



Resilience of Urban Water and Sanitation Infrastructure & Services in Coastal Towns

Situational Assessment Report

MANDVI, GUJARAT

2026

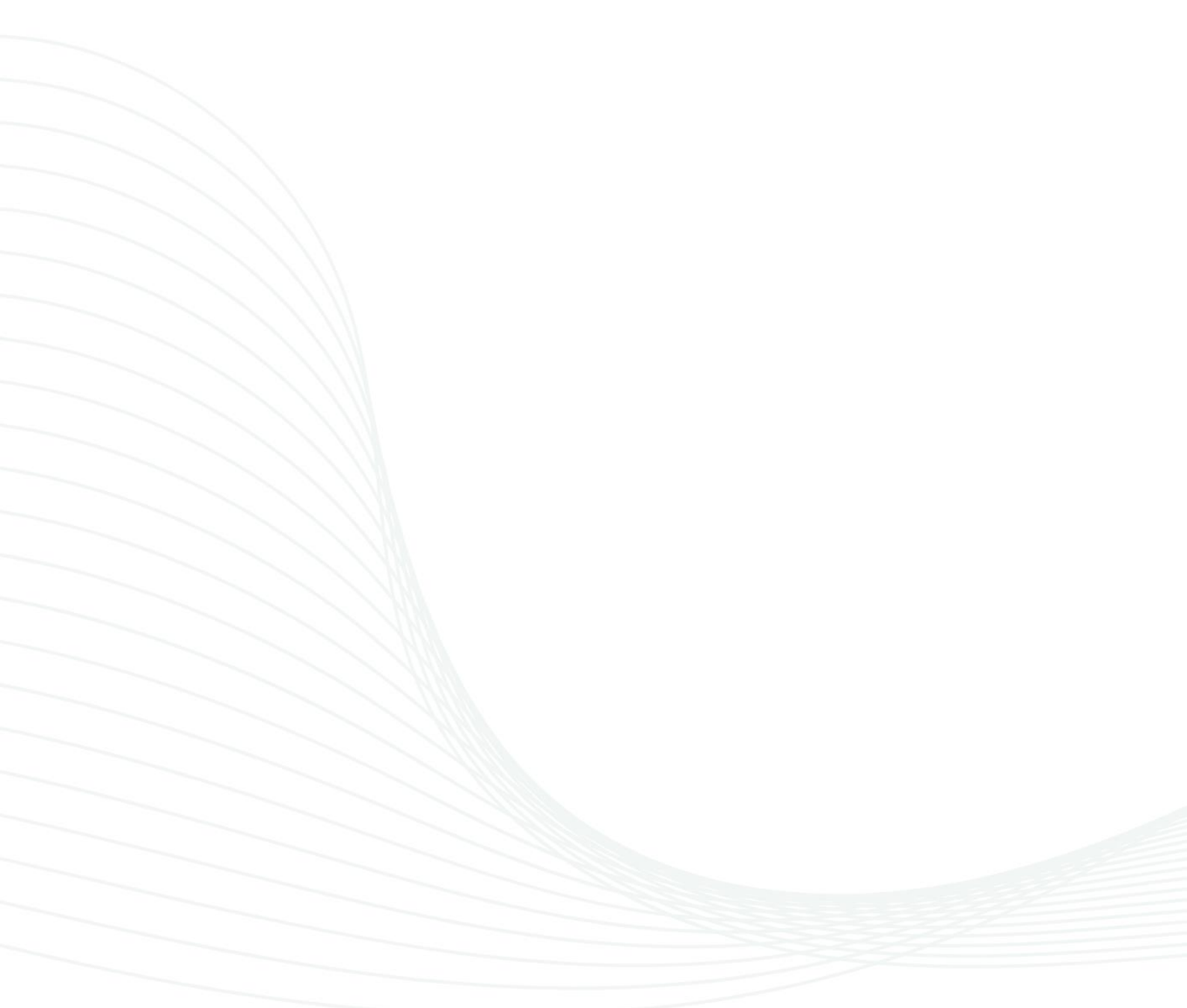


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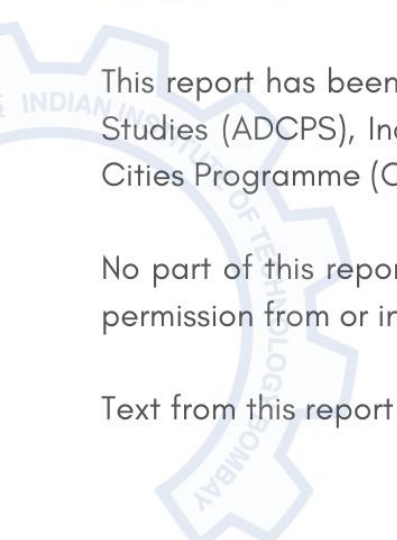
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TITLE

Resilience of Urban Water and Sanitation Infrastructure & Services in Coastal Towns :
Situational Assessment of Mandvi, Gujarat.

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EXECUTIVE SUMMARY

India ranks among the most climate-vulnerable countries globally, with coastal populations facing severe risks from cyclones, floods, sea level rise, and ecosystem loss. The west coast has seen a sharp rise in Arabian Sea cyclones due to rising sea surface temperatures, alongside threats of erosion, land submergence, and saltwater intrusion. Weak Water and Sanitation infrastructure and inadequate services further heighten risks, particularly for disadvantaged groups.

This report, as part of the Landscape Analysis for Coastal Towns on Climate-Resilient Water and Sanitation Infrastructure Project, supported by HSBC-India, **focusses on Mandvi town- a Class-II coastal town in Kachchh District of Gujarat**. The report examines Mandvi's water and sanitation systems to assess climate resilience, service disparities, institutional gaps, financial sustainability, and greenhouse gas (GHG) emissions. It identifies both adaptation and mitigation opportunities, with actionable recommendations for strengthening urban resilience.

Mandvi is situated on the banks of the Rukmavati River, a seasonal river in the primarily dry and arid district. Mandvi was once a major port town and an important centre for maritime trade in the region. It was famous as a traditional ship building centre. Today, it is a thriving tourist location and is famous for its unique location, history, royal heritage, Kutch culture and temples. With a growing population, the city faces high climate vulnerability due to its arid conditions and exposure to droughts and floods. Situated at an average elevation of 5-6 meters above mean sea level, the town is exposed to seismic activity (Zone V), intense cyclonic storms, storm surges, flash flooding, and saltwater intrusion environmental degradation, contamination of land and water, disruptions in essential services, and potential infrastructure failures.

Its water and sanitation infrastructure suffers from poor water quality, an underused and understaffed Water Treatment Plant (WTP), inefficient drainage and sewage systems, and unreliable services during disasters. These challenges undermine climate resilience, public health, and environmental sustainability. To adapt to climate change, the town must upgrade its infrastructure to ensure 100% coverage, improve metering and resource management, and strengthen WTP operations. Sanitation systems need revamping to prevent flood-related contamination and reduce GHG emissions from inefficient wastewater management. Integrated on-site sanitation and desludging improvements can significantly cut methane emissions. Financial and human resource constraints within the Urban Local Body (ULB) hinder investments in resilient infrastructure. Enhanced financial management, cost-reflective tariffs, better billing, and operational efficiency are essential. While Mandvi has initiated rainwater harvesting mandates and solar panel installations, limited adoption and non-functional infrastructure (like the WTP) reduce their impact. Overall, significant investments in resilient systems, climate-smart operations, and institutional capacity are needed to safeguard water supply, public health, and climate sustainability in Mandvi.

KEY RECOMMENDATIONS:

Water and sanitation

1. **Decentralize Water Management** – Promote rainwater harvesting, watershed management, and reduce dependency on distant sources.
2. **Strengthen Distribution Networks** – Upgrade pipes, smart meters, and leak detection to cut losses.
3. **Wastewater Recycling & Reuse** – Reuse treated water for irrigation/industry to ease freshwater demand.
4. **Data-Driven ULB Capacity** – Support participatory planning and real-time decision-making.
5. **Climate-Resilient Practices** – Build local storage (ponds, check dams) and plan for erratic rainfall.
6. **Equitable Services** – Improve WTP operations, target vulnerable groups, and monitor water quality.
7. **Sewage Treatment** – Invest in efficient STPs, monitor ponds, and cut GHG from untreated sewage.
8. **Septage Management** – License operators, track desludging digitally, and enforce safe disposal.
9. **Water Supply Efficiency** – Reduce NRW, universal metering, upgrade pumps, and improve energy use.
10. **Sanitation Emissions** – Upgrade septic systems, improve desludging, and green oxidation ponds.
11. **Stormwater Emissions** – Use green infrastructure to cut nutrient runoff and N₂O emissions.
12. **Holistic Wastewater Management** – Adopt decentralized, low-carbon technologies with resilience + mitigation.

Financial Sustainability

1. **Water Supply** – Revise tariffs, improve billing/collections, digitize payments, and raise awareness.
2. **Sewerage & Sanitation** – Adjust user charges, explore new revenues (septage fees, connections), digitize systems, and cut inefficiencies.

Infrastructure Resilience

1. **Emerging Coastal Risks** – Address flooding, saline intrusion, outages, and system failures with local risk assessments and alerts.
2. **Contextualized Design** – Avoid one-size-fits-all; adopt decentralized, hybrid systems suited for Mandvi's topography.
3. **Flexibility & Reliability** – Diversify sources (wells, ponds), decentralize networks, add backups, and retrofit septic systems.
4. **Risk Governance** – Build local capacity, integrate ULBs into disaster planning, improve data/alerts, and enable autonomy in decision-making.
5. **Resilience Investments** – Promote waste-to-energy, wastewater reuse, water markets, and cluster-based WaSH planning; establish ring-fenced DRR budgets.
6. **Urban Flood Management** – Upgrade drainage in flood-prone/low-income areas; integrate health safeguards.
7. **Disaster-Resilient WASH** – Equip shelters, train communities, and ensure access during floods/cyclones.
8. **Climate-Resilient Infrastructure** – Power backups, resilient standards for extreme weather.

CHAPTER 1: INTRODUCTION

NEELAM RANA, PRIYAKSHI GOGOI, SUCHARITA ROY, ASHISH DANGI, ABHAY JUNAGHARE, TEJASH ANAND AND N.C. NARAYANAN

1.1 BACKGROUND

Global Climate Risk Index 2021 ranks India as the seventh-most exposed and vulnerable country to climate extremes¹. 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. This is especially true for the large coastal population (171 million population in coastal districts). India is highly susceptible to cyclones and their related dangers such as storm tide, intense winds, and substantial rainfall. More than 300 extreme events have hit the country in recent decades, causing losses of more than INR 5,600 billion (Mohanty, et al., 2020)². A recent evaluation indicates that more than 75% of districts in India, including 95% of coastal districts, are hotspots for extreme events (ibid).

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 (Rumbach, 2018);(Yenneti, Tripathi, Wei, Chen, & Joshi, 2016)³⁴. **Climate change induced water stress and insecurity can increase the incidences of waterborne infectious diseases, thereby, hindering or reversing advancements made in related Sustainable Development Goal (SDG) targets and amplifying inequalities** (Braks & Husman, 2013)⁵. Water and sanitation services face significant threat from climate change induced hazards, and it's crucial to comprehend and enhance the ability of water and sanitation infrastructure and services to withstand it. This is particularly critical in small towns, which are already finding it challenging to provide universal access to water and sanitation services (Central Pollution Control Board, 2021)⁶. and are now exposed to climate change-related risks. This requires adopting climate-responsive policies, infrastructure planning, financing mechanisms, and institutional frameworks across all levels of governance. Such measures contribute to strengthening urban resilience—enhancing a city's ability to absorb shocks, adapt to changing conditions, recover from disruptions, and continue to thrive.

With this understanding, a project “Landscape analysis for four coastal states on climate resilient water and sanitation infrastructure project” was initiated with funding support from HSBC. The project focuses on both adaptation and mitigation strategies to strengthen climate-resilient urban water and sanitation infrastructure and services, with an emphasis on developing actionable policy recommendations that are grounded in local realities.

The project focuses on 12 west coastal towns of Maharashtra, Gujarat, Goa, and Karnataka. While the east coast has been more exposed to tropical cyclones, recent years show a greater

number of tropical cyclones (TC) forming in the Arabian Sea (west coast)(Deshpande, et al., 2021)⁷. In recent years, the Arabian Sea has emerged as a key region for the formation of tropical cyclones, which have led to severe impacts across western coast of India(Thomas & Lekshmy, 2022)⁸. For instance, the Arabian Sea region has witnessed a 52% surge in the occurrence of cyclonic storms in the recent period (2001–2019), whereas the Bay of Bengal (east coast) has experienced an 8% decline(Deshpande, et al., 2021). Along India's west coast, the coastal districts of Gujarat specifically have become increasingly vulnerable to tropical cyclones in recent years(Boragapu, Guhathakurta, & Sreejith, 2023)⁹. This increase in the frequency and intensity of cyclones in the Arabian Sea has been attributed to rapid rise in sea surface temperatures(Deshpande, et al., 2021). 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 land (Woodruff, BenDor, & Strong, 2018)¹⁰. 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 UNFCC-IPCC 2023 report.

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.

The current report focuses on Mandvi- Class-II town- a coastal town in Kachchh District of Gujarat. Gujarat's 1,600 km coastline is prone to hydro-meteorological hazards like cyclones, storm surges, gusty winds, and heavy rains (Gujarat State Disaster Management Authority, 2024). Mandvi is a coastal town of historical significance located in the Kutch district of the state of Gujarat, India. It is situated on the banks of the Rukmavati River, a seasonal river in the primarily dry and arid district. Mandvi was once a major port town and an important centre for maritime trade in the region. It was famous as a traditional ship building centre. Today, it is a thriving tourist location and is famous for its unique location, history, royal heritage, Kutch culture and temples. With a growing population, the city faces escalating climate threats. Situated at an average elevation of 5-6 meters above mean sea level, the town is exposed to seismic activity (Zone V), intense cyclonic storms, storm surges, flash flooding, and saltwater intrusion environmental degradation, contamination of land and water, disruptions in essential services, and potential infrastructure failures.

This report examines the current status of water and sanitation services in town, highlights challenges, and identifies opportunities related to water and sanitation services, with a particular emphasis on disparities in service access placing it within the context of changing climate. It maps the institutional framework governing the urban sanitation, analyzing the roles of different institutions involved in service delivery—an essential step, as effective climate change measures rely on a clear understanding of institutional responsibilities. Additionally, the report presents the

findings on Greenhouse Gas (GHG) emissions associated with the urban water and wastewater cycle at the town level, aimed at identifying actionable steps the town can take to reduce its GHG emissions. These findings inform the risk assessment of water and sanitation infrastructure in the context of climate change. The study also evaluates the financial sustainability of the Urban Local Body (ULB), examining its capacity to meet current and future demands while implementing climate change adaptation and mitigation measures. Additionally, the study highlights key climate initiatives undertaken by the town's water and sanitation sector that contribute directly or indirectly to both adaptation and mitigation efforts.

The report begins with Chapter 1, which establishes the link between climate change and water and sanitation, offers a brief overview of the importance of studying west coastal towns, and introduces the study area—**Mandvi**. It also outlines the study's objectives, the methodology adopted to achieve them, and the criteria used for town selection. **Chapter 2** presents a detailed town profile, covering demography, climate, topography, land use and land cover, as well as key climate risks highlighted in literature. **Chapter 3** focuses on the status of urban water supply in the context of a changing climate, highlighting major challenges. **Chapter 4** examines the sanitation service chain, and reviewing institutional arrangements, highlighting major challenges. **Chapter 5** focuses on the estimation of GHG emissions in urban water and wastewater services in the town. **Chapter 6** examines the whether the town meets national service-level benchmarks (SLBs) in urban water and sanitation, and financial health of the ULB with respect to sustaining and upgrading water and sanitation services. **Chapter 7** examines risks to WaSH infrastructure and services. **Chapter 8** explores key climate change initiatives being undertaken at the town level. Finally, **Chapter 9** concludes the report with sector-specific recommendations.

1.2 OBJECTIVES

- **Conduct a comprehensive assessment** of the current state of water and sanitation infrastructure and services in the town.
- **Highlight critical issues and challenges** confronting the town's water and sanitation systems.
- **Quantify the GHG footprint** associated with the urban water and wastewater cycle.
- **Assess the financial sustainability** of the urban local body in managing water and sanitation services.
- **Assess risk of water and sanitation** infrastructure of the town.
- **Propose recommendations to enhance resilience** of the water and sanitation infrastructure and services

1.3 METHODOLOGY

Twelve towns were selected for the study. This section outlines the criteria used for town selection and describes the steps and data collection methods employed to meet the study's objectives.

TOWN SELECTION CRITERIA

Across the four states, the study focuses on 12 selected towns (Table 2). 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, 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 Water, Sanitation and Hygiene (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.

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		

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

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 MC	4,99,487	Class-I
	Kundapura TMC	30,444	Class-III
	Karwar CMC	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

1.3.2 STEPS

Adopting resilient infrastructure not only helps reduce the intensity of adverse consequences or 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 of the town due to climate change has been undertaken 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)¹¹, **a three-step, contextualized 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 has been mapped and analysed on basis the data gathered from various sources, on performance, coverage, socio-spatial variability, technology, governance, key stakeholders, existing policies and, climate change initiatives, financial health of the urban local body, budgets, and future projects.
2. **Identifying the Infrastructure Exposure and Vulnerability:** The climate hazards faced by the settlement has 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 have 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.

1.3.3 DATA COLLECTION

1. **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, SBM-U, 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.

2. **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 pre-assessment for risk study was undertaken to identifying low-lying zones and densely populated areas based on elevation and building proximity from remote sensed data. Areas exhibiting both characteristics were marked as climate vulnerability hotspots for field visits. Ten hotspots were then investigated through visual assessment for ground truthing of secondary data and semi structured interviews with residents undertaken to capture the challenges faced by the residents.

- **Secondary Data Collection from Town Water and Sanitation Departments:** Meetings with ULBs were held to collect a wide range of documents and data, including city maps, land-use and land cover 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 oxidation ponds, sewerage network

connection, and the number, condition, and operation and maintenance (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 Mandvi Municipal Council (MMC), we interviewed (semi-structured interviews) key ULB officials—Water engineer (1), Additional Chief officer (1), SBM-U Coordinator (1), AMRUT coordinator (1), Accountant (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.
- **Site Visits:** Site visits were conducted to validate the functioning of critical water and sanitation infrastructure, such as oxidation ponds, sewerage network connections and Water Treatment Plant (WTP). 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 Assessments:** The assessment process combined on-ground observations with semi-structured interviews, particularly targeting high-risk zones such as low-income neighbourhoods, low-lying areas, sites prone to extreme weather events, and densely populated clusters. These hotspots were identified through consultations with ULB officials and spatial analysis of WaSH infrastructure, highlighting zones with heightened vulnerability due to their proximity to each other. Areas characterized by both low elevation and high building density were prioritized for field investigation. Municipal officials also helped identify locations that would provide socio-demographic diversity for sampling. The interviews served to validate and triangulate data from secondary sources on WaSH systems, offering grounded insights into local infrastructure and the lived realities of residents—especially those in vulnerable communities—during events such as heavy rainfall, cyclones, and storms. The assessment process included on-ground observations and in-depth conversations with (10) residents, with a particular focus on low-income neighbourhoods and areas identified as vulnerable to extreme events during interviews with ULB officials.

The primary 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. 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 (10) residents across the city, carefully selecting locations to represent a range of socio-economic backgrounds. Our discussions with residents primarily focused on their access to and the quality of water and sanitation services. Additionally, the team visited 2 Public Toilets and 1 Community Toilet to assess their condition firsthand. During our rapid field assessment, we visited the public toilet located in junctions where people can use.

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-II. The workshop also helped define the way forward for the research team.

1.3.4 GREENHOUSE GAS EMISSION 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** as mentioned in table 3. Each category captures different sources of carbon emissions within the urban water cycle.

Table 3 : 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*	<i>2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement)</i>
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	<i>Electricity consumption data obtained from urban local bodies and an average grid emission factor 0.716 tCO₂/MWh (FY 2022-23, Central Electricity Authority) for Indian grid used for CO₂ estimation.</i> <i>Diesel consumption for desludging trucks based on information obtained from interviewing truck operators.</i>
Embedded Emissions	- Life cycle GHG emissions associated with the materials used in the physical infrastructure. *	<i>Not estimated due to non-availability of data on material footprint.</i>
*Emissions not considered in the estimation due to non-availability of reliable activity data for the same.		

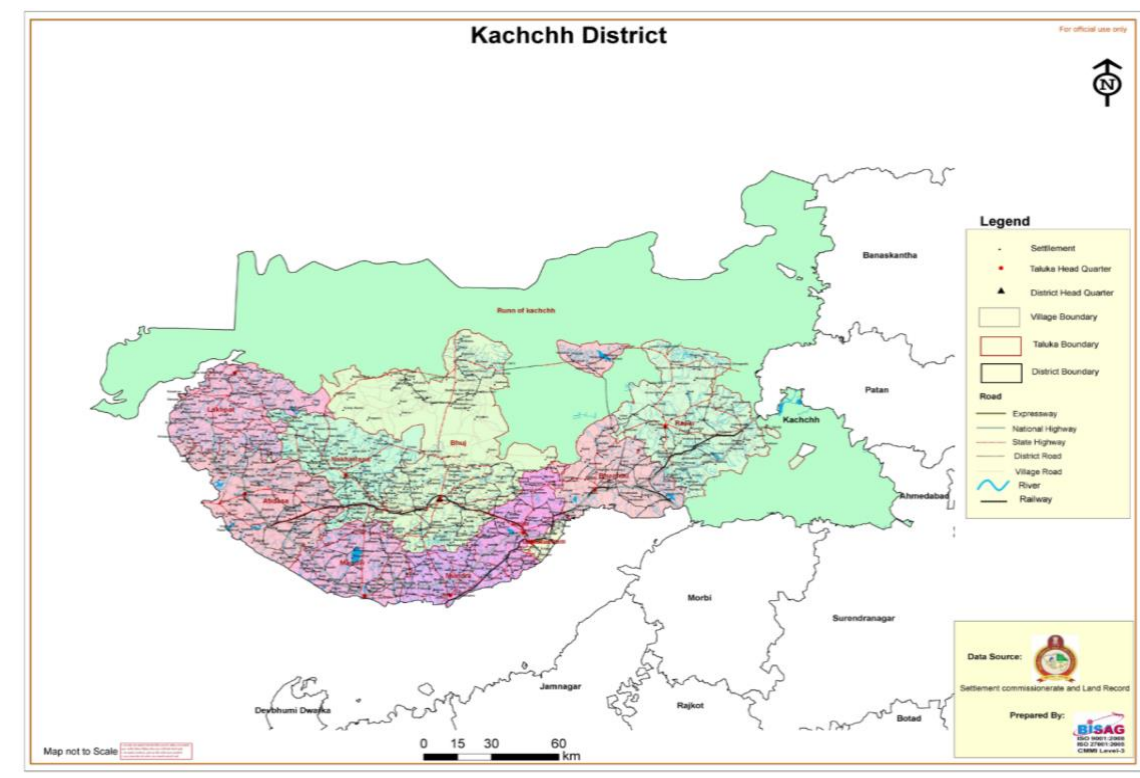
The study also identified several critical data gaps that limit comprehensive assessment and effective decision-making. These gaps, detailed in Annexure-II, highlight the need for improved data collection, systematic reporting, and stronger integration of information across institutions to better inform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

CHAPTER 2: TOWN PROFILE: MANDVI

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

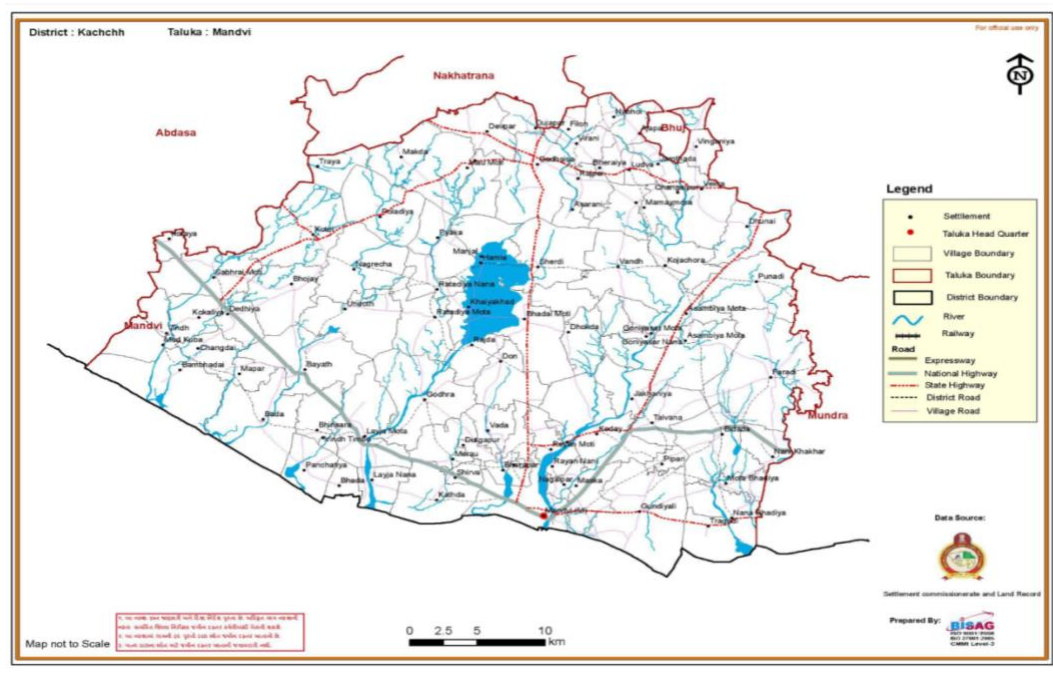
Mandvi is a municipal town situated in Gujarat's Kachchh district, spanning an area of 14.89 square kilometres. The town is located at 22°50'00"N ; 69°21'20"E. The Kachchh district occupies the westernmost region of Gujarat (refer figure 1). It is bordered by Rajkot district to the south, Banaskantha district to the east, and shares its northeastern boundary with the state of Rajasthan.

Figure 1 : Kachchh District Map



Source: Revenue Department, Government of Gujarat ¹²

Figure 2 : Mandvi Taluka Map



Source: Revenue Department, Government of Gujarat

Demographic Profile: According to the 2011 Census of India, Mandvi Municipality has a population of 51,376, comprising 26,075 males and 25,301 females. Children aged 0–6 years make up 6,181 of the population, accounting for 12.03% of the total.

Mandvi shows a favourable gender balance, with a female sex ratio of 970—higher than the Gujarat state average of 919. The child sex ratio also stands at 933, surpassing the state average of 890. The city's overall literacy rate is 80.38%, which is higher than the state average of 78.03%. Male literacy in Mandvi is around 88.11%, while female literacy is 72.46%. Mandvi Municipality oversees the administration of 10,346 households¹³.

Scheduled Castes (SC) make up 9.28% of Mandvi's total population, while Scheduled Tribes (ST) account for 0.13%. Out of the total population, 16,608 individuals are engaged in work or business activities, including 14,247 males and 2,361 females. Among the working population, 91% are involved in main work (employment or business lasting more than six months), while the remaining 9% are engaged in marginal work, which provides livelihood for less than six months a year.

Topography: Mandvi is a city situated in the westernmost district of Gujarat, Kutch, renowned for its deserts known as the Ranns - a salty desert which dries up seasonally and at other parts of the years is filled with shallow water. Kutch is an arid region with low and unpredictable rainfall. Winters are mildly cold, while summers are hot. The district comprises sandy and saline soils.

However, Mandvi, located on the low-lying southern coastal region of this district, has developed alongside a seasonal river and is surrounded by several non-flowing water bodies. The general slope dips towards south side towards Gulf of Kutch. Rukmavati River passes through the town, and it is a seasonal river.

Land use and Landcover: Mandvi city is divided into 9 wards with variable population ranging from around 3300 in ward 3 to around 9300 in ward 2. A large part of the city is under cropland and a dense vegetation patch along the beach at the south is a defining feature of the city. Land use surface in urban settlements is made of roofs, streets and others paved surfaces and can be estimated from the built-up footprint of the city. Runoff flows through impervious surfaces to the storm-sewers or towards the natural conveyance regime of the ecosystem. It also changes the hydrologic cycle, increasing the overland flow, reducing groundwater flow and with peak discharge increases the flood frequency.¹⁴

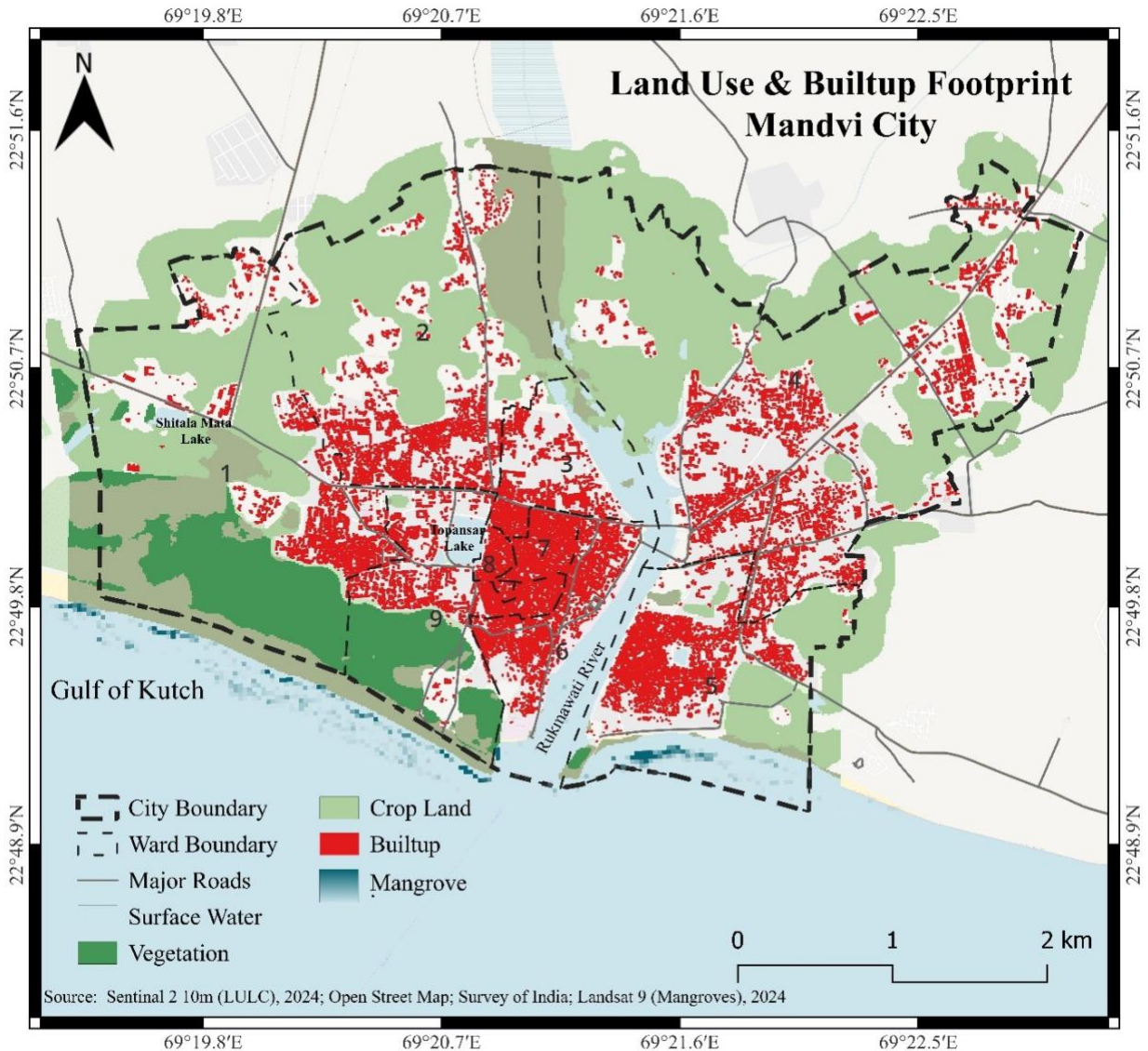
Wards 1, 2, and 4 in the north and northwestern part of the city are the largest wards by spatial size with wards 2 is also the largest by size of population (18% of total). The city is limited in its expansion on the south by the sea. The new expansions are clearly directed along the transport corridors which connect the city to the district at its north. However, ward 7 and 8 in the centre of the city have the highest density of population and nearly 85 – 93 % built up and can clearly be assumed to be the city core (refer Table 4).

Table 4 : Density of Population and Wad Level Built-up Footprint

Ward no	Population (2011)	Estimated Ward Area (sq. km)	Estimated Population Density (per sq. km)	Built Area %
1	6139	3.69	1664	10%
2	9301	3.06	3040	18%
3	3295	0.76	4336	30%
4	4385	5.83	752	16%
5	4825	2.09	2309	24%
6	6161	1.07	5758	36%
7	6728	0.18	37378	93%
8	5129	0.09	56989	85%
9	5413	1.41	3839	26%

Source: GIS Analysis

Figure 3 : Land use and Built up Footprint of Mandvi



Source: Sentinel 2 10m LULC; Open Street Map; Landsat 9 (Mangroves), 2024; Mandvi Municipal Corporation

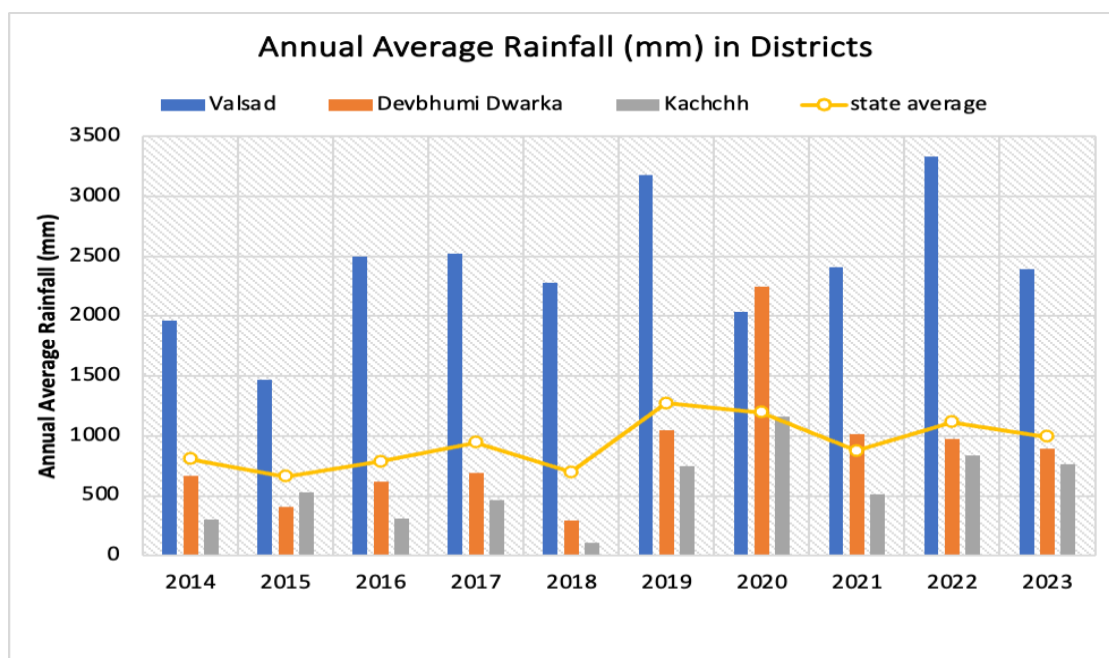
Climate: The climate of Kachchh district is characterized by extremes, with hot summers and cold winters, although overall weather conditions remain generally pleasant throughout the year. The Kachchh-Bhuj region, in particular, experiences a predominantly dry climate. **Mandvi is a coastal port town situated at 22.81°N latitude and 69.36°E longitude, where the Rukmavati River flows into the Gulf of Kutch.** It experiences a typical hot semi-arid climate characteristic of Gujarat, marked by three distinct seasons. The hot season, lasting from March to mid-June, is intensely warm and dry. **However, Mandvi's proximity to the coast helps moderate the temperatures, making it somewhat less severe than the interior regions of the state.**

Disasters and Climate Change Vulnerability: Town level data on disasters and climate impacts is lacking. Hence, we relied upon district, administrative division and taluk level secondary data on disasters and climate change projections.

Droughts

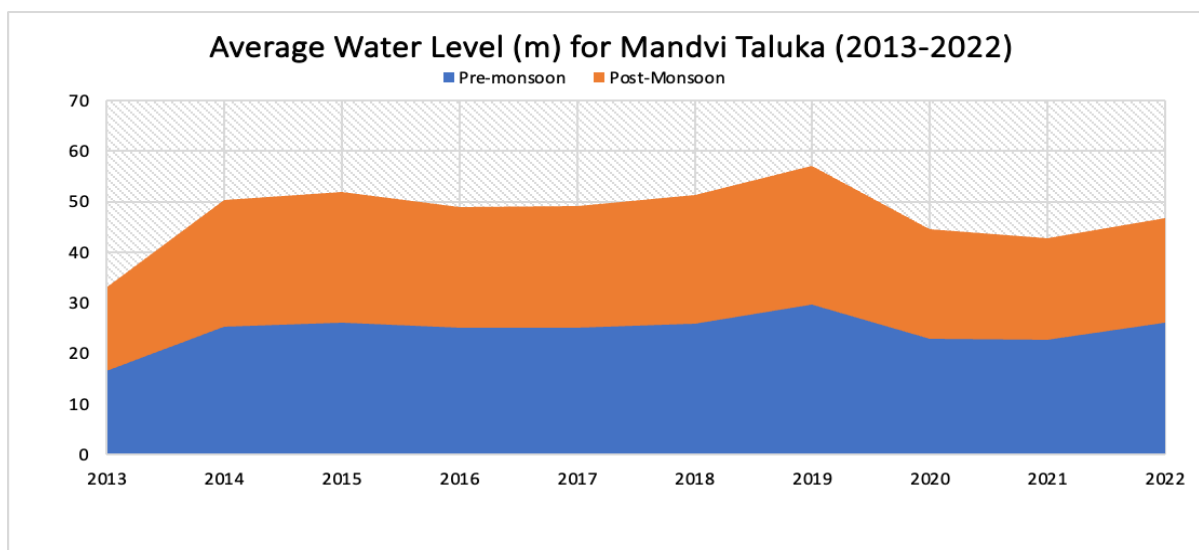
Large parts of Gujarat lie in arid and semi-arid zones, with regions like Saurashtra, Kutch, and North Gujarat experiencing famine approximately every three years. Gujarat is among the chronically drought-prone states in India, with over half of its Talukas receiving low annual rainfall in the range of 200–400 mm (Gujarat State Disaster Management Plan). Figure 4 illustrates the rainfall pattern in Kachchh district, which records one of the lowest average annual rainfall levels as compared to other districts. Figure 5 also shows erratic behaviour of the monsoon. The low rainfall coupled with erratic behaviour of the monsoon make Mandavi/Kachchh the most vulnerable to drought. The scarcity of surface water has led to extensive groundwater exploitation. Monsoon delays and deficits have triggered severe droughts, notably in 2002 and 2016. **To add to this, groundwater extraction in Mandvi Taluka currently falls within the critical category (95.4%)** (Central Ground Water Board , 2023)¹⁵.

Figure 4 : Annual Average Rainfall (mm) in Districts of Gujarat



Source: (Central Ground Water Board , 2023)

Figure 5 : Pre-monsoon and post-monsoon Average Ground Water Level (m) for Mandvi Taluka



Source: (Central Ground Water Board , 2023)

Heatwave

The Kachchh district is also prone to heatwaves (National Centre for Disease Control, 2022). Between 1980-2019, the highest number of hot days and the most significant increases have been observed in regions such as Kachchh, Devbhumi Dwarka, Jamnagar, Rajkot, Amreli, Gir Somnath, Junagadh, Porbandar, Morbi, and Bhavnagar (Government of Gujarat, 2021)¹⁶. This is going to get worse, as **noticeable warming across Gujarat is shown under different RCP scenarios. The parts of Kachchh and Ahmedabad—are expected to experience the more pronounced warming (ibid).**

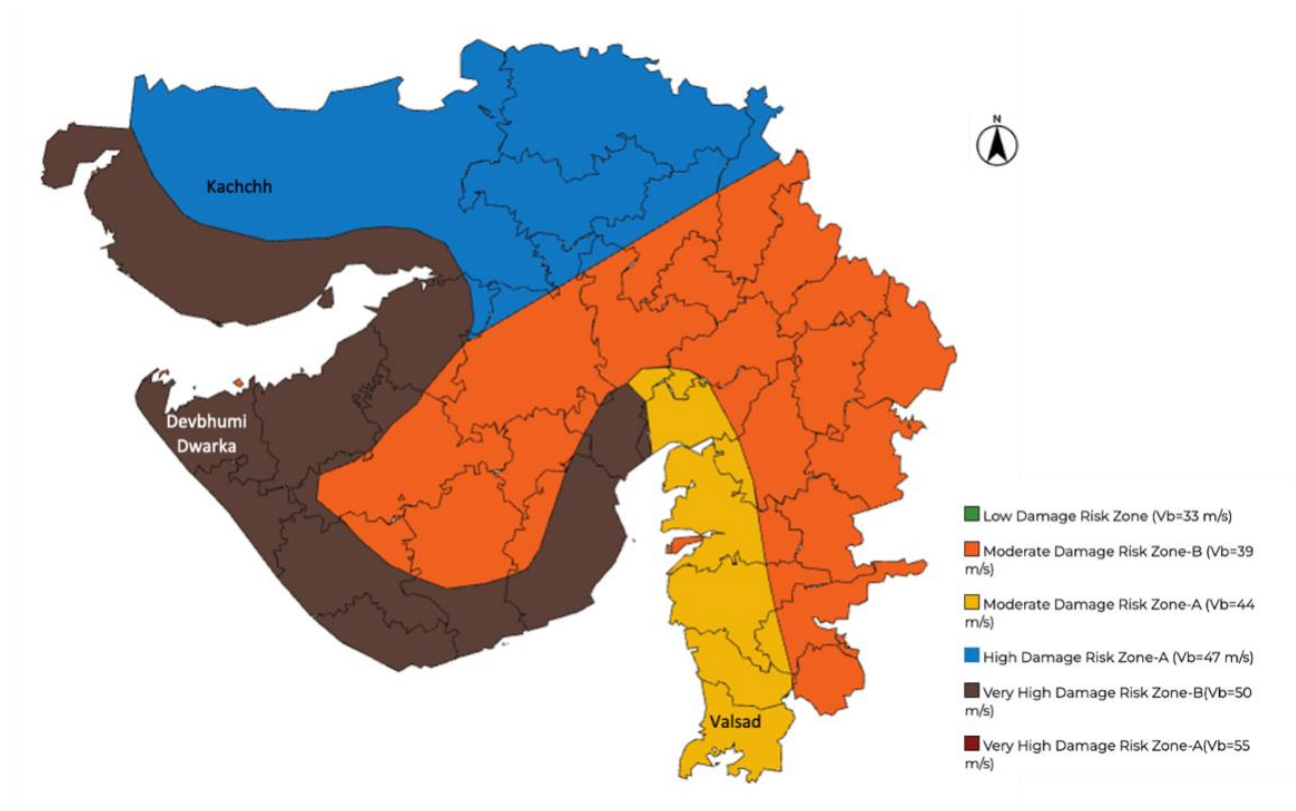
Cyclones

Gujarat lies within the tropical cyclone zone and, with the longest coastline in India—about 1,600 km—it is particularly susceptible to cyclones and related hazards like flooding and storm surges. Most cyclones impacting the state originate in the Arabian Sea, typically moving north-eastward and striking the coast, especially in southern Kutch, southern Saurashtra, and western parts of Gujarat.

As per NITI Ayog, Kachchh district and Mandvi town falls under the high maximum wind speed of 64-90 m/s and a very high damage risk zone (Figures 6). Coastal areas in the district including Mandvi are particularly prone to cyclones. The Mandvi region is also highly vulnerable to Tsunami as per the district disaster management plan (Disaster Management Cell, 2016)¹⁷. The cyclones and storm surges can impact infrastructure and services. For instance, Cyclone Vayu, which struck Gujarat in 2019 disrupted cargo operations at several ports, necessitating the evacuation of

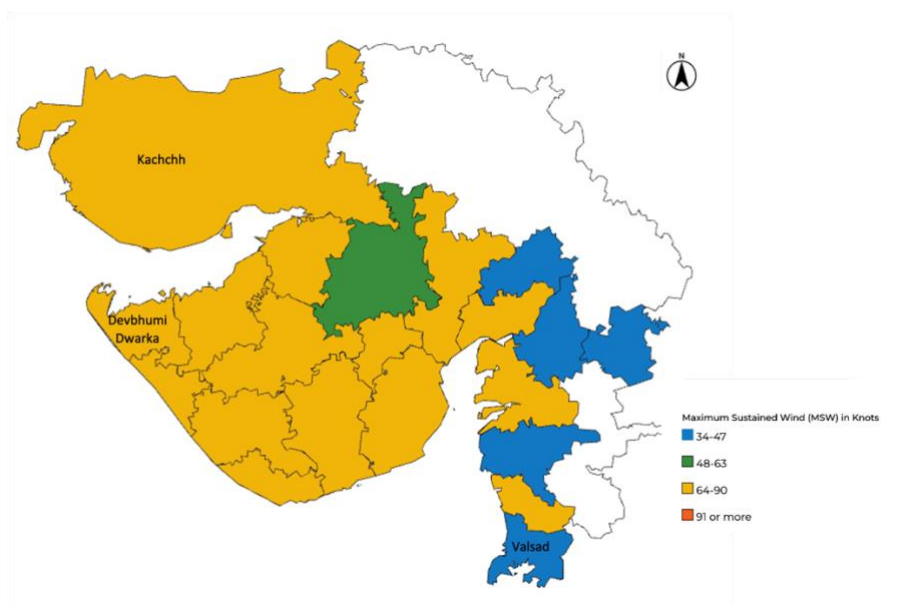
workers to safer locations. The cyclone also led to the suspension and cancellation of Western Railway services, and educational institutions were temporarily closed. Cyclone Biparjoy in 2023, a severe cyclonic storm, brought strong winds and heavy rainfall to Gujarat's coastal regions. Residents in low-lying areas of Kachchh districts were relocated to safer locations as a precautionary measure (Gujarat State Disaster Management Authority, 2024). In Mandvi, Biparjoy cyclone caused severe flooding, with some buildings submerged and widespread power outages, highlighting challenges in disaster response and the gap between official claims and community experiences (interview with the ULB officials).

Figure 6 : District Exposure to Wind Hazard



Source: (Niti Aayog, 2025)¹⁸

Figure 7 : District Exposure to Maximum Sustained Winds During Cyclonic Activities



Source: (Niti Aayog, 2025)

Floods

Average seasonal rainfall has shown an upward trend in the Saurashtra and South Gujarat regions. As per Niti Aayog Mandvi is not flood prone (figure 8). Similarly, according to a study by IIT Gandhinagar, the region has low exposure and flood risk; however, it exhibits moderate to high levels of hazard and vulnerability (Figure 9).

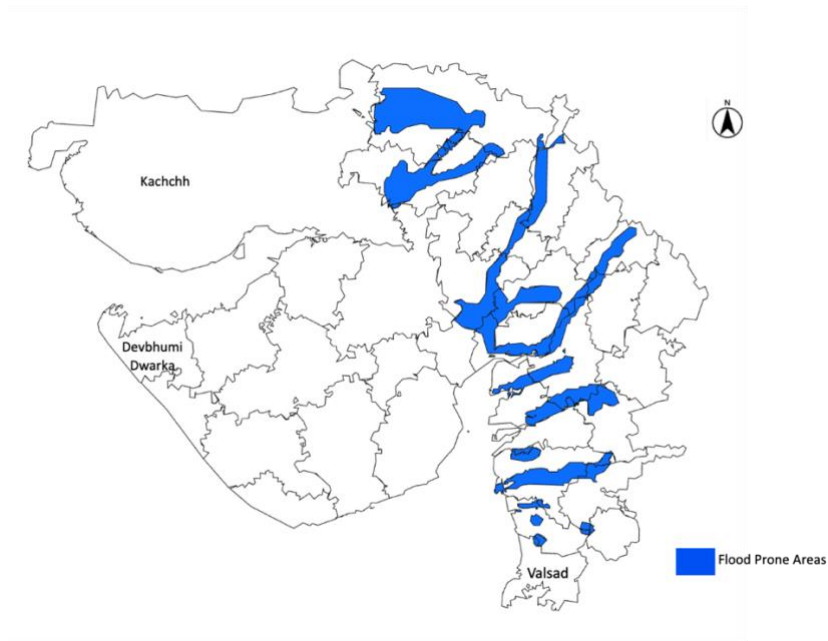
Most of Gujarat's major rivers flow through extensive flat terrain before emptying into the sea. These low-lying areas in the lower river basins are particularly susceptible to flooding. Floods cause widespread damage to infrastructure such as roads, buildings, and tunnels, while also increasing soil erosion—especially affecting railway lines and water infrastructure. They further disrupt waste disposal and drainage systems. In addition to causing fatalities and injuries from its immediate effects, flooding can also heighten the risk of both communicable and non-communicable diseases due to increased stress and disruptions in regular healthcare services.

Sea Level Rise

Studies indicate that 45.67% of Gujarat's coastline falls under high to very high risk from projected sea-level rise, while the remaining 54.33% is considered to be at moderate to low risk. **The areas most at risk include the northwestern parts of the Gulf of Khambhat, the northernmost regions of the Gulf of Kachchh, and the western Kachchh coastline**(Gujarat State Disaster Management Authority, 2024); (Mahapatra et al., 2015 in (Government of Gujarat, 2021). Rising sea levels are accelerating saltwater intrusion, disrupting daily life and posing health risks for coastal communities. Saline water is unsuitable for drinking without desalination, making it essential to invest in measures

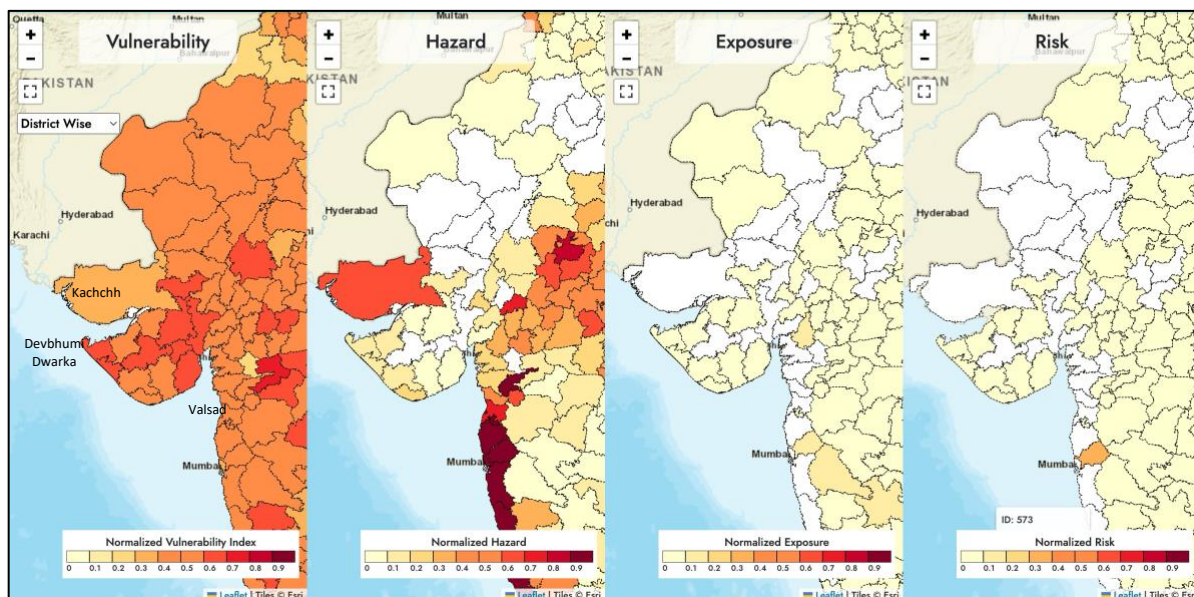
that improve water quality. These include expanding wastewater and water treatment infrastructure—particularly desalination technologies—installing devices to prevent seawater backflow into stormwater drains, and setting up rainwater harvesting systems to supplement freshwater supply (Government of Gujarat, 2021).

Figure 8 : Flood Prone Areas in Gujarat



Source: (Niti Aayog, 2025)

Figure 9 : Flood Vulnerability, Hazard, Exposure and Risk: Districts of Gujarat



Source: IIT Gandhinagar¹⁹

CHAPTER 3: STATUS AND CHALLENGES OF WATER SUPPLY INFRASTRUCTURE AND SERVICES AT MANDVI

ABHAY JUNAGHARE & NC NARAYANAN

3.1 BACKGROUND

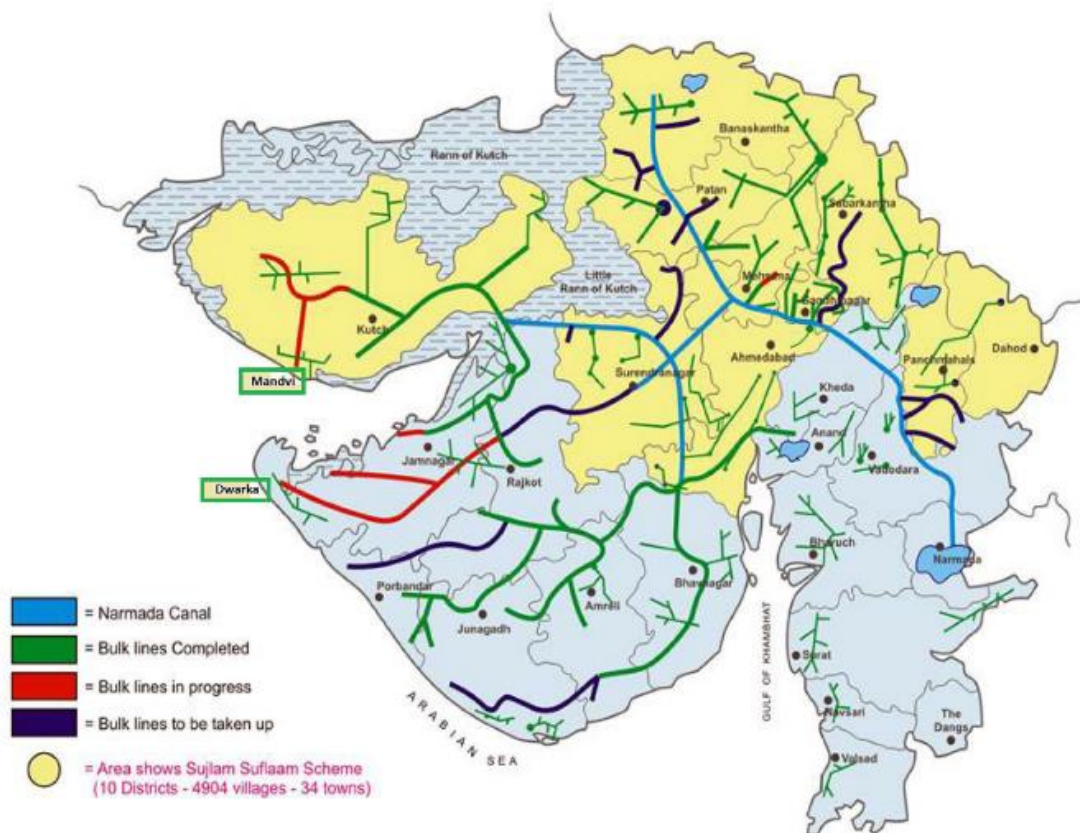
Water infrastructure and services in rapidly urbanizing coastal towns are increasingly under pressure due to the dual challenges of urban growth and climate change (Dodman, 2023²⁰; Moraci, 2020²¹; Nicholls et al., 2007²²). Coastal cities like Mandvi are particularly vulnerable, as they depend on monsoon-driven surface water, groundwater aquifers, and fragile coastal ecosystems. Already facing constraints on freshwater resources, these towns are seeing rising demands for water and sanitation services while simultaneously grappling with the impacts of changing precipitation patterns, more frequent extreme weather events, rising sea levels, and saltwater intrusion (MoEFCC, 2018²³; USEPA, 2025²⁴; Datta et al., 2024²⁵; Rosińska et al., 2024²⁶). To better understand how current water management practices interact with broader environmental challenges, it is essential to assess the state of water infrastructure in these towns (Pal et al., 2023²⁷; Siddha & Sahu, 2020²⁸; Rajasree & Deo, 2020²⁹; Govindarajulu, 2020³⁰). The chapter provides status of water infrastructure and services in the town and highlights key challenges.

3.2 WATER SOURCES

3.2.1 SURFACE WATER SOURCES

Being a coastal city, Mandvi has long faced challenges in securing a sustainable and reliable water supply due to its proximity to the coast and the limited local water sources. By receiving water from the Narmada Canal³¹ (Fig. 10), Mandvi Municipality is able to meet the growing demand for drinking water, as well as water for sanitation and other municipal needs. The canal provides a reliable and consistent supply, which is crucial, especially during the dry summer months when local sources may not be sufficient.

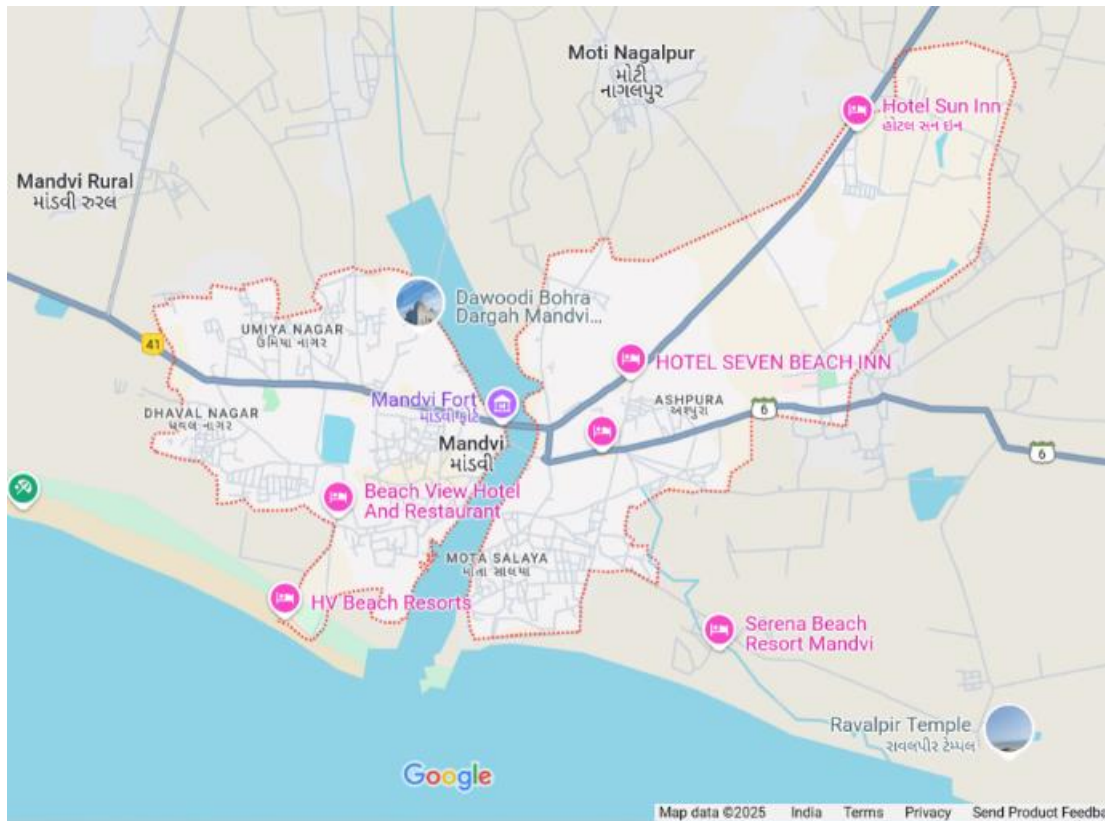
Figure 10: Narmada Canal Network



Source: Narmada Control Authority (<https://nca.gov.in/>)

Mandvi city was largely dependent upon domestic wells before the existing piped water supply system came into existence (Fig. 11). After the advent of piped water supply system, the city now has both surface and ground water sources. Mandvi has two bulk water supply sources, viz., 1) Narmada Canal, and 2) Borewells. The Narmada Canal and the Borewells are located within the city. There is one water tapping point at Narmada Canal and taps 4 MLD water from this source. However, there are 22 tapping points from Borewells that taps 4 MLD water. Hence, the city is largely dependent upon Borewells as compared to the Narmada Canal. The total bulk water tapped from all the sources at Mandvi city is 8.0 MLD (AMRUT, 2025).

Figure 11: Mandvi City Boundary



Source: Google Maps

Under AMRUT 2.0, Mandvi city has drafted the project report with a total estimated project cost of INR 1.97 Crores to rejuvenate the Mangleshwar Lake. MMC has also drafted a plan for Rukmavati Riverfront Development under AMRUT 2.0 with an estimated project cost of INR 5.0 Crores. Previously, Mandvi had multiple sources for its protected water supply. According to census 2011, the town relied on Tap water from treated source (TT) and Tubewell /Borehole (TW/B) sources for water supply. The total storage capacity from all the sources was 21.85 MLD (Census, 2011).

Mandvi taluka, located on the Tropic of Cancer, experiences an arid climate and is a part of the semi-arid region in Gujarat. The area faces high drought frequency, with average annual rainfall of about 429 mm from 2011 to 2016. The region has three main seasons: monsoon (June to October), winter (November to February), and summer (March to June), with temperatures ranging from 9°C in January to 39.5°C in June. The relative humidity varies from 43.5% in March to 77% in August, while wind velocity ranges from 124 km/d in November to 375 km/d in June. Kachchh district, where Mandvi lies, is known for its erratic rainfall and frequent droughts (CGWB, 2022).

The district's physiography is diverse, consisting of coastal plains, hill ranges, and the unique Rann salt flats. The Kachchh mainland includes elevated areas such as the Dhinodhar, Jura, and Vavar hills, as well as islands like Pachham and Khadir. The coastline is approximately 350 km long, with

flat terrain interspersed with creeks. The Great and Little Rann, spanning 25,000 sq. km, and the Banni plain, covering about 2,000 sq. km, make up some of the district's most distinct landforms. Despite being a harsh environment, Banni is noted for its superior grasslands, which are vital for local ecosystems (CGWB, 2022).

3.2.2 GROUND WATER SOURCES

The aquifer system in Mandvi, Kutch district, is a complex network shaped by the region's geological formations and proximity to the Arabian Sea. The aquifers are made up of various sedimentary materials, including alluvium, limestone, and marine deposits (Table 5). These aquifers are divided into shallow and deep systems, with shallow aquifers located at depths of 35 to 120 meters and deeper confined aquifers extending from 110 to 300 meters. The shallow aquifers are more prone to contamination, particularly in coastal areas where salinity intrusion from the sea is a significant concern. In contrast, deeper aquifers tend to have fresher water, though they can still experience brackish conditions, especially in regions with high extraction rates or seawater intrusion.

Water quality in Mandvi's aquifers varies from fresh to brackish, with shallow aquifers typically being more susceptible to surface contamination and salinization. Groundwater in Mandvi is crucial for agricultural, industrial, and domestic use, but over-extraction, saltwater intrusion, and climate variability pose significant challenges. Seasonal fluctuations in rainfall exacerbate these issues, making groundwater management a key concern. The region relies heavily on groundwater, and initiatives such as rainwater harvesting, artificial recharge, and efficient irrigation practices are being promoted to improve sustainability. However, the region's dependency on a single source of water and increasing demands from a growing population and agricultural expansion continue to stress the aquifer system.

Table 5: Aquifer System at Mandvi

Aquifer Type	Material	Depth of Occurrence (m)	Nature of Aquifer	Water type
Aquifer I	Alluvium, Limestone, Manchar/Gaj Series, Basalt, Bhuj Series to Pachchham series	35 to 120	Phreatic	Fresh to Brackish
Aquifer II	Alluvium, Manchar/Gaj Series, Bhuj Series to Pachchham series	33 to 290	Confined	Fresh to Brackish
Aquifer III	Alluvium, Manchar/Gaj Series, Bhuj Series to Pachchham series	110 to 290	Confined	Fresh to Brackish
Aquifer IV	Bhuj Series to Pachchham series	250 to 300	Confined	Fresh to Slightly brackish

Source: CGWB, 2022

As per the Ground Water Resource Estimation (GWRE-2020), the stage of Ground Water extraction of Dwarka (Okhamandal Taluka) is 113.59%, which is considered as **over-exploited**

(CGWB, 2022). Groundwater in Mandvi and Kachchh shows significant variations in water quality, with several parameters exceeding acceptable limits for both drinking and agricultural use. pH levels range from highly acidic (2.9) to slightly alkaline (9), while Total Dissolved Solids (TDS) levels in Mandvi are alarmingly high, i.e., more than 3000 mg/l, indicating high salinity likely due to seawater intrusion (Table 6). Chloride, nitrate, fluoride, and hardness levels also surpass the recommended thresholds, with chloride concentrations exceeding 3000 mg/l in Mandvi, indicating severe salinity issues, while high nitrate levels pose health risks like methemoglobinemia. Fluoride concentrations, exceeding 1.5 mg/l in some areas, could lead to dental and skeletal fluorosis, further complicating water quality.

Table 6: Hydrochemistry of Mandvi

Constituents	Minimum (Kachchh)	Mandvi	Maximum (Kachchh)	Acceptable Range
pH	2.9	NA	9	6.5 to 8.5
TDS (mg/l)	563	>3000	30960	500 mg/l and 2000 mg/l
CO ₃ (mg/l)	12	NA	36	200 mg/l
HCO ₃ (mg/l)	122	NA	1220	200 mg/l
Cl (mg/l)	92	>3000	8400	250 mg/l and 1000 mg/l
NO ₃ (mg/l)	0.1	<45	210	45 mg/l
SO ₄ (mg/l)	4	NA	1220	200 mg/L
F (mg/l)	0.22	0.5 to 1.5	10.1	1 mg/l and 1.5 mg/l
Alkalinity (mg/l)	2.15	NA	1000	200 mg/l
Ca (mg/l)	24	NA	429	200 mg/l
Mg (mg/l)	5	NA	555	100 mg/l
TH (mg/l)	110	NA	2313	200 mg/l
Na (mg/l)	52	NA	9999	200 mg/l
K (mg/l)	0.79	NA	391	10 md/l

Source: CGWB, 2022

These water quality challenges are compounded by high levels of alkalinity, calcium, magnesium, and sodium, contributing to very hard water, which can cause scaling and affect both domestic use and irrigation. Sulphate concentrations above 200 mg/l can affect taste and cause gastrointestinal issues. The combined effects of high salinity, hardness, and contaminants make groundwater in these regions unsuitable for direct consumption or agriculture without significant treatment. Immediate solutions, including desalination, difluorination, and better water management practices, are necessary to mitigate health risks and ensure sustainable water use in Mandvi and Kachchh.

3.3 WATER DEMAND AND SUPPLY

According to the 2011 Census, the population of Mandvi was 51,376, with a total of 10,346 households and seven slum settlements. By 2021, the population had increased to 57,600, with 14,168 households. The city's population density stands at 2,429 persons per square kilometre. Projections indicate that by 2025, the population will reach 62,208, with a total of 15,301 households and 2,036 slum households (AMRUT, 2025). The current water demand in the city is 7.0 MLD, while the available water supply is 9.7 MLD, creating a deficit of 2.7 MLD. According to AMRUT 2025, MMC does not have any water treatment capacity, leaving a future operational gap of 9.7 MLD. Additionally, only 12,438 households have access to tap water connections in 2021, and the projected demand in 2025-26 is 15,301 households, creating a gap of 2,863 households without access to tap water connections in 2025-26 (AMRUT, 2025), as provided in Table 7 below.

Table 7: Household coverage plan for water supply

#	Financial Year	Under AMRUT	Under other Schemes
1.	FY 2022	0	0
2.	FY 2023	0	100
3.	FY 2024	500	200
4.	FY 2025	1,230	300
5.	FY 2026	0	533
Total		1,730	1,133

Source: AMRUT 2.0, MMC

The city supplies 0.5 MLD water to 606 commercial establishments, 1.15 MLD to 1,885 slum households and 7 MLD water is supplied to 12,438 residential households. The average per capita water supply in Mandvi is 138.28 litres per capita per day (lpcd). Future projections indicate a total water demand of 9.7 MLD, with 8 MLD required for residential households, 0.7 MLD for commercial use, 0.5 MLD for institutional and industrial establishments, and 1.25 MLD for slum settlements. As of 2021, 12,438 households had functional tap water connections. Under AMRUT 2.0, Mandvi planned to cover 2,863 additional households in phases from 2022 to 2026. However, the implementation of this plan has not progressed as expected, and the number of household connections remains stagnant. These initiatives remain crucial for improving water supply efficiency and addressing the city's growing water demand.

3.4 WATER INFRASTRUCTURE

Water Treatment Plant: The water from Borewells is sent to the WTP having a total designed capacity of 4.0 MLD. The existing WTP is situated near Rukmavati River Main Head Work (HW). The Narmada Canal water is collected here in raw water UG Sump with Bore Well, where the SUMP capacity is 40 LL. The existing WTP was constructed 15 years ago, however, currently, it is not in working condition. The raw water is directly collected into clear water sump and then water is supplied to each head works. At present, town is getting water without any treatment. Borewell water is directly collected without any primary treatment into Sump and then supplied to HHs. Also, the inspected WTP severely lacks manpower and is in weary condition.

Distribution Network of Water Supply: The MCC receives a daily bulk water supply of 7.0 MLD from two primary sources, viz., Narmada Canal, and ground water (Borewell). The raw water from Borewells flows into the WTP. After treatment, the water is discharged from the WTP outlet and stored in a Ground Level Storage Reservoir (GSR), from where it is distributed to households through the city's network. The existing length of the water supply distribution network is nearly 54 KM. Before being flown into the distribution tributaries, the water is temporarily stored at 7 Elevated Storage Reservoirs (ESRs) and 7 GSRs with a total storage capacity of 67.75 lakh litres (LL). The location-wise operational status is as given in Table 8.

Table 8: Storage Capacity of ESR & GSR at Mandvi

#	Location	ESR Capacity (LL)	SUMP/ GSR Capacity (LL)	Operational Status
1.	ZONE I Near Narmada Sump	1.00	5.00	Working
2.	Zone II Near Mandvi Civil Hospital	8.00 (Under AMRUT)	5.00	Working
3.	Zone III Gamtal Part	6.75	10.00	Working
4.	Nagarpalika HW	5.00	0.00	Working
5.	Near Riverside HW	10.00	5.00	Working
6.	Near St. Xaviour School	3.00 (Under Nal Se Jal Scheme)	5.00 (Under Nal Se Jal Scheme)	Working
7.	Near Power House	1.00	3.00	Not Working
Total Capacity		34.75	33.00	

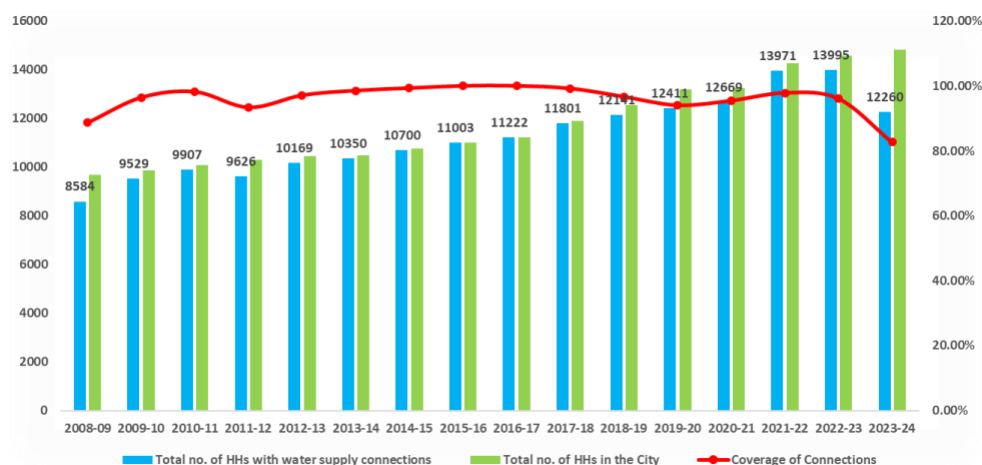
Source: Water Supply DPR, 2021, MMC

Household Piped Water Supply in Mandvi: The coverage of water supply connections in MMC has shown a varied but generally improving trend over the years, reflecting both the progress made and challenges faced in extending water supply services to all households. The data from 2008 to 2023 highlights key periods of growth, as well as some concerning drops in recent years (Fig. 12). Between 2008 and 2016, there was a significant increase in the coverage of water supply

connections. In 2008-09, the coverage was at 88.76%, meaning that nearly 11% of households in MMC did not have access to a direct water supply. Over the next several years, the coverage steadily improved, reaching 100% in 2015-16. This period indicates a substantial effort by MMC to ensure that almost all households received water supply connections, aligning with the CPHEEO benchmark of universal coverage. However, after 2015-16, there has been a noticeable decline in the coverage of water supply connections. In 2023-24, the coverage stands at 82.74%, a sharp drop from the 100% coverage achieved in 2015-16. This drop of 17.26% below the benchmark is concerning, as it suggests that some households may have been removed from the water supply grid or are facing issues with connection maintenance, new installations, or quality of service. The decrease could be attributed to a variety of factors, including population growth, infrastructure limitations, or inefficiencies in the water supply network.

The CPHEEO benchmark for water supply coverage is 100%, which MMC had achieved by 2015-16, but the subsequent decline below this benchmark highlights significant challenges in maintaining or expanding water supply services to meet the needs of an increasing population. The coverage of 82.74% in 2023-24 is far from ideal and is particularly concerning because it reflects a reduction in service rather than an expansion. This trend is out of step with the benchmarks, suggesting that while there was progress in earlier years, sustaining and expanding access to water supply is a challenge that needs urgent attention. Several factors could explain the drop in the coverage of water supply connections in recent years. One possibility is that the infrastructure, originally designed for a smaller population, is struggling to keep up with the demands of a growing urban population. Mandvi's population has been steadily increasing, from 9,671 in 2008-09 to 14,817 in 2023-24, which puts pressure on the existing water supply system. Without sufficient upgrades or expansions to the distribution network, new households may not be getting connected as expected.

Figure 12: Coverage of Water Supply at MMC



Source: MMC, 2025

Additionally, economic factors, budget constraints, or issues related to the procurement and installation of infrastructure could be contributing to the stagnation or decline in the number of

households with connections. There may also be technical challenges related to the last-mile connectivity, where the infrastructure is in place but certain areas remain underserved due to logistical or environmental barriers. Mandvi Municipal Council's performance in terms of water supply connection coverage has been commendable in the past, with the city achieving universal coverage in 2015-16. However, the decline in recent years to 82.74% coverage in 2023-24 is alarming and signals the need for greater attention to both infrastructure expansion and maintenance. MMC should focus on addressing the causes of this decline, which may involve upgrading and expanding the water distribution network, improving efficiency, and ensuring that all households, especially those in expanding or underserved areas, are brought into the water supply fold. Sustainable development practices, along with increased investment in water supply infrastructure, will be key to meeting the CPHEEO benchmarks and providing equitable access to water for all residents.

Tariff structures for Water Supply in Mandvi: The water supply in Mandvi operates under a flat tariff system, where consumers are charged based on the monthly water tariff. The monthly residential and institutional tariff is INR 60/month, commercial tariff is INR 200/month, and industrial tariff is INR 600/month. For a new water connection, the charges are as given below in Table 9.

Table 9: New Water Connection Charges in Mandvi

#	New Connections	Charges (INR)
1.	Residential – General	1,520.00
2.	Residential - Urban Poor	1,520.00
3.	Institutional	1,520.00
4.	Commercial	3,200.00
5.	Industrial	8,000.00

Source: MMC , 2025

Moreover, the sanctioned intake staff capacity at MMC is 10, however, the current working staff capacity is only 2. The sanctioned Engineering staff intake is 1, and no one is working against the intake capacity. There are no linemen/ plumbers against the sanctioned intake capacity of 2, whereas, there are only 2 labourers working against the sanctioned intake capacity of 7.

3.5 KEY CHALLENGES

Mandvi faces several critical challenges in its water supply system, including a significant gap between current performance and national benchmarks. Despite a relatively high coverage rate of 82.74%, the municipality falls short of the CPHEEO target of 100%, and the per capita water supply (120.72 lpcd) is below the ideal 135 lpcd. The lack of metered connections (0%) hampers accurate billing and efficient resource management, while the low continuity of supply (0.5 hours per day) and operational inefficiencies, such as a cost recovery rate of only 29.6%, exacerbate the situation. Although the quality of potable water meets standards, there is a need for improvements in metering, non-revenue water reduction, and financial sustainability. Additionally, the city's water treatment plant is underused and lacks sufficient staffing, resulting in untreated water being supplied to residents. The distribution network's coverage has also declined from 100% in 2015-16 to 82.74% in 2023-24, indicating difficulties in maintaining infrastructure for a growing population. Addressing these challenges requires substantial investments in infrastructure, better management practices, and enhanced revenue collection systems to meet future demands.

CHAPTER 4: URBAN SANITATION SYSTEMS IN MANDVI: STATUS, INSTITUTIONS AND CHALLENGES

NEELAM RANA, PRIYAKSHI GOGOI, AND NC NARAYANAN

4.1 BACKGROUND

Climate risks are significantly exacerbated by inadequate infrastructure in critical, interlinked sectors such as water and sanitation —disproportionately affecting socio-economically disadvantaged communities (Rumbach, 2018); (Yenneti, Tripathi, Wei, Chen, & Joshi, 2016); (Central Pollution Control Board, 2021). **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** (Braks & Husman, 2013). WaSH services are essential for preventing disease outbreaks, particularly in the aftermath of climate hazards such as heavy rainfall and flooding (Carlton et al., 2014; Jones et al., 2020)³²³³. 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 scenarios** (Cutter et al., 2012)³⁴. 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 role in building climate resilience (Caretta et al., 2022)³⁵.

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 practices.' (Ministry of Urban and Housing Affairs, 2008, p. 6)³⁶. 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 Mandvi. 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** 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 use (UNICEF, 2020)³⁷Refer figure 13.

- **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 10,346 households in the area, 191 households did not have **access to individual toilets**. However, according to recent information from the Mandvi Urban Local Body (March 2025), which is SLB 2023-24, confirms that all households now have individual toilet facilities. The town has been officially declared Open Defecation Free Plus (ODF++), in line with the SLBs set by the Government of India and the SDG Target 6.2.

However, our field observations in March 2025 revealed certain discrepancies. For instance, one settlement—reported by residents to have existed for at least a decade and primarily inhabited by daily wage labourers—continues to lack access to individual toilets and a reliable tap water supply. In addition, residents face inadequate and substandard housing conditions, underscoring persistent gaps in basic service delivery and infrastructure. When asked about their sanitation practices, **residents reported continuing to practice open defecation as they do not have access to the public or community toilets.** For water needs, a local Civic Society Organization provides free supply via water tankers. This means the city is not fully complying with the ODF++ certificate conditions.

Detailed information on toilet typologies is essential—not only to evaluate the quality and adequacy of sanitation services but also to accurately estimate the GHG emissions associated with different sanitation systems. However, the most recent comprehensive assessment was conducted during the 2011 Census, and no updated data has been made available since, at the national, state, or city levels. Gathering this information would necessitate a dedicated household-level survey, which lies beyond the scope of routine assessments.

Photo 1 : Settlements without piped water supply and toilet facilities



Source: IITB team

Photo 2 : Private Water Tanker Supply to Low-income Settlement



Source: IITB team

- **Community Toilets and Public Toilets³⁸:** According to information from the ULB, which aligns with data from the SBM Urban dashboard, the city currently has two community toilets (CTs) and three public toilets (PTs). The two CTs are located in Ward 2, while the PTs are situated in Wards 2, 6, and 9. 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**.

The ULB officials stated that the **locations of these** public toilets were strategically chosen based on the footfall and the public's need for a dedicated public toilet. Additionally, two Aspirational Public Toilets, under the SBM 2.0, are under construction near ward 2 and 4. According to ULB officials, these areas were selected because unused ULB land is often at risk of encroachment by individuals or other departments; however, this rationale should not override more pressing priorities—particularly when communities of approx. **15 households** residing in the area still **lack access to basic sanitation facilities**.

To assess the condition of community and public toilets, we spoke with ULB officials, who reported that the facilities are in good condition and well maintained. To verify these claims, our team visited 1 community toilet out of two and all three public toilets. During our visits, we observed that both toilets were indeed clean, well maintained, and had access to running tap water. Water supply to all these toilets is managed by the municipality through direct piped tap connections. However, the ULB does not maintain any formal records of cleaning activities. During our visit to the community toilets in March 2025, we observed that one of the facilities is located

within a town hall campus and is primarily used during events held at the venue. Relocating or establishing additional toilets closer to communities that currently lack access to sanitation facilities could enhance the effectiveness and utilization of public sanitation infrastructure, ensuring it better serves local needs.

Photo 3 : Public Toilet in Mandvi



Source: IITB team

Photo 4 : Community Toilet in Mandvi City



Source: IITB team

- **Containment:** According to data provided by the ULB, as of 2022 (SLB 2021-22), the city had a total of 21,376 properties. Of these, 14,271 properties were connected (66.8%) to the sewerage network, while 6,805 properties (31.8%) relied on OSS systems equipped with septic tanks with soak pits. Field observations also revealed that even low-income areas have been connected to the sewerage network. However, the quality of service in these areas remains poor. During a site visit to one such low-income neighbourhood, visible overflow was observed in the sewerage connections. Moreover, residents reported that during the monsoon season, the area frequently experiences flooding because of heavy rain and inadequate drainage system, causing sewage water to enter their homes. This highlights significant gaps in both infrastructure maintenance and service delivery in vulnerable communities.

Understanding the typology of OSS is crucial for accurately assessing GHG emissions. We inquired with ULB officials about the availability of such data; however, they were unable to provide any. Consequently, collecting this information would require a dedicated household-level survey, which falls beyond the scope of the current project.

Photo 5 : Sewage Overflowing in High Density Low-Income Areas



Source: IITB team

- **Emptying and Transport:** Currently, the city has a 25 years old sewerage network connection with 4 pumping stations. As mentioned in the previous section, currently, the city's sewerage network covers 68.1% of households, and approximately 31.8% of properties rely on septic tanks with soak pits, which are emptied by a single vacuum truck owned by the ULB, with a capacity of 4,500 liters. Households are charged between INR 2,000 and 3,000 per trip for septic tank cleaning services, depending on the distance. Commercial establishments pay higher fees, ranging from INR 3,000 to 5,000 per trip. The frequency of residency clean is 5 to 6 trips per day. In some cases, the total cost can escalate to INR 15,000 if multiple trips are required. The city also has 2 to 3 private operators who charge between INR 1,500 and 2,000 per trip for sludge removal. However, the ULB prohibits these operators from disposing of sludge in the oxidation ponds. Instead, they are required to dispose of it at the nearest STP. Operators who deposit sludge within city limits without authorization are subject to fines imposed by the ULB.

As per the ULB officials, the wastewater from CT and PT gets collected in the sewerage network.

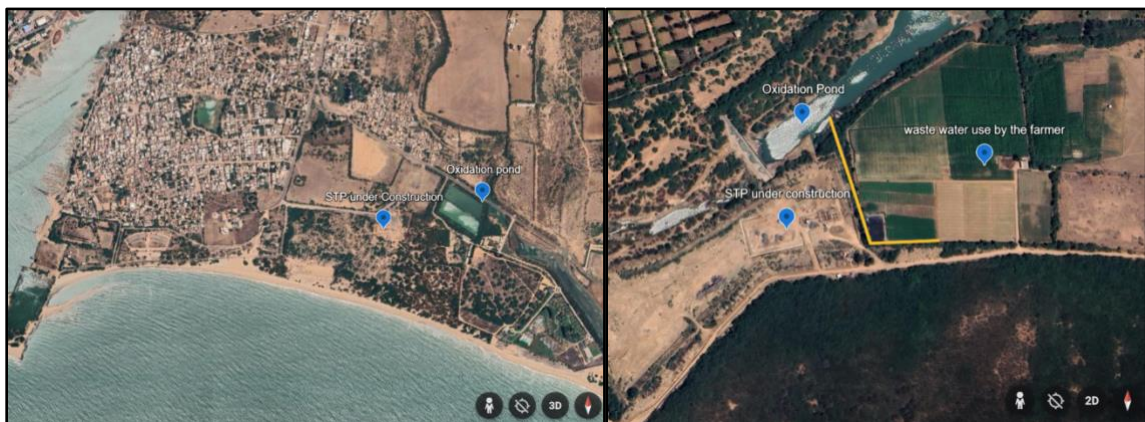
The city has a stormwater drainage network (*pucca*) that spans 5.5 km, covering only 6.29% of the total 87.5 km road length, according to the SLB - 2023-2024 data. This is evident from our field observations, which revealed significant poor drainage specifically in low-income areas during the rainy season. These areas are frequently affected by flooding due to heavy rain and inadequate storm water drainage, which impacts their housing, sanitation and water infrastructure. However, beyond this coverage figure, there is a lack of secondary data on the drainage network's typology or its potential GHG

emissions. Assessing these aspects would require in-depth technical studies, which are beyond the scope of the current study.

- **Treatment:** According to the SLB 2021-22 report, the town generates 5.9 million litres per day (MLD) of wastewater but lacks its own STP. Currently, wastewater is diverted to two Oxidation Ponds via the sewerage network, and a single vacuum truck owned by the ULB is used for collection and transport. Under the AMRUT 2.0 scheme, the Gujarat Water Supply and Sewerage Board (GWSSB) is constructing two STPs near the existing oxidation ponds. These new STPs will have treatment capacities of 3.2 MLD and 5.5 MLD, respectively.

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.

Figure 13 : Location of Oxidation Ponds and Under Construction STP



Source: Location Plotted on Google Earth

- **End-use Disposal (Septage and Sludge Management)**³⁹: The city currently lacks a dedicated Faecal Sludge and Septage Treatment Plant (FSSTP). Instead, it relies on 1 vacuum truck owned by the ULB and also private vacuum trucks. The septage collected by these trucks is transported to two oxidation ponds.

Photo 6 : Oxidation Pond in Mandvi



Source: IITB team

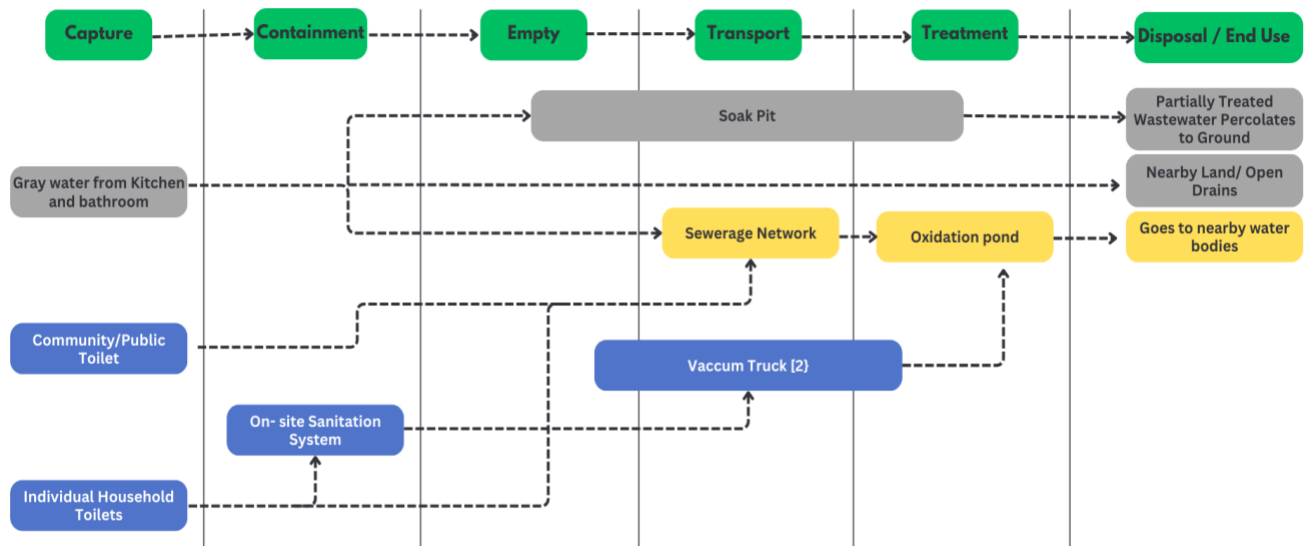
- **Recycling and Reuse:** The town currently lacks the necessary infrastructure to recycle or reuse its wastewater and sludge . The wastewater is directed to two oxidation ponds, and farmers use this water for agricultural purposes.

Photo 7 : Wastewater Usage in Agriculture



Source: IITB team

Figure 14 : Sanitation Service Chain in Mandvi



Source: Authors' Illustration

4.3 INSTITUTIONAL ARRANGEMENTS

This section explores the institutional arrangements for sanitation governance, highlighting the roles of various departments, agencies, and organizations involved in delivering sanitation infrastructure and services (refer table 10). It underscores the pivotal role of ULBs in disaster governance and their broader responsibilities within India's multi-level governance framework. Sanitation is constitutionally a state subject, with ULBs designated as the primary entities responsible for water supply and sanitation services under the 74th Constitutional Amendment Act. However, in practice, sanitation governance involves a complex multi-stakeholder framework spanning national, state, and city levels.

At the household level, neither ULB nor other institutions are actively involved in enforcing standards for toilets or OSS systems. For larger establishments, compliance mechanisms exist through building plan approvals managed by state-level agencies like GWSSB.

At the ULB level, smaller sanitation interventions like PTs and CTs 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 15th Finance, capital

funding was provided for all the PTs. Some PTs have outsourced their O&M to private vendors, who recover the costs through user charges.

ULBs serve as nodal agencies for delivering sanitation services, but their involvement in large-scale infrastructure projects such as STPs is often constrained. While the **Mandvi ULB** has the authority to **engage consultants and prepare Detailed Project Reports (DPRs)** for establishing the sewerage network, the **approval and finalization** of these projects rest with the **Gujarat Urban Development Mission (GUDM)**, and implementation is carried out by the **Gujarat Urban Development Company (GUDC)**. The state has the discretion to modify or reject DPRs submitted by ULBs if they do not align with state priorities or technical standards. And for STP GWSSB is responsible for its implementation.

Moreover, the funding for such projects largely comes from central government schemes like Atal Mission for Rejuvenation and Urban Transformation (AMRUT)- 1.0, with the selection of technology, approval, and implementation overseen by state-level agencies such as the Gujarat Urban Development Company. This centralized approach limits the autonomy of ULBs, making them dependent on higher tiers of government for both financial resources and critical decision-making in infrastructure development

Table 10 : Institutional Arrangements: Sanitation Services

Intervention	Technology Selection	Land	Capital	Technology Provision	Technology implementation	O&M	O&M Funding
Toilets	HH	HH	HH	Local mesons/private vendors	Local mesons/private vendors	HH	HH
OSS	HH	HH	HH			HH	HH
						Septage removal by vehicles of ULB and private operators	
PT	ULB	ULB	Central Government (14th and 15th Finance commission) ULB own Sources	ULB	ULB	ULB	ULB Own Source
CT	ULB	ULB	Central Government (14th and 15th Finance commission) ULB own Sources	ULB	ULB	ULB	ULB's Own Source
Sewage Network Connection	GWSSB	NA	State Fund	GWSSB	GWSSB	ULB	ULB's own source

Source: (Rana, Gogoi, & Narayanan, Forthcoming)⁴⁰

Furthermore, in terms of disaster management, during flood events, the municipality is responsible for dewatering waterlogged areas to restore normal conditions. In the case of cyclones, they implement early warning systems to alert residents and coordinate preparedness measures. The municipality organizes evacuation programs to move people to safe locations, arranges food and temporary accommodation, and ensures the provision of water and sanitation facilities. According to the ULB official planning is done in advance by estimating the population, segregating by gender, age, and vulnerability, and accordingly preparing for food distribution and shelter needs.

The District Disaster Management Authority (DDMA) informs the ULB about impending disasters, and existing municipal staff are expected to manage their respective duties, though they do not have a dedicated disaster response team in the ULB. After evacuation, the municipality continues to provide essential services like water and sanitation in temporary shelters. During Cyclone Biparjoy, the municipality reported that they provided sufficient support to impacted people, deploying disaster response teams, and ensuring the safety of vulnerable groups. However, field visits revealed discrepancies: residents claimed that official assistance was limited, with only a one-time payment of INR 2,500 from the government, and that most relief—such as food, water, and shelter—was organized by local community committees rather than the ULB.

4.4 CHALLENGES AND OPPORTUNITIES IN SANITATION INFRASTRUCTURE AND SERVICES

It is clear that 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.

1. **Ensuring Reliable and Equitable Delivery of Improved Water and Sanitation Services:** The city's **ODF++ status** represents a notable milestone in sanitation management; however, **significant gaps persist**, particularly in **vulnerable communities**. Further, residents report **serious water quality issues**, including **increased turbidity during the monsoon**, a **persistent raw fish-like odour**, and a **muddy taste**. These indicators point to **poor maintenance and potential inefficiencies in the operation of the local water treatment plant**. Addressing these deficiencies is important not only for public health and dignity but also for building climate resilience against floods, water scarcity, and salinity intrusion.
- **Enhancing Urban Flood Management through Robust Drainage:** In high-density, low-income neighbourhoods, inadequate drainage systems were observed, contributing not only to recurring flooding during the monsoon season but also exacerbating public health risks. Flooding can lead to the contamination of water sources, promote the spread of waterborne

diseases like cholera and typhoid, and exacerbate existing health conditions such as respiratory and vector-borne diseases (e.g., malaria and dengue). The lack of proper drainage infrastructure thus directly impacts the health and well-being of vulnerable populations, underlining the need for integrated approaches that address both urban planning and public health resilience.

Photo 8 : Flood Vulnerable Densely Populated, Low- income areas



Source: IITB team

- **Inefficient Sewage Treatment and Management:** Site visits uncovered significant malpractices in sewage management, including the discharge of effluent from the oxidation pond into nearby natural water bodies. Foam-like substances were also observed accumulating on the water's surface. This could potentially lead to groundwater contamination and pose risks to public health and local biodiversity. Ultimately, this polluted water makes its way to the sea, threatening marine ecosystems. Further, this partially treated sewage may also be a potential source of GHG emissions.

To build climate resilience, it is essential to address these environmental hazards by establishing a comprehensive sewage treatment facility that not only mitigates water pollution but also strengthens the region's ability to adapt to climate-induced changes, safeguarding both public health and the environment.

Photo 9 : Flood Vulnerable Densely Populated, Low- income areas



Source: IITB team

- **Reliable Water and Sanitation Services During Disasters:** The city is prone to cyclones and recurring floods. Access to safe shelters, clean water reserves, reliable sanitation, and pre-positioned relief supplies is essential for strengthening community resilience and protecting public health during disasters. Although the ULB has outlined its commitment to disaster response, residents shared that during cyclones and floods, they often relied on local committee volunteers or made personal arrangements to secure necessities such as food, water, and shelter.

Building on these existing community networks and efforts, there is an opportunity to further strengthen disaster response by establishing permanent, well-equipped emergency facilities managed by trained personnel. Such infrastructure would help ensure timely and equitable access to essential services, reinforcing the city's preparedness for future climate-related events.

- **Climate-Resilient Infrastructure Planning:** Cyclones can cause widespread power outages, disrupting critical services such as water supply and sewage management, as witnessed during Cyclone Biparjoy. To enhance resilience, the ULB needs to invest in reliable power backup systems to ensure the continuity of essential services during extreme weather events.
- **Resources Constraints:** Interviews with the ULB revealed two closely linked challenges undermining the ULB's capacity to deliver quality services: financial constraints and human resource management issues. Officials indicated that, similar to many ULBs across India, the Mandvi ULB faces significant financial constraints that limit its ability to cover essential operational expenses, including electricity costs for the Water Treatment Plant (WTP) and Sewerage network pumping stations. As a result, the ULB remains heavily reliant on state-

level grants, particularly under schemes such as the Swarna Jayanti Mukhya Mantri Sahari Vikas Yojana, to sustain these critical urban infrastructure services.

This dependence reflects broader challenges faced by ULBs nationwide, where limited own-source revenues and fiscal capacity necessitate ongoing support from higher tiers of government to maintain basic service delivery and infrastructure operations (discussed in detail in the *financial health* chapter). This situation exemplifies a widespread challenge among Indian ULBs, where constrained finances lead to dependence on state and central funding, limiting their operational independence and efficiency in service delivery.

Additionally, the official highlighted a critical human resource challenge: insufficient staffing levels to manage the workload effectively. This shortage hampers timely completion of tasks, as staff must balance implementation duties with equally important administrative paperwork, causing delays and inefficiencies. This reflects broader issues in ULB workforce capacity, where inadequate human resources impede both operational and administrative functions necessary for effective urban service management. Together, these financial and human resource challenges create a cycle that limits the ULB's ability to enhance service quality and responsiveness—reflecting broader systemic issues faced by many urban local bodies across India. These constraints not only impact day-to-day governance but also weaken the ULB's capacity to effectively respond to climate-related emergencies, highlighting the need for strengthened institutional support and capacity building.

- **Strengthening Monitoring and Regulation Mechanisms for Effective Sludge/Septage Management:** The ULB manages septic tank emptying through one vacuum truck, while two to three private operators also provide desludging services. Although these private operators are not formally licensed, they have obtained No Objection Certificates (NOCs) from the ULB, allowing them to operate under specific conditions. They are permitted to use their trucks for desludging but are prohibited from disposing of the waste within city limits or at the oxidation ponds. Instead, they are required to transport the sludge outside the city for disposal. According to ULB officials, the preferred disposal sites are old, dried-up ponds. However, there are concerns regarding the enforcement of these guidelines, as it remains unclear whether all operators consistently follow the stipulated practices. This raises the risk of improper disposal, including potential dumping of sludge into local water bodies, posing environmental and public health risks. Strengthening monitoring and regulatory mechanisms would be essential to ensure safe and compliant desludging practices.

CHAPTER 5: GHG EMISSIONS FROM URBAN WATER AND SANITATION SYSTEMS IN MANDVI

ASHISH DANGI⁴¹ AND NC NARAYANAN

5.1 BACKGROUND

The water sector is not just a victim of climate change; it is also a significant contributor to GHG emissions. Energy is a key input in the management of the urban water services. Conventional water and wastewater systems are energy dependent systems that contribute to indirect carbon emissions and water withdrawals for energy generation. Similarly, wastewater treatment processes emit methane and nitrous oxide, potent GHG that further drive climate change. As local water availability declines, cities increasingly depend on energy-intensive alternatives such as long-distance water transfers and advanced treatment technologies, driving up energy use and carbon emissions. This, in turn, exacerbates climate change, intensifying the very impacts these measures aim to address. By examining the entire water cycle including sourcing, treatment, distribution, wastewater management, and the associated material and energy flows, this chapter highlights the critical linkages between water, sanitation, and climate resilience. Understanding these connections is essential for developing a sustainable and adaptive urban water management strategy.

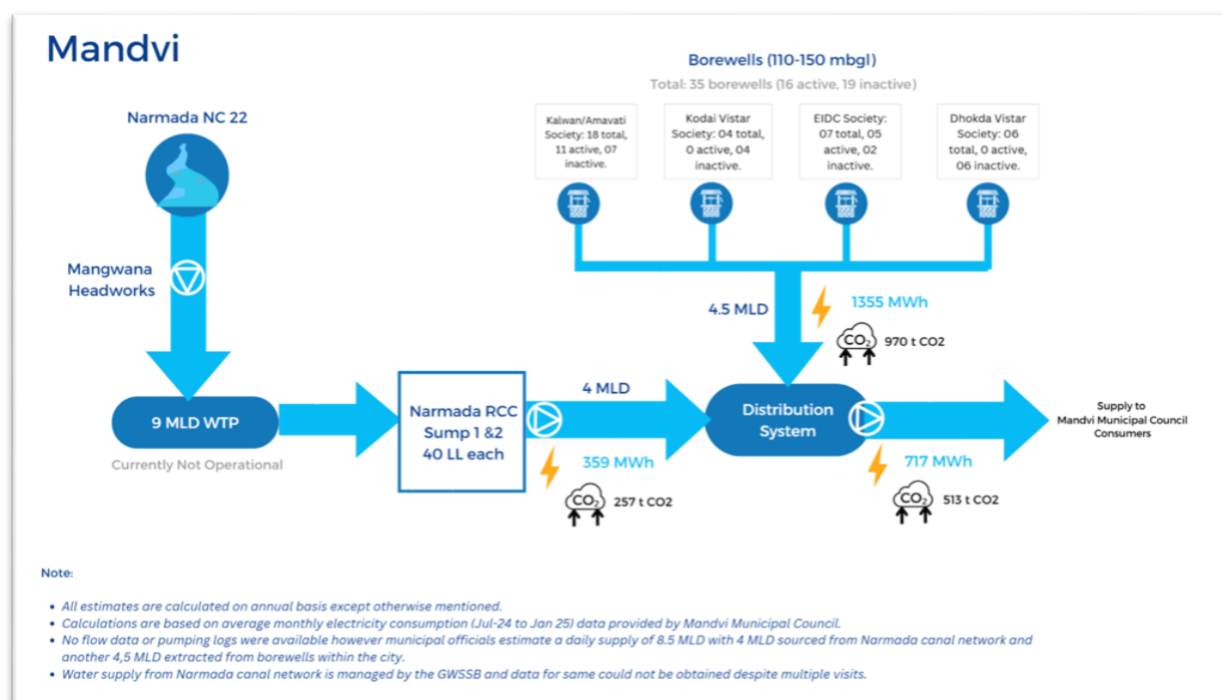
As cities strive to meet rising water demands, they are often locked into a cycle of increasing energy consumption and emissions. The push for climate resilience must therefore consider not only how water systems are impacted by climate change but also how they contribute to it. This chapter assesses the carbon footprint of existing water and wastewater management practices in MMC, highlighting the energy dependencies and emissions associated with each stage of the water cycle. By quantifying these emissions, the assessment aims to provide insights into the trade-offs between different management strategies and explore opportunities for decarbonising urban water systems. A shift towards more energy-efficient practices, integration of renewable energy, and nature-based solutions can help mitigate emissions while ensuring long-term water security. Understanding these dynamics is essential in designing sustainable water management systems that align with both climate adaptation and mitigation goals.

5.2 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 sediments⁴². However, these are excluded from this analysis given methodological limitations. This section focuses solely on electricity-related emissions across key components of the water supply chain, as shown in **Figure 15**.

Figure 15 : Carbon and energy footprint of Mandvi's water supply



Source: (Dangi & Narayanan, forthcoming)⁴³

The Mandvi municipal water supply system depends on two primary sources: the **Narmada NC-22 Canal** and a network of **borewells** within the city. Water from the Narmada system passes through the Mangwana Headworks and is routed to the **9 MLD Water Treatment Plant (WTP)**, which is currently **non-operational**. Instead, the supply is managed via **RCC sumps** (40 lakh litres each) and active borewells.

According to municipal estimates, Mandvi supplies approximately **8.5 MLD of water daily**, split between **~4 MLD from the Narmada system** and **~4.5 MLD from borewells**. Due to the absence of flow logs, these figures are indicative rather than measured.

The energy and emissions profile of the system reveals three significant components:

- **Narmada RCC sumps to distribution:** Annual energy use of **359 MWh**, resulting in **257 tonnes of CO₂ emissions**.
- **Borewell extraction (16 active of 35):** Annual consumption of **1,355 MWh**, equivalent to **970 tonnes of CO₂ emissions**.
- **Distribution pumping within the network:** Annual consumption of **717 MWh**, corresponding to **513 tonnes of CO₂ emissions**.

Together, the Mandvi system consumes approximately **2,431 MWh annually**, producing an estimated **1,740 tonnes of CO₂ emissions**.

It is important to note that these estimates **exclude the energy required for abstraction at the Mangwana Headworks**, as no data was available despite multiple attempts to obtain it. Similarly, with the **9 MLD WTP not operational**, no treatment-related energy or emissions are reported. As such, the presented figures represent only part of the overall emissions footprint of Mandvi's water supply system.

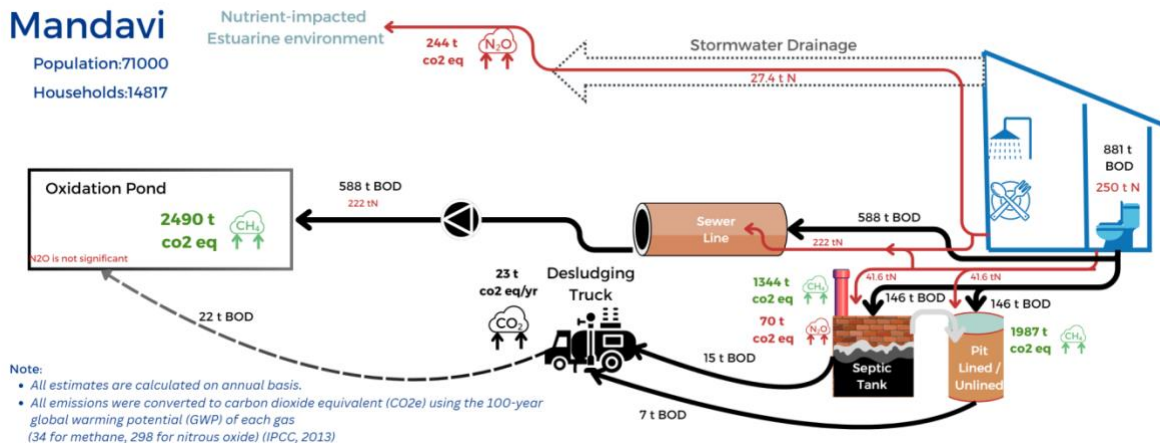
The lack of reliable upstream data underscores the need for improved monitoring of energy use across all stages of water supply. Without a complete dataset, it is not possible to determine whether groundwater extraction or canal-based supply is more energy- or carbon-intensive.

5.3 GREENHOUSE GAS EMISSIONS FROM SANITATION

Energy plays a crucial role across the sanitation service chain, particularly in the treatment and transportation of wastewater and sludge, leading to indirect GHG emissions linked to electricity consumption. Wastewater treatment plants alone are estimated to account for 3% global electricity consumption⁴⁴. 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 WWTPs⁴⁵. With the increased variability posed by climate change the emission in WWTPs could further increase⁴⁶. 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) emissions. Direct emissions in wastewater treatment are significant at ~1.57% of global GHG emissions⁴⁷.

An assessment of the carbon footprints is thus important for understanding not only its implication for sustainability of the sanitation systems but also for energy security and climate mitigation due to growing evidence on rising emissions.

Figure 16 : Carbon footprint estimation of Urban Water Cycle



Source: (Dangi & Narayanan, forthcoming)⁴³

The **figure 16** presents the energy consumption and carbon emissions associated with water wastewater management in Mandvi. The flow diagram reveals that even for a small town, urban water services quickly become a significant climate actor.

- **Wastewater treatment:**

- Nearly 67 % of the city's wastewater is contained in a sewer network which pumps it to two oxidation ponds for treatment.
- **Oxidation pond treatment of 588 t BOD produces a significant 2,490 t CO₂-eq of methane (CH₄). As per IPCC, N₂O emissions from stabilisation ponds are not significant.**
- The **Septic tank systems (including pit latrines) add 1,334 t CO₂-eq of methane and contribute to the carbon footprint of the wastewater system.**

- **Onsite Sanitation:**

- The **septic tank systems** contribute to **1,334 t CO₂-eq of methane plus 70 t CO₂-eq of N₂O.**
- Leaky, unlined **pits** release an estimated **1,987 t CO₂-eq of CH₄** each year

- **Desludging operations:**

- **Desludging trucks** contribute around **23 t CO₂-eq/yr**, further adding to the carbon load, though this remains a smaller source compared to other points in the system.

- **Stormwater drainage:**
 - **Stormwater flows** contribute **27.4 t N** of nutrients to the environment, generating **244 t CO₂-eq of N₂O** through the drainage system.

Mandavi demonstrates the importance of **integrating on-site sanitation management** with **wastewater treatment** processes. The primary source of emissions is **methane from septic tanks**, highlighting a major opportunity for **improved desludging schedules** and **methane capture**. Also, upgrading **pit liners**, improving **sanitation network coverage**, and **greening the oxidation pond** could help mitigate the town's carbon emissions. The chapter underscores the need for holistic approaches to wastewater management, considering both **water supply and sanitation** as critical for enhancing **climate resilience** while reducing carbon footprints.

5.4 CONCLUSION AND STRATEGIC PRIORITIES

The carbon footprint assessment of the Mandvi Municipal Council (MMC) reveals a pressing dual challenge: the town must adapt its water systems to declining local availability while simultaneously curbing the significant greenhouse gases these systems produce. Understanding these dual dynamics is the first step toward transforming Mandvi's water infrastructure from a climate liability into a resilient, low-carbon network.

KEY TAKEAWAYS

- **The Heavy Cost of Groundwater Extraction:** Mandvi's water supply is highly energy-dependent, generating an estimated 1,740 tonnes of CO₂ annually. Over half of this energy burden (1,355 MWh) comes directly from borewell extraction. Furthermore, with the 9 MLD WTP non-operational and critical upstream data missing, the actual energy and carbon footprint of the water supply is likely much higher.
- **Oxidation Ponds as Methane Hotspots:** While achieving 67% sewer network coverage is a commendable public health milestone, routing this wastewater to open oxidation ponds creates a massive climate burden. The biological degradation in these ponds accounts for a staggering 2,490 tonnes of CO₂-eq in methane emissions annually.
- **On-Site Sanitation Deficits:** Decentralized containment remains a major emission driver. Unlined pits and traditional septic tanks collectively release over 3,300 tonnes of CO₂-eq in methane, proving that on-site systems require as much active management as the centralized sewer network.
- **The Stormwater Nutrient Trap:** Unmanaged stormwater flows are depositing significant nutrient loads (27.4 tonnes of nitrogen) into the local environment, which converts into 244 tonnes of CO₂-eq of potent N₂O.
-

THE WAY FORWARD

To align local water security with global climate mitigation goals, Mandvi must pivot from energy-intensive, open-loop systems to optimized, resource-efficient management. Key strategic priorities include:

1. **Modernise Wastewater Treatment:** MMC must rethink its oxidation ponds. Introducing methane capture technologies, aeration upgrades, or greening the ponds can drastically reduce fugitive emissions, turning Mandvi's high sewer coverage into a genuine climate asset.
2. **Optimise Supply and Close Data Gaps:** Bringing the 9 MLD WTP back online and installing comprehensive flow meters across the Narmada and borewell networks is essential. You cannot manage what you do not measure. Transitioning high-draw borewells and distribution pumps to solar energy will also immediately slash the town's massive electricity-related carbon footprint.
3. **Upgrade On-Site Containment:** For the ~33% of the city not covered by the sewer network, a systematic program to line open pits, upgrade septic tanks, and optimize vacuum truck desludging schedules will capture fugitive methane at the source.
4. **Integrate Nature-Based Stormwater Solutions:** Deploying green infrastructure—such as bioswales or constructed wetlands—can naturally filter nutrient runoff before it enters the environment. This prevents the generation of N₂O emissions while buffering the town against extreme rainfall and urban flooding.

Ultimately, securing Mandvi's long-term water future requires looking beyond just providing drops at the tap. By addressing these specific emission hotspots, the municipality can build an urban water cycle that is both ecologically sustainable and deeply climate-resilient.

CHAPTER 6: PERFORMANCE AND FINANCIAL ANALYSIS OF WATER SUPPLY AND SANITATION AT MANDVI MUNICIPAL COUNCIL

ABHAY JUNAGHARE⁴⁸ AND NC NARAYANAN

6.1 BACKGROUND

This chapter analyses the revenue streams and grants available to Mandvi Municipality 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)⁴⁹. The above given ratios are essential to identify the financial health of the water utility and sewerage & sanitation at ULB.

6.2 PERFORMANCE ANALYSIS: SERVICE LEVEL BENCHMARKS

6.2.1 WATER SUPPLY

The analysis of water supply indicators at MMC reveals several notable gaps when compared to CPHEEO benchmarks and the national average for 2023-24 (Table 11). These gaps suggest areas where the council's performance deviates from optimal standards, and each of these areas requires targeted interventions to improve service delivery and efficiency. MMC has a coverage rate of 82.74%, which falls short of the CPHEEO benchmark of 100%. This gap of -17.26% indicates that a significant proportion of households in Mandvi still lack direct water supply connections. The national average of 70% highlights that MMC is doing better than the country as a whole, but there is still substantial room for improvement to achieve universal coverage. MMC provides 120.72 litres per capita per day (lpcd), which is below the CPHEEO benchmark of 135 lpcd. This shortfall of 14.28 lpcd indicates that while MMC's water supply is relatively adequate, it still does not meet the ideal quantity. Compared to the India average of 114 lpcd, Mandvi's performance is slightly

better but still below the target level of sufficiency. Addressing this gap would require increasing water production or optimizing distribution efficiency to meet the demand.

Table 11: Performance Indicators for Water Supply at MMC

#	Water Supply	Calculations	Benchmarks	India Average*	2023-24*	Gaps
1.	Coverage Connections	(Total no. of HHs with water supply connections)/(Total no. of HHs in the City)	100%	70.00%	82.74%	-17.26%
2.	Per capita supply (lpcd)	(Water supplied)/(Population served)	135 lpcd	114 lpcd	120.72	14.28 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%	0.00%	-100.00%
4.	Non-revenue water (NRW)	(Total water produced) - (Total water sold)/(Total water produced)	15%	31%	17.78%	-2.78%
5.	Continuity of water supply (hours)	Average hours of water supply	24 hours	2.7 hours	0.50	23.10 hours
6.	Quality and treatment	(Number of samples that meet the specified potable water standards)/(Total number of water supply related complaints received)	100%	95%	100.00%	0.00%
7.	Redressal of customer complaints	(Total number of complaints redressed)/(Total number of water supply related complaints received)	80%	89%	97.76%	17.76%

Source: * CPHEEO Guidelines for 24x7 WSS (Drink from Tap), Dec 2021; ** MMC, 2025

The indicator for extent of metering, highlights a severe gap, as MMC has no metered connections (0%) while the CPHEEO benchmark is 100%. Metering is essential for accurate billing, leak detection, and water conservation. The India average of 22% indicates that there is some progress in other areas of the country, but Mandvi has not made any headway in this area. The lack of metering can result in inefficiencies and financial losses, and it is crucial to implement a system of metered connections to improve revenue collection and resource management. With a NRW rate of 17.78%, MMC's performance is closer to the CPHEEO target of 15%, though still slightly higher. However, the gap of -2.78% suggests that MMC is losing water through leaks, illegal connections, or inefficiencies in the distribution system. The India average of 31% is much higher, indicating that MMC is doing better than most other parts of the country. Nevertheless, reducing NRW should remain a priority to ensure the efficient use of water resources. The average water supply duration in Mandvi is only 0.5 hours per day, significantly lower than the CPHEEO benchmark of 24 hours. This represents a staggering gap of 23.10 hours. While the national average of 2.7 hours also shows limited water supply continuity, MMC's situation is far more critical. Improving supply duration is essential to meet basic domestic needs and improve public health and sanitation standards.

MMC's water supply meets potable water standards in 100% of cases, aligning perfectly with the CPHEEO benchmark of 100%. This indicates that the water quality is satisfactory, and treatment processes are functioning well. The India average of 95% shows that MMC is performing at par or even better than many other municipalities in ensuring safe drinking water quality. This is a strong point of MMC's water supply management. MMC has an impressive record for Redressal of Customer Complaints, with 97.76% of water supply-related complaints being redressed. This surpasses the CPHEEO benchmark of 80% and is also better than the national average. However, there is still a minor gap of 17.76% compared to the benchmark, suggesting room for improvement in ensuring that all complaints are addressed in a timely manner. This metric is important for maintaining public satisfaction and trust in the water supply system. The analysis reveals that while MMC performs relatively well in some areas, such as water quality and customer complaint resolution, there are significant gaps in some key performance indicators.

6.2.2 SEWERAGE AND SANITATION

The analysis of sewerage and sanitation indicators for MMC reveals significant gaps in comparison to the CPHEEO benchmarks, highlighting critical areas for improvement in sewage services and management (Table 12). The gaps indicate that many key areas require substantial improvement to meet the expected standards of sewerage and sanitation management. MMC has achieved full coverage of toilets, with 100% of households having access to either individual or community toilets within walking distance. This result meets the CPHEEO benchmark of 100%, and no gap exists in this indicator.

Table 12: Performance Indicators for Sewerage & Sanitation at MMC

#	Sewerage and Sanitation Indicators	Calculations	Benchmarks	2023-24*	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%	100.00%	0.00%
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%	29.53%	-70.47%
3.	Collection Efficiency of the Sewage Network	(Wastewater collected)/ (Total water supplied + Estimated water use from other sources)	100%	50.61%	-49.39%
4.	Adequacy of Sewage Treatment Capacity	(Treatment plant capacity)/ (Total water consumed + Total number of HHs with direct connection to sewage network)	100%	0.08%	-99.92%
5.	Quality of Sewage Treatment	(Number of samples that pass specified secondary treatment standards)/ (Total number of wastewater samples tested in a month)	100%	0.00%	-100.00%
6.	Extent of Reuse and Recycling of Sewage	(Wastewater recycled or reused after appropriate treatment)/ (Wastewater received at STPs)	20%	0.00%	-20.00%
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%	97.83%	17.83%

Source: MMC, 2025

This suggests that MMC has successfully addressed the basic sanitation needs of its population, ensuring that all households have access to toilet facilities, which is a key aspect of public health. The coverage of sewage network services is a critical area of concern for MMC, as only 29.53% of households are connected to the sewage network. This is far below the CPHEEO benchmark of 100%, with a gap of -70.47%.

The low percentage of households with sewage network connections points to insufficient infrastructure and indicates a large portion of the population relying on other, often less hygienic, methods of sanitation. Improving the coverage of the sewage network is vital for ensuring that wastewater is properly managed and to reduce the risks of waterborne diseases.

MMC's collection efficiency stands at 50.61%, significantly below the CPHEEO target of 100%. The gap of -49.39% reflects a substantial inefficiency in capturing the wastewater generated within the city. This low efficiency could be due to outdated or inadequate infrastructure, leakage in the sewage system, or the lack of sufficient connections to the sewage network. Enhancing collection efficiency is essential to prevent untreated wastewater from contaminating the environment and water bodies, which could lead to serious health and environmental issues. The adequacy of sewage treatment capacity is alarmingly low, with only 0.08% of the required capacity in place.

This gap of -99.92% highlights a severe underdevelopment in sewage treatment infrastructure. The limited capacity of treatment plants suggests that a significant portion of the wastewater generated in Mandvi is not being adequately treated, which could lead to contamination of local water resources and environmental degradation. Expanding treatment capacity is crucial for meeting the city's sewage treatment needs and complying with environmental standards. The quality of sewage treatment is another area of concern, with no samples passing specified secondary treatment standards (0%). This is a stark contrast to the CPHEEO benchmark of 100%, showing a complete failure in meeting treatment quality standards. The absence of proper treatment processes raises serious concerns about the safety of water and the overall environmental impact. To bridge this gap, MMC must invest in improving the treatment facilities, ensuring that wastewater undergoes adequate secondary treatment before being released into the environment.

At present, MMC is not reusing or recycling any of the treated sewage (0%). This is well below the CPHEEO benchmark of 20%. The gap of -20% reflects a missed opportunity for resource recovery, particularly in a context where water conservation and sustainable practices are increasingly vital. Reusing and recycling treated sewage can reduce the demand on fresh water supplies and mitigate the environmental impact of wastewater. MMC should prioritize the development of recycling infrastructure to promote water sustainability. MMC performs well in terms of addressing sewage-related complaints, with 97.83% of complaints redressed, far exceeding the CPHEEO benchmark of 80%. This reflects a high level of customer service and responsiveness. The positive performance indicates that MMC is effectively managing public grievances related to sanitation and sewerage services, contributing to a higher level of public satisfaction.

6.3 REVENUE STREAM

This section analyses the revenue streams and grants available to MMC 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 MMC'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) MMC's own revenue, and 4) Ratio of grants to own revenue at Mandvi for water supply and sewerage & sanitation.

6.3.1 WATER SUPPLY

Central Government Funds

The funding pattern for water supply in MMC has evolved significantly over time, reflecting changes in national fiscal policies and priorities (Table 13). From 2011 to 2018, MMC primarily relied on the 11th Finance Commission Grant, which accounted for the majority of funding, peaking at INR 3.34 crore in 2017–18. In 2018–19, the introduction of the 14th Finance Commission Grant brought a substantial one-time allocation of INR 5.82 crore, but this was not sustained in subsequent years.

Table 13: Funds received by MMC for Water Supply under Central Government Schemes (in INR)

Year/ Scheme	11 th Finance Commission Grant	14 th Finance Commission Grant	15 th Finance Commission Grant	Amrut 2.0 Scheme	Local Development Grant (MP)
2011-12	237405.00	0.00	0.00	0.00	0.00
2012-13	12425900.00	0.00	0.00	0.00	0.00
2013-14	12864123.00	0.00	0.00	0.00	87384.00
2014-15	21155065.00	0.00	0.00	0.00	0.00
2015-16	25028420.00	0.00	0.00	0.00	250000.00
2016-17	28917977.00	0.00	0.00	0.00	250000.00
2017-18	33453038.00	0.00	0.00	0.00	112500.00
2018-19	0.00	58246762.00	0.00	0.00	972000.00
2019-20	0.00	0.00	21527422.00	0.00	0.00
2020-21	0.00	0.00	22547872.00	0.00	61274.00
2021-22	0.00	0.00	40693412.00	8892000.00	0.00
2022-23	0.00	0.00	37350505.00	1900000.00	0.00
Total	134081928.00	58246762.00	122119211.00	10792000.00	1733158.00

Source: Budget Documents, MMC

From 2019–20 onward, the 15th Finance Commission became the dominant funding source, providing over INR 12.2 crore across four years, with annual disbursements peaking at INR 4.07 crore in 2021–22. In addition, the AMRUT Scheme 2.0, introduced in 2021–22, contributed modestly, while the Local Area Development Grant (MP) played a minimal role. This shift towards more diversified funding sources, including performance-based schemes like AMRUT, indicates a shift towards targeted urban development, but the variability in funding highlights the need for MMC to adopt multi-source budgeting strategies for long-term planning and infrastructure development.

State Government Funds

The state government funding for water supply to MMC between 2011 and 2023 reveals a decentralized and fragmented funding structure, with a heavy reliance on specific schemes like the UDP (Urban Development Programme) 76 and UDP 88, which together contributed around INR 23.9 crore (Table 14). UDP 88, in particular, provided consistent support from 2015 to 2023, while UDP 76 focused on earlier years. Other significant contributors included the Swarnim Gujarat Urban Development Mission (INR 4.55 crore) and various localized grants like the District Planning Grant and MLA Grants, which addressed smaller-scale water supply needs.

Table 14: Funds received by MMC for Water Supply under State Government Schemes (in INR)

Year/ Scheme	Capacity Building Grant	Natural Disaster Relief Grant	SJC MUDS	UDP 56	UDP 76	UDP 78	UDP 88	Natural Calamity Grant	Lack of water supply grant	Swarnim G UDM	Lake Improvement Grant	District Planning Grant	MLA Grant
2011-12	0.00	0.00	2496 000. 00	0.00	0.00	0.00	0.00	0.00	0.00	1128 3000 .00	0.00	3500 0.00	0.00
2012-13	0.00	0.00	0.00	0.00	3419 4821 .00	0.00	7300 00.0 0	1900 000. 00	0.00	3419 4821 .00	0.00	3500 0.00	0.00
2013-14	0.00	0.00	0.00	0.00	7764 255. 00	0.00	0.00	2000 0.00	0.00	0.00	0.00	0.00	6934 00.0 0
2014-15	0.00	0.00	0.00	0.00	5077 1129 .00	0.00	0.00	1200 000. 00	0.00	0.00	0.00	2500 000. 00	1882 050. 00
2015-16	0.00	0.00	0.00	0.00	3950 62.0 0	1124 9998 .00	7500 000. 00	0.00	0.00	0.00	0.00	3200 000. 00	3025 65.0 0
2016-17	0.00	0.00	0.00	9985 56.0 0	0.00	4008 375. 00	1987 8628 .00	3000 000. 00	0.00	0.00	0.00	4297 680. 00	2245 700. 00
2017-18	0.00	0.00	0.00	0.00	0.00	0.00	2892 3427 .00	0.00	0.00	0.00	4000 000. 00	0.00	1404 912. 00

2018-19	0.00	0.00	0.00	0.00	0.00	3590417.00	24098026.00	0.00	0.00	0.00	0.00	0.00	1006955.00
2019-20	0.00	0.00	0.00	0.00	0.00	13212459.00	22570892.00	0.00	0.00	0.00	0.00	0.00	1162285.00
2020-21	0.00	1000000.00	0.00	1899131.00	0.00	2073044.00	6000000.00	0.00	1800000.00	0.00	0.00	0.00	367406.00
2021-22	18073.00	1500000.00	0.00	0.00	0.00	816171.00	18752275.00	0.00	0.00	0.00	0.00	0.00	698800.00
2022-23	520539.00	2000000.00	0.00	5475661.00	0.00	0.00	17068495.00	0.00	0.00	0.00	0.00	0.00	400000.00
Total	538612.00	4500000.00	2496000.00	8373348.00	93125267.00	34950464.00	145521743.00	6120000.00	1800000.00	45477821.00	4000000.00	10067680.00	10164073.00

Source: Budget Documents, MMC Mandvi

However, the absence of recurring support for certain programs, such as Swarnim G UDM and the Lake Improvement Grant, highlights a lack of long-term continuity. Disaster relief grants and capacity-building grants were minimal, further indicating a reactive rather than proactive approach to water supply issues. The fragmented nature of funding across multiple schemes has created administrative challenges for MMC, emphasizing the need for better strategic alignment with state programs and a more integrated approach to urban water infrastructure planning and disaster resilience.

\Own Revenue

MMC has generated nearly INR 12 crore in own revenue for water supply from 2012 to 2024, with the water tax emerging as the most stable and significant source, contributing around INR 9.55 crore over the years (Table 15). The revenue from construction water charges, totalling over INR 11.9 crore, has seen a steady increase, reflecting growing urban development, though it remains vulnerable to fluctuations in the real estate market. Water connection charges and other charges have contributed smaller amounts, suggesting underutilized or inconsistent revenue streams.

Table 15: Revenue Income from Water Supply at Mandvi (in INR)

Year	Water Tax	Water Connection Charges	Other Charges	Construction Water Charges
2012-13	8349410.00	244770.00	443185.00	355940.00
2013-14	9410610.00	136400.00	174735.00	189021.00
2014-15	7969290.00	106530.00	864450.00	152586.00
2015-16	9448490.00	118570.00	5070.00	218770.00

2016-17	9091435.00	68500.00	94310.00	77163.00
2017-18	9532311.00	579550.00	167040.00	382103.00
2018-19	9605387.00	198790.00	138960.00	193575.00
2019-20	939144.00	111500.00	264955.00	1434115.00
2020-21	9838585.00	140140.00	275410.00	1339887.00
2021-22	2348724.00	104300.00	99980.00	2333811.00
2022-23	9446839.00	69750.00	134080.00	2872119.00
2023-24	9473638.00	122800.00	210459.00	2363634.00
Total	95453863.00	2001600.00	2872634.00	11912724.00

Source: Budget Documents, MMC Mandvi

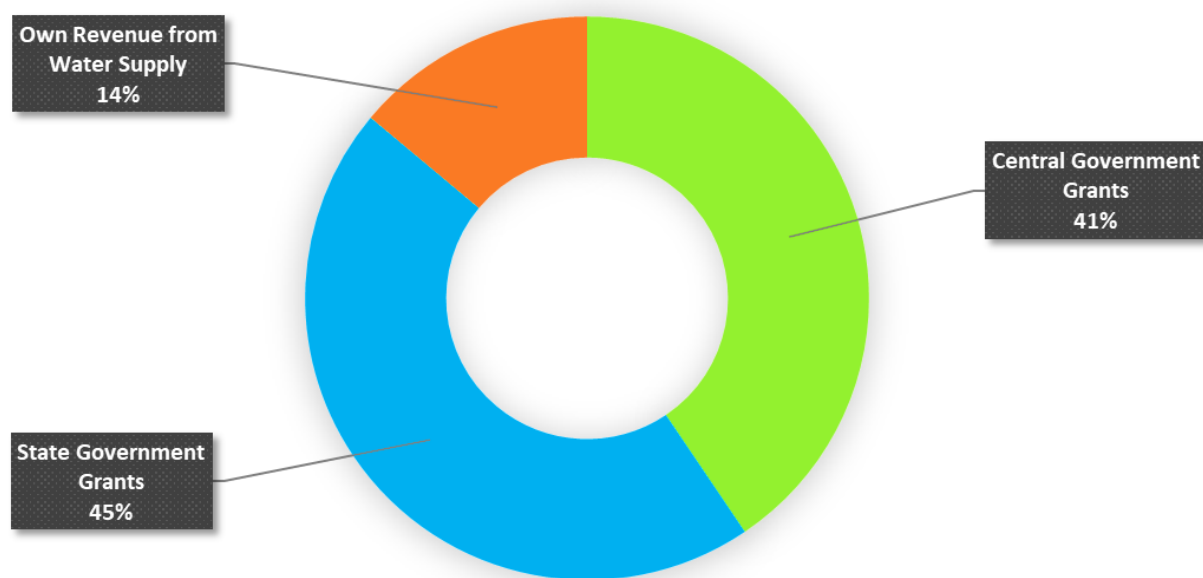
The dip in water tax revenue during 2019-20 and 2021-22, coupled with higher construction water charges, indicates potential administrative challenges or external shocks, such as the COVID-19 pandemic. While MMC has effectively mobilized internal resources, the reliance on irregular and market-sensitive charges exposes it to financial volatility. To ensure long-term sustainability, MMC should diversify its revenue base, improve fee collection efficiency, and explore dynamic pricing strategies.

Ratio of grants and own revenue

The funding structure for water supply at MMC reveals a mixed yet imbalanced reliance on central grants (INR 32.7 crore), state grants (INR 36.7 crore), and own revenue (INR 11.2 crore), with state grants forming the largest share (Fig. 16). MMC's dependence on state funding highlights its vulnerability to changes in state policy or fiscal conditions. While central government grants contribute significantly, they are smaller than state grants and largely supplement local resources through finance commissions and urban schemes.

MMC's own revenue generation, primarily from water taxes and connection charges, provides a steady stream of income but is much smaller, making up only about a third of the total funding. Over the years, the ratio of own revenue to grants has fluctuated, often staying low (around 10-20%), signalling a high dependence on external grants, with a notable drop to just 3.13% in 2019-20. For long-term sustainability, MMC needs to diversify its revenue streams, improve collection efficiency, and reduce its reliance on external funding by enhancing local resource mobilization.

Figure 17: Share of grants vs own revenue for water supply at MMC Mandvi



Source: Budget Documents, MMC Mandvi

6.3.2 SEWERAGE & SANITATION

Central Government Funds

The central government funds received by MMC for sewerage and sanitation reveal fluctuating support over the years, with varying levels of consistency and volume (Table 16). The most substantial funding came from the 11th Finance Commission, which allocated INR 13.41 crore until its phase-out in 2018-19. The 14th Finance Commission provided a one-time INR 5.82 crore in 2019-20, while the 15th Finance Commission adopted a multi-year disbursement approach, totalling over INR 12.21 crore by 2023-24.

SBM 2.0 also played a role, though with significant fluctuations, peaking at INR 1.38 crore in 2022-23. The Member of Parliament (MP) Grant, however, contributed a minimal INR 17.33 lakh over 12 years. The varying funding patterns reflect both a shift in financial mechanisms and the broader national priorities, posing challenges for MMC's long-term planning and infrastructure development, despite the cumulative total of over INR 32.96 crore in central funding.

Table 16: Funds received by MMC for Sewerage & Sanitation under Central Government Schemes (in INR)

Year	Swachh Bharat Mission Grant 2.0	11th Finance Commission	14th Finance Commission	15th Finance Commission	Local Development Grant (MP)
2012-13	0.00	237405.00	0.00	0.00	0.00
2013-14	4134000.00	12425900.00	0.00	0.00	0.00
2014-15	2806000.00	12864123.00	0.00	0.00	87384.00
2015-16	2568220.00	21155065.00	0.00	0.00	0.00
2016-17	106886.00	25028420.00	0.00	0.00	250000.00
2017-18	2953265.00	28917977.00	0.00	0.00	250000.00
2018-19	0.00	33453038.00	0.00	0.00	112500.00
2019-20	209915.00	0.00	58246762.00	0.00	972000.00
2020-21	373260.00	0.00	0.00	21527422.00	0.00
2021-22	54500.00	0.00	0.00	22547872.00	61274.00
2022-23	13830000.00	0.00	0.00	40693412.00	0.00
2023-24	3710000.00	0.00	0.00	37350505.00	0.00
Total	30746046.00	134081928.00	58246762.00	122119211.00	1733158.00

Source: Budget Documents, MMC Mandvi

State Government Funds

The state government funds received by MMC for sewerage and sanitation reflect a complex, multifaceted funding structure that includes a mix of large, project-based grants and targeted schemes (Table 17). Key contributors to MMC's sanitation funding include the UDP series, particularly UDP 76 and UDP 88, which cumulatively provide substantial and consistent amounts, especially from 2013-14 onwards, highlighting a state-driven push for urban infrastructure development. The Nirmal Gujarat 2.0 grant, introduced in 2021-22, added a significant boost, signalling a renewed focus on sanitation.

Table 17: Funds received by MMC for Sewerage & Sanitation under State Government Schemes (in INR)

Year	Nirmal Gujarat 2.0	Cleanliness Grant	Community Toilet / Public Toilet / APT/ Urinal	Capacity Building Grant	Earthquake, Cyclone, Natural Disaster Relief Grant	Swarim Jayanti Chief Minister Urban Development Scheme	UDP 56	UDP 76	UDP 78	UDP 88	Natural Calamity Grant (Earthquake, Tornado, etc.)	Swarim G UDM	District Planning Grant	MLA Grant
2012-13	0.00	9624143.00	0.00	0.00	0.00	2496000.00	0.00	0.00	0.00	0.00	0.00	11283000.00	35000.00	0.00
2013-14	0.00	8171522.00	0.00	0.00	0.00	0.00	0.00	34194821.00	0.00	730000.00	1900000.00	34194821.00	35000.00	0.00
2014-15	0.00	118555.00	0.00	0.00	0.00	0.00	0.00	7764255.00	0.00	0.00	20000.00	0.00	0.00	693400.00
2015-16	0.00	3305751.00	0.00	0.00	0.00	0.00	0.00	50771129.00	0.00	0.00	1200000.00	0.00	2500000.00	1882050.00
2016-17	0.00	0.00	0.00	0.00	0.00	3302640.00	0.00	395062.00	1124998.00	7500000.00	0.00	0.00	3200000.00	302565.00
2017-18	0.00	0.00	0.00	0.00	0.00	0.00	998556.00	0.00	4008375.00	19878628.00	3000000.00	0.00	4297680.00	2245700.00
2018-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28923427.00	0.00	0.00	0.00	1404912.00
2019-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3590417.00	24098026.00	0.00	0.00	0.00	1006955.00
2020-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13212459.00	22570892.00	0.00	0.00	0.00	1162285.00
2021-22	40085520.00	0.00	0.00	0.00	1000000.00	0.00	1899131.00	0.00	2073044.00	6000000.00	0.00	0.00	0.00	367406.00
2022-23	0.00	0.00	0.00	18073.00	1500000.00	0.00	0.00	0.00	816171.00	18752275.00	0.00	0.00	0.00	698800.00
2023-24	0.00	0.00	1459140.00	520539.00	2000000.00	0.00	5475661.00	0.00	0.00	17068495.00	0.00	0.00	0.00	400000.00
Total	40085520.00	21219971.00	1459140.00	538612.00	4500000.00	5798640.00	8373348.00	93125267.00	34950464.00	145521743.00	6120000.00	45477821.00	10067680.00	10164073.00

Source: Budget Documents, MMC Mandvi

Other notable funding streams include the Cleanliness Grant, which tapered off after 2015-16, and disaster relief funds, which underscore the need for infrastructure recovery after natural calamities. Smaller grants, such as those for community toilets and capacity building, reflect a focus on localized sanitation improvements and institutional strengthening. While these varied funding sources ensure a diversified approach, the heavy reliance on a few large grants may create challenges in ensuring balanced and continuous support across all sanitation needs. Effective planning and coordination will be key to optimizing these resources for both infrastructure development and long-term maintenance.

Own Revenue

MMC's own revenue generation from sewerage and sanitation services shows a stable but narrowly concentrated pattern, with the majority of income derived from sewerage tax, which totals INR 25.03 crore over 12 years (Table 18). This tax consistently forms the backbone of MMC's sewerage funding, peaking at INR 3.04 crore in 2019-20, although a dip in 2021-22 indicates potential challenges. Other revenue sources, such as sewer connection fees and sanitation charges, contribute modestly, with sewer connection fees generating only INR 6.19 lakh, suggesting limited expansion or new connections.

Table 18: Revenue Income from Sewerage & Sanitation at Mandvi (in INR)

Year	Sewerage Tax	Sewer Connection Fee	Other Sewer Connection	Sewer Dish Connection Charges	Sewer Connection Name Transfer Fee	Sanitation Charges
2012-13	1633460.00	131250.00	44850.00	0.00	0.00	783418.00
2013-14	1842670.00	68400.00	16600.00	0.00	0.00	868080.00
2014-15	1709500.00	48550.00	17200.00	0.00	0.00	871348.00
2015-16	1379178.00	95950.00	17555.00	0.00	0.00	1747750.00
2016-17	2171310.00	51000.00	13500.00	0.00	0.00	0.00
2017-18	2346074.00	33800.00	28600.00	0.00	0.00	0.00
2018-19	2368300.00	38800.00	25830.00	0.00	0.00	0.00
2019-20	3039320.00	38000.00	20900.00	550.00	1100.00	9700.00
2020-21	2451630.00	27100.00	53600.00	600.00	1250.00	36600.00
2021-22	1439038.00	29750.00	28300.00	700.00	2050.00	900000.00
2022-23	2316787.00	24950.00	63390.00	100.00	100.00	9200.00
2023-24	2336386.00	31700.00	69540.00	0.00	0.00	1500.00
Total	25033653	619250	399865	1950	4500	5227596

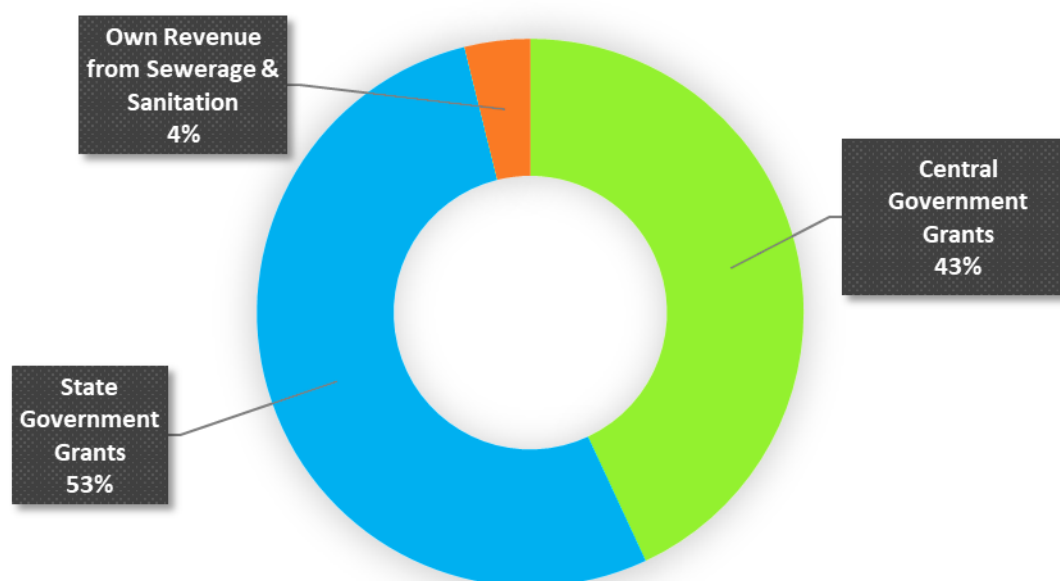
Source: Budget Documents, MMC Mandvi

Sanitation charges show variability, with notable spikes in certain years, reflecting sporadic fee increases. However, overall, MMC's revenue base remains narrow, and there is room for growth in connection fees and sanitation charges. To enhance financial sustainability, the council could consider revising its fee structures, improving collection systems, and expanding revenue sources, especially for infrastructure development and long-term maintenance.

Ratio of grants and own revenue

MMC relies heavily on external grants, with central and state government funding making up over 95% of its sewerage and sanitation budget, while its own revenue contributes a mere INR 3.13 crore (less than 5%). Central government grants total INR 34.69 crore, and state grants surpass this, totalling INR 42.74 crore, indicating a significant role of state-driven programs like Urban Development and disaster relief funds. In contrast, MMC's own revenue is largely dependent on sewerage taxes, which show a steady but modest increase (Fig. 18). Despite some initial years where own revenue contributed a higher share, this ratio has steadily declined over time, with the cumulative ratio standing at just 4.04% over 12 years.

Figure 18: Share of grants vs own revenue for Sewerage & Sanitation at MMC Mandvi



Source: Budget Documents, MMC Mandvi

This heavy dependence on external funds raises concerns about the council's fiscal autonomy and sustainability, as fluctuations in government grants can disrupt long-term planning and maintenance. To improve financial resilience, MMC must enhance its revenue generation mechanisms, such as revising tax structures, improving fee collection efficiency, and exploring new revenue streams, to ensure more balanced and sustainable financing for sanitation services.

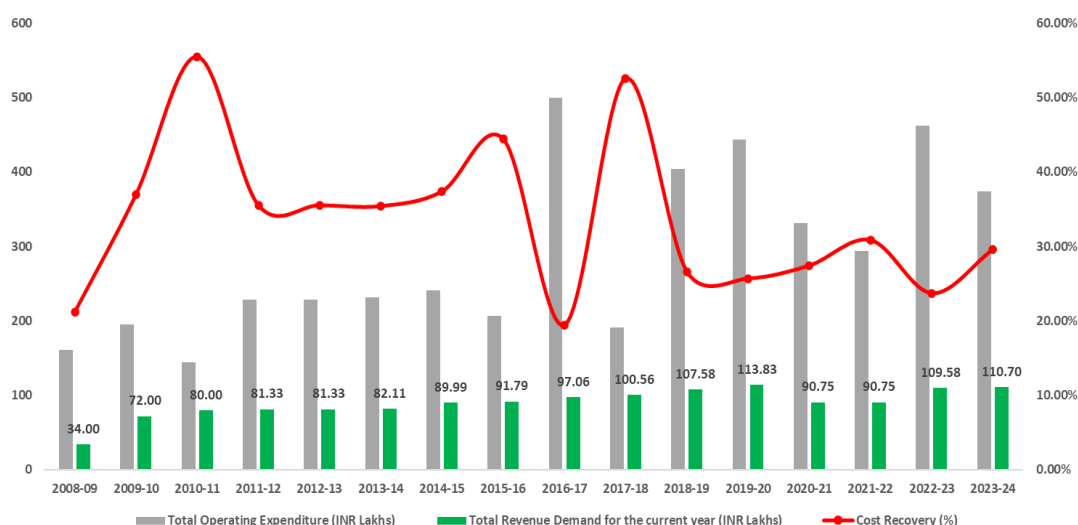
6.4 ASSESSMENT OF FINANCES

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

6.4.1 WATER SUPPLY

Cost recovery for water supply at MMC has been inconsistent over the years, reflecting both improvements and regressions in financial sustainability (Fig. 19). Initially, from 2008 to 2010, cost recovery was very low (21.16% to 36.96%), likely due to ineffective billing practices, low tariffs, and outdated infrastructure. Between 2010 and 2015, some improvement was observed, reaching 55.49% in 2010-11, but fluctuations persisted. From 2016 to 2020, cost recovery sharply declined to as low as 19.45% in 2016-17, driven by rising operational costs, arrears, and poor collection efficiency.

Figure 19: Trend analysis of cost recovery in water supply charges at MMC



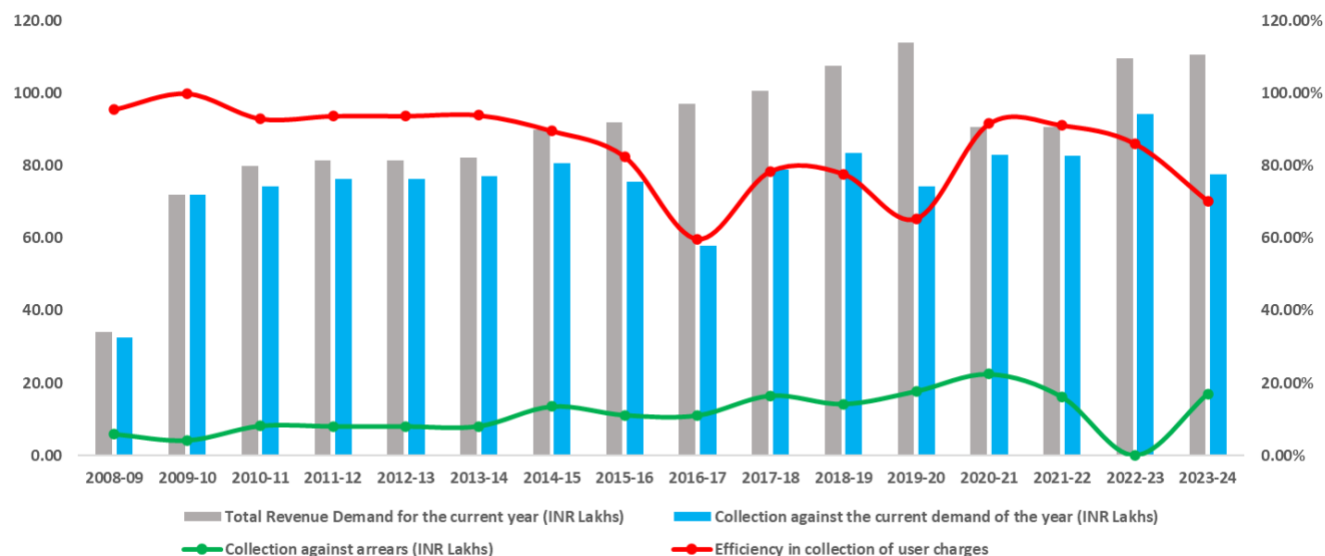
Source: MMC, 2025

Despite slight improvements in 2021-2023 (30.85% in 2021-22 and 29.60% in 2023-24), recovery rates remain insufficient to fully cover operating expenses. High energy costs, outsourced staff, and maintenance further exacerbate financial challenges. While revenue demand has stabilized, operational costs continue to fluctuate, complicating cost recovery. To improve sustainability, MMC needs to focus on stabilizing revenue through better water pricing, reducing inefficiencies, timely collections, and managing energy and maintenance costs effectively.

The **collection efficiency** for water supply at MMC has shown significant fluctuations over the years, with periods of improvement and decline (Fig. 20). Initially, from 2008 to 2010, MMC's collection efficiency was high, peaking at 99.89% in 2009-10, suggesting effective billing and collection systems. However, from 2011 to 2015, collection efficiency began to decline, dropping to 89.58% in 2014-15 due to rising revenue demands and increasing arrears. The situation worsened between

2016 and 2020, with a sharp decline to 59.61% in 2016-17, driven by mounting arrears and poor payment compliance.

Figure 20: Trend analysis of collection efficiency in water supply charges at MMC



Source: MMC, 2025

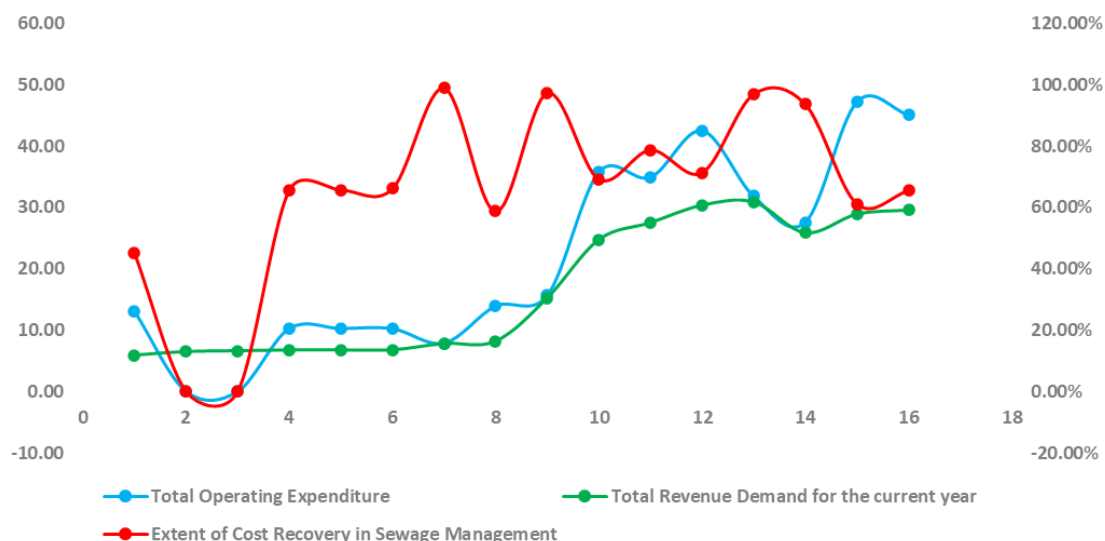
Although collection efficiency improved slightly from 2021 to 2023, reaching 91.10% in 2021-22 and 86.06% in 2022-23, the overall performance in 2023-24 (70.18%) remains suboptimal. This indicates that while some improvements have been made in managing current dues, challenges with arrears persist, highlighting the need for better systems for collection, customer engagement, and addressing outstanding dues to ensure long-term financial sustainability in the water supply sector.

6.4.2 SEWERAGE & SANITATION

The **cost recovery** for sewerage and sanitation services at MMC has been marked by significant fluctuations, reflecting challenges in balancing operating costs with revenue generation (Fig. 21). Early years (2008-2012) saw weak cost recovery, with figures as low as 45.14%, due to low user charges and limited revenue sources. However, by 2014-15, cost recovery peaked at 98.98%, driven by a sharp increase in user charges, but this was not sustainable, with subsequent years seeing declines as operational costs outpaced revenue growth. In 2016-17, cost recovery dropped to 69.24%, and despite minor improvements in the following years, it reached just 61.21% by

2023-24. Contributing factors include rising arrears, fluctuating repair and maintenance costs, and insufficient revenue from user charges.

Figure 21: Trend analysis of cost recovery in sewerage & sanitation charges at MMC



Source: MMC, 2025

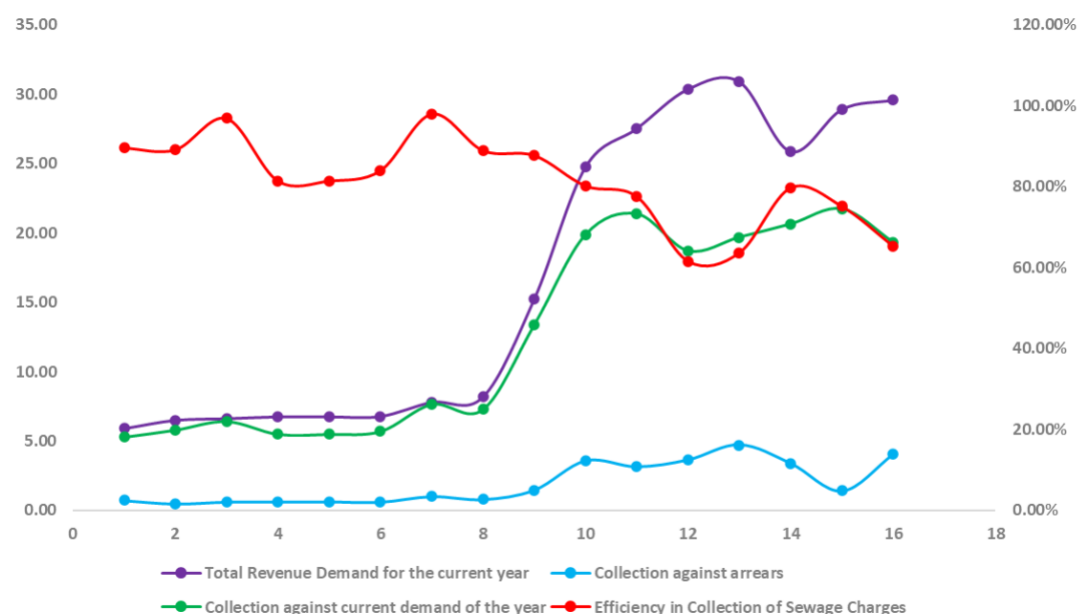
MMC's reliance on taxes or cess is minimal, and inefficiencies in billing and collections have exacerbated financial strain. While there has been some progress in cost recovery, the municipality still faces significant challenges in fully covering the operational costs of its sewerage and sanitation services. To improve sustainability, MMC must focus on reducing arrears, increasing service efficiency, and exploring additional revenue sources.

The **collection efficiency** for sewerage and sanitation charges at MMC has fluctuated over the years, reflecting both progress and challenges in revenue collection (Fig. 22). Initially, from 2008 to 2013, collection efficiency varied, peaking at 96.98% in 2010-11 but dipping as low as 81.48% in 2012-13, due to issues with arrears recovery and inefficiencies in billing. A significant improvement occurred in 2014-15, with efficiency reaching 98.08%, thanks to better collection and management practices.

However, from 2016 onward, efficiency started to decline, particularly in 2019-20, when it fell to 61.59%, likely exacerbated by the COVID-19 pandemic and rising arrears. By 2023-24, efficiency dropped further to 65.33%, indicating persistent challenges in collecting both current charges and overdue payments. The growing backlog of arrears and inefficiencies in the collection system remain major obstacles. To improve efficiency, MMC must focus on better managing arrears,

streamlining billing systems, and enhancing consumer engagement through improved payment processes and public awareness campaigns.

Figure 22: Trend analysis of collection efficiency in sewerage & sanitation charges at MMC



Source: MMC, 2025

6.5 KEY FINANCIAL CHALLENGES

The key financial challenges for water supply at MMC include inconsistent cost recovery and declining collection efficiency. Despite improvements in cost recovery from 2010 to 2015, fluctuations in revenue generation have prevented full financial sustainability. Key issues contributing to low-cost recovery include inadequate tariffs, inefficiencies in billing systems, rising operational costs (particularly energy and maintenance), and a growing backlog of arrears. While there have been improvements in collection efficiency since 2021, challenges remain, with significant arrears still impacting the overall collection rate. The high variability in both operational expenditures and revenue demand, coupled with delays in collecting payments, has further strained MMC's ability to cover water supply costs. To address these challenges, MMC needs to enhance its revenue collection mechanisms, adjust tariffs, improve billing practices, and reduce arrears, while also managing escalating operational expenses.

The key financial challenges for sewerage and sanitation services at MMC include inconsistent cost recovery and low collection efficiency. Despite some improvements in cost recovery, the municipality struggles to generate sufficient revenue from user charges to cover rising operational costs, particularly maintenance and repairs. Fluctuating cost recovery rates, such as a decline to 61.21% in 2023-24, highlight the ongoing financial instability. A significant factor is the growing arrears, which exacerbate the difficulty in collecting revenue and maintaining financial sustainability. The collection efficiency has also fluctuated, with a sharp decline in recent years, particularly after 2019, due to rising arrears, operational inefficiencies, and external factors like the COVID-19 pandemic. To improve financial stability, MMC needs to enhance its arrears recovery systems, streamline billing processes, and improve consumer engagement to ensure timely payments.

CHAPTER 7: RISK ASSESSMENT OF WASH INFRASTRUCTURE AND SERVICES IN MANDVI

SUCHARITA ROY, TEJASH ANAND AND NC NARAYANAN

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. This chapter captures the exposure and vulnerability of the WaSH infrastructure of Mandvi in Kutch district of Gujarat. The situational analysis has been based on the detailed sectoral analysis undertaken by sectoral teams and captured in Chapters 3 (Water), 4 (sanitation), and 6 (finances). The resilient assessment of the WaSH infrastructure captures the contextual risks and gaps in the systems.

7.2 EXPOSURE TO CLIMATE RISK

Mandvi is highly vulnerable to severe earthquakes and cyclones; extremely high storm surges have been recorded in the region due to the narrowing of the sea in the form of a gulf. Rising high tide levels, intense rainfall events, tropical cyclones, and stronger winds originating from the Arabian Sea have heightened the city's vulnerability to flooding and inundation.

Over the years, there has been a significant increase in the frequency of rainy days and in the heavy rainfall days from June to September in Kutch along with other districts of Gujarat. There is high positive variation in the western portion of India. These are high indicators of the increasingly erratic nature of rainfall over India in the long-term trend. The conditions that Gujarat is facing are indicators of the extreme situation that will occur in the future, and extreme rainfall in a lesser number of days will create flood-like situations within the state and hinder mobility.⁵⁰

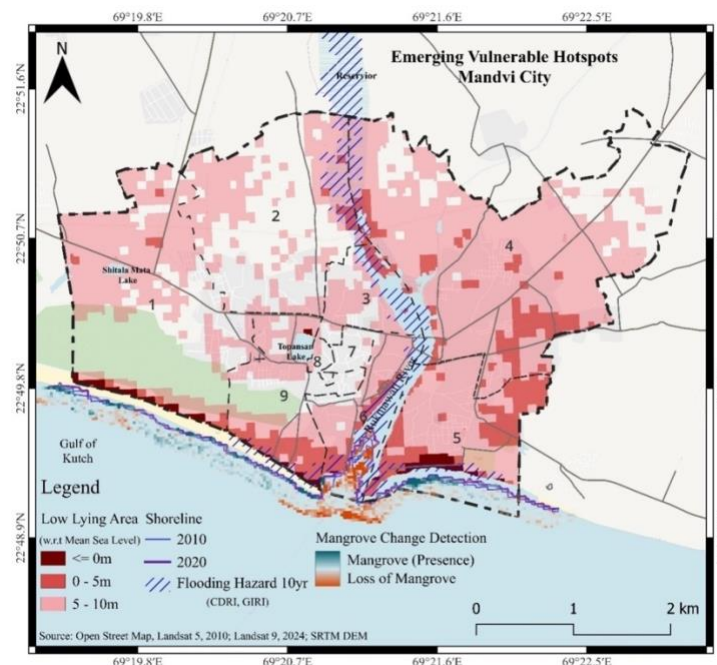
Low Elevation Coastal Zones (LECZ) are land area contiguous with the coastline up to a 10-metre rise elevation that are hydrologically connected to the sea.⁵¹⁵². In LECZ and floodplains, severe flooding occurs when the soil is saturated and infiltration is minimum, water levels in creeks and rivers are 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.

Flood hazard mapping over the past 10 years, with current climate scenarios undertaken by CDRI⁵³ has identified the flood zones from runoff and river overflow. Mandvi lies in the Low Elevation Coastal Zone (contiguous land within 10 m elevation above sea level) with a mean elevation of the city is 5 to 6mts with more than 70% of the land area at an elevation less than 10m above mean sea level (refer Figure 23). Of the 9 wards of the city, 6 wards have more than 50 % of the land at an elevation less than 10m, most located alongside the river Rukmavati. Majority of the ward 4, 5 and 6, located on either side of the river mouth, are very highly vulnerable to coastal surge as well as river overflow.

Flooding occurs when floodplains are encroached obstructing flood ways, reducing natural flood storage and there is increase in built up surfaces resulting in major runoffs overwhelming drainage and the already compromised conveyance systems. Runoffs often overwhelm the sewerage systems where they escape resulting in “combined sewerage overflow” which is common across most Indian cities. The existing capacity of sewerage is not equipped for such elevated flows and leads to widespread contamination of land and water during flood like situations.⁵⁴

Mandvi has faced severe flooding in 2024, due to intense precipitation events seen in the region, and was inundated for many days. Mandvi received 300 mm rainfall in 12 hours, 100 mm in first 2 hours, with water rising to 6 feet in many housing societies, and damaging a bridge as reported on August 29, 2024. A week after Mandvi town was flooded following extremely heavy rainfall of over 315 mm, waterlogging persisted and around 1000 houses remained inundated even as the government deployed 15 dewatering pumps to address the issue.⁵⁵

Figure 23 : Emerging Vulnerability Hotspots and Exposure of Mandvi City to Climate Hazards



Source: Sentinel 2 10m LULC; Open Street Map; Landsat 9 (Shoreline), 2020; Landsat 6 (Shoreline), 2010; Landsat 9 (Mangroves), 2024 Mandvi Municipal Corporation

Table 19 : Ward-level Elevation and vulnerability to Flooding

Ward	Ward Population	% Built up	Very High Vulnerability (<5m above MSL)	High Vulnerability (<10m Above MSL)	Low Vulnerability (>10m Above MSL)
1	6139	10%	4	55	45
2	9301	18%	2	45	55
3	3295	30%	19	74	26
4	4385	16%	11	78	22
5	4825	24%	53	100	0
6	6161	36%	50	92	8
7	6728	93%	0	7	93
8	5129	85%	0	29	71
9	5413	26%	21	66	34

Source: GIS analytics

Groundwater flooding can exacerbate flooding caused by monsoon rains and runoff or due to inundation from storm surges. The city's inability to release floodwater even after 10-12 days, as seen in August 2024, suggests that groundwater flooding may have worsened the situation, as is common in most low-lying coastal towns and cities.

Change detection based on Sentinel data spanning 10 years (2010 – 2020) reveals Mandvi coast has significant changes seen in status of mangroves and the coastal shoreline. (Refer Figure 24) These changes increase the risk of saltwater intrusion into groundwater and contamination of open dug wells and other surface water sources, particularly near river mouths. Mangroves serve as effective natural barriers to storm surges and cyclones and should be used as preventive measures to protect the city.

Mandvi is also located in the path of most of the cyclones generated in the Arabian Sea which move North-East and hit the coast. Arabian Sea cyclones have battered India's west coast at the rate of one per year since 2018, a frequency not seen in five decades (CEEW). It is hence exposed to high intensity cyclonic and storm of 51 to 55 m/sec class. Two cyclonic storm seasons are experienced in Gujarat: May to June (advancing southwest monsoon) and September to November (retreating monsoon). Though located in an arid district, due to its low-lying riverine setting, Mandvi is part of the few locations of the district which is not exposed to drought though can face seasonal scarcity of water. On the other hand, due to its low-lying terrain, and presence of a seasonal river and reservoir and dam close by Mandvi faces flash flooding due to concentrated runoff caused by heavy rainfall.

Mandvi is particularly vulnerable to storm surges due to its location at the mouth of Gulf of Kutch and at the mouth of the river. Cyclone generated storm surges penetrate riverine mouths and further propagate upstream resulting in widespread flooding along the riverbanks. These surges can lead to the contamination of surface and groundwater with saltwater, as well as the overflow of on-site sanitation pits or poorly constructed septic tanks.

A storm surge refers to the abnormal rise in water levels caused by a storm, surpassing the predicted astronomical tide. Storm tide, a combination of storm surge and astronomical tide, can lead to extreme coastal flooding, especially when it coincides with high tide. Wave action on top of a surge can further elevate water levels, compounding flooding risks. Disruptions in vertical ocean circulation during these events often push seawater inland, contaminating freshwater resources.⁵⁶ Additionally, heavy rainfall and sediment accumulation at river mouths increase the likelihood of flooding in low-lying areas.

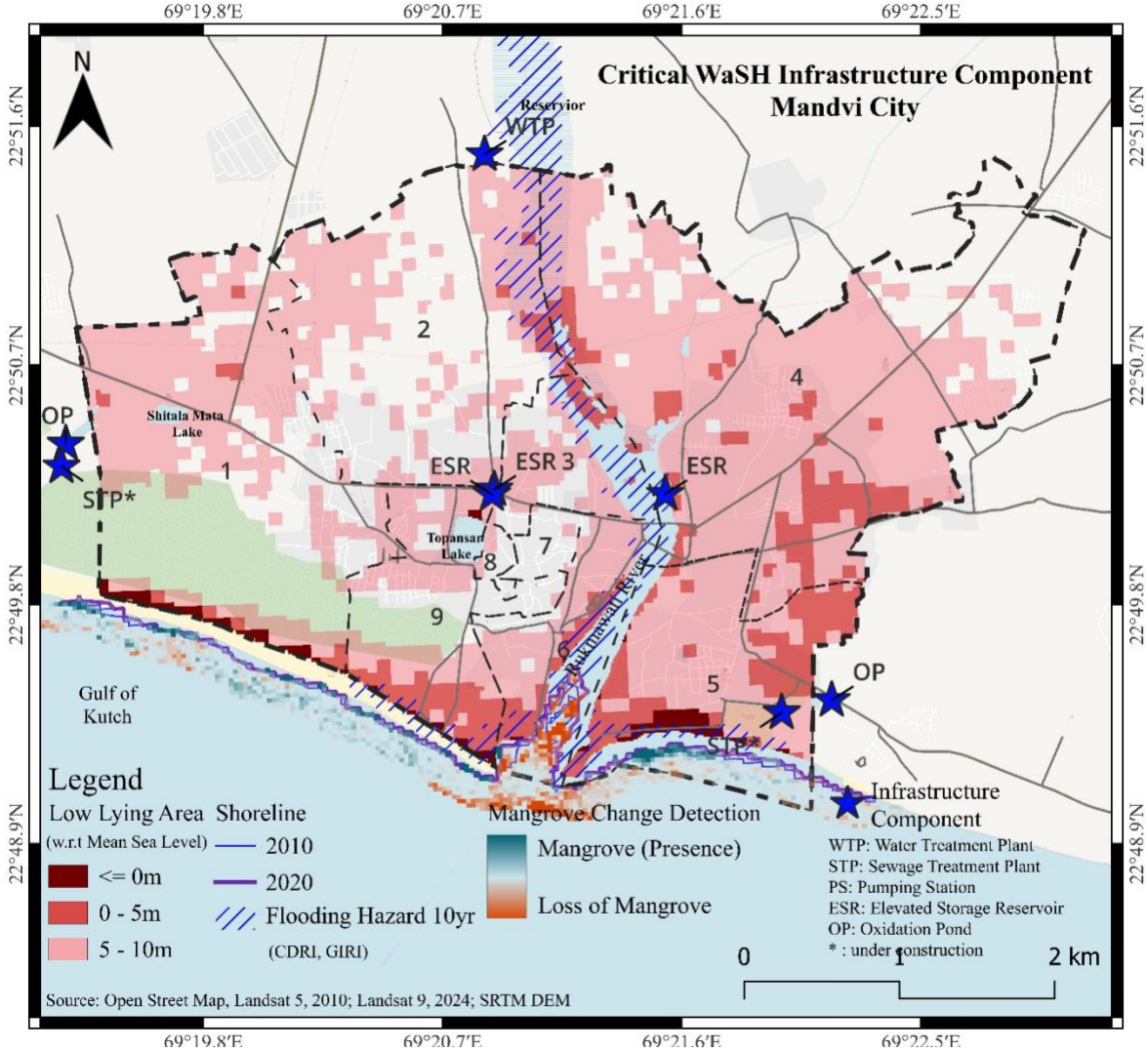
Saltwater intrusion presents a critical challenge for Mandvi in two primary ways. For areas without piped water, it compromises access to safe, fresh water. The increased conductivity of groundwater caused by saltwater accelerates the corrosion of underground water and wastewater collection pipes. The aging infrastructure in some parts of Mandvi compounds these risks.

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.⁵⁷

Areas alongside the river which can often help in moving storm surges inland exposing inland wards to inundation and intrusion, as noted during field visits. *These locations are low lying like inward 4, where significant flooding and inundation was faced by the residents despite the distance from the coast. These vulnerabilities necessitate monitoring at local levels and contextualized solutions. for the low-lying coastal wards 1, 2, 4, 5, 6, and 9 (Refer Table 10).*

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.⁵⁸

Figure 24 : Location of Critical Components of WaSH Infrastructure



Source: Sentinel 2 10m LULC; Open Street Map; Landsat 9 (Shoreline), 2020; Landsat 6 (Shoreline), 2010; Landsat 9 (Mangroves), 2024; Mandvi Municipal Corporation

The district of Kutch, due to the extreme temperature and the ecological features is exposed to heat waves. Mandvi is also exposed to cold waves. ⁵⁹

Located in Zone V seismic zone, Mandvi has high vulnerability from earthquakes of magnitude 8 faces the risk of loss of lives, built structures as well as livelihoods. Mandvi was one of the towns severely impacted by the 2001 Gujarat earthquake. Mandvi is exposed to Tsunamis and inundation due to its proximity active fault area of Makran Subduction Zone (MSZ) -Southwest of Karachi and thereby and the high probability of occurrence of near and offshore submarine earthquakes in the Arabian Sea which can result in waves ranging from 10 – 20 feet.

Seismic activities can compound coastal risks like subsidence of land, change in ecological system, diversion of river flow or tsunami leading to extreme high waves as has been witnessed in Kutch coasts. Similarly, co- occurrence of two or more hazards has often been witnessed for example earthquakes and landslides, earthquakes, and heavy precipitation. Mandvi has a medium risk exposure to tsunamis. Tsunamis are most often generated by earthquake-induced movement of the ocean floor. Areas at greatest risk are those less than 25 feet above sea level and within one mile of the shoreline. To ensure resilience in infrastructure, Mandvi shall need to factor in all major risks and cascading risks into infrastructure development plans. Mandvi has a reservoir to the north and a dam on its western border. In the event of seismic activities or intense precipitation during the monsoon season, the overflow or breach of these reservoirs could affect the city.

7.3 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 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 where 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.

7.3.1 ADEQUACY OF INFRASTRUCTURE

The WaSH infrastructure in Mandvi is not adequate for the city or resilient to climate risks. While Mandvi has access to adequate safe freshwater sources, treatment of the water to render it safe for consumption is inadequate. This should be considered as the most urgent requirement for the city which faces annual flooding.

Areas further away from the coastline face seasonal shortages in well water and are then completely dependent on piped water supply.

The city employs a mix of technology solutions, ranging from simple unlined pits to a centralised sewerage network and from nature-based treatment through oxidation ponds to the new under construction STP. Having initiated a transition into centralised sewerage network, Mandvi is still struggling to provide adequate conveyance and containment of sewage from the city.

The sewerage network is visibly under distress due to flooding. For low lying cities prone to ground water flooding and inundation along with combined sewerage overflow. Long networks of centralised sewerage need pumping for conveyance to treatment site, as in Mandvi. There are lifting stations and pumping stations on both sides of the river and final disposal location into large Oxidation Pond on southeastern side of the city, away from the main city and outside city boundaries in a low-lying region near the coast. This is not only difficult to sustain as it is energy

intensive, but also highly prone to failure and disruption during shock events. Open defecation is still practiced in some slum like settlements housing informal and daily wage labour. Aging infrastructure, nonfunctional water treatment facilities, corrosion and leakage, backflows due to flooding of sewerage networks, dependence on pumping of sewerage for conveyance, dependence on nature-based sewerage treatment solutions close to the coast, which faces annual flooding and inundation has resulted in major sanitation and hygiene challenge.

7.3.2 RELIABILITY, FLEXIBILITY AND REDUNDANCY

Mandvi's location in a semi-arid to arid eco-climatic zone makes source sustainability a challenge which shall require to be addressed for the future climate scenarios. MMC has two water sources: borewells and the Narmada canal, providing redundancy to the water infrastructure and reducing the likelihood of complete disruption. Additionally, Mandvi has three lakes and experiences significant flooding from intense precipitation. The city's lakes and river system offer opportunities for flood management through the design of retention system, which can serve both the city and the hinterland during drier months.

Groundwater contamination can pose a serious challenge, with saltwater intrusion, fluctuating water tables, and poorly constructed sanitation systems leading to higher Total Dissolved Solids (TDS) levels during flooding. For the low-lying city, dependence of pumping of sewage, across the river in the centralised sewerage network, to the oxidation ponds across the river, exposes it to risk of failure during shock events like unprecedented flooding of Aug 2024. Long networks of centralised sewerage are not only difficult to maintain but can be unfeasible due to corrosion, leakages, reverse flows, and need for frequent uphaul. This was visibly seen in Mandvi. Residents complained of reverse flows of sewage into their houses during the flooding of 2024.

The current technology adopted for sewerage treatment involves natural treatment using oxidation ponds located outside city limits. However, *this nature-based solution - oxidation ponds - can be risky for the city due to its proximity to the coast*. This method is unreliable for a city exposed to storm surges, inundation, salinity ingress, and high-water tables during intense monsoon rainfall, which lasts for more than four - five months. *The location of the STP under construction, in a low-lying area close to the oxidation ponds, exposes it to all the identified coastal risks*. Saltwater contamination can interfere with the natural process in oxidation ponds, and overflow can lead to land and sea contamination. For Mandvi, cyclone can disrupt the electricity supplies. In the event of failure of electricity, the impact on sewerage conveyance and treatment facilities can be catastrophic for the city. Similarly heavy reliance of water supply systems on electricity makes them vulnerable to disruptions caused by intense winds and cyclonic formations—common in coastal regions with overhead power transmission networks.

7.3.3 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.

Mandvi is a growing city, with new developments under way. The WaSH infrastructure of the city is struggling to keep pace with the growing needs as well as the adverse impacts of the climatic shock events. The transformative action needed in the infrastructure of Mandvi, the new projects under conceptualisation and the funds that are proposed for investment, offers a significant opportunity to integrate resilience through evidence-based planning, agile governance, and innovative finance models.

For a thriving Class II city with new development and growing population, fluctuations in operating ratios, fiscal revenue, and expenses, year on year indicates that service operations have not reached a sustainable stage. Dependence on non-revenue sources of funding remains high. MMC is constrained in undertaking planning for city-wide safe sanitation due to its dependence on central, state government, and IFIs for capital funds. This has resulted in fragmented development of the sanitation infrastructure. For example, while STP is under construction, there is a need for overhaul of the existing sewerage. Aging and dilapidated critical components, flood ravaged systems, and nonfunctional treatment facilities have made the WaSH infrastructure inadequate. New developments MMC, like other smaller cities and towns is struggling to mobilize funds for extending the sewerage network to vulnerable locations, which accounts for approximately 70 - 75 percent of the cost for developing complete sanitation infrastructure.

Dependence on external technical consultants to design infrastructure solutions and for detailed project proposal development for external funders further limits the municipal council's ability to undertake repair and retrofitting of existing infrastructure and integrate new developments. Dependence on external funds for infrastructure development reduces the scope for timely action. With vacancies in technical posts, MMC is ill equipped to handle the challenges of providing resilient infrastructure and uninterrupted services.

MMC has submitted detailed project proposals to upgrade its water supply and sanitation infrastructure under the various schemes available for funding. There is a window of opportunity to look innovatively and strategically develop resilient plan of the future infrastructure. Mandvi has an opportunity of engagement of private sector into the WaSH infrastructure. For a city which experiences annual flooding and disruption of services and dilapidation of critical components, regulating and partnering with private services in water distribution, desludging services, and treatment of sludge needs to be explored. Water tankers, desludging carrier operators play a key role in filling missing gaps and can also play a significant role during disasters. The interagency development model in WaSH infrastructure has significant challenges and limitations and reduces the opportunity for decentralised and local level planning. Gujarat Water Supply and Sewerage Board (GWSSB) undertakes the development of most major WaSH infrastructure projects, with the role of operation and maintenance of the assets and in some cases the implementation of the projects is the responsibility of the local authority. The capital expenditure is dependent on state and central schemes.

Risk Governance of WaSH is influenced by not only multiple development agencies and stakeholders but also disaster management institutions with preventive and preparatory actions being part of the Disaster Management Plans, often at district level, for the coastal towns. And the role of local bodies, enablers of risk governance at local level have limited roles and mandates.

The State Disaster Management Plan of Gujarat has identified the hazard, vulnerability and risks the state faces, and defined the risk governance mechanisms, disaster risk reduction (DRR) and mainstream DRR with climate adaptation plans. It has defined the role of the various stakeholders in preparedness, response, and relief and in recovery and rehabilitation. It also defines the financial arrangements which could enable the stakeholders to do so. The role of the local authorities, as defined in the SDMP, is to aid in disaster management activities, ensure training of resources to be readily available for use in the event of a disaster, ensure that all constructions conform to the standards and carry out relief, rehabilitation and reconstruction activities in the affected area within its jurisdiction.⁶⁰

However, though infrastructure repairs and reconstruction post disaster are the responsibility of the local body, it has limited role in its selection, designing and implementation. This is a significant gap in risk governance of infrastructure which often leads to disrupted services as seen in the malfunctioning and state of disrepair observed in STPs and WTPs post disaster where the re - operationalising has often taken many months due to paucity of funds and need for external experts.

The system resilience assessment of Mandvi's infrastructure reveals that it is focused on response and recovery mechanisms post disaster which are centralized at the district level. However, the distance from the district headquarters can create vulnerabilities, as coastal climate hazards often disrupt essential linear infrastructure such as power transmission lines, roads, and telecommunications. The risk reduction functions for Water Supply and Sanitation are primarily the function of Gujarat Water Supply and Sewerage Board (GWSSB).

The DDMP elaborate the responsibilities as well as the SoPs for prevention, preparedness, rescue response and recover across very sectors and agencies. Based on the interim assessment of risk and vulnerabilities, the district focuses on mitigation, preparedness, and prevention; resilience of lifeline systems (water, power, and communications) and to mainstream DRR into the district plan.

Early warning is primarily controlled at district and taluka level. A city disaster management committee is proposed at the city level oversee all activities in disaster management. Climate change adaptation planning and preventive and preparedness planning for infrastructure at local level is absent in the DDMP.

CHAPTER 8 : CLIMATE CHANGE INITIATIVES IN MANDVI

NEELAM RANA, PRIYAKSHI GOGOI, NC NARAYANAN

Adaptation Efforts

Kachchh district is one of the driest regions in the state, receiving minimal rainfall, which makes water conservation and rainwater recharge efforts critically important. In response, the ULB has mandated through building by-laws that property owners must incorporate rainwater harvesting structures in new constructions. The Area Development Authority cell within the ULB is responsible for granting building permissions and occupancy certificates, ensuring adherence to these regulations. However, despite these mandates, the actual adoption of rainwater harvesting systems remains low, primarily due to space constraints on individual plots and the high initial installation costs. Moreover, the absence of state government subsidies or incentives further discourages widespread adoption. As one resident pointed out, the high cost of setting up rainwater harvesting systems makes it difficult for many households to implement them. Nevertheless, the ULB has taken the lead by installing rainwater harvesting structures in its own buildings, setting an example for the community.

Regarding groundwater regulation, municipal officials stated that there is little tradition of using wells for water in Mandvi, largely due to the city's proximity to the sea, which results in saline groundwater. Groundwater extraction and its regulation are overseen by the Mamlatdar office at the city level, while the ULB does not hold any jurisdiction in this area.

Mitigation Efforts

As part of its efforts toward climate change mitigation, the ULB has installed solar panels on its own buildings to promote renewable energy use and reduce carbon emissions. During our site visit, it was observed that the WTP is equipped with solar panels. However, despite this investment, the WTP has been non-operational for the past eight years, limiting the potential benefits of the installed solar infrastructure. This situation highlights the importance of not only adopting renewable energy technologies but also ensuring that critical infrastructure remains functional to fully realize climate mitigation goals.

Table 20 : Climate Change Initiatives in Mandvi

Initiative Name	Relevance	Status
Rainwater Harvesting in New Buildings	Enhances water conservation and recharge in a drought-prone area (Adaptation)	• Mandated through Municipal by-laws • Adoption is low due to space constraints, high costs, and no subsidies
Rainwater Harvesting in Public Buildings	Enhances water conservation and recharge in a drought-prone area(Adaptation)	Implemented in public buildings
Groundwater Use Regulation	Addresses over-extraction and salinity issues in coastal areas (Adaptation).	• Regulated by Mamlatdar office • ULB has no jurisdiction
Installation of Solar Panels on Municipality Buildings	Reduces carbon emissions and promotes renewable energy (Mitigation).	• Implemented, including at WTP • limited impact as WTP has been non-functional for 8 years.

CHAPTER 9: RECOMMENDATIONS FOR ENHANCING CLIMATE RESILIENCE OF WASH INFRASTRUCTURE & SERVICES IN MANDVI

NEELAM RANA; PRIYAKSHI GOGOI, SUCHARITA ROY, ASHISH DANGI , ABHAY JUNAGHARE, TEJASH ANAND & N.C. NARAYANAN

9.1 BACKGROUND

The previous chapter of this report analysed the status of water and sanitation infrastructure and services, and their interaction with climate change. It also examined the financial sustainability of ULB and identified both direct and indirect climate change initiatives currently underway at the town level. Key challenges and gaps were highlighted as part of this assessment.

Mandvi, a coastal town in Gujarat's Kachchh district, faces high climate vulnerability due to its arid conditions and exposure to droughts and floods. Its water and sanitation infrastructure suffers from poor water quality, an underused and understaffed WTP, inefficient drainage and sewage systems, and unreliable services during disasters. These challenges undermine climate resilience, public health, and environmental sustainability. To adapt to climate change, the town must upgrade its infrastructure to ensure 100% coverage, improve metering and resource management, and strengthen WTP operations. Sanitation systems need revamping to prevent flood-related contamination and reduce GHG emissions from inefficient wastewater management. Integrated on-site sanitation and desludging improvements can significantly cut methane emissions. Financial and human resource constraints within the ULB hinder investments in resilient infrastructure. Enhanced financial management, cost-reflective tariffs, better billing, and operational efficiency are essential. While Mandvi has initiated rainwater harvesting mandates and solar panel installations, limited adoption and non-functional infrastructure (like the WTP) reduce their impact. Overall, significant investments in resilient systems, climate-smart operations, and institutional capacity are needed to safeguard water supply, public health, and climate sustainability in Mandvi.

Building on these insights, the following section presents town-level recommendations for strengthening the water and sanitation sectors, with a focus on enhancing climate resilience and service delivery.

9.2 WATER

1. Decentralize Water Management in SMTs

- Promote *rainwater harvesting* and *watershed management* to enhance local water security.
- Reduce *dependency on distant water sources* by strengthening local resource management.

2. Strengthen Water Distribution Networks

- Upgrade infrastructure with *smart meters* and *leak detection systems*.
- Use *real-time monitoring* to reduce *Non-Revenue Water (NRW)* and improve supply efficiency.

3. Promote Local-Level Wastewater Recycling and Reuse

- Implement reuse systems for *non-potable applications* like irrigation and industry.
- Alleviate pressure on freshwater resources through *circular water use* strategies.

4. Enhance ULB Capacity with Data-Driven Tools

- Support *community-based water management* and participatory planning.
- Equip ULBs with tools for *evidence-based decision-making* and citizen engagement.

5. Integrate Climate-Resilient Practices

- Increase *water storage capacity* using check dams, ponds, and other structures.
- Address *climate variability and erratic rainfall* through resilient design and infrastructure planning.

9.3 SANITATION

1. Ensure Reliable and Equitable Water and Sanitation Services

- **Improve water quality** by enhancing maintenance and operational efficiency at the WTPs.
- **Target vulnerable communities** to bridge service delivery gaps despite ODF++ status.
- **Address monsoon-related turbidity, odour, and taste issues** through regular water quality monitoring and timely interventions.

2. Strengthen Urban Flood Management

- **Conduct assessment studies to examine status and typology of storm water drainage**
- **Upgrade drainage infrastructure** in high-density, low-income areas to prevent recurring flooding.
- **Integrate public health safeguards** by preventing water contamination and disease outbreaks.

- **Adopt a climate-health approach** in planning for drainage and flood resilience.

3. Improve Sewage Treatment and Management

- **Establish comprehensive sewage treatment facilities** to prevent contamination of groundwater and marine ecosystems.
- **Address GHG emissions** from partially treated sewage by investing in efficient treatment technologies.
- **Regularly monitor and audit oxidation ponds** to reduce public health and environmental risks.

4. Build Disaster-Resilient WaSH Services

- **Develop and equip permanent emergency shelters** with clean water, sanitation, and relief supplies.
- **Leverage community networks** by training local committees for emergency response.
- **Ensure equitable access** to WaSH services during floods and cyclones.

5. Climate-Resilient Infrastructure Planning

- **Invest in power backup systems** for critical services like water supply and sewerage to withstand disruptions during cyclones.
- **Adopt resilient design standards** for key infrastructure prone to extreme weather events.

6. Address Financial and Human Resource Constraints

- **Reduce reliance on state grants** by improving revenue generation and financial planning.
- **Strengthen staffing capacity** to balance implementation and administrative functions.
- **Enhance institutional efficiency** through improved HR practices and operational autonomy.

7. Regulate and Monitor Septage Management

- **Formally license private desludging operators** and enforce strict compliance.
- **Monitor sludge disposal** with digital tracking and penalties for violations.
- **Strengthen ULB capacity** to regulate and manage sludge safely, preventing illegal dumping.

9.4 GHG EMISSIONS

1. Improve Water Supply Efficiency

- **Reduce Non-Revenue Water:** Conduct water audit. Address leakages and unmetered use, which currently wastes ~18% of total water produced and the energy used to treat it.
- **Implement Universal Metering:** To monitor consumption and identify losses more accurately.

- **Improve Energy Efficiency:** Conduct energy audit. Upgrade pumps and reduce energy use in water treatment processes.

2. Better Wastewater and On-Site Sanitation Systems

- **Greening of Oxidation Ponds:** Introduce low-emission treatment alternatives to reduce methane emissions from BOD treatment.
- **Upgrade Septic Systems:**
 - Replace **leaky or unlined pits** to prevent the release GHG.
 - Improve **pit lining standards** and introduce **methane capture** mechanisms.
- **Improve Desludging Practices:**
 - Optimize desludging schedules to prevent excessive methane emissions.
 - Mandate proper disposal and tracking of desludging operations

3. Manage Stormwater to Reduce Emissions

- **Green Infrastructure:** Enhance stormwater retention and treatment to reduce nutrient runoff contributing to N₂O emissions
- **Nutrient Capture Strategies:** Implement systems to reduce nitrogen discharge (27.4 t N) into the environment.
- **Map storm water drainage** – coverage, typology

4. Holistic Wastewater Management

- **Adopt an Integrated Approach:** Treat water supply, wastewater, and on-site sanitation as interconnected systems.
- **Invest in Low-Carbon Technologies:** Focus on decentralised, context-specific, and energy-efficient treatment systems.
- **Climate Resilience + Mitigation:** Ensure infrastructure upgrades also contribute to emission reduction goals.

9.5 FINANCIAL SUSTAINABILITY

Water Supply – Financial Sustainability Recommendations

1. **Revise Water Tariffs**
 - Align tariffs with rising operational costs, especially energy and maintenance.
2. **Improve Billing and Collection Systems**
 - Reduce arrears through better tracking, timely follow-up, and enforcement.
 - Offer **flexible payment options** and penalties for non-compliance.
 - Digitize billing and streamline the payment process.
3. **Enhance Revenue and Cost Control**
 - Reduce dependence on external funding.
 - Focus on **energy efficiency** to lower operational costs.

4. **Public Engagement and Awareness**

- Run campaigns on the importance of timely payments.
- Create incentives for **early or timely settlement** of dues.

Sewerage and Sanitation – Financial Sustainability Recommendations

1. **Revise User Charges**

- Adjust to cover actual operational and maintenance costs.

2. **Explore Additional Revenue Sources**

- Introduce **connection fees**, septage service charges, or similar user-based contributions.

3. **Strengthen Collection Strategies**

- Improve tracking of overdue payments and send **timely reminders**.
- Penalize chronic defaulters and encourage compliance with **flexible payment options**.

4. **Digitize Payment Systems**

- Automate billing and collections to reduce inefficiencies.

5. **Improve Public Awareness and Engagement**

- Build a culture of responsibility around payments through targeted outreach.

6. **Innovative Financing and Cost Control**

- Explore new funding mechanisms and strengthen overall **financial management**.
- Reduce operational inefficiencies to enhance system sustainability

9.6 INFRASTRUCTURE RESILIENCE

Provisioning for emerging coastal risks:

Coastal risks like submergence and erosion, salt intrusion, groundwater and coastal flooding and inundation, Tsunamis, storm surges and wave shoaling are unique to the context. Differential secondary and cascading hazards like environmental degradation, contamination of water resources and land, outages, corrosion of underground networks, disease outbreaks and system failure require context suitable action.

Many climate risks are very local phenomena, like saline intrusions, changes in local water bodies, risk to critical infrastructure due to flooding etc. There is need for local risk assessments and information systems which capture data risks from saltwater intrusion and effluent contamination, outages, and system failures, etc to provide data for timely and adequate safeguarding of the infrastructure.

IPCC in its policy recommendations in the Sixth Assessment Report mentions that some coastal accommodation measures, such as early warning systems and flood-proofing of buildings, are often both low cost and highly cost-efficient under current sea levels (high confidence).

There are no alerting systems for failures due to inefficiency, energy outages, or creeping disasters. Information flow is top-down, missing ground intel and early warnings. For coastal towns like

Mandvi, multiple sudden local risks can result in disruption and delink the settlement from the district and the state. **Alerts at local level can give the local administration time to react adequately. It also helps in generating real time and current database for decision making.** IPCC recommends that coastal challenges can be eased using locally appropriate combinations of decision analysis, land-use planning, public participation, diverse knowledge systems and conflict resolution approaches that are adjusted over time as circumstances change (high confidence). Community ownership of the systems can reduce secondary risks like environmental degradation, contamination, and health challenges. Active participation at the local level and ecological awareness is critical for managing coastal risks like shoreline erosion, saline intrusions, land, and water contaminations and for safeguarding of coastal water resources from contamination.

For a low-lying city with comparatively high ground water levels, the high level of wastewater load can disturb the balance in the ecosystem already overburdened and exposed to increased runoffs, flooding, and coastal sea level rise. Service benchmarks need to be re-evaluated for recurring flood prone settlements with positive ground water zones of LECZ. Backflow and overflow of sewerage networks have been observed in Mandvi.

System designs like centralized sewerage networks in LECZ often need energy intensive pumping systems to ensure conveyance velocity. Energy based pumping dependent systems increase the risk of system failure or disruptions. Alternative energy sources should be integrated into formal systems.

Saline intrusions can corrode underground drainage networks, increasing the cost of repair and maintenance, non-revenue water and efficiency of the systems. Large networks of interconnected conveyance or distribution networks and long transmission systems are thus more vulnerable to system overloads during flooding, leakages, and disruptions. Shorter and decentralized yet interconnected networks with opportunity for compartmentalization can offer flexibility and reliability in distribution and conveyance. Infrastructure Safety and Resilience Plans for larger infrastructure should be part of the disaster management plans with ring fenced infrastructure protection and risk governance budgets provisioned and made available to local bodies for upkeep and maintenance.

Contextualized infrastructure design and suitable technological solutions for coastal ecosystems

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. IPCC highlights that many coastal decisions with time horizons of decades to over a century are being made now and can be improved by taking relative sea level rise into account, favouring flexible responses (i.e., those that can be adapted over time) supported by monitoring systems for early warning signals, periodically adjusting decisions (i.e., adaptive decision making), using robust decision-making approaches, expert judgement, scenario-building, and multiple knowledge systems (high confidence).

Modular and decentralised designs with scope for scaling and integration, redundancy, and continuity plan for infrastructure as it transitions help in reducing the vulnerability of already exposed population. Settlements transitioning in sizes, nature of urbanisation, local administration capacities and type of infrastructure provisioning have higher vulnerability. Mandvi is in a stage of transitioning into centralised infrastructure systems design. These transitioning periods often spread over a decade or two and makes services inequitable and unreliable.

It is critical to re – evaluate the system design and technology choices for such towns and cities. Centralised conveyance systems based on gravity are often difficult to design due to the low lying and undulating topography of the west coast. Sophisticated, capital intensive and energy intensive technologies for e.g., SBR technology for sewage treatment require not only high level of skilled workforce for operations at local level but are also more vulnerable to storm surges, inundations as well as saltwater intrusions. Location of these critical components, at the lowest elevation points of the of the of the city, can expose the systems to coastal risks. Infrastructure citing limitations should guide the choice of technologies for coastal towns. The diversified sanitation infrastructure offers an opportunity to explore decentralised technologies in sludge management which is currently completely inadequate. The diverse technology base provides an opportunity for hybrid sanitation solutions, such as "waste watersheds" and "sanitation zones" identified through socio-spatial zoning, participatory mapping, and a weighted analysis of geomorphological and hydrological indicators.⁶¹ When overlayed with emerging hotspots due to emerging climate risks and terrain conditions, the location and placement of critical components of infrastructure can be designed and choice of technology must be reliable in face of such risks. Mandvi will particularly need these approaches to undertake planning for sustainable, risk-free WaSH systems.

Coastal ecosystems can benefit from an ecosystem-based approach in design of sanitation infrastructure. Mandvi, which is part of a larger, arid, agro-ecological zone, can benefit by integrating its hinterlands into its infrastructural planning. Sludge and wastewater treatment with NBIS, aggregation models for operations in scale and development of viable waste markets such as the cluster approach for sewerage treatment adopted in South Goa district. Insufficient technical capacity to integrate traditional community infrastructure into formal systems, is a missed opportunity to enhance flexibility and of optimising the investments made for sanitation under Swachh Bharat Mission. These need to be explored and further retrofitted as sustainable and socially relevant informal NBIS solutions for WaSH infrastructure design.

Enhancing flexibility and reliability in systems:

Overdependence on centralized water supply and sewerage system increase the risk of city scale outages and disruption due to intense storms, precipitations, or technical failure due to salinity ingress. Increased dependencies on electric supply for operations, skilled manpower for sophisticated systems and funds for repair and maintenance increase risks to the infrastructure systems. Currently, the absence of redundancy (backup) plans, clear SoPs for continuity of

interconnected services and emergency/ contingency/ repair funds for repairs increases the vulnerability in infrastructure in Mandvi.

Mandvi could benefit from integration of the numerous dug wells and robust groundwater tables as part of the water supply infrastructure. These resources can be transformed into protected, monitored, and scientifically recharged wells that act as redundant water sources. When integrated with localized water treatment facilities, located at high grounds or with adequate structural mitigation to avoid contamination, and connected through decentralized pipeline networks, standposts, or community collection centers, these measures can significantly enhance water supply reliability during flood like situations. Furthermore, sensor-based alert systems—linked to mobile devices in the most exposed wards—can send timely notifications about water quality or levels, enabling prompt and efficient management of community resources by communities in partnership with the local administration. Corrective retrofitting of traditional pit latrines to scientifically designed septic tanks, particularly those adapted for high water table areas, is essential.

Redundancy is key to ensuring that water systems continue to operate smoothly, even in the event of component failures. Water treatment plants, sewerage treatment plants, pumping systems integrated into the conveyance systems, equipped with redundant options can continue delivering clean water or safe sanitation even if one system fails due to contamination or technical issues. By diversifying water sources and utilizing smaller, decentralized treatment solutions, backup facilities can maintain supply if one component fails.

Enhancing risk governance of Infrastructure

The transformative action needed in the infrastructure of Mandvi, the new projects under conceptualisation and the funds that are proposed for investment, offers a significant opportunity to integrate resilience through evidence-based planning, agile governance, and innovative finance models. There is need to evaluate the systemic risks and contingent liabilities, adopt redundancy and continuity planning and establish protocols for infrastructure recovery post crisis. There is need for building capacities of the local administration and of handholding support for transitioning settlements.

There is need for of handholding support for transitioning settlements. The role of municipalities has yet not been clearly established in the SDMP and the DDMP. While the former provides advisory recommendations and defines some role for ULBs, the DDMP fails to effectively integrate the ULBs into the institutional structure of disaster management. There is limited capacity for evidence-based decision-making and the absence of decision-support systems at local level. Data gaps and mismatches have been noted in published SLBs, SBM data, municipal data, and community information. This highlights the need for integration of real time alerting systems, data management systems and community level data integration to generate, validate and audit data to support effective data- driven planning and governance. The generation of local level data, early warning

and integrated alert systems, regular risk assessment at local level is critical for building resilience in infrastructure in coastal ecosystems.

Local authorities are the key enablers of local level coordination and locally suited adaptations, need to be provided autonomy in decision-making in the local infrastructure development. Multiple agencies engagement in WaSH infrastructure development has resulted in gaps in asset ownership and accountability, fragmented development of infrastructure which leads to operational challenges. The active engagement of local bodies in disaster prevention and preparedness planning at district and city level can enable the provisioning of resilience measures in WaSH infrastructure and a formal collaboration structure is critical for enhancing resilience in infrastructure.

There is need for clear regulatory authority and oversight at local level to integrate DRR and CCA for the infrastructure design, a dedicated climate cell (integrated with the city disaster management cell as advised in the DDMP), process integration of organizational learning at local level or evaluation of the outcomes from its actions. Town development plans and strategy do not include DRR and CCA. There is no ring-fenced budgeting for DRR and CCA.

Disaster resilience Investment planning and revenue diversification for sustainability:

Local infrastructure development can improve revenue generation from business models in waste-to-energy, wastewater markets in rural areas, and WaSH taxes from tourism, industries, and ports.

Where space is available, ecosystem-based adaptation can reduce coastal risk and provide multiple other benefits such as carbon storage, improved water quality, biodiversity conservation and livelihood support (medium confidence). (IPCC, 2019) There is need for developing an integrated water resource and sewerage management perspective for the city and the region. WaSH infrastructure in low lying cities like Mandvi, should be looked at as an ecosystem sensitive and integrated infrastructure. The opportunities of use of treated wastewater, from a large city catchment and the arid hinterland should not be overlooked. It also opens the opportunity for water markets as a source of revenue to the city administration. A cluster-based approach in WaSH infrastructure planning and waste treatment can achieve economies of scale and reduce costs. Shared WaSH services between settlements can reduce expenditure and provide alternative revenue sources.

There is currently no provision or scope for disaster resilience investment planning by local bodies. Access to investment tools, resources, and processes to avoid, reduce, and transfer risk is needed. Current resilience measures are dominated by post-disaster response and recovery activities. There is need to provision for a ring-fenced budget for DRR-related initiatives at a local level. There is an absence of safeguards to protect infrastructure maintenance budgets. For small cities struggling with financial sustainability, DRR and CCA mainstreaming will require funding support.

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ANNEXURE -I: DATA GAPS

The project design necessitated 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.

Water

1. **Inadequate Granular Water Consumption Data:** Household-level water consumption is not metered in many areas; bulk metering data (number of connections × billed consumption) does not accurately capture per capita usage or disparities across income groups or geographies (e.g., slums vs. apartments).
2. **Unaccounted for Water (UFW) and NRW:** Accurate estimation of transmission and distribution losses is hampered by the absence of metering at intermediate system points and outdated infrastructure records, making it difficult to precisely attribute inefficiencies or quantify water losses.

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 SDGs and is relevant for climate adaptation frameworks. Additionally, it plays a critical role in estimating 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)⁶² 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.
3. **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 Ministry of Housing and Urban Affairs (MoHUA) guidelines, 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.

4. **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 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.
5. **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 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.

Risk Resilience

ULB does not have GIS-compatible shapefiles. Hence boundary estimations were made through referencing paper-based image maps.

ANNEXURE-II: STAKEHOLDER CONSULTATION WORKSHOP ‘CLIMATE RESILIENT URBAN WATER AND SANITATION INFRASTRUCTURE SERVICES IN COASTAL TOWNS’: KEY HIGHLIGHTS AND WAY FORWARD

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, Goa, 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%. Non-revenue water (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 Goa 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 -III: ABBREVIATIONS AND GLOSSARY

AMRUT Atal Mission for Rejuvenation and Urban Transformation

CCA Climate Change Adaptations

CDRI Coalition for Disaster Resilient Infrastructure

DDMP District Disaster Management Plan

DM District Magistrate

DRR Disaster Risk Reduction

FSSTP Faecal Sludge and Septage Treatment Plant

GIRI Global Infrastructure Risk Model and Resilience Index

GIS Geographic Information System

GSR Ground Level Storage Reservoir

IFIs International Financial Institutions

IPCC Intergovernmental Panel on Climate Change

LPCD Litres Per Capita per Day

LULC Land Use Land Cover

MLD/ KLD Million Litres per Day/ Kilo Litres per Day

MMC Mandvi Municipal Council

MSL Mean Sea Level

NbIS Nature-Based Infrastructure Solutions

NRW Non-Revenue Water

ODF Open Defecation Free

OSS On Site Sanitation Systems

RIS Risk Information Systems

SBM Swachh Bharat Mission

SBR Sequence Batch Reactors

SLBs Service Level Benchmarks

SoP Standard operating Procedure

STPs Sewage Treatment Plants

UNDRR United Nations Office for Disaster Risk Reduction

WTP Water Treatment Plant

WaSH Water, Sanitation, and Hygiene

Term	Definition
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) ⁶³
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) ⁶⁴
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)

⁶² International Institute for Population Sciences. 2020 National Family Health Survey – 5 (2019-2020). District Fact Sheet. Ministry of Health and Family Welfare.

⁶³ CDRI. (2023). Map Viewer. Retrieved from Global Infrastructure Risk Model and Resilience Index, Measuring Risk and Resilience in Infrastructure Solutions: <https://giri.unepgrid.ch/map>

⁶⁴ Ministry 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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