December 2023

MAPPING WATER IN A SMALL TOWN

Data and Insights on Water Management in Chintamani, Karnataka

WELL LABS — WATER · ENVIRONMENT · LAND · LIVELIHOODS

BORDA SOUTH ASIA

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Federal Ministry for Economic Cooperation and Development

DCB BANK

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About WELL Labs

Water, Environment, Land and Livelihoods (WELL) Labs co-creates research and innovation for social impact in the areas of land and water sustainability. It is based at the Institute for Financial Management and Research (IFMR) Society. WELL Labs designs and curates systemic, science-based solutions using a collaborative approach to enable a high quality of human life while simultaneously nurturing the environment.

About the Urban Water programme

The impacts of flooding and urban drought are expected to worsen as more people live in cities, more and more land is built up, and extreme climate events grow more intense and frequent. The Urban Water programme at WELL Labs designs pathways towards water-resilient cities. We do this by addressing knowledge gaps to enable effective decision making and building coalitions between governments, market players and civil society groups.

We focus on:

- Aggregating data and drawing actionable insights
- Building an ecosystem for water resilience
- Co-creating evidence-based and user-centric solutions
- Designing market instruments and policies

About TIDE

TIDE is a 30-year-old not-for-profit science and technology organisation which was conceived as a link between research organisations and communities, in adapting technologies for a greener future and building resilient communities. Over the span of our 30-year journey, TIDE believes technology, if tailored to align with the local conditions, has the potential to address various societal challenges.

TIDE has executed more than 250+ projects on energy, livelihood, climate education and WASH benefitting a million Indians spread across 15 states of India. In the last 3 years, TIDE has extensively engaged with and supported Chikkaballapura and Chintamani CMCs by demonstrating innovative and decentralised WASH interventions thus providing improved access to the underserved communities.

About BORDA

Bremen Overseas Research and Development Association (BORDA) e.V. is a specialist organisation active in the fields of sanitation, poverty alleviation, sustainable protection of natural resources and the strengthening of social structures. BORDA was established as a German non-governmental, not-for-profit organisation in 1977, by concerned citizens from Bremen, with assistance from the Bremen Overseas Museum (Überseemuseum), various institutes of Bremen Universities, and trade and industry enterprises as well as with support from Bremen's Senate.

BORDA's mission is to improve the living conditions of disadvantaged communities and to keep the environment intact through the expansion of Basic Needs Services in the areas of decentralised sanitation, water, and energy supply as well as wastewater and solid waste disposal. Since 2001, BORDA has concentrated on development-oriented cooperation projects and services in the field of improving Basic Needs Services (BNS) for the water and sanitation sector.

As a part of our recent projects, BORDA is supporting small and medium sized towns in South Asia (India, Nepal and Bangladesh) to tackle the challenges arising due to unplanned urbanisation in water and sanitation sector, by improving the infrastructure and service delivery of local government, municipalities, and other public utilities.

BORDA works under the following mandates:

- Develop decentralised basic needs services on local government/municipal level
- Protect natural resources: Value renewable energy sources and recycling
- Develop capacity, know-how and facilitate technology transfer
- Advising sector policies – local to global level
- Provide technical expertise, global insights, and access to decision makers, to make a meaningful contribution in the form of knowledge, technology, and empowerment

ಡಾ. ಎಂ.ಸಿ. ಸುಧಾಕರ್, ಎಂ.ಡಿ.ಎಸ್.
Dr. M.C. SUDHAKAR, M.D.S.

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ಜಿಲ್ಲಾ ಉಸ್ತುವಾರಿ ಸಚಿವರು, ಚಿಕ್ಕಬಳ್ಳಾಪುರ
ಕರ್ನಾಟಕ ಸರ್ಕಾರ
Minister for Higher Education &
District-incharge Minister, Chikkaballapur
Govt. of Karnataka

Date: 31-01-2024

Foreword

As the Higher Education Minister overseeing the vibrant district of Chikkaballapura, I am pleased to offer my perspective on the critical issues presented in this comprehensive study.

The urbanization narrative in India is evolving, and the significance of small and medium towns is on the rise. Unfortunately, these towns often face neglect in terms of attention and resources, particularly in critical areas such as water infrastructure and sanitation. The project looks into the specific case of Chintamani, situated in the Deccan Plateau, shedding light on the interconnected challenges of groundwater and surface water management, coupled with the town's financial constraints.

The findings emphasize the over-dependence on groundwater, a critical resource depleting at an alarming rate. The harsh reality of only weekly water supply to residents, supplemented by expensive alternatives, reflects the urgent need for sustainable solutions. Nevertheless, within these challenges lie opportunities. The study points towards the potential of local surface water sources, emphasizing that up to 50% of Chintamani's drinking water needs could be met through strategic utilization of these resources. It calls for an integrated approach to water management, one that bridges the gap between surface and groundwater, and pictures a future where small towns become catalysts for economic growth.

I applaud the efforts of the researchers, who, through rigorous analysis, have brought to light not just the problems but also the possibilities. This is a clear call to policymakers, administrators, and communities to work collectively towards informed water management and policy implementation in Karnataka's small towns.

I extend my gratitude to all involved in this effort and trust that this study will serve as a catalyst for positive change in our approach to water and sanitation challenges in small towns.

(DR.M.C.SUDHAKAR)

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As an Assistant Executive Engineer at Karnataka Urban Water Supply Drainage Board (KUWSDB) in Chikkaballapura, I've seen the complex water management challenges in cities like Chintamani deal with up close.

The issues highlighted in this report connect with the daily struggles faced by residents and underscore the urgent need for technical solutions and strategic interventions. By adopting a comprehensive and integrated approach to water management and sanitation, we can pave the way for sustainable development and a brighter future for communities across Karnataka's cities.

In Chintamani and other similar cities of Chikkaballapura district, the management of sewage and drainage systems presents a complex set of challenges. Inadequate infrastructure, coupled with rapid urbanization, amplifies the problem, leading to issues such as pollution, environmental degradation, and public health hazards. Moreover, the limited financial resources available to municipal authorities further compound these challenges, making it difficult to implement effective solutions.

The potential of Nekkundi lake and other surface water bodies to meet a significant portion of Chintamani's water demand highlights a promising opportunity for sustainable water management. However, the current imbalance between water supply and wastewater treatment infrastructure poses a grave risk to our environment and public health. Initiatives such as the proposed sewage treatment plant near Bhukkanahalli lake demonstrate the potential for transformative change. With adequate funding and support, such projects can not only mitigate pollution but also provide a sustainable source of freshwater for the community.

I appreciate the efforts of the researchers and stakeholders involved in this study for highlighting these crucial aspects. Their dedication and commitment to finding solutions serve as an inspiration to us all.

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CITY MUNICIPAL COUNCIL, CHINTAMANI

CHIKKABALLAPUR DISTRICT

FOREWORD

As a person with strong ties to Chintamani, it's significant for me to address the water challenges we encounter. This study tells us that our town, like many others, is struggling with water and sanitation problems. It's clear that we need to act soon.

We're growing fast, but our infrastructure isn't keeping up. We're using too much groundwater, which is running out quickly. Furthermore, the limited understanding of sanitation and responsible water usage among our residents amplifies these challenges. Additionally, the untreated sewage significantly adds to pollution, this emphasizes the urgent need for complete solutions.

But amidst these challenges, there's hope. We can work together to find solutions. By thinking smart and using new ideas, we can make a difference. This study is a wake-up call for all of us to take action.

It is imperative that we take a holistic approach to water management, one that integrates surface and groundwater sources while prioritizing the treatment and recycling of wastewater. By doing so, we can ensure the long-term sustainability of our water resources and safeguard the well-being of our communities.

As the Commissioner, I am committed to working tirelessly alongside municipal officials, elected representatives, and community members to tackle these challenges head-on and ensure that every resident has access to clean water and sanitation facilities.

I'm grateful to everyone who participated in this study, shedding light on our challenges, and guiding us ahead. Let's unite and work towards a brighter future for Chintamani together.

Mr. Chalapathi G N
Commissioner, Chintamani

Municipal Commissioner
City Municipal Council,
Chintamani.

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LIST OF ABBREVIATIONS

BOD	Biological Oxygen Demand
BORDA	Bremen Overseas Research and Development Association
CMC	City Municipal Council
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DO	Dissolved Oxygen
DEM	Digital Elevation Model
FC	Faecal Coliform
ft	Feet
FY	Financial Year
GLSR	Ground Level Service Reservoir
GW	Groundwater
HH	Household
IMD	India Meteorological Department
IUWM	Integrated Urban Water Management
KGIS	Karnataka Geographic Information System
KLD	Kilo Litres Per Day
KSRSAC	Karnataka State Remote Sensing Applications Centre
KSSIDC	Karnataka State Small Industries Development Corporation
KUWSDB	Karnataka Urban and Water Supply Development Board
L	Litres
lpcd	Litres Per Capita Per Day
Mcft	Million Cubic Feet
ML	Million Litres
MLD	Million Litres Per Day
ML/Y	Million Litres Per Year
mg/l	Milligrams per Litre
MPN	Most Probable Number
NRW	Non-Revenue Water

N-Total	Total Nitrogen
NRSC	National Remote Sensing Centre
OHT	Over Head Tank
O&M	Operation and Maintenance
Rs.	Rupees
SCS	Soil Conservation Service
sq.km.	Square Kilometre
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
TIDE	Technology Informatics Design Endeavor
TSS	Total Suspended Solids
UGD	Underground Drainage
WTP	Water Treatment Plant
WW	Wastewater

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EXECUTIVE SUMMARY

India's urbanisation narrative is entering a new phase, one in which the significance of small and medium towns is on the rise. The government's establishment of industrial parks in and around towns, combined with the increasing prevalence of remote work, is shaping a transformed India where small towns assume a more pivotal role. Currently, small and medium towns, characterised by populations below 100,000, account for 44.2% of the overall urban area in India and constitute 26% of the nation's total urban population (Census 2011).

Despite this transition, significant attention and resources continue to be directed towards large metropolises, neglecting towns and peri-urban areas. As a result, many towns grapple with meeting the requirements and ambitions of their growing populations, lacking essential infrastructure for even fundamental services, particularly in water and sanitation.

Small towns could play a crucial role in advancing India's economic growth, but addressing their water and sanitation challenges is key for sustained development.

According to a 2021 Niti Aayog report, over half of the 7,933 urban settlements in India lack any master plan. The absence of a comprehensive planning approach for cities and towns results in challenges for surface water bodies, natural drainage systems, and floodplains, which are vital components for ensuring water resilience.

Limited financial resources, staffing, and technical capacity pose significant challenges for most small and medium towns in managing water and sanitation issues. This often prompts towns to address immediate needs through short-term measures, resulting in a disjointed collection of piecemeal interventions that fail to function as a unified system.

These fragmented systems will be more susceptible to issues like water scarcity, droughts, and extreme weather events in regions prone to climate variability.

To understand the problems and potential solutions to these water and sanitation systems, we studied the town of Chintamani, which, like many other small towns in India, lacks access to a major river and relies on groundwater.

Chintamani is situated in the Deccan Plateau, to the north of the capital Bengaluru in Karnataka. Our involvement in Chintamani commenced with an effort to understand the issues by first engaging in discussions with municipal officials and elected representatives. From June to December 2022, spanning a six-month period, we conducted primary data collection through household surveys, gathered municipal records, and sought to address information gaps through interactions with Chintamani City Municipal Council (CMC) officials.

Our analytical framework centred around the urban water balance, which provides a quantified basis for urban flows; water resources feeding the city, areas of significant usage, losses, discharge and storage. This exercise proved useful when we applied it in the context of Bengaluru, which is already confronted with extremes of water scarcity and flooding. But regardless of location, the process of creating an urban water balance reiterates that water management cannot be done in a siloed manner because of the interdependence of different systems. A comprehensive view of all the flows and stores of water is a necessary starting point to narrow down on key problem areas and potential opportunities.

Through this analysis, we found that Chintamani is plagued by challenges related to both groundwater and surface water management. It also highlighted the town's financial precarity, a problem not unique to Chintamani but documented on a nationwide scale; municipalities simply do not earn enough revenue to meet their rising expenditure and are increasingly reliant on state and central government grants.

GROUNDWATER

Chintamani is over-reliant on groundwater, which meets a whopping 80% of the town's freshwater needs.

The Chintamani CMC runs deep borewells round the clock and yet is able to supply water to the town's residents only once a week. To address this water deficit, households compensate by arranging supply through private borewells and tankers. This is expensive and thus limits access to freshwater, a critical public good.

The household survey we conducted, albeit a small sample size, offered further proof of this. It indicated that there is a high degree of inequality in household consumption patterns that could be linked to socio-economic status. We found that a majority of respondents, around 70%, consume between 45-70 litres per person per day (lpcd), while 30% of the surveyed population was found to consume double this quantity, around 100-175 lpcd.

There is a significant burden on the aquifer underlying Chintamani, but there are data gaps that impede better aquifer management and recharge.

Focus group discussions held with the municipal officials and ward councillors revealed that the understanding of the aquifer remains low. They faced frequent borewell failures; in fact, our analysis of municipal borewell records from 2020 found a documented failure rate of 40%. Out of 322 borewell sites, 126 failed at the time of drilling or in subsequent years.

To get a better understanding of how to manage groundwater in the region, we conducted resistivity surveys to map the aquifer. We found pockets across the town where shallow aquifers had higher storage potential due to deeper depth to bedrock.

Efforts to recharge aquifers through blue-green infrastructure such as permeable surfaces and rain gardens could target these locations. Such a planned approach is critical to boost groundwater availability in the region.

Water supply alone accounts for nearly 40% of the municipality's operational expenses.

Running these borewells rakes up a high electricity bill. Close to 40% of the town's revenue expenditure was spent on running water supply infrastructure, an analysis of operating expenses over the last three financial years – 2019-20, 2020-21 and 2021-22 – showed. Half of this meets electricity charges and fuel, while the rest is used to pay salaries, and carry out repairs and maintenance.

While state grants for electricity and salary help meet a large part of these expenses, there is still a perpetual deficit as cost recovery through user charges is as low as 10%. This is because of non-revenue water (NRW), i.e. municipal water supply that is lost or unaccounted for and thus not billed to the user. We found that the Chintamani CMC has only 8,308 registered connections, which is significantly lower than the total number of registered properties of over 20,000. The town's pipeline network reaches most parts of the town but a high number of unauthorised connections along with leakages contributes to NRW, and thus limited revenue for the local body through user fees. But these losses and high power bills do not make a dent in water extraction.

To sum up, groundwater is expensive to source and is rapidly depleting. This raises the question of whether surface water bodies could reduce stress on scarce groundwater sources. There are many towns like Chintamani that are not in close proximity to rivers or large reservoirs.

SURFACE WATER

Our preliminary analysis showed that over 50% of the town's drinking water needs could be met through local surface water.

Chintamani's largest water body is the Nekkundi lake, which could supply 1.5 to 2 Million Litres Per Day (MLD) of water when it is filled to capacity. Supplemented by smaller lakes in the region, up to 4 MLD could be drawn from surface water bodies as opposed to the meagre 1 MLD currently sourced from the Kannampalli lake.

Add to this a recently-commissioned project to supply 3 MLD of water from Bhaktharahalli Arasikere located 15 kms away from the town under the state government's Nagarothana scheme. This means that fully functional, the town's current demand of 7 MLD could be met in an average monsoon year through surface water sources. While this would need to be supplemented to meet future demand, improving surface water storage would lead to other benefits such as increasing groundwater levels.

The high investment in water supply infrastructure precludes investment in wastewater treatment, resulting in pollution.

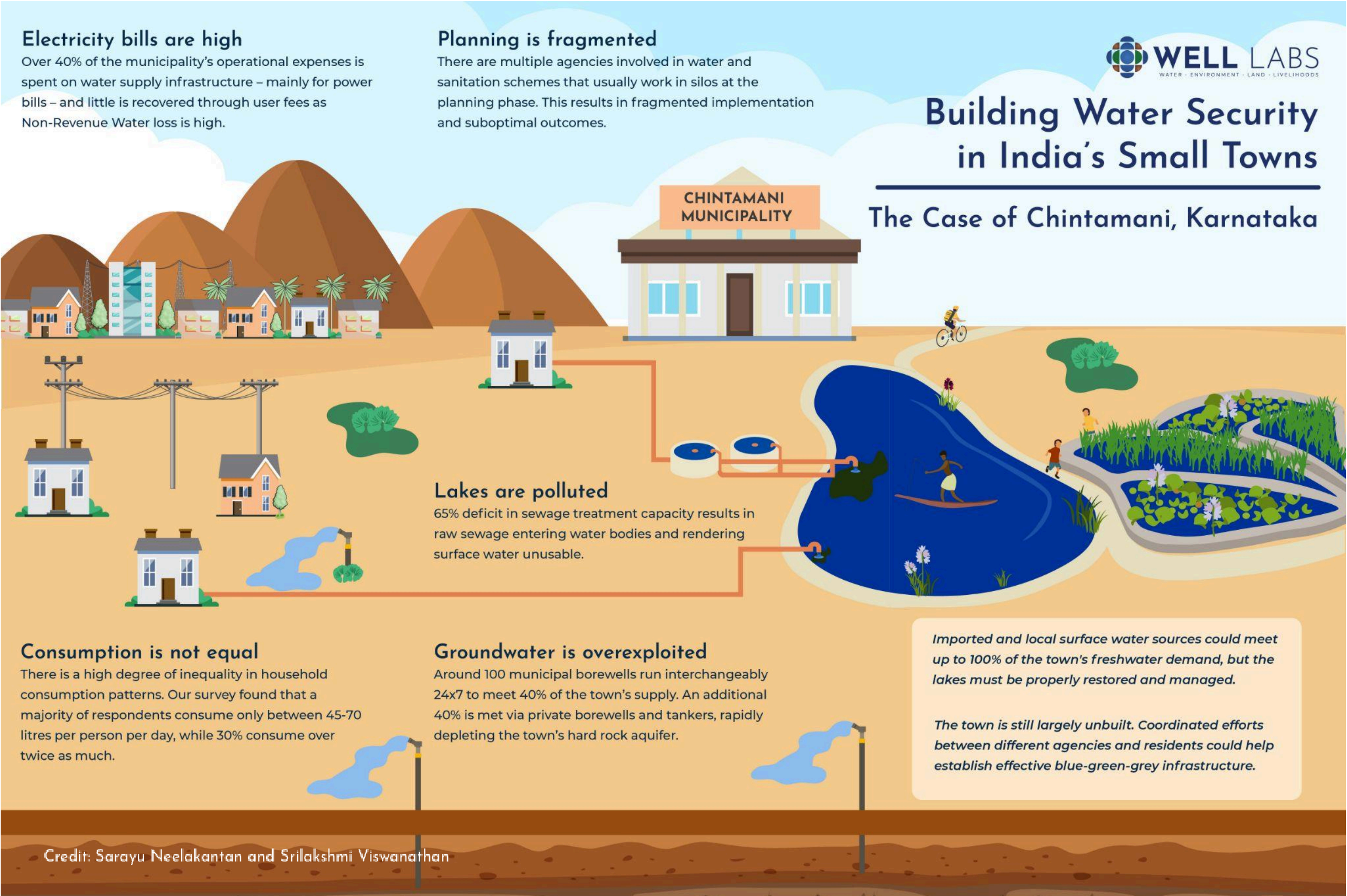
Chintamani generates 5.72 million litres of wastewater per day. Sewerage network maps showed extensive coverage; however, Chintamani CMC records revealed that few households are actually connected to the network. Moreover, because of inadequate treatment capacity, only 2 MLD is treated, resulting in a majority of the town's sewage flowing directly into lakes.

