INTEGRATED URBAN WATER MANAGEMENT SYSTEM FOR CHANDIGARH

THESIS

Submitted

In fulfillment of the requirements of degree of

DOCTOR OF PHILOSOPHY

By

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December, 2020

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CANDIDATE'S DECLARATION

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I, **Nitish Kumar Sharma** (PHDENG16044) hereby declare that the research work, which is being carried out in this thesis entitled, **"Integrated Urban Water Management System for Chandigarh"** for the partial fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D) submitted in the Department of Civil Engineering, Chitkara University, Himachal Pradesh** is an authentic record of my own research work, carried out under the supervision and support of **Dr. Varinder Singh Kanwar**, Professor, Civil Engineering Department, Chitkara University, Himachal Pradesh and **Dr. Harpreet Singh Kandra**, Lecturer, Federation University, Gippsland, Churchill, Australia. I have not submitted the matter presented in this thesis for the award of any other degree.

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This is to certify that the thesis entitled **"Integrated Urban Water Management System for Chandigarh"** submitted by **Mr. Nitish Kumar Sharma** with **Regd. No. PHDENG16044** to Chitkara University, Himachal Pradesh is a *bonafide* record of research work carried out by him under our supervision and is worthy of consideration for the award of the degree of **Doctor of Philosophy**.

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ACKNOWLEDGEMENT

It gives me immense pleasure to express profound gratitude to Dr. Varinder Singh Kanwar, Professor and Dr. Harpreet Singh Kandra for their able guidance, constructive criticism and concrete suggestions, timely help and constant encouragement. I am indeed indebted to them for sparing their valuable time, tremendous help and encouragement provided during the tenure of my work. It was their able and esteemed guidance that always motivated me and provided a stimulating working environment. Their inimitable support helped me in channeling my efforts in proper directions. Their ideas and insight together with clear and accurate line of thought, proved to be precious for me while learning what research is all about. It was both an honour and pleasure working with them. Their pains, taking efforts in checking the manuscript that enabled me to complete this thesis are gratefully acknowledged.

I would also like to thank the members of our Research Committee: Dr. Sita Ram, Dr. Ishwar Dutt and Dr. Shefali Batra, for carefully reviewing my work at different stages.

I also express my profound gratitude to Dr. Abhishek Kanoungo, Civil Engineering for providing Ph.D details and to Chitkara University for providing all services I required during the research work.

Finally, I would like to thank my beloved parents (Sh. Rajnesh Sharma and Smt. Rama Sharma), my in-laws (Sh. Rakesh Kumar Sharma and Smt. Aarti Sharma), my colleagues, my relatives and my friends for supporting me spiritually throughout my research work.

A big thanks to my beloved wife Mrs. Swedika Sharma without whose invaluable assistance I would not have finished this thesis.

Above all I give glory and honour to the "Almighty".

NITISH KUMAR SHARMA

LIST OF PUBLICATIONS

1. Conference paper entitled "Need for Integrated Urban Water Management for India - A Concept Note" authored by Dr. Varinder S Kanwar, Dr. Harpreet Singh Kandra and Mr. Nitish Kumar Sharma was published in NITTTR Conference, International Conference on Clean Technology and Sustainable Development, p-28-30, February, 2018. In this paper, Future Water Management was carried out to evaluate the performance of the water in the country.

2. Paper entitled "Water Balance Evaluation of Chandigarh City, India" authored by Mr. Nitish Kumar Sharma, Dr. Varinder S Kanwar and Dr. Harpreet Singh Kandra was published in Elsevier, International Journal of Innovative Technology and Exploring Engineering (IJITEE) Scopus Journal, 8(11), p-4072-4083, September, 2019. In this paper, Water Balance of city, Rainfall analysis was carried out to evaluate the performance of the water system.

3. Conference paper entitled "Integrated Urban Water Management of Chandigarh Region, India" authored by Mr. Nitish Kumar Sharma, Dr. Varinder S Kanwar and Dr. Harpreet Singh Kandra was published in Symposium on Synthesis, Characterization & Processing of Inorganic, Bio and Nano Materials Conference (SCPINM), Chandigarh University, Gharuan, India, p-47-55, December, 2019.

4. Patent Filed on "An Integrated System and method for Water Management" authored by Mr. Nitish Kumar Sharma, Dr. Varinder S Kanwar, Application No. 202011005032 (TEMP/E-1/4889/2020-DEL), Chitkara University, Baddi, India, February, 2020.

5. Conference paper entitled "Water Balance Model for Chandigarh Region" authored by Mr. Nitish Kumar Sharma, Dr. Varinder S Kanwar and Dr. Harpreet Singh Kandra was published in International Conference on Advancements in Engineering and Technology (ICAET), BGIET Sangrur, Punjab, India, p-577-

582, March, 2020.

6. Paper entitled “Integrated Urban Water Management for Chandigarh Region, India” authored by Mr. Nitish Kumar Sharma, Dr. Varinder S Kanwar and Dr. Harpreet Singh Kandra was published in Test Engineering and Management (TEM) Scopus Journal, 83(5), p-419-429, June, 2020.

7. Paper entitled “Integrated Urban Water Management of Chandigarh Region, India” authored by Mr. Nitish Kumar Sharma, Dr. Varinder S Kanwar and Dr. Harpreet Singh Kandra is under process in Materials Today Proceedings Elsevier.

ABBREVIATIONS

IUWM – Integrated Urban Water Management

SUWM- Sustainable Urban Water Management

MCC – Municipal Corporation Chandigarh

LPCD – Litres per Capita per Day

BIS – Bureau of Indian Standards

RWH – Rain Water Harvesting

ETP – Effluent Treatment Plant

MGD – Millions of Gallons per Day

STP – Sewage Treatment Plants

ENVIS – Environment Information System

MC- Municipal Corporation

CGWB – Central Ground Water Board

ET – Evapotranspiration

WW – Waste Water

MoUD – Ministry of Urban Development

WB – Water Balance

MCM – Million Cubic Metres

IMD- Indian Meteorological Department

AET- Actual Evapotranspiration

PET- Potential Evapotranspiration

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ABSTRACT

Integrated urban water management (IUWM) is a philosophy of varying definitions and interpretations. IUWM is described as the practice of managing freshwater, wastewater and storm water as components of a basin-wide management plan. IUWM seeks to change the impact of urban development on the natural water cycle based on the premise that by managing the urban water cycle as a whole; a more efficient use of resources can be achieved providing not only economic benefits but also improved social and environmental outcomes. One approach is to establish an inner, urban, water cycle loop through the implementation of reuse strategies. Developing this urban water cycle loop requires an understanding both of the natural, pre-development, water balance and the post-development water balance.

Chandigarh is a rapidly growing city and expected population of the city in 2021 will be 13.38 lakhs. Existing storm water drains in Chandigarh in some areas are not sufficient due to rapidly increasing paved area. Storm water drains are not capable of draining storm water so ponding occurs in various places. The increase in the population and increasing water supply has resulted in increased sewage flow. This has necessitated augmentation of sewage treatment plant for every residential building or newly constructed towers to reuse that water after treatment.

This study conducts water balance assessment of IUWM plan case studies from Chandigarh. In this study, we have implemented the concept of double plumbing in Chandigarh and in nearby areas so that we can use waste water and storm water for future use. We have designed storage tank of waste water and storm water in the study area in which we have stored waste water and storm water and then further after treatment of that water, we have provided double plumbing system in the houses. In one pipeline, supply of fresh water takes place which can be used for bathing and drinking and in second pipeline; we provided is treated waste water which can be used for flushing of the toilet, gardening, car washing, AC service etc. As the demand of water usage in Chandigarh is rising day by day, we have to look forward for saving water by conserving it either in the form of storm water conservation or wastewater treatment for the future use.

The benefit of the double plumbing system will help us to save fresh water as we can use treated water for various other purposes which are required for our daily use. This idea can be implemented in residential, commercial and educational institutions. Till now, the idea of water management is not used wisely. For a better future and in order to save the resources, the municipal corporation, environmental agencies, researchers, design engineers and policy planners must come together forward to execute the plan. With the combined efforts of everyone, we can develop a design like sewer pipeline, which can collect storm water and waste water at the same time. This design can help us to meet the end use volume requirements. We can also construct large treatment tanks so that a large amount of water can be treated.

The outcome of this study shows that by using IUWM plan, this study have sought to test the hypothesis related to perceptions of Integrated Urban Water Management (IUWM) include elements pertaining to an ideology, method and set of objectives. In order to assess this, a survey was conducted which received responses from various industry experts. Survey responses show a wide variety of perspectives on IUWM, ranging from specific processes, to broad all-encompassing and vague descriptions. According to the results the specific methods most commonly associated IUWM are: stakeholder engagement, coordinated planning, holistic option assessment and integrated modelling. And the objectives most commonly associated with IUWM are diversification of water sources, environmental improvements, reduced cost, and improved livability outcomes. Preliminary examination of the current state of these methods and objectives has shown that, so far, not all of the methods are resulting in the achievement of these objectives. We propose that the water sector re-evaluate its perception of IUWM, water balance modeling, implementation of the double plumbing system mentally separating its meaning into an ideology, objectives and a variety of methods which can then be independently scrutinised. The value of IUWM appears to be in promoting communication between organisations and well-structured stakeholder engagement rather than large scale and highly detailed "integrated" plans or complex option assessment methods.

From this study, we got the results related to recharge and drought and as the water demand is rising day by day so for the future purpose, we have to recharge the water system by doing water balance of the city. From rainfall analysis, we got the results of rainfall like total compiled rainfall for 10 years is 890.91 mm, average value is 74.65 mm, maximum value is 406.5 mm and Standard Deviation is 95.77. We have also calculated the expected population in 2031 from the existing population by doing forecast population in Matlab and the value of the population is 1761314. This population forecast is very important to check the water demand in the future so that we can do the calculations and arrangements accordingly. The water quality of the city would be helpful for the citizens to get the proper knowledge of the water that comes to their house as well as water existing in the city like lakes, drains, STPs etc. After testing the various samples of water of different areas of the city we got the various results related to BOD, COD, pH, TSS, Nitrogen etc. From various tested samples; a comparison was done on various parameters with the earlier stakeholder's testing. The results were evaluated for every month and the result values were in permissible limits. The testing identifies the issues that water managers face today and also brings the impact of using water, which was tested properly in the city so that we can use it whenever necessary.

We have successfully implemented the concept of double plumbing in residential towers which would be helpful in preventing fresh water. With this type of construction, we can say that it is simple to construct and easy to implement. The location for the case study considered to be Zirakpur (Mohali) and concept was implemented in residential towers on one of the prominent builders. The double plumbing concept brings the impact over 700 people with 200 houses in the towers. 29000 liters per day (29 KLD) of treated water is used every day for flushing and gardening after treatment. So we save 29000 liters of fresh water every day from this case study. Buildings fresh water requirement is 94.5 KLD out of which 65.5 KLD will be used as fresh water and we saved, treated water, i.e. 29 KLD will be used for 50,000 sq. ft. green area of the society and also for flushing toilet where we were using fresh water source earlier.

CHAPTER 1

INTRODUCTION

1.0 Introduction to Integrated Urban Water Management (IUWM) in India

Water covers a large part of Earth's surface however, only 3% of the available water is fresh water. Further, fresh water is found on Earth is four major forms which are atmosphere water vapors, surface water bodies, groundwater and cryosphere. Human beings can utilize only two components of fresh water available on Earth and these are surface water bodies and groundwater. These two fresh water sources comprise only 23% of the available fresh water [Akissa Bahri et al., 2012]. However, with development in industrialization and other aspects of urban development, the content of drinkable fresh water is getting converted into wastewater. Urban water management is under rapid modifications in order to meet the escalating demands of the urban community and uncertainties caused in the existing system by climate change. Therefore growing global grievances, shortages and water contamination has made it important to put in more efforts in development of water management strategies in different aspects of urban water usage. Integrated Urban Water Management (IUWM) is one of such urban water management strategies which aim to implement the concept of sustainable development while managing the water, land and economic interests of the society.

IUWM provides the holistic framework for urban water management which not only includes the planning and designing of the sewerage and water supply systems but also enables the stakeholders to predict the effects of any future interventions. While conducting water management under IUWM the various factors that are considered include: environment management, economic growth, social development, research and technical innovativeness and political limitations of the region. By adopting all these factors IUWM can shift the mindset of humans from resource users to resource managers, optimize their consumption of water, enhance the recycling of wastewater and maintain a balance between supply and extraction of water from any urban dwelling. Under the guidelines of IUWM, separate provisions are made each for domestic use, gardening, washing, flushing etc. [Akissa Bahri et al., 2012]. Hence, IUWM regulates both the water quality and quantity, predicts the future needs, dodges the implications from climate change and maintains a balance between development and sustainability.

Beside the environmental change conjecture, another factor influencing future security of urban water supply is the expansion in water request attributable to development in population, thriving and ensuing urban improvement. Indian urban communities are confronting issues identified with water accessibility, quality and administration. Approximately 30% of the India's population is residing in urban dwellings and this percentage is expected to double by 2050 [Francois Brikkes et al., 2015]. In developing nations, such as, India with adoption of unsustainable ways development, the burden of existing natural resources, including fresh water, is increasing horrendously. Therefore, understanding the importance of the water conservation and international organizations are getting univocal to control the situation and hence Indian legislature has also demonstrated zeal to incorporate the concept of IUWM in its conventional water management system.

1.1 Need for Integrated Water Management System

Urban water and wastewater technology should be designed in such a way that it can provide hygienic water to the residents for their specific activities, collect the used water and then treat it before disposing it into the nearby water bodies for dilution. In addition, such structures also hold the capacity to collect and dispose the rain water which could otherwise lead to flooding. In this way, such systems are expected to fulfill the needs of the mankind without causing harm to Earth. However, in India, several urban dwellings have to suffer either because of shortage of water supply or due to the compromised quality of the drinking water. Ministry of Urban Development (MoUD) has also indicated that 182 urban areas of India require stringent and innovative actions with respect of water and wastewater management legislations [Francois Brikkes et al., 2015]. Although, administrations have improved the scope of water and wastewater management, yet these arrangements are still lacking in controlling the asset manageability and spillages.

An idea about lack of maintenance of the water and wastewater structures in urban areas of India can be obtained from the fact that because of uncontrolled spillages while supplying 210 l/d/capita of water only 125 l/d/capita is received by the residents [Francois Brikkes et al., 2015]. Lack in strengthening the existing structures with up to date technology in comparison to urbanization and populace development has put the authorities under noteworthy test. Improper management of water supply and treatment has also compromised the quality of the surface water bodies which are ultimate destination for water after usage. It is estimated that wastewater from approximately 160 restrooms and septic tanks are disposed into the surface water bodies leading to 80 % of the total contamination [Francois Brikkes et al., 2015].

Groundwater is also not spared from the products of improper water and wastewater management. In India, after surface water bodies have got contaminated with industrial and domestic effluents, burden on groundwater has severely increased. Moreover, in India, there are no norms set which can control the amount of groundwater to be used in the homes [Francois Brikkes et al., 2015]. Individual can use groundwater for bathing, washing cars, cleaning roads, gardening etc. In agricultural sector, also cultivation of kharif crops demands a lot of water and this need is solely fulfilled by drawing groundwater at high rate. Moreover, with global warming and consequently increased global temperature has also decreased the rate of replenishment of the groundwater. Urbanization and burden due to population have also pressurized the land cover. With the increase in population more and more trees are cut to provide land for shelter. Moreover, it has also lead to increase in pressure on the watersheds of a number of streams [Francois Brikkes et al., 2015]. The larger the demand the larger amount of water will be drawn out of the watershed, which eventually decides the flow of water into these water bodies. Hence, urban areas are the most modified form of natural surfaces and all the components of the existing hydrological cycle of these areas are decreased leading to drastic alterations in local water resources [Francois Brikkes et al., 2015].

Further, conversion of green areas into concrete surface also decreases the seepage of rain water into the ground. Increase in impervious area of the watershed reduces the infiltration and enhances the surface water runoff [Arnold et al., 1996]. Therefore, there is inclining in soil erosion and flooding but there is also decline in the amount of water reaching into the groundwater reservoirs of the area. The extent of damage caused by urbanization with respect to changes in hydrology of the area varies across physiographic regions depending on their climatic conditions, green cover, inclination of the area, geography and other hydrologic events [Arnold et al., 1996].

Entirely it can be said that inconsistent management of water supply and its disposal, has caused trouble with respect to human health and the nearby watershed of the area. Therefore, cumulative management of watershed and urban development is one of the pressing issues among the global scientific community. Maintaining the quality of domestic wastewater generated in urban dwellings has also proven to be a problem for developed nations such as, United States of America. For an instance, Unites States Environmental Protection Agency (USEPA) has lately mentioned the storm water coming from urban areas as one of the largest contributors in the increasing the pollution of the fresh water bodies [USEPA, 1995]. In order to draw global attention towards this matter, EPA has also declared urban storm water discharge and urban surface runoff as second most and third most sources of pollution, after industrial effluent, in the regional fresh water reservoirs, respectively. Surface water runoff from the agricultural areas, which contains large amount of fertilizers, pesticides and other chemicals, is considered as the fourth prominent source of lake contamination. EPA has also estimated that, contamination of fresh water bodies with toxic chemicals may alter the hydrology and also the habitat of several ecosystems, residing in them. Several international studies have estimated and compiled the impacts of the urbanization on different aspects of the natural fresh water streams such as, hydrology, physico-chemistry and ecology [Paul et al., 2002].

Surface runoff from urban areas contaminate the watershed via two ways i.e., point and non-point sources. Non-point sources do not have an unidentified multiple sources of contamination and are generally spread in large area. These pollutants once spilled are taken into the nearby water bodies by mixing with the storm water from time to time. This kind of pollution from urban areas is reported in the City Beautiful i.e., Chandigarh city of India. Moreover, depending on the perviousness of the surface of the urban area, these pollutants can also penetrate the land beneath them and seep all the way down into the groundwater reservoirs.

In this way, the non-point sources can contaminate the groundwater of the urban areas also. The other factors that can enhance the seepage ability of the contaminants include population density of the area, geology, material of construction, amount of precipitation and efficiency of storm water management [Paul et al., 2002]. The pollutants generated in urban areas any comprise of harmful toxic chemicals that can cause several carcinogenic and non-carcinogenic health impacts to humans. Hence, to maintain the water quality and quantity of the fresh water in the watersheds and groundwater aquifers it is of utmost importance to incorporate the concept of IUWM in urban development.

1.2 Potential Solutions for Water Management in India

Today is the best time for Indian urban societies to adopt IUWM in their water management systems. IUWM is one of the water management systems that bring paradigm shift to not only the existing urban areas but also the one which are under construction. Moreover it also maintains a balance between environment and development by making arrangements for hydrological, ecological and financial wellbeing. The success of IUWM is possible only when following key factors are also fulfilled:

a. **Importance of IUWM:** To introduce the IUWM in already existing system it is imperative to bring all the stakeholders on the same platform. It can only be possible if all the stakeholders understand the importance of IUWM and are willing to bring a balance between environmental safety and financial gains. These stakeholders may include the general, private, social and governmental sectors. Among them the government sector is always the principle convenor and contributor. The investment of partners is required while considering the basic need of breaking the 'storehouses' between various segments and exercises; achieve a typical comprehension and vision of difficulties and exercises; comprehend and adjust premiums and necessities of various partners; fortify collaboration, manageability and possession; and instigate conduct change and practical request administration.

b. **Comprehensive Approach:** An adoption of a comprehensive approach which takes care of all the branches of urban water security such as, water supply, water quality, collection, storage, extraction, treatment, disposal and storm water collection. In order to achieve the goals, implementation of these actions is not enough but it is important to update the technology from time to time. With more prospects of development larger population from rural areas is attracted to urban areas and hence burden keeps on increasing therefore, timely enhancement of the existing capacity is needed. Moreover, authorities should also conduct time to time check for spillage, treatment, cleaning and health of the related ecosystems.

c. **Recycling:** Recycling is one the key factors that can assist in maintaining the balance between economy and environmental safety. For an instance, wastewater released from domestic use can be used for different purposes depending on the level of treatment provided. It can be used for urban horticulture, in nearby agricultural farms, gardening, washing vehicles and roads. The sludge generated from sewage treatment facilities can be used for compost formation that can act as manure for agricultural farms.

d. **Optimum Framework:** Optimum framework configuration suggests the accompanying key focuses: innovative motivation to avail water at each door step, wastewater collection and effective treatment and hygienic water rely on multi-criteria and emotionally supportive network to understand a large range of factors; such factors incorporate water quality, monetary state of family units, size of populace, access to cutting edge advancements and gifted labor, accessibility of area, structural design and then some; and this incorporates sustainable foundation, minimal effort, vitality proficient choices, regular frameworks and inventive advances.

Compelling water administration with an IUWM viewpoint incorporates numerous angles with the primary after key components: receiving another outlook, a comprehensive and multi-facet methodology connecting urban water administration with general urban arranging; modifying some arrangements and enactment considering utilization of water, recycling it and then trying to use it again; further dividing the concentrated and decentralized administration; evaluating the impacts of IUWM on fiscal budgets; enhancing the technical capacity of the already available manpower; and offering data to people in general and clients. Therefore, there are vulnerabilities about the appropriateness of the outline of existing tempest water collecting frameworks and how these frameworks perform in connection to the administrator destinations. Only one prominent instance of general wellbeing or ecological disappointment of a tempest water-reusing venture could undermine open trust in this elective supply choice and make a huge hindrance to its far reaching selection. Before implementing IUWM in the urban society it is crucial to set criteria to choose the various parameters which need to be changed in an urban water management. Resultant to it is that a list of eight major markers/criteria is finalized.

These markers mainly deal with the three basic endeavors of the urban water management, which are:

a. Consumable water- availability and decontamination;
b. Storm water runoff management and
c. Used water and sludge- recycling of the waste material.

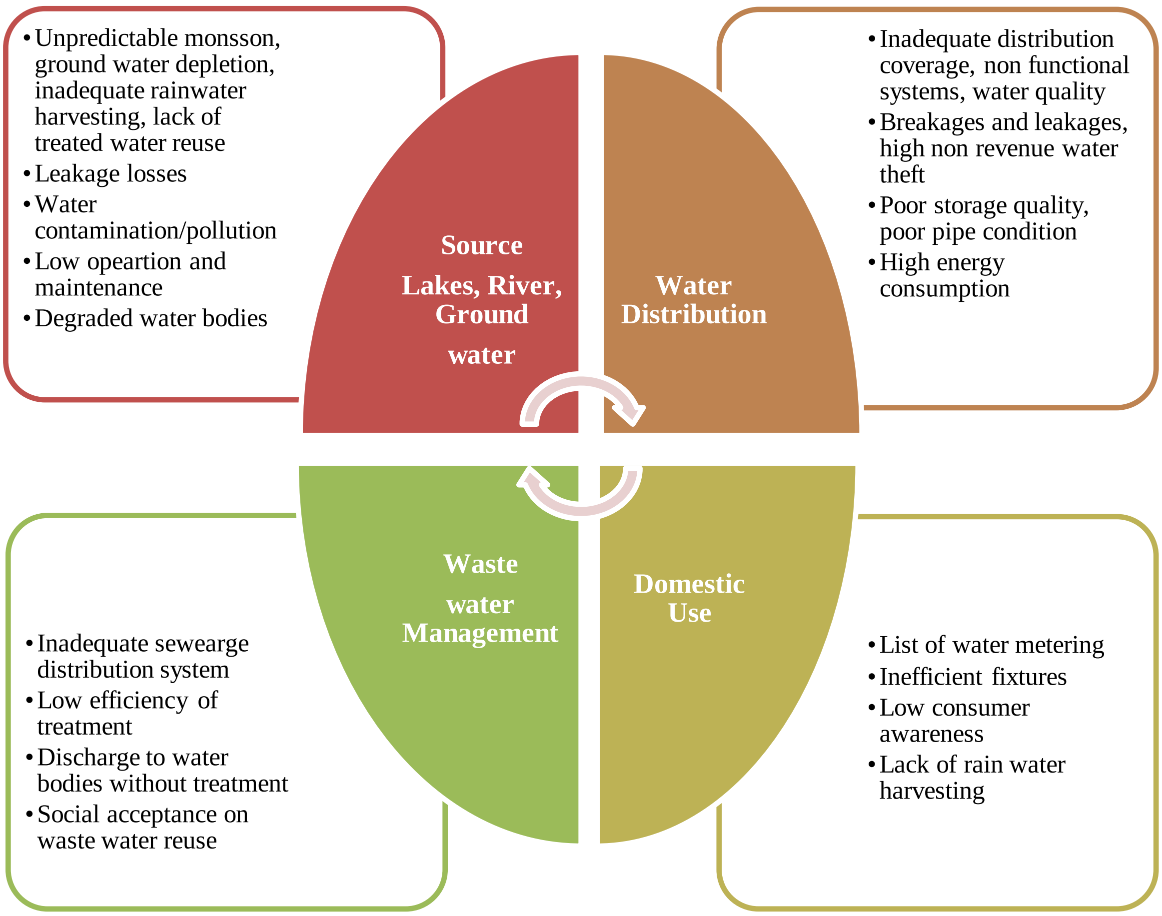

Fig. 1.1: Water Management in India [CSE, 2016]

The planning of the IUWM mainly deals with: 1) social wellbeing, 2) sterile perspectives, 3) risk estimation followed by analyses and 4) re-use of material recovered while water management [IRAP, 2010]. A water system chosen for this purpose should be examined for holistically. It should not only evaluate the initial steps of supply of drinking water but also the wastewater collection, transportation and treatment. It should also consider the storm water runoff, type and number of different assets that are required in this complete process. Such a system can be designed either from the already available system or it can be drawn out of the theoretical approaches.

The structure finalized, for examining the management system, in this way can also be segregated into three levels (considering the three types of urban water: storm, drinking and wastewater) i.e., centralization, source partition and system scaling. The system designed in this way will consider the different components of watershed management and IUWM into a single frame and there will not be any heterogeneity left in any urban water system and wastewater administration.

In case of urban areas of India, approximately eighty percent of the water that is supplied for the domestic use comes out as wastewater. As per the reporting of Central Pollution Control Board [CPCB, 2015], while India was having the waste treatment capacity of `23 MLD, 61.7 MLD wastewater was generated from the domestic urban societies. Therefore, 38.7 MLD of the wastewater finds its way into the freshwater bodies without being treated and it all happened because of incompetency of India wastewater treatment facilities. Moreover, these estimations did not considered the usage of groundwater by the various unregistered households and other units. Hence, India is in a dire need to speed up the process of increasing the capacity of its wastewater treatment facilities. From February, 2013 to March, 2017, the project under the Adopting IUWM, four cities namely, Rajasthan and Maharashtra (Jaisalmer, Kishangarh, Ichalkaranji and Solapur) have improved their wastewater treatment capacity and its encouraging results can be seen from Table 1.1.

From these encouraged results, it is visible that after adopting IUWM in Indian water systems, the conservation of water has drastically improved. The major causes of adopting IUWM in India water management system is to improve the efficiency of water supply, manage storm water runoff appropriately, treat and recycle wastewater, save the freshwater bodies such as, lakes and also conserve the other sources of freshwater such as, rain water and groundwater. These targets can only be achieved if all the urban areas are availed with clean water without disturbing the existing political policies, and advancing the available technology for treatment and recycling of the wastewater. There is also a need for understanding the models which can predict the demand of the urban area based on various varying factors such as, population, imperviousness, type of water fixture etc.

Table 1.1: Saving water in India with IUWM

Water supply apparatus	Used before intervention (litres/flush)	Water used after intervention (litres/flush)	Water saved using IUWM (litres/flush)
Toilet	10–13	3-6	4–11
Urinals	10–13	Sensor operated	2.2–10
Taps	10–18	Sensor operated taps	5.5–15.5 litres/minute
Showers	10–15 litres/minute	Restricted flow	4–20 litres/minute

Source: [CSE, 2016]

1.2.1 Wastewater Classification

Water is supplied to human beings for various purposes such as, industrial, agricultural and domestic. After human usage, the quality of water is degraded and it cannot serve its purpose any further. Such kind of water is called as wastewater. If wastewater is not managed properly and discharged as it is, it can severely contaminate the surface water bodies and groundwater [IUWM, 2015].

In India, due to lack of sewerage treatment capacity, 26000 MLD of wastewater is discharged directly into the freshwater bodies [ENVIS, 2016]. Therefore, in Indian urban societies, there is humungous difference between the generation and treatment of the wastewater. The generation of wastewater in any urban areas can be explained using Fig. 1.2.

Water supplied to the urban areas serve several purposes and depending on the type of usage the pollutants present in the wastewater also varies. Therefore, wastewater generated in urban bodies can be classified on the basis of the source of its generation. There are three categories of the wastewater generated from urban societies and they are as follows:

a. Domestic or sanitary wastewater
b. Industrial wastewater
c. Surface runoff/Storm water

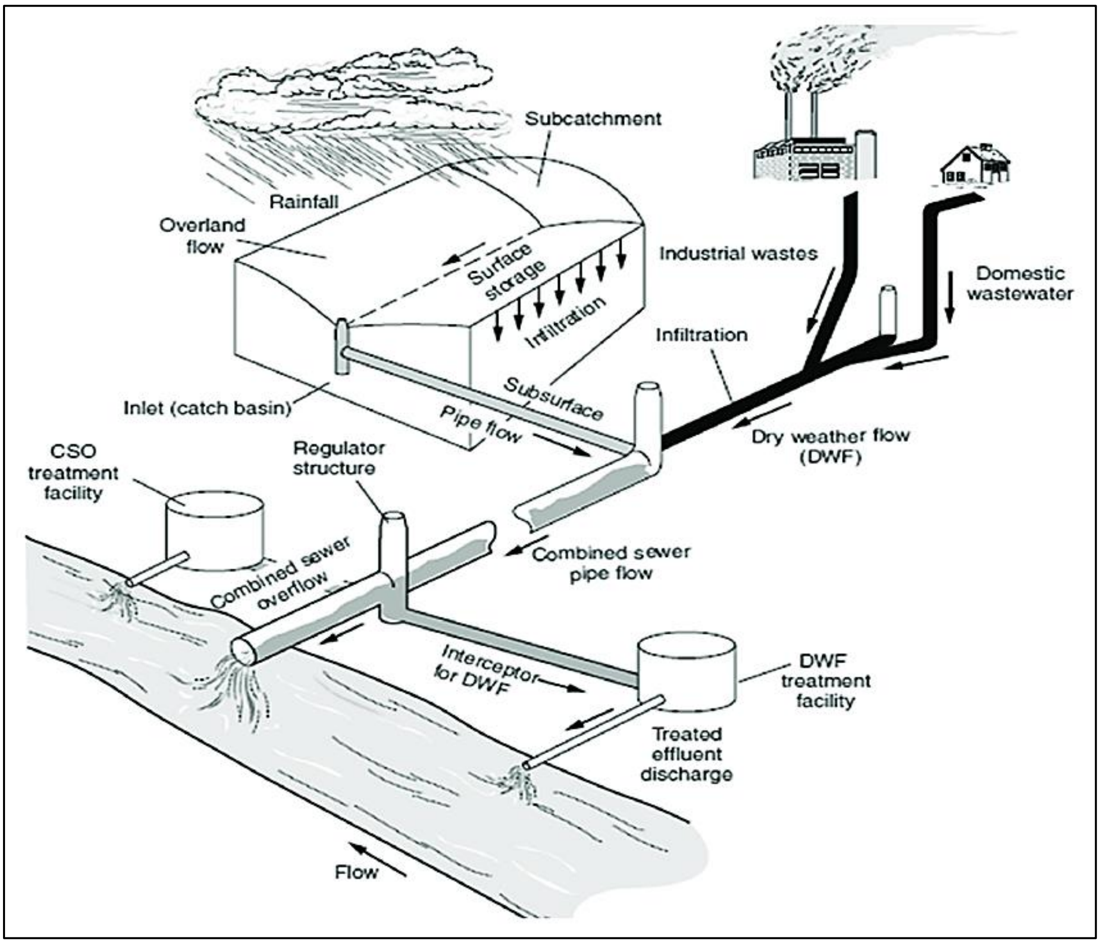

Fig. 1.2: Origin of Wastewater [IUWM, 2015]

1.2.2 Domestic or Sanitary Wastewater

Domestic or sanitary wastewater is generated from the household of the urban society. It contains the wastewater generated during daily activities of human beings at their houses such as, cooking oil, food particles, human excreta, detergent mixed water, dirt, grease etc. Therefore, it mainly contains putrescible organic compounds that can be degraded by microbial activity.

1.2.3 Industrial Wastewater

Every urban body is generally surrounded by industrial buildings which need water for different manufacturing processes of different type of products. When discharged from industries the wastewater may contain several toxic compounds such as, acids, chemicals, heavy metals etc. Such type of water can be treated along with domestic wastewater as it comprises mainly inorganic compounds and if dumped without precaution may lead to disastrous impacts on the natural water reservoirs and various habitats surviving within them.

1.2.4 Surface Runoff/Storm Water

Conversion of green cover of the land to urban localities demands covering the ground surface with impervious layer of concrete. In response the amount of rain water that falls on such surfaces are not able to percolate through the land into the groundwater but are collected on the surface. This kind of water in urban areas leads to the generation of surface runoff or storm water. Such kind of water if not collected and transported, in time, can lead to flooding on the roads of the urban areas and alter the other characteristics of an idle urban area. Moreover, rain carries various ionic compounds with it from the polluted air over the urban localities which eventually get mixed with the storm water. Storm water also contains various compounds from the roads, buildings and other surfaces of the urban areas and hence degrading its quality. Collection and transport of such water, to appropriate treatment facilities, is very crucial for urban areas which otherwise, will lead to several human health issues as well [Kayaga et al., 2007].

1.3 Significance of the Study

Chandigarh is a well-planned urban city which is fulfilled in every aspect of a perfect urban locality. It is designed and architecture in such a way that it can take care of the needs of frequently growing urbanization [Statistical Abstract, 2012]. Therefore, from time to time, it attracts the residents from all over the world because of which authorities need to grow along its boundaries and cut more trees. Increased population of Chandigarh, brought several problems in front of the authorities such as, deforestation, air pollution, noise pollution, water pollution, wastewater management, storm water management etc. Census of India has reported that population density in

Chandigarh is growing continuously since 1961 and presently it is accommodating approximately 13 lacs residents which are almost 5 lakhs greater than its optimum capacity [Statistical Abstract, 2012]. Chandigarh has also attracted people to construct villages and slums in and around the city, causing trouble for authorities to maintain a balance between needs and resources available.

It has also brought forward a problem of converting green area more and more into urban localities which are impervious in nature. This impervious nature of Chandigarh has made it mandatory to provide provisions for storm water management, also. As Chandigarh receives comparatively more precipitation than Punjab and Haryana, therefore, storm water collected on the roads of Chandigarh may also give rise to several diseases such as, malaria, dengue etc. Storm water mixes with it several toxic substances deposited on the surfaces of urban constructions such as, acids, heavy metals, oil etc., and carry it along with it to the nearby water bodies and contaminate them. In addition, with increase in imperviousness recharge of groundwater reduces because of which aquifers beneath Chandigarh does not get replenished with water and its water level get lower from time to time.

Therefore, in Chandigarh, adoption of IUWM is crucial so that a solution to the appropriate management of the domestic wastewater and storm water can be derived. IUWM will not only bring solution to the problem but it also takes into the economical and future requirements also into consideration, because of which it is a very reliable method to solve the issue of water management in Chandigarh.

The findings of this study will assist the regional authorities in understanding the importance of implementing IUWM in Chandigarh and provide them a hold to initiate their efforts in direction of managing the wastewater, storm water and preserve the naturally available resources of the town.

1.4 Probable Solutions

The project for managing the domestic wastewater and storm water provides guidance with respect to various aspects of the water management such as, location of the sewerage treatment plant, sewer lines, capacity, designing of the various tanks etc. In this study, we have given the solution for the best use of storm water and waste water in the residential multi storey buildings as well as commercial buildings. We can best use the dual system after the treatment of storm and waste water as a water supply in the buildings. In first pipeline we will supply the recycled or treated waste water and storm water for the purpose of car washing, latrines, gardening etc. and in second pipeline we will supply fresh water for drinking, bathing etc. This methodology will be followed by our design engineers at the time of construction of buildings so that we can best use the planning of water for future purpose. Designers will construct the proper storage tanks for storm and waste water for the collection of water so that we can implement the dual system in a better way for the building. To implement these ideas we have to figure out the total water demand of the city, actual scenario, water collection for treatment, design parameters, water quality, daily water usage, best use of treated water. It would we helpful for our study for the management of urban India.

1.4.1 Approach to Design

Storm water harvesting/conservation and recycling need an extensive planning before implementation. Generally, storm water management project is planned with first motive to minimize the cost as much as possible. In addition, at the one terminal of the water management system, the parameters are most considered are collection of storm water, its storage and treatment. The preliminary design of the storm water management system is based on the flow of the water. The major things kept in mind while designing the storm water management system are as following:

a. First of all, it is crucial to identify the basic requirements of the system such as, quantity and quality. In to adjust the quantity and quality, it is important to consider the quota for irrigation purposes. For this purpose, one should also evaluate the demand of water for irrigation and estimate other factors such as, peak flow of the area.
b. Estimate the water balance of the area/Chandigarh so that an idea could be made for storage capacity of the storm water runoff.
c. An off-line storage collection system should also be designed which can be estimated by deriving a relation between average yearly volume of storm water and diversion flow rates.
d. Designing of treatment system is directly related to flow rates of the storm water. In case, treatment is to be designed before storage than, treatment system should

be designed as per diversion flow rate or otherwise according to distribution flow rate.

1.4.2 Collection

The major factors which need to be considered while designing the collection of storm water and wastewater are as follows:

a. Collection capacity of the storm water or wastewater should be enough to meet the requirements of the area.
b. The pumping out of water from catchments should not affect the flora and fauna of the area.
c. In case, storm water is contaminated and harmful for its intended purpose, the collection must be stopped immediately. Resumption should only be done after the matter is solved.
d. The capacity of storm water flow and collection should be designed in such a way that upstream flooding is prevented.

1.4.3 Storage

The designing of water structure must consider following recommendations about the storage of storm water:

a. The capacity of storage should be enough to fulfill the objectives and needs of the project.
b. The storage tanks for storm water should be designed above the ground so that a time to time check can be taken to prevent the growth of parasites such as malaria parasite. Moreover, contamination of groundwater, eutrophication and neglecting of dam safety can be prevented.

1.4.4 Treatment

Following issues need to be considered while designing the treatment unit for storm water management:

a. Adopting storm water and waste water quality criteria.
b. Substances arising from treatment unit must not impact the health of the public.
c. The treatment process adopted in storm water management must not cause any environmental issue.

d. Be prepared to handle any additional requirement arising in any eventuality.

e. The design of treatment process must fulfill the objectives of the project.

1.4.5 Barriers

Nowadays, storm water management is a secondary issue in the economy driven societies. To improve manageability of water-quality- administration frameworks, top to bottom research of the related boundaries and the important moderation approaches is wanted. In this study, late improvements, progressions, difficulties, and boundaries related with practices of water-quality administration were investigated. Various related techniques, applications, and arrangement contemplations were analyzed.

1.4.6 Opportunities

For making the India stronger in water management by 2030, the work carried out in this research work of double plumbing system will help us to serve better. The objectives incorporate the review appraisal of dual water frameworks which are two conveyance frameworks working mutually, which are:

a. Supply consumable and

b. Supply non-consumable water.

Rather, double frameworks have the ability to disperse any source of non-consumable water, yet the objective of this report which is to use the recycled water will be given more consideration. From the future point of view, the Chandigarh city has to adopt dual water system which comprise of treated waste water and fresh water for various household purposes. In dual water system, one pipeline consists of fresh water for bathing purpose, drinking etc. and second pipeline consists of treated water which can be used for gardening, car washing, flush water etc.

As the rising demand of water usage in Chandigarh, we have to look forward for saving water by conserving it either in the form of storm water conservation or waste water treatment for the future use of our generation. The benefit of double plumbing system will help us to save fresh water as we can use treated water for various other purposes which are required for our daily use. This idea can be implemented in residential, commercial and educational institutions. Till now, the idea of water management is not used wisely.

For a better future and in order to save the resources, the municipal corporation, environmental agencies, researchers, design engineers and policy planners must come together forward to execute the plan. By the combined efforts of everyone, we can develop a design like sewer pipe line which can collect storm water and waste water at the same time. This design can help us to meet the end use volume requirements. We can also construct large treatment tanks so that a large amount of water can be treated.

1.5 Research Hypothesis

a. It is possible to do a water balance study for Chandigarh with reasonable accuracy.

b. The stakeholders agree that the principles of IUWM can be applied to Chandigarh.

c. It is possible to apply frameworks and models to test pilot applications of IUWM in Chandigarh.

1.6 Research Objectives

Based on the hypothesis stated above following research objectives were finalized for the present study:

a. To estimate the water balance of Chandigarh.

b. To quantify sustainable sourcing of water and effective use of multiple sources such as rain, storm, ground and treated water in Chandigarh.

c. To ensure the availability, equitable provisioning and efficient distribution of integrated water.

d. To use waste water as resource effectively.

e. To apply frameworks and models to test pilot applications of IUWM in Chandigarh.

1.7 Thesis Outline

The present thesis is divided into eight chapters with some supporting material such as, appendices. The brief introduction to each chapter is as following:

Chapter 1: Introduction

In this section, reader is introduced with the details of the study area, research problem, need of the study and finally the objectives. This chapter shows the importance of integrated urban water management for Chandigarh region. With a developing economy and changing ways of life the weight on officially stressed water assets is expanding.

The legislature has demonstrated an enthusiasm for IUWM as another structure and method for the country. For the future point of view we have chosen the city beautiful for our study to protect it from adverse effect of water shortage by 2030. In this study we have to implement our best ideas for the protection of environment as well as water shortage too. The storm water and waste water management project gives advice to the design bureau and the town planner/architect/engineer on the choice of the best management practice, which most suits the location of their project by giving a method, not a specific solution. The project for managing the domestic wastewater and storm water provides guidance with respect to various aspects of the water management such as, location of the sewerage treatment plant, sewer lines, capacity, designing of the various tanks etc.

Chapter 2: Literature Review

This chapter presents the trend of development with respect to increasing population in Chandigarh. Also, it compiles the scientific literature presenting the background of IUWM, its advantages, various case studies with positive outcomes and designing aspects of the water management system. This literature review helped in understanding the research gaps present in the studies related to IUWM and helped in identifying the objectives for present study.

Chapter 3: Water Balance

In order to, estimate the capacity of various water treatment units, it is of utmost importance to estimate the water balance of the area. This chapter defines and calculates the water balance for the study area in different times. A comprehensive approach which should be considering the various parameters of an urban area was used in this estimation such as, population, water usage trend, irrigation requirement, industrial usage etc.

Chapter 4: Methods and Tools for IUWM Study

This chapter focuses on collection of data includes the rainfall, wastewater, stormwater, ground water and treated water from the various organisations working in Chandigarh. The primary data related to water characteristics prevailing in study area are generated through various tools like on- site observations related to water sample collection, laboratory testing, questionnaires and interviews are conducting in the progressive manner. Water samples are collected from various STPs and drains to check the quality of water. In the data analysis, we have used the statistical approach by using Matlab, MS Excel to figure out the results for the future.

Chapter 5: Data Collection

This chapter describes the Chandigarh data used for this study. Data was collected from the environmental departments of Chandigarh like ENVIS (Environmental Information System) Centre, Sector 19, Meteorological Department, Sector 39. Data collected was based on Rainfall, Storm water, Waste water, Canals, tube wells, STPs etc.

Chapter 6: Case Study

This chapter focuses on the implementation of double plumbing in various towers and buildings. This case study includes the double plumbing concept which we have implemented in Chandigarh and nearby areas by using waste water and storm water. We have designed storage tanks according to the water demand of the towers with proper calculations and designs, in which we stored waste water and storm water, and then further we treated that water and provided double plumbing system in the houses. In one pipeline, we supplied fresh water which will be used for bathing and drinking and in second pipeline; we provided treated waste and storm water which will be used for flushing of toilet, gardening, car washing, AC service etc.

Chapter 7: Results and Discussion

This chapter focuses on the results related to recharge and drought and as the water demand rising day by day so for the future purpose we have to recharge the water system by double plumbing and by saving storm water and treated water. Various samples of water were tested of different areas of Chandigarh like STPs, Drains, Choes etc. to get the various results related to BOD, COD, pH, TSS, Nitrogen etc.

Chapter 8: Conclusion and Further Study

This chapter presents the crux of the findings of the investigations (both laboratory and field-based) performed during the study. In the present study, the author has attempted to provide a complete assessment of the water management problems in Chandigarh, India.

Certain recommendations regarding the IUWM of Chandigarh that are drawn from this study are:

a. A water management with appropriate water balance;

b. A comprehensive explanation of the futuristic plan in order to manage the urban water system with changing population, climate and other miscellaneous factors;

c. A scheme to implement the methodology for efficient urban water management, defined by the various authorities including, government and NGOs, shows the content of this chapter.

CHAPTER 2

LITERATURE REVIEW

2.0 General

The review of literature demonstrated that incentives for recycled water use incorporate urbanization pressures on water supply sources, lessening normal water resources and progressively rigid wastewater release guidelines. Recycled water is required particularly in dry districts and recycled water extends that target huge water users are probably going to be increasingly possible.

Subjects in the accompanying passages cover the writing survey on scope of issues required to evaluate the exhibition of incorporated urban water management including: water quality and general wellbeing parts of water distribution; developing population; involvement in water reuse system; appropriation framework resource and financial aspects and institutional plans.

2.1 Review of Literature

Management of water and intake pattern has called the consideration of economists, administrators, researchers, sociologists, environmentalists and also non-governmental organizations. A number of uneven and portion of studies related to urban water condition have been organized and this review mainly focus on the various issues like:

a. Shortage of water and reasons associated with it;
b. Reduction of resources of water in surface water and also groundwater;
c. Water supply considerations in urban areas;
d. Water pollution and water quality;
e. Participation of users with awareness on water education;
f. Water pricing;

Anna Hurlimann et al., 2018 portrayed the game plan of an affordable water flexibly is an unquestionably irksome task to achieve in various urban circumstances. This rises taking into account loads related to masses improvement. Also, natural alteration is influencing the standard example related to water in various territories, with an essential impact foreseen for what's to come. Various scientists support water management in urban areas a system which can report the fundamental drivers of these troubles. This paper gives information and contraptions to help water coordinators achieve water management in urban areas and an inside and out balanced water part and urban condition, in an organized, widely inclusive and complete way for meeting the future water needs. Attaining these destinations would require shared actions over various manufactured condition disciplines.

Nitin Bassi et al., 2018 highlights the institutional change prerequisites for achievable urban water organization in India. The institutional change will include: 1) one or blend of definitive change measures including decentralization, private territory intrigue and, system based organization; 2) request changes and; 3) human resource improvement. The better viewpoints will depend on the physical and budgetary condition, political situation and administrative set up that exist in the urban domain. The institutional changes will be even more so crucial for minimal urban towns where open utilities are given little thought. All these together can add to improving Indian urban networks orchestrated dismissing the risk, in face of quick urbanization, ecological change and water lack.

Casey Furlong et al., 2014 justifies the Integrated Urban Water Management model or IUWM model, including ideas, for example reuse of water, and adaptable seepage frameworks in urban areas, has gotten well known inside Melbourne, Australia and it made new administration matters. This study investigates the connection between varying administration arrangements and IUWM execution. It is discovered that IUWM usage has transcendently quickened by a significant dry season and actualizing the Office of Living Victoria (OLV) as an all-encompassing body. Endeavors by the OLV have expanded between office joint efforts and organized coordinated arranging. Be that as it may, there is still no accord on what the points of interest of IUWM arranging and framework courses of action ought to really lookalike.

Hatt et al., 2012 states a coordinated management and reusing of storm water as a survey of practices in Australia. With the utilization of water drawing closer, and occasionally mind blowing, the cutoff motivations behind agreeableness in different zones, there is a stretching out assertion of the need to use storm water for non-consumable prerequisites, thusly diminishing the sales on consumable sources. This paper shows an audit of Australian storm water treatment and reusing rehearses and in like manner a discussion of key activities and saw information holes. Where potential, suggestions for conquering these information holes are given. There is an undeniable essential for the movement of imaginative systems for the gathering, treatment and cutoff of storm water. Existing storm water reusing method is far before examination, and there are no advances framed particularly for storm water reusing.

Jethoo et al., 2011 in their paper on, water utilization India with everything taken into account and in Rajasthan, explicitly is working miserable. There is a drought like situation in the State. 99% dams in the state are absolutely drying. Huge urban regions are standing up to a serious matter related to drinking water. Over the latest couple of years, quantity of occupants has been exponentially extending, inciting extraordinary lack of consumption of water. The examination broke down the particular compensation pack customer's lead in regards to the diminishing water supply. As per observation, the absence of exhausting water tables and serious absence in consumption of water; in view of less care, public was using considerably extra water than it was required. It needs proper knowledge towards usage of water by the help of media and by conducting open mindfulness sessions.

Aijaz et al., 2010 examined on water for the use in Indian cities: Concern on government practices and policies noted that due to quickly rising population, the need for basic arrangement and facilities has increased. Such expanding requests frequently influence the nature of urban life, the monetary efficiency and also feasible turn of events. The primary reason in paper was to feature the issues engaged with improving access to supply of water in Indian urban communities confronted with a serious water lack emergency. This study showed the status for the supply of water service which includes three cities i.e. Kolkata, Delhi and Mumbai. There was an urgent need suggested to construct the infrastructure for water and organizations which focused on the challenges for the stakeholder‘s to fasten up the development process and the practices were implemented for effective water governance.

