सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India

Water Resources Management

TRAINING MANUAL

NIUA | C3
Climate Centre for Cities

ClimateSmart Cities Assessment Framework

Water Management

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Water Resources Management
Training Manual

Developed by:
Climate Centre for Cities, NIUA

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December, 2021

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Executive Summary

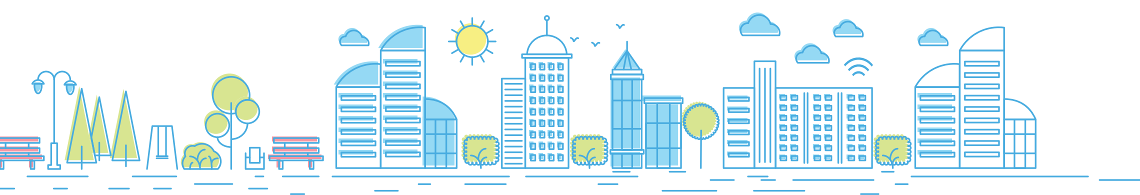
On one hand, cities are a significant contributor of carbon emissions aggravating climate change and on the other, cities are considerably impacted by climate disasters. The recently released Global Climate Risk Index 2021 ranks India as the 7th most affected country from climate related extreme weather events *(storms, floods, heatwaves etc.)*. Further, studies indicate that poor planning and urban management are expected to cost Indian cities somewhere between $2.6 and $13 billion annually. Cities are increasingly at the forefront of addressing both urbanization and climate change and to strengthen climate-sensitive urban development, a holistic understanding of the urban development from a climate lens is crucial. The ClimateSmart Cities Assessment Framework (CSCAF) launched in 2019 by the Ministry of Housing and Urban Affairs (MoHUA), Government of India aimed to address this gap. This first-of-its-kind assessment with 28 progressive indicators across 5 thematic areas helps cities to benchmark their development, understand the gaps and further prioritize climate relevant development.

With a focus on building local capacities to develop and adopt climate measures, the Climate Centre for Cities (C-Cube) at the National Institute of Urban Affairs (NIUA) initiated a series of training aligned to the thematic areas of CSCAF - Energy and Green Buildings, Urban Planning, Green Cover & Biodiversity, Mobility and Air Quality, Water Management, Waste Management. The focus of the training is to provide a step-by-step approach of conducting studies, assessments and stakeholder consultations, establishing committees, developing action plans and implementing relevant measures that not only makes the cities climate resilient but also helps them progress across the assessment of CSCAF. The focus of this training is on the 'water resource management' indicator under the thematic areas of water management in the CSCAF.

The number of cities facing great rise in water risks across the world has been rapidly increasing in recent times. The challenges around availability and quality of water resources specifically in urban areas have been exacerbated by rapid urbanisation and climate change. Climate change has altered rain fall patterns increasing intensity of droughts and floods. This module focuses on taking stock of current and future water demand and availability in the context of climate changes and adopting appropriate measures for water management.

The objective of this module is to build capacities of smart cities to understand and improve their performance with respect to the CSCAF indicator 'water resource management' by enabling them to undertake informed climate action. The training will be provided to select training institutes for further dissemination.

The module will elaborate on hydrological cycle and the impact of urbanisation and climate change on availability of both surface and ground water in cities and the concept of water scarcity, stress and risks along with concept of 'Day Zero'. Policies, programmes and guidelines influencing water resource management are touched upon. The learnings from this module will enable cities to conduct water resource assessments and formulate water resource management plan to include strategies to be implemented on ground to address the shocks and stresses climate change poses to cities.



Who is the training manual designed for?

What is the focus of the training manual?

How to make use of this manual?

What are the Learning outcomes of the training?

Scope and limitations of the training

The training module on the indicator Water Resource Management is intended for Urban Local Bodies (ULBs), specifically the water utility department and other water service providers along with other development authority or parastatal officials involved in water management and water supply service delivery in urban areas. A basic understanding or water supply service delivery systems in urban areas is a prerequisite for various the stakeholders.

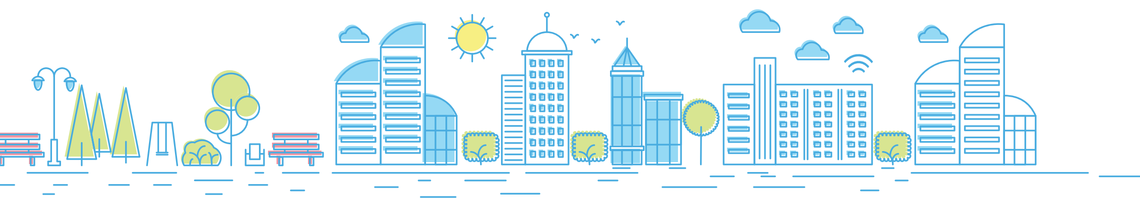
This training manual focuses on understanding the impacts of urbanisation and climate change on the availability and quality of water resources in urban areas. It highlights the principles around water as a resource which influence how water resources management strategies. It outlines the components of a water resource management plan incorporating climate impact scenarios and includes elements of a water resource assessment which is imperative in taking stock in current and future demand and availability. Based on the assessment strategies need to be formulated for effective implementation.

This manual is to be used as a technical reference material which delves into details touched upon in the presentation with references to additional reading material to aid participants in following the training sessions.

The learning outcomes of this training for cities is to develop a better understanding of water resource management and introduce effective ways for implementing actions plans for water management addressing climate related risks. This training module would also equip cities in conducting water resource assessments to establish current and future demand and availability based on which strategies can be formulated and implemented.

As the training module is designed and developed as a 2 – hour online training session with interactive exercises for city officials its scope is limited to establish a basic understanding of water as a resource, requirements of the CSCAF indicator and outline of water resource management plan and assessments.

Contents



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Abbreviations

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BBMP	Bruhat Bangalore Mahanagara Palike
BDA	Bangalore Development Authority
BWSSB	Bangalore Water Supply and Sewerage Board
CDP	City Development Plans
CGWB	Central Ground Water Board
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health & Environmental Engineering Organisation
CSCAF	ClimateSmart City Assessment Framework
CSE	Centre for Science and Environment
DEM	Digital Elevation Model
EWR	Environmental Water Requirement
GEMS	Global Environmental Monitoring System
IEC	Information, Education & Communication
IMD	India Meteorological Department
IUWM	Integrated Urban Water Management
IWA	International Water Association
IWRM	Integrated Water Resource Management
LID	Low Impact Development
LPCD	Litre Per Capita Per Day
LULC	Land Use / Land Cover
MINARS	Monitoring of Indian National Aquatic
MoHUA	Ministry of Housing and Urban Affairs
NIUA	National Institute of Urban Affairs
NBS	Nature Based Solutions
NSSO	National Sample Survey Office
NWMP	National Water Quality Monitoring Program
NWP	National Water Policy
PCC	Pollution Control Committees
RCUP	River Centric Urban Planning
RWH	Rain Water Harvesting
SPCB	State Pollution Control Boards
SPV	Special Purpose Vehicle
STP	Sewage Treatment Plants
UFW	Unaccounted for Water
ULB	Urban Local Body
UN	United Nations
UN DESA	UN Department of Economic and Social Affairs
UTTIPEC	Unified Traffic and Transportation Infrastructure
WRA	Water Resource Assessment
WRIS	Water Resources Information System
WRM	Water Resource Management
WSUD	Water Sensitive Urban Design
WTP	Water Treatment Plant
WWF	World Wide Fund for Nature
YAP	Yamuna Action Plan

Photo Credits: Riverfront Indore Smart city

1

Water as a Resource

1.1. Are we running out of water?

1.3.1. Are we running out of water?

As of 2018, around 55% of the world's population was living in urban areas and it is estimated that by 2050 this would increase to around 68% of the world's population. A majority of this increase will be taking place in Asia and Africa and further the *2018 Revision of the World Urbanisation Prospects* notes that this increase will be highly concentrated in just a few countries. The same report projects that India will add 416 million urban dwellers by 2050 (*UN DESA, 2018*). In 2020, about 2 billion people i.e 26% of the world's population lacked safely managed drinking water services (*UN-Water, 2021*). This rapid urbanisation will pose serious implications on the demand for fresh water resources and its availability, which will only be exacerbated by factors of climate change.

It has been observed in recent times, that the instances of water-related risks such as floods and droughts are occurring more frequently and their severity has also increased. With 2.3 billion people residing in water-stressed countries (*UN-Water, 2021*) and 100 cities are facing the greatest rise in water risks by 2050 house 350 million people (*WWF, 2020*). As per the WWF Water Risk Filter which lists cities with overall water risk for the current and future, India dominates with 30 of 100 cities listed.

In India currently 31% of urban households lack access to piped water or public tap as per the 2015-16 National Family Health Survey and the per capita water availability is dwindling (*Padmanabhan & Srivastava, 2019*).

Figure 1: State of drinking water services globally and in India.

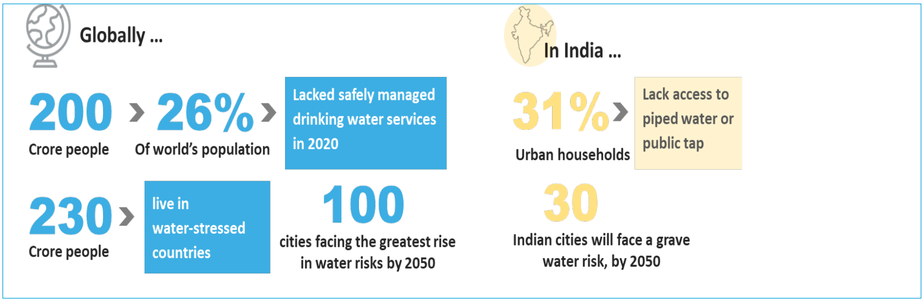

Image credits: Author

These statistics provide a glimpse of the water-related stresses and shocks climate change could bring forth in the near future. In order to get ahead of these challenges cities should prioritise initiatives to better understand the complexities surrounding the management of water resources and their principles in practice.

Figure 2: Newspaper articles on water-related risks.

The 11 cities most likely to run out of drinking water - like Cape Town

11 February 2018

BBC NEWS

GETTY IMAGES

A quarter of the world's major cities face a situation of water stress

CLIMATE CHANGE

36 per cent cities to face water crisis by 2050

An estimated 400 million people currently live in cities with perennial water shortage. The number is slated billion by 2050 due to rising urban population and the impact of climate change

By Shreeshan Venkatesh, Sushmita Sengupta

Published: Saturday 31 March 2018

India's urban water crisis: Cities at risk of running out of water

By 2050, at least 30 Indian cities will face a grave water risk, according to the WWF. The problems range from poor management of water sources, contaminated supplies, leaky distribution networks and vast volumes of untreated wastewater being poured into India's rivers.

Kaushik Deka

New Delhi March 20, 2021

ISSUE DATE: March 29, 2021 | UPDATED: March 22, 2021 14:03 IST

Roughly 30 Cities in India Will Face Acute Water Crisis by 2050

03/11/2020

Women fetch water from an opening made to filter water next to a polluted lake in Thane, India June 13, 2019. Photo: Reuters/Prashant Waydande.

THE WIRE STAFF

New Delhi: A survey has found that nearly 30 cities in India, including Jaipur,

Image credits: Author, compiled from various newspaper articles[1]

1.2. Fresh water is a renewable resource but it is finite in nature

Water is a renewable resource and all of Earth's water is naturally recycled through the water cycle or hydrologic cycle. The hydrological cycle is the continuing process of evaporation of water from the various surfaces, followed by condensation to form clouds, these clouds accumulate and precipitate to form rainfall which runs across surfaces in the form of surface water bodies and the water further percolates into the ground to form ground water which is collected in aquifers. The hydrological cycle directly affects the avail ability of freshwater resources and anthropogenic activities such as excessive withdrawals and pollution disrupt this natural process and result in water-related risks (*SIWI, 2020*)

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[1] *Newspaper articles include BBC News - The 11 cities most likely to run out of drinking water - like Cape Town. https://www.bbc.com/news/world-42982959 , Down to Earth - 36 per cent cities to face water crisis by 2050. https://www.downtoearth.org.in/news/climate-change/36-per-cent-cities-to-face-water-crisis-by-2050-59985 India Today - India's urban water crisis: Cities at risk of running out of water. https://www.indiatoday.in/magazine/nation/story/20210329-the-cities-of-woe-1781275-2021-03-20 and The Wire - Roughly 30 Cities in India Will Face Acute Water Crisis by 2050. https://science.thewire.in/environment/wwf-water-risk-filter-india-cities/*

Figure 3: Natural water cycle or Hydrological cycle.

Image credits: Artisticco (2014). Water Cycle illustration. DepositPhotos. https://depositphotos.com/59989075/stock-illustration-water-cycle-illustration.html

With 97% of the Earth's water resources in the form of saltwater and only 3% as freshwater of which 70% is in the form of glacier ice, water is a limited resource. Water is required to support both ecological systems and serve human needs for economic and social development (SIWI, 2020).

Water resources classified based on type of water resources into –

1. Natural sources such as rain, snow, hail or sleet which are precipitated on the surface.
2. Surface water accumulates as a result of direct runoff from precipitation in the form of streams, lakes and ponds which are natural or artificial storage sites.
3. Ground water which is precipitated water that infiltrates into the ground.

Water is also classified based on its usage in the production chain as green water, blue water, grey water or black water.

1.3. The Urban Water Cycle

Figure 4: The urban water cycle.

