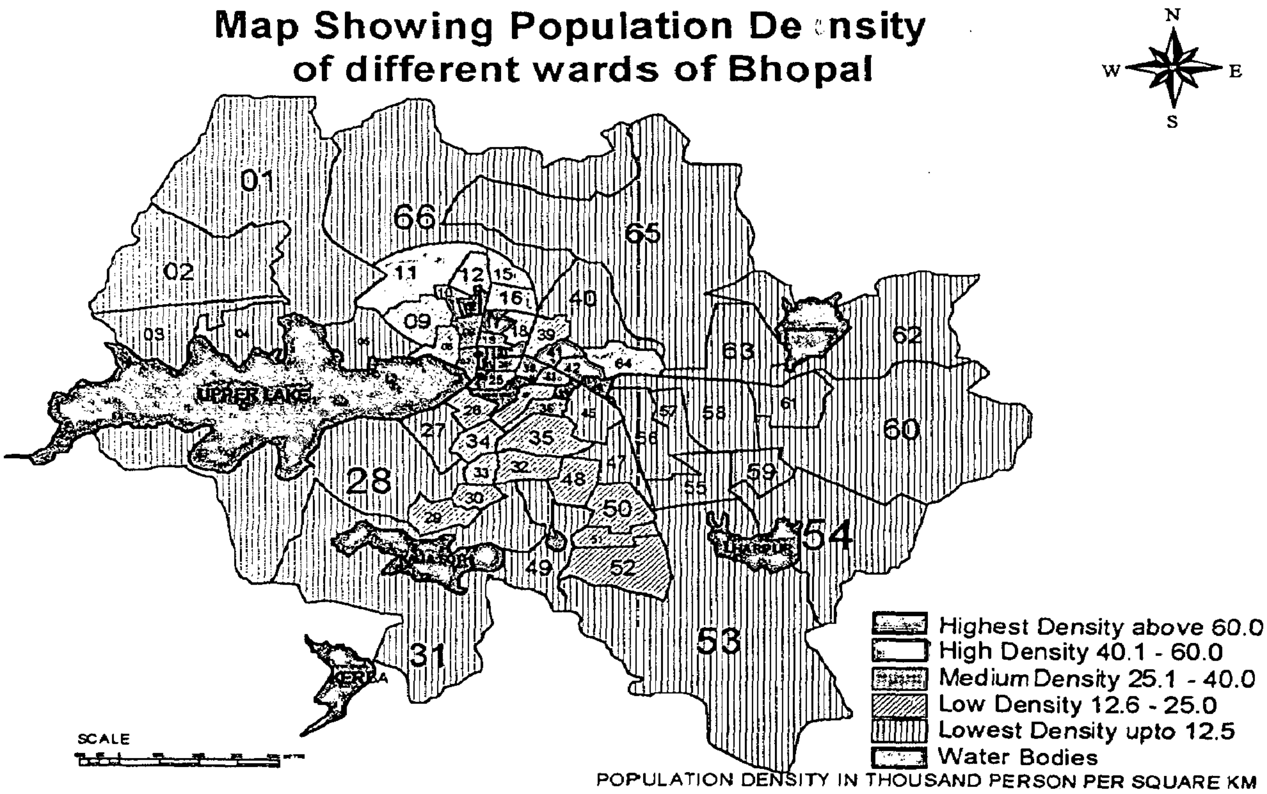
Source: Census of India 2001, Madhya Pradesh.

Table 3.7 Ward wise population density of Bhopal

WARD WISE POPULATION DENSITY OF BHOPAL 2001					
WARD No	DENSITY	WARD No	DENSITY	WARD No	DENSITY
1	1,668	23	99,370	45	10,340
2	1,734	24	44,218	46	65,914
3	3,916	25	42,460	47	8,223
4	8,170	26	14,045	48	13,109
5	6,094	27	11,184	49	7,027
6	17,722	28	1,355	50	13,067
7	38,277	29	21,569	51	22,221
8	32,921	30	21,596	52	12,807

WARD No	DENSITY	WARD No	DENSITY	WARD No	DENSITY
9	13,827	31	1,695	53	1,143
10	36,206	32	13,506	54	2,990
11	10,138	33	16,428	55	5,857
12	21,985	34	12,950	56	7,275
13	68,793	35	12,795	57	8,514
14	118,969	36	27,906	58	3,003
15	24,583	37	20,800	59	8,507
16	14,939	38	46,918	60	1,221
17	52,014	39	20,031	61	4,899
18	19,747	40	5,920	62	2,822
19	35,730	41	50,115	63	10,485
20	50,588	42	55,079	64	24,542
21	83,024	43	39,625	65	1,473
22	60,950	44	64,490	66	3,399

Source: Census of India 2001, Madhya Pradesh.



Map 3.12 City map showing population density of different wards of Bhopal. (BMC)

3.17. SOCIO-ECONOMIC PROFILE: The city is visualized by its planners to be a conglomerate of sub cities comprising of the following parts 1 Bairagah, 2 Old City, 3 New Bhopal comprising of New market, TT Nagar, Arera Colony areas And BHEL. One of the reasons for such subdivision is physical segregation and distances between the parts. Another reason is that these areas show a dominant and uniform social and economic character within their boundary and this character is different from that exhibited in other sub-cities.

Thus we observe that BHEL town ship though beautifully developed and better endowed with facilities than rest of the city served as socio-physical block to the growth in that direction. The capacity of a city to provide a variety of jobs and absorb its working population in various sectors of economy is an indicator of the economic viability of the city.

In 1961, the proportion of economically active population in Bhopal town was **36.5 percent.** This shows that dependant population did not migrate by 1961. By 1971, this proportion came down to 28 percent. Partly, due to the change in definition of workers in 1971 census. During the last two decades, there was considerable increase in the economic activities of the city. The fact that ratio of economically active population is more or less same as that of other cities of the state indicates that the city has absorbed the impact of urbanization. Future growth of Bhopal may now be anticipated as a result of natural growth of economic activity.

3.17.1 OCCUPATIONAL PATTERN:

The distribution of workers in three sectors reveals that according to census 1991 that

64 % of total workers are engaged in tertiary sector,

32.8 % in the secondary sector whereas only

3.2 % earn their livelihood from occupation in primary sector.

Table 3.8 Occupational pattern of Bhopal City

CATEGORY	1961	1971	1981	1991
A. PRIMARY SECTOR	3111	3563	11956	15476
a. Cultivate	851	1265	3873	4751
b. Agriculture	295	943	4616	4348
c. Mining, Quarrying and live-stocks	1965	1355	3467	6407
B. SECONDARY SECTOR	36201	36218	68706	93110
a. Household industry	3016	2542	9756	3217
b. Manufacturing	19392	28870	47211	56279
c. Construction	13793	4806	11739	33614
C. TERTIARY SECTOR	42989	70535	112357	197022
a. Trade and commerce	10955	16301	29572	619533
b. Transport & communication	6344	9256	16446	27133
c. Services	25690	44978	66339	107936

Source: Census of India 1991, Madhya Pradesh.

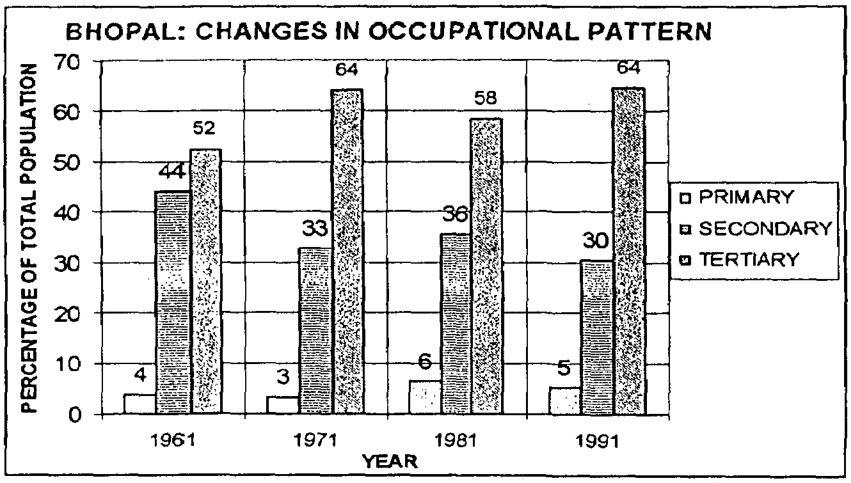


Chart 3.7 Changes in occupational pattern in Bhopal

The construction activity for the new capital was in full swing by 1961. Upon completion of these projects, the development work slowed down till 1971. The position was retrieved to near normal level by 1981 due to increased activity in the private sector. ·The number of employees in the manufacturing industries and services has been continuously, increasing at a rapid rate.

Government records show that in 1961 highest proportions (60%) of the workers were engaged in administrative, clerical and other government/private services and 13% were craftsman and related workers The rest were in trade and commerce.

It should be noted that this 60% population comprises almost entirely of government servants who were due for en-mass retirement every year from 1985 onwards.

Thus, around 1985 there was a sudden demand for dwelling units and plots as the government staff that had migrated from other areas started settling down. Those were the days when people started making there houses only after having completed the education of their children and resolving other family issues of marriages etc.

This unique thrust was in a way anticipated in the development plan of 75 -95.

The study of occupational patterns and population growth must be directly translated into land requirements (in terms of what type of land, for what use and how much), to make any sense in physical planning.

The basic relationship is simple. Greater the number of people, greater the land requirement. Thus, planners talk in terms of spread of a city, in hectares per 1000 persons.

At the time of plan preparation in 1971, the urban spread of Bhopal was at the rate of 7.18 Hectares per 1000 persons. As compared to Indore, which was only 4.29 Hectares per 1000 persons. The development plan went ahead and provided land at the rate of 10 Hectares /1000 persons.

However, in observation we see that population growth out stripped the estimates by more than 65000 persons, and land availability was hampered due to reasons discussed ahead.

The estimates of land requirements did not take into account the investment pressure from people living in neighboring towns and villagers desirous of creating a base for themselves in the capital city. Such people do not figure in the census surveys, as they are not residents of Bhopal.

Another problem not so obviously felt on land requirement is the problem of migrant labor moving into the town and increasing the density of existing slums or creating new slums.

All these inflow of population in Bhopal exerting extra pressure on the available infrastructure, especially which is limited e.g. water, so it will be needed to have some planning approach for sustainable water supply to cope with to increasing requirements.

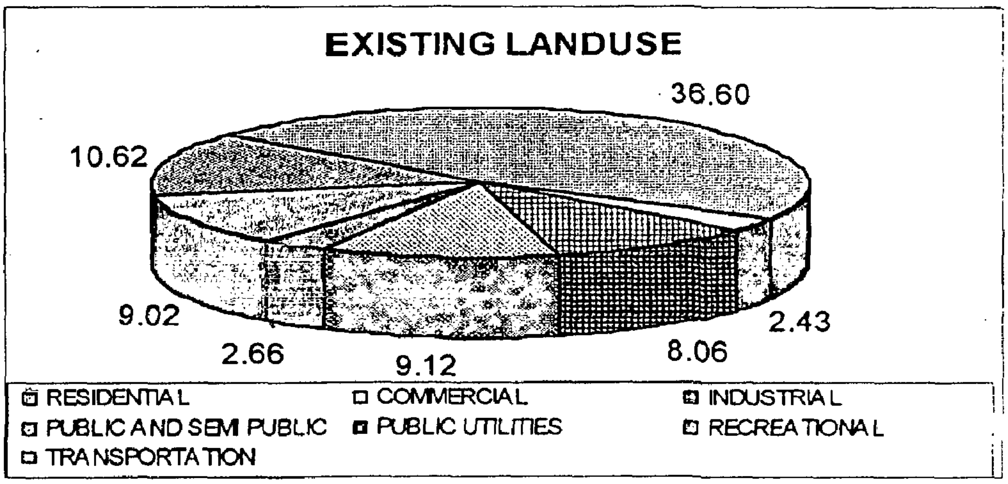
3.18 LANDUSE PATTERN:

Table 3.9 Land use allocation at city level.

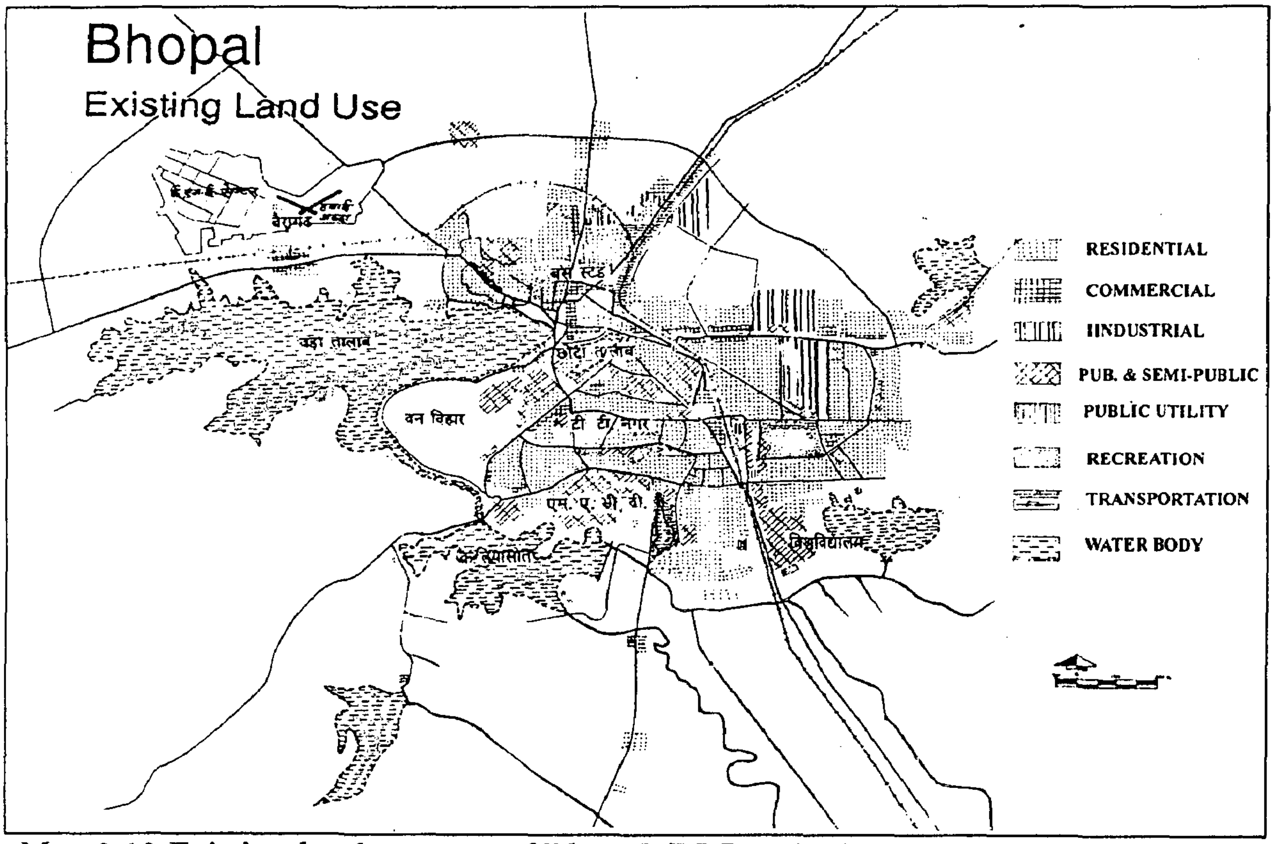
BHOPAL: LAND USE ALLOCATION AT CITY LEVEL					
S.NO	CATEGORY	EXISTING DEV. AREA IN SQKM	(%) 1994	PROPOSED DEV. 2005 AREA IN SQKM	(%) 2005
1	RESIDENTIAL	36.60	46.62	81.90	46.80
2	COMMERCIAL	2.43	3.10	6.50	3.71
3	INDUSTRIAL	8.06	10.27	13.89	7.94
4	PUBLIC AND SEMI PUBLIC	9.12	11.62	12.58	7.19
5	PUBLIC UTILITIES	2.66	3.39	4.88	2.79
6	RECREATIONAL	9.02	11.49	29.25	16.71
7	TRANSPORTATION	10.62	13.53	26.00	14.86
	Total	**78.51**	**100.00**	**175.00**	**100.00**

Source: BDP 2005.

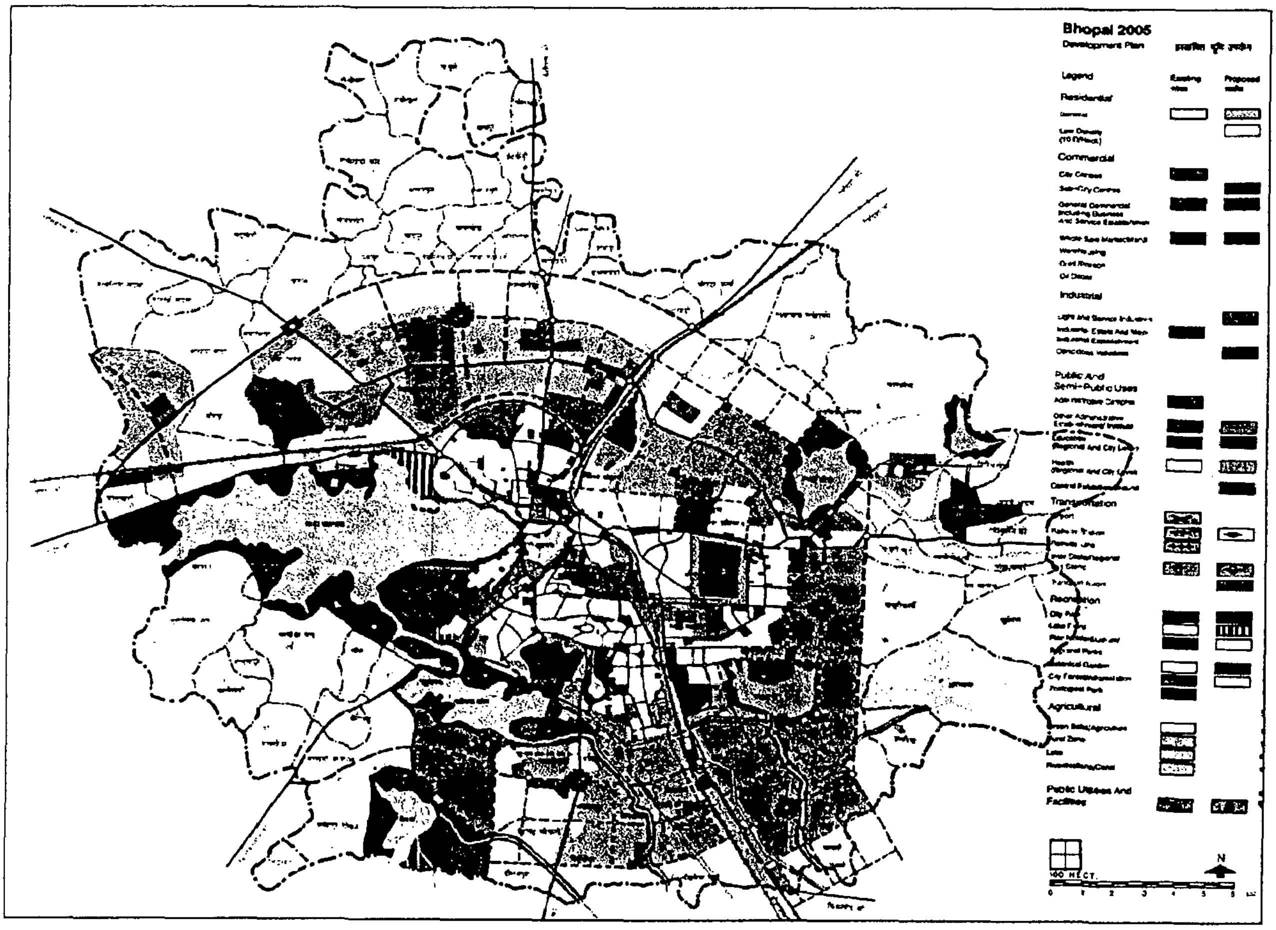
Chart 3.8 Existing landuse pattern in Bhopal upto year 1995



Source: BDP 2005.

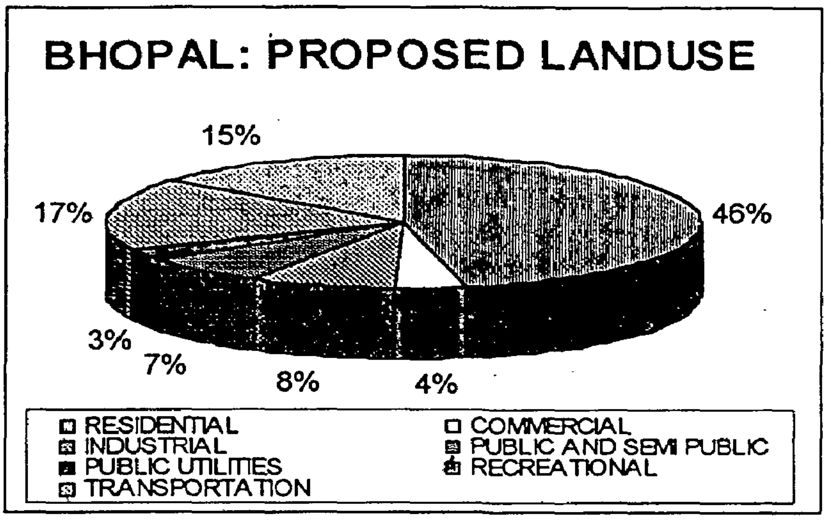


Map 3.13 Existing land use map of Bhopal (BDP - 2005)



Map 3.14 Proposed land use map of Bhopal (BDP - 2005)

Chart 3.9 Proposed land use pattern in Bhopal



3.19. POWER SUPPLY: Almost whole of the Bhopal is provided with Power supply whose are is 306 sqkms. Chambal sub-station receives the 220 KV supply and steps it down to 33 KV and supplies to 21 sub-station all around the city whose total capacity is 187.8 MVA. 224.59 Km run of 33 KV line, 54.5 km of 11 KV and 1844.5 km of LT line are running all along the city there are 107 HT consumers and 161686 LT consumers where the total number of occupied residential houses in Bhopal are 192726 and the difference of 31040 households connection is attributed to foul connection. Slums and Juggies are also connected in the single point connection under the scheme "Grihjyoti" at a nominal cost. *(Vandna Tiwari, 2001)*

(**Note:** *All the Maps of this chapter are supposed* ***NOT TO SCALE****, if scale is not mentioned.)*

*****

Scenario of Water Supply Of Bhopal

Topics covered in this chapter

- INTRODUCTION
- VARIOUS USES OF WATER
- WATER SUPPLY ZONES
- ISSUES RELATED TO WATER SUPPLY
- WATER SUPPLY DEPARTMENT, BMC
- WATER RESOURCES IN AND AROUND BHOPAL
- DEMAND & SUPPLY OF WATER
- GOVERNMENT INITIATIVE
- FINDING FROM STUDY OF 11 ZONES OF BHOPAL
- CONCLUSION

CHAPTER 4

4.1. INTRODUCTION: Quality of life in any urban area is very much conditioned by level of availability, accessibility and quality of physical and social infrastructure it can be provide and could be afforded by its inhabitants. The rapid population growth necessities augmentation of water along with new urban development extension. The various uses of water are:

4.2. VARIOUS USES OF WATER: The various uses of water in urban area are:

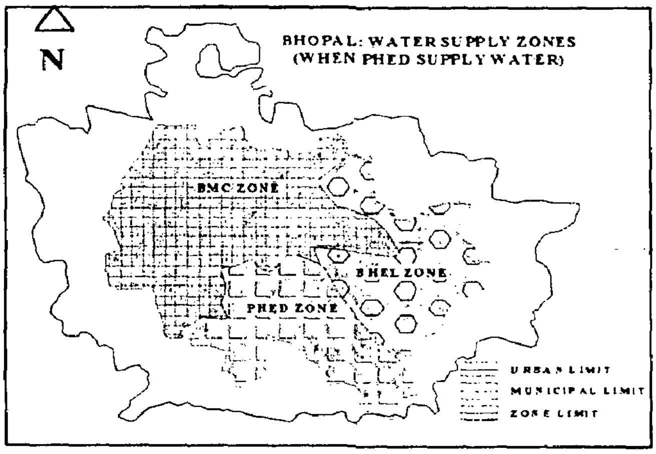
a) Domestic
b) Institutional
c) Public purposes
d) Fire fighting
e) Industrial and commercial
f) Others

4.3. WATER SUPPLY ZONES: Earlier Bhopal was divided into three zones based on the water supply agencies covering the areas. They are:

I. Bhopal Municipal Corporation (BMC) zone (Consisting of 37 wards)

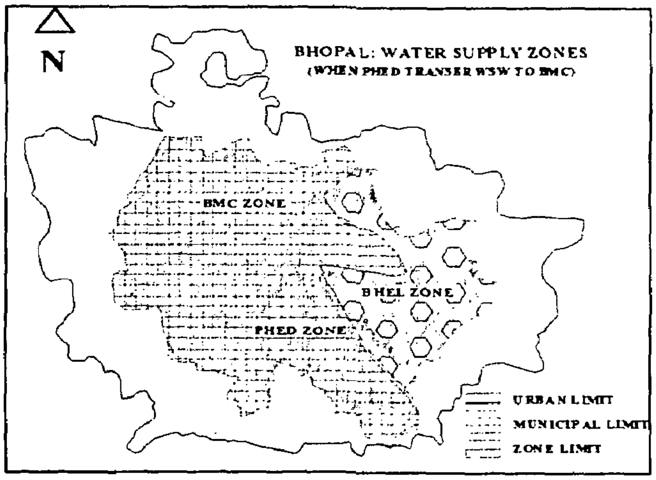
II. PHED zone (consisting of 13 wards

III. BHEL zone (consisting of 6 wards)



Map 4.1 Earlier water supply zones of Bhopal *(BDP - 2005)*

Establishments: such as Railways and MES, which supply water to their own establishments. After transfer of the water supply Department to BMC, there are only 2 supplying agencies remains. So we can divide Bhopal into 2 zones, BMC zone and BHEL zone.



Map 4.2 Map of present water supply zones of Bhopal *(BDP - 2005)*

Note: Earlier Bhopal was divided into 56 wards and above zoning is based on that basis. At present Bhopal has divided in 11 zones and each zones consist of 6 wards, so total 66 wards.

4.3.1 BMC WATER SUPPLY: BMC draws water from upper lake (6 Mgd); Kolar project (7.0 Mgd), Mini (2.5 Mgd). It has intake points at (1) Yatch club (2) Karbala (3)

Pulpukhta. Treatment plants are located at (1) Shyamla Hills (capacity 4.5 Mgd) (2) Idgah (3.0 Mgd) (3) Pulpukhta (2 Mgd).

BMC supplying water to 2,00,000 people free of cost through public tap.

4.3.2 PHED WATER SUPPLY: It draws water from Kolar project 5 to 15 Mgd. Its in-take points on upper lake are: Kamala park pump house, Yatch Club pump house. It has treatment plants at (1) Kamala Park (capacity 5.0 Mgd), this plant is used only when Kolar water is stopped, otherwise water form Kolar directly reaches here and gets diverted. (2) Shyamla Hills (2.0 Mgd). Presently Kolar water is directly reaching here too. (3) Treatment plant for BHEL (8.0 Mgd). (4) Hamidia Hospital treatment plant (0.5 Mgd).

(Note: Water supply work of PHED is now transferred into BMC, but every thing remains the same only ownership status has changed. Now PHED only responsible for feeding water to Bhopal from Kolar.)

4.3.3 BHEL SUPPLY: It draws water from upper lake during normal period and from Kolar (6.0 Mgd) during scarcity period. Pumping and filtering is done by BMC while supply is done by BHEL. The comparatively higher intake, as compared city area is due to industrial use (The area includes Govindpura industrial area apart from BHEL itself).

Earlier there were three agencies in Bhopal, involved in water supply work independently. But at present the whole water supply (feeding and distribution) has been carrying by Water supply Department under BMC. BHEL take care of only their industrial area, excluding Govindpura, which was earlier supplied by it. PHED now its only takes care of the sewerage disposal system, quality control measure of water supply and feeding OHTs, sumpwells and treatment plants from Kolar project.

4.4. ISSUES RELATED TO WATER SUPPLY:

4.4.1 AREA GROSSLY AFFECTED BY WATER SHORTAGE:

OLD CITY: Shahjahanabad, Kazi Camp, Karond Square, Lakherapura.

NEW CITY: Lajpat nagar, Trilanga, Gulmohor Colony, Alka puri, Indrapuri.

Problems - a. Low to very low pressures and little duration.

b. Duration of supply is very little with tolerable pressure.

c. Longer with almost no pressure.

d. Hence consumers dig pits for increase of some slight pressure & install booster pumps (tullu pump) -creating further loss of meager available pressure to others.

This creates a situation of unequal distribution of available quantity.

4.4.2 DURATION & TIMING OF SUPPLY: Duration of water supply is 3/4 to 1.5 hr in the most of the area of Bhopal. In many areas there is no fixed time of supply e.g. Indrapuri, old city Even the supply is at odd hours e.g. 4.0 am. The consumers have to keep constant watch and have to keep awake at odd hours in all sorts of weather.

REASONS

- Inadequate distribution system
- Grossly under capacity service storage to meet the peaks.
- A common practice nowadays is to provide a Sump of larger capacity and an elevated storage of smaller capacity with pumps on the sump for filling the ESR. Since the ESRs are comparatively expensive. However due to the erratic power supply conditions the pumping arrangement fails to meet the peaks resulting in the drawbacks stated earlier.
- Grossly under size and inappropriate, old distribution pipe lines e.g. 2", 3", 4" dia G.I. pipes-rusted –leaking resulting in wastage and pollution,
- Very Poor O & M of the system -almost No Preventive maintenance by unqualified and incompetent staff.

4.4.3 DISTRIBUTION PLANNING FOR NEW DEVELOPMENTS: At present it is done by a number of agencies e.g. Housing Board, BDA, Private builders etc.

Problems -

- Faulty Design, execution and O&M of comparatively new distribution systems (including service storages) by the above agencies.
- Quantity and quality of the source not ensured before implementation resulting in scarcity conditions almost perpetually, besides pollution of supply.
- Such grossly inappropriate and inadequate systems are then handed over to the BMC for O&M.

4.4.4 FERRULES: All consumer connections have to be through a ferrule i.e. a control mechanism on the distribution line. At present about 75% of the connections are without ferrule and are direct -1/2", ¾", 1" and more Size.

4.4.5 SLUMS: 216 slums and squatter settlements are receiving free water supply. At present about 7500 public standposts (without ferrule connections) are provided to serve the Slums. These are mostly without taps. As a result there is considerable Wastage and Pollution.

4.4.6 LEAKAGES: Mostly from old distribution pipes (old city area, 100 years old distribution system), joints, and valves and also from pumping mains causing wastage and pollution. 30 percent of total supplied water loosed due to leakages. (Source BMC)

4.4.7 POLLUTION:

- At the source Upper lake mostly bacteriological-due to city drainage.
- In tube wells and bawdis due to faulty construction poor 0 & M and proximity to drains, dumps ,polluted nallas polluting ground water.
- In the defective distribution lines and service lines of the consumers-through public drains in the old city. During off supply hours polluted liquid enters the empty pipes and is carried to the taps of consumers. Pollution from the city's main sources is expected to be mitigated in the treatment plants of water works of each main source. Due to Poor 0 & M ,no preventive maintenance and due to financial constraints some times the appropriate equipment initially provided becomes defective resulting in improvised methods e.g. bleaching powder in place of gas chlorine etc.

4.4.8 O & M OF THE ABOVE ORGANISATION SYSTEMS: Since 0 & M of such systems is of paramount importance it is imperative that a competent organization is entrusted with this work. Unfortunately the present set up is lacking in appropriate and adequate staff, finances and decentralized powers(in the BMC). Hence the present system needs reframing/reorganization with support of adequate finances after study in depth by a competent agency.

4.4.9 TARIFFS: At present there is no co-relation between consumption and billing, as the billing is on the basis of flat rates/per connection. the sufferer is the consumer barring a few lucky ones. This encourages massive wastage. The tariff is also high.

Table 4.1 Water tariffs

Water Tax For-Public Sector	Domestic Purpose	Non Domestic Purpose
1/2" Water Connection	150 /-	500 /-
3/4" Water Connection	300 /-	1000 /-
1" Water Connection	600 /-	1500 /-
Raw Water Rates For Following Supplies :-		
BHEL	Re 1.25 /-	per 1000 Ltr.
Railway	Re 1.25 /-	per 1000 Ltr.
Military	Re 1.25 /-	per 1000 Ltr.

Table 4.2 Some other rates

Type	1/2"	3/4"	1"	1-1/2"	2"
Other Then Residential	500/-	1000/-	1500/-	1500/-	1500/-
Industrial	600/-	1000/-	1500/-	1500/-	1500/-
New Connection Deposit	3000/-	5000/-	12000/-	25000/-	50000/-
New Connection Deposit for Ews/Slumes/Janta Qtrs.	1500/-	1500/-	1500/-	1500/-	1500/-
Application Fees	20/-	20/-	20/-	20/-	20/-
Connection Charges	300/-	300/-	400/-	1500/-	2000/-

Source: Water supply Deptt. BMC

4.4.10 NEW PROJECT: A new water supply project for augmentation is under consideration now. It is suggested that all the options/alternatives must be studied in depth particularly its tariff (which effects the consumer directly) before any project is finalized. For example, Augmentation of Kolar Project, Augmentation of Bairagarh Project, Water Supply in affected area of Gas Tragedy, Narmada Project etc.

4.4.11 NUMBER OF CONNECTIONS GIVEN BY BMC: At present total number connection given by BMC is 1,35, 570. Their details are given in table 4.3.

Table 4.3 Details of connections given by BMC.

S.No	Types	Number
1.	Domestic connection (Old Bhopal)	82,000
2.	Domestic connection (New Bhopal)	42,000
3.	Stand Post	3,570
4.	Religious Places (Free service)	3,500
5.	Non Domestic(office, hospital, factory)	4,500
Total		**1,35,570**

Source: Water supply Deptt. BMC

4.5. WATER SUPPLY DEPARTMENT, BHOPAL MUNICIPAL CORPORATION: Earlier water supply work was done by three agencies BMC, PHED and BHEL. After 73rd constitutional amendment to empower UBL's the whole water supply work has been done bye "Water Work Department" under the umbrella of BMC.

4.5.1 REVENUE – EXPENDITURE PATTERN: WATER SUPPLY DEPARTMENT - BMC:

REVENUE GENERATED:

Table 4.4 Details of revenue collected by BMC from PHED supply network.

S.No	Charges	Amount
1.	Water Charge	4.5 crore
2.	Water Tax	1.81 crore
3.	Miscellaneous	0.25 crore
Total		**6.56 crore**

EXPENDITURE:

Table 4.5 Details of expenditures to established water supply department and merging sections of PHED related to water supply in new city.

S.No	Particulars	Amount
1.	Establishment cost	
	I. BMC	750 crore
	II. PHED	240 crore
2	Simple Repairing	169 crore
3	Chemicals	100 crore
4	New Pipe lines, pumps, hand pumps	325 crore
5	Electricity Bill	800 crore
6	Tax payment	365 crore
Total		**2747 crore**

Source: Water supply Deptt. BMC, 1999-2000

Above data's gives the clear picture of losses bear by BMC due acquisition of water supply network, and related infrastructure (e.g. plants, manpower, equipments etc.) from PHED. BMC had expend 2507 crores Rs. And in return he gets only Rs. 6. 56 crores as a revenue through water supplied area covered by PHED.

4.5.2 ANNUAL REVENUE – EXPENDITURE PATTERN, WATER SUPPLY DEPARTMENT– BMC, 2002 – 2003:

A. REVENUE:

Table 4.6 Details of the water tax collected by water work deptt.

S.No	*Charges*	*Amount (Rs.)*
1.	**Water Tax**	**14,59,87,025**
2.	**Details of Water Tax**	
3.	**Water tax**	**13,03,18,455**
	Water tax	*13,03,18,455*
	Total 3. Water tax	**13,03,18,455**
4.	**Supplying agencies**	
	a. BHEL	*91,90,628*
	b. Indian Railway	*15,00,000*
	c. MES	*35,73,880*
	Total 4. Supplying agencies	**1,42,64,508**
5.	**Miscellaneous Charges**	
	a. Meter connection & Road cutting	14,04,062
	Total 5. Miscellaneous Charges	**14,04,062**
6.	**Total**	**14,59,87,025**

B. EXPENDITURE:

Table 4.7 Details of expenditures by water work deptt during year 2002-2003

S.No	*Charges*	*Amount (Rs.)*
1.	**Total expenditure**	**29,36,64,666**
2.	**Details Expenditure**	
3.	*Salary*	*1,99,44,172*
	Total 3. Salary	**1,99,44,172**
4.	**Maintenance**	
	a. Annual repairing of filtrations plants	14,16,7000
	b. Repairing of buildings & plants	*4,23,363*
	c. Repairing of pump	*14,15,572*
	d. Repairing of water supply networks	*13,08,346*
	Total 4. Maintenance	**46,02,981**
5.	**New Project**	
	a. RWH	*41,700*
	b. Water supply under Govt. grant	*2,91,58,623*
	c. Construction of Tanks	*20,41,874*
	d. Water supply through tank	*24,87,480*

	e. Construction of sump tank in MP Nagar	*3,37,540*
	Total 5 New Project	**3,40,67,217**
6.	**Miscellaneous**	
	a. Temporary workers	*58,74,631*
	b. Electricity bill	*4,05,41,559*
	Total 6. Miscellaneous	**Miscellaneous**
7.	**PHED**	
	a. Electricity	*15,74,33,127*
	b. Chemicals & purchasing of chlorinator	*1,24,71,494*
	c. Kolar augmentation	*1,09,62,884*
	d. T.T.Nagar project	*49,61,481*
	e. Sant Haridas Nagar project	*9,15,546*
	f. Hamidiya Hospital project	*1,15,339*
	g. BHEL project	*7,03,847*
	h. Filter media kolar project	*3,61,427*
	i. Miscellaneous	*6,72,961*
	Total 7. PHED	**18,86,34,106**
	Total Expenditure	**29,36,64,666**

Source: Budget 2004-2005, BMC

Revenue	Expenditure	Loss	% Loss
14,59,87,025 Rs.	**29,36,64,666 Rs.**	**14,76,77,641**	**50.29%**

Above data gives the clear picture of losses bear by BMC due to water supply in the city. Total revenue collected (**14,59,87,025** Rs in 2002-03) from water charges are even not enough to pay the electricity bill {**19,79,74,686** Rs in 2002-02 *(4,05,41,559Rs. WSD + 15,74,33,127 PHED)*}, which is consumed only to run the pumps water for feeding OHT and distribution.

4.5.3 DEVICES FOR WATER SUPPLY, PURIFICATION AND ITS DISTRIBUTION:

Table 4.8 Details of devices used for water supply, purification and its distributions by BMC.

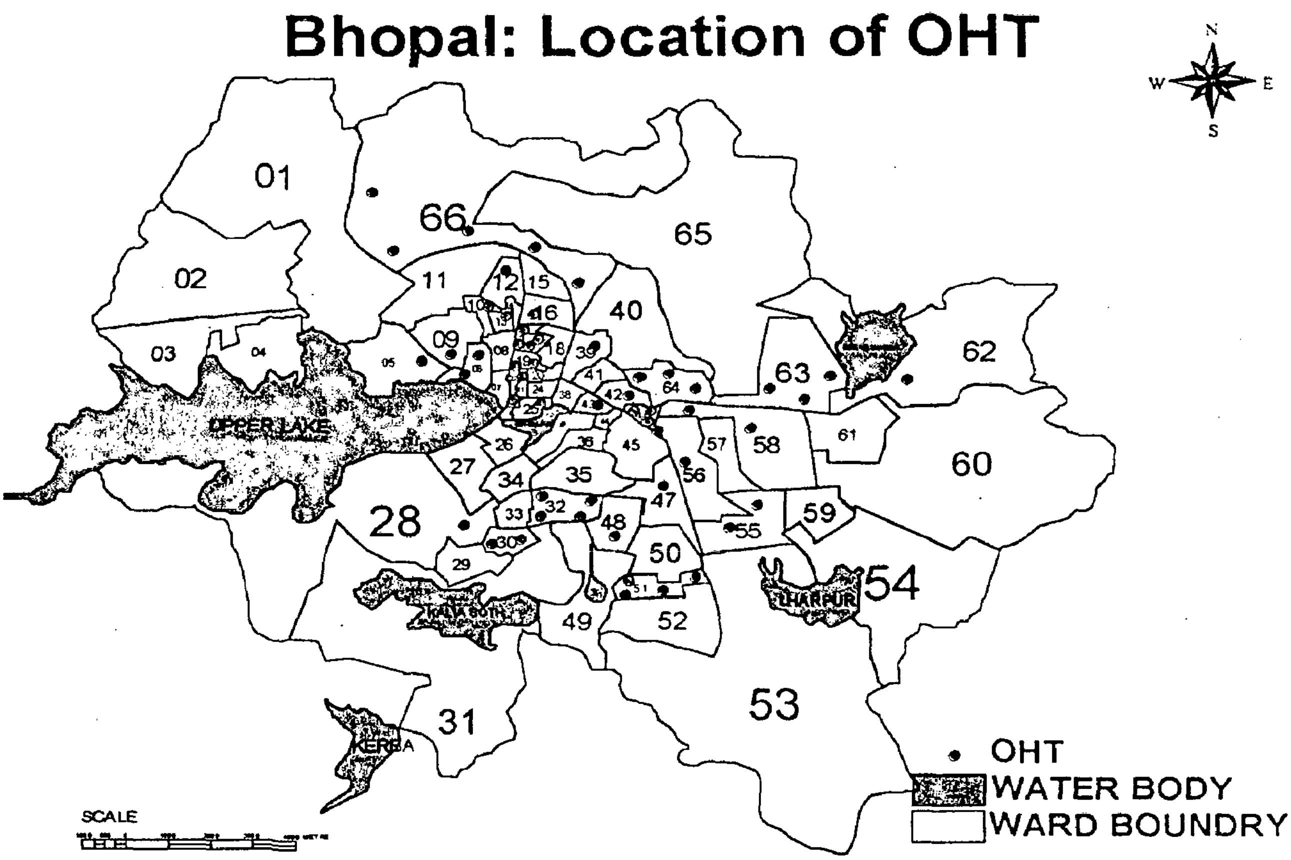
S.No	Device	Numbers
1.	OHT	54
2.	Sump well	73
3.	Well and Babdi	44
4.	Water Treatment Plants	11
5.	Bore Well with Power Pump	575
6.	Hand Pump (In Working condition)	1096
7.	Mobile Tanker	33
8.	Standing Trolley	38

Source: Water supply Deptt. BMC, 1999-2000

Table 4.9 Details of ward wise distribution of handpumps and their existing condition.

Zone	Wards	Handpump				Population	WHP* per 10,000 person
		Total	Working	Not working but repairable	Not working & not repairable		
1	1,2,3,4,65,66	176	158	6	12	194,542	8
2	5,6,7,8,9,10	72	70	1	1	102,357	7
3	11,12,13,14,15,16	107	105	2	0	131,530	8
4	17,18,19,20,21,22	145	139	0	6	83,210	17
5	23,24,25,26,27,28	89	86	0	3	104,570	8
6	29,30,31,32,33,34	121	108	13	0	117,180	9
7	35,36,37,38,43,44	71	71	0	0	105,952	7
8	39,40,41,42,45,46	69	65	4	0	150,596	4
9	47,48,49,50,51,52	128	103	19	6	153,608	7
10	53,54,55,56,57,58	148	110	32	6	124,391	9
11	59,60,61,62,63,64	109	81	18	10	169,418	5
Total	**66 Wards**	**1235**	**1096**	**95**	**44**	**1,437,354**	

*WHP- Working Hand pumps



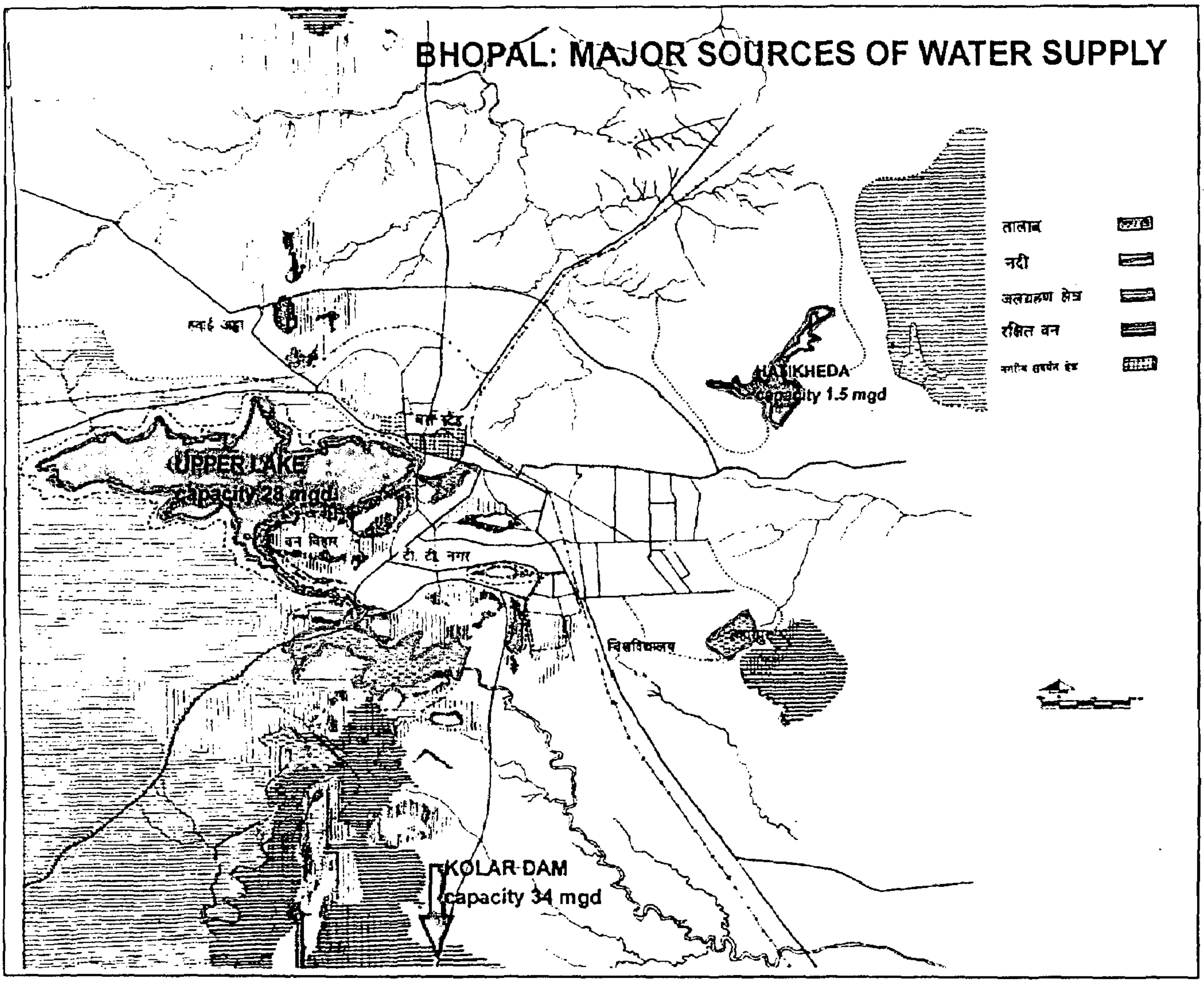
Map 4.3 Location of OHT's in Bhopal

4.6. WATER RESOURCES IN AND AROUND BHOPAL:

4.6.1 UPPER LAKE: It is the major source of water supply in the city with capacity of 28 mgd. If normal rainfall occure.

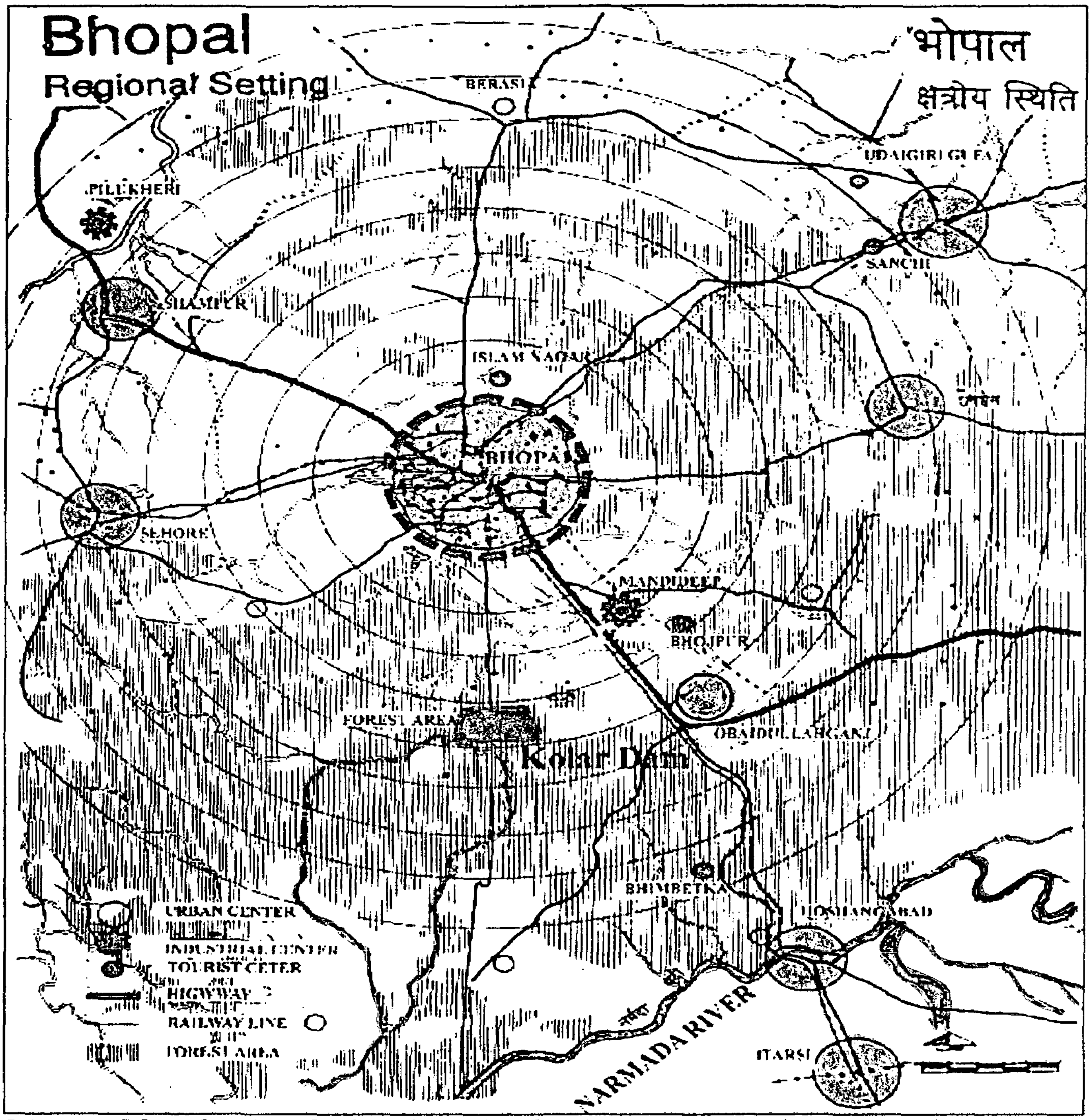
4.6.2 HATAIKHEDA: It is a mini source of water with capacity of 1.5 mgd, again the same condition if normal rainfall occurs.

4.6.3 UNDERGROUND TUBE WELL AND OTHER SOURCES: Their combined capacity is 5.0 mgd but this could reduce to 2.5 in summer.



Map 4.4 Major water sources of Bhopal, Kolar falling outside the boundry of the above therefore not show only its direction& capacity are shown. *(BDP - 2005)*

4.6.4 KOLAR: Kolar dam is located at a distance of 35 Kms from Bhopal. It has a treatment plant near by it at Jhuri Hills. From there water flows down under gravity to various reservoirs and tanks at different locations. It can supply to 34 Mgd. when installed fully. But at present its capacity has 21 mgd. It is constructed in 1985 funded by World Bank for the Irrigation purpose. But due to rapid urbanisation in Bhopal the water potential available in city are insufficient to cater the requirements. So 25% of its water is diverted to Bhopal for drinking water supply.



*Map 4.5 Map showing the location of **Kolar** (major source of water supply in Bhopal city 34 mgd) and **Narmada*** *(BDP - 2005)*

4.6.5 NARMADA: Narmada River one of the most holly river of Hindus has flowing from Hosangabad 90 km away from Bhopal. It capacity is sufficient to meet the need of Bhopal in all season, as it is a perennial river. Estimated capacity 121 mgd. But it is too far from Bhopal and there is a level difference of 200 m between Hosangabad and Bhopal, so it will be very expensive to bring its water to thirsty people of Bhopal.

4.7. DEMAND & SUPPLY OF WATER:

4.7.1. DEMAND OF WATER: According to 2001 data the total water requirements of the city is 57.03 mgd. According to population projection made in chapter 3 the future water requirements envisaged are given in the table below.

Table 4.10 Demand of water in Bhopal

YEAR	POPULATION	DEMAND @180 lpcd	DEMAND @250 lpcd
2001	14,37,354	57.03 mgd (6.19*)(10.57**)	79.22 mgd (32.47*)(35.62**)
2011 (proj.)	18,11,046	71.87 mgd (25.56*)(29.04**)	99,86 mgd (46.40*)(48.90**)
2021 (proj.)	21,84,738	86.7 mgd (38.29*)(41.18**)	120.41 mgd (55.59*)(57.64**)
Note: According to WHO norms water supply in a city is 250 liters per capita			

** figure in first bracket represent percentage inadequacy of water supply during normal period*

** figure in second bracket represent percentage inadequacy of water supply during scarcity period.

4.7.2 WITHDRAWAL OF WATER:

Table 4.11 Total water generation

S.No	Source	Capacity (mgd) (Existing***)	Capacity (mgd) (supply)	Remark
1.	Upper lake	28	26	Major source
2.	Kolar Dam	34*	21	Largest source, 35 km away from main city.
3.	Hataikheda	1.5	1.5	Mini Source
4.	G. W & others	5**	5	Smaller sources
5.	Total	68.5	53.5 (51.0 mgd during scarcity)	

** But presently supply 21 mgd. ** 2.5 mgd during scarcity period.*

**** the existing yield capacity of above reservoirs and lake are only true if normal rainfall takes place other wise it goes down drastically.*

4.7.3 DISTRIBUTION OF WATER: Bulk supply of raw water to institutions:

1. BHEL(for industry and residential)	(-) 6.0 MGD
2. MES	(-) 1.0 MGD
3. RLY	(-) 0.5 MGD
4. HOSPITAL (HAMIDIA)	(-) 0.5 MGD
TOTAL	**8.0 MGD**

BALANCE TO OLD AND NEW CITY=(53.5 – 2) = 51.5 MGD

INADEQUACY (NORMAL PERIOD) : 3.53MGD (6.19%)

INADEQUACY (SCARCITY PERIOD) : 6.03 MGD(10.57%)

Table 4.12 Shortages in water supply when leakages are not considered.

Year	Demand	Inadequacy (mgd)		% Inadequacy	
		NP	SP	NP	SP
2001	57.03	3.53	6.03	6.19	10.57
2011	71.87	18.37	20.87	25.56	29.04
2021	86.7	33.2	35.7	38.29	41.18
NP – During Normal Period, SP – During Scarcity Period					

The above analyses are based upon the raw data from reliable secondary sources. They only give the gap between demand and supply at the point of source and distribution. They don't consider losses of water due to O&M and leakages. Therefore the result came out is something different from the ground reality. If we consider the losses due to leakages then above results become some thing different as given in Table 4.13 next page. Now be can see the severity of water supply problem in Bhopal where people

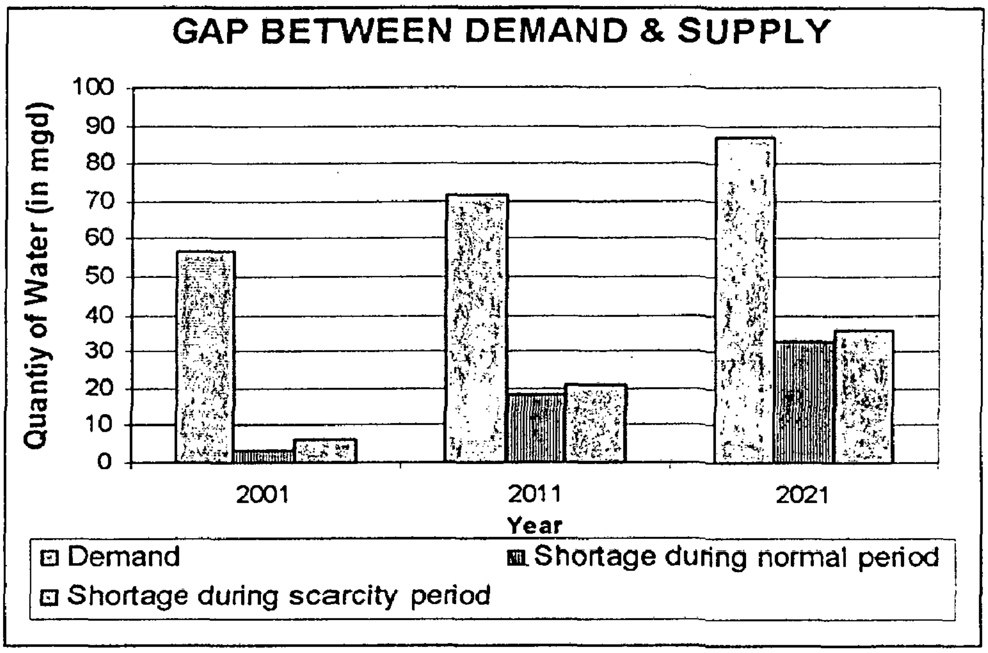


Chart 4.1 Gap between demands and supply for year 2001 and anticipated gap for year 2011 & 2021 when leakages are not considered

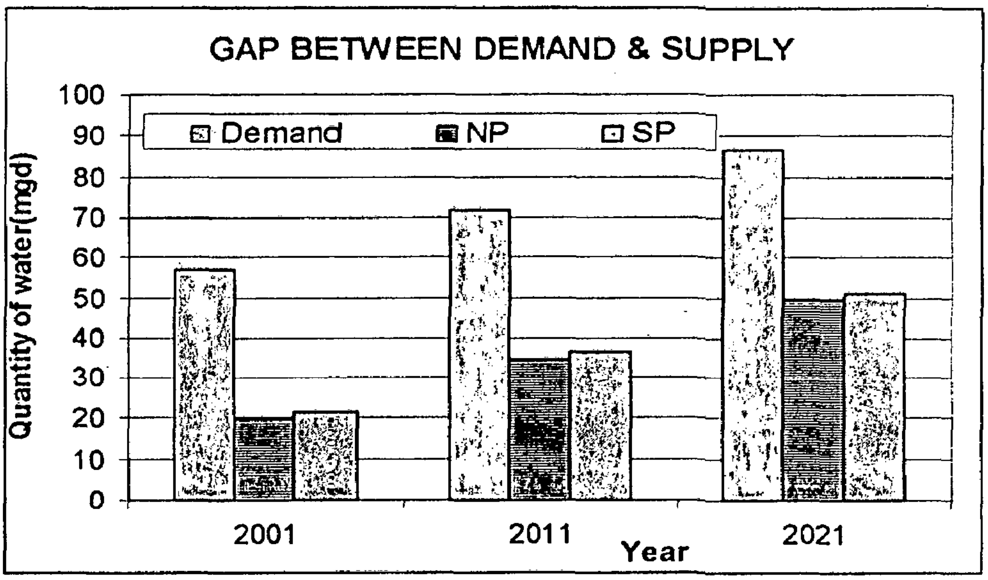


Chart 4.2 Gap between demands and supply for year 2001 and anticipated gap for year 2011 & 2021 when leakages are considered

receive 34.3% less water than that claimed by BMC, during normal period, and during scarcity period they got 39.9% less water.

Table 4.13 Shortages in water supply when leakages are considered.

Year	Demand	Supply (mgd)		Loss due to leakage (mgd)		Net supply (mgd)		Shortage (mgd)		% Shortage	
		NP	SP	NP	SP	NP	SP	NP	SP	NP	SP
2001	57.03	53.5	51	16.1	15.3	37.5	35.7	19.6	21.3	34.3	39.9
2011	71.87	53.5	51	16.1	15.3	37.5	35.7	34.4	36.2	47.9	67.6
2021	86.7	53.5	51	16.1	15.3	37.5	35.7	49.3	51	56.8	95.3
NP – During Normal Period, SP – During Scarcity Period											

The above Data revels that availability of water shall be critical factor for future growth of the Bhopal. As per the water resource potential in and around Bhopal, the urban area may not be able to support population beyond **20 lakh**. In view of this, it would be necessary to explore, new sources to meet the city growth beyond **22 lakh** *(Estimated population for 2021)* or so.

4.8 GOVERNMENT INITIATIVE: Government of MP gave due attention to meet the growing demands of Bhopal for its sustainability. Following are the some of the new project/proposal to towards conservation of water bodies and capacity augmentations of water supply of Bhopal.

- Augmentation of Kolar Project.
- Augmentation of Bairagarh Project
- Water Supply in affected are of Gas Tragedy
- Asian Development Bank Project
- Narmada Project.
- Bhoj Wetland Project

4.8.1 AUGMENTATION OF KOLAR PROJECT: This project in yet to start, because part of the project are within the reserve forest and forest sanctuary, so the matter has been pending and waiting for green single from Supreme Court. Project has designed to meet the water supply requirement for year 2033 when projected population became 39,20,000 with the designed capacity of 88.62 mgd. The total project cost Rs. 8852 crores.

No doubt it will meet the requirements of the city but there is a question mark, is it cope with the sustainable development of Bhopal. We already were utilizing approximately 40% of water, which is made exclusively for irrigation. If we further extract more than this then what will be the fate of farmer's involved agricultures, is it justified?

4.8.2 AUGMENTATION OF BAIRAGARH PROJECT: M/s S. K. Banergee of Nagpur executing this project. It only related to filtration plant and distribution of water in and around the Bairagarh area of Bhopal. Total project cost 11.50 crores financed by HUDCO. The project in on going.

4.8.3 WATER SUPPLY IN AFFECTED AREA OF GAS TRAGEDY: Water supply and distribution system of 10 wards under this area are completed by government with total project cost of 3.00 crors. Main work done under this project are construction of OHTs and filtrations Plants. The project is completed.

4.8.4 ASIAN DEVELOPMENT BANK PROJECT: Work under this project includes expansion of distribution pipelines, replacement of damaged and old pipes, development of sewerage system and improvement in distribution system. The project is yet to be start.

4.8.5 NARMADA PROJECT: Bringing Narmada for the People of Bhopal to meet their requirements is still not looking viable. It is a multicore project. One of the estimate made by PHED that only pumping water from Narmada to Bhopal and its operation and maintenance cost reaches upto 900 crores per year. Which ultimately put on the put on the inhabitants of Bhopal. At present they are still paying good amount for drinking water when we compare with other capital city of India. This project is also related to some political stunt, and playing emotion of the devotees of Narmada holly river. The project in the nascent stage.

4.8.6 BHOJ WETLAND PROJECT: The project is envisaged to execute sewage disposal scheme of Bhopal for specific area of Old city. The Bhoj wet land Project is a project to conserve and manage the lakes of Bhopal. Areas, which are polluting the lakes by one reason or the other, are to be tackled. By way of executing this proposed project work of "Bhopal sewage disposal scheme" it is proposed to divert all non point polluting sources and nala letting in all major pollutions in from the shoreline habitation thickly & densely populated areas of Old Bhopal.

Proposed scheme consist of giving sewer network facilities to all old Bhopal City, especially to the area in the catchments of Upper lakes. Estimated project cost 5896.60 lakh. This project on the verge on completion.

4.9. FINDING FROM STUDY OF 11 ZONES OF BHOPAL: From the through study of all zone of Bhopal we get the following data listed in the table below, when I plot these data on bar chart, give some interesting out put which are listed on next page.

Table 4.14 Zone wise information of Bhopal within municipal limit.

Zone	Population	Area	Density	HP* Working	House holds	Total Female population	Literate female	Total no of OHT
1	194542	81.19	2396	158	35918	90684	50429	6
2	102357	6.70	15282	70	18545	49227	31663	4
3	131530	6.77	19428	105	22976	62498	35354	7
4	83210	1.98	42010	139	14157	39778	26546	4
5	104570	20.94	4995	86	19370	49673	32663	2
6	117180	25.80	4543	108	24397	55987	38989	6
7	105952	4.42	23997	71	20293	49731	29071	1
8	150596	8.54	17640	65	28294	71199	42827	6
9	153608	13.65	11252	103	33714	72973	48903	5
10	124391	51.20	2429	110	26160	58512	36485	6
11	169418	42.24	4011	81	34663	79684	51789	7
Total	**1437354**	**263.42**		**1096**	**278487**	**679946**	**424719**	**54**

*HP- Handpump

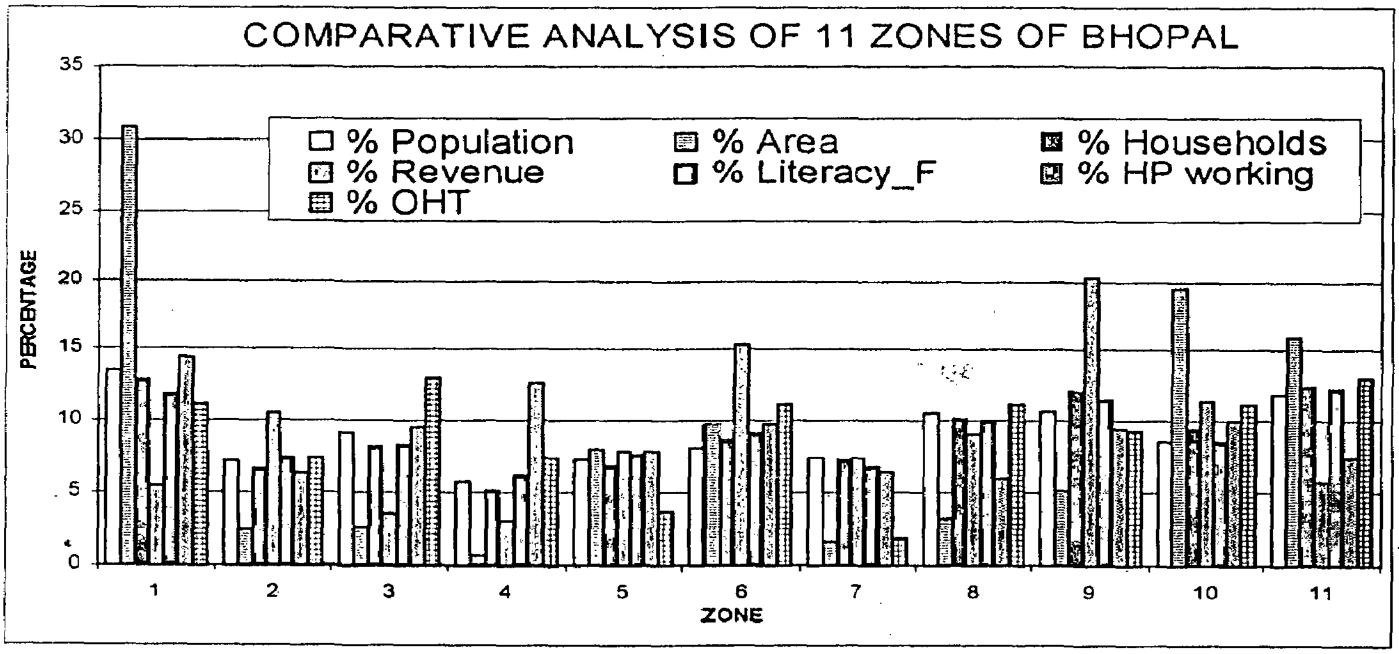


Chart 4.3 Comparative analysis of 11 zone of ward.

- Zone contributing higher percentage of total revenue (water tax) are availing good water supply service. e.g. Zone 9 where percentage of revenue collected is too high when compared with the percentage population of that zone. Zone 4 produces very less revenue with respect to population share of that zone, so suffering from water shortage. So there should be realistic price policy, at least on the basis of "no loss no profit" principle.
- Density also plays a major role on water supply facility. Zone 4 & 7 having high density seriously affected by water shortage.
- Max number of Handpumps are located in only those area where acute water shortages (eg zone 4.) or where distribution system is yet to cover the hole zone (eg. Zone 1).
- Number of OHT's are also affect the water supply of that zone, where there are in least in number with comparison to population suffering from acute water shortages(eg. Zone 4).
- Size of households also affects the water supply. Larger the household size more the consumption, which results in water scarcity. In Zone 9 & 10 where the size of households are smaller than that of zone 3 & 4, so former experience less water shortages that later.

4.10 CONCLUSION: There is no water supply problem in the southern part, but the north part suffers from lack of water and distribution facilities. The southern part receives about 50% more water as compared to the rest of the town. Reason Kolar systems water has not reached to old and water supply is based on underground source with in insufficient capacity, whereas Kolar System does part water supply southern part.

As against 100% tap water connections in the southern part, only 67% of the North part of the city has tap water connections. It is further burdened with supplying free water to about 200000 people through water taps.

(**Note:** *All the Maps of this chapter are supposed "**NOT TO SCALE**", if scale is not mentioned.)*

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Potential of Rain Water Harvesting

Topics covered in this chapter

- INTRODUCTION
- SCOPE OF RAINWATER HARVESTING IN BHOPAL
- POTENTIAL OF RAINWATER TO MEET THE CITY DEMAND
- POTENTIAL ACCORDING TO DEVELOPMENT TYPE
- ECONOMIC FEASIBILITY OF ROOFTOP RWH
- NEED FOR INTEGRATING RWH
- AN EXAMPLE OF RWH
- RECYCLING OF WASTE-WATER

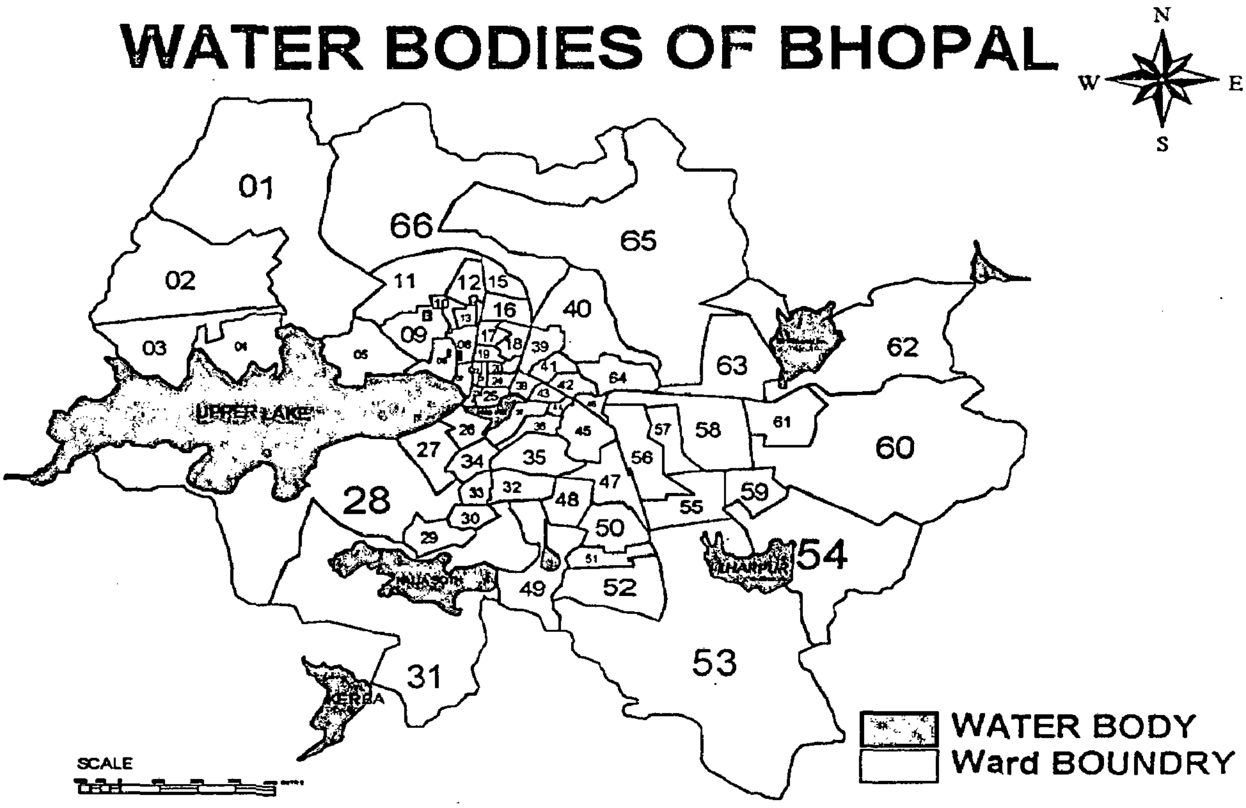
CHAPTER 5

5.1 INTRODUCTION: The city of Bhopal endowed with plenty of water bodies in and around Bhopal. These lakes are enumerated below in table 5.1

Table 5.1 Major Water bodies of Bhopal

1. Upper Lake	8. Hathaikheda Reservoir
2. Lower Lake	9. Kerwa Reservoir
3. Shahpura Lake	10. Kaliasote Reservoir
4. Lendia Talab	11. Laharpur Reservoir
5. Motia Talab	12. Char Imali Pound.
6. Noor Mahal Talabs	13. The piplani Pond
7. Munsi Hussain Khan	14. Dahod Tank Talab

Source: BDP 2005.



Map 5.1 Map showing the spatial location of water bodies within and out side the municipal limit of Bhopal. *(BDP 2005)*

But unfortunately these water bodies are being polluted due to inflow of untreated municipal liquid waste and human intervention. These water bodies have enormous potential to harvest the rainwater provided the ecosystem of these pounds are restored by adequate measures and surfaces runoff are diverted into these water bodies after necessary treatment. Besides these water bodies, 11.5% (16.71%proposed in BDP 2005) open spaces are existing, these spaces can be also utilizes for rainwater harvesting.

5.2 SCOPE OF RAINWATER HARVESTING IN BHOPAL: There are plenty of scopes for rainwater harvesting in city which can explain under following headings,

5.2.1 PLENTY OF WATER BODIES: Bhopal endowed with plenty of water bodies, they are listed in table 5.1 on previous page, these lakes have enormous potential to catch rainwater, provided they are maintained and regular desilting has been done.

5.2.2 GOOD RAINFALL: Bhopal receives annual rainfall of 1209 mm. Maximum rainfall 429 mm during month of July and minimum 03 mm in February. Still the city facing water scarcity in summer during normal rainfall, when rainfall less than normal then even before summer city start facing water shortages, because the available potential is not fully exploited. If city like Jodhpur can sustain itself in desert of Rajasthan with 400-500 mm annual rainfall only, reason better water management then why not Bhopal if proper water management has done.

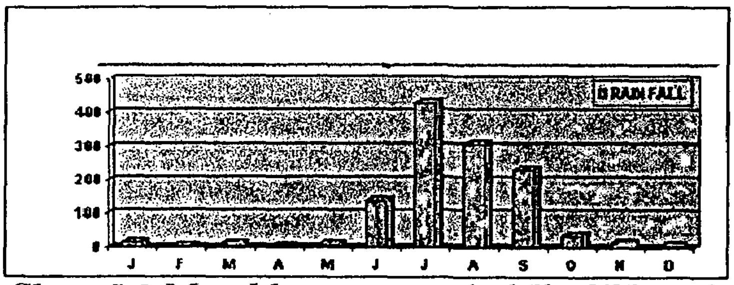


Chart 5.1 Monthly average rainfall of Bhopal

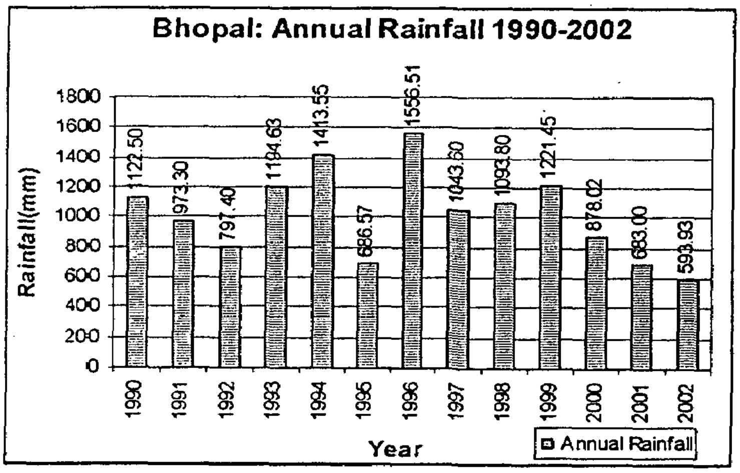


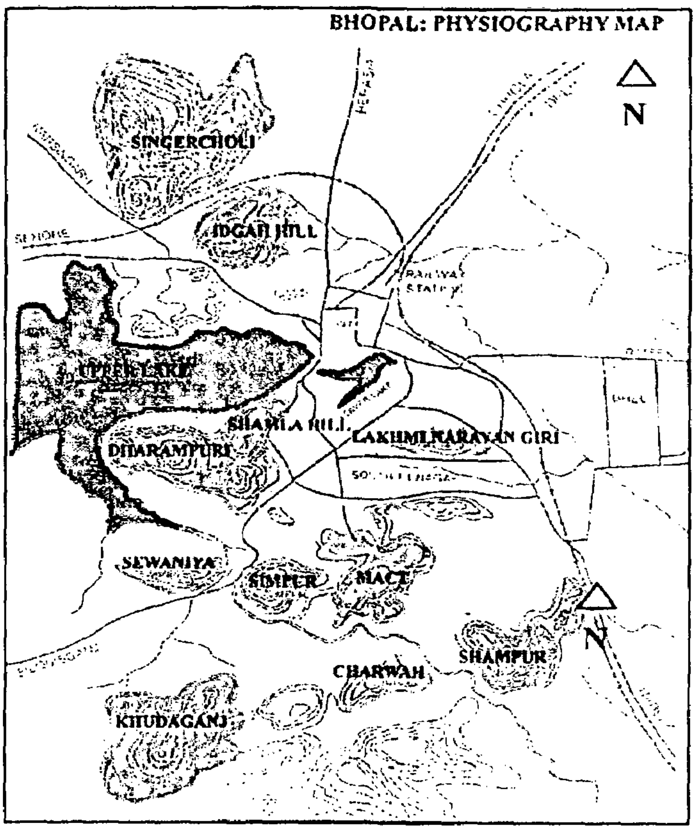
Chart 5.2 Annual average rainfall of Bhopal
(Source: State data storage center Bhopal)

Surface water is the major source of water supply in Bhopal 91.5% of supplied water meet by lakes and reservoir as a surface water source.

Look at the rainfall trends during last 13 years from 1990 to 2002 there is quantum fluctuation, and during last couple of years there were gradual decrease in rainfall leading Bhopal to face acute water shortages.

Rainfall is the ultimate source of surface water sources, so rainwater harvesting is the ultimate solution to solve water scarcity.

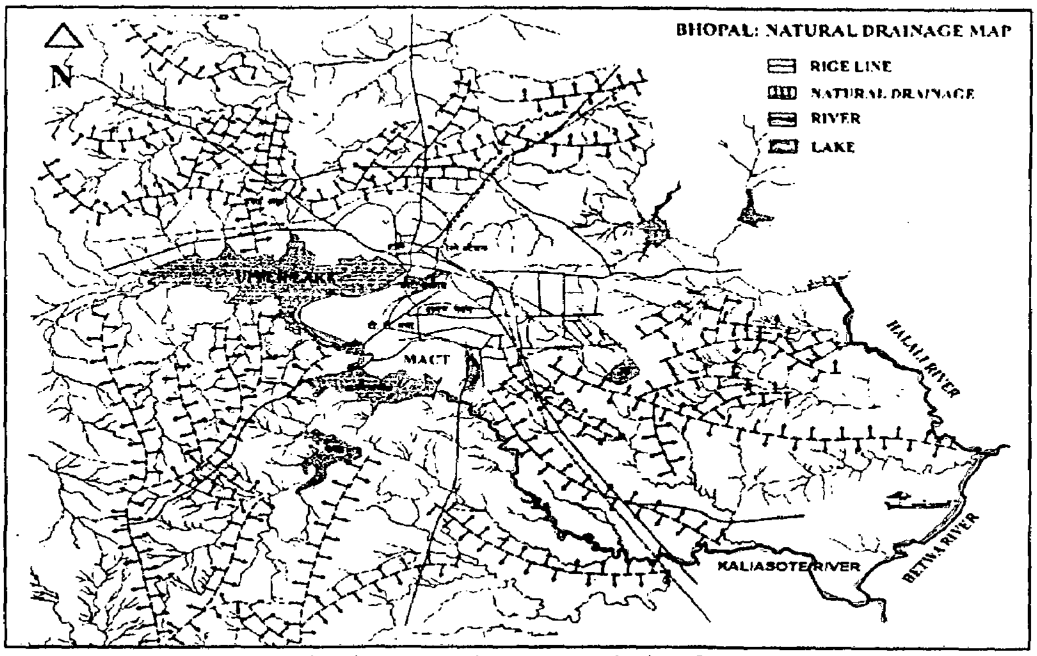
5.2.3 TOPOGRAPHY: The city is situated on a hilly terrain, which slopes towards north and southeast hillocks of different altitude along the Southwest & Northwest portion of the city. These hillocks form a continuous belt from Singarcholi in the northwest to the Vindhyachal ranges to the South. There are plenty of hillocks in city having large surface area and consist of large, settlements, e.g. MANIT hillock has surface 265 acre, and sparsely developed only an engineering college is there, at present all water received by as rainfall going wastage as surface runoff due to absence of harvesting system. So all these hillocks can be used as a good natural water catchment area and after little purification these water can directly supplied to low lying nearby area through gravitational force only, which can save significant amount of electricity.



Map 5.2 Important hillock of city having huge potential of RWH (Source: BDP 2005)

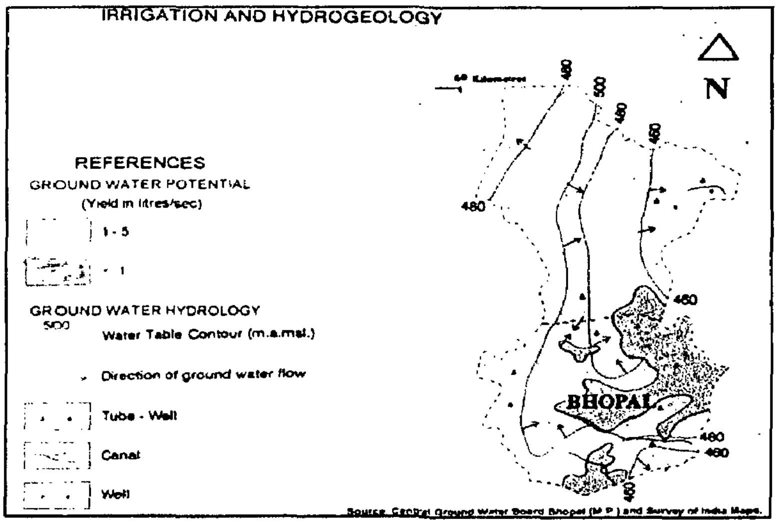
5.2.4 NATURAL DRAINAGE:

The natural drainage of the city is by three main steams (*Halali river in north-eastern, Kaliasoat in soth-eastern & Kolar river in south*), which are, joined by Nallahs and Rivulets. The intricate network of rivulets and drainage has great potential to harvest rainwater, no additional effort will require to drain rainwater to a particular location, where water will store, only thing required is that the design should follow the natural drainage pattern. This features is totally missing in plain area.



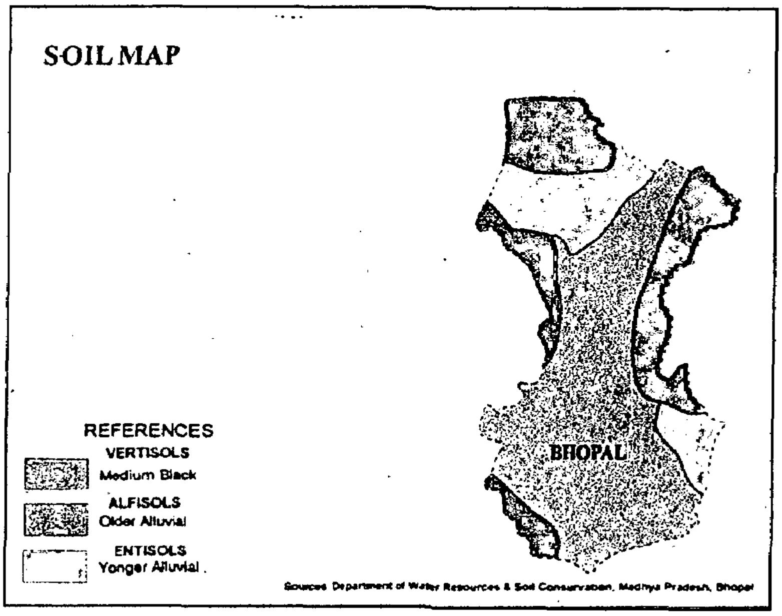
Map 5.3 Natural drainage, ridges and rivulets of Bhopal.
(Source: BPD 2005)

5.2.5 HYDROLOGY: 40 percent area of Bhopal falls under the low ground water potential (yield < 1 litre/sec.) and 60 under moderate *(yield 1-5 litre/sec)* as shown in the map. Direction of ground water flow towards north (towards Upper lake good for water harvesting) and south-eastern where new development taking place rapidly. The direction of flow of underground water is favorable for rainwater harvesting. Where ever we inject the rainwater into the ground they used by the inhabitants only.



Map 5.4 Ground water potential & flow of underground water in Bhopal. *(Source: District Planning map series, Bhopal, SOI)*

5.2.6 SOIL CONDITION: The old city area is characterized by Red sand stone strata of Malwa Plateau, which make this area to produce highest percentage of rainwater as runoff during rainfall. The top portions of various hillocks and the slopes have red soil mixed with boulders. As we move down the slopes of hills, Black cotton soil in depths of 1 to 2 ½ meters is observed on the North, north-eastern, South and south-eastern directions. Hence we can say that south-eastern parts are most suitable of recharging ground aquifer and in the old city area & hillocks most suitable method has to collecting runoff water from these areas and store into a centralized surface water reservoirs or lakes after necessary treatment. Water from old city can also be diverted into upper lake after necessary treatment till now these water are mixed with sewer line drain to the lower lakes and thus pure form of rainwater become polluted and remains as non-potable quality.



Map 5.5 Map showing the types of soil present in Bhopal. *(Source: District Planning map series, Bhopal, SOI)*

5.2.7 MATERIAL OF ROOFING: If we look at the table 5.2 given below, maximum number of houses having concrete roofing (61.01%) and very few houses having other materials like grass, thatch, bamboo, wood, mud, plastic, polythene, tiles, slate etc, which are generally missing in urban area. It is said that concrete roofing is most suitable and economical for adopting rooftop rainwater harvesting. So this is a positive factor for utilizing rainwater harvesting to augmentation of water supply.

Table 5.2 Classification of houses according to their roofing material, within MCB.

S.No	Type of Roofs	Number	Percentage
1	Grass, Thatch, Bamboo, Wood, Mud etc.	4,889	1.38
2	Plastic, Polythene	19,710	5.56
3	Tiles	14,045	3.96
4	Slate	750	0.21
5	G.I., Metal, Asbestos sheet	93,141	26.27
6	Brick	2,125	0.60
7	Stone	2,965	0.84
8	Concrete	216,275	61.01
9	Any other material	606	0.17
	Total*	**354,506**	**100.00**
*Total number of census houses 2001(Within BMC)			

Source: * MP Housing Census 2001

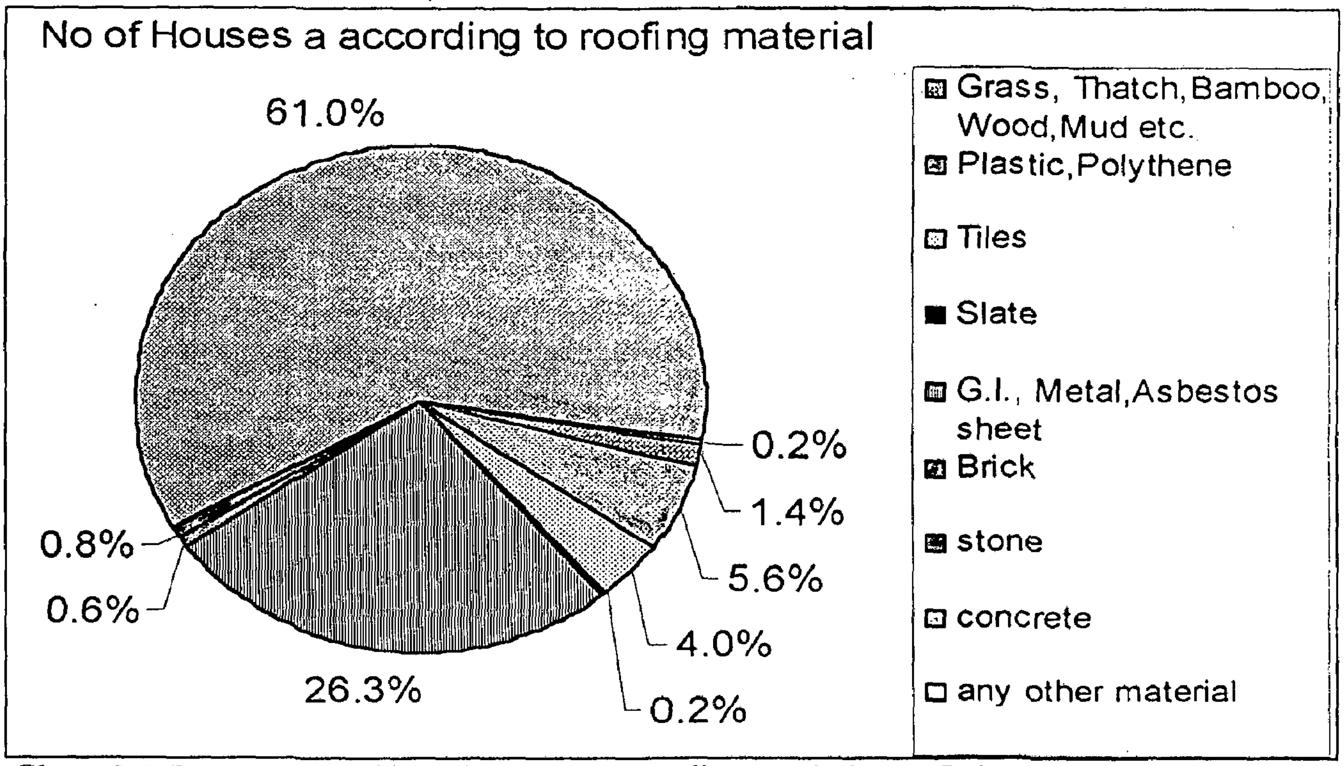


Chart 5.3 Percentage of housing type according to their roofing material.

(Source: MP Housing Census 2001)

5.3 POTENTIAL OF RAINWATER TO MEET THE CITY DEMAND: The city of Bhopal can be divided on the basis of its development and built up areas. It is important because when we talk about catchment area landuse comes first.

5.3.1 FIRST METHOD TO CALCULATE BUILTUP AREA OF CITY: Bhopal has been divided into three categories of development. As show in the table below.

Table 5.3 Types of development in Bhopal according to development & built-up area.

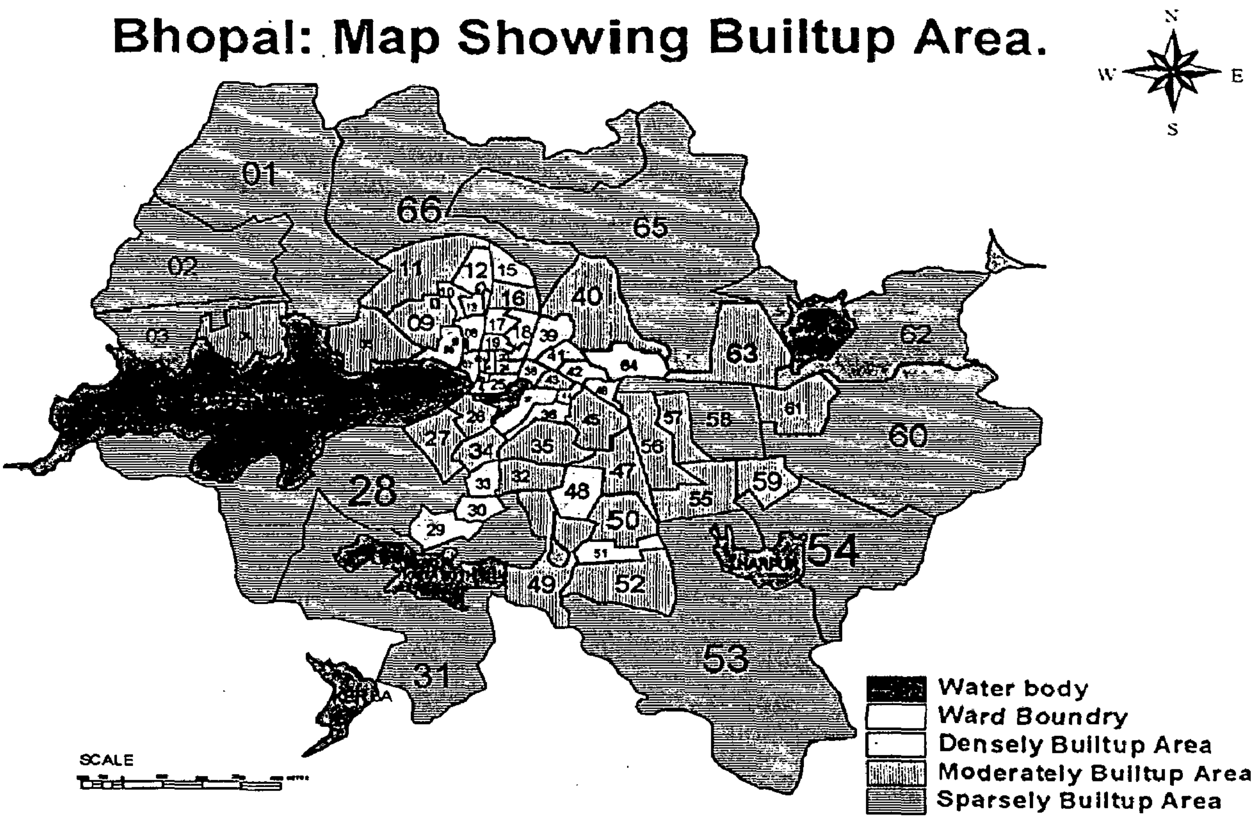
Category	Types of development	Builtup area	Wards under each category
I	Densely developed area	≥ 50%	6,7,8,10,12,13,14,15,17,18,19, 20,21,22,23,24,25,29,30,33,36,37 ,38,39,41,42,44,46,48,51,64 = 31
II	Moderately developed area	20-50%	4,5,9,11,16,26,27,32,34,35,40,43, 45,47,49,50,52,55,56,57,59,61,63 = 23
III	Sparsely developed area	< 20%	1,2,3,28,31,53,54,58,60,62,65,66 = 12

Category I is densely developed area where the built up area is more than **50%** of the total area of respective wards. Category II is moderately developed area where the built up area is in between **20% to 50%** of the total area of respective wards. Category III is the sparsely developed area where the built up area is less than **20%** of the total area of respective wards. **Table 5.4** shows-the areas under different type of wards. From the table it is clear that most of the area in the city is sparsely built up and there is further scope of development in the city. Hence it can accommodate the increased population up to a certain extent. The quantity of sparsely developed area is high also because of the topography of the city and lack of public transport system.

When we compare the total built up area of the city with its total area it comes very low of just about 17.55% 1991. But the pace of growth since then was very high and presently this ratio may be as high as about 20 –25% of the total city area. The question raises that when that much portion of the city left open then why recharging of ground water is not sufficient or at least equal to withdrawal.

Assumptions for calculation of builtup area.

1. *Each households living in single-family houses in Bhopal, except old city area.*
2. *Each households of ward Number-13, 14, 17, 21, 22, 23, 36, 41, 42, 44, 46 are living in two or multiple family houses.*
3. *10% of each wards in taken as road, except old city area, where only 5% taken as road, because of availability of narrow streets.*
4. *Size of each plots are taken as 9.0 X 15.0 m, because this is the most common plot size available in Bhopal.*
5. *Total built up area = Rooftop area + Paved area.*



Map 5.6 Ward Map of Bhopal Showing Builtup Area

Table 5.4 Area under different categories of development types in Bhopal.

	Development type			Total
	Dense	Moderate	Sparse	
Number of wards	31	23	12	66
Total Built up area (sq.km)	12.96	17.73	28.24	58.93
% Built up area	*70.05%*	*34.49%*	*14.59%*	
Total open area (sq.km)	5.54	33.68	165.26	204.48
% Open up area	*29.95%*	*65.51%*	*85.41*	
Total area (built + open)	**18.50**	**51.41**	**193.50**	

The absolute value of area *(both builtup and open)* under **sparsely built up wards** are highest because these wards are of larger area(see Map 5.6). Wards under this category are ***Word No. 1,2,3,28,31,53,54,58,60,62,65 & 66*** *(Total 12 wards),* these wards consists of large institutions which are having large premises. Bhopal University, Museum of Man, WALMI (Water and Land Management Institute), Indian Institute of Forest, Maulana Azad National Institute of Technology. Air port, Metrological Department etc. are the few large having large premises.

Strategy of water management and rainwater harvesting should be distinct for each type of development. Landuse is also varying in each type of development. In densely built up wards major activities are of residential and commercial. While some government organisations and schools can be attributed to these wards.

In the **moderately built up wards** main landuse is residential but the development is somewhat planned. The wards constituting the area are ***Ward No. 4,5,9,11,16,26,27,32,34,35,40,43,45,47,49,50,52,55,56,57,59,61 & 63****(total 23 wards)*. Residences are having medium plot size and most of them are having gardens within the site. These sites can be very good for rainwater harvesting and recharge of groundwater the only thing is to make some small provisions within the area. This zone of development contains large Institutions and Government offices (Vdihan Sabha, old and new, Ballabh Bhawan, Satpura Bhawan, Prayawas Bhawan, Board Office, Professional education Board, etc) and small parks. These offices are having large roof areas and a large quantity of rainwater can be harvested from rooftop area of these institutions. Hence the strategy of rainwater practice from management point of view shall be different than that of individual house or institutions.

The third category of development is **densely built up areas**. The wards constituting this are ***Ward No. 6,7,8,10,12,13,14,15,17,18,19,20,21,22,23,24,25,29,30,33,36,37, 38,39,41,42,44,46,48,51,64*** (Total 31 wards). Whole city area (Old Bhopal) and few areas of New Bhopal are coming under this category. The area under these wards are least but the population is highest thus development is very high. These wards need special attention as there is very less area or no area left open even of minimum standard. But the development in the area is of contiguous type providing large continuous stretch of roof area that can be effectively utilized for roof top rainwater harvesting.

Mixed type of development gave rise to the high population density during daytime. Hence water requirement in these areas is not only for the permanent residents of the area but also for the working people and persons coming for shopping and other activities also add to the requirement of the water in the area.

Another character of this area is that large number tenant population which lives in the rented houses. This population does not have any property rights in the area but utilize all the infrastructure facility of the area. Hence care should be taken to involve this population in the water management of the area at the local level.

Generally the entire area is having metal roads, but open drainage channel and inefficient sewer system. People in the area used to divert the rainwater of the house along with the sewage in the same drain. Hence this aspect should also be kept in mind while preparing the water management plan for the area. Social interaction in the area is very high hence there great possibility of community driven approach to be successful.

5.3.2 SECOND METHOD TO CALCULATE BUILTUP AREA OF CITY:

Table 5.5 Area under different development types in Bhopal.

S.No	Occupancy type	Number*	Per unit area** (sqm)	Ground*** coverage(%)	Builtup area
1	Residences(unoccupied)	38,731	135	100	5.23
2	Residential only	257361	135	100	34.74
2	Residence cum other uses	8,889	135	100	1.20
3	Office, shop	30,490	288	80	7.02
4	School, college etc	1,393			0.00
	a.Colleges/University/Insitit ution	13	200000	25	0.65
	b.School	54	16000	30	0.26
	c. Nursery & Pre nursery	7	1000	40	0.00
	d. others	1,319	1000	33	0.44
5	Hotel lodge guest house etc	862	2000	30	0.52
6	Hospital, dispensary etc	1,067			0.00
	a. Government Hospital	11	100000	33	0.36
	b. Private Hospital	34	3000	33	0.03
	c. dispensary	1,022	800	33	0.27
7	Factory, workshop, workshed etc.	3,294	600	30	0.59
8	Place of worship	1,477	5000	30	2.22
9	Other no residential uses	10,942	200	100	2.19
	Total Houses	356,966			
Total builtup area of city					**55.73**
Note: For residences ground coverage taken as 100%, because people paved all there open spaces for cleaning proposes & our target to calculate impermeable surface,					

Source: * *MP Housing Census 2001, www.mp.nic.in,* ** *BDP 2005,* *** *BDP-2005.*

When I compared both methods for calculation of built up area of the city explained above, the results obtained from both methods are almost same. So we can adopt any of the above methods for calculation of potential of rainwater harvesting. Here I'm using first method for further calculations.

5.4 POTENTIAL ACCORDING TO DEVELOPMENT TYPE: Although rain falls equally on all the places within BMC limit with slight variations. But the potential of rainwater harvesting differs according to development type and topography of that area and landuse. On the basis of development type the entire municipal area has divided into three types of developments viz. **dense, moderate and sparse**. The built up area taken constitutes the rooftop area and paved surfaces. Built up area is pucca area, which does not allow water to percolate into the ground hence maximum rainwater is generated as runoff water. The losses from the runoff mainly due to the evaporation of the water from the surface. Rainwater from open area generates less runoff as compare to the built up area, due to the percolation of water into the ground. Soil of Bhopal is vertisol medium black with low percolation. Due to steep slope in the city speed of runoff generated has very high and the time of contact between ground and water reduces. It is because of it that rate of infiltration or recharge is very less in comparison to the withdrawal of groundwater leading to depletion of groundwater in many areas of the city. The potentials of rainwater harvesting from different development types are given in the Table 5.6. Harvested water from the sparsely developed area is highest due to its highest share of land under built up area in the city. This is the zone from where maximum water is expected to harvest through various type of rainwater harvesting techniques.

Table 5.6 Potential of RWH of builtup areas in different development types of Bhopal

Type of development	Dense	Moderate	Sparse	Total
Built-up area (sq.km)	12.96	17.73	28.24	58.93
Harvested rainwater from built-up area (million liter)	15670.50	21438.15	34141.65	71250.29
@ 50% collection efficiency harvested water (million liter)	7835.25	10719.08	17070.82	35625.15
@ 35% collection efficiency harvested water (million liter)	5484.67	7503.35	11949.58	24937.60
Availability of RW @ 50% efficiency (mld)	21.47	29.37	46.77	97.60
Availability of RW @ 35% efficiency (mld)	15.03	20.56	32.74	68.32
Note: average annual rainfall of Bhopal city has been taken as 1209mm.				

Total built up area within BMC limit is 58.93sq. km. from where 71.25 thousand million liter of rainwater can be harvested. This quantity of rainwater is collected when we collect all the rains which fall on the built up area. But it is never possible because of various factors like evaporation, and loss due to surface runoff and due to the very reason which states that any system cannot be 100 percent efficient in practical. In this case due to various practical hurdles, it may not be possible to harvest more than 70 percent of total rainwater. For the purpose of calculation I assume in the beginning that efficiency could not be more than 50 percent. According to the collection efficiency of 50 % we shall be able to collect about 35.62 thousand million liters and at the collection efficiency of 35% this quantity comes to be 24.94 thousand million liters. This quantity of rainwater is collected from a year. If we see the per day availability of the rainwater then it comes 97.60 million liter per day(mld) at the rate of 50% collection efficiency and 68.32 million liter per day at the rate of 35% collection efficiency.

Table 5.7 Potential of RWH of open areas in different development types of Bhopal

Type of development	Dense	Moderate	Sparse	Total
Open Area (sq.km)	5.54	33.68	165.26	204.48
Harvested rainwater from open area (million)	6697.86	40719.12	199799.34	247216.32
@ 50% collection efficiency harvested water (million)	3348.93	20359.56	99899.67	123608.16
@ 35% collection efficiency harvested water (million)	2344.25	14251.69	69929.77	86525.71
Availability of RW @ 50% efficiency (mld)	9.18	55.78	273.70	338.65
Availability of RW @ 35% efficiency (mld)	6.42	39.05	191.59	237.06
Note: average annual rainfall of Bhopal city has been taken as 1209mm.				

Above table illustrates the figures of rainwater harvesting capacity of unbuilt or open areas. Area under open areas is highest in sparsely developed wards. From open area of 204.48 sq. km. we can collect maximum of 247.22 thousand million liters of rainwater. While at the collection efficiency of 50% availability is 123.61 thousand million liters and at 35% it is 86.52 thousand millions liters per year. 338.65mld and 237.06 mld are harvested at the 50% and 35% collection efficiency respectively.

The water demand of the city at present is 57.03 mgd @ 180 litre *(deficit of 70 liter, as per WHO norms for water supply in a city is 250 lpcd)*. The total supply of water from all sources by BMC is only 51. mgd (during scarcity period). Hence there is a big gap of 6.0 mgd. After completion of the proposed project of augmenting the water supply this is expected to meet the future demand, but how much time it will take to come into ground reality no one can exactly said so it is necessary to do some innovative work to bridge the present and anticipated gap between demand and supply which we are going of face in future.

Table 5.8 Capacity of rainwater to fulfill the city demands

	Harvested rainwater(mld)	Harvested rainwater(mgd)	Demand (mgd)	Inadequacy
Water demand @180 lpcd 2021			86.7	33.2
Water demand @250 lpcd 2021			120.41	66.91
@100% Harvested rainwater from built-up area	**195.21**	**43.03**		
@50% collection efficiency harvested water	97.60	21.52		
@35% collection efficiency harvested water	68.32	15.06		
@100% Harvested rainwater from open area	**677.30**	**149.32**		
@50% collection efficiency harvested water	338.65	74.66		
@35% collection efficiency harvested water	237.06	52.26		
@ 100% from total area	**872.51**	**192.35**		
@ 50% from total area	436.26	96.18		
@ 35% from total area	305.38	67.32		

The future projected demand in 2021 is calculated **86.7 mgd** (@ 180 Ipcd). But as the population grows the standard of water supply changes and as per the standard this should be about 250 Ipcd. If we take this standard then future demand projected is **120.41 mgd** in the year 2021. So it is clear that in near future there will be acute problem of water shortage. Now if we see the figures of rainwater harvested from the city it presents a quite satisfactory picture of water supply. Table 5.8 shows the capacity of rainwater to fulfill the demand of city water. It is clear from the table that the rainwater harvested from open area will be enough to fill the gap between demands and supply in future if the harvested at the efficiency of 35 percent. Rain water from builtup area can full fill the present gap of 3.53 mgd at the collection efficiency of 35 percent. Hence if we make the rooftop rainwater compulsory in all the buildings then at least we shall be able to collect 35 % of total rainwater from built up areas, which can contribute to some extent to reduce the shortfall.

Table 5.9 Population served through rainwater

Collection efficiency	Harvested RW(mgd)	Population that can be served though rainwater		% of Population that can served through RWH in 2021	
		@180	@250	@180	@250
@50% collection efficiency from builtup area	21.52	542,240	390,413	24.82	17.87
@35% collection efficiency from builtup area	**15.06**	**379,568**	**273,289**	**17.37**	**12.51**
@50% collection efficiency from open	74.66	1,881,403	1,354,610	86.12	62.00
@35% collection efficiency form open	**52.26**	**1,316,982**	**948,227**	**60.28**	**43.40**
@50% from total area	96.18	2,423,642	1,745,023	110.94	79.87
@35% from total area	**67.32**	**1,696,550**	**1,221,516**	**77.65**	**55.91**

Thus harvested water alone is sufficient to serve a big number of populations. In the table 5.8 the number of population at the most which can be serve through rainwater harvesting from built up area is about 3.79 lakhs at efficiency of 35%. But if we see the total rainwater harvested from the entire city then it is capable of serving 16.96 lakhs, which is equal to the 77.65% of the total population in year 2021. Hence we can say that if rainwater is harvested at the collection efficiency of 35% then population ranging between 70-80 % can be served by rainwater alone @ 180 lpcd.

5.5 ECONOMIC FEASIBILITY OF ROOFTOP RAINWATER HARVESTING:

Table 5.10 Average consumption in an Indian city.

S.No	Ues	Capacity (lpcd)	% Composition
1	Drinking	5	3.70
2	Cooking	5	3.70
3	Bathing	55	40.74
4	Washing of cloths	20	14.81
5	Washing of utensils	10	7.41
6	Washing or cleaning of houses and residences	10	7.41
7	**Flushing of latrine**	**30**	**22.22**
8	Total	135	100.00

Table 5.11 Consumption breakup at city level

S.No	Ues	Capacity (lpcd)	% Composition
1	**Domestic**	**135**	**50.00**
2	Industrial	50	18.52
3	Commercial	20	7.41
4	Public	10	3.70
5	Waste & theft	55	20.37
6	Total	270	100.00

Source: Bureau of Indian Standard (IS: 1172:1971)

Table 5.12 Analysis of cost of water for flushing requirements for at house hold level as well as at city level

Population (2001)	1437354
Number of House holds	**278487**
Flat rate for 1/2"' domestic connect (per month)	150.00
Annual bill paid by each household (in Rupees)	1800.00
Annual bill paid by each household for flushing only (in Rupees)	400.00
Annual saving if flushing requirement meet by RWH or gray water	**400.00**
% Saving	22.22 %
Each household receiving total quantity of Water per year @ 135 lpcd (5 person per household)	246375.00
Per litre water cost to consumer (paise)	0.731
Per household annual consumption of water for for flushing (liter)	54750.00
Annual consumption of water for flushing in Bhopal (mgd)	**9.51**
Per liter cost of water to BMC (paise)	0.0033
Annual saving of BMC if flushing requirement meet by RWH or gray water (in Rupees)	52175720.27
Annual Saving of BMC per house hold	187.35

From above table it is evident that we are wasting 9.31 mgd potable water to meet flushing requirements, not just wasting water but also wasting the man power and effort to make this water for drinking purpose.

If this requirement is meet by RWH or by the use of gray water then each household can save 400 Rs per annum and BMC save 5,21,75,720 per annum. Which show the potentiality of RWH.

5.5.1 COST OF RECHARGE STRUCTURE: The cost of each recharge structure varies from place to place. The approximate cost of the following structures is as under:

Table 5.13 Approximate cost of recharge structure.

S.No.	Recharge Structure	Approximate cost (Rs.)
1.	Recharge pit	2500 – 5000
2.	Recharge Trench	5000 – 10000
3.	Recharge through hand pump	1500 – 2500
4.	Recharge through dug well	5000 – 8000
5.	Recharge well	50000 – 80000
6.	Recharge shaft	60000 – 85000
7.	Lateral Shaft with Bore well	Shaft per m. 2000 – 3000 Bore well 25000 - 35000

Source: central ground water board (www.cgwb.nic.in

5.5.2 ANNUAL SAVING: Annual saving by adoption of RWH practice are given under

Table 5.14 Annual saving due to adoption of RWH.

S. No	Saving	Amount (Rs)
1	Due to use of rainwater for flushing	400.00
2 *	Due to incentives of 6% on property tax	120.00
3 **	Due to relaxation in water tax	180.00
4	**Total saving**	**600.00**

** A rebate of 6 percent on property tax has been offered as an incentive for implementing RWHS.*
*** No tax for water has been offered as an incentive for implementing RWHS. (Proposal)*

Recharge pit method is a common method to harvesting water in Bhopal, according to rate list given in table 5.13 total cost of installation come to be 5000, which can be refund as saving in 7 years. So people have no problem to adopt RWH practice. Hence its is economically feasible.

5.6 NEED FOR INTEGRATING RAINWATER HARVESTING: Water resources consist and important part of the wealth of any settlement. History reveals that all the major civilization has grown along the course of water. It is only the increasing population, and over exploitation of water which has led the water crisis. Bhopal is also among those cities, which are facing the water shortage not because that it does not have the resource but because of its imprudent use and human intervention in the natural cycle of water. There is need to reconcile the water use with the natural cycle of water and this cycle consists of Groundwater, Surface water and Rainwater. Actually all the waters that we use come from precipitation. Hence it is important to take care of precipitation.

There is an urgent need to integrate rainwater harvesting with our water resource management. Following are some are the reasons, which compelled me to resort for rainwater harvesting in Bhopal.

- It is difficult in many areas where water table has gone down too much below the ground level, to have individual borewell (area out side the municipal limit). And in those areas populace has dependent on municipal water supply (Old city area of Bhopal), which is very unreliable, hence rainwater is the only available source to exploit.
- Water supply in Bhopal is through tubewells in Old city area and for rest of the area source is surface water. This has caused groundwater depletion in old area which is

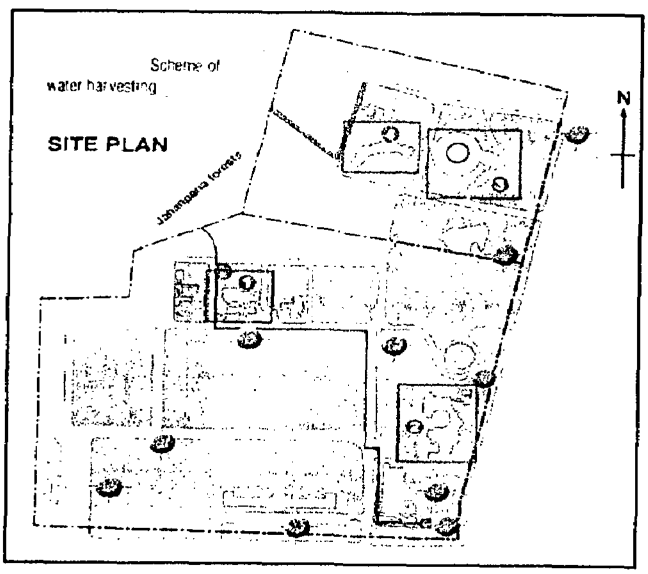
very badly suffered by water shortage during summer (April to June) all the community hands pumps are dry during this season. To arrest it, it is necessary to harvest rain and recharge groundwater.

- Some of the areas, which are not served by municipal water supply, are facing acute water scarcity. Rainwater is boon for those areas.
- Due to high gradient soil erosion is very rampant. To stop this, it is important to check the runoff and harvest it.
- Increased urbanisation has led to increased demand, reduced recharge of groundwater due to paved surfaces and inadequate supply of water and increased runoff.
- Rainwater harvesting is a best and most economical method for Bhopal scenario, where there is scarcity for drinking and domestic water in spite of very good rainfall. This method is also eco-friendly and economical.

5.7 AN EXAMPLE OF RAIN WATER HARVESTING: Jamia Hamdard University, New Delhi, *(Source: A Water Harvesting Manual, for urban area A CSE - Publication)*

5.7.1 CASE BACK GROUND: The area of the property is about 3,15,380 sq.m, which includes rooftop, paved and unpaved areas. The total water requirements are around 6 lakhs liters per day, out of which 2 lakh liters is extracted from 6 borewells and the rest is sourced through private tanker.

5.7.2 MEASURES TAKEN FOR WATER HARVESTING: The rainwater endowment of the area is 674 lakhs liters annually. In this campus rainwater from various catchments, including rooftops, surface runoff from open areas and runoff from the adjacent Jahanpanah Reserve forest are harvested (see Map. 5.7). The cost of installing the system was Rs. 6.25 lakh. The system was installed in June 2001.



Map 5.7 Scheme of water harvesting.

5.7.3 RAINWATER HARVESTING SYSTEM: The surface runoff from the Jahapanah Reserved Forest, which flows in an open storm water drain, adjacent to Scholar House (see fig. 5.2.1). In the Library Building area, while the rooftop rainwater is harvested in a recharge well, the surface runoff from the adjacent area is collected - in a trench constructed across the road and diverted to a recharged well on the southwest of the Library building (5.2.3) and to an abandoned open well on the north east of the library building.

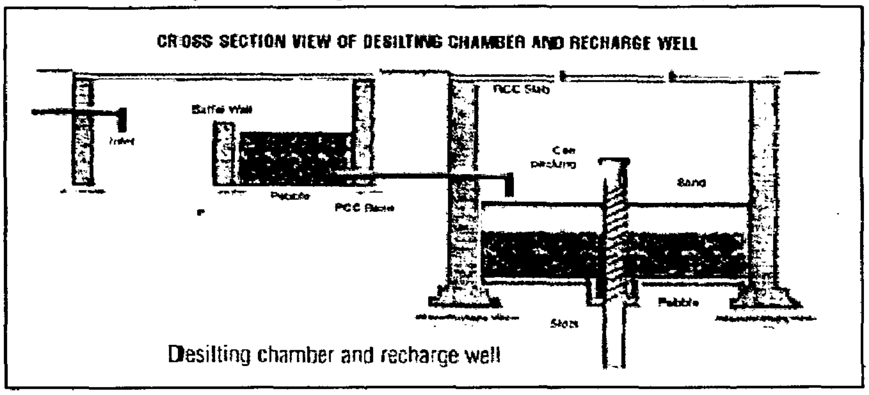


Figure 5.1 Desilting Chamber and recharge well

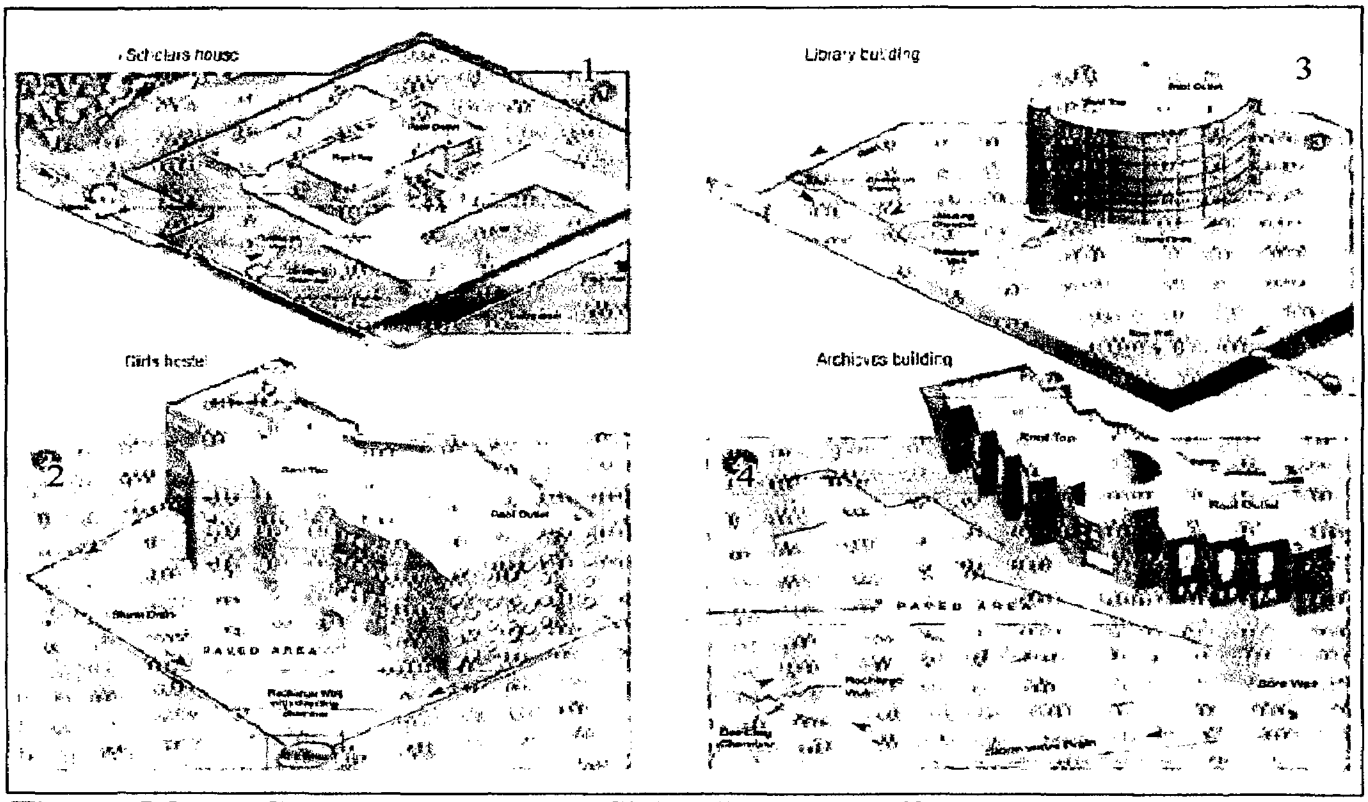
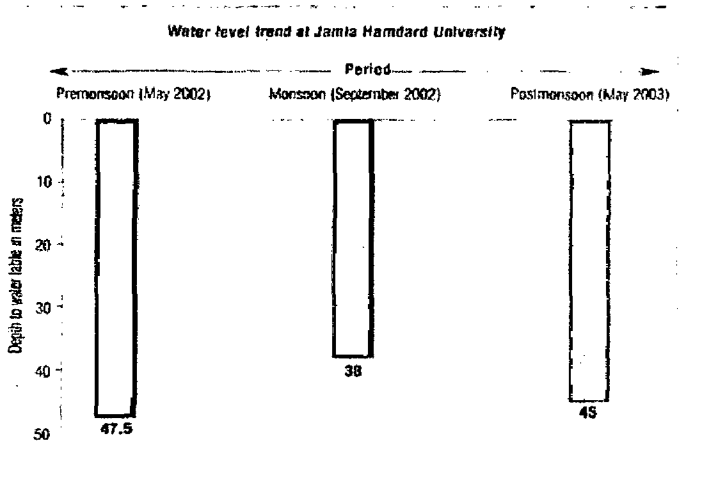


Figure 5.2: 1. Scholars Hostel, 2. Girls Hostel, 3. Library Building, 4. Archives Building

The rooftop rainwater from the Girl's hostel is diverted to a recharge well through a desilting chamber (see fig 5.2.3). Rooftop rainwater and the surface runoff from the Archieves building are collected in a stormwater drain and diverted to recharge well through a desilting chamber (see figure 5.2.4)

5.7.4 THE IMPACT: The water level which was around 47.5 meter below ground (bgl) level in May 2002, before implementation of the system, rose to 45 m bgl as on May 2003 (see chart 5.4).

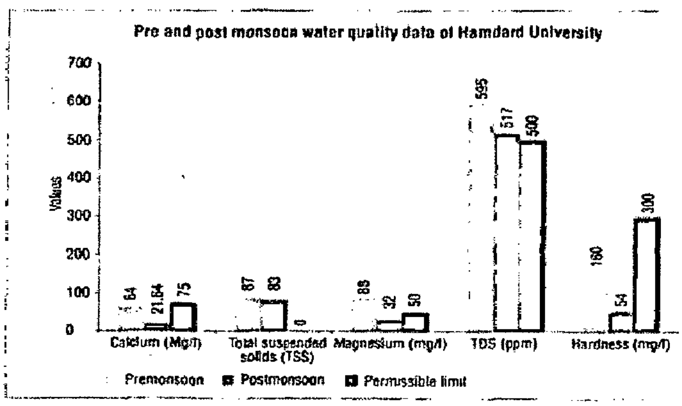
Chart 5.4 Water level trends



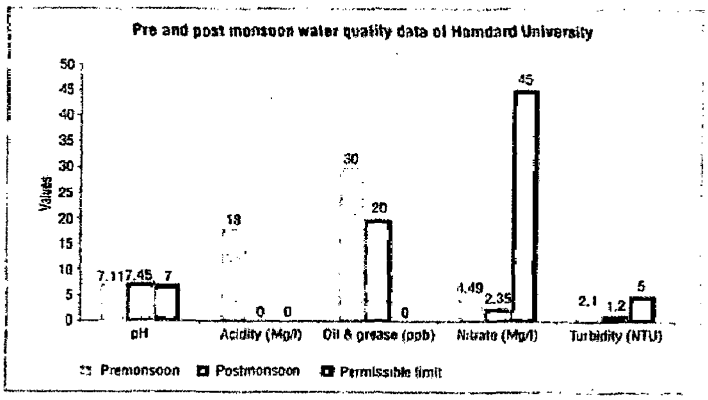
Water level trend

A comparative analysis of pre monsoon and post monsoon water samples collected from the borewells in the site show significant decline in Acidity, Nitrate, Turbidity, Hardness and Total dissolved solvent (see chart 5.5)

Chart 5.5 Graph of pre and post monsoon quality.



Pre and post monsoon water quality



Pre and post monsoon water quality

5.8 RECYCLING OF WASTE-WATER:

5.8.1 SEWAGE DISPOSAL: Sewage in Bhopal is handled by BMC, PHED and BHEL. *(Vandna Tiwari, 2001)*

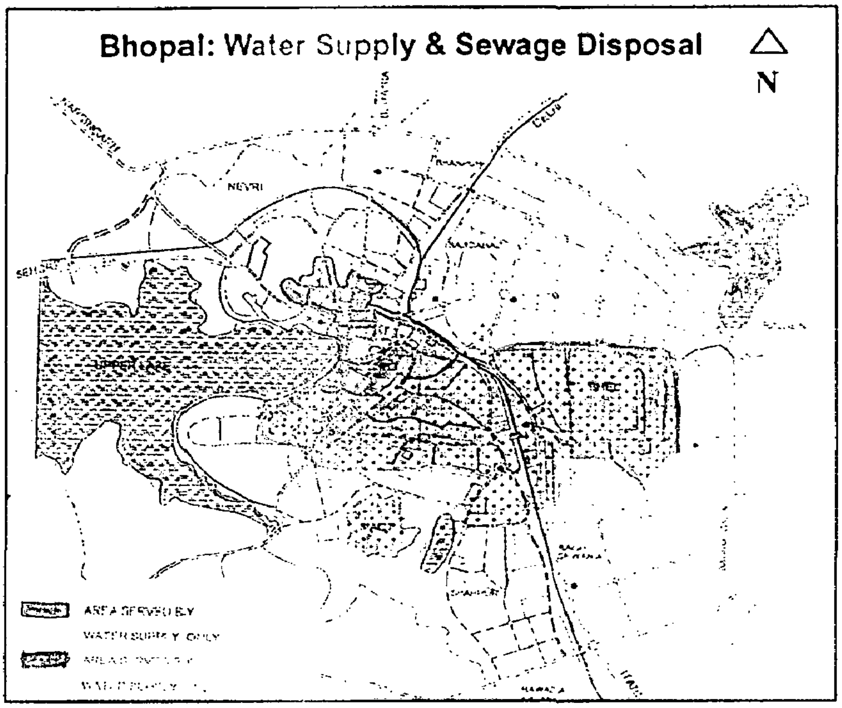
In **BMC** area there is no under ground sewerage system. A line joining 8 wards has been laying and it is on the verge of completion. Sewage just flows in open drains and joins in nearby nallahs, this is leading to underground water pollution.

In **PHED** areas (13 wards) on an average sanitary sewerage of 150 Ipcd is collected through underground sewerage system. Treatment facilities in the form of oxidation ponds are at (a) Area colony (3 Mgd) (b) Biofilter (1Mgd) at PHED office (c) O.P at Bhadbada (1 Mgd). Treated sewage is used for cultivation.

BHEL area is totally sewered and sewage is treated at oxidation pond at Piplani (2 Mgd), at Bharkheda -Main plant (1Mgd). At Govindpura (2 septic tanks). Still 80% of Bhopal has to be covered with sewage system.

Again, it is observed that the development in the southern portions is 100% connected to sewer lines and sewage disposal facilities. The northern part of the city is still not connected to sewer line even though some lines have been laid.

Thus, it may be concluded that the perception of common man that the old city is under developed and lacks basic infrastructure as compared to the development on southern side, is well founded on fact.



***Map 5.7 Map showing water supply and sewage disposal.** (Vandna Tiwari, 2001)*

Table 5.15 Sewage Treatment Plants Location and Capacity

S.No	Sewage Treatment Plant	Capacity	Method of Sewage Treatment
Existing			
1.	Area colony	3 Mgd	Oxidation Pond
2.	Biofilter at PHED office	1 Mgd	Not Available
3.	Bhadbada	1 Mgd	Oxidation Pond
5.	Bharkheda	1 Mgd	Not Available
Proposed			
7.	Gadhinagar	7.72 Mgd	UASB
8.	Bhadbhada	5.51 Mgd	UASB
9.	Maholi-Damkheda	56.44Mgd	Treatment
	Total	**75.66 Mgd**	

Source: Bhoj Wetland Project, Bhopal

5.8.2 CONCLUSION: From the total capacity of water treatment plant (proposed and existing) it becomes clear that their capacity is more than the that of present requirements. Therefore in coming future all the water will be disposed after treatment so there is a greater possibilities to reuse there treated / recycled water. So there are good possibilities for sustainable development for Bhopal.

(**Note:** *All the Maps of this chapter are supposed "**NOT TO SCALE**", if scale is not mentioned.)*

*****

Consumer Survey and Findings

Topics covered in this chapter

- INTRODUCTION
- SURVEY TECHNIQUE
- SURVEY TOOLS
- GOAL OF THE SURVEY
- SURVEY METHODOLOGY
- HOW CATEGORISATION HAS DONE
- FINDINGS OF SURVEY
- CONCLUSION

CHAPTER 6

6.1. INTRODUCTION: It is a fact that the data on the paper is little bit / quite different form the ground reality. So to understand the ground reality I made a consumer survey of all 66 wards of Bhopal.

6.2. SURVEY TECHNIQUE: It involves the collection of primary data about subject, usually by selecting a representative sample of population. " **Pilot Survey Technique**" & "**Stratified Sampling**" has been used for primary data collection. *(When data is collected from a limited number of subjects selected from the population targeted by the research project. we refer to it as a pilot study.)*

6.3. SURVEY TOOLS: Interview (Face-to-Face) tool has been adopted to collect data and opinion of each consumer.

6.4. GOAL OF THE SURVEY:

The goal this survey is "to workout the ground reality of water supply scenario in Bhopal".

6.5. SURVEY METHODOLOGY:

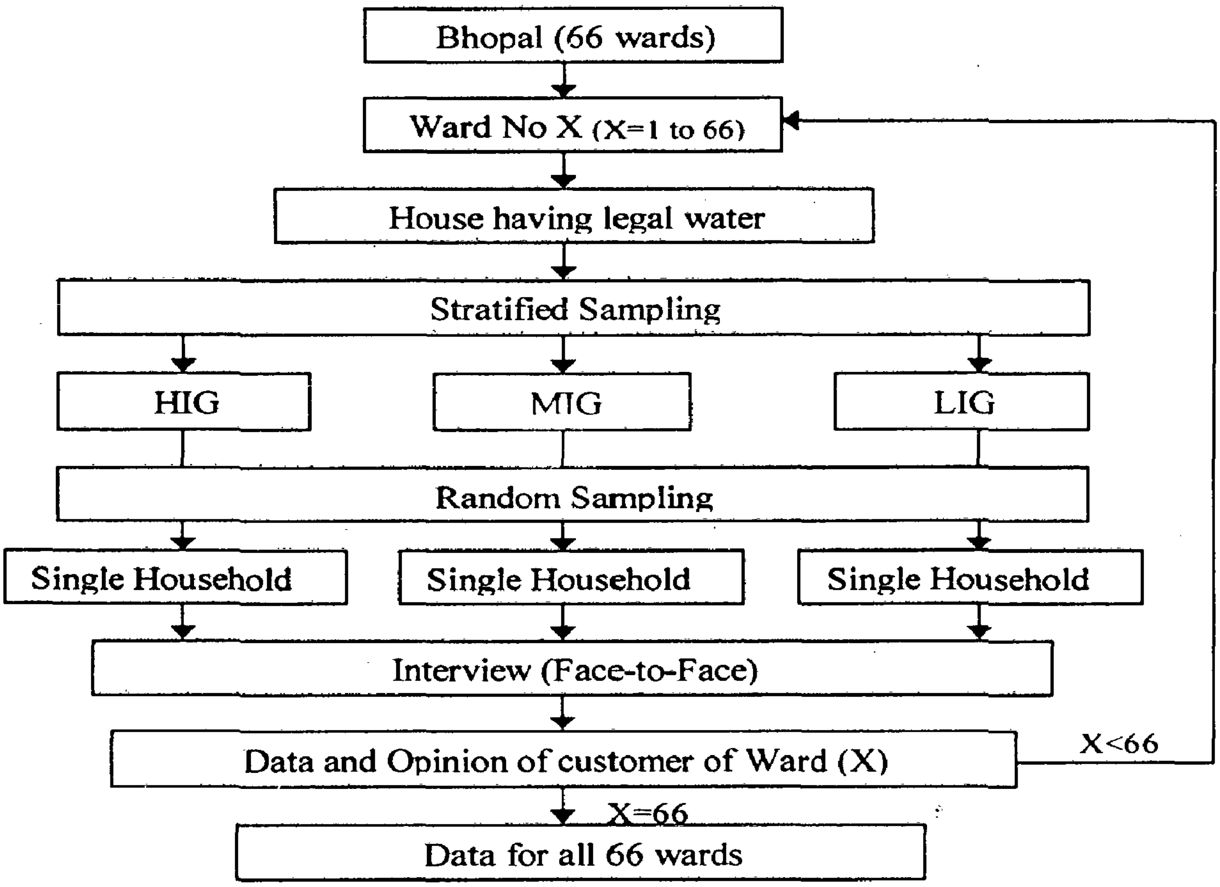


Chart 6.1 Survey Methodology

6.6. HOW CATEGORISATION HAS DONE: Bhopal is divided into 3 categorie according to the water shortages in that area,

I. High Water Stress Area,
II. Moderate Water Stress Area,
III. Low Water Stress Area,

This has been done in the following steps

Step1: A comprehensive list of data collected from consumer survey of each type of housing (HIG, MIG, LIG) of all 66 wards of Bhopal is prepared.

Step 2: These data are thoroughly studies and processed,

Step 3: After through study of data, I fix 12 parameters as the indicator to represent the actual scenario of concerned ward.

Step 4: These 12 parameters are then arranged in the tabular form, in descending order of their priorities. Their priorities are decided after considering views of consumer and observations made during survey (*detail of these parameter are given in Table 6.1*).

Step 5: After fixing the parameter relative weightage are given to each parameter (F*or detail see Table 6.1).*

Step 6: Against each ward & for each type of housing all these parameter are assessed and relative weightages are given.

Step 7: All the weightages for each category of housing are added to get total.

Step 8: Total obtain from each type housing are added to get overall weightage of that ward.

Step 9: Range are fixed to decide each category (by using simple statistic principal)

Category	**Weightage**
High Water Stress Area,	Less than 416
Moderate Water Stress Area,	416 – 433
Low Water Stress Area,	Grater than or equal to 433

Table 6.1 List of Parameters in the order of Priority

S. No	Symbol	Parameter	Classification	Weightage	Remark
1	P1	Quantity of water supplied	a. Adequate	25	Quantity play most important role because most of the area suffered from water scarcity.
			c. Inadequate	21	
2	P2	Quality of supplied water	a. Good	23	Quality is one most important next to quality because it can be improved by the using various purification processes.
			b. Poor	19	
3	P3	Pressure of supplied water	a. Adequate	21	It's important for upper floors & area lying on higher elevation.
			c. Inadequate	17	
4	P4	RWH in practice	a. Yes	19	It's very important for sustainable development of Bhopal.
			b. No	15	
5	P5	Recycling/reuse of waste water	a. Yes	17	It's also an important factor for sustainable development of Bhopal.
			b. No	13	
6	P6	Acute shortage in month of April to June	a. No	15	During this period most of areas of Bhopal suffered from acute water scarcity
			b. Yes	11	
7	P7	Frequency	a. Twice in a day	13	Frequency of water supply has not uniform every were, it depends upon supply agencies, population density & locality.
			b. Once in a day	11	
			b. Alternate day	9	
8	P8	Supply timing	a. 6.30 - 8.30 am	11	In some of the areas of Bhopal water supply during has been done during odd hours of the day, i.e. 4.0 am, which is very inconvenient for the consumers.
			b. Others	8	
9	P9	Duration of water supply	a. > 1.5 hr	9	Most of the area receive water for less than 1.5 hr and rare part of city receives more than 1.5 hr.
			b. 3/4 – 1.5 hr	7	
			c. < 3/4 hr	5	
10	P10	Alternate source of water supply with 1 km	a. Yes	7	During scarcity period bore well & handpump provide backup to resident otherwise they have to be rely on tanker provided by BMC or other private agencies.
			b. No	4	
11	P11	Use of Tullupump to suck the water form supply main	a. No	5	Most important reason of unequal distribution and low pressure.
			b. Yes	3	
12	P12	Borewell	a. Yes	3	Borewell without RWHS show exploitation of GW, but simultaneously reduce the load on existing water supply system.
			b. No	2	

Table 6.2 Analysis of collected data through survey, to identify water stressed ward of Bhopal (By using relative weightage method)

S.No	Type	Parameters												Total	Sum*	Density**	Remark
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	HIG	25	23	17	19	13	15	11	11	9	7	5	3	158			
1	MIG	25	23	17	15	13	15	11	11	9	7	5	2	153	464.0	1143	Lowest population density, handpumps and borebell successful
	LIG	25	23	17	15	13	15	11	11	9	7	5	2	153			
	HIG	25	23	17	19	13	15	11	11	9	7	5	3	158			
2	MIG	25	23	17	15	13	15	11	11	9	7	5	2	153	464.0	1734	Lowest population density, handpumps and borewell successful
	LIG	25	23	17	15	13	15	11	11	9	7	5	2	153			
	HIG	21	23	17	15	13	11	11	11	7	7	5	3	144			
3	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141	426.0	3916	Lowest pop density, & developing, WSS*** not adequate
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
4	HIG	21	23	17	15	13	11	11	11	7	7	5	3	144			
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141	426.0	8170	Low pop density, & developing, WSS* not adequate
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	HIG	21	23	17	15	13	11	11	11	7	7	5	3	144			
5	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141	426.0	6094	Low pop density, & developing, WSS* not adequate
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	HIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
6	MIG	21	23	17	15	13	11	11	11	7	7	5	2	143	429.0	17722	Medium density & old distribution network
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
	HIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
7	MIG	21	23	17	15	13	11	11	11	7	7	5	2	143	429.0	38277	Highest density & old distribution network
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
	HIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
8	MIG	21	23	17	15	13	11	11	11	7	4	5	2	140	420.0	32921	Highest density & old distribution network
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
	HIG	21	23	17	15	13	11	11	11	7	4	5	2	140			Medium density, lack of alternate source & old distribution network
9	MIG	21	23	17	15	13	11	11	11	7	4	5	2	140	420.0	13827	
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
10	HIG	21	23	17	15	13	11	11	11	5	4	3	2	136	408.0	36206	Highest density & old distribution network, tube well system
	MIG	21	23	17	15	13	11	11	11	5	4	3	2	136			
	LIG	21	23	17	15	13	11	11	11	5	4	3	2	136			
11	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	416.0	10138	Medium density, old distribution network, tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	3	2	138			
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
12	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	418.0	21985	Medium density, tube well system
	MIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
[illegible]	HIG	21	23	17	15	13	11	11	11	5	4	3	2	136	408.0	68793	Highest density & old distribution network, tube well system
	MIG	21	23	17	15	13	11	11	11	5	4	3	2	136			
	LIG	21	23	17	15	13	11	11	11	5	4	3	2	136			
1[illegible]	HIG	21	23	17	15	13	11	11	11	5	4	3	2	136	408.0	118969	Highest density & old distribution network, tube well system
	MIG	21	23	17	15	13	11	11	11	5	4	3	2	136			
	LIG	21	23	17	15	13	11	11	11	5	4	3	2	136			
15	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	416.0	24583	High density, old distribution network, tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	3	2	138			
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
16	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	416.0	14939	Medium density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	3	2	138			
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
[illegible]	HIG	21	23	17	15	13	11	11	11	5	4	3	2	136	408.0	52014	Highest density & old distribution network, tube well system
	MIG	21	23	17	15	13	11	11	11	5	4	3	2	136			
	LIG	21	23	17	15	13	11	11	11	5	4	3	2	136			
18	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	416.0	19747	Medium density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	3	2	138			
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
19	HIG	21	23	17	15	13	11	11	11	7	4	5	2	140	420.0	35730	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
20	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	417.0	50588	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	3	2	138			
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
21	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	417.0	83024	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	3	2	138			
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
22	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	417.0	60950	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	3	2	138			
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
23	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	423.0	99370	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
24	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	423.0	44218	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
25	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	425.0	42460	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
26	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	425.0	14045	Medium density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
27	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	425.0	11184	Medium density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
28	HIG	21	23	17	15	17	11	11	11	7	7	3	2	145	429.0	1355	Low density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
29	**HIG**	21	23	17	15	13	11	11	11	7	5	3	2	139	417.0	21569	High density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
	LIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
30	HIG	21	23	17	15	13	11	11	11	7	5	5	2	141	423.0	21596	High density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	5	5	2	141			
	LIG	21	23	17	15	13	11	11	11	7	5	5	2	141			
31	**HIG**	21	23	17	19	17	11	11	11	7	4	5	3	149	435.0	1695	Low density, Posh area, Kolar system
	MIG	21	23	17	19	13	11	11	11	7	4	5	2	144			
	LIG	21	23	17	19	13	11	11	11	7	4	3	2	142			
32	HIG	21	23	17	19	13	11	11	11	7	4	5	3	145	433.0	13506	Medium density, Posh area, Kolar system
	MIG	21	23	17	19	13	11	11	11	7	4	5	2	144			
	LIG	21	23	17	19	13	11	11	11	7	4	5	2	144			
33	**HIG**	21	23	17	15	13	11	11	11	7	5	3	2	139	417.0	16428	Medium density, Posh area, Kolar system
	MIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
	LIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
34	**HIG**	21	23	17	15	13	11	11	11	7	5	3	2	139	417.0	12950	Medium density, Posh area, Kolar system
	MIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
	LIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
35	HIG	21	23	17	15	13	11	11	11	7	5	3	2	139	417.0	12795	Medium density, Posh area, Kolar system
	MIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
	LIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
36	**HIG**	21	23	17	15	13	11	11	11	7	5	3	2	139	417.0	27906	High density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
	LIG	21	23	17	15	13	11	11	11	7	5	3	2	139			
37	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	425.0	20800	High density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
38	**HIG**	21	23	17	15	13	11	11	11	7	7	3	2	141	425.0	46918	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
39	HIG	21	23	17	15	13	11	11	11	7	7	5	2	143	429.0	20031	High density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
40	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	423.0	5920	Low density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
	LIG	21	23	17	15	13	11	11	11	7	7	3	2	141			
41	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	416.0	50115	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
	LIG	21	23	17	15	13	11	11	11	7	4	3	2	138			
42	HIG	21	23	17	15	13	11	11	11	7	7	5	2	143	429.0	55079	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
43	HIG	21	23	17	15	13	11	11	11	7	7	5	2	143	429.0	39625	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
44	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	427.0	64490	Highest density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
45	HIG	21	23	17	15	13	11	11	11	7	7	3	2	141	427.0	10340	Medium density, old distribution network tube well system.
	MIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
	LIG	21	23	17	15	13	11	11	11	7	7	5	2	143			
46	HIG	25	23	21	15	13	11	11	11	9	7	3	2	151	457.0	65914	*Highest density, posh area, adequate O&M*
	MIG	25	23	21	15	13	11	11	11	9	7	5	2	153			
	LIG	25	23	21	15	13	11	11	11	9	7	5	2	153			
47	HIG	21	23	21	15	13	11	11	11	9	7	3	2	147	445.0	8223	Low density, Posh & planned, Kolar system
	MIG	21	23	21	15	13	11	11	11	9	7	5	2	149			
	LIG	21	23	21	15	13	11	11	11	9	7	5	2	149			
48	HIG	25	23	21	19	17	11	13	11	9	7	5	3	164	476.0	13109	Medium density, Posh & planned colony, Kolar system
	MIG	25	23	21	15	13	11	13	11	9	7	5	3	156			
	LIG	25	23	21	15	13	11	13	11	9	7	5	3	156			

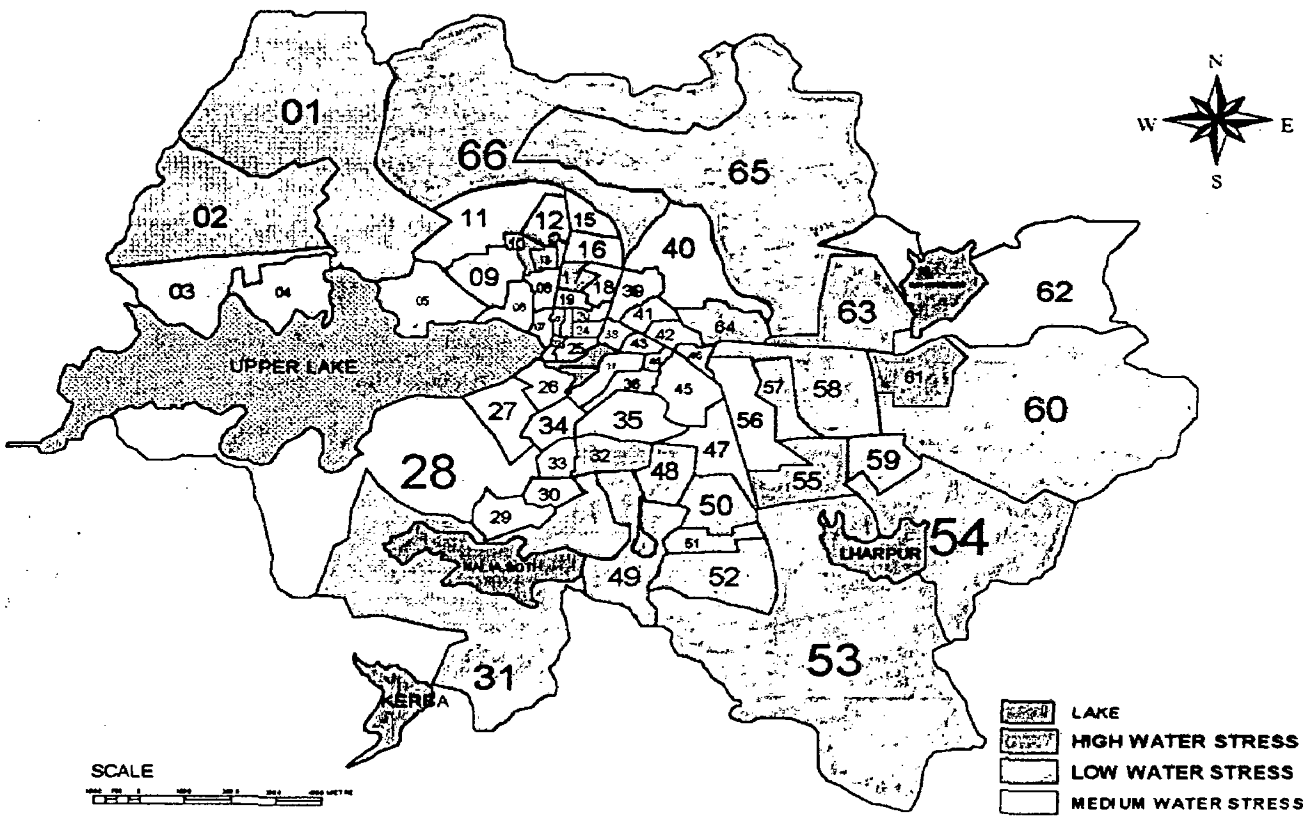
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
49	HIG	21	23	21	15	13	11	11	11	9	7	3	2	147	445.0	7027	Low density, Posh & planned colony, Kolar system
	MIG	21	23	21	15	13	11	11	11	9	7	5	2	149			
	LIG	21	23	21	15	13	11	11	11	9	7	5	2	149			
50	HIG	21	23	17	15	13	11	11	11	9	7	5	2	145	435.0	13067	Medium density, Posh & planned colony, Kolar system
	MIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
	LIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
51	HIG	25	23	21	19	17	11	13	11	9	4	3	3	159	465.0	22221	High density, Posh & planned colony, Kolar system
	MIG	25	23	21	15	13	11	13	11	9	4	5	3	153			
	LIG	25	23	21	15	13	11	13	11	9	4	5	3	153			
52	HIG	21	23	17	15	13	11	11	11	9	7	5	2	145	435.0	12807	Medium density, Posh & planned colony, Kolar system
	MIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
	LIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
53	HIG	21	23	17	15	13	11	9	8	5	4	5	3	134	396.0	1143	Lowest density, rapid construction activity, partially covered by BMC water supply network
	MIG	21	23	17	15	13	11	9	8	5	4	3	2	131			
	LIG	21	23	17	15	13	11	9	8	5	4	3	2	131			
54	HIG	21	23	17	15	13	11	9	8	5	7	5	3	137	405.0	2990	Lowest density, rapid construction activity, partially covered by BMC water supply network
	MIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
	LIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
55	HIG	21	23	17	15	13	11	11	8	5	4	5	3	136	402.0	5857	Lowest density, rapid construction activity, partially covered by BMC water supply network
	MIG	21	23	17	15	13	11	11	8	5	4	3	2	133			
	LIG	21	23	17	15	13	11	11	8	5	4	3	2	133			
56	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	418.0	7275	Low density, developing, kolar system
	MIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
57	HIG	21	23	17	15	13	11	11	11	9	7	5	3	146	436.0	8514	Low density, supplying agencies BHEL, BHEL township
	MIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
	LIG	21	23	17	15	13	11	11	11	9	7	5	2	145			

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
58	HIG	21	23	17	15	13	11	11	11	9	7	5	3	146	436.0	3003	Lowest density, supplying agencies BHEL, BHEL Industrial area
	MIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
	LIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
59	HIG	21	23	17	15	13	11	11	11	9	7	5	3	146	436.0	8507	Low density, supplying agencies BHEL, BHEL township
	MIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
	LIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
60	HIG	21	23	17	15	13	11	11	11	9	7	5	3	146	436.0	1221	Lowest density, supplying agencies BHEL, BHEL township
	MIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
	LIG	21	23	17	15	13	11	11	11	9	7	5	2	145			
61	HIG	21	23	17	15	13	11	9	8	5	4	5	3	134	402.0	4899	Lowest density, developing, partially covered by MCB water supply network
	MIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
	LIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
62	HIG	21	23	17	15	13	11	11	11	7	4	3	2	138	418.0	2822	Lowest density, developing area
	MIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
	LIG	21	23	17	15	13	11	11	11	7	4	5	2	140			
63	HIG	21	23	17	15	13	11	9	8	5	4	5	3	134	402.0	10485	Medium density, BHEL, population exceeded the designed population
	MIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
	LIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
64	HIG	21	23	17	15	13	11	9	11	7	4	5	3	139	412.0	24542	High density, supplied by BHEL, population exceed the designed population
	MIG	21	23	17	15	13	11	9	11	7	4	3	2	136			
	LIG	21	23	17	15	13	11	9	11	5	7	3	2	137			
65	HIG	21	23	17	15	13	11	9	8	5	4	5	3	134	402.0	1473	Lowest density, developing, partially covered by MCB water supply network
	MIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
	LIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
66	HIG	21	23	17	15	13	11	9	8	5	4	5	3	134	402.0	3399	Lowest density, developing, partially covered by MCB water supply network
	MIG	21	23	17	15	13	11	9	8	5	7	3	2	134			
	LIG	21	23	17	15	13	11	9	8	5	7	3	2	134			

*Sum = Sum of totals of each housing type,
**density = Population density & its unit is person per square kilometer,
***WSS water supply system

Legend High water stress | Medium water stress | Low water stress

BHOPAL: WATER STRESSED AREA IDENTIFIED



Map 6.1: Map showing the water stressed area of Bhopal on the basis analysis of consumer survey.

6.7. FINDINGS OF SURVEY: The out come of 198 person surveyed is as follows.

(I) Ward No.10, 13, 14, 17, 53, 54, 55, 61, 63, 64, 65 & 66 (Total 12 Wards) are facing high water stress due to the following reasons:

a. Among above wards ward no. 10, 13, 14, 17 having very high density.

b. Distribution system of old Bhopal area is very old (approx 100 year old). So there is substantial loss due to leakages, tubewell system and inadequate O&M.

c. Ward no 53, 54, 55, 61, 63, 64, 65 & 66 are sparsely populated but distribution system are not fully developed but in developing stage.

d. No tubewells and borewells are in highly populated old city area leading to high pressure on municipal water supply.

No alternate source of water supply.

(II) Ward No. 3, 4, 5, 6, 7, 8, 9, 11, 12, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 56 & 62 (Total 39 Wards) are facing moderate water stress due to the following reasons:

a. Ward No. 8, 9, 11, 12, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26 having high population density but there is proper O & M.
b. In medium and low density area there are alternative source of water (tubewell & borewell etc) lessen the pressure on municipal supply.
c. Kolar System feed few wards.

(III) Ward No. 1, 2, 31, 32, 46, 47, 48, 49, 50, 51, 52, 57, 58, 59 & 60(Total 15 Wards) are facing low water stress due to the following reasons:

a. These wards are sparsely populated and planned colony.
b. They are served by the Kolar system (modern technology), which provide better service and adequate O & M.
c. Some of the area are posh colony so due consideration is given by BMC so good service.
d. Most of the detached housing (HIG) having their own borewell lessen the burden on BMC.
e. Alternative source are also available some of the wards.
f. People are having good civic sense they are even aware water conservations.
g. Some houses employed RWHS & reusing the wastewater for gardening purpose.

6.8. CONCLUSION: After analyzing each 66 wards, we find that more or less each ward are facing water shortages to some extent only difference is that some of them are highly affected, some of moderately & some of least affected. Pressure, quantity and duration of water supply are the main problem of the city.

Accordingly to world Bank Estimates, the average water supply in large Indian cities is only 5-6 hours a day. Which when compares very poorly with other major cities of Asia. But in Bhopal supply is only for ¾ to 1.5 hr. So no need to say about the water crisis in Bhopal. During the months of April-June all wards are facing acute shortage in the same order as discussed above.

So proposal should be aimed to fill the gap between demands and supply during moths of April-June.

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Plan for Sustainable water supply

Topics covered in this chapter

- PLANS
- POLICY RECOMMENDATIONS

CHAPTER 7

7.1. PLANS: The plans/proposals for sustainable water supply consist of four parts;

a. Implementation of Rainwater Harvesting.

b. Rectification of water supply systems of Bhopal.

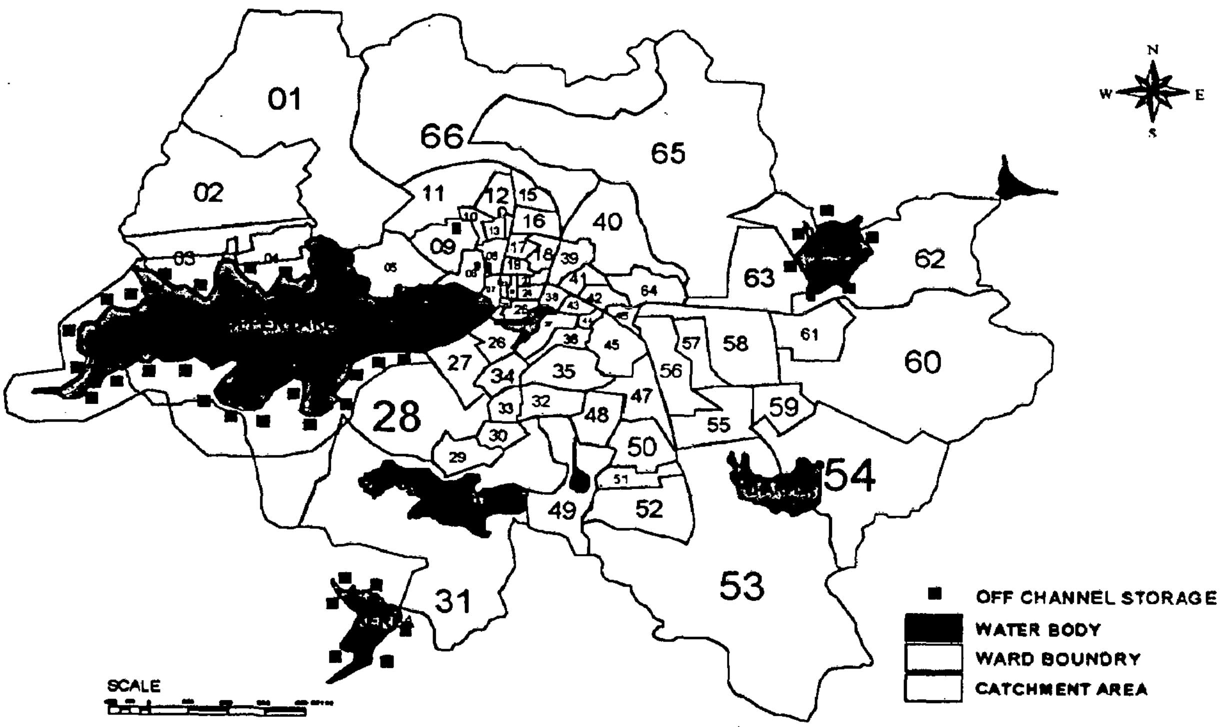
c. Recycling of wastewater.

d. Public participation & community awareness.

7.1.1 IMPLEMENTATION OF RAINWATER HARVESTING: Rainwater is the primary source of water while lakes and rivers and ground water are the secondary sources. Therefore harvesting rainwater is important for sustainable water supply. Following proposals are given to below to harvest rain.

1. Integrating Rainwater harvesting at city level planning and rooftop Rainwater Harvesting at individual level. Combination of conventional and modern technology of rainwater harvesting practice should be utilized.

Map showing off-Channel Storages & Catchment Area



Map 7. 1 Location off channel storages & catchment area of upper lake.

2. Off channel storages should be made nearby Upper Lake, Kerba Reservoir and Hataikheda. These storages will be used to store surplus water during monsoon instead of draining out. They are designed in such a manner that minimum loss due to evaporation takes place. Their total capacity should be to equal to the amount of water needed to meet drinking and cooking (5+5=10 lpcd, IS: 1172 - 1971) requirements during summer seasons. Collective capacity of all reservoirs is 3300 million liters. For detail design consideration and capacity see Appendix I.

3. **Efficient information network** should be developed among various organizations associated with water supply, water management & research and information. BMC should function, as coordinating agencies for smooth flow of information, for this a coordinating committee should be establish. To transfer to information, idea, suggestion to public a Kiosk should be setup in each 11 zone of Bhopal, with responsibility to provide information and suggestion regarding RWH & other matter related to water supply.

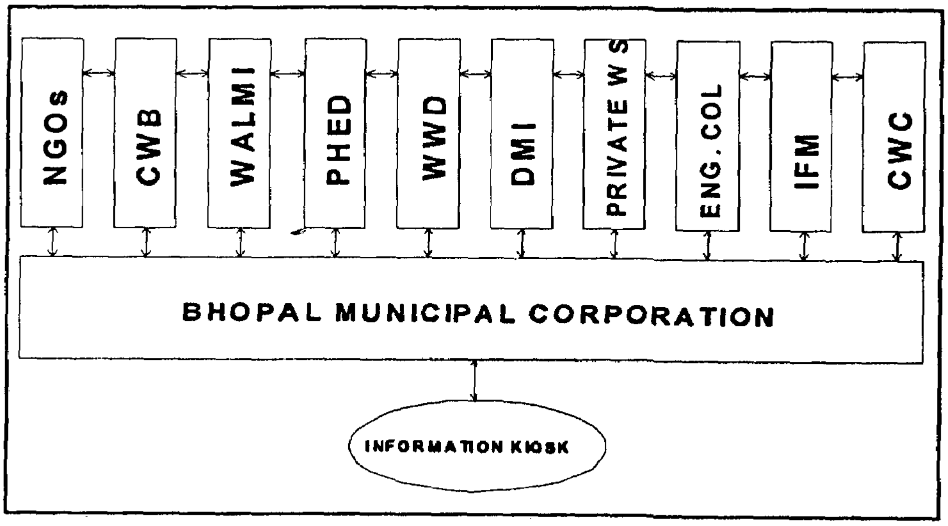


Chart 7.1 Flow chart showing the flow of information among different organization.

4. Permission for housing colony is approved only if proposal incorporate RWH and recycling and reuse of water to meet their non-potable water requirements, whether it's a Govt. project or private. These systems are maintained by housing society at own expenses. But it would be the responsibility of BMC to provide necessary suggestions and technical assistance to run system smoothly.

5. There should be the afforestation programme at the city level and plantation in sensitive area around lakes and along the roadside is necessary.

6. New development should take care of natural drainage pattern. No construction activity should be allowed in watershed areas.

7. All big institutions which are used in only during day times and their water needs are very low can divert excess rainwater to the nearby population and should be paid for

that. They can also recharge the groundwater if it is not possible to divert to the other localities.

8. Upper Lake should be preserved and maintained to keep it free from pollution.

9. Enacting legislation that promote harvesting on one hand and regulate water extraction on other hand.

10. Revised Development plan should be made, with following recommendations

- Main problem of water is only due to the to extra burden on existing source due to increase in population and new development, so a model should be developed for the new development incorporation rainwater harvesting at sector level.
- The replacing proposed landuse planning with alternate combined landuse-wateruse planning for developments, in which certain part of planning area reserved for development of new water bodies if there is no water bodies there as we reserve land for park and commercial spaces. 10% of land in new development reserve for water bodies. For detail see Appendix I.
- No new construction activity should be allowed in identified in development plan watershed areas. Those who already got permission to construct house should follow low-rise & low-density development.
- Grid of small watersheds in new and developing wards has to be proposed for efficient utilization of surface water.
- There should be separate storm water drainage to collect the runoff and leads to ponds and reservoirs. It would be then treated and supplied for non-potable uses. Hence there should be two separate water supply lines one for drinking and other for non-drinking water supply.
- Water contour map should be incorporated in development plan. On which there is demarcation of sensitive area and protected aquifer, prohibited drilling work in that area.
- 17. Recommendation made for adopting type of RWH for each wards of Bhopal considering lithology, soil type and hydrology conditions & type of development (high development, low development & planned).
- Area specific RWH plan be incorporated in development plan as below:

- In city areas or densely built up areas community level structures for harvesting rain should be constructed and the rights of the water should be given to the community itself.
- In the densely built up wards community recharge pits and storage tanks are proposed which will collect the rainwater from the rooftops of the buildings in the area. The runoff water in excess can be diverted to other open areas, where recharge facility should be provided.
- In moderate development existing buildings should make provision for harvesting of rainwater within their plot.

11. Revised building byelaws should be made, with following recommendations
    - At least 10 percent of the area in every house and building should be left unpaved. It should be made compulsory.
    - Rooftop rainwater harvesting should be made mandatory for all the new construction as well as old construction in within urban area of Bhopal, what ever the size of plot, he should adopt water harvesting either to recharge ground aquifer directly or drain out storm water to community water harvesting system, that depends upon plot size.
    - Most of the big institutions, government and private, in Bhopal are having their own water supply system from their own tubewells and resources. They are just withdrawing the water from ground and not contributing in its replenishment. Therefore it is mandatory for all the institution to harvest rain and recharge the groundwater. The ground water should not be seen as a commodity for granted. They must pay for it and participate in its enhancement.
    - Paving should be avoided in open area, if paved then it must be perforated.

IMPLEMENTATION STRATEGIES:

1. Rooftop area of each house should be calculated and a surcharged for not adopting RWHS, equal amount of wasted rainwater at the same rate at which BMC supplied water.
2. Subsidies should be given on devices to for RWH.

3. Relaxation is water tax should be given as an incentive for adopting RWH system.

4. In Bhopal there are more than 10 big parks and more the 70 small gardens in the form of road divider and roundabout etc. At present most of small gardens meet their requirements through municipal, proper Rainwater Harvesting arrangements should me made to save sufficient quantity of drinking water.

5. Some of Water harvesting structures of city should be given to the private sectors on lease to construct maintain and supply the collected water charges at reasonable rates from different sectors.

6. At present large amount of sewerage is disposed in the natural drainage due to the lack of proper sewer system in the city. These pollute the groundwater resource and the water in the channels. Ban on disposing the sewer into these natural drainage channels is recommended.

7. A remote sensing cell should me established in BMC to monitor water supply, water management and RWH, it should also used to identify appropriate location for construction of large RWH structure.

8. Depth of the Upper Lake has been reducing due to immersion of Durga & Ganesh idols, so it should be banned.

9. Motorboat should be banned, only manual or paddle-boats are allowed for recreation.

10 No boring should be permitted without prior permission of the Sub-divisional Magistrate.

7.1.2 RECTIFICATION OF WATER SUPPLY SYSTEMS OF BHOPAL:

1. Metering system had removed in Bhopal due to lack of maintainace and irregularities in water bill. It should be adopted again used with modification in order to remove previous defects (*V Suresh*, 2001).

2. Digital electronic meter should be developed and used in placed of traditional mechanical meter which was fixed to service main and placed inside a pit, often dark and damp attracting shanks and frogs. But this meter can be placed any where in the home like electric meter. Which would be easy to check and difficult to manipulate.

3. From Kolar Reservoir to Bhopal water has supplied through single pipe, any cut off of supply, be it due to power failure or maintainace work, wreck havoc on the city. So it show be supplied by double pipeline.

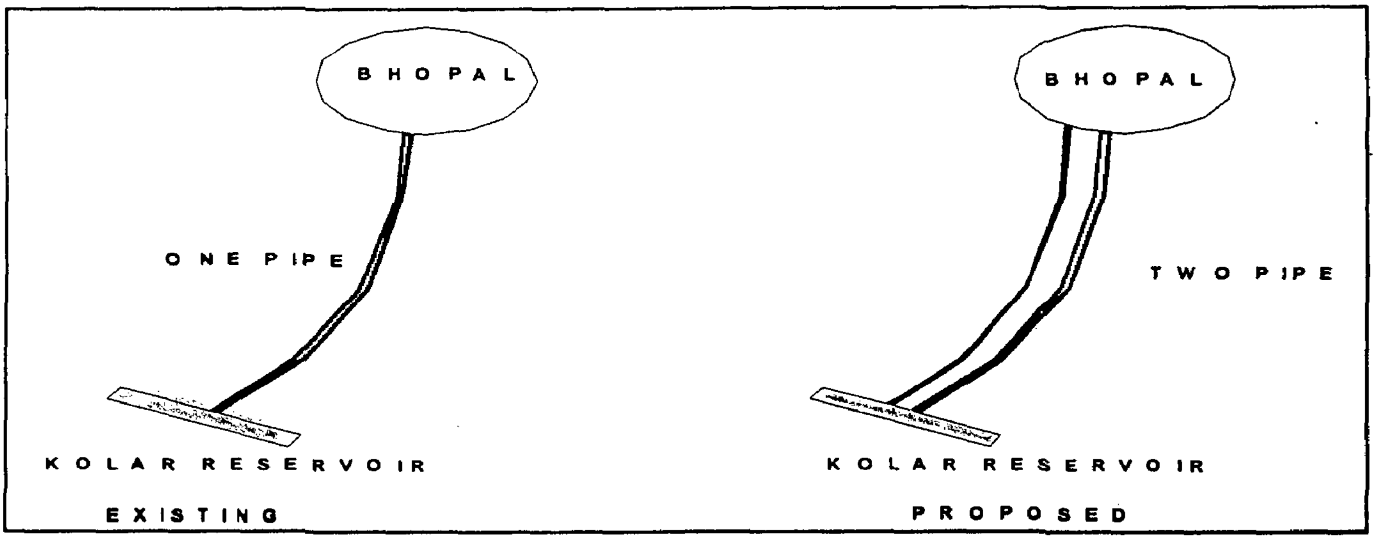


Figure 7.1 Two-pipe systems form Kolar Reservoir to Bhopal city to be proposed.

4. Large mass of city living without having property right, their share does not considered into design of water supply system but they are using considerable amount of water, which leads to shortage. Hence these population must be given due consideration while designing a water supply system of an area.

5. Some consumer gets favorable topography and connections allow then to get plentiful quantity of water with excess pressure, while others less fortunate receive less then the recommended bare minimum rations of 20 lpcd. So such locations are identified and boosters should provided to ensure uniform water supply to each household.

6. Financial condition of Water supply department should be strengthen. Tariff fixation should be based on average incremental cost including O & M expenses, depreciations charges, debt & dues etc.

7. Older distribution system should be renovated after detailed study, appropriate design and quality execution on Top Priority i.e. even before augmentation of quantity, in some specific area for smooth water supply.

8. At present 75% of the connections are without ferrules (source: NCHSE Bhopal). All connections must be with ferrules.

9. 7500 public stand post (without ferrule connection) in slums and mostly without taps, resulting considerable amount of wastage and pollution. Provide ferrule connection on all such stand posts. Provide heavy duty CI taps (old Rly type) welded with pipe. Citizens local committee to act as Watch dog and provide for penal action / fine on the beneficiaries, in case of default. . Provide a small SR./cistern with taps instead of direct connection on the distribution.

10. Mostly from old distribution pipes, joints, and valves and also from pumping mains causing wastage and pollution. So leak detection studies be taken up now, i.e. before *renovation and defects rectified. Such studies are to be entrusted to competent agency of* repute with sound knowledge and experience.

11. O & M of water supply system should be improved.

12. Dual distributions system should be applied in the new development, in which separate supply lines would be furnish potable water for drinking, cooking, bathing and laundry, while used water would be furnished for toilet flushing and irrigation of lawns and garden.

IMPLEMENTATION STRATEGIES:

1. A notice should be issued to all consumers to install Electronic water meter within stipulated date, if someone fail to do the same a fine should be imposed.

2. A notice should be issued to all consumers to install Electronic water meter within stipulated date, if someone fail to do the same a fine should be imposed.

3. BMC should direct the PHED to make estimates to layout another pipeline from Kolar to Bhopal city for water supply. After finalisation of total estimates, and evaluation of economical viability of the project green single will be given for implementation of the project.

4. BMC should invite a bid for purchase of Electronic Water Meter and it's also his responsibility to install to every consumer.
5. BMC has to assess the actual water requirements in each ward. On the basis of observation, quantity of water to be released in respective ward revised.
6. A plan should be prepared showing the distribution network and topography of Bhopal so that each favourable and unfavourable condition regarding water supply should be identified. Renovating the existing distribution system & attempt should be made to provide ferrules on all connections. These ferrules are then adjusted as to provide equitable pressure distribution as far as possible.
7. Tariff should be revise time to time it should be based on full cost recovery and also based on principal of sectorisation and fragmentation

   For instance, a HIG, which consumes vast quantities of water for washing cars, landscaping and recreation and supplied water at the same rate as the LIG, which consumers a limited amount of water one note that rate chart specifies users as commercial, domestic & industrial. Govt. rate has been fixed, 150 Rs per month for domestic use but the classes of domestic users are not mentioned. Thus we can say that quantity and rate of water supply is not related to economic stratification of urban communities, the poor often paying more for few buckets of water.
8. Remote sensing technique help lot identify the trouble area which require to renovate.
9. Special training should be given to engineer other staff of water supply department to improve their standard.
10. Distribution system of city are more than 100 years old & one of the factor for considerable loss of potable water and scarcity. So new supply should be laid and older one can utilize to supply water for non-potable purpose

7.1.3 RECYCLING OF WASTEWATER:

1. For irrigating crops, horticulture, watering public lawns/garden, flushing of sewers, fire-fighting etc. reclaimed water should be used.
2. For new establishment like Housing colony, Industries, Institutions and large commercial establishment, permission is only given if they ensure competent authority that they can utilized reclaimed water for their non-potable proposes.
3. New technology should be introduce to recycle and reuse of waste water.

IMPLEMENTATION STRATEGIES:

1. State govt should create urban development fund for urban infrastructure development and the same can also used for setting up of pilot projects for waste reuse and recycling.
2. Awareness should developed the understand importance of recycle and reuse of rainwater. For this it will be necessary to understand each and every aspects of water recycling and its positive effect to environment and socio-economic condition of city.
3. Incentives should be given to those who adopt recycle of wastewater. Incentives may be in the form reduction in water tax.
4. Districtwide programme should be made to demonstrate the success of recycle and reuse of waste-water.
5. Success stories should be disseminated through media (T. V., Radio, Internet, Newspaper so that the same may be replicated.

7.1.4 PUBLIC PARTICIPATIONS & COMMUNITY AWARENESS:

1. People's participation and social acceptance is essential for success of rainwater harvesting projects. This is the best way to mass awareness for popularizing water management practices.
2. Projects/schemes related to water management be evaluated and success stories should be disseminated through media (T. V., Radio, Internet, Newspaper etc), so that the same may be replicated.
3. Women participation should be necessary in water supply system, so that they understand each and every aspect of supply how to save water. It's also important due to fact that women are the main consumer of water.
4. From the experience of Pani Panchayat working in Purandhar tehsil of Maharastra, we can learn various lessons, some of them with little modification can be implemented in Bhopal. The following recommendations shall be useful at the community level (Anil Agrawal, 2003)
   - Water should be shared on the basis of the number of family members and not size of landholding: In this way we can incorporate the principle of equity.
   - Water right should not accompany land rights. If the land is sold, the water rights revert to the group.

- Beneficiaries must share, in cash, a total of 20 percent of the capital cost of any water-harvesting project in the area according to their water share, before the commencement of the project. People's participation is thus ensured. The balance 80 percent should be given by the Government and other agencies as an interest free loan to be paid in five years.
- Uses other than residential should not be permitted in the area, which consume more water.
- Slum dwellers should also get a share of the water so that they can share the labour in the project. This helps them to get employment in the area itself and checks unemployment.

5. District-wide demonstration projects in selected areas to provide useful information.

IMPLEMENTATION STRATEGIES:

1. There should be a committee formed in each ward, which should take care of the water management of local area and maintain the local water harvesting structures.
2. Project beneficiaries should administer, manage and operate the scheme, this will foster the felling self-reliance among the communities.
3. For any proposal only group scheme should be taken.
4. Introducing of RWH as a new subject in IX-X syllabus as disaster management has introduced in CBSE syllabus.
5. Success stories people participation and community awareness should be disseminated through media (T. V., Radio, Internet, Newspaper so that the same may be replicated.

7.2 POLICY RECOMMENDATIONS:

1. For augmenting water supply focus should be given of resource management rather than resource creation.
2. Promotion of decentralization of water supply by encouraging RWH in urban development.
3. Protection of catchments area of lake system should given top priority in the development process of the city.
4. RWH project should not implement without proper investigation, simulation and public participations.

5. Multidisciplinary approach including hydrogeological, remote sensing hydrological and geophysical aspects need to be adopted for designing rainwater-harvesting sachems.
6. Secure water supply for emergency.
7. Promotion of research in field Rainwater harvesting – research that is people oriented rather than technology.
8. Pricing policy should be based on cost recovery, but always follow the principle of "NO LOSS NO PROFITS". It should be revised after each five-year period.
9. Use of water connection without ferrule is al legal offence.
10. BMC has to made collaboration with other water supply agencies of other states to technology transfer and upgradation existing distribution system.
11. It should be mandatory in Phases that large industries and commercial establishment must meet a sizeable percentage of their non-potable water requirements.
12. An amendment in the municipal byelaws for irrigating crops, horticulture, watering public lawns/garden, flushing of sewers, fire-fighting etc. reclaimed water should only be used fresh water used for domestic proposes.
13. It's mandatory to publish/to show/to transmit any information related to water supply, RWH and recycle and reuse of waste water thorough New papers/TV/Radio at free of cost for public interest.
14. The aim of the Master Plan for Bhopal should be towards model ecocity (According to Japanese Architect Koichi Nagashima, an ecocity is one, which aims at a degree of self-sustainability within its own ecology system.

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Conclusion

Topics covered in this chapter

- CONCLUSION

CHAPTER 8

8.1 CONCLUSION: To sum up it may be said that only last few decades have focused our attention to the problems of water shortage which we are likely to face in the next few decades at national level but in case of Bhopal it's too late, we wakeup in 2002 and realized the importance of rain, when city suffering from acute shortage of water due to short rain fall since 1998. Nature and intensity of problem of water quality & quantity varies from wards to wards in the city, but our effort should have to augment total water supply. We have to look in all directions, but incorporate such solution only, which are specific to particular situation, and it should also technically viable, economically feasible and socially accepted. Need of hours is to focus on resource management rather than resource creation. Strategy and planning towards Rainwater harvesting and recycle and reuse of water can help to reduce pressure on the available limited sources of drinking water supply. It is not possible to claim to achieve 100% success in first attempt but I sure by adopting plans, which I proposed we must get substantial result.

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- APPENDIX
- REFERENCES
- BIBLIOGRAPHY

APPENDIX - I

A. Calculation to find out the capacity off-channel storage reservoir for year 2021	
Average water requirement for drinking & cooking (in litre) (drinking 5 lpcd, cooking 5 lpcd)	10
Main shortage during April to June, total 91 days therefore design period = 100 day.	
Tanks are design to meet a demand of one year	
Total water requirement of city to meet drinking & cooking and cooking requirements (in Litre)	2184738000
Total quantity of water in cubic meter	2184738
Safety factor 50%	
Total quantity of water in cubic meter	3277107
Volume of one tank (250x20x20) (in cubic meter)	100000
Total no of tanks	32.77107
Therefore, Total no tanks	33
Collective Volume of all 33 tanks (in cubic meter)	3300000

These tanks are constructed near by lakes and connect with lakes by channel. Longer side along north-south axis, and plantation on both sides to reduce evaporation daytime.

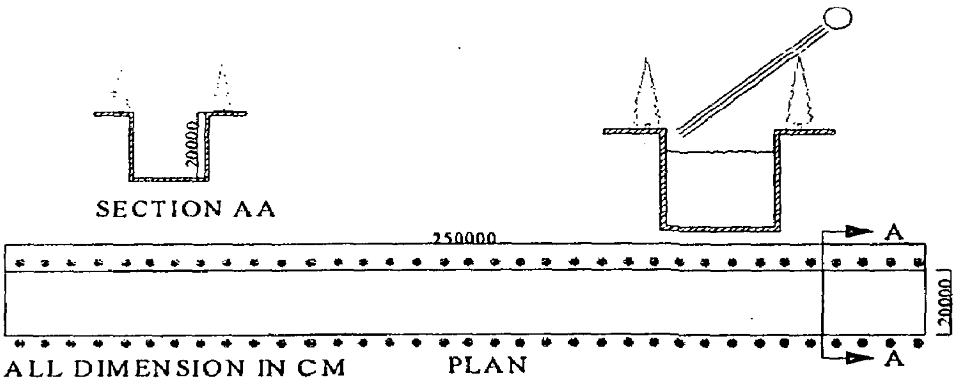


Figure showing plan & section of tank

B. Calculation of Percentage of Water Bodies in Model Development	
Suppose the area of a Mode development	1sq. Km
Rainfall received by it	1209000
Rainfall captured at the efficiency of 50%	604500
Suppose the avg depth of Water bodies	6 metre
Area of water body	100750
% of water body in Model	10.075
% of other landuse	89.925

If 10.07 % land will be reserved for water bodies then it would arrest 50% of total downpour, which help to augment water supply also check urban flood during rainy season. Other use includes (Residential, commercial, public semipublic, transport, recreation, public utility, and industry.

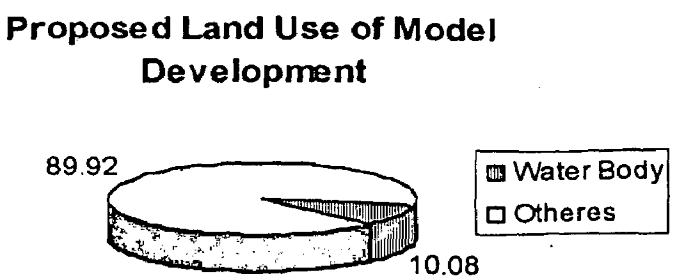
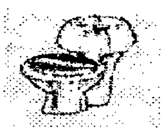
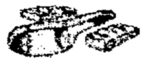


Chart: show the landuse patter of model development.

APPENDIX II

WE SHOULD CHANGE OUR HABIT OF USING WATER

GENERALLY WE DO		WE SHOULD DO		SAVING
USING SHOWER FOR BATH (180 L)		USING BUCKET FOR BATH (18 L)		**162 L**
USING TUB & TAP FOR BATH (25 L)		USING BUCKET FOR BATH (18 L)		**7 L**
USE OF TOILET FLUSH (20 L)		USE OF SMALL BUCKET FOR TOILET (5 L)		**15 L**
SAVING WITH OPEN TAP (10 L)		SAVING WITH WATER IN MUG (1)		**9 L**
MOUTH WASH WITH OPEN TAP (10 L)		MOUTH WASH USING MUG (1 L)		**9 L**
WASHING CLOTH BY OPEN TAP (116 L)		USING BUCKET FOR WASHING CLOTHS (18 L)		**98 L**
WASHING VEHICLE WITH TAP (25 L)		WASHING WITH DAMP CLOTH (18 L)		**7 L**
WASHING FLOOR BY USING PIPE (50 L) (15 x 10 FT)		WASHING FLOOR BY USE OF BUCKET (10 L)		**40 L**

IF WATER IS LEAKING FROM AT TAP AT THE RATE OF ONE DROP PER SECOND THEN NET LOSS IS 17 L IN A DAY

APPENDIX – III

DEPARTMENT OF ARCHITECTURE AND PLANNING, IIT, ROORKEE –247667

Thesis title: Planning Proposals for Sustainable Water Supply For Bhopal

Survey Questionnaire

(Information collected will be confidential & entirely used for the academic purpose only)

Name of Area: ____________________ Surveyor: **Manish Kumar Verma** Ward
No. ____________________ MURP-II. IIT-Roorkee.
Flat No. ____________________ Address House of B. P. Saini (SBI)
Name of head of family____________________ Garam Gadhha Road
Date ______Time______ Survey No.________ Bhopal, Ph: 0755-2730032(R)
Ownership status: Govt. accommodation ( ) Rented accommodation ( ) Own house ( )

1. HOUSEHOLD INFORMATION

How many members are there in your family? Male_____ Female_____ Total_____
How many members are working?

Age (Years)	<18	18-24	>24
No of Members			

2. INFORMATION RELATED TO HOUSE

House Type	HIG		MIG	LIG
Occupancy	Numbers			
	1	2	3	More than 3
Habitable Rooms				
Bath				
W.C				
Plot area (Sq.ft)	<1500	1500-2600	>2600	
Built up area (Sq.ft)	< 1500	1500-3000	3000-4500	> 4500

3. INFORMATION RELATED TO WATER SUPPLY

Months	Nov-Feb	March-June	July-Oct
Consumption (lpd)			

Storage Tank	Yes	No	Under ground	OHT
Capacity (liter)	<500	500-1000	1000-1500	>1500
Frequency of Water supply		Once in a day	Twice in a day	Alternate day
Duration of water supply		< 1.5 hr	1.5 - 2.0 hr	> 2.0 hr
Supplying agency		BMC	PHED	BHEL
Depth of hand pump/bore well		<100'	100-150'	>150'
Other source of water		Community HP/Tap	Lakes	Tanker
Distance of other source		<0.5 km	0.5-1.0 km	> 1.0 km
Is any arrangement of water recycling		Yes	No	
Rainwater Harvesting		Yes	No	
Water connection (ferrule size)		½"	¾"	1"
Expanses on water other than municipal bill		Mineral Water	Bore well	Tanker
What is the mode of disposal of waste water			Sewerage	Septic tank

4. PROBLEMS RELATED TO WATER SUPPLY

Shortage of Water in month of		
Pressure	Insufficient	Sufficient
Quality	Poor	Good
Quantity	Insufficient	Sufficient

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