Araral et al., 2010 contributed on urban request of water in the board in ASIAN nations: difficulties and arrangements showed the challenges faced by the system in supervising demand of water in urban areas when demand for water is rising, moving toward lack of water is also rising and urbanization is an appropriate example. Dependent upon the condition of the country, both present and future plans comprising obligation arrangements, the executives game plans, particular/building courses of action, institutional/regulatory game plans and activity, state subsidized preparing and system affiliation were proposed. Transitory courses of action consolidate diminishing business incidents, watching out for meter exactness and reducing pressure. Long stretch plans join pipe circumstance programs moving towards money related estimation of water organization and execution. Another institutional plan join progressively incredible rule, private region backing and cash related modifying of water utilities. These courses of action must be planned for the staff, notice organizations could be improved and authority attributes could be made.

Farrelly et al., 2010 included thorough survey of research embraced everywhere throughout the world on different parts of urban water administration by researchers and specialists, including yet not restricted to urban hydrology, administration of water supply foundation, water assets administration, water quality administration (WQM), groundwater administration, specialized and monetary instruments for water request administration, specialized and financial parts of spillage decrease, ecological and financial parts of wastewater treatment and reuse, storm water administration, limit working for IUWM and legitimate and administrative structures.

Essential information accumulation for 27 urban areas/towns and auxiliary information gathering for 300 urban communities/towns was completed, covering all the 16 outlined typologies. Reasonable arrangements of IUWM mediations were distinguished for every typology in view of the comprehension of how the common qualities of these typologies impact the physical, monetary, institutional, money related and natural execution of urban water utilities.

Jha et al., 2010 explored on access supply of water and sanitation considered that safe access for drinking water is essential for occupations. An appraisal uncovers the growing access to water system despite the fact that in sanitation progress is shy of its points. As a general rule, most essential perceptions demonstrate that water flexibly inclusion isn't comparable. Monetary, particular institutions just as social variables oblige to water drinking, sanitation for urban areas. Networks require dealing with water plans and sanitation plans in urban zones. There are positive focal points to such an institutional course of action if the change to network the executives is done easily. The odds of accomplishment of network management are vitiated in light of the fact that strategy makers misjudge and twist the ideas that are significant for the achievement of water plans and sanitation plans.

Monteiro et al., 2010 examined on household water demand in Portugal assumed that the growing tariffs block for water was broadly utilized. Growing tariffs block are acceptable instrument for accomplishing the destinations of value, water protection and income adequacy. Growing tariffs block are estimating the component rehearses submerged shortage and spending adjusting requirements, at the point when buyers are heterogeneous and the fixed charge is simply allowed to deal with fixed costs. Since, in these conditions, the choice of expense plan arrangement is dependent on the worth flexibility of intrigue and the way in which it vacillates with use levels.

Mithra et al., 2010 explored on consumption of water in urban areas in India shown that all-around, 1.1 billion individuals need access to improved consumption of water smoothly and drink water that is degraded. Thus, assessment of water treatment recognizes most uncommon significance so as to guarantee the security of the water ate up particularly in quick creation urban regions. This assessment gives data of drinking water the director's practices in the appraisal district. The appraisal analyzed the sources, the treatment and storerooms of savoring water family units and in addition evaluated the free chlorine levels in the consumption of water.

Shiroma et al., 2010 states a Coordinated Urban Water the board is a developing methodology for urban water utilities to design and oversee urban water frameworks to limit their effect on the indigenous habitat, to expand their commitment to social and monetary imperativeness and to cause by and large network improvement. The conspicuous beginning stage for embracing the IUWM approach is the strategic planning phase. Notwithstanding, little has been composed on forms that empower utilization of the IUWM way to deal with arranging. Distinguishing this information hole, the Water Research Foundation and the CSIRO, Australia mutually built up a structure to receive IUWM way to deal with key arranging of urban water supply (alluded to as IUWM Arranging System). This paper examines standards, drivers and advantages of IUWM approach and gives a review of the IUWM Arranging System.

Wild et al., 2010 in their examination on, "Water: A market of future", indicated that providing water of satisfactory quality and in adequate amounts is one of the significant difficulties confronting present day society. In numerous nations the accessible water assets are presently being over exploited to such a degree, that the negative results have been happening. Nations situated in bone-dry locales are thinking that it’s hard to water the harvests. Simultaneously numerous individuals despite everything don't approach safe drinking water, since water assets are constrained or dirtied by household and modern wastewater. Worldwide populace development has made the circumstance graver. Interest for water is expanding, alongside the individual needs of people. In the coming years significantly more water will be expected to create nourishment for the world's expanding populace. In numerous nations the framework for providing the populace with drinking water and wastewater treatment is faulty. Significant ventures will be required in the present moment to overhaul water mains and sewer frameworks specifically. Arrangements additionally should be found to address the new difficulties emerging from new smaller scale contaminations that are turning into an issue in industrialized nations particularly. Environmental change will cause noteworthy varieties in the hydrological system in numerous districts, coming full circle in a water emergency in some areas.

Joel et al., 2009 depicted Surveying supply dangers of reused water designation procedures. A device to assess the flexibly risks related with water assignment system used at exuding reuse workplaces is depicted. The instrument is month to month water modify model and affectability examination. Through assessment of air records at the

Hawkesbury water reuse scheme site (the region of a merged profluent and whirlwind water reuse office), it was found that a measure of water framework demand took after standard genuine assignments.

The assessed dissemination of water system request was utilized as a part of conjunction with a water adjust model to evaluate future storage distributions and thus dangers of future over-or under- supply situations. The tool is reasonable for use in an operational environment to assess the impact of demand management strategies.

McKenzie et al., 2009 in their paper on," Urban water flexibly in India", noticed that huge amounts of families in urban networks around creating world don't approach safe drinking water. Country encountered the issue to access water in urban districts and the different choices open for change. Utilizing two game-plans of information from the National Health Survey also as coursed and unpublished right hand sources, the status of access to savoring water urban India, the presentation of India's urban water section when appeared differently in relation to other Asian metropolitan areas, and the change attempts that are in progress in a couple of Indian urban networks is the accentuate point. A review of these constant changes outlines a part of the political economy challenges related with improving the water portion. Every nation experiences challenge and openings, the degree and extent gives bits of information to some low-pay countries.

Maria et al., 2008 examined on the Delhi water emergency: Companions reactions with possible situations of advancement in lacking water flexibly through open utility, included through abnormality, insecurity and upgraded through extraction of groundwater which is a regular segment of urban zones of Indian similarly making urban networks on the planet close by the noteworthy degree of tainting of urban springs, the standard end involves in making an allowance for reserved groundwater extraction as a troublesome result, one which will without a doubt evaporate when fitting changes are completed for extending the extension and by improving the standard of organization gave through metropolitan water effortlessly orchestrate. The condition of mixing to comprehensive drinking water access to flexibly by united open framework isn't the primary long stretch circumstance that can happen in making urban networks like Delhi. Private adjusting systems accept an occupation in embellishment the drawn out particular heading of the urban water the administrators structure; grant the highlighting of certain critical technique mechanical assemblies in achieving the acceptability of water the board in making urban territories.

Arlosorof et al., 2007 showed on request of water management – technique to manage shortage of water in Israel: An analysis found methodologies for water request. The water management terms showed a great move in perspective to the organization of intrigue side, conveying extra measures for the general public water needs by the arrangement of essential water measures, by methods of extended cultivating and per unit mechanical creation of water, similarly the water import concentrates the rural items.

Emoabino et al., 2007 in their paper on, ―Water request the board, issues and prospects of executions in Nigeria, called attention to that water gracefully in Nigeria was facing real troubles and flexibly arranged augmentation of water flexibly establishments was concentrating on the available budgetary conveyances to the zone beyond what many would consider possible. Governments have been looking for after water supply tasks and sponsor workplaces similarly have been advancing endeavors to broaden water flexibly structures. Regardless of these undertakings there are still liberal numbers of individual that are not made sure about with water sanitation and drinking safe water.

Fletcher et al., 2007 investigated storm water collecting productive to urban channel ecological streams. Urbanization spoils the hydrology and water nature of courses. Changes to stream organizations join extended repeat of surface overflow, extended streams and a development in hard and fast flood. Meanwhile, water use in various urban networks is moving nearer, and occasionally astounding, viable limits. Storm water procuring can ease a portion of these negative impacts. The results show that using these common gathering circumstances brought stream and water quality back towards their pre-made levels. From time to time, regardless, procuring realized an over-extraction of stream, displaying the prerequisite for propelling the social occasion system to meet both supply and common stream goals. The results show that urban storm water procuring is a likely framework for achieving both water safeguarding and characteristic streams.

Kayaga et al., 2007 in their paper on, ―Water request the executives: A key Structure hinder for coordinated asset getting ready for the city of things to come, examined that moving toward water lack nearby unfriendly characteristic impact powers water part to rethink the procedure by the makers in which they accomplish resources of water. For water management related to demand of water tools should be applied. Planning for resource integrated approach to be applied for managing the demand in the essentialness portion. Resource integrated approach relies upon by consuming water even more viably.

Mathur et al., 2007 in their examination, norms and guidelines of metropolitan fundamental administrations in country detailed the prevalent establishment level, urban organizations rates are at intersection. There is an improvement in the degree of significant associations, for example, water precisely; sanitation and strong waste association at any rate the quality and proportion of these associations are still underneath the rules grasped by different commissions and warning gatherings. Different associations and ace packs sheets of trustees have given an extent of standards of fundamental establishment and organizations in India. The asset holes and further to beat any issues and increase the level organizations level in India were dismembered.

Rao et al., 2007 examined on the access to consumption of water and water sanitation assumed that comprehensive development will promise well except if targets are set and approaches, projects, and activities are figured to accomplish widespread water and sanitation get to. Composite pointers like the Human Development Index are of inconceivable help with highlighting the zones where movement is required. An Index of Drinking Water Adequacy (IDWA) is proposed which is anything but difficult to loosen. Its parts show heading for methodology, program, and undertaking exercises. In any case, there is a need to reconsider how water and sanitation get to data are accumulated and how a sensible degree of accuracy and cross country similitude can be ensured. At present, almost during that Millennium Development Goals timespan, tweaking the destinations on water and sanitation may be considered by making part countries of the Asian Development Bank, with the ultimate objective of achieving general house relationship by an appropriate date.

Raju et al., 2007 explored on growing groundwater dependence and declining water quality in urban water gracefully examined that the degree of groundwater reliance and quality status in urban zones has been broadening. Family unit audit demonstrated reliance of 31, 52, 38 and 99 percent while the quality evaluation showed 46, 43, 21 and 98 percent as non-consumable in the above urban systems independently. Water markets got a turnover of Rs. 51 crore in Kolar locale alone was Rs. 121 million for each annum.

Ray et al., 2007 explored on advancement of water and featured the job in the administration and protecting of water. Water the authorities is particularly colossal for the creation scene where an impressive people need access to water for the principal needs. The nonappearance disaggregated information on the effects of water moves close and the essential differences and improvement must to be speculated makes it hard to appear at objectives on which procedures can best guarantee weak ladies solid access to water for their lives and occupations.

Shaban et al., 2007 explored on the dynamics of population, availability of water and Indian consumption patterns shows the accessibility of water in the country, as a rule, and in urban communities, specifically, have declined quickly in the ongoing years because of fast development of populace. The expanded populace has prompted the expanded interest of food, bringing about changing horticultural examples which need huge amount of water. Additionally, the varying economy has brought about expanded natural toxins – influencing the nature of freshwater.

Sridhar et al., 2007 in his paper on, "Transforming conveyance of urban administrations in creating nations", guessed that urban foundation draws in firm area, expanding work and encouraging financial development. Open help conveyance in Ludhiana needs changes when decided against national benchmarks. The city's budgetary presentation and its conveyance of urban administrations are substantially less than the national guidelines recommended by different offices. The likely bottlenecks to change in administration conveyance, and the triggers for change in administration conveyance were investigated. A few estimates, for example, the development of populace and land zone, administration conveyance, and its present funds, recommended a requirement for transforming open administrations in this city. The overall decrease in the administration level of water flexibly and sewerage in the city was ascribed to a decrease in its capital uses on these administrations. Further, client charges didn't sufficiently took care of the creation expenses of providing water. The significant bottlenecks to changing open help conveyance in this city were money related and institutional, as they relate to existing plans for water, sewerage and land use. Significant triggers that could cause the change to occur in this city relate to changes in institutional game plans for administration conveyance and public participation.

Worthington et al., 2007 in their working paper on, ―A best in class audit of private water request demonstrating detailed that the expanded dependence on request side administration arrangements as a urban water utilization the board apparatus has invigorated impressive discussion among financial analysts, water utility supervisors, controllers, buyer intrigue gatherings and policymakers. This has cultivated an expanding volume of writing planned for giving best-practice appraisals of cost and pay versatility, measuring the effect of non-value water limitations and checking the effect of non-optional ecological elements influencing private water request. This paper gives a succinct review of experimental private water request examination directed in the last a quarter century. Both model determination and estimation and the results of the examination are talked about.

Wolf et al., 2007 in his paper named, shared waters: struggle and collaboration, inspected the condition of contention and participation over transboundary water assets from a natural, political and human improvement point of view. Despite the fact that the potential for inside and out war between nations over water is low, participation is frequently absent in disagreements regarding transboundary assets. The idea of contention and encounters of collaboration over transboundary assets and a calculated reason for getting participation and the expenses of noncooperation over water are the pushed regions. The paper shows the potential triggers for struggle over water sharing and the suggestions on the jobs of customary networks. It offer proof on the possible expenses of noncooperation or even clash over water assets and investigate power asymmetries between riparian states and they influence the results of exchanges.

Zhuo Chen et al., 2007 distinguished examination of Sydney's reused water plans. Reused water gives a reasonable chance to incompletely enhance new water supplies just as generously reduce ecological burdens. As of now, a great many reused water plans have been effectively led in various nations and Sydney is one of the main urban communities, which has paid incredible exertion in applying water recovery, reusing and reuse.

Bouselly et al., 2006 explored on water considered for urbanization was liable for extended dejection in urban areas and increasingly essential enthusiasm for some value organizations in country. The weight on untamed utilities of water gets enormous that overall can't offer sorts of help of better quality. Urban people persevere through the maximum by virtue of the water lacking deftly as they can't endure the expense of the portions that must be made as adjusting strategies and neither would they have the option to stand to put vitality staying in lines.

Among the different segments answerable for the exposed assistance development the most critical is the small regarding of the water, which disheartens interests in the framework and shields the locales from getting a handle on any water saving plans. Since the Lawmaking bodies are either reluctant or unacceptable to raise loads and improve cost recuperation, the central course of action is permitting private assistance in the domain. Privatization close by improving cost recuperation and drawing in quality and cost enhancements will in like way guarantee a certainly able and careful assistance transport structure. Concerning the conflicts against privatization of the water, the obvious dissatisfaction and reluctance of the poor to pay the charges under the privatized framework both are shown to be extraordinary. The poor do pay and as frequently as conceivable remuneration essentially more per liter than the rich even while they don't eat up as much as the remainders of the majority do. Experience has demonstrated that penniless people would pay higher customer charges in the event that they were guaranteed a certainly decent and incredible deftly. As such we have privatization as the model strategy to counter the unlucky deficiencies of the stream water nimbly structure.

Bhandari et al., 2006 in their investigation on helpless arrangement in India for water: The business visionaries response to counterfeit deficiency saw that the water isn't cautiously an open better than average, in numerous nations the water course of action is the organization's space. It is the circumstance in India as well and has supported the most flawlessly awesome basic resources of water on earth’s surface.

Dwarakanath et al., 2006 explored on the rain water collecting in urban regions along with the effects in Indian urban regions have been going up against extreme water lacks these days. On one side, there is a serious lack of water and on the other side; roads are regularly facing floods at the time of heavy rainfall. This shows incited noteworthy issues related to water table depletion on one side, on the different side there is disintegrating of the ground water. Maximum standard water gathering arrangements in urban networks require being dismissed and decreased to disregard, exacerbating the integrated urban water circumstance. The urban responses for water crisis is water collecting getting an overflow.

Gidey et al., 2006 explored on the dealing with the limited resources: The demand related organization in urban area water administration, noticed to accomplish natural water needs successfully and the fast growing world is transforming into an assessment to water utilities. Older practices have exhibited to water organization which has shown insufficient fulfillment of water needs in urban zones. New water sources are not open way and securing the earth. Fresh sources of water are not accessible.

Additionally, natural limitations, political just as financial real factors have introduced new arranging situations. Water preservation has hence turning into the need of hour. With regards to fulfilling urban water need and guaranteeing proficient and practical utilization of assets, request side administration is engaging as a complimentary arrangement and is as of now being advanced as a fitting amount to guarantee productivity of water use.

Protection of water targets in the districts of urban areas can be cultivated by intrigue way administration practices. Specific assessment target investigates basically water assurance that results the premium side organization strategies. This endeavors to research how much measures being used along with the various challenges and necessities looked at the same time. This examination closes after communicating through administration approach to get water for urban domains in the reasonable manner.

Gupta et al., 2006 examined on measuring the performance of water in the associations for managing water benefits for assessing specialized effectiveness. Urban areas were sorted as per the administration arrangements for the utilities of water. The outcomes proved that the normal specialized effectiveness scorings between these two gatherings were not altogether extraordinary, yet the decay of this all out proficiency showed that the utilities oversaw by Regions in a joint effort with parastatal were generally scale proficient in contrast with the other gathering. Besides, the outcomes additionally have suggestions for urban household water valuing.

Hoffmann et al., 2006 explored on the water request for an enormous region: Instance of Brisbane, Australia stated the private usage that is charged by using an yearly assistance cost with no water capability. Demand of water gets resolved as would be expected four times a year family water usage along with the intrigue qualities consolidate the insignificant water expense. Disclosures not simply approve private water as cost and pay inelastic, yet also that the expense and pay adaptability of enthusiasm for owner included nuclear families is greater than the rented families.

Kumar et al., 2006 explored on rain water restraining, collecting, evaluated the resources of water which are confined and transforming of water into a scant thing because of ever spreading demand corresponding to growing people. By and by it is where the concentration required for assurance of the feature source.

For the protection of resources of water, reaping of rain water from housetop areas must be finished as ground water invigorating is made required in the urban zones. The reasonability for resources of water consumes risk by driving forces of precipitation and disproportionate unforeseen expansion. A perfect progression could be cultivated through conjunctive usage of surface water and ground water.

Khitoliya et al., 2006 examined the water that executives in irregular gracefully announced the 1/6 proportion of all out masses doesn't move toward safe drinking water. A huge segment of this unserved people lives in the urban domains. Quick masses advancement and development from common place regions are more exacerbating the condition by way of driving additional weight on water groups. Head assignment for utilities of water is toward pass on appreciating water required sum and quality to buyers. This assignment includes the need to grasp the specific points of view. The course of action of water effortlessly grasped in a huge bit of the building countries like of alternating nature. As a result of cash related and pay availability confinements it is past the domain of creative mind to hope to work water deftly structures for twenty-hours out of each day. Thus alternating supply through the period of around 8 hours is seen as sufficient to precisely water drinking.

Landge et al., 2006 explored on the solution related to scarcity of water in Narkhed city which point out the drinking water is an essential requirement of the individual. It is only possible through resources of water i.e. by ground and surface water resources opens in conduits or storage tanks. In towns and little networks, the ground water is removed for consumption and for various purposes. Consistent removal of ground water achieves liberal utilization of ground water. Subsequently the need critical is to reestablish the depleted springs by catching surface flood in rainstorm and grant it to pervade to the helpless springs.

Marsalek et al., 2006 investigated International report on Storm water management. A survey of storm water management (SWM) practice in urban areas was directed for IWA and created contributions by 18 nations. The fundamental discoveries of the overview incorporate clear signs of an across the board enthusiasm for storm water administration and of the acknowledgment of a comprehensive way to deal with SWM advancing maintainable urban seepage frameworks (SUDS). Particular ramifications of this logic incorporate accentuation on source controls in SWM, change from customary "hard" frameworks to green foundations, requirements for framework support and restoration, arrangement of storm water offices (inside bigger coordinated water offices) with interest of both open and private areas, and reasonable subsidizing through seepage expenses as opposed to general duties. Further advancement in this field requires focused on innovative work, information sharing, a significant level of open cooperation in arranging, executing and working storm water the executives frameworks.

Nallathiga et al., 2006 estimated on water reforming administration and foundations for refining effectiveness evaluated that the advancement of the urban supply of water section has been moderate by excellence of lacking changes in the urban neighborhood bodies. Point of fact, even immense urban domains like Mumbai are yet to get a handle on changes for improving the gainfulness of water association strategy. Mumbai's future fundamentals of water assets could be met through just if the water precisely structure can be loosened up in a predictable way. Regardless, such a framework has now gone under scanner taking into account a speedy move in water request on one hand and checks in smoothly on the other. In that limit, there has hardly been any complement on 'request the executives' and on improving the effectiveness in domain. No movements have been tried in urban water assets the authorities as the utilities won't see the water inadequacy condition in Mumbai.

Naik et al., 2006 studied on resources of water in Solapur analyzed the urbanization impact and the masses exploding on the framework of ground water in Solapur by unprecedented highlight on the association of the present and remarkable excitement of water in 2020 Advancement. Contamination hazard to the ground water system has besides been broke down. The goal was to assess the city facilitators and administrators of the impacts of urbanization on the ground water structure in a quickly making medium-sized city where the foundation types of progress are not in closeness with the speedy headway in masses. With such immense development, Solapur was a little while later perceived as one of the quickly making urban systems in India.

Oliver et al., 2006 research paper named ―Water levy increment in Manaus (Brazil): An assessment of the effect on families, found that growing square taxes search for a cross-allocation instrument between the water sort out customers, considering the fundamental assumption of low water esteem adaptability. In Manaus a tremendous piece of the 1.5 million inhabitants are given the basic water. The costs were move in 2004-2005 and there was liberal drop in the use instance of the families. This drop watches out for the cross-sponsorship limit of the current structure.

The 31.61 percent commitment increment as a brand name assessment applied to the entire system client individuals of Manaus and has the effect on month to month utilization of metered families, utilizing month-on-month contrasts in 2004-2005.

Rahman et al., 2006 examined on filtering of an elective hotspot for drinking reason; saw that Bangladesh has been experiencing sufficient drinking water emergency. This might be an after effect of the customary corruptions, for example, diminishing cases of stream, extraction of over the top extent of ground water, utilization of pesticides and manures and other anthropogenic exercises. Arsenic in ground water pollution has broadened different clinical issues.

In urban zones, guided water easily is available somewhat in spite of how that is again given to the beneficiaries without being overseen appropriately. As such, individuals need to experience the detestable effects of various water borne messes. However urban individuals has obliged access to the coordinated water deftly, in any case the individuals living in the towns don't have any entry to even that. This issue is even certifiable in the towns, where country poor also as harsh races are living. They need to exclusively rely on neighborhood lakes and in an indirect manner discovered chamber wells.

Sridhar et al., 2006 in their paper named, costs of urban framework: Proof from India's urban areas, brought up that the minimal expenses of giving water supply in a few Indian urban areas are substantially more than the value that is charged from them. A couple of enormous urban communities are under-valuing their water, so shutting the urban areas to movement to families probably won't be the arrangement. They found that the peripheral working expense of giving one kilolitre of water in a few Indian urban areas ran from $0.06 to $0.11 and that numerous urban areas are undercharging their water, in view of minor cost estimates.

Gulyani et al., 2005 experimented on the inadequate water. Considering an outline of 674 families, this paper broke down stream water usage and urban networks attempted for the capacity of the segregated channeled water. The assessment brought into question related to measures of water; address greater prices for it. Examination settled on organization movement decisions which can be improved without appropriate institutional courses of action, specific plans, for instance, water stalls may not win concerning passing on a moderate help of needy individuals.

Howard et al., 2005 experimented on the viable supply of water reconnaissance in the urban regions of creating nations featured the water measure, supply of water that impacts arrangement and broad prosperity. Until this point in time, World Health Organization failed to provide the guidance for the measure of water which is necessary for the worthy prosperity. Considering evaluations of requirements in larger to anticipated temperatures, at any rate 7.5 liters/capita consistently fulfill the necessities of considerable number of individuals. This capacity doesn't speak to prosperity and thriving related solicitations outside normal nearby use, for instance, water use in therapeutic administrations workplaces, food creation, financial development or accommodation use. The central necessity for water consolidates water used for singular arrangement, yet describing a base with restricted vitality as the capacity of water used depends upon receptiveness as chose fundamentally by partition, time and cost.

Amiraly et al., 2004 highlights on Water collecting option in contrast to the supply of urban Indian water determined the shortage of water is a primary element of Indian northern-western conditions. Population consistent increment and budgetary, authoritative and specialized lacks in supply system had prompted the water crumbling in the city of Ahmedabad. The request for water has expanded because of the improvement in the ways of life of the majority. This has brought about a regularly expanding pressure on underground water assets, which has prompted a disturbing exhaustion of springs.

The objective of the investigation to survey how much the customary structure may build up an extra water source inside the Ahmedabad city and the demand of water weight was declined, expecting the flow system supply wasn't accomplishing the customer's prerequisites. The eventual outcomes for this study coordinated in the city, which united assessable and emotional perspectives, offer a perspective toward people's musings and practices with respect to the two methods.

Ramachandraiah et al., 2004 studied on the effect of urban advancement on water bodies: The occurrence of Hyderabad, pronounced that Hyderabad City has been specked with various lakes, which surrounded basic part of its condition. State and private affiliations control, and quick ceaseless suburbia of the city, made tremendous amounts of the water utilities completely broken. Many have been withered while the waters of two or three lakes got polluted with the appearance of untreated private and present day wastewater. The negative aftereffects of the loss of water bodies are felt in the shaky decline in water table and the resultant water crisis in a couple of regions. The truth of flooding that was found in Aug, 2000 was in like way because of a decrease in the passing on limit of lakes and water channels. The state has put forth an attempt not to either execute the current laws or focus on the recommendation of customary relationship in such manner.

Raju et al., 2004 in their paper on abatement in water-A contextual analysis featured 65 % of the nuclear families in Kolar city had diverted water deftly, 68 percent of them had unapproved relationship, thusly preventing the utilities from claiming its salary. The per capita water that is being given to them was just 33% of the urban water deftly norms; in like manner the area is absolutely reliant on groundwater. Nitrate and fluoride substance are past beyond what many would consider possible, which powers families to rely upon private water dealers. By far most of the nuclear families needed to consume $2.30-$12.38 consistently for water consumption, while vast water charge was basically $1.03 / house each month, in this manner putting a phenomenal cash related load on the families.

Sampath et al., 2004 explored on water privatization and suggestions in country stated that because of expanding utilization designs, water is getting scant and this shortage is a developing danger to the total populace. Worldwide utilization of water is multiplying at regular intervals, more than twofold the pace of human masses advancement. At present more than one billion people on earth need access to fresh drinking water.

Consistently 2025 the enthusiasm for freshwater is depended upon to rise to 55 percent above what right now available water can pass on, stream designs persevere. To comprehend the creating water crisis, the game plan that is proposed by World Trade Organization and International Monetary Fund through overall understandings, for instance, General Tariff Agreement and Services is privatization of water. Water privatization will propel insurance. This co-alteration of water has quite recently happened in a couple made countries and is being pushed in many making countries through helper change draws near. The control of water by exclusive organizations expels this advantage from everybody and spots it in private control.

Mathur et al., 2003 in their examination, "Urban water valuing: Making way for changes, surveyed that legitimate expenses are basic to gracefully sufficient drinking water to India's routinely making urban individuals. Water in most Indian urban systems and towns is thought little of, with pounding since quite a while back run suggestions for families who have constrained and low quality water associations and for water giving parts that can't contribute and grow water thought. Most water utilities run at a difficulty, and they spread the disaster from government distributions. The outcome is a low-level congruity: low cost, exposed associations, and necessities on get to, particularly of feeble family units. While the essential for a genuine evaluating of urban water has been for a long time pushed and is generally observed as basic for urban zone changes, what contains water regard change stays a straightforward issue. Also, the goals and focal points of water assessing are once in a while clashing ones. Utilizing city-level encounters of water regarding, especially in regard of the size of the client base, different instruments of charging, regard separation between various water client parties, and worth cost linkages, gives a system that illuminates key regions of progress, objectives that may oversee water evaluating, and cutoff points of tax legitimization.

Narayanamoorthy et al., 2003 examined on the ways to deal with water estimating in urban areas highlighted that water deficiencies in basic urban systems and the dependence on vital limitations have hailed a question mark on the evaluating of urban water associations. Three broad elective ways to deal with oversee charging for urban water associations were proposed. These methods were the current methodologies or old news, need evaluating, and urban client exchanging or a tradable advantage system. These methodology were explored in the light of money related ability, compensation ampleness and adaptability, ease of development and managerial straightforwardness and worth.

Palnisami et al., 2003 in his paper on sustainable organization of tank water framework structure in India kept an eye on that Tank water plan of India are unimaginably old. Most by a wide margin of the tanks have, defiled into open access asset taking into account powerless property relations. Infringements, privatization and government task of the tanks have been the fundamental eventual outcomes of the mix-up of near to situate structure to keep up the institutional strategy under customary property assets the board system.

Whittington et al., 2003 in his paper on, municipal water estimating and tax structure: A change plan for South Asia, noticed that the water taxes being used in many urban communities in South Asia were not achieving their points. They are not producing adequate incomes with the goal that utilities can recoup their monetary expenses. They were not imparting the right monetary signs to families, i.e., that water is scant and should be treated as a product. They were not helping most of the helpless family units, a large number of whom were not associated with the channeled dispersion framework. The changes ought to be made in the South Asia utilities so they can extend buyer base; associations can be metered, evaluating strategies can be executed, arrangements to protect poor families to be set up, water charge computation for family units, business clients and so forth ought to be changed. The master helpless strategies that recommended were to guarantee that helpless family units can have a private water association when they need it, giving open draws from as a water wellspring after all other options have run out for the exceptionally poor, authorizing water selling by neighbors' and it is to be guaranteed that private administrators not the slightest bit abuse the helpless families by charging excess prices.

Chaudhary et al., 2002 concentrated on status of water supply, water sanitation and strong discarded waste administration in urban zones establish that the urban people of country is turning out to be rapidly and is squeezing urban administrations. Urban framework has been not able to keep awake with the creating people. A mind blowing test for Indian urban zones is to make urban territories to give every occupant basic organization. Governments are determined with the assignment of giving these key associations yet they are typically shy of advantages and lacking to release their duties acceptably. So as to comprehend what should be done to improve the game-plan of crucial associations; we have to know the degree of plan of these associations. The goal was to survey the status of water deftly, sanitation and strong waste association in 300 picked urban systems and towns and to check the fundamental of focal points for full consolidation of individuals by these associations in the urban zones of India.

Choudhary et al., 2002 examined on the analysis of groundwater weakness strategies of water in India changes the set up that for a human need the water is a major source, a restricted life emotionally supportive network with vital aspect for thriving. Offhand industrial development, urban development and impact of wastes got ready for the reusing have ominously affected the circumstances of water. Measures must be taken to decide the ground water issues. While ground water resources are all around assessed, over abuse in spite of everything happens regularly. There has been an amazing need completing existing methodologies similarly as developing new laws and techniques.

Kumar et al., 2002 examined the field study for supply of water, water sanitation along with related wellbeing influences in urban area helpless networks revealed the openness for water through audit for inhabitants, vagrants and asphalt tenant networks in Mumbai. This study shows the less usage of water with average of 30 lpcd with zero sewerage and evacuation of excreta workplaces appeared through great occasion related to water borne contaminations. Yearly a lot of cases were surveyed related to diarrhea, typhoid and intestinal ailment for each thousand crowds independently.

Ruet et al., 2002 examined on water and cleanliness situation in Indian metropolitan urban areas. Assets and the board in Delhi, Calcutta, Chennai, Mumbai, justified the urban supply of water and sanitation sector is not on correct path. Confronted with expanding request and growing contamination issues, Indian urban areas can't offer types of assistance to the individuals on the loose. New ventures are required notwithstanding an adjustment in the administration of the water gracefully and sanitation in order to give satisfactory flexibly. This paper looked into the water in urban areas and cleanliness situation in urban communities, for example, the utilization of execution markers of the water organizations to evaluate flexibly proficiency or questions in regards to request examination. The standard highlight was put on the institutional and progressive structure of the pro centers by looking at particular and managerial level of these four urban networks. The improvement of safeguarding based technique and the prerequisite for a logically participative strategy by including the normal society should be the principal need. This would mean an adjustment in standpoint for the water nimbly and sanitation division. Without a doubt, demand side courses of action are every so often thought of and the issue of water smoothly is generally tended to by the deftly point.

Shao et al., 2002 in his examination paper on, water evaluating towards manageability of water assets: A contextual investigation in Beijing, talked about that job of water estimating for overseeing water assets is significant as the approaching shortage of water assets. To improve the supportability of water assets the standard of full cost evaluating in which the expense ought to incorporate flexibly cost, open door cost and externalities was proposed as a way to accomplish the maintainability of water assets.

Low water cost was one explanation behind impractical water utilization in Beijing. In this manner water estimating is fundamental. It was proposed to force water cost in staged way and in the long run towards full cost estimating. The evaluation of effects on water assets by raising water value shows water estimating could wipe out the contention between water supply and request.

Whittington et al., 2002 concentrate on smart water: A similar investigation of urban water use over the Southwest, brought up that low-thickness improvement and wasteful urban scene configuration can bring about inefficient water use, basically because of relatively a lot of water utilized for open air scene water system. With urban populaces proceeding to develop all through the Southwest and water supply staying limited, cautious urban arranging is turning out to be increasingly basic. Despite the fact that per capita water utilization and even per capita land territory improvement are diminishing in some urban regions, the general impact of populace development on spread and completes water utilization proceeds. In any case, regardless of whether populace development proceeds in the Southwest, we have a decision about how we build up our urban scenes. Urban structure methodologies, including infill advancement and higher-thickness blended use improvement, help boost water productivity. Consolidating other water effectiveness measures into such advancements increases the potential water reserve funds. Advancements that join plan methodologies comparative to that of the Civano improvement in Tucson show how savvy improvement can yield critical water savings.

Zerah et al., 2002 in his exploration paper on, water flexibly and sanitation in Vijayawada: Examination of families' circumstance towards modes and cost of access, utilization and level of satisfaction‖, brought up that in his investigation in Vijayawada that 77 percent of the families believed water to be modest or modest. If there should be an occurrence of associations or month to month charges the families' eagerness to pay was multiple and an a large portion of the normal, in this way affirming for the manageability of water charges as a methods for financing interest around there.

This study aims to make a comprehensive analysis of recycled water schemes in Sydney for a wide range of end uses such as landscape irrigation, industrial process uses and residential uses (e.g. golf course irrigation, industrial cooling water reuse, toilet flushing and clothes washing etc.). For each representative recycled water scheme, this study investigates the involved wastewater treatment technologies, the effluent water quality compared with specified guideline values and public attitudes towards different end uses.

Based on these obtained data, multi criteria analysis (MCA) in terms of risk, cost-benefit, environmental and social aspects can be performed. Consequently, from the analytical results, the good prospects of further expansion and exploration of current and new end uses were identified towards the integrated water planning and management. The analyses could also help decision makers in making a sound judgment for future recycled water projects.

Ramachandriah et al., 2001 studied on utilization of water as a basic right highlighted the advancing accomplishment judgment by the Unique Court, setting acknowledging water the quick overview of essential rights. The assessment underscores that the worry of the legitimate authority should fill in as a remorseless notice to the organization official government representatives nexus that have, beginning late, chose not to see the making debasement in Indian streams. The court furthermore has reinforced individuals, and has helped in starting a discussion on a colossal issue that has genuine repercussions for the proceeded with thriving and prospering of most occupants.

Boland et al., 2000 explored on the design of water tariff in evolving countries indicated the expanding of tariff blocks which were broadly utilized in the creating scene, demoralize inefficient utilization of water, support cost-effective efficiency and security access for sufficient water for the fundamental sanitation. Truth be told, these cases are mistaken. Practically speaking, tariff blocks are probably going to advance wastefulness, imbalance, shamefulness, net income unsteadiness, and other negative outcomes. An elective levy structure, a uniform price with rebate (UPR), was introduced.

This paper recommends reasonable markers for the proposed criteria. It additionally contains a concise examination of the commitment to different natural impacts and asset usage of the Swedish urban water framework in connection to the effect of Swedish society altogether, to take into account a right prioritization of the criteria.

Daniel Hellstrom et al., 2000 inspected a structure for systems examination of supportable urban water the executives. The growing enthusiasm for financial progression will significantly influence wide scope of urban establishments. In any case, there is a nonappearance of learning of how acceptable improvement should be accomplished and how practicality of various particular structures should be overviewed. This paper depicts the structure of a systems examination adventure dealing with the above issues, which focuses on urban water and wastewater systems. The errand is a bit of generous national examination program in Sweden entitled "Maintainable Urban Water Administration."

Fox et al., 2000 explored on the augmentation and development of open administrations is a major for the improvement of the individual fulfillment in addition to effectiveness. A research was made which shows a part including African nations must be resolved in stretching out system critical to offer open kinds of help, yet unfortunately, a great movement of paying for it. This relevant water investigation gracefully benefits and underscores the importance of customer concerns for allowing development of water consideration adaptation benefits.

Bathla et al., 1999 examined on the resources of water potential in the North India: Limitations in addition to examination of cost with non-value arrangements, analyzed the water linkages, reliable masses advancement and monetary turn of events. The resulting water table fall could provoke necessities in water usage. This shows strong discomfort proposals for the use of resources. The mixture of intercessions reliant on esteem courses of action, non-esteem game plans and institutional set up are conclusive in bringing a practical turn of events and use of asset.

Franceys et al., 1999 explored the government role in amending economies built the data from India signifies the Indian populace probably not going to significantly affect conveyance of public services, for example, supply of water, on account of personal stakes inside the current institutional examples.

Molden et al., 1997 estimated on the water accounting for the use and profitability noticed that with restricted resources of water, there is an urgent need worldwide to oversee water assets. All water resources are dispersed to different organizations. Notable philosophy for making sure about increasingly imperative profit while improving the earth must be figured. Wastes and non-advantageous utilizations must be carefully investigated to see likely hold saves. To achieve these undertakings, improved frameworks to address water assets use and capability are required.

Perry et al., 1997 in their exploration report on water as a financial decent: An answer, or an issue? Confirmed that there are irregularities on thought of viewing water as a monetary average. Nevertheless, the activity of water—as a basic need, authenticity better than average, and a social, fiscal, budgetary, and common resource—makes the assurance of a reasonable course of action of costs irksome. The use of cost put together instruments is particularly problematic with respect to record of water. This is so considering the way that the movement of water through a bowl is awesome, and gives wide degree to externalities, feature frustration, and high trade costs. In the occasion that showcase mechanical assemblies were applied shrewdly they can without a doubt carry profits. Suitable expenses can provide noteworthy yields.

Saleth et al., 1997 in their specialized paper named, ―Satisfying urban thirst: Water gracefully increase and evaluating strategy in India justified that water shortfall in the urban areas could meet by deftly broadening by tapping far away and distinctive use water sources every now and again agitates winning sectoral part and causes between sectoral water conflicts. To decide these disputes grandstand based approach to manage between sectoral water assignment can be made in uneconomic rate structure and unpreventable use inefficiency and wastage in the urban water portion, between sectoral water moves are most likely going to cover inefficiency, hurt inspiration structure, and hose the tendency to explore deftly increment decisions. Utilizing fundamental and discretionary information identifying with the water portion of Hyderabad city, India, methodology changes and institutional conditions essential to ensure the money related sensibility of market-based response for between sectoral dissemination issues in a urban setting. Outer just as inner, organized and unstructured gracefully increase alternatives ought to be applied in order to overcome any issues among request and flexibly parts.

Belinda Hatt et al., 1996 examined on coordinated storm water Treatment and Re-use Structures - Load of Australian Practice. Recently indications of biological degradation, showing up through declining nature of ground water and surface water have been found in different bits of Australia. For instance, the conduits of the Murray Dear Bowl and Hawkesbury-Nepean Bowl have incapacitated to some degree by ideals of urban water requests and sullied whirlwind water releases [Anderson, 1996]. The utilization of water assets in different bits of Australia is drawing closer, and in some urban focuses outflanking, the cutoff motivations behind feasibility. Better arranged organization of urban water (flexibly, wastewater and storm water) is required if the water needs of the customary masses are to be fulfilled without assistance decay of nature.

M.I. Lvovich et al., 1973 researched water balance study which characterized the salary of water from precipitation and different sources and the misfortune or out progression of water by methods for Evapo-transpiration which speaks to the consolidated loss of water from the earth by methods for dissipation and transpiration just as from different sources. The idea of water balance has as of late increased extensive significance among the climatologists, Meteorologists, Geographers, Geologists, Hydrologists and from different controls concerned principally with water issues.

The above given review of literature shows that although a large number of studies on Integrated Urban Water Management (IUWM) have been conducted by various researchers, organizations and the institutions, yet these studies are fragmented, disorganized and by and large address one or two special aspects of the urban domestic water supply. A comprehensive study taking into account all the issues related to urban water management of a particular city was conspicuous by its absence. More importantly there is a dearth of studies on integrated urban water management situation in Chandigarh. This study will be an effort in this direction and will be able to fill this research gap.

2.2 Estimating Groundwater Balance Components

The issues identified with groundwater the management are clear; however the arrangements are most certainly not. An expanding accentuation is laid on the most proficient method to oversee ground and surface water in a practical way [Downing et al., 1998].

a. **Groundwater Recharge:** A significant hindrance to discovering arrangements is the absence of quantitative comprehension of the association among surface and groundwater. It is commonly acknowledged that the communication of atmosphere, geography, morphology, soil condition and vegetation decide to differing degrees the revive procedure to fluctuating degrees [Stews et al., 2002]. Groundwater recharge in semiarid areas is more susceptible to near surface conditions as compared to humid areas; the potential evaporation is higher than the rainfall making recharge dependent on rainfall. However, more subtle considerations may affect the recharge process. Defining direct groundwater recharge as the downward flow of water to the saturated zone creates conceptual problems regarding the recharge processes [Stews et al., 2002]. Just as the net precipitation arriving at the ground is diminished by capture attempt not all permeating water may not really arrive at the water table. Permeation might be hampered by low vertical conductivity skylines bringing about sidelong stream to close by miseries [Stews et al., 2002].

b. **Groundwater Extractions:** Direct vanishing and transpiration from the immersed zone additionally brings about decrease of complete revive to spring [Stews et al., 2002]. Despite the fact that these connections control the conduct of groundwater stream frameworks, energize to the spring and ensuing man-incited groundwater extractions are unsure, which are reflected in the quantitative depiction of association among surface and groundwater system change. Explaining this inquiry requires a total comprehension of the hydrological forms at the land surface according to the aquifers.

c. **Groundwater Balance:** Noteworthy exploration efforts have tended to the estimation of different parts of groundwater balance. In these examinations, a few methodologies, for example, physical, synthetic and numerical displaying procedures have been created by [Stews et al., 2002]. These can be gathered into five classes: observational strategies, direct estimations, tracer procedures, Darcian approaches, and water balance techniques [Stews et al., 2002].

d. **Strategies:** The decision and utilization of strategies rely upon numerous variables. It is frequently revealed that in parched and semiarid districts, groundwater energize is heterogeneous in both existence [Stews et al., 2002].

e. **Quantification and Prediction:** Stews et al., 2002 reported that "no single comprehensive estimation technique can yet be identified from the spectrum of methods available; all are reported to give questionable results". Therefore, for reliable quantification and prediction of spatially distributed recharge, it is recommended to use more than one method. This is a tedious task for most of the arid and semiarid regions because of wide spatial and temporal variations and scarce hydro-geological information. Groundwater use estimates in large irrigated schemes are often based on the number of tube wells, their discharge capacity and their operational hours [Stews et al., 2002]. The operational hours are determined from power/fuel use or through studies in that water systems plot. Such estimates just give a scope of groundwater extraction esteems and don't represent groundwater reusing.

f. **Hydrological Forms:** Late advances in distant detecting procedures make it conceivable to evaluate different hydrological boundaries with expanding precision, particularly in the fields of flooded zone and genuine evapotranspiration planning. Distantly detected data on these boundaries upgrades our comprehension of the hydrologic cycle [Stews et al., 2002]. A creative road is to incorporate Remote Sensing (RS), Geographical Information System (GIS), geo-insights and particular ground information. This geo-data can help in depicting the spatial variety in hydrological forms, outstandingly the water motions at the land climate interface, groundwater utilize and revive in an information scant condition. Energize estimation is a significant and crucial exploration in the current day world because of colossal weight on groundwater assets.

g. **Water Table Fluctuation:** Groundwater recharge from water stockpiling structures under semiarid states of western India has been evaluated by utilizing water table fluctuation (WTF) and chloride mass balance (CMB) methods. Groundwater recharge was evaluated as 7.3% and 9.7% of the yearly precipitation by WTF technique for the years 2003 and 2004, individually while the two years normal revive was assessed as 7.5% utilizing CMB strategy [Stews et al., 2002]. Water table variance strategies are utilized in registering energize as the technique is straightforward and suppositions are less.

h. **Frameworks:** The WTF technique is best applied to frameworks with shallow water tables that show sharp ascents and decreases. Stews et al., 2002 have utilized twofold WTF strategy to process energize in Maheshwaram watershed of A.P. The examination exhibits that DWTF is a proficient revive estimation technique however the precision of this strategy relies upon the representativeness of the piezometric information of the territory from which the water table vacillations are determined. In this way, the estimation thickness is of most extreme significant. An extremely high estimation thickness will build the time and cost of field estimation and then again, a low estimation thickness can bring about losing indispensable data. [Stews et al., 2002] have revealed a decay of 5-6 meters in water level of Maheshwaram watershed of Rangareddy locale of A.P from 2000 to 2005.

i. **Evaluation of groundwater recharge:** A few examinations have demonstrated that sensible provincial groundwater recharge appraisals can be acquired utilizing promptly accessible field information without thinking about little scope neighborhood varieties. Techniques utilized incorporate isotope dating chloride mass equalization calculation and mixing cell modeling Darcian flow modeling and direct measurement of stream and spring release [Stews et al., 2002]. Evaluating the flow pace of groundwater recharge is a fundamental essential for productive groundwater asset the executives and is for all intents and purposes crucial in parched and semiarid districts where such assets are frequently the way to monetary turn of events [Stews et al., 2002].

j. Methods to Evaluate Recharge: Stews et al., 2002 demonstrate that the methodology to evaluate recharge from different sources incorporate direct estimations, water balance strategies, tracer procedures and experimental techniques. Various techniques were utilized to assess groundwater revive in semiarid climatic conditions in India [Sridhar et al., 2006]. As a component of the investigation, water table change and chloride mass equalization strategies were applied. The water table change depends on the rule that the ascent in groundwater level in any spring is corresponding to the water coming to the water table.

k. Difficulties in the Estimation of Groundwater Recharge: Stews et al., 2002 distinguishes a few difficulties in the estimation of groundwater recharge and the need to completely comprehend the brief and spatial variation of recharge, advancement of different strategies to assess recharge from point estimations and completely unraveling the effect of land use especially in urban improvements on groundwater recharge. The water assets the executives challenge is in any case, to discover savvy, basic and fast appraisal strategies for assessing recharge.

2.3 Direct Methods

a. Direct Measurements: Direct measurements with lysimeters containing undisturbed soil profiles are potentially the most accurate method for estimating recharge and evapotranspiration. The main problem with this method is that it is difficult, time consuming and expensive to set-up [Gadgil et al., 1998].

b. Outcomes: The outcomes speak to point scale data and their application is constrained to test examines. They are more appropriate for moist atmospheres than for parched to semiarid atmospheres. Since the recharge procedure is fast in humid areas, information gathered over a brief timeframe period are adequate to get total knowledge into the recharge procedure.

c. Water Balance Components: Bradon et al., 1995 noted that lysimeter results indicate an apparent annual threshold value of rainfall below which no recharge takes place. A lysimeter is a device, consisting of an in situ weighable column or volume of soil for which the inflow and outflow water can be measured and changes in storage can be monitored by weighing. These techniques used to determine evaporation in a natural environment by measuring the other water balance components, but as is mentioned above measuring recharge using this technique at reasonable spatial scale is difficult.

2.4 Empirical Methods

a. **Empirical methods:** These methods are often used in a data scarce environment. Empirical methods seek to correlate recharge with other measurable hydrological data such as rainfall and surface flow through the use of mathematical formulae and equations [Singh et al., 2005]. The advantage of such approaches is that they can be transposed in time and space and render themselves practically useful for preliminary recharge estimates.

b. **Disadvantage:** Their main disadvantage is that they are site specific and derived from other methods of recharge estimation. As such they can only be as accurate as the methods from which they are derived. Secondly, since they are not physically based they can be rendered obsolete by changes in catchment physiology, if not reviewed periodically. Despite this setback, many researchers consider them of valuable importance in estimating recharge for water resources management purposes particularly in areas of data scarcity and limited technical and financial resources.

c. **Hybrid Method:** An improvement to the empirical methods can be termed the ‘hybrid method’. In this approach combining physically based techniques with empirical methods reduces somewhat the shortcomings of the latter. Such an approach combines the influence of climate, geology, terrain geometry and land cover on recharge into a single estimate.

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2.5 Water Balance Methods

Water balance strategies are pertinent for both point and basin scale estimates. They have three classifications: soil water balance, waterway channel water balance and groundwater (soaked zone) balance [Nadhamuni et al., 2012]. The significant bit of leeway of water balance strategies are that they utilize promptly accessible information, can be applied quickly and record for all water entering and leaving the framework. In any case, the significant disservice of these techniques is that energize is the leftover term, so their precision relies on the exactness of the various water balance terms. In the event that these groundwater balance strategies incorporate some spatial averaging, the level of averaging is typically indistinct and relies on the thickness of perception focuses. Their application is restricted to information scant situations in semiarid districts.