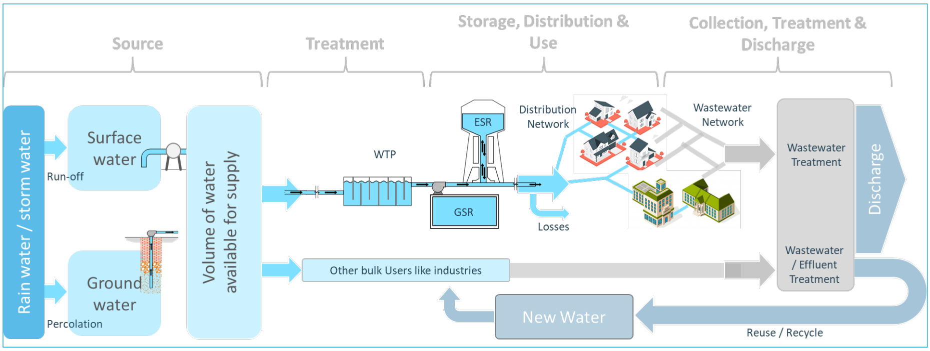


Image credits: Author

The urban water cycle is the process by which water from the environment or the source is delivered to its consumers and is sent back to the environment or the sink after treatment. The steps in the urban water cycle include –

1. The **Source** from which the volume of water required for consumption for various purposes can be obtained.
2. The **Treatment** of water obtained from the source is required to meet drinking water standards in the Water Treatment Plants (WTPs)
3. The treated water required **Storage** along the service chain in elevated storage reservoirs or under-ground storage reservoirs.
4. **Water distribution** from the treatment plant to the reservoirs and finally to the end-user is done through a network of pipes.
5. The **wastew**ater which is generated is collected through the sewerage network or through on-site systems.
6. Wastewater Treatment is required to remove contaminants from the water.
7. The treated wastewater is then **discharged** back into the environment (IDRICA, 2020).
8. In recent times, with the increase in instances of water shortages, efforts are being undertaken to **reuse and recycle** the treated wastewater. This treated wastewater which is reused and recycled is referred to as 'New water'.

This urban water cycle has enabled water to be distributed from the environment to the end-users with ease however it has caused serious disruptions to the hydrological cycle as the rate of withdrawals have increased drastically.

1.4. Definitions of water scarcity, water stress and water crisis

Water Scarcity, refers to the lack of volumetric abundance of freshwater resources (*CEO Water Mandate Secretariat, 2014*). Scarcity is a human-driven factor and is calculated as the ratio of total water consumption to the total available renewable supply. It refers only to the physical abundance of fresh water.

Water consumption is the volume of freshwater extracted for consumptive use and not returned after use.

Physical scarcity is when more than 75% of river flows are withdrawn for usage.

Economic scarcity is when less than 25% of river flow is withdrawn due to lack of appropriate infrastructure (*Seckler et al, 1998*).

Figure 5: Relationship between water scarcity and stress.

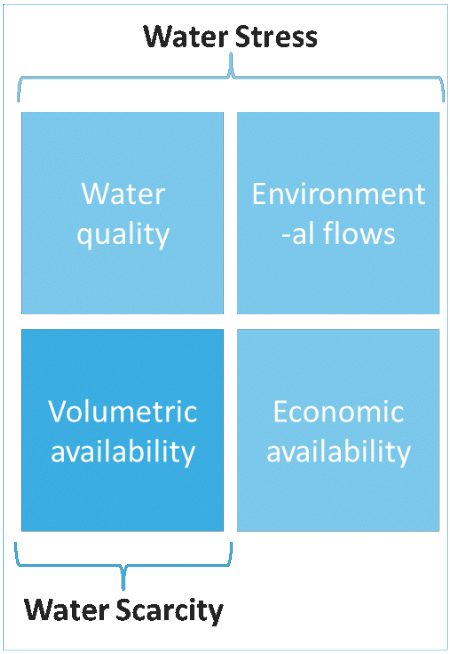


Image Credits: (Shiao & Reig, 2013) Clarify Water Stress, Water Scarcity, and Water Risk. (Slide 6)

Water Stress, refers to the lack of ability to meet human and ecological demand for fresh water (*CEO Water Mandate Secretariat*, *2014*). It's a broader concept and is more inclusive. It considers not only the physical abundance of freshwater but also includes aspects of water availability, quality and accessibility to water which is a function of infrastructure and affordability. It also includes the requirement for environmental flows. Water stress is calculated as ratio of the total water withdrawal to the total available renewable supply.

Water Risk, refers to the possibility of an entity experiencing a water related challenge such as floods, droughts or infrastructural decay. The extent of the risk depends on the likelihood of a specific challenge and the severity of the challenge (*CEO Water Mandate Secretariat*, *2014*).

Water withdrawals is the total volume of water extracted from surface or ground water sources, without accounting for how much of this water can be replenished. Water stress requires an understanding of the consumption and withdrawal of water.

Comparing the volume of "consumption" relative to available water resources allows one to understand how much water is remaining in the freshwater source, and is directly related to the concept of "scarcity". Additionally, understanding whether the volume of "withdrawals" exceeds available water resources in a given area, sheds light on whether this is enough water to meet human and ecological demand (*CEO Water Mandate Secretariat*, *2014*).

Environmental water flows or Environmental Water Requirement (EWR) is the mean total annual volume of water that is needed by the aquatic ecosystems to maintain it.

Environmental water stress is an indicator of the proportion of utilizable water in the world river basins being withdrawn for direct human use and where it conflicts with EWR.

Surface water stress or scarcity refers to the ratio of withdrawal of surface water to the total available resource. Ground water stress or scarcity similarly refers to the ratio of withdrawals of groundwater to the total available resource (*The World Bank*, *ND*).

The idea of Day zero was introduced in Cape Town when the city experienced extreme water shortages and the consumption of water was managed by coaxing consumers to reduce their usage (*Winter*, *2018*). Day zero is when most of the city's taps will be switched off literally (*Winter*, *2018*). In Cape Town, as the city was approaching day zero residents had to stand in line to collect 25 *litres* of water per person per day, and active water rationing was started and water from residential and business taps was cut off and people were forced to go to collection sites to access drinking water.

1.5. Water Resources Management

Cities face challenges of water shortages, scarcity and stress due to various factors such as –

1. Rapid urbanisation due to population growth or migration
2. Over extraction of water to meet the demands from competing uses or their inability to establish an economic value for water.
3. Climate change brings rise to extreme weather conditions leading to high intensity rainfall in short durations along with longer duration of dry spells.
4. Most cities are dependent on water from distant sources which exacerbates the problems.
5. Cities also lack appropriate infrastructure in terms of storage or treatment capacities which also give rise to the challenges of water stress and scarcity.

In order to tackle these challenges cities need to adopt Water Resource Management actions (*World Bank, 2017*).

Water Resources Management (WRM) is the process of planning, developing, and managing water resources, in terms of both water quantity and quality, across all water uses. It requires the support and guidance of institutions, infrastructure, incentives, and information systems. Water resource management also entails managing water-related risks, including floods, drought, and contamination (*World Bank, 2017*).

Figure 6: Water Resource Management.

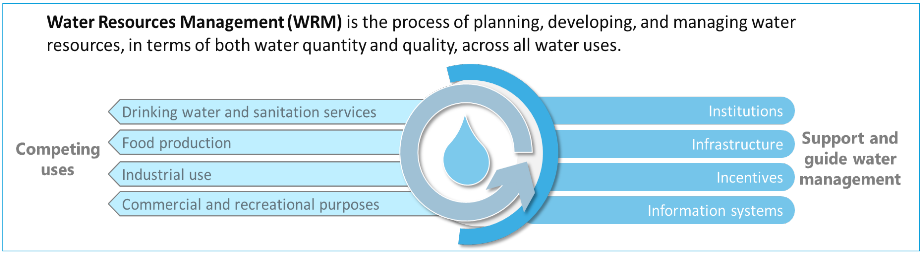


Image credits: Author adapted from World Bank (2017) Water Resources Management – Strategy. *https://www.worldbank.org/en/topic/waterresourcesmanagement#2*

1.6. Policies Programmes and guidelines with respect to water resource management

In India, the management of water resources is guided by various policies and programmes established over many years. The jurisdiction of water resources in India with respect to their planning, development and management is with the States as per the 7th Schedule. As per the 74th Constitutional Amendment under the 12th schedule it is the responsibility of the Urban Local Bodies (ULBs) to provide water supply to citizens within their jurisdiction.

Legal provisions related to water are available in the constitution, court decisions, central and state laws, and various irrigation acts. However, India does not have any exclusive or comprehensive water law (*Cullet & Gupta, 2009*). India does not have any specific law defining the ownership of and rights over water sources making it difficult to govern and manage these resources efficiently. In recent times numerous efforts are being undertaken to enable better management of water resources specially ground water.

The National Legislations as applicable to water include - Water prevention and Control of Pollution Act 1974; Air prevention and Control of Pollution Act 1977; Environment Protection Act 1986; Forest Conservation Act 1980 and amended in 1988; Public Liability Insurance Act 1991; Environment Assessment Development of Projects, 1994.

Figure 7: Institutional Framework for Urban Water Supply Services

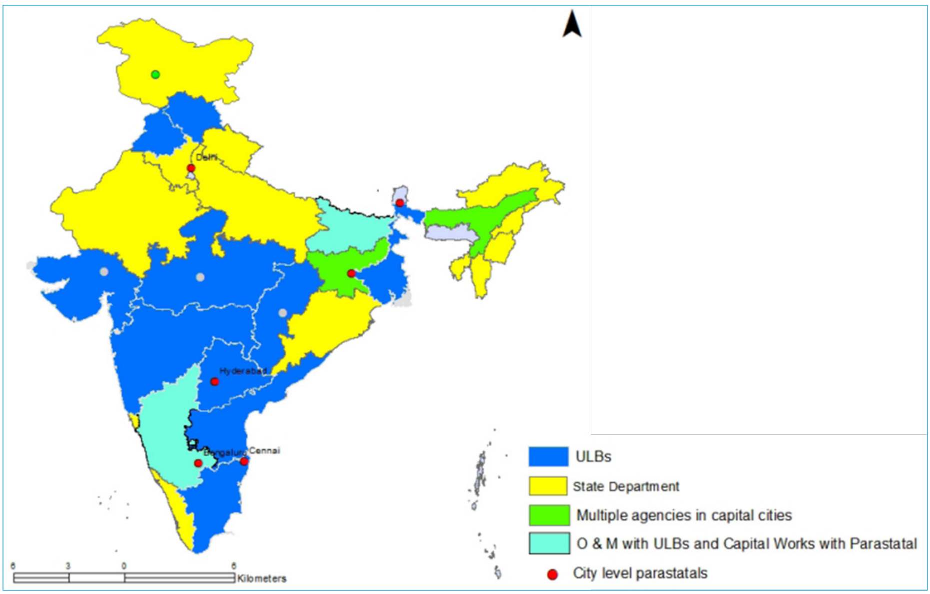


Image credits: Crisil Infrastructure Advisory, Abhay Kantak (n.d) Institutional Framework for urban water supply services. https://mohua.gov.in/upload/uploadfiles/files/PPT_CRISIL_Water_Sector_0.pdf (Slide 14).

The following are the policies, programmes and guidelines influencing current water resource management initiatives.

1.6.1. National Water Policy 2012

The Ministry of Water Resources, now the Jal Shakthi Ministry of the Government of India, formulated the National Water Policy (NWP) 2012 to govern the planning and development of water resources for efficient use building on learnings from previous policies NWP 1987 and NWP 2002. The objective of the NWP 2012 is to take cognizance of the existing situation and propose a framework for the creation of a system of laws and institutions for better water management (*MoWR, GOI, 2012*).

The NWP 2012 outlines certain basic principles for governing water resources which includes having an integrated perspective at local, state and national levels for planning and management of water resources, giving consideration to minimum ecological needs, safe water and sanitation as a pre-emptive need and the need to factor in the impact of climate change on water resources to state a few.

The NWP 2012 emphasises the need for planning and management of water resources to incorporate strategies for adaptation to climate change. It also prioritizes enhancing water availability as a whole through regular assessments of trends in water availability and accounting the water allocations for different uses. Another important aspect the NWP 2012 focuses on is the conservation of river corridors, water bodies and infrastructure in a scientifically planned manner while engaging with the various stakeholders.

1.6.2. CPHEEO guidelines

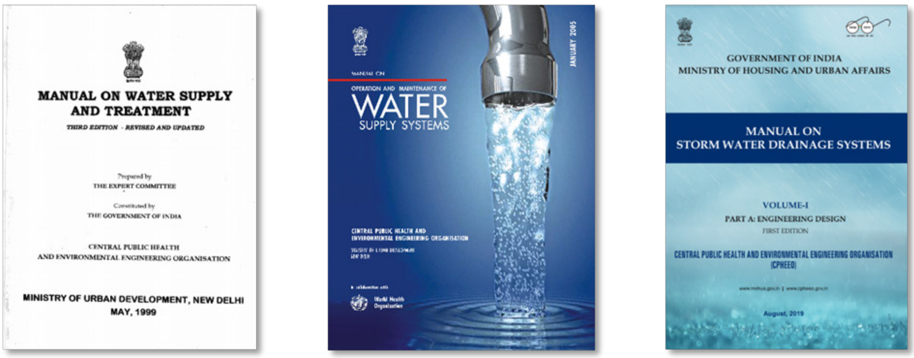
The Central Public Health & Environmental Engineering Organisation (CPHEEO) provides detailed manuals, advisories and guidelines on the planning, design, operation and maintenance of water supply, sanitation and storm water drainage systems.

The Manual on Water Supply and Treatment 1999 provides planning and design guidelines, water quality guidelines, per-capita water supply norms, water sources and an assessment of their yield and development methods and various water conservation measures. This manual also details out the methods for design of water transmission systems and water treatment technologies. It also details the content of detailed project reports and feasibility reports.

The Manual on Operation and Maintenance of Water Supply System – 2005 details out the need for modification in the policy framework for effective operation and maintenance of water supply systems including the need for Public-Private Partnership and issues around Unaccounted for Water (UFW) or Non-Revenue Water and metering of water supply systems. It includes strategies for good Operation and Maintenance (O&M) along the entire water supply service chain from the source till the end-user.

The Manual on Storm Water Drainage Systems – 2019 comprises two volumes, one on the engineering design and the second on the operation, maintenance and management. This manual identifies the causes of urban flooding and details out methods for project planning and investigation and preparation of city drainage master plans. It also provides methods for conducting rainfall analysis and runoff estimation. It also mentions methods for integration of rainwater harvesting in storm water drainage design and other innovative storm water management practices like Water Sensitive Urban Design (WSUD) and Low-impact Design (LID) which look at integrating green infrastructure with existing grey infrastructure systems.

Figure 8: CPHEEO guidelines for water supply and storm water systems.



