DESIGN GUIDELINES FOR SUSTAINABLE WATER MANAGEMENT IN HOUSING

A DISSERTATION

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

MASTER OF ARCHITECTURE

By

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the dissertation entitled **"GUIDELINES FOR SUSTAIBABLE WATER MANAGEMENT IN HOUSING "** in partial fulfillment of the requirements for the award of the Degree of **MASTER OF ARCHITECRURE** and submitted in the Department of Architecture and Planning of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out for a period of about one year from July 2007 to June 2008, under the supervision of **Dr. Mahua Mukherjee,** Assistant Professor and **Dr. Pushplata,** Associate Professor, Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee.

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

Dated: 26th June '08

Place: Roorkee

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CERTIFICATE

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

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ABSTRACT

Water management in built environments particularly in the urban areas is a major challenge facing architects, town planners and the city manager the world over. India, like many other countries is likely to face acute water scarcity. It is estimated that increase in demand of water on account of population growth; increases effluence and existing shortage along with depletion of aquifers; reduction in sources of water (surface and subsurface); grossly adequate and inefficient water infrastructure in most of the cities coupled with climate change and ground water conflicts in some areas is likely to result in water crisis.

Since buildings consume large amounts of resources and produce wastes in their process of construction, maintenance and use their proper management become crucial and more so in cases of housing, which form the bulk of buildings in all cities. Sustainable water management in housing not only makes a significant contribution to sustainable development in general but also improves quality, durability and cost effectiveness of housing on one hand and reduces the adverse impact of building on natural environment.

The thesis aims at insuring water efficiency along with optimum utilization of energy resources, materials, waste management, indoor air quality and use of sustainable site is crucial for making sustainable building. Sustainable water management in housing involves reduction in water use by conserving water through use of appropriate/ water efficient fixtures and fittings; rainwater harvesting, recycling of wastewater at micro level (building and area level), water smart landscaping i.e. Xeriscape and watershed management at macro level.

This thesis will culminate towards a construction of theory/design guidelines for Sustainable Water Management in housing by taking a case of Sahara States Housing in Lucknow. Universality of this research finding will also help in framing guidelines for Sustainable Water Management in housing for India as a whole.

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ABBREVIATIONS

CSEB	Compressed Stabilised Earth Blocks
GPCD	Gallons Per Capita Daily
LPCD	Liters Per Capita Daily
MLD	Master Plan of Delhi
MPD	Millions Litre per Day
NMC	National Media Centre Co-Operative Housing
SUDS	Sustainable Drainage System
SW	Sustainable Housing
SWM	Sustainable Water Management
WELS	Water Efficiency Labelling and Standards
WSAA	Water Sensitive Urban Development
WSUD	Water Services Association of Australia
WTS	Wastewater Treatment Systems

Organizations

CPCB	Central Pollution Control Boards
CPHEEO	Central Public Health Engineering and Environmental Organization's
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature and Natural Resources
MINARS	Monitoring of Indian Aquatic Resources programme
UNEP	United Nation Environment Program
WCED	World Commission on Environment and Development
WWF	World Wide Fund for Nature

This chapter introduces the present scenario of the sustainable development and the need of sustainable housing. It deals with the process of selection of topic after problem identification; framing aim, objectives, scope and limitation for the thesis. To attain the set aim and objectives, methodology and organization of thesis have been worked out.

CHAPTER 1

INTRODUCTION

"The Wars on the next century will be on waters."

\- **Ismail Serageldin.**

V. President, World Bank (1992-2000)

1.1 BACKGROUND

Buildings, in their process of construction and execution have the drastic effect on the environment. They consume large amount of non-renewable resources and emit greenhouse gases which leads to greenhouse effect and global warming. These two are the major problems day's today world. To tackle these problems *Sustainable Development* is the keyword. Site, energy, water, materials, waste and community are the major issues in sustainable developments. Water management is a major and crucial challenge faced by the professionals' world today, be it town planner, builders or architects. The availability of water particularly for drinking and domestic use, is a critical concern on account of the increasing population, contamination of water supply sources (both surface and ground water), depletion of water table and higher living standard. Management of water in Housing in particular can make a significant contribution to sustainability because it consumes large amounts of resource in its construction, maintenance and use, it is a fixed asset with a long life and it is central to quality of life and has implications beyond housing affecting transport, health, employment, community and environment.

1.2 PROBLEM IDENTIFICATION

Planning and design of built environment consists of two approaches i.e. Present and Sustainable approach. *(Krishan A., 2007)* Present approach to habitat/building is linear, resulting in waste of all natural (water, air, energy, materials, etc) and man-made resources, while the sustainable one is based on the understanding of the cyclic nature of earth's ecosystem and natural resources that flow as a generic part of the habitat/building (Fig.1.1). In present approach resources are consumed and the outcome is the production of waste, which is again difficult to handle and further creates problem. In sustainable approach, which is inspired by the earth's ecosystem, it is believed that every thing on earth has its own life cycle, thus making the earth sustainable. Human beings interfere in that and disturb the whole life cycle of the earth, which create imbalance and destroy the ecosystem. By applying the sustainable approach to the buildings we can regain the life cycles of the resources and again can bring the earth to the stable conditions.

The World Bank estimates that by the year 2025 one person in three, in other words 3.25 billion people, in 52 countries will have condition of water shortage. As per the world wide water development Report *(www.worldbank.org/ World Bank urges action to manage water scarcity.pdf)*, by the middle of this century, at worst seven billion people in 58 countries will be faced with water scarcity, at best two billion in 48 countries will be faced with water scarcity, depending on population growth and policy making. Climate change will account for an estimated 20% of this increase in global water scarcity. Global consumption of water is doubling every 20 years and billion people already lack access to fresh drinking water. Hence, now it's high time, some action should to be taken to have sustainable management of water.

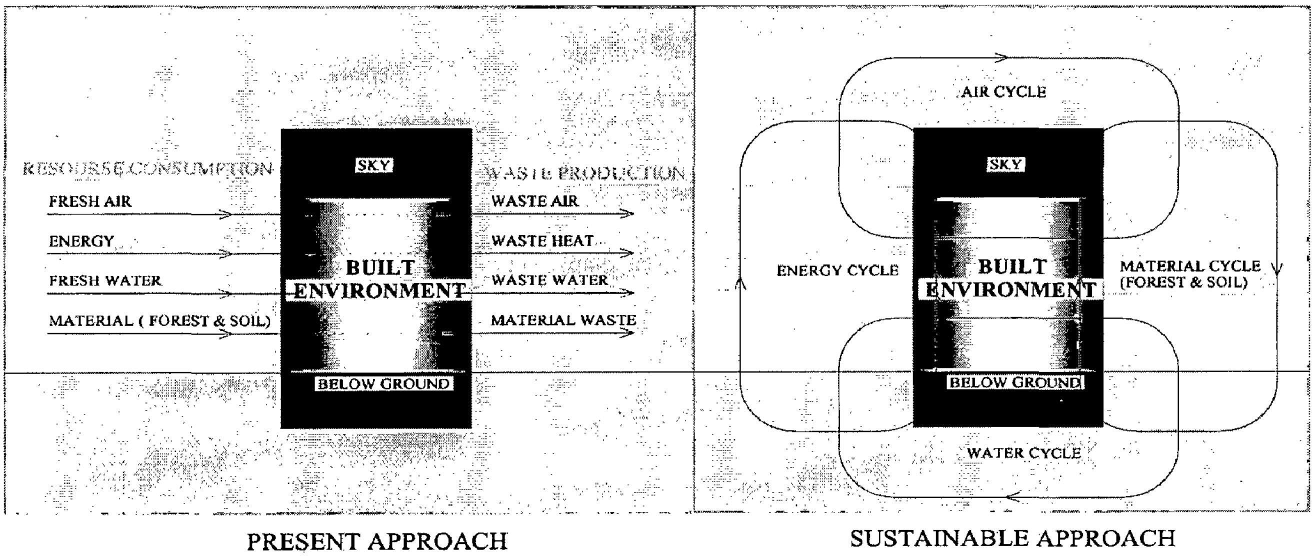


Fig 1.1: Approaches to Planning and Design of Built Environment

India is likely to face a turbulent water future. Unless water management practices are changed – and changed immediately – India will face a severe water crisis within the next two decades and will have neither the cash to build new infrastructure nor the water needed by its growing economy and rising population. A draft World Bank report *(Briscoe, 2001)*, examines the challenges threatening the India's water sector and suggests critical measures to address them. These are Crumbling Water Infrastructure, Depleting Groundwater, Growing Water Conflicts and Climate Change. There is clearly an urgent need for action. First, India needs a lot more water infrastructure. Secondly, policies and practices have to come to grip with the challenges of the future.

1.3 AIM

The thesis aims at, to understand and analyze issues related to sustainable water management in housing in developing countries like India and to frame guidelines for the same.

1.4 OBJECTIVES

To attain the set aim of the thesis, various objectives have been formalized. These objectives are to:

i. Understanding issues related to sustainable development and sustainable housing.
ii. Identifying/selecting one of the important issue related to sustainable housing.
iii. Understanding and analyzing the methods and techniques of sustainable water management in housing.
iv. Exploring the modern trends and methods of sustainable water management in housing.
v. Study of one of the selected housing in Luckow and framing guidelines for the study area making it sustainable with respect to water.

1.5 SCOPE AND LIMITATION

Study will be limited to the environment issues of sustainability encompassing issues like optimum usage, conservation, replenishment and management of nonrenewable resources. This will be done as a whole to the part concept, wherein the sustainable development understood at global level then at the country level i.e. India and then at the city level. The study is limited to the one housing schemes in Lucknow.

As the guidelines will be according to the study of Lucknow, it may not be applicable to the whole country. The study is limited to sustainable water management whereas there are so many other issues related to sustainable housing, soil, air, etc which integrally contributes towards total sustainable development.

1.6 METHODOLOGY

The following methodology (Fig 1.2) has been framed out to attain above-mentioned aim and objectives:

1. After selection of topic, literature review has to be done to frame aim, objectives, scope and limitations. To attain set aims and objectives, methodology and organization of thesis has to be done.
2. Identification and selection of one of the important issue related to sustainable housing i.e. sustainable water management, its importance in housing and community as a whole has to be established.
3. Review of available relevant literatures on the methods and techniques of sustainable water management in housing to understand and analyze the pertinent issues would be conducted.
4. Case studies of the exemplar practices with respect to management of water sustainably would be analyzed according to the literature review done previously.
5. Selection one the housing in Lucknow and identification of the problems and issues related to sustainable water management would be the next step.
6. Framing design guidelines for the selected housing project in Lucknow, to make it sustainable with respect to water is to followed next.
7. Finally, conclusion and recommendations in general for sustainable water management in India would be suggested.

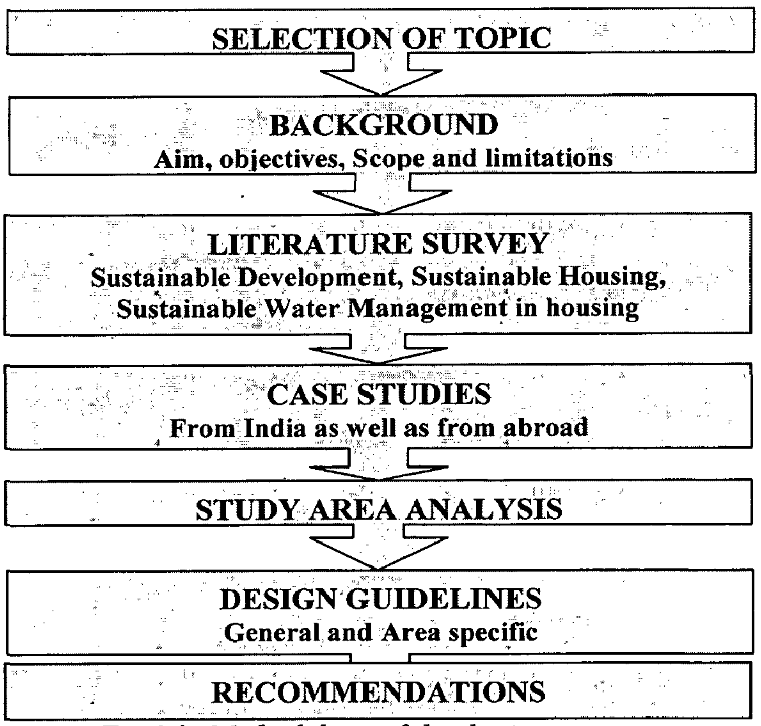


Fig 1.2: Methodology of the thesis

1.7 ORGANISATION OF THE THESIS

The thesis has been organized into **four sections. Section one** sets the background of the thesis, establishes the need of the study, selection criteria of the topic and defines aim and objectives of the thesis. It also includes the methodology and organization of the thesis to achieve the set goal. **Second section** comprises of review of literature, in which various aspects of sustainable development and sustainable housing are discussed. Sustainable water management and issues related it are studied and analyzed. Selected case studies are done to out the different methods and techniques of water management in housing in India as well as in abroad. Selection criteria of Study Area has been discussed in **section three** with the identification of the problems related to water, water supply and demand and present scenario of water management in the housing. In **section four**, design guidelines for sustainable water management in housing would be given first in general and then study area specific and finally framing the recommendations. These four sections are divided into **seven chapters.**

Chapter one introduces the present scenario of the sustainable development and the need for the study of sustainable housing development. It discusses the aims, objectives, scope and limitations of the thesis. The later part of the chapter provides with the methodology and the organization of the thesis.

Chapter two discusses the sustainable development, various viewpoints related to it and the three dimensions of sustainability. It further gives an idea about the issues of sustainable development. The environmental sustainability and the various other concepts similar to it have been included in this chapter. Issues of sustainable development have been identified and water management as one of the crucial one. The interrelationship between housing and sustainability is also discussed. **Chapter three** will deal with the sustainable water management in general and the with respect to housing. Various aspects and measures would be studied and analyzed in this chapter for their implementation to make housing sustainable with respect to water. Case studies of the exemplar practices with respect to management of water sustainably are included in **Chapter four**. Analysis will be done according to the literature review done on sustainable water management in hosing.

Chapter Five is about the Project area case study. This chapter deals with the study of one of the housing of the Lucknow. The present trend of housing scheme in

Lucknow, finding out the shortcomings and analyze it with respect to the issue of management of water are the prime features of this chapter.

Chapter Six will formulate the design guidelines for the country and for the selected housing project in Lucknow, to make it sustainable with respect to water. **Chapter Seven** deals with the overall conclusion and recommendations in general for sustainable water management in India; and scope for the future study.

Definitions of sustainable development, various viewpoints related to it and the three dimensions of sustainability are discussed in this chapter. It further gives an idea about the issues of sustainable development. It explains the interrelationship between housing and sustainability and environmental sustainability and the various other concepts similar to it. Issues related to sustainable development have been explored and water management has been identified as one of the crucial one.

CHAPTER 2

SUSTAINABLE HOUSING

"Water is the most basic of all resources. Civilizations grew or withered depending on its availability."

Dr. Nathan W. Snyder,
Ralph M. Parsons Engineering

2.1 SUSTAINABLE DEVELOPMENT

2.1.1 General

"Sustainable development is development which meets the needs of the present without compromising the ability of future generation to meet their own needs." This definition has been formulated by the World Commission on Environment and Development *(WCED, 1987),* led by the Norwegian prime minister Gro Harlem Brundtland, in 1987. The definition is based on two concepts, the concept of *needs*, comprising of the conditions for maintaining an acceptable life standard for all people, and the concept of *limits* of the capacity of the environment to fulfill the needs of the present and the future, determined by the state of technology and social organisation.

2.1.2 Definitions of Sustainable Development

Many other definitions of sustainable development have also been offered, both general and specific. The following definitions illustrate the variety of foci evident in discussions of sustainable development.

> *"It improves the quality of human life while living within the carrying capacity of supporting ecosystems."* *(Gland, 1991)*

> *"It uses natural renewable resources in a manner that does not eliminate or degrade them or otherwise diminish their renewable usefulness for future generations while maintaining effectively constant or non-declining stocks of natural resources such as soil, groundwater, and biomass."* World Resources Institute, Dimensions of sustainable development (*World Resources, 1992).*

> *"It maximizes the net benefits of economic development, subject to maintaining the services and quality of natural resources."* (*Goodland and Ledec , 1987)*

> *"It is based on the premise that current decisions should not impair the prospects for maintaining or improving future living standards. This implies that our economic systems should be managed so that we live off the dividend of our resources, maintaining and improving the asset base." (Repetto R., 1986)*

2.1.3 Aspects of Sustainability

Sustainable development does not focus solely on environmental issues. More broadly, sustainable development policies encompass three general policy areas: economic, environmental and social. In support of this, several United Nations texts, most recently the 2005 World Summit Outcome Document (*http://en.wikipedia.org/wiki/Sustainable_development)*, refered to the "interdependent and mutually reinforcing pillars" of sustainable development as economic development, social development, and environmental protection (refer Fig2.1).

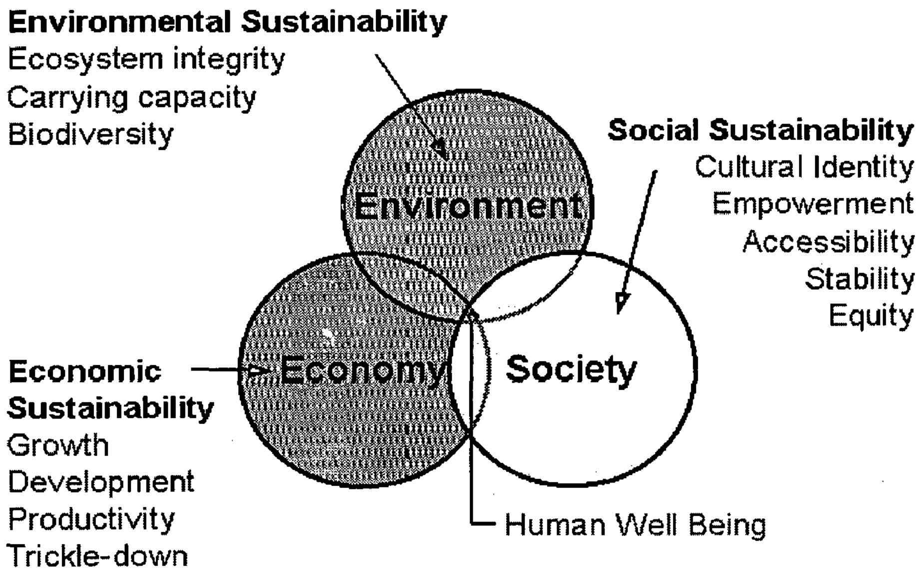


Fig 2.1 Aspects of sustainability
Source: http://en.wikipedia.org/wiki/Sustainable_development

Economic dimensions of sustainability include cost reduction through efficiency improvements and reduced energy and raw material inputs and creation of additional added value. **Social dimensions of sustainability** include worker health and safety, impacts on local communities, quality of life and benefits to disadvantaged groups e.g. women, children, disabled, etc. **Environmental dimensions of sustainability** include reduced waste and effluent generation, lowering emissions to environment, reduced impact on human health, use of renewable raw materials and elimination of toxic substances.

2.2 SUSTAINABLE HOUSING

2.2.1. General

Sustainability of housing is an issue of rising importance in India. Increasing concerns about climate change and water supply shortages have focused attention on the need to design energy and water efficient homes. Population growth in India adds further impetus to the need of sustainable housing. Sustainable Housing (SH) has the potential to produce good quality housing at a price that is affordable both in the short and long term. The concept has been around for a number of years now; however its application to housing has been slow. Sustainable housing project incorporates economic, social and environmental issues in the planning and design stages with the aim of providing a building that is affordable, accessible and environmentally sound.

2.2.2 Interrelationship between housing and sustainability

The relationship between sustainability and housing is two-way. Incorporating principles of sustainability into housing development, maintenance and refurbishment will not only make a significant contribution to the achievement of general sustainability objectives, but will also provide important advances in the quality, durability and cost effectiveness of our housing

2:2.2.1 Contribution of housing towards Sustainability

Housing contributes towards sustainability by minimizing climate change, reducing the need for physical resources and ultimately creating sustainable settlements. *(Stevenson F. and Williams N., 2000)*

i. Minimizing climate change

The most widespread and potentially damaging environmental problem at present is global climate change as a result of the emission of greenhouse gases, notably carbon dioxide. This would be damaging to agriculture and the tourist industry and increase the risks of flooding. The housing sector has an important role to play, both in terms of dwelling characteristics and the structure and location of residential developments.

ii. Reducing the need for physical resources

By improving the way of design, taking into consideration the principles of sustainability, the use of materials can be reduced. Recycled materials would reduce the need for quarrying and other source activities. "Managing the use, development and protection of natural and physical resources in a way, or at a rate which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety while safeguarding the life-supporting capacity of air, water, soil, and ecosystem; and avoiding, remedying or mitigating any adverse effects of activities on the environment." *(Stevenson and Williams, 2000)*

iii. Creating sustainable settlements

The single biggest source of greenhouse gases is the transport sector and emissions from transportation system can be significantly reduced by planning and building in such a way that travel is reduced, and where necessary can be achieved by keeping province for walking, cycling or public transport. Housing should be located close to employment and services and also near to public transport. The co-operation of housing developers, land use planners and transport planners will be crucial to ensure maximized accessibility and minimized car dependency.

2.2.2.2 Benefits to Housing through Sustainable Development

In the previous sections, contributions of housing towards sustainable development objectives have been discussed. This is a two-way process because the most cost-effective way to develop and maintain a high quality housing stock in the long term requires incorporating principles of sustainability into all parts of the housing development process. Since new building comprises only a small fraction of the existing stock, it is also important that refurbishment incorporates sustainability principles. *(Stevenson and Williams, 2000)* Sustainable housing enables environmental, social and economic well-being. (as shown in Fig. 2.2)

i. Environmental

"Environmental sustainability is defined as the ability of the environment to continue to function properly indefinitely. This involves meeting the present needs of humans without endangering the welfare of future generations. The goal of environmental sustainability is to minimize environmental degradation, and to halt and reverse the processes they lead to." (*Thomas and Fordham, 2005*)

An "unsustainable situation" occurs when natural capital (the sum total of nature's resources) is used up faster than it can be replenished. Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally. Theoretically, the long term result of environmental degradation would be local environments that are no longer able to sustain human populations to any degree. Such degradation on a global scale could imply extinction for humanity.

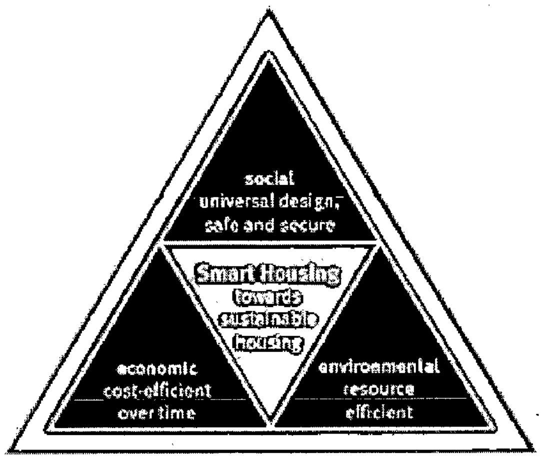


Fig 2.2 Benefits of Sustainable Housing
Source: http://en.wikipedia.org/wiki/Sustainable_housing

ii. Social

The problems of the large peripheral schemes of our major cities are testament to the importance of building communities rather than merely groupings of dwellings. A sustainable housing development would not only have environment friendly and energy efficient buildings, it would also have access to employment, schools, shops, places of entertainment, primary health care, and it would be accessible by public transport. It would be mixed in terms of tenures, incomes and age groups. For a house to be a home it must be geographically located such that its inhabitants can use it as a base from which to enter society at large; it must facilitate social inclusion and not be a mechanism of social exclusion as many Indian housing have been in the past. Scale is an important dimension of sustainability. Housing developments should not be so large that they alienate the people who live in them. Residents should be given the opportunity to take responsibility for their environment whether they are tenants or owner occupiers, and this is only possible when they live in developments or management units which are small enough for this to be practicable. Residential development which is designed to contribute to sustainability will provide not only healthy homes and reduce the need to travel, but also a setting which enhances quality of life from generation to generation and which integrates people into society at large. It will maximize the effectiveness of housing investment and be crucial to the building of cohesive communities. *(Mathur, 2006)*

iii. Economic

Making economies in the short term can often lead to poor value for money in the long term. Building cheaply may produce more dwellings for money spent, but in the long term may cost more. The essence of sustainability is a consideration of long term costs and benefits. Residential development according to sustainability principles may cost more in the short term, but will have a significant downward effect on overall, long term costs. Extra expenditure on energy efficiency, for example, may increase capital costs but there is evidence that in the long term the savings in running costs will exceed the initial extra capital costs. There is also evidence that building to a high environmental specification leads to lower maintenance and management costs. Life cycle costing can be used to estimate long term costs and allocate them to different people and agencies. (*Thomas and Fordham, 2005*)

2.3 ARCHITECTURAL CONCEPTS INCORPORATING ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability is defined as the ability of the environment to continue to function properly indefinitely. It is the process of interaction with the environment, is pursued with the idea of keeping the environment as pristine as possible, by avoiding a severe level of degradation, for future generations. An "unsustainable situation" occurs when natural capital (the sum total of nature's resources) is used up faster than it can be replenished. Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally. In the following section different relevant architectural concepts have been looked into.

2.3.1 Environmental Architecture

Fisher (1992) advocated five principles of an environmental architecture (*Fisher, 1992*):

i. *Healthful Interior Environment*: All possible measures are to be taken to ensure that materials and building systems do not emit toxic substances and gasses into the interior atmosphere. Additional measures are to be taken to clean and revitalize interior air with filtration and plantings.

ii. *Energy Efficiency*: All possible measures are to be taken to ensure that the building's use of energy is minimal. Cooling, heating and lighting systems are to use methods and products that conserve or eliminate energy use.

iii. *Ecologically Benign Materials*: All possible measures are to be taken to use building materials and products that minimize destruction of the global environment. Wood is to be selected based on non destructive forestry practices. Other materials and products are to be considered based on the toxic waste out put of production.

iv. *Environmental Form*: All possible measures are to be taken to relate the form and plan of the design to the site, the region and the climate. Measures are to be taken to replenish the ecology of the site. Accommodations are to be made for recycling and energy efficiency. Measures are to be taken to relate the form of building to a harmonious relationship between the inhabitants and nature.

v. *Good Design:* All possible measures are to be taken to achieve an efficient, long lasting and elegant relationship of use areas, circulation, building form, mechanical systems and construction technology. Symbolic relationships with appropriate history, the Earth and spiritual principles are to be searched for and expressed. Finished buildings shall be well built, easy to use and beautiful.

2.3.2 Ecological Building

"This is a movement in contemporary architecture, which aims to create environmentally friendly, energy-efficient buildings and developments by effectively managing natural resources. This entails passively and actively harnessing solar energy and using materials which, in their manufacture, application, and disposal, do the least possible damage to the so-called 'free resources' water, ground, and air." (*Thomas and Fordham, 2005*)

2.3.3 Green Building

"A green approach to the built environment involves a holistic approach to the design of buildings. All the resources that go into a building, be they materials, fuels or the contribution of the users need to be considered if a sustainable architecture is to be produced. Construction of green buildings involves resolving many conflicting issues and requirements. Each design decision has environmental implications." *(Wines J., 2000)*

Green design advocates on a number of environmental, resource and occupant health concerns; such as:

i. Reduction human exposure to noxious materials.
ii. Conservation non-renewable energy and scarce materials.
iii. Minimization life-cycle ecological impact of energy and materials used.
iv. Use of renewable energy and materials that are sustainably harvested.
v. Protection and restoration of local air, water, soils, flora and fauna.
vi. Supporting pedestrians, bicycles, mass transit and other alternatives to fossil-fuel.

The concepts discussed above are quite effective and qualitative appreciation of them can be done through various assessment tools. Some of these tools are listed in the section below.

2.4 ENVIRONMENTAL ASSESSMENT

An **Environmental Assessment** is an assessment of the likely positive and/or negative influence a project may have on the environment. "Environmental Impact Assessment can be defined as: The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made." *(http://en.wikipedia.org/)* The purpose of the assessment is to ensure that decision-makers consider environmental impacts before deciding whether to proceed with new projects.