The premise of the dirt dampness balance technique for assessing energize is that the dirt turns out to be free depleting when the dampness substance of the dirt arrives at a constraining worth called the field limit. To decide when the dirt arrives at this basic condition, it is important to reproduce soil dampness conditions consistently. This includes the portrayal of the significant properties of the dirt and the limit of harvests to gather dampness from the dirt and to come to pass water to the climate. On the off chance that no yields are developing or if there is just fractional harvest spread, exposed soil dissipation must be thought of. Exposed soil vanishing is significant both in semiarid areas to speak to soil dampness conditions toward the finish of the dry season and in calm atmospheres where energize happens in winter when dissipation is normally the significant misfortune from the dirt. Transpiration and dissipation frequently happen at not exactly their likely rate because of yield pressure emerging from restricted soil dampness accessibility. The contribution to the water balance is penetration which rises to the everyday precipitation less interference or overflow. The recharge (R_e) for water balance is frequently composed as:

$$\boldsymbol{R_e = P_r + Q_r + ET + W_s} \qquad \textbf{(2. 1)}$$

Where; R_e is recharge, P_r is precipitation, Q_r is net runoff, ET is actual evapotranspiration and W_s is the change in soil moisture storage.

2.6 Hydrological Models

Various kinds of models are accessible for deciding recharge: one-dimensional semi-conveyed numerical models, for example, SWAP, one-dimensional lumped parametric models, for example, EARTH and three-dimensional completely appropriated numerical groundwater stream models, for example, MODFLOW. The benefit of the hydrological models is that the effect of moving water between contending areas can be recreated and the impacts of man-incited situations on local hydrology can be anticipated. The disadvantage however is that significant aptitude in model utilize and broad field information are required to make legitimate model reenactments at local scale achievable.

The unsaturated zone truly based numerical models, for example, SWAP unravel the unsaturated zone water stream condition for example the Richards condition for permeable media. As opposed to the lumped parametric water balance models, numerical models permit definite assessment of the consequences for groundwater energize of vadose zone pressure driven properties and their spatial fluctuation. These techniques depend on soil profile dividing with various homogeneous layers with their own trademark pressure driven properties. They recreate the change of precipitation into stream considering all the halfway procedures, for example, evapotranspiration, block attempt, invasion and spillover. They are hence ready to evaluate energize at numerous focuses and at commonly. For recreating recharge, limit and starting conditions must be forced on the models along with water powered soil properties and vegetation properties [Baumann et al., 1998].

Parametric models, for example, EARTH utilize a numerical or explanatory connection among precipitation and recharge. These models have been created to manage theoretical recharge circumstances that can't be enveloped by existing numerical models. Models are recharge through hard rock development. A few scientists have utilized both the SWAP and EARTH models to anticipate groundwater vacillations in the Veluwe region which is portrayed by permeable media, and the two models could depict the profound groundwater level variance very well. Hence the parametric models, for example, Earth can be utilized both in permeable and hard rock arrangements.

2.7 Tracer Methods

Tracer procedures are among the most generally utilized strategies for recharge estimation in dry and semiarid areas. They as well, just give point or field scale data. There are three sorts of tracers. Nonetheless, the most normally utilized in this field are the natural tracers. These are broken down substances brought into the huge scope water cycle either essentially or by man over extensive stretches of time. They can follow water development over significant stretches rather than falsely applied tracers which show water development over little spatial and transitory scales. The most significant tracer is chloride. Moderate tracers like chloride are the standard in many examinations. In spite of the fact that advantageous and at times the main accessible strategy for dry zones, tracer strategies endure the debilitation of mass twists from auxiliary sources of info and blending or potentially double stream instruments [Baumann et al., 1998]. Baumann et al., 1998 upheld that tracer techniques are more fruitful recharge estimation strategies than the roundabout physical strategies since they are easy to utilize, moderately modest and all around applicable. Be that as it may, Baumann alert that fume transport especially for tritium profiling, can influence the outcomes for energize gauges under 20 mm for each year.

Baumann et al., 1998 further cautions that in addition to the fact that it is hard to decide the barometrical testimony of chloride the statement has significant worldly and areal changeability. In spite of these inadequacies tracer strategies remain the most broadly utilized for a wide range of groundwater recharge gauges in semiarid zones. To lessen the room for give and take in estimation the pattern has been to utilize techniques in mix either as various tracer strategies or as tracer and some physical strategy. In Indian situation a direct connection among precipitation and characteristic recharge exists for all the four significant hydrogeological units stones, basalt, residue (for the most part sandstone) and alluvium. Tritium based revive estimation has been applied to gauge recharge in Kongal stream bowl of Nalgonda locale, A.P. The figured normal recharge was evaluated to be 5% of yearly precipitation [Chaudhary et al., 2002].

2.8 Darcian Approach

The Darcian approach dissects the water fluctuations in the unsaturated zone. The data from this strategy is legitimate just for field scale studies, despite the fact that it is regularly utilized for atmosphere examines [Stewart et al., 2006]. The advantage of this technique is an endeavor to distinguish the real physical procedures of water stream in the unsaturated zone. The use of Darcian strategies to the unsaturated zone has been hampered by the dependence on soil boundaries like the unsaturated water driven conductivity which are hard to decide. Stewart et al., 2006 created improved techniques dependent on soil information to counter this issue. Endeavors have additionally been made to evaluate groundwater recharge as an element of soil temperature changes in the unsaturated zone [Stewart et al., 2006].

2.9 Remote Sensing Applications

Exact estimation of groundwater balance segments is troublesome and needs a multi-procedure approach. Assessing the pace of aquifer renewal is the most troublesome of all measures in the assessment of ground water assets. Various models utilizing far off detecting and GIS have been utilized to ascertain recharge all inclusive [Ray et al., 2007]. Remote sensing detecting based recharge estimation has been effectively exhibited in west bank locality of Palestine with ET, TRMM precipitation and spillover as information boundaries. Month to month recharge estimation is determined by applying a basic water balance where month to month evapotranspiration got from SEBAL and runoff is deducted from the month to month precipitation [Ray et al., 2007].

The estimation of groundwater recharge requires demonstrating the entirety of the significant procedures in the hydrological cycle, for example, invasion, surface runoff, evapotranspiration and groundwater level varieties. The impact of land use has been researched utilizing 'at point' Cl profiles at various occasions for a similar point [Wolf et al., 2007]. Correlative plot size examinations have been directed to research the little scope variety in revive. Ongoing investigations have investigated the utilization of field estimations, distant detecting information and geostatistics. Wolf et al., 2007 joined relapse investigation of field information with GIS overlays to decide provincial revive while [Ray et al., 2007] related energize to soil type, precipitation and land use information by joining field information with an everyday water balance. Wolf et al., 2007 demonstrated that revive territories can be recognized over a 2000 mm^2 district utilizing aerial photographs and Landsat images.

2.10 Precipitation Measurements Using Satellite Data

Precipitation is a key variable in the hydrological cycle, paying little heed to the atmosphere of area. In semiarid districts precipitation events are of brief length and high power and frequently described by an enormous level of spatial heterogeneity [Pangare et al., 2006]. These qualities are much increasingly articulated in locales with geographical unpredictability, for example, mountain ranges. Notwithstanding the low thickness of downpour checks in semiarid locales, the spatial evaluations of precipitation are typically registered from point estimations utilizing entrenched spatial addition strategies, for example, thiessen polygons or kriging. Satellite based innovations can possibly give improved precipitation assessments to huge regions of the reality where rain gauge check perceptions are constrained.

A few investigations have utilized TRMM (Tropical Rainfall Measuring Mission) information to evaluate precipitation and other rainfall [Pangare et al., 2006]. An ongoing report was completed in the Sinai Peninsula that utilized TRMM 3B42 three hour information (0.25°×0.25°) to remove, distinguish and check precipitation occasions all through the most recent ten years [Montogomery et al., 2007]. A correspondence of R_2 = 0.92 is assessed between precipitation got from TRMM and an eight downpour measure informational collection. TRMM sensor tends to misidentify precipitation, giving a bogus sign for light precipitation (<0.5 mm hr-1) [Montogomer et al., 2002].

Since TRMM estimations are gained at regular intervals, short occasions beginning and closure in the middle of two back to back TRMM acquisitions can go undetected [Montogomer et al., 2002]. Correlations directed by Chiu et al., 2006 on TRMM recoveries with downpour check rates over New Mexico show high inclination for just satellite calculations. Combined satellite-measure items, for example, the 3B43 are seen as better related with check information [Montogomer et al., 2002]. Chiu et al., 2006 have approved TRMM (3B43) and Precipitation Radar (PR) with the GPCC worldwide precipitation over the major climatic areas of Africa. Significant seasonal and local contrasts have been watched and a conclusion is drawn showing that the best understandings are accomplished with TRMM (3B43) information. Various endeavors have been made by different specialists to utilize TRMM informational collections related to IMD information to examine precipitation situation of the India. TRMM informational collections when converged with IMD information will give an extremely exact estimation of storm precipitation. Anyway more ground approval locales over the Indian area (land and ocean) will be helpful in understanding Indian rainstorm design [Montogomer et al., 2002]. For portraying enormous scope day by day precipitation design consolidated TRMM and downpour check datasets might be sensible asset [Montogomer et al., 2002]. Nair, 2009 looked at orographic precipitation assessed by TRMM 3B42.v6 satellite every day item and IMD precipitation information over Maharashtra state. In view of their exploration, TRMM estimations are predictable on occasional, month to month and day by day scales however orographic overwhelming precipitation is unacceptably caught by TRMM over particular investigation districts.

It is additionally finished up by [Montogomer et al., 2002] that in every day precipitation informational collections the lower precipitation is overestimated and higher precipitation is thought little of by satellite however relationship among's TRMM and IMD precipitation at month to month and occasional scale is worthy. The elaborative investigation of day by day and occasional changeability of Indian summer storm over Indian locale utilizing TRMM, GPCP and IMD precipitation information. They watched high summer rainstorm downpour over WG and Himalayan lower regions is caught well by TRMM information.

Despite the fact that TRMM portrays right period of intra occasional varieties precisely with that of IMD, it underestimates means of season inconstancy in precipitation over Indian district. The huge standard deviation (SD) in occasional precipitation amount noted by IMD every day downpour records from year 1998 to 2003 is well caught by TRMM day by day by precipitation information.

Montogomer et al., 2002 watched the connection among IMD and TRMM over west coast and saw that over this district, the regional mean precipitation is 7.4 mm every day recorded by IMD information while it is 6.4 mm every day by TRMM 3B42 and SD from IMD record is (13.8 mm every day) while SD from TRMM 3B42 is 13.5 mm every day for a long time (1998-2003). Consequently, as indicated by Montogomer et al., 2002, TRMM precipitation gauges are sensible enough to be utilized for synoptic and longer time scale examination of Indian summer storm precipitation.

2.11 Runoff Measurements Using GIS

Modeling of rainfall-runoff is a significant examination that can be used for arranging and for the management of water resources. In the vast majority of dry and semiarid districts specifically, where there is lack of hydro-climatological information and long term records are practically missing this research is much increasingly significant. Likewise, future expectations with various situations as far as changes in atmosphere just as condition can be embraced by modeling of rainfall-runoff.

Precipitation runoff connections have been one of the focal subjects of hydrological research for a long time [Stews et al., 2002]. Runoff demonstrating is considered as a huge part of hydrological displaying tree and a mainstream implies in evaluating flood hydrograph and watershed yields. The elements of this unpredictable procedure comprise one of the most significant and testing issues in hydrology [Stews et al., 2002]. The reaction of hydrological frameworks can be anticipated by recreation models.

Recently GIS based surface runoff modeling studies by several workers, Stews et al., 2002 have tried to address complex environmental and water resources problems by calculating runoff. Stews et al., 2002 used GIS based model Arc-SWAT to measure the runoff effectively in a granitic terrain of Andhra Pradesh, India.

Remote sensing integration and GIS methods gives solid, exact and forward-thinking data on land and resources of water, which is an essential with the end goal of multi-rules dynamic, site appropriateness examination for water collecting structures [Ramachandra et al., 2015]. Stews et al., 2002 utilized Arc-Info and various topical guides, for example, soil, waste, land use, geological form map, lineament, crack direction and example guide of a territory chose from IRS-1A symbolism for choosing check dam locales as per reasonableness, positioning, thinking about specific rules for assessing spillover. A few strategies are accessible for estimation of overflow, among them the USDA soil protection administration bend number (SCS-CN) strategy is the most well-known and broadly utilized. This model is basic and compelling for little rural and urban watersheds for management of water resources.

The advantage of this strategy is its effortlessness, consistency, stability and its dependence on just a single boundary in particular the curve number (CN). This technique is internationally applied in ungauged watersheds to assess overflow. The land use/land spread classes can be incorporated with the hydrologic soil gatherings of the sub bowl/watershed in GIS. The fundamental data sources required to the SCS-CN technique are depiction of the watershed limit, arrangement of soil map, readiness of land use/land spread topical guide and predecessor dampness condition to evaluate every day runoff. Ramachandra et al., 2015 have utilized NRCS bend number strategy in IDRISI GIS programming to evaluate overflow in three ungauged farming watersheds of Karim Nagar area, Andhra Pradesh.

Before evaluating overflow for a storm event, the curve numbers must be balanced dependent on the season and complete 5-day predecessor precipitation. The bend numbers for AMC II condition for hydrologic soil spread buildings and bend number alterations for forerunner soil dampness conditions AMC I and AMC III are looked over the data introduced in [USDA-NRCS, 1972] and other existing writing like [Burton et al., 2002].

The significant boundaries that impact spillover are land use, soil type, precipitation and soil dampness conditions. Every one of these boundaries can be successfully estimated by far off detecting either as immediate estimations practically identical to conventional structures, as proxies of customary structures, or as altogether new informational index [Ramachandra et al., 2015].

The pixel configuration of advanced distant detecting information makes it appropriate to blend it with geographic information system (GIS). The greater part of the past work on overflow demonstrating has included the natural resources conservation service (NRCS) spillover curve number (CN) model [USDA, 1972]. Burton et al., 2002 utilized Landsat information to build up a bowl wide overflow file and effectively showed how distantly detected information can be utilized to follow the adjustments in runoff that happen in a basin because of change in land use.

Antecedent moisture condition (AMC) has a significant effect on runoff. Considering this aspect, the soil conservation service (SCS) developed three AMC conditions such as AMC I, AMC II and AMC III. Prior to estimating runoff for a storm event, the curve numbers should be adjusted based on the season and total 5-day antecedent precipitation. The curve numbers for AMC II condition for hydrologic soil cover complexes and curve number adjustments for antecedent soil moisture conditions AMC I & AMC III are chosen from the information presented in [USDA-NRCS, 1972] and other existing literature like [Burton et al., 2002].

The important parameters that influence runoff are land use, soil type, rainfall and soil moisture conditions. All these parameters can be effectively measured by remote sensing either as direct measurements comparable to traditional forms, as surrogates of traditional forms, or as entirely new data set [Burton et al., 2002]. The pixel format of digital remote sensing data makes it suitable to merge it with geographic information system (GIS). Most of the previous work on runoff modeling has involved the natural resources conservation service (NRCS) runoff curve number (CN) model [USDA, 1972]. Burton et al., 2002 used Landsat data to develop a basin wide runoff index and successfully demonstrated how remotely sensed data can be used to track the changes in runoff that occur in a basin due to land use change.

2.12 Integrated Urban Water Management

The literature writing demonstrated that incentives for recycled water use incorporate urbanization pressures on sources of water supply, decreasing resources of natural water, and progressively wastewater release guidelines. Recycled water is required particularly in dry areas and recycled water extends that target of water users are probably going to be progressively feasible.

Following paragraphs spread the scope of issues required to survey the exhibition of double frameworks including: water quality and general public wellbeing by distribution double water; involvement in water reuse frameworks; dispersion framework resource; and financial aspects and institutional arrangements by action of double appropriation frameworks. M.I. Lvovich et al. 1973 investigated water balance study which defined the income of water from precipitation and other sources and the loss or out flow of water by means of evapotranspiration which represents the combined loss of water from the earth by means of evaporation and transpiration as well as from other sources.

The concept of water balance has recently gained considerable importance among the climatologists, Meteorologists, Geographers, Geologists, Hydrologists and from other disciplines concerned primarily with water problems. Belinda Hatt et al., 1996 explores on Integrated Storm water Treatment and Re-utilize Frameworks - Stock of Australian Practice. Lately indications of environmental degradation, showing through declining nature of surface and ground water, have been seen in numerous parts of Australia. For instance, the waterways of the Murray Darling Basin and Hawkesbury-Nepean Bowl have weakened to some extent on account of urban water requests and polluted storm water releases.

The utilization of water assets in numerous parts of Australia is drawing closer, and in some urban focuses surpassing, the cutoff points of maintainability. Better coordinated management of urban water (supply, wastewater and storm water) is required if the water needs of the normal populace are to be fulfilled without assist decay of nature. Marsalek et al., 2006 investigated International report on Storm water management. A survey conducted internationally for urban storm water management (SWM) practices for IWA and made contributions from the 18 countries. Fundamental discoveries of the overview incorporate clear signs of an across the board enthusiasm for storm water administration and of the acknowledgment of a comprehensive way to deal with SWM advancing maintainable urban seepage frameworks (SUDS).

Particular ramifications of this logic incorporate accentuation in SWM for source controls, change by expected best frameworks to green foundations, framework support requirements and restoration, arrangement of storm water offices (inside bigger coordinated water offices) with interest of both open and private areas, and reasonable subsidizing through seepage expenses as opposed to general duties. This field requires further progress in targeted study and growth, sharing of knowledge, public participation at high level in implementing, planning and working of storm water system management. Fletcher et al., 2007 explored storm water harvesting gainful to urban conduit environmental flows. Urbanization debases the hydrology and water nature of conduits. Changes to stream administrations incorporate expanded recurrence of surface spillover, expanded pinnacle streams and an expansion in all out overflow.

In the meantime, water use in numerous urban communities is drawing closer, and now and again surpassing, maintainable breaking points. Storm water obtaining can possibly alleviate some of these unfavorable effects. The outcomes demonstrate that utilizing these run of the mill collecting situations brought stream and water quality back towards their pre- created levels. Now and again, in any case, reaping brought about an over-extraction of stream, exhibiting the requirement for advancing the gathering procedure to meet both supply and natural stream destinations. The outcomes demonstrate that urban storm water reaping is a potential system for accomplishing both water preservation and natural streams. Zhuo CHEN et al., 2007 identified recycled water scheme analysis of Sydney. Reused water gives a feasible chance to halfway enhancement new water supplies just as significantly mitigate ecological burdens.

At present, a huge number of reused water plans have been effectively led in various nations and Sydney is one of the main urban communities, which has paid incredible exertion in applying water recovery, recycling and reuse. This investigation intends to make an extensive examination of reused water plans in Sydney for a wide scope of end uses, for example, water system, mechanical procedure utilizes and private uses (for example fairway water system, industrial cooling water reuse, flushing toilets and garments washing etc.).

For every reused water structure, this examination explores the included wastewater treatment advancements; the treated water quality contrasted and determined rule esteems and attitude of public for various end uses. In view of this information, multi criteria analysis (MCA) as far as hazard, money saving advantage, ecological and social perspectives can be performed. Thus, from the systematic outcomes, the great possibilities of further development and investigation of new end utilizes were recognized towards the integrated management of urban water. The examinations could likewise help decision makers in making a decision for future reused water plans. Daniel Hellstrom et al., 2008 examined a structure for frameworks investigation of sustainable urban water management.

The expanding interest for economic advancement will profoundly affect a wide range of urban foundations. Be that as it may, there is an absence of learning of how supportable improvement ought to be achieved and how maintainability of different specialized frameworks ought to be surveyed. This paper portrays the structure of a frameworks investigation venture managing the above issues, which concentrates on urban water and wastewater frameworks. The task is a piece of substantial national research program in Sweden entitled "Maintainable Urban Water Administration." This paper recommends reasonable markers for the proposed criteria. It additionally contains a concise examination of the commitment to different natural impacts and asset usage of the Swedish urban water framework in connection to the effect of Swedish society altogether, to take into account a right prioritization of the criteria.

Joel Stewart et al., 2009 described Assessing supply risks of recycled water allocation strategies. A tool to evaluate the supply dangers related with water designation systems utilized at emanating reuse offices is portrayed. The tool is month to month water adjust model and affectability investigation. Through examination of atmosphere records at the Hawkesbury water reuse conspire site (the area of a consolidated profluent and storm water reuse office), it was discovered that a gauge of water system request took after standard factual appropriations.

The assessed dissemination of water system request was utilized as a part of conjunction with a water adjust model to evaluate future storage distributions and thus dangers of future over-or under-supply situations. The tool is reasonable for use in an operational environment to assess the impact of demand management strategies. Shiroma et al., 2010 states an emerging approach for urban integrated management of water for urban water utilities to design and oversee urban water frameworks to limit their effect on the common habitat, to boost their commitment to economic, social and financial vitality and to induce improvement of overall community.

The beginning stage for embracing the IUWM approach is the key planning stage. In any case, very less has been composed on processes that empower use of the IUWM way to deal with arranging. Distinguishing this information gap, the Water Research Foundation and the CSIRO, Australia mutually built up a structure to embrace IUWM way to deal with vital arranging of urban water frameworks (referred to as IUWM Preparation Structure). This paper talks about standards, drivers and advantages of IUWM approach and gives an overview of the IUWM Preparation Structure. Arghyam et al., 2010 included thorough survey of research embraced everywhere throughout the world on different parts of urban water administration by researchers and specialists, including yet not restricted to urban hydrology, administration of water supply foundation, water assets administration, water quality administration (WQM), groundwater administration, specialized and monetary instruments for water request administration, specialized and financial parts of spillage decrease, ecological and financial parts of wastewater treatment and reuse, storm water administration, limit working for IUWM and legitimate and administrative structures.

Essential information accumulation for 27 urban areas/towns and auxiliary information gathering for 300 urban communities/towns was completed, covering all the 16 outlined typologies. Reasonable arrangements of IUWM mediations were distinguished for every typology in view of the comprehension of how the common qualities of these typologies impact the physical, monetary, institutional, money related and natural execution of urban water utilities.

Hatt et al., 2012 states an integrated treatment and recycling of storm water as a review of Australian practice. With the utilization of water drawing closer, and at times surpassing, the cutoff points of supportability in numerous areas, there is an expanding acknowledgment of the need to use storm water for non-consumable prerequisites, in this way diminishing the request on consumable sources. This paper exhibits a survey of Australian storm water treatment and reusing rehearses and in addition a discourse of key lessons and recognized information holes. Where conceivable, suggestions for conquering these information holes are given. There is an unmistakable requirement for the advancement of creative systems for the accumulation, treatment and capacity of storm water.

Existing storm water reusing practice is a long ways in front of research, in that there are no advances composed particularly for storm water reusing. Casey Furlong et al., 2014 justifies the IUWM pattern, including ideas like reuse of water, Urban Drainage Sustainable Systems, and it has formed new control issues and develops popularity in Melbourne. This paper investigates the connection between changing administration structures and IUWM execution.

It is discovered that IUWM execution has dominatingly been quickened by: a significant dry season, and actualizing the Office of Living Victoria (OLV) as a larger body. Endeavors by the OLV have expanded between organization coordinated efforts, and systematized integrated planning. Be that as it may, there is still no consensus on what the particulars of IUWM planning and framework courses of action actually resemble. Anna Hurlimann et al., 2018 described the arrangement of a sustainable supply of water is an undeniably troublesome undertaking to accomplish in numerous urban situations. This emerges as a result of rising population growth and expanded per capita interest for water. Also, environmental change is affecting the common pattern of water in numerous areas, with a critical effect anticipated for the future.

Numerous researchers advocate urban management of sustainable water as a methodology that can address the underlying drivers of these difficulties. This paper provides information in addition to tools for assisting planning of water to achieve SUWM, adaption of good water sector and city location, in a united, complete and broad way, for future needs for the supply of water. Achievement of these aims requires several environment corrections through collaborative activities.

Nitin Bassi et al., 2018 features the change like institutional requirements used for possible administration of water in urban areas of India.

This change includes:

a. Authoritative measures involving change in decentralization, interest for private area and administration based on network.

b. Order changes and;

c. Human asset improvement.

The better perspectives will rely on the physical and financial condition, political circumstance and managerial set up that exist in the urban territory. The institutional changes will be all the more so vital for little urban towns where open utilities are given little consideration. All these together can add to improving Indian urban communities arranged for turning away the hazard, in face of fast urbanization, environmental change and water shortage.

2.13. Experts and Organisational Structures in Chandigarh

2.13.1 ENVIS (Environment Information System)

It is a decentralized framework with a system of appropriated subject arranged Centers confirming combination of national hard work in environmental data collection, assembling, storing, recovery and distribution to all concerned.

ENVIS network comprises of Focal Point at the Ministry of Environment and Forest and ENVIS Centers arrangement in various associations/foundations in the nation in selected areas of environment. Various regions have these centres set up for the control of pollution, harmful toxic substances, fundamental and environmental science offshore, environmentally sound and proper innovation, waste biodegradation and management of environment etc. [ENVIS, 2019].

ENVIS works as a stakeholder in the city and guarantees the efforts in environment related data collection, assembling, storing, recovery and distribution to all concerned. In this study, ENVIS centre helped a lot for providing valuable data source.

Environmental Information System Objectives:

1. Long term objectives:

a. To build up a repository and dissemination centre in Environmental Science and Engineering.
b. To develop the new tools of gaining, treating, storing, recovery and distribution of data of natural environmental; and
c. To enhance the research, growth and improvement in environmental data tools.

2. Short-term objectives:

a. To give environmental national data facility related to introduce necessities and equipped for advancement to meet the future needs of the clients, originators, processors and disseminators of data;
b. To develop storing, recovery and distribution abilities with aim of spreading information to the users quickly;
c. To encourage, nationwide and worldwide support and connection for information exchange related to environment;
d. To promote learning and employees teaching programmes aimed to boost processing information of environment and usage skills;
e. To encourage the interchange of data amongst emerging nations.

2.13.2 Municipal Corporation for Developing Chandigarh

Chandigarh Municipal Corporation or Municipal Corporation Chandigarh (MCC) is the city body that oversees the arranged city of Chandigarh. Under the Punjab Municipal Corporation Act, 1976, MCC appeared in the Union Territory of Chandigarh, as pushed out to the Union Territory, Chandigarh by the Law Act of Punjab Municipal Corporation, 1994 [MC Chandigarh, 2019].

On April 1, 2018, the MC began its drive to stop wastage of water. For the three months finishing June 30, there was restriction on washing vehicles, watering of patios and yards prohibited during morning hours, checking wastage of water because of flood from overhead or underground water tanks, spillage in pipeline and spillage or flood from desert coolers.

2.13.3 Central Ground Water Board for Developing Chandigarh

Table 2.1: Chandigarh data for developing model

S.NO.	Chandigarh Parameters	Chandigarh Data
1	Location of city	Longitude: $76^0 42'$: $76^0 51'$ Latitude: $30^0 40'$:$30^0 46'$
2	Area coverage	114 Sq. Km. (Urban 78 Sq.km. Rural 36 Sq.km.)
3	Population of city	1054686 (2011 Census) Density-7903 persons/sq.km.
4	Literacy Rate of city	86% (2011 Census) Total –847208 Persons Male-484563 Female-362645
5	Physiography of city	Hills Piedmont zone (kandi area) Sirowal zone Alluvial Plain
6	Rainfall of city	1074 mm (Normal annual rainfall)
7	Temperature of city	Maximum 48.5 ^{0}C (20th June 2019)
8	Geology of city	Alluvium Sirowal Quaternary Kandi Siwaliks] Tertiary

Source: [CGWB, 2019]

SOILS

Sand to sandy loam (Northern Part) Loamy sand to silt loam (Southern Part)

Land Usage Scenario

Table 2.2: Land Use

S.NO.	AREA	LAND USE
1	Area not available for cultivation	88.60 Sq.km. (79%)
2	Net area sown	15.22 Sq.km (13.35 %)
3	Current fallow	0.25 Sq.km (0%)
4	Fallow other than current	5.08 Sq.km (4%)
5	Forest area	2.10 Sq.km (2%)
6	Other uncultivable land excluding fallow land	2.75Sq.km (2%)

Source: [CGWB, 2019]

Depth to Water Level:

1	Shallow (unconfined aquifer)	5 to 10 m
2	Deep (Confined aquifer)	20 to 45 m

Depth of Tubewells:

1	Shallow	90 m
2	Deep	240-305 m

Projected Water:

2006 – 0.567 million cubic metres or MCM (125 MGD)

2011 – 0.621 million cubic metres or MCM (137 MGD)

2016 – 0.671 million cubic metres or MCM (148 MGD)

2020 – 0.712 million cubic metres or MCM (157 MGD)

Artificial Recharge Schemes:

Completed under Central Sector Schemes

A. Roof Top Rainwater Harvesting –2

a. CSIO Complex

b. Basic Medical Sciences Building, Panjab University

B. Utilising Monsoon Runoff – 1

a. Leisure Valley, Sector-10

C. Schemes Approved Under Central Sector

a. DAV Senior Secondary School, Sector-8

b. TTTI , Sector-26

c. Chandigarh Housing Board Office Complex, Sector-9

d. Dividing roads Sectors-26,27, 19, 30 & 20

e. Bhu-Jal Building , Sector-27-A

Fast and intense changes in monetary development are making greater levels of popularity for specialized trainings particularly in building instructions. Building training faces noteworthy difficulties as it looks to satisfy the needs on designing calling in the 21st century as joblessness, research work and social angles. To meet these progressions and nonstop requests for example from industry or society, these organizations have redesigned themselves consistently with nature of instruction that can get ready understudies to confront and beat the difficulties of water shortage. The investigation presents a survey on IUWM and conversation on various partners, for example, controllers, the executives, understudies, workforce with their desires, key jobs in the water the board. [Source: ENVIS, 2019]

2.13.4 International Level Studies

a. Use of geological data framework (GIS) in the portrayal of the Cunha Canal, Rio de Janerio, Brazil was finished by [Borges et al., 2015] to consider the impacts of the urbanization on water quality and it has been seen that the water of Cunha waterway is modified and corrupted, most likely because of the extreme urbanization of the watershed environs. It has been proposed that the development of a sewage treatment plant is a choice to lessen the contamination in the examination region.

b. Vandeberg et al., 2015 worked out the spatial appraisal of water quality in the region of Lake Alice National Wild Life Refugee and results featured the raised convergences of phosphorus, nitrate-nitrite and E.coli from upstream sources prone to have most prominent possible effect on Lake Alice Refugee.

c. Liu et al., 2015 did an investigation on describing overwhelming metal develop on urban street surfaces and suggestion on storm water reuse and saw that Zn, Cd, Cu and Ni develop on urban streets were at reasonably to vigorously contaminated levels while Pb and Cr were at the dirtied level. Zn, Cd, Cu and Ni were essentially from anthropogenic exercises, for example, traffic exercises.

d. Venkatramanan et al., 2014 directed study on examination of hydrogeochemistry, metals and immersion files of minerals in Nakdong surface water and nearby deltaic groundwater utilizing WATEQ4E geochemical model. It was seen that the soaked lists of carbonate, sulfate and oxides minerals spoke to under immersed and equilibria state. Results featured that the water science was dictated by lithological impacts by complex enduring procedure or particle trade alongside the impact of particles from anthropogenic effect.

e. Ferguson et al., 2013 observed the substantial metal circulation, chance appraisal and water quality portrayal by water quality list of stream Soan, Pakistan. Results indicated that the raised grouping of substantial metals has been ascribed to normal procedures and anthropogenic exercises along the stream Soan course. Potential hazard list uncovered moderate environmental hazard in the suspended dregs tests of urban regions.

f. Fielding et al., 2013 did the investigation on spatial varieties in the connections between land use and water quality over a urbanization angle in the watersheds of Northern Georgia, USA and results featured that the connection between urban land and explicit conductance were more grounded in less urbanized watersheds, while those between urban land and broke up supplement were more grounded in exceptionally urbanized watersheds and proposed that so as to diminish the water corruption, land use arranging ought to be balanced dependent on essential toxins in watershed.

g. Daniel et al., 2013 checked the water nature of the Zarivar Lake utilizing physico-concoction boundaries and NSF-WQI pointer, Kurdistan Province-Iran and discoveries unmistakably showed that broke dissolved oxygen (DO), phosphate, alkalinity and complete suspended solids as predominant components affecting lake water quality appraisal ought to be overseen. Supplement improvement was a worry to inhabitants living along Zarivar Lake alongside its suggestions on the drawn out oceanic wellbeing of the framework.

h. Thompson et al., 2012 assessed the overwhelming metals take-up and hazard evaluation of vegetable developed in Yargalma of Northern Nigeria and saw that the variety in the substantial metals in plants and soil were because of contrasts in the wellsprings of the metal. A portion of the metals are as of now present in the plant and the dirt would add to the metal bioavailability. The all out metal convergence of plants in this investigation was a commitment of the considerable number of parts of plants.

i. Oliver et al., 2012 directed study for the appraisal of surface water getting sewage effluents for cultivating water system purposes: a contextual investigation of Ona stream in Ibadan Southwest nearby government region of Oyo State, Nigeria. The outcome demonstrated that in spite of the enormous substance of sewage effluents described by a portion of the zones, the nature of the surface water stayed inside as far as possible for water system purposes. Subsequently, Ona waterway water can be created for lasting through the year crop creation in the investigation territory. Nonetheless, the need to ceaselessly screen and evaluate surface water quality for water system is focused.

j. Ray et al., 2011 checked the impacts of urbanization on stream physico-synthetic and full scale invertebrate collections in the tropical urban watershed in Puerto Rico and results featured that the urbanization negatively affected physicochemical and organic states of the streams and discoveries recommended that the far reaching watershed the executives plans created in the mild districts could be actualized adequately in creating urban communities of Puerto Rico.

k. Stewart et al., 2011 directed study on urbanization adjusting watershed hydrology in the Piedmont of North Carolina, it was seen that the concentrated urbanization raised watershed top stream rate and the yearly release volume incompletely because of the decrease in evapotranspiration during the developing season. They inferred that keeping up the evapotranspiration limit of the vegetation in a urbanizing watershed was significant being developed getting ready for decreasing storm water stream and debasement of watershed.

l. Stews et al., 2011 talked about the reasonableness of surface water for water system purposes in the Southwestern and seaside waterway frameworks in Ghana and saw that the nature of surface water from these bowls is controlled primarily by leachate of synthetic substances from strong and mine squanders, the science of precipitation, enduring of hidden silicate mineral-rich shakes and dregs, horticultural and household squanders.

m. Monterio et al., 2010 examined the substantial metal contamination in the urban stream residue and its tributaries and study uncovered that factor examination produced three wellsprings of poisons in the Nakivubo channelized stream dregs: (1) blended inception or maintenance wonders of vehicular and modern discharges portrayed by Pb, Cu, and Zn; (2) Terrigenous divisions in the overflow, described by Mn, Fe and Cu; and (3) double wellspring of vehicular and mechanical outflows, described by Zn.

n. Mckenzie et al., 2009 did the hydrochemical examination to evaluate the groundwater tainting in a modern city, Sialkot, Pakistan and the investigation presents the convenience of multivariate factual procedures in groundwater quality appraisal, distinguishing proof of critical boundary to improve data about the wellspring of contamination. The investigation featured the critical need to control the substantial metal defilement of groundwater and severe control on the removal of untreated effluents around the enterprises.

o. Maria et al., 2008 worked out the effect appraisal of gushing release on physicochemical boundaries and some overwhelming metal fixations in surface water of River Challawa Kano, Nigeria and the discoveries plainly showed that the constant release of waste and wastewater contamination occasion particularly with high Cd and Cr inside the investigation region was probably going to have serious yet confined impacts.

p. Joel et al., 2008 worked out the wellbeing dangers of overwhelming metals in sullied soils and food crops watered with wastewater in Beijing, China and results showed that there was considerable development of substantial metals in wastewater inundated soil; overwhelming metal fixation in plants developed in the wastewater flooded soils were fundamentally higher than in plants developed in reference soils.

q. Hatt et al., 2006 checked the effect of urbanization on the Glinscica stream arranged in the focal piece of Slovenia and watched the generous occasional variety of convergence of broke up oxygen, nitrate and ammonium content because of biochemical procedures in the diverted streams.

r. Marsalek et al., 2006 did the investigation of substantial metal circulations in groundwater in regular slants and exceptionally urbanized spaces in Mid-levels region, Hong Kong. The investigation proposed that the vadose zone could expel huge numbers of the substantial metal. Factual examination recommended that specific measure of Mn and Co was probably going to re-assembled from characteristic soils because of progress in the ordinary redox conditions ,while Mn, Co, V, Mo may likewise be gotten from steel erosion because of delayed submergence.

s. Michell et al., 2000 directed study on mimicking overflow conduct in a urbanizing watershed to examine the connection between spillover proportion and base stream as capacity of percent impenetrable spread and percent soil immersion for Upper Gwynns Falls watershed, Baltimore, MD, USA. Hydrologic model yield was utilized to characterize rundown articulations to portray these connections and consolidate complex framework conduct. The outline articulation for the overflow proportion relationship demonstrated the presence for a limit percent impenetrable spread, above which the spillover proportion changes all the more drastically.

t. Hellstorm et al., 2000 announced the stream wellbeing after urbanization and results uncovered the base stream release in the mid year months (comparative with catchment region) was incredibly low once the complete impenetrable territory expanded past 20-40 percent. They saw that in the examination streams, the decrease in stream speed was a lot bigger than the decrease in water profundity.

u. Brandon et al., 1995 worked out on condition effect of water system from wastewater in Central Mexico; the examinations did on soil ripeness proposed the event of significant nitrogen misfortunes, which could speak to likely dangers to general wellbeing actuated by raised nitrate focuses in groundwater. There was proof of expanded pervasiveness of parasitic diseases among farming specialists and their families presented to crude wastewater water system. Negative ecological impacts may result from long-term wastewater application, because of overwhelming metal amassing in soils, expanding measures of promptly versatile and effectively mobilizable metal parts, just as yields take-up.

2.13.5 National Level Studies

a. Ramachandra et al., 2015 monitored urbanization and its implications in Delhi from space and studied [Ramachandra, 2015] observed urbanization and its suggestions in Delhi from space and examined spatio- temporal examples and its markers. In the investigation spatial information of four decades were utilized to comprehend land use and land spread elements. Aftereffects of the scene networks demonstrated that the urban focuses were profoundly totaled, while edges and cradle zones are very nearly collecting urban patches. It has been recommended that so as to guarantee groundwater recharge, the administration specialists need to keep up least vegetation spread in the area separated from recharge through percolation pits and rain water harvesting.

b. Suhas et al., 2015 contemplated transient variety and substantial metal aggregation in urban storm water stream with uncommon accentuation on water system utility, Chandigarh, India, for examination of water system water quality file (IWQI). The outcomes indicated that IWQI ran between 70-85 for both the examining seasons in this way the worth falling under the „Low restriction‟ classification for water system purposes. Water of this classification ought to be utilized in the dirts with light surface or moderate porousness and ought to be kept away from in soils with high mud. The territory saw substantial finished soil and water which was utilized for water system reason for existing was conceivably prompting the sodicity issue. The metal focus in the examples taken from the examination zone indicated the pattern of Fe>Ni>Mn>Cd in this way demonstrated a serious drop in the water quality.

c. Mankad et al., 2015 checked the ground and surface water quality along the waterway Varuna, Varanasi, India and saw that the connection coefficient determined for different physico-concoction boundaries for ground and surface water set up the relationship between's them. This examination demonstrated the utility of multivariate factual investigation for assessment of proposed collaborations and viable future checking of expected locales.

d. Dillon et al., 2014 directed study on the impacts of land change water nature of Dal Lake, Srinagar, India, saw that huge land use changes has happened during recent years (1981-2011) and due to this lake water has contaminated because of the expansion of different toxins from Hanjis exercises. The investigation presumed that the land change has changed over the once new water lake into much decayed lake.

e. Tiwari et al., 2014 directed an examination on the appraisal of surface water quality utilizing substantial metal contamination record in Subarnarekha River, India and results exhibited that the centralization of metals indicated noteworthy irregularity and most factors displayed more significant levels in the pre rainstorm season. The improved convergence of certain overwhelming metals in the surface water was because of the anthropogenic exercises in the investigation territory.

f. Sidhu et al., 2014 led the examination to dissect the hazard appraisal of overwhelming metal circulation and their harmful ramifications on vegetables flooded with storm water in the region of Chandigarh, India. The outcomes showed that substantial metal focuses were a few overlap higher in all the gathered examples from wastewater inundated site contrasted with the spotless water flooded ones. The vegetables gathered at dirtied locales indicated Ni 57.1%, Cd 35.7% and Cr 28.5%, which surpassed PFA (1954) limits. The investigation proposed that storm water system prompted amassing of substantial metals in vegetables causing potential wellbeing danger to the shoppers.

g. Akissa et al., 2012 directed study on the examination of urban development utilizing LANDSAT Thematic Mapper/Enhanced Thematic Mapper information and GIS-a contextual analysis of Hyderabad, India, showed that urban development in the city was continuing every which way. During the investigation it has been seen that urban development has likewise corrupted the water assets in these regions.

h. A concentrate on the overwhelming metal gathering in sewage inundated vegetables in various areas of Agra region, India was done by [Akissa et al., 2012] and watched the higher centralization of Fe in the dirt, as the region was alluvial and alluvial soil has higher ability to retain Fe. Pb and Cd were watched more in untreated destinations when contrasted with the rewarded site.

i. Akissa et al., 2012 worked out the discovery of land use and land spread change with distant detecting and GIS: A contextual analysis of Punjab Siwaliks and discoveries plainly demonstrated that changes were found wherever in the zone of Punjab Siwaliks (between waterway Satluj and Ghaggar) and it was discovered that in the examination region common vegetation was losing its degree at a fast rate.

j. Sidhu et al., 2012 examined groundwater quality variety concerning spring dispositioning in urbanized watershed of Chandigarh, India. The hydrochemical information showed the way that there was a significant distinction in the creation of the groundwater taken from shallow and more profound spring inside the examination territory the shallow spring framework in the zone displayed a solid level of defilement through draining and were increasingly inclined to contamination. To maintain a strategic distance from the danger of defilement, the water was being tapped from more profound spring over the city and this brought about reduction or fall in the piezometric top of the more profound spring.

k. Aijaz et al., 2010 directed study on urbanization and nature of urban condition utilizing far off detecting and GIS procedures in East Delhi-India, featured that Remote detecting information and GIS strategies are helpful for extraction of data like developed territories, open green space, urban land use planning that are significant properties for surveying the urban ecological quality for a major urban agglomeration.

l. Aijaz et al., 2010 completed the examination on effect of industrialization on groundwater quality in a modern belt of District Solan, Himachal Pradesh to recognize the groundwater sullying issues. The factual connection between different particles present in the water has been considered and watched the raised centralization of overwhelming metals like Fe, Cu, Pb and Mn in groundwater tests upto the level at which it has gotten unsatisfactory for human utilization. This can be straightforwardly liable for the evil wellbeing of the individuals dwelling there. In this manner water treatment plants are prescribed in the territory to give consumable drinking water to the nearby populace.

m. Shiroma et al., 2010 directed study on unfriendly regenerative and youngster wellbeing results among individuals living close to exceptionally harmful material water channels in Punjab, India, showed that the overwhelming metal and pesticide presentation might be potential hazard factors for unfavorable conceptive and kid wellbeing results in the territory.

n. Shiroma et al., 2010 worked out the groundwater contamination due to mechanical contamination in Ludhiana and checking of wellspring of contamination uncovered that point, line and diffuse contamination was occurring. The emanating released from the ventures permeated into the dirt close to the source or travel through unlined channels to shallow pits where drainage into the dirt and vadose zone happens which in the long run taints groundwater. Copper and zinc have arrived at the soaked zone which shows that dirt and vadose zone in regard of these components have become immersed and further contamination was conceivable in future.

o. Shiroma et al., 2010 did the investigation of effect of sewage water system of speciation of nickel in the dirts and its gathering in the yields of mechanical town of Punjab. They inferred that the raised convergence of diethylene triamine pentaacetic corrosive extractable nickel (DTPA-Ni) was found in the sewage took care of soils in all the modern town of Punjab when contrasted with the cylinder very much flooded soil, on the grounds that the waste water were stacked with Ni discharged from enterprises like electroplating, machine devices, hardened steel, bike and bikes fabricating, where Ni was utilized to confer consumption obstruction which prompted the advancement of soil with this metal.

p. Raju et al., 2007 directed study on substantial metal convergence of sewage-polluted water and its effect on groundwater, soil, and yield plants in alluvial soils of northwestern India, showed that drawn out amassing of poisonous metals in soils and their take-up by crop plants had a high potential for phytotoxicity just as for going into the natural way of life.

q. Punjab Pollution Control Board, Patiala, 2006 distributed a report on portrayal investigation of stream Ghaggar which conveyed effluents from enterprises and private states situated along its bank and its impact on water, soil and vegetables. Study uncovered that the estimation of BOD, COD and TSS in the water of stream Ghaggar were found in overabundance of as far as possible. The estimations of Cd, Pb, Cr and Fe have been discovered higher in the vegetables than the cutoff points endorsed by BIS.

r. According to the examination led by Rahman et al., 2005 on long haul effect of water system with sewage effluents on substantial metal substance in soils, crops and groundwater, demonstrated that develop of overwhelming metals especially Zn, Cu and Ni in sewage flooded soil should be observed occasionally taking into account their noteworthy aggregation in bio-accessible pool related with decrease in pH. Apparent exhaustion in accessible Mn under these seriously developed sewage inundated soil was probably going to initiate un-maintainability in soil profitability and along these lines, Mn should be remembered for adjusted preparation program.

s. Punjab Pollution Control Board, Patiala, 2004 published a report on effect of contaminants in [Punjab Pollution Control Board, Patiala, 2004] distributed a report on impact of contaminants in wastewater on soil and vegetables, a contextual analysis has been led to find out the impact of different toxins present in the channels, which are conveying sewage from different areas and modern effluents of various businesses arranged in Chandigarh and SAS Nagar territory and distinguished disturbing degree of substantial metals in the wastewater which was used by the ranchers in the encompassing towns to water their field. Microorganisms were likewise found in all the root vegetables.

t. Kumar et al., 2002 did the examination on post-water system effect of local sewage profluent on piece of soils, crops and groundwater, recommended that raised convergence of harmful particles like Ni, Cd, Pb in plants ought to be the matter of concern and demonstrated the need of persistent observing and treatment of sewage water before it was allowed into removal channel for water system.

u. According to the examination directed by Raju et al., 2004 on the appraisal of supplements in urban storm water overflow on Mysore city, it was seen that contaminations and supplements in enormous amounts got washed into the surface water bodies during storm occasion from various non-point sources, in this way causing the algal sprouts, weed development in new water bodies, at last winding up with eutrophic status of the water body.

v. Iyer et al., 1998 completed the examination on the effect of the reuse of residential waste water for water system on groundwater quality showed that the fecal coliform were found in water from all shallow hand siphons in the region. High boron substance of sewage profluent affirmed hazard for crops delicate to boron. Groundwater quality was contrarily influenced from sewage profluent with respect to nitrogen substance (ammonium and nitrate), phosphate, substantial metals and fecal coliform. The aggregation of substantial metals and phosphorus in the dirt unfavorably influenced the dirt framework.

2.13.6 Challenges of Urbanization and Environment Implications

Urbanization majorly affects watershed hydrology. Urban zones adjust their nearby and local atmosphere through the urban warmth island impact and by modifying precipitation designs, which together will significantly affect net essential creation, biological system wellbeing and biodiversity. Urban extension will intensely draw on normal assets, including water and will regularly expend prime rural land prompting the adjustment of biodiversity and biological system administrations.

2.13.7 Impacts on Hydrological Processes and Surface Runoff

Over misuse and direct anthropogenic adjustment of the land cover, for example, farming, deforestation, mining, urbanization and intercession on hydrological system like water system and damming have brought about a stamped change in water quality in different catchment zones [Shiroma et al., 2010]. Extension of urban populace and expanded inclusion of local water flexibly and sewage offers ascend to more noteworthy amounts of metropolitan wastewater.

The nature of the surface water inside an area is administered by both regular procedures, (for example, precipitation rate, enduring procedures and soil disintegration) and anthropogenic impacts, (for example, urban, modern and rural exercises and the human misuse of water assets) [Shiroma et al., 2010]. The land use changes increment the measure of impenetrable surfaces bringing about storm overflow occasions that contrarily influence stream biological systems and water quality. Overflow contamination happens each time downpour or snowmelt streams over the ground and gets contaminants.

It happens on ranches or other farming destinations, where the water diverts composts, pesticides and residue from cropland or field land. Storm water diverts a wide assortment of contaminants as it stumbles into housetops, streets, parking garages, building destinations, fairways, gardens and different surfaces in our urban communities and rural areas. Dissimilar to mechanical or metropolitan wastewater treatment plant releases, most storm water contamination is gotten from progressively diffuse sources that are firmly identified with ordinary city and individual exercises. While these qualities represent a few difficulties, they additionally give the chance to numerous ways to deal with address the issue.

The issue of contaminated storm water overflow has two principle parts:

1) The expanded volume and pace of spillover from impenetrable surfaces; and

2) The grouping of toxins in the spillover.

The two segments are exceptionally identified with advancement in urban and urbanizing territories. Ordinary exercises, including driving and looking after vehicles, keeping up gardens and stops, discarding waste and in any event, strolling ways, regularly spread these impenetrable surfaces with a covering of different unsafe materials. Building destinations, power plants, bombed septic frameworks, illicit releases and ill-advised sewer associations additionally contribute significant measures of contaminations to overflow. Residue, harmful metal particles, pesticides and composts, oil and oil, microbes, abundance supplements and refuse are regular storm water toxins.

A significant number of these constituents end up on streets and parking areas during dry climate possibly to be washed into water bodies when it downpours or when snow dissolves. Together, these poisons and the expanded speed and volume of spillover cause emotional changes in hydrology and water quality that brings about an assortment of issues. Stream corruption is frequently connected with expanded impenetrability and has been alluded to as the urban stream syndrome [Shiroma et al., 2010].

