CHENNAI'S WATER SYSTEM: BUILDING AND IMPROVING RESILIENCE

Discovery Area Report

Image: Kapaleeshwarar Temple Tank Cynthia van Elk | Water as Leverage

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List of Abbreviations

ADB	Asian Development Bank
BCM	Billion Cubic Meters
BMRDA	Bengaluru Metropolitan Regional Development Authority
CAG	Comptroller and Auditor General
CPHEEO	Central Public Health and Environmental Engineering Organisation
CMA	Chennai Metropolitan Area
CMCDM	Chennai Mega City Development Mission
CMWSSB	Chennai Water Supply and Sewerage Board
CMDA	Chennai Metropolitan Development Authority
CRRT	Chennai Rivers Restoration Trust
Cr	Crore
CSR	Corporate Social Responsibility
DA	Discovery Area
DEWATS	Decentralised Wastewater Treatment Systems
DPR	Detailed Project Report
DTCP	Directorate of Town and Country Planning
EIA	Environmental Impact Assessment
EC	Environmental Clearance
EFI	Environmentalist Foundation of India
GCC	Greater Chennai Corporation
HPEC	High Powered Expert Committee
HUD	Housing and Urban Development Department
ISWDP	Integrated Storm Water Drain Project
IT	Information Technology
JNNURM	Jawaharlal Nehru National Urban Renewable Mission
KL	Kilolitre
kfw	Kreditanstalt für Wiederaufbau (German Development Bank)
Lpcd	Litres per capita per day
MoUD	Ministry of Urban Development
MLD	Million Litres per Day
MSME	Micro, Small and Medium Enterprises
NRW	Non-Revenue Water
O&M	Operation and Maintenance
PWD	Public Works Department
RWH	Rain Water Harvesting
RWAs	Resident Welfare Associations
SBR	Sequencing Batch Reactor
STP	Sewage Treatment Plant
SWD	Storm Water Drains
SWM	Solid Waste Management
SMERA	Small and Medium Enterprises Ratings Agency Limited
SuWSM	Sustainable Water Securities Mission
TTRO	Tertiary Treatment Reverse Osmosis
TNSUDP	Tamil Nadu Sustainable Urban Development Project
TNPCB	Tamil Nadu Pollution Control Board
TNSCB	Tamil Nadu Slum Clearance Board
TNSCCC	Tamil Nadu State Climate Change Cell
ULB	Urban Local Body
100RC	100 Resilient Cities

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Executive Summary

Chennai joined the 100 Resilient Cities (100RC) network in 2014 with the aim of building resilience to short term shocks and long term stresses related to urbanisation and climate change. At the end of Phase 1 of the programme, the Resilient Chennai team produced a Preliminary Resilient Assessment (PRA) which highlighted 6 priority or discovery areas (DA) for deeper engagement which includes a section titled 'building a better understanding of Chennai's water system to ensure its sustainability'. This document presents a succinct account of key challenges (shocks and stresses) that affect six different but related thematic areas – or 'diagnostic questions' that are critical to increasing Chennai's resilience with respect to its water resources. A summary of each question, associated challenges and potential solutions or interventions are presented below.

	Diagnostic Question (DQ)	**Challenges and Interventions**
DISCOVERY AREA (DA): WATER SYSTEMS	DQ 1: How do we promote efficient and responsible water management among end users? (*primary focus on households*)	Challenges - Effective water pricing: no metering, no political benefits for metering or effective pricing, high cost of installing meters; - Alternatives such as RWH systems: limited monitoring of existing systems, design issues; - Groundwater: regulatory enforcement does not incentivize conservation, over exploitation; - Waste water recycling: limited sewage collection, social acceptance barrier to reusing treated waste water, costs of recycling; - Limited awareness on importance of water management
		Interventions - Electromagnetic flow meters for monitoring water supply; - Review and monitoring of RWH systems to understand their efficiency; - Sensors for monitoring groundwater quality and levels; - Policy mandate requiring water meters in domestic buildings; - Policy mandate requiring recycled grey water use across CMA; - Awareness campaign advocating recycled grey water for domestic use; - Integrated water and waste water strategy for the CMA that includes water supply and demand management, responsibilities of different agencies and water conservation; - Decentralised waste water management systems at a ward/zonal level for localised treated waste water usage.
	DQ 2: How can we foster greater dependency on waste water recycling? How might decentralized waste water treatment systems help? (*primary focus on commercial and industrial users)*	Challenges - Effective water pricing: price of alternatives (fresh water is cheaper); - Space and quality constraints: different industries/ commercial users require different quality of water; - High costs associated with recycling and retrofitting infrastructure; - Insufficient data on extent of recycling, what works, what does not and for whom; - Limited awareness on recycling options.
		Interventions - New sewage treatment plants to increase capacity; - Policy mandate requiring recycled grey water usage across CMA industries;

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	Diagnostic Question (DQ)	Challenges and Interventions
		- Decentralised waste water management systems at a ward/zonal level for localised treated waste water usage; - Integrated water and waste water strategy for the CMA that includes water supply and demand management, responsibilities of different agencies and water conservation; - Data repository on water recycling best practices in commercial, institutional, and industrial settings.
	DQ 3: How do we redesign our storm water drain system to maximise water storage and improve water management practices?	Challenges - Appropriate design: implementing design that can serve multiple functions of draining excess water and recharging water bodies; - Suitability of design for Chennai's geography; - Budgetary: limited budget allocation for O&M and desilting.
		Interventions - Multi-purpose and green storm water drains system to enhance and replicate the natural drainage system and manage rainfall close to where it falls. - Common database on underground infrastructure that includes water, sanitation, communication, storm water drains, electricity and transport. It will contain data on location, function and inter-dependencies of these infrastructure to facilitate integrated planning; - Embedded and green infrastructure such as, porous paving and rainwater harvesting in driveways, to recharge groundwater and lower flooding vulnerability.
	DQ 4: How can we encourage more coordinated and collective efforts by multiple agencies for better water system management? *[taking the example of lake restoration efforts undertaken by a number of public, private and civic agencies]*	Challenges - Identifying and documenting lake restoration efforts: several definitions of restoration, no mutual learning; - Increasing general interaction between government, civic and private agencies: interaction between departments is restricted to projects; - Multiple water bodies owners: inter-agency tension; - Uniform interaction throughout entire project cycle: project objectives do not specify coordination at implementation stage; - Lack of communication to linesmen implementing on the ground;
		Interventions - Integrated river eco-restoration efforts that go beyond beautification to address waste water management, encroachments, SWM and flood management; - Developing comprehensive lake restoration guidelines and blueprints; - Developing a dash board on status of restoration efforts for public viewing; - Restoration and protection of water bodies and waterways within CMA through strict regulatory measures; - Common database on underground infrastructure that includes water, sanitation, communication, storm water drains, electricity and transport. It will contain data on location, function and inter-dependencies of these infrastructure to facilitate integrated planning;
	DQ 5: How can we better plan for and address water related shocks (drought, floods), and stresses	Challenges - Lack of Integrated flood/drought management: reactive measures, mismanagement leading to alternative cycles of

	Diagnostic Question (DQ)	Challenges and Interventions
	(climate change, sea level rise, encroachments and poor solid waste management)?	flood and drought - Chronic stresses aggravating flood risk: encroachment and solid waste - Inadequate outreach activities by government on climate change: perceived as distant threat - Mainstreaming climate risks in development projects and in disaster management plans
		Interventions - Integrated eco-restoration of rivers, going beyond beautification to address waste water management, encroachments, SWM and flood management. - Multi-hazard GIS based mapping tool to identify vulnerable areas/zones; - Climate change adaptation strategy: awareness campaign on areas particularly vulnerable to climate risks; - Flood monitoring and forecasting tool at a ward/zonal level.
	DQ 6: As the city grows into its peri-urban areas, how do we restore, protect and reintegrate the water bodies in our water catchment areas (Kancheepuram and Tiruvallur) in a sustainable manner?	Challenges - Risk of encroaching/damaging existing water bodies and green spaces: development pressure - Enforcing land-use regulations (DCR): who? Centralized or decentralized? - What institutional arrangement would be ideal for more coordinated management of land and water resources in expanded CMA? - How do we make sure that CMA expansion does not end up meeting the needs of the city at the cost of the periphery?
		Interventions - Restoration and protection of water bodies and waterways within CMA through strict regulatory measures; - Integrated river eco-restoration that goes beyond beautification to address waste water management, encroachments, SWM and flood management; - Integrated water and waste water strategy for the CMA that includes water supply and demand management, responsibilities of different agencies and water conservation; - Embedded and green infrastructure such as, porous paving and rainwater harvesting in driveways, to recharge groundwater and lower flooding vulnerability.

As a city, Chennai currently addresses water reactively, by building storm water drains to quickly transport water away, or by meeting water demand increases by augmenting supply. Water management requires a more balanced approach that focuses and plans for demand management as much as supply side interventions in an integrated manner. City water experts and citizens collectively believe that the way forward is to protect and conserve water bodies rather than augmenting supply. A survey of residents across the city reveals that they (51% of total respondents) are willing to pay a higher price for water and support (71% of total respondents) government metering policy. Further, contrary to popular opinion, 58% of total respondents are willing to pay for recycled water and a conclusive 79% will likely support government policy on recycling for domestic purposes. (Please see Appendix 2 for comprehensive survey results). A working group meeting with varied stakeholders also revealed similar views (see appendix 1 for details). Simultaneously, Chennai's water experts recognise the inter-related issues of encroachment, solid waste management, climate risks and waste water management and emphasize the need for integrated planning in the water sector.

A reflection of Chennai's key challenges, makes it clear that we must build more resilience in our water system by thinking about water holistically. **Building resilience, therefore, should be about a) bouncing back, if not bouncing forward, on occasions of disruptions and, more importantly, b) building linkages and integrated efforts on a continual basis so Chennai's water problems can be addressed more holistically and in the longer term.**

CHAPTER 1: DISCOVERY AREA – BACKGROUND

Chennai joined the 100RC network in 2014 with the aim of building resilience to short term shocks and long term stresses related to urbanisation and climate change. At the end of Phase I of the programme, the Resilient Chennai team brought out a Preliminary Resilient Assessment (PRA) that was based on engagement with a wide range of stakeholders including government leaders, civil society, academia and corporate. The PRA provided an overview of the city's urban context and challenges and highlighted five priority or discovery areas (DAs) for deeper engagement which includes one titled 'building a better understanding of **Chennai's water system** to ensure its sustainability'. The PRA also defined a set of key questions (Diagnostic Questions/DQs) that seemed critical for building resilience in our water system. These questions or thematic areas range from improving demand management and encouraging waste water recycling to leveraging existing infrastructure for multiple benefits and improving institutional coordination.

In phase II, these DQs form the basis for further examining the current state of affairs and key problems associated with water. Drawing on PRA work, ongoing stakeholder engagement, and secondary research, this document presents a succinct account of existing challenges and suggests relevant interventions and strategies that can help address current water system challenges.

Chennai's water system is complex. It traverses between natural and socio-technical environments with limited and fragmented information, and comprises of multiple actors with often overlapping jurisdiction. The current institutional setup for managing Chennai's water bodies is riddled with actors across a wide variety of state, local and para-state bodies such as the Greater Chennai Corporation, the Public Works Department and Chennai Metropolitan Water Supply and Sewerage Board. Siloed thinking and insufficient financial and human capital hamper information collection, exchange and analysis across these different actors. For example, a variety of lake restoration efforts are carried by multiple agencies that do not interact. This limits a common understanding across all actors of the city's water system, its priorities, challenges and interactions with other urban processes such as solid waste management and housing. It also restricts the understanding of likely collective impact of efforts on the water basin as a whole.

Further, the system is at risk from climate change which is likely to manifest through extreme precipitation events, sea level rise and increasing temperatures, which individually and collectively exacerbate existing water system challenges. This coupled with institutional and data fragmentation and inadequate resources limits key stakeholders' ability to collectively come up with robust and high impact interventions that address the water system as whole.

Therefore, this Discovery Area Report on Chennai's water system aims to be the catalyst that spurs change by building a better understanding of the various physical, institutional and socioeconomic components of the system and their interactions, and by suggesting critical interventions that will be important to ensuring the viability of the city's water resources.

CHAPTER 2: DIAGNOSTIC QUESTIONS

A. Key questions that shape Chennai water system resilience

In this chapter we present the key questions or thematic areas that have shaped this report's water system discussion. As mentioned, these questions were identified through research and wide-ranging consultations with stakeholders during the first phase of Resilient Chennai's work. In this chapter, we discuss existing challenges and present possible interventions for each of these questions.

	Diagnostic Questions (DQ)
DQ1	How do we promote efficient and responsible water management practices among end-users?
DQ2	How can we foster greater dependency on waste water recycling? How may decentralized waste water treatment systems help?
DQ3	How do we redesign storm water drain systems to maximise water storage and improve water management practices?
DQ4	How can we encourage more coordinated and collective efforts by multiple agencies for better water system management?
DQ5	How can we better plan for and address water related shocks (drought, floods), and stresses (climate change, sea level rise, encroachments and poor solid waste management)?
DQ6	As the city grows into its peri-urban areas, how do we restore, protect and reintegrate the water bodies in our water catchment areas (Kancheepuram and Tiruvallur) in a sustainable manner?

B. Analysis of diagnostic questions

DQ 1: How do we promote efficient and responsible water management practices among end users?

Existing debate on water supply vs. demand

Like in most other Indian cities, piped water supply in Chennai is intermittent and available only for a few hours a day (or on alternate days) irrespective of amounts of rainfall. The Chennai Metro Water Supply and Sewage Board (CMWSSB) has the capacity to supply 830 million litres a day (MLD) through its piped network. However, the actual amount supplied is lower. In February 2018, it supplied 650 MLD. This is not only lower than capacity but also far lower than its supply benchmark of 135 litres per capita per day (lpcd) (Graft et al., 2018). Because supply is intermittent, domestic, industrial and commercial users in Chennai rely on a combination of sources to meet their water needs: a) piped and "mobile" (tankers) supply from CMWSSB, b) self-provision through privately dug bore wells and c) a private market consisting of water tankers and packaged water (ibid).

This dependence on multiple formal and informal sources suggests a mismatch between water supply and demand, where users are often forced to manage their own supply, particularly during drought periods. A number of experts believe this mismatch could be attributed to water mismanagement rather than natural shortages (Roy et al., 2018a). However, it is clear that integrating supply and demand driven measures are important for sustainable long-term water management (UNEP, 1995; Varis and Somlyody, 1997; Gleick, 2000). Supply side measures include developing new sources while demand approaches comprise of price and non-price mechanisms such as water pricing, reducing leakage, awareness campaigns, technological interventions and promoting the use of alternate water sources (Araral et al., 2013; Sharma and Vairavamoorthy, 2009).

