Situation Analysis Report: Chikkaballapur-Chintamani Transformation Lab

Sustainable Transition Explorations in Water and Agriculture for Resilient Dryland Systems (STEWARDS)

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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. We design and curate systemic, science-based solutions using a collaborative approach to enable a high quality of human life while simultaneously nurturing the environment.

WELL Labs is based at the Institute for Financial Management and Research (IFMR) Society. Together with Krea University and other centres at IFMR, such as the Abdul Latif Jameel Poverty Action Lab (J-PAL) South Asia and Leveraging Evidence for Access and Development (LEAD), WELL Labs is part of an ecosystem of labs and research centres with a mission to help prepare for an unpredictable world.

Dr Veena Srinivasan, a water expert with 20 years of experience, set up WELL Labs in 2023. She is leading the centre's mission to transform scientific research into real-world impact by designing solutions that simultaneously create livelihoods and conserve the environment.

About STEWARDS

Sustainable Transition Explorations in Water and Agriculture for Resilient Dryland Systems (STEWARDS) addresses the critical need to identify equitable, sustainable and climate-resilient development pathways in tropical drylands. The project is creating long-term data, tools and capacities to achieve transformational change.

Our focus in India is on 'Transformational Labs' (T-Lab) that capture the complex challenges of rural/urban water resilience under rapid development. The T-Labs are envisioned as collaborative spaces where people take an active role in co-developing sustainable, equitable pathways. To ensure these pathways are both sustainable and socially just, we attempt to understand how the power dynamics, priorities and capacities differ among different actors and how those of under-resourced and marginal stakeholders, in particular, can be strengthened.

Under this project we will be working in two T-Labs in semi-arid regions of peninsular India (Chikkaballapur-Chintamani and Raichur-Koppal districts). Both T-Labs are at the urban-rural interface, with shallow and deeper aquifers depleted for almost two decades.

About the Authors

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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. Cities are continuously sprawling outward with expanding urban boundaries. This over-spill of population and increasing demand for resources such as water and agricultural produce is accommodated within and by the peri urban interface of cities. Small and medium sized towns are also playing a vital role in the process of peri urbanisation in India but are not taken into account in the literature. (Shaw & Das, 2018)

A periurban interface is a socioeconomic-environmental interface where all three systems comprising agriculture, urban dimension, and natural resources constantly interact with one another (Allen, 2003; Narain & Nischal, 2007). The fact that what is peri urban today would be urban tomorrow makes it significant to plan for sustainable development of peri urban areas, specially through the lens of water security. Many towns already grapple with meeting the requirements and ambitions of their growing populations, lacking essential infrastructure for even fundamental services, particularly in water and sanitation.

Chintamani is one such town, situated in the Deccan Plateau, to the north of the capital Bengaluru in Karnataka in Chikkaballapur district, and is a representative of many towns located in semi-arid climatic zones in India that are plagued with problems described above. The district has no perennial water sources for agriculture or drinking water purposes. The only source is groundwater, which has been overexploited in the district.

The town is plagued by challenges related to both groundwater and surface water management. Some of the concerns the town is dealing with currently:

- *A high borewell failure rate due to* a lack of knowledge on the geology and aquifer of the region.
- *Using funds to pump water extensively leaving* little funds to operate and manage water and wastewater infrastructure.
- *Unaccounted water use* leading to revenue losses for the municipality and a lack of clarity on demand.
- *Dumping of untreated sewage* into water bodies polluting surface water resources.

Limited financial resources, staffing, and technical capacity 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. A report by Ramamoorthy et al. (2024a) documents the current scenario of water flows in the town and delves into its water problems. Drawing insights from the same report, this situation analysis lays out the next steps towards creating a more water secure Chintamani.

1.0 The Chintamani-Chikkaballapur T-Lab

Chikkaballapur district falls in the south-eastern part of Karnataka, very close to Bengaluru, the capital city of Karnataka, India. Chikkaballapur district was carved out from the existing Kolar district in 2007. The district has 6 Talukas - Gowribidanur, Gudibande, Bagepalli, Chikkaballapur, Sidlaghatta and Chintamani.

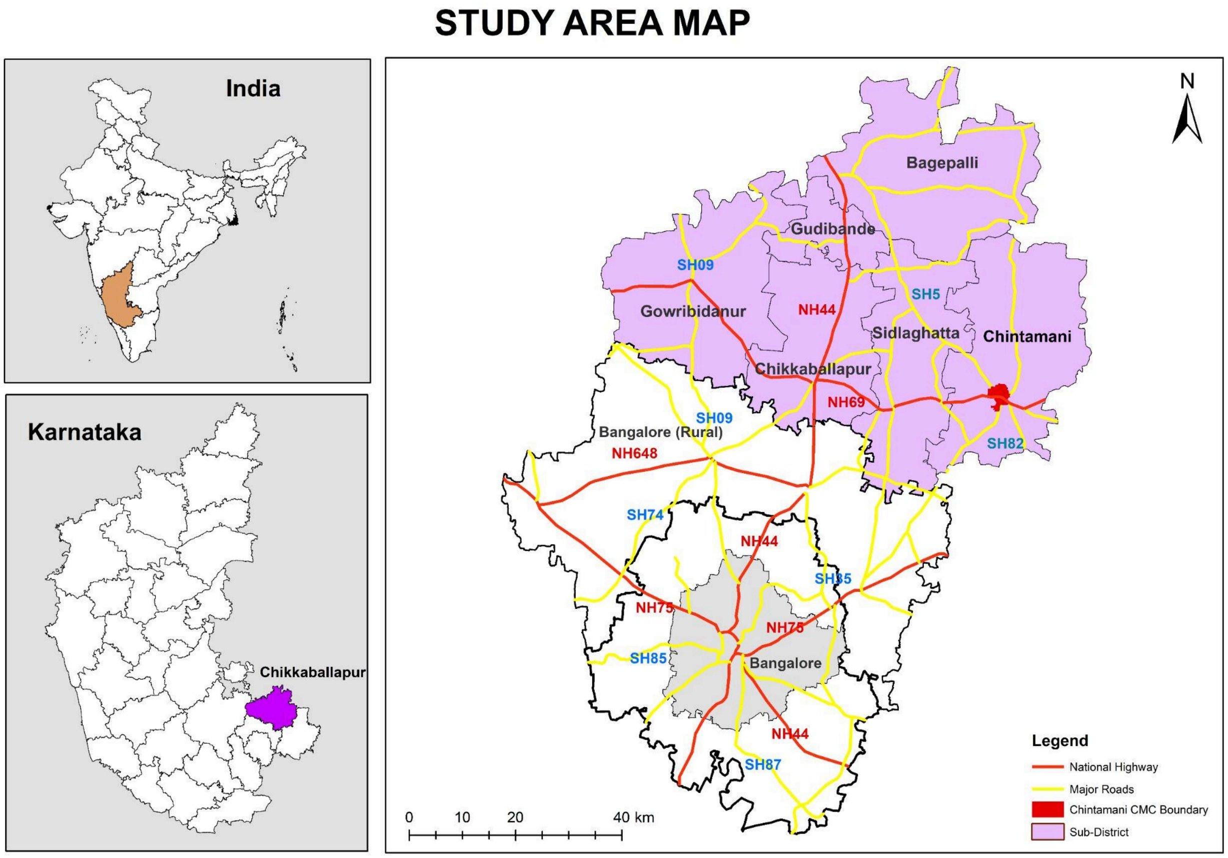

Figure 1: Map of Chikkaballapur district and Chintamani town

The town of Chintamani (latitude 13.4020 N, longitude 78.0551 E) will be our main focus in this district, which is the administrative headquarter (taluka) of the district. Situated in the Deccan plateau, Chintamani is located at the urban-rural interface, and is classified as an urban centre. It is also the economic centre for the district. Chintamani lies about 75 kilometres from Bengaluru and the current population is estimated to be 92,802.[1] Hereafter Chikkaballapur district and Chintamani town will be mentioned as Chikkaballapur and Chintamani respectively.

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[1] Chintamani City Municipal Council (CMC)

1.1 Chintamani-Chikkaballapur T-Lab

According to the most recent Population Census conducted in 2011 for Chikkaballapur, the total population was 12.54 lakhs (1.2 million)[2] with a sex ratio of the district is 968 females per 1000 males. The density of population is 298 per km^2 with most of the population residing in rural areas.

According to the District Disaster Management Plan of Chikkaballapur 2019-20, Chikkaballapur district is located in the Southern-interior region of Karnataka state, which is drought prone and falls in the arid tract of the country. The climate of the district can be termed as mild to severe, with mild winters and hot summers. December is the coldest month with mean daily minimum of 15.7 degrees Centigrade, while April is the hottest month with mean daily maximum temperature of 36.0 degrees Centigrade. Relative humidity of over 75% is common during monsoon. Wind speeds exceeding 15 km/h are common during the months of June and July. The recorded annual potential evaporation is around 1950 mm with May registering over 220 mm and December around 120mm. The normal annual rainfall of the district is 621 mm. The annual number of rainy days is about 30 – 35 days. Nearly 67% of the rain is received during the southwest monsoon period (June- Sept) and the northeast monsoon contributes about 14%, during the post monsoon period.

Chikkaballapur District

The district has a geographical area of 4045 km^{2,} of which approximately 12% is classified as forest area, with mostly dry deciduous and scrub type vegetation. Agriculture is the predominant economic activity in the district, with cultivators (1.98 lakh) and agricultural labourers (1.54 lakh) constituting 55% of the total working population of 6.4 lakh (NABARD, 2020-21). The predominant food crops grown are ragi, maize, tur dal and groundnut.

The district is the commercial hub for the silk industry. It is the second-largest district practising sericulture with an average cocoon production higher than the state average. To cater to the needs of the sericulture farmers there are five government grainages at Chadalapur, Chintamani, Gowribidanur, Sidlaghatta, Thalagawara and there are 65 private licensed seed preparers. The government provides subsidies for drip irrigation, rearing equipment, constructing rearing houses and incentives for cocoon production. (Chikkaballapur, Digital India 2013)

According to the District Disaster Management Plan of Chikkaballapur 2019-20, the district has been identified as a chronically drought prone area. This is mainly attributed to water intensive crops, lack of water conservation measures and

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[2] 1 lakh = 1,00,000

drainage systems. Chikkaballapur district has one of the highest poverty levels in the state with per capita incomes in 2015-16 of ₹99,600/- that are below the state average of ₹1,42,267 (Nabard, 2020-21).

A study by Esteves et. al., 2016 states that the district is predominantly rainfed with a low percentage of land area under irrigation, making it highly vulnerable to climate variability. A study by Kumar, Raizada and Biswas (2014) found that among districts in Karnataka, Chikkaballapur has "moderate equity", measured in terms of access to livelihoods and political systems regardless of class or caste. Economically, the district is primarily dependent on agriculture. The GDP during the period of 2019-20 was ₹20,54,320 lakh at current price (Indiastatdistricts, n.d).

Urban and Rural components of Chikkaballapur District

The district comprises a mix of rural villages and urban towns. The Karnataka Population Census of 2011 states that there are 115 villages in the districts. There are six urban towns (4 City Municipal Councils & 2 Town Municipal Councils) that also serve as taluka headquarters – Chikkaballapur, Sidlaghatta, Chintamani, Gowribidanur, Gudibande and Bagepalli. This T-Lab will focus on Chintamani town.

Chintamani Town

Table 1: Population and households in Chintamani. Source: Census 2011 and Chintamani City Municipal Council

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

According to the Census 2011, the literacy rate in Chintamani town is 84%. Chintamani has a higher literacy rate compared to 70% across Chikkaballapur district. The male literacy rate is 88% whereas the female literacy rate is 79% (Karnataka Census, 2011). The town's economy is based on agriculture and produce from Chintamani is one of the main sources of food supply to Bengaluru. The average sex ratio of Chintamani town is 984 females per 1000 males. The population of children aged 0-6 years in Chintamani city is 8,437 accounting for 11% of the total population. Chintamani City Municipal Council (CMC) is administratively divided into 31 wards. As per one estimate, Chintamani's population has risen by 22% from 76,068 in 2011 to 92,802 in 2022 (Ramamoorthy et al., 2024a).

The Karnataka Census conducted in 2011 mentions that the percentage of total workers in Chintamani is 50.2 percent. The data suggests a significant gender gap in workforce participation in Chintamani, with males accounting for nearly three-fourths of the total workers. Out of the total population, 30,592 people were engaged in work or business activity in Chintamani City Municipal Council area. Of these, 22,268 were males and 8,324 were females. Total percentage of Agriculture farmers is 15.3 percent and the labour percentage is 12.4 percent in Chintamani.

Figure 2 shows the ward map with the population distributed according to the Census of India 2011.