2.13.8 Impacts on Surface and Subsurface Hydrology

As a watershed experiences urbanization the hydrology or water development in the watershed starts to change. Water which once pooled on a superficial level and afterward separated into the ground, presently frequently falls increasingly more upon hard, impenetrable surfaces like cement and can't invade into the groundwater. Before advancement, around 50 % of precipitation normally penetrates into the dirt and in the end into the groundwater, yet after improvement in the watershed around 55 % runs off and just around 10 % enters the groundwater framework.

This implies with the standard examples of advancement there is much more spillover created from a similar size precipitation occasion than was produced before improvement in the watershed. This expanded spillover makes various issues:

1. It streams quicker over impenetrable surfaces making expanded flooding.
2. Due to expanded release rates streams endeavor to build their ability (either by extending, down cutting or both).
3. Less penetration into the shallow groundwater and hence groundwater release to streams is diminished bringing about littler warm/dry season stream streams.

As obvious from Fig 2.1, urbanization changes radically the hydrologic pattern of the regular zones. Expanded impenetrability prompts increment in volume of water, expanded pinnacle stream span and changes in dregs load. Every one of these impacts can bring about flooding, environment misfortune, disintegration, channel augmenting and streambed adjustment.

Living space misfortune can likewise result from expanded stream temperature and diminished base stream, which are additionally impacts of expanded impenetrability. This variable can be effectively estimated at all sizes of improvement, as the level of the zone that isn't "green." Scientific proof relates impenetrability to explicit changes in the hydrology, territory structure, water quality and biodiversity of amphibian frameworks. Above all, impenetrability is one of only a handful scarcely any factors that can be unequivocally evaluated, oversaw and controlled at each phase of land improvement [Schueler, 1987].

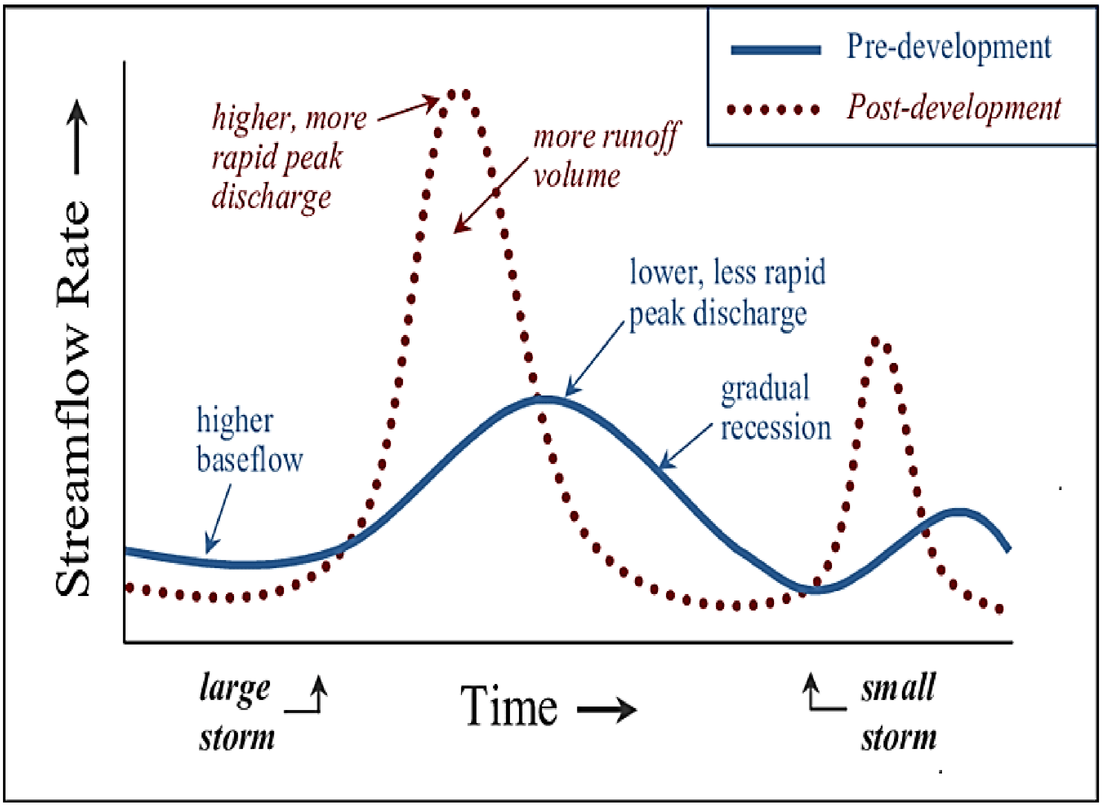

Fig. 2.1: Impacts of urbanization on stream flow [Schueler, 1987]

Impenetrable surfaces gather and amass contaminations kept from the environment, spilled from vehicles or got from different sources. During storms, aggregated contaminations are immediately washed off and are quickly conveyed to sea-going frameworks. Checking and demonstrating examines have reliably shown that urban poisons are straightforwardly identified with watershed impenetrability [Schueler, 1987]. Impenetrable surfaces additionally both assimilate and reflect heat.

Throughout the late spring months, impenetrable zones can have neighborhood air and ground temperatures that are 10 degrees to 12 degrees hotter than the fields and timberlands that they supplant. The trees that could have given shade to balance the impacts of sun based radiation are missing too. Water temperature in headwater streams is firmly affected by neighborhood air temperatures.

Stream temperatures all through the late spring are expanded in urban watersheds, and the level of warming has all the earmarks of being straightforwardly identified with the impenetrability of the contributing watershed. Numerous free lines of examination meet toward one regular end: it is incredibly hard to keep up predevelopment stream quality when watershed improvement surpasses 10 percent to 15 percent impenetrable spreads.

2.13.9 Impact on Water Quality

The other part of urbanization that adds to urban storm water contamination is the raised release of toxins. Land in the urban regions are being changed over into private, recreational, business and mechanical uses and subsequently faces intense contamination issue with the release of a great many liters of local waste, sewage, modern and horticultural effluents straightforwardly into the streams which contain substances differing in qualities from basic supplements to exceptionally poisonous substances [Khurana et al., 2005]. All the contaminants initially go into surface water framework and in this manner into the groundwater, therefore falling apart the nature of surface just as groundwater. As human action increments in a given region, the measure of waste material kept on the land and in seepage frameworks increments. When the contaminations are kept onto street and stopping surfaces, they are accessible for transport through spillover to accepting waters during storm occasions.

Suspended solids can prompt improvement of ooze stores and anaerobic conditions when untreated wastewater is released to the sea-going condition. Biodegradable organics are mainly comprised of proteins, starches and fats. They are ordinarily estimated as far as BOD and COD. Whenever released into inland waterways, streams or lakes, their organic adjustment can exhaust regular oxygen assets and cause septic conditions that are inconvenient to sea-going species. Pathogenic life forms found in wastewater can cause irresistible maladies. Need poisons, including natural and inorganic mixes, might be profoundly poisonous, cancer-causing, mutagenic or teratogenic.

Substantial metals typically included by business and modern exercises must be evacuated for reuse of the wastewater. Broken down inorganic constituents, for example, calcium, sodium and sulfate are frequently at first added to local water supplies, and may must be evacuated for wastewater reuse. Oil, oil and different hydrocarbons identified with vehicle use and upkeep likewise defile water. These originate from removal of utilized oil and different liquids on the ground or into storm channels, spills of fuel or oil, and holes from transmissions or different pieces of vehicles and trucks.

While the hydrologic changes are a wellspring of a significant part of the effect from storm water overflow, poisons in storm water spillover can affect the water quality (Fig. 2.2). The degree and extent of these effects rely ashore use inside every catchment or watershed inside the urban or rural scene. These contamination loadings can significantly affect urban streams and watersheds especially when joined with the effects that urbanization can deliver in hydrology and stream morphology.

2.13.10 Storm Water Irrigation Challenges

Storm water is one of the major undiscovered urban water assets that can be misused as an alternate water asset for water system. Water that channels into the surface water is probably going to build the amount of solutes accordingly expanding the centralization of specific particles that lower the quality of water for irrigation system reason. Long haul utilization of rewarded and untreated wastewater brought about critical development of substantial metals in soil, vegetables, oats and their ensuing exchange to evolved way of life causing potential wellbeing danger to buyers [Singh et al., 2005].

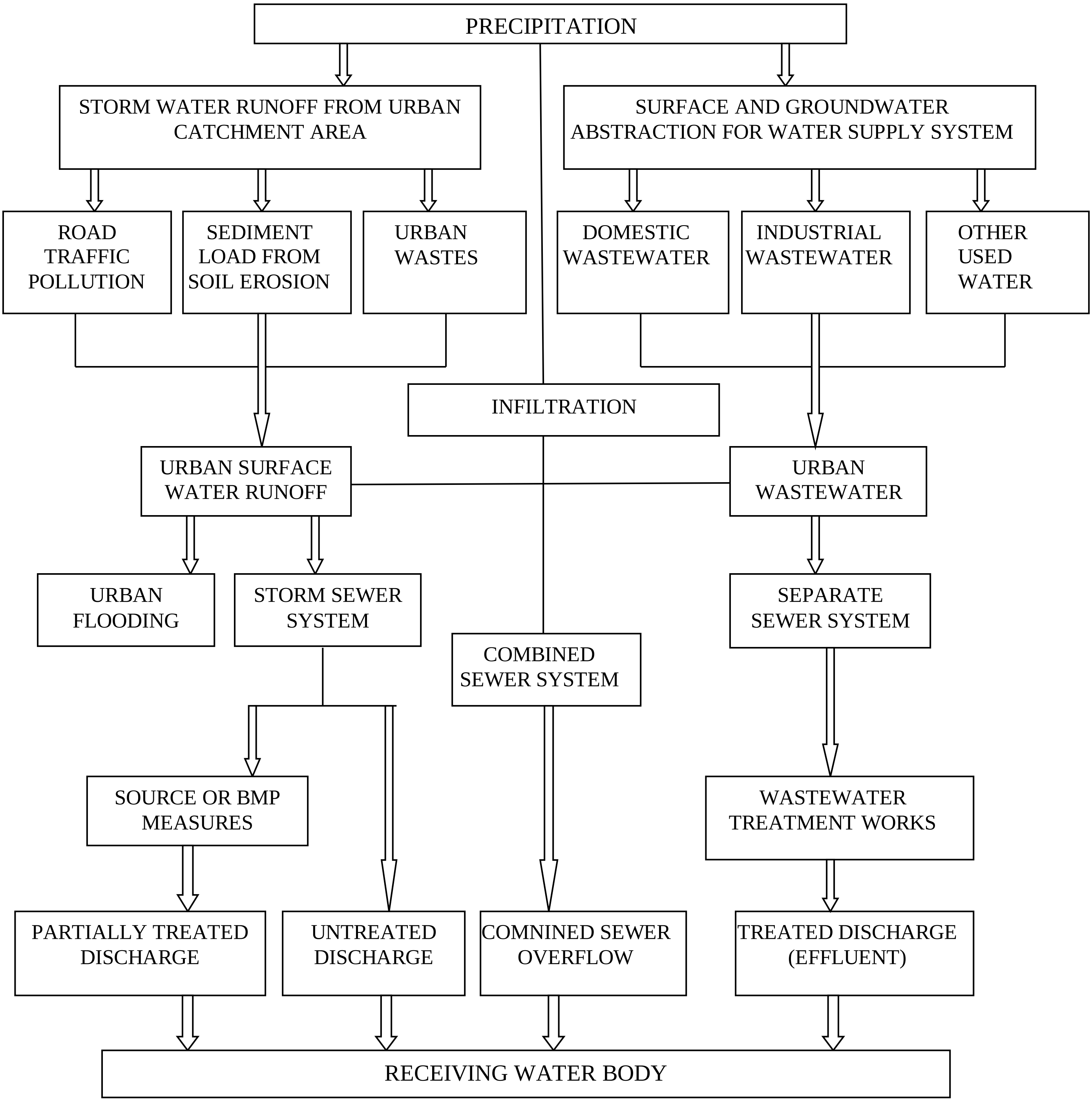

Fig. 2.2: Movement of water in urban environment [UNESCO, 2016]

Substantial metal focus in plants developed in wastewater-inundated soils was altogether higher than in plants developed in the reference soil [Singh et al., 2005]. In urban territories of many creating nations, urban and peri urban horticulture relies upon wastewater as a wellspring of water system. Metals are an imperative piece of our condition and assume positive job in different natural procedures, for example, flagging, homeostasis and catalyst catalysis.

In any case, at higher focus, they will in general have harmful impacts. Overwhelming metals block working of liver, cerebrum and lungs, demonstrating trademark side effects since they are inclined to bioaccumulation and biomagnification along natural way of life. Vegetables developing around overwhelming metal compromised zones are at higher danger of amassing harmful degrees of substantial metals.

Through bio-amplification, utilization of established vegetables antagonistically influences the combination of haem in the blood of people [Singh et al., 2005]. Ordinarily, the root estimations of overwhelming metals are one to two significant degrees higher than the shoot esteems. Whatever the sum collected by verdant and root/tuber vegetables, there is a reasonable possibility of direct passage into human eating regimen.

2.13.11 Why this research work is still not done in Chandigarh?

When the design of Chandigarh city was planned, no one had thought that an ample amount of water will be required in future. Since Chandigarh adjoins the states like Punjab, Haryana and Himachal Pradesh, which increased the population of the city as well as the demand of water. The beautiful city somehow lacks in designing and planning of proper water management so far.

There are two different concepts regarding the work are not performed till date is:

a. Combined storm water and waste water treatment.
b. Concept of double plumbing.

No one has focused on the matter of combining storm water and waste water as the necessity of the same was not felt earlier.

2.13.12 Research Questions

a. How Chandigarh area is handling the water resources with rising population?

b. What are the barriers to sustainable integrated urban water management in the region?

c. How is the resident's participation in water resources management of the city?

d. How double plumbing is going to help in city water management?

2.13.13 Delimitations

This study will make no attempt to decline or prove certain theories and concepts. The aim of this thesis is only to examine and describe the barriers to sustainable integrated urban water management resources. The phenomenon is observed in Chandigarh province of India.

CHAPTER 3

WATER BALANCE FOR CHANDIGARH

3.1 Water Balance

The water balance describes the inputs and outputs water accounting. For a particular place, the water balance constitutes a cultivated area, region and watershed that include computing the input and output of water sources with storage variations of water at the surface of earth. The evaluation additionally considers the current source adoption of the system along with their future. Precipitation is the reason behind input of water sources. Evapotranspiration constitutes plants transpiration and evaporation. The two amounts are assessed regarding the measure of water per surface unit yet they are for the most part converted as statures of water, millimeter being the presently utilized unit. Numerically, precipitation (P_r) [Shahriar Shams et al., 2013] can be communicated as

$$P_r = E_v + \frac{dS_t}{dt} \quad (3.1)$$

Where; P_r = Precipitation and is calculated in mm per unit area,

E_v = Evapotranspiration and is calculated in mm per unit area,

dS_t/dt = Storage change per unit time and is calculated in mm per unit area,

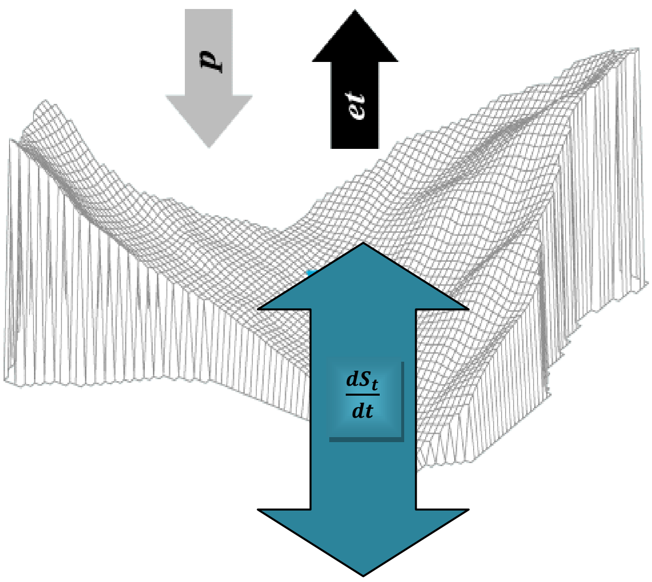

Fig. 3.1: Diagram of Water Balance [C.P. Kumar et al., 2003]

In other form, Precipitation (P_r) [Shahriar Shams et al., 2013] can be expressed as per hydrological way:

$$\boldsymbol{P_r = E_v + R_u + I_n + \frac{dS_t}{dt}} \tag{3.2}$$

Where P_r = Precipitation and is calculated in mm per unit area,

E_v = Evapotranspiration and is calculated in mm per unit area,

R_u= Runoff and is calculated in mm per unit area,

I_n = Infiltration and is calculated in mm per unit area,

dS_t/dt = Storage change per unit time and is calculated in mm per unit area,

Every framework of water is interesting in which the water source and the water measure moving with the help of system which depends on outside elements, for example, precipitation rate, stream area, evapotranspiration rate and surface water bodies and so on. The only normal element which works for water frameworks, nonetheless, includes aggregate sum which shows entering of water, water leaving, and water being put away by the framework shows the balance. The total sum of the considerable number of inflow of water, water outflow, and storage change per unit time is known as water balance.

The study of water balances is complicated by the fact that the two commanding variables are not independent of each other. The quantity of evaporated water obviously depends on the total available quantity of water: it stops when the water volume brought by precipitation is exhausted. This idea gets prompted as it shows the presentation of likely evapotranspiration: water amount which goes inside the air, expecting accessible water amount that definitely a component which is not constraining. Water measure can be added inside the blossom container so as to maintain the steady level which shows the expected evapotranspiration proportion contingent upon the climate condition. In the common way, during the water regulates investigation, it tends to think about rainfall likely evapotranspiration which can be denoted as ETP and helps in conceiving to recognize various circumstances as per edges that are of uncommon importance for a given spot or timeframe:

a. When P < ETP, evaporation considered to be equivalent to P; it shows an appropriation of reserves and an absence of runoff; the period will be said to be a deficit period.

b. When P > ETP, evaporation considered to be equivalent to the ETP; shows the runoff along with reserves building up; this is known as surplus period [Shahriar Shams et al., 2013].

3.2 Water Balance Study and Key Variables

3.2.1 Rainfall or Precipitation

It is the type of water on which Earth's surface is totally dependent. It shows the various types which incorporate shower, rainfall, storm, snowfall etc. It shows a significant segment which includes water cycle and is also helpful for water storage on the earth's surface. Roughly 900 mm of yearly water falls as rainfall in the study area of 114 km^2 [Chowdhury et al., 2005].

3.2.2 Evapotranspiration (ET)

Evapotranspiration (ET) means transport of water into the atmosphere from surfaces, including soil (soil evaporation), and from vegetation (transpiration). The latter two are often the most important contributors to evapotranspiration. Other contributors to evapotranspiration may include evaporation from wet canopy surface (wet-canopy evaporation), and evaporation from vegetation-covered water surface in wetlands.

The process of evapotranspiration is one of the main consumers of solar energy at the Earth's surface [Qingzhou Zheng et al., 2020]. Energy used for evapotranspiration is generally referred to as latent heat flux; however, the term latent heat flux is broad, and includes other related processes unrelated to transpiration including condensation (e.g., fog, dew), and snow and ice sublimation. Apart from precipitation, evapotranspiration is one of the most significant components of the water cycle. Assuming that moisture is available, evapotranspiration is dependent primarily on the availability of solar energy to vaporize water. Evapotranspiration therefore varies with latitude, season of year, time of day, and cloud cover. There are two types of evapotranspiration which can be named as:

a. AE or Actual Evapotranspiration

b. PE or Potential Evapotranspiration

First shows the AE which means Actual Evapotranspiration is the water amount which is a surface expelled because of transpiration and evaporation procedures.

Seconds shows the PE which means Potential Evapotranspiration depend on the air capacity to expel surface water because of transpiration and evaporation procedures accepting zero water control.

In this manner, PE is viewed as the most extreme ET rate conceivable through the arrangement of boundaries which includes physical and meteorological boundaries. By this principle, the water system which provisions water greater than PE is known as waste water. On the surface of earth, the rate of evapotranspiration at any area is controlled by a few aspects, for example,

a. The availability of energy: The more energy available, the greater the rate of evapotranspiration.

b. The humidity gradient away from the surface: The rate and quantity of water vapor entering into the atmosphere both become higher in drier air.

c. The surface wind speed: This is the ET procedure which moves fume of water from the surface of ground or from the surface of water to an adjoining shallow layer.

d. Availability of water: Evapotranspiration cannot occur if water is not available.

e. Vegetation physical qualities: Vegetative spread, surfaces of plant contributes to the evapotranspiration pace. Woodlands reflect just about 25% of sun oriented vitality in this manner holding generous warm vitality to advance transpiration; conversely, deserts reflect as much as 50 % of the sun based vitality, contingent upon the thickness of vegetation [physicalgeography.net].

f. Stomata resistance: Plants regulate transpiration through adjustment of small openings in the leaves called stomata. If there is stomata obstruction then leaf starts building the water fume loss and water fume dispersion starts diminishing through plants into the environment.

g. Qualities of soil: It attributes and influences ET which incorporates the warmth limit and science of the soil.

3.2.4 Interception

Interception is the amount of rainfall, which is intercepted and will not infiltrate into the ground or take apart in the runoff process. It essentially lessens rainfall power by briefly putting away water and there is a loss of ample amount of water. Interception is the part of the rainfall and it does not arrives on the surface of earth, since interception dissipates through shelter and from close ground plants and leaf or less significantly is consumed by plants.

Interception increases exponentially during a storm until the interception capacity is achieved and the weight of more rain overcomes the surface tension holding the water on the plants. Interception depends on the following factors:

i. Trees growth, bushes, grasslands:

a. 25 to 35 percent of yearly rainfall interception by coniferous trees.

b. 15 to 25 percent of yearly rainfall interception by deciduous trees.

ii. Thickness of plants:

a. Information of Biomass (mass per unit region).

b. Forest data.

3.2.5 Surface Runoff

Surface Runoff is flow from a drainage basin or watershed that appears in surface streams. It generally consists of the flow that is unaffected by artificial diversions, storages or other works that society might have on or in a stream channel. Runoff from surface gets collected on the streams by the channels, overflow subsurface which penetrates the soil surface and also collects dirt’s from the groundwater runoff.

Some portion of the subsurface stream enters the stream rapidly while the rest of the bit may take a more drawn out period before joining the water in the stream. When each of the component flows enters the stream, they form the total runoff. The total runoff in the stream channels is called stream flow and it is generally regarded as direct runoff or base flow.

3.2.6 Infiltration

It is the procedure which physically includes water development by the limit zone in the soil environment interface. This surface phenomenon is administered by soil surface conditions. Water transfer is related to the porosity of the soil and the permeability of the soil profile. Typically, the infiltration rate depends on the striking of the water at the soil surface by the impact of raindrops, the texture and structure of the soil, the initial soil moisture content, the decreasing water concentration as the water moves deeper into the soil filling of the pores in the soil matrices, changes in the soil composition.

3.2.7 Base flow

Base flow shows the seepage of ground water into a channel of stream. During most of the year, stream flow is composed of both groundwater discharge and land surface runoff. When groundwater provides the entire flow of a stream, base flow conditions are said to exist. The amount of base flow a stream receives is closely linked to the permeability of rock or soil in the watershed.

3.3 Water Balance Importance

Water balance idea gives a system to contemplating the hydrological qualities and conduct of a catchment. The water balance estimation is vital in water assets improvement for financial examination of the undertaking as well as to check the dependability which includes general example on water accessibility by month to month or yearly premise. Water project includes arranging, improvement, and activity assets water project and is dependent on water accessibility to the necessary amount. Study of water balance gives number of methods for testing, affirming the framework for hydrological understanding [C.P. Kumar et al., 2003]. Key terms to describe various water balance conditions are:

a. **Water Surplus:** There is excess water available to the system. This occurs when precipitation exceeds evapotranspiration.

b. **Deficiency:** There is a reduction of water available within the system. This occurs when evapotranspiration exceeds precipitation.

c. **Recharge:** After a period of deficiency precipitation will occur and replace the lost water in the soil. This needs to occur before a period of surplus can reoccur.

d. **Field capacity:** The maximum amount of water that soil can hold before it becomes saturated.

3.4 Sustainable Water Management

It is the water resource management which considers the requirements according to the needs of present and future. In any case, it includes substantially more than its name infers. It includes an entirely different perspective on we utilize our valuable water assets.

"Water problems cannot be tackled through specialized arrangements; answers for water issues require the thought of social, instructive, correspondence and logical perspectives. After expanding water significance acknowledgment, fresh water maintenance in the area by the management assures commitment to keep away from water-related issues including future clashes which can be found."

In this manner, it endeavors to manage water in a comprehensive style considering the different areas influencing use of water which includes political, social, financial, innovative and ecological contemplations. With this in mind, accompanying assets the executive’s destinations are pivotal:

a. Balancing groundwater recharge against abstraction is the main emphasis of groundwater management.

b. Sustainable management of water resources cannot be achieved only by addressing surface water management but must include groundwater. Another methodology directed through IUWM objectives and standards must be required for strengthening of water administration and the board.

CHAPTER 4

METHODS AND TOOLS USED FOR WATER BALANCE & IUWM STUDY

4.0 Methods Used for Water Balance Study

Methods used for water balance includes the principle hydrology subjects are a means of solution of important theoretical and practical hydrological problems. On the basis of the water balance approach it is possible to make a quantitative evaluation of water resources and their change under the influence of environmental and climatic activities [Alam et al., 2016].The storage change(ΔS_t) in water balance plan of a catchment for an interval of time Δt is composed as

$$\Delta \boldsymbol{S_t} = \boldsymbol{P_r} - \boldsymbol{R_s} - \boldsymbol{G_w} - \boldsymbol{E_v} - \boldsymbol{T_r} \qquad \textbf{(4.1)}$$

Where;

P_r = Area precipitation

E_v = Total evaporation

T_r = Total transpiration

R_s = Runoff over the surface

G_w = Catchment groundwater flow

ΔS_t = Storage changes

Three components of storage are as follow:

$S_t = S_w + S_i + S_r$

Where; S_w = Storage of surface water

S_i = Soil moisture water storage

S_r = Groundwater storage.

Therefore, $\Delta S_t = \Delta S_w + \Delta S_i + \Delta S_r$

4.1 Methodology to Carry Out the Study for Water Balance

Various localities are confronting difficulties managing fresh water sustainably. Allotment of constrained water assets concerns with respect to its quality, arranging under climate variability and vulnerability, necessity to execute economic efficiency all progressively creates problems to the water asset organizers. Conventional supply-oriented simulation models are not always adequate for exploring the full range of management options. In order to calculate, water balance a number of methods can be used, from simple to complex [Alam et al., 2016].

Method 1: This method is simplest one with equation: $\boldsymbol{P_r = E_v + \frac{dS_t}{dt}}$ **(4.2)**
This technique is especially helpful to the catchment region including vegetation types which must be identified and overflow on surface with penetration are unimportant when contrasted with evapotranspiration. Since infiltration is excessively little and consequently groundwater storage would be too little to even consider here. This strategy shows broad aspects after applying to vast areas of catchment and processing of water must be dependent for future atmosphere situation including ET changes and precipitation changes. Spread of snow and ice dissolving influence ignored continuously. Rainfall impacts all the species of plant, their quality and the amount for proper water utilization, conditions for profundity of root along with conditions of concealing [Rao et al., 2002]. Surface water does not get utilized by aged trees and hence this shows water balance to be less essential [Rao et al., 2002]. Multifaceted natural interactions among components including climate soil and plant framework, worldly change ability spread to the vegetation, accessible measures to water along with dynamic conditions of environment includes specialists for the unpredictability calculations for the ET which occur as water fume motions, a typical water boundary with balance vitality conditions which recognized hydrological displaying like a key feature. Few strategies due to this reason have been created to compute expected evapotranspiration [Rao et al., 2002]. This shows a fundamental boundary through ground water to the calculation which includes viable revive and dissipation.

Method 2: For the calculation of infiltration and runoff, this method shows more accuracy than the previous one as shown in the equation below:

$$\boldsymbol{P_r = E_v + R_u + I_n + \frac{dS_t}{dt}} \qquad \textbf{(4.3)}$$

Runoff of water and water infiltration is based on the type of soil and therefore physical features related to area of the catchment must require for the calculation of runoff. The catchment region can be sub-separated into various little sections along with the known geo-attributes. This GIS information utilization can be useful for distinguishing of dust profile with catchment zone spatial conveyance. For every section ΔS shows the capacity and to assess the capacity it could be figured and summarized.

Assessing of immediate runoff can utilize the strategy of CSS-CN (Conservation of Soil Service). This strategy of CSS can utilized effectively as it shows very useful outcomes to the estimation runoff [Rao et al., 2002]. The CSS method can be used for the following equations below:

$$R_s = \frac{(P_r - 0.2S_t)^2}{(P_r + 0.8S_t)}$$

If; $P_r > 0.2S_t$

And $R_s = 0$ if $P_r < 0.2S_t$

Where R_s shows the volume of collected runoff, P_r shows the total precipitation and S_t shows the maximum soil to water retaining factor calculated from
$S_t = (25000/CN) - 254$ (Q, P_r and S_t in mm),
Where *CN* shows the curve numbers.

Method 3: It shows the maximum accuracy as stream net groundwater available far from the catchment area (G_w) and water extraction or removal (W_s) for water supply or agricultural consumption is taken into consideration.

$$\boldsymbol{P_r = E_v + R_u + I_n + G_w + W_s + \frac{dS_t}{dt}} \qquad \textbf{(4.4)}$$

Flow of ground water or horizontal flow from subsurface can be registered utilizing hydrograph. While overflow and penetration relies upon the type of soil the catchment territory can be further divided into various little fragments utilizing GIS information and calculation can be completed. Notwithstanding, the absolute water withdrawal must be deducted and determined, process complete storage capacity ΔS for acquiring catchment zone storage.

Method 4: This method is the easier and accurate one as recharge by rainfall, recharge by canals, recharge by field irrigation, total recharge and average annual drought is taken into consideration [Alam et al., 2016].

$$\boldsymbol{Water\ Balance\ (W) = R - D} \qquad \textbf{(4.5)}$$

In this study, we have applied method 4 for water balance study of Chandigarh region to calculate rainfall, recharge and drought values because this method is easy to get accurate results for the region. We have applied this method and got the overall recharge value for the region and we also came to know the estimate required to recharge the region by double plumbing and how much water is to be treated for this purpose.

In this study, we have included Chandigarh area and for more accuracy in the thesis, we had done a case study on Tricity residential building construction, where we finally implemented our results and made this study helpful for managing future water crisis.

4.2 Sustainable Sources of Water

a. Water stored in tanks and water bodies.
b. Study area collects overall rainfall greater than 70% in the city. It shows an effectiveness to enhance the water resources of the city.
c. Recycled water usage will be compulsory in newly constructed large buildings or in new developments for the non-potable uses. If MC fails to supply that water then there must be a water treatment plant nearby the building for the waste water reuse.

4.3 Identified Places in Chandigarh to Carry out this Study

a. Sukhna Drain
b. Patiala ki Rao Drain
c. STP Diggian Outlet (30MGD)
d. STP Raipur Khurd Outlet (1.25MGD)
e. STP Raipur Kalan Outlet (5MGD)
f. STP Dhanas Outlet (1.6MGD)

Proposed Areas (under construction) by Municipal Corporation and CPCC:

a. Khuda-ali-sher with capacity 1.7MGD.
b. Diggian Mohali with capacity 15MGD.

From above places, we have collected 2 samples each which include drains, outlets, and lakes to check their water quality.

4.4 Type and Source of Data Collected

a. Rainfall – Meteorological Department, Sector-39, Chandigarh.

b. Waste water- Paryavaran Bhawan, Sector-19 B, Chandigarh Pollution Control Committee (CPCC), Madhya Marg, Chandigarh.

c. Storm water- CPCC, Chandigarh.

d. Ground water- Environment Information System, Sector 19-B, Paryavaran Bhawan, Chandigarh.

e. Treated water- Municipal Corporation, Sector 17-C, Chandigarh.

4.5 Data and Sample Collection

Collection of data includes the rainfall, wastewater, storm water, ground water and treated water from the various organisations working in Chandigarh like Environment Information System, Chandigarh Water Resources, Municipal Corporation, Meteorological Department etc. The primary data related to water characteristics prevailing in study area are generated through various tools like on- site observations related to water sample collection, laboratory testing and from the various organisations, questionnaires were conducted. Water samples were collected from various lakes, STPs and drains to check the quality of water. Then we have checked the water quality of these samples in the laboratory.

Fig 4.1: Water Sampling location and sample for testing

4.6 List of Organisations Working in this Field and Type of Data They Have

a. Institutional Organisations

b. Environmental Information System

c. Chandigarh Water Resources
d. Environment Protection Authority
e. Municipal Corporation
f. Local Government
g. Land Developers
h. Consultants

4.7 Frequency Period

It includes 10 years of data analysis in which we have analyzed the data on Matlab. We have collected the data of 10 years and then divided that data into January to March, April to June, July to September and October to December segments.

4.8 Data Analysis

In the data analysis, we used the statistical approach using Matlab, XLSTAT, MS Excel. In this we used the 10 years data to analyse it appropriately. We have also used hydrological model like water balance model for more accuracy.

4.9 To Develop a Method of Using Combined Treated Water (Stormwater and Wastewater)

We have considered this project for the study which would be helpful for the water management in the city. It includes Tricity where we finally implemented our results and made this study helpful for future water crisis and also for future generation.

CHAPTER 5

DATA COLLECTION AND ANALYSIS

5.1 Study Area Chandigarh

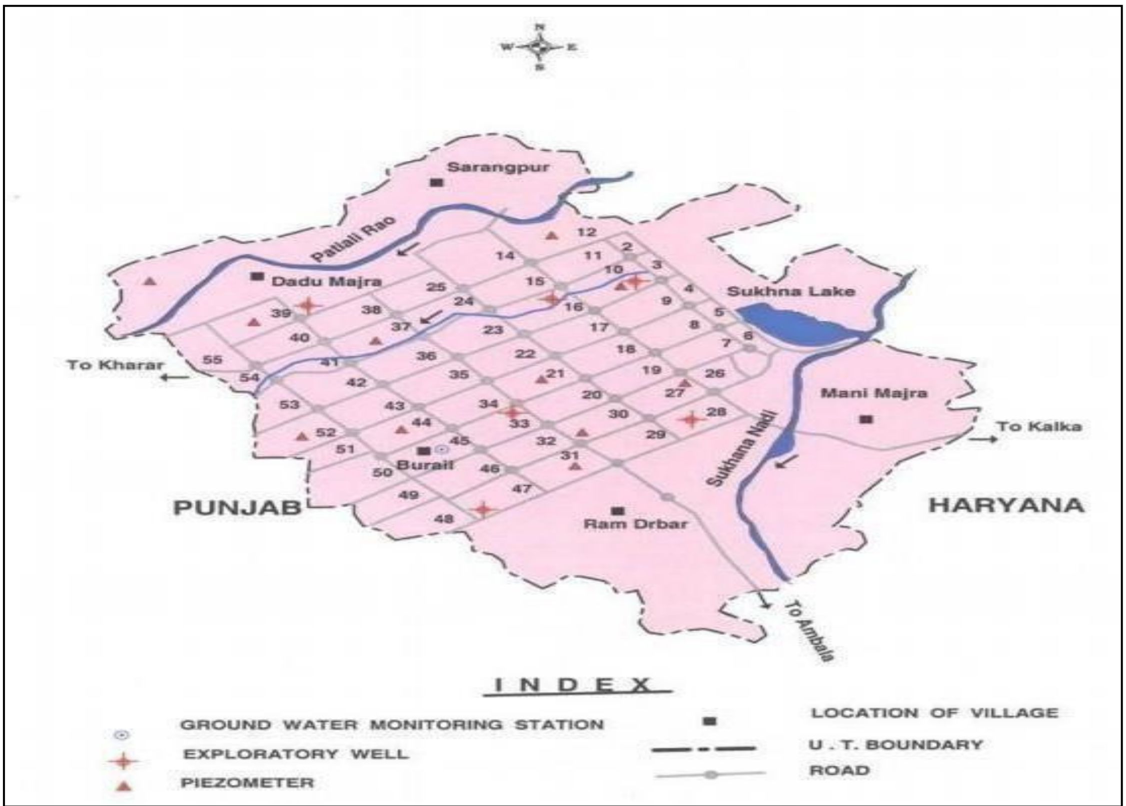

Fig. 5.1: Study Area Chandigarh

As demand of water in the country is rising day by day, it is very important to take some actions for the country as well as for the city's water planning. For this study we have selected the city beautiful where we have to implement our research outcomes for the protection of environment as well as to cater for water shortage problem. Chandigarh is the centre of Punjab, Himachal, Uttrakhand and Haryana, so everyday population is rising because of students as Chandigarh is a hub of study for these regions. Due to this we have to manage water requirements accordingly. In this chapter firstly we have to understand the current scenario of the city.

The present water supply service area of Municipal Corporations Chandigarh (MCC) is 114 km^2, which includes MCC area 79.34 km^2 and rural area of 34.69 km^2. The urban area falls in jurisdiction of Municipal Corporation and the water supply system is entrusted to Public Health wing of MCC. The transmission mains carry raw water from Kajauli to the water treatment plants located at Sector 39, Chandigarh. At

Sector 39, the water is treated, disinfected and transmitted to subsidiary water works located in sectors 12, 26, 32, 37, 39, 52 and Manimajra.

The average availability of water in Chandigarh is reasonably high at 332 Litres per Capita per Day (LPCD), stands second in the country after Goa (343 LPCD). Chandigarh gets 14.5 million gallons per day (MGD) water as its share from each phase of Kajauli water supply scheme. It is estimated that by 2026, the water demand will be 523.41 MLD (138.27 MGD) that is about 22.72% higher over the 2011 demand of 426.50 MLD (112.67 MGD) [MC Chandigarh, 2019].

5.1.1 Water Connections

An increase in the population had likewise increment the request of water for the everyday purposes. Water supply in Chandigarh is directed by the metropolitan organization of the city and it was ascertained that the aggregate water connections have been expanded from 1,36,094 out of 2009-10 to 1,56,668 in the year 2016-17. Regularization of the unmetered associations is likewise moving at a quicker rate in the city. The table underneath speaks to the aggregate residential and commercial associations alongside the aggregate length of water supply pipeline laid in the city till 2017.

Table 5.1: Water Connections (2004-2017)

Water Connections			
Year	**Domestic Connections (No's)**	**Commercial Connections (No's)**	**Total length of Pipelines laid (Km's)**
2004-05	113525	7814	1300
2005-06	115603	7854	1300
2006-07	117625	7891	1400
2007-08	121797	7974	1450
2008-09	143766	13396	1650
2009-10	122953	13141	1650
2010-11	127103	13139	1650
2011-12	147692	12610	2730

Water Connections			
Year	**Domestic Connections (No's)**	**Commercial Connections (No's)**	**Total length of Pipelines laid (Km's)**
2012-13	137790	13346	1381
2013-14	141927	14803	1399
2014-15	145033	13330	1404
2015-16	142633	14731	1613
2016-17	134879	21789	1800

Source: [MC Chandigarh, 2019]

5.1.2 Total Water Availability and the Possible Projection of its Demand in Near Future

As per Bureau of Indian Standards (BIS) code 1172-1993 the per capita water prerequisite for the urban areas with homes more than 1,00,000 population with full flushing frameworks require 150-200 Liters per day. This may boil down to 135 LPCD for Economically Weaker area of the general public. In this specific situation, Chandigarh is giving more water per capita than required. Water request in light of the current population (statistics 2011) is around 426.50 MLD. This incorporates 158.25 MLD for local utilization, 29.09 MLD for plugs/mechanical request, 46.15 MLD for group/institutional request, 20.07 MLD for stand post rest room squares and wastage of water almost 15% stands at 38.04 MLD. In addition, agricultural water demand is 134.90 MLD [MC Chandigarh, 2019].

5.1.3 Status of Drinking Water in Chandigarh

The City has been partitioned into 7 zones with the end goal of circulation of drinking water including town of Manimajra. The aggregate introduced limit of drinking water from the four periods of surface source is around 67 MGD. Aside from the channeled supply, around 20 MGD is additionally pre-occupied through profound borewells with control pumps. Out of the aggregate 156730 water associations, over 94% associations are metered and level rate associations are given to restore settlements. Other than there are 800 stand posts in the city 332 LPCD water is 10-12 hours [ENVIS Chandigarh, 2019].

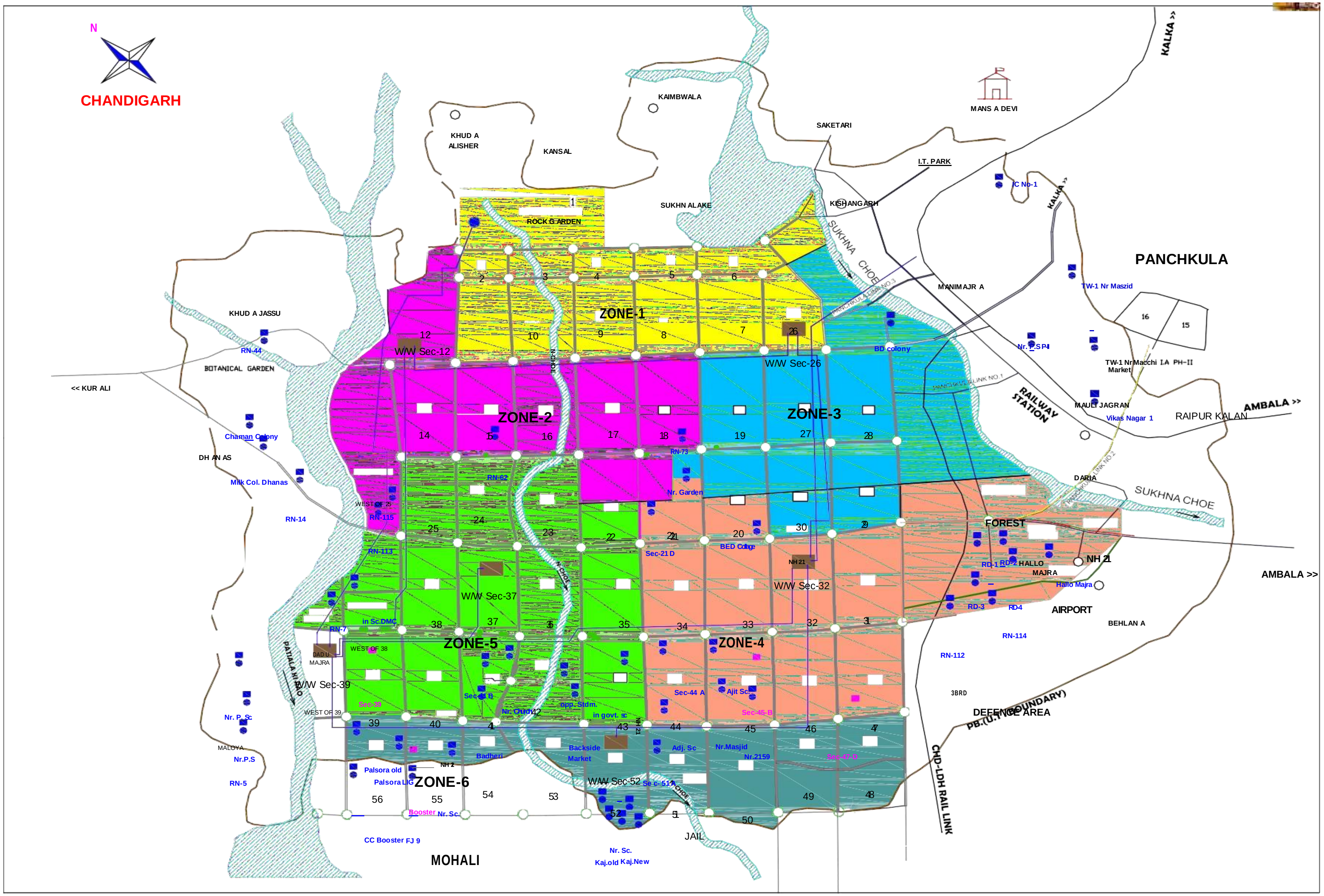

Fig. 5.2: Zoning Plan of Water Supply Distribution [MC Chandigarh, 2019]

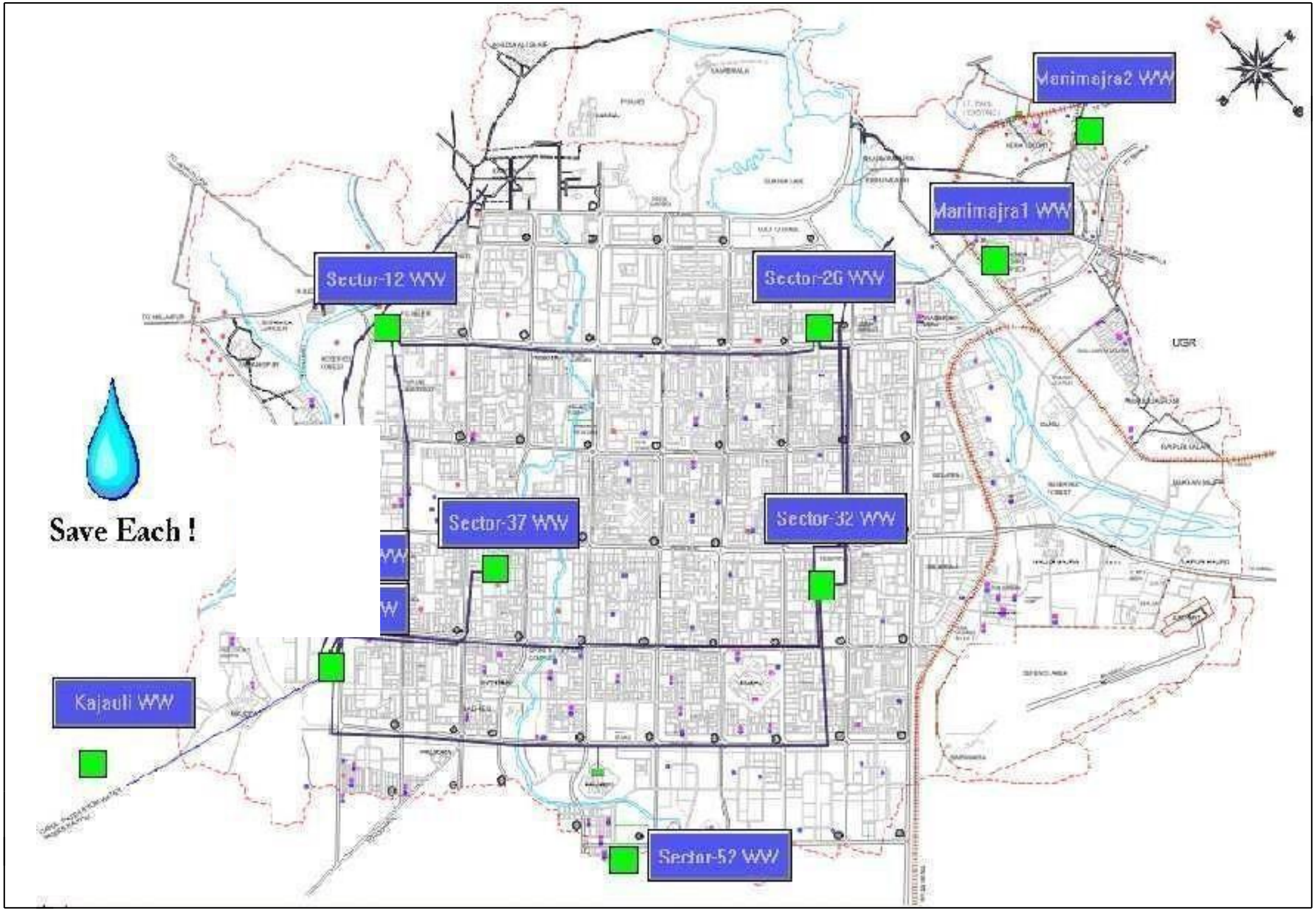

Fig. 5.3: Water Works Location Plan [MC Chandigarh, 2019]

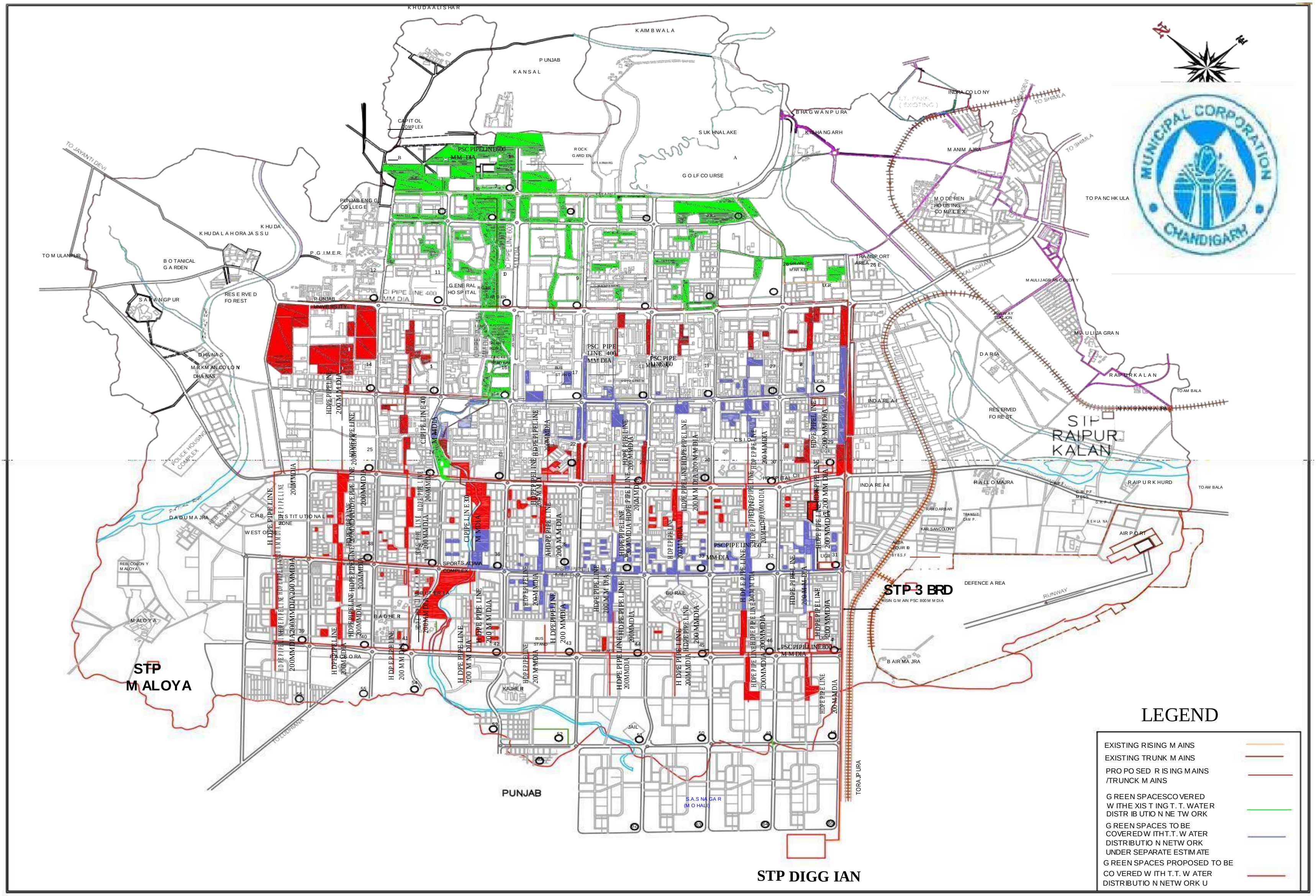

Fig. 5.4: Water Supply Pipe Network in Chandigarh [MC Chandigarh, 2019]