The emphasis on demand management is apparent in India's National Water Policy, 2012 which advocates for a demand driven approach to water efficiency and states that 'recycling and reuse of water should be the general norm and water pricing should ensure its efficient use, and reward conservation' (MoWR, 2012, p.6). However, despite this policy push, little is actually being done at the ground level to manage and reduce demand due to several challenges. Some of these relate to limited knowledge and awareness among end users around a) the need to conserve water and b) water efficient technology and household appliances. Other challenges involve institutional mechanisms including water pricing and regulation, as discussed below:

Challenges

A. water pricing

Perhaps the biggest challenge associated with urban water demand management in India is a lack of an optimal pricing policy that incentivises water conservation. Water prices are typically in the form of flat rates that are levied at fixed intervals and do not enable cost recovery (HPEC, 2011; ADB, 2007). This is in contrast to effective pricing policies which are based on consumption and strike the right balance between cost recovery, economic efficiency and conservation. These are found to be the most direct way to promote demand management (Whittington, 2003; Rogers et al., 2002) but are difficult to implement, especially in India, because water pricing tends to be a political decision (CMWSSB interview 2018). As McKenzie and Ray (2009; p.455) suggest, any small change in price requires public approval and political benefits from the price rise are low. Therefore, reforming water prices requires finding a way to raise the political benefits of reform efforts, or of increasing the political costs of not reforming. Also, the basis for any consumption-based tariffs is consumption measurement, which is difficult in most Indian cities because end users mostly do not have water meters. In Chennai, the extent of water metering is less than 10% (ADB, 2007). A lack of water meters also has implications for another demand management technique: reducing non-revenue water (*see box 1).*

Box 1: Water Meters and Non-Revenue Water (NRW)

Apart from enabling consumption-based water pricing, water metering allows cities to avoid or curtail losses from NRW. NRW refers to the physical loss of water through bad piping infrastructure, commercial loss through theft and illegal water usage and unbilled authorized user loss (Gupta et al., 2016). NRW is considered one of the biggest challenges associated with urban water demand management in developing countries (Araral and Wang, 2013). On average, it accounts for around 20% of the water produced in Chennai (ADB, 2007). High NRW has consequences, notably for water quality and energy costs because a high percentage of leaks indicate higher chances of infiltration and consequently higher treatment and energy costs to maintain water pressure. Further, from a water equity perspective, illegal connections siphon off water from other legal users. CMWSBB regards NRW as its biggest concern and views efficient and accurate water metering as the way forward to tackle it (Roy et al., 2018).

One reason for a limited extent of water metering could be the costs involved in installing meters, and the poor financial health of most Indian water service providers who are unable to recover even operation and maintenance costs (Bhatnagar and Ramanujam, 2011). One interview with CMWSSB indicated installing water meters would require external funding since the utility hardly makes enough income to cover O&M costs.

Indian households are also reluctant about water metering, fearing the possibility it will mean higher water tariffs. These households have been paying low tariffs for water for many years (HPEC, 2011). The CMWSSB attempted to introduce residential metering through a pilot project in the Anna Nagar zone in 2008, but the project had to be abandoned for numerous reasons: One, deposition of grime in the meter chamber, making it faulty; two, already existing pressure and water quality issues; three, logistical issues involving fixing water meters near the sump, at a depth of five to six feet – making water reading difficult and four, substantially higher monthly water tariffs, as against the existing fixed rate of Rs. 50 per month per household that covers water and sewage (The Hindu 2008; Graft et al. 2018).

However, a recent survey conducted by the 100 RC team with residents[1] from across the city including from informal settlements, suggests the contrary. Among 543 residents, 51% stated that they are willing to pay a higher price for water, if it is 24*7 and of higher quality. While 27% are unsure of their decision, only 22% stated that they will not pay a higher price. Further, even among low income communities, there is a willingness to pay higher prices 24*7 water with 47% declaring the same. Respondents also showed their support (72%) for government policy on water meters and a consumption based tariff. (Refer Appendix 1 for exhaustive results). This coupled with the experience in Anna Nagar indicates that people would be willing to pay a higher price for water if quality and logistical issues were resolved.

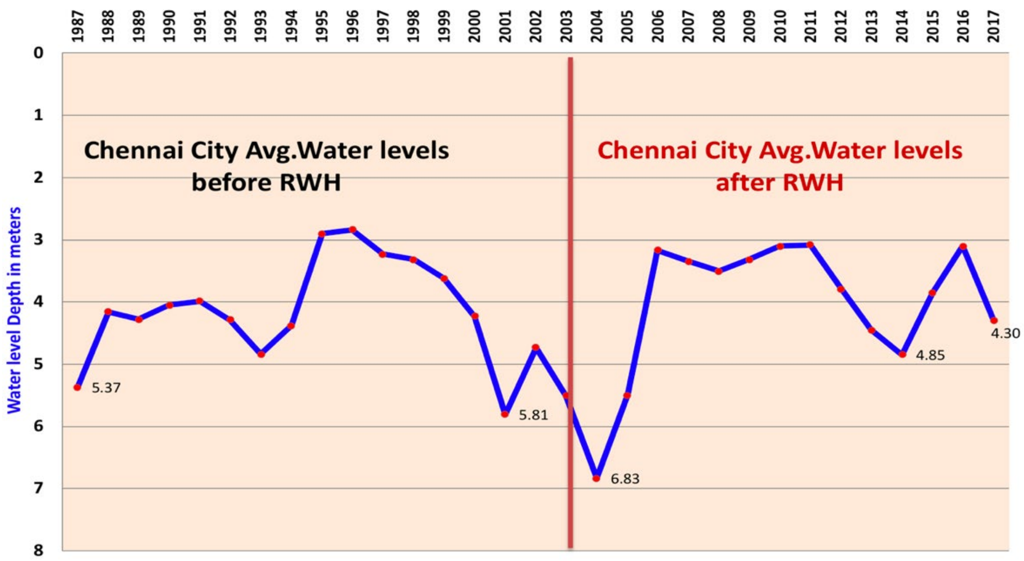
Due to the lack of formal cost-based incentives to manage water demand, water conservation relies largely on individual commitment to increase conservation efforts at a decentralised level.

B. Rain water harvesting (RWH)

One such effort is RWH. Currently, this effort relies mainly on people volunteering to set up their own systems. RWH was actually mandated by the government in 2003 after two years of successive drought and a shutdown of the piped water system. Amendments were made to Section 215 (a) of the Tamil Nadu District Municipalities Act, 1920 and Building Rules 1972, making it mandatory that all buildings provide RWH structures (Graft et al., 2018). This mandate defines RWH not so much in the common usage of the term – collection of rain water for end use – but rather in terms of enhancing aquifer recharge by installing rooftop and yard structure that divert water into the ground and rejuvenating temple tanks and ponds as infiltration structures (Srinivasan et al., 2010). Data shared by CMWSSB through interviews show that groundwater tables improved by almost 50% as a result of RWH between November 2004 and December 2007, making more water available for extraction (figure 1).

Figure 1: Average groundwater levels in Chennai city before and after RWH

[1] From here on referred to as 100 RC survey



Source: CMWSSB interview September 2018

Despite its apparent success, the implementation of RWH was actually rushed and meant that systems were poor and malfunctioning. Only around 50% of RWH structures are functional today and the ordinance is no longer being implemented (Roy et al., 2018). However, CMWSSB officials insist that they are rigorously checking the status of existing RWH structures and that, while there is no data on the extent of functioning systems, almost all the structures that have been checked are functioning well (CMWSSB September 2018).

Further, the distinction between the type of RWH structure implemented is important because it has implications on the extent of reliable water available for users at a later date. It is unclear if the RWH ordinance has resulted in a direct decrease in piped water consumption over time. This is because, while improved recharge from RWH allows groundwater to become available for consumers through private wells (Srinivasan et al., 2010), the aquifer(s) is not confined to a single user and it is not certain that households that have harvested a certain amount of rain water will have access to the same quantity of water at a later stage, raising questions of adequacy and reliability during periods of water shortage, when more users will be dependent on the aquifer. The extent of direct and indirect costs associated RWH and how dynamic and interlinked hydro-geological factors including rainfall, saline water intrusion, impact of extraction and impervious structures and soil profile affect recharge remain ambiguous.

C. Groundwater regulation

The focus of the RWH ordinance to increase groundwater levels suggests that groundwater extraction is a serious issue in Chennai and surrounding areas. The groundwater extraction rate in Chennai is estimated at 185% (Graft et al., 2018). Indeed, the groundwater table is severely stressed throughout most of the country, and yet it has largely remained an unmonitored resource. Pricing and regulating groundwater is challenging, primarily because Colonial laws still govern groundwater extraction through the Easement Act, 1882 and riparian right theory. The Act states that owners of property are automatically entitled to use water (ground and surface) found on that property. Ramesh (2018) argues that relying on this Act even today has paved the way for over extraction and indiscriminate groundwater pumping. The CMWSSB, however, has tried to restrict groundwater extraction through a counter Act, the Chennai Metropolitan Area Groundwater (Regulation) Act, 1987 which obligates obtaining permission and licenses to sink wells and extract or use or transport groundwater. The Act gives CMWSSB in Chennai city and the Collectorate of Chengalpattu in the rest of the CMA the authority to cancel groundwater permits or licences (Graft et al., 2018). Accordingly, while domestic users are exempt from obtaining permissions to extract groundwater, CMWSSB has not officially granted new permissions to commercial and industrial users since 1996. Yet CMWSSB representative suggests that they are not checking illegal extraction because they have not been able to supply the minimum supply benchmark of 135 lpcd as set by Ministry of Urban Development (MoUD). The Revenue department is, however, checking groundwater extraction for packaged drinking water companies (CMWSSB interview September 2018).

Thus, just as the existing institutional set-up for RWH does not directly benefit the user if they conserve water nor does it monitor and punish the illegal extractors of groundwater.

D. Waste water recycling

Efficient water demand management systems also rely on alternate water sources such as recycled waste water. Like RWH, however, adopting waste water recycling in the CMA currently depends on individual commitment rather than an institutional mandate. The biggest challenge associated with institutionalising waste water recycling and reuse in the existing centralised structure is that only less than 30% of sewage from households is actually collected (Hingorani, 2011). In Chennai, there is a discrepancy in the amount of sewage collected and treated. CMWSSB estimates it collected and treated 550 MLD in 2017, but others estimate that far more – possibly as much as 1500 – 2000 MLD – is produced (Arappor Iyakkam,2017).

Therefore, adopting a decentralised system that encourages households or neighbourhoods to manage waste water at the local level could be the way forward. Decentralised wastewater treatment systems (DEWATS) is a low-cost alternative for large scale centralised treatment systems that may no longer be viable in many cities due to high costs and resource needs (UNESCO, 2017). DEWATS technology serves individual or small groups of properties, requires less up-front investment and land than large systems and are more effective at coping with the need to scale up (or down) services to correspond to needs (ibid). CMWSSB issued an advisory in April, 2017 stating that new water and sewage connections will not be given to 'special and multi-storied buildings' that do not recycle or use waste water (Roy et al., 2018). Correspondingly, applicants for new water and sewage connections have to include a self-declaration that they will comply with this rule. However, it is unclear how CMWSSB monitors compliance.

According to Graft et al. (2018) and CMWSSB, Chennai is not suited to waste water reuse at the domestic level because citizens have a so-called 'mental block' against it. However, the 100 RC survey presents a different picture. More than 55% of respondents stated that they would consider using waste water recycled by the government for domestic purposes in future. While, 29% said they might consider it. Respondents also reacted on the factors that would influence their decision to recycle (*figure 2)*. This decision depends primarily on two factors – 'feeling good for conserving' and 'operation and maintenance (O&M)'. Interestingly, only ~11% chose 'yuck factor' contradicting what several government officials believe is the primary detriment to recycling. As (Lakshmi & Srikanth, 2015) point out through another survey with city residents, the reason for selection of O&M could be a because people find it difficult to find the right maintenance contractor.

Figure 2: Factors that influence citizens' decision to recycle water

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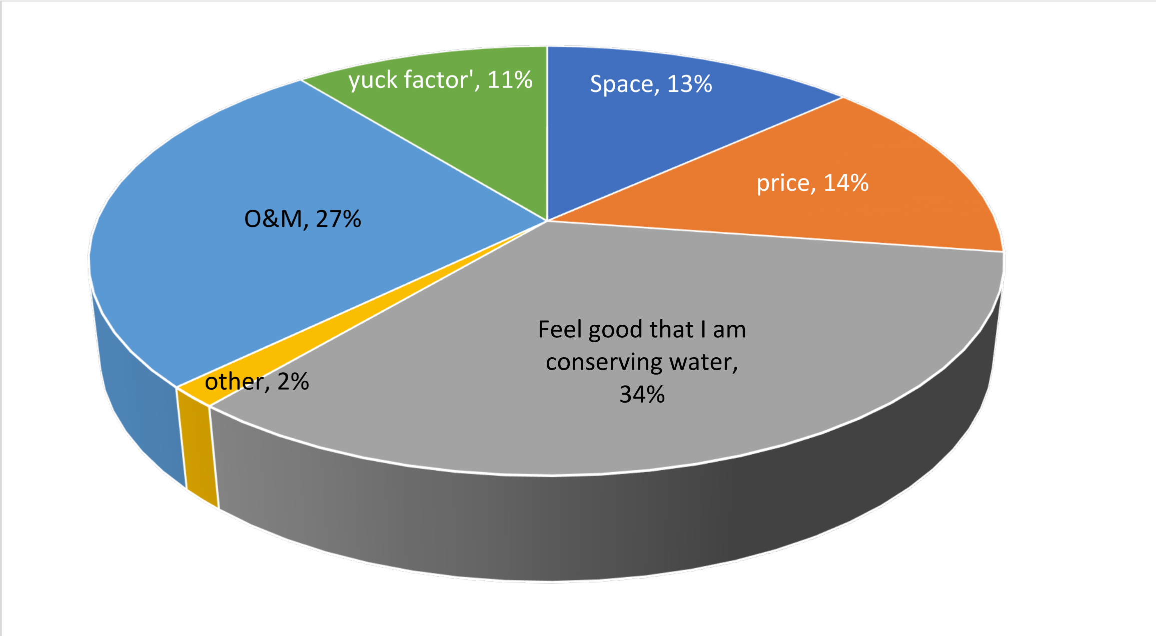


Wide spread adoption of decentralised, domestic waste water recycling systems in other Indian cities are also plagued by relatively high capital and O&M costs. A study by Ravishankar et al. (2018) in peri-urban region of Bangalore revealed that the cost of recycling waste water is higher than other options such as drawing fresh water from bore wells making residents prefer fresh water.