Following are the tools of Environmental Assessment:

a. Assessment Methods: Design [University of Salford]
b. BEES (Building for Environmental and Economic Sustainability)
c. BRE Environmental Profiles

d. BREEAM UK
e. BREEAM Canada
f. Building Environmental Quality Evaluation for Sustainability Through Time (BEQUEST)
g. Construction and City Related Sustainability Indicators CRISP
h. EcoHome (UK)
i. Eco-Pro (Finland)
j. Eco-Quantum (Netherlands)
k. ENVEST (environmental impact estimating design software) [UK BRE]
    i. Assessment Process & Benifits [Battle McCarthy]
l. Environmental Support Solutions
m. EQUER (France)
n. GBTool
    i. Green Building Assessment Tool - GBTool 1.3
    ii. A Second-Generation Environmental Performance Assessment System for Buildings
o. Interactive Tools Survey [University of Weimar, Germany]
p. International Association for Impact Assessments (IAIA)
q. LCAid (Australia)
r. LEED Green Building Rating System
s. LISA (LCA in Sustainable Architecture)
t. New Measures for Building Performance
u. SimPro life-cycle assessment software (PRe, Product Ecology Consultants)
v. TERI–GRIHA (TERI–Green Rating for Integrated Habitat Assessment), India

There are various *Assessment Methodologies,* i.e. indoor air quality audit, life cycle energy and costing audit, initial embodied energy, recurring embodied energy, operational energy, benchmarking and greenhouse gas assessment, lighting, thermal and ventilation (LTV) audit, hydraulic audit, and post occupancy evaluation. Environment assessment and assessment methodologies are very important aspect in sustainable architecture but in this thesis, it is beyond the scope of study.

2.5 ISSUES IN ENVIRONMENTAL SUSTAINABLITY

Site, energy, water, materials, waste and community are the broader issues of environmental sustainability. Dealing with these issues with concept of optimum utilization, reuse, recycle and making community healthy and safe can make a built environment sustainable (*Muller, 2002).*

2.5.1 Site

The physical structure of a settlement and its natural content can affect the local microclimate. Appropriate site selection, site planning and settlement layout can improve local conditions and enhance thermal comfort. Site planning includes landform/microclimate, site design, infrastructure efficiency, land use, transportation and on-site energy resources.

2.5.2 Energy

The energy-efficient siting and design of buildings would offer economic (saving money), social (reducing fuel poverty) and ecological (reducing resource exploitation and emissions) benefits. Every new development ideally should have an explicit energy strategy, setting out how these benefits are to be achieved.

2.5.3 Water

As our population grows, so too do the rates of water extraction and pollution. To ensure future supplies of fresh, clean water we must start to think more carefully about how we use it. Good building design can greatly reduce the amount of water use and the degree of contamination.

2.5.4 Materials

Embodied energy in building materials has been studied for the past several decades by researchers interested in the relationship between building materials, construction processes, and their environmental impacts. The energy input required to quarry, transport and manufacture building materials, plus the energy used in the construction process, can amount to a quarter of the 'lifetime' energy requirement of a very energy-efficient building. To reduce embodied energy, without compromising longevity or efficiency re-use existing buildings and structures wherever possible to be practiced. Designing buildings for longer life, with ease of maintenance and adaptability to changing needs is a crucial demand on the Architects.

2.5.5 Waste

Environmental sustainability also seeks to reduce waste of energy, water and materials. During the construction phase, one goal should be to reduce the amount of material going to landfills. Well-designed buildings also help to reduce the amount of waste generated by the occupants as well, by providing on-site solutions such as compost bins again resulting in reduction of landfills matters. Waste can be managed sustainably in many ways i.e.waste prevention, recycling of demolished materials, architectural reuse (include adaptive reuse, conservative disassembly, and reusing salvaged materials) and design for material recovery (durability, disassembly, adaptive reuse)

2.5.6 Community

Making towns and cities, especially their inner areas and peripheral schemes, more attractive as places to live is both an essential part of urban regeneration and also an opportunity for residential development to become more sustainable This covers not only the environmental dimension but also the social aspects of sustainability in terms of cohesive neighbourhood communities. The most energy efficient and environment friendly neighbourhood possible is useless if people don't want to live in it. Fortunately, it is possible to develop and redevelop in neighbourhoods such a way that environmental and social dimensions reinforce each other.

From the above study, we see that all the issues discussed hold the equal importance for attaining sustainable development. But it is universally accepted that water is needed in all aspects of life. For sustainable development, it is necessary to take into account water's social, environmental and economic dimensions and all of its varied uses. Water management requires an integrated approach. And, the present dissertation is focused on the issue of sustainable water management.

2.6 SUMMARY

This chapter deals with the concept of sustainable development, sustainable housing and two way interrelation of housing with sustainability, environmental sustainability various environmental Assessment tools and methods and finally the issues of sustainable development. Out of these issues, management of water has been identified as crucial. If water can be managed better, this would be a major step toward achieving sustainable development. The next chapter will deal the various aspects of water management in housing.

This chapter deals with the sustainable water management in general and the need of sustainable water management in housing in specific. The sources of fresh water, its supply and distribution at the national and city level, reasons for water stress and various uses of fresh water discussed in brief. Various aspects and measures are studied and analyzed so as to make housing sustainable with respect to water.

CHAPTER 3

SUSTAINABLE WATER MANAGEMENT IN HOUSING

"By means of water, we give life to everything."

- Koran, 21:30

3.1 GENERAL

The term Sustainable Water Management 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. Concept of **Sustainability** as stated by the Bruntland Report *(WCED, 1987)*, has been defined it as ones where the needs of the present generation are met without compromising the needs of future generations. The concept of **Management** as stated in Wikipedia is, "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." *(http://www.wikipedia.org)*

Understanding the needs of the stakeholders and possibilities/ limitations of the resources are necessary 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. Needless to say, effective communication is the key to managing a resource shared between various users and managed by different levels. Only once the needs of each user are mutually understood, the resource can be allocated and managed in a sustainable manner.

Sustainable Water Management (SWM), like sustainable development of built environment, involves the management of water resources in such a way that it meets the need of present and future users effectively. Proper management of resources ensures that the need of all users is understood and the resource is allocated and managed in sustainable manner. Management of water resources addresses the needs and concerns of the users, sharing of resources between different users, management of water resources at different levels thereby affecting the society as a whole. The concept of SWM involves a whole new way of looking at how the precious water resources are used. The approach of SWM is highlighted by The International Hydrological Programme, a UNESCO initiative, according to which, *"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." (http://www.dainet.org/water/whatisswm.htm)*

Therefore, SWM attempts to deal with water in a holistic fashion, taking into account the various factors affecting water use i.e. environmental, economic and social considerations. The environmental considerations require water shed protection, ecosystem balance and waste water recycling; whereas the community requires the sufficient and reliable water supply but also participation in planning and recreational use of water and economic considerations require sustainable and long term growth. All these are interrelated and interdependent as shown in Fig.3.1.

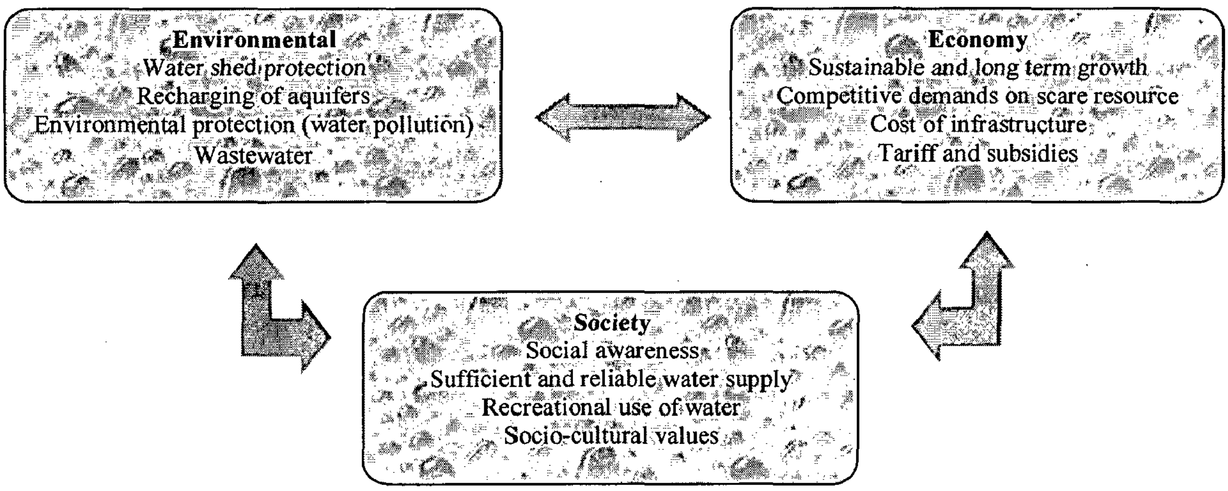


Fig 3.1 Linking of Sustainable Water management system

To understand the deep root of managing water sustainability, the present chapter discusses the sources of the water and specifically of fresh water, its supply and distribution at the national and city level, reasons for water stress and various uses of fresh water. Then it is being discussed the need of water management in housing has been explored.

3.2 SOURCES OF WATER

Both surface water and ground water are used as drinking water sources. *Surface water* is taken from above-ground sources such as rivers, lakes, wetlands, or estuaries. *Ground water* is pumped from underground aquifers through drilled wells or from springs. A **well** is a bored, drilled or driven shaft, or dug hole with a depth that exceeds its largest surface dimension. Its purpose is to reach underground water supplies or oil, or to store or bury fluids below ground. A **spring** is ground water seeping from the earth where the water table intersects the ground surface. An **artesian well** is free flowing water held under pressure in porous rock or soil confined by impermeable geologic formations.

Access to high-quality water source helps protect the safety of drinking water and helps limit the need for expensive treatment.

Storage of Rainwater and use of recycled water is of very importance at present. The availability of water in lakes and rivers is diminishing day by day except during monsoon. Construction of dam has become an environmental issue which takes along time in construction and consumes energy and non renewable resources; some other sources are to be considered simultaneously for water supply. Ground water had already shown the signs of depletion. Depletion of ground water is also resulting into concentration of salts and thus cost for treatment for water supply is rising sharply. Hence use of used water and rainwater are now economic water sources.

3.4 SUPPLY AND DISTRIBUTION

National Building Code (1998) prescribes minimum requirements of water as 135 liters per capita daily (LPCD). The 2001 'Master Plan of Delhi' (MPD) recommends 70 gallons per capita daily (GPCD) (equivalent to 265 LPCD), while a manual on water supply and treatment produced by the Central Public Health Engineering and Environmental Organization's (CPHEEO) recommends 60 GPCD (227 LPCD) as a minimum..In general everybody may be consuming water at a rate of say 225litres/ day. *(http://www.sdnetwork.net/files/)*

Food and water are two basic human needs. However, global coverage figures from 2002 indicate that, of every 10 people, roughly 5 have a connection to a piped water supply at home (in their dwelling, plot or yard); 3 make use of some other sort of improved water supply, such as a protected well or public standpipe and 2 are unserved. In addition, 4 out of every 10 people live without improved sanitation.

3.3 WATER STRESS

3.3.1 General

The concept of water stress is relatively simple: According to the *World Business Council for Sustainable Development (2000),* it applies to situations where there is not enough water for all uses, whether agricultural, industrial or domestic.

Main reasons for water stress are:

1. Population growth
2. Increased affluence
3. Expansion of business activity
4. Rapid urbanization
5. Climate change
6. Depletion of aquifers
7. Pollution and water protection

3.3.2 Population growth

In 2000, the world population was 6.2 billion. The UN estimates that by 2050 there will be an additional 3 billion people with most of the growth in developing countries that already suffer water stress. Thus, water demand will increase unless there are corresponding increases in water conservation and recycling of this vital resource.

3.3.3 Increased affluence

The affordability of middle income group is increasing especially within the two population giants of China and India. However, increasing affluence inevitably means more water consumption; as clean fresh water demand for 24 hours a day, 7 days a week for kitchen, washing and basic sanitation service, to water gardens and car washing, to feed jacuzzis or private swimming pools etc.

3.3.4 Expansion of business activity

Business activity ranging from industrialization to services such as tourism and entertainment continues to expand rapidly. This expansion requires increased water services including both supply and sanitation, which can lead to more pressure on water resources and natural ecosystems.

3.3.5 Rapid urbanization

The trend towards urbanization is accelerating. Small private wells and septic tanks that work well in low-density communities are not feasible within high-density urban areas. Urbanization requires significant investment in water infrastructure in order to deliver water to individuals and to process the concentrations of wastewater – both from residential and from industrial. These polluted and contaminated waters must be treated or they pose unacceptable public health risks. In 60% of European cities with more than 100,000 people, groundwater is being used at a faster rate than it can be replenished. Even if some water remains available, it costs more and more to capture it. In India there is no concrete government policy on industrial water use. The recent study observes: "The existing policies are merely a patchwork of public health and water availability concerns. Though CPCB (Central Pollution Control Boards) has prescribed water consumption levels for some industrial sectors, they are mere recommendations and cannot be enforced by laws. India also has some obsolete laws related to groundwater extraction. In Indian law, the person who owns the land also owns the groundwater below. Though this law has some relevance as far as the domestic groundwater use is concerned, it is outright absurd for industrial and commercial use. The result is that today, industries withdraw groundwater that remains unregulated and unpriced." *(http://www.cseindia.org/dte-supplement/)*

3.3.6 Climate change

Climate change could have significant impacts on water resources around the world because of the close connections between the climate and hydrologic cycle. Rising temperatures will increase moisture in the air through evaporation and leading to high precipitation, though there will be regional variations in rainfall. Overall, the global supply of freshwater will increase. Both droughts and floods may become more frequent in different regions at different times, and dramatic changes in snowfall and snowmelt are expected in mountainous areas. Higher temperatures will also affect water quality in ways that are not well understood. Climate change could also mean an increase in demand for farm irrigation, garden sprinklers, and perhaps even swimming pools.

3.3.7 Depletion of aquifers

Due to the expanding human population, competition for water is growing such that many of the worlds major aquifers are becoming depleted. This is due both for direct human consumption as well as agricultural irrigation by groundwater. Millions of small pumps of all sizes are currently extracting groundwater throughout the world. "Irrigation in dry areas such as northern China and India is supplied by groundwater, and is being extracted at an unsustainable rate. Cities that have experienced aquifer drops between 10 to 50 meters include Mexico City, Bangkok, Manila, Beijing, Madras and Shanghai." *(http://www.cseindia.org/dte-supplement/)*

3.3.8 Pollution and water protection

Water pollution is one of the main concerns of the world today. The governments of many countries have striven to find solutions to reduce this problem. Many pollutants threaten water supplies, but the most widespread, especially in underdeveloped countries, is the discharge of raw sewage into natural waters; this method of sewage disposal is the most common method in underdeveloped countries, but also is prevalent in quasi-developed countries such as China, India and Iran.

3.3.9 Miscellaneous reasons for non availability of water

i. Leakage in the main line and the branch line
ii. Overflow from the overhead tanks.
iii. Use of filtered water for other purposes such as construction, industries, workshops, gardening, car washing etc.
iv. Leakage and seepage from general taps.
v. Use of filtered water by unauthorized connections for bathing etc. and wastage of water particularly in small hotels, restaurants and shops etc.
vi. Wastage of water by throwing the stored water and refilling with concept of fresh water.

vii. Apart from this there is a large variation of availability of water pressure in the lines and at many places, it is not sufficient at all. In such cases, the residents are using on line pumps resulting to leakage and wastage of water.

viii. Un-designed water supply networks.

ix. Puncturing designed networks at a later stage without adequate technical considerations

3.5 USE OF FRESH WATER

3.5.1 General

Use of fresh water can be categorized as consumptive and non-consumptive, sometimes called "renewable" *(http://en.wikipedia.org/wiki/Water_resources).* Use of water is consumptive if that water is not immediately available for another use. Losses to sub-surface seepage and evaporation are considered consumptive, as is water incorporated into a product (such as farm produce). Water that can be treated and returned as surface water, such as sewage, is generally considered non-consumptive if that water can be put to additional use. Water is used in irrigation, industry, houses as well as in recreation and landscaping (see Fig 3.2)

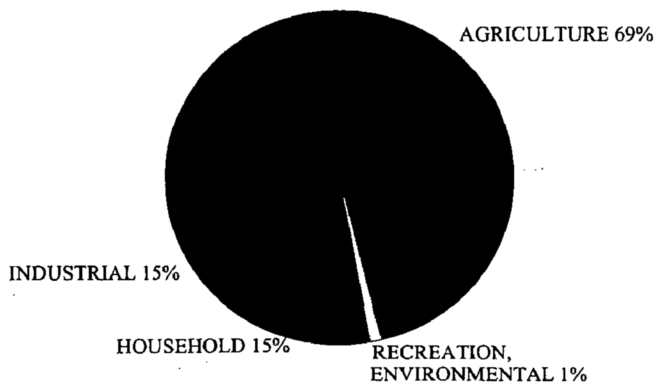


Fig 3.2 world-wide use of fresh water

3.5.2 Agricultural

It is estimated that 69% of world-wide water use is for irrigation, leaving very less percentage of fresh water available for other uses.

3.5.3 Industrial

It is estimated that 15% of world-wide water use is industrial. Major industrial users include power plants (which use water for cooling or as a power source, i.e. hydroelectric plants), ore and oil refineries (which use water in chemical processes) and manufacturing plants (which use water as a solvent). The portion of industrial water usage that is consumptive varies widely, but as a whole is lower than agricultural use.

3.5.4 Recreation

Recreational water use is usually a very small but growing percentage of total water use. Recreational water use is mostly tied to reservoirs. If a reservoir is kept fuller than it would otherwise be for recreation, then the water retained could be categorized as recreational usage. Release of water from few reservoirs is also timed to enhance whitewater boating, which could be considered a recreational usage. Other examples are anglers, water skiers, nature enthusiasts and swimmers.

3.5.5 Environmental

Explicit environmental water use is also a very small but growing sector of total water use. Environmental water usage includes artificial wetlands, artificial lakes intended to create wildlife habitat, fish ladders around dams, and water releases from reservoirs timed to help fish spawn.

3.5.6 Household

It is estimated that 15% of world-wide water use is for household purposes. These include drinking water, bathing, cooking, sanitation, and gardening .

Though household water use is not the largest, the requirement increasing unprecedentedly. Ensuring accessibility to safe water to the people of both and rural areas, who need it in an affordable manner is very crucial. In fact, the health problems associated with unclean water are so enormous that globally, nearly three and a half million people are dying each year by water related diseases. *Thus the emphasis of the present dissertation is mainly on the sustainable water management in housing.* The next section discusses the various methods and aspects of sustainable water management in housing *(http/wikipedia.org/wiki/Water_resources).*

3.6 METHODS OF WATER MANAGEMENT IN HOUSING

Sustainable water management in housing involves management of natural sources of water and their optimal utilization. Surface and sub surface sources of water can be managed through proper watershed management and augmentation through rainwater harvesting and sustainable drainage systems. Judicious consumption of water and recycling waste water are essential for optimal utilization of existing resources. Five major areas in housing in which measures need to be taken for sustainable use of water are listed below:

i. Conservation of water
ii. Water Smart landscaping: Xeriscape
iii. Rainwater harvesting
iv. Sustainable Drainage System (SUDS)
v. Waste water reuse and recycling

3.7. CONSERVATION OF WATER

3.7.1 General

Water conservation in housing is related to judicious consumption of water in housing- within the buildings and landscaped areas (parks, playgrounds, spaces between the buildings and road side plantation) in the neighborhoods. According to the report of *Hoekstra and Chapagain, 2006 (Source:www.waterfootprint.org/),* 41% *of* per capita consumption of water in urban context i.e. 200-250 LPD, in Indian houses is used for bathing and 29% for cleaning/washing and 22 % for flushing toilets. The detail break-up of water consumption is shown below (Fig. 3.3)

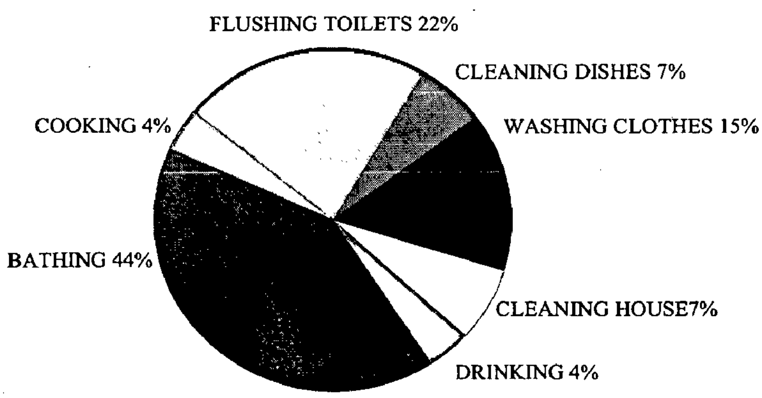


Fig 3.3 Domestic Water Usage

3.7.2 Water efficient fixtures

Following are the area where the water consumption can be reduced by using appropriate water efficient fixtures:

i. Toilets:-
   a. Low flush toilets
      i. Dual flush toilets (3/6 litres)
      ii. Vacuum or compressed air toilets
   b. Cistern displacement devices
   c. Waterless toilets
      i. Composting toilets (heated or unheated)
      ii. Incinerating toilets

ii. Urinals:-
   a. Urinal controls (infrared, radar, autoflush)
   b. Waterless urinals

iii. Wash hand basins:-
   a. Push taps
   b. Flow control, self closing
   c. Tap flow regulators

iv. Shower:-
   a. Shower mixers
   b. Water saving showerheads
   c. Self closing shower system

Toilets are the key areas in a residential building where water consumption can be reduced drastically by installing appropriate fittings for showers and taps which can reduce the pressure on reticulated water supplies and reduce water bills.

3.7.3 The AAAAA Rating System

The Water Services Association of Australia (WSAA) conducts a National Water Conservation Labelling Scheme to provide consumers with information on the relative water efficiency of products. Unlike the energy labelling scheme, this one is not compulsory. This scheme covers washing machines, dish washers, showerheads, toilet suites, taps and commercial urinals. Labels are displayed on merchandise in the form of a 'rating label' as shown in Fig 3.4. Products must conform to the appropriate Australian Standard for performance, such as Australian Standard AS/NZS 3662 for showerheads. For example, a showerhead that provides a high quality shower using less than 9 litres per minute will be 'AAA' rated. One that uses 9 to 12 litres per minute will receive 'AA' rating. A 12-15 litre/minute showerhead will have an 'A' rating Those using more than 15 litres per minute do not comply with this scheme. The labelling scheme generally means the following (Table 3.1) in terms of water efficiency:

Table 3.1: Rating label scheme
Source: www.waterrating.gov.au

RATING	*WATER EFFICIENCY*
AAAAA	*Excellent*
AAAA	*Very high*
AAA	*High*
AA	*Good*
A	*Moderate*

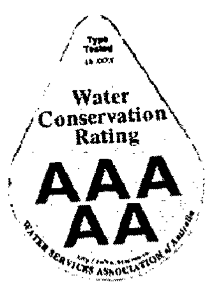


Fig 3.4: Rating label
Source: www.waterrating.gov.au

The environmental benefits of using these fixtures are lower water use, decreased wastewater volume and reduced CO_2 emissions from reduced hot water use.

3.8 WATER SMART LANDSCAPES: XERISCAPE

Xeriscape Landscaping or Water Smart landscapes reduce the use of water in the landscaped garden in housing as well as in individual house. Water-smart landscapes include creative, solution to reducing the yard's need for supplemental irrigation water. This concept can save as much as 50 percent of water in the landscape. Water in the landscape is over 25 percent of a resident's water usage in houses which have lawn/garden (*www.xeriscape.org)*. These water-saving landscaping concepts incorporate several landscaping principles that help to reduce the overall demand for irrigation water to maintain landscaping, while at the same time promoting attractive, region-specific yard that anyone would be proud to call their own. Xericapes involve good garden design, zoning, plant selection according to specific zone and mulching which help to preserve soil moisture by dramatically reducing (Fig 3.5).

(a) *(b)*

Fig.3.5 Details of Xeriscape
Source: www.xeriscape.org

Reducing lawn area is the easiest way to save water. Create garden beds, or mulch areas that are used infrequently or where grass grows poorly. Replace lawn areas with porous paving, pebbles or drought-tolerant ground covers. This is the division of the various areas of the property into three zones: low-, moderate-, and high-water use (refer Fig 3.6). Plants are then grouped in the landscape according to their water requirements, which prevents over watering certain plants within an irrigation zone when taking care of the water needs of other more water-demanding plants. High water-use plants are best located where they can be sheltered from drying winds and strong sunlight.

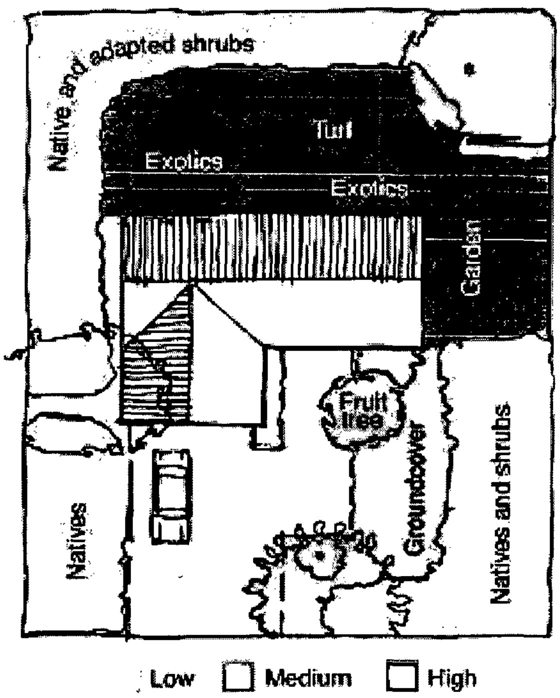


Fig.3.6 Zoning according to water use
Source: www.xeriscape.org

3.9 RAIN WATER HARVESTING

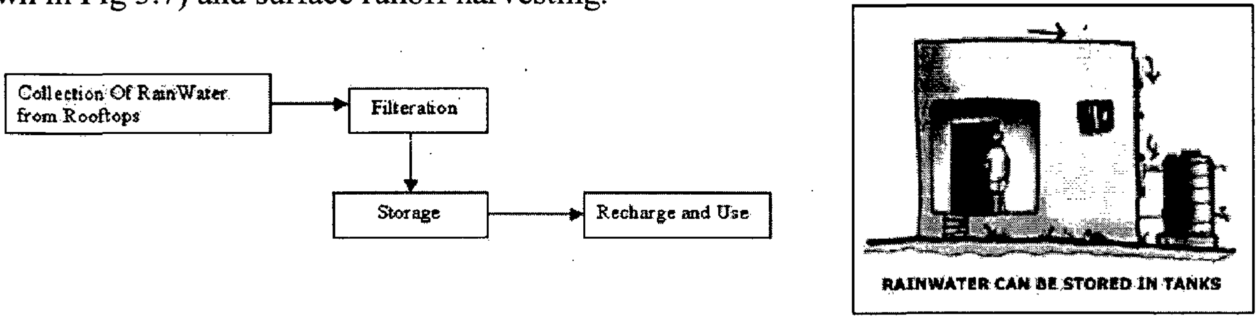
3.9.1 General

Rainwater harvesting refers to the mechanisms involved in collecting, storing and putting rainwater to use when it is most needed. Rainwater harvesting is most useful for supplementing water needs locally, recharging bore wells and reducing dependence on external sources of water. Rainwater harvesting mechanisms are designed by studying the features of the site such as incident rainfall, subsurface strata and their storage characteristics, and by building suitable structures to collect and store rainwater.

Advantages and benefits of Rainwater Harvesting are:

i. Helps to conserve ground water
ii. Allows use of rainwater, thus saving on purchase of water
iii. Inexpensive and simple technology
iv. Saves Money and energy
v. Provides control over water source
vi. Can be kept free from contamination
vii. Minimizes urban flooding

Rain Water Harvesting Techniques are storage of rain water on surface for future use and recharge to ground water. It can be done two ways rooftop rainwater harvesting (shown in Fig 3.7) and surface runoff harvesting.



(a) *(b)*

Source: http://www.rainwaterharvesting.org

Fig 3.7 Rooftop rainwater harvesting

Surface runoff harvesting involves collection of rainwater from open surface followed by filtration, storing that water in sump or tanks and then recharge it to the subsurface aquifers as shown in Fig. 3.8

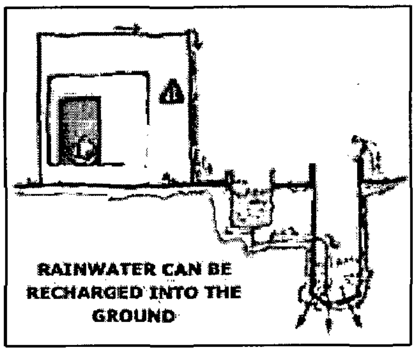


Fig 3.8 Surface runoff harvesting
Source: http://www.cseindia.org

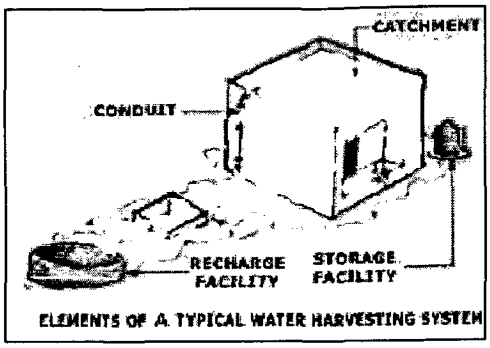
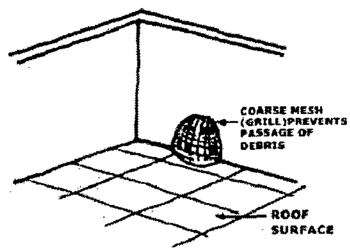


Fig 3.9 Typical rainwater harvesting system
Source: http://www.cseindia.org

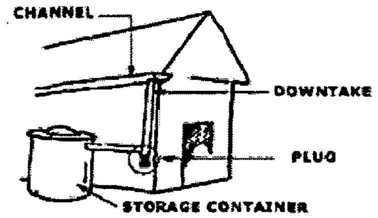
3.9.2 Components of a Rainwater Harvesting System

A rainwater harvesting system comprises components of various stages - transporting rainwater through pipes or drains, filtration, and storage in tanks for reuse or recharge (Fig 3.9). The common components of a rainwater harvesting system involved in these stages are illustrated in Table 3.2

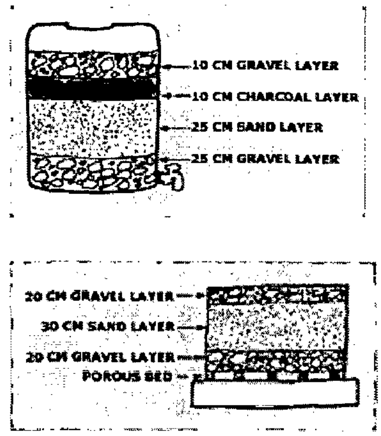
Table 3.2 Components of a Rainwater Harvesting System, source: www.cse.org

Components & Description	Figure
Catchments: The catchment of a water harvesting system is the surface which directly receives the rainfall and provides water to the system. It can be a paved area like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground. A roof made of reinforced cement concrete (RCC), galvanised iron or corrugated sheets can also be used for water harvesting.	
Coarse Mesh: It is located at the roof to prevent the passage of debris	
Gutters: Channels all around the edge of a sloping roof to collect and transport rainwater to the storage tank.	
Conduits: They are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Conduits can be of any material like polyvinyl chloride (PVC) or galvanized iron (GI), materials that are commonly available.	

First-Flushing: A first flush device is a valve that 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

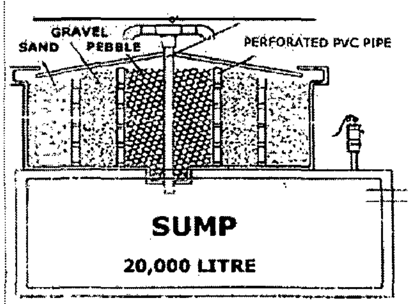


Filter: The filter is used to remove suspended pollutants from rainwater collected over roof. A filter unit is chambers filled with filtering media such as fibre, coarse sand and gravel layers to remove debris and dirt from water before it enters the storage tank or recharge structure. Charcoal can be added for additional filtration



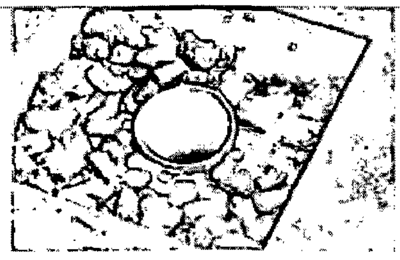
Charcoal & sand filter

Filter for large rooftops: When rainwater is harvested in a large rooftop area, the filtering system should accommodate the excess flow. A system is designed with three concentric circular chambers in which the outer chamber is filled with sand, the middle one with coarse aggregate and the inner-most layer with pebbles.



Storage Facility: There are various options available for 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.
Position of tank: Depending on space availability these tanks could be constructed above ground, partly underground or fully underground. Some maintenance measures like cleaning and disinfection are required to ensure the quality of water stored in the container


A storage tank made of galvanised iron sheets

Recharge structures: Rainwater may be charged into the groundwater aquifers through any suitable structures like dugwells, borewells, recharge trenches and recharge pits. Various recharge structures are possible - some which promote the percolation of water through soil strata at shallower depth (e.g., recharge trenches, permeable pavements) whereas others conduct water to greater depths from where it joins the groundwater (e.g. recharge wells).	 Filter material in the soakway

Storage tanks should be so located and designed to overflow to the gardens. The tank should be provided with a tap installed at its base. A tank of 400 to 1000 litres capacity is needed. If rainwater is used for drinking only and if rainwater is to be the sole supply a tank with a capacity of 50,000 to 100,000 litres would be needed. Regular maintenance and desluging of storage tanks is very important to ensure the quality and safety of rainwater for different requirements of the household, including drinking.

3.10 SUSTAINABLE DRAINAGE SYSTEM (SUDS)

3.10.1 General

The management of runoff in urban areas has taken a 'green' approach due to the emergence of Sustainable Drainage System (SUDS), which collect, store, treat, redistribute and/or recycle water. Examples of these techniques are permeable pavements, swales, filter strips, wetlands and ponds. A central element of sustainable storm water management is the utilization of storm water as a resource. In countries such as Norway, Sweden and Denmark, water in open systems is used recreationally and in the development of ecosystems and landscapes *(Scholz and Grabowieki, 2007).*

These controls should be located as close as possible to where the rainwater falls, providing attenuation for the runoff. They also provide varying degrees of treatment for surface water, using the natural processes of sedimentation, filtration, adsorption and biological degradation.

SUDS can be designed to function in most urban settings, from hard-surfaced areas to soft landscaped features. The variety of design options available allows designers and planners to consider local land use, land take, future management and the needs of local people when undertaking the drainage design, going beyond simple drainage and flood control. The range of options means that active decisions have to be made that balance the wishes of different stakeholders and the risks associated with each option.

3.10.2 Techniques of SUDS

SUDS are made up of one or more structures built to manage surface water runoff. They are used in conjunction with good management of the site, to prevent flooding and pollution.

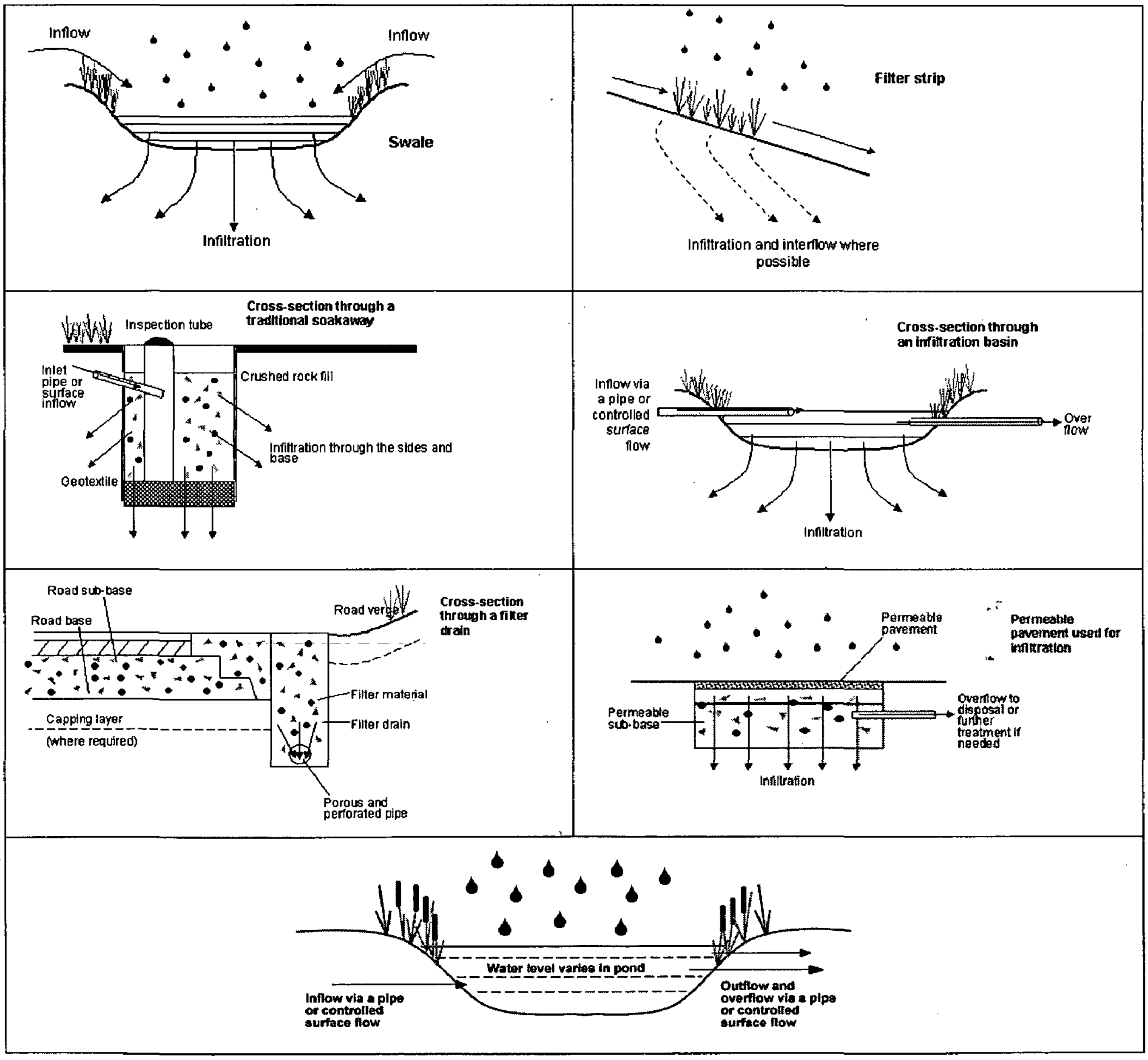


Fig.3.10 Techniques of Sustainable Drainage System (Source: www.environment-agency.gov.uk/suds/)

Sustainable housing should follow a hierarchy of techniques (Fig 3.10). These are:

i. Prevention: When applying the philosophy of sustainable drainage, the adage "prevention is better than cure" can make practical economic sense. Managing the site can significantly reduce quality and quantity problems, and can provide improved amenity. Site management includes design and maintenance as well as the education of users.

ii. Filter strips and swales: Filter strips and swales are vegetated surface features that drain water evenly off impermeable areas. Swales are long shallow channels whilst filter strips are gently sloping areas of ground (Fig 3.11).

Fig.3.11 Filter strips and swales
Source: www.environment-agency.gov.uk/suds/

iii. Permeable surfaces and filter drains: Filter drains and permeable surfaces are devices that have a volume of permeable material below ground to store surface water. *Runoff* flows to this storage area via a permeable surface. This can include:

i. Grass (if the area will not be trafficked)
ii. Reinforced grass
iii. Gravelled areas
iv. Solid paving blocks with large vertical holes filled with soil or gravel
v. Solid paving blocks with gaps between the individual units
vi. Porous paving blocks with a system of voids within the unit
vii. Continuous surfaces with an inherent system of voids

iv. Infiltration devices: Infiltration devices drain water directly into the ground. They may be used at source or the *runoff* can be conveyed in a pipe or *swale* to the infiltration area. They include *soakaways*, *infiltration trenches* and *infiltration basins* as well as swales, *filter drains* and *ponds*. Infiltration devices can be integrated into and form part of the landscaped areas. Soakaways and infiltration trenches are completely below ground, and water should not appear on the surface. Infiltration basins and swales for infiltration store water on the ground surface, but are dry except in periods of heavy rainfall. *(Moulitz et al., 1999)*

v. Basins and ponds: Basins are areas for storage of surface runoff that are free from water under dry weather flow conditions. These structures include flood plains, detention basins and extended detention basins.Ponds contain water in dry weather, and are designed to hold more when it rains. They include balancing and attenuation ponds, flood storage reservoirs, lagoons, retention ponds and wetlands.

The structures can even be mixed, including both a permanently wet area for wildlife or treatment of the runoff and an area that is usually dry to cater for flood attenuation. Basins and ponds tend to be found towards the end of the surface water management train, so are used if source control cannot be fully implemented, if extended treatment of the runoff is required or if they are required for wildlife or landscape reasons.

3.11 WASTEWATER RE-USE

3.11.1 General

On-site wastewater re-use provides numerous opportunities to reduce water use within the home (refer Fig.3.12). At present, potable (drinkable) water is used for practically everything in the house and garden and carwash. Wastewater recycling can be seen as the alternative source of water, reducing the consumption of portable water in housing by using it in toilet flushing, gardening, car wash, etc.

There are two types of wastewater created in a building, each of which can be treated and used in different ways- grey water and black water. *Blackwater* is water that has been mixed with waste from the toilet. And requires biological or chemical treatment and disinfection before re-use. Black water should only be re-used outdoors. *Greywater* is wastewater from non-toilet plumbing fixtures such as showers, basins and taps.

Depending on its use, greywater can require less treatment than blackwater and generally contains fewer pathogens. Greywater must be treated and disinfected before storage. Treated greywater can be re-used indoors for toilet flushing and clothes washing, both of which consume significant amount of water.. Greywater can also be used for watering gardens, car washing and washing pets. There are many types of greywater treatment systems. Disinfection is required for general re-use of greywater. All disinfection requires regular maintenance. The treated black water can be used to recharge the aquifers through percolation pits.

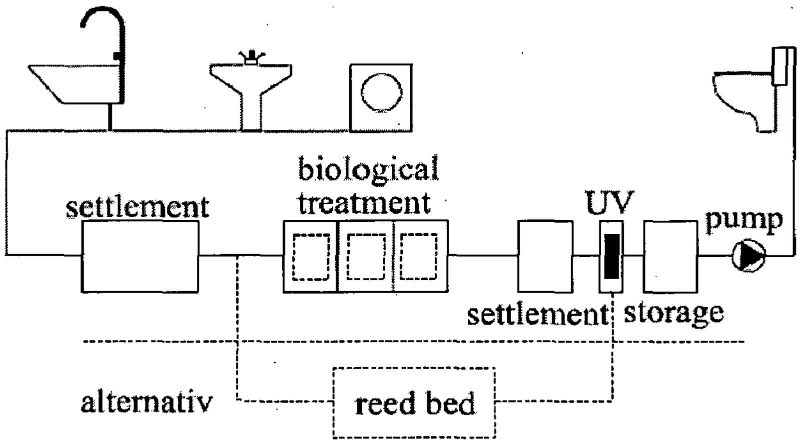


Fig 3.12 Schematic diagram of Waste water Reuse in a house
Source: www.huber-solutions.com

3.11.2 Calculating Wastewater Volume

In Australia, 113 liters of grey water and 22 liters of black water is expected from a house daily typically as shown in Table 3.3 and Fig 3.13.

Table 3.3 Amount of waste water expected from a house

BLACKWATER	LPCD
Toilet	22
GREYWATER	LPCD
Shower	56
Hand Basin	6
Kitchen tap	12
Dishwasher	5
Laundry tap	7
Washing Machine	27
Total - Greywater	113
Total - Overall	135

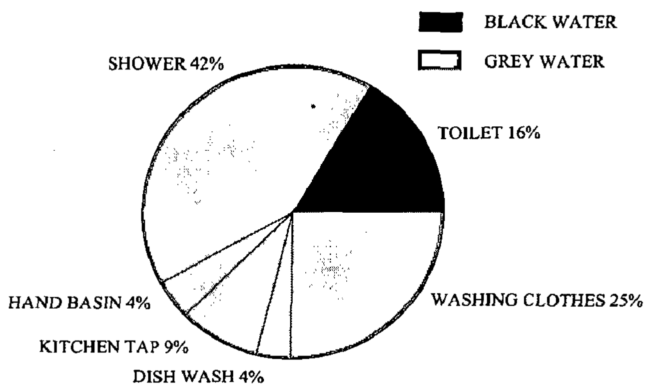


Fig 3.13 Wastewater expected from a house
Source: http://www.yourhome.gov.au/technical

3.11.3 The Benefits of Greywater Recycling

Using greywater indoor and outdoor benefits the housing by making it sustainable and also community. Greywater recycling lower fresh water use, lessen the strain on septic tank or treatment plant, useful where site is unsuitable for a septic tank, use of Less energy and chemical, Groundwater recharge etc are detailed below.

3.11.3.1 Lower fresh water use

Greywater can replace fresh water in many instances, saving money and increasing the effective water supply in regions where irrigation is needed. Residential water use is almost evenly split between indoor and outdoor. All except toilet water could be recycled outdoors, achieving the same result with significantly less water diverted from nature.

3.11.3.2 Less strain on septic tank or treatment plant

Greywater use greatly extends the useful life and capacity of septic systems. For municipal treatment systems, decreased wastewater flow means higher treatment effectiveness and lower costs.

3.9113.3 Highly effective purification

Greywater is purified to a spectacularly high degree in the upper, most biologically active region of the soil. This protects the quality of natural surface and ground waters.

3.11.3.4 Site unsuitable for a septic tank

For sites with slow soil percolation or other problems, a greywater system can be a partial or complete substitute for a very costly, over-engineered system.

3.11.3.5 Less energy and chemical use

Less energy and chemicals are used due to the reduced amount of both freshwater and wastewater that needs pumping and treatment. For those providing their own water or electricity, the advantage of a reduced burden on the infrastructure is felt directly. Also, treating your wastewater in the soil under your own fruit trees definitely encourages you to dump fewer toxic chemicals down the drain.

3.11.3.6 Groundwater recharge

Greywater is not being used for gardening and washing cars etc, can be used to recharge the groundwater.

3.11.3.7 Plant growth

Greywater enables a landscape to flourish where water may not otherwise be available to support much plant growth.

3.11.5.8 Reclamation of otherwise wasted nutrients

Loss of nutrients through wastewater disposal in rivers or oceans is a subtle, but highly significant form of erosion. Reclaiming nutrients in greywater helps to maintain the fertility of the land.

3.11.5.9 Increased awareness of and sensitivity to natural cycles

Greywater use yields the satisfaction of taking responsibility for the wise husbandry of an important resource.

3.12 SUMMARY

In this chapter various methods of managing water sustainably have been discussed in details. These are water conservation, water efficient landscaping, rainwater harvesting sustainable drainage system and waste water recycle. This study will help to analyze the case studies selected with respect to the aspects of sustainable water management in housing. Taking into consideration the above study on various methods of sustainable water management and case studies, the design guidelines for the study area selected i.e. Sahara States Housing, Lucknow would be proposed.

Case studies of the exemplar practices of India and abroad, with respect to management of water sustainably are studied analyzed. Analysis had been done on the basis of the literature review done on sustainable water management in housing.

CHAPTER 4

CASE STUDIES

"Everyone understands that water is essential to life. But many are only just now beginning to grasp how essential it is to everything in life – food, energy, transportation, nature, leisure, identity, culture, social norms, and virtually all the products used on a daily basis."

-World Business Council for Sustainable Development (WBCSD) 2000,

4.1 GENERAL

Sustainable water management in India is practiced since ages. There are several good examples of housing both in India and the world those used different techniques of sustainable water management. For the present study, three housing and one individual house has been identified as case studies one individual house; namely Vikas Community ,Auroville; National Media Centre Co-Operative Housing Scheme, Gurgaon; Figtree Place, Australia and Healthy Home, Australia. These cases have been discussed in detail so as to find out the salient features and techniques employed. Two case studies are form India and two from Australia, to understand the water management aspects employed in India and what advanced techniques are used in Australia to manage water in housing as well as in a house. Following are the case studies selected:

1. Vikas Community, Auroville, Tamil Nadu, India
2. National Media Centre Co-Operative Housing Scheme, Gurgaon, India
3. Figtree Place, Hamilton, Newcastle, Australia
4. Healthy Home, Gold Coast, Australia

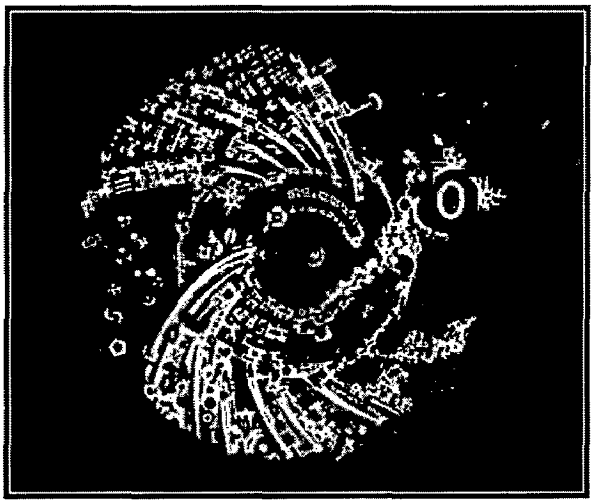
4.2 VIKAS COMMUNITY, AUROVILLE, INDIA

4.2.1 Auroville, example of sustainable settelement

Auroville is composed of a cluster of properties some 12km north of Pondicherry in India. Auroville is a universal township in the making for a population of up to 50,000 people from around the world. (Fig 4.1 and Fig 4.2) The concept of Auroville - an ideal township devoted to an experiment in human unity - came to the Mother as early as the 1930s. In the mid 1960s the Sri Aurobindo Society in Pondicherry proposed to Her that such a township should be started.

As an experiment in sustainable urban living, it has become a demonstration site for eco-technologies and the integrated management of human and natural resources in a residential setting that has **features of both urban and rural settings**.

The community's will endeavour to use alternative forms of energy and resouces such as solar power, rainwater and treated wastewater is appricable. Eco-friendly building materials have been used in this project keeping with Auroville's commitment to these values. 55% of the site has green area and a kitchen garden grows organic food for consumption within the community.



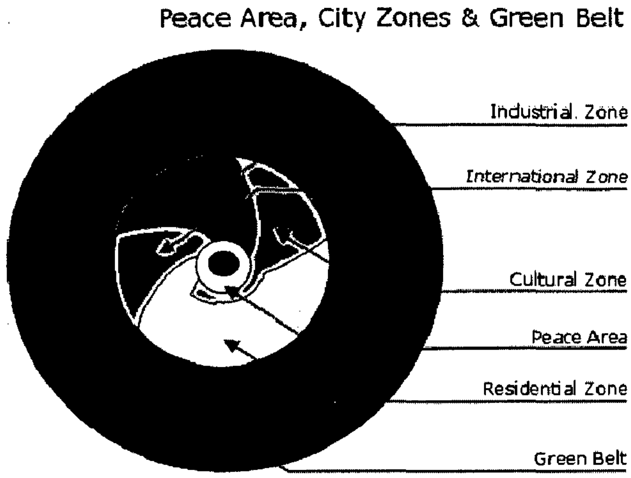


Fig 4.1 Auroville City Plan
Source: www.xgeronimo.files.wordpress.com

Fig 4.2 Overview of City Plan
Source: www.auroville.org/images/

The Vikas Community Housing has been designed to offer cost-effective, attractive, functional housing of environmentally low impact, suitable for a wide variety of residents. It offers a positive alternative to the growing trend of individually funded, private housing. These experiments with guidelines for preparing the community for harmonious living that can be applied to future housing projects and serve as a model of human unity in cross-cultural diversity. *(www.earth-auroville.com)*

4.2.2 Project Details: Vikas Community, Auroville

The creation of this community was based on a particular spirit, life style and appropriate architectural design. It was related to Sri Aurobindo's integral yoga and Auroville's ideal. The extensive use of environmentally sound materials (earth and ferrocement), appropriate building technologies, renewable energies (solar and wind) and ecological water management (watershed harvesting and biological waste water treatment), are the basis of its practicle implementation. Individual apartments, a few individual houses and common facilities were built in this phase. This project was the first development in Auroville, which used stabilised earth right from foundations to roof. To date, Vikas community still represents the most synthetic holistic development, which has been materialised in Auroville.

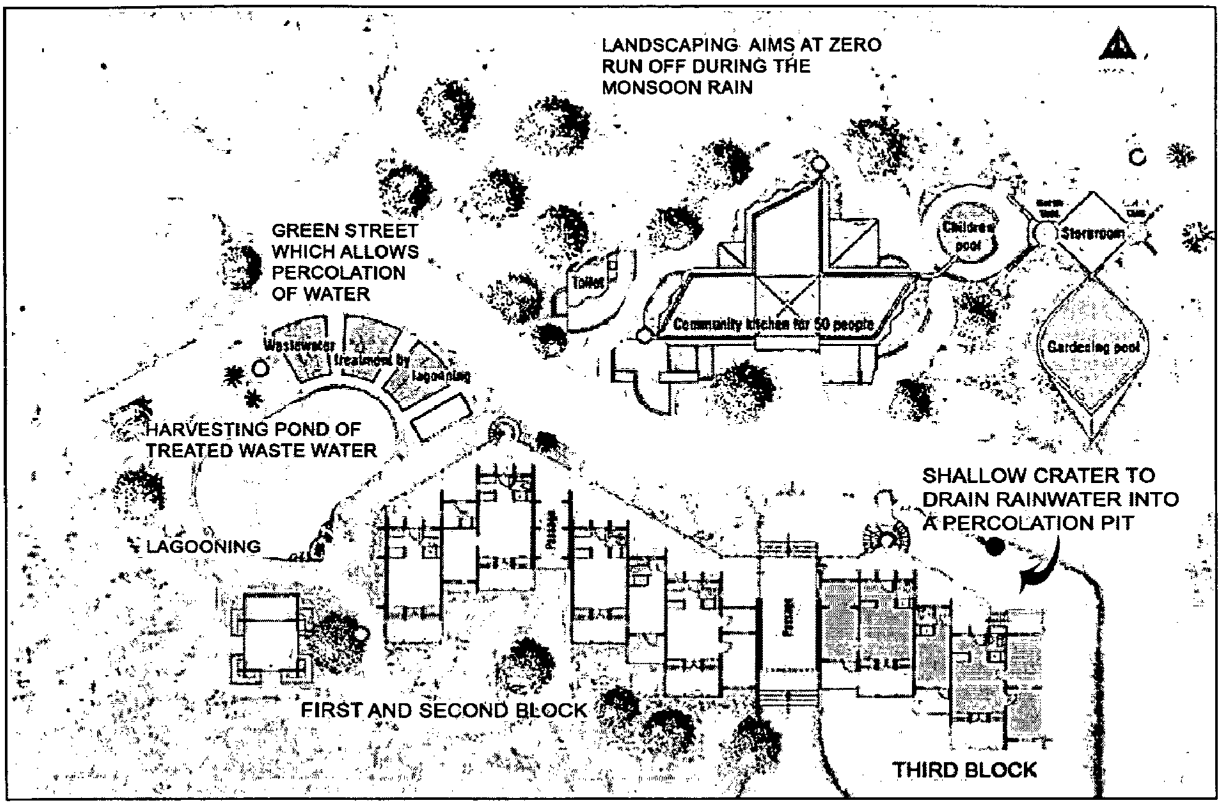


Fig 4.3 Lay-Out of VIKAS community showing the water management features
Source: Teri, Energy efficient buildings in India, ed. Mili Majudar, Tata Energy Research Institute, 2002

The community has been built in several steps, from 1992 to 1998, and the third block of thirteen apartments has a basement floor with three floors above it. The concept of this building is such that it is self-sufficient for its soil needs. The soil was dug from the basement floor (1.2m below the original ground level) to produce compressed stabilized earth blocks (CSEB) for building the structure of 819 m², carpet area, on 4 floors.