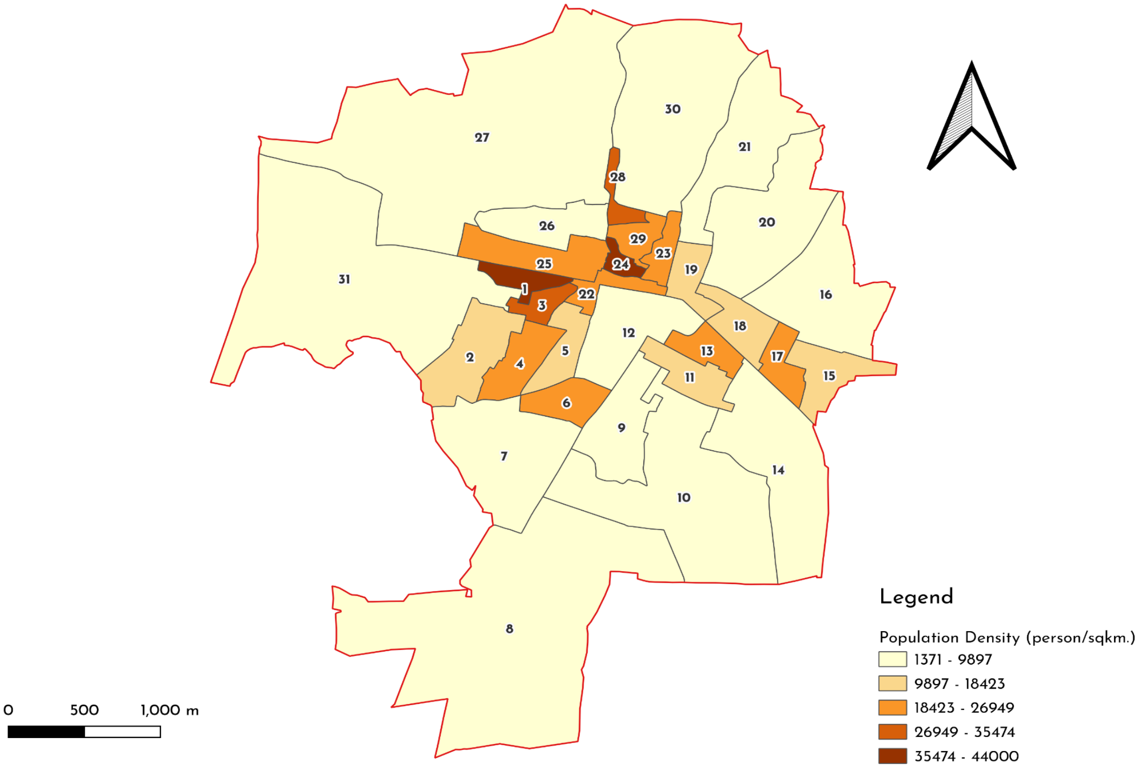

Figure 2: Ward map of Chintamani CMC and population density. Source: Ramamoorthy et al., 2024a

1.1 Water Availability

1.1.1 Rainfall

Chikkaballapur district experiences high inter-annual rainfall variability around a range of 220- 510 mm. (Chikkaballapur District Disaster Management Plan, 2019-20).

Chintamani also has similar inter-annual rainfall variability, experiencing cyclical years of drought and excess rainfall. Similar to the wider district, Chintamani has a dry agro-climatic zone, receiving mean annual rainfall of 787 mm during the southwest monsoon period between June to September every year, which is lower than the state mean annual average of 1,153 mm.

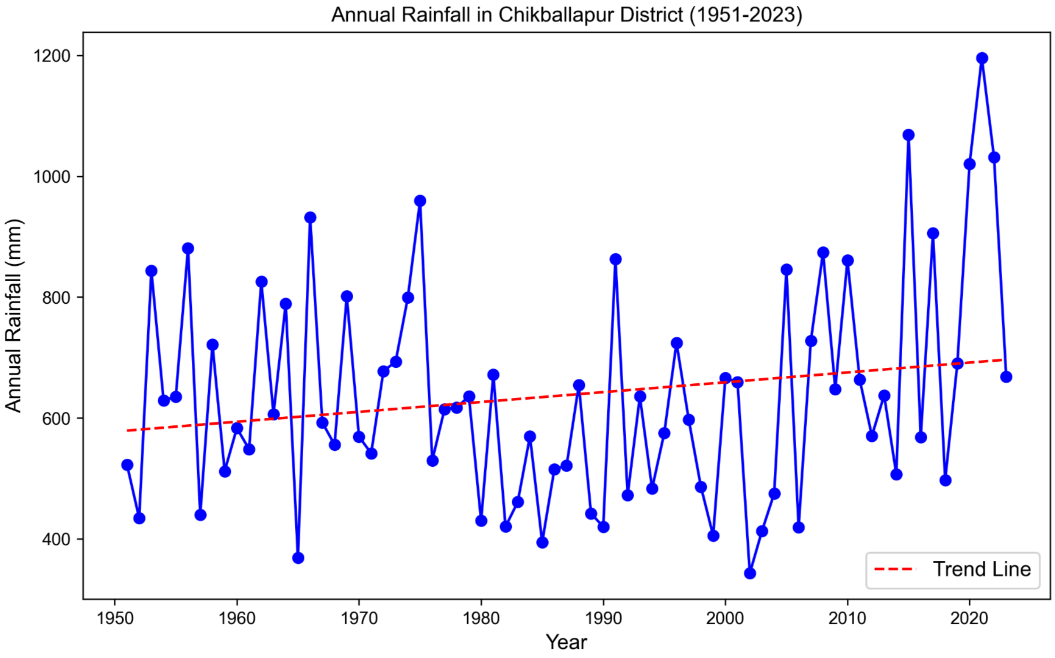

Figure 3: IMD gridded datasets (0.25*0.25) of Annual rainfall in Chikkaballapur District. Source: Pai et al., 2014

To assess the projected impact of climate change in the region, downscaled debiased datasets covering the Indian subcontinent (Mishra et al.,2020) were explored. Over the period from 1951 to 2014, The climate predictions are driven by a bundle of land-use scenarios and emissions built on the Shared Socioeconomic Pathways (SSPs) scenarios, and new future social development pathways (O'Neill et al., 2016). SSPs are based on five narratives describing alternative socio-economic developments, including sustainable development, regional rivalry, inequality, fossil-fueled development, and middle-of-the-road development (Riahi et al., 2017). The datasets, representing four scenarios (SSP126, SSP245, SSP370, and SSP585)[3] forced in the Coupled Model Intercomparison Project phase six (CMIP6) model, were used for this exercise.

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[3] SSPs are shared socio-economic pathways

Chikaballapur experienced an average annual rainfall of 581 mm, with a discernible decreasing trend in annual precipitation. **Erratic rainfall patterns with strong inter-annual variability, ranging from 241 to 882 mm characterises precipitation in the region. The projected precipitation trends exhibit pronounced inter-annual variation and precipitation range varies according to the scenarios.** However, compared to the historical period (1951-2014), there is an overall increasing trend in mean precipitation across all scenarios except SSP126, which shows a decreasing trend.

The temperature has also exhibited a rising trend over Chikkaballapur. Between 1951 and 2014, mean maximum temperature rose by 0.60°C whereas the mean minimum temperature rose by 0.83°C. The rise in Minimum temperature is more pronounced than maximum temperature. It is anticipated that the rise in minimum temperature will be more pronounced than the maximum temperature. This elevated temperature is likely to adversely impact agricultural outputs and the regional economy.

1.1.2 Groundwater Profile

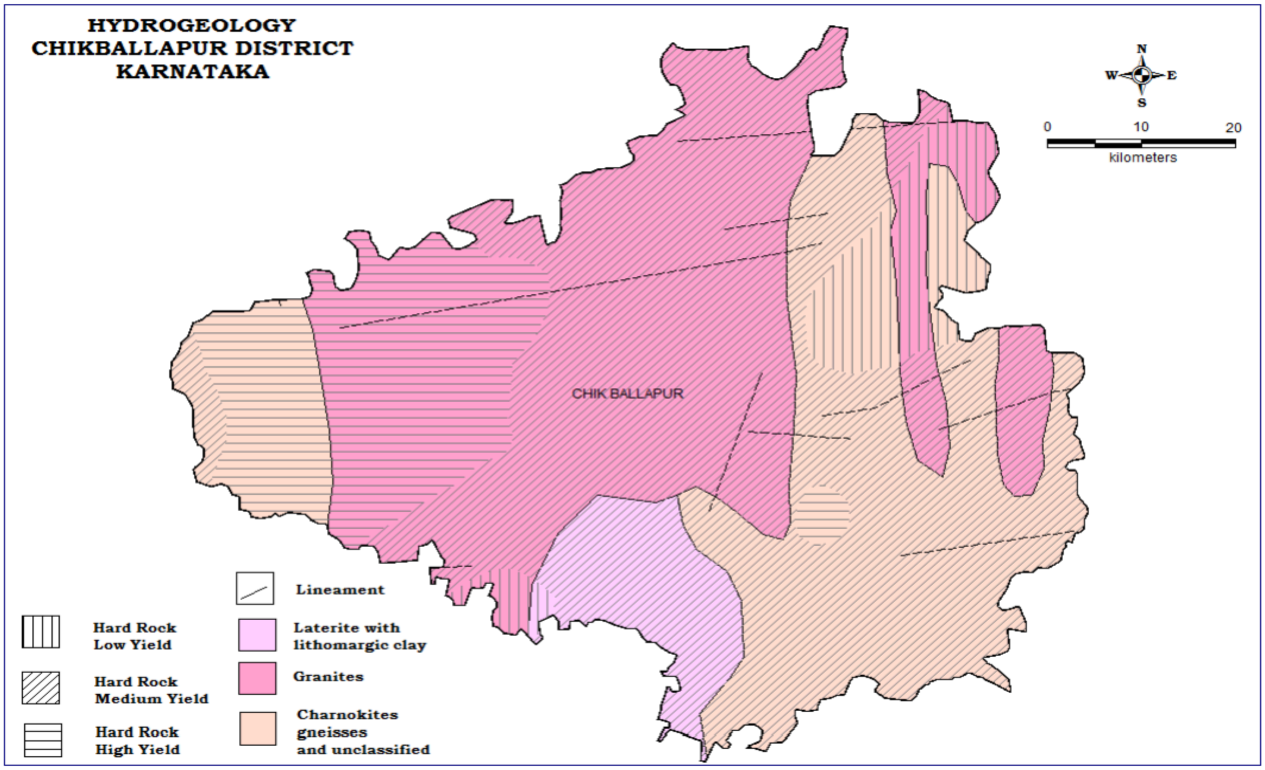

Figure 4: Hydrogeology Chikkaballapur District, CGWB 2012

The district of Chikkaballapur has no perennial water sources for agriculture or drinking water other than groundwater, which has been overexploited. Groundwater occurs under phreatic (unconfined) and semi-confined to confined conditions. The thickness of the regolith overlying the crystalline bedrock varies from 6 to 18m across the majority of the district, except in parts of Sidlaghatta and Chikballapura taluks, where it varies from 40 to 60 m. The depth of water level in monitoring wells generally ranges from 12 to 49 mbgl (m below ground level). The general mode of ground water abstraction is through borewells in the district. This aquifer system is developed by borewells ranging in depth up to 300 m. Well yields range up to 1200 m3/day and can be highly variable. Most of the groundwater abstracted in the district is used for agriculture (Groundwater Information Booklet, CGWB 2012).

The district is underlain by hard-rock aquifers. The variety of rocks found in the district has been classified into four categories.They are 1) Dharwar Schists 2) Gneissic Complex 3) Dolerite dykes and 4) Laterite.

Dharwar Schists are a type of metamorphic rock that form transmissive aquifers when weathered and fractured. Groundwater in these aquifers is typically found under phreatic (unconfined) conditions in the weathered zone, and under semi-confined or confined conditions within the fractures and fissures of the bedrock. The Gneissic Complex, which includes granite and gneiss, also forms productive aquifers when weathered and fractured. Similar to the Dharwar Schists, the groundwater flowing in these aquifers exists under both phreatic and semi-confined/confined conditions. Dolerite dykes are intrusive igneous rocks that can act as barriers to groundwater flow, creating localised aquifer systems. The groundwater in these dykes is typically found under semi-confined to confined conditions. Laterite, a consolidated weathered product of the underlying regolith, also forms shallow aquifers in some areas of the district. However, the groundwater potential of these laterite aquifers is generally low compared to the other rock types. (CGWB, 2022)

Chintamani is characterised by a weathered and fractured aquifer system made up of gneisses and granites. The groundwater in hard rock areas mainly occurs in top weathered zones and within the joints and fractures at greater depths. The unconfined (unconsolidated) weathered zone (regolith) is considered a source of water storage to the underlying fracture zone, which is semi-confined (CGWB, 2022).

A recent resistivity study (Ramamoorthy et al., 2024a) indicates that the town has an 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 to 15 m
- **Saturated bedrock** with fissures with a thickness of up to 20 m
- **Unweathered bedrock**, commonly referred to as basement rock

Hard rock aquifers underlying Chintamani town can be characterised as having sufficient (although not large) storage permittings usage, but are prone to depletion through excess abstraction, exceeding freshwater capture (Cuthbert et al., 2023) especially during consecutive years of low rainfall (Ramamoorthy et al., 2024a).