Isolated examples do exist, however, of individual apartment buildings recycling waste water for non-potable uses such as for gardening and toilet flushing. One residence in South Chennai recycles its sewage through a tried and tested Sequencing Batch Reactor (SBR) method which does not use any chemicals. The recycled water is then used for gardening (Oppili, 2013). Another apartment building in the centre of the city, has been recycling grey water (which includes water from sinks, washing and bathing) for 16 years by means of a dual piping system that separates grey water from sewage (from the toilet) and diverts it to a bed of water loving plants (Shekhar, 2018). Both these systems were possible as a result of citizen commitment in terms of time, effort and finances – reiterating a heavy reliance on voluntary efforts.

***Interventions** to support effective demand management*

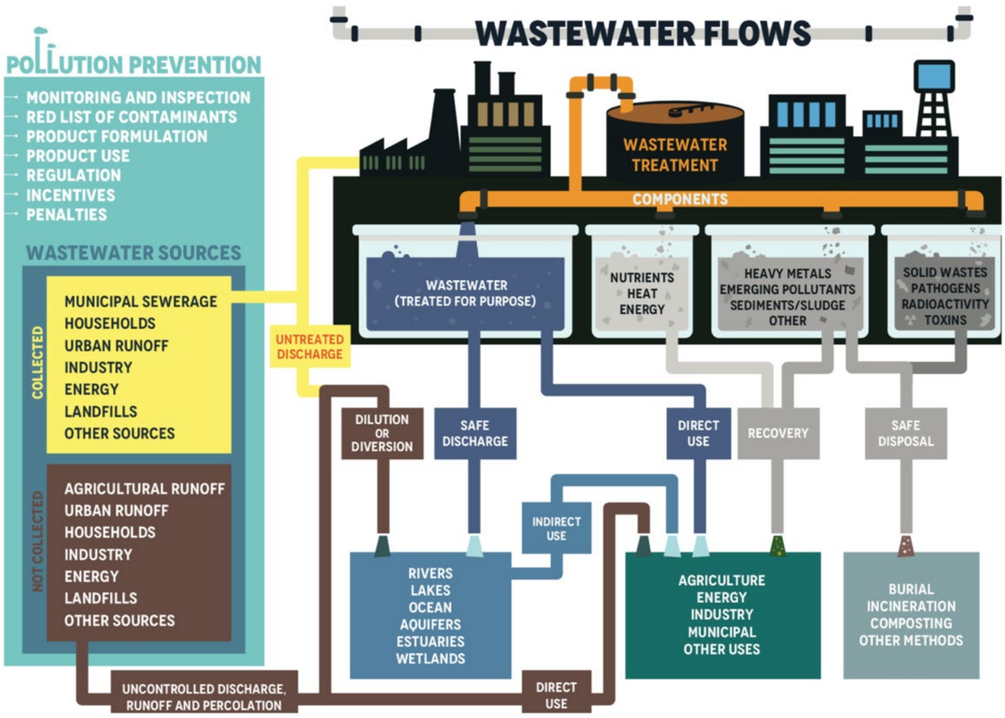
Sl. No.	Intervention	Description	City – Learning
1	Electromagnetic flow meters for monitoring water supply	Monitoring water supply through smart flow meters which can be installed in CMWSSB's water treatment and distribution plants. These flow meters quantify water supply and demand, thus indicating how to use resources judiciously. They can also estimate the extent of water lost (non-revenue water).	Surat
2	Review and monitor RWH systems in domestic and commercial buildings	Comprehensive review of RWH systems in domestic and commercial buildings to understand the type, level of functionality and efficiency.	
3	An integrated water and waste water strategy for the larger CMA	The strategy document will act as a guide to thinking about and planning for water and waste water in an integrated fashion. It will include planning for supply and demand with multiple sources, responsibilities of different agencies and how to stop treated waste water from being let out into the sea.	New Orleans Santiago

Sl. No.	Intervention	Description	City – Learning
4	Policy mandate requiring installation of water meters in domestic buildings	Installation of water meters across all households in the CMA to quantify water used and set tariffs accordingly.	
5	Awareness campaign advocating the use of recycled grey water	Extensive government campaign across the CMA to create awareness on the process of obtaining recycled water, quality of recycled water and benefits of use.	
6	Policy mandate requiring the use of recycled grey water across the CMA	Recycled grey water to be used for gardening, vehicle wash and in toilets across all households in the CMA to reduce the strain on fresh water sources.	
7	Sensors for monitoring groundwater	Installation of sensors in observation wells for monitoring and regulating groundwater quality, quantity and levels of extraction by private water tankers and private individuals with bore wells.	Rome
8	Sewage network augmentation and rehabilitation	Comprehensive infrastructure intervention to fix, revitalize and improve the sewage network in the CMA.	
9	Decentralized waste water management systems	Construction of decentralized waste water management plants at a ward/zonal level for localised use of treated waste water.	

DQ 2: How can we foster greater dependency on waste water recycling? How may decentralized waste water treatment systems help?

Efficiently managing waste water, whether through centralised or decentralised systems, provides an opportunity not just for sustainable water management but also for meeting increased demand from different economic sectors, including industrial and commercial. One estimate for India suggests that the collection and treatment of 80% of urban wastewater by 2030 would produce a total volume of around 17 billion cubic meters (BCM) per year. Captured, this resource would equal almost 75% of the projected industrial demand for 2025 (WSP, 2016). However, India is far from achieving this. The country generates an estimated 38,254 million litres of sewage a day, of which less than 30% collected is treated, much of which is disposed into freshwater bodies and the sea (Hingorani, 2011). The WSP (2016) reported that the annual economic impact of inadequate sanitation was equivalent to around 6.4% of GDP in 2006. *Figure 3* provides a comprehensive schematic of primary waste water flows -- from generation at source to where it is discharged.

Figure 3: Waste water flows



Source: UNESCO 2017

What's happening in Chennai?

In Chennai an insignificant amount of recycled water – approximately 28 MLD – is treated by CMWSSB and sold to two industrial companies, Chennai Petroleum Corporation Ltd. And Madras Fertilizers and Manali Petro Products, at Rs 11 per kilolitre (KL) (Graft et al., 2018). In addition, two new tertiary treatment reverse osmosis (TTRO) plants, each with a capacity to treat 45 MLD, are being set up at Koyambedu and Kodungaiyur to provide for industrial water needs in Irrungattukottai and Sriperumbudur, North Chennai (MAWS, 2018). This new capacity could replace the 35 MLD of freshwater that CMWSSB currently provides to peripheral area industries (Lakshmi, 2018). However, the extent of its impact on total industrial water demand is uncertain because, like domestic users, industry also has multiple sources of water including their own private bore wells (which are unregulated and not priced) and water tankers. Moreover, industrial demand is not metered.

Apart from government efforts to provide recycled waste water, several companies such as Saint Gobain and Apollo Tyres are individually recycling and reusing waste water on their premises. However, there is no data on the extent of collective water recycling and whether and how it impacts water demand. Further, government and other water experts in Chennai believe that several commercial and industrial users are unaware of the extent of recycling options available to them. Nor are they fully aware of the consequences of not recycling. Some experts also believe that, like in the case of domestic level water users, psychosocial inhibitions may prevent commercial and industrial users from reusing waste water for gardening, toilets and other nonindustrial purposes.

Challenges

A. Price, space and quality constraints affecting the adoption of decentralised waste water recycling

Individual, commercial and industrial establishment efforts to recycle waste water are not well documented. However, in order for industrial and commercial users to switch to waste water, it must be priced competitively compared to alternate water types that have a significantly better level of quality.

For industries, recycled water is charged at Rs. 11 per KL. For commercial users, the capital cost for a sewage treatment plant (STP) that uses the common sequential batch reactor (SBR)[2] technique ranges from Rs 1 lakh for a small plant that serves 6 people to Rs 65 lakh for a plant catering to 1000 people (Oppili, 2013). When combined with the costs of required O&M, the cost of waste water recycling is significantly higher than alternatives such as groundwater because the latter is practically free. Also, CMWSSB commercial tariffs for piped fresh water are anywhere between Rs 500 and Rs 1400 per month (CMWSSB website). It is also true that, piped water from CMWSSB is not enough to meet the needs of commercial establishments in wet and dry periods, and they turn to water tankers to fill the gap (Srinivasan et al., 2010). CMWSSB tanker charges are Rs. 1000 for a 9000l tanker and Rs. 1700 for a 16000 KL tanker (CMWSSB website). These options might work out cheaper in the short term because they don't involve capital investment such as land and requirements for treating and reusing waste water. The Secretary of the Hotel Association of Tamil Nadu cited lack of space as one of the biggest constraints with setting up decentralised waste water recycling plants (Philip, 2014).

In terms of water quality, commercial and industrial users have varying requirements. Power plants and commercial users such as malls or offices require large volumes of water (primarily for air conditioning and toilet flushing) with lower quality needs and devoid of nutrients to prevent algae growth. On the other hand, hotels may require tertiary treated water for gardening and other purposes as also other industries such as Madras Fertilizers which requires high quality water and treats the water it buys from CMWSSB at a tertiary level (Hingorani, 2011).

***Interventions –** to support decentralised waste water systems*

SL. No.	Intervention	Description	Learning from other cities
1	New sewage treatment plants	STP construction to increase the share of recycled water used by industries to ease the strain of increasing demand for water from this sector, as well as help relieve stress on sewer systems. Will also reduce the quantity of fresh water currently being supplied to industries.	
2	Policy mandate requiring the use of recycled grey water across industries in CMA	Requirement that all industries across the CMA use recycled grey water (by secondary or tertiary processes) to reduce the strain on fresh water sources.	
3	An integrated water and waste water strategy for the larger CMA	The strategy document will act as a guide on thinking about and planning for water and waste water in an integrated manner. It will include planning for supply and demand with multiple sources and responsibilities of different agencies and indications for how to stop treated waste water from being let out into the sea.	Santiago New Orleans
4	Decentralized waste water management systems	Construction of decentralized waste water management plants at a ward/zonal level for localised use of treated waste water.	
5	Data repository on best	The repository will include information on which	

[2] Common treatment options preferred by water utilities in India are activated sludge process (ASP) and sequential batch reactor (SBR) (Hingorani, 2011). Both methods are primarily biological but require some use of chemicals, particularly for tertiary treatment. SBR requires 33 – 50% less land than ASP and has 40% less civil construction expenditure than ASP (CSE, 2010).

SL. No.	Intervention	Description	Learning from other cities
	practices for water recycling for commercial and industrial purposes	industries are recycling and reusing waste water and to what extent. Can inform monitoring and enforcement by TWAD/CMWSSB/TNPCB.	

DQ 3: How do we redesign our storm water drain systems to maximise water storage and improve water management practices?

History and links to present

The history of Chennai's existing storm water drain network can be traced back to erstwhile colonial Madras when the British built enormous arch drains. The first of these was constructed in George Town in 1875. Much of this 800 km network continues to exist today, particularly in older and core city areas such as Broadway and Mylapore. In fact, it is widely acknowledged that areas where these drains have been maintained saw a lesser extent of inundation during Chennai's December 2015 flooding event (Lopez 2017a). However, due to several challenges such as the non-existence of plans or information about the old system and damage from telecom, power and water supply projects, the Greater Chennai Corporation (GCC) struggles to maintain this original system, opting instead to rebuild and extend a new network in other parts of the city.

The current network spans a length of 1894 km with 7360 drains and is constructed and maintained by GCC. A large part of this network (if not the entire network) was constructed through multiple, large-scale projects, including the JNNURM and the Chennai Mega City Development Mission (CMCDM). Going forward, the Integrated Storm Water Drain Project (ISWDP) sees itself providing drains to new areas through a basin approach with different funders for each of the three basins, Adyar and Cooum, Kovalam and Kosasthalaiyar.

Challenges with the existing network

I.Design challenges

While these consistent efforts would certainly help to mitigate the impacts of flooding, the primary objective of the network has not changed since it was conceived during British rule: to carry excess surface runoff, as quickly as possible, from roads to the Bay of Bengal via canals and the Adyar and Cooum rivers. This early objective is problematic today because it serves only one purpose: that of flood management. In reality, the network has the potential to simultaneously serve multiple objectives including enhancing water storage, groundwater retention – in addition to flood management. As Jameson and Baud (2016) point out, flood management in Chennai has not been thought about in an integrated manner that incorporates rain water harvesting, recognition of natural sinks and marshlands and contributions of the traditional *ery* (or tank) system to underground recharge. Serving multiple purposes is critical in the present context of climate change and is required in order to build urban resilience. The existing storm water network and approved designs for new projects fail to provide a holistic solution to these multiple challenges; like the original networks they only allow for alleviating the impact of floods. Indeed, this system, in a way, offsets rainwater harvesting efforts by preventing rainwater seeping through into the ground. This disconnect is evident from project documents for the three projects: ISWDP, CMCDM and JNNURM.

For the JNNURM project a limited amount of information is available in the public domain. What is available is information about the fact that this network covered most parts of the core city.

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However, for the CMCDM, a performance audit by the Comptroller and Auditor General (CAG) of India in 2016 provided some insights. The network was built without basis in a hydrological, topographical and meteorological study. In other words, it did not ultimately link to a natural water body and was inadequate in size. Jameson and Baud (2016) reiterate this point and also indicate that the existing system was designed to work on gravity, which is unsuitable for Chennai's almost flat topography with little gradient, meaning that water remains stagnant in water pools. Indeed, in several areas, drains are built above the height of the adjacent road, defeating the purpose for which it was constructed. Some experts (Sengupta, 2015; Narain, 2015) argue that a more appropriate design for Chennai would be the traditional *ery system* that was designed to mediate flood risk through slow and gradual water movement through unpaved tank beds.

The CAG report (2016) further states that the storm water network was not planned to ultimately link to natural water ways or water bodies and because of these inadequacies the same areas were proposed for reconstruction under the ISWDP. Another problem is the limited awareness about the network and its functions among citizens and stakeholders: as a result, encroachment occurs along drain entryways in several areas, preventing free water flow.

In the case of the ISWDP, only works under Phase 1 have begun (*Table 1)*. The projects under this phase are funded by the World Bank and are incorporated within the framework of the Tamil Nadu Sustainable Urban Development Project (TNSUDP).

