Sustainable Water Conservation Techniques for an Office Building

Rajeev Kumar Verma[1], Dr. Deepashree[2], Ar. Kanika[3]

[1]M.Arch 1st Year, AIT-SAP, Greater Noida, India
[2]Professor At AIT-SAP, Greater Noida, India
[3]Professor At AIT-SAP, Greater Noida, India

Abstract:
Water is an essential element for the existence of life. As a biological component of living things and a sustainer of life's flora and fauna, it bears economic, social, and cultural value. It is no longer true to hold that water is an endless resource with boundless potential for regeneration. The population growth and the ongoing rise in polluting activities have led to a rise in catastrophic events occurring all over the world due to a lack of this invaluable resource, either in terms of quantity or quality, to meet the demands of humankind.

As the world's population continues to rise and our cities and suburbs fill up with additional buildings to meet the development, we face enormous challenges in managing and safeguarding our vital water resources.

Wastewater and storm water should be viewed as alternate and valuable sources of water rather than as annoyances that need to be managed, as pure freshwater resources grow rarer. Consequently, the practice of collecting and reusing rainwater and highly treated wastewater effluent is becoming more and more widespread.

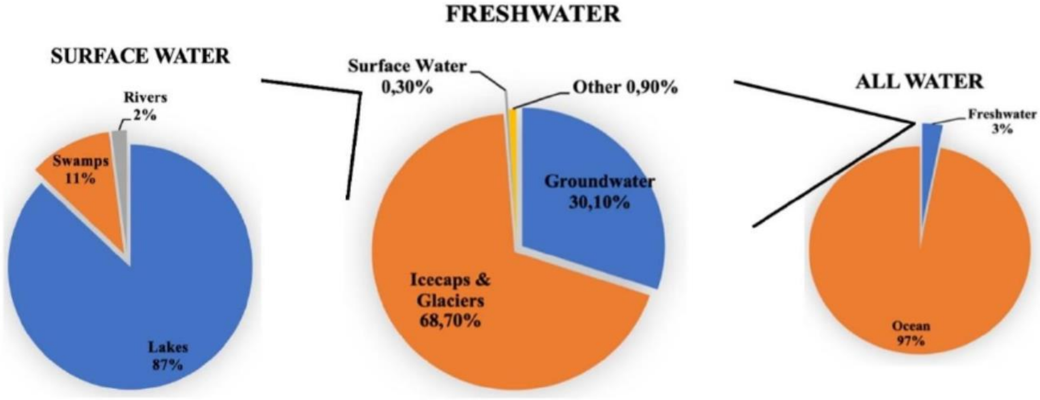
Keywords: Resource, Harvesting, Water, Conservation, Management, and Consumption.

1. Introduction:

Although 97% percent of the Earth's surface is covered in water, just 3% of that water is fit for human use (fig. 1a). The fast global population growth in recent years has made water conservation a major concern. Around the world, people are practicing sustainability to reduce their use of resources, mitigate negative environmental effects, and maintain a clean environment. Water conservation is becoming a more crucial consideration in the design of green or sustainable buildings due to the growing demand for water.

The word "water conservation" refers to the strategies, plans, and actions utilized to manage fresh water as a long-term resource in order to meet both the demands of the present and the future while also protecting the environment. Population density, household size and growth, and economic status all have an impact on the amount of water used. For instance, the effects of climate change will be felt more strongly on natural water supplies, especially in the irrigation of agriculture and industry.

Figure 1a: Water cycle



Among the list of water conservation initiatives are the following ones:

Sustainability: To ensure that freshwater resources are available for future generations, the rate at which they are depleted from an ecosystem must not surpass the rate at which they naturally renew themselves.

Energy conservation is important since waste water treatment, distribution, and pumping systems consume a lot of energy. In many regions of the world, water management accounts for over 15% of total electricity consumption.

Reduced human water use not only lessens the need for new dams and other water diversion infrastructure, but it also helps preserve freshwater habitats for migratory waterfowl and local species.

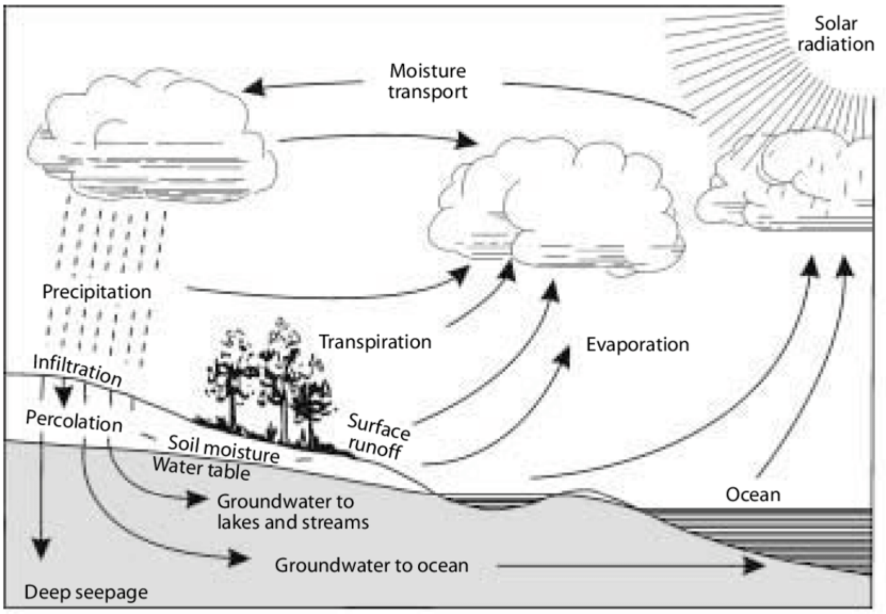
Water is an essential element for the existence of life. In addition to being a biological component of living things and a sustainer of life's flora and fauna, it has symbolic economic, social, and cultural value. It is no longer true to hold that water is an endless resource with unbounded potential for regeneration. There are now more catastrophic situations worldwide related to the lack of this invaluable resource, either in terms of quantity or quality, to meet humankind's basic needs as a result of population growth and a continuous rise in polluting activities.As the world's population continues to rise and our cities and suburbs fill up with additional buildings to meet the development, we face enormous challenges in managing and safeguarding our vital water resources. Wastewater and storm water should be viewed as alternate and valuable sources of water rather than as annoyances that need to be managed, as pure freshwater resources grow more limited. Consequently, the practice of collecting and reusing rainwater and highly treated wastewater effluent is becoming more and more widespread.

Conservation:

One could classify recycled water as a renewable water source. Conversely, the Water cycle's (fig. 1b) limited supply of useable water bestows an economic and intrinsic worth on this finite resource, suggesting that it be utilized multiple times before being reintroduced into the cycle.

Water reuse is becoming a more important component of the planning, development, and overall use of water resources in both desert and humid climates as the demand for water rises. Reducing water pollution has led to treated water effluent, which is a substantial and affordable source of supply when contrasted to the ever-increasing costs of creating fresh supply. Wastewater has the potential to be a competitive alternative to treated and potable water because it can be used for non-potable uses in agriculture or for industrial cooling. Flexibility in satisfying short-term demand while simultaneously guaranteeing long-term supply should be enabled by the integrated management of potable resources and wastewaters, as well as their reuse. Since urban wastewater systems are not significantly affected by droughts, recycling offers a dependable supply of water during dry spells.

Figure 1b: Water cycle



A secure water supply is essential for both economic and social stability in any nation. When integrated, the many techniques for water conservation, recycling, and reuse serve as the cornerstone of an efficiency revolution. Large-scale water availability for cities, industry, and agriculture is now possible because to widely accessible methods and technologies. But society is still on the verge of change because of laws and practices that reward waste and misuse over economy and conservation.

Significant changes in the pricing, distribution, and management of water are required in order to move toward more economical, sustainable, and ecologically friendly patterns of water usage. All nations, especially those with water shortages, should strive for appropriate pricing, the development of markets for the purchase and sale of water, and other financial incentives for water use. The following institutes and organizations support recycling and reuse of technologies:

State of California, California Municipal Wastewater Reclamation, California State Water Resources Control Board, Office of Water Recycling, Sacramento, CA, USA.

- Dames & Moore, Water Pollution Control Engineering Services, EPA 430/9- 77-013, Office of Water Program Operations,US Environmental Protection Agency, Washington, DC, USA.
- World Health Organization, Geneva, Switzerland.
- American Water Works Association Research Foundation, Denver, CO, USA.

Because the type of construction directly affects how much water is used, a steel and glass building may have an embodied water footprint primarily due to the materials used, whereas a cast-in-situ strengthened cement concrete and brick building may have significant on-the-spot water use. Water potency is therefore required in the first case during the manufacturing stage, whereas the second class requires thoughts and actions during the consuming stage. This study looks at a number of related issues, such as the need for water during the material production and construction phases, as well as the embodied water of typical Asian urban constructions, which was found to be in the range of roughly 27 kilolitres/square meter of total settled area.

1.1 Aim:

This research is based on data critically analyse existing research on sustainable water use techniques in office buildings and identify key research gaps to inform future studies, and the aim of this research is to promote and to make recommendations for water-saving measures for a commercial office building that is currently in use and to compute the building's water consumption decrease following the implementation of sustainable water management practices.

