DETAILED PROJECT REPORT

Holistic Solution for Water Management and Equitable Access,

Sreenarayanapuram

Grama Panchayat, Mathilakam Block Panchayat, Thrissur, Kerala

Integrated Drinking Water Management Plan

K-DISC Kerala Development and Innovation Strategic Council

Ashank Desai Centre for Policy Studies Indian Institute of Technology Bombay
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TAGS

DETAILED PROJECT REPORT:

Integrated Drinking Water Management Plan:

Holistic Solution for Water Management and Equitable Access, Sreenarayanapuram Grama Panchayat, Mathilakam Block Panchayat, Thrissur, Kerala

Submitted by

Technology and Governance Support Forum

Submitted to:

Kerala Development and Innovation Strategic Council

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LIST OF ABBREVIATION

SI No.	Abbreviation	Expansion
1	OLOI	One Local Government One Idea
2	K-DISC	Kerala Development and Innovation Strategic Council
3	LSGIs	Local Self-Government Institutions
4	CoP	Community of Practice
5	TAGS Forum	Technology and Governance Support Forum
6	MCM	million cubic meters
7	OHT	overhead tank
8	MSL	mean sea level
9	KWA	Kerala Water Authority
10	MAR	Managed Aquifer Recharge
11	FGD	Focus Group Discussion
12	KII	Key Informant Interviews
13	GP	Gram Panchayat

14	OSS	Onsite Sanitation System
15	WRIS	Water Resource Information System
16	JJM	Jal Jeevan Mission
17	AE	Assistant Engineer
18	RO	Reverse Osmosis
19	TDS	Total Dissolved Solids
20	CFC	Central Finance Commission
21	AWPL	Ajivam Water Private Limited
22	LPH	Liters per hour
23	UV	ultraviolet
24	TH	Total Hardness
25	DO	Dissolved Oxygen

26	Kh	hydraulic conductivity
27	CPHEEO	Central Public Health and Environmental Engineering Organization
28	O&M	Operation and Maintenance
29	ULBs	Urban Local Bodies
30	WSSs	Water Supply Systems
31	IWS	Intermittent Water Supply
32	ESR	Elevated Service Reservoirs
33	HGL	Hydraulic Grade Line
34	CSR	Corporate Social Responsibility

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Part I

1. Broader Vision and Strategic Aim of the Project

1.1. Concept of the project

The ***One Local Government One Idea*** (OLOI) program, initiated by the **Kerala Development and Innovation Strategic Council** (K-DISC), aims to tackle the second-generation developmental challenges faced by Local Self-Government Institutions (LSGIs) in Kerala. It serves as a platform to empower LSGIs by fostering innovative, community-driven solutions that go beyond traditional approaches. The program encourages collaboration among local governments, academic institutions, experts, and private enterprises to co-create practical and sustainable solutions tailored to the unique needs of each locality. With a focus on knowledge-sharing and participatory governance, OLOI is designed to facilitate comprehensive problem-solving, support economic development, and improve service delivery through a blend of technical expertise and community input. This initiative envisions a transformation towards a knowledge society, where localized innovations drive sustainable growth and social equity across Kerala.

- **Mission of the programme:**
  The mission of the One Local Government One Idea (OLOI) program is to empower Local Self-Government Institutions (LSGIs) in Kerala by fostering innovative, community-driven solutions to address second-generation developmental challenges. The program aims to transform traditional problem-solving approaches through collaboration among local governments, academic institutions, experts, and practitioners. It focuses on creating sustainable and practical solutions that directly respond to the unique needs of each locality, enabling effective governance, improved service delivery, and inclusive economic growth.
- **Vision of the programme:**
  The vision of the OLOI program is to transform Kerala into a knowledge society where innovation drives local development and governance. By leveraging the expertise of a Community of Practice and fostering collaborations between LSGIs, academic institutions, and private enterprises, OLOI envisions a future where every local government body is capable of addressing complex challenges through a participatory and data-driven approach.

The program seeks to establish a culture of continuous innovation, making Kerala a model for sustainable development through localized, context-specific solutions.

➔ **Scope of the programme:**

The OLOI program operates as a platform for knowledge exchange and problem-solving, addressing the developmental issues of LSGIs through a participatory and collaborative approach. Its scope includes:

- **Fostering Innovation:** Enabling LSGIs to develop and implement innovative solutions for local economic development, enterprise creation, and service delivery, moving beyond conventional methods.
- **Building Collaborations:** Creating a collaborative framework that involves LSGIs, academic and research institutions, experts, and startups to jointly address local challenges. This collaboration helps in capturing, analyzing, and curating real-life problems faced by LSGIs.
- **Community of Practice (CoP):** Utilizing CoPs to bring together domain-specific practitioners and experts who contribute to analyzing problem statements, identifying innovative solutions, and ensuring the solutions' technical and community readiness.
- **Holistic Problem-Solving:** Emphasizing a multidisciplinary approach for complex and interwoven local issues, which requires stakeholder engagement, root cause analysis, and the development of detailed problem canvases.
- **Scalable Solutions:** Supporting the implementation of pilot projects, analyzing their impact, and scaling successful interventions to other areas, thus providing sustainable and replicable models for addressing local challenges.
- **Knowledge Society Transition:** Aiming to transform Kerala into a knowledge society by integrating academic insights, practical experiences, and community input, ultimately co-creating solutions that foster sustainable development and social equity.

By integrating these elements, the OLOI program helps LSGIs address their unique challenges through tailored, sustainable solutions, enabling them to become self-reliant and resilient in their development journey.

The problem, as stated by the SN Puram Grama Panchayat:

"The issue of inadequate access to drinking water within various wards of the Panchayat "

The problem description as submitted by the Panchayat:

The project falls under the theme of '*Water Conservation and Drinking Water Shortage'* as part of the OLOI program.

After receiving the problem statement, the Technology and Governance Support Forum (TAGS Forum) team undertook extensive field studies, desk reviews, and stakeholder meetings to conduct a comprehensive ground situation analysis. This phase involved identifying the root causes of the issues and pinpointing areas that required potential interventions. Following the detailed ground study and problem framing, TAGS proceeded to the solution scouting and finalization phases, where various organizations with expertise in hydraulics and hydro-geology were identified, given these were critical areas for intervention in S.N.Puram. The team also consulted experts from IIT Bombay, the domain organization of TAGS Forum as part of building collaborations and transitioning to a knowledge society. Furthermore, students from different universities across India were engaged in various field activities and analyses to facilitate knowledge transfer. This approach aligns closely with the scope put forward by the OLOI project under K-DISC, emphasizing collaborative problem-solving and the integration of diverse expertise to address local challenges effectively. Through these efforts, TAGS aims to foster innovative solutions that not only address immediate concerns but also contribute to the long-term sustainability and resilience of the community in SN Puram.

1.2. Overview of the project

Kerala's water resources exhibit a paradoxical duality of abundance and scarcity. The state is blessed with numerous rivers, lakes, ponds, and backwaters. Of its 44 rivers, 41 flow westward into the Arabian Sea or backwater lakes. These rivers play a crucial role in Kerala's hydrology, complemented by an average annual rainfall of 3000mm, with 70% occurring during the South-West monsoon (June to September) and additional rainfall from the North-East monsoon (October to December). However, the uneven spatial and temporal distribution of rainfall contributes to Kerala's recurring challenges with both floods and droughts. Despite an annual water yield of approximately 7,030 crore cubic meters, nearly 40% of water resources are lost as runoff, emphasizing the need for better water resource management (P. Maneesh 2015)[1].

Kerala's estimated groundwater resource is 7,048 million cubic meters (MCM). Projected demand stands at 4,970 MCM, with 3,000 MCM allocated for agriculture, 750 MCM for domestic use, and 1,220 MCM for saltwater intrusion prevention. Demand is shifting toward drinking water, with reduced emphasis on irrigation. As a result, public investments in water supply infrastructure have been prioritized to ensure access to clean drinking water for all, making it a critical concern (P. Maneesh 2015)[2].

Saline intrusion and mineral leaching are critical issues affecting groundwater and surface water quality in coastal regions. These challenges are primarily caused by the excessive extraction of freshwater from coastal aquifers, which results in a decline in groundwater levels. This imbalance allows seawater to migrate into the aquifers, either laterally or vertically, leading to significant degradation of groundwater quality. Addressing these issues requires a focus on sustainable groundwater management practices to prevent further deterioration of water resources (Anil Kumar et al., 2015)[3].

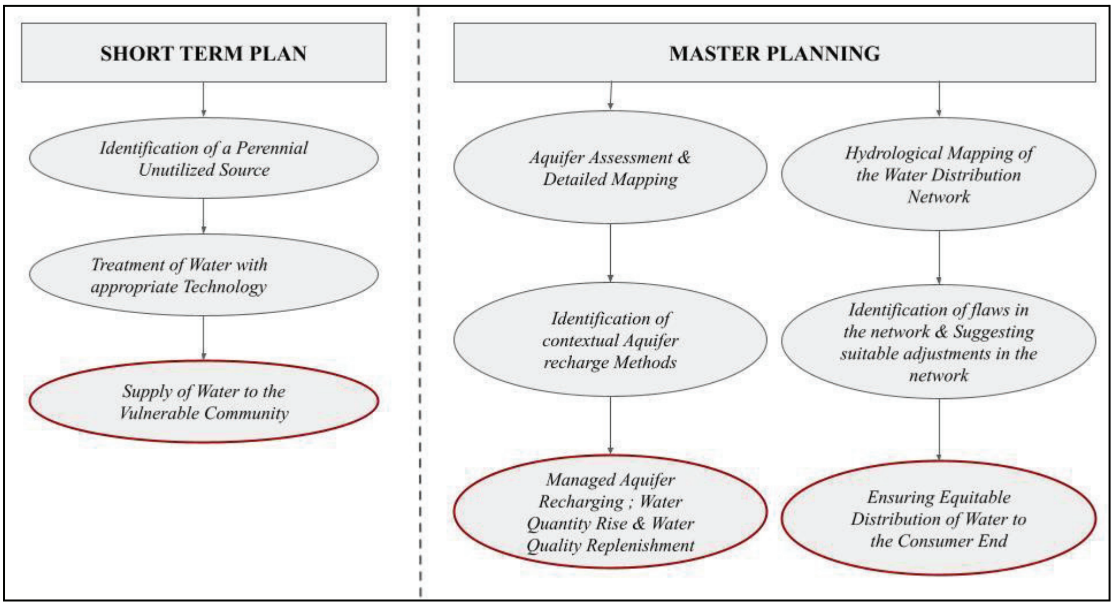

Fig. 1: Focus areas of the Master plan

[1] P, Maneesh. (2015). Access to water and drinking water supply coverage: Understanding water security in Kerala.
[2] P, Maneesh. (2015). Access to water and drinking water supply coverage: Understanding water security in Kerala.
[3] K.S. Anil Kumar, C.P. Priju, N.B. Narasimha Prasad, Study on Saline Water Intrusion into the Shallow Coastal Aquifers of Periyar River Basin, Kerala Using Hydrochemical and Electrical Resistivity Methods, Aquatic Procedia, Volume 4, 2015, Pages 32-40, ISSN 2214-241X, https://doi.org/10.1016/j.aqpro.2015.02.006.

The panchayat faces multiple challenges due to its geographical and infrastructural context. Being situated between the sea and backwaters, it is highly susceptible to saline water intrusion, directly affecting groundwater quality. This issue is compounded by the fact that the region lies below mean sea level (MSL), which increases the risk of contamination from sewage waste. Most septic tanks in the area are unscientific in design, a concern corroborated by water quality analysis reports from selected sources within the panchayat. Another critical issue is the over extraction of high-quality aquifers, leading to the depletion of these valuable groundwater sources. This practice not only reduces the availability of potable water but also exacerbates saline intrusion.

The water supply infrastructure also presents significant challenges. The outdated pipe network, combined with the considerable distance of the overhead tank (OHT) from the panchayat, hinders effective water distribution. The absence of functional valves in the network results in frequent pipe bursts, leading to resource wastage and supply disruptions. Addressing these challenges requires a comprehensive and strategic approach to water management, encompassing infrastructure upgrades, scientific practices, and sustainable extraction policies.

In the context of water supply challenges in Kerala, the interplay between equitable distribution and governance emerges as a critical focus area.The existing drinking water supply system managed by the Kerala Water Authority (KWA) is predicated on the belief that a centralized network will guarantee equitable access to safe drinking water for all residents. However, this approach may overlook the complexities of local demand and this is aggravated in areas characterized by variations in water quantity, quality, and topography, which present unique contextual challenges. Research indicates that, current practices often fail to consider the specific local contexts, leading to insufficient service delivery (Ghorpade et al., 2021)[4], particularly contributing to drinking water scarcity and mostly affected by the marginalized communities due to their vulnerabilities. Addressing these disparities requires a nuanced understanding of community-specific needs and the incorporation of decentralized solutions that empower local management and governance. Studies indicate that decentralized water management can enhance service efficiency and community satisfaction by allowing for more localized decision-making

[4] Ghorpade, A., Sinha, A. K., & Kalbar, P. P. (2021). Drivers for Intermittent Water Supply in India: Critical Review and Perspectives. Frontiers in Water, 1-15.

and infrastructure maintenance (Ghorpade et al., 2021)[5] . Furthermore, effective groundwater governance is paramount to maintaining water quality, quantity and ensuring sustainable access .

By addressing these multifaceted issues, the project aims not just to resolve immediate water scarcity but to establish a comprehensive master plan that ensures long-term sustainability and equity in water distribution across SN Puram Grama Panchayat.

The '*SN Puram Grama Panchayat Drinking water Supply Project'* is more than just an isolated intervention. It is part of a broader vision that aims to holistically address the deep-rooted issues of water scarcity and ensure sustainable water management for the entire panchayat. This project is not limited to a short-term solution for localized problems; rather, it strives to develop a comprehensive, long-term plan that aligns with the panchayat's overarching developmental goals. By adopting a systematic approach, this initiative aims to transform water governance, improve water quality, ensure equitable distribution, and strengthen the community's resilience to water shortages.

1.3. A Holistic Approach to Root Cause Analysis

The preliminary studies conducted as part of this project have gone beyond surface-level observations to identify the core issues contributing to the water crisis in SN Puram. Unlike previous attempts conducted on SN Puram that often addressed symptoms rather than underlying causes, our study dives deeper into the root causes of water scarcity, considering factors such as:

- Topographic and climatic conditions that impact the flow, quality and availability of water.
- Governance-related challenges include mismanagement of the current water supply schemes and a lack of community involvement in providing suggestions for improvements

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[5] Ghorpade, A., Sinha, A. K., & Kalbar, P. P. (2021). Drivers for Intermittent Water Supply in India: Critical Review and Perspectives. Frontiers in Water, 1-15.

- The inefficiencies of the existing centralized water supply system, which struggles to address grass root level issues and fails to reach certain regions effectively and the inefficiency of finding proper water treatment and management methods.

By identifying and addressing the underlying challenges, this project aims to provide solutions that have been overlooked in the past, thereby creating a more targeted and effective impact on the community's water management system.

The next phase will involve a comprehensive study and strategic planning for implementing managed groundwater recharge systems. This includes mapping and optimizing the use of currently underutilized water sources. To address existing water supply issues, a detailed hydrologic mapping and analysis will be conducted. This analysis will identify the flaws in the water supply network, uncover causative factors, and recommend the most suitable methods for mitigating these issues and bridging the gaps. These concerted efforts aim to ensure the long-term sustainability and effective management of drinking water resources.

The detailed master plan for the SN Puram Grama Panchayat Water Supply project is centered on a systematic approach to address the key water supply challenges of the region. This approach begins with a thorough problem identification process, leveraging expert consultations, detailed fieldwork, and analytical assessments. The focus is on decentralizing the existing drinking water network, aiming to identify the most vulnerable clusters. By studying these clusters, the plan seeks to understand their specific issues related to water scarcity, which are further validated through expert input.

To address the critical water quality and supply challenges in the region, a pilot-scale intervention will be implemented in the most affected cluster, guided by recommendations from the preliminary studies. The Master Planning approach seeks to resolve water quality and supply issues not through high-cost technological interventions but by optimizing and renovating the existing systems.

Phase 1: Pilot-Scale Intervention

A pilot project is planned for a vulnerable area along the Cannoli Canal. The intervention involves treating high-TDS water from the backwaters to supply safe drinking water to the community. While effective in the short term, this approach considers the associated energy consumption and carbon footprint, making it less sustainable for long-term reliance.

Phase 2: Comprehensive Master Plan

1. **Water Distribution Network Optimization:**
    - Conduct a **hydrologic mapping** of the entire pipeline network to identify pressure drops and variations using pressure gauges.
    - Address distribution inefficiencies, such as tail-end supply issues, by implementing necessary adjustments and upgrading the system for equitable water distribution.
2. **Groundwater Quality and Quantity Enhancement:**
    - Map and analyze the region's aquifer systems to understand their characteristics and dynamics.
    - Design and implement a managed aquifer recharge (MAR) system to replenish groundwater resources. This strategy will enhance water levels, reduce saline intrusion, and improve water quality over time.
    - Establish a monitoring mechanism to track aquifer health and system performance.

Looking ahead, the long-term strategy centers around employing Managed Aquifer Recharge (MAR) to address saline intrusion sustainably. This approach involves:

- Restoring hydraulic pressure,
- Diluting salinity levels,
- Establishing a freshwater buffer zone, and
- Utilizing MAR techniques to mitigate saline intrusion.

Achieving this involves detailed aquifer mapping and rejuvenation of existing water resources. Rather than relying on large-scale technological interventions, the focus is on sustainable, nature-based solutions tailored to the region's unique challenges. This vision aligns with the TAGS Forum's commitment to holistic, context-sensitive water management strategies.

These efforts aim to rejuvenate natural water resources and reduce reliance on energy-intensive treatment systems. Over time, residents can rely on rejuvenated groundwater resources to meet their drinking water needs sustainably and affordably. Additionally, addressing pipeline issues will improve the efficiency and reliability of the water supply system.

By integrating short-term solutions with sustainable long-term strategies, this approach ensures both immediate relief and the establishment of a resilient water management system for the community. Following the pilot phase, the plan will move to a comprehensive analysis stage, including detailed hydraulic mapping of the pipe network to assess hydraulic flow parameters and pinpoint areas requiring further intervention. Concurrently, a source mapping initiative will document and manage available potential in the region using geospatial tools, ensuring they are utilized as decentralized sources to meet local water demands and minimize wastage.

Decentralizing the water network will alleviate pressure on the existing centralized water supply systems managed by the Kerala Water Authority. This project aims to address challenges such as pressure variations and inconsistencies in water distribution across various local self-government institutions (LSGIs). Initially, pressure and level sensors will be integrated for network monitoring, with the potential for a comprehensive IoT-based system for real-time data collection and monitoring.

Groundwater management is a critical component of the master plan, with a focus on both quality and quantity. Detailed geological and aquifer assessments will be conducted to understand water storage potential and the permeability of various aquifer strata. By monitoring water quality and quantity and analyzing the hydraulic potential of aquifers, recharge-bearing zones will be identified. Successful recharge methods will be implemented and closely monitored. Once validated, these methods can be replicated across other regions to elevate groundwater levels and ensure long-term water sustainability and quality of the ground water.

Through this multi-layered plan, the project progresses from addressing immediate needs with pilot interventions to creating a sustainable framework for water management. By emphasizing expert-driven insights, and advanced monitoring technologies, the master plan aims to establish a resilient water supply system that adapts to evolving needs and provides a blueprint for addressing similar challenges in other regions. This approach encourages the utilization of multiple water sources, reducing dependence on and over-exploitation of a single source.

While centralized water supply systems play a crucial role in providing potable water, their efficacy diminishes when addressing grassroots challenges. In SN Puram Grama Panchayat, the centralized system, though functional, has not resolved critical issues faced by residents in water-scarce areas. Despite being part of the supply network, many households experience inconsistent access to water. Decentralizing the water supply system presents a challenge due to the lack of reliable, accessible potable water sources.

This project envisions a water management model to complement and enhance existing infrastructure. By integrating context-specific treatment technologies and aquifer management practices and retrofitting the current pipe network, the initiative seeks to ensure equitable water distribution and address disparities in access.

As part of the immediate action plan, the most vulnerable area, an isolated island-like region without direct access to supply networks, has been identified. A sustainable water source has been pinpointed, and plans are underway to treat and supply water from this source. The treated water will either be distributed through a kiosk system or integrated into the existing pipe network, subject to collaboration between the Panchayat and the Water Authority.

1.4. Project Approach and Master Planning

Our approach acknowledges that addressing drinking water scarcity in the panchayat requires a shift from isolated problem-solving to a comprehensive understanding of the region's complex hydrological, social, and economic challenges. The project's ultimate aim is to create a detailed master plan for the entire panchayat, serving as a blueprint for effective and sustainable water management. This plan will focus on key areas such as:

- **Water Quality Improvement:** Identifying and addressing contamination and deteriorating water quality in existing sources.
- **Equitable Distribution:** Designing mechanisms to ensure all residents, including those in scarce and high-altitude areas, have access to clean, safe drinking water.
- **Groundwater Governance:** Establishing frameworks for better management of groundwater resources, with an emphasis on community participation and awareness.
- **Resilience Building:** Enhancing the region's capacity to adapt to seasonal variations and climate change that impact water availability.
- **Mapping and Utilization of Untapped Resources:** Identifying and managing unutilized resources such as unutilized aquifer systems and ponds and rainwater, ensuring their efficient use and equitable distribution.
- **Infrastructure Optimization:** Upgrading and retrofitting existing water supply infrastructure to minimize losses, improve water flow, and increase supply reliability, especially in underserved areas.
- **Automation of the Existing Drinking Water Supply System:** Introducing IoT-based sensors to monitor pressure and water levels, enabling real-time data collection and system adjustments. We will also explore the feasibility of fully automating the entire pipe network for enhanced efficiency and responsiveness in water distribution across the panchayat.