Table 1: Overview of Integrated Storm Water Drain Project

Basin	Zones	Funder	Tentative funding	Time Frame	Scope of Work (Project Objectives)
I. Adyar and Cooum	Valasavakkam, Alandur, Ambattur	World Bank	₹ 1126 Cr. (approx.)	Apr. 2015 – Mar. 2022	Drain peak storm water run-off through 329 km of drains into water ways, canals and Adyar and Cooum rivers – and ultimately into the Bay of Bengal
II. Kovalam	Perungudi and Shozhinganallur	Kfw	₹ 1243.15 Cr.	Not known	
III. Kosasthalaiyar	Thiruvottiyur, Manali, Madhavaram, Surapet, Korattur	ADB *(not yet finalised)*	₹ 2100 Cr.	Not Known	- Construct/ restore 765 km of drains - Increase the capacity of 71 water bodies through desilting - Groundwater recharge

Source: GCC (2017); Lopez (2018)

In fact, the storm water drains component makes up 30% of the overall project cost. The Project Appraisal Report (2015) details the intervention and states that the project will construct and restore 329 km of drains in peri-urban areas that were recently added to GCC. It further states that the new network is designed such that it will "drain peak storm water run-off into natural water ways, canals and into the Adyar and Cooum rivers and ultimately into Bay of Bengal" (World Bank, 2015), highlighting the project's narrow focus. However, an associated environmental and social impact assessment conducted by a 'Project Development Consultant' appointed by the Greater Chennai Corporation (GCC) did attempt to consider the potential water storage opportunity by suggesting periodic groundwater recharge structures at 100m intervals along the network (TNUIFSL, 2015).

Regardless, these groundwater recharge structures are not being constructed. Rather, recharge wells are constructed outside of the drainage network, where there is space or where water stagnates (GCC interview, October 2018). There are also tensions between GCC and CMWSSB regarding illegal sewage inflow into drains. A CMWSSB official stated that, while it is mandatory for GCC to approach and notify CMWSSB of any storm water drain work, they do not do this and that sewage pipes break during storm water drain construction (interview with CMWSSB, September 2018). The GCC, on the other hand, did not deny this, saying instead that it was up to the project development consultant (who is appointed by GCC) to ensure sewage and water pipes are not broken, and if broken, repaired – since the project includes funding for repair of damaged pipes (GCC interview October 2018). However, accountability mechanisms to ensure the project development consultant does this do not exist.

Further, while GCC is seriously considering groundwater recharge as a project objective for the third phase of the program (Lopez, 2018), it remains to be seen what the design and structure of the recharge wells will look like and if it will contribute towards an integrated flood management system.

Experts believe that a paradigm shift is required to address the storm water drain problem and make it more holistic. One suggestion is to rename the GCC's Storm Water Drain (SWD) department to something that better reflects the multi-purpose functions that a SWD can perform, including, for example, redirecting storm water to recharge wells.

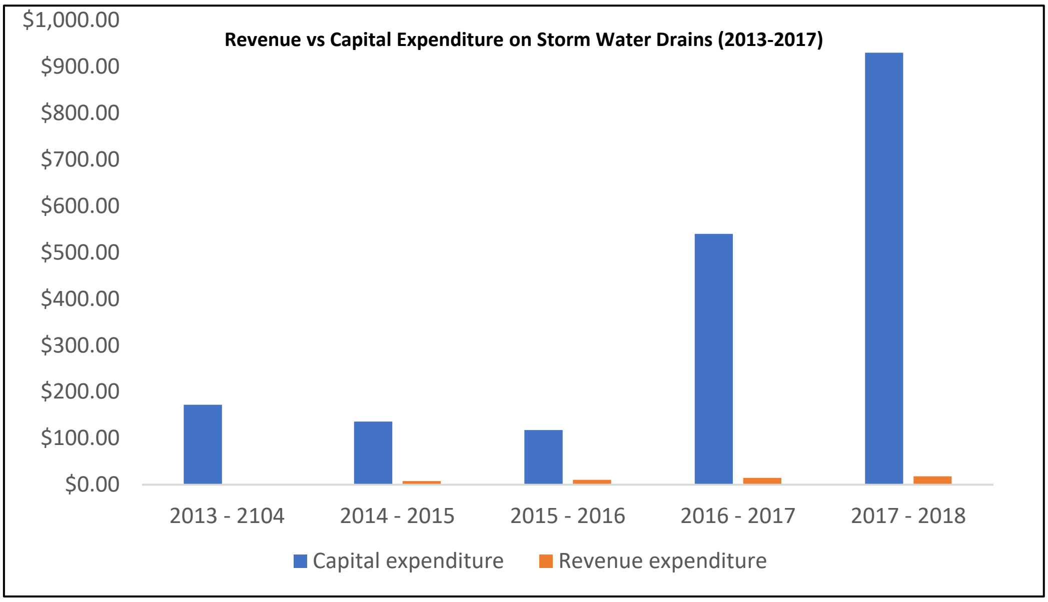
II. *O&M challenges*

Other issues regarding this system are linked primarily to the extent of operation and maintenance. Over the years, and especially following the December 2015 floods event, the GCC has been criticized for failing to clean or desilt drains ahead of the northeast monsoon (Lopez, 2017b; Govindarajan, 2017). This is corroborated by Jameson and Baud (2017), who disclose that the system is inadequate, inefficient, blocked by debris and not desilted often enough. The GCC's vision, however, continues to be to expand the system rather than properly maintain what already exists. This can be seen in its budgetary expenditure. An analysis by Roy et al. (2018b) reveals that during the last five years – 2013/14 to 2017/18 – expenditure on storm water drains was predominantly on capital expenditure, with much less appropriated for regular O&M (see figure 3).

Box 2: O&M challenges

The Greater Chennai Corporation is woefully short on funding, particularly for O&M works. Roy et al. (2018b) find that a majority of expenditures on SWDs have been capital in nature, indicating that the focus is more on adding new infrastructure, while, by comparison, much less is spent on the regular operations and maintenance of existing systems. Further, there is a substantial increase in spending during 2016-17 (approx. INR 540 Cr from INR 117 Cr in 2015-16). This increase could be the result of the impact of the December 2015 floods, which revealed the inadequacies of the existing drainage system (figure 4).

Figure 4: GCC expenditure on storm water drains



Source: Roy et al, 2018b

***Interventions** – to redesign storm water drains*

SL. No.	Intervention	Description	Learning for other cities
1	Multipurpose and green storm water drains	Introducing/retrofitting the SWD system to enhance and replicate the natural drainage system and manage rainfall close to where it falls. Beyond flood mitigation, this system can have multiple benefits, including beautifying neighbourhoods, capturing and using storm water for other purposes, for example permeable pavements, building recharge wells, etc.	Bristol Berkeley New Orleans
2	Common database on underground infrastructure	Create a common database of underground infrastructure that includes water, sanitation, communication, storm water drains, electricity and transport. This database should be accessible	Rotterdam

		be all relevant government departments and will contain data on the location, function and inter-dependencies. Knowledge of where what is will increase awareness of risk, consequently making the city more resilient.	
3	Embedded and green infrastructure	Scale-up green infrastructure interventions across CMA, such as, porous paving and rainwater harvesting in driveways, to recharge groundwater and lower flooding vulnerability.	

DQ 4: How can we encourage more coordinated and collective efforts by multiple agencies for better water system management?

Water governance in Chennai is characterised by the involvement of multiple agencies and the issues that exist today can be traced back to the period of colonial rule. The British introduced a centralised water management system and a 'public works department' (PWD) to manage and maintain water – primarily for irrigation purposes. Ramesh (2018) points out that poor service problems existed as early as 1890 when farmers in Madurai complained about delays in repairing tanks. Since then, however, several other government departments have emerged, including parastatal agencies such as the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) who play key roles in water management. In addition to government agencies, non-governmental organisations including academic institutions, bi-lateral and multi-lateral organisations, civil society organisations and corporations also support several government departments for water management in various capacities. However, the presence of multiple government and parastatal agencies in this space with overlapping responsibilities and jurisdictions results in system inefficiencies and poorly implemented efforts to manage water (Roy et al., 2018).

Interactions between the PWD, CMWSSB and Chennai Metropolitan Development Authority (CMDA), each of which has interdependent roles, are exemplary of the extent and nature of communication and coordination within the government. PWD and CWMSSB interact for maintenance and management of water tanks and reservoirs supplying water to the Chennai Metropolitan Area. The PWD owns the major tanks and reservoirs that supply water to the city. CMWSS's role is to supply water to the city, yet, with respect to these reservoirs, it depends on PWD for maintenance and operations such as opening and closing valves, desilting and removal of encroachments. Therefore, CMWSSB's role is restricted to extracting, treating and distributing water released by PWD. This gives rise to stresses regarding water discharge and maintenance and raises questions about whether PWD should be maintaining the tanks at all, since their primary role is to ensure water supply for irrigation (Roy et al., 2018).

PWD and CMDA also interact for planning purposes. PWD is tasked with maintaining Tamil Nadu's macro drainage, while CMDA is responsible for preparing Chennai Metropolitan Area master plans. Details of drainage channels and water bodies at the village level that are available with the PWD were not, until recently, referred to in CMDA's master plan which identified substantial sections of natural drainage channels for residential and commercial developments (Ibid). As such, communication between these departments is characterised by limited data sharing and collaboration.

Apart from these examples, the limited extent of coordination and data sharing between departments is evident in lake restoration efforts. Ever since the December 2015 and resulting devastation, myriad interventions from myriad actors have emerged in Chennai and its peripheries, all with the overarching objective of restoring and rejuvenating water bodies including lakes, rivers, ponds and tanks. Some ongoing efforts include the Sustainable Water Security Mission, Eco-restoration of Adyar Creek, multiple efforts of resident welfare associations (RWAs) and Integrated Cooum River Restoration Project. Yet, these seem to be playing out in an isolated manner with seemingly little awareness among implementing agencies about other efforts, what they entail or who is doing what.

Challenges

A. Varied definitions of restoration

A closer look at many of the lake restoration projects reveals that each one defines restoration differently. For instance, the Sustainable Water Security Mission of the Government of Tamil Nadu includes activities around restoration and rejuvenation of water bodies by removing garbage, weeds, creepers and bushes, desilting, fencing, digging percolation pits and erecting signage. A similar scope of activities is followed by Corporates through their corporate social responsibility (CSR) funded initiatives and volunteer led efforts. For instance, local resident efforts supported by non- governmental organization Environmentalist Foundation of India (EFI) involves building percolation trenches, bunds, roosting islands in specific water bodies along Chennai's Information Technology (IT) Corridor (Majumdar, 2018). On the other hand, Chennai Rivers Restoration Trust (CRRT) initiated a '*Final Master Plan – Water bodies and waterways'* and the Integrated Cooum River Restoration Project encompasses a broader scope of activities. CRRT's master plan for restoring approximately 42 water bodies in the Chennai Metropolitan Area (CMA) discloses that, apart from removing garbage and desilting, it includes activities that divert sewage, protect embankments and create walk ways for public use (Graft et al., 2018). The Integrated Cooum River Restoration Project also includes similar activities. Other projects spearheaded by CRRT such as the eco-restoration project of Adyar Creek and the Narayanapuram Wetland Restoration efforts focus on restoration from an environmental point of view: rehabilitating the coastal ecology of the wetlands, recreating vegetation typical of the local region, plugging sewage inflows, capacity building and training programmes for local residents to inculcate a sense of ownership (CRRT website; Gopalakrishnan, 2017). Evidently lake restoration efforts remain project based as different water bodies have different issues that need to be addressed. However, without any common consensus on what are the range of technical, human and environmental parameters that restoration efforts should consider or common understanding of what works and what doesn't, the collective impact of such efforts remain limited whilst also allowing some efforts to address the issue fairly superficially.

B. Coordination between departments

It's possible this wide ranging definition of the term restoration is attributable to the fact that so many different agencies are involved in the process (see figure 5) and these agencies have certain interests and expertise. The presence of multiple agencies makes it challenging to keep track of each project and assess overall project impact on the larger water basin. For instance, beyond the GCC boundaries, multiple government agencies own water bodies. The PWD is responsible for maintaining all rivers and owns all the tanks in Tamil Nadu that irrigate more than 40 hectares. Those tanks that irrigate a smaller area are owned by urban local bodies (ULBs), which could be a town panchayat, village panchayat or a panchayat union. The extent and nature of inter-departmental interaction (specific to government departments) is based on individual project objectives and can vary with each project. The nature of interaction could be for implementation, finance, policy formulation or research purposes (Roy et al., 2018b). Therefore, a ULB's interaction with PWD may or may not take place depending on whether there is a project. Yet, interaction between PWD and ULB is critical for effective and sustainable management of water at the basin and sub-basin levels.

Figure 5: Snapshot of organisations involved in water body restoration

Source: authors' own

Within the GCC limits, some water bodies covered under the Sustainable Water Securities Mission (SuWSM) are being restored through the SMART Cities Project. It is interesting to note that the nodal agency for the SuWSM is CMWSSB and because funds are yet to be released for it, the restoration of 34 lakes is being implemented through the SMART Cities Project (CMWSSB interview, September 2018). In an effort to involve citizens in the restoration effort, the SuWSM website has a 'get involved' tab which links to a page on the Chennai Smart Cities Website, but this latter page shows a message that 'does not exist'. Further, there is an overlap between the functions of CMWSSB as the SuWSM nodal agency and that of the Chennai River Restoration Trust. CRRT's role is "planning, coordination, funding and monitoring along with various agencies with the objective of rehabilitation of Chennai water ways and water bodies (CCRT website)."

The extent of data sharing and coordination between government agencies can also be seen within specific projects. Most government restoration efforts do have some amount of coordination at the project planning and design stage, and not necessarily at the project implementation stage. For instance, for the Integrated Cooum River Restoration project, coordination remains at project planning stage as it includes an operational working group constituted by CRRT, involving CMWSSB, PWD, GCC, Commissioner of Municipal Administration, CMDA, Tamil Nadu Pollution Control Board (TNPCB) and Tamil Nadu Slum Clearance Board (TNSCB)' (TNUIFSL and CRRT, 2014). The extent of coordination appears to have been limited to discussions and allocation of sub-projects for each agency, and did not include developing guidelines or steps on how agencies should interact while implementing the various sub-projects. There is, however, agreement between the departments on sub-projects for each of them.