During our fieldwork, we found that there were flaws with the existing system with sewer lines found to be either not operational or broken in places. Additionally, improper maintenance such as the failure to carry out pond desludging on time appear to have impaired the efficacy of the existing STP, located downstream of Gopasandra lake. An STP has been proposed, one with a capacity sufficient to meet the town's requirements near the Bhukkanahalli lake. It is critical that such infrastructure is funded and completed on a war footing to stem the flow of sewage into lakes and open up a new source of freshwater.

Chintamani bears lessons for other small towns

This overview of the water situation in Chintamani underlines how interconnected surface and groundwater sources are and how important it is to adopt an integrated approach to water management. We detail each of these facets in the report, drawing from secondary data sources as well household surveys, interviews and focus group discussions with key stakeholders in the town, to compile a comprehensive picture of how water flows, is stored and managed in this small town.

This quantitative analysis of Chintamani's water balance coupled with qualitative insights from our fieldwork highlighted challenges and opportunities that, we believe, extend beyond this town's limits. Urbanisation and population growth is far outpacing the delivery of basic infrastructure. Moreover, municipalities struggle to meet rising expenditure requirements through its revenue and they remain beholden to state and central governments to get by. Given this context, crucial aspects such as water and sanitation fall through the cracks. This is an attempt to push for informed water management and policy in India's small towns.


Electricity bills are high
Over 40% of the municipality's operational expenses is spent on water supply infrastructure – mainly for power bills – and little is recovered through user fees as Non-Revenue Water loss is high.
Planning is fragmented
There are multiple agencies involved in water and sanitation schemes that usually work in silos at the planning phase. This results in fragmented implementation and suboptimal outcomes.
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Building Water Security in India's Small Towns
The Case of Chintamani, Karnataka
CHINTAMANI MUNICIPALITY
Lakes are polluted
65% deficit in sewage treatment capacity results in raw sewage entering water bodies and rendering surface water unusable.
Consumption is not equal
There is a high degree of inequality in household consumption patterns. Our survey found that a majority of respondents consume only between 45-70 litres per person per day, while 30% consume over twice as much.
Groundwater is overexploited
Around 100 municipal borewells run interchangeably 24x7 to meet 40% of the town's supply. An additional 40% is met via private borewells and tankers, rapidly depleting the town's hard rock aquifer.
Imported and local surface water sources could meet up to 100% of the town's freshwater demand, but the lakes must be properly restored and managed.
The town is still largely unbuilt. Coordinated efforts between different agencies and residents could help establish effective blue-green-grey infrastructure.
Credit: Sarayu Neelakantan and Srilakshmi Viswanathan

1. CHINTAMANI WATER BALANCE

Credit: TIDE

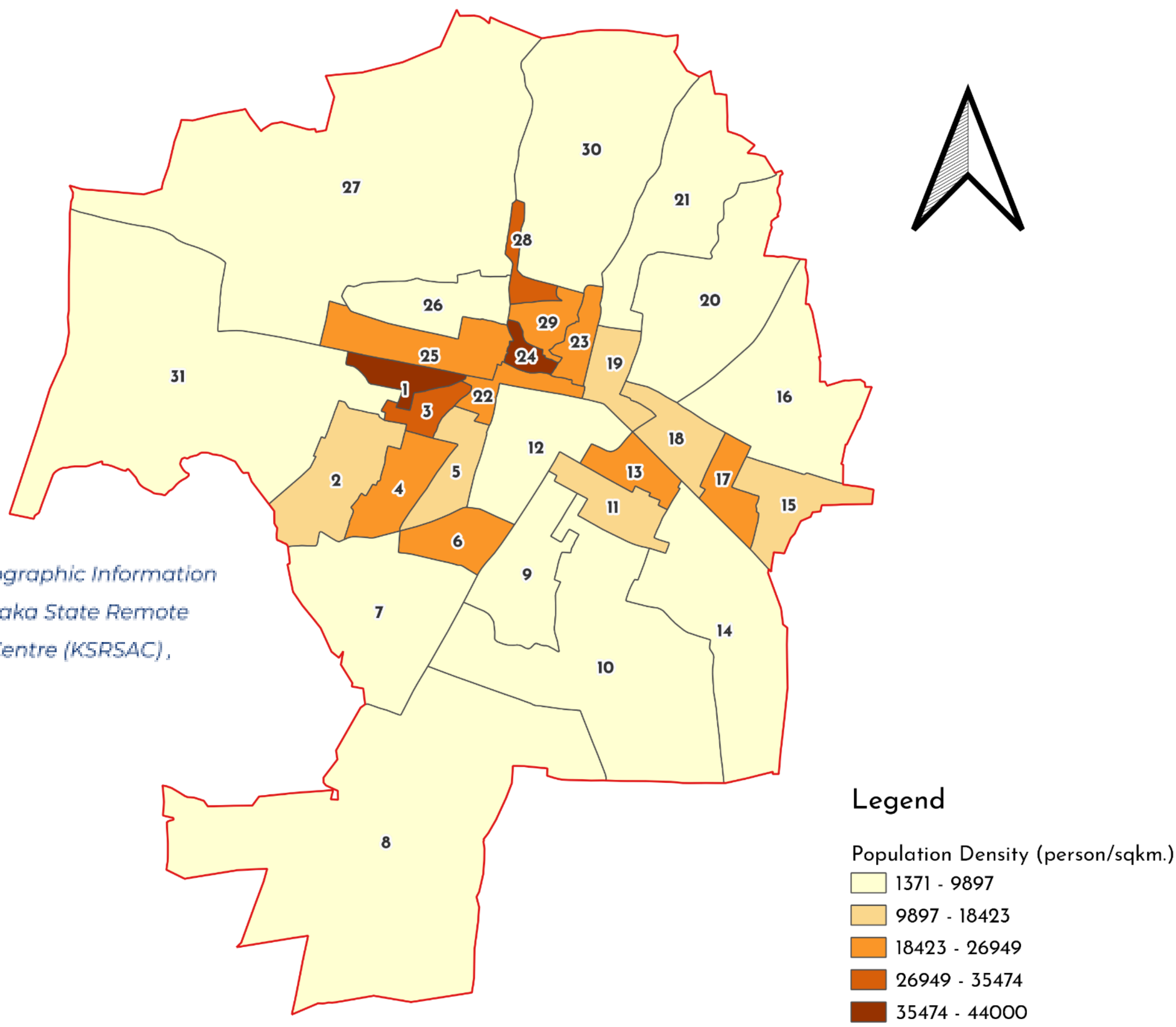
1.1 Background

Chintamani is located in semi-arid southern Karnataka

Chintamani lies about 75 kilometres from the city of Bengaluru. It is the administrative (*taluk* headquarters) and economic centre of the district, and home to a thriving market for commodities. Its current population is estimated to be 92,802, according to the Chintamani municipality. The town lies towards the southeast of the state, classified as a dry agro-climatic zone. It receives an average of 787 mm of rainfall every year, which is on the lower end of the state average of 1,153 mm. During our study period, the region experienced 50% above average rainfall in 2021 and 2022. This is typical of the cyclical years of drought and surplus the region is documented to receive, pointing to a need to prepare for both extremes, particularly worsening water scarcity.

Water supply, sanitation and waste management are responsibilities that lie with the town Urban Local Body (ULB). First constituted in 1938, it became the Chintamani City Municipal Council (CMC) in 1995 as the population grew and more villages came under its jurisdiction. The CMC is administratively divided into 31 wards. Figure 1.1 shows the ward map with the population distributed according to the Census of India 2011. As per projection estimates, Chintamani's population has risen by 22% from 76,068 (2011) to 92,802 (2022).

Figure 1.1 Ward map of Chintamani CMC and population density



Source: Karnataka Geographic Information System (KGIS) - Karnataka State Remote Sensing Applications Centre (KSRSAC), Census 2011

0 500 1,000 m

Table 1.1 Population and households in Chintamani

	Census 2011	Projection for 2022
Population	76,068	92,802
Households	17,849	20,622

Source: Census 2011 and Chintamani CMC

In India, small and medium town ULBs are funded through various sources such as the Finance Commission – union and state, central or state government missions or schemes, loans from international funding agencies, banks and other financial institutions. This is apart from the ULB's own revenue generation through property tax, fees and user charges as well as rentals.

The Chintamani CMC managed to generate a revenue share of 44.83% in the 2021-22 financial year, which is higher compared to previous years. This shows an improvement but a continued reliance on state transfers or grants to meet its requirements.

Chintamani is thus prone to water scarcity and is governed by a cash-strapped municipality. Its proximity to a metropolis like Bengaluru also makes it likely that the town will continue expanding, underlining the need to ensure basic infrastructure is prioritised. Chintamani makes for an important case study to: i) understand the challenges faced by the people and by the local government; and ii) apply a water balance framework and work towards a long-term roadmap for water security planning in India's small towns.

1.2 Methods

The Rationale for a Water Balance

An urban water balance is an effective means to summarise all the flows of water in the urban system. Essentially, urban water systems consist of complex patterns of water extraction, consumption and discharge, bound by the town's broader hydrological context. It provides a quantified basis for urban water flows; water resources feeding the city, areas of significant usage, losses, discharge and storage (Kulranjan et. al. 2023). The different phases are captured in Figure 1.3.

A water flow diagram needs to have a spatial and temporal scope. This implies that the data needs to be calculated based on a defined geographical area and a time period (Nesi, 2022). For this case study, we selected an urban administrative unit – the jurisdiction of Chintamani town, which spans 15 sq.km., was used as a base for estimating water flows. This region is overseen by the Chintamani CMC.

With Chintamani veering between droughts and excess rainfall, we decided to use an average rainfall year for the purpose of these calculations.

Figure 1.2: The different components of a water balance chart

- Available freshwater sources: Rainfall, groundwater and surface water bodies.
- Distribution of freshwater to citizens through municipal supply, supplemented by private borewells and tankers.
- Losses in the municipal water supply (non-revenue water)
- Water demand across major sectors such as domestic, commercial, and institutional
- Wastewater generated, both treated and untreated.
- Water flows downstream and discharge into lakes

An urban water balance makes it easier to identify knowledge gaps, understand the implications of potential interventions and makes it easier to analyse how strategies can simultaneously address multiple dimensions of water security planning.

How We Developed a Water Balance for Chintamani

Given the dearth of studies and data on water management in Chintamani, we first prioritised speaking directly with key stakeholders to start mapping the water situation here. In January 2022, we gathered a preliminary understanding of the key pain points faced by CMC officials. This conversation was an important starting point because we were given lines of inquiry to investigate and corroborate through the process of preparing the urban water balance.

Some of the concerns that emerged in this discussion were:

- ***There is a high borewell failure rate***, there is lack of awareness on the geology and aquifer of the region.
- ***Pumping water is expensive***, there is little left for other projects such as wastewater treatment.

- ***A lot of water use is unaccounted for***, leading to revenue losses for the municipality and a lack of clarity on demand.
- ***Pollution of water bodies*** because of untreated sewage.

These problems stood out through the course of our fieldwork. We started out with field visits to the town's water bodies and collected samples to assess lake water quality at the start of the monsoon period in June-July 2022. We employed GIS to delineate the town's watersheds and lake catchments to understand drainage patterns and estimate the amount of flows into each lake.

We relied on borewell records from the CMC to understand groundwater extraction. We later felt that while this data was useful, there were unanswered questions and that it was necessary to understand the underlying aquifer better – particularly, to know what could be done to help with recharge in the town. We engaged with Geovale, a firm with geophysical expertise to carry out a resistivity survey at Chintamani. Such surveys are used to determine the features of the subsurface and thus assess the potential for groundwater storage.

We also consulted with the Karnataka Urban Water Supply and Drainage Board (KUWSDB) to understand the experience of implementing water supply and sewerage schemes along with proposed plans for the town.

While we visited pump houses and interacted with valvemen to understand how water is distributed across town, we felt it would be necessary to understand the extent of supply and gain a better sense of consumption patterns and undertook a survey of 427 households across the 31 wards. We also relied on previously carried out assessments by TIDE-BORDA at Chintamani that included commercial & institutional surveys along with an assessment of the WTP.

In November 2022, we had a second workshop with CMC officials to present preliminary findings from the water balance exercise and gather inputs on current focus areas that required further investigation.

As mentioned above, our analysis and calculations were bound by the Chintamani town's jurisdiction of 15 sq. km., governed by the Chintamani CMC. We decide not to consider agricultural activities taking place in the town since it falls outside the purview of the CMC. There are also no major industries located within Chintamani town. The Karnataka State Small Industries Development Corporation (KSSIDC) has a relatively small industrial estate located on Bengaluru Road outside town limits.

This was the scope we began with and the methods we followed to fill the gaps and better understand the intricacies that make up a complete water balance. In the following section, we explain each component of the urban water balance chart along with our estimates, and list specific assumptions and sources. We wind up the section by acknowledging the limitations of the steps we followed and the gaps that remain.

1.3 Results: Calculating Urban Water Flows

Rainfall, Run-off and Recharge

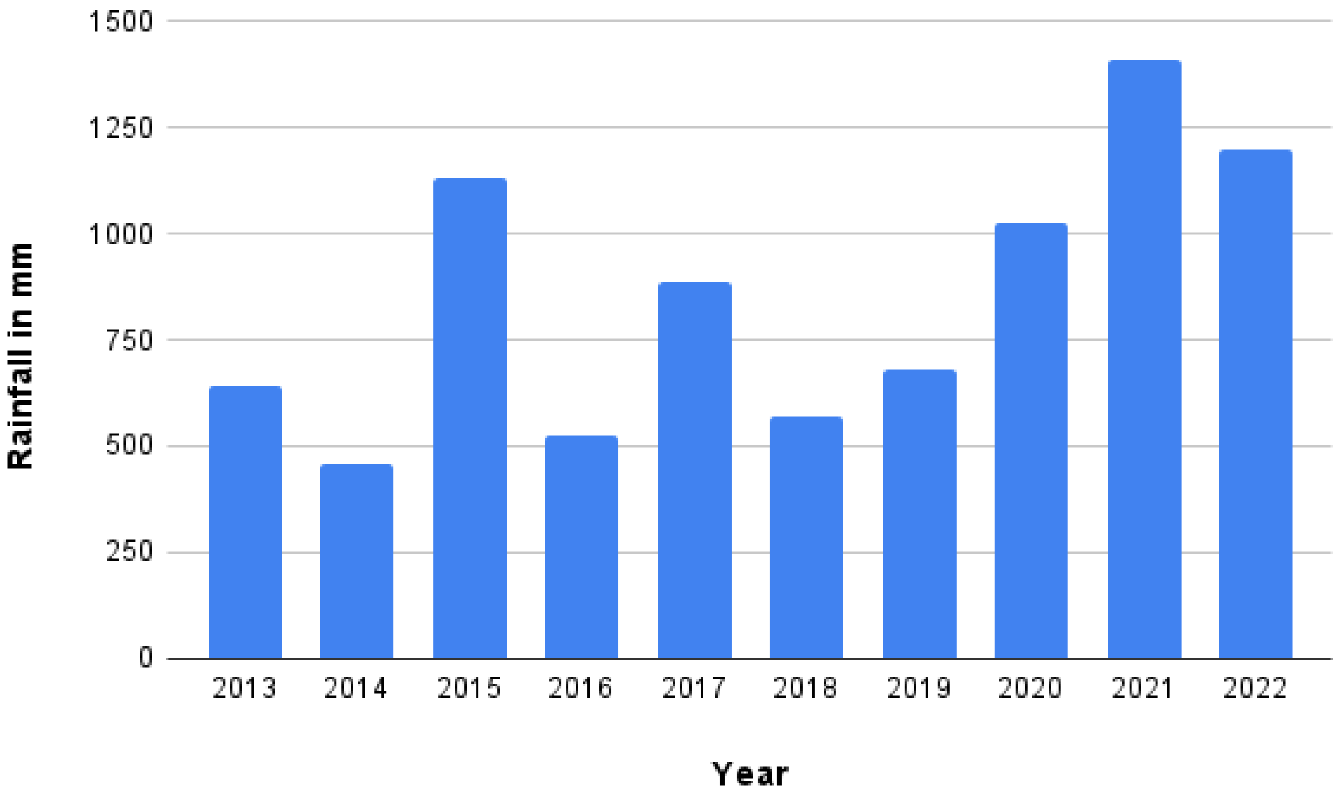
Chintamani experiences cyclical years of drought and excess rainfall

We began by examining the total amount of rainfall received in the town, how much run-off is generated based on town's land use pattern as well as recharge based on the underlying aquifer profile and the extent lost to evapotranspiration due to climatic conditions. The annual rainfall average is 787 mm, but during the study period, the region experienced excess rainfall in 2021 and 2022. Chintamani receives half its rainfall during the southwest monsoon period between June to September with an annual average of **787 mm with 32.34 MLD** falling within the town limits.

Chintamani faces cyclical years of drought and excess rainfall – 2014, 2016 and 2018 were drought years, while 2015, 2017, 2020, 2021 and 2022 were excess rainfall years. The region recorded 50% above average rainfall in 2021 and 2022.

At the end of the 2023 southwest monsoon season, Chintamani received below average rainfall validating the cyclical pattern. Only one ward was reported to have experienced water logging, which is why we did not focus on flood mitigation in this town. We argue that the town has to be prepared for both extremes but drought, in particular, as it worsens water scarcity.