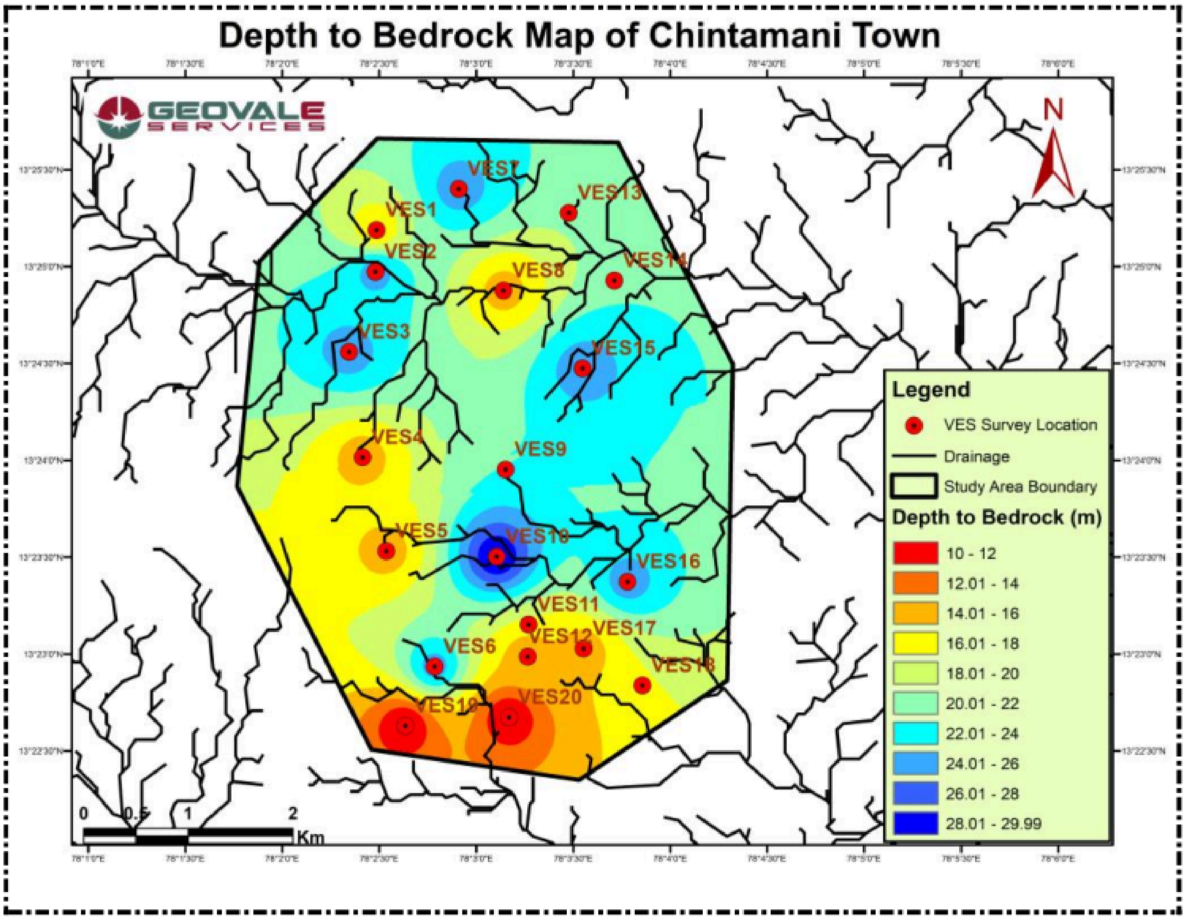

Figure 5: Depth-to-bedrock map for Chintamani town. Source: Vertical Electrical Sounding (VES) surveys carried out by Geoovale, December 2022

The weathered zone provides the capacitive function while the fissured bedrock acts as the transmissive layer. Figure 5 shows the deepest depth to unweathered bedrock occurring 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.

1.1.3 Surface Water Hydrology

Chitravathi, Arkavathy, Papagni and Penna are seasonal rivers flowing through Chikkaballapur district. In Chikkaballapur District there are three river basins namely North Pennar, South Pennar and Palar basins. River Papagni originates near Sidlaghatta district in Karnataka, and flows in the north-eastern direction before joining River Pennar near Kamalapuram, a town in AndhraPradesh. The river has its catchment in the hills of Ambajidurga. The river's catchment area runs through Bagepalli, Chintamani, Sidlaghatta, Madenapally and Chittoor. Chintamani lies in the catchment of Papagni river. The river is seasonal and no river discharge measurements are available (Krishniah, 2014).

Chintamani lies in the upper region of the Palar basin. Chintamani town drains three distinct catchment areas – 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 center of the town (Figure 6).

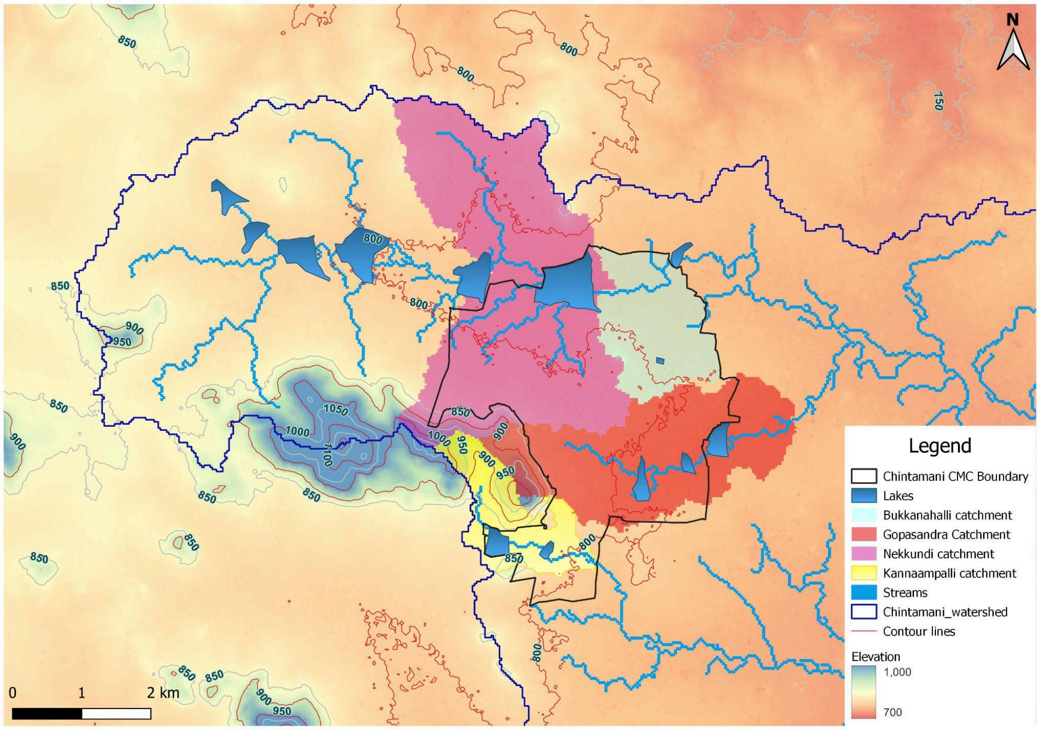

Figure 6: Map of Chintamani town watershed and catchment areas for its lakes. Source: Cartosat 2 from Bhuvan - NRSC, KGIS - KSRSAC

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. 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. 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.

Gopasandra Catchment

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 other lakes – Mallapalli and Chikka Mallapalli in this catchment area.

The final catchment area 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. Though the smallest catchment of the three, Kannampalli is important because, currently, it has been the drinking water source for the town for many years. A water treatment plant treats the water from this lake before supplying it to residents.

Table 2: Catchments in Chintamani town. Source: Ramamoorthy et al., 2024a

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
		Mallapalli	88,791
		Chikka Mallapalli	38,948

Figure 7: Nekkundi (top left), Kannampalli (top right), & Gopasandra (above) lakes in late 2022. Credits: Shashank Palur and Rajesh Ramamoorthy, 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 and plan viable next steps for the town's water security.

1.2 Water Use

1.2.1 Domestic Water Use and Supply

In September-October 2022, WELL Labs together with TIDE-BORDA conducted, on average, 12-15 household surveys per ward, bringing up a total of 427 households. The findings from the household survey were extrapolated to the current projected population of ~92,000. The total domestic consumption was estimated to be **6.9 MLD** (Ramamoorthy et al., 2024a).

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.

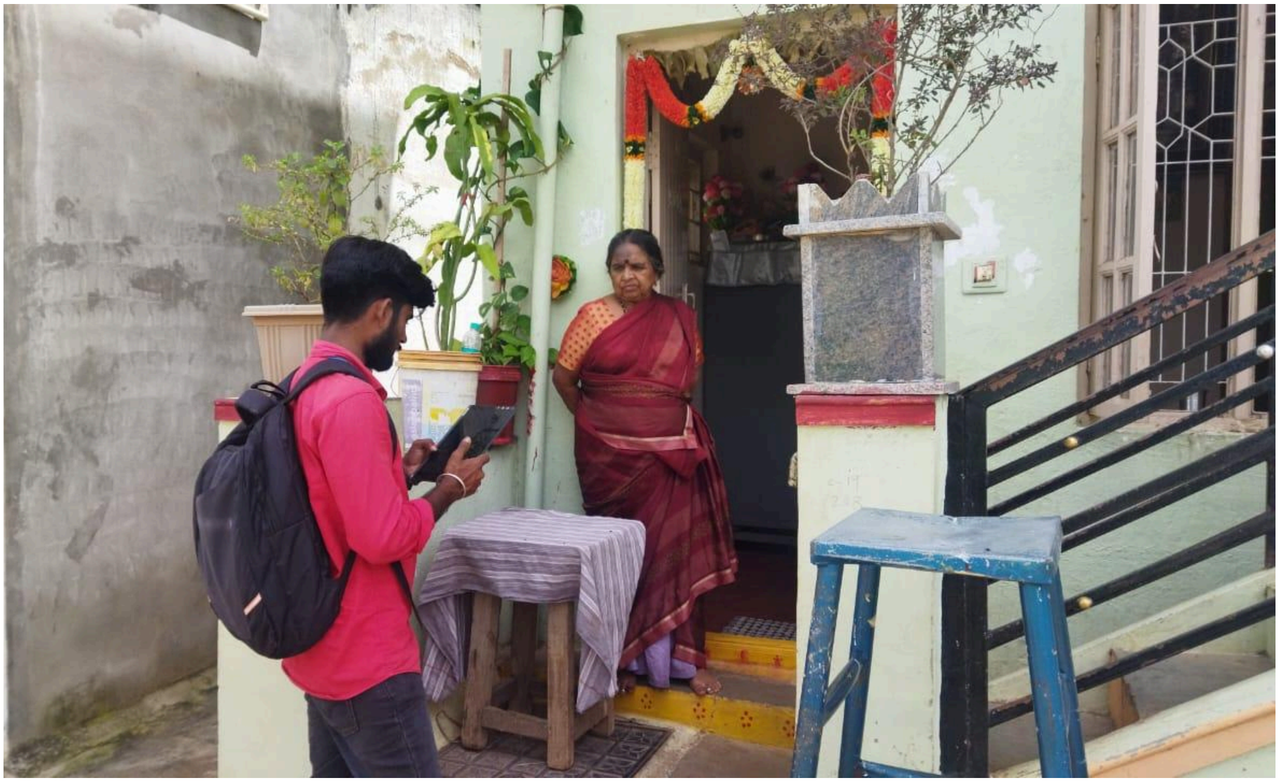

Figure 8: Household surveys on water consumption in Chintamani. Credit: TIDE

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 litres per capita (lpcd) and the remaining 30% consuming significantly higher – 100 - 175 litres per capita. Given the sample size of the household survey, arriving at spatial differences may require further investigation.

Table 3: Water consumption by households. Source: Household survey by WELL Labs-TIDE

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

2.2 Industrial/ Commercial Water Use

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

TIDE-BORDA 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 these are shops and small eateries, followed by garage repair establishments, hospitals and educational institutions.

In July 2022, 537 of these establishments were surveyed to understand their patterns of water consumption and municipal water supply. It was 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. 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 (Ramamoorthy et al., 2024a).