***Interventions** – to encourage coordinated efforts for water management*

SL. No.	Intervention	Description	Learning from other cities
1	Integrated eco-restoration of rivers	Scientific restoration of rivers through targeted interventions to effectively improve sewage management, sanitation, bio-diversity, solid waste	Rome

SL. No.	Intervention	Description	Learning from other cities
		management and flood management.	
2	Restoration and protection of water bodies and waterways within CMA	Map and prioritize waterways and water bodies in CMA and identify, prioritize and prepare master plans for water bodies and waterways in CMA for restoration. Protection will involve strict regulatory measures.	Rome
3	Developing comprehensive guidelines and blueprints for lake restoration	Developing an overarching guiding template that encompasses physical, environmental and social parameters for lake restoration to be followed by interested actors (CSR, NGO, civil society).	
4	Developing a dash board on status of restoration efforts for public viewing	Developing an integrated dashboard with information on the progress of restoration which will include name, location, cost and funding partners.	
5	Common database on underground infrastructure	Create a common database of underground infrastructure that includes water, sanitation, communication, storm water drains, electricity and transport. This database should be accessible be all relevant government departments and will contain data on the location, function and inter-dependencies. Knowledge of where what is will increase awareness of risk, consequently making the city more resilient.	Rotterdam

DQ 5: How can we better plan for and address water related shocks (drought, floods), and stresses (climate change, sea level rise, encroachments and poor solid waste management)?

Dealing with floods and related stresses

Chennai city is vulnerable to both shocks and stresses. Shocks are acute and sudden like floods and droughts while stresses affect the city on a daily basis and aggravate the impact of shocks. Climate change, for example, is a stress on Chennai. Much of policy maker and planner focus has been on mitigating the impact of floods – perhaps because the issue is so visible and extent of impact on the city and its people, so widespread. Every year, there is a flurry of activity in the government in the lead up to the monsoon. This ranges from desilting and constructing missing links in the existing SWD network to building new drains. It also includes a number of flood mitigation meetings.

What is missing is the understanding that the region is prone to alternate cycles of flood and drought. In 2003–2004, the extent of drought was so severe that Chennai's piped water system was shut down. This was followed by unprecedented rainfall levels of upwards of 142.4 mm on one single day in November. Similarly, a below normal monsoon in 2013 and 2014 was followed by another unprecedented rainfall event in 2015, with 246.5 mm of rain recorded in 24 hours in early December – followed by a drought in 2016 and a cyclone at the end of 2016 (Graft et al., 2018; Arabindoo, 2016).

What is also missing is the understanding that flood and drought management is looked at only from a natural disaster perspective. The rainfall events in November and December 2015 were referred to as unprecedented and the damages inevitable (Arabindoo, 2016). However, the media and academics have critiqued this response. They firmly believe that ineffective planning and implementation of regulations, particularly regarding encroachments and illegal solid waste dumping, loss of water bodies and poor maintenance of drainage channels contribute largely to such so-called natural disasters (PTI 2016; Esther and Devadas, 2016). Consequently, the floods caused substantial loss to life and property: A Small and Medium Enterprises Ratings Agency Limited (SMERA) study reported that the Micro, Small and Medium Enterprises (MSME) sector lost INR 1,700 crores in two weeks of flooding (DNA India, 2015). While the official death toll was 347 persons, 17.64 lakhs of people were rescued, evacuated and accommodated in relief centres (The Hindu, 2015).

Figure 6: Inundated roads during the 2015 floods

Dealing with encroachments, however, is challenging for several reasons. First, many encroachments are legal and regularised developments, making their removal difficult. For example, the National Institute of Wind Energy is located on Pallikaranai Marsh, the Mass Rapid Transport System (MRTS) train line and stations have been built on the Buckingham Canal and Ennore Creek in northern Chennai was demarcated for hazardous industries such as thermal power plants. Second, a large portion of illegal encroachments include informal settlements, and these are tricky to deal with. This is because it means resettling occupants to government housing in peripheral areas, and this means disruption to their lives, livelihoods, education, access to basic services, social ties and networks because resettlement colonies are ill-equipped with access to basic services such as quality education and health care, adequate transportation, water and sanitation (Coelho et al., 2012). Also, many resettlement colonies are built on low lying land that are as prone to flooding as river banks – which is where families originally lived (in illegal encroachments), suggesting that quality of lives is not likely to improve after they move. Removing encroachments requires coordinated efforts from multiple departments such as the PWD, the judiciary, the police force, the slum clearance board and service providers such as CMWSSB. In a system of governance where agencies tend to work in silos this is extremely difficult to achieve. Furthermore, dealing with encroachment remains a topic of extreme complexity since many residents, experts, and activists feel that current methods are insensitive to the needs of the vulnerable and are often discriminatory towards different socio-economic groups and different uses, for instance commercial establishment vs. informal settlement. Therefore, despite the fact that restoration of waterways and water bodies in most cases need to find a way of dealing with encroachment, this is also perhaps most difficult task to implement.

Unregulated solid waste dumping in water bodies poses a similarly major challenge. Around 1.32 lakh tonnes of garbage was removed from the city after the December 2015 flood, which amounts to approximately 25 days of waste (Roy et al., 2018a). Many experts believe that such large-scale inundation was the result of open water way clogging and storm water drain choking caused by poor solid waste management (Narasimhan et al., 2015). Several problems are associated with solid waste management. First, GCC, which is responsible for city SWM, faces severe staff and financial resource shortages that prevent it from effectively managing solid waste. Second, logistical challenges prevent solid waste removal in certain areas. According to GCC officials, it is practically impossible to remove solid waste from river beds because the waste gets embedded in the soil. Third, fines and other methods to curb littering in public places, source segregation and scientific waste disposal are not being enforced despite the 2016 SWM Rules. However, GCC is currently preparing to pass SWM By-laws which provide a legal mandate for enforcing the 2016 SWM Rules and is also in the process of modifying the vendor contract for private interventions in SWM with the aim of increasing service standards and reducing illegal dumping.

Planning for climate change

Stresses include not just those that are man-made but climate related risk as well. Increasing temperatures, torrential downpours and droughts have become frequent in Chennai, and they are driven in part by a changing climate. Future climate projections for the larger region, including Chennai, highlight multiple stresses including changes in temperature, precipitation patterns and sea level (see figure 7).

Figure 7: Climate projections for Tamil Nadu

Source: Authors' own

Frameworks to build Chennai city resilience should recognise and address these potential climate change threats. Target 13.2 in the United Nations Sustainable Development Goals recommends that countries specifically focus on integrating climate change measures into national policies, strategies and planning. This process includes coming up with a detailed understanding of projected climate impacts, expected socio-economic threats, historical disaster risks, vulnerable population and sectors. It also includes long term adaptation measures as well as mitigating impact of disasters before, during and after each event (UNDP, 2011).

In Chennai, specific challenges exist with respect to planning for climate change, including disseminating information, mainstreaming climate change in infrastructure planning and disaster risk mitigation.

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Challenges

A. Dissemination of information related to climate change

Knowledge about climate change and related threats exists; however, it doesn't appear to penetrate into policy making or development projects. Instead, decision makers seem to largely view it as a vague and distant threat, hovering somewhere in the future. Efforts to meet immediate needs and concerns, therefore, don't emphasize climate change related threats. The limited extent of dissemination could also be the result of Tamil Nadu State Climate Change Cell (TNCCC)'s limited reach and poor coordination around providing policy guidance pertaining to climate change in the state.

In part, TNCCC's role is to build capacity and disseminate relevant information to government and other stakeholders on any information related to climate change for the entire state. However, whether it is actively discharging this duty is unclear. Its web portal – through which, it is mandated to act as 'a central hub of information, data and reports related to climate change' – is perpetually unreachable. TNCC has indicated that it would work closely with Anna University's Centre for Climate Change and Adaptation Research by setting up a Centre for Excellence to 'develop a scientific understanding of climate change issues' and 'undertake capacity building and broadcasting of technical innovation' (DOE 2015). This process is currently underway, and the University is developing a website through which information related to climate change at the state level will be available and publicly accessible.

At the city level, no specific government body has been assigned the task of disseminating climate change information, although the GCC is the likely candidate. GCC's only attempt in this regard was in 2017 when it published a Disaster Management Plan and associated zonal plans with the vision of "enhancing disaster preparedness, maximising the ability to cope with disasters and minimise vulnerability to disasters." While the primary disaster management plan is accessible on the GCC website, the zonal plans, that were once publicly available, have since been taken off the website. This means the general public has no way to understand and know whether they live in vulnerable areas. Further, both the main plan and the zonal plans are not yet available in Tamil, restricting access to significant number of communities, including low income segments that are highly vulnerable to disasters and typically don't speak or understand English well.

B. Integration of climate change risks in development projects

At the state and city level, government agencies responsible for policy making and planning do not have specific process for factoring climate change impacts into policy making and planning. This is primarily because they don't have the knowledge on how to mainstream (Roul, 2017). Effective mainstreaming ensures that climate risks are built into development project objectives such that they support long term sustainable development. Several examples of mainstreaming can be seen from the Netherlands where the threat from coastal flooding and extreme precipitation events has been recognised and integrated it into infrastructure projects. Areas in the city of Rotterdam that are at risk from long term flooding advocate for adaptive building and design which entails raising properties and quays and working with builders and real estate developers to ensure new buildings and essential infrastructure are also raised (Rotterdam Climate Change Adaptation Strategy, 2015).

In Tamil Nadu (including Chennai), infrastructure projects such as road development, storm water drains, housing projects and water supply and sanitation works follow the usual tendering process with the project going to the lowest bidder. The ensuing contract and vetting process for detailed project reports (DPRs) is based on existing service benchmarks of, for example, Central Public Health and Environmental Engineering Organisation (CPHEEO) for water supply and sanitation that do not address climate change risks. Chennai's failure to integrate climate change knowledge into planning and policy making is evident in the way critical infrastructure such as desalination plants, roads, sewage treatment plants (STPs) and electricity infrastructure are located in areas that are likely to be at risk from rising sea level and storm surge (Ramachandran et al., 2017). Specifically, relevant to building resilience with respect to water, is the question, how prudent is it, to depend on desalination plants located in coastal areas to improve water supply when climate change involves a clear threat of this expensive infrastructure being inundated? Interviews with Chennai's primary planning agency and local water utility revealed that these agencies do not believe climate change (specifically flooding) poses any significant risk, let alone risk to existing desalination plants (which supply 30% of water city water needs):

" sea level rise occurs only during tsunami, we have no mapping of high tide and any kind of data or proof of sea level rise" (CMDA interview October 2018).

"desalination plants withstood the impact of Vardha and 2015 floods. So they will be able to withstand any future event" (CMWSSB interview September 2018).

I. Integration of climate change risks for disaster management

Climate change adaptation includes not just long-term mainstreaming of climate risks in policy making but also disaster risk integration and disaster mitigation. In Tamil Nadu, measures to adapt and mitigate impacts of climate change largely comprise of ad-hoc measures that are reactive in nature, which increases community and infrastructure vulnerability.

The Tamil Nadu State Disaster Management Perspective Plan 2018 – 2030 and the Chennai Disaster Management Plan (2017) are key documents that attempt to integrate disaster risk into policy making and planning. The State plan envisions "building a safe and disaster resistant Tamil Nadu through a systems approach, inclusive development and mainstreaming disaster risk concerns into the development ethos of the State" (TNSDMA, 2018). It is based on the Sendai framework's multi-hazard approach and accordingly includes a list of districts that are vulnerable to different disasters from natural to chemical, biological, nuclear and radiological. It also provides information regarding vulnerable areas at a district level and a preparedness strategy for specific disasters.

With respect to the city, the GCC Disaster Management Plan (2017) discusses how to manage flooding, mandatory maintenance works for various infrastructures and after event measures such as relief centres in the event of floods, earthquakes, cyclones and tsunamis. This document also includes a disaster management plan for each zone, with each plan proving maps of roads that are prone to inundation and that were inundated during the 2015 floods. They also include details of relief centres and contact details for officers in charge of disaster mitigation and relief. This is a significant step forward and should be replicated in other municipalities.

However, a significant drawback to the GCC plan is that it is not a comprehensive document and does not incorporate a multi-hazard approach as recommended by the National or State Disaster Management Plans. Specifically, related to natural disasters, it ignores protection against storm surge that is already affecting coastal communities. Around 100 households in fishing villages along Chennai's northern coast have been damaged by storm surges and tidal waves and a substantial portion of land in the area has been lost to the sea (Ramakrishnan 2017). It also ignores drought preparedness. The city has witnessed wide variation in rainfall patterns with rainfall as low as 624 mm (in 1999) and as high as 2570 mm (in 2005), impacting ground water recharge (Graft et al., 2018). Simultaneously, city groundwater tables have been significantly low for several years since 1987, with the lowest levels recorded during the drought years of 2001 – 2004 (CMWSSB interview, September 2018) indicating the risk of drought.

Understanding the full gamut of risks entails building forecasting knowledge, observation networks and information systems, monitoring and warning systems for multiple disasters (NDMA, 2016). A failure to recognise all possible risks has critical consequences for disaster preparedness, adaptation and resilience. In the event of a hazard the city will not be prepared to deal with it – with potentially disastrous results in terms of loss of life and property. Another consequence is that interventions to mitigate impact of a specific event might be counterproductive to measures taken to mitigate another event. For instance, the GCC Disaster Management Plan (2017) includes plans to implement a set of new infrastructure projects to extend the storm water drain network, with the first project phase currently underway. While this is certainly a measure to reduce the impact of flooding by quickly carrying surface run-off to the ocean, the existing design prevents groundwater percolation and does not allow for redirecting storm water into other water storage structure, contradicting potential drought mitigation measures.

Interventions – *to address water related shocks and stresses*

SL. No.	Intervention	Description	Learning for other cities
1	Integrated eco-restoration of rivers	Scientific restoration of rivers through targeted interventions to effectively improve sewage management, sanitation, bio-diversity, solid waste management and flood management.	
2	Multi-hazard mapping tool	The tool will contain GIS based risk maps that detail ward/ zonal level vulnerability to climate, industrial and other non-climatic risks such as earthquakes and storm surge to effectively manage and improve disaster preparedness.	Bangkok Bristol Boston Rio de Janeiro
3	Climate Adaptation Strategy for the CMA	The plan will aim to future proof the city and neighbouring districts by identifying major climate hazards and their potential impact including one time extreme events, a framework for adaptation and identification of strategies to build climate resilience. The plan would also identify critical vulnerable infrastructure and adaptation measures for these.	Bristol Rotterdam
4	Flood monitoring and forecasting tool	The tool enables monitoring and forecasting floods at a ward/zonal level using new weather forecasting technologies, climate change, online monitoring, real-time hydro-meteorological information and modelling tools based on new scientific knowledge. This tool will be tied to the climate change adaptation strategy and include early warning systems.	Santiago

DQ 6: As the city grows into its peri-urban areas, how do we restore, protect and reintegrate the water bodies in our water catchment areas (Kancheepuram and Tiruvallur) in a sustainable manner?