Figure 1.3: Annual rainfall in Chintamani



Source: KSNDMC

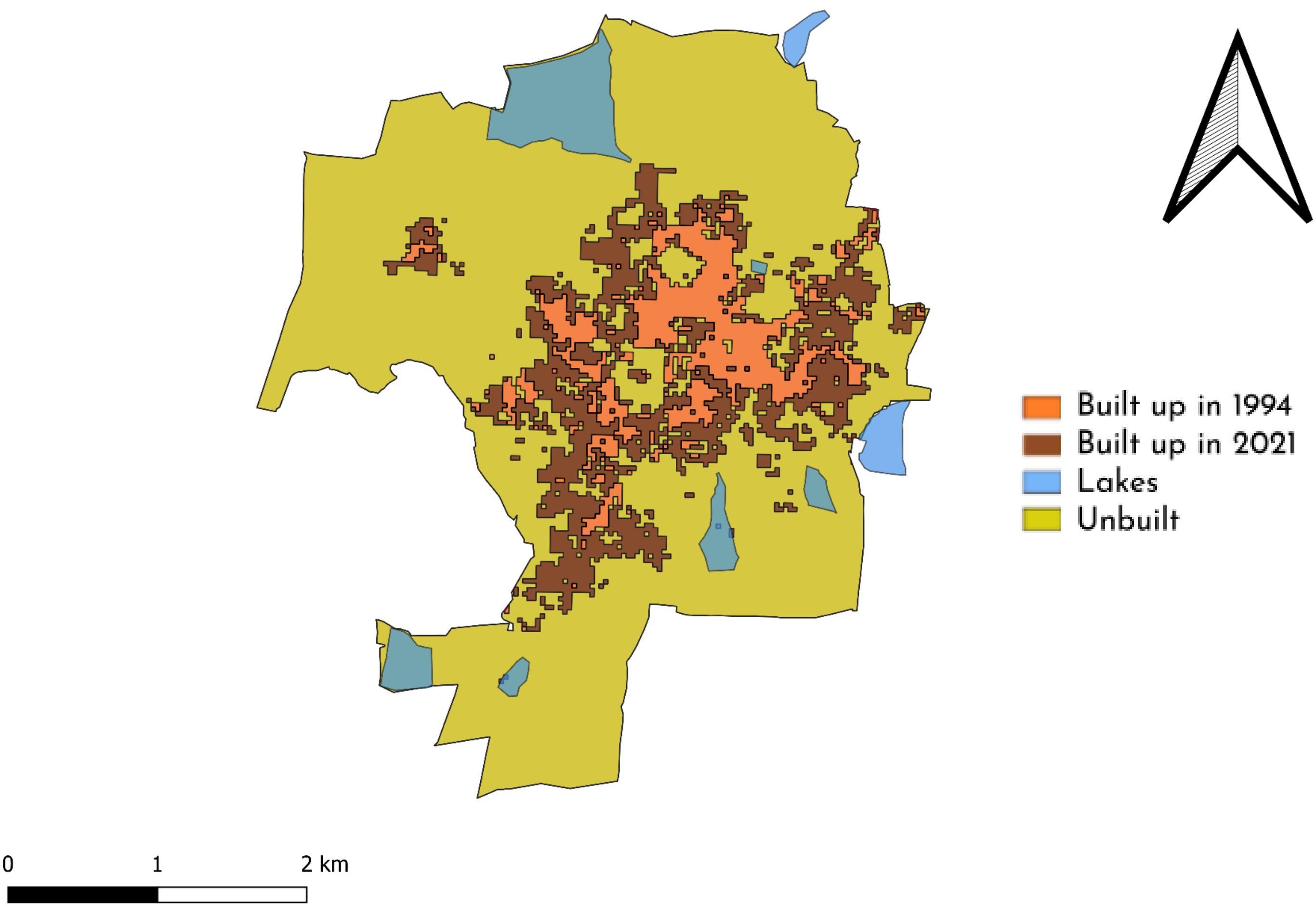
Rainfall run-off increases with built-up land

Built-up spaces concentrated in the centre of the town have tripled in size in the past 25 years. The spatial analysis we carried out showed that only 7% of the land was built up in 1994, but this increased to 21% in 2021.

The significant portion of land within municipal limits remains un-built; around 75% of the 15 sq. km. area is either fallow or agricultural land, although much of it is expected to become urbanised over time. The remaining 4% is occupied by water bodies such as the town's lakes. Run-off rates are dependent on the extent of built and unbuilt spaces in the town. We used the curve number method (which uses a coefficient based on soil conditions, land-use and hydrological conditions including infiltration) to estimate an average annual run-off of **8.27 MLD**.

It is important to calculate run-off rates because it can help estimate the potential of capturing more run-off and using it to recharge groundwater. It's also important in the context of small towns because these are not yet fully urbanised and there is room to plan better and put in place infrastructure such as permeable surfaces and 'sponge' parks that would allow more rain to be captured.

Figure 1.4 Land use in Chintamani town 1994 vs 2021



Source: Landsat 8, USGS

Aquifers and recharge rates are key for a town dependent on groundwater

Chintamani is characterised by a weathered and fractured aquifer system. FES (2010) carried out a hydrogeological study of six micro watersheds in the Chintamani region that considered infiltration as 12% of rainfall based on aquifer characteristics and groundwater recharge from surface water bodies (estimated to account for 20% of the total water stored during the monsoon season).

Therefore, natural recharge in the town is estimated to be **3.88 MLD** while groundwater recharge from the lakes in the town is **3.06 MLD**.

We also calculated evapotranspiration; this includes evaporation that occurs through soil and other surfaces as well as water released from plants into the atmosphere. By deducting the run-off and recharge volumes, we arrived at 20.19 MLD as the amount lost via evapotranspiration.

Table 1.2: Data summary: Rainfall, runoff and recharge

Component	Avg annual flow (MLD)
Rainfall volume	**32.34**
Data source - Annual report from Karnataka State Natural Disaster Monitoring Calculation : - Total rainfall volume = (annual rainfall x total town area) / number of days in a year	
Run-off	**8.27**
Calculation : Curve number method - Total run-off volume = (run-off from built area) + (run-off from unbuilt area) - Total built area / run-off coefficient = 3.12 km^2 / 35% - Total unbuilt area / run-off coefficient = 10.98 km^2 / 25%	
Total natural groundwater recharge	**3.88**
Groundwater recharge (lakes)	**3.06**
Assumption: - Natural recharge rate for hard rock aquifer is considered to be 12% (FES 2010) - Recharge rate through lakes is considered to be 20% (FES 2010) - Total volume of water entering the lake comprises of run-off within the town and from lake catchments outside town boundary along with untreated wastewater flowing into them	
Evapotranspiration	**20.19**
Calculation: - Evapotranspiration = (total rainfall) - (run-off) - (GW recharge). *Please note that the GW recharge does not include recharge from lakes*	

Municipal Water Supply

We move on to examine the sources of municipal water supply to the town, mainly groundwater supported by surface water. We also estimate the extent of non-revenue water (NRW) for the town. Both these aspects – heavy groundwater dependence and high NRW – are key to building water security here.

Municipal borewells form a significant part of the town's water supply.

These are spread across town including some on the periphery of lakes that fall outside the town limits. The Chintamani CMC estimates that on average between **3 to 4 MLD** is extracted from their own borewells. As per 2022 borewell records, the CMC maintained over 100 borewells that are interchangeably run. These borewells are run continuously and are connected to nearby pump houses. These feed ground-level service reservoirs (GLSR) and overhead tanks (OHTs), from where water is supplied to areas – in turns, once a week.

Municipal borewell yields are variable based on rainfall received during years. In 2022, based on back-to-back years of surplus rainfall, the CMC was able to take advantage of the rise in water table to increase supply by 1-1.5 MLD; in good monsoon years, the supply could rise up to **5 MLD**. In Section 2, we detail the key challenges pertaining to groundwater management in Chintamani.

Chintamani has one surface water source

Kannampalli lake, situated to the southwest of the town, is able to supply **1 MLD** of supply, which is rationed to last most parts of the year. A jackwell at the lake is pumped to a WTP (Water Treatment Plant) located three kms away with a capacity of treating 1.6 MLD.

We assessed the performance of the WTP in late 2021 to find that it failed to treat water to meet drinking water quality standards and required a complete overhaul. Water quality tests conducted in July 2022 showed that most parameters were within limits except Fecal Coliform (FC), pointing to the importance of the WTP in treating and supplying safe water to the town.

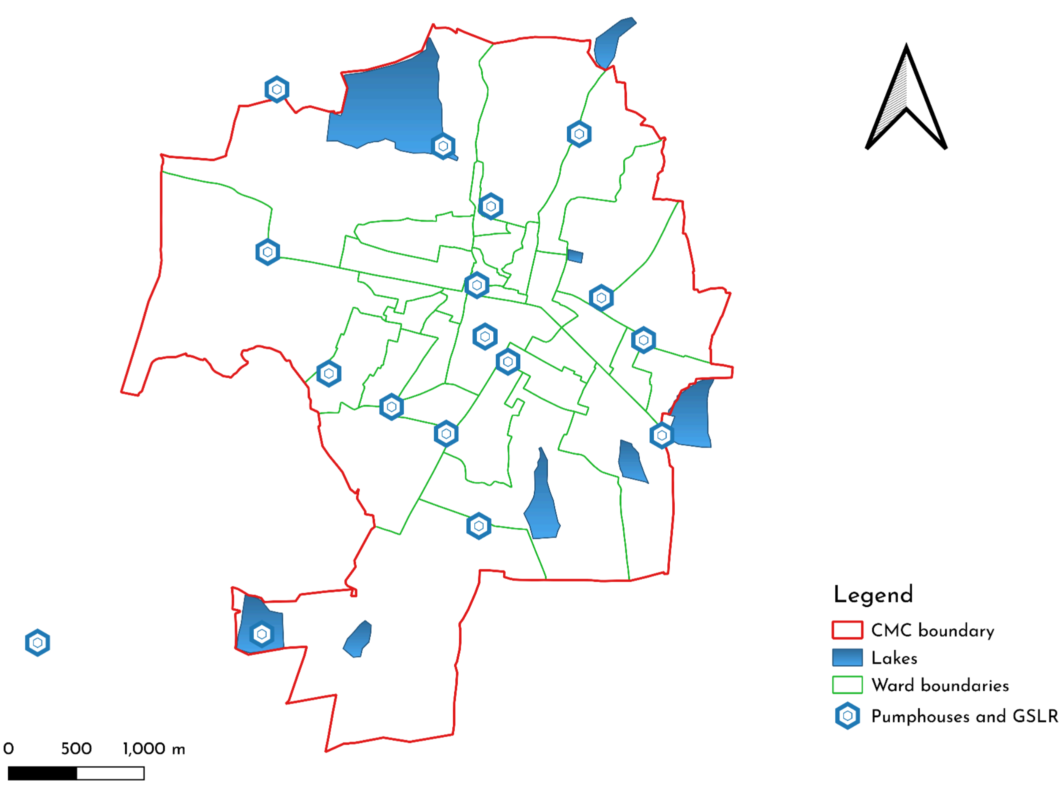
In late 2022, the CMC initiated the process of revamping and upgrading the WTP to 3 MLD in a phased manner. The CMC is also planning to operationalise the defunct WTP at Agrahara and upgrade its capacity from 1.5 MLD WTP to 3 MLD. Surface water sources are expected to increase through a new water supply project to bring water from Bhaktarahalli Arsikere 15 kms away that is being operationalised. This will play an important role in curbing the pressure on scarce groundwater sources.

Non-revenue water (NRW) is one of the town's biggest challenges

In our conversations with CMC officials, we found that unauthorised connections to the water supply network are one of the big challenges the town faces. Data from 2020 showed that the Chintamani CMC had only 8,308 water supply connections, while there are around ~20,000 registered properties across town.

The majority of municipal borewells feed into nearby pump houses. These borewells are run continuously except when there are power outages. In a few areas, borewells are directly connected via pipelines to a set of households. Once GLSRs or OHTs used for last mile delivery near their capacity, the water supply staff manually operate valves to distribute water to service areas on a turn-by-turn basis, ensuring households receive water once a week, on average.

Figure 1.5 Location of pumping stations / OHT / GLSR in Chintamani



Source: KGIS - KSRSAC, Chintamani CMC data

A study supported by the Asian Development Bank on urban water supply improvement projects in towns in Karnataka considered a 40% baseline for NRW (Matsunaga et. al, 2020). We therefore estimated **40% (1.8 MLD) of the supply** to be considered as NRW with 25% (1.125 MLD) going towards unauthorised connections and the remaining 15% (0.675 MLD) towards leakages through the pipeline network.

While unauthorised connections still count towards the town's consumption, leakages can be seen as helping recharge the aquifer (Sekhar et. al, 2017)

Table 1.3: Data summary: Municipal water supply

Component	Avg annual flow (MLD)
Kannampalli Lake	**1.0**

Component	Avg annual flow (MLD)
Municipal borewells (Municipal GW extraction)	**3.50**
Municipal supply - Total	**4.50**
Data source: - CMC officials	
Non-revenue water - Leakages	**0.675**
Non-revenue water - Unauthorised	**1.125**
Non-revenue water - Total	**1.8**
Data sources:: - CMC officials for unauthorised connections - ADB report for overall NRW average for towns	
Groundwater recharge from freshwater pipelines	**0.675**

The absence of household-level metering along with the lack of monitoring of the bulk meters at select pump houses meant that information is limited to pump house running hours and a register maintained by valve men who obtain signatures from residents every time supply is released.

Figure 1.6: Water supply staff operating valves for water supply

Credit: TIDE

Therefore, we planned for household surveys across the town to understand consumption patterns. While the CMC did not have an updated water pipeline distribution map, we narrowed down areas served by each OHT or GLSR with the help of valvemen to cover a broader set of households. In September-October 2022, we conducted, on average, 12-15 household surveys per ward, bringing up a total of 427 households.

In this section, we attempt to characterise demand from households, commercial establishments and institutions in the town. We further analyse whether municipal supply would be sufficient to cater to the town's demand.

Freshwater Demand and Supply

Domestic demand makes up 95% of the total demand in the town

We extrapolated the findings from the household survey to the current projected population of ~92,000. To estimate household consumption rates, we decided to use the filling frequency of overhead tanks as a proxy. Sumps and overhead tanks were commonly found across households for storing water with 65% of low income neighbourhood households and 90% of higher-income areas reporting having either one of them. Typical OHT capacity sizes varied between 500 to 2,250 litres, refilled between two to four times a week.

We computed the weighted average per capita consumption to be 75 liters per day. The total domestic consumption was estimated to be **6.9 MLD**.

Figure 1.7 Water consumption household surveys

Credit: TIDE

A majority of households (86.7%) depend on a single source of water – municipal piped supply – while 6.9% of households supplemented their municipal supply with private tankers. A small portion of households reported using open wells or private borewells either with or without municipal supply.

Among 427 surveyed households, 29% of households were located in lower income neighbourhoods, residing across 16 out of the 31 wards. In these neighbourhoods too, a majority was found to depend on municipal supply, and a small proportion of households (less than 2%) reported using handpumps.

In terms of frequency of municipal supply, a majority of households reported receiving water once every 7-8 days for 2-3 hours. Some households also reported receiving water less frequently – once in 10 days.

An important point worth noting here is that there was wide variation in consumption patterns across the town, with the majority (70%) of the surveyed households found to consume between 45-70 liters per capita (lpcd) and the remaining 30% consuming significantly higher – 100 - 175 liters per capita. Given the sample size of the household survey, it was difficult to arrive at spatial differences which may require further investigation.

Table 1.4 Water consumption by households

Sampled households (427)	Consumption (litres per capita per day)
45%	45
25%	70
20%	100
10%	175

Source: Household survey by WELL Labs-TIDE

Commercial and institutional demand account for a small portion of overall water demand

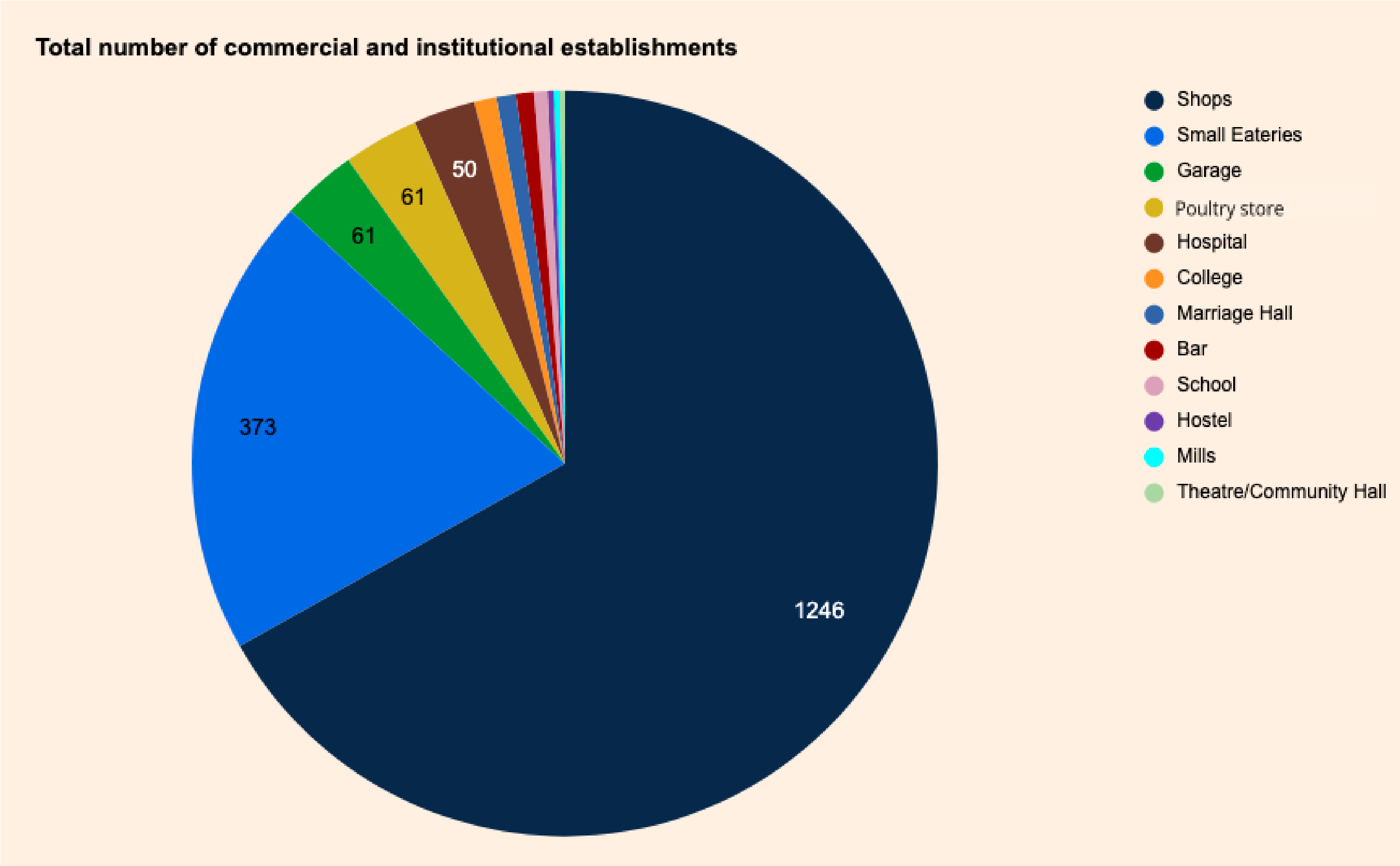
We conducted a solid waste survey that found that there were 1,847 commercial establishments and institutional users present in the town. A large majority of them are shops and small eateries, followed by garage repair establishments, hospitals and educational institutions.

In July 2022, we surveyed 537 of these establishments to understand their water consumption patterns and whether they received municipal supply. We found that a majority of the surveyed buildings depended on tankers, followed by their own borewells, to meet their water requirements. Municipal supply was reported as inadequate and not frequent enough.

We found that the largest individual consumers were hostels, hospitals, schools and colleges. Even though each shop and small eatery accounted for less, their sheer numbers lead to such establishments accounting for the highest overall water consumption

We also found that surveyed establishments reported water consumption across a wide range. The weighted average reported consumption for each category was extrapolated to the total number in each category across town to arrive at the commercial and institutional demand of **0.33 MLD**. This appears to be a small portion of the overall water demand for the town.

Figure 1.8: Number of commercial and institutional establishments



Source: Establishments survey by TIDE-BORDA

Extent of private water supply is unclear

We attempted to estimate the extent of private supply in the town be it directly through borewells or tankers. The Chintamani CMC did not maintain a record nor have estimates on the number of private borewells in the town. During our household surveys, only a handful of households reported having private borewells.

Chintamani last experienced drought conditions in 2018-19 when borewell yields dropped and the town depended entirely on private tanker supply. Private water tankers that ply in the town typically bring water from villages beyond the town's boundary. CMC officials reported that Chintamani used to hire 300-400 private tankers per day to meet the town's water requirements. During field visits in 2022, demand for tankers appeared to be muted and we were unable to estimate the amount of water brought in by tankers.

Therefore, we resorted to calculating private sources by subtracting the municipal supply from the total demand, which came to **3.33 MLD**, on average. This means that municipal supply can cater to about 53% of overall town demand.