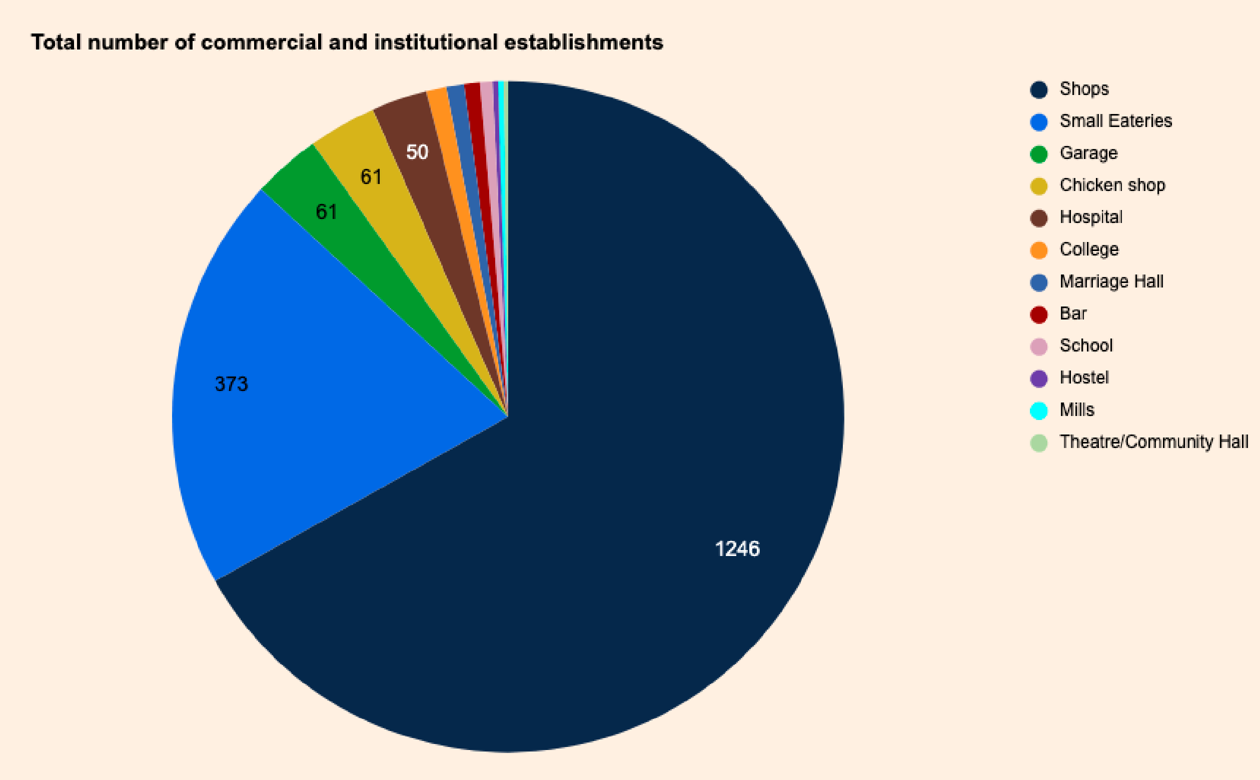

Figure 9: Number of commercial and institutional establishments. Source: Establishments survey by TIDE-BORDA

The surveyed establishments also reported a wide range in water consumption. 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 amounts to a small portion of the overall water demand for the town (Ramamoorthy et al., 2024a).

1.3 Chintamani's Drinking Water System

Kannampalli lake, situated to the southwest of the town, is able to supply 1 MLD of water, which is rationed to last most parts of the year. A jackwell at the lake is pumped to a WTP located 3 km away with a capacity of treating 1.6 MLD.

The performance of the WTP was assessed 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. The CMC has begun the process of rehabilitating the WTP and upgrading its capacity to 3 MLD as well as planning to operationalise the defunct WTP (Water Treatment Plant) at Agrahara and upgrade its capacity from 1.5 MLD WTP to 3 MLD. This will ensure that the town has sufficient capacity to treat water before it is supplied.

In late 2022, a new drinking water supply scheme was commissioned to bring water from Bhaktharahalli Arasikere located 15 km away with a design capacity of 3 MLD, while currently 2 MLD is being used on average.

Water distribution infrastructure of ground-level service reservoirs (GLSR) and overhead tanks (OHTs) and pipeline network dictate which wards receive water from either surface water sources or borewells or sometimes a blend of both. More often than not, a borewell is always considered a dependable source that can plug into the network to bridge deficits. Municipal borewell yields are variable based on rainfall received during years. In good monsoon years such as 2022, supply is increased by 1-1.5 MLD due to increase in water tables.

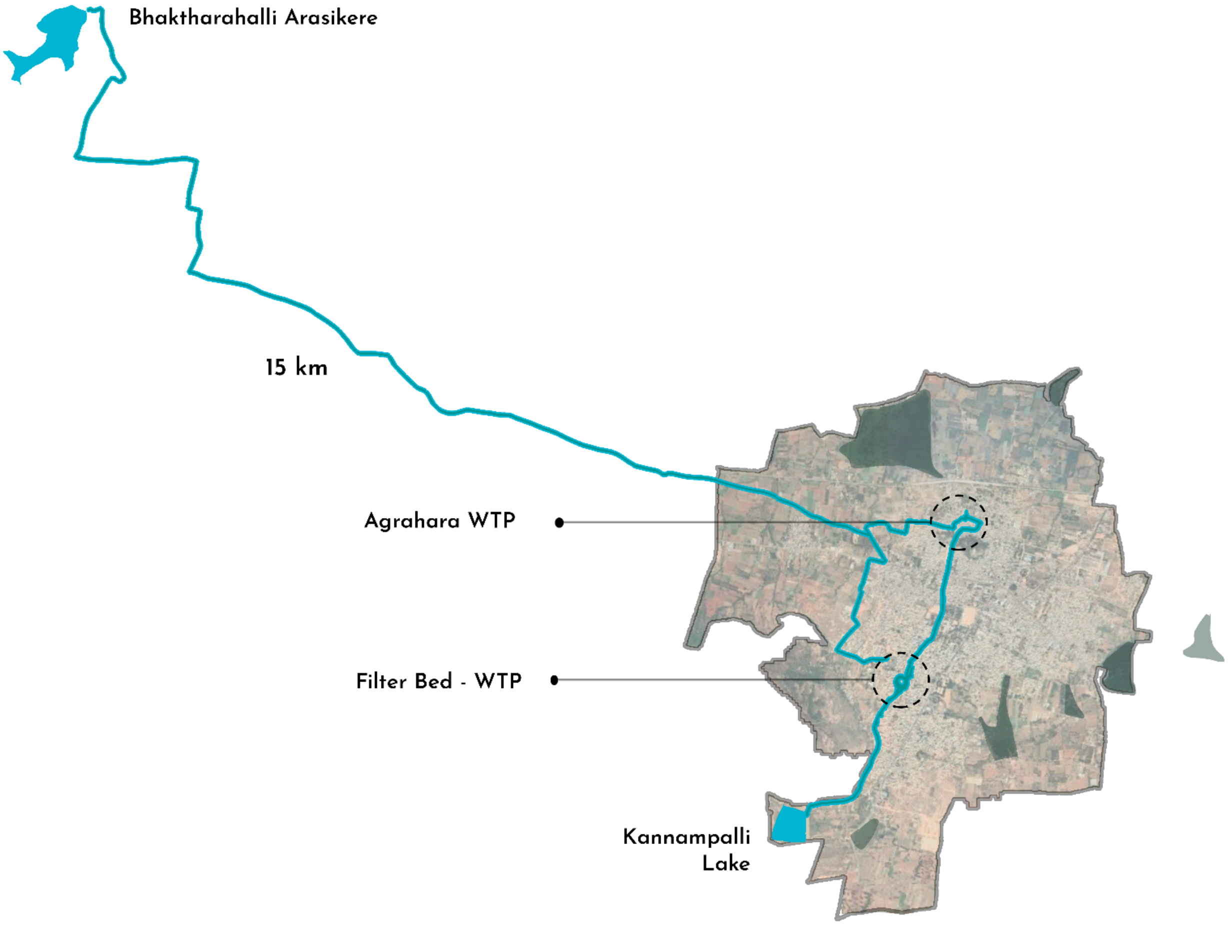

Figure 10: Map of current surface water sources

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

Unauthorised connections to the water supply network are one of the big challenges the town faces. Ramamoorthy et al., 2024a calculate NRW to be 40% of the supply (1.625 MLD) going towards unauthorised connections and the remaining 15% (0.975 MLD) towards leakages through the pipeline network. Table 8 summarises the different components of municipal water supply in Chintamani.

Table 4: Municipal water supply overview from June 2022. Source: Ramamoorthy et al., 2024a

Component	Average annual flow (MLD)
Kannampalli Lake	1.0
Bhaktharahalli Arsikere	2.0
Municipal borewells (Municipal groundwater extraction)	3.50
Municipal supply: Total	6.5
Data source: CMC officials	
Non-revenue water: Leakages	0.975
Non-revenue water: Unauthorised	1.625
Non-revenue water: Total	2.6
Data sources: CMC officials for unauthorised connections. ADB report for overall NRW average for towns	
Groundwater recharge from freshwater pipelines	0.975

1.4 Chintamani's Overall Water Balance

Ramamoorthy et al., 2024a estimates Chintamani's water balance accounting for **rainfall, run-off and recharge**. Built-up spaces are factored in as run-off rates are dependent on the extent of built and unbuilt spaces. The built up space increased to 21% in 2021 from 7% of the built-up land in 1994 in Chintamani. Currently, a significant portion of land within municipal limits remains un-built; around 75% of the 15 km^2 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.

For Chintamani town, evapotranspiration loss was calculated to be 20.19 MLD (Ramamoorthy et al., 2024a). This includes evaporation that occurs through soil and other surfaces as well as water released from plants into the atmosphere.

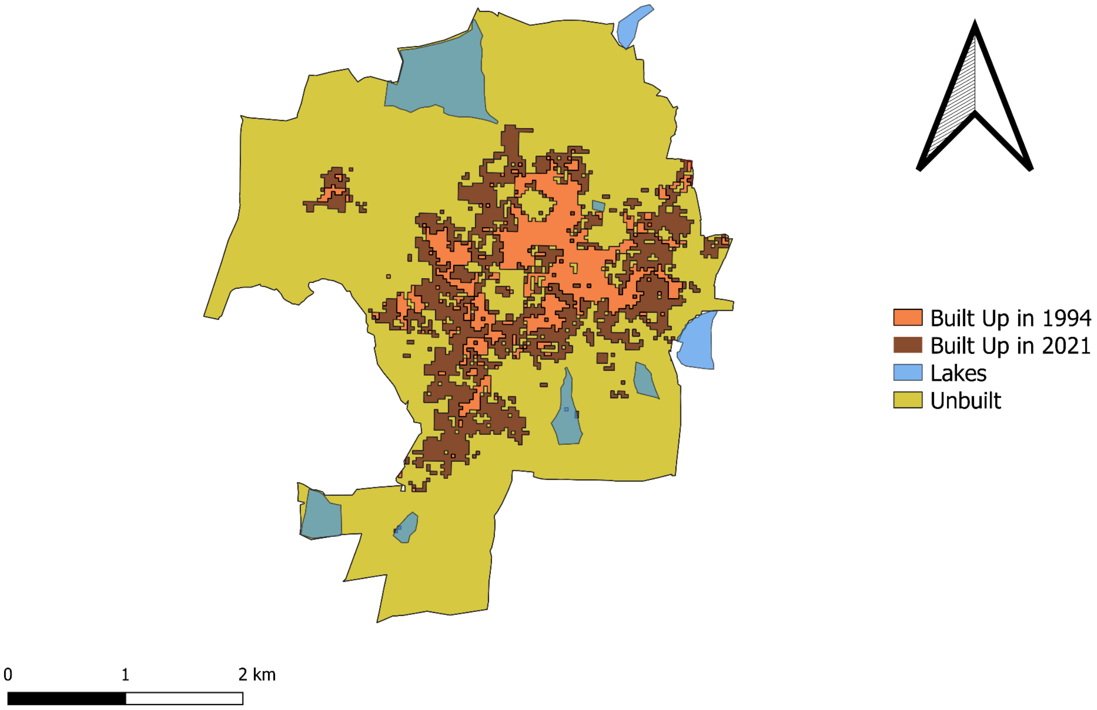

Figure 11: Land use in Chintamani town, 1994 versus 2021. Source: Landsat 8, USGS

Table 5: Chintamani's water balance. Source: Ramamoorthy et al., 2024a

Component	Average annual flow (MLD)
Rainfall volume	32.34
Data source: Annual report from Karnataka State Natural Disaster Monitoring *Calculation: Total rainfall volume = (annual rainfall x 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
Assumptions: - *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 run-off within the town and from lake catchments outside the town boundary along with untreated wastewater flowing into them*	
Evapotranspiration	20.19

Component	**Average annual flow (MLD)**
Calculation: - *Evapotranspiration = (total rainfall) - (run-off) - (GW recharge).* *Please note that the GW recharge does not include recharge from lakes*	

2.0 Chintamani's Water Management Problems

2.1 Inadequate Water Quality and Inefficient Water use

Most parts of Chikkaballapur district suffer from elevated concentrations of fluoride, nitrate, magnesium and sulphates in groundwater.[4] The map below gives an overview of water quality in different parts of the district

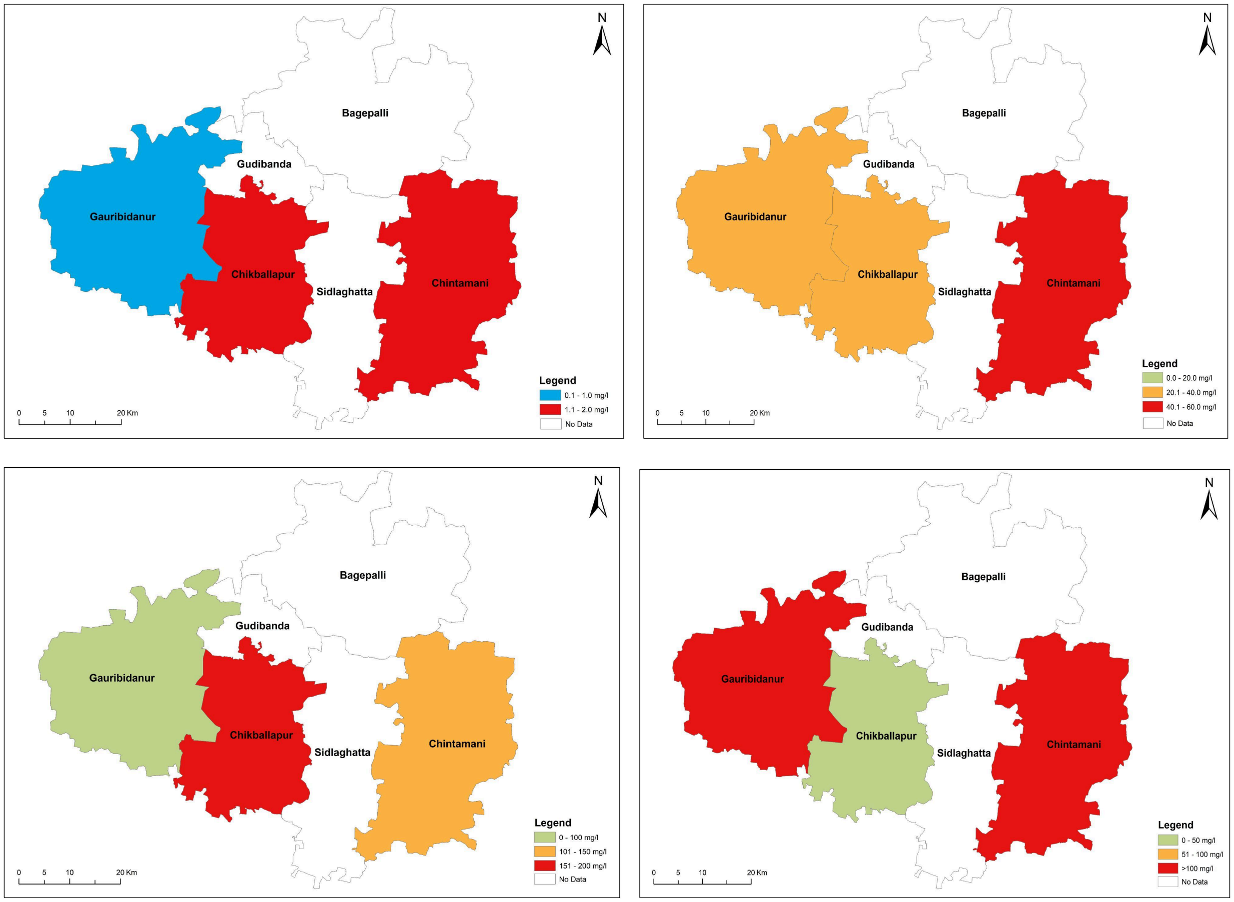

Figure 12: Average Water Quality of taluks in Chikkaballapur clockwise: Fluoride, Magnesium, Nitrate and Sodium. Source: WELL Labs

In Chintamani, since much of the population in the town doesn't get water for more than 1-2 days/week and geogenic contamination may not be a priority.

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[4] Atal Bhujal Yojana, District Groundwater Department, Karnataka

Inefficiency: A lot of water use is unaccounted for, leading to revenue losses for the municipality.

We examined the sources of municipal water supply to the town, which is primarily groundwater supported by surface water. We also estimated the extent of NRW for the town. Both these aspects – heavy groundwater dependence and high NRW – are key to building water security here. NRW is as high as 40%. The town's pipeline network reaches most parts of the town but there are a high number of unauthorised connections along with leakages contributing to NRW that impair revenue for the local body through user fees (Ramamoorthy et al., 2024a)

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. Most feed ground-level service reservoirs (GLSR) and overhead tanks (OHTs), from where water is supplied to areas – in turns, once a week while a few borewells supply water directly to a small area.

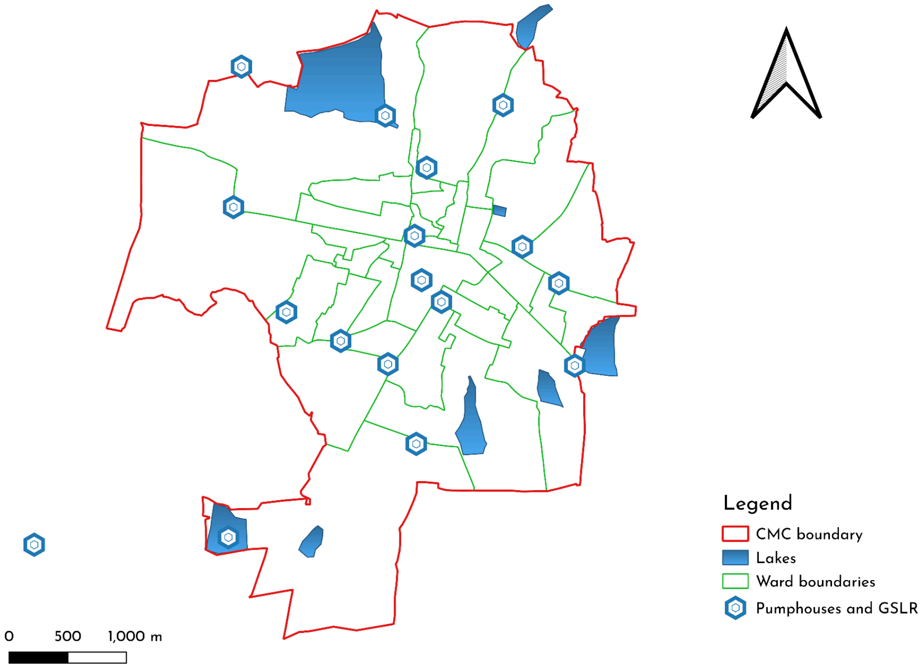

Figure 13: Location of pumping stations / OHT / GLSR in Chintamani. Source: KGIS - KSRSAC, Chintamani CMC data

2.2 Inadequate sewage treatment capacity

The town lacks the treatment capacity to handle the wastewater generated, resulting in a majority of the town's sewage flowing directly into lakes.

The town's wastewater generation – from domestic, and commercial and institutional establishments is estimated to be **5.72 MLD** (Ramamoorthy et al., 2024a). Considering average rainfall and supply scenarios, wastewater generation rates are expected to largely be in this range.

Sewerage network maps showed extensive coverage but Chintamani CMC records reveal that fewer households are actually connected to the network than the map implies. Because of the inadequate treatment capacity, only 2 MLD is treated, resulting in a majority of the town's sewage flowing directly into lakes.

An Sewage Treatment Plant (STP) has been proposed, one with a capacity sufficient to meet the town's requirements near the Bhukkanahalli lake just outside the town boundary. Additionally, CMC data showed that there were only 4,381 household sewerage connections, far lower than 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.

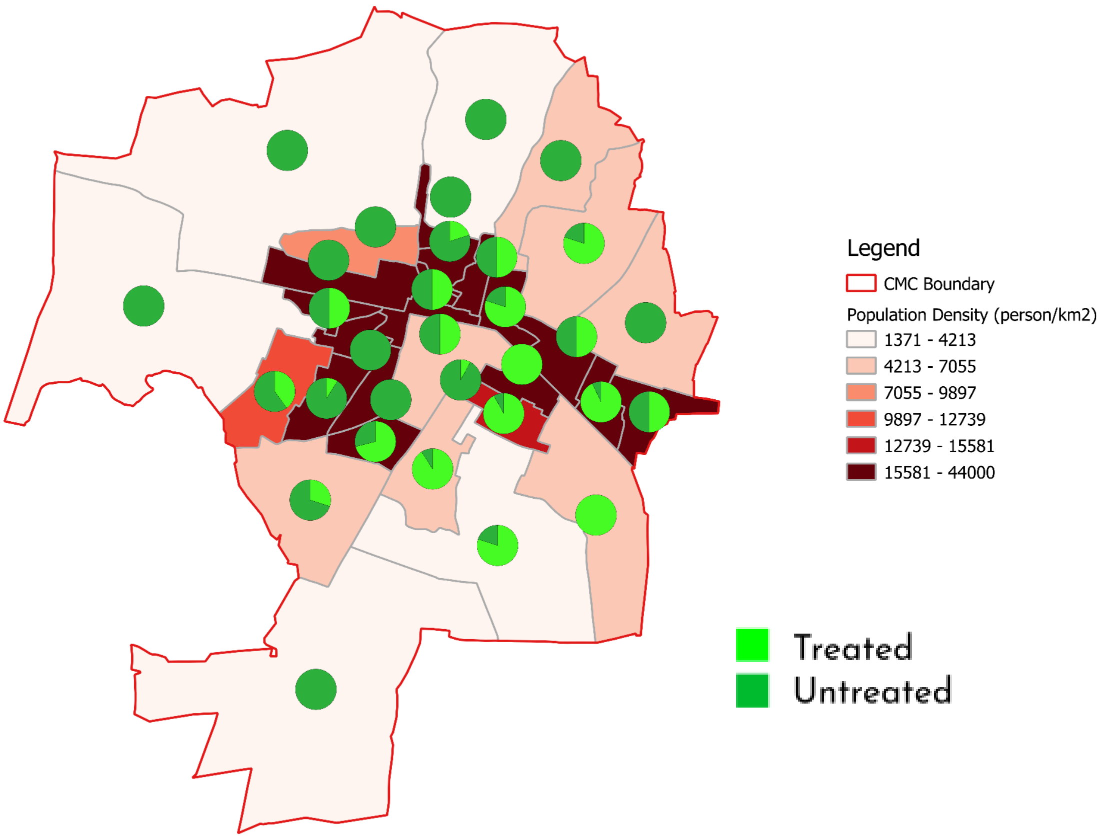

Figure 14: Map showing ward-wise population density and level of wastewater treatment. Source: KGIS - KSRSAC, base sewerage map by the Karnataka Urban Water Supply and Drainage Board

Table 6: Overview of wastewater management

Component	Average annual flow (MLD)
Freshwater consumption	6.82 (Domestic) + 0.33 (C&I)
Domestic Wastewater produced	5.46
C&I Wastewater produced	0.26
Assumptions: - *Wastewater produced is 80% of freshwater consumed*	
Total Wastewater produced	5.72

Component	Average annual flow (MLD)
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

2.3 Biophysical Unsustainability

The shallow aquifer has dried up in many places and the town is reliant on deep fractures.

Chintamani town is over-reliant on groundwater and currently meets a whopping 50% of the town's freshwater needs. The Chintamani CMC pumps deep borewells round the clock yet is able to supply water to the town's residents only once a week (Ramamoorthy et al., 2024a).

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

Figure 15 shows typical borewells in hard rock areas have casing pipes put against the upper weathered zones that tap the fissures and fractures occurring in the weathered-fractured zone 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).

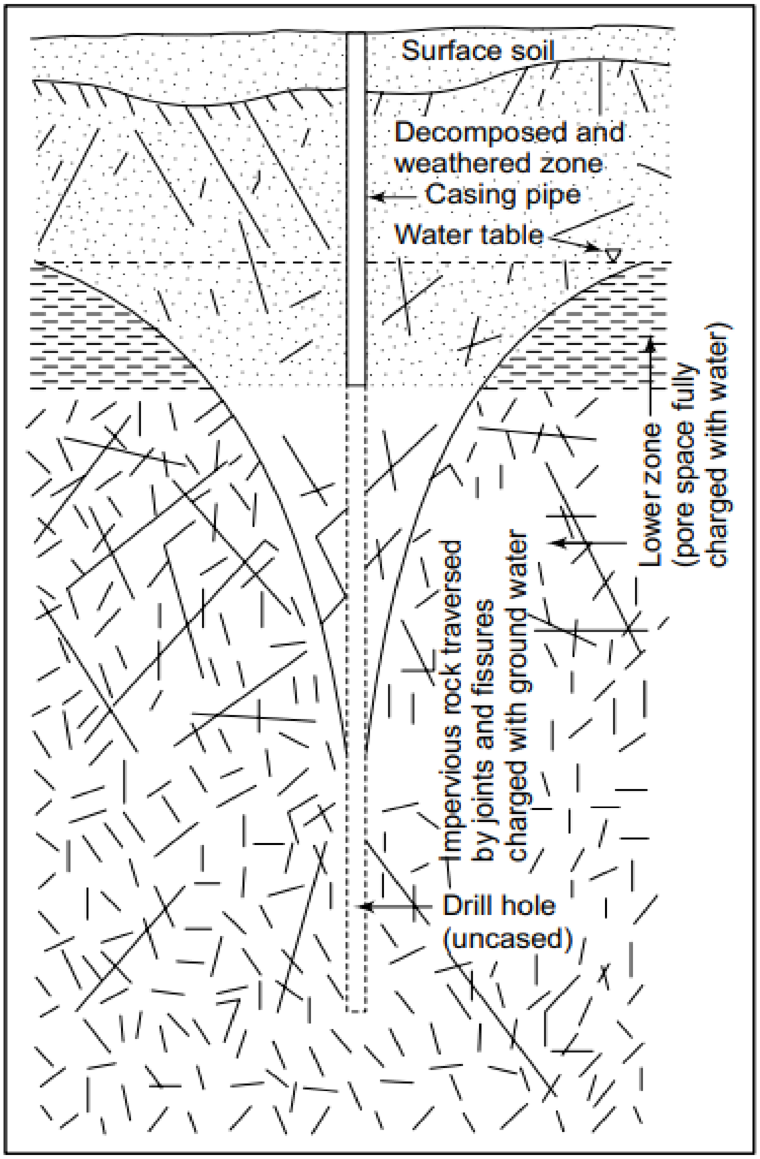

Figure 15: Schematic of a borewell tapping weathered-fractured hard-rock area. Source: Michael et. al (2008)

Around 40% of the borewells have failed in Chintamani town since 2020

The groundwater situation in the town was investigated 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. (Ramamoorthy et al., 2024a)

Table 7: 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 16, 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 (Ramamoorthy et al., 2024a). Based on the depths, many borewells draw from fractures below shallow aquifers. This also means that submersible pumps with higher suction power ratings are needed to pump the water.

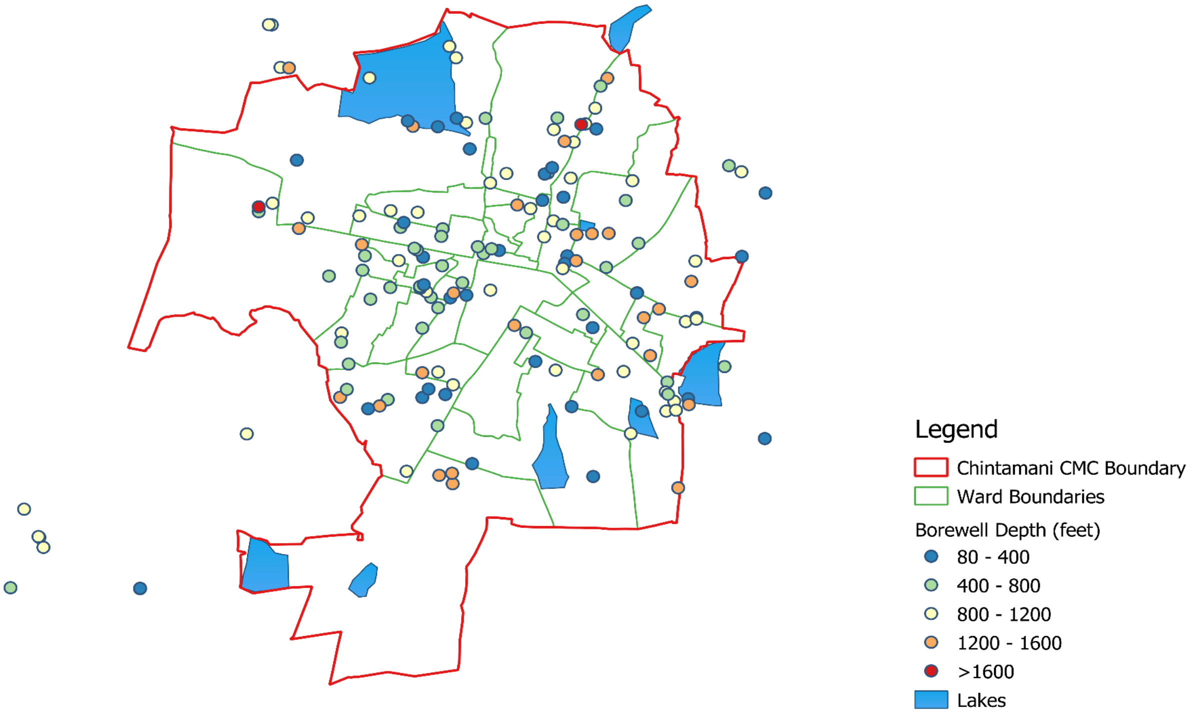

Figure 16: Spatial distribution of municipal borewells: Source: Cartosat 2 from Bhuvan - NRSC, KGIS - KSRSAC, CMC records

2.4 Climate Vulnerability

There is massive variability between wet and dry years

Chintamani faces cyclical years of drought and excess rainfall – 2014, 2016 and 2018 were drought years whereas 2015, 2017, 2020, 2021 and 2022 were excess rainfall years (Fig. 15). 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. 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. The observed annual mean rainfall has a standard deviation ± 201 mm/yr in this region. (Ramachandra T V et al., 2017)

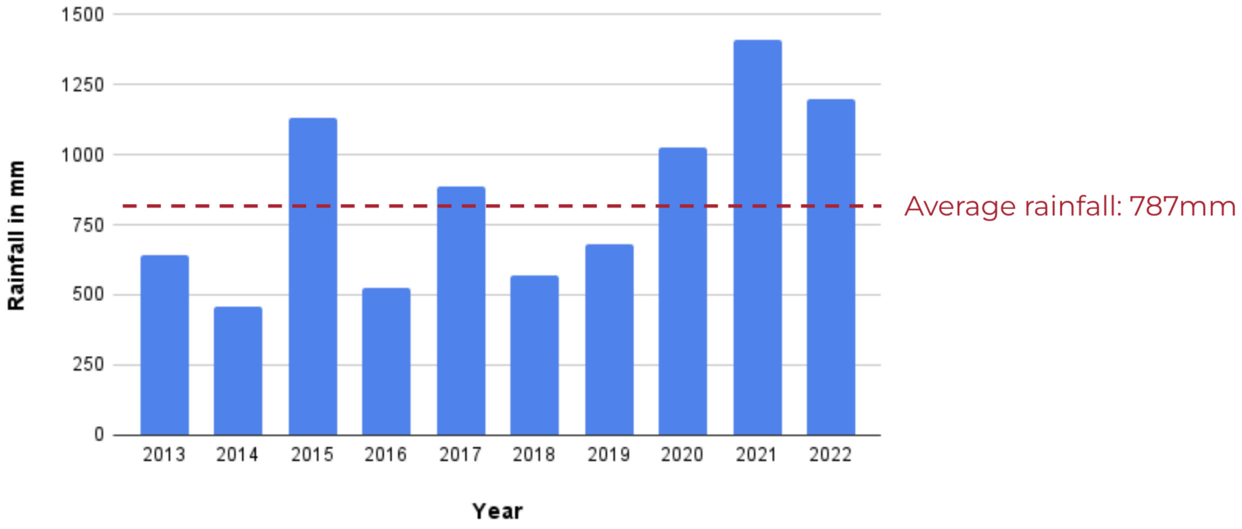

Figure 17: Annual rainfall in Chintamani

In 2018-19, when Chintamani last experienced drought conditions, borewell yields dropped and the town depended entirely on private tanker supply. Private water tankers 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.

2.5 Water Pollution

Existing water bodies are highly polluted due to inadequate investment in sewage treatment.

Faecal coliform levels were found to be higher than safe limits in all the lakes. Water quality samples collected from the three lakes (Table 7) showed coliform levels higher than desirable limits (below 500 MPN per 100 ml is desirable).

Table 8: Overview of Chintamani's lakes' water quality: Source: Laboratory test results for samples collected in July 2022, (Ramamoorthy et al., 2024a)

Lake	Kannampalli	Nekkundi	Gopasandra
TDS (mg/l)	118	478	828
N-Total (mg/l)	1	2.8	6.1
Ammoniacal Nitrogen (mg/l)	<1	<1	1.2
DO (mg/l)	5.7	5	5.5
BOD (mg/l)	2.4	2	2.6

COD (mg/l)	14	10	18
Fecal Coliform MPN/100ml	Above desirable limits	Above desirable limits	Above desirable limits

However, the lakes meet CPCB standards for use with conventional treatment. For instance, the water treatment plant that syphons water from Kannampalli Lake, despite its small capacity, plays a key role as it carries out conventional treatment and disinfection before supply. Therefore, maintenance of the WTP becomes equally important.

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

The high nutrient levels in these lakes here may arise from sewage inflows from urban pockets or agricultural runoff given that there are no major industries in the catchment area.

2.6 Financial Unsustainability

There is a high borewell failure rate and the city incurs massive pumping costs.

Water supply alone accounts for nearly 40% of the municipality's operational expenses. Running these deep municipal borewells results in high electricity bills. Close to 40% of the town's revenue expenditure was spent on running water supply infrastructure as shown by an analysis of operating expenses over the last three financial years – 2019-20, 2020-21 and 2021-22. Half of these expenses are for electricity charges and fuel whereas the rest is used to pay salaries, and carry out repairs and maintenance.

In Chintamani town, the municipality does not have a system of registering privately-dug borewells. Attempts made during the household survey in 2022 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. (Ramamoorthy et al., 2024a).

Groundwater is expensive to source and is rapidly depleting in Chintamani. There is a high borewell failure rate and lack of awareness of the geology and aquifers (Ramamoorthy et al., 2024a).Continued growth of Chintamani as a town and increased groundwater depletion imposes a major financial burden on local communities (Srinivasan et al., 2024).

2.4.1 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 45% 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 9 : Income and expenditure summary. Source: Chintamani CMC budget documents for FY 2020-21, 2021-22, 2022-23

Financial Year	2021-22	2020-21	2019-20
Tax Income (Rs, in lakhs)	339.12	322.7	306.98
Non-Tax Income (Rs, in lakhs)	858.88	790.55	823.41
Own Source Income (Rs, in lakhs)	1198	1113.26	1130.39
% of Own Source Income out of Total Income	45%	35%	37%
State Transfers or Grants (Rs, in lakhs)	1468.99	2028.61	1912.24
Total Income (Rs, in lakhs)	2672.31	3141.87	3042.63
Total Revenue Expenditure (Rs, in lakhs)	4620.32	3332.80	3091.99
% of Own Source Income out of Total Revenue Expenditure	26%	33%	37%

Ideally, the majority of the municipality's revenue expenditure should be covered by its own revenue. However, in the case of Chintamani, this has ranged between 26%

and 37% 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 & Raghunathan, 2023). This shows that the trend in Chintamani is not different from other larger towns in Karnataka state.

A World Bank report on funding urban infrastructure across Urban Local Bodies (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[5] 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).

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 terms of capital expenditure, water supply and sewerage infrastructure has ranged from 29% to 56% of the total capital expenditure between the financial period of 2019 - 2021.

Table 10: Capital expenditure for water supply & sewerage. Source: Chintamani CMC budget documents for FY 2020-21, 2021-22, 2022-23

Financial Year	Total CAPEX (Rs, in lakhs)	Water supply CAPEX (Rs, in lakhs)	Sewerage CAPEX (Rs, in lakhs)	Water supply + Sewerage CAPEX / Total CAPEX (%)
2018-19	446.45	206.78	42.52	56
2019-20	861.47	186.7	62.27	29
2020-21	847.32	233.37	99.4	39

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[5] 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

Electricity charges[6] 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.

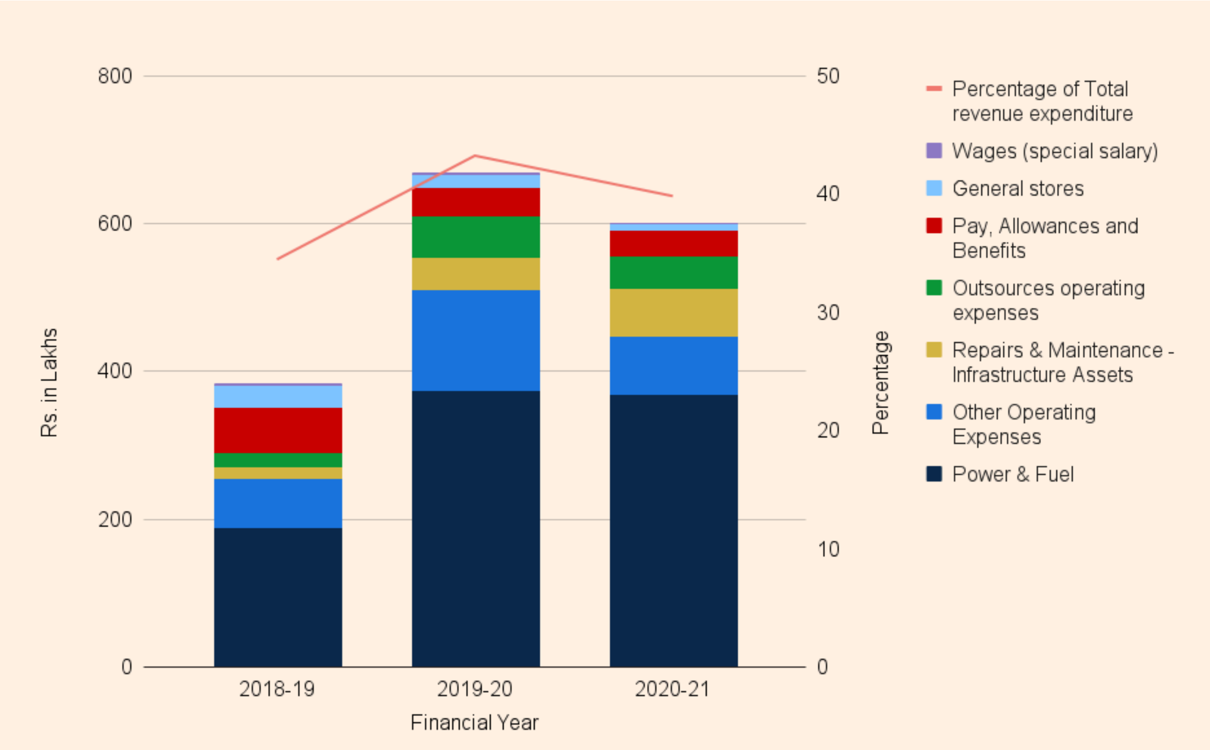

Figure 18: Water supply revenue expenditure. Source: Chintamani CMC budget documents for FY 2020-21, 2021-22, 2022-23

The municipality faces challenges to meet operational expenses

The findings of the report by Ramamoorthy et al. 2024a emphasise that current investment levels are notably lower than these needs, with 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; 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

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[6] 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)

services. Ramamoorthy et al. (2024a)'s 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 conditions.

- **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.

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 grants 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).

The larger institutional framework in place also limits the municipality from breaking out of current unsustainable models they are locked into, this is covered at length in the following section

2.7 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.

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 urban local body (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.

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. The CMC sets tariff, collects connection fees and 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.

Figure 16 shows an adapted version of ‘activity maps’ developed by Ramesh & Basu (2021) that showcased implementation of water supply schemes in two small and medium town ULBs in Karnataka.

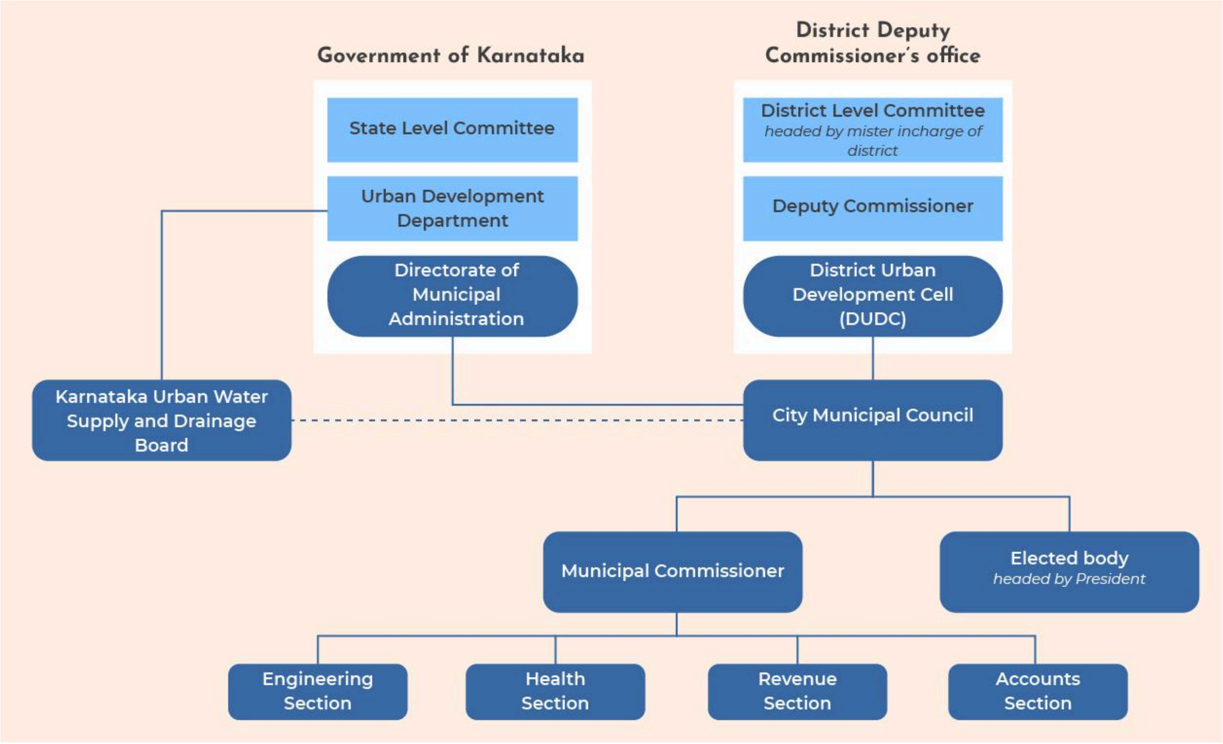

Figure 19: Implementation framework for water supply projects at Chintamani CMC. Source: Mallapalli Lake Catchment Analysis and Visioning, 2024

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.

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, it was found that 59% of sanctioned posts remain vacant out of an overall strength of 175[7]. 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.

2.8 Urban Expansion

The rise of urbanisation in major cities such as Bengaluru is reflected in the increasing concentration of population density. Chintamani's proximity to a

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

metropolis like Bengaluru makes it likely that the town will continue to expand, underlining the need to ensure basic infrastructure is prioritised. Below are land use land change (LULC) maps of Chikkaballapur and Chintamani for years 2021-2022.

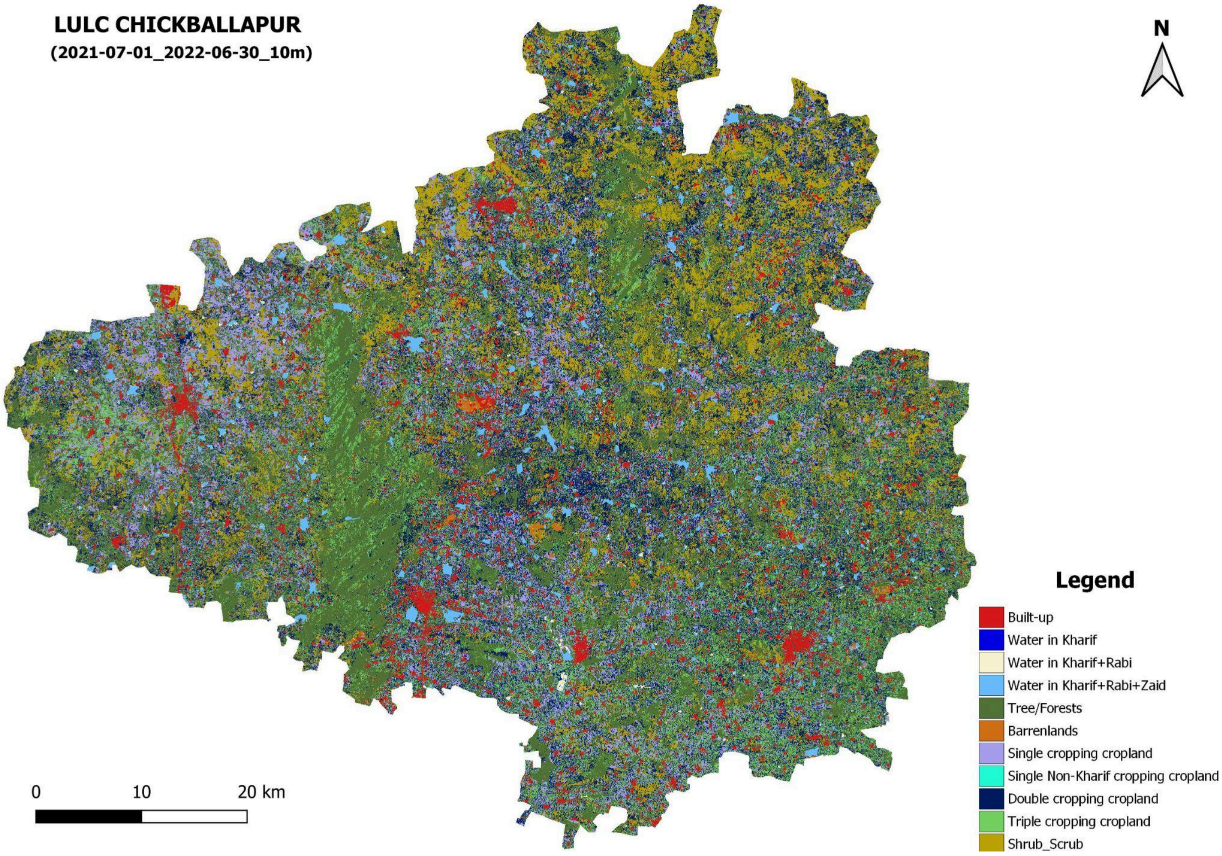

Figure 20: Land use land change for Chikkaballapur. Source: WELL Labs

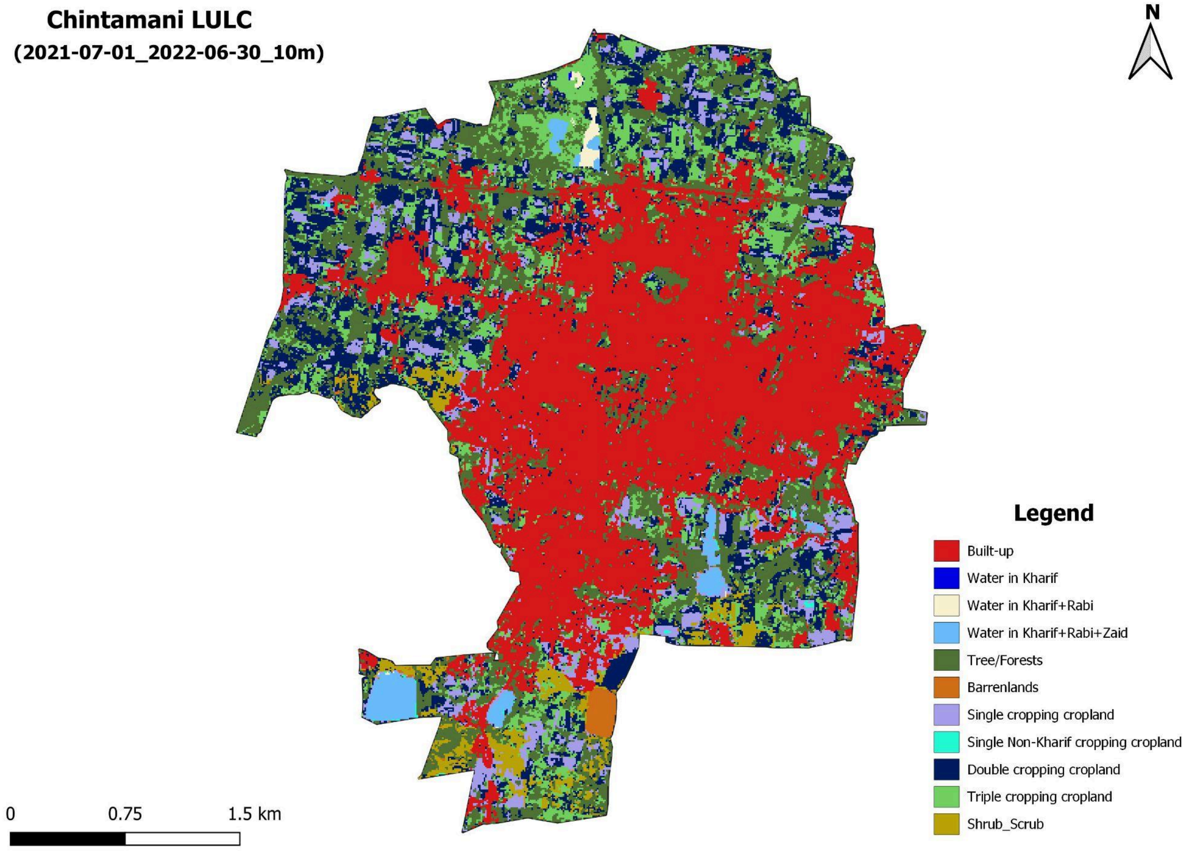

Figure 21: Land use land change for Chintamani. Source: WELL Labs

The Local Planning Area Map for 2031 by the Town Planning Authority (Fig. 22) indicates that there will be further urbanisation and commercial expansion in Chintamani. Areas around lakes of the town are marked for residential development which raises the concerns of increased inflow of sewage and maintenance of the lakes. The urban and commercial expansion of Chintamani will have spillover effects on the town's water security as well. Planning for it in advance, and having a blueprint ready to tackle issues of today and the future, accounting for climate change, will be crucial.

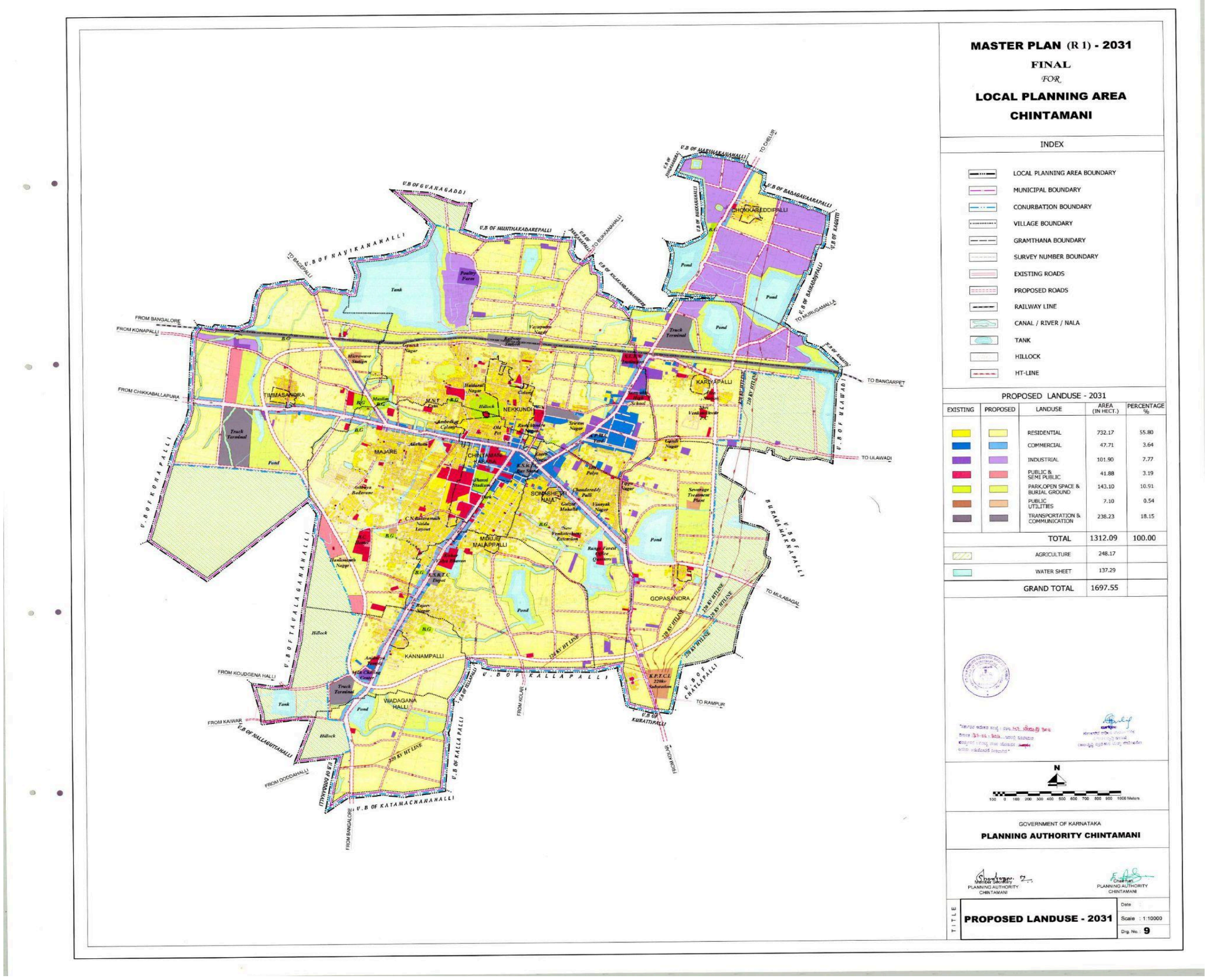

Figure 22: Local Planning Area Map of 2031. Source: Chintamani Town Planning Authority

3.0 Solutions to Chintamani's Water Problems

3.1 Restoring surface water bodies for drinking water

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

Tapping into surface water sources could take the pressure off depleting groundwater as the local water bodies can meet upto 40 to 50% of the town's drinking water needs (Ramamoorthy et al., 2024a). Given that the town continues to rely on groundwater for its municipal and private supply, large water bodies, such as Nekkundi, become critical for potential surface storage and groundwater recharge—restoring the tank or lakes system to create water security by improving water quality.

Chintamani's largest water body is Nekkundi lake and it can be a possible source of supply by providing 1.5 to 2 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.

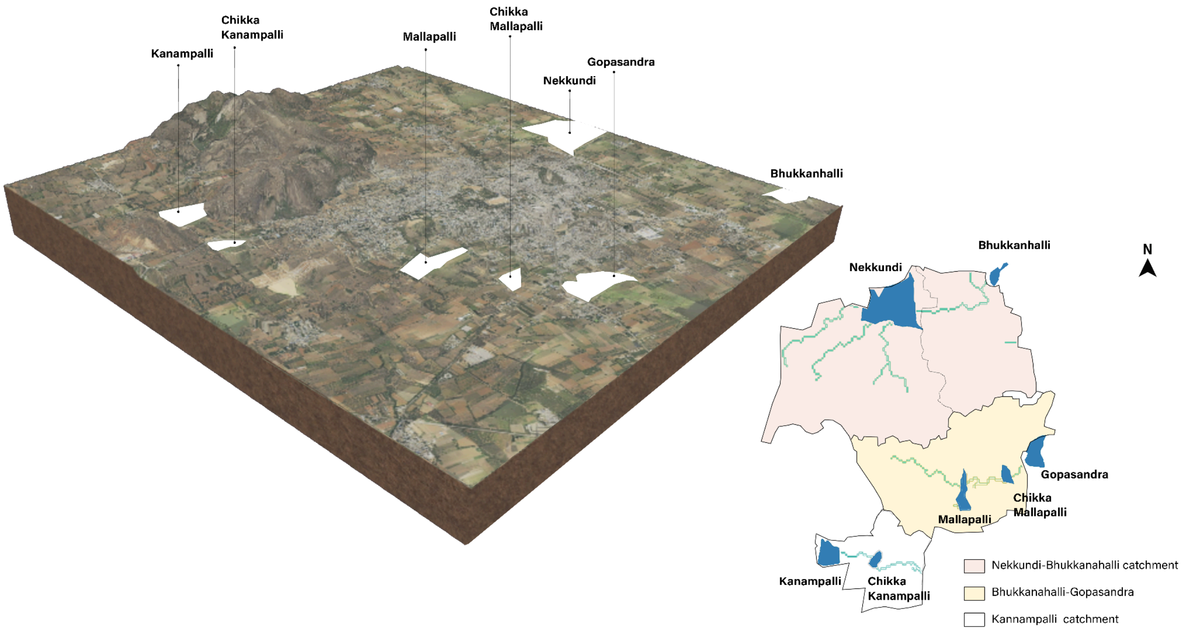

Figure 23: Lakes of Chintamani, along with their catchment areas. Source: Ramamoorthy et al., 2024b, not to scale

This means the town's current demand of 7 MLD could be met in an average monsoon year through surface water sources both local and imported. 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.

Blue-green spaces can capture run-off and act as recharge zones

The average annual run-off of **8.27 MLD** as calculated by Ramamoorthy et al., 2024a can be captured, and be used to recharge groundwater, if the capacity for capturing run-off is increased. In the context of small towns which are not yet fully urbanised, there is room to plan better and put in place infrastructure such as permeable surfaces, stormwater capture or bioswales and 'sponge' parks that would allow more rain to be captured.

3.2 Rethink water systems through circular economy and resilience principles

To deal with water pollution, there is a need to address untreated sewage flowing into lakes rendering them unusable. One of the main reasons for this issue to persist is the dependence on external sources of funding be it through central or state governments needed to improve wastewater management. Other issues around availability of land for sewage treatment plants and pumping stations also contribute to delays in setting up such necessary infrastructure. Treating wastewater and preventing pollution must be coupled with lake rejuvenation measures.

a. Improve wastewater infrastructure by ensuring all households are connected and broken lines are repaired. Currently, storm water drain channels are carrying sewage in some pockets as a result they dump sewage into lakes.

b. Plan for adequate wastewater treatment to meet current and future needs. Setup mechanisms to use treated wastewater within town and the periphery.

3.3 Community engagement

Community engagement is crucial to ensure that members of the community safeguard water resources in the future, beyond the duration of the project. Community engagement can be a means to account for social inclusion, providing us with a wider bandwidth to understand complex issues. Ideas of social inclusion need to be central to climate change adaptation and mitigation.

As part of the Mallapalli lake rejuvenation, WELL Labs has carried out a lake visioning exercise that involved consultation with residents of Mallapalli area surrounding the lake as well as mapping various activities that are taking place within and on the periphery of the lake. Further, engagement with Mallapalli area residents are planned once rejuvenation is completed to set up community driven ownership of lake assets.

Fifty percent of the seats on the elected council of Chintamani are reserved for women; women have held the roles of president and vice presidents of Chintamani CMC. About 30% of the *pourakarmikas* in CMC are women.

Further research will need to be conducted in Chintamani to understand gender and inclusion dynamics, and explore with local stakeholders to strengthen forums to ensure meaningful and inclusive participation in decision-making.

3.4 Create an aquifer management plan

Understanding the aquifer is key towards sustainable groundwater management

One of the most important insights is that nearly 50% of Chintamani’s drinking water requirements are being met through municipal borewells as well as privately-owned borewells and tankers. This dependence places a significant burden on the aquifer underlying Chintamani, which is characterised by weathered-fractured hard rock aquifer system with limited storage capacity and is 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 surface geophysics constrained by borehole lithological logs. There is also a push from the level of the central government through flagship schemes such as the AMRUT mission, which mandates that cities 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 is a small town, not a sprawling metropolis, and is largely unbuilt. There is a brief window of opportunity to develop and implement a blue-green infrastructure plan through fallow land, green spaces and water bodies that could capture and store water, but also recharge the aquifer.

3.5 Map financial flows

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 by Ramamoorthy et al. 2024a 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.

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. Mapping financial flows in Chintamani will aid in moving towards identifying mechanisms to finance wastewater treatment, waterbody rejuvenation and creation of blue green infrastructure to make Chintamani water secure.

4.0 Stakeholders

The primary beneficiaries of the T-Lab are the Chintamani City Municipal Council (CMC) and the town's residents. As a town located in historically semi-arid areas with intermittent water supply, both the urban local body and the residents' would benefit from improved water availability conditions, resulting in a more predictable supply of water.

Addressing Chintamani's WASH challenges involves navigating through a network of actors at different levels - beginning with state's Urban Development Department (UDD), the Directorate of Municipal Administration (DMA) that oversees the functioning of ULBs in the state as well as parastatal agencies such as the Karnataka Urban Water Supply and Drainage Board (KUWSDB) are involved in planning and augmenting water supply and sewerage schemes. At the district level, the District-in-Charge Minister and Deputy Commissioner together with the District Urban Development Cell (DUDC) provide a supervisory role for all the ULBs in Chikkaballapur district. At the town level, Chintamani CMC is responsible for municipal service delivery, comprising both an elected wing headed by the President with a fixed term and the executive wing headed by the Municipal Commissioner. The Member of Legislative Assembly (MLA) Chintamani Assembly constituency is consulted for key projects and decisions from time to time.

The villages on the periphery of Chintamani who happen to be part of the Chintamani watershed will be part of the stakeholder process, we will engage with Village & Taluk Panchayats that administer these villages, and reach out to the Zilla Panchayat if necessary.

WELL Labs has been working with BORDA and TIDE in Chintamani town and produced a water balance study report that has been quoted previously. Both BORDA and TIDE's focus have been providing technical support and capacity building for towns in the Chikkaballapur district and beyond. Foundation for Ecological Security (FES) is a large NGO with a presence in Chintamani although they operate in rural areas of Chikkaballapur - Chintamani, WELL Labs will leverage existing relationships with them.

WELL Labs has partnered with Friends of Lakes, a citizen group who have been championing scientific lake restoration in and around Bangalore to restore Mallapalli lake located in the town.

In addition, WELL Labs will explore engagement with local NGO/CSOs, Resident Welfare Associations (RWAs) and SHGs operating in the town.

5.0 Conclusion

The situation analysis report of Chintamani town and Chikkaballapur district acts as a lens to understand the underlying connections between surface water, groundwater hydrology, aquifer characteristics and how solutions are based on these interconnected data points. There has to be further research on ways to rejuvenate water bodies and enhance sewage treatment in order to reduce groundwater dependency and meet the town's water demand. Sustainable groundwater management hinges on a comprehensive understanding of the aquifer system and community engagement. To ensure long-term viability, it is imperative to explore solutions that bolster surface water improvement and groundwater recharge as well as strategies to prevent groundwater depletion. Preparation of a comprehensive water security plan incorporating the pointers mentioned above will be a crucial next step.

The report offers insights into the complexities of governance and finance relating to water supply and sewerage infrastructure in towns. Chintamani is highly reliant on external funding sources — federal and state government schemes and finance commission grants to fund capital expenditure. There are also challenges in terms of navigating a complex institutional framework of district-level authorities and parastatal agencies in planning and implementing water supply and sewerage infrastructure at the town level. In these aspects, Chintamani is representative of other towns in Karnataka

To overcome these challenges, the preparation of a water security plan has to be a collaborative and inclusive process, actively involving a range of stakeholders, from decision-makers at the state, district and town levels 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 identifying areas for new borewells or rejuvenating lakes. Planning should provide for short-term adjustments to address 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.

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