In January 2018, the Housing and Urban Development Department (HUD), Government of Tamil Nadu, announced that it was considering a plan to expand the Chennai Metropolitan Area (CMA) from the current area measuring 1189 square kilometre to one measuring 8878 square kilometres. The new area would include neighbouring districts of Kanchipuram and Thiruvallur in its new boundaries. This expansion, if it follows the current pattern of unregulated growth, is likely to severely impact water bodies and green spaces, consequently hampering the capacity of individuals, communities and businesses in the city to survive and adapt to shocks and stresses, specifically related to the water system.

While, the expansion may not actually happen, actions by the government suggest it is likely. As such, a Government Order (No. 13) dated 22.01.2018 from the CMDA, provides a list of villages in Kanchipuram and Thiruvallur districts and Arrakonam and Nemili Taluks in Vellore district that are to be included in the expanded area (HUD, 2018). Further, public hearings were held in all three districts – Kanchipuram, Thiruvallur and Chennai – to record citizen views on the proposed expansion. The hearing in Chennai, held on 23rd April 2018, brought together citizens, academia and representatives from civil society organisations to voice their opinions on the expansion. These ongoing efforts indicate the possibility of future transformation that is likely to impact water bodies, ecologically sensitive zones and agricultural areas unless government undertakes strict steps to protect these assets.

Challenges

A. Land use regulations and classification

It is not clear whether the current CMDA Master Plan will apply to the extended CMA or a new plan will be prepared. There is cause for concern, however, specifically with respect to the practice/enforcement of land use regulation and classification if the current Master Plan is followed. Three specific issues exist in this regard. First, there is no consistency in the classification of water bodies under a land use category across different sections of the Master Plan. As per the Development Regulations, rivers such as Adyar and Cooum, including their buffer zones are classified under the 'open space and recreational use' category, which allows for water-front development, memorials and museums as a "normally permissible use". In addition, developments such as theme parks, sports stadiums, open air theatres etc. are allowed if CMDA provides "special sanction". However, in another section of the Master Plan (Volume 1), water bodies have been classified under 'other land use' category along with forests, the Redhill catchment area and roads, with no mention in the Development Regulations. This ambiguity, particularly in the Development Regulations is problematic because it is the primary document that determines planning permission and guides planning in the CMA.

Second, water bodies have been converted to other uses including for special and hazardous use. Roy et al. (2018b) present an in-depth analysis of the CMDA's land reclassification decisions between 2008 and 2017. They find that 10.997 ha of water bodies in the Chennai Metropolitan Area were converted to other uses during this period. Water bodies, including ponds, *erys*, lakes and canals, were mostly converted to residential and special and hazardous use areas. While the extent of water body conversion is not high, occasional permissions being granted for conversion of water bodies specifically for special hazardous use is worrying.

Third, land use regulation and classification do not completely capture the extent of water body conversion because of a fundamental flaw in the legal definition of specific water bodies such as wetlands. The colonial classification of these as *poromboke* or wastelands continues to be operational paving the way for legal development without land use reclassification. While there have been instances where wetlands have been reclassified – Pallikaranai marshland was reclassified as an ecologically sensitive zone in the mid 2000s – this is an exception and took place after several years of systematic protests and consultations.

The existing practice of land use regulation and reclassification highlights the manner in which development is occurring at the cost of the environment. It also suggests that development regulations themselves need more clarity and have to be modified in such a manner that makes them more robust and sensitive to the health of water bodies and surrounding areas. Re-classification processes also need to be made more stringent.

B. Institutional arrangement

The newly proposed expansion presents challenges for selecting an appropriate institutional arrangement that would enforce land use planning codes and monitor development to prevent encroachment on water bodies and green spaces. At present, any new development near a water body in the CMA requires a 'No Objection Certificate' from the department that owns the water body. Whether it is the CMDA that continues to enforce and monitor this or the Directorate of Town and Country Planning (DTCP) or indeed another body, the process of enforcement and monitoring should be transparent, robust and without loopholes that permit such developments. Here it is also pertinent to carefully and critically think through the ideal governance approach that would encourage a more coordinated management of land and water resources for the region, whether it is a centralised or decentralised approach or a combination of the two.

A case in comparison would be the Bengaluru Metropolitan Region which spreads across 8005 sq. km and was established in 1985. The Bengaluru Metropolitan Region Development Authority (BMRDA) comprises of 11 local planning authorities, each of which have their own master plan. However, despite decentralised local planning authorities, there is a lack of integration on the overall vision for the city's development. This has benefitted developers the most because agricultural land can be converted to urban uses relatively easily compared to before the expansion (Srivathsan, 2016). Further, several lakes in the region have disappeared and dry lake beds have been converted to residential layouts, roads, public offices and shopping complexes (PTI, 2010).

C. Expansion to meet city needs

Concerns already exist about Chennai city being heavily dependent on peripheral areas for water supply. Reservoirs, tanks and desalination plants that produce city water are located outside the city and do not cater respective local areas. In fact, concerns are increasing about negative impacts of desalination plants on local environments, livelihoods and energy requirements, as well as around whether involved costs outweigh the benefits of increased supply (Roy et al., 2018a). Further, water tanker operators that mainly serve commercial and large industrial complexes are often engaged in illegal groundwater extraction in villages outside the city, which affects local environments and lives, including farmer livelihoods that depend on this water (Nurullahl, 2017). Therefore, the challenge is to a) ensure that these existing issues do not exacerbate with the expansion, but rather ensure that there are regulatory mechanisms in place that prevent such practises and b) ensure communities can access water from local sources.

***Interventions –** to restore and protect water bodies in our water catchment areas (Kancheepuram and Tiruvallur) in a sustainable manner*

SL. No.	Intervention	Description	Learning from other cities
1	Integrated eco-restoration of rivers	Scientific restoration of rivers through targeted interventions to effectively improve sewage management, sanitation, bio-diversity, solid waste management and flood management.	Rome
2	Restoration and protection of water	Map and prioritize waterways and water bodies in CMA and identify, prioritize and prepare master	Rome

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SL. No.	Intervention	Description	Learning from other cities
	bodies and waterways within CMA	plans for water bodies and waterways in CMA for restoration. Restoration will be preceded by research on which channels have maximum water storage potential, can alleviate flooding risks etc. Protection will involve strict regulatory measures.	
4	An integrated water and waste water strategy for the larger CMA	The strategy will act as a guiding document on thinking about and planning for water and waste water in an integrated manner. It will include planning for supply and demand with multiple sources and responsibilities of different agencies and how to stop treated waste water from being let out into the sea.	Santiago New Orleans
5	Embedded and green infrastructure	Scale-up green infrastructure interventions across CMA, such as, porous paving and rainwater harvesting in driveways, to recharge groundwater and lower flooding vulnerability.	

CHAPTER 3: METHODS

A mixed method approach was followed to prepare the Diagnostic Report. This approach aimed to collect primary and secondary data through interviews, a working group meeting, a citizen survey and extensive secondary research (see figure 8).

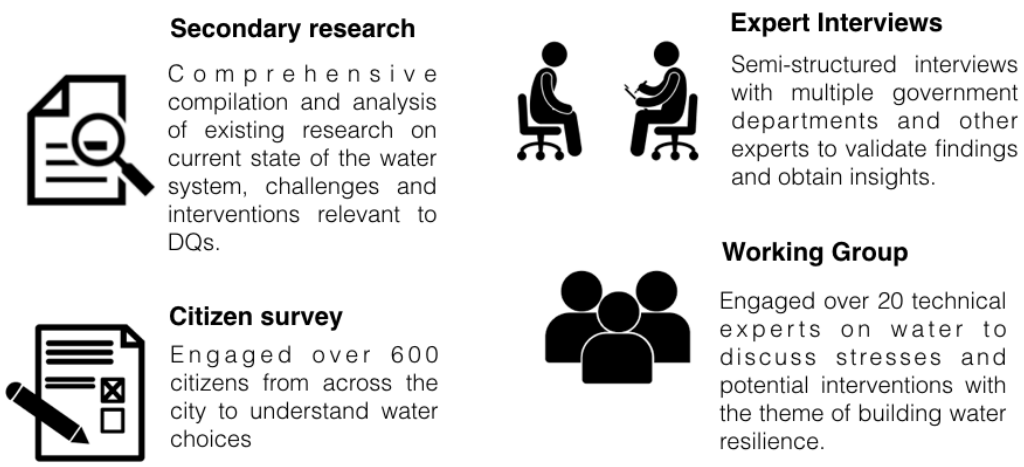

Figure 8: Methodology followed for the Discovery Area: Water Systems

Extensive secondary research was undertaken to document the current state, challenges and interventions in the water sector, with particular relevance to the diagnostic questions. Data sources included government reports, journal articles, research reports, policy documents and project reports. This desk research was complemented by a citizen survey. More than 600 citizens from across the city and socio–economic backgrounds were surveyed through electronic questionnaires and face to face interviews. The latter was conducted with residents of informal settlements. The aim of the survey was to ascertain consumer willingness to utilise recycled waste water for domestic purposes and understand the extent and impact of RWH systems (see Appendix 2 for a detailed analysis of the survey results). Simultaneously, interviews were conducted with several government officials and other experts to validate the desk research and gather insights into possible interventions (see table 2).

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Table 2: Organisations contacted for expert interviews

Organisations contacted	
Greater Chennai Corporation	Solid Waste Management Department
	Storm Water Drains Department
Chennai Metropolitan Water Supply and Sewerage Board	Planning and Development
	Hydro-Geology and Rain Water Harvesting Department
	Operation and Maintenance Department
	Waste Water Recycling
Chennai Metropolitan Development Authority	Master Plan Unit

A working group meeting was also held with over 20 technical experts on water ranging from government officials, academicians and civil society representatives. The primary purpose of the meeting was to come to a consensus on the top 10 interventions for the water sector that stakeholders, particularly the government, can implement. See appendix 1 for a summary of the outcome of this meeting along with a list of participating stakeholders and photos.

APPENDIX 1: Working Group Meeting Summary

CHENNAI'S WATER SYSTEM

Building and Improving Resilience

27th September 2018
Madras Boat Club, Chennai

RESILIENT CHENNAI
PIONEERED BY THE ROCKEFELLER FOUNDATION

OKAPI

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Over the past six months, the Resilient Chennai team has worked with multiple stakeholders from government, industries, academia, and civil society to understand the city's context and identify the key resilience challenges. Based on this stakeholder-driven process in Phase I, six broad areas have been prioritized for deeper engagement in the next phase of strategy development. These six discovery areas are: Water, Metro Governance, Civic Engagement, Informal Settlements, Healthy & Planned Urbanization and Urban Finance.

Resilient Chennai's Phase I work and pre-existing knowledge offers a strong basis for understanding the current state of affairs and key problems around each of these discovery areas. In Phase II, the focus is more on the relevant interventions and strategies that can help address the current challenges these discovery areas face.

Therefore, on the 27th of September, an Opportunity Assessment Session was organized to call upon the Water Systems working group to come together and brainstorm around actions and interventions that present an opportunity to make our city more resilient with respect to its water resources.

The experts (r*efer Appendix 1a*) on water resources from government, civic, academic, private institutions were invited to:

- Map out Chennai's water related challenges
- Ideate to find ways of addressing these challenges through technical, research-based, regulatory, and/or infrastructural interventions and
- Develop a priority list based on their understanding of what is relevant, feasible, and necessary to address Chennai's water woes.

Session 1: Problem Mapping

The discovery area was broken down in to six pertinent diagnostic questions (DQ) and the participants engaged in a brain-storming exercise to map out the relevant challenges for each of the questions. Based on the secondary research, some challenges were identified and were provided to the participants for reference.

Observations

Based on the inputs from the session, the following challenges were identified under each DQ.

DQ1: How do we promote efficient and responsible water management among end users (households)?

- Lack of awareness on importance of water management.
- Lack of community engagement and ownership.
- Current technology and appliances waste water.
- Waste water recycling: Limited sewage treatment capacity, social acceptance, cost.
- Effective Water pricing: No metering, no political will, costs of installation.
- Lack of monitoring at ward level.

DQ 2: How can we better plan for, and deal with, water related shocks (drought/floods), and stresses (climate change, sea-level rise and waste)?

- Lack of Integrated flood/drought management: reactive measures
- Poor maintenance of infrastructure
- Illegal dumping of garbage on river banks/sewage into water bodies.
- Inadequate outreach activities by government on climate change: perceived as distant threat.

DQ 3: How can we foster greater dependency on waste water recycling? How may decentralized waste water treatment systems help? (Industrial, commercial and domestic.)

- Lack of awareness of what recycling options exist.
- Lack of data on best practices – what works where & what doesn't.
- Expensive alternative.
- Sociological and psychological inhibitions.
- Lack of decentralized waste water treatment facilities.

DQ 4: How do we redesign our storm water drain systems to maximize water storage and improve water management practices?

- Lack of appropriate design: implementing design that can serve multiple functions of draining excess water and recharging water bodies.
- Poor implementation.
- Encroachment of SWDs.
- Suitability of design for Chennai's geography.

DQ 5: How can we leverage more coordinated and collective efforts by multiple agencies for better management of water system? For instance while multiple agencies are working in silos on lake restoration, how can we make these efforts more effective through coordination?

- Lack of willingness to collaborate.
- Lack of a single database with details on ongoing interventions.
- Lack of integrated planning.
- Lack of communication between line departments implementing on the ground.

DQ 6: As the city grows into its peri-urban areas, how do we restore, protect and reintegrate the water bodies in our water catchment areas (Kancheepuram and Tiruvallur) in a sustainable manner?

- Lack of regional plan.
- Lack of research on existing structures – water channels that are critical.
- No elaborate mapping exercise to identify ecologically vulnerable areas.
- Lack of institutional arrangement for more coordinated management of land and water resources in expanded CMA.
- No clear timeline on the intended expansion.

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Session 2: Interventions

This session comprised of a prioritization exercise to help identify stakeholder-driven preferences. This exercise was meant to capture possible solutions relevant to each DQ.

Based on the secondary research, a list of possible interventions was provided to the participants for reference. Please refer Appendix 1b for the initial list of interventions.