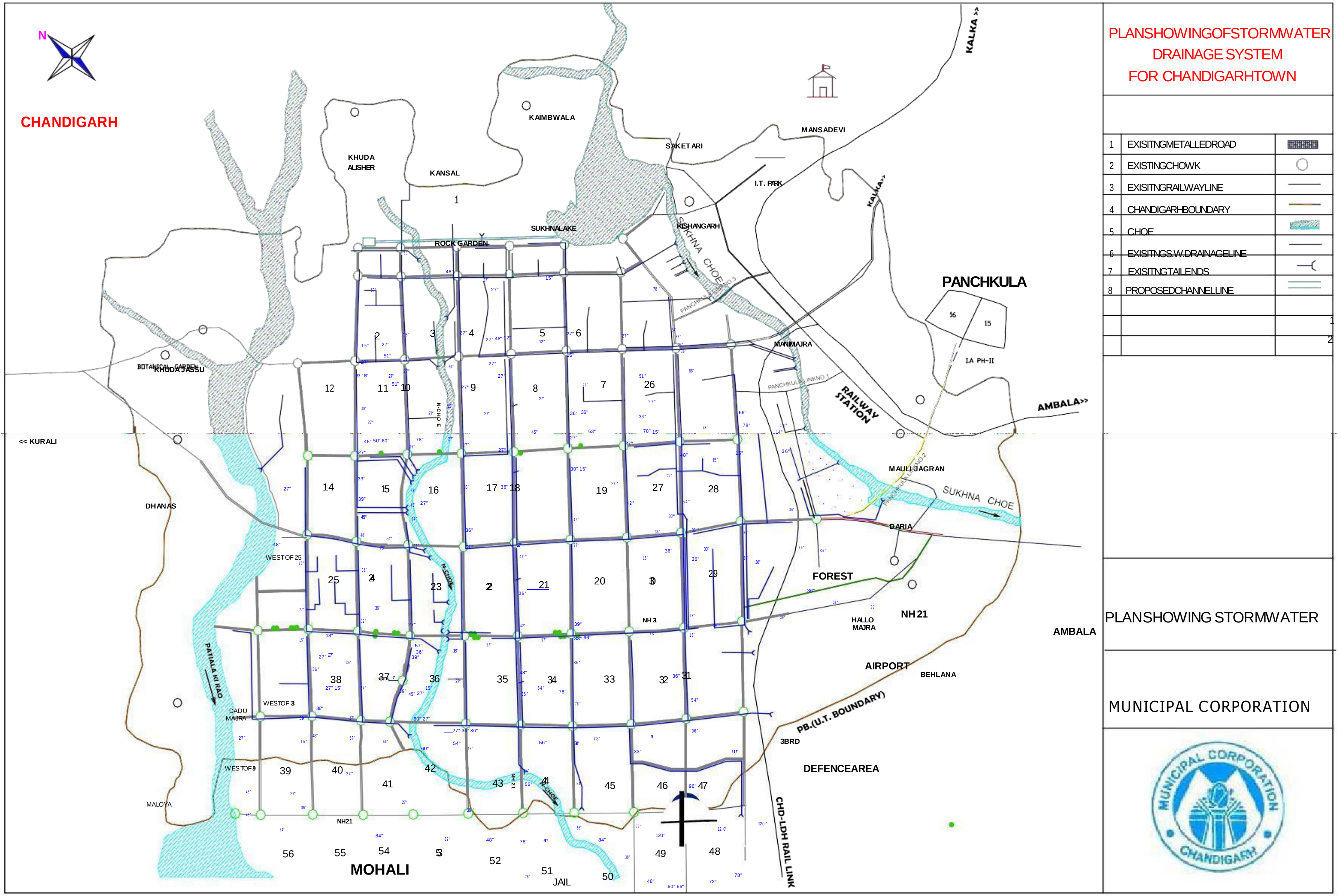

Fig. 5.5: Water Drainage System in Chandigarh [MC Chandigarh, 2019]

5.1.4 Water Supply and Demand Scenario

Table 5.2: Water Supply and Demand Scenario (2006-2036)

Year	Population in lacs	Domestic requirement in MLD	Industrial commercial @4 000 gallon(Acres) Day area in acres	Industrial commercial requirement in MLD	Community Institutional @40 00 gallon/acres	Community Institutional Requirement in MLD	Requirement for stand Post Lav Blocks MLD	Wastage water leakage %	Total leakage in MLD	Total requirement	Horticulture requirement @5400 gallon/acres/ day area in acres	Horticulture requirement in MLD	Gross requirement in MLD
2006	10.98	164.7	1921.6	34.91	3048.50	55.34	16.47	22	59.71	331.13	6600	161.80	492.93
2009	12.36	185.4	1921.6	34.91	3048.50	55.34	17.00	15	43.90	336.55	6600	161.80	498.35
2011	13.38	200.7	1921.6	34.91	3048.50	55.34	20.07	15	46.65	357.67	6600	161.80	519.47
2016	16.29	244.3	1998.5	36.27	3170.44	57.56	24.43	8	29.00	391.61	6600	161.80	553.41
2021	19.85	297.7	2078.4	37.72	3297.25	59.88	29.77	8	34.00	459.12	6600	161.80	620.92
2026	24.19	362.8	2161.6	39.27	3429.15	62.28	36.29	8	40.05	540.74	6600	161.80	702.54
2031	29.46	441.9	2248.0	40.82	3566.32	64.76	44.19	8	47.33	639.00	6600	161.80	800.80
2036	35.91	538.6	2338.0	42.46	3709.00	67.35	53.86	8	56.19	758.51	6600	161.80	920.31

Source: [MC Chandigarh, 2019]

5.1.5 Water Conservation Practices in Chandigarh

Water preservation implies protecting our water assets from contamination and being wasted. It is imperative since plants, people and creatures all need water to survive. Without water, the earth would have no life. Because of reliable water assets, however expanding population and request of water; the city wonderful has likewise been rehearsing water protection by following diverse preservation methodologies.

Rain Water Harvesting: Rainwater harvesting (RWH) for revive enlargement is among the real exercises being taken by the Central Ground Water Board forth eviable execution of decisive plans. With the exponentially expanding interest of water assets because of heightening populace, the city wonderful "Chandigarh", has likewise ensnared the plan at the exceptional speed in a limited ability to focus time. The water reaping capability of Chandigarh with the normal yearly precipitation is 1059.3 [ENVIS Chandigarh, 2019]. In this manner, the potential is more than the water drew out of aquifers and along these lines, effective harvesting of water and legitimate energizing of groundwater will go far in contributing towards manageability of water supply.

5.1.6 Drainage System in Chandigarh

The drainage system of Chandigarh includes the sectors from 1 to 56 along with the length of storm water drainage pipeline in the city. The scenario is shown below in the table:

Table 5.3: Drainage System in Chandigarh (2007-2016)

Year	Sectors With Planned Drainage System	Sectors With Originally Planned Drainage System	Sectors With Modified Planned Drainage System	Length of Storm Water Drainage (KM)
2007	1 To 56 Sectors	1 To 56 Sectors	1 To 56 Sectors	713
2008	1 To 56 Sectors	1 To 56 Sectors	1 To 56 Sectors	713
2009	1 To 56 Sectors	1 To 56 Sectors	1 To 56 Sectors	713
2010	1 To 56 Sectors	1 To 56 Sectors	1 To 56 Sectors	713
2011	1 To 56 Sectors	1 To 56 Sectors	1 To 56 Sectors	715
2012	1 To 56 Sectors, 61 & 63 Sector	1 To 56 Sectors	1 To 56 Sectors	720
2013	1 To 56 Sectors, 61 & 63 Sector	1 To 56 Sectors	1 To 56 Sectors	722
2014	1 To 56 Sectors, 61 & 63 Sector	1 To 56 Sectors	1 To 56 Sectors	1030
2015	1 To 56 Sectors, 61 & 63 Sector	1 To 56 Sectors	1 To 56 Sectors	1030
2016	1 To 56 Sectors, 61 & 63 Sector	1 To 56 Sectors	1 To 56 Sectors	1050

Source: [MC Chandigarh, 2019]

5.1.7 Recycle and Reuse of Treated Waste Water

Chandigarh is completely secured with sewerage office and furnished with the 100% sewerage treatment facility. Out of 87 MGD water being provided to the occupants of the city, 57 MGD sewage effluent is being created every day. Out of which, normal 53.85 MGD waste water is treated consistently.

Table 5.4: Recycle and Reuse of treated waste water (2019)

City Data	Waste Water Related Data
Municipal population	11 lacs (approx..)
Domestic & Industrial waste water generated	57 MGD (approx.)
Treated waste water	53.85 MGD
No. of STPs	5
Capacity of each STP	16 MGD – 3BRD
	5 MGD – Raipur Kalan
	30 MGD – Diggian
	1.25 MGD – Raipur Khurd
	1.6 MGD – Dhanas
	Total: 53.85 MGD
Proposed STPs	1.7 MGD at Khuda-ali-sher
	15 MGD is under renovation Diggian, Mohali
	Total: 16.7 MGD
Mode of disposal	Natural Choe for all except Diggian. Diggian STP effluent goes to Irrigation Channel.

Source: [MC Chandigarh, 2019]

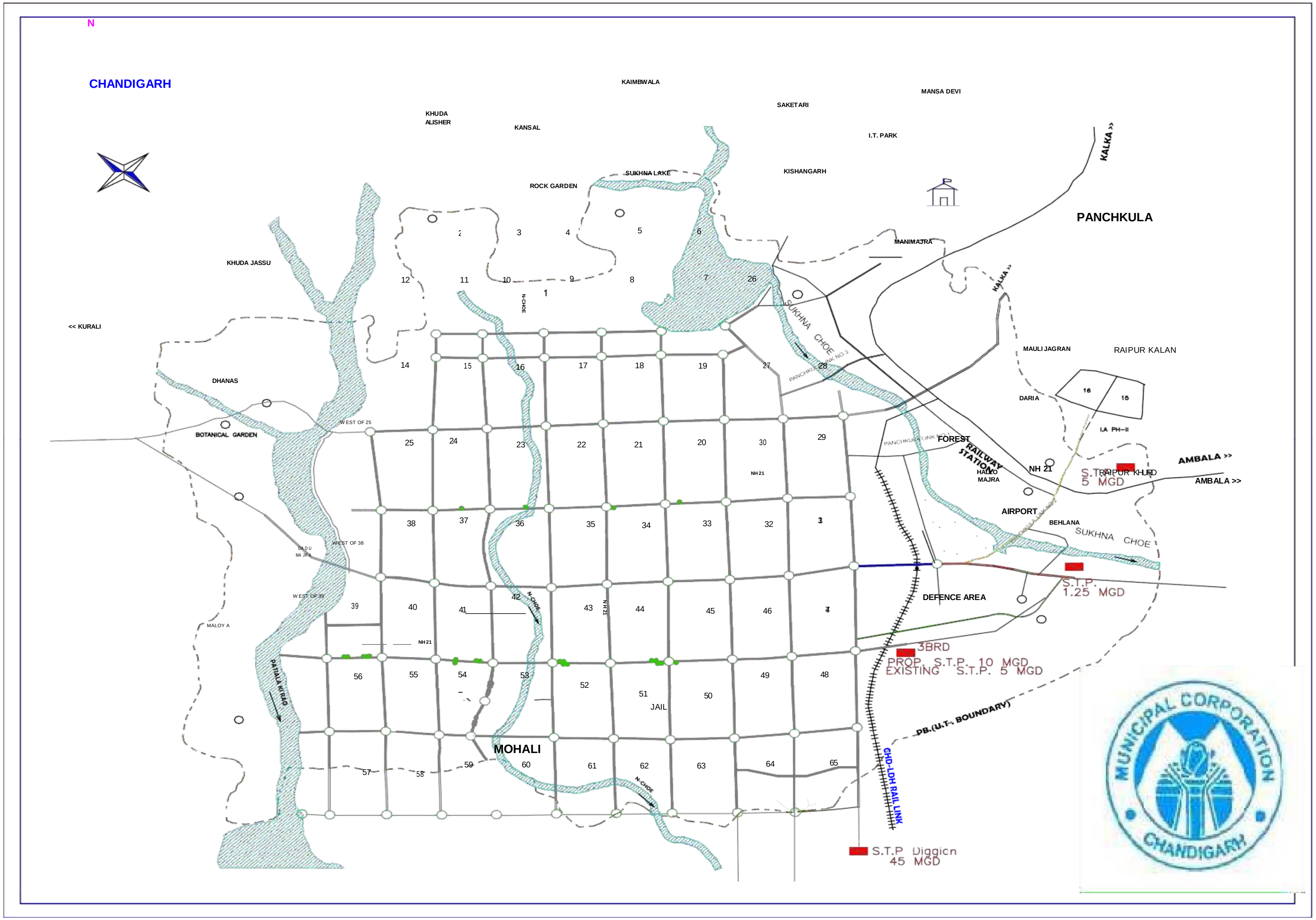

Fig. 5.6: Sewage Treatment Plants in Chandigarh [MC Chandigarh, 2019]

5.1.8 Water Quality Analysis of Drains/STP

Water quality examination of the considerable number of water channels like Choes, drains and sewage treatment plants set up in the U.T. area are quite frequently (monthly basis) to watch out for the quality of water moving through the city. Except the open drains (Sukhna Choe, Patiala Ki Rao, North Choe) going through the city, the treated water of STP's lies close to the acceptable limits.

According to the new rules upgradation by MC Chandigarh of all STP's is proposed to take the BOD of treated water underneath the limit of 10 mg/L. No groundwater from shallow tube wells in Chandigarh is endorsed as drinkable. MC weakens in utilization of hand pumps for drinking water.

Table 5.5: Water Quality Analysis of Drains/STP

Parameters	**Sukhna lake**	**Attawa**	**Sukhna Choe /Drain**	**PKR**	**Baltana**	**Lake - 42**	**Dhanas Lake (D1)**	**Diggian Tertiary Treatment**	**Diggian**	**3 BRD**	**Raipur Khurd**	**Raipur Kalan**
pH	7.9	7.5	7.8	7.6	7.3	8.6	7.5	7.5	7.7	7.3	7.9	7.4
DO (mg/l)	<1	1.8	<1	< 1	<1	5.2	<1	<1	1.1	< 1	<1	<1
COD (mg/l)	40	96	101	400	61	20	32	44	105	263	97	307
BOD (mg/l)	8	40	28	141	22	4	13	13	28	71	31	92
TSS (mg/l)	14	90	55	270	45	15	40	30	50	120	28	25
NH3-N (mg/l)	1.2	5.6	3.5	18.2	2.6	BDL	1.6	1.8	3.2	8.5	3.6	12.4
NO3-N (mg/l)	2.1	1.9	2.6	1.8	3.1	BDL	2.1	1.3	1.5	2.1	2.1	1.7

Source: [ENVIS Centre Chandigarh, 2018-2019]

5.1.9 Waste Water Conservation and Treatment Practices in Chandigarh

The city of Chandigarh has an all-around arranged underground system of channels for the transfer of sewerage produced in the city. The sewerage arrangement of the city has been planned by considering the characteristic slant of the city, which is from north to south. The sewage of the city streams under gravity in different pipes of various distances across going from 152.4 mm to 457.2 mm S.W. Pipes and 609.6 mmx914.4 mm to 1676.4 mm dia roundabout Brick sewer.

The aggregate length of the sewer lines in the city is 890 km. The sewage is conveyed to a site in the south of the city where a plant has been built for its treatment and the treated sewage is than arranged off in an open Nallah. There are few compartments in the city which are at bring down level and in this way the sewage of these compartments can't be released under gravity into the centralized sewerage arrangement of the city. The sewage of these compartments is drawn into the sewerage structure and from there to the streams under gravity to the Sewage Treatment Plant.

The Sewage Treatment Plant is situated at Sector 66 of S.A.S. Nagar in Punjab Territory which is at a distance of around 4 km from the closest arranged Sector 47. The present limit of the Sewage Treatment Plant is 30 MGD although around 48 MGD sewage is developed at the Sewage Treatment Plant. The sewage got at S.T.P. is subjected to essential, optional and tertiary treatment. Out of the 48 MGD sewage got at the Sewage Treatment Plant, 35 MGD is dealt with upto possible level and out of this 13 MGD is additionally treated upto tertiary level.

The tertiary treated sewage is reused back to the city for water system of open spaces/gardens. The Secondary treated sewage is discharged in an open Nallah. There were break downs in the supply of tertiary treated water because of spillages in the line. Zero speed valves have been given in the line to keeping away from break downs [MC Chandigarh, 2019].

5.1.10 Water Drainage in Chandigarh

The city has well laid out underground storm water seepage framework. The Storm Water Drainage System has been composed from North West to South East. It was at first intended for 12.7 mm every hour. On the account of the expanded green zones/open spaces going under development, the run off coefficient has expanded massively. This has brought about the over loading of storm water seepage framework and thus flooding of low lying sections in the city. The Municipal Corporation had led a study and recognized 35 such sections.

The storm water waste framework in these pockets has been increased by giving extra lines and street gullies. So as to meet the circumstance of flooding, it had been wanted to expand the principle trunk lines running from North to South.

One source running between part 17 and 18, 21 and 22, 34 and 35, 43 and 44 and releasing in the N-Choe in division 51 has been laid. To expand the waste framework, extra lines have been given in division 7, 8, 15, 24, 28, V3 street isolating part 34 and 44, 38, 41 [MC Chandigarh, 2019].

5.2 Collection and Analysis of Data

Data and sample collection includes:

a. Rainfall
b. Canals
c. STPs
d. Drains
e. Lakes
f. Treated water
g. Tube wells
h. Stormwater

5.3 Treated Water & STP's Data

Chandigarh is completely secured with sewerage office and furnished with the 100% MGD sewage effluent is being created every day. Out of which, normal 53.85 MGD wastewater is treated consistently.

Perceiving the significance of water, Chandigarh had started tertiary treatment of wastewater at Diggian STP (10 MGD) and later provided it for the non- consumable uses, for example, water system of greenery enclosures, green belts and yards, washing autos and so forth, to various divisions.

Directly, the introduced limit with respect to tertiary treatment is 20 MGD at Diggian STP which is treating 10 MGD water (avg.)

Table 5.6: Data of Treated Water & STP’s

Year	Municipal Population (Lac)	No. of STPs	Capacity of Each STP	Treated waste per STP	Volume of domestic (MGD)	Volume of waste water collected (MGD)	Treated waste water (MGD)	Secondary treatment of waste water (MGD)	Tertiary treatment of waste water (MGD)	Mode of disposal
2018	1128065	5	3 BRD; 5 MGD, Diggian 30 MGD Raipur Kalan	Raipur Kalan: 5 MGD on UASB Technology	57	65/57	52.9	57	10	10 MGD sewer age after treatment

Source: [ENVIS CENTRE Chandigarh, 2019]

Table 5.7: Data of Treated Water & STP’s

Year	Municipal Population (Lac)	No. of STPs	Capacity of Each STP	Mode of Disposal
2018	10 : (Urban)	3 BRD, 5 MGD	Raipur Kalan: 5 MGD, Maloya: 5 MGD	Tertiary level is pumped back to city for irrigation of lawns & open spaces and the balance after treatment upto secondary level is discharged into Natural Streams.
2019	11 : (Urban)	5	Kalan: 5 MGD, Raipur Khurd : 1.25, Dhanas:1.65 MGD, Maloya: 5 MGD	Tertiary level is pumped back to city for irrigation of lawns & open spaces and the balance after treatment upto secondary level is discharged into Natural Streams.

Source: [ENVIS CENTRE Chandigarh, 2019]

Table 5.6 shows the various parameters and total quantity of treated water whereas table 5.7 shows the areas where water is going after the treatment e.g. irrigation.

5.4 Tube well & Canal Water

Chandigarh has a population of roughly 10 lakhs today. To cater to the water demand of the population, it requires 493 MLD (108 MGD) water, whereas available supply is only 363 MLD (80 MGD). Thus there is a shortage of about 130 MLD (28 MGD). A major part of water requirement of the city is met by canal water. Canal water supply to the city is approximately 272 MLD (60 MGD).

Table 5.8: Data of Tube well & Canal Water

Year	Tube Wells Deep Shallow	Canals
2017-19	281 Nos.	From Bhakra Main Canal

Source: [ENVIS CENTRE Chandigarh, 2019]

5.5 Storm Water

The city has well laid out underground storm water seepage framework. The storm water drainage system has been composed keeping in see the incline of the city i.e. from North West to South East. It was at first intended for a rain force of half inch every hour. Notwithstanding, on account of the expanded green zones/open spaces going under development, the keep running off co-proficient has expanded enormously. This has brought about the over stacking of storm water seepage framework and thus flooding of low lying pockets in the city.

The Corporation had led a study and recognized 35 such pockets. The storm water waste framework in these pockets has been increased by giving extra lines and street ravines. So as to meet the circumstance of flooding, it had been wanted to expand the principle trunk lines running from North to South. One trunk principle running between part 17 and 18, 21 and 22, 34 and 35, 43 and 44 and releasing in the N-Choe in division 51 has been laid at a cost of about Rs.2 crores. To expand the waste framework extra lines have been given in division 7, 8, 15, 24, 28, V3 street isolating part 34 and 44, 38, 41.

Extra lines have additionally been given on street prompting railroad station. Around 500 vertical street ravines have been given to build the admission of water in the storm water distribution lines. The storm water channels have likewise been given in rehabilitation state Maloya, Janta and Kumhar Colony segment 25 to expand the waste extra lines framework. The Municipal Corporation has attempted an examination to set up a storm water waste strategy to ease the issues of flooding. The study suggested extending and enlarging of the nallahs for the segments influenced by infringements, adjustment to cross seepage works, some delicate estimates, for example, anticipation of unloading of waste into the nallahs to prevent clogging.

Table 5.9: Data of Storm Water

Year	Sectors With Planned Drainage System	Sectors With Originally Planned Drainage System	Sectors With Modified Planned Drainage System	Length of Storm Water Drainage (KM)
2007	1 to 56 Sectors	1 to 56 Sectors	1 to 56 Sectors	700
2008	1 to 56 Sectors	1 to56 Sectors	1 to56 Sectors	705
2009	1 to 56 Sectors	1 to 56 Sectors	1 to 56 Sectors	713
2010	1 to 56 Sectors	1 to 56 Sectors	1 to 56 Sectors	713
2011	1 To 56 Sectors	1 to 56 Sectors	1 to 56 Sectors	715
2012	1 to 56 Sectors,61 & 63Sector	1 to 56 Sectors	1 to 56 Sectors	720
2013	1 to 56 Sectors,61 & 63Sector	1 to 56 Sectors	1 to 56 Sectors	722
2014	1 to 56 Sectors,61 & 63Sector	1 to 56 Sectors	1 to 56 Sectors	1030
2015	1 to 56 Sectors,61 & 63Sector	1 to 56 Sectors	1 to 56 Sectors	1030
2016	1 to 56 Sectors,61 & 63Sector	1 to 56 Sectors	1 to 56 Sectors	1050
2017	1 to 56 Sectors,61 & 63Sector	1 to 56 Sectors	1 to 56 Sectors	1050
2018	1 to 56 Sectors,61 & 63Sector	1 to 56 Sectors	1 to 56 Sectors	1060

Source: [ENVIS CENTRE Chandigarh, 2019]

Chandigarh has an aggregate rain water collecting limit of over 70% of the aggregate land region.

The aggregate limit of water that would be accessible for energize every year is:
58 sq. km (area) x 1059.3 (rainfall) x 0.5 (rainfall coefficient) = 30,720 million litres.

Table 5.10: Area wise Storm water (2018-2019)

Area	Collection of Storm Water from different areas
From Roads	15.89 sq. km
From the Rooftop of Residential area	30.19 sq. km
From Public and Institutional Buildings	7.94 sq. km
From Shopping area	3.97 sq. km

Source: [ENVIS CENTRE Chandigarh, 2019]

5.6 Rainfall Data

Rainfall data was collected from the Daily report of the Indian Metrological Department, Sector-39, Chandigarh [IMD Chandigarh, 2019].

Fig. 5.7: Ordinary Rain Gauge

Table 5.11: Data of Rainfall 2016

Year	Month	No. of Rainy Days	Total Rainfall During the Month (mm)
2016	January	5	1
2016	February	3	1
2016	March	9	53.1
2016	April	9	24.4
2016	May	9	40.4
2016	June	17	133
2016	July	28	109.5
2016	August	25	113.5
2016	September	8	63
2016	October	0	0
2016	November	0	0
2016	December	1	29.4

Source: [IMD Chandigarh, 2019]

Table 5.11 shows the rainfall data for the month of 2016 taken from meteorological department, Sector-39, Chandigarh. Daily data month wise was collected for the analysis purpose. From the table, it is clear that July and August have maximum rainfall in the city which shows the maximum generation of storm in the city. Rest other months has less rainfall, so the generation of storm water will be less too. In the peak months, storm water management is necessary to reduce water wastage in the Chandigarh city. We can use this storm water for irrigation purposes, future water use, gardening, car washing, toilet flushing etc. We have analysed this data by proper calculations and this data will definitely help to predict the amount of rainfall that will occur in the future and also in the prediction of floods and drought too.

Table 5.12: Data of Rainfall 2017

Year	Month	No. of Rainy Days	Total Rainfall During the Month (mm)
2017	January	8	132
2017	February	2	3
2017	March	4	23.2
2017	April	6	13.9
2017	May	3	5.3
2017	June	9	69
2017	July	27	242.2
2017	August	22	264.8
2017	September	6	154.2
2017	October	0	0
2017	November	0	0
2017	December	3	16.6

Source: [IMD Chandigarh, 2019]

Table 5.12 shows the rainfall data for the month of 2017 taken from meteorological department, Sector-39, Chandigarh. Daily data month wise was collected for the analysis purpose. From the table, it is clear that July and August have maximum rainfall in the city which shows the maximum generation of storm in the city. Rest other months has less rainfall, so the generation of storm water will be less too. In the peak months, storm water management is necessary to reduce water wastage in the Chandigarh city. We can use this storm water for irrigation purposes, future water use, gardening, car washing, toilet flushing etc. We have analysed this data by proper calculations and this data will definitely help to predict the amount of rainfall that will occur in the future and also in the prediction of floods and drought too.

Fig. 5.8: Ordinary Rain Gauge Set up Area

Table 5.13: Data of Rainfall 2018

Year	Month	No. of Rainy Days	Total Rainfall During the Month (mm)
2018	January	1	4.4
2018	February	3	59.6
2018	March	3	3
2018	April	15	26
2018	May	4	8
2018	June	15	121.6
2018	July	23	319.2
2018	August	28	304.6
2018	September	15	270
2018	October	2	18.6
2018	November	2	9.6
2018	December	2	11.5

Source: [IMD Chandigarh, 2019]

Table 5.13 shows the rainfall data for the month of 2018 taken from meteorological department, Sector-39, Chandigarh. Daily data month wise was collected for the analysis purpose. From the table, it is clear that July and August have maximum rainfall in the city which shows the maximum generation of storm in the city. Rest other months has less rainfall, so the generation of storm water will be less too. In the peak months, storm water management is necessary to reduce water wastage in the Chandigarh city. We can use this storm water for irrigation purposes, future water use, gardening, car washing, toilet flushing etc. We have analysed this data by proper calculations and this data will definitely help to predict the amount of rainfall that will occur in the future and also in the prediction of floods and drought too.

Table 5.14: Data of Rainfall in mm (2009-2018)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2009	7	19	19.8	11.6	31.2	37.8	202.2	192.9	32.6	11.2	14.7	1.4	581.4
2010	8.8	5	0	3.7	2.2	174.8	406.5	225.8	357	16	9	51.2	1260
2011	4.1	14.5	13.8	2.2	36.2	226.6	207.2	227.3	111.8	0	0	17.9	861.6
2012	22.8	1.5	2	76.6	1	51.2	275.1	296.7	202.3	6.8	0.6	15.7	952.3
2013	66.4	90.9	10.1	1.6	7	223.1	214.3	256	79	40.2	12	9	1009.6
2014	79.5	41.7	82.3	24.8	84.7	58.6	195.3	43.3	142.7	8.1	0	95.2	856.2
2015	1	44.6	117.8	16.4	19	90.1	290.2	104.8	87.7	15	0.6	2	789.2
2016	1	1	53.1	24.4	40.4	133	109.5	113.5	63	0.2	0	29.4	568.5
2017	13.2	3	23.2	13.9	5.3	69	242.2	264.8	154.2	0	0	16.6	924.2
2018	4.4	59.6	3	26	8	121.6	319.2	304.6	270	18.6	9.6	11.5	1156.1

Source: [IMD Chandigarh, 2019]

Table 5.14 shows the rainfall data for the year 2009-2018 taken from meteorological department, Sector-39, Chandigarh. Daily data month wise was collected for the analysis purpose. From the table, it is clear that July and August have maximum rainfall in the city which shows the maximum generation of storm in the city. Rest other months has less rainfall, so generation of storm water will be less too.

In the peak months, storm water management is necessary to reduce water wastage in the Chandigarh city. We can use this storm water for irrigation purposes, future water use, gardening, car washing, toilet flushing etc. We have analysed this data by proper calculations and this data will definitely help to predict the amount of rainfall that will occur in the future and also in prediction of floods and drought too.

Fig. 5.9: Sample collection after rainfall

Fig. 5.10: Sample measurement after rainfall

5.7 Chandigarh Water Supply Distribution

Chandigarh's sectoral grid has a very much planned arrangement of channeled water supply and sewerage removal. Under the city's water management, each arranged dwelling unit must have water and sewerage associations. With the development of U.T in 1966, all the works for the city's physical foundation were taken care of by the particular divisions of the Chandigarh Administration. After making of the Municipal Corporation of Chandigarh in 1994, the city's water flexibly, sewerage framework, storm water seepage, strong waste administration and disinfection have been moved to the Municipal Corporation [MC Chandigarh, 2019].

At the point when Chandigarh was planned, the acceptable accessibility of sub soil water was viewed as satisfactory for meeting the city's prerequisites as the yield of tubewells was sufficient. With increment in the city's populace, numerous tubewells began evaporating. It was chosen to tap surface water of the Bhakra main line streaming a ways off of 27.5 Kms from Chandigarh to meet the city's developing water necessities. The main period of enlargement of water segment from the trench was appointed in 1983. It was chosen by the Government of India that this amount of water will be shared by Punjab, Haryana, Chandigarh Administration and Chandimandir Cantonment in the accompanying proportions:

a. Union Territory Chandigarh: 29 cusecs (14.5 mgd)
b. Punjab (for Mohali): 5 cusecs (2.5 mgd)
c. Haryana (Panchkula): 3 cusecs (1.5 mgd)
d. Chandimandir Cantonment: 3 cusecs (1.5 mgd)

To meet the city's future prerequisites of water, Government of India had endorsed water flexibly conspire from Kajauli. The Punjab Government had at first consented to deliver 40 mgd crude water out of which U.T's offer was to be 29 mgd. Be that as it may, Government of Punjab currently needs to utilize this water only for Mohali territory themselves but another period of carrying more water to Kajauli is being arranged.

With constantly expanding interest for water and vulnerability and questions disturbing growth of channel water gracefully, Chandigarh needs to build up a complete water harvesting plan to guarantee long term supportability of water sources for the city [MC Chandigarh, 2019].

5.7.1 Water Supply Distribution

The city has been isolated into 7 zones with the end goal of distribution including the town of Manimajra. The drafting of the city has been finished keeping in see the north to south slope of the land. Each zone has a headwork named after its area.

5.7.2 Waste Water Recycling

The Government of India has consented to the proposition of Chandigarh Administration for reusing of treated wastewater. Establishments like PGI, schools, schools, specialized organizations and Punjab University have been approached to detach the consumable water flexibly from water system of gardens and get association of tertiary treatment water to spare valuable consumable water. The Municipal Corporation has gotten great reaction to the proposition. In like manner, MC has executed an undertaking for supply of treated tertiary water having biochemical oxygen demand (BOD) under 10 mg/l. Further endeavors are being made to use tertiary treated water in every green belt and houses having land of more than one kanal (500 square yards) [MC Chandigarh, 2019].

5.7.3 Drainage of Storm water

The characteristic slope of Chandigarh's site encourages simple removal of storm water through Sukhna Choe, N-choe and Patiala ki Rao. Because of the arrangement of legitimate street gaps and great slope of lines, the storm water seepage of Chandigarh is in acceptable condition. The city anyway encounters the choking of channels because of plastic packs and other strong waste during substantial rains particularly close to round abouts [MC Chandigarh, 2019].

5.7.4 Flood Reasons in Chandigarh

The key purposes behind this circumstance are evaluated as follows:-

a. Some zones of city experience floods because of lacking seepage framework which was intended for precipitation of 12 mm/hour over the top centralization of flood because of substantial deluge. Disappearance of flood engrossing 'N'-choe due to urbanization.

b. Dumping of garbage, debris and trash out from the dark nallahs/N-choe.

c. Illegal infringement of characteristic water courses.

d. Indiscriminate laying of service lanes and across regular natural courses.

e. Filling of 'N'- choe in Chandigarh which diminishes the seepage limit.

f. Diversion of characteristic water courses to oblige homes.

g. Increased run off because of increment in impenetrable regions.

5.7.5 Sewerage System

The common slope of Chandigarh's site encourages simple removal of storm water through Sukhna Choe, N-choe and Patiala ki Rao. Because of the arrangement of legitimate street gullies and great incline of lines, the storm water seepage of Chandigarh is in acceptable condition.

The city anyway encounters the stifling of channels because of plastic sacks and other strong waste during weighty rains particularly close to traffic circles. The principal stage (sector 1-30) of Chandigarh's sewerage framework was laid during 1952 to 1965, the subsequent stage (sector 31 to 47) from 1965 to 1976 and the third stage from 1976 onwards. There are discrete sewer and storm water seepage frameworks in Chandigarh. The sewerage and storm water is released by gravity stream because of good regular slope from north east to south west.

The slope likewise causes the sewers to be normally cleaned because of the great self-purifying speeds. There is an efficient organization of main and branch sewerage channels. The fundamental sewage runs from west to east with inter association of sewer line from south to north. No pumping is included in view of the city's geography. The length of stoneware sewage pipe network is 742 km. The populace took into account by the sewerage framework is 95% [MC Chandigarh, 2019].

5.7.6 Quantum of Sewage Generation

At present 65.25 million gallons of sewage is generated per day in Chandigarh. Out of this, 45 MGD is treated at Sewage Treatment Plant (STP) at Diggian, Phase X1, Mohali and the remaining at Raipur Khurd (1.25 MGD), Raipur Kalan (5 MGD), 3 BRD (5MGD), Sector 47, Chandigarh. Another I0 MGD STP is under construction at 3 BRD. After commission of this STP, total sewerage generated will be treated upto required standards [MC Chandigarh, 2019].

5.7.7 Proposals for Water Conservation & Increasing Use of Recycled Water

The utilization of consumable domestic water will be limited to kitchen (including drinking, washing) and washing garments. Reused water should be utilized for non-consumable uses, for example, watering parks, gardens scenes, greens, use for development, mechanical cycle, flushing, washing streets and so forth. Utilization of reused water will be necessary for all non-consumable utilizations for all large buildings with a land of more than 2000 sq. m. in every single construction. On the off chance that such water isn't provided by the MC, at that point the structure should set up its own water treatment plant inside its premises for reuse of waste water. All apartments or group housing complexes with in excess of 20 apartments and commercial, institutional and industrial buildings with a region of more than 2000 sq.m should make plumbing and framework arrangement for empowering localized sewage treatment, utilization of recycled water for flushing, washing and for watering gardens [MC Chandigarh, 2019].

5.7.8 Implementation

All building, all structure plans and land improvement plans with a territory of more than 2000 sq. m. presently need to show the on-site wastewater treatment and removal courses of action and water reuse framework including the plumbing plans and so forth. Separate frameworks must be accommodated sewage and sludge treatment to encourage reuse of sludge water for planting and washing purposes. This may require reasonable store tanks that are to be shown on the buildings plans. Utilization of consumable water in all new structures can be decreased by utilizing water proficient fittings. At any rate 25% decrease in water utilization can be accomplished from all sources. The Municipal Corporation has attempted an examination to set up storm water seepage all inclusive strategy to ease the issues of flooding. The study suggested extending and enlarging of the nallahs for the segments influenced by infringements, adjustment to cross seepage works, some delicate estimates, for example, anticipation of unloading of waste into the nallahs to prevent clogging. Substitutions of old flush toilets and faucets with new low-flush and water efficient taps will be staged in through refunds in water bills and afterward made compulsory. To begin with open institutional structures and huge business structures, for example, shopping centers will be focused on [MC Chandigarh, 2019].

CHAPTER 6

CASE STUDY

6.1 General

Chandigarh is a rapidly growing city and expected population of Chandigarh in 2021 will be 13.38 lakhs. Existing storm water drains in Chandigarh in some areas are not sufficient due to rapidly increasing paved area. Storm water drains are not capable of draining storm water so ponding occurs in various places. The increase in the population and increasing water supply has resulted in increased sewage flow. This has necessitated augmentation of sewage treatment plant for every residential building or newly constructed towers to reuse that water after treatment.

Real estate is proclaimed to be one of the most promising sectors today. Projects in this sector require end-to-end storm water and wastewater treatment that come with hassle-free setup and management. These solutions should be flexible to fit specific needs, scalable to fit future requirements and should be cost-effective. Communities are increasingly demanding eco-friendly lifestyles. As the news about water scarcity is fast becoming a reality, citizens are themselves driving the demand for greener projects that allow water conservation along with recycling and energy savings.

6.2 Concept of Double Plumbing System

In this study, we have implemented the concept of double plumbing in Chandigarh and in nearby areas so that we can use waste water and storm water for future use. We have designed tank of waste water storage in our area or near our buildings or flats in which we have stored waste water and storm water and then further after treatment of that water, we provided double plumbing system in the houses. In one pipeline, supply of fresh water takes place which can be used for bathing and drinking and in second pipeline; we provided treated waste water which can be used for flushing of toilet, gardening, car washing, AC service etc.

As the demand of water usage in Chandigarh is rising day by day; we have to look forward for saving water by conserving it either in the form of storm water conservation or waste water treatment for the future use. For example, there was a huge water crisis in Chennai in 2019.

So, for such situations, to meet the needs of our future generation there is a requirement of water, so, we have to implement double plumbing concept in Indian residential and commercial buildings.

6.3 Case Study of Residential Building

In this case study of residential building, we focused on saving water which we can be further used for our 50,000 sq. ft. green area where earlier we were using fresh water. So to save this fresh water, we had done this study to minimise the requirement of fresh water for gardening, car washing and toilet flushing.

In this case study, we have taken a building named as Exotica Heights. The approximate people living in this society are around 700 with 200 houses. The water capacity of the building is 94.5 KLD which is totally fresh water source. To reduce the amount of usage of fresh water for green area of the society and for toilet flushing, we have implemented the concept of double plumbing. For the double plumbing system we have used one pipeline for fresh water and the other pipeline for latrines and other uses (using treated wastewater and storm water). We have proposed storage tank using storm water and waste water with dimensions 23.6 m×11.80 m×2 m and the capacity of proposed storage tank is 94500 liters.

The design process should aim to:

a. Design the reuse scheme for ease of operations and maintenance.

b. Cost-effectively meet the project's objectives identified during project planning.

6.3.1 Volume of Water Requirement

For an exotica towers (700 members), 200 houses;

Water Tank Size & Capacity Calculation

As per IS code (National Building Code 2016, BIS), 135 liters are needed for daily use per person per day. Breakup of the IS assumptions

a. Drinking – 2700 liters

b. Cooking – 2700 liters

c. Bathing & Toilet – 71900 liters

d. Washing Clothes & Utensils – 12200 liters

e. Cleaning House – 5000 liters

Total water requirement is 135 liters × 700 = 94500 liters per day.

Volume of water is; 1 m^3 = 1000 liters of water.

In order to get the size of the water tank, we need to mention at least one dimension (Length, Width or Depth of the water tank).

From the above, volume of water formula, 1 m^3 = 1000 liters

1 litre = 0.001 m^3

Our requirement is 94500 liters, Therefore, 94500 liters = 94.5 m^3

Assuming our water tank depth as 2 m

Note: you can also replace your input if you know the length,

Area of tank = 94.5/2 = 47.25 m^2

$L \times B = 47.25$

Take length as 2 times of B, [L=2B]

$2B \times B = 47.25$

$B^2 = 23.625$

B = 11.80 m

$L = 2 \times B = 2 \times 11.80$, L = 23.6 m

So, for 94500 litre water tank size,

L = 23.6 m,

B = 11.80 m &

D = 2 m

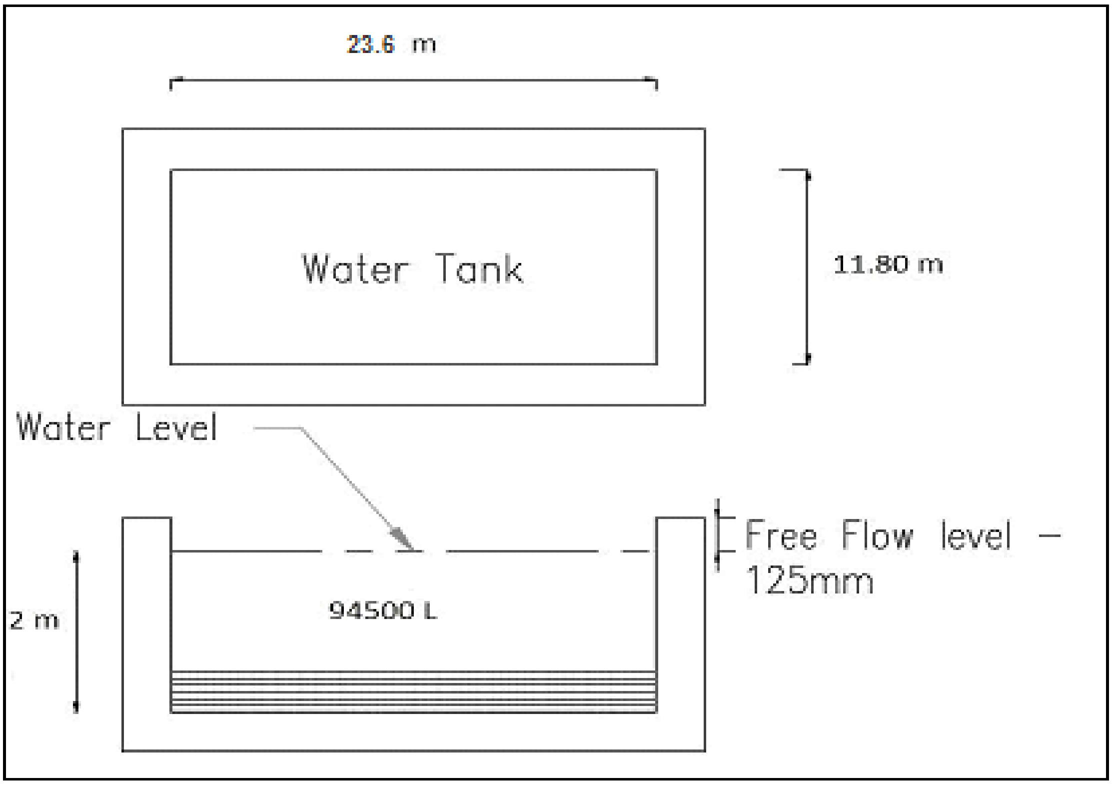

Fig. 6.1: Tank Design

Fig. 6.2: Site Construction

Fig. 6.3: Construction in process

Fig. 6.4: Storm water and Waste water collection tank

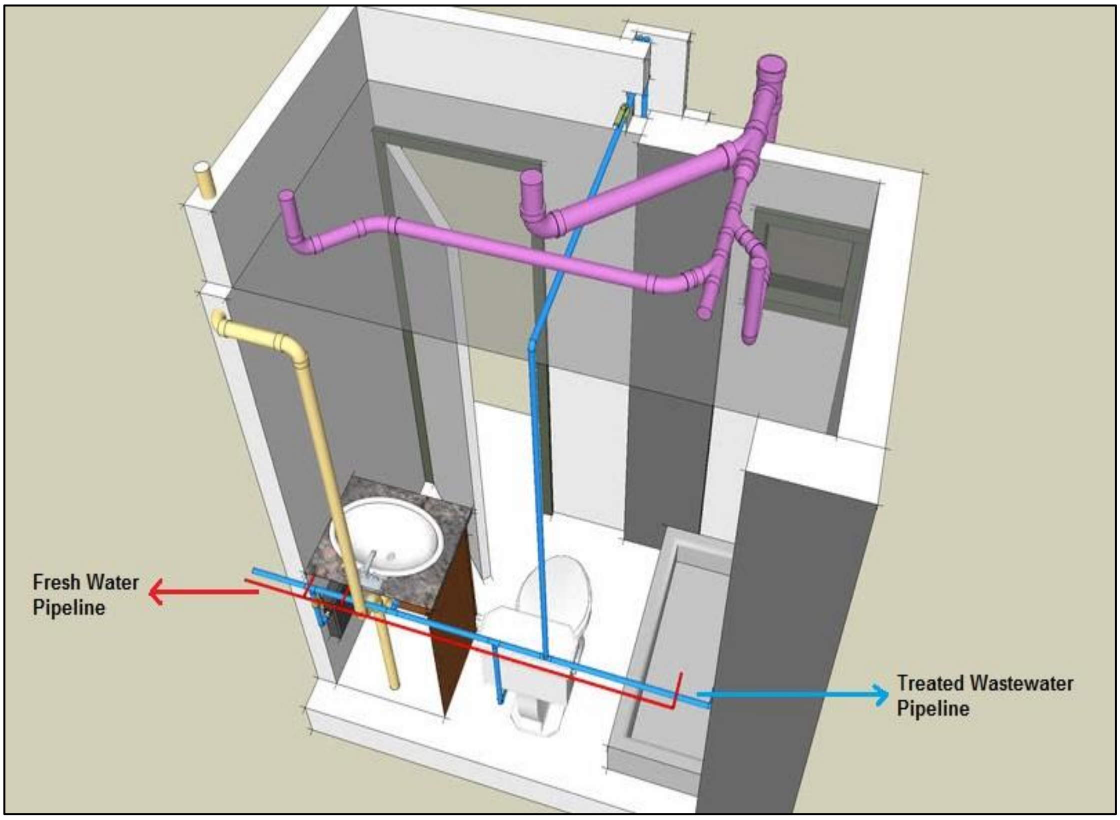

Fig. 6.5: Piping System in Towers

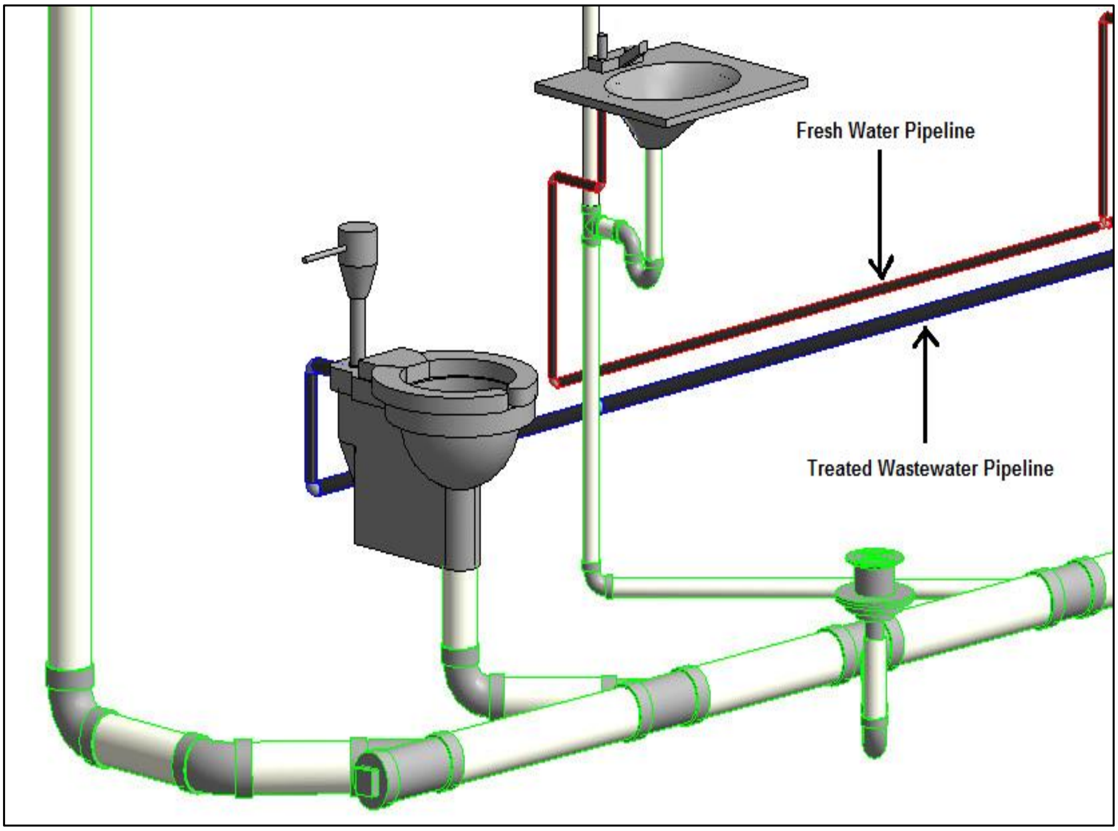

Fig. 6.6: Concept of Double plumbing

6.4 Comparison with Previous 20 Years of Construction

6.4.1 1990s Construction:

No such high rise towers or large society type construction at that time in Chandigarh.

