CHAPTER 1

Water Resources in India: An Overview

1.1 Introduction

Depleting water resources is one of the major concerns of urban India and it is likely to create a severe crisis in future as our urban population is expected to increase from 377 million in 2011 to 600 million by 2031 (Amarasinghe 2004). Despite being rich in surface water resources, water scarcity is being recognized as an important problem facing India. Currently, India is home to about 18% of the world's population and accounts for about 2.4% of the world's geographical area. India consumes 4% of the total water resources. As an important economic resource, water is essential for all forms of livelihood activities, agriculture, animal husbandry and most of the industrial production processes (Merrett 1997; Kay et al. 1997). Along with that, various reports and scientific studies suggest that the absence of provision of public water will pose difficulties for local governments in the majority of Indian cities. This extends to other civic services such as sanitation, housing, healthcare, transportation.

In India, the demand for freshwater resources has been steadily growing over the past few decades, making it one of the most water-challenged countries in the world (WRI 2015). Rivers and lakes are dying, and groundwater levels are dropping due to the overexploitation of surface and groundwater by farmers, city dwellers, and industries. Furthermore, the limited available water is highly polluted (TERI 2021). The per capita water availability has declined by almost 75%, from 6008 m3 per year in 1947 to approximately 1545 m3 per annum in 2011.

The country's water demand is projected to be twice the available supply by 2030, resulting in extreme scarcity that will affect millions of people as well as industrial and economic processes (NITI Aayog 2019). From a macro perspective, the average rainfall across India remains relatively consistent at 118 cm, with some annual variations. However, from a micro-perspective, freshwater supplies in many states, river basins, geographical areas, and localities are declining due to changes in hydrologic balances, over-exploitation, and increased pollution of freshwater reserves. Rapid population growth, industrialization, and climate change have emerged as the primary factors contributing to India's water crisis. Many western, southern, and northwestern states, which happen to be relatively more urbanized, are experiencing severe water scarcity."Water scarcity in urban India has been exacerbated in two ways by the country's growing urban population. On one hand, urban areas in India are consuming greener areas, agricultural land, eco-sensitive areas, and permeable open spaces to create developed, salable land. On the other hand, we are over-exploiting the already depleted groundwater resources. Across the globe, urbanization is typically associated with the expansion of impermeable, concretized built-up regions over agricultural fields and natural areas like wetlands, lakes, and rivers. This reduction in the land's ability to absorb and recharge groundwater leads to a decrease in aquifer levels and an increase in rainwater runoff, ultimately resulting in a higher risk of floods. The downside is that large, heavily populated urban areas can impose an enormous burden on the region's natural resources, with water being the most notable. (Horward & Gelo 2002).

This working paper aims to provide an analytical overview of the emerging water resources management issue in India and to comprehend the gravity of the current water situation in Delhi. The study also seeks to explore the role of community participation in rainwater harvesting (RWH) as an alternative water conservation method in Delhi. To assess the feasibility of RWH, a field survey of 11 rainwater harvesting systems across various areas of Delhi has been conducted. The present study assumes that Delhi can enhance groundwater levels through a decentralized approach to rainwater harvesting.

The paper is divided into three sections. The first section provides an overview of water resources in India. The second section delves into the water management issues and challenges faced by Delhi City. The final section examines the outcomes of the Delhi Government's Financial Assistance Scheme for Promoting Roof Top Rainwater Harvesting Systems using field observations and a primary survey.

1.2 Water Availability in India

India has an average annual precipitation of around 3880 billion cubic meters (BCM) and boasts a vast river system and snow-capped mountains. However, due to the uneven distribution of rainfall and high evaporation rates, the net available water resources for use are estimated to be around 1,123 BCM. This figure includes water from various sources, such as precipitation (rainfall and snow), surface water in rivers, lakes, and reservoirs, and replenishable groundwater. Out of the total available water resources, approximately 690 BCM is surface water, while the remaining 436 BCM is groundwater. Out of the total available water resources, around 690 BCM is surface water, and the remaining 436 BCM is groundwater. According to the most recent estimate, India's annual groundwater recharge totals 437.60 BCM. When accounting for natural discharge, the yearly extractable groundwater resource is projected to be 398.08 BCM. In 2022, the annual groundwater extraction is 239.16 BCM (CGWB 2022). Thus, with the extraction of 239 billion cubic meters groundwater per year, India stands as the largest groundwater extractor in the world.