1.5. Laying the Groundwork for Future Steps

This chapter lays the groundwork for the detailed analysis presented in the subsequent sections of this DPR. It highlights the project's commitment to addressing broader challenges faced by the panchayat, extending beyond resolving immediate water scarcity. The following chapters will explore the project's background, methodologies, problem framing, the identification of causative factors, and design and cost estimation for piloting filtered solutions in the selected region. This approach aims to create a comprehensive roadmap for the evolution of the project into a sustainable, community-centered solution.

While our long-term vision involves a master plan for sustainable water management and equitable access, this report primarily focuses on short-term measures to address the urgent drinking water needs of vulnerable communities most affected by these challenges. The focus is on piloting targeted solutions for vulnerable groups, based on the intensive methodologies and analyses we have conducted so far.

2. General Background of the Project

2.1 Introduction

Kerala's water resources exhibit a dual nature of abundance and scarcity. Kerala is a land abundant in water resources, which include rivers, lakes, big and small ponds and backwaters. Kerala is endowed with 44 rivers, the vast majority of which, 41 in total, flow westward, ultimately draining into the Arabian Sea or backwater lakes connected to the sea. These rivers play a pivotal role in the state's hydrology. The state receives an average annual rainfall of 3000mm, with the majority (70%) occurring during the South-West monsoon, typically from June to September. Additionally, Kerala experiences rainfall from the North - East monsoon between October and December. However, the spatial and temporal distribution of rainfall is a key factor contributing to the region's recurrent challenges with both floods and droughts. In a typical year, Kerala's annual water yield amounts to approximately 7030 crore cubic meters, nearly 40 % of available water resources are lost as run off underscoring the significance of water resources management in this region (P. Maneesh 2015).

In Kerala, the estimated groundwater resource stands at 7048 million cubic meters (MCM). A rough projection of demand indicates a requirement of 4970 MCM, with 3000 MCM earmarked for agriculture, 750 MCM for domestic use, and 1220 MCM for saltwater intrusion prevention. Demand dynamics are gradually shifting, with an increasing emphasis on drinking water and decreasing irrigation requirements. Consequently, there is a resolute commitment to enhance public investments in water supply infrastructure to ensure access to clean drinking water for all, across urban and rural areas, making it a top-priority concern(P. Maneesh 2015)[6].

Sreenarayanapuram Grama Panchayat, situated within the Mathilakom block, has grappled with an enduring challenge of drinking water scarcity that has persisted for over four decades and the situation worsened after the 2018 flood. This issue has cast a long shadow over the region and has had varying impacts on the different wards of the Panchayat.

Sreenarayanapuram Panchayat is positioned in a coastal region, offering close proximity to both the Arabian Sea and the Canoli Canal. Within its administrative boundary, five wards have a

[6] P, Maneesh. (2015). Access to water and drinking water supply coverage: Understanding water security in Kerala.

direct proximity to the Canoli Canal, while four wards are situated adjacent to the Arabian Sea. However, despite its picturesque coastal setting, the Panchayat grapples with significant water-related challenges.

One of the primary issues revolves around the distribution of water supply within the Panchayat. The quality of drinking water poses a relevant concern for the local population. The shortage of potable water is arised by the intrusion of saline water and the presence of elevated iron content and E. coli in the water supply. These factors collectively contribute to the major water-related challenges faced by the Panchayat, impacting the accessibility and quality of drinking water for its residents. Efforts to address and resolve these issues are vital to ensure the well-being of the community.

Through this report, we aim to not only outline the existing status of existing drinking water infrastructure and services while shedding light on the factors influencing access to clean, safe and reliable drinking water to the community.

The next headings of the report outline the objectives and methodology of the study.Chapter 2 details the profile of Sreenarayanapuram Grama Panchayat and discusses the aspirations of the consumers in chapter 3, while the subsequent chapters incorporate the status of existing drinking water infrastructure and the available potential source that can be utilized. The report concludes with a discussion of the way forward.

2.2 Objectives of the project

- Problem Identification and Root Cause Analysis based on LSGI inputs.
- Solution Development through expert consultation, ensuring technical feasibility and community acceptance.
- Mentoring and Technical Support for LSGIs and innovators during the solution implementation phase.
- To foster sustainability by creating solutions that are both environmentally and economically viable for long-term use.

3. Profile of the Study Area

The Sreenarayanapuram Panchayat offers a fascinating blend of history and cultural significance. The Panchayat is located with geographic coordinates 10.20 latitude and 76.170 longitude. Located slightly west of National Highway No. 17, the name "Sree Narayanapuram" is derived from the esteemed Sree Krishna Temple, which graces the north side of Asmabi College Road. The land encompassing the Sreenarayanapuram Panchayat spanning from Kodungallur to Mathilakam in bygone centuries. During the inception of the Common Era, Kodungallur was known as Musiri (referred to as "Musiris" by the Greeks), while Matilakam was known as Trikka Matilakam and Kunavaikote. These locales share a common historical narrative (GoK 2022-2027)[7].

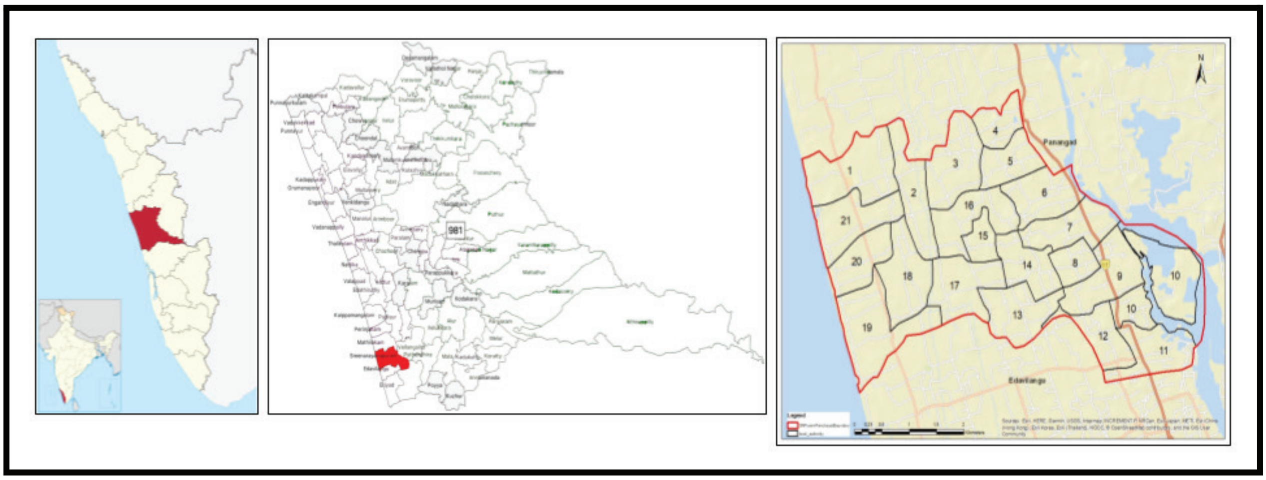


Figure 2: Location map of Sreenarayanapuram Grama Panchayat

Sreenarayanapuram falls within the jurisdiction of Thrissur district in the state of Kerala, India. Specifically, it is situated in the Assembly constituency of Kaippamangalam. This locality is further divided into several villages, including Aala, Panangadu, and P. Vemballur. Sreenarayanapuram is part of the block panchayat and falls within the administrative boundaries of Kodungallur Taluk. The geographical boundaries of Sreenarayanapuram are defined as follows: to the north, it is adjacent to the Mathilakam Grama Panchayat, while to the east, it is demarcated by the Canoli canal. To the west, the Arabian Sea forms the natural boundary, and to the south, it shares borders with the Kodungallur municipality and Edavilangu Grama Panchayat.

[7] Vikasana Rekha Government of Kerala (2022- 2027)

Sreenarayanapuram Panchayat is situated in close proximity to water bodies including Perum Thodu, Valiya Thodu (Figure 3), and the Canoli Canal(GoK 2022- 2027)[8].

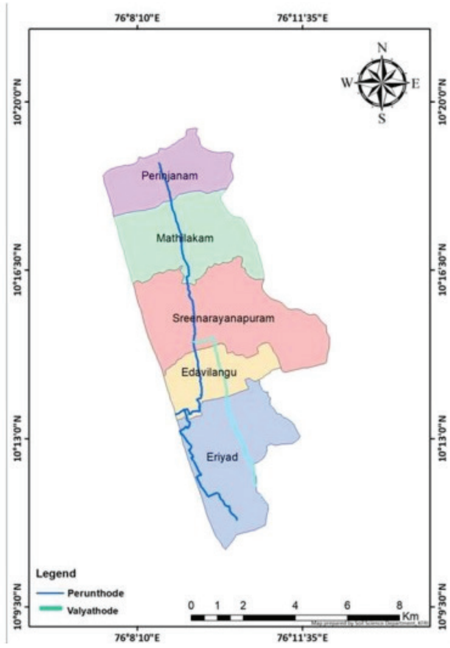


Figure 3:Perum thodu and Valiya Thodu

The administration of Sreenarayanapuram Panchayat is organized into several divisions namely Eriyaad and Kayipamangalam, comprising three Block Panchayat divisions, which include Sree Narayanapuram, Panangadu, and Vemballur. Each of these divisions plays a distinct role in the governance and management of the region. Sreenarayanapuram consists of wards 3, 4, 14, 15, 16, and 17. Panangadu encompasses wards 5, 6, 7, 8, 9, 10, 11, 12, and 13. Lastly, P. Vemballur includes wards 1, 2, 18, 19, 20, and 21(GoK 2022- 2027)[9].

[8] Vikasana Rekha Government of Kerala (2022- 2027)
[9] Vikasana Rekha Government of Kerala (2022- 2027)

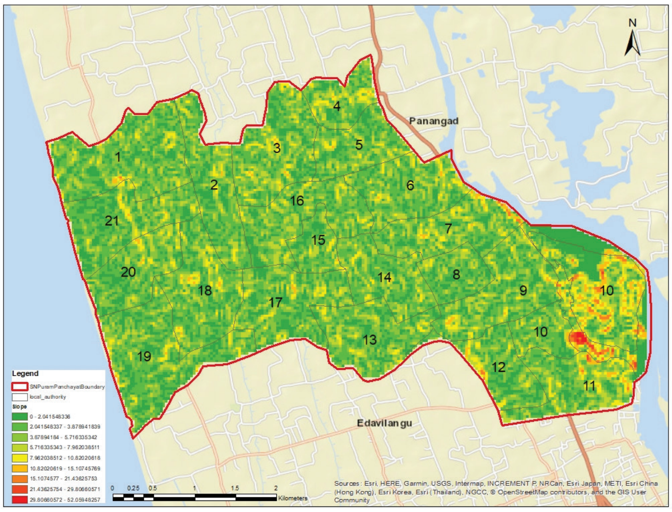


Figure 4: Slope map of Sreenarayanapuram Grama Panchayat

The figure 4 represents the slope map of Sreenarayanapuram Grama Panchayat. In this map, the green-colored areas indicate a relatively gentle slope, with a percentage of 2.04%, covering a substantial portion of the region. On the other hand, the red-colored areas represent steeper slopes, with a slope percentage of 52.05%, but these steeper slopes make up only a small portion of the area. The yellow coloured region indicates a slope percentage of about 7.96- 10.82. Additionally, the contour map, which consistently shows elevations which is less than 10 meters above the mean sea level and confirms that the region is predominantly characterized as a flat plain (FGD).

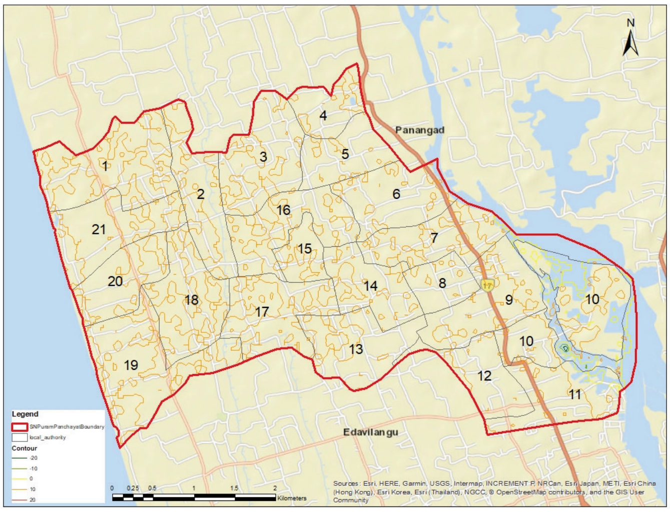


Figure 5: Contour map of Sreenarayanapuram Grama Panchayat

The Panchayat encompasses a total area of 19.26 square kilometers and is divided into 21 wards. The population density of this region is 1904 people per square kilometer. The Panchayat is home to a total population of 37,959 individuals and approximately 10,000 households, comprising 17,910 males and 20,049 females. Scheduled castes constitute 12.22% of the total population of Sree Narayanapuram gram panchayat, out of which 1144 scheduled castes live here. There are 4,405 individuals belonging to the Scheduled Caste (SC), with 2,167 males and 2,238 females within this category.Furthermore, the Panchayat has a voter list that includes a total of 27,801 eligible voters. These statistics provide a comprehensive overview of the demographic and electoral characteristics of the Sreenarayanapuram Panchayat(GoK 2022-2027)[10].

[10] Vikasana Rekha Government of Kerala (2022- 2027)

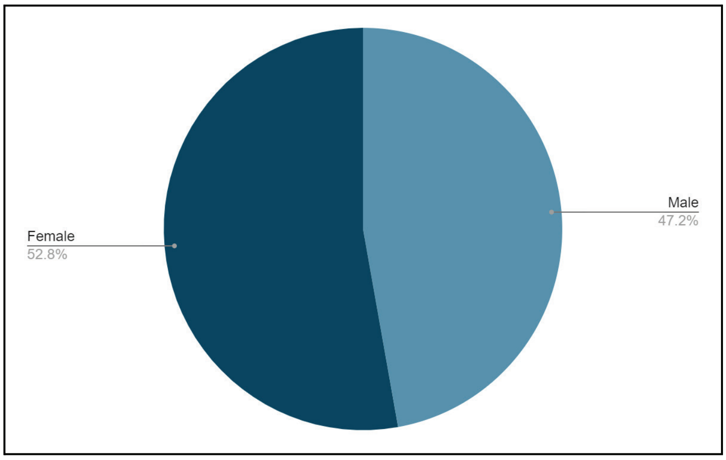


Figure 6: Sex ratio of Sreenarayanapuram Grama Panchayat

The male to female sex ratio in Sree Narayanapuram Panchayat indicates that there is a slightly higher proportion of females, accounting for approximately 52.8% of the population, while males make up about 47.2%. This ratio suggests a relatively larger female population within the Panchayat.The Scheduled Caste (SC) population in Sreenarayanapuram is approximately 12.2% of the total population. This demographic data indicates the presence of a significant SC community within the Panchayat, reflecting the diversity and composition of the local population(GoK 2022- 2027)[11].

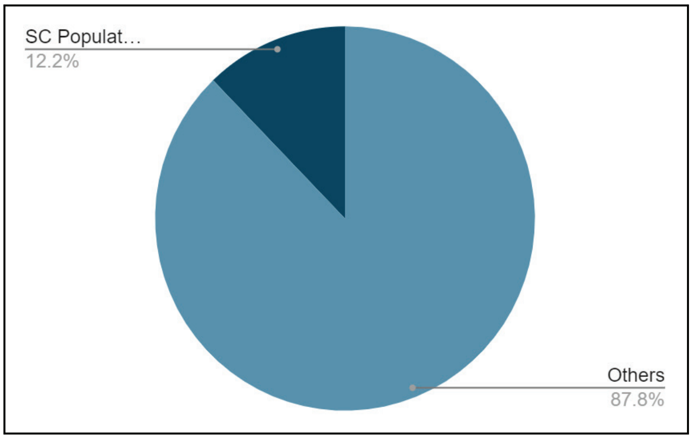


Figure 7: Social background of Sreenarayanapuram Grama Panchayat

[11] Vikasana Rekha Government of Kerala (2022- 2027)

The land use pattern in Sreenarayanapuram Panchayat reveals a diverse distribution of land types as shown in Figure 8. Approximately 5% of the total land is characterized as water bodies, which include rivers,canals, and other aquatic features. Furthermore, 10.8% of the land is categorized as swale coastal, indicating areas along the coastline with specific ecological characteristics. An additional 1.6% of the land is identified as mud flat coastal, suggesting intertidal areas near the coast. The majority of the land, accounting for 82.7%, is designated as coastal plain. This category typically comprises relatively flat and open terrain near the coast, which can have various land uses, including residential, agricultural, and commercial activities(GoK 2022-2027)[12].

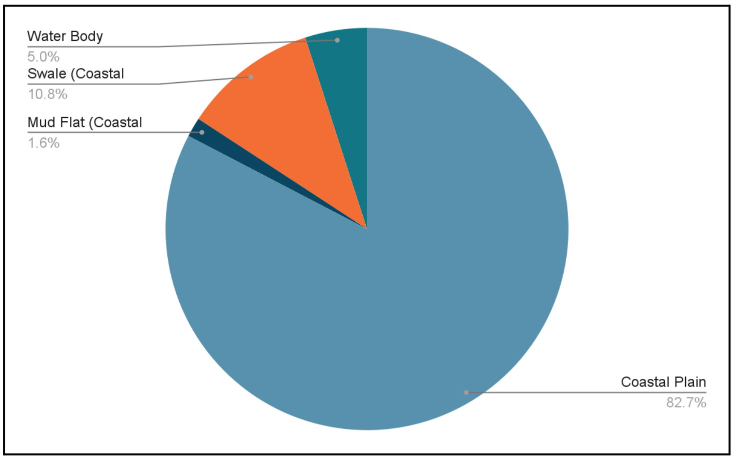


Figure 8: Percentage Distribution of Land Use classification

The land distribution in Sreenarayanapuram Panchayat reveals a varied pattern of land usage. Specifically, 0.8% of the total land is dedicated to paddy cultivation, encompassing both Virippu and Mundakan varieties. Approximately 8.9% of paddy fields have been transformed into coconut plantations signifying a shift in agricultural practices according to the Kerala Land Use Board report 2013. In response to these challenges, a notable shift has occurred in the land use pattern. Approximately 175 hectares have been allocated for coconut plantation, representing a transition from paddy fields to a different agricultural crop. Moreover, 165 hectares are now dedicated to banana plantation, and another 100 hectares are designated for vegetable cultivation (GoK 2022-2027)[13].

[12] Vikasana Rekha Government of Kerala (2022- 2027)
[13] Vikasana Rekha Government of Kerala (2022- 2027)

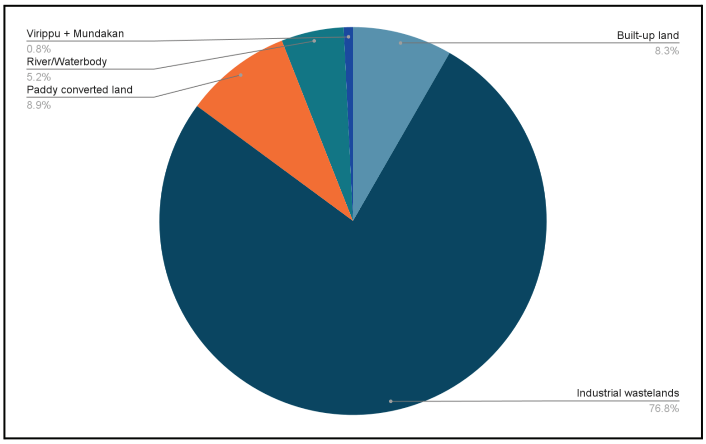


Figure 9: Percentage Distribution of Land use classification

8.3% of the land is classified as built-up areas, indicating residential expansion. Notably, a substantial portion, approximately 76.8% of the land, is designated as industrial wetlands as shown in Fig 9. This designation implies that these areas are employed for industrial or commercial purposes(GoK 2022- 2027)[14].

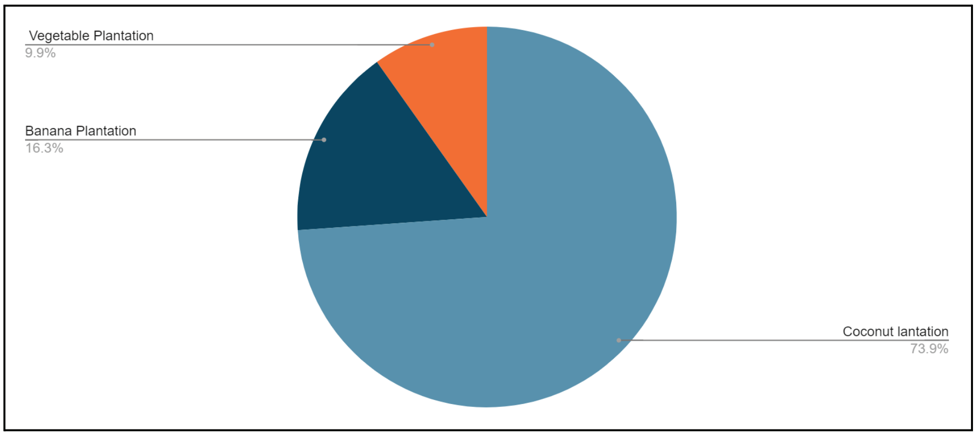


Figure 10 : Shift in Paddy cultivation (GoK 2022-2027)

In the past, agriculture held significant importance in the Sreenarayanapuram Panchayat, serving as the primary source of income for its residents. Paddy cultivation played a pivotal role, sustaining the livelihoods of local farmers. However, a series of challenges have led to a

[14] Vikasana Rekha Government of Kerala (2022- 2027)

transformation in the agricultural landscape. The excessive use of chemical pesticides and fertilizers has not only incurred financial losses for the farmers but has also detrimentally affected the natural structure and permeability of the soil. As a result, the fertility of the land has declined, posing a serious challenge to agricultural productivity (GoK 2022- 2027)[15].