Two Pipe System in Drainage for Houses in Chandigarh:

a. The drainage system of building shall be of two pipe system in which the soil and waste pipes are distinct and separate. The soil pipes being connected to the drain direct and waste pipes through a trapped gully. All traps of all appliances are completely ventilated.

b. In commercial complexes, commercial, institutional, industrial, other building specified by the competent authority in accordance with rule, the water from waste pipes shall be treated within the premises from appropriate treatment plant.

Water storage tanks: Nil

Water treatment: Common water treatment tank in the city

Double water plumbing: No concept

Separate water storage tanks: No separate tanks were provided

In 1990s there was no water recycling tanks and no water storage near the society. There was only supply of fresh water and no concept of double water plumbing existed. This means a lot of water was wasted in drains.

6.4.2 2001-2010 Construction:

Building Name: Silver City

Building Water Capacity: 112 KLD

Population: 1400 Nos., 300 houses.

Two Pipe System In Drainage:

a. The drainage system of building shall be of two pipe system in which the soil and waste pipes are distinct and separate. The soil pipes being connected to the drain direct and waste pipes through a trapped gully. All traps of all appliances are completely ventilated in the system.

b. In Group housing, commercial complexes, commercial (other than plotted), institutional, industrial, other building specified by the competent authority in accordance with rule, the water from waste pipes shall be treated within the premises from appropriate treatment plant. The treated water shall be used for flushing, horticulture and cooling tower purposes. Further, no soil/ waste pipe shall be allowed in common wall.

Water consumption: Only fresh water source and borewells

Water storage tanks: Nil

Water treatment: Common water treatment tank in the city

Double water plumbing: No concept

Separate water storage tanks: Concept of rain water harvesting tank was there but not introduced.

In 2000-2010 construction, there was concept of rain water harvesting tank but not introduced and no water storage near the society. There was only supply of fresh water through pipeline and also bore wells was there. There was no concept of double water plumbing. This means a lot of water was wasted and this also proves the need of storage of water in the society so that we can use it in future as well as on regular basis by providing double plumbing concept.

6.5 Results of Case Study

We have successfully implemented the concept of double plumbing in residential towers which would be helpful in preventing fresh water. This construction must be adopted in the Tricity to meet the future water needs. With this type of construction, we can say that it is simple to construct and easy to implement. So for the future India, we have to look forward for these types of steps and make our buildings green and free from water scarcity. 29000 liters per day (29 KLD) of treated water is used every day for flushing and gardening after treatment. So we save 29000 liters of fresh water every day from this case study. Buildings fresh water requirement is 94.5 KLD out of which 65.5 KLD will be used as fresh water and we saved, treated water, i.e. 29 KLD will be used for 50,000 sq. ft. green area of the society where we were using fresh water source earlier.

CHAPTER 7

RESULTS AND DISCUSSION

7.0 General

The results and discussion part analyses the rainfall, variations, population, water balance, forecast and testing of samples. The 10 year data were analyzed to check the results for future predictions. Different tests were conducted related to rainfall, water balance and water quality for the future point of view. Various equations, models and graphs were plotted to check the variations and for the compilation of results. This study also brings the impact of using water in the city so that we can use it whenever necessary. The test results are compiled and are presented in this chapter.

7.1 Rainfall Analysis

The table 7.1 comprises the yearly values of rainfall for the year 2009 to 2018. The mentioned values show the 10 years of data analysis.

Table 7.1: Rainfall values in mm (2009-2018)

Yearly Values	Rainfall (mm)
Total Compiled Rainfall of 10 years	890.91
Average Rainfall of 10 years	74.65
Maximum Value of 10 years	406.5
Minimum Value of 10 years	0
Standard Deviation of 10 years	95.77

The table 7.2 comprises the previous and expected values of population from the year 2001 to 2031. The mentioned values show the expected population in the city for next 10 years so that the water requirements can be managed accordingly. The main purpose of producing population projections is to provide an estimate of the future population as a common framework for use in planning, policy formation and decision making in a number of different fields.

Table 7.2: Previous and Expected Population Data Values

Year	Population
2001	900635
2011	1060000
2021	1338000
2031	1761314

Source: [MC Chandigarh, 2019]

The table 7.3 comprises the statistical values used for forecast rainfall. The mentioned values were used in the Matlab so that the exact forecast values of rainfall could be evaluated.

Table 7.3: Forecast Statistical Values

Statistic	Value
Alpha	0.10
Beta	0.10
Gamma	0
Mase	0.08
Smape	0.03
Mae	2.06
Rmse	3.04

7.1.1 Rainfall Analysis of 10 years (2009-2018):

The figure 7.1 and 7.2 comprises the yearly values of rainfall from the year 2009 to 2018. The mentioned values show the 10 years of data analysis. The samples were collected after the occurrence of rainfall from the Meteorological Department of Chandigarh with their permission. The data was then analyzed on Matlab by putting the values for 10 years and then the total rainfall, average rainfall, maximum, minimum, standard deviation etc. were calculated. This rainfall data analysis will help the city for the prediction of floods, droughts in the upcoming years that would also help in the water management city practices. In the below figures, it shows the annual rainfall graphs from 2009-2013 and 2014 to 2018 which shows the month wise maximum rainfall in the city.

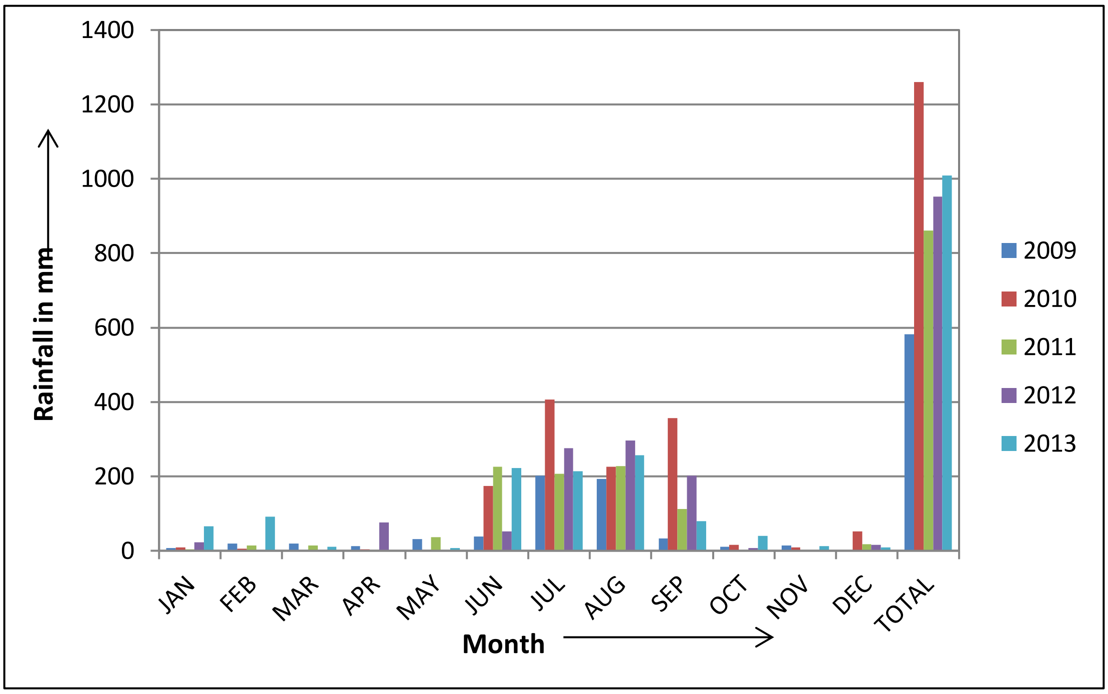

Fig. 7.1: Yearly rainfall (2009-2013) values in mm

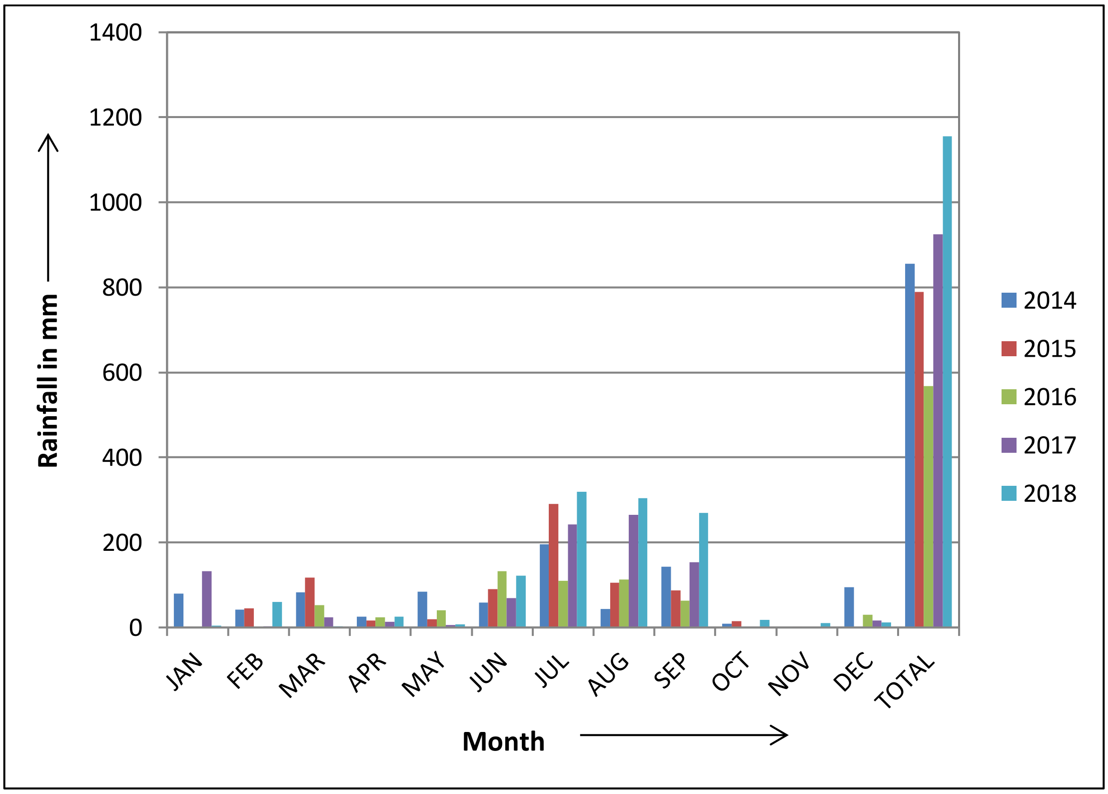

Fig. 7.2: Yearly rainfall (2014-2018) values in mm

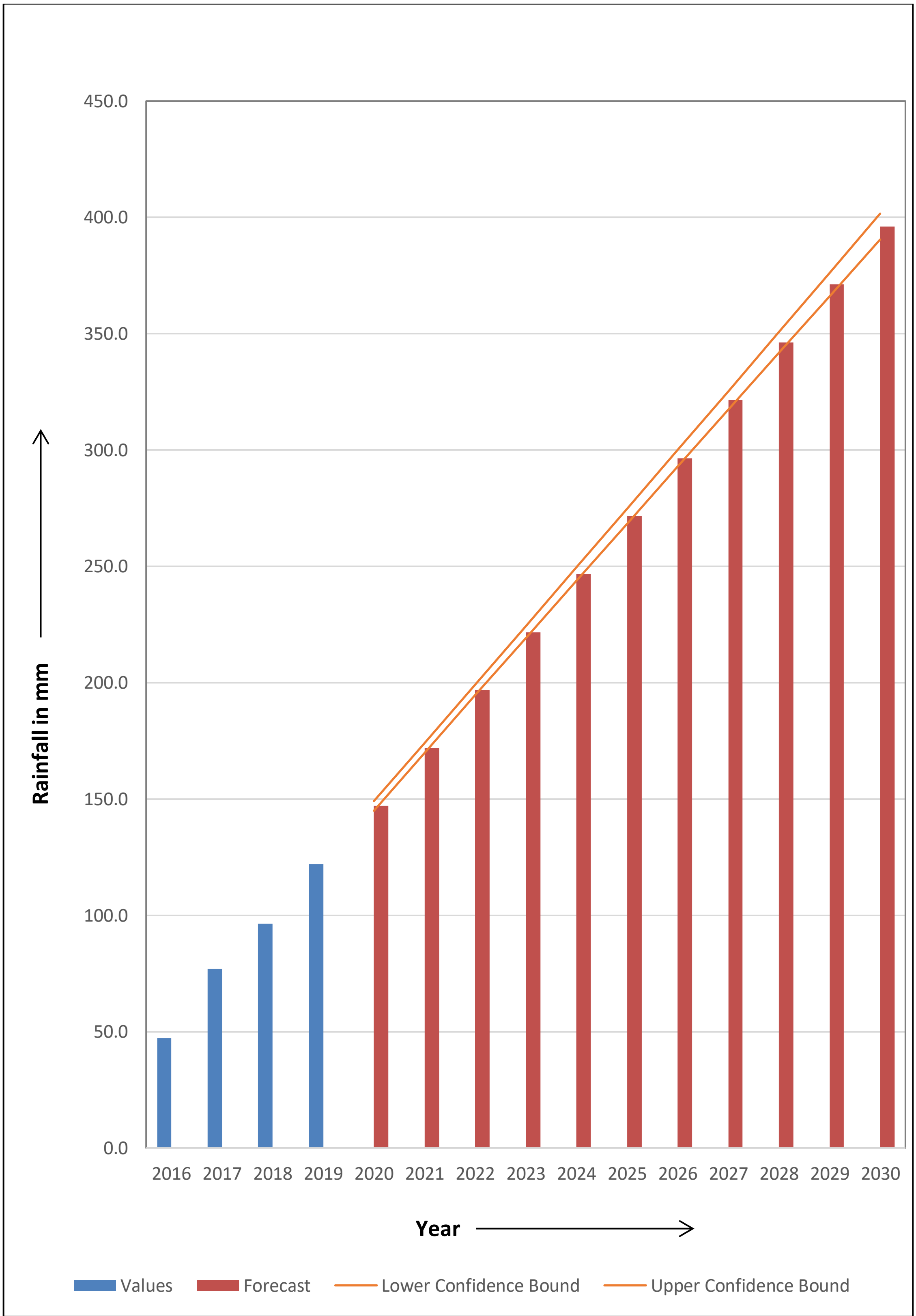

Fig. 7.3: Forecast Rainfall Values

The figure 7.3 comprises the forecast values of rainfall from the year 2016 to 2030. The mentioned graph shows the expected rainfall in the city for upcoming years so that the water requirements can be managed accordingly.

7.1.2 Variation Analysis of Rainfall

The table 7.4 comprises the variation analysis of rainfall for the year 2009 to 2018. The mentioned values show the 10 years of data analysis. In the below analysis, variability of rainfall has been calculated to figure out the dependability of rainfall over the study area.

Table 7.4: Variation Analysis in mm

MONTH/ YEAR	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**-**	**TO TA L**	**VARIATION**
JAN	7	8.8	4.1	22.8	66.4	79.5	1	1	132	4.4	-	327	-415.42
FEB	19	5	14.5	1.5	90.9	41.7	44.6	1	3	59.6	-	280.8	-461.62
MAR	19.8	0	13.8	2	10.1	82.3	117.8	53.1	23.2	3	-	325.1	-417.32
APR	11.6	3.7	2.2	76.6	1.6	24.8	16.4	24.4	13.9	26	-	201.2	-541.22
MAY	31.2	2.2	36.2	1	7	84.7	19	40.4	5.3	8	-	235	-507.42
JUN	37.8	174.8	226	51.2	223.1	58.6	90.1	133	69	121.6	-	1185.2	393.375
JUL	202.2	406.5	207.2	275.1	214.3	195.3	290.2	109.5	242.2	319.2	-	2461.7	1719.27
AUG	192.9	225.8	227.3	296.7	256	43.3	104.8	113.5	264.8	304.6	-	2029.7	1287.27
SEP	32.6	357	111.8	202.3	79	142.7	87.7	63	154.2	270	-	1500.3	757.87
OCT	11.2	16	0	6.8	40.2	8.1	15	0.2	0	18.6	-	116.1	-626.32
NOV	14.7	9	0	0.6	12	0	0.6	0	0	9.6	-	46.5	-695.92
DEC	1.4	51.2	17.9	15.7	9	95.2	2	29.4	16.6	11.5	-	249.9	-492.52
TOTAL	581.4	1260	861.2	902.3	1009.6	856.2	789.2	568.5	924.2	1156.1	**890.91**	**792.42**	-
VARIATION	-309.51	369.09	-29.31	11.39	118.69	-34.71	-101.71	-322.4	33.29	265.1	-	-	-

The figure 7.4 comprises the month wise variability of rainfall for the year 2009.

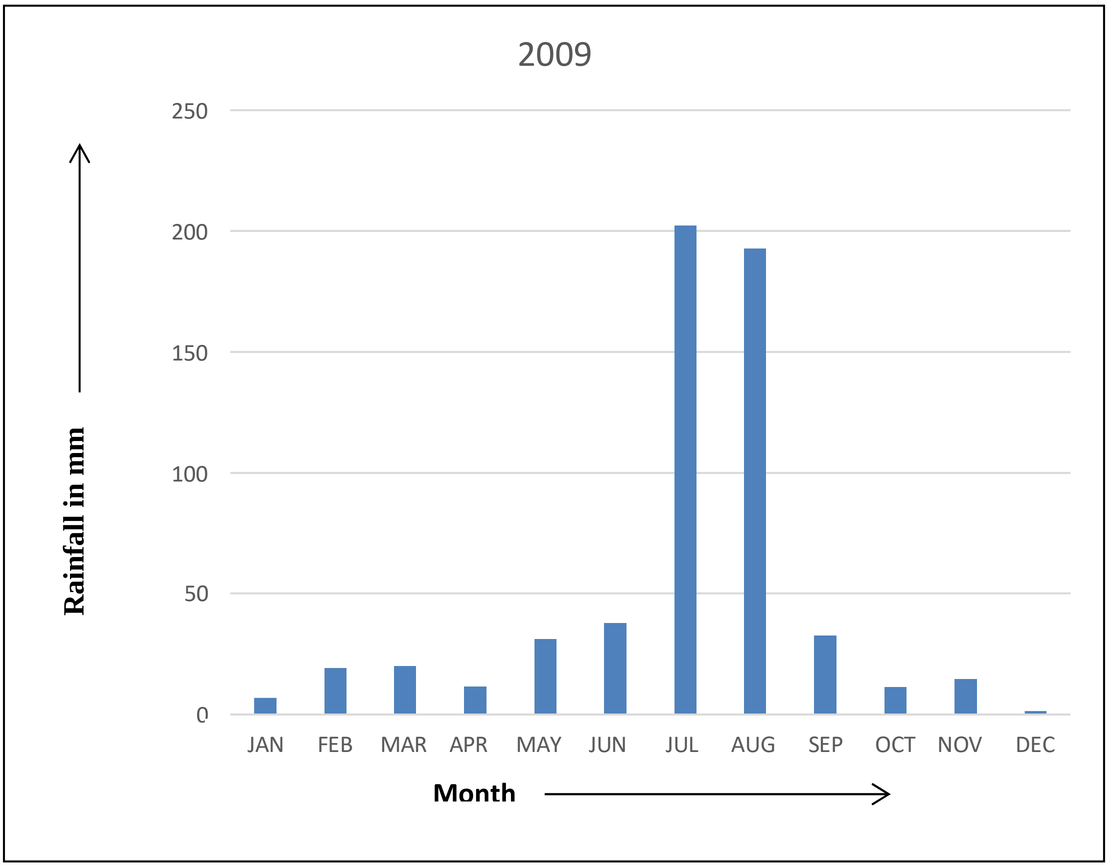

Fig. 7.4: Month wise variability of rainfall for the year 2009

The figure 7.5 comprises the month wise variability of rainfall for the year 2010.

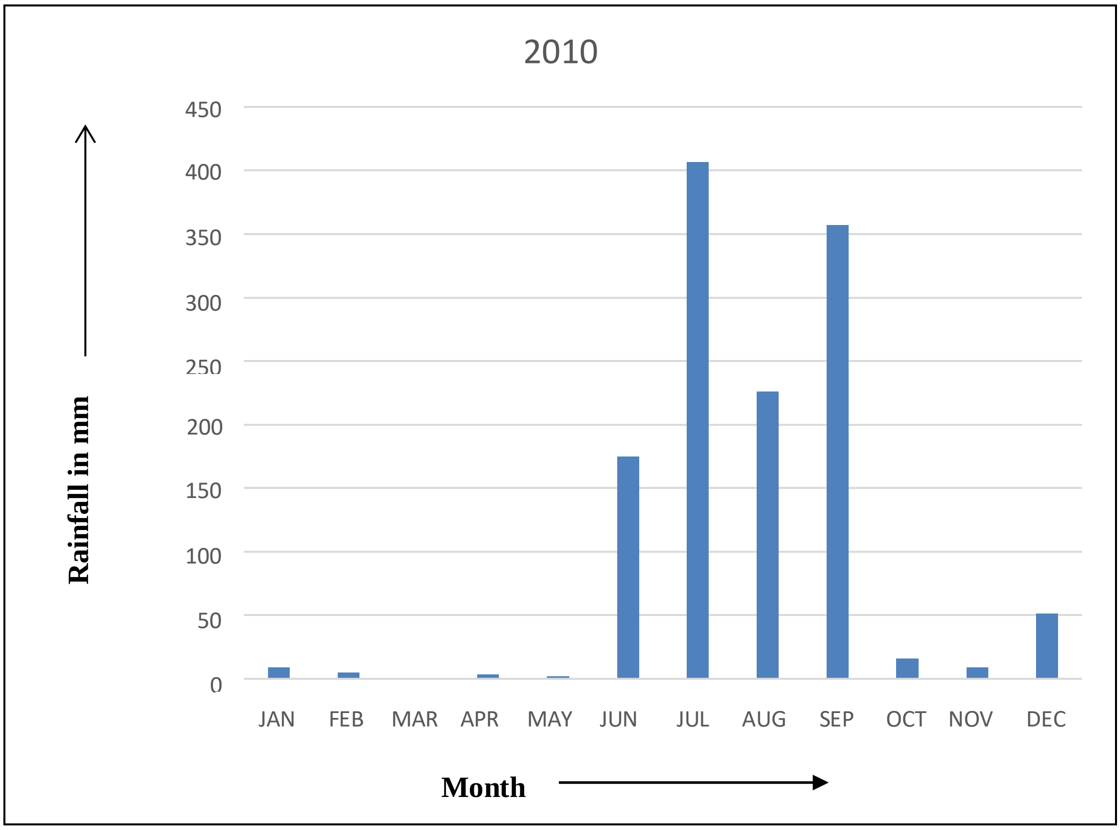

Fig. 7.5: Month wise variability of rainfall for the year 2010

The figure 7.6 comprises the month wise variability of rainfall for the year 2011 and figure 7.7 comprises the month wise variability of rainfall for the year 2012.

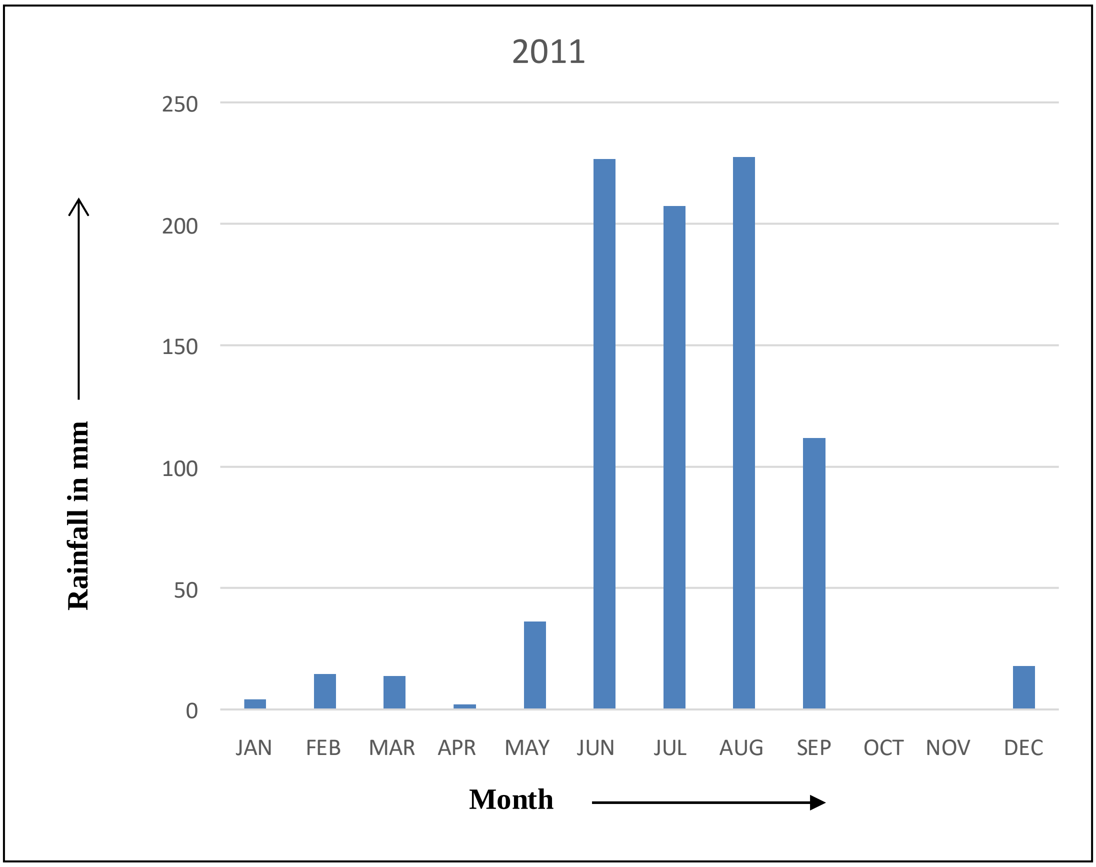

Fig. 7.6: Month wise variability of rainfall for the year 2011

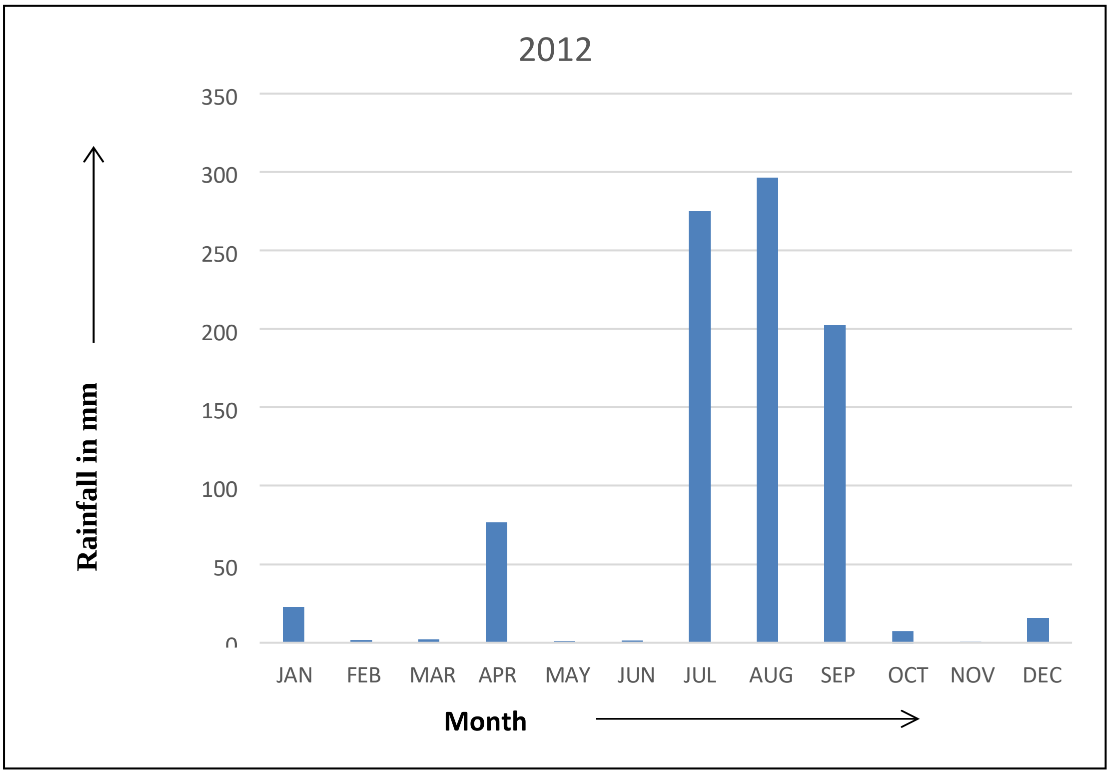

Fig. 7.7: Month wise variability of rainfall for the year 2012

The figure 7.8 comprises the month wise variability of rainfall for the year 2013 and figure 7.9 comprises the month wise variability of rainfall for the year 2014.

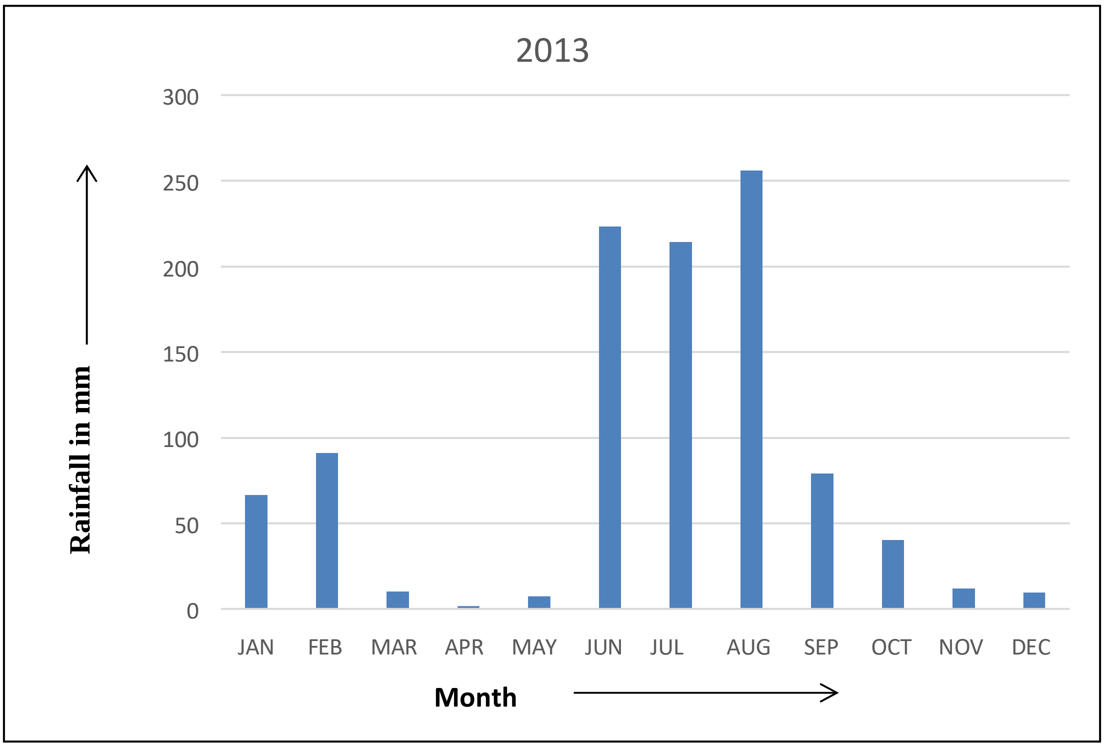

Fig. 7.8: Month wise variability of rainfall for the year 2013

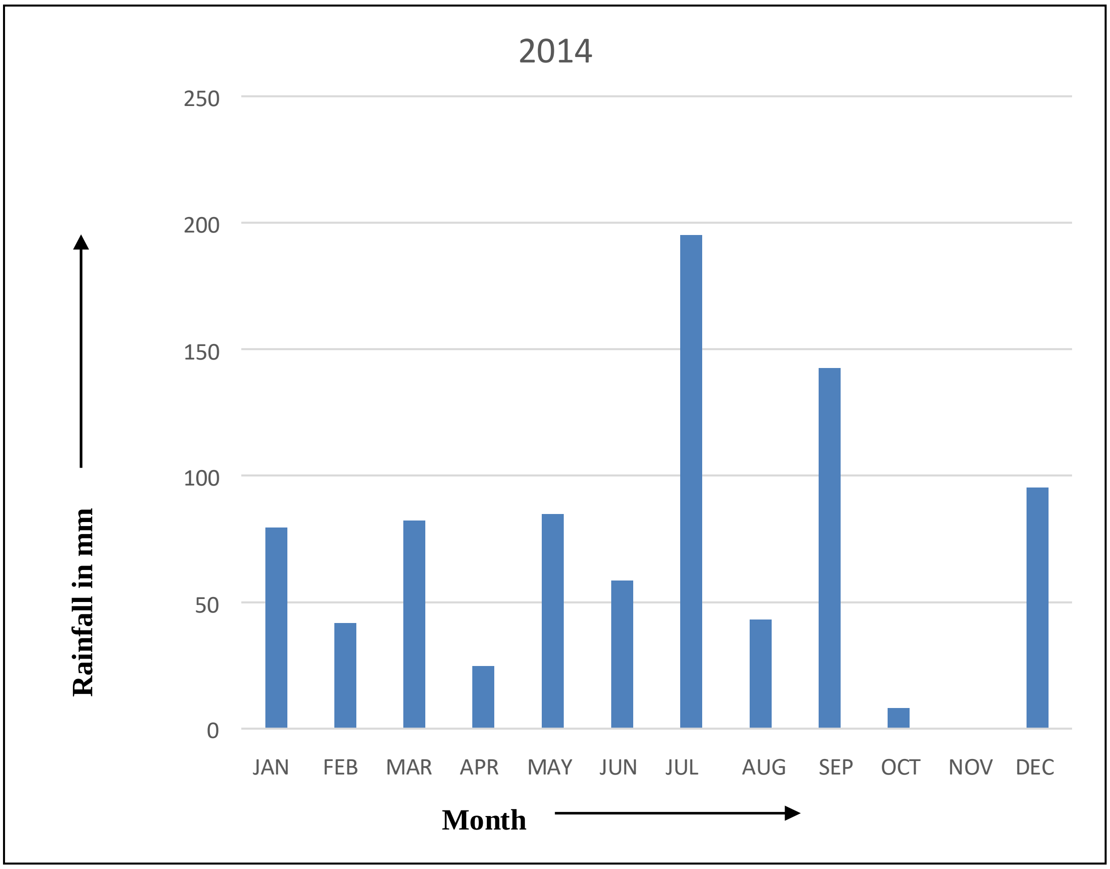

Fig. 7.9: Month wise variability of rainfall for the year 2014

The figure 7.10 comprises the month wise variability of rainfall for the year 2015 and figure 7.11 comprises the month wise variability of rainfall for the year 2016.

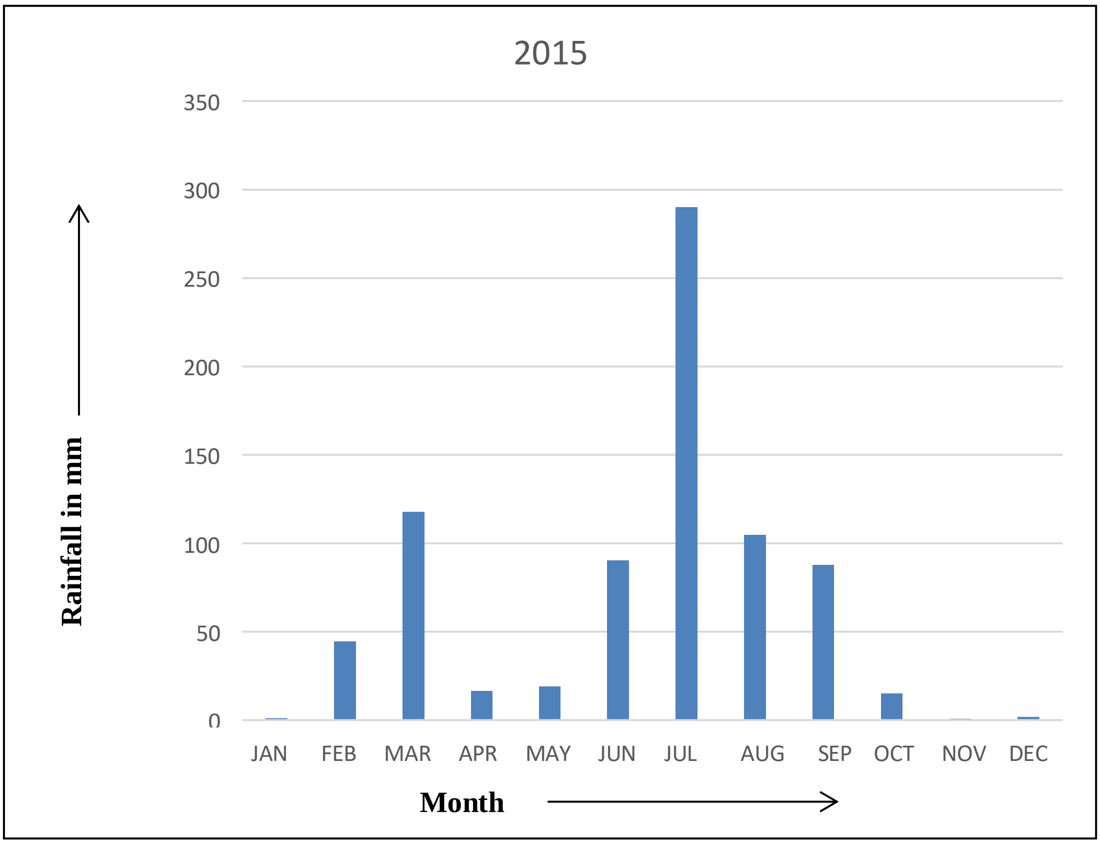

Fig. 7.10: Month wise variability of rainfall for the year 2015

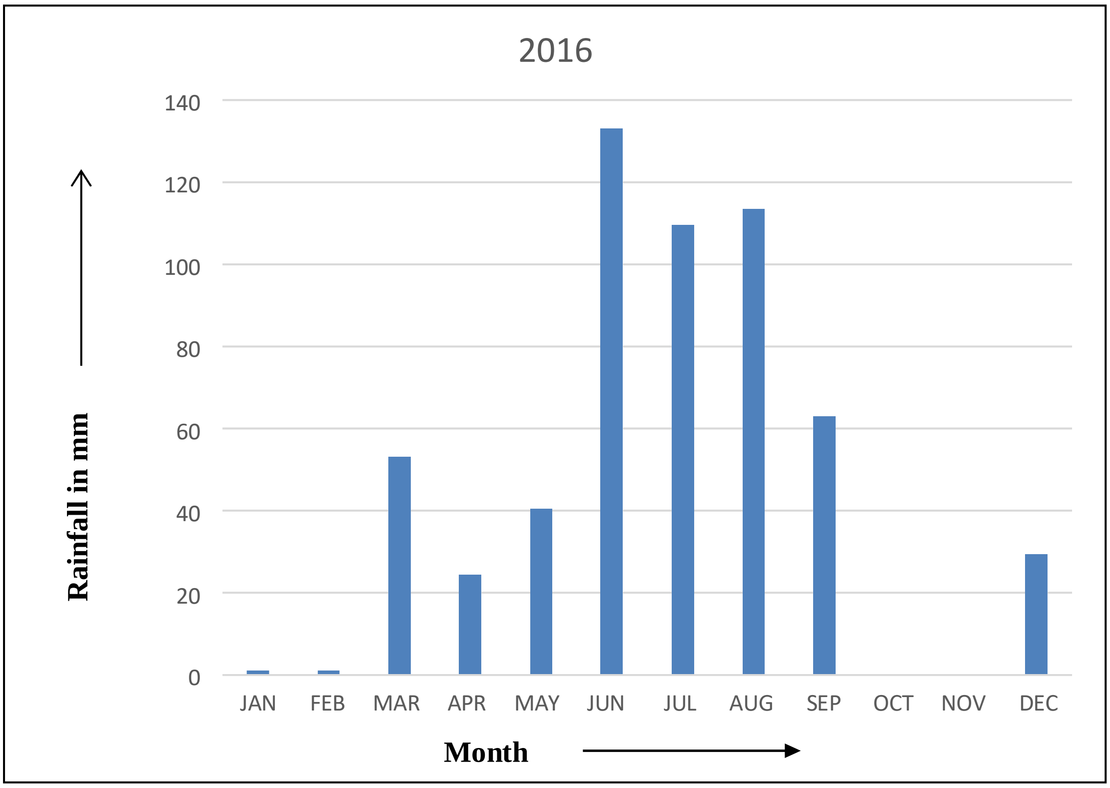

Fig. 7.11: Month wise variability of rainfall for the year 2016

The figure 7.12 comprises the month wise variability of rainfall for the year 2017 and figure 7.13 comprises the month wise variability of rainfall for the year 2018.

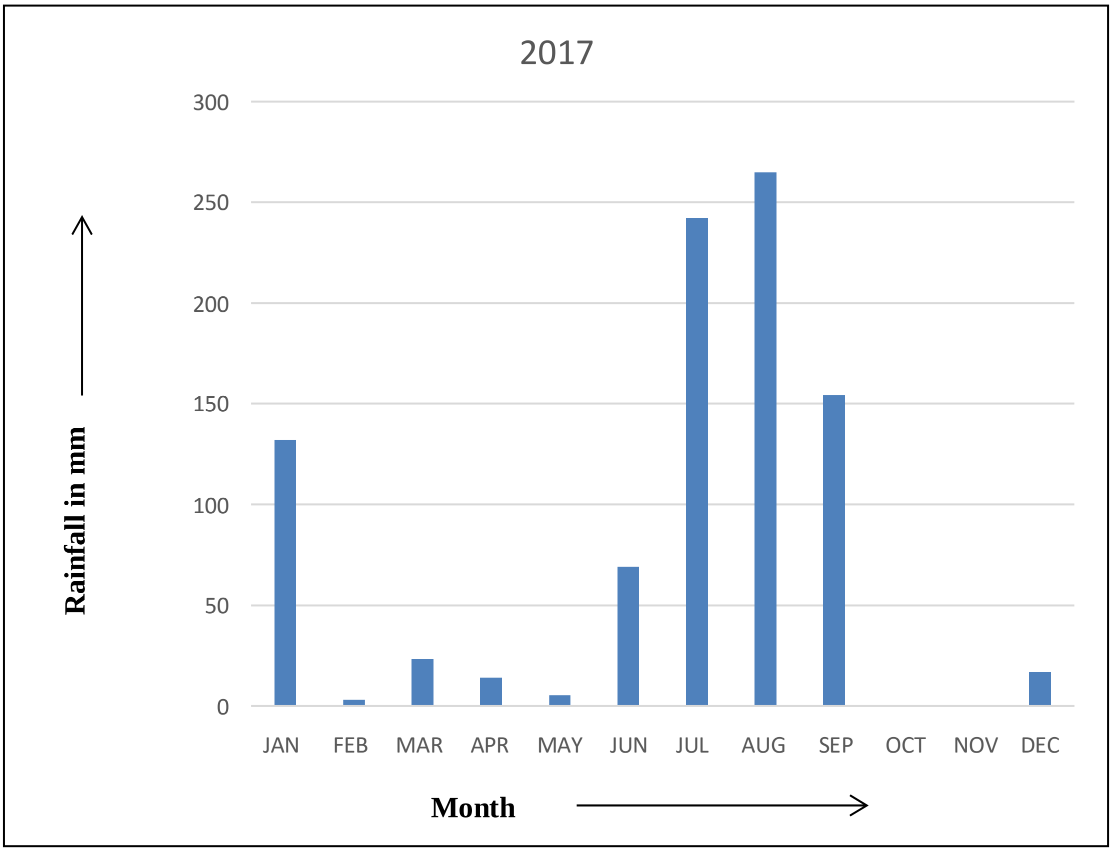

Fig. 7.12: Month wise variability of rainfall for the year 2017

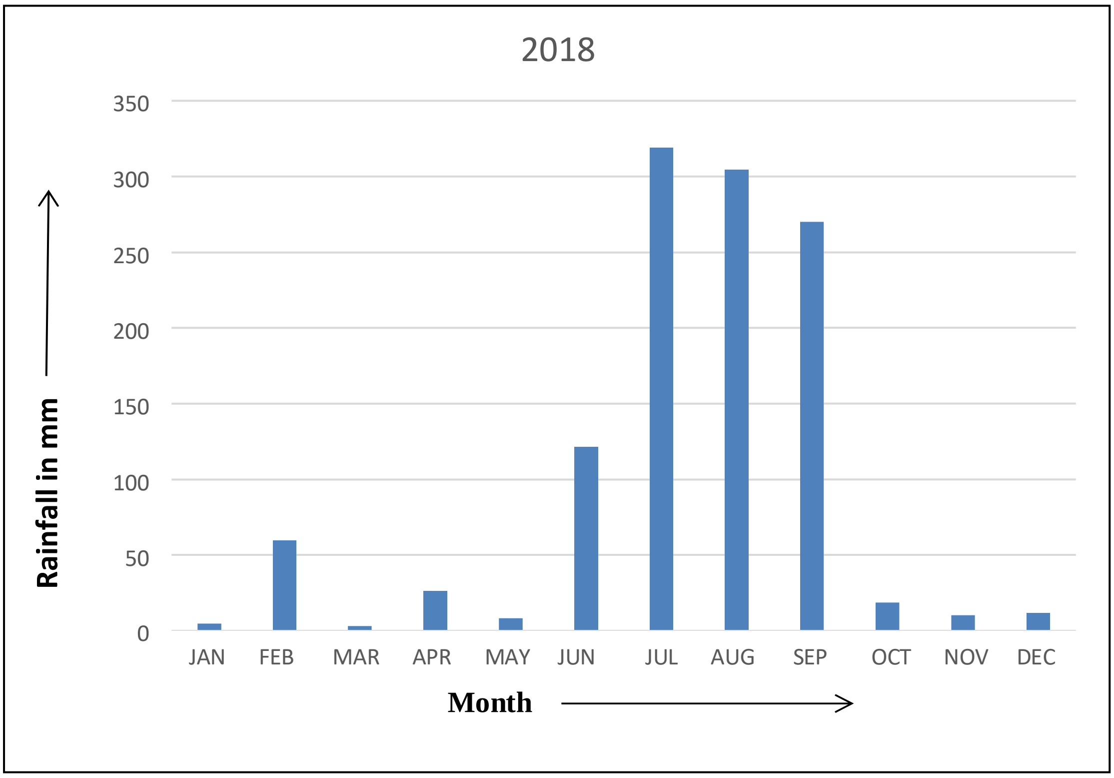

Fig. 7.13: Month wise variability of rainfall for the year 2018

The figure 7.14 and 7.15 comprises the variation analysis of rainfall for the month wise and year wise from 2009 to 2018 as calculated above in table 7.4.