Manual on Water Supply and Treatment (1999) - http://cpheeo.gov.in/cms/manual-on-water-supply-and-treatment.php

Manual on Operation and Maintenance of Water Supply System (2005) - http://cpheeo.gov.in/cms/manual-on-operation--and-maintenance-of-water-supply-system-2005.php

Manual on Storm Water Drainage Systems (2019) - http://cpheeo.gov.in/cms/manual-on-storm-water-drainage-systems---2019.php

1.6.3. Jal Jeevan Mission – Urban

The Jal Jeevan Mission - Urban launched on 2nd February was rolled-out to provide a comprehensive and holistic approach to achieve a water-resilient future for India (*Jainer & Basak, 2021*) and tackle water risks which are more intense and frequently occurring. The main objective of Jal Jeevan Mission - Urban is universal coverage of water supply to all households through functional taps in all 4,378 statutory towns in accordance with SDG Goal- 6. However, it also prioritizes the rejuvenation of water bodies to augment sustainable fresh water supply, circular economy of water, technology Sub-Mission for water, IEC campaign about conservation of water (*MoHUA, GOI, 2021*). The mission prioritizes the preparation of City Water Balance Plans, City Used Water or City Reuse Plans and City Aquifer management Plans. The central government will provide funding for initiatives based on the population of cities (*MoHUA, GOI, 2021*).

Photo Credits: Chennai Smart City

2

CSCAF Indicators for Water Management

The ClimateSmart Cities Assessment Framework includes six indicators for Water Management which are:

- **Water Resources Management**
- Extent of Non-Revenue Water
- Wastewater Recycle and Reuse
- Flood/water stagnation risk management
- Energy efficient water management system
- Energy Efficient wastewater management system

These indicators help cities assess their present situation and guide them on implementing relev ant climate actions with respect to water management (*MoHUA, Government of India and C-Cube, NIUA, 2021; MoHUA, Government of India, 2020*).

2.1. Water Resource Management Indicator

Climate change impacts water resources and their availability and so it becomes imperative to take stock of water availability and demand for water in the context of changing climate and take adoptive and mitigative measures.

The indicator requires cities to assess whether they are on course to meet their future water demand. The indicator requires cities to assess the current and future availability of water both surface and ground water and also current and future demand for water.

Figure 9: CSCAF Indicators.

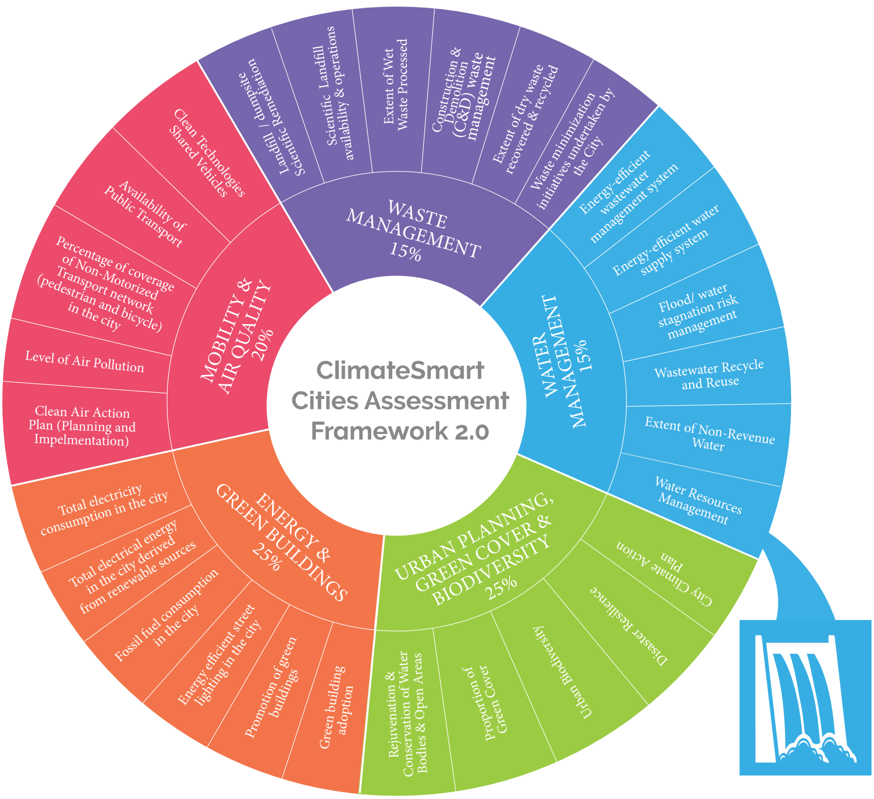


Image credits: C-Cube, NIUA (2020). Indicators of ClimateSmart Cities Assessment Framework 2.0. https://www.niua.org/csc/assets/pdf/CSCAF_2_Booklet.pdf

Table 1: CSCAF indicator for Water Resource Indicator levels of action.

Develop-ment stages	1 Star	2 Stars	3 Stars	4 Stars	5 Stars
	Level 1	Level 2	Level 3	Level 4	Level 5
Score	0	25	50	100	
Progression Levels	No water resource assessment has been carried out	Assessment of current water resources along with future demand and water availability for at least five years	Water Resource Management (WRM) Plan is prepared with Short, Medium- and Long-Term Actions	Actions for Water Resource Management	
Data required		A Report/study that indicates stock of existing water resources with projections, its uses for various sectors; projected future water demand water availability and water quality for at least five years. The Report/study shall include: Main water resources of the city including ground water / surface water Quantum of water available at source Details of water allocation for domestic, industry and agriculture purposes Water quality test report at source and after treatment. Map of major (catering to 5% of more of the city's water needs) ground & surface water sources as .kml file (additional evidence) * Report/study older than 5 years will not be considered	A Report/ study/ plan that estimates future water availability. The Report/ study/plan shall include: Demand management Plan for best utilization of available water resources Augmentation of existing water resource through recharge, rejuvenation and storage (includes rain-water harvesting)	Actions initiated for execution of works specified in the water resource management plan The city has reviewed and revised the Water resource Management Plan to include climate change factors.	

Cities will be marked based on evidence provided for the actions initiated and implemented and they are required to conduct Water Resource Assessments to look at both surface and groundwater. The water availability and water demand need to be quantified using scientific techniques and the water allocations for various sectors should be factored into the assessment. The cities are also required to prepare a Water Resource Management Plan which takes into account climate change factors.

The agencies responsible for developing and sharing information with respect to this indicator include ULBs, water utilities or water boards, flood and irrigation departments, central ground water departments, industrial corporations, or any SPV or relevant implementation agency and IMD.

2.2. Current performance of cities

As per the *ClimateSmart Cities Assessment Framework 2.0 - Cities Readiness Report 2021* it was observed that of the 126 participating cities only three cities were in Level 5 and eighteen cities in Level 4 (*MoHUA, Government of India and C-Cube, NIUA, 2021*).

Figure 10: Performance of 126 cities in CSCAF assessment conducted in 2020.

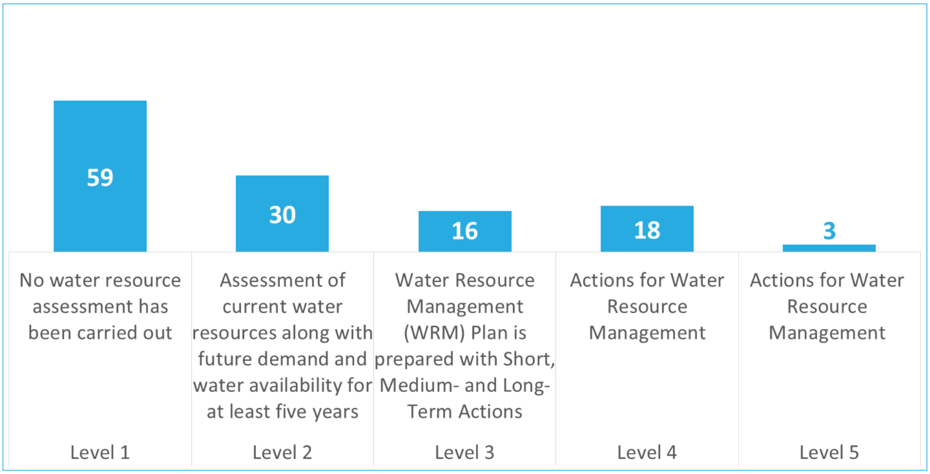


Image Credits: Author based on information from MoHUA, Government of India and C-Cube, NIUA (2021) Cities Readiness Report.

In order for cities to move up the ladder they would have to improve their performance by conducting regular Water Resource Assessments, develop Water Resource Management Plans and further undertake actions on ground for better water resource management.

3

Water Resource Management Plan

A Water Resource Management Plan for a city comprises a Water Resource Assessment (WRA), which would consist of an assessment of current water availability, current demand, future water availability and future demand. It would also include a Demand Management Plan and strategies or actions for Water Resource Management.

Figure 11: Components of a Water Resource Management Plan.

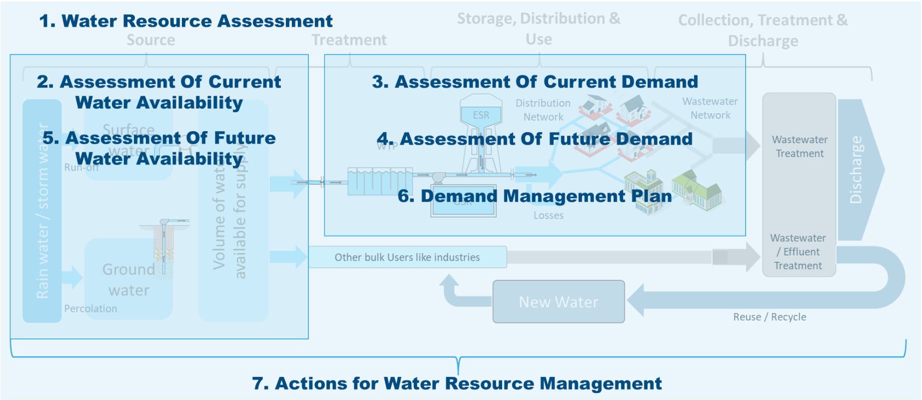


Image credits: Author.

The WRA needs to be conducted across the entire water supply service chain and should look at water allocations for various sectors being supplied through the municipal services. The assessment of current and future water availability is based on the identified potential sources of water supply to the city whereas the assessment of the current and future demand focus primarily on the water distribution network and end-users. In an urban context, the concept of Integrated Urban Water Management (IUWM) is one such approach where all components of the urban water cycle (*water supply*, *sanitation*, *storm water*) are brought under a single umbrella. It adopts concepts from Integrated Water Resource Management (IWRM) which is generally applicable at the catchment level at the local governance level. The following section will detail out each of these components.

3.1. Water Resource Assessment

Water resources assessment is the process of measuring, collecting and analysing relevant parameters on the quantity and quality of water resources for the purpose of a better development and management of water resources (*Keller, 2008*). It is a systematic study of the status of water services, resources and trends in accessibility and demand (*Keller, 2008*).

It is also defined as – "Water resources assessment is the determination of the sources, extent, dependability and quality of water resources for their utilization and control, and water resources are the water available, or capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand" in the Technical Material For Water Resources Assessment by the World Meteorological Organisation (*World Meteorological Organisation, 2012*).

The purpose of a WRA is it helps in understanding the following –

1. Current status of water resources including inter-and intra-annual variability
2. The social and environmental trade-offs of current water use patterns
3. Factors affecting accessibility of water and its reliability
4. It informs on opportunities for making the services efficient and equitable (*Keller, 2008*).

3.1.1. Water Resource Assessment Process

Figure 12: Process for conducting a WRA study.

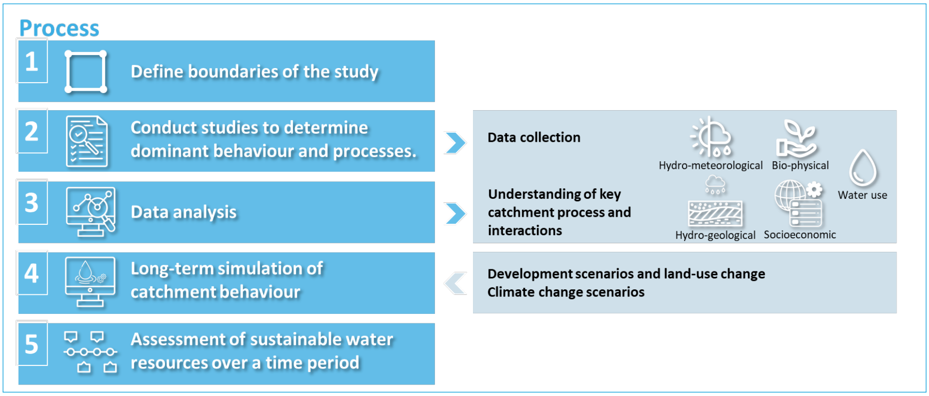


Image credits: Author adopted from the 'Outline schematic of the water resource assessment development process' by the World Meteorological Organization (2012) from the Technical Material for Water Resources Assessment. https://library.wmo.int/doc_num.php?explnum_id=7783

The process of a WRA includes defining the boundaries of the study, it could be conducted at the catchment level, the micro-catchment level or at the city or district levels. The WRA depends on understanding the water flows and storages, their interrelationship over time and their relation to human impact or demand within the defined boundary (*World Meteorological Organisation, 2012*).

The next step involves conducting a high-level review of the defined boundary to determine the dominant behaviour and processes. It includes comprehensive data collection which includes current and historical hydrological data. It includes data sets on the following –

1. Hydro-meteorological data such as climate characteristics, data on precipitation, evaporation, soil moisture.
2. Hydro-geological data such as catchment, river basin, river flows, surface storage, soil characteristics and details on the groundwater system.
3. Bio-physical data such as land-use land cover, natural vegetation and water bodies changes over time, and topographic data like elevations, contours, drainage patterns,

4. Socio-economic data such as population, major economic activities, standard of living.
5. Water use data for all purposes such as domestic, commercial, industrial, recreational purposes.

The next step involves data analysis to understand key interactions in the catchment and identifying features of both short-term and long-term water balances. It is important to include factors of water quality and environmental issues.

This analysis will help in developing a long-term simulation of the catchment behaviour which should include various development, land-use change, and climate change scenarios. The simulation will help identify and assess various sustainable sources over a long period of time.

3.1.2. Water Resource Assessment outline

Based on various Water Resource Assessments an outline for the same has been developed as follows. The WRA will help estimate the current and future demand for water supply and estimate the current and future availability for water within the municipal jurisdiction.

Figure 13: Outline for a Water Resource Assessment.