The geology of Sreenarayanapuram Grama Panchayat is characterized by a diverse coastal plain that spans approximately 1598.54 hectares. Mud flat covering 30.18 hectares, which serves as a coastal wetland periodically inundated by tidal waters. Additionally, swales, with a collective area of 209.23 hectares, create depressions and low-lying areas within the coastal plain. The presence of saline intrusion is notable (Oteri et al.,2003)[16], signifying the infiltration of saltwater into freshwater aquifers or areas, which can have implications for water quality and agriculture. Also, the water bodies span 96 hectares of the entire area. This geological description offers a glimpse into the unique features and environmental considerations within Sreenarayanapuram Grama Panchayat's coastal plain (GoK 2014)[17].

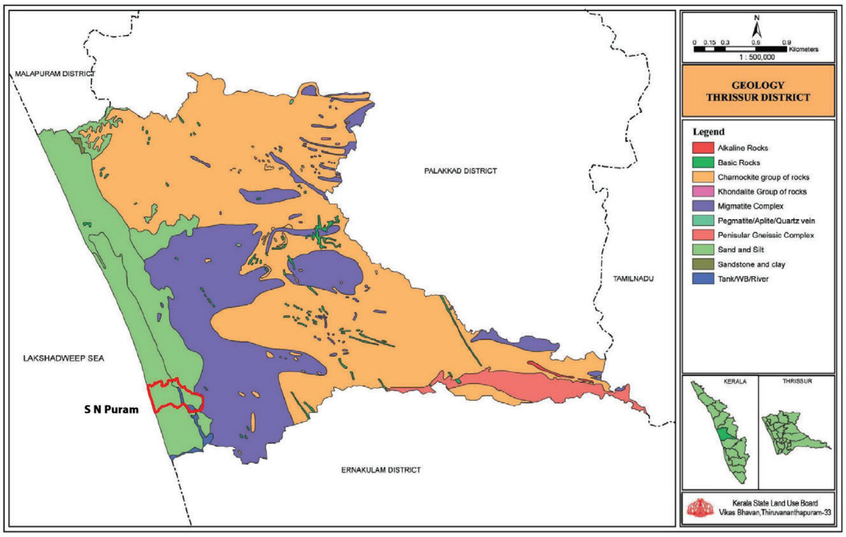


Figure 11: Geology of Thrissur District-Sreenarayanapuram (Kerala State Land Use Board 2013)

In the context of the area's geomorphology (Figure 11), two prominent features come to the forefront. The first encompasses the category of Tanks, Water Bodies, and Rivers, collectively

[15] Vikasana Rekha Government of Kerala (2022- 2027)
[16] Oteri, A. U., and F. P. Atolagbe. "Saltwater intrusion into coastal aquifers in Nigeria." the Second International Conference on Saltwater Intrusion and Coastal Aquifer-Monitoring, Modeling, and Management. Mirada, Yucatan, Mexico. 2003.
[17] Vikasana Rekha Government of Kerala (2022- 2027)

spanning an area of 89.21 hectares. Unconsolidated Sediments, primarily consisting of sand and silt, extend across a substantial 1844.75 hectares (GoK 2014)[18].

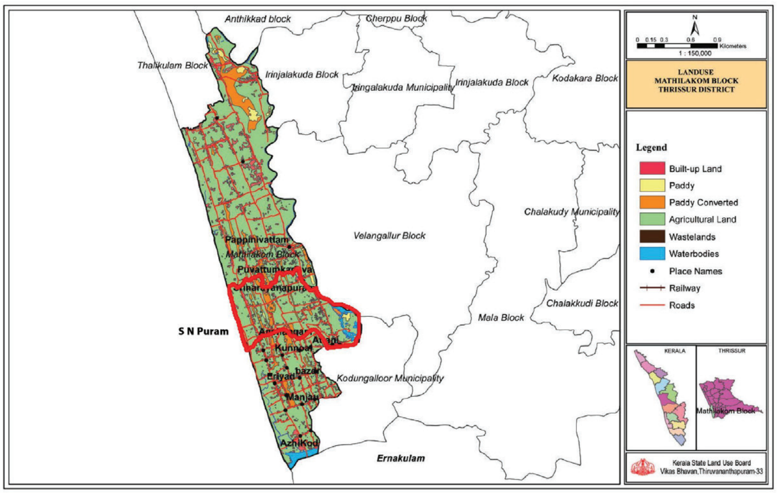


Figure 12: Landuse Pattern of Mathilakam block Panchayat (Kerala State Land Use Board 2013)

Figure 13 provides a comprehensive overview of the mean yearly precipitation trend in Mathilakam block Panchayat for the period spanning 1979 to 2022. By delving into the analysis of the past decade within this dataset:In 2022, Thrissur experienced a mean precipitation of 3157.3 mm, with a precipitation anomaly of 800 mm. This indicates that in that year, Thrissur received significantly higher rainfall compared to the long-term average, with a substantial surplus in precipitation. In contrast, in 2012, the mean precipitation was 2162.6 mm, and the precipitation anomaly was -179.6 mm. This suggests that in 2012, Thrissur received less rainfall than the long-term average, with a notable deficit in precipitation. It's worth noting that the mean precipitation for the state of Kerala is around 3000 mm. In both 2012 and 2022, Thrissur's precipitation levels deviated from the state average. In 2012, it was drier than the average, while in 2022, it was wetter. These variations in precipitation highlight the region's susceptibility to annual weather fluctuations and the importance of understanding local climate patterns for effective resource management and planning.

[18] Vikasana Rekha Government of Kerala (2022- 2027)

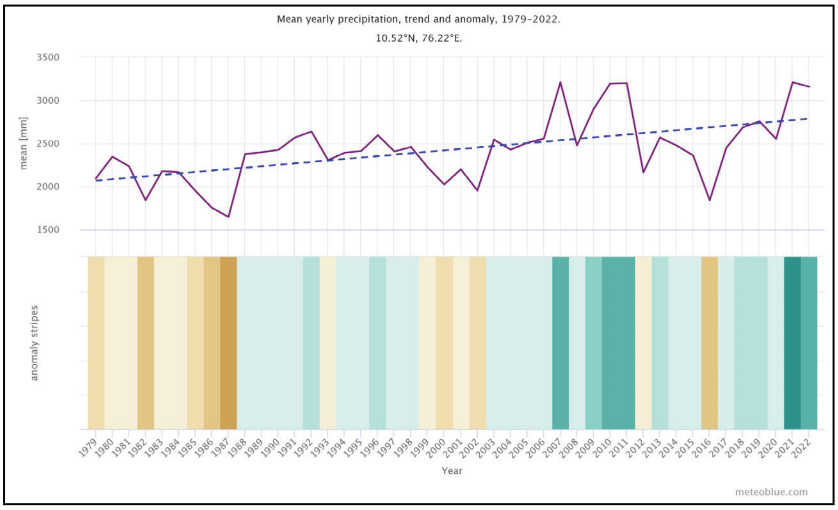


Figure 13 : Mean yearly precipitation trend of Thrissur District (1979-2022)

Figure 14 offers a comprehensive depiction of the mean yearly temperature trend in Thrissur District 1979 to 2022. In 2022, Thrissur experienced a mean temperature of 27.4 degrees Celsius, with a temperature anomaly of 0.3 degrees. This suggests that the temperature in 2022 was slightly warmer than the long-term average, indicating a modest deviation from the expected climate conditions. Comparatively, in 2012, the mean temperature was slightly higher at 27.6 degrees Celsius, with a temperature anomaly of 0.5 degrees. This data reveals a subtle cooling trend over the decade, as the mean temperature in 2022, at 27.4 degrees, is marginally lower than that recorded in 2012. The average annual temperature of Kerala falls between 270 C and 300 C.

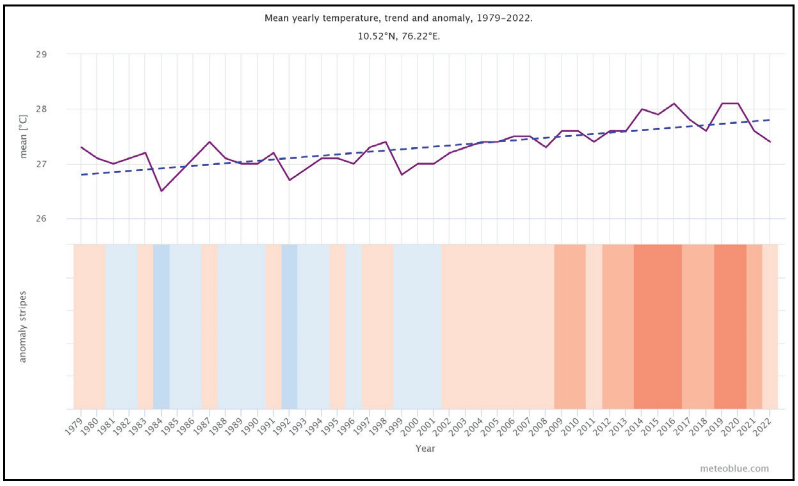


Figure 14 : Mean yearly temperature trend of Thrissur District (1979-2022)

The upcoming section of the report presents the findings from our preliminary studies along with the insights derived.

4. Findings from Preliminary Study

From the preliminary stage of our study, we undertook various research activities, conceptualization exercises, and validation checks to identify the core issues and causative factors affecting drinking water quality, quantity, and supply in Sreenarayanapuram Grama Panchayat. These activities included gathering past study reports, water quality assessments, holding multiple phases of Key Informant Interviews (KII) with the Panchayat, Kerala Water Authority, Groundwater Department, and other relevant stakeholders and site investigations. Additionally, aspiration-gathering meet-ups with Gram Panchayat (GP) officials and residents were conducted to better understand the local concerns and demands. A detailed resource mapping of the existing drinking water infrastructure and conduction of household surveys provided further insights into the region's water management challenges. The findings from the field assessment are detailed below.

The aspiration raised by the Panchayat is;

Panchayat officials and ward members articulated their collective aspirations and objectives through a comprehensive focus group discussion conducted at the Panchayat office, as well as during a workshop organized by K-DISC. During the Focus Group Discussions (FGD) and workshop, the representatives of the Panchayat expressed their aspirations, placing strong emphasis on specific factors, including the availability of good quality drinking water, ensuring affordability for all residents, and expediting governmental initiatives. These aspirations collectively underscore the primary goal of the Panchayat, to ensure the community's access to an adequate and quality supply of drinking water that effectively meets the needs of residents without having any fail. The residents of the panchayat aspire to receive a reliable and equitable water supply through individual household connections, ensuring access to water at least once every week without fail. This expectation underscores the critical need for enhancing the efficiency of the existing water distribution network, addressing infrastructure deficits, and ensuring sustainable water resource management to meet community demands.

4.1 Problem Assessment of S.N. Puram GP

There is a pressing concern that the acute shortage of drinking water in many of the wards of the region including the, selected wards of Sreenarayanapuram Grama Panchayat.The wards of panchayat faces issues affecting the quality of water which includes saline intrusion, iron content intrusion and E Coli contamination as mentioned during the FGD. The wards 1, 7, 9, 10, 11, 19, 20 and 21 are majorly affected wards as shown in Figure 14. It was mentioned during the FGD that the western parts of Wards 7 and 8, along with an area called Panangad, have access to good quality water (FGD).

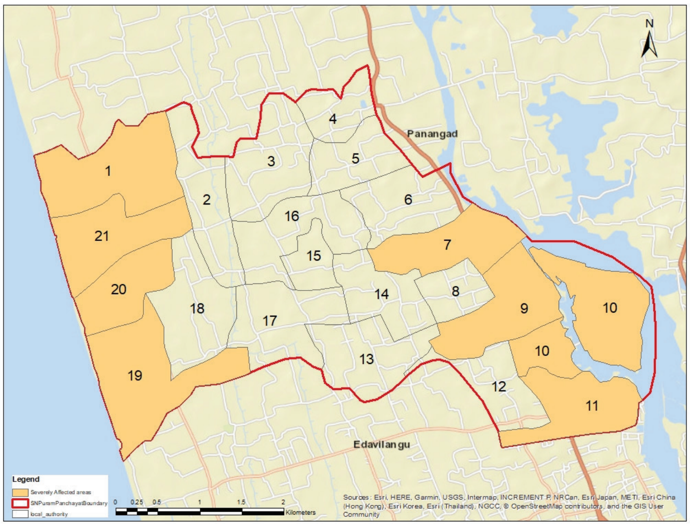


Figure 15: Wards at High Risk of Drinking Water Scarcity

The areas affected by saline intrusion are concentrated in two distinct zones as shown in the Figure15 those in close proximity to the sea, specifically Wards 1, 19, 20, and 21, and those situated near the Canoli canal , comprising Wards 7, 9, 10, and 11 (Figure 16). This geographical delineation highlights the urgency of addressing water scarcity in these specific regions and underscores the need for tailored solutions to meet the unique challenges faced by residents in these areas(FGD).

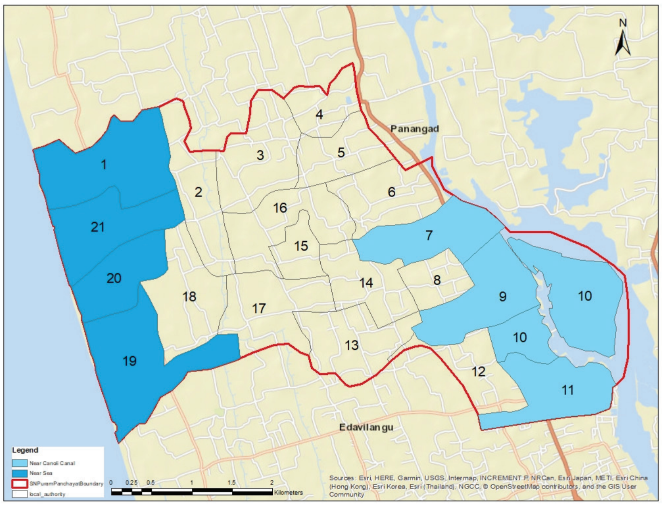


Figure 16: The wards situated in proximity to Canoli canal and Arabian sea

In addition to the persistent quality issues, the region faces significant challenges in water supply. These include insufficient quantities of water provided by the Water Authority, which has proven to be an unreliable source, particularly for tail-end regions of the distribution network. This inconsistency makes it difficult for residents to depend on the current system, exacerbating the challenges faced by the community in meeting their daily water needs.

The geographical layout of the area is defined by the presence of two significant roads. The first is the National Highway, which traverses the region and is linked to the Canoli Canal. The second is the West Tipu Sultan Road situated in the vicinity to the area adjacent to the sea. The sea and the canal are located on the left and right sides of these two roads.This road infrastructure presents an obstacle to the installation process of the pipe network, leading to difficulties in ensuring access to water supply as reported by the OLOI coordinator.

In a concerted effort to combat the issue of saltwater intrusion, the Panchayat has employed the construction of bunds as a preventive measure. These bunds serve as barriers to halt the encroachment of saline water, helping to safeguard freshwater resources and protect against the detrimental effects of saltwater intrusion in the region as mentioned during the FGD

The wards located in the central portion of the area appear to be unaffected by saline water intrusion, as indicated in figure 16 and as per the table 1. However, the water sources of wards located in the mid portion of the Panchayat are unable to fulfill the drinking water requirements due to the presence of E. coli contamination which was proved by the drinking water quality analysis report shown in the table below. A study conducted and published by the KITES foundation during the year 2022 has unveiled a quality analysis report concerning Perum Thodu(Figure 17). The report, presented in Table 1, reveals the test results of parameters including salinity, pH, E.coli, Nitrite and Ammonia of the wards 3,16,17 and 19.

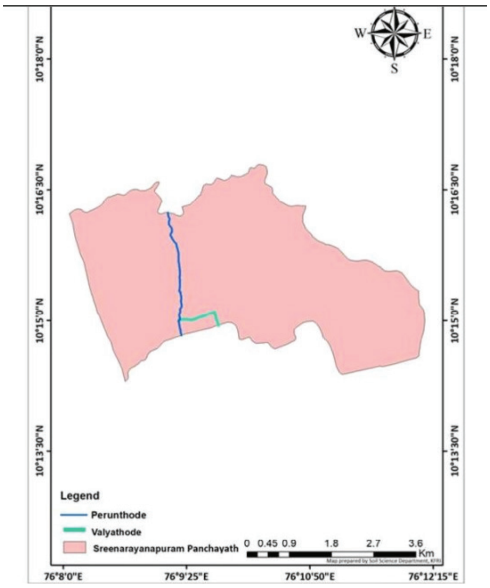


Figure 17: Perumthod and Valiyathodu flowing through Sreenarayanapuram (KITES Foundation)

The results of the water quality assessment reveal that salinity, pH, nitrite, and ammonia values fall within permissible limits, signifying a positive outcome in these aspects across all the tested wards. However, a concerning finding is the presence of E. coli in all the sampled wards, which raises a critical issue regarding water safety. Even in wards 3, 16, and 17, situated at the central part of the Panchayat and unaffected by saline intrusion, the presence of E. coli indicates that the water source cannot be deemed suitable for drinking. E. coli is an indicator of fecal contamination and poses health risks if consumed. This may be due to the poor drainage network, dumping wastes and opened drain outlets towards the water bodies and unscientific Onsite Sanitation System(OSS).

Table 1: Water quality analysis report of certain Panchayts in Sreenarayanapuram (KITES Foundation)

SI. no.	Ward no.	Salinity (ppt)	pH	E.coli	Nitrite (ppm)	Ammonia (mg/l)
1	3	0	7	+	0	0- 0.5
2	16	0	7	+	0	0.5
3	17	0	7	+	0	0- 0.5
4	19	0	7	+	0	0- 0.5
Permissible Limit		-	6.5 to 8.5	-	-	0.5 mg/L

As part of the ‘Thelineer Ozhukum Nava Keralam’ campaign, the Panchayat conducted a study on the Canoli canal, encompassing the survey of a total of 396 buildings. The survey revealed that 59 of these buildings, constituting approximately 14.89% of the total, were found to be discharging black water into the canal. This shows severe pollution exists in the canal and a causative factor for the presence of E Coli contamination. According to the insight, the FGD conducted by the OLOI coordinator reports that a need arises from the panchayat representatives for a centralized sanitation system which can hinder this issue that Sreenarayanauram is currently facing. The maintenance of drainage canals in the panchayats is being carried out under the leadership of health workers. Additionally, the Panchayat has made plans to implement a project related to providing soak pits in all the wards (2023-2024). This suggests a proactive approach to managing drainage and ensuring the overall health and sanitation of the community (FGD).

During the monsoon season, both the sea and Canoli canal overflow due to heavy rainfall. However, the presence of sandy terrain limits the water retention, leading to less groundwater recharge. In regions of clayey terrain limits water permeability, causing acute flooding in some regions. To tackle this issue, the Panchayat can consider implementing various water restoration initiatives, such as diverting excess rainwater for agricultural purposes as reported by the OLOI coordinator from the insights of the FGD conducted. The lack of adequate drinking water during the monsoon contributes to diarrhea (FGD- OLOI Coordinator).

The stage of groundwater extraction in the Thrissur district falls within the safe limit category, with an annual groundwater extraction rate of 56.73% as shown in Table 2. However, when we specifically look at the Mathilakam Block Panchayat, the annual groundwater extraction rate is slightly higher at 63.66% but within the permissible limit. It's important to monitor and manage groundwater extraction carefully to ensure it remains within sustainable limits, being below 70% is generally considered a positive sign for groundwater sustainability (Ground Water Department of Kerala, India, Water Resource Information System (WRIS))

Table2: Groundwater Extraction rate (*Ground Water Department of Kerala, India- Water Resource Information System (WRIS*))

Stage of groundwater extraction	<=70%
Categorization	Safe
District Annual Ground Water Extraction	Thrissur- 56.73%
Block Annual Ground Water Extraction	Mathilakam-63.66%

Analysis of the annual groundwater level data for Mathilakam Block Panchayat over the years 2011, 2013, 2017, and 2020 reveals significant trends. Firstly, the net groundwater availability reached its peak in 2020, reflecting an overall increasing trend from 2011. This suggests a gradual improvement in groundwater availability in the region. In terms of natural discharge during the non-monsoon season, 2017 recorded the highest value, indicating a substantial release of groundwater during that year. Notably, the annual replenishable groundwater resources showed their highest values in 2011, indicating a year when natural replenishment exceeded other periods.

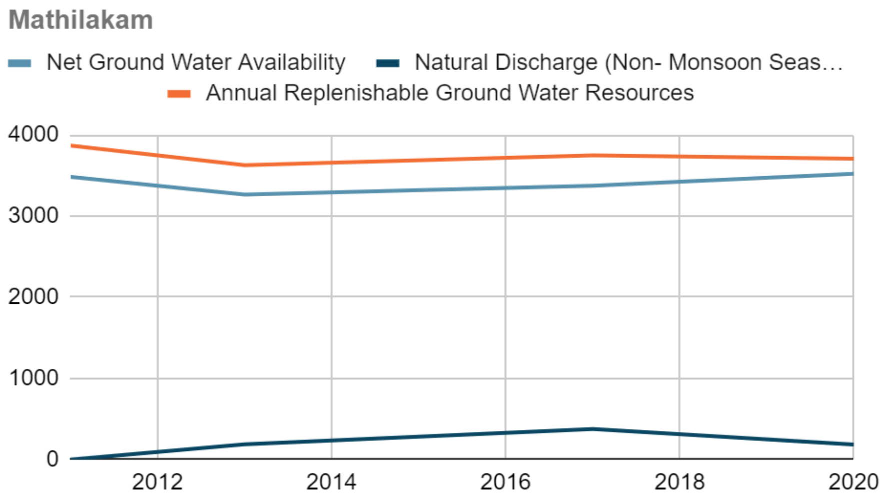


Figure 18: Annual Ground Water Level Data of Mathilakam block Panchayat (India- Water Resource Information System (WRIS))

4.2 Existing Drinking Water Situation of the Panchayat

The Grama panchayat is currently facing issues in water quality and supply. The residents of the panchayat use multiple available sources such as filter point wells and Kerala Water Authority pipe connections to meet their drinking water demand. The Resilience on Peak Period includes the usage of Water Kiosk, Water Atms, Panchayat Tankers, Private agencies, Public Wells and Public Ponds. The tap connections include tap connections established under the Jal Jeevan Mission, as well as through some other schemes under KWA.