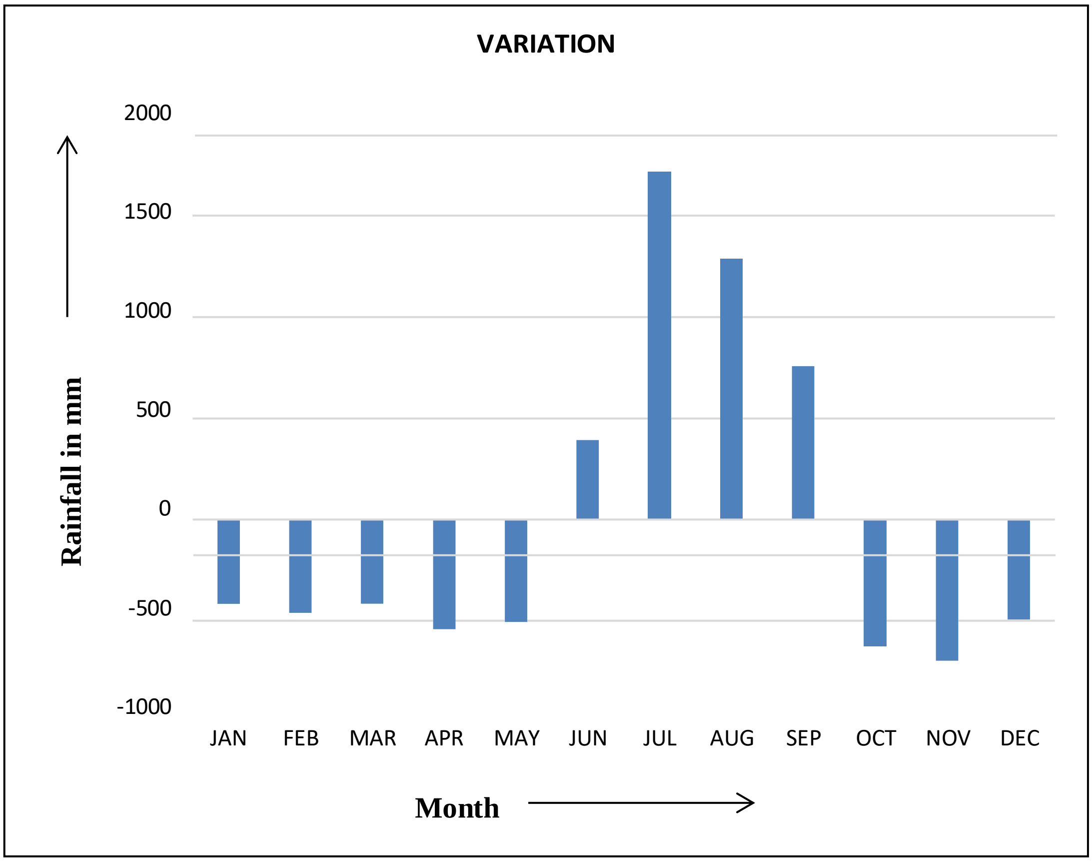

Fig. 7.14: Variation analysis month wise of 2009-2018

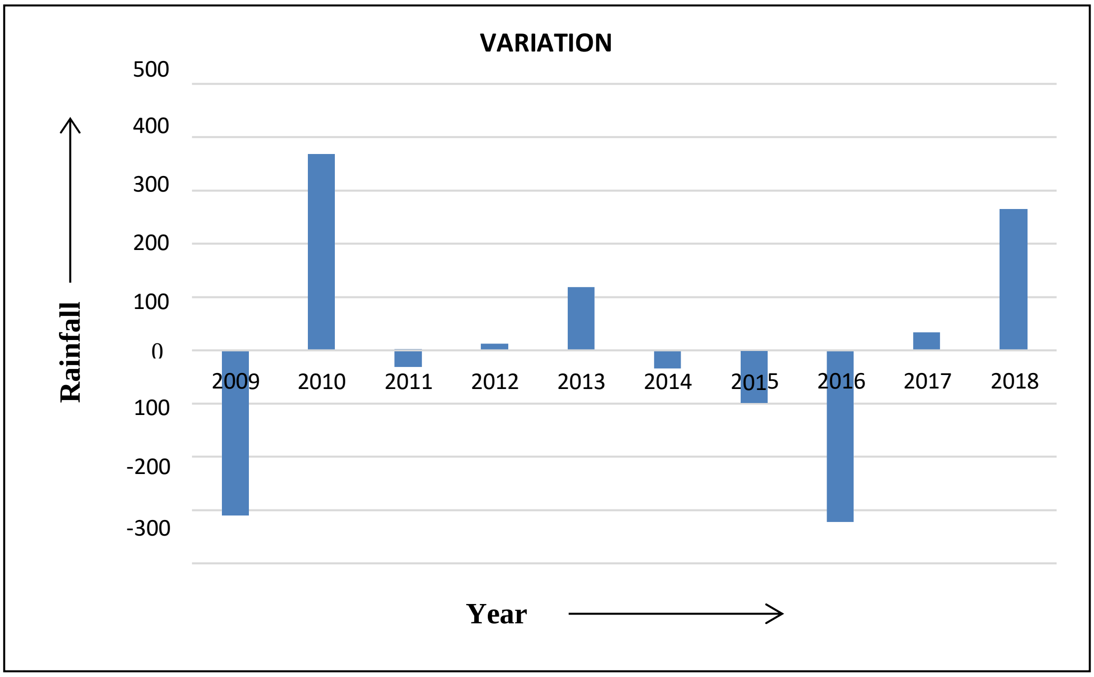

Fig. 7.15: Variation analysis year wise of 2009-2018

7.2 Recharge by Rainfall

7.2.1 Monsoon Recharge

$$Monsoon\ Recharge\ (hectare\ meter)$$
$$= (Geographical\ Area\ \times Specific\ Yield\ \times W.T.Fluctuation) + Gross\ Draft$$
$$- (Monsoon\ Canal\ Seepage\ + Monsoon\ Recharge\ from\ Surface\ water\ Irrigation$$
$$+ Monsoon\ Recharge\ from\ Groundwater\ Irrigation) \times (Normal\ Monsoon\ Rainfall)$$
$$+ Monsoon\ Recharge\ (Average\ Monsoon\ Rainfall) from\ surface\ irrigation$$
$$+ Monsoon\ recharge\ from\ canal\ seepage\ [\mathrm{GEC}, 2015]$$

Monsoon recharge (ham) = (11400 ×0.17 × 1.03) + 804 - (493 + 804 + 25.15) × 891.90/660 + 804 + 493 = 2312.24 ham = 23.12 Million Cubic Metres (MCM)

7.2.2 Non Monsoon Recharge

Non Monsoon recharge (ham) = Geographical area × Non-monsoon rainfall × Infiltration factor.

Non Monsoon recharge (ham) = 11400×0.388×0.25 = 1105 ham = 11.05 MCM

7.2.3 Total Recharge

Total recharge (ham) = Monsoon Recharge + Non Monsoon Recharge

= 2312.24+1105 = 3417.24 ham = 34.17 MCM

7.3 Recharge by Canals

Chandigarh has a population of roughly 11 lakhs. To cater to the water demand of the population, it requires 493 MLD (108 MGD) water, whereas available supply is only 363 MLD (80 MGD). Thus there is a shortage of about 130 MLD (28 MGD). A major part of water requirement of the city is met by canal water. Canal water supply to the city is approximately 272 MLD (60 MGD) [CGWB, 2019].

Total seepage (ham) = Length of canal × Average wetted parameter ×Running days × Seepage factor [GEC, 2015]

Applied seepage factor - 15 ham/day/10^6 m^2 of wetted area of canal [CGWB, 2019]

Average wetted parameter = 15.27 m, Length = 27400m. Running days (Monsoon = 70 days, Non-monsoon = 200 days)

Non-monsoon seepage = 27400×15.27×200×15×10^{-6} = 1255 ham = 12.55MCM

Monsoon seepage = 27400×15.27×70×15×10^{-6} = 439 ham = 4.39 MCM

7.4 Recharge by Field Irrigation

There are 37 irrigation tube wells managed by UT Chandigarh Administration in the various villages of the city. The depth of these wells is in the range of 180 m-250 m. These tube wells tap confined aquifers below 78 m from ground level. The annual unit draft is 21.74 hectare meters (hams) and gross draft was 804 hams (8.04 million cubic metres). There are 239 tube wells for drinking water supply to the rural and urban population. These tube wells tap confined aquifers below 90 m from ground level. The depth of these wells ranges from 200-300 m. The average unit well draft is 25.15 hams. The annual draft is 4401 hectare meters (44.01 million cubic metres) [CGWB, 2019].

Total yearly crop-wise return seepage (ham) = Average irrigated area (ha) × Average wetted depth (m) × Seepage factor % [GEC, 2015]

Seepage factor = 40%, Average wetted depth = 0.40 m, Average irrigated area = 11400 ham

Monsoon return flow = 11400 × 0.40 × 0.40 = 1824 ham = 18.24 MCM

Seepage factor 30%, Average wetted depth 0.4 m. Average irrigated area = 11400 ham

Non-monsoon return flow = 11400×0.30×0.40 = 1368 ham = 13.68 MCM

Total Return Flow= 18.24+13.68 = 31.92 MCM

7.5 Annual Recharge

Annual Recharge = Recharge by Rainfall + Recharge by Canals + Recharge by Irrigation [GEC, 2015]

= 34.17+16.94+31.92 = 83.03 MCM = 8303 ham

7.6 Draft

For each type of minor irrigation works, the draft was calculated by multiplying the number of minor irrigation work with the drafting capacity. Thus, the annual draft values ranges are as follows:

a. Draft by dug wells:

No. of dug wells = 170, unit draft = 1.40/year

Yearly draft = 170x1.40 = 238 ham.

b. Draft by tube wells:

No. of tube wells = 239, unit draft / year = 2 ham,

Yearly draft = 239×2 = 478 ham.

c. Draft by irrigation tube wells:

No. of irrigation tube wells = 37, unit draft/year = 18 ham

Yearly draft = 37×18 = 666 ham

Gross annual draft = 1382 ham = 13.82 MCM

The total draft was found out by summing up the drafts for various types of minor irrigation works i.e. 13.82 million cubic meters.

7.7 Water Balance

For the water balance of the Chandigarh city, we can apply the formula:

$Water\ Balance\ (W) = (R - D)$ *million cubic meters* [Alam et al., 2016]

Water Balance = Annual Recharge – Annual Draft

= 83.03-13.82 = 69.21 MCM = 6921 ham

Table 7.5: Water Balance of Chandigarh City (2009-2018)

Area	Annual Recharge (million cubic meters)				Annual Draft (million cubic meters)			Annual Draft (D) million cubic meters	Water Balance = (R – D) million cubic meters
	Recharge by rainfall	Recharge by Canals	Recharge by field Irrigation	Total Recharge (R)	Dug wells	Tubewells	Irrigation wells		
Chandigarh	34.17	16.94	31.92	83.03	2.38	4.78	6.66	13.82	69.21

7.7.1 Water Balance Model:

Available water holding capacity = 40 %

Rooting depth (d) = 1000 mm

Available Water Content (AWC) = FC×d = 400 mm

Reservoir Coeff. (f) = 0.80

Table 7.6: Water Balance Model for Chandigarh city in mm

MODEL INPUTS				MODEL CALCULATIONS										
Month (2009-18)	**S.NO.**	**P**	**PET**	**P-PET**	**APWL**	**SW**	**dSW**	**AET**	**Deficit**	**Surplus**	**Storage**	**Runoff**	**Detention**	**Actual flow**
Jan	1	32.7	25.63	7.1	0.0	400.0	0.0	25.6	0.0	0.0	0.0	0.0	0.0	0.0
Feb	2	28.08	26.71	1.4	0.0	400.0	0.0	26.7	0.0	1.4	1.4	1.1	0.3	1.6
Mar	3	32.51	36.2	-3.7	-3.7	396.3	-3.7	36.2	0.0	0.0	0.3	0.2	0.1	0.3
Apr	4	20.12	37.06	-16.9	-20.6	379.9	-16.4	36.6	0.5	0.0	0.1	0.0	0.0	0.1
May	5	23.5	61.99	-38.5	-59.1	345.0	-34.9	58.4	3.6	0.0	4.0	0.0	0.0	0.0
June	6	113.58	138.04	-24.5	-83.6	324.6	-20.5	134.0	4.0	0.0	33.0	0.0	0.0	0.0
July	7	246.17	147.04	99.1	0.0	400.0	75.4	147.0	0.0	23.7	93.7	19.0	4.7	28.4
Aug	8	202.97	136.44	66.5	0.0	400.0	0.0	136.4	0.0	66.5	111.0	57.0	14.3	85.5
Sept	9	150.03	116.95	33.1	0.0	400.0	0.0	117.0	0.0	33.1	47.3	37.9	9.5	56.8
Oct	10	11.61	26.51	-14.9	-14.9	385.4	-14.6	26.2	0.3	0.0	9.5	7.6	1.9	11.4
Nov	11	4.95	25.88	-20.9	-35.8	365.7	-19.6	24.6	1.3	0.0	1.9	1.5	0.4	2.3
Dec	12	24.99	15.87	9.1	-26.0	374.8	9.1	15.9	0.0	0.0	0.4	0.3	0.1	0.5
Total	-	891.21	794.32								302.9	124.6	31.3	186.9

Annual Totals				
Simulated flow	**Actual flow**	**AET**	**Rain**	**Drainage**
124.6	186.9	784.6	891.2	-27.1

Monthly precipitation data = From Meteorological Department

Monthly PET Data = From Meteorological Department

P = Precipitation

PET= Potential Evapotranspiration

APWL = Accumulated Potential Water Loss SW = Soil Water

dSW = Change in soil water

AET = Actual Evapotranspiration Deficit = Defined when PET>AET

Surplus = Defined when SW>AWC

Storage = Net accumulated from previous storage accounting for previous days runoff

f = Linear reservoir coefficient (fraction of surplus available for runoff each month)

When P>PET, AET =PET

When P<PET, AET = dSW + P

Drainage = P - AET - Flow – dSW

All units are in mm.

Table 7.6 shows the water balance model for the Chandigarh City, where we have put the values of different parameters related to water balance so that proper management of water will take place in the city. This model is used as a calculation tool by everyone by simply putting your values in it. Water Balance shows the total inflow minus outflow of water. So by this model we can predict the runoff, water left over, drainage etc. We have used this model for 10 years of month wise data analysis from 2009 to 2018. A water balance equation can be used to describe the flow of water in and out of a system. From table 7.5, we get the results 83.03 million cubic meters of water which we can be used for recharge purpose. Our total inflow is 83.03 million cubic meters and outflow is 13.82 million cubic meters. Our water balance for the city is 69.21 million cubic meters. For the proper distribution of system, we have to utilize this water balance for the proper water storage and usage. From table 7.6, we have done the modeling in Matlab for the water balance of the city and out of annual rainfall of 891.21 mm; we find approx. 300 mm of water storage as recharge.

7.8 Water Quality Testing Results

Table 7.7: SUKHNA LAKE (2019)

Sr. No.	**Parameters**	**Unit**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	pH	-	7.1	7.4	6.9	7.3	8.1	7.6	6.7	7.8	7.4	7.4	6.7	8.2
2	Conductivity	µs/cm	152	137	176	142	218	179	205	178	180	202	224	244
3	DO	mg/l	6.9	8.2	9.7	8.6	6.9	7.2	7.9	8.8	5.1	9.2	7.9	8.7
4	COD	mg/l	24	28	20	32	24	35	40	17	28	36	48	69
5	BOD	mg/l	9	2	3	4	7	5	10	5	2	2	3	3
6	Total Suspended Solids	mg/l	32	35	20	44	15	50	12	30	22	12	19	28
7	TDS	mg/l	115	90	92	98	125	116	163	149	92	93	116	157
8	Turbidity	NTU	2	66	10	40	15	45	10	55	27	28	29	52

Table 7.7 shows the testing of Sukhna Lake sample conducted in the laboratory and Figure 7.16, 7.17, 7.18 and 7.19 shows the pH, conductivity, turbidity, BOD, COD,

DO, total dissolved solids, total suspended solids values for Sukhna Lake sample testing.

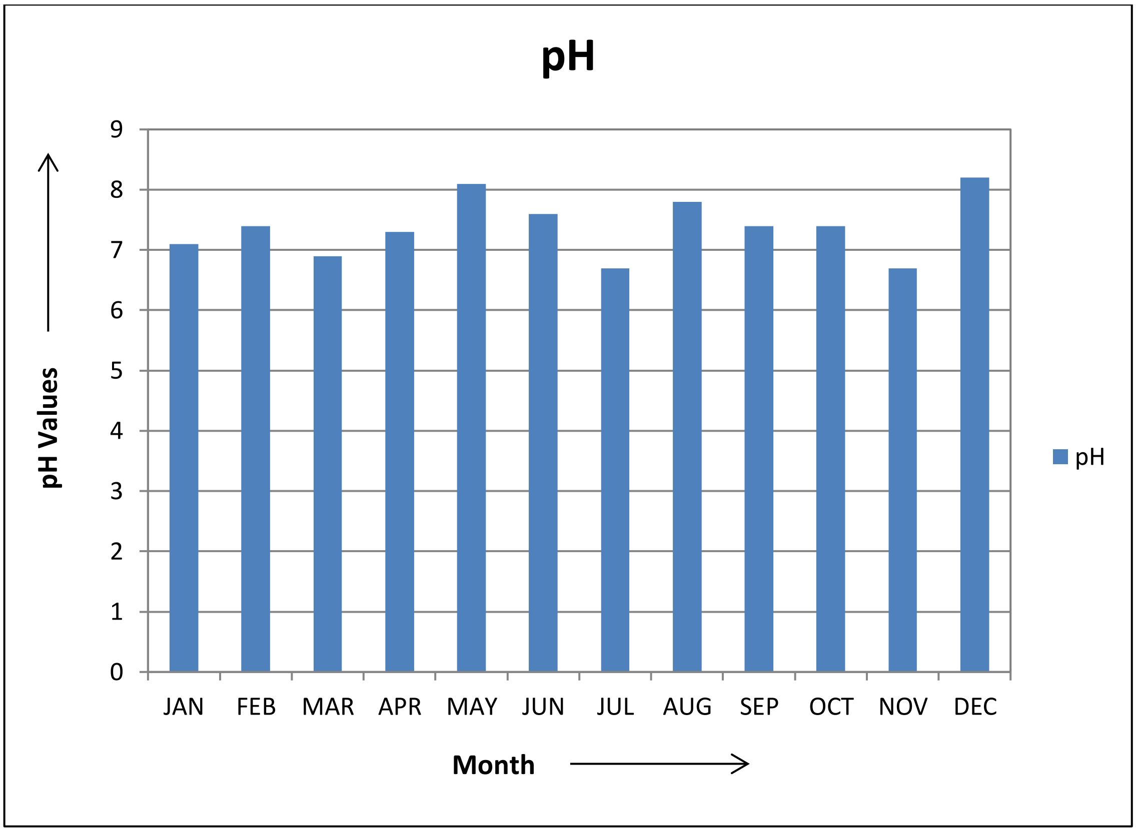

Fig. 7.16: Graphical representation of Sukhna Lake pH results

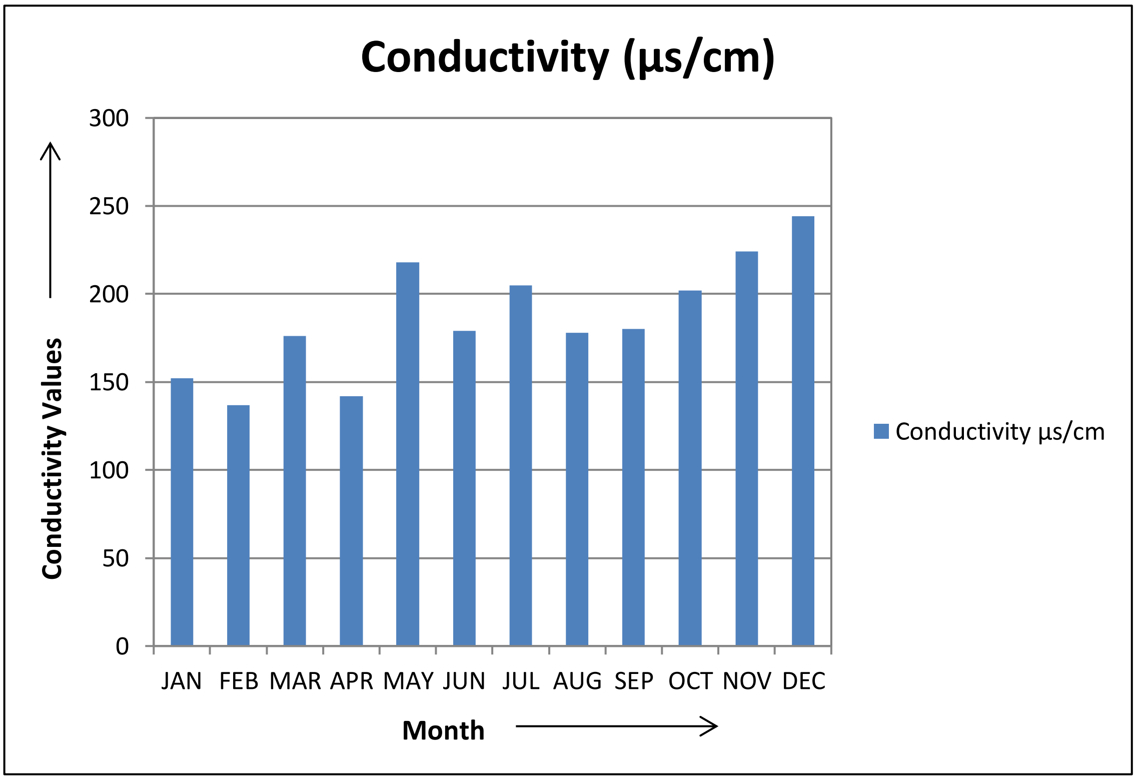

Fig. 7.17: Graphical representation of Sukhna Lake Conductivity results

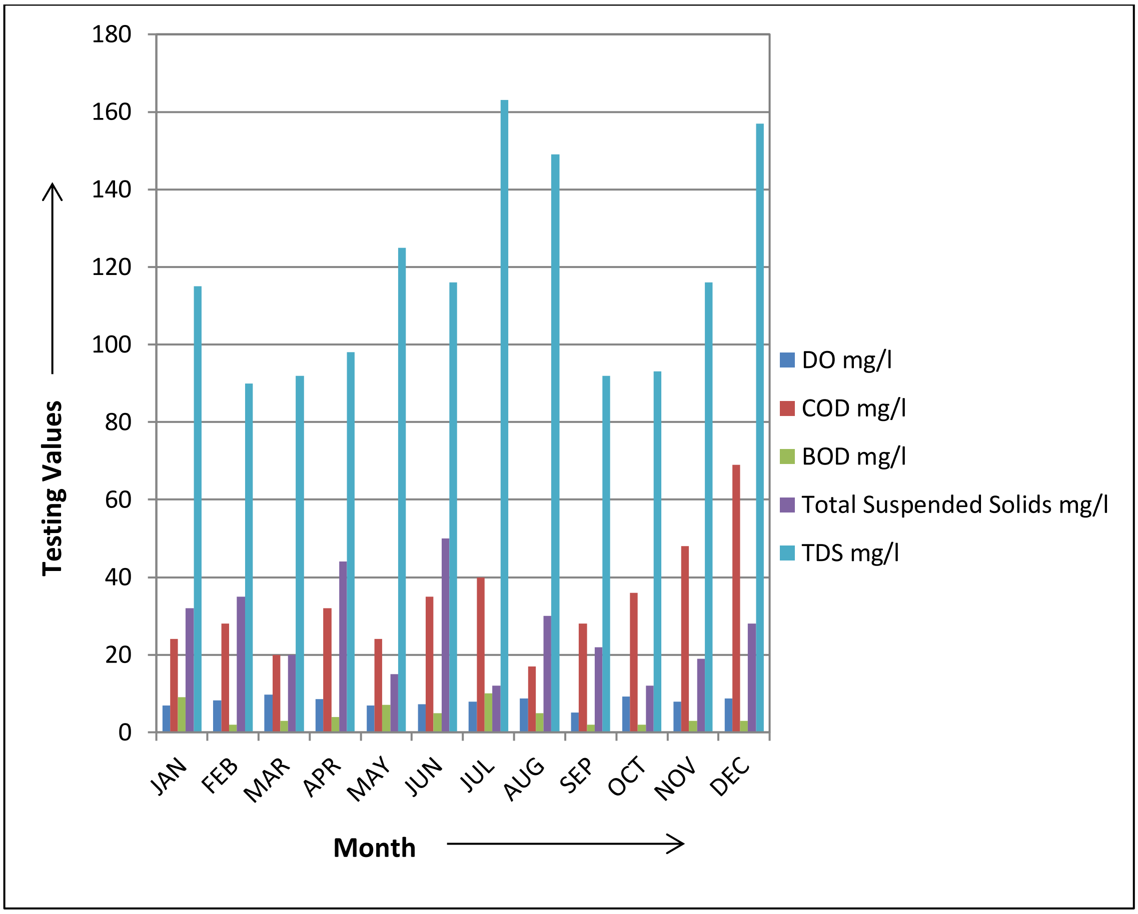

Fig. 7.18: Graphical representation of Sukhna Lake DO, COD, BOD, TSS, TDS results

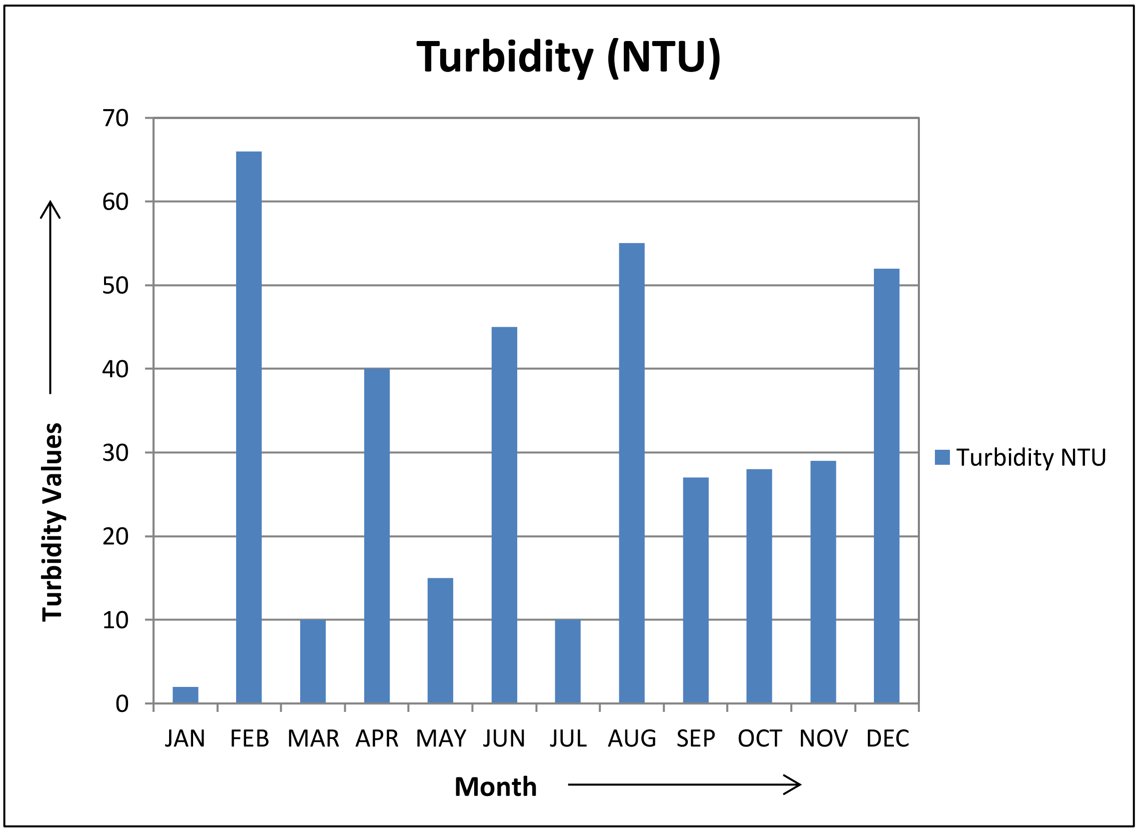

Fig. 7.19: Graphical representation of Sukhna Lake Turbidity results

Table 7.8: SUKHNA CHOE/DRAIN (2019)

Sr. No.	Parameters	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	pH	-	7.5	7.3	7.5	7.3	7.2	7.3	7.7	7.5	7.4	7.1	7.5	7.4
2	Conductivity	µs/cm	612	794	913	872	1309	624	489	1084	1003	973	1015	428
3	DO	mg/l	2.2	<1	2.1	<1	2.2	2.0	0.7	0.9	0.5	2.0	0.2	2.1
4	COD	mg/l	114	144	157	141	176	148	80	330	248	310	318	307
5	BOD	mg/l	24	46	42	46	50	42	22	203	77	99	132	133
6	Total Suspended Solids	mg/l	26	160	59	170	75	160	32	100	170	62	90	105
7	TDS	mg/l	337	516	449	562	720	405	286	639	496	515	389	274
8	Turbidity	NTU	42	30	80	40	65	75	29	83	47	78	105	190

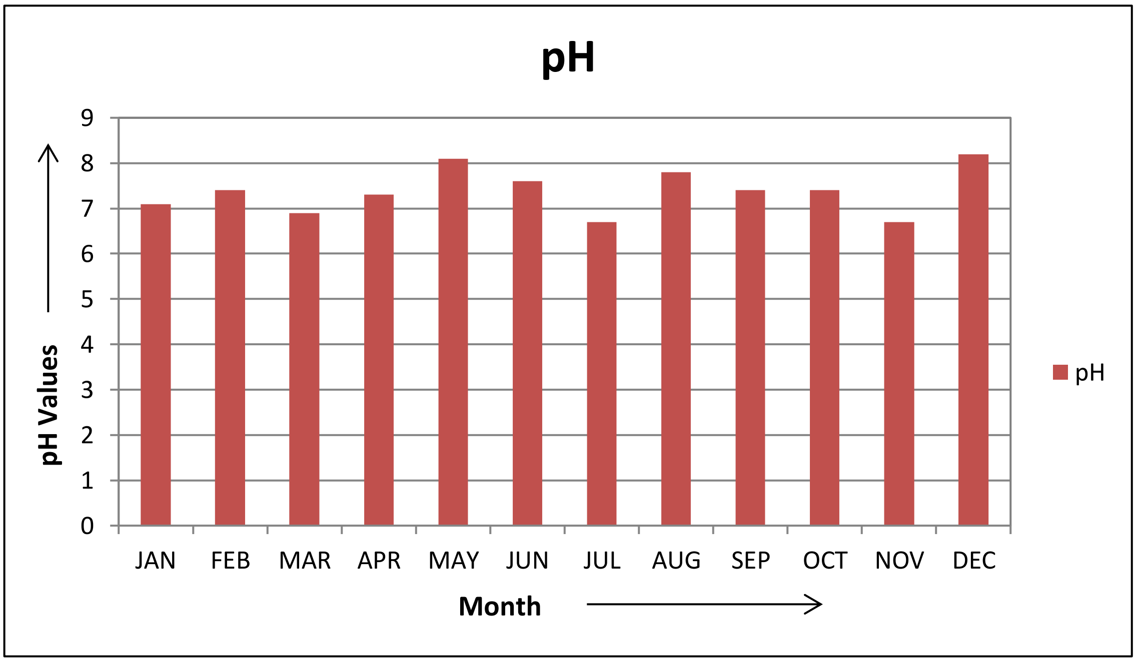

Fig. 7.20: Graphical representation of Sukhna Choe/Drain pH results

Table 7.8 show the testing of Sukhna Choe/Drain sample conducted in the laboratory and Figure 7.20, 7.21, 7.22, 7.23 shows the pH, conductivity, turbidity, BOD, COD, DO, total dissolved solids, total suspended solids values for Sukhna Choe/Drain sample testing.

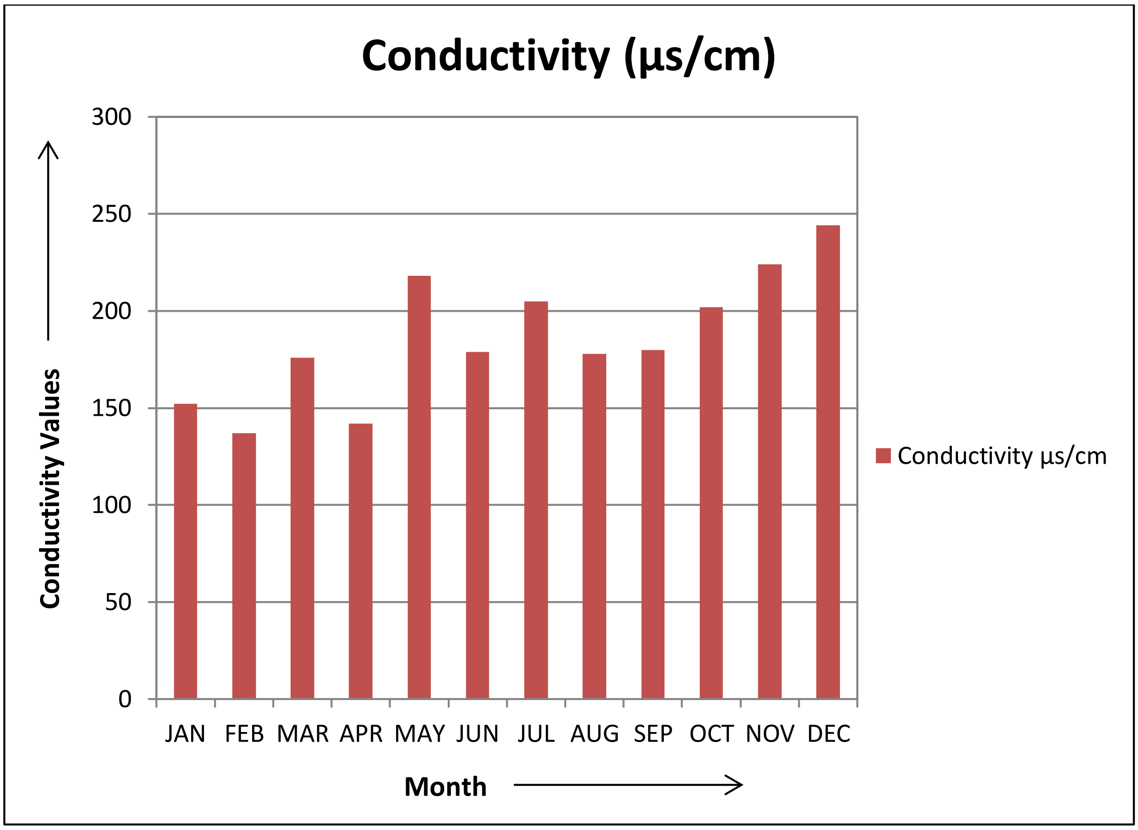

Fig. 7.21: Graphical representation of Sukhna Choe/Drain conductivity results

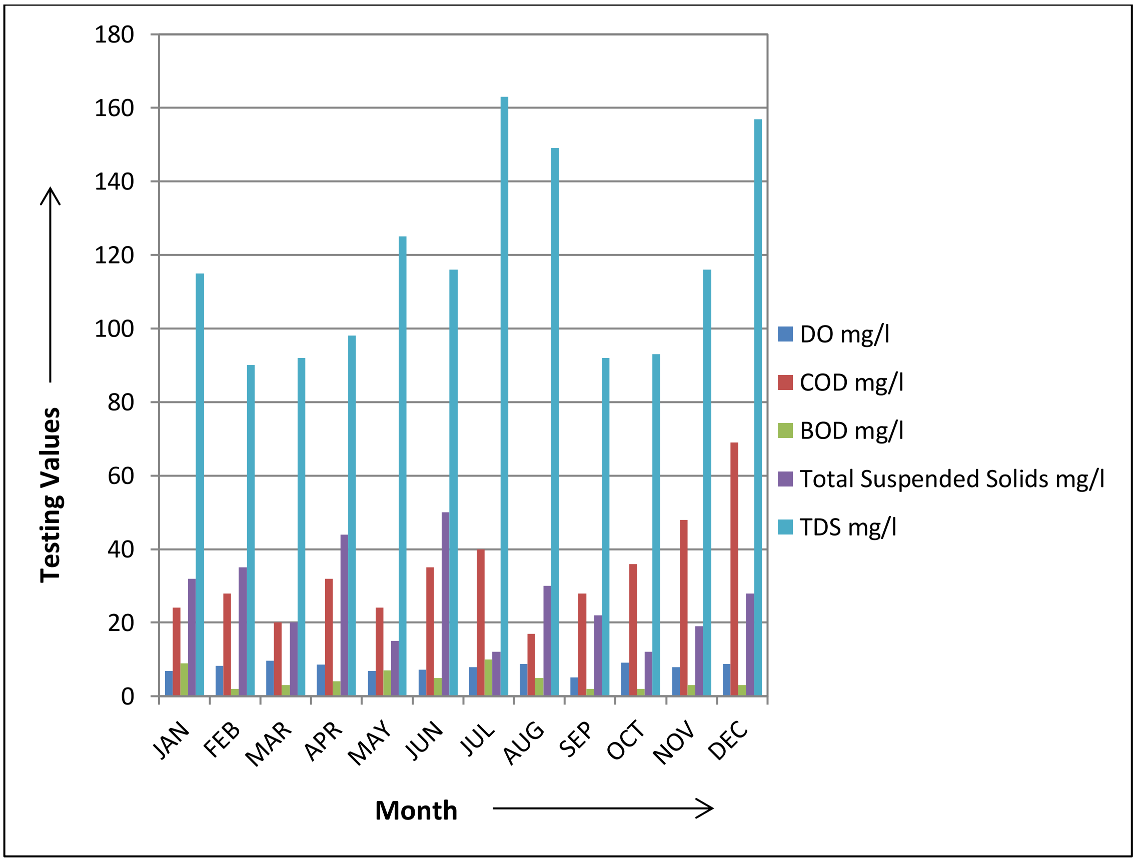

Fig. 7.22: Graphical representation of Sukhna Choe/Drain DO, COD, BOD, TSS, TDS results

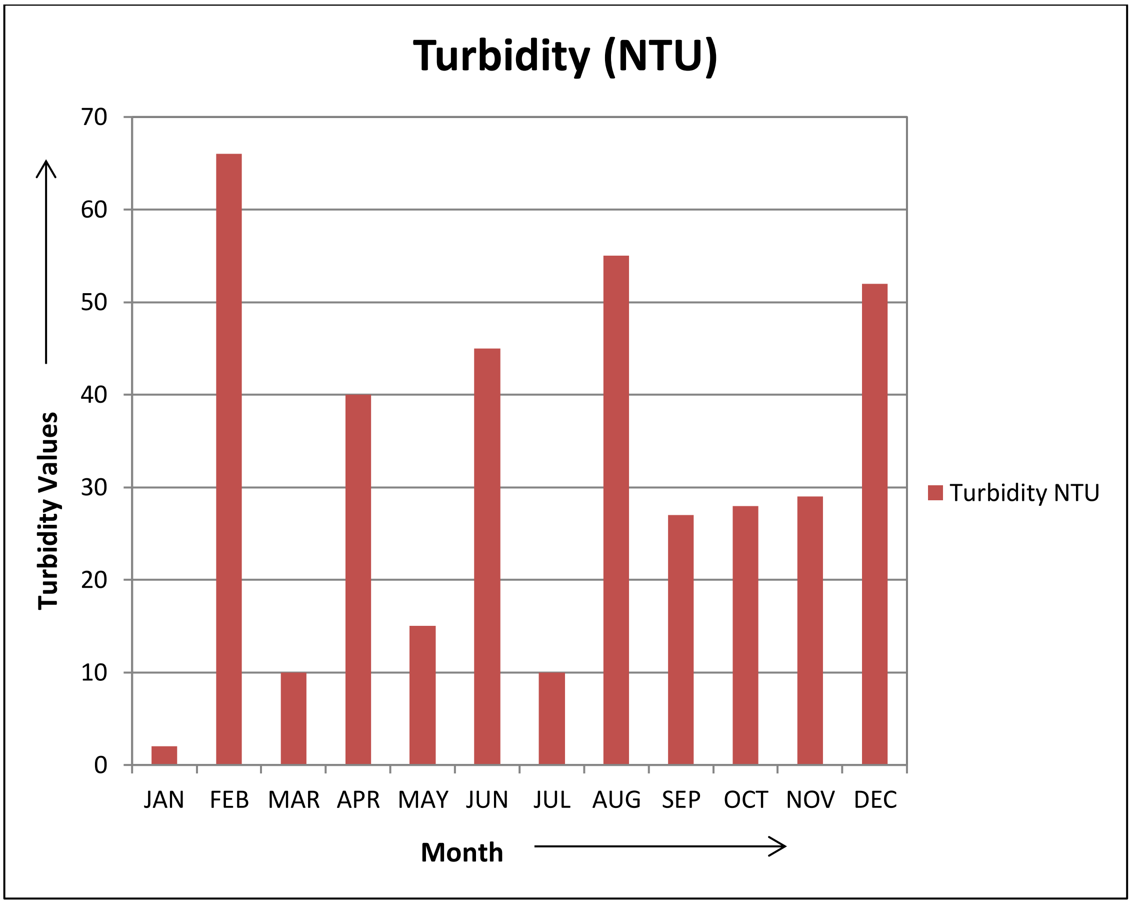

Fig. 7.23: Graphical representation of Sukhna Choe/Drain turbidity results

Table 7.9: PATIALA KI RAO CHOE/DRAIN (2019)

Sr. No.	Parameters	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	pH	-	7.2	7.4	7.5	7.7	7.4	7.7	7.3	7.6	7.7	7.5	7.8	6.6
2	Conductivity	µs/cm	891	800	1049	852	1054	766	1032	644	589	950	1091	1080
3	DO	mg/l	0.1	<1	0.3	<1	0.1	<1	0.7	0.2	0.8	0.5	0.2	0.7
4	COD	mg/l	176	202	186	206	194	212	200	230	298	396	530	610
5	BOD	mg/l	71	75	87	82	72	79	80	58	72	172	298	299
6	Total Suspended Solids	mg/l	97	100	89	100	105	90	110	220	477	277	336	715
7	TDS	mg/l	600	521	570	560	655	498	576	268	304	515	559	519
8	Turbidity	NTU	64	55	80	65	55	70	99	230	495	260	278	380

Table 7.9 shows the testing of Patiala Ki Rao Choe/Drain sample conducted in the laboratory and Figure 7.24, 7.25, 7.26, 7.27 shows the pH, conductivity, turbidity, BOD, COD, DO, total dissolved solids, total suspended solids values for Patiala Ki Rao Choe/Drain sample testing.

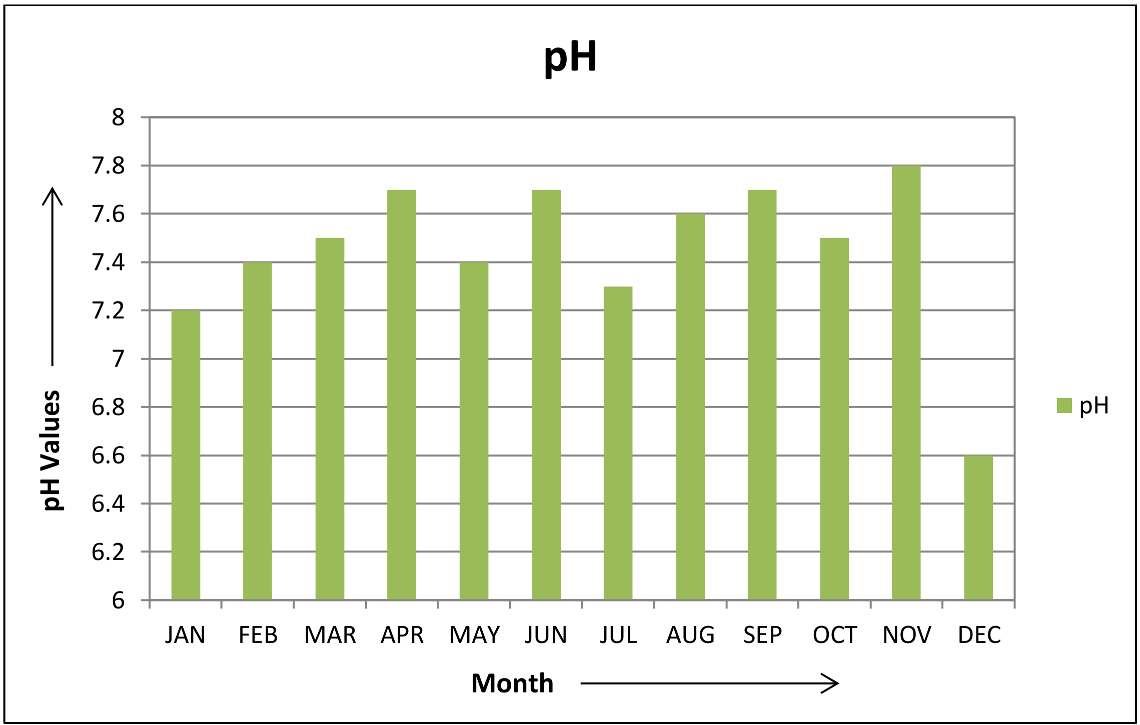

Fig. 7.24: Graphical representation of Patiala Ki Rao Choe/Drain pH results

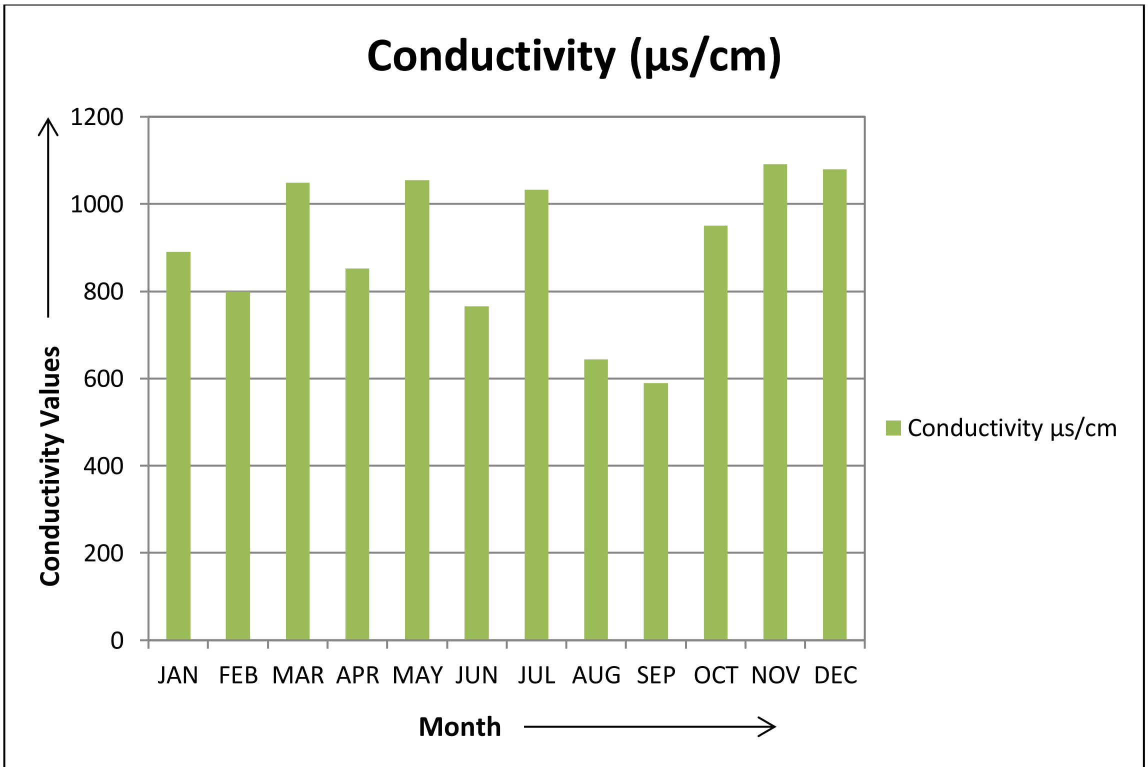

Fig. 7.25: Graphical representation of Patiala Ki Rao Choe/Drain conductivity results

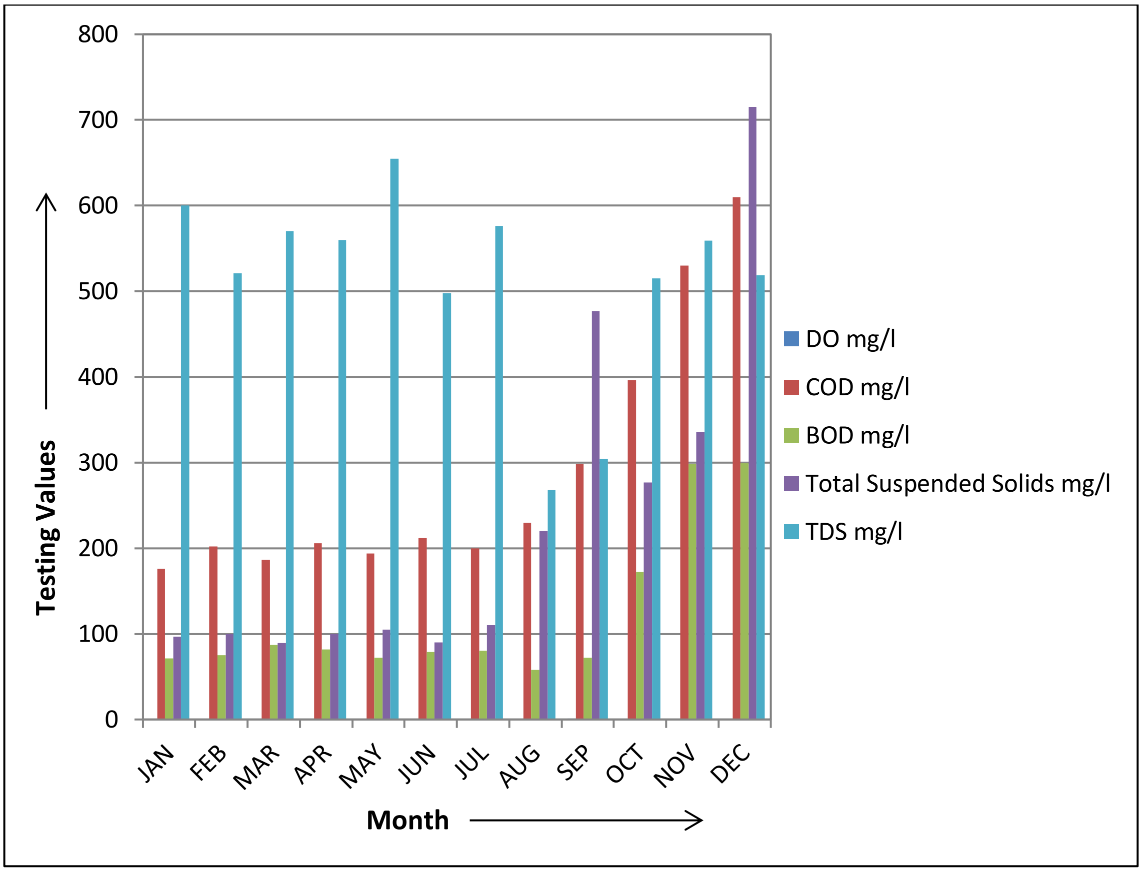

Fig. 7.26: Graphical representation of Patiala Ki Rao Choe/Drain DO, COD, BOD, TSS, TDS results

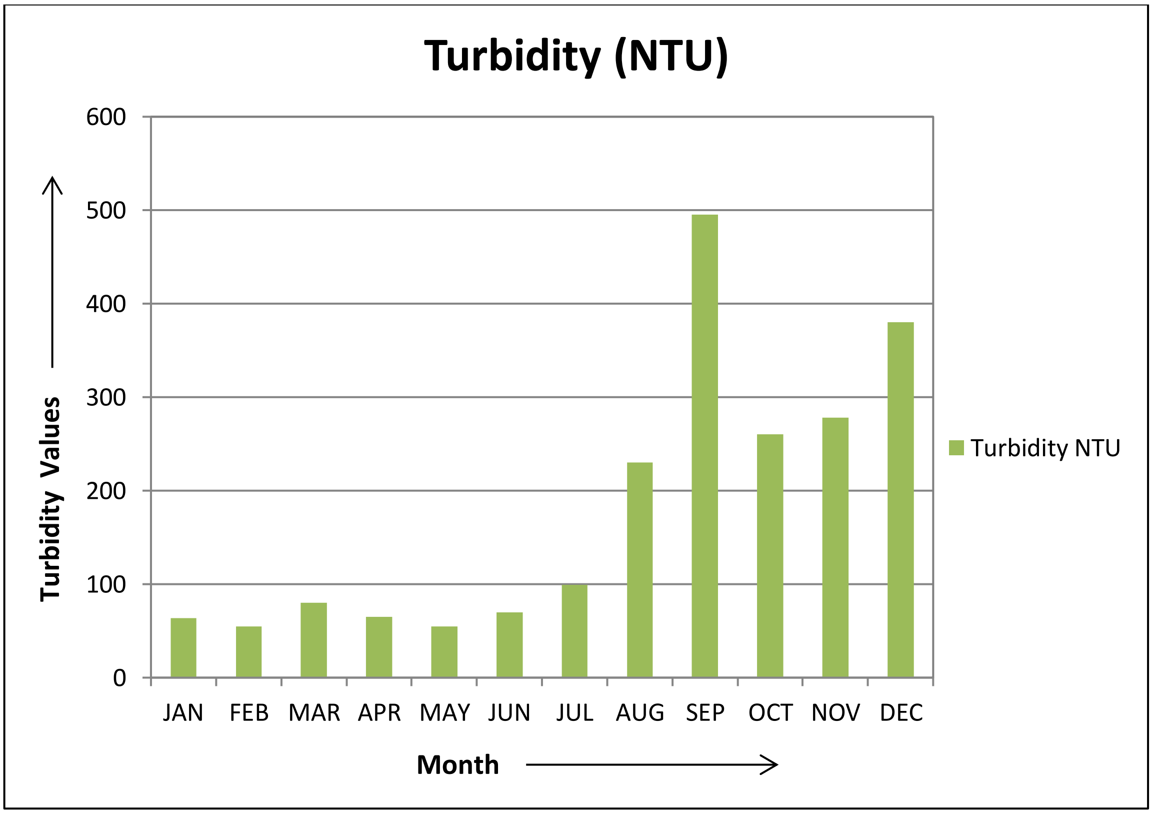

Fig. 7.27: Graphical representation of Patiala Ki Rao Choe/Drain turbidity results

Table 7.10: STP DIGGIAN OUTLET (2019)

Sr. No.	Parameters	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	pH	-	7.6	7.5	7.3	7.0	7.4	7.3	7.2	6.3	7.3	7.9	7.1	7.3
2	DO	mg/l	4.9	3.2	4.1	4.2	3.2	4.5	4.3	6.3	4.1	3.6	4.5	4.5
3	COD	mg/l	128	82	120	89	127	83	100	90	87	148	142	180
4	BOD	mg/l	32	25	48	27	31	32	26	37	29	49	27	55
5	TSS	mg/l	38	85	32	75	56	80	49	66	58	25	49	85
6	Total Nitrogen	mg/l	1.80	13.90	1.36	13.50	1.42	13.70	1.22	13.90	1.40	1.4	13.8	1.6

Table 7.10 shows the testing of STP Diggian outlet sample conducted in the laboratory and Figure 7.28, 7.29 shows the pH, DO, BOD, COD, total suspended solids, total nitrogen values for STP Diggian outlet sample testing.