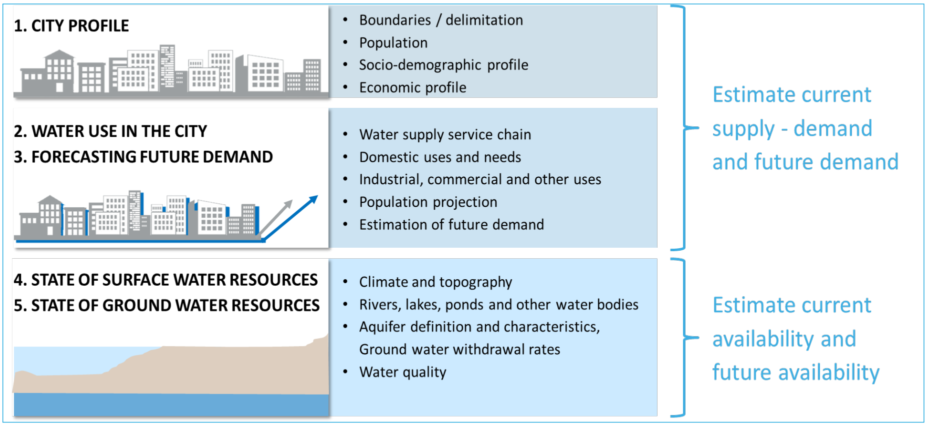


Image credits: Author

City Profile

The city profile consists of details on the boundary of the study area along with any land-use plans, population, socio-demographic profile and economic profile. This information will help identify the levels of development and land-use patterns in the city and economic activities influencing water demand. It will help identify patterns of high consumption across the city.

The data sources for the same will be –

1. Boundaries, delimitation and jurisdictional information will be available in old maps, master plans or development plans
2. Population data will be available in census and NSSO survey reports
3. Socio-demographic details similarly will be available in census and NSSO survey reports.
4. Economic profile details will be available in Census, NSSO, historical literature, master plans, CDPs.

Water Use in the City

This section should comprise information on the entire water supply service chain from the source to the end-user, and should include information on the demand of water for various purposes. Details about the total water withdrawn from various surface and ground water sources for municipal supply is computed. The per-capita demand or per-unit of production demand for water is established and wastages within the system are identified. Based on the current demand computed, the demand – supply gap can be computed. The data on the supply side will be available from the water supply department or water utilities of the ULB and in case of bulk purchase it will be available with the State Irrigation Department. The demand side information can be established through existing metering practices or by conducting detailed surveys. The standards for water usage have already been established by CPHEEO or IS-1172-1993, based on these over usage can be identified. The city would need to conduct a water audit across the entire water supply service chain and establish the supply, demand, gap and losses.

Figure 14: Formulae for calculating current supply, current demand and the demand-supply gap.

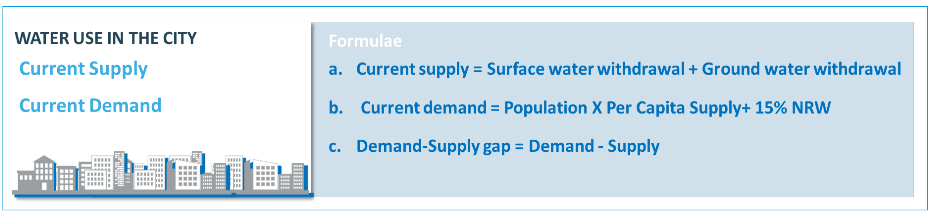


Image credits: Author

Forecasting Future Demand

Forecasting the future demand requires projecting the population for an established design period for which the water resource management plan will be prepared and estimating the demand based on that population size. There are numerous methods of population projection recommended by CPHEEO based on the characteristics of the city and it also details out standards for per-capita or per-unit of production requirement for water which can help compute the future demand. This will help us assess the trends in demand for water and help decide whether the Business–as–usual scenario for water usage is sustainable and viable for the city. It will also help the city assess its vulnerability to future stress or shock due to water demand.

CPHEEO provides eight methods for population projection in the Manual on Water Supply and Treatment 1999. The most commonly used of these are the following –

1. **Arithmetical Increase method** – this method is suitable for large and old city with considerable development.
   i. Formula: $P_p = P_t + n\,(P_1 - P_2)\,/N$
   ii. P_p – Population projection in the future
   iii. P_1 – Present population as per the recent census
   iv. P_2 – Size of population in the previous census
   v. n – Number of years between the P_p and the P_1
   vi. N – Total number of years between the P_1 and P_2.

2. **Geometrical Increase Method** – this method should be applied for a new industrial town at the beginning of development for only few decades.
   Formula: $P_p = P_1\,(1 + r)\,n$
   i. P_p – Projected population
   ii. P_1 – Population as per the recent census
   iii. r – Annual rate of increase or decrease of population
   iv. n – Number of years between P_p and P_1

3. **Incremental Increase Method** – this is suitable for an average size town under normal condition where the growth rate is found to be in increasing order.
   Formula: $P_p = P_1 + n\,(I_a + I_c)$
   i. P_p – Projected population
   ii. P_1 – Population as per the recent census
   iii. n – Number of years between P_p and P_1
   iv. I_a = Average Arithmetical increase
   v. I_c is the average incremental increase

The same manual also provides standards for per-capita water supply for a city based on size of city, characteristics of the population or standard of living, industries and commerce and climatic conditions.

Table 2: Recommendations for Per capita water supply.

	City type	LPCD
1	Piped water supply provided but no sewerage network	70
2	Piped water supply with existing sewerage system	135
3	Metropolitan and Mega cities with piped water supply and sewerage system	150

Credits: CPHEEO (1999) Manual on Water Supply and Treatment.

The following are the formulae for calculating the future demand, the future supply and the demand-supply gap.

Figure 15: Formulae for future demand, supply and demand-supply gap.

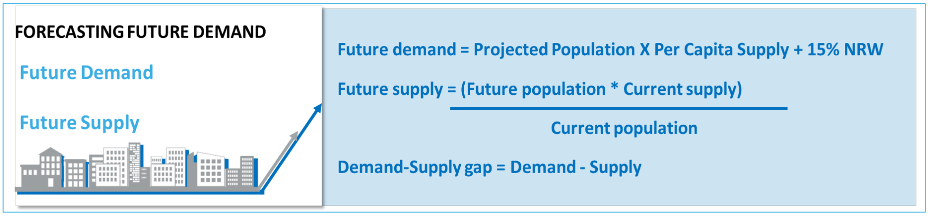


Image credits: Author

Calculating Water Availability

Water Balance is a comprehensive way to understand flow of water in and out of a catchment or system, giving a balance of the water retained in the ecological system. It is computed as the change in storages of water within that system and it can be calculated by subtracting the total inflow from the total outflow (*Dasgupta*, *2021*).

Figure 16: Urban water balance.

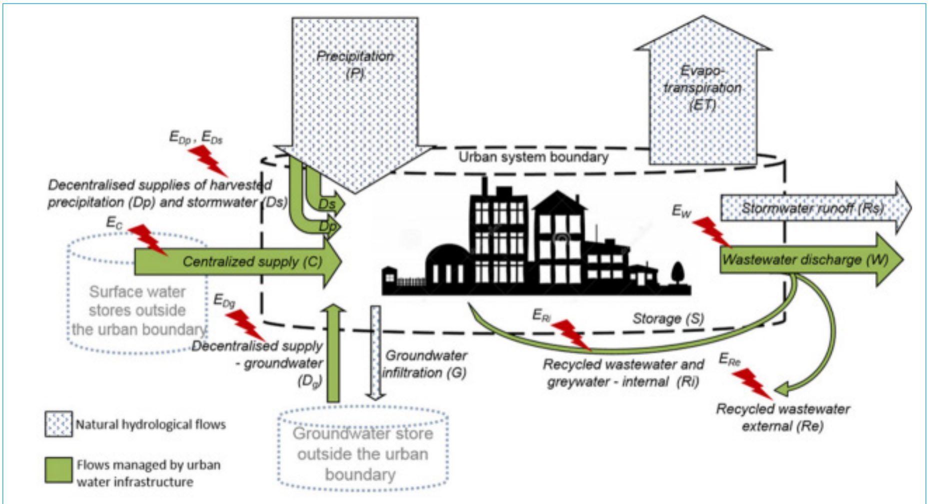


Image Credits: Farooqui, Renouf, & Kenway, (2016) from 'A Metabolism Perspective on Alternative Urban Water Servicing Options Using Water'. https://doi.org/10.1016/j.watres.2016.10.014

The formula for the urban water balance equation without any urban abstraction is as follows (*Chatterjee & Roy, 2021*).

1. Changes in storage = Total inflow – Total outflow
2. Changes in Storage = (Precipitation + Soil Moisture) - (Runoff + Evapotranspiration)
3. (Src + Sc + Suw + Gwd + Hr) = (P + Ic + Iu + Gwi + Ds) - (T + Rs + Gwo)
4. Src: Remote captive storage
5. Sc: City storage
6. Suw: Urban water body
7. Gwd: Annual dynamic groundwater addition to the aquifer
8. H_r: Harvested rainwater
9. P: Direct precipitation
10. Ic: Inflow into captive storage
11. Iu: Inflow into urban watershed
12. Gwi: Groundwater inflow into urban aquifer
13. Ds: Annual desalinated water
14. T: Evapotranspiration
15. Rs: Surface runoff
16. Gwo: Groundwater outflow from urban aquifer

The formula for the water balance equation for the linear water supply service chain is as follows (*Chatterjee & Roy, 2021*).

1. Changes in storage = Total inflow – Total outflow
2. (Src + Sc + Suw + Gwd + Hr) = (P + Ic + Iu + Gwi + Ds) - (T + Rs + Gwo) - (Wcd + Wci) - (Dww) - (Ls + Drf)
3. Src: Remote captive storage
4. Sc: City storage
5. Suw: Urban water body
6. Gwd: Annual dynamic groundwater addition to the aquifer
7. H_r: Harvested rainwater
8. P: Direct precipitation
9. Ic: Inflow into captive storage
10. Iu: Inflow into urban watershed
11. Gwi: Groundwater inflow into urban aquifer
12. Ds: Annual desalinated water
13. T: Evapotranspiration
14. Rs: Surface runoff
15. Gwo: Groundwater outflow from urban aquifer
16. Wcd: Consumptive domestic water use
17. Wci: Consumptive industrial water use
18. Dww: Wastewater discharge
19. Ls: Return flow, supply leakages
20. Drf: Return flow, wastewater discharges

The details for computing each of these components requires a detailed simulations and studies to be conducted on climate and topography data. These components include the following.

Table 3: Components for computing Water Availability.

	Components	Sub-components	Data sources
1	Topographic data	Elevations, often available as a Digital Elevation Model (DEM) Relief, often represented on maps by contour lines Drainage patterns of surface water bodies (rivers, lakes, streams) Infrastructure including highways, roads, railways, power plants, etc. Land use (agricultural zones, forests, cities, industrial zones) Geographical position (using a projection to a 2-D surface)	Google earth GIS based maps CARTOSAT-DEM Datasets Central Ground Water Board (CGWB)
2	Climate data	precipitation, humidity temperature, Sunshine, wind speed, density, cloud cover	Rain-gauge stations of IMD State departments stations District ground water brochure by CGWB
3	Soil data	Soil texture, structure, depth, class Infiltration rate	CGWB State Irrigation Department soil surveys.
4	Natural vegetation data	Temporal and spatial variations in vegetation patterns	Land use land cover (LULC) map and wasteland maps -Bhuvan

Credits: Author

State of Surface and Ground water resources

The state of surface water bodies which include rivers, lakes, ponds etc. should map all the water bodies within the area of study and also their drainage zones or catchments. It should include the storage capacities of these water bodies and estimate the surface runoff generated within their catchments along with any disruptions which prevent the runoff from being captured with in them. The change in coverage area of these water bodies over time should also be studied along with an assessment of the quality of water within them.

The data regarding the surface water bodies can be sourced from Central Water Commission which maintains hydrological data at the national level or the State Irrigation Departments or through India-WRIS geo-portals which contains information on reservoir level, rivers, wetlands, quality of water. Other detailed information should be generated by conducting on ground studies.

Ground water data includes details on the depth of aquifer, aquifer thickness, and aquifer characteristics. The ground water development status, identifying if it over exploited by establishing the ground water draft and annual dynamic discharge of aquifers. Some of this data will be available with the Central Ground water Board which monitors approximately 15,640 ground water observation wells in the country four times a year. I-WRIS also has water measurement stations across the country which captures some of this data. The city bore logs will also provide insight on ground water drafts across the city. In case sufficient data isn't available the city can conduct detailed aquifer mapping with the help of CGWB or other relevant agencies.

Water quality for drinking water, ground water and other ambient surface water bodies should be monitored regularly. The standards for drinking water are detailed in the CPHEEO Manual on Operation and Maintenance of Water Supply System 2005 and under best designated use as per Central Pollution Control Board (*CPCB*). It is the ULBs responsibility to monitor the water quality along its water supply service chain from the source till the end-user and identify and prevent the pathways for pollution.

The Water (*Prevention and Control of Pollution*) Act was enacted in 1974 provides for the prevention and control of water pollution, and for the maintaining or restoring of wholesomeness of water in the country. The quality of surface water bodies especially at the points of discharge from sewage treatment plants (*STPs*), industries and storm water drains should be monitored to ensure it is within acceptable limits as per the Guidelines for Water Quality Monitoring CPCB. CPCB has laid out water quality standards for various uses of river water, including those relevant to discharges in surface water bodies, public sewers and oceans, and reuse for irrigation. CPCB along with the State Pollution Control Boards (*SPCBs*) and Pollution Control Committees (*PCCs*) established the National Water Quality Monitoring Network to assess the status of water quality and facilitate the prevention and control of pollution in water bodies (*CPCB, 2020*). Under this program there are 4111 monitoring stations across India. Similarly the Global Environmental Monitoring System (*GEMS*), Monitoring of Indian National Aquatic (*MINARS*) and Yamuna Action Plan (*YAP*) have various monitoring stations for monitoring water quality across various rivers, water bodies and ground water sources. The CGWB also has approximately 15640 ground water observation wells across the country which monitor water quality.

The agency conducting the WRA should collate and map the data available from various monitoring stations within their jurisdiction. Analyzing time-series data on water quality will help identify and prevent pollution in the same.

The information on the state of surface and ground water resources will help in calculating the water availability.

3.2. Demand Management Plan

Demand management focuses on effectively controlling the demand for water resources for various purposes and efficiently managing and using the available resources (*UN-HABITAT, 2006*).

The purpose of implementing an effective water demand management strategy include:

1. Reduced water usage in terms of both average and peak demands
2. Reduced water leakage or loss.
3. Reduced wastewater flows.
4. Improved financial performance of the ULB through deferment of infrastructure investments, and reduced operational costs.
5. Generating greater awareness for consumers on the financial and environmental value of water.