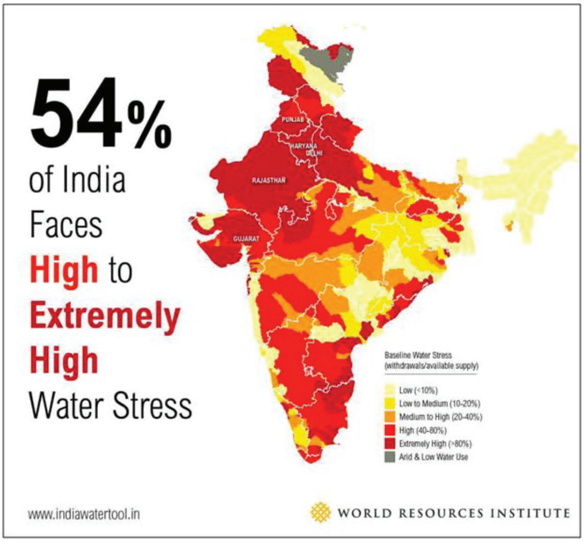
Table 1.1: Water resources in India

Sl. No.	Parameter	Unit (Billion Cubic Meter/Year)
1	Annual water availability	1,869
2	Usable water	1,126
3	Surface water	690
4	Ground water	436

Sources: Central Water Commission, 2015

However, over the last few decades, rapid population growth, changes in agricultural practices, food consumption patterns, lifestyle shifts, and alterations in land use have placed an enormous strain on our water resources. Despite India receiving ample rainwater during the monsoon season, only a small percentage of it contributes to water reserves due to a lack of storage capacity. Notably, rivers in India receive 80 percent of their annual flow during the four months of the southwest monsoon season (Kaul, 1999).

Figure 1: Level of Water Stress in India



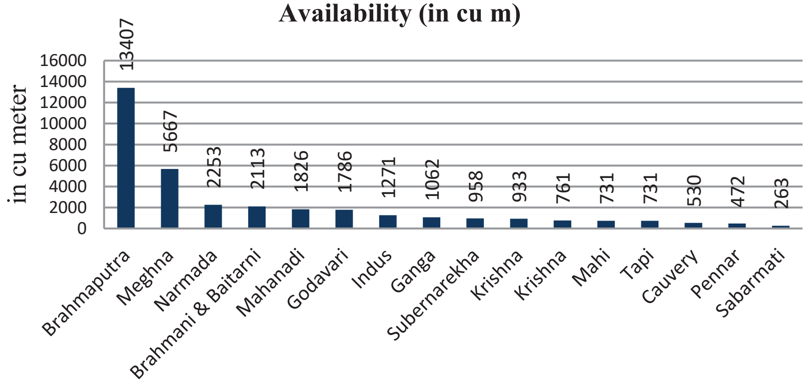
Regarding groundwater resources, they have steadily emerged as the backbone of India's agricultural and drinking water security. Groundwater contributes nearly 62% to irrigation, 85% to rural water supply, and 50% to urban water supply.

The situation is particularly worrying in India, where a significant mismatch exists between available water and the spatial distribution of the population. Surprisingly, regions and states in India with higher populations tend to have less accessible water (Figure 1.1). The number of rainy days varies from about 5 in Rajasthan to around 150 in northeastern India (Rao, 1976).

Additionally, there is significant regional variation in water availability due to differences in rainfall patterns, geographical features, and hydrological factors. India boasts an extensive surface water network, including major rivers like the Ganges, Yamuna, Brahmaputra, and Godavari, among others. However, the availability of surface water varies across different regions and seasons. Some areas face water scarcity, especially during dry seasons, while others experience seasonal flooding.

For instance, India's hydrological area can be divided into 19 major river basins. The per-capita water resource availability of these basins varies from a low of 263 m3 in the Sabarmati basin to a high of 13407 m^3 in the Brahmaputra basin. Water withdrawals also vary from 243 m3 in the Meghna basin to 1,670 m^3 in the Indus basin.