Table 1.5: Data summary: Total demand vs supply

Component	Avg annual flow (MLD)
Domestic demand	**6.90**
Data source: - Household survey carried out by WELL Labs-TIDE Calculations: - Demand calculated based on a projected population of 92,000 with avg per capita consumption of 75	
Domestic municipal supply - Effective	**3.825**
Assumption:: - Domestic municipal supply minus pipeline leakages is being considered	
Domestic private supply	**3.075**
Calculations: - Domestic groundwater demand = (domestic demand) - (domestic municipal supply - effective)	
Commercial & Institutional (C&I) demand	**0.33**
C&I municipal supply	**0.10**
C&I private supply	**0.23**
Data source: - C&I survey carried out by TIDE-BORDA Assumption - 70% of C&I demand is met through private supply	
Total private supply	**3.33**
Municipal GW extraction	**3.5**
Total GW extraction	**6.83**
Calculations: - Total GW extraction = total private supply + municipal GW extraction	

Wastewater Management

One of the main problems raised by the municipality was that the untreated sewage caused pollution and rendered the town's lakes unusable. We began by estimating the quantum of wastewater generated based on consumption. We then studied whether the wastewater generated is safely transported to a treatment facility, and finally, whether sufficient treatment capacity exists to match the volume of wastewater generated in the town.

The town lacks the treatment capacity to handle the wastewater generated

The town's wastewater generation – from domestic, and commercial and institutional establishments – was computed based on the assumption that 80% of the freshwater consumed turns to waste. This came up to **5.72 MLD.** As we considered average rainfall and supply scenarios, we expect wastewater generation rates to largely be in this range.

The sewerage network for any city or town is built in phases. As-built drawings for the 3rd stage of the underground sewerage scheme available from the KUWSDB showed the sewerage network in Chintamani had covered almost all parts of the town.

However, the town only has one functional Sewage Treatment Plant (STP) with a capacity of 2 MLD. Preliminary analysis of pumping records showed that the STP received flows higher than its capacity.

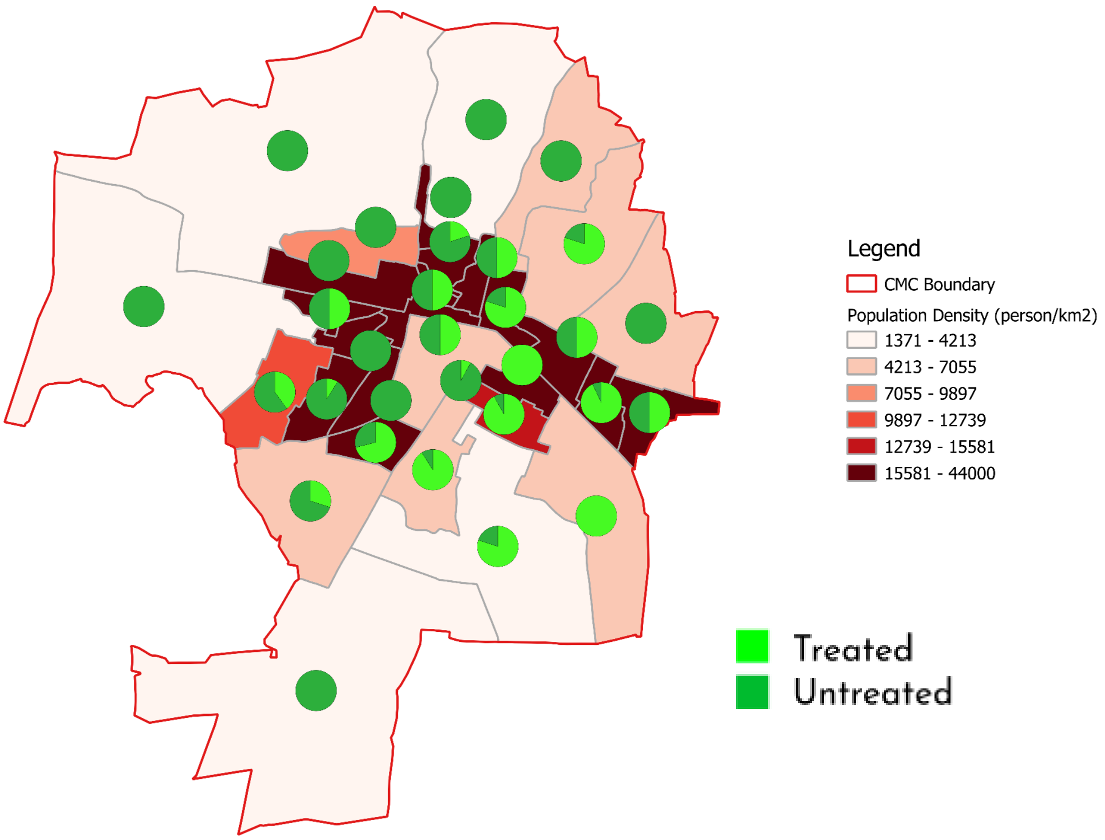
This STP is located downstream of Gopasandra lake; this means that the treated water flows away from the town and thus limiting scope for reuse. Some amount of treated water is informally used for pisciculture and irrigation.

The drawings also showed that parts of the sewerage network that flow towards Nekkundi-Bhukkanahalli catchment, one of two major catchments in the region, were not connected to the STP.

Additionally, CMC data showed that there were only 4,381 household sewerage connections, far lower than even water supply connections (CMC, 2020). This means that a majority of the town's sewage **3.72 MLD (65%) goes untreated**.

A new STP has been proposed to meet the town's treatment deficit but is awaiting funding and approval.

Figure 1.9: Map showing ward-wise population density and level of wastewater treatment



Source: KGIS - KSRSAC, base sewerage map by the Karnataka Urban Water Supply and Drainage Board

Table 1.6: Data summary: Wastewater management

Component	Avg annual flow (MLD)
Freshwater consumption	6.82 (Domestic) + 0.33 (C&I)
Domestic WW produced	5.46
C&I WW produced	0.26
Assumptions: - Wastewater produced is 80% of freshwater consumed	
Total WW produced	5.72
Water treated at STPs	2
Untreated domestic & C&I WW	3.72
Data source: - As-built drawing of 3rd stage UGD scheme from KUWSDB - CMC data for sewerage connections	
Reuse within & beyond the city	0

Lakes and downstream flows

There are two major water catchments in Chintamani

At the end of the water balance chart are water bodies and downstream flows. We explain this further in Section 3. Within Chintamani town, there are two major catchments: the Nekkundi-Bhukkanahalli and Malapalli-Gopasandra catchments, and a third smaller catchment that originates at Kannampalli lake. These lake catchments receive run-offs from within the town as well as untreated wastewater due to inadequate treatment capacity.

In addition, the Kannampalli lake receives a majority of its water from an adjacent hill catchment that lies outside the town, whereas Nekkundi, being part of a cascading lake series, also receives runoff from areas beyond town boundary.

Kulranjan et al (2023) used a mass balance equation to estimate lake volumes accounting for inflows from the catchment run-offs inside and outside town boundaries, along with wastewater flows and outflows primarily being evaporation and recharge. This approach was adopted to estimate inflows into lakes and outflows including downstream flow.

Table 1.5: Data summary: Downstream flows

Component	Avg season flow (MLD)
Run-off from external catchment into Nekkundi & Kannampalli lakes	**3.28**
Runoff into lakes from town boundary	**8.27**
Calculation: - GIS based catchment analysis for lakes in the town	
Treated wastewater into lakes	**0**
Untreated wastewater into lakes	**3.72**
Recharge from lakes	**3.06**
Assumption ▪ Recharge rate through lakes is considered to be 20% (FES 2010)	
Evaporation from lakes	**4.58**
Assumptions: - In semi-arid regions, up to 30% of lake volume is lost by evaporation	
Downstream flow from lakes	**7.64**
Calculation - Downstream flow from lakes = (run-off from external catchment into lakes) + (run-off into lakes from town boundary) + (untreated wastewater) - (recharge from lakes) - (evaporation from lakes)	

1.4 Data Gaps and Limitations

This exercise is largely based on data and information sources available with the Chintamani CMC. We also attempted to triangulate the data through interactions with CMC and KUWSDB staff as well as secondary literature available for towns in similar contexts.

The attempt to quantify Chintamani is a first in many aspects, therefore we do not claim that these estimates are completely accurate but can serve as reasonable estimates and be the starting point to trigger further conversations. In the process of developing a water balance, we uncovered data gaps that exist, particularly related to the method and frequency of updating municipal data. These caveats have been mentioned in respective sections. In addition, we highlight specific gaps below:

- **Construction activity**: We had limited success in mapping construction activity in the town. Chintamani CMC officials mentioned that they receive only a handful of applications per month for processing, but that there was an equal number of unapproved construction taking place within the town limits. The CMC handles building plans for residential-ground + first floor buildings, while all other building approvals go through the Chintamani town planning authority. While the building plan approval process has moved online, we were not able to gain access to the number of applications processed.
- **Water supply distribution maps**: We approached CMC to procure water supply distribution maps to understand pipeline coverage in each ward. However, the CMC did not have an updated water supply distribution map, so we relied on watermen and made visits to pumping stations to gain a high level understanding of water distribution in the town even if we were not able to capture more precise details of the town's water supply network.
- **Private tanker supply**: We were not able to uncover the extent of private tanker supply in the town. An interview with a tanker operator revealed that their tanker filling points were located on the outskirts of the town.
- **Water quality:** Water quality sampling was limited to one cycle at the start of the monsoon period in 2022. CMC did not follow a practice of periodically testing water quality of municipal supply or treated water from the STP. Therefore, water quality analysis was limited to sampling carried out during our fieldwork.
- **Low income settlements**: Low income households were briefly covered during the household survey. Despite the small sample size, we were still able to glean that there were disparities in access to water with a few consuming far more than a majority. This needs to be investigated further with a detailed mapping of low income settlements and their access to water and sanitation.

2. GROUNDWATER

Aquifer characteristics and the high cost of extracting water

Photo Credit: Geovale Services Pvt Ltd

For the purpose of this analysis, we are sectioning our report across two themes – groundwater and surface water – for ease of navigation. This allows us to delve into specific issues communicated at the stakeholder workshops and reiterated through the process of quantifying Chintamani's water balance.

There are two key points we want to highlight in this section about groundwater dependence and management in Chintamani. The central point is the town's dependence on groundwater, which meets a whopping 80% of the town's freshwater needs. Second, this dependence means there is a significant burden on the aquifer underlying Chintamani. This is aggravated by data gaps that impede better aquifer management and recharge. Groundwater is energy intensive resulting in water supply alone accounting for nearly 40% of the municipality's operational expenses. This is a big financial burden on already cash-strapped municipalities. We detail this aspect in Section 4 of the report on governance and finance in Chintamani

2.1 Chintamani needs an aquifer management plan

Given Chintamani's high reliance on groundwater, it was important to construct a conceptual understanding of the town's aquifer. This includes trying to identify recharge zones and assessing current extraction patterns through borewells. These would form the base for developing an aquifer management plan for the town.

Chintamani region has an underlying hard rock aquifer

Such aquifers are made up of gneisses and granites. The groundwater in hard rock areas mainly occurs in top weathered zones and also within the joints and fractures at greater depths, the weathered zone feeds the deeper fracture zone, which is semi-confined (CGWB, 2022).

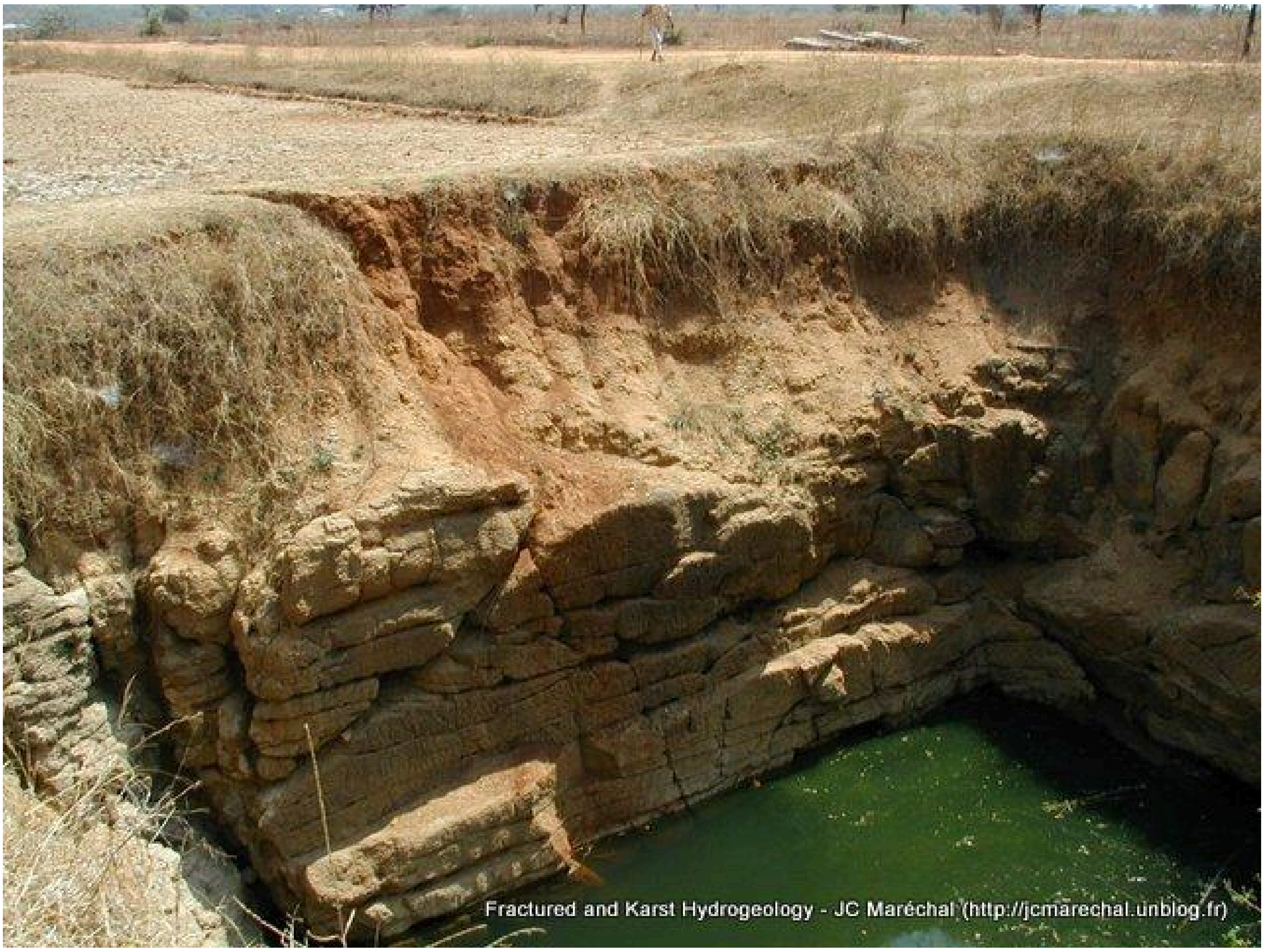
A simpler way of understanding key features of a hard-rock aquifer is by comparing it with the other type – alluvial aquifer that underpin the Indo-Gangetic plains towards the north of the country – and using the analogy of an egg-carton and a bathtub, first raised by Beattie (1981) and later used in the Indian context by Srinivasan (2022):

> *'These aquifers differ in the extent to which local rainfall and pumping affect the water table locally... The egg carton analogy assumes that the aquifer is local and therefore the pumping impacts are local and experienced by a small group of people – say one or two villages. In India, the hard-rock aquifers of peninsular India tend to behave like egg cartons. They are fast responding and local – like filling and emptying the individual cups in an egg carton. They quickly empty in the dry season if local rains have been deficient but also fill up in wet years. The filling and emptying is driven by local rainfall and local pumping and relatively insulated from what happens in the neighbouring district or state.'*

This differs from alluvial aquifers, which is one massive system that is not immediately affected by poor rainfall. It takes time for the groundwater to deplete when pumping exceeds recharge in alluvial aquifer.

Figure 2.1 shows the profile of a dugwell in a hard rock region in the Deccan plateau that shows weathering on top that takes place over time.

Figure 2.1 Weathering profile of a dugwell



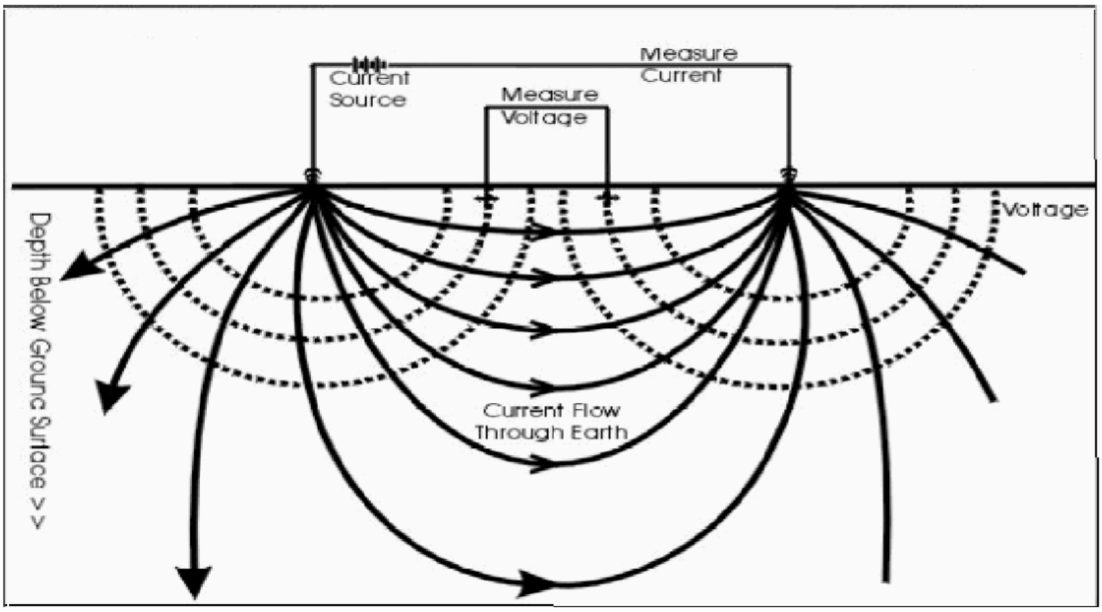
Credit: JC Marechal

We conducted a resistivity survey to map the shallow aquifers in the town.

Resistivity surveys are commonly used for groundwater exploration; Vertical Electrical Sounding (VES) survey is a one such non-invasive method where subsurface variations of electrical current flow exhibited by an increase or decrease in electrical potential (voltage) between two electrodes is measured. Based on variation resistivity values, we can infer the depth and thickness of subsurface layers including water bearing formations that manifest due to lithology and characteristics of groundwater present.

Using geophysical studies, we can interpret the depth of weathered zone thickness, occurrence of fissures in bedrock etc., to map the shallow aquifer present in the area. Twenty locations were shortlisted for the VES survey along three vertical grid lines across Chintamani town.