Figure 17: Purpose of a Demand Management Plan.

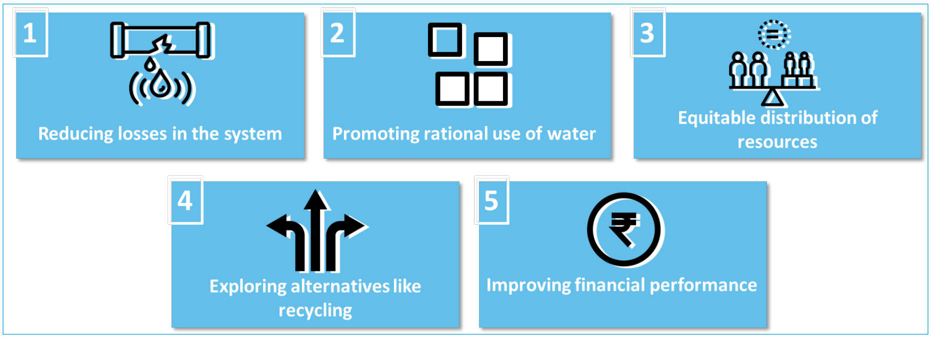


Image credits: Author

A Demand Management Plan would consist of the following sections.

1. **Status of Water Supply** – which would detail out information about current water supply sources, the components of the water supply service chain and the losses within the distribution system, the consumption of water for various purposes within the system and any upcoming augmentation projects to enhance current supply of water in the network.
2. **Water balance assessment** – or a water audit should be conducted to establish the various components of an IWA water balance chart which would help establish where losses are happening within the network.

Figure 18: IWA water balance chart.

System Input Volume	Authorized consumption	Billed authorized consumption	Billed meter consumption	**Revenue water**
			Billed un metered consumption	
		Unbilled authorized consumption	Unbilled metered consumption	**Non revenue water (NRW)**
			Unbilled un metered consumption	
	Water losses	Apparent losses	Unauthorised consumption	
			Metering inaccuracy	
		Real losses	Leakages on transmission and / or distribution mains	
			Leakages and overflows at Utility's storage tanks	
			Leakage on services connections up to point of customer metering	

Image credits: International Water Association

1. **Identification of the issues** – within the water supply service chain.
2. **Water demand management strategy** – which would include water demand reduction strategies like volumetric charging, restrictions on water use and generating awareness amongst consumers and supply rationalisation strategies like consumer metering, leakage mapping, detection and repair.

Figure 19: Water demand management strategies

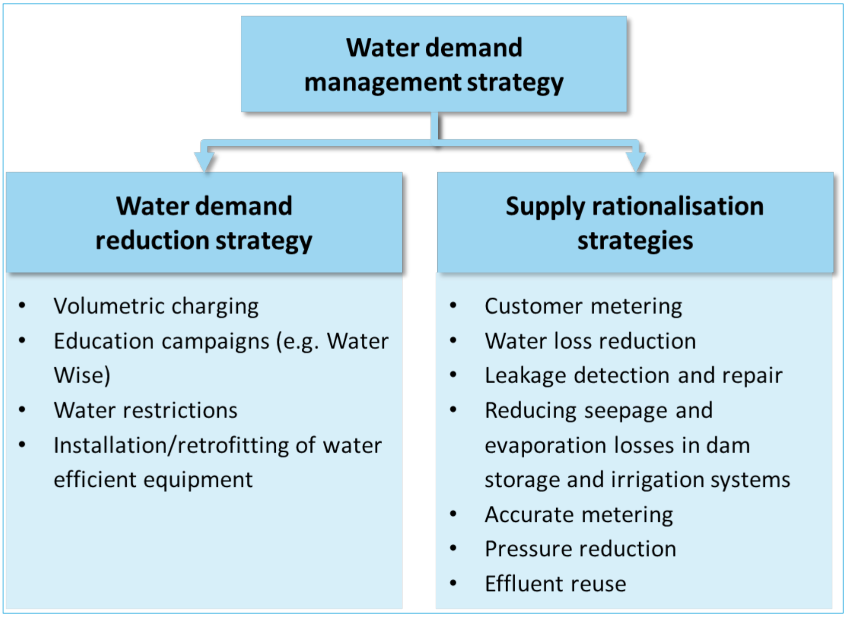


Image credits: Pacific Water, 2010) from Water Demand Management Implementation Guide.

3. **Financial assessment** – of the water utilities or water supply department to assess if they have financial viability to sustain without external aid and the methods they can adopt to enhance their financial resources by charging citizens while improving their performance.

3.3. Water Resource Management Strategies

Based on the findings from the Water Resource Assessment, strategies can be adopted focusing on key priorities and engaging all stakeholders to ensure sustainability and viability of the interventions. Some of these strategies include the following.

1. Establishing a WRM team within the Water utility department.
2. Augmentation of water resources
3. Management of groundwater resources
4. Rainwater harvesting
5. Urban water demand optimization
6. Wastewater treatment and reuse.

These strategies along with case studies will be detailed out in the following section.

Photo Credits: Varanasi on Wallpaperuse.com

4

Water Resource Management Strategies

The strategies which can be adopted for water resource management are as follows. Based on the context of the city considering climate and topographic conditions, a combination of these strategies can be adopted.

1. **Establishing a WRM** team within the Water utility department to carry out WRA, prepare water resource management plans and implement strategies for better water management.
2. **Augmentation of water resources** through the following methods
   i. Rejuvenation and maintenance of surface water bodies
   ii. River centric urban planning
   iii. Traditional water conservation practices
   iv. Nature based solutions and Low impact design to capture storm water.
3. **Management of groundwater resources** through groundwater conservation, recharge, and restoration of depleted aquifers by regulating indiscriminate usage and through direct injection or well recharge.
4. **Rainwater harvesting mandated** through regulations in building bye-laws for new constructions.
5. **Urban water demand optimization** by adopting demand management strategies.
6. **Wastewater treatment, recycle and reuse**.

4.1. Establishing a Water Resource Management Team or Committee

A Water Resource Management *(WRM)* Team or Committee established at the local level would perform the following functions[1] in a city to ensure the planning and implementation of strategies for water resource management.

1. **Conduct Water Resource Assessments** taking stock of existing water resources and its use in various sectors based on the past trends forecasting the future water demand and availability for at least five years.
2. **Prepare Water Resource Management Plans** to formulate short, medium and long-term actions for managing and developing water resources to augment existing resources and be prepared for any future stresses or shocks that might arise.
3. **Prepare Demand Management Plans** to improve the utilization of available water resources.
4. **Implement and monitor actions for water resource management** based on the actions formulated and to be executed as per the water resource management plan.
5. **Monitor and enforce water quality** by undertaking activities to improve water quality and monitor water pollution to ensure they remain below accepted standards.
6. **Preparedness actions against water disasters** such as floods and droughts should be put in place along with strategies for coping against these disasters.
7. **Protecting the ecosystem** through awareness campaigns and monitoring.

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[1] *The functions for the Water Resource Management Team or Committee at the Local level were adapted from the functions of River Basin Organisations and based on the requirements for moving up the progression levels of the CSCAF indicators.*

The water resource management team or committee can include representatives from the water utility department, water boards, other relevant departments within the ULB like the sanitation department, storm water management department or the groundwater departments, SPVs working in this domain. It should include a range of technical experts such as engineers, planners, infrastructure specialists, environmentalists.

4.2. Augmentation of water resources

Augmentation of both surface and groundwater resources are interlinked and the following methods can be adopted at different scales to ensure their effectiveness.

4.2.1. Traditional water conservation practices

India various traditional systems were developed for the conservation of local water resources *(Rohilla, Matto, Jainer, Kumar, & Sharda, 2017)*. These traditional system focus on water harvesting and storing techniques of rain water. Some of the techniques are as follows.

The Eri *(tank)* system or temple tanks of Tamil Nadu is one of the oldest water management systems in India. Still widely used in the state, eris act as flood-control systems, prevent soil erosion and wastage of runoff during periods of heavy rainfall, and also recharge the groundwater *(Pal, 2016)*.

A 2020 paper on *Investigation of Role of Retention Storage in Tanks (Small Water Bodies) on Future Urban Flooding: A Case Study of Chennai City, India* analysed the impact of disappearance of tanks on flooding in the metropolitan area and noted that – "If the tanks in the upstream portion of the basin lose their storage completely in the future, coupled with urban sprawl, then even a moderate flood like the one that occurred in 2005 will behave like the extreme flood that occurred in 2015." *(Devi et. al, 2020).*

Figure 20: Examples of traditional water conservation practices.

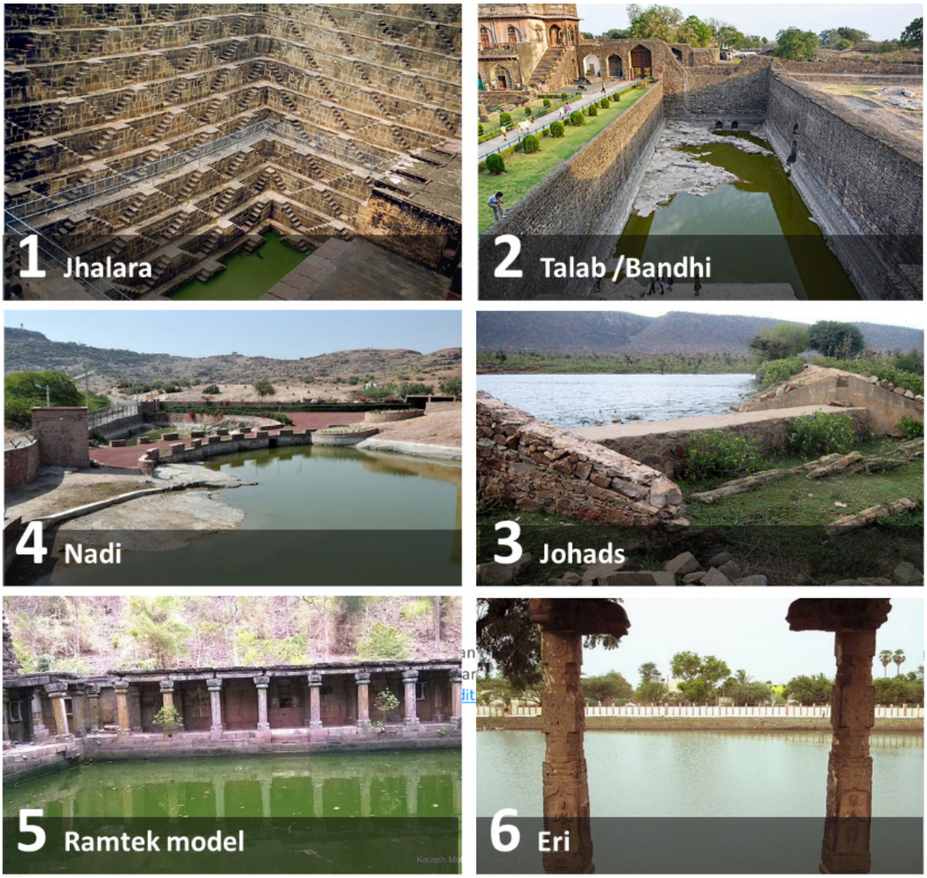

Image credits: The Better India, article by Sanchari Pal 'Modern India Can Learn a Lot from These 20 Traditional Water Conservation Systems'

Chennai has 39 temple tanks and the prominent temples are maintained well while, the not-so-well-known ones are crying for attention *(Shekhar, 2019)*. Currently efforts are being undertaken by the temple managements to maintain them by desilting and cleaning.

Figure 21: Condition of different temple tanks in Chennai.

Image credits: Citizen Matters (2019) 'In photos: How temple tanks are helping the city conserve rain water'.

4.2.2. Rejuvenation and maintenance of urban water bodies

Urban water bodies include lakes, ponds, and wetlands[2] which are critical for the ecosystem. They provide vital ecosystem services such as micro-climate regulation, groundwater recharge, absorbing excess surface run-off, preventing urban floods, mitigating heat-island effects and supporting biodiversity.

However, various factors lead to degradation of these water bodies such as rapid and often unplanned urbanisation, discharge of untreated sewage and effluents from industries, nutrient rich agricultural run-off leading to eutrophication and reclamation leading to siltation. These factors inhibit the ecosystem services provided by these water bodies. In order to tackle these challenges the Government of India has released various guidelines and advisories for the conservation, restoration and management of these urban water bodies.

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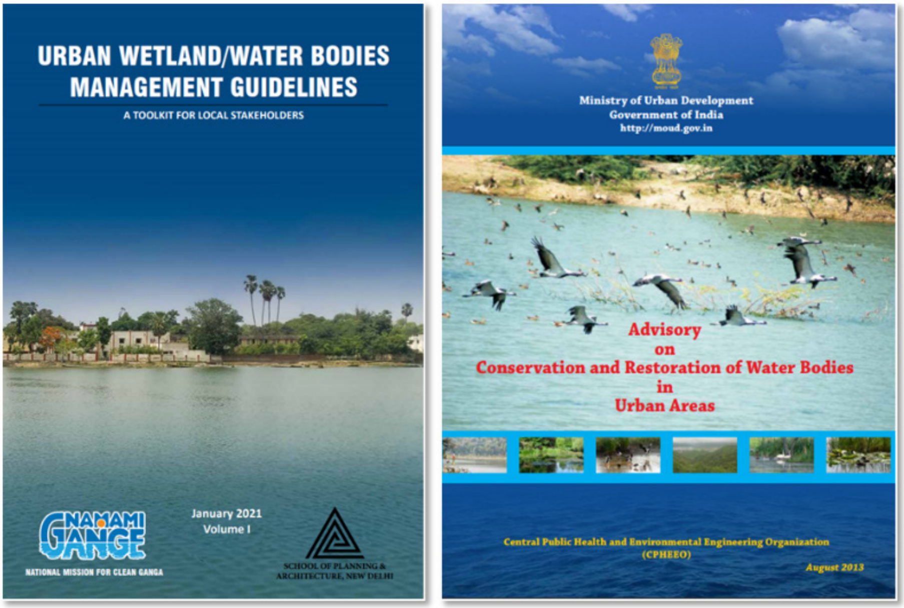
[2]*Wetland is an area of marsh, fen, peatland or water; whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.*

Figure 22: Government guidelines and advisories for conservation, restoration and management of urban water bodies.