1.2 Objective:

1.2.1 To assess the current state of the building's water distribution system.
1.2.2 To examine the current method of managing water resources.
1.2.3 To make a comparison between the feasible water techniques that can be used and the current water techniques used in the chosen building.
1.2.4 To propose and advise actions for adapting new techniques or retrofitting current ones.
1.2.5 To highlight research gaps in the existing body of literature.
1.2.6 To propose future research directions based on identified gaps.

1.3 Scope:

The purpose of the study is to apply sustainable water management strategies to optimize operational and maintenance costs in a government office building and compare the results with traditional expenses of the same.

1.4 Limitations:

The study solely looks at sustainable water techniques for lowering O&M expenses; it leaves out other aspects of life cycle costs. Additionally, because an office building in an urban CBD will have a suitable water supply, drainage system, and maintained records, the study is limited to only those buildings.

1.5 Methodology:

6.1 Gathering background information on the O&M expenses associated with water delivery.
6.2 Data collection using a live case study of an existing government building and literature.
6.3 Data analysis based on case studies and real-world case studies, with research parameters determined by comparing the cases.
6.4 Research and data interpolation using a building's sustainable water resource factors.
6.5 Conclusion based on problems and drawbacks.
6.6 Moving the dissertation research in the direction of creating a thesis short.

2. Literature:

2.1 Water Conservation:

The types of water sources that people can use on a daily basis are limited. The demand for water is rising in tandem with the population's rapid growth. The planet may eventually experience a shortage of water if all available water supplies run out. Protective water is therefore desperately needed, as is the prevention of water pollution. Reducing water use and maintaining its quality is one of the main ls of new construction. Water conservation over a building's lifetime can be accomplished by designing dual plumbing that recycles the water used for wash cars and water closets, as well as by utilizing water-efficient fixtures and fittings like low-flow showerheads, bidets, and ultra-low flushing toilets. Other technologies are also being used, such as greywater reprocessing and harvesting from rainwater.

Depletion of water supplies is becoming a global environmental issue of the utmost importance due to the rapid development of the global economy. According to the World Development Report (WWDR), there is a water crisis since there is less water available for all of our needs. The outcomes in a certain industry will be more obvious in the setting than in the construction industry. Water from the surrounding environment is heavily used in building construction and operations.

Water tables have significantly dropped as a result of increased urban water usage, needing enormous supplies that are drawn from agriculture. Water used for building operations may account for a significant portion of the country's water use. But this might not be the only type of water used throughout a building's lifetime. In addition, water is used in the actual on-the-scene construction process, as well as in the extraction, manufacture, producing, and distribution of goods and materials to the site.

Figure 2

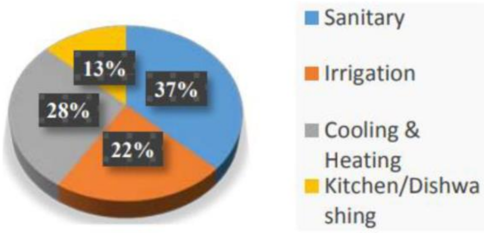


Figure 3. Every Drop Count…!

Figure 3a. Water is a life essential resource.

Water efficiency pertains to a reduction in both the amount of water used and wasted. Water resources are depleted as a result of water waste and excessive use, which draws a lot of water from them. Water-efficient technologies are therefore created to preserve both potable and non-potable water, thereby preserving the already limited supply of H2O.

Water-efficient fixtures and fittings are the primary embodiment of water-efficient technologies in buildings. They also include collecting rainwater, using it, and repurposing gray water.

Water conservation will be outlined as:

- Any beneficial reduction in the usage, loss, or waste of water.
- A decrease in water use achieved through the application of conservation or water potency techniques; or,
- Better water management techniques that reduce or increase the beneficial use of water are defined as any activity, behavioural change, tool, technology, or improved way of doing things that is required to reduce water loss, waste, or use. Potency of the water could be a conservation tool. This

results in extremely economical water use, which lowers water demand. When assessing a water potency live's worth, price, and value, consideration should be given to how it affects the cost and use of various natural resources.(For instance, chemicals or energy)

Among the objectives of conservation initiatives are:

- Sustainability: Water removal from the AN system shouldn't surpass its natural replacement rate in order to provide convenience for future generations.
- Energy conservation is important since sewer water treatment facilities, water pumping, and delivery systems use a lot of energy. Water management accounts for more than V-J Days of global electricity usage in some areas (like California 2).
- Habitat conservation: Reducing water use by humans not only lessens the need to build new dams and other water diversion infrastructure, but also helps to protect H2O habitats for native species and migratory water birds.

One of the easiest ways to reduce water use in your building and save a lot of water is through water conservation.

Installing showerheads, low-flow fixtures, and bathrooms, for example, will have a significant effect. The American state Building business Association provides the following installation and maintenance advice for low-flow fixtures:

There exist several tactics that can be implemented to minimize the quantity of water utilized within a facility. Broadly speaking, these techniques consist of:

- System optimization (i.e., efficient water systems design, leak detection, and repair);
- Water conservation measures; and
- Water reuse/recycling systems.

2.2 Rain Water Harvesting System:

Drinking clean water has become a luxury in certain rural areas due to the phenomenon of water emergencies. Potable water may be becoming scarcer these days. There isn't always potable water available, and in many situations, it's only feasible with prohibitively large initial and ongoing costs that prevent implementation. With the right treatment, fresh water may be a relatively safe and sustainable resource. In addition to preserving premium drinking water sources, rain water harvesting (fig. 4 &4a) is a suitable solution for lowering high wastewater levels, reducing floods, and halting land erosion.

Figure 4 Schematic of Rain Water Harvesting

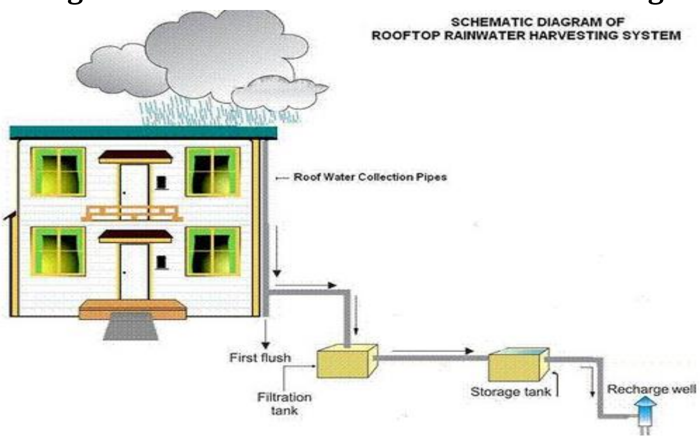
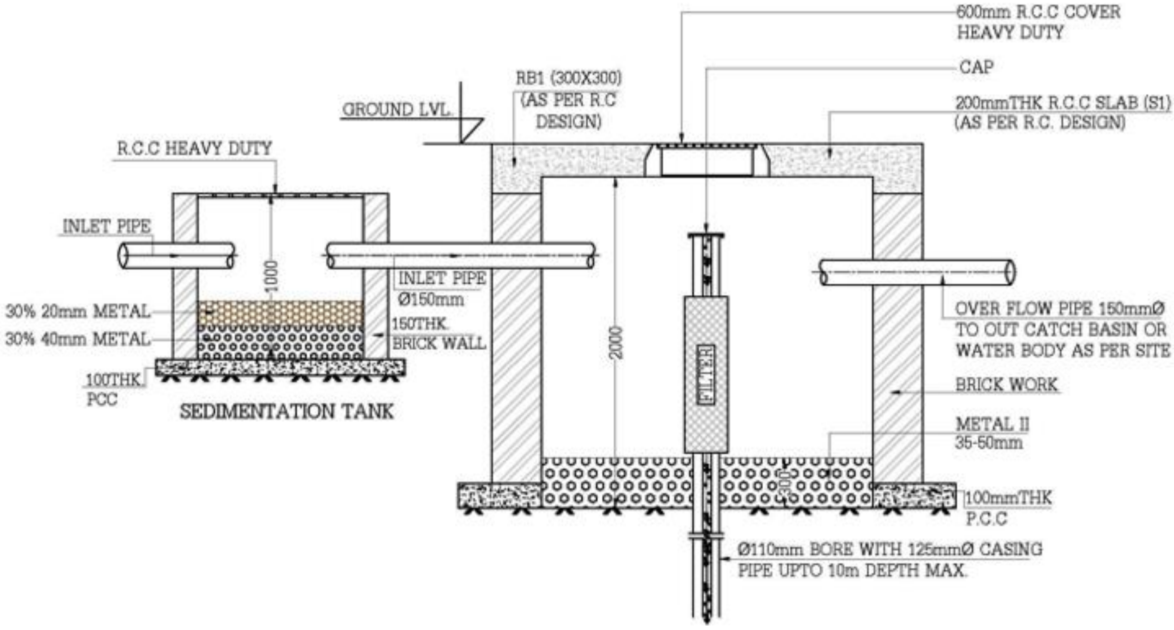


Figure 4a. Recharge Pit



Rainwater Harvesting Stages

03- steps make up a standard rainwater collection system:

Collection Stage

This is the first stage in collecting rainwater. In a catchment area, rainwater is gathered in a container on rooftops, paved surfaces, or the surface of the soil during periods of precipitation. Channels that go around the perimeter of a sloping roof gather and carry rainwater to a storage tank.