Figure 2.2. Typical VES schlumberger arrangement

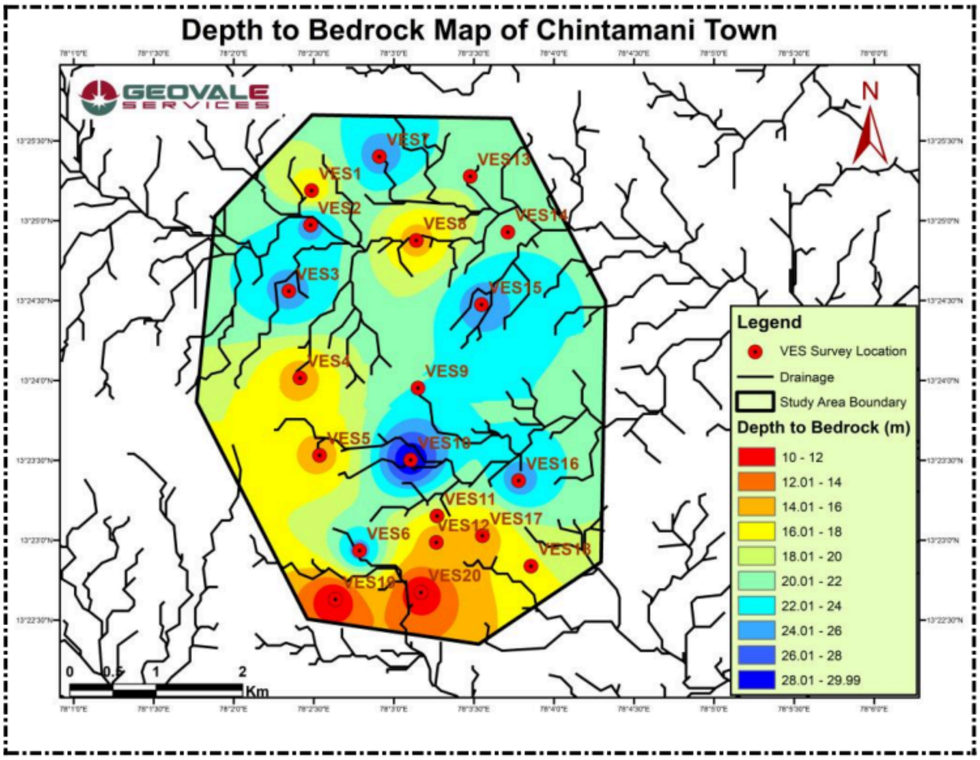


Source: Meshram et.al (2015)

The resistivity data obtained indicated that the town has a aquifer profile consisting of:

- **thin topsoil layer** followed by a loamy-clayey soil layer up to 5 to 10 m
- **weathered zone** with a thickness of 10-15 metres
- **saturated bedrock with fissures** with a thickness of up to 20 metres
- **unweathered bedrock,** commonly referred to as basement rock

Figure 2.3 Depth-to-bedrock map for Chintamani town



Source: VES surveys carried out by Geoovale, December 2022

The weathered zone provides the capacitive function while the fissured bedrock acts as the transmissive layer. Figure 2.3 shows the deepest depth to unweathered bedrock occurred across two north-easterly flowing streams, found to be in the north west near Nekkundi lake and southeast along Malapalli lake.

However, in some locations, the bedrock appears at shallower depths. Locations that recorded the maximum weathering depth indicate zones that could be targeted for recharge, either through rainfall or other surface water structures.

2.2 Chintamani has more than 300 borewell sites and only 60% have yielded water

We explained how shallow aquifers can be mapped to identify zones that could be prioritised for recharge. Here, we go deeper into groundwater management in the town by analysing how municipal borewells operate and source water from much greater depths.

Figure 2.4 Schematic of a borewell tapping weathered-fractured hard-rock area

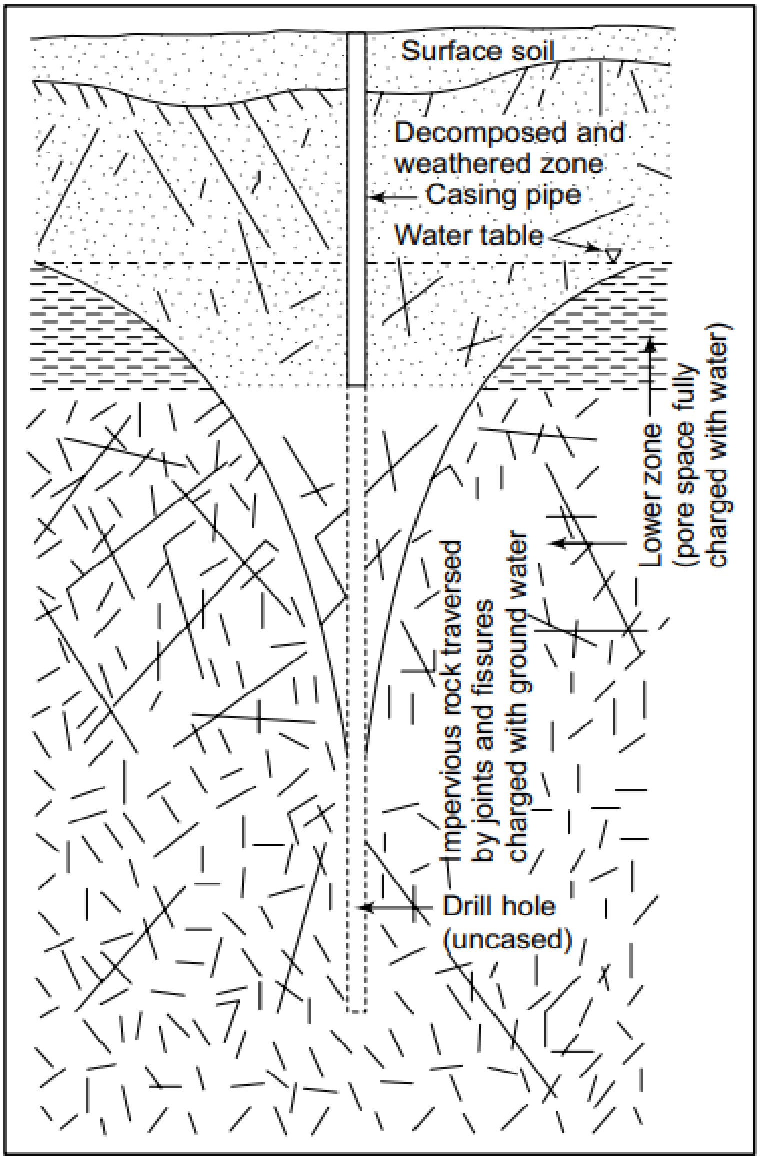


Figure 2.4 shows typical borewells in hard rock areas have casing pipes put against the upper weathered zones that tap the fissures and fractures that occur in the bedrock at depth to obtain water. Some borewells go much deeper in the basement rock, where one can expect a good yield only if it is located in a shear, fracture or fault zone (Michael et al, 2008).

Inadequate groundwater data

We began investigating the groundwater situation in the town by collecting municipal borewell records and speaking to CMC water supply staff. As per municipal borewell data records from 2020, there were a total of 322 municipal borewell sites in Chintamani. Of these, only 196 of them yielded water at some point; the remaining 126 failed at the time of drilling or in subsequent years. The failure rate has been around 40%, which means that two out of five borewells have failed in the town.

Source: A M Michael et. al (2008)

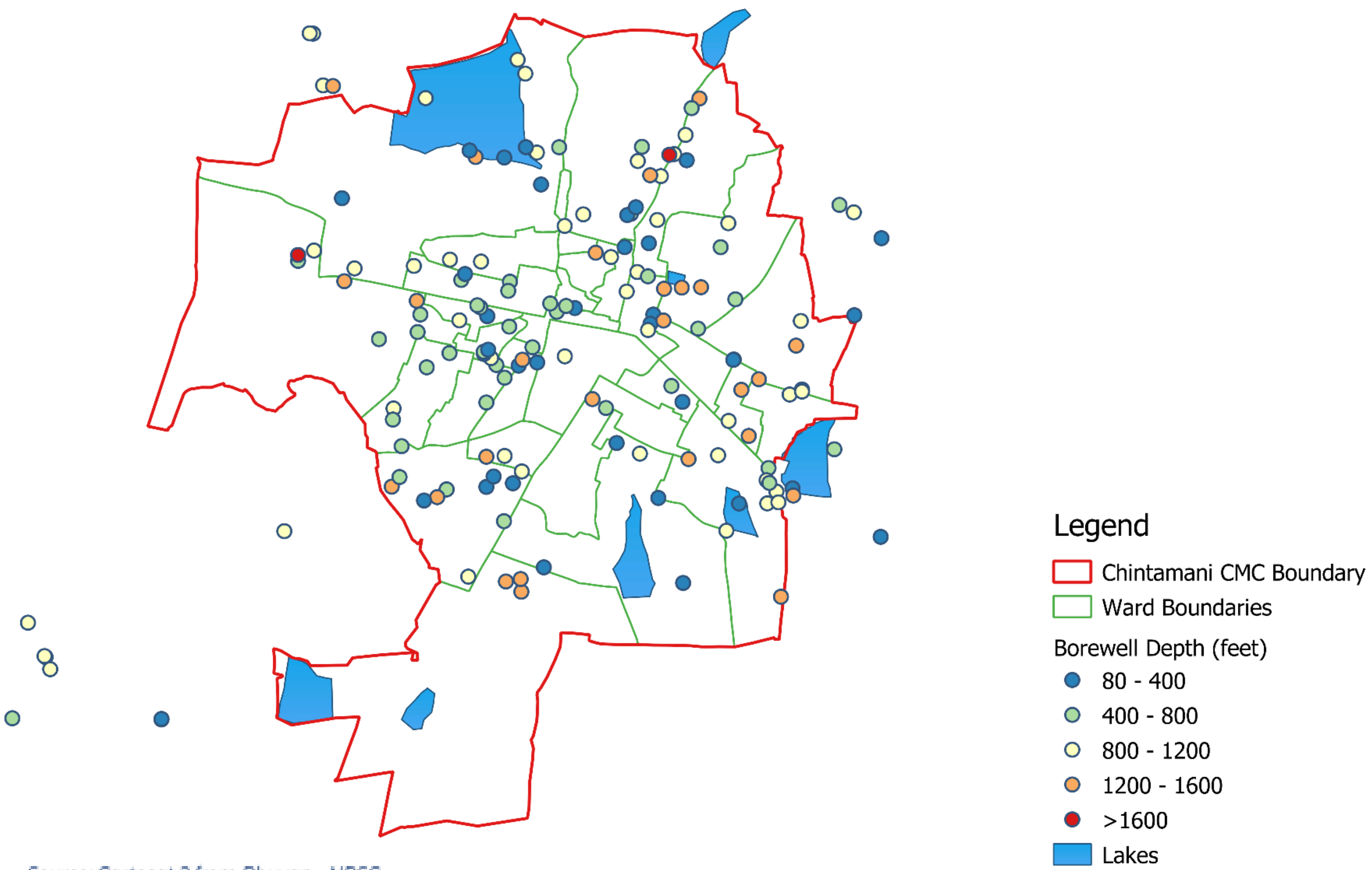
Table 2.1 Municipal borewells and their depth

Depth in feet (ft)	Number of Borewells
0-500	46
500-1000	66
1000-1500	73
>1500	11
Total	196

Source: CMC records

As shown in Figure 2.5, the majority of shallow borewells (<500 feet) lie in and around the lakes in the town. However, within 100-metre-radius clusters of borewells, we observe that depths vary from 300 feet to 1,300 feet in depth. Based on the depths, most borewells were tapping into fractures in the bedrock for water going beyond shallow aquifers. This also means that submersible pumps with higher suction power ratings are needed to pump the water.

Figure 2.5 Spatial distribution of municipal borewells



Source: Cartosat 2 from Bhuvan - NRSC, KGIS - KSRSAC, CMC records

We compared borewell records between 2020 and 2022 and found that there were 107 working borewells in 2022, compared to 72 in 2020. The increase in functioning borewells could be attributed to excess rainfall in 2021 and 2022. The extent of borewell failure underlines how inadequate groundwater data leads to challenges in predicting borewell productivity.

To understand changes in groundwater levels between years as well as during pre and post-monsoon periods, water level in borewells need to be monitored. However, municipal borewell records contained information on pump motors and their depth but water level and casing depth had not been captured. Hence, although water supply staff attributed the increase in yield and number of functional borewells to the copious amount of rainfall in 2021-22, we were not able to quantify the extent to which this has taken place.

Additionally, information on borewell failure is restricted to the location of dry borewells; there is no information on the depth at which they failed to interpret whether there is a pattern to when water is struck given that the borewells are located in a relatively small radius. Without historical data capture, it is difficult to arrive at patterns in borewell productivity and failure rates.

Poor information on private borewells

Moreover, the municipality does not have a system of registering privately-dug borewells in the town. Attempts made during a household survey to understand the extent of private borewells did not yield any useful information apart from a handful of households that reported having their own borewell.

Figure 2.6 Community open well in ward 29

A number of open wells are present in ward 29, located towards the north of the town near Nekkundi lake, both at the community level as well as in individual properties. The water drawn here is used for non-potable purposes due to it being salty in taste.

Credit: TIDE

Municipal borewell water quality and monitoring

We carried out water quality tests in June and July 2022, when we took 21 samples from different municipal borewells across the town. They were collected at different depths, ranging from 500 ft to 1,500 ft. All water quality parameters, apart from TDS in some areas, were within range. This means the groundwater can be made potable post basic treatment. As of late 2022, CMC did not have a process in place for periodic water quality testing.

Table 2.2 Municipal borewell water quality summary

Parameter	Unit	Permissible level	Test results
TDS	mg/l	<500 <2000 (in absence of alternate source)	136-1984
Fluoride	mg/l	<1.0	0.1-1.0
Nitrate	mg/l	<45	0.3-7.3

Source: Laboratory test results for samples collected in June and July 2022

The VES exercise along with an analysis of borewell records provided a starting point to understand the groundwater scenario in the town. Hard rock aquifers such as ones underlying Chintamani town can be characterised as having sufficient (although not large) storage permits usage during the summer but are prone to depletion through excess abstraction especially if there are consecutive years of poor rainfall (H. Gardino et. al 2009).

These findings point to a need to develop a blue-green infrastructure plan to boost recharge given that the majority of the town's spaces are unbuilt. Measures such as rain gardens and green spaces that allow rainwater run-off to be trapped and percolate below ground could be key to improving groundwater tables. Simultaneously, understanding extraction patterns, better borewell records management along with studies such as Electrical Resistivity Tomography (ERT) profiling to improve mapping of aquifer geometry are necessary.

Pumping groundwater to meet almost the entire town's needs is expensive. We cover this aspect in Section 4 on governance and finance in Chintamani.

3. SURFACE WATER BODIES

Chintamani faces water pollution

Credit: TIDE

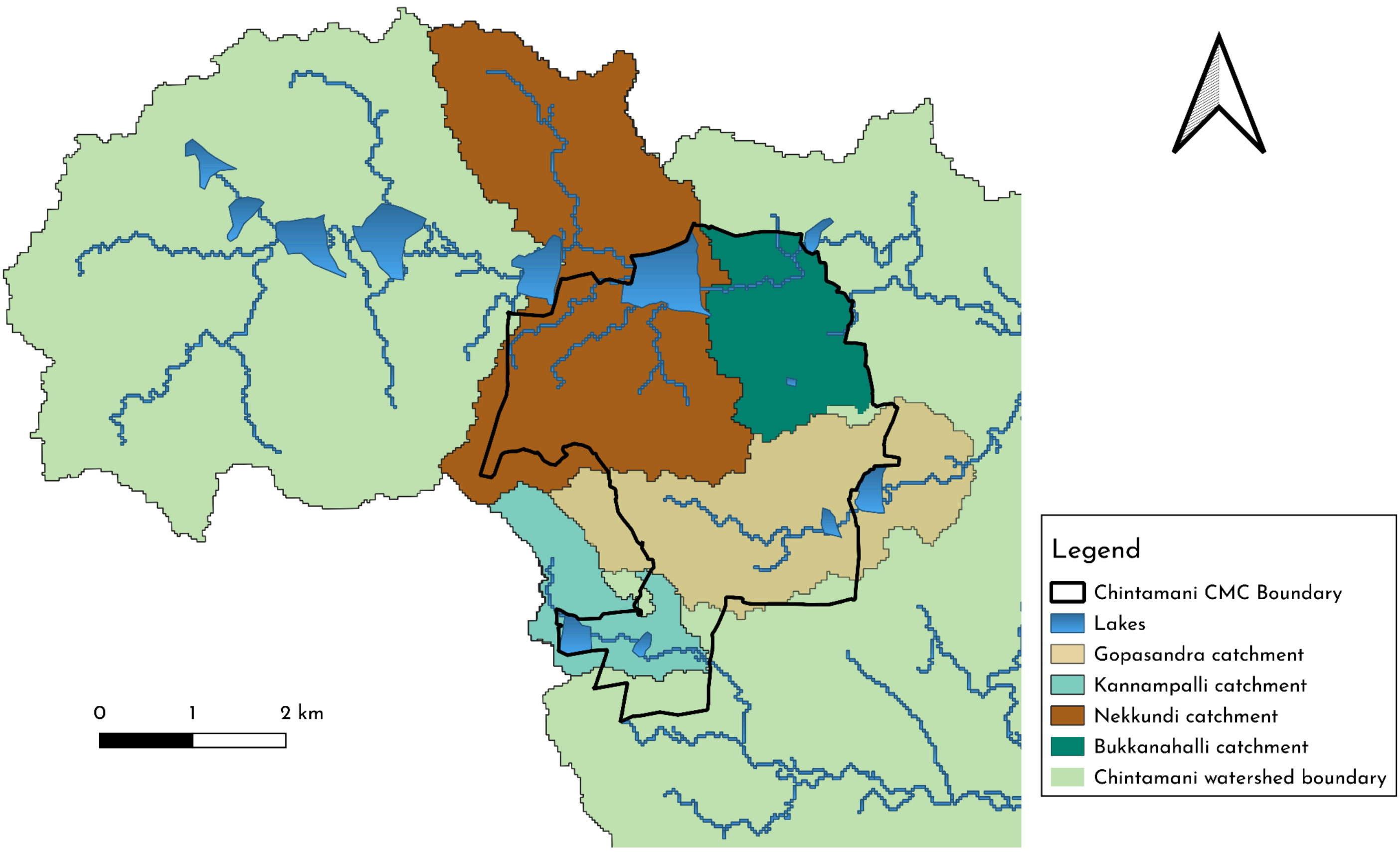
The heavy dependence on groundwater raises the question of what role surface water bodies play in Chintamani – are there viable sources that could be tapped and thus could take the pressure off depleting groundwater? Our preliminary analysis showed that up to 50% of the town's drinking water needs could be met through local surface water. But water pollution is a problem; this was a key point that was raised during initial discussions with Chintamani municipality. Untreated sewage flows into lakes rendering them unusable. One reason is that high investment in water supply infrastructure precludes investment in wastewater treatment. Other issues around availability of land also contribute to delays in setting up such necessary infrastructure, we learnt through our conversations with KUWSDB officials.

In this section, we explain the surface water hydrology of the region and discuss how it could be leveraged to meet the town's freshwater requirements.

3.1 Chintamani town's watershed comprises of two major and one minor catchment

We began looking at Chintamani's hydrological flows by first examining two aspects: i) the town's drainage divide that forms major and minor catchments; ii) the state of its lakes and catchment areas.