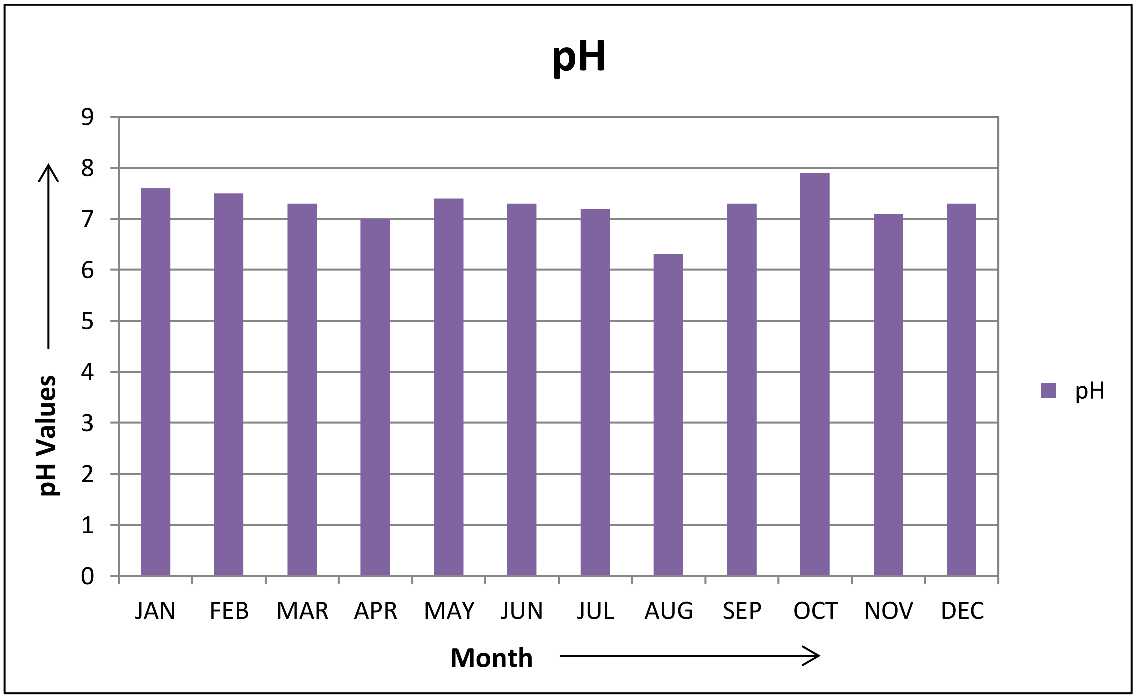

Fig. 7.28: Graphical representation of STP Diggian outlet pH results

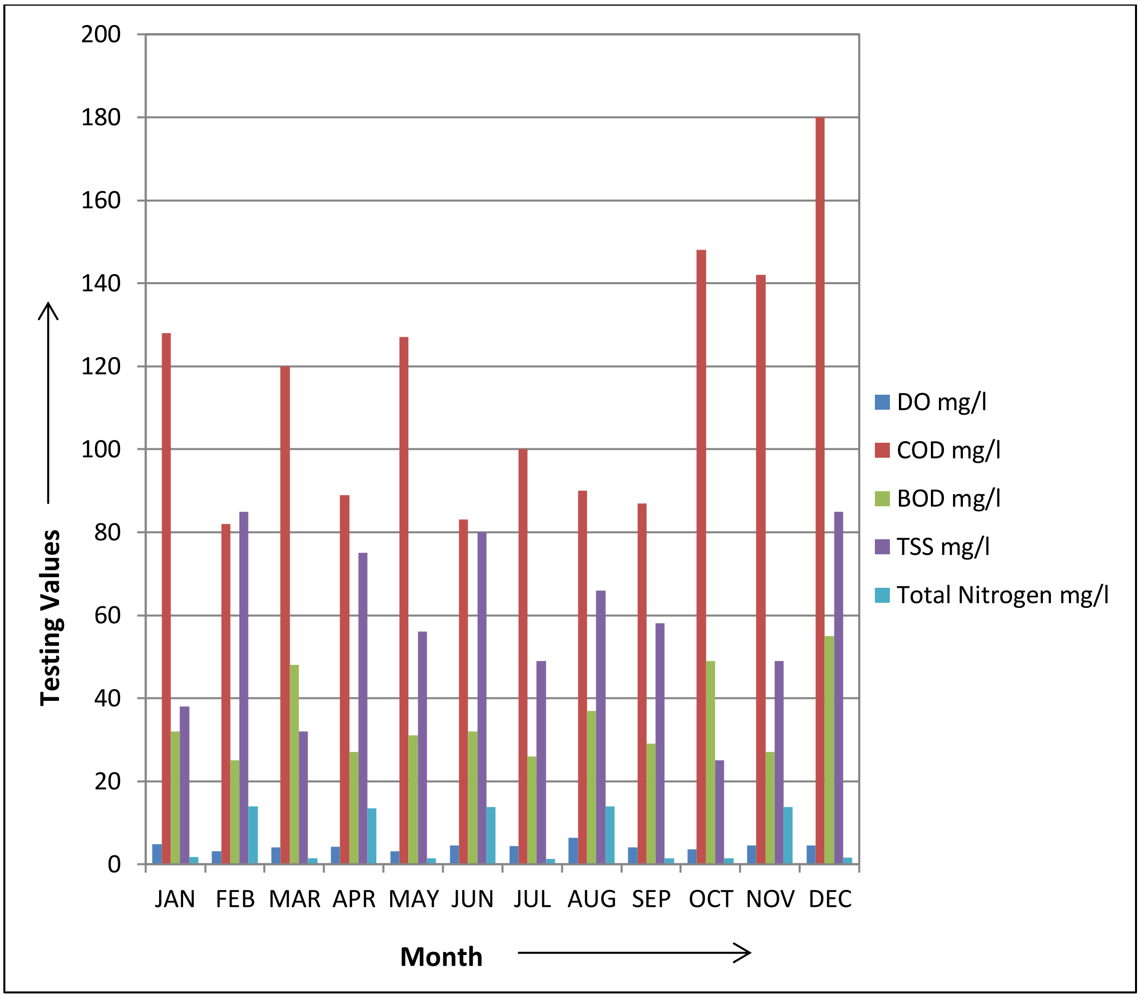

Fig. 7.29: Graphical representation of STP Diggian outlet DO, COD, BOD, TSS, Total Nitrogen results

Table 7.11: STP RAIPUR KHURD OUTLET (2019)

Sr. No.	Parameters	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	pH	-	7.4	7.3	7.3	7.2	6.7	7.4	6.9	6.8	7.4	6.8	7.2	7.5
2	DO	mg/l	1.9	<1	1.1	<1	1.2	<1	0.8	0.7	0.93	1.1	0.50	0.49
3	COD	mg/l	205	82	118	78	136	82	77	81	190	292	308	230
4	BOD	mg/l	41	24	38	29	45	26	31	47	54	73	82	122
5	TSS	mg/l	89	50	72	50	57	50	51	85	127	58	97	92
6	Total Nitrogen	mg/l	1.4	14.5	1.05	7.2	1.21	14.0	1.9	7.1	1.98	13.9	1.8	1.5

Table 7.11 shows the testing of STP Raipur Khurd outlet conducted in the laboratory and Figure 7.30, 7.31 shows the pH, DO, BOD, COD, total suspended solids, total nitrogen values for STP Raipur Khurd outlet sample testing.

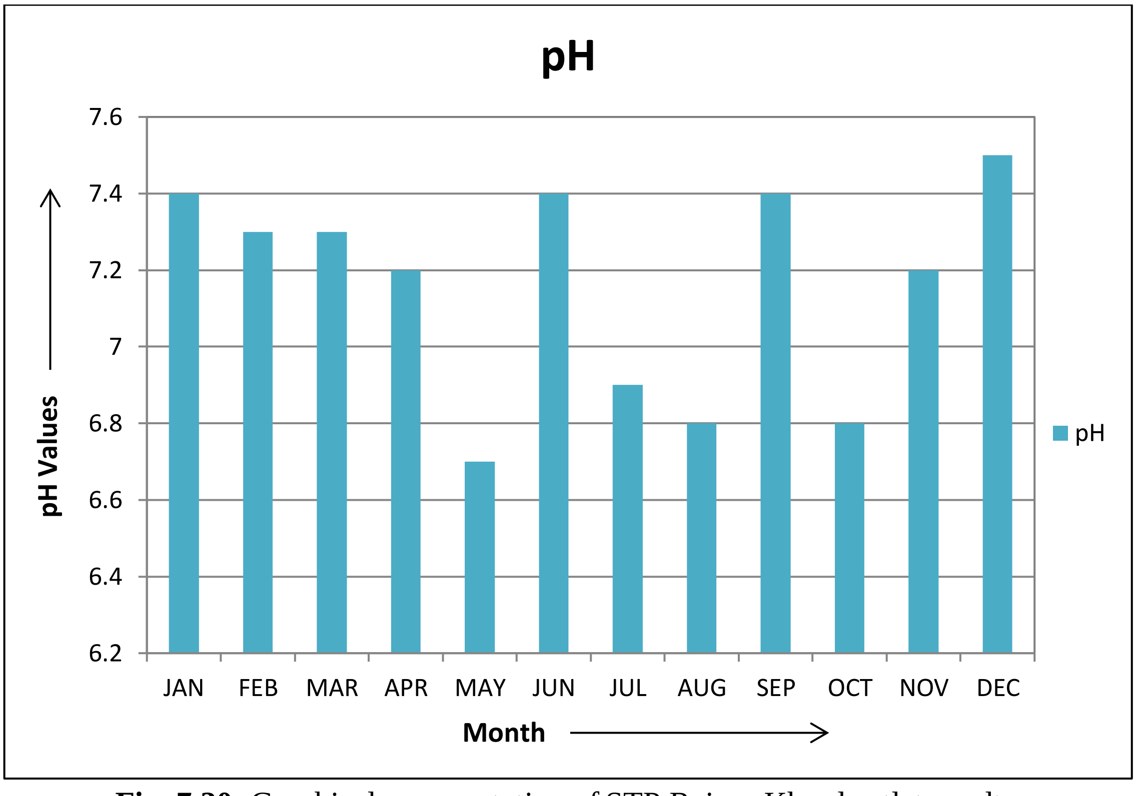

Fig. 7.30: Graphical representation of STP Raipur Khurd outlet results

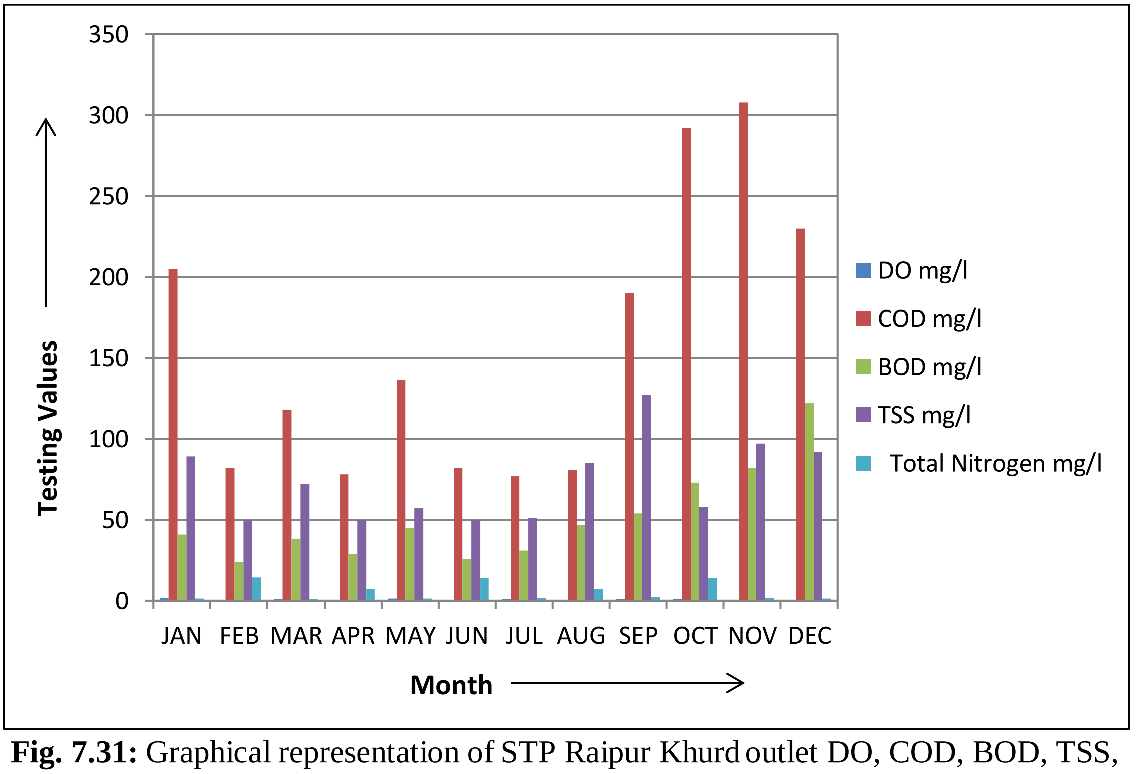

Fig. 7.31: Graphical representation of STP Raipur Khurd outlet DO, COD, BOD, TSS, Total Nitrogen results

Table 7.12: STP RAIPUR KALAN OUTLET (2019)

Sr. No.	Parameters	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	pH	-	7.1	7.3	7.2	6.9	7.1	7.0	7.4	7.1	6.9	6.8	7.0	7.3
2	DO	mg/l	0.2	<1	0.5	0.3	2.1	<1	0.1	0.2	2.1	0.6	NIL	2.2
3	COD	mg/l	130	103	127	135	105	74	220	318	178	358	418	178
4	BOD	mg/l	80	31	62	31	41	27	46	80	98	98	94	72
5	TSS	mg/l	39	45	24	51	33	55	31	109	123	89	252	47
6	Total Nitrogen	mg/l	1.9	12.4	2.0	2.1	1.8	14	1.72	13.7	2.4	12.1	2.2	2.1

Table 7.12 shows the testing of STP Raipur Kalan outlet sample conducted in the laboratory and Figure 7.32, 7.33 shows the pH, DO, BOD, COD, total suspended solids, total nitrogen values for STP Raipur Kalan outlet sample testing.

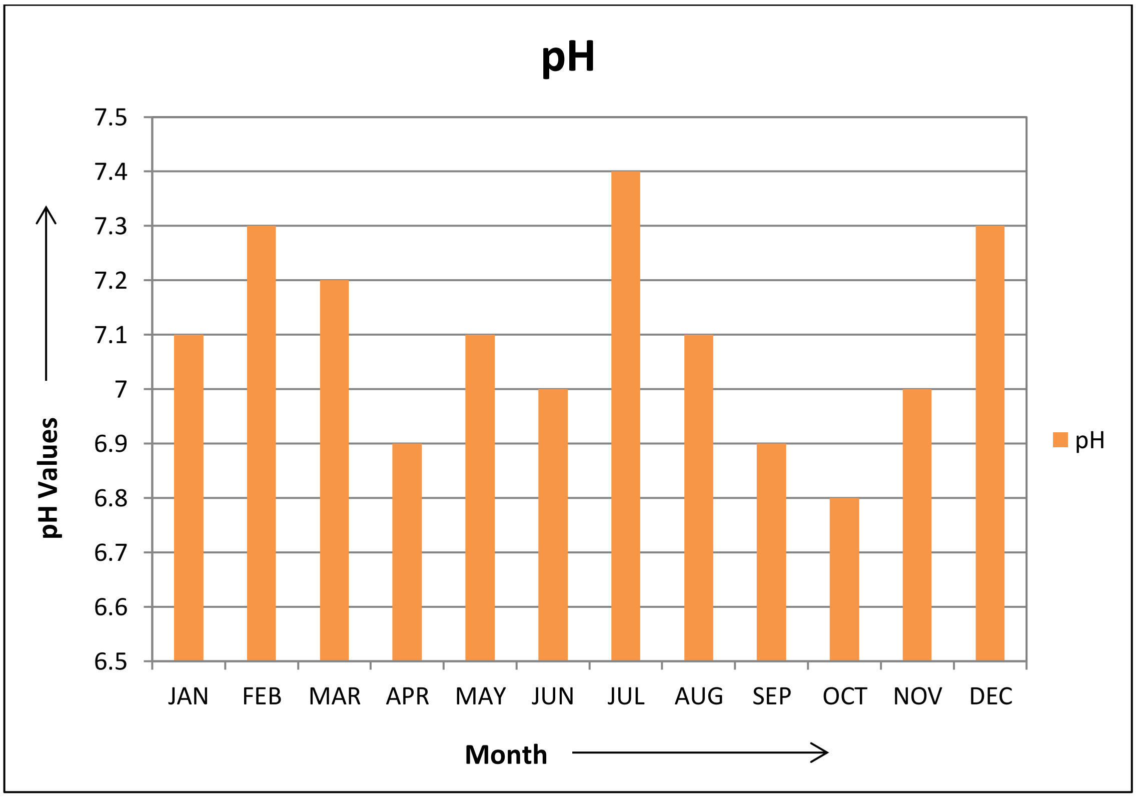

Fig. 7.32: Graphical representation of STP Raipur Kalan outlet pH results

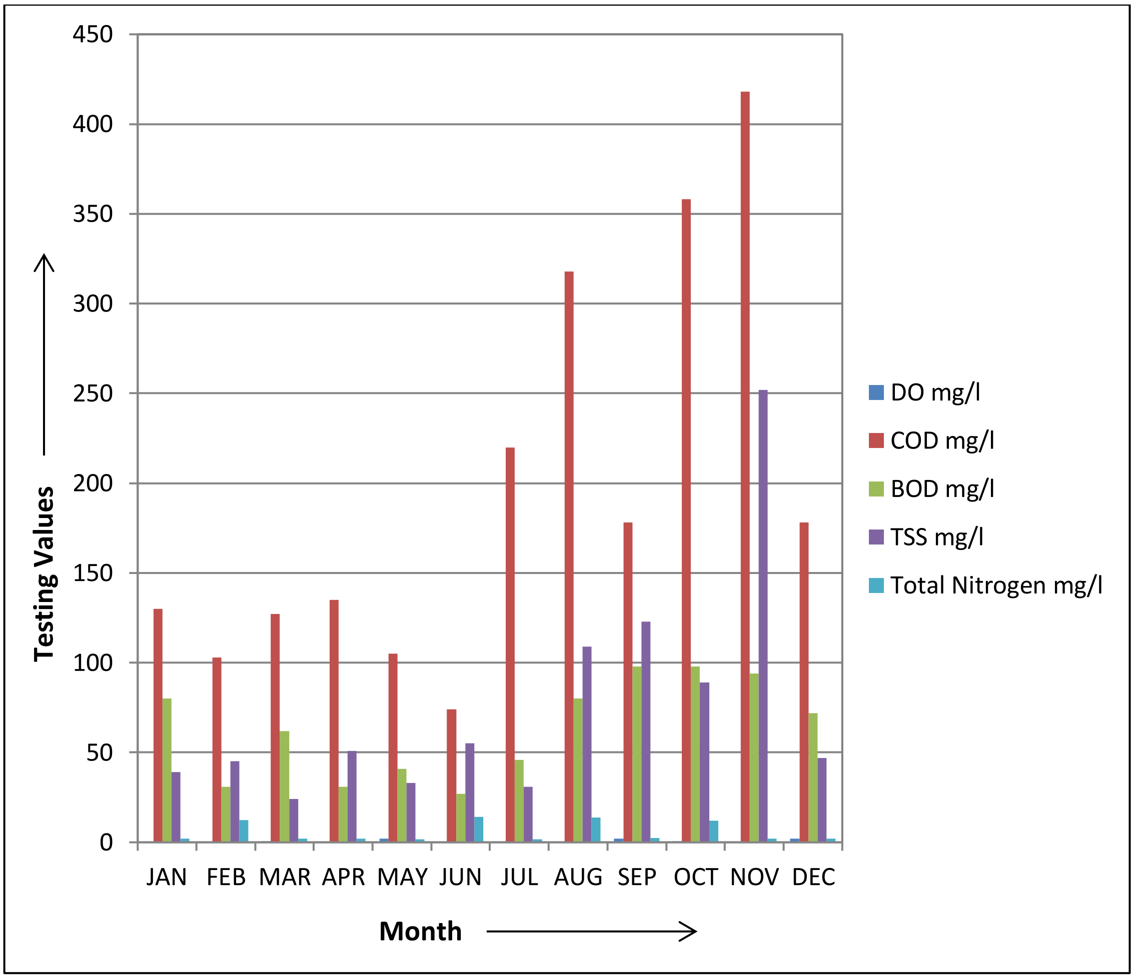

Fig. 7.33: Graphical representation of STP Raipur Kalan outlet DO, COD, BOD, TSS, Total Nitrogen results

Table 7.13: STP DHANAS OUTLET (2019)

Sr. No.	Para meters	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	pH	-	7.3	7.1	8.0	8.9	7.2	7.8	7.5	7.8	7.8	6.7	7.8	6.8
2	DO	mg/l	3.2	3.8	5.1	4.9	6.0	5.1	3.6	5.3	3.7	5.7	3.4	5.7
3	COD	mg/l	157	71	170	78	108	74	60	134	194	79	116	102
4	BOD	mg/l	31	39	45	23	22	32	12	21	28	10	29	10
5	TSS	mg/l	84	31	75	20	52	25	46	14	37	8	12	14
6	Total Nitrogen	mg/l	1.1	1.1	1.0	9.5	1	9.9	0.9	9.1	0.8	0.7	0.5	1.2

Table 7.13 shows the testing of STP Dhanas outlet sample conducted in the laboratory and Figure 7.34, 7.35 shows the pH, DO, BOD, COD, total suspended solids, total nitrogen values for STP Dhanas outlet sample testing.

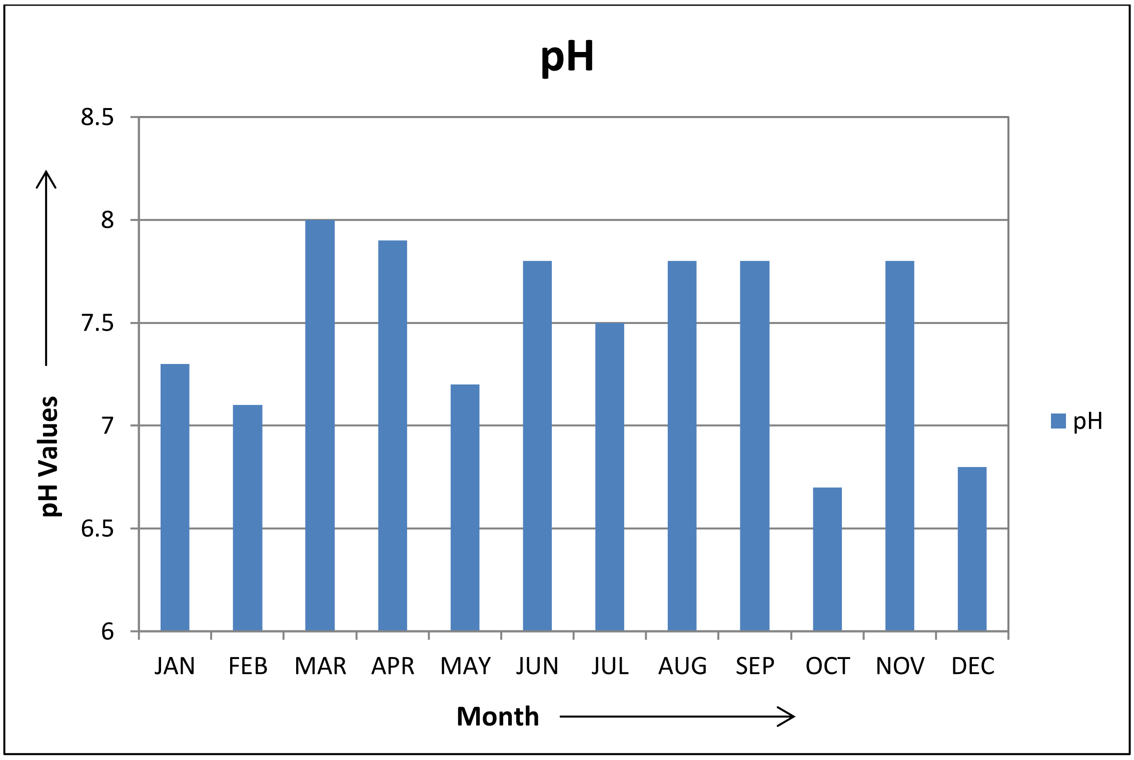

Fig. 7.34: Graphical representation of STP Dhanas outlet pH results

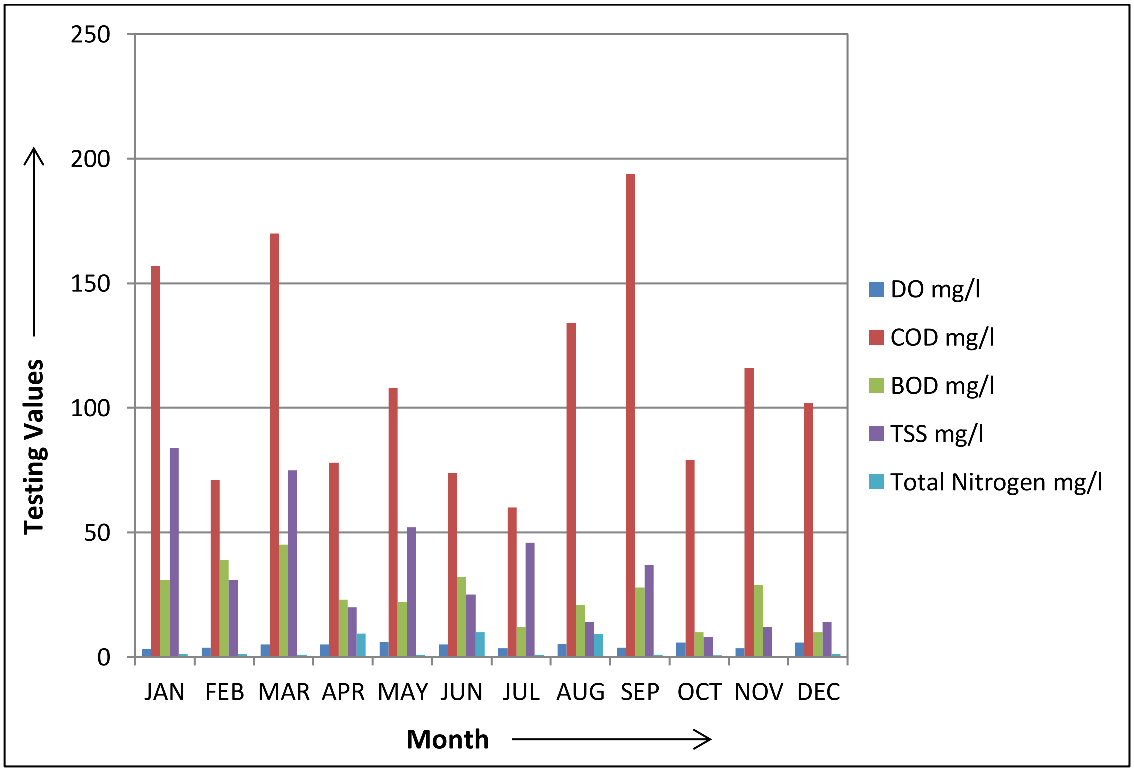

Fig. 7.35: Graphical representation of STP Dhanas outlet DO, COD, BOD, TSS, Total Nitrogen results

Above tables and figures shows the testing of various samples taken from lakes, STPs, drains, outlets etc. to check the water quality in order to protect our environment and to improve the water standards as well as to get the various results related to BOD, COD, pH, TSS, Nitrogen etc. All the testing was done in the environment engineering laboratory inside the university campus. As we have successfully implemented the concept of dual plumbing in our case study for residential towers which would be helpful in preventing fresh water, we can check the parameters like BOD, COD, pH, TSS, Nitrogen etc. for the wastewater stored in the tank.

Freshwater resources are inadequate to meet domestic, economic development and ecological needs. In such areas, the absence of sufficient clean water to meet human drinking water and sanitation needs is for sure an imperative on human wellbeing and efficiency and consequently on financial improvement. We all associated with research must discover approaches to eliminate these requirements. We face various difficulties in managing fresh water particularly given a changing and unsure future atmosphere, and a quickly developing populace that is driving expanded social and economic development, globalization, and urbanization. To address these difficulties it requires best research in all parts of water management.

This testing identifies the issues that water managers face today. This testing also brings the impact in using water which was tested properly in the city so that we can use it whenever necessary.

CHAPTER 8

CONCLUSION

8.1 Conclusion

The water is most consumable natural resource around the world, whether it is for construction purpose, sanitation purpose, hydropower projects, irrigation of fields, drinking and what not; the humanity can't be imagined without water. Although, study of water is quite an old topic in the field of research, but its availability and properties differs from region to region, thus it is quite difficult to incorporate the results or recommendation from one case study to any other regional study. Secondly, land of Northern India is known for its crop growing amenities and crops are illusory without water. So to fulfill the water requirement of crops, farmers are majorly relying on the ground water source, thus leads to scarcity or decreasing ground water levels. Thirdly, the growth of industrialization because of ease in government policies and make in India concept has put the quality of water and resources on stack.

Nationally and internationally, researchers have attempted to understand the various prospective of water means either related to quality or quantity and their conclusions and recommendation have helped planners in a fruitful manner as well. But need of the hour is to present a state-of-the-art report to cover all the aspect of water. So, in the present study attempt has been made to understand the pattern of water use, availability, adequacy, water quality, scarcity and stress in the Chandigarh – The City Beautiful. The pressures from the growing population, change in land use, expansion of urban amenities and present status of water supply system, water storage facility, untapped surface water, declining ground water level and over dependence on the ground water resources have adversely affected the hydrological cycle and created scarcity condition in regard to drinking water availability and supply in the study area.

1) The present study proposed concept of the proper distribution system via incorporating the concept of double plumbing for saving storm water and treated waste water.
2) As Chandigarh is rapidly growing and in the last decade (2010 to 2020), its population growth rate has tremendously increased and average annual rainfall is

900 mm. Therefore, more runoff is generated and existing storm water drains in Chandigarh in some areas are not sufficient due to tremendously increasing paved area. Earlier in past 15-20 years, Chandigarh city was 30-40% impervious with less storm water generation, but by rapid growth in the city, it led to 60-75 % increase in impervious surface which led to generation of maximum storm water. So by adopting Integrated Urban Water Management (IUWM) in the city, it will effectively reduce the runoff generation by implementing more and more storage tanks nearby residential towers and houses.

3) Thereafter, rainfall data have been evaluated, such as total average rainfall for 10 years is 890.91 mm, maximum value reaching 406.5 mm and Standard Deviation is 95.77. In addition, to make city future ready, the projection of water demand in next one decade i.e. up to 2031 has been assessed. To understand the demand, the population in next one decade is augmented to 1.1 million to 1.76 million and has been incorporated using Matlab.

4) As water is necessary for citizens and aquatic life, so, it is important to check the existing water quality in lakes, drains, STPs etc. For the three cases we considered here in the study, the first case includes the lake sample which requires minimum treatment and we can use lake water as a good source other than drinking at the time of shortage of water. Other two cases (Drain and STP Outlet) can also be used but require more treatment than the first one as lake water is a good source for utilization. From various tested samples; a comparison was done on various parameters with the earlier stakeholder’s testing. The results were evaluated for every month and the result values were in permissible limits. The testing identifies the issues that water managers face today and also brings the impact of using water which was tested properly in the city so that we can use it whenever necessary.

5) The water balance has been incorporated as the requirement of water is 493 MLD (drinking, domestic and other purposes) with respect to the availability of 363 MLD, thus results in a deficiency of 130 MLD. The water balance equation has been used to describe the flow of water in and out of a system. Water balance calculation presents the total inflow (recharge from rainfall, canals, irrigation) as 83.03 million cubic meters and outflow of water (runoff, deficit, evaporation, ground water seepage and drought) as 13.82 million cubic meters respectively.

Thus, water balance in the city is 69.21 million cubic meters out of which some water stores and some water goes to drains, ground water seepage, evaporation and runoff. The deficiency of water in the city can be proposed by our study, which fulfills the sufficient requirement of water. It has to notify that the above calculation is counted for 1.1 million population of the city, Chandigarh.

6) In order to apply our research on the actual ground situation, the present work supports the concept of double plumbing in residential towers which would be helpful in preventing fresh water. The location for the case study considered to be Zirakpur (Mohali) and concept was implemented in residential towers on one of the prominent builders. By adopting this concept, the double plumbing brings the impact over 700 people with 200 houses in the towers. The analysis of stats for the considered locations has shown total saving of 29000 liters per day (29 KLD) of fresh water, i.e. 30% of the overall saving in the residential towers. In addition, the saved water is utilized for irrigation of the green area counts around 50,000 sq. ft. and also for flushing purpose where we were using fresh water source earlier. Charges of water in Chandigarh are Rs 25 per kilo liter (1 KL = 1,000 liters) [https://indianexpress.com/article/cities/chandigarh/chandigarh-mc] and from our case study we are not only saving water but also reducing the water bills. The cost which we are saving in the case study is Rs 725 per kilo litre of water per day, monthly saving Rs 21,750 per kilo litre of water and yearly saving of Rs 2,61,000.

The present finding provides a potential solution to water crisis in Chandigarh. The concept of double plumbing will work as a great approach for the region. Eventually, In order to sustain the availability of water, extraction should be avoided especially in urban areas and should be used judiciously, otherwise the future generation will have to face crisis of water. Micro-level water harvesting culture should be adopted in every household. Some water demands can be reduced by providing alternatives. Flush toilets require a large volume of water (up to 60 lpcd). Flush toilets use 6-10 litres per flush. The savings in water use can be upto 40-50% by switching over to double plumbing system. Thus, switching to double plumbing concept, flush toilets will make a great impact on the total water consumed in urban buildings. Problem of scarcity of water can be mitigated by using an integrated approach aimed at reducing water consumption, recycling and reusing of water. Quality of water needs to be maintained by treatment of water. Water should be stored and used with utmost care, using right practices prescribed for the purpose to avoid contamination. Community participation at all the stages of planning, formulation and implementation of water related programmes, watershed programmes and community water harvesting structure need to be strengthened.

8.2 Future Scope

The subject of management of water is vast and has many aspects. The study has thrown light on certain issues which can open doors for further research. The study is expected to solve the challenges related to the management of water in Chandigarh for the future purpose. The future research could include the following aspects:

1) The present study examines the quality, quantity and harvesting of water in Chandigarh. A detailed study could be carried out to examine the ground water recharge systems.
2) A depiction of the capability of strategic planning ready for urban management of water under varying situations and uncertainty.
3) To execute urban management of water plans through the government and nongovernment parts.
4) An action research can be carried out on management of water.

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ANNEXURE-I

Tin No. : 03382071570
AJUPM 4387PSD001

Mob. : 9814904926

N. T. B.

NEW TECH BUILDER

Engineer & Contractor

GSTIN- 03AJUPM4387P3Z7

H. O. : 14, Golden Estate, Baltana, N.A.C., Zirakpur-01762-653514

Letter of Approval

To mr. Nitish Kumar sharma Roll no- PHDCN 916044

Implementation of Double Plumbing System on our construction site at mohali Pb

NEW TECH BUILDER'S
GSTNo-03AJUPM4387P3Z7

For New Tech Builder

Proprietor

ANNEXURE-II

LETTER OF APPROVAL

Mr Nitish Sharma Roll No PHDENG16044 has the Permission to use our society ..SILVERCITY.... EXTENSION Name, which was constructed in year 2001 -2010.

Infra Maintenance
Derahassi

Management

ANNEXURE-III

LETTER OF APPROVAL

Mr Nitish Sharma Roll No PHDENG16044 has the Permission to use our society ...SILVERCITY........ ...MAIN....... Name, which was constructed in year 2001 -2010.

Management

ANNEXURE-IV

CERTIFICATE OF UNDERTAKING

(To be signed by the party receiving meteorological data of the India Meteorological department)

With reference to your letter No. 41(1)/2415 Dated 13/01/2020 it is certified that:

1. The data supplied by India Meteorological Department will be used only for the purpose for which it has been asked and supplied.
2. The data are meant exclusively for our own use and shall not be passed or transmitted to any other party, agency (Indian or Foreign)/media (Magnetic or Electronic) either in part or in full. If so needed, prior approval in writing will be taken from India Meteorological for the same.
3. The data shall not be used for commercial purpose or to earn consultancy fees, honoraria etc.
4. Due acknowledgement shall be given to India Meteorological Department for the source of data in all reports/publications etc. brought out by us.
5. The data supplied by India Meteorological Department will not be put on Internet or Nicnet or will not be transmitted through any electronic media.

Station : Chandigarh

Date : 13/01/2020

SIGNATURE AND NAME OF
Head of the Office/Department

Head
Civil Engineering Department
Chandigarh University
Gharuan, Mohali (Pb.)

(Stamp/Seal of the Office/Dept.)

ANNEXURE-V

Questionnaire

INFORMATION ABOUT YOU

This brief introductory section asks you questions that will help us understand the range of people participating in this questionnaire. Please remember that this information is not for the purpose of trying to identify any individual and remains anonymous.

1. Which stakeholder group do you represent?

- ☐ Institutional Organisation
- ☐ Environmental Information System
- ☐ Chandigarh Water Resources
- ☐ Environment Protection Authority
- ☐ Department of Sustainability and Environment
- ☐ Municipal Corporation
- ☐ Meteorological Department
- ☐ Department of Human Services
- ☐ Essential Services Commission
- ☐ Local Government
- ☐ Land Developers
- ☐ Consultants
- ☐ Politicians
- ☐ Community / Environment Groups
- ☐ Researchers
- ☐ Other (Please specify, e.g. specific trades, other government departments)

2. At what level are you positioned within your organisation's hierarchy?

- ☐ Junior
- ☐ Middle
- ☐ Senior
- ☐ Executive

3. Broadly, what is the main type of work that you do?

- ☐ Strategy / Policy
- ☐ Design / Technical / Operations
- ☐ Regulation / Auditing
- ☐ Research / Science
- ☐ Education / Marketing
- ☐ Other (please specify)

4. Which area of water management do you primarily work in?
(You can tick more than one if needed)

- ☐ Stormwater / Waterways
- ☐ Sewage
- ☐ Water Supply
- ☐ Land Development Broadly
- ☐ Total Water Cycle Management
- ☐ Other (please specify)

5. What is your primary professional background and training?
(You can tick more than one if needed)

- ☐ Planning
- ☐ Engineering
- ☐ Science
- ☐ Education
- ☐ Law
- ☐ Business / Economics
- ☐ Marketing
- ☐ Humanities / Social Science
- ☐ Urban Design / Landscape Architecture
- ☐ Other (please specify)

6. How long have you been working in your current position?

- ☐ 0-1 year
- ☐ 2-5 years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ 16-20 years
- ☐ 20+ years

7. How many years of experience do you have working in the area of urban watermanagement?

- ☐ year
- ☐ 2-5 years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ 16-20 years
- ☐ 20+ years

Stormwater and Wastewater Quality Management

This part of the questionnaire asks you questions about Stormwater Quality Management across Chandigarh for protection of the receiving waterways. This part is much shorter, and we estimate that it will take you about 10-15 minutes to complete.

It is divided into four sections:

1) Storm water and Waste water Quality Management for Waterway Health
2) Timeframes for Stormwater Quality TreatmentTechnologies
3) Factors Influencing Storm water and Waste water Quality Treatment Practices
4) Stakeholder Commitment

We have provided 'comment boxes' throughout the questionnaire. Please note: it is entirely optional to add your comments, and it may add to the overall time that we estimated it would take you to complete the questionnaire.

1. Storm and Waste water Quality Management for Waterway Health

This section is focused on storm water quality management from an environmental protection perspective.

1. In YOUR opinion, how important is advancing storm water and waste water quality management practices across Chandigarh to the following groups for protection of the receiving waterways?

	Very Low	Low	Average	High	Very High	I don't know
You						
Your Organisation						
The Community						
Current State Politicians						

If you would like to comment on the question above, please write in the box below.

2. Timeframes for Stormwater Quality Treatment Technologies

In this section we ask for YOUR view on the envisaged timeframes that a range of stormwater quality treatment technology types could potentially be implemented across Chandigarh for protection of the receiving waterways.

When (if ever) do you envisage that the following technology types are likely to become mainstream on-ground practice in new developments across Chandigarh for protection of the receiving waterways?

	Already Mainstream Practice	Next 5 yrs	6-15 yrs	16-30 yrs	Over 30 yrs	I don't know	Not Applicable
Treatment Wetlands							
Gross Pollutant Traps							
Infiltration Systems							
Sedimentation Basins / Ponds							
Porous Pavements							
Rain gardens / Bio-retention systems							
Street tree bio-retention systems							

When (if ever) do you envisage that the following technology types are likely to become mainstream on-ground practice in EXISTING areas across Chandigarh for protection of the receiving waterways?

	Already Mainstream Practice	Next 5 yrs	6-15 yrs	16-30 yrs	Over 30 yrs	I don't know	Not Applicable
Treatment Wetlands							
Gross Pollutant Traps							
Infiltration Systems							
Sedimentation Basins / Ponds							
Porous Pavements							
Rain gardens / Bio-retention systems							
Street tree bio-retention systems							

If you would like to comment on any of the two questions above, please write in the box below:

3. Factors Influencing Storm water and Waste water Treatment Practices

This is the second-last section of the questionnaire. Here, we ask three questions that seek YOUR views on the current 'drivers' and 'barriers' to a small number of different technologies.

While there are a vast range of potential 'drivers' and 'barriers' (as well as technologies) for stormwater and Waste water quality treatment practices, the following questions are limited to the most significant "institutional" related factors that have been identified in previous research.

These factors can be related to the 'scale' and 'location' of the storm water and waste water treatment measures. The following three questions focus on these differences by asking about the:

1) LOCAL SCALE - typically streetscape or local park level

2) PRECINCT SCALE - typically serves over 100 lots

3) REGIONAL SCALE - typically catchment scale treatments

4. In your opinion, how do each of the following factors influence the current UPTAKE of LOCAL SCALE storm water and waste water quality treatment practices across Chandigarh?

(e.g. rain gardens / bio-retention systems, street tree bio-retention, side-entry pit traps etc.)

	Strongly Prevents	Slightly Prevents	Neither Prevents or Encourages	Slightly Encourages	Strongly Encourages	I don't know
Community Perception						
Capital Cost						
Maintenance Cost						
Technical Feasibility & Performance						
Professional Knowledge & Expertise						
Current Government Policy						
Management Arrangements & Responsibilities						
Regulation & Approval Processes						

Property Access Rights						
Environmental Outcomes						
Public Health Outcomes						
Social Amenity						

If you would like to comment on the question above, please write in the box below.

5. In your opinion, how do each of the following factors influence the current UPTAKE of PRECINCT SCALE (i.e. typically serves over 100 lots) Storm water and Waste water quality treatment practices across Chandigarh?

(e.g. small ponds, constructed wetlands, sedimentation basins, linear and basin bio-retention systems, infiltration systems)

	Strongly Prevents	Slightly Prevents	Neither Prevents or Encourages	Slightly Encourages	Strongly Encourages	I don't know
Community Perception						
Capital Cost						
Maintenance Cost						
Technical Feasibility & Performance						
Professional Knowledge & Expertise						
Current Government Policy						
Management Arrangements & Responsibilities						
Regulation & Approval Processes						

Property Access Rights						
Environmental Outcomes						
Public Health Outcomes						
Social Amenity						

If you would like to comment on the question above, please write in the box below.

6. In your opinion, how do each of the following factors influence the current UPTAKE of REGIONAL SCALE.

(i.e. typically catchment scale treatments) Stormwater and Waste water quality treatment practices across Chandigarh? (e.g. constructed wetlands and ponds)

	Strongly Prevents	Slightly Prevents	Neither Prevents or Encourages	Slightly Encourages	Strongly Encourages	I don't know
Community Perception						
Capital Cost						
Maintenance Cost						
Technical Feasibility & Performance						
Professional Knowledge & Expertise						
Current Government Policy						
Management Arrangements & Responsibilities						
Regulation & Approval Processes						
Property Access Rights						

Environmental Outcomes						
Public Health Outcomes						
Social Amenity						

If you would like to comment on the question above, please write in the box below.

4. Stakeholder Commitment
This is the final section of the questionnaire!

Here we ask about YOUR VIEWS on the current level of 'commitment' of different stakeholder organisation's across Chandigarh to advancing Integrated Urban Water Management (IUWM).

Integrated Urban Water Management (IUWM) has evolved from its early association with stormwater and waste water management and aims to ensure that water is given due prominence within urban design processes. This is through the integration of total urban water cycle thinking in the detailed planning and design of the built form. In particular, IUWM reintroduces the aesthetic and intrinsic values of waterways back into the urban landscape.

7. In YOUR OPINION, how 'committed' are the following stakeholders to advancing Integrated Urban Water Management across Chandigarh?

(Please rate the level of 'stakeholder commitment' using the scale below)

1 = No commitment
2 = Some individuals committed
3 = Increasing organisational / sector awareness and senior support
4 = Major organisational departments and internal champions committed
5 = Organisation / sector fully committed

	1	2	3	4	5	I don't know	Not Applicable
Institutional Organisation							
Environmental Information System							
Chandigarh water resources							
Environment Protection Authority							
Municipal Corporation							
Department of Sustainability and Environment							
Meteorological Department							

Essential Services Commission							
Local Government							
Land Developers							
Consultants							

8. In YOUR opinion, how EFFECTIVE are the existing institutional arrangements across Chandigarh for enabling the practice of IUWM?

Very Poor	Poor	Neutral	Good	Very Good	I don't know

Final Comments

If you would like to add any final comments, we would be very pleased to include them in our analysis. Please write them in the box below.

Your comments:
