

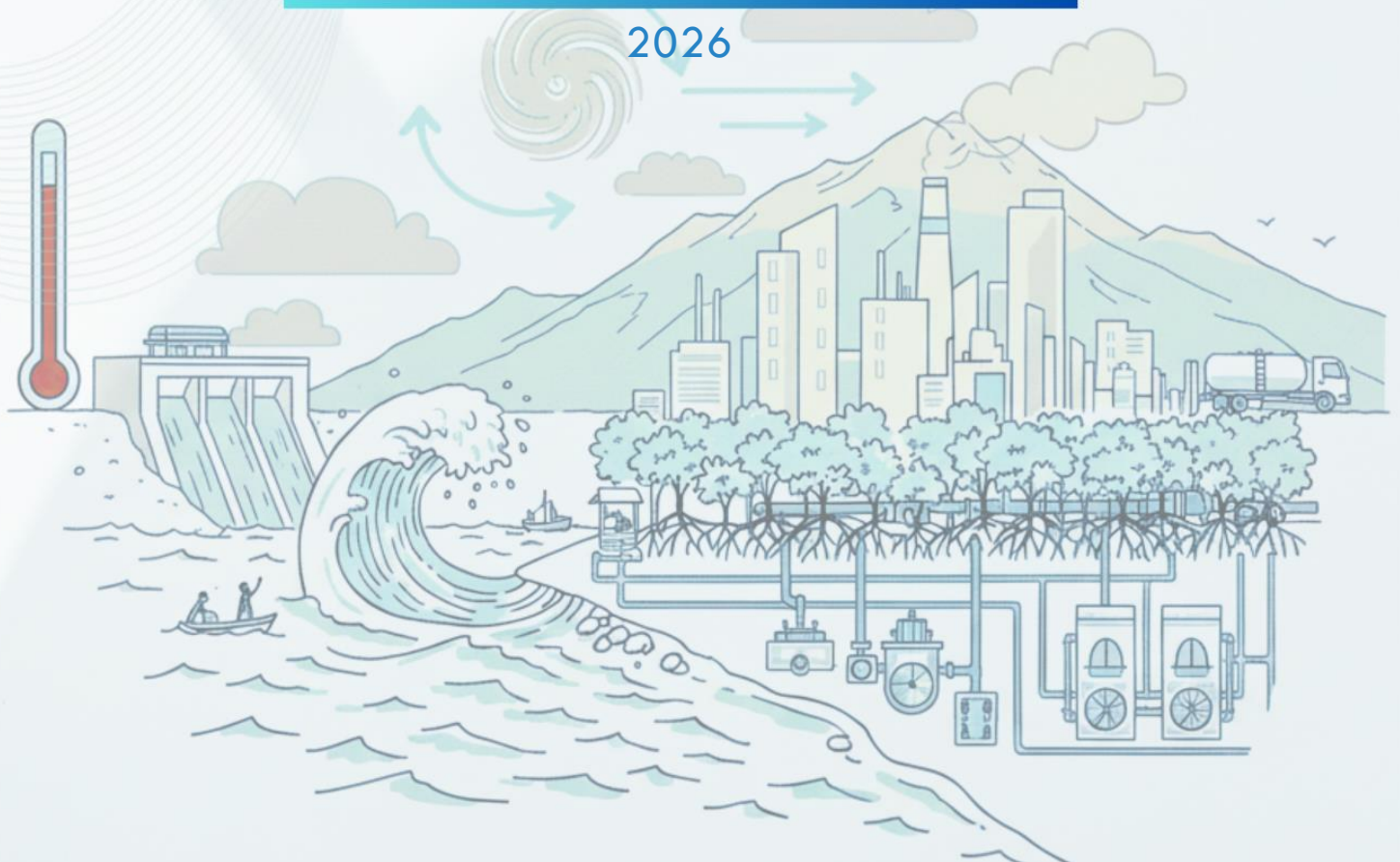


Towards Climate-Resilient Urban Water & Sanitation Systems

Situational Assessment Report

MANGALURU, KARNATAKA

2026

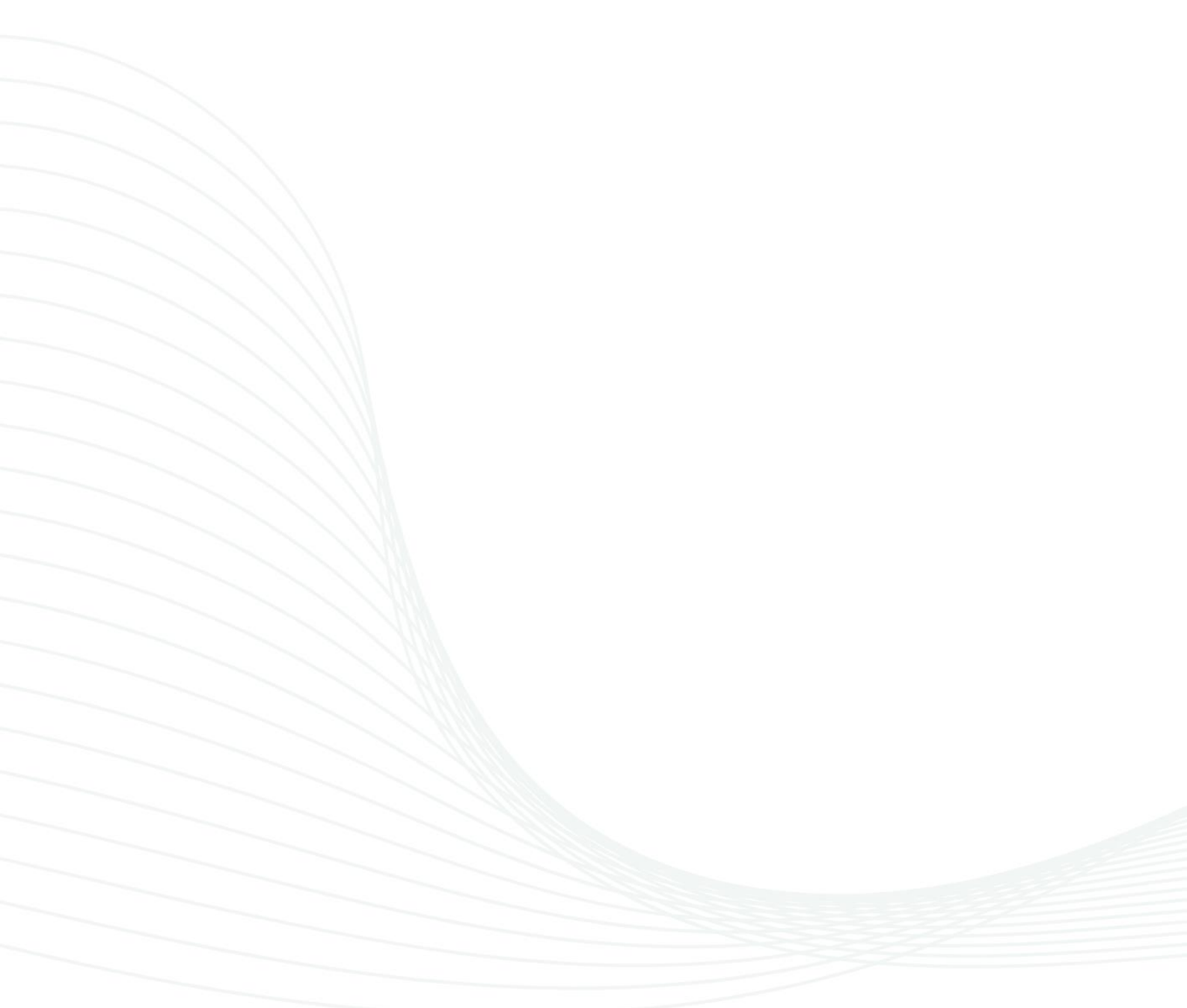


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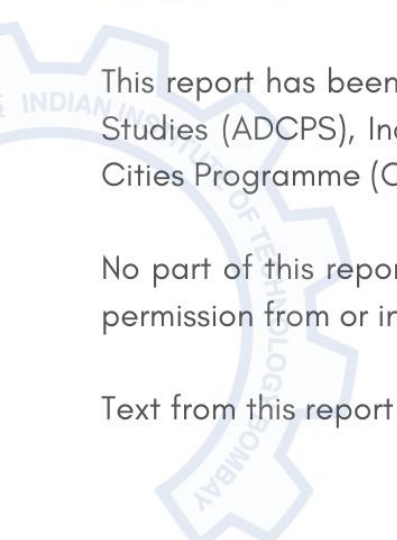
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TITLE

Towards Climate-Resilient Urban Water and Sanitation Systems: Situational Assessment of Mangaluru, Karnataka

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EXECUTIVE SUMMARY

Climate change is fundamentally reshaping global water systems through more frequent extremes and growing hydrological uncertainty. The resulting impacts threaten water security while escalating risks to lives, critical infrastructure, and ecosystems, with coastal cities at the forefront. Against this backdrop, the 'Climate Resilient Coastal Cities' initiative was initiated by Ashank Desai Centre for Policy Studies (ADCPS), IIT Bombay in collaboration with India Sanitation Coalition (ISC) and CDD India with financial support from HSBC India. Under the initiative, ADCPS, IIT Bombay led the scientific research component and conducted comprehensive situational assessments of the Water and Sanitation Systems in 12 coastal towns across Gujarat, Maharashtra, Karnataka and Karnataka. The primary objective of our assessment is to evaluate the operational and institutional readiness of water and sanitation systems to adapt to an increasingly volatile hydro-climatic regime in these coastal towns. To achieve this, we map the physical water and sanitation infrastructure within the biophysical environment of the city, and evaluate specific risks and challenges to service delivery against local and felt climate realities. Through a comprehensive analysis of greenhouse gas (GHG) emissions, energy footprints, institutional and policy landscape, and municipal finances, the report identifies critical gaps and opportunities for adaptation and mitigation. Rather than prescribing final solutions, this situational assessment provides the crucial evidence base needed to lay the foundation for climate-resilient WaSH futures and to inform future research on actionable, context-specific resilience strategies.

Coastal towns on India's west coast represent extreme cases for analysing the implications of increasing climate variability for urban water security. Unlike the acute disaster risks of the east coast, these towns face chronic, persistent stress: an observed 52% increase in Arabian Sea cyclones since 2001, rapid degradation of protective mangroves, and a reliance on short, seasonal rivers. These towns oscillate between monsoon flash floods and acute summer water scarcity, worsened by saline intrusion into local aquifers. Studying these locations offers critical insights into the long-term resilience challenges that many Indian cities will confront in the coming decades. Our case studies across 12 coastal towns not only highlight the increasing vulnerabilities of existing infrastructure-heavy approaches but also illuminate the pathways forward (figure 1).

The future of urban water security will depend not on a single intervention, but on whether cities can build coherent, adaptive, and low-carbon water systems that align engineering solutions with ecological processes, financial innovation with equitable service provision, and climate foresight with institutional reform.

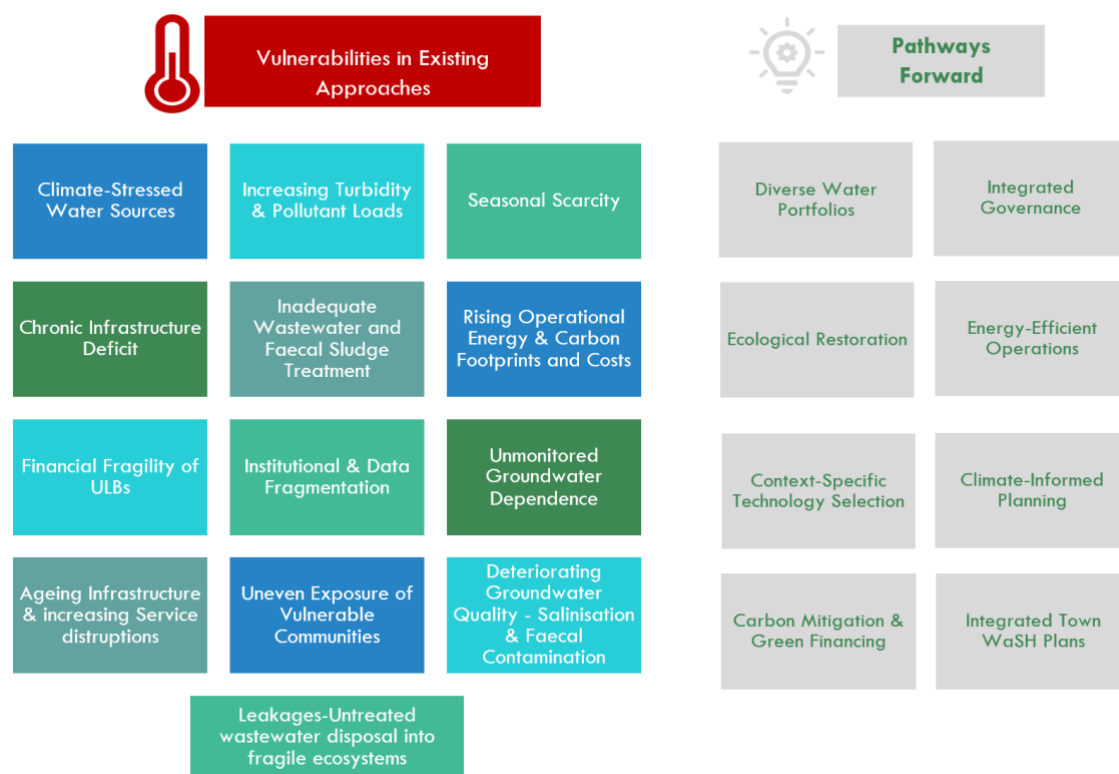


Figure 1: Systemic Vulnerabilities in existing approaches to WaSH and Pathways forward.

The report presents the study findings for **Mangaluru**, a Class-I coastal town in Karnataka's Dakshina Kannada district. Our assessment of Mangaluru revealed some critical challenges of WaSH infrastructure & services:

WATER SUPPLY:

Vulnerabilities in Surface Water Dependency: The primary municipal water source, the Netravati River, faces cumulative risks from erratic rainfall patterns, upstream dams, and industrial extractions. These factors disrupt base flows, degrade water quality, and threaten long-term supply availability.

Underutilisation of Local Aquifers: Local groundwater reserves remain largely excluded from the formal supply matrix. Furthermore, the viability of these aquifers and traditional decentralised water bodies is increasingly threatened by rapid urbanisation, reduced recharge rates, and wastewater infiltration from compromised sewerage networks.

Systemic Losses and Path Dependency: A substantial discrepancy exists between raw water extraction (approximately 172 MLD) and actual delivery (roughly 112 MLD), indicating significant systemic losses. Furthermore, ongoing investments in rigid,

centralised infrastructure limit municipal adaptability to emerging climate threats like saltwater intrusion and extreme weather.

Carbon Intensity of Centralised Conveyance: Reliance on long-distance surface water transfers necessitates substantial energy inputs.. This dynamic creates a feedback loop where climate-induced water degradation requires increasingly energy-intensive treatment.

Financial Constraints and Capital Dependency: Large-scale water infrastructure projects rely heavily on external loans and state funding. Documented delays and cost escalations highlight the financial vulnerabilities of these capital-intensive systems, which inflate long-term maintenance obligations and restrict fiscal flexibility.

SANITATION:

Ageing Infrastructure and Capacity Constraints: The existing sewerage network and treatment facilities, some dating back over fifty years, are approaching the end of their operational lifecycles. Facilities such as the Pachanady Sewage Treatment Plant (STP) frequently exceed their design capacities during monsoon seasons due to rainwater intrusion, highlighting systemic vulnerabilities to climate stress and extreme weather events.

Topographical Barriers to Centralised Expansion: Extending the conventional sewerage network is actively constrained by local geographical factors. Undulating, hilly terrains present spatial and logistical limitations, while high groundwater tables in coastal belts make deep sewer excavations unfeasible, thereby increasing the ongoing reliance on decentralised onsite containment systems in these zones.

Environmental Compliance and Sludge Accumulation: Current compliance data indicates that three of the four municipal STPs fail to meet environmental norms, frequently exceeding parameters for total suspended solids, total nitrogen, and biochemical oxygen demand (BOD). Concurrently, the absence of a formalised end-use market for dried sludge results in material accumulation and leaching risks, while reliance on unscientific containment pits in high-water-table areas elevates the risk of groundwater contamination.

Governance Constraints and Financial Autonomy: Urban Local Bodies (ULBs) exhibit a heavy reliance on state and central government funding for large-scale capital infrastructure projects. This financial dependency frequently introduces conditionalities that limit decentralised decision-making and structural autonomy in local sanitation planning, constraining the municipality's capacity to swiftly adapt to emerging infrastructural needs.

ENERGY USE & GHG EMISSIONS:

Carbon Intensity of Surface Water Conveyance: The abstraction, treatment, and distribution of surface water across major municipal facilities (Thumbe, Padil, Bendoor, and Panambur) consume over 36,000 MWh annually, resulting in approximately 26,000 tonnes of CO₂ emissions. In contrast, groundwater extraction demonstrates a markedly lower energy intensity, generating just 3,075 tCO₂/year, which highlights the substantial carbon burden inherent in the current centralised surface water network.

Treatment Technology and Methane Hotspots: Municipal sewage treatment plants (STPs) contribute significantly to the sector's overall carbon profile, with specific technological configurations acting as major operational hotspots. Most notably, the Kavoor Upflow Anaerobic Sludge Blanket (UASB) facility generates over 51,000 tCO₂e annually in uncontrolled methane emissions due to the absence of biogas capture mechanisms, vastly exceeding the combined direct emissions of the city's other activated sludge plants.

Fugitive Emissions from Network Leakages: Although 91% of the population is connected to the underground drainage network, structural gaps and discontinuities prevent an estimated 1,433 tonnes of biochemical oxygen demand (BOD) from reaching treatment facilities annually. The resultant anaerobic conditions within these compromised network sections generate an estimated 14,617 tCO₂e of methane and 4,812 tCO₂e of nitrous oxide per year, representing a substantial environmental burden comparable to operational STPs.

Climate Impact of Onsite Systems and Greywater: Despite serving only 9% of the population, onsite sanitation systems contribute significantly to the local greenhouse gas inventory, with pit latrines and septic tanks generating over 8,600 tCO₂e annually, primarily as methane. Furthermore, the unchecked discharge of untreated greywater into stormwater drains introduces significant nitrogen loading into sensitive estuarine environments, resulting in an estimated 630 tCO₂e of indirect nitrous oxide (N₂O) emissions each year.

FINANCIAL HEALTH:

Contraction in External Funding: A documented decline in government grants and shifting state priorities have reduced the availability of external financial support. This contraction actively restricts the funding pool necessary for sustaining critical water supply operations and developing future infrastructure.

Escalating Operational Costs and Revenue Deficits: Rising operational expenditures—driven significantly by increased electricity and maintenance requirements—have generated pronounced revenue deficits across both water supply and sanitation services. The municipality's declining operating ratio highlights a structural mismatch between the escalating costs of service delivery and insufficient internal revenue generation.

Revenue Volatility and Grant Dependency: The financial architecture for sewerage and sanitation demonstrates a growing reliance on external grants. This dependency is compounded by ongoing fluctuations in local revenue streams, such as underground drainage (UGD) development fees and cesspool service charges, which collectively complicate long-term fiscal stability and operational planning.

Stagnation in Capital Investments: The municipality is currently experiencing negative growth in both capital receipts and capital expenditures across the water and sanitation sectors. This sustained reduction in capital spending limits the structural expansion of new infrastructure and presents long-term challenges to the maintenance and sustainability of existing service networks.

The situational assessment of Mangaluru highlights a complex interplay between ageing infrastructure, escalating climate vulnerabilities, and constrained fiscal autonomy. The city's ongoing reliance on energy-intensive, centralised surface water networks and overburdened sanitation systems not only amplifies the municipal carbon footprint but also continually drives up operational costs. Coupled with declining capital investments and structural revenue deficits, this path-dependent approach limits the municipality's capacity to adapt to emerging climate threats, such as erratic rainfall and extreme weather events. Moving forward, navigating these systemic gaps underscores the necessity of decoupling service provision from high-carbon, capital-heavy infrastructure. Future institutional planning must prioritise reconciling the revenue-expenditure divide to enable the rehabilitation of existing networks, the integration of low-emission decentralised treatment technologies, and the strategic diversification of local water sources, ultimately transitioning the municipality towards a more resilient, self-sustaining, and climate-adaptive service model.

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1. URBAN WATER & SANITATION SYSTEMS IN A CHANGING CLIMATE

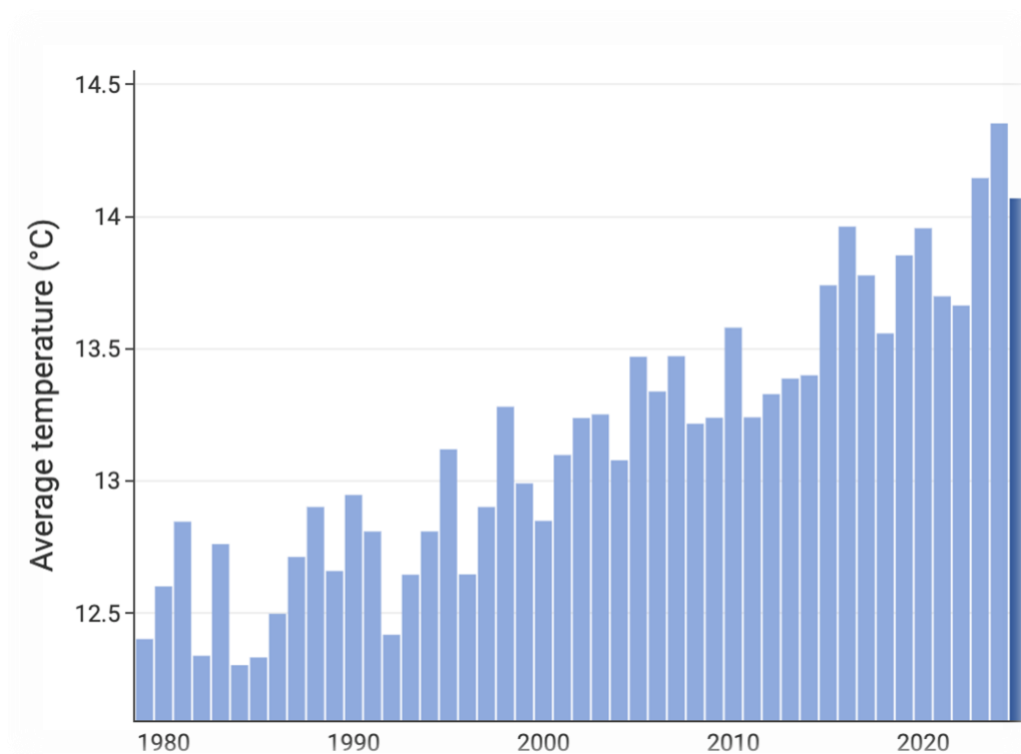
ASHISH DANGI, NEELAM RANA, N.C. NARAYANAN AND PRIYAKSHI GOGOI

This chapter establishes the universal climate-WaSH context and methodology utilised for our study of 12 coastal towns in India. It examines the impact of an intensifying global water cycle on urban water security, focusing on the emerging climate risks along India's West Coast. It is a shared chapter across all reports in this series. Town-specific findings begin in Chapter 2.

1.1 BACKGROUND

The global average air temperature over land shows a significant rising trend over the past decades with 2025 recorded as the third hottest year¹ (Figure 1). The persistent warming of the atmosphere effectively turns it into a larger sponge that can hold more water.

Figure 1: Global annual average land temperature (1979-2025).



Data Source: Global Water Monitor¹

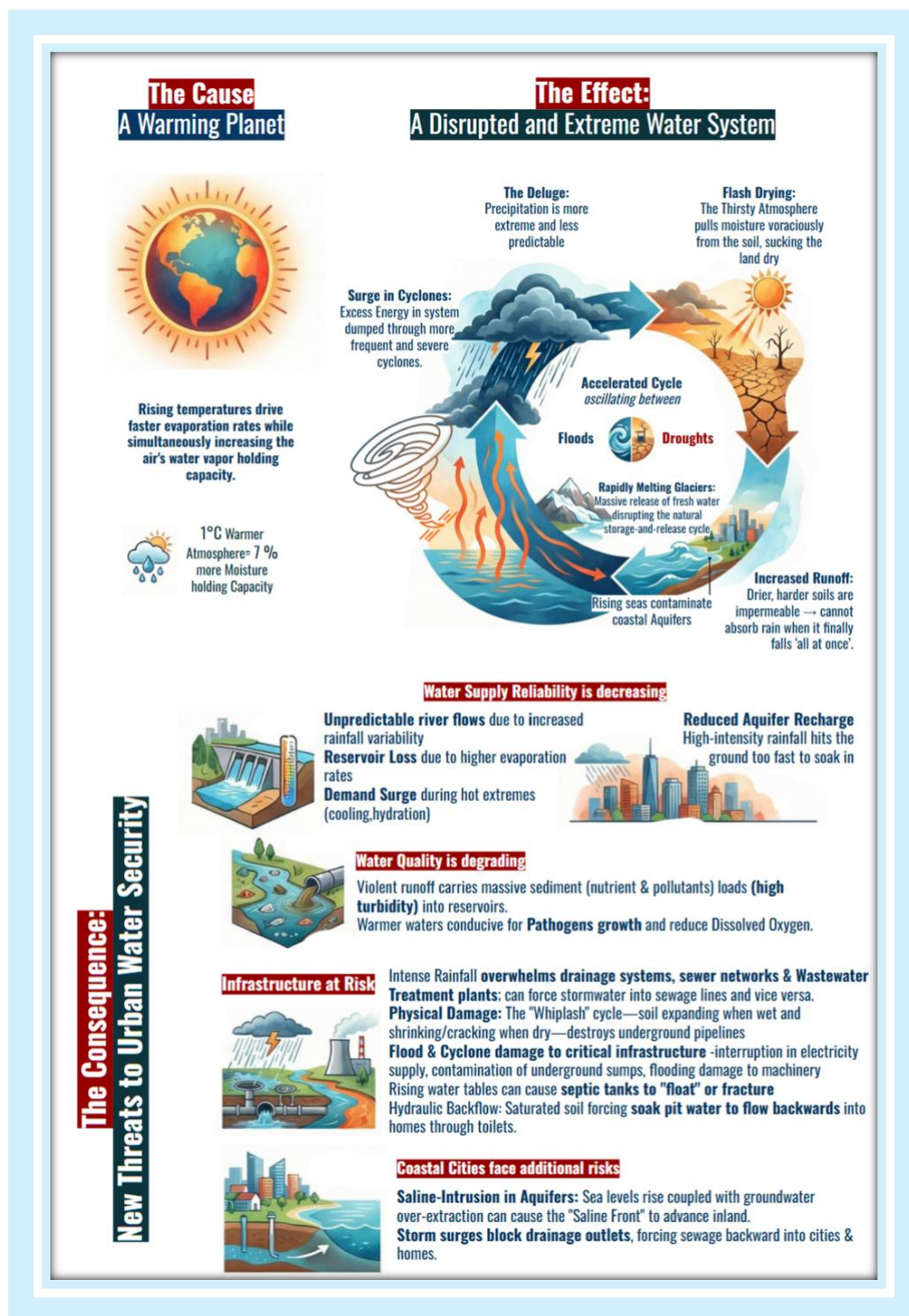
This leads to a volatile cycle: during dry periods, the 'thirstier' atmosphere aggressively evaporates moisture from soil and reservoirs, deepening drought conditions. However, once this moisture-laden air is triggered to release by a cyclone or orographic lift, it discharges with explosive intensity. Thus, cities are confronted with a dual reality referred to as the *climate whiplash*: longer, more intense dry spells that threaten source sustainability, interspersed with violent, short-duration rainfall events that overwhelm drainage infrastructure. These hydro-climatic shifts due to intensification of the hydrological cycle, destabilise water availability while escalating the threat of water-related disasters to human lives, critical infrastructure, and natural ecosystems. In fact, these hydrological extremes now constitute some of the most tangible and widespread impacts of climate change.

Between 2001 and 2018, over 74% of global natural disasters were water-related, causing over 300,000 fatalities and ~ 1.7 trillion USD in economic damages worldwide causing immense human and economic losses^{2,3}. Global Climate Risk Index 2021 ranks India as the seventh-most exposed and vulnerable country to climate extremes⁴. With high risk of concurrent flood incidents, the country is among the most vulnerable countries to climate change as per Intergovernmental Panel on Climate Change (IPCC) sixth assessment report. More than 300 extreme events have hit the country in recent decades, causing losses of more than INR 5,600 billion⁵. A recent evaluation indicates that more than 75% of districts in India, including 95% of coastal districts, are hotspots for extreme events.⁶

However, focusing solely on these acute disasters obscures the more insidious, *long-term erosion of water security* that cities now face. The fundamental shift in the hydrological baseline is creating a crisis of chronic unreliability. The rising temperatures on one hand result in a surge in water demand and volatility in water availability on the other. Furthermore, warmer temperatures actively degrade water quality by promoting algal blooms and reducing dissolved oxygen levels, meaning that even when water is physically available, it is increasingly difficult and energy-intensive to treat. Ultimately, these shifts threaten to render conventional infrastructure obsolete, transforming water security from a manageable operational challenge into a persistent existential risk for growing urban populations.

Figure 2 illustrates the intensification of the water cycle driven by global warming and its cascading consequences for urban water security. A disrupted natural system reduces reliability of water supply, degrades water quality and places infrastructure at risk. Coastal cities are particularly vulnerable in this changing regime, facing compounding threats from surging cyclones, sea-level rise, and storm surges that overwhelm drainage networks and force saline intrusion into freshwater aquifers.

Figure 2: Intensification of the water cycle due to global warming and its impact on urban water security.



Source: Author's Illustration

Nowhere are these hydro-meteorological shifts more immediately felt than in coastal cities, where land, ocean, and atmospheric systems intersect. The rapid retreat of glaciers and ice cover is causing sea levels to rise at unprecedented rates, further compromising the water availability and quality in coastal areas⁷. More intense rainfall combined with rising sea levels amplify storm surges, salinity intrusions and surface run-off placing coastal settlements at heightened risk. These shifts not only impact freshwater resources but also exacerbate existing vulnerabilities to flooding and inundation. A warmer atmosphere and ocean provide additional energy for storm intensification, leading to a greater number of extreme weather events. Cyclones, in particular, pose catastrophic threats not just to lives and infrastructure, but to the very backbone of urban resilience: access to WaSH. By damaging water supply and wastewater infrastructure, such events jeopardise public health and disrupt the essential services that coastal cities rely on, placing them at even greater risk. These hazards compound the existing pressures of urbanisation, placing critical water infrastructure under significant stress and exposing vulnerabilities in already stretched systems. These new risks are especially critical in India, where approximately 18% of its population resides in 72 coastal districts⁸.

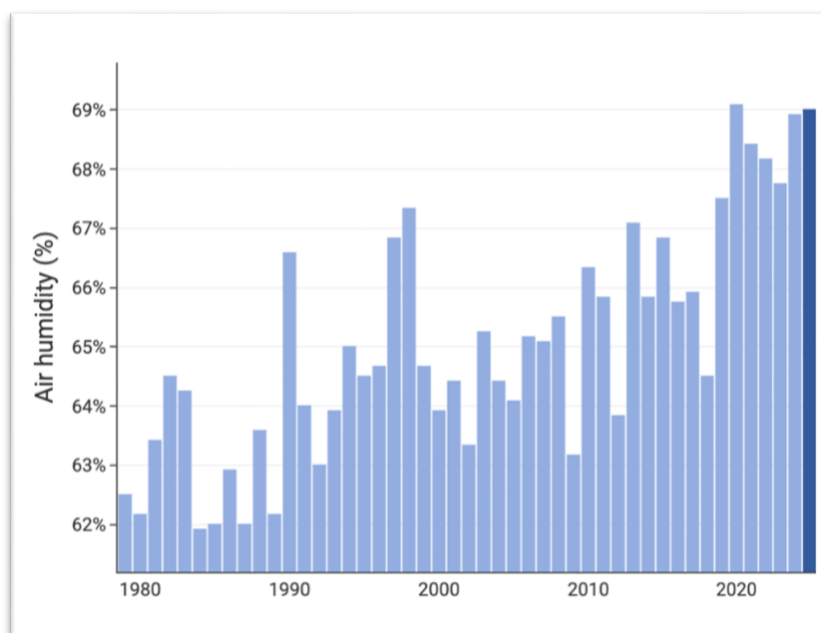
This escalating hydro-climatic volatility inevitably converges on Water management, particularly in cities, where dense populations, concentrated infrastructure, and increasingly fragile ecosystems intersect. Urban water systems spanning water supply, wastewater management, drainage, and groundwater regulation, were designed for a different climatic reality and are now struggling to cope. For instance, the January 2025 wildfires in Los Angeles exposed critical vulnerabilities in urban water systems. Firefighting efforts were crippled when water storage tanks ran dry; officials acknowledged the system was "designed to put out house fires, not multiple neighbourhoods on fire"⁹. Traditional management focused solely on balancing supply and demand becomes obsolete. Instead, WaSH systems must evolve into adaptive instruments for disaster preparedness and public health. In an era of uncertainty, safeguarding urban liveability requires transforming these interdependent systems to withstand the dual threats of chronic scarcity and acute extremes, *making resilient WaSH infrastructure the cornerstone of sustainable cities*.

1.2 THE RISING CLIMATE THREAT TO INDIA'S WEST COAST

The West Coast of India is rapidly emerging as a new frontier of climate risk, driven by a dangerous synergy between the warming Arabian Sea and the region's unique topography. While the Bay of Bengal has historically been the more active basin, recent data reveals a paradigm shift: the Arabian Sea has witnessed a 52% increase in the frequency of cyclonic storms and a threefold rise in very severe cyclonic storms during the recent epoch (2001–2019).¹⁰ This intensification is fuelled by rising Sea Surface Temperatures and Ocean Heat Content, which act as a massive "moisture pump" ensuring a constant supply of water vapour

to the warming air with a greater water holding capacity¹¹. This is corroborated by long-term atmospheric data showing a sharp surge in India's average annual air humidity, particularly in the 2020s where levels have consistently exceeded 68% (*Figure 3*). When this moisture-laden air intercepts the steep barrier of the Western Ghats, the resulting orographic lift triggers explosive, high-intensity rainfall events.

Figure 3: Annual time series of air humidity over Indian landmass.



Data Source: Global Water Monitor Data Explorer¹²

Along India's west coast, the coastal districts of Gujarat specifically have become increasingly vulnerable to tropical cyclones in recent years¹³. Further, west coast states are more exposed to sea level rise; every one-metre rise in sea level can inundate almost 5,763 km² of land¹⁴. Making the west coast more susceptible to coastal flooding and cyclones is the significant loss of the complex mangrove ecosystem, which will continue to increase beyond 2100 as per IPCC 2023 report¹⁵.

Furthermore, historically established as fishing villages and trading posts near river mouths or perched along the slopes of the Konkan and Sahyadri mountains, the coastal settlements have evolved into thriving industrial hubs, port cities, and tourist centres. The region's undulating terrain, fragile slopes, rising sea levels, erratic weather patterns, and increasing cyclonic activity exacerbate its vulnerability. Challenges such as land submergence, wave shoaling, shoreline erosion, salt intrusion, groundwater flooding, and coastal inundation are increasingly evident. These threats contribute to environmental degradation, contamination of land and water, disruptions in essential services, and potential infrastructure failures.

1.3 SYSTEMIC VULNERABILITIES AND THE CLIMATE MULTIPLIER EFFECT

Densely populated coastal cities have long grappled with rising demand amid diminishing water availability. Over the years, infrastructure expansion, intensified water pumping, and landscape modification became embedded in policy and practice as conventional approaches to water management. Yet these approaches often degrade natural environments both within and beyond city boundaries. Water flows are altered through water extraction, river diversions, reservoir construction, and flood control measures. Impermeable built surfaces reduce rainwater infiltration and groundwater recharge, while the loss of vegetation disrupts processes like transpiration that help sustain the natural water cycle. At the same time, cities generate massive amounts of wastewater that flows back into the natural cycle, often untreated and poorly managed. In their determined efforts to cope up, cities have often compromised the very ecosystems they depend upon. In the water-stressed context of India, short-term needs are often understandably prioritised over long-term sustainability particularly for a need as vital as water: the lifeblood of urban life. However, this trade-off may no longer be tenable.

Even without climate pressures, water management in Indian cities faces deep structural challenges: widening demand–supply gaps, shrinking freshwater sources, falling groundwater tables, and the degradation of rivers, wetlands, and aquifers. Conventional approaches such as large dams, long-distance water transfers, deeper extraction, and engineered flood-control measures, have historically prioritised short-term supply augmentation at the expense of ecological stability.

The consequences are far-reaching:

- *Altered river flows and disrupted drainage systems* due to unplanned urban development
- *Low groundwater recharge* caused by impermeable surfaces
- High dependence on *energy-intensive pumping*, increasing carbon emissions
- *Large volumes of untreated wastewater* discharged into rivers, seas, and aquifers
- *Increased vulnerability to floods and salinity intrusion* as coastal ecosystems such as mangroves and estuaries decline

As a result, urban water systems across India operate under chronic stress, with climate change amplifying existing weaknesses and introducing new, compounding risks.

Further exacerbating the risks posed by climate change is the inadequate infrastructure and services in critical areas such as housing, sanitation, water, and public health, particularly for

socio-economically disadvantaged groups^{16,17,18,19} and are now exposed to climate change-related risks.

Governance and Policy Gaps: A Structural Barrier to Resilience

Despite clear evidence of climate impacts, policy responses across water, energy, and urban development remain fragmented. Governance arrangements continue to operate in sectoral silos:

- *Water policies* focus on augmenting supply rather than reducing demand or building resilience.
- *Energy policies* rarely account for the energy footprint of WaSH services and the water footprint of energy generation and distribution.
- *Climate strategies* frequently overlook the carbon footprint and vulnerabilities of water and wastewater infrastructure.

Urban Local Bodies (ULBs) face chronic financial and technical capacity constraints. Many rely on ad-hoc, project-driven solutions that respond to immediate complaints but do little to address systemic vulnerabilities. Institutional inertia, overlapping jurisdictions, and limited accountability impede long-term planning. Meanwhile, the most severe impacts are disproportionately borne by marginalised communities, deepening socio-spatial inequities.

Without integrated governance mechanisms, cities remain locked into cycles of over-extraction, infrastructure stress, ecological decline, and rising climate vulnerability. For comprehensive insights on policy landscape refer to our policy analysis reports.

1.4 REIMAGINING URBAN WATER RESILIENCE IN THE FACE OF CLIMATE CHANGE

Climate change on one hand, underscores the urgent need for effective urban water management to enhance the health resilience of populations and mitigate its impacts on cities. On the other, it intensifies existing water-related challenges brought by urbanisation, threatening the sustainability of urban water systems. As temperatures continue to rise, conventional water management approaches focused on large-scale infrastructure, and reactive coping strategies may prove insufficient under these compounded pressures. In fact, such strategies could worsen long-term vulnerabilities by disrupting the natural water cycle, especially in fragile coastal ecosystems.

Climate change thus acts as a wake-up call, urging policymakers to reassess the fragile relationship between urban water systems and the natural water cycle. Ensuring long-term water security and resilience demands a new paradigm that not only addresses the immediate

impacts of climate change but also strives to harmonise existing water systems with natural cycles.

With this understanding, a study titled *“Landscape analysis for four coastal states on climate resilient water and sanitation infrastructure”* was initiated under the Climate Resilient Coastal Cities (CRCC) initiative financially support by HSBC India. The study focuses on evaluating the existing water and sanitation systems in the backdrop of emerging climate realities in 12 coastal towns across Maharashtra, Gujarat, Karnataka, and Karnataka (*Figure 4*).

Figure 4: Case study towns across 4 west coastal states of India

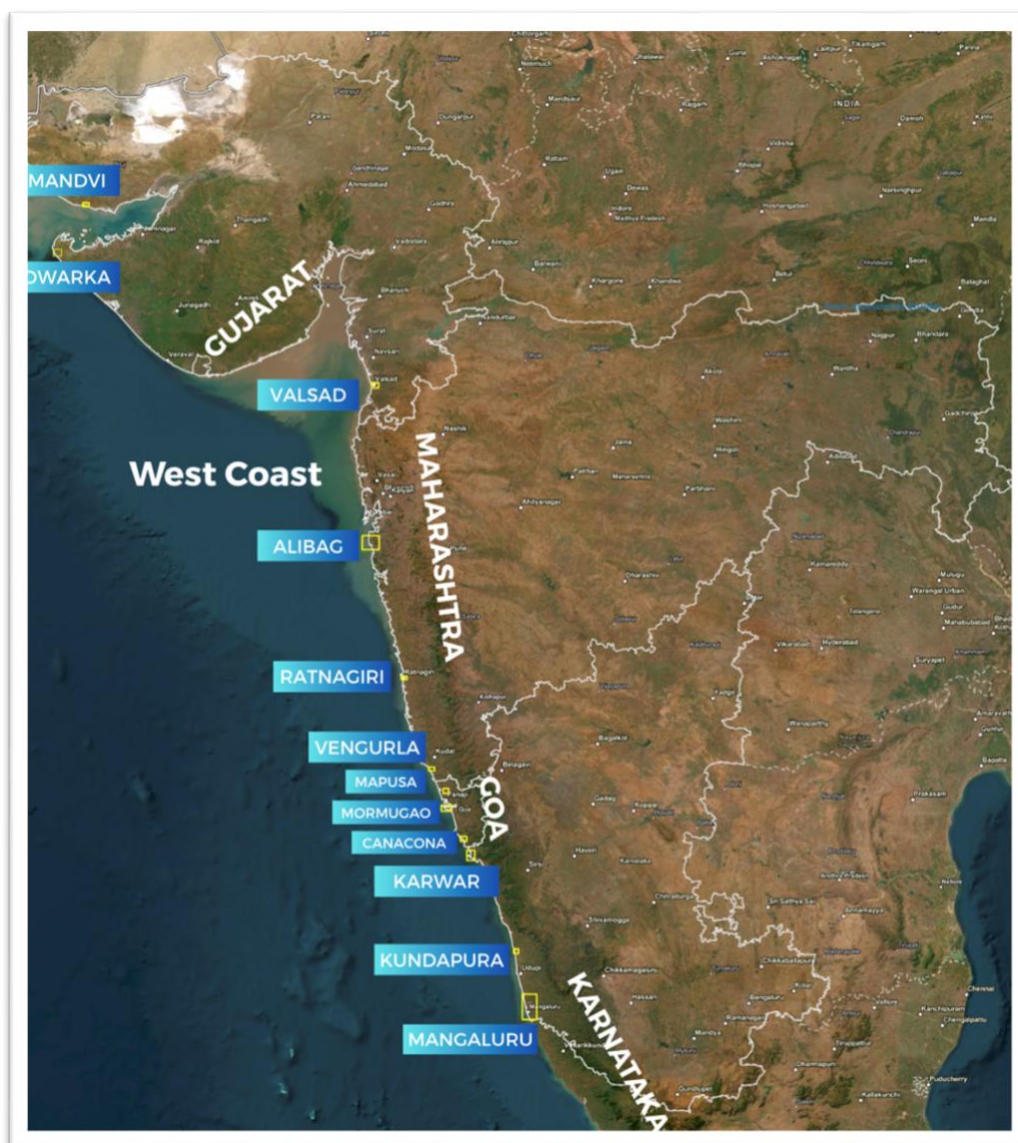


Image Source: Author's Illustration

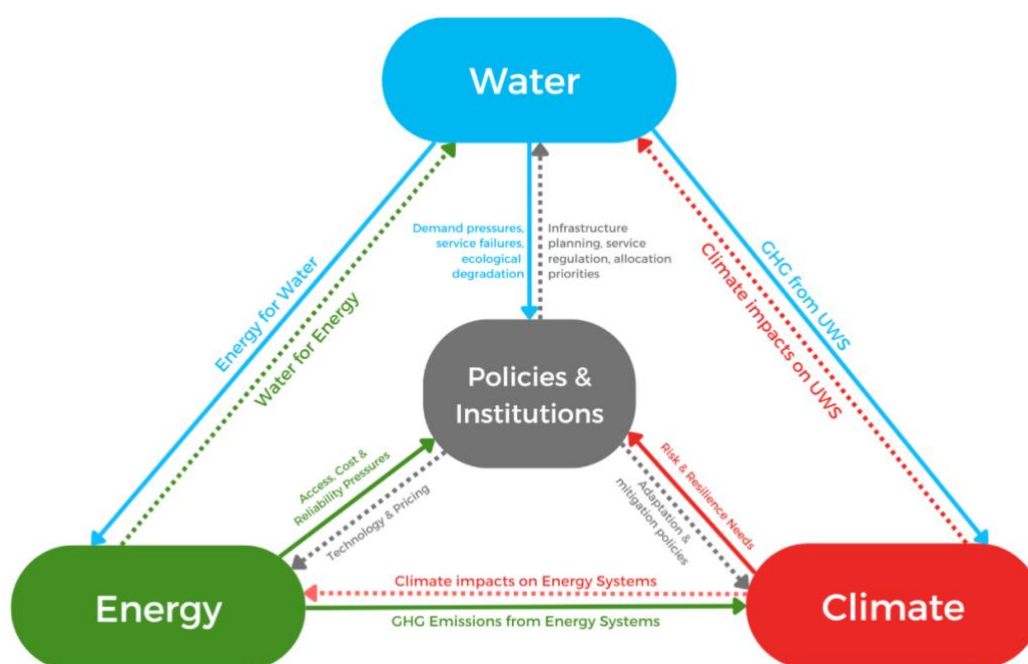
1.5 METHODOLOGY

The *primary objective* of our study is to assess the operational and institutional readiness of the Urban Water & Sanitation sector to adapt to a changing hydro-climatic regime, while identifying pathways for low-carbon and sustainable service delivery. The methodology is structured to build a cumulative evidence base, moving from baseline profiling to detailed diagnostics and resilience evaluation.

1.5.1 ANALYTICAL FRAMEWORK

The process begins with a systematic literature review to establish the analytical framework governing the interaction between climate impacts and water and sanitation (WaSH) infrastructure.

Figure 5: The Water-Energy-Climate Nexus in urban water systems.



Source: Author's Illustration

Our methodological approach is grounded in a systems-thinking framework that conceptualises urban water and sanitation (WaSH) not as an isolated sector, but as a dynamic component of the Water-Energy-Climate nexus. As illustrated in [Figure 5](#), this approach

evaluates the bi-directional interactions between these three critical domains, all of which are mediated by central governance structures.

The framework is structured around four primary nodes and their interacting flows:

1. **The Water-Climate Interaction:** The framework assesses the dual relationship between WaSH infrastructure and climate change. It evaluates the physical climate impacts on Urban Water Systems (UWS) such as extreme weather events, altered hydrological cycles, and coastal hazards while simultaneously quantifying the GHG emissions from UWS, establishing the carbon footprint of current water management practices.
2. **The Water-Energy Interdependency:** It maps the resource interdependencies, specifically focusing on the Energy for Water requirement. This involves auditing the energy intensity of extracting, treating, and distributing water, as well as conveying and treating wastewater.
3. **The Energy-Climate Linkage:** The framework acknowledges that the energy systems powering WaSH are themselves vulnerable to climate impacts, while their baseline GHG emissions dictate the overall carbon intensity of the urban water cycle.
4. **Policies & Institutions:** Placed at the core of the framework, institutional governance acts as the primary mediating force. The framework analyzes how governing bodies respond to systemic stressors such as demand pressures, ecological degradation, and risk/resilience needs and how they shape the physical systems through infrastructure planning, resource allocation, technology pricing, and the implementation of adaptation and mitigation policies.

By applying this holistic framework, the situational assessment moves beyond simple infrastructure mapping. It allows us to systematically identify operational vulnerabilities, calculate environmental footprints, and evaluate the institutional readiness required to build climate-resilient WaSH systems.

1.5.2 TOWN SELECTION CRITERIA

The town selection followed a two-step process. First, a set of criteria was developed through a comprehensive literature review (*outlined in Table 1*). These criteria were designed to ensure diversity among the case study towns in terms of WaSH infrastructure and services, geography, demographics, and climate vulnerability, administrative status, thus enabling a more representative and contextually grounded analysis.

- **Current understanding of climate risks:** The selection process considered the known climate risks each town faces, as these are critical for assessing the vulnerability of WaSH infrastructure to climate-related hazards.
- **Variation in infrastructure and urban characteristics:** Towns were selected to reflect diversity in water and sanitation infrastructure and service levels, population size, climatic conditions, and economic activities—factors that influence exposure and adaptive capacity and GHG emissions.
- **Socio-economic profile:** Differences in socio-economic conditions lead to varied water consumption and sanitation practices. These factors are crucial for understanding a town's climate resilience and estimating GHG emissions in the WaSH sector.
- **Administrative status:** The administrative status of a town significantly influences its capacity for climate change planning and response, especially in critical sectors like water and sanitation. Towns with higher administrative status—such as municipal corporations or class-I and beyond—tend to have greater autonomy, better institutional structures, and access to financial and technical resources. They are more likely to have dedicated departments, skilled personnel, and the ability to integrate climate considerations into urban development plans. These towns also benefit from larger budgets, greater revenue-generating powers, and enhanced eligibility for national and international funding schemes focused on climate adaptation and mitigation. In contrast, smaller towns or panchayats often rely heavily on state or district-level agencies, leading to delays in planning and implementation. Moreover, higher status towns typically have better data systems and monitoring capabilities, which are essential for assessing climate risks and emissions. Their greater political visibility further enhances their chances of being included in pilot projects or targeted policy interventions. Thus, a town's administrative status directly shapes its ability to design and implement effective, context-specific climate-resilient infrastructure and services.

The above process generated a preliminary list of towns, from which the final selection was made in consultation with the state Directorates of Swachh Bharat Mission Urban (SBM-U).

Table 1: Town Selection Criteria

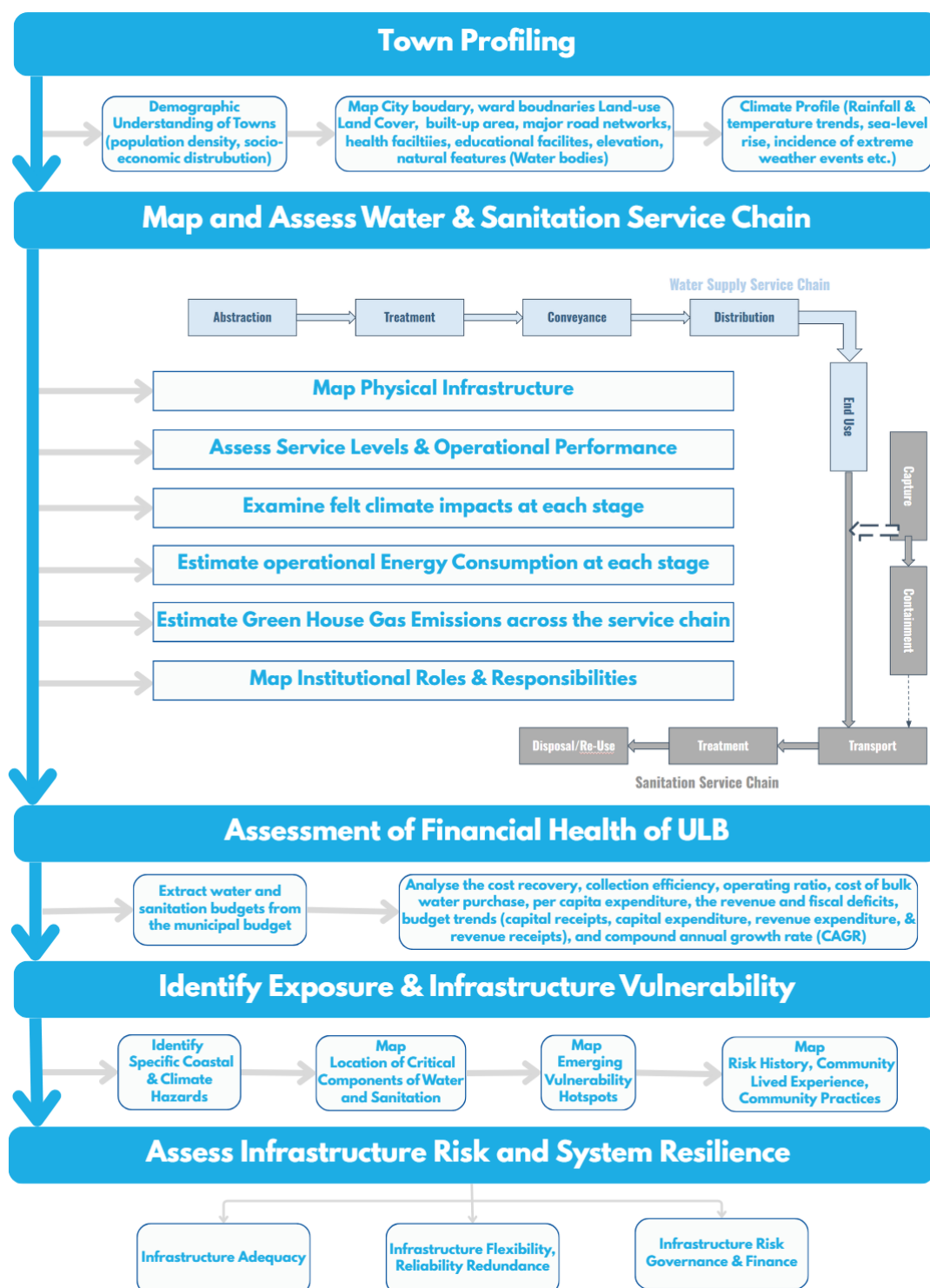
Key Parameters	Selection criteria		
Administrative status	Municipal Corporation	Municipal Council (A and B)	Nagar Panchayat (C and D)
City Size based on population	Class-I to Class IV		
Socio-economic profile	Capturing variability in socio-economic profile of the town population		
Climate Change Exposure and vulnerability	Low Risk/vulnerable	Medium Risk/vulnerable	High Risk/vulnerable
Sanitation Infrastructure Services Status	Only On-site Sanitation	OSS + % networked system	OSS+ % networked + Non-networked (NBS/Conventional/ FSSTP)
Economic Contributions /Profile	Industrial, agricultural, tourism, service sectors		
State government and ULB support	Past and current partnerships, collaborations		

Table 2 : Selected Towns

State	Town	Population (2011)	Class
Maharashtra	Alibag	20,743	Class-III
	Ratnagiri	76,229	Class-II
	Vengurla	12,392	Class-IV
Karnataka	Mangaluru	4,99,487	Class-I
	Kundapura	30,444	Class-III
	Karwar	77,139	Class-II
Goa	Canacona	12,434	Class-IV
	Mormugao	94,393	Class-II
	Mapusa	39,989	Class-III
Gujarat	Dwaraka	38,873	Class-III
	Mandvi	51,376	Class-II
	Valsad	1,70,060	Class-I

1.5.3 STEP-BY-STEP APPROACH TO SITUATIONAL ASSESSMENT

Figure 6: Methodological framework for the situational assessment and resilience evaluation of urban WaSH systems.



As illustrated in [Figure 6](#), our town-level situational assessment follows a logical, multi-step progression that begins with town profiling to establish demographic, spatial, and climatic baselines. We then map the entire water and sanitation service chain to evaluate physical infrastructure, operational performance, environmental footprints, and institutional responsibilities. This is followed by a financial health assessment of the Urban Local Body to analyse municipal budgets and expenditure trends. Next, we identify specific vulnerabilities by mapping coastal hazards against critical infrastructure locations and emerging risk hotspots. These steps finally culminate in a comprehensive resilience assessment that evaluates the overall adequacy, flexibility, reliability, and financial risk governance of the system.

1.5.4 DATA COLLECTION

To assess the resilience of water and sanitation infrastructure, the study employed a mixed-method approach combining extensive desk-based research with targeted fieldwork. Initial reviews of national and municipal datasets (e.g., Census, SBM-U) established the analytical framework and identified critical data gaps, which were subsequently addressed through stakeholder consultations with ULB and state-level officials. This was complemented by on-ground validation, including technical site visits to key infrastructure assets (WTPs, reservoirs) and rapid assessments of vulnerability hotspots, where semi-structured interviews with residents provided critical insights into service delivery challenges and local climate impacts. Detailed data collection steps and questionnaire for ground truthing (resident interviews) are provided in [Annexure-I](#) of the report.

The study also identified several critical data gaps that limit comprehensive assessment and effective decision-making. These gaps, detailed in [Annexure-II](#), highlight the need for improved data collection, systematic reporting, and stronger integration of information across institutions to better inform future planning and resilience-building efforts.

This situation assessment report presents the study findings for **Mangaluru, Class-I coastal town in Karnataka's²⁰ Dakshina Kannada district, situated in one of the four most climate-vulnerable states in India²¹**. Mangaluru is an administrative headquarters of the district. The town was the second-largest contributor to Karnataka's GDP in 2022-23, accounting for 5.5%, and has the second-highest per capita income in the state at INR 4,92,074, following Bangalore Urban district²². Dakshina Kannada district is specifically classified under a moderate damage risk zone for wind hazards, with a low risk regarding maximum sustained wind speeds²³. However, Mangaluru faces growing climate-related challenges including increased flooding, coastal erosion, and saltwater intrusion, exacerbated by its low-lying coastal topography and aging infrastructure. Coastal erosion and land submergence have been observed in Mangaluru (GoK, 2022)²⁴. The absence of a city-level climate adaptation or mitigation strategy, along with fragmented governance, hinders

proactive planning. Intense rainfall, coupled with poor drainage, leads to both riverine and flash flooding, while tidal activity and sea level rise contribute to saltwater intrusion into freshwater sources and corrosion of underground infrastructure.

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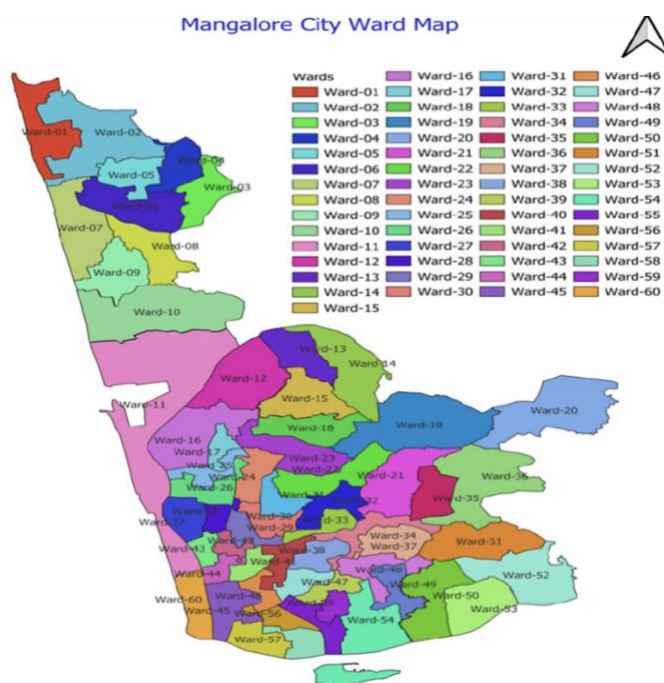
2. TOWN PROFILE

NEELAM RANA, PRIYAKSHI GOGOI, SUCHARITA ROY, TEJASH ANAND & N.C. NARAYANAN

This chapter presents a detailed town profile, covering demography, climate, topography, land use and land cover, as well as key climate risks highlighted in literature.

Mangaluru is a significant port city on the southwestern coast of Karnataka, India, and the fourth-largest city in the state. It serves as the district headquarters of Dakshina Kannada and is strategically located between the Western Ghats to the east and the Arabian Sea to the west, contributing to its prominence as one of India's key port cities. Situated about 350 kilometers from Bangalore, Mangaluru lies at a latitude of 12°50'30" N and longitude of 74°48' 0" E, with an average elevation of 72 feet above sea level. The city is positioned at the confluence of the Netravali and Gurupura rivers, which define its boundaries. Well-connected by three major national highways—NH-13, NH-17, and NH-48—Mangaluru's accessibility is further enhanced by its international airport located in Bajpe (Ingaldi & Angadi, 2023)²⁵. The Mangaluru city corporation (MCC) is responsible for city administration, comprising a legislative wing led by the Mayor and an executive wing headed by the City Commissioner. The city has been divided into 60 wards and each ward represented by corporate.

Figure 7: Mangaluru City Map



Source: Mangaluru City Corporation

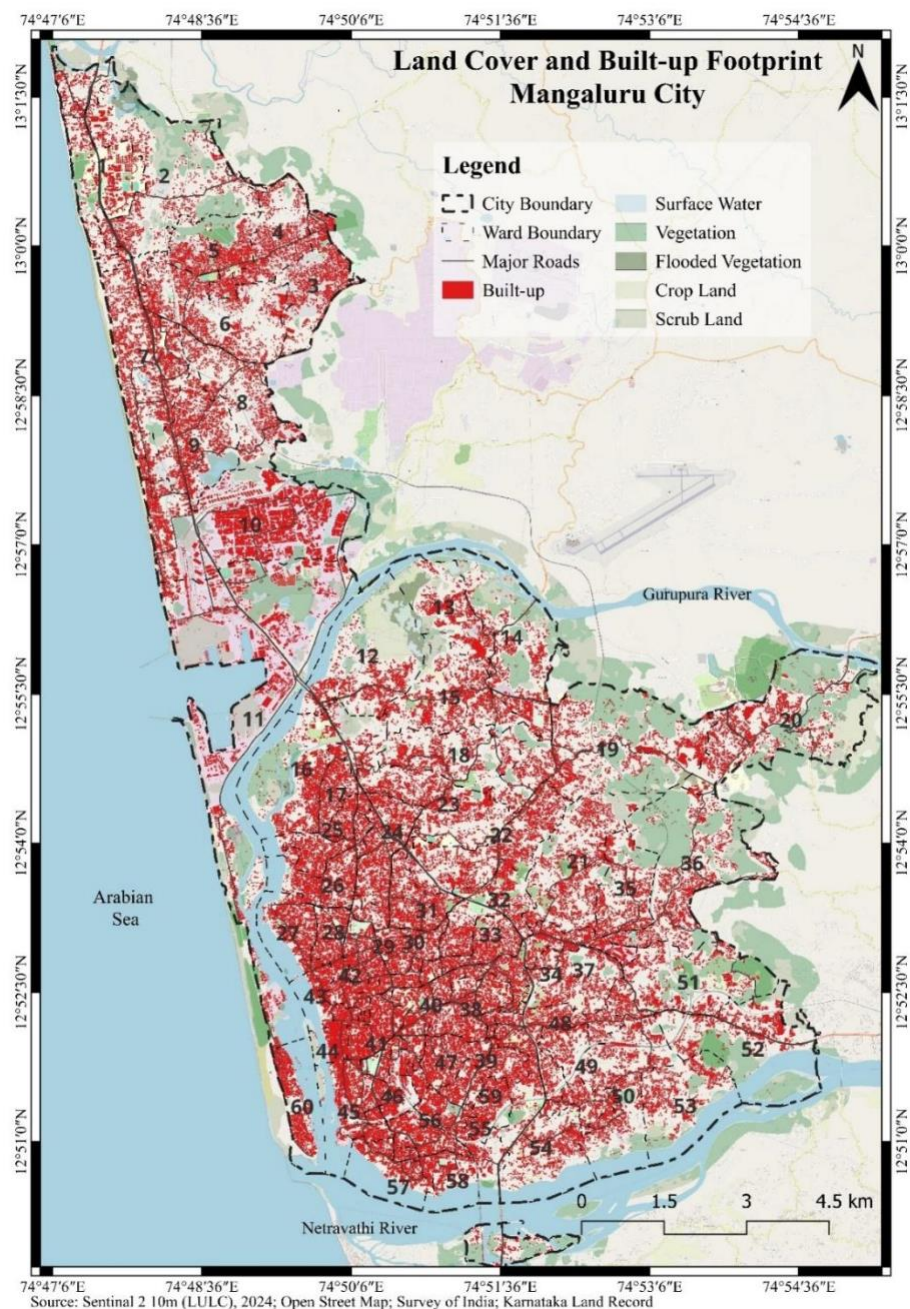
Demographic Profile: The city, with areas 132.45 sqkm, has 1,12,444 households according to the 2011 census in 60 wards. As per the 2011 census, Mangaluru city has a total population of 4,88,487, including 242512 males and 246456 females. The average sex ratio is 984 females per 1,000 males. The child population aged 0-6 years is 43340, which is 9% of the total population. Mangaluru is notably high at 93.72%, with male literacy at 96.09% and female literacy at 91.41%. The city has a small slum population, comprising about 1.55% of its total population (Census of Indian, 2011).

A total of 203396 individuals in the Municipal City Corporation area, were engaged in work activities. Of these workers, 189078 were employed in main work (defined as employment lasting more than six months), while 14318 were involved in marginal work, earning a livelihood for less than six months. Among the 189078 main workers, only 887 were cultivators (either owners or co-owners), and 766 were agricultural labourers (Census, 2011).

Landuse and Landcover: Mangaluru is a tier 1 city and flanked by the two rivers – Gurupur and Netravati in the north and the south. There has been a rapid increase in the built-up area largely induced by intense in fill growth in the core range of the city indicating the compact nature of city growth (refer Figure 8). Built-up area has increased, and agricultural land decreased significantly over the past decades. The spatial trend of change analysis reveals the expansion of built-up land along with the transport network, primarily along a north–south course(Dhanaraj, 2020)²⁶ .

Economy: The administrative headquarters of Dakshina Kannada is Mangaluru city, located in Mangaluru Taluka, which is also the focus of this study. Dakshina Kannada district is the second-largest contributor to Karnataka's GDP in 2022-23, accounting for 5.5%, and has the second-highest per capita income in the state at Rs. 4,92,074, following Bangalore Urban district (Government of Karnataka, 2024). The district is rich in extensive river network systems. The two major rivers, Netravathi and Gurupura, run through Mangaluru Taluka. Mangaluru's economic growth is reflected in the rapid expansion of its international airport, one of the fastest-growing airports in India, and the only one in Karnataka with two operational runways (Ingalgi & Angadi, 2023) . The northern part of Mangaluru is home to Mangaluru Refinery and Petrochemicals Limited (MRPL), a subsidiary of the Oil and Natural Gas Corporation (ONGC), playing a vital role in India's petrochemical sector. While Mangaluru has modernized rapidly, it has also preserved its traditional fishing industry, which continues to be a key element of the local economy and diet (Ingalgi & Angadi, 2023) . In recent years, Mangaluru has emerged as a centre for information technology and outsourcing, with over 15,000 IT professionals and more than 55 companies based in the city. Major firms such as Cognizant, Thomson Reuters, Polaris Financial Technology Limited, Infosys, and Emphasis have offices in Mangaluru (ibid).

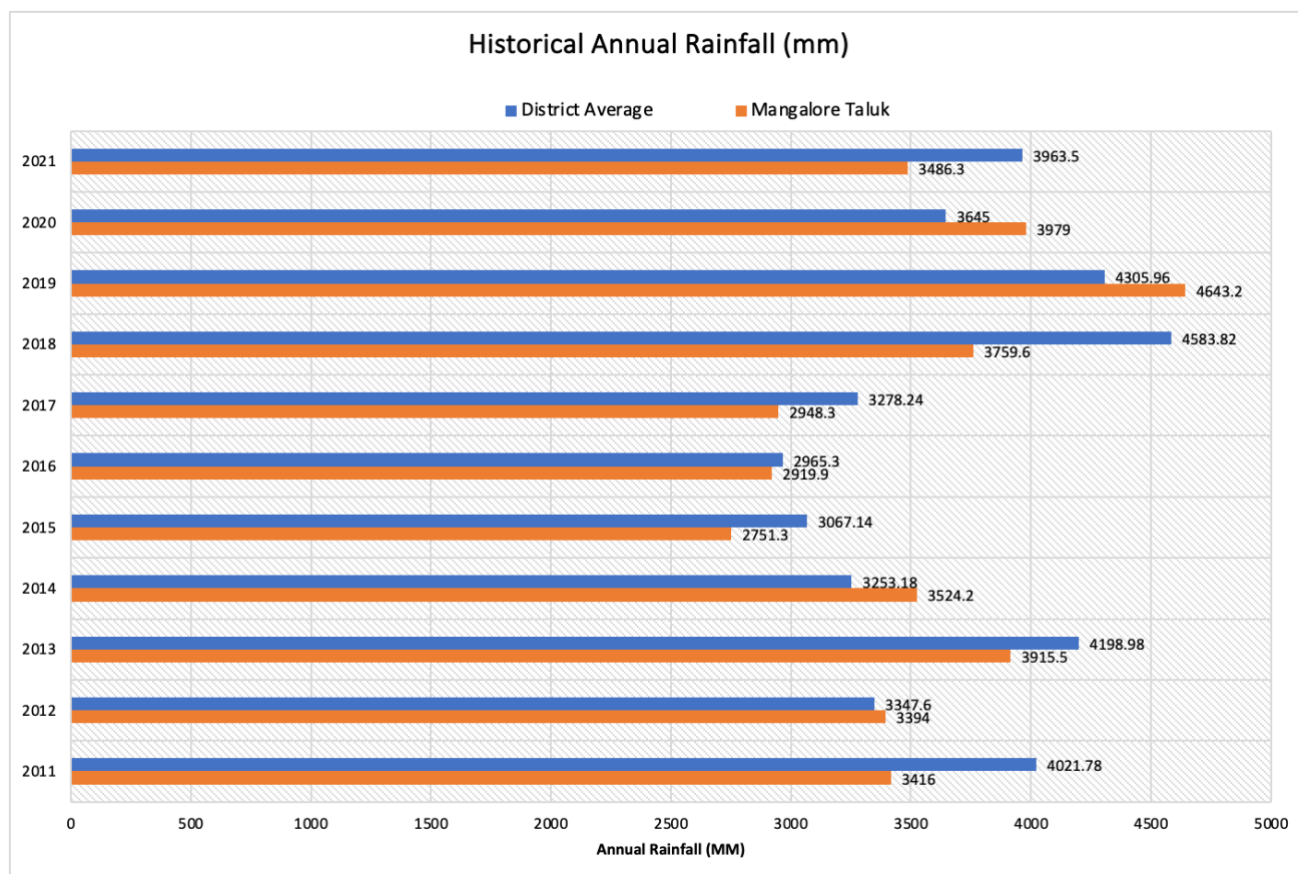
Figure 8: Land Cover and built-up footprint of Mangaluru



Climate: The town falls under the coastal agro-climatic zone within Dakshina Kannada District. The district has a tropical monsoon climate, with hot and humid conditions along the coast year-round. Temperatures rise from January, peaking around 30°C in May, occasionally reaching 38°C. As compared to other districts, the coastal districts of Dakshina Kannada, (and Uttara Kannada and Udupi) record higher average annual rainfall (exceeding 2000 mm between

1992 and 2022). Between 2011 and 2021, Mangaluru taluka recorded an average annual rainfall lower than the district's overall average, with the exception of the years 2012, 2014, 2019, and 2020 (refer Figure 9).

Figure 9 : Historical Annual Rainfall (mm) in Mangaluru Taluka (Dakshina Kannada), Karnataka



Source: (Uttara Kannada District Disaster Management Authority, 2023)²⁷

Climate Change and Disasters: Town level data on disasters is lacking. Hence, district and taluka level secondary data on disasters were relied upon. While coastal districts in Karnataka excel in HDI, MPI, and poverty levels, they face increasing vulnerability due to direct threats from cyclones in the Arabian Sea and indirect impacts from eastern coastline cyclones. The coastal areas struggle with cyclones and seawater intrusion (GoK, 2022)²⁸. Dakshina Kannada district is classified under a moderate damage risk zone for wind hazards, with a low risk in terms of maximum sustained wind speeds (Niti Aayog, 2025)²⁹. As shown in Table 3, the **cyclones** are identified as high impact and low frequency disaster events (Dakshina Kannada District Disaster Management Authority, 2023). The most severe cyclone on record was in 1979, although no major damage was reported at that time. In 2019, however, the district experienced four significant cyclones in the Arabian Sea—Vaayu, Hika,

Kyarr, and Maha—which led to heavy rainfall due to the cyclonic effects. **As shown in the Table 3, the floods are identified as high impact and high frequency disaster events in the district (District Disaster Management Authority, 2022)³⁰. Historically there have been incidents of floods in the low-lying areas along the major rivers especially Netravathi and Gurpur. Highest amount of rainfall expressed (400mm) in Mangaluru Taluka on May 29th, 2018, causing Urban Flooding. Mangaluru taluka received highest annual rainfall in year 2019 (District Disaster Management Authority, 2022).**

Mangaluru taluka and Bantwal taluka were declared **drought (mostly due to deficit of rainfall and area under sowing) hit in 2016-17 by the state government** (District Disaster Management Authority, 2022). As per climate change projections, the drought' years are projected to decline, in the range of 1 to 3 years under RCP 4.5 scenario, and 1 to 4 years under RCP 8.5 scenario for Short-term (2030s), in Uttara Kannada and Dakshina Kannada. As shown in the Table 3, heat waves are identified as high impact high frequency disaster events by the District Disaster Management Authorities³¹. The district is expected to experience a warming of 0.5°C to 1°C. About 15 districts in Karnataka, excluding Dakshina Kannada, are particularly vulnerable to heat waves (Government of Karnataka, 2023)³². Approximately 30% of the coastal zone experiences moderate **sea erosion**, with 16% facing severe erosion, especially in Dakshina Kannada and Udupi. Coastal erosion and land submergence have been observed in areas like Ankola, Bhatkal, Malpe, **Mangaluru**, and Gokarna.

Table 3: Impact vs frequency mapping of Hazards in Dakshina Kannada District

Events	High impact low frequency	High impact High frequency
Cyclones/Heavy Rains		
Floods		
Sea Erosion		
Heat Wave		

Source: (District Disaster Management Authority, 2022)

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3. STATUS OF WATER INFRASTRUCTURE AND SERVICES

ASHISH DANGI³³ AND NC NARAYANAN

This chapter provides a situational assessment of Mangaluru's water sector, mapping the town's existing infrastructure from source to consumer. By analysing the systemic challenges along with emerging climate risks, the chapter uncovers the structural and environmental pressures that define the town's current water security landscape.

Mangaluru, a coastal city bounded on three sides by the Arabian Sea, Gurupura River, and Netravati River, enjoys a diverse hydrological setting. This unique geography supports both surface and subsurface freshwater sources, including shallow, deep, and estuarine aquifer systems. These varied sources have historically sustained the city's water needs and continue to play a critical role in meeting domestic, industrial, and agricultural demands (refer Figure 10). Mangaluru is flanked by two major west-flowing rivers: the **Netravati** and **Gurupura**, which converge near the city before discharging into the Arabian Sea. These rivers are vital lifelines, serving not only as primary water sources but also supporting agriculture, navigation, and biodiversity.

3.1 SURFACE WATER SOURCES

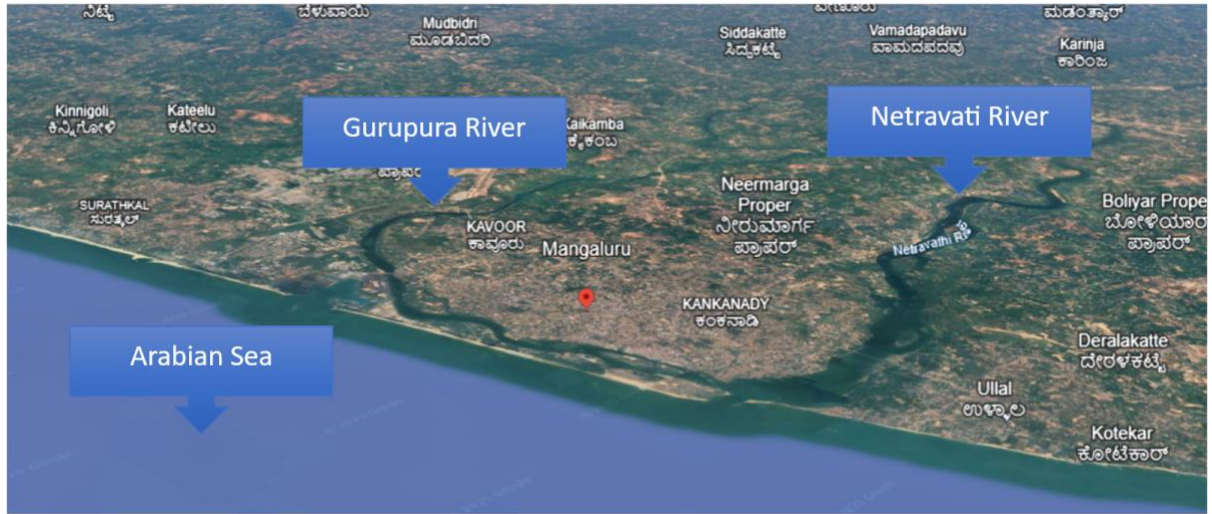
Netravati River – Primary Water Source for Mangaluru

The Netravati River has been Mangaluru's primary water source since 1956. It is a perennial river originating in the Western Ghats at an elevation of about 1,000 meters and stretches 103 km before discharging into the Arabian Sea near the city. It flows initially in a north-south direction before turning west at Gohattu and merging with the Arabian Sea. Its drainage basin spans approximately 3,657 sq. km, with the Kumaradhara River joining as a major tributary near Uppinangadi.

The Netravati River basin experiences a tropical monsoon climate, characterized by heavy rainfall, high humidity, and hot summers. The annual rainfall ranges from 2,002 mm to 5,277 mm, while temperatures vary between 16°C (minimum) and 42°C (maximum). Wind speeds fluctuate between 7.2 km/h and 9.6 km/h. While the Netravati River currently provides a reliable surface water supply, existing risks such as upstream deforestation, sedimentation,

and pollution from urban and industrial runoff are already affecting water quality and base flows.

Figure 10: Surface Water Source - Haladi River



Source: Ashank Desai Centre for Policy Studies, IIT-Bombay using Google Earth Historical Imagery

A study from IIT Bombay³⁴ highlights how the urban footprint in the Netravati basin has quadrupled since 1972, reducing groundwater recharge and increasing surface runoff. This has led to declining water availability, higher flood risks, and worsening water quality. The basin has also experienced significant deforestation (18% since 1972, with a projected 26% decline by 2030), further affecting the region's hydrology. These pressures are compounded by emerging climate risks like erratic rainfall patterns and rising temperatures. Increasing urban demand and potential upstream diversions for agriculture or hydropower further threaten long-term flow reliability, especially during lean seasons.

3.2 GROUNDWATER

Ground water is found in mainly two types of aquifer systems (refer figure 11):

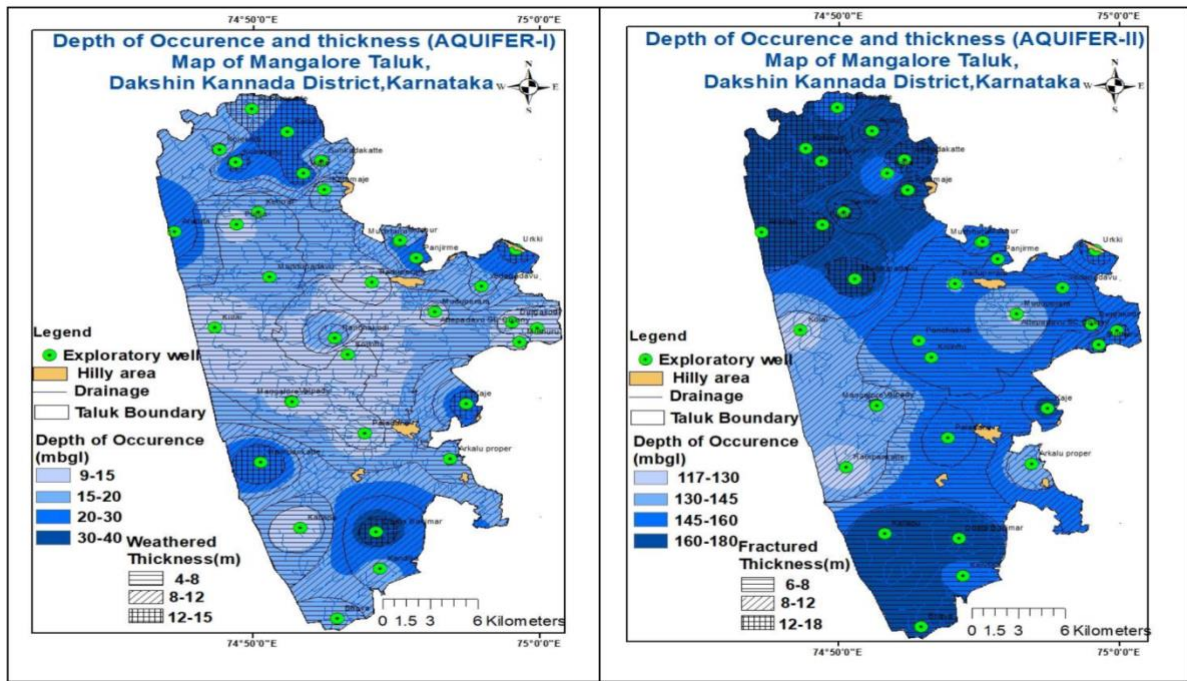
- **Shallow Phreatic Aquifer (Aquifer-I)**- Comprises Alluvium, Laterite and weathered granitic gneiss. In most areas of Mangaluru City Corporation (MCC), the shallow aquifer is found at depths ranging from **9 to 15 meters below ground level (mbgl)**. However, in the southern parts of the city, the aquifer depth increases to **15–20 mbgl**, with the deepest occurrences, reaching **20–30 mbgl**, observed in the southernmost region, particularly in

the Hampankatta area. The **weathered zone thickness** of the aquifer varies between **4 and 8 meters**, while deeper fractures extending **12–15 meters** are found in the Hampankatta region.

- **Deeper Fractured Aquifer (Aquifer-II)** - comprises of Alluvium, laterite and fractured Granite Gneiss rock. The deeper aquifer is generally found at depths of **130–145 meters below ground level (mbgl)** across most parts of the city, with a **fractured thickness ranging from 8 to 12 meters**. However, in the Hampankatta area, located in the southern part of the city, it occurs at a shallower depth of **117–130 mbgl**.

The spatial distribution of depth of occurrence and aquifer thickness is depicted in below Figure 5.

Figure 11: Depth of occurrence and weathered thickness map of Aquifer-I and Aquifer-II in Mangaluru Block

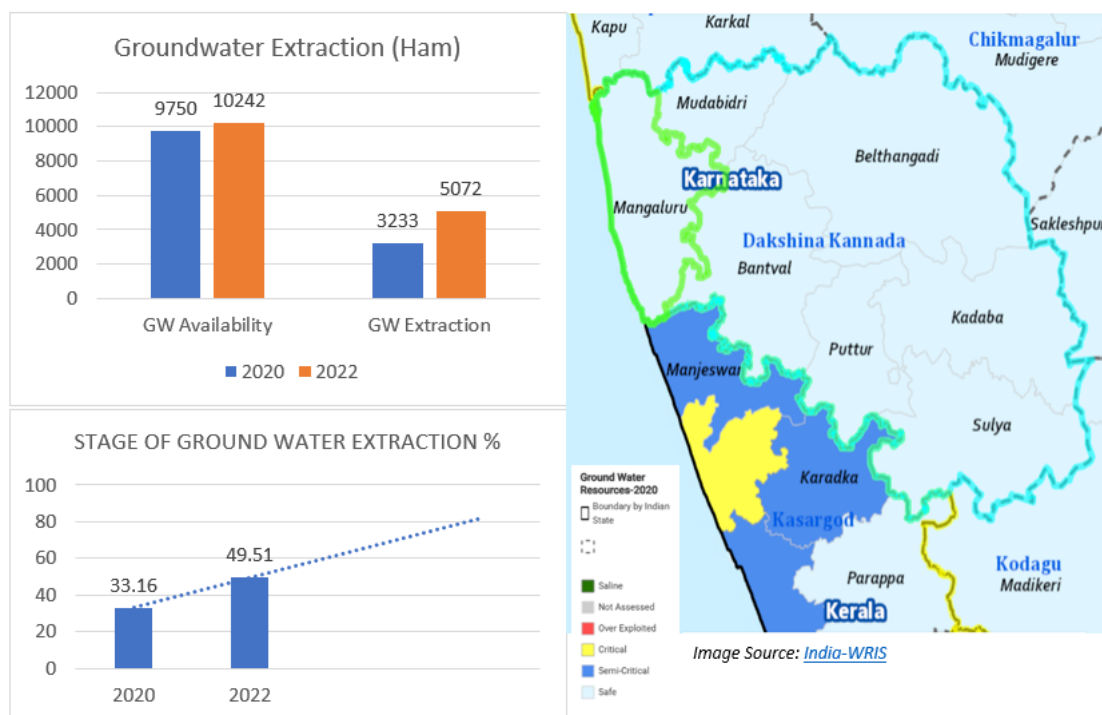


Source: Central Ground Water Board (CGWB), May 2023³⁵

As of 2022, the Central Ground Water Board (CGWB) classifies **Mangaluru Block as 'Safe'**, with just **50% of total groundwater resources currently utilised**. However, extraction has increased since 2020, indicating a rising demand driven by urbanization and agricultural expansion. Additionally, climate change-induced temperature rise, and erratic rainfall are affecting recharge rates and overall groundwater availability. While the current situation

remains stable, long-term sustainability challenges necessitate proactive measures (refer Figure 12).

Figure 12: Status of groundwater extraction in Mangaluru block



Source: Central Ground Water Board (CGWB), May 2023³⁵

Groundwater in Mangaluru remains a critical buffer, but shallow aquifers face increasing salinity, uneven recharge, and contamination risks from poorly managed on-site sanitation. While current extraction levels are within safe limits, rising demand, impermeable urban surfaces, and erratic monsoons are constraining natural recharge. Climate-induced temperature rise and more intense rainfall events further threaten aquifer sustainability, particularly in densely built areas with limited infiltration and weak aquifer protection measures.

3.3 WATER INFRASTRUCTURE

Water Storage Infrastructure

Mangaluru's initial water supply relied on direct river intake, but as seasonal flow declined, it became insufficient to meet rising demand. To address this, a 4-meter-high vented dam was

constructed in 1993 at Thumbe, downstream of the intake, exclusively for Mangaluru's water supply. Key features of this dam include:

Length: 350 meters

Number of vents: 135 (each with gates)

Storage capacity: 9.56 MCM (million cubic meters)

Submergence area: 5.19 sq. km

To further support Mangaluru's growing water demand, the Karnataka Urban Water Supply and Drainage Board (KUWSDB) started building a second dam in 2010, just 50 meters downstream of the 1993 dam, which was commissioned in 2016 (Figure 13). Features of this second dam include:

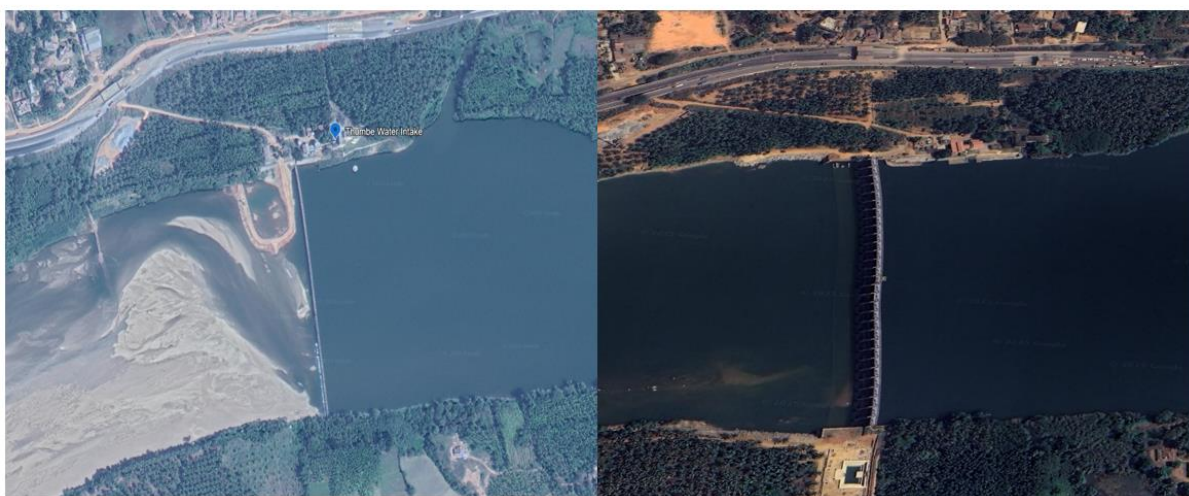
Length: 343 meters

Gate size: 10 m (width) × 5.5 m (height)

Design height: 7 meters

Storage capacity: 14.73 MCM (currently maintained at 6 m, storing 10.83 MCM)

Figure 13: Left - Construction of new dam begins in 2009 upstreams of the existing vented dam to augment storage. Right - Dam commissioned in 2016



Source: Google Earth Historical Imagery

In addition to these, Mangaluru also receives raw water from the AMR Power Project Dam, located at Shamboor, 12 km upstream of the Thumbe Dam (refer Figure 14). This dam, built by the AMR Group, has a storage capacity of 14.25 MCM. An agreement between Mangaluru City Corporation (MCC) and AMR Power Project ensures that from January to May/June, or during the river's lean flow season, power generation is halted, and stored water is released downstream to the Thumbe Dam to support Mangaluru's water supply.

Figure 14: AMR hydel power project located upstream of Thumbe intake



Source: Google Earth Historical Imagery

Mangaluru Water Supply Infrastructure: A Growing and Evolving System

Mangaluru's water supply infrastructure has evolved over multiple decades to cater to the city's expanding population, industrial growth, and rising water demand. The system primarily sources water from the **River Nethravathi**, with intake works located at Thumbe, **about 17 km from the city**. Over time, the network has been upgraded through successive schemes in 1956, 1971, 2003 (KUDCEMP), and the ongoing augmentation project under Karnataka Integrated Urban Water Management Investment Program (**KIUWMIP**), aiming to culminate in a comprehensive water supply system aimed at ensuring 24x7 supply with future-ready infrastructure.

- *Phase 1: 1956 Scheme – The Foundation*

The first piped water supply system for Mangaluru was introduced in 1956, designed to serve 1.8 lakh people with a capacity of 11.35 MLD and a supply rate of 70 LPCD. Water is drawn through 450 mm dia intake pipes and pumped via a 450 mm dia RCC rising main to a settling tank at Ramalkatte. From there, it is transferred to the Bendoor treatment complex through a 450 mm dia CI rising main (16.72 km) for final treatment before distribution. The system combined gravity-based and pumped distribution, supplying water to enroute villages as well.

- *Phase 2: 1971 Scheme – Meeting Growing Demand*

To address rapid urban expansion and rising industrial demand, an augmentation and improvement scheme was commissioned in 1971, increasing the city's supply capacity to 81.70 MLD. The intake system was upgraded with three 1200 mm dia pipes, and the raw water transmission main was designed for the same capacity. Initially, only 40.85 MLD pumping capacity was installed, but in 1986, additional pumping machinery was added to achieve the full 81.70 MLD capacity.

- *Phase 3: 2003 KUDCEMP Scheme – Modernization and Expansion*

The third major water supply scheme, commissioned in 2009 under Karnataka Urban Development and Coastal Environmental Management Project (KUDCEMP), added another 80 MLD capacity, expanding coverage to Mangaluru City, Ullal, Mulky, enroute villages, and industrial/institutional users. The raw water intake was connected via a 1.5 km 1100 mm dia MS rising main to an 80 MLD Water Treatment Plant (WTP) at Ramalkatte, where it underwent tube settlers and rapid sand filtration. Treated water was then conveyed via a 14 km 1100 mm dia MS rising main to a 120 LL Master Balancing Reservoir (MBR) at Padil, from where it was distributed to zonal reservoirs and consumers.

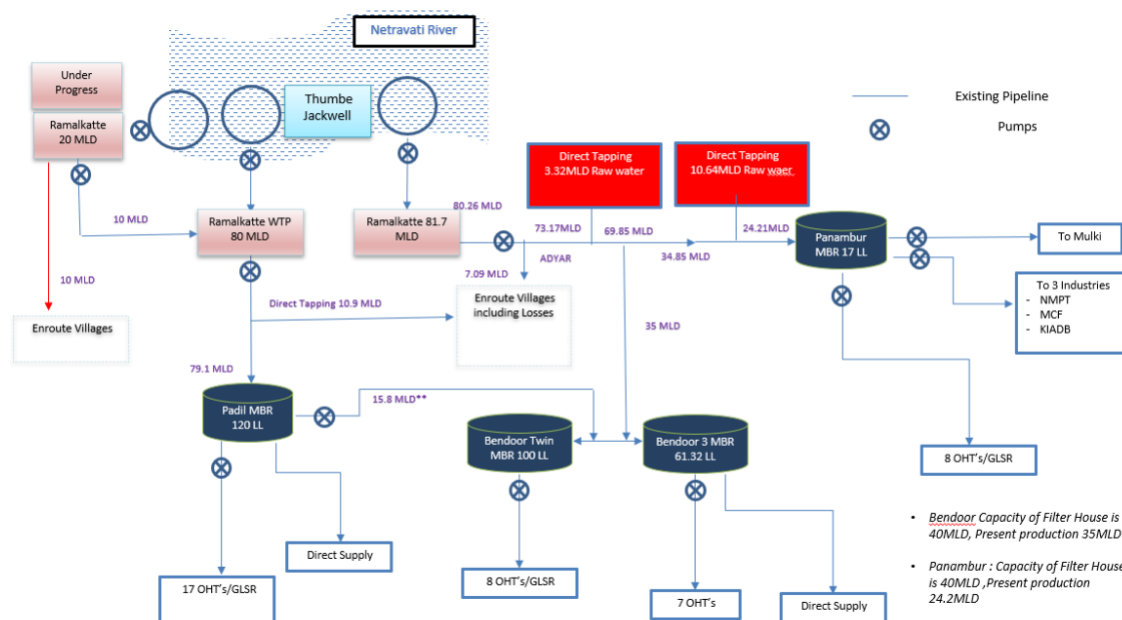
- *Phase 4: Ongoing*

Recognising the need for long-term water security, additional augmentation projects have been undertaken. Phase-IV of the water supply improvement plan focuses on expanding and modernising infrastructure to ensure a reliable, 24x7 water supply. Key upgrades include an 81.7 MLD filter house, additional pumping stations, and extensive pipeline replacements (65 km of feeder mains and 982.8 km of distribution lines). The project also adds 20 overhead tanks, two sumps, and 96,300 metered house connections for better pressure management as well as a SCADA system.

Mangaluru Water Supply Network

The water supply network comprises of the following key components (as shown in Figure 15):

Figure 15: Schematic diagram of a water supply network, illustrating the flow of water from river intake points to various storage, treatment, and distribution facilities



Source: Mangaluru City Corporation

River Intake

Three intake systems were constructed in 1956, 1971, and 2007 on the Nethravathi River at Thumbe. The 1956 intake was designed for 11.35 MLD with 500 mm CI pipes. The 1971 scheme increased capacity to 81.7 MLD with an 8m-dia intake well and 1000 mm CI pipes. The 2007 KUDCEMP scheme added another 80 MLD capacity with a 7m-dia well and 1200 mm CI pipes. Another 20 MLD uptake capacity is added under the ongoing project.

Jack Wells & Pump Houses

The 1956 intake included a 5.5m-dia masonry jack well, while the 1971 scheme built an 8m-dia, 14.5m deep masonry well. The 2007 KUDCEMP scheme added a 12m-dia RCC jack well, 18.75m deep, designed for 2026 demand.

Raw Water Transmission

Raw water mains from the intake to treatment facilities were laid in different phases. The 1956 pipeline (450 mm RCC, 1.44 km) has serious leakage issues and is due for an upgrade. The 1971 scheme (1000 mm MS, 1.2 km) remains functional. The 2007 KUDCEMP pipeline (1100 mm MS, 1.5 km) serves an 80 MLD WTP at Ramalkatte.

Water Treatment Plants (WTPs)

1956 Scheme: Settling tanks at Ramalkatte supply water to enroute villages through a 450 mm CI main (13 km). A new 20 MLD WTP has been commissioned in 2024 at the site.

1971 Scheme: Clariflocculators (4x20.43 MLD) at Thumbe, pumping to a 1.02 ML break pressure tank and then via a 17.12 km, 1000 mm pipe to Bendoor's 40.85 MLD rapid sand filters. Panambur has a 27.2 MLD WTP for industrial and port supply.

2006-07 KUDCEMP: 80 MLD WTP at Ramalkatte (17 km from Mangaluru) and a 23.5 MLD WTP at Panambur, designed for 2026 demand, treating a total of 103.5 MLD.

Clear Water Transmission & Pumping

Clear water is pumped from WTPs to service reservoirs through pipelines laid in different phases:

- 1971 Scheme: 1000 mm MS pipe (17.12 km) from Thumbe to Bendoor, then 900 mm MS (9.63 km) to Panambur, both in good condition.
- 2007 KUDCEMP: 1100 mm MS main (14 km) from Ramalkatte WTP to Master GLSR at Padil along NH-75.

Pumping stations at Bendoor, Padil, Ladyhill, Maryhill, Silver Gate, and Panambur ensure water distribution.

Service Reservoirs & Distribution

Mangaluru is divided into 34 water supply zones. Reservoirs are sized for eight-hour average demand. The city's Distribution network spans 760 km, using CI, GI, and PVC pipes. Water is supplied from core locations - Padil, Bendoor, and Panambur, serving three distinct master zones: North of Gurpur River, Between Nethravathi & Gurpur Rivers and South of Nethravathi (Ullal area). Water from the 3 MBRs is further distributed through a systems of pump houses, GLSRs and OHTs (Table 4):

Table 4: Water Distribution network components for Mangaluru water supply

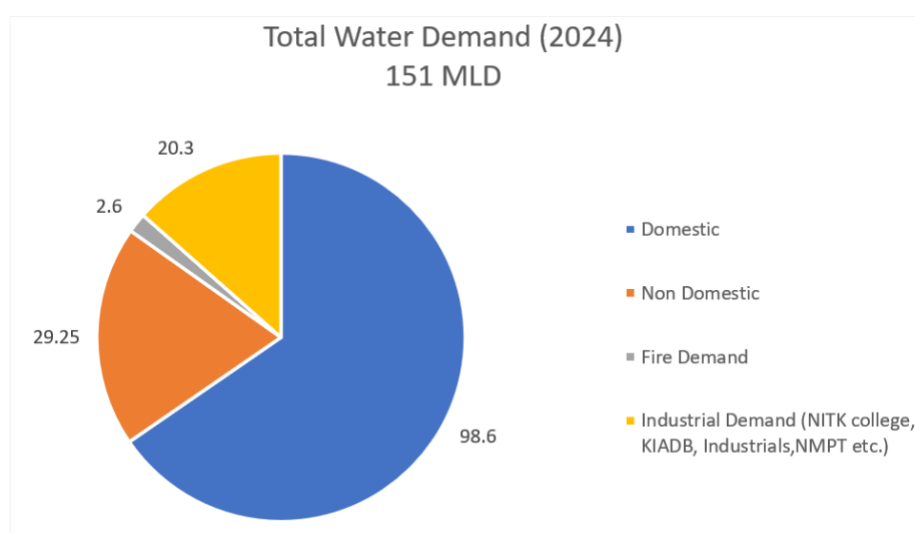
SI No	MBR	Pump House	GLSR	OHT
1	Padil	5	6	17
2	Bendoor	4	3	11
3	Panambur	3	1	14
Total		12	10	42

Additionally, 15 intermediate pump houses (IPS) ensure water conveyance over the vast distribution network.

3.4 WATER DEMAND & SUPPLY

As of 2024, Mangaluru's **total water demand** is estimated to be around **151 MLD (Figure 16)**. This includes **98.6 MLD** for domestic use including 10% additional demand by floating population, **29.25 MLD** for non-domestic purposes, **2.6 MLD** for fire safety, and **20.3 MLD** for bulk consumers such as industries and institutions.

Figure 16: Total Water Demand (2024)



Source: MCC, Mangaluru

Table 5: Water demand estimation for Mangaluru Municipal Corporation based on consumer survey

Mangalore Total Demand									
	2020			2024		2031		2046	
Property	2020 Population	Demand in LPCD	Total Demand (2020) in MLD	2024 Population	Total Demand (2024) in MLD	2031 Population	Total Demand (2031) in MLD	2046 Population	Total Demand (2046) in MLD
Domestic	571249	135	84.83	663698	98.6	825483	122.58	1129921	167.79
Non Domestic			27.78		29.25		31.82		36.01
Fire Demand			2.39		2.6		2.87		3.36
Total Zone Demand			115.00		130.37		157.28		207.16
Bulk Demand (NITK college, KIADB, Industrials, NMPT etc.)			20.30		20.30		20.30		20.30
Total Demand + 20% losses			164.05		183.27		216.90		279.25
Available water			161.7		171.7		90+125*		90+125*
Surplus/Deficiency			-2.35		-11.57		-1.90		-64.25

* Proposed 125 MLD WTP near Aadyar dam

Source: Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC)³⁶

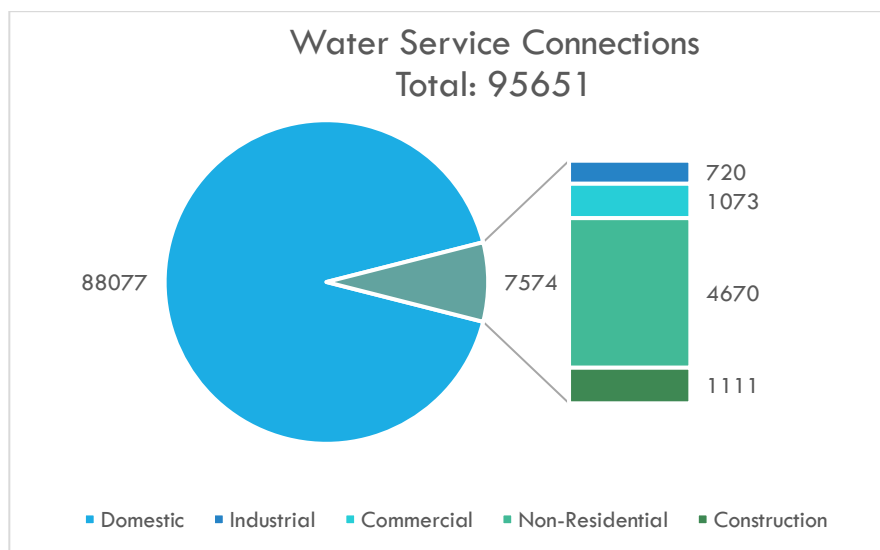
Table 5 shows a detailed breakdown of Water demand calculations currently used by the Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC) for infrastructure planning.

The piped water supply scheme in Mangaluru currently supplies 171.7 MLD water to Mangaluru city. Out of this around 32 MLD is taken up by illegal direct tapping by enroute villages and clear water transmission losses as per the flow measurement records. Considering distribution losses of 20%, a total of 112 MLD reaches to users in MCC. The remaining deficit of 39 MLD is presumed to be met through groundwater withdrawals directly by the consumers from.

Water Service Connections

As per MCC, a total of **88077 domestic water** supply connections is issued. However, certain areas with the corporation limits remain unserved and the laying of distribution network is in progress for the same. Apart from domestic consumers there are 4670 institutional connections, 1073 commercial connections, 1111 construction connections and 720 industrial connections (refer Figure 17).

Figure 17: Water Service Connections Status by category as on 31.12.2024



Source: MCC, Mangaluru

3.5 CLIMATE RISKS AND CHALLENGES

Mangaluru's water sector is increasingly vulnerable to a range of climate-induced and systemic challenges. While the city has made substantial investments in expanding and modernizing its water infrastructure, multiple risks from overdependence on a single source to rising greenhouse gas (GHG) emissions, threaten long-term sustainability. This sub-section identifies key risks under interconnected themes of water source vulnerability, demand-supply stress, climate-induced operational pressures, and institutional-financial constraints.

SOURCE VULNERABILITY AND SUSTAINABILITY

Surface Water: Strained by Climate and Competing Demands: The **Netravati River**, Mangaluru's primary water source, is under growing pressure from both natural and anthropogenic drivers. While the river is perennial, changing rainfall patterns such as short, intense spells and prolonged dry periods, disrupt base flows and recharge cycles. During lean months, reduced flows result in stagnation and algal blooms, degrading water quality. In contrast, the monsoon season brings high turbidity, increasing the energy and chemical inputs required for treatment. Upstream infrastructure projects such as the **AMR dam, Jakribettu barrage, and the yet-to-operational Harekala-Adyar dam** further alter flow regimes and contribute to seasonal shortages downstream. Industrial and agricultural extractions amplify these risks, often leading to conflicts and the reallocation of water for drinking purposes during

peak scarcity. Future proposals, such as the **Netravati–Hemavati link project**, risk diverting additional water out of the basin, raising concerns about long-term availability for Mangaluru.

Groundwater: Underused but at Risk: Groundwater currently plays a limited role in Mangaluru's formal water supply system, though it remains crucial for private and peri-urban users. The Central Ground Water Board (CGWB) classifies the city's aquifers as "safe," with only ~50% of annual recharge being utilized. However, increasing urbanization, impermeable surfaces, and erratic rainfall patterns are affecting recharge rates. Additionally, groundwater is increasingly at risk from poor sanitation infrastructure, especially sewerage network with missing links and leakages, which allow wastewater to infiltrate shallow aquifers, compromising water quality. Local water bodies like wells, ponds, temple tanks, and small reservoirs have historically supported local recharge and supply, but many have degraded due to encroachment, pollution, and neglect³⁷. Reviving these decentralised sources could diversify the supply mix and improve urban aquifer resilience.

WATER-ENERGY-CLIMATE NEXUS: A VICIOUS CYCLE

Urban water supply systems are both **victims and contributors** to climate change. Mangaluru's reliance on long-distance water transfers from the Netravati River involves significant energy use for extraction, treatment, and pumping particularly at **Thumbe, Padil, Bendoor, and Panambur** facilities. As shown in **Chapter 5**, the system consumes over **36,000 MWh of electricity annually**, resulting in **26,000+ tCO₂ emissions per year** largely from surface water operations. In contrast, groundwater extraction though modest in volume accounts for just **3,075 tCO₂/year**, underlining its potential as a lower-emission alternative. However, overexploitation or contamination could undermine its viability.

This dynamic illustrates the **vicious cycle** of the water-energy-climate nexus:

- Climate change leads to more variable rainfall and degraded water quality.
- Water treatment becomes more energy- and chemical-intensive.
- Rising emissions from energy use exacerbate climate change.
- More extreme weather events then further disrupt supply and infrastructure.

Breaking this cycle requires interventions that both **reduce energy demand** and **enhance source resilience**, such as decentralised water treatment, nature-based systems, and improved leakage control.

URBANISATION, INFRASTRUCTURE, AND FUNDING GAPS

Demand–Supply Mismatch: Mangaluru has long struggled to keep up with **rising water demand** due to urban growth, industrial expansion, and increasing per capita usage. Despite infrastructure upgrades over the decades (1956, 1971, 2003, and 2016), demand still outpaces supply, especially during summers when river flows decline. Current extraction from Netravati (~172 MLD) significantly exceeds actual water supplied (~112 MLD), indicating substantial losses and inefficiencies.

Path Dependency and Limited Adaptability: Mangaluru’s water infrastructure is shaped by a path-dependent approach, with new investments reinforcing older centralised systems. While this reduces short-term costs, it limits adaptability to emerging climate and operational risks. New challenges including **sea-level rise, saltwater intrusion, variable rainfall** and **extreme rainfall events** may not be adequately addressed by rigid, centralised systems without strategic redesign and innovation.

Financial Vulnerability: Large-scale projects such as **KUDCEMP** and **KIUWMIP** depend heavily on **external loans (ADB)** and **state funding**. Delays in project implementation and cost escalations, as seen in Mangaluru’s 24x7 water supply plan, highlight the need for a **sustainable financial model**. Heavy capital investments also increase long-term operation and maintenance costs, creating dependency and reducing flexibility for future transitions.

NEGLECT OF DECENTRALISED AND TRADITIONAL SOURCES

Traditional water bodies in Mangaluru such as **Kavoorkere, Padil Tank, Gujrikere**, and **temple tanks** are now severely degraded or defunct. Their loss represents not just a missed opportunity for localised water resilience but also contributes to aquifer stress and urban flooding. The erosion of community-based water stewardship has coincided with a growing reliance on centralised, energy-intensive systems.

Restoring and integrating these local sources could:

- Enhance groundwater recharge and urban microclimates.
- Reduce pressure on imported water.
- Offer low-carbon supply alternatives.

NOTES & REFERENCES

- ³³ Author's Note: This chapter is based on ongoing doctoral research by Ashish Dangi under the supervision of Prof. N. C. Narayanan at the Ashank Desai Centre for Policy Studies (ADCPS), Indian Institute of Technology Bombay. Key findings and interpretations presented here are part of a broader analysis that is currently being prepared for publication in a peer-reviewed academic journal. Readers are requested to cite this report appropriately and direct any academic queries to the author.
- ³⁴ Sinha, R.K., Eldho, T.I. Effects of historical and projected land use/cover change on runoff and sediment yield in the Netravati river basin, Western Ghats, India. *Environ Earth Sci* 77, 111 (2018). <https://doi.org/10.1007/s12665-018-7317-6>
- ³⁵ Central Ground Water Board (CGWB). (2023). Report on AQUIFER MAPPING AND MANAGEMENT PLAN: Mangaluru Taluk, Dakshin Kannada District, Karnataka. Ministry of Jal Shakti, Department of Water Resources, Government of India. Retrieved June 25, 2025 from <https://antharjala.karnataka.gov.in/storage/pdf-files/NAQUIM%20REPORTS/161.pdf>
- ³⁶ Revised Detailed Project for 'Strengthening Distribution System for Implementing 24x7 water supply to Mangaluru City' under Karnataka Integrated Urban Water Management Investment Programme (KIUWMIP), Tranche 2 implemented by Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC), Calculations by M/s Suez Projects Pvt Ltd- M/s DRS Infra Pvt Ltd (JV). Data provided by MCC.
- ³⁷ Temporary Ponds - A Neglected Ecosystem. (n.d.). Retrieved July 1, 2025. <https://wgbis.ces.iisc.ac.in/energy/water/proceed/section6/paper6/section6paper6.htm#address>

4. URBAN SANITATION SYSTEMS IN MANGALURU: STATUS, INSTITUTIONS AND CHALLENGES

NEELAM RANA, PRIYAKSHI GOGOI, NC NARAYANAN

Assessing the state of sanitation services is critical for identifying infrastructure gaps, service-related vulnerabilities, and climate-related risks, and for informing adaptive, resource-efficient, and low-carbon development strategies. This assessment also involves mapping institutional arrangements to clarify the roles of Urban Local Bodies (ULBs), their interactions across governance levels, and the interdependencies among key stakeholders. This chapter addresses these objectives through a detailed case study of Mangaluru, drawing primarily on secondary data supplemented by semi-structured interviews with ULB officials, district disaster management officers, and residents to validate findings and address data gaps. The chapter examines the sanitation service chain and reviews the institutional framework governing sanitation services, and concludes by identifying key challenges and opportunities for strengthening sanitation infrastructure, service delivery, and governance.

4.1 BACKGROUND

Climate risks are significantly exacerbated by inadequate infrastructure in critical, interlinked sectors such as water and sanitation which disproportionately affecting socio-economically disadvantaged communities^{38,39,40}. *Climate change-induced water stress and insecurity have been linked to a rise in waterborne infectious diseases, threatening to reverse progress toward the SDGs and exacerbating existing social and health inequities*⁴¹. WaSH services are essential for preventing disease outbreaks, particularly in the aftermath of climate hazards such as heavy rainfall and flooding^{42, 43}. In this context, *ensuring access to safe, reliable water, sanitation, and hygiene services* is widely recognized as a *low-regret adaptation measure*—offering substantial benefits *regardless of the severity of future climate scena*⁴⁴. The IPCC highlights *universal access to WaSH*—specifically the achievement of SDG targets 6.1 and 6.2—as a *high-confidence adaptation strategy*, underscoring its central role⁴⁵.

India has only one national-level policy dedicated to urban sanitation—the National Urban Sanitation Policy (NUSP), introduced in 2008. The policy defines sanitation as the 'safe management of human excreta, including its safe confinement, treatment, disposal, and associated hygiene-related practices⁴⁶. In the context of climate change, the policy links sanitation to GHG emissions and advocates the adoption of low-energy solutions, such as

decentralized or onsite wastewater treatment technologies and distributed utilities. City Sanitation Plans (CSPs) are expected to incorporate these concerns, including the impacts of climate change, diminishing water resources, and the need for energy-efficient infrastructure (ibid).

Although sanitation is not explicitly identified as a focus area in India's *National Action Plan on Climate Change (NAPCC)*, it is closely linked to climate action through missions on water, sustainable habitats, and energy. The *National Water Mission (NWM)* emphasizes water conservation and efficiency—critical for sustainable sanitation systems, especially in water-stressed urban areas. The *National Mission on Sustainable Habitat (NMSH)* more directly addresses sanitation-related concerns, including urban waste management, wastewater recycling, and climate-resilient infrastructure, thereby contributing to both mitigation and adaptation objectives. Sanitation is also aligned with the NAPCC's broader emphasis on *energy efficiency and GHG emission reduction*, as centralized wastewater treatment plants are significant sources of methane and nitrous oxide. Innovations such as *waste-to-energy systems and resource recovery from faecal sludge* further support this agenda. Additionally, *State Action Plans on Climate Change (SAPCCs)*—developed in line with the NAPCC—are increasingly acknowledging sanitation as a key sector for climate intervention, particularly in climate-vulnerable regions. Though the NAPCC predates the *SDGs*, it has gradually evolved to align with global frameworks. National programs such as *SBM and AMRUT* have also begun integrating climate resilience and sustainability into urban sanitation planning and implementation.

Hence, assessing the current state of sanitation services is essential for identifying infrastructure gaps, vulnerabilities, and climate-related risks. Such an assessment supports the design of proactive adaptation measures, promotes efficient resource use, and enables low-carbon development strategies. A critical component of this process is mapping existing institutional arrangements—clarifying responsibilities, particularly the role of ULB, their engagement across different governance levels, and the interdependencies among key stakeholders. This chapter seeks to address these objectives through a detailed case study of *Mangaluru*. Data collection was primarily conducted through secondary sources, supplemented by primary data gathered via semi-structured interviews with ULB officials, district disaster management officers, and residents. These interviews helped fill information gaps and validate secondary data.

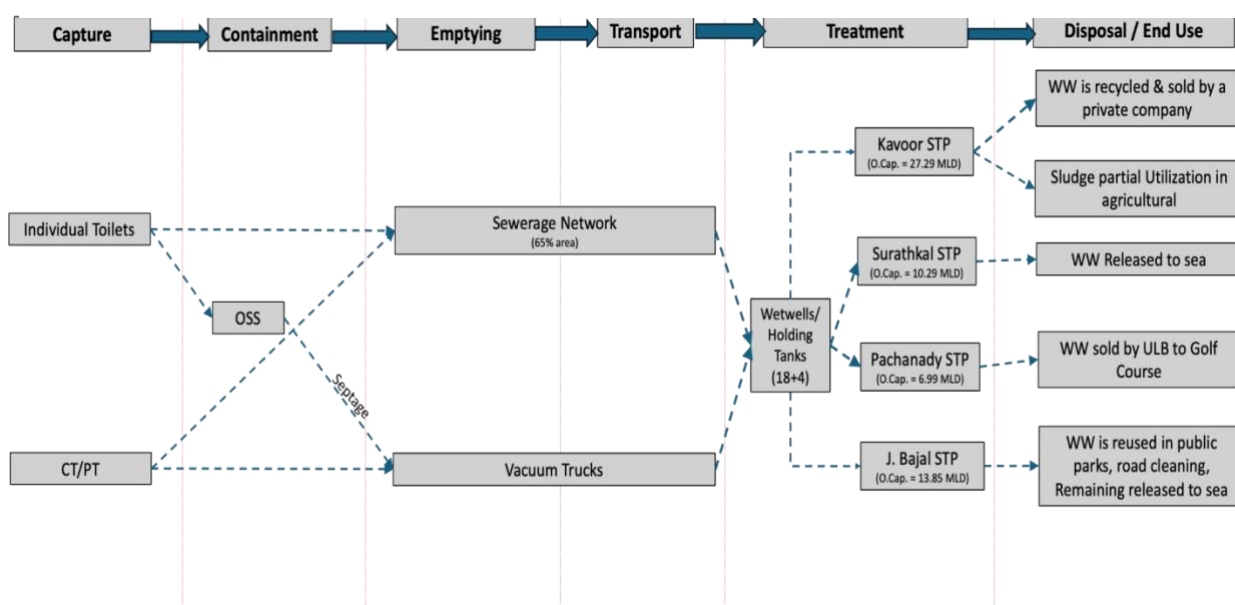
The chapter is organized into the following sections: Section two discusses the sanitation service chain, covering all critical stages—toilet access, containment, transportation, treatment, and final disposal or end-use. *Section three* evaluates the city's performance against the national SLBs for urban sanitation and *Section four* reviews the institutional framework, detailing the roles and responsibilities of various stakeholders involved in sanitation governance. *The final*

section concludes the chapter by highlighting key challenges and opportunities for improving sanitation infrastructure, service delivery, and governance.

4.2 SANITATION SERVICE CHAIN

Human waste must be safely managed throughout the entire sanitation service chain, which may have different stages, including capture, containment, emptying, transport, treatment, and disposal or end use⁴⁷. This section outlines the service chain and identifies the key gaps. The entire service chain is depicted in *Figure 18*.

Figure 18: Sanitation Service Chain in Mangaluru



Source: Authors' Analysis and Illustration

- **Capture:** This includes toilets (individual household level, community, public). The primary function of a toilet is to capture excreta while effectively separating people from the waste to ensure safety and hygiene.
 - **Toilets:** According to the 2011 census, out of 1,15,036 households (including municipal corporation and outgrowth areas), 7,443 households lacked individual toilets. However, according to more recent information through interviews with the municipal officials, **all households in the city now have individual toilets and the city has been officially declared 100% Open**

Defecation Free (ODF), which aligns with the SLB norms of Government of India, and the target (6.2) outlined in the SDGs.

- **Community Toilets and Public Toilets⁴⁸:** According to the data received from the ULB, currently, the city has one community toilet located in Ward 57, near the fishing community, and a total of 36 public toilets. Of these, 23 are functional, while 13 remain non-operational due to water supply issues and are only opened during public events. According to Urban Local Body (ULB) officials, the locations of these public toilets were strategically selected based on footfall and need. However, some are situated in residential areas due to the unavailability of ULB land elsewhere, resulting in infrequent use.

Water supply to all these toilets is managed by the municipality through direct piped tap connections. Recently, the ULB received INR 18 lakhs under the Swachh Bharat Mission Urban 2.0 (SBM-Urban) to construct an aspirational public toilet with 12 seats.

It is important to note a data discrepancy between ULB records and the SBM Urban dashboard, which reports 88 public toilets in the city. When questioned, ULB officials clarified that the dashboard figure includes all privately managed toilets accessible to the public, such as those at petrol pumps. However, information on **community and public toilet coverage** is unavailable, as the ULB does not maintain any registers or records tracking the number of users or whether the facilities are **able to cater the demand**.

- **Containment:** According to a Detailed Project Report (DPR) prepared by the Urban Local Body (ULB), approximately 35% of Mangaluru lacks access to a sewerage network. As a result, residents in these areas depend on on-site sanitation systems (OSS) or resort to discharging untreated wastewater—both greywater and blackwater—into drains, stormwater systems, water bodies, or open ground. This situation poses significant risks to both environmental quality and public health. Due to the unavailability of secondary sources such as SLBs data from the Mangaluru Municipal Corporation, this analysis relies solely on information from the DPR and interviews with the ULB officials.

Currently, there is no secondary data available on **the types of OSS in use within the city**. Upon inquiry during the field visit, ULB officials were unable to provide any data. Generation of such information would necessitate primary data collection

through a household-level survey based on a representative sample of the town. Undertaking such an exercise was beyond the scope of the present study.

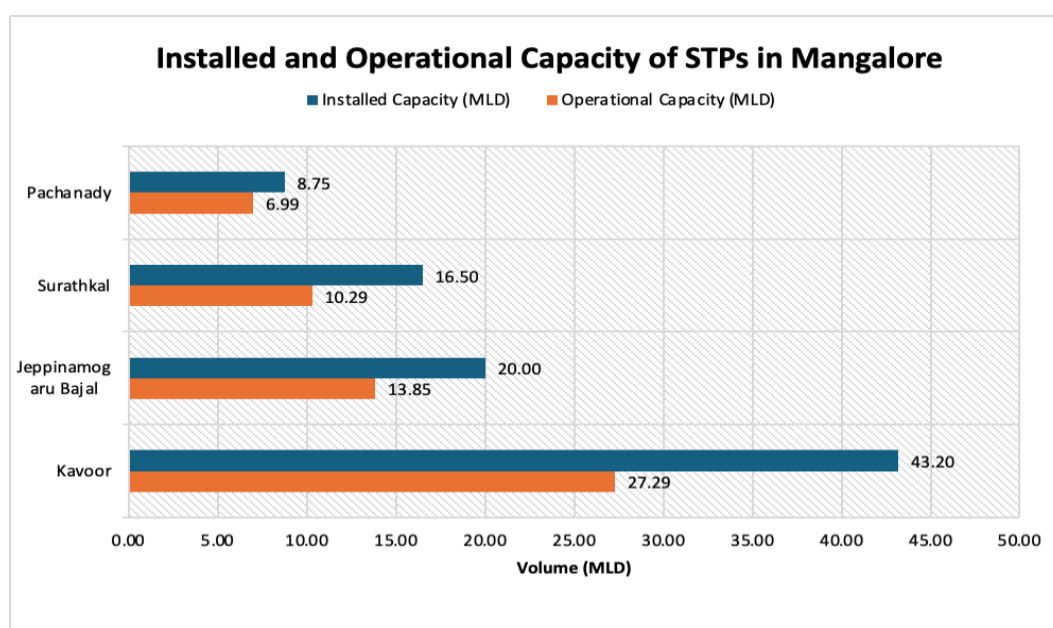
To address this, a rapid assessment was conducted through transect walks and interactions with residents that indicated the presence of both septic tanks and soak pits. As far as typology of sewerage network, it wasn't within the scope of the study, it is not possible to **assess the drainage network, including whether it is underground or overground**. Based on interviews with the ULB, the research team learned that the existing drainage network is constructed from stone and operates as an underground system. Currently, it faces significant challenges such as missing links, blockages, leaks, and water contamination. However, there are projects in the pipeline aimed at upgrading and improving this aging infrastructure.

- **Emptying and Transport:** Currently, the city's sewerage network spans 855 km and covers 65% of the total area (132.45 sq km) as outlined in the DPR provided by the ULB. The remaining properties rely on septic tanks with soak pits, which are serviced by 24 privately licensed vehicles, each paying an annual fee of INR 1,20,000. While the ULB does not regulate the service charges imposed by these private operators, it does monitor the number of trips and the frequency of desludging for on-site sanitation systems (OSS) in both residential and commercial establishments. Wastewater from most community toilets (CT) and public toilets (PT) is discharged into the sewerage network. Only a few public toilets are equipped with septic tanks, and waste from these is collected by the 16 vacuum trucks owned and operated by the ULB. Proposals detailed in the DPR aim to expand the sewerage network, address existing gaps, and replace outdated sewer pipes—many of which are over 50 years old. These aging systems pose significant risks to both the environment and public health, particularly during flooding, cyclonic events, and storm surges, which are of special concern in coastal areas. Secondary data on **the coverage and typology of the stormwater drainage network** is unavailable, as obtaining such information would require comprehensive research beyond the scope of this study. However, interviews with representatives from the ULB official indicate that the city possesses a well-developed stormwater drainage network across most areas.
- **Treatment:** According to data provided by the Urban Local Body (ULB) and detailed in the current project's Detailed Project Report (DPR), Mangalore operates four Sewage Treatment Plants (STPs) with a combined installed capacity of 88.45 Million Liters per Day (MLD) (refer Figure 19). These facilities were originally established in 1961 and underwent significant upgrades during 2008–2009. Despite this, the overall operational efficiency of the STPs is approximately 65%, primarily due to gaps and

aging connections within the existing sewerage network. As a result, only about 58.42 MLD of sewage is currently being treated. The four STPs are located at Surathkal (16.5 MLD), Kavoor (43.2 MLD), Pachanady (8.75 MLD), and Jeppinamogaru Bajal (20 MLD). Of these, the Pachanady STP operates at nearly 80% efficiency, followed by Jeppinamogaru Bajal at 69%, while Surathkal and Kavoor function at around 65% efficiency each. The suboptimal performance of these plants is largely attributed to deficiencies in the city's sewerage network.

To address these challenges, the city has initiated infrastructure upgrades, with funding secured under SBM 2.0 and the National Green Tribunal (NGT). **A new Detailed Project Report (DPR) has already been prepared to guide these improvements with a future projection of the city.**

Figure 19: Installed and Operational Capacity of STPs



Source: data from MCC

The predominant treatment technology across three of the plants is the Activated Sludge Process (ASP), while one STP employs the Up-flow Anaerobic Sludge Blanket Reactor. Additionally, the Surathkal plant uses ASP followed by an Extended Aeration Process for advanced treatment. The STPs in Kavoor and Pachanady, according to the ULB, can treat wastewater up to tertiary standard, however the environmental compliance documents show scope of improvement (discussed in next sub-section).

In terms of **greywater management**, field visits revealed a wide variation in practices across households. Some homes direct greywater into separate soak pits, while others discharge it into nearby drains. A few households even **channel greywater directly into the sewerage network**.

- **End-use Disposal (Septage and Sludge Management)**⁴⁹: The city does not have a Faecal Sludge Treatment Plant (FSTP). The city currently has 40 desludging trucks - 16 owned by MCC and 24 private licensed vehicles (annual fee of INR 1,20,000). Only private licensed vehicles are allowed to collect septage from properties without sewerage network connection at a certain charge rate decided by them. The MCC desludging vehicles are utilized only for de-clogging and desilting purposes in sewerage networks. The septage collected by private desludging trucks gets transported and stored in 4 designated wet wells situated in Kudroli, BangaraKuloor, Pandeswar, Jeppinamogaru and processed through STPs. After treatment, the sludge is further dried in sludge drying beds⁵⁰.

Photo: Sludge drying beds in Kavoov STP



Source: IIT-Bombay team

Not all plants are reusing sludge effectively. At the Kavoov plant, although farmers occasionally collect treated and dried sludge for free to use as fertilizer, significant

quantities of sludge remain unutilized. The accumulation of sludge poses significant operational challenges, particularly during the rainy season. Additionally, it creates public health and environmental concerns due to leaching. This underscores the urgent need for a more comprehensive sludge and septage management plan to ensure the efficient and environmentally responsible disposal or utilization of treated sewage byproducts.

- **Recycling and Reuse:** The city recycles approximately 29.5 MLD of treated effluent, which represents about 48% of the total sewage processed by the sewage treatment plants (STPs) according to the data collected from the ULB which is the project detailed report. According to the ULB official, of this, 6.8 MLD is sold by the City Corporation to the Pilikula Golf Club, while the remaining 22.7 MLD is sold by Mangaluru Special Economic Zone Ltd. (MSEZL) to industries, after being treated to tertiary standards. This arrangement is governed by an agreement between MSEZL and the Urban Local Body (ULB), where MSEZL treats the secondary effluent from the Kavoor STP at its tertiary treatment plant, located on ULB land. MSEZL generates revenue by selling the tertiary treated wastewater and, in return, covers 70% of the operations and maintenance costs for the pumping stations and Kavoor STP, which are managed by the Mangaluru City Corporation (MCC).

4.3 ENVIRONMENTAL COMPLIANCE

The Karnataka State Pollution Control Board (KSPCB) regional office conducts monthly sampling of STP effluent. According to the KSPCB report (December 2024) provided by the MCC, the Pachanady STP and Jeppinamogaru Bajal STP appear to be struggling to meet all environmental standards. The Kavoor STP is only marginally failing to meet the TSS standard. However, the Surathkal STP is fully compliant with all environmental standards. All STPs meet the stipulated pH and faecal coliform standards, except for the Kavoor STP. This poses a serious threat to public and environmental health if such poor-quality wastewater is released into or mixes with water bodies used for human consumption. It also has significant implications for GHG emissions, particularly in areas like Pachanady and Jeppinamogaru Bajal, where environmental standards, especially for BOD and nitrogen levels, are not being met (refer Table 6).

There is no data on environmental compliance of CT and PT as most of the CT and PTs are connected with the sewerage network or the waste is transported to the STP for further treatment. There is no environmental data on the quality of sludge produced either.

Table 6: Environmental Performance of STPs (as of Dec 2024)

STP	Technology	TSS (Not more than 20 mg/l)	pH [5.5-9.0]	BOD3 (Not more than 10 mg/l)	COD (Not more than 50 mg/l)	Total nitrogen (Not more than 10 mg/l)	Faecal coliform (MPN/100ml) DL-100;PL-230
Kavoor	Up-flow Anaerobic Sludge Blanket Reactor	24	7.6	6.4	47	45.8	350
Surathkal	Activated Sludge Process followed by Extended Aeration Process	16	7.6	4.2	30	2.2	21
Pachanady	Same as above	40	7.3	25	86	31.4	94
Jeppinamog- aru Bajal	Same as above	26	7.7	14	58	34.8	63

Source: Data from MCC

4.4 INSTITUTIONAL ARRANGEMENTS

This sub-section examines the institutional arrangements, outlining the various departments, agencies, and organizations, along with their respective roles in delivering sanitation infrastructure and services (refer Table 7). It also emphasizes the role of the urban local body in disaster governance.

Sanitation is a state subject, and under the 74th Constitutional Amendment Act, Urban Local Bodies (ULBs) are primarily responsible for delivering water supply and sanitation services. However, in practice, a multi-stakeholder, multi-level governance framework involved in the provision of sanitation infrastructure and services was observed.

Sanitation infrastructure (toilets and on-site sanitation systems) at the household level is largely the responsibility of the household itself. For sludge management, households may opt to rely on vacuum trucks, typically provided by private operators. However, there is a lack of regulation concerning both on-site sanitation systems and toilet designs.

Table 7: Institutional Arrangements: Sanitation Services

Intervention	Technology Selection	Land	Capital	Technology Provision	Technology implementation	O&M	O&M Funding
Toilets	Household	Household	Household	Local masons/private vendors	Local masons/private vendors	Household	Household
On-site Sanitation Systems	Household	Household	Household			Household	Household
						Septage removal by vehicles of ULB	
Community Toilets	ULB	ULB	ULB	ULB	ULB	ULB	ULB
			Centre (15th Finance Commission and SBM 1.0)				
Public Toilets	ULB	ULB	ULB	ULB	ULB	ULB (13 are maintain by the ULB) + 13 are maintained by different club committees in pay and use basis	ULB (own revenue for 13PT)
			Centre (15th Finance Commission and SBM 1.0)			Private (3 are maintain by the Sulabh International agency)	User pays charges to private O&M vendor
Sewerage Network	State (KUIDFC)	ULB	IFIs	State (KUIDFC)	State (KUIDFC)	ULB	ULB
Sewage Treatment Plant (4)	State (KUIDFC)	ULB	IFIs	State (KUIDFC)	State (KUIDFC)	ULB	ULB
Note: HH = Households; ULB = Urban Local Body; IFIs = International Financial Institutions							

Source: Authors' Analysis

At the ULB level, smaller sanitation interventions like community toilets (CT) and public toilets (PT) are primarily the ULB's responsibility, with independent decision-making power in key areas such as land selection, technology choice, operation, and maintenance (O&M), and funding. Under the Swachh Bharat Mission (SBM), capital funding was provided for some PTs. The environmental compliance of CTs and PTs is uncertain. Some PTs have outsourced their O&M to private vendors, who recover the costs through user charges.

For larger infrastructure projects, the ULB's role is primarily limited to operation and maintenance (O&M). The responsibility for preparing the Detailed Project Report (DPR), as well as the design and establishment of these facilities, lies with the state authorities (KUIDFC). Capital funding is sourced from International Financial Institutions (IFIs), such as ADB in this case, while the ULB is responsible for managing and arranging the O&M. Environmental monitoring also falls under the purview of state agencies. Furthermore, interviews with the ULBs revealed that their role in disaster governance and planning is limited. They primarily focus on providing sanitation and water supply during the relief phase of a disaster.

4.5 CHALLENGES AND OPPORTUNITIES IN SANITATION INFRASTRUCTURE AND SERVICES

The town is not fully meeting several of the SLB norms set by the Government of India. The challenges outlined below are key barriers to achieving the required service levels, but they also present valuable opportunities in provision of equitable and affordable sanitation services to all.

- *Lack of adequate infrastructure and services:* Low levels of service delivery across the sanitation chain from household access to treatment and safe disposal continue to undermine public necessities, health and resilience. Existing systems are unable to keep pace with growing urban demands and climate stresses. Strengthening service delivery therefore requires adaptive approaches, such as decentralized solutions, technology upgrades, and community-led practices, to ensure sustainable and resilient sanitation for all.
- *Limited Role of ULB in Infrastructure development and planning:* The ULBs' reliance on state or central government for capital funding limits their decision-making authority in infrastructure development and planning, particularly for large-scale projects like sewerage networks and sewage treatment plants. This undermines the intent of the 74th CAA and compromises the autonomy of ULBs. Additionally, these funds often come with conditionalities, further restricting ULBs' autonomy.

- *Opportunity to Integrate Resilience into Infrastructure Planning and Development:* The city's sewer pipes, many of which are over 50 years old, present a valuable opportunity to strengthen the resilience of the infrastructure. In addition, the few of the STPs in Mangalore are outdated, with their operational life expected to end by 2026, making replacement necessary (Assistant Executive Engineer, Sanitation, Mangalore City Corporation, 13 August 2025, Stakeholder consultation workshop, Indian Institute of Technology- Bombay, Mumbai, Maharashtra, India). Likewise, the Sewage Treatment Plants (STPs), initially developed in 1963 and later upgraded in 2008-2009, are also due for further improvements. Furthermore, the Pachanady STP faces challenges during the monsoon season, when the inflow rises to nearly 10 MLD due to rainwater intrusion, exceeding its designed capacity of 8.75 MLD (ibid). Upgrading and modernizing these systems is essential to enhance their ability to withstand extreme weather events, which can place significant stress on the existing infrastructure, potentially causing blockages, leaks, and water contamination. The city is currently developing a Detailed Project Report (DPR) aimed at upgrading the sewerage network. The expectation is to ensure that resilience considerations are thoroughly integrated into the planning process, ensuring long-term sustainability and improving water and sanitation services. This initiative will also equip the infrastructure to better adapt to future climate challenges, ensuring a reliable and future-ready system for the city. The AEE (Sanitation), MCC, emphasized the urgent need to adopt affordable and modern techniques to detect and track missing links in sewer connections. Addressing these gaps through repair and extension of sewer lines can significantly reduce the existing problems.
- *Opportunity to Explore Sanitation Technology Alternatives:* The MCC is navigating land availability constraints, especially in undulating and hilly areas, which makes extending the sewerage network to these properties more challenging. In such cases, decentralized solutions and FSSTPs (Faecal Sludge and Septage Treatment Plants) present practical and sustainable alternatives.
- *Need of Appropriate Technologies for High Water table Areas:* Although the municipality plans to extend its sewerage network to unserved areas, coastal regions are not included in this expansion due to the need for sewer systems to be placed at greater depths, which is not feasible because of the high-water table in the coastal belt. In such areas, decentralized systems could provide a viable alternative.
- *Need for Sludge Management Strategy and Plan:* Current sludge management is inadequate especially without a proper market or end-use plan. Large quantities of dried sludge remain unused after meeting agricultural demand, leading to significant operational challenges, and public health and environmental risks due to leaching. Similarly, lack of proper management of sludge from certain community and public

toilets poses a serious threat to environmental and public health. Similarly, at household level since many of the households have pits instead of the scientific septic tanks and the fact that the area is a high-water table area, there are chances of groundwater contamination. This highlights the urgent need for a comprehensive sludge management strategy and plan to ensure the efficient and environmentally responsible disposal or utilization of treated sewage byproducts.

- *Need of Stricter Environmental Compliance:* Environmental compliance data reveals that, out of the 4 STPs, only one meets the required norms. The most exceeded parameters are total suspended solids and total nitrogen, followed by BOD. Violations related to BOD and total nitrogen are significant concerns, particularly in terms of their impact on GHG emissions. Out of 4 plants, one plant i.e., Pachanady shows ongoing challenges in consistently meeting environmental standards, indicating areas where performance can be improved.

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⁴⁸ As per SBM guidelines “Public Toilets are toilets which are provided for the floating population/ general public in places such as markets, train stations, tourist places, near office complexes, or other public areas where there are a considerable number of people passing by. PTs are to be accessible to one and all and well-connected to important areas and pedestrian junctions. Community Toilets are the shared facilities provided by and for a group of residents or an entire settlement. CT facilities are used primarily in low-income and/or informal settlements / slums, where space and/or land are constraints in providing individual household toilet. These are for a more or less a fixed user group.” (CPHEEO, 2018, p. 1)

⁴⁹ Faecal Sludge is raw or partially digested, in a slurry or semisolid form, the collection, storage or treatment of combinations of excreta and black water, with or without grey water. It is the solid or settled contents of pit latrines and septic tanks (NFSSM, 2017, p9). Septage is the liquid and solid material that is pumped from a septic tank, cesspool, or such onsite treatment facility after it has accumulated over a period of time”. Septage is the combination of scum, sludge, and liquid that accumulates in septic tanks (ibid).

⁵⁰ The city has 22 wet wells connected to the UGD, which then connect to the STPs. 4 of these wet wells are dedicated to private vehicle sludge dumping.

5. CLIMATE IMPACTS OF WATER & SANITATION SYSTEMS

ASHISH DANGI⁵¹ AND NC NARAYANAN

This chapter focusses on the climate impacts of the water and sanitation systems, i.e., the greenhouse gas (GHG) emissions throughout the service chain. By estimating stage-wise energy consumption and GHG emissions, our assessment provides baseline evidence for planning climate mitigation strategies in the WaSH sector.

5.1 BACKGROUND

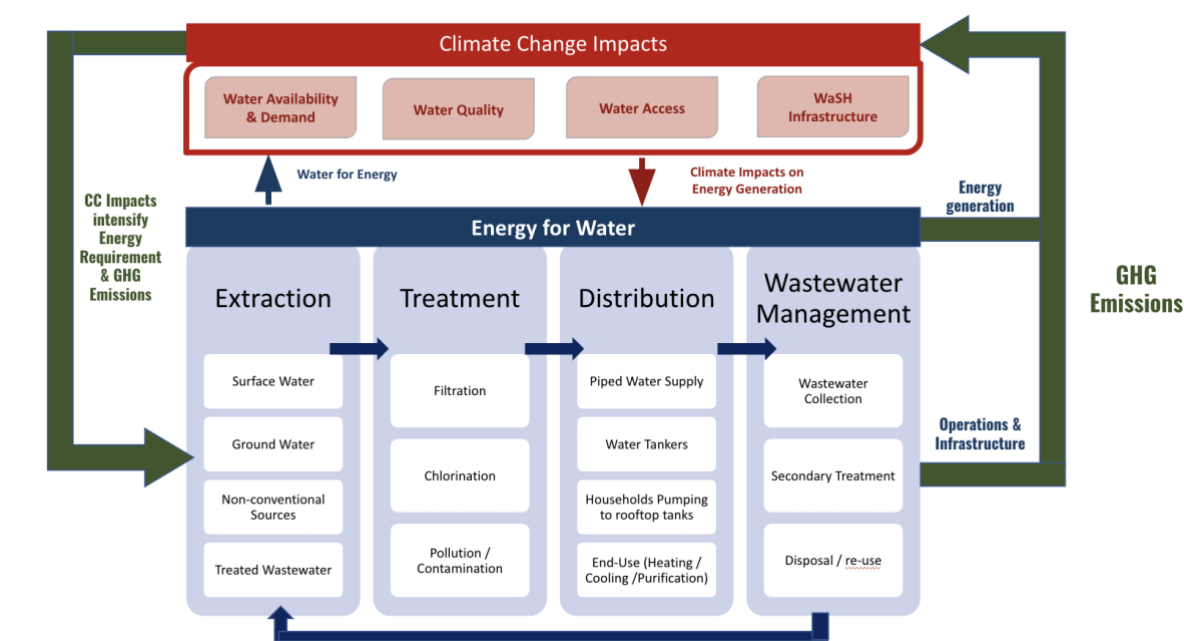
Globally, the water and sanitation systems are increasingly recognised not only as climate victims, but also significant contributors to climate change as the GHG emissions from WaSH continue to grow. Energy is the key input to every step in an urban water cycle right from water extraction to conveyance, treatment, distribution, and end-use; as well as for wastewater collection, conveyance, treatment, and re-use. This energy use further translates into GHG emissions associated with energy generation. Water sector which includes the collection and treatment of wastewater, accounts for *4% of total global electricity consumption and around 3% of global greenhouse gas emissions*⁵². According to another estimate, wastewater treatment plants alone are estimated to account for 3% global electricity consumption⁵³. Additionally, biological degradation of the organic matter present in sewage and grey water across the containment, transport, treatment and discharge pathways in a sanitation service chain results in direct methane (CH₄) and nitrous oxide (N₂O) emissions⁵⁴. *Direct emissions in wastewater treatment are estimated to be significant at ~1.57% of global GHG emissions*⁵⁵.

Climate change impacts on water availability, quality, and access as well as on wastewater and stormwater management, are going to *further exacerbate the scenario* by directly increasing the energy and carbon intensity of the water cycle. Additional water demand by cities is often met by higher energy use in the water cycle⁵⁶. For instance, between 2005 and 2015, while Beijing's water supply increased by only 10%, the energy consumption associated with water supply surged by 215%⁵⁷. In fact, *Water sector's electricity consumption is projected to significantly increase* with rising scarcity and could rise to as high as 16% of total energy consumption for countries faced with severe water scarcity such as those in Middle East⁵⁸. With the rise in sewage generation and treatment capacity, *the energy and carbon footprint of wastewater is likely to increase dramatically in the near future* in the absence of interventions. For example, domestic wastewater emissions increased by 400% between

2000-2014 in China due to growth in WWTPs⁵⁹. *With the increased variability posed by climate change the emission in WWTPs could further increase*⁶⁰.

Just as water systems are becoming increasingly energy-dependent, *energy generation remains heavily reliant on water*, with energy-sector's water consumption projected to rise by 60% between 2014 and 2040 and *the future water demand for projected energy use in 2030 likely to surpass the available supply*⁶¹. *Clean energy transitions could exacerbate the water stress* as biofuels production, concentrating solar power, carbon capture and storage, green hydrogen and nuclear power can have more significant water demands.

Figure 20: The Water-Energy-Climate nexus in Urban Water Cycles.



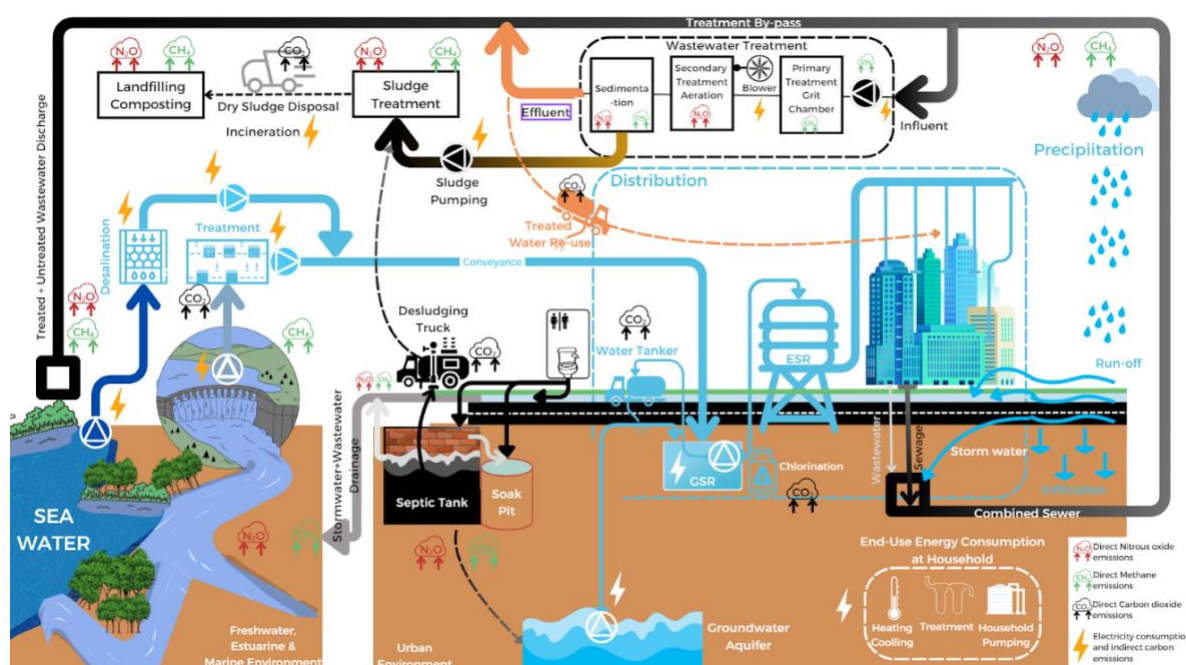
Source: Author's Illustration.

As illustrated in *figure 27*, urban water cycles relying on conventional energy-dependent approaches remain trapped in a vicious cycle where intensification of climate impacts results in increased carbon and energy footprint of urban water cycles which in turn results in worsening of climate impacts. **This escalating interdependence demonstrates exactly why designing climate-resilient urban water and sanitation systems is such an urgent priority.** The unavoidable overlap of water consumption and carbon emissions in urban environments means that achieving true resilience requires explicit coordination between water and carbon management⁶². *An assessment of the energy and carbon footprints is therefore crucial, not only for ensuring the sustainability of urban water and sanitation systems, but also for informing broader macro-policy karnatakals like energy security and greenhouse gas (GHG) mitigation.*

5.2 SOURCES OF GHG EMISSIONS IN URBAN WATER AND WASTEWATER SYTEMS

Energy is the most vital input for operating a typical urban water and wastewater system. Energy is often consumed in the form of electricity for powering pumps and machinery, resulting in indirect greenhouse gas (GHG) emissions, depending on the mode of power generation. Energy is also consumed in the form of fossils fuels in trucks that are used to transport water, sludge, material and chemicals throughout the service chain-resulting in direct GHG emissions. Direct GHG emissions can also come from large water reservoirs due to sedimentation. Further, biological degradation of the organic matter present in sewage and grey water results in direct methane (CH₄) and nitrous oxide (N₂O) emissions. Additionally, there is embedded energy and carbon footprint associated with the physical infrastructure and the materials and chemical used. *Figure 28* schematically illustrates the various steps in a typical urban water cycle in India as well as the electricity consumption and GHG emissions sources.

Figure 21: Graphical representation of various steps and processes in a typical urban water cycle showing sources of energy consumption and greenhouse gas emissions.



Source: Author's Illustration

5.3 SCOPE OF GREEN HOUSE GAS ESTIMATION

Assessing the carbon footprint of urban water systems requires a comprehensive approach that accounts for emissions across different stages of water abstraction, treatment, conveyance, distribution, and wastewater management. These emissions originate from various

processes, including direct GHG releases, energy and chemical consumption in operations, and emissions embedded in materials that make up the physical infrastructure. In this estimation, emissions are classified into three broad categories: *Direct Emissions*, *Indirect Emissions*, and *Embedded Emissions mentioned in Table 10*. Each category captures different sources of carbon emissions within the urban water and sanitation systems.

Table 8: Scope of emissions methodology for carbon footprint assessment of the urban water cycle

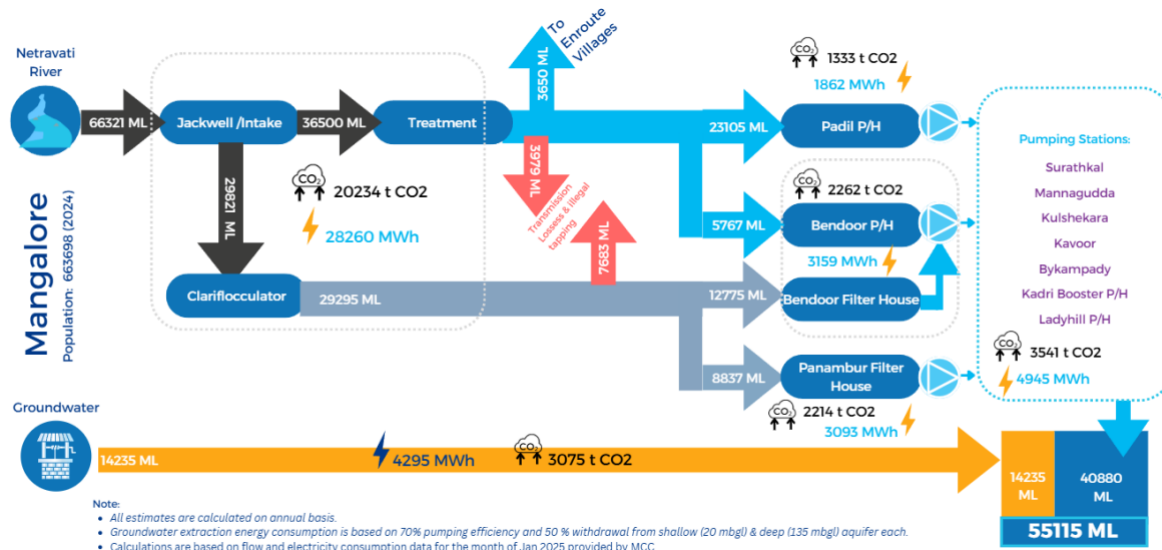
Category	Possible Sources of Emissions	Methodology
Direct Emissions	- Methane (CH₄) emissions from anaerobic decomposition of organic matter in wastewater. - Nitrous Oxide (N₂O) Emissions from nitrification and denitrification of nitrogen compounds wastewater - Methane (CH₄) emissions from the decomposition of organic matter in anaerobic sediments in freshwater reservoirs*	2006 IPCC Guidelines for National Greenhouse Gas Inventories ⁵⁴ (2019 Refinement ⁶³)
Indirect Emissions	- Indirect emissions from electricity consumption - Life cycle GHG emissions associated with the chemicals used in water and wastewater treatment processes (alum, hypo, chlorine etc.)* - Emissions from diesel combustion for transportation	Electricity consumption data obtained from urban local bodies and an average grid emission factor 0.716 tCO₂/MWh (FY 2022-23, Central Electricity Authority)⁶⁴ for Indian grid used for CO₂ estimation. Diesel consumption for desludging trucks based on information obtained from interviewing truck operators.
Embedded Emissions	- Life cycle GHG emissions associated with the materials used in the physical infrastructure. *	Not estimated due to non-availability of data on material footprint.
*Emissions not considered in the estimation due to non-availability of reliable activity data for the same.		

5.4 GREENHOUSE GAS EMISSIONS FROM WATER SUPPLY

The energy-intensive nature of water supply spanning extraction, treatment, conveyance, and distribution results in substantial indirect GHG emissions, primarily from electricity use. Additionally, household-level pumping, purification, and heating contribute to the carbon footprint, although such household level energy use is not accounted for here. Emissions related to treatment chemicals, construction materials, and logistics also remain outside the scope of this estimation due to data constraints. Furthermore, scientific studies suggest that freshwater reservoirs may also release direct GHG emissions due to anaerobic decomposition of organic matter in sediments⁶⁵. However, these are excluded from this analysis given methodological limitations. Hence, our assessment focuses solely on electricity-related emissions across key components of the water supply chain, as shown in *Figure 22*.

Mangaluru's water supply system exhibits a significant carbon and energy footprint, largely driven by the high dependence on pumped surface water from the Netravati River and energy-intensive treatment and transmission infrastructure. The scheme supplies around 112 million litres per day (MLD) water to service connections within MCC. In order to supply this, a total of 171.7 MLD is extracted from the Netravati River. A notable portion of this water is lost throughout the system due to treatment, transmission, and distribution inefficiencies as well as by illegal direct tapping on the transmission mains by enroute users.

Figure 22: Carbon and energy footprint of Mangaluru's water supply.



Source: Dangi & Narayanan, forthcoming⁶⁶

- **Thumbe:** For extracting a total of 181.7 MLD, treating 100 MLD, clari-flocculation of another 81.7 MLD and pumping this water to the city.

Electricity use: **28260 MWh/year** Associated GHG emissions: **20234 tCO₂/year**

- **Padil MBR and Pump House:** The treated water from Ramalkatte is received at the Padil MBR from where it is pumped to 17 OHTs/ GLSRs for distribution to end users, directly supplied to users and around 16 MLD is further pumped to Bendoor.

Electricity use: **1862 MWh/year** GHG emissions: **1333 tCO₂/year**

- **Water Treatment & Pumping at Bendoor:** 35 MLD clarified water is received and filtered here (Capacity of Filter House is 40 MLD, Present production 35 MLD). Additionally, around 16 MLD of treated water from Ramalkatte WTP is received at Bendoor Master Balancing Reservoir (MBR). Water is then pumped to 7 OHT's for further distribution as well directly supplied to users from the MBR.

Electricity use: **3159 MWh/year** GHG emissions: **2262 tCO₂/year**

- **Water Treatment & Pumping at Panambur:** ~ 24 MLD clarified water is received and filtered here (Capacity of Filter House is 40 MLD, Present production 24 MLD). From Panambur MBR water is further pumped to 8 OHT's/ GLSR for further distribution as well as to Mulki and industrial area.

Electricity use: **3093 MWh/year** GHG emissions: **2214 tCO₂/year**

- **Groundwater Extraction:** Groundwater contributes an estimated **14235 MLD per year**, but at a much lower energy cost **4295 MWh/year**, resulting in **3075 t CO₂/year** in emissions.

The carbon footprint is likely to increase further with rising demand, expansion of piped supply coverage, and climate-induced challenges such as higher turbidity, frequent backwashing, and increased energy and chemical use during monsoons. These insights underline the urgent need to reduce losses, promote energy efficiency, and explore low-energy, low-carbon alternatives to ensure both climate and water security in Mangaluru.

5.5 GREENHOUSE GAS EMISSIONS FROM SANITATION

The MCC manages its wastewater through 4 sewage treatment plants as depicted in Table 9.

Table 9: Wastewater district-wise population and wastewater generation estimates

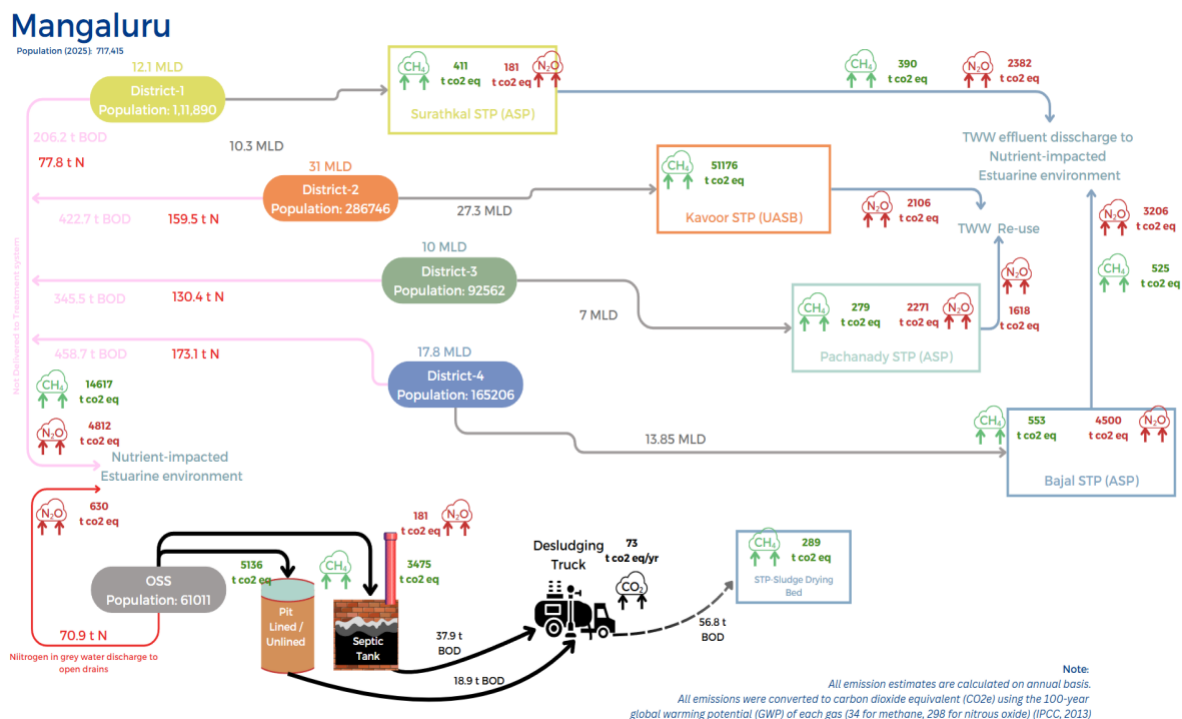
STP at Kavoor District-2	43.5MLD Total 10 Wet wells are connected to this STP The technology used in this treatment plant is "Up-flow Anaerobic Sludge Blanket Reactor (UASBR)"	STP at Bajal District-4	20 MLD The technology used in Sewage Treatment Plant is "Activated Sludge Process followed by Extended Aeration Process".
STP at Pachanady District-3	8.75 MLD The technology used in Sewage Treatment Plant is "Activated Sludge Process followed by Extended Aeration Process".	STP at Surathkal District-1	16.5 MLD The technology used in Sewage Treatment Plant is "Activated Sludge Process followed by Extended Aeration Process".

WW District	Population 2025	Domestic WW Generation (MLD)	WW Rec'd at STP (MLD)
District 1	1,11,890	12.08412	10.29
District 2	2,86,746	30.968568	27.29
District 3	92,562	9.996696	6.99
District 4	1,65,206	17.842248	13.85
		70.891632	58.42
Unserved Population 61011			

Source: Mangaluru City Corporation

The GHG emissions throughout the sanitation service chain in Mangaluru are illustrated in [Figure 23](#). Sanitation systems in Mangaluru contribute significantly to the city's greenhouse gas (GHG) emissions, arising from both network-based sewerage and onsite sanitation systems. These emissions are primarily driven by methane (CH₄) and nitrous oxide (N₂O) released during the decomposition of organic matter in wastewater and sludge under anaerobic conditions. Additional emissions result from greywater discharge, transport activities, and leaks in the underground sewerage network. Due to data limitations, electricity-related emissions from sewage pumping and treatment operations have not been included; however, the direct emissions from wastewater treatment and containment systems are substantial and form the basis of this analysis.

Figure 23: Greenhouse gas emission estimation of urban waste water management in Mangaluru City corporation



Source: Dangi & Narayanan, forthcoming⁶⁶

Wastewater Generation and BOD Load

Mangaluru generates substantial quantities of domestic wastewater, driven by a population of 717,415. Of this, 91% (656,404 people) are connected to the underground drainage (UGD) network, while the remaining 9% (~61,000 people) rely on onsite sanitation systems such as septic tanks and pit latrines. Based on a standard BOD generation rate of 34 g/person/day⁶⁷, the total BOD load from domestic wastewater is estimated at 8,903 tonnes per year. However, due to gaps and discontinuities in the sewer network, an estimated 1,433 tonnes of BOD from UGD-connected households is not delivered to treatment facilities and is instead released into the environment untreated.

Emissions from Network-Based Sanitation Systems

Each of the four sewage treatment plants (STPs) contributes to GHG emissions both through **on-site treatment processes** and through **off-site emissions** from the discharge of treated effluent into the environment.

At the **Surathkal STP** (activated sludge process), direct on-site emissions are estimated at 411 t CO₂-eq of methane and 181 t CO₂-eq of nitrous oxide annually. In addition, off-site emissions from the treated effluent account for 390 tCO₂-eq of CH₄ and 2,382 tCO₂-eq of N₂O.

The **Kavoor STP**, which uses an Upflow Anaerobic Sludge Blanket (UASB) process, exhibits extremely high on-site methane emissions, amounting to 51,176 tCO₂-eq/year. This is due to the absence of methane capture or flaring mechanisms, allowing large volumes of biogas to escape. UASB processes generate negligible nitrous oxide emissions. However, despite tertiary treatment that eliminates methane from effluent, Kavoor still contributes 2,106 tCO₂-eq/year of N₂O through effluent discharge.

At **Pachanaddy STP** (ASP), on-site methane and nitrous oxide emissions are estimated at 279 and 2,271 tCO₂-eq/year respectively. Its off-site N₂O emissions from treated effluent add another 1,618 tCO₂-eq/year, although methane emissions from effluent are negligible due to tertiary treatment.

Bajal STP, also an ASP, contributes 553 tCO₂-eq/year of CH₄ and 4,500 tCO₂-eq/year of N₂O from on-site processes. Additionally, it is responsible for 525 tCO₂-eq/year of CH₄ and 3,206 tCO₂-eq/year of N₂O from treated effluent released into the environment.

A significant but often overlooked source of emissions comes from **leaks in the underground sewerage network**. Anaerobic conditions in these leak-prone sections result in an estimated 14,617 tCO₂-eq/year of methane and 4,812 tCO₂-eq/year of nitrous oxide, representing a large portion of the total emissions burden from network sanitation.

Emissions from Onsite Sanitation Systems

Methane emissions from **lined/unlined pits** are estimated at 5,136 tCO₂-eq/year, while **septic tanks** contribute an additional 3,475 tCO₂-eq/year. Nitrous oxide emissions from septic tanks are estimated at 181 tCO₂-eq/year, whereas emissions from pit latrines are assumed to be negligible, consistent with IPCC guidelines.

Greywater Discharge and Associated Emissions in OSS

Mangaluru's greywater, typically from kitchens, bathing, and laundry, is discharged untreated into stormwater drains and ultimately into nearby estuarine environments. This greywater contains nitrogen from household products, kitchen waste, and commercial discharges, which

leads to nitrous oxide emissions during environmental degradation. Based on nitrogen loading estimates (70.9 tonnes N/year), greywater discharge results in approximately 630 tCO₂-eq/year of N₂O emissions.

Desludging and Sludge Management

Desludging operations add another layer of emissions to the sanitation chain. Diesel-fueled vacuum trucks used for transporting sludge from onsite systems emit an estimated 73 tCO₂-eq/year. The sludge is delivered to STPs for drying, where it undergoes further anaerobic decomposition, producing an additional 289 tCO₂-eq/year of methane.

Key Findings and Insights

1. **High Emissions from STPs:** The Kavour UASB plant is a major hotspot, with over 51,000 tCO₂-eq/year of uncontrolled methane emissions. Upgrading this plant with biogas capture and flaring systems could significantly reduce the city's emissions.
2. **Leaky Sewer Networks are a Hidden Risk:** Emissions from undetected leaks in the sewer system are substantial and comparable to, or even greater than, those from operational STPs. This highlights the need for proactive sewer monitoring and rehabilitation.
3. **Onsite Systems Still Matter:** Though a smaller share of the population uses onsite sanitation, the emissions especially methane from pit latrines are considerable and must be addressed through improved designs, better maintenance, and potentially decentralized treatment.
4. **Greywater is a Silent Contributor:** Nitrous oxide emissions from untreated greywater highlight a blind spot in current wastewater planning. Encouraging household-level greywater treatment and reuse could reduce both environmental and climate impacts.
5. **Data Gaps Limit Full Emissions Accounting:** Electricity-related emissions from pumping stations and treatment operations are not accounted for due to data gaps. Including them in future assessments will provide a more complete emissions profile.

Need for a Targeted Mitigation Strategy:

To effectively curb urban sanitation-related greenhouse gas emissions, a targeted and multi-pronged mitigation strategy is essential. The Kavour UASB sewage treatment plant, for instance, stands out as a major emissions hotspot, releasing over 51,000 tCO₂-equivalent

annually due to uncontrolled methane. Upgrading this facility with biogas capture and flaring systems could significantly reduce the city's carbon footprint. In parallel, emissions from undetected leaks in the sewer network—which may equal or even exceed those from operational STPs—highlight the urgent need for systematic sewer monitoring and rehabilitation. While onsite sanitation systems cater to a relatively smaller portion of the population, their methane emissions, particularly from pit latrines, are far from negligible. These must be addressed through better system design, regular maintenance, and where appropriate, decentralized treatment options. Additionally, nitrous oxide emissions from untreated greywater remain an overlooked yet significant contributor to climate impact. Encouraging household-level greywater treatment and reuse could help bridge this gap in wastewater planning. Together, these interventions offer a clear pathway toward low-carbon, climate-resilient urban sanitation systems.

5.6 CONCLUSION & WAY FORWARD

The combined energy and emissions profile of the municipal water and sanitation sectors reveals a significant carbon footprint inextricably linked to current infrastructural choices. In the water sector, the overwhelming reliance on energy-intensive, long-distance surface water conveyance and treatment generates substantial operational emissions, a dynamic that contrasts sharply with the lower carbon intensity of available groundwater resources. Parallel to this, the sanitation sector is characterised by distinct emission hotspots, most notably the uncontrolled methane release from specific treatment technologies (such as the Kavour UASB plant) and substantial fugitive emissions arising from systemic leakages within the ageing underground sewerage network. Furthermore, unchecked greywater discharge and onsite containment systems add considerable, yet often overlooked, layers of methane and nitrous oxide to the municipal inventory. Navigating these interconnected climate impacts identifies a clear transition pathway for future urban planning. Aligning utility management with broader decarbonisation objectives will depend upon upgrading existing treatment facilities to incorporate biogas capture, rehabilitating compromised sewer networks to minimise fugitive emissions, and strategically diversifying the municipal supply matrix to include lower-carbon, decentralised alternatives.

NOTES & REFERENCES

- ⁵¹ **Author's Note:** This chapter is based on ongoing doctoral research by Ashish Dangi under the supervision of Prof. N. C. Narayanan at the Ashank Desai Centre for Policy Studies (ADCPS), Indian Institute of Technology Bombay. Key findings and interpretations presented here are part of a broader analysis that is currently being prepared for publication in a peer-reviewed academic journal. Readers are requested to cite this report appropriately and direct any academic queries to the author.
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6. PERFORMANCE AND FINANCIAL ANALYSIS OF WATER SUPPLY AND SANITATION

ABHAY JUNAGHARE⁶⁸ AND NC NARAYANAN

This chapter evaluates the operational and financial health of the water supply and sanitation systems. It begins by assessing current service delivery against established performance benchmarks for both the water and sewerage networks. Next, it analyses the underlying revenue streams, focusing on retail tariffs and the sector's reliance on external grants versus internally generated revenue. Finally, the chapter provides a comprehensive financial assessment to pinpoint the primary fiscal challenges hindering sustainable service delivery in these sectors.

6.1 BACKGROUND

This section analyses the performance analysis against SLBs for urban water supply and sanitation by the Ministry of Housing and Urban Affairs (MoHUA). The section also analyses the revenue streams and grants available to MCC for water supply and sewerage & sanitation. The revenue sources include central government grants, state government grants, and their own revenue sources. Here, the ratio of grants to own revenue sources is analyzed to identify the percentage availability of each source for water supply and sewerage & sanitation. The assessment of financial health of the water utility and sewerage & sanitation is performed here by examining the capital receipts, capital expenditure, revenue expenditure, & revenue receipts from the city municipal budget statements. The water and sanitation budgets are created from the municipal budget to analyse the cost recovery, collection efficiency, operating ratio, cost of bulk water purchase, per capita expenditure, the revenue and fiscal deficits, budget trends (capital receipts, capital expenditure, revenue expenditure, & revenue receipts), and compound annual growth rate (CAGR)⁶⁹. The above given ratios are essential to identify the financial health of the water utility and sewerage & sanitation at MCC.

6.2 PERFORMANCE ANALYSIS: SERVICE LEVEL BENCHMARKS

The performance⁷⁰ of the utility for water and sanitation services can be assessed based on the performance indicators. These nine performance indicators known as the SLBs for urban water supply and sewerage and sanitation in India were proposed by the then ministry of

urban development (now MoHUA) These SLBs are able to ascertain the inefficiencies in the urban water supply system (UWSS) and sewerage & sanitation besides providing the corrective measures that are vital to achieve sustainable water supply and sewerage & sanitation. The SLBs can be distinguished into four major indicator groups, viz., access, quality of water supply and treated used water, financial viability and environmental sustainability that further fits into the dimensions of social, economic and environment. Increasing urbanization, unplanned floating tourist population and changing consumption patterns have stressed the existing water supply and sewerage & sanitation infrastructure of the town.

6.2.1 WATER SUPPLY

The service level benchmarks for water supply in Mangaluru highlight significant improvements in various key performance indicators while also revealing areas where further progress is needed (Ref. Table 10). The percentage of households with water supply connections in Mangaluru has improved from the national average of 70% to 91% in 2020-21, maintaining the same target for 2021-22. However, the city still falls short of the 100% benchmark by 9%, indicating the need for further expansion of water connections to unserved areas. Mangaluru has successfully met the benchmark of 135 litres per capita per day (lpcd) in both 2020-21 and the 2021-22 target. This is a significant improvement from the national average of 114 lpcd, ensuring that residents receive adequate water supply in terms of quantity. The percentage of metered connections in Mangaluru has seen a remarkable increase from the national average of 22% to 98% in 2020-21 and is targeted to reach 99% in 2021-22. While this is close to the 100% benchmark, a minor 1% gap remains, suggesting that full metering should be achieved for better accountability and water conservation.

The proportion of non-revenue water, which includes losses due to leakages, theft, and unbilled consumption, remains a concern. Though reduced from the national average of 31% to 20% in Mangaluru, it still exceeds the benchmark of 15% by 5%. Further efforts in leakage detection, pipeline maintenance, and improved billing systems can help bridge this gap. One of the most significant challenges is the limited availability of water supply hours. Mangaluru has improved from a mere 2.7 hours (national average) to 14 hours in 2020-21 and aims for 20 hours in 2021-22. However, this remains 4 hours short of the target, indicating a need for better distribution infrastructure and supply management to move towards the ideal 24-hour supply. Mangaluru has achieved the 100% benchmark in terms of water quality compliance, ensuring that all supplied water meets potable standards. This is a positive achievement, especially compared to the national average of 95%.

Table 10: Performance Indicators for Water Supply at MCC

Sl. No.	Water Supply Indicators	Calculations	Benchmarks	India Average*	2020-21	2021-22 (Target)**	Gaps (Target)
1.	Coverage of Connections	(Total no. of HHs with water supply connections)/ (Total no. of HHs in the City)	100%	70%	91%	91%	-9%
2.	Per capita supply (lpcd)	(Water supplied)/ (Population served)	135 lpcd	114 lpcd	135 lpcd	135 lpcd	0 lpcd
3.	Metering of connections	(No. of metered connections + No. of metered Public Standposts)/ (Total no. of connections + Total no. of Public Standposts)	100%	22.00%	98%	99%	-1%
4.	Non-revenue water (NRW)	(Total water produced) - (Total water sold)/ (Total water produced)	15%	31%	20%	20%	-5%
5.	Continuity of water supply (hours)	Average hours of water supply	24 hours	2.7 hours	14 hours	20 hours	-4 hours
6.	Quality and treatment	(Number of samples that meet the specified potable water standards)/ (Total number of complaints received related to water supply)	100%	95%	100%	100%	0%
7.	Redressal of customer complaints	(Total number of complaints redressed)/ (Total number of complaints received related to water supply)	80%	89%	96%	100%	+20%

Source: * CPHEEO Guidelines for 24x7 WSS (Drink from Tap), December 2021; **Government of Karnataka, 2021

The city has made significant strides in addressing consumer grievances, surpassing the 80% benchmark. From an already high 96% in 2020-21, Mangaluru aims to achieve 100% in 2021-22, reflecting a well-functioning complaint resolution mechanism. While Mangaluru has made commendable progress in water supply service levels, areas such as coverage, NRW reduction, and continuity of supply still require attention. Strengthening infrastructure, addressing losses, and ensuring universal coverage can help the city achieve optimal water service delivery.

6.2.2 SANITATION SERVICES

The analysis of the performance indicators for sewerage and sanitation indicators at Mangaluru City reveals both strong performance and areas requiring improvement (Ref. Table 11). The city has achieved 100% coverage of toilets, meaning all households (HHs) have access to individual or community toilets within walking distance. This is in line with the target and shows no gaps, maintaining optimal sanitation for its residents. While the target for sewage network coverage was 100%, Mangaluru is currently at 62% coverage, with a planned increase to 65% for the year 2021-22. This represents a significant gap of -38%, suggesting that a substantial portion of the city's households lacks direct connection to the sewage network, which could be a major sanitation concern. The collection efficiency is set to improve from 85% in 2020-21 to 95% in 2021-22, indicating a moderate gap of -15%. This suggests that while most wastewater is being collected, a portion of it still goes uncollected, which may impact overall sewage management. The sewage treatment capacity is currently 82% of what is needed based on the water consumed and the number of households with sewage connections, with a target of 85%. The gap of -18% indicates that the city's sewage treatment capacity is not yet fully adequate to handle the total sewage volume, potentially leading to treatment inefficiencies.

In terms of sewage treatment quality, the city has a pass rate of 87% of wastewater samples meeting the specified secondary treatment standards, with a target of 95%. This represents a -13% gap, suggesting room for improvement in ensuring that more treated wastewater meets the quality standards. The city aims for a significant increase in the reuse and recycling of sewage, from 80% in 2020-21 to 90% in 2021-22, achieving a large improvement of 60% over the benchmark of 20%. This indicates strong progress in the city's efforts to recycle treated sewage, which is an important sustainability initiative. The city has performed well in resolving customer complaints, with a performance of 90% in redressing sewage-related complaints, up from the 85% target. The 5% improvement reflects the city's effective customer service in dealing with sanitation issues. The city's cost recovery in sewage management is near the target, with a 95% recovery rate of operating expenses, slightly below the benchmark of 100%. The gap of -10% suggests that there is still some shortfall in fully covering the operational costs, which may impact long-term financial sustainability. With a

collection efficiency of 95%, the city is on target to achieve the desired 90% collection rate of sewage charges. This efficiency reflects good financial management in ensuring that revenues are collected as per the billed amounts, indicating a stable financial environment for sewage management.

Table 11: Performance Indicators for Sewerage & Sanitation at MCC

Sl. No.	Sewerage and Sanitation Indicators	Calculations	Benchmarks	2020-21	2021-22 (Target)	Gaps
1.	Coverage of Toilets	(Total number of HHs with access to individual or community toilets within walking distance in the city)/ (Total number of HHs without individual or community toilets within walking distance)	100%	100%	100%	0%
2.	Coverage of Sewage Network Services	(Total number of HHs with direct connection to the sewage network)/ (Total number of HHs in the city)	100%	62%	65%	-38%
3.	Collection Efficiency of the Sewage Network	(Wastewater collected)/ (Total water supplied + Estimated water use from other sources)	100%	85%	95%	-15%
4.	Adequacy of Sewage Treatment Capacity	(Treatment plant capacity)/ (Total water consumed + Total number of HHs with direct connection to sewage network)	100%	82%	85%	-18%
5.	Quality of Sewage Treatment	(Number of samples that pass specified secondary treatment standards)/ (Total number of wastewater samples tested in a month)	100%	87%	95%	-13%
6.	Extent of Reuse and Recycling of Sewage	(Wastewater recycled or reused after appropriate treatment)/ (Wastewater received at STPs)	20%	80%	90%	60%
7.	Efficiency in Redressal of Customer Complaints	(Total number of complaints redressed within the month)/ (Total number of sewage-related complaints received per month)	80%	85%	90%	5%

Source: Government of Karnataka, 2021

Mangaluru has made significant strides in toilet coverage, sewage treatment, and complaint redressal efficiency, but it faces challenges in expanding sewage network coverage, improving treatment capacity. The gaps indicate areas where further investment and attention are required for sustained improvement in sanitation services.

6.3 REVENUE STREAMS AT MANGALURU CITY CORPORATION

This section analyses the revenue streams and grants available to MCC for water supply and sewerage & sanitation. The revenue sources include central government grants, state government grants, and their own revenue sources. Here, the ratio of grants to own revenue sources is analysed to identify the percentage availability of each source for water supply and sewerage & sanitation. The assessment of financial health of the water utility and sewerage & sanitation is performed here by examining the capital receipts, capital expenditure, revenue expenditure, & revenue receipts from the city municipal budget statements. The water and sanitation budgets are created from the municipal budget to analyse the revenue streams. This helps assess MCC's preparedness to meet current and future demands for water supply and sewerage & sanitation infrastructure and services, and to enhance climate resilience of its residents. These actions ultimately contribute to improved public health outcomes and more sustainable urban environments. This section is structured in four subsections viz., 1) funds received from central government schemes, 2) funds received from state government schemes, 3) MCC's own revenue, and 4) Ratio of grants to own revenue at Mangaluru for water supply and sewerage & sanitation.

6.3.1 WATER SUPPLY

Central Government Funds

Mangalore city's water supply funding has been progressively supported through various central government schemes and finance commissions over the years (Ref. Table 12). The 12th Finance Commission (2005-2010) provided incremental funding, peaking at ₹409.48 lakh in 2009-10, before transitioning to the 13th Finance Commission (2010-2015), which allocated ₹5331.50 lakh, with funding rising to ₹1780.94 lakh in its final year. The 14th Finance Commission (2015-2020) made the most significant contribution, providing ₹9563.81 lakh, with allocations increasing to ₹2824.16 lakh by 2019-20.

Table 12: Funds received by MCC (in INR Lakhs) for Water Supply under Central Government Schemes

Year/ Schemes	AMRUT Scheme	12 th Finance Commission	13 th Finance Commission	14 th Finance Commission	15 th Finance Commission
2006-07	0.00	149.20	0.00	0.00	0.00
2007-08	0.00	233.32	0.00	0.00	0.00
2008-09	0.00	253.33	0.00	0.00	0.00
2009-10	0.00	409.48	0.00	0.00	0.00
2010-11	0.00	0.00	369.36	0.00	0.00
2011-12	0.00	22.64	709.13	0.00	0.00
2012-13	0.00	66.36	861.52	0.00	0.00
2013-14	0.00	0.45	1607.15	0.00	0.00
2014-15	0.00	0.00	1780.94	0.00	0.00
2015-16	360.54	0.00	0.00	1900.81	0.00
2016-17	203.33	0.00	0.00	1544.74	0.00
2017-18	184.05	0.00	0.00	1543.10	0.00
2018-19	134.41	0.00	3.40	1751.00	0.00
2019-20	337.94	0.00	0.00	2824.16	0.00
2020-21	12.07	0.00	0.00	0.00	2345.00
2021-22	0.00	0.00	0.00	0.00	1738.00
2022-23	0.00	0.00	0.00	0.00	863.50
Total Grants Received	1232.34	1134.79	5331.50	9563.81	4946.50

Source: Budget Documents, MCC Mangalore

The 15th Finance Commission (2020-2026) initially allocated ₹2345 lakh, but funding has since decreased, totalling ₹4946.50 lakh to date. The AMRUT scheme, introduced in 2015-16, provided supplementary funding, totalling ₹1232.34 lakh, though its contribution was much smaller compared to the Finance Commissions. This overall trend shows a peak in funding under the 14th Finance Commission, followed by a decline under the 15th, possibly reflecting a shift in government priorities or alternative funding strategies.

State Government Funds

Mangalore city's water supply has received funding through various state government schemes, with notable fluctuations in allocation patterns (Ref. Table 13). The Deferred Income scheme, focusing on infrastructure, peaked at ₹900.47 lakh in 2017-18, totalling ₹3275.82 lakh. The Area Development Grant from MLAs provided intermittent funding, with a total of ₹536.73 lakh, while a one-time ₹1091.92 lakh allocation for Thumbe Water Storage in 2017-18 highlights its strategic importance.

The Mahatma Gandhi Nagara Vikas Yojane played a significant role in recent years, receiving ₹3550.00 lakh, particularly in 2021-22 and 2022-23. The State Finance Commission's (SFC) Drinking Water Grant was the largest contributor, totalling ₹5043.86 lakh, though funding has declined in recent years. Other contributions, like grants from NHAI and Natural Disaster Relief Funds, provided targeted support, with NDRF allocating ₹897.00 lakh in 2019-20 for emergency relief. Overall, the state funding has been diverse, with a strong emphasis on infrastructure in the past, while more recent years have focused on specific projects and relief efforts.

Own Revenue

Mangalore city's water supply revenue primarily comes from user charges, which have grown significantly from ₹1181.45 lakh in 2006-07 to ₹4575.03 lakh in 2022-23, totalling ₹48,680.53 lakh (Ref. Table 14 below). These charges reflect the city's heavy reliance on consumer payments, possibly driven by increased consumption or tariff hikes. Another major source is SFC Grant for Electricity and Maintenance, which peaked at ₹9170.94 lakh in 2021-22, and an overall contribution of ₹34,444.70 lakhs.

Other revenue sources, such as Water Supply Connection Fees, Supervision Fees, and Reconnection Penalties, have contributed modestly, with fluctuating figures and minimal impact on total income. While user charges and SFC grants are essential, their variability creates risks, and improvements in fee collection, enforcement, and a more self-sustaining revenue model are needed for long-term financial stability. The city's reliance on grants and occasional fee fluctuations highlights the need for a balanced approach involving efficient billing, policy reforms, and stronger enforcement to ensure sustainable water supply funding.

Table 13: Funds received by MCC (in INR Lakhs) for Water Supply under State Government Schemes

Year/ Schemes	Deferred Income in respect of Assets created out of Grants & Contributions	Area Development Grant - Members of legislative assembly	Land acquisition for Thumbe Water storage - State Govt.	Mahatma Gandhi Nagara Vikas Yojane	State Finance Commission Drinking (SFC) water grant	Grants NHAI	Natural disasters NDRF SDRF
2006-07	0.00	2.00	0.00	0.00	0.00	0.00	0.00
2007-08	0.00	14.14	0.00	0.00	0.00	390.00	0.00
2008-09	0.00	0.00	0.00	0.00	0.00	50.00	0.00
2009-10	0.00	0.00	0.00	0.00	0.00	25.00	0.00
2010-11	0.00	0.45	0.00	0.00	0.00	0.00	0.00
2011-12	0.00	16.68	0.00	0.00	0.00	0.00	0.00
2012-13	0.00	52.19	0.00	0.00	0.00	0.00	0.00
2013-14	0.00	126.90	0.00	0.00	0.00	0.00	0.00
2014-15	0.00	81.39	0.00	0.00	0.00	0.00	0.00
2015-16	49.93	55.19	0.00	0.00	1,229.12	0.00	0.00
2016-17	195.64	0.00	0.00	0.00	3201.20	0.00	0.00
2017-18	900.47	58.00	1000.00	0.00	207.86	0.00	0.00
2018-19	241.13	31.82	91.92	0.00	52.21	0.00	0.00
2019-20	761.82	37.08	0.00	0.00	335.47	0.00	897.00
2020-21	613.95	16.68	0.00	0.00	5.00	0.00	0.00
2021-22	300.65	30.56	0.00	1550.00	3.50	0.00	0.00
2022-23	212.23	13.65	0.00	2000.00	9.50	0.00	0.00
Total Grants Received	3275.82	536.73	1091.92	3550.00	5043.86	465.00	897.00

Source: Budget Documents, MCC Mangalore

Table 14: Revenue Income from Water Supply at Mangalore (in INR Lakhs)

Year/ Own Revenue Sources	Registration fee for contractors, plumbers, etc.	Water Supply reconnection Penalty	Supervision fee	Meter testing fee	User Charges Water Supply	Water supply connection fee	Regularisation Fees - Water Supply Connections	SFC Salary Grant	Initial Water Deposit	SFC Grant for Electricity and Maintenance
2006-07	0.00	0.00	13.32	4.43	1181.45	69.65	22.20	173.75	0.00	863.15
2007-08	0.00	0.00	1.49	0.09	1222.50	45.01	0.40	179.76	7.95	754.54
2008-09	0.00	0.00	1.51	0.33	2097.34	41.01	0.36	143.00	6.33	0.00
2009-10	0.00	0.00	1.17	0.27	2061.54	54.65	0.53	0.00	6.48	322.70
2010-11	0.00	0.00	0.99	0.30	1994.97	66.03	0.32	0.00	13.81	988.09
2011-12	0.00	0.00	0.97	0.96	2077.01	66.07	0.28	0.00	20.15	1536.71
2012-13	0.00	0.00	1.11	1.62	2236.90	80.58	0.46	0.00	37.99	1193.45
2013-14	0.00	0.00	0.94	1.53	3175.88	88.74	0.29	0.00	30.01	1838.29
2014-15	0.00	0.00	0.53	1.70	2722.12	69.39	0.00	0.00	36.23	1068.16
2015-16	5.00	5.35	0.00	0.00	3,406.92	126.53	0.00	0.00	18.47	2,009.64
2016-17	0.00	0.00	0.00	0.00	3430.73	299.10	10.60	0.00	11.11	2339.68
2017-18	1.72	0.00	4.74	0.80	3282.06	308.06	0.25	0.00	0.00	2965.90
2018-19	6.51	1.32	7.78	0.72	3619.56	89.75	0.01	0.00	0.00	2231.32
2019-20	6.89	3.38	6.68	0.30	3821.80	102.58	0.00	0.00	0.00	2100.00
2020-21	7.32	0.57	11.84	0.31	3582.80	85.45	0.00	0.00	0.00	2556.12
2021-22	4.36	4.47	5.72	0.14	4191.92	105.60	0.00	0.00	0.00	9170.94
2022-23	1.72	0.59	26.13	0.10	4575.03	75.86	0.00	0.00	0.00	2506.00
Total	33.52	15.68	84.91	13.60	48680.53	1774.06	35.69	496.51	188.53	34444.70

Source: Budget Documents, MCC Mangalore

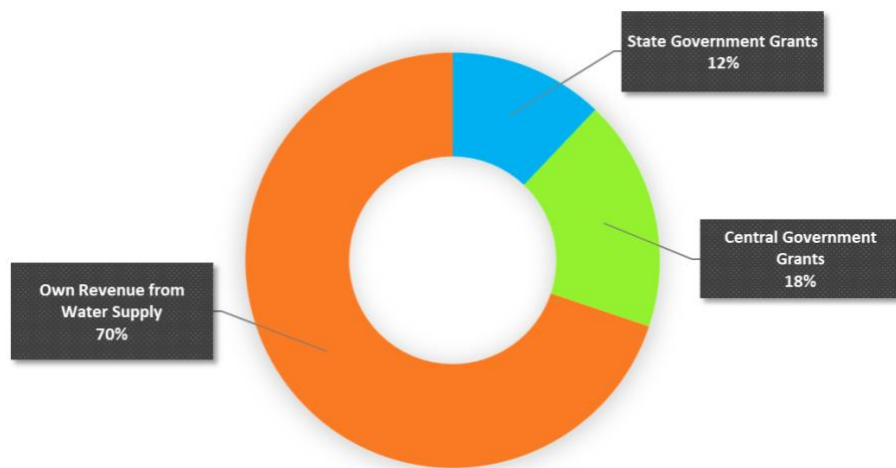
Ratio of grants and own revenue for water supply

Mangalore city's water supply system is largely self-sustaining, with own revenue significantly outpacing external grants. The total own revenue stands at ₹85,791 lakh, while state and central government grants total ₹37,069 lakh. The ratio of state grants to own revenue is just 0.17, and central grants to own revenue is 0.26, reflecting a higher reliance on central support but still showing a dominant role for local revenue (Ref. Figure 24).

With grants accounting for only 43% of the total funding, the city's water supply is primarily funded by user charges, connection fees, and SFC grants, with own revenue nearly 2.3 times higher than total grants. The data suggests that while grants play a supportive role in financing infrastructure, Mangalore's water supply system depends mainly on local revenue,

emphasizing the importance of a strong revenue collection system for long-term sustainability and financial independence.

Figure 24: Share of grants vs own revenue for water supply at MCC Mangaluru



Source: Author's Analysis of Municipal Budgets from 2007-08 till 2023-24, MCC

6.3.2 SEWERAGE & SANITATION

Central Government Funds

Central Government grants have been essential for supporting sanitation services in Mangalore, with the 13th and 14th Finance Commission Grants being the primary contributors, totalling ₹5,331.50 lakh and ₹9,563.81 lakh, respectively (Ref. Table 15). The SBM grant and ULB share for AMRUT & SBM, introduced later, provided a total of ₹144.89 lakh and ₹360.54 lakh, but these were smaller compared to the Finance Commission grants.

However, a notable decline in funding is observed, particularly with the reduction in the 15th Finance Commission grants (₹4,946.50 lakh) and the absence of new grants in recent years. This declining trend, coupled with minimal funding from schemes like SJSRY and Members of Parliament Grants, suggests a shift in priorities and raises concerns about the long-term sustainability of sanitation infrastructure unless alternative funding mechanisms are found.

Table 15: Funds received by MCC (in INR Lakhs) for Sewerage & Sanitation under Central Government Schemes

Year/ Schemes	ULB Share for AMRUT and SBM	SBM Grant	Central Govern- ment Grants (SJSRY)	12th Financial Grant	13th Financial Grant	14th Finance Grant	15th Finance Grant	Member s of Parliame nt Grants
2006-07	0.00	0.00	0.00	149.20	0.00	0.00	0.00	2.00
2007-08	0.00	0.00	0.00	233.22	0.00	0.00	0.00	4.00
2008-09	0.00	0.00	0.00	253.33	0.00	0.00	0.00	0.00
2009-10	0.00	0.00	0.00	409.48	0.00	0.00	0.00	0.00
2010-11	0.00	0.00	0.00	0.00	369.36	0.00	0.00	0.00
2011-12	0.00	0.00	0.00	22.64	709.13	0.00	0.00	7.00
2012-13	0.00	0.00	0.00	66.36	861.52	0.00	0.00	50.89
2013-14	0.00	0.00	0.00	0.45	1607.15	0.00	0.00	14.25
2014-15	0.00	0.00	18.53	0.00	1780.94	0.00	0.00	81.39
2015-16	360.54	0.00	0.00	0.00	0.00	1,900.81	0.00	55.19
2016-17	0.00	0.00	0.00	0.00	0.00	1544.74	0.00	0.00
2017-18	0.00	13.23	0.00	0.00	0.00	1543.10	0.00	21.00
2018-19	0.00	0.00	0.00	0.00	3.40	1751.00	0.00	31.82
2019-20	0.00	0.99	0.00	0.00	0.00	2824.16	0.00	37.08
2020-21	0.00	31.05	0.00	0.00	0.00	0.00	2345.00	16.68
2021-22	0.00	99.62	0.00	0.00	0.00	0.00	1738.00	30.56
2022-23	0.00	0.00	0.00	0.00	0.00	0.00	863.50	13.65
Total Grants Received	360.54	144.89	18.53	1134.69	5331.50	9563.81	4946.50	365.51

Source: Budget Documents, MCC Mangalore

State Government Funds

State government grants have played a vital role in supporting Mangalore's sanitation services, with key funding sources including State Government Schemes (₹4,430.32 lakh) and the Mahatma Gandhi Nagara Vikas Yojane (₹3,550.00 lakh), which saw substantial allocations in specific years like 2015-16 and 2016-17 (Ref. Table 16). However, there has

been a declining trend in certain funding categories, such as Area Development Grants (MLA) and Deferred Income, raising concerns about the long-term sustainability of sanitation projects.

Table 16: Funds received by MCC (in INR Lakhs) for Sewerage & Sanitation under State Government Schemes

Year/ Schemes	Deferred Income in respect of Assets created out of Grants & Contributions	Area Developme nt Grant - Members of Legislative Assembly	Grants from State Governmen ts Schemes/ Programme s	Grants from State Governmen t - Others	Mahatma Gandhi Nagara Vikas Yojane	Natural disasters NDRF & SDRF & DC	CSR Fund - Toilet constructio n
2006-07	0.00	5.21	0.00	0.00	0.00	43.28	0.00
2007-08	0.00	10.14	0.00	0.00	0.00	3.07	0.00
2008-09	0.00	0.00	0.00	0.00	0.00	33.60	0.00
2009-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010-11	0.00	0.45	0.00	0.00	0.00	0.00	0.00
2011-12	0.00	9.68	0.00	0.00	0.00	2.47	0.00
2012-13	0.00	1.30	0.00	0.00	0.00	2.29	0.00
2013-14	0.00	112.65	0.00	0.00	0.00	0.00	0.00
2014-15	0.00	81.38	0.00	0.00	0.00	0.00	0.00
2015-16	1,161.52	0.00	1,229.12	50.01	0.00	0.00	0.00
2016-17	235.92	0.00	3201.20	71.96	0.00	0.00	0.00
2017-18	399.99	37.00	0.00	0.00	0.00	0.00	0.00
2018-19	202.78	0.00	0.00	0.00	0.00	0.00	61.33
2019-20	283.82	0.00	0.00	0.00	0.00	897.00	0.00
2020-21	194.72	0.00	0.00	0.00	0.00	0.00	0.00
2021-22	172.04	0.00	0.00	0.00	1550.00	0.00	0.00
2022-23	169.93	0.00	0.00	0.00	2000.00	0.00	0.00
Total Grants Received	2820.72	257.81	4430.32	121.97	3550.00	981.71	61.33

Source: Budget Documents, MCC Mangalore

Notably, the 2019-20 allocation for natural disaster recovery (₹897.00 lakh) underscores the importance of sanitation infrastructure in disaster management. With CSR funding remaining minimal (₹61.33 lakh), there is a need for Mangalore to explore more diverse funding sources

and greater corporate involvement to ensure continued progress and stability in sanitation infrastructure.

Own Revenue

Mangalore's sanitation services rely heavily on revenue from UGD development fees, which make up over 90% of total collections, amounting to ₹5,034.76 lakh over the years (Ref. Table 17). Other sources include cesspool services, which started generating revenue in 2017-18, reaching ₹136.83 lakh by 2022-23, and sewer connection fees, which peaked in 2017-18 but have since declined. SFC salary grants were received only from 2006-09, amounting to ₹126.72 lakh in total, before being discontinued.

Table 17: Revenue Income from Sewerage & Sanitation at Mangalore (in INR Lakhs)

Year/ Own Revenue Sources	Cesspool	Grants Received - SFC Salary Grants	UGD Development Fee	Sewer Connection Fee/ UGD Connection Charges	User Charges UGD	Total Sanitation Charges
2006-07	0.00	42.35	301.81	0.58	0.00	344.74
2007-08	0.00	46.37	282.69	5.08	0.00	334.14
2008-09	0.00	38.00	204.66	7.01	0.00	249.67
2009-10	0.00	0.00	108.70	2.66	0.00	111.36
2010-11	0.00	0.00	308.30	2.27	0.00	310.57
2011-12	0.00	0.00	357.80	3.98	0.00	361.78
2012-13	0.00	0.00	668.59	6.19	0.00	674.78
2013-14	0.00	0.00	460.49	37.37	0.00	497.86
2014-15	0.00	0.00	252.22	50.19	0.00	302.41
2015-16	0.00	0.00	294.65	80.00	0.00	374.65
2016-17	0.00	0.00	249.14	32.35	0.00	281.50
2017-18	16.85	0.00	308.06	179.67	0.00	504.58
2018-19	27.18	0.00	220.31	34.71	11.23	293.43
2019-20	24.05	0.00	171.16	16.29	0.00	211.50
2020-21	22.60	0.00	231.20	16.66	0.00	270.46
2021-22	23.15	0.00	202.33	12.91	0.00	238.39
2022-23	23.00	0.00	412.65	11.36	0.00	447.01
Total	136.83	126.72	5034.76	499.28	11.23	5808.83

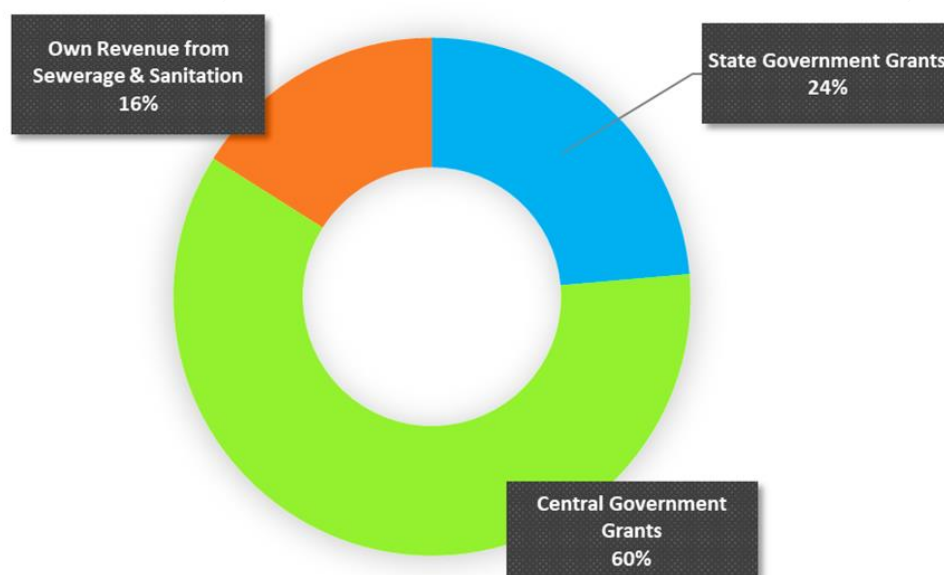
Source: Budget Documents, MCC Mangalore

User charges for UGD, introduced in 2018-19, generated modest revenue but were not sustained, highlighting inefficiencies in collection or enforcement. The fluctuations in these revenue streams suggest a lack of consistency in financing sanitation services. To improve financial sustainability, Mangalore should focus on stabilizing user charge collections, increasing cesspool service revenue, and exploring new funding sources for sanitation infrastructure.

Ratio of grants and own revenue

Mangalore's sewerage and sanitation system has seen a significant decline in the ratio of own revenue to grants over the years, with central government grants accounting for 60%, state government grants 24%, and only 16% from self-generated revenue (Ref. Figure 25). Initially, in 2006-07, the city had a higher ratio of 1.73, meaning it generated more revenue than it received in grants. However, this trend reversed, with the ratio dipping below 1 in 2008-09, signalling an increasing reliance on grants.

Figure 25: Share of grants vs own revenue for Sewerage & Sanitation at MCC



Source: Author's Analysis of Municipal Budgets from 2007-08 till 2023-24, MCC

By 2015-16, the ratio fell drastically to 0.08, indicating an even greater dependence on grants. The ratio reached its lowest point of 0.05 in 2019-20, but there was a slight recovery in 2022-23 to 0.15, although it remained low. This trend reflects growing challenges in boosting local revenue, possibly due to issues in taxation or system inefficiencies, while grants have become an increasingly vital source of funding for the city's sanitation system.

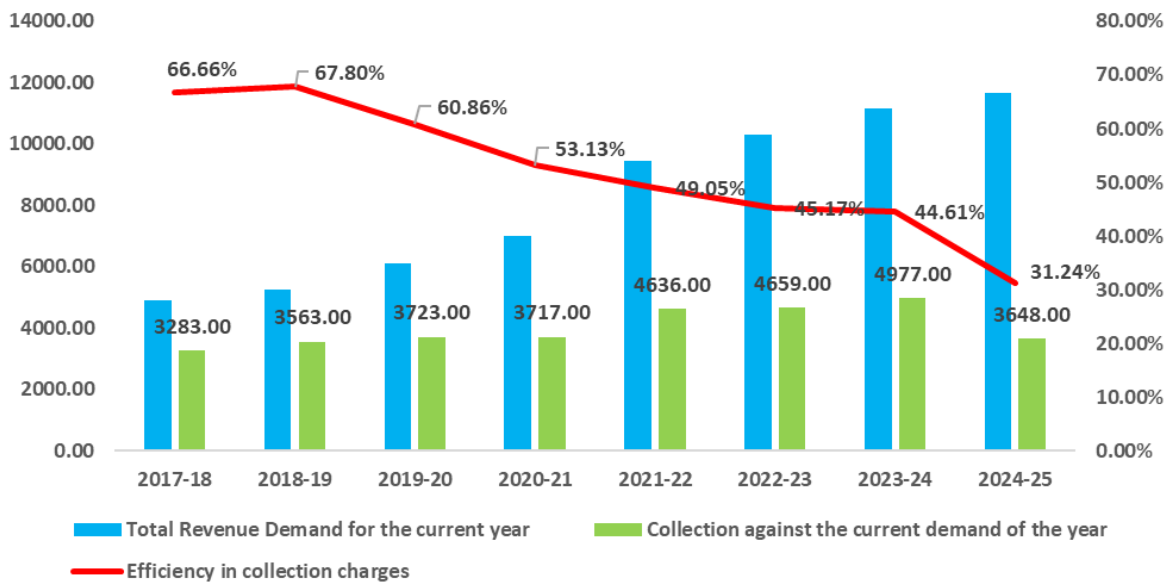
6.4 ASSESSMENT OF FINANCES

The upcoming sections analyse the trends from SLBs for water supply and sewerage & sanitation at MCC.

6.4.1 WATER SUPPLY

The financial performance indicators for water supply at MCC in 2020-21 and 2021-22 show a positive outlook in terms of cost recovery and collection efficiency, with MCC meeting the benchmark of 100% for cost recovery and exceeding the 90% benchmark for collection efficiency (Ref. Figure 26).

Figure 26: Trend analysis of collection efficiency in water supply charges at MCC



Source: MCC, 2025

However, a closer examination of trends over the years reveals a concerning decline in collection efficiency, with a significant drop from 66.66% in 2017-18 to a projected 31.24% in 2024-25. This steady decrease suggests operational challenges, such as poor payment enforcement and higher arrears, that could affect the financial sustainability of the water supply service. Despite the increasing revenue demand, MCC is not keeping pace with collections, which may hinder its ability to cover costs and invest in infrastructure. Addressing this decline will require improved billing systems, stricter payment enforcement, and innovative measures to encourage timely payments and reduce illegal connections.

6.4.2 SEWERAGE & SANITATION

The financial performance indicators for Sewerage and Sanitation at MCC reflect a slightly mixed performance in 2020-21 and 2021-22, especially in terms of cost recovery and collection efficiency. The Extent of Cost Recovery in Sewage and Sanitation, which measures the ratio of operating revenues to operating expenses, shows a shortfall in MCC's performance. While the benchmark is 100%, MCC achieved 90% in 2020-21, and a modest improvement is targeted for 2021-22 with 95%. However, a gap of -10% still exists when compared to the benchmark, suggesting that MCC is not fully covering its sewage management costs and may need to explore more sustainable financing strategies or efficiency improvements. On the other hand, the Efficiency in Collection of Sewage Charges, which evaluates the proportion of billed revenues actually collected, aligns well with the benchmark, showing 95% collection efficiency in both 2020-21 and the target for 2021-22. This reflects a robust performance, with no gap relative to the benchmark, indicating that MCC has been effective in revenue realization for sewage services. Thus, while MCC shows strong efficiency in collecting charges, it faces challenges in achieving full cost recovery in sewage management, indicating the need for further financial optimization.

6.5 CONTINUOUS WATER SUPPLY SYSTEM AT MANGALURU CITY CORPORATION

To support its growing population and industrial activities, the city has embarked on an ambitious project to establish a 24x7 water supply system, aiming to provide continuous and reliable potable water to its residents. In 2019, MCC awarded a contract to SUEZ, a French-based utility company, to implement a comprehensive 24x7 water supply system. This project, financed by ADB, encompasses the strengthening of the city's water distribution network, including the provision of water connections to approximately 96,300 households and the installation of around 2,148 kilometres of water distribution pipeline, covering an area of approximately 132 square kilometres. A significant component of this initiative involves the rehabilitation of a water treatment plant that is over 50 years old. The cost estimate for providing 24x7 water supply system in Mangalore City is as given below in Table 18.

The ADB is the primary lending agency for the project, and the agreed contribution of funds by other agencies is as given below in Table 19.

Table 18: Cost Components for 24x7 Water Supply System in Mangalore

#	Cost Components	Total Estimated Cost (INR Crores)
1.	Civil Works for Bulk Improvements	137.63
2.	Mechanical works	26.56
3.	Electrical works	12.38
4.	Distribution Network	177.23
5.	House service connections	72.52
6.	SCADA	27.08
7.	Sub Total – 1	453.40
8.	1% Cess	4.53
9.	Lump Sum Provision	2.89
10.	Sub Total – 2	460.83
12.	O & M Cost	197.24
13.	Total	658.07

Source: "DPR for Strengthening Distribution System for Implementing 24 X 7 Water Supply to Mangalore City", GKW Consult GmbH, 2015

Table 19: Funding Share of Lending Agencies

#	Agency	Agreed Provision of Funds
1.	Government of Karnataka / KIUWMIP	40%
2.	Asian Development Bank	50%
3.	Mangalore City Corporation	10%

Source: "DPR for Strengthening Distribution System for Implementing 24 X 7 Water Supply to Mangalore City", GKW Consult GmbH, 2015

To augment the 24x7 water supply project, the MCC has prepared a DPR to lay an additional pipeline between Adyar and Panambur, estimated at a cost of Rs. 68 crores. This proposal has been submitted to the government for approval. The new pipeline is expected to enhance water distribution efficiency and ensure consistent supply across all wards under the city corporation's jurisdiction. The 24x7 water supply project at Mangalore represents a significant stride toward ensuring uninterrupted water access for its residents. The successful

implementation of this project is anticipated to substantially improve water accessibility and reliability for the city's inhabitants.

6.6 KEY FINANCIAL CHALLENGES

Mangalore's water supply system faces key financial challenges including declining revenue collection efficiency, with projections showing a sharp drop to just 31.24% by 2024-25, which threatens revenue realization. Rising operational costs, particularly in 2022-23, are outpacing revenue growth, causing a strain on financial sustainability despite consistent cost recovery. Irregular capital expenditure and inconsistent infrastructure investment further complicate long-term planning, with fluctuating fiscal and revenue deficits, especially in 2021-22. The system's reliance on external funding through capital receipts, borrowings, and government grants highlights its vulnerability. To ensure future stability, there is a pressing need for more effective revenue collection, cost control, and strategic infrastructure investment planning. Mangalore's sanitation services face key financial challenges due to an unsustainable financial model characterized by a sharp decline in the Operating Ratio since 2014, signalling that expenses are consistently outpacing revenues. The city's increasing reliance on irregular government grants and external funding has led to widening revenue and fiscal deficits, with a high fiscal deficit of ₹2,902.28 Lakhs in 2021-22. Despite significant investments in infrastructure, fluctuating capital and revenue spending has created financial instability. The growing gap between operational costs and revenue income, along with heavy capital expenditures, exacerbates the situation. To address these challenges, Mangalore must enhance local revenue collection through user charges and cesspool fees, align capital investments with stable operational funding, and reduce dependency on external funding for long-term sustainability.

NOTES & REFERENCES

⁶⁸Author's Note: This chapter is based on ongoing doctoral research by Abhay Junaghare under the supervision of Prof. N. C. Narayanan at the Ashank Desai Centre for Policy Studies (ADCPS), Indian Institute of Technology Bombay. Key findings and interpretations presented here are part of a broader analysis that is currently being prepared for publication in a peer-reviewed academic journal. Readers are requested to cite this report appropriately and direct any academic queries to the author.

⁶⁹Capital receipts are comprised of reception of grants from central and state government through its schemes. Capital expenditures are the funds used to acquire or upgrade the infrastructure that are typically large purchases. Revenue expenditures are the recurring operating expenditure that are short term and essential to run daily operations. Revenue receipts are the recurring receipts of income generated from the daily service provisions. Cost recovery is the ratio of the total annual operating revenues to the total annual operating expenses. Collection efficiency is the ratio of current revenues collected in the given year to the total operating revenues billed during the given year. The operating ratio is the ratio of revenue expenditure to revenue income, which helps assess the financial sustainability. A value greater than 1.0 indicates that revenue income exceeds operating expenses, ensuring financial stability. The revenue deficit is calculated as the difference between the revenue expenditure and revenue income. The fiscal deficit is calculated as the difference between the total expenditure and total revenue income's is annual growth rate over a specific period.

⁷⁰Source: Mangaluru Municipal Council. (2025)

7. RESILIENCE ASSESSMENT OF WASH INFRASTRUCTURE

SUCHARITA ROY, TEJASH ANAND, AND N.C. NARAYANAN

Urban infrastructure faces mounting pressure from rapid urbanization and intensifying climate-related extreme events. Inadequate infrastructure amplifies losses and increases disaster risks, underscoring the need for resilient systems that can absorb shocks, maintain essential services during crises, and recover while reducing future risks. This chapter examines the exposure and vulnerability of water, and sanitation infrastructure in Mangaluru. The assessment draws on detailed sectoral analyses presented in previous chapters. By synthesising these findings, the section identifies contextual risks, systemic gaps, and vulnerabilities affecting the resilience of Mangaluru's WaSH infrastructure.

7.1 BACKGROUND

Urban infrastructure today faces dual pressures: rapid urbanization and extreme natural events driven by climate change. The World Risk Report 2016 highlights that inadequate infrastructure amplifies losses to life and property while increasing the likelihood of disasters arising from extreme natural events. Resilient infrastructure, by definition, refers to systems capable of absorbing, rebounding, and adapting to hazards and shocks to ensure continuity and safety.

Urban infrastructure in coastal cities like Mangaluru is increasingly pressured by rapid urbanization, rising service expectations, and extreme natural events spurred by climate change. Inadequate infrastructure not only heightens the risk of loss of life and property; it also increases the likelihood that a natural hazard will escalate into a disaster. Accordingly, resilient infrastructure is defined as systems and networks that can absorb shocks, maintain essential services during crises, and swiftly recover while simultaneously reducing future risks.

This section captures the exposure and vulnerability of the WaSH infrastructure of Mangaluru, a class III town and an important regional settlement in North Karnataka district of Karnataka. The situational analysis has been based on the detailed sectoral analysis undertaken by sectoral teams and captured in the previous chapters of this report. The resilience assessment of the WaSH infrastructure captures the contextual risks and gaps in the systems.

7.2 METHODOLOGY FOR RESILIENCE ASSESSMENT

Adopting resilient infrastructure not only helps reduce the intensity of adverse consequences from disasters but also provides an opportunity to shift to lower carbon pathways. The risk of infrastructure failure during disruptive events depends on several factors, including exposure to hazards, locational limitations, technology, sensitivity of the infrastructure, its governance, access to funding, and systemic agility. The Sendai Framework for Disaster Risk Reduction identifies the resilience of critical infrastructure as key for risk reduction.

An assessment of the resilience of the WaSH infrastructure, the town has been undertaken in the context of climate change to inform future planning and build climate-resilient WaSH infrastructure and services in the town. Guided by the Global Methodology for Infrastructure Resilience -UNDRR (2023)⁷¹, *a three-step, contextualised methodology has been developed*. This methodology analyses the adequacy, reliability, and flexibility of WaSH infrastructure in the face of climate change and the robustness of governance and finance to handle future risks. This framework enables a comparative understanding of system resilience for WaSH infrastructure across towns and cities, irrespective of the level of urbanization, population size, and local body capacity. It helps identify trends and patterns across various classes of cities and develop a structured approach towards building resilience of WaSH infrastructure in coastal cities.

1. *Mapping the Existing Infrastructure and Services*: The existing infrastructure and services have been mapped and analysed based on data gathered from various sources on performance, coverage, socio-spatial variability, technology, governance, key stakeholders, existing policies, climate change initiatives, financial health of the ULB, budgets, and future projects
2. *Identifying the Infrastructure Exposure and Vulnerability*: The climate hazards faced by the settlement have been identified based on literature review. Three critical coastal risks—flooding and inundation, storm surges and coastal erosion, and saltwater intrusion—have been considered. Satellite data has been utilized to assess land use and land cover (LULC), elevation, built-up footprints, road networks, shoreline change detection, mangrove and water bodies, storm surge locations, and flood risk zones. This data has been overlaid with information from municipal bodies on administrative boundaries, flood hotspots, population distribution, critical utility locations to identify the exposure. Primary data on water usage, sanitation practices, water quality, access disparities, socioeconomic vulnerability, behavioural practices, and exposure history collected through discussions, interviews, household surveys, and ground-truthing via transect walks and visual surveys were further collated and overlaid to identify ward level exposure and infrastructure vulnerability.

3. *Assessing the resilience:* The adequacy, flexibility and reliability of the infrastructure, its governance and financial sustainability and systemic gaps have been identified and assessed along with the exposure and vulnerability. The summary of risks to WaSH infrastructure provide insights into the resilience measures needed for the coastal town.

7.3 EXPOSURE TO CLIMATE RISK

Mangaluru, located in Dakshin Kannada district, experiences a tropical monsoon climate with hot and humid conditions along the coast year-round. Average temperatures hover around 27-28°C, and the city receives over 3500mm of rainfall annually. Monthly mean of daily maximum temperatures shows an increasing trend significant at 95% (DDMA). Wind speeds are generally below 20 KMPH, but gusts above 50 KMPH, westerly in direction, are also observed in association with thunderstorms and active monsoon rains. In low elevation coastal zones and floodplains, severe flooding occurs when the soil is saturated and infiltration is minimum, water levels in creeks and rivers are elevated after a prolonged spell of monsoon rains and ground water levels rise - the flood water is unable to recede. These flood-like situations result in inundations which can continue from several hours to many days as seen in many low-lying coastal cities and towns. In a dense built-up area, an intense rainfall burst within a brief period can also result in flash flooding.

Zoning control includes designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area. Most of the physical, social and economic problems associated with flooding, soil erosion and water pollution stormwater are attributable to inappropriate urbanization of the floodplain, unwise land use within the city, insufficient attention to drainage in urban planning, ineffective updating of existing stormwater control facilities and lack of enforcement of zoning ordinances.⁷²

Since 2018, the city has faced the impact of cyclones every year. The highest amount of rainfall recorded was 400mm in Mangaluru Taluk on May 29th, 2018, which caused urban flooding as recorded by DDMA. As a result, the city is exposed to flooding and inundation, saltwater intrusion, and coastal erosion. Mangaluru city and taluka have been identified as high risk from flooding and inundation, with severe flooding reported in the month of July (monsoons) for the past two years (2023-24). Historically, there have been incidences of floods in the low-lying areas along the major rivers, especially Netravathi and Gurupur. In August 2019, heavy monsoon rains led to widespread flooding in Mangaluru city, causing significant transportation disruptions and property damage. Intense rainfall, combined with dam releases, led to severe waterlogging and inundation, submerging parts of National Highway 66 and temporarily disconnecting Mangaluru from Goa.

Flood hazard mapping over the past 10 years on the GIRI platform of CDRI⁷³, aligned with current climate scenarios, reveals that: Wards 10–14 and 16, near the mouth of the Gurupur River, are prone to flooding. Wards along the Netravathi River (52–54, 57, and 58) experience inundation due to heavy precipitation and upstream runoff. Wards 26,

27, and 43–45 are vulnerable to flooding from runoff and river overflow, though these risks can be mitigated using nature-based flood management solutions. (Ref. Figure 27)

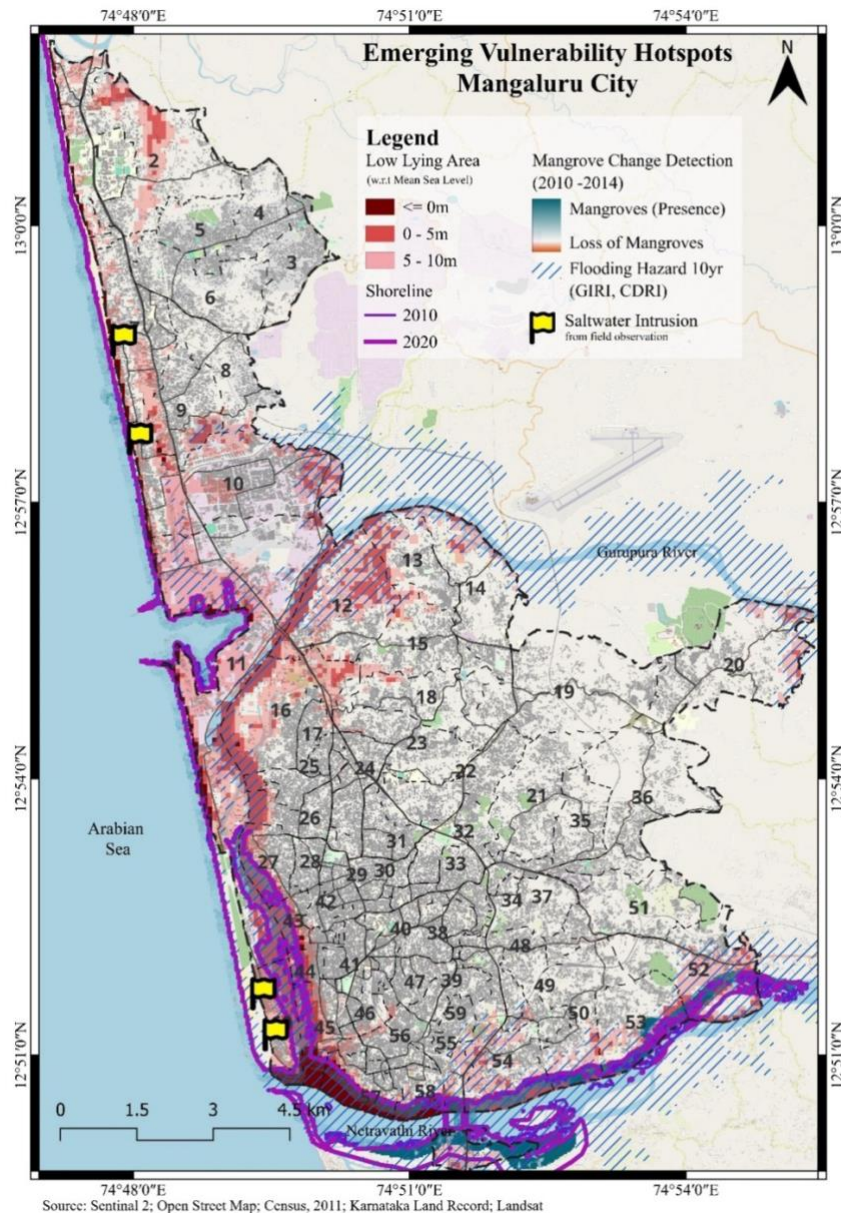
Based on Digital Elevation Mapping undertaken to understand the terrain of Mangaluru, it is found that about 10% of Mangaluru lies at less than 5 meters above sea level, and nearly 25% of the administrative area has an elevation of less than 10 meters above mean sea level – classified as LECZ. The city is situated between the mouths of the Netravali and Gurupur rivers, which define its boundaries. Mangaluru is exposed to moderate risk from cyclones and is in seismic zone III (MSK intensity VII), making it prone to minor to medium intensity earthquakes. The Karnataka coast faces erosion due to the synchronization of high floods in the rivers and strong wave activity during the southwest monsoon. Dynamic equilibrium of erosion and accretion is seen along the coast. Coastal erosion and land submergence have been observed in Mangaluru. The coast is subjected to three types of erosion: erosion along open beaches, along river/estuaries mouth, and the tidal reaches of rivers, causing loss of land, vegetation and revenue. Around 60 Km of the beach is confronted with appreciable or severe erosion. Erosion is more severe in Dakshina Kannada and Udupi coasts, where about 28 % of the total stretch is critical. In Uttar Kannada region, just 8% of this is subjected to severe erosion. The erosion becomes severe due to synchronization of high flood in the rivers and strong wave activity during the southwest monsoon. Erosion/bank collapse in the tidal reaches of the river is also severe and extends at least to about 12 Km.⁷⁴ An overall average accretion was found to be 1.265 m/year throughout the Mangaluru coast and overall average erosion as 1.136 m/year. On an overall view, maximum accretion rate of 3.54 m/year was observed at the Tannir Bavi beach and maximum erosion of 5.23 m/year was observed at Ullal beach.⁷⁵ Change detection based on Sentinel data spanning 10 years was undertaken and it reveals significant alterations along the coastline and Netravathi River edge. (Ref, Figure 27). These changes increase risks such as saltwater intrusion into groundwater and contamination of open dug wells and other surface water sources, particularly near river mouths.

The west coast of India is, however, less exposed to storm surges compared to the east coast, with surge heights based on the last 10 years of data being less than 0.654 meters as seen in the GIRI Platform of CDRI. However, a high tide level, coupled with intense precipitation events, can expose communities and result in damage to infrastructure. Hence, storm surges have been considered a risk for the city.

Storm surge is an abnormal water level rise generated by a storm over and above the predicted astronomical tide. Storm tide is the water level rise due to the combination of storm surge and astronomical tide. This rise in water level can cause extreme flooding in coastal areas, particularly when storm surge coincides with normal high tide. However, to avoid confusion, "storm surge" is used interchangeably. Wave action occurring on top of the surge, which can add additional feet to the overall water level.⁷⁶ These events can force seawater inland, contaminating freshwater resources. When heavy rainfall and sediment accumulation converge at river mouths, flooding in low-lying areas becomes an almost inevitable consequence—a risk that has been increasing in the east Arabian Ocean.

CGWB finds a highly mineralized ground water with Electrical Conductivity (EC) at 6400 $\mu\text{s}/\text{cm}$ at 25°C from the ground water monitoring well in Ullal Beach at the southern bank of Netravathi River, during May 2019, indicating that the ground water is highly mineralized. Chloride levels were found to be beyond permissible limits.⁷⁷

Figure 27: Emerging vulnerability hotspots in Mangaluru



Source: Derived from Sentinel 2; Open Street Map; Karnataka Land Record; Landsat; SRTM DEM

A study undertaken on sea water intrusion in the coastal aquifers of India in 2020 has also identified tidal activity as the main cause of seawater intrusion in some cases. It is further observed that the effect of seawater is limited up to 200 m throughout the year, which may extend up to 5 km during dry periods. Studies have indicated that the coastal regions

in the Karnataka have adequate water sources, which are suitable for various usages. However, continued industrialization in the coastal belt may lead to salinization of coastal aquifer in near future.⁷⁸ Low lying spots identified through DEM analysis were rapidly assessed during field visits and ward 11 (primarily residential) and ward 60 (majorly beach areas) were found to show vulnerability due to inundation and saltwater intrusion. Salinity intrusions in wells were reported from wards 7, 9, and 60, wards located near the river mouths (Ref. Figure 27). This, when triangulated with EC data from Ullal beach monitoring well of CGWB, indicates that salt intrusion is an emerging concern for coastal areas of Mangaluru and needs to be further investigated for resilience planning.

Saltwater intrusion (near the coast in ward 1) presents a critical challenge for Mangaluru in two primary ways. For areas without piped water, it compromises access to safe, fresh water. Additionally, the increased conductivity of groundwater caused by saltwater accelerates the corrosion of underground water and wastewater collection pipes. Research indicates that changes in soil and groundwater chemistry due to saltwater intrusion and rising sea levels can significantly shorten the service life of infrastructure like ductile iron pipes, which are expected to last between 80 and 100 years under ideal conditions.⁷⁹ The aging infrastructure, particularly the 50-year-old sewerage networks in some parts of Mangaluru, compounds these risks for Mangaluru.

Saltwater accumulation in treatment units—such as wastewater treatment plants, activated sludge tanks, sanitation pits, or septic tanks—can reduce their efficiency in removing pollutants like organic matter and nutrients. High electrical conductivity, characteristic of saltwater, adversely affects microbial diversity and organic matter removal efficiency.⁸⁰

Mangaluru also faces significant risks from industrial accidents and other climate-related hazards. Pipelines from New Mangaluru port transport hazardous chemicals and petroleum products, passing by habitation zones as per the Dakshina Kannada Disaster Management Authority. However, to focus this study on the hazards affecting WaSH infrastructure, the exposure of the city to cascading risks has been kept out of the purview of this assessment.

7.4 VULNERABILITY OF THE WASH INFRASTRUCTURE

The vulnerability of the WaSH infrastructure analyses the status of the infrastructure with respect to its adequacy, reliability, and risk governance. Adequacy has been investigated with respect to coverage of the services, suitability of technology, safety of infrastructure based on its age. Reliability of the services has been studied based on data were available on outages, response and recovery including contingencies and redundancies, ownership and accountability and provision of monitoring and regulation of the systems. The infrastructure risk governance looks at the financial stability and safeguards, autonomy in decision making, and jurisdictions regarding preparedness and recovery in the context of disasters, and climate change extreme events.

7.4.1 ADEQUACY OF INFRASTRUCTURE

Inadequacy in service coverage due to technology unsuitability for coastal topography and one-size-fits-all projects in infrastructure development increases the vulnerability of the systems. Coastal cities on west coast are often undulating and low lying at the same time. Conveyance systems based on gravity often are difficult to design due to the topography and hence require energy intensive pumps increasing emissions from WaSH infrastructure. Salt intrusion can impact efficiencies of STPs and corrode underground conveyance systems increasing the inefficiencies in systems, NRW, leakages etc.

The WaSH infrastructure of Mangaluru is inadequate. While 74% of households having access to piped water and 100% have access to sanitation units, and 65% of properties are connected to the sewerage network, there are significant gaps in access, quality and adequacy of the services.

The development of Mangaluru water supply infrastructure reflects a continuous effort to meet growing demand, urban expansion, and industrial development. However, despite multiple upgrades these successive upgrades, water availability continues to challenge the city's water infrastructure.

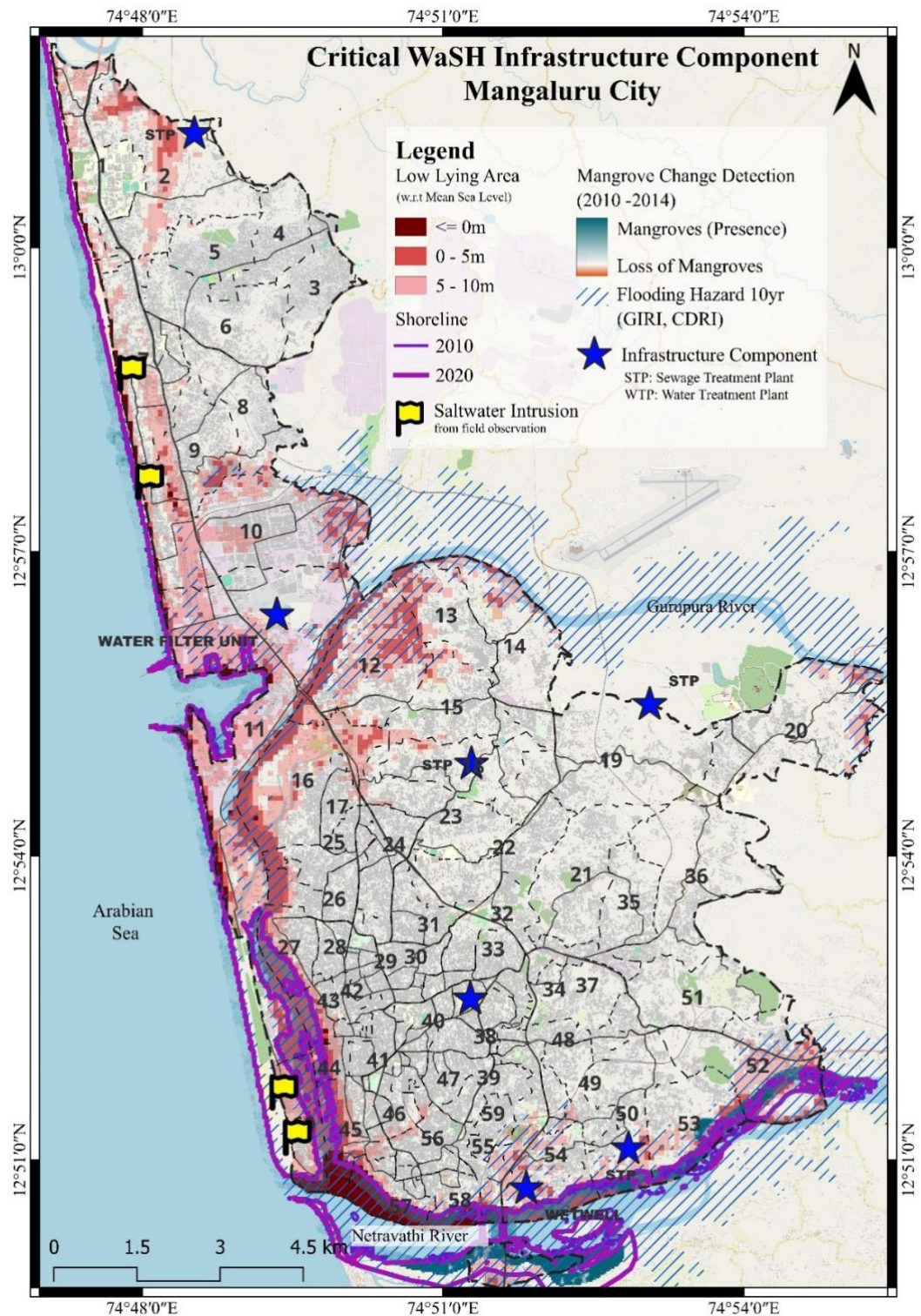
Continuous Water Supply (CWS) or 24x7 access is limited to only a few administrative wards. During rapid assessments in some of the wards, residents informed that they either supplement or in some cases completely rely on groundwater either due to inadequate water pressure or due to non-availability of piped water.

Though the city has 100% access to sanitation units, some gaps in access were noted during field visits remain. For example, a fishing community in Ward 57 relies on a community toilet, and only one-third of public toilets (13 out of 36) are functional due to limited water access.

The city's sanitation infrastructure presents a mix of old and new technologies – OSS and centralised sewerage networks and STPs. In coastal areas, extending centralized sewerage networks is difficult due to the depth required for underground drainage systems to maintain conveyance velocity. Coastal cities on west coast are often undulating and low lying at the same time making conveyance systems dependent on pumps else variable service performance and sometimes lack of coverage in certain areas seen in Mangaluru. Lack of capacities to integrate existing community infrastructure has also left some areas of Mangaluru vulnerable w.r.t access to adequate basic services.

Field studies reveal that many households relying on OSS systems use soak pits instead of septic tanks, resulting in inadequate sewage containment. In some locations there were indications that some households have connected only their grey water outlets to the sewerage system, preferring to retain existing OSS for black water. This information shall need to be investigated in detail to study the reasons for resistance to connecting with the sewerage networks. These gaps have left the city's sewage treatment plants underutilized, despite significant investments in their development.

Figure 28: Location of critical components of the WaSH Infrastructure in Mangaluru administrative boundary



Source: Sentinel 2; Open Street Map; Karnataka Land Record; Landsat; SRTM DEM and spot checks on the field (indication of salt intrusion); Note: Locations are limited to those accessed and tagged during field visits by project team

There is lack of community ownership to the systems, resulting in increased secondary risks like environmental degradation, contamination, and health challenges. Resistance of residents to connecting their sanitation systems to the centralised sewerage highlights the need for participation to improve ownership of infrastructure.

A part of the underground sewerage network is over 50 years old, making it vulnerable to salt intrusion, blockages, and leakages, particularly as the city experiences more frequent flooding due to increasing precipitation. The STPs in Mangaluru vary in age and technology, reflecting the city's evolving infrastructure. The Karnataka State Pollution Control Board report (December 2024) reveals that 2 out of the four STPs fail to meet all environmental standards. Aging infrastructure can compound climate risks.

Many wet wells or sumps for pumping sewage, found located near the riverbanks (Ref. Figure 28) can be cause of contamination, not only affecting coastal habitations but also polluting river water. Observations from the field visits and mapping of critical infrastructure indicate that the water table depth near the coast varies between 2 to 10 meters, suggesting remarkably high groundwater levels.

7.4.2 RELIABILITY, FLEXIBILITY AND REDUNDANCY

Flexibility design of systems can ensure reliable services even during disruptions. Redundancy ensures that systems can withstand failures and continue to operate during disruptions. It minimizes the chances of a single point of failure leading to a catastrophic breakdown.

Source sustainability is an emerging concern for Mangaluru and other burgeoning cities. The city relies heavily on water sourced from upstream dams located far away. The growing reliance on imported water through long-distance transfers and centralized supply systems has resulted in the neglect of vital local sources, such as wells, ponds, and small reservoirs. While large-scale water transfers may seem reliable, they introduce vulnerabilities, making regions overly dependent on single external sources. This dependence can be disrupted by infrastructure failures caused by climate impacts such as droughts, floods, cyclones, and landslides.

Furthermore, these systems are highly energy-intensive, relying on consistent power supplies for pumping and conveyance. Power shortages or outages can therefore severely impact water availability. Coastal cities often face disruptions during strong winds and cyclones, as overhead electrical networks can fail, impacting water pumping and treatment facilities. To ensure continuity, water systems should incorporate alternative energy sources as backups to reduce dependency on the main power grid.

A diversified water portfolio ensures communities have alternative supply options, reducing risks associated with climate variability, rising demand, and resource conflicts. Strengthening both imported and local sources is critical for achieving long-term water security amid climate uncertainty. However, groundwater contamination poses a challenge,

with saltwater intrusion, fluctuating water tables, and poorly constructed sanitation systems during flooding leading to higher TDS levels. Aging pipelines, salt corrosion, and a heavy reliance on pumps due to hilly terrain further complicate Mangaluru water supply.

MCC water supply systems equipped with redundant pipelines, standposts, pumps, and treatment facilities ensure a continuous supply of clean water. Diversified water sources and smaller, decentralized treatment solutions offer resilience—if one component fails or becomes contaminated, backups can sustain the supply. However, excessive redundancy may increase costs and complexity.

7.4.3 INFRASTRUCTURE RISK GOVERNANCE AND FINANCE

Effective governance is essential for resilient infrastructure. This involves the policies, frameworks, norms, processes, and tools that public bodies use to plan, decide on, implement, and monitor the entire lifecycle of public infrastructure. In the context of resilience, governance transformation may include progressive decision-making, regular updates to codes and standards, comprehensive regulatory frameworks, and dedicated risk and resilience funding. With a population nearing 7 lakhs, Mangaluru is evolving from a Class I city into a metro city, presenting unique opportunities in upgrading its infrastructure systems.

Ensuring reliable and equitable water supply in Mangaluru requires continuous infrastructure expansion and modernization. ADB assisted Karnataka Urban Development and Coastal Environmental Management Project improved water supply and underground drainage systems in 10 coastal towns and cities, including Mangaluru. Ensuring reliable and equitable water supply in Mangaluru requires continuous infrastructure expansion, upgradation and modernization. Despite large investments, infrastructure utilization and efficiency are constrained by funding limitations.

The adoption of capital-intensive infrastructure in coastal cities has led to an increased footprint in water and energy usage, making WaSH infrastructure unsustainable. The import of water, use of water for conveyance in undergrounds sewerage network leads to generation of significant volumes of wastewater which needs to be adequately treated.

Mangaluru revenue for sanitation services heavily relies on development fees, which account for over 90% of collections. The city's sewerage and sanitation system upgradation and development increasingly depend on grants, with central government grants contributing 60%, state government grants 24%, and only 16% generated from own revenue.

Large cities like Mangaluru, which is also an industrial and port city, can generate larger revenues from tertiary treated wastewater through upgraded STPs and reduce its dependence on grants for the upgradation of its WASH infrastructure. MCC has initiated the use of tertiary treated wastewater however needs to scale it up to make it a source of revenue to balance the deficit and reduce dependence on external funds.

In Mangaluru, for larger projects, state authorities like KUIDFC oversee design and establishment of facilities and capital funding is provided by International Financial Institutions (IFIs), with environmental monitoring managed by state agencies. The role of the municipal corporation is limited to O&M of the facilities, and smaller sanitation interventions like CTs and PTs are primarily the responsibility of Municipal Corporation. There is limited autonomy at the local level in developing WaSH infrastructure.

Overdependence on centralized, capital-intensive systems water supply systems can increase the risk of disruption due to coastal risks. Insufficient technical capacity to integrate community infrastructure reduces the scope to enhance flexibility in the WaSH infrastructure. The project-based approach in WaSH development is based on capital-intensive and grey infrastructure solutions and misses the opportunity for CCA-NbIS integration into WaSH infrastructure design.

DDMP of Dakshina Kannada aims to align disaster risk reduction (DRR), sustainable development, and climate change actions. It emphasizes the vertical and horizontal integration of DRR plans across different government levels, agencies, and neighbouring local bodies. The DDMP defines ULB responsibilities, such as preparing and updating hazard maps, implementing local plans for SDGs and climate resilience, and integrating DRR through periodic regulatory reviews. ULBs are also tasked with capacity building, participatory approaches, and grievance redressal mechanisms. The plan highlights the need for information systems, monitoring, forecasting, early warning facilities, and the establishment of Emergency Operations Centres (EOCs) in every local body.

Integrating smart mapping, alerting and EWS systems, monitoring and hot spotting technologies with the ICCC can help local bodies in ensuring adequate and equitable provisioning of resilient infrastructure.

Current resilience measures are dominated by post-disaster response and recovery activities. There is an absence of safeguards to protect infrastructure maintenance budgets. There is need to evaluate the systemic risks and contingent liabilities, adopt redundancy and continuity planning and establish protocols for infrastructure recovery post a crisis.

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8. STATUS OF CLIMATE CHANGE INITIATIVES IN MANGALURU

NEELAM RANA, PRIYAKSHI GOGOI, NC NARAYANAN

Several national and state-level programmes and schemes—both directly and indirectly—address climate change concerns within the water and sanitation sector. This chapter presents the implementation status of key initiatives in Mangaluru. The analysis draws primarily on interviews conducted with officials from ULB and the Disaster Management Office..

CLIMATE GOVERNANCE AND INSTITUTIONAL GAPS

Mangaluru currently lacks a dedicated climate change adaptation and mitigation strategy, as well as a city-level climate policy framework. There is no established climate or environmental cell, as mandated under the Karnataka Building Bye-laws, 2017. Nor are there designated personnel tasked with addressing climate-related challenges. This institutional gap significantly hampers proactive planning, coordination, and response to the growing impacts of climate change.

WATER RESOURCES MANAGEMENT

The city has mandated the incorporation of Rainwater Harvesting (RWH) systems in new building designs as part of its regulatory efforts to promote sustainable water use. However, compliance remains inconsistent across different areas of the city, indicating the need for stronger enforcement and awareness mechanisms. Mangaluru has also introduced a groundwater regulation policy that requires a No Objection Certificate (NOC) from ULB for groundwater extraction. Despite this, Departments of Mines and Geology Department holds the primary responsibility for regulating groundwater, creating a fragmented governance structure and limiting the effectiveness of local monitoring and control according to the ULB officials.

Mangaluru recycles approximately 29.5 MLD of treated wastewater—representing around 48% of the total sewage processed by its STPs. Of this, 6.8 MLD is sold by the City Corporation to the Pilikula Golf Club, and 22.7 MLD by the Mangaluru Special Economic Zone Ltd. (MSEZL). This reflects a positive step toward resource recovery and reuse, although there is potential for expanding these initiatives citywide.

ENERGY EFFICIENCY AND RENEWABLE ENERGY INITIATIVES

Under the central government's Municipal Energy Efficiency Programme (MEEP), the city is set to replace 188 existing water pumps with energy-efficient models (Energy Efficiency Services Limited, 2024)⁸⁷. This transition will contribute to reduced energy consumption and operational costs in water supply services. In addition, although not directly related to water and sanitation, the installation of a solar power plant at the municipal corporation building—funded entirely from city revenues—demonstrates Mangaluru's growing commitment to adopting green energy solutions and supporting climate change mitigation efforts.

Table 20: Implementation Status of Programmes /Schemes related to Climate Change in Mangaluru

Initiative	Details	Gaps / Observations
Climate Governance		- Absence of climate/environmental cell and designated personnel - No dedicated climate adaptation/mitigation strategy or city-level climate policy.
Rainwater Harvesting (RWH)	Mandated integration of RWH in new building designs to promote sustainable water use.	- Compliance is inconsistent; - enforcement mechanisms need strengthening
Groundwater Regulation	Users requires No Objection Certificate (NOC)	Regulatory authority lies with the State level Geology Department, leading to fragmented governance and weak local oversight.
Wastewater Recycling	29.5 MLD of treated effluent (48% of total sewage) is recycled. - 6.8 MLD sold to Pilikula Golf Club.- 22.7 MLD sold by MSEZL.	Positive example of resource recovery; potential exists to scale up wastewater reuse across more sectors and geographies.
Energy Efficiency (MEEP programme)	188 water pumps are being replaced with energy-efficient models.	Will contributes to sustainability and reduced energy use in service delivery.
Renewable Energy	A solar power plant has been installed at the corporation building using municipal funds.	Reflects broader municipal commitment to climate mitigation through green energy initiatives

Source: Primary data from ULB official interviews

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ANNEXURE-I: DATA COLLECTION & VALIDATION

Desk Based Research: An extensive desk study was conducted to review existing literature and collect secondary data from various government sources. The study utilized secondary data and information from a range of national, state, district, and town-level sources, including the Census, National Family Health Survey, Swachh Bharat Mission (Urban), Central Pollution Control Board, Performance Assessment System for urban water and sanitation (PAS) website, District Disaster Management Plans, and the municipality website. Additionally, the review was instrumental in mapping key stakeholders, defining their roles and responsibilities, and developing the analytical framework for various thematic studies, including GHG emission estimation.

The desk study not only informed the overall research design but also facilitated the identification of data gaps and discrepancies, which subsequently guided the development of data collection protocols as well as the planning and execution of the fieldwork.

Field Work: To address data gaps, validate secondary data, and resolve data discrepancies, the study incorporated rapid field assessments, site visits, and semi-structured interviews. These interviews were conducted with local residents, as well as district and municipal officials from the town planning, water and sanitation, sewerage, public works, and disaster management departments. These interviews were conducted with local residents, as well as district and municipal officials from the town planning, water and sanitation, sewerage, public works, and disaster management departments. Field work also involved mapping of the critical infrastructure in the water and sanitation sector.

The vulnerability assessment began by identifying low-lying zones and areas with high population density, using building proximity and elevation as primary indicators. Areas that exhibited both low elevation and compact construction were marked as high-priority hotspots. The field studies including visual assessment and semi-structured interviews with residents of three towns were undertaken at different hotspot locations to capture the diversity of issues across different wards and communities and ground truthing of secondary data.

- **Secondary Data Collection:** Meetings with ULBs were held to collect a wide range of documents and data, including city maps, land-use and land cover maps, UGD (Underground Drainage) maps, and electricity bills. Additional information was gathered

on SLB indicators, SBM-U, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), financial reports, and other relevant datasets. We also obtained detailed information on STPs, such as their capacity, collection and treatment volumes, and water reuse practices. Furthermore, data on the number, condition, and O&M structures of community toilets (CTs) and public toilets (PTs) in the city were collected to better understand the scale and performance of the existing sanitation infrastructure.

- **Semi-Structured Interviews:** In MCC, we interviewed (semi-structured interviews) key ULB officials—including the Commissioner (2), Water engineer (1) and Sanitation Engineers (2), Environmental Engineer (1), Senior Environmental Engineer (1), SBM-U Coordinator (2), Town Planner (2), Accountant (1), System Operators, Junior Engineers (2), Laboratory technician (1), Junior engineer in Tertiary Treatment Plant (TTP) (1) to understand the status of water and sanitation infrastructure and services, as well as to gather information on recent and past extreme events—such as floods, droughts, cyclones and heavy rainfall—and their impacts. These discussions also provided insights into the effects of climate change as experienced locally. Importantly, the interviews helped identify vulnerable areas and communities within the town, which informed the design of the rapid assessment study. A meeting with the District Disaster Management Authority (DDMA) representative to understand the authority's role and responsibilities in the city. Based on secondary data, a preliminary mapping of low-lying zones and high-density population clusters was undertaken using visual analysis, primarily determined through the proximity of built-up structures. These overlapping zones were considered potential hotspot areas for the vulnerable population for assessment.
- **Site Visits:** Site visits were conducted to validate the functioning of critical water and sanitation infrastructure, such as water treatment plants (WTP), Elevated Level Storage Reservoir (ELSR) and Ground Level Storage Reservoir (GLSR), STPs, Pumping stations and disposal, and reuse and recycle. These visits focused on gathering information on operational status, environmental compliance, and electricity consumption. These site visits also facilitated the integration of critical infrastructure into the GIS platform for further spatial analysis.
- **Rapid field assessment:** The assessment process included on-ground observations and semi-structured interviews with the residents, with a particular focus on hot-spots such as low-income neighbourhoods, areas vulnerable to extreme events, low-lying areas, and densely populated clusters. These were determined during interviews with the ULB officials and using spatial proximity between WaSH structures to highlight zones with high

vulnerability. Areas exhibiting both low elevation and high building density were mapped as potential hotspots for field investigation. Municipal officials were asked to suggest locations that would yield greater diversity for sampling. These interviews were designed to validate and triangulate data gathered from secondary sources on WaSH, offering valuable insights into the state of local infrastructure and the lived experiences of residents—particularly during past high-precipitation events, cyclones, and storms—with a focus on vulnerable communities.

The process involved on-ground observations and in-depth conversations with residents (24#), particularly in low-income neighbourhoods and areas identified as vulnerable to extreme events during interviews with ULB officials. This approach yielded valuable insights into both the state of infrastructure and the lived experiences of residents, especially those from vulnerable communities. The emphasis was on understanding challenges related to access, affordability, and reliability of water and sanitation services in the context of climate change.

Residents were asked whether they had private toilets on their premises, and if so, whether these were connected to the sewage network. For those not connected, questions focused on how and where human waste was disposed of. In cases where onsite sanitation systems (OSS) were used, we gathered information on the type of system, frequency and cost of septic tank cleaning, service providers involved, and affordability and other challenges of these services. Additional questions covered methods of greywater disposal, sources of tap water, costs associated with water connections, and any support received from the ULB during disaster events. For households without individual toilets, we explored the alternative sanitation arrangements they relied on.

The team engaged with 24 residents across the city, carefully selecting locations to cover a range of socio-economic backgrounds. Our questions with residents focused primarily on service access and quality.

The study findings were shared during a stakeholder and expert consultation workshop held on 13th August 2025, with participation from State Public Works Departments, ULBs, and State Pollution Control Boards. The feedback and comments received have been incorporated into the town assessment reports, details of which are provided in the annexure-III. The workshop also helped define the way forward for the research team.

ANNEXURE-II: DATA GAPS

The study on Mangaluru was primarily a comprehensive review of secondary data sources pertaining to the water and sanitation sector and climate change across various levels—national, state, district, and town. This exercise highlighted several significant data gaps, which are detailed below.

Sanitation

1. **Typology of Individual Household Toilets and On-site Sanitation Systems:**

Understanding the typology of individual household toilets and on-site sanitation systems is essential for assessing current levels of access to sanitation infrastructure and determining whether these constitute improved sanitation services. This information is a key indicator for tracking progress towards the Sustainable Development Goals (SDGs) and is relevant for climate adaptation frameworks. Additionally, it plays a critical role in estimating greenhouse gas (GHG) emissions from the sanitation sector. However, the last comprehensive assessment of household toilet typologies was conducted during the 2011 Census, and no updated data is currently available from national, state, or city-level sources. The National Family Health Survey-5 (2019–2020)¹ provides district-level data on access to improved sanitation facilities, defined as the “population living in households that use an improved sanitation facility.” However, disaggregated data at the town or municipal level is not available. Collecting such data would require a detailed household-level survey.

2. **Operational Status of Community and Public Toilets:** Community and public toilets are intended to serve populations without access to individual sanitation facilities, as well as the floating population in public spaces. The operational status of these facilities—including aspects such as functionality, availability of water supply, and cleanliness—is a key requirement under the ODF+ certification framework. According to the MoHUA guidelines, Urban Local Bodies (ULBs) are mandated to conduct regular audits of these facilities. However, data on the coverage and adequacy of community and public toilets and operational status is not available with the ULB.

3. **Data on Storm Water Drainage:** The role of stormwater drainage systems in urban resilience is well recognized. However, the data available at the town level is limited

¹ International Institute for Population Sciences. 2020 National Family Health Survey – 5 (2019-2020). District Fact Sheet. Ministry of Health and Family Welfare.

to information on overall coverage and does not provide details on the typology of the drainage systems—such as whether they are open or closed, underground or surface-level, mapped or unmapped, or man-made or natural. A comprehensive understanding of these aspects would require detailed studies.

4. **Integrated role of Sewerage Network, Creeks, and Nallahs:** It is essential to determine whether natural and man-made water bodies—such as creeks and nallahs—are integrated into the town's wastewater and stormwater management systems, and to clarify their functional roles, whether they carry greywater, blackwater, stormwater, or a combination of these. Equally important is evaluating the degree of interconnection between these natural channels and engineered infrastructure. However, such information is not available through secondary data sources, and the Urban Local Body (ULB) does not maintain a detailed sewerage network map.

GHG Emissions

1. **Groundwater Use Estimation Uncertain:** There is no systematic monitoring of groundwater abstraction volumes, especially from private borewells and tankers. The growing reliance on groundwater is not reflected in official supply data, resulting in underestimation of its energy and carbon footprint.
2. **Missing Real-Time Energy Consumption Data:** Energy data for various components (pumping, treatment, household-level usage) are often estimated based on assumed intensities (MWh/MLD) due to a lack of sub-metering across the water supply system.
3. **Limited Data on On-Site Sanitation Systems:** There is no centralized inventory of septic tanks, pits, or their design standards. Emission estimates rely on assumed containment types, desludging frequencies, and containment conditions, introducing uncertainty in CH₄ and N₂O emissions from faecal waste.
4. **Industrial and Tourism Sector Use Opaque:** Water and wastewater usage and discharge data from hotels, industries, and large commercial establishments are often not disaggregated or reported, masking the full impact of tourism and commercial activity on urban emissions.
5. **Stormwater and Greywater Flows Untracked:** Greywater is often discharged into storm drains without treatment or monitoring, leading to nutrient loading and emissions not captured in inventories.
6. **Sanitation GHG Methodology Limitations:** Emission estimates are based on global default emission factors and standard GWP values (IPCC 2013), which may not reflect local climatic, operational, or containment-specific variables.

Resilience

1. Due to the city's large geographical spread, it was challenging to obtain the exact location of all WaSH infrastructure components within the field timeframe.

Overall

1. **Research Boundaries:** While the scope defines what this report covers, the limitations reflect aspects that could not be addressed. These should not be viewed as research gaps but as boundaries determined by data availability and by differing approaches adopted by the research and implementation partners of the 'Climate Resilient Coastal Cities' project². Variations in this report and those based on research by CDD-India reflect these methodological differences.
2. **Town-level Focus:** This report addresses issues specific to the town studied. The 'Climate Resilient Coastal Cities' initiative comprises a National Report, four State Reports, and fifteen Town Reports. This document represents one of the three town-level studies from Karnataka. A broad level state analysis of Karnataka is provided separately in the Karnataka State Report, which draws on all three town studies.
3. **Data Availability:** The study relies primarily on secondary research, and the extent of analysis is therefore dependent on the quality and availability of published data and literature. Wherever possible, secondary information has been supplemented with primary inputs.

² The 'Climate Resilient Coastal Cities' Project was rolled out in September 2023. Project partners include - Funding Partner: HSBC; Anchor, Advocacy, Outreach, Dissemination Partner: India Sanitation Coalition (ISC); Research Partner: Ashank Desai Centre for Policy Studies (IIT-Bombay), and Research and Implementation Partner: CDD-India.

ANNEXURE-III: STAKEHOLDER CONSULTATION WORKSHOP: KEY HIGHLIGHTS AND WAY FORWARD

WORKSHOP TITLE: 'CLIMATE RESILIENT URBAN WATER AND SANITATION INFRASTRUCTURE SERVICES IN COASTAL TOWNS'

Programme Highlights

On **13th August 2025**, the **Stakeholder Consultation Workshop on Climate Resilient Urban Water and Sanitation Infrastructure Services** was held at **VMCC, Room No. 21, Indian Institute of Technology Bombay, Mumbai, Maharashtra**, in a **hybrid format** accommodating both in-person and online participation. The workshop brought together **policymakers, experts, practitioners, and project partners** from Maharashtra, Karnataka, Gujarat, and Karnataka to discuss challenges and opportunities in enhancing the resilience of water and sanitation systems in coastal towns. It provided a platform to **share project findings, examine policy and governance frameworks, and explore strategies for integrated, climate-responsive urban infrastructure planning**, fostering dialogue aimed at strengthening the adaptive capacity of urban water and sanitation services.

The workshop commenced with **registration from 9:00 AM to 9:30 AM**, followed by a **welcome address by Prof. NC Narayanan, Ashank Desai Centre for Policy Studies, IIT Bombay**, at 9:30 AM, who set the context for the discussions ahead. This was followed by an overview of the project by **Mr. Romit Sen, HSBC-India**, highlighting the objectives, scope, and significance of the Landscape Analysis for Climate Resilient Coastal Cities.

From **9:55 AM to 10:50 AM**, the **project highlights** were presented. Prof. NC Narayanan began with an overview of the background, tracing the history of water and sanitation research conducted by the lab, which laid the foundation for the HSBC project. He highlighted the rationale for the project, the significance of the West Coast, and why this region was chosen. This was followed by a presentation on the **Urban Water-Energy-Climate Nexus** by Mr. Ashish Dangi, which outlined the research framework and underscored the interconnections between water, energy, and climate. Subsequently, **Dr. Neelam Rana** presented on **Policy, Governance, and Finances in WaSH and Climate Change**, providing a comprehensive overview of the current landscape, key challenges, and potential opportunities for enhancing climate resilience. The presentation highlighted that policies remain largely focused on **adaptation**, which is appropriate in a developing country context where ensuring access to basic services such as water and sanitation continues to be a priority. The session emphasized the importance of

generating evidence on GHG reductions in the WaSH sector to inform mitigation policies. The session concluded with a **discussion and Q&A**, allowing participants to clarify key aspects of the study and share preliminary observations.

The session was followed by **tea and town-level poster presentations from 10:50 AM to 11:25 AM**, enabling participants to engage directly with the project team and explore data, findings, and visual insights from individual coastal towns.

State-wise discussions were held from 11:25 AM to 12:45 PM, moderated by domain experts:

- **Karnataka:** Mr. Vishwanath S, BIOME Environmental Solutions
- **Goa:** Mr. Depinder Kapur, National Institute of Urban Affairs (NIUA)
- **Maharashtra:** Ms. Lubaina Rangwala, World Resources Institute (WRI)
- **Gujarat:** Prof. Ajay Deshpande, IIT Bombay

These sessions facilitated a deep dive into state-specific and town-specific challenges, opportunities, and lessons learned from local implementation of urban water and sanitation systems, including climate and disaster resilience considerations.

From **12:45 PM to 1:15 PM**, participants gained practical insights from **field implementation in three coastal towns of Maharashtra—Malvan, Dhanu, and Guhagarh**. The session was presented by **Mr. Irfan from the Centre for DEWATS Dissemination (CDD), India**, highlighting on-the-ground experiences, key challenges in service delivery, and innovative approaches adopted to enhance the resilience of water and sanitation infrastructure in smaller towns. Additionally, Mr. Irfan showcased the **vulnerability assessment tool developed by CDD-India as part of the project**, which aids in evaluating climate and disaster risks to water and sanitation infrastructure at the local level.

After the **lunch break**, the **Feedback and Way Forward Session** was held from **2:15 PM to 4:15 PM**. This session brought together **key partners and experts**, including Mr. Amit Mishra (India Sanitation Coalition), Mr. Irfan (CDD India), Mr. Romit Sen (HSBC India), Mr. Vishwanath S, Mr. Depinder Kapur (NIUA), Ms. Lubaina Rangwala (WRI), and Prof. Ajay Deshpande (IITB), who discussed **actionable recommendations, capacity-building needs, and strategies for future collaboration**. The session also featured contributions from **state and city representatives**, such as **PWD officials from Goa, CO Vengurla, MPCB officials, and officials from Mangaluru and Karwar**, whose feedback, suggestions, and observations provided valuable insights and guidance for the project team.

The workshop concluded with a **vote of thanks from 4:15 PM to 4:30 PM**, followed by **high tea at 4:30 PM**, marking the close of a productive day of knowledge sharing, deliberation, and collective strategizing for climate-resilient urban water and sanitation infrastructure in coastal towns.

Key Discussion Points

1. Maharashtra

During the Maharashtra session, several observations and recommendations were shared. Ms. Lubaina Rangwala emphasized that climate financing currently favors large cities, while small and medium-sized towns remain underserved. She highlighted the need to make tier-3 cities future-ready, through cross-sectoral and networked thinking, incremental funding, and decentralized options that generate co-benefits, particularly for coastal livelihoods.

Mr. Irfan from CDD shared insights from work in Malvan, Dhanu, and Guhagarh, emphasizing the importance of source strengthening in smaller towns and accounting for tourism's impact on local water, sanitation, and solid waste management systems. He noted technical and financial gaps in implementing infrastructure plans and suggested the development of localized, climate-resilient treatment systems.

Alibag, Vengurla, and Ratnagiri: While no specific sectoral recommendations were recorded for these towns, the general discussion reinforced the importance of focusing on smaller towns with limited service delivery infrastructure.

2. Karnataka

Mr. Vishwanath S highlighted the potential of treated wastewater for groundwater recharge, emphasizing co-benefits in cost savings, water conservation, energy savings, and climate change mitigation. He noted that political and operational challenges often limit the functionality of STPs and stressed the need to incorporate these challenges into reports.

Groundwater recharge in coastal towns was flagged as challenging due to high salinity levels. Discussions around financial sustainability highlighted discrepancies in cost recovery, with **Mangaluru** and Kundapura achieving over 95%, whereas Karwar had not yet reached the 50% mark. Mr. Vishwanath S also underscored the low level of service delivery and the need for adaptation-focused interventions.

Karwar: The Commissioner noted that STPs frequently stop functioning due to drought, monsoon flooding, and high tides, which cause corrosion in metal components. It was recommended to replicate models from Mangaluru and Kundapura, including engaging private vendors for utility management.

Mangaluru Officials highlighted that STPs are outdated, with end-of-life expected by 2026, and suggested adopting modern sewerage network techniques to detect and fix missing connections. Pricing and cost recovery remain a challenge, with reported O&M losses of INR 15–16 crore, although updated data indicates higher recovery.

3. Goa

PWD officials shared that Goa relies heavily on deep borewells and has implemented a 100% metering system with annual tariff increases of 5%. NRW is estimated at 25%, with 15% attributable to manual errors. Initiatives include smart metering (3,000 units in Panaji), free water up to 16m³, and slab-wise tourism tariffs. They aim to supply 24×7 water and are planning energy audits to optimize energy use per cubic meter.

Mr. Vishwanath S and Goa, PWD officials noted that energy audits for water supply are underway, but GHG emissions are not currently a primary focus for the state. Challenges include high turbidity in raw water and local religious constraints on supply timing. Officials emphasized the need for unified platforms for dialogue and knowledge-sharing to improve WASH infrastructure performance.

Mapusa: The town sources water primarily from the Sal River, with a high water table and salinity concerns. Financial challenges were noted regarding one-time settlement schemes for water revenue, which were not continued after 2021–22.

4. Gujarat

Prof. Ajay Deshpande highlighted models for small and medium towns to assess WASH systems and evolve into climate-resilient cities. He recommended standards for abstraction and infrastructure and suggested policy advocacy measures. Ms. Nagma Modi, representing Valsad town, noted severe waterlogging and flooding in coastal areas of Valsad, requiring immediate attention. Mr. Depinder Kapur explained methods used to estimate population growth and future water demand for planning purposes.

5. Expert Panel Comments and General Observations

Across states, several general observations emerged. Prof. Satish Agnihotri suggested triaging ODF data with health metrics to identify towns where sanitation systems are failing or where positive outcomes can be studied. Mr. Vishwanath S emphasized the need to ring-fence water utilities and upgrade tariffs to achieve economies of scale. Prof. Ajay Deshpande recommended differential vulnerability assessments, highlighting that ULBs often lack the capacity to interpret complex assessments. Updated CRZ regulations were noted as an important tool for empowering ULBs.

Lubaina stressed the need for future-ready cities, equitable distribution of climate finance to smaller towns, and community awareness. Vishwanath S highlighted low-cost technologies and the importance of understanding groundwater extraction and aquifer potential. Mr. Depinder Kapur underscored the need to consider both sewer-connected and non-sewered decentralized systems as viable solutions.

PWD officials from Karnataka noted ongoing energy audits, while Gujarat representatives stressed the importance of industrial wastewater management in Valsad and policy-led sewage treatment.

Way Forward

In the **short term**, the team will incorporate the suggestions and feedback received, including additional town- and state-specific information, into the respective reports. In the **medium term**, the team plans to develop research papers, publications, and other outreach and communication materials in collaboration with advocacy and implementation partners, namely the **India Sanitation Coalition (ISC)** and **CDD-India**, aiming to achieve broader recognition and secure buy-in from government stakeholders and the academic community. In the **long term**, the team aims to engage governance stakeholders and local academic institutions through targeted capacity-building exercises, leveraging the forthcoming toolkit designed to assess and enhance the resilience of water and sanitation infrastructure and services in coastal towns across India.

ANNEXURE-IV ABBREVIATIONS AND GLOSSARY

ABBREVIATIONS

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
CCA	Climate Change Adaptations
CDRI	Coalition for Disaster Resilient Infrastructure
CST	Community Septic Tanks
CT	Community Toilet
DDMP	District Disaster Management Plan
DM	District Magistrate
DRR	Disaster Risk Reduction
ESLR	Elevated Level Storage Reservoir
FSSTP	Faecal Sludge and Septage Treatment Plant
FSTM	Faecal Sludge Treatment and Management
GIRI	Global Infrastructure Risk Model and Resilience Index
GIS	Geographic Information System
GLSR	Ground Level Storage Reservoir

IFIS	International Financial Institutions
IPCC	Intergovernmental Panel on Climate Change
MMC	Mangaluru Municipal Council
LPCD	Litres Per Capita per Day
LULC	Land Use Land Cover
MLD/ KLD	Million Litres per Day/ Kilo Litres per Day
MSL	Mean Sea Level
NBIS	Nature-Based Infrastructure Solutions
NRW	Non-Revenue Water
ODF	Open Defecation Free
OSS	On Site Sanitation Systems
O&M	Operation & Maintenance
PT	Public Toilet
RIS	Risk Information Systems
SAPCC	<i>State Action Plans on Climate Change</i>
SBM	Swachh Bharat Mission
SBR	Sequence Batch Reactors
SLBS	Service Level Benchmarks

SOP	Standard operating Procedure
SPV	Special Purpose Vehicle
STPS	Sewage Treatment Plants
UNDRR	United Nations Office for Disaster Risk Reduction
WRD	Water Resources Department
WTP	Water Treatment Plant
WASH	Water, Sanitation, and Hygiene

GLOSSARY

<i>Term</i>	<i>Definition</i>
ADEQUACY	Making available in a universal and equitable manner which is sufficient, acceptable and affordable for all.
BASIC INFRASTRUCTURE	Infrastructure that provides essential services to individuals, households, communities, and businesses and includes water, drainage, sanitation networks, local road, river, and rail networks, health and education facilities, post-harvest processing and storage facilities etc. (CDRI, 2023) ⁸²
CLIMATE ADAPTATION	Adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects. It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change (UNFCCC, https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction).
EXPOSURE	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected. (UNDRR)

FLEXIBILITY	Ability of an infrastructure asset or system to perform the desired function based on specified requirements over time without interruption or degradation. (CDRI, 2023)
GREY INFRASTRUCTURE	Engineered physical structures that underpin energy, transport, communications (including wireless and digital), built form, water and sanitation, and solid-waste management systems and that protect human lives and livelihood. (CDRI, 2023)
HAZARD	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. (UNDRR)
INFRASTRUCTURE	CDRI has defined infrastructure as “Individual assets, networks and systems that provide specific services to support the functioning of a community or society” (CDRI, 2023)
INFRASTRUCTURE GOVERNANCE	Infrastructure governance can be understood as the policies, frameworks, norms, processes and tools used by public bodies to plan, make decisions, implement and monitor the entire life cycle of public infrastructure. (OECD)
INFRASTRUCTURE RESILIENCE	Infrastructure systems and networks, the components, and assets thereof, and the services they provide, that can resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover in such a manner that future risks are reduced or prevented. (CDRI,2023)
NATURE BASED INFRASTRUCTURE SOLUTIONS	Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, and resilience and biodiversity benefits (UNEP, 2022c).
ODF	A city / ward can be notified/declared as ODF city/ ODF ward if, at any point of the day, not a single person is found defecating in the open (Ministry of Housing and Urban Affairs, 2020) ⁸³
ODF+	A city / ward / work circle can be notified/declared as SBM ODF+city/SBMODF+ward/SBMODF+work circle if, at any point of the day, not a single person is found defecating and/ or urinating in the open, AND all community and public toilets are functional and well maintained

	(Ministry of Housing and Urban Affairs, 2020).
REDUNDANCY	Alternative or back-up means created within an infrastructure system to accommodate disruption, extreme pressures, or surges in demand. (CDRI)
RELIABILITY OF SERVICES	The ability of the system to maintain its required capacity and performance during a given period under stated conditions or disastrous events. (CDRI, 2023)
RESILIENCE	The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. (AR6, IPCC)
SENSITIVITY	The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. (AR6, IPCC)
SYSTEM RESILIENCE	The resilience of social, economic, territorial and environmental systems, at all scales, that conditions the ability of infrastructure assets and the services they provide to resist and absorb disaster impacts. (Definition adopted in CDRI Biennial Report)

⁸²CDRI. (2023). Map Viewer. Retrieved from Global Infrastructure Risk Model and Resilience Index, Measuring Risk and Resilience in Infrastructure Solutions: <https://giri.unepgrid.ch/map>

⁸³Ministry of Housing and Urban Affairs. (2020). Declaring your City/Town SBM ODF+ and SBM ODF++ Toolkit for Urban Local Bodies. New Delhi: Government of India.



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