Distribution Stage

The core of RWH's distribution network is its pipeline network. They move rainwater from the rooftop or catchment area to the gathering system. They can be semi-circular or rectangular and are constructed from bamboo, PVC, and galvanized iron sheet (20 to 22 gauge).

Storage Stage

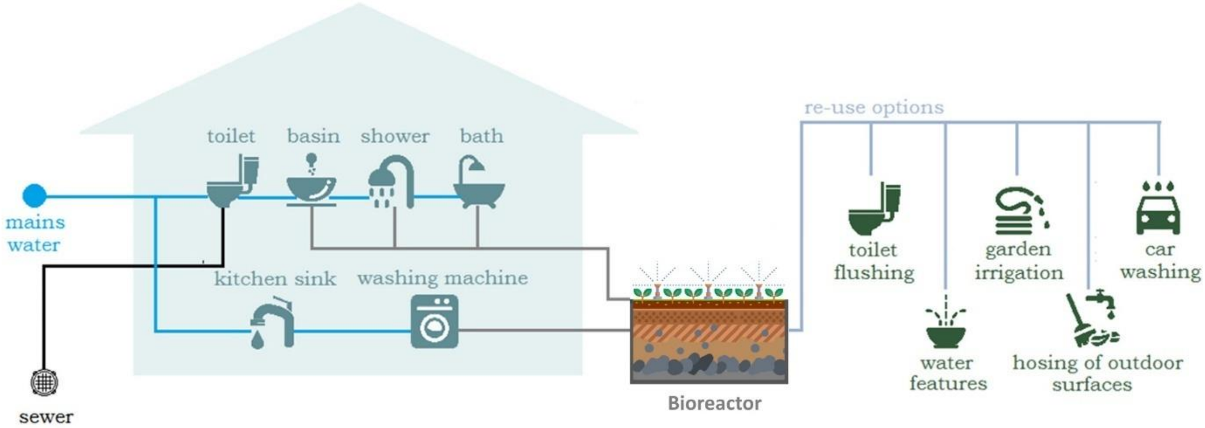
- Rainfall
- The duration of the dry season
- Approximate need

The groundwater table is falling as a result of the increasing demand for water. The groundwater table is refilled by rainfall. Although these water sources are erratic, they can be found in lakes, rivers, ponds, aquifers, etc. Rainwater that has been treated can meet home water demands. The majority of the time, water sources are situated far from towns. The ability to collect and utilize rainfall will lower the cost of delivery.

2.3 Grey Water Recycling:

Greywater is wastewater from bathtubs, showers, and wash basins that can be recycled on-site and used for landscape irrigation, toilet flushing, and other non-potable uses. Grey-water does not contain wastewater output from dishwashers, washing machines, or kitchen sinks because of the high nutrient levels. Wastewater tainted with feces is categorized as bathroom waste.

Figure 5. Grey Water, Treatment and Re-use



Grey water's quantity and quality will, in part, determine how it is reused (fig.5). Examples of regular use include flushing the toilet and irrigation. Grey water irrigation is a feasible solution for food crops, ornamentals, lawns, and trees. Grey-water guidelines are applicable in both situations, even though outside watering and greenhouse irrigation systems are very different. Toilet flushing can consume a large amount of grey-water because it can account for as much as 50% of indoor water use. Because the water is disposed of in the septic or sewage system, using low-quality grey-water for toilet flushing does not present a concern. A grey-water recycling system consists of the following parts: collecting, transporting, treating, storing, and reusing recycled grey-water. One benefit of grey-water recycling is that it allows for the reuse of water lost in daily life, which makes up around 40% of an individual's daily water use. One of the biggest concerns with grey-water recycling is the potential for a health issue brought on by inadequate disinfection methods.

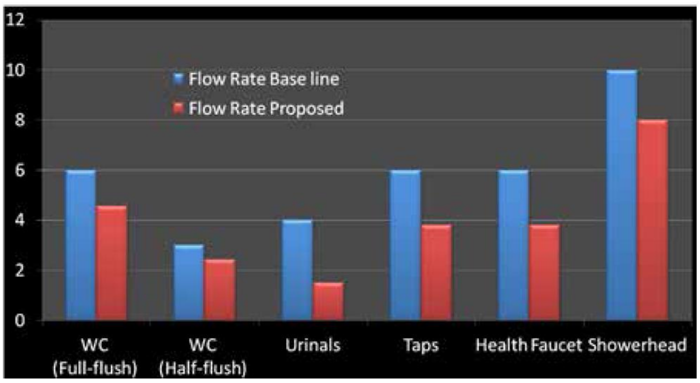
2.4 High-Efficiency Water Fixtures and Water pressure reducing Valves:

Effective facilities are needed for good sustainable designs to be realized. The following four factors are largely represented by the significance of using water-efficient flush and flow fixtures to improve water sustainability: lowering the amount of water used per flush or per unit time without sacrificing performance, increasing water efficiency, lowering water waste from needless leaks, and lowering water use helps lower energy consumption in water supply and drainage. We must compare a fixture's water usage (fig 6a) to a baseline, sometimes referred to as the standard value, in order to assess if it is water-efficient. These facilities' installation reduces the price of water delivery.

Figure 6 Dual flush Urinal and WC

Figure 6a: BAR Diagram Showing Water Usage [normal fixtures v/s low flow fixtures]

Figure 6b:Aerators



(Source: IGBC certification report for kiosk building at New SAC Campus Bopal, Ahmedabad)

Water pressure reducing valves have become increasingly more important because they automatically provide the advantage of conserving water and energy. Reducing the pressure from 100 lbs. to 50 lbs. will result in a savings of approximately 1/3 because 1/3 less water flows at this lower pressure. Remember, there is more "push" behind the water at 100 lbs. than at 50 lbs. and most of this water is wasted. Almost twice as much water flows at 150 lbs. than 50 lbs., most of which is wasted. Moderate savings would result if your supply pressure was 65 lbs. However, even at this lower pressure, savings with a water pressure reducing valves would be 20%. when water pressure reducing valves save 1/3 of the metered water, they also contribute to saving up to 1/3 of the wastewater, which is extremely important because it benefits both the user, by a lower sewer bill, and the community.

These facilities installation reduces the price of water delivery.

2.5 Water Water-conserving landscaping:

Water-wise landscaping is superior landscaping that is both ecologically benign and water-efficient. Water friendly landscaping is based on planning and design, soil preparation, rational plant selection, workable grass areas, efficient irrigation, and other fundamental ideas. This kind of landscaping avoids waste and pollution of the water supply while producing a lush, lovely environment in a time, cost, and energy-efficient manner.

One of the most important areas to focus on cutting water use is landscaping, which may easily account for 20% or more of the water used in facilities. When creating a water-efficient landscaping for a new building, there are three main elements to consider:

- Lessen the amount of turf and other areas that receive irrigation.
- Ensure irrigation systems are designed with water efficiency in mind.
- Indicate whether landscape materials are native or suitable for the climate.

Less turf grass and irrigated land means less water used and related expenses, as well as less time and money spent on mowing, fertilizing, cleaning up trash, and maintenance. For the remaining landscaping areas that need irrigation, water-efficient irrigation systems (low-flow sprinkler heads, effective system design and layout, and optimized irrigation schedules and controls) should be employed to reduce water use and maximize plant health. Use Xeriscaping techniques whenever you can to reduce the cost of labour, water, fertilizer, trimming, upkeep, and other expenses.

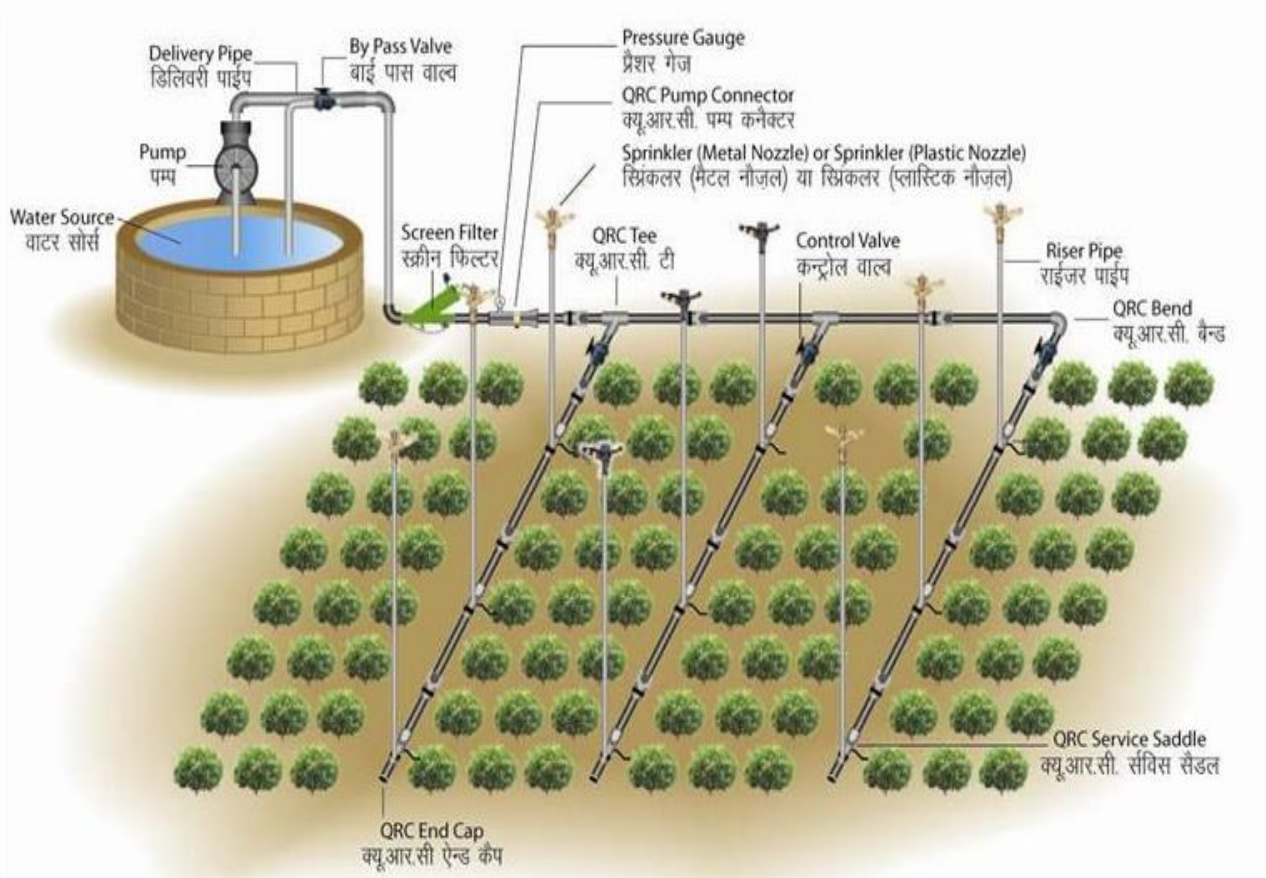
Xeriscaping refers to the use of locally native or climate-appropriate plants that are disease and insect resistant, require less water, and are more likely to weather droughts. A thorough Xeriscaping method examines how local soil and climate factors affect the growth patterns, upkeep needs, and interactions of plants suitable for the local climate. The following is a discussion of the various methods used to conserve water:

2.6 Use of Micro-Scale Irrigation Systems:

- **Water Sprinkler System**

One method of applying irrigation water that is comparable to rainfall is sprinkler irrigation (fig.7). Pumping is used to transfer water through a network of pipes, as seen in Fig. 2. After that, the water is shot into the air via spray heads, where it disperses into tiny water droplets that land on the ground and irrigate the whole soil surface. Sprinklers offer effective coverage for small to big areas and can be used on a variety of irrigable soil types. Adopting this strategy results in more area being available for farming and more efficient use of water.

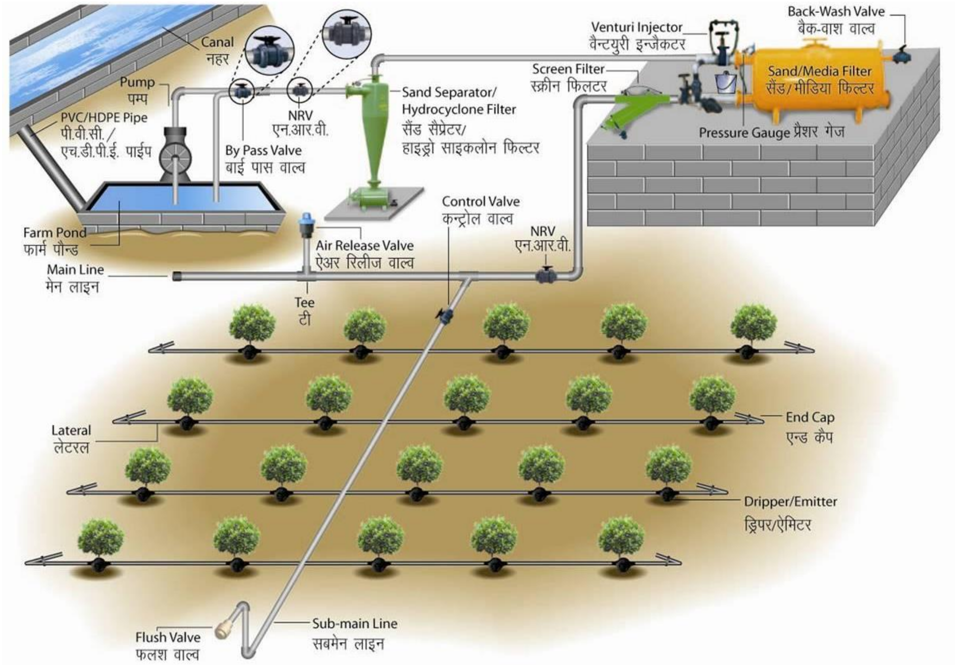
Figure 7. Sprinkler Irrigation System Layout



- **System of Drip Irrigation**

Drip irrigation is the most effective method of irrigation. Drip systems (fig. 8) are frequently 90% or more efficient, whereas sprinkler systems are usually 75–85% efficient. As seen in Figure 3, drip irrigation applies water to the soil directly and softly using a dripper/emitter. The high effectiveness of drip irrigation can be attributed to two important factors. First, the water soaks into the soil before it evaporates or runs off. The second distinction is that the water is only sprayed where it is required, at the roots of the plant, as opposed to being sprayed everywhere.

Figure 8. Drip Irrigation System Layout



2.7 Cooling Towers:

Water saving measures for cooling tower and reuse

Cooling towers use lots of water. Given that their purpose is to dissipate heat from recirculating water used to cool air conditioners, that fact is hardly a surprise. All this evaporative water loss, however, is wasteful and expensive.

Cooling tower efficiency can be improved through proper management of the recirculated water. Here are seven measures an organization can take to maximize cooling tower efficiency and lower water consumption.

2.7.1 Maximize the cycles of concentration. Cycles of concentration, also referred to as blow-down, is the quantity of times a tower recycles water before it has to be emptied. Stated differently, it refers to the maximum number of times that the tower can be filled with fresh make-up water before the dissolved minerals cycle up to the point where they separate from the solution. Three concentration cycles are typically regarded as the minimal efficiency. The make-up water quality and the water treatment strategy determine how many cycles a cooling tower system can actually endure. Treatment systems that minimize and monitor chemical use are making significant progress. They enable towers to function safely at higher concentrations ratios while lowering the risk of corrosion, scaling, and biological development.Increasing the number of cycles from three to six lowers cooling tower blow-down by fifty percent and cooling tower make-up water by twenty percent. Significantly higher cycles of concentration are achievable in various regions of the nation. To find the appropriate number, consult your water treatment provider or the relevant local government organizations.

2.7.2 Reduce blow-down through careful monitoring and agreed-upon set points. Many operators boost blow-down water to reduce biological development and scaling, which results in water loss. But by reducing the pH, this process can also make corrosion worse. Water waste can be decreased with the help of diligent monitoring, setting and maintaining set points, and installing a conductivity meter (see #3). Additionally, you'll cut down on sewage, which could result in big cost savings.

2.7.3 Install a conductivity controller to automatically control blow-down. The capacity of water to conduct electricity is measured by its conductivity. It shows the concentration of dissolvedminerals in cooling water. A conductivity meter, or controller, does exactly what its name suggests: it continuously detects conductivity and only releases water when the conductivity set point is exceeded.

2.7.4 Install flow meters on make-up and blow-down lines. Verify the make-up flow to blow-down flow ratio. Next, compare the conductivity of the make-up water to the blow-down water. The ratios ought to line up with the intended concentration cycles. In the event that the two ratios diverge, examine the tower for any illegal draw-off or leakage. Check the conductivity controller, make-up water fill valve, and blow-down valve, among other system components, if the system is not running at or close to your l cycles of concentration. To detect any decline in performance, monitor make-up and blow-down volumes, conductivity, and concentration cycles.

2.7.5 Monitor water levels. Consider moving to more dependable fill valves from ballcock-style fill valves, which are prone to leaks and regularly go out of alignment. An overly elevated fill level could be another cause of water loss. Strong sump airflow in these circumstances may result in water overflow and choppiness on the water's surface. To prevent using too much water, the sump's water level should be routinely checked to make sure it is enough below the overflow outlet.

2.7.6 Keep air handler coils well maintained. The chilled water system has to work harder to maintain the set point temperatures of the conditioned air as coils get clogged or unclean. The extra load strains the evaporative cooling system, requiring increased water usage in addition to increasing the amount of power used.

2.7.7 Carefully select your water treatment vendor based on their commitment to water conservation. Verify that the vendor you have chosen is aware of the importance of water efficiency and has a track record of delivering outcomes in this domain. Because it typically entails selling fewer pesticides, not all vendors are eager to work with clients who prioritize conservation (savings on chemicals is an indirect and not insignificant additional advantage of water conservation). The price of treating make-up water and keeping a cooling tower at the maximum system water cycle of concentration should be taken into consideration when choosing a water treatment provider.

2.7.8 Technological Advances: Membrane bioreactors and advanced oxidation processes have been employed to effectively treat wastewater from HVAC systems, ensuring it meets required quality standards for reuse.

These are just a few ways in which you can reduce water loss from your cooling tower system.

3. Effectiveness and Limitations

While these techniques have demonstrated potential in reducing water consumption, their effectiveness can be influenced by various factors, including building design, user behaviour, and economic considerations.

4. Building Design

The design and infrastructure of office buildings can impact the efficiency of water-saving technologies. For example, older buildings may require significant retrofitting to accommodate modern water conservation systems (Lehmann et al., 2020).

5. User Behaviour

Occupant behaviour plays a crucial role in the success of water conservation measures. Behavioural interventions, such as awareness campaigns and real-time usage feedback, have been shown to enhance the effectiveness of water-saving technologies (Thomas et al., 2020).

6. Economic Considerations

The initial cost of implementing water-saving technologies can be a barrier. However, long-term savings on water bills and maintenance costs often justify the investment (Johnson et al., 2019)

7. Conclusions from Literary Studies:

Table-01, Inferences from the literature

S.No.	Title	AUTHOR	YEAR	OBJECTIVE	ANALYSIS IS CRITERIA	MENTHODOLOGY	INFERENCES
1.	Smart and Sustainable techniques for water conservation and management	Narendra Singh		This study's objectives are to outline the shortcomings of the way water is now managed and to suggest smarter, more sustainable ways to conserve and manage water.		Based on literature	Water must be conserved and used wisely, with sustainable practices. The maxim "reduce, reuse, recycle" applies here, and recycling water will surely help to solve the issue. Water scarcity is a concern on the earth.

2.	Assessment of water resource consumption in building construction in india	S. Bardhan	2011	This essay looks at a few linked topics, such as the need for water during the building and material production stages.	Ground water, Site Water Management	Based on literature	This paper examines some of the issues surrounding the topic, including water consumption in the manufacturing and construction of materials and the embodied energy that results. It was found that the amount of water used in typical Indian urban structures was approximately 27 kilolitres per square meter of total built-up area.
3.	Design of a sustainable building: A	Peter O.Akadiri,EzekielA. Chinyio and Paul O. Olomolaiye	2012	It outlines a conceptual framework intended		Based on literature	The task facing designers is to devise novel approaches

	Conceptual framework for implementing sustainability in the building sector			to bring sustainability ideas to the subject of architecture.			for merging these diverse sustainability requirements. In the new design approach, each design choice needs to be evaluated for how it will affect the natural and cultural resources of the local, regional, and global contexts.
4.	Green building handbook for South Africa	Dr. Jeremy Gibberd		This chapter describes the water systems used in green buildings and suggests some potential objectives. Furthermore, it lays out the fundamental calculatio		Based on literature	Its l is to develop solutions that lower pollution and resource use. Carefully considered plumbing, ecological sanitation, and rainwater harvesting systems enable buildings to meet their

				ns for water system design in green buildings. subject of architecture.			own water requirements without contaminating the water supply. This reduces the requirement for large-scale, potentially inefficient, energy-intensive water and sanitation infrastructure.
5.	IGBC Green Existing Building O&M rating system			It encourages the self-sustaining use of water by implementing strategies including reducing, recycling, and reusing. With this rating system, green buildings that are already in place can reduce		Based on literature	It outlines the standards for a range of sustainability initiatives, such as water management and efficiency.

				their portable water use by 15 to 33%.			

Comprehensive table to summarize key inferences from the literature on sustainable water use techniques for office buildings can provide a clear overview of the current knowledge and findings. Below is a structured table that includes various techniques, their benefits, challenges, and key findings from existing studies:

Technique	**Benefits**	**Challenges**	**Key Findings from Literature**
Low-flow Fixtures	- Reduces water consumption without compromising usability.	- Initial cost of installation.	- Can reduce water usage by up to 50% (Smith et al., 2020).
	- Lower utility bills and operational costs.	- Requires periodic maintenance.	
Grey water Recycling	- Reduces demand for potable water.	- Water quality standards and regulatory compliance.	- Potential to reduce potable water demand by 30-50% (Jones & Brown, 2019).
	- Environmental benefits through wastewater reuse.	- Initial investment and operational complexity.	
Rainwater Harvesting	- Mitigates storm water runoff and reduces water demand.	- Space requirements for storage tanks.	- Effective in reducing mains water usage in office buildings (Taylor et al., 2018).
	- Can be used for non-potable purposes.	- Maintenance of filtration and storage systems.	
Smart Water Management	- Real-time monitoring and leak detection.	- Initial setup costs and integration with existing systems.	- Improves efficiency and detects leaks early (Barbhuiya et al., 2021).
	- Optimizes water use based on occupancy and usage patterns.	- Data security and privacy concerns.	
Behavioural Interventions	- Raises awareness and promotes water-saving habits.	- Sustainability of behaviour change over time.	- Effective in reducing water consumption with ongoing reinforcement (Thomas et al., 2020).
	- Low-cost implementation	- Requires ongoing	

	compared to infrastructure changes.	education and engagement.	

8. Research Gaps

8.1 Lack of Long-Term Studies: Most studies on water-saving technologies focus on short-term benefits. There is a need for longitudinal studies to evaluate the long-term effectiveness and sustainability of these measures (Green et al., 2020).

8.2 Limited Data on Grey water Recycling and Rainwater Harvesting: While grey water recycling and rainwater harvesting have shown promise, there is limited empirical data on their long-term performance and economic viability in office buildings (Tsai et al., 2019).

8.3 Integration of Multiple Techniques: Few studies have explored the combined impact of multiple water-saving techniques. Research is needed to understand how different technologies can be integrated to maximize water conservation (Lehmann et al., 2020).

8.4 Cross-Disciplinary Approaches: There is a lack of interdisciplinary research that combines technical, economic, and behavioural aspects of water conservation. Integrated models that consider these factors are needed to optimize water use in office environments (Brown et al., 2021).

9. Future Research Directions

9.1 Longitudinal Studies: Future research should focus on conducting longitudinal studies to evaluate the long-term benefits and challenges of water-saving technologies in office buildings.

9.2 Comprehensive Analysis of Grey water Recycling and Rainwater Harvesting: More empirical studies are needed to assess the feasibility, efficiency, and economic viability of grey water recycling and rainwater harvesting systems in office settings.

9.3 Integration of Multiple Techniques: Research should explore the combined impact of various water-saving technologies to develop integrated solutions that maximize water conservation.

9.4 Policy and Regulation: Studies evaluating the effectiveness of current policies and proposing new regulatory frameworks for water conservation in office buildings are needed.

9.5 Cross-Disciplinary Research: Future research should adopt a cross-disciplinary approach, integrating technical, economic, and behavioural aspects to develop comprehensive models for sustainable water use in office buildings.

10. Case Development:

Shipyard Limited Coorporate Office:

Figure 9. Project development case location

Location :Swatantra Path, Vaddem, New Vaddem, Vasco Da Gama, 403802

Figure 10. 3D Rendered view

Figure 11. Actual physical Image

Table 2: Break-up of Consumption of Domestic & Flushing Water Requirement as per NBC:

S.No.	Description	Population As per NBC-2016, Part-9, Section-1, clause 4.1	Water Requirement (Ltrs)		
			Domestic	**Flushing**	**Total**
1.	Office Area	10 sqm/person			
1a.	Staff		25	20	45
1b.	Visitors/Audi/Amphi		5	10	15
2	Food Court	1.2 sqm/person	25	10	35

Table 3: Break-up of Consumption of Domestic & Flushing Water Requirement of office:

S. No.	Description	Occupancy	Domestic Water Req.	Flushing Water Req.	Gross Water Req.	Water Flow to STP
			LPD	**LPD**	**LPD**	**LPD**
1	**Office Area**	2022				
1a	Office Staff (90% of population)	1819	45475	36380	81855	72760
1b	Visitors(10% of population)	202	1010	2020	3030	2828
2	Auditorium & Amphitheatre	3765	18825	37650	56475	52710
3	Food Court	380				
3a	Staff @ 10%	38	950	760	1710	1520
3b	Visitors @ 90%	342	8550	3420	11970	10260
4	Yoga, Gym etc.	1056	5280	10560	15840	14784
5	Security & Maintenance Staff	50	1250	1000	2250	2000
6	Main Swimming Pool	LS	10000		10000	-
7	Filter Back wash	LS	5000	0	5000	-
	Total		96340	91710	188130	156822

	Say(KL)		96	92	188	157

It is expected that all flushing water (100%) and 80 % of domestic water will end up in the sewer. The projected daily water demand for an office building, excluding fire requirements, is 263,000 litres per day based on the number of users and other consumption points. Below is a summary of the requirements:

Domestic Water Demand	96 KLD
Flushing Water Demand	92 KLD
Water for Horticulture	5 KLD
Cooling Tower (Soft Water Demand)	70 KLD
Total water requirement for office	**263 KLD**

Through Selection Criteria:

Smart Water Fixture:

The maximum flow rate and flush volumes shall be as given below as per NBC:

PLUMBING FIXTURES/FITTINGS MAXIMUM	**FLOW RATE**
WATER CLOSETS	6 litre/flush
URINALS	3.8 litre/flush
LAVATORY, METERED FAUCET (PUBLIC)	1 litre/use
LAVATORY, FAUCET (PRIVATE)	8 litre/min
SINK, FAUCET	8 litre/min
BIDET, HAND HELD SPRAY	8 litre/min
SHOWER HEAD	10 litre

Roughly 2022 people use the building's water supply on a daily basis. Over 90% of them, we think, are workers, with the remaining percentage being guests. Based on our calculations, we project that the building will need about 263 KLD of water every day.

FIXTURE TOTAL	NO. OF FIXTURE	NO. OF USE PER DAY(ASSUMING)	CONSUMPTION RATE (L)	WATER USES
Water Closet	94	20	6	11280
Wash Basin	74	50	8	29600
Urinal	28	122	3.8	12980.8
Ablution Tap	94	20	3	5640
Drinking	20	505	1	9090

This covers the water used for building operations like ventilation as well as water drunk by staff members and guests.

According to the National Building Code, the total amount of water used with typical fixtures is roughly 68590.8litres per day, or 68.5 KLD.

Decreased the amount of potable water used by installing water-efficient fixtures and flushing with STP-treated water. To minimize indoor water usage, IGBC-compliant water-efficient flow fixtures are fitted for taps, faucets, urinals, and toilet flush fixtures.

Table II: Maximum flow rate as per IGBC

Fixture Type	Maximum Rate/Consumption	Duration	Estimated daily use per person*
Water Closet	6.0 LPF	01 Flush	01 for male; 03 for females
Faucet/ Tap**	8.0 LPM	0.25 min	04
Urinals	4.0 LPF	01 Flush	02 for males



FIXTURE	TOTAL NO.OF FIXTURE	NO.OF USE PER DAY(ASSUMING)	COMSUMPTION RATE (L)	WATER USES (1/DAY)
WATER CLOSET	94	19	3.5	6225
WASH BASIN	74	50	2	7400
URINAL	28	121	0.5	1694
ABLUTION TAP	94	19	1.5	2679
DRINKING	20	505	1.25	12625

Numerous companies have calculated that the overall water consumption through smart fixtures is about 30623 litres per day, or approx. 30 KLD.

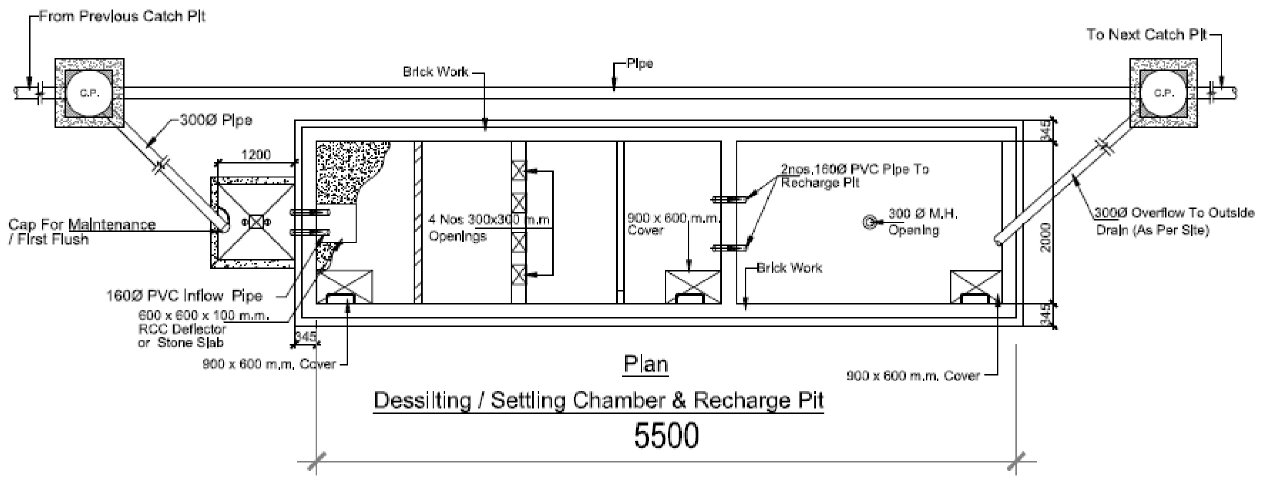
Consequently, office buildings that install smart, efficient fixtures save almost 43% of the water utilized by those that use standard fixtures. Rainwater Collection Rainwater pipes are used to direct rainfall from the roof into the drainage system. Subdivided areas of the entire complex will be used for recharging structures.

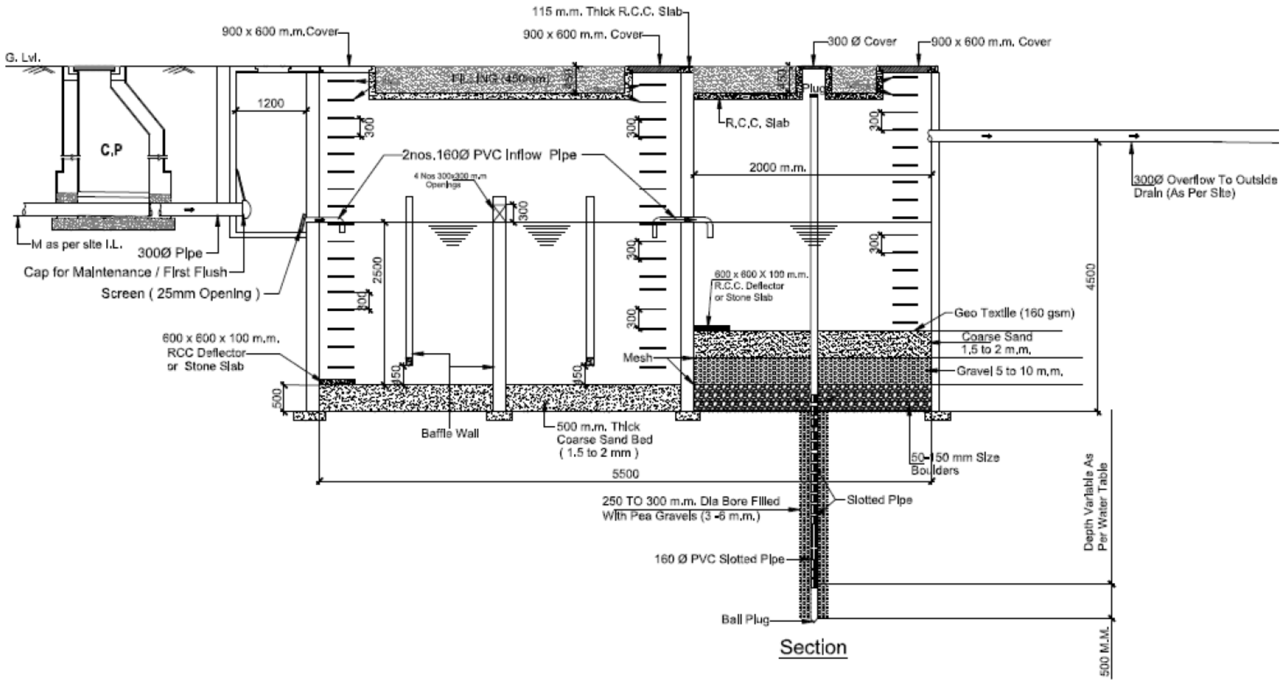
For the intended use, de-silting tanks and recharge wells are suggested. To eliminate inorganic impurities, rainwater will be sent into a desilting tank, and the tank's outflow will be poured into a recharge well.

S.No.	**Type of Area**	**Areas**
	Total Area in Acre	**7.16**
a)	Site Area in Square Meter	29000.00
b)	Terrace / Roof Area (approx.)	7000.00 Sq.m
c)	Paved / Pavement / Road/Sub Soil Drainage (approx.)	12000.00 Sq.m
d)	Green Area / Loose Area (approx.)	10000.00 Sq.m
2.0 Co-efficient and factors adopted (As per NBC-2016)		
a)	Harvesting efficiency factors for terrace and roof tops	0.9
b)	Harvesting efficiency factors for roads and paved surface/SSD	0.8
c)	Harvesting efficiency factor for Green/ soft soil	0.15
3.0 Co-efficient for calculations of capacity for collection wells for Harvesting		
a)	Rain Fall intensity	50 mm/hr
b)	Retention time for capacity of recharge tank	15 min
c)	Net runoff for which holding is required for infiltration	= 12.5 mm
1.0 Roof / Terrace		
i)	Average runoff co-efficient for terrace	0.9
ii)	Terrace / Roof Area	7000.00 Sq.m
iii)	Rain fall intensity	50 mm/hr
iv)	Infiltration well capacity design period	15 min
v)	Net runoff for which holding is required for infiltration	12.5 mm
vi)	Required approx. theoretical volume of infiltration **wells (Total Area x Coefficient x Net Runoff)**	**78.75 Cu. Mtr**

2.0	**Road / Paved / Pavement Area**		
i)	Average runoff co-efficient for terrace	0.8	
ii)	Road / Paved / Pavement Area	12000.00 Sq.m	
iii)	Rain fall intensity	50 mm/hr	

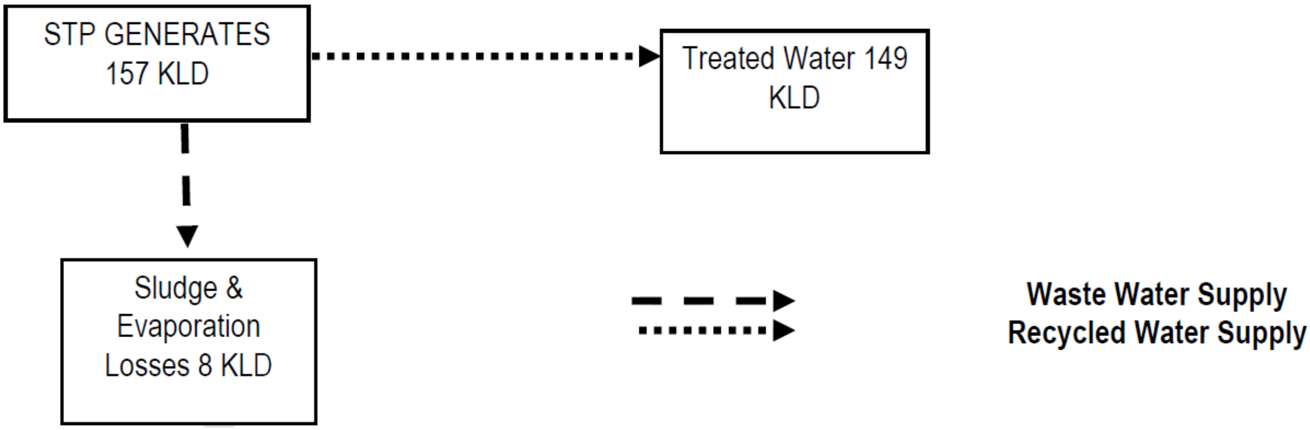
iv)	Infiltration well capacity design period	15 min	
v)	Net runoff for which holding is required for infiltration = 12.5 mm		
vi)	Required approx. theoretical volume of infiltration wells **(Total Area x Coefficient x Net Runoff)**	**120.00 Cu.Mtr**	
3.0 Green / Loose Area			
i)	Average runoff co-efficient for terrace	0.15	
ii)	Green / Loose Area	10000.00 Sq.m	
iii)	Rain fall intensity	50 mm/hr	
iv)	Infiltration well capacity design period	15 min	
v)	Net runoff for which holding is required for infiltration	12.5 mm	
vi)	Required approx. theoretical volume of infiltration wells **(Total Area x Coefficient x Net Runoff)**	**18.75 Cu.Mtr**	
Total Volume of Infiltration		**217.50 Cu.Mtr**	
Circular Pits:			
Dia	**Effect. Depth**		
3.0 M	**3.5 M**	= 24.73 Cu.Mtr	
	De-silting Chamber		
Length	Width	Height	Volume
2.0 M	2.0 M	1.5 M	= 6.00 Cu.Mtr
Total Capacity of Pair of Pit and Chamber		**30.73 Cu.Mtr**	
Total No. Pits		**7.08 Nos.**	
Say		**= 7.0 Nos.**	


From Previous Catch Pit
To Next Catch Pit
C.P.
C.P.
Brick Work
Pipe
300Ø Pipe
1200
Cap For Maintenance / First Flush
4 Nos 300x300 m.m Openings
900 x 600 m.m. Cover
2nos.160Ø PVC Pipe To Recharge Pit
300 Ø M.H. Opening
300Ø Overflow To Outside Drain (As Per Site)
Brick Work
2000
345
160Ø PVC Inflow Pipe
600 x 600 x 100 m.m. RCC Deflector or Stone Slab
345
900 x 600 m.m. Cover
900 x 600 m.m. Cover
Plan
Dessilting / Settling Chamber & Recharge Pit
5500


115 m.m. Thick R.C.C. Slab
900 x 600 m.m.Cover
900 x 600 m.m. Cover
300 Ø Cover
900 x 600 m.m. Cover
G. Lvl.
C.P
1200
R.C.C. Slab
2nos.160Ø PVC Inflow Pipe
2000 m.m.
300Ø Overflow To Outside Drain (As Per Site)
M as per site I.L.
300Ø Pipe
Cap for Maintenance / First Flush
Screen (25mm Opening)
2500
600 x 600 X 100 m.m. R.C.C. Deflector or Stone Slab
4500
Geo Textile (160 gsm)
Coarse Sand 1.5 to 2 m.m.
Gravel 5 to 10 m.m.
600 x 600 x 100 m.m. RCC Deflector or Stone Slab
Mesh
Baffle Wall
500 m.m. Thick Coarse Sand Bed (1.5 to 2 mm)
5500
50-150 mm Size Boulders
250 TO 300 m.m. Dia Bore Filled With Pea Gravels (3 -6 m.m.)
Slotted Pipe
160 Ø PVC Slotted Pipe
Depth Variable As Per Water Table
Ball Plug
500 M.M.
Section

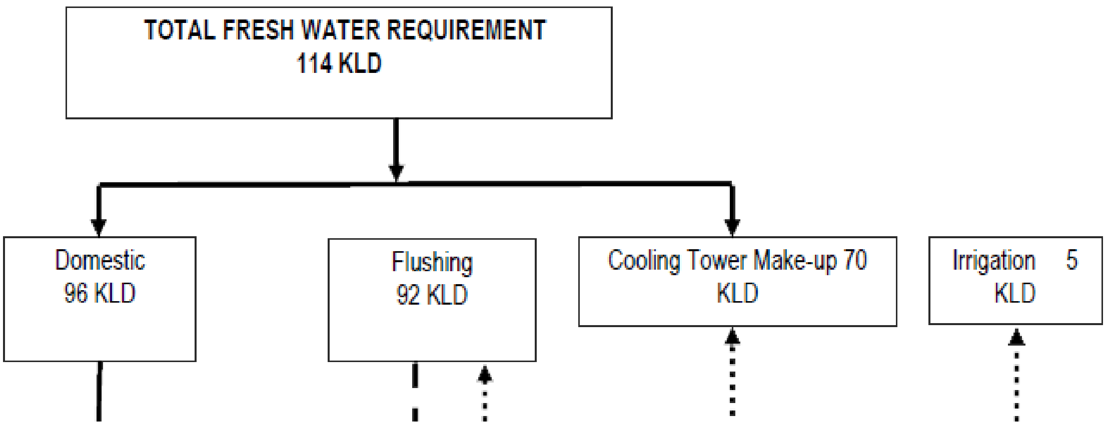
Waste water treatment

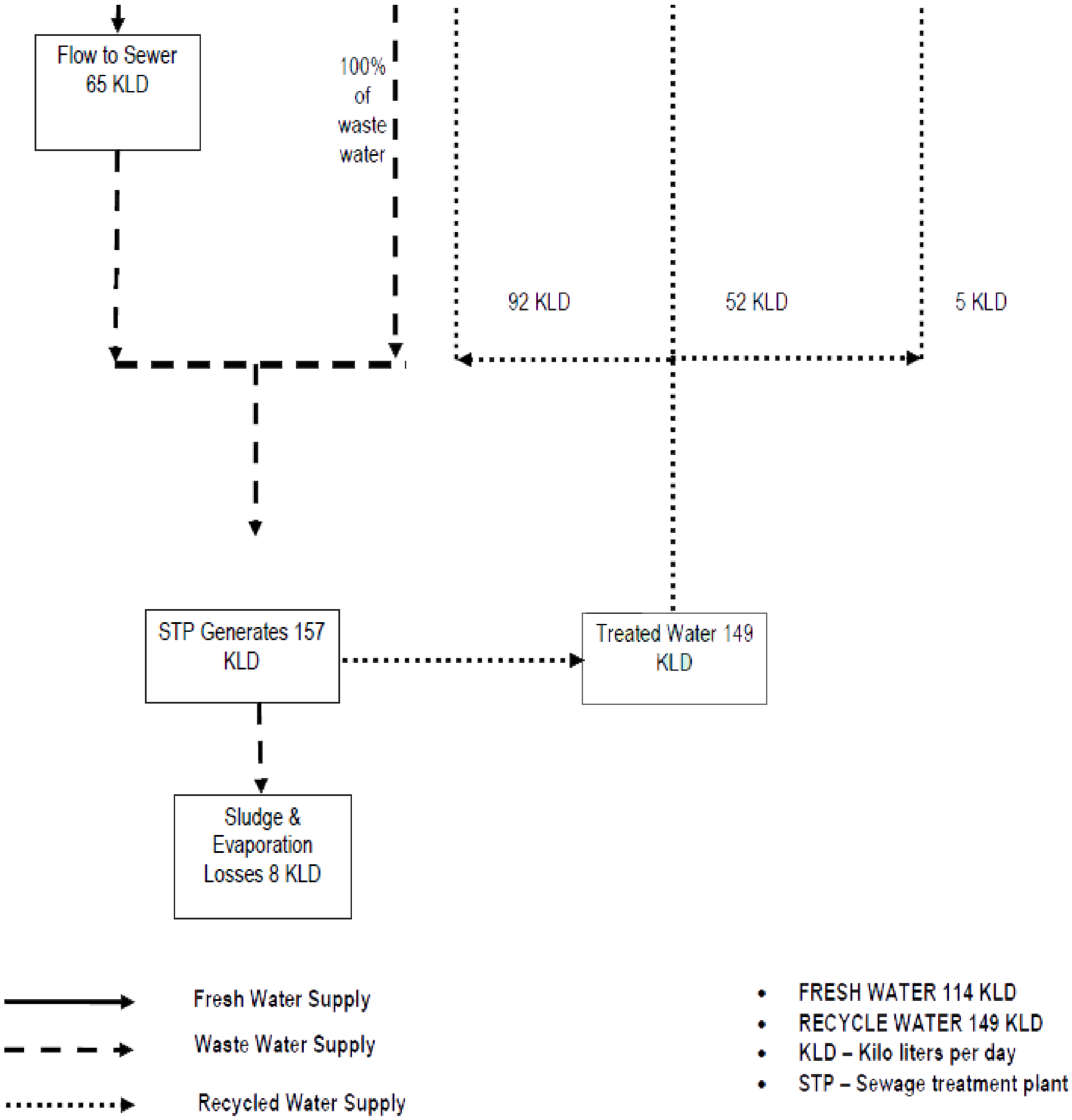
Intent is to avoid damaging receiving streams, treat waste water generated on site so that it can be reused or safely disposed of. Because of the scarcity of fresh water and the necessity for recycled water for various reasons such as flushing and landscaping, installing a sewage treatment plant reduces the amount of fresh water used. The project is providing an on-site sewage treatmentSystem to treat 100% of waste water generated through MBBR Process. The project is using this treated water for flushing & landscaping which will comply standards suitable for respective purpose. STP of capacity 190 KLD is proposed to treat the domestic sewage water in a scientific manner through a properly planned sewage/effluent treatment plant. The objective is to stabilize theDecomposable organic matters present in sewage so as to get an effluent and sludge having characteristics which are within safe-limits, and which can be recycled and re-utilized for various purposes to help in maintaining the ecology of nature and save energy resources.



Waste water reuse: Using treated waste water helps to lessen reliance on potable water.
Show that flushing, cooling water make-
up, and irrigation are all done with treated waste water from a waste water treatment plant.
100% of the 157 KLD of waste water produced on site is treated, with the remaining 8 KLD going to Sludge and evaporation to produce 149 KLD of treated water that is then utilized for the following purpo ses:

1. 92 KLD Flushing
2. Gardens (5 KLD)
3. Making-up cooling tower (52 KLD)





Below is an explanation of the case development's conclusion:

This chapter examines the situation of water management today using an experimental case study of a conventional commercial office building in .In this section, I'll examine the current water distribution system and contrast the results with the water efficiency that can be achieved through the application of sustainable water practices.

A case study featuring a 2022-person capacity, G+10.

story structure has been presented.NBC rules state that this building has a required water demand of 263 KLD.If we implement water management measures in this typical building, we can calculate the amount of water saved based on the overall water demand and the NBC water usage per person after these strategies are put into place.The IGBC recommendations and water certification standards that were covered in the research above have also led me to certain actions that can be made to enhancewater efficiency and conservation.

Initially, an analysis was conducted based on smart water fixtures and the amount of water they will save when installed in a conventional building.

The building's current daily water usage was estimated for about 2022 occupants. The remaining percentage is probably made up of visitors, with over 90% likely being employees. We calculated the building's water consumption and deduced from NBC that it will be 263 KLD per day. Included in this is the water required for building services like cooling and ventilation, as well as water used by employees and guests.

In the study, I have recorded the number of water fixtures needed for 2022 inhabitants, the rate of consumption, and the daily water usage in litres, all in accordance with NBC guidelines. This leads us to the conclusion that the daily average water consumption from typical fixtures is approximately 68590.8 litres, or 68.5 KLD.

Potable water use was decreased by installing water-efficient fixtures and flushing with STP-treated water again. IGBC-compliant water-efficient flow fittings for urinals, faucets, taps, and toilet flush fixtures are installed to minimize indoor water usage. We calculated that the overall amount of water used by smart fixtures is approximately 29036 litres per day, or 29 KLD, based on our data.

Consequently, intelligent and effective fixtures conserve approximately 43% of the water used by conventional fixtures in office buildings.

Additionally, we have examined the daily usage count in relation to the consumption rate based on the conclusions drawn from the case studies. Next, another water conservation parameter—rainwater harvesting was analysed in the suggested instance. It was found that rainfall is moved via rainwater pipes from the rooftop to the drainage system. It is suggested that the entire Complex be separated for recharging structures. Recharge wells and de-silting tanks are advised for the intended use. To filter out inorganic contaminants, rainwater will be sent into a de-silting tank. The recharge well will then receive the output of the de-silting tank. As a result, it was determined that ground water recharge uses up all of the water saved from rainfall. As a further step in the case, we created a prototype for the building's waste water treatment system. Based on our estimations, the building produces roughly 157 KLD of waste water annually.

149 KLD of treated water is generated, which can then be used for flushing (92 KLD), landscape design (5 KLD), and cooling tower makeup (52 KLD), while 8 KLD of waste water can be turned into sludge and evaporated. As a result, it was determined that 114 KLD of freshwater were needed. It is estimated that waste water can be reused for 96 KLD of household uses, 92 KLD of flushing, 70 KLD of cooling tower makeup, and 5 KLD of irrigation.

Therefore, it was determined that there was a 56.6% disparity between the total water requirement, which was 263 KLD, and the fresh water requirement, which is 114 KLD. Based on our experimental case study of a conventional office building, we have determined that employing water-efficient techniques and adhering to sustainable water management guidelines can result in an overall 56.6% water conservation. This will not only help reduce the overall maintenance costs but also the building's lifetime costs, and it will also contribute to a cleaner and greener environment.

11. Conclusion and Recommendation

The need for water is growing as the world's population rises. By 2050, the world's population is expected to reach 9 billion, according to UN estimates, creating a huge need for water. Water is a necessary resource for living and a prerequisite for conducting business. Conserving water is crucial to running a building effectively. It has several advantages, such as less maintenance costs, less of an impact on the environment, and increased occupant comfort. The most water-efficient structures consume a great deal less water than traditional buildings, which makes water an important resource. But for the majority of structures, water is also the single biggest operational expense. It is impossible to exaggerate the significance of water conservation in office buildings. The greatest category of commercial buildings and the biggest users of water are office buildings. Office buildings use water from a range of sources, such as surface water, public water systems, and private wells. Right now, one of the most urgent problems facing humanity is the global water crisis. Consequently, global environmental organizations have enforced several mandatory regulations in diverse domains to enhance water governance by reducing the consumption of drinkable water. Several strategies for encouraging water sustainability in buildings have been investigated, and prior research has emphasized their advantages.

The literature examines the water quality cascade's guiding principles in relation to alternative water supply alternatives, water-saving technologies, and commercial building water management. Such effective techniques are reasonable to put into practice in an effort to get water consumption in buildings that is sustainable. It is stated that, given causal factors like population growth, urbanization, and rapid development, applying such principles would be a basic necessity in developing economies like India. Furthermore, applying these strategies to outdated office buildings (mostly owned by the government) might lower the buildings' operating and maintenance costs while simultaneously bringing them up to date with modern technologies. The need for water conservation has grown so great that the water efficiency category in the LEED grading system now includes ten points instead of the five it had before. Additionally, research has been done on the IGBC's sustainable building criteria to determine how adhering to water efficiency standards might render a building sustainable.

This study offered creative wastewater solutions and illustrated the application of improved water management through a case development study of a Goa workplace. Based on the literature research, the problem of inadequate water conservation metrics is brought to light. The case development study focused on the management of water in a traditional office building in Goa, India, and looked at ways to save water so that it might become sustainable in terms of water efficiency. The use of these water-efficient solutions within the building resulted in a successful 50% reduction in water usage.

The review of the literature suggests that in order to guarantee appropriate water management, the government should impose mandatory policies on the public and private sectors. This paper's case study should help government organizations and private investors understand the financial advantages of implementing cutting-edge technologies like low-flow fixtures in sustainable architecture projects. There is also a great deal of potential for combining elements of water management and energy management because these concerns overlap. Lower expenses and greater benefits may result from this.

In order to increase and secure the adoption of cutting-edge commercial building technologies and practices, regulatory authorities and councils will need to include the aforementioned notions into development controls and regulatory guidelines in order to make these types of systems a reality. Establishing demonstration projects that monitor and evaluate the benefits and cost savings of these structures is also essential.

12. Acknowledgement:
"In this research paper, we extend our heartfelt gratitude to all those who contributed to the exploration and development of sustainable water conservation techniques for office buildings. Special thanks to our collaborators, mentors, and supporters for their invaluable guidance and encouragement throughout this journey."

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