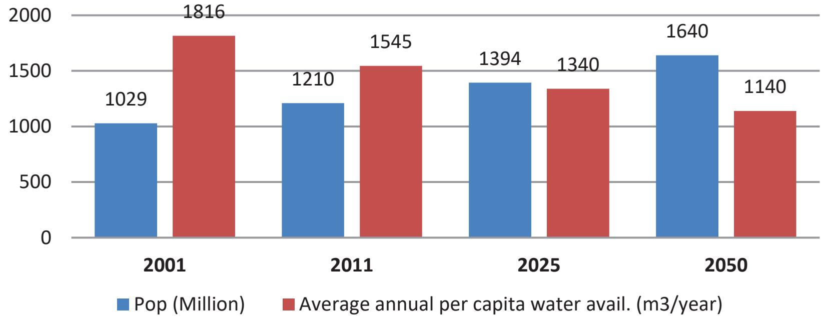
Figure 1.2: Basin Wise Annual Per Capita Water Availability (in cu m)



As per United Nations criteria, a region with an annual water supply of less than 1700 m^3 per individual is categorized as being under 'water stress'. When annual water supplies drop below 1,000 m^3 per person, the population faces 'water scarcity', and below 500 cubic meters, it's considered 'absolute scarcity'. Looking at this standard in the Indian context, we find that in the year 1951, the per capita water availability was 5100 m^3, which has decreased to 1816 m^3 in 2001. Figure 1.3 clearly indicates that the availability of water per person in India is declining over time.

So, as per international standards, the per capita water availability in India is relatively low at around 1,545 cubic meters per person per year in 2011. This is expected to decrease further to 1340 m^3 in 2025 and 1140 m^3 2050 with increasing population growth and urbanization.

FIgure 1.3: Average annual per capita availability trend of water in India



Source: PIB, 02 Mar 2020

In fact, over the last few decades, high population growth, changes in food consumption, lifestyle, and land use patterns have exerted tremendous pressure on our water resources. Although India receives ample rainfall during the monsoon season, only a small percentage of that water is actually stored due to a lack of storage capacity. In a country like India, where there is a significant mismatch between the spatial distribution of available water and the population, the situation becomes alarming. Ironically, less water is available where more people live

1.3 Pressure on Groundwater

Generally, utilizing surface water is more convenient than extracting water from underground sources. Nevertheless, in India, the extensive and dispersed availability of groundwater across the country has led to its widespread exploitation for agricultural purposes and the supply of drinking water. Eighty-nine percent of groundwater resources are used for irrigation in the agricultural sector, leaving 11% for household and industrial use. Again, when it comes to drinking water, groundwater is the primary source of domestic water supply for both rural and urban India, accounting for more than 80% of all supplies.

However, data from the Central Ground Water Board (CGWB) indicates an alarming situation as many states are excessively extracting their groundwater. In these states, groundwater resources are either critical or overexploited. According to CGWB, at the state level, Punjab, Haryana, Rajasthan, and Delhi are states where the Stage of Groundwater Extraction is more than 100%, indicating overexploitation. This implies that in these states, annual groundwater consumption exceeds annual groundwater recharge. Similarly, in the states of Himachal Pradesh, Tamil Nadu, Uttar Pradesh, and the Union Territory of Puducherry, the level of groundwater development is 70% and above. In the rest of the states, the level of groundwater development is below 70%, as illustrated in Table 1.2 Over the years, the usage of groundwater has increased in areas where the resource was readily available.

Table 1.2: State wise ground water extraction

State	Category	Stage of GW extraction (%)	% of over-exploited & critical blocks
Punjab	Overexploited	166 %	80 %
Rajasthan		140 %	74 %
Haryana		137 %	63 %
Delhi		120%	71 %
Himachal Pradesh	Semi-Critical	86 %	50 %
Tamil Nadu		81 %	46 %
Puducherry		74 %	25 %
Uttar Pradesh		70 %	17 %
Karnataka	Safe	70 %	30 %
Telangana		66 %	23 %
Gujarat		64 %	12 %
N.E. States		< 10 %	**0 %**

Source: Central Groundwater Board, 2017.

Groundwater resources in these states are either critical or overexploited. According to CGWB, at the state level, Punjab, Haryana, Rajasthan, and Delhi have more than 100% groundwater extraction, indicating overexploitation. This means that annual groundwater use in these states exceeds annual groundwater replenishment. Similarly, the states of Himachal Pradesh, Tamil Nadu, and Uttar Pradesh, as well as the Union

Territory of Puducherry, have groundwater development rates of 70% or higher. Table 1 shows that the amount of groundwater development in the remaining states is less than 70%. Groundwater use has expanded over time in various locations.

1.4 Projected Water Demand in India

The changing composition of India's population over the past few decades, which has witnessed a significant shift from rural to urban areas, has had a profound impact on the country's water resources. This change has several ramifications on consumption patterns, water resource management, and India's overall water security. As the urban population continues to grow, the demand for water in other sectors is also increasing exponentially.

When discussing the largest consumers of water in India, the main users of water resources can be broadly grouped under five major categories (Table 1.3) – (i) irrigation, (ii) domestic, (iii) industrial, (iv) energy, and (v) other (including environmental requirements and evaporation losses). Of these, irrigation is by far the largest consumer of water resources

Table 1.3: Projected Water Demand in India (By Different Use) in Billion Cubic Mt

Demand Sector	2010	% Share in Demand	2050	% Share in Demand	% increase (2010-50)
Irrigation	557	78.4	807	68.4	44.9
Drinking Water	43	6.0	111	9.4	158.1
Industry	37	5.2	81	6.9	118.9
Energy	19	2.7	70	5.9	288.9
Other	54	7.7	111	9.4	105.6
Total	710	100.0	1180	100.0	**50.5**

Source: Basin Planning Directorate, CWC, XI Plan Document.

This change in water demand from different sector will have several implications for water availability, usage patterns, and overall water resource management. As mentioned earlier, agriculture is the largest consumer of water in India, accounting for around 78 % of the total water withdrawals in 2010. As per the table 1.3, the demand for water in the agricultural sector is projected to grow due to population growth, increasing food demand, and the need to enhance agricultural productivity. However, with more people migrating from rural-to-urban areas, other sectors will demand additional water for domestic consumption, industrial growth, energy production and other activities. This shift will result in reduced share of water demand in agriculture sector (68.4 % in 2051). Expansion of irrigation facilities, adoption of more water-intensive crops, and changing cropping patterns will also contribute to the efficient use of water resources in this sector.

Most importantly, India intends to become the world's third largest economy by 2030. To meet this goal, the demand for energy will surge as industrial and commercial expansion accelerates. As a result, there will be an increased need for water resources for energy production. Various reports also show that the energy sector will account for the majority of the expected rise in water consumption. According to the Basin Planning Directorate, CWC, XI Plan Document, the demand for water in the sphere of energy production will increase by 288 percent by the year 2050. Similarly with urbanization and population growth, the demand for water in the domestic sector is projected to increase by 158 %. The domestic sector includes residential areas, public institutions, and commercial establishments. Apart from this, to reduce the damage caused by climate change, we have to maintain the natural flow of the rivers. Thus we can take special care of the ecological health and sustainability of our water resources.

1.5 Growing Water Concerns in Urban India

At present, India holds the distinction of being the largest user of groundwater in the world, and many cities heavily rely on groundwater for their daily needs. However, due to rapid urbanization, population growth, and inadequate management of water resources, the groundwater table has been rapidly declining in many parts of the country. The situation is particularly severe in cities like Hyderabad, Delhi, Jalandhar, Jaisalmer, Amritsar, Gurugram, Jaipur, Jodhpur, Nagpur, Chennai, and Bengaluru, where the groundwater table has dropped to alarming levels due to their excessive groundwater usage that surpasses what is replenished by both natural and artificial processes. This has led to the depletion of aquifers, saltwater intrusion, and even land subsidence in some areas..

Table 1.4: Over exploitation of Ground Water Resources in Urban Areas

City	% of GW Utilization/ GW Recharge	City	% of GW Utilization/ GW Recharge
Hyderabad	294.48	**Jaipur**	219.83
Delhi	360	**Jodhpur**	218.6
Jalandhar	472.16	**Amritsar**	363
Jaisalmer	292.85	**Chennai**	171.88
Gurugram	299.8	**Bengaluru**	143.81

Source: CGWB, 2022

Overall, the extraction for ground water in India is projected to increase due to population growth, economic development, and changing consumption patterns. Managing this growing demand while safeguarding water resources and ensuring sustainable water management practices remains a critical challenge for the country. Various strategies, including water conservation, efficient water use practices, recycling and reuse, and integrated water resource management, will be essential to meet the future water demands of different sectors in India.

Cities in India are facing significant challenges when it comes to recharging their groundwater due to following reasons:

1. **Over-Extraction of Groundwater:** One of the primary reasons for groundwater depletion in India is excessive pumping for various purposes like irrigation, industrial use, and domestic water supply. As we are seeing that the demand for water in our cities often exceeds the natural recharge rate, leading to a decline in groundwater levels.

2. **Urbanization and Land Use Changes:** India is having rapid urbanization which results in increased impervious surfaces like concrete and asphalt, reducing the area available for rainwater infiltration. At the same time, as cities expand, natural recharge areas like forested lands and open green spaces are converted into built-up

areas, further limiting the potential for groundwater recharge. Rainfall in India is very sporadic and this prevents rainwater from percolating into the ground and recharging the aquifers.

3. **Lack of Rainwater Harvesting:** Many cities in India have not amended their building bylaws to make rainwater harvesting systems compulsory, which would capture and store rainwater during the monsoon season. This water could otherwise recharge groundwater and offset water demand during drier periods.

4. **Encroachment on Water Bodies:** Natural water bodies like ponds, lakes, and wetlands, which play a crucial role in groundwater recharge, are often encroached upon or converted for other purposes, reducing their capacity to recharge aquifers. The first-ever census report on water bodies undertaken by the Ministry of Jal Shakti reports that almost 1800 water bodies in urban areas are reported as encroached (MoJS 2023). The same report says that of the 893 water bodies in Delhi, 216 or 24.19% are encroached, indicating the city's poor water conservation status.

5. **Pollution and Contamination:** Pollution from various sources, including untreated sewage, industrial effluents, and agricultural runoff, can contaminate groundwater, making it unsuitable for consumption and reducing its recharge potential. About 70% of India's surface water is thought to be unsafe for human consumption. Only a small portion of the nearly 40 million litres of effluent that enter rivers and other water bodies each day is properly treated (WEF 2019).

6. **Inefficient Water Management:** In many cities, water supply networks have leaks and losses, leading to wastage of treated water. The inefficiency in water management reduces the availability of water for recharge. According to Mehreen Mattoo (2019), 40 to 50 percent of potable water in India is wasted during distribution due to water theft and pipeline leaks.

7. **Lack of Skilled Manpower:** Despite the availability of technologies and solutions, there is often a lack of awareness among our human

resources about the importance of groundwater recharge and inadequate implementation of recharge projects in cities.

8. **Inadequate Policy and Regulation:** Some cities lack effective policies and regulations to promote and enforce groundwater recharge practices. The absence of proper incentives and penalties for water management can hinder progress.

To address these challenges, cities need to adopt integrated water management strategies that encompass rainwater harvesting, the safeguarding of water bodies, efficient water distribution, and strict regulations to prevent over-extraction and contamination. Community involvement and public awareness campaigns are also vital to create a sense of ownership and responsibility toward groundwater conservation and recharge.

The Conceptual Background

The water table in NCT Delhi is depleting due to increasing water demand and extensive dependence on groundwater. In the city, surface water storage is limited, and people rely heavily on groundwater sources. The situation has been aggravated by the paucity of open wells in various regions over the last two decades, leading to large-scale digging of deep bore wells and groundwater extraction.

Tragically, natural groundwater recharge has decreased during this period, primarily as a result of urban development, which has made more parts of the city impermeable to water infiltration. Consequently, there is an urgent need to prioritize efforts towards enhancing groundwater recharge to ensure the sustainability of the current groundwater supply.

1.7 Purpose of this study

Against this backdrop, this article examines the developing concerns and management challenges related to water resources in Delhi. The paper argues that the demand for water will grow by leaps and bounds during the next few decades due to high population growth in Delhi. Studies suggest that while water resources would continue to deplete due to groundwater degradation, surface water pollution, and depletion of existing surface, government should involve local community to conserve and augment the ground water resources of Delhi along with other measures.

This paper attempts to shed light on the role of the government in rainwater harvesting implementation and identify areas for improvement. The study's outcomes can help policymakers make informed decisions, allocate resources effectively, and develop strategies to address water scarcity challenges in the city. Studying the role of the community in rainwater harvesting in Delhi can provide valuable insights into how collective efforts can contribute to sustainable water management in urban areas. Here are some potential objectives for such a study

1.7.1 Objectives

Here are some potential objectives for such a study:

1. To evaluate the existing government policies and regulations related to rainwater harvesting in Delhi.
2. To evaluate the level of awareness and knowledge among the community members in Delhi regarding rainwater harvesting techniques, its benefits, and the importance of conserving water resources.
3. To investigate the extent of community involvement in rainwater harvesting initiatives. Identify the factors that motivate or hinder active participation in such projects.
4. To identify the barriers and challenges faced by the community in implementing rainwater harvesting systems.
5. To examine the existing policies and institutional frameworks in Delhi that promotes or hinders community-based rainwater harvesting initiatives.

By pursuing these objectives, the research paper tries to gain a comprehensive understanding of how community engagement and participation can contribute to sustainable water management through rainwater harvesting in Delhi. The findings can inform policy decisions, community outreach programs, and future urban water planning initiatives.

1.7.2 Methodology

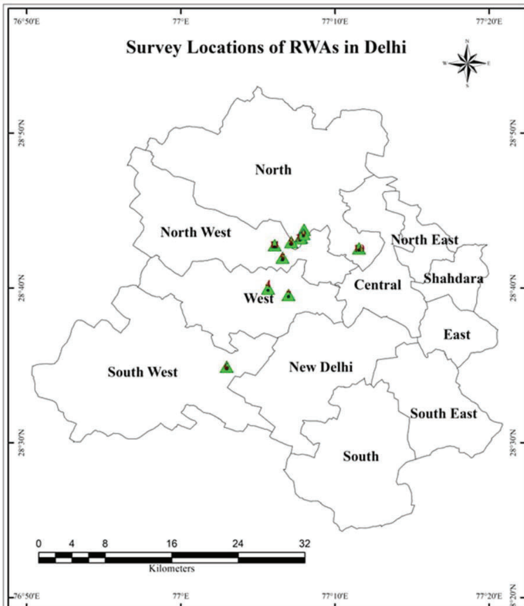
This research paper presents an empirical investigation aimed at identifying key aspects of the Delhi Government's Financial Assistance Scheme for Promoting Roof Top of Rainwater Harvesting (RWH) Systems. The study involved comprehensive fieldwork, examining 11 RWH systems installed in various residential and office spaces across different parts of Delhi (Table1.5). Both official data from Delhi Jal Board and data from primary surveys were utilized for analysis. The data collection methods included interviews and focus group discussions with scheme beneficiaries and other stakeholders, using semi-structured questionnaires. To complement the findings, qualitative observations were also subjected to appropriate qualitative research methods. The evaluation of the scheme aligns with its objectives, and the research concludes by offering recommendations to enhance its implementation.

Table 1.5: Details of the studied RWH systems

S. No.	Name and Location of the studied RWH systems	District
1	Printers Society, Rohini	North
2	The Arya Apartments, CGHS, Rohini, Sector 15	North
3	The Hans Aman Society, Rohini-15	North
4	Lucky Homes, Rohini 13	West
5	DAV School, Pachim Vihar	West
6	MRG School, Rohini-3	North West
7	Vasundhra Apartment, Dwarka	South West
8	Vijay Apartments, Vijay Vihar, Rohhini	West
9	Sundaram Enclave, Dwarka	South West
10	Model Town Homes, Near Marwaha Associates	North
11	Vasudha Apartment, Sector 9, Rohini	North West

For this study, the effectiveness of scheme implemented in different societies and offices was assessed through a primary survey. The survey employed a specially designed semi-structured questionnaire, primarily consisting of closed-ended questions tailored to the objectives of the research. The gathered primary data will be compiled, cleaned, and analyzed based on the responses received through the structured schedules.