Figure 3.1 Map of Chintamani town watershed and catchment areas for its lakes



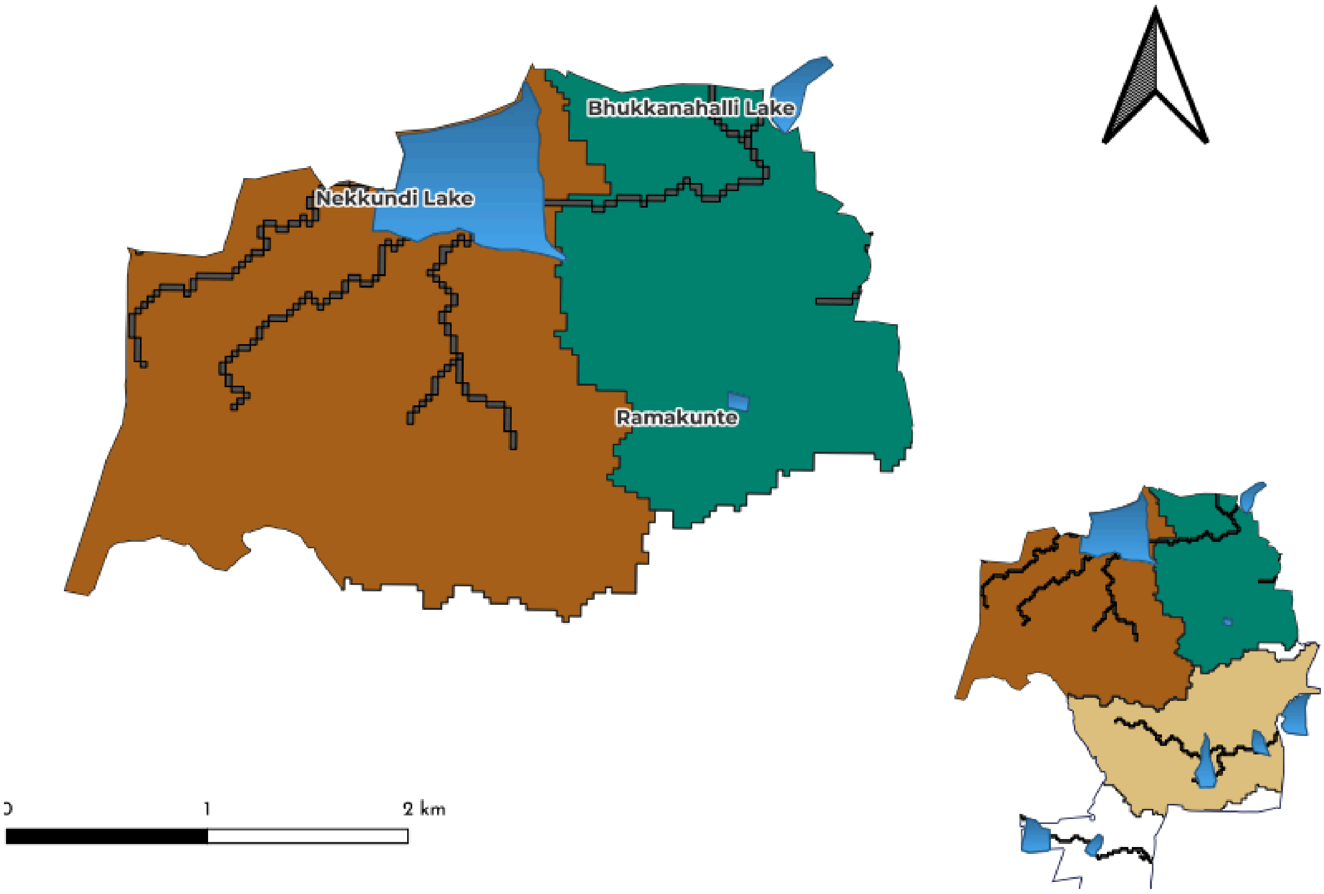
Source: Cartosat 2 from Bhuvan - NRSC, KGIS - KSRSAC

Chintamani town lies in the Palar basin; a majority of this basin's drainage area lies in Tamil Nadu but it also extends to southeastern parts of Karnataka. Chintamani lies in one of the initial upper regions of the Palar basin. The town is divided into two major catchments – the Nekkundi-Bhukkanahalli catchment to the north and the Gopasandra catchment that lies towards the southeast. A third smaller catchment in the south surrounds the Kannampalli lake – the source of drinking water for the town. The ridge between the major catchments intersects at the centre of the town as evident from the figure above.[1]

The Nekkundi and Bhukkanahalli catchments lie towards the north.

The catchment area for Nekkundi is part of a cascading lake system – where when one lake fills up, the excess empties into the next one in the chain, which lies outside the town boundary.

Figure 3.2 Nekkundi-Bhukkanahalli catchment areas within town

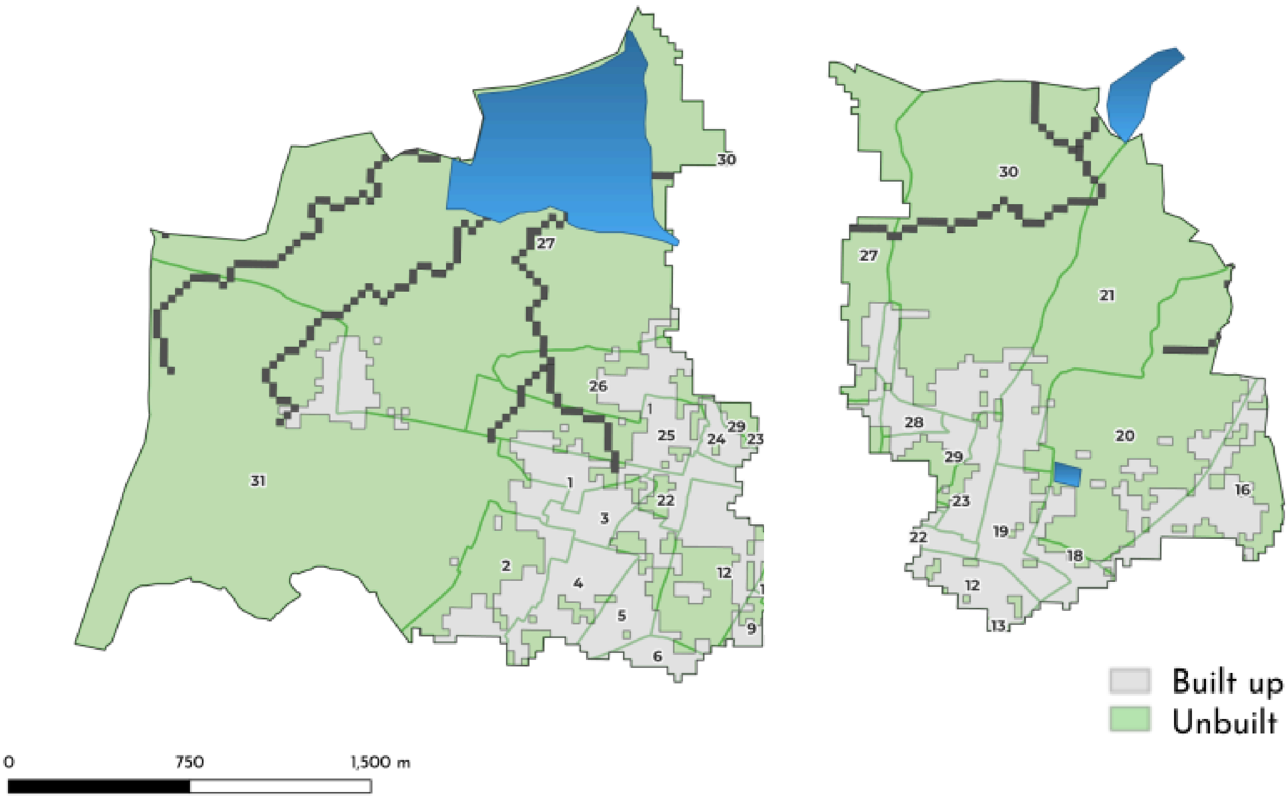


Source: Cartosat 2 from Bhuvan - NRSC, KGIS - KSRSAC

[1] The terms catchment and watershed are often used interchangeably but we differentiate between the two here. A catchment is an area from which surface runoff is carried away by a single drainage system to one destination. It's on a much smaller scale and could centre around a lake. Multiple catchments make up a watershed, which refers to a much larger area drained by a river and its tributaries. For example, the area demarcated as Nekkundi catchment feeds runoff and sewage flows to the Nekkundi lake because of the topography here. Along with other catchments in Chintamani, it makes up a part of the larger watershed.

Within the town's boundary, the contributing catchment of Nekkundi lake lies in the northwest. The stormwater run-off and the sewerage network in the area flow towards the lake due to the natural slope; that's what the darker lines in the image below indicate. The Bhukkanahalli lake falls to the northeast, just outside the town limits. It is situated downstream of the Nekkundi lake, which means it receives the overflow from the lake in addition to stormwater and sewage from its own catchment.

Figure 3.3: Distribution of wards in Nekkundi and Bhukkanahalli catchments



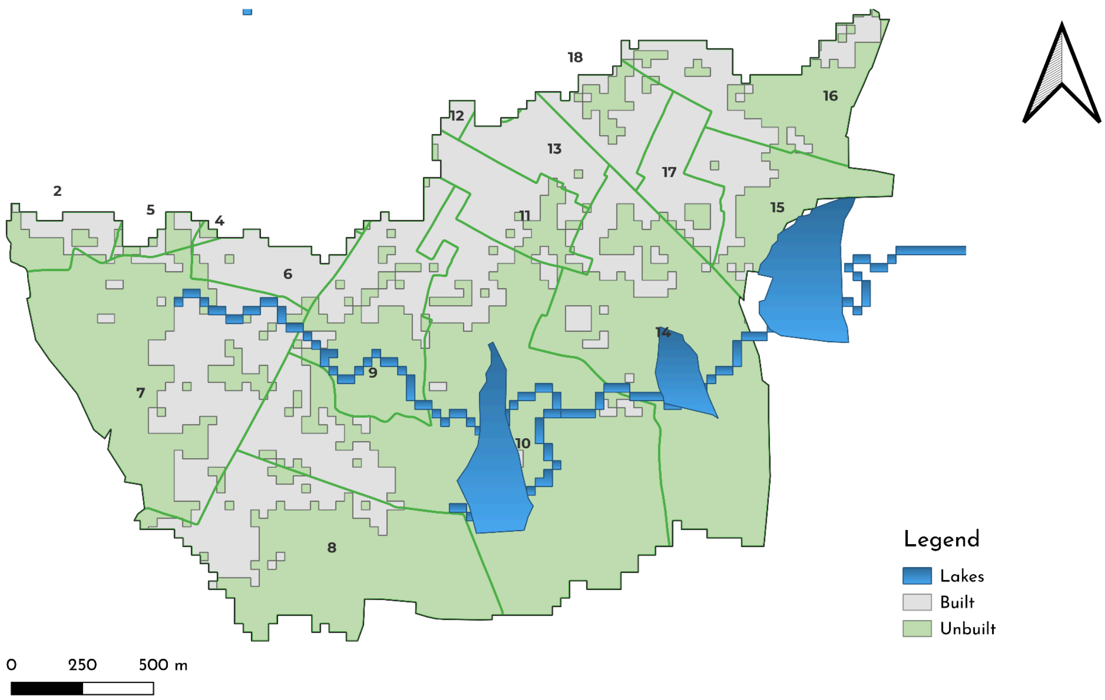
Source: *Cartosat 2 from Bhuvan - NRSC, KGIS - KSRSAC*

The maps above show the distribution of municipality wards in each catchment.

The next major catchment in Chintamani is Gopasandra.

This catchment spans the centre and southeastern parts of the town, the most built up and densely-populated regions. It has its origin at the Kadu Malleshwara hillock, which overlooks the built-up areas in Chintamani. Aside from Gopasandra lake, there are two others, Malapalli and Chikka Malapalli lakes, located in this catchment area.

Figure 3.4: Distribution of wards in Gopasandra catchment

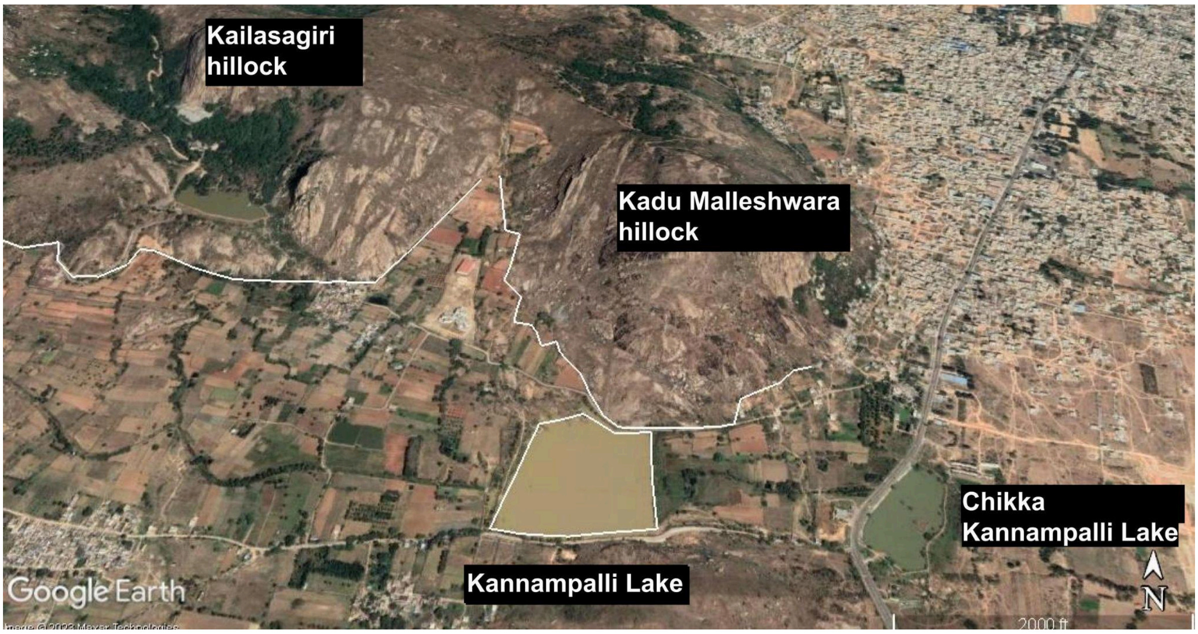


Source: Cartosat 2 from Bhuvan - NRSC, KGIS - KSRSAC

The final catchment area relevant to this discussion is Kannampalli.

This catchment lies towards the south and falls largely outside the Chintamani municipality's jurisdiction. The Kannampalli lake is fed by two hill catchments - Kailasgiri and the Kadu Malleshwara hillocks on the periphery of the town.

Figure 3.5 : Kannampalli lake catchment map



Credit: Google Earth, Cartosat 2 from Bhuvan - NRSC, KGIS - KSRSAC

The overflow from Kannampalli flows into Oat Kere also known as Chikka Kannampalli. Though the smallest catchment of the three, Kannampalli is important because, currently, it is the sole surface water drinking source for the town. A water treatment plant with a 1.6 MLD capacity set up by the municipality pumps water from this lake to supplement groundwater supply.

Table 3.1 : Lake catchments in Chintamani town

Catchment	Catchment area (sq.km.)	Lakes falling under the catchment	Lake size (sq.m)
Nekkundi - Bhukkanahalli	**13.4**	Nekkundi	**470,427**
		Bhukkanahalli	**49,375**
		Ramakunte	**7,728**
Kannampalli	**2.1**	Kannampalli	**108,976**
		Chikka Kannampalli	**31,305**
Gopasandra	**5.9**	Gopasandra	**117,211**
		Malapalli	**88,791**
		Chikka Malapalli	**38,948**

Source: GIS analysis carried out by WELL Labs

The above background on the topography and location of Chintamani's surface water bodies, demarcation of catchment areas and direction of flow, is essential to understand to plan viable next steps for the town's water security.

3.2 Pollution impairs these lakes from meeting the town's requirements.

To add detail to this blueprint of Chintamani's lakes and surface water flows, we visited the different lakes over a span of six months in 2021. We focused on the three largest – Nekkundi, Gopasandra and Kannampalli lakes, where we collected water quality samples and investigated the causes behind issues such as lake pollution, one of the main reasons why these water bodies are rendered unusable. The appearance of Kannamappali lake, which is used as a drinking water source, was markedly different from Nekkundi and Gopasandra. In the wake of a strong monsoon, it was filled to capacity and was free from visible signs of ill lake health.

The photograph on the left below shows the jackwell, which pumps water from the lake to a water treatment plant three kilometres away. Nekkundi and Gopasandra, the two pictures on the right, were covered with vegetation, indicating that nutrients flowing into the lake was causing vegetation to grow at a rapid pace[2].

[2] When nutrients such as nitrogen and phosphorus flow into lakes, the water body can become enriched with nutrients, thus increasing the amount of plant growth. This could cut out sunlight and deplete oxygen, leading to degradation of the aquatic ecosystem. This part of water pollution is called eutrophication.

Figure 3.6: Kannampalli, Nekkundi & Gopasandra lakes in late 2022

Credit: Shashank Palur and Rajesh R, WELL Labs

Faecal coliform levels were found to be higher than safe limits in all the lakes.

We tested the water quality samples we collected from the three lakes to find that all of them showed coliform levels higher than desirable limits (below 500 MPN per 100 ml is desirable[3]). This means that the water treatment plant that siphons water from the Kannamapalli, despite its small capacity, plays a key role as it carries out conventional treatment and disinfection before supply.

The poor water quality also points to the need for periodic monitoring of the lakes to establish trends in water quality changes over time, and ensure treatment infrastructure can handle and purify this water.

[3] MPN stands for Most Probable Number and is a common measure of water quality. It is an estimate of the number of microorganisms like bacteria in a sample of water.

Table 3.2 Lake water quality summary

Lake	TDS (mg/l)	N-Total (mg/l)	Ammonical Nitrogen (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Faecal Coliform MPN/100ml
Kannampalli	**118**	**1**	**<1**	**5.7**	**2.4**	**14**	Above desirable limits
Nekkundi	**478**	**2.8**	**<1**	**5**	**2**	**10**	Above desirable limits
Gopasandra	**828**	**6.1**	**1.2**	**5.5**	**2.6**	**18**	Above desirable limits

Source: Laboratory test results for samples collected in July 2022[4]

The eutrophication of lakes here could be attributed to sewage inflows from urban pockets or agricultural run-offs given that there are no major industries in the catchment area. We investigated this further to understand the underlying causes of pollution and how this could be stemmed to improve the quality of water in these lakes.

Sewerage network covers the entire town but not all households are connected

Chintamani town is reported to have nearly 98% sewerage network coverage. However, CMC data for 2021-22 showed that only 4,381 household connections have been recorded. This means less than a quarter of the town's ~20,000 properties are actually linked to the sewerage network.

We inferred that a majority of the town residents are either not connected or have unauthorised connections to the network. Using the as-built drawings for the underground sewerage scheme implemented in the town, made available by the KUWSDB, we mapped the sewerage network against the catchment that drains water into the lakes to get a better understanding of the flow of polluted water from nearby urban settlements.

[4] Water quality criteria and classification of lakes is detailed here: https://cpcb.nic.in/water-quality-criteria/

Figure 3.7: Nekkundi lake catchment - UGD network

Source: Base sewerage map by the KUWSDB. Annotations based on analysis by WELL Labs.

Considering the Nekkundi catchment area, there are two main sewer pipelines – one that traverses the periphery of the lake (along the bottom) joining the second line that merges at the outlet of the lake before continuing towards Bhukkanahalli[5] (not in image as this lake is outside Chintamani).