Table 3: Available Drinking water sources in Sreenarayanapuram Grama Panchayat (Gok 2022-2027)

SI no:	Sources	Number
1	Public pipe connection	7500
2	Private pipe connection	1500
3	Public open well	24
4	Private open well	2030
5	Public bore well	0

SI no:	Sources	Number
6	Private bore well	0
7	Others (Public)	12
8	Others (Private)	214

In the Panchayat, there exists a diverse array of water sources, as outlined in the provided table. Public pipe connections number 7,500, while private pipe connections stand at 1,500. The Panchayat also relies on 24 public open wells and a substantial 2,030 private open wells. In addition to these, there are 12 other public sources and 214 other private sources that contribute to the water supply infrastructure.

4.3 Existing Drinking Water Infrastructure and Its Challenges

The Kerala Water Authority (KWA) pipeline infrastructure in the region was initially designed to serve 12 wards, catering to a population of approximately 14,000. However, with the expansion of the area to include 21 wards and a current population of 43,842, the infrastructure has become inadequate to meet the growing demand for water. Despite various modifications made to the system, several challenges persist, primarily due to the outdated infrastructure that was laid down 38 years ago.

The pipeline system was originally designed with the assumption of relatively flat terrain. Water is sourced from the Karuvannur River, using a pump set to draw water. The water is then pumped from a 9-meter-deep well cum pump house to the Vellayani facility, which houses a 20 MLD water treatment plant. In addition, the facility includes an 850,000-liter capacity sump and an 800,000-liter capacity overhead tank. The treated water from this facility is distributed to different areas: Kaipamangalam receives 5.4 lakh liters, Perinjanam 3.75 lakh liters, and Mathilakam has a sump capacity of 4 lakh liters.

At Mathilakam, the water from the sump is pumped to a 4.7 lakh liter overhead tank, utilizing gravity for distribution over a span of three days. Although Mathilakam employs a booster pump system, only 10 out of the 30 turns are utilized due to the inability of the aging pipes to withstand the required pressure. The specifications of the pumps are as follows: a 60 HP pump operates at

5 bars and fills water in 1.5 hours with a 250 mm inlet and outlet diameter, while a 40 HP pump operates at 3.6 bars and fills water in 3 hours with the same inlet and outlet diameter.

In SN Puram Panchayat, there are additional tanks with capacities of 3.7 lakh liters and 3.6 lakh liters, but these tanks are currently non-operational. Water is pumped directly to SN Puram for five consecutive days, bypassing the overhead tanks and supplying water directly to the pipe connections. This direct pumping method, combined with the absence of functional valves, worsens the water supply challenges. Moreover, frequent pipe bursts, sudden power outages, and disruptions caused by highway construction further exacerbate the situation.

The key issues contributing to the drinking water crisis in the panchayat are summarized in Figure19. As depicted, challenges exist both at the source and within the supply system. Source-related challenges include issues of water quantity and quality. Quality concerns are attributed to factors such as salinity, turbidity, the presence of E. coli, and high iron content. Quantity-related challenges involve the over-extraction of existing good-quality water sources and the insufficient availability of such sources to meet demand.

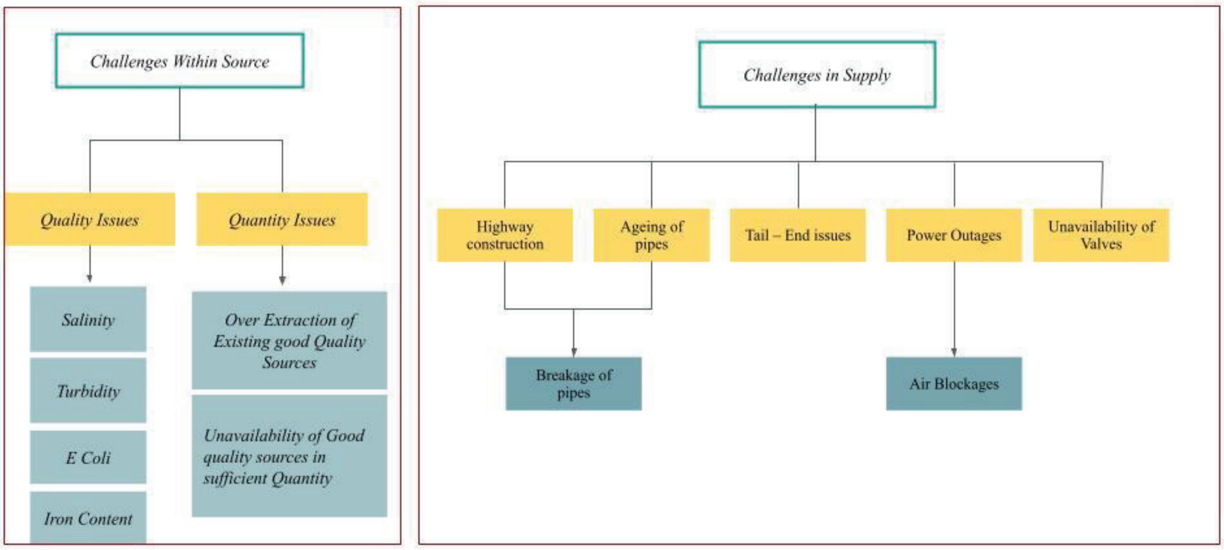


Figure 19: Factors Contributing to Drinking Water Stress in SN Puram

Supply-related challenges primarily arise from disruptions caused by ongoing highway construction and the deterioration of the aging pipeline infrastructure. The main pipe network, over 40 years old, has not undergone significant renovations, with efforts focused only on adding additional pipelines. This has led to frequent pipe breakages and water leakage, severely hindering supply efficiency and reliability at the consumer end.

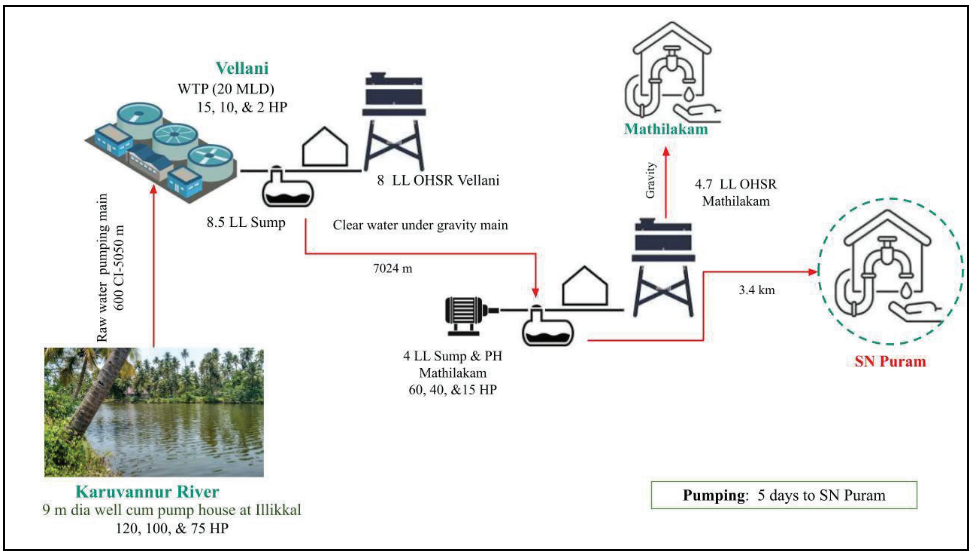


Figure 20. Drinking Water Infrastructure of SN Puram GP.

There is a persisting tail end issue in the region as, source located almost 10 km away from the panchayat and also the sump from which water is coming from is also 7 /8 kms away from the panchayat, lies at the Mathilakam region. The Mathilakam itself is using the same source, so no much water will come from the region, only left overs of their usage.

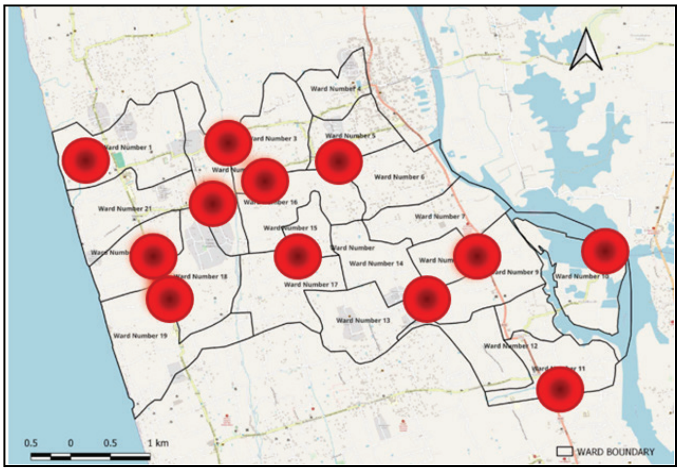


Figure 22: Areas Facing Tail-End Drinking Water Scarcity

The regions shaded in red (Figure 22) indicate areas that are not receiving water due to tail-end issues and pipe bursts caused by supply challenges.

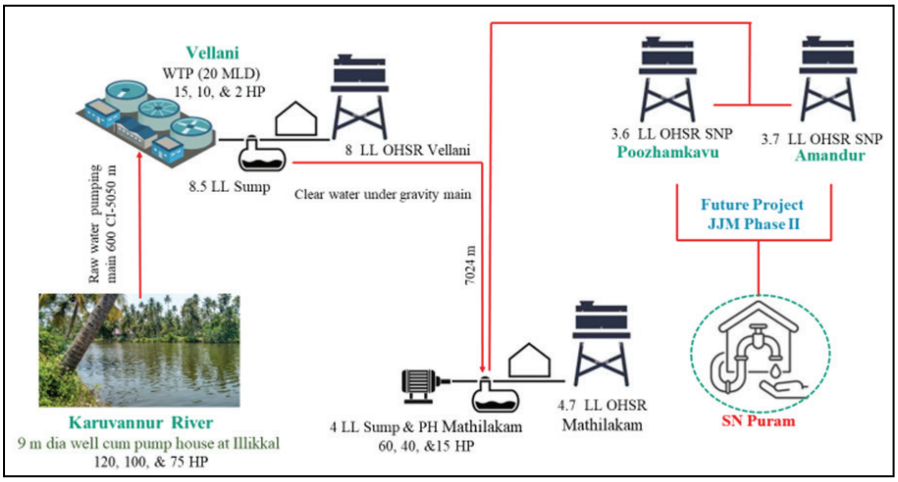


Figure 23: Implementation Plan of Phase II JJM

Figure 23 illustrates the water authority's plan to address drinking water issues, including improving tail-end water supply for regions lacking adequate access. But the project has not been initiated yet.

4.4 JJM in SN Puram Panchayat

The Jal Jeevan Mission (JJM), launched by the Government of India in August 2019, aims to provide safe and adequate drinking water through individual household tap connections in rural India by 2024. Its core objectives include: the goal of achieving "Har Ghar Jal" (water in every household) emphasizes ensuring accessible and equitable water supply to all. The initiative seeks active involvement from state governments, local communities, NGOs, and private entities to foster sustainable water resource management through participatory approaches. The program is centrally sponsored, with funding structured on a cost-sharing basis between the central and state governments, ensuring collaborative financial responsibility and accountability in its implementation.

The mission has achieved a remarkable 99% success rate in installing pipe connections across SN Puram Panchayat, marking a significant milestone in water accessibility. The next phase of the initiative focuses on two key areas to enhance water supply efficiency:

1. **Renovating Unused Overhead Tanks**: Priority is given to the renovation of two out of five overhead tanks located at Poozhamkavu and Aamandor. These efforts aim to resolve supply challenges, particularly in tail-end areas, and ensure consistent and reliable water distribution (Figure 23).
2. **Addressing Pressure Variations**: This involves analyzing and fixing issues related to valve malfunctions and pipe breakages caused by pressure fluctuations within the network, thereby enhancing the system's performance.

The challenges faced by SN Puram's water infrastructure are deeply rooted in outdated systems and inadequate maintenance. Addressing these issues requires a multi-faceted approach involving infrastructure upgrades, phased implementation, and community participation. The Jal Jeevan Mission's initiatives, combined with focused research and innovative solutions, provide a pathway to alleviate water scarcity and improve the quality of life for residents as claimed by the KWA. .

The primary source for the Panchayat's drinking water supply is the Kerala Water Authority (KWA). The schools and Anganwadis in the area have KWA (Kerala Water Authority) pipe connections. The primary challenge in relying solely on the Kerala Water Authority (KWA) to fulfill the Panchayat's drinking water requirements stems from the degradation in the quality of available water resources.This is mainly due to the lack of maintenance of the existing sources free from saline intrusion and the pollution of available canals. The Water Authority derives its water supply from the Karuvannur River. The water collected from this source is then subjected to processing at the treatment plant located in Vellayani.

Figure 23 illustrates the proposed pipe network layout of the Jal Jeevan Mission (Kerala Water Authority) within the Panchayat, offering a detailed overview of the intended water supply infrastructure. Currently, the network's design indicates coverage for approximately 85% of the Panchayat's HHs. It is important to note that this network remains in the planning and implementation phase, and the depicted coverage represents the projected extent of the initiative rather than a fully operational system.To complete the installation of these connections to their full extent, it is necessary to cut through PWD roads. This has led to a conflict between PWD and the Kerala Water Authority (KWA). Unfortunately, this dispute has resulted in residents on both sides of the road not receiving water. Efforts are currently underway to resolve this issue, and discussions involving the MLA are in progress. The diagram employs (Figure 23) a color-coded system to denote various pipe diameters, and it is evident that the predominant usage of 90 mm Class 3 PVC Pipes which is denoted by yellow color. This color dominance highlights the prevalence of this particular pipe diameter in the JJM's distribution network.

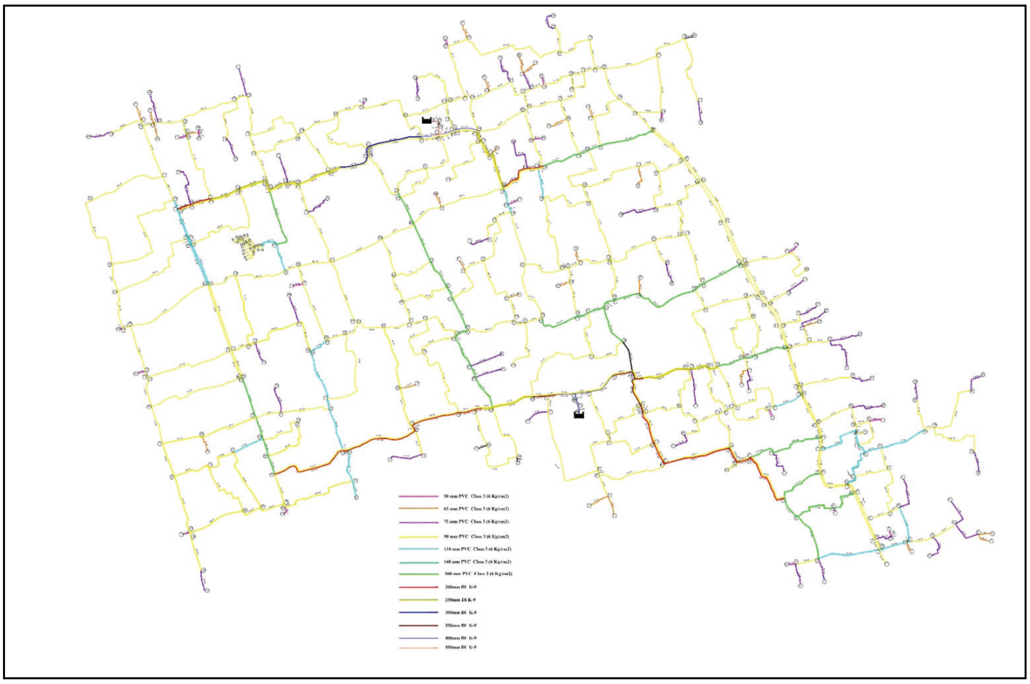


Figure 23: Jal Jeevan Mission Distribution Network Diagram of Sreenarayanapuram Grama Panchayat

In addition to the prevalent 90 mm Class 3 PVC Pipes, the network diagram encompasses a range of pipe diameters, each denoted by distinct color codes. These diameters include 50 mm, 63 mm, 75 mm, 110 mm, 140 mm, 160 mm, 200 mm, 250 mm, 300 mm, 350 mm, 400 mm, and 450 mm. The nodes located at the junctions of the pipeline serve as indicators of the reduced level from the ground. Furthermore, the length of each individual pipe segment has been clearly marked or indicated above the corresponding pipes. This information is critical for understanding the elevation changes and dimensions of the pipeline network, contributing to effective planning and maintenance of the system.

Initially, an amount of 150,000 rupees was paid to the water authority for access to approximately 304 public taps. An additional payment of 450,000 rupees was made for water supposedly obtained from these public taps.This amounts to 15,000 rupees per tap, even though it is available once in a week and the water supply falls significantly short of the expected quantity which is less than 15000 Liters. Moreover, there is a charge of 6,5000 rupees to install a tap at a household as part of the Jal Jeevan Mission. Out of this Rs 6500 is beneficiary share. State and central governments have to spend the related share. Approximately 160 kilometers of roads have not been handed over by the Panchayat to the water authority. The reason for this withholding is that the Kerala Water Authority (KWA) is expected to bear the cost of road maintenance related to the installation of the pipe network. Because of that, there is a complaint from the KWA that the panchayat is hindering the implementation of the Jal Jeevan Mission project. The existing sources of water for the water authority are Vellayani and Vainthala, both of which are located approximately 30 kilometers away. During the summer season, the water authority provides the distribution of free water from the above sources as reported from the FGD conducted by the OLOI coordinator. The KWA claims that their next phase of renovation will include the refurbishment of the existing two tanks and enhancements to the water supply system. These measures aim to achieve equitable water distribution across the region.

4.5 KWA Perspective: Issues and Solutions

The Assistant Engineer (AE) of KWA acknowledges the issues and has expressed willingness to implement proposals suggested by the TAGS Forum. However, she clarified that the execution is contingent upon approvals from higher authorities, such as the Planning and Design Department (PPD). Funding constraints remain a significant barrier, requiring the panchayat to deposit funds with KWA to proceed.

The AE identified the following key challenges:

- **Aging Pipes:** The 38-year-old pipes frequently burst under pressure, hindering efficient water distribution.
- **Valve Malfunctions:** The absence of functional valves prevents controlled water flow during emergencies.
- **Tail-End Issues:** Houses at the distribution network's extremities receive insufficient or no water due to low pressure and pipe breaks.

- **Infrastructure Disruptions:** Highway construction and power outages further disrupt water supply.

To address these issues, the AE emphasized the importance of replacing old pipes, installing functional valves, and renovating unused infrastructure.

Rather than depending on the unreliable water supply from the Kerala Water Authority (KWA), residents have turned to multiple alternative sources to meet their drinking water needs. To understand these practices, we conducted a comprehensive review of the available drinking water sources in SN Puram Grama Panchayat. The findings from this assessment highlight the various sources and practices the residents currently depend on.

4.6 Water Usage Practices Adopted

4.6.1 Water Kiosks and Water ATMs

In the years 2022-2023, the Panchayat has taken a significant step to address the water quality issue by installing water kiosks and water ATMs which are sourced by ground water. These kiosks are equipped with RO (Reverse Osmosis) water purification systems, complete with a double filtration mechanism. The impact of this initiative is especially evident in the nine wards facing the challenge of brackish water. In these areas, only 20% of the water was previously considered suitable for drinking due to saline intrusion in about 9 wards. However, through the introduction of water kiosks, an amount of the water is treated and made potable. Water kiosks are free of cost and water ATM charges at a rate of just Rs 1 per liter.

Figure 24. Water Kiosks in Panchayat (a) Kiosk situated at ward 11 which is under maintenance (b) Kiosks situated at ward 10 under usage (c) Not in usage

The water kiosks are maintained by the installed agency itself (FGD) in association with the panchayat.

Figure 25: Drinking Water ATMs Located in Ward 5 and Ward 1

Proper maintenance and regular backwashing of water kiosks are essential to ensure their efficient functioning. Without these measures, the system may easily collapse, particularly during the summer season (KII Panchayat Officials) when water quality deteriorates due to increased Total Dissolved Solids . High TDS levels can lead to scaling on membrane layers and other complications. Regular monitoring and modification of the technology used in these units are crucial to better address the specific needs of the area. The available kiosks and ATMs in the panchayat, along with their operational status, are illustrated in Map . One of the systems is currently under maintenance due to membrane scaling, which, according to the panchayat, may be attributed to seasonal saline intrusion.

Water ATMs aim to provide access to quality water at minimal cost in regions where good-quality water is available. These units represent a valuable addition to areas with sufficient water resources, enhancing water distribution and convenience for the community.

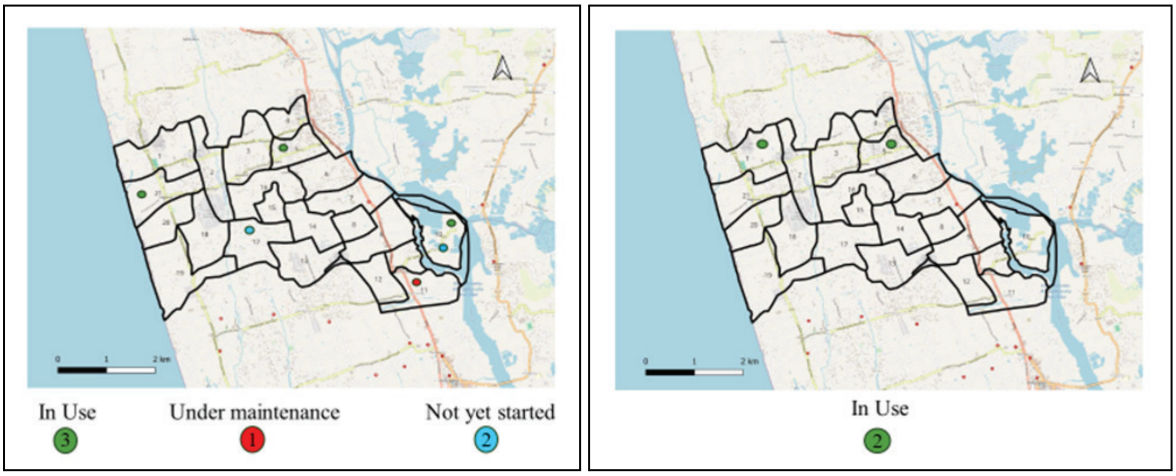


Figure 26: (a) Availability of Water Kiosks in SN Puram Grama Panchayat
(b) Availability of Water ATMs in SN Puram Grama Panchayat

In general, the Panchayat land is more in demand. So it is necessary to arrange the kiosks within limited space . Normally the kiosks in Sreenarayanapuram measure 10 feet length and 8 feet width. At present, 30 houses can benefit from 1 kiosk.In the Panchayat, 2 water kiosks and 2 water ATMs have been successfully installed. Moreover, the Panchayat has set aside a fund of 26 lakhs for the implementation of such projects. Currently, 30-liter tanks are in use, but in response to the observed demand and usage patterns, the Panchayat is planning to upgrade these tanks to 60 liters, providing residents with larger water storage capacity. Strategically, the water ATMs and kiosks have been placed in proximity to schools and markets, ensuring that they are conveniently accessible to the community. Initially, the water kiosks were established using the Panchayat's own funds. However, recognizing the need for broader funding sources, the approach has evolved. Currently, the Panchayat relies on funds, particularly the CFC (Central Finance Commission) fund, to support and maintain these vital water kiosks(FGD - OLOI Coordinator).

4.6.2 Public and Private wells

In addition to other water sources, the Panchayat depends on a total of 24 public open wells and a substantial number of 2,030 private open wells(Gok 2022-2027)[19]. However, during the Focused Group Discussion (FGD), it was mentioned that the water from these wells often

[19] Vikasana Rekha Government of Kerala (2022- 2027)

exhibits discoloration, which has led to reduced dependence on them. It is suggested that the presence of iron content in the water may be the underlying issue contributing to the discoloration (FGD)and impacting the acceptability of these wells as a reliable source of drinking water.

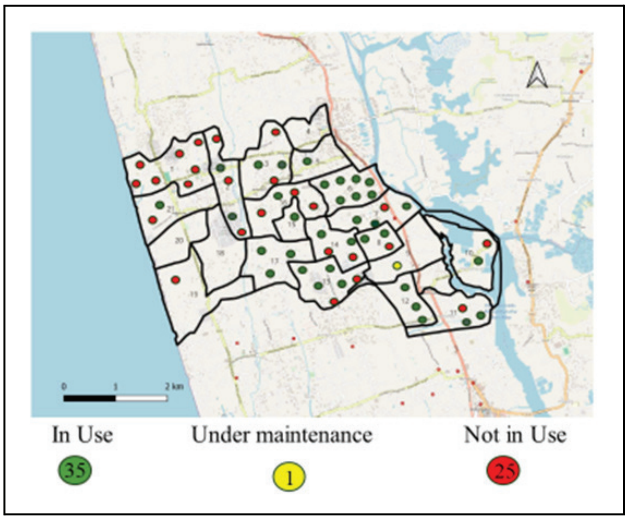


Figure 27: Availability of Public Wells at SN Puram GP.

Most houses do not have private wells in their compound.Adequate maintenance of wells is necessary. Renovate old and damaged wells if possible, or otherwise completely close abandoned wells. Creating small rainwater harvesting units near the wells to recharge them is beneficial. Additionally, providing a single pipe connection directly from the well itself can reduce people’s hardship, allowing them to access water through pipes from the well.

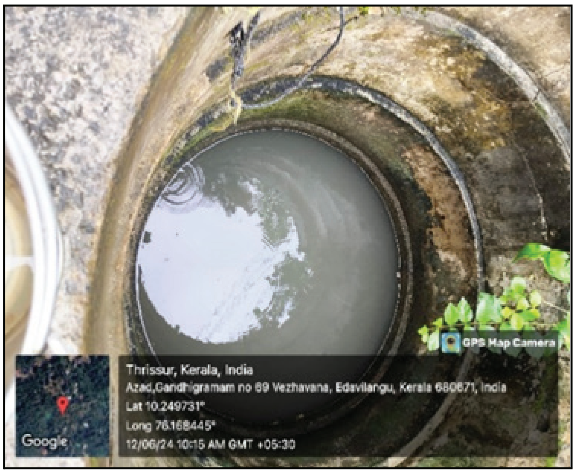


Figure 28: Situation of Public Wells in SN Puram GP

4.6.3 Filter Point Wells

Filter point wells have traditionally been adopted as an indigenous water extraction practice. However, these wells have not yielded particularly positive results in many areas, leading to decreased reliance on them among the community, as reported by the OLOI coordinator. Furthermore, water extracted from filter point wells often exhibits discoloration, which diminishes their appeal as a dependable water source, as observed during Focus Group Discussions (FGD).

4.6.4 Filter Wells

Filter wells are another type of water source that some communities depend on despite challenges such as staining and discoloration of the water. These issues can be mitigated through proper maintenance of the wells and the installation of effective filtering systems. Encouraging communities to adopt regular cleaning and upkeep practices can significantly improve water quality. Additionally, panchayat-level support schemes, such as subsidies for maintenance or minor infrastructure upgrades, can be instrumental in enhancing the reliability of these wells.

4.6.5 Filter Units

The Panchayat is mostly situated in a coastal area, where iron contamination is a major issue. Previously, the population was smaller, but it has increased drastically, leading to a higher demand for water. This increase has also reduced the areas available for digging wells of better quality. Therefore, the most appropriate solution is to install borewells, which can be done manually at a cost of ₹3,000 to ₹4,000, as the water table is high and water can be obtained within a depth of 10 feet without the need for machines.

In this region, borewells are dug by breaking through impermeable or permeable layers to access water. After breaking the hard strata, soft soil or clay-like material is encountered, resulting in a high-water flow that can be filtered. Initially, the pumped water appears to be of good quality—pure and clear. However, when it comes into contact with air, its color fades due to the presence of iron. This problem also occurs when the water is pumped to overhead tanks in houses. The heat from the fiber tanks causes the color to fade, and sludge deposits form at the bottom. This results in staining of vessels, bathroom fittings, ceramic tiles, etc.

An iron filter unit cylinder can help to mitigate these conditions, as shown in Figures 6.9 and 6.10. The filter vessel is cylindrical and consists of three layers of filter materials of different sizes (e.g., 4mm). Activated carbon is placed to remove color and smell, magnesium dioxide to catch iron, and fine sand to trap small impurities. Each layer is placed at a specific depth according to specifications, and proper backwashing should be done weekly to prevent blocking. Approximately 75% of the cylinder is filled with these materials. The fed water enters from the top, passes through each layer, and clear water exits at the bottom. Backwashing is done by passing water in the opposite direction. However, this filter cannot address the issue of saltwater intrusion and is thus not found in regions affected by it. They are only present in areas with color issues in the water.

As part of the visit to Ward 17, residents mentioned that currently, around 2,000 houses are using the filter units in the Panchayat, and this number is expected to increase to 6,000 in the next six months, as shown in Figure 6.8. The filter unit is installed outside the house. One end is connected to the filter well, while the other end is connected to a tank or pipe system. According to users, the filter removes color from the water. This water is used to meet all their needs. However, the installation costs around ₹12,000, making it unaffordable for people below the poverty line.

Figure. 29: Some of the filter point wells used by residents of SN Puram

Discoloration and staining of water are common issues in areas where water is drawn from filter point wells or traditional wells. While these issues can be effectively resolved using filter units, the high cost of such units often makes them unaffordable for many residents. It is suggested that the panchayat implement a subsidy scheme to assist economically constrained households in purchasing these units. However, it is essential to note that these filter units are not effective in areas affected by saltwater intrusion.

4.6.6 Purchasing Water

Even though there is plenty of water surrounding them, there is no water available for drinking, and they do not have access to any nearby water sources. Purchasing water may not be a reliable practice as the quality may vary. Therefore, it is advisable to boil purchased water before consumption to ensure it is safe for drinking.

4.6.7 Rainwater Harvesting

- Due to extreme water scarcity, they rely on rainwater for their needs, eliminating the need to purchase water.
- Instead of collecting rainwater in small vessels inside the house, some residents construct a water tank in their premises. This allows water to be accessed directly through pipes and can also be used to recharge the well. It is important to ensure the tank is free from contamination.

4.6.8 Temporary Migration

- **Reason for Dependence:** Extreme water scarcity results in higher costs for purchasing water compared to renting a house in areas where water is readily available.
- Migration should only be considered as a temporary solution. It is crucial to explore and implement alternative long-term solutions.

4.6.9 Collecting Water from Nearby Houses

- **Reason for Dependence:** There is no access to nearby water sources or adequate transportation facilities available.
- Collecting water from nearby houses cannot be criticized, as this action is often born out of their desperate situation.

4.6.10 RO Filter

- **Reason for Dependence:** Small RO water filter units in houses are used to obtain purified water for drinking and cooking purposes. They effectively remove colloidal impurities from the water.
- Small RO filter units can indeed be quite expensive, making them unaffordable for many people. While they are a good choice for water purification, affordability remains a challenge for various income levels.

4.6.11 Jal Jeevan Mission

- **Reason for Dependence:** Hoping to meet everyone's per capita water demand.
- The planning of Jal Jeevan Mission is promising and has the potential to alleviate water scarcity in many regions. However, its success heavily depends on proper implementation. The primary aim of installing pipelines in all the regions was successfully achieved. The next phase involves planning to renovate 2 old tanks, which has not yet commenced and appears to be time-consuming.

4.6.12 Public Pipe

- **Reason for Dependence:** To facilitate easier access to KWA water in areas where it is not readily available.
- Public pipes are beneficial only if they can adequately supply water; otherwise, they serve little practical purpose.

4.6.13 Water Hoarding

- **Reason for Dependence:** Water is not available for a prolonged period, so whenever it is available, people try to store it as a precaution.
- Storing large quantities of water from KWA supply, which deprives others who also need it, cannot be encouraged. This behavior reflects greed and negatively impacts those who cannot afford to store water.

4.7 Dependency during peak period

The cost of buying water at Rs. 600 for a 1000 liters is undoubtedly high and can be considered unaffordable and inconvenient for the community, regardless of their financial background. During periods of peak water scarcity, the Panchayat takes proactive measures to address the issue by supplying water through tankers. This critical intervention is funded by the Panchayat itself and typically occurs in the months of April and May when no other reliable source of drinking water is readily available (FGD).

Various government institutions and private individuals have initiated rainwater harvesting schemes.

4.8 Site Visit: Vulnerable Cases Observed

A site visit was carried out on the western side of the Panchayat to conduct an in-depth assessment of the existing conditions and circumstances of the local communities.

4.8.1 Site Visit 1 - Near Canoli Canal:

During our site visit near the Canoli Canal, we encountered a household facing exceptional challenges. This family consisted of a bedridden father, a mother responsible for household management, and their autistic son, who was around 30 years old. Their primary source of income was the father's monthly pension, which amounted to approximately 1200 Rs per month. Of particular concern to this family was the cost of water. Priced at Rs 600 per 1000 liters, obtaining an adequate water supply to meet their daily needs posed a significant financial burden. To cope with these expenses, the family had no choice but to restrict their water usage and limit the number of times they refilled their water supply to just three times a month, resulting in a monthly expenditure of Rs 1800.This poignant visit shed light on the profound impact that water affordability has on vulnerable individuals, such as their autistic son, and emphasized the pressing need for a comprehensive solution to address the drinking water issue within the community.

4.8.2 Inland Island of Canoli Canal:

The second site visit took us to a household in an inland island situated along the Canoli Canal. The family, led by a woman, included a child under the age of three. The presence of a young child naturally increased the household's demand for water, given the various domestic needs.

This household was part of a marginalized community, and despite having a tap connection, they reported irregular water supply. Due to significant pressure from residents, possibly in conjunction with the regional festival of Onam, which held great significance, they received water through the pipes on the day and the day after Onam irrespective of time constraints. This occurrence prompted residents to question whether the drinking water issue might be more rooted in governance challenges than an actual shortage of water in the region. Additionally, the household revealed that, due to the exorbitant price of water, they were compelled to make difficult choices, such as limiting the frequency of laundry, despite the added demands of the young child.

This visit raised important questions about the consistency of water supply, affordability, and the role of local governance in addressing these issues. From the desk review and field assessment, it is revealed that there are issues related to the water quality as well as quantity. The issues that the residents of the panchayat are facing are depicted in the following fig.

4.9. Potential sources identified during the preliminary study

Sreenarayanapuram Grama Panchayat has access to water sources, but the quality issues mentioned earlier present a significant challenge in utilizing these resources effectively. However, based on secondary data analysis and insights gathered from focus group discussions (FGD), it is clear that the following resources can be effectively utilized if they are properly maintained and treated:

4.9.1 Ponds

The existing ponds in various wards offer a promising opportunity to address the Panchayat's drinking water needs. If these ponds are appropriately maintained and their suitability is verified through the analysis of water quality and quantity, they have the potential to serve as valuable water sources.

4.9.2 Water Tanks

The ongoing construction of a water tank at Karuvannur is an important infrastructure project that holds the potential to provide significant benefits to the local community. This water tank is expected to enhance the water supply system, particularly for households with Jal Jeevan Mission (JJM) pipe connections.

4.9.3 Public Well

The public well located at Pozhankavu holds the potential to serve as a potential water source. This well is under the jurisdiction of the Kerala Water Authority (KWA).To ensure its suitability as a water source, it is essential to conduct assessments to evaluate both the yield (the amount of water it can provide) and the water quality. These evaluations are critical in ensuring that the water from this source meets the required standards for safe consumption. The maintenance activity and suitability checking is in progress in assistance by the KWA.

4.9.4 Perunthodu and Valiyathodu

These water bodies are located in the central portion of the Panchayat, as illustrated in Figure 17. They are not susceptible to saline intrusion, but they face issues related to pollution (E coli contamination) and discharge, as indicated in Table 2. With proper maintenance and treatment, these water bodies have the potential to provide significant benefits to the wards within its proximity, contributing to improved water quality and accessibility.

4.9.5 Canoli Canal

The Canoli Canal is currently experiencing challenges related to saline intrusion and is heavily polluted, as highlighted in the survey conducted by the 'Thelineer Ozhukum Nava Keralam' campaign. However, if these issues are effectively addressed with the appropriate technology and remediation measures, the canal water has the potential to become a valuable and reliable source of water supply for the region. This transformation would greatly contribute to improving water availability and quality in the area.

The potential sources identified, can indeed be optimally utilized with the adoption of specific technologies if needed to address water quality and availability. Moreover, it is crucial to address governance-related issues, as highlighted in the preceding chapter, to ensure the efficient and sustainable management of these resources.

Part II

5. Plan and Design Approach

Through extensive discussions with sectoral experts, including Prof. Pradeep Kalbar and Prof. N.C. Narayanan from IIT Bombay, a critical flaw in the water supply chain was identified. Despite the availability of multiple water sources and tap connections, the Kerala Water Authority's (KWA) current supply fails to meet consumer demand at the tail end of the network. This is primarily due to the significant distance (up to 10 km) between the source and the Overhead Tank (OHT), coupled with inefficiencies in the water distribution network, including the absence of proper valve systems. As part of the process, we conducted multiple field visits and interviews to develop the current approach. During this process, M.Tech Environmental Engineering students from the College of Engineering Trivandrum interned with us as part of their academic program, assisting in conducting field surveys and Key Informant Interviews (KIIs).

Additionally, the lack of reliable, good-quality water sources poses a major challenge, particularly when considering the decentralization of the centralized distribution system, which currently relies heavily on the KWA. As a solution, the focus has shifted toward rejuvenating the quality of available water sources.

The proposed system incorporates both short-term immediate measures and long-term sustainable solutions. While treatment solutions inherently involve some level of energy consumption and occasional chemical use, these can be tailored to the specific context. The detailed exploration of these short-term solutions and the overall long-term design approach is presented in subsequent sections.

Figure 30:. Field Visit Conducted to Gothuruth along with team AWPL.

The expert team, in collaboration with the Panchayat, agreed that the outlined approach addresses the majority of the region's drinking water challenges. The decision-making process involved partnerships with agencies such as ACWADAM (Pune, Maharashtra) and Ajivam Water Private Limited (AWPL) for situation assessment studies. Additionally, IIT Bombay’s patented retrofitting shaft technology was presented to the Kerala Water Authority at Mathilakam, showcasing its potential to enhance pressure and efficiency in water distribution.

As an immediate solution, the installation of an high TDS removal RO unit with sufficient capacity is planned in consultation with Umang Systems (Navi, Mumbai). A pilot implementation will target regions most affected by these issues to assess the technology's impact. Detailed information on the pilot site, implementation strategies, and cost estimates is provided in the forthcoming sections.

Figure 31: (a), (b), (c) Key Informant Interviews and presentations conducted at S.N Puram GP, (d) Presentation conducted at Kerala Water Authority Mathilakam.

The water scarcity issue in this region is not primarily man-made but is largely influenced by natural factors stemming from its geographical location and context. Addressing this issue necessitates the adoption of sustainable practices rather than relying solely on novel technological solutions. While sustainable approaches are time-consuming to show results, an immediate intervention is required to mitigate the drinking water crisis in the short term, while also laying the groundwork for long-term solutions to manage saline intrusion sustainably.

To address the issue, we decided to implement a pilot-scale solution in the most vulnerable area of the panchayat, which faces severe drinking water challenges. Based on Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and desk reviews, wards 10 and 11 were identified as the priority areas for intervention. This includes the Gothuruth region, an island-like area where the population suffers acutely due to limited access to good-quality water sources. The geographic isolation of the region restricts it from benefiting fully from the existing supply schemes, making it an ideal location for pilot-scale implementation.

As part of the short-term solution, we conducted a detailed examination of the available water sources in the region. We found very few sources of good quality, all of which were already being heavily utilized. This prompted us to explore various treatment methods to enhance the quality of existing poor-quality water. After evaluating several options, we decided to implement an RO system to treat the poor-quality backwaters available in the region.

Additionally, we explored a patented method by Vayujal Technologies Private Limited, capable of converting atmospheric humidity into potable water. However, a detailed life cycle cost analysis (Annexure 1) revealed that the method was unaffordable and cost-ineffective for the context. Consequently, we chose to proceed with a Reverse Osmosis (RO) system, which proved to be more cost-effective for removing high Total Dissolved Solids (TDS) from the water.

To identify a sustainable water source, we assessed the backwaters, which are abundantly available in the region, and finalized the Cannoli Canal as a potential source. A water quality analysis (Annexure 2) was conducted during the rainy season in July 2024. However, due to seasonal variations, the results are not fully representative. Therefore, a water quality test will be conducted during the summer season and will be included in Annexure 2(b) upon completion. We also assessed other potential sources, and treated water from household RO units.

Based on the water quality analysis, we concluded that desalination units are not necessary to treat the available water to meet potable standards for consumer use, as the TDS value is 378 and the conductivity is 713, also the iron content exceeds limits as 0.5 mg/L.

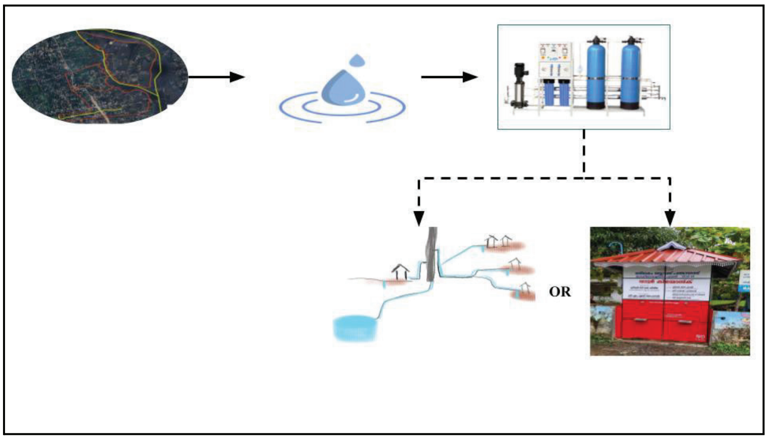


Figure.32: Short term plan approach

In the short-term plan, we have outlined an approach to immediately address the issue of water quality and supply water to the most vulnerable group of residents. To achieve this, we have planned to treat the water from the Cannoli Canal, which is available year-round but has non-potable water quality. The water quality report of the samples taken from various sites within the study area is attached as Annexure 2.

5.1 Region for Pilot Scale Implementation

As a part of the KIIs and FGDs conducted during the study, and from our desk reviews as well, we planned to move with the ward 10 and 11, where the Gothuruth region included, which is an island like region where people are very much suffering due to their water scarcity as there are only good quality limited sources in the region. As it is an island-like region, there is a limitation in accessing benefits out of the existing supply scheme.So the region is finalised for doing any immediate action for the pilot scale implementation. **Ward 10** has a population of 525 residents, while **Ward 11** has a population of 368, making a total of 893 people who would benefit from the project. Figure 23 shows the Mangalathu Pond and Cannoli Canal, which are the probable potential sources available in the Panchayat. While the Mangalathu Pond is a temple pond and visibly has lower yield, the yield test has not yet been completed. However, the water quality test has been conducted and is provided in Annexure 2. Despite this, we have decided to move forward with the Cannoli Canal as the primary source for our interventions. Any adjustments made during the process will be added to the Annexure section. The beneficiary region is potentially outlined as shown in Figure 23.

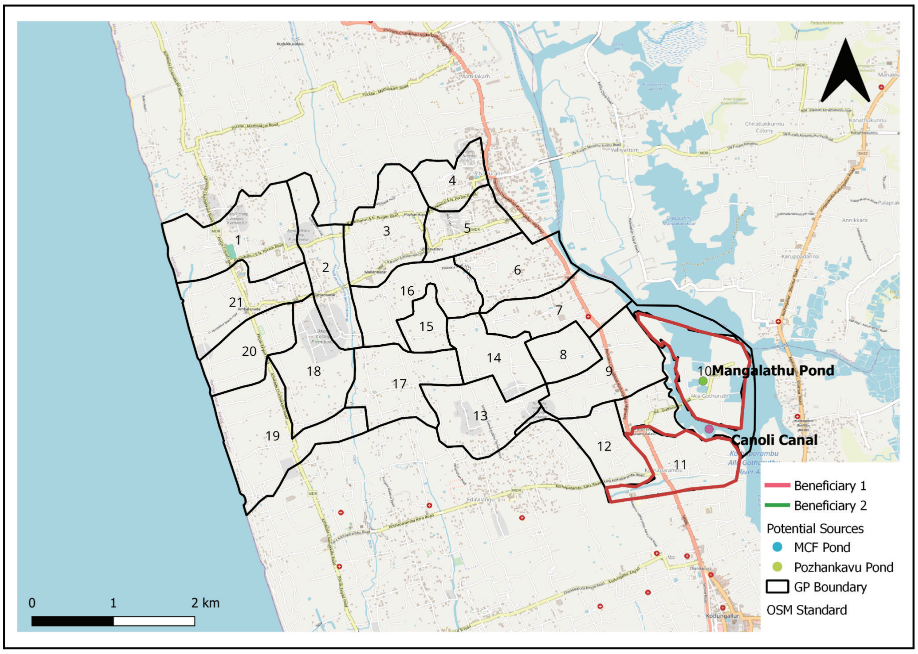


Figure. 33: Potential Sources & Beneficiaries as Suggested initially identified

5.2. Short Term Plan: Implementation of a high TDS RO system

High Total Dissolved Solids (TDS) levels in water pose a significant challenge to its utilization for domestic, industrial, and agricultural purposes. Reverse osmosis (RO) is a highly effective technology for the removal of TDS, providing a reliable solution for water treatment in various contexts, including brackish water, seawater, and industrial wastewater. This chapter discusses the principles, mechanisms, and applications of RO for high TDS removal, along with its advantages and limitations(Greenlee et al., 2009)[20].

Reverse osmosis operates on the principle of forcing water through a semipermeable membrane under high pressure. The membrane's pore size, approximately 0.0001 microns, allows water molecules to pass while rejecting dissolved salts, ions, and larger contaminants. By applying pressure greater than the osmotic pressure of the feed water, RO systems achieve effective separation of impurities (Greenlee et al., 2009)[21].

[20] Greenlee, L. F., Lawler, D. F., Freeman, B. D., Marrot, B., & Moulin, P. (2009). Reverse osmosis desalination: Water sources, technology, and today's challenges. Water Research, 43(9), 2317-2348. DOI: 10.1016/j.watres.2009.03.010
[21] Greenlee, L. F., Lawler, D. F., Freeman, B. D., Marrot, B., & Moulin, P. (2009). Reverse osmosis desalination: Water sources, technology, and today's challenges. Water Research, 43(9), 2317-2348. DOI: 10.1016/j.watres.2009.03.010

1. **Feed Water Pretreatment:** Essential for removing particulates, hardness, and biological contaminants to prevent membrane fouling and scaling.
2. **High-Pressure Pump:** Generates the required pressure for water to pass through the membrane.
3. **RO Membrane:** Acts as the core filtration component.
4. **Post-treatment:** Adjusts the treated water's pH and adds minerals if needed for consumption or specific uses.

5.3 Performance of High TDS Removal RO System

RO systems can achieve TDS reduction rates of 95–99%, depending on feed water characteristics and system design. The technology is particularly effective for treating water with TDS levels exceeding 2,000 mg/L.

Challenges in high TDS removal by RO system

- **Energy Consumption:** Treating water with very high TDS levels, such as seawater (up to 35,000 mg/L), requires significant energy to generate operating pressures of 55–80 bar.
- **Brine Management:** The disposal of concentrated brine, a by-product of the RO process, poses environmental challenges.
- **Scaling and Fouling:** High-TDS water increases the risk of scaling and fouling, necessitating effective pre-treatment and regular maintenance.

To address the environmental and economic concerns of RO:

1. **Energy Recovery Devices:** Improve energy efficiency by recycling the energy from brine discharge.
2. **Alternative Disposal Methods:** Reduce brine's ecological impact through advanced disposal and reuse techniques.

Reverse osmosis is an indispensable technology for high TDS water treatment, ensuring water quality across diverse applications. Its efficacy, coupled with advancements in energy efficiency and waste management, underscores its continued relevance in water treatment systems.

For the application of an RO plant, we have planned to install a fully automatic MPV 2000 LPH FRP UV removal RO unit in the region. To facilitate this, we engaged in discussions with UMAG Systems,Navi, Mumbai, to understand the technical requirements and specifications for the implementation.

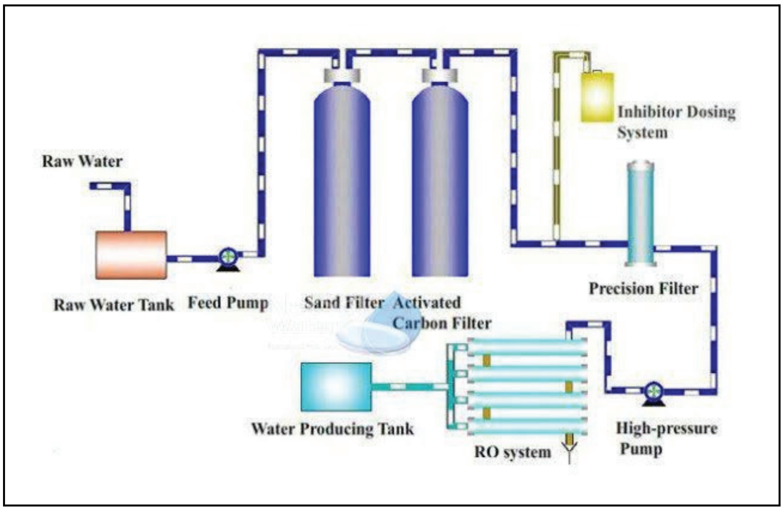


Figure 34: Schematic Flow Diagram of the RO System Planned for Implementation

At this stage, it is confirmed that we can move forward with the RO system for the treatment of water. So our plan includes constructing a water storage tank to store the water after treatment and a KIOSK model like already planned for the rest of the regions.

The components of RO treatment system, includes

1. **Raw Water**:
    - Raw water is the untreated water sourced from the Cannoli Canal, which is of poor quality due to high TDS and contamination. This water serves as the input for the entire filtration and treatment process. It is essential to analyze and assess the quality of the raw water to determine the appropriate treatment steps.
2. **Raw Water Tank**:
    - The raw water tank is a storage unit that holds the untreated water before it undergoes the filtration and treatment process. This tank ensures a steady supply of water to the treatment system. The tank's size is designed based on the expected volume of water to be treated daily.

3. **Feed Pump**:
    - The feed pump is responsible for transferring the raw water from the raw water tank to the subsequent stages of the filtration system. It ensures a continuous flow of water to the next components, maintaining a steady pressure for efficient filtration.
4. **Sand Filter**:
    - The sand filter is a pre-treatment component that removes larger particles, sediments, and debris from the raw water. It uses a layer of sand or a similar media to trap suspended solids, improving the quality of the water entering the next filtration stage and protecting other components from clogging.
5. **Activated Carbon Filter**:
    - The activated carbon filter is used to remove dissolved organic compounds, chlorine, and other impurities from the water. This step is essential for eliminating odors, improving taste, and reducing contaminants that may interfere with the performance of the reverse osmosis (RO) membrane.
6. **Inhibitor Dosing System**:
    - The inhibitor dosing system is used to add a chemical agent that prevents scaling or fouling of the RO membrane. This system ensures that the membrane operates efficiently and is protected from damage due to mineral buildup. The dosage is carefully controlled based on water quality parameters. In this scenario, 7000 ml of antiscalant liquid will be used for every 10 hours of operation.
7. **Precision Filter**:
    - The precision filter is a fine filtration system that removes very small particles and contaminants that might have passed through the previous filters. This is typically a micro or ultrafilter that ensures only clean water enters the RO system, minimizing the risk of membrane damage, which is currently a concern in the SN Puram RO plants that are under maintenance.
8. **High-Pressure Pump**:
    - The high-pressure pump is a critical component that provides the necessary pressure for the water to pass through the RO membrane. Reverse osmosis

requires a significant amount of pressure to force water through the semipermeable membrane, separating clean water from contaminants.

9. **RO System**:
   - The Reverse Osmosis (RO) system is the heart of the water treatment process. The semi-permeable RO membrane allows only water molecules to pass through while rejecting dissolved salts, contaminants, and other impurities. The RO system provides high-quality treated water that meets potable standards.
10. **Water Producing Tank**:
    - The water producing tank collects the treated water from the RO system. This tank stores the clean, potable water before it is distributed to consumers. The size of this tank is designed to meet the demand of the local population while maintaining a constant supply of clean water.

These components together form an integrated system that ensures the water from the Cannoli Canal is treated to a level that is safe for consumption by the residents.

Design Water Quality Assumptions:

1. Raw Water Quality (Input) Assumptions:
   - pH: 7–8 (neutral to slightly alkaline): Dosing pumps can be provided in between to adjust water pH levels as needed.
   - Total Dissolved Solids (TDS): 2000 mg/l (maximum)
   - Total Hardness (TH): 300 mg/l (maximum)
   - The raw water should be free of turbidity, suspended solids, oil, and grease for effective treatment.
2. Permeate Water Quality (Output of RO System):
   - pH: 5–6 (slightly acidic, which is typical after RO treatment)
   - TDS: <50 ppm (significant reduction in TDS)
   - This permeate water quality assumes that the raw water quality remains within the specified parameters. Any deviation in raw water characteristics may necessitate additional treatment steps.
3. Important Notes:

 - The provided specifications assume no presence of oxidizing agents, heavy metals (such as Strontium, Barium, Zinc, Nickel, Chromium), oil/grease, or organics (e.g., COD, BOD). The treatment system, as designed, does not account for these contaminants. If these are present, they may impair the performance of the system and additional pre-treatment will be required. For analysing this an additional Water Quality Analysis will be conducted and added to the annexure part.

4. System Design Specifications:
    - RO Plant Type: Single Stream Reverse Osmosis Plant.
    - Maximum Flow: 2000 liters per hour (LPH).
    - Permeate Water Production: 40,000 liters over 20 hours of operation, with 15 minutes used daily for backwashing and rinsing the filters.
5. System Components:
    - Raw Water Tank
    - Raw Water Pump: Moves the water into the treatment system.
    - Dual Media Filtration: Removes large particulates and some dissolved materials.
    - Activated Carbon Filter: Removes chlorine, organic compounds, and some heavy metals.
    - Micron Filtration: Provides finer filtration for removing smaller particulates.
    - RO Block: The core of the reverse osmosis system that removes salts, heavy metals, and other dissolved contaminants.
    - UV Treatment: Additional disinfection step to ensure microbial safety.
    - Water Tank: Final storage for treated water, provided by the client.

Key Assumptions:

- Raw Water Quality: It’s assumed to be free from harmful contaminants like oil/grease, and high organic loads. Anyways we can conduct a heavy metal test prior to the implementation if needed.
- Backwash and Maintenance: 15 minutes daily for backwashing and rinsing, essential to maintain system performance.

- No Oxidizing Agents: The design assumes there are no oxidizing agents (e.g., chlorine) that could damage the RO membranes. If present, the system might require additional chemical treatment or dechlorination stages.

The RO system has been designed based on the provided raw water quality and flow parameters. Any changes in the raw water quality may lead to performance degradation or the need for additional pretreatment steps. The system is engineered to produce potable water with reduced TDS and pH values suitable for safe consumption.

6. Long Term Solution Plan and Way Forward

The above described plan is designed immediately to address the solution, but then a long term sustainable practical approach is needed to curate the existing DW quality crisis. As a cause, we collaborated with the team ACWADAM for the SN Puram groundwater management project. The design approach put forward for the implementation is detailed out below.

6.1 Plan I: Managed Aquifer Recharging

6.1.1 Targeted Approach Overview

To address groundwater depletion inSN Puram, we have developed a targeted approach based on findings from our pilot-scale study. Our data analysis has guided the design of a region-specific plan, illustrated in Figure 25 below.

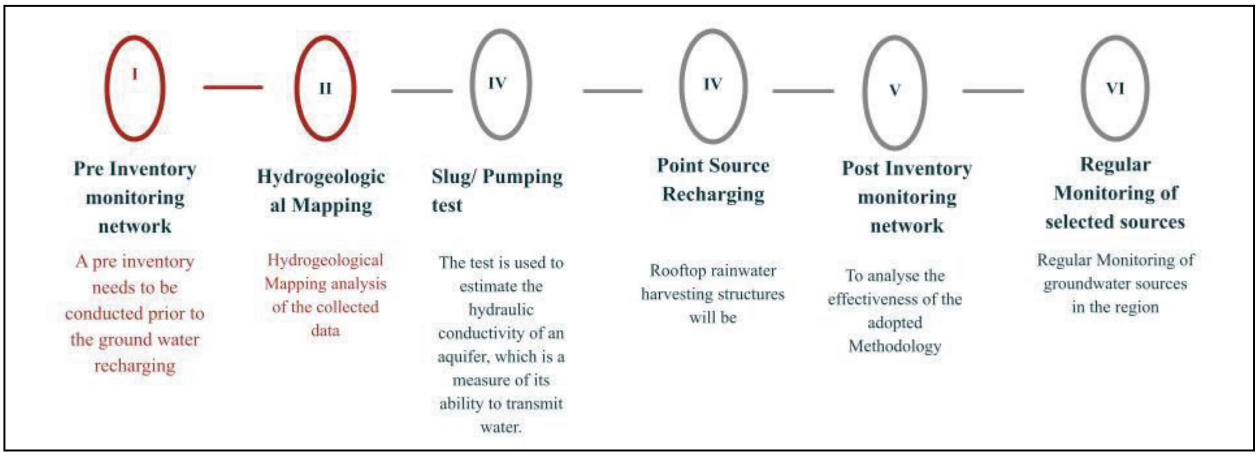


Figure 35. Design Approach

Likewise in the figure, the approach planning to implement for the SN Puram case is listed below in the order.

1. Pre Inventory Analysis of ground water sources
2. Hydrogeological Mapping
3. Selection of monitoring wells and monitoring.
4. Slug or Pump Testing
5. Identification of recharge bearing zone
6. Managed Aquifer Recharging

7. Post Inventories
8. Continuous Monitoring & Evaluation of GroundWater Sources

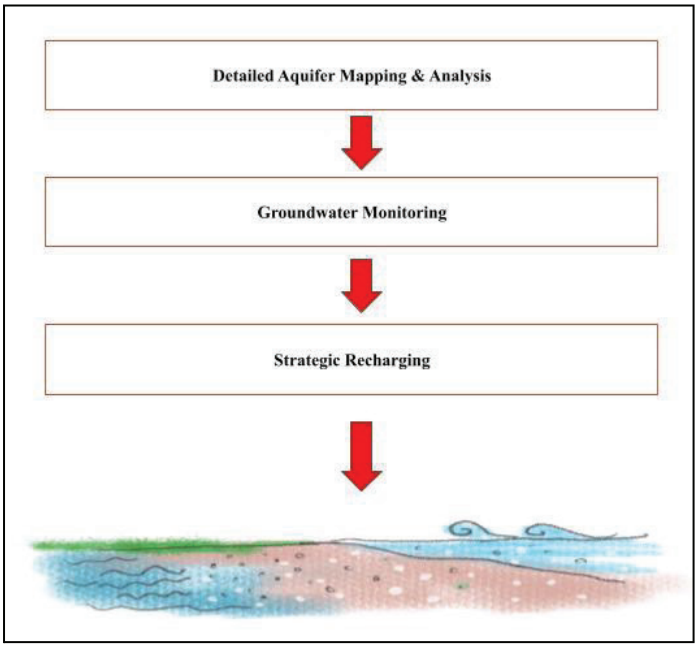


Figure 36: Schematic Illustration of Strategic Groundwater Management Plan

a. **Pre Inventory Analysis of ground water sources:** The pre-inventory assessment focuses on monitoring water quality parameters such as pH, Total Dissolved Solids (TDS), temperature, Dissolved Oxygen (DO), salinity and other indicators using a handheld device. Key quality metrics, including fluoride and iron content, are measured using an instantaneous quality check kit. Additionally, aquifer types, water quality, and quantity are assessed to build a comprehensive profile of the region's groundwater status.
b. **Hydrogeological Mapping:** This is the process of mapping out the geological parameters from the ground for the conduction of detailed analysis of the geologic patterns and their correlation with the hydrologic parameters and the context of situation of their co existence and their effect on the groundwater fluctuations both in quantity as well as quantity. After the assessment detailed analysis can be conducted and analysis maps can be prepared based on that.
c. **Monitoring of selected sources:** Identifying monitoring wells from the above surveyed wells through a method, ensuring all the wells are covered for all the clusters and the uniform sampling can be assured through the hydrogeological mapping. These sources

have to be monitored every month to ensure the fluctuations of ground water pattern and to assess the ground water recharging effectiveness if we are providing any.

d. Slug or Pump Testing

i. **Pumping Test:** This field experiment involves pumping a well at a controlled rate while monitoring water-level drawdown in one or more nearby observation wells, as well as in the pumped well. Data from pumping tests help determine key hydraulic properties of aquifers, including:

- **Transmissivity**
- **Hydraulic Conductivity (both horizontal and vertical)**
- **Storativity (storage coefficient)**

Pumping tests are also valuable for assessing aquifer boundaries, recharge areas, and identifying no-flow boundaries, which are crucial in layered systems for estimating properties like vertical hydraulic conductivity and specific storage in aquitards (Snijders et al., ,2016)[22].

ii. **Slug Test:** This method is suitable for mini-piezometers or wells, aiming to estimate hydraulic conductivity (Kh). In a slug test, the water level in a well is rapidly altered either raised or lowered and the time required for the water to return to its original level is recorded. This data, combined with details on well construction, helps correlate the well-water level response to the transmission properties of the surrounding sediments, ultimately aiding in the calculation of hyporheic flux at the point of measurement.

e. Identification of recharge bearing zone

All the above processes will help in the identification of a recharge bearing zone. Identifying recharge-bearing zones within the pilot-scale study site. By applying contextually suitable recharge methods in these identified regions, the discharge areas typically located at lower altitudes can benefit from the increased groundwater flow from the recharge zones, which are often in elevated areas of the study region. Once the recharge-bearing zone is confirmed, the recharge method has to be finalized.

f. Managed Aquifer Recharging: For doing the managed aquifer recharging in the recharge area, the recharge methods have to be finalized. The below are some recharge methodologies we reviewed.

[22] A.L. Snijders, B.C. Drijver. (2016) 9 - Open-loop heat pump and thermal energy storage systems,nEditor(s): Simon J. Rees, Advances in Ground-Source Heat Pump Systems, Woodhead Publishing,

g. **Recharge Methods**

- **Point Source Recharge:** Point source recharge is a concentrated method of groundwater recharge where water is directed to a single point, such as a sinkhole, fissure, or deep well. This approach includes both natural and artificial types:
  - **Natural Point Source Recharge:** In limestone terrains, features like sinkholes and dolines act as funnels, allowing near-surface water to recharge aquifers directly.
  - **Artificial Point Source Recharge:** Constructed recharge wells or deep dug wells are used to inject treated water deep into the ground.

Point source recharge can result in large volumes of water recharge over a short time, especially during heavy rainfall events. This can also create low-salinity freshwater pockets, known as freshwater plumes, around the recharge source. These plumes develop as large amounts of surface water enter the aquifer.

- **Diffuse Recharging Method**

Diffuse recharge involves the widespread infiltration of water from the land surface to the water table, where precipitation percolates through soil into the unsaturated zone. Unlike focused recharge, which originates from specific surface water sources, diffuse recharge occurs across the landscape, gradually replenishing groundwater.

By adopting the above approach to the entire panchayat, the practical benefits causing the region is detailed out below:

6.1.2 Benefits of Managed Aquifer Recharge (MAR)

Managed Aquifer Recharge (MAR) involves the intentional recharge of aquifers using methods such as infiltration basins, injection wells, and natural recharge enhancement. It plays a critical role in addressing groundwater depletion, especially in regions facing overexploitation and saline water intrusion.

Key Benefits of managed aquifer recharging involves:

1. **Elevating Groundwater Levels:** MAR techniques effectively restore depleted aquifers by introducing surface water, rainwater or treated wastewater, into the subsurface. This replenishment increases groundwater storage, stabilizes water tables, and enhances water availability for domestic, agricultural, and industrial purposes (P., et al. 2019)[23].
2. **Reducing Saline Ingression:** In coastal regions, MAR is instrumental in mitigating saline intrusion caused by over-pumping of aquifers. By maintaining or increasing freshwater pressure, MAR prevents seawater from migrating inland, protecting freshwater resources (Todd, D.K., & Mays, L.W. 2005)[24].
3. **Improving Groundwater Quality:** By introducing cleaner recharge water into the aquifer, MAR can dilute existing contaminants and improve overall groundwater quality. Coupled with natural filtration during subsurface flow, this process enhances water usability (Bouwer, H. 2002)[25].

   Implementing MAR requires careful planning, including the selection of recharge methods suitable to local hydrogeological conditions and ensuring the quality of recharge water to prevent aquifer contamination.

As detailed in the first and third sections of this report, we aim to develop a comprehensive master plan to retrofit the entire pipe network by identifying and addressing its deficiencies. To accomplish this, we propose conducting a study to analyze pressure drops and identify regions facing tail-end supply issues. This study will include detailed hydrological mapping of the existing pipe network to pinpoint specific challenges and recommend suitable retrofitting solutions. In partnership with Ajivam Water Private Limited, we plan to explore the use of shaft technology in areas affected by inadequate water supply due to tail-end issues, as depicted in Figure 22.

6.2 Plan II: Hydraulic Isolation System(Shaft) Based Water Supply Management

6.2.1 Targeted Approach Overview

In India, most of the Water Supply Systems (WSSs) are typically designed for 24x7 operation. The designs are based on rigorous surveys and primary data collection, and entire WSSs are

[23] Dillon, P., et al. (2019). Managed Aquifer Recharge: Rediscovering the Value of Underground Water Storage. *Water*, 11(11), 2288. MDPI.
[24] Todd, D.K., & Mays, L.W. (2005). Groundwater Hydrology. Wiley.
[25] Bouwer, H. (2002). Artificial Recharge of Groundwater: Hydrogeology and Engineering. *Hydrogeology Journal*, 10(1), 121-142.

designed and simulated using hydraulic modeling software. The Central Public Health and Environmental Engineering Organization (CPHEEO) in India is responsible for issuing guidelines for infrastructure creation related to water supply and sanitation, including municipal solid waste management. The water supply manual (CPHEEO, 1999) is the prime reference for all engineers in India for water supply scheme designs and operations. Once the design is completed, the contractor will construct the WSS through a competitive bidding process. Typically, a contractor may operate the scheme for a specific period defined in the contract, after which the WSSs are handed over to the government body, e.g., Urban Local Bodies (ULBs) for Operation and Maintenance (O&M).

One of the main reasons for not being able to achieve a 24x7 continuous water supply in India is that the schemes are not operated as designed, i.e., there exists a gap between the demand pattern considered for the design and the one that gets applied during the operation. Operators tend to divide the systems into small zones and try to smoothen the resistances of consumers by increasing the pressure in the systems by creating entire diversions of flow to a particular area. This is true even for the initial stages (i.e., in the first five years after commissioning) when the scheme component sizes are oversized and the demands are comparatively lower than the ultimate design capacities. An inevitable result of such an operation is that the consumers do not get accustomed to the 24x7 water supply and tend to consume more in the available water supply hours, unknowingly. Consumers try to store water in their storage systems and consume water during non-supply hours. Such an Intermittent Water Supply (IWS) is prevalent globally in developing countries, owing to similar circumstances such as poor system operation, unplanned expansion of the network, unskilled workforce, and interrupted electricity supply.

6.2.2. Problem Statement

In India, IWS is existent throughout the country. Conventional water supply techniques and pressure management technologies are designed for continuous water supply. Hence, they are not suitable in the Indian context. Since consumers in the IWS are unsure of the next supply hours, they try to fetch as much water as possible. This situation creates the problem of unequal water distribution and pressure management throughout the network. At times, the water tanks are bypassed. The main aim of the operators is to deliver water to the consumers irrespective of the pressure. Moreover, problems are faced such as unequal water distribution to the consumers, differential pressures in upstream and tail end of service area, and inadequate pressure in households is commonly observed.

Therefore, it is essential to develop innovative sustainable solutions which are field relevant and address the challenges faced by the consumer. Hydraulic isolation structures like Multi-outlet storage tanks, shafts, and manifolds help in controlling withdrawal and achieving pressure development in the WSS. However, a thorough understanding of the existing problem is a must before implementing any intervention. Multiple site visits and field studies were conducted with both experts and our internal team. Based on their analysis, it was determined that intervention in the existing water distribution system is necessary. Consequently, we collaborated with our domain experts to develop a solution aimed at resolving the current distribution issues faced by the GP. To address these existing problems, we have decided to retrofit shafts at strategic points within the supply network. The details of the project are outlined below.

6.3 .Possible Solutions for Improving Efficiency of the Water Supply System

6.3.1. Scope of the proposal

Based on the findings from the field study, the installation of various hydraulic isolation structures is recommended in the distribution network. The fundamental way of achieving scientific hydraulic zoning is providing multiple outlets at the MBR/GSR as per the requirement. The benefits of multi-outlet tanks are discussed in the following section. A manifold system helps convert the existing single-outlet system into multiple outlets. Moreover, a shaft with multiple outlets helps achieve an equitable water supply. The theoretical background and the case studies of the hydraulic isolation structures like shaft and manifold are discussed in a subsequent section.

6.3.2. Multi-outlet tanks to achieve hydraulic efficiency and ease of operation

In developing countries like India, haphazard urbanization has led to the formation of different high-rise buildings and slums. Also, there is mixed land use and building usage, *e.g.*, the area served by one tank typically has residential, commercial, and slum areas. In current practice, consumers with varying demand (both quantity and pattern) are connected to a single outlet

(Refer Figure 27). Simultaneous withdrawal of water from the storage tank causes the inequitable distribution of water. Certain users get more water compared to others based on the location and ground level. Due to the existing socio-political situation, the areas with high-income group residence are supplied more water by manipulating valves, marginalizing the supply to the low-income residential area/slums. Creating a dedicated outlet for different groups (residential, commercial, high rise area, slums) will undoubtedly help create more equitable distribution and pressure improvements. As shown in Figure 27 multi-outlet tanks offer segregation of service zones, and the same head is available at the start of each outlet.

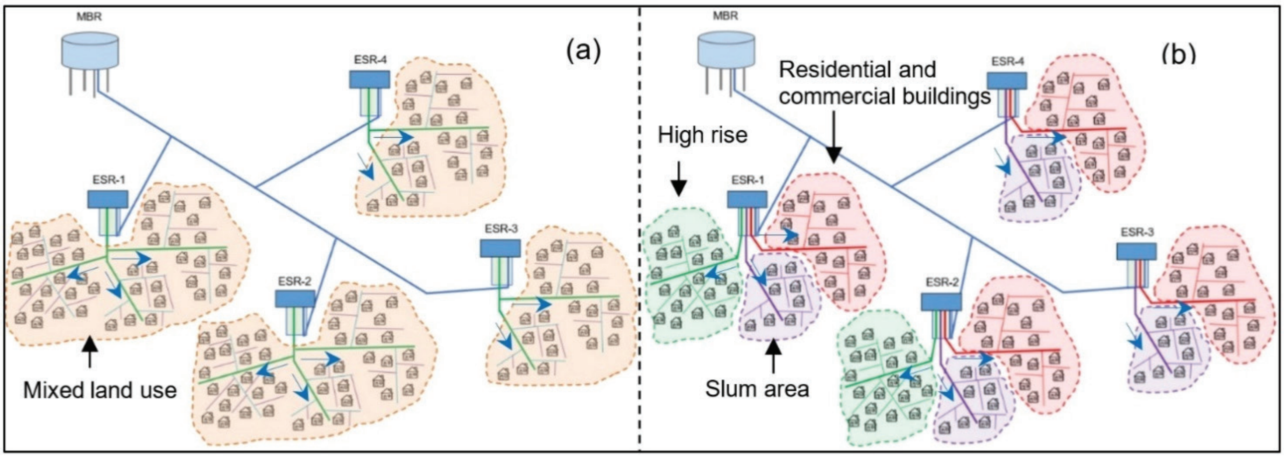


Figure 37: (a) Single outlet and *(b)* Multi-outlet storage tank arrangement. MBR- Master Balancing Reservoir, ESR- Elevated Storage Reservoir. (Source: Ghorpade et al., 2021a)

Multi-outlet tanks help in dealing with the following situations:

i. ***In areas with rapid urbanization and where population growth is difficult to predict***: Separate outlets will not hamper the operation of all influence zones because of unexpected population growth in certain small areas.

ii. ***Maintaining separate DMAs***: As each outlet can be designed to serve a small population, this will automatically create DMAs as per the guidelines of WHO (2001), i.e., this design enables DMAs to be implemented in the field without requiring any field intervention from the operator.

iii. ***In hilly areas where the serving area of the tank has significant elevation differences***: The separate outlets will avoid effects of ground undulations on the entire zone, and equitable pressure can be established easily by express feeders.

iv. When land is not immediately available for a new ESR, one of the standby outlets can serve the new area.
v. Dampening of the peak demand and hence optimizing investment
vi. In India, there is a tendency to construct storage tanks near the existing storage. This results in mixed influence zones of the individual storage tanks, and the advantage of widespread distribution is lost. Multi-outlet tanks help in avoiding such situations.

For all practical purposes, it is recommended to provide at least three outlets at the initial stage and one blank/standby outlet for future expansion that can meet future demand due to unplanned extensions from the same storage tank. The sizes of the outlets can be determined as per the standard hydraulic modeling process. Reduction of outlet size due to split demand will also optimize the present working demand, which is expected to be met with curtailment of valve opening in the present stage. In the initial stages, the draining capacity of the system is more than the actual demand as per the design peak factor. A multi-outlet system allows time-staggering among the outlets (i.e., each outlet can be opened individually), matching with the peak factor, and fast draining of the storage tank can be avoided.

6.4. Use of Shaft as an Efficient Distribution Device

In the WSSs, there are several situations where pressure needs to be reduced due to topography or local conditions. In such situations, to break the Hydraulic Grade Line (HGL), it is necessary to create hydraulic isolation. A shaft can be used in these scenarios to create a hydraulic barrier. Shafts are a vertical pipe structure, with the top of the shaft open to the sky, as shown in Figure 28. The internal inlet pipe in the shaft is a divider of the incoming head and demand side, which works as a hydraulic separator.

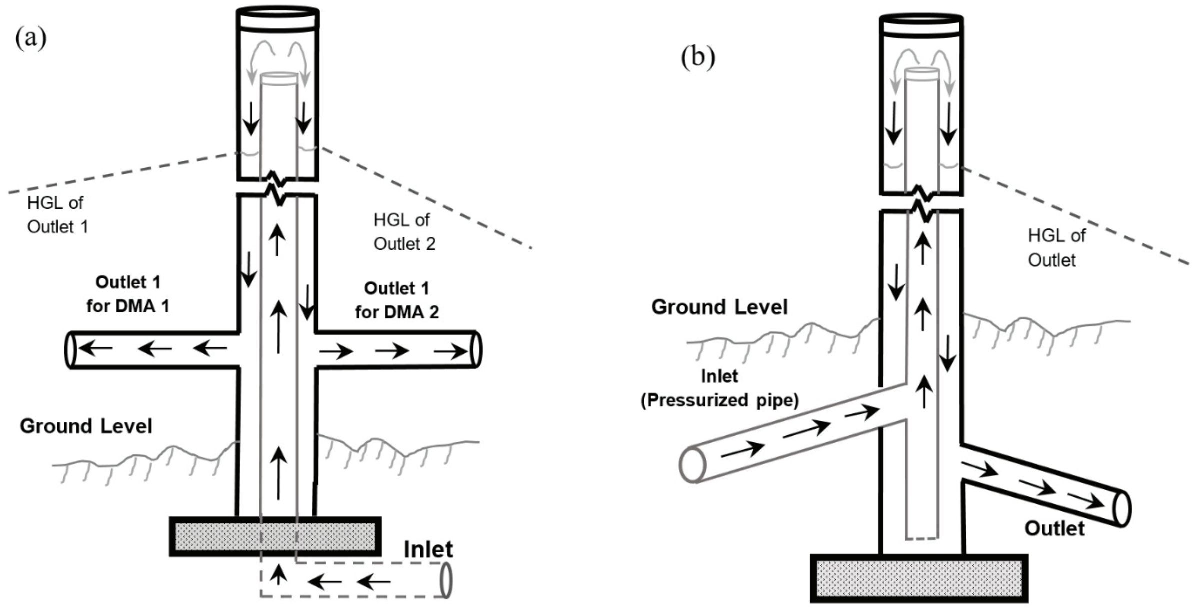


Figure 38. a) Shaft for the distribution system. *(b)* Shaft for the Transmission system. (Source: Kalbar and Gokhale, 2019)

Storage tanks in WSSs serve two purposes, first, to store the water to meet the demand-supply gap and to create a pressure head. However, due to the current operational practice, consumer behavior, and network conditions explained above, there is an uncontrolled water withdrawal from the tanks. Therefore, the tanks get immediately empty before supply hours. Hence, in most WSSs in India, storage tanks are bypassed, and the transmission network is directly connected to distribution.

Such a practice affects the entire operation of the WSSs and leads to inequitable distribution. Instead, shafts can be used on the leading distribution line, which generally carries 1.2–1.5 times the average flow. Shafts have one inlet and can have more outlets simultaneously or at various levels (Refer Figure 28), with varying diameters as per the particular demand of the sub-Zone, leading to separate influence Zones. These outlets can have variable operating times and feature preset valve opening. The height of the shaft will be dependent on the inlet velocity and the characteristics of the outlet(s). Shafts act as directed HGL near the consumer and help in matching the required pressure head.

Overall shafts can serve the following purposes when used in different settings:

i. In the low-lying areas of the influence Zone of the tank, a shaft can be implemented to stop unnecessary draining of the water as it will affect the pressure in other areas. The shaft will disconnect the HGL, and a new HGL can be established as per the requirement of the residual pressure to be maintained in the low-lying area.
ii. When the land for ESR/OHR is not available, a temporary shaft can be created, and water can be provided intermittently.
iii. Shafts can be constructed at the end of the distribution system to take load during the water supply peak. Distribution behind the shaft will not be drained out, which is normally seen in IWS. The head available in the shaft will help satisfy the peak demand of the tail-end consumers of the influence area. Appropriate volume can also be provided in such shafts to serve the peak hour demand.
iv. In the distribution system, the shaft takes out the additional head from the upstream side. It helps achieve equal water distribution on the downstream side by operating the appropriate threads of the valves on the multi-outlets.
v. As shafts have smaller diameters than the conventional storage tanks, any reduction in the downstream demand will significantly increase the head in the shaft, which helps maintain the overall system pressure for a longer duration with the same flow.

Case Study 1: Shaft at Saphale, Palghar, Maharashtra

At Saphale, the issues like high Non-Revenue Water, inequitable water supply, low per capita water, and improper operation and maintenance practices were existent. Moreover, it was observed that the leaking ESR was bypassed, and the transmission line is directly connected with the distribution network. Various valves are operated daily to satisfy the demand for hydraulic Zones. The wide gap between the design and actual operation of the WSS results in various issues mentioned above.

To improve the performance of the distribution network, a shaft was proposed to supply water in two hydraulic Zones viz., Nandade and Chaphanagar. The hydraulic Zones were finalized based on field data and discussion with Gram Panchayat officials. The construction of a shaft with multiple outlets was completed, and commissioning was done in December 2020. Figures 29 and

30 depict the existing and present scenario of the distribution network in the selected hydraulic Zones. The inlet of the shaft is tapped from the 150 mm distribution main. The inlet diameter is 100 mm, and the outer diameter is 300 mm, both made up of Mild steel. Three 100 mm outlets are provided from the shaft. Out of the three outlets, two outlets are utilized to serve the Chaphanagar and Nanded area. The distribution system with the shaft is running completely satisfactorily, and positive feedback is reported from the consumers.

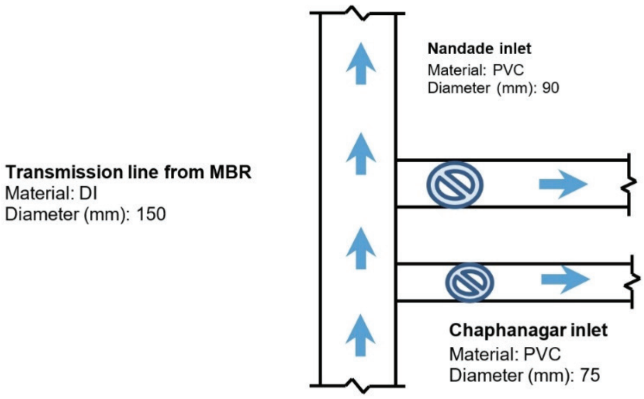
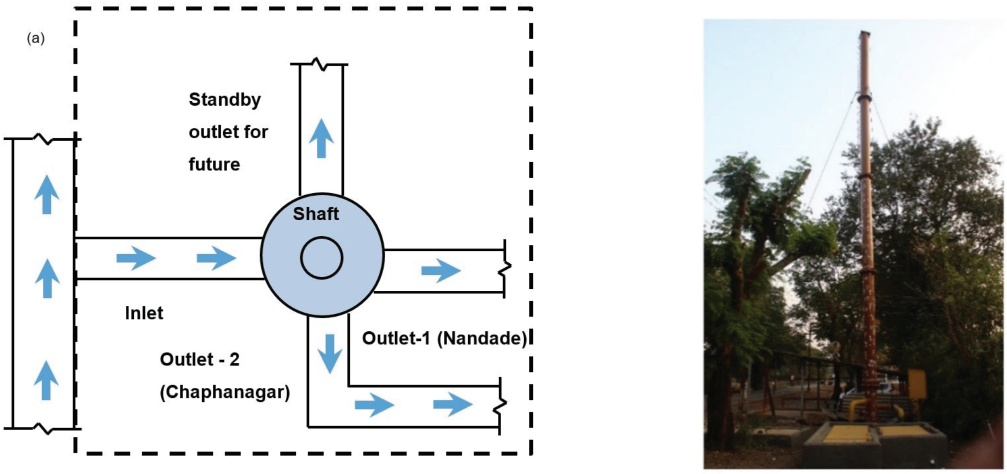


Figure 39: Existing scenario of Chapahanagar and Nandade, Saphale



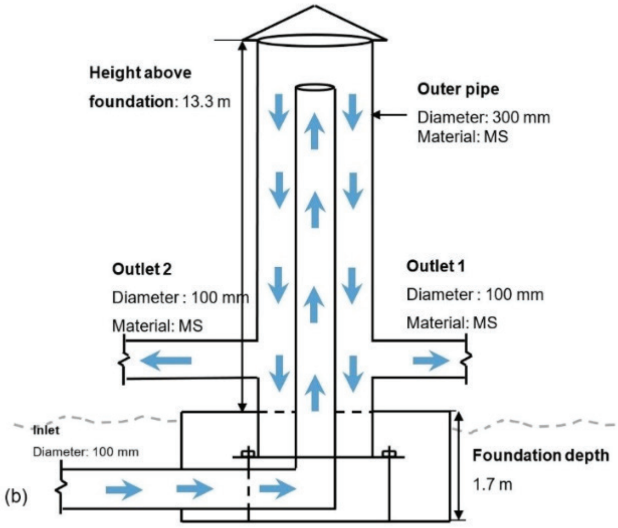


Figure 40: (a) Top view of inlet arrangement for Nandade and Chaphanagar, *(b)* Cross-section of the shaft along with outlet details, *(c)* Shaft at Saphale, Palghar, Maharashtra

Case Study 2: Shaft at Dahanu Town, Palghar, Maharashtra

Dahanu, a coastal town in the Palghar district of Maharashtra is urbanizing at a rapid rate. Over the years, due to urbanization, there has been an increase in the water demand. However, there were few issues in the overall water supply with consumers being supplied intermittently for only a few hours a day. There were issues of very low pressure at the consumer end at certain locations, especially at the tail ends of the network, and hence, required immediate intervention. Additionally, there were complaints of leakages due to deteriorated infrastructure. Dahanu Municipal Council in collaboration with IIT Bombay planned hydraulic interventions to improve the status of water supply in one of the water supply zones called as "Integrated Forest Zone" the details of which are provided in Table 4. IIT Bombay appointed AWPL as the execution agency for the project. STEM Water Distribution and Infrastructure Company Pvt. Ltd., Thane provided Corporate Social Responsibility (CSR) funds for completion of the project.

Table 4 : *Details of Integrated Forest Zone*

Sr.no.	Description	Details
1	Area of the zone (sq. km)	1.47

2	Number of Tanks	1 – Integrated Forest Tank
3	Capacity of Tank (liters)	7,50,000
4	Staging Height of Tank (m)	16 m
5	Supply Duration	1 hour with supply from tank between 6:45 am to 7:45 am (as of December 2022)

As a first step, the team from AWPL carried out digitization of pipelines in GIS after extensive field visits in the zone. Following this, a pressure audit in the zone was carried out to assess the network performance. It is observed that many areas experience low pressure resulting in consumer dissatisfaction. The areas at the tail end and higher elevations were the most critical. Extensive branching at a single location (near tank and few junctions) and were observed resulting in huge pressure head losses as shown in Table 3. Additionally, there were high leakages observed at the valve location near the tank. To summarize, the following are the problems identified by the team.

- Low pressure observed at the tail ends and high elevation areas.
- Inequitable water supply.
- Significant head loss observed in the system.
- High leakages at the valve location near the tank.

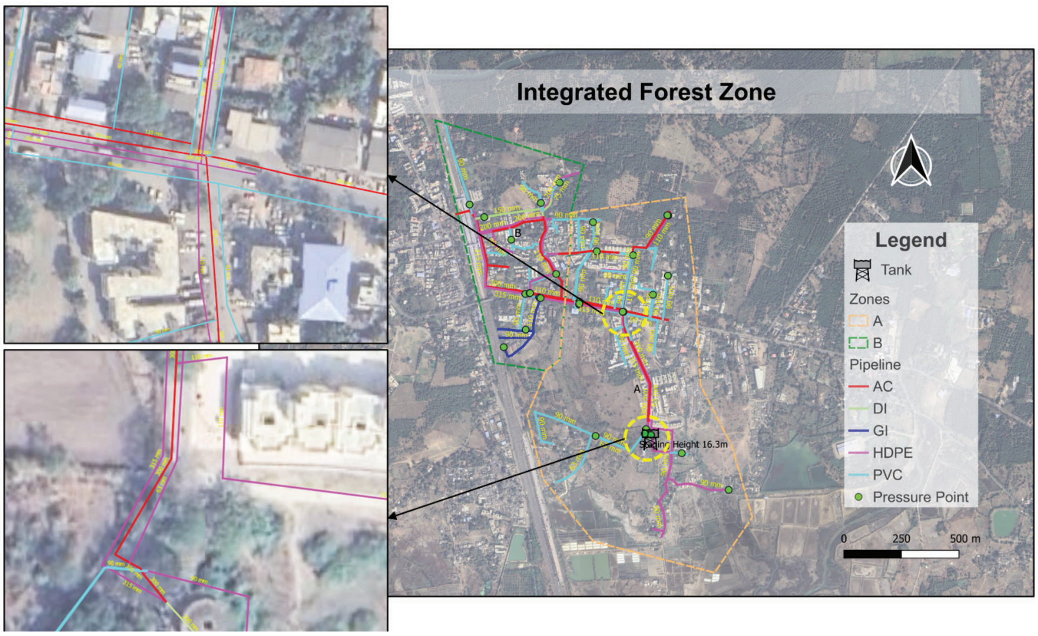


Figure 41: Extensive branching at single location at Integrated ESR, Dahanu

The historical reliance on centralized approaches has led to challenges in equitable water distribution, aging infrastructure, leakages, and resilience during extreme events. To address these issues, a paradigm shift towards scaled decentralization is gaining momentum, driven by sustainability and resilience goals. Hence, decentralized water supply solutions such as Shaft and Manifolds installed in Dahanu are viable strategies to overcome the above-mentioned challenges.

