



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

Situational Assessment Report

DEVBHUMI DWARKA, GUJARAT

2026

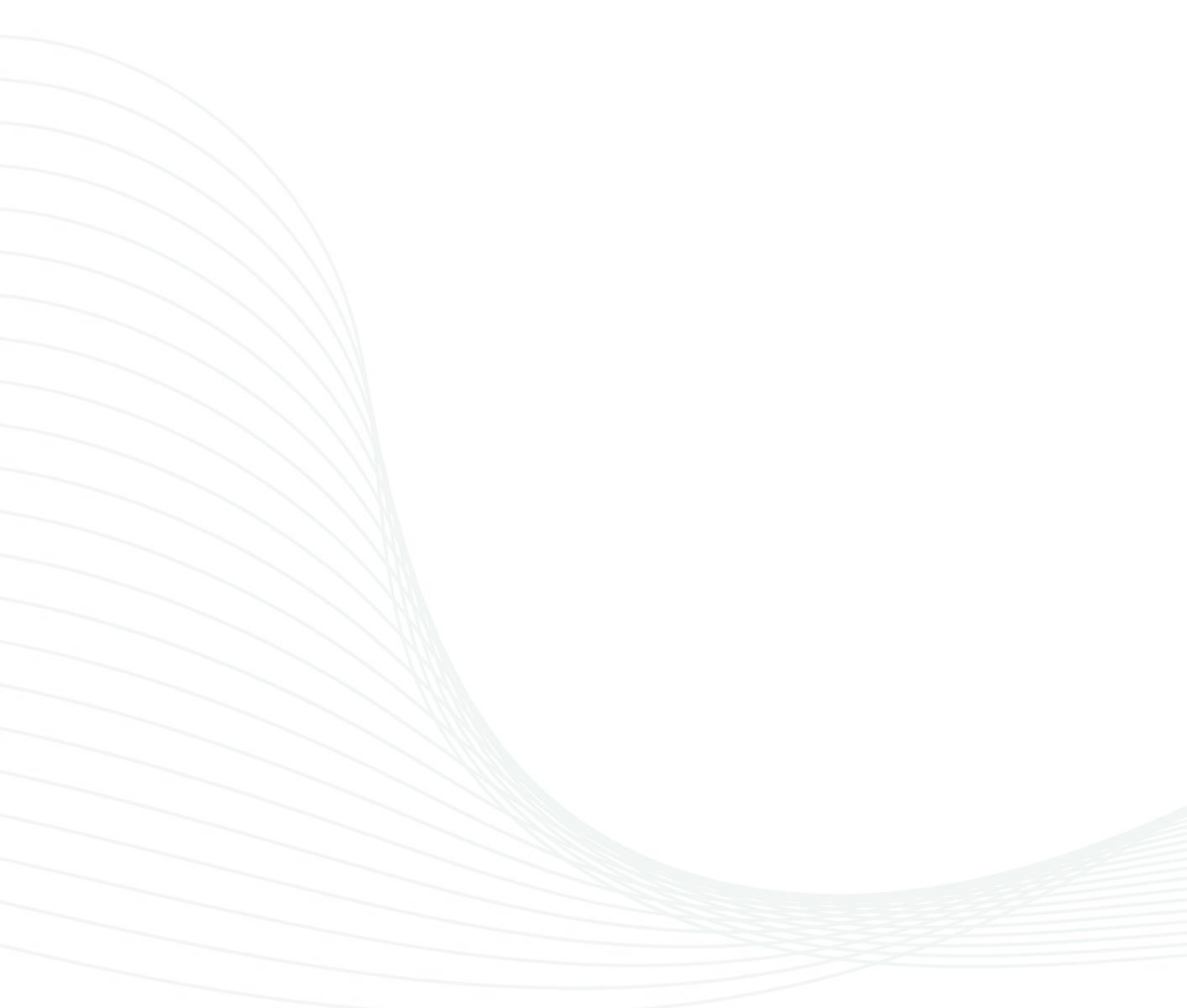


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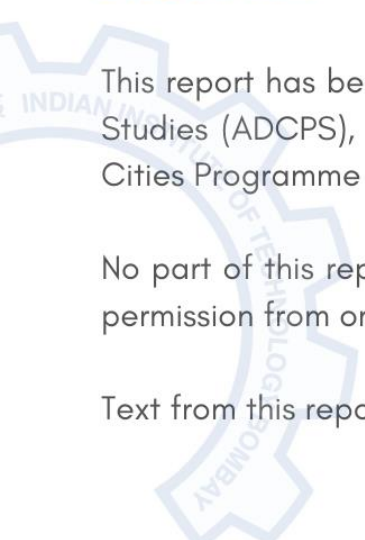


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## TITLE

Resilience of Urban Water and Sanitation Infrastructure & Services in Coastal Towns :  
Situational Assessment of Devbhumi Dwarka, 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, **focuses on Devbhumi Dwarka town- a Class-III coastal town in Gujarat**. The report examines town'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.

**Devbhumi Dwarka**, a town of religious significance, faces heightened exposure to multiple climate hazards such as earthquakes, cyclones, storm surges, intense precipitation events, and tsunamis. Over 80% of its land area lies at an elevation less than 10 meters above mean sea level, making the town highly vulnerable to flooding and infrastructure disruptions. Additionally, Dwarka is exposed to high-intensity cyclonic and storm impacts, with storm surges reaching heights of up to 3 meters. Groundwater flooding is another significant risk, worsening the adverse impacts faced due to heavy rainfall and coastal inundation.

The town also faces significant challenges in its water and sanitation infrastructure amid climate change impacts. Despite being classified as a “safe” groundwater zone, parts of the town experience water stress due to urbanization and weak monsoons. While community-led rainwater harvesting initiatives show local adaptation, critical issues persist, including a non-functional water treatment plant and limited water coverage. The town has achieved progress in sanitation, reaching ODF++ status, but gaps remain in inclusive service delivery, particularly for underserved communities. Frequent flooding damages aging infrastructure like the sewage treatment plant, exacerbated by limited drainage and low-lying terrain. Capacity and financial constraints hinder sustainable wastewater management, highlighting the need for improved billing, tariff reforms, and external partnerships. Additionally, poor system performance contributes to GHG emissions, emphasizing the need for comprehensive solutions like sewer coverage and biogas recovery. To enhance climate resilience, Dwarka must focus on inclusive service expansion, flood risk integration, infrastructure modernization, and capacity building for local authorities.

## KEY RECOMMENDATIONS:

### WATER AND SANITATION

- Repair and restore non-functional WTPs to close infrastructure gaps.
- Decentralize water management in SMTs with rainwater harvesting, watershed management, and reduced dependence on distant sources.
- Upgrade distribution networks using smart meters, leak detection, and real-time monitoring to cut NRW.
- Promote wastewater recycling for non-potable uses (irrigation, industry) to ease freshwater demand.
- Build ULB capacity through data-driven decisions, community-based water management, and citizen engagement.
- Integrate climate-resilient practices with check dams, ponds, and natural infrastructure to address erratic rainfall.
- Expand water and sanitation access in low-income communities via modular, flood-resilient shared toilets; ensure inclusive service delivery; prioritize vulnerable areas; involve communities; deploy decentralized nature-based solutions.
- Address flooding with upgraded stormwater systems, flood-risk-based planning, regular maintenance, and rapid response teams.
- Replace aging sewer lines, implement GPS mapping, and ensure transparent monitoring.
- Bridge O&M capacity gaps with ULB staff training and peer-learning platforms.
- Strengthen ULB autonomy per the 74th CAA, involving them in decision-making and context-specific technology choices.

### FINANCIAL SUSTAINABILITY

1. **Enhance revenue collection for water supply:**
  - Improve billing systems
  - Address arrears effectively
  - Introduce incentives for timely payments
2. **Revise water tariffs:**
  - Align tariffs with operational costs and inflation
  - Consider dynamic pricing to stabilize revenue
3. **Focus on cost management:**
  - Reduce inefficiencies in maintenance
  - Explore lower-cost bulk water procurement
4. **Diversify revenue sources:**
  - Seek external funding and grants
  - Establish partnerships to buffer fluctuating revenues
5. **Strengthen sewerage and sanitation financial systems:**

- Establish robust billing and collection mechanisms
  - Expand tax base and adjust service charges to rising costs
  - Introduce incentives or penalties to improve payment compliance
6. **Improve financial planning and public engagement:**
- Conduct better fiscal planning
  - Run public awareness campaigns to boost payment adherence

## INFRASTRUCTURE RESILIENCE

### 1. Coastal Risks

- Needs: localized risk assessments, early warning, real-time data, alternative energy, decentralized/compartmentalized systems.
- Community ownership and ecological awareness reduce risks.

### 2. Context-Specific Infrastructure

- Avoid one-size-fits-all; designs must suit coastal topography.
- Prioritize modular, decentralized, scalable, and flexible systems.
- Account for sea-level rise, salinity, and storm surges in location and technology choices.
- Hybrid sanitation (sanitation zones, participatory mapping) and ecosystem-based approaches (NbS, hinterland, clusters).

### 3. System Flexibility & Reliability

- Overreliance on centralized WaSH increases outage risks.
- Lacking redundancy, SoPs, and contingency funds.
- Use dug wells, decentralized treatment, sensors, septic retrofitting, and backup power.
- Diversify water sources and ensure decentralized treatment.

### 4. Governance & Capacity

- New infrastructure = opportunity for resilience via data-driven, evidence-based planning and innovative finance.
- Needs: clear local authority, climate cells, Disaster Risk Reduction /Climate Change Adaptation mainstreaming.
- Shared WaSH, ecosystem-based adaptation, and revenue generation (waste-to-energy, wastewater markets, WaSH taxes).
- Ring-fenced DRR/CCA funds and resilience investment support for small towns

# 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 extremes<sup>1</sup>. With high risk of concurrent flood incidents, the country is among the most vulnerable countries to climate change as per the 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)<sup>2</sup>. 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)<sup>3</sup> <sup>4</sup>. **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)<sup>5</sup>. Water and sanitation services face significant threat from climate change induced hazards, and it is 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)<sup>6</sup>. 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 forming in the Arabian Sea (west coast)** (Deshpande, et al., 2021)<sup>7</sup>. 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)<sup>8</sup>. 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)<sup>9</sup>. 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)<sup>10</sup>. 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)<sup>11</sup>. Further, west coast states are more exposed to sea level rise; every one-metre rise in sea level can inundate almost 5,763 km<sup>2</sup> of land (Woodruff, BenDor, & Strong, 2018)<sup>12</sup>. 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.

**This report focuses on Devbhumi Dwaraka, a Class-III coastal town in Gujarat.** The report primarily examines the town's adaptive capacity in the water and sanitation sector amid climate change and assesses the sector's GHG emissions to inform the risk assessment of climate change impacts on its infrastructure and services.

**Devbhumi Dwarka**, a town of religious significance, faces heightened exposure to multiple climate hazards such as earthquakes, cyclones, storm surges, intense precipitation events, and tsunamis. Over 80% of its land area lies at an elevation less than 10 meters above mean sea level, making the town highly vulnerable to flooding and infrastructure disruptions. Additionally, Dwarka is exposed to high-intensity cyclonic and storm impacts, with storm surges reaching heights of up to 3 meters. Groundwater flooding is another significant risk, worsening the adverse impacts faced due to heavy rainfall and coastal inundation.

**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, analysing 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 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—Devbhumi Dwarka. 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 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 greenhouse gas (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.

### 1.3.1 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 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**

| <b>Key Parameters</b>                     | <b>Selection criteria</b>                                              |                                |                                                             |
|-------------------------------------------|------------------------------------------------------------------------|--------------------------------|-------------------------------------------------------------|
| Administrative status                     | Municipal Corporation                                                  | Municipal Council<br>(A and B) | Nagar Panchayat<br>(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) 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   | Mangalore 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)<sup>13</sup>, **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 overlayed 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, Swachh Bharat Mission (Urban), Central Pollution Control Board, Performance Assessment System for urban water and sanitation (PAS) website, District Disaster Management Plans, and the municipality website. Additionally, the review was instrumental in mapping key stakeholders, defining their roles and responsibilities, and developing the analytical framework for various thematic studies, including GHG emission estimation.

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

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.

In Dwarka, vulnerability assessment began by identifying low-lying zones and areas with high population density, using building proximity and elevation as primary indicators. Areas that exhibited both low elevation and compact construction were marked as high-priority hotspots. The field studies including visual assessment and semi-structured interviews with residents of Dwarka were undertaken at 11 hotspot locations to capture the diversity of issues across different wards and communities and ground truthing of secondary data.

1. **Secondary Data Collection:** Meetings with Urban Local Bodies (ULBs) were conducted to collect a variety of documents, including city maps, land-use land cover maps, electricity bills, data on Service Level Benchmark (SLB) data, Swachh Bharat Mission-Urban (SBM-U), Atal Mission for Rejuvenation and Urban Transformation (AMRUT), along with financial reports and other relevant datasets. Detailed information on sewage treatment plant (STP) size, collection and treatment volumes, and water reuse was also gathered to understand the scale and performance of existing infrastructure.

2. **Semi-Structured Interviews:** In Dwarka, we interviewed (semi-structured interviews) key ULB officials—including the Chief Officer (1), water and sanitation Engineers (2), Swachh Bharat Mission (urban) Coordinator (2), Town Planner (1), Accountant (2), and System Operators (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. We also conducted interview with District disaster officials. 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.
3. **Site Visits:** Site visits were conducted to validate the functioning of critical water and sanitation infrastructure, such as water treatment plants (WTP), ESR and GSR, sewage treatment plants (STPs), Pumping stations and disposal. 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.
4. **Rapid Field Assessment:** 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 process involved on-ground observations and in-depth conversations with residents (11#), particularly in low-income neighbourhoods and areas identified as vulnerable to extreme events during interviews with ULB officials. The emphasis was on understanding challenges related to access, affordability, and reliability of water and sanitation services in the context of climate change. Residents were asked

whether they had private toilets on their premises, and if so, whether these were connected to the sewage network. For those not connected, questions focused on how and where human waste was disposed of.

In cases where onsite sanitation systems (OSS) were used, we gathered information on the type of system, frequency and cost of septic tank cleaning, service providers involved, and affordability and other challenges of these services. Additional questions covered methods of greywater disposal, sources of tap water, costs associated with water connections, and any support received from the ULB during disaster events. For households without individual toilets, we explored the alternative sanitation arrangements they relied on. Additionally, the team visited two public toilets to assess their condition firsthand. During our rapid field assessment, we did not follow any specific strategy or have a particular reason for selecting these toilets. Instead, we visited public toilets located in busy market areas to observe their condition and usage.

**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**

| <b>Category</b>                                                                                             | <b>Possible Sources of Emissions</b>                                                                                                                                                                                                                                                                                                                                                                                     | <b>Methodology</b>                                                                                                                                                                                                                                                                                                                                                |
|-------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Direct Emissions</b>                                                                                     | <ul style="list-style-type: none"> <li>- Methane (CH<sub>4</sub>) emissions from anaerobic decomposition of organic matter in wastewater.</li> <li>- Nitrous Oxide (N<sub>2</sub>O) Emissions from nitrification and denitrification of nitrogen compounds wastewater</li> <li>- Methane (CH<sub>4</sub>) emissions from the decomposition of organic matter in anaerobic sediments in freshwater reservoirs*</li> </ul> | <i>2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement)</i>                                                                                                                                                                                                                                                                             |
| <b>Indirect Emissions</b>                                                                                   | <ul style="list-style-type: none"> <li>- Indirect emissions from electricity consumption</li> <li>- Life cycle GHG emissions associated with the chemicals used in water and wastewater treatment processes (alum, hypo, chlorine etc.) *</li> <li>- Emissions from diesel combustion for transportation</li> </ul>                                                                                                      | <p><i>Electricity consumption data obtained from urban local bodies and an average grid emission factor 0.716 tCO<sub>2</sub>/MWh (FY 2022-23, Central Electricity Authority) for Indian grid used for CO<sub>2</sub> estimation.</i></p> <p><i>Diesel consumption for desludging trucks based on information obtained from interviewing truck operators.</i></p> |
| <b>Embedded Emissions</b>                                                                                   | <ul style="list-style-type: none"> <li>- Life cycle GHG emissions associated with the materials used in the physical infrastructure. *</li> </ul>                                                                                                                                                                                                                                                                        | <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. |                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                   |

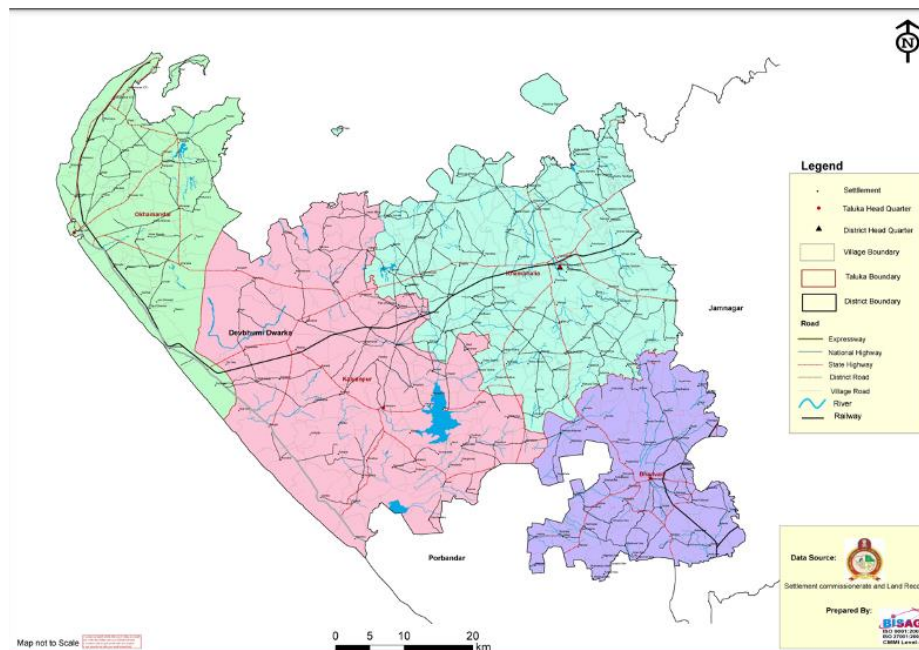
The study also identified several critical data gaps that limit comprehensive assessment and effective decision-making. These gaps, detailed in Annexure-II, highlight the need for improved data collection, systematic reporting, and stronger integration of information across institutions to better inform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

# CHAPTER 2: TOWN PROFILE: DEVBHUMI DWARKA

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

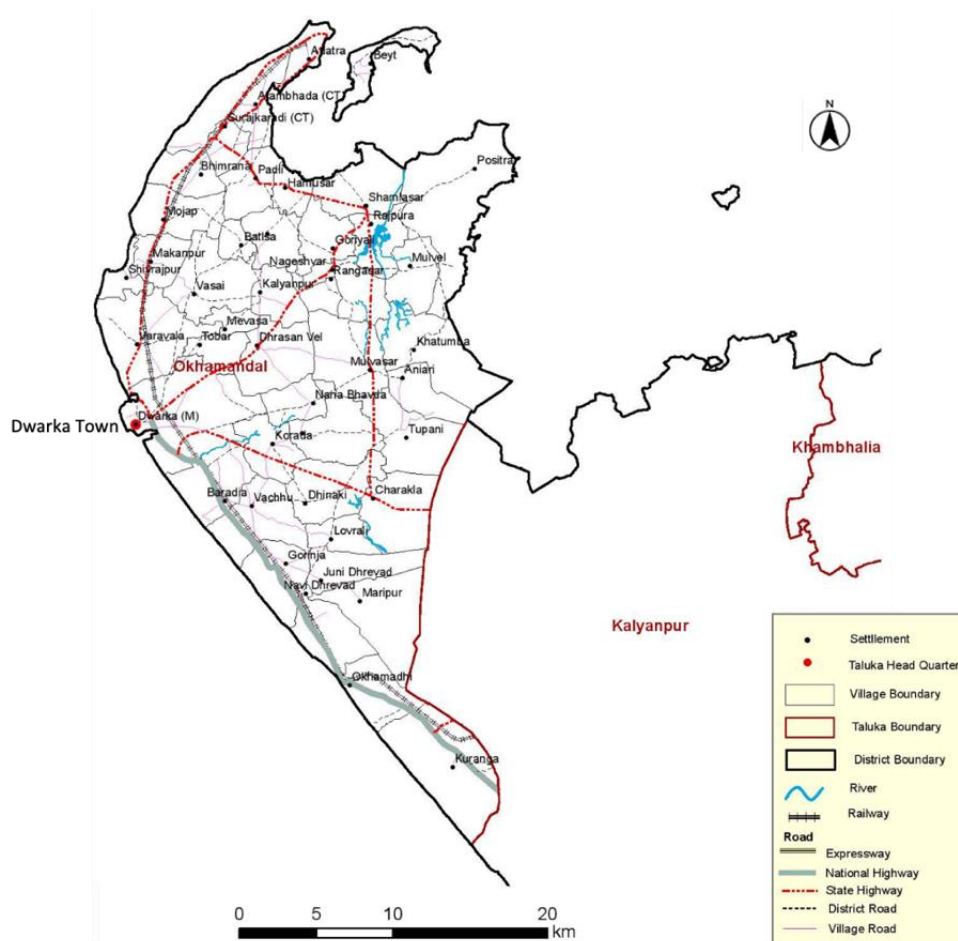
Dwarka Municipality is situated in the Devbhumi Dwarka district. It comprises 7 wards and is classified as a Class C town, covering an area of 42.07 square kilometres. The Devbhumi Dwarka District is located in the southern coast of gulf of Kuchchh in Gujarat state. Devbhumi Dwarka town was once a part of Jamnagar district, later it was separated as Devbhumi Dwarka district in 2013. Devbhumi Dwarka District comprises two sub-division named Khambhalia and Dwarka. Khambhalia sub division includes Khambhaliya and Bhanvad talukas while Dwarka sub division includes Okhamandal and Kalyanpur talukas. Dwarka Municipality is part of the Okhamandal taluka.

**Figure 1 : Devbhumi Dwarka District Map Showing Okhamandal Taluka**



Source: Revenue Department, Government of Gujarat

**Figure 2 : Map showing Dwarka town**



Source: Revenue Department, Government of Gujarat

**Demographic Profile:** According to the 2011 Census of India, Dwarka Municipality has a population of 38,873, consisting of 20,306 males and 18,567 females. The Female Sex Ratio in Dwarka stands at 914 females for every 1,000 males, which is slightly lower than the state average of 919. The literacy rate in Dwarka is 75.94%, which is lower than the state's average of 78.03%. The municipality has 8,207 households.

In terms of social composition, Scheduled Castes (SC) constitute 4.98% of the population, while Scheduled Tribes (ST) represent 0.88%. A total of 12,690 individuals are engaged in work or business activities, with 11,229 males and 1,461 females. Among the working population, 94.16% are involved in Main Work, while 5.84% are engaged in Marginal Work. According to PAS data,

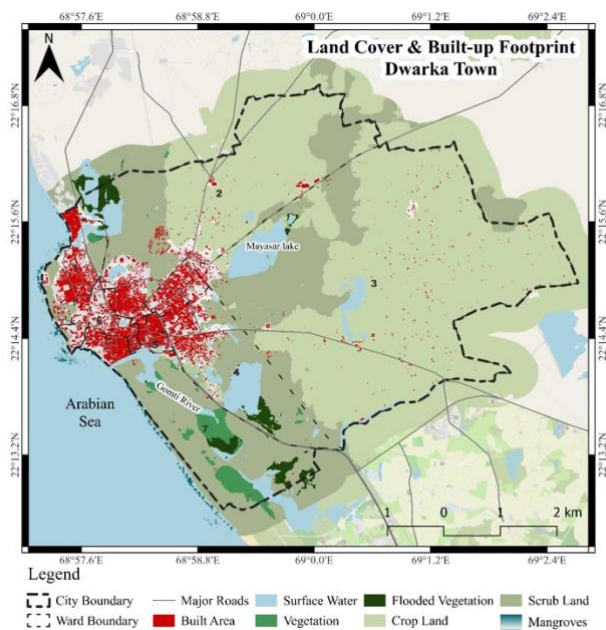
the total population of the city in 2022-2023 was 52,800, with 3,100 individuals residing in slums. The number of households during this period was approximately 11,088, of which 700 were located in slum areas in 3 slum settlements. However, these figures slightly differ from the data provided by the ULB in the AMRUT report.

**Topography:** Dwarka is located at the western edge of the Saurashtra Peninsula which is characterised hilly track sprinkled with low mountains. Dwarka town itself is a lowland but influenced by the peninsular landform, which dominates the northern eastern zones. The northern part of the town is influenced by the coastal wetlands and is characterised by salt marshes on its northern and western ends.

A low-lying town, nearly 35 % of the land area of Dwarka is at an elevation of less than 5m above MSL and nearly 80 % of its administrative area at a less than 10 m above sea level. The district of Devbhumi Dwarka has no major rivers only seasonal streams flowing into the Gulf of Kutch in the north and north-west.

**Land use and Landcover:** The Saurashtra Peninsula, where Dwarka city is located, is characterised by wastelands, hilly tracks and sprinkling of low mountains. A sizeable portion of the town is under scrublands and crop land. Dwarka town is flanked by the seasonal Gomti river in the east, Arabian sea on its south and coastal wetlands on the southwest. The north-western side of the city is part of the coastal wetland with salt marshes, mangroves, and low rocky outcrops. (Refer Figure 3).

**Figure 3 : Landcover and Built-up Footprint of Dwarka Town**



Source: Sentinel 2 10m LULC; Open Street Map; Landsat 9 (Mangroves), 2024; Devbhumi Dwarka Municipalities

Dwarka has 7 wards each accommodating population ranging between 13 – 15 %. However, the population distribution and built-up footprint of Dwarka (Refer Table 4) shows ward 5 as the smallest ward in size with the highest population density located at the town centre. Dwarka, bound by the sea in its west with no scope of expanding any further, has grown towards its east along the transport corridors.

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

| Ward no | Population | Estimated Ward Size (sq. km) | Estimated Population Density (per sq. km) | Built Area % |
|---------|------------|------------------------------|-------------------------------------------|--------------|
| 1       | 6062       | 1.5                          | 4090                                      | 2%           |
| 2       | 5703       | 9.5                          | 599                                       | 13%          |
| 3       | 5115       | 21.2                         | 242                                       | 5%           |
| 4       | 5440       | 3.9                          | 1391                                      | <b>64%</b>   |
| 5       | 5347       | 0.3                          | <b>19658</b>                              | 34%          |
| 6       | 5411       | 0.9                          | 6019                                      | 5%           |
| 7       | 5795       | 4.9                          | 1174                                      | 42%          |

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 (Shrestha, 2021)<sup>14</sup>.

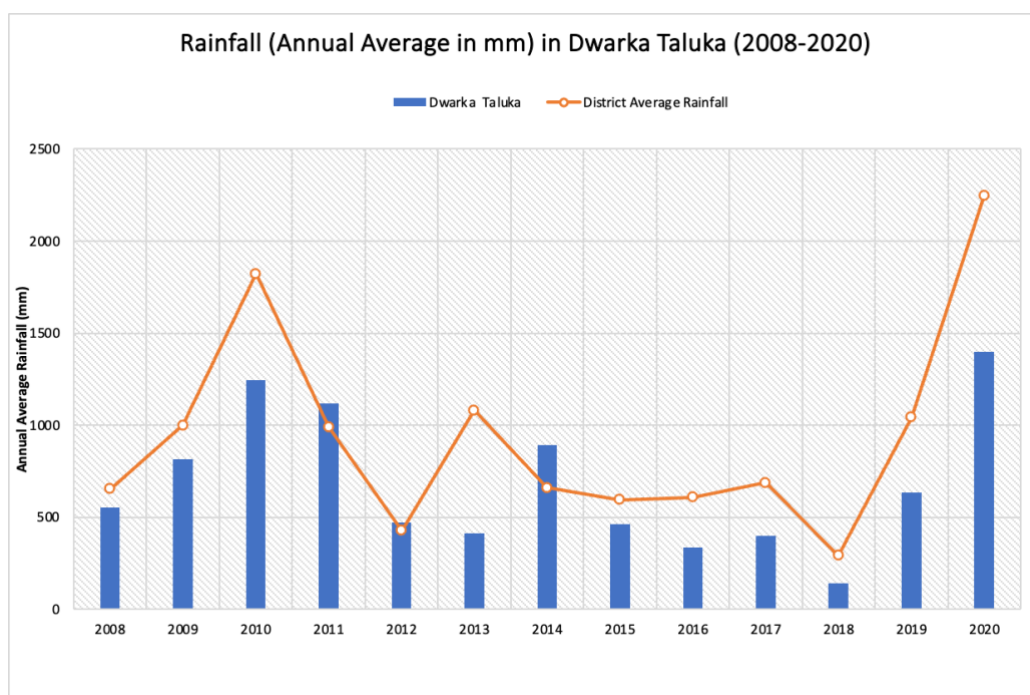
**Climate:** The Climate of Devbhumi Dwarka District can be regarded as one of extreme kind with hot summers & cold winters except in the coastal region, where it is generally pleasant all throughout the year. The air is humid due to the coastal location. The temperature at Devbhumi Dwarka district headquarters ranges from 42.0 degree centigrade higher in the summer and 4.2 degree centigrade lowest in the winter. The average annual rainfall in the town is 16.25mm in 2022-23 as per the Government of Gujarat's report on District statistics (Directorate Of Economics and Statistics., 2023)<sup>15</sup>.

**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

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 Authority, 2024)<sup>16</sup>. The figure below (figure 4) illustrates the rainfall pattern in Dwarka Taluka, which records one of the lowest average annual rainfall levels in the district, falling significantly below the district average. The figure also shows erratic behaviour of the monsoon. The low rainfall coupled with erratic behaviour of the monsoon make Devbhumi Dwarka/Jamnagar the most vulnerable to drought. In 2016, about 1115 villages of 6 Districts including Dwarka were declared drought affected (Directorate Of Economics and Statistics Government Of Gujarat, 2022).

**Figure 4 : Rainfall in Dwarka Taluka (2008-2020)**



Source: (Collector Office , 2021)<sup>17</sup>

**Although groundwater extraction in Okhamandal Taluka currently falls within the 'safe' category (as shown in the table 5),** the area experiences one of the lowest recharge rates from rainfall. Groundwater quality is another significant concern. The Dwarka region, composed of gypsiferous and calcareous red clay beds along with sandy limestone, has poor-quality groundwater, with chloride concentrations ranging from 500 to 700 mg/l.

**Table 5 : Ground Water Resources Development (2023) in Okhamandal Taluka**

| Annual Replenishable GW resources (ham) |                             |                             | Total Annual Ground Water Recharges (ham) | Environmental Flows (ham) | Annual Extractable GW (ham) | Annual Ground water Draft (Ham) |            |          |         | Stage of GW extraction (%) | Categorisation of Assessment unit |
|-----------------------------------------|-----------------------------|-----------------------------|-------------------------------------------|---------------------------|-----------------------------|---------------------------------|------------|----------|---------|----------------------------|-----------------------------------|
| Monsoon                                 |                             | Non-monsoon                 |                                           |                           |                             | Irrigation                      | Industrial | Domestic | Total   |                            |                                   |
| Recharge from Rainfall                  | Recharge from other sources | Recharge from other sources |                                           |                           |                             |                                 |            |          |         |                            |                                   |
| 2144.68                                 | 135.68                      | 223.39                      | 2503.75                                   | 125.19                    | 2378.56                     | 874.1                           | 30.78      | 163.51   | 1068.39 | 44.92 %                    | safe [ $\leq 70$ %]               |

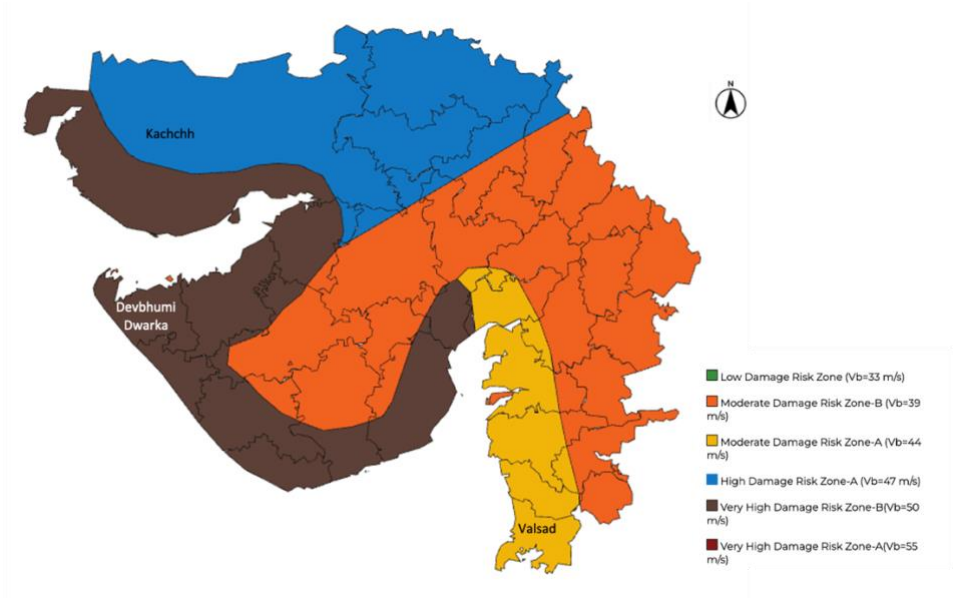
Source: (Central Ground Water Board , 2023)<sup>18</sup>

## 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, Dwarka district and town falls under the high maximum wind speed of 64-90 m/s and a very high damage risk zone (Figures 5 and 6).

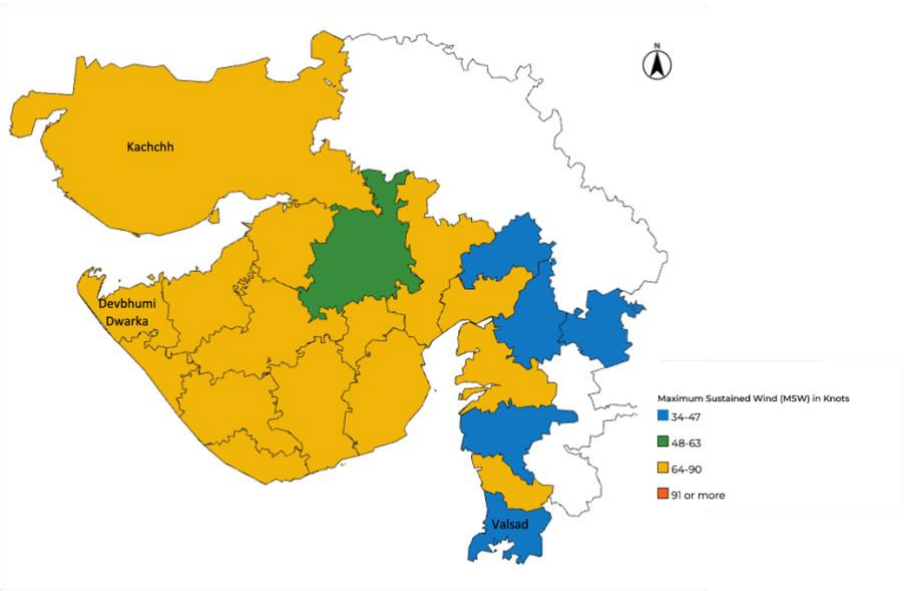
The coastal district of Dwarka is particularly prone to cyclones. For example, Cyclone Biparjoy in 2023, a severe cyclonic storm, brought strong winds and heavy rainfall to Gujarat's coastal regions. Residents in low-lying areas of Devbhumi Dwarka and Kachchh districts were relocated to safer locations as a precautionary measure (Gujarat State Disaster Management Authority, 2024, pp. 11-13).

**Figure 5 : District Exposure to Wind Hazard**



Source: (Niti Aayog, 2025)<sup>19</sup>

**Figure 6 : District Exposure to Maximum Sustained Winds During Cyclonic Activities**



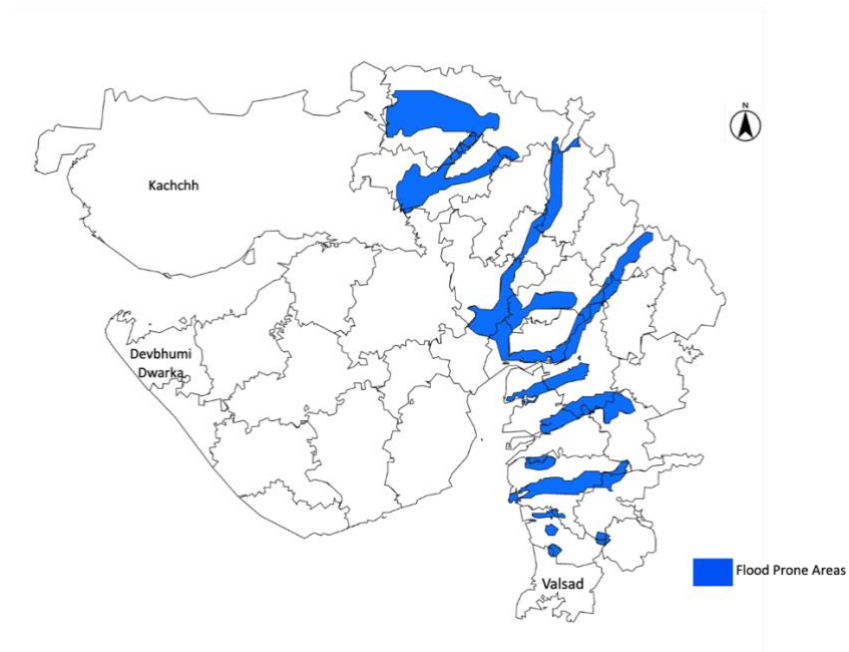
Source: (Niti Aayog, 2025)

## Floods

According to the NITI Ayog, the Devbhumi Dwarka district is not prone to floods (figure 7). As per the India Flood Atlas, the district is vulnerable to floods (0.631) with low score for hazard, exposure, and risk. However, flooding from rivers is a common challenge in the district, with all major river systems identified as vulnerable in the vulnerability Atlas. Urban centres like Devbhumi Dwarka, Jodiya, Khambhalia, and Kalyanpur frequently experience floods, largely due to poor drainage infrastructure and increased runoff from paved and non-porous surfaces.

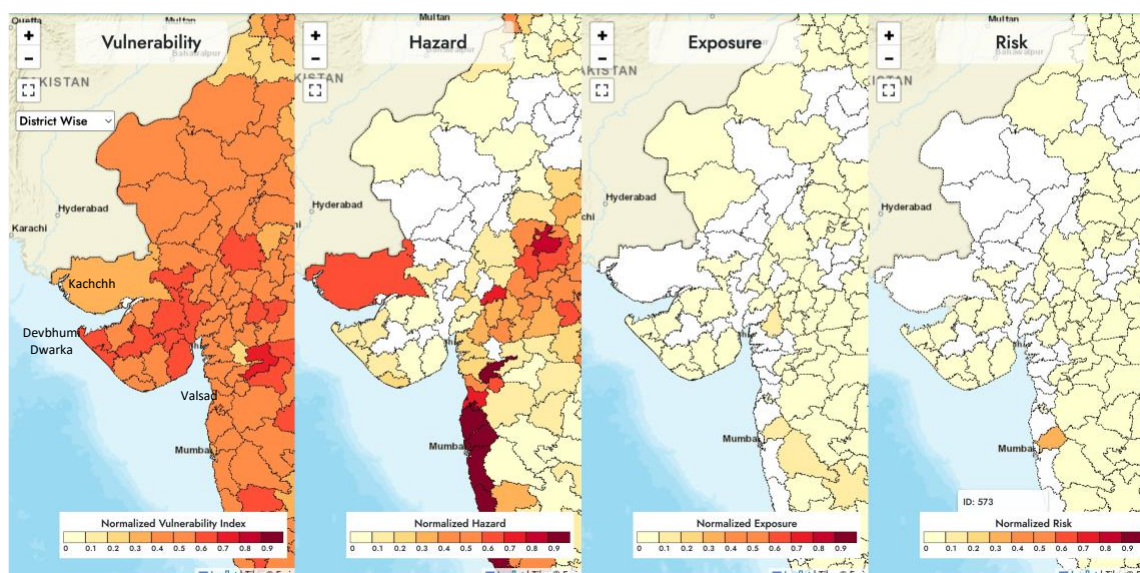
The 2013 floods in Devbhumi Dwarka Taluka resulted in 11 human fatalities and the loss of 74 cattle. In 2022, heavy rainfall resulted in the loss of 2 human lives and 24 cattle (Gujarat State Disaster Management Authority, 2021). 2024 monsoon brought heavy downpour caused widespread flooding, submerging numerous villages and cities, including the pilgrimage site of Dwarka. The district recorded an extraordinary 316% of its average annual rainfall, the highest among all talukas in the state (Times of India, 2024) <sup>20</sup>. It was confirmed during our field interactions in Dwarka town.

Figure 7 : Flood Prone Areas in Gujarat



Source: (Niti Aayog, 2025)

**Figure 8 : Flood Vulnerability, Hazard, Exposure and Risk: Districts of Gujarat**



Source: IIT Gandhinagar<sup>21</sup>

The table 6 provides a summary of infrastructure damage and loss of life during various past disaster events.

**Table 6 : Summary of Damages and Losses During Past Disaster Events**

| SI No. | Hazard                                                       | Vulnerability Rating                             | Specific Locations and populations of concern                                                                                      |
|--------|--------------------------------------------------------------|--------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| 1      | Wind (cyclone)                                               | 12 (Medium) Very High Damage risk zone [50 m/s.] | Ports and 3 Talukas (Khambhaliya, Kalyanpur and <b>Dwarka</b> )                                                                    |
| 2      | Sea surge (cyclone)                                          | 9 (Medium)                                       | 0.22 Million [2, 27,264] population and 41 coastal villages in 3 talukas are likely to be affected. Maximum surge record 3 meters. |
| 3      | Flood                                                        | 20 (High)                                        | May occur due to very heavy rainfall, sea serge or drainage failure                                                                |
| 4      | Drought                                                      | 6 (Low)                                          | Whole District                                                                                                                     |
| 5      | Heat/cold wave                                               | 8 (Medium)                                       | NA                                                                                                                                 |
| 6      | Critical Infrastructure Failure (e.g. extended power outage) | 12 (Medium)                                      | The Hydrocarbon Cross-country pipeline running for <b>Devbhumi Dwarka</b> may be affected                                          |

Source: (Gujarat State Disaster Management Authority, 2021)

# CHAPTER 3: STATUS AND CHALLENGES OF WATER SUPPLY INFRASTRUCTURE AND SERVICES AT DWARKA MUNICIPAL COUNCIL

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, 2023<sup>22</sup>; Moraci, 2020<sup>23</sup>; Nicholls et al., 2007<sup>24</sup>). Coastal cities like Dwarka 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, 2018<sup>25</sup>; USEPA, 2025<sup>26</sup>; Datta et al., 2024<sup>27</sup>; Rosińska et al., 2024<sup>28</sup>). 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., 2023<sup>29</sup>; Siddha & Sahu, 2020<sup>30</sup>; Rajasree & Deo, 2020<sup>31</sup>; Govindarajulu, 2020<sup>32</sup>). 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, Dwarka 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 Canal<sup>33</sup>, Dwarka Municipality can 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.

Dwarka city was largely dependent upon domestic wells before the existing piped water supply system came into existence. After the advent of piped water supply system, the city has shifted its

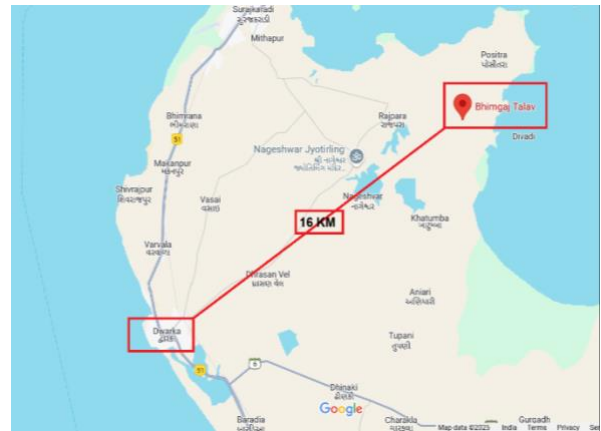
primary requirement of water supply from the surface water sources. Dwarka city has three bulk water supply sources, viz., 1) Narmada Canal, 2) Bhim Gaja Talav, and 3) Mayasar Talav. The Narmada Canal is located 20 KM from the city, and the freshwater perennial lakes, i.e., Bhim Gaja Talav and Mayasar Talav are situated 16 KM and 3 KM outside the city respectively (cf. Figures 9, 10, 11, & 12).

**Figure 9: Narmada Canal Network**



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

**Figure 10: Location of Bhim Gaja Talav**



Source: Google Maps

**Figure 11: Location of Mayasar Talav**



Source: Google Maps

**Figure 12: A glimpse of Mayasar Talav**



Source: Team, IITB

There is one water tapping point at Narmada Canal and 2 MLD water is tapped from this source. At Bhim Gaja Talav, there are 3 tapping points, which taps 1 MLD water in total, whereas, Mayasar Talav has only one tapping point that taps 0.3 MLD water. Hence, the city is largely dependent upon Narmada Canal for the water supply, as the two lakes have limited capacity. The total bulk water tapped from all the sources at Dwarka city is 3.3 MLD (AMRUT, 2025).

Dwarka has a semi-arid climate, influenced by its coastal location along the Arabian Sea. It experiences hot summers, moderate winters, and a short rainy season. The region received 480 mm of average annual rainfall during 1987 till 2021, most of which occurs during the monsoon months of June to September, with sporadic and erratic rainfall patterns. However, in 2020, Dwarka received 1 296 mm of rainfall (CGWB, 2022).

Summer temperatures often exceed 40°C, while winters are milder, ranging from 15°C to 25°C. The city also experiences moderate to strong winds, especially during the monsoon, with speeds ranging from 15–30 km/h (9–18 mph), and occasional gusts up to 50 km/h (31 mph) during storms or cyclones. Dwarka's climate is marked by high summer temperatures, limited rainfall, and moderate winds, shaped by its coastal environment<sup>3435</sup>.

### 3.2.2 GROUND WATER

Dwarka's aquifer system is a complex mix of shallow, coastal, and fractured aquifers, each with its own set of challenges, especially regarding saline water intrusion and over-extraction. Sustainable management practices, including rainwater harvesting, water conservation, and careful groundwater extraction, are essential to ensuring the long-term availability of fresh groundwater for both domestic and agricultural use in the region. The aquifer system at Dwarka is as given in Table 7.

The aquifer system at Dwarka consists of multiple layers of groundwater-bearing formations, each with different characteristics and water quality. The shallowest aquifer, Aquifer I, is composed of alluvium, primarily sand and kankar, occurring at depths ranging from 0 to 57 meters below ground level (mbgl). This is a phreatic aquifer, with water quality varying from fresh to brackish. Beneath it lies the Aquitard, made up of sandy limestone mixed with marl, gypseous clay, and shells of milonite, occurring at depths of 27 to 170 mbgl, acting as a semi-confined to confined aquifer with fresh to brackish water. Aquifer II, consisting of limestone from the Dwarka and Gaj beds, is found at depths between 134 to 200 mbgl and is classified as semi-confined to confined, with slightly brackish to saline water. The weathered basalt aquifer occurs from the surface to 18 meters and is a phreatic aquifer with fresh to slightly brackish water. Below this, the fractured basalt aquifer extends from 3 to 200 mbgl, also semi-confined, with fresh to slightly brackish water. The aquifers in Dwarka demonstrate varying degrees of confinement and water quality, with the deeper layers tending to have more saline or brackish water, while the shallow layers typically have fresher water.

**Table 7: Aquifer System at Dwarka**

| <b>Aquifer Type</b>     | <b>Material</b>                                                 | <b>Depth of Occurrence (mbgl)</b> | <b>Nature of Aquifer</b>  | <b>Water type</b>           |
|-------------------------|-----------------------------------------------------------------|-----------------------------------|---------------------------|-----------------------------|
| <b>Aquifer I</b>        | Alluvium - Sand, and Kankar                                     | 0 to 57                           | Phreatic                  | Fresh to Brackish           |
| <b>Aquitard</b>         | Sandy Limestone, with shell of Milonite, Marl and Gypseous Clay | 27 to 170                         | Semi-confined to Confined | Fresh to Brackish           |
| <b>Aquifer II</b>       | Limestone of Dwarka beds and Gaj beds                           | 134 to 200                        | Semi-confined to Confined | Slightly brackish to Saline |
| <b>Weathered Basalt</b> | Basalt                                                          | 0 to 18                           | Phreatic                  | Fresh to Slightly brackish  |
| <b>Fracture Basalt</b>  | Basalt                                                          | 3 to 200                          | Semi-Confined             | Fresh to Slightly brackish  |

Source: CGWB, 2022

**Table 8: Hydrochemistry of Dwarka**

| <b>Parameters</b> | <b>Values at Dwarka</b> | <b>Acceptable Range</b>     |
|-------------------|-------------------------|-----------------------------|
| Source            | DW                      | NA                          |
| pH                | 7.92                    | 6.5 to 8.5                  |
| EC                | 2590                    | 1,500 $\mu$ S/cm (WHO 2004) |
| TDS               | 1735                    | 500 mg/l and 2000 mg/       |
| CO <sub>3</sub>   | 0                       | 200 mg/l                    |
| HCO <sub>3</sub>  | 366                     | 200 mg/l                    |
| Cl                | 518                     | 250 mg/l and 1000 mg/l      |
| NO <sub>3</sub>   | 200                     | 45 mg/l                     |
| SO <sub>4</sub>   | 72                      | 200 mg/L                    |
| F                 | 0.11                    | 1 mg/l and 1.5 mg/l         |
| Alk               | 300                     | 200 mg/l                    |
| Ca                | 56                      | 200 mg/l                    |
| Mg                | 56                      | 100 mg/                     |
| TH                | 370                     | 200 mg/l                    |
| Na                | 378                     | 200 mg/l                    |
| K                 | 34                      | 10 md/l                     |
| SiO <sub>2</sub>  | 18                      | >30 mg/l                    |
| SAR               | 8.54                    | 3 to 12 mg/l                |

Source: CGWB, 2022

As per the Ground Water Resource Estimation (GWRE-2020), the stage of Ground Water extraction of Dwarka (Okhamandal Taluka) is 21.22%, which is considered as safe (CGWB, 2022). The hydrochemistry of water in Dwarka (Table 8) shows deviations from acceptable ranges, with high levels of electrical conductivity (2590  $\mu\text{S}/\text{cm}$ ), total dissolved solids (1735 mg/l), chloride (518 mg/l), bicarbonates (366 mg/l), and nitrate (200 mg/l), indicating elevated mineral content and potential contamination. While pH (7.92), fluoride (0.11 mg/l), and sodium adsorption ratio (8.54) are within acceptable limits, the water quality may not be suitable for consumption without treatment due to excessive mineral and contaminant concentrations.

The aquifer system in Dwarka is a complex structure consisting of various layers, each with distinct characteristics and water qualities. The shallow aquifers generally contain fresh to slightly brackish water, while deeper layers exhibit more saline or brackish conditions. Despite the system's current extraction stage being considered safe at 21.22%, the hydrochemistry of the region reveals concerning deviations from acceptable water quality standards, such as high electrical conductivity, total dissolved solids, chloride, bicarbonates, and nitrates. These elevated levels indicate a risk of contamination or pollution, making the water unsuitable for direct consumption without treatment. Sustainable management practices, including careful groundwater extraction, rainwater harvesting, and conservation efforts, are vital to ensure the long-term availability of fresh water for both domestic and agricultural uses in Dwarka, preventing further degradation of its water resources.

### 3.4 WATER DEMAND & SUPPLY

According to the 2011 Census, the population of Dwarka was 38,873, with a total of 8,207 households and three slum settlements. By 2021, the population had increased to 46,648, with 11,518 households. The city's population density stands at 1,092 persons per square kilometre. Projections indicate that by 2025, the population will reach 50,380, with a total of 12,440 households and 853 slum households (AMRUT, 2025). The current water demand in the city is 8.2 MLD, while the available water supply is 2.0 MLD, creating a deficit of 6.2 MLD. Although the city has a water treatment capacity of 4.0 MLD, only 2 MLD is being treated, leaving a current operational gap of 2 MLD. Additionally, only 6,435 households have access to tap water connections in 2021, creating a gap of 6,005 households without access to tap water connections in 2025 (AMRUT, 2025).

The city supplies 0.5 MLD water to 200 commercial establishments, another 0.3 MLD to 20 institutional establishments, 0.1 MLD to 790 slum households and 2 MLD water is supplied to 6,435 residential households. The average per capita water supply in Dwarka is 76.74 litres per capita per day (lpcd). Future projections indicate a total water demand of 8.2 MLD, with 7 MLD required for residential households, 0.7 MLD for commercial use, 0.5 MLD for institutional establishments, and 0.3 MLD for slum settlements. As of 2021, 6,616 households had functional tap water connections. Under AMRUT 2.0, Dwarka planned to cover 5,824 additional households in phases from 2022 to 2026, as provided in Table 9 below.

**Table 9: Household coverage plan for water supply**

| #            | Financial Year | Under AMRUT  | Under other Schemes |
|--------------|----------------|--------------|---------------------|
| 1.           | FY 2022        | 0            | 0                   |
| 2.           | FY 2023        | 0            | 0                   |
| 3.           | FY 2024        | 1,456        | 0                   |
| 4.           | FY 2025        | 2,038        | 0                   |
| 5.           | FY 2026        | 2,330        | 0                   |
| <b>Total</b> |                | <b>5,824</b> | <b>0</b>            |

Source: AMRUT 2.0, Dwarka Municipal Council (DMC), 2025

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.

### 3.5 WATER INFRASTRUCTURE

**Water Treatment Plant:** The water from Bhim Gaja Talav and Mayasar Talav is sent to the Mayasar Lake Water Treatment Plant (WTP) having a total designed capacity of 4.0 MLD. However, due to low availability of surface water, the operational capacity of the WTP is only 1.3 MLD.

**Figure 13: Non-functional clari-flocculator at WTP**



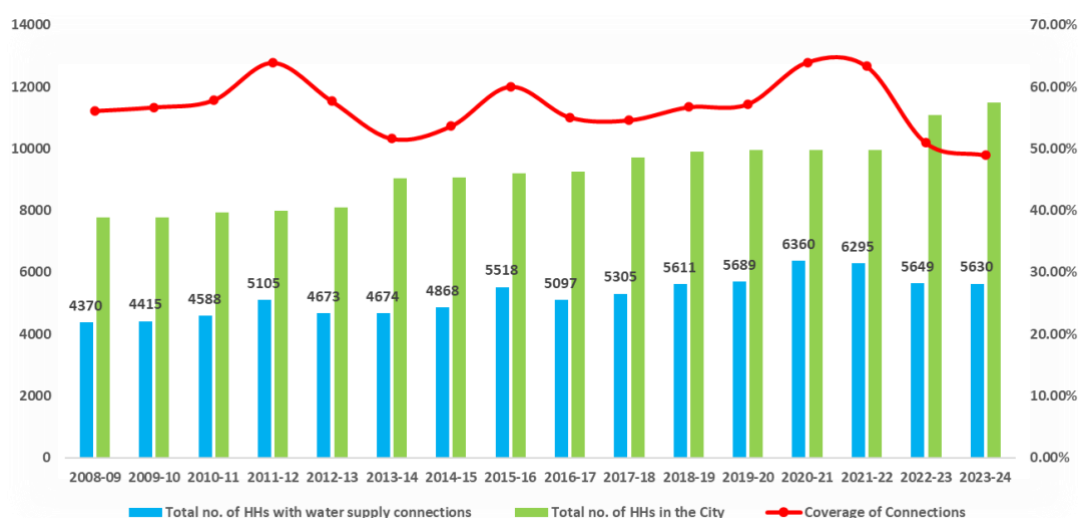
Source: Team, IITB

The inspected WTP severely lacks manpower and is in weary condition (Fig. 13). It offers only basic treatment with chlorination and alum usage during rainy season. During the field visits, the WTP operator confirmed that in most seasons, no water treatment is offered.

**Distribution Network of Water Supply:** The Dwarka Municipal Council (DMC) receives a daily bulk water supply of 3.3 MLD from three primary sources, viz., Narmada Canal, Bhim Gaja Talav, and Mayasar Talav. The raw water from Bhim Gaja Talav and Mayasar Talav flows into the Water Treatment Plant (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. Before being flown into the distribution tributaries, the water is temporarily stored at 4 Elevated Storage Reservoirs (ESRs) with a total storage capacity of 37 lakh litres (LL). Moreover, there are 8 GSRs with added storage capacity.

**Household Piped Water Supply in Dwarka:** The data on the coverage of functional household tap connections (FHTCs) at Dwarka Municipal Council (DMC) reveals several key trends in water supply connections from 2008-09 to 2023-24 (Fig. 14). The figures highlight fluctuations in both the total number of households with water supply connections and the overall coverage percentage of the city's households. In the early years, from 2008-09 to 2012-13, there is a gradual increase in the number of households with water supply connections, with the coverage percentage rising from 56.13% in 2008-09 to a peak of 63.90% in 2011-12. This increase can be attributed to the expansion of water supply infrastructure, likely driven by growing urbanization and efforts to improve the municipal water network.

**Figure 14: Coverage of Water Supply at DMC**



Source: Dwarka Municipal Council (DMC), 2025

However, in the years following 2012-13, there is a noticeable decline in the coverage percentage. In 2013-14, the coverage drops sharply to 51.65%, the lowest recorded during the entire period. This decline could be the result of factors such as a mismatch between the growth of new households and the capacity of the water supply system, or possibly administrative and logistical challenges in extending water connections to new areas.

After the sharp dip, the coverage percentage fluctuates over the next several years, showing some recovery but not consistently reaching the earlier peak. For instance, in 2016-17, coverage rises to 56.73%, but then dips again to 50.95% in 2022-23, just before the most recent figure for 2023-24, which is 48.96%. This indicates that, despite some efforts to increase the number of households with functional tap connections, the expansion of water supply has not kept pace with the growing population of the city.

The city's population has been steadily rising, from 7,785 households in 2008-09 to 11,500 households in 2023-24, but the total number of households with water connections has not seen a corresponding increase. Several factors could explain these trends. First, the relatively flat trajectory of coverage in the latter years suggests that while there have been improvements in water supply connections, the overall infrastructure may be facing constraints in terms of capacity to extend services to newer areas. Additionally, population growth may have outpaced the expansion of essential services like water supply.

Another possibility is that local government or financial challenges might have slowed progress in addressing the water connection gap. While there have been periods of improvement in FHTC coverage, Dwarka Municipal Council is facing challenges in maintaining consistent and sustainable expansion of water supply connections. The coverage percentage, after reaching its peak in the early 2010s, has fluctuated in recent years and even declined. Addressing these issues may require targeted investments in water supply infrastructure, better resource management, and a focus on areas with significant growth to ensure that the increasing population is adequately served with functional water connections.

**Tariff structures for Water Supply in Dwarka:** The water supply in Dwarka operates under a flat tariff system, where consumers are charged based on the monthly water tariff. The residential tariff is INR 45/month, the institutional, commercial, and industrial tariff is INR 125/month. For a new water connection, the charges are as given below in Table 10.

**Table 10: New Water Connection Charges in Dwarka**

| #  | Components for New Connections                                | Charges (INR) |
|----|---------------------------------------------------------------|---------------|
| 1. | New tap connection form fee                                   | 220.00        |
| 2. | New tap connection charge (Residential)                       | 2,500.00      |
| 3. | New tap connection charge (Commercial)                        | 10,000.00     |
| 4. | Corrective Repairing Charges                                  | 1,000.00      |
| 5. | Water tanker Charges (Tractor Tanker)                         | 900.00        |
| 6. | Road Excavation Fee (For CC Road) per meter                   | 1750.00       |
| 7. | Road Excavation Fee (For Asphalt Road/ Paver Block) per meter | 1500.00       |
| 8. | Road Digging Fee (For Unpaved Road) per meter                 | 500.00        |

Source: Dwarka Municipal Council, 2025

### 3.6. KEY CHALLENGES

Dwarka Municipal Council's water supply system faces several key challenges, including inadequate coverage (48.96%) and low per capita supply (63.13 litres per day), which fall significantly short of the required benchmarks. The system suffers from inefficient metering (21.86%) and high non-revenue water (21%), leading to substantial water losses. The continuity of supply is alarmingly low at just 0.75 hours per day, far below the expected 24 hours, while the financial sustainability of the system is weak, with a cost recovery ratio of only 26.45%. Although water quality is ensured and customer complaints are resolved promptly, the city's outdated infrastructure, limited water treatment capacity, and slow progress in expanding coverage contribute to a growing shortfall in meeting demand. With increasing water needs and limited resources, addressing these gaps in infrastructure, metering, distribution, and financial management is critical for improving service delivery and meeting the demands of a rapidly expanding urban population.

# CHAPTER 4: URBAN SANITATION SYSTEMS IN DEVBHUMI DWARKA: STATUS, INSTITUTIONS AND CHALLENGES

NEELAM RANA, PRIYAKSHI GOGOI, 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, At the Roots of Urban Disasters: Planning and Uneven Geographies of Risk in Kolkata, India', 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 Sustainable Development Goals (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)<sup>3637</sup>. 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)<sup>38</sup>. 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)<sup>39</sup>.

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)<sup>40</sup>. 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 **Swachh Bharat Mission (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 Dwarka. 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)<sup>41</sup> (refer figure 16).

- **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 data, out of 8,207 households in the area, 2,207 lacked individual toilets. However, recent information from the Dwarka ULB (SLB 2023-24) confirms that all the 15035 properties now have access to individual toilets. The town has been declared Open Defecation Free Plus (ODF++), aligning with the Service Level Benchmarks (SLB) set by the Government of India and Sustainable Development Goal target 6.2.

However, despite these official claims, interviews with residents in certain localities reveal significant gaps. **Approximately 35 households, predominantly reliant on milk-selling for livelihood, still lack both toilet facilities and piped water connections (photo 4). These families resort to defecating in nearby fields as they do not have access to the public or community toilets.**

**Photo 1 : Settlement without toilet and tap water connection**



Source: IITB Team

**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.

- **Community Toilets and Public Toilets**<sup>42</sup>: According to data obtained from the ULB, the city currently has a total of seven public toilets but no community toilets. However, information on the coverage and usage of both community and public toilets is unavailable, as the ULB does not maintain registers or records tracking the number of users or whether these facilities meet demand. **ULB officials stated that the locations** of the public toilets were strategically selected based on footfall and local need.

However, there is a discrepancy in the data, as both the SBM Urban Dashboard and ULB records classify these facilities as community toilets. Upon further clarification with ULB officials, it was confirmed that these are public toilets, though no clear explanation was provided for their classification as community toilets in official documents. **To assess the condition of the public toilets**, we consulted ULB officials, who reported that the facilities are well maintained and in good condition. To verify this, our team conducted site visits to two of the seven public toilets. We found both to be clean, well maintained, and equipped with running tap water. However, the ULB does not maintain formal records of cleaning schedules or activities.

**Photo 2 : Public Toilet in Dwarka City**



Source: IITB Team

- **Containment:** According to SLB (2023–24) data obtained from the ULB, only 2.53% of properties are connected to the sewerage network, while the remaining properties depend on on-site sanitation systems (OSS). Field interactions with residents highlighted that, in certain informal settlement areas, many properties remain unconnected to the sewerage network despite the main sewer line running directly in front of their homes. Most households in these communities depend on daily wage labor for their livelihood.

**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.

- **Emptying and Transport:** As noted in the previous section, only 2.53% of properties are connected to the sewerage network, according to the SLB 2023-24 report. The properties relying on septic tanks, are serviced by two vacuum trucks owned by the ULB, each with a capacity of 4,000 liters, as confirmed by ULB officials. Residential households are charged INR 2,000 per trip for septic tank cleaning, while commercial establishments pay INR 3,000 per trip.

Field observations revealed significant challenges in low-income areas during the rainy season. These neighbourhoods frequently experience flooding due to heavy rainfall and an inadequate stormwater drainage network, which adversely affects housing, sanitation, and water infrastructure. Interviews with residents indicated that septic tanks in flood-prone zones often require annual cleaning because of recurring damage, such as broken pipes caused by floods.

**The SLB 2023-24 data indicates that the stormwater drainage network covers only 18 km of the total 55.08 km, reflecting limited coverage.** Our field observations corroborate this finding, as we encountered minimal evidence of extensive drainage infrastructure on the ground. Beyond coverage, there is a lack of secondary data on the typology of the drainage system and associated GHG emissions. Addressing these gaps would require detailed studies, which fall outside the scope of our current project.

**Regarding the sewerage network and storm water drainage typology,** this aspect was outside the scope of our study. Furthermore, the ULB does not even maintain maps of the sewerage network, and storm drainage and no information on the type of drainage system is available from secondary sources.

Photo 3 : Sanitation and Water Infrastructure in Low-income and Flood prone Area

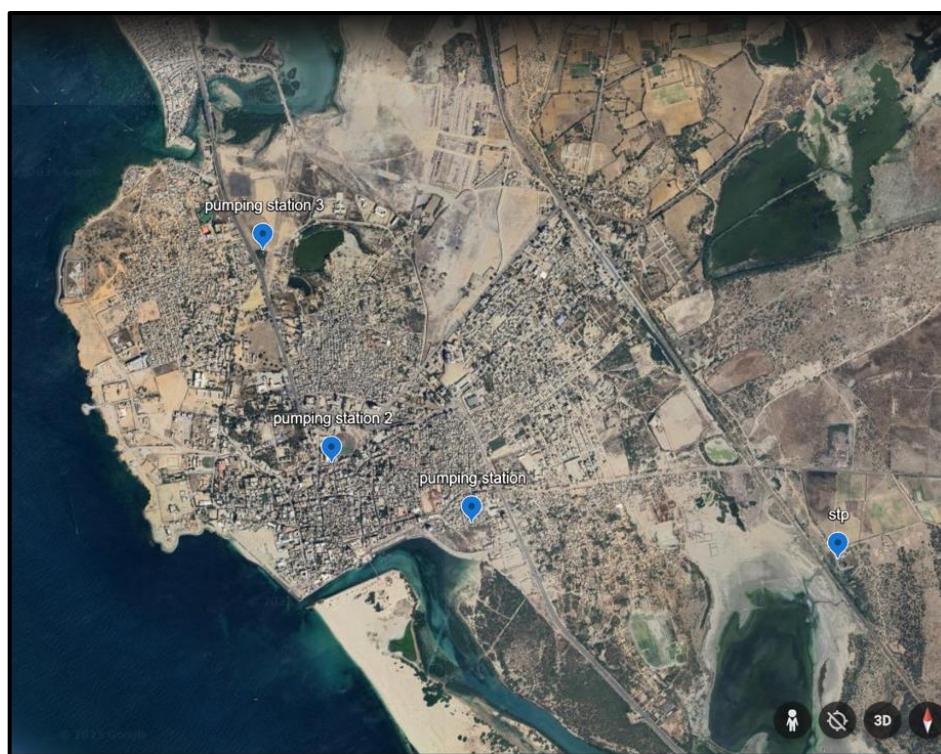


Source: IITB Team

- **Treatment:** The city of Dwarka generates 2.22 million liters per day (MLD) of wastewater, according to the SLB 2023-24. Its Sewage Treatment Plant (STP), commissioned in 2017, utilizes Sequencing Batch Reactor (SBR) technology and is supported by three pumping stations. The STP has an installed capacity of 7.4 MLD. As reported by the ULB until August 2024, the STP was implemented and managed by the Gujarat Water Supply and Sewerage Board (GWSSB), after which it was handed over to the ULB. However, during the 2024 monsoon (July), severe flooding rendered the STP non-functional until February 2025. Even during our visit on March 25, 2025, the plant was only partially operational and lacked laboratory testing records.

Field data and insights from the SLB 2023–24 report indicate that the majority of households are not connected to the sewerage network. Instead, they rely on vacuum trucks to collect sewage, which is then transported to pumping stations before being conveyed to the sewage treatment plant (STP).

**Figure 15: Location of Sanitation Infrastructure in Dwarka**



**Source: Plotted on Google Earth**

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. This inconsistent management underscores the need for standardized practices and public awareness campaigns to improve greywater handling.

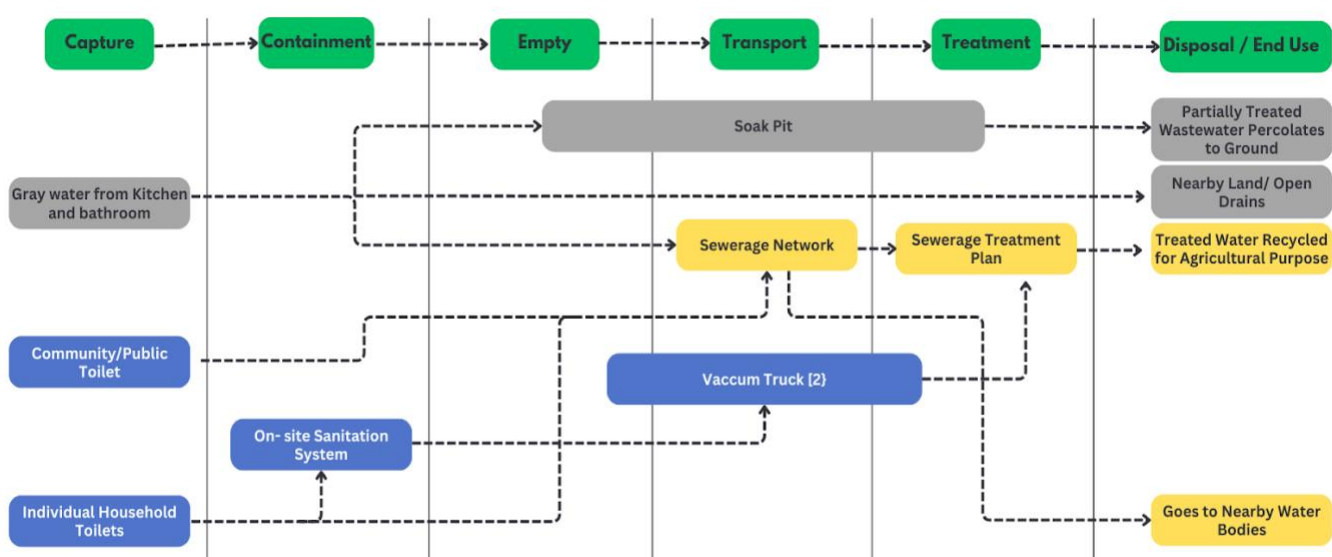
**To examine whether the system includes natural water bodies such as creeks and nallahs—and to understand their functional role in carrying greywater, blackwater, stormwater, or a combination thereof—and to evaluate the degree of interconnection between these natural elements and man-made infrastructure, detailed data is required.** This would also involve assessing whether this integration reflects effective or poor design, considering factors such as flow efficiency, contamination risks, and maintenance challenges. However, such data is not available from secondary sources and lies beyond the scope of our current study.

- **End-use Disposal (Sludge Management):** The city currently lacks a dedicated Faecal Sludge and Septage Treatment Plant (FSSTP). Instead, it relies on 2 vacuum trucks owned

by the ULB. The septage collected by these trucks is transported to pumping stations before being directed to the STP, where it undergoes treatment. The STP unit does not have any drying bed to dry the sludge though.

- **Recycling and Reuse:** The treated wastewater from the STP is recycled and reused for agricultural purposes by local farmers situated near the facility for free.

**Figure 16 : Sanitation Service Chain in Dwarka**



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 11). It underscores the pivotal role of Urban Local Bodies (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 on-site sanitation systems (OSS). 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 public toilets (PT) are primarily the ULB's responsibility, with independent decision-making power in key areas such as land selection, technology choice, operation and maintenance (O&M), and funding. Under the 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.

While ULBs act as nodal agencies for sanitation services, their role in larger infrastructure projects such as STPs and Faecal Sludge and Septage Treatment Plants (FSSTPs) is often limited. These projects are primarily funded through the Central scheme AMRUT 1.0 and with technology selection, approval, and implementation managed at the state level by entities such as the Gujarat Urban Development Mission (GUDM) and Gujarat Water Supply and Sewerage Board (GWSSB). After installation and initial operation by state-level agencies, operation and maintenance (O&M) responsibilities are transferred to municipal councils, such as the Dwarka Municipal Council. Given ULBs' critical role in managing community and public toilets as well as O&M for large-scale infrastructure, their financial health is a key determinant of project sustainability.

In conclusion, while ULBs play a central role in sanitation governance at the local level, their limited capacity both financially and operational poses significant challenges. Addressing these gaps requires enhanced coordination across governance levels, improved financial support mechanisms, and robust monitoring frameworks to ensure sustainable sanitation service delivery. Furthermore, interviews with the ULBs revealed that their role in disaster governance and planning is limited. The town has a district disaster management Authority. They primarily focus on disaster related events. The role of the ULB is largely limited to dealing with post-disaster relief and recovery efforts such as provision of drinking water sources by providing water tankers, sanitation facilities, establishing shelters and providing temporary accommodations. If public utilities are affected, they are responsible for restoring them.

**Table 11 : Institutional Arrangements: Sanitation Services**

| <b>Intervention</b>              | <b>Technology Selection</b> | <b>Land</b> | <b>Capital</b>                               | <b>Technology Provision</b>  | <b>Technology implementation</b> | <b>O&amp;M</b>                     | <b>O&amp;M Funding</b>    |
|----------------------------------|-----------------------------|-------------|----------------------------------------------|------------------------------|----------------------------------|------------------------------------|---------------------------|
| <b>Toilets</b>                   | HH                          | HH          | HH                                           | Local mesons/private vendors | Local mesons/private vendors     | HH                                 | HH                        |
| <b>OSS</b>                       | HH                          | HH          | HH                                           |                              |                                  | HH                                 | HH                        |
|                                  |                             |             |                                              |                              |                                  | Septage removal by vehicles of ULB |                           |
| <b>PT</b>                        | ULB                         | ULB (7)     | ULB                                          | ULB                          | ULB                              | ULB [2]                            | ULB's own source          |
|                                  |                             |             | Central Government (15th finance commission) |                              |                                  | Sulabh international [4]           | Pay and Use by the Agency |
|                                  |                             |             |                                              |                              |                                  | Local NGO [1]                      | Pay and Use by the NGO    |
| <b>Sewage Network Connection</b> | State GUDM                  | ULB         | Central Government (AMRUT 1.0)               | State GUDM                   | State GWSSB                      | ULB                                | ULB's own source          |
| <b>STP</b>                       | State GUDM                  | ULB         | Central Government (AMRUT 1.0)               | State GUDM                   | State GWSSB                      | ULB                                | ULB's own source          |

Source: (Rana, Gogoi, & Narayanan, Forthcoming)<sup>43</sup>

#### 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.

- **Promoting Inclusive Access to Services for Climate Resilience:** The city's achievement of ODF++ status reflects significant progress in sanitation and waste management. However, ongoing field interactions suggest opportunities to further enhance service delivery, especially in areas where access remains limited. One such example is a community of approximately 35 households, primarily engaged in milk selling, that currently does not have piped water connections, individual household toilets, or a shared community toilet.

Improving access to water and sanitation in such communities is not only essential for public health and dignity but also plays a critical role in building urban climate resilience. Ensuring that all residents, including those in underserved areas, are equipped with basic services strengthens the city's ability to adapt to climate-related challenges such as flooding, water scarcity, and salinity intrusion. In areas where water quality is already affected by high salinity, targeted interventions can have a particularly meaningful impact. Integrating inclusive service provision into climate adaptation strategies ensures that no community is left behind. As a forward-looking step, establishing a community toilet near this settlement would help address immediate needs while aligning with broader goals of equity, sustainability, and climate resilience.

- **Integrating Flood Risk Assessment into Infrastructure Resilience Planning:** Interviews conducted across various areas revealed that flooding is a recurring issue in the city, particularly during the monsoon season. These events negatively impacted the large sanitation infrastructure such as STP and essential services at household level. For example, ULB officials reported that the STP was severely damaged during the July 2023 monsoon and remained nonfunctional until February 2024. During our site visit on March 25, 2025, the STP was observed to be only partially operational. The pumping stations suffered extensive damage during floods in 2024, including missing doors and non-working pumps, which rendered them incapable of effectively managing wastewater inflows. Furthermore, laboratory testing for key water quality parameters such as BOD and COD was discontinued after the flooding event due to malfunctioning analytical equipment. This lack of monitoring compromises the ability to ensure treated sewage meets regulatory standards.

**Photo 4 : Condition of Pumping Stations Post 2024 Floods**



Source: IITB team

Household interviews further underscored the plight of residents, who reported severe disruptions during every monsoon season. Many homes get inundated, forcing families to evacuate and seek shelter in elevated areas or hotels until floodwaters recede. The damage extends to sanitation infrastructure, with broken pipes and underground water storage tanks becoming common issues. Residents expressed frustration over the lack of support from ULBs or government agencies during these crises.

**A key contributor to the city's recurring flooding is the combination of heavy rainfall and an inadequate stormwater drainage network.** While the city's road network extends over 55 kilometres, only 18 kilometres are equipped with stormwater drains, as reported in the SLB 2023–24. Residents, however, note that in practice, only around 1 kilometre is served by functional drainage, resulting in frequent water stagnation. Furthermore, ULB officials highlighted that backflow from the sea significantly delays drainage, especially given the city's low-lying topography, prolonging flood conditions.

These challenges reveal critical vulnerabilities in the city's urban infrastructure, particularly its limited capacity to withstand monsoon-related flooding. They underscore the urgent need to integrate flood risk reduction and climate resilience into infrastructure planning and development. Strengthening stormwater management systems, accounting for sea-level interactions, and prioritizing climate-adaptive infrastructure are essential to minimize disruptions, protect assets, and maintain essential services.

To enhance resilience, targeted upgrades are necessary—such as flood-proofing pumping stations with submersible pumps, elevating electrical systems to prevent water damage, and expanding the sewerage network to accommodate increasing wastewater loads driven by urban growth. Additionally, aligning Dwarka's wastewater management practices with national standards, such as those set by the Central Pollution Control Board (CPCB), will not only improve operational efficiency but also ensure regulatory compliance.

Collectively, these measures are vital for building a more robust and future-ready urban system—capable of delivering sustainable wastewater treatment and public services in the face of intensifying climate risks.

- **Climate Resilience Planning for Aging Critical Infrastructure:** The city is currently grappling with the challenges of aging sanitation infrastructure—a concern that was highlighted during our interviews with officials from the Regional Municipal Commission (RMC). For example, the existing sewerage network has been in operation for nearly 30 years. Compounding this issue are the recurring floods the city experiences each year. As highlighted by the RMC officials, these flood events place additional pressure on the already aging infrastructure, further weakening its performance. The strain not only accelerates wear and tear but also exacerbates operational and maintenance challenges, making it increasingly difficult for the ULB to ensure consistent and uninterrupted service delivery.

To address this, replacement work is underway through the central scheme Atal Mission for Rejuvenation and Urban Transformation (AMRUT) scheme, aiming to modernize the system. According to the Chief Officer (CO) of Dwarka, approximately 75% of the work has been completed. However, the pace of progress is being affected by the phased nature of funding.

- **Capacity Gaps and Implications:** Discussions with ULB officials revealed significant capacity constraints in effectively operating and managing the Sewage Treatment Plant (STP). The plant, which was previously under the management of the Gujarat Water Supply and Sewerage Board (GWSSB), was recently transferred to the ULB. This transition has resulted in operational challenges, as the ULB currently lacks the resources and expertise

needed for efficient management. According to officials, while the plant was well-maintained under GWSSB's administration, its condition has since declined.

Several factors might be contributing to the situation. For one, the recent transfer of the Sewage Treatment Plant (STP) to the ULB may have resulted in some challenges, including potential gaps in staff expertise for efficient operation and maintenance. Additionally, the area has experienced flooding, which could have impacted the plant's machinery. However, it is unclear whether the ULB has sufficient financial resources to address the full scope of the facility's needs and repairs. This situation underscores an urgent need for capacity-building initiatives, including technical training for ULB personnel for the sustainable wastewater management.

- **Financial Sustainability Challenges: Consequences for ULB Autonomy and Effective Service Delivery**

Interviews with the Chief Officer (CO) of Devbhumi Dwarka revealed two interconnected challenges that are affecting the ULB's ability to deliver quality services: financial constraints and issues related to human resource management. Like many other ULBs across India, the Dwarka ULB faces significant financial limitations (discussed in detail in Chapter 5). With minimal revenue generation, the ULB is heavily reliant on grants from the State Finance Commission (SFC) to fund operations. This dependency restricts their capacity to independently manage essential services, including staffing for the cleaning of the STP and water treatment facilities. For example, the state government sets guidelines on the number of permanent staff the ULB can employ. As a result, the ULB supplements its workforce with contractual and daily wage workers to meet operational needs. This situation highlights a broader challenge faced by ULBs across India, where financial constraints lead to heavy dependence on state and central funding, limiting their autonomy and hindering their ability to deliver services efficiently.

# CHAPTER 5: GHG EMISSIONS FROM URBAN WATER AND SANITATION SYSTEMS IN DEVBHUMI DWARKA

ASHISH DANGI<sup>44</sup> 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 greenhouse gases 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 Devbhumi Dwarka Municipal Council, 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 sediments<sup>45</sup>. 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 17.

**Figure 17 : Carbon and energy footprint of Devbhumi Dwarka's Water Supply**



Source: (Dangi & Narayanan, forthcoming)<sup>46</sup>

The Dwarka municipal water supply system is primarily fed from two sources: the Narmada NC21 Canal and the Mayasar Talav. While the Bhimgaj Talav is connected to the network, it is not currently in use.

From the Narmada Canal, raw water is treated at the Kalyanpur WTP and supplies around 3.5 MLD directly to the distribution system for Dwarka. Water supply from Narmada canal network is managed by the GWSSB and data for same could not be obtained despite multiple visits.

Mayasar Talav feeds into a 4.5 MLD WTP, which delivers around 4 MLD into the network through pumping stations.

The energy consumption profile of the system indicates two major emission-intensive stages:

- **Sourcing and Treatment at Mayasar WTP:** Annual electricity consumption is estimated at 77 MWh, leading to about 55 tonnes of CO<sub>2</sub> emissions.
- **Distribution through pumping stations** (near Hospital, Post Office, TV Station, and Sanatan): These require significant energy, with an estimated annual consumption of 365 MWh, corresponding to 261 tonnes of CO<sub>2</sub> emissions.

Together, the Dwarka water supply system consumes approximately **442 MWh annually, resulting in 316 tonnes of CO<sub>2</sub> emissions.**

No reliable flow data on abstraction and delivery is available for Dwarka, preventing a precise estimate of transmission and distribution losses. However, the dependency on energy-intensive pumping highlights potential inefficiencies and carbon intensity in the system.

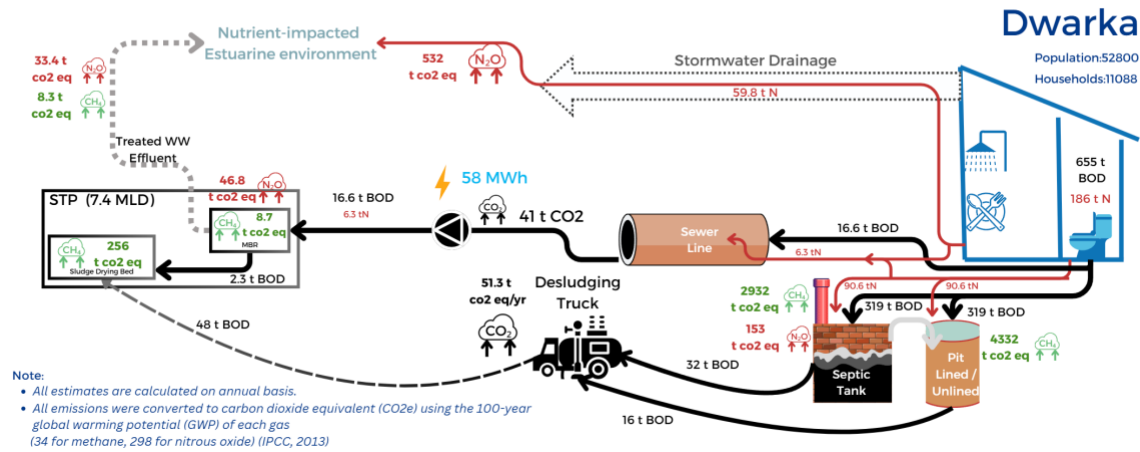
This pattern suggests that improving energy efficiency in pumping operations and integrating loss monitoring could substantially reduce both emissions and system vulnerabilities, contributing to a more sustainable water supply for Dwarka.

### 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 consumption<sup>47</sup>. 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 WWTPs<sup>48</sup>. With the increased variability posed by climate change the emission in WWTPs could further increase<sup>49</sup>. 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 (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions. Direct emissions in wastewater treatment are significant at ~1.57% of global GHG emissions<sup>50</sup>.

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 18 : Carbon footprint estimation of Urban Water Cycle**



Source: (Dangi & Narayanan, forthcoming)<sup>46</sup>

The **figure 18** presents the energy consumption and carbon emissions associated with water supply, treatment, distribution, and wastewater management in Dwarka. The flow diagram reveals that even for a small town, urban water services quickly become a significant climate actor.

- Toilets and other indoor uses generate **655 t BOD and 186 t N** annually, the precursors of methane and nitrous-oxide emissions downstream.
- **Centralised treatment handles only about 2.5 % of city's wastewater.** The 7.4 ML d<sup>-1</sup> STP treats <1 MLD ( $\approx 16$  t BOD and 6 t N annually) of wastewater that reaches the treatment plant. The energy consumption for STP operation could not be obtained as the STP is non-operational post flooding damage in July 2025. Pumping this wastewater to the treatment plant consumes **58 MWh** of electricity releasing **41 t CO<sub>2</sub>**. Fugitive methane from its sludge-drying bed still adds  $\approx 256$  t CO<sub>2</sub>-eq each year.
- **On-site containment**
  - Traditional pits emit an estimated **4332 t CO<sub>2</sub>-eq of methane** a year.
  - Septic tanks add **2932 t CO<sub>2</sub>-eq CH<sub>4</sub>** plus **153 t CO<sub>2</sub>-eq N<sub>2</sub>O**. Together they account for more than **90 % of the town's water-sector climate footprint** for managing around 98 % of city's wastewater.

- **Logistics-related CO<sub>2</sub> is small but visible.** Vacuum trucks that haul faecal sludge to the STP add about **50 t CO<sub>2</sub>-eq per year**; this could rise if desludging is intensified without shifting to cleaner fuels or optimised routes.
- **Nutrient leakage amplifies nitrous-oxide release.** Storm-drain discharge of **~60 t N yr<sup>-1</sup>** into the estuarine environment generates over **530 t CO<sub>2</sub>-eq N<sub>2</sub>O**, illustrating how weak grey-water management can overturn gains made at the STP.

Dwarka confirms that energy efficiency alone will not decarbonise small coastal towns. The dominant levers are **sealed, regularly serviced on-site tanks, full sewer capture, and biogas recovery or flaring at treatment plants**. Tackling these hotspots would cut the water-sector GHG footprint by an order of magnitude and align local water security with climate-mitigation goals.

## 5.4 CONCLUSION AND STRATEGIC PRIORITIES

The assessment of Devbhumi Dwarka's water and sanitation infrastructure underscores a critical climate reality: urban water systems are not merely vulnerable to climate change, but are substantial drivers of it. The findings reveal that addressing the local water-climate nexus requires looking far beyond standard energy-efficiency measures.

### KEY TAKEAWAYS

- **The Sanitation Emissions Giant:** The most significant climate footprint in Dwarka's water cycle stems from unmanaged fugitive emissions, not electricity consumption. Traditional pits and septic tanks account for over 90% of the sector's climate impact, generating over 7,200 tonnes of CO<sub>2</sub>-eq annually in methane emissions.
- **Underutilised Infrastructure:** With centralized treatment handling only about 2.5% of the city's wastewater, the vast majority of organic matter degrades anaerobically in the environment. This localized pollution compounds both public health risks and greenhouse gas emissions.
- **Energy-Intensive Distribution:** While secondary to sanitation emissions, the water supply network's reliance on high-energy pumping for sourcing and distribution generates over 316 tonnes of CO<sub>2</sub> annually. The lack of reliable flow data suggests that undetected physical losses are likely driving unnecessary pumping and, consequently, unnecessary emissions.
- **The Grey-Water Blind Spot:** Nutrient leakage from storm-drain discharges into the estuarine environment creates a significant secondary source of nitrous oxide (N<sub>2</sub>O). This illustrates that neglecting grey-water management can rapidly erase climate gains achieved at treatment facilities.

## THE WAY FORWARD

To break the cycle of escalating water demands driving higher emissions, Dwarka must transition from reactive management to a proactive, low-carbon water strategy. Transforming this infrastructure from a climate liability into a model of urban resilience requires targeted interventions across the water cycle:

1. **Overhaul On-Site Sanitation:** Energy efficiency alone will not decarbonize Dwarka. The immediate priority must be transitioning to safely sealed, regularly serviced on-site systems and aggressively expanding full sewer capture to eliminate fugitive methane emissions at the source.
2. **Optimise and Up-cycle Treatment:** Rehabilitating the flood-damaged STP is crucial, but future upgrades must incorporate biogas recovery or flaring mechanisms. Treating wastewater must be viewed as an opportunity for resource recovery rather than just waste disposal.
3. **Modernise Sourcing and Supply:** The municipality should conduct comprehensive water audits to map distribution losses. Upgrading to high-efficiency pumping systems and integrating renewable energy (like solar) at treatment plants and pumping stations will immediately reduce the 442 MWh annual energy burden.
4. **Deploy Nature-Based Solutions:** Utilising green infrastructure to filter and manage stormwater and grey-water can naturally reduce the nutrient loads reaching local estuaries, mitigating potent N<sub>2</sub>O emissions while improving local biodiversity.

Ultimately, securing Dwarka's long-term water future cannot be decoupled from its climate mitigation goals. By tackling these specific emission hotspots, the municipality can align its water security needs with sustainable, climate-resilient urban development.

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

ABHAY JUNAGHARE<sup>51</sup> AND NC NARAYANAN

## 6.1 BACKGROUND

This chapter analyses the performance analysis against the SLBs for urban water supply and sanitation by the MoHUA. This chapter analyses the revenue streams and grants available to Devbhumi Dwarka 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 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 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)<sup>52</sup>. 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

The performance<sup>53</sup> of the water utility and sewerage & sanitation in Ratnagiri can be assessed based on the performance indicators. These nine performance indicators known as the service level benchmarks (SLBs) for urban water supply and sewerage and sanitation in India were proposed by the then ministry of urban development (now MoHUA). These SLBs are able to ascertain the inefficiencies in the urban water supply system (UWSS) and sewerage & sanitation besides providing the corrective measures that are vital to achieve sustainable water supply and sewerage & sanitation. The SLBs can be distinguished into four major indicator groups, viz., access, quality of water supply and treated used water, financial viability and environmental sustainability that

further fits into the dimensions of social, economic and environment. Increasing urbanization, unplanned floating tourist population and changing consumption patterns have stressed the existing water supply and sewerage & sanitation infrastructure of the town.

### 6.2.1 WATER SUPPLY

The performance of water supply system at DMC reveals a mixed picture, with significant gaps in some areas and strong performance in others (Table 12). The effectiveness and efficiency of DMC's water supply services can be evaluated by comparing several key performance indicators with established benchmarks from the CPHEEO (Central Public Health and Environmental Engineering Organisation) and India's average performance. DMC's water supply coverage stands at 48.96% in 2023-24, significantly below the CPHEEO benchmark of 100% and India's average of 70%. This is a major concern, as almost half of the households in Dwarka lack direct access to water supply connections. The gap of -51.04% highlights the urgent need for infrastructure development to expand the water supply network and provide equitable access to all households. Improving coverage is essential to ensure that the entire population benefits from a reliable and safe water supply. DMC's per capita supply of 63.13 lpcd in 2023-24 is far below the CPHEEO benchmark of 135 lpcd and even the India average of 114 lpcd. With a gap of -97.21 lpcd, the water supply per person in Dwarka is substantially inadequate. This low supply likely contributes to issues of water scarcity and could have a significant impact on public health, sanitation, and quality of life. To meet the benchmarks, DMC must increase the total volume of water supplied and ensure better distribution.

**Table 12: Performance Indicators for Water Supply at DMC**

| #  | 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%         | 48.96%    | -51.04%    |
| 2. | Per capita supply (lpcd) | (Water supplied)/(Population served)                                             | 135 lpcd   | 114 lpcd       | 63.13     | 97.21 lpcd |
| 3. | Metering of connections  | (No. of metered connections + No. of metered Public Standposts)/ (Total no. of   | 100%       | 22.00%         | 21.86%    | -78.14%    |

|    |                                    |                                                                                                                                |          |           |          |             |
|----|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|----------|-----------|----------|-------------|
|    |                                    | connections + Total no. of Public Standposts)                                                                                  |          |           |          |             |
| 4. | Non-revenue water (NRW)            | (Total water produced) - (Total water sold)/(Total water produced)                                                             | 15%      | 31%       | 21%      | -6%         |
| 5. | Continuity of water supply (hours) | Average hours of water supply                                                                                                  | 24 hours | 2.7 hours | 0.75     | 22.45 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%       | 100.00 % | 20.00%      |

Source: \* CPHEEO Guidelines for 24x7 WSS (Drink from Tap), Dec 2021; \*\*Dwarka Municipal Council, 2025

Metering is a crucial element for managing water resources efficiently, as it allows for accurate billing and consumption monitoring. However, DMC has a metering rate of 21.86%, which is far below the CPHEEO target of 100%. This represents a gap of -78.14% and suggests that much of the water supply is not being properly measured, leading to inefficiencies in both consumption and revenue collection. The India average for metering is only 22%, so DMC is slightly better than the national average, but the gap to the benchmark remains substantial. To improve billing accuracy and water management, DMC should prioritize expanding metering infrastructure across the city. DMC's NRW stands at 21%, which is an improvement compared to the India average of 31%, but still above the CPHEEO benchmark of 15%. Non-revenue water includes water losses due to leakage, illegal connections, or unmetered consumption. A gap of -6% indicates that there is still considerable room for improvement. Reducing NRW will help DMC recover more of its water production and improve operational efficiency. Strategies such as infrastructure upgrades, leak detection systems, and stricter monitoring of illegal connections should be implemented.

DMC's continuity of water supply is alarmingly low at just 0.75 hours per day in 2023-24, far below the CPHEEO benchmark of 24 hours and even the India average of 2.7 hours. With a gap of -22.45 hours, it is evident that DMC is failing to provide a reliable and consistent water supply to its residents. This indicates severe challenges in water distribution and storage capacity. DMC

must invest in infrastructure to ensure round-the-clock water supply, which is a basic expectation for residents in urban areas. In terms of water quality, DMC performs well, meeting the CPHEEO benchmark of 100%. The 2023-24 performance reports a perfect 100% compliance with potable water standards, which is a strong point for the municipal council. This indicates that the water supplied is safe for consumption and the treatment processes in place are effective. Continued adherence to these high standards will be important in maintaining public health. DMC shows excellent performance in handling customer complaints related to water supply. The redressal rate stands at 100%, well above the CPHEEO benchmark of 80% and significantly better than the India average of 89%. This reflects an effective customer service system, where all complaints are addressed promptly. Maintaining and even enhancing this high level of customer satisfaction will be essential for public trust and transparency in water management.

### 6.2.2 SEWERAGE AND SANITATION

DMC has achieved a remarkable 100% coverage in terms of access to individual or community toilets for households, aligning perfectly with the CPHEEO benchmark of 100% (Table 13). This indicates that every household in the area has access to toilet facilities within walking distance, ensuring that sanitation needs are adequately addressed. This is a crucial achievement as it reflects the municipality's commitment to ensuring basic sanitation for its residents. The performance in sewage network services is equally commendable with 100% of households having direct connections to the sewage network, in line with the CPHEEO benchmark of 100%. This suggests that all residential areas in Dwarka are effectively linked to the sewage system, which is vital for managing wastewater and preventing open defecation or unhygienic practices. DMC has successfully integrated its population into the central sewage infrastructure, which is essential for the overall health and sanitation of the city.

While the coverage of sewage network services is high, the collection efficiency is alarmingly low at 45.05%, far below the CPHEEO benchmark of 100%. This indicates that although there is a sewage network in place, only a small portion of the wastewater generated is being effectively collected. This gap could be due to leakage, blockages, or inefficiencies in the system's operation, leading to significant losses in the wastewater collection process. A performance gap of -54.95% suggests that substantial investments in system upgrades and maintenance are needed to enhance the collection efficiency. The adequacy of the sewage treatment capacity is critically low, with DMC only meeting 0.08% of the required capacity as per the benchmark, falling short by -99.92%. This indicates that the existing sewage treatment plants (STPs) are grossly under-capacitated for the volume of wastewater generated in Dwarka. The lack of adequate treatment capacity poses a serious risk to environmental health and water quality, potentially leading to untreated or partially treated wastewater being discharged into the environment. This is a critical area where DMC must prioritize investments in expanding treatment plant capacity (Table 13).

**Table 13: Performance Indicators for Sanitation and Sewerage at DMC**

| #  | 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%       | 100%     | 0.00%    |
| 3. | Collection Efficiency of the Sewage Network    | (Wastewater collected)/ (Total water supplied + Estimated water use from other sources)                                                                                                         | 100%       | 45.05%   | -54.95%  |
| 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%        | 100.00%  | 20.00%   |

Source: Dwarka Municipal Council, 2025

DMC currently has a zero-success rate in meeting specified secondary treatment standards, as none of the sewage treatment samples pass the required quality tests. With a performance gap of -100%, this points to major deficiencies in the operation and maintenance of sewage treatment

facilities. Lack of adherence to treatment standards could lead to the discharge of untreated or inadequately treated effluent, posing significant health and environmental risks. Immediate improvements in treatment processes and monitoring are essential to meet health and regulatory standards. The extent of sewage recycling and reuse in DMC is non-existent, with a gap of -20% against the CPHEEO benchmark of 20%. This reflects missed opportunities in water conservation and environmental sustainability. Effective sewage reuse and recycling can reduce the demand on freshwater sources, mitigate wastewater treatment costs, and contribute to overall resource efficiency. DMC must focus on developing systems for the recycling of treated sewage for non-potable uses such as irrigation and industrial processes. DMC performs well in redressing customer complaints, with a redressal rate of 100%, surpassing the CPHEEO benchmark of 80%. This shows that DMC is responsive to public grievances and addresses issues related to sewage services efficiently. This high performance in complaint resolution reflects a customer-centric approach and helps maintain public trust in municipal services.

## 6.3 REVENUE STREAMS

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

### 6.3.1 WATER SUPPLY

#### **Central Government Funds**

The Dwarka Municipal Council (DMC) has received mixed and irregular allocations from central government schemes for water supply projects between 2013 and 2023 (Table 14). While AMRUT 1.0 provided substantial funds, especially from 2018-19 onwards (totalling INR 152.9 million),

there was no funding from AMRUT 2.0, missing an opportunity for urban transformation. Other schemes like the Nal Se Jal Scheme only saw funding starting in 2022-23, with INR 27.8 million allocated for tap water access.

**Table 14: Funds received by DMC for Water Supply under Central Government Schemes (in INR)**

| Year         | AMRUT 1.0           | Nal Se Jal Scheme  | 11 <sup>th</sup> Finance Commission | 13 <sup>th</sup> Finance Commission | 14 <sup>th</sup> Finance Commission | 15 <sup>th</sup> Finance Commission | Local Area Development Scheme - MP |
|--------------|---------------------|--------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|------------------------------------|
| 2013-14      | 0.00                | 0.00               | 0.00                                | 13816200.00                         | 0.00                                | 0.00                                | 231186.00                          |
| 2014-15      | 0.00                | 0.00               | 0.00                                | 10239119.00                         | 0.00                                | 0.00                                | 0.00                               |
| 2015-16      | 0.00                | 0.00               | 826000.00                           | 1320230.00                          | 0.00                                | 0.00                                | 391875.00                          |
| 2016-17      | 0.00                | 0.00               | 0.00                                | 0.00                                | 43639533.00                         | 0.00                                | 300375.00                          |
| 2017-18      | 0.00                | 0.00               | 0.00                                | 0.00                                | 12787622.00                         | 0.00                                | 0.00                               |
| 2018-19      | 49067980.00         | 0.00               | 0.00                                | 0.00                                | 29586082.00                         | 0.00                                | 0.00                               |
| 2019-20      | 32374768.00         | 0.00               | 0.00                                | 0.00                                | 39976896.00                         | 0.00                                | 0.00                               |
| 2020-21      | 41800000.00         | 0.00               | 0.00                                | 0.00                                | 0.00                                | 19086578.00                         | 0.00                               |
| 2021-22      | 10199065.00         | 0.00               | 0.00                                | 0.00                                | 0.00                                | 9724616.00                          | 2850250.00                         |
| 2022-23      | 19462021.00         | 27760000.00        | 0.00                                | 0.00                                | 0.00                                | 32175019.00                         | 750000.00                          |
| <b>Total</b> | <b>152903834.00</b> | <b>27760000.00</b> | <b>826000.00</b>                    | <b>25375549.00</b>                  | <b>125990133.00</b>                 | <b>60986213.00</b>                  | <b>4523686.00</b>                  |

Source: Budget Documents, DMC

The Finance Commissions (particularly the 13<sup>th</sup> and 14<sup>th</sup>) also contributed significant funds, with the 13<sup>th</sup> Finance Commission alone allocating INR 43.6 million in 2016-17. However, the distribution of funds was irregular, making long-term planning challenging. Local Area Development Scheme allocations were minor but regular. The funding inconsistency, coupled with the lack of AMRUT 2.0

support, underscores the need for more reliable and consistent funding to sustain water supply improvements in Dwarka.

### State Government Funds

The Dwarka Municipal Council (DMC) has received state government funding for water supply projects through various schemes, with notable contributions from the Swarnim Jayanti Mukhya Mantri Shaheri Vikas Yojana (SJMMSVY) and UDP 78-56 (Table 15). SJMMSVY played a significant role in urban development, particularly in 2015-16 and 2017-18, but funding declined after 2017-18, with no allocations in some years like 2019-20 and 2020-21. UDP 78-56 received consistent support in 2015-16, 2019-20, and 2020-21, indicating a focus on improving water supply infrastructure.

**Table 15: Funds received by DMC for Water Supply under State Government Schemes (in INR)**

| Year         | SJMMSVY (UDP)       | SJMMSVY (Distinguished Identity) | UDP 78-56           | District Planning Board Discretionary Grant | Local Area Development Scheme - MLA | UIDSSMT          | Interest received from grants | Scheme for urban poor/ Other Income and Grants |
|--------------|---------------------|----------------------------------|---------------------|---------------------------------------------|-------------------------------------|------------------|-------------------------------|------------------------------------------------|
| 2013-14      | 0.00                | 0.00                             | 0.00                | 1835955.00                                  | 255000.00                           | 150480.00        | 0.00                          | 0.00                                           |
| 2014-15      | 0.00                | 0.00                             | 0.00                | 4690449.00                                  | 0.00                                | 0.00             | 8568214.00                    | 0.00                                           |
| 2015-16      | 6905700.00          | 0.00                             | 1325000.00          | 5397700.00                                  | 0.00                                | 0.00             | 8349530.00                    | 0.00                                           |
| 2016-17      | 2500000.00          | 0.00                             | 0.00                | 2500000.00                                  | 0.00                                | 0.00             | 5694853.00                    | 0.00                                           |
| 2017-18      | 4140000.00          | 1000000.00                       | 0.00                | 2410000.00                                  | 0.00                                | 0.00             | 3417165.00                    | 0.00                                           |
| 2018-19      | 5259604.00          | 0.00                             | 0.00                | 1075300.00                                  | 0.00                                | 0.00             | 4638836.75                    | 0.00                                           |
| 2019-20      | 0.00                | 0.00                             | 2784106.20          | 5921938.00                                  | 0.00                                | 0.00             | 4413539.00                    | 0.00                                           |
| 2020-21      | 0.00                | 7500000.00                       | 2366749.10          | 2738800.00                                  | 0.00                                | 0.00             | 11135776.04                   | 0.00                                           |
| 2021-22      | 0.00                | 7500000.00                       | 2672777.30          | 2500000.00                                  | 0.00                                | 0.00             | 1832824.00                    | 0.00                                           |
| 2022-23      | 0.00                | 1500000.00                       | 3448520.20          | 2974200.00                                  | 0.00                                | 0.00             | 1948441.00                    | 851096.00                                      |
| <b>Total</b> | <b>165553040.00</b> | <b>40000000.00</b>               | <b>125971528.00</b> | <b>32044342.00</b>                          | <b>255000.00</b>                    | <b>150480.00</b> | <b>49999178.79</b>            | <b>851096.00</b>                               |

Source: Budget Documents, DMC Dwarka

Other schemes like the UIDSSMT and District Planning Board Discretionary Grant provided additional but smaller contributions, with fluctuating funding levels. Despite significant investments in certain years, the inconsistency in funding allocations, particularly after 2017-18, poses challenges for long-term water infrastructure planning in Dwarka. For sustained development, DMC may need more stable and predictable financial support from the state government.

## Own Revenue

The Dwarka Municipal Council (DMC) has shown mixed performance in generating revenue from water supply sources, with a heavy reliance on the General Water Tax, which accounts for 90% of the total revenue (Table 16). This dependency on a single revenue stream makes DMC's finances vulnerable to policy changes or inefficiencies in tax collection. While the General Water Tax has steadily increased over the years, other revenue sources, such as Unauthorized Water Connection Penalties, New Water Connection Charges, and Water Tanker Charges, have been inconsistent or underutilized.

**Table 16: Revenue Income from Water Supply at Dwarka (in INR)**

| Year         | General Water Tax  | Unauthorized water connection penalty | New water connection charge | Water re-connection charge | Water tap repairing charge | Contract or: Water charge recovery (Admin) | Water tanker charge | Provision of Tanker at the Fair (Mela) | Sale of water tap connection application form |
|--------------|--------------------|---------------------------------------|-----------------------------|----------------------------|----------------------------|--------------------------------------------|---------------------|----------------------------------------|-----------------------------------------------|
| 2013-14      | 2340589.00         | 0.00                                  | 27250.00                    | 0.00                       | 1858.00                    | 27400.00                                   | 0.00                | 0.00                                   | 5710.00                                       |
| 2014-15      | 3003307.00         | 0.00                                  | 241760.00                   | 1060.00                    | 0.00                       | 0.00                                       | 0.00                | 0.00                                   | 12600.00                                      |
| 2015-16      | 3339142.00         | 0.00                                  | 50798.00                    | 566.00                     | 0.00                       | 67000.00                                   | 0.00                | 0.00                                   | 12700.00                                      |
| 2016-17      | 3470189.00         | 0.00                                  | 200086.00                   | 1912.00                    | 0.00                       | 0.00                                       | 0.00                | 129200.00                              | 20900.00                                      |
| 2017-18      | 1622603.00         | 400.00                                | 300350.00                   | 320.00                     | 0.00                       | 7500.00                                    | 0.00                | 35000.00                               | 22300.00                                      |
| 2018-19      | 3835106.00         | 0.00                                  | 688650.00                   | 0.00                       | 0.00                       | 0.00                                       | 0.00                | 33000.00                               | 27700.00                                      |
| 2019-20      | 4066120.00         | 0.00                                  | 539900.00                   | 0.00                       | 0.00                       | 0.00                                       | 0.00                | 9000.00                                | 17000.00                                      |
| 2020-21      | 3451941.00         | 0.00                                  | 367600.00                   | 0.00                       | 0.00                       | 0.00                                       | 0.00                | 0.00                                   | 57400.00                                      |
| 2021-22      | 3384853.00         | 0.00                                  | 329800.00                   | 0.00                       | 0.00                       | 0.00                                       | 68400.00            | 0.00                                   | 13200.00                                      |
| 2022-23      | 4304571.00         | 0.00                                  | 258750.00                   | 72650.00                   | 50.00                      | 0.00                                       | 37800.00            | 0.00                                   | 25700.00                                      |
| <b>Total</b> | <b>32818421.00</b> | <b>400.00</b>                         | <b>3004944.00</b>           | <b>76508.00</b>            | <b>1908.00</b>             | <b>101900.00</b>                           | <b>106200.00</b>    | <b>206200.00</b>                       | <b>215210.00</b>                              |

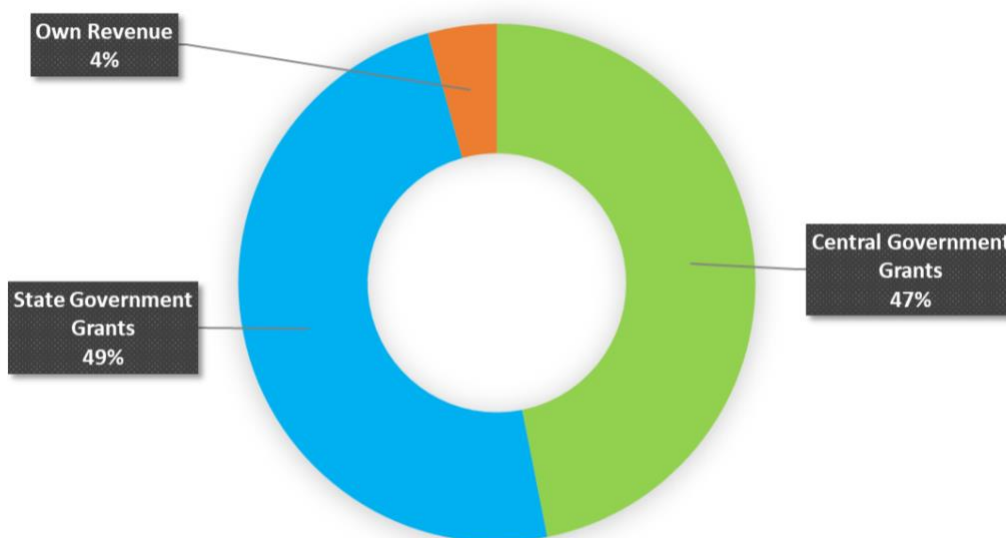
Source: Budget Documents, DMC Dwarka

The Unauthorized Water Connection Regularization Fees and Penalties show some potential but remain irregular, indicating a lack of consistent enforcement. Smaller revenue streams, like Water Tap Repairing Charges and Sale of Application Forms, also contribute minimally. While the General Water Tax remains a stable source, DMC could benefit from diversifying its revenue sources and improving enforcement and collection mechanisms in areas such as unauthorized connections and water services to enhance financial sustainability.

### Ratio of grants and own revenue

The Dwarka Municipal Council (DMC) heavily relies on central and state government grants for its water supply, with these grants accounting for 96% of the total revenue (Fig. 18). Central grants make up 47% (INR 39.83 crore), while state grants contribute an even larger share of 49% (INR 41.48 crore). DMC generates only 4% of its revenue from its own sources, such as water taxes, penalties for unauthorized connections, and new water connections, indicating limited financial autonomy.

**Figure 19: Share of grants vs own revenue for water supply at DMC Dwarka**



Source: Budget Documents, DMC Dwarka

Despite efforts to increase local revenue, the ratio of own revenue to grants has remained low, averaging 4.49%, highlighting the council's dependence on external funding and the potential risks associated with fluctuating government priorities or funding cuts. To improve financial sustainability,

DMC should focus on enhancing revenue collection from local sources, such as water taxes and penalties, to reduce its dependency on grants and increase operational flexibility.

### 6.3.2 SEWERAGE & SANITATION

#### Central Government Funds

The Dwarka Municipal Council (DMC) heavily relies on central government funding for its sewerage and sanitation projects, with significant contributions coming from the Finance Commission grants, particularly the 14th and 15th Finance Commissions, which together accounted for over INR 125 crore of the total INR 81.32 crore received between 2013 and 2023 (Table 17). While the Swachh Bharat Mission (SBM) did provide funding, its contributions were sporadic and relatively small compared to the finance commission grants, reflecting potential limitations in how DMC accessed or utilized SBM resources.

**Table 17: Funds received by DMC for Sewerage & Sanitation under Central Government Schemes (in INR)**

| Year         | Swachh Bharat Mission (SBM) | 11 <sup>th</sup> Finance Commission | 13 <sup>th</sup> Finance Commission | 14 <sup>th</sup> Finance Commission | 15 <sup>th</sup> Finance Commission | Local Area Development Scheme - MP |
|--------------|-----------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|------------------------------------|
| 2013-14      | 0.00                        | 0.00                                | 13816200.00                         | 0.00                                | 0.00                                | 231186.00                          |
| 2014-15      | 0.00                        | 0.00                                | 10239119.00                         | 0.00                                | 0.00                                | 0.00                               |
| 2015-16      | 0.00                        | 826000.00                           | 1320230.00                          | 0.00                                | 0.00                                | 391875.00                          |
| 2016-17      | 0.00                        | 0.00                                | 0.00                                | 43639533.00                         | 0.00                                | 300375.00                          |
| 2017-18      | 0.00                        | 0.00                                | 0.00                                | 12787622.00                         | 0.00                                | 0.00                               |
| 2018-19      | 0.00                        | 0.00                                | 0.00                                | 29586082.00                         | 0.00                                | 0.00                               |
| 2019-20      | 0.00                        | 0.00                                | 0.00                                | 39976896.00                         | 0.00                                | 0.00                               |
| 2020-21      | 2007421.00                  | 0.00                                | 0.00                                | 0.00                                | 19086578.00                         | 0.00                               |
| 2021-22      | 0.00                        | 0.00                                | 0.00                                | 0.00                                | 9724616.00                          | 2850250.00                         |
| 2022-23      | 0.00                        | 0.00                                | 0.00                                | 0.00                                | 32175019.00                         | 750000.00                          |
| <b>Total</b> | <b>2007421.00</b>           | <b>826000.00</b>                    | <b>25375549.00</b>                  | <b>125990133.00</b>                 | <b>60986213.00</b>                  | <b>4523686.00</b>                  |

Source: Budget Documents, DMC Dwarka

Local Area Development Scheme (MP) funds also contributed in certain years but were minimal. DMC's dependency on central government grants highlights the lack of local revenue generation

for sanitation services, which could impact long-term sustainability. To improve financial independence and ensure better sanitation services, DMC should focus on diversifying its revenue streams, including exploring local fees and enhancing access to SBM resources for urban sanitation initiatives.

## State Government Funds

Between 2013 and 2023, the DMC received significant funding from various state government schemes for sewerage and sanitation, with the largest contributions coming from the Swarnim Jayanti Mukhya Mantri Shaheri Vikas Yojana (SJMMSVY), particularly its Urban Development Program (UDP) component, which allocated INR 12.6 crore over the years (Table 18). Other important funding sources included the Mahatma Gandhi Swachhata Mission, Nirmal Gujarat Cleanliness Campaign, and Pay and Use Toilet Grants, though these provided smaller, more sporadic amounts.

**Table 18: Funds received by DMC for Sewerage & Sanitation under State Government Schemes (in INR)**

| Year    | SJMM SVY (UDP) | SJMM SVY (Distinct Identity) | UDP 78-56   | Pay and Use Toilet Grant | Mahatma Gandhi Swachhata Mission | Nirmal Gujarat Cleanliness Campaign Grant | Nirmal Gujarat Toilet Grant | District Planning Board Discretionary Grant | Local Area Development Scheme - MLA | UIDSS MT  | Interest received from grants | Scheme for urban poor/ Other Income and Grants |
|---------|----------------|------------------------------|-------------|--------------------------|----------------------------------|-------------------------------------------|-----------------------------|---------------------------------------------|-------------------------------------|-----------|-------------------------------|------------------------------------------------|
| 2013-14 | 0.00           | 0.00                         | 0.00        | 0.00                     | 0.00                             | 0.00                                      | 1448000.00                  | 1835955.00                                  | 255000.00                           | 150480.00 | 0.00                          | 0.00                                           |
| 2014-15 | 0.00           | 0.00                         | 0.00        | 1098000.00               | 0.00                             | 14569000.00                               | 0.00                        | 4690449.00                                  | 0.00                                | 0.00      | 8568214.00                    | 0.00                                           |
| 2015-16 | 69057000.00    | 0.00                         | 13250000.00 | 578525.00                | 0.00                             | 0.00                                      | 2441200.00                  | 5397700.00                                  | 0.00                                | 0.00      | 8349530.00                    | 0.00                                           |
| 2016-17 | 2500000.00     | 0.00                         | 0.00        | 0.00                     | 290794.00                        | 0.00                                      | 0.00                        | 2500000.00                                  | 0.00                                | 0.00      | 5694853.00                    | 0.00                                           |
| 2017-18 | 4140000.00     | 10000000.00                  | 0.00        | 0.00                     | 975265.00                        | 0.00                                      | 0.00                        | 2410000.00                                  | 0.00                                | 0.00      | 3417165.00                    | 0.00                                           |
| 2018-19 | 52596040.00    | 0.00                         | 0.00        | 0.00                     | 7070924.00                       | 0.00                                      | 0.00                        | 1075300.00                                  | 0.00                                | 0.00      | 4638836.75                    | 0.00                                           |
| 2019-20 | 0.00           | 0.00                         | 27841062.00 | 0.00                     | 8146280.00                       | 0.00                                      | 0.00                        | 5921938.00                                  | 0.00                                | 0.00      | 4413539.00                    | 0.00                                           |
| 2020-21 | 0.00           | 7500000.00                   | 23667491.00 | 0.00                     | 0.00                             | 0.00                                      | 0.00                        | 2738800.00                                  | 0.00                                | 0.00      | 11135776.04                   | 0.00                                           |

|              |                               |                              |                               |                        |                              |                              |                        |                              |                       |                       |                              |                       |
|--------------|-------------------------------|------------------------------|-------------------------------|------------------------|------------------------------|------------------------------|------------------------|------------------------------|-----------------------|-----------------------|------------------------------|-----------------------|
| 2021-22      | 0.00                          | 7500<br>000.0<br>0           | 2672<br>7773.<br>00           | 0.00                   | 5000<br>00.00                | 0.00                         | 0.00                   | 2500<br>000.0<br>0           | 0.00                  | 0.00                  | 1832<br>824.0<br>0           | 0.00                  |
| 2022-23      | 0.00                          | 1500<br>0000.<br>00          | 3448<br>5202.<br>00           | 0.00                   | 0.00                         | 0.00                         | 0.00                   | 2974<br>200.0<br>0           | 0.00                  | 0.00                  | 1948<br>441.0<br>0           | 8510<br>96.00         |
| <b>Total</b> | <b>16555<br/>3040.<br/>00</b> | <b>40000<br/>000.0<br/>0</b> | <b>12597<br/>1528.<br/>00</b> | <b>16765<br/>25.00</b> | <b>16983<br/>263.0<br/>0</b> | <b>14569<br/>000.0<br/>0</b> | <b>38892<br/>00.00</b> | <b>32044<br/>342.0<br/>0</b> | <b>25500<br/>0.00</b> | <b>15048<br/>0.00</b> | <b>49999<br/>178.7<br/>9</b> | <b>85109<br/>6.00</b> |

Source: Budget Documents, DMC Dwarka

Despite the substantial support from these state programs, the funding was inconsistent, with some years seeing significant investments and others with smaller allocations. DMC's reliance on specific schemes like SJMMSVY highlights the need for more predictable and sustained funding to ensure long-term infrastructure development and maintenance. To improve the sustainability of sanitation services, DMC should focus on better utilizing existing programs, exploring additional funding opportunities, and ensuring that infrastructure projects are complemented by ongoing maintenance for lasting impact.

## Own Revenue

The Dwarka Municipal Council (DMC) generates revenue for its sewerage and sanitation services primarily through taxes and user charges, with the General Cleaning Tax contributing the most at 68% of the total revenue (Table 19). Other key sources include the Sewerage Tax, Sludge Tank Cleaning Charge, and the Waste Water Management Charge. However, the revenue model is heavily reliant on taxes, particularly the General Cleaning Tax, which has fluctuated over the years, highlighting challenges in consistent tax collection and compliance.

**Table 19: Revenue Income from Sewerage & Sanitation at Dwarka (in INR)**

| Year    | General Cleaning Tax | Sewerage Tax | Waste Water Management Charge | Drainage/Sewer connection - new connection charge | Drainage/Sewer connection - Reconnection charge | Sludge Tank Cleaning Charge | Sale of sewer connection application form |
|---------|----------------------|--------------|-------------------------------|---------------------------------------------------|-------------------------------------------------|-----------------------------|-------------------------------------------|
| 2013-14 | 1015999.00           | 1102500.00   | 0.00                          | 0.00                                              | 0.00                                            | 436300.00                   | 0.00                                      |
| 2014-15 | 910741.00            | 0.00         | 22950.00                      | 0.00                                              | 0.00                                            | 253250.00                   | 0.00                                      |
| 2015-16 | 946096.00            | 0.00         | 43000.00                      | 0.00                                              | 0.00                                            | 564550.00                   | 0.00                                      |
| 2016-17 | 1005892.00           | 0.00         | 73000.00                      | 0.00                                              | 0.00                                            | 195800.00                   | 0.00                                      |
| 2017-18 | 453180.00            | 0.00         | 80000.00                      | 0.00                                              | 0.00                                            | 0.00                        | 0.00                                      |

|              |                   |                   |                  |                  |                 |                   |                |
|--------------|-------------------|-------------------|------------------|------------------|-----------------|-------------------|----------------|
| 2018-19      | 1079837.00        | 0.00              | 194900.00        | 0.00             | 0.00            | 62100.00          | 0.00           |
| 2019-20      | 1023208.00        | 0.00              | 183600.00        | 5000.00          | 0.00            | 24300.00          | 0.00           |
| 2020-21      | 945760.00         | 0.00              | 62600.00         | 20900.00         | 0.00            | 12400.00          | 0.00           |
| 2021-22      | 864980.00         | 0.00              | 0.00             | 159700.00        | 18000.00        | 14500.00          | 0.00           |
| 2022-23      | 0.00              | 156000.00         | 0.00             | 149200.00        | 0.00            | 9000.00           | 7700.00        |
| <b>Total</b> | <b>8245693.00</b> | <b>1258500.00</b> | <b>660050.00</b> | <b>334800.00</b> | <b>18000.00</b> | <b>1572200.00</b> | <b>7700.00</b> |

Source: Budget Documents, DMC Dwarka

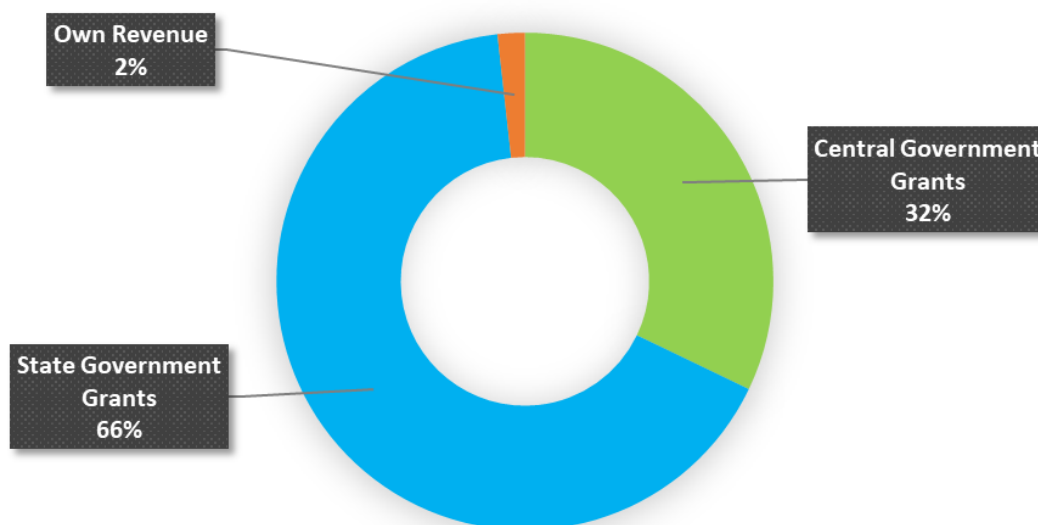
The Sewerage Tax has shown inconsistent growth, and revenues from one-time charges like connection fees and sludge tank cleaning are irregular. While the Waste Water Management Charge has potential for growth, its collection has been inconsistent, pointing to billing and service delivery challenges. To improve financial sustainability, DMC should focus on enhancing tax collection, expanding user fees, and diversifying revenue sources through new charges or services, ensuring a more stable and predictable income stream for ongoing operations and infrastructure investments.

### Ratio of grants and own revenue

The Dwarka Municipal Council (DMC) relies heavily on external grants for its sewerage and sanitation services, with state grants contributing 66% (INR 45.19 crore) and central grants accounting for 32% (INR 21.97 crore) of the total funding (Fig. 20). The council generates only 2% (INR 1.21 crore) of its revenue from local sources, such as sewerage taxes and user fees, reflecting a limited capacity for self-sustenance. This over-reliance on external funding makes DMC vulnerable

to fluctuations in state and central budget allocations, potentially jeopardizing the continuity and sustainability of its services.

**Figure 20: Share of grants vs own revenue for Sewerage & Sanitation at DMC Dwarka**



Source: Budget Documents, DMC Dwarka

The ratio of own revenue to grants has steadily declined over the years, reaching a low of 0.37% in 2022-23, indicating a growing dependency on grants. To enhance financial resilience, DMC needs to improve its revenue collection systems, reassess fee structures, and explore alternative revenue sources like public-private partnerships or waste-to-energy projects. Strengthening local revenue generation would provide greater flexibility, reduce vulnerability to external funding changes, and ensure more sustainable and efficient sanitation services.

## 6.4 ASSESSMENT OF FINANCES

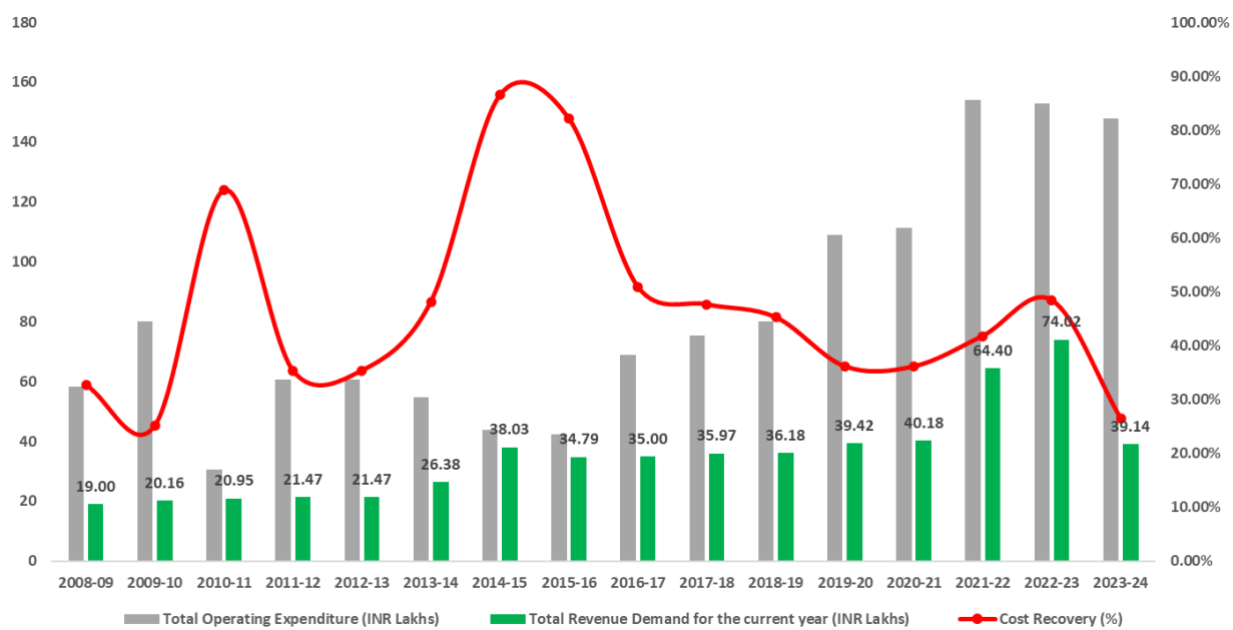
The upcoming sections analyse the financial trends from the service level benchmarks (SLBs) for water supply and sewerage & sanitation at Dwarka City Corporation (DMC Dwarka).

### 6.4.1 WATER SUPPLY

The **cost recovery** trends for water supply at Dwarka Municipal Council (DMC) from 2008-09 to 2023-24 (Fig. 21) have experienced significant fluctuations due to various factors, including operational costs, revenue generation, and policy changes. In the early years, the cost recovery percentage was low, peaking briefly at 68.85% in 2010-11 before falling again in 2011-13. A

significant rise in recovery began in 2013-14, peaking at 86.51% in 2014-15, thanks to increased revenue from taxes and better cost management.

**Figure 21: Trend analysis of cost recovery in water supply charges at DMC**



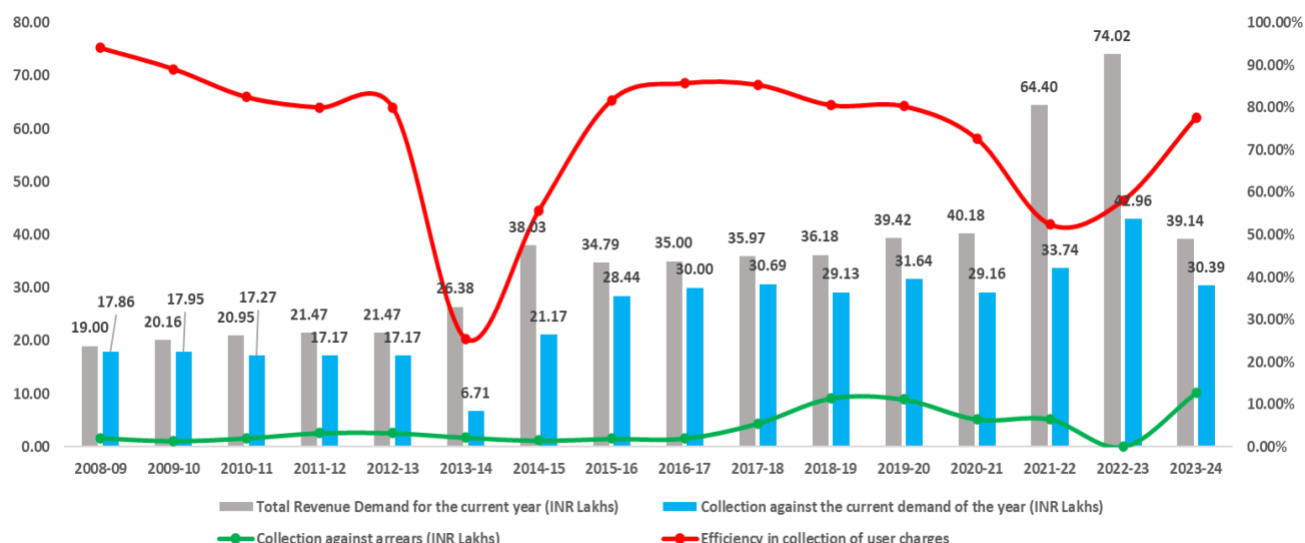
**Source: Dwarka Municipal Council (DMC), 2025**

However, after this peak, the recovery rates fluctuated and declined sharply after 2020-21, reaching as low as 26.45% in 2023-24. This decline was due to reduced revenue collection, arrears, and high operating costs, indicating that DMC faces challenges in achieving sustainable cost recovery. The trend highlights the need for better fiscal planning, improved revenue collection, and cost control measures to ensure long-term financial stability.

The **collection efficiency** for water supply user charges at Dwarka Municipal Council (DMC) has shown significant volatility, reflecting challenges in revenue recovery. In the early years (2008-09 to 2012-13), efficiency was relatively strong, peaking at 94% in 2008-09, but gradually declined

over the next few years, reaching a low of 25.44% in 2013-14 due to difficulties in managing arrears and possibly other operational challenges (Figure 22).

**Figure 22: Trend analysis of collection efficiency in water supply charges at DMC**



**Source: Dwarka Municipal Council (DMC), 2025**

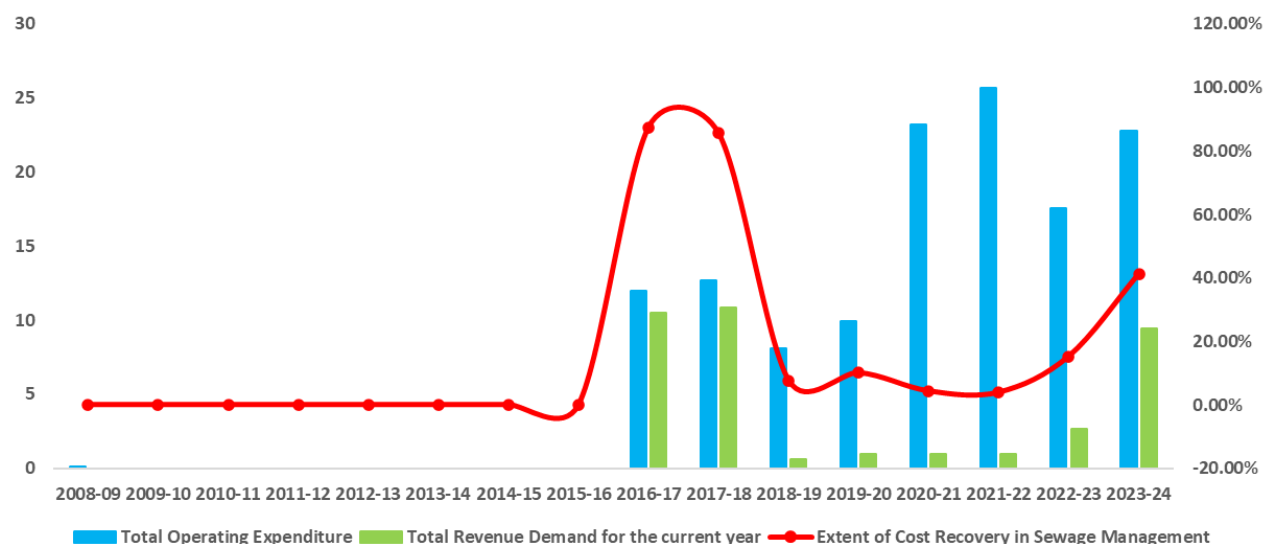
After this sharp drop, collection efficiency improved steadily from 2014-15 to 2016-17, reaching 85.71%, aided by better arrears collection and financial management. However, post-2017, efficiency began to decline again, falling to around 52-58% in 2021-23, before slightly improving to 77.64% in 2023-24. This decline suggests ongoing issues with arrears, non-payment, and administrative inefficiencies. DMC's fluctuating collection efficiency highlights the need for better infrastructure, more effective billing and collection systems, and stronger policies to address arrears and ensure consistent revenue generation.

#### 6.4.2 SEWERAGE AND SANITATION

**The cost recovery** for sewerage and sanitation services at Dwarka Municipal Council (DMC) has been inconsistent and fluctuating over the years, with significant challenges in matching revenues to operational costs. Initially, from 2008-09 to 2012-13, there was no revenue demand, suggesting either underdeveloped infrastructure or ineffective policies. From 2013-14 onwards, operational costs increased, but revenue generation remained low until 2021-22 (Fig. 23). A notable

improvement occurred in 2016-17, when the cost recovery rate peaked at 87.5%, driven by better revenue from user charges.

**Figure 23: Trend analysis of cost recovery in sewerage & sanitation charges at DMC**



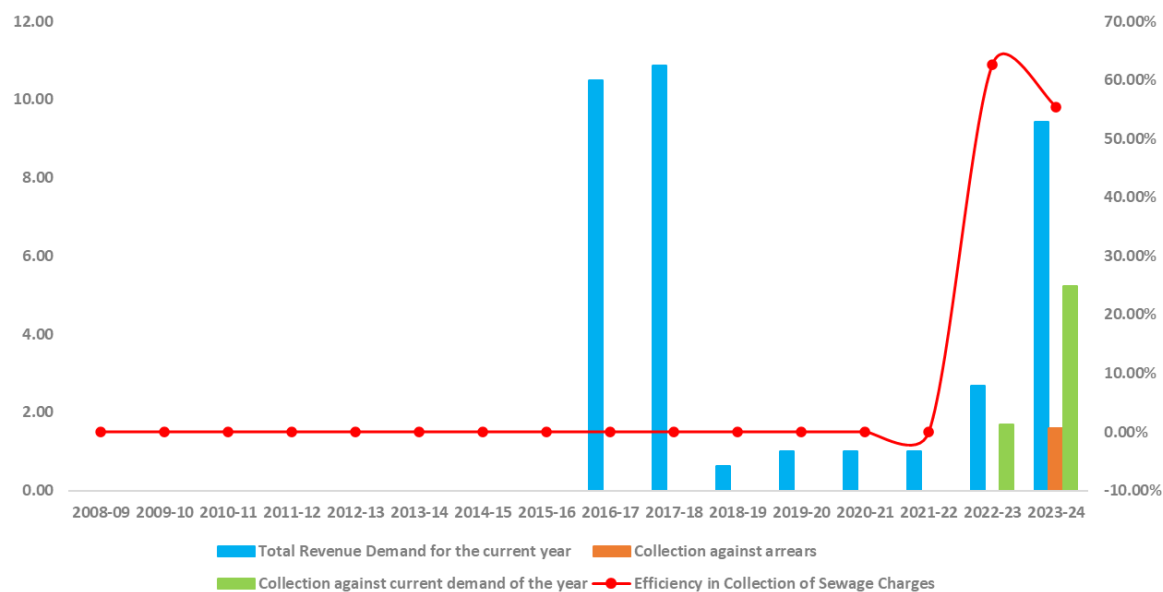
**Source: Dwarka Municipal Council (DMC), 2025**

However, this was short-lived, and by 2018-19, recovery plummeted to just 7.68%, due to rising operational costs and insufficient revenue growth. The period from 2019-20 to 2022-23 saw consistently low recovery, with figures ranging from 3.89% to 4.31%. In 2023-24, cost recovery improved to 41.28%, reflecting better revenue generation, particularly through increased tax/cess, but it remains far from adequate to cover costs. Hence, DMC faces persistent challenges in achieving sustainable cost recovery for sewerage and sanitation, requiring enhanced revenue collection, tax base expansion, and potential adjustments to service charges to ensure long-term financial stability.

The trends in **collection efficiency** for sewerage and sanitation charges at Dwarka Municipal Council (DMC) reflect significant challenges in revenue generation and collection, particularly in the early years (Fig. 24). From 2008-09 to 2017-18, there was little to no revenue collected, indicating

a lack of structured billing and collection mechanisms. This period likely coincided with the underdevelopment of the sewerage and sanitation system.

**Figure 24: Trend analysis of collection efficiency in sewerage & sanitation charges at DMC**



**Source: Dwarka Municipal Council (DMC), 2025**

Starting in 2018-19, DMC began to make modest improvements in collection, but efficiency remained low, with minimal collections in the subsequent years. However, from 2021-22 onwards, collection efficiency began to improve significantly, reaching 62.69% in 2022-23, signalling progress in the billing and collection system. Despite a slight dip to 55.41% in 2023-24, the trend shows a positive shift towards better revenue collection, though challenges remain in optimizing the process, addressing arrears, and ensuring regular payments to support the long-term sustainability of sewerage and sanitation services at DMC.

6.5 KEY FINANCIAL CHALLENGES

The financial challenges for water supply at the Dwarka Municipal Council (DMC) are marked by significant volatility in both cost recovery and collection efficiency. Over the years, DMC has struggled to align revenue with operational costs, resulting in fluctuating cost recovery percentages, from as low as 25% in some years to peaks of around 86%. The introduction of water service taxes and efforts to improve arrears recovery have helped at times, but inconsistent revenue collection, high operating costs (e.g., repairs, maintenance, electricity), and a reliance on external taxes have undermined long-term sustainability. Similarly, collection efficiency has been erratic, with notable

drops, particularly in 2013-14, due to challenges in managing arrears and growing infrastructure demands. While there have been improvements, recent years show a decline in efficiency, pointing to systemic issues in billing, collection processes, and user compliance. These financial fluctuations highlight the need for better fiscal planning, more reliable revenue collection mechanisms, and strategic cost management to achieve sustainable water supply financing.

The financial challenges for sewerage and sanitation services at Dwarka Municipal Council (DMC) are primarily driven by inconsistent cost recovery and collection efficiency. In the early years (2008-09 to 2017-18), there was a lack of structured billing and collection mechanisms, leading to zero revenue collection and no cost recovery. Even after the introduction of revenue generation strategies in 2013-14, the cost recovery remained low, with significant fluctuations, peaking at 87.5% in 2016-17 but declining sharply afterward. By 2023-24, cost recovery improved to 41.28%, but still fell short of covering operational costs. Collection efficiency showed a similar pattern, with minimal revenue collected in the early years and a gradual improvement from 2021-22 onwards, reaching 62.69% in 2022-23. Despite some progress, DMC continues to face challenges in ensuring sustainable financial management for sewerage and sanitation, requiring further improvements in billing systems, collection infrastructure, and revenue generation strategies to meet long-term operational needs.

# CHAPTER 7: RISK ASSESSMENT OF WASH INFRASTRUCTURE & SERVICES IN DEVBHUMI DWARKA

SUCHARITA ROY, TEJASH ANAND, AND NC NARAYANAN

## 7.1 BACKGROUND

Urban infrastructure in small towns—such as Dwarka—is increasingly pressured by urbanization, rising service expectations, and extreme natural events spurred by climate change, geographical challenges and for Dwarka, the extreme risks from hazards like earthquakes, tsunamis, and severe annual cyclones. Inadequate infrastructure not only heightens the risk of loss of life and property; it also increases the likelihood that a natural hazard will escalate into a disaster. Accordingly, resilient infrastructure is defined as systems and networks that can absorb shocks, maintain essential services during crises, and swiftly recover while simultaneously reducing future risks.

This chapter captures the exposure and vulnerability of the WaSH infrastructure of Dwarka in Devbhumi Dwarka 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.

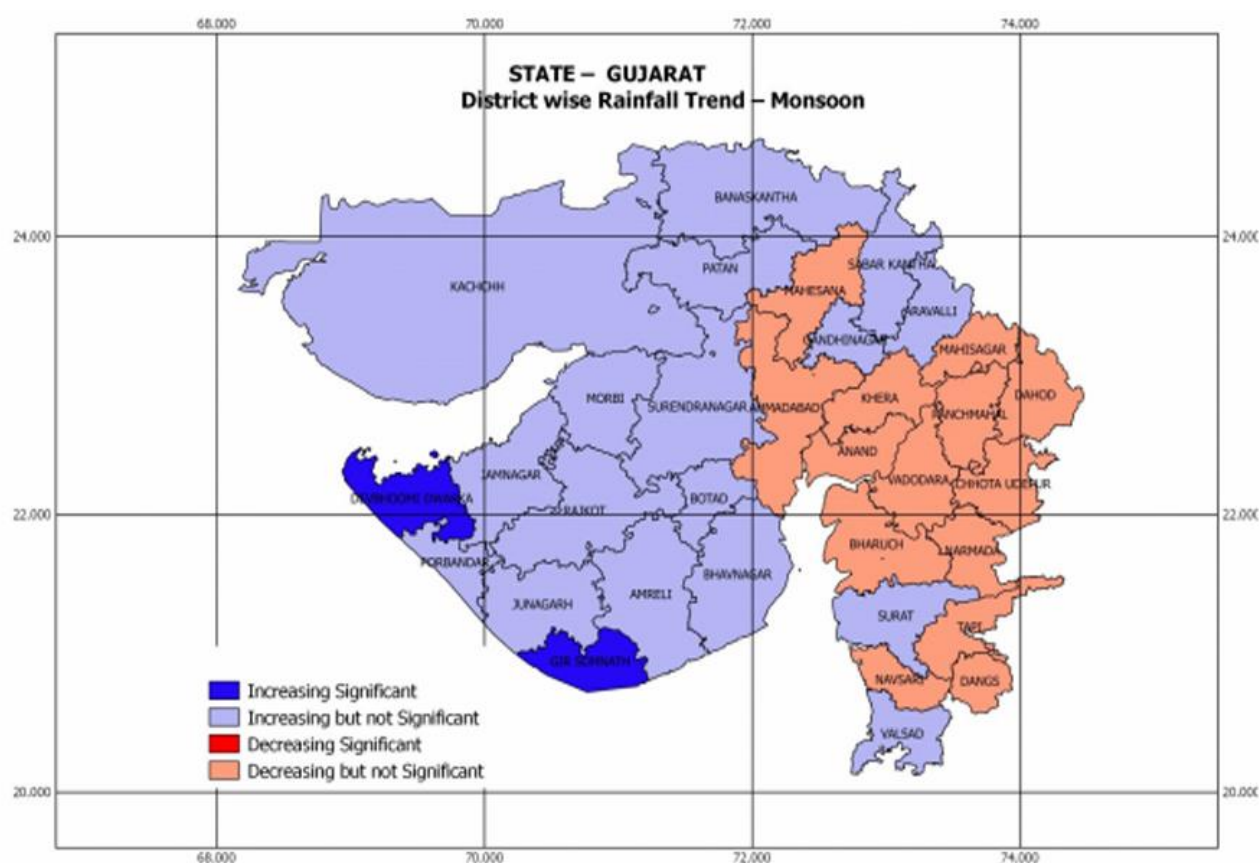
## 7.2 EXPOSURE TO CLIMATE RISK

Dwarka is exposed to multiple hazards like earthquake, cyclones, storm surges, intense precipitation events, tsunamis (Collector, 2024) and hence is has high vulnerability and risks from flooding and inundation, strong winds and damages thereby along with disruption of services and many secondary risks like polluted water and salt intrusion, increasing vulnerability of building stock, adequacy of basic services etc.

As per Dwarka has a dry and humid climate. 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, Devbhumi, Dwarka, Porbandar, Rajkot, Jamnagar, Junagadh, Amreli, Patan, Valsad, Surat, and Sabarkantha districts. The increasing global warming has created an imbalance in the rainfall

changes across the world, as suggested by the regional rainfall variation pattern, and these changes are predicted to amplify with a further increase in global warming (refer figure 25). The future projections suggest that the greenhouse gas-induced warming will increase global monsoon rainfall; according to the long-term trend (2081-2100), the effect on monsoon rainfall change will show asymmetry, inducing a more significant increase in monsoonal rainfall in the northern hemisphere compared to rains in the southern hemisphere. The east-west asymmetry projected an increase in rainfall from the Asian- African monsoon with medium confidence. 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.<sup>54</sup>

**Figure 25 : District wise rainfall trends in Gujarat during entire summer monsoon period from 1989 to 2018**



Source: IMD

There is high vulnerability to flooding due to heavy rainfall, storm surges, coastal inundation, ground water flooding and or dam failure. The Okhamandal district has 10 medium and minor dams and

multiple lakes. Dwarka has nearly 80 % of the land area at an elevation less than 10 m above sea level. However, a significant part of the sea edge is a cliff like formation. Dwarka slopes towards its north and south making ward 2, and wards 4 and 5, with a significant part of the low-lying wards at an elevation of less than 5 m above mean sea level. Storm surges, rise in sea level and heavy precipitation make these wards extremely high risk. **(Refer Table 20)**

**Table 20 : 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    | 6062            | 2%         | 42                                      | 65                                  | 35                                 |
| 2    | 5703            | 13%        | 30                                      | 93                                  | 7                                  |
| 3    | 5115            | 5%         | 21                                      | 66                                  | 34                                 |
| 4    | 5440            | 64%        | 74                                      | 100                                 | 0                                  |
| 5    | 5347            | 34%        | 60                                      | 100                                 | 0                                  |
| 6    | 5411            | 5%         | 5                                       | 66                                  | 34                                 |
| 7    | 5795            | 42%        | 69                                      | 94                                  | 6                                  |

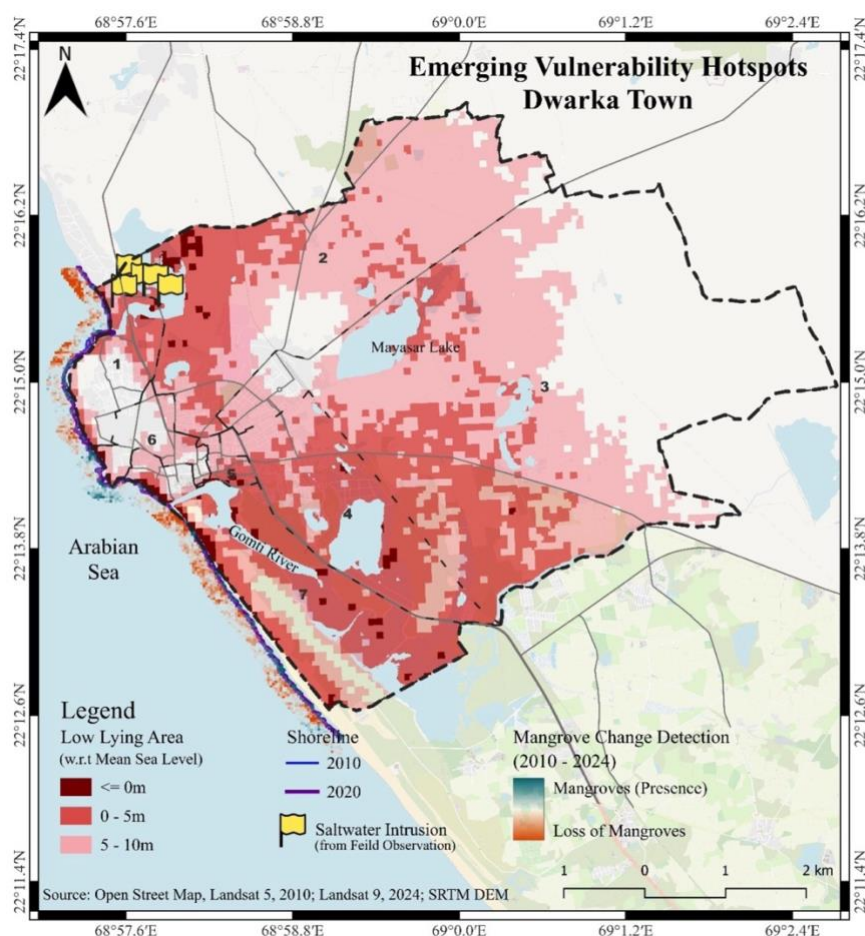
*Source: Sentinel 2 10m LULC; Open Street Map; Landsat 9 (Shoreline), 2020; Landsat 6 (Shoreline), 2010; Devbhumi Dwarka Municipalities and Field Observation*

Approximately 80% of Dwarka administrative area lies at an elevation of less than 10 m above mean sea level. Storm surges here can be up to 3 m and coupled with rising high tide levels, intense precipitation, tropical cyclones, and stronger winds from the Arabian Sea significantly raises the town's vulnerability to flooding and inundation. Dwarka faces annual flooding every August and September with flood water rising to 5 – 6 ft in 2024 as per residents from low lying locations in ward 1 lying in the northwestern edge of the town. This situation persisted over 10 – 12 days last year and necessitating evacuation since many homes got inundated, forcing families to seek shelter in elevated areas, shelters or with relatives until floodwaters receded. A considerable damage to infrastructure was reported post the flooding incident. Wards 4 and 7 are equally vulnerable to flooding, which is also proven by the fact that the STP located in Ward 4 was majorly disrupted during the floods of 2024. However, no flood risk zonation maps could be found from secondary

sources for the purpose of this study and hence data collected on the field and digital elevation data has been considered as proxy data to identify the risk to critical infrastructure components.

In the groundwater scenario analysis undertaken on Aug 2024 by CGWB finds the depth to water level in unconfined aquifer to be 0 mbgl for Devbhumi Dwarka, this strongly indicates ground water flooding as one of the reasons for the flooding situation faced along with rainfall and coastal inundation. Annual fluctuation i.e., rise and fall in piezometric levels of water in the observations wells was found to be greater than 4 m the highest in the state of Gujarat. <sup>55</sup> Field enquiries have revealed that certain sections of the town are exposed to flooding every year with water not receding for 5 -6 days at a time specifically in low lying regions of Ward 1 and 2 near the northern edge of the city where salt intrusion into the ground water has been reported by the residents.

Figure 26 : Emerging Vulnerability Hotspots and Exposure of Dwarka Town to Climate Hazards



Source: Sentinel 2 10m LULC; Open Street Map; Landsat 9 (Shoreline), 2020; Landsat 6 (Shoreline), 2010; Devbhumi Dwarka Municipalities and Field Observation

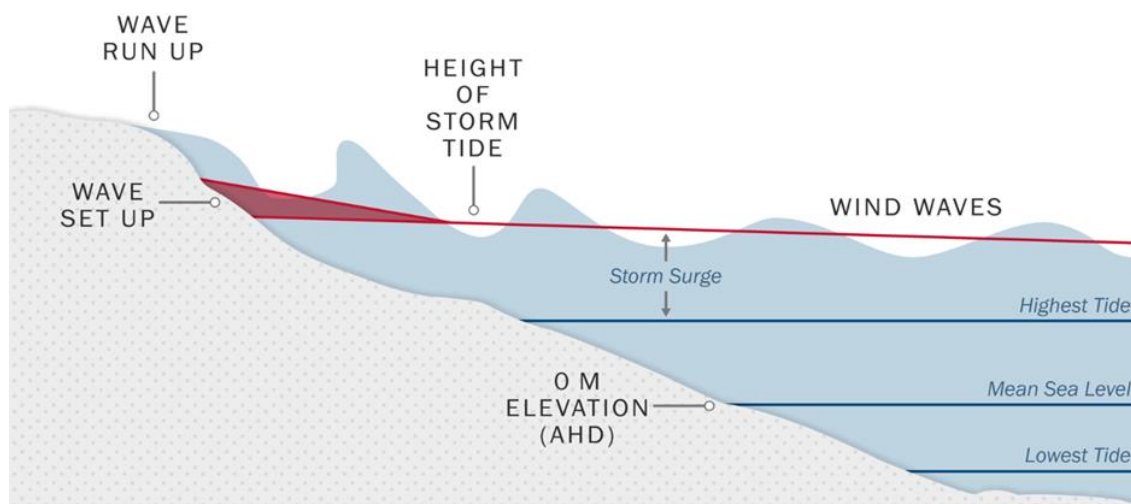
In low elevation coastal zones and floodplains, severe flooding occurs when the soil is saturated and infiltration is minimum, water levels in creeks and rivers are elevated after a prolonged spell of monsoon rains and ground water levels rise - the flood water is unable to recede. These flood-like situations result in inundations which can continue from several hours to many days as seen in many low-lying coastal cities and towns. In a dense built-up area, an intense rainfall burst within a brief period can also result in flash flooding. Zoning control includes designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area. Most of the physical, social, and economic problems associated with flooding, soil erosion and water pollution stormwater are attributable to inappropriate urbanization of the floodplain, unwise land use within the city, insufficient attention to drainage in urban planning, ineffective updating of existing stormwater control facilities and lack of enforcement of zoning ordinances.<sup>56</sup>

It is also in the extremely high damage risk zone [50 m/s] from cyclone. Two cyclonic storm seasons are: May to June (advancing southwest monsoon) and September to November (retreating monsoon). Maximum wind speed class of more than 55 m/sec along the Saurashtra coast, specifically in Junagadh, Porbandar, Jamnagar, Morbi, and Kutch districts, which are exposed to high intensity cyclonic and storm impact. Height of storm surges due to cyclone is to a height of 3 m. 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.<sup>57</sup>

Storm surge is an abnormal water level rise generated by a storm over and above the predicted astronomical tide. Storm tide is the water level rise due to the combination of storm surge and astronomical tide. This rise in water level can cause extreme flooding in coastal areas, particularly when storm surge coincides with normal high tide. However, to avoid confusion, "storm surge" is used interchangeably. Wave action occurring on top of the surge, which can add additional feet to the overall water level.<sup>58</sup> Disruptions in vertical ocean circulation during these events can force seawater inland, contaminating freshwater resources. When heavy rainfall flooding in low-lying areas becomes an almost inevitable consequence—a risk that has been increasing in the Saurashtra coast.

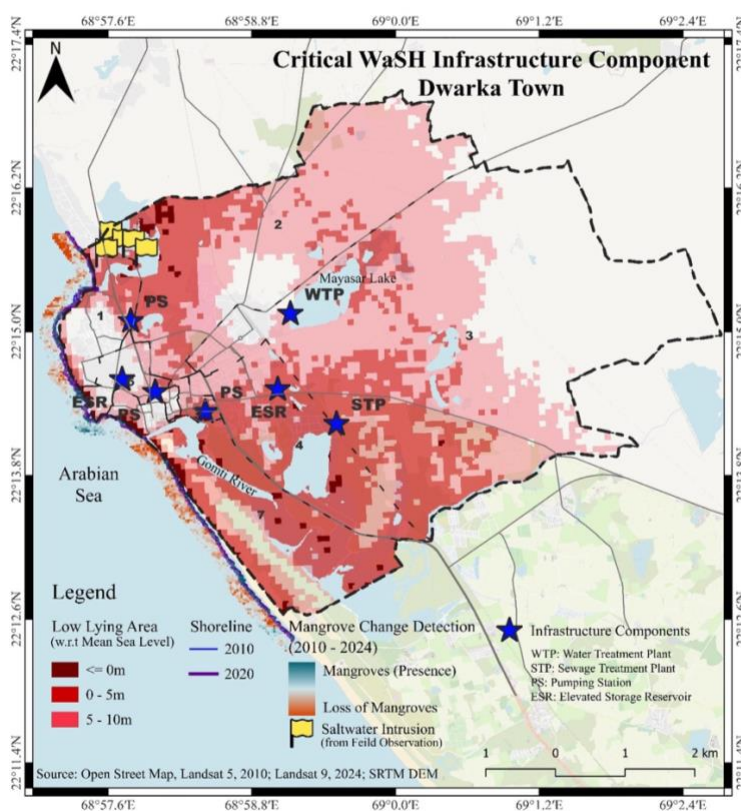
Torrential rainfalls for 4 – 5 consecutive days in Aug 2024 lead to severe flooding in the district as well as the region. Dwarka, which is visited by lakhs of pilgrims, was under waist-high water after being lashed by 344mm of rainfall in 4 hours, 230 mm in just 2 initial hours. Dwarka has received 316% of its average annual rainfall, the highest in the state, as per media reports. Many people including tourists were marooned in the town. While Dwarka's annual rainfall has ranged at around 800 mm, Dwarka received up to 170 – 190 mm rainfall per day for four consecutive days. (TOI, 2024). Dwarka's STP stopped functioning from July 2024 and could be partially restored by Feb 2025, 7 months later.

**Figure 27 : Representation of the compounded risk from hightide, storm surges and wave setups resulting in total water level rise.**



Source: [Storm Surge Overview](#), National Oceanic and Atmospheric Administration, US Dept of Commerce.

**Figure 28: Location of critical components of the WaSH Infrastructure in Dwarka municipal boundary**



Source: Sentinel 2 10m LULC; Open Street Map; Landsat 9 (Shoreline), 2020; Landsat 6 (Shoreline), 2010; Devbhumi Dwarka Municipalities and field observations

Saltwater intrusion presents a critical challenge in two primary ways. For areas without piped water, it compromises the access to safe, fresh water. Moreover, saltwater increases the conductivity of groundwater, which accelerates the corrosion of underground water and wastewater collection pipes. Research has shown that changes in soil and groundwater chemistry due to saltwater intrusion—and rising sea levels in general—can significantly shorten the service life of infrastructure such as ductile iron pipes, which are typically expected to last between 80 and 100 years under ideal conditions.<sup>59</sup>

The case study of Dwarka reveals that for a coastal city in the LECZ zone with major part of its land area at less than 10 m elevation above mean sea level, the current policies and technologies governing WaSH infrastructure provision need to be evaluated for resilience. Instances of salinity intrusion in wells have already been reported in the northwestern wards by residents during field studies. With flooding and inundation and increasing intensity of cyclones and storm surges, Dwarka can face contamination of wells and disruption of natural treatment processes in the OSS units in wards with low lying regions. Dwarka, a town located primarily in a wetland ecosystem, is struggling to keep its water treatment and sewage treatment plants, installed at a significant cost, functioning.

Similarly, the accumulation of saline influents in treatment units and sanitation pits—including septic tanks—can impair the removal of pollutants like organic matter and nutrients. High electrical conductivity, a hallmark of saltwater, has been found to adversely affect microbial diversity and the efficiency of organic matter breakdown.<sup>60</sup>

The town lies in Zone IV as per the seismic zonation of the region with the District Disaster Management Plan has a high vulnerability to damage falling in the very severe intensity zone. Gujarat is prone to tsunami risk due to its long coastline and probability of occurrence of near and offshore submarine earthquakes in the Arabian Sea. Makram Subduction Zone (MSZ) -Southwest of Karachi is an active fault area which may cause a high magnitude earthquake under the sea leading to a tsunami. Dwarka has a medium risk exposure to Tsunamis. Tsunamis are most often generated by earthquake-induced movement of the ocean floor. Landslides, volcanic eruptions, and even meteorites can also generate a tsunami. Areas at greatest risk are those less than 25 feet above sea level and within one mile of the shoreline. The housing stock of Dwarka is vulnerable and can be at risk of collapse as has been noted in the DDMP for Devbhumi Dwarka.<sup>61</sup>

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. In a recent study appearing in Science Advances, the researchers report that episodes of heavy snowfall and rain likely contributed to a swarm of earthquakes over the past several years in northern Japan. The study is the first to show that climate conditions could initiate some quakes.<sup>62</sup>

## 7.2 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.

### ADEQUACY OF INFRASTRUCTURE

The WaSH infrastructure of Dwarka is inadequate due to inequitable, inadequate access to safe water and sanitation, state of the infrastructure and its exposure of the infrastructure.

While Dwarka has traditionally used ground water sources for meeting its water requirements, treated piped water is available to about 50 % of the households. The rest of the population depends on ground water. Saline intrusion has been reported in ward 1. With multiple flooding and inundation events every monsoon, contamination of drinking water is eminent.

The total bulk water tapped from all the sources at Dwarka is much less than the projected demand. (Refer Chapter 3). Water availability is inadequate in summers with unregulated private tanker services filling in the gap between demand and supply. The quality of water and quantity of water available to residents of Dwarka is hence inadequate. Water sources are strained too.

Only half the capacity of water treatment plant is currently under use. Water treatment is primarily through chlorination and use of alum during monsoons and little to no treatment in other seasons. The water treatment plant was found to be in dilapidated state. The treatment processes during monsoon with chlorine and alum do not adequately address concerns arising from sewage contamination during flooding.

Sanitation services in Dwarka are inadequate and unreliable. Dwarka is primarily dependent on household level, on-site sanitation systems. Sewerage network covers a very small section of the town. The construction of these sanitation systems is not regulated and field interactions with residents reveal that many of these existing systems are simple sand lined pits. Safe containment of sewage in flood like situations can be a serious challenge for the town of Dwarka increasingly exposed to heavy precipitation, coastal inundation, and ground water flooding in monsoons.

The town does not have access to safe treatment of sewage. The STP, which is fed by desludging trucks, had been damaged by floods of 2024 and was nonfunctional for 7 months(refer Chapter 4 on sanitation) Based on SBR technology, is located on low lying land which is prone to flooding. While SBR technology, effectively treats wastewater and are easy to control in case of incidents, flexible in operation and energy efficient too, but SBR tanks require sophisticated and modern monitoring systems hence shall need to be safeguarded from unprecedented flooding or damage due to earthquakes etc.

Desludging service providers are unregulated, and the trucks were forced to dump collected sewage in dry surface water ponds in the outskirts of the town when the only STP of the town was nonfunctional for 7 months due to flood damage increasing the possibility of secondary risks due to contamination of land, surface and subsurface water and health outbreaks. Open defecation is still practiced in some slum like settlements housing informal labour in ward 1 and 2. Community toilets are absent in such locations. Flood-proof solutions for community sanitation in vulnerable locations is an emerging need. For the socio economically vulnerable households forced to evacuate to higher grounds during flood prone months are forced into open defecation.

#### RELIABILITY, FLEXIBILITY AND REDUNDANCY

Source sustainability is an emerging concern for Dwarka. Water sourced from non-flowing sources are often open to being impacted by seasonal fluctuations like intense precipitation trends of monsoon which result in excessive runoff, sedimentation and lesser retention and infiltration, and thereby becomes a risk-prone component of the water supply system. While Narmada canal is at 20 kms from the town, a regional source for multiple settlements, it is under the jurisdiction of state agencies, with limited management control of local administration.

The reliability of groundwater as a source of water is increasingly at risk of contamination from saltwater intrusion, fluctuating water tables, poorly constructed or unmonitored on-site sanitation systems during flooding and storm surges, flooding, and inundation.

Enhancing flexibility in water systems is critical for ensuring reliable services during disruptive events. Flexibility is the ability of an infrastructure asset or system to perform the desired function based on specified requirements over time without interruption or degradation. Source diversification and regulated utilization of the ground water resources in water positive coastal areas, distributed storage and treatment facilities and compartmentalization of the services, alternative technologies etc. need to be explored and integrated to reduce the risk of town level disruptions.

Redundancy is key to ensuring that water systems continue to operate smoothly, even in the event of component failures. The failure of the STP post flooding in 2024 exposed the entire town to risk

from contamination due to unsafe disposal of sewerage. Alternatives like smaller sized STPs, or shared treatment services etc could offer the flexibility in operations in case of climate events. Heavy dependencies 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.

## 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.

Dwarka Municipal Council has been unable to increase its coverage of treated water supply and the coverage has declined over recent years. The non-revenue water in the water supply systems has increased in recent years.

At the household level, DMC is not engaged in the design, construction, or enforcement of standards for toilets and OSS. This gap is especially concerning for a coastal city like Dwarka—exposed to annual flood and cyclone season and dependent on OSS for sanitation (refer chapter 4 on sanitation).

The interagency development model in WaSH infrastructure has significant challenges and limitations and reduces the opportunity for decentralised and local level planning. The Dwarka Municipal Council (DMC) is responsible for the management and maintenance of all municipal water works and the construction or acquisition of new works as obligatory functions in water supply services for the city. However, 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.

The dependence on non-revenue sources of funding is high and involves a time-consuming process the proposal making by technical agencies and receiving approval from funders post which implementation can be planned and executed. The technical and governance capacities are limited and need handholding support to conceptualise and design significant transformative changes needed by the town based on the tied-funding available.

Governance arrangements, in many contexts, too fragmented across administrative boundaries and sectors to provide integrated responses to the increasing and cascading risks from climate-related changes in the ocean and/or cryosphere (high confidence). The capacity of governance systems is not sufficiently rapid or robust to adequately address the scale of increasing projected risks (high confidence). In high mountains, coastal regions and small islands, there are also difficulties in coordinating climate adaptation responses, due to the many interactions of climatic and non-climatic risk drivers (such as inaccessibility, demographic and settlement trends, or land subsidence caused by local activities) across scales, sectors and policy domains.<sup>63</sup>

Intensifying cooperation and coordination among governing authorities across scales, jurisdictions, sectors, policy domains, and planning horizons can enable effective responses to change in the ocean, cryosphere and to sea level rise (high confidence).<sup>64</sup>

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.<sup>65</sup>

Commissioner of Relief (COR) is the at the centre of the risk governance at the state level and declares a disaster and strategizes the action to be taken and is supported by and municipal commissioners (municipal corporations), district collectors, state EOCs and non-state stakeholders. At a district level the District Collector anchors the district disaster management plan. Small towns like Dwarka are dependent on the District Magistrate and Collector's office for disaster risk reduction and resilience for most measures. Local bodies are responsible for timely sharing of warning information and support the development of ecologically sound zonation and protection of natural barrier, construction of shelters, monitoring embankments, wetlands, flood resisting structures, afforestation, enforcement of regulations and standards and other prevention, rescue, and response support measures. Local bodies are responsible for ensuring adequate human resource to respond during cyclones and floods also lies with the urban local bodies. For small local bodies like Dwarka, capacities in execution of these responsibilities shall need enhancement.

The Disaster Management Plan of Devbhumi Dwarka, developed by the Collector's office, defines not only the hazard, vulnerability, and risks of the district, but also the institutional arrangement, roles and responsibility and SoPs for prevention and mitigation, preparedness, response, and Recovery measures needed or the disaster management. It also details the financial arrangements for doing so. The resilience assessment of Dwarka's infrastructure reveals that it is focused on response and recovery mechanisms post disaster which are centralized at the district level. The District Magistrate (DM), acting as the chairman of the District Disaster Management Authority

(DDMA), is responsible for overall incident response, while the District Emergency Operations Centre (EOC) functions as the nerve centre during critical incidents. 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 DDMP elaborate the responsibilities as well as the SoPs for prevention, preparedness, rescue response and recover across very sectors and agencies. The District Coordination Committee includes officers from relevant departments. to mainstream DRR into the district plan. The risk reduction functions for Water Supply and Sanitation are primarily the function of Gujarat Water Supply and Sewerage Board (GWSSB). 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 not adequately covered in the DDMP. SBR based STP of Dwarka was nonfunctional for seven months post the flood damage post which it could only be partially restored. The WTP was found to be functioning inadequately and in a need for uphaul. Skills required for maintaining the functionality of such technologies can often overwhelm small town authorities and lead to outages and disruptions as seen in Dwarka.

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.

Actionable under Climate Risk management such as research, forecasting / early warning, data management, zoning, mapping, Hazard Risk Vulnerability and Capacity Assessment (HRVCA) and Climate Change Adaptations (CCA) which are primarily the state and district functions with extremely limited role etched out for local authorities. However, SDMP provides broad perspective on mainstreaming DRR and CCA. The SDMP mentioned that “each department and agency must review current programmes to include DRR and CCA to the extent possible cost effectively within their main budget and ensure comprehensive appraisal of all new initiatives (policies, plans, programmes, projects, etc.) However, the mainstreaming of DRR and CCA till the local level shall still not adequately underway.

# CHAPTER 8: CLIMATE CHANGE INITIATIVES IN DEVBHUMI DWARKA

NEELAM RANA, PRIYAKSHI GOGOI, NC NARAYANAN

This section outlines key climate-related adaptation and mitigation efforts observed in Dwarka town, based on field insights (refer table 21).

## **Adaptation Efforts**

As noted in the second chapter, Okhamandal taluka is classified as a “safe category” zone for groundwater extraction. However, our field interactions indicate that residents in certain areas experience water stress, particularly during lean monsoon periods.

In response to ongoing water scarcity, residents have taken proactive, community-led steps to build resilience. Many households are constructing underground tanks for rainwater storage during home construction. The rainwater harvesting systems have also been installed in several municipal buildings. Rainwater harvesting initiatives can be financed through the 15th Finance Commission’s tied funds. Such decentralized efforts reflect a growing recognition of the need to adapt to shifting climate patterns, including erratic rainfall and increasing water stress. Promoting and scaling such community-driven practices, alongside institutional support, can play a vital role in strengthening local water resilience and reducing vulnerability to climate-related risks.

Additionally, groundwater extraction is also regulated; by the Mamlatdar office at the city level. Under this system, any household or entity planning to extract or use groundwater is required to obtain a No Objection Certificate (NOC) from the *Mamlatdar* office before initiating such activities.

## **Mitigation Efforts**

Under the state’s Solar Policy, electricity subsidy schemes are provided to encourage the installation of solar power systems. This has led to widespread adoption of solar energy among commercial establishments. Notably, the STP in Dwarka is also equipped with solar panels, demonstrating a shift toward cleaner energy sources in public infrastructure. The power generated by the solar panels is sold rather than being used for STP operations. These efforts contribute directly to climate change mitigation by reducing dependence on fossil fuels, lowering GHG emissions, at both institutional and community levels.

**Table 21 : Climate Change Initiatives in Dev Bhumi Dwarka**

| <i>Initiative</i>                                                   | <i>Relevance</i>                                                                                  | <i>Status</i>                                                           |
|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| <b><i>Adaptation Efforts</i></b>                                    |                                                                                                   |                                                                         |
| <b><i>Household-level underground rainwater storage tanks</i></b>   | Community-led response to seasonal water stress and erratic monsoons                              | Being implemented voluntarily during home construction in some areas    |
| <b><i>Rainwater harvesting in municipal buildings</i></b>           | Strengthens municipal water resilience and reduces dependency on external sources                 | Installed in several public buildings                                   |
| <b><i>Financing via 15th Finance Commission's tied funds</i></b>    | Institutional support to scale decentralized rainwater harvesting initiatives                     | Available for municipal use; can be further leveraged                   |
| <b><i>Groundwater extraction regulation by Mamlatdar office</i></b> | Prevents over-extraction and promotes sustainable water use                                       | No Objection Certificate (NOC) required prior to groundwater extraction |
| <b><i>Mitigation Efforts</i></b>                                    |                                                                                                   |                                                                         |
| <b><i>Electricity subsidies under Gujarat Solar Policy</i></b>      | Encourages clean energy adoption among commercial establishments                                  | Widely availed; supports transition to renewable energy                 |
| <b><i>Solar panels at Dwarka STP</i></b>                            | Institutional shift toward renewable energy; reduces GHG emissions from infrastructure operations | Installed; power is sold rather than used internally at the STP         |

# CHAPTER 9: SECTORAL RECOMMENDATIONS FOR ENHANCING CLIMATE RESILIENCE OF WASH INFRASTRUCTURE & SERVICES IN DEVBHUMI DWARKA

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## 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 Urban Local Bodies (ULBs) 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.

Devbhumi Dwarka, a coastal town in Gujarat, faces significant challenges in its water and sanitation infrastructure amid climate change impacts. Despite being classified as a “safe” groundwater zone, parts of the town experience water stress due to urbanization and weak monsoons. While community-led rainwater harvesting initiatives show local adaptation, critical issues persist, including a non-functional water treatment plant and limited water coverage. The town has achieved progress in sanitation, reaching ODF++ status, but gaps remain in inclusive service delivery, particularly for underserved communities. Frequent flooding damages aging infrastructure like the sewage treatment plant, exacerbated by limited drainage and low-lying terrain. Capacity and financial constraints hinder sustainable wastewater management, highlighting the need for improved billing, tariff reforms, and external partnerships. Additionally, poor system performance contributes to GHG emissions, emphasizing the need for comprehensive solutions like sewer coverage and biogas recovery. To enhance climate resilience, Dwarka must focus on inclusive service expansion, flood risk integration, infrastructure modernization, and capacity building for local authorities.

**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. Prioritize repairing and restoring the non-functional Water Treatment Plant (WTP) to address critical infrastructure gaps.
2. Decentralize Water Management in Small and Medium Towns (SMTs) in Gujarat:
  - Promote rainwater harvesting and watershed management techniques.
  - Reduce dependence on distant water sources to enhance local water security.
3. Strengthen Existing Water Distribution Networks with Advanced Technologies
  - Implement smart meters and leak detection systems.
  - Utilize real-time monitoring to minimize Non-Revenue Water (NRW) and improve supply efficiency.
4. Promote Wastewater Recycling and Reuse at the Local Level
  - Prioritize non-potable uses such as irrigation and industrial processes.
  - Alleviate pressure on freshwater resources by maximizing water reuse.
5. Enhance Urban Local Bodies' Capacity through Data-Driven Decision-Making
  - Encourage community-based water management approaches.
  - Empower citizens and local governments to collaborate effectively on water-related challenges.
6. Integrate Climate-Resilient Practices to Ensure Sustainable Water Supply
  - Increase water storage capacity using check dams, ponds, and other natural infrastructure.
  - Mitigate the impacts of erratic rainfall patterns to improve water reliability.

## 9.3 SANITATION

1. **Limited Access to Water and Sanitation in Low-Income Communities:**
  - Provide shared community toilets in settlements lacking individual household toilets, using modular, flood-resilient designs.
  - Mandate inclusive service delivery in city-level climate adaptation and urban development policies.
  - Prioritize vulnerable areas in municipal planning and funding allocations.
  - Engage local communities in the design and management of shared facilities to foster ownership and respect.
  - Deploy decentralized nature-based solutions in such communities.
2. **Flooding and Inadequate Stormwater Drainage:**

- Upgrade stormwater drainage systems with climate-adaptive designs, prioritizing low-lying and flood-prone areas.
  - Integrate flood risk assessments into all new infrastructure projects.
  - Mandate regular maintenance and monitoring of drainage and pumping stations.
  - Create rapid response teams for flood emergencies, including clear protocols for evacuation and support.
- 3. Aging Sanitation Infrastructure**
- Accelerate replacement of old sewer lines and implement GPS mapping of the network.
  - Monitor progress transparently and publish regular updates for public accountability.
  - Implement GPS mapping of the water and sanitation infrastructure
- 4. Capacity Gaps in Operation and Management (O&M) of STP**
- Mandate minimum training standards for ULB staff.
  - Create peer-learning platforms with other cities to share best practices.
- 5. Limited Autonomy of ULB**
- Grant greater administrative and decision-making powers to ULBs in line with the 74th Constitutional Amendment Act to enable context-specific decision-making.
  - Involve ULBs in designing and planning phase of technology selections to enable context-specific technology selection

## 9.4 FINANCIAL SUSTAINABILITY

**key financial recommendations** for Dwarka Municipal Council (DMC) to address water supply and sewerage challenges:

- 7. Enhance revenue collection for water supply:**
  - Improve billing systems
  - Address arrears effectively
  - Introduce incentives for timely payments
- 8. Revise water tariffs:**
  - Align tariffs with operational costs and inflation
  - Consider dynamic pricing to stabilize revenue
- 9. Focus on cost management:**
  - Reduce inefficiencies in maintenance
  - Explore lower-cost bulk water procurement
- 10. Diversify revenue sources:**
  - Seek external funding and grants
  - Establish partnerships to buffer fluctuating revenues
- 11. Strengthen sewerage and sanitation financial systems:**
  - Establish robust billing and collection mechanisms

- Expand tax base and adjust service charges to rising costs
  - Introduce incentives or penalties to improve payment compliance
12. **Improve financial planning and public engagement:**
- Conduct better fiscal planning
  - Run public awareness campaigns to boost payment adherence

## 9.5 INFRASTRUCTURE RESILIENCE

### Provisioning for emerging coastal risks

In the context of Dwarka coastal risks like submergence and erosion, salt intrusion, groundwater and coastal flooding and inundation, Tsunamis, storm surges and wave shoaling are emerging risks. 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 Dwarka, 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 Dwarka. 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.

### **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. Dwarka 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 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.<sup>66</sup> 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. These approaches will particularly be needed by Dwarka to undertake planning for sustainable, risk-free WaSH systems.

Coastal ecosystems can benefit from an ecosystem-based approach in design of sanitation infrastructure. Dwarka, which is part of a larger, semi-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.

### **Flexible and reliable systems for system resilience in the face of shock events:**

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. Technology in water and sanitation infrastructure are a missed opportunity to enhance flexibility for Dwarka and increase the risk of outages in the 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 Dwarka.

Insufficient technical capacity to integrate community infrastructure is a missed opportunity to enhance flexibility for Dwarka and increases the risk of outages in the systems. Dwarka 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. In Dwarka, cyclone can disrupt the electricity supplies and thereby the dependant services in WaSH STPs and water treatment facilities should operate with generators as a backup measure. Resilience could be further enhanced by equipping critical components like pumping stations with alternative energy sources.

### **Risk governance of Infrastructure.**

The transformative action needed in the infrastructure of Dwarka, 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 decisionn-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. 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.

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. 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.

For smaller districts like Devbhumi Dwarka, a cluster-based approach in infrastructure development could help in reducing the disruptions in sewage treatment as seen in 2024. Shared WaSH services between settlements can reduce expenditure and provide alternative revenue sources. 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 little capacity and 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 no 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.

## NOTES & REFERENCES

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- <sup>1</sup> Global Climate Risk Index 2021. Who suffers Most from Extreme Weather Events? Weather-related Loss Events in 2019 and 2000 to 2019 <https://www.germanwatch.org/en/19777> .
- <sup>2</sup> Mohanty, S. K., Bhagat, R. B., Dwivedi, L. K., Sharma, S., Jose, J., Nair, A., & Chandrasekar, R. (2020). Assessing Urban Vulnerabilities In Maharashtra. Government Of Maharashtra, UNICEF, IIPS.
- <sup>3</sup> Rumbach, A. (2018). At The Roots Of Urban Disasters: Planning And Uneven Geographies Of Risk In Kolkata, India'. *Journal Of Urban Affairs*, 39 (6), 1–17.
- <sup>4</sup> Yenneti, K., Tripathi, S., Wei, Y. D., Chen, W., & Joshi, G. (2016). The Truly Disadvantaged? Assessing Social Vulnerability To Climate Change In Urban India. *Habitat International*, 56, 124–35.
- <sup>5</sup> Braks, M. A., & Husman, A. M. (2013). Dimensions Of Effects Of Climate Change On Water-Transmitted Infectious Diseases. *Air Water Borne Diseases*.
- <sup>6</sup> Central Pollution Control Board . (2021). National Inventory Of Sewage Treatment Plants. New Delhi: Ministry Of Environment, Forest And Climate Change. Government Of India.
- <sup>7</sup> Deshpande, M., Singh, V.K., Gandhi, M.K. Et Al. Changing Status Of Tropical Cyclones Over The North Indian Ocean. *Clim Dyn* 57, 3545–3567 (2021). <https://doi.org/10.1007/S00382-021-05880-Z>
- <sup>8</sup> Thomas, S., Lekshmy, P. Recent Trends In Tropical Cyclones Over The Arabian Sea And The Vulnerability Of India's West Coast. *Arab J Geosci* 15, 1713 (2022). <https://doi.org/10.1007/S12517-022-10992-9>
- <sup>9</sup> Deshpande, M., Singh, V.K., Gandhi, M.K. Et Al. Changing Status Of Tropical Cyclones Over The North Indian Ocean. *Clim Dyn* 57, 3545–3567 (2021). <https://doi.org/10.1007/S00382-021-05880-Z>
- <sup>10</sup> Boragapu, R., Guhathakurta, P. & Sreejith, O.P. 2023. Tropical Cyclone Vulnerability Assessment For India. *Nat Hazards* 117, 3123–3143. <https://doi.org/10.1007/S11069-023-05980-5>
- <sup>11</sup> Deshpande, M., Singh, V.K., Gandhi, M.K. Et Al. Changing Status Of Tropical Cyclones Over The North Indian Ocean. *Clim Dyn* 57, 3545–3567 (2021). <https://doi.org/10.1007/S00382-021-05880-Z>
- <sup>12</sup> Woodruff, S., Bendor, T. K., & Strong, A. L. (2018). Fighting The Inevitable. *Infrastructure Investment And Coastal Community Adaptation To Sea Level Rise. System Dynamics Review*, 34(1), 48–77.
- <sup>13</sup> UNDRR, C. (2023). Global Methodology for Infrastructure Resilience Review. United Nations Office for Disaster Risk Reduction (UNDRR) and Coalition for Disaster Resilient Infrastructure (CDRI).
- <sup>14</sup> Shrestha, S. C. (2021). Land Use Change Due to Urbanisation on Surface Runoff Using GIS-Based SCS–CN Method: A Case Study of Xiamen City, China. . *Land*, 10(8), 839.
- <sup>15</sup> Directorate Of Economics and Statistics. (2023). Statistics Of Municipal Towns and Cities Gujarat 2022–23. Gandhinagar: Government Of Gujarat.

- 
- <sup>16</sup> Gujarat State Disaster Management Authority. (2024). Gujarat State Disaster Management Plan -2024-25. Gandhinagar.
- <sup>17</sup> Collector Office . (2021). District Disaster Management Plan - Devbhumi Dwarka. Gujarat State Disaster Management Authority.
- <sup>19</sup> Niti Aayog. (2025, January 1). Natural Disasters In India. Retrieved from India Climate and Energy Dashboard: <https://iced.niti.gov.in/state-report/karnataka>
- <sup>20</sup> Times of India. (2024, September 4). Gujarat Floods Worsened By Rapid Urban Development and Compromised Drainage. IIT Gandhinagar Study Reveals. Retrieved from India Times: [https://economictimes.indiatimes.com/News/India/Gujarat-Floods-Worsened-By-Rapid-Urban-Development-And-Compromised-Drainage-IIT-Gandhinagar-Study-Reveals/Articleshow/113049171.Cms?Utm\\_Source=Contentofinterest&Utm\\_Medium=Text&Utm\\_Campaign=Cppest](https://economictimes.indiatimes.com/News/India/Gujarat-Floods-Worsened-By-Rapid-Urban-Development-And-Compromised-Drainage-IIT-Gandhinagar-Study-Reveals/Articleshow/113049171.Cms?Utm_Source=Contentofinterest&Utm_Medium=Text&Utm_Campaign=Cppest)
- <sup>21</sup> IIT Gandhinagar.<https://indiafloodatlas.in/#/flood-risk> accessed on 15 April 2025
- <sup>22</sup> Dodman, D., Hayward, B., Pelling, M., Castán Broto, V., Chow, W., Chu, E., ... & Ziervogel, G. (2023). Cities, settlements, and key infrastructure.
- <sup>23</sup> Moraci, F., Errigo, M. F., Fazia, C., Campisi, T., & Castelli, F. (2020). Cities under pressure: Strategies and tools to face climate change and pandemic. *Sustainability*, 12(18), 7743.
- <sup>24</sup> Nicholls, R. J., Wong, P. P., Burkett, V., Codignotto, J. O., Hay, J., Ragoonaden, S., & Woodroffe, C. D. (2007). Coastal systems and low-lying areas.
- <sup>25</sup> MoEFCC, (2018). Climate Change And The Vulnerable Indian Coast, Edited by Ramesh. R, Bhatt J.R. Ministry of Environment, Forest and Climate Change, New Delhi.
- <sup>26</sup> USEPA (2025), Climate Change Impacts on Freshwater Resources, Retrieved from <https://www.epa.gov/climateimpacts/climate-change-impacts-freshwater-resources> on August, 2025
- <sup>27</sup> Datta, P., Behera, B., & Rahut, D. B. (2024). Climate change and water-related threats in the Indian Sundarbans: food security and management implications. *International Journal of Water Resources Development*, 40(3), 323-344.
- <sup>28</sup> Rosińska, W., Jurasz, J., Przestrzelska, K., Wartalska, K., & Kaźmierczak, B. (2024). Climate change's ripple effect on water supply systems and the water-energy nexus—A review. *Water Resources and Industry*, 32, 100266.
- <sup>29</sup> Pal, I., Kumar, A., & Mukhopadhyay, A. (2023). Risks to coastal critical infrastructure from climate change. *Annual review of environment and resources*, 48(1), 681-712.
- <sup>30</sup> Siddha, S., & Sahu, P. (2020). Status of seawater intrusion in coastal aquifer of Gujarat, India: a review. *SN Applied Sciences*, 2(10), 1726.
- <sup>31</sup> Rajasree, B. R., & Deo, M. C. (2020). Assessment of coastal vulnerability considering the future climate: A case study along the Central West Coast of India. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, 146(2), 05019005.

- 
- <sup>32</sup> Govindarajulu, D. (2020). Strengthening institutional and financial mechanisms for building urban resilience in India. *International Journal of Disaster Risk Reduction*, 47, 101549.
- <sup>33</sup> The Narmada Canal is one of the largest drinking water and irrigation distribution systems in Gujarat. The canal network extends across vast parts of the state, including areas like Kutch, Saurashtra, and the Kathiawar region. Through this network, water is distributed to meet both agricultural and municipal water requirements.
- <sup>34</sup> India Meteorological Department. (2020). *Climatic Data of Dwarka, Gujarat*. Ministry of Earth Sciences, Government of India. Retrieved from <https://mausam.imd.gov.in/> on 3<sup>rd</sup> July, 2025
- <sup>35</sup> Climate-Data.org. (2020). *Climate: Dwarka, Gujarat*. Retrieved from <https://en.climate-data.org> on 3<sup>rd</sup> July, 2025
- <sup>36</sup> Carlton, E.J., Et Al., (2014). Heavy Rainfall Events And Diarrhea Incidence: The Role Of Social And Environmental Factors. *Epidemiologic Reviews*. , 179 (3), 344–352, Doi:10.1093/Aje/Kwt279.
- <sup>37</sup> Jones, N., Et Al., (2020). Water, Sanitation And Hygiene Risk Factors For The Transmission Of Cholera In A Changing Climate: Using A Systematic Review To Develop A Causal Process Diagram. *J. Water Health*, 18 (2), 145–158, Doi:10.2166/Wh.2020.088.
- <sup>38</sup> Cutter, S., Osman-Elasha, B., Campbell, J., Cheong, S. M., McCormick, S., Pulwarty, R., . . . Ziervogel, G., (2012). Managing The Risks From Climate Extremes At The Local Level. In: Managing The Risks Of Extreme Events And Disasters To Advance Climate Change Adaptation. A Special Report Of Working Groups I And II Of The Intergovernmental Panel On Climate Change. [Field, C. B., V. Barros, T. F. Stocker, Q. Dahe, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G. K. Plattner, S. K. Allen, M. Tignor And P. M. Midgley (Eds.)]. Cambridge University Press, Cambridge, United Kingdom And New York, NY, USA, Pp. 291–338.
- <sup>39</sup> Caretta, M.A., A. Mukherji, M. Arfanuzzaman, R.A. Betts, A. Gelfan, Y. Hirabayashi, T.K. Lissner, J. Liu, E. Lopez Gunn, R. Morgan, S. Mwanga, And S. Supratid, (2022). Water. In: Climate Change 2022: Impacts, Adaptation And Vulnerability. Contribution Of Working Group II To The Sixth Assessment Report Of The Intergovernmental Panel On Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (Eds.)]. Cambridge University Press, Cambridge, UK And New York, NY, USA, Pp. 551–712, Doi:10.1017/9781009325844.006.
- <sup>40</sup> Ministry of Housing and Urban Affairs. (2008). National Urban Sanitation Policy-2008. New Delhi.
- <sup>41</sup> UNICEF. (2020). What do safely managed sanitation services mean for UNICEF programmes? WASH Discussion paper.
- <sup>42</sup> As Per SBM Guidelines “Public Toilets Are Toilets Which Are Provided For The Floating Population/ General Public In Places Such As Markets, Train Stations, Tourist Places, Near Office Complexes, Or Other Public Areas Where There Are A Considerable Number Of People Passing By. Pts Are To Be Accessible To One And All And Well-Connected To Important Areas And Pedestrian Junctions. Community Toilets Are The Shared Facilities Provided By And For A Group Of Residents Or An Entire Settlement. Ct Facilities Are Used Primarily In Low-Income And/Or Informal Settlements / Slums, Where Space And/Or Land Are Constraints In Providing Individual Household Toilet. These Are For A More Or Less A Fixed User Group.” (CPHEEO, 2018, P. 1)

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<sup>45</sup> Mäkinen, Kirsi, and Shahbaz Khan. 2010. "Policy Considerations for Greenhouse Gas Emissions from Freshwater Reservoirs." *Water Alternatives* 3(2):91–105.

<sup>46</sup> Dangi, Ashish & Narayanan, N. C. (forthcoming). Findings from ongoing doctoral research on *Urban water systems in a changing climate*. Ashank Desai Centre for Policy Studies (ADCPS), Indian Institute of Technology Bombay.

<sup>47</sup> Dickin, Sarah, Moustafa Bayoumi, Ricard Giné, Kim Andersson, and Alejandro Jiménez. (2020). Sustainable Sanitation and Gaps in Global Climate Policy and Financing. *Npj Clean Water* 3(1):1–7. doi: 10.1038/s41545-020-0072-8.

<sup>48</sup> Du, Mingxi, Qiuhan Zhu, Xiaoge Wang, Peng Li, Bin Yang, Huai Chen, Meng Wang, Xiaolu Zhou, and Changhui Peng. (2018). Estimates and Predictions of Methane Emissions from Wastewater in China from 2000 to 2020. *Earth's Future* 6(2):252–63. doi: 10.1002/2017EF000673.

<sup>49</sup> Khalkhali, Masoumeh, and Weiwei Mo. (2020). The Energy Implication of Climate Change on Urban Wastewater Systems. *Journal of Cleaner Production* 267:121905.

<sup>50</sup> Lu, Lu, Jeremy S. Guest, Catherine A. Peters, Xiuping Zhu, Greg H. Rau, and Zhiyong Jason Ren. (2018). Wastewater Treatment for Carbon Capture and Utilization. *Nature Sustainability* 1(12):750–58.

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

<sup>52</sup> Capital Receipts Are Comprised Of Reception Of Grants From Central And State Government Through Its Schemes. Capital Expenditures Are The Funds Used To Acquire Or Upgrade The Infrastructure That Are Typically Large Purchases. Revenue Expenditures Are The Recurring Operating Expenditure That Are Short Term And Essential To Run Daily Operations. Revenue Receipts Are The Recurring Receipts Of Income Generated From The Daily Service Provisions. Cost Recovery Is The Ratio Of The Total Annual Operating Revenues To The Total Annual Operating Expenses. Collection Efficiency Is The Ratio Of Current Revenues Collected In The Given Year To The Total Operating Revenues Billed During The Given Year. The Operating Ratio Is The Ratio Of Revenue Expenditure To Revenue Income, Which Helps Assess The Financial Sustainability. A Value Greater Than 1.0 Indicates That Revenue Income Exceeds Operating Expenses, Ensuring Financial Stability. The Revenue Deficit Is Calculated As The Difference Between The Revenue Expenditure And Revenue Income. The Fiscal Deficit Is Calculated As The Difference Between The Total Expenditure And Total Revenue Income's Is Annual Growth Rate Over A Specific Period.

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- <sup>53</sup>Source: Canacona Municipal Council. (2025)
- <sup>54</sup>GIDM . (2022). Rainfall Variability over Gujarat State, 2022. Gandhinagar: Gujarat Institute of Disaster Managment.
- <sup>55</sup>CGWB. (2024). Ground Water Level Bulletin, Aug 2024, Gujarat.
- <sup>56</sup> Chakrabarti, A. K. (2009). Urban Floods and Case Studies. Disaster & Development.
- <sup>57</sup>CEEW. (2021, May 18). 29 districts in Gujarat vulnerable to extreme climate events: CEEW. Ahmedabad, Gujarat, India. Retrieved from [ceew.in](http://ceew.in).
- <sup>58</sup>National Oceaninc and Atmospheric Administration. (n.d.). Storm Surge Overview. Retrieved from National Hurricane Center and Central Pacific Hurricane Center: <https://www.nhc.noaa.gov/surge/>
- <sup>59</sup> Berrin Tansel, K. Z. (2022). Effects of saltwater intrusion and sea level rise on aging and corrosion rates of iron pipes in water distribution and wastewater collection systems in coastal areas. Journal of Environmental Management.
- <sup>60</sup>Alvaro Javier Moyano Salcedo, M. C.-A.-C.-B. (2024). Assessing the effects of salinity on microbial communities and pollutant removal in urban wastewater treatment plants. Journal of Water Process Engineering, Volume 66.
- <sup>61</sup> Collector. (2024, April 07). District Disaster Management Plan - Devbhumi Dwarka. Khambhaliya : Collector's Office. Retrieved from [devbhumidwarka.nic: https://devbhumidwarka.nic.in/history/](https://devbhumidwarka.nic.in/history/)
- <sup>62</sup>Wang, Q.-Y. (2024). Untangling the environmental and tectonic drivers of the Noto earthquake swarm in Japan. Science Advances.
- <sup>63</sup>IPCC. (2019). Summary for Policy Makers, Special Report: Special Report on the Ocean and Cryosphere in a Changing Climate, Sixth Assessment Report. IPCC.
- <sup>65</sup>GSDMA. (2024). Gujarat State Disaster Management Plan. Gandhinagar: Governement of Gujarat.
- <sup>66</sup>Narayanan, N. C., Ray, I., Gopakumar, G., & Argade, P. (2018). Towards sustainable urban sanitation: a capacity-building approach to wastewater map

## 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  $\times$  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 Sustainable Development Goals (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)<sup>67</sup> provides district-level data on access to improved sanitation facilities, defined as the “population living in households that use an improved sanitation facility.” However, disaggregated data at the town or municipal level is not available. Collecting such data would require a detailed household-level survey.

2. **Operational Status of Community and Public Toilets:** Community and public toilets are intended to serve populations without access to individual sanitation facilities, as well as the floating population in public spaces. The operational status of these facilities—including aspects such as functionality, availability of water supply, and cleanliness—is a key requirement under the ODF+ certification framework. According to the Ministry of Housing and Urban Affairs (MoHUA) guidelines, Urban Local Bodies (ULBs) are mandated to conduct regular audits of these facilities. However, data on the coverage and adequacy of community and public toilets and operational status is not available with the ULB.
3. **Data on Storm Water Drainage:** The role of stormwater drainage systems in urban resilience is well recognized. However, the data available at the town level is limited to information on overall coverage and does not provide details on the typology of the drainage systems—such as whether they are open or closed, underground or surface-level, mapped or unmapped, or man-made or natural. A comprehensive understanding of these aspects would require detailed studies.
4. **Integrated role of Sewerage Network, Creeks, and Nallahs:** It is essential to determine whether natural and man-made water bodies—such as creeks and nallahs—are integrated into the town's wastewater and stormwater management systems, and to clarify their functional roles, whether they carry greywater, blackwater, stormwater, or a combination of these. Equally important is evaluating the degree of interconnection between these natural channels and engineered infrastructure. However, such information is not available through secondary data sources, and the 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 CH<sub>4</sub> and N<sub>2</sub>O emissions from faecal waste.
4. **Industrial and Tourism Sector Use Opaque:** Water and wastewater usage and discharge data from hotels, industries, and large commercial establishments are often not disaggregated or reported, masking the full impact of tourism and commercial activity on urban emissions.
5. **Stormwater and Greywater Flows Untracked:** Greywater is often discharged into storm drains without treatment or monitoring, leading to nutrient loading and emissions not captured in inventories.
6. **Sanitation GHG Methodology Limitations:** Emission estimates are based on global default emission factors and standard GWP values (IPCC 2013), which may not reflect local climatic, operational, or containment-specific variables.

## Resilience

- The ULB lacked a **digitized city map** suitable for GIS use, which makes referencing boundaries a time-consuming task.

# 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 16m<sup>3</sup>, 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

DMC Dwarka Municipal Council

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

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

| <b>Term</b>               | <b>Definition</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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) <sup>68</sup>                                                                                                                                                                   |
| 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, <a href="https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction">https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction</a> ). |
| 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) <sup>69</sup>                                                                                                                                                          |
| 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)                                                                                                   |

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<sup>67</sup> International Institute for Population Sciences. 2020 National Family Health Survey – 5 (2019-2020). District Fact Sheet. Ministry of Health and Family Welfare.

<sup>68</sup> 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>

<sup>69</sup> 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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