During field visits in late 2022, it appeared that these two lines were not fully operational and were broken in parts resulting in wastewater entering the lake as shown in Figure 4.5. We also noted that these lines were not connected to any Sewage Treatment Plant (STP), which means these pipelines were ferrying raw sewage away from the town to the water body. This is a public health hazard and squanders the potential of either of these lakes – Nekkundi or Bhukkanahalli – from serving as a safe water source.

[5] We did not carry out water quality tests in Bhukkanahalli because it's one of the smallest lakes and is located outside Chintamani town limits.

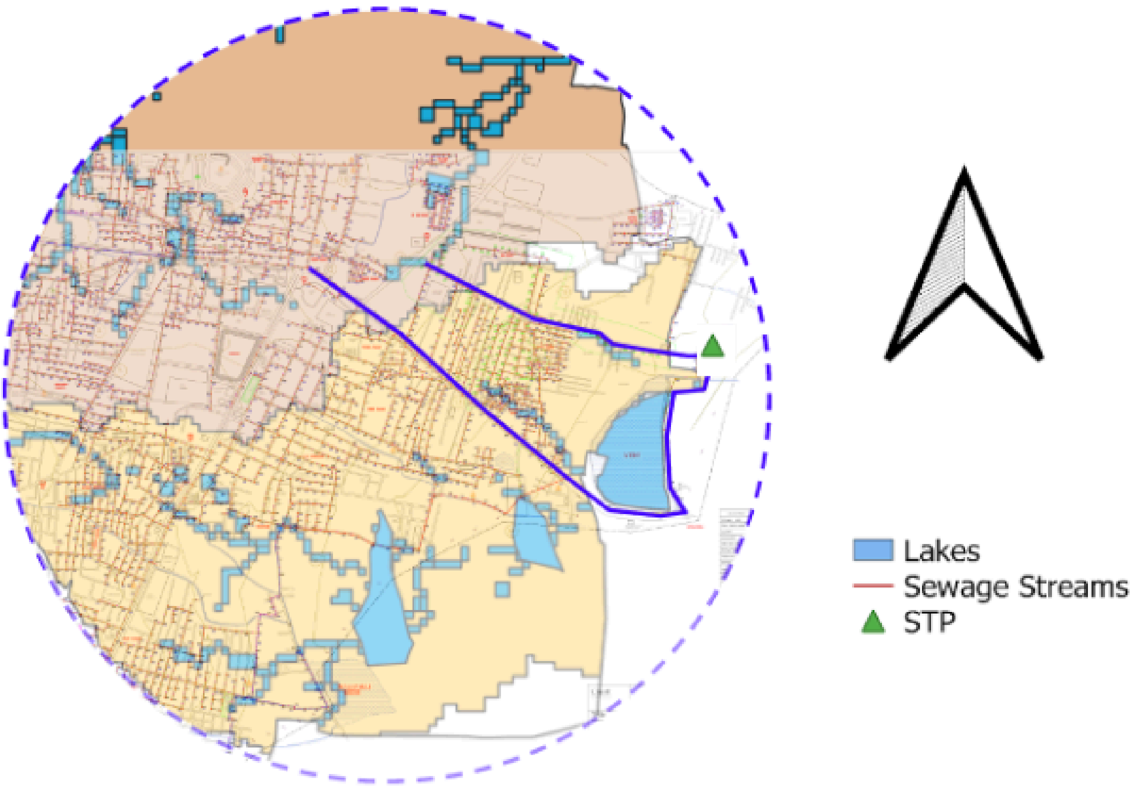
Figure 3.8 : Broken underground drainage pipes near Nekkundi lake

Credit: Rajesh R, WELL Labs

The Gopasandra catchment area has a similar story to tell except that the town's sole operational STP is located downstream of the Gopasandra lake. There are two main sewer lines here, one heads towards the north and the other loops around the length of the lake. Through our interviews with CMC officials, we understood that there were maintenance issues with the sewer pipelines in this catchment as well, although we could not verify this when we visited the lake.

The location of the STP being downstream of the Gopasandra lake makes the water body vulnerable. Typically, STPs are located upstream to allow treated wastewater to be released into the lake, and not raw sewage.

Figure: 3.9 Gopasandra lake catchment - UGD network



Source: Base sewerage map by the KUWSDB. Annotations based on analysis by WELL Labs.

Sewage treatment infrastructure is inadequate, only 35% of the total wastewater generated is treated.

In Section 1.3 (page 16 on wastewater management), we estimated that Chintamani generates 5.72 MLD of wastewater. Chintamani's operational STP, which is based on oxidation ponds to treat wastewater, has a capacity of 2 MLD. This means that a vast majority of the wastewater goes untreated; this is particularly apparent from the flow of run-off and wastewater in the Nekkundi catchment.

Records of the STP's pump operations showed that the facility has been receiving sewage well beyond its capacity. We interviewed the STP operator, who reported that the ponds have not been desludged for a long period of time. Typically, anaerobic ponds need to be desludged once sludge reaches one-third of pond depth along with periodic removal of scum on the surface for facultative ponds (Mara, D. 2008). Proper maintenance of the STP, if not done frequently, impacts treatment efficiency.

We observed that treated water from the STP was tinged green, indicating that some amount of algae was getting past the treatment process. The Chintamani municipality did not have monthly STP effluent testing results.

Treated water from this STP flows downstream and is used for pisciculture and irrigation outside the town's limits, but there appears to be no formal arrangement with users.

Figure 3.10: Treated water from the STP

Credit: Rajesh R, WELL Labs

New STPs have been proposed, which could address water pollution in the region

As Chintamani's population grows, it becomes more critical that the town's wastewater treatment capacity is enhanced. To meet future treatment requirements, the KUWSDB has proposed a 6.4 MLD STP near Bhukkanahalli lake. Additionally, to address the flow of pollutants into Nekkundi lake, the Chintamani CMC had considered a 75 KLD interceptor-type STP near the lake boundary, where one of the major storm water drain channels enters into the lake.

Expediting the construction of another treatment facility near Nekkundi lake coupled with improvement of existing systems could significantly cut down on water pollution. This means ensuring all households are connected to the sewerage network as well as repair and maintenance of the sewerage network pipelines. These measures alone could ensure that at least 4 MLD[6] treated water would be available for reuse purposes both within the town and in the farmlands outside Chintamani town for irrigation.

[6] 5.73 MLD is the total wastewater generated. Post transport and treatment (losses during the process) will mean at least 4 MLD is available for reuse.

Lakes in Chintamani town could meet up to 50% of current demand, if rejuvenated and managed properly.

The current extent of pollution and state of the lakes in Chintamani paints a dire picture. But it is also clear that the lakes scattered across the town's semi-arid landscape are a big part of the answer to Chintamani's water woes.

We examined to what extent cleaning up the town's lakes and inlet channels could address the drinking water requirements of the town. Assuming an average year's rainfall, our preliminary analysis showed that rejuvenating Nekkundi and the two smaller lakes – Malapalli & Chikka Kannampalli – along with its feeder channels, could provide between **2.25 to 3 MLD** of water, adding to the meagre 1 MLD currently sourced from the Kannampalli lake[7].

Accounting for *imported* water as well could further increase the potential contribution of surface water sources. There is a proposed scheme being implemented to supply water from Bhaktharahalli Arsikere lake located 15 kms away from Chintamani, which will yield about 3 MLD. Along with 1 MLD currently being drawn from Kannampalli lake, we could meet over 90% of the current demand of ~7 MLD completely through surface water, greatly reducing pressure on depleting groundwater.

Figure 3.11: Bhaktharahalli Arsikere lake

Credit: TIDE

[7] Please check Annexure 1 for a breakdown of these estimates and how we calculated them.

Enhancing surface water storage would create multiple benefits such as improving groundwater recharge, lowering the cost of pumping and increasing biodiversity. But rejuvenation of lakes needs to be done in a systematic and scientific manner. To accurately assess storage and recharge potential, we need to conduct a detailed assessment of the water bodies such as siltation levels and bathymetry.

It is also important to understand the local communities' aspirations – how are they vulnerable to water and sanitation-related hazards, how do they perceive these water bodies and the services it could provide, and how can it be monitored and managed in the long run? These are some of the questions that must be considered for surface water rejuvenation in the region.

4. GOVERNANCE AND FINANCE

Planning and financing water supply and sewerage infrastructure.

Credit: TIDE

Strong local governance is pivotal for ensuring water supply and sewerage infrastructure is planned, funded, implemented and managed effectively. We have mentioned the Chintamani City Municipal Council (CMC) in other chapters of the report specifically in terms of how they manage groundwater and wastewater treatment. In this chapter, we take a closer look at their role and the extent of influence of state and district actors with respect to water and sanitation service provisioning and delivery.

One of the main parts of this analysis is the municipality's budget allocations. Though beyond the scope of this report to conduct an in-depth study on finances, we still aimed to understand their overall fiscal performance, their spending on water supply and sewerage infrastructure and whether the Chintamani CMC are able to meet the expenditure incurred.

4.1 Institutional framework for water supply and sanitation

Municipal governments often lack autonomy with certain functional domains limited and controlled by state governments (Jain & Joshi, 2015). Karnataka is one of the states where water and sewerage functions are managed by boards appointed by the state government in a bid to better manage urban agglomerations that may extend beyond the jurisdiction of a single municipality. District-level authorities and parastatal agencies thus play a key role in planning and implementing water supply and sewerage infrastructure in Chintamani

The institutional framework governing a small town urban local body is complex.

There are different administrative levels across state, district, and town levels – Directorate of Municipal Administrator (DMA) and Karnataka Urban and Water Supply Development Board (KUWSDB) at the state, Deputy Commissioner along with Project Director - District Urban Development Cell (DUDC) at the district level, and Municipal Commissioner and President of CMC at the town level.

Within the ULB, the engineering section oversees functions such as water supply supported by field-level staff such as valve men. Similarly, an environment engineer works alongside senior and junior health inspectors to oversee sanitation infrastructure and operations including solid waste. The ULB has an elected body of councillors representing each ward who in turn elect a President for a fixed term who presides over council meetings.

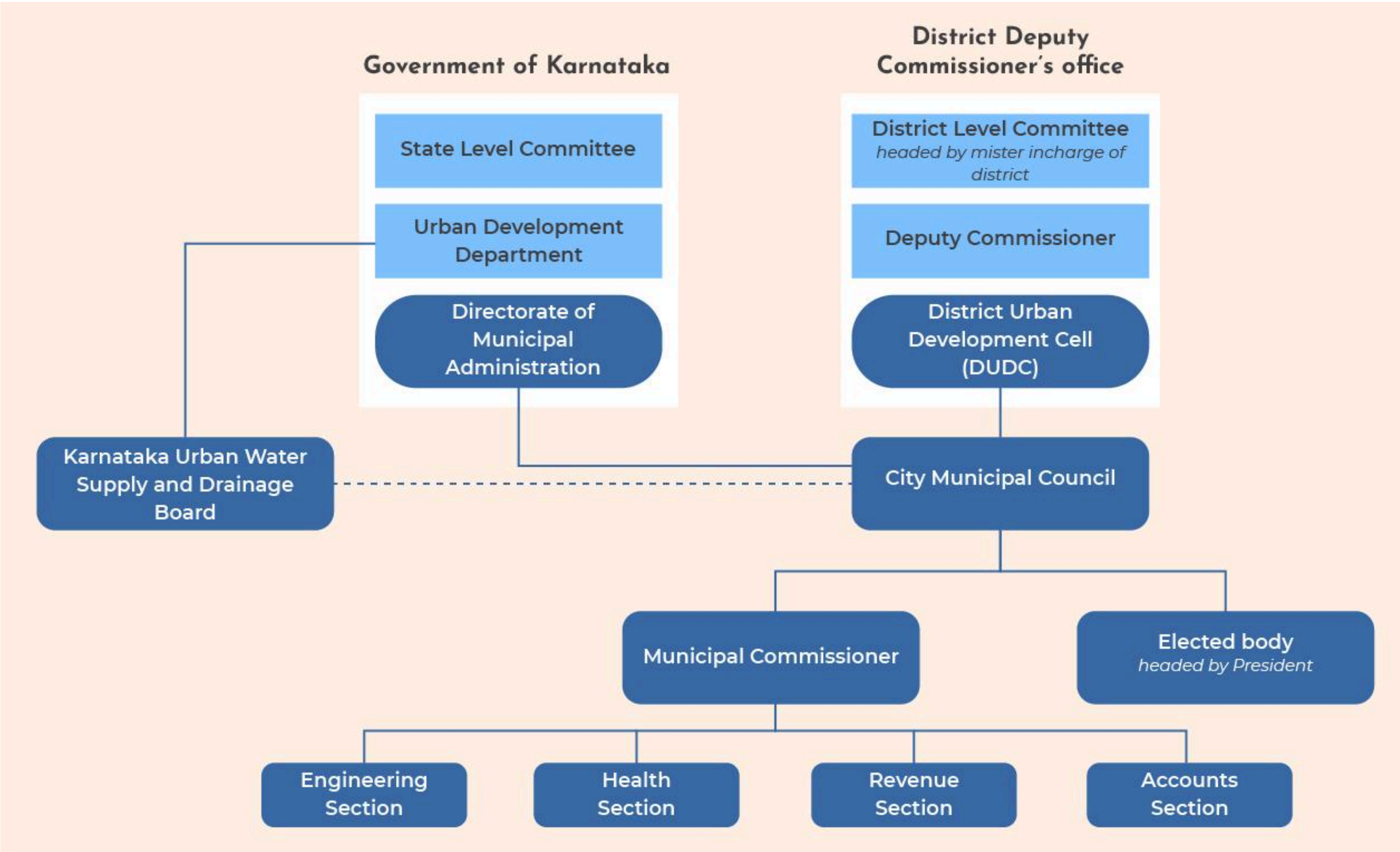
In order to access funds for major central or state government schemes such as AMRUT or Nagarothana[8], the KUWSDB prepares an action plan based on existing guidelines in consultation with the Chintamani CMC.-The KUWSDB, a parastatal body responsible for planning and execution of water supply and sewerage projects, oversees operations and maintenance for a period before it is transitioned to the Chintamani CMC. For example, it prepares Detailed Project Reports (DPR), obtains necessary approvals and oversees implementation of the proposed STP. The CMC sets tariff, collects connection fees and

[8] The Atal Mission for Rejuvenation and Urban Transformation was launched in 2015 by the central government to improve water supply and sewerage infrastructure in urban areas in India. The Nagarothana scheme was launched to improve infrastructure in the urban local bodies across Karnataka.

user charges, and manages last mile infrastructure such as digging supplementary borewells. Depending on the financing arrangements, the funds may be directed to KUWSDB from the state or channelled through the Chintamani CMC for implementation.

Ramesh & Basu (2021) developed 'activity maps' showcasing implementation of water supply schemes in two small and medium town ULBs in Karnataka; Figure 4.1 shows an adapted version of the map. The study highlighted that the process of planning for urban infrastructure remains centralised with minimal participation from ULBs despite the fact that they have to share the financial burden. Further, ULBs lack the capacity to monitor implementation of projects that are executed by private consultants engaged by parastatal agencies.

Figure 4.1: Implementation framework for water supply projects at Chintamani CMC



Source: Adapted from Ramesh & Basu (2021)

In terms of funds, small and medium town ULBs in India are funded through various sources such as the Finance Commission – union and state, central or state government missions or schemes, loans from international funding agencies, banks and other financial institutions. This is apart from the ULB's own revenue generation through property tax, fees and user charges as well as rentals.

Despite this web of institutions and sources of finance, staff shortage hinders municipal service delivery. As per information from the Chintamani CMC in June 2023, we found that 59% of sanctioned posts remain vacant out of an overall strength of 175[9]. This is particularly acute among workers such as *pourakarmikas* and water supply staff. The inadequate number of health inspectors and the absence of a full-time Assistant Executive Engineer also impact, not just provisioning, but also day-to-day operations of essential water supply and sanitation services.

Overview of Chintamani's budget

A town's dependence on external sources of funds is taken as one of the key indicators of financial health of a municipality. In the case of Chintamani, the CMC's own revenue's share stood at 44.83% in the 2021-22 financial year, which is higher compared to previous years. This shows an improvement but a continued reliance on state transfers or grants to meet its requirements.

Table 4.1 : Income and expenditure summary

Financial Year	2021-22	2020-21	2019-20
Tax Income (Rs. lakhs)	339.12	322.7	306.98
Non-Tax Income (Rs. lakhs)	858.88	790.55	823.41
Own Source Income (Rs. lakhs)	1198	1113.26	1130.39
% of Own Source Income out of Total Income	44.83%	35.43%	37.15%
State Transfers or Grants (Rs. lakhs)	1468.99	2028.61	1912.24
Total Income (Rs. lakhs)	2672.31	3141.87	3042.63
Total Revenue Expenditure (Rs. lakhs)	4620.32	3332.80	3091.99
% of Own Source Income out of Total Revenue Expenditure	25.93%	33.40%	36.55%

Source: Chintamani CMC budget documents for FY 2020-21, 2021-22, 2022-23

Ideally, a majority of the municipality's revenue expenditure should be covered by its own revenue. However, in the case of Chintamani, this has ranged between 25 and 36% over the three financial years from 2019 to 2022. Municipal corporations in Karnataka, such as Hubli-Dharwad, Tumakuru, Belagavi and Shivamogga, had averages in the range of 34%-44% for their own revenue/total revenue and between 31%-55% for own revenue/revenue expenditure for financial years 2015-16 to 2019-20 (Subalakshmi &

[9] While there are uncertainties associated with these figures, we nonetheless feel that this serves as a valuable initial estimate.

Raghunathan, 2023). This shows that the trend in Chintamani is not different from other larger towns in Karnataka.

A World Bank report on funding urban infrastructure across ULBs in India showed that own source revenue as a share of total municipal revenue nationwide declined from three-quarters to two-thirds in the FY 2011-2018 period. Concurrently, un-tied[10] fiscal transfers from central and state governments increased substantially in this period, along with increasing tied/conditional fiscal transfers for investments becoming the source of financing for urban infrastructure (Athar et. al 2022).

4.2 Capital and revenue expenditure for water supply is high

Expenditure for ensuring water supply in the town is a sizable portion of Chintamani's budget. In fact, one of the most striking learnings from this analysis was that electricity charges and fuel expenses account for more than 50% of the municipality's total operating expenses. In terms of capital expenditure, water supply and sewerage infrastructure has ranged from 28.9% to 55.84% of the total capital expenditure between the financial period of 2019 - 2021.