The proposed interventions, i.e., shaft and manifold for the Integrated Forest zone and, have been successfully implemented. Figure 32 shows the location of the shaft in the Integrated zone. The actual installation of the shaft is depicted in Figure 33.

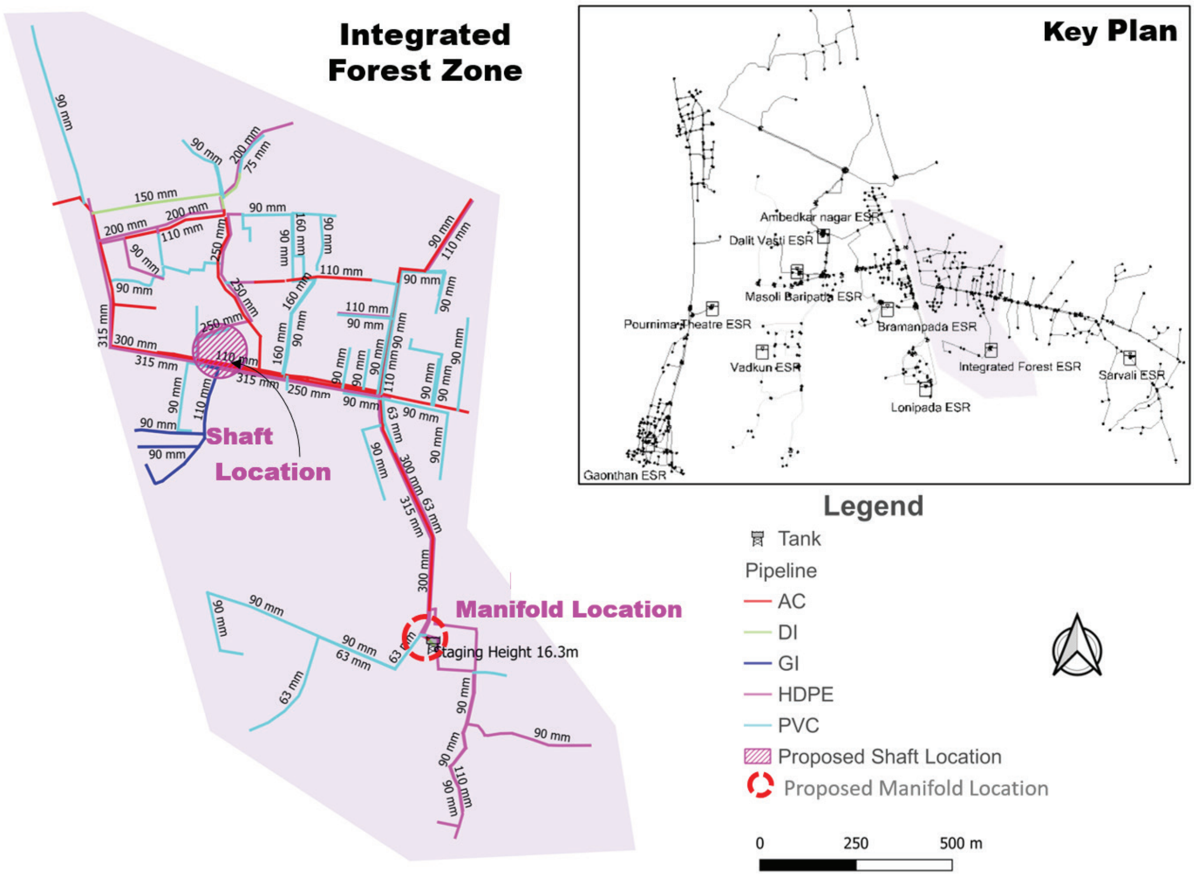


Figure 42: Map showing location of shaft and manifold in the Integrated Forest zone

Shaft helped to manage field problems, prevent unnecessary draining in low-lying areas, and provide relevant water supply solutions where land for Elevated Service Reservoirs (ESRs) is limited. The use of shafts is adaptable to different settings, making them a vital component in decentralized water supply strategies. On the other hand, Manifolds, comprising a pipe–valve arrangement, provide controlled gravity flow in the system. This system, with internal assembly valves and equal pressures on both sides, balances the variations of flows.

Figure 43: Shafts installed at Dahanu water supply zone

In the Integrated Forest Zone, installing a manifold near the tank helped to mitigate the challenge of multiple branching at a single point on the main line, resulting in an improved pressure head. This has also converted a single tank outlet into multiple outlets, facilitating a more equitable and efficient water distribution system. Simultaneously, the Shaft installed in the Integrated zone is operational, ensuring improved pressure heads in problematic areas. An express feeder from the transmission line serves as the Shaft's inlet. The substantial pressure from the transmission line has provided sufficient pressure on the Shaft. Thus, the multiple outlets from the Shaft are now facilitating a balanced and equitable distribution of pressure across different areas of Ram Tekdi and Patelpada in the Integrated Forest Zone area.

As the shaft is installed in the Mission area the demand load of this sub-zone is relieved from Integrated ESR which results in better pressure in the overall zone. After commissioning of shaft, ESR is now not filled during the supply time and the same flow is taken into the shaft, which shows in the same water supply and without affecting supply schedule shafts can be used in different zones in Dahanu city. Overall the installation of manifold and shaft has resulted in significant improvement in the pressure and flow rate. IIT Bombay team is monitoring the pressure and flows after the installations at the same locations during the benchmarking.

Currently the average pressure in the Integrated ESR has increased by 3 to 4 m and flow at the HH connections has increased by 5 Liter per minute. The overall water supply has improved and residents in this zone have expressed great satisfaction to receive water in a reliable and equitable manner.

The following section of the report outlines the project's cost estimation in detail.

7. Project Finance and Duration

7.1 Installation of a High TDS RO Unit with a KIOSK : Short Term Plan

The cost of the proposed project and its breakdown is mentioned in table 5. The cost of the proposed project of shaft implementation by Umang Systems, Navi, Mumbai, will be Rs. 12, 96,000 (plus 18% GST). The fee includes the expenses of human resources, charges of IIT Bombay advisory, scientific analysis of the problems, and documentation. Also, the design, fabrication, civil works, and commissioning of the interventions. Moreover, monitoring of the performance of the interventions for three months after the commissioning of the interventions. Additionally, the cost of the water treatment unit, which includes sand filtration, carbon and iron filtration, and a chlorination unit encased within a cabin, is also included in Table 5. The commissioning of this unit is expected to be completed within a month. The expense for human resource monitoring to maintain the system will be borne by the Grama Panchayat (GP). The detailed O and M is also provided in section 7.1.

Table 5: *Cost estimation of designed short term technological approach for SN Puram drinking water project*

<table>
<tr><th></th><th>Name of Scheme</th><th>Project cost (Rs.) including GST</th><th>Time Duration</th><td rowspan="6">Umang Systems
Contact : +91-7517701365, R 314, RABALE IND ESTATE, Navi Mumbai- 400701
GST: 27AAGFU9058C1ZY</td></tr>
<tr><td>1</td><td>2000 LPH R.O With 3000 LPH UV FRP With SS Skid</td><td>8, 00, 000</td><td>One Month</td></tr>
<tr><td>2</td><td>Collection Tank (1 No.) and Others</td><td>3 Lakhs</td><td>Three Weeks</td></tr>
<tr><td>3</td><td>Annual O and M</td><td>96, 600</td><td>-</td></tr>
<tr><td>3</td><td>Contingencies</td><td>1,00,000</td><td>-</td></tr>
<tr><td colspan="2">Total</td><td>12, 96, 000</td><td>Two to Three Months</td></tr>
</table>

1. **Routine Maintenance:**
    - **Task:**
        - Regular inspection and servicing of the pump, valves, and filtration units.

        - Ensure timely detection and rectification of system faults.
    - **Cost:** Maintenance fees (to be calculated based on service contracts)

7. 1.1 Operation and Maintenance Costs

- **Cartridge Costs:**
    - Monthly cost = ₹1,300
    - Annual cost = ₹1,300 × 12 = ₹15,600
- **Routine Maintenance Costs:**
    - Annual maintenance fees = ₹15,000
- **Electricity Costs:**
    - Monthly cost = Average of ₹5,000 and ₹6,000 = ₹5,500
    - Annual cost = ₹5,500 × 12 = ₹66,000

Total Operation and Maintenance Costs (Annual):
₹15,600 (Cartridge) + ₹15,000 (Maintenance) + ₹66,000 (Electricity) = **₹96,600**

- **Annual Operation and Maintenance Costs:** ₹96,600
- **Daily Water Requirement:** 17,915 liters
- **Monthly Electricity Consumption:** ₹5,500

7.1.2 Scope of project:

(a) Scope of the project by Umang Systems

The scope of the project includes the procurement, installation, operation, and maintenance of a fully automated Reverse Osmosis (RO) water treatment plant equipped with advanced features to ensure efficient and reliable operation. Below are the key components and features covered under this project:

(a) Equipment and System Components

1. **Raw Water Tank**: Storage for untreated water, ensuring a continuous supply to the system.

2. **Feed Pump**: High-quality stainless steel pump (1 nos) to transport water from the raw water tank to the filtration system.
3. **Sand Filter**: Removal of sediment and particulate matter to protect downstream equipment.
4. **Activated Carbon Filter**: Elimination of chlorine, organic compounds, and odors from the feed water.
5. **Inhibitor Dosing System**: Automatic dosing system with a level sensor to prevent scale formation and maintain membrane longevity.
6. **High-Pressure Pump**: Stainless steel pump (1 nos) to drive water through the RO membranes at the required pressure.
7. **RO System**: Paramount quality FRP membrane pressure tubes and membranes to ensure optimal water purification.
8. **Water Producing Tank**: Storage for purified water equipped with level sensors for automated monitoring.
9. The treated water is being supplied through a **KIOSK system.**

(b) Key Features

1. Fully automated operation with **Auto Multiport Valves**, minimizing manual engagements.
2. **Antiscalant Liquid System**: Requires daily refilling; an integrated alarm and stop function prevent damage to membranes in case of tank depletion.
3. **Cartridge/BAG Filters**: Includes 12 units to ensure high-quality filtration.
4. **Level Sensors**: Installed in the pure water tank and dosing tank for seamless monitoring and operation (IoT based).
5. **Piping and Valves**: Durable PVC piping up to the high-pressure pump and SCH 80 piping thereafter, with SS flange valves included for effective control and junction design.
6. **Monitoring Panel**: Real-time monitoring of Total Dissolved Solids (TDS), inlet flow, pure water outlet flow, low pressure, and high pressure.

(c) Operational and Maintenance Aspects

1. **Manpower Requirement**: Only one operator needed to refill antiscalant liquid once a day for 20-hour plant operation.
2. **Maintenance**:
   - Replacement of 12 cartridge filters annually.
   - Regular inspection and servicing of pumps, valves, and other system components.
3. **Guidance and Support**: Training, online troubleshooting, and operational guidance provided by the vendor.

Additional Specifications

1. Fabrication completed at the factory to ensure precision and quality.
2. RO plant weight: 500–700 kg.
3. FRP vessels and membranes are of paramount quality and brand.
4. Enhanced safety features to prevent operational errors and extend equipment life.

This project ensures the implementation of a robust and sustainable water purification system, capable of meeting the long-term needs of the community with minimal operational overhead and advanced automation.

7.2 Cost Estimation for long term Plans

The cost of the proposed project and its breakdown is mentioned in table 6. The cost of the proposed project of shaft implementation by Ajivam Water private ltd.(AWPL) and its automation will be Rs. 30,00,000 (plus 18% GST). The fee includes the expenses of human resources, charges of IIT Bombay advisory, scientific analysis of the problems, and documentation. Also, the design, fabrication, civil works, and commissioning of the interventions. Moreover, monitoring of the performance of the interventions for three months after the commissioning of the interventions. Additionally, the cost of the water treatment unit, which includes sand filtration, carbon and iron filtration, and a chlorination unit encased within a cabin, is provided in Table 6. The commissioning of this unit is expected to be completed within a month. The expense for human resource monitoring to maintain the system will be borne by the Grama Panchayat (GP). The cost estimation below indicates the cost of installing one such shaft in the water supply network. The number of structures and benefitting population can be finalised only after conduction of the hydraulic study.

The total time required is two to three months, once the work order to AWPL is provided. A summary of the cost and project duration is shown below.

Table 6: *Cost estimation of designed long term technological approach for SN Puram drinking water project*

Plan I: Water Supply Management : Hydraulic Isolation Structures				
Sr.no.	**Name of Scheme**	**Project cost (Rs.)**	**Time Duration (months)**	**Agency Involved**
1	Shaft based water supply system in SN Puram GP.	25,00,000	Two to Three	Ajivam Water Private ltd. Bombay
2	Automation of the shaft system with pressure sensors	5,00, 000	Two to Three	
Plan II: Sustainable Groundwater Management for Water Quality & Quantity Improvement				
	Managed aquifer recharge study	5,00,000	2- 3 Weeks (Initial Study)	ACWADAM, Pune Maharashtra.
	Strategic Recharging & Continuous Monitoring of the Network	5,00,000	Upto 10 years	
	Total			**40,00,000**

The long-term cost of implementing a sustainable aquifer management program, to be undertaken in collaboration with the ACWADAM team, is detailed in Table 6. The cost estimation includes expenses for a comprehensive study on aquifer management, identification and implementation of suitable recharge technologies, and monitoring of water quality and quantity over the coming years.

8. Conclusion

The SN Puram Grama Panchayat Drinking Water Supply Project is a strategic initiative aimed at addressing the critical issues of water scarcity, saline intrusion, and inefficient water supply infrastructure in the region. Through a comprehensive analysis of the root causes and existing challenges, the project has identified actionable solutions that align with the broader vision of sustainable and equitable water management. By incorporating scientific practices, stakeholder participation, and innovative approaches, this initiative seeks not only to resolve the immediate drinking water concerns but also to establish a resilient and adaptive framework for future water governance in the panchayat.

The findings from this study underscore the importance of decentralized management, participatory governance, and sustainable resource utilization in achieving long-term water security. The project represents a significant step toward creating a master plan that addresses the panchayat's overarching developmental goals while ensuring that the community's specific needs and vulnerabilities are addressed effectively.

Way Forward

1. **Implementation of Managed Aquifer Recharge (MAR) Systems**
    - Develop detailed implementation strategies for MAR systems based on the findings from hydrogeological mapping and site suitability analysis.
    - Ensure periodic monitoring of recharge efficiency and water quality to measure the impact of interventions.
2. **Upgradation of Water Supply Infrastructure**
    - Conduct hydrogeological mapping of the Panchayat's existing pipeline network to identify flaws and implement additional hydrologic management technologies, such as shafts and manifolds, for improved efficiency.
    - Request replacement of outdated pipelines and install functional valves to improve water distribution efficiency.
    - Explore and implement advanced technologies like IoT-based monitoring systems for real-time assessment of water flow, pressure, and quality.
3. **Community Involvement and Capacity Building**

- Conduct awareness campaigns to educate the community on water conservation and sustainable usage practices.
- Train local stakeholders and panchayat officials in maintaining and managing the upgraded infrastructure.

4. **Policy and Governance Enhancements**
    - Advocate for decentralized water management policies that prioritize local needs and governance.
    - Facilitate partnerships between the panchayat, academic institutions, and private organizations to leverage expertise and ensure continuous monitoring and maintenance practices.
5. **Pilot Testing and Scaling Up**
    - Begin with pilot-scale implementation of identified solutions in select wards to validate their effectiveness.
    - Use insights from pilot projects to refine strategies and scale up interventions across the panchayat.
6. **Monitoring and Evaluation**
    - Establish a robust monitoring framework to assess the outcomes of implemented measures periodically.
    - Incorporate adaptive management practices to address emerging challenges and improve project sustainability.

By adhering to this roadmap, the SN Puram Grama Panchayat can transition from reactive problem-solving to proactive resource management, ensuring a sustainable and equitable water future for its residents.

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ANNEXURE 1

Table 1: *Water Quality Analysis Test Report Conducted for different Sample Points at SN Puram*

Sl no	Sample name / Parameter	Canoli canal	Pond (temple)	Water kiosk near school (ward 10)		Filter cylinder		Water kiosk in progress (ward 10)	Water kiosk (ward 11)	Water purifier		Method of analysis	Permissible limit
				Inlet	Outlet	Inlet	Outlet			Inlet	Outlet		
1	TDS (mg/L)	378	177	57.2	6.52	102	202	155	468	97.9	6.69	IS 3025 : 1984	500
2	Conductivity (µs/cm)	713	331	105	11.2	192	381	293	883	184	12	IS 3025 : 1983	-
3	Alkalinity (mg/L)	39	66	14	5	12	110	27	124	19	8	IS 3025 : (part 23)	200
4	Total hardness (mg/L)	120	146	24	10	46	206	140	242	72	38	IS 3025 : (part 21)	200
5	Iron content (mg/L)	0.5	0	0	0	0	0	0	0	0.1	0	IS 3025 : (part 53)	0.3
6	E.coli (No of E.coli/100ml)	50 colonies	>100 colonies	50 colonies	10 colonies	>100 colonies	50 colonies	>100 colonies	>100 colonies	>100 colonies	>100 colonies	IS 1622 : 1981	Shall not detectable in any 100 mL of sample
7	Coliform (No of Coliform/ 100ml)	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	IS 1622 : 1982	
8	DO (mg/L)	6.9	7.9	-	7.5	-	-	-	7.4	-	-	IS 3025 : 1993	-
9	BOD (mg/L)	1.0	0.18	-	0.21	-	-	-	0.40	-	-	IS 3025 : 1993	-

ANNEXURE 2

LCC analysis of different configurations of units developed by Vayujal with high TDS RO treatment membrane.

Calculations

Vayujal Technologies Private limited.

Vayujal technologies basically convert atmospheric humidity to water. They use the basic principle of condensation for the conversion. They have different configurations of conversion units such as, Vayu Jal Plus, Vayu Jal Ultra, Vayu Jal Grand and Vayu Jal Max.

Table 2: *Yield and Estimated Power Consumption of each Configuration developed by Vayu Jal.*

Service	Initial Setup Cost	Yield	Power Consumption/ L	Power Consumption/ day	Estimated Electricity charges per day

Vayu Jal Plus	Rs. 2, 28, 456	165 L/d	0.32 KWh/ 1 L	52.8 KWh	Rs. 448
Vayu Jal Ultra	Rs. 6, 90, 690	485 L/d	0.27 KWh/ 1 L	130.95 KWh	Rs. 1113.75
Vayu Jal Grand	Rs. 13, 28, 250	1460 L /d	0.24 KWh/ 1 L	350.4 KWh	Rs. 2978.4
Vayu Jal Max	Rs. 23, 24, 437.5	2950 L/ d	0.23 KWh/ 1 L	678.5 KWh	Rs. 5767.25

Comparison Chart of Vayu Jal Models

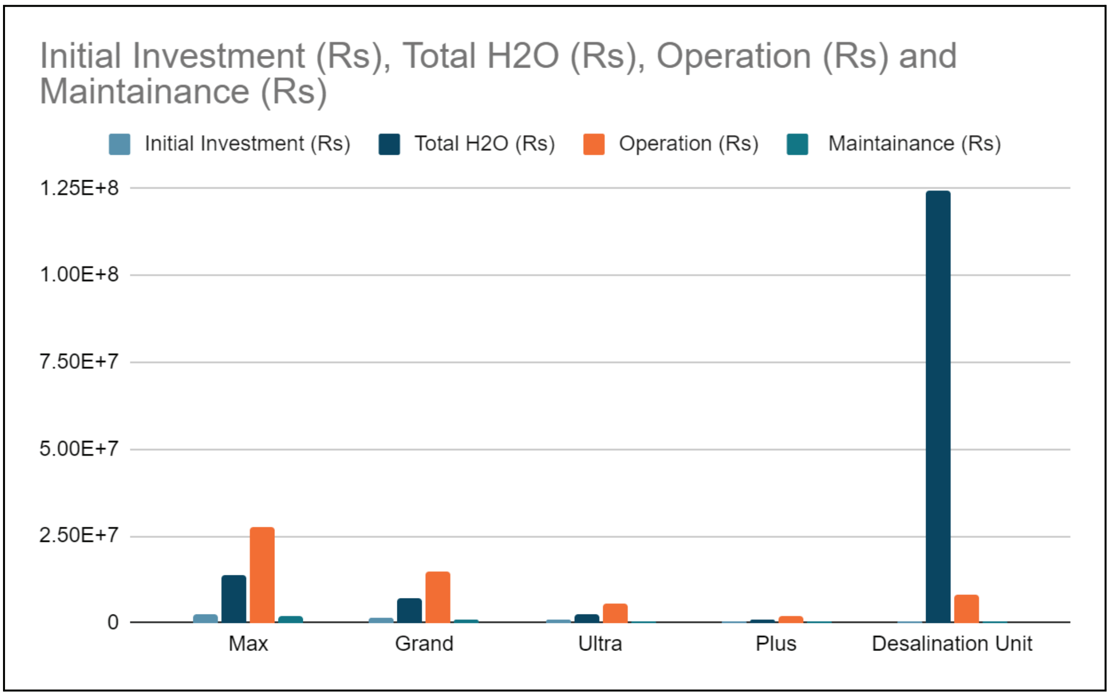

Figure 1: Vayu Jal Models - Comparative Chart