An overview of the process for conservation and management of urban water bodies adapted from the *Urban Wetland/Water Bodies Management Guidelines a Toolkit for Local Stakeholders (2021)* includes mapping of the urban water bodies and its attributes such as coverage area, catchment area and characteristics, water quality parameters, seasonal variations, and presence of aquatic life followed by identifying the ecosystem services they provide. This will be followed by conduction land suitability studies, provisions for the water bodies in the master plan or development plans and impact of urban development trends in the catchment on the water body. It is also important to identify the stakeholders dependent on these water bodies for various purposes. This information will assist in the preparation of an action and management plan for these urban water bodies.

Figure 23: Process of conservation and management of urban water bodies.

Image credits: Author

Table 4: Activities for conservation, restoration and management of water bodies

	Action and management plan components	Activities
1	Boundary Delineation and Demarcation	Boundary mapping and delineation Removal of encroachments Shoreline management
2	Catchment Conservation	Afforestation and aided Regeneration Selective dredging and desilting to improve hydrological connectivity Interception, diversion and treatment of point sources of pollution Small scale engineering measures (gully plugging, check dams, etc.) maintenance of water regimes and flood control
3	Institutional Development	Setting regulatory regimes Development of monitoring and evaluation system Communication and Outreach for awareness generation.

Credits: Namami Ganage and SPA-Delhi (2021) 'Urban wetland/Water Bodies Management Guidelines. A toolkit for local stakeholders.'

4.2.3. Case study for Rejuvenation and maintenance of urban water bodies

Jakkur Lake in north Bangalore, Karnataka faced numerous challenges due to urbanization in its catchment which was highly encroached. The waterbody covers an area of 160 acres and is 1.5 *km* long. The lake received rain water from three streams flowing from Yelahanka, Agrahara and Shivanahalli, however the quantity of storm water reaching the lake decreased making the streams dry. The lake started receiving sewage from 12,500 households in its vicinity which threatened the lake ecology *(Vishwanath & Kumar, N.D).*

Figure 24: Fisher-folk clearing the layer of water hyacinth, a plant that threatens the lake ecology.

Photo by Jockim Retrieved from: https://india.mongabay.com/2021/04/the-story-of-jakkur-lake-sets-an-example-for-inclusive-rejuvenation-projects/

The state government, local governing bodies, fishermen, end users *(domestic purposes)*, lake revival groups and bird watching enthusiasts made numerous efforts to revive the lake. The organisations responsible for implementing actions were the Bangalore Development Authority *(BDA)* and Bangalore Water Supply and Sewerage Board *(BWSSB)*.

The steps undertaken for reviving the lake were –

1. The area surrounding the lake's boundary was demarcated and it was fenced. The lake was desilted and an STP was constructed to treat the wastewater before it is discharged into the lake.
2. Wetland Plantation at the discharge point of the STP was put in place to further filter the water through natural processes as it is entering the lake. Wetlands help in improving and maintaining the quality of water let into the lake.
3. Islands were created and trees were planted on the edges of the lake to maintain natural flora and fauna.
4. A separate tank was built for religious and cultural festivities such as Ganesh immersion.
5. Social sustainability was ensured through community engagement and ownership.

Figure 25: Steps for urban lake management for Jakkur Lake.

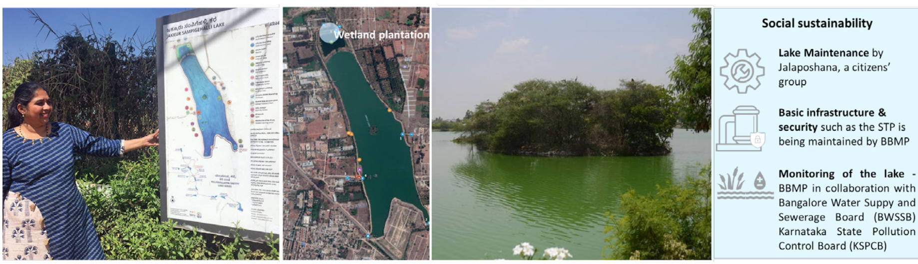


Image credits: Centre for Science and Environment (CSE), Jakkur Lake - Urban Lake Management https://www.cseindia.org/jakkur-lake-urban-lake-management-6402

The biodiversity around the lake has improved significantly and the lake currently provides livelihood to fishermen.

Figure 26: Revived Jakkur Lake

Image credits: Centre for Science and Environment (CSE), Jakkur Lake - Urban Lake Management https://www.cseindia.org/jakkur-lake-urban-lake-management-6402

4.2.4. Nature Based Solutions

Nature-based solutions *(NBS)*, or "nature-based infrastructure" is an approach that uses natural systems to provide critical services *(World Bank Group, 2019)*. Nature-based solutions for water resources management involve the planned and deliberate use of ecosystem services to improve water quantity and quality and to increase resilience to climate change *(UN Environment-DHI, UN Environment and IUCN, 2018)*.

NBS can be applied through using and protecting existing ecosystems, restoring degraded ecosystems or by creating new ecosystems *(IUCN, 2016)*.

Figure 27: Nature Based Solution examples.

Image credits: World Bank Group (2019) Nature-based Solutions: a Cost-effective Approach for Disaster Risk and Water Resource Management. https://www.worldbank.org/en/topic/disasterriskmanagement/brief/nature-based-solutions-cost-effective-approach-for-disaster-risk-and-water-resource-management

They complement grey infrastructure. Some examples of NBS are as follows.

Table 5: NBS and the ecosystem services they provide.

Urban green infrastructure solutions		Water management service provided	Corresponding grey-infrastructure solutions
1	Wetlands restoration/ conservation	Water supply regulation, water purification, biological control, Water temperature control	Dams, Levees, Water treatment plants etc.
2	Constructing wetlands	Water supply regulation, water purification, biological control, Water temperature control	
3	Water harvesting*	Water supply regulation, water purification,	Urban storm water infrastructure
4	Green spaces (bioretention and infiltration)	Water supply regulation, water purification, urban storm water runoff management	
5	Green roofs	Urban storm water runoff management	
6	Permeable pavements*	Water supply regulation, water purification,	

Credits: UNEP, UNEP-DHI Partnership, IUCN, TNC, WRI (2014). 'Green Infrastructure solutions for water resources management' in 'Green Infrastructure Guide for Water Management: Ecosystem-based management approaches for water-related infrastructure projects'.

**Built elements that interact with natural features to enhance water-related ecosystem services. (UNEP, UNEP-DHI Partnership, IUCN, TNC, WRI, 2014)*

NBS helps regulate water supply, moderate water quality, and moderate extreme climate events by increasing water storage capacity, reducing flood water velocity, and drought impact by maximizing groundwater storage. They provide cost-effective and flexible approaches for disaster risk and water resource management *(World Bank Group, 2019)*.

4.2.5. Case study for Nature based Solutions

In Indian Institute of Technology *(IIT)* Mumbai a constructed wetland was installed adjacent to Lake Powai which treats sewage generated on campus before it is discharged into the lake. The project was initiated by Centre for Environment Science and Engineering *(CESE)*, IIT Powai. The designed capacity of the wetland is 25 KLD, it consists of a primary settling tank followed by a 400 m^2 planted filter bed with wetland plants over gravel media designed for horizontal sub-surface flow *(HSSF)*. The water quality at various points along the bed is monitored using monitoring ports *(Asolekar, N.D)*.

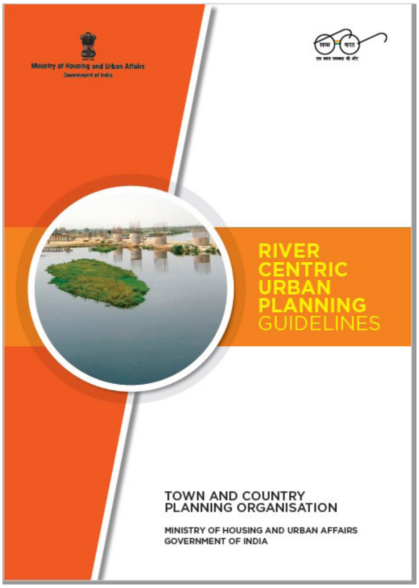
Figure 28: Constructed wetland at IIT Powai campus.

Image credits: The Indian Express article 'IIT-Bombay team ready with a natural system to treat Powai lake water'. https://indianexpress.com/article/cities/mumbai/iit-bombay-team-ready-with-a-natural-system-to-treat-powai-lake-water/

4.2.6. River Centric Urban Planning

An Urban River is a stretch or section of a water resource located within a catchment that contains a town or a city, where the structure and function of that water resource is altered from its natural state *(Town and Country Planning Organisation, 2021)*.

Figure 29: River Centric Urban Planning Guidelines.



The pressures of urbanization such as encroachment of banks, sewerage or effluent discharge and solid-waste dumping has severely degraded the urban rivers. The Town and Country Planning Organisation with MoHUA recently published *River Centric Urban Planning Guidelines* to assist cities in better planning and management to improve the conditions of the urban rivers.

The objective of these guidelines is to –

1. Prepare a framework for river water conservation and development of river water front.
2. Devise development regulations or zoning for river front development
3. Recommend suitable planning strategies for river water management.

The Guidelines also outlines three alternative approaches for the planning and development of cities while conserving the floodplains of the river.

The **River Ecology Conservation Plan** is the first. It takes an environmental approach for the conservation of the river by conserving natural areas such as swamps, marshes and riparian edge and developing a hierarchy of green spaces such as urban forests and parks depending on existing accessibility and viability of the abutting areas. The pollution of the rivers will be reduced by installing STPs with detention facilities at discharge points.

Figure 30: The ecologically restored Cheonggyecheon stream, Seoul.

Image credits: AFP/Getty Images

The second approach is the **Integrated Development Scenario,** proposes the integration of the river into the urban fabric considering the local requirements of the adjoining areas. The essential features of the eco – based scenario such as pollution control, green spaces, conservation of natural areas need to be retained and modification of existing uses can be incorporated to improve environmental qualities. Based on demand and suitability recreational activities can be incorporated.

Figure 31: Tom McCall Waterfront Park, in Portland, Oregon.

Image credits: Steve Morgan

The last approach is the **Post channelization development scenario** which is an extension of the integrated development scenario with partial or limited channelization as a precondition. This scenario would require reduction in peak flows which will increase due to channelization.

Figure 32: Sabarmati River rejuvenated with accessible river front, 2012.

4.2.7. Case study for reviving an urban river

The Cheonggyecheon River located in the Central District, Seoul, South Korea was a seasonal which was concreted and a highway was built over it after it had been increasingly polluted and canalised. In 2002, the Seoul Metropolitan Government decided to dismantle the roadway and the elevated highway to improve the air quality, water quality and quality of live of the citizens and also reconnect the two-parts of the city divided by the roads.

Figure 33: Before reviving the Cheonggyecheon River.

Image credits: Global Designing Cities Initiative, Case Study: Cheonggyecheon; Seoul, Korea. https://globaldesigningcities.org/publication/global-street-design-guide/streets/special-conditions/elevated-structure-removal/case-study-cheonggyecheon-seoul-korea/

The funding for the project was by the Seoul Metropolitan Government but involved various other public agencies, Private groups and partnerships, citizens associations and research organisations. Public engagement was critical to streamlining the process. The key elements of the project included removing the elevated highway concrete structure, daylighting the covered river, creating extensive green open spaces along the river which included pedestrian amenities and recreational spaces and constructing 21 new bridges, reconnecting the urban fabric *(Global Designing Cities Initiative, N.D)*.

Figure 34: After reviving the Cheonggyecheon River.

Image credits: Landscape Architecture Foundation, Case study brief on Cheonggyecheon Stream Restoration Project. https://www.landscapeperformance.org/case-study-briefs/cheonggyecheon-stream-restoration

This project brought significant environmental, social and economic benefits to the city. It provides flood protection for up to a 200-year flood event, significantly increased the biodiversity, reduced urban heat-island effect, and reduced small-particle air pollution *(Landscape Architecture Foundation, N.D)*.

4.3. Management of groundwater resources

Groundwater resources across urban India have been intensively exploited for domestic, private, industrial purposes and sometime have been used to augment the municipal supply. Excessive overdraft and groundwater contamination has caused a serious groundwater crisis and since it is a common pool resource it is necessary to recognise that it cannot be treated as private property. Using this understanding the Government of India formulated the Model Bill for the Conservation, Protection, Regulation and Management of Groundwater, 2016. This legislation in line with the Model bill has currently been enacted in 11 states and union territories and 18 other states are in the process of enacting the same.

The Model Bill identifies groundwater protection zones and requires the preparation of groundwater security plans based on dynamic resource assessments. It also proposes that urban areas should appoint Ward Groundwater Committees and Municipal Water Management Committees.

4.4. Rain Water Harvesting (RWH)

Rain water harvesting is the collection and storage of rainwater that runs off from roof tops, parks, roads, open grounds, etc. This water runoff can be either stored or recharged into the ground water *(Centre for Science and Environment, N.D)*. A rain water harvesting system will consist of a catchment, a conveyance system, first flush mechanism, filters to remove pollutants and a storage tank or recharge structure.

Figure 35: A simple RWH system.

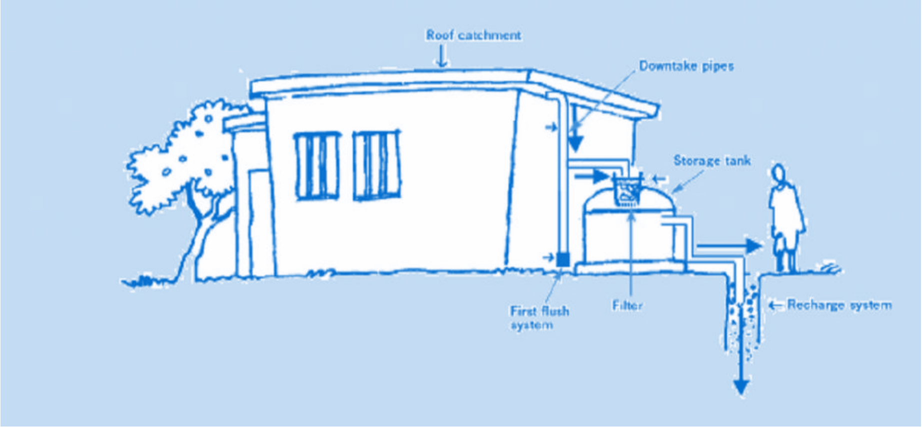


Illustration credits: CSE. 'Rainwater Harvesting'. https://www.cseindia.org/rainwater-harvesting-1272

These systems can be installed in individual houses, colonies, institutions, hospitals, industries and more.

Before installing a RWH system the following components need to be examined –

1. **Area contributing to run off** *(existing / projected)* i.e. how much area and type of land use pattern – industrial, residential or general built up pattern of the area and water related infrastructure.
2. **Hydro-meteorological and physical characters** – rainfall duration, general pattern and intensity of rainfall, topography and soil.
3. **Hydrogeology** of the area including nature and extent of aquifer, depth to water levels and chemical quality of groundwater.

Though technologies for RWH have existed for a long time, ensuring their implementation requires legislation which is generally linked to the byelaws. The implementation of RWH byelaws exists in different states and cities across India.

4. **States** – Kerala, Tamil Nadu, Rajasthan, Gujarat, Haryana, Goa, Daman & Diu, Karnataka,
5. **Cities** – New Delhi, Indore, Kanpur, Hyderabad, Mumbai.

4.4.1. Case study on legislation for mandating RWH

In Bangalore, Nearly 40% of the city is dependent on groundwater, but it is declining rapidly due to indiscriminate extraction and drilling. As Bangalore was facing increasing water challenges, emphasis was given to RWH. Bangalore receives 970*mm* of rainfall on average annually spread over 8 months and 59 rainy days making it ideal for efficient RWH systems. Two main Acts have been enacted in Bangalore with respect to RWH. The Bruhat Bangalore Mahanagara Palike *(BBMP)* Building Bye Laws, 2003 and Bangalore Water and Sewerage Amendment Act under which are the BWSSB Bangalore Water and Sewerage Amendment Regulations, 2015 *(Biome Environmental, 2018)*.

The BBMP Bye Laws 2003, byelaw 32 pertaining to RWH is applicable to all properties in its jurisdiction. All buildings which exceed a built-up area of 100m^2 and site area of 200m^2 are mandated to implement RWH. The penalty for not implementing the same includes a fine of 1000 Rs p.a. for every 100m^2.

The BWSSB Amendment Regulation 2015, is applicable to all properties with a BWSSB water supply connection, however if they come under BBMP jurisdiction that law holds precedence. Under the BWSSB regulations, any property with a built-up area of 1200ft^2 and a site area of 2400ft^2 are required to install RWH. The penalty for not implementing the same include disconnection of water supply *(2011 BWSSB Regulations Amendment)* and 25% additional charge for 3 months, 50% additional charge thereafter *(residential)*; 50% additional charge for 3 months, 100% additional charge thereafter *(non-residential)* *(Biome Environmental, 2018)*.

4.5. Urban water demand optimization

Urban water demand optimization requires implementation of water demand management strategy which would include water demand reduction and supply rationalisation.

Volumetric charging for water is an important economic instrument for improving water use efficiency, enhancing social equity and securing financial sustainability of the utility. It is a type of water tariff where per unit volume of water consumed is charged. It could be uniform charges[3] per unit or increasing[4] or decreasing[5] block tariffs. This strategy should be coupled with customer metering to help consumers account for the quantum of water they are utilizing.

Figure 36: Water demand management strategies

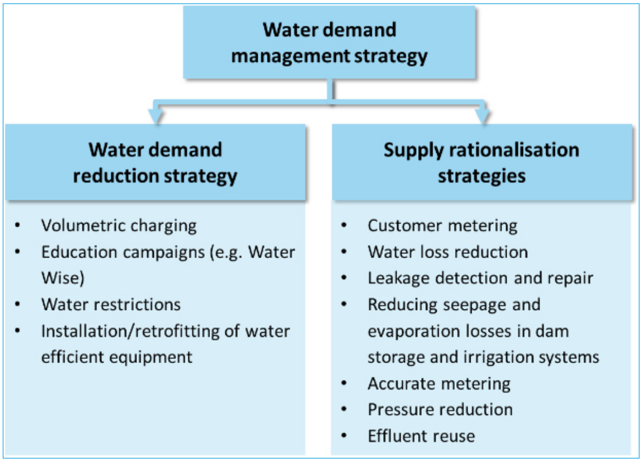


Image credits: Pacific Water, (2010) from Water Demand Management Implementation Guide

4.5.1. Wastewater Reuse and Recycle

Cities across India have been facing numerous water challenges especially water shortages and recycling wastewater provides an additional source of water for non-potable uses. The treated wastewater can be reused for irrigation of agricultural land, urban water or cleaning for parks and gardens, industrial purposes. The following section is further detailed out as part of the training module for indicator 'Wastewater Reuse and Recycling'.

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[3] *Water Pricing - Uniform Volumetric Charge: https://sswm.info/water-nutrient-cycle/water-distribution/softwares/economic-tools/water-pricing---uniform-volumetric-charge*

[4] *Water Pricing - Increasing Block Tariffs: https://sswm.info/water-nutrient-cycle/water-distribution/softwares/economic-tools/water-pricing---increasing-block-tariffs*

[5] *Water Pricing - Decreasing Block Tariffs: https://sswm.info/water-nutrient-cycle/water-distribution/softwares/economic-tools/water-pricing---decreasing-block-tariffs*

Photo Credits: Nainital by Shivansh Singh on Unsplash

5

Exercises

5.1. Principles of water as a resource exercise

This exercise was developed for cities as an ice-breaker to reiterate the concepts around water as a resource. Mentimeter was used as a tool to engage with the audience where they answer questions and their responses are visualised in real-time. The following questions were asked to the participants.

1. ***What type of resource is water? Select multiple options.***
    a. Non-renewable resource
    b. Renewable resource
    c. Infinite resource
    d. Finite resource.

    Answer – Renewable and finite resource.

2. ***What are the competing uses of water?***

    Answer – domestic, commercial, industrial etc. The answer to this question is in the form of a word cloud. The idea was to emphasize that there are numerous competing uses for water which is a limited resource, some uses are prioritized over others through water allocations for each sector.

3. ***What is the value of water? What does water mean to you?***

    Answer – precious resource with economic, social, environmental and cultural value. The answer to this question is in the form of a word cloud. This question highlights the need to value the limited resource of freshwater and is based on the World Water day 2021 theme 'The Value of Water' and the listening exercise conducted on social media using the hashtag '#Water2me'[1].

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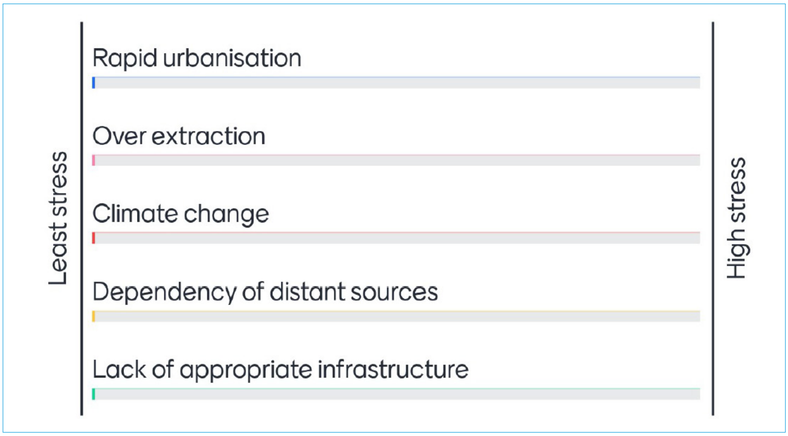
[1] *The summary of the exercise is available at https://www.unwater.org/publications/world-water-day-2021-listening-exercise-summary/*

4. **Based on your city's experience prioritize the cause of water stress for your city.**
    a. Rapid urbanisation
    b. over extraction
    c. climate change
    d. dependency on distant sources
    e. lack of appropriate infrastructure.

Answer – the options had to be prioritized by equating a value on a scale of 0 to 5, with 0 accounting for least stress and 5 as high stress using the slider.

Figure 37: Mentimeter template for prioritizing factors of water stress in a city on a scale from least stressed to high stress.



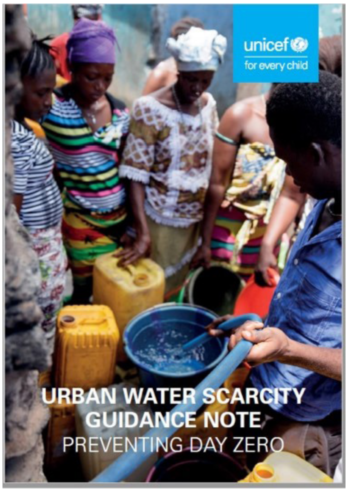
5. **The UN World Development Report 2018 stated that nearly 6 billion people will suffer from water scarcity by 2050. What are the causes for scarcity?**

   Answer - urbanization, population growth, climate change, etc. The answer is in the form of a word cloud. This question delves deeper into the factors influencing water scarcity.

5.2. Water resource management strategies as preparedness actions, immediate actions and long-term actions

Urban areas around the world have increasingly been facing extreme water shortages with every one in four cities categorised as water stressed. When the city of Cape Town faced impending 'Day zero', a day when the city was predicted to run out of water it informed the world on the threat posed by urban water scarcity. If we follow the business-as-usual trend for water usage, urban water shortages whether seasonal, intermittent or prolonged are predicted to increasingly become the norm. With this in mind UNICEF prepared a guidance note[2] which builds on the experiences of cities that have faced water scarcity crises to outline some specific actions that can be considered to mitigate the effects of urban water scarcity.

Figure 38: UNICEF's urban water scarcity guidance note.



An exercise 'PREVENTING DAY ZERO through preparedness, immediate and long-term actions' was formulated based on the same guidance note to enable participants to better understand how actions for water resource management are to be planned and prioritized. A list of actions for water resource management based on the guidance note

[2]*UNICEF (2021). Urban Water Scarcity Guidance Note Preventing Day Zero. Retrieved from: https://www.unicef.org/media/95381/file/Urban%20Water%20Scarcity%20guidance%20note.pdf*

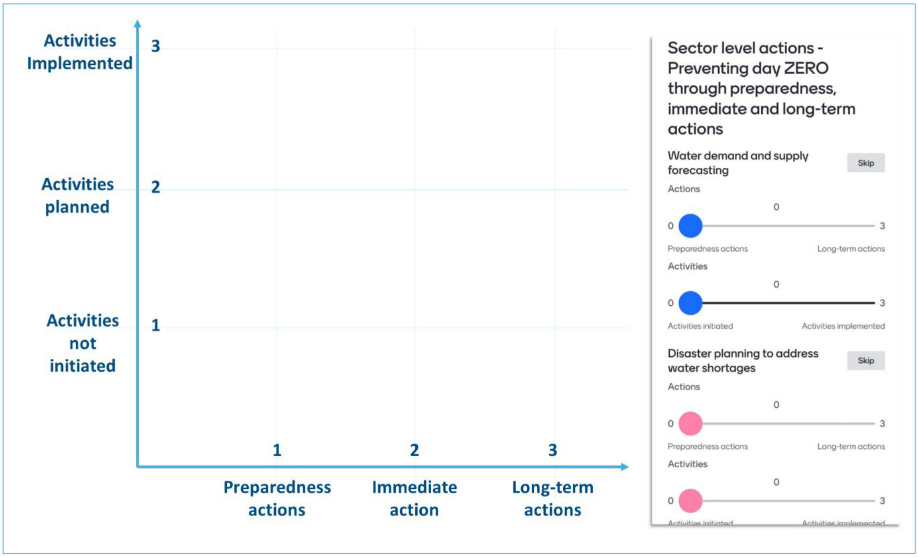
and the strategies from the presentation are collated. These actions are divided based on the scale of implementation which is at the sector level which considers the water supply service system along with all ambient water bodies or service level considering the source of supply and the water distribution network or the user level. The participants are required to categorise the actions into the following.

Preparedness actions - Actions which can be undertaken prior to a water crisis, they are risk management actions undertaken to prepare for the risk of water shortages, including protecting the most vulnerable *(UNICEF, Water and Environment team, 2021)*.

Immediate actions - Actions in support of authorities to be undertaken during a water shortage crisis, these actions need to simultaneously reduce water usage in the city drastically while protecting access for the most vulnerable *(UNICEF, Water and Environment team, 2021)*.

Long-term actions – these are mitigation actions to reduce or eliminate long-term risk an enable cities to inculcate a resilience-based approaches towards sustainable and equitable water use *(UNICEF, Water and Environment team, 2021)*.

This exercise is conducted in mentimeter. The participants are required to assign values to each action along two scales. The x-axis is to identify if actions are a preparedness action *(assign value 1)*, immediate action *(assign value 2)* or long-term action *(assign value 3)*. The values can be assigned by moving the slider to the respective value. On the y-axis participants are required to state if activities for the action are not initiated *(assign value 1)*, planned for *(assign value 2)* or implemented *(assign value 3)*. The responses will be plotted on a dot graph.



The following are the actions listed in the exercise.

Sector level actions –

i. Water demand and supply forecasting.
ii. Disaster planning to address water shortages
iii. Vulnerability mapping
iv. City-wide communication strategies such as a 'city water dashboard'.
v. Supply augmentation including alternative sources
vi. Promoting wastewater recovery and reuse
vii. Policy changes such as RWH in building codes.

Service level actions –

i. Restrictions on per capita usage
ii. Demand management strategies such as high tariffs on excessive use
iii. Demand management through network repair to reduce leaks
iv. Actions for supporting vulnerable population
v. Upgrading infrastructure by reducing NRW to 15%
vi. Implementing a metering policy

User level actions –

i. Assess ways to increase use efficiency at household level from water taps, flushing etc.
ii. Introducing volumetric tariffs
iii. Consumer metering
iv. Behaviour change campaigns for creating positive social norms around water conservation.

5.3. Water demand calculator tool

A Water Demand Calculator Tool was developed for cities to simplify the process of estimating the current and future water demand for the WRA. The tool has been prepared based on standards from the Manual on Water Supply and Treatment – 1999. The tool is in the form of a Macro-enabled excel workbook. It consists of two sheets. The first sheet is the data input sheet and the second sheet is the water demand calculator sheet. The ULB will require population data from past census to forecast the population and calculate future domestic demand. The ULBs would also require information on commercial and institutional facilities in the city such as number of hospital beds, hotel rooms, etc.

The steps to be followed for data input are included in the instructions on the data input sheet. After data entry click on calculate water demand.

Figure 39: Data input sheet on the Water Demand Calculator tool.

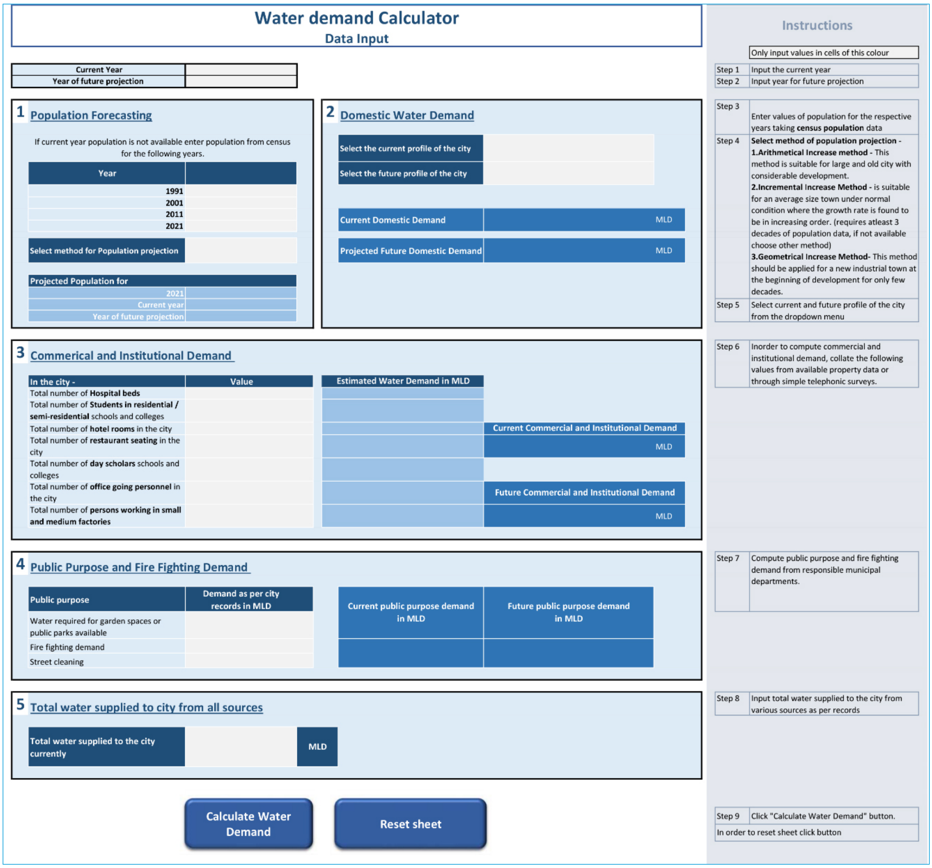


Image credits: Author.

In the data entry sheet, values need to be entered in the grey cell boxes. The following steps are to be followed for calculating the demand.

1. Download the 'Water Demand Calculator' tool from the here: *https://www.niua.org/c-cube/content/water-demand-calculator*
2. Enter the current year
3. Enter the year for future projection.
4. In section 1 – Population forecasting, enter the census population for the respective years. The census population of at least three years is required for to estimate using incremental population projection method else select other methods of population projection.
5. Select the method for population projection from the drop-down menu based on CPHEEO guidelines. The options for population forecasting are arithmetical increase method, incremental increase method and geometrical increase method.
6. The population projection for the current year and year of future projection will be computed.
7. In section 2 – Domestic water demand, select the current and future profile of the city from the drop-down menu. This will compute the current and future domestic demand.
8. In section 3 – Commercial and institutional demand, enter available information based on available property data or through telephonic surveys. This will compute current and future commercial and institutional demand.
9. In section 4 – Public purpose and firefighting demand, enter necessary information from city records.
10. In section 5 – Total water supplied to city from all sources, enter the necessary information from city records.
11. Click on 'Calculate Water Demand'.

The Total Current Demand and the Projected Water Demand for the city is calculated on the second sheet, along with projected water supply based on existing supply. It will further establish the Demand Supply gap for the current and future based on which actions are indicated. The tool can be reset by clicking on 'Back to main' and clicking 'Reset'.

Figure 40: Calculation sheet on the Water Demand Calculator tool.

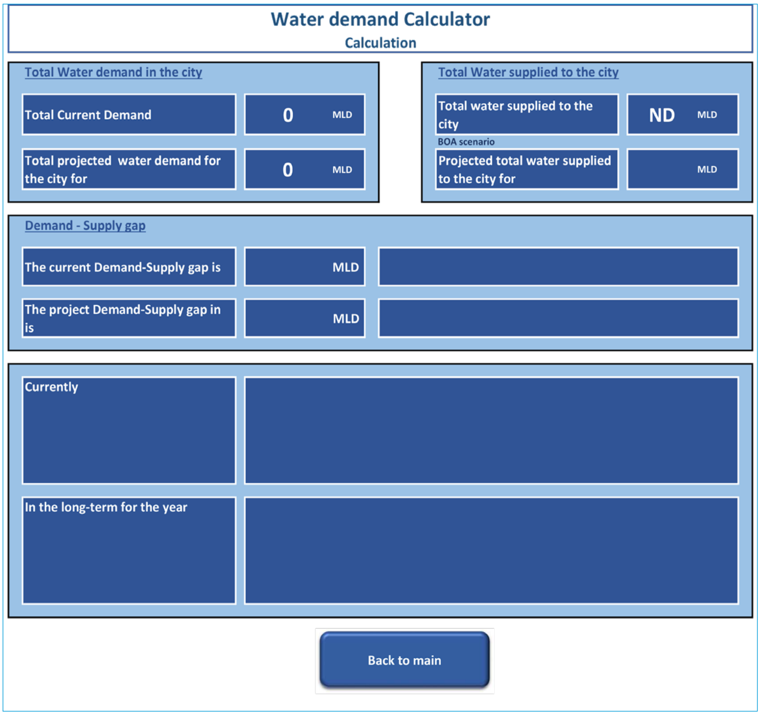


Image credits: Author.

6

List of Additional Readings

6.1. Additional readings

1. **Summary Progress Update 2021 – SDG 6 – water and sanitation for all.**
   The Summary progress report gives a brief idea of the current status achievements in moving towards SDG 6.
   https://www.unwater.org/app/uploads/2021/07/SDG-6-Summary-Progress-Update-2021_Version-July-2021.pdf

2. **How the Urban Water cycle works.** This webpage provides detailed information on how the urban water cycle works and how its different from the hydrological cycle.
   https://www.sehinc.com/news/how-urban-water-cycle-works

3. **Principles and Practices of Integrated Water Resources Management.**
   Integrated Water Resource Management (IWRM) is a holistic approach to water use and management and this manual was designed to introduce the concept, principles and practice of IRWM.
   https://www.siwi.org/wp-content/uploads/2020/06/IWRM_Manual1_final.pdf

4. **National Water Policy (2012)**
   The National Water Policy in detail.
   http://nwm.gov.in/sites/default/files/national%20water%20policy%202012_0.pdf

5. **Manual on Water Supply and Treatment – 1999**
   This manual details guidelines on basic norms, standards with respect to water for public health engineering departments, water boards and municipal bodies.
   http://cpheeo.gov.in/cms/manual-on-water-supply-and-treatment.php

6. **Manual on Operation and Maintenance of Water Supply System – 2005**
   This manual provides detailed guidelines on the operation and maintenance of urban water supply systems for field engineers in the water supply and sanitation sector.
   http://cpheeo.gov.in/cms/manual-on-operation--and-maintenance-of-water-supply-system-2005.php

7. **Manual on Storm Water Drainage Systems – 2019**
   This manual was designed taking into account the increased instances of urban flooding and how efficient storm water management will help tackle this vulnerability of urban areas.
   http://cpheeo.gov.in/cms/manual-on-storm-water-drainage-systems---2019.php

8. **Draft guidelines of Jal Jeevan Mission (urban) / AMRUT 2.0.**
   This document consists of the draft operational guidelines for implementation of the Jal Jeevan Mission (urban), it provides the necessary actions to be undertaken.
   https://cdma.cgg.gov.in/cdma/Circulars/344913JalJeevanMissionAMRUT2.0withdraft-proposal.pdf

6.2. Additional readings for CSCAF Indicators

1. **ClimateSmart Cities Assessment Framework 2.0 - Cities Readiness Report**
   This report is collates the performance of 126 cities with respect to the CSCAF framework which was developed and rolled-out by MoHUA to initiate sustainable urban planning and climate informed development actions across urban India.
   https://niua.org/c-cube/sites/default/files/Cities%20Readiness%20Report%20(High%20Res).pdf

2. **Best Practices Compendium: ClimateSmart CITIES**
   The compendium provides a collection of promising case studies of successful actions undertaken for improving the climate action of cities both in India and globally.
   https://www.niua.org/csc/assets/pdf/imp-document/Best%20Practices%20Compendium_final.pdf

6.3. Water Resource Management Plan

1. **Guidelines for Water Quality Monitoring, CPCB**
   The guidelines provide strategies for systematic water quality monitoring for drawing up and implementing a water quality management plan which is essential for the restoration of water bodies.
   https://www.mpcb.gov.in/sites/default/files/water-quality/standards-protocols/GuidelinesforWQMonitoring%5B1%5D.pdf

2. **Technical Material for Water Resources Assessment**
   This is a manual which aids in assess the availability of freshwater resources and the necessary data required to assess the same.
   https://library.wmo.int/doc_num.php?explnum_id=7783

3. **Water Demand Management Strategy and Implementation Plan for JABALPUR.**
   This document provides a comprehensive framework for developing a Water Demand Management Strategy and Implementation Plan for the city of Jabalpur involving institutional, financial and technical issues and is aimed at the efficiency improvements in management and utilization of water.
   https://unhabitat.org/sites/default/files/download-manager-files/Water%20Demand%20Management%20Strategy%20and%20Implementation%20Plan%20for%20Jabalpur.pdf

4. **Creating Urban Water Resilience in India, a Water Balance Study of Chennai, Bengaluru, Coimbatore, and Delhi**
   This study attempts analyse the gaps and constraints in the current urban water balance and the city water bu dgeting process which is based on primary and secondary data, analyses the water supply and demand scenarios in four water-stressed cities.
   https://www.orfonline.org/wp-content/uploads/2021/03/Monograph_Urban_Water.pdf

6.4. Water Resource Management Strategies

1. **Urban Wetland/Water Bodies Management Guidelines**
   This is a toolkit for local stakeholders in urban areas for management of urban water bodies which increasingly being transformed as a sink for both solid and liquid waste, causing their rapid degradation.
   https://nmcg.nic.in/writereaddata/fileupload/40_Urban%20Wetlandwater%20 bodiesmanagement%20guidelines.pdf

2. **Advisory on Conservation and Restoration of Water Bodies in Urban Areas.**
   An advisory prepared by CPHEEO for the guidance of state governments and urban local bodies to conserve and restore urban water bodies.
   http://mohua.gov.in/upload/uploadfiles/files/Advisory%20on%20Urban%20Water%20 Bodies.pdf

3. **Jakkur Lake - Urban Lake Management**
   A detailed case study on the efforts undertaken to revive Jakkur Lake in Northern Bangalore. *https://www.cseindia.org/jakkur-lake-urban-lake-management-6402*

4. **River Centric Urban Planning Guidelines**
   These guidelines are in line with the Government's vision of clean rivers by 2030, prepared for the Town and Country Planning departments, urban local bodies and urban development authorities to ensure sustainability of rivers passing through urban areas.
   http://mohua.gov.in/upload/whatsnew/60b0c96d3481cRCUP%20Guidelines.pdf

5. **Cheonggyecheon Stream Restoration Project**
   This a case study on a stream restoration project in Seoul which was revived to provide numerous environmental, social and economic benefits for the city.
   https://www.landscapeperformance.org/case-study-briefs/cheonggyecheon-stream-restoration#/project-team

6. **Nature-Based Solutions for Water Management A Primer.**
   This primer is a product of a collective effort by UN Environment-DHI, Centre on Water and Environment, the United Nations Environment Programme (UN Environment) on mainstreaming, accelerating and scaling-up implementation of Nature-based solutions for sustainable development.
   https://wedocs.unep.org/bitstream/handle/20.500.11822/32058/NBSW.pdf?sequence=1&isAllowed=y

7. **UTTIPEC (2010) Street design guidelines.**
   It outlines a set of 10 non-negotiable Street Design Components as well as additional guidelines for world class streets and introduces the concept of Water Sensitive Urban Design (WSUD) for streets.
   http://www.uttipec.nic.in/upload/uploadfiles/files/7554441800.pdf

8. **Green Infrastructure Guide for Water Management: Ecosystem-based management** approaches for water-related infrastructure projects
   This is a guide for implementing green infrastructure systems to provide ecosystem services to provide primary water management benefits to complement existing grey infrastructure.
   http://nwrm.eu/sites/default/files/documents-docs/med/WEB-UNEP-DhiGroup-Green-infrastructure-Guide-EN-20140805.pdf

9. **Policy Paper: Water Efficiency and Conservation in Urban India**
   This document details recommendations for practise water efficiency and conservation and its approach which aligns with the UN's Sustainable Development Goals to be achieved by 2030.
   https://cdn.cseindia.org/userfiles/Urban-Water-Efficiency-and-Conservation.pdf

10. **Modern India Can Learn a Lot from These 20 Traditional Water Conservation Systems**
    This is a detailed article on the numerous traditional practices from across India on water conservation practices. *https://www.thebetterindia.com/61757/traditional-water-conservation-systems-india/*

11. **Towards Better Management of Ground Water Resources in India**
    An article on the current practices with respect to ground water resources and actions that can be undertaken for improved management.
    http://cgwb.gov.in/documents/papers/incidpapers/Paper%201-B.M.Jha.pdf

12. **Model Bill for the Conservation, Protection, Regulation and Management of Groundwater, 2016**
    This is a model bill on the principles, legal status of ground water use, institutional framework and details on how groundwater security plans based on dynamic resource assessment.
    http://jalshakti-dowr.gov.in/sites/default/files/Model_Bill_Groundwater_May_2016_0.pdf

13. **Rainwater Harvesting Regulations in Bangalore Rules and Regulations for property owners, 2016**
    A brief on the Rainwater Harvesting Regulations in Bangalore for property owners.
    http://bengaluru.urbanwaters.in/wp-content/uploads/sites/3/2018/09/Rainwater-Harvesting-Regulations-1.pdf

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सत्यमेव जयते

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