Table 4.2 Capital expenditure for water supply & sewerage

Financial Year	Total CAPEX (Rs. Lakhs)	Water supply CAPEX (Rs. Lakhs)	Sewerage CAPEX (Rs. Lakhs)	Water supply + Sewerage CAPEX / Total CAPEX
2018-19	446.45	206.78	42.52	55.84
2019-20	861.47	186.7	62.27	28.9
2020-21	847.32	233.37	99.4	39.27

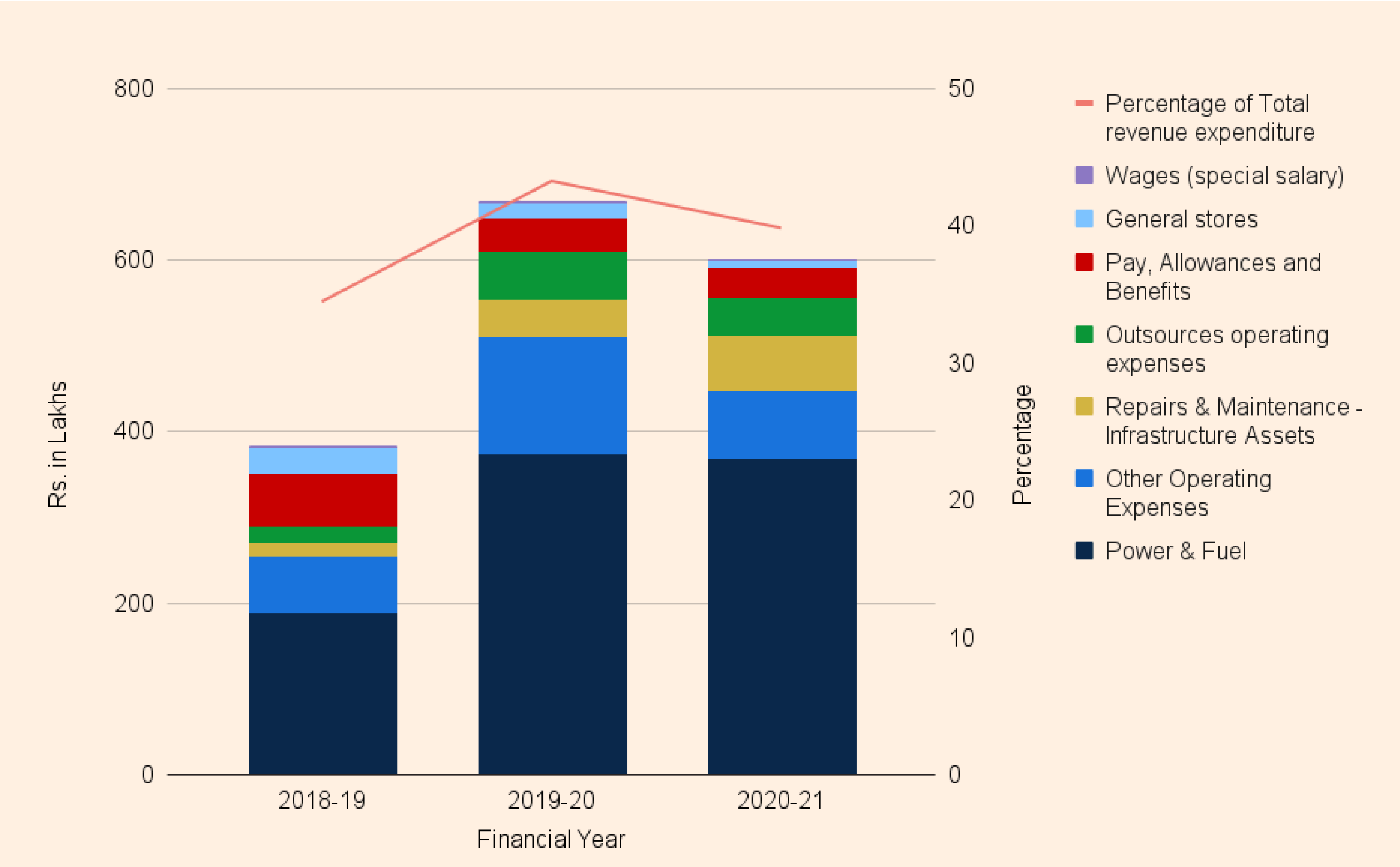
Source: Chintamani CMC budget documents for FY 2020-21, 2021-22, 2022-23

Electricity charges[11] account for more than half of the operating expenses for water supply. As a proportion of overall revenue expenditures, water supply is thus a significant component coming up to between 34% and 43%. High electricity charges could be attributed to continuous running of borewells apart from other water distribution infrastructure.

[10] Un-tied implies flexibility to use funds for different functions or services of the ULB vs tied where it is specified as only to be spent for, say, drinking water

[11] Tariff category HT-1 is applicable for water supply and sewerage infrastructure based on demand charges (fixed based on sanctioned load) and energy charges (based on consumption)

Figure 4.2 Water supply revenue expenditure



Source: Chintamani CMC budget documents for FY 2020-21, 2021-22, 2022-23

The municipality faces challenges with meeting operational expenses

In the broader context of municipal budgeting challenges, a 2020 World Bank report underlines the substantial financial requirements for India's urban infrastructure. Projections suggest that cities and towns necessitate an estimated capital investment of 840 billion USD (Rs. 67,200 billion) over the next 15 years until 2036, with over half of the portion dedicated to essential infrastructure like water, sanitation, and roads. The report emphasises that current investment levels are notably lower than these needs, with the fiscal transfers from state and national governments being the primary financing mechanism that has increased over time. ULB revenue surpluses make up about 15%, with loans from Housing and Urban Development Corporation Ltd (HUDCO) accounting for 8% of total capital expenditure and only 5% is sourced through debt financing by ULBs and Public Private Partnerships.

The financial challenges faced by small and medium ULBs are pervasive, with their revenue streams failing to keep pace with the escalating demand for essential services. Our analysis of Chintamani's budget revealed three key reasons behind the town's ongoing struggle to meet its operational expenditure; these points could also apply to other small towns in the region and thus hold wider implications:

- **Unauthorised connections**: While the CMC claims that piped water supply network reaches most households in town, the municipality's records in 2021-22 showed only 8,308 water supply and 4,381 sewerage connections. The glaring disparity, considering the town's 20,000-plus households, indicates a high number of unauthorised/illegal connections.
- **Flat tariff structure**: The Chintamani CMC employs a flat tariff structure of Rs. 820 for residential and Rs. 1,640 for commercial establishments per annum. The last revision of water charges took place in the year 2016 , reflecting a lack of responsiveness to changing economic dynamics.
- **Gap between receivables and receipts**: As per the audited accounts for financial years 2020-21 and 2021-22, there appears to be a significant gap between the accrued income (receivables) from water and underground drainage charges, amounting to Rs. 540 lakhs, and the actual receipts recorded under the Water Supply Fund, which is only Rs. 18.9 lakhs for FY 2020-21 and Rs. 23.5 lakhs for FY 2021-22, respectively (Chintamani CMC, 2022b). The stark difference raises concerns about the municipality's ability to verify whether the receivables can be accounted against the municipality's dues as the Demand Collection Balance register is not updated. As a result, the verification of the legitimacy of receivables becomes challenging, impeding effective financial management.

As we conclude this section, we are left with an important question: how does a ULB manage to cover its operational costs? In the case of Chintamani municipality, a large sum comes from the Karnataka state government, which releases electricity grant matching the power bills incurred by the municipality. Another vital contributor is the State Finance Commission which covers salaries and thus reduces the deficit to a range of 20-30%, demonstrating a reliance on strategic financial support mechanisms to navigate fiscal challenges. Data for 14 cities, including some state-level averages, show that they recovered less than half (45%) of O&M costs pertaining to water supply, on average, let alone capital costs. Low O&M cost recovery rates indicate that service charges are well below the required levels for financial sustainability, and thus undermine the viability of infrastructure without substantial fiscal support (Athar et. al 2022).

This report focuses mainly on the hydrology aspect of the region and therefore, we are unable to provide more concrete steps in terms of governance and finance. This is a hefty part of the puzzle that needs separate analyses. The key takeaway is that water supply infrastructure is a huge drain on the municipality's finances particularly because of the energy required to run borewells in such a groundwater-dependent region. The larger institutional framework in place also limits the municipality from breaking out of current unsustainable models they are locked into. They remain beholden to external grants to provide basic services.

5. CONCLUSION

From water budgeting to water security planning.

Credit: Shashank Palur, WELL Labs

This study involved primary data collection – interviews and field visits – as well as an extensive review of secondary resources to map how water flows through a small town in semi-arid peninsular India. We quantified sources, storage and wastewater, a comprehensive picture that is necessary to enable better water management through strategic interventions.

We divided this report into three key sections. The first contains the meat of our quantitative analysis as we detail the data we gathered and calculated on Chintamani's water balance. We explained our methods and its limitations. Groundwater and surface water sources are interlinked but we split out analysis based on this categorisation because it allowed us to go into each resource's unique characteristics and challenges. We concluded with a primer on the state of governance and finance in Chintamani to illustrate that water management needs to be made more efficient to enable cash-strapped municipalities to save money.

Understanding the aquifer is key towards sustainable groundwater management

One of the most important insights is that nearly 80% of Chintamani's drinking water requirements are being met through municipal borewells as well as privately-owned borewells and tankers. This places a significant burden on the aquifer underlying Chintamani, which is characterised by weathered-fractured hard rock that has relatively limited storage potential and is being overexploited. With borewell failure rates in the past being 40%, developing a conceptual understanding of the aquifer characteristics, its storage/recharge potential and the consumption patterns across domestic, commercial and institutional segments remain key to developing an aquifer management plan.

An important step in putting together this plan is to delineate and characterise the aquifer through methods such as geophysical techniques, borehole lithology etc,. There is also a push from the level of the central government through flagship schemes such as the AMRUT mission, which mandates cities to prepare an urban aquifer management plan. The Central Ground Water Board leads the National Project on Aquifer Management (NAQUIM), which aims to map aquifers with a thrust on participatory groundwater management.

This brings us to another critical point, which is that Chintamani, being a small town and not a sprawling metropolis, is largely unbuilt. This means that fallow land, green spaces and water bodies have not yet been encroached upon by concrete structure and impermeable surfaces. There is a brief window of opportunity to develop and implement a blue-green infrastructure plan that could capture and store water, and also recharge the aquifer.

Rejuvenation of water bodies and improving sewage treatment remain key to meeting town demand in turn lowering groundwater dependence.

The state of underground water sources are closely linked to above ground water bodies like lakes. Our analysis showed that rejuvenating Chintamani's largest water body – Nekkundi lake and smaller lakes in the city, such as Malapalli, could supplement the current solitary surface water source of Kannampalli lake to provide up to 4 MLD. This accounts for ~50% of the town's current freshwater requirements.

But for this to take place, addressing the sewage infrastructure gap of 65% (3.72 MLD[12]) is key to ensuring that water bodies remain pollution free. Right from our first conversations with municipality members and other stakeholders in the region, it was apparent that the flow of raw sewage into lakes is a major concern in terms of public health. Moreover, it rendered the lakes in the region unusable.

There is currently only one sewage treatment plant but its low capacity is further undermined by the fact that operations and maintenance, including periodic desludging of ponds, is not carried out properly. Moreover, during our fieldwork, we found that parts of the pipeline network were broken, including those in close proximity to lakes like Nekkundi and Gopasandra, resulting in raw sewage flowing into water bodies.

With improved and more resilient sewerage infrastructure, not only would it become possible to utilise the local surface water sources, it also becomes possible to pump in or *import* water. The recently-commissioned Bhaktharahalli Arasikere project, which is slated to supply 3 MLD of water, could mean that the town potentially shifts from being groundwater dependent to being surface water reliant. This would also allow for the aquifer to recharge and be used to meet deficit or future demand.

High operational expenditure along with low O&M cost recovery makes it challenging to operate water supply infrastructure

Analysis of the town's revenue expenditure showed that 40% is spent on running water supply infrastructure. Electricity and fuel charges account for a majority share, incurred as a result of running borewells as well as pumping infrastructure. On the other hand, unauthorised connections to the network form a large component of non-revenue water. Out of 20,000 households, CMC records in 2021-22 showed only 8,308 water supply and 4,381 sewerage connections while network coverage claimed to cover most parts of the town.

Apart from employing a flat tariff structure that was last revised in 2016, there appears to be a huge disparity between the accrued income (receivables) from water and underground drainage charges as opposed to actual receipts. Further, there are staff shortages at the level of essential workers such as *pourakarmikas* and water supply staff that hinder service delivery of water supply and sanitation infrastructure.

Chintamani is representative of other towns in Karnataka

The case study of Chintamani offers valuable insights into the complexities of governance and finance surrounding water supply and sewerage infrastructure in towns. There is a high reliance on external sources – central and state government schemes and finance commission grants to fund capital expenditure – coupled with challenges in terms of navigating a complex institutional framework of district-level authorities and parastatal

[12] We estimated that the total amount of wastewater generated in the town is 5.72 MLD. With the STP here having a capacity of 2 MLD, an estimate of the amount of untreated sewage amounts to 3.72, indicating an infrastructure deficit that fails to treat 65% of wastewater produced.

agencies in planning and implementing water supply and sewerage infrastructure at the town level.

Chintamani also serves as a valuable reference point to illustrate the interconnectedness of surface and groundwater sources, and how improved water management practices in small Indian towns can make a significant difference in the quality of life for local communities. In this regard, employing analytical tools such as a water balance could play a significant role in reshaping water management and thus the landscape.

How can water balances help planning for towns in India

The water balance charts a journey from data to decision, and is guided by participatory approaches and institutional integration. It offers a blueprint for achieving sustainable water security. As Indian cities, especially small towns, grapple with the escalating challenges of water management, initiatives such as the Jal Jeevan Mission - Urban (JJM(U))[13] have mandated water balance plans for all cities, encompassing 4378 statutory towns. Aligned with the framework set by these flagship schemes, city water balance tools have become integral, providing municipal officials and stakeholders with a robust foundation for water resource assessment and management.

In the context of small towns, where short-term planning, insufficient budgets and a dearth of data-driven management practices prevail, the introduction of water balance tools becomes transformative. Applying a water balance helps quantitatively assess whether an urban region's water resources are at risk and identifies gaps that must be targeted. Integrating findings from the water balance into the region's water security plans is essential to formulating a dynamic and adaptive strategy for resilient water resource management.

Preparation of a water security plan has to be a collaborative and inclusive process, actively involving stakeholders at every level, from state/district/town decision-makers to local communities. An enhanced understanding of local water dynamics can facilitate the development of targeted interventions to address town specific water challenges, such as narrowing down areas for new borewells or rejuvenating lakes. Planning should provide for short-term adjustments for immediate challenges, encourage medium-term objectives by identifying trends and emerging issues, and support the development of a long-term vision for sustainable water resource management.

As we conclude, it is important to acknowledge that development of a water balance and water security planning necessitates specialised knowledge and skills, which may not be readily available, particularly in small towns with limited resources. This may pose a hurdle to scaling up such an initiative across municipalities in India. Institutionalising the water balance creation process would mean embedding the practice within the administrative framework of each municipality, complete with access to relevant datasets as well as trainers who can build capacity. However, this is not a straightforward task and demands a considerable investment in terms of time, resources, and soft infrastructure.

[13] The Jal Jeevan Mission was first launched with a focus on rural water supply infrastructure. JJM-Urban is the new chapter of the Atal Mission for Rejuvenation and Urban Transformation (AMRUT).

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Annexure 1: Chintamani's lake volume estimation and water availability analysis

Lake volume estimation

Lake Name	Area(m2)	Depth(m)	Volume (Million Litres)
Nekkundi	4,70,427	0.98	461.02
Malapalli	88,791	1.2	106.55
Chikka Kannampalli	31,305	1.2	37.57

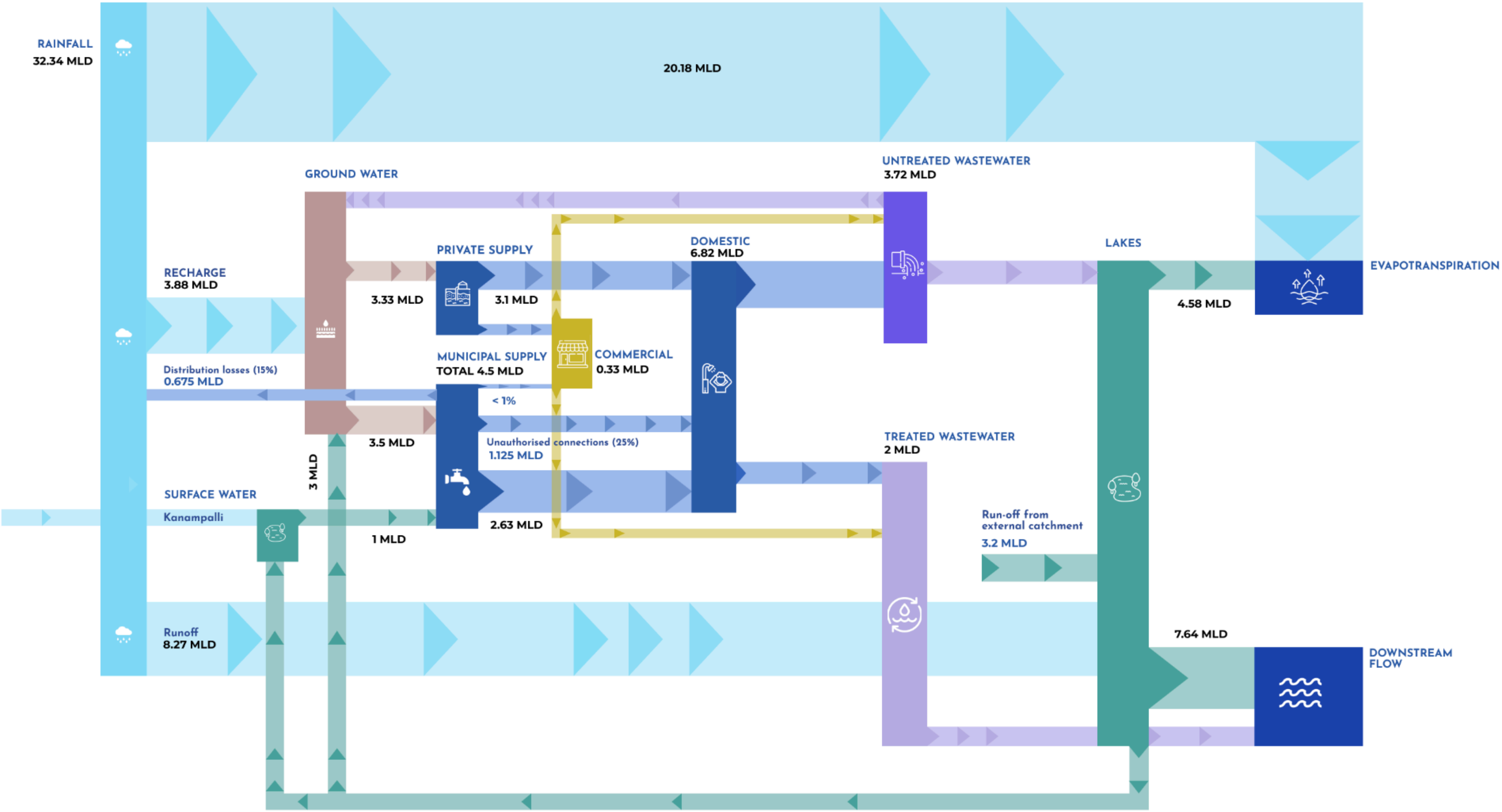
Source: GIS analysis carried out by WELL Labs

Lake water availability estimation

Description	Unit	Nekkundi	Malapalli	Chikka Kannampalli
Storage capacity	Million Litres	461.02	106.55	37.57
Siltation	20% of total storage capacity	92.2	21.31	7.51
Getting filled	70% of total storage capacity	322.71	74.58	26.30
Evaporation & Percolation	30% of Water Getting Filled	96.81	22.38	7.89
Effective capacity	Million Litres	272.00	62.86	22.16
Number of days	Days	150	100	100
Total Water Available	Million Litres	1.81	0.63	0.22

Source: *Analysis carried out by WELL Labs*

Annexure 2: Water Balance Chart Source: Analysis carried out by WELL Labs



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