Map 1.1: Location of Sample RWH Systems



Survey Locations of RWAs on Google Earth Imagery

S. No.	Name and Location of the studied RWH systems
1	Printers Society, Rohini
2	The Arya Apartments, CGHS, Rohini, Sector 15
3	The Hans Aman Society, Rohini-15
4	Lucky Homes, Rohini 13
5	DAV School, Pachim Vihar
6	MRG School, Rohini-3
7	Vasundhra Apartment, Dwarka
8	Vijay Apartments, Vijay Vihar, Rohhini
9	Sundaram Enclave, Dwarka
10	Model Town Homes, Near Marwaha Associates
11	Vasudha Apartment, Sector 9, Rohini

As part of the research process, the IIPA Research team conducted on-site inspections of constructed Rainwater Harvesting (RWH) Systems, some of which have already received or are yet to receive financial assistance under the Delhi Government Scheme. During the physical inspections, the research team documented project sites through photographs for further analysis. Additionally, a focused effort has been made to ascertain the level of community participation in achieving the success of Roof Top Rainwater Harvesting (RWH).

Reference

1. Amarasinghe, U. A.; Sharma, B. R.; Aloysius, N.; Scott, C.; Smakhtin, V.; de Fraiture, C. (2004). Spatial variation in water supply and demand across river basins of India. Research Report 83. Colombo, Sri Lanka: International Water Management Institute. Retrieved from

https://www.iwmi.cgiar.org/Publications/ IWMI_Research_Reports/PDF/pub083/RR83.pdf

2. CGWB (2022), Dynamic Ground Water Resources of India - 2022, Central Ground Water Board Department of Water Resources, Govt of India.
3. Hirani P. & Dimble V. (2019), Water pollution is killing millions of Indians. Here's how technology and reliable data can change that, World Economic Forum, retrieved from https://www.weforum.org/agenda/ 2019/10/water-pollution-in-india-data-tech-solution/
4. K.W.F. Howard (1) & K.K. Gelo (2002), Intensive groundwater use in urban areas: the case of megacities, retrieved from

   https://fundacionbotin.org/89dguuytdfr276ed_uploads Observatorio%20Tendencias/PUBLICACIONES/ LIBROS%20SEM%20INTERN/ intensive%20use%20groundwater/cap02-intensiveuse.pdf
5. Kaul, M.K. (ed.) (1999), Inventory of the Himalayan Glaciers: A Contribution to the International Hydrological Programme. Vedams Book Publisher, India, 1999, p.165.
6. Kay, Melvyn et al. (1997) Water: Economics, Management and Demand. London: E and FN Spon.
7. Mahreen Matto, (2019) "India's water crisis: The clock is ticking," Down to Earth, June 21,2019
8. Ministry of Jal Shakti (2023), Water Bodies 1 Census Report, Ministry of Jal Shakti, Govt of India, https://cdnbbsr.s3waas.gov.in/s3a70dc40477bc2adceef4d2c90f47eb82/uploads/2023/04/2023040672.pdf
9. Nath, D.; Peramaiyan, P; & Laik, R. (2022), Water resources of rural India: Challenges and management strategies for sustainable development in book Water Resources Management for Rural Development, Challenges and Mitigation, Publisher: Elsevier, 1st Edition - July 1, 2023

10. NITI Aayog (2019), Composite Water Management Index, retrieved from

http://social.niti.gov.in /uploads /sample/water_index_report2.pdf

11. PIB, GoI (2015),

https://pib.gov.in/newsite/PrintRelease.aspx?relid=121540#:~:text=India% 20receives% 20an%20average

%20rainfall,Billion%20Cubic%20Metre)%20including%20 snowfall.

12. Rao, Y.P.: Southwest Monsoon. Meteorological Monograph No. 1, India Meteorological Department, New Delhi, 1976, p.367.

13. TERI, 2021, Water – Key Facts for its Sustainable Management in India, World Sustainable Development Summit 2022, retrieved from https://www.teriin.org/sites/default/files/2021-06/water-factsheet.pdf

14. The Hindu Business Line (2021)

https://www.thehindubusinessline.com/opinion/promoting-ease-of-living-in-cities/article37216896.ece

15. Tien S.; Maddocks A, Carson C.; and Emma L. 2015, 3 Maps Explain India's Growing Water Risks, Water Resource Institute, retrieved from https://www.wri.org/insights/3-maps-explain-indias-growing-water-risks