

Water-Sensitive Urban Planning Strategies for Greater Chennai Corporation

Aakhila Fathima A1 , Prof. Thasneem Kahar2

1Student, S4 MPLAN (M24MUP01), Department of Urban Planning, 2024-26

2Guide, Department of Urban Planning

Abstract - Greater Chennai Corporation (GCC) faces recurring urban flooding, drought cycles, and fragmented water infrastructure across its 426 km² jurisdiction serving over 7 million residents. This paper examines water-sensitive urban planning (WSUP) strategies for stormwater management in high-risk flood zones of GCC. Through primary surveys (n=50 households; n=22 stakeholders), secondary data analysis, literature review, and spatial analysis of 5-year and 10-year flood return period maps, this study identifies key flood vulnerability drivers including unscientific grey drain design, institutional fragmentation between GCC and CMWSSB, wetland loss, and rapid urbanization. Five integrated WSUD proposals are presented: a multi-scalar blue-green infrastructure framework, a citywide sponge park network, a restored tank-canal chain for macro-drainage revival, permeable neighbourhood retrofits, and wetland buffer protection as an ecological conservation corridor. Drawing from global precedents including Singapore's ABC Waters Programme, China's Sponge City strategy, and Lisbon's Drainage Master Plan, the proposals are adapted to Chennai's tropical monsoon context. Findings demonstrate that integrating nature-based solutions with existing grey infrastructure can reduce peak runoff by 30–70%, improve groundwater recharge, and build long-term flood-drought resilience for one of India's most flood-vulnerable megacities.

Key Words: *Water-Sensitive Urban Design, Stormwater Management, Urban Flooding, Greater Chennai Corporation, Blue-Green Infrastructure, Sponge City, Nature-Based Solutions, Flood Resilience, WSUD, Urban Planning*

1. INTRODUCTION

Water Sensitive Urban Planning (WSUP) is an approach to urban development that combines water management with urban design to create sustainable, resilient, and livable cities. WSUP aims to integrate urban water management by imitating natural water cycles, focusing on stormwater reuse, pollution reduction, and sustainable urban development. Unlike conventional flood risk management (FRM), which emphasizes risk mitigation through drainage systems and emergency responses, WSUP has the potential to reduce freshwater pollution, decrease flooding potential, protect the ecosystem, and improve urban life.

Greater Chennai Corporation (GCC) faces acute flood-drought cycles, rapid urbanization, and fragmented water infrastructure, making water-sensitive urban planning essential for resilience. WSUD addresses these challenges by integrating blue-green infrastructure with grey drains to manage stormwater holistically, unlike GCC's current reactive, grey-only approach. In 2015, Chennai experienced a catastrophic urban flooding event recording 1,049 millimetres of rainfall during the northeast monsoon significantly surpassing the seasonal average resulting in widespread devastation. This event exposed the inadequacy of existing stormwater infrastructure and catalysed demand for integrated water-sensitive planning.

Megacities face intense population growth and densification, resulting in higher percentages of impervious surfaces. This increases stormwater runoff and overwhelms existing drainage infrastructure, leading to more frequent and severe urban flooding. The intensity and frequency of extreme rainfall events are rising, and traditional drainage systems designed based on historical rainfall records are increasingly unable to cope with present and projected conditions, amplifying flood risk and community vulnerability.

2. BACKGROUND OF THE STUDY

2.1 Flood Vulnerability Drivers

GCC spans 426 km² with flat terrain, three rivers (Cooum, Adyar, Kosasthalaiyar), and extensive wetlands, all prone to monsoon extremes intensified by climate change (up to 90 mm/hr rainfall). Encroachments, wetland loss, and impervious surfaces amplify runoff, causing frequent inundation despite 1,144 km of drains laid (2021–2025, Rs. 5,000 crore). CAG audits highlight unscientific drain design without hydrological or topographical studies, poor linkages to waterbodies, and execution losses (Rs. 54 crore), failures made evident during the 2015 and 2021 floods.

2.2 Drought and Institutional Fragmentation

Chennai endures summer droughts with shrinking groundwater and polluted waterbodies from sewage-stormwater mixing. GCC's drains prevent natural recharge, offsetting rainwater harvesting while solid waste clogs systems. WSUD infiltration tools — permeable pavements and rain gardens — enable recharge from small rainfall events, enhancing long-term water security. GCC handles stormwater and solid waste management, but CMWSSB manages water supply and sewerage, creating gaps in planning, maintenance, and pollution control. The absence of a unified agency leads to operational inefficiencies. WSUD implementation requires integrated governance comparable to Singapore's Public Utilities Board (PUB) model.

2.3 Urbanization Pressures

GCC serves 7+ million residents across core and extended areas. Added urban zones lack integrated drainage, while population density blocks stormwater outlets. Land-use changes disconnect hydrology from ecology, demanding WSUD's multi-scale strategies spanning site, neighbourhood, and city scales. The average population density is 66.72 lakhs based on 2011 census, with the population fast approaching 1 crore. Land use is dominated by buildings (241.50 sq km, 56.7%), trees (72 sq km, 16%), and tanks (35.72 sq km, 8.9%).

3. STUDY AREA: GREATER CHENNAI CORPORATION

Chennai Corporation is located on the Coromandel Coast in the central-eastern coastal region of the Deccan Plateau in northern Tamil Nadu. The city stretches along the coast covering about 43 km of sandy beach and extending approximately 19 km inland, encompassing 426 sq km. Chennai has one of the lowest per capita green space values in India. The watershed area is divided into four major basins: Kosasthalaiyar (north), Cooum (central), Adyar (south), and Kovalam (southeast).

The terrain is very flat with contours ranging from 2 m to 10 m above mean sea level, with average altitude not exceeding 7 m and average slope of 0.7 m/km. Terrain slope varies from 1:5,000 to 1:10,000. The geology comprises mostly clay, sediment rocks, and sandstone. There are 5 major waterways maintained by the Water Resources Department and 44 canals maintained by GCC. The stormwater drain network extends 3,041 km, draining into major and minor drainage systems. Velachery and T-Nagar are the most highly flood-prone areas in GCC. The floods that occurred in the past were severe along the waterways of Adyar, Cooum, and Kosasthalaiyar Rivers, Buckingham Canal, and along the Pallikaranai Marshland.

Table -1: River Basins of Greater Chennai Corporation

Basin	Key Areas/Zones	Length/Catchment	Main Challenges
Kosasthalaiyar	Zones 1-3, 7 (full); 6, 8 (partial)	127.8 km ²	Flood management
Cooum	Kilpauk, Nungambakkam, Triplicane	65 km / 682 km ²	Pollution, urbanization
Adyar	Southern Chennai	42.5 km	Estuarine flow, pond surplus
Kovalam	Sholinganallur, Pallikaranai	Coastal peri-urban	Water scarcity, seawater intrusion

4. METHODOLOGY

The study followed a multi-stage methodology designed to satisfy five research objectives. The methodology framework proceeded from need identification through literature review, background study, and site selection to primary and secondary data collection, analysis, and finally proposal development.

Literature review covered journals, articles, and conference papers on WSUD, flood risk management, and urban water governance from databases including Scopus and Web of Science. Primary survey covered 50 household residents and 22 stakeholders from GCC departments including planning, hydrology, disaster management, and stormwater drainage. Secondary data included demography, land use, topography, geology, water environment, flooding zones, waterlogging extents, socio-economic status, and built-up density. Spatial analysis using GIS-based flood inundation mapping for 5-year and 10-year return periods identified high-risk zones. The study culminated in five proposal frameworks informed by both empirical data and international best practices.

5. LITERATURE REVIEW

Eight key studies inform the WSUD framework proposed for GCC. Rashednia et al. (2025, Water) demonstrate that site-scale WSUD approaches can retain 30–100% of stormwater and reduce potable water demand by 18–100% through bio-retention systems, grassed swales, rain gardens, filter strips, and infiltration trenches. Khalaji et al. (2025, Water) employ stakeholder analysis finding that effective WSUD formulation must consider stakeholder dynamics, social impacts, and broader economic benefits, not just technical performance.

Meng and Kenway (Water e-journal, Australian Water Association) demonstrate that water mass balance frameworks provide urban planners a holistic technique to evaluate WSUD impacts, showing that urbanization substantially increases stormwater runoff and targeted WSUD interventions can restore natural water cycling. Palazzo (Journal of Urban Design, 2019) argues for a paradigm shift from water-sensitive to 'floodable' urbanism, proposing adaptive design incorporating multifunctionality, transdisciplinarity, evidence-based design, co-management, and decentralised systems. Wu et al. (Water Research, Elsevier) demonstrate a catchment-scale WSUD planning framework using SWMM modelling linking WSUD storage capacity to measurable flood reduction outcomes.

The systematic review by Tasnia and Grove (Land, 2025) of 100+ publications maps synergies between WSUD and flood risk management, finding WSUD excels in stormwater retention but requires FRM integration for extreme events. Kumar et al. (Water, 2023) propose a contextualised framework for water-sensitive urban planning tailored to rapidly urbanising Global South cities, emphasising equity, hybrid grey-green infrastructure, and decentralised governance. Sharma et al. (Water, 2016) using a comprehensive mixed-methods approach confirm that WSUD systems contribute simultaneously to stormwater reuse, water demand reduction, pollution abatement, urban cooling, amenity improvement, and flood mitigation.

6. FLOOD HAZARD ANALYSIS AND PRIMARY SURVEY FINDINGS

6.1 Flood History and Causes

The northeast monsoon of October 2015 produced 1,113.80 mm of rainfall — the wettest month in 100 years for Chennai. The maximum single-day rainfall of 319.60 mm on 02.12.2015 remains the highest on record. GCC monitors 87 flood-prone areas, of which 26 are classified high-risk. Key causes of flooding include: (1) plain terrain with average altitude of 7 m; (2) sandbar formation at river mouths slowing discharge; (3) drain clogging from solid waste; (4) inadequate stormwater drain design capacity; (5) lack of connectivity between stormwater drainages and macro drainage; (6) encroachments; (7) tidal influence; and (8) excess surplus water exceeding the designed carrying capacity of tanks and water bodies upstream.

6.2 Spatial Analysis: 5-Year and 10-Year Return Periods

GIS analysis of flood return period maps reveals dense hazard clusters in northern and central Chennai (Kodungaiyur, Vyasarpadi, Otteri), southern zones (Adyar, Velachery, Pallikaranai), and coastal belts from Ennore southward. The 5-year return period map displays broader, more fragmented red coverage indicating frequent localised flooding. The 10-year map shows more contiguous, intensified clusters along coast and river basins, consistent with hydraulic models showing rainfall volumes exceeding infrastructure capacity. Core persistent hotspots include coastal lowlands, Adyar-Coom basins, and southern marshes.

Table -2: Flood Hazard Priority Zones of Greater Chennai Corporation

Zone/Region	Specific Areas/Wards	Key Vulnerabilities
North Chennai	Tondiarpet, Ennore, Royapuram, Manali, Madhavaram, Kodungaiyur	Industrial runoff, Buckingham Canal encroachments, low-lying coastal; frequent stagnation
Central Chennai	Perambur, Pulianthope, Chetpet, Kilpauk, Egmore	Cooum River pollution/blockages, high density (30k+/sq km), waste-clogged nullahs (Otteri)
South Chennai	Adyar, Velachery, Palavaram, Perungudi, Tambaram, Sholinganallur, Medavakkam	Adyar River/Pallikaranai marsh siltation, IT corridor imperviousness; post-2015 hotspots

6.3 Primary Survey Findings

Household survey (n=50 residents): Nearly all respondents (99%) experienced flooding multiple times in the past 5 years. Water stagnation typically lasted more than 24 hours, with severe cases lasting 5–20 days. Key impacts included property damage (57.5% of households), income loss of 25–40 workdays (95%), and health issues from waterborne diseases (37.5%). About 40% adopted rainwater harvesting. Support for nature-based solutions such as bioswales stood at 75%, though 60% expressed concerns over maintenance. GCC maintenance awareness rated only 2.1 out of 5.

Stakeholder survey (n=22 GCC officials, planners, NGOs): 85% of the 3,000 km network was found unmapped. Land-use integration of WSUD mandates was present in only 20% of areas. Wetland loss contribution from encroachment was estimated at 60%. Departmental coordination rated 2.5 out of 5. WSUD pilots such as bioretention in Perungudi demonstrated 30–40% runoff reduction but face scalability challenges due to costs and urban density. New drains of 1,144 km were built at Rs. 5,000 crore, yet sponge parks received Rs. 88 crore in NBS funding.

7. INTERNATIONAL CASE STUDIES

7.1 Singapore's ABC Waters Programme

Singapore's Active, Beautiful, Clean (ABC) Waters Programme, launched in 2006, applies water-sensitive design to infrastructure achieving 33% peak flow reduction in storms. The flagship Bishan-Ang Mo Kio Park (2012) naturalized a concrete canal into wetlands, rain gardens, and bioswales along a floodplain. By 2018, 75 projects had been certified. Singapore meets its 430 million gallons daily demand through four national taps with integrated nature-based solutions, including local catchments (40% of land), NEWater (recycled greywater), and desalinated water. Key programmes include the LUSH Programme (2009) offering incentives for green roofs/walls, and the Biophilic Town Framework (2013).

7.2 China's Sponge City Strategy

China's sponge city concept adopts a hierarchical framework rooted in nature-based stormwater management, emphasising absorption, retention, and adaptive reuse of rainwater to mimic natural hydrological cycles. Three core principles guide the 2015 National Guideline: ecology-first, planning-led, and multi-stakeholder. The '4R' processes — infiltrate, retain, store, purify — operationalise this framework alongside drainage and reuse. China targets 70–90% annual rainfall capture by 2030 via pilots in 30+ cities. For GCC, adaptation includes permeable roads, rainwater harvesting in apartments, and a phased target of 40% capture by 2028 in high-risk zones like Adyar.

7.3 Lisbon's Drainage Master Plan

Lisbon's Drainage Master Plan (2016–2030, €170M+) pairs tunnels with upstream nature-based solutions including retention basins and infiltration trenches. The Alto da Ajuda retention basin (2,150 m³) handles 10-year storms. Since 2015, Lisbon has increased green space by 13% and planted 55,000+ street trees. Ribeira das Naus waterfront rehabilitation with treatment wetlands demonstrates integration of ecological restoration with flood control. The PLERAL 2020 recycled water network targets 1.6 million m³/year of non-potable water supply, saving 4–5 million m³ of potable water annually.

Table -3: Analysis of International Best Practices for GCC Adaptation

Framework	Core Tools	GCC Adaptation
Singapore ABC Waters	Bioswales, wetlands, rain gardens, certified design	Restore Adyar/Cooum canal edges; wetland certification in Pallikaranai zone
China Sponge City (4R)	Infiltrate/retain/store/purify rainwater	Permeable roads, rainwater harvesting; target 40% capture by 2028 in high-risk zones
Lisbon Drainage Plan	Retention basins, NbS upstream, monitoring sensors	Community-led pilots; annual reviews tied to GCC desilting management cycle
WSPD Colombo	Catchment planning, blue-green infrastructure	Restore Adyar/CKB rivers; wetland zoning in lowlands
DAnCE4Water Parma	SWMM scenarios, green roofs/porous pavements	Model 30% BMP coverage in 200 wards; quantify against monsoons

8. SWOT ANALYSIS

Table -4: SWOT Analysis for WSUD Implementation in Greater Chennai Corporation

Factor	Key Points
Strengths	Existing stormwater network (3,041 km drains, 44 canals); pilots like Perungudi bioretention (30-40% runoff reduction); natural assets including 210 waterbodies and 4 river basins; stakeholder support post-2015 floods
Weaknesses	Reactive grey-only infrastructure undersized for 90 mm/hr rains; institutional fragmentation between GCC and CMWSSB; poor maintenance due to waste blockages; data gaps with no full hydrological modelling; limited coverage in added areas
Opportunities	Integrate WSUD into CMDA master plans (rain gardens, permeable pavements); ADB and Tamil Nadu Resilience funding for pilots in high-risk wards; multi-benefits including recharge, biodiversity, and equity via community NBS
Threats	Climate-intensified monsoons (1,049 mm/2015) and sea-level rise in coastal Chennai; rapid urbanization (7M population, 56.7% built-up) amplifying runoff; enforcement gaps and economic barriers to scaling green infrastructure

9. PROPOSALS: WATER-SENSITIVE URBAN DESIGN STRATEGIES FOR GCC

9.1 Proposal 1: Multi-Scalar WSUD Framework for Flood-Prone GCC Neighbourhoods

The multi-scalar WSUD framework combines blue-green infrastructure with existing grey stormwater drains so the system can both convey and store excess runoff. Target areas include Adyar, Kodungaiyur, Perungudi, and similar low-lying or water-sensitive wards in Chennai. The expected runoff reduction is 30–70% depending on site conditions, design intensity, and maintenance quality — treated as a planning target, not a guaranteed citywide outcome.

The framework operates across four spatial levels:

Table -5: Multi-Scalar WSUD Intervention Framework

Scale	Intervention	Function
Household / Plot	Rainwater harvesting, soak pits, permeable driveways	Capture runoff near the source and support recharge
Street / Corridor	Bioswales, tree trenches, permeable shoulders	Slow flow, filter pollutants, and reduce runoff volume
Ward / Neighbourhood	Bioretention basins, detention ponds, restored open spaces	Temporarily store water and reduce downstream flooding
Basin / Catchment	Wetland restoration, floodplain protection, linked drainage routes	Restore natural retention capacity and improve flood buffering

Implementation should be phased and decentralised, with GCC leading coordination across stormwater, planning, and ward-level operations. A pilot-first model starting with high-risk micro-catchments, followed by performance monitoring and expansion, is the most practical approach. Community participation is essential because Chennai's resilience experience has emphasised consultations, preparedness, and behavioural change alongside infrastructure.

9.2 Proposal 2: Sponge Park – Citywide Decentralised Retention Strategy

A sponge park is a public open space reshaped to temporarily store runoff, filter stormwater, recharge groundwater, and remain usable as a park during dry periods. For GCC, sponge parks should form a connected network of flood-buffer landscapes across vulnerable wards rather than isolated sites. Chennai faces recurring urban flooding because heavy rainfall meets impervious surfaces and reduced natural storage in wetlands, tanks, and open land. Suitable locations include underused parks, OSR lands, school grounds, vacant government plots, and low-lying community grounds where ponding already occurs. Strategic areas include Adyar, Perungudi, Thoraipakkam, Padi, Vyasarpadi, Korattur, and Madhavaram.

Functional design includes a shallow depression or ponding basin at the lowest point, vegetated slopes, infiltration trenches, and overflow routes connected safely to nearby drains. The sponge park network should be developed at three levels: neighbourhood (intercept local runoff from streets and rooftops), ward (detention nodes), and catchment (linked to canals, drains, tanks, and wetlands). Technical criteria for site selection include elevation, soil permeability, drainage connectivity, existing park size, flood history, and community use patterns.

9.3 Proposal 3: Restored Tank-Canal Chain — Blue-Green Macro-Drainage Revival

The proposal restores the original function of Chennai's tank-and-canal network so stormwater moves through a linked storage system instead of depending only on overloaded drain lines. Chennai historically had approximately 320 tanks/lakes in the metropolitan area, many of which still exist as flood accommodators despite weakened connectivity. The chain should work as a sequence: runoff enters local drains, moves into feeder channels, fills tanks, spills into surplus channels when needed, and finally reaches rivers or the sea through designated outfalls.

Table -6: Tank-Canal Chain Network Elements and Design Interventions

Network Element	Role in the System
Tanks and lakes	Store runoff temporarily and reduce flood peaks
Feeder channels	Bring water into tanks and move surplus onward
Surplus canals	Carry excess water safely to downstream systems or the sea
Wetlands and marsh edges	Detain, filter, and slow runoff
Urban drains	Collect local runoff and connect it to the macro network

Priority pilot zones include the Adyar basin, the Cooum corridor, north Chennai tank groups, and the Pallikaranai-linked southern drainage area. Design interventions include tank desilting, removal of blockages, rehabilitation of feeder

channels, repair of bunds and sluices, regrading of surplus courses, and restoration of missing links. The restored chain can reduce flood peaks, extend detention time, improve groundwater recharge, and revive ecological corridors through the city.

9.4 Proposal 4: Permeable Neighbourhood Retrofits

Permeable neighbourhood retrofits mean replacing selected hard paving with materials that allow rainwater to soak into the ground rather than running immediately into drains. This is especially useful in older, denser neighbourhoods where widening stormwater drains is difficult due to dense development and narrow streets. Suitable locations include footpaths, parking bays, school yards, temple forecourts, internal lanes, public plazas, and low-traffic residential streets that repeatedly flood. Priority zones include OMR neighbourhoods like Perungudi and Sholinganallur, older dense central areas, and low-lying localities near channels or tanks.

A phased rollout is the most practical approach. Phase 1 targets public institutions (schools, corporation offices, bus stops, parking lots). Phase 2 extends to road shoulders, footpaths, and selected residential lanes in flood-prone wards. Phase 3 focuses on larger neighbourhood blocks and redevelopment areas. Design includes pavers, porous concrete, or permeable blocks over a graded aggregate base with edge restraints, sub-base storage, underdrains where needed, and sediment traps. Maintenance requires vacuum sweeping, desilting of edge traps, and inspection after every major rain event.

9.5 Proposal 5: Wetland Buffer Protection — Flood-Resilience and Ecological Conservation Corridor

Wetland buffer protection creates a legally and ecologically protected transition zone around marshes, tanks, floodplain edges, and connected lowlands so the wetland can absorb floodwater without encroachment pressure. In Chennai, this is especially critical around Pallikaranai and adjoining southern lowlands, where wetland shrinkage has directly increased flood risk, particularly in the OMR-Perungudi-Velachery belt.

The buffer should be designed as a layered zone: inner core wetland (undisturbed), middle reed beds and seasonal retention edges with shallow floodable areas, and outer controlled green open space with walkways and low-impact land uses. Priority locations include Pallikaranai Marsh, Perungudi, Kandanchavadi, Velachery, Medavakkam, and Thoraipakkam. Design interventions include native wetland vegetation, sediment traps, shallow depressions, bioswales, raised boardwalks, and floodable public edges. This proposal helps Chennai in three ways: it reduces flood peaks, protects biodiversity, and preserves groundwater-recharge landscapes.

Table -7: Wetland Buffer Structure and Functions

Buffer Element	Function
Core wetland	Primary flood storage and biodiversity habitat
Reed bed fringe	Filters runoff and slows water movement
Retention edge	Temporarily stores excess stormwater during monsoon peaks
Controlled floodable landscape	Accepts overflow safely without damage
Outer transition zone	Limits hard development and reduces edge pressure

10. VISION, MISSION, AND GOALS

Vision: Transform GCC into a water-sensitive city mimicking natural cycles, reducing runoff and pollution, restoring wetlands and canals, and achieving sustainable urban development with equitable, multi-benefit outcomes including recharge and biodiversity.

Mission: Integrate WSUP principles into GCC's master and local plans to mitigate pluvial and canal flooding via blue-green infrastructure, enhancing resilience in flood-drought cycles for 7 million residents.

Goals: (1) Integrate WSUP principles into GCC's planning framework; (2) Mitigate pluvial and canal flooding through blue-green infrastructure; (3) Improve resilience against flood and drought conditions; (4) Restore and strengthen wetlands, canals, and connected drainage systems; (5) Reduce runoff, pollution, and environmental stress in urban areas; (6) Enhance recharge, biodiversity, and ecological balance; (7) Support equitable and sustainable urban development in Greater Chennai Corporation.

11. CONCLUSIONS

This study demonstrates that Greater Chennai Corporation's recurring flood-drought cycle cannot be resolved through grey infrastructure alone. The five WSUD proposals — multi-scalar blue-green framework, sponge park network, restored tank-canal chain, permeable neighbourhood retrofits, and wetland buffer protection — form a complementary system that addresses Chennai's hydrology at multiple scales.

The proposals are grounded in GCC's existing institutional capacities and align with global precedents from Singapore, China, and Portugal that have demonstrated measurable flood mitigation outcomes. A phased pilot-first approach, beginning with high-risk micro-catchments in Adyar, Kodungaiyur, and Perungudi, provides a practical pathway to scale. Long-term success depends on integrated governance between GCC and CMWSSB, community participation, clear maintenance responsibilities, and embedding WSUD into CMDA master plan frameworks. If designed and maintained well, these interventions can reduce peak runoff by 30–70%, support groundwater recharge, protect biodiversity, and improve quality of urban life for Chennai's most flood-vulnerable residents — contributing to the city's transition toward genuine water sensitivity.

Limitations: The analysis relies primarily on secondary data and limited primary surveys; detailed hydrological or hydraulic modelling and micro-level engineering design are beyond the scope of this study. Economic analysis is limited to qualitative or order-of-magnitude considerations.

ACKNOWLEDGEMENT

The author gratefully acknowledges the guidance of Prof. Thasneem Kahar throughout this research. Thanks are due to the officials of Greater Chennai Corporation, CMWSSB, and the 22 stakeholder respondents and 50 household survey participants who contributed to the primary data. This study was conducted as part of the M.Plan final semester thesis project (S4 MPLAN; M24MUP01), 2024-26.

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