Further, they were given the bandwidth to add other interventions/solutions of their choice. The interventions recommended (added) by the participants are listed below:

S.NO	INTERVENTIONS
1	Mapping Linkages Between Waterbodies
2	Creating More Smaller Ponds Than One Big Reservoir
3	Incentivising Water Management
4	Decentralized Water Management Systems
5	Dual Plumbing for Grey Water Recycling
6	Data Repository on Best Practices for Water Recycling for Commercial and Industrial Purposes
7	Awareness Campaign on Vulnerable Areas
8	Climate Adaptation Strategy for Larger CMA
9	Flood Monitoring and Forecasting Tool
10	Common Database on Underground Infrastructure
11	Multi-Hazard Mapping Tool

Following which, the participants identified and ranked the top ten interventions from the list, based on what they thought were absolutely necessary for building resilience within Chennai’s water system. From which, the following list of interventions (see below) were consistently placed in the top ten. This prioritization will be crucial in identifying the interventions that should be shortlisted for Chennai's Resilience Strategy.

Top Ranked Interventions

RANK	INTERVENTION
1	Restoration and Protection of Water Bodies and Waterways Within CMA
2A	Integrated Eco-Restoration of Rivers
2B	Decentralized Waste Water Management Systems
3	Water Supply Network - Augmentation and Rehabilitation
4	Multipurpose and Green Storm Water Drains

5	Policy Mandate Requiring Installation of Water Meters in Domestic Buildings
6	Awareness Campaign Advocating the Use of Recycled Grey Water
7	Review and Monitoring of RWH Systems in Domestic and Commercial Buildings
8	Policy Mandate Requiring Usage of Recycled Grey Water Across CMA
9	Decentralized Waste Water Management Systems
10	Sensors for Monitoring Groundwater

The second session also sought to flesh out low priority interventions identified by participants (see below). It is worth noting that all the interventions chosen as low priority were pertaining to source augmentation. While, water source restoration and conservation practices and policies were predominantly chosen as high priority interventions. This corroborated the findings from our secondary research and was consistent with the water management narrative among key stakeholders in the city, who have advocated for restoring existing water bodies and implementing comprehensive water conservation measures against adding new sources for water supply (desalination plants, additional reservoirs etc.)

Low Priority Interventions

S.NO	INTERVENTIONS
1	New Desalination Plants
2	Fifth Reservoir for Chennai
3	New Sewage Treatment Plants

Session 3: Opportunity Assessment

In this session, participants were tasked with justifying their selection for three high priority and one low priority, chosen in the earlier exercise, based on the following parameters.
Funding, Cross cutting impact, Immediate requirement for the city, Alignment with ongoing plans/visions, Political will and Major Policy change.

Based on which the following list of interventions were scrutinised.

HIGH PRIORITY INTERVENTIONS	Integrated Eco-Restoration of Rivers
	Restoration and Protection of Water Bodies and Waterways Within CMA
	Multipurpose and Green Storm Water Drains

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	Review and Monitoring of RWH Systems in Domestic and Commercial Buildings
	An Integrated Water and Waste Water Strategy for the Larger CMA
	Decentralized Waste Water Management Systems
	Embedding Green Infrastructure in Urban Planning
LOW PRIORITY INTERVENTION	New Desalination Plants
	Fifth Reservoir for Chennai

Observations:

High priority interventions

- Most of the intervention required high willingness from the political establishment
- The impact from the interventions were cross-cutting and moved beyond the realm of water systems
- The interventions were deemed as immediate requirement for the city.
- High political willingness was observed for interventions advocating for source augmentation and interventions for source conservation did not produce enough political traction.
- Interestingly, most of the chosen interventions were in alignment with existing policies/visions/plans.

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Low priority interventions

- Despite the high funding requirement, restricted impact, long time required for implementation, these interventions had high political will.

Session 4: Call to Action

In the final session, with the problems and respective solutions marked and prioritized, participants provided open ended suggestions on how they as an individual or organization may support better implementation of the discussed interventions. Their modes of engagement could be related to the following:
Funding, Data, Knowledge, Technology, Training, Volunteer, Advisory, Design and Implementation

This exercise was positioned to understand if specific interventions have higher stakeholder support and interest. Participants chose to contribute to the following interventions:

INTERVENTION	NO. OF STAKEHOLDERS WILLING TO PARTNER
Integrated Eco-Restoration of Rivers	8
Restoration and Protection of Water Bodies and Waterways Within CMA	9
Embedding Green Infrastructure in Urban Planning	4
Water Supply Network – Augmentation and Rehabilitation	3
Sewage Network - Augmentation and Rehabilitation	3
Decentralized Waste Water Management Systems	4
Awareness Campaign Advocating the Use of Recycled Grey Water	6
Review and Monitoring of RWH Systems in Domestic and Commercial Buildings	4
Developing Comprehensive Guidelines and Blueprints for Lake Restoration	4

Observations

- Most of the participants chose Advisory/Consulting as their preferred mode of engagement
- Other preferred modes of engagement were spread across knowledge Transfer, training, technology, project design and implementation
- None of the participants chose Funding
- Very few participants, including stakeholders from the government were willing to engage in data sharing

Conclusion

The findings from the workshop proved crucial for shortlisting a definite set of intervention for improving Chennai's water systems. The recurring theme from the responses revealed that the participants were more inclined toward protecting and conserving water bodies than augmenting sources for water supply. Based on the response from Sessions 2, 3 and 4, the following list of interventions are likely to make their way into Chennai's resilient strategy.

S.NO	INTERVENTIONS
1	Restoration and Protection of Water Bodies and Waterways Within CMA
2	Integrated Eco-Restoration of Rivers
3	Decentralized Waste Water Management Systems
4	Water Supply Network - Augmentation and Rehabilitation
5	Multipurpose and Green Storm Water Drains
6	Policy Mandate Requiring Installation of Water Meters in Domestic Buildings
7	Awareness Campaign Advocating the Use of Recycled Grey Water
8	Review and Monitoring of RWH Systems in Domestic and Commercial Buildings
9	Policy Mandate Requiring Usage of Recycled Grey Water Across CMA
10	Policy Mandate Requiring Usage of Recycled Grey Water Across Industries in CMA
11	Sensors for Monitoring Groundwater
12	Embedding Green Infrastructure in Urban Planning
13	An Integrated Water and Waste Water Strategy for The Larger CMA
14	Sewage Network - Augmentation and Rehabilitation
15	Developing Comprehensive Guidelines and Blueprints for Lake Restoration
16	Electromagnetic Flow Meters for Monitoring Water Supply

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Appendix 1a

List of Participants

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Appendix 1b

Initial List of Interventions

1	INTEGRATED ECO-RESTORATION OF RIVERS	13	POLICY MANDATE REQUIRING USAGE OF RECYCLED GREY WATER ACROSS INDUSTRIES IN CMA
2	RESTORATION AND PROTECTION OF WATER BODIES AND WATERWAYS WITHIN CMA	14	DEVELOPING COMPREHENSIVE GUIDELINES AND BLUEPRINTS FOR LAKE RESTRORATION
3	NEW DESALINATION PLANTS	15	DEVELOPMENT OF A DASH BOARD ON STATUS OF RESTORATION EFFORTS FOR PUBLIC VIEWING
4	INTEGRATED STORM WATER DRAINAGE NETWORK	16	FLOOD MONITORING AND FORCASTING TOOL
5	NEW SEWAGE TREATMENT PLANTS	17	AN INTEGRATED WATER AND WASTE WATER STRATEGY FOR THE LARGER CMA
6	FIFTH RESERVOIR FOR CHENNAI	18	SENSORS FOR MONITORING GROUNDWATER
7	ELECTROMAGNETIC FLOW METERS FOR MONITORING WATER SUPPLY	19	WATER SUPPLY NETWORK - AUGMENATION AND REHABILITATION
8	MANDATORY WATER RECYCLING PLANTS FOR NEW METROWATER CONNENCTIONS	20	SEWAGE NETWORK - AUGMENATION AND REHABILITATION
9	REVIEW AND MONITORING OF RWH SYSTEMS IN DOMESTIC AND COMMERCIAL BUILDINGS	21	COMPARTMENTALIZING GRIEVANCE REDRESSAL MECHANISMS
10	POLICY MANDATE REQUIRING INSTALLATION OF WATER METERS IN DOMESTIC BUILDINGS	22	DECENTRALIZED WASTE WATER MANAGEMENT SYSTEMS
11	AWARENESS CAMPAIGN ADVOCATING THE USE OF RECYCLED GREY WATER	23	EMBEDDING GREEN INFRASTRUCTURE IN URBAN PLANNING
12	POLICY MANDATE REQUIRING USAGE OF RECYCLED GREY WATER ACROSS CMA		

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Appendix 1c

APPENDIX 2: Water Citizens survey

Introduction

This document presents results from a survey conducted with 543 residents of the city. The purpose of the survey was to a) understand resident's views and practices on water conservation, pricing and recycled water and b) validate our secondary research.

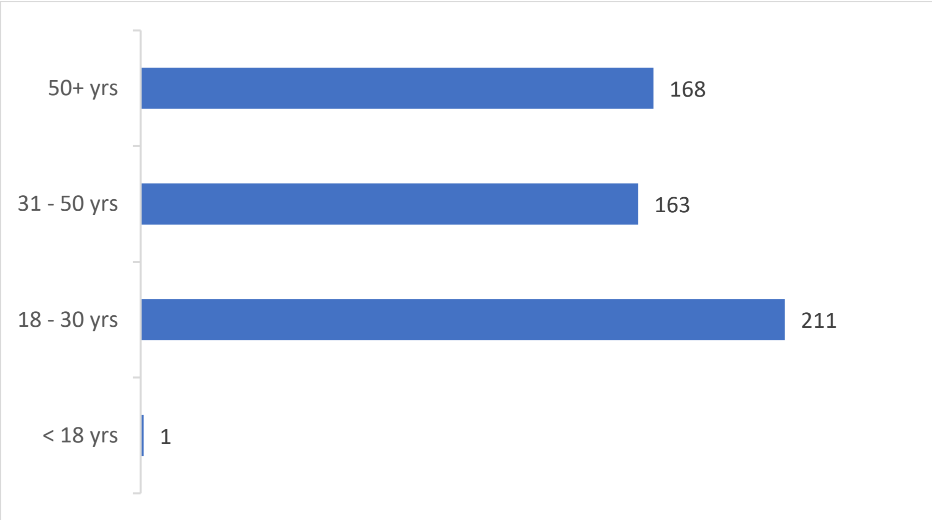
Key results

- Majority of respondents (~85%) have a post-graduate education suggesting that results might be skewed towards middle class and higher
- Respondents have multiple water sources and most common are bore wells, water from Metro Water and packaged water (bubble top cans).
- More than half the respondents (~51%) are willing to pay a higher price for 24*7 and ~71% support government policy on water metering and consumption based tariff.
- Based on a self-assessment, ~48% respondents stated that they conserve water while ~37% stated they 'somewhat conserve'.
- Around 29% of respondents conserve water through regular maintenance of leaks and rain water harvesting systems respectively.
- Only ~25% of respondents use recycled water, mostly for flushing, gardening and car washing.
- However, ~59% are willing to consider using recycled water in future. This decision depends primarily on two factors – 'feeling good for conserving' and 'operation and maintenance'. Interestingly, only ~11% chose 'yuck factor' contradicting what several government officials believe is the primary detriment.

Results

A. Socio-economic background of respondents

Age



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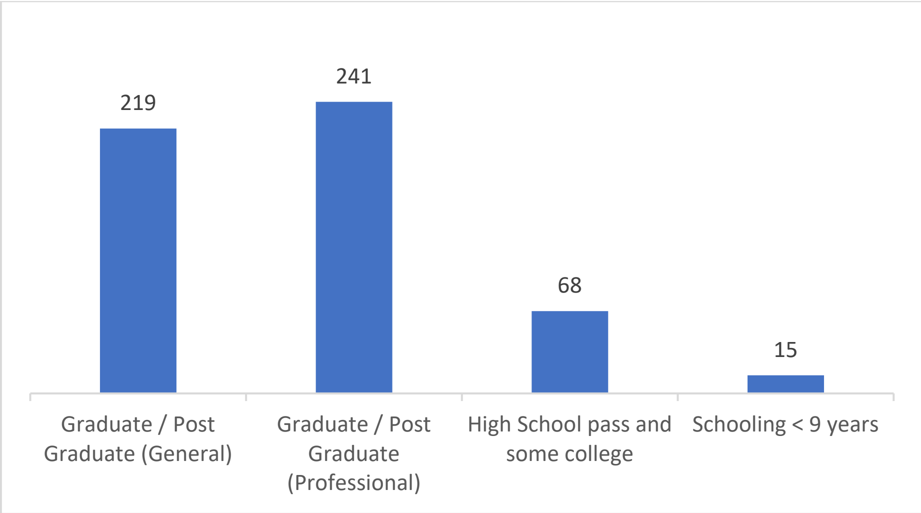
Educational Background:



Representation of zones:

Zones	Count of Zone	Percentage
Tiruvottiyur (I)	33	6.08%
Manali (II)	3	0.55%
Madhavaram (III)	3	0.55%
Thiru-Vi-Ka Nagar (VI)	5	0.92%
Royapuram (V)	28	5.16%
Tondiarpet (IV)	9	1.66%
Ambattur (VII)	15	2.76%
Anna Nagar (VIII)	109	20.07%
Teynampet (IX)	60	11.05%
Kodambakkam (X)	69	12.71%
Valasaravakkam (XI)	29	5.34%
Alandur (XII)	25	4.60%
Adyar (XIII)	68	12.52%
Perungudi (XIV)	70	12.89%
Shollinganallur (XV)	17	3.13%
Grand Total	**543**	

Representation of informal settlements:

Row Labels	Count of Informal Settler
Informal Settlers	88
Total	**88**

Primary Water source(s):

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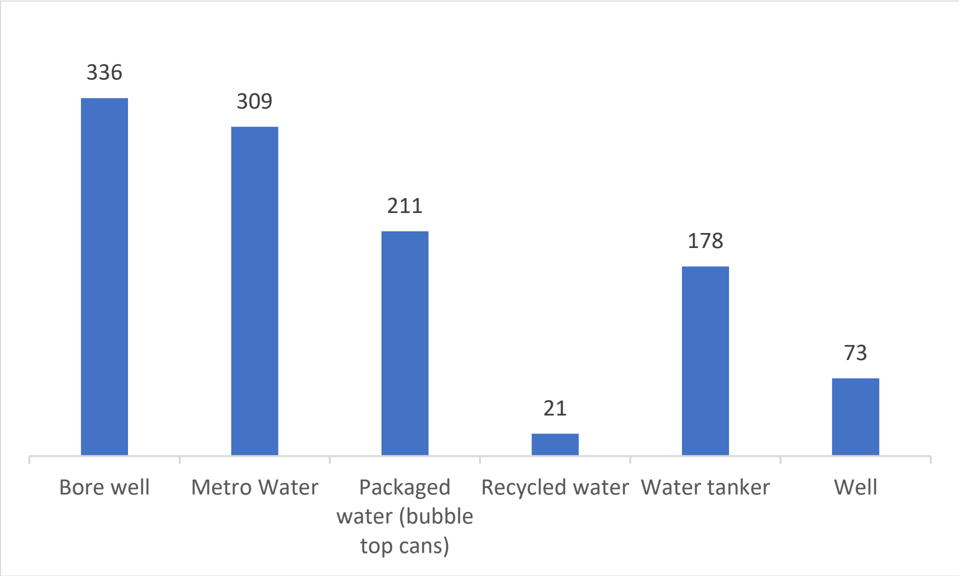
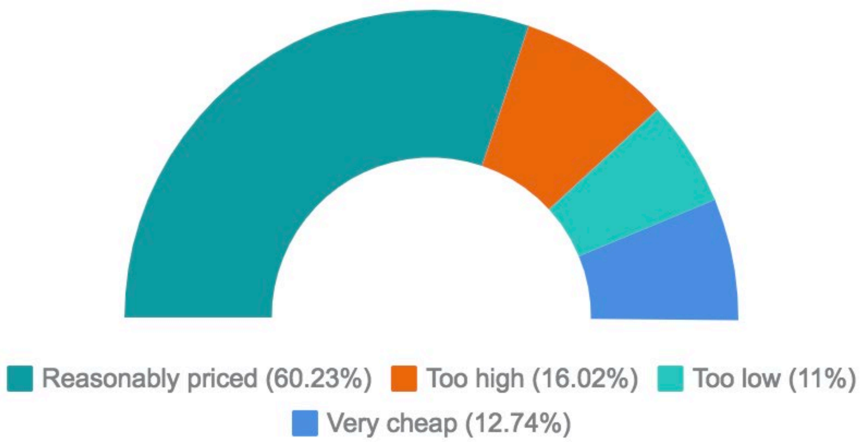


Summary

- The educational background of respondents reveals a bias towards the middle class with high levels of qualification. Around 85% of respondents have a post graduate degree – either general or professional. This could be a result of the manner in which the survey was conducted – through an online platform, shared through WhatsApp.
- Approximately 69% of respondents were from the zones, Anna Nagar, Adyar, Kodambakkam, Teynampet and Perungudi predominantly in the core area of the city, except Perungudi. Other zones are under-represented.
- The survey also includes a representation of low income communities living in informal settlements across different zones, thereby attempting to cover a range of people with varied socio-economic backgrounds.

B. Water pricing and metering

Current opinion on water charges



Current opinion on water charges only among informal settlements

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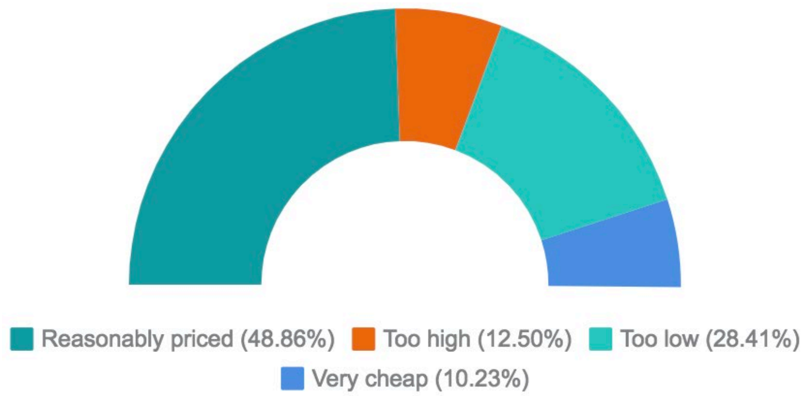
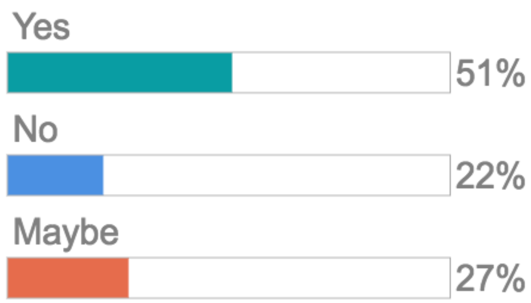
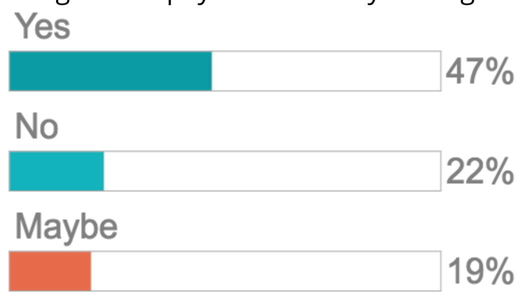


Willingness to pay for 24*7 water



Willingness to pay for 24*7 only among informal settlements



Supporting government policy on water metering

Support govt. policy on water meters and consumption based payments	**Count**	**Percentage**
Yes	391	72.01%
No	71	13.08%
Maybe	81	14.92%
Total	**543**	

Summary:

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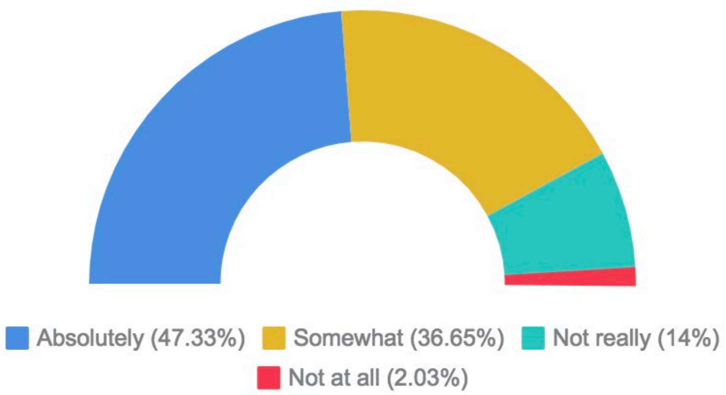
- By and large, respondents believe that water charges in the city are reasonable (~60% and ~ 49% in informal settlements).
- However, ~51% of respondents are willing to pay a higher price for 24*7 and ~71% support government policy on water metering and consumption based tariff.

C. Water conservation and rain water harvesting

Self-assessment of water conservation



Methods used to conserve water

How do people conserve water	Count
Dual flush	157
Regular maintenance	325
Water efficient shower heads	187
RWH	325
Recycling	13
Other	23
Not Applicable	82

Type of RWH system used

Type of RWH system	Grand Total
Connected to open well	2
Don't know	138
Dug wells	35
Hand pumps	17
Lateral shaft with bore wells	19
Recharge shafts	38
Recharge wells	104
Spreading techniques	25
Trenches	36
Other	2
Not applicable	127
Total	**543**

Reasons for not practicing RWH

Reasons for not practicing RWH	count
Finding the right people to install it	83

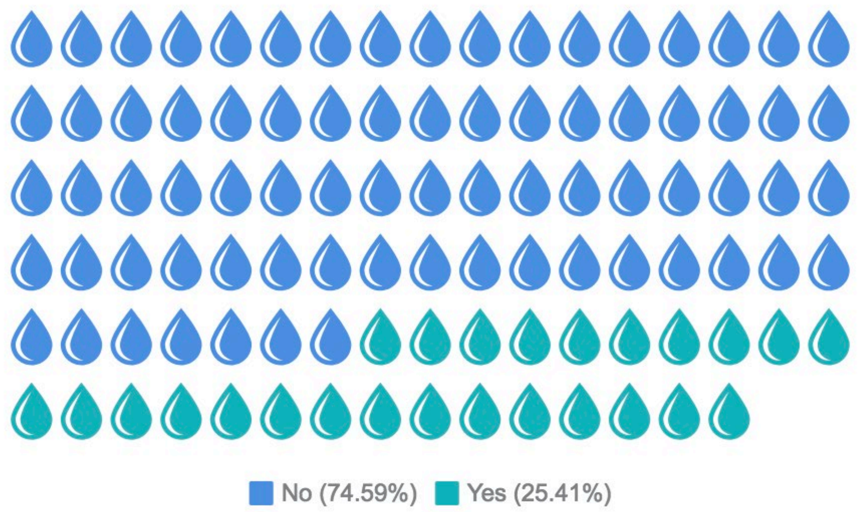
Maintenance	76
Price	22
other	1
Not aware	51
Not applicable	348
No space	3
Total	**543**

Summary

- Based on a self-assessment, ~48% respondents stated that they conserve water while ~37% stated they 'somewhat conserve'.
- Around 29% of respondents conserve water through regular maintenance of leaks and rain water harvesting systems respectively.

D. Water Recycling

Self- assessment: Do you use recycled water ?



Do you recycle water? (by dwelling type)

Currently use recycled water at home for domestic purpose?	Yes	No	Total
Flat	75	216	291
Independent house	55	170	225
Others	8	19	27
Total	**138**	**405**	**543**

Purposes for which recycled water is used

if yes, for what?	Count

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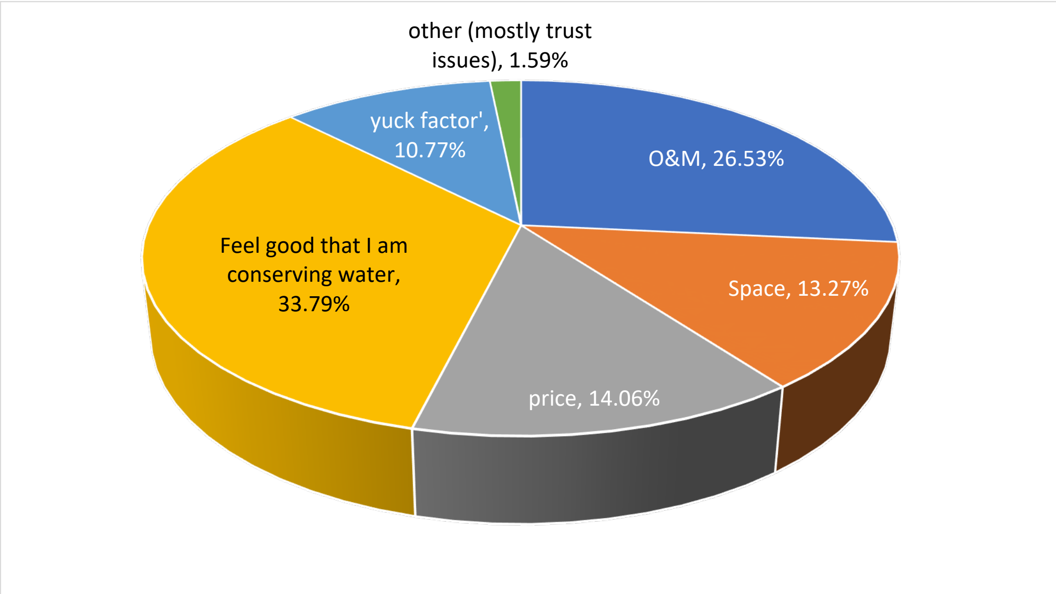
Toilet/ Flushing	143
Gardening	140
Car Washing	72
Cleaning and washing	6
Not Applicable	311
Other	2
Total responses	**679**

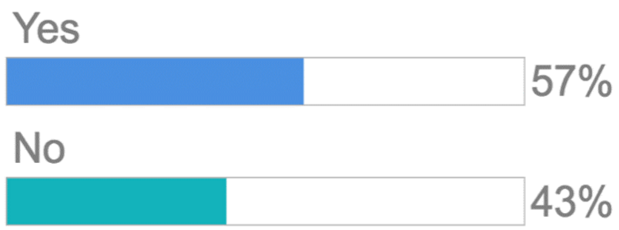
Would you consider using recycled water in future?

If NO, would you consider using waste water that is recycled by the government for domestic purposes in future?	Count	Percentages
Maybe	159	29.28%
No	61	11.23%
Yes	323	59.48%
Total	**543**	

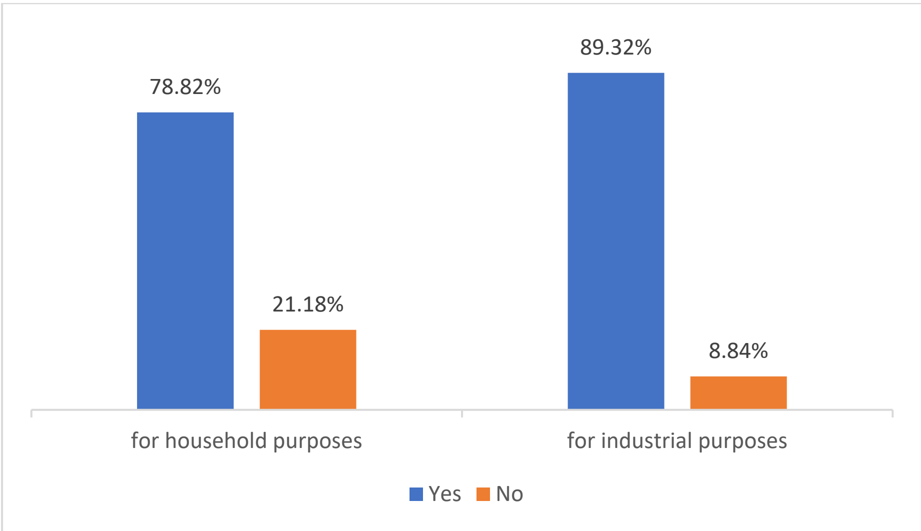
Factors that influence decision to recycle/not recycle water



Willingness to pay for recycled water



Support for government policy on recycling



Summary

- Only ~25% of respondents use recycled water, mostly for flushing, gardening and car washing, irrespective of whether they live in a flat or individual house
- However, ~59% are willing to consider using recycled water in future. This decision depends primarily on two factors – 'feeling good for conserving' and 'operation and maintenance'. Interestingly, only ~11% chose 'yuck factor' contradicting what several government officials believe is the primary detriment.
- An overwhelming ~90% of residents support government policy on water recycling for industries while ~79% support government policy on water recycling for domestic use.

Methods

- Reached out to more than 600 respondents through an electronic survey. In addition, 100 face to face interviews with residents of informal settlements were conducted.
- The survey was structured with multiple-choice questions.
- Data cleaning process: removal of duplicate entries, correcting pin codes, removal of responses outside Chennai and matching pin codes to zones; Open ended/ qualitative responses were coded; Outliers were excluded.

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