The foundations are of stabilised rammed earth and the 13.40m high walls are of CSEB of 24 cm thick. All floors and roofs are made of very flat vaults and domes for the living rooms. These vaults and domes were built with CSEB, by using the “Free-spanning” technique. All stabilisation used 5 % cement by weight. The experiment of Vikas found its roots in Auroville’s ideals. Nonetheless, its material developments could be implemented elsewhere in the world. Vikas community was a finalist for the World Habitat Award 2000.

4.2.3 Water management aspects in housing

Earth has been used, from the first developments of Vikas, in all parts of the buildings, from foundations to roof. The proper management of earth resources was always the first priority. The quarries where the soil is taken from were always planned first. This procedure allowed a perfect integration of the excavations with the buildings and landscape.

The first and second developments of the collective kitchen and 10 apartments on two floors could integrate the quarries as a garden reservoir and for wastewater treatment. The soil needs for these developments were already exceeding the outcome of excavations, and some soil had to be supplied from elsewhere.

The soil requirement for the third building (see Fig 4.4), which has four floors, was tremendous and the development of Vikas did not require any hole. Thus it was not possible to integrate any earth excavation in the project and therefore this building was planned with a basement floor, which was half underground (1.20m below the original ground level) shown in Fig 4.5.

The volume of this basement floor was equivalent to the volume of soil, which was needed to produce the blocks and all the various works of the third building.

(a) *(b)*

Fig 4.4 Third Block, 13 apartments on 4 floors (3 floors above a basement floor)
Source: www.earth-auroville.com

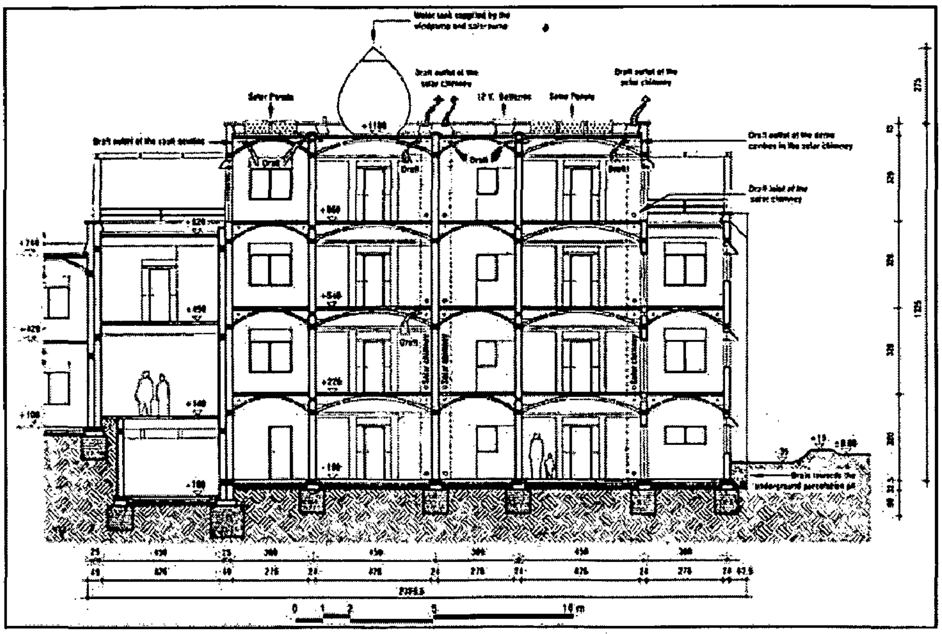


Fig 4.5 Section of the third building
Source: http://www.earth-auroville.com/photos/14-3rd-building-section.jpg

To protect the basement from the inflow of rainwater a particular landscape has been designed shown in Fig. 4.6. The immediate surrounding has been shaped like a shallow crater to drain rainwater into a percolation pit. This landscape design generated even more soil than needed for the building sites at Vikas. It was given to other projects in Auroville, which could not implement the concept of a basement floor.

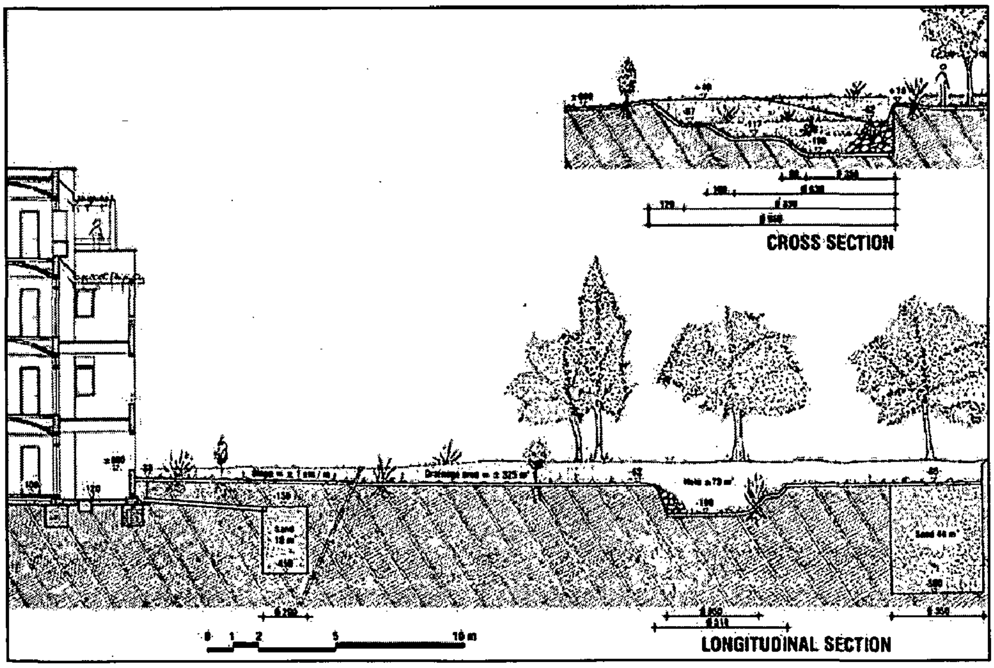
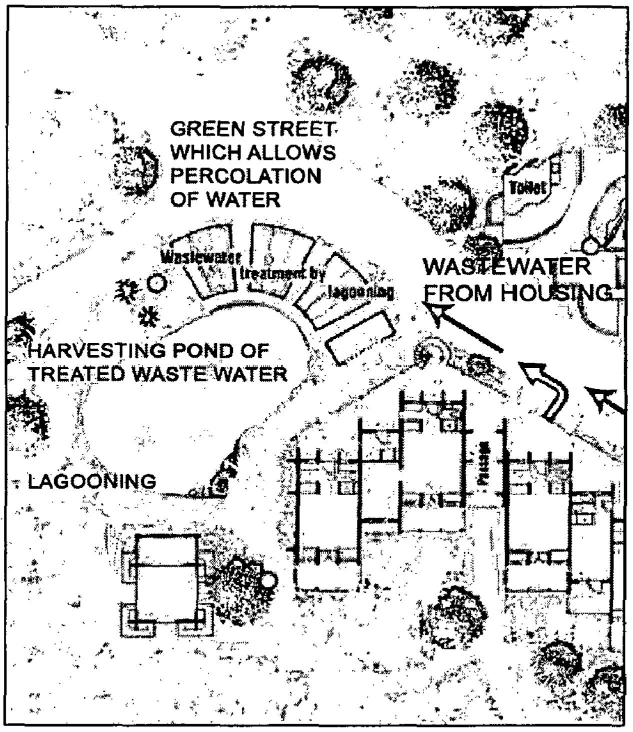


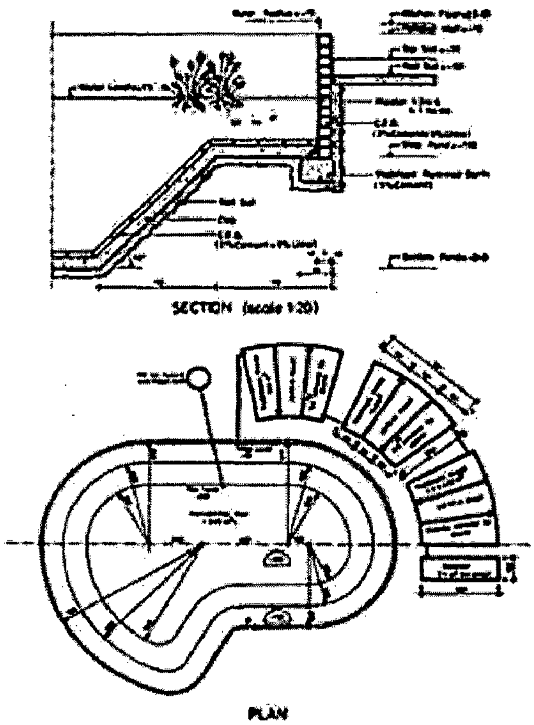
Fig 4.6 Percolation system of the third building
Source: http://www.earth-auroville.com/photos/19-percolation-section.jpg

Biological Waste Water Treatment by Lagooning

The Lagooning system consists of two distinct phases: an anaerobic decantation-digestion, followed by a macrophyte water treatment and the progressive re-establishment of aerobic conditions. The anaerobic treatment takes place in a watertight pit called the "decanter-digester", which is open at the top, and which gets covered by the accumulated floating matter. (refer Fig 4.7 & Fig. 4.8)



(a) Plan showing the path of wastewater from the housing to the treatment pond



(b) Detail of wastewater Treatment by Lagoonin

Fig 4.7: Wastewater Treatment by Lagooning
Source: www.earth-auroville.com

The macrophyte water treatment is covered with diverse species of floating aquatic plants. The first 2/3 of the watertight pit is fully covered and the plant covering in the last third is restricted to 20 % of the surface to promote more re-oxygenation and photosynthesis. The aquatic plants were at the beginning water hyacinths and duckweeds.

This wastewater treatment worked well but it is a fragile system, which requires a lot of maintenance. Use of toxic products, such as bleach, house hold products with caustic soda, etc. can destroy this fragile water treatment system. It happened twice that people thrown such thing in the toilets and the biological system died for sometimes. It started to smell, fishes died and the area was infested by mosquitoes. Once normal wastewater goes into the system, the latter require a few weeks to function again properly.

(a)

Fig 4.8 Lagooning: Wastewater Treatment Pond
Source: www.earth-auroville.com

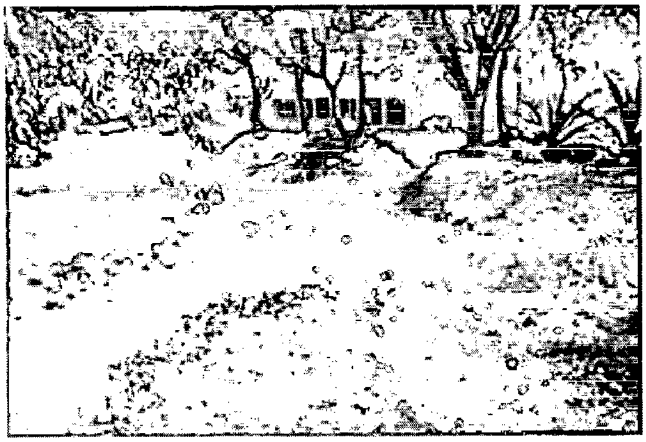


Fig 4.9 Rainwater percolation system of third building
Source: www.earth-auroville.com

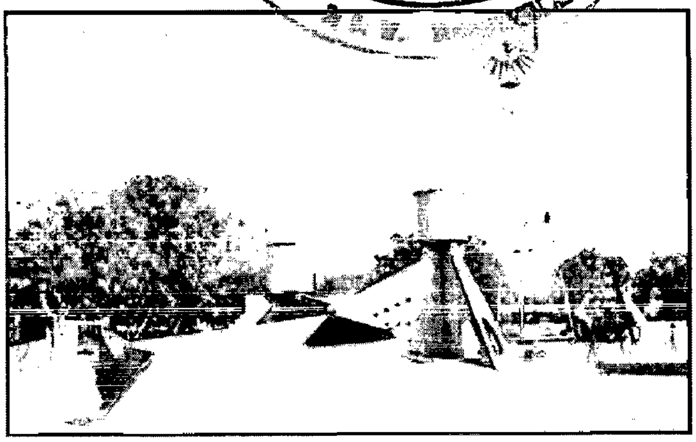


Fig 4.10 Water tank in Vikas settlement
Source: www.earth-auroville.com

The lagooning system was finally changed for a baffle reactor system which more resistant and needs less maintenance. Along with an ecological approach for this biological wastewater treatment, the idea is to fulfill technical requirements with a sense of integration, harmonization with the buildings & surrounding nature. Therefore, buildings nearby took the advantage of lagooning system. It proposes an agreeable place, where people can walk, sit and stay for a while, so as to enjoy a pleasant pond, which is treated as a lake.

4.2.4 Salient features of the case study

Following features have been analyzed as a study of Vikas Community:

i. Carefully designed landscaping aims at a zero run off during the monsoon rains as shown in Fig 4.9.
ii. A biological wastewater treatment is done with help of an aerobic process, called lagooning.
iii. Water from reservoirs for water gardening further reducing the consumption of fresh water.
iv. The overflow of the windmill and the solar pumps is used to water the gardening.
v. Wastewater treatment pond reduces the pressure on fresh water supply.

4.3 NATIONAL MEDIA CENTRE CO-OPERATIVE HOUSING SCHEME, GURGAON, INDIA

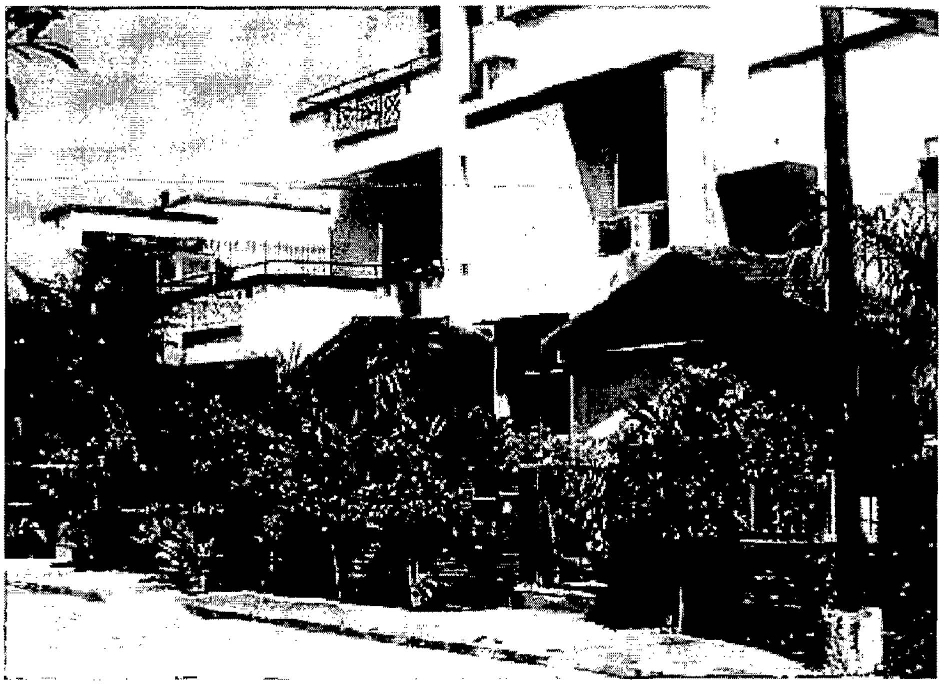


Fig 4.11 View of National Media Centre Co-Operative Housing Scheme, Gurgaon
Source: ww.space-design.com/

4.3.1 Project Details

This cooperative housing project designed by Vinod Gupta, L P Singh, Anita Narula and Harvinder Singh, consisting of 180 houses on individual plots with a built-up area of 35,000 m², completed in 1996 is located in an area where there is no municipal water supply and all colonies depend upon tube wells for their water supply Owner of this housing is National Media Centre Co-operative Housing Society Ltd. The climate is Composite. Project costs Rs170million. The project attempts at creating houses suited to the needs of the individual owner. *(TERI, 2002)*

4.3.2 Water Management aspects in housing

This housing aims to achieve resource conservation in a group housing society with varying requirements and finances. There were those who wanted a very small unit of 70 m^2 while others were not satisfied with 300 m^2.There is no municipal water supply in the area and all colonies depend upon tube wells for their water supply. The underground water table is threatened by overuse and poor recharge. Buildings and roads surfaces do not allow rainwater to percolate into the ground. At NMC the impervious hard paved areas have been minimized. Parking areas and service lanes are paved with open jointed bricks which allow percolation (refer Fig 4.12).

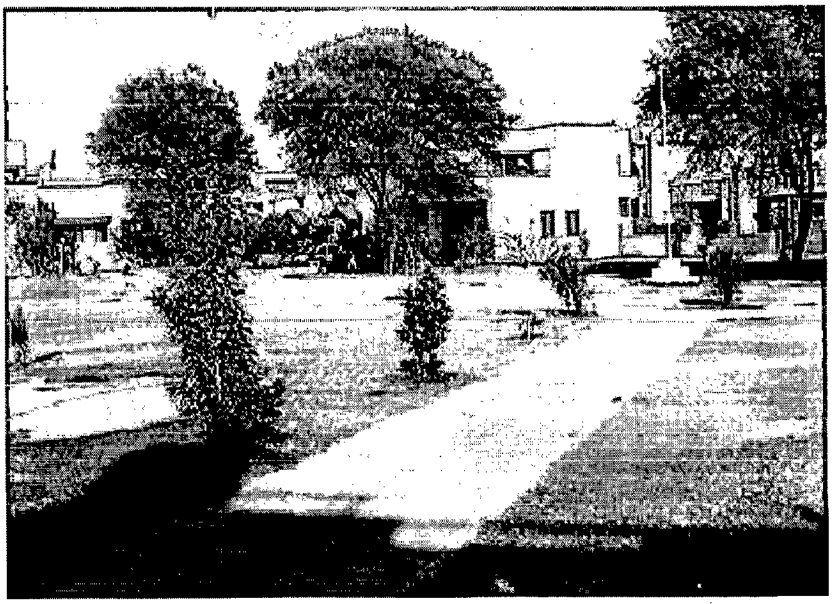


Fig 4.12 View of housing showing Parking areas and service lanes paved with open jointed bricks which allow percolation.
Source: ww.space-design.com/

To compensate for the buildings and the roads, the percolation capacity of the green areas has been enhanced by providing a series of soak pits connected to the drainage system as shown in Fig. 4.13. This system of rainwater harvesting is so effective that most of the rainwater is absorbed within the site and even after a heavy downpour there is little outflow from the colony. It is hoped that this system will preserve the underground water supply of the colony.

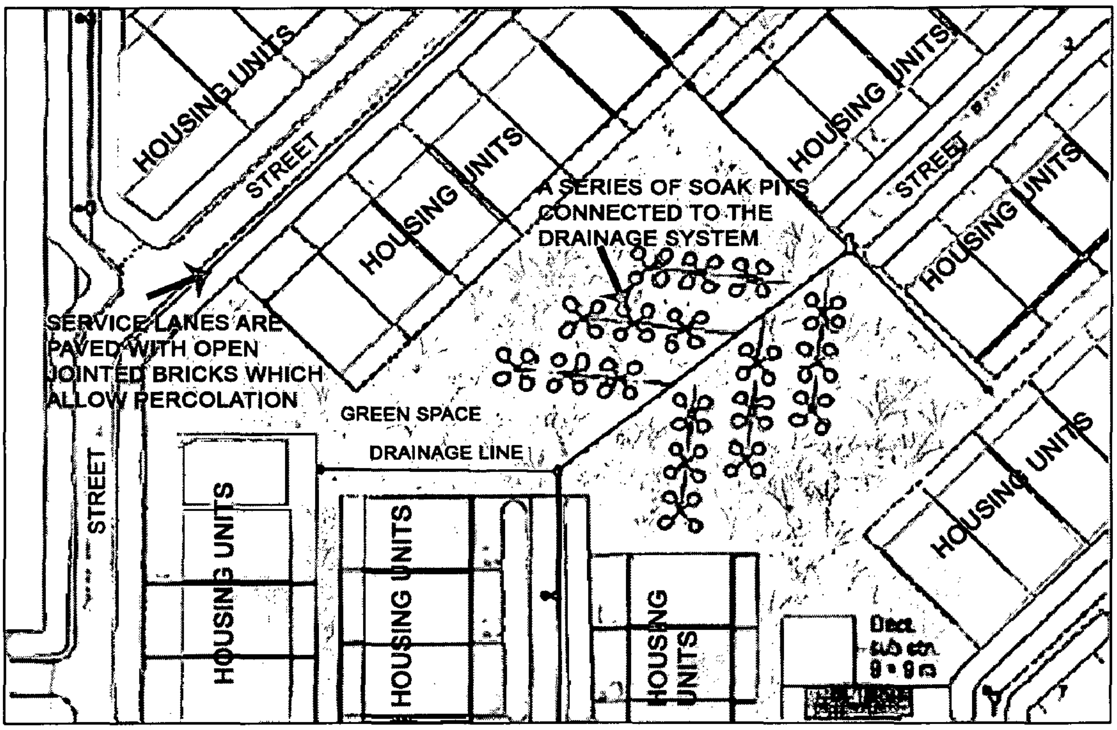


Fig 4.13 Layout of housing showing water management features
Source: Teri, Energy efficient buildings in India, 2002

4.3.3 **Salient features of the case study**

Followings are the outcome of the water management features in this cooperative housing:

i. Recharging of aquifers through rainwater harvesting, helps to maintain the water table of the area
ii. The water below the ground would be available for the present generation as well as for the future too.
iii. Demands on local infrastructure and waterways are reduced.
iv. Significant on-going net savings from reduced water bills.
v. Reduced energy and chemical usage as the housing is self sufficient in meeting the water demands and thus reduce the pressure of building dams and can save energy and money on water infrastructure.

4.4 FIGTREE PLACE, AUSTRALIA

Fig 4.14 Figtree Place is a community housing project with 27 units located in Newcastle NSW. Source: http://www.eng.newcastle.edu.au/~cegak/Coombes/

4.4.1 Project Details

Figtree Place is a 0.6 Ha development consisting of 27 townhouses in Hamilton, an inner suburb of Newcastle. The project showed capital savings from using stormwater on-site rather than the building of traditional drainage.This case study is of interest for minimising development cost, collecting rainwater, conserving potable water and minimising stormwater discharge. Completed in 1998, the Figtree Place development incorporates rainwater harvesting and water sensitive design elements, including aquifer storage and retrieval. The site retains a connection to both mains water supplies and sewerage. All houses are supplied with a potable (drinking) and non-potable water supply. *(http://www.eng.newcastle.edu.au/cegak/)*

4.3.2 Water Management Features

The principles of the Water sensitive urban development (WSUD) approach have been incorporated into this demonstration project, funded by the Australian Government's "Building Better Cities" program.

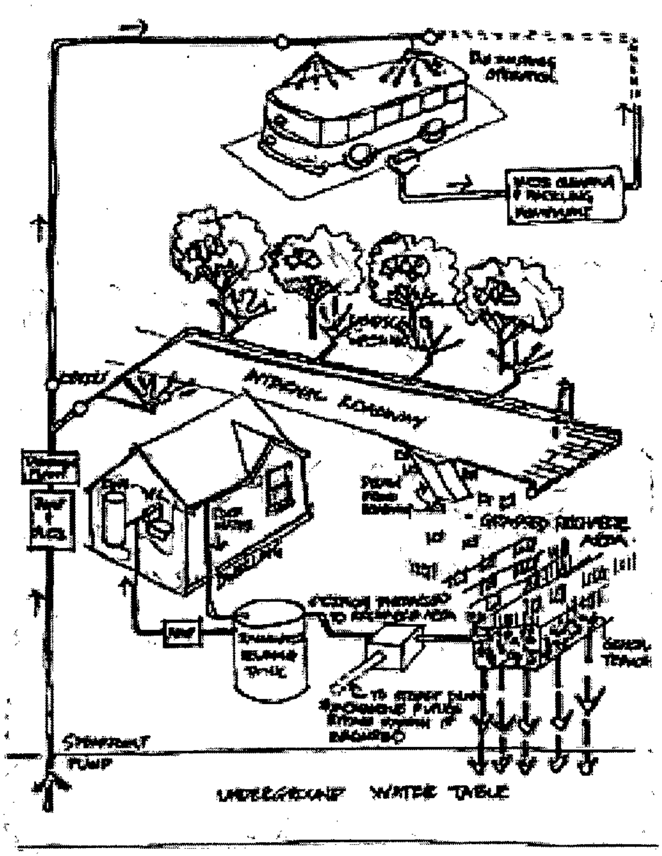


Fig 4.15 Water Sensitive design features of Figtree Place
Source: http://www.eng.newcastle.edu.au/

The ground water at the project site, previously occupied by the bus station, was highly contaminated. The concrete "cap" and the upper 300 mm of soil was removed and replaced with clean sand fill. Every effort was made to decontaminate, to whatever depth necessary, pollutants found in "hot spot" concentrations. Rainwater is collected from all roofs and passes through first-flush pits to storage in four communal in-ground (8 to 10kL) tanks. Pumps and a pressure vessel return this water to supply hot water systems and toilet flushing. Rainwater is therefore used in showering and dishwashing. The rain water tanks are backed up by the mains supply to the site. (refer Fig.4.15)

Gravel infiltration trenches and a central recharge basin deal with the remaining stormwater. The recharge basin in the middle of the development acts as temporary storage for stormwater, which is directed to the basin along the internal road. The basin, which provides a grassed recreational area, overlays a 750 mm layer of gravel enclosed in goe-textile fabric. Stormwater filters downward from the basin, is cleansed by the existing deep sand on the site, and enters an unconfined aquifer for retention. A pump placed ten metres below ground then supplies water from the aquifer for all outdoor irrigation and for bus washing in the adjoining bus station. Rainfall in Hamilton averages

930mm/annum. An added advantage of the stormwater harvesting proposal was the retention of a large portion of the stormwater runoff. This added value to the project by reducing the downstream flood peak, thereby reducing strain on the stormwater infrastructure, including pollution control installations. Stormwater runoff from paths, lawns and gardens is directed into the Detention Basin via internal roadways (Fig 4.16 and 4.17). The Detention Basin recharges the unconfined aquifer and provides an open space recreation area during dry spells. The Detention Basin has been sized to contain, without overflow, all storms up to and including the "once in 50 years" event.

Fig 4.16 Figtree Place: Water from driveways and paved areas is collected in a detention basin to recharge the groundwater aquifer.
Source: http://www.eng.newcastle.edu.au/~cegak/Coombes/

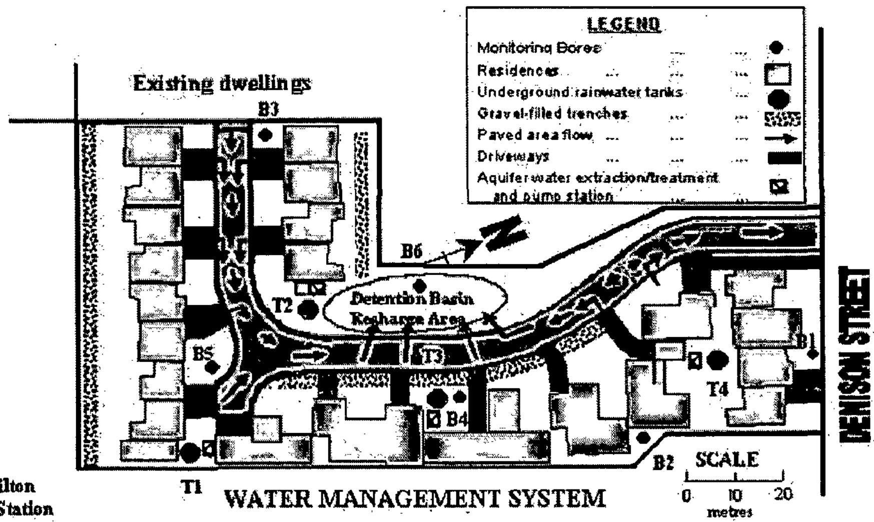


Fig 4.17 Layout of Figtree Place: Stormwater runoff is almost completely eliminated.
Source: http://www.eng.newcastle.edu.au/~cegak/Coombes/

A comprehensive monitoring program (manual and automated) was conducted to assess water quality, water use, social acceptance of water-sensitive design elements, maintenance issues and economy. An unexpected but much commented upon benefit of Figtree Place is a strong sense of community, security and amenity derived from the layout of the development which is centered on a common open space area The project showed capital savings from using stormwater on-site.

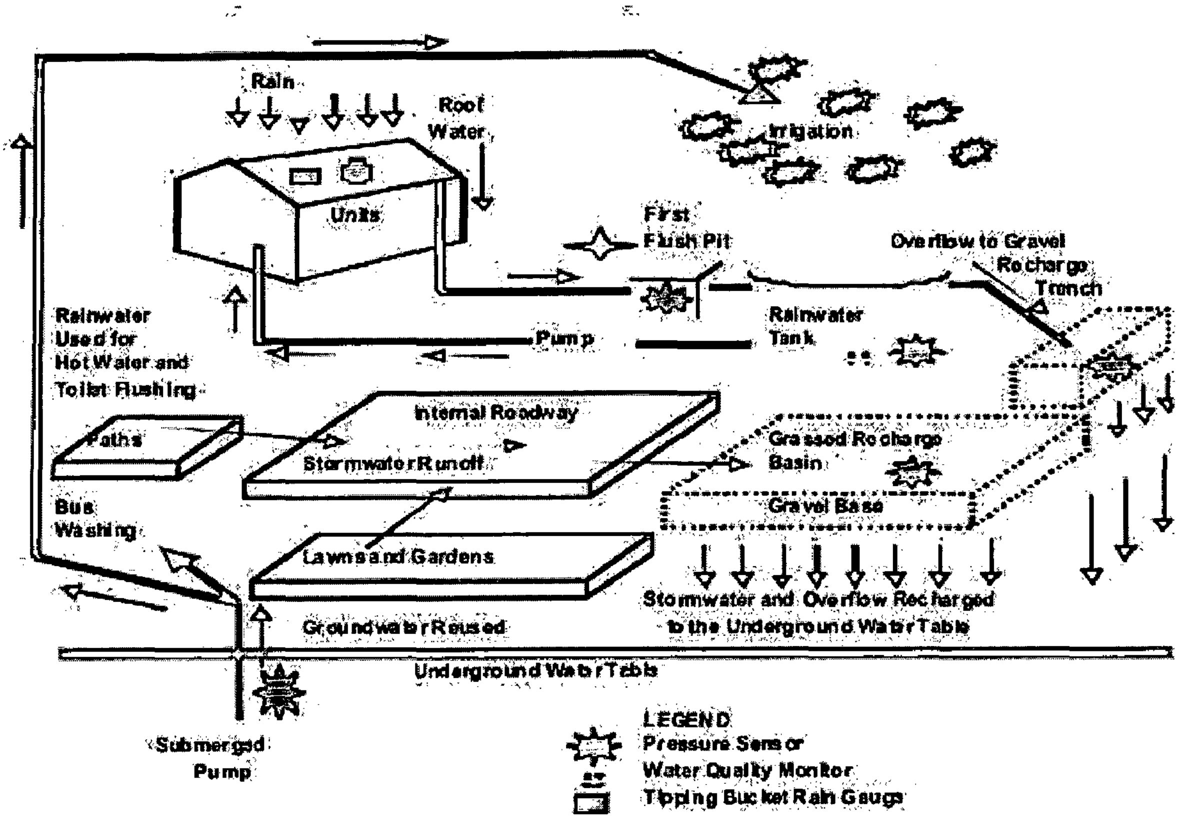


Fig 4.18 Overview of Water Sensitive Design Features of Figtree Place
Source: http://www.eng.newcastle.edu.au/~cegak/Coombes/

4.4.3 Salient features of the case study

i. Reticulated water use can be reduced by 50 to 100 percent in urban areas. This can help to reduce the need for new dam construction, protect remaining environmental flows in rivers, reduce infrastructure operating costs and reduce the energy used in pumping water, thereby lowering greenhouse gas emissions.

ii. Rainwater can aid self-sufficiency, providing a back-up supply in case of water restrictions caused by drought, peak supply shortages, or water quality problems.

iii. Rainwater, being chlorine free, can provide a better quality potable supply than mains, bore or dam water.

iv. Rainwater tanks can also provide cost-effective on-site detention of stormwater.

v. Wastewater after treatment can be recycled to flush toilets, water gardens and even to wash clothes. By using wastewater as a resource rather than a waste product one can reduce water bills. Use of less water resources cut down the amount of pollution going into waterways and help save money on new infrastructure for water provision and wastewater treatment.

vi. Wastewater re-use decreases effluent volumes, reducing the stress on existing centralised wastewater disposal systems, which will work better and last longer.

4.5 HEALTHY HOME, AUSTRALIA

Fig 4.19 Healthy Home, Queensland, Australia
Source: http://www.bluescopesteel.com.au/go/case-study/healthy-home

4.5.1 Project Details

The healthy home is an innovative ecologically designed house on a 460m² urban site on the Gold Coast in Queensland. An advanced water system for a new house has been introduced which includes rainwater harvesting for potable use, greywater collection and treatment, and solar water heating

This case study is of interest for collecting rainwater, reusing indoor greywater conserving potable water and minimising wastewater discharge.

4.5.2 Water Management Aspects

A roof area of 150 m² supplies roof runoff via a first flush diverter to a 22KL concrete tank below the house. From this tank, a 0.7kW pump and pressure vessel supplies all water to the house. The tank is backed up by mains supply.

Greywater from the household is collected to a surge tank/treatment system also located under the house. Greywater from the bathroom and laundry entering the tank are circulated by pump through an Envirotech sand filter within the tank. The sand filter is dosed by programmed flow controller to maximise contact time and allow for biological treatment. A second pump discharges treated greywater to a storage tank. Under current Queensland law it is not possible to reuse greywater in a sewered area, so treated greywater is directed to the sewer with toilet and kitchen waters. When laws allow, the greywater system will supply the toilet and out door irrigation (refer Fig. 4.20). Disinfection will be required before reuse is possible. Rainfall in the Gold coast averages 1460mm/a

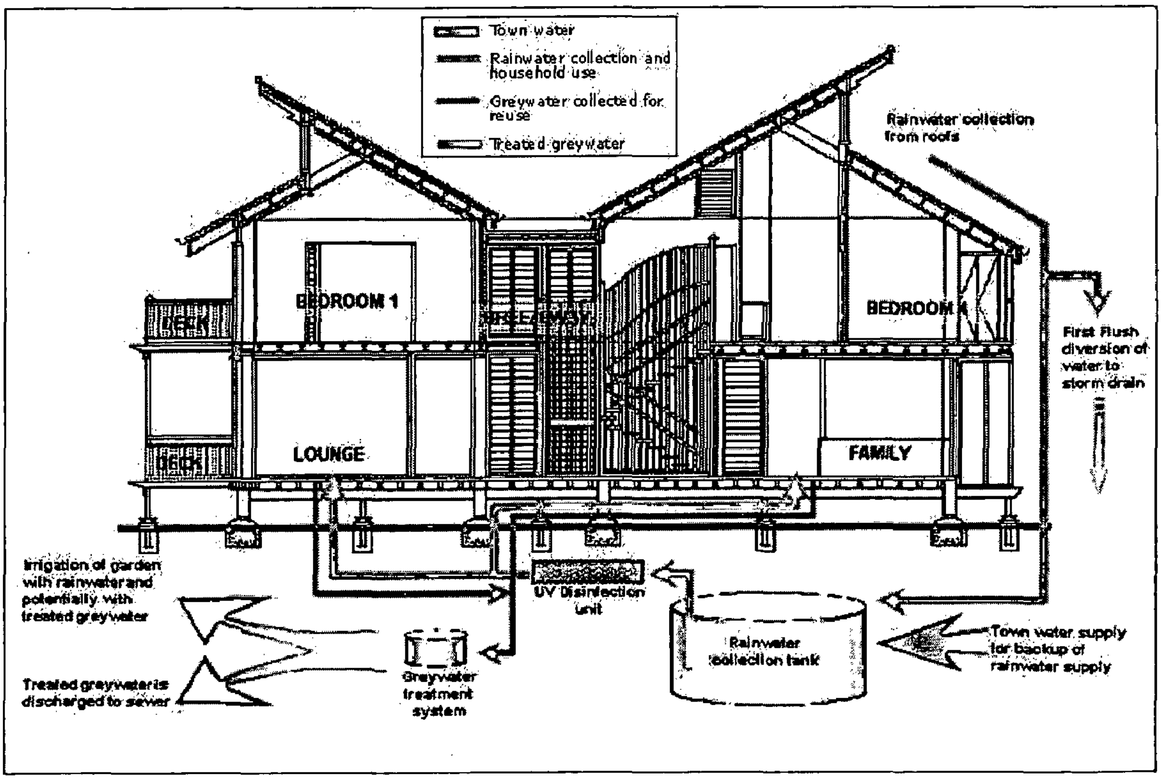


Fig 4.20 Overview of house showing water management features
Source: www.yourhome.gov.au/technical/fs33.html

4.5.3 Salient features of the case study

i. Analysis of water usage estimated that an 80 percent reduction in potable water use could be expected from the combined rain tank and greywater system if fully installed.
ii. Chemical analysis has shown that the re-circulating sand filter effectively removes organic and suspended solids.
iii. The pumps on the rainwater and greywater systems were found to use 1.7kWh per day. Energy use for small pumps is the Achilles heel of advanced water reuse systems and needs to be considered.
iv. Significant reductions in potable water usage and stormwater runoff from the site have been shown.
v. The rainwater and greywater systems are not currently cost effective on the Gold Coast. Payback periods of 23 and 100 years respectively were calculated on the rain and greywater systems.

4.6 SUMMARY

From the above case studies, it is evident that sustainable water management in housing involves management of natural sources of water and their optimal utilization. Surface and sub surface sources of water can be managed through proper watershed management and augmentation through rainwater harvesting and sustainable drainage systems. Judicious consumption of water and recycling waste water are essential for optimal utilization of existing resources. The findings and analysis from the above study will help to frame the design guideline for the project selected in Lucknow.

This chapter deals with the study of one of the housing of the Lucknow i.e. Sahara States Housing. Reasons for water stress in Luckow, water demand and demand ratio have been studied, and identified the problems and the present scenario of water management in Sahara States Housing.

CHAPTER 5

STUDY AREA: SAHARA STATES HOUSING, LUCKNOW

"Water is a very good servant, but it is a cruel master."

C.G.D. Roberts,
"Adrift in America", 1891

5.1 GENERAL

Sustainable development and the role of sustainable housing in a built environment, has been introduced in the second chapter. Measures for making a residential area sustainable with respect to water and exemplar case studies, known for sustainable management of water are analyzed in third and fourth chapter. From all the literature review this is understood that there is an urgent need of sustainable water management. Housing form the bulk of the city i.e. why managing water sustainably in housing can considerably reduce the consumption of fresh water and affect the city as a whole. Sahara States housing has been selected as a model case to show that incorporation of strategies based on all the acquired knowledge about the principles and measures of sustainable water management. This housing is a major trend setter in Lucknow housing sector and it is assumed that this can be a representative sample for all the upcoming housing will be of this type. This chapter discusses the water crisis in Lucknow and need of integral water management in Sahara States Housing.

5.2 CONTEXT OF STUDY AREA: LUCKNOW CITY

Lucknow is the historic city and the capital of India's most populous state, Uttar Pradesh. It is situated about 500 km southeast of New Delhi in the heart of the state. The City has a humid subtropical climate with a cool dry winter from December to February and a hot summer from April to June. It recieves receives about 100 cm of annual rainfall mostly from the southwest monsoons between July and September. The city lies at an average altitude of 110 meters above mean sea level and generally slopes to the east. Lateral slopes are towards the River Gomti, which flows from north-west to south-east through the heart of the city, dividing it into the Trans-Gomti and Cis-Gomti regions. Area of the city is 3,204 km2 (1,237 SQ MI) (Fig. 5.1). The temperature extremes vary from about 45 degrees Celsius in the summer to 3 degrees Celsius in the winter.

Lucknow is the administrative capital of the largest state in India, with a rich cultural heritage and history. The key characteristics that determine its economic base include – the position of the City as an administrative centre, a centre for education and tourism. In recent years there has been a noticeable rise in retail trade and health services. The real estate market is undergoing a growth and the Master Plan 2021 anticipates a steady growth in the services sector over the next 15 years.

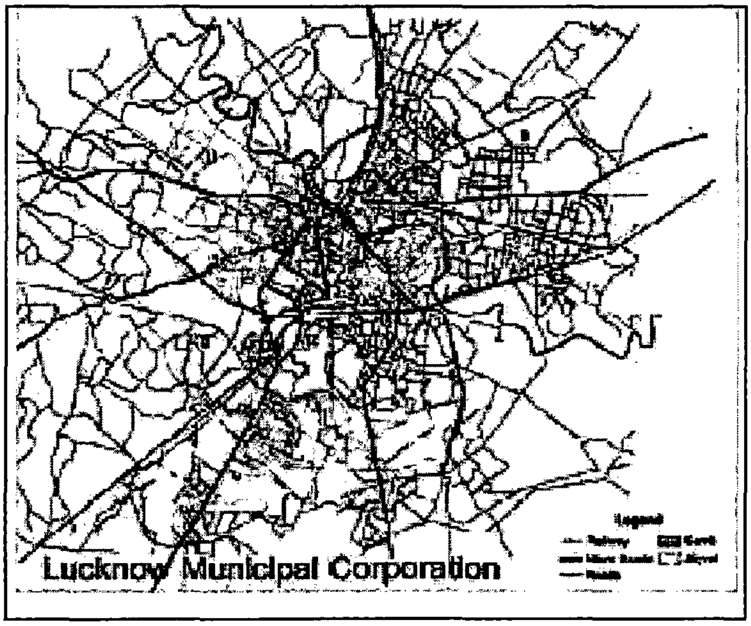


Fig 5.1 Map of Lucknow
Source: http://jnnurm.nic.in/toolkit/LucknowCdp/

Lucknow Urban Agglomeration (LUA) became a million-plus city in 1981. Besides the areas under jurisdiction of the Lucknow Municipal Corporation, the agglomeration also includes the Lucknow Cantonment. Census 2001 estimated the population of the Lucknow Urban Agglomeration at 22.46 lakhs. This included an estimate of about 60,000 as population of the Lucknow Cantonment and 21.85 lakh population of Lucknow City.

5.3 SELECTION OF THE STUDY AREA

Nowadays, Lucknow faces serious problem of water stress, reasons as being identified in section 3:

i. Population growth
ii. Pollution and water protection
iii. Depletion of aquifers
iv. Increased affluence
v. Expansion of business activity
vi. Rapid urbanization
vii. Climate change

5.3.1 Population growth

It is projected that till 2021 the population of Lucknow will reach 40 lakhs, which is double the population of the present stage as shown in Fig. 5.2.

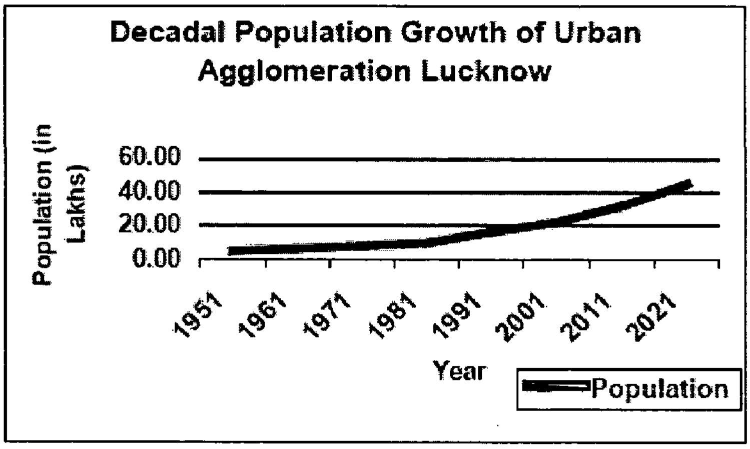


Fig 5.2 Population Growth
Source: http://jnnurm.nic.in/toolkit/LucknowCdp/

Migration into Lucknow accounts for 36% increase in population over the last decade. Of the 5.76-lakh people added to the LUA during 1991-2001, about 2 lakh were migrants. In comparison, the natural growth was 3.68 lakh. Census 2001 estimates that in the last decade, Lucknow received 2,07,307 migrants, 56.6% from rural areas.

Table 5.1 Composition of growth during 1991-001

Composition	Population Increase	
Natural Increase	368998	64%
In Migration	207307	36%
Total Increase	576305	100%

Source: Census of India 2001 - Migration Tables D-3 Series.

5.3.2 Pollution and decreasing level of Gomati River

Increasing population growth of the city coupled with increasing commercial and industrial activity has resulted in rising water pollution both in the River Gomti as well as of the ground water sources. The pollution levels have been further aggravated by the lack of treatment or disposal facilities for solid and liquid wastes. As per a study conducted under 'Monitoring of Indian Aquatic Resources (MINARS) programme, the average time series yearly in this regard (1997 to 1999) is shown in Table 5.2

Table 5.2 Water quality of Gomti River at Lucknow

Sampling Point/Year	1997			1998			1999		
	DO (mg/l)	BOD (mg/l)	Total coll. MPN/100 ml.	DO (mg/l)	BOD (mg/l)	Total coll. MPN/100 ml.	DO (mg/l)	BOD (mg/l)	Total coll. MPN/100 ml.
Gomti Lucknow	8.48	2.2	3500	7.5	2.5	4500	8.6	2.3	3442
Gomti Lucknow Barrage	2.9	6.6	332000	3.8	6.6	350000	4.2	6.9	445833

***Source:** U.P. Pollution Control Board, Lucknow*

The River Gomti water is fit for drinking after treatment at Dandnamau Ghat, but when it enters Lucknow city at Gaughat, 27 drains carrying domestic sewage discharge directly into it; thus deteriorating the water quality. It is estimated that these drains discharge around 32 million litres of sewerage and household wastes each day into the River Gomti. The release of industrial effluents along the course of the river further aggravates the problem and the water is rendered highly unfit for drinking. Although the Jal Sansthan treats the river water before supplying to the City, consumers do not consider this to be safe. Being able to address the pollution of the River Gomti is an area of great concern for the residents of the City. Times of India also featured the polluted water of river Gomti, which states that 52-63% of water samples were found to be bacteriologically unsafe and another article talks about the presence of arsenic content in water (Fig 5.3a, b)

52-63 PC WATER UNSAFE IN CITY

6 Jun 2006, Aparna Singh , Times of India

LUCKNOW: An alarming 52-63 per cent of water samples from Prime Minister Vajpayee's constituency were found to be bacteriologically unsafe, according to a survey conducted by the aquatic toxicology division of Industrial Toxicology Research Centre (ITRC).

The ITRC incubated 80 samples of municipal supply water for bacteriological quality assessment to determine the total coliforms and faecal coliforms. It was found that an average 53 per cent did not conform to the Bureau of Indian Standards (BIS) drinking water specifications. This effectively means that more than half the population of the state capital does not have access to potable water.

A WHO study suggests that 80 per cent of diseases are directly linked to contaminated water. Little surprise then that diseases like gastroenteritis, dysentery, typhoid, diarrhoea thrive.

Environmental degradation was further reflected in an 'Assessment of environmental status of Lucknow' survey presented on Thursday by Dr S K Bhargava of the Environmental Monitoring Division, ITRC, as part of World Environment Day. The city is bursting at its seams due to population explosion. The number of vehicles has increased by a 10.93 per cent.

Twelve sample areas were identified for assessment — Indiranagar, Vikasnagar, Gomtinagar and Aliganj under residential category; Charbagh, Hazratganj, Chowk, Aminabad and Alambagh under commercial; and Amausi and Talkatora under industrial. The concentration of respirable suspended particulate matter (RSPM) was found to be 219-312 ug/m3, 243-366 ug/m3 and 250-321 ug/m3, respectively, in the above- mentioned categories — way above the prescribed standard of 100-150 ug/m3 of National Ambient Air Quality Standard.

(a)

High Arsenic content in groundwater

TIMES NEWS NETWORK

Lucknow: For example, in Lakhimpur Kheri six of the 15 blocks have Arsenic concentration of more than 50 micrograms per litre.

However, Dr Idris added that recent findings indicate that even such a high level of arsenic can be considered safe in India. Presence of Arsenic in water leads to Arsenicosis, a skin disease with sores and discoloration as visible symptoms.

Dr Idris said that the metal effects Keratin and Melanin, the two proteins found in the skin. "The disease resembles leprosy and thus has a social effect as well," he said at the conference.

Arsenic was first reported in the ground water of Ballia in 2003. Soon afterwards a team of experts from UP Jal Nigam and Unicef conducted surveys and studies in eight districts of the state.

In Ballia, the concentration of the metal found to be touching critical level. The task force, which conducted the study in 55 villages in three blocks of Ballia, revealed that approximately 1.20 lakh people could be affected by Arsenic.

(b)

Fig 5.3 Articles from Times of India about polluted water of Gomti River

5.3.2 Depletion of aquifers/ water table.

It is estimated that against a summer demand of 702 MLD of water, the Lucknow Jal Sansthan manages to supply only around 450 MLD. The balance demand is met through the use of hand pumps and tube wells. Tube wells used in indiviual houses is one of the major reasons. Increasing hard surfaces and no recharge of ground water lowers the ground water table from 0.80 meters to 3.08 meters in just one year (1999-2000).

5.3.3 Increased affluence

Change in living standard, need of water 24 hours and 7 days week, need of water for washing cars, gardening and jacuzzis, etc have increased the demand of water.

5.3.5. Expansion of business activity

Business activities ranging from industrialization to services such as tourism and entertainment continues to expand rapidly, which leads to more pressure on water resourse.

5.3.6 Rapid urbanization

Increase in population due to migration, increase in business activities, high density urban areas, and exploitation of fresh water resources leads to water stress in Lucknow

5.3.7 Climate change

Extreme summers and winters and Global warming extensively affect the source of water supply. The rivers are drying and ground water table is moving down day by day, thus action has to be taken so that there will be water available for future generation.

5.4 WATER DEMAND FOR THE CITY

The total quantity of water produced as per the Jal Sansthan records in 2006 is as shown in Table 5.3.

Table 5.3 Water produced in Lucknow

River Water source	200 mld from Aishbagh Water Works 70 mld from 2nd Water Works.	Capacity: 240 mld Capacity: 90 mld
Total produced	270 mld	Capacity: 330 mld
Ground Water	190mld from 407 tube wells 15 mld	from 6150 hand pumps.
Total	**205 mld**	

Source: Lucknow Jal Sansthan, Progress report, Dec, 2007

At present a total of 475 millions litre per day (MLD) of water is produced amounting to a supply of 175 LPCD (litres per capita per day) for the present population. The entire volume of water produced does not reach the customers and it is estimated that almost 53% is lost due to leakages and pilferage. Although compared to the norm adopted for per capita water supply viz., 150 LPCD, the supply is not adequate and also considering the leakages, at present only about 80 LPCD of water may be reaching the consumers.

Water Demand

The population projections for the City as per the Lucknow Master Plan 2021 are:

Table 5.4 Population projection

Year	**2006**	**2011**	**2021**
Total population (in millions)	2.714	3.166	4.440

Source: Lucknow Jal Sansthan, Progress report, Dec, 2007

Based on per capita supply of 150 litres per day plus 15% as unaccounted for water due to leakage and wastage the corresponding water demand during different years works out as below:

Table 5.5 Water Demand

Year	**2006**	**2011**	**2021**
Water demand in mld	468	546	766.

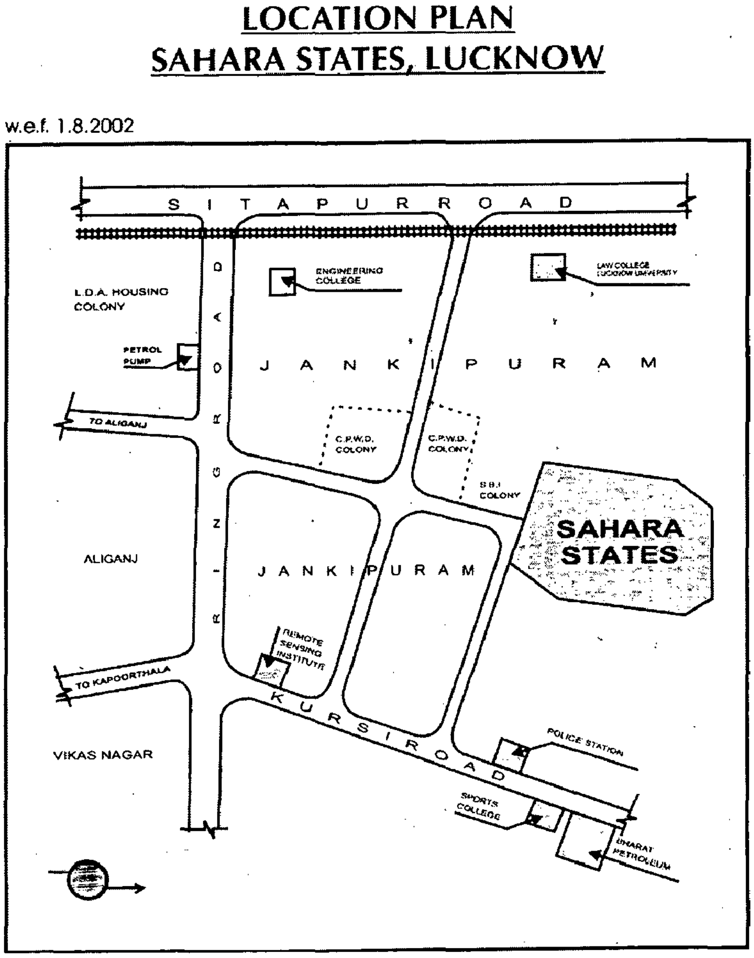
Source: Lucknow Jal Sansthan, Progress report, Dec, 2007

Considering above data at least three sets of issues regarding water supply need to be considered in planning for the future:

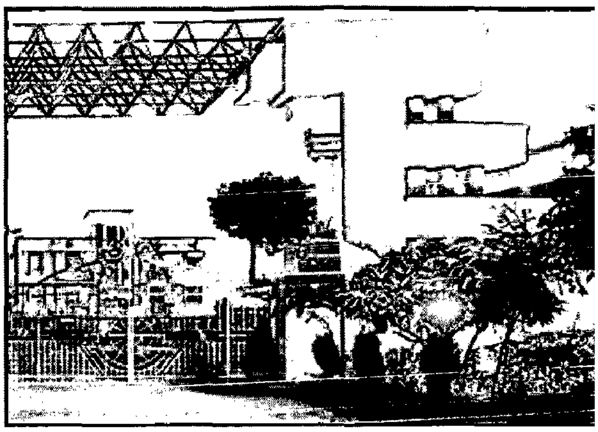
1. ***Inadequate service delivery and management of water supply:*** Lucknow, inspite of, having acute water resource constraint, water supply is intermittent and restricted to a few hours a day and quality of water inconsistent, imposing high coping costs on consumers and increasing health risks. Estimated leakages are high, which affects service delivery negatively and deprives the water agencies of revenue.
2. **Sustainable *Water resource management:*** In the absence of regulation governing the exploitation and use of ground water, extraction has become expensive and unsustainable. Rising contamination of the River Gomti with the discharge of sullage from 27 drains as well as industries has meant that costs of treatment are higher. The total volume of water produced is assessed crudely on the basis of pumping plant capacity and number of hours of pumping in the absence of proper measuring devices. This also means that there is no control on leakage, wastage and theft of water is high. The overhead storage reservoirs have, in most cases exhausted their capacities leading to inadequacy of supply and rising exploitation of ground water.
3. ***Data is inadequate***. Because there is no metering, it is impossible to accurately assess consumption, leakage and revenue potential. General data on distribution network plans, details of pipes, material, location of fittings and other infrastructure is too weak to support planning, management, monitoring and maintenance. The system therefore is 'reactive' rather than 'proactive', and unable to ensure efficient supply.

From all the above data (*Lucknow Jal Sansthan, 2007)* we know, there argent need of sustainable water management. Housing form the bulk of the city i.e. why managing water sustainable in housing can considerably reduce the consumption of fresh water and affect the city as a whole. For this purpose Sahara States Housing has been selected to incorporate the principles of sustainable water management as it the major trend setter in housing sector and all the upcoming housing will be of this type.

5.5 SAHARA STATES HOUSING, JANKIPURAM, LUCKNOW



(a)



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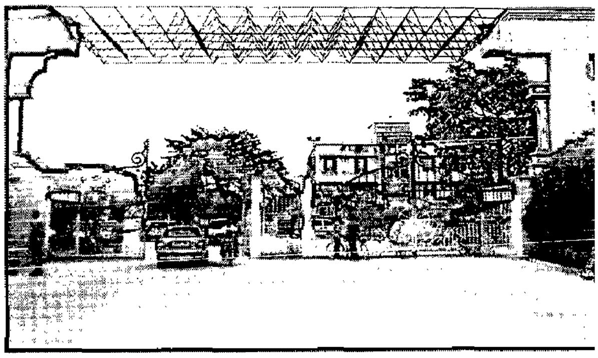
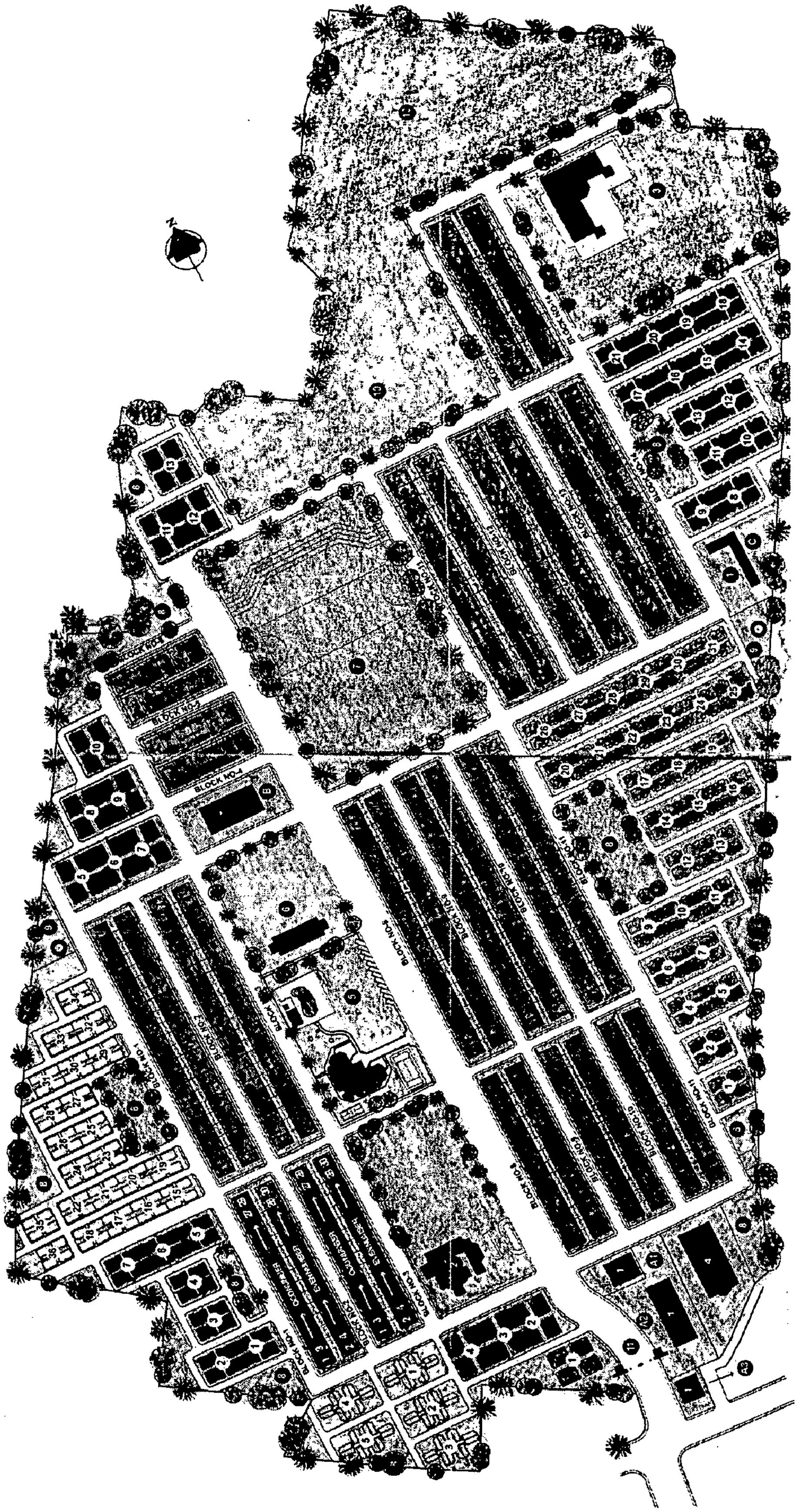


(c)

Fig 5.4 Sahara States Housing. Lucknow

5.5.1 Project Detail

Sahara States in Lucknow laid the foundation of quality living. Launched in February, 1999 it is developed on an area of 84.22 acre in Jankipuram, one of the fast growing areas of Lucknow (Fig 5.4). This is a well-connected & ideally located township, where approximately **1770 units** are built & almost taken possession of. It is located at Jankipuram Lucknow, on the road connecting to the Sitapur Road and Ring Road (Fig 5.5). Best amenities & facilities are being offered at the door step of the residents so as to give them an experience of a life time.



1. States plaza
2. Primary School
3. High School
4. Health Centre
5. Club and welfare centre
6. Playfield
7. Park
8. Over head water tank
9. Future development
10. Entrance gate

Fig 5.5 Site Plan of Sahara Estate Housing

Whole township is build with a keen civic sense & is based on modern architectural concepts. Stringent measures to provide a secured environment include earthquake resistant construction. Where Lucknow lies in seismic zone-3, the construction is done as per laws applicable for seismic zone-4 therefore ensuring highest level of security. It has also been awarded with the ISO: 9001 certification for quality management system.

5.5.2 Identification of Problem and Issues Related to Water Management

Present scenario of water as a resource in the housing:

i. Water supplied from two water tanks 6 lac litres capacity fed by Balaganj Water Works through Tube wells.
ii. No provision of rain water harvesting.
iii. No wastewater recycling system used.
iv. No water tax

Water Demand

The estimated demand of water is calculated in below in Table 5.6.

Table 5.6: Water Demand in Sahara State housing

Type of house	**Number**	**No of persons per house**	**Water demand (litres) (150 LPCD according to Lucknow Jal Sansthan)**
Single room	60x3=180	1	27000
One bed room	88x3=284	2	85200
Two bed room	32x3=96	4	57600
Three bed room	52x3=156	6	140400
Duplex	142+370=512	7	537600
15% wastage			127170
TOTAL			974570

Approximately 10 lac liters of water in needed per day for 5,652 persons, in the Sahara State Housing

Water Supply

24 hours pressurized water supply through two overhead tanks, six lac litres capacity each. Water supplied at present a total of 12 lac litres per day of water amounting to a supply of 215 LPCD (litres per capita per day) for the present population of Sahara State housing. It is more than what is required. As there is already scarcity of water in Lucknow (Table 5.7), Sahara State Housing is exploiting the water resource more than what is needed. Compared to the norm adopted for per capita water supply viz., 150 LPCD, the supply is inadequate, at present only about 80 LPCD of water may be reaching the consumers.

Table 5.7: Water Stress in Lucknow at present

Population according to 2001 census	22,45,509
Estimated present population (approx.)	26,00,000
Water demand at present (150LPCD +15% wastage)	449 MLD
Water produced at present: From River Gomti From ground water Total production (-15% leakage)	 270 MLD 205MLD 391 MLD
Water scarcity (on daily basis)	**58 MLD**

Source: Lucknow Jal Sansthan, Progress report, Dec, 2007

5.6 SUMMARY

It is evident from the present scenario of the water supply and distribution pattern and reasons for water stress and water scarcity in the city, there is an urgent need of water management in housing. As the amount of water supply is less than the demand. There are many places in Lucknow, where the water supply is not sufficient. From the Sahara States Housing, it is identified that the consumption of fresh water in this housing is very high. Thus, there is an urgent need of water management in Sahara State housing, so that the remaining population of the city gets the adequate amount of water supply.

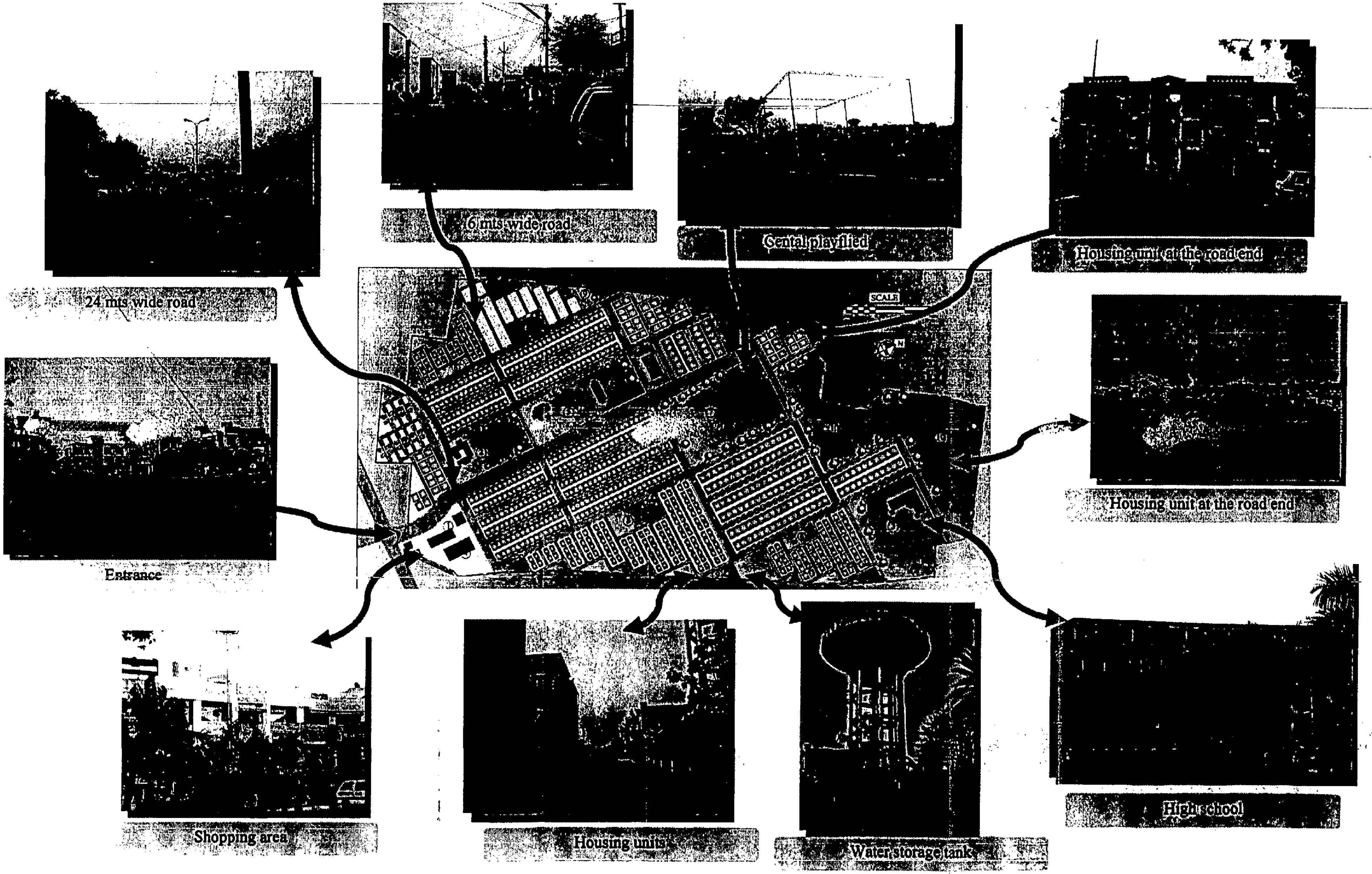


Fig 5.6 Various amenities of Sahara States Housing

In this Chapter design guidelines has been formulated for the housing to make it sustainable with respect to water, based on the review of literature and case studies done in the previous chapters. Finally the design guidelines for the study area, Sahara State Housing in Lucknow are been given taking into consideration the problems identified in the Chapter five, retrofit it to make it sustainable with respect to water.

CHAPTER 6

DESIGN GUIDELINES FOR SUSTAINABLE WATER MANAGEMENT IN HOUSING

"We used to think that energy and water would be the critical issues for the next century. Now we think water will be the critical issue. "

-Mostafa Tolba of Egypt,
President of the International Center for Environment and Development

6.1 GENERAL

Maintaining the balance between supply and demand in housing sector by means of supply management does not always depend on exploiting new water resources. Available fresh water resources are expected to decline with changes in rainfall patterns accompanying global climate change *(IPCC Report, 2007)*. As the population grows the pressure on water use also increases. To ensure future supply of fresh clean water it should be used more carefully. Good building design can greatly reduce the amount of water used and also the degree of contamination. The following design guidelines show how to use water in optimized way. The alternative sources like rainwater and recycled greywater can also be used as supply. Improved management of water resources will make the water available for future generation to use. Conservation of water in housing (reduce indoor water use by choosing water efficient showers, toilets, taps and appliances), Rain water harvesting (an alternative source of water), waste water reuse (recycled water use whereever possible); minimization of outdoor water use through reducing grass cover areas and planting native species, minimizing paving of outdoor areas (as this increases heat radiation and water runoff from the site) and installation of infiltration basins for recharging ground water, etc. are alternative strategies to be used in combination to get the best result.

6.2 DESIGN GUIDELINES FOR REDUCING WATER DEMAND IN HOUSING

6.2.1 General

Reduction of water consumption in housing is a simple and easy way to decrease water and energy bills and subsequently it will reduce the impact on the environment. Successful conservation of scarce water resource would reduce production of waste water, the need to dam rivers and also lower greenhouse gas emissions. The low cost techniques of water reduction can opted in every household, often with costs recoverd through water and energy savings within one year. Simple changes can reduce the pressure on available water supplies i.e. by reduction of indoor water use by segregation of fresh water and recycled waste water, installing water efficient fixtures and also by minimizing outdoor water use in lawns. For these design guidelines are given below separately.

1. Segregation

i. Fresh water supply and recycled grey water should be separated as per there use (indoor and outdoor) as shown in Fig 6.1.

ii. Rainwater may be replaced by fresh water supply as shown in Fig 6.1.

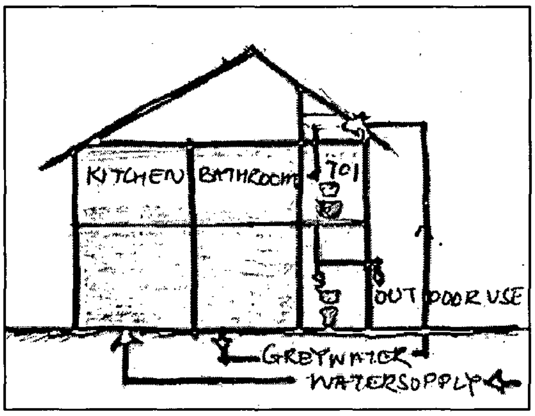


Fig 6.1: separated fresh water y and recycled grey water

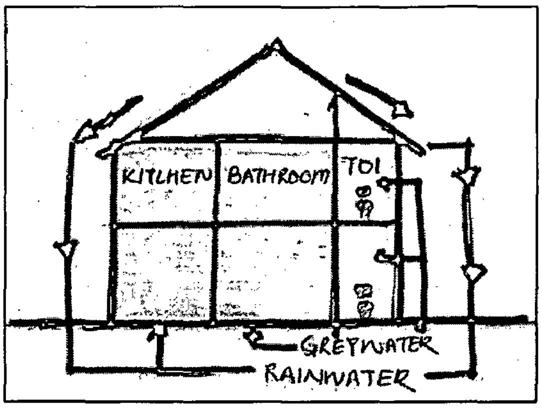


Fig 6.2: Rainwater could be replaced by fresh water supply

2. Changes

i. Water efficient products and appliances should be used more and more, wherever possible. Australia has a Water Efficiency Labelling and Standards (WELS) Scheme (Fig 6.3), which enables consumers to see the water efficiency rating of new taps, showers, toilets, urinals, clothes washing machines and dishwashers. The blue 6-star arch label shows the relative efficiency and a water consumption or flow Figure. The more stars, the more water efficient. Taps, toilets and showers are key areas where water consumption can be reduced by installing water efficient products.

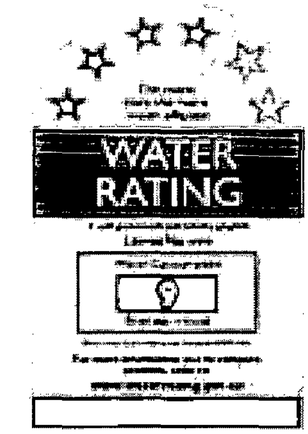


Fig 6.3: Water Efficiency Labelling and Standards (WELS) Scheme

ii. An inefficient showerhead can use more than 20 litres of water every minute while an efficient AAA rated will provide a high quality shower using a maximum of 9 litres every minute. (Fig 6.4)

iii. Flushing cisterns toilets should be replaced with a 6 litre/3 litre dual flush. Cistern of an old toilet would be replace

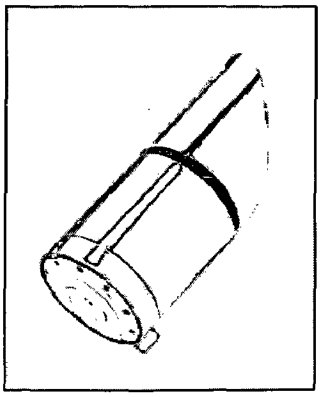
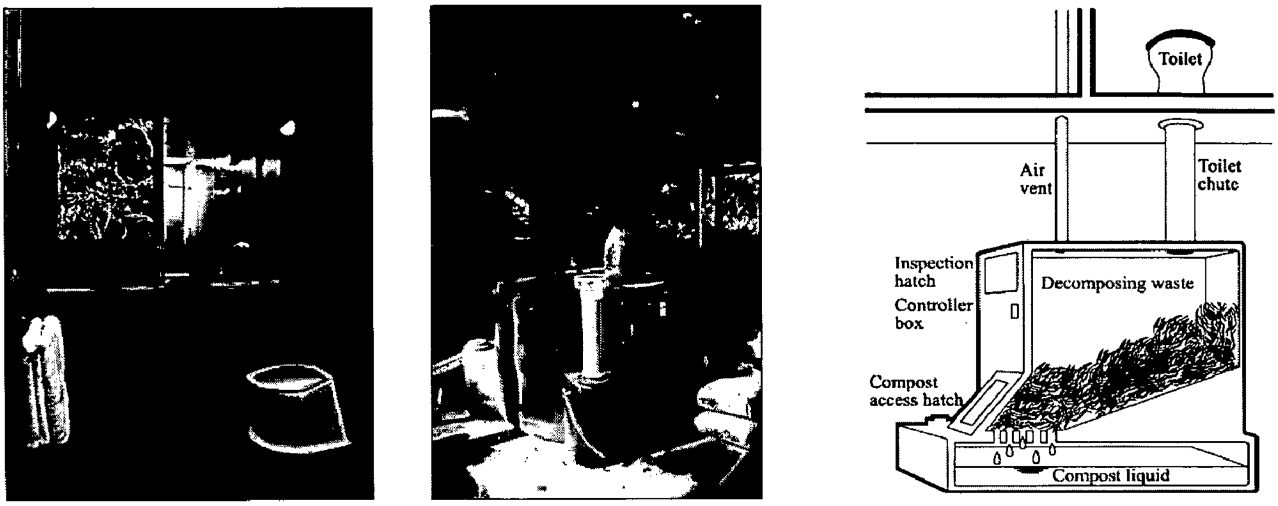


Fig 6.4: Shower AAA rated. Source: www.waterrating/

the with a 9 litre/4.5 litre cistern. The most water efficient toilet is a waterless toilet, of which there are a range of models and types available (Fig 6.5). They work with no odour and little maintenance while providing excellent compost.

iv. All new taps should be water efficient (AAA rated). Mixer taps should be installed in showers. They reduce the potential for scalding and save large quantities of water wasted through running the shower while trying to get a comfortable water temperature.



(a) *(b)* *(c)*

Fig 6.5: Waterless toilet
Source: www.compostingtoilet.org

3. Maintenance

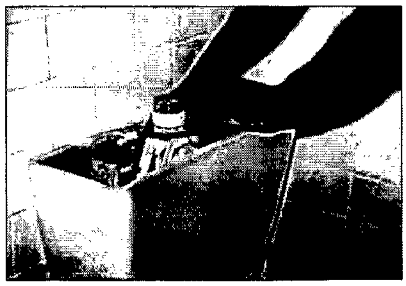


Fig 6.6: Leakages in toilet should be checked time to time.

i. Leaking toilets should be fixed immediately. A slow, barely visible leak can waste more than 4,000 litres per year. Visible, constant leaks can waste over 95,000 litres. *(http://www.yourhome/).* Leaks can be checked by placing a couple of drops of food colouring or dye into the cistern. If colour appears in the bowl within 15 minutes without flushing, then a leak exists and the system should be repaired. (Fig 6.6)

ii. Leakages of taps should be fixed immediately. A tap leaking at the rate of one drip per second will waste more than 12,000 litres of water a year. A flow regulator should be installed on kitchen and bathroom sink taps.

i. The laundry is a great place to reduce water consumption and is a potential source of water for garden. There are a number of ways to improve the efficiency of water use in the laundry. Water level on the machine should be adjusted so it is appropriate for the size of the load. Full loads of laundry should be tried to wash. The wash water from your laundry should be diverted to other uses, such as flushing toilet or watering garden.

6.2.2 Comments

i. Tremendous amount of water can be conserved by avoiding wastage of water, installation of leak proof water supply.pipes and the length of the pipes should be made minimum with lesser joints and bend as possible to reduce the possibility of leakage. (Fig 6.7)
ii. The diameter of the pipes should be appropriate to assure the adequate pressure head in the pipe so as avoid leakages.
iii. Cars and bikes should be washed on the lawn so that the grass is watered at the same time.
iv. Paths and drives should be swiped instead of hosing them.(Fig 6.8)

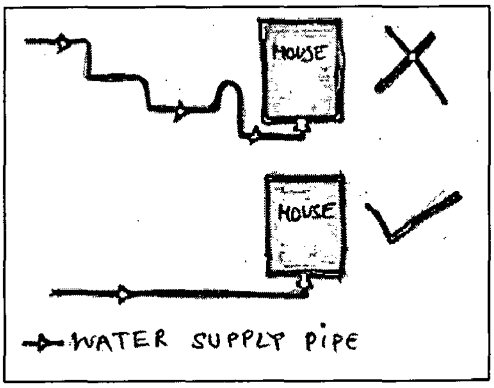


Fig 6.7: lesser joints and bend recommended

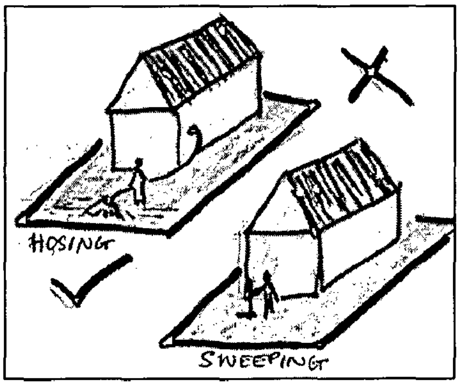


Fig 6.8: swiped instead of hosing

v. The public awareness and socio-cultural values are most important factor and highly effective to reduce consumption of water in a house. The attitude of the people towards the reduction of water and leaving behind the socio-cultural values by reusing waste water will greatly help to conserve the water in housing.

The environmental benefits of using water efficient fixtures are lower water use, decreased wastewater volume and reduced CO_2 emissions from reduced hot water use.

6.3 DESIGN GUIDELINES FOR WATER SMART LANDSCAPES IN HOUSING

The fundamental element of Xeriscape design is water conservation. Landscape designers constantly make efforts to reduce the amount of applied water and to maximize the use of natural precipitation. Following five principles of Xeriscaping i.e, soil improvement, creating limited turf areas, using appropriate plants, mulching and through proper planning and design, can reduce the consumption of water in housing significantly.

6.3.1 Soil Improvement

i. Water holding capacity is determined by the texture of the soil. Finer soils have greater capacity to hold water due to their greater particle surface area. There are three main soil types – sand, loam and clay. Sandy soils drain rapidly, clay soils hold water but make it difficult for many plants to grow. Proper soil should be used for different plants, as per requirement.

ii. A soil with plenty of organic matter and a mixture of fine and coarse particles that form into small composite particles (called 'peds') is ideal.

6.3.2 Creating Limited Turf Areas

i. Size of turf areas should be reduced as much as possible, while retaining some turf for open space, functionality and visual appeal.

ii. When planting new turfs, or reseeding existing lawns, use water-saving species adapted to that area.

6.3.3 Use Appropriate Plants

i. For best results, plants should be selected that are native to that region.

ii. Drought-resistant plants should be used. Generally, these plants have leaves which are small, thick, glossy, silver-grey or fuzzy coloured leaves, these characteristics which help them to save water.

iii. Plants are then grouped in the landscape

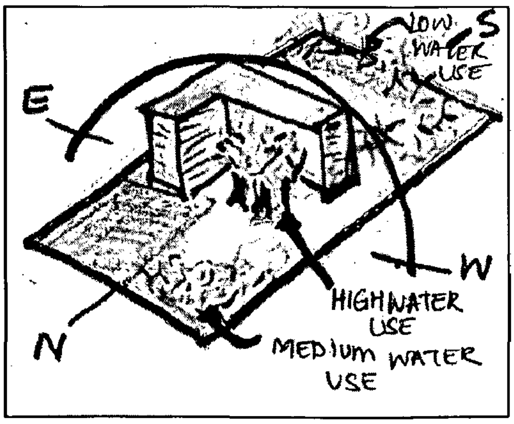


Fig 6.9: Plants should be grouped according to water use

according to their water requirements. Segregation of more water-demanding plants will prevent over watering of certain other plants. (Fig 6.9)

iv. Examples of plants for high water-use are vegetables, fruit trees, exotic shrubs like azaleas and camellias, flowering herbaceous annuals and many bulbs; Medium water-use are hardy vegetables like pumpkins and potatoes, hardy fruit trees and vines like nut trees and grapes, many herbs, some exotic shrubs, most grey or hairy leafed (tomentous) plants, roses and daisies and low water-use are banksias, grevilleas, eucalypts, succulents and cacti, olive trees and some exotic ornamentals such as bougainvillea.

v. High water-use plants are best located where they can be sheltered from drying winds and strong sunlight.

vi. Rainwater run off from downpipes should be directed towards high water-use areas.

vii. For hot, dry areas with south and west exposure, plants which need only a minimum of water should be used.

viii. Along north and east-facing slopes and walls, plants should be choosen that like more moisture. Trees help to reduce evaporation by blocking wind and shading the soil. Trees should be planted to create natural shade and windbreaks to reduce evaporation.

6.3.4 Mulching

Any water-smart landscape will have mulch as a major component. All plants benefit from a layer of organic mulch on the surface of the soil. Pine needles, pine or cypress bark, compost, and chopped leaves all help to preserve soil moisture by dramatically reducing evaporation. Mulched soils are also cooler than unmulched soil, reducing the ambient air temperature around the plants. organic mulches add nutrients and improve soil structure as they decompose, furthering the health of the plants. By using mulching in the following ways can reduce water consumption in landscaping:

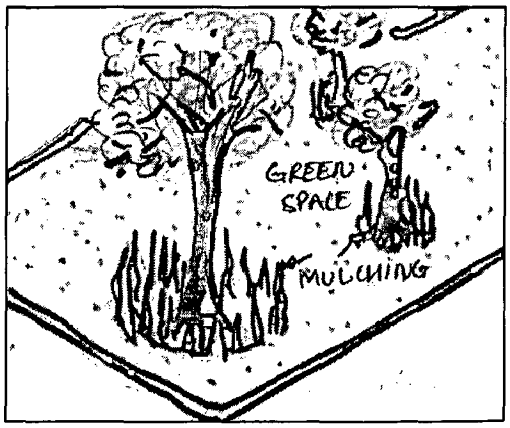


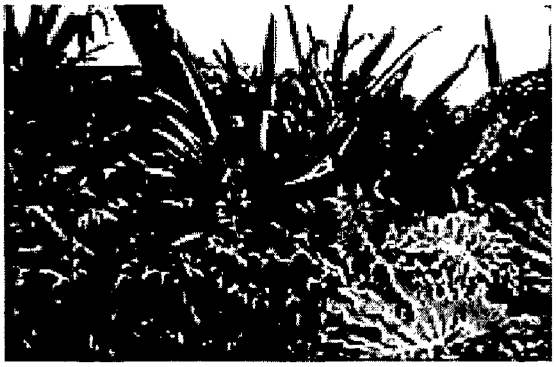
Fig 6.10: Mulching under shade of big trees

i. High water use plants may be mulched near the roots to retain moisture.(Fig 6.10)

ii. Landscapes should have large mulched areas that take the place of lawns and ground covers, especially in heavily shaded areas where turf struggles to grow.

iii. Organic mulches need to be renewed every year as they break down.

(a)



(b)

Fig 6.11: Detail of Xeriscape
Source: www.xeriscape.org

6.3.1 Planning and Design

i. Reducing lawn area is the easiest way to save water. Proper planning should integrate creation of garden beds, or mulch areas that are used infrequently or where grass grows poorly.

ii. Lawn areas should be replaced with porous paving, pebbles or drought-tolerant ground covers such as prostrate grevilleas, snake vine (Hibbertia scandens), or myoporum. (Fig 6.11)

iii. The plot should be oriented marking down north, south, east and west. Areas of sun and shade should be noted, which help to establish zones of differing will water needs, and then plants should be grouped with similar watering needs for most efficient water use.(Fig6.12)

iv. the study of natural contours and drainage patterns of the land help in developing treccaes, which add visual interest and help

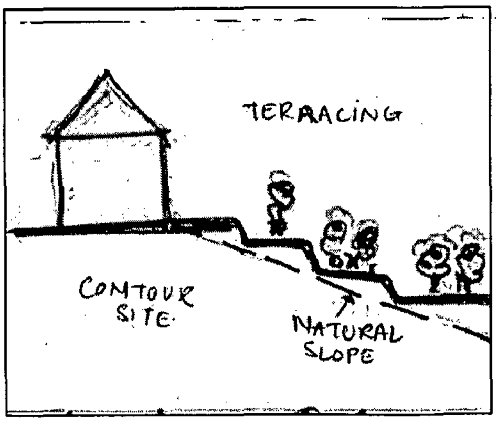


Fig 6.12: Mulching under shade of big trees

reduce soil loss and erosion due to rain or irrigation. Terraces can be as little as 3" and still offer visual appeal; terraces over 12" will require considerable support, such as rock walls or timbers reinforced with steel stakes. (Fig 6.12)

v. Planning of areas for seating, walkways, visual barriers, dining or play are also helpful.

vi. Areas to be left as turf should be designed to be easily mowed. Curved swaths are usually better than straight runs with sharp turns.

vii. Larger plantings, such as shrubs and trees, can be positioned to provide natural heating and cooling opportunities for adjacent buildings.

6.4 DESIGN GUIDELINES FOR RAINWATER HARVESTING IN HOUSING

6.4.1 General

Rainwater is a valuable natural resource that needs to be collected for domestic use. Not only the use of rainwater can reduce the consumption of fresh water but also it provides a chlorine-free supply of fresh drinking water which subsequently reduces community infrastructure cost. Rainwater harvesting system has three main aspects i.e. **collection, storage and distribution**. Following guidelines needs to be considered in all these aspects:

i. After collection of rainwater, it should be treated well, to ensure the quality of water before use.

ii. Tanks should be properly covered and thoroughly screened to exclude mosquitoes, birds and animals, especially in areas where mosquito-borne disease is an issue (Fig 6.13).

iii. Tanks should be designed so that when it overflows its water goes into gardens, infiltration trenches or the stormwater system. It should be desludged periodically with a tap installed at its base.

iv. If rainwater and mains supply are both used then mains water must be isolated from the rainwater system by a valve mechanism or tap (Fig 6.114).

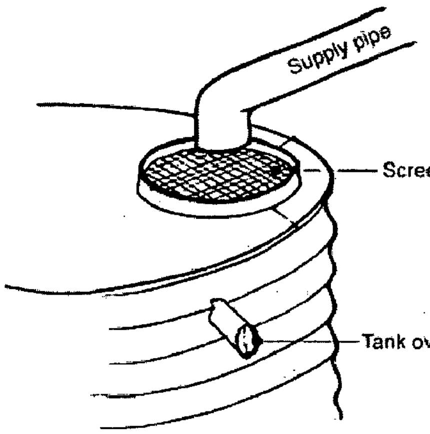


Fig 6.13: Screen used in the tanks
Source: http://www.yourhome/

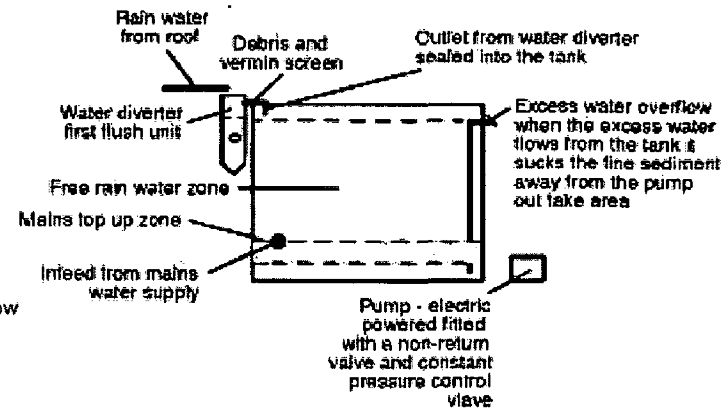


Fig 6.14: Arrangement of main supply and rainwater system (Source: http://www.yourhome/)

v. Tanks should protect water from sunlight, so as to stimulate algal growth. Plastic tanks may allow light to penetrate so they should be kept out of the sun or painted.

vi. Chemical disinfection or filtration of rainwater is not necessary if used for non-potable uses. If rainwater is used for drinking, it should be properly treated nad filtered.

6.4.2 System Maintenance of rain water harvesting

Regular maintenance is very important to ensure that the rainwater is safe for all requirements around the home, including drinking. The main contamination risks come from animals or birds leaving droppings on the roof and gutters or accidently entering the tank and becoming trapped. In urban areas there is also a risk of contamination from airborne pollutants, therefore following guidelines should be followed:

i. Screens around the tank should be checked and maintained.

ii. First flush diverter should be installed. This device fits onto the tank inlet and prevents the initial flow of contaminated water from the roof entering the tank when it rains (Fig 6.13).

6.4.3 Design guidelines for Rainwater Tank

The major determinant of tank size is whether or not to have access to a centralized water supply system. If not then a tank that is sufficient for all needs throughout the year is required for the family. The following are guidelines for selecting rainwater storage tank:

i. The size required will vary depending on the local climate.

ii. Factors that affect the size of the tank include the intended use of the rainwater the typical water consumption of the users and the area of the roof.

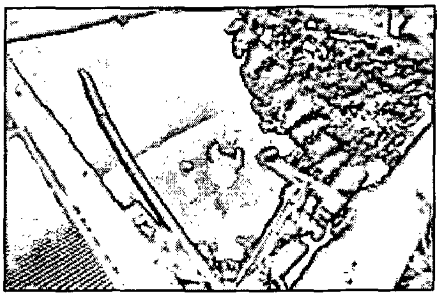


Fig 6.15: Masonary tank

iii. The most common tank materials include masonary, concrete, ferrocement, plastic (polyethylene), concrete, and galvanised steel (Fig 6.15, 6.16, 6.17).

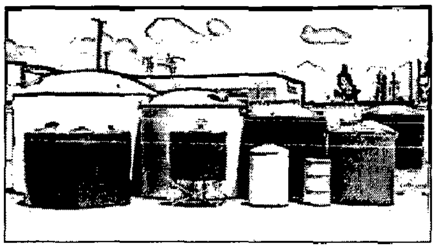


Fig 6.16: Plastic tanks, syntax

iv. The type of material selected for the tank depends on the budget; the size of tank required and water use.

v. Galvanised steel is the least expensive, but its lifespan is limited because of its affinity for corrosion. Concrete tanks are strong and long lasting. They are typically constructed on-site and can therefore be designed to meet specific site and domestic requirements.

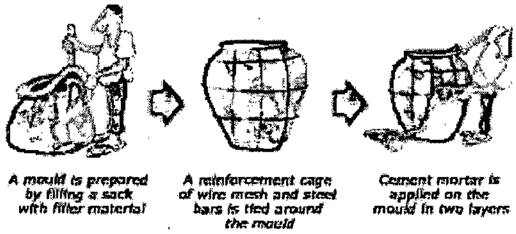


Fig 6.17: Ferrocement tank
Source: www.cse.org

vi. Plastic tanks are available in a range of sizes and colours (Fig 6.16). They are tough and durable and relatively lightweight.

vii. The most economic large tank is normally a concrete tank built in situ.

6.4.4 Choosing the Right System

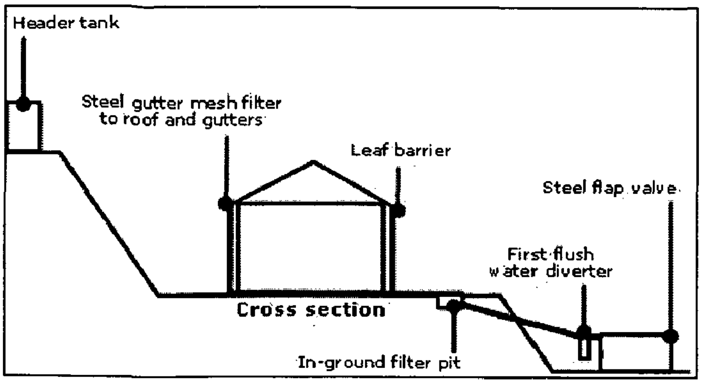
i. The tank should be elevated, so that its base is higher than the kitchen bench to assure proper water pressure separate tap in the sink.

ii. Alternatively, a small pump can be used to provide pressure, but this should be avoided if possible due to the energy requirements of the pump.

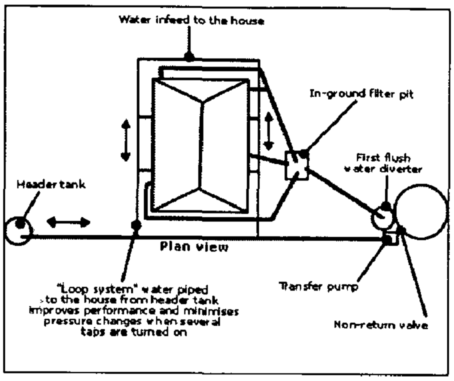
iii. A tap can be fit directly to the rainwater tank for watering the garden, washing cars and for other outdoor uses. A sprinkler essentially requires a pressure pump.

6.4.5 Rainwater System ConFigurations

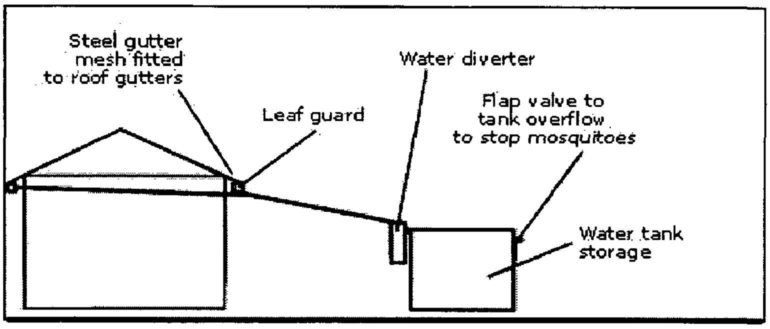
There are various types of arrangements for harevesting rainwater. Some are listed below with diagram (refer Fig 6.18).



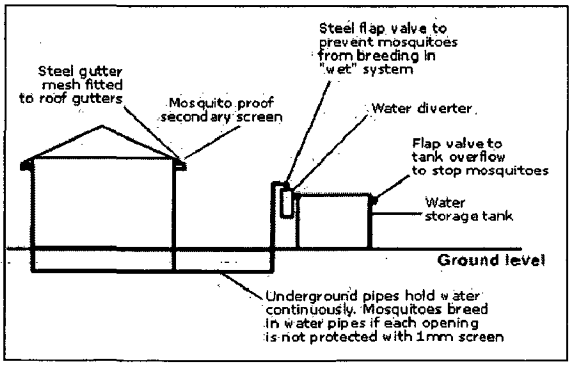
(b) Gravity fed system with pump, section



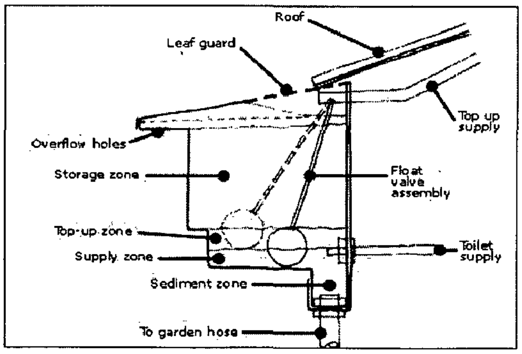
(a) Gravity fed system with pump, plan



(e) Dry System



(d) Wet System



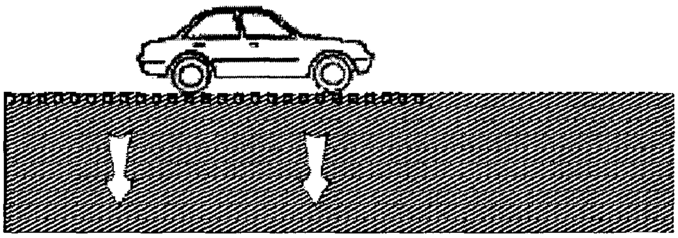
(c) Gutter storage System

Fig 6.18: Rainwater System ConFigurations
Source: http://www.yourhome/

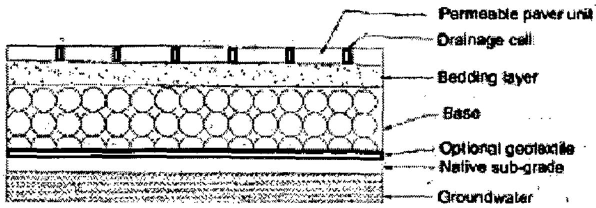
Gutter storage involves directing and storing rainwater in specially constructed large capacity gutters surrounding a house. Gutter storage systems are best suited for new houses, as the cost of the gutters can be managed by savings in building materials. The system is designed to gravity feed non-potable water for toilet flushing and garden watering.

6.5 SUSTAINABLE DRAINAGE SYSTEMS (SUDS)

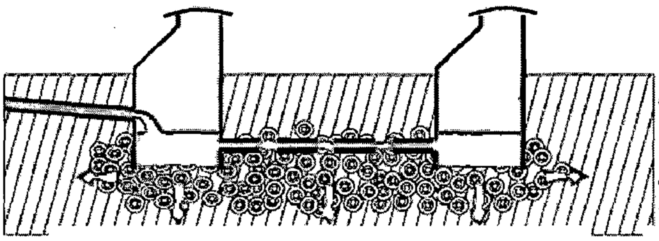
i. The appropriate technique of SUDS should be used according to the climate, location and topography of the site. Examples of these techniques are permeable pavements swales, filter strips, wetlands and ponds. Some of the techniques of Suds are shown in Fig 6.19 with details. .A central element of sustainable storm water management is the utilization of storm water as a resource.



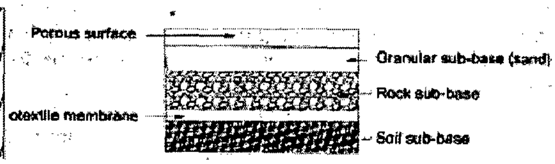
(a) Permeable Pavement



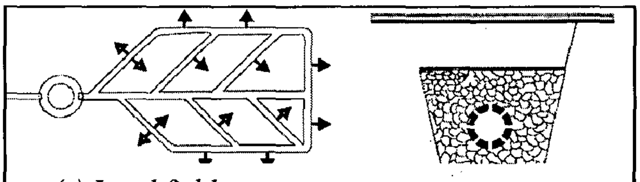
(b)Typical schematic layout of a permeable pavement system



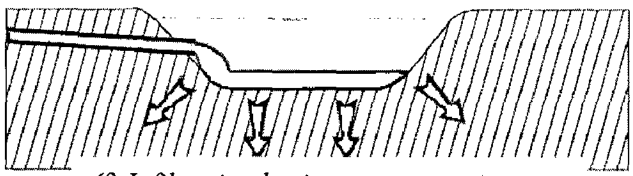
(c) Soakaways



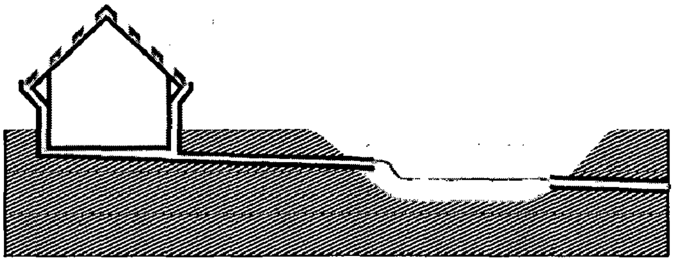
(d)Typical schematic layout of a pourous pavement system



(e) Leachfields



(f) Infiltration basins



(g) Pond

Fig 6.19: Techniques of Sustainable Drainage Systems

ii. Infiltration basins, ponds, soak ways should be placed according to the slope of the site so that all storm water drains toward it, as shown in Fig 6.19

Sustainable Drainage System supports groundwater recharge, decreases groundwater salinity, allows smaller diameters for sewers (resulting in cost reduction) and improves water quality of receiving waters, because pollutants and high peak flow are effectively controlled.

6.6 DESIGN GUIDELINES FOR WASTEWATER RE-USE IN HOUSING

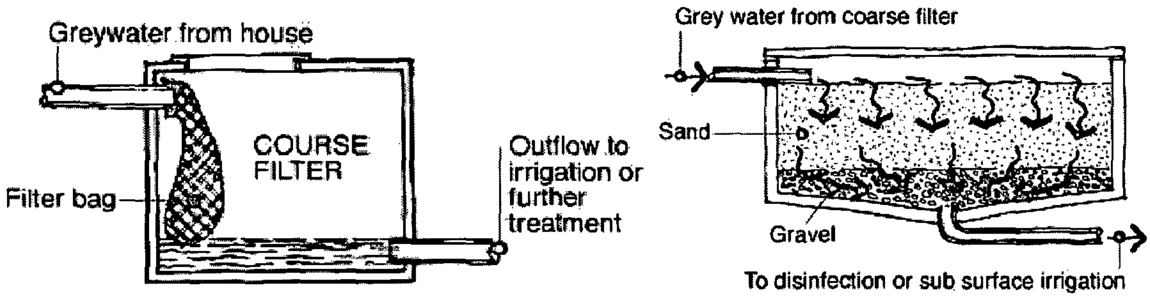
Waste water can be seen as the alternative source of water and by reusing in house considerably reduces the consumption of fresh water. It can be used inside the house for flushing toilets and outside for watering lawns and washing cars.

6.6.1 Using recycled and treated Wastewater Indoors

Toilets and clothes washers are two of the biggest users of water in an average household. Reusing wastewater for toilet flushing will save approximately 65 litres of potable water in an average household every day. Reuse of treated wastewater in clothes washer will save approximately 90 litres of potable water in an average household every day. Following guidelines should be considered while using waste water for indoor use:

i. In order to re-use indoor greywater indoors for toilet flushing and clothes washing; greywater and blackwater waste streams should be separated.
ii. Greywater must be treated and disinfected before storage and general re-use because it can contain significant numbers of pathogens which spread disease and it cannot be stored for longer than a few hours untreated as it begins to turn septic and foul smell starts coming out.
iii. Greywater can be directly diverted from the shower or bathroom sink drains for re-use in the toilet only. However, it should not be stored for more than a couple of hours before re-use or disposal to sewer.
iv. When reusing greywater for clothes washing discoloration of clothing from dissolved organic material may be an issue. This can be avoided by installing an activated carbon filter. There are many different types of greywater treatment systems, a few examples are given in Fig 6.20.

v. Greywater needs to be filtered before being treated in order to remove large size waste particles. After coarse filtering, greywater should be treated using a sand filter. The basic structure is a waterproof box filled with coarse sand laid over a gravel bed. (Fig 6.20a, b) Greywater flows in from the top and drains out from the bottom. Reed beds and sand filters treat the wastewater through filtration and some biological nutrient uptake. Wastewater needs to be pre-treated to allow removal of large particles, otherwise clogging will occur, and the lifetime of the system will be reduced.



(a) Coarse Filter *(b) Sand Filter*

Fig 6.20: Types of filter used in greywater recycling
Source: http://www.yourhome/-

vi. Disinfection is required for general re-use of greywater. All disinfection requires regular maintenance. Chlorine is most commonly used for disinfection, for example Aerated Wastewater Treatment Systems (AWTS) require chlorine pellets. However, chlorine disinfection has been found to have adverse environmental impacts. Alternatives should be used where possible.

6.6.2 Reusing Wastewater Outdoors

Reusing treated greywater outdoors can reduce household potable water use by 30 to 50 percent. Following guidelines should be considered while using waste water for indoor use:

i. Treated wastewater can be re-used to water gardens either by subsurface or above ground irrigation (Fig 6.21). Only treated and disinfected wastewater should be used for above ground irrigation due to presence of pathogens.

ii. The level of re-use of wastewater in the garden needs to be balanced with the amount of water, solids and nutrients that the plants and soil in garden can absorb. In order to solve these problems, garden should be planted carefully by using phosphate-free liquid or environmentally-friendly detergents used prefiltered to remove solids, and should not be irrigated if the soil is already saturated.

iii. There are different types of treatment systems suitable for outdoor re-use. Wet composting systems treat all household wastewater and also allow the composting of other household organic wastes (kitchen and green waste). Compost must be removed periodically and disposed of carefully. The effluent from wet composting systems typically requires further treatment and/or disinfection if it is to be re-used above ground.

iv. Storage is recommended as it maximises the usefulness of wastewater. Wastewater should be treated and disinfected before storage.

v. The only place where blackwater can be safely re-used is outdoors. But before using it should be treated well and disinfected as shown in Fig 6.22

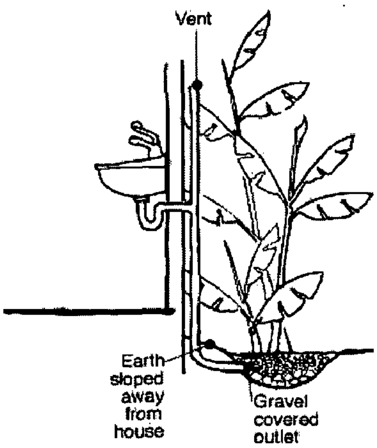


Fig 6.21: Outdoor use of wastewater

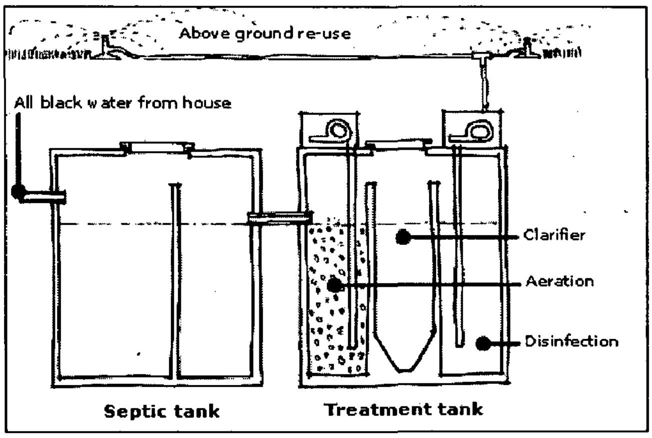


Fig 6.22: Treatment system of blackwater
Source: http://www.yourhome/

In the above section of this chapter, various design guidelines have been proposed to make any housing sustainable. Some of these guidelines have been incorporated in the study area, Sahara State Housing at Lucknow to make it sustainable with respect to water. For the preparation of the retrofit proposal, considerations have been taken to suit the climate, location, topography, attitude and socio-cultural values of the people residing in that housing.

6.7 PROPOSALS FOR STUDY AREA, SAHARA STATES HOUSING TO MAKE IT SUSTAINABLE WITH RESPECT TO WATER

The water management program in the Sahara States Housing (located at Jankipuram in Lucknow) has been analyzed in Chapter 5. As a result of study number of issues have been identified which need immediate attentions; e.g. shortage of city supply, unreliable quality of water etc. The proposal integrates the salient features from the literature review and case studies done on sustainable water management. Incorporation of rainwater harvesting at the maximum and recharging the remaining to aquifers are the key features of the proposal. Storm water surface runoff has been directed to the infiltration basin for recharging aquifers. In duplex, separate system for wastewater management and rainwater harvesting has been used to reduce the consumption of fresh water as providing alternative water sources.

6.7.1 Overview of proposed water management features

The following features are proposed on the existing housing of Sahara States for the sustainable managemant of water:

i. As per the progress report of Lucknow Jal Sansthan, 2007, 250 MLD of water is extracted from river Gomti and 207 MLD through tudewell from groundwater. Water supplied by Jal Sansthan to Sahara States housing is being taken from ground water through tubewells. Thus to recharge aquifers is the prime concern of the proposal, so that water is available in the aquifers for the further extractiom.

ii. Rainwater from the rooftops is collected and stored in tanks for outdoor use and gardening, the remaining rainwater is being directed for infilteration trench to recharge ground water.

iii. The surface runoff from open areas (parks and playgrounds) and roads, is challenalized through stormwater drain sytem to the detention basin, placed as appropriate place, to recharge ground water.

iv. Greywater and rainwater from the duplex are individually treated. Greywater after treatment is stored and used for flushing toilets and for outdoor use like car washing. Stored rainwater is used indoor in bathroom and outdoor for watering lawn.

v. **Hence, all the above features together make the complete water cycle as shown in Fig 23**

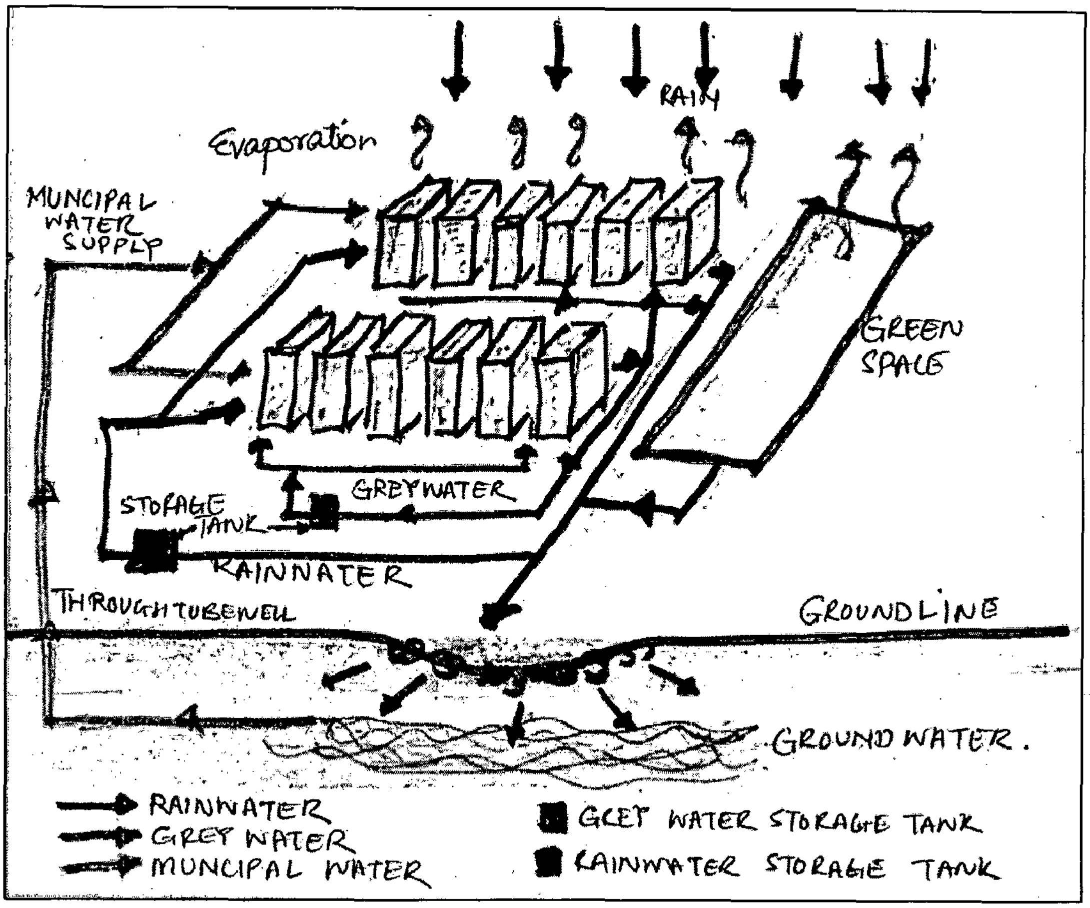


Fig 6.23: Overview of proposed water management features in Sahara States Housing

Fig 6.24: Left over space in the housing that can be used for constructing rainwater tanks and infilteration trenches

6.7.1 Rainwater harvesting from single room, one bedroom, two bedroom and three bedroom units

Rainwater from rooftops of single room, one bedroom, two bedroom and three bedroom units collected, filtered and then stored for use in houses for wasing utensils and clothes. This will reduce the consumption of water in housing. Following illustrates the amount of rainwater that can be collected and stored:

i. Average annual rainfall in Lucknow is 1000 mm (1m).
ii. **Runoff coefficient for the rooftop surface is 0.85.**
iii. Amount of rainwater that can be harvested from the rooftops of single room units 1,920x1x.85= 1,632 cu.mt i.e. 1632,000 litres.
iv. Four rainwater underground storage tanks of 4m x 4m x 1m constructed. Total volume of stored water would be 64,000 litres (Table 6.1).

The overflow from the rainwater storage tanks can be used to water garden and forrecharging aquifers (Fig 6.27).

Table 6.1: Total rooftop Area of Sahara State housing

Type of house & area of roof	**No. of units**	**Area of roof (sq. mts)**	**Amount of rainwater can be harvested (litres)**	**Amount of rainwater stored (litres)**
Single room (32 sq mt)	60	1920	1632,000	64,000
One bed room (57 sq mt)	88	5016	4263,600	192,000
Two bed room (87 sq mt)	32	2784	2366,600	128,000
Three bed room (121 sq mt)	52	6292	5348,200	512,000

The Table 6.1 shows the amount of rainwater that can be harvested from the different units and the amount of rainwater stored. The remaining rainwater is directed to recharge the aquifers through infiltration trenches. The water, overflowed from the tank and the first flush is also directed to infiltration trenches. The underground tanks are located in the left over green spaces and some tanks are places in the green space located between the housing units. The pots of plants can be places on the underground tanks, as a part of landscape, thus the construction of rainwater storage tank would not affect the beauty of the landscaped green space (see Fig 6.27)

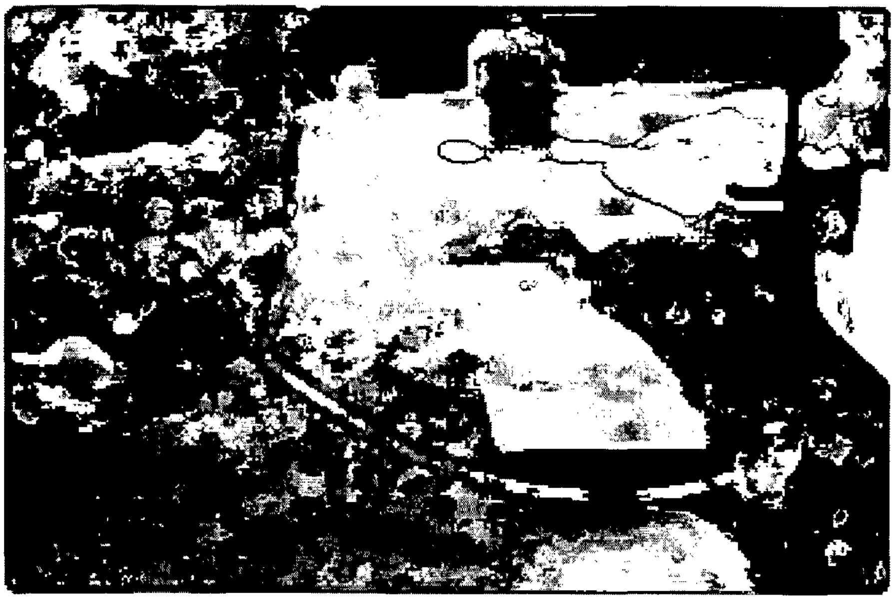


Fig 6.25: Rainwater harvesting: Underground Tank below plant pot

6.7.2 Incorporation of sustainable drainage system in the housing

Total Area of housing is 84.22 acre i.e. 340.754 sq mts. The surface runoff from the roads and open green spaces has been directed to the two **Detention Basins** proposed on the site. The placed of infiltration basin is such that the slope of all the storm water drains is towards it, so that it captures all most of the storm water surface runoff (Fig 6.28) . The infiltration basin is used to recharge the ground water and improves the quality of ground water by diluting it and also the quantity.

6.7.3 Wastewater reuse and rainwater harvesting in duplex

Separate system for wastewater management and rainwater harvesting has been used in duplex, to reduce the consumption of fresh water as it provides an alternative water source in the house. The recycled grey water is stored in rooftop tanks and used for flushing toilets and outdoor use (gardening and car washing). Rainwater collected from the rooftop is supplied to bathroom for washing clothes and bathing (Fig 6.29). The Table 6.2 tells the amount of rainwater that can be harvested and amount of grey water that can be recycled. Before using rainwater and recycled greywater, it should be filtered and treated.

Table 6.2: Amount of rainwater and grey water in duplex

Type of house & area of roof	Amount of rainwater can be harvested (litres)	Amount of grey water generated (litres per day)
Duplex (120 sq mt)	102,000	791
Duplex (200 sq mt)	170,000	791

6.7.2 Proposals for water smart landscaping

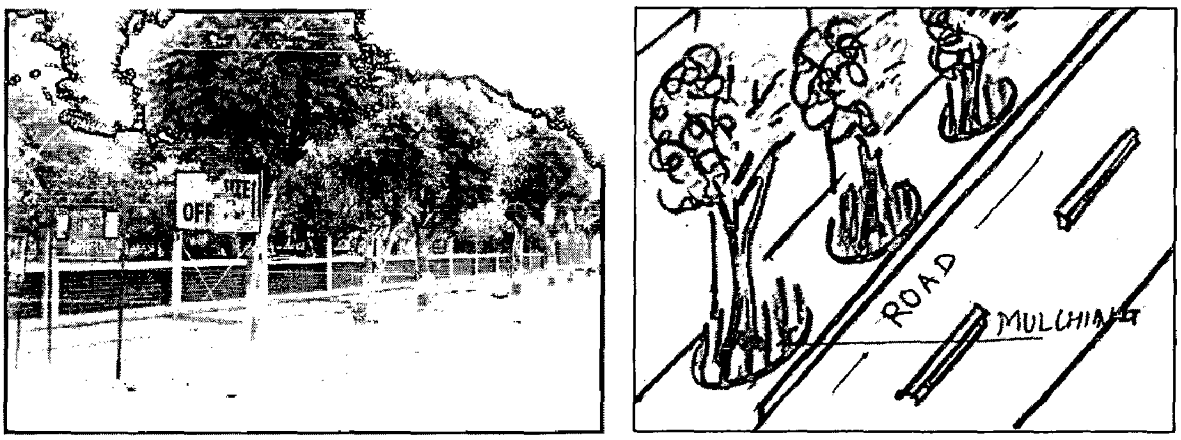
The Sahara States housing have large parks and playgrounds, thus amount of water needed to irrigate them is also very large. This can be effectively reduced by incorporating some of the features of water smart landscaping, Xeriscape. These are:

i. Various areas in a site should be divided into three zones: low-, moderate-, and high-water use. Plants should be then grouped in the landscape according to their water requirements, which prevents over watering certain plants within an irrigation zone when taking care of the water needs of other more water-demanding plants.

ii. High water-use plants should be located where they can be sheltered from drying winds and strong sunlight. These reduce the overall demand for water to maintain landscaping, while at the same time promoting attractive, region-specific residential premises that anyone would be proud to call their own.

iii. Garden beds or mulch areas should be created in areas that are used infrequently or where grass grows poorly.

iv. The road side trees should be mulched near the roots. This would retain moisture and reduce the water consumption. (Fig 26)



(a) Original: Before mulching *(b) Proposed: After mulching*

Fig.26 Proposal for water smart landscaping

6.8 SUMMARY

The proposals suggested above for Sahara States Housing, are with due consideration that the storage of rainwater and maintaining its quality is a difficult task and also the usage of recycled wastewater is not acceptable due to socio-cultural reasons, thus the main emphasis of the proposal is to trap the rainwater at its maximum and recharge it to aquifers. This would improve the quantity and quality of ground water. The outcomes of the proposals are as follows:

1. Reduction of the consumption of fresh water due to incorporation of water conserving methods.
2. Reduce the load on fresh water supply by the using rainwater in bathroom and recycled greywater for flushing.
3. Detention Basin recharges the storm water to the aquifers, improving the quality of water by diluting it. This also reduces the construction of storm water drainage system.
4. Using grey water in toilets and washing cars would considerably reduce the consumption of fresh water.
5. Overall advantage of the above proposal is that it maintains the water cycle and helps to improve the ecosystem.

The main purpose of the proposal (to retrofit the Sahara States housing) is to show the implementation of features of sustainable water management and the outcomes after that. Thus, by using various techniques of water management in any housing (old or new) can be made it sustainable, assure the availability of water in the future.

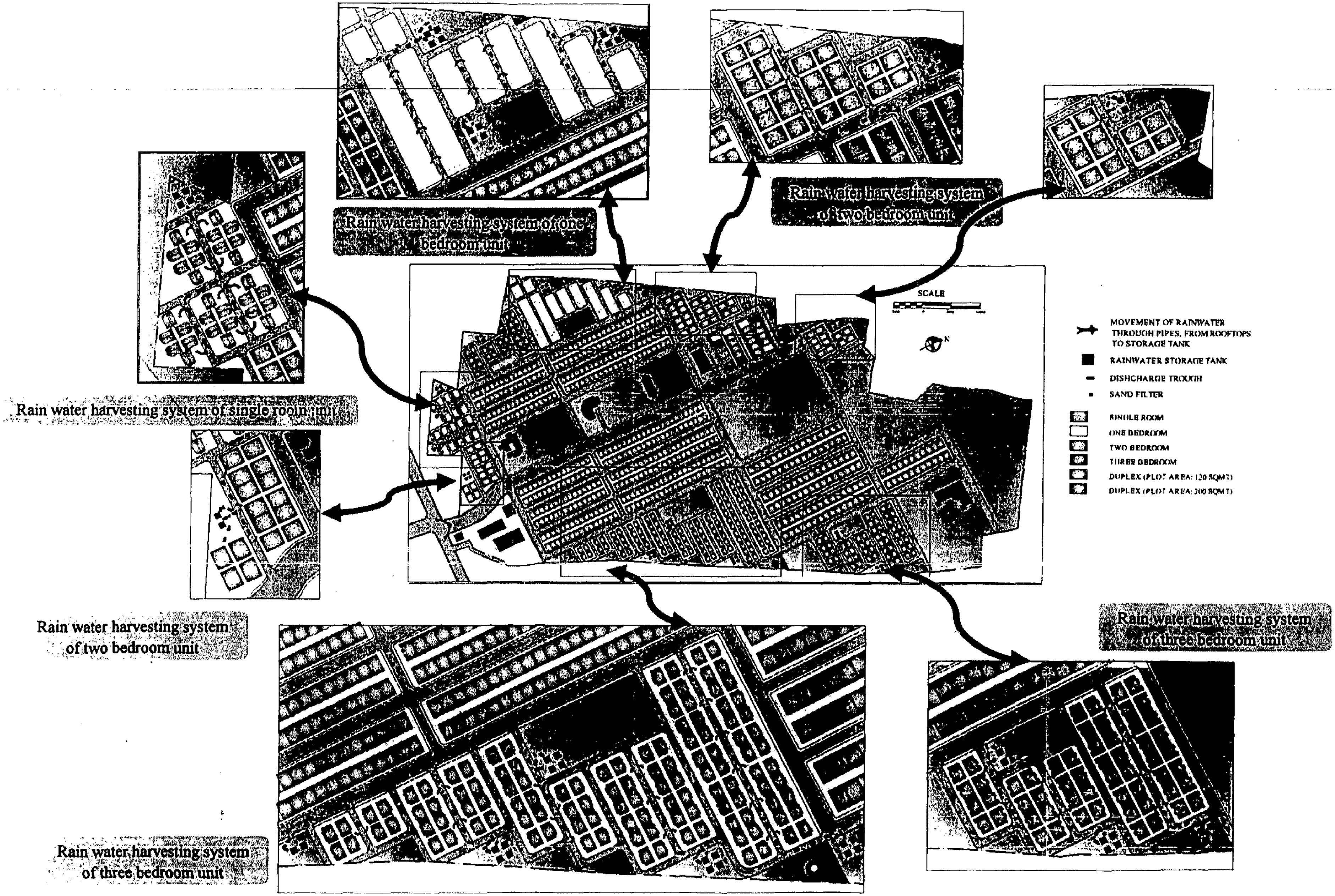


Fig 6.27: Rainwater harvesting system in Sahara State housing

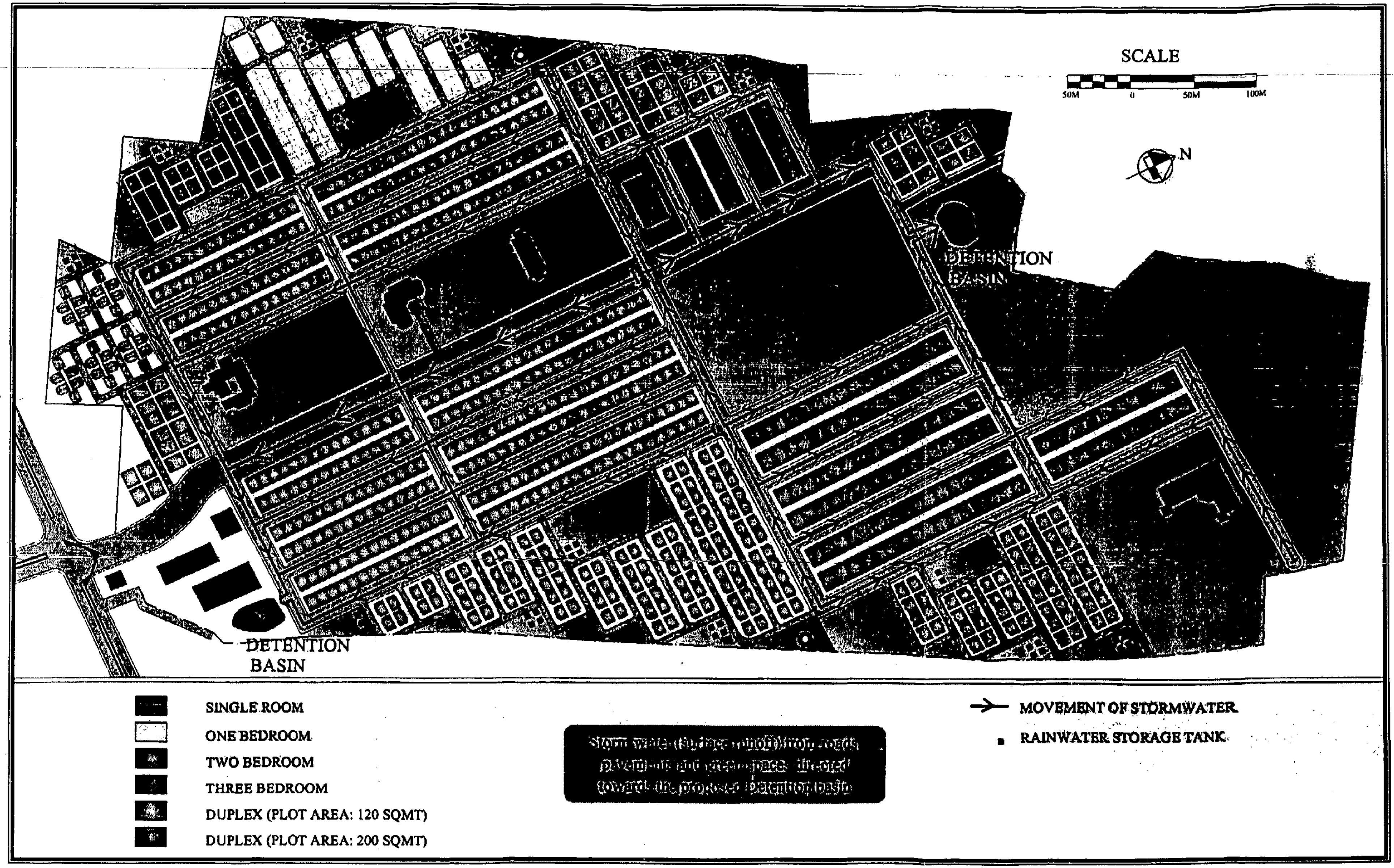
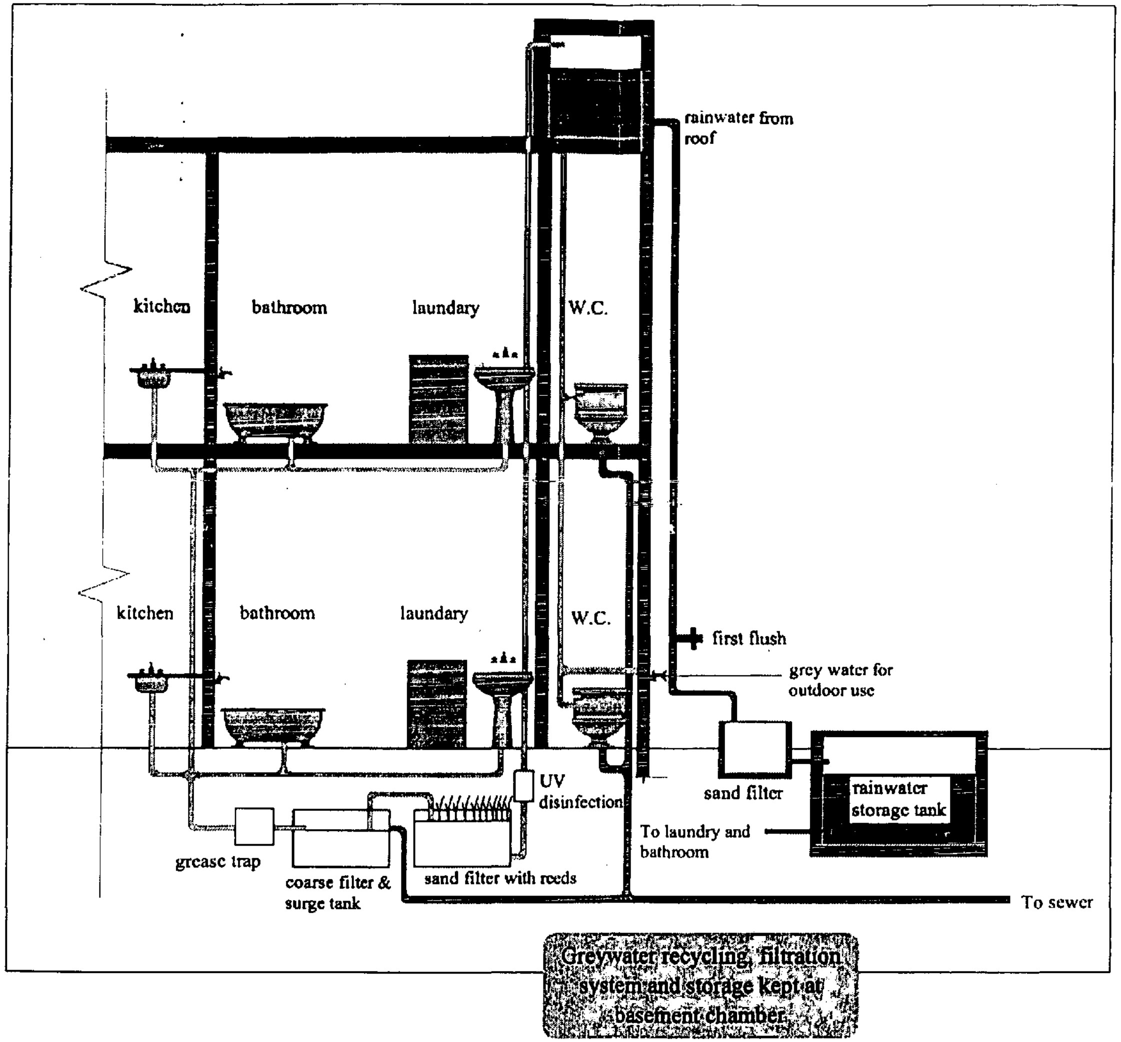
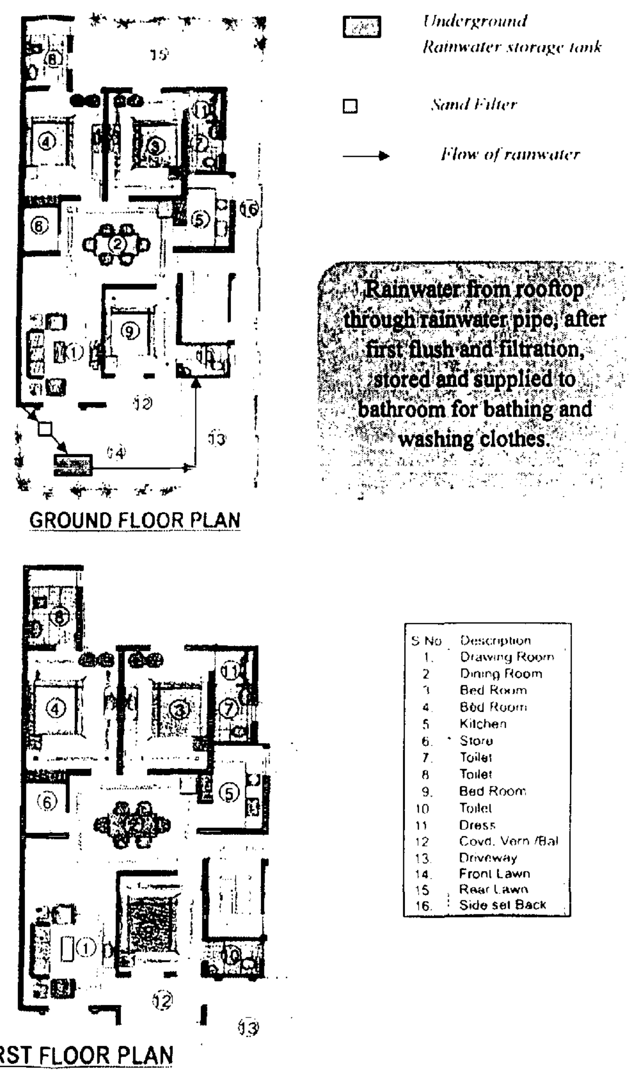


Fig 6.28: Sustainable Drainage system proposed at Sahara State housing



(a) Rainwater harvesting and waste water recycling shown in a section of the house



(b) Ground and first floor plan

Fig 6.29: Water management features in a duplex

This chapter concludes the study done in all the previous chapters and finally giving the recommendations for sustainable water management in housing. It also tells the scope of further study for sustainable water management in housing.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

"Anyone who can solve the problems of water will be worthy of two Nobel prizes - one for peace and one for science."

John F. Kennedy
Thirty-fifth President of the United States,
1961 -1963.

7.1 CONCLUSIONS

Water is, literally, the source of life on earth. Human being can survive for only few days without water. In India, water is free commodity. But those who have the best access to it are the wealthy farmers and urban dwellers, because they are the ones who are connected to the systematic irrigation water supply system. Poor people in rural areas or slum dwellers pay a high price for their water. **Pricing Water** would be an effective mechanism in putting a curb on its unlimited use. Water pricing policy has the potential to mitigate water scarcity. "In India, nearly 90 percent of the available water is used for irrigation purpose, 6 percent for industries and 3 percent for domestic" (*Bansil, 2004*). Though household water use is less in comparison to other sectors, the requirement is in the details of ensuring that water is safe and getting it to the people of both and rural areas who need it in an affordable manner.

In most part of the country the groundwater resources have been over exploited causing alarming environment problems. Rain water harvesting appears to be the major solution. India needs sustainable water management in housing. Proper management of surface and subsurface sources is essential for the survival and growth of human settlements, more so in housing which form the bulk of built environment in all cities. In addition to the measures for water conservation, reducing consumption, water efficient landscape, wastewater recycling, rainwater harvesting and sustainable drainage systems as suggested in previous chapters. In addition to this water shed development programs; public awareness; community participation and administrative measures for ensuring separate use and dual pricing system for treated and untreated water; maintenance of water pipelines and prevention of leakages are all essential for sustainable water management. Increased awareness of architects and planners along with an appropriate institutional and legislative frame work, monitoring system, tariff restructuring is vital. A holistic approach to water management and its integration with planning, design and development of housing is essential for sustainable human settlements.

Keeping in view the urgency of managing efficient supply and demand of quality water for various uses and conserving this precious resource, **National Water Policy** had been formulated by Ministry of Water Resources, Government of India in 1987. However, over time, the situation further aggravated needing a fresh look to the existing policy and a new water policy was adopted in 2002. "The revised policy of 2002 emphasizes integrated water resources development and management for optimal and sustainable utilization of available surface and ground water, creation of well developed information system, use of traditional methods of water conservation, non –conventional methods of water utilization and demand management." *(Kathpalia and Kapoor, 2002)* Despite many shortcomings, the National Water Policy, 2002 is considered a well thought out document conveying the message that **water is an increasingly scare and extremely valuable resource, without which sustainable development is impossible and all efforts should be made to guarantee sustainable use of fresh water.**

7.2 RECOMMENDATIONS

After understanding the need, issues, methods of sustainable water management in housing and keeping in view the supply and demand situation of fresh water in the country, following recommendations are made for consideration and implementation.

1. Considering the high losses and low revenues plague current water supply systems, some reforms that definitely need to be implemented include the introduction of comprehensive **metering.** This will require a policy change and it is highly recommended that action be taken at the earliest. Plugging the leaks through infrastructure interventions as well as effective penalties on those pilfering water are required immediately.
2. **Water privatization** is recommended to address the issue of water scarcity. Water privatization involves transferring of water control and/or water management services to private companies. The water management service may include collection, purification, distribution of water, and waste water treatment in a community.
3. **Water tariff** should be set at levels that discourage excessive use of water. Water efficient systems for flushing toilets should be made mandatory. Severe penalties should be imposed on those found responsible for leakage and wastage of water.
4. Use of non-conventional sources of water, such as recycling of waste water, after appropriate treatment is strongly recommended.
5. Use of potable water for purposes like washing of vehicles, maintenance of gardens, etc. should be prohibited. The **recycled wastewater** should be used for these purposes.

6. Ground water should be treated as a national property and tube well or bore well should not be allowed in the private premises of the owner. Exploitation of ground water in an approved manner may be allowed only by granting licenses.
7. Provision of **rooftop rainwater harvesting** structures should be made mandatory to the building as well as to the old buildings. Before carrying out the construction of such structures, the factors which need to be taken in account are soil cover, topographical gradient, aquifer system, depth of water, amount and pattern of rainfall, runoff coefficient and area of roof from where the rainwater is to be collected.
8. The present mindset of a majority of population is that water is government's business. Thus the **public awareness and people's participation** is very important for the conservation and management of water in housing.
9. A holistic approach to the water management should be evolved, integrating the surface and subsurface water interests for **quantity and quality of water**.
10. Hard surfaces such as roofs and pavements that decrease groundwater percolation, constitute the catchment areas, has to be guided in storage reservoirs or recharged into the groundwater table through **sustainable drainage system** or infiltration basins for subsequent extraction.
11. Effort should be made to implement all the provisions of the **New Water Policy, Govt. of India, 2002.**

7.3 SCOPE FOR FURTHER STUDY

Issues like watershed management, quality and monitoring of harvested rainwater, water pricing and subsidies, water policies, metering of water, public participation, socio-cultural values, etc are beyond the scope of this thesis. This presently can be extended or taken for further study by taking